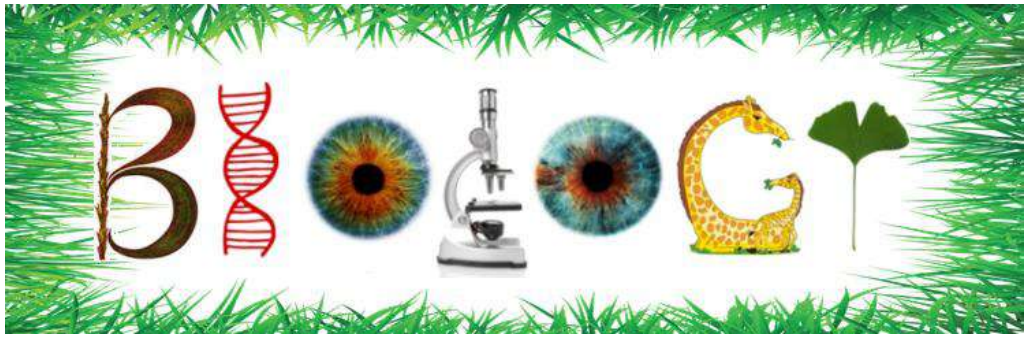
GPB 1.1: INTRODUCTORY BIOLOGY (1+1=2)

for

First Semester B.Sc (Hons.) Agri.



LECTURE: 1

INTRODUCTION TO THE LIVING WORLD, DIVERSITY AND CHARACTERISTICS OF LIFE

INTRODUCTION LIVING WORLD:

Biology is the science of life forms and living processes. The living world comprises an amazing diversity of living organisms. Early man could easily perceive the difference between inanimate matter and living organisms. Early man deified some of the inanimate matter (wind, sea, fire etc.) and some among the animals and plants. A common feature of all such forms of inanimate and animate objects was the sense of awe or fear that they evoked. The description of living organisms including human beings began much later in human history. Societies which indulged in anthropocentric view of biology could register limited progress in biological knowledge. Systematic and monumental description of life forms brought in, out of necessity, detailed systems of identification, nomenclature and classification. The biggest spin off of such studies was the recognition of the sharing of similarities among living organisms both horizontally and vertically. That all present day living organisms are related to each other and also to all organisms that ever lived on this earth, was a revelation which humbled man and led to cultural movements for conservation of biodiversity. In the following chapters of this unit, you will get a description, including classification, of animals and plants from a taxonomist's perspective.

Born on 5 July 1904, in Kempten, Germany, ERNST MAYR, the Harvard University evolutionary biologist who has been called 'The Darwin of the 20th century', was one of the 100 greatest scientists of all time. Mayr joined Harvard's Faculty of Arts and Sciences in 1953 and retired in 1975, assuming the title Alexander Agassiz Professor of Zoology Emeritus. Throughout his nearly 80-year career, his research spanned ornithology, taxonomy, zoogeography, evolution, systematics, and the history and philosophy of biology. He almost single-handedly made the origin of species diversity the central question of evolutionary biology that it is today. He also pioneered the currently accepted definition of a biological species. Mayr was awarded the three prizes widely regarded as the triple crown of biology: the Balzan Prize in 1983, the International Prize for Biology in 1994, and the Crafoord Prize in 1999. Mayr died at the age of 100 in the year 2004. How wonderful is the living world! The wide range of living types is amazing. The extraordinary habitats in which we find living organisms, be it cold mountains, deciduous forests, oceans, fresh water lakes, deserts or hot springs, leave us speechless. The beauty of a galloping horse, of the migrating birds, the valley of flowers or the attacking shark evokes awe and a deep sense of wonder.

The ecological conflict and cooperation among members of a population and among populations of a community or even the molecular traffic inside a cell make us deeply reflect on – what indeed is life? This question has two implicit questions within it. The first is a technical one and seeks answer to what living is as opposed to the non-living, and the second is a philosophical one, and seeks answer to what the purpose of life is. As scientists, we shall not attempt answering the second question.

WHAT IS LIVING?

When we try to define 'living', we conventionally look for distinctive characteristics exhibited by living organisms. Growth, reproduction and ability to sense environment are unique features of living organisms. One can add a few more features like metabolism, ability to self-replicate, self-organise, interact and emergence to this list. Let us try to understand each of these. All living organisms grow. Increase in mass and increase in number of individuals are twin characteristics of growth. A multi-cellular organism grows by cell division. In plants, this growth by cell division occurs continuously throughout their life span. In animals, this growth is seen only up to a certain age. However, cell division occurs in certain tissues to replace lost cells. Unicellular organisms also grow by cell division. One can easily observe this in *in vitro* cultures by simply counting the number of cell under the microscope. In majority of higher animals and plants, growth and reproduction are mutually exclusive events. One must remember that increase in body mass is considered as growth. Non-living objects also grow if we take increase in body mass as a criterion for growth. Mountains, boulders and sand mounds do grow. However, this kind of growth exhibited by non-living objects is by accumulation of material on the surface. In living organisms, growth is from inside. Growth, therefore, cannot be taken as a defining property of living organisms. Conditions under which it can be observed in all living organisms have to be explained and then we understand that it is a characteristic of living systems. A dead organism does not grow.

Reproduction, likewise, is a characteristic of living organisms. In multi-cellular organisms, reproduction refers to the production of progeny possessing features more or less similar to those of parents. Invariably and implicitly we refer to sexual reproduction. Organisms reproduce by asexual means also. Fungi multiply and spread easily due to the millions of asexual spores they produce. In lower organisms like yeast and hydra, we observe budding. In Planaria (flat worms), we observe true regeneration, i.e., a fragmented organism regenerates the lost part of its body and becomes, a new organism. The fungi, the filamentous algae, the protonema of mosses, all easily multiply by fragmentation. When it comes to unicellular organisms like bacteria, unicellular algae or Amoeba, reproduction is synonymous with growth, i.e., increase in number of cells. We have already defined growth as equivalent to increase in cell number or

mass. Hence, we notice that in single-celled organisms, we are not very clear about the usage of these two terms – growth and reproduction. Further, there are many organisms which do not reproduce (mules, sterile worker bees, infertile human couples, etc). Hence, reproduction also cannot be an all-inclusive defining characteristic of living organisms. Of course, no non-living object is capable of reproducing or replicating by itself.

Another characteristic of life is metabolism. All living organisms are made of chemicals. These chemicals, small and big, belonging to various classes, sizes, functions, etc., are constantly being made and changed into some other bio-molecules. These conversions are chemical reactions or metabolic reactions. There are thousands of metabolic reactions occurring simultaneously inside all living organisms, be they unicellular or multi-cellular. All plants, animals, fungi and microbes exhibit metabolism. The sum total of all the chemical reactions occurring in our body is metabolism. No non-living object exhibits metabolism. Metabolic reactions can be demonstrated outside the body in cell-free systems. An isolated metabolic reaction(s) outside the body of an organism, performed in a test tube is neither living nor non-living. Hence, while metabolism is a defining feature of all living organisms without exception, isolated metabolic reactions in vitro are not living things but surely living reactions. **Hence, cellular organisation of the body is the defining feature of life forms.**

Perhaps, the most obvious and technically complicated feature of all living organisms is this ability to sense their surroundings or environment and respond to these environmental stimuli which could be physical, chemical or biological. We sense our environment through our sense organs. Plants respond to external factors like light, water, temperature, other organisms, pollutants, etc. All organisms, from the prokaryotes to the most complex eukaryotes can sense and respond to environmental cues. Photoperiod affects reproduction in seasonal breeders, both plants and animals. All organisms handle chemicals entering their bodies. All organisms therefore, are 'aware' of their surroundings. Human being is the only organism who is aware of himself, i.e., has self-consciousness. **Consciousness therefore, becomes the defining property of living organisms.**

When it comes to human beings, it is all the more difficult to define the living state. We observe patients lying in coma in hospitals virtually supported by machines which replace heart and lungs. The patient is otherwise brain-dead. The patient has no self-consciousness. Are such patients who never come back to normal life, living or non-living?

In higher classes, you will come to know that all living phenomena are due to underlying interactions. Properties of tissues are not present in the constituent cells but arise as a result of interactions among the constituent cells. Similarly, properties of cellular organelles are not present in the molecular constituents of the organelle but arise as a result of interactions among the molecular components comprising the organelle. These interactions result in emergent

properties at a higher level of organisation. This phenomenon is true in the hierarchy of organisational complexity at all levels. Therefore, we can say that living organisms are self-replicating, evolving and self-regulating interactive systems capable of responding to external stimuli. Biology is the story of life on earth.

Biology is the story of evolution of living organisms on earth. All living organisms – present, past and future, are linked to one another by the sharing of the common genetic material, but to varying degrees.

DIVERSITY IN THE LIVING WORLD:

If you look around you will see a large variety of living organisms, be it potted plants, insects, birds, your pets or other animals and plants. There are also several organisms that you cannot see with your naked eye but they are all around you. If you were to increase the area that you make observations in, the range and variety of organisms that you see would increase. Obviously, if you were to visit a dense forest, you would probably see a much greater number and kinds of living organisms in it. Each different kind of plant, animal or organism that you see, represents a species. The number of species that are known and described ranged between 1.7-1.8 million. This refers to **biodiversity** or the number and types of organisms present on earth. We should remember here that as we explore new areas, and even old ones, new organisms are continuously being identified.

As stated earlier, there are millions of plants and animals in the world; we know the plants and animals in our own area by their local names. These local names would vary from place to place, even within a country. Probably you would recognise the confusion that would be created if we did not find ways and means to talk to each other, to refer to organisms we are talking about.

Hence, there is a need to standardise the naming of living organisms such that a particular organism is known by the same name all over the world. This process is called **nomenclature**. Obviously, nomenclature or naming is only possible when the organism is described correctly and we know to what organism the name is attached to. This is **identification**.

In order to facilitate the study, numbers of scientists have established procedures to assign a scientific name to each known organism. This is acceptable to biologists all over the world. For plants, scientific names are based on agreed principles and criteria, which are provided in International Code for Botanical Nomenclature (ICBN). You may ask how animals named. Animal taxonomists have evolved International Code of Zoological Nomenclature (ICZN). The scientific names ensure that each organism has only one name. Description of any organism

should enable the people (in any part of the world) to arrive at the same name. They also ensure that such a name has not been used for any other known organism.

Biologists follow universally accepted principles to provide scientific names to known organisms. Each name has two components – the **Generic name** and the **specific epithet**. This system of providing a name with two components is called **Binomial nomenclature.** This naming system given by Carolus Linnaeus is being practised by biologists all over the world. This naming system using a two word format was found convenient. Let us take the example of mango to understand the way of providing scientific names better. The scientific name of mango is written as *Mangifera indica*. Let us see how it is a binomial name. In this name *Mangifera* represents the genus while *indica*, is a particular species, or a specific epithet. Other universal rules of nomenclature are as follows:

1. Biological names are generally in Latin and written in italics. They are Latinised or derived from Latin irrespective of their origin.

2. The first word in a biological name represents the genus while the second component denotes the specific epithet.

3. Both the words in a biological name, when handwritten, are separately underlined, or printed in italics to indicate their Latin origin.

4. The first word denoting the genus starts with a capital letter while the specific epithet starts with a small letter. It can be illustrated with the example of *Mangifera indica*.

Name of the author appears after the specific epithet, i.e., at the end of the biological name and is written in an abbreviated form, e.g., *Mangifera indica* Linn. It indicates that this species was first described by Linnaeus.

Since it is nearly impossible to study all the living organisms, it is necessary to devise some means to make this possible. This process is **classification.** Classification is the process by which anything is grouped into convenient categories based on some easily observable characters. For example, we easily recognise groups such as plants or animals or dogs, cats or insects. The moment we use any of these terms, we associate certain characters with the organism in that group. What image do you see when you think of a dog ? Obviously, each one of us will see ‘dogs’ and not ‘cats’. Now, if we were to think of ‘Alsatians’ we know what we are talking about. Similarly, suppose we were to say ‘mammals’, you would, of course, think of animals with external ears and body hair. Likewise, in plants, if we try to talk of ‘Wheat’, the picture in each of our minds will be of wheat plants, not of rice or any other plant. Hence, all these - ‘Dogs’, ‘Cats’, ‘Mammals’, ‘Wheat’, ‘Rice’, ‘Plants’, ‘Animals’, etc., are convenient categories we use to study organisms. The scientific term for these categories is **taxa**. Here you must recognise that taxa can indicate categories at very different levels. ‘Plants’ – also form a taxa. ‘Wheat’ is also a taxa.

Similarly, ‘animals’, ‘mammals’, ‘dogs’ are all taxa – but you know that a dog is a mammal and mammals are animals. Therefore, ‘animals’, ‘mammals’ and ‘dogs’ represent taxa at different levels.

Hence, based on characteristics, all living organisms can be classified into different taxa. This process of classification is **taxonomy**. The external and internal structures, along with the structure of cell, development process and ecological information of organisms are essential and form the basis of modern taxonomic studies. Hence, characterisation, identification, classification and nomenclature are the processes that are basic to taxonomy. Taxonomy is not something new. Human beings have always been interested in knowing more and more about the various kinds of organisms, particularly with reference to their own use. In early days, human beings needed to find sources for their basic needs of food, clothing and shelter. Hence, the earliest classifications were based on the ‘uses’ of various organisms. Human beings were, since long, not only interested in knowing more about different kinds of organisms and their diversities, but also the relationships among them. This branch of study was referred to as **systematics.** The word systematics is derived from the Latin word ‘Systema’ which means systematic arrangement of organisms. Linnaeus used Systema Naturae as the title of his publication. The scope of systematics was later enlarged to include identification, nomenclature and classification. Systematics takes into account evolutionary relationships between organisms.

TAXONOMIC CATEGORIES:

Classification is not a single step process but involves hierarchy of steps in which each step represents a rank or category. Since the category is a part of overall taxonomic arrangement, it is called the **taxonomic category** and all categories together constitute the **taxonomic hierarchy.** Each category, referred to as a unit of classification, in fact, represents a rank and is commonly termed as **taxon** (pl.: taxa).

Taxonomic categories and hierarchy can be illustrated by an example. Insects represent a group of organisms sharing common features like three pairs of jointed legs. It means insects are recognisable concrete objects which can be classified, and thus were given a rank or category. Can you name other such groups of organisms? Remember, groups represent category. Category further denotes rank. Each rank or taxon, in fact, represents a unit of classification. These taxonomic groups/ categories are distinct biological entities and not merely morphological aggregates.

Taxonomical studies of all known organisms have led to the development of common categories such as kingdom, phylum or division (for plants), class, order, family, genus and species. All organisms, including those in the plant and animal kingdoms have species as the lowest category. Now the question you may ask is, how to place an organism in various

categories? The basic requirement is the knowledge of characters of an individual or group of organisms. This helps in identifying similarities and dissimilarities among the individuals of the same kind of organisms as well as of other kinds of organisms.

CHARACTERISTICS OF LIFE:

1. **Definite size & shape:** All living organisms have a definite shape and size which may change, while no-living matters are formless.
2. **Organisation:** Living organisms have different organs systems to perform various functions in the body in coordinated manner.
3. **Growth and development:** All living organisms show growth and development.
4. **Reproduction:** Reproduction leads to generate of new individuals for survival on the earth.
5. **Metabolism:** The chemical reactions are continuously going in to the cells called metabolism (e.g. Anabolism & Catabolism).
6. **Homeostasis:** All living organisms keep themselves stable by maintaining their internal conditions in order to continue their metabolic processes known as Homeostasis.
7. **Consciousness:** Response and Sensitivity (Irritability)
8. **Healing & Repairing:** Heal wounds & Repairs broken parts
9. **Excretion:** Useless and harmful waste products as a result of metabolism are thrown out from body.
10. **Adaptations:** An organism makes to adjust well and suit to its way of life.
11. **Evolution:** Living things gradually get modified into new varieties/spices/races with time due to natural selection.
12. **Death:** Death is the ultimate termination of functional life.

SUMMARY

The living world is rich in variety. Millions of plants and animals have been identified and described but large number still remains unknown. The very range of organisms in terms of size, colour, habitat, physiological and morphological features make us seek the defining characteristics of living organisms. In order to facilitate the study of kinds and diversity of organisms, biologists have evolved certain rules and principles for identification, nomenclature and classification of organisms. The branch of knowledge dealing with these aspects is referred to as taxonomy. The taxonomic studies of various species of plants and animals are useful in agriculture, forestry, industry and in general for knowing our bio-resources and their diversity. The basics of taxonomy like identification, naming and classification of organisms are

universally evolved under international codes. Based on the resemblances and distinct differences, each organism is identified and assigned a correct scientific/biological name comprising two words as per the binomial system of nomenclature. An organism represents/occupies a place or position in the system of classification. There are many categories/ranks and are generally referred to as taxonomic categories or taxa. All the categories constitute a taxonomic hierarchy.

QUESTIONS:

1. Why are living organisms classified?
2. Why are the classification systems changing every now and then?
3. What different criteria would you choose to classify people that you meet often?
4. What do we learn from identification of individuals and populations?
5. Given below is the scientific name of Mango. Identify the correctly written name.

Mangifera Indica

Mangifera indica

6. Define a taxon. Give some examples of taxa at different hierarchical levels.
7. What are the characteristic features of life?

LECTURE: 2

ORIGIN OF LIFE, EVOLUTION AND EUGENICS

The origin of life is a scientific problem which is not yet solved. There are plenty of ideas, but few clear facts. The Miller's 1953 experiment showed that abiotic synthesis of organic molecules is possible.

It is generally agreed that all life today evolved by common descent from a single primitive life form. We do not know how this early form came about, but scientists think it was a natural process which took place perhaps 3,900 million years ago. This is in accord with a philosophy called naturalism.

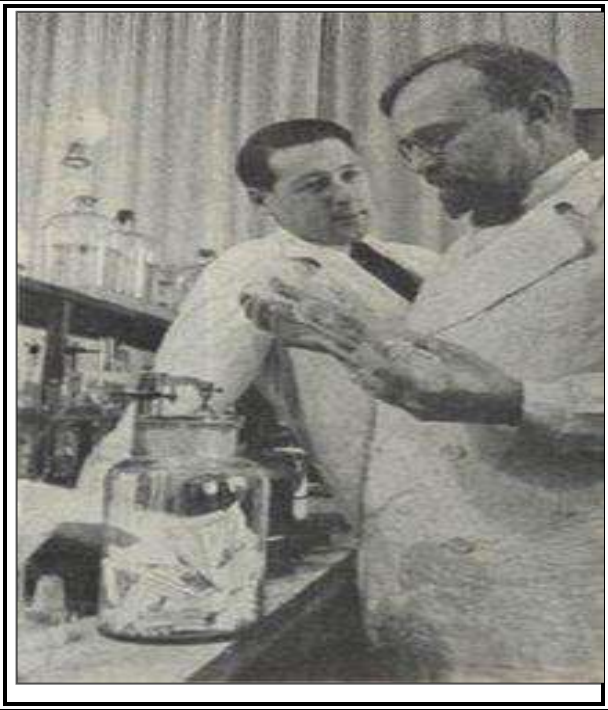
When we look at stars on a clear night sky we are, in a way, looking back in time. Stellar distances are measured in light years. What we see today is an object whose emitted light started its journey millions of year back and from trillions of kilometres away and reaching our eyes now. The universe is very old – almost 20 billion years old. Huge clusters of galaxies comprise the universe. Galaxies contain stars and clouds of gas and dust. Considering the size of universe, earth is indeed a speck.

The **Big Bang** theory attempts to explain to us the origin of universe. It talks of a singular huge explosion unimaginable in physical terms. The universe expanded and hence, the temperature came down. Hydrogen and Helium formed sometime later. The gases condensed under gravitation and formed the galaxies of the present day universe. In the solar system of the milky way galaxy, earth was supposed to have been formed about 4.5 billion years back. There was no atmosphere on early earth. Water vapour, methane, carbon dioxide and ammonia released from molten mass covered the surface. The UV rays from the sun broke up water into Hydrogen and Oxygen and the lighter H_2 escaped. Oxygen combined with ammonia and methane to form water, CO_2 and others. The ozone layer was formed. As it cooled, the water vapour fell as rain, to fill all the depressions and form oceans. Life appeared 500 million years after the formation of earth, i.e., almost four billion years back.

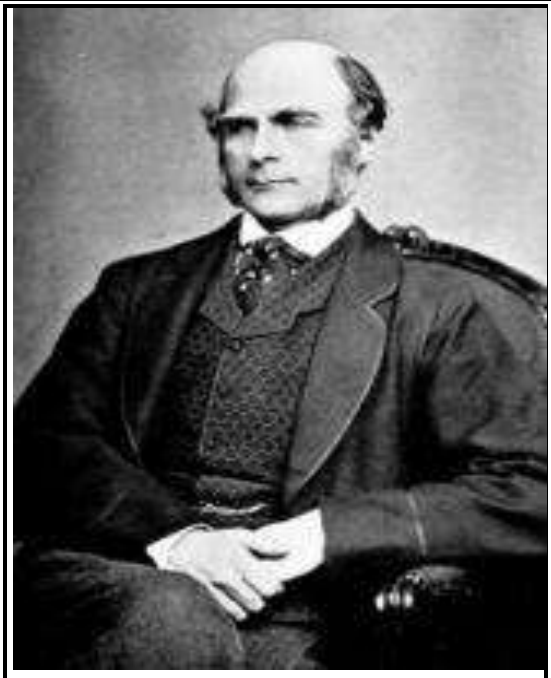
Some scientists believe that life came from outside. Early Greek thinkers thought units of life called **spores** were transferred to different planets including earth.

'Panspermia' is still a favourite idea for some astronomers. For a long time it was also believed that life came out of decaying and rotting matter like straw, mud, etc. This was the theory of spontaneous generation. Panspermia is the idea was suggested by Arrhenius, and developed by Fred Hoyle, that life developed elsewhere in the universe and arrived on Earth in the form of spores. This is not a theory of how life began, but a theory of how it might have spread.

Louis Pasteur by careful experimentation demonstrated that life comes only from pre-existing life. He showed that in pre-sterilised flasks, life did not come from killed yeast while in another flask open to air, new living organisms arose from 'killed yeast'. Spontaneous generation theory was dismissed once and for all. However, this did not answer how the first life form came on earth. Oparin of Russia and Haldane of England proposed that the first form of life could have come from pre-existing non-living organic molecules (e.g. RNA, protein, etc.) and that formation of life was preceded by chemical evolution, i.e., formation of diverse organic molecules from inorganic constituents.



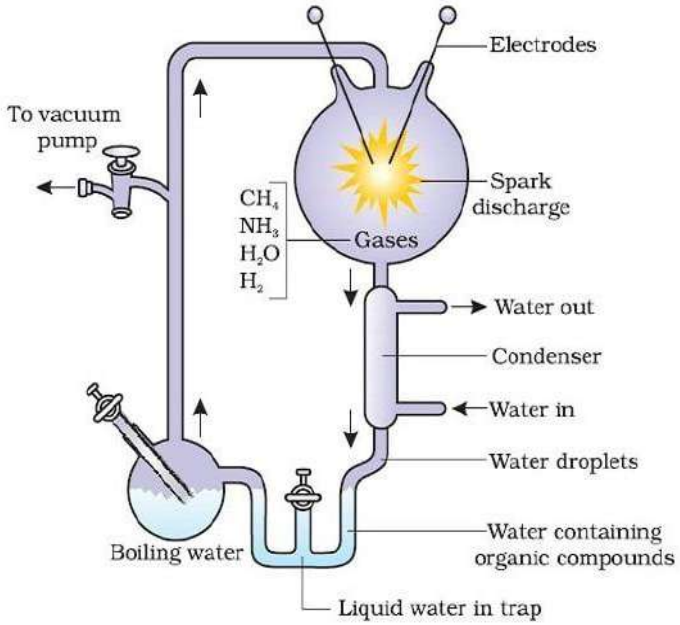
Alexander Oparin (right) in the laboratory



Francis Galton was an early eugenicist

The conditions on earth were – high temperature, volcanic storms, reducing atmosphere containing CH_4, NH_3, etc. In 1953, S.L. Miller, American scientist had created similar conditions in a laboratory scale (Figure 2.1).

Figure 2.1 Diagrammatic representation of Miller's experiment:



He created electric discharge in a closed flask containing CH_4, H_2, NH_3 and water vapour at 800^0C. He observed formation of amino acids. In similar experiments others observed, formation of sugars, nitrogen bases, pigment and fats. Analysis of meteorite content also revealed similar compounds indicating that similar processes are occurring elsewhere in space. With this limited evidence, the first part of the conjectured story, i.e., chemical evolution was more or less accepted. We have no idea about how the first self replicating metabolic capsule of life arose. The first non-cellular forms of life could have originated 3 billion years back. They would have been giant molecules (RNA, Protein, Polysaccharides, etc.). These capsules reproduced their molecules perhaps. The first cellular form of life did not possibly originate till about 2000 million years ago. These were probably single-cells. All life forms were in water environment only. This version of a biogenesis, i.e., the first form of life arose slowly through evolutionary forces from non-living molecules are accepted by majority. However, once formed, how the first cellular forms of life could have evolved into the complex biodiversity of today is the fascinating story that will be discussed below.

EVOLUTION OF LIFE FORMS – A THEORY

Conventional religious literature tells us about the theory of special creation. This theory has three connotations.

1. All living organisms (species or types) that we see, today were created as such.
2. The diversities were always the same since creation and will be the same in future also.
3. Earth is about 4000 years old. All these ideas were strongly challenged during 19^{th} century.

Based on observations made during a sea voyage in a sail ship called H.M.S. Beagle round the world, Charles Darwin concluded that existing living forms share similarities to varying degrees not only among themselves but also with life forms that existed millions of years ago. Many such life forms do not exist anymore. There had been extinctions of different life forms in the years gone by just as new forms of life arose at different periods of history of earth. There has been gradual evolution of life forms.

Any population has built in variation in characteristics. Those characteristics which enable some to survive better in natural conditions (climate, food, physical factors, etc.) would outbreed others that are less-endowed to survive under such natural conditions. Another word used is fitness of the individual or population.

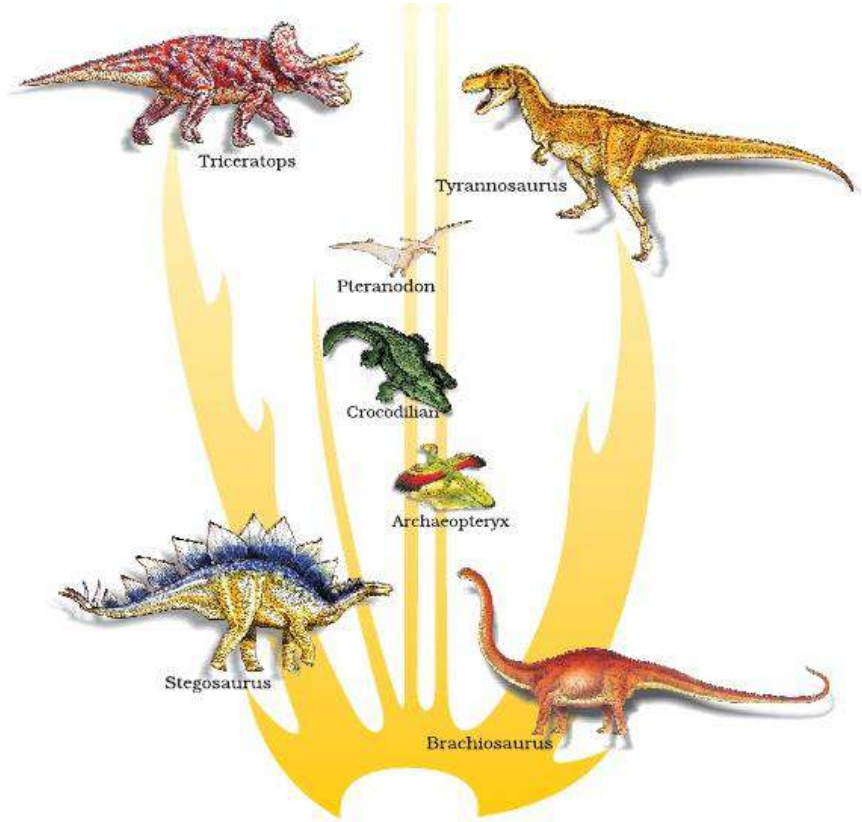
The fitness, according to Darwin, refers ultimately and only to reproductive fitness. Hence, those who are better fit in an environment, leave more progeny than others. These, therefore, will survive more and hence are selected by nature. He called it natural selection and implied it as a mechanism of evolution. Let us also remember that Alfred Wallace, a naturalist who worked in Malay Archepelago had also come to similar conclusions around the same time. In due course of time, apparently new types of organisms are recognisable.

All the existing life forms shares similarities and share common ancestors. However, these ancestors were present at different periods in the history of earth (epochs, periods and eras). The geological history of earth closely correlates with the biological history of earth. A common permissible conclusion is that earth is very old, not thousands of years as was thought earlier but billions of years old.

EVIDENCES FOR EVOLUTION:

Evidence that evolution of life forms has indeed taken place on earth has come from many quarters. Fossils are remained of hard parts of life-forms found in rocks. Rocks form sediments and a cross-section of earth's crust indicates the arrangement of sediments one over the other during the long history of earth. Different-aged rock sediments contain fossils of different life-forms who probably died during the formation of the particular sediment. Some of them appear similar to modern organisms (Figure 2.2).

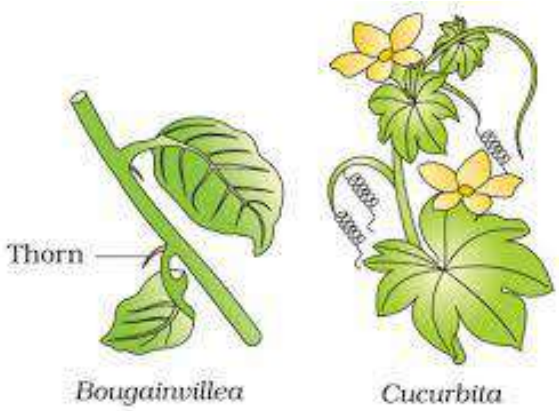
Figure 2.2 A family tree of dinosaurs and their living modern day counterpart organisms like crocodiles and birds



They represent extinct organisms (e.g., Dinosaurs). A study of fossils in different sedimentary layers indicates the geological period in which they existed. The study showed that life-forms varied over time and certain life forms are restricted to certain geological time-spans. Hence, new forms of life have arisen at different times in the history of earth. All this is called paleontological evidence. Do you remember how the ages of the fossils are calculated? Do you recollect the method of radio-active dating and the principles behind the procedure?

Comparative anatomy and morphology shows similarities and differences among organisms of today and those that existed years ago. Such similarities can be interpreted to understand whether common ancestors were shared or not. For example whales, bats, Cheetah and human (all mammals) share similarities in the pattern of bones of forelimbs (Figure 7.3b). Though these forelimbs perform different functions in these animals, they have similar anatomical structure – all of them have humerus, radius, ulna, carpals, metacarpals and phalanges in their forelimbs. Hence, in these animals, the same structure developed along different directions due to adaption to different needs. This is divergent evolution and these structures are homologous. Homology indicates common ancestry. Other examples are vertebrate hearts or brains. In plants also, the thorn and tendrils of Bougainvillea and Cucurbita represent homology **(Figure 2.3a).**

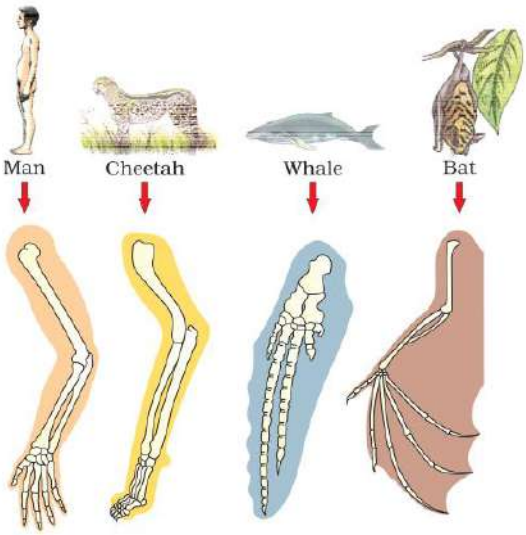
Figure 2.3 (a) Example of homologous organs in Plants



Homology is based on divergent evolution whereas analogy refers to a situation exactly opposite. Wings of butterfly and of birds look alike. They are not anatomically similar structures though they perform similar functions. Hence, analogous structures are a result of convergent evolution - different structures evolving for the same function and hence having similarity. Other examples of analogy are the eye of the octopus and of mammals or the flippers of Penguins and Dolphins. One can say that it is the similar habitat that has resulted in selection of similar adaptive features in different groups of organisms but toward the same function: Sweet potato (root modification) and potato (stem modification) is another example for analogy.

In the same line of argument, similarities in proteins and genes performing a given function among diverse organisms give clues to common ancestry. These biochemical similarities point to the same shared ancestry as structural similarities among diverse organisms **(Figure 2.3b).**

Figure 2.3 (b) Example of homologous organs in Animals



Man has bred selected plants and animals for agriculture, horticulture, sport or security. Man has domesticated many wild animals and crops. This intensive breeding programme has

created breeds that differ from other breeds (e.g., dogs) but still are of the same group. It is argued that if within hundreds of years, man could create new breeds, could not nature have done the same over millions of years?

Another interesting observation supporting evolution by natural selection comes from England. In a collection of moths made in 1850s, i.e., before industrialisation set in, it was observed that there were more white-winged moths on trees than dark-winged or melanised moths. However, in the collection carried out from the same area, but after industrialisation, i.e., in 1920, there were more dark-winged moths in the same area, i.e., the proportion was reversed.

The explanation put forth for this observation was that 'predators will spot a moth against a contrasting background'. During post-industrialisation period, the tree trunks became dark due to industrial smoke and soot. Under this condition the white-winged moth did not survive due to predators, dark-winged or melanised moth survived. Before industrialisation set in, thick growth of almost white-coloured lichen covered the trees - in that background the white winged moth survived but the dark-coloured moth were picked out by predators. Do you know that lichens can be used as industrial pollution indicators? They will not grow in areas that are polluted. Hence, moths that were able to camouflage themselves, i.e., hide in the background, survived **(Figure 2.4).**

Figure 2.4: Showing white - winged moth and dark - winged moth (melanised) on a tree trunk (a) In unpolluted area (b) In polluted area



(a) (b)

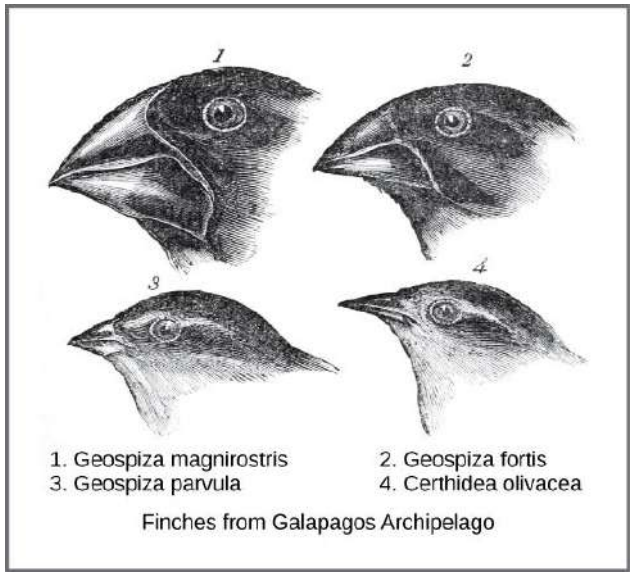
This understanding is supported by the fact that in areas where industrialisation did not occur e.g., in rural areas, the count of melanic moths was low. This showed that in a mixed population, those that can better-adapt, survive and increase in population size. Remember that no variant is completely wiped out. Similarly, excess use of herbicides, pesticides, etc., has only resulted in selection of resistant varieties in a much lesser time scale. This is also true for microbes against which we employ antibiotics or drugs against eukaryotic organisms/cell. Hence, resistant organisms/cells are appearing in a time scale of months or years and not centuries. These are examples of evolution by anthropogenic action. This also tells us that evolution is not a direct

process in the sense of determinism. It is a stochastic process based on chance events in nature and chance mutation in the organisms.

WHAT IS ADAPTIVE RADIATION?

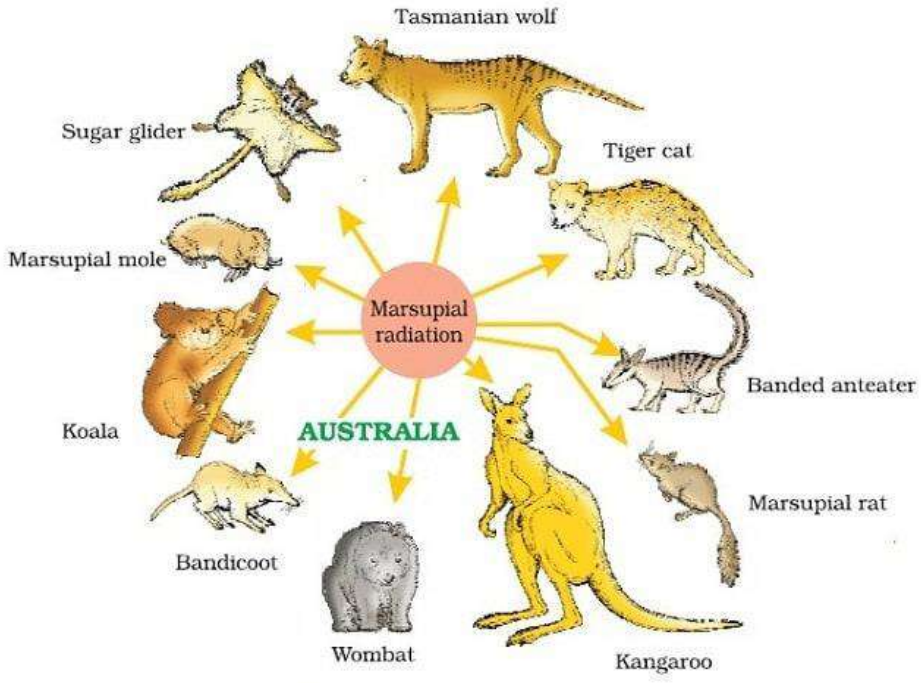
During his journey Darwin went to Galapagos Islands. There he observed an amazing diversity of creatures. Of particular interest, small black birds later called Darwin's Finches amazed him. He realised that there were many varieties of finches in the same island. All the varieties, he conjectured, evolved on the island itself. From the original seed-eating features, many other forms with altered beaks arose, enabling them to become insectivorous and vegetarian finches **(Figure 2.5).**

Figure 2.5 Variety of beaks of finches that Darwin found in Galapagos Island



This process of evolution of different species in a given geographical area starting from a point and literally radiating to other areas of geography (habitats) is called adaptive radiation. Darwin's finches represent one of the best examples of this phenomenon. Another example is Australian marsupials. A number of marsupials, each different from the other **(Figure 2.6)** evolved from an ancestral stock, but all within the Australian island continent. When more than one adaptive radiations appear to have occurred in an isolated geographical area (representing different habitats) one can call this convergent evolution.

Figure 2.6 Adaptive radiation of marsupials of Australia



BIOLOGICAL EVOLUTION

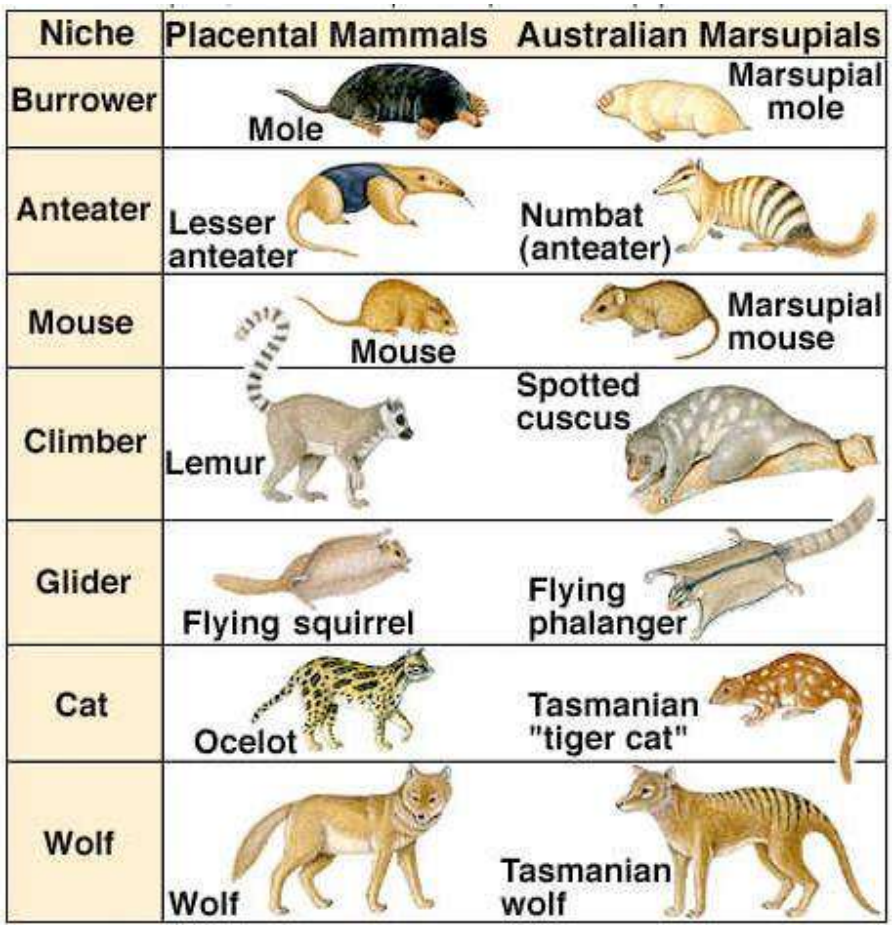
Evolution by natural selection, in a true sense would have started when cellular forms of life with differences in metabolic capability originated on earth.

The essence of Darwinian Theory about evolution is natural selection. The rate of appearance of new forms is linked to the life cycle or the life span. Microbes that divide fast have the ability to multiply and become millions of individuals within hours. A colony of bacteria (say A) growing on a given medium has built in variation in terms of ability to utilise a feed component. A change in the medium composition would bring out only that part of the population (say B) that can survive under the new conditions. In due course of time this variant population outgrows the others and appears as new species. This would happen within days. For the same thing to happen in a fish or fowl would take million of years as life spans of these animals are in years. Here we say that fitness of B is better than that of A under the new conditions. Nature selects for fitness. One must remember that the so-called fitness is based on characteristics which are inherited. Hence, there must be a genetic basis for getting selected and to evolve. Another way of saying the same thing is that some organisms are better adapted to survive in an otherwise hostile environment. Adaptive ability is inherited. It has a genetic basis. Fitness is the end result of the ability to adapt and get selected by nature.

Branching descent and natural selection are the two key concepts of Darwinian Theory of Evolution **(Figures 2.7 and 2.8).** Placental mammals in Australia also exhibit adaptive

radiation in evolving into varieties of such placental mammals each of which appears to be 'similar' to a corresponding marsupial (e.g., Placental wolf and Tasmanian wolfmarsupial).

Figure 2.7: Placental mammals and Australian marsupial



Even before Darwin, a French naturalist Lamarck had said that evolution of life forms had occurred but driven by use and disuse of organs. He gave the examples of Giraffes who in an attempt to forage leaves on tall trees had to adapt by elongation of their necks. As they passed on this acquired character of elongated neck to succeeding generations, Giraffes, slowly, over the years, came to acquire long necks. Nobody believes this conjecture any more.

Is evolution a process or the result of a process? The world we see, inanimate and animate, is only the success stories of evolution. When we describe the story of this world we describe evolution as a process. On the other hand when we describe the story of life on earth, we treat evolution as a consequence of a process called natural selection. We are still not very clear whether to regard evolution and natural selection as processes or end result of unknown processes.

It is possible that the work of Thomas Malthus on populations influenced Darwin. Natural selection is based on certain observations which are factual. For example, natural

resources are limited, populations are stable in size except for seasonal fluctuation, members of a population vary in characteristics (in fact no two individuals are alike) even though they look superficially similar, most of variations are inherited etc. The fact that theoretically population size will grow exponentially if everybody reproduced maximally (this fact can be seen in a growing bacterial population) and the fact that population sizes in reality are limited, means that there had been competition for resources. Only some survived and grew at the cost of others that could not flourish. The novelty and brilliant insight of Darwin was this: he asserted that variations, which are heritable and which make resource utilisation better for few (adapted to habitat better) will enable only those to reproduce and leave more progeny. Hence for a period of time, over many generations, survivors will leave more progeny and there would be a change in population characteristic and hence new forms appear to arise.

MECHANISM OF EVOLUTION:

What is the origin of this variation and how does speciation occur? Even though Mendel had talked of inheritable 'factors' influencing phenotype, Darwin either ignored these observations or kept silence. In the first decade of twentieth century, Hugo deVries based on his work on evening primrose brought forth the idea of mutations – large difference arising suddenly in a population. He believed that it is mutation which causes evolution and not the minor variations (heritable) that Darwin talked about. Mutations are random and directionless while Darwinian variations are small and directional. Evolution for Darwin was gradual while deVries believed mutation caused speciation and hence called it saltation (single step large mutation). Studies in population genetics, later, brought out some clarity.

HARDY-WEINBERG PRINCIPLE:

In a given population one can find out the frequency of occurrence of alleles of a gene or a locus. This frequency is supposed to remain fixed and even remain the same through generations. Hardy-Weinberg principle stated it using algebraic equations. This principle says that allele frequencies in a population are stable and is constant from generation to generation. The gene pool (total genes and their alleles in a population) remains a constant. This is called genetic equilibrium. Sum total of all the allelic frequencies is 1.

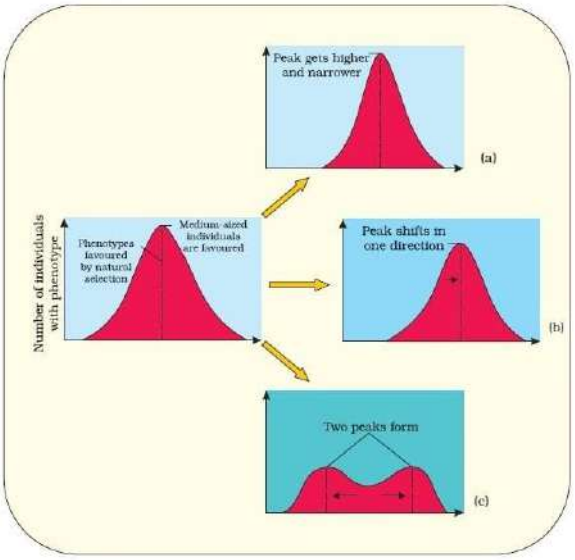
Individual frequencies, for example, can be named p, q, etc. In a diploid, p and q represent the frequency of allele A and allele a. The frequency of AA individuals in a population is simply p2. This is imply stated in another ways, i.e., the probability that an allele A with a frequency of p appear on both the chromosomes of a diploid individual is simply the product of the probabilities, i.e., p2. Similarly of aa is q2, of Aa 2pq. Hence, p2+2pq+q2=1. This is a binomial expansion of (p+q)2. When frequency measured, differs from expected values, the

difference (direction) indicates the extent of evolutionary change. Disturbance in genetic equilibrium, or Hardy- Weinberg equilibrium, i.e., change of frequency of alleles in a population would then be interpreted as resulting in evolution.

Five factors are known to affect Hardy-Weinberg equilibrium. These are gene migration or gene flow, genetic drift, mutation, genetic recombination and natural selection. When migration of a section of population to another place and population occurs, gene frequencies change in the original as well as in the new population. New genes/alleles are added to the new population and these are lost from the old population. There would be a gene flow if this gene migration, happens multiple times. If the same change occurs by chance, it is called genetic drift. Sometimes, the change in allele frequency is so different in the new sample of population that they become a different species. The original drifted population becomes founders and the effect is called founder effect.

Microbial experiments show that pre-existing advantageous mutations when selected will result in observation of new phenotypes. Over few generations, this would result in Speciation. Natural selection is a process in which heritable variations enabling better survival are enabled to reproduce and leave greater number of progeny. A critical analysis makes us believe that variation due to mutation or variation due to recombination during gametogenesis, or due to gene flow or genetic drift results in changed frequency of genes and alleles in future generation. Coupled to enhance reproductive success, natural selection makes it look like different population. Natural selection can lead to stabilisation (in which more individuals acquire mean character value), directional change (more individuals acquire value other than the mean character value) or disruption (more individuals acquire peripheral character value at both ends of the distribution curve) **(Figure 2.8).**

Figure 2.8 Diagrammatic representation of the operation of natural selection on different traits: (a) Stabilising (b) Directional and (c) Disruptive



A BRIEF ACCOUNT OF EVOLUTION:

About 2000 million years ago (mya) the first cellular forms of life appeared on earth. The mechanism of how non-cellular aggregates of giant macromolecules could evolve into cells with membranous envelop is not known. Some of these cells had the ability to release O_2. The reaction could have been similar to the light reaction in photosynthesis where water is split with the help of solar energy captured and channelized by appropriate light harvesting pigments. Slowly single-celled organisms became multi-cellular life forms. By the time of 500 mya, invertebrates were formed and active. Jawless fish probably evolved around 350 mya. Sea weeds and few plants were existed probably around 320 mya. We are told that the first organisms that invaded land were plants. They were widespread on land when animals invaded land. Fish with stout and strong fins could move on land and go back to water. This was about 350 mya. In 1938, a fish caught in South Africa happened to be a Coelacanth which was thought to be extinct. These animals called lobefins evolved into the first amphibians that lived on both land and water. There are no specimens of these left with us. However, these were ancestors of modern day frogs and salamanders. The amphibians evolved into reptiles. They lay thick shelled eggs which do not dry up in sun unlike those of amphibians. Again we only see their modern day descendents, the turtles, tortoises and crocodiles. In the next 200 million years or so, reptiles of different shapes and sizes dominated on earth. Giant ferns (pteridophytes) were present but they all fell to form coal deposits slowly. Some of these land reptiles went back into water to evolve into fish like reptiles probably 200 mya (e.g. Ichthyosaurs). The land reptiles were, of course, the dinosaurs. The biggest of them, i.e., Tyrannosaurus rex was about 20 feet in height and had huge fearsome dagger like teeth. About 65 mya, the dinosaurs suddenly disappeared from the earth. We do not know the true reason. Some say climatic changes killed them. Some say most of them evolved into birds. The truth may live in between. Small sized reptiles of that era still exist today.

The first mammals were like shrews. Their fossils are small sized. Mammals were viviparous and protected their unborn young inside the mother's body. Mammals were more intelligent in sensing and avoiding danger at least. When reptiles came down mammals took over this earth. There were in South America mammals resembling horse, hippopotamus, bear, rabbit, etc. Due to continental drift, when South America joined North America, these animals were overridden by North American fauna. Due to the same continental drift pouched mammals of Australia survived because of lack of competition from any other mammal.

Lest we forget, some mammals live wholly in water. Whales, dolphins, seals and sea cows are some examples. Evolutions of horse, elephant, dog, etc., are special stories of evolution. You will learn about these in higher classes. The most successful story is the evolution of man with language skills and self-consciousness.

Rough sketches of the evolution of life forms, their times on a geological scale are indicated in **(Figure 2.9 and 2.10).**

Figure 2.9 A sketch of the evolution of plant forms through geological periods

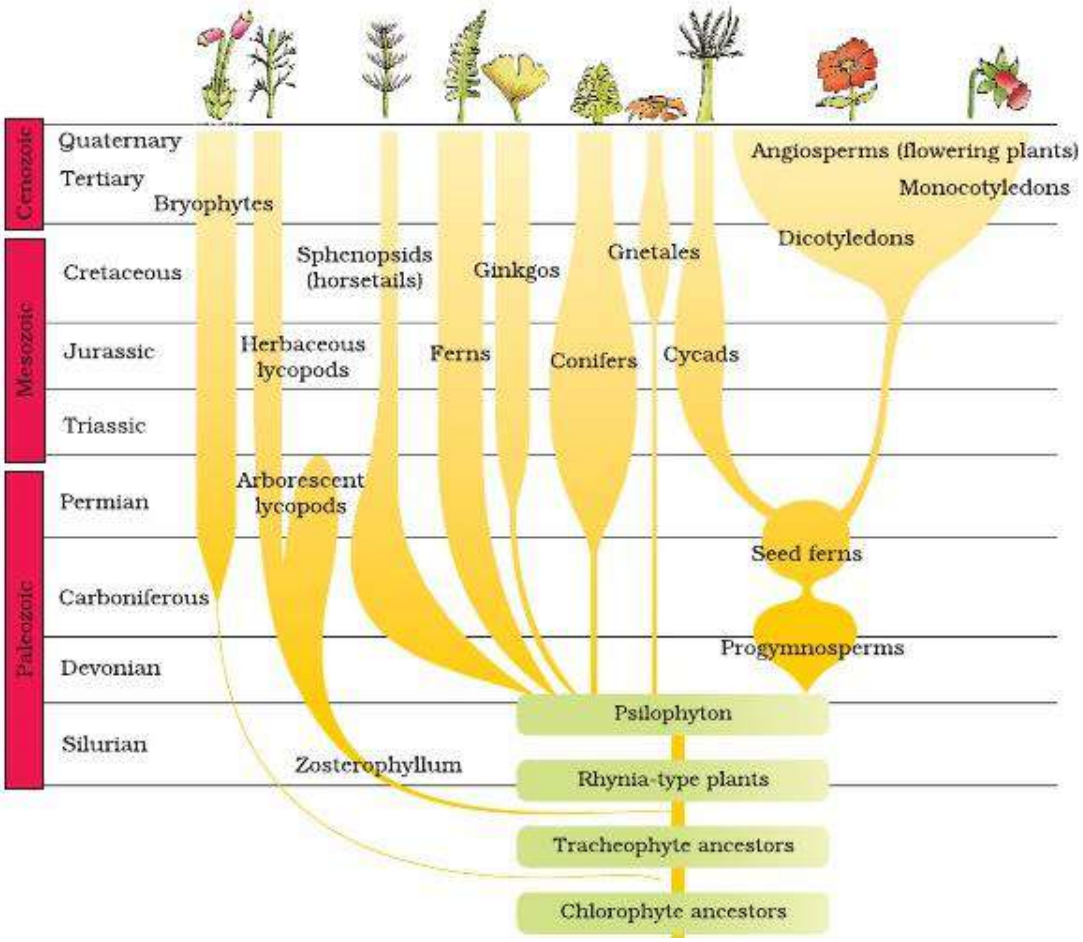
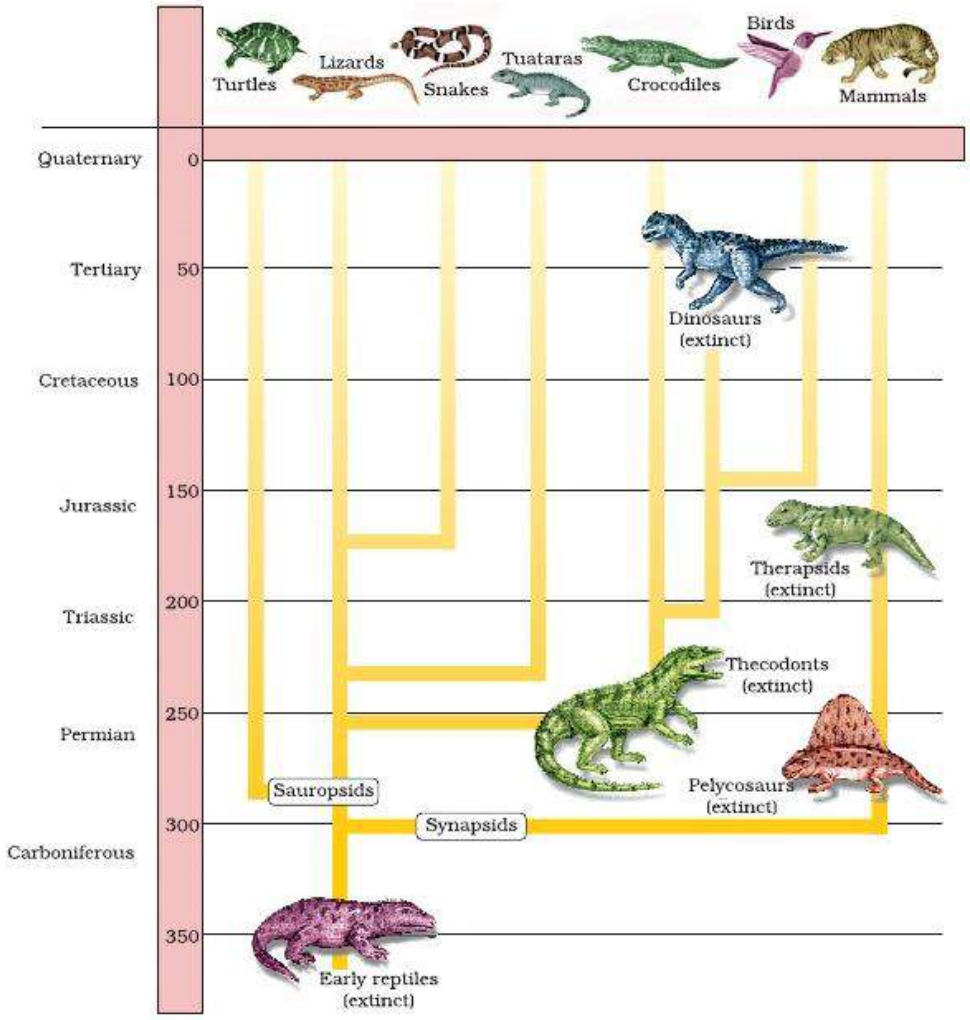


Figure 2.10 Representative evolutionary history of vertebrates through geological period

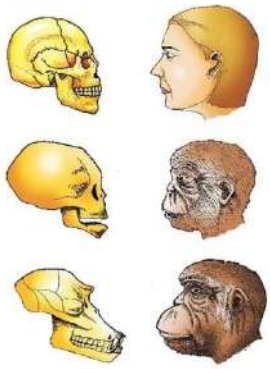
ORIGIN AND EVOLUTION OF MAN:

About 15 mya, primates called Dryopithecus and Ramapithecus were existing. They were hairy and walked like gorillas and chimpanzees. Ramapithecus was more man-like while Dryopithecus was more ape-like. Few fossils of man-like bones have been discovered in Ethiopia and Tanzania (Figure 2.11). These revealed hominid features leading to the belief that about 3-4 mya, man-like primates walked in eastern Africa. They were probably not taller than 4 feet but walked up right. Two mya, Australopithecines probably lived in East African grasslands. Evidence shows they hunted with stone weapons but essentially ate fruit. Some of the bones among the bones discovered were different. This creature was called the first human-like being the hominid and was called Homo habilis. The brain capacities were between 650-800cc. They probably did not eat meat. Fossils discovered in Java in 1891 revealed the next stage, i.e., Homo erectus about 1.5 mya. Homo erectus had a large brain around 900cc. Homo erectus probably ate meat. The Neanderthal man with a brain size of 1400cc lived in near east and central Asia



between 1,00,000-40,000 years back. They used hides to protect their body and buried their dead. Homo sapiens arose in Africa and moved across continents and developed into distinct races. During ice age between 75,000-10,000 years ago modern Homo sapiens arose. Pre-historic cave art developed about 18,000 years ago. Agriculture came around 10,000 years back and human settlements started. The rest of what happened is part of human history of growth and decline of civilisations.

Figure 2.11: A comparison of the skulls of adult modern human being, baby chimpanzee and adult chimpanzee. The skull of baby chimpanzee is more like adult human skull than adult chimpanzee skull.



EVOLUTION OF ANGIOSPERMS:

(General Evolutionary Trends in Angiosperms)

Basic Evolutionary Trends:

Different groups of angiosperms, reveal different lines of evolution. Many of the trends are recognised from comparative studies of living and fossil plants during attaining diversity. General trends in evolution of angiosperms include:

Evolution of Vegetative Structures:

Flowering plants are enormously variable in their vegetative structures but the earliest ones and their living representatives are mainly shrubs or trees and all living gymnosperms are woody. It is likely that herbaceous plants are derived from woody forms originally, but some woody plants, including monocot trees, may be secondarily evolved from herbaceous plants. There is difference of opinion about evolution of leaf structure, phyllotaxy, stomatal apparatus etc. of angiosperms.

Evolution of Floral Structures:

The earliest flowering plants have flowers which were simple and tiny up to 3 mm long, hermaphrodite or unisexual with no sepals and petals (some have a bract, one or three stamens and/or one carpel). During the course of early evolution, active adaptive radiation, *i.e.* their spread and diversification through the Cretaceous period, parallel to other seed plant groups, resulted in appearance of some other living families. Outer whorls of flower became differentiated early on, the outermost whorl, referred to as calyx even if there is only one whorl, probably evolving from bract and when there are two different whorls, the inner whorl is referred to as the corolla, but some probably evolved from a second whorl of sepals, others from stamens losing their anthers and becoming organs purely for attracting insects. Some water lilies and nympheoids *(Nymphaea)* have intermediate organs, stamens with flattened coloured filaments between the fertile stamens and larger entirely sterile petals. Cultivated *double flowers* such as of roses have some stamens replaced by petals. Transitional stages of converting fertile stamens to fully developed petals can be seen in many flowers, *e.g., Rosa* and *Nymphaea.* One main early line of evolution was towards a fix number in each whorl, often five in dicots (rarely four) and three in the monocots, making the flowers radially symmetrical. *i.e.* actinomorphic.

There was a specialisation for pollination, by beetles along one line of evolution including magnolias, and by wind along other line leading to the catkin-bearing trees. The insect-pollinated group had hermaphrodite flowers of, at first increasing, size and complexity through later insect-pollinated flowers were smaller. By the end of Cretaceous period, many families with actinomorphic insect-pollinated flowers had appeared, such as buttercups, pinks and heathers.

The wind-pollinated group retained small unisexual flowers, with few parts borne in inflorescences, usually with male and female on the same plant (monoecious), although such breeding system includes less than five per cent of living species, such as oaks, beeches, birches, hazels etc.

At the end of Cretaceous and beginning of the Tertiary period (between 75 and 50 mya), there was a second and much larger adaptive radiation which witnessed the increasing dominance of angiosperms and the appearance of the majority of modern plant families. This was closely associated with the adaptive radiation of specialist insect pollinators and leaf feeders-the butterflies and moths, long tongued flies and bees. Innovation included the fusion of the lower parts of the petals and/or the sepals into a tube and fusion of the carpels, zygomorphic flowers appeared, usually facing sideways rather than upwards and with lower petal or petals forming a lip as a landing platform for insects, Some plants, such as members of thyme family, have fused petals and zygomorphic flowers. These were adaptations for specialised insect pollination and at least in part serve to exclude other visitors. Adaptations for pollination by birds or bats appeared later, mainly derived from specialist-pollinated flowers,

The general processes involved in attaining adaptive radiation, *i.e.* the spread and diversification of angiospcrrns, included fusion of different floral parts, reduction in floral parts, change in symmetry (actinomorphy to zygomorphy), elaboration (in number of flowers) and remoration (evolutionary retrogression). The main trends are outlined in the table below.

Evolutionary Trends in Flowers from the End of Cretaceous to the Early Tertiary (Many trends occurred in parallel in different families; some also happened in reverse).

1.	Radial symmetry	Bilateral symmetry
2.	Separate petals	Fused petals
3.	Large number of floral parts	Fixed small number of floral parts
4.	Large flowers	Small flowers
5.	Carpels inserted above the petals	Carpels inserted below the petals
6.	Carpels free	Carpels fused
7.	Flowers as pollen as food rewards	Flowers as nectars as food rewards
8.	Pollination by unspecialized insects	Pollination by specialized bees/ butter flies / moths, long tongued flies / birds or bats
9.	Insect pollinated species, hermaphrodite flowers	Unisexual flowers
10.	Insect pollinated species	Wind pollinated species

Aggregation of flowers in inflorescence is an adaptative trend in many angiosperm families but it has taken an extreme specialisation in daisy family (Asteraceae) in which there are often two different forms of flower in each inflorescence, the whole aggregation, sometimes of more than 100 flowers, resembling a single flower (capitulum inflorescence).

A few flowers exhibit extreme specialisation in their pollination. For example, in many orchids, each flower needs a single visit for the successful formation of hundreds of seeds, so they become highly selective in the species that they use. Some tropical species have a long spur growing out of the back of the flower with nectar at its base, which only moths with long thin tongues can reach. The European bee orchid group and a few other groups of orchids in other parts of the world, have flowers that resemble the female bee, both in appearance and in scent, each orchid species *(e.g. Ophrys)* resembling a different bee; they are visited and successfully pollinated by the males of that bee species. The figs, a large group of tropical trees and stranglers, have flowers in an inverted inflorescence with flowers opening into a central cavity, surrounded by a solid mass-hypanthodium. The inflorescence can only be penetrated by small wasps through a whole at the tip. The wasps lay their eggs, grow and mate in the inflorescence before collecting pollens and dispersing to another fig. Plant and wasps are totally independent but a kind of interdependence is seen in *Yucca* and moth. Such cases substantiate the parallel evolution of insects and flowers.

More generalised flowers, much more common than the specialists, particularly among the dominant vegetation, are usually pollinated either by wind or by a range of insects and sometimes birds as well. Pollinating insects (and animals) can vary manifold in number from year to year and place to place, so specialisation to one or a few species can be risky.

Specialisation for wind pollination, has nearly always involved a reduction in size and number of floral parts. Some families are nearly all wind-pollinated, *e.g.* grasses, but wind-pollinated species occur in numerous, mainly insect-pollinated families and have evolved many times. Evolution in the reverse direction, from wind to insect-pollination, has rarely occurred.

Evolution of Fruits and Seeds

There occurs some controversy over which fruit type is primitive. Fossil evidence gives few clues, but it is likely that the early fruits were fleshy, as many of the representatives of primitive groups have fleshy fruits, sometimes with outgrowths from the seed (an aril). Trends in the evolution of fruits have gone in many directions-towards larger or smaller fruits or seeds and towards dry dehiscent fruits. But main trend appears to have been for a reduction in size and in number of seeds per fruit. There has been parallel evolution of fruit types in many plant families, *i.e.,* evolution along similar paths in unrelated groups.

Primitive seeds are likely to have been fairly large and rich in endosperm features retained in some specialised large-seeded plants such as coconuts. The small seeds, mainly filled by embryo, seen in many families, are likely to be derived. Some of the most successful families such as grass family (Poaceae) and daisy family (Asteraceae) have one-seeded fruits, but another large family, the Orchidaceae have many hundreds or thousands of tiny seeds per pod, although with very poor germination percentage.

EUGENICS:

It is a set of beliefs and practices that aims at improving the genetic quality of a group of individuals.

Francis Galton was an early eugenicist, coining the term itself and popularizing the collocation of the words "nature and nurture". Eugenics became an academic discipline at many colleges including the British Eugenics Education Society in 1907 and American Eugenics Society in1921.

Edward M. Miller claims that, Eugenic policies could also lead to loss of genetic diversity, in which case a culturally accepted "improvement" of the gene pool could very likely—as evidenced in numerous instances in isolated island populations —result in extinction due to increased vulnerability to disease, reduced ability to adapt to environmental change, and other factors both known and unknown.

In the past, eugenics had more to do with sterilization and enforced reproduction laws. Now, in the age of a progressively mapped genome, embryos can be tested for susceptibility to disease, gender, genetic defects, and alternative methods of reproduction such as *in vitro* fertilization are becoming more common.

SUMMARY

The origin of life on earth can be understood only against the background of origin of universe especially earth. Most scientists believe chemical evolution, i.e., formation of biomolecules preceded the appearance of the first cellular forms of life. The subsequent event as to what happened to the first form of life is a conjectured story based on Darwinian ideas of organic evolution by natural selection. Diversity of life forms on earth has been changing over millions of years. It is generally believed that variations in a population result in variable fitness. Other phenomena like habitat fragmentation and genetic drift may accentuate these variations leading to appearance of new species and hence evolution. Homology is accounted for by the idea of branching descent. Study of comparative anatomy, fossils and comparative biochemistry provides evidence for evolution. Among the stories of evolution of individual species, the story of evolution of modern man is most interesting and appears to parallel evolution of human brain and language.

QUESTIONS

1. Explain antibiotic resistance observed in bacteria in light of Darwinian selection theory.
2. Find out from newspapers and popular science articles any new fossil discoveries or controversies about evolution.
3. Attempt giving a clear definition of the term species.
4. Try to trace the various components of human evolution (hint: brain size and function, skeletal structure, dietary preference, etc.)
5. Find out through internet and popular science articles whether animals other than man has self-consciousness.
6. List 10 modern-day animals and using the internet resources link it to a corresponding ancient fossil. Name both.
7. Practise drawing various animals and plants.
8. Describe one example of adaptive radiation.
9. Can we call human evolution as adaptive radiation?
10. Using various resources such as your school Library or the internet and discussions with your teacher, trace the evolutionary stages of any one animal say horse.
11. Differentiate between homology and analogy.
12. What are the basic principles of Darwin's theory of evolution?
13. Enlist the evolutionary trends in flowers.
14. Define eugenics.
15. Explain natural selection in Europe during industrialization with proper example.
16. Explain the significance of Miller's experiment.

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LECTURE: 3

INTRODUCTION AND CHARACTERISTICS OF PLANT

Taxonomic studies require a perfect knowledge of technical terms for description and identification of the plants. Following are some commonly used terms and their meanings.

HABITAT AND HABIT

- **Habitat:** The immediate environment occupied by an organism (plant), eg. aquatic or terrestrial.
- **Habit:** The general external appearance of a plant, *e.g.* herbs, shrubs or trees.
- **Habitat form:** A plant showing some typical features but can be related to the place where it is growing, such as dwarfing under adverse environment.
- **Annual:** A plant completing its life cycle in a single season, *i.e.*, from seed to germination, reproduction and death, *e.g. Anagalis.*
- **Ephemeral:** A plant which completes its life cycle in a very short time, say within some weeks, *e.g. Chenopodium.*
- **Biennial:** A plant which completes its life cycle in two seasons, *e.g.* radish *(Raphanus sativus).*
- **Perennial:** A plant which grows for several years.
- **Herb:** A plant which has no persistent parts above the ground, *e.g. Chenopodium, Ranunculus, Fumaria* etc.
- **Shrub:** A woody short plant (less than thirty feet) in which side shoots are well developed, so that there is no trunk, *e.g. Lantana.*
- **Tree:** A tall woody perennial plant with a well-marked trunk, *e.g. Eucalyptus, Mangifera, Tectona* etc.

Forms of Trees may be:

(i) **Caudex**-rnain trunk straight, unbranched and columnar, bearing crown of leaves, *e.g. Cocos nucifera* (fig. 14.1A).

(ii) **Excurrent**-rnain trunk keeps on growing but bears lateral branches in acropetal order, giving a conical shape to the tree, *e.g. Polyalthia* (fig. 14.1 B).

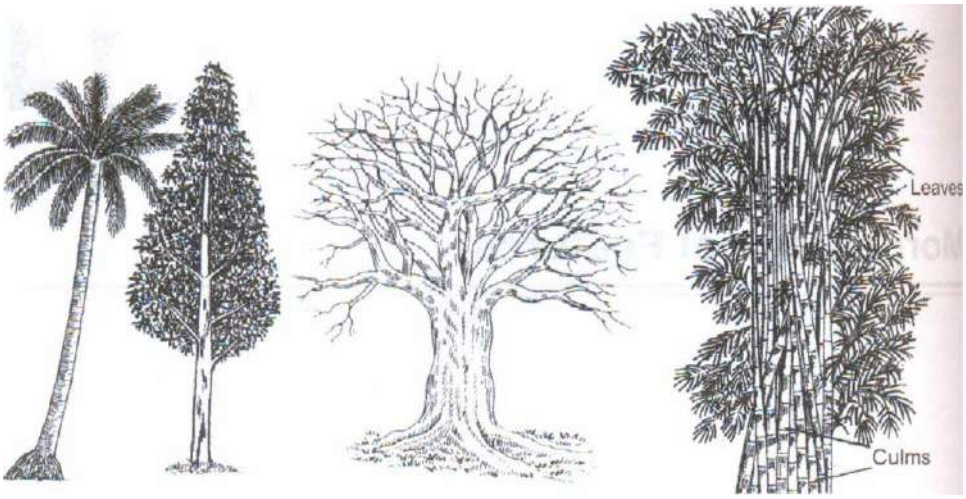


Fig. 3.1 Types of trees. A-caudex, B-excurrent, C--deliquescent and D-culm.

(iii) **Deliquescent**-canopied spreading habit due to suppressed apical bud and dominant lateral buds, *e.g. Mangifera* and *Ficus* (fig. 3.1C). **Culms:** Grass-like strong stem with distinct nodes (solid) and internodes (hollow), may look-like tree, as in bamboo (fig. 3.1 D).

Weak forms

Creeper: Plants with stem growing along the surface of the ground and rooting at its node, *e.g. Hydrocotyle asiatica* (fig. 3.2 A) and *Ipomoea batatas.*

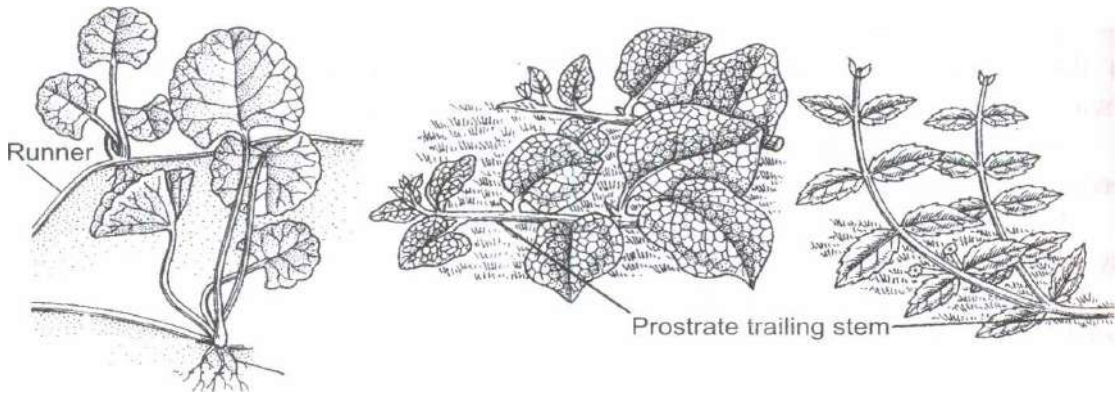


Fig. 3.2 Weak forms of plants. A-creeper *(Hydrocotyle),* B-procumbent *(Basel/a)* and C-decumbent *(Lindenbergia).*

Trailor: A plant which trails over the ground surface by its weak, prostrate and slender stem. A trailer may be : (i) **procumbent,** *i.e.,* trailing flat on the ground, *e.g. Basella* (fig. 3.2B), or (ii) **decumbent.** *i.e.,* trailing on the ground to some distance and then straightens upright. *e.g. Lindenbergia* (fig 3.2C) and *Portulaca* or (iii) **diffuse**, *i.e.,* trailers growing in all directions, *e.g. Boerhaavia.*

Climber: A plant with weak stem which climbs by taking support of neighbouring objects. A climber may be:

(I) Stem Climbers

Twiners, i.e. Climbing by twinning around its support, e.g. *Ipomoea quamaclit* (Fig. 3.3A) or *Dolichos lablab* (Fig. 3.3B)

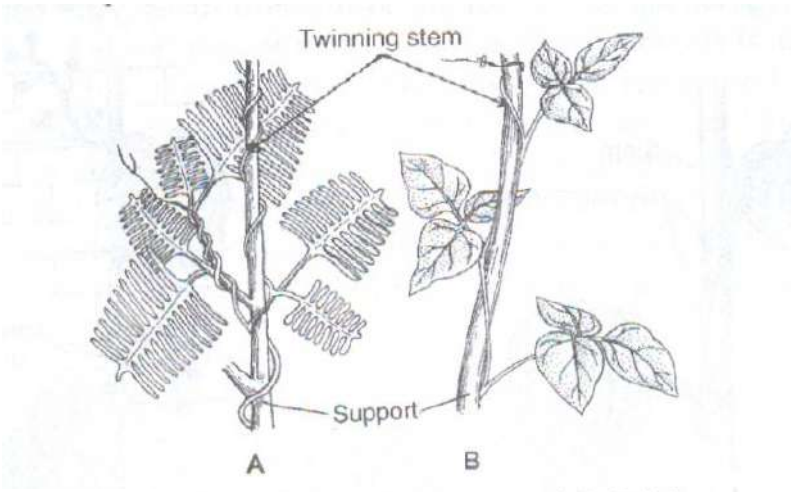


Fig. 3.3 Stem climbers, A-*Ipomoea* and B-*Dolichos*.

(II) Tendril Climbers. Climbing by formation of special wire-like structures twining around to seek support. A tendril may be formed by (i) **the leaf**, e.g. *Lathyrus* (Fig. 3.4A), (ii) **the stem apex or axillary branch**, e.g. *Vitis and Passiflora* (Fig. 3.4B, C).

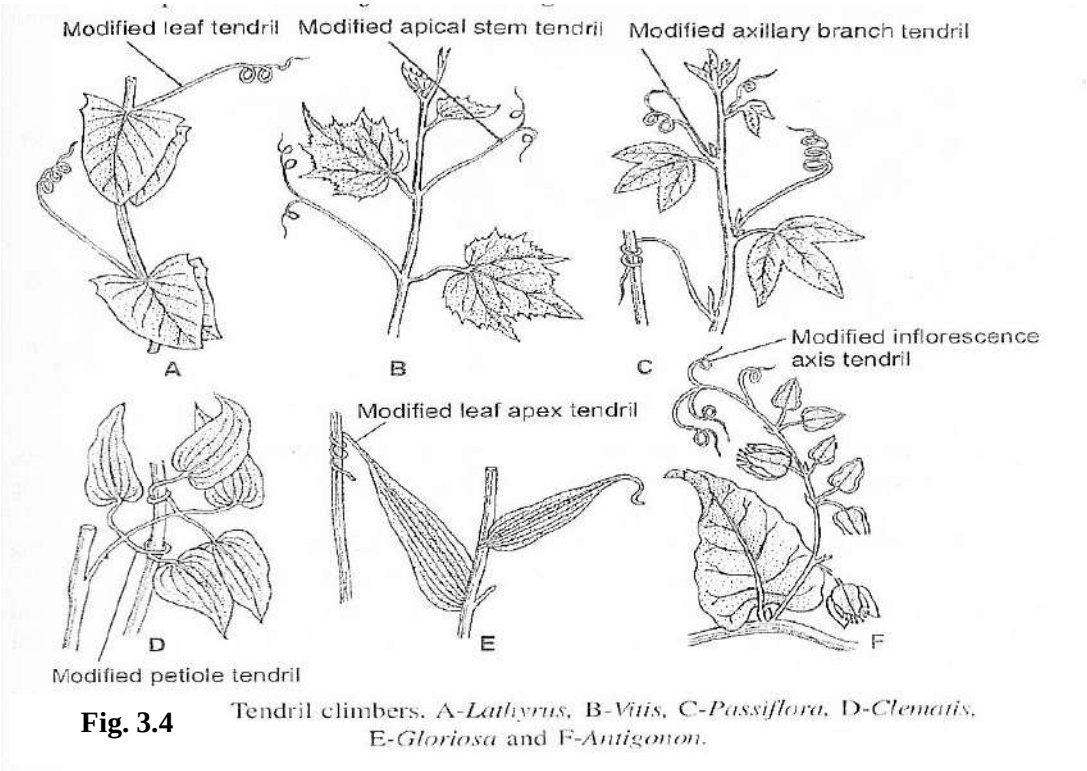


Fig. 3.4 Tendril climbers. A-*Lathyrus*, B-*Vitis*, C-*Passiflora*, D-*Clematis*, E-*Gloriosa* and F-*Antigonon*.

(iii) **The petiole.** E.g. *Clematis* (Fig. 3.4D,) (iv) **the leaf tip**, e.g. *Gloriosa* (Fig. 3.4E) or by (v) the inflorescence axis, e.g. *Antigonon* (Fig. 3.4F)

(III) Root Climbers: Climbing by the formation of adventitious roots arising from the nodes, e.g. *Piper betle* and *P. Longum* (Fig 3.5).

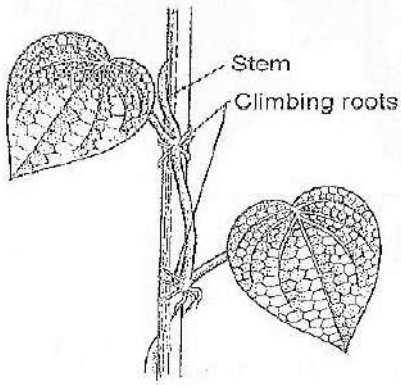


Fig. 3.5 *Piper betle*

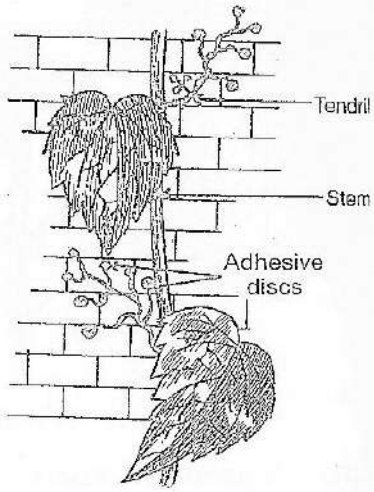


Fig. 3.6 *Ampelopsis*

(IV) Scramblers or Hook Climbers: Climbing by the formation of hooks (e.g. *Artabotrys*) (Fig. 3.7A). or curved prickles (e.g. Rosa) (Fig. 3.7B) and *Lantana (*Fig. 3.7C)

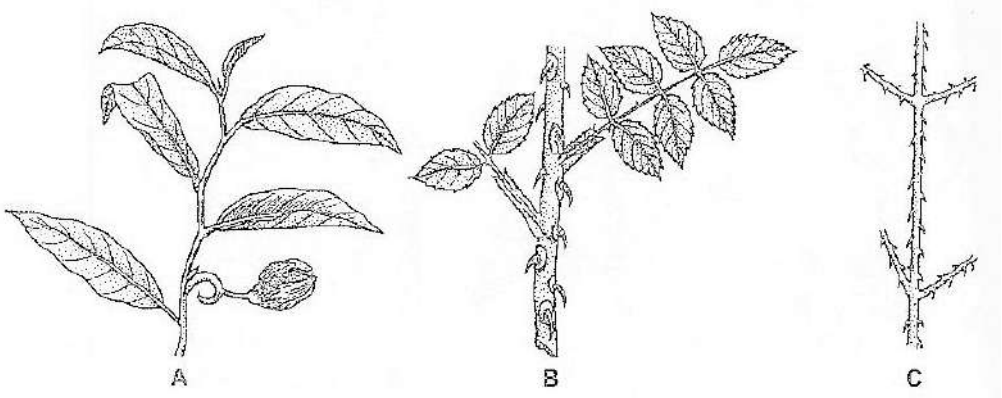


Fig. 3.7 A-*Artabotrys*, B-*Rosa* and C-*Lantana*

(V) Adhesive Climbers. Climbing by the formation of adhesive discs, either by the tendrils as in *Ampelopsis* (fig. **3**.6) or by the climbing roots, *e.g. Hedera helix* (ivy).

(VI) Lianas. Climbing by twinning woody and stout stems which hang down by thick ropes, *e.g. Tinospora, Hiptage, Quisqualis* etc.

Epiphyte: A plant growing on another plant, but not deriving any food from it- It grows on other plant lo gel only mechanical support, e.g. most orchids.

Parasite: A plant living on another organism (or plant) and extracts food from it (called host), *e.g. Cuscvta*.

QUESTIONS

1. Define habitat, habit and habitat form.
2. Differentiate between tree, herb and shrub.
3. Differentiate between epiphytes and parasites.
4. Enlist the different forms of trees with example for each.
5. Enlist the waek forms of plant with example for each.

LECTURE: 4

BINOMIAL NOMENCLATURE AND CLASSIFICATION

(A) PLANT NOMENCLATURE

FUNDAMENTALS OF PLANT NOMENCLATURE

Definitions: Assignment of definite names to plants is called ***plant nomenclature.***

In the present botanical world, the nomenclature involves the principles governed by rules formulated and adopted by International Botanical Congresses. The rules developed by IBC are listed formally in a *code* called International Code of Botanical Nomenclature (Voss *et al,* 1983), abbreviated as ICBN. The major goal of ICBN is to provide one correct name for each *taxon.*

Taxa (singular, *taxon**)*** are the taxonomic groups of any rank. The ascending hierarchy of taxa includes species, genus, family, order, class and division.

Who is a Nomenclaturist?

A nomenclaturist is a taxonomist who assigns names to new taxa, determines the right names for old taxa according to the rules of International Code of Botanical Nomenclature, and finalizes the right name for a specimen according to an established system of classification.

Why is Nomenclature Needed?

Imagine for a few moments about the state of affairs if there are no *names* for all the things we see, make or handle. How strange and chaotic the life would be in such a condition? The entire business affairs of the world would stop, and practically there will be no "give and take" of knowledge. It would also be impossible for all of us to communicate our feelings to others. Practically, the life would stop. Therefore, nomenclature for everything is needed.

COMMON NAMES AND SCIENTIFIC NAMES

Vernacular or *common names* are made up of words from the native language of the country or the region. They may vary in different countries as well as in different regions of the same country. They may be Portuguese words in Portugal; Spanish in Spain; English in England, U.S.A. and Australia; and Hindi, Bangla, Oriya or Tamil, etc. in U.P., West Bengal, Orissa and Tamilnadu, respectively. 'Papita', 'Kela', 'Gazar' and Tamatar, of India are known in U.S.A. as papaya, banana, carrot and tomato, and by other names in Spain. There is therefore no international uniformity in common names.

On the other hand, *scientific names* which are based mainly on Latin language have international uniformity. By the name *Saccharum officinarum*, all botanists of the world would understand that it is sugarcane.

Jones and Luchsinger (1987) have stated that common names present five major problems mentioned in the following table:

S. No.	Common Names	Scientific Names
1.	These are not universal. They vary in different languages.	These are universal and are *recognised* throughout the world.
2.	They do not provide information indicating generic and family relationships.	They provide information regarding these relationships.
3.	A well-known plant may have hundreds of common names.	A well-known plant has only one scientific name.
4.	Sometimes, two or more plants have the Same common name.	Two or more plants always have different scientific names.
5.	Many species do not have any common names.	All known plants have a scientific name.

The scientific name of a plant consists of two separate words. The first word designates the *genus* of the organism and the second word designates the *species.* Details of this two-name system were first given by Linnaeus (1753) in his famous *binomial system of nomenclature.*

BINOMIAL NOMENCLATURE

What is Binomial Nomenclature?

In the earlier days plant names were long and descriptive e.g. in the herbal of Clusius (1383) a species of willow is named *Salix pumila angustifolia altera.* Then, in 1623, Gaspar Bauhin (1560-1624) devised a plan of adopting two names for each plant in his *Pinax Theatri Botanici.* But it was Carolus Linnaeus (1707-1778), the great Swedish naturalist, to whom the actual credit goes for devising and methodically employing the binomial system of nomenclature. Linnaeus employed this system in the first edition of his *Species Plantarum* in 1753. According to this system the scientific name of a plant consists of two Latin or latinized words: (1) The first is the name of the genus, i.e. generic name or *generic epithet,* and (2) the second is the name of the species, i.e. *specific epithet.* For example, the botanical name of sugarcane is *Saccharum officinarum.* The first word *(Saccharum)* designates the *genus* of the plant and the second word *(officinarum)* designates the *species* of this genus.

Generic Name

It is always a noun, and written with a capitalised initial letter and the remainder small. The generic name is also always singular in number. It may have following types of origin:

1. Several generic names may be in honour of the names of well-known persons, e.g. *Theophrasta* in honour of Theophrastus and *Candollea* in honour of A.P. de Candolle.
2. They may be descriptive, with reference to some common characteristics of the included species, e.g. *Cercocarpus* (coiled fruit), *Xanthoxylum* (yellow wood), etc.
3. They may be of poetic or mythological origin, e.g. *Theobroma* (god's food).
4. They may also be the aboriginal name of the plants, e.g. *Betula* and *Quercus* which were the old Greek names for Birch and Oak.

Specific Epithet

According to the 1983 recommendations of the International Code of Botanical Nomenclature (Voss, *et al*, 1983), all specific epithets be written with a small initial letter. But if the specific epithet is derived from common names, or from former generic names, or from a person's name, the initial letter of the epithet may be a capital letter. In the typed or handwritten matter, both the specific epithet and generic names should be underlined. They should be printed in *italics* or *boldface*. The authority, written after the specific epithet, is never underlined.

The specific epithet is often an adjective. According to Article 23 of ICBN, a specific epithet (i) may be a name in honour of a person, or (ii) may be derived from a geographical location, 01 (iii) may originate from an old common name, or (iv) may be derived from some characteristics of the plant, or (v) it may also be named arbitrarily.

Authority

The name of the species is incomplete if it is not followed by full or abbreviated name(s) of the author(s). For example, *Pyrus malus* is incomplete. The complete name is *Pyrus malus* L. where L. is abbreviated for Linnaeus. Citation of the full or abbreviated form of the author is necessary because this will verify the date or time of the first valid publication of the name of a particular taxon.

INTERNATIONAL CODE OF BOTANICAL NOMENCLATURE (ICBN)

What is ICBN?

The *International Code of Botanical Nomenclature* (ICBN) is the set of rules and recommendations dealing with the formal *botanical names* mat are given to plants. Its main aim is that each taxon or taxonomic group of plants has only one *correct botanical name* and that is accepted throughout the world. Two main principles of ICBN are listed below:

1) *Priority* is the guiding principle in botanical nomenclature; Tim ICBN sets the formal starting date of plant nomenclature at 1 May, 1753, which is the publication date of *Species Plantarum* by Linnaeus.
2) Each botanical name is fixed to a taxon by a *type,* which is almost invariably dried plant material usually deposited and preserved in a herbarium.

Very few hard rules of TCBN apply above the taxonomic rank of family. Each new edition of ICBN supersedes the earlier editions and is retroactive back to 1753.

Who can Change ICBN?

The TCBN can only be changed by an International Botanical Congress (IBC), with the International Association for Plant Taxonomy providing the supporting *infrastructure.*

To which Organisms does ICBN Apply?

The ICBN applies not only to plants, as they are now defined, but it also applies to other organisms studied traditionally by botanists, e.g., Cyanobacteria (blue-green algae), fungi, photosynthetic protists and taxonomically related non-photosynthetic groups. For fossils, there are special provisions in ICBN.

Whether ICBN is Applicable to Cultivated Plants?

No. For naming of cultivated plants, there is a separate code called the International Code of Nomenclature for Cultivated Plants (ICNCP).

History of ICBN

Linnaeus in 1737 and again in 1751 proposed the elementary rules of naming plants in his *Philosophia Botanica.* Then in 1813, A.P. de Candolle set forth a detailed set of rules regarding plant nomenclature in his *Theorie elementaire de la botanique.* The same rules of Linnaeus, A.P. de Candolle and his son Alphonse de Candolle were later evolved into our present *International Code of Botanical Nomenclature* (ICBN).

Alphonse de Candolle convened the *First International Botanical Congress* in 1867 in Paris. It was attended by the botanists of several countries. They adopted a set of rules of plant nomenclature, most of which were proposed by A. de Candolle. These excellent rules of plant nomenclature are known as *de Candolle rules* or *Paris Code* of 1867. Subsequent meetings of the International Botanical Congress were held in 1892 *{Rochester Code),* 1905 *(Vienna Code),* 1907 *(American Code)* and 1910, but a general agreement, regarding the internationally acceptable rules of plant nomenclature, was reached in the meeting of the IBC at Cambridge in 1930. Lawrence (1951) has discussed the detailed history of the Code and may be quoted that in 1930

at the Cambridge Congress "for the first time in botanical history, a code of nomenclature came into being that was international in function as well as in name". This code is called the *International Code of Botanical Nomenclature.* Scientists in the International Botanical Congresses suggest the modifications or amendments which are incorporated in the ICBN on a regular basis.

The international code of botanical nomenclature code of botanical nomenclature, 1983, was adopted by the Thirteenth International Botanical Congress, Sydney (Australia) in August 1981, and the chairman of the editorial committee was E.G. Voss. ICBN is divided into three parts, i.e. *Principles, **Rules*** and ***Recommendation***.

Principles of ICBN

The philosophical basis of the Code is formed by the following six principles:

1. Botanical nomenclature is independent of zoological nomenclature.
2. The application of names of taxonomic groups is determined by means of nomenclatural types.
3. The nomenclature of a taxonomic group is based upon priority of publication.
4. Each taxonomic group with a particular circumscription, position, and rank can bear only one correct name, the earliest that is in accordance with the Rules, except in specific cases.
5. Scientific names of taxonomic groups are treated as Latin regardless of their derivation.
6. The Rules of nomenclature are retroactive unless expressly limited.

Rules and Recommendations of ICBN

According to the ICBN (1983) the detailed provisions of the Code "are divided into Rules, set out in Articles, and Recommendations". As mentioned under point No. 4 of the Preamble of 1983 ICBN 'The object of the Rules is to put the nomenclature of the past into order and to provide for that of the future; names contrary to a rule cannot be maintained".

As mentioned under point No. 5 of the *Preamble* of 1983 ICBN 'The *Recommendations* deal with subsidiary points, their object being to bring about greater uniformity and clearness, especially in future nomenclature; names contrary to a recommendation cannot, on that account, be rejected, but they are not examples to be followed.**

The Rules and Recommendations of ICBN apply to all organisms treated as plants (including fungi but excluding bacteria), whether fossil or non-fossil. Nomenclature of bacteria is governed by a separate code called International Code of Nomenclature of Bacteria (1CNB).

It is stated under point No. 10 of ICBN (1983) that the latest "edition of the Code supersedes all previous editions.

Some Later Codes

St. Louis Code (1999)

The 16th International Botanical Congress was held at St. Louis, Missouri, USA in August 1999, and the International Code of Botanical Nomenclature adopted in this Congress is called St. Louis Code. Botanists of 85 nations attended this Congress. Hectic discussions were made mainly in view of the facts that "as many as two-thirds of the world's 3,00,000 plant species are in danger of extinction in nature during course of the 21st century**, and almost every aspect of the life of human beings depends on plants. Botanists made some resolutions and recommendations, of which some major ones are under mentioned:

(A) Resolutions Six resolutions were passed in this International Botanical Congress at St. Louis.

(1) Resolution I Botanists agreed on 10 major aspects in this resolution, of which some arc mentioned below. They call for:

(i) "the establishment of a new coordinating body associated with United Nations to monitor the status of plants throughout the world, detect those in most danger, and take steps to conserve them in nature, in botanic gardens, or in gene banks";

1. "Securing additional funds for study of plants throughout the world";
2. "Making all the information about plants .generally available on the internet";
3. Placing additional emphasis on the importance of the "survival of biodiversity throughout the world";
4. Maintaining "an active census of the status of each country's plants" at national level;
5. "Actively developing and implementing plans to conserve the world's economic plants ";
6. "Devoting special attention to the conservation of medicinal plants ....";
7. "Funding internationally an ongoing program of research on plant population biology..."

(2) Resolution II Botanists of the 85 nations attending this Congress call on governments and policy makers to:

1. "Recognize the importance of developing and maintaining scientific expertise, provide resources for the education and training of scientists, and maintain career opportunities".... especially in biological sciences;
2. 'Actively develop floras and detailed accounts of plants of all regions
3. "Support collaborative program between and among developed and developing countries";
4. "Ensure high priority be given to the maintenance of botanical museums, herbaria, libraries, gardens, living plant collections and gene banks.":

(3) Resolution III Botanists in this resolution resolved to:

(i) "increase our knowledge of diversity and relationships of plants ..." and "to make that knowledge accessible to all";

(ii) "advocate to policy makers the relevance of plant sciences ....", and thus "maintain the quality of human life on earth";

(4) Resolutions IV to VI. These three resolutions are regarding the (i) importance and programmes of biodiversity (Resolution IV); acceptance of the decisions of Nomenclature Section of the Congress (Resolution V); and selection of sites for future Congresses to facilitate the "attendance of botanists from all regions of the world" (Resolution VI).

(B) Recommendations Several recommendations have been made in ICBN in the *St. Louis Code* by botanists attending the XVI International Botanical Congress, of which only some are under mentioned:

1. The scientific names under the jurisdiction of the *Code,* irrespective of rank, "are consistently printed in *italic type.* The *Code* sets no binding standard in this respect, as typography is a matter of editorial style and tradition, not of nomenclature".
2. To set off scientific names even better, the use of *italics* for technical terms and other words in Latin, "has now been abandoned".
3. For style of bibliography, the titles of the books are "abbreviated in conformity with *Taxonomic* d *Literature,* ed. 2 by Stafleu & Cowan (1976-1988; with supplements by Stafleu & Mennega, 1999-2000)".
4. For style of bibliography the *journal titles* are abbreviated in conformity with *Botanico-periodicum-huntianum* (1968) and its supplement (1991).
5. Author citations of scientific names are standardized in conformity with *Authors of Plant Names* by Brummitt and Powell (1992).
6. The single largest area of change in *St. Louis Code* concerns typification, where many pro-posals have been made on *Lectotypification (for details refer to original code).*
7. All reference to registration of new botanical names, to become "mandatory from a future date, be deleted from the Code ....".
8. Fossil plant nomenclature underwent profound changes in St. Louis Code *(for details refer \ to original Code).*
9. Fungal nomenclature was only affected in a marginal way by decisions of the St, Louis Congress.
10. One new term *"isonym"* has been introduced into the Code, "defined to mean the same name used independently by different authors at different times
11. In the field of terminology, the terms "homotypic synonym", "heterotypic synonym" and "replacement names" were accepted as optional equivalents of the earlier "nomenclatural synonym", "taxonomic synonym" and "avowed substitute".
12. The terminations *-viridae, -virales, -virales,* and *-virus* were "outlawed for names of sub-classes orders, subtribes and genera, respectively.

Vienna Code (2005)

The latest XVII International Botanical Congress was held in Vienna in 2005 (XVI being at St. Louis, Missouri, USA), and the International Code of Botanical Nomenclature accepted in this Congress is called *Viena Code*. It is written entirely in English and has been translated in several other languages. One of the reasons invoked for the choice of Vienna as the site of XVII Congress was that the second International Botanical Congress had been held there exactly 100 years earlier, i.e., in 1905. It was in this XVII Congress in 1905 that the first internationally developed rules governing nomenclature of plants were accepted, and these rules were recognised as *Vienna Rules*. The XVII IBC held on 12-16 July, 2005 at Vienna was attended by 198 registered members carrying 402 institutional votes. On the other hand, St. Louis Congress at Missouri, held six years ago in 1999 was attended by 297 members carrying 494 institutional votes.

The Vienna Code does not differ substantially in overall presentation and arrangements from the St. Louis Code, and the number of Articles remains the same. Some selected additions and recommendations of Vienna Code are listed below:

1. The most notable feature of Vienna Code "is the inclusion for the first time a Glossary, which appears in Appendix VII. This Glossary is very tightly linked to the wording of the Code, and "only nomenclatural terms defined in the Code can be included".
2. The scientific names under the jurisdiction of **Code,** irrespective of rank, are consistently printed in **italic type.** The **"Code** sets no binding standard in this respect, as typography is a matter of editorial style and tradition not of nomenclature".
3. The titles of the books in bibliographic citations are abbreviated in conformity with "Taxonomic Literature, ed. 2, by Stafleu and Cowan (1976-1988; with 6 supplements by Stafleu and Mennega, 1992-2000)", but with capital initial letters.
4. For titles of the journals in bibliographic citations, the abbreviations follow the *Botanico-periodicum-huntianum*, ed. 2 (2004).
5. Author citations of scientific names appearing in the Code are "standardized in conformity with Authors of Plant Names, by Brummitt & Powell (1992)"; these are "also adopted and updated by the International Plant Names Index".
6. "Perhaps the most important single decision incorporated into the Vienna Code was to deal with what many have recognized as a bomb waiting to explode, the publication status of theses submitted for a higher degree". The Code decided that "no independent non-serial publication stated to be a thesis submitted for a higher degree on or after 1 January 1953 would be considered an effectively published work without a statement to that effect or other internal evidence" (for details, readers should consult the original Code).'

7. Regarding valid publication of names, Vienna Code made it clear that "names be composed only of letters of Latin alphabet, except as otherwise provided in the Code."
8. St. Louis Code accepted that all fossil taxa should be treated as morphotaxa. In Vienna Code, this has not been considered appropriate. A distinction between a morphotaxon and a regular fossil taxon is now established in Vienna Code.
9. In Vienna Code, it was agreed that "the starting date for valid publication of suprageneric names of spermatophytes, pteridophytes and bryophytes be 4 August 1789, the date of publication of Jussieu's Genera Plantarum".
10. Vienna Code also established that parenthetic author citation is not permitted at suprageneric ranks.
11. Four family names, previously overlooked in Berchtold and Presl's rare, later, multivol-umc work of the same name (1823-1825) have been updated: Aquifoliaceae, Cornaceae, Potamogetonaceae and Punicaceae.
12. Under the concept of "minimum invalidity" (Art. 33.10), the "rules determining when a rank is denoted by a misplaced term (and hence not validly published) were clarified and made more practical".
13. From 1 January, 2007, a new combination, a new generic name with a basionym, or an allowed substitute "is not validly published unless its basionym or replaced synonym is cited".
14. Vienna Code establishes that only if validly published does a name have any status; indeed, unless otherwise indicated, the word "name" in the Code means a name that has been validly published".

Future Botanical Congress and Legality of ICBN

The International Code of Botanical Nomenclature (ICBN) is published under the authority of the j International Botanical Congresses (IBC). The next meeting of the IBC will be held in Melbourne, Australia, from 23—30 July, 2011. Similar to other international codes of nomenclature, ICBN also has no legal status and is dependent on the voluntary acceptance of its rules by scientists in general and botanists in particular.

SOME IMPORTANT RULES OF NOMENCLATURE

1. **Ranks and Endings of Taxa** In an accepted system of classification, each individual plant is treated as belonging to a number of taxa of different ranks. Generally, the species is considered as the basic unit of classification. Other main ranks in the flowering plants in an ascending order are genus, family, order, subclass and class. However, ICBN (Voss *et al,* 1983) has mentioned 22 different ranks and some standardized grammatical endings *(suffixes)*

for the ranks from division down to the level of genus. All these ranks are mentioned under Article No. 1.5 (Table 1.1, Chapter 1).

2. **Principle of Priority** One plant might have been described under different botanical names by various plant nomenclaturists in different parts of the world. But, according to the "principle of priority" "each taxon is to be known by its earliest name". For example, *Cleome gynandra* Linn, was first described and named by Linnaeus in 1753. Then he himself changed its name as *Cleome pentaphylla* Linn. In 1824 de Candolle recognized three separate genera *(Cleome, Polanisia* and *Gynandropsis)* and named the Linnean genus as *Gynandropsis pentaphylla* (Linn.) DC. litis in 1960 merged *Gynandropsis* and *Cleome* into one genus, i.e. *Cleome.* So according to the "Principle of priority", the oldest name *(Cleome gynandra* Linn.) is the correct valid name.

Because of Principle of Priority, names of several plants have now been changed.

3. **Type Method** The type method is a legal device to provide the correct name for a taxon. A *type specimen* is a herbarium sheet (or rarely a drawing or a photograph) of a specimen which was used by the author to provide its authentic description. According to Article 9 of ICBN the type of a genus is a species (e.g. the type of genus *Vernonia* is *V. noveboracensis* (L.) Michx.), and the type of a family is a genus (e.g. *Aster* is the type genus of Asteraceae). Several *kinds of types* designated by ICBN are undermentioned:

   i. Holotype It is a specimen used by the author in the original publication as the nomenclatural type.

   ii. Isotype It is a duplicate specimen of the holotype, i.e. from the same collection, with the same locality, date and number as the holotype.

   iii. Lectotype It is a specimen selected by a competent worker from the original material studied by the author of the species, when no holotype was designated **or when the holotype has been destroyed or lost.**

   iv. Neotype It is a specimen selected to serve as a substitute for the holotype when all material, on which the name of the taxon was based, is missing.

   v. Nomenclatural Type It is that element with which the name of a taxon is permanently associated.

   vi. **Syntype** It is one of the two or more specimens cited by an author of a species when no holotype was designated; or, a syntype is any one of the two or more specimens originally designated as types.

   vii. Paratype or "Co-types It is a specimen other than isotype or holotype. If two or more specimens have been cited as types by the author, the remaining cited specimens are called *"Co-types"* or *paratypes.*

viii. Topotype It is a specimen collected from the same locality from where the holotype was *collected.*

4. **Synonyms and Related Definitions** A name rejected due to misuse or difference in taxonomic judgement is called **synonym.**

   A specific or intraspecific name which has priority and is retained when transferred to a new taxon, is called a **basionym.**

   A case in which two or more identical names are based on different types, of which only one can be a legitimate name, is called a **homonym.**

   An illegitimate binomial, in which the name of the genus and the name of the species is the same, is called a **tautonym,** e.g. *Armoracia armoracia* (L.) Britton.

   An automatically created legitimate tautonym for infraspecific or infrageneric taxa is called an **autonym,** e.g. *Hypericum* subgenus *Hypericum* section *Hypericum.*

5. **Citation of Author** Some of the rules related to author citation are undermentioned:

   i. Original Author The name of a taxon is complete and accurate only when it is followed by a full or abbreviated form of the author(s) who first validly published the concerned name, e.g. *Liliaceae* and *Lilium superbum* are incomplete; the complete names are *Liliaceae* Adans. and *Lilium superbum* Linn.

   ii. Joint Author If two authors have jointly published the name of a taxon, the names of both the authors should be cited and linked by the words *et* or & e.g. *lllicium griffithi* Hook & Thorns (or Hook et Thorns).

   iii. Rank Alteration When a taxon of a lower rank is upgraded in a higher rank but retains its name, the author's name who published it first should be cited in the bracket It is to be followed by the name of the author who made the alteration, e.g. Allioni raised the rank of variety *Medicago polymorpha* var. *orbicularis* L. to the species rank. Therefore, it becomes *Medicago orbicularis* (L.) All.

   iv. Name Proposal When the name of a taxon is proposed but not validly published by one author, and is later on validly published by another, the word *ex* should be used as a connecting link between the name of the former author and the name of the subsequent author, e.g. *Gossypium tomentosum* Nutt ex Seem.

6. **Names of Cultivated Plants** Wild plants brought under cultivation retain their original names.

7. **Latin Diagnosis** The diagnosis, details and description of new taxa published before 1st January, 1955 were accepted by ICBN as valid, irrespective of the language. After this date the description of any new taxa would be considered valid only if accompanied by Latin diagnosis.

8. **Effecttve and Valid Publication** The publication of new names and description are effective and considered valid only when they are distributed in a printed form to the general public or to at least ten well-established botanical institutions.

A validly published names, as specified in the ICBN, is the one in which the basic provisions are (1) effective publication, (2) publication in the form specified for the name of each category of taxa, (3) publication with a description, or a reference to a previously published description, of the taxon to which the name applies, (4) accompanied by a Latin description or by a reference to a previously and effectively published Latin description of the taxon, and (5) an indication of the nomenclatural type. On the other hand, an *effectively published name* is the one published in printed matter generally available to botanists.

9. **Choice of Names when the Taxon Rank is Changed** When the rank of a taxon is changed *(viz.* a species becomes a genus or *vice-versa)* the earliest legitimate name in its new rank is its correct name.

10. **Choice of Names when same-rank Taxa are United** When two or more taxa of the same rank *(viz.* two or more genera, two or more species, etc.) are united into one, the oldest legitimate name of these taxa would be retained as the name of the united taxon.

11. **Retention of Names of Divided Taxa** When a genus or a species is divided into two or more genera or species, respectively, the original name of the genus or species must be retained.

12. **Retention of Names of Taxa on Transference** When a subdivision of a genus is transferred to another genus, or a species is transferred to another genus without the change of the rank, the original legitimate name must be retained. For example, *Hydrocotyle asiatica* L., on transference to genus *Centetta,* must be named as *Centella asiatica* (L.) Urban.

13. **Rejection of Names** Names of taxa must be rejected in the following conditions:

- **i.** When the names are illegitimate (i.e. if it is a tautonym, later homonym, rejectable generic name, nomenclaturally superfluous, etc.).
- **ii.** When the names give different meanings, and become a permanent source of confusion.
- **iii.** When the characters of the name of the taxon are derived from two or more different elements.
- **iv.** When the generic names coincide with a morphological term, or are unitary designations to species, or are words not intended as names.
- **v.** When the specific names are tautonyms, or are published without any consideration of binomial system, or are words not intended as names.

14**.** **Names of Different Taxa** According to the International Code of Botanical Nomenclature (1983) the following should be the pattern of naming different taxa:

- **i.** Genera and higher ranks should be *monomials,* e.g. *Aesculus* L., *Rosa* L., Rosaceae Juss.
- **ii.** Species should be *binomials,* e.g. *Gossypium tomentosum* Nutt.

iii. Subspecies should be *trinomials,* e.g. *Hibiscus moscheutos* ssp. *Palustris* (L.) Clausen.

iv. Varieties should be quadrinomials, e.g. *Lilium catesbaei Walter ssp.* Catesbaei *var*. longii *Fernld.*

(B) BOTANICAL NAMES

Botanical names are either Latin words or words that have been latinized from Greek or some other language.

The name of a species is a ***binomial*** and consists of a generic name and a specific epithet. A specific epithet is the second part of the binomial. However, one must be quite clear about the fact that it is wrong to use the specific epithet alone to designate a particular species; it must always be used with a generic name to form the binary combination for that species. The specific epithets are formed from nouns, adjectives, etc. and may join these words with a large number of prefixes and suffixes.

COMMON PREFIXES USED IN SPECIFIC EPITHETS

Some Latin prefixes of *numbers* **are as follows:**

1. **uni-(L.):** *uniflorus* **(one-flowered)**
2. **bi-(L.):** *bifoliatus* **(two-leaved)**
3. **tri-(L.):** *triangularis* **(with 3 angles)**
4. **quadri-(L.):** *quadrangularis* **(with 4 angles)**
5. **quinque-(L.):** quinquefolius **(5-leaved)**
6. **sex-(L.):** *sexangularis* **(6-angled)**
7. **septem-(L.):** *septemlobus* **(7-lobed)**
8. **octo-(L.):** *octoflorus* **(8-flowered)**
9. **noveme-(L.):** *novemneris* **(with 9 nerves) 10. decum-(L.):** *decumlobus* **(with 10 lobes)**

Some of the Greek prefixes of numbers include *mon-* **(for one, e.g.** *monandra), di-* **(for 2),** *tri-* **(for 3),** *tetra-* **(for 4),** *penta-* **(for 5),** *hex-* **(for 6),** *hepta-* **(for 7),** *octo-* **(for 8),** *ennea* **(for 9) and** *deca-* **(for 10, e.g.** *decapetalus).*

Some of the other common prefixes of numbers are *amphi-* **(Gr.): for two kinds;** *diplo-* **(Gr.): for double;** *haplo-* **(Gr.): for single;** *multi-* **(L.): for many;** *poly-(Gr.)* **for many;** *a-* **or** *ab-* **(L.): away from;** *ecto-* **(Gr.): outside;** *endo-* **(Gr.): inside;** *inter-* **(L.): between, and;** *intra-* **(L.): within.**

COMMON SUFFIXES USED IN SPECIFIC EPITHETS

Some of the common suffixes along with one example of each of them are undermentioned: -aceus: *crustaceus;* **-alis:** *digitalis',* **-aris:** *angularis;* **-arium:** *aquarium;* **-aticus:** *aquaticus;* **-estris:** *campestris;* **-eus:** *roseus;* **-ilis:** *sexitilis; -osus: foliosus.*

PLANT PARTS USED AS EPITHETS

Almost all plant parts, including root, stem, leaf, bud, flower, fruit and seeds, have been used as names of specific epithets. Some of the specific epithets, along with the related plant parts in parenthesis, are under-mentioned:

receptaculum (for receptacle), *sepalum* (for sepals), *carpellum* (for carpel), *loculus* (for locules), *stylus* (for style), *petalum* (for petals), *discus* (for disc), *ovarium* (for ovary), *ovulum* (for ovule), *pediceUus* (for pedicel), *pistilium* (for pistil), *fructus* (for fruit), *sperma* (for seed), *folium* and *phyllon* (for leaf), *rhiza* (for root), *caulos* (for stem), etc.

SPECIFIC EPITHETS LINKED WITH COLOUR

Some of the specific epithets linked with colour, along with the name of the colour in the parenthesis, are under-mentioned alphabetically:

albicans (whitish), *albus* (white), *atrovirens* (dark green), *aureus* (golden yellow), *calcareus* (chalky white), *candid us* (shining white), *croceus* (saffron yellow), *flavidus* (slightly yellow), *flavus* (pale yellow), *fulvus* (dull yellow), *glaucus* (grey-green), *luteolus* (pale yellow), *niger* (black), *niveus* (snow white), *purpureus* (purple), *roseus* (rosy), *violaceous* (Violet), *virens* (green) and, *viridis* (green).

SPECIFIC EPITHETS LINKED WITH GEOGRAPHY

Some of the geography-linked specific epithets, along with their related geographical places in parenthesis, are undermentioned alphabetically:

africanus (of Africa), *americanus* (of America), *arabicus* (of Arabia), *argentinus* (of Argentina), *asiaticus* (of Asia), *australiensis* (of Australia), *austriacus* (of Austria), *brasiliensis* (of Brazil), *canadensis* (of Canada), *chinensis* (of China), *cubensis* (of Cuba), *europaeus* (of Europe), *germani-cus* (of Germany), *helveticus* (of Switzerland), *indicus* (of India), *italicus* (of Italy), *mexicanus* (of Mexico), *sinensis* (of China), *virgnicus* (of Virginia) and, *zeylanicus* (of Ceylon).

SPECIFIC EPITHETS LINKED WITH SIZE

Some of size-linked epithets are mentioned below alphabetically:

altus (altitude or tall), *exaltatus* (very tall), *giganteus* (gigantic or very large), *grandis* (large), *humilis* (dwarf), *major* (greater), *minor* (less), *minutus* (very small), *procerus* (very tall), *pumilus* (dwarf) and, *robustus* (stout or robust).

SPECIFIC EPITHETS JINKED WITH HABIT

Epithets, along with the name of the related habit in parenthesis, are undermentioned alphabetically: *arborescens* (arborescent), *dichotomus* (dichotomous), *erectus* (erect), *furcatus* (forked), *prostratus* (prostrate), *ramosus* (branched), *repens* (creeping) and, *stoloniferus* (stoloniferous).

SPECIFIC EPITHETS LINKED WITH HABITATS

Some of such epithets, along with the name of the related habitat in the parenthesis, are listed below alphabetically:

amphibius (living both on land and in water), *aquaticus* (living in water), *arvensis* (growing in ploughed field), *campestris* (of field), *hypogeus* (underground), *lacustris* (of ponds or lakes), *litto-ralis* (growing on seashores), *maritimus* (of sea), *montahus* (of mountains), *palustris* (of swamps), *rupestris* (on rocks), *sativus* (cultivated), *sylvaticus* (of woods), *sylvestris* (growing in woods) and, *terrestris* (growing in dry soil).

(C) PHYLOCODE: A NEW SYSTEM OF NOMENCLATURE

WHAT IS PHYLOCODE?

Recently, Cantino and de Queiroz (2001) proposed a new code for naming organisms by clear "reference to phylogeny (ancestry and descent), rather than on the basis of the Linnaean hierarchy of taxonomic categories (species, genus, family, and so on)", as stated by Robinson and Kommedahl (2002), and this "new code" has been named by then as *"Phylocode"*. They also proposed a new term *"clades"* in this code. According to them, "clades" is a "group (s) of species comprising a common ancestor and all its descendants". Clades are the constituents of the "free *of life"*. All clades should have explicit and unambiguous names that do not change with time. The current systems of nomenclature are based on Linnaean hierarchy, and they do not "boast such immutability".

The International Code of Phylogenetic Nomenclature is known in short as *"Phylocode"*. It is a developing "draft for a formal set of rules governing phylogenetic nomenclature". The current version of Phylocode is specifically designed "to regulate the naming of clades, leaving the governance of *species* names up to the rank-based codes".

How has Phylocode Come into Existence?

Phylocode is not a new idea. It is actually "based on ideas presented in the literature since the late 1980s and, more formally, on the outcome of a workshop held at Harvard University in August 1998" (Robinson and Kommedahl, 2002). In this workshop, a draft proposal was put forward, and this draft covers only the naming of clades. It was also decided in this workshop

that "rules governing species names will be added later". However, as a temporary measure, "Linnaean binomial nomenclature is used in the draft Phylocode where species names are needed".

How are the Species Named in Phylocode?

As mentioned above under Article 8.14.1, the final rules governing species names have not been decided yet. According to Robinson and Kommedahl (2002), "the form that species names should take hi the Phylocode" is still controversial. Cantino *et al.* (1999) earlier presented 13 possibilities for naming species phylogenetically and compared these methods with each other and also with the Lipiaean *system". It is,* however, for the scientific community to finally decide whether or not the "Phylocode should become the sole code governing the names of the taxa" (Robinson and Kommendahl, 2002).

What is the Basic Difference between Phylocode and Linnaean Binomial Nomenclature?

The fundamental characteristic "that distinguishes the Phylocode from the conventional hierarchic nomenclatural systems is its *ranklessness"* according to Robinson and Kommendahl (2002). The proposed Phylocode will cover the naming of clades and species, but in this Code, these terms will refer not 10 ranks but to different kinds of biological entities. It is so because in Phylocode "both (clades and species) are the products of evolution that are discovered, rather than created, by systematists, and both have an objective existence regardless of whether they are named*' (Cantino and de Queiroz, 2001).

What would be the Starting Date for Phylocode?

Regarding the starting date for Phylocode, Robinson and Kommedahl (2002) stated that the "starting date for the new Code, which has not yet been decided, will coincide with the publication of a companion volume providing definitions of widely used clade names".

What does Phylocode Advisory Group now want from the Scientific Community?

There is an advisory group which is now working on formulation and implementation of Phylocode. This group is now coordinating work and seeking *comments* and ideas concerning this proposal from as many people as possible. Anybody interested is welcome to review the current draft of Phylocode and communicate it to the Phylocode Advisory Committee.

PRINCIPLES OF THE PHYLOCODE

The proposed Phylocode is based on certain principles. It allows freedom of taxonomic opinion with reference to hypotheses about relationships. It only deals how the names are to be applied with reference to a given phyiogenetic hypothesis. As published in Division 1 (Principles) of Phylocode, the five basic principles of Phylocode are reference, clarity, uniqueness, stability, and phyiogenetic context.

1. *Reference* The most basic purpose of names of taxon is to "provide a means of referring to

taxa, as opposed to indicating their characters, relationships, or membership".

2. *Clarity* The names of taxon should be "unambiguous in their designation of particular taxa. Clarity in nomenclature is achieved through explicit definitions.
3. *Uniqueness* For promoting clarity, "each taxon should have only one accepted name, and each accepted name should refer to only one taxon".
4. *Stability* During course of time, the names of taxa should not change. "As a corollary, it must be possible to name newly discovered taxa without changing the names of previously discovered taxa". There should, therefore, be a complete stability in the names of taxa.

(5) *Phylogenetic context.* The concern of Phylocode is only with the "naming of taxa and the application of taxon within a phylogenetic context".

PHYLOCODE: AN OVERVIEW

The phylogenetic nomenclature will be regulated by the Phylocode because the latter will provide rules for the following:

1. How to decide which combinations of names and definitions will be considered validly published *(for details, refer to Chapter II of Phylocode)!*
2. Which of the names and definitions will be considered homonyms or synonyms *(for details, refer to Articles 13 and. 14)1*
3. Which one of a set of homonyms or synonyms will be finally considered vaiId? Furthermore, the Phylocode will only allow:
   (i) The naming of clades *(for details, refer to Article 1.1),* and
   (ii) The use of specimens, species, and amorphics as specifiers *(for details, refer to Article 11).*

REGISTRATION DATABASE OF PHYLOCODE

RegNum

The future of the Phylocode is still undecided. If and when it is finally implemented, the "Phylocode will be associated with a registration database called *RegNum.* The RegNum will store the names of all clades and definitions that will be considered potentially valid".

The utility of RegNum will be to "provide a publicly-usable tool for associating clade names with definitions". In the latter stages, this will be "associated with sets of subtaxa or specimens through phylogenetic tree databases (such as *TreeBASE)".* RegNum will also be an important tool in taking a decision that "which one of a number of synonyms or homonyms will be considered valid".

MAIN EVENTS IN THE HISTORY OF PHYLOCODE

1. As mentioned earlier under Article 8.14.1, the idea of Phylocode came as an outcome of a workshop of systematists held at Harvard University in August 1998. An advisory group of leading systematists was formed in this workshop.
2. In April 2000, these systematists prepared a draft of Phylocode- and made it public on the *web*. They also invited comments from the systematists globally.
3. In July 2002, a second workshop on Phylocode was held at Yale University, USA. Several modifications were made in the rules and recommendations of Phylocode in this workshop.
4. From July 6,2004 to July 9, 2004, the First International Phylogenetic Nomenclature Meeting took place in Paris (France). It was attended by about 70 systematists and evolutionary biologists from 11 nations. A society was formed, namely *International Society for Phylogenetic Nomenclature* (ISPN). An advisory group was formed to have a complete control on the development of Phylocode.
5. From June 28, 2006 to July 2, 2006 the Second International Phylogenetic Nomenclature meeting took place at Yale University, USA.
6. From July 21, 2008 to July 23, 2008, the Third International Phylogenetic Nomenclature meeting was held at Dalhousie University, Halifax, Nova Scotia, Canada.

FUTURE OF PHYLOCODE

Still there exists some definite criticism of the Phylocode, and therefore, the Code as such is still controversial. Till the late 2007, the "number of supporters for the official adoption of Phylocode is still small", and it is still uncertain when, actually, "the Code will be implemented, and how widely it will be followed" Majority of its supporters believe that the registration database or RegNum should be made popularised as much as possible among the scientific community, as a first major step in this direction. A lot, however, depends on following the recommendations of the Third International Phylogenetic Nomeclature meeting held at Dalhousie University, Canada between July 22, 2008 and July 23, 2008.

QUESTIONS

1. Instead of common names, why do we need scientific names for all plants? Give three differences between common names and scientific names.
2. What is binomial nomenclature? Who proposed it and when?
3. What is International Code of Botanical Nomenclature? It applies to which organisms? Who can make changes in ICBN?

4. Write any four principles of ICBN.
5. The XVIII meeting of International Botanical Congress is scheduled to be held in July, 2011. Name the host city and country of this meeting.
6. Define: (a) holotype, (b) isotype, (c) lectotype, and (d) neotype.
7. What is the difference between a validly published name and an effectively published name?
8. Give a brief account of phylocode: a new system of nomenclature.
9. What is binomial nomenclature?
10. Explain generic and specific epithet in detail.
11. What is type method? Differentiate between paratype and syntype.
12. Name two important rules of nomenclature.
13. Expand ICBN. What are its principles?
14. Give three examples of common specific prefixes.
15. Give one example each for different suffixes used in specific epithets.
16. Define Phylocode. What are its principles? What is the name of the database of phylocode?

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LECTURE: 5

CELL AND CELL DIVISION

CELL

Definition: The cell could be described as a small unit of living protoplasm always surrounded by cell membrane. It is the basic unit of structure and function in an organism.

Robert Hook coined the term **cell** and named it as when he observed a honey comb like structure in section of cork under a very primitive microscope.

The matrix between the nucleus and the cell membrane is known as cytoplasm. This contains a variety of organelles. An organelle is a distinct part of a cell which has a particular structure and function. The nucleus is the largest intra cellular cell organelle, which contains deeply staining material known as chromatin, which has a particular structure and function. It contains DNA (or RNA in some primitive organisms), the genetic material.

In the case of prokaryotic cell, the DNA lies free in the cytoplasm and the region is known as nucleoid, where as in the case of eukaryotic cells, the DNA is found inside the nucleus, which is surrounded by nuclear envelope.

Different parts and different organelles of a cell

- **Cytoplasm:** The portion of cell other than nucleus
- **Hyaloplasm:** The portion of cytoplasm other than cell organelles

Cell organelles: Various membrane bound structure that are found within a cell are called cell organelles. Various structures which are found within a cell are:

3. Nucleus 2. Plastids 3. Mitochondria
5. Endoplasmic reticulum 5. Golgi bodies 6. Cell wall
9. Ribosome 8. Lysosomes 9. Centriole 10. Plasma membrane

Nucleus (Director of the cell), was discovered by Robert Brown in 1823. It contains DNA in specialized structure called chromosomes.

Plastids are self-replicating cytoplasmic organelles found in plant cell. Plastids are absent in bacteria, fungi and animals. According to presence or absence of pigments, Shimper classified the plastids into:

i. **Leucoplasts (Leukos - white):** These are colourless.
ii. **Chromoplasts:** These are coloured but other than green
iii. **Chloroplasts:** These are green plastids bearing chlorophyll, the sites of photosynthesis

Mitochondria, the term was given by C. Benda in 1887. It is a rod like, cytoplasmic organelle which is the main site of cellular respiration

Endoplasmic Reticulum (E.R.): The term was given by Porter in 1948 to identify fine reticulum that he observed in cytoplasm. It is attached to nuclear membrane on one side and cell membrane on other. There are types of E.R., Rough or granular ER and Smooth or agranular ER.

Lysosomes, in 1955, Dave named 'Lysosome'. These are cellular particles containing several diagestive enzymes such as acid phosphatase, acid ribonuclease etc.

Golgi complex/Golgi bodies/Golgi apparatus, first described by Camillo Golgi, golgi bodies arise from rough ER

Centrioles are cylindrical cellular bodies always found in pairs known as centriole pairs. The members of the pair remain at an angle of 90º to each other, they are found in animal cells only.

Cell wall is found only in plant cell and is absent in animal cell. Cell wall is differentiated into 3 parts: Middle lamella, Primary cell wall and Secondary cell wall.

Plasma membrane/Plasma lemma is the outer most living boundary of the cytoplasm.

Central Vacuole is present in plant cell only. It contains water and other liquids

Ribosomes are small cellular particles which are site of protein synthesis. Since they are rich in RNA they are called ribosomes.

Generally the animal cells are similar to plant cells but the former contains centriole which is absent in plant cell.

Some of the chief differences which are present in the plant cells are:

1. Cell wall which is present outside the cell membrane in plant cells and has pores containing fine threads known as plasmodesmata, which link the cytoplasm of neighboring cells through cell walls.
2. Chloroplasts are found in photosynthetic plant cells.
3. Large central vacuoles are found in plant cells only.

CELL DIVISION

Definition: The process of reproduction or formation of new cells from the pre-existing cells is referred to as cell division. In lower organisms like bacteria, cell division takes place by fission of pre-existing cell. But in higher organisms like eukaryotes there are two types cell division *viz*., Mitosis and Meiosis. In both of these two types, the nucleus of a cell first undergoes division, known as Karyokinesis (Karyon=Nucleus, Kinesis=Division) and then the cytoplasm divides (Cytokinesis).

Mitosis

The term Mitosis was coined by Flemming in 1882. Mitosis is the process by which a cell nucleus divides to produce two daughter nuclei containing identical set of chromosomes to the parent cell. It is usually followed immediately by division of the whole cell to form two daughter cells. This process is known as mitotic cell division.

Cell cycle

The sequence of events which occur between one cell division and the next is called cell cycle. It has two main stages.

1. Interphase
2. Mitosis or M phase (period of cell division)

1. Interphase

It is the period between successive cell divisions consisting of process associated with growth and preparation for mitosis. The period of DNA synthesis during interphase is called the 'S' phase or synthetic phase and it is separated in time from the previous cell division by a gap called 'G_1' phase. G_1 phase is the period between the beginning of interphase and that of DNA synthesis (S phase).

After DNA synthesis a further gap called 'G_2' phase occurs before the next cell division begins, which is the period between termination of DNA synthesis and beginning of prophase of next cell division.

2. Mitotic phase

The mitotic phase leads to separation of replicated DNA into two daughter nuclei without recombination. The M phase consists of two major events viz., division of nucleus (Karyokinesis) followed by division of cytoplasm (cytokinesis). The karyokinesis has got four distinct stages as follows.

Prophase: Coiling and condensation of chromosome takes place which make them visible as thread like Structures.

Metaphase: Claerly visisble chromosomes move and arrange on metaphase plate or equatorial plate.

Anaphase: This is the shortest phase of the mitotic division.

This stage allows the sister chromatids to separate and move to opposite poles.

Telophase: Chromosomes reach the opposite poles, again become thinner and longer by uncoiling and unfolding.

Cytokinesis: It is the division of cytoplasm. This stage normally follows telophase and leads in to G_1 phase of interphase.

Significance of mitosis

1. Genetic stability 2. Growth 3. Cell replacement 4. Asexual reproduction

Meiosis

Meiosis is the process by which a cell nucleus divides to produce four daughter nuclei each containing half the number of chromosomes of the original nucleus or cell. It is also called as reduction division since it reduces the number of chromosomes in the cell from the diploid number (2n) to the haploid number (n). Like mitosis, it involves DNA replication during interphase in the parent cell, but this is followed by two cycles of nuclear and cytoplasmic divisions known as Meiosis I (reduction division) and Meiosis II (multiplication division). Thus, a single diploid cell gives rise to four haploid cells.

First meiotic division (reduction division)

It has four stages namely Prophase I, Metaphase I, Anaphase I, and Telophase I.

Prophase I

It is the longest phase of meiotic division. It has five sub stages namely, Leptotene, Zygotene, Pachytene, Diplotene and Diakinesis.

Metaphase I, Anaphase I, Telophase I are similar to mitotic phase with some differences to be studied later.

The brief period (interphase) between the first and second meiotic divisions is called interkinesis. Sometimes it is present, sometimes the dividing cell directly goes into Meiosis II.

Second meiotic division (multiplication/equational division)

The second meiotic division is equal to mitotic division.

Significance of meiosis

Meiosis enables the chromosome number of a sexually reproducing species to be kept constant from generation to generation.

Meiosis introduces the genetic variation in the offsprings of sexually reproducing individuals by means of independent assortment and crossing over (recombination).

QUESTIONS

1. Define: Cell division, Interphase, cell
2. Write a brief note on cell organelles.
3. Enlist different sub stages of Prophase-I

LECTURE: 6

SEED AND SEED GERMINATION

SEED

Seed is a product of a fertilized ovule, consisting of an embryo, enclosed in the testa which is derived from the integument (s). Food reserves may or may not be contained in the endosperm.

- **Testa.** Also called seed coat, derived from the outer integument and Is protective in nature.
- **Aril.** A fleshy covering on the seed which arises as an outgrowth of the funicle or base of the ovule. It may be a tuft of hairs. A fleshy white aril is distinctive and is the edible part of litchi.
- **Caruncle.** An outgrowth near the micropyle and hilum of the seed (as in castor).
- **Cotyledon.** The leaf formed directly from the embryo of an angiosperm (also in gymnosperms). In angiosperms, *monocots* have one *cotyledon (i.e.* Monocotyledons) or dicots have two cotyledons (i.e. Dicotyledons.)
- **Kernel.** The seed inside the stoney endocarp of a drupe.
- **Perisperm.** A nutritive tissue derived from the nucellus of the ovule (present in some seeds) or may be called persistent nutritive nucellus (as in members of Nymphaeaceae). In coffee seed, it is the perisperm that is the source of coffee powder.
- **Straphiole.** An appendage of hilum (found in some seeds).

Types of seeds

1. Dicotyledonous exalbuminous (two cotyledons, no endosperm/perisperm)

Pea (*Pisum sativum*), Gram (*Cicer areitinum*), all beans, tamarind, mango, jackfruit, cucurbits, sunflower, mustards, sesame, flax, orange, lemon, oak, pomegranate

2. Dicotyledonous albuminous (two cotyledons, with endosperm and/or perisperm)

Castor (*Ricinus communis*), papaw, jute, cotton, water lily, black pepper, coffee

3. Monotyledonous exalbuminous (one cotyledon, with endosperm and/or perisperm)

Rice (*Oryza sativa*), wheat (*Triticum* spp.), maize (*Zea mays*), onion (*Allium cepa*), cardamom, Canna (*Canna indica*)

Coconut (*Cocos nucifera*), date palm (*Phoenix sylvestris*), palmyra palm (*Borassus flabellifer*), betel nut (*Areca catechu*)

4. Monocotyledonous exalbuminous (one cotyledon, no endosperm/perisperm)

Very rare, Found in seeds of Aroideae (*Amorphallus campanulatus*), Hydrocharitaceae (*Vallisneria),* Alismaceae (*Alisma plantago)*

Radicle and cotyledon can be observed in a curved embryo

SEED GERMINATION

According to Seed Physiologists, **'Germination is the mere protrusion of radicle'**, but according to Seed Analysts **'Germination is the emergence and development from the seed embryo of those essential structures, which indicates the ability of seed to produce a normal plant under favorable conditions'.** Others consider germination to be resumption of active growth by the embryo resulting in the rupture of the seed coat and emergence of young plant.

According to ISTA 'Germination may be defined as the resumption of growth by the embryo and development of a seedling from the seed, and the ability to develop into a normal plant under favourable conditions in the soil'.

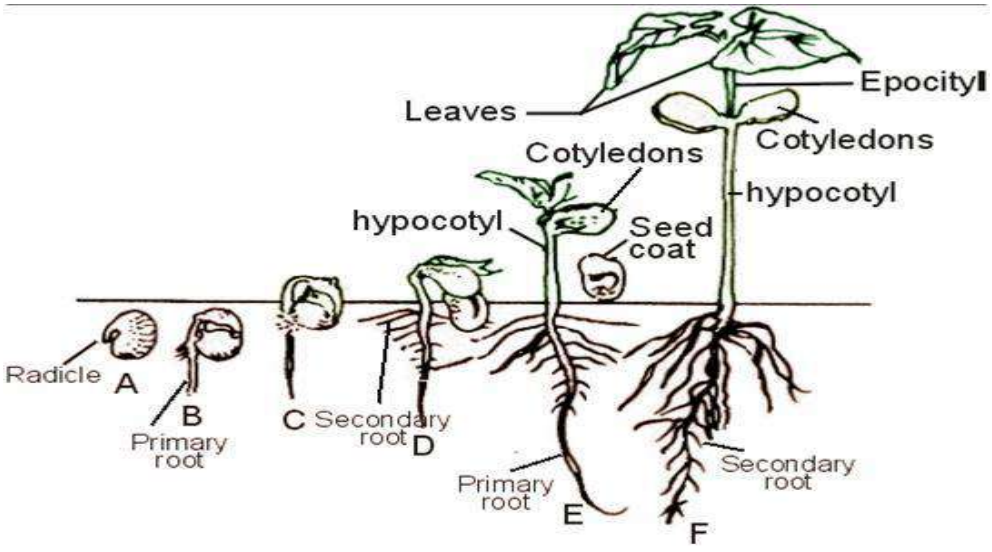
Some seeds are capable of germination only few days after fertilization, while others require an extended period of rest before germination.

Seed germination test is an index indicating its capacity of producing normal healthy seedlings under optimum condition. The emergence of essential structures of seedlings from embryo i.e. root system, shoot axis, cotyledons, terminal bud and coleoptiles (*Poaceae)* determine its potential to develop into a normal plant under favorable condition.

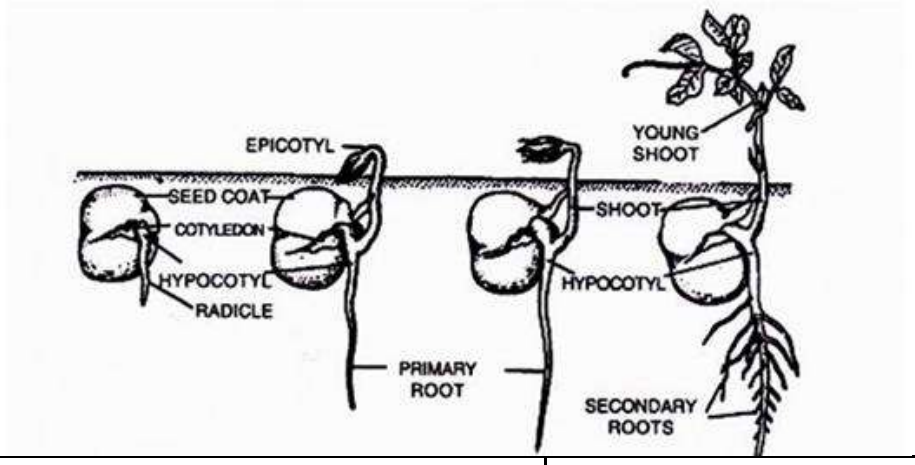
Morphology of seed germination

Based on the behaviour of storage organ, seed germination is of two types.

1. **Epigeal germination:** In this type germination, the cotyledons are raised above the ground and provide nutritive support to the growing points. During root establishment, hypocotyl is the elongating structure, it breaks the soil surface, pushing cotyledons and plumule through the ground, e.g. pine and bean seeds.



2. **Hypogeal germination:** In this type germination, food storage organs remain beneath the soil surface. Epicotyl is the elongating structure, plumule is pushed upward and emerges above the ground. The coleoptile (a temporary sheath enclosing the plumule) is found e.g. grasses and cereals. Most of the monocotyledons show hypogeal germination. Among dicotyledons, gram, pea, groundnut are some common examples of hypogeal germination



S.r.	**Epigeal germination (epi-upon, ge-earth)**	**Hypogeal germination (hypo-below, ge-earth)**
1	In this type of germination, cotyledons (including epicotyl and plumule) are pushed upwards above the soil surface due to rapid elongation of hypocotyl.	In this type of germination, plumule is pushed upwards above the soil surface due to rapid elongation of epicotyl.
2	The cotyledons may turn green like normal leaf.	The cotyledons remains in the soil, do not turn green and dry up.
3	e.g. bean, groundnut, cucumber, sunflower, cotton castor, bottle gourd, onion etc.	e.g. gram, pea, mango, wheat, rice, maize, sorghum, pearlmillet, sugarcane, etc.

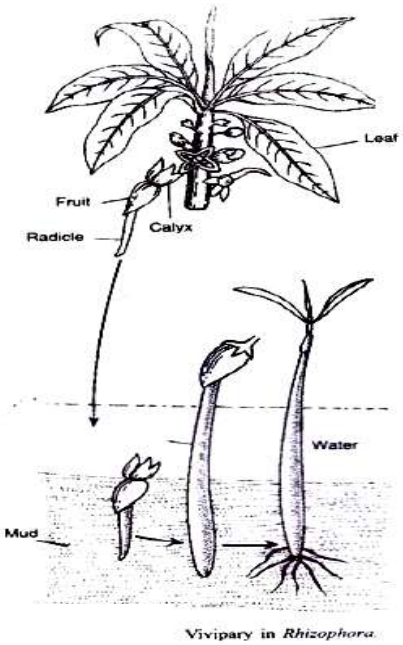
Sr.	**Epicotyl**	**Hypocotyl**
1.	The portion of axis lying immediately above the cotyledons.	The portion of axis lying immediately below the cotyledons.
2.	It takes active part in hypogeal germination.	It takes active part in epigeal germination.

3. **Vivipary:** Germination occurs in fruits without completing the requirement of maturation is known as vivipary. e.g. mangrove. Vivipary is the phenomenon of giving birth to young ones in advanced stage of development. It occurs in mammals (among animals) and mangrove plants. In mangrove plants (e.g., Rhizophora, Sonneratia, Heritiera) the seeds cannot germinate on the ground because of the excessive salt content and lack of oxygen in marshy habitat. In such plants seed dormancy is absent.

4. Pre-harvest sprouting

Sprouting of seed due to high moisture on the matured plants standing on the field is known as pre-harvest sprouting and it is different than vivipary. e.g. onion, garlic and groundnut.

The process of seed germination starts with the imbibition of water by seed coat and emergence of growing root tip of embryo. The process ends with the development of embryo into a seedling.



Vivipary in *Rhizophora*

Factors Affecting Germination Process of Seeds:

- **Temperature**: Extremely low or cold temperature is not favorable for seed germination. They prefer higher temperatures. The germination rate of seed is directly proportional to the rise in temperature.
- **Moisture or water**: Dry seeds do not germinate. Water is an essential factor to trigger off the process of seed germination.
- **Soil**: During growth, seeds require mineral elements for further growth which is obtained from the soil.
- **Light**: For seed germination light is not essential in the early stages of germination but plays a main role in the later stages of the life cycle of plants.
- **Viability of the seeds**: After the seeds are formed, they remain viable up to certain period which may vary from plant to plant or seed to seed. Many sees die or incapable of supporting growth after a certain period of time.
- **Dormancy period**: Many seeds do not germinate abruptly after they are produced . Certain seeds undergoe a resting time through which they stay dormant and germinate when conditions are favourable. Preence of growth inhibitors like abscisic acid induce dormancy in seeds.
- **Thinness or thickness of seed coa**t: Different seeds have varying degrees of thickness to enable the seeds to remain feasible. Seeds with a thin seed coat tend to germinate faster than those with thicker seed coats.

QUESTIONS

1. Define seed. What are the different parts of a seed?
2. Define germination. Explain in detail the different types of germination with proper example and diagram.
3. Enlist the different factors influencing germination.
4. Differentiate between epigeal and hypogeal germination.

LECTURE: 7

MORPHOLOGY & MICRO-MORPHOLOGY OF FLOWERING PLANTS

Botany: Study of plants
Plant Morphology – Branch of botany which deals with external features of plants.
External Morphology – Study of external forms and position of plant organs
Internal Morphology – Study of internal structure of various organs of plant
Anatomy – Study of overall internal structures such as sections of stem, root and leaf which can be studied under microscope.
Histology – the study of tissues and tissue systems

In this section some information related to internal structure of plants will be covered, which comes under anatomy, internal morpgology as well as histology.

THE TISSUE: Tissue is a group of cells of the same type or the mixed type, having a common origin and performing an identical function. Tissues may primarily be classified into two groups: **meristematic** and **permanent**

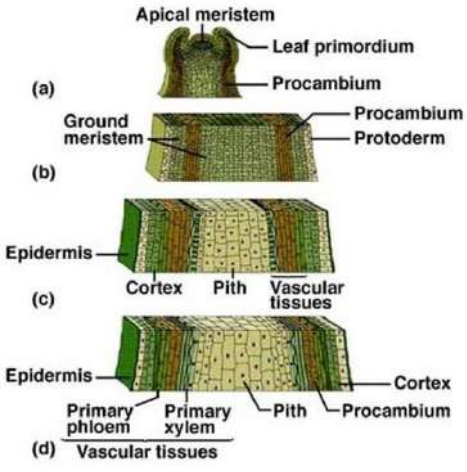
MERISTEMATIC TISSUES: These are composed of cell that are in a state of division or retain the power of dividing. The cells which remain meristematic are called initiating cells and cells derived from them are called derivatives through differentiation.

Meristematic tissues according to their **position**:

Apical: The apical meristem lies at the apex of the stem and the root and gives rise to primary permanent tissues

Intercalary: It is present in the nodal region and is prominently found in monocotyledons, e.g. grasses. As the name indicates, it is present in between the permanent tissues. It is derived from the apical meristem and is responsible for the elongation of internodes.

Lateral: The lateral meristem, e.g. cambium, lies among masses of permanent tissues and gives rise to secondary permanent tissues.



APICAL MERISTEM

I. Stem Apex: Apical meristem or growing region is composed of a mass of small, usually rounded or polygonal cells which are all

essentially alike are in a state of division; these meristematic cells constitute the **periblem.** The cells of the promeristem soon differentiate into three regions:

(1) Dermatogen: The single outermost layer of cells. The dermatogen gives rise to the skin layer or epidermis f the stem.

(2) Periblem: This lay internal to the dermatogen, is the middle region of the apical meristem. It forms the cortex of the stem, which, particularly in dicotyledons, is differentiated into hypodermis, general cortex and endodermis.

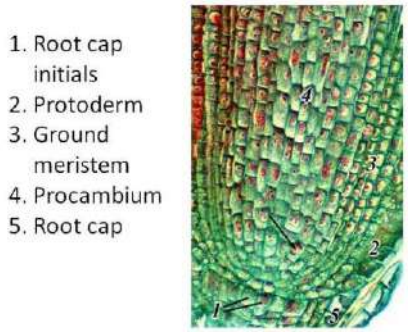
(3) Plerome: This lay internal to periblem, is the central region of the stem apex. Plerome as a whole gives rise to the central cylinder or **stele,** which in a dicotyledonous stem is differentiated into the pericycle, medullary rays, pith and the vascular bundles.

II. Root Apex: Promeristem, in the roots also stem differentiates into three regions:

(1) Dermatogen: This is single-layered but at the apex it merges into the periblem; outside this, the dermatogen cuts off many new cells, forming a small-celled tissue known as the **calyptrogen.**

(2) Periblem: This is also single-layered at the periblem, forms the middle region or cortex of root.

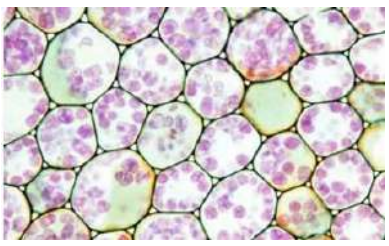
(3) Plerome: Its structure and function are practically same as those of the stem.



PERMANENT TISSUES: These are composed of cells that have lost the power of dividing, having attained their definite form and size. Permanent tissues are formed by differentiation of the cells of the meristems and may be **primary** and **secondary.** The primary permanent tissues are derived from the apical meristems of growing regions and the secondary permanent tissues from the lateral meristems.

PRIMARY PERMANENT TISSUES: Primary permanent tissues may, be classified as **simple and complex** and a third special group of **Secretory or special tissue**.

I. SIMPLE PRIMARY TISSUES: A simple tissue is made from one type of cell forming a homogeneous or uniform mass, and a complex tissue is made from more than one type of cells working together as a unit.

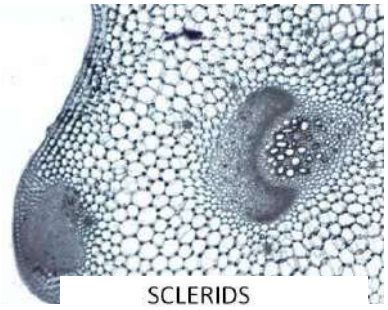


1. Parenchyma: Parenchyma is called the fundamental tissue of plants and precursor of all other

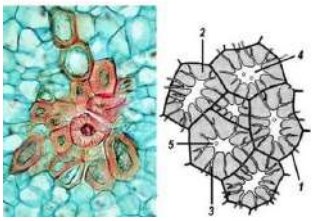
tissues of plants. It consists of a collection of living cells which are more or less isodiametric with thin cellulose

walls. Different types are Chlorenchyma, Aerenchyma, Idioblasts. It is of universal occurrence in all the soft parts of plants. Its function is mainly storage of food material.

2. **Collenchyma:** These are elongated living cells with the corners or intercellular spaces much thickened with a deposit of cellulose and pectin. The cells often contain some chloroplasts. Different types are Angular, Lacunate/tubular, Plate/lamellar. It gives tensile strength to the stem.



3. Sclerenchyma: It consists of very long, narrow, thick-walled and lignified dead cells, usually pointed at both ends. This tissue is divided into Sclerenchyma fibres and sclereids or sclerotic cells.



Sclereids have very hard cell wall. Sclerieds include brachysclereids, osteosclereids, found in the *Crotalaria*, *Pisum etc*. **Fibre** cells are very long and narrow with pointed ends. Sclerenchyma serves mechanically providing strength and rigidity to the plant.

II COMPLEX TISSUES:

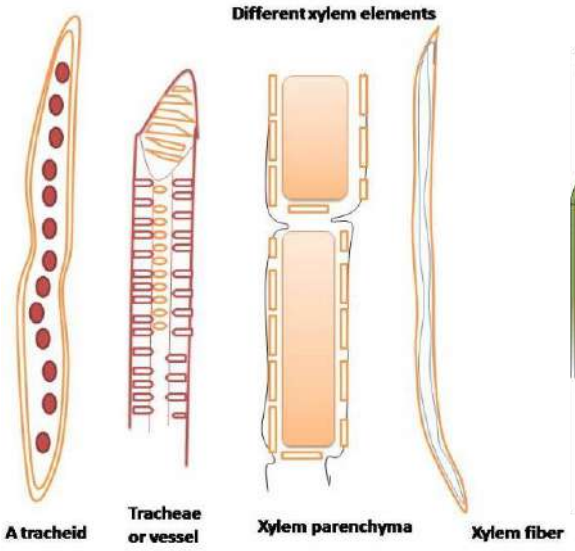
1. Xylem: Xylem or wood is meant to conduct water and mineral salts upward from the root to the leaf, and to give mechanical strength to the plant body. It is composed of following elements:

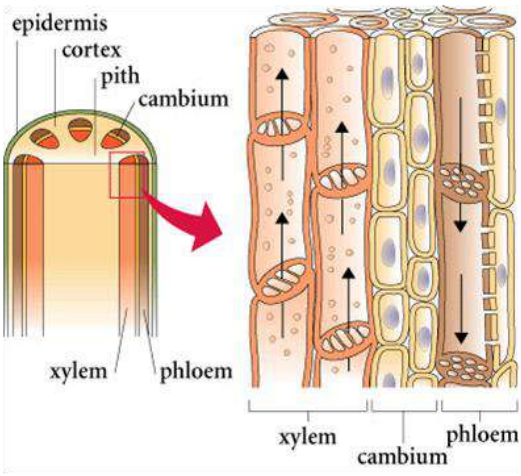
(a) Tracheid: Lignified and hard, tracheids give strength to the plant body other than conduction

(b) Vessels/ Tracheae: Elongated dead cells, placed in rows with transverse walls dissolved

(c) Xylem Fibers (wood): Sclerenchymatous cells associated with wood or xylems

(d) Xylem Parenchyma (wood): Living parenchymatous cells associated with xylem

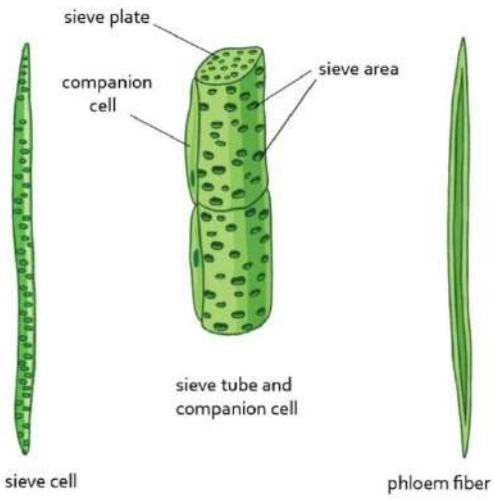




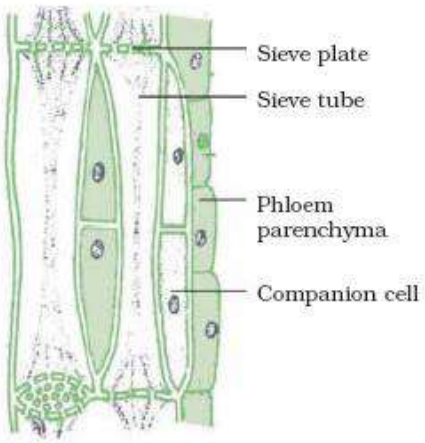
2. Phloem: Phloem or bast is meant to conduct prepared food materials from the leaf to the storage organs and the growing regions. It is composed of the following elements:

(a) Sieve-tubes: Slender, tube-like structures composed of elongated cells, placed end on end

(b) Companion Cells: Associated with each sieve-tube and connected by simple pits. Present only in angiosperms.



(c) Phloem Parenchyma: Living parenchymatous cells in the phloem



(d) Bast Fibres: Sclerenchymatous cells occurring in the phloem

III. SECRETORY TISSUES

1. Laticiferous Tissue: Thin-walled, very elongated, much-branched ducts containing milky juice known as latex

2. Glandular Tissue: Special glands containing some sccretory or excretory products. They may be internal or external.

Internal glands are (i) oil-glands (ii) mucilage secreting glands (iii) glands secreting gum, resin tannin. (iv) digestive glands secreting enzymes (v) special water-secreting glands

External glands are (i) water-secreting hairs/ glands; (ii) glandular hairs (iii) glandular hairs secreting irritating, poisonous substances (iv) honey glands or nectarines (v) enzyme secreting glands

3. Hydathodes: Specialized structure in many angiosperms for exudation of water

MECHANICAL TISSUE

Some tissues are specially meant for providing mechanical strength when plants are subjected to various stress and strain.

The most important mechanical tissue is sclerenchyma fibres along with sclereids with highly lignified walls. Collenchyma also gives sufficient strength because of their thickened

cellulose walls. Xylem trachaea and tracheids though primarily are conducting tissue they also provide mechanical support.

The main features of mechanical tissue are Inflexibility, inextensibility, incompressibility and shearing stresses.

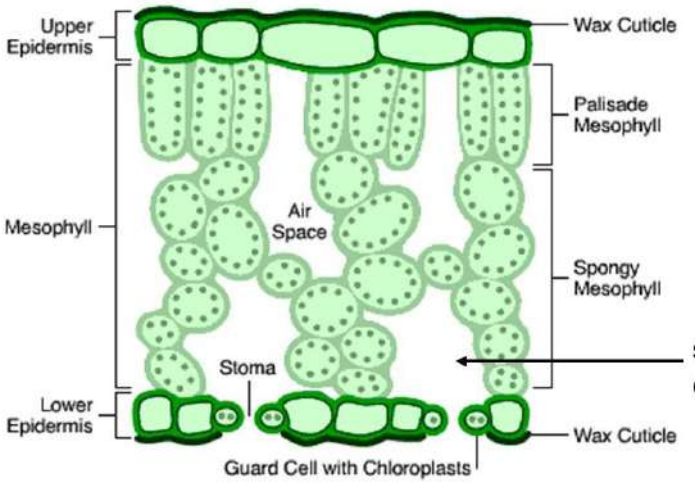
THE TISSUE SYSTEM

According to their large number and various function tissues are classified into three systems which are: (1) Epidermal tissue system (2) Ground or fundamental tissue system (3) Vascular tissue system.

1. The Epidermal Tissue System: Epidermis is developed from protoderm, which gives rise to epidermal tissue system. Cells are parenchymatous and are arranged in a single outermost layer called **epidermis.** It functions as a protective tissue. The outermost layer of root is called **epiblema** or **piliferous layer.**

Thickened and cutinized outer walls of epidermis is called **cuticle** which checks evaporation of water. In the leaves and young green shoots the epidermis possesses numerous minute openings called **stomata.**

Structure and Behaviour:



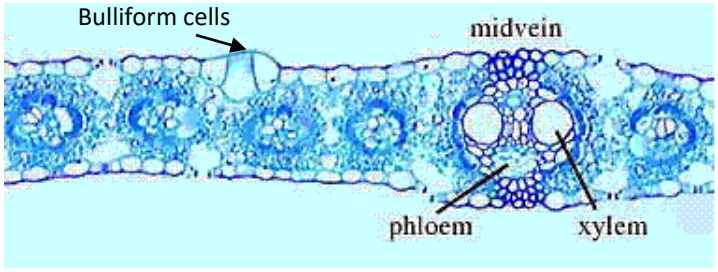
Stomata (singular stoma) are very minute openings called the stomatal aperture formed in the epidermal layer in green aerial parts of the plant.

Each stoma is surrounded by two semi-lunar cells known as **guard cells**. Guard cells are living, have thicker inner, and thinner outer walls and always contain chloroplasts. Often neighbouring cells to guard cells differ from other epidermal cells and are associated functionally with stomata. These cells are called **subsidiary cells**. A cavity beneath the stoma is called **sub stomatal chamber**.

Under normal conditions the stomata remain closed at night, i.e. in the absences of light, and they remain open during the daytime, i.e. in the presence of light. The opening and closing of the stomata are due to the movement of guard cells. In the presence of light the guard cells absorb water from the neighbouring cells, expand and bulge in an outward direction and the stoma opens. They close up through reverse process in the night.

Functions and Distribution

Stomata are used for interchange of gases between the plant and the atmosphere. Stomata are most abundant on the lower epidermis of dorsiventral leaves. In isobilateral leaves, stomata are more or less evenly distributed on all sides. In the floating leaves, like of water lily, stomata remain confined to the upper epidermis alone; in the submerged leaves no stoma is present.



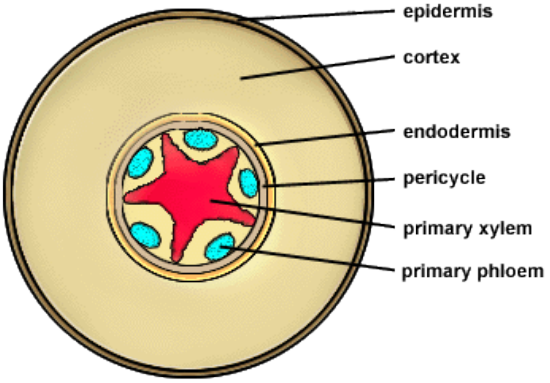
Bulliform cells: In most of the monocotyledonous plants highly vacuolated thin walled balloon like cells are observed which appear as fan under the microscope as the median cell is the largest. They may be present on both sides of the leaves but are more common on the lower side. They might play a role in unfolding of leaves.

Water stomata/Hydathodes: Explained earlier

Epidermal outgrowths: Trichomes may be dead or alive and are grouped as hairs, scales, colleters, water vesicles or bladders.

Root Hairs: Root hairs unlike trichomes are prolonged epidermal cells called trichoblasts.

2. The Ground or Fundamental Tissue System (Roots and stems): It is the main bulk tissue of the body of the plant (shoot & root), and extends from below the epidermis to the center (excluding the vascular bundles). It is differentiate into the following zones and sub-zones, Cortex, Stele and Pith.



(a) Cortex: This is the zone that lies between the epidermis and the pericycle; it is usually differentiated into the following sub-zones:

i. Hypodermis ii. General cortex iii. Endodermis.

Functions: In stems the cortex primarily functions as a protective tissue; in roots the cortex is essentially a storage tissue.

(b) Stele: The central core of the axis is called stele enveloped by cortex which includes vascular tissues and pericycle along with pith when present. Pericycle is a multi-layered zone between the endodermis and the vascular bundles and occurs as a cylinder encircling the vascular bundles and the pith, as in dicotyledonous stems. In some angiosperms, young stems

have abundant starch content in the inner most layer of cortex known as starch sheath. Statoliths are observed in roots containing starch grains.

Functions: In all roots, the pericycle is the seat of origin of lateral roots. In all stems, the pericycle is the seat of origin of adventitious roots.

(c) Pith and Pith Rays: The **pith** or **medulla** forms the central core of the stem and in the root it is usually made of large-celled parenchyma with abundant intercellular spaces. The parenchymatous ground tissue passing in between the vascular bundles constitute pith rays or medullary rays.

Ground tissue of leaf

The ground tissue of leaf is called **mesophyll** mainly composed of thin walled parenchymatous cells with profuse chloroplasts. In most dicotyledons, mesophyll is differentiated into **palisade** parenchyma found beneath the upper epidermis or adaxial surface. They are elongated cells. Cells occurring on the abaxial or lower epidermis are called **spongy** parenchyma.

Functions: They serve to store food material.

3. The Vascular Tissue System: This system consists of a number of vascular bundles which are distributed in the **stele.** The function of this system is to conduct water and raw food materials from the roots to the leaves, and from the leaves to the storage organs & growing regions respectively.

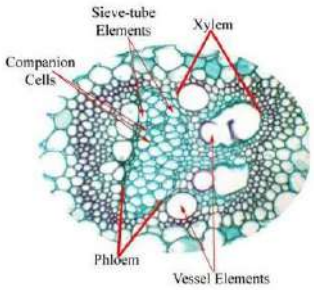
Elements of a Vascular Bundle: Consists of three well-defined tissues: (1) Xylem or Wood (2) Phloem or Bast and (3) Cambium. Vascular bundle originates from procambium.

(1) Xylem or Wood: This lies towards the centre. The first formed xylem is called protoxylem and lately formed are known as metaxylem. Include details from **complex tissue**.

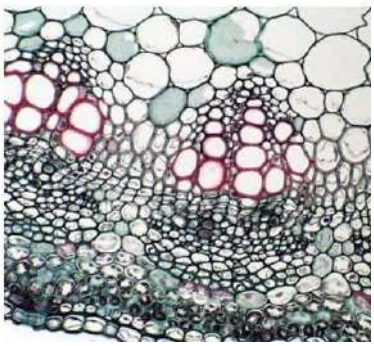
(2) Phloem or Bast: This lies towards the circumference. The first formed phloem is called protophloem and lately formed are known as metaphloem. Include details from **complex tissue**.

(3) Cambium: This is a thin strip of primary meristem lying in between xylem and phloem. Cambium is responsible for secondary growth in thickness of the plant body.

Maize or Corn – vein in cross section



Alfalfa – vein in cross section



Types of Vascular Bundles: According to the arrangement of xylem and phloem, the vascular bundles are of the following types:

(1) Radial: When xylem and phloem from separate bundles and these lie on different radii alternating with each other, as in roots.

(2) Conjoint: When xylem and phloem combine into one bundle. There are different types of conjoint bundles.

(a) Collateral: When xylem and phloem lie together on the same radius, xylem being internal and phloem external.

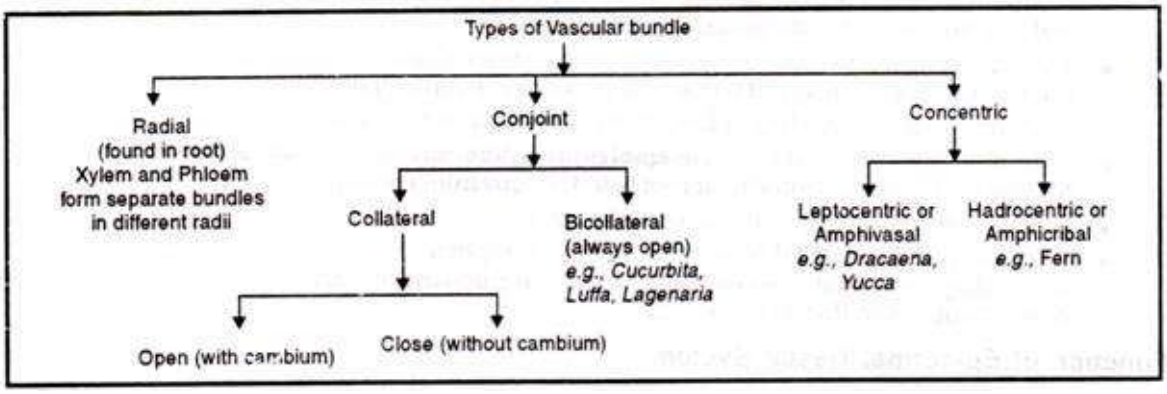
i. **Open, Conjoint, Collateral:** Vascular bundle in which cambium is present, xylem and phloem are on same radius and phloem is present only on one side.

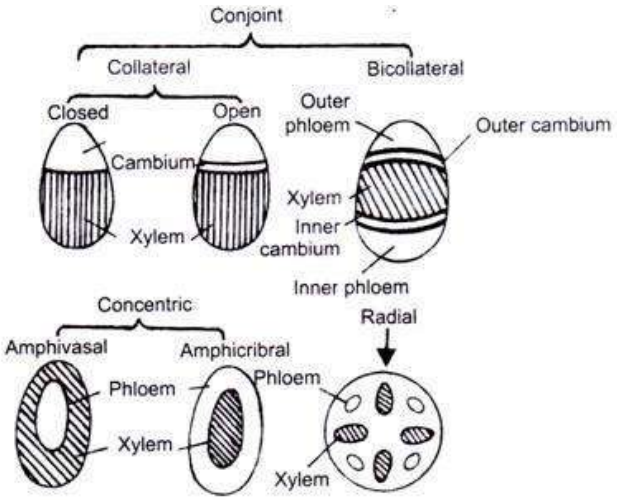
ii. **Closed, Conjoint, Collateral**: Vascular bundle in which cambium is absent, xylem and phloem lies on the same radius and phloem is present only on one side.

(b) Bicollateral: When in a collateral bundle both phloem and cambium occur twice.

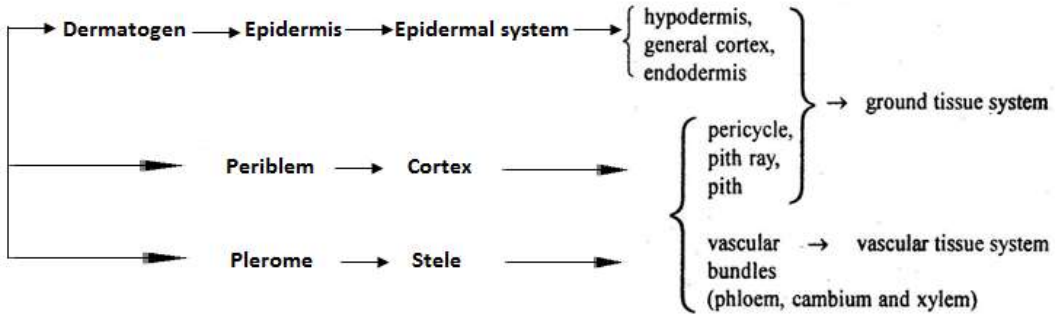
Open, Conjoint, Bicollateral: Vascular bundle in which cambium is present, xylem and phloem are on same radius and phloem is present on both sides.

(3) Concentric: When xylem lies in the center and is surrounded phloem. Here amphivasal or leptocentric bundles have phloem at the centre surrounded by xylem. In the amphicribal or hadrocentric bundles opposite is observed.





Apical Meristems and Tissue system:



ANATOMY OF STEMS

DICOTYLEDONOUS STEMS:

(1) Epidermis: This forms the outermost layer, and consists of a single row of cells, flattened tangentially and fitting closely along their radial walls, with a well-defined cuticle extending over it.

(2) Cortex: This is the zone that line between the epidermis and the pericycle, and consists of hypodermis externally, general cortex centrally and endodermis internally.

(a) Hypodermis (collenchyma): This lies immediately below the epidermis, and consists of some 4 or 5 layers of collenchymatous cells. The cells are living and contain a number of chloroplasts.

(b) General cortex: This lies internal to the hypodermis and consists of a few layers of thin-walled; large, rounded or oval parenchymatous cells.

(c) Endodermis: This is the innermost layer of the cortex consisting of more or less barrel shaped cells.

(d) Starch sheath: Limiting layer of extrastelar ground tissue

(3) Stele: All the tissue internal to starch sheath constitute stele**.**

(a) Pericycle: This is the region lying in between the endodermis and vascular bundles.

(b) Medullary Rays: A few layers of fairly big polygonal or radially elongated cells, lying in between two vascular bundles, constitute a medullary ray.

(c) Pith: It extends from below the vascular bundles to the center, and is composed of rounded or polygonal, thin-walled, living cells with conspicuous intercellular spaces between them.

(d) Vascular Bundles: These are collateral and open, and are arranged in a ring with a patch of sclerenchyma forming like a cap known as bundle cap. Each bundle is composed of

a. **Phloem** or **bast** b. **Cambium** and c. X**ylem** or **wood**.

a. Phloem: This lies externally and consists of:

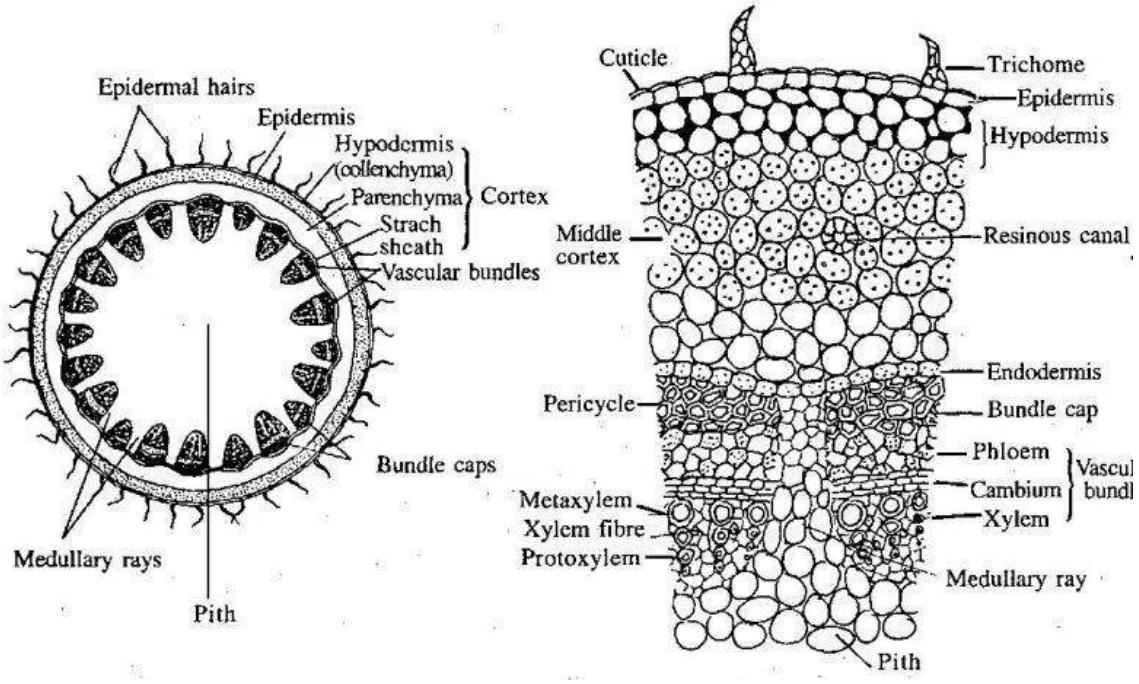
i. Sieve-tubes ii. Companion cells iii. Phloem parenchyma

Phloem as a whole is meant to conduct prepared food materials from the leaves to the storage organs, and later from the storage organs to the growing regions.

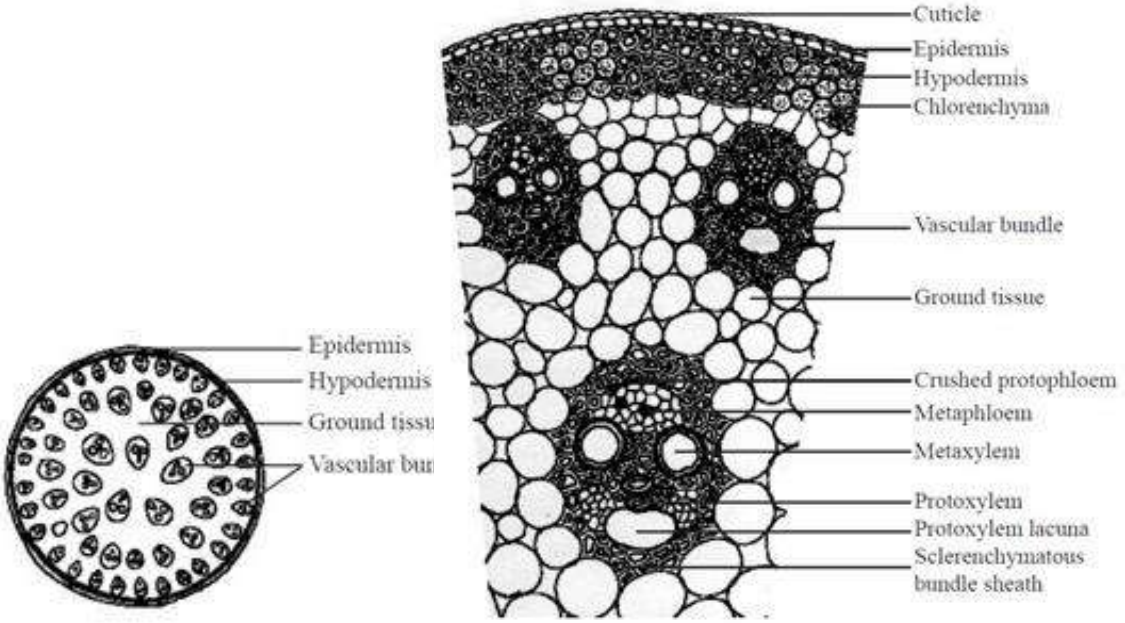
b. Cambium: Lying in between phloem and xylem. Cambium is responsible for secondary growth in thickness of the plant body.

c. Xylem or **Wood:** This lies internally and consists of the following elements.

i. Wood vessels ii. Tracheids iii. Wood fibers iv. Wood parenchyma



Transverse section (T.S.) of a young dicot stem A part enlarged



Transverse section (T.S.) of a young monocot stem A part enlarged

MONOCOTYLEDONOUS STEMS

(1) Epidermis: This is a single outermost layer with a thick cuticle on the outer surface. Here and there in the epidermis a few stomata may be seen.

(2) Cortex: Not well differentiated. Hypodermis (sclerenchyma) of 2 or 3 layers thick lying below epidermis is observed.

(3) Stele: This is the continuous mass of thin-walled parenchyma, extending from below the sclerenchyma to the center. It is not differentiated into pericycle, etc., as in a dicotyledons.

(a) Vascular Bundles: These are collateral and closed, and lie scattered in the ground tissue. The bundle consists of xylem and phloem only; cambium is altogether absent.

Xylem: Mainly consist of usually four distinct vessels arranged in the form of a Y, and a small number of tracheids arranged irregularly.

Phloem: Consists exclusively of sieve-tube and companion cells; no phloem parenchyma is present in the monocotyledonous stem.

Difference between Dicotyledonous and Monocotyledonous Stems:

		Dicotyledonous stem (e.g. sunflower)	**Monocotyledonous Stems (e.g. maize)**
1.	Hypodermis	Collenchymatous	sclerenchymatous
2.	General Cortex	a few layers of parenchyma	a continuous mass of
3.	Endodermis	a wavy layer	parenchyma up to the center (ground tissue)
4.	Pericycle	a zone of parenchyma and sclerenchyma	without differentiation into distinct tissues
5.	Medullary Ray	a strip of parenchyma in between vascular bundles	not marked out
6.	Pith	The central cylinder	not marked out
7.	Vascular Bundles	(a) collateral and open (b) arranged in a ring (c) of uniform size (d) phloem parenchyma present (e) usually wedge-shaped (f) bundle sheath absent	collateral and closed scattered larger towards the center it is absent usually oval strongly developed

ANATOMY OF ROOTS

DICOTYLEDONOUS ROOTS:

(1) Epiblema or **Piliferous Layer:** This is a single outermost layer of thin-walled cells; the outer walls of most of these cells extend outwards and from unicellular root-hairs. This layer is used for absorption of water and various mineral salts from the soil and, therefore, has no cuticle. Root-hairs increase the absorbing surface of the root.

(2) Cortex: This consists of many layers of thin-walled rounded cells, with numerous intercellular spaces between them. The cells of the cortex contain leucoplasts and store starch grains. **Endodermis** is a single ring-like layer of barrel-shaped cells. The endodermis is the innermost layer of the cortex.

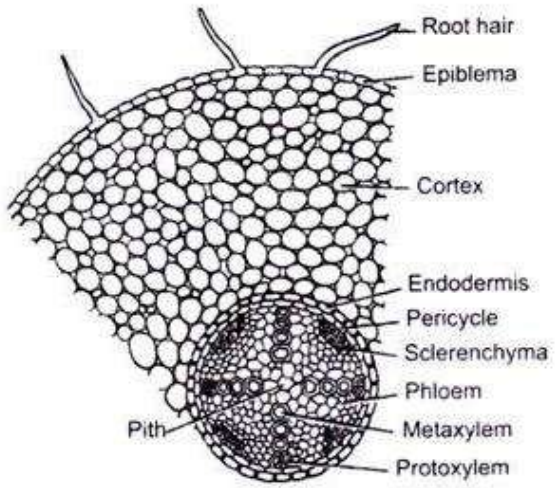
(3) Stele: The central cylinder is a protostele.

(a) Pericycle: This lies internal to the endodermis and, like it.

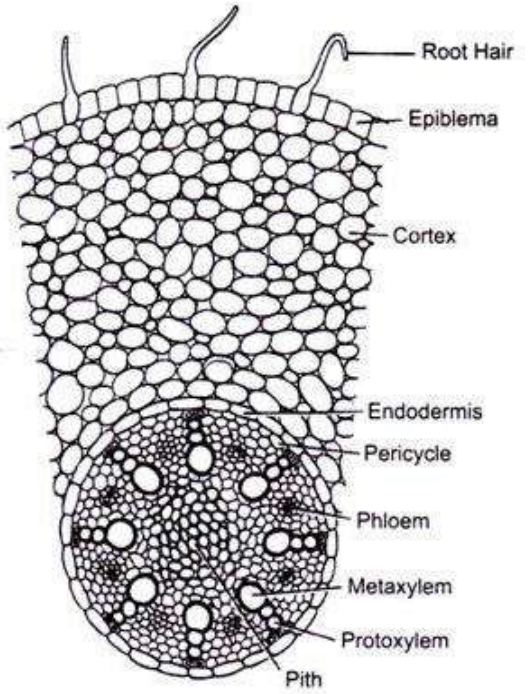
(b) Conjunctive Tissue: The parenchyma lying in between xylem and phloem bundles constitutes the conjunctive tissue.

(c) Pith: This occupies only a small area in the centre of the root.

(d) Vascular Bundles: These are arranged in a ring, as in the dicotyledonous stem but here xylem and phloem form an equal number of separate bundles, and their arrangement is *radial*. Protoxylem occurs towards periphery and metaxylem towards centre giving exarch appearance typical of roots.



T.S. view of dicot root



T.S. view of monocot root

MONOCOTYLEDONOUS ROOT:

(1) Epiblima or **Piliferous Layer:** This is the single outermost layer with a number of unicellular root-hairs.

(2) Cortex: This is a many-layered zone of rounded or oval cells with intercellular spaces between them. Sometimes a suberized layer is observed known as **exodermis**. **Endodermis** is the innermost layer of the cortex and forms a definite ring around the stele. Cells of the endodermis are barrel-shaped.

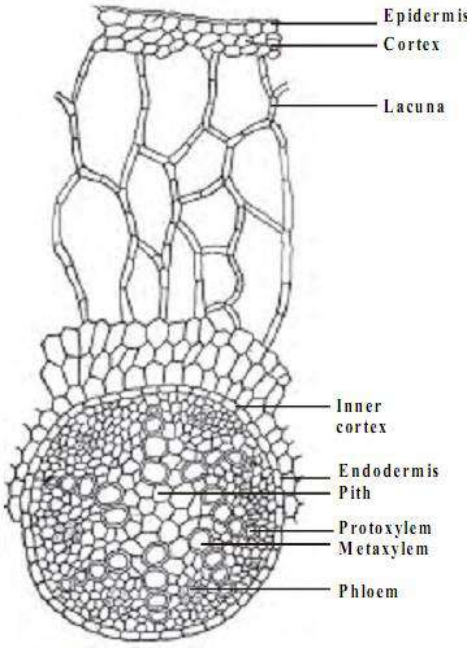
(3) Stele:

(a) Pericycle: This is the ring-like layer lying internal to the endodermis.

(b) Conjunctive Tissue: The parenchyma in between the xylem and phloem bundles is known as the *conjunctive tissue.*

(c) Pith: The mass of Parenchymatous cells in and around the center is the pith.

(d) Vascular Bundles: Xylem and phloem from an equal number of separate bundles, and they are arranged in a ring. The arrangement is *radial.*



T.S. view of root of a watery plant

Difference of dicot root and monocot root

	Dicotyledonous Root	**Monocotyledonous Root**
Xylem bundles	Vary from 2 to 6 rarely more	Numerous rarely a limited number
Pitch	Small or absent	Large and well-developed
Pericycle	Gives rise to lateral roots, cambium and only cork-cambium	Give rise to lateral roots
Cambium	Appears later	Absent altogether

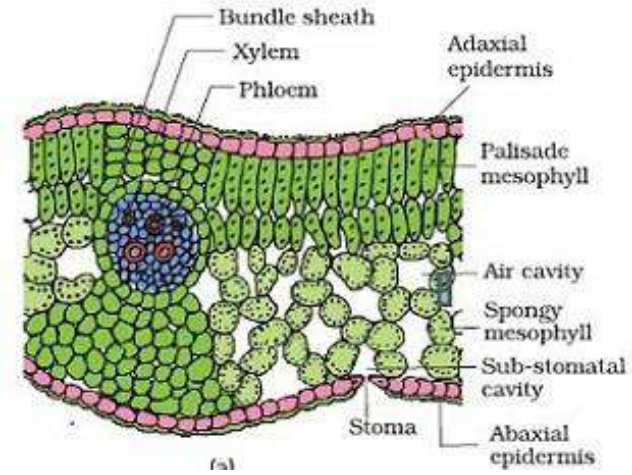
ANATOMY OF LEAVES

DORSIVENTRAL LEAF: Differentiated mesophyll, generally found in dicot plants

(1) Epidermis:

Upper Epidermis: This is a single layer of cells with a thick cuticle which checks excessive evaporation of water from the surface. It does not contain chloroplasts. Stomata are also usually absent.

Lower Epidermis: This is also a single layer but with a thin cuticle. The lower epidermis of the leaf is meant for the exchange of gases (oxygen and carbon dioxide) between the atmosphere and the plant body. Excess water also evaporates from the plant body mainly through the lower epidermis.



T.S. view of a dicot/dorsiventral leaf

(2) Mesophyll: The ground tissue lying between the upper epidermis and the lower one is known as the Mesophyll. It is differentiated into (a) palisade parenchyma and (b) spongy parenchyma.

(a) Palisade Parenchyma: Consists of usually one to two or three layers of elongated, more or less cylindrical cells, closely packed with their long axes at right angles to the epidermis. The cells contain numerous chloroplasts and manufacture sugar and starch in the presence of sunlight.

(b) Spongy Parenchyma: Consists of oval, rounded, or more commonly irregular cells, loosely arranged towards the lower epidermis, enclosing numerous, large, intercellular spaces and air-cavities. The cells contain a few chloroplasts.

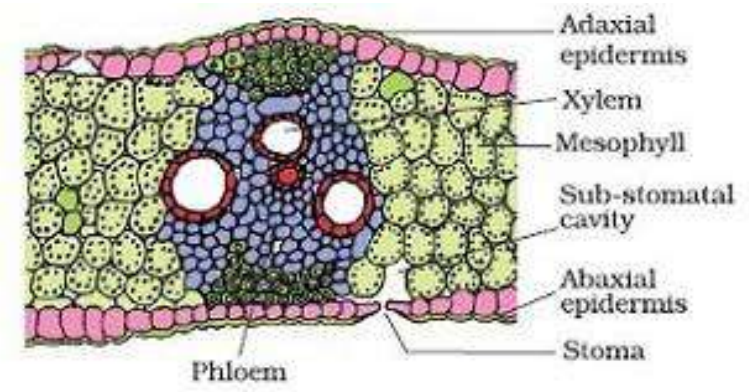
(3) Vascular Bundles: Each vascular bundle which are observed as veins in leaves (collateral and closed) consists of xylem towards upper epidermis and phloem towards the lower.

ISOBILATERAL LEAF: Mesophyll undifferentiated, generally found in monocot plants

The structure is more or less uniform from one surface to the other. These leaves also consist of

(1) Epidermis (2) Mesophyll (3) Vascular bundle

The epidermis on either side bears more or less an equal number of stomata, and is also somewhat uniformly thickened and cutinized. The Mesophyll is often not differentiated into palisade and spongy parenchyma, but consists of spongy cell only, in which chloroplasts are evenly distributed.



T.S. view of a monocot/isobilateral leaf

LEAF LAMINA (EPIPODIUM): It is the broad and flattened part of leaf

Function: Photosynthesis, starch formation, gaseous exchange and transpiration

Lamina is classified on the basis of:

A. Surface differentiation	E. Lamina margin	I. Lamina colour
B. Shape	F. Lamina apex	J. Lamina odour
C. Incision	G. Lamina surface	K. Lamina taste
D. Lamina base	H. Lamina texture	L. Lamina venation

Types of lamina according to surface differentiation

Dorsiventral: Lamina differentiated into two surfaces, namely, upper adaxial (Ventral), facing the stem and lower abaxial (dorsal), facing away from the stem; found in most dicot leaves

Isobilateral: Upper and lower surfaces are identical; found in most monocots

Centric: Cylindrical with no upper or lower surface

Leaf lamina surface types and leaf lamina texture types are very important for taxonomic identification and are considered under micro-morphology of plants.

A. LEAF LAMINA SURFACE TYPES:



1.Glabrous: No hair on leaf lamina surface; Mango

2. Glaucus: Shiny, green with waxy coating; Lotus, arum of *Calotropis*

3. Scabrous: Rough lamina surface; Fig leaves

4. Viscose: Leaf surface sticky due to excretion; *Cleome viscose, Nicotiana tabacum*



Scabrous **Viscose**

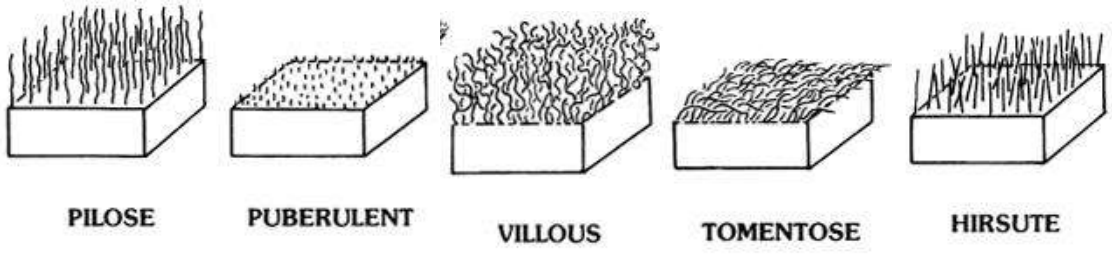


5. Rugose: Wrinkled surface; *Rubus rugosus*

6. Gland-dotted: Surface with glands; Lemon grass

Rugose **Gland dotted**

7. Hairy: There are different sub-types under hairy leaf surface depending upon the length, texture and distribution of hairs, as described below.



a. Pilose: Hairs are long, scattered; *Grevia pilosa*

b. Pubescent: Hairs are **s**oft and wooly; Tomato

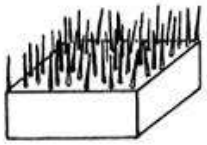
c. Villose: Long, close: *Leucas aspera*

d. Tomentose: Hairs are short dense, cottony; *Terminalia tomentosa, Calotropis procera*

e. Hirsute: Hairs are stiff, fine, scattered; *Eclipta alba*

f. Hispid: Long, rigid; Cucurbits

g. Spinose: Small prickles not spines; Brinjal





Spinose

B. Leaf lamina Texture



Herbaceous: Lamina is thin, membranous; China rose, rose

Coriaceous: Lamina firm, leathery; Mango



Herbaceous **Coriaceous**



Succulent: Leaves are Soft, juicy; *Bryophyllum*

Gland-dotted: Presence of glands; lemon leaves (Surface & texture both)



Succulent **Gland dotted**

SECONDARY GROWTH IN THICKNESS

Dicotyledonous Stem: secondary growth takes place as a result of the formation of new (secondary) tissues in them. Secondary tissues are formed by two meristems – **cambium** in the stellar region and **cork-cambium** formed later in the extra-stellar or cortical region. The increase in thickness due to addition of secondary tissues cut off by the cambium and the cork-cambium in the stellar and extra-stellar regions respectively is known as **secondary growth.**

Cambium Ring: Fascicular cambium present in the bundle tissues is responsible for production of secondary tissues initially. Later a portion of each medullary ray in a line with the cambium becomes meristematic and forms a strip of cambium called the **interfascicular cambium.** The joins on to the cambium proper on either side and forms a complete ring known as the **cambium ring**. Secondary growth occur with the activity of this cambium ring. The structures formed due to secondary growth of xylem and phloem are, **annual ring** or **growth ring, cork**, **bark,** l**enticels.**

QUESTIONS

1. Define: Anatomy, histology, stele, cortex, parenchyma, hypodermis
2. Differebtate between the following with proper example and diagram:
   a. Monocot stem and dicot stem b. Monocot root and dicot root
   c. Monocot leaf and dicot leaf
3. Enlist different leaf lamina types based on surface and texture with proper example
4. Define vascular bundle. What are its types? Explain.
5. Describe stomata nd bulliform cells with proper diagram.

LECTURE: 8

ROOT

A root is the positively geotropic leafless lower portion of the plant axis. Basically, it arises from radicle and is characterized by non-green smooth *surface and* not differentiated into nodes and internodes. Lateral branches arise endogenously. Main function of the root is the anchorage of the plant into the soil and absorption of water and dissolved minerals from the soil by means of root hairs. Three kinds of roots have been recognized on the basis of their nature (tap roots, seminal roots and fibrous roots), and into two types on the basis of their origin (normal roots and adventitious roots).

Tap root:

A root system with a prominent main root, directed vertically downwards bearing small lateral roots. It is characteristic to dicot plants, *e.g.* carrot, radish, rose, trees etc. (fig..8.1A*).* Tap loot is primary in nature as it is formed from the radicle.

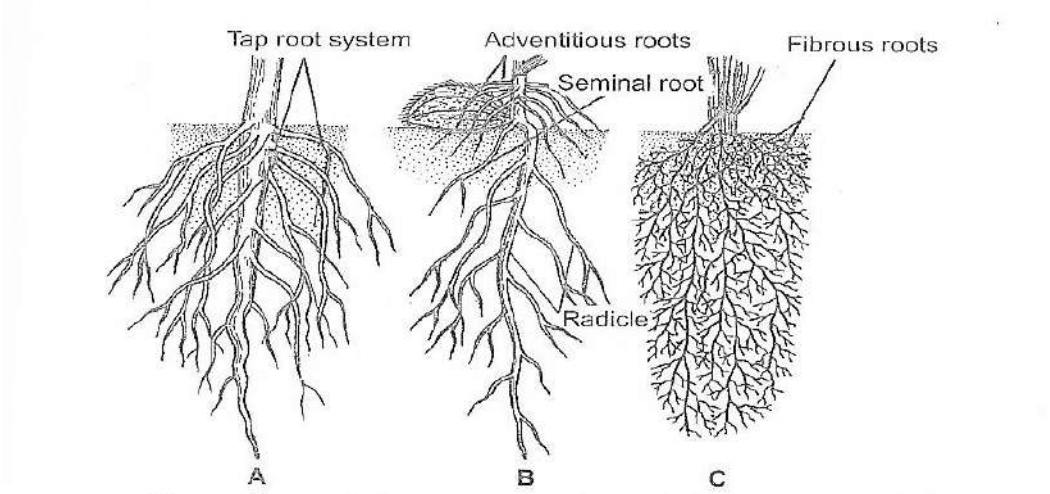


Fig. 8.1 Types of roots. A-tap root system, B-seminal roots in rice seedlings and C-fibrous root system.

Seminal root: In monocots, such roots arise from near the base of the radicle, as in rice (fig. 8.1B) and barley seedlings.

Fibrous root: A root system that develops from the base of the plumule (hypocotyl) in which all roots are equally prominent, as characteristically found in monocots (grasses) (fig. 8.1C).

Normal root: A root arising from the radicle.

Adventitious root: A root developing from any other plant part, except the radicle. It may arise from the underground or aerial stem or from leaf margins.

Modified Roots: Some roots are modified to carry out specialised functions of mechanical and physiological nature.

Modified tap roots: Some tap roots are modified for food storage. These are classified on the basis of their shape as follows:

(i) **Fusiform roots:** swollen in the middle and tapering at the two ends. as in radish *(Raphanus sativus)* (fig. 8.2A).

(ii) Conical roots - broad at the upper end and gradually tapering towards *the* lower end, as in carrot *(Daucus carota)* (fig. 8.2B).

(iii) Napiform roots-almost spherical at the upper end which abruptly tapers at the lower end, *e.g.* beet root *(Beta vulgaris)* and turnip *(Brassica oleracea)* (fig. 8.2C).

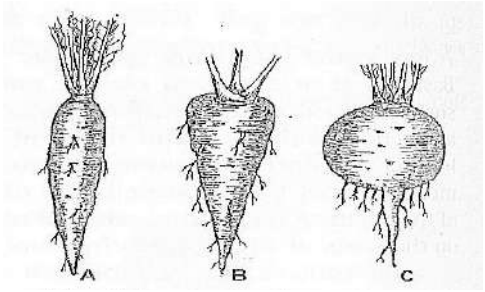


Fig. 8.2 Modification of tap roots

A. Radish (fusiform) B. Carrot (Conical)
B. C. Turnip (Napiform)

Modified adventitious roots: Some adventitious roots are *modified* for various purposes, as follows:

a. **Modified adventitious roots for food storage:**

(i) Root tubers: arising from the node. These swell like tubers for food storage, e.g. sweet potato *(Ipomoea batatas)* (fig. 8.3A).

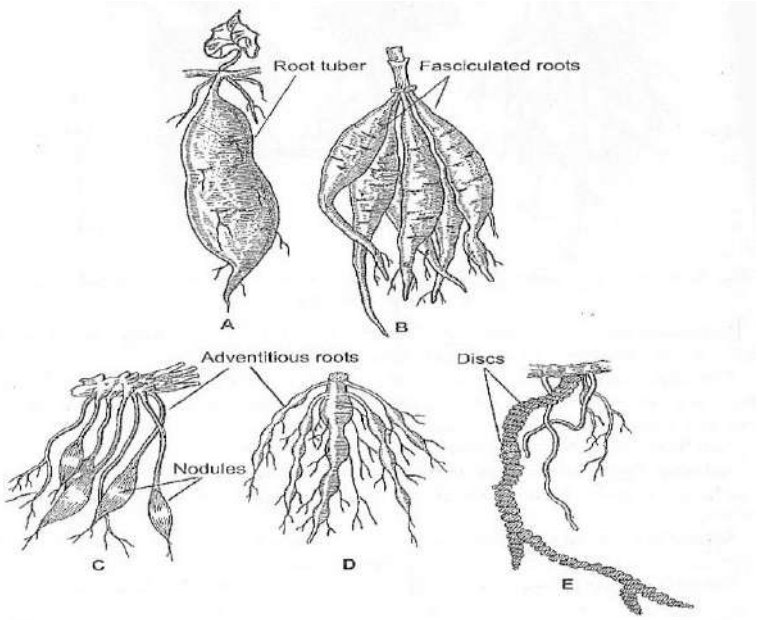


Fig. 14.10 Modifications of adventitious roots. A-root tuber (sweet potato), B-fasciculated (dahlia), C-nodulose (mango-ginger), D-moniliform (grasses) and E-annulated (ipecac).

(ii) Fasciculated roots: the cluster of adventitious tuberous roots, as found in *Aspatagus* and *Dahlia* (fig. 8.3B).

(iii) Nodulose roots: apices of the roots swell up to form bead-like structures, *e.g.* mango ginger *(Curcuma amada)* (fig.8.3 C).

(iv) Moniliform roots: roots develop alternate swellings and constrictions to give a beaded appearance, as found in *Vitis*, *Dioscorea* and some grasses (fig. 8.3D).

(v) Annulated roots: roots appear as if a number of discs are place done above the other, as in ipecac *(Cephalis ipecacuanha)* (fig. 8.3E)

Modified roots for absorption - Aerial roots: Orchids grow as epiphytes on trees and bear hanging aerial routs to absorb atmospheric moisture with the help of spongy velamen tissues (fig. 8.4 A).

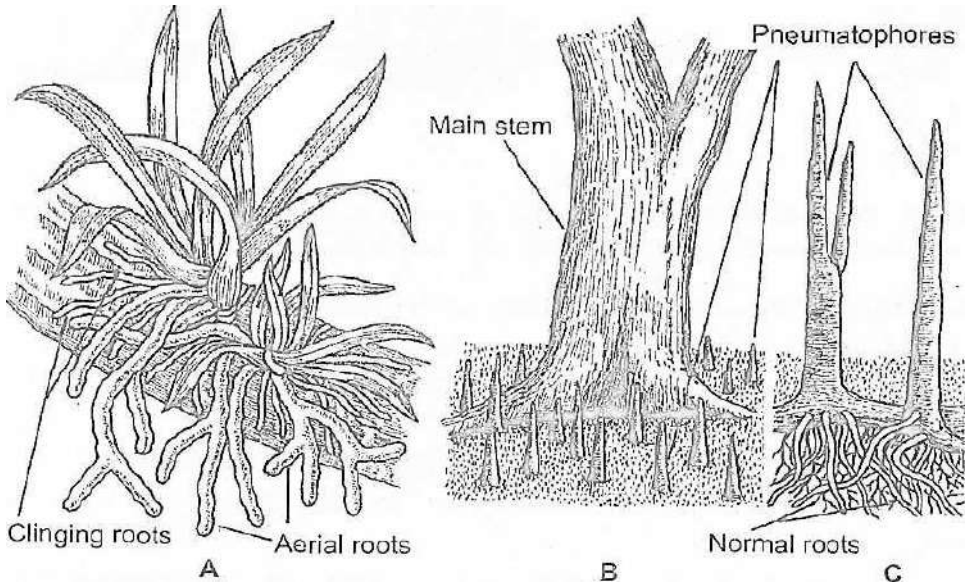


Fig. 8.4 A-aerial roots of orchids and B & C-respiratory roots (pneumatophores) of mangrove plants.

Modified Assimilatory roots: These are hanging green aerial roots which have the power of assimilation (photosynthesis), as found in *Tinospora cordifolia.*

Modified Respiratory roots: These are negatively geotropic vertically growing roots into air for breathing or oxygen requirement found in mangrove plants growing in saline waters, as in *Rhizophora*, *Heritiera*, *Avicennia* etc. These are also called pneumatophores (fig. 8.4B & C).

Modified Parasitic or haustorial roots: These absorb nutrition by sending out haustoria *into* the tissue of *hosts*, as found in parasitic plants like *Loranthus* and *Cuscuta* (fig. 8.5A and B).

Modified Reproductive roots: Roots that bear adventitious buds which grow into plantlets as *elephantum).*

Modified Mycorrhizal roots: Roots of higher plants infested with fungal mycelia which absorb food from the soil. Mycorrhiza facilitates nutrient absorption specially N, P and K by the higher plants. These are found in *Monotropa* (a saprophytic angiosperm), *Sarcodes* and *Pinus* (fig. 8.5C and D).

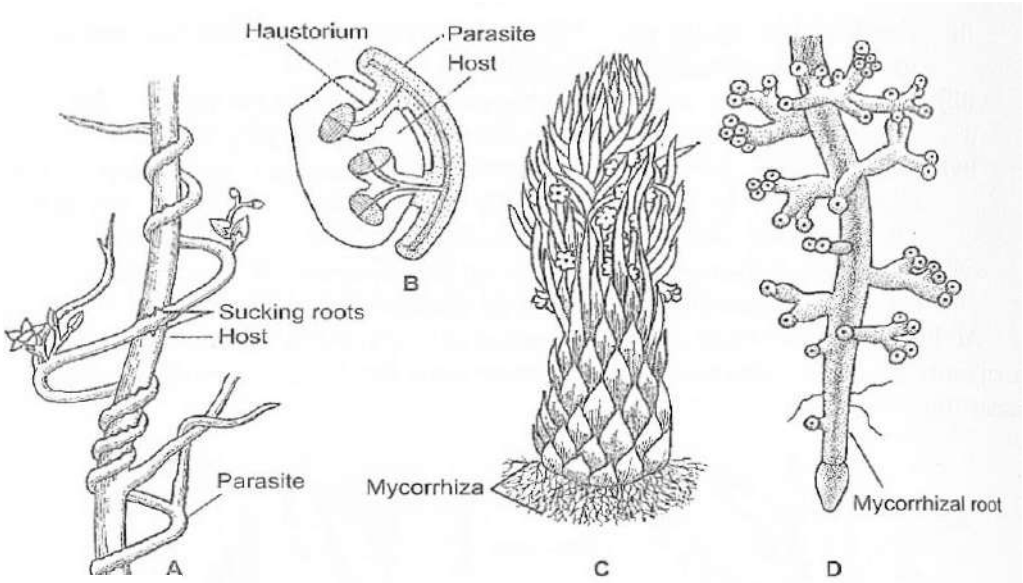


Fig. 8.5 A-haustorial roots of *Cuscuta*, B-T.s. of host plant showing haustoria of *Cuscuta*, C-mycorrhizal roots of *Sarcodes* and D-mycorrhizal root of *Pinus*.

Food storing roots: These accumulate reserve food material to carry out physiological functions, *e.g.* fusiform, conical and napiform roots (tap roots) or tuberous, fasciculated, nodulose, moniliform or annulated roots (adventitious roots).

Roots modified for mechanical support: Roots may be modified variously to provide mechanical support to the plants and are named accordingly, *e.g.*

(i) Prop roots: Strong, woody and sunken in the soil, these aerial roots arise from horizontal branches (stem) to provide stem-like support, as found in banyan tree *(Ficus benghalensis)* (fig. 8.6A).

(ii) Stilt roots: Roots arising from lower nodes of the stem and growing obliquely downwards to anchor the plant into the soil, as found in maize (Zea ***mays),*** sugar cane ***(Saccharum officinarum),*** screw pine ***(Pandanus foetidus)*** and in some mangrove plants ***(Rhizophora)*** (fig. 8.6 B and C).

(iii) Clinging roots: found in epithytic plants (orchids) to cling the plant on the stem of other plant (fig. 8.4 A).

(iv) Climbing roots: adventitious roots arising from the node of the stem that help in climbing or twinning of the plant, as found in betel vine ***(Piper betle)*** (fig. 3.5) and money plant ***(Pothos).***

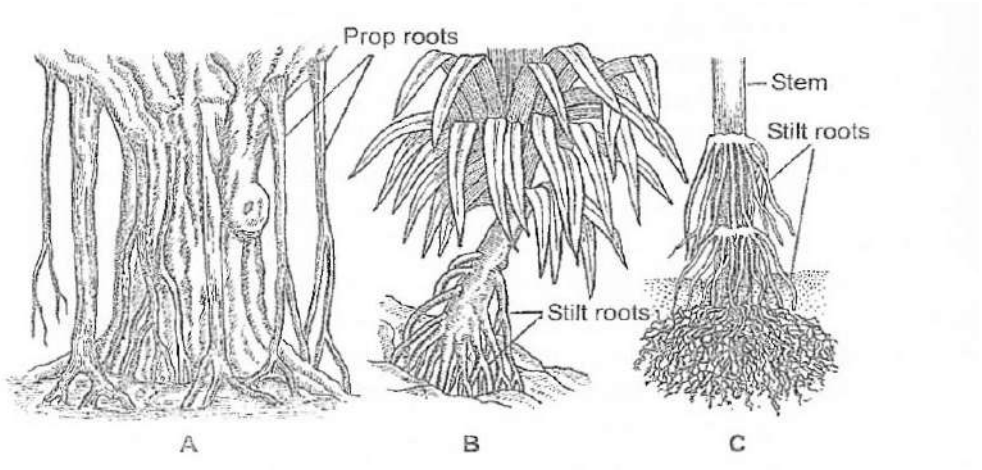


Fig. 8.6 A-prop roots of banyan, B-stilt roots of screw pine and C-stilt roots of maize.

(v) Root buttresses: found in some large trees to provide additional support by producing plank-like roots arising from base of trunk, in ***Salmalia, Ficus*** and ***Terminali***.

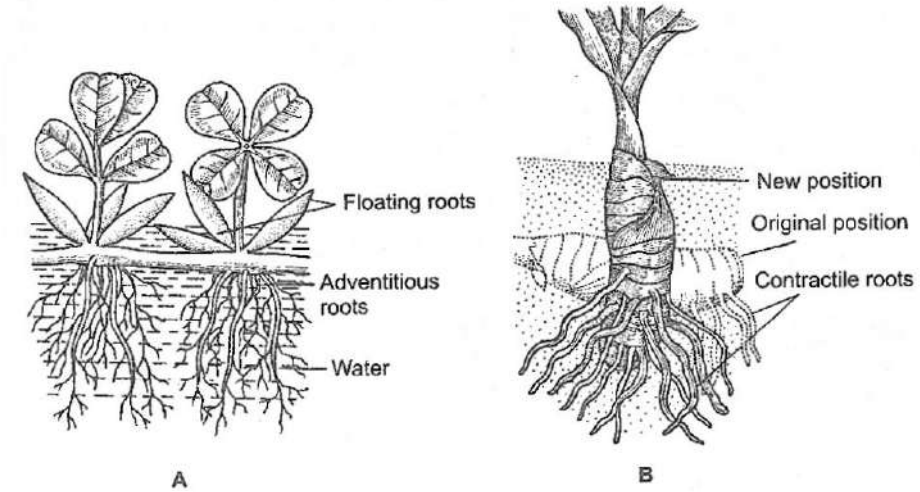


Fig. 8.7 A-floating roots of *Jussiaea* and B-contractile roots of *Canna*.

Other modified roots

(i) Floating roots: Found in aquatic floating plants-special adventitious spongy and whitish roots filled with air to facilitate plant floating on the water. These also help in respiration, as found in *Jussiaea repens* and *Pistia stratiotes* (fig. 8.7A).

(ii) Contractile roots: special type of roots which can contract or pull the stem deep into the soil, as found in *Lilium, Allium* and *Cmm* (fig. 8.7B).

QUESTIONS

1. Define and draw properly a Tap root system. Mention its functions.
2. Enlist different types of modified roots (tap & adventitious) for physiological functions with suitable example.
3. Enlist different roots modified for mechanical function with suitable example.

LECTURE: 9

STEM

Stem is the axis of a plant bearing leaves with buds in their axils. It is formed by the plumule of the seed.

Acaulescent: A plant which is stemless or without visible stem.

Arborescent: A plant almost tree-like with a short main trunk.

Arboreous: A tree with well-developed trunk.

Culm. A jointed stem with distinct nodes and internodes, as in grasses and sedges (fig.14.ID).

Branching of the Stem: Branching may be:

(i) Racemose or **monopodial** branching-main stem (terminal bud) grows indefinitely and lateral branches are produced in an acropetal order (i.e., older towards base), as in *Polyalthia.*

(ii) Cymose - the terminal (apical) bud loses its activity and axillary buds grow vigorously to form a large spreading tree as in mango *(Mangifera indica)*, neem *(Azadirachta indica)*, banyan *(Ficus benghalensis)* etc. Cymose branching may be: *(a) Uniparous* (only one branch at each node), *(b) Biparous* (two branches at each node) or *(c) Muitiparous* (more than two branches at each node).

Modified Stems

(I) Underground Modifications

(1) Rhizome-underground, dorsiventral, horizontally growing below the soil surface with distinct nodes and internodes. Nodes bear scale leaves on the upper surface and adventitious roots on the lower surface. They are usually fleshy due to the storage of food, as found in ginger *(Zingiber officinale)* and turmeric *(Curcuma longa)* (fig. 9.1A).

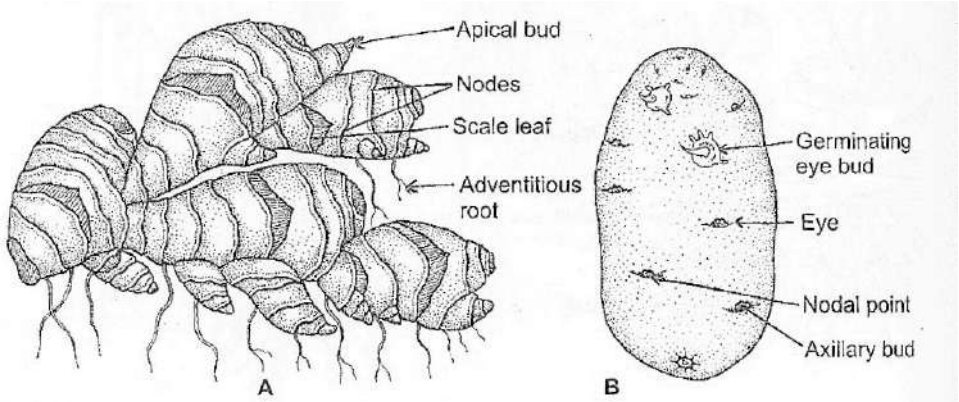


Fig. 9.1 A-rhizome of ginger and B-tuber of potato.

(2) Tubers-fleshy, swollen, underground stem bearing scale leaves with buds (eyes) in their axils. The eyes are spirally arranged, but more crowded towards the distal end (called *rose end),* each eye develops into a small shoot. Stem tubers are commonly found in potato *(Solanum tuberosum)* (fig. 9.1B), Jerusalem artichoke *(Helianthus tuberosus)* and *Cyperus rotundus.*

(3) Bulb-a rounded, modified, underground bud bearing highly reduced (disc-like) stem and fleshy scale leaves which make up the bulk of the organ. According to the arrangement of the scale leaves, the bulbs are called *(i)* **tunicated**-scale-leaves arranged in a concentric manner and the whole bulb is enclosed by dry membranous scale leaves, called ***tunic***, as seen in onion *(Allium cepa)* , tulips *(Tulipa)* and tuberose *(Polianthes)* (fig. 9.2 A, B),

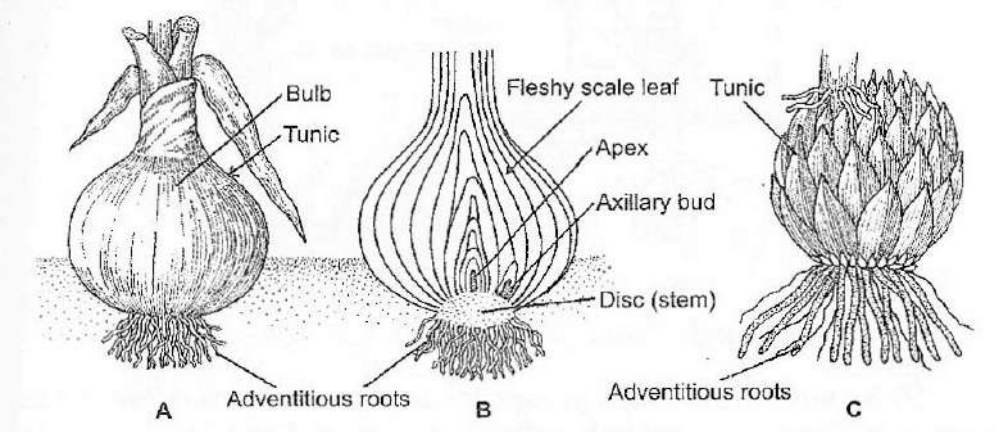


Fig. 9.2 Bulbs. A-tunicated bulb of onion, B-L.S. of the bulb and C-scaly bulb of lily.

and *(ii)* **scaly or imbricated**-scale-leaves arranged loosely with overlapping margins and are not covered by any common tunic, as in garlic *(Allium sativum)* and lily *(Lilium)* (fig. 9.2 C).

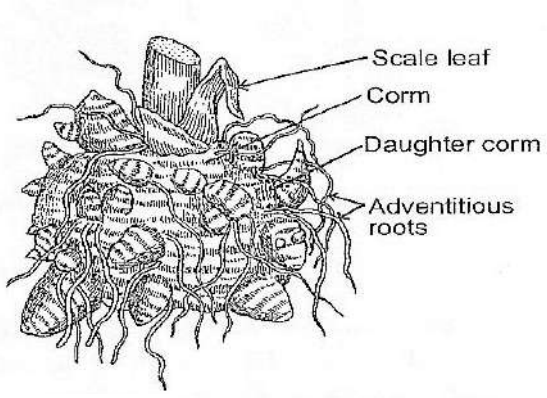


Fig. 9.3 Corm of *Amorphophallus complanatus.*

(4) Corm-a solid, highly condensed, vertical root-stock with a large apical bud. Some scale leaves are present on its body and adventitious roots grow either from the base or all over its body. Corms are found in *Colocasia, Crocus, Colchicum, Gladiolus* and *Amorphophallus.* In *Amorphophallus complanatus,* the corm is single internode with numerous adventitious buds and roots all over its body (fig. 9.3).

(II) Sub-aerial Modifications;

(1) Runners-develop from the basal internode of the axillary buds of the lowest leaves and which elongate horizontally along the ground carrying the buds, and after trailing for a short distance along the ground, each runner attaches itself to the soil by means of adventitious roots and develops into a new daughter plant, as in *Cynodon, Oxalis* (fig. 9.4A) and **Hydrocotyl.** Sobole is a special type of underground runner found in many grasses. The grasses send out soboles in all directions and develop numerous offsprings (fig. 9.4B). It is a more effective method of propagation, as in *Saccharum spontaneum, Agropyron* and *Imperata arundinacea.*

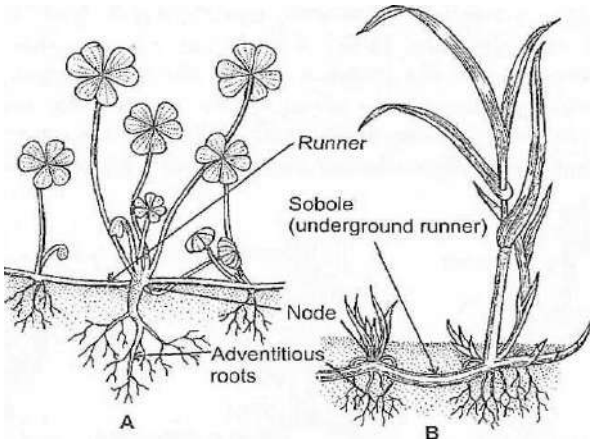


Fig. 9.4 A-runner *(Oxalis*) **and** B-sobole

(2) Stolon-a special type of runner which grows upward like ordinary branch and then archs down to strike roots in the soil and forms a daughter plant, as in *Mentha* (fig. **9.5A).**

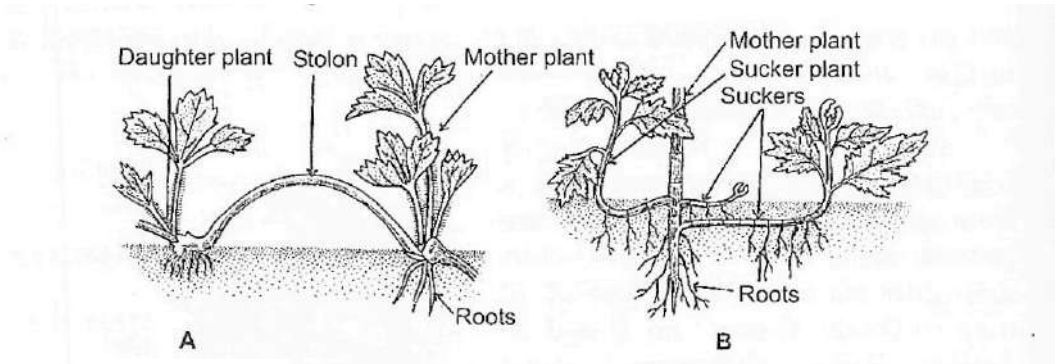


Fig. 9.5 A-stolon *(Mentha)* and B-sucker (*Chrysanthemum*).

(3) **Sucker-**an underground runner which after travelling a short distance grows up and forms a daughter plant. These may also develop from the axillary buds. Suckers are commonly found in *Mentha arvensis, Musa* and *Chysanthemum* (fig. 9.5B).

(4) **Offset-**similar to a runner but shorter and thicker and found in aquatic plants. It runs for sometimes under-water and then surfaces to bear a bunch of leaves and adventitious roots, as in ***Pistia stratiotes*** and ***Eichhornia crassipes*** (fig. 9.6).

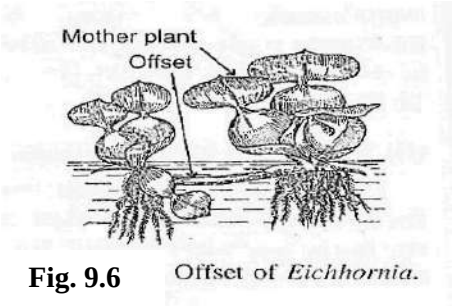


Fig. 9.6 Offset of *Eichhornia.*

(III) Aerial Modifications

(1) **Phylloclade or Cladophyll-**a stem in which several nodes and internodes become flattened or swollen, fleshy and green leaf-like. Such stems carry out the photosynthesis and also store the food. Leaves, present on the nodes, are reduced to scales or modified into spines. Phylloclade is a xerophytic adaptation to reduce transpiration, as found in cocoloba **(*Muehlcnbeckia platyclada*),** cactus (***Opuntia***) and ruscus **{*Ruscus*)** (fig. 9.7 A, B and C). In ***Ruscus,*** phylloclades look exactly like leaves, but occurrence of flower at the nodal points, justify their stem nature.

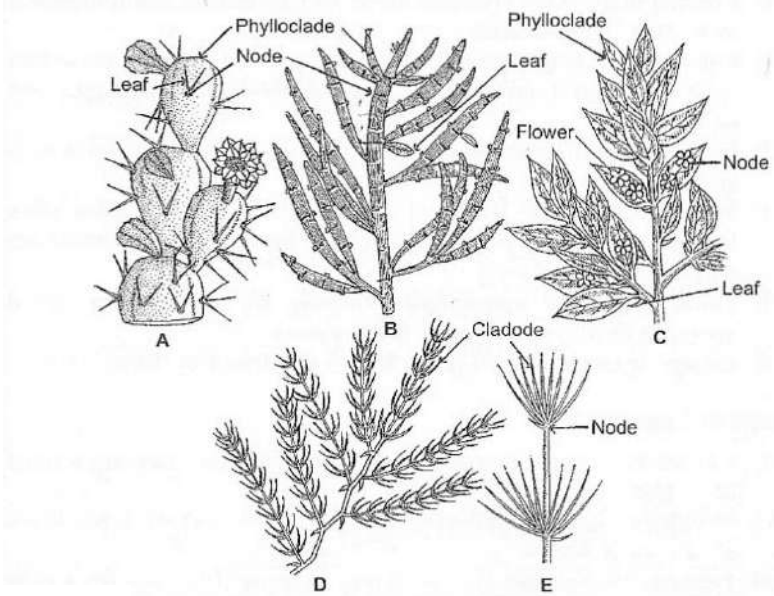


Fig. 9.7 A-phylloclade (*Opuntia*), B-phylloclade of *Muehlenbeckia*, C-phylloclade of *Ruscus* and D and E-cladodes of *Asparagus.*

Cladode - A special type phylloclade consisting of one or two internodes only. In *Asparagus*, the ultimate branchlets are of one internode only and modified into cylindrical leaf-like structures, whereas leaves are reduced to scales or spines (fig. 9.7 D, E). It is a xerophytic adaptation to reduce transpiration.

(2) **Thorn**-a modified straight, hard and pointed axillary branch. Thorns are deep seated, direct prolongations of the stem and have vascular connections. These are xerophytic adaptations. Thorns of *Duranta* bear leaves(fig. 9.8) and those of *Prunus* flowers

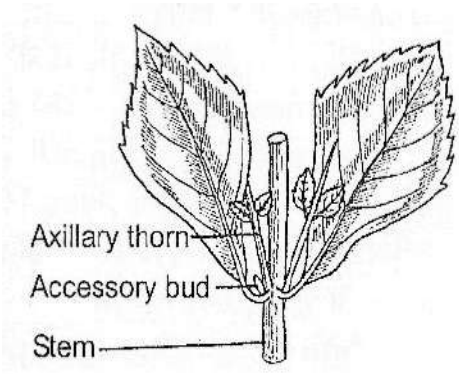


Fig 9.8 Axillary branch modified into thorn (*Duranta*).

(4) **Stem-tendril**-a modified axillary or terminal bud into tendril for climbing. Tendrils of *Passtflora* (fig. 3.4C) are modified axillary branches whereas those of *Vitis* are modified tips of sympodial branches.

QUESTIONS

1. Define: Shoot system, Acaulescent, Arborescent, Arboreous, Culm
2. Enlist different types of stem modifications with function and proper examples in tabulated form.
4. Write down the important functions of stem.
5. Differentiate between

   Stem and root

   Culm and Caudex

LECTURE: 10

LEAF

Leaf is a lateral appendage of the stem borne at the node and bears an axillary bud in its axil. It is usually expanded and concerned with the manufacture of food (photosynthesis).

Kinds of Leaves

1. **Cotyledonary leaf**-cotyledon green and appearing like foliage leaf as in *Tilia* and *Geranium.*
2. **Cataphylls or Scale leaves**-dry, papery or fleshy scale leaves or bud scales, as found on various parts of *Casuarina, Asparagus* and bamboos.
3. **Hypsophylls or bract leaves**-special leaves which bear floral buds at their axils.
4. **Prophylls**-first few leaves of a branch which differ from other leaves as found in wood apple *(Aegle marmelos)* where these are represented by spines.
5. **Floral leaves or sporophylls**-stamens and carpels are called sporophylls in common with lower plants.
6. **Foliage leaves**-common green leaves (discussed in detail here).

Duration of Leaves

1. **Caducous or fugacious**-leaves fall off as soon as they are formed as in *Opuntia*.
2. **Deciduous or annual**-leaves fall off at the end of a particular season as in *Acer*.
3. **Persistent-leaves** last for a long time as in most tropical trees, as in *Polyalthia.*

Phyllotaxy

It is the mode of arrangement of leaves on the stem.

Leaves borne directly on the main trunk are called **cauline** as in *Dracaena* and other *monocots* and borne on the branches are called **ramal** as in most dicot trees. Leaves are called **radical** if these arise from reduced stem and appear as if arising from the root as in radish.

In **cauline** or **ramal** leaves, there may be one, two, three or more leaves at each node. When there is only one leaf on each node, the arrangement is called **spiral, alternate or acyclic** and if there are, two or more leaves on each node, it is called **cyclic**.

Spiral or alternate phyllotaxy. Leaves are produced alternately or spirally on the long axis or stem. If these are found to lie in a fixed number of vertical rows, the arrangement is called **orthostichous** and is variously termed:

(1) **Distichous or $\frac{1}{2}$ phyllotaxy**–the leaf of second node is just opposite the leaf of the first node, as in grasses.

(2) **Tristichous or $\frac{1}{3}$ phyllotaxy**–leaves are three ranked and the fourth is just above the first leaf as in *Cyperus rotundus.*

(3) **Pentastichous or $\frac{2}{5}$ phyllotaxy**–the sixth leaf is found above the first leaf and seventh above the second leaf as in china-rose (*Hibiscus rosa-sinensis*) (fig. 14.24).

(4) **Octastichous or $\frac{3}{8}$ phyllotaxy**–the ninth leaf is found above first leaf and so on, as in *Carica papaya.*

Parastichous term is used when it is not possible to establish orthostichy, as on date palm trunk.

Cyclic phyllotaxy. The leaves at each node form a whorl with the leaves placed on a circle in which the angles between adjacent leaves are same. It can broadly be of two types:

(1) Opposite phyllotaxy-two leaves on each node and opposite to one another. It can be of two kinds : *(i)* ***Opposite*** **decussate**-successive pairs of leaves placed at right angles to one another as in *Calotropis* (fig. 10.1) or ***Opposite superimposed***-successive pairs of leaves exactly on top of one another so that all leaves lie in one plain as in *Psidium guajava* and *Quisqualis* (fig. 10.1).

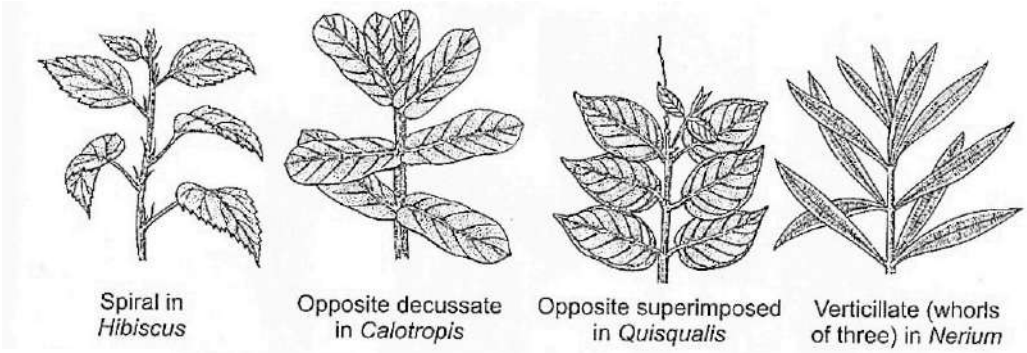


Fig. 10.1 Phyllotaxy-spiral, opposite decussate, opposite superimposed and verticillate.

(2) **Verticillate phyllotaxy**-also called whorled phyllotaxy in which three to five leaves form a whorl in each node as three leaves in *Nerium odorum* (fig. 14.24) and five or more in *Alstonia scholaris.*

Heterophylly. Presence of different types of foliage leaves as in *Ranunculus aquatilis* and *Limnophila heterophylia* where submerged leaves (in water) are dissected and aerial leaves are more or less entire.

Anisophylly. In some opposite phyllotaxy, leaves are of unequal size, as in *Pellionia daveanana.*

Leaf Parts (of Foliage Leaves)

A typical leaf is made up of three parts, (i) the leaf base or hypopodium, (ii) the stalk or petiole or mesopodium and (iii) the leaf blade or lamina or epipodium (fig. 10.2).

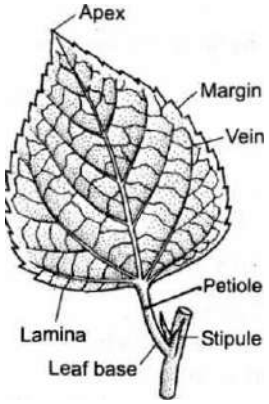


Fig. 10.2 Parts of a typical leaf.

Leaf base. The point of attachment of the leaf to the stem. It may be variously modified, *e.g. (a)* ***pulvinus****-a* swollen leaf base, as in mango *(Mangifera)* and *Mimosa pudica* (fig. 10.3A). *(b)* ***sheathing****-(*clasping or forming sheath around the stem, as in banana *{Musa paradisiaca)* (fig. 10.3B), *(c)* ***amplexicaul****-a* sheathing leaf base which surrounds stem completely, as in grasses and *Aethusa cynapium*, (fig. 10.3C) and *(d)* ***decurrent****-a* winged leaf base which extends down to the stem, as in *Symphytum* (fig. 10.3D).

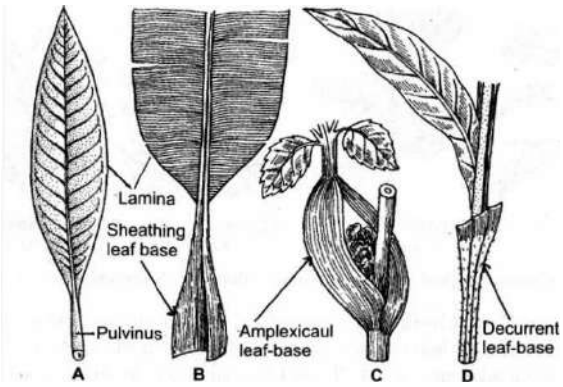


Fig. 10.3 Variations in leaf bases. A-pulvinus *(Mangifera indica),* B-sheathing leaf base *(Musa paradisiaca),* C-amplexicaul *(Aethusa cynapium)* and D-decurrent *(Symphytum officinale).*

Stipules. A pair of lateral outgrowth present at the base of the leaf. Leaves possessing stipules are called **stipulate** and lacking are **exstipulate** (as in mango). Stipules may be of various types, *e.g.* (i) **Adnate**-adhering to the petiole upto a certain height and making it somewhat winged as in rose *(Rosa)* (fig. 10.4A), (ii) **Free lateral**-free on the two sides of the leaf base as in china rose *(Hibiscus rosa-sinensis),* (fig. 10.4B), (iii) **Intrapetiolar**-present between the leaf and the

axis as in *Gardenia* (fig. 10.4C), (iv) Interpetiolar-two stipules lying between the two leaves, as in *Ixora* (fig. 10.4D), (v) **Ochreate**-stipules which form a hollow tube encircling the stem from the node upto a certain height, as in *Polygonum* (fig. 10.4E),

(vi**) Tendrillar** - stipules modified into tendril, as in *Smilax* (fig. 10.4F),

(vii)**Foliaceous**-leafy stipules, as in *Pisum* (fig. 10.4G), (viii) Scaly-small and dry as in *Artocarpus*, and (ix) **Spinous**-modified into spines, as in *Acacia* and *Zizyphus* (fig. 10.4H)

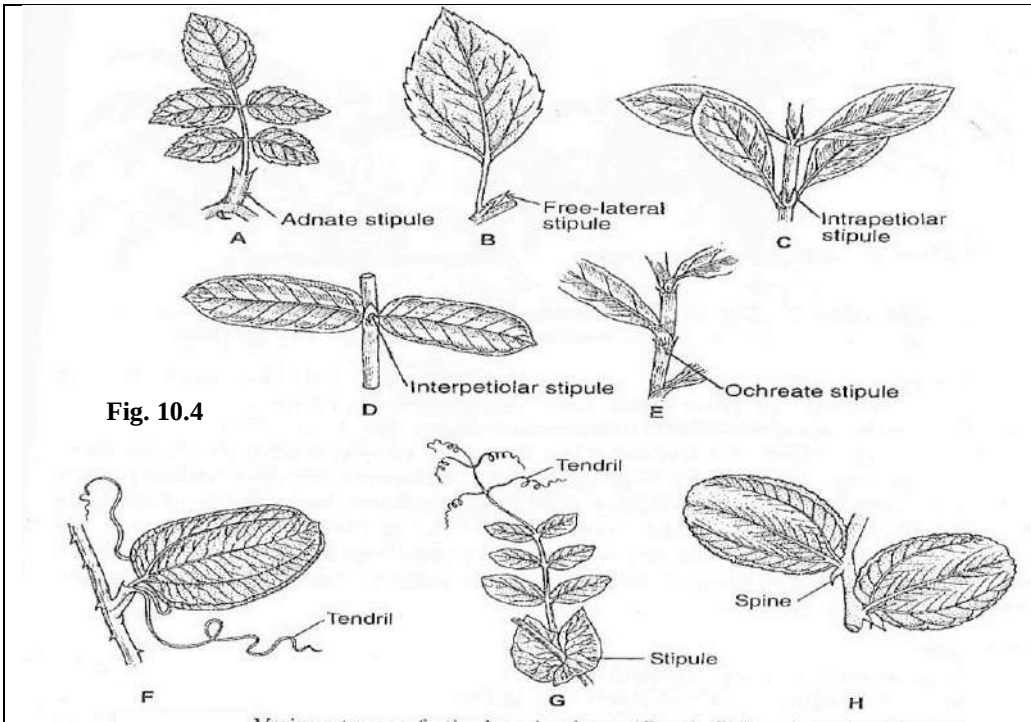


Fig. 10.4

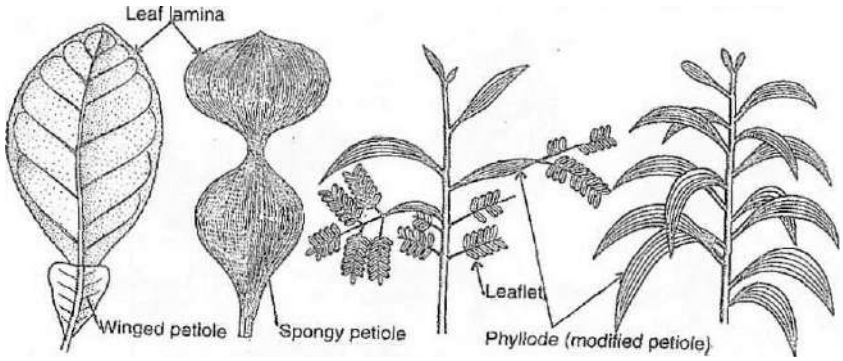
Various types of stipules. A-adnate (*Rosa*), B-free lateral (*Hibiscus rosa-sinensis*), C-intrapetiolar (*Gardenia*), D-interpetiolar (*Ixora*), E-ochreate (*Polygonum*), F-tendrillar (*Smilax*), G-foliaceous (*Pisum*) and H-spinous (*Zizyphus*).

The duration of the stipules may be (i) **Caducous**-shed very early as in *Michelia champaca,* (ii) **Deciduous**-lasting for one season, as in *Cassia tora* or (iii) **Persistent**-as in foliage leaves, *e.g. Pisum* and *Rosa.*

Stipels. Stipule-like appendages at the base of leaflets, as in *Dolichos lablab, Vicia faba* and *Desmodium gyrans* (all leguminous plants).

Petiole. Stalk of the leaf, and also called the **mesopodium**. A leaf having a petiole is called *petiolate* as in mango *{Mangifera indica)* and without petiole is called sessile, as in *Calotropis.* The petiole shows, sometimes modifications, as it is **winged** in *Citrus* (fig. 10.5A), swollen and spongy in *Eichhornia* (fig. 10.5B) and *Trapa,* flattened or leaf-like called ***phyllode*** in australian

acacia *{Acacia auricuiaeformis)* (fig. 10.5C and D), **tendrillar** in *Smilax*, partly **wing-like** and partly **tendrillar** in *Nepenthes* and spinous in *Quisquatis.*



A B C D

Fig. 10.5 Modifications of petiole. A-winged *{Citrus),* B-spongy *(Eichhornia)* and C-phyllode *(Acacia).* C-young seedling part and D-mature leaf (phyllode)

Lamina (Epipodium). The most important part of the leaf and a seat of gaseous exchange for photosynthesis, respiration, transpiration etc. If the upper surface *(adaxial)* differs in structure from the lower *(abaxial)* surface, the leaves are called **dorsiventral** as in most dicots and if both surfaces receive equal light and there is no difference between the two surfaces, they are called **isobilateral,** as in maize and other grasses. Sometimes, leaves are cylindrical or centric (no distinct two surfaces), *e.g. Allium cepa.*

Several features of leaf are considered regarding appearance of lamina, such as shape, base, margin, apex, surface, texture, venation, incision and simple or compound etc.

(I) Shape: Important shapes of lamina are:

1. **Acicular**-needle-shaped (as in *Pinus).*
2. **Linear**-longer and slightly broader as in grasses and tube roses (*Polianthes tuberosa).*
3. **Lanceolate**-lance-shaped as in *Nerium* and *Polyalthia.*
4. **Oblong**-more or less rectangular as in banana *(Musa).*
5. **Ovate**-egg-shaped as in china-rose *{Hibiscus rosa-sinensis)* and banyan.
6. **Cordate**-heart-shaped as in betel vine *{Piper betle).*
7. **Sagittate**-shape like arrow head with two basal lobes as in *Sagittaria sagittifolia.*
8. **Hastate**-like sagittate but the two basal lobes are directed outwards as in some *Ipomoea.*
9. **Reniform**-kidney-shaped as in *Hydrocotyle.*
10. **Lunate**-half moon-shaped as in *Passtflora lunata*.
11. **Obovate**-reverse of ovate as in jackfruit (*Artocarpus*).
12. **Obcordate**-reverse of cordate with an apical notch as in *Bauhinia*.
13. **Spathulate**-spathula-shapcd as in *Lippia nodiflora* and *Euphorbia nerifolia*.
14. **Cuneate**-wedge-shaped as in *Pistia stratiotes*.

15. **Elliptical**-like an ellipse as in *Vinca rosea* and guava (*Psidium guajava*).
16. **Rotund**-orbicular or circular as in water lily and lotus (*Nelumbo*)

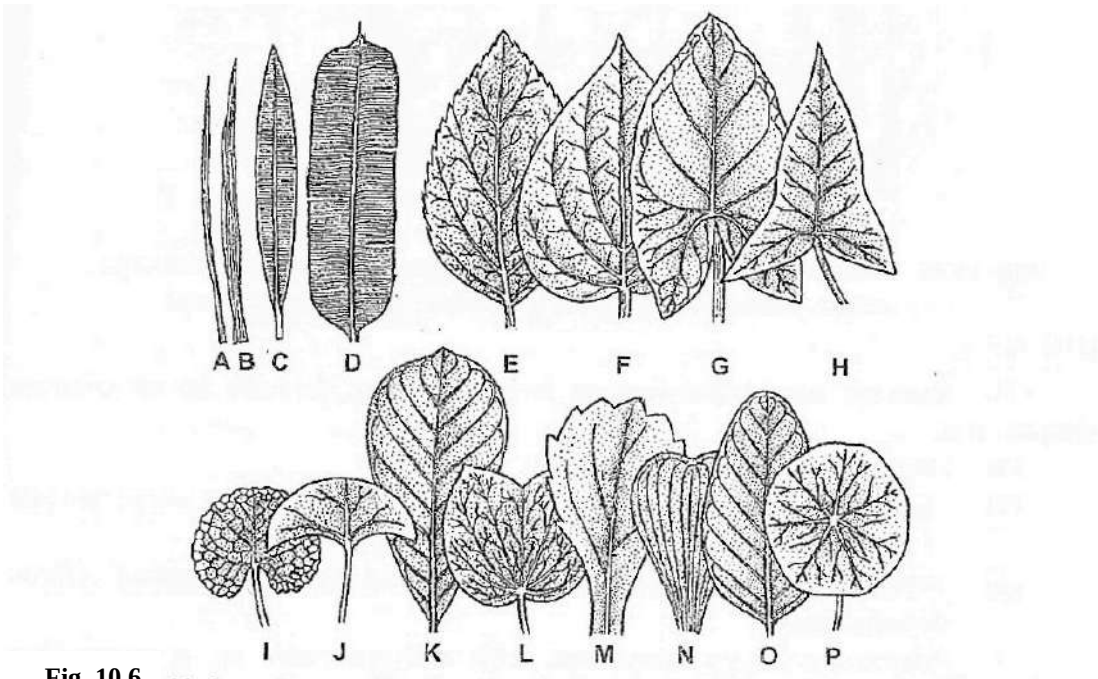


Fig. 10.6 Various shapes of lamina. A-acicular (pine), B-linear (tuberose), C-lanceolate (*Nerium*), D-oblong (banana), E-ovate (china-rose), F-cordate (betel vine), G-sagittate (*Sagittaria*), H-hastate (*Ipomoea*), I-reniform (*Hydrocotyle*), J-lunate (*Passiflora*), K-obovate (jackfruit), L-obcordate (*Bauhinia*), M-spathulate (*Lippia*), N-cuneate (*Pistia*), O-elliptical (guava) and P-rotund (water-lily).

(II) Margin: The outermost boundary of the lamina is known as margin. Margins show variation

1. **Entire-smooth margin as in mango (**Mangifcra**).**
2. **Repand-wavy margin as in** Polyalthia**.**
3. **Serrate-** margin with teeth pointed upwards as in saw, e.g. china-rose *(Hibiscus rosa-sinensis)* and rose.
4. **Biserrate**-teeth again serrated as in elm (*Maple).*
5. **Retroserrate**-teeth pointed downwards.
6. **Dentate**-margin toothed, but teeth pointed outwards (at right angles) as In water-lily or *Nymphaea.*
7. **Bidentatc**-tccth again dentate.
8. **Crenatc**-margin with rounded teeth as in *Bryophyllum* and *Hydrocotyl.*
9. **Bicrenate**-margin with tooth and teeth again crenate.
10. **Spiny**-teeth pointed to form spines as in *Ananas* (pineapple) and *Argemone* (Mexican poppy).
11. **Lobed or incised**-margin much dissected or incised as in *Raphanus.*

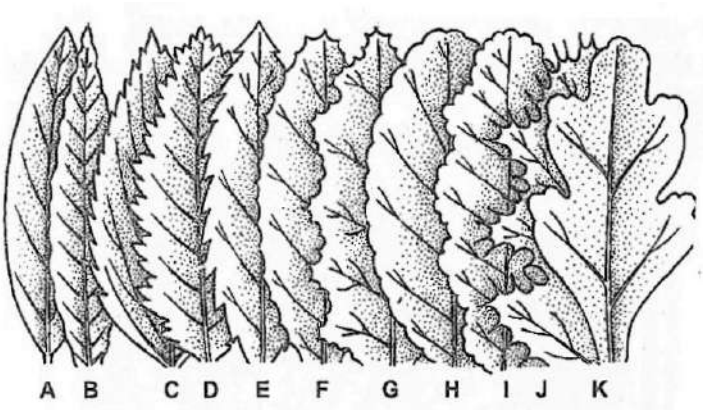


Fig. 10.7 Leaf margin. A-entire, B-repand, C-serrate, D-biserrate, E-retroserrate, F-dentate, G-bidentate, H-crenate, I- biserrate, J-spiny and K-lobed.

(III) Apex: The anterior tip of the lamina is called apex. It may be of various shapes

1. **Acute-**pointed and narrow as in mango.
2. **Acuminate-**apex drawn out into long tapering tail as in peepal *(Ficus religiosa).*
3. **Obtuse-**apex blunt or broad angled as in banyan (*Ficus benghalensis*).
4. **Mucronate -**apex broad but with a sharp point as in periwinkle **(*Vinca rosea*)**.
5. **Cuspidate-**spiny as in pineapple (*Ananas*), date palm *(Phoenix)* screw-pine (*Pandanus)* etc.
6. **Tendrillar-** apex forms tendril for climbing as in ***Gloriosa***.
7. **Cirrhose-** mucronate apex with a fine thread-like structure as in banana (*Musa*).
8. **Truncate-**apex abruptly cut across as in *Paris* ***polyphylla.***
9. **Retuse**-slightly notched obtuse apex as in ***Pistia*** and ***Clitoria.***
10. **Emarginate-**deeply notched obtuse apex as in ***Bauhinia.***

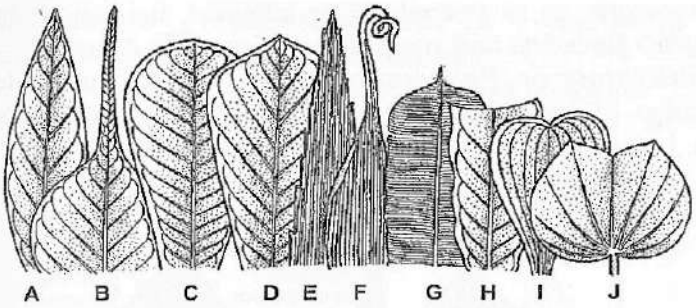


Fig. 10.8 Leaf apices. A-acute, B-acuminate, C-obtuse, D-mucronate, E-cuspidate, F-tendrillar, G-cirrhose, H-truncate, I-retuse and J-emarginate.

(IV) Surface: The external surface of lamina may show variation,

1. **Glabrous-**smooth and without any hair, as in mango.
2. **Glaucus-**shiny and covered with waxy coating as in *Calotropis* and lotus.
3. **Scabrous-**rough because of the presence of short rigid points, *e.g.* fig leaves.

4. **Viscose-**sticky because of the some secretion as in leaves of *Cleome* and *Nicotians tabacum,* sometime called glutinous.
5. **Rugose-**wrinkled surface as in *Rubus rugosvs.*
6. **Gland dotted-**glands found on the leaf surface as in lemon *(Citrus).*
7. **Hairy-**surface covered with hairs. Hairs may be of various types and accordingly called:
   (a) **Pubescent-**hairs soft and woolly as in tomato.
   (b) **Pilose-**hairs long, distinct and scattered as in *Grewia pilosa.*
   (c) **Villose-**hairs long, soft, closely set as in ***Leucas aspara.***
   (d) **Tomentose-**hairs short, dense, cottony as in *Terminalia tomentosa* and *Calotropis procera.*
   (e) **Hirsute-**hairs stiff, fine scattered as in *Eclipta alba.*
   (f) **Hispid-**hairs long and rigid as in *Cucurbita.*
8. **Spinose-**surface covered with small prickles as in brinjal *(Solarium melongena).*

(V) Venation: The pattern of arrangement of vascular system in the lamina is called venation. It is mainly of two types:

(A) Reticulate venation. The main vein branches repeatedly to form a network or reticulum covering the entire leaf. It is a characteristic of dicotyledons except in *Callophyllum.* It shows two variations:

(1) Unicostate or Pinnate-almost racemose type. One prominent mid-rib runs from the base to the apex with several secondary and tertiary and so on anatomizing veinlets forming a net-like framework, as in peepal *(Ficus religiosa),* banyan *(F. benghalensis), Eugenia jambolina* and most dicots (fig. 10.9 A and B).

(2) Muticostate or Palmate-from the base of the lamina arises a number of equally strong veins (or costas) which spread out like fan, hence called palmate. Palmate veins may be:

a) **Convergent-**veins converging towards the tip as in *Zizyphus jujuba* and *Cinnamomum tamala* (fig. 10.9C)
b) **Divergent-**veins spread out from one point to different directions as in *Cucurbita maxima* (fig. 10.9D).

(B) Parallel or Striate venation. Main veins run parallel to one another with laterally connected unbranched veinlets. Parallel venation may be:

(1) Unicostate or Pinnate-presence of single strong mid-rib which gives rise to parallel branches, joined by parallel transverse veinlets, as in banana *{Musa)* (fig. 10.10A) and *Canna.*

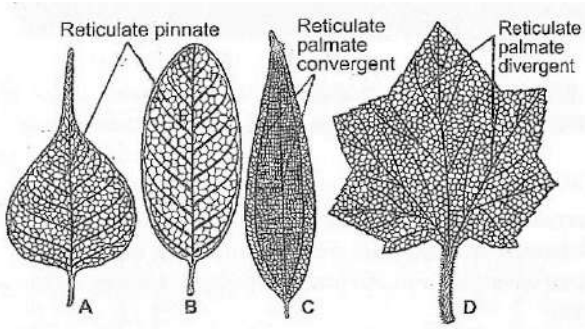


Fig. 10.9 Reticulate venation. A-unicostate (peepal), B-unicostate showing submarginal veins (*Eugenia jambolana*), C-palmate convergent (*Cinnamomum*), and D-palmate divergent (*Cucurbita*).

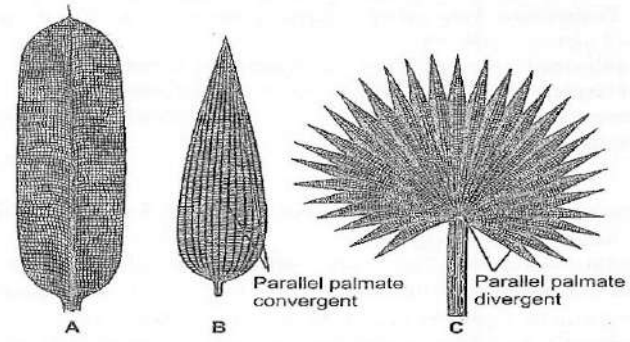


Fig. 10.10 Parallel venation. A-unicostate (banana), B-palmate convergent (bamboos) and C-palmate divergent (fan palm).

(2) Multicostate or Palmate-presence of a number of strong veins arising from the base, this may be:

(a) Convergent-as in bamboos (fig. 10.10B) and grasses or

(b) Divergent-as in fan palm *(Borassus flabellifer)* (fig, 10.10C)

(VI) Leaf Incision (Simple and Compound Leaves)

Indentation of the lamina margin is called leaf incision. Accordingly two main categories are recognized, *i.e.*, simple leaf and compound leaf.

Simple Leaf: A leaf having entire margin (as in mango) (fig. 10.11A) or, if dissected, presenting a single appearance due to presence of some apparent laminar connection as in radish and mustard *(Raphanus satlvus* and *Brassica campestris).* Leaf-shape of radish is called lyrate.

Compound Leaf: The leaf has incised margin, and the incision goes so deep, touching the mid-rib, so that lamina breaks up into lobes or segments called leaflets. A compound leaf may be (A) Pinnate or (B) Palmate.

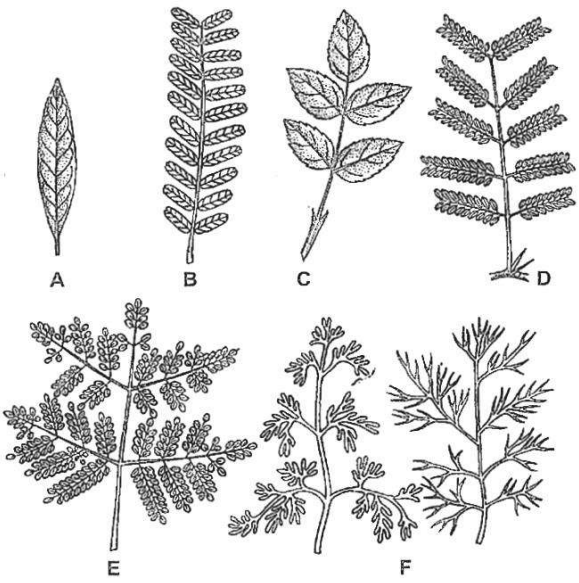


Fig. 10.11 Types of leaf. A-simple (mango), B-pinnate-paripinnate compound (*Tamarindus*), C-pinnate-imparipinnate compound (rose), D-bipinnate compound (*Mimosa*), E-tripinnate compound (*Moringa*) and F-decompound (*Foeniculum*).

(A) Pinnate Compound; The midrib (or rachis) directly bears the leaflets or pinnae along both the sides. It may be simple pinnate, bipinnate, tripinnate and decompounds.

(i) **Simple pinnate or unipinnate**-leaflets borne directly on rachis, and may be.

(a) **Paripinnate-**leaflets present in pairs as in *Tamarindus indica* (fig. 10.11B), *Cassia, Swietinia* etc.

(b) **Imparipinnate**-rachis is terminated by an odd leaflet as in rose (*Rosa indica)* (fig. 10.11C), *Clitoria, Murraya, Melia azadirachta* etc.

(ii) Bipinnate-a compound leaf with main segments again pinnately divided into ***pinnules, i.e.,*** leaflets (pinnules) borne on the rachis but on its branches as in *Acacia arabica. Mimosa pudica* (fig. 10.11 D), *Caesalpinia pulcherrima* etc.

(iii) **Tripinnate-**incision goes to the third order so that leaflets are found on secondary branches of the rachis, as in *Moringa pterygosperma* (fig. 10.11E).

(iv) Decompound-incision high in number to give dissected appearance of the leaf as in fennel ***(****Foeniculum vulgare****)*** (fig. 10.11F) and other plants of Apiaceae.

(B) Palmate Compound: In such leaves, rachis does not differentiate and the lamina appears articulated or attached to a point on the top of the petiole. Such compound leaves may be of following types:

(i) **Unifoliate**-single leaflet attached to the top of the petiole, as in *Citrus* (fig. 10.12A).

(ii) **Bifoliate**-only two leaflets articulated to the rachis, as in *Hardwickia binata* and *Bignonia grandiflora* (fig. 10.12B).

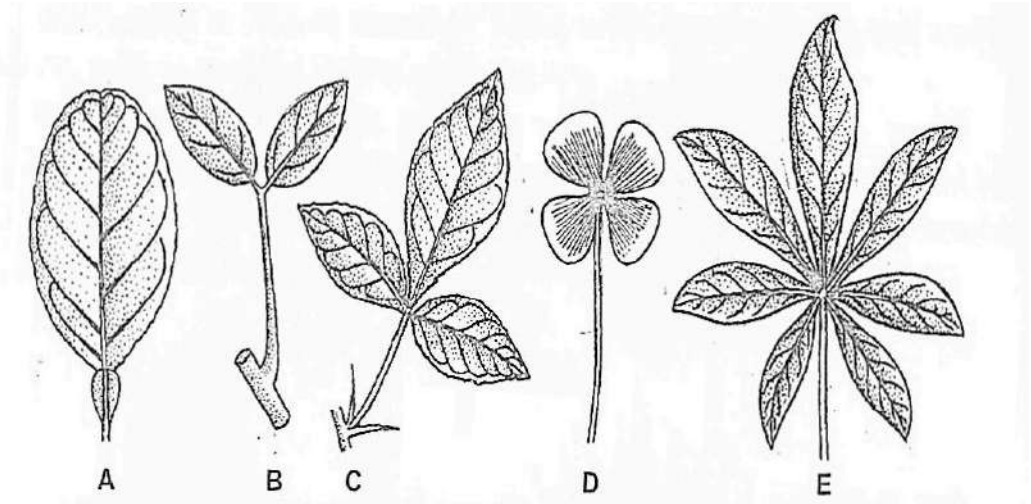


Fig. 10.12 Palmate compound leaves. A-unifoliate (*Citrus*), B-bifoliate (*Bignonia*), C-trifoliate (*Aegle*), D-quadrifoliate (*Marsilea*) and E-multifoliate (*Bombax*).

(iii) **Trifoliate**-three leaflets articulated at the top of the rachis, as in *Trifolium, Aegle marmelos, Oxalis corniculata, Dolichos lablab* (fig. 10.12C).

(iv) **Quadrifoliate**-four leaflets articulated to the top of the rachis, as in *Paris quadrifoiia* and in a pteridophyte, *Marsilea quadrifoliata* (fig. 10.12D). It is a rare type.

(v) **Multifoliate**-more than four leaflets attached at the top of rachis (petiole), as in *Cleome viscosa, Gynandropsis pentaphylla, Bombax* (fig. 10.12E) or *Salmalia malabarica.*

Modifications of the Leaf Lamina: The lamina or sometimes the entire leaf undergoes modification to suit *various* purposes. Some important modifications are:

(1) **Leaf tendrils**-tendrils formed by climbing plants which may be modification of entire leaf or its parts, *e.g.* petiole tendril (as in *Clematis),* entire lamina (in *Lathyrus),* terminal leaflets *(Bignonia vensuta* and *Pisum)* and leaf apex *(Gloriosa superba)* (fig. 3.4E).

(2) **Hooks**-leaf modified into hooks for climbing as in *Bignonia unguis-cati,* three terminal leaflets become claw-like hooks.

(3) **Spines**-entire or part of leaf modified into spines (pointed hard structure), as in *Opuntia,* whole leaf is modified into a spine; in pineapple *(Ananas), Agave* and *Argemone mexicana,* leaf margin and in *Phoenix,* the apex is modified into a hard spine. In *Chrus,* prophyll is a spine.

(4) **Pitche**r-a pitcher-like structure formed either by entire leaf (as in *Dischidia rafflesiana)* or by part of it such as by lamina (as in *Nepenthes,* the pitcher plant). In *Nepenthes,* pitchers are modified to catch insects to meet the need of nitrogenous substances (fig. 10.13B) and in

Dischidia (an epiphytic climber), the pitcher accumulates the rain water as well as debris which is absorbed by the adventitious roots formed within.

(5) **Bladder**-in *Utricularia* (aquatic insectivorous plant), the leaf segments modify into bladder to catch the insects (fig. 10.13D).

(6) **Fleshy leaves**-in some xerophytes and halophytes leaves become fleshy or succulent to store water due to presence of special storage tissue. Such plants are commonly called succulents, *e.g. Portulaca oleracea, Basella rubra, Suaeda maritima* and species of *Aloe, Agave, Bryophyilum, Sedum* etc.

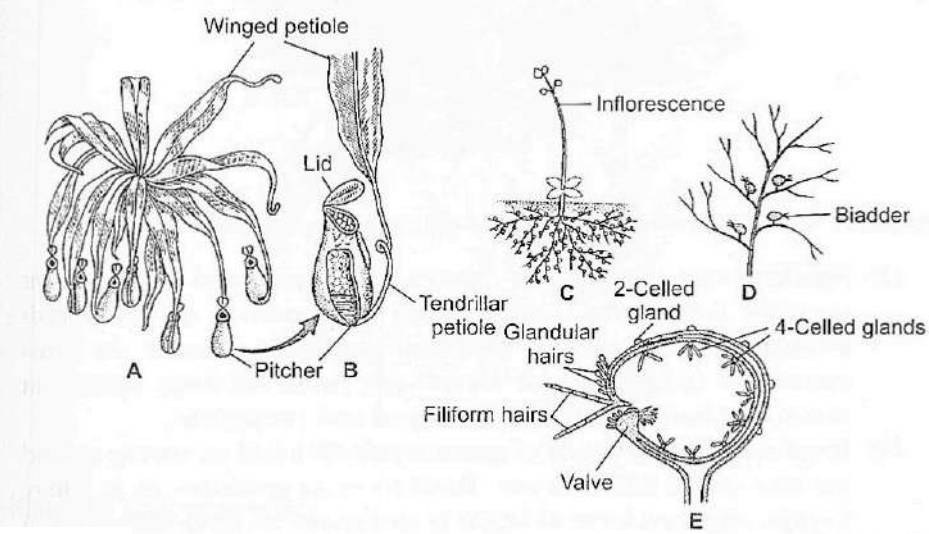


Fig. 10.13 Leaves in insectivorous plants. A-a plant of *Nepenthes*, B-a single leaf with pitcher, C-a plant of *Utricularia*, D-a part of leaf bearing bladders and E-c.s. of the bladder.

(7) **Absorbing organs** – submerged leaves of aquatic plants absorb water by their general surface. Such plants are often rootless, e.g. *Ceratophyllum* and *Utricularia*

QUESTIONS

1. Enlist different types of leaves and mentions its functions.
2. Describe phyllotaxy with suitable example.
3. Draw and describe a typical foliage leaf.
4. Enlist various leaf lamina features.
5. Enlist various leaf lamina surface features with proper example.
6. Define leaf venation and describe in detail.
7. Define compound leaf and it different types with proper example.
8. Enlist different modifications of leaf lamina with example and purpose for each modification.
9. Differentiate between palmate compound leaf and pinnate compound leaf.

LECTURE: 11

THE REPRODUCTIVE ORGANS AND FRUITS

BRACT AND BRACTEOLES

Axillary floral buds are usually borne in the axils of the specialized leaves called bracts. Such flowers are called **bracteate**, as in most members of Acanthaceae. In some cases, bracts are absent where flowers are called **ebracteate**, as in Brassicaceae and Boraginaceae. Sometimes additional bract-like small and thin structures are borne on the pedicel (or peduncle) between the flower and bracts. These are called **bracteoles** and such flowers are called **bracteolate.**

Bracts and bracteoles may be variously modified, such as:

(1) **Foliaceous or Leafy bract**-bract appears like ordinary green leaf, as in China rose *(Hibiscus rosa-sinensis).*

(2) **Petalloid bract**-bract becomes brightly colored and appears like a petal as in *Bougainvillea spectabilis* (fig. 11.1A) in which three small flowers are enclosed within three colored bracts. Similarly, bright red or orange bracts are found in *Poinsettia pulcherrima.*

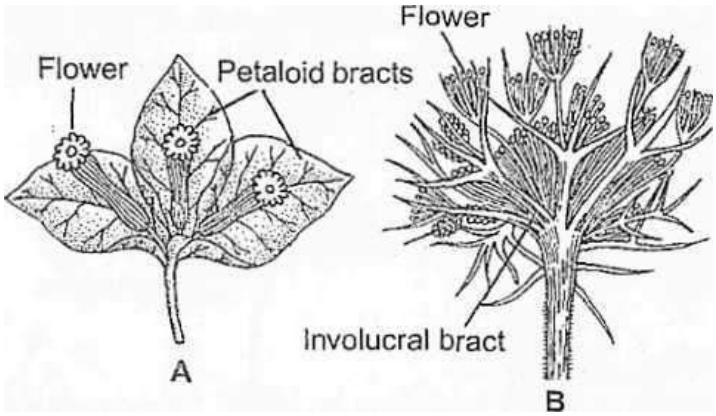


Fig. 11.1 A-petaloid bracts of *Bougainvillea* and B-involucral bracts of *Daucus carom.*

(3) **Spathy bract**-large, thick, boat-shaped bract and called *spathe* covering full or a part of a *Spadix* inflorescence, as in *Colocasia antiquorum* (fig. 11.4D)' and *Amorphophallus titanum.* In some palms, the spathe may be several feet (upto 20) long. Spathes in maize and banana are well developed and prominent.

(4) **Involucral bract**-whorls of green sepaloid bracts occurring around the base of the inflorescence. These form an involucre, as in family Compositae. Involucre of bracts is also found in Apiaceae (as in *Daucus carota* fig. 11.1B). In addition to bracts, there may be smaller involucres "round the base of each branch of the inflorescence as in *Daucus* and these are called involucels or partial involucres.

(5) **Scaly bract**-additional scaly bracts found with each individual floret as in *capitulum* (fig. 11.2), *catkin* or *cyathium* inflorescences.

(6) **Cupule**-hard and woody bracts and bracteoles found at the base of flower, somewhat like an involucre, as in Cupulifere These fuse together to form a cup-like structure (cupule) as the fruit matures.

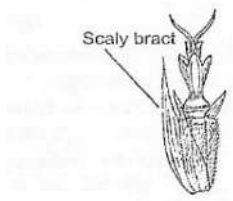


Fig. 11.2 Scaly bract of a floret of sunflower (*Helianthus*).

(7) **Epicalyx**-a whorl of sepaloid green bracteoles found below the calyx, as in china rose.

(8) **Glumes**-two scaly bracts present at the base of each spikelet as in Poaceae, also called *empty glumes* (fig. 11.5C).

(9) **Lemma and Palea**-in the spikelet of Poaceae, each flower bears a bract called *flowering glume* or *lemma* and a bracteole called *palea* which fits within the lemma (fig. 11.5C).

INFLORESCENCE: The arrangement of flowers and mode of distribution of flowers on the shoot system of a plant is called inflorescence. Sometimes, flowers are found singly and such a condition is called solitary. Solitary flowers may be terminal as in *Papaver* or axillary as in *Hibiscus rosa-sinensis* (fig. 11.3).

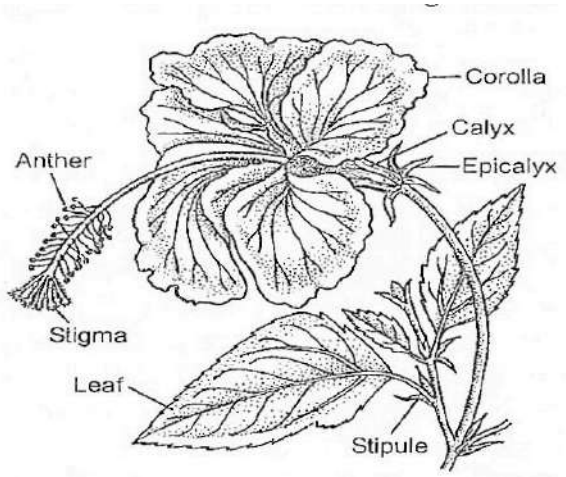


Fig. 11.3 Fig. 14.39 Solitary axillary flower of *Hibiscus*.

Kinds of Inflorescence

Different types of inflorescences are grouped into three categories:

(i) Simple inflorescence (ii) Compound inflorescence (iii) Special inflorescence

(A) SIMPLE INFLORESCENCE

In such inflorescence, flowers are arranged directly on the main axis. These are of two types.

I. Racemose or indefinite inflorescence **II. Cymose or definite inflorescence**

I. Racemose inflorescence. It has indeterminate growth of main axis, all flowers are lateral and arranged in acropetal succession, i.e., oldest towards base and youngest towards apex. These are of following types:

1. **Raceme.** Peduncle is elongated and flowers are pedicillate (stalked), *e.g.* mustard (fig. 14.40A) and larkspur *(Delphinium).*

2. **Spike.** It is similar to raceme but flowers are sessile, e.g. *Achyranthes* (fig. 11.4C) and *Amaranthus.*

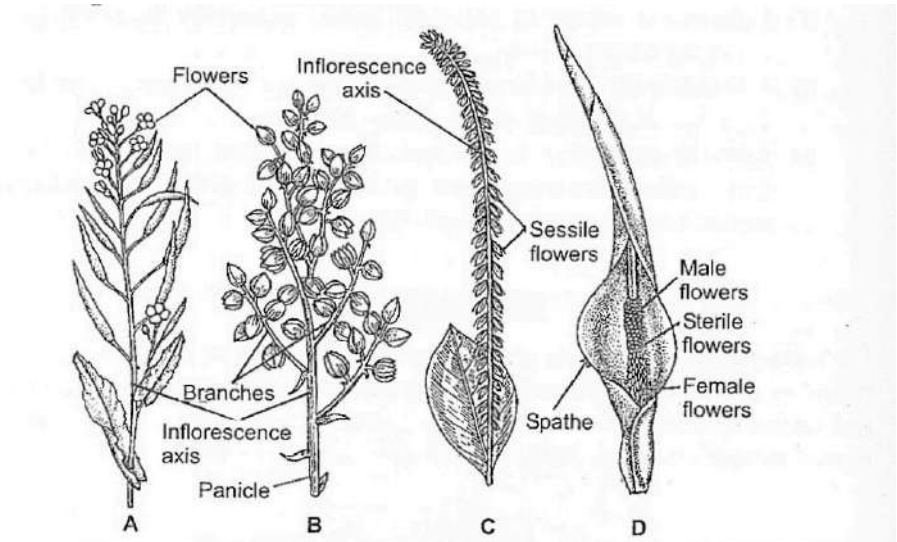


Fig. 11.4 Different types of racemose inflorescences. A-raceme of mustard, B-panicle of *Yucca,* C-spike of *Achyranthes* and D-spadix of *Colocasia.*

3. Spikelet. It is a secondary small spike with one or a few flowers. Spikelets are arranged in spike, raceme or panicle (fig. 11.4B). Each spikelet bears at its base two minute bracts called empty glumes. Above this is a fertile glume, a third bract or bracteole. The fertile bracteole may be called pa/ea or *lemma.* Opposite to the lemma, it bears a small glume called upper palea (or superior palea). Each flower of the spikelet remains enclosed by a lemma and palea. Such inflorescence is characteristic to family Poaceae (Wheat and rice) (fig. 11.5B, C).

4. Catkin (Ament). It has a delicate and pendulous floral axis which bears unisexual flowers. All flowers are sessile and densely set Entire inflorescence appears like one unit, *e.g.* mulberry (Moms) (fig. 11.5A) and *Acalypha.*

5. Spadix. It has a fleshy floral axis which remains covered with large and coloured bract, called **spathe**. Flowers are sessile and unisexual Male flowers are arranged on the upper part of the axis while female flowers on the lower part of the axis. Space on axis left between two types of flowers remains covered with sterile hairs. Spadix is found in *Arum, Colocasia* (fig. 11.4D) and *Musa.*

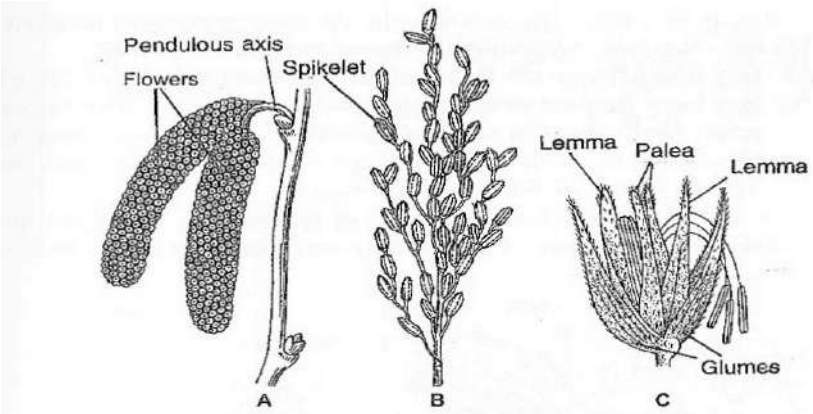


Fig. 11.5 Inflorescence. A-catkin (mulberry), B-spikelet (rice) and C-spikelet with two florets.

6. **Corymb.** It has a comparatively short main axis and the lower flowers have much longer pedicels than the upper ones so that all flowers are brought more or less to the same level, *e.g.* candytuft *(Iberis)* and cherry (fig. 11.6A).

7. **Umbel.** It has a very much shortened main axis and all flowers appear to be arising from the same point. Flowers are bracteate. Younger flowers are arranged towards centre while older flowers towards periphery. The whorl of bracts is called involucre. Such inflorescence is characteristic to family Apiaceae ***(Coriandrum,*** *Foeniculum* (or fennel), *Daucus* etc. (fig. 11.6B, C).

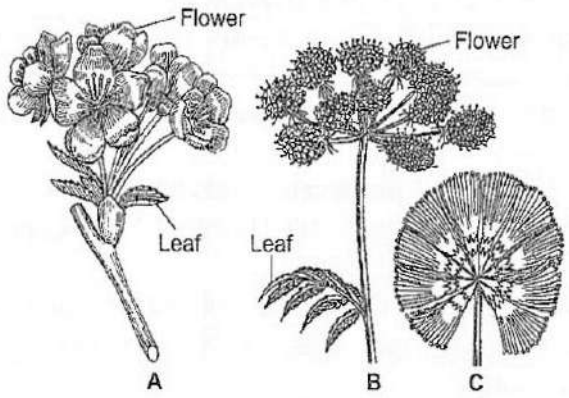


Fig. 11.6 A-corymb of cherry, B-compound umbel, and C-a single umbel (enlarged).

8. **Capitulum** or **Head**. It has a flattened receptacle on which several sessile small florets are arranged in a centripetal manner, i.e. youngest in the centre and oldest towards the periphery. Individual florets bracteate. The whorl of bracts present is celled involucres. On the receptacle, two kinds of florets are usually found:

(i) **Ray florets.** These are found at the rim of receptacle (periphery) and have ligulate or strap-shaped showy corolla. Flowers are either sterile (neuter) or female (pistillate) and are zygomorphic.

(ii) **Disc florets.** These are grouped in the centre and are actinomorphic, tubular and bisexual. Capitulum of sunflower has both types of flowers (fig. 11.7) but that of *Ageratum* has only disc florets. Capitulum inflorescence is characteristic to family Asteraceae.

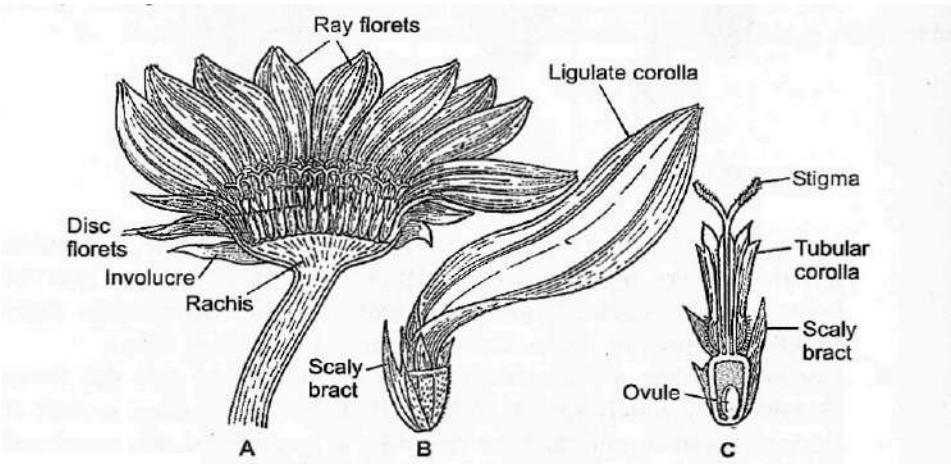


Fig. 11.7 Capitulum inflorescence. A-L.S. of inflorescence of sunflower, B-a ray floret and C-a disc floret.

II. Cymose inflorescence. Such inflorescence has determinate (definite) growth of the main axis, as the apical bud forms the first flower. Other flowers are produced on lateral branches which also bear terminal flower. Thus, every time new lateral branch is formed to produce new flower. Flowers are arranged centrifugally.

Cymose inflorescences are of following types:

1. Monochasial or Uniparous cyme. A single lateral branch arises from the peduncle of old flower which terminates in a flower. The lateral branch also terminates in a flower. Monochasial cyme can be of two types:

(i) Helicoid cyme (Bostryx). In this case, all lateral branches arise only on one side of main axis, *e.g. Heliotropium* and *Drosera* (fig. 11.8B).

(ii) Scorpoid cyme. In this case, lateral branches arise alternately on left and right sides, as in *Ranunculus* and *Gossypium*(fig. 11.8A).

2. Dichasial or **Biparous cyme.** The peduncle bears a terminal flower and stops growing. From the main peduncle arise two lateral branches, each of which also terminates in a flower. From the pedicel of each lateral flower further branching may arise repeatedly, as in *Dianthus* (fig. 11.8C).

3. Polychasial, Polychasium or Muciparous cyme. The peduncle bears a single terminal flower and below it more than two branches arise. These also bear terminal flowers. In *Calotropis*, the inflorescence is a polychasial umbellate cyme, i.e., groups of multiparous cymes in which main peduncle becomes much short (fig. 11.8D).

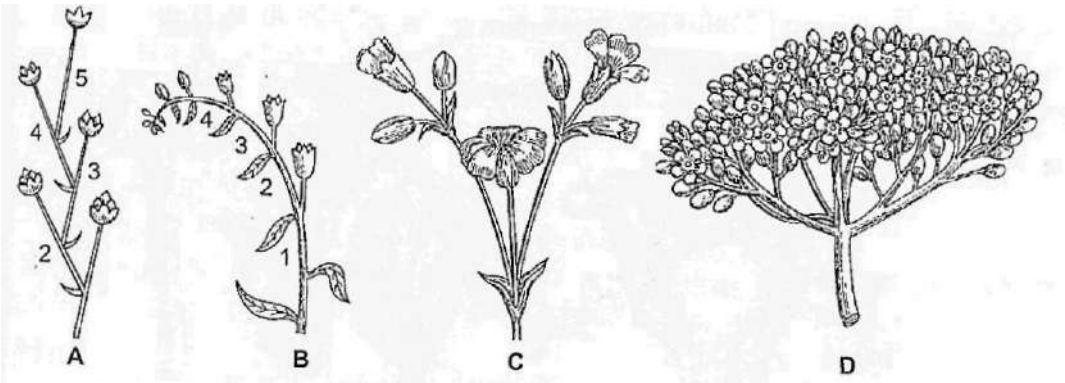


Fig. 11.8 A, B-monochasial cyme (A-scorpoid cyme and B-helicoid cyme), C-dichasial cyme and D-polychasial cyme.

(B) COMPOUND INFLORESCENCE

In a compound inflorescence, the peduncle (main axis) branches repeatedly once or twice in racemose or cymose manner and ultimate branches bear flowers in a racemose or cymose manner.-These can be of following types:

1. **Compound raceme or panicle**, *e.g.* gold mohur *(Delonix regia)* and *Yucca.*
2. **Compound spike or spike of spikelets,** *e.g.* wheat
3. **Compoud corymb,** e.g. cauliflower
4. **Compound umbel,** *e.g. Coriandrum* and *Foeniculum* (fig. 11.8B)

(C) SPECIAL INFLORESCENCES

These are of following types:

1. Cyathium. The bracts or involucre becomes fused to form a cup-shaped structure. Few nectaries are found in the involucral cup. This cup completely encloses a centrally placed female flower surrounded by a large number of male flowers. Each male flower is bracteate and achlamydeous and is represented by a single stalked stamen. The female flower is bracteate and achlamydeous and is represented by stalked (gynophore), tricarpellary and syncarpous gynoecium. This type of inflorescence is characteristic to genus *Euphorbia.* The inflorescence is a special cymose type in which male flowers are arranged basipetally (fig. 11.9).

2. Verticillaster. In this type, leaves are borne on opposite side on a node; each node bears flowers arranged in dichasial cyme. After the formation of three flowers, each dichasial cyme passes on to monochasial cyme of scorpoid type. Flowers are condensed, sessile, bisexual and bilipped. The inflorescence is characteristic to family Lamiaceae (e.g. ***Ocimum)*** (fig. 11.10).

3. Hypanthodium. The fleshy receptacle forms a *hollow* pear-shaped cavity with a narrow small opening. The flowers are borne on the inner wall of the cavity and are unisexual. Male flowers are borne on upper side, *i.e.,* towards mouth and female flowers are borne at the base of cavity. Such inflorescence is characteristic to genus *Ficus* (fig- 11.11).

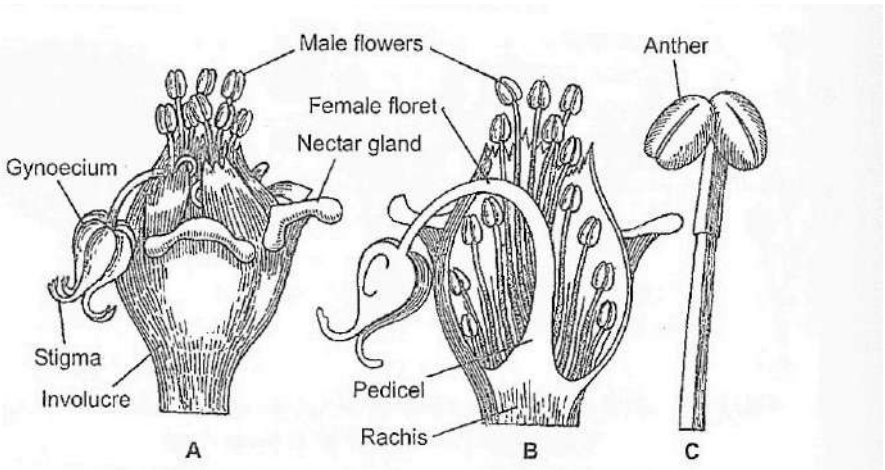


Fig. 11.9 Cyathium inflorescence in *Poinsettia* or *Euphorbia pulcherrima*. A-external view. B-L.S. of inflorescence and C-a male (staminate) flower.

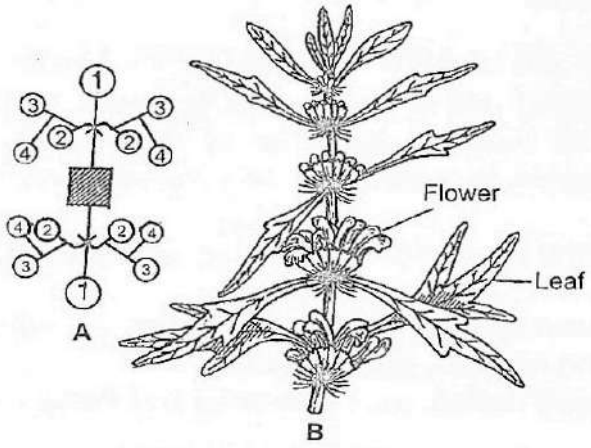


Fig. 11.10 Verticillaster inflorescence. A-flowering sequence and B-a twig with inflorescence.

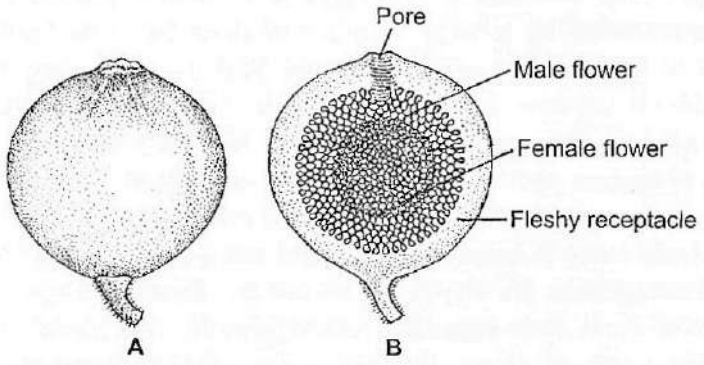


Fig. 11.11 Hypanthodium inflorescence. A-external view and B-L.S. of inflorescence.

Some Special Terms:

- **Peduncle.** A stalk which bears inflorescence.
- **Scape.** A leafless inflorescence stalks arising from the middle of a rosette of leaves. It bears a flower, several flowers, or a crowded inflorescence (as in onion).
- **Rachila**, The axis in the centre of a grass spikelet.
- **Strobile.** A spike in which each flower is borne in the axil of a persistent membranous bract.
- **Umbellule.** A unit of a compound umbel. Cymule. A diminutive of cyme inflorescence.
- **Cincinus** (or **Cincinnus**). A cymose inflorescence with the lateral axes arising on alternate sides of the relatively main axis.
- **Drepanium.** A monochasial cyme in which all branches arise from the same side of the relatively main axis.
- **Rhipidium.** A monchasial cyme in which the branches lie in one plane, so that it becomes fan-shaped.
- **Glomerule.** A cluster of short-stalked cyme. It is distinguished from a head inflorescence by blooming of the central flower first.
- **Tassel.** Male inflorescence in maize.
- **Thyrse** (or Thyrsus). A densely branched inflorescence with the main branching racemose (indeterminate), but the lateral branches cymose (determinate), as in grapes.
- **Secund.** Having lateral members all turned to one side, *i.e.*, appearing as if arising from one side.

QUESTIONS

1. Define bract. Differentiate it from bracteole.
2. Define inflorescence. Enlist the major types of inflorescences with suitable example for ech in tabulated form.
3. Describe the inflorescence of capitulum and hypanthodium with proper diagram.
4. Define Peduncle, Polychsial cyme, Scorpioid cyme.

LECTURE: 12

FLOWER

Flower is considered as a modified shoot in which every appendage represents a single leaf. Sepals and petals are sterile leaves while stamens and carpels are fertile leaves. The different floral appendages are arranged in whorls. Different parts of flower are shown in fig. 12.1.

1. **Calyx.** It is a collective name for sepals which are present in the outermost whorl. Sometimes a whorl of epicalyx may be present outer to it as in china rose.

2. **Corolla.** It is a collective name of petals found next to calyx. Petals are variously coloured.

3. **Androecium.** It is third inner whorl of a flower that consists of male reproductive structures called stamens.

4. **Gynoecium.** It is a collective name of female reproductive structures called carpels which are centrally placed in a flower.

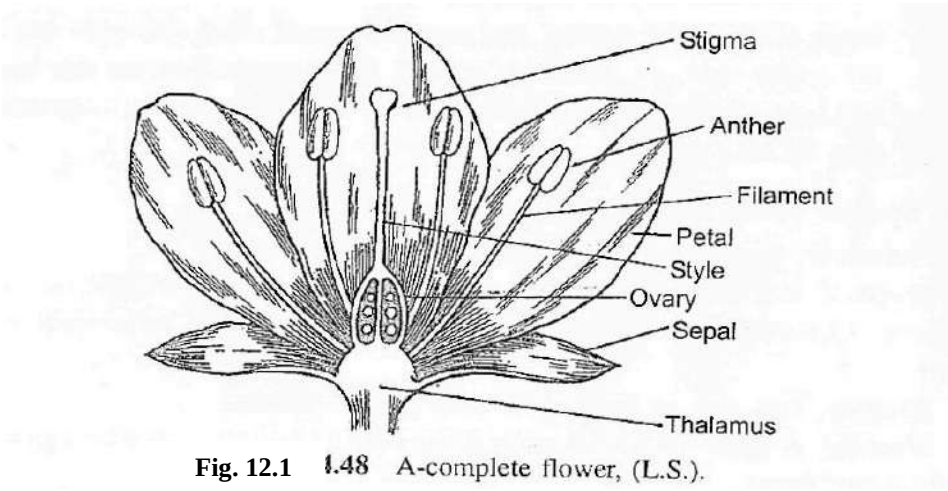


Fig. 12.1 1.48 A-complete flower, (L.S.).

These structures give a fundamental organisation to a flower; however, there may be several variations. These variations are described under the heading Terminology.

Terminology

- **Bracteate.** A flower is said to be bracteate when bract is present.
- **Ebracteate.** Bracts are not found.
- **Pedicillate.** Flower is produced on a stalk or pedicel.
- **Sessile.** Stalk is not found.
- **Complete.** A flower when it contains all the four whorls (calyx, corolla, androecium and gynoecium) is called complete.
- **Incomplete.** Absence of either one of the whorls.
- **Hermaphrodite.** Bisexual, bearing both androecium and gynoecium.
- **Unisexual.** Presence of only one type of sex organs.

- **Staminate.** Presence of only male reproductive structures (stamens).
- **Pistillate.** Presence of gynoecium (stamens are absent).
- **Neuter.** Sex organs are altogether absent (no androecium and gynoecium).
- **Actinomorphic.** A flower with radial symmetry and the parts with similar size and shape (fig. 12.2 A, B)

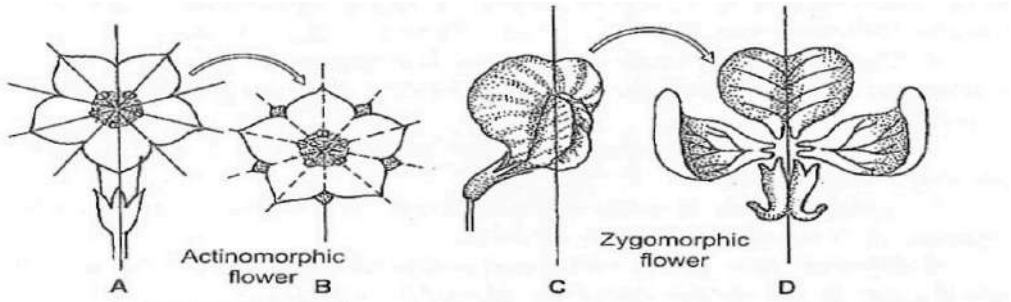


Fig. 12.2 A&B-actinomorphic flower (B-surface view) and C&D-zygomorphic flower (D-petals separated).

- **Zygomorphic**. A flower capable of equaJ division by only one plane of symmetry (fig. 12.2 C,D).
- **Asymmetric.** A flower which cannot be divided equally from any plane.
- **Dioecious.** When male and female flowers are produced on separate plants.
- **Monoecious.** When male and female flowers are present separately on the same plant.
- **Polygamous**. A plant in which both bisexual and unisexual flowers are present.
- **Trimerous.** The floral whorls contain units in multiple of three (as in Liliaceae).
- **Tetramerous**. The floral whorls contain units four in number or in multiple of four (as in Cruciferae).
- **Pentamerous.** The floral whorls contain units five in number or in multiple of five (as in Malvaceae).
- **Hypogynous.** A flower with superior ovary (as in Brassicaceae).
- **Perigynous**. A flower with half embedded or sunken ovary (as in Rosaceae) (fig. 12.3B).

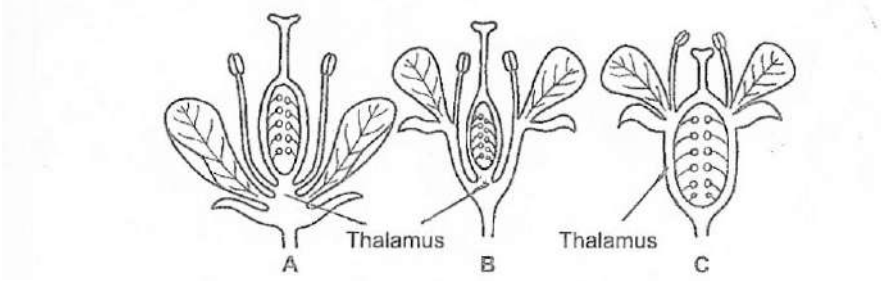


Fig. 12.3 A-hypogynous flower, B-perigynous flower and C-epigynous flower.

- **Epigynous.** A flower with inferior (completely sunken) ovary (as in Asteraceae) (fig. 12.3C).

Terms Used in Description of Calyx

- **Polysepalous.** Sepals are free, i.e not united with each other (as in *Brassica).*
- **Gamosepalous.** Sepals are fused with each other.
- **Asepalous.** Sepals are absent.
- **Caducous.** Sepals fall off after fertilization (as in ***Brassica).*** Persistent Sepals do not fall off rather these remain with the developing fruits (as in brinjal and tomato).
- **Petaloid**. Sepals are colored.
- **Tubular**. Sepals fuse to form a tubular structure (fig. 12.4B).
- **Cupulate.** Sepals fuse to form a cup-like structure (fig. 12.4E).
- **Urceolate.** Sepals fuse to form urn-shaped *structure* (fig. 12.4C)
- **Campanulate.** Sepals fuse and form a bell-shaped structure (fig.12.4D).
- **Bilabiate.** Sepals fuse and form a two lipped structure (fig. 12.4G)
- **Infundibuliform.** Sepals form a funnel-shaped structure (fig. 12.4F)

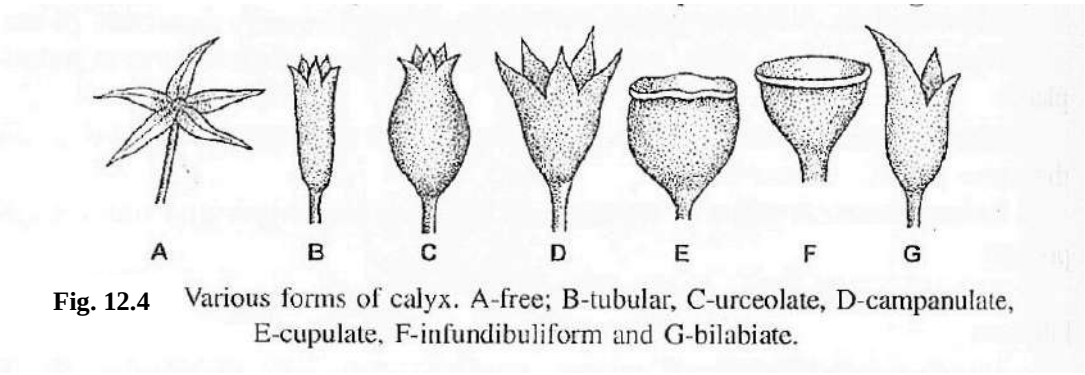


Fig. 12.4 Various forms of calyx. A-free; B-tubular, C-urceolate, D-campanulate, E-cupulate, F-infundibuliform and G-bilabiate.

- **Spurred.** One or more sepals form a long, pointed, spine-like structure, which is called spur (fig. 12.5A).
- **Pappus.** Sepals are modified into hair-like structures (fig. 12.5B).
- **Spinous.** Sepals are modified into spines as in water chestnut (fig. 12.5C)
- **Leaf-like.** Sepals form a leaf-like structure (fig. 12.5D).
- **Hooded.** Sepals enlarge to form a hood-like structure (fig. 12.5E).

Aestivation of calyx. Arrangement of sepals in the bud. It may be of following types :

(i) **Valvate**. Sepals are closely arranged in a circle without overlapping to each other (as in Mimosa*)* (fig. 12.6).

(ii) **Twisted**. With parts roiled up in such a way that the outer part of each covers the inner part of the one in front of it, while in turn its inner part is covered by the one behind it (fig. 12.6).

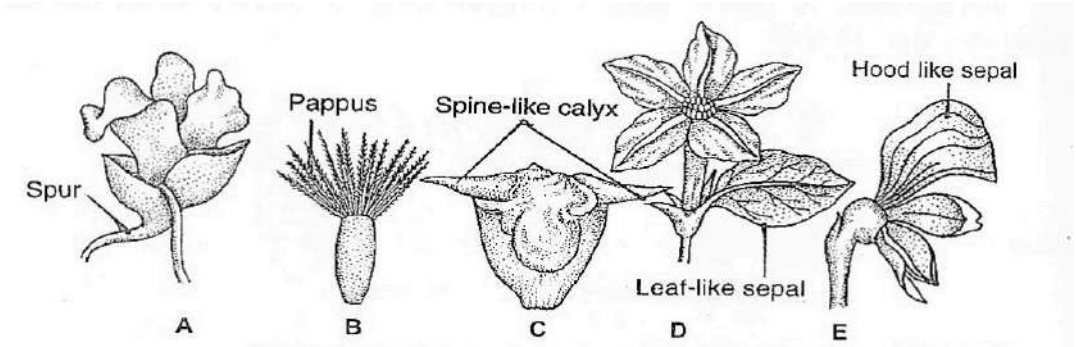


Fig. 12.5 Different forms of calyx. A-spurred, B-pappus, C-spinous, D-leaf-like and E-hooded.

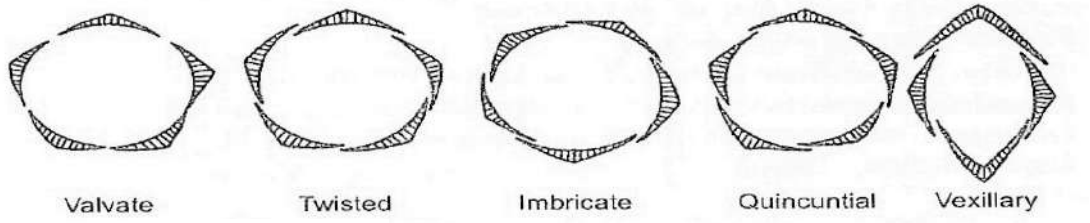


Fig. 12.6 Different aestivations of the calyx.

(iii) **Imbricate.** Both ends of one sepal are outer and of another sepal are inner while other three sepals have one end outer and another one inner (fig. 12.6).

(iv) **Quincuncial.** Two sepals are outer and two sepals are inner while one sepal has one overlapped and one exposed margin (fig. 12.6).

(v) **Vexillary.** See description under corolla (fig. 12.6).

Terms Used in Description of Corolla

- **Polypetalous.** Petals are free (not united) as in Brassicaceae.
- **Gamopetalous.** Petals are fused as in Solanaceae.
- **Apetalous.** Petals are absent.
- **Sepaloid.** Petals are green in colour or similar to sepals.
- **Caducous.** Petals fall off after fertilization.
- **Persistent.** Petals do not fall off, rather remain attached with fruits.
- **Deciduous.** Petals fall off after drying.
- **Cruciform.** Petals arranged in a cross-like fashion as in *Brassica* (fig. 12.7A).
- **Rosaceous.** Petals arranged as found in rose (fig. 12.7B).
- **Caryophyllaceous.** Petals with comparatively long claws and with limbs placed at right angles to the claws (fig. 12.7C).
- **Papilionaceous.** Petals appearing butterfly like; a zygomorphic corolla with one large posterior *standard,* two lateral *wings* and two inner most fused petals, the *keel* (fig. 12.7D), as in pea.

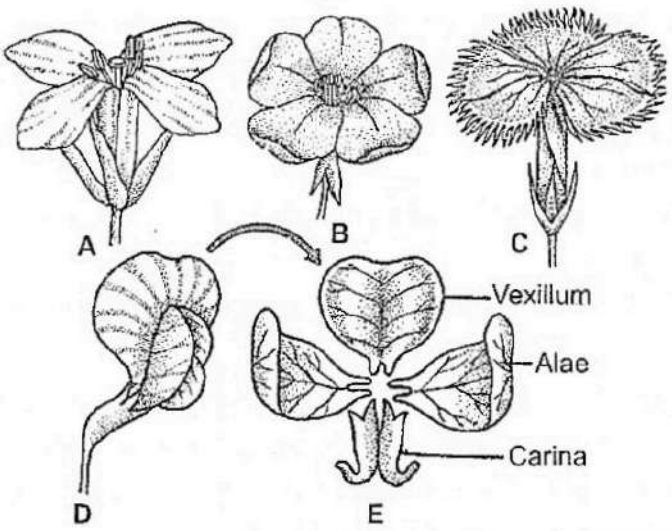


Fig. 12.7 Various forms of polypetalous corolla. A-cruciform, B-rosaceous, C-caryophyllaceous and D-papilionaceous (E-exposed petals of D).

- **Tubular.** Petals fused forming tube-like structure (fig. 12.8A).
- **Infundibuliform.** Petals fused forming funnel-shaped structure (fig. 12.8B).
- **Campanulate.** Petals fused forming bell-shaped structure (fig. 12.8C).
- **Hypocrateriform.** Petals fused with basal portion narrow and tube-like and upper portion bowl-shaped (fig. 12.8D).
- **Trumpet-shaped.** Petals fused with basal portion tube-like and upper funnel-like appearance.
- **Urceolate.** Petals fuse to form a pitcher like structure (swollen in middle and narrow at the apex).
- **Rotate.** Petals fuse to form a saucer-shaped structure at their uper part (fig. 12.8E).
- **Bilabiate ringent.** Corolla irregular with petals used to form a bilipped structure but the slit in between two remains open or broader (fig. 12.8G).
- **Bilabiate personate.** Corolla irregular with petals fused to form a bilipped structure having compactly closed slit (fig. 12.8H).
- **Ligulate.** Petals fused to form a tube-like structure at the base and broad flap-like structure in the upper part (fig. 12.8F), as in ray florets of Compositae.

Aestivation. Arrangement of petals in the bud which may be valvate (fig. 12.9A), twisted (fig. 12.9B), imbricate (fig. 12.9C), quincuncial (fig. 12.9D) or vexillary (fig. 12.9E). The details are described under the aestivation of calyx.

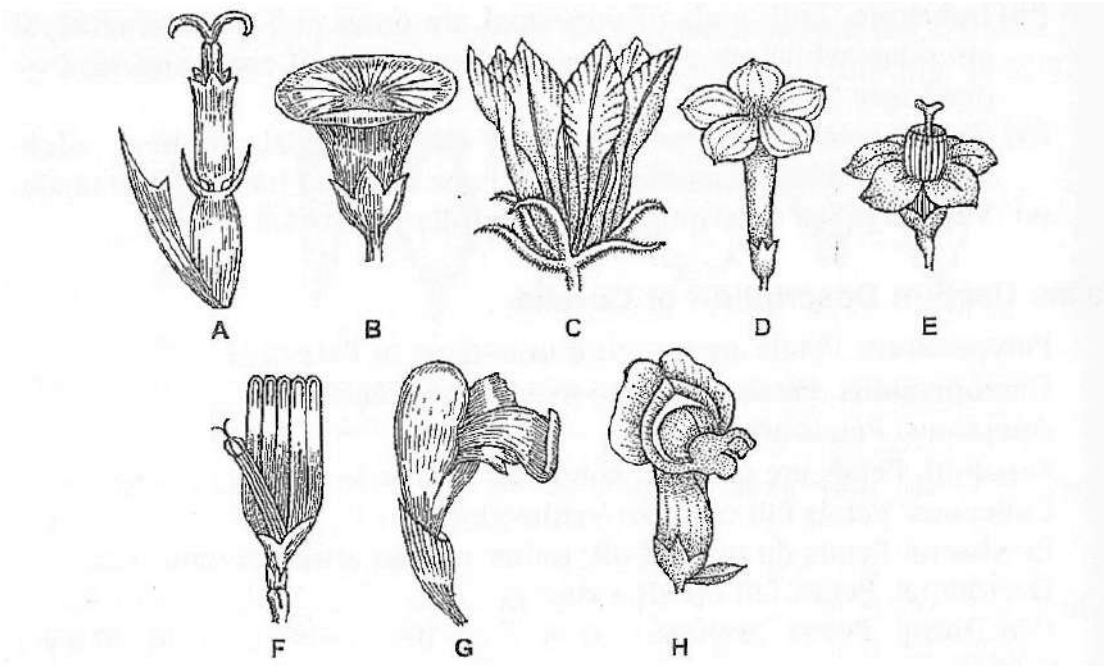


Fig. 12.8 Various forms of gamopetalous corolla. A-tubular, B-infundibuliform, C-campanulate, D-hypocrateriform, E-rotate, F-ligulate, G-bilabiate ringent and H-bilabiate personate.

- Perianth. Petals and sepals are of similar appearance and the two cannot be distinguished. The unit of perianth is called tepal. If tepals are fused, the condition is called gamotepalous and if free called polytepalous. If tepals are green in colour, these are called sepaloid and if coloured like petals called petaloid.

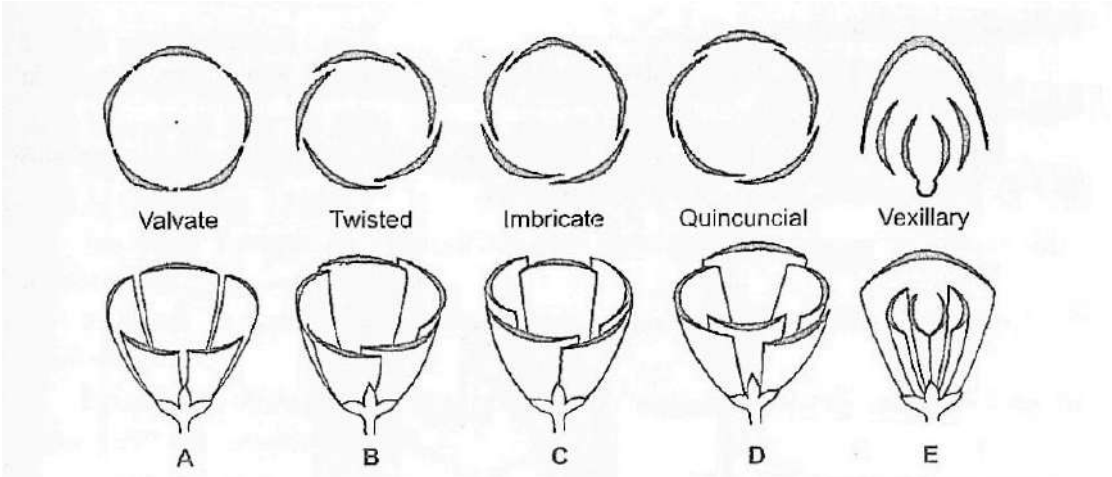


Fig. 12.9 Aestivation of corolla. A-valvate, B-twisted, C- imbricate, D-quincuncial and E-vexillary in two different views.

Terms Used in Description of Androecium

Androecium is a collective name given to male reproductive organs, the unit of which is called stamen. A stamen consists of **filament, connective and anther** (fig. 12.10). The two lobes of anther remain connected by a connective.

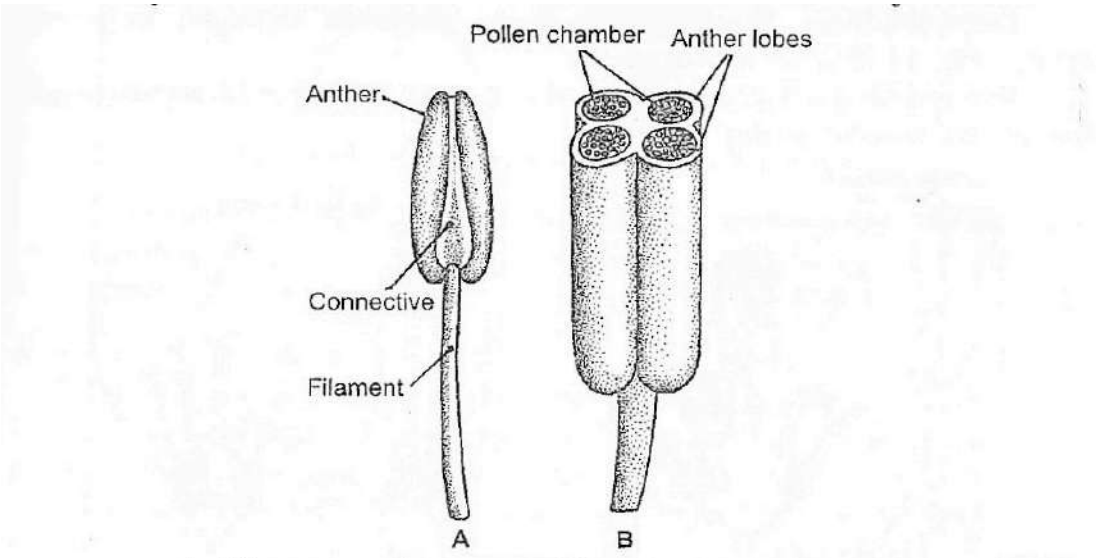


Fig. 12.10 A-different parts of a stamen and B-anther showing internal structure in T.S.

Other terms used to describe androecium are as follows:

Number of Stamens:

- **Monandrous**. Single stamen in each flower as in *Euphorbia.*
- **Diandrous**. Two stamens in each flower as in *Coronopus.*
- **Triandrous.** Three stamens in a flower as in *Triticum.*
- **Tetrandrous**. Four stamens in a flower as in *Scoparia.*
- **Pentandrous.** Five stamens in a flower as in *Solatium.*
- **Hexandrous.** Six stamens in a flower as in *Gynandropsis.*
- **Polyandrous.** Indefinite number of stamens as in *Nymphaea.*

Cohesion of Stamens:

- **Monadelphous**. Filaments are fused but anther lobes are free as in Malvaceae (fig. 12.11A)
- **Diadelphous.** Stamens with fused filaments arranged in two groups (9+1) (fig. 12.11B) as in *Pisum* (Fabaceae).
- **Polyadelphous.** *Stamens* with fused filaments arranged in several groups (fig. 12.11C), as in *Salmalia.*
- **Syngenesious.** Anthers are fused with each other but filaments remain free as in Compositae (fig. 12.12A).
- **Synandrous.** Both anthers and filaments remain fused as in Cucurbitaceae (fig. 12.12B)

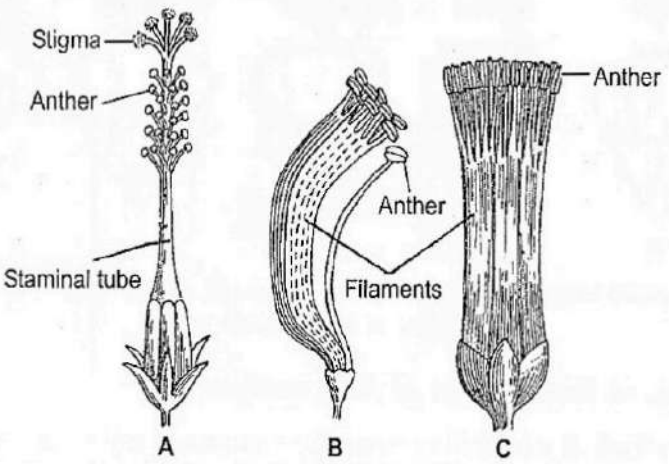


Fig. 12.11 Stamen types. A-monadelphous, B-diadelphous and C-polyadelphous.

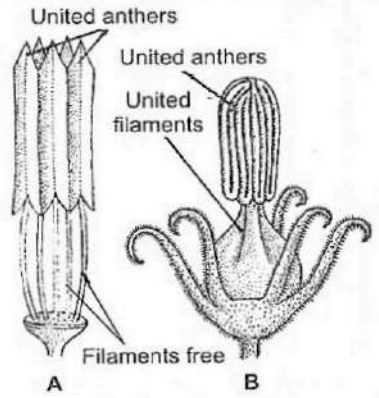


Fig. 12.12 Stamen types : A-syngenesious and B-synandrous

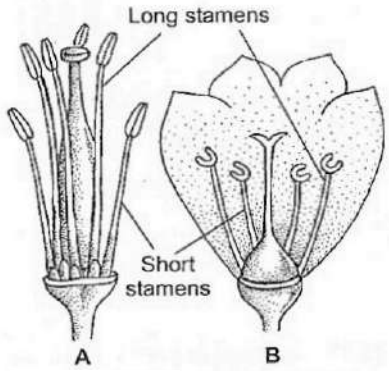


Fig. 12.13 A-tetradynamous and B-didynamous.

Synandrous. Both anthers and filaments remain fused as in Cucurbitaceae (fig. 14.59B).

Adhesion of Stamens

- **Epipetalous.** Stamens are found attached to petals, as in ***Solanum.***
- **Epiphyllous.** Stamens are found attached to tepals, as in *Asparagus.* It may also be called epitepalous.
- **Gynandrous**. Stamens are fused with the gynoecium, as in *Calotropis* (12.14B).

Length of Filaments:

- **Didynamous.** Four stamens, of which two have long filaments and two short filaments (fig. 12.13B), as in Labiatae and Scrophulariaceae.
- **Tetradynamous.** Six stamens with outer two short and inner four long as in *Brassica* (fig. 12.13A).
- **Inserted.** Length of stamens shorter than petals so these remain within corolla tube.

- **Exerted.** Length of stamens longer than petals so these come out of corolla tube.
- **Branched stamens.** Filaments of the stamens found branched as in castor *(Ricinus communis)* (fig. 12.14A).
- **Gynostegium.** Anthers crowning the column are adnate by the connective to the pentagonal stigma and form gynostegium (fig. 12.14B) as in *Calotropis.*

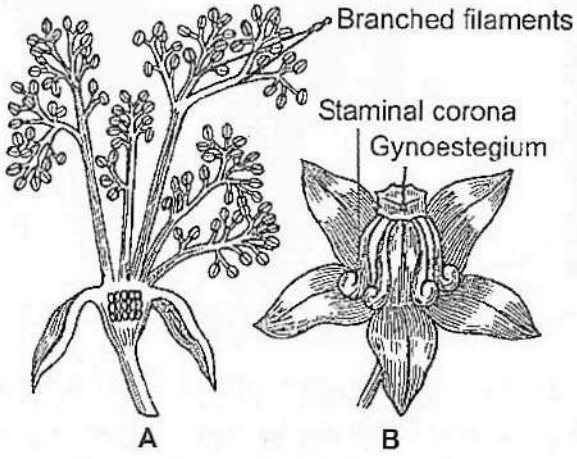


Fig. 12.14 . 14.61 A-branched stamens and B-gynostegium.

Insertion on Thalamus

- **Diplostemonous.** Stamens arranged in two whorls on the thalamus and stamens of outer whorl alternate with petals and of inner whorl opposite the petals, as in Rhamnaceae and Portulacaceae.
- **Obdiplostemonous.** Stamens are arranged in two whorls and stamens of outer whorl opposite and inner whorl alternate with the petals, as in Rutaceae.

Attachment of Filament with Anther Lobe

- **Basifixed.** Filament attached with the base of anther lobe (fig. 12.15A), as in *Brassica.*
- **Dorsifixed.** Filament attached to the dorsal surface of anther (fig. 12.15B), as in *Passiflora.*
- **Adnate.** Filament running the whole length of the anther from the base to the apex (fig. 12.15C), as in *Magnolia.*

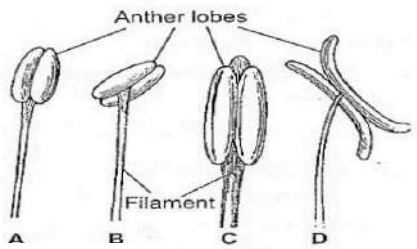


Fig. 12.15 Fixation of anthers with filament, A-basifixed, B-dorsifixed, C-adnate and D-versatile.

- **Versatile.** Filament attached to the back of anther at a point only, so that anther can swing freely, as in grasses (fug. 12.15D)

Dehiscence

- **Extrorse.** An anther dehiscing towards the periphery of the flower.
- **Introrse**. An anther dehiscing towards the centre of the flower.
- **Longitudinal.** Anther lobe bursts along longitudinal suture (fig. 12.16A). It is common type, as in *Datura.*

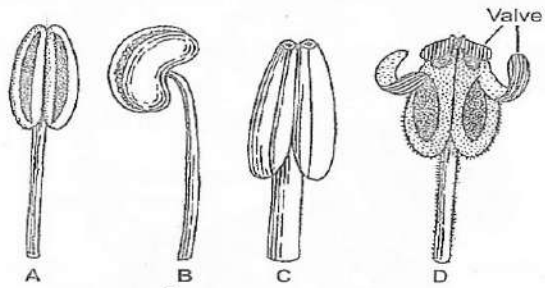


Fig. 12.16 Dehiscence of anthers. A-longitudinal, B-transverse, C-porous and D-valvular.

- **Transverse.** Found in unilocular anthers, it appears to be transverse because suture is placed that way, as in Malvaceae (fig. 12.16B).
- **Porous or Apical**. Discharge of pollens through apical pore, as in potato (fig. 12.16C).
- **Valvular.** Wall of the anther opens like trap door, as in *Barberis* (fig. 12.16D).

Terms Used in Description of Gynoecium

Gynoecium is the collective name of female reproductive organs and the unit of which is carpel. A carpel consists of ovary, style and stigma (fig. 12.17). Ovules are contained in the ovary

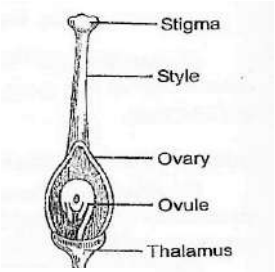


Fig. 12.17 A carpel showing different parts.

Fusion of Carpels:

- **Apocarpous.** Carpels are free (not united), as in *Nymphaea* and *Ranunculus* (fig. 12.18A).
- **Syncarpous.** Carpels are fused, as in *Brassica* (fig. 12.18B).

Number of Carpels:

- **Monocarpellary.** Presence of a single carpel in a flower, as in Fabaceae.
- **Bicarpellary.** Gynoecium formed by fusion of two carpels, as in Brassicaceae.
- **Tricarpellary.** Gynoecium that consists of three carpels, as in Cucurbitaceae.
- **Pentacarpellary.** Gynoecium that consists of five carpels. It may also be called multicarpellary as in Malvaceae.

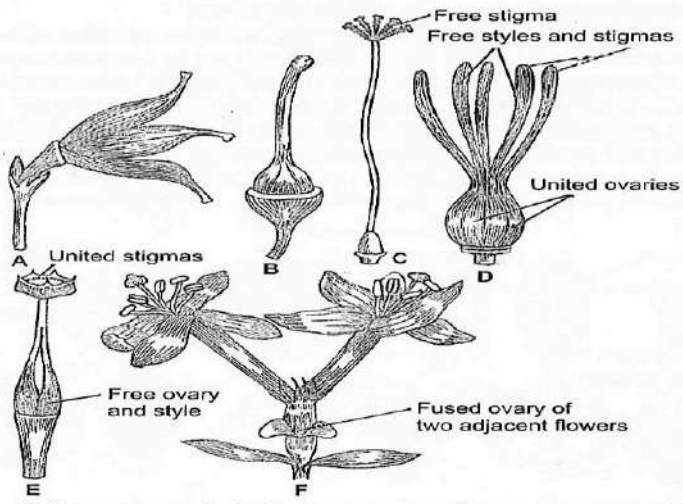


Fig. 12.18 Different types of pistils A-apocarpous, B-syncarpous, C-pistil with free stigmas (Malvaceae), D-free style and stigma (*Linum*), E-ovary and style free (*Calotropis*) and F-fused ovary of two adjacent flowers, *i.e.*, syngynia (*Lonicera*).

Number of Locules

- **Unilocular**. Ovary with single chamber (locule), as in Fabaceae and Asteraceae (fig. 12.19A,B).
- **Bilocular.** Ovary with two chambers, as in Brassicaceae and Solanaceae (fig. 12.19C).
- **Trilocular.** Ovary with three chambers, as in Liliaceac (fig. 12.19D).
- **Tetralocular.** Ovary with four chambers, as in Labiatae or *Ocimum* (fig. 12.19E).
- Penta or polylocular. Ovary with 5 or more chambers as in Malvaceae (fig. 12.19F).

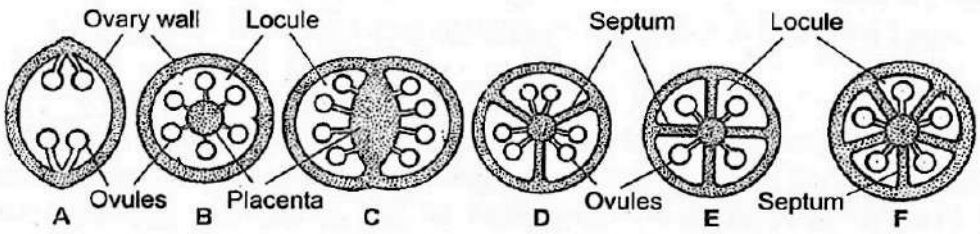


Fig. 12.19 Locules of ovary, A-B-unilocular, C-bilocular, D-trilocular, E-tetralocular and F-pentalocular.

Placentation *(*arrangement of ovules within the ovary):

- **Marginal.** Placenta present along the junction of two margins of the carpel in one chambered ovary (fig. 12.20 A,B), as in Fabaceae.
- **Parietal.** Placentae bearing ovules developed on the inner wall of the ovary and their position corresponds to the confluent margins of carpel in which ovary is unilocular (fig. 12.20 C,D), as in Brassicaceae and Cucurbltaceae.

- **Axile.** Ovules present at or near the centre of ovary on the axis *formed* by the fusion of septa and usually in vertical rows (ovules are attached on the axis of a compound ovary) (fig. 14.67 E,F), as in Malvaceae, Solanaceae and Liliaceae.

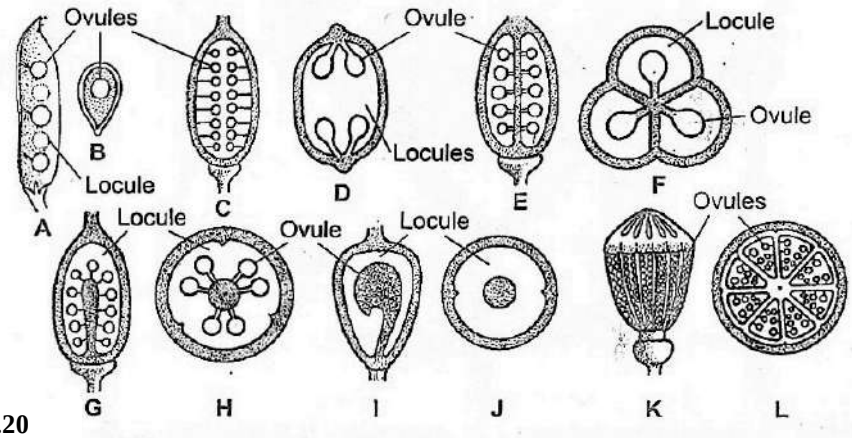


Fig. 12.20 Different types of ovaries with placentation. A, B-monocarpellary with marginal placentation, C, D-bicarpellary with parietal placentation, E, F-tricarpellary with axile placentation, G, H-tricarpellary with free central placentation, I, J-bicarpellary with basal placentation and K, L-multicarpellary with superficial placentation.

- **Free central.** The ovules are borne on a central column with no septa present, the ovary remains unilocular (fig. 12.20 G.H), as in Caryophyllaceae.
- **Superficial.** The placenta develop all round the inner surface of a multilocular and multicarpellary gynoecium, as in *Nymphaea* (fig. 12.20 K,L).
- **Basal.** A single ovule borne'-at the base of a unilocular ovary, as in Asteraceae (fig. 12.20 I,J).

Position on Thalamus

- **Superior.** Ovary placed above the point of attachment of corolla and stamens.
- **Inferior.** Ovary borne below attachment of all other floral parts and adnate to them.
- **Semi-inferior**. A condition intermediate to superior and inferior.

Style: Part between ovary and stigma is called style. Commonly, it arises from the top (apex) of ovary. However, style may arise laterally as in mango (fig. 12.21A), or from the central base of the ovary, i.e. *gynobasic* (as in Lamiaceae (fig. 12.21 B). Sometimes, style may be branched (fig. 12.21C), as in some plants of Euphorbiaceae.

Stigma: The apex of carpel is called stigma on which pollen grains are collected. It may be bilobed, trilobed, bifid, capitate, discoid, dumbell-shaped, feathery, linear, highly branched or striate as illustrated in fig. 12.22.

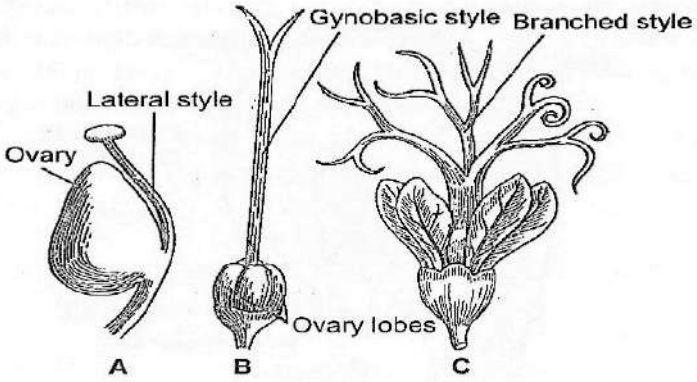


Fig. 12.21 A-lateral style, B-gynobasic style and C-branched style.

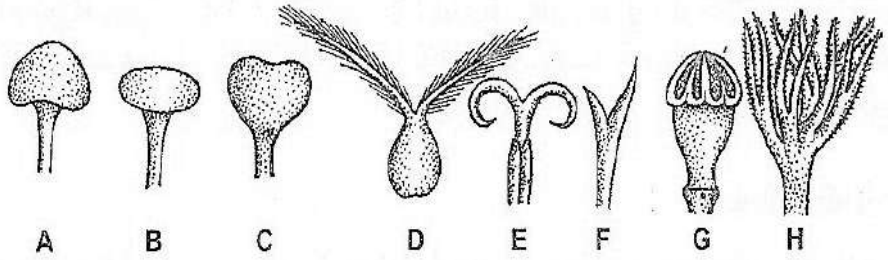


Fig. 12.22 Stigma types. A-capitate, B-discoid, C-lobed, D-bifid, E-bifid curved, F-bifid straight, G-sessile and straight and H-highly branched.

OVULE

Ovules are found in the basal part of the carpel and are:

(i) integumented megasporangia

(ii) the nucellus containing the embryo sac and enclosed by one or two integuments, which after fertilisation, and subsequentdevelopment, becomes a seed, or

(iii) Young seed in the course of development.

Ovule arises from the placenta and the arrangement of ovules in an ovary is called **placentation.**

The various parts of the ovule are - **Funicle** or Funiculus (short stalk through which it remains attached), **Raphe** (a ridge-like structure formed by fusion of funicle and body of the ovule), **Integument** (the membrane enclosing the nucellus), **Nucellus** (the central tissue of the ovule, containing embryo-sac), **Micropyle** (a canal-like pore or structure formed by an upgrowth of the integuments), **Chalaza** (the base of the nucellus of the ovule), Embryo-sac (the female gametophyte of the angiosperm comprising antipodal cells, polar nuclei/secondary nucleus, egg and synergid cells) etc.

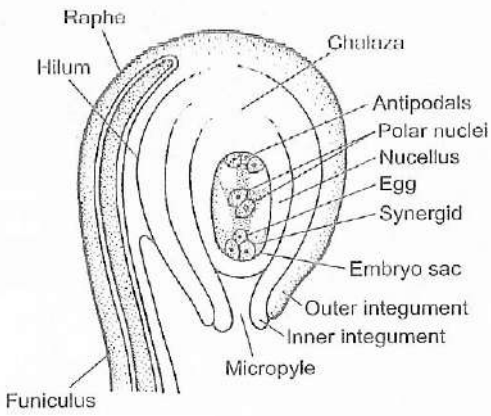


Fig. 12.23 L.S. of an ovule.

- **Ategmic ovule.** The ovule without any integument as found in ***Loranthus*** and ***Santalum.***
- **Tegmic ovule.** The ovule with integument. It may be unitegmic (with a single integument as generally found in sympetalae / gamopetalae, *e.g.* Compositae / Asteraceae), or bitegmic (with two integuments found generally in polypetalae and monocots).

Types of Ovules

The mature ovule may be classified into six types, based on the position of micropyle in relation to the funiculus (fig. 12.24).

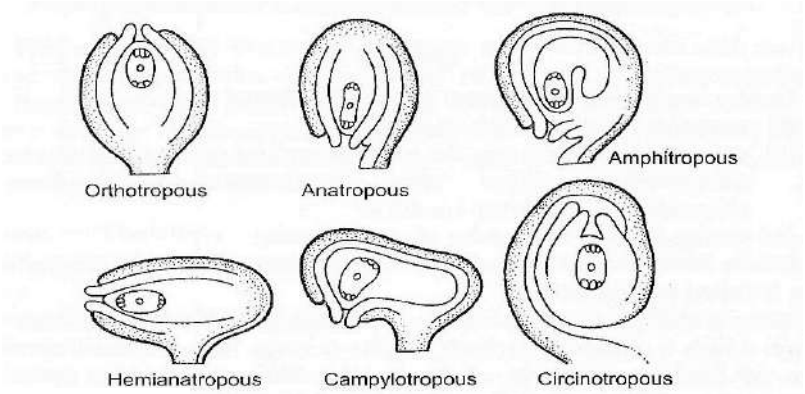


Fig. 12.24 Fig. 14.71 Different types of ovules.

1. **Orthotropous type** (also called *atropous).* The mature ovule is straight and the micropyle and funiculus are in a straight line and above the hilum, as found among members of Polygonaceae and Piperaceae.

2. **Anatropous type** (also called inverted). It is the most common type of ovule found in angiosperms and is characteristic of sympetalous families. The ovule bends at 180° and gets inverted, so that the micropyle comes to lie close to the funicle.

3. **Campylotropous type**. In this type of ovule, the curvature is incomplete, and the body of the ovule lies at right angle to the funiculus, and is somewhat curved, as in Capparaceae/ Capparidaceae and Leguminosae.

4. **Amphitropous type.** When the curvature of the body of the ovule becomes more than that of campylotropous and the embryo sac assumes a horse-shoe shape, the ovule is said to be amphitropous type. It is commonly found in Alismaceae.

5. **Hemianatropous type** (also called *hemitropous).* It is a modified type of anatropous ovule in which the body of ovule lies at right angle lo the funicle and micropyle and chalaza lie in a straight line. The micropyle is not found near the funicle as in *Ranunculus* and in members of Primulaceae.

6. **Circinotropous type.** It is a special type of ovule formed due to unilateral growth. Initially, the nucellar mass is in line with the funicle and appears orthotropous, then unilateral growth of ovule takes place and it gets inverted, thus becoming anatropous. The curvature continues till *the* ovule takes a complete 180° turn and the micropyle again faces upwards as in *Opuntia* (Cactaceae).

POLLINATION: The transfer and deposition of pollen on the stigma of the flower. Terms related to pollination are:

Self pollination. The pollination between the different flowers or same flower of the same plant, as in groundnut, tobacco, barley, oat, wheat etc.

- **Autogamy.** The transfer of pollen grains from the anther to the stigma of the same flower.
- **Geitonogamy.** The transfer of pollen grains from the anther to the stigma of another flower of the same plant.
- **Homogamy.** Simultaneous maturation of sex organs, as in *Mirabilis jalapa* and *Ymca rosea.*
- **Cleistogamy**. Flowers do not open at the time of the fertilisation and do not expose their sex organs, as in *Commelina benghalensis.*

Cross pollination (Allogamy). The transfer of pollen grains from the anther of a flower to the stigma of another flower (i.e., pollination between the flowers of two different plants).

- **Xenogamy.** Pollination between flowers of different genetic constitution.
- **Dicliny or Unisexuality.** Plant bearing unisexual flowers, either only male or only female flowers, as in *Carica papaya. Phoenix sylvestris, Morus alba* etc.
- **Dichogamy.** Maturation of sex organs at different time periods. If anthers mature first, flowers are called **protandrous,** and if stigma (female sex organ) mature first, they are called **protogynous**.
- **Protandrous.** A dichogamous flower in. which anthers mature first, as in Lamiaceae (Labiatae), Malvaceae and Rubiaceae.

- **Protogynous**. A dichogamous flower in which *stigma matures* before the anthers, as in *Magnolia, Michelia* and *Adhatoda.*
- **Heteromorphy.** The phenomenon of bearing two types of morphologically dissimilar flowers, as in *Primula vulgaris.*
- **Herkogamy.** Presence of some morphological barriers which make self pollination impossible, as in *Calotropis, Asclepias, Ptsrgularia, Coelogyne* etc.
- **Entomophily.** Pollination brought about by insects, as in *Salvia, Yucca, Ficus, Calotropis* etc.
- **Ornithophily.** Pollination carried out by birds, as in *Salmalia, Callistemon, Erythrina* etc.
- **Cheiropterophily.** Pollination carried out by bats, as in *Kigelia pinnate, Bauhinia megalandra, Eperua falcata* etc.
- **Malacophily.** Pollination carried out by snails and slugs, may be found in subterranean runners.
- **Anemophily.** Pollination by wind as in wheat, maize;, coconut, bhang etc.
- **Hydrophily.** Pollination by water as found in *Elodea, Hydrilla* and *Vallisnaria.*

QUESTIONS

1. Define: Flower, Actinomorphy, Zygomorphy, Perfect flower, Imperfect flower, Pedicel, Thalamus, Dioecious
2. Enlist and draw different kind of aestivation with examples.
3. Write a short note on placentation.
4. Differentiate between self –pollination and cross pollination.
5. Draw a typical orthotropous ovary and label properly.
6. Enlist:
    - Types of ovules
    - Types of anther dehiscence
    - Types of anther attachmen
    - Ttypes of cohesion and adhesion of anthers
    - Types of different types of ovary position on thalamus
7. Draw a typical androecium and gynoecium and label properly.
8. Draw a typical flower and label properly.

LECTURE: 13

FRUIT

A ripened ovary is called fruit, and study of fruit and fruit bearing plants is called **pomology**. Fruit is an important constituent of a balanced diet and is rich in carbohydrates, minerals, vitamins etc.

On the basis of climate, three types of fruits are recognized:

1. **Temperate fruits.** These plants grow in cold climate, *e.g.* apple, pear, cherry, musk melon, water melon, mulberry, strawberry etc.
2. **Tropical fruits.** These plants grow in warm climate, *e.g.* pineapple, custard apple, jack fruit, cheeku, mango, lemon, mandarin, banana, guava, papaya etc.
3. **Sub-tropical fruits**. These plants grow in moderate climate, e.g. litchi, ber, pomegranate, loquat, fig, date, phalsa, jamun, grapes, bel etc.

Classification of Fruits: There are three main types of fruits:

I. Simple fruits. These develop from monocarpellary ovary or multicarpellary syncarpous ovary.

II. Aggregate fruits (Etaerio). These develop from multicarpellary, apocarpous ovary.

III. Composite fruits (Multiple). These develop from the complete inflorescence.

I SIMPLE FRUITS

On the basis of nature of pericarp, simple fruits are divided into two types:

A. **Dry fruits.** Pericarp remains dry and undifferentiated into three layers.

B. **Succulent fruits**. Pericarp is fleshy or fibrous and remains distinguishable into three layers. These are indehiscent.

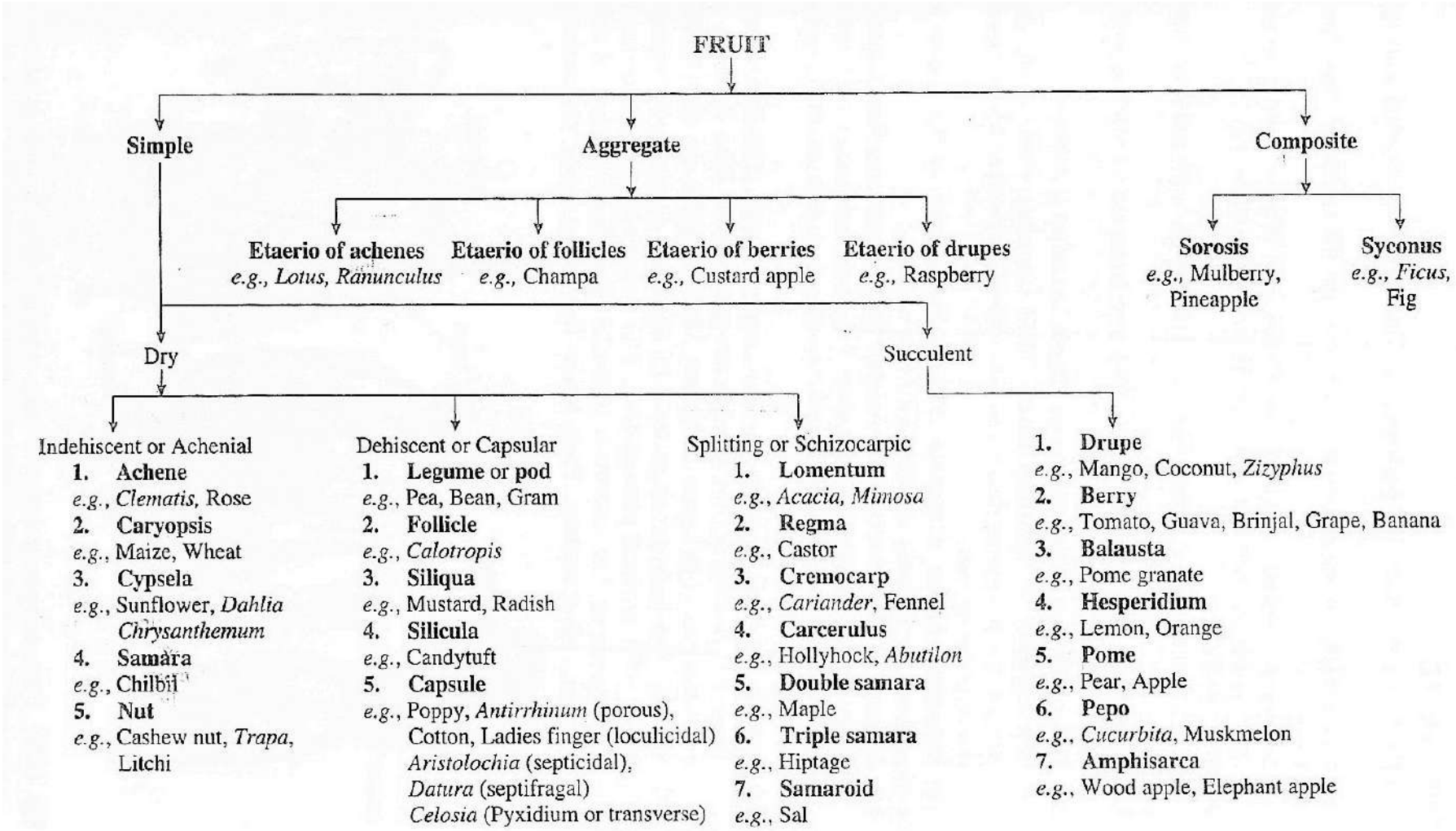
A. DRY FRUITS

According to mode of dehiscence, these fruits are divided into three groups:

(a) **Dehiscent or Capsular fruits**. Pericarp is ruptured after ripening and seeds are dispersed.

(b) **Indehiscent or Achenial fruits.** These fruits do not dehisce.

(c) **Schizocarpic or Splitting fruits.** After ripening, these fruits split (divided) into one seeded segments, called mericarps. Mericarps do not rupture further.


FRUIT
Simple
Aggregate
Composite
Etaerio of achenes
e.g., Lotus, Ranunculus
Etaerio of follicles
e.g., Champa
Etaerio of berries
e.g., Custard apple
Etaerio of drupes
e.g., Raspberry
Sorosis
e.g., Mulberry, Pineapple
Syconus
e.g., Ficus, Fig
Dry
Succulent
Indehiscent or Achenial
1. Achene
e.g., Clematis, Rose
2. Caryopsis
e.g., Maize, Wheat
3. Cypsela
e.g., Sunflower, Dahlia Chrysanthemum
4. Samara
e.g., Chilbil
5. Nut
e.g., Cashew nut, Trapa, Litchi
Dehiscent or Capsular
1. Legume or pod
e.g., Pea, Bean, Gram
2. Follicle
e.g., Calotropis
3. Siliqua
e.g., Mustard, Radish
4. Silicula
e.g., Candytuft
5. Capsule
e.g., Poppy, Antirrhinum (porous), Cotton, Ladies finger (loculicidal) Aristolochia (septicidal), Datura (septifragal) Celosia (Pyxidium or transverse)
Splitting or Schizocarpic
1. Lomentum
e.g., Acacia, Mimosa
2. Regma
e.g., Castor
3. Cremocarp
e.g., Cariander, Fennel
4. Carcerulus
e.g., Hollyhock, Abutilon
5. Double samara
e.g., Maple
6. Triple samara
e.g., Hiptage
7. Samaroid
e.g., Sal
1. Drupe
e.g., Mango, Coconut, Zizyphus
2. Berry
e.g., Tomato, Guava, Brinjal, Grape, Banana
3. Balausta
e.g., Pome granate
4. Hesperidium
e.g., Lemon, Orange
5. Pome
e.g., Pear, Apple
6. Pepo
e.g., Cucurbita, Muskmelon
7. Amphisarca
e.g., Wood apple, Elephant apple

(a) Dehiscent Fruits (Capsular Fruits). According to mode of dehiscence, these are broadly divided into five groups:

1. **Legume or Pod.** Such fruits develop from monocarpellary superior ovary with marginal placentation. Ovary is unilocular with many ovules. The fruit dehisces by both sutures, as in pea, gram, red gram etc. (fig. 13.1A).
2. **Follicle.** Such fruit develops from superior and unilocular ovary. These are usually found in pairs or groups. The fruit dehisces by one suture as in larkspur, *Calotropis*, *Michelia*, *Vinca* etc. (fig. 13.1B).
3. **Siliqua.** The fruit develops from bicarpellary, syncarpous, superior ovary with parietal placentation. The ovary remains unilocular in the beginning but becomes bilocular due to formation of false septum, called replum. Each locule has many seeds. On maturity fruit dehisces from below to upwards. Such fruits are characteristic of family Brassicaceae, ***e.g.*** mustard, radish, turnip etc. (fig. 13.1C).
4. **Silicula.** It resembles with siliqua but its breadth and length are equal. It is wide and flat, as in candytuft (*Iberis amara*) and shephard's purse *(Capsella bursa-pastoris)* (fig. 13.1D).

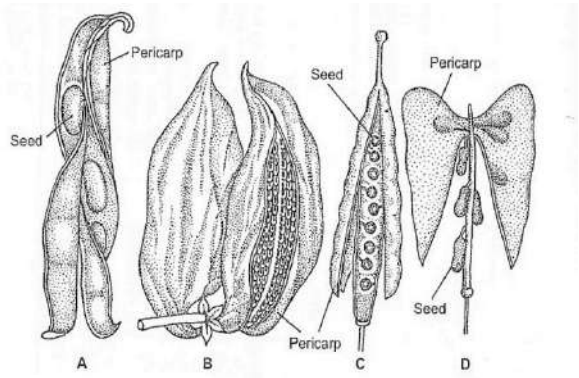


Fig. 13.1 Different types of dehiscent fruits. A-legume (Pea), B-a pair of follicle (*Calotropis*), C-siliqua (*Brassica*) and D-silicula (*Capsella*).

5. **Capsule.** It develops from multicarpellary syncarpous, superior ovary with several locules and axile placentation. According to mode of dehiscence, these fruits are further classified as follows:

(i) **Porous dehiscence**. Fruit dehisces through the pores developed in the terminal part. Seeds are slowly dispersed by wind through these pores,, as in poppy *[Papaver).*

(ii) **Loculicidal dehiscence**. In these fruits pericarp opens through the middle of locules and placenta is divided, as in cotton *(Gossypium)* and okra *(Hibiscus esculentus).*

(iii) **Septicidal** dehiscence. In such fruits, during dehiscence septa are ruptured and locules are separated. Pericarp is also separated in the form of valves, as in linseed and *Aristolochia.*

(iv) **Septifragal dehiscence**. In such fruits, during dehiscence placenta remains attached in the centre of undivided fruit and pericarp's *segments* become separated. Dehiscence can be either septicidal or septifragal, as in *Datura* (fig. 13.2B).

(v) **Transverse dehiscence**. In such fruits, pericarp dehisces transversely into two parts. The upper part opens out like a lid and exposes the seed to the wind for dispersal, as in *Celosia.* Such fruits are also called *pyxidium* (fig. 13.2).

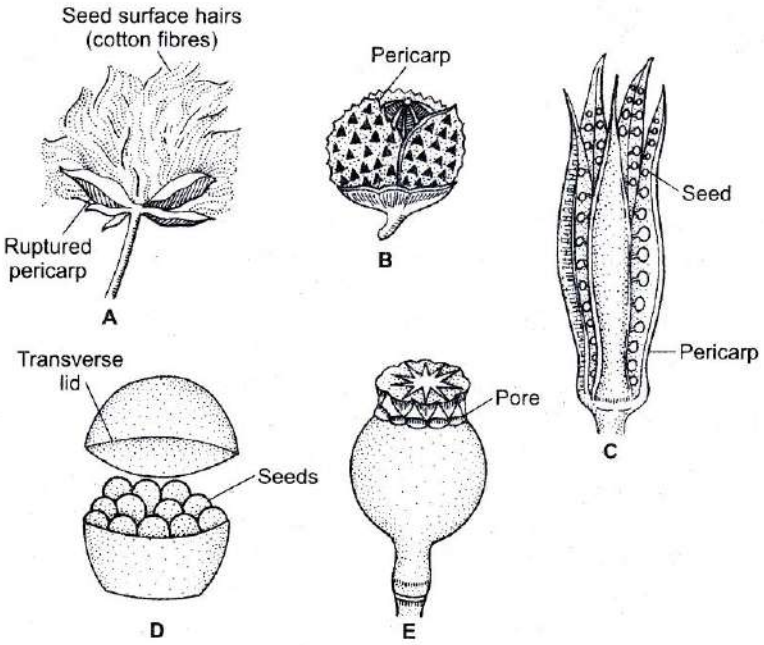


Fig. 13.2 Different modes of dehiscence in capsule fruits. A and C-loculicidal, B-septifragal, D-pyxidium and E-poreus.

(**b) Indehiscent or Achenial Fruits.** In such fruits, pericarp docs not rupture and seeds remain enclosed within it. Achenial fruits are further divided into:

1. **Achene**. The fruit develops from monocarpellary superior ovary. It is unilocular and single seeded. The pericarp does not fuse with seed coat, as in *Clematis* and *Naravelia* (fig. 13.3A).
2. **Caryopsis**. The fruit develops from monocarpellary, superior ovary and it remains unilocular and single seeded. The **pericarp remains fused with testa**. Such fruits are characteristic to family Poaceae, ***e.g.*** wheat, rice, maize etc.
3. **Cypsella.** The fruit develops from bicarpellary, syncarpous, inferior ovary with basal placentation. Fruits are unilocular and single seeded. Persistent hairy calyx (pappus) are found at the apex of fruit. These are characteristic to family Asteraceae, ***e.g.*** *Taraxacum* and *Cosmos* (fig. 13.3B).
4. **Nut.** Fruit develops from unilocular, syncarpous, multicarpellary, superior ovary. The fruit is single seeded. Pericarp becomes hard j and stoney as in cashew nut *(Anacardium),* litchi, water chestnut *(Trapa)* (fig. 13.3C).
5. **Samara.** The fruit develops from bicarpellary, syncarpous, superior ovary. It is single seeded. The pericarp becomes flat like wings, ***e.g.*** chilbil *(Holoptelea)* (fig. 13.3D).

(c) Schizocarpic or Splitting Fruits. These fruits are dry and multiseeded, and after ripening are divided into one seeded segments or mericarps. Mericarps do not rupture further. Such fruits are further divided into:

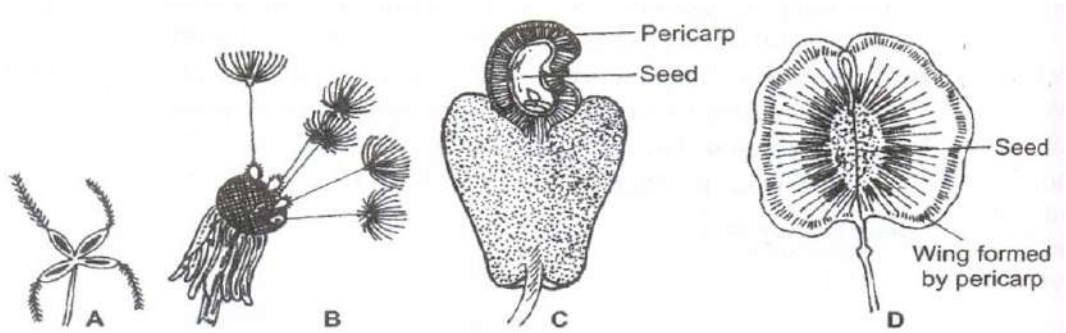


Fig. 13.3 A-achene (*Clematis*), B-cypsella (*Taraxacum*), C-nut (cashew), D-samara (*Holoptelea*).

1. **Lomentum.** The fruit develops from monocarpellary, unilocular, superior ovary. It is a modification of legume. These are bisutural fruits which are constricted or divided into one seeded mericarps as in groundnut, *Mimosa, Tamarindus* etc. (fig. 13.4A).
2. **Cremocarp.** The fruit develops from bicarpellary, syncarpous, inferior ovary, on maturation, these divide along with carpophore into two mericarps, and each single seeded (fig. 13.4B). The fruit is characteristic to family Apiaceae, as in coriander, carrot, fennel etc.
3. **Regma.** The fruit develops from tricarpellary (multicarpellary), syncarpous, superior ovary. The fruit is multilocular. On maturation, after splitting, these divide into as many parts as the number of carpels. Each part is known as **coccus** and has one seed, as in castor *(Ricinus)* and *Geranium* (fig. 13.4C).
4. **Carcerulus**. The fruit develops from bi- or polycarpellary, syncarpous, superior ovary and is mutilocular. Number of locules may increase due to false septation. On maturity, single seeded mericarp splits away, as in *Althaea, Ocimum* and *Malva* (fig. 13.4D).
5. **Double samara.** The fruit develops from bicarpellary, syncarpous, superior ovary. Pericarp develops into two wings. On maturation it is divided into two one seeded parts, as in *Acer* (maple) (fig. 13.4E).

Samaroid. In sal *(Shorea robusta),* persistent calyx forms wing, hence look-like samara fruit.

B. SUCCULENT OR FLESHY FRUITS

In these fruits, the pericarp is distinguished into three layers - epicarp, mesocarp and endocarp. Mesocarp is fleshy or fibrous. These are of following types :

1. **Drupe.** The fruit develops from mono- or polycarpellary, syncarpous, superior ovary. Fruits are usually single seeded, rarely many seeded. Pericarp comprises three layers. The epicarp forms the skin of the fruit. Mesocarp is fleshy or fibrous and endocarp is hard and stoney, as in mango, coconut, peach, walnul, cherry, almond etc. (fig. 13.5A).
2. **Berry.** The fruit develops from mono- or multicarpellary, syncarpous, superior or inferior ovary with axiie or parietal placentation. Epicarp forms (he rincl of the fruit, mesocarp becomes fleshy and endocarp remains thin or membranous, as in tomato, brinjal, guava, date, papaya, chiku, areca nut etc. (fig. 13.5B).

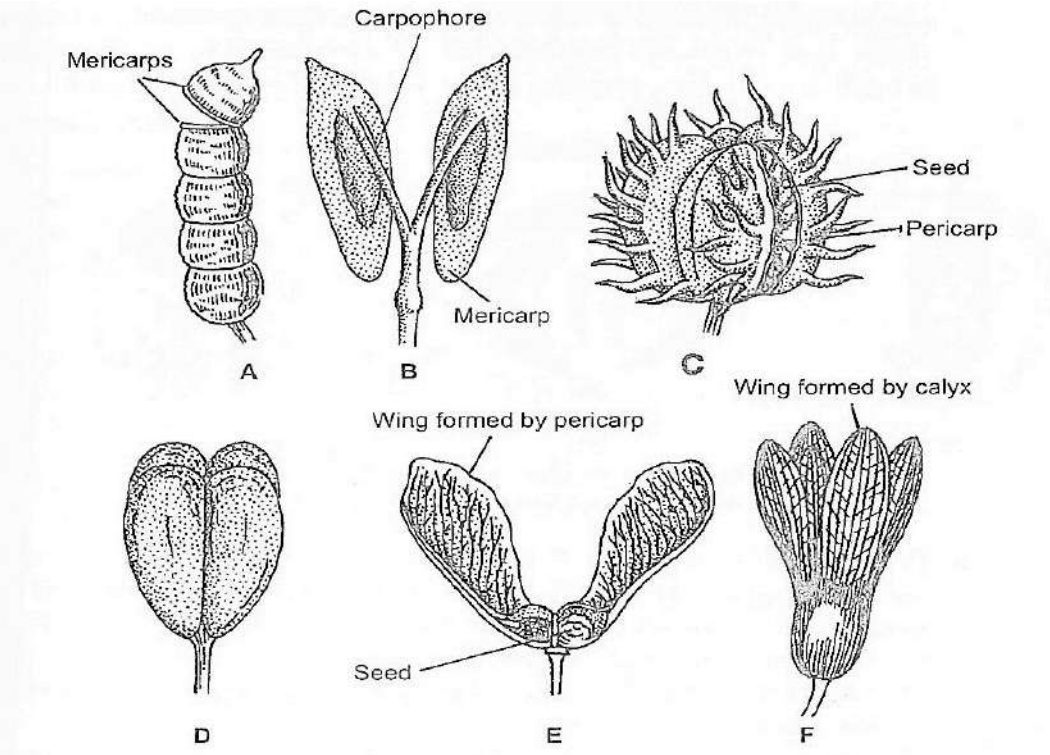


Fig. 13.4 Different types of fruits. A-lomentum (*Mimosa*), B-cremocarp, C-regma, D-carcerule (*Labiatae*), E-double samara and F-samaroid.

3. **Pepo.** The fruit develops from tricarpeilary, syncarpous, unilocular, inferior ovary with parietal placentation. These fruits are full of swollen placenta and are many seeded. Epicarp makes the hard rind. Mesocarp and endocarp are fleshy. Such fruits are characteristic of family Cucurbitaceae as in bottle gourd, cucumber, muskmelon etc. (fig. 13.5C).
4. **Hesperidium.** The fruit develops from multicarpellary, syncarpous, superior ovary with axile placentation. These are multilocular. Epicarp is firm and leathery and has several oil glands. Mesocarp is in the form of white, fibrous part fused with epicarp. Membranous endocarp projects inwards forming distinct chambers. Many juicy unicellular hairs are found on the inner side of endocarp, as in lemon and orange (fig. 13.6A).
5. **Balausta.** The fruit develops from multicarpellary, syncarpous, multilocular superior ovary. It is a many seeded fruit. The epicarp is rough and leathery, mesocarp is papery and thin and endocarp is hard and it forms chambers to enclose seeds irregularly. The fruit has persistent calyx. Testa is red and *fleshy* whereas tegmen becomes hard, as in pomegranate (fig. 13.6B).
6. **Amphisarca.** The fruit develops from multicarpellary, syncarpous, multichambered superior ovary. The fruit is many seeded-Epicarps is hard. Mesocarp and endocarp are fleshy on which are found scattered seeds, as in wood apple *(Aegk marmelos)* (fig. 13.7A).
7. **Pome.** The fruit develops from bi- or polycarpellary, *syncarpous,* inferior ovary. The thalamus becomes fleshy and swollen and surrounds the fruit. So it is a false fruit. The pericarp is thin and papery. Fleshy swollen thalamus *forms* the edible part of the fruit, as in apple and pear (fig, 13.7 B and C).

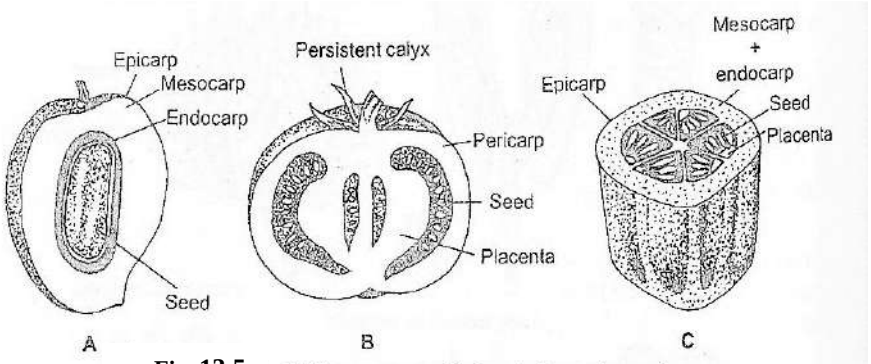


Fig. 13.5 Different types of fruits. A-drupe (mango), B-berry (tomato) and C-pepo (cucumber).

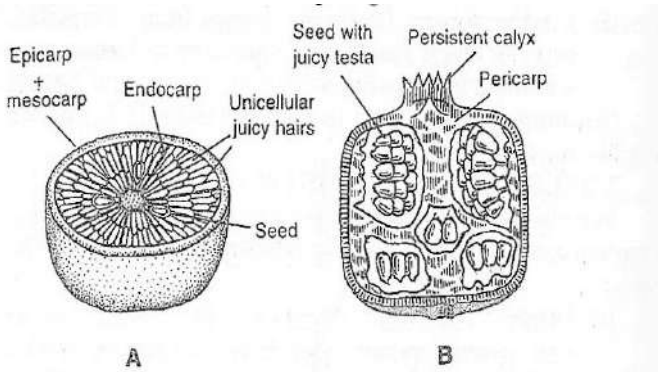


Fig. 13.6 Different types of fruits. A-hesperidium fruit (T.S.) and B-balausta (L.S.).

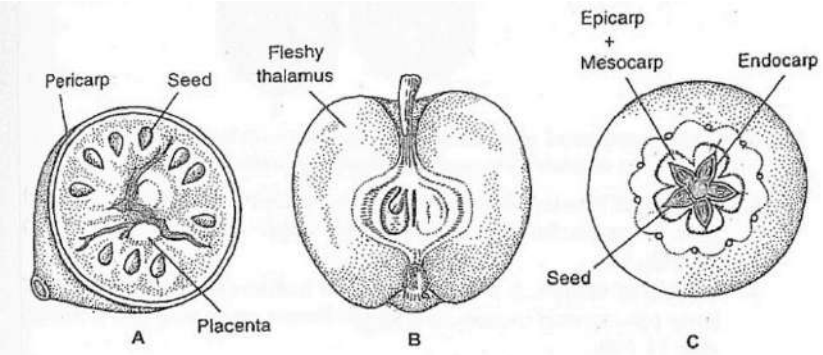


Fig. 13.7 Different types of fruits. A-amphisarca fruit (T.S.), B and C-pome (L.S. and T.S.).

II. AGGREGATE FRUITS

Infact, these fruits are the group of fruitlets developed from multicarpellary, apocarpous ovary of a single flower. Such type of aggregate fruits is called **etaerio,** *i.e.*, aggregate of fruitlets.

These are of following types:

1. **Etaerio of follicles.** In such fruits, each free (separate) carpel develops into a fruitlet which is known as follicle. Many follicles of a flower make it etaerio, i.e., etaerio of follicles, as in *Calotropis* and *Catharanthus* (aggregate of two follicles) and *Michelia* (aggregate of several follicles) (fig. 13.8A).
2. **Etaerio of achenes.** It is an aggregate of achene fruitlets developed from a *single* flower, as in rose, strawberry, *Clematis* and *Naravelia* (fig. 13.8C).
3. **Etaerio of berries**. It is an aggregate fruitlets of berries developed from a single flower, as in custard apple *(Annona)* (fig. 13.8D and E).

4.

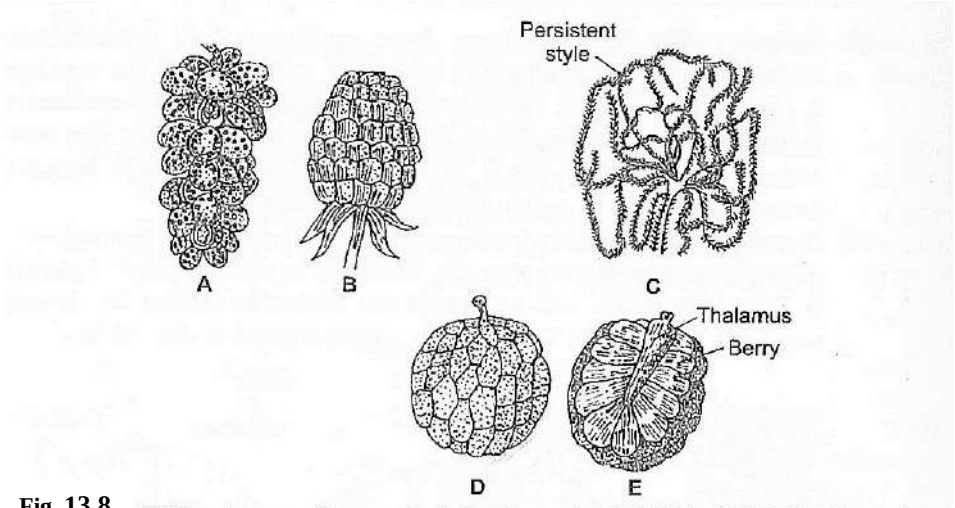


Fig. 13.8 Different types of aggregate fruits. A-etaerio of follicles (*Michelia*), B-etaerio of drupes, C-etaerio of achenes (*Naravelia*), D-etaerio of berries (*Annona*) (E = L.S.).

5. **Etaerio of drupes**. It is an aggregate of fruitlets of drupes developed from apocarpous ovaries of a single flower, as in raspberry *(Rubus)* (fig. 13.8B).

III. COMPOSITE OR MULTIPLE FRUITS

These fruits develop from complete inflorescence and are known as infructescence. These are of two types:

1. Syconus. Such fruit develops from hypanthodium inflorescence. The receptacle becomes fleshy and hollow cup-shaped with a narrow apical opening. Unisexual flowers are found on its inner surface, male flowers towards upper side and female (pistillate) flowers towards lower side. Larvae of insects live in gall flowers (female flowers). The fruit is achene. Fleshy receptacles form the edible part, as in figs *(Ficus)* (fig. 13.9D).

2. Sorosis. This type of fruit develops from spike, spadix or catkin inflorescence, as in jack fruit, mulberry and pineapple. The fruits are so compactly set that entire inflorescence appears as one fruit. In jackfruit, stigmas fuse with each other to make rough and spiny rind. Bracts, perianth and seeds become edible in jackfruits. In mulberry, perianth present around the dry achenes is eaten up (fig. 13.9A, B & C).

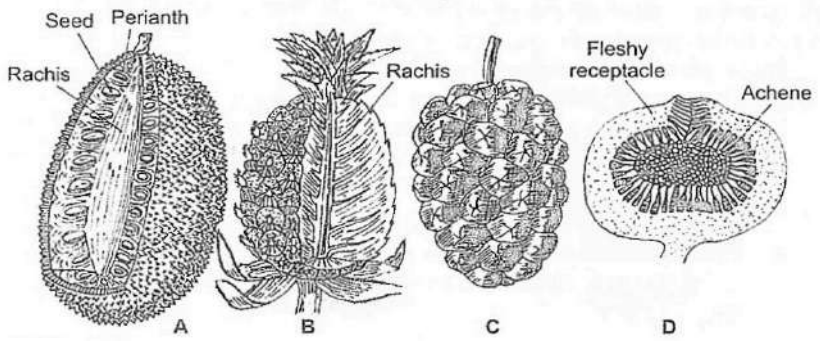


Fig. 13.9 Different types of composite fruits. A-jackfruit (sorosis), B-pineapple (sorosis), C-mulberry (sorosis), and D-fig (syconus).

Table 13.1 Some Common Fruits and their Edible Parts

Name		Type of fruit	Edible parts
I. Simple Fruits			
1	Pea *(Pisum sativum)*	Legume	Seeds
2	Okra or ladies finger *(Abelmoschus esculentus)*	Capsule	Whole fruit
3	Wheat *(Triticum aestivum)*	Caryopsis	Endosperm and embryo
4	Cashew nut *(Anacardium occidentale)*	Nut	Cotyledons and fleshy peduncles
5	Litchi *(Nephelium litchi)*	Nut	Fleshy aril
6	Water chestnut *(Trapa bispinosa)*	Nut	Cotyledon
7	Tamarind *(Tamarindus indica)*	Lomentum	Mesocarp
8	Groundnut *(Arachis hypogea)*	Lomentum	Embryo
9	Coconut *(Cocos nucifera)*	Drupe	Endosperm
10	Walnut *(Juglans regia)*	Drupe	Lobed cotyledons
11	Mango *(Mangifera indica)*	Drupe	Mesocarp
12	Grape Vitis *vinifera)*	Berry	Pericarp and placenta
13	Areca nut (Areca *catechu)*	Berry	Endosperm
14	Guava *(Psidium guajava)*	Berry	Whole fruit
15	Banana *(Musa sapientum)*	Berry	Mesocarp and endocarp
16	Tomato *(Solanum lycopersicon)*	Berry	Pericarp and placenta
17	Cucumber *(Cucumis sativus)*	Pepo	Mesocarp, endocarp and placenta
18	Muskmelon *(Cucumis melo)*	Pepo	Mesocarp and endocarp
19	Bottle gourd (Lagenaria siceraria)	***Pepo***	***Mesocarp and endocarp***
20	***Pome granatc*** (Punica granatum)	***Balausta***	***Fleshy testa***
21	***Madarin orange*** (Citrus reticulata)	***Hesperidium***	***Fleshy unicellular hairs of endocarp***

22	***Sweet orange*** (Citrus sinensis)	***Hesperidium***	***Fleshy unicellular hairs of endocarp***
23	***Lemon*** (Citrus lemon)	***Hesperidium***	***Fleshy unicellular hairs of endocarp***
24	***Lime*** (Citrus aurantifolia)	***Hesperidium***	***Fleshy unicellular hairs of endocarp***
25	***Apple*** (Pyrus malus)	***Pome***	***Fleshy thalamus***
26	***Pear*** (Pyrus communis)	***Pome***	***Fleshy thalamus***

II. Aggregate Fruits

1	Lotus *(Nelumbium speciosum)*	Etaerio of achenes	Thalamus and seeds
2	Strawberry *(Fragaria indica*	Etaerio of achenes	Fleshy receptacle
3	Custard apple *(Annona squamosa)*	Etaerio of berries	Pericarp (except apical part)

III. Composite Fruits

1	Fig *(Ficus carica)*	Syconus	Fleshy receptacle and seeds
2	Pineapple *(Ananas sativus)*	Sorosis	Outer rachis, bracts, perianth and pericarp
3	Jackfruit *(Artocarpus heterophyllus)*	Sorosis	Bracts, perianth, seeds
4	Mulberry *(Morus indica)*	Sorosis	Perianth

DISTINGUISHING CHARACTERS OF THE FRUITS

Table 13.2 Differences between Achene, Caryopsis and Cypsella

Achene		**Caryopsis**	**Cypsella**
1	The fruit develops from monocarpellary and superior ovary.	The fruit develops from monocarpellary and syncarpous ovary.	The fruit develops from bicarpellary, syncarpous and inferior ovary.
2	Pericarp and testa (seed coat) are separate.	Pericarp and testa are fused and cannot be separated.	Pericarp and testa are separate.
3	The fruit is etaerio of *achenes.*	Fruit is not found in groups.	Fruit is not developed in groups.

	Examples. *Clematis, Naravelia* and *Ranunculus*	**Examples.** *Triticum,Oryza* and Zea.	**Examples.** *Helianthus* and *Cosmos.*

Table 13.3 Differences between Legume and Follicle

	Legume or Pod	**Follicle**
1	The fruit develops from monocarpellary, unilocular and superior ovary.	It also develops from monocarpellary, unilocular and superior ovary.
2	Fruit is found singly	Fruit is found usually in pairs, two or more in number.
3	It dehisces from both the sutures and from top towards base.	It dehisces by a single suture
4	When fruit dehisces, all seeds come out.	When fruit dehisces, seeds are exposed and are released slowly with drying.
	Examples. Fruit is characteristic of family Fabaceae**,** i.g. *Pisum, Dolichos, Vigna* etc.	**Examples.** *Calotropis* and *Michelia*

Table 13.4 Differences between Siliqua and Silicula

	Siliqua	**Silicula**
Both types of fruit are found in **Brassicaceae**		
1	The fruit is long and cylindrical	The fruit is broad and flat
2	Fruit has a number of seeds	Fruit contains a few seeds.
	Examples. *Brassica* and *Raphanus*	Examples. *Iberis* and *Capsella*

Table 13.5 Differences between Legume and Lomentui

	Legume	**Lomentum**
1	It is a multi seeded dry and dehiscent fruit.	It is a multiseeded schizocarpic fruit.
2	Mericarps are not formed.	Mature fruit breaks transversely into single seeded parts, called mericarp.
3	The fruit has two sutures and dehisces by both the sutures.	Mericarps are indehiscent.
	Examples. *Pisum, Cicer. Phaseolus* etc.	Examples. *Arachis. Tamarindus. Mimosa* etc.

Table 13.6 Differences between Aggregate and Composite Fruits

	Aggregate Fruits	**Composite Fruits**
1	It is a group of fruitlets which develops from multicarpellary and apocarpous gynoecium of a single flower.	It develops from an entire inflorescence.
2	The fruit develops from carpels of a single flower.	In the formation of a fruit, ovaries, perianths and thalamus participate.
	Examples. *Michelia, Calotropis, Annona* etc.	**Examples.** *Morus* (mulberry), *Ananas, Ficus* etc.

Tabid 13.7 Differences between Follicle and Capsule

	Follicle	Capsule
1	It develops from a single carpel with unilocular and superior ovary.	It develops from multicarpellary, syncarpous and superior ovary.
2	The fruit dehisces by the single suture.	On *maturity*, the *fruit* shows longitudinal, transverse and porous dehiscence.
3	The fruits are formed in pairs or in groups.	The fruit is formed singly.
4	The fruit is dehiscent.	Fruit is schizocarpic or splitting.
	Examples. *Calotropis* and *Michelia*.	**Examples.** *Papaver*, *Gossypium*, *Datura* etc.

Table 13.8 Differences between Caryopsis and Regma Fruits

	Caryopsis	Regma
1	The fruit is dry and indehiscent.	The fruit is dry and schizocarpic.
2	The fruit develops from monocarpellary and superior ovary.	The fruit develops from tri-carpellary, syncarpous and superior ovary.
3	Fruit is single chambered and single seeded.	The fruit is multichambered, each chamber with a single seed.
4	Pericarp and testa are fused and cannot be separated. The seed remains completely enclosed in the fruit.	Fruit on maturity splits into as number of parts as the number of carpels. Each part is called coccus. Cocci split to release seed.
	Examples. *Triticum, Oryza, Zea mays* etc.	Examples. *Ricinus* and *Geranium.*

Table 13.9 Differences between Cremocarp and Regma Fruits

	Cremocarp	Regma
1	The fruit develops from bicarpellary, syncarpous and inferior ovary.	The fruit develops from tricarpellary, syncarpous and superior ovary.
2	The fruit is bilocular and two seeded.	The fruit is multilocular and many seeded.
3	The fruit on maturity splits into two mericarps, each placed at the top of carpophore. The mericarp is single seeded.	The fruit *splits into* as many number of cocci as the number of carpels. The coccus is single seeded.
4	Fruit wall has ridges and furrows.	On the outer surface of the fruit wall, spiny structures are found:
	Examples. *Foeniculum* and *Coriandrum.*	**Example.** *Ricinus communis.*

Table 13.10 Differences between Drupe and Schizocarpic Fruits

	Drupe	Schizocarpic Fruit
1	It is a succulent type of fruit.	It is a dry type of fruit.
2	Fruit develops from mono - or polycarpeilary, syncarpous, superior ovary.	It develops from monocarpellary or polycarpeilary, syncarpous, superior ovary.
3	Pericarp is clearly distinguishable into three layers: epicarp, mesocarp and endocarp.	Such differentiation in pericarp is not found.
4	The epicarp forms skin of the fruit, rnesocarp is fleshy or fibrous and *endocarp is* hard and woody.	No such structure is found.
5	The fruit is usually single seeded.	The fruit is usually multiseeded.
6	Fruit does not split open at maturity	Fruit breaks into number of indehiscent mericarps.
	Examples. *Mangifera* (mango) and *Cocos* (coconut).	Examples. *Arachis* (groundnut) and *Tamarindus* (tamarind).

Table 13.11 Differences between Pome and Drupe Fruits

	Pome	Drupe
1	It is a kind of false fruit as the fleshy fruit-like structure develops from the thalamus.	It is a true fruit that develops from ovary wall
2	The fruit develops from bi- or polycarpeilary, syncarpous, inferior ovary and it remains surrounded by enlarged fleshy thalamus.	The fruit develops from monocarpellary or polycarpeilary superior ovary.
3	The pericarp is thin, papery and inedible.	The pericarp is well developed and. differentiated into epicarp, mesocarp and endocarp
4	The edible part is actually a fleshy thalamus.	The edible part is mesocarp.
5	The fruit has 5-6 seeds.	The fruit has a single seed.
	Examples. *Pyrus* (apple and pear).	**Examples.** *Mangifera* (mango) and *Cocos* (coconut).

Table 13.12 Differences between True and False Fruits

	True Fruit	False Fruit
1	It develops from ovary after fertilization.	In its formation, thalamus, perianth or rachis participate along with ovary.
2	**Examples.** *Mangifera* (mango) and *Carica* (papaya).	**Examples.** *Pyrus* (apple) and *Ficus* (fig).

Table 13.13 Differences between Pepo and Pome Fruits

	Pepo	Pome
1	It is a true fruit that develops from ovary after fertilization.	It is a false fruit in which fruit like structure is formed by the thalamus.
2	It develops from tricarpellary, syncarpous, inferior ovary with parietal placentation.	It develops from bi- or polycarpellary, syncarpous inferior ovary and remains surrounded by fleshy thalamus.
3	The pericarp is well developed and differentiated into epicarp, mesocarp and endocarp.	The pericarp is thin and papery and indistinguishable into three layers.
4	Seeds are produced in a large number.	Only **5-6** seeds are formed.
5	The edible part is fleshy mesocarp and endocarp.	The edible part is thalamus.
	Examples. *Cucurbita, Citrullus, Momordica* etc.	**Example.** *Pyrus malus* (apple).

Table 13.14 Differences between Lomentum and Caryopsis Fruits

	Lomentum	Caryopsis
1	The fruit develops from monocarpellary and superior ovary.	It develops from monocarpellary superior ovary.
2	The fruit is unilocular, multiseeded and bisutural. It is divided into several mericarps.	The fruit is unilocular and single seeded.
3	Pericarp and testa remain separate.	Pericarp and testa are united or fused.
	Examples. *Arachis* (groundnut) and *Tamarindus* (tamarind).	**Examples.** *Triticum* (wheat) and *Oryza* (rice).

Table 13.15 Differences between Drupe and Berry Fruits

	Drupe	Berry
1	The fruit develops from mono - or polycarpellary, syncarpous and superior ovary.	The fruit develops from mono- or" polycarpellary, syncarpous, superior or interior ovary.
2	Pericarp is divided into three layers, i.e., epicarp, mesocarp and endocarp. The endocarp is hard and woody.	Pericarp is divided into epicarp, mesocarp and endocarp. The endocarp is thin and membranous.
3	The fruit is usually single seeded but sometimes multiseeded.	The fruit is usually multiseeded.
	Examples. *Mangifera* (mango) and *Cocos* (coconut).	**Examples.** *Lycopersicum* (tomato) and Vitis (grapes).

Table 13.16 Differences between Hesperidium and *Syconua Fruits*

	Hesperidium	Syconus
1	Fruit develops from the ovary of a single flower.	The fruit develops from the entire inflorescence, thus a type of false fruit. It develops from hypanthodium inflorescence and each fruit is achene.
2	Pericarp is distinguishable into three layers, the epicarp, the mesocarp and the endocarp.	Pericarp is indistinct.
3	The edible part of the fruit is the fleshy unicellular juicy hairs developed from endocarp.	The edible part comprises pericarp, thalamus, perianth and rachis.
4	The epicarp has a large number of oil glands.	Oil glands are not found
	Example. *Citrus* species.	**Example.** *Ficus* species (figs).

QUESTIONS

1. Define fruit.
2. Classify fruit into different categories in tabular form with examples.
3. Write a short note on
    - Legumes
    - Aggregate fruits
    - Syconus
    - Pineapple
4. Differentiate between fruits of tomato, cucurbits and Lemons.

Methodical Vegetative and Floral Description (Taxonomic Description)

As far as possible fresh flower must be taken for description. The minute vegetative and floral structures should be viewed under dissecting microscope. For the study of carpels and locules a transverse section through immature ovary should be examined.

The taxonomic description should be written adopting following sequence:

1.	**Habitat**	**(a)**	Hydrophyte, mesophyte or xerophyte.
		(b)	Cultivated, ornamental, food crop or wild.
		(c)	Tropical, temperate or arctic.
2.	**Habit**	**(a)**	Herb (whether prostrate, erect, diffuse or weak-stemmed), shrub or tree.
		(b)	Annual, biennial or perennial.
3.	**Root**	**(a)**	Tap or adventitious.
		(b)	Branched or unbranched.
		(c)	Any modification (Both for tap and adventitious types of roots).
4.	**Stem**	**(a)**	Erect, prostrate or climbing.
		(b)	Modification-bulb, tuber, corm, rhizome etc.
		(c)	Branching: monopodia or sympodial.
		(d)	Herbaceous (solid or fistular) or woody
		(e)	Angular, cylindrical or flattened.
		(f)	Hairy, spiny, glabrous or glaucous
		(g)	Colour: green or brown.
5.	**Leaves**	**(a)**	Radical, cauline or ramal.
		(b)	Alternate, opposite (superposed or decussate) or whorled.
		(c)	Sessile or petiolate.
		(d)	Stipulated or exstipulated, type of stipule (if present).
		(e)	Leaf base sheathing connate, perfoliate or ligulate.
		(f)	Simple or compound.
		(g)	If compound, pinnate or palmate, number of leaflets.
		(h)	Venation-uni or Multicostate, parallel or reticulate.
		(i)	Leaf margin : entire, serrate or reticulate
		(j)	Surface: hairy, glabrous or glaucous.
		(k)	Apex : acute, acuminate or obtuse
6.	**Inflorescence**	**(a)**	Racemose, cymose or any special type
7.	**Flower**	**(a)**	Pedicellate or sessile.
		(b)	Bracteate or ebracteate.
		(c)	Complete or incomplete.
		(d)	Unisexual or bisexual.
		(e)	Regular or irregular.
		(f)	Actinomorphic or zygomorphic.
		(g)	Hypo, peri- or epigynous.
		(h)	Colour.
		(i)	Nectaries present or absent.

8.	**Calyx**	**(a)**	Number of sepals.
		(b)	Gamosepalous (fused) or polysepalous (free).
		(c)	Shape and form.
		(d)	Green or petaloid.
		(e)	Aestivation: valvate, twisted or imbricate (ascending, descending or quincuncial).
9.	**Corolla**	**(a)**	Number of petals.
		(b)	Gamopetalous (fused) or polypetalous (free).
		(c)	Shape or form.
		(d)	Coloured or sepaloid.
		(e)	Aestivation.
10.	**Perianth**	When there is no distinction between calyx and corolla it is called perianth.	
		(a)	Number of tepals.
		(b)	Gamophyllous (fused) or polyphyllous (free).
11.	**Androeclum**	**(a)**	Number of stamens.
		(b)	Polyandrous (free), adelphous (fused to form a tube) or syngenesious (anthers fused).
		(c)	Epipetalous or free.
		(d)	Filament long or short.
		(e)	Anthers basifixed, dorsifixed Or versatile.
		(f)	Anthers monothecous or dithecous, introrse or extrorse.
12.	**Gynoecium**	**(a)**	Number of carpels.
		(b)	Syncarpous (fused) or apocarpous (free).
		(c)	Ovary superior or inferior.
		(d)	Number of locules.
		(e)	Placentation (marginal, axile, parietal, free central or basal).
		(f)	Number of ovules in each locule.
		(g)	Styles free or united.
		(h)	Stigma simple, lobed, capitate etc.
13.	**Seed**	**(a)**	Endospermic or non-endospermic.
		(b)	Number of cotyledons.
14.	**Fruits**	**(a)**	Kinds of fruits-dry, succulent or of any special type

Floral Formula. It is written the help of the following symbols:

Br	Bracteate
brl	bracteolate
%	Zygomorphic
	Actinomorphic
♂	Staminate
♀	Pistillate
	Bisexual or Hermaphrodite
	Neuter
Ep. K	Epicalyx
K	Calyx free
(K)	Calyx fused

C	Corolla free
(C)	Corolla fused
p	Perianth
A	Stamens free
(A)	Stamens fused
G	Gynoecium free
(G)	Gynoecium fused
G	Ovary inferior
G	Ovary superior
<x	Indefinite
CA	Epipetajous stamens
PA	Epiphyllous stamens

For example floral formula of shoe flower *(Hibiscus rosa-sinensis)* is:

$$\oplus\ \mathbb{Q}\ \mathrm{Epi}\ K_{5-8}\ K_{(5)}\ \overset{\frown}{C_5}\ A_{(\alpha)}\ \underline{G}_{(5)}$$

Floral diagram. Arrangement of floral parts and method of drawing the floral diagram is illustrated in fig. 13.10.

The procedure of drawing floral diagram should be taken up carefully, starting from **outermost** whorl to central whorl (gynoecium). The position of each floral part should be ascertained with its relative position in respect to mother axis (hypothetical).

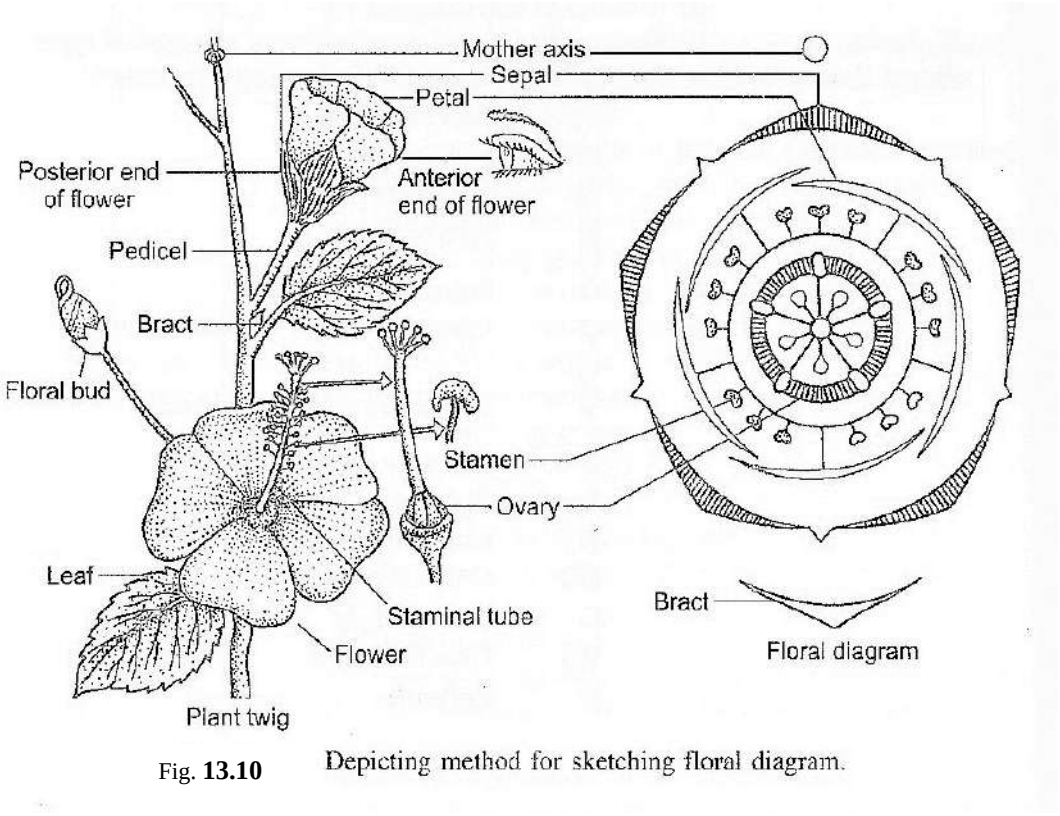


Fig. **13.10** Depicting method for sketching floral diagram.

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LECTURE: 14

INTRODUCTION TO PLANT TAXONOMY AND PLANT SYSTEMATICS

INTRODUCTION

The term taxonomy was coined by a French botanist A.P. de Candolle (1813) in his book Theorie elementaire de la botanique. It comprises two words (Greek, taxis = arrangement; + nomos = study). Strictly speaking, taxonomy is the study of principles and practice of classification, but in a broader perspective, it deals mainly with identification, nomenclature and classification of objects of biological origin. In addition, origin and relationships also form important aspects of taxonomy. Plant taxonomy is often treated as synonymous with Systematic Botany. According to Jeffrey (1968), plant taxonomy, otherwise known as systematic botany is concerned with identification, classification and naming of plants. On the other hand in the opinion of authors like Porter (1959), taxonomy is a very broad and comprehensive subject and comprises (i) Systematic botany (ii) Taxonomic system (iii) Nomenclature and (iv) Documentation. The main objective of systematic botany is systematic description of plants, based primarily on their morphology. In present day taxonomy, information from other disciplines of botany e.g. anatomy, palynology cytology, genetics, ecology, physiology, photochemistry, etc. are collected. Thus it can be said that taxonomy, on one hand is basic to all branches of botany and on the other hand dependent on them. Today anyone dealing with plants in anyway has to depend on the labor of the taxonomists. According to Radford et al. (1974), taxonomy is the pedestal, upon which biology is built. The information obtained about the characteristics of plants are utilized to frame taxonomic concept of taxa at various levels, e.g. species, genera, etc.; concept of the evolutionary sequence of characters, i.e. what characters are primitive or what are advanced, or transitional; classification and arrangement of taxa in some recognised system and description of taxa. These aspects form parts of taxonomic system.

Plant taxonomy is therefore, regarded a synthetic discipline, and systematic botany is one of the four disciplines mentioned earlier. However, it is a matter of opinion and both the terms e.g. plant taxonomy and systematic botany are used interchangeably (Lawrence 1951).

Likewise a term 'systematics' is often used. Simpson (1961) defined systematics, a science usually considered as dealing with a comprehensive study of diverse organisms with regard to their natural relationships. Taxonomy, on the other hand is a science usually considered as dealing with principles and procedures of classification (Radford et al. 1974). Adopted in a broad sense, systematics includes not only the theory and practice of classification (Taxonomy sensu stricto) but also deals with the scientific study of origin and evolution of plants.

AIMS OF TAXONOMY: In modern taxonomy, there are mainly three aims which are widely accepted:

(i) To provide a convenient method of identification and communication.

(ii) To provide a classification which expresses natural relationship of organisms as far as possible.

(iii) To detect evolution at work, discovering its process and interpreting the results.

Out of the above, the first two aims mainly involve an empirical approach which is based on observed characters and it results in a basic classification. The third aim involves interpretative approach which affects the improvement in classification, and is interpreted in evolutionary or phylogenetic terms.

Our knowledge of the world flora is extremely uneven and its classification can be considered in four overlapping phases:

(1) Pioneer or exploratory phase: It is primarily concerned with identification. During this phase, the flora is known mainly from herbarium material.

(2) Consolidation phase: The phase in which the species have been studied both, in the herbarium and field. This initiated the publication of floras and monographs.

(3) Biosystematic phase: It is related to evolution at infraspecific level and takes into account of geographical and ecological variations on cytological grounds including morphology, number of chromosomes, breeding behavior and barriers.

(4) Encyclopaedic phase: It synthesizes the evidences derived from the first three phases and tries to express systematic and evolutionary relationships of plants at every taxonomic unit. It lays great emphasis on infraspecific categories like ecotype, ecophene, biotype, etc.

The first two phases correspond to alpha taxonomy or alpha classification (Turrill, 1938) and the other two come under omega taxonomy in which there is a synthetic approach to taxonomic studies.

DEFINITION OF TERMS

Identification

It is defined as assignment of plant to a particular taxonomic group, ultimately to a species. The plant is therefore, given a name by recognizing that it belongs to a previously described taxon (Davis and Hey wood 1963). In case, the comparison with the taxa of the same rank already recorded, shows that the plant is significantly different, it may be described as a new taxon and a new name is given to it. According to Lawrence (1951) identification is the determination of a taxon as being identical with or similar to another and already known element. Identification is done by comparing a plant specimen with authentically identified specimen or with the help of keys, descriptions, illustrations given in various local, regional or state floras.

Nomenclature

It is concerned with the determination of the correct scientific name of a known plant, according to a nomenclatural system. For this, there are international rules given in International Code of Botanical Nomenclature (ICBN) which directs the process to be followed for the determination of the name applied to a particular plant. Correct and scientific name is of utmost importance because of the fact that either the same plant is known by different names or a common name is applied to a variety of plants in different

languages in the same country or in different countries. In order to avoid all these confusions, standard scientific names are given to plants.

Classification

It is concerned with the placing of a plant or group of plants in a hierarchy or categories or groups, according to a plan or sequence and in conformity with a nomenclatural system. In this way a species is classified as a member of a genus; a genus is classified as a member of family; a family of an order and order to a class and so on. The product is an arrangement or system of classification designed to express interrelationship of plants. This can be referred to as box-in-box arrangement on the basis of overall similarities. This arrangement can also be called as pigeonholing of alike objects.

Classification is a natural occupation of man. According to Hopwood (1957-1958). "The urge to classify is a fundamental human instinct, like the predisposition to sin; it accompanies us into the world at the time of birth and stays till end." Classification is the basic method by which man can organize the external world. Which kinds of features are employed, depends on the kind of classification we have in mind, since classification is done for a purpose and different classifications are needed for different purposes. Even in early stages of civilization, man soon came to recognize the kind of plants he should eat, which to be used as medicine, which for shelter, etc. This was based not only on the morphology of plants but also on their smell; taste and nutritive value. Later some conspicuous features of plants attracted the man, so that certain groups of flowering plants were created, e.g. Fabaceae, Brassicaceae etc. Nature is full of diversities and these led man to classify. According to Grant (1963) in plant kingdom, angiosperms are represented by nearly 286,000 species as compared to 640 species of gymnosperms, 10,000 species of ferns and fern allies, 23,000 species of bryophytes, 8675 species of algae (green, red and brown), 40,400 species of fungi and slime moulds, 30,000 species of protista, 1,400 species of blue green algae, 1630 species of bacteria and 200 species of viruses.

In angiosperms great range of variations occurs in form and structure. For example, there are minutest plants like Wolffia (Lemnaceae) which measure not more than 2 mm in size. On the other hand Eucalyptus regnans (Myrtaceae) of Australia are tallest plants, attaining a height of more than 100 metres. Similarly, diversification on nutritional basis is found in angiosperms which are saprophytes like Monotropa; parasites like Cuscuta, Loranthus, Orobanche; insectivorous plants like Nepenthes, Sarracenia, Drosera and epiphytes like Dendrobium. Like vegetative characters, angiosperms show great variations in floral characters. There are unisexual, bisexual or polygamous flowers. The floral organisation may be simple or complicated. For example in Euphorbia, the male flowers are reduced to single stamen. In Lemna, the female flower is reduced to an unilocular ovary. The flowers may be naked or may have well developed perianth. The ovules may be completely closed in the ovary or simply protected by folded conduplicate carpels, e.g. Winteraceae. The ovules may be integumented or may be without integument, e.g. Loranthaceae or Santalaceae. The variations are mostly discontinuous that help

to a larger extent in a workable classification. When the variations are continuous, classification becomes problematic.

Documentation

It is concerned with warehousing of plants (both living and fossil) in herbarium or museum. There are various techniques for herbarium preparation (to be discussed in separate chapter). Documentation also includes preservation of type materials on which the description and names of taxa is based. Icones, which may sometimes serve as type, and maps showing geographical distribution of taxa, also form part of documentation.

Units of Classification and Their Concepts

The taxonomic group of any rank which forms units of classification is termed Taxon (pi. Taxa). It can be used to denote a division, class, order, family or even a species. Various taxonomic units may be placed in two categories, i.e. major and minor. In the former are included categories up to families, while the later forms the name of the plant itself.

MAJOR UNITS

Division

Within the plant kingdom, division represents the category of highest magnitude. The number of divisions in which plant kingdom is divided, varies from authors to authors. According to Engler and Prantl (1887-1899), there are 13 divisions in plant kingdom. Eichler (1875) recognised two main groups in plant kingdom viz. Cryptogamia and Phanerogamia: the former being further divided into Thallophyta, Bryophyta and Pteridophyta whereas, the later into Gynmosperms and Angiosperms. Cronquist, Takhtajan and Zimmerman (1966) leaving aside Algae and Fungi, recognized 8 divisions into Embryobionta, e.g. Rhinophyta,

Bryophyta, Psilophtya, Lycopodiophyta, Equisetophyta Polypodiophyta, Pinophyta and Magnoliophyta. The names of divisions have the ending—'phyta' but in case of Fungi it is— mycota. The divisions are characterised by the possession of a very few selected common characters. For example, the Magnoliophyta (Angiosperms) are characterized by possession of a sporophytic generation dominant over much reduced gametophytic generation and reproductive structures called seeds enclosed in carpellary wails. The divisions are often divided into sub divisions and have the ending—'phytina'. In earlier system ending ‘ae' was added, e.g. the spermatophyta being divided into Angiospermae and Gymnospermae, which are distinguished on the basis of closed or naked seeds.

Class

It is the next full category, subordinate in rank to the division. The names applied to classes are in Latin names and have the ending 'opsida'. In earlier classifications ending 'eae' was applied, e.g. Monocotyledoneae and Dicotyledoneae. The classes are created on the basis of certain more additional characters as compared to the division. For example Magnoliopsida (Dicots) and Liliopsida (Monocots) are distinguished by the number of cotyledons, venation of leaves and nature of flowers. The class is often

divided into sub-classes which have the ending 'idae'. For example Magnoliidae, Hamamelididae, Asteridae, etc. The subclasses polypetalae, gamopetalae and monochlamydeae of Bentham and Hooker's system or Archichlamydeae and Metachlamydeae of Engler and Prantl's system are not in conformity with the ICBN. The sub-classes are erected, taking into consideration some more characters in addition.

Order

Each class or sub-class is divided into orders. The order is the category next in the line and subordinate to that of class. The orders have the ending ‘ales', e.g. Rosales, Cycadales, etc. There are exceptions like Glumiflorae or Tubiflorae as mentioned in Engler and Prantl's classification. When the orders are very large, they are divided into sub-orders which have the ending 'ineae'. Orders are characterized by more additional characters than class. Cohort, Nixus, Alliance or Reihe are equivalent to orders which have been used in earlier literature. An order possesses greater degree of phylogenetic unity than that of division or class.

Family

An order or a sub-order comprises one or more families. Usually two or more genera resembling one another in certain characters collectively constitute a family. When a family contains a single genus, it is said to be monotypic. Family name has the ending 'aceae'.

There are certain families having names not ending with—'aceae'. e.g. Leguminosae, Palmae, Gramineae, Cruciferae, Guttiferae, Umbelliferae, Labiatae, Compositae and these families have been given alternative names, like Fabaceae, Arecaceae, Poaceae, Brassicaceae, Clusiaceae, Apiaceae, Lamiaceae, Asteraceae, respectively.

The family usually represents a more natural unit than any of the higher categories. The families of higher plants are recognized by characters generally inherent in the reproductive structures such as inflorescence, ovary, placentation, carpels, androecium, etc. Apart from reproductive characters, there are certain vegetative characters which are very prominent and constant in many families. They can be useful in delimiting one family from the other. To explain this, one can examine the plants, like Barleria prionitis, Peristrophe bicalyculata, Justicia simplex, Adhatoda vasica or Thunbergia erecta. All these plants are different from each other in many characters, yet, have been kept in family Acanthaceae because they have some characters in common, i.e. zygomorphic, bisexual flowers with gamopetalous corolla, epipetalous stamens, bicarpellary pistil and superior ovary.

When a family is very large and comprises many components, it is often divided into sub-families which have the ending—'oideae', e.g. Oleoideae, Jasminoideae of family Oleaceae. Similarly, the sub-families are divided into Tribes and Subtribes which have the ending—'eae' and—'inae', respectively.

MINOR UNITS

A minor unit of classification is the one which becomes part of the name of plant. It may be genus, species or sub-species etc.

Genus

The genus is subordinate in rank to the family. The generic name is the first of the two words comprising a binomial name e.g. Cucurbita maxima. Cucurbita is the generic name. By and large, several species constitute a genus. If there is a single species in a genus, it is said to be monotypic. A genus is defined as an assemblage of species which resemble one another in general structure and appearance more than they resemble any other genera within the family. The genera of Linnaeus, Hooker, Gray and other later botanists, is based on the belief that a genus is a category, whose components (i.e. species) have more characters in common with each other than they do with the components of other genera within the same family. Take for example Euphorbia which belongs to family Euphorbiaceae, differs from other genera like Jatropha, Croton, Ricinus, Acalypha, etc. of same family by having cyathium type of inflorescence. Within the genus Euphorbia, there are several species like E. royleana, E. geniculata. E. dracanculoides,, E. prostrata, E. hirta, etc. These various species although different in certain vegetative and reproductive characters, have in common one character, e.g. cyathium. Usually the characters of a genus are derived from reproductive organs, while those of a species from all parts of the plant body. Therefore, a genus can be defined as a collection of species which bear similarities to one another in general characters of their reproductive organs.

The concept of the genus was first of all given by Tournefort (1700) in his publication Institutions Rei Herbarie, although Otto Brunfels (1464-1534) is credited by having the clearest concept of the category of a genus. Tournefort recognised two types of genera: The first contained genera based on the form of flower and fruit, e.g. Nigella or Ranunculus,and the second contained genera for which vegetative differences were needed, e.g. Pinus, Abies and Larix, which differ from each other in position of their leaves. For flowering plants, he proposed that one should consider the flower and fruit, and add characters from other organs, whenever necessary for a better distinction.

Linnaeus adopted Tournefort's generic concept and elaborated upon them. A genus may be divided into sub-genus, sections, sub-section and series.

Species

A species has been considered as a basic unit of classification. The specific epithet follows the generic name and is written in small letters, e.g. Cucurbita maxima. By the term species, it is understood that a collection of individuals which resemble one another closely in all important characters of vegetative and reproductive organs, and are therefore, supposed to have descended from a common ancestor. If we walk in a field of pea, we observe thousands of individuals which resemble each other in all characters, and thus, constitute a species. This can be verified if they breed true from generations to generations, i.e. produce offspring exactly resembling their parents. However, it should be kept in mind that such a thing is possible only if individuals in question are exposed to influence of same environmental factors such as soil, heat, moisture, light, etc. as the parents. The application of this definition becomes problem in cases where similar individuals have lost the capacity of sexual

reproduction and multiply exclusively by vegetative means, yet they constitute same species. Various authors have defined the species in various ways, which have been broadly classified under two concepts:

(1) Typological, essentialist or taxonomic concept

(2) Biological species concept.

Typological concept

Literally, species which comes from its latin root "specere" refers to appearance. According to Mayr (1957), typological is the simplest and most widely held species concept. Under this concept, species are defined on the possession of certain morphological or phenotypic characteristic, not possessed by members of other species. This concept treats species as random aggregates of individuals which have the essential properties of the type of the species and agrees with the diagnosis.

Biological concept

The biological species concept was formulated by Mayr (1969). Unlike typological concept, biological species is defined by genetic kinship (Love 1964, Mayr (1969) and breeding behaviour. Such a species is defined as a community of cross fertilizing individuals linked together by bands of mating and isolated reproductivity from other species (Grant 1957). In other words a biological species is constituted by groups of interbreeding natural populations that are reproductively isolated from such other groups. This concept lays emphasis on two points: (i) Interbreeding between members of the same species and (ii) reproductive isolation between the members of different species.

Jeffrey (1968) defines species as a series of intergrading and interfertile populations recognizably distinct from other such series and separated from other such series by genetically controlled barriers preventing interbreeding. Different species, therefore, are different such series. Doyen and Slobodchikoff (1974) proposed an operational definition of species as "groups of phenetically similar, interbreeding populations that share similar ecological niches". However, this cannot be applied to asexual organisms (Slobodchikoff 1976).

According to Lawrence (1951), species is the product of individuals, judgment. Further, Mason (1950) says that, a species to one taxonomist may be a sub-species to the other and a family to one may be an order to another. The taxonomic categories possess only relative values.

Subspecies

These are baby species or species of small magnitude that are distinguished by the obvious or less significant morphological features than are more obvious species within the same genus. Mayr (1969) defined a subspecies as "an aggregate of phenotypically similar populations of a species and differing taxonomically from the populations of the species. Davis and Heywood (1963) opines that a subspecies is a segment of species with a distinct area and more or less distinct morphology often showing some intergradations.

Variety

Under certain conditions, particularly changed external conditions, a species may exhibit certain variations in form, size, colour, etc. These are termed varieties.

Forma

It is the smallest category used in ordinary taxonomic work. It is generally applied to specific variations occurring among individuals of any population. Some botanists consider Forma to be any variant that occur sporadically in a species population, irrespective of the degree of morphological variation or constancy. The forma of this category is equivalent to the variety of many botanists.

Some of infraspecific units of classification are:

Biotypes: These are local variants among individuals belonging to the same species in same environment.

Ecophene or ecad: These are individuals of the same species which differ in certain minor morphological or physiological characters. The differences are due to the differing environment in which they grow. If they grow under identical environmental conditions, the differences amongst them may disappear. Thus, ecad or ecophene is a form showing adaptation to a particular habitat in which they grow and the adaptive characters are not genetically determined, but are due to environmental agencies.

Ecotype: A term proposed by Turesson (1922) defined as a phyletic unit adapted to a particular environment and capable of producing fully fertile hybrids with other ecotype of the same ecospecies. The differences are genetical as well as environmental.

TAXONOMIC LITERATURE AND INDIAN FLORA

TAXONOMIC LITERATURE:

A vast literature, concerned with the plant taxonomy existing globally, would require thousands of volumes to review.

The monumental work Flora of British India (7 volumes) was compiled by Sir JD Hooker (1872-97). A manual of CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) plants in India. i.e. the Negative List of Export, is on way of preparation. The major forms of literature with names of important ones are accounted here.

Floras, Manuals etc:

A flora is an inventory of plants of a defined geographical region. The coverage of a flora may range from a small patch of forest, a valley, a mountain range, a city, district, state, and nation or even to a continent. Since it is difficult to make an inventory of all plants growing all over the world, limited areas are selected. A flora may be fairly illustrative or simply synoptic but ideally it should provide systematic enumeration, comprehensive description, key for identification and if possible illustrations of various plant species included in it. Depending on their scope and the area covered, the floras may be categorised as

:

Local Flora: It covers a limited geographical area, usually a city, district, state, country, a valley or a small mountain range, e.g. Flora of Delhi by JK Maheshwari (1963), Flora Simlensis by H Collet (1921), Flora of Tamil Nadu by KM Mathew (1983), Flora of Texas by RC Reeves (1972) ete.

Regional Flora: It includes a larger geographical area, usually a large country or a botanical region, e.g. Flora of British India by Sir JD Hooker (1872-97), Flora of Malaysia by CC Steenis (1948). Flora Iranica by KH Rochinger (1963) ete. A flora covering a country is more appropriately called National Flora. Botanical Survey of India (BSI) has recently taken up the publication of Flora of India.

Continental Flora: It covers the entire continent, e.g. Flora Europea by TC Tutin, et al. (1964-80), Flora Australiensis by G. Bentham (1863-78) ete.

Comprehensive Treatments have much broader scope and are the joint efforts of comprehending several important taxonomic works which took place worldwide, e.g. Genera plantarum of C Bentham and JD Hooker (1862-83), Die naturarlichen pflanzenfamilian of A Engler and KA Prantil (1887-1915), Das pflanzenreich of A Engler etc.

A manual differs slightly from flora in that it emphasises mainly on providing suitable keys for identification, descriptions and glossary. They are more exhaustive than floras and generally cover specialised groups of plants, e.g. Manual of Cultivated Plants by LH Bailey (1949), Manual of Cultivated tree and Shrub Hardy in North America by A Rehder (1940), Manual of Aquatic Planes by NC Fossel (1957) etc. A manual differs from a monograph in that the latter has a detailed taxonomic treatment of a taxonomic group.

Botanical Survey of India is actively engaged in documentation of plant diversity in the form of district, state, regional and national flora (Flora of India). By March 2006, Flora of Medak District, Andhra Pradesh was more or less ready for publication; Flora of Uttar Pradesh. Vol 11: Taxonomic description of 199 species was completed; Flora of Cold Deserts of Western Himalayas, Vol II: five species completed and Flora of India: Lamiaceae, was underway of revision.

SF Blake (Part 1. 1941; Part 11. 1961) has elucidated the list of floras more comprehensively in his Geographical Guide to Floras of the World. Frodin (1984) has also given a comprehensive list of world floras in his Guide to the Standard Floras of the World. One can also know more about them in Lawrence (1951), Core (1955), Heywood (1963), Reed (1969), Volumes of Taxon etc.

Monographs, Revisions, Conspectus, Synopsis etc:

A Monograph is a comprehensive treatment of a taxonomic group, generally a genus or a family, dealing compilation of worldwide available all significant information concerning the taxon. The geographical scope is worldwide because it is impossible to discuss a taxon without including all its members and often its entire species, subspecies, varieties and formas, It also incorporates an exhaustive

review of literature, as also a report on author's research work. An ideal monograph contains all information related to nomenclature, designated types, keys, exhaustive description, full synonymy and citation of specimens examined. Since preparation of monographs involves vast disciplines biosystematics) to be undertaken, it takes several years of patience for the study to be completed. This is the reason that till today there are relatively few monographs on record, e.g. The Genus Pinus by TN Mirov (1967). The Genus Datura by AF Blakslee et al., (1959). The Genus Iris by WR Dykes (1913), Monograph of the Genus Avena by BR Baum (1977).

A revision is generally less comprehensive than a monograph and is often based only on herbarium studies. It incorporates less introductory material and includes a synoptic literature review. Although it includes complete synonymy but the descriptions are shorter and often confined to diagnostic characters. The numbers of revisions is more than thousand world over.

A conspectus, an effective outline of the revision, enlists all taxa with all or major synonyms with or without short diagnosis and with a brief mention of the geographical range. An ideal example of a conspectus is Species plantarum of C Linnaeus (1753).

A synopsis is a list of taxa with much abbreviated diagnostic distinguishing statements that are often in the form of keys.

Illustrations (Icones): Illustrations (Icones) are usually published along with the text in Floras and Monographs but may sometimes be compiled exclusively. They are often detailed analysis that serves as useful tools for identification. As such many species of plants based on published illustrations only, without any accompanying description or diagnosis before 1.l.1980, have been accepted as validly published. The two principal compilations of icones are Hooker's Icones and Wights !cones. Others worth mentioning are: Illustrations of plants from Europe (Hegi, 1906-1931), North America (Gleason, 1963), Pacific coast trees (Mc Minn and Maino, 1946), Germany (Garcke, 1972), Korea (Lee, 1979) etc.

Regulations: Since 1867 onwards, International Botanical Congresses are being held periodically at usually four years of interval. Legislation has been agreed upon to recommend universally adaptable principles, rules and recommendations for naming the plants and publish the Code, subject to revision at every congress.

Periodicals (Journals): Floras, Manuals and Monographs are published after a lot of taxonomic input. They require several decades for incorporating information on the results of ongoing research in the field with the help of journals or periodicals which play a significant role for continuance of taxonomic study. They provide a continuous update on additional taxa described or reported from a region and also information about nomenclatural changes and other taxonomic information. Reference to a publication in them includes volume number (which remains the same in all issues published within a year); issue number (numbered within a volume-a monthly journal will have 12 issues, quarterly 4, half-yearly 2 and

annual 1); and page numbers on which the particular article appears. Various herbaria, botanical gardens, botanical societies and many other agencies worldwide, publish the findings of their studies in the form of research papers, short articles, notes, abstracts ete, in these journals published at regular intervals. The numbers of journals may exceed several thousands. Lawrence and Bensen have compiled an excellent list of periodicals known to them by that time about published taxonomic literature. These periodicals arc the authentic and learned treatises on concerned plant taxa and are quite useful in taxonomic study and research. Some of the common journals devoted largely to taxonomic research are: Taxon (International Association of Plant Taxonomy, Berlin), Kew Bulletin (Royal Botanic Gardens, Kew, England). Plant Systematic and Evolution (Denmark), Botanical Journal of Linnaeun Society (London), Journal of the Arnold Arboretum (Harvard), Bulletin Botanical Survey of India (Kolkata), Botanical Magzine (Tokyo), Systematic Botany (New York), American Journal of Botany (USA), Botanical Gazzette (USA), Botanical Society of Bengal Bulletin (India) etc.

Index: An index is an alphabetic catalogue of taxa with reference to their publication. It is prepared to depict a synoptical background of the work done in respect of names of flowering plants published throughout the world. They are volumes of compiled work that continuously compile abstracts of papers published. These include Index Kewensis (Royal Botanic Gardens, Kew, England, 1893). Index Londiensis (London, 1935), Flowering Plant Index of Illustrations and Information compiled by RT Issacson (1979), Index Nominum Genaricum (1986). Gray Herbarium Card Index (l893-1962)-Supplement in 1978, Index Holminesis (1969) etc.

Index Kewensis: Index Kewensis-Plantarum phanerogarum (2 volumes, 15 supplements), Oxford (1893-supplements to date), the most comprehensive list of the scientific names of flowering (seed) plants, started its ublication in 1893 from Royal Botanic Gardens, Kew, England-the largest botanical garden in the world. The entire work (from 1846 to 1927) was initiated by Sir JD Hooker who remained the Director of this prestigious Garden in collaboration with Benjamin, Daydon and Jackson. Index Kewensis enlists names of new and changed names of flowering plants with their bibliographic references to the place of first publication. In its first publication it included 3.75,000 scientific names known since the time of Linnaeus. Around ninteen eighties, the data was transferred to a computer database which continues to expand at the rate of about 6000 records per year. To make this data generally available, the whole Index Kewensis has been published in CD-ROM in 1993 that contains almost 9,68,000 records. Index Kewensis is an indispensable reference, most useful to any study of taxonomy of flowering plants.

Dictionaries and Glossaries: Dictionaries and glossaries are the alphabetical lists of difficult botanical terms which are in usage in the literature. They also provide valuable information concerning genera and families providing name of author, distribution, family of the genus and number of species it includes. e.g.Dictionary of Flowering Plants and Ferns by JC Willis-6th edition (1973), Botanical Dictionary, 1960

(Moscow), Dictionary of Gardening by Chittenden (1951), The Wealth of India-A Dictionary of Indian Raw Materials and Industrial Products, 1948 (CSIR, New Delhi), Glossary of Botanical Terms Commonly used in Range Research by Day ton (Washington-1931), Glossary of Botanic Terms with their Derivation and Ascent by jackson (1928), Dictionary of Economic Plants in India by Singh et al. (1983) etc. They are valuable in taxonomic studies.

Pictorial Encyclopaedias, Keys etc:

Pictorial encyclopaedias provide all available information on cultivated plants throughout the world. More famous among them are Standard Cyclopaedia of Horticulture by Baily (1914-17), Indian Trees by Brittan (1908), North American Trees by Covens (1950) etc.

Keys, provided in most of the manuals and floras in addition to the description, are not considered here. Keys prepared for general purpose of identification of plant families are widely used, particularly in determining plants from rich and diverse botanical provinces, e.g. Key to the Families of Flowering Plants of the World by Hutchinson (1967), The Identification of Flowering Plant Families by Davis and Cull ens (1965), The Identification of Flowering Plant Families by Hansen and Rahn (1969), etermination of Angiosperm Families by Punch-Card System by Simpson and [anos (1974), Punch Card Key to the Dicot Families of South India by Naik (1977) etc.

Specific Literature on Cultivated Plants; Wild Plants; Trees, Shrubs and Grasses:

Literature on cultivated plants has always been predominant since ancient period. This was due to man's interest of plants providing food, medicines and many more desirable plant products for his needs and greed. Some of the important ones are listed as: A Manual of Cultivated Plants by Bailey (1924), Origin of Cultivated Plants by de Candolle (1885), The Mango: Its Cultivated Varieties by Woodrow (1904), Roses by Pemberton (1920), Coconut: Cultivation by John (1955), South Indian Bananas by [acob (1934), The Indian Cottons by Gammie (1907), Field and Garden Crops of the North-West Provinces and Oudh by Duthie and Fuller (1882-93), Some Bananas at Assam by Dutta (1952) etc.

Literature on wild plants appeared because of man's anxiety on plants growing around him. As a result of many ongoing explorations, plant taxonomists reported a large number of plant species, many of them were wild. Among literature on wild plants, worth mentioning to include are: Wild Flowers by Kosch (1964), Wild Flowers of the West by Clements (1927), Some Useful Wild Plants of Delhi Province by Singh (1945), New or Noteworthy Plants from the Upper Gangetic plain by Raizada (1950), Our Early Wild Flowers by Keeler (1916) etc.

Literature on trees and shrubs includes many publications on forest trees and shrubs and these growing elsewhere. Trees produce vast number of valuable commercial products and are grown as ornamentals

whereas shrubs are valued for their economic products, especially drugs and used as fuel wood. Some important publications on trees and shrubs are: Indian Trees by Brandis (1906), The Silviculture of Indian Trees by Troup (1921), Field Manual of Trees by Schaffner (1926), Flowering Trees of India by Randhawa (1957), Beautiful Trees of India Randhawa (1958), Shade and Ornamental Trees of California by Pratt (1921), Trees and Shrubs of the Rocky Mountain Region by Longyear (1927), Some Beautiful Climbers and Shrubs (Bombay) by Bor and Raizada (1954), Trees and Shrubs from Mexico by Standly (1920-26), A List of Trees and Shrubs of Indore State by Biscoe (1910).

Literature on grasses comprises publications on various grasses. Although grasses include important undergrowth of forests and grow elsewhere, yet little is known about them. Some important publications on grasses include : Some Uttar Pradesh Grasses and Common Grasses of United Provinces by Bor (1941), The World Grasses by Bews (1940), Grasses of North America by Beal (1896), The Gramineae by Arhar (1934). First Book of Grasses by Chase (1922). The Bambuseae of British India by Gamble (1896), A Key to the Genera of the Common Grasses of Lucknow and its Environment by Pal (1966), Grazing Lands in Himachal Pradesh by Raina (1966).

As stated by Lawrence (1951) that "Taxonomy demands an almost encylopaedic of world's pertinent literature, taxonomists must identify the various sources of taxonomic literature. The closer we reach the taxonomic literature, more we know about plants and better shall be our understanding of the floras". India needs close cooperation among taxonomists in various botanical institutes such as Botanical Survey of India (Kolkata), National Botanical Research Institute (Lucknow}, Forest Research Institute Dehradun), Central Arid Zone Research Institute (Jodhpur), Indian Fodder and Grassland Research Institute (Jhansi), various herbaria and many universities and colleges carrying out research in plant taxonomy.

INDIAN FLORA

India, an important subcontinent of world's largest continent-Asia, with richest plant wealth, remained unexplored till 1565 when Garcia d' Orta published the first account of Indian plants in the Portuguese language which was later translated in Latin by Clusius. The works entitle Coloquios dos Simples e Drogas da India attracted European botanists to India. Subsequently Hortus Indicus alabaricus (Hendrick von Rheede-1670 to 1703), Flora Indica (Burmann, 1768), Plants of Coast of Coromendel (Roxburgh-1820 to 24), Plants Asiaticae Rsriores (Wallich-1830 to 32), Icones Plantarum Indiae (Robert Wight-1838 to 53) and a few others appeared. Sir J. D. Hooker, in 1897, on compilation of the seventh and the last volume of Flora of British India (1872-97), expressed a wish that his work would facilitate the preparation and compilation of local floras and monographs of the genera of India which he onsidered "the richest and most varied botanical area on the surface of the globe, where ample work is still to be done". Inspired with his pioneering work, the main theme of botany, in nineteenth century, became the comprehensive study of floras of various parts of the country. Simultaneously, the establishment of

Botanical Survey of India in 1890 and the organisation of extensive botanical explorations in the British India, caused to emerge many local and regional floras namely Flora of Bombay Presidency by Cooke (1901-08) and Talbot (1909-11), Flora of the Presidency of Madras by Gamble and Fischer (1915-36), Flora of Bengal by Prain (1903), Flora of Upper Gangetic Plain by Duthie (1903-22), Flora of Nilgiris and Pulney Hill-tops by Fyson (1915), Flora of Biber and Otisss by Haines (1921-25), Flora of Rajasthan by Blatter and Hallberg (1918-21). Apart from these floras, several other shorter floristic accounts on limited regions and monographic studies on plant groups, such as orchids by King and Pantling (1898), Asiatic palms by Beccari (1908-31) ete., and genera like Dalbergia by Prain (1904), Impatiens by Hooker (1904-11), Dioscoree by Prain and Burkill (1936-38) etc., were made.

QUESTIONS

1. Define taxonomy. Mention the aims of taxonomy.
2. Enlist the major and minor units of classification.
3. Define the various infraspecific classification units.
4. Write a short note on Indian Flora.
5. Differentiate between manual and flora.

LECTURE: 15

ROLE OF ANIMALS IN AGRICULTURE

Livestock are domesticated animals raised in an agricultural setting to produce commodities such as food, fibre, and labour. The term is often used to refer solely to those raised for food, and sometimes only farmed ruminants, such as cattle and goats.

Animal husbandry is the science of breeding, rearing, and caring for farm animals. Animal husbandry is the branch of agriculture concerned with the care and breeding of domestic animals such as cattle, hogs, sheep, and horses.

India's livestock sector is one of the largest in the world. It has 56.7% of world's buffaloes, 12.5% cattle, 20.4% small ruminants, 2.4% camel, 1.4% equine, 1.5% pigs and 3.1% poultry.

The Role of Animals and Animal Products in Agriculture:

(1) Animal products are an important source of high quality, balanced and highly bio-available proteins and numerous critical micronutrients, including iron, zinc, and vitamins B-12 and A, many of which are deficient in a large portion of the world's population.

(2) Animals are recognized as high-quality foods, global demand for animal products is almost certain to continue to increase dramatically.

(3) Farm animals are critical to a sustainable agricultural system and especially for smallholders that improve nutritional status and additional resources such as manure for fertilizer for maintaining soil fertility, on-farm power, and other by-products and provide economic diversification.

(4) The ruminants such as buffalo, cattle, goats, and sheep, efficiently convert the forages from grasslands into high-quality animal products and grazing also can promote the health and biodiversity of grasslands if managed appropriately. This is important because grassland pastures cover >25% of the Earth's land surface.

(5) The Genetic selection of animals and improved management technologies has saved a large amount of resources including water and land.

(6) Dung and other animal wastes serve as very good farm yard manure and the value of it is worth several crores of rupees.

(7) Cow Dung is useful for preparation of good quality of vermicompost as a food for earth warms.

(8) Livestock are also used as biological control (weed control) of brush plants and weeds.

(9) In rural areas dung is used for several purposes which include fuel (bio gas and dung cakes can

replace charcoal and wood), and plastering material (poor man's cement) in the huts.

(10) Draft animals such as Bullocks are the back bone of Indian agriculture. Despite lot of advancements in the use of mechanical power in Indian agricultural operations, the Indian farmer especially in rural areas still depend upon bullocks for various agricultural operations. The bullocks are saving a lot on fuel which is a necessary input for using mechanical power like tractors, combine harvesters etc.

(11) The livestock also contributes to the production of wool, hair, hides, and pelts. Leather is the most important product which has a very high export potential.

(12) Grazing animals help in maintain the biodiversity of plant spices.

(13) Pack animals (an animal used to carry loads) like camels, horses, donkeys, ponies (Hilly Horse), mules etc are being extensively used to transport goods in different parts of the country in addition to bullocks. In situations like hilly terrains mules and ponies serve as the only alternative to transport goods. Similarly, the army has to depend upon these animals to transport various items in high areas of high altitude.

(14) Livestock are considered as **"moving banks"** because of their potentiality to dispose off during emergencies. They serve as capital and in cases of landless agricultural labourers many time it is the only capital resource they possess. Livestock serve as an asset and in case of emergencies they serve as guarantee for availing loans from the local sources such as money lenders in the villages.

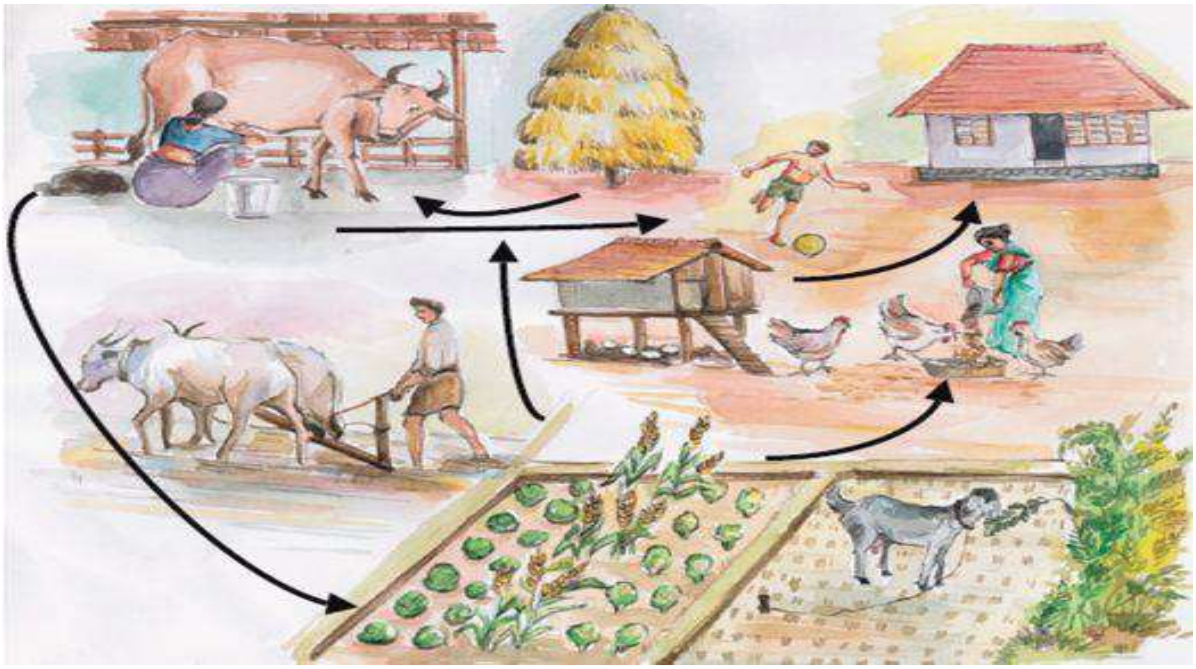
(15) Livestock offer security to the owners and also add to their self esteem especially when they own prized animals such as pedigreed bulls, dogs and high yielding cows/ buffaloes etc.

(16) People also use the animals like cocks, rams, bulls etc for competition and sports. Despite ban on these animal competitions the cock fights, ram fights and bull fights (jalli kattu) are quite common during festive seasons.

(17) Dogs are known for their faithfulness and are being used as companions since time immemorial. When the nuclear families are increasing in number and the old parents are forced to lead solitary life the dogs, cats are providing the needed company to the latter thus making them lead a comfortable life.

(18) In IFS waste materials are effectively recycled by linking appropriate components, thus minimize environment pollution.

Animals integrated into the farm, showing the flow of fodder, dung and products



Livestock Resources of India:

- World's highest livestock owner at about 512.05 million
- First in the total buffalo population in the world - 105.3 million buffaloes
- Second in the population of cattle and goats – 200 million cattle & 140 million goats
- Second largest poultry market in the world - production of 63 billion eggs and 649 million poultry meat.
- Third in the population of sheep (72 millions)
- Fifth in the population of ducks and chicken
- Tenth in camel population in the world

QUESTIONS

1. What is animal husbandary?
2. What is integrated farming?
3. Describe five major roles of animals in agriculture.

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Suggested Reading

- Taxonomy of Angiosperms By S. N. Pandey and S.P. Misra, Ane Books Pvt,. Ltd , New Delhi
- Introduction to Taxonomy of Angiosperms by B. K. Verma, PHI Learning Pvt. Ltd. , New Delhi
- Plant Taxonomy by O. P. Sharma, McGraw Hill Education India Pvt. Ltd., New Delhi
- Botany in Forestry and Environment by Ashok Kumar, Kumar Media Pvt. Ltd. , Gandhinagar
- Plant Physiology by S.N Pandey and B.K. Sinha, Vikas Publishing, New Delhi
- Genetics by P.K. Gupta, Rastogi Publications
- Plant Anatomy by B.P.Pandey, S.Chand (G/L) & Company Ltd;
- Plant Anatomy by A. Fahn, Butterworth-Heinemann Ltd
- A textbook of Animal Husbandry by Banerjee G. C, Oxford &IBH publishing Co. Pvt Ltd

Best of Luck for Your Bright Carrier Ahead

1. INTRODUCTION TO GENETICS

Genetics is *a* biological science which deals with the principles of heredity and variation.

Heredity refers to the transmission of characters from parents to their offspring. Thus, genetics is a science which unravels the inheritance of various characters from one generation to another.

The foundation of this new branch of biology was laid by Mendel in 1866 when he discovered the basic principles of heredity. However, Mendel's findings came into light only in 1900 when similar results were obtained independently by three scientists, *viz.*, de Vres, Carl Correns and Tschermak. Thus, genetics was born in 1900.

The **term genetics** was first used by **Bateson in 1905**, *i.e.*, five year, after its birth. The word genetics has been derived from the Greek word gene, which means to become or to grow. Since characters are governed by genes, genetics is the study of structure, composition and function of genes.

BRANCHES OF GENETICS

There are several branches of genetics. These branches have been identified on the basis of experimental material used for the study and are briefly described below:

Plant Genetics:- It deals with inheritance of characters in various plant species. **Microbial Genetics:-** It deals with inheritance of traits in microorganisms like bacteria,viruses and fungi.

Animal Genetics:- It deals with inheritance of traits in animals.

Molecular Genetics:- It deals with the structure, composition, function and replication of chromosomes and genes, representing genetic material, *viz.*, DNA and RNA.

Biochemical Genetics:- It deals with the role of genes in controlling biochemical pathways in an organism.

Population Genetics:- It deals with frequencies of genes and genotypes in a population as well as with various agencies which tend to alter gene frequencies in a population leading to evolutionary changes.

Radiation Genetics. It deals with effects of various types of radiations on chromosomes and genes.

Eugenics. It deals with the application of genetic principles for the betterment of human race.

Mendelian Genetics. It deals with the inheritance of qualitative characters or oligogeniccharacters which display discontinuous variation.

Quantitative Genetics. It deals with the inheritance of polygenic or quantitative characterswhich display continuous variation. This branch of genetics is also known as biometricalgenetics or statistical genetics or mathematical genetics.

Cytogenetics. It deals with combined study of cytology and genetics. **Euphenics.** It deals with the control of hereditary diseases especially inborn errors of metabolism.

PRE-MENDELIAN CONCEPTS ABOUT HEREDITY

Various views were prevailing about heredity before rediscovery of Mendel's laws of inheritance. Some of the important theories or concepts about the heredity which were proposed by various scientists prior to the discovery of Mendel are: (i) preformation, *(it)* epigenesis, *(iii)* inheritance of acquired characters, (iv) pangenesis, and, (v) germplasm theory. These are briefly presented below:

(i) Preformation Theory

This theory was proposed by two Dutch biologists, Swammerdam and Bonnet (1720-1793). This theory states that a miniature human called humunculus was already present in the egg and sperm. In other words, a miniature human was preformed in the gametes. The development of zygote resulted only in the growth of miniature human who was already present in the egg and sperm. However, this theory was soon given up because this could not be proved scientifically.

(ii) Theory of Epigenesis

This theory was advocated by Wolff (1738—1794), a German biologist. This theory states that egg or sperm cells do not contain miniature human. In other words, egg or sperm cells are undifferentiated. The differentiation into various organs or parts takes place only after fertilization from the zygote resulting into development of adult tissues and organs. This concept is known as epigenesis which is universally accepted.

(iii) Theory of Acquired Characters

This concept was proposed by Lamarck (1744—1829), a French biologist. This theory states that a new character once acquired by an individual shall pass on to its progeny. It means if

a man develops a strong muscle by exercise all his children will have strong muscle. On the other hand, if a person becomes weak all his children will be weak. This theory was disproved by Weismann. He cut the tail of mice for 22 successive generations and always got the baby mice with tail. Thus, this theory was soon given up.

(iv) Theory of Pangenes

This theory was proposed by Charles Darwin (1809—1882), this theory states that very small, exact but invisible copies of each body organ (gemmules) are transported by the blood stream to the sex organs. These invisible copies of each body organ are called the gemmules. These gemmules are assembled in the gametes. After fertilization these gemules move out to different parts of the body resulting in the development of respective organ. A defective gemmule will lead to the development of defective organ in an individual. This theory was given up because it did not have scientific basis.

(v) Germplasm Theory

This theory was advocated by August Weismann (1889), a German biologist. This theory states that body tissues are of two types, *viz.,* germplasm and somatoplasm. The germplasm refers to the reproductive tissues or cells which produce gametes. The somatoplasm includes all other body tissues which are not related to sexual reproduction. Thus, transmission of characters from one generation to other takes place only through germplasm. Any change in the germplasm will lead to change in the next generation. This theory is accepted in a broad sense.

CONTRIBUTION OF SOME GENETICISTS

Several scientists have contributed for the advancement of genetics. A brief contribution of some earlier geneticists is presented below:

Mendel Gregor (Johann)

He was an Austrian botanist who laid the foundation of the science of genetics. He worked with garden gea (Pisum sativum) and formulated two important laws of inheritance, *viz., (i)* law of segregation and, (li) law of independent assortment. For this pioneer work he is rightly called as the father of genetics. He presented his results in two papers at the meetings of Natural

Qu:- Enlist five Nobel prize winner Scientist with their major contribution/discovery.

History Society on February 8 and March 8 in 1865 which were published in the proceedings of the society in 1866. However, his results were neglected for 34 years. Mendel died in 1884 and his work came into being after 16 yrs. of his death in 1900 when same results were independently discovered by de Vries, Correns and Tschermak.

Correns, Carl Erich

He was a German botanist and geneticist who in 1900, independently but simultaneously with the biologists Tschermak (Austria) and Hugo de Vries rediscovered Mendel's historic paper outlining the principles of heredity. He conducted research with garden peas and came to the same conclusions which were drawn by Mendel in 1865. Later on, he worked with variegated plants such as four O' clock (Mirabilis jalapa) and established the first conclusive example of extrachromosomal or cytoplasmic Inheritance.

Hugo, de Vries

He was a Dutch biologist and geneticist. He rediscovered independently but simultaneously with Correns and Tschermak in 1900 Mendel's Law's of inheritance. Later on, working with Oenothera lamarckiana he coined the term mutation for sudden heritable changes in the
Characters.

Tschermak, V.S.E.

He was an Austrian botanist and geneticist. He was one of the codiscoverers of Mendel's classic papers on the garden pea. Working with garden pea, Tschermak saw a cross reference to Mendel's work and found that his results were in agreement with the findings of Mendel. In the same year 1900, when Tschermak reported his findings, Hugo de Vries and Correns also reported their discoveries of Mendel's papers. Later on, he applied Mendel's Laws of heredity in barley, wheat-rye hybrids and oats hybrids for development of new plants.

Bateson, William and Punnett, R.C.

He was a British biologist who coined the term Genetics in 1905. Bateson translated Mendel's paper from German into English and became Mendel's champion in England. He worked with pea and discovered the phenomena of linkage which is now known to be the result

of closely locater[1] genes on the same chromosome. He also demonstrated that in pea certain characters are governed by two or more genes.

Punnett was an English geneticist who with Bateson discovered genetic linkage in 1905. Working with poultry and sweet peas, Punnett and Bateson discovered some fundamental concepts of genetics like linkage, sex determination, sex linkage and first case of autosomal linkage. In 1901, Bateson and Punnett founded the journal of genetics.

Johannsen, W.L.

He was a Danish botanist and geneticist. He developed the concept of pure line. He worked with princess beans and coined the terms phenotype and genotype in 1903. He supported the mutation theory of Hugo de Vries, which refers to sudden heritable changes in a gene. The terms phenotype and genotype are widely used in genetics. He also recognized the importance of environment in the expression of characters.

Morgan, T.H.

He was an American zoologist and geneticist famous for his experimental research with the fruitfly, *Drosophila melanogaster*. He established the chromosome theory of heredity in 1910. He showed that genes are linked in a series on chromosomes and are responsible for observable genetic traits. For this work he received Nobel Prize for Physiology or Medicine in 1933. Thus, he was awarded Nobel Prize for his discovery of hereditary transmission mechanisms in Drosophila. He also observed sex linkage in Drosophila.

Bridges, C.B.

He was a U.S. geneticist who helped establish the chromosomal basis of heredity and sex. He constructed detailed gene mape of the giant chromosomes found in the salivary gland cells of fruitfly larva. He also discovered genie balance theory of sex determination and gene duplication in Drosophila. He had opportunity to work with Morgan.

Muller, H.J.

He was a U.S. geneticist best known for his demonstration in 1927, that X-rays speed up the natural process of mutation. For experimental induction of mutation he was awarded Nobel Prize for physiology or medicine in 1946. He went to USSR and worked with N.I. Vavilov

inLeningrad for about 4 years. He also helped to organize 7th International Congress of Genetics in Great Britain.

Beadle, G.W.

He is a U.S. geneticist. He worked in the field of biochemical genetics and discovered that genes affect heredity by determining enzymatic structure. He worked on fruitfly with Morgan and on *Neurospora* with Edward Tatum. They exposed *Neurvspora* with X-rays and studied the altered nutritional requirements of the mutants thus produced. These experiments enabled them to conclude that each gene determined the structure of a specific enzyme which in turn allowed a single chemical reaction to proceed. This one gene one enzyme hypothesis concept won Beadle and Tatum (with Joshua Lederberg) the Nobel Prize for physiology or Medicine in, 1958.

Tatum, E.L.

He was a U.S. biochemist, whose research on bacteria, yeast and *Neurospora* created a new field of genetic studies known as molecular genetics. He worked in collaboration with Beadle and Lederberg and developed the concept of one gene one enzyme hypothesis in 1941 for which they were awarded Nobel Prize for Medicine or Physiology in 1958. They demonstrated that :

1. All biochemical processes in all organisms are ultimately governed by genes.
2. Each reaction in some way is controlled by a single gene and,
3. Mutation of a single gene results only in an alteration in the ability of a cell to carry out a single chemical reaction. Later on, with Lederberg he discovered genetic recombination or sex in *E. coli* bacteria. This bacteria has become important source of genetic investigations for biochemical process after the discovery of one gene one enzyme hypothesis.

Sutton, W.S.

Sutton was a U.S. geneticist who working with Grasshopper gave a hypothesis in 1903 that chromosomes carry the units of inheritance and they are the physical basis of the Mendelian laws of heredity. Thus, his work formed the basis for the chromosomal theory of heredity.

Avery, O.T. ; Mac Leod, CM. and Mc Carty, M.

.....Avery was a Canada born U.S. bacteriologist. His research on pneumococcus bacteria laid the foundation of immunochemistry. He discovered that pneumonia causing bacteria produce a capsular envelope consisting of polysaccharide. He also discovered the phenomenon of nansformation. Avery with his coworkers (Mac Leod and Mc Carty) reported in 1944 that the substance which caused the transformation was deoxyribonucleic acid (DNA). Thus, they were the pioneer workers to demonstrate that DNA was the genetic material.

Mc Carty is a U.S. biologist, who with Avery and Mac Leod provided the fir§t experimental evidence in 1944 that the genetic material of living cells is composed of DNA. When the DNA extracted from capsulated bacteria (virulent) was mixed with living cells of second type of bacteria lacking capsules, the transformation occurred. The results of this experiment indicated that the substance responsible for the change was DNA.

Watson, J.D. and Crick, F.H.C.

Watson is a U.S. geneticist and biophysicist. He is famous for his discovery of the molecular structure of deoxyribonucleic acid (DNA), the genetic material, in 1953. This investigation brought him (with Francis Crick and Maurice Wilkins) the Nobel Prize for Physiology or Medicine in 1962. They proposed double helical model for DNA. This model also showed how the DNA molecule could duplicate itself. Thus, it became known how genes and eventually chromosomes duplicate themselves. Watson published three books, *viz.,* (1) Molecular Biology of Gene in 1965, (2) The Double Helix in 1968, and (3) The DNA story in 1981. Crick is a British biophysicist, who worked with Watson and Wilkins and discovered the DNA double helical model.

M.H. Wilkins is a New Zealand born British biophysicist whose X-ray diffraction studies of DNA proved crucial for the discovery of the molecular structure of DNA by James Watson and Sir Francis Crick. For this work the three Scientists were awarded Nobel Prize as mentioned above.

Barbara McClintock

Miss. Barbara McClintock (1950), a U.S. geneticist working with maize observed that some genes are capable of changing their position on a chromosome and from one chromosome

to another. Such genes are known as transpozons or transposable elements or jumping genes. Since this was an unusual finding, people did not appreciate it for a long time. This concept was recognized in early seventies and McClintock was awarded Nobel Prize for this work in 1983.

Benzer, S.

He is a U.S. molecular biologist, who developed a method in 1955 for determining the detailed structure of viral genes and coined the term cistron to denote functional subunit of genes. He also explained non-sense mutations in terms of molecular sequence of DNA. Benzer (1955) gave sub-divisions of genes *viz.*, Cistron, Recon and Muton. These are the units of function, recombination and mutation with in a gene. He worked with r-II locus of T4 bacteriophage.

Jacob, F. and Monod, J.L.

Jacob is a French biologist and Monod was French biochemist. They explained in 1961 the way in which genes regulate cell metabolism by directing the biosynthesis of enzymes. Jacob discovered that genes of bacteria are arranged in linear fashion in a ring and the ring can be broken at almost any point. They developed the concept of gene regulation known as operon concept in 1962. They discovered regulatory genes which control the activities of structural genes. For this work, they were awarded Nobel Prize for physiology or medicine in 1965.

Nirenberg, M.W. and Khorana, H.G.

Nirenberg is a U.S. biochemist, who played a major role in deciphering the genetic co He demonstrated that with the exceptions of non-sense codons, each possible triplet (c-.lle a codon) of four different kinds of nitrogen containing bases found in DNA and in sone ther viruses in RNA ultimately causes the incorporation of specific amino-acid into a cell protein.

Har Gobind Khorana is an Indian born U.S. biochemist. He discovered how the genetic components of the cell nucleus control the synthesis of protein. He was awarded Nobel Prize for physiology or medicine with Nirenberg and Holley in 1968. Later on, he prepared the first artificial copy of a yeast gene in 1970.

HISTORICAL DEVELOPMENTS IN GENETICS

Year	Scientist	Contribution
1485	L. da Vinci	Recommended the use of lenses for viewing small objects
1590	Z. Janssen & H. Janssen	Produced the first operational microscope
1665	R. Hooke	Introduced the term " cell " and described cork cells.
1668	F. Redi	Disproved the theory of spontaneous generation of maggots.
1672	Malphigi	Classified the tissues.
1674	A.van Leeuwenhoek	Improved lens system of microscope by grinding.
1682	N. Crew	Described bladders and pores in wood and pith.
1694	J.R. Camerarius	Conducted early experiments on pollination and reported the existence of sex in plants.
1700	R. Linnaeus	Classified the biological organisms.
1761	J.C. Kolreuter	Hybridized various species of tobacco and concluded that each parent contributed equally to the characteristics of the progeny.
1779	C.F Wolff	Founder of embryology.
1809	J.B. Lamarck	Coined the word " biology " and stressed the importance of cell in living organisms. He put forth the theory of inheritance of acquired characters.
1824	Dutrochet	Showed that all plants and animals are composed of cells.
1825	F.V. Raspail	Developed the frozen-section technique and used iodine for detection of starch.
1835	H. von Mohli	Emphasized the importance of protoplasm and described cell division
1837	R. Brown	Discovered the nucleus in cells of flowering plants.
1838	M.J. Schleiden & T. Schwann	Formulated the cell theory in plants and animals.
1840	J.E. Purkinj	Gave the term " protoplasm ".
1845	A. Donne	Used photomicroscopy for the first time.

1846	K. Nageli	Showed that plant cells arise from the division of pre-existing cells.
1846	G.B. Amici	Showed that egg in the ovary is stimulated to develop into an embryo by the entrance of pollen tube.
1858	R. Virchow	Showed that animal cells arise from the division of pre-existing cells.
1859	C. Darwin	Put forth the theory of natural selection.
1862	Kolliker	Used the term " cytoplasm "for the living material surrounding the nucleus
1865	G. Mendel	Developed the fundamental principles of heredity
1870	W. His	Invented the microtome
1871	F. Meischer	Isolated nucleic acids from pus cells.
1873	H. Fol	Described spindle and astral rays
1875	O. Hertwig	Studied reproduction in sea urchins and concluded that fertilization involves the union of sperm and egg nucleus.
1875	E. Strasburger	Discovered cell division in plants and gave the terms "cytoplasm " and " nucleoplasm ".
1879	W. Flemming	Introduced the term "chromatin ".
1879	H. Fol	Showed that only one sperm enters the egg during fertilization.
1881	E.G. Balbiani	Discovered giant chromosomes in salivary glands of Drosophila.
1882	W. Flemming	Coined the term " mitosis "
1883	W. Rouse	Proposed that chromosomes contain genes which are the units of heredity.
1885	A.F.W. Schimper	Introduced the term " plastids ".
1888	Th. Boveri	Coined the term " centrosomes".
1888	W. Waldeyer	Coined the term " chromosomes ".
1892	O. Hertwig	Proposed the protoplasm theory of inheritance.
1892	J. Ruckert	Described lamp brush chromosomes in oocytes of shark.
1892	W. Weisman	Stated that chromosomes are the most important part of the nucleus.

1892	Th. Boveri	Described meiosis in Ascaris.
1898	C. Golgi	Described the golgi apparatus in nerve cells.
1898	C. Benda	Discovered mitochondria in spermatozoa and other cells.
1899	S. Altman	Introduced the term "Nucleic acid ".
1900	C.E. Correns, H. de Vries and E. Tschermak	Re-discovered Mendel's laws of inheritance.
1901	E. Strasburger	Introduced the term "Plasmodesmata ".
1902	C.E. McClung	Identified sex chromosomes in bugs.
1902	H. de Vries	Coined the term "Mutation ".
1902	W.S. Sutton Th. Boveri	Proposed the chromosome theory of heredity and identified chromosomes as carriers of genetic material.
1903	W. Waldeyer	Proved centromeres are the chromosomal regions with which the spindle fibres become associated during mitosis
1905	L.Cuenot	Discovered lethal genes affecting coat colour in mice.
1905	J.B. Farmer and J.E. Moore	Coined the term " Meiosis ".
1905	W. Bateson	Coined the term "Genetics "and proposed the concept of allele.
1906	W. Bateson and R.C. Punnet	Discovered genetic linkage in sweet pea.
1906	W.L. Johannsen	Coined the terms "gene", "genotype" and "phenotype".
1909	W. Bateson	Coined the term " epitasis ".
1909	C. Correns	Reported cytoplasmic inheritance in *Mirabilis jalapa.*
1909	F.A. Janssens	Indicated that chiasmata are produced by exchanges between non -sister chromatids of homologous chromosomes.
1910	T.H. Morgan	Studied crossing over and recombination in Drosophila and coined the term "Crossing over ".
1910	H. Nilsson-Ehle	Proposed the multiple factor hypothesis.
1911	A.H. Sturtevant	Constructed the first linkage map in Drosophila.

1912	Vejdovsky	Coined the term " chromonema ".
1915	T.H. Morgan	Correlated genetic studies with cytological studies. He put forth the theory of linkage and studied sex linked inheritance in *Drosophila melanogaster.*
1917	C.E. Allen	Discovered sex determination in plants.
1921	Banting & Best	Isolated insulin.
1922	C.B. Bridges	Put forth the genic balance theory of sex determination.
1923	C.B. Bridges	Discovered duplications, deletions and translocations in Chromosomes.
1923	Crew	Reported complete reversal of sex in hens.
1924	A.F. Blakeslee & J. Belling	Studied trisomics in Jimson weed *(Datura stromonium).*
1924	R. Feulgen	Described a test to confirm the presence of DNA.
1926	A.H. Sturtevant	Discovered inversions in chromosomes.
1927	G.K Karpechenko	Synthesized Raphano brassica
1927	H.J. Muller	Induced mutations in Drosophila melanogaster by X-rays
1928	L.J. Stadler	Induced mutations in maize and barley by X-rays.
1928	F. Griffith	Conducted expt. on transformations in *Diplococcus pneumonia.*
1931	C. Stern	Gave cytological proof for crossing over in Drosophila.
1931	H. Creighton & B. McClintock	Gave cytological proof for crossing over in maize.
1932	M. Knoll & E. Ruska	Developed the electron microscope.
1933	M. Rhodes	Reported cytoplasmic male sterility in corn.
1935	F. Zernicke	Developed the phase contrast microscope.
1935	R.B. Goldschmidt	Coined the term "Phenocopy ".
1939	R.A. Steinberg	Induced mutations in Aspergillus sp. with chemicals.
1944	O.T. Avery, C.M. MacLeod & M. McCarty	Explained the significance of DNA and proved that it is the genetic material.

1946	C. Auerbach and J.M. Robson	Induced mutations in *Drosophila melanogaster* using chemicals.
1946	E.S. McFadden, E.R. Sears and H. Kihara	Synthesized *Triticum spelta* in the laboratory.
1948	K.R. Porter	Described the endoplasmic reticulum.
1950	B. McClintock	Discovered jumping genes in maize.
1951	A. Muntzing	Synthesized Triticale.
1952	A.D. Hershey & M.J. Chase	Provided experimental proof of DNA as genetic material.
1953	Robinson & Brown	Observed ribosomes in plant cells.
1953	J.D. Watson, F.H.C. Crick & M.H.F. Wilkins	Proposed the double helix model for DNA molecule.
1954	E.R. Sears	Produced monosomic series of "Chinese Spring " variety of wheat
1955	S. Benzer	Described the fine structure of gene –Cistron, Recon and Muton.
1955	C. De Duve	Coined the term " lysosomes ".
1955	G.E. Palade	Observed ribosomes in animal cells.
1955	L. Pauling	Studied the relationship between the structure of the DNA molecule and protein synthesis.
1958	G.W. Beadle, E.L. Tatum and J. Lederberg	Put forth the one gene – one enzyme hypothesis.
1958	F.H.C. Crick	Explained the central dogma of molecular biology.
1958	M.S. Meselson and F.W. Stahl	Proved experimentally that DNA replicates by Semi-conservative Mechanism.
1959	A. Kornberg and S. Ochoa	Synthesized the DNA molecule in vitro.

1961	A.E. Jacob and J. Monod	Explained the genetic regulatory mechanism in protein synthesis – Operon concept.
1968	N.W. Nirenberg H.G. Khorana & H. Holley	Deciphered the genetic code and polynucleotide synthesis.
1968	Woodcock and Fernandez	Isolated DNA from chloroplasts.
1974	Clande, G.E. Palade & C. DeDuve	Re-discovered a number of cell organelles by electron microscope.
1975	R. Dulbecco, H. Temin & D. Baltimore	Discovered the mechanism of reverse transcription – Teminism.
1975	N. Borlaug	Responsible for development of dwarf wheat and green revolution.
1978	D. Nathans, H.O. Smith & W. Arber	Isolated restriction enzymes.
1985	Potrykus	Used electroporation technique for direct gene transfer in plants.
1986	Helentzaris	Developed the RFLP map in maize and tomato.
1986	Ow	Transferred and studied the expression of gene for enzyme lucifersase (causes fire flies to glow) in tobacco cells.
1987	Fischoff	Developed insect resistant transgenic tomato plants with Bt gene.
1987	K.B. Mullis	Developed polymerase chain reaction technique.
1988	Ouozzo	Developed transgenic tobacco with CMV coat protein.
1991	Oeller	Developed transgenic tomato with an antisense gene.
1992	Vasil	Developed herbicide resistant transgenic wheat.
1993	Sharp Roberts	Proposed the split gene concept.
1993	Smith	Studied site directed mutagenesis.

1994	Gilman and Rodbell	Studied G proteins and their role in turning external signals into action within cells.
1995	Lewis, Volard & Wieschaus:- Studied the role of genes in organ differentiation.	
1997	I. Wilmut	Cloned sheep – Dolly.
1997	Prusiner	Studied prions – Mad cow disease.
1998	Delta& Pine Co.	Developed the terminator gene technology.
1998	Monsanto Co.	Developed bollguard variety of cotton.
1998	T. Wakayama & R. Yanagimachi:- Created the first cloned mice.	
2000	Roslin Institute:- Created the first cloned pigs.	
2001	Advanced Cell Technology Birth of first cloned Asian ox called "Gaur".	
2001	Human Genome Project and Celera Genomics. First draft sequences of the human genome are released	
2002	Natl. Institute of Agronomic Research, France.:- Created the first cloned rabbit	
2003	Successful completion of Human Genome Project with 99% of the genome sequenced to a 99.99%	
2004	Merck introduced a vaccine for Human Papillomavirus which promised to protect women against infection with HPV 16 and 18, which inactivates tumor suppressor genes and together cause 70% of cervical cancers.	
2007	Michael Worobey traced the evolutionary origins of HIV by analyzing its genetic mutations, which revealed that HIV infections had occurred in the United States as early as the 1960s.	
2007	Timothy Ray Brown is the first person cured from HIV/AIDS trhough a Hematopoietic stem cell transplantation	
2008	Houston-based Introgen developed Advexin (FDA Approval pending), the first gene therapy for cancer and Li-Fraumeni syndrome, utilizing a form of Adenovirus to carry a replacement gene coding for the p53 protein.	
2016	A genome is sequenced in outer space for the first time, with NASA astronaut Kate Rubins using a MinION device aboard the International Space Station.	

GLOSSARY

PLANT GENETICS: A branch of genetics which deals with inheritance and variation of characters in plant species.

ANIMAL GENETICS: A branch of genetics which deals with inheritance and variation of traits in animals.

MICROBIAL GENETICS: A branch of genetics which deals with inheritance of characters in microorganisms like bacteria, viruses and fungi.

MOLECULAR GENETICS: A branch of genetics which deals with structure, composition, function and replication of chromosomes and genes.

POPULATION GENETICS: A branch of genetics which deals with frequencies of genes and genotypes in a population, and also with various forces which tend to alter gene frequencies in a population leading to evolutionary changes.

RADIATION GENETICS: A branch of genetics which deals with effects of various types of radiations on chromosomes and genes.

EUGENICS: A branch of genetics which deals with the application of the principles of heredity for the betterment of human race.

MENDELIAN GENETICS: Genetics which deals with the inheritance of oligogenic characters.

QUANTITATIVE GENETICS: A branch of genetics which deals with the inheritance of quantitative or polygenic characters.

CYTOGENETICS: Combined study of cytology and genetics.

EUPHENICS: Genetics which deals with the control of hereditary diseases especially inborn errors of metabolism.

PROKARYOTE: Unicellular organisms whose cells lack nucleus like bacteria, bacteriophages and blue green algae.

EUKARYOTE: Organisms whose cells contain well defined nucleus.

BACTERIA: Unicellular free living organisms without well defined nucleus.

BACTERIOPHAGE: Special types of virus which grow only inside the bacteria and kill them.

HEREDITY: Transmission of characters from parents to their offspring.

VARIATION: Differences for various characters among the individuals of the same species.

GEMMULES: Invisible copies of each body organ as per theory of pangenes.

QUESTIONS

Q.1 Define genetics. Describe in brief its role in crop improvement.

Q.2 Give a brief account of pre-Mendelian concepts about heredity.

Q.3 Describe in brief the role of various disciplines in the advancement of genetics.

Q.4 Write short notes on the following

1. Genetics
2. Theory of epigenesis
3. Theory of pangenes
4. Germplasm theory
5. *Drosophila*
6. Bacteriophages
7. Neurospora
8. Garden pea

Q.5 List the names of Nobel Prize winners in genetics. Describe in brief the contribution of any five Nobel Prize winners.

Q.6 Describe in brief the role of following disciplines in the advancement of genetic

1. Cytology
2. Biochemistry
3. Biophysics
4. Statistics

Q.7 Give in brief the contribution of the following scientists in the field of genetics

1. Gregor Mendel
2. C.E. Correns
3. Hugo de Vries
4. V.S.E. Tschermak
5. William Bateson
6. J.D. Watson
7. J.L. Monod
9. T.H. Morgan
10. C.B. Bridges
11. E.L. Tatum
12. Barbara Mc Clintock
13. O.T.Avery
14. F.H.C. Crick
15. Har Gobind Khorana
16. S. Benzer
17. F. Jacob
18. M.W. Nirenberg
19. H.J. Muller
20. G.W. Beadle

Reference Book:-

Elements of Genetics by Phundan Singh (Kalyani Publisher)

2. CELL & CELL ORGANELLES

Cell structure and organelles

Cell – It is the structural and functional unit of all living organism

Plant cell_: A structural and physiological unit of plant, which have protoplasm. Which consist following organelles. Plant cell consist following types of parts

- The basic constituents of plant and animal cells are the same, *viz.*, nucleic acid, proteins, carbohydrates, lipids and various inorganic substances.
- They organized in the same fundamental manner.
- The shape of plant cell is rectangular and that of animal cell is round with irregular appearance.
- Cell organelles: various membrane bound structures that are found within a cell such as nucleus, plastids, mitochondria, endoplasmic reticulum, etc.,

CELL

- Non-living inclusions (Cell wall)
- Living materials (Protoplast)
  - Nucleus
    - Nuclear membrane
    - Nucleoplasm
    - Chromatin
    - Nucleolus
  - Cytoplasm
    - Plasma-membrane
    - Endoplasmic reticulum
    - Ribosomes
    - Golgi body
    - Vacuoles
    - Mitochondria
    - Plastids
    - Lysosomes
    - Centrosomes
    - Microtubules

Cell wall

- It is the outermost part of the cell and is always non-living (Rigid and Strong) but it is produced and nourished by living protoplasm.
- The cell wall is found only in plants and absent in animals.

- Multilayered *viz.,* middle lamella, primary cell wall (dispersed arrangement) and secondary cell wall (parallel arrangement of cellulose fibrils).

Functions

1. To protect inner parts of the cell
2. To give a definite shape to the cell
3. To provide mechanical support

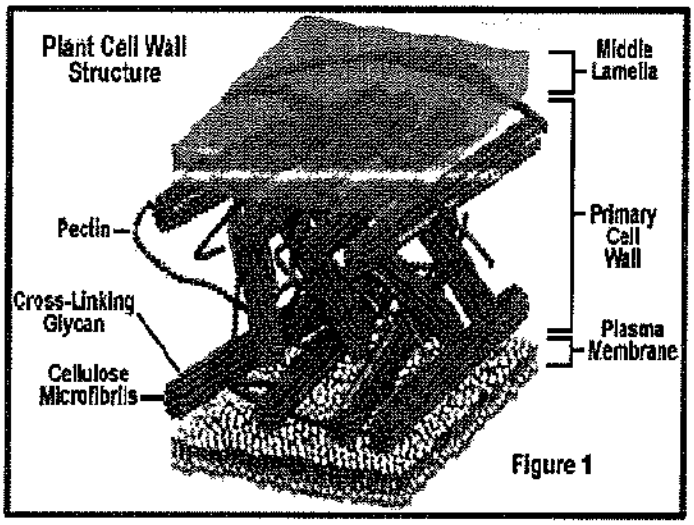
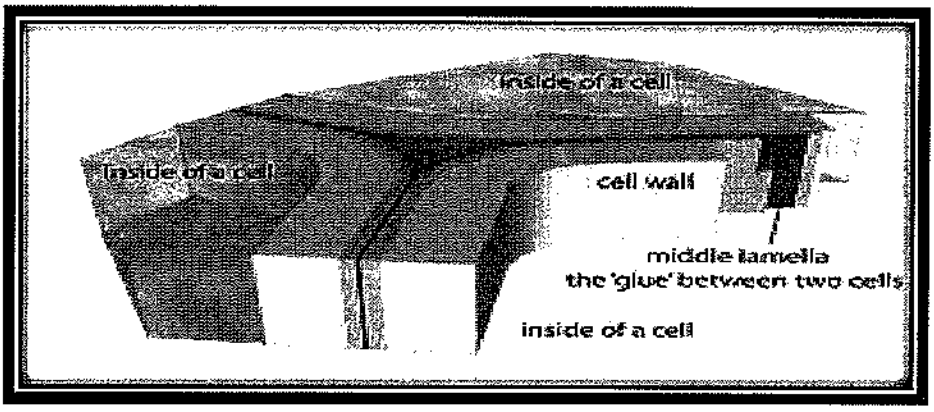


Figure 1

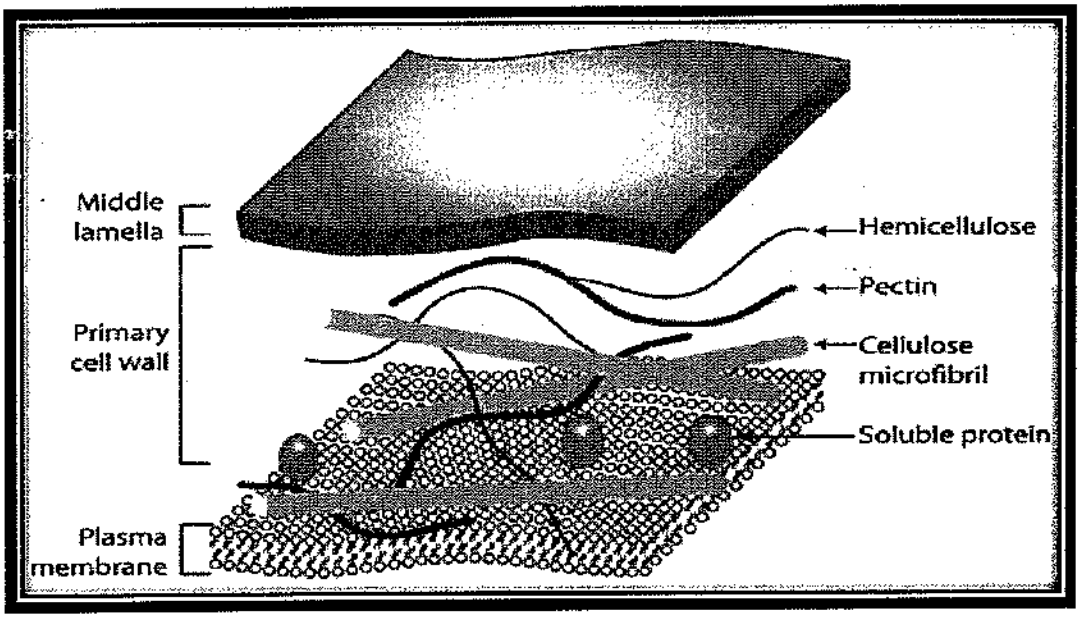
Middle Lamella

- A specialized region associated with the cell walls of plants, and sometimes considered an additional component of them, is the middle lamella.
- The middle lamella cements together the primary walls of two contiguous cells.
- The middle lamella is mainly composed of a pectic compound which mostly appears to be calcium pectate.



Primary Cell Wall

- The main chemical components of the primary plant cell wall include cellulose in the form of organized microfibrils, a complex carbohydrate made up of several thousand glucose molecules linked end to end.
- In addition, the cell wall contains two groups of branched polysaccharides, the pectins and cross-linking glycans.
- It is soft, elastic, transparent and readily permeable to water.



Secondary Cell Wall

- The secondary plant cell wall, which is often deposited inside the primary cell wall as a cell matures, sometimes has a composition nearly identical to that of the earlier-developed wall.
- More commonly, however, additional substances, especially lignin, are found in the secondary wall.
- It gives sufficient rigidity and strength to the plant body.
- It is permeable to water and solutes.
- Lignin also makes plant cell walls less vulnerable to attack by fungi or bacteria.
- Cutin, suberin, and other waxy materials that are sometimes found in plant cell walls.
-

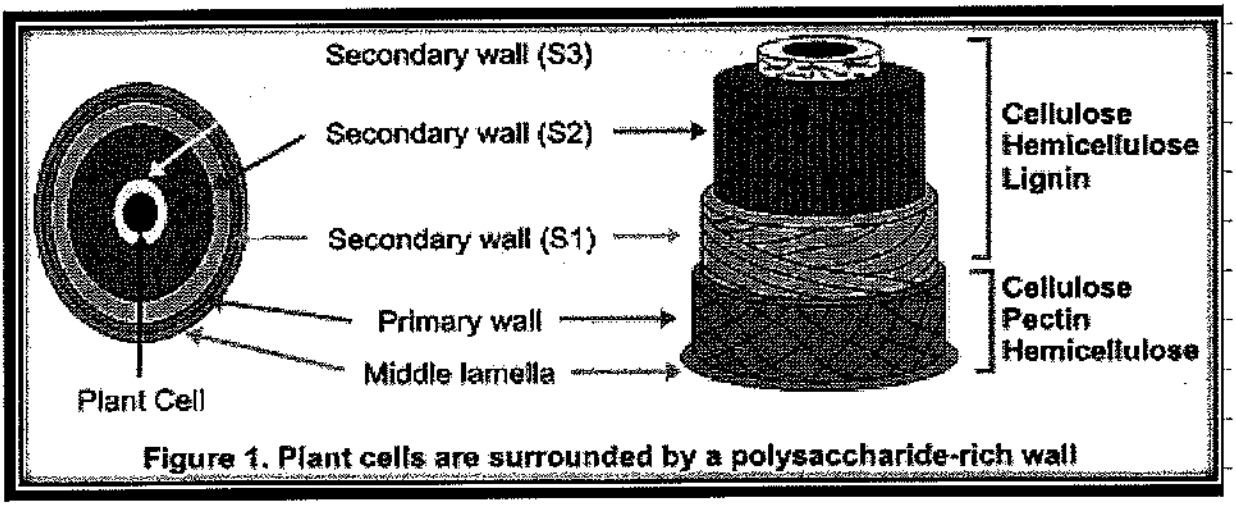


Figure 1. Plant cells are surrounded by a polysaccharide-rich wall

Plasma lemma or plasma membrane

- The cytoplasm which is surrounded by thin and flexible membrane is called plasma membrane
- It present both in plant as well as animal cell
- Which composed of lipids and proteins

Functions

1. It regulates the passage in and out of the cell
2. It act as selective permeable membrane
3. It checks the entry of toxic elements from outside into cytoplasm
4. It permits passage of molecules like minerals into the cell and restrict their outward movement

Protoplasm

- Its substance which provide life to the plants/animals
- It is granular, semi fluid – translucent
- Protoplasm differentiated into Cytoplasm and Nucleus

Cytoplasm

- Variety of structure remain suspended such as living and non living
- Non living : Non membrane bounded – lipid, starch granules
- Living : membrane bounded

Cytoplasmic inclusions (Non living) :

- They are not metabolic active parts but they are the storage site of end products
- Suspended in cytoplasmic matrix
- It includes oil drops, yolk granules, pigments, starch granules etc.

Cytoplasmic organelles

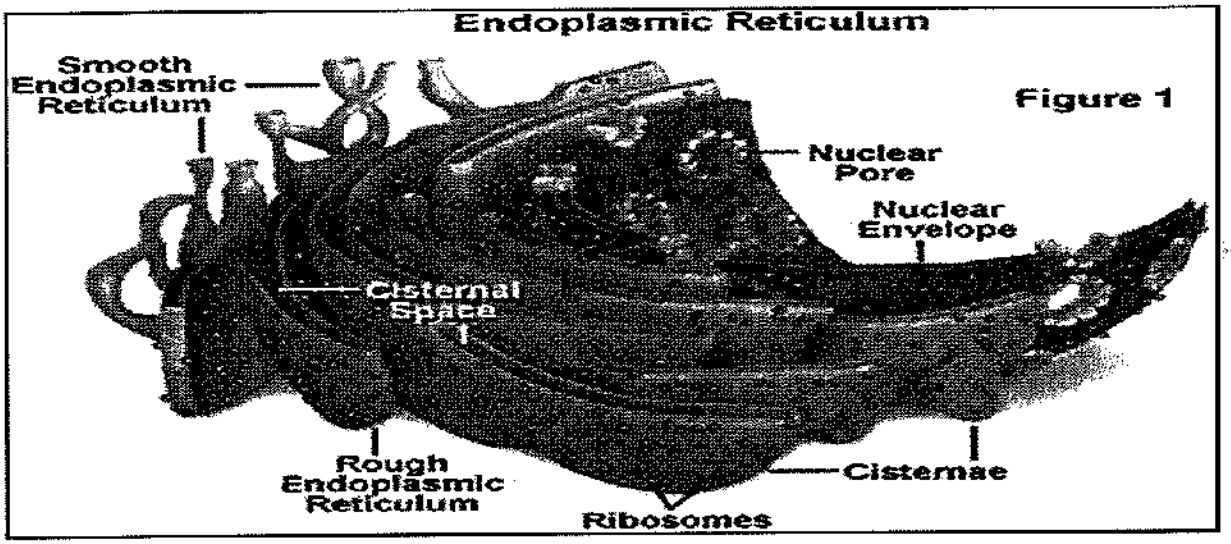
- They are membrane bounded, living structures – lipid, starch granules
- They perform important activities like biosynthesis, metabolic and respiratory
- They are also engaged in transportation and storage of food materials and reproduction

Microtubules

- Complex structure made up of 13 individual protofilaments arranged to form hallow cylinder
- Responsible for transportation of small molecules

Endoplasmic Reticulum (E. R.)

- The term E. R. was first used by Porter in 1948 to describe a fine reticulum in the endoplasmic cells
- It is thread or tube like floating in cytoplasm on which ribosomes are attached
- Two types of E. R.
- Smooth E. R. – In this case both outer and inner surface are regular and they do not have attached ribosomes. They do not involved in protein synthesis
- Rough E. R. – Outer and inner membrane found attached with ribosomes. They also actively involved in protein synthesis. Both smooth and rough E. R. are interchangeable as per the needs of the cell



Functions: (E.R.)

1. It is associated with the synthesis of proteins (rough E. R.), lipids and phospholipids (Both E. R.)
2. Provide channels for the transportation of synthesized material to various parts
3. Provide controlled passage for the export of m-RNA from nucleus to rough E. R.
4. Several enzymes are embedded in the membrane eg. Glucose-6-phosphate, ATPase etc.

Golgi complex

- Golgi body first described by Camilo Golgi in 1822 in nerve cell of cat and owl
- It is a structure like stalk of filaments arranged one above the other
- Composed –Lamellae, tubules, vesicles and vacuoles

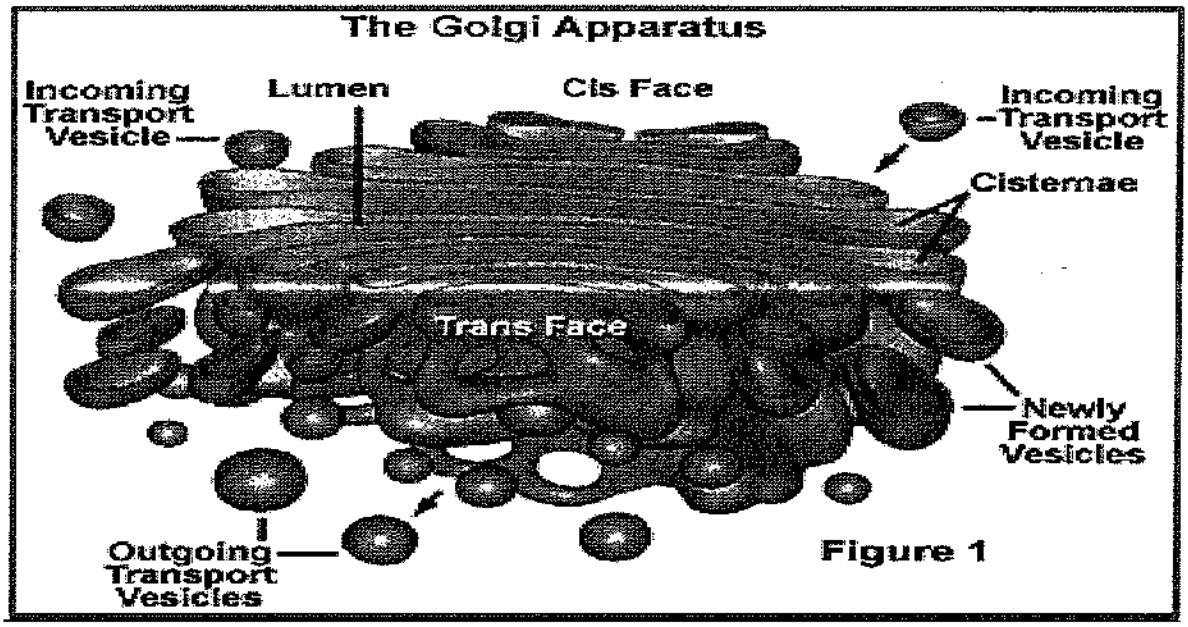


Figure 1

Functions:

1. Packaging food materials such as proteins, lipids and phospholipids for transport to other cells
2. It secrete many granules and lysosomes

Lysosomes :

- The term lysosome was first used by Dave in 1955
- In plant cell they are bounded storage granules and containing hydrolylic digestive enzymes

Functions:

1. It is responsible for digestion of intracellular substances and foreign particles.
2. When cell dies lysosomes releases its enzymes, which digest the dead cell resulting in cleaning of debris.

Cytoplasmic vacuoles:

- Its small to large sized liquid filled structure
- Sometimes more numbers of vacuoles fuse to gather and formed large size structure
- Each vacuoles is surrounded by vacuolar membrane called as tonoplast. Tonoplast having a selective semi permeable membrane composed of lipoprotein
- The fluid inside the vacuoles is called as cell sap, which made up organic substances like sugars, organic acids, inorganic salts, proteins and pigments

Functions:

1. Storage and transmission of the materials and maintenance of the internal pressure

Ribosomes:

- Ribosomes are the small cellular particles composed of RNA + Protein
- Ribosomes are the site of protein synthesis
- They contain nearly 40-60 per cent RNA and other several kinds of protein
- In young actively dividing cell they are usually free in the cytoplasm but in the mature cells, they are attached with ER.
- The size or weight of the ribosomes molecules is expressed in S units (sedimentation rate or coefficient)
- Mainly three kinds –

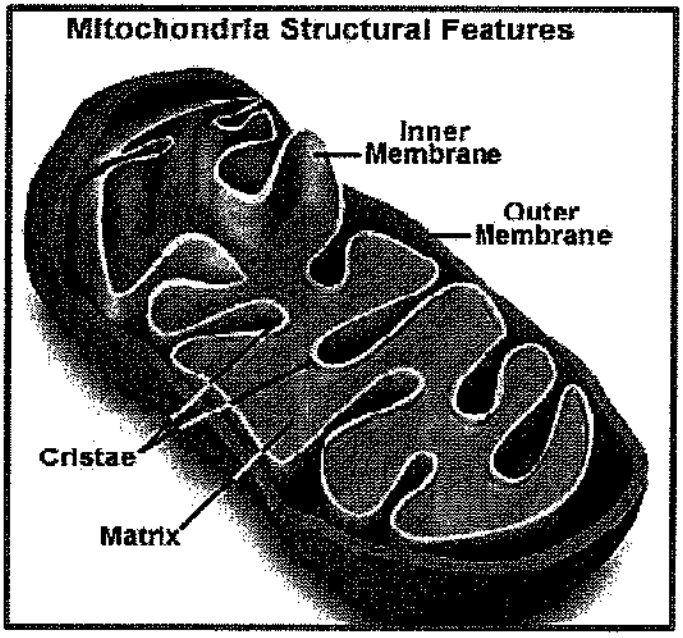
  (1) Mitochondrion – 70 S (2) Chloroplastic – 70 S (3) Cytoplasmic – 80 S

Functions:

1. To carry out protein synthesis with the help of m-RNA

Mitochondria:

- Mitochondria are the rod like cytoplasmic organelle, which is the main site of cellular respiration
- They are the source of energy and known as the power house of the cell
- There average number is vary from 200 to 800 per cell



- They consist three main parts
  1. Membrane – outer as well as innner membrane (60 A^0 thick), which are made up of proteins and lipids
  2. Cristae – It is the inner membrane which has series of inside folds known as cristae
  3. Matrix – DNA of mitochondria are attached to these part

Functions:

1. It involved in respiration, oxidation and metabolism of energy (Power house of the cell)
2. They contain circular DNA and ribosomes, so they are capable of synthesis of certain proteins
3. They contain DNA, so also contribute to heredity by the way of cytoplasmic inheritance

Plastid:

- They are the self replicating cytoplasmic organelles founds in plant cell
- They are absent in bacteria, cerain fungi and animals
- Mainly three types : Leucoplast, Chromoplast and Chloroplast
- Leucoplast – They are colourless and associated with storage of starch, protein and fats
- Chromoplast – Coloured but other than green viz., Plucoxanthin and Phycocynin. There functions are still not clear. They contain pigments of different colour – Yellow, orange and red. The coluring matter is associated with Xanthophyll and Carotene.
- Cloroplast – They are green in colour due to chlorophyll pigment. They are acting as the sites of photosynthesis. The ultra structure of chloroplast consist three parts – Membrane, Stroma and Granna

  Stroma : It consist the enzymes related to dark reaction of photosynthesis

  Granna : It is associated with electron transport and photophosphorilation

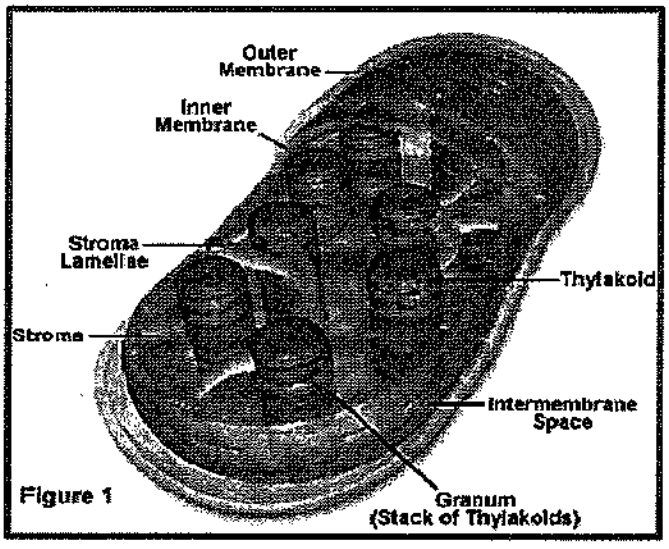
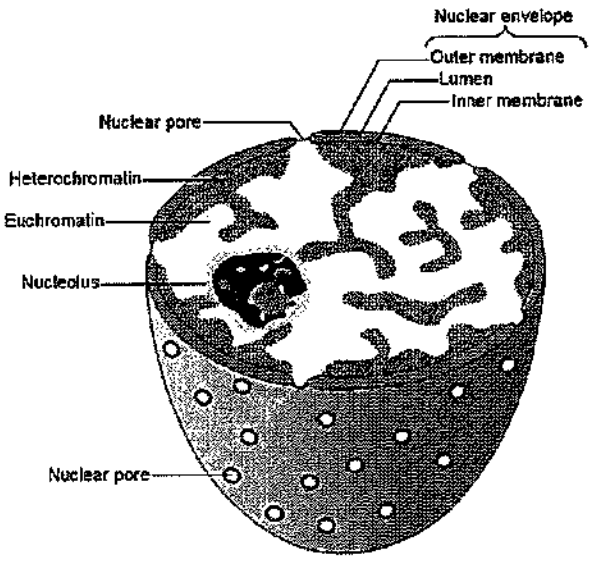


Figure 1

Que:- Show the components of nucleus with the help of diagram

Nucleus and its structure:

- First discovered by Robert Brown in 1833
- Nucleus contains chromosomes and genes, so it known as <u>controlling center of cell</u>
- Generally single nucleus per cell
- Multi nucleus per cell – protozoa and some fungi (repeated division of nucleus without cytoplasmic division)
- They are spherical or oval shaped
- Large in size in active cell than in resting cells
- Store house of all genetic information
- It consist four parts
  1. Nuclear membrane
  2. Nucleoplasm
  3. Nuclear reticulum
  4. Nucleous



Cell Nucleus

Nuclear membrane:

1. Nucleus is enclosed by two membranes of lipo proteins, which separate nucleus and cytoplasm
2. They are not continuous but having several nuclear pores in between
3. Having space between two membrane, which is known as peri nuclear space
4. Outer membrane is attached with ER on which ribosomes are attached

<u>Functions</u> :

- It protect the chromosomes from cytoplasmic effetcts
- It permits transport of electrons and exchange of materials between nucleus and cytoplasm
- It give rise to some cell organelles

The nuclear pores regulates the exchange of micro molecules i.e. protein, r-RNA and m-RNA

Nucleoplasm

1. Its watery substances in higher nucleolus
2. It is also known as nucleoplasm or nuclear sap or Karyolymph
3. It is shapeless and contain dissolved phosphorous ribose sugar proteins, nucleotides and had nucleic acid

Nucleolus

- A spherical body found in the nucleus is called nucleolus
- It is found in the higher organisms and is attached with specific region of a particular chromosome.
- It disappear during prophase of mitosis and meiosis and reappear during telophase.
- Chemically it is composed of ribosomal proteins and RNA

Functions :

1. Formation of ribosome and synthesis of proteins
2. It provide energy for all nuclear activities

Chromatin or Nuclear reticulum

- Its thread like, coiled and much elongated structures
- During cell division process (mitosis and meiosis) chromatin structure becomes thick ribbon like structure which are known as chromosomes

Functions :

1. Chromatin is the basic unit of chromosomes contain genes and thus play important role in the inheritance of the character from the parents to offspring

Structural differences between Eukaryotic and Prokaryotic cells

PROKARY PROTIC CELL	EUKARYOTIC CELL
1. Prokaryotes are primitive organisms (Pro = primitive; Karyon = nucleus)	1. Eukaryotes are higher organisms (Eu = good or true; Karyon = nucleus)
2. They are generally uni-cellular	2. They are generally multi-cellular
3. The average diameter of prokaryotic cell ranges from 5 - 10μm	3. The average diameter of eukaryotic cell ranges from 10–100 μm
4. Posses only one envelope system	4. Posses two envelope system

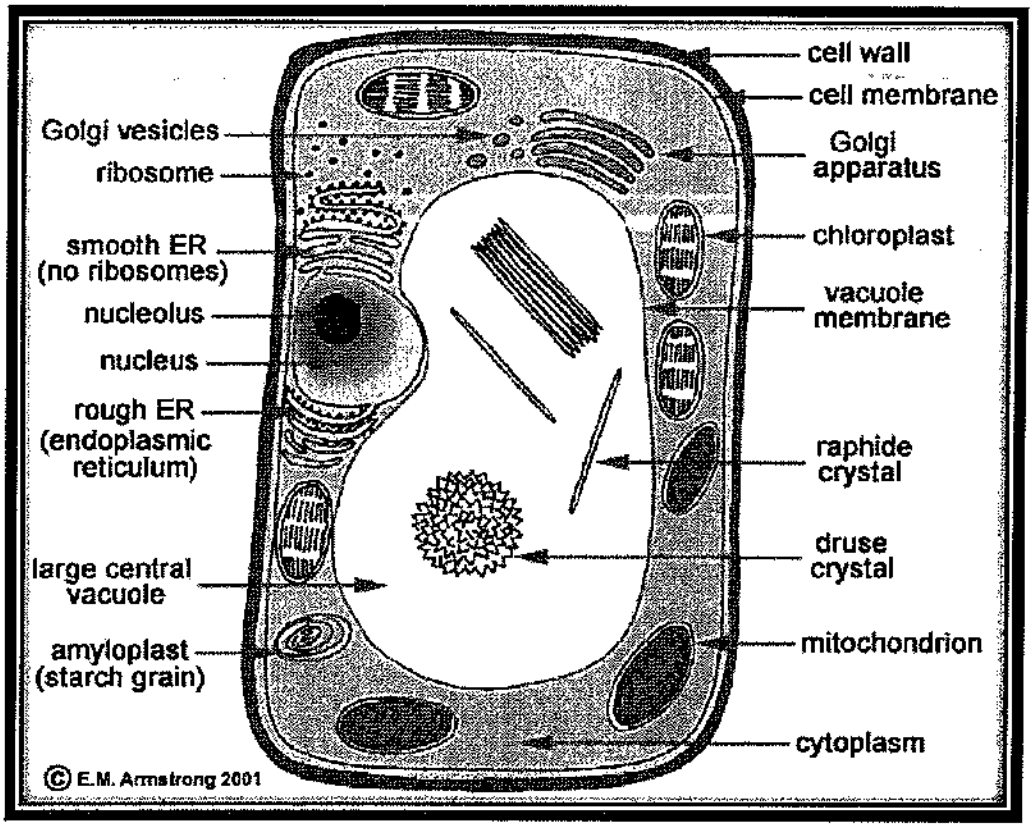
5. Don't posses well defined cytoplasmic organelles	5. Posses well defined cytoplasmic organelles like endosplasmic reticulum., golgi bodies, chloroplast, mitochondria
6. They lack nucleus and chromosomes	6. Posses well developed nucleus and chromosomes
7. DNA is circular and lies free in the cytoplasm	7. DNA is linear and lies within the nucleus
8. Cell division is by amitosis (binary fission)	8. Cell division is by mitosis and meiosis
9. Posses ribosomes of 70 S type	9. Posses ribosomes of 80 S type
10. Nucleolus is absent	10. Nucleolus is present
11. Spindle fibres are absent	11. Spindle fibres are present
12. Cell wall is made up of polysaccharides Eg: Muramic acid	12. Cell wall is made up of cellulose, hemicellulose and pectins
13. Histone proteins are absent	13. Histone proteins are present
14. Pigments are distributed throughout the Cytoplasm	14. Pigments are present in plastids
15. Nuclear membrane is absent	15. Nuclear membrane is present
16. Mesosomes support respiration	16. Mitochondria support respiration
17. Eg: Bacteria, blue green algae, E. coli, PPLOs (Pleuropheumonia like organisms)	17. Eg: Plant and animal cells

Difference between plant cells and animal cells

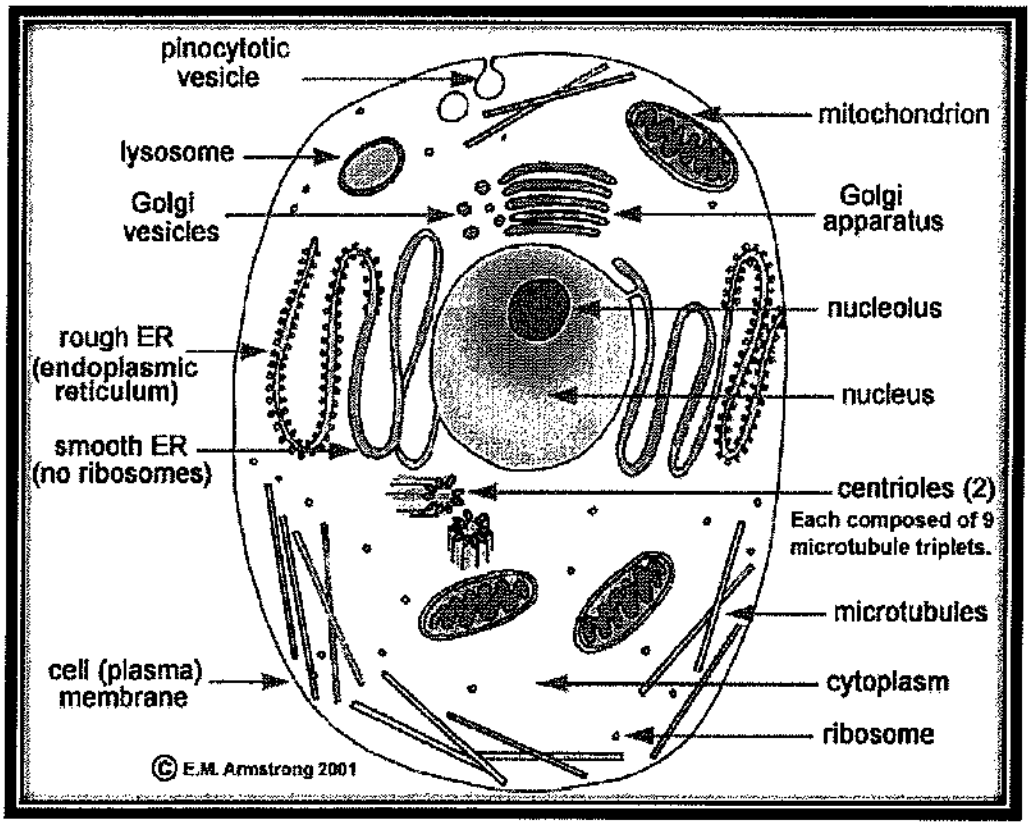
PLANT CELL	ANIMAL CELL
1. Plant cell has a rigid wall on the out side	1. The cell wall is absent
2. Usually larger in size	2. Comparatively smaller in size
3. Can not change its shape	3. Can often change its shape
4. Plastids are found	4. Plastids are usually absent. Chromatophores are present
5. Posses chlorophyll containing plastids called Chloroplasts	5. Chloroplasts are absent

6. A mature plant cell contains a large central Vacuole	6. Vacuoles are numerous and very small
7. Nucleus lies on one side in the peripheral Cytoplasm	7. Nucleus usually lies in the centre
8. Mitochondria are comparatively fewer	8. Mitochondria are generally more numerous
9. Cristae are tubular in plant mitochondria	9. Cristae are plate like in animal mitochondria
10. Plant cells do not burst if placed in hypotonic solution due to presence of cell wall	10. Animal cells burst if placed in hypotonic solution unless and until it posses contractile vacuole
11. Centrioles are usually absent in lower Plants	11. Centrioles are found in animal cell
12. Spindle fibres formed during nuclear division are anastral	12. Spindle fibres formed during nuclear division are amphiastral
13. Golgi apparatus consists of a number of distinct / unconnected units called Dictyosomes	13. Golgi apparatus is either localized or consists of a well connected single complex
14. Cytoskeleton does not con tain intermediate fibres	14. Cytoskeleton contains intermediate fibres
15. Lysosomes are rare and their activity is performed by specialized vacuoles	15. Typical lysosomes occur in animal cell
16. Glyoxysomes may be present	16. Glyoxysomes are absent
17. Crystals of inorganic substances may occur inside the cells	17. Crystals usually do not occur in animal cells
18. Reserve food is generally starch and fat	18. Reserve food is usually glycogen and fat
19. A tissue fluid does not bathe the individual cells	19. A tissue fluid contain in a NaCl bathes the cells
20. Adjacent cells may be connected through plasmadesmata.	20. Adjacent cells are connected through a number of junctions

* Draw the well labelled diagram of Plant cell



Labeled diagram of Plant Cell



Label diagram of Animal cell

GLOSSARY

Cell. A basic unit of structure & function in all living organisms

Cell organelles. various membrane-bound structures that are found within a cell such as nucleus, plastids, mitochondria, endoplasmic reticulum, etc.,

Nucleus. In eukaryotes, a double membrane, oval or spherical structure which contain" chromosomes.

Nuclear envelope. A double membrane outer boundary of the nucleus. Nucleolus. A spherical body found within the nucleus. Chromatin. A partly clumped and tangled mass of nuclear chromosomes.

Plastids. Self replicating cytoplasmic organelles found in plant cells.

Leucoplasts. Colourless plastids which are associated with storage of starch, protein and fat.

Chromoplasts. Plastids with other than green colour.

Chloroplasts. Plastids of green colour that are associated with photosynthesis.

Grana. Small cylindrical structures found inside the inner membrane of a chloroplast.

Stroma. The space found inside the inner membrane of a chloroplast.

Mitochondria. A rod like cytoplasmic organelle which is the main site of cellular respiration.

Endoplasmic reticulum. A vast network of membrane enclosed tubules vesicles and sacs found in the cytoplasm.

Ribosomes. Small cellular particles that are the sites of protein synthesis.

Lysosomes. Cellular particles which contain several digestive enzymes.

Cell wall. The outermost part of a plant cell. Middle lemella. A common layer found between adjacent cells.

Primary cell wall. A thin and elastic membrane which lies between middle lemella and secondary cell wall.

Secondary cell wall. The inner most layer of cell wall which lies between primary wall and plasma membrane.

Plasma lemma. A thin and flexible membrane covering the cytoplasm.

Golgi bodies. A cell organelle which is associated with packaging of food material such as proteins, lipids and phospholipids for transport to other cells.

Centrioles. Cylindrical cellular bodies always in pair found in animal cells.

Tonoplast. A vascular membrane surrounding a vacuole.

Cristae. A series of inside folds in mitochondria.

Cytoplasm. The portion of cell other than nucleus.

Hyaloplasm. The portion of cytoplasm other than cell organelles.

QUESTIONS

Q.1 Define nucleus. Describe in brief ultrastructure and functions of nucleus.

Q.2 Give a brief account of the ultrastructure, origin and functions of chloroplasts.

Q.3 Describe briefly ultrastructure, origin and functions of mitochondria.

Q.4 What are cell organelles? Give a list of various organelles found in a plant cell. Describe anyone of them in detail.

Q.5 What is cell wall? Describe briefly the structure and functions of cell wall with suitable diagrams.

Q.6 Write short notes on the following

1. Endoplasmic reticulum
2. Lysosomes
3. Centrioles
4. Peroxisomes
5. Ribosomes
6. Golgi complex
7. Microtubules
8. Spherosomes

Q.7 Give differences between the following:

1. Plant cell and animal cell.
2. Nucleus and nucleolus
3. Primary and secondary cell wall.
4. Plastids and mitochondria.

//*//*//*//

★ Difference between mitosis and meiosis.
or,
Diff. betⁿ somatic cell division (mitosis) & gametic cell division (meiosis)

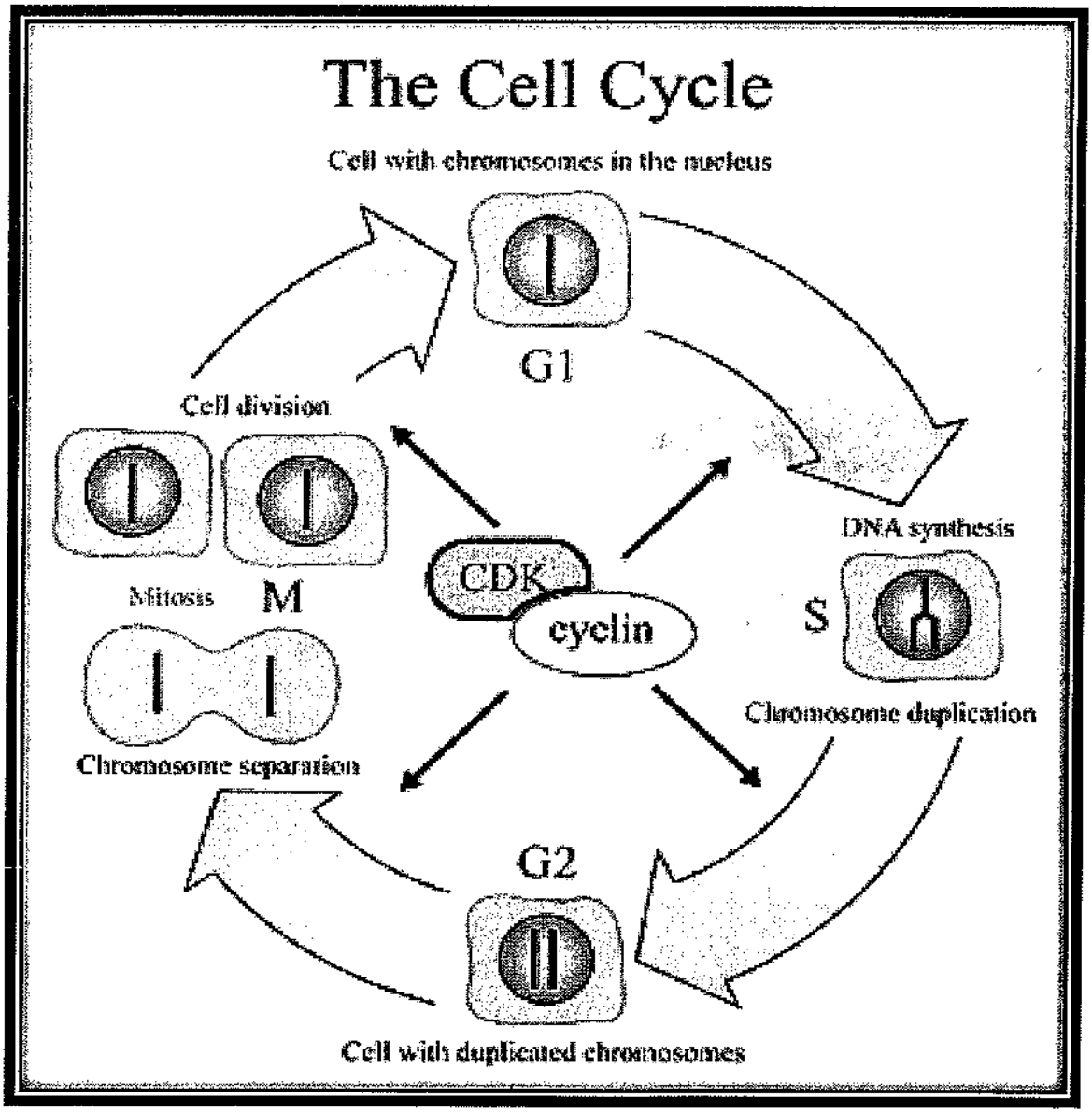
3. CELL DIVISION

Cell is the basic unit of structure and function of all living systems. The process of formation of new cells from pre-existing cells is referred as cell division. In cell division process, the cell going under the division process is referred as mother cell and the new cells which are formed due to the process of cell division is termed as daughter cells. There are mainly two types of cell division *viz.*, mitosis and meiosis.

The process of cell division is divided into two parts : (1) Karyokinesis and (2) Cytokinesis

1. Karyokinesis : It is the process of nucleus division.
2. Cytokinesis : It is the process of division of cytoplasm. Cytokinesis follows to karyokinesis.

★ Draw the diagram of cell cycle.



Cell cycle with different sub-stages

Que:- Write short note on cell cycle

CELL CYCLE

It is the period in which one cycle of cell division is completed is called cell cycle. It consists of two phases *viz.*, Interphase and Mitotic phase.

INTERPHASE :

It is the phase of the DNA synthesis in which the chromosomal material is in special stage, which is known as metabolic stage or interphase. It occupies the time between the end of telophase of previous mitotic division and the beginning of the next prophase. It occupies the largest period in a cell cycle. It is often not regarded as a stage of cell division. The interphase is divided into three sub stages i.e. G_1, S and G_2 (Fig-3.1).

1. G_1 : Synthesis of RNA and protein (Pre DNA replication phase). It occupies 25-50 % of interphase duration
2. S : Synthesis of DNA (DNA replication phase). It occupies 35-40 % of interphase time
3. G_2 : Synthesis of mRNA and some fraction of RNA (Post DNA replication phase). It occupies 15-25 % of interphase duration

During interphase chromosome do not goes any observable cytological changes but chromosomes are in form of chromatin fibers. While, during mitotic phase (M phase) chromosomes are duplicated and as a result chromosome number remain constant and definite in each species. The M phase consists of four stages *viz.*, prophase, metaphase, anaphase and telophase. (Fig 3.2).

MITOSIS

The term mitosis was coined by Flemming in 1892. Mitosis refers to the cell division process in which two identical daughter cells are produced from a mother cell. The chromosome numbers of newly developed daughter cells are also remaining same as mother cell in mitotic division. Mitotic division is take place in somatic cells, so it is also referred as a somatic cell division.

SIGNIFICANCE OF MITOSIS : Que:- Give the significance of Mitosis

1. The chief function of the mitosis is growth of organisms and regeneration of damaged tissues.
2. To keep the chromosome number constant.
3. It multiplies the cell number and causes vegetative growth and development.
4. Regeneration of damaged tissues and organs.
5. Replacement of old tissues and organs.
6. Production of new tissues and organs like roots, shoots, branches etc.

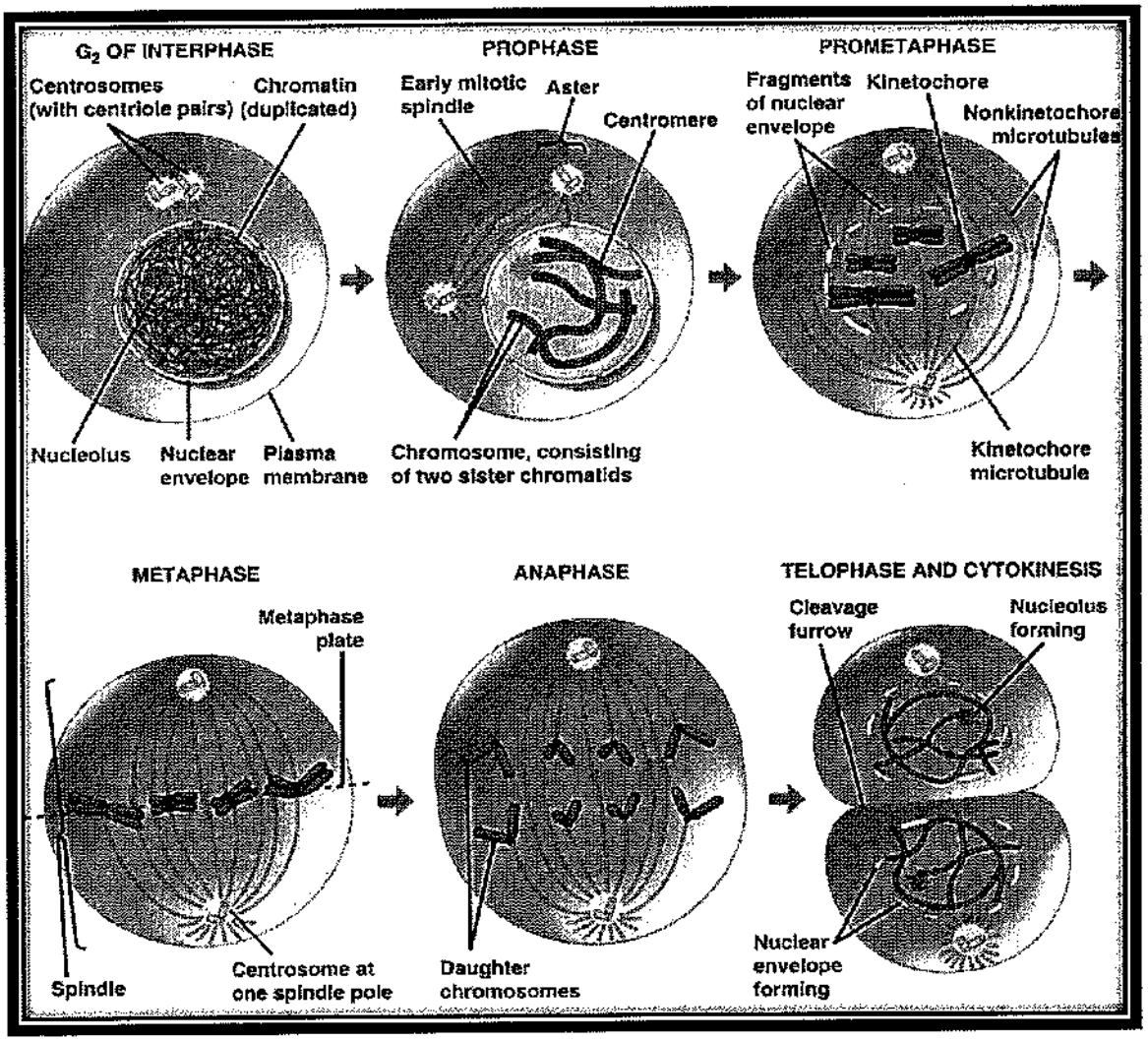
STAGES OF MITOSIS

Mitosis is divided into four different stages *viz.*, (1) Prophase (2) Metaphase (3) Anaphase and (4) Telophase. (Fig-3.2).

PROPHASE

Prophase starts immediately after G_2 stage of interphase.

- It is the longest mitotic stage.
- Formation of individual chromosome from a chromosomal reticulum.
- Chromosome become shorter, thicker and stains darkly due to condensation and coiling.
- Each chromosome consists of two chromatids and attached at the centromere.
- At the end of prophase nucleolus disappears and nuclear envelop start to breakdown.



* Difference between cytokinesis & karyokinesis

METAPHASE

- Metaphase phase begins after prophase.
- Metaphase is shorter than prophase but slightly longer than anaphase.
- Nuclear membrane dissolves and formation of spindle fibers takes place.
- Individual chromosomes are arranged at the equatorial plate (metaphase plate).
- The centromere of the each chromosomes serves as its point of orientation
- Each centromere is attached to the spindle fibers.
- Each chromatids of chromosome are clearly visible.

ANAPHASE

- It is the shortest of all stages in the mitotic cycle.
- The centromere splits longitudinally.
- Two sister chromatids of same chromosome are separated from each other and move towards opposite poles.
- At end of anaphase, due to contraction of spindle fibers and repulsion forces between newly formed chromosomes, the daughter chromosomes reach to the respective poles.
- Two groups of chromosomes are visible at each pole.

TELOPHASE

- Uncoiling of chromosome takes place, so that they become long and thin
- The nucleolus and nuclear membrane reappears around each group of daughter chromosomes

CYTOKINESIS :

- At the end of telophase, new cell wall is formed at equatorial plate, which divides the cytoplasm into two equal parts. This process is known as cytokinesis. The division of cytoplasm into two daughter cells may take place in two ways.
  - In plants, the division of cytoplasm takes place due to formation of cell plate. The formation of such plate begins in the center of the cell, which moves towards periphery in both sides dividing the cytoplasm into two daughter cells.
  - In animals, the separation of cytoplasm starts by furrowing of plasma lemma in the equatorial region, which results into division of cytoplasm into two daughter cells.

Que :- List out different phases & sub-phases of Meiosis-I

MEIOSIS

The term meiosis was coined by Moore and Farmer (1905). It is a cell division process in which, from a single mother cell four haploid daughter cells are produced. The process of meiosis is divided into two types of division. The first division (meiosis-I) is known as reductional division and the second division (meiosis-II) is known as equational division.

IMPORTANT FEATURES OF THE MEIOSIS:

- Meiosis results in the formation of four daughter cells from a single mother cell in each cycle of cell division.
- Newly developed daughter cells are identical to mother cell in shape and size but it differ in chromosome number.
- Meiosis occurs in reproductive organs like anthers and ovaries.
- The complete process of meiosis consists of two types of division. The first division results in the reduction of chromosome number to half (Reductional division) and the second division is like mitotic division (Equational division).
- Meiosis results in segregation of chromosomes and genes and their independent assortment. Crossing over and recombination also occurs during meiosis.

Que :- Write the significance / importance of Meiosis.

SIGNIFICANCE/IMPORTANCE OF MEIOSIS :

- Meiosis maintains a definite and constant number of chromosomes from one generation to the next generation produced by sexual reproduction.
- It facilitates the segregation and independent assortment of chromosomes and genes.
- The recombination of genes takes place during meiosis, which act as the basis of genetic variation.

STAGES OF MEIOSIS

FIRST MEIOTIC DIVISION (REDUCTIONAL DIVISION)

In first meiotic division, the chromosome number of newly developed cells is half in compared to the mother cell, therefore it is referred as reductional division. It consist four different phases *viz.*, Prophase-I, Metaphase-I, Anaphase-I and Telophase-I.

1) PROPHASE –I : This phase consist very long duration and it is sub divided into five stages *viz.*, Leptotene, Zygotene, Pachytene, Diplotene and Diakinesis.

a) **LEPTOTENE :**

- Chromosomes look like long, thin thread under light microscope, They are inter woven like a loose ball of wool.
- Chromosomes are scattered throughout the nucleus in a random manner.
- RNA and protein synthesis also take place.

b) **ZYGOTENE :**

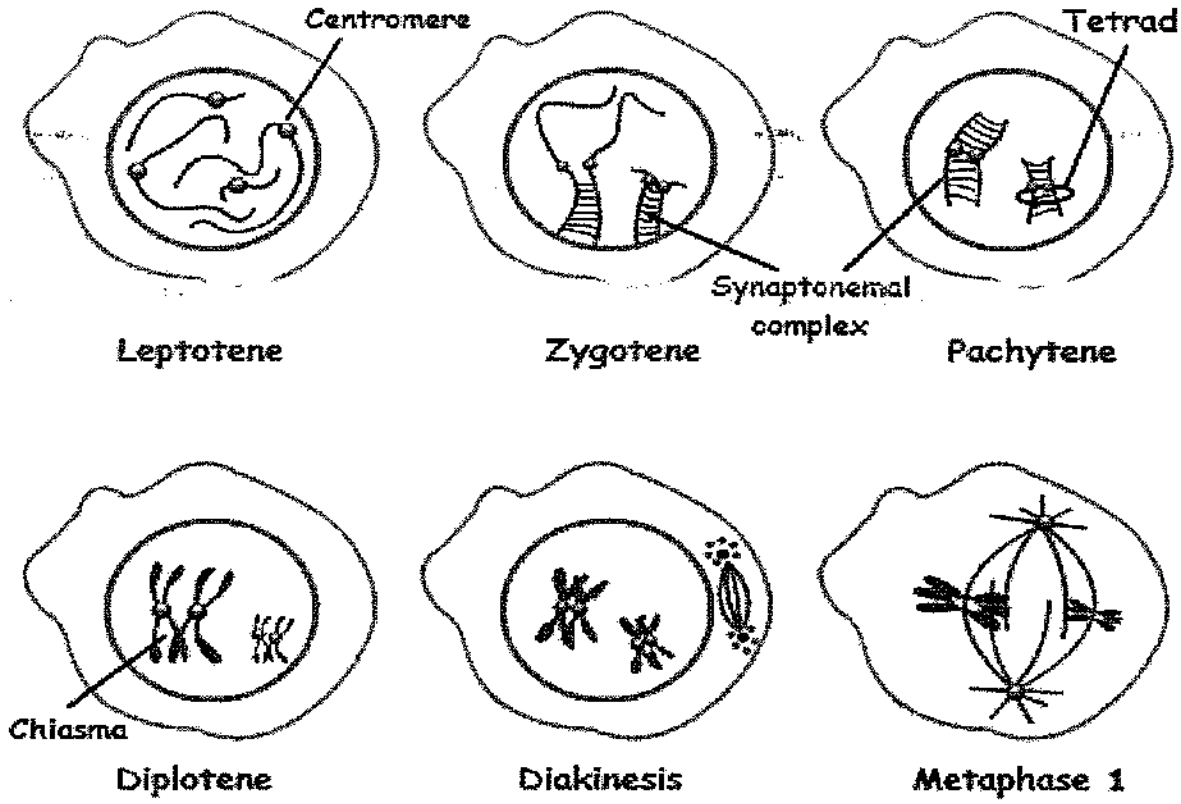
- Each chromosome divides into two chromatids. Chromatids become clear due to continuous coiling.
- Chromosomes become shorter and thicker.
- This stage is also characterized by pairing of homologous chromosomes (Synapsis).
- The pairing take place in zipper like fashion and may start at centromere, at chromosome ends or any other position.

c) **PACHYTENE :**

- Chromosomes look like bivalent and each bivalent has now two chromatids. Thus each chromosome has four chromatids generally known as tetrads.
- In this stage, the chromosome number look likes haploid number (but actually it is diploid).
- Nucleolus is present and attached to a chromosome.
- Formation of chiasmata and crossing over take place i.e exchange of segments between non homologous chromatids of homologous chromosomes take place.

d) **DIPLOTENE :**

- In this stage further thickening and shortening of chromosomes take place.
- Homologous chromosomes start separating from each other. The separation starts from centromere and proceeds towards terminal end (Chromosome terminalization)
- Homologous chromosomes are held together only at certain point, such points are referred as chiasma or chiasmata.
- Nucleolus decrease in size.



Stages of Prophase-I

b) **DIAKINESIS :**

- This stage begins after complete terminalization of chiasmata.
- Chromosomes are further condensed.
- Bivalents are distributed throughout the cell.
- Nucleolus and nuclear membrane disappear towards the end of the diakinesis.

2) METAPHASE - I

- This is the best stage to counting the chromosome number.
- Spindle fibers attached from poles to the centromere.
- Bivalents are arranged at equatorial plate with homologous chromosomes oriented towards opposite poles.
- Chromatids are clearly visible.
- The centromere of each homologous chromosomes separates from each other.

3) ANAPHASE - I

- From each bivalent, one homologous chromosome moves toward one pole and another opposite pole. In another word one homologous chromosomes moves towards one pole and another to opposite pole.

- Sister chromatids of each chromosome remain attached at the centromere.
- Homologous chromosomes reach the opposite pole at the end of this phase.

4) **TELOPHASE - I**

- Chromosomes uncoiled and relax and regrouping of chromosome occurs.
- Nucleolus and nuclear membrane reappear.
- Two haploid daughter nuclei are formed.

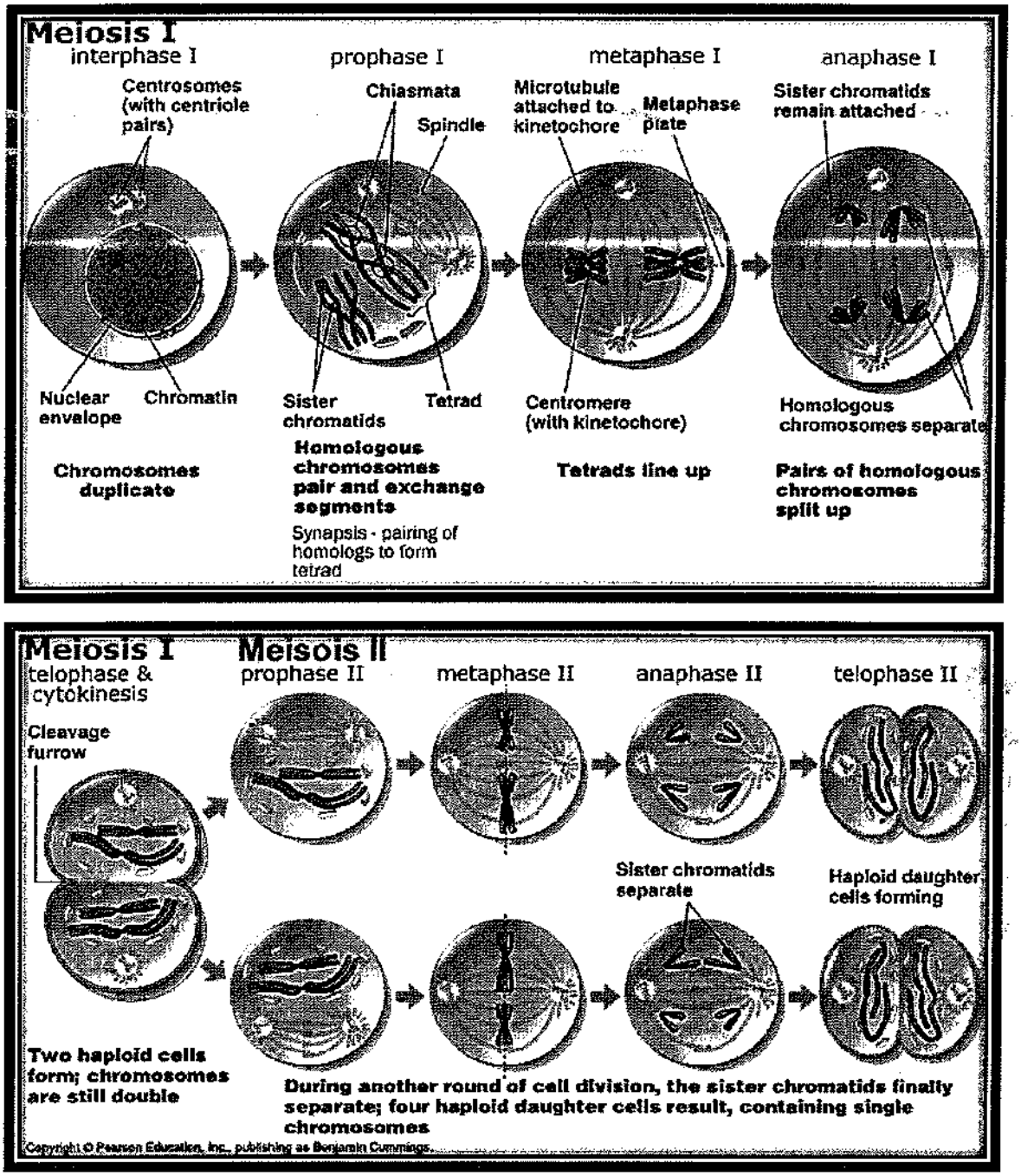
CYTOKINESIS :

- At the end of telophase-I, cytoplasm is divided into two halves and each two halves are staying to gether, this structure is called Dyad.

SECOND MEIOTIC DIVISION (EQUATIONAL DIVISION)

The first meiotic division (meiosis-I) results in reduction of chromosomes number from diploid to haploid. The second nuclear division (meiosis-II) is required to reduce the number of chromatids per chromosomes. Meiosis –II differs from mitosis in the following three aspects :

1) The interphase prior to meiosis II is very short. It does not have S phase because each chromosome already contains two chromatids.
2) The two sister chromatids in each chromosomes are not sister chromatid throughout. In other words, some chromatids have alternate segments of non sister chromatids due to recombination.
3) The meiosis-II deals with haploid chromosome number, whereas normal mitosis deals with diploid chromosome number.



Different stages of meiosis (2n=4)

Rest of the features of meiosis –II is similar to mitosis. It also consist the phases like prophase-II, metaphase-II, anaphse-II and telophase-II.

1) **PROPHASE - II**

- This stage is quite similar to that of mitosis but it differs in several aspects
- There is no relational coiling between sister chromatid, as a result two sister chromatids of each chromosome are clearly visible.

- The chromosomes are much more condensed and appeared shorter and thicker.
- At the end of prophase, nucleolus and nuclear membrane are disappearing.

2) **METAPHASE - II**

- In this stage, chromosomes become arranged on the equatorial plate.
- Nucleolus and nuclear envelope are absent.
- Spindle apparatus is present and centromere of each chromosome is arranged at the equatorial plate.
- Two sister chromatids of each chromosome are distinctly separated from each other.
- Chromosomes become more condensed, thicker and shorter.
- The stage is quite short in duration.

3) **ANAPHASE - II**

- In this stage, centromere of the each chromosome divides longitudinally.
- Two sister chromatids of each chromosome begins to separate and move away to opposite poles.

4) **TELOPHASE - II**

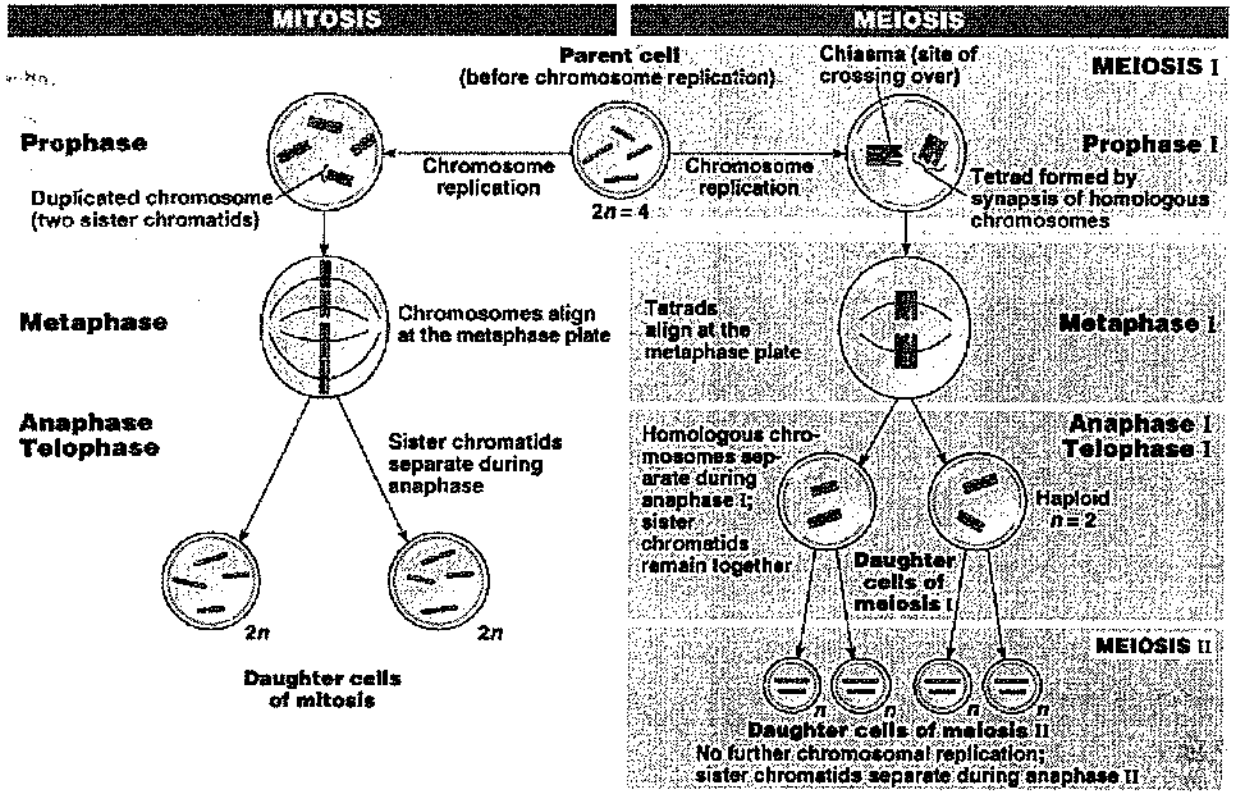
- In this stage, uncoiling of chromosomes take place.
- Reappearance of nucleolus and reformation of nuclear envelop around each group of chromosomes.

CYTOKINESIS :

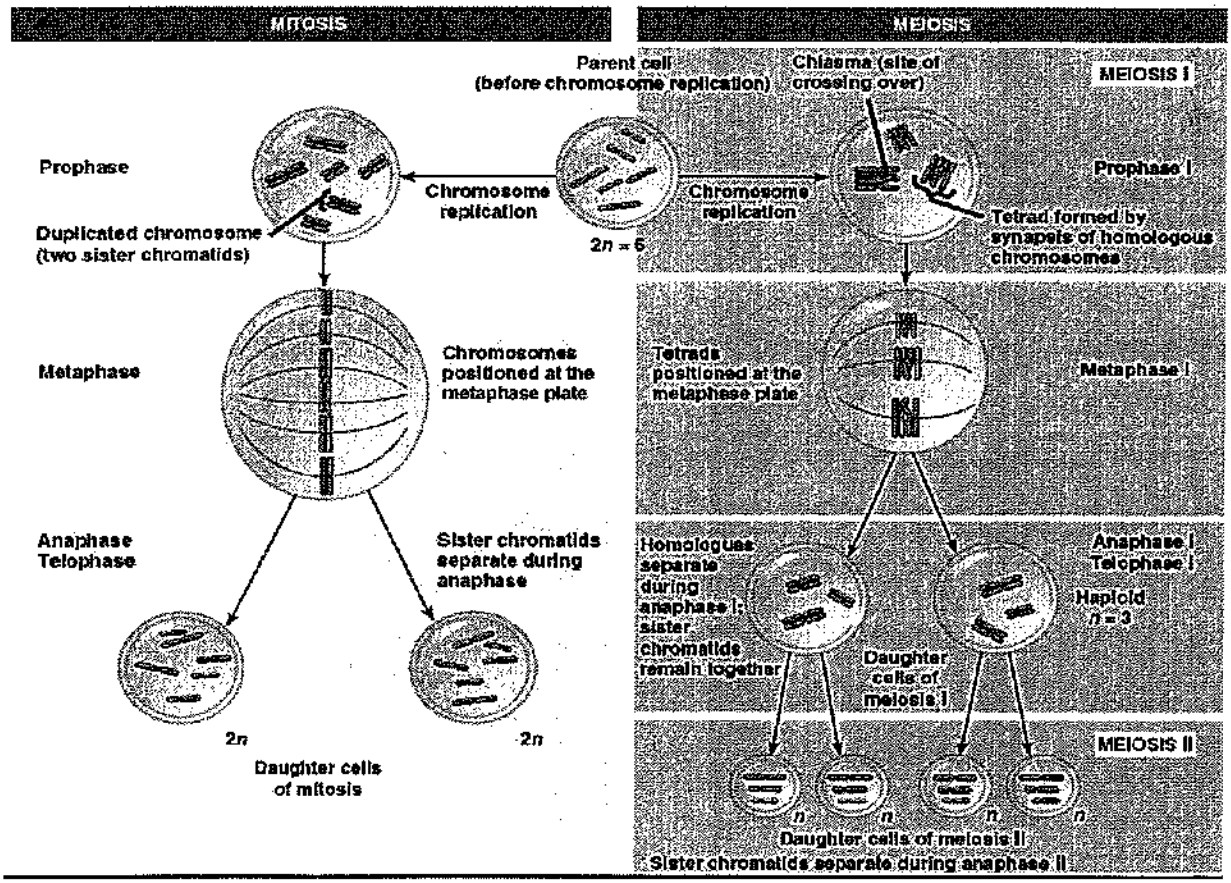
- By the end of telophase- II, the cytoplasm of each of the two cells divides into two parts, so total four haploid daughter cells are produced after completion of two meiotic divisions. These four haploid daughter cells are all to gether referred as Tetrad.
- Then this four haploid cells differentiate into gamete and this process is known as gametogenesis

Draw a diagram of Mitosis / Meiosis

Assuming 2n = 4, following are the stages of Mitosis and meiosis



Assuming 2n = 6, following are the stages of Mitosis and meiosis



GLOSSORY

Cell division. The process of reproduction of new cells from the pre existing cell.

Mother cell. The cell which undergoes division.

Daughter cells. The new cells which are formed by the process of cell division.

Mitosis. The spindle using nuclear division which produces two identical daughter cells from a mother cell.

Cell cycle. The period in which one cycle of cell division is completed. It consists of interphase and mitotic phase.

Interphase. A stage in spindle using cell division during which DNA synthesis takes place. It lies between telophase and prophase. It consists of three substages, *viz.*. G_1 S and G_2.

G1. A pre-DNA replication phase. It lies between telophase and S phase.

S. A chromosome and DNA replication phase. It lies between G_1 and G_2 stages.

G_2. A post DNA replication phase during which protein and RNA synthesis take place.

Mitotic phase. A phase of separation of replicated DNA into two identical daughter nuclei without recombination. It consists of prophase, metaphase, anaphase and telophase.

Prophase. A stage of spindle using cell division when chromosomes become shorter and thicker. It lies between interphase and metaphase.

Metaphase. A stage of spindle using cell division during which chromosomes are arranged at the equatorial plate. It lies between prophase and anaphase.

Anaphase. A stage of spindle using cell division during which chromatids/chromosomes move towards opposite poles.

Telophase. A stage of spindle using cell division in which chromosomes reach the opposite poles.

Karyokinesis. The process of the division of nucleus.

Cytokinesis. The process of division of cytoplasm.

Meiosis. Two successive spindle using divisions which reduce the chromosome number from diploid to haploid.

Leptotene. A sub stage of meiotic prophase I in which chromosomes look like thin thread and are interwoven like a loose ball of knitting wool.

Zygotene. A sub stage of meiotic prophase I in which homologous chromosomes begin to pair.

Pachytene. A sub stage of meiotic prophase I in which chromosomes look like bivalent.

Diplotene. A sub stage of meiotic prophase I in which separation of homologous chromosomes begin.

Diakinesis. A sub-stage of meiotic prophase. I in which bivalents are distributed throughout the cell.

Synaptonemal complex. A protein frame work which is found between paired chromosomes.

QUESTIONS

Q.1 Define mitosis. Describe in brief various features of mitotic cell division and give its significance.

Q.2 What is meiosis? Discuss important features of meiosis and its significance.

Q.3 Assuming 2n = 6, draw various stages of meiosis I and meiosis II.

Q.4 Mitosis and meiosis are genetically controlled. Give evidences in support of this statement.

Q.5 Describe in brief various similarities and dissimilarities between mitosis and meiosis.

Q.6 Write short notes on the following

1. Cell cycle
2. Significance of mitosis
3. Significance of meiosis
4. Synaptonemal complex
5. Karyokinesis
6. Spindle fibres
7. Cytokinesis

//*//*//*//

STUDY OF CHROMOSOME STRUCTURE

CHROMOSOME

- The darkly stained rod shaped bodies observed under light microscope in a cell during metaphase stage of mitosis is referred as chromosome.
- **Strasburger** discovered the chromosomes (thread like structure) in 1875.
- The term chromosome was coined by **Waldeyer in 1888**

Features of Eukaryotic chromosomes:

- Chromosomes are not visible during interphase. They are visible during other stages of cell division but more clearly visible during mitotic metaphase
- The genes are located on the chromosome in linear fashion, which are responsible for transmission of characters from generation to generation
- In eukaryotes the chromosomes are enclosed by nuclear membrane
- They are vary in shape, size and number in different species of plants and animals
- Chromosomes having property of self replication, segregation and mutation
- Chromosomes are composed of DNA, RNA and histone proteins. DNA is the major genetic material of chromosome.

CHROMOSOME SHAPE

Chromosome shape is usually observed during anaphase. The shape of chromosomes is determined by the position of centromere, a part of chromosome on which spindle fibres are attached during metaphase. Chromosomes have generally three different shapes, *viz.*. rod shape, J shape and V shape. These shapes are observed when the centromere occupies terminal, sub-terminal and median (middle) position on the chromosomes, respectively.

CHROMOSOME SIZE

Chromosome size is measured with the help of micrometer at mitotic metaphase. It is measured in two ways, viz., in length and in diameter. Plants usually have longer chromosomes than animals. Moreover, species or individuals which have fewer chromosome number have larger chromosomes. The maximum length of chromosome is observed during interphase and minimum during anaphase. Thus chromosome size varies from species to species (Table 4.1). Giant chromosomes have length upto 300 p

TABLE 4.1. Chromosome size in some plants and animals

Name of Plant/animal	*Chromosome size in* **p.**
Maize	8-12
Lilium. Allium and Tradescantia	10-12
Trillium	30-32
Human	4
Drosophila	3

CHROMOSOME NUMBER

There are three types of chromosome number, *viz.*, haploid, diploid and basic number as given below :

Haploid

It represents half of the somatic chromosome number of a species and is denoted by **n**. Since haploid chromosome number is usually found in the gametes, it is also known as **gametic number.**

Diploid

It refers to **somatic chromosome number** of a species and is represented by **2n**. Since diploid chromosome number is found in zygotic or somatic cells it is also referred to as **zygotic or somatic number.**

Basic Number

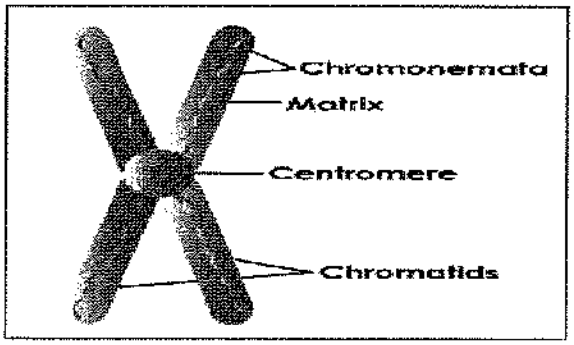
The gametic chromosome number of a true diploid species is called basic number. It is the minimum haploid chromosome number of any species which is denoted by **x.** For example, in wheat, the basic number is 7, whereas the haploid number is 7, 14 and 21 for diploid, tetraploid and hexaploid species, respectively.

Thus haploid chromosome number differs from basic number. Both are same in case of true diploid species but differ in case of polyploid species. Thus, basic number can be a haploid number but all haploid numbers cannot be basic number. Chromosome number differs from species to species (Table 4.2). In plant kingdom, chromosome number usually is higher in dicots than in monocots.

Common name	*Scientific name*	*Chromosome number*	
		n	*2n*
PLANTS			
Monocots			
Barley	*Hordeum vulgare*	7	**14**
Corn	*Tea mays*	10	20
Rice	*Oryza saliva*	12	24
Rye	*Secale cereale*	7	**14**
Wheat	*Triticum aestivum*	21	**42**
Jowar	*Sorghum bicolor*	10	**20**
Pearl millet	*Pennisetum americanum*	7	14
Dicots			
Bean	*Phaseolus vulgaris*	1!	22
Cabbage	*Brassica oleracea*	9	18
Chiltt	*Capsicum annum*	12	24
Cucumber.	*Cucumis sativa*	7	14
Datura	*Datura stramonium*	12	24
Garden Pea	*Pisum sativum*	7	14
Mustard	*Brassica campestris*	10	20
Onion	*Allium cepa*	8	16
Pepper	*Piper nigrum*	64	128
Potato	*Solanum tuberosum*	24	48
Tobacco	*Nicotiana tabacum*	24	48
Tomato	*Lycopersicon esculentum*	12	24
Upland cotton	*Gossypiwn hirsutum*	26	52
ANIMALS			
Fruitfuly	*Drosophila melanogaster*	4	8
Human	*Homo sapiens*	23	46
Pigeon	*' Columbia Livia*	40	80
Cow	*Bos taurus*	30	. 60

✶ CHROMOSOME MORPHOLOGY:

1. Chromosome morphology is studied in the cells of root tip during metaphase



Each chromosome consist seven parts

1. Centromere
2. Chromatid
3. Secondary constriction and satellite
4. Telomere
5. Chromomere
6. Chromonema
7. Matrix

Que 1.- Types of chromosome as per position and number of centromes

Centromere :

The region of the chromosome with which spindle fibers are attached during metaphase is known as centromere or primary constriction or kinetochore

Functions

- Responsible for orientation of chromosome
- For movement of chromosome during anaphase
- For the formation of chromatid
- For the chromosome shape

Depending upon the position of centromere and its number on the chromosome, it cab be grouped into five classes

Position of centromere	**Chromosome type**	**Number of centromere**	**Chromosome type**
Median	Metacentric	Nil	Acentric
Sub-median	Sub metacentric	One	Monocentric
Sub-terminal	Acrocentric	Two	Dicentric
Terminal	Telocentric	Three	Tricentric
Diffuses	Holokinetic/holocentric	Many	Polycentric

Chromatid :

- One of the two distinct longitudinal subunits of chromosome is called chromatid
- These two subunits get separated during anaphase. Basically they are two types : sister chromatid and non sister chromatid
- Sister chromatid : It is derived from the same chromosome
- Non sister chromatid : They are not from the same chromosome but they originate from homologous chromosome
- Two chromatids of a chromosomes are held to gather by centromere

Secondary constriction :

- The constriction or narrow region other than that of centromere is called secondary constriction
- Generally found on the short arm of the chromosome and away from the centromere, but some time it is also found on long arm
- A chromosome segment separated from the main body of the chromosome by one secondary constriction is called satellite
- The chromosome with secondary constriction is referred as satellite chromosome or sat-chromosome

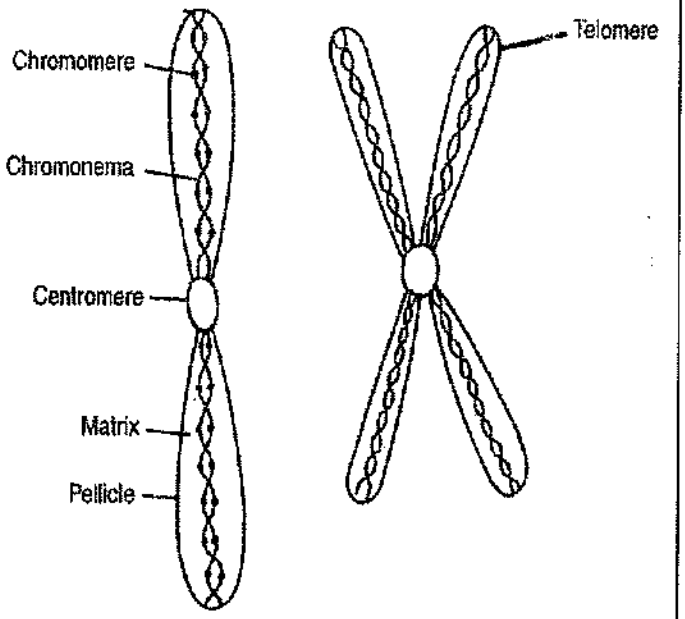
Telomere :

The terminal region of a chromosome on either side is known as telomere. These are not visible in the light or electron microscope, they are rather conceptual structures. Each chromosome has two telomeres. The telomere of one chromosome cannot unite with the telomere of another chromosome due to polarity effect. In other words, translocations can occur when the ends of two chromosomes are damaged.

Chromomeres :

The linearly arranged bead like structure founds on the chromosomes are known as chromomeres.

- They are clearly visible in polytene chromosomes.
- They are responsible for
  1. Unit of DNA replication
  2. Chromosome coiling
  3. RNA synthesis
  4. RNA processing



Chrmonema :

- The thread like coiled structures are found in the chromosome and chromatids are called as chromonema

Functions :

1. It controls the size of the chromosome
2. It is gene bearing portion on the chromosome

Matrix :

- A mass of acromatic material in which chromonemeta is embedded is called matrix
- Matrix enclosed in a sheath which is known as pellicle
- Both matrix and pellicle are non genetic materials

Karyotype :

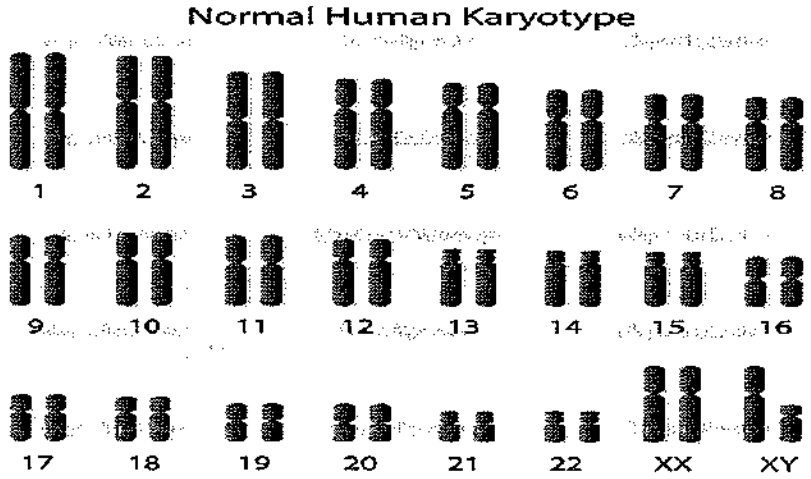
- The characteristics features of chromosome of a species is referred as karyotype

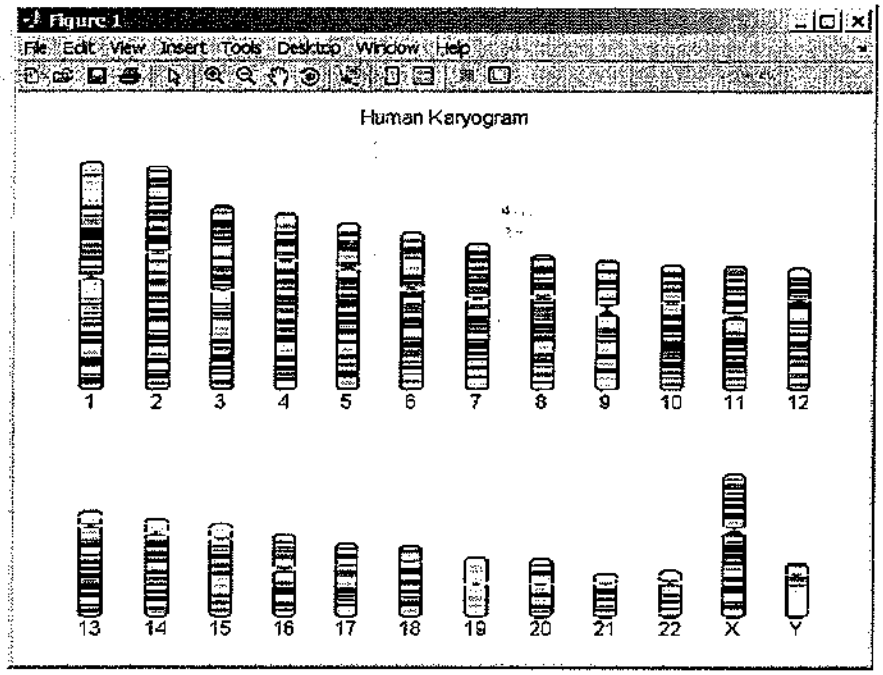
OR

- Its phenotypic appearance of the chromosomes of a particular species. It is represented by a specific diagram, which is known as ideogram
- Ideogram is generally identical for particular species but it varies from species to species
- Features taken into consideration in karyotype study
    1. Number
    2. Position of centromere
    3. Size
    4. Position of satellite
    5. Degree and distribution of heterochromatin

Karyotype : They are two types – Symmetrical and Asymmetrical

- **Symmetrical :**
    1. All the chromosomes have median and sub-median position of centromere
    2. Less variation in the size of chromosome
    3. Plant species with this type of karyotype are considered as primitive ones
- **Asymmetrical** :
    1. The chromosme have terminal position of centromere
    2. Wide variation observed in the size of chromosomes (Smallest – Longest type)
    3. Plant species with this type of karyotype are considered as advance one
- The ideogram generally depicted in descending order of chromosome length





Heterochromatin and Euchromatin :

- There is clear cut differences are observed in staining behaviour of different regions of chromosomes during interphase
- The darkly stained region of the chromosome : Heterochromatin
- The lightly stained region of the chromosome : Euchromatin

Diff. betn ↓

	Heterochromatin	**Euchromatin**
1.	It represents the dakrly staining region	It represents the lightly staining region
2.	Contain few inactive cells	Contain lot of active genes
3.	Cover small regions of the chromosome	Covers large region of chromosome
4.	Usually found near the centromere and telomere	Usually found in the middle of the chromosome

CLASSIFICATION OF CHROMOSOMES

Chromosomes can be classified in different ways. The various criteria which are usually used for the classification of chromosomes include, (1) position of centromere, (2) number of centromere, (3) shape at anaphase, (4) structure and appearance, (5) role in heredity essentiality, (6) role in sex determination, and (7) structure and function. A brief classification on the bases of these criteria is presented below

1.Based on the Position of centromere	
Metacentric Chromosome	A chromosome in which centromere is located in the middle portion, such chromosomes assume V shape at anaphase.
Sub-metacentic	A chromosome in which centromere is located slightly away from the centre point or has sub-median position. Such chromosomes assume J shape at anaphase.
Acrocentric Chromosome	A chromosome in which centromere is located very near to one end or has subterminal position. Also called as sub-terminal chromosome. Such chromosome assumes J shape or rod shape during anaphase.
Holokinetic Chromosome	A chromosome with diffused centromere. Centromere does not occupy a specific pqsition, but is diffuses throughout the body of chromosome. Whole body of such chromosome exhibits centromeric activity. Also called holocentric chromosome.
2. Based on the Number of centromere	
Acentric Chromosome	A chromosome without centromere. Such chromosome remains as laggard during cell division and is eventually lost.
Monocentric Chromosome	A chromosome with one centromere. It represents normal type of chromosomes.
Dicentric Chromosome	A chromosome having two centromeres. Such chromosome makes dicentric bridge at anaphase and are produced due to inversion and translocations.
3. Based on the Shape at anaphase	
V shaped Chromosome	A chromosome which assumes V shape at anaphase. It includes metacentric chromosome.
J shaped	A chromosome which assumes J shape at anaphase. It includes sub-

Chromosome	metacentric and sub-terminal chromosomes
Rod shaped Chromosome	A chromosome which assumes rod like shape during anaphase. It includes telocentric chromosome.

4. Based on the Structure and appearance

Linear Chromosome	A chromosome with linear structure or having both the ends free. Such chromosomes are found in cukaryotes.
Circular Chromosome	A chromosome with circular shape and structure. They are found in bacteria and viruses.

5. Based on the Essentiality

A-Chromosome	Normal members of chromosome complements of a species which are essential for normal growth and development.
B-chromosome	Chromosomes which are found in addition to normal chromosome complements of a species. They are also called as accessory, supernumerary or extra chromosomes and are not **essential** for normal growth and development.

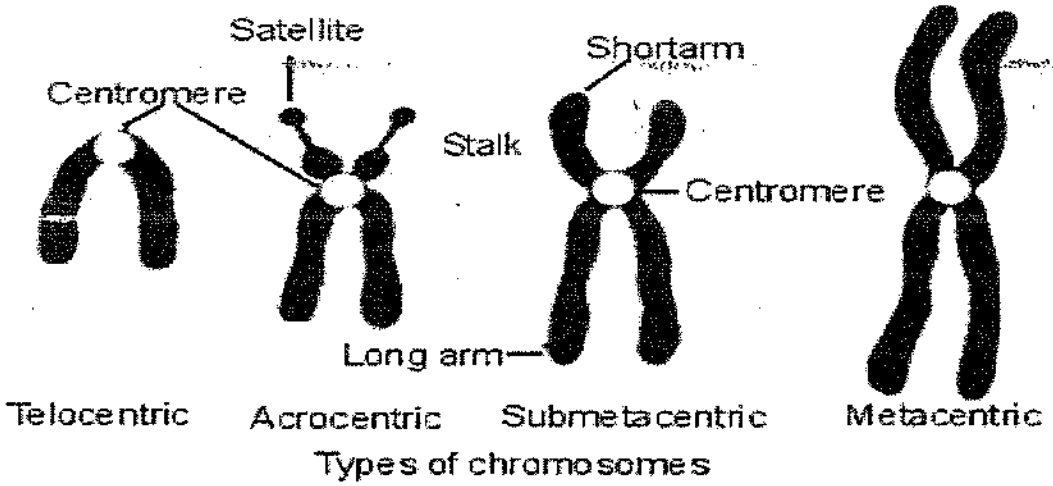
6. Based on the Role in Sex Determination

Allosomes	Chromosomes which differ in morphology and number in male and female sex and contain sex determining genes. They are generally of two types, *viz.*, X and Y or Z and W types (for details see under sex determination).
Autosomes	Chromosomes which do not differ in morphology and number in male and female sex and rarely contain sex determining genes.

7. Based on the Structure and Function

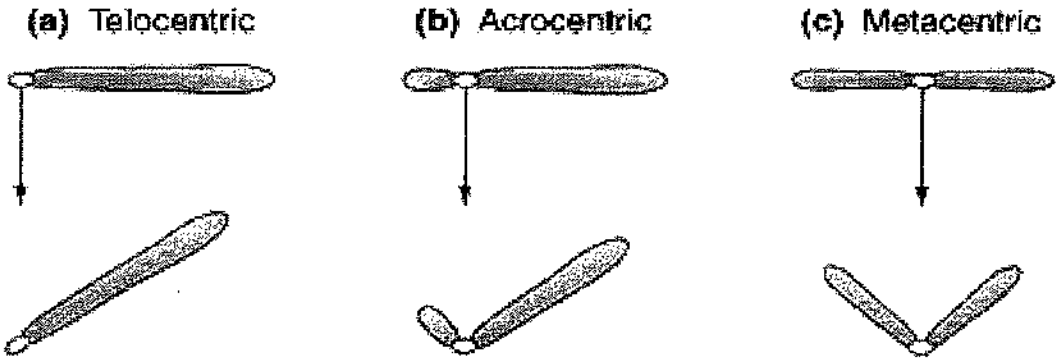
Normal Chromosome	Chromosomes with normal structure (shape and size) and function.
Special Chromosome	Chromosomes which significantly differ in structure and function from normal chromosomes. Such chromosomes include lampbrush chromosomes, polylene chromosomes and B-chromosomes.

Types of chromosomes based on position of centromere:



Types of chromosomes

Shape of chromosome based on position of centromere :



Chemical composition of chromosomes

- Major chemical components are DNA, RNA, histone proteins and non histone proteins
- Example : In Pea
  - ✓ Embryonic axis contain 39 % DNA, 10 % RNA, Proteins – 40 % histone 11 % non histone protein
  - ✓ Protein contents > DNA

Special types of chromosomes

- This type of chromosomes significantly differ in their structure and functions
- Three different types
  1. Lampbrush Chromosome
  2. Polytene chromosome
  3. B chromosome

1. **Lampbrush chromosome** ★ Short note on lampbrush chromosome

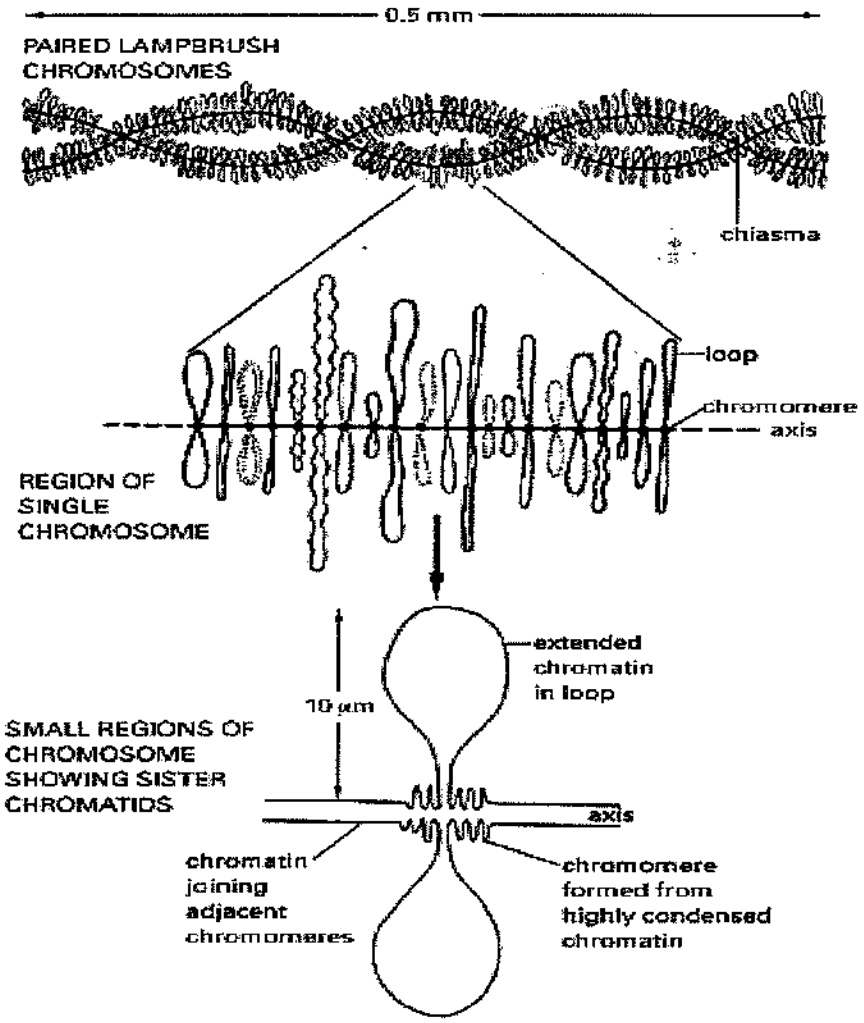
In this type of chromosome large number of loops are found on the chromatin axis, which gives lampbrush appearance. They found in the nuclei of both vertebrate and invertebrates and spermatocyte nuceli of Drosophilla during diplotene stage. They have three main features:

1. **Extra ordinary length**
   - Having remarkable length
   - Length is large than polytene chromosome
   - Length is recorded upto 1 mm in some of the amphibian

2. **Large number of loops**
   - One to none loops may arise from a single chromosome
   - Loops are found in the pairs
   - Here the chromomeres are interconnected by inter chromomere fibres

3. **Lampbrush appearance**
   - Here large number of loops are found in pair, which gives lampbrush appearance
   - Gradually the loops increase its number and it found maximum in diplotene stage and declining after diplotene
   - In diplotene stage lampbrush chromosomes consist of two homologous chromosomes

➢ In lampbrush chromosome the chromosomal axis, chromomere and loop axis are all made up of DNA and which is having hereditary function or considered as the region of genetic activity



Lambrush chromosome

Write Short note ↓

★ **Polytene or Giant or Salivary gland chromosome :**

The multiple replicates of the same chromosome holding to geather in a same parallel fashion, which results into very thick chromosome are known as polytene chromosome. It was first reported by Balbiani (1981) in the salivary gland of dipteran insect. Also found in salivary gland of Drosophilla and several other insect. These chromosomes found in salivary gland, so it is also known as salivary gland chromosome. Three main features :

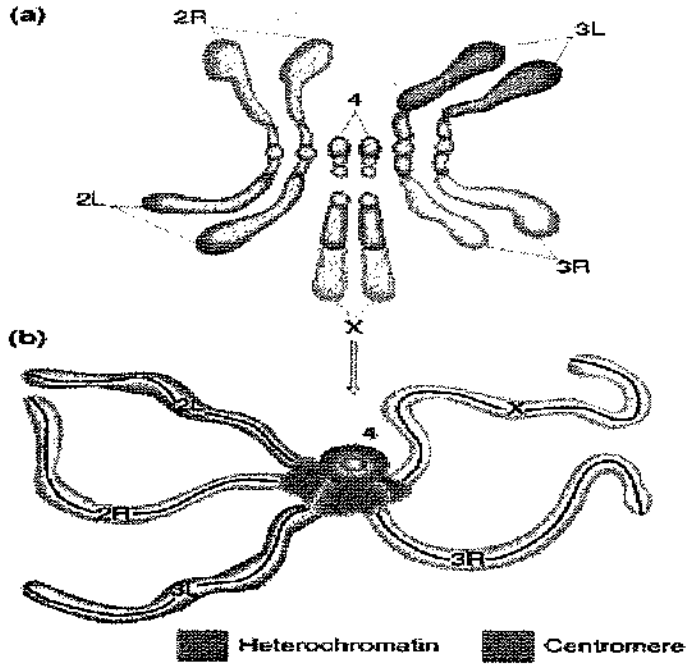
1. Bands
2. Puffs
3. Giant size

Bands : The strips which are found in this chromosomes are known as bands

Puffs : Some band are swollen or in expanded form, which are known as Puffs or Balbiani ring. The puffs are reversible and considered as the region of genetic activity. The puff

formation process at different site of polytene chromosome is referred as puffing. Puffs are the site of DNA synthesis

Giant Size : Polytene chromosome having giant size. Some time the size observed to be 200 times bigger than normal chromosome



Polytene/Giant chromosome

B- chromosome

- The normal member of the chromosome known as the A-chromosome
- Some species possesses extra chromosomes which are not the members of normal chromosome complement, which are known as B-chromosome
- Also known as supernumerary chromosomes or accesory or extra chromosomes
- B – chromosome first reported in maize by Longley 1927 and Randolph 1928
- B – chromosomes classified in following two ways
    1. On the basis of their size
        1. Stable
        2. Unstable
    2. On the basis of stability
        1. Standard type
        2. Small type
        3. Very small type
        4. Large type

GLOSSORY

CHROMOSOME. Darkly stained rod shaped bodies visible under light microscope in a cell during mitotic metaphase.

HAPLOID NUMBER. The gametic chromosome number of a species (n)

DIPLOID NUMBER. The somatic chromosome number of a speciest (2n)

BASIC NUMBER. The gametic chromosome number of a true diploid species (x)

CENTROMERE. The region of chromosome with which spindle fibres are attached during metaphase. Also called **primary constriction or kinetochore.**

CHROMATID. One of the two distinct longitudinal sub-units of a chromosome.

SECONDARY CONSTRICTION. The narrow or constricted region in a chromosome other than centromere. Telomere. The terminal region of chromosome on either side.

CHROMOMERE. The linearly arranged bead like structures found on the chromosomes.

CHROMONEMA. Thread like coiled structures found in the chromosomes and chromatids (Pleural chromonemeta).

MATRIX. A mass of acromatic material in which chromonemeta are embedded.

KARYOTYPE. The characteristic features of chromosomes of a species.

IDIOGRAM. The diagram which is used to represent karyotype.

EUCHROMATIN. Lightly staining region of chromosomes during interphase. Usually found in the middle of chromosome, genetically active and takes part in transcription.

HETEROCHROMATIN. Darkly staining region of chromosomes during interphase, usually inactive in transcription, found near centromere and telomere.

A-**CHROMOSOME**. Normal members of chromosome complements of a species which are essential for normal growth and development.

B-**CHROMOSOME**. Chromosomes which are found in addition to normal chromosome complements of a species and are not essential for normal growth and development. Also known as accessory supernumerary or extra chromosomes.

NORMAL CHROMOSOMES. Chromosomes with normal structure (shape and size) and function.

SPECIAL CHROMOSOMES. Chromosomes which significantly differ in structure and function from normal chromosomes such as lampbrush chromosomes, polytene chromosomes and B-chromosomes.

METACENTRIC CHROMOSOME. A chromosome in which centromere is located in the middle portion. Such chromosomes assume V shape at anaphase. Sub-Metacentric chromosome. A chromosome in which centromere has sub-median position. Acrocentric chromosome. A chromosome in which centromere is located very near to one end or has sub-terminal position.

TELOCENTRIC CHROMOSOME. A chromosome in which centromere is located at one end.

HOLOKINETIC CHROMOSOME. A chromosome with diffused centromere.

ACENTRIC CHROMOSOME. A chromosome without centromere.

MONOCENTRIC CHROMOSOME. A chromosome with one centromere.

DICENTRIC CHROMOSOME. A chromosome having two centromeres.

V-SHAPED CHROMOSOME. A chromosome which assumes V shape at anaphase.

J-SHAPED CHROMOSOME. A chromosome which assumes J share at anaphase.

ROD SHAPED CHROMOSOME. A chromosome which assumes rod shape at anaphase.

LINEAR CHROMOSOME. A chromosome having both the ends free; found in etikaryotes.

CIRCULAR CHROMOSOME. A chromosome with circular shape and structures; found in bacteria and viruses.

LAMPBRUSH CHROMOSOME. A chromosome having lampbrush appearance.

POLYTENE Chromosome. The multiple replicate of the same chromosome holding together in a parallel fashion resulting in very thick structure; also called giant or salivary gland chromosome.

BANDS. The strips which are found on polytene chromosome.

PUFFS. The swollen regions found on polytene chromosome; also called Balbiani rings.

ISO-CHROMOSOME. A chromosome with two identical arms.

RING CHROMOSOME. A physically circular chromosome, usually found in prokaryotes such as bacteria and viruses.

CHROMOSOME MODELS. The pattern of organization of chromatin fibres in a chromosome.

CHROMOSOME BANDING. The differentially stained regions of chromosomes, as a result of treatment with various dyes, visible under light or fluorescence microscope.

QUESTIONS

Q.1 Define chromosome. Describe briefly the variation found in shape, size and number of chromosomes in crop plants.

Q.2 Give a brief account of the internal morphology of chromosomes in eukaryotes.

Q.3 What are special chromosomes ? Describe anyone of them in detail with suitable diagrams.

Q.4 What are polytene chromosomes ? Describe briefly their origin and significance.

Q.5 Defince B chromosomes. Give their classification and describe their meiotic behaviour and genetic effects.

Q.6 Describe briefly the role of chromosomes in heredity.

Q.7 What are chromosome models ? Describe two types of chromosome models with suitable diagrams.

Q.8 What is chromosome banding ? Explain various types of chromosome banding and their significance in genetics.

Q.9 Write short notes on the following

1. Basic number
2. Chromatid
3. Centromere
4. Karyotype
5. Chromonema
6. Lampbrush chromosome
7. Giant chromosome
8. Isochromosome

Q.10 Differentiate between the following :

1. Heterochromatin and euchromatin
2. Chromosome and chromatid
3. Primary constriction and secondary constriction

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Ques. Short note on structural chromosomal aberration.

CHROMOSOMAL ABERRATION

Chromosomal aberration

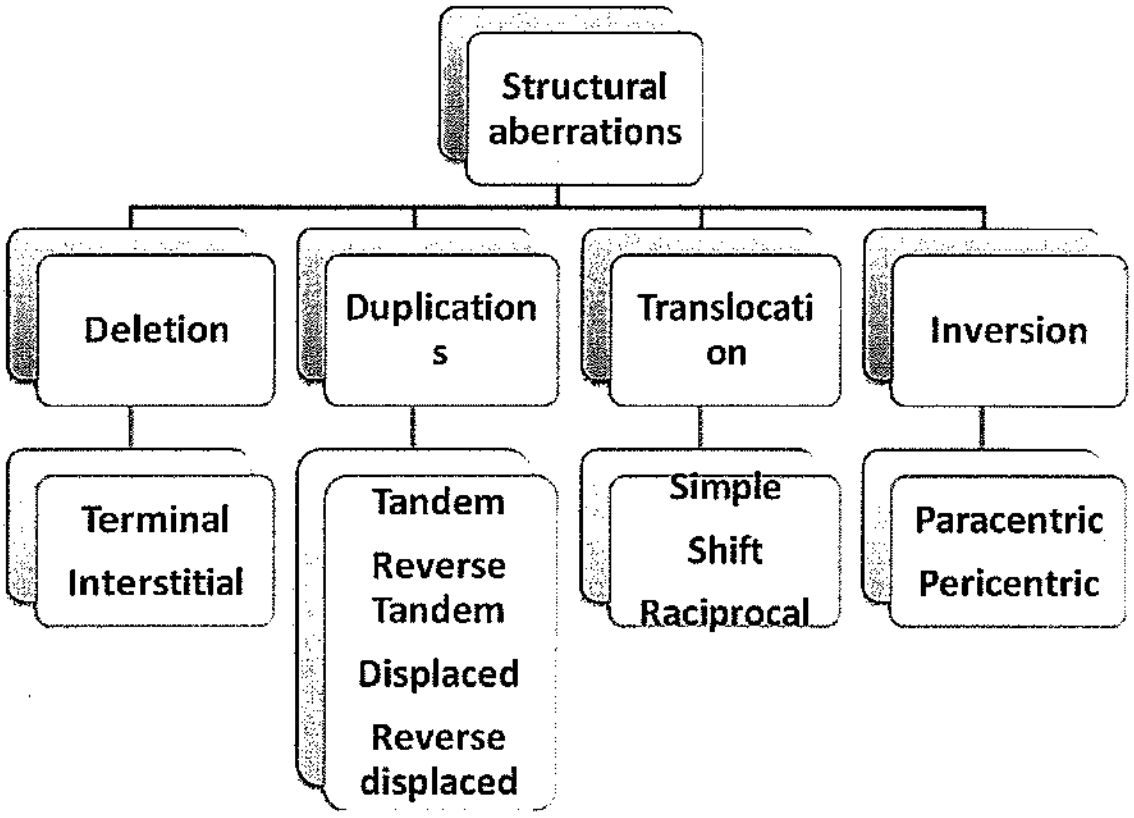
- The change or modification in the structure and number of chromosome is known as **chromosomal aberrations**
- There are two types of chromosomal aberrations
  1. **Structural aberrations** – Any change which alter the normal structure of chromosome is known as structural aberrations
  2. **Numerical aberrations** – Any change which alter the normal chromosome number is known as numerical aberrations
- **Restitution.** Union of broken chromosome segments which restores original gene sequence.

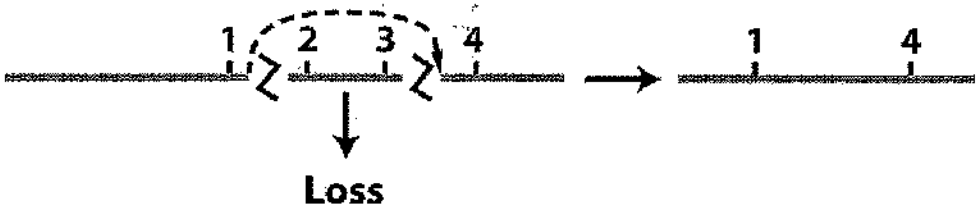
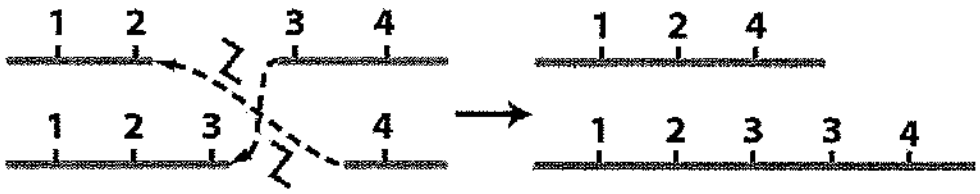
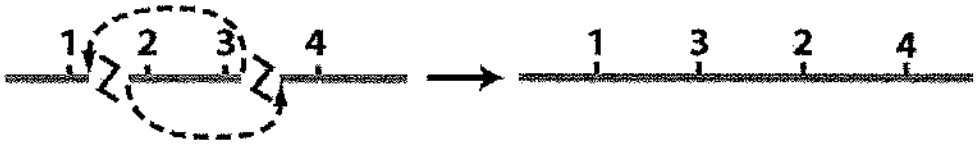
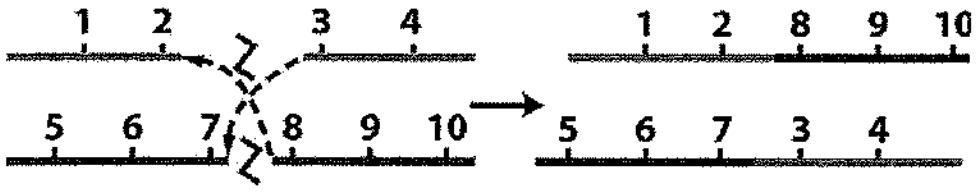
Causes of chromosomal aberrations :

- Cytological accidents
- Radiation effects
- Mutagenic treatment

Ques:- Give the classification of structural chromosomal aberration

Different types of structural aberrations :



	Breakage and rejoining
Deletion	
Deletion and duplication	
Inversion	
Trans-location	

1) Deletion/Deficiency :

- Deletion refers to the **loss of portion of segment from a chromosome.**
- Also known as **deficiency**
- Deletion have been reported in Drosophilla, maize, tomato, wheat and several other crops
- Depending upon the location deletions are of two types
    1. Terminal deletion
    2. Interstitial deletion

Terminal deletion :

- The loss of either **terminal segment of a chromosome** is known as terminal deletion
- A chromosome has two terminal end
- In case of terminal deletion **only one break occurs** and after the break injured end healed up

Interstitial deletion :

- The loss of intercalary or intermediate portion of chromosome is known as **interstitial** or **intercalary deletion**
- In this type of deletion the **loss of segment of chromosome from intermediate portion between centromere and telomere**
- The interstitial deletion **does not involve centromere**
- In interstitial deletion **breaks occurs at two places**

Original chromosome :

A B C D E F G H
----------O----------

Terminal deletion :

A B C D E F
----------O----------

Interstitial deletion :

A B C D G H
----------O----------

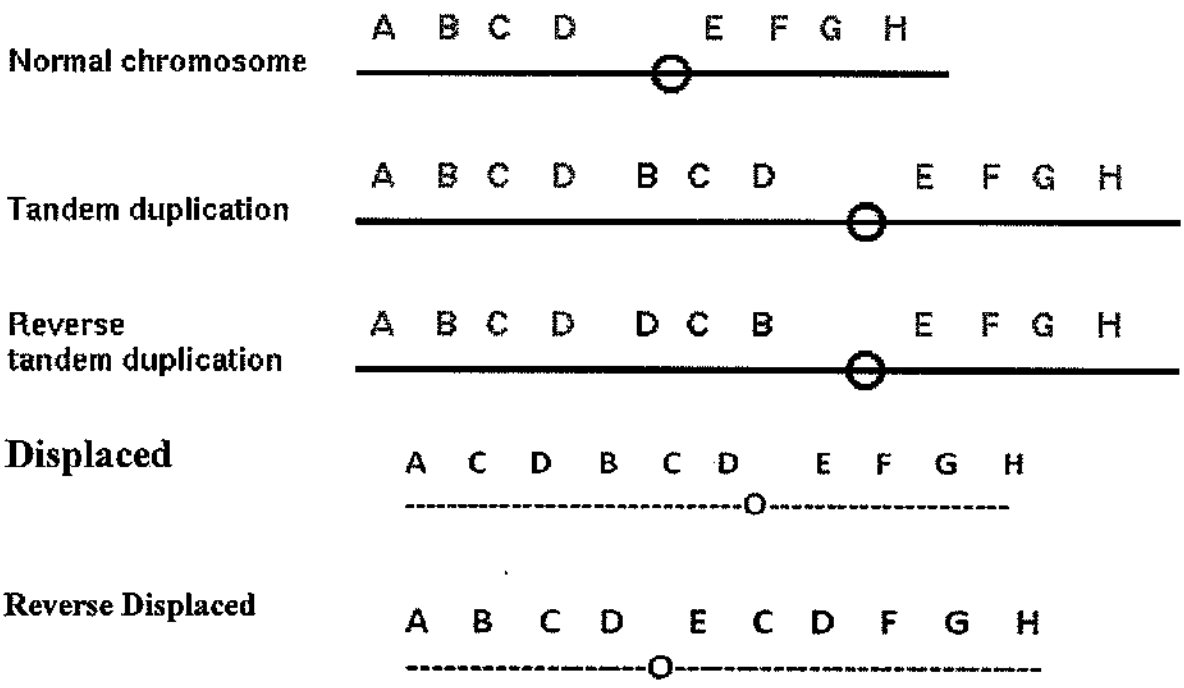
Significance of deletion:

- Deletion play an important role in species formation and releasing variability through chromosomal mutation
- Its important cytological tools for mapping genes

2) Duplication:

- Duplication refers to **occurrence of segment twice in the same chromosome**
- It results in addition of one or more genes to the chromosome
- It is also known as **repeat** and was first reported in **Drosophilla by Bridges in 1919**
- Now it is reported in maize, wheat, barley, rice, *Nicotiana* and tredescantia
- They are four types viz., **Tandem, Reverse tandem, displaced and reverse displaced**

1) **Tandem**: In this case, the sequence of genes in the duplicated segment is similar to the sequence of genes in the original segment of a chromosome.
2) **Reverse Tandem**: In this case, the sequence of the genes in the duplicated segment is reverse to the sequence of genes in the original segment of a chromosome. Tandem and reverse tandem duplications are known as adjacent duplication because they are adjacent to the original segment.
3) **Displaced:** When the duplication found away from the original segment but on the same arm of the chromosome, it is known as displaced duplication.
4) **Reverse Displaced:** When the duplication found away from the original segment but on the other arm of the chromosome, it is known as reverse- displaced duplication.



3) Translocation:

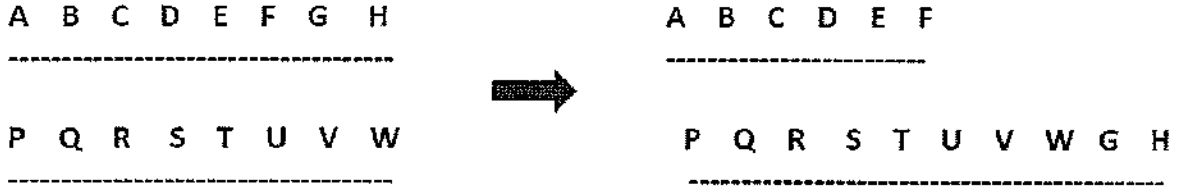
- One way or reciprocal transfer of segments of chromosome between non-homologous chromosomes is known as translocation.
- Translocations have been reported in *Oenothera*, Datura, maize, barley, rye and wheat.
- Translocation are of three types *viz*., simple, shifts and reciprocal.

1) **Simple translocation**: When a segment from one chromosome is transferred and attached to the end of a non-homologous chromosome is known as simple translocation.

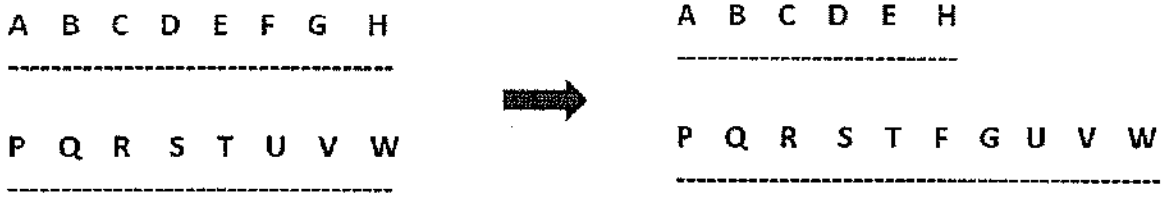
2) **Shifts:** Transfer of an intercalary segment from one chromosome to the intercalary position in a non-homologus chromosome is referred as shift.

3) **Reciprocal translocation:** When there is mutual exchange of segments between non-homologous chromosomes is known as reciprocal translocation.

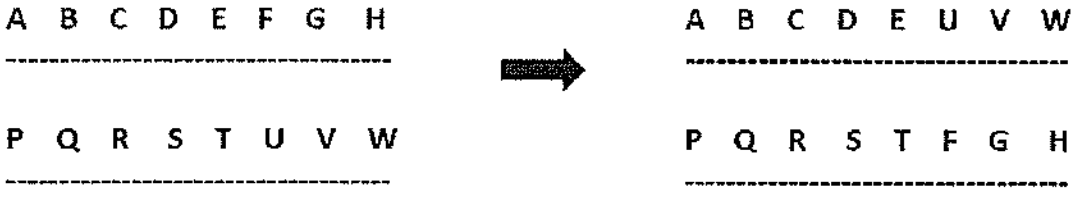
Simple translocation :



Shift :



Raciprocal translocation :



4) Inversion :

- Inversion refers to structural change in a chromosome in which **segment is oriented in a reverse order.**
- It was first time discovered by Strutevant (1926) in Drosophila. It has been also reported in maize, *Nicotiana* and several other plants.

- Inversion are of two types *viz.*, paracentric inversion and pericentric inversion.

1) **Paracentric inversion:** The inversion in which the inverted segment not involved centromere is called as paracentric inversion.

2) **Pericentric inversion:** The inversion in which the inverted segment include involved centromere is called as pericentric inversion.

Paracentric inversion :



Pericentric inversion :



Numerical chromosomal aberrations:

- The variation in the chromosome number is referred as numerical aberration
- Chromosome number :
    1. Original number or Basic number = **x**
    2. Somatic number or Diploid number = **2n**
    3. Gametic number = Haploid number = **n**

Difference betn euploidy & aneuploidy.

Classification of Numerical chromosomal aberrations:

	Term	Type of change	Symbol
A.	**Aneuploid**	One or few chromosomes are extra or missing Chromosome number is not exact multiple with basic number	**2n ± few**
1.	**Hypoploidy**	Loss of one or two chromosome from diploid set.	
	Monosomic	One chromosome missing	**2n-1**
	Nullisomic	One chromosome pair is missing	**2n-2**
	Double monosomic	Two non homologous chromosome are missing	**2n-1-1**
2.	**Hyperploidy**	Addition of one or two chromosomes to the one pair or two different pair	
	Trisomic	One chromosome extra	**2n+1**
	Tetrasomic	One chromosome pair extra	**2n + 2**
	Double trisomic	Two non homologous chromosome extra	**2n + 1 + 1**
B.	**Euploidy**	**Chromosome number are exact multiple with basic chromosome number**	
1.	**Autopolyploid**	Two or more copies of the same genome	
	Autotriploid	Three copies of same genome	**3x**
	Autotetraploid	Four copies of same genome	**4x**
	Autopentaploid	Five copies of same genome	**5x**
	Autohexaploid	Six copies of same genome	**6x**
2.	**Allopolyploid**	Two or more distinct genomes	
	Allotetraploid	Two copies of each of two distinct genome	**$2X_1 + 2X_2$**
	Allohexaploid	Two copies of each of three distinct genome	**$2X_1 + 2X_2 + 2X_3$**
	Allooctaploid	Two copies of each of four distinct genome	**$2X_1 + 2X_2 + 2X_3 + 2X_4$**

Amphidiploid :

- Naturally occurring allopolyploid ordinarily contain two copies of each of the genome present in it and show normal bivalent formation during meiosis are known as **amphidiploid.**

Genome AA x Genome BB

↓

F1 (AB)

F1 Sterile -because there is no paring between A & B

↓

Chromosome doubling

↓

AABB – Amphidiploid - Fertile

//*//*//*//

Difference between autopolyploidy & allopolyploidy.

POLYPLOIDY

Polyploidy :

An organism or individual having more than two basic sets of chromosomes is called **polyploid** and such condition is known as **polyploidy.** About one third species of flowering plants are polyploids. The polyploidy has been reported upto 70% in case of wild species of grass family. In animals, polyploidy is very rare occurrence because of its lethal effects. However, it is found only in those species of animal which develop parthnogenetically.

Classification of Polyploidy : Polyploidy is of two main types.

1. Autopolyploid
2. Allopolyploid

Autopolyploidy :

- Polyploids which originate by multiplication of the chromosome number of a single species are called as autoployploids or autoploids and such condition is referred to as autopolyploidy.
- Autoploids are also known as simple polyploids or single species polyploids.
- Autoploids includes autotriploids (3x), autotetraploids (4x), autopentaploids (5x), autohexaploids (6x) etc.
- Examples : Seedless watermelon, sugarbeet, banana, jowar, tomato, wheat etc.

Autotriploids :

- They can occur naturally or can be produced artificially by crossing autotetraploid and diploid species.
- They are generally sterile due to defective gamete formation (due to meiotic abnormalities).
- **Example:** Banana, sugarcane, apple, sugarbeet and watermelon (seedless or rudimentary seeds), etc.
- All other autotriploids with odd chromosomes sets, *viz.*, autopentaploids (5x), autoseptaploids (7x) etc also behave like autotriploids.

Autotetraploids :

- They may occur spontaneously in nature or can be induced artificially by doubling the chromosomes of a diploid species with colchicine treatment.

- They are usually very stable and fertile due to availability of pairing partners during meiosis and it lead to diploid gamete (2n) formation.
- Autotetraploids are generally larger in size and more vigorous than the diploid species.
- **Examples :** Aurotetraploid rye, grapes, alfalfa, groundnut, potato, coffee etc.
- All other autoploids with even chromosomes sets, *viz.*, autohexaploids (6x), autooctaploids (8x) etc also behave like autotetraploids.

Allopolyploidy :

- Polyploids which originate by combining complete chromosome sets from two or more species are called as alloployploids or alloploids and such condition is referred to as allopolyploidy.
- Alloploids are also known as hybrid polyploids or bispecies or multispecies polyploids.
- Alloploids includes allotetraploids ($2x_1 + 2x_2$), Allohexapolids ($2x_1 + 2x_2 + 2x_3$), allooctaploids ($2x_1 + 2x_2 + 2x_3 + 2x_4$) etc.
- An alloplyploid which arises by combining the genomes of two diploid specis followed by chromosome doubling with colchicines is termed as **amphidiploids.**
- They can be produced by interspecific cross and fertility is restored by chromosome doubling with colchicine treatment.
- About 50% of crop plants are allopolyploids. Therefore, allopolyploidy has played greater role in crop evolution than autopolyploidy.
- Allopolyploids are of two types (a) Natural allopolyploid (b) Artificial allopolyploid.

(a) Natural Allopolyploids :

- Alloploids which naturally originate through interspecific crossing followed by chromosome doubling in nature are called natural allopolyploids.

Examples:

Wheat

The bread wheat **(Triticum aestivum)** is an allopolyploid. It is believed that A genome of wheat has come from **Triticum monococcum** (2n = 14), D genome from **Triticum tauschi** (2n = 14) and B genome from unknown source probably from an extinct species (2n = 14). Thus hexaploid wheat has two copies of the genomes from three species. First allotetraploid **Triticum turgidum** developed from a cross between

Triticum monococcum and unknown species of B genome. Then cross between **T. turgidum** and **T. tauschi** resulted in the development of hexaploid wheat **T. aestivum.**

Tobacco

There are two cultivated species of tobacco, ***viz.,*** **Nicotiana tabacum** and **N. rustica. N. tabacum** is an amphidiploid between **N. sylvestris** (2n = 24) and **N. tomentosa** (2n = 24). **N. roptica** is believed to be amphidiploid between **N. paniculata** and **N. undulata.** Each of these two species has 2n = 24.

Cotton

The tetraploid American cotton **(Gossypium hirsutum)** is believed to be an amphidiploid between **G. africanum,** an old world species, and **G. raimondii,** a new world species. Both these species are diploid with 2n = 26. The chromosomes of old world species are larger than new world species.

Oat

The cultivated oat **(Avena sativa,** n = 21) is an allohexaploid which is considered to have originated from a cross between **A. barbata** (tetraploid, n = 14) and **A. strigosa** (a diploid, n = 7).

Brassica

In **brassica,** there are three basic species, ***viz.,*** **Brassica nigra** (BB, n =8) **B. oleracea** (CC, n = 9) and **B. campestris** (AA, n = 10). The cross between **B. nigra** and **B. oleracea** gave rise to **B. carinata.** Cross between **B. campestris** and **B. oleracea** led to the development of **B. napus,** and cross between **B. campestris** and **B. nigra** resulted in the development of **B. juncea.** All the resulting species are amphidiploids.

(b) Artificial Allopolyploids :

- Alloploids which have been synthesized through artificial interspecific crossing followed by chromosome doubling in nature are called artificial allopolyploids.
- They are synthesized with two main objectives:
    1. To study the origin of naturally available allopolyploids
    2. To explore the possibilities of creating new species.

Example :

1. **Raphnobrassica :** A cross between radish (2n=18) and cabbage (2n=18) was first developed by Karpencheko (1927). He wanted to develop a fertile hybrid with roots of radish and leaves of cabbage. But he got a fertile allotetraploid (4n=36) by spontaneous chromosome doubling which had roots of cabbage and leaves of radish.

2. **Triticale :** A cross between tetraploid wheat (2n=28) or hexaploid wheat (2n=42) and rye (2n=14) was first developed by Rimpu (1889) produced allohexaploid triticle or allooctaploid triticle, respectively. Triticle is commonly grown in Canada, Mexico etc.

Methods to induce polyploids :

A) **Induction of polyploidy using colchicine :**

- Polyploidy is mainly induced by treatment with a chemical known as **colchicines.** The colchicines induced polyploidy is known as **Colchiploidy.**
- It is the most effective and the widely used treatment for chromosome doubling.
- It is widely used in large numbers of monocot and dicot crop plants.
- Colchicine [$C_{22}H_{25}O_6N$] is poisonous alkaloid which is isolated from seeds (0.2 – 0.8 %) and bulbs (0.1 – 0.5 %) of autumn crocus (*Colchicum autumnale*), which belongs to the family *Liliaceae*.
- It is soluble in alcohol, chloroform or cold water but is relatively less soluble in hot water.
- Colchicine does not affect *Colchicum* from which it is extracted, as this plant has an anticolchicine substance.
- Colchicine is applied in very low concentration, because high concentration is highly toxic to the cells.

Mode of action of Colchicine :

- Colchicine induces polyploidy by blocking the formation of spindle fibres.
- The chromosomes do not line up on the equatorial plate and thus inhibits the movement of sister chromatids to opposite poles. The nuclear membrane is formed around them and cell enters into interphase. As a result, the chromosome number of cell is doubled in the nucleus without division of cell.
- **For effective induction of polyploidy,** usually concentration of 0.01 to 0.5 % is used in different plant species. In plant species, it is applied to growing tips, meristematic cells, seeds and axillary buds in freshly prepared aqueous solution or mixed with lanolin. The duration of treatment varies from 24 to 96 hours depending upon the species of plants.
- Colchicines affects only dividing cells, so it should be applied to a shoot-tip meristem only when its cells are actively dividing. At any given time, only small proportion of the cells would be in division, so repeated treatments should be given at brief intervals to double the chromosome number in large number of cells of apex.

Methods of colchicine application :

a) **Seed Treatment :** The seeds are generally soaked in 0.001 to 1 % (0.2 % most common) freshly prepared aqueous solution of colchicines for one to ten days.

b) **Seedling Treatment :** Germinating seedling or *in vitro* derived seedling may be inverted so that only young shoots are exposed to colchicines solution for 3 to 24 hours and roots are protected.

c) **Growing shoot apices :**

- It is most commonly used treatment with 0.1 to 1.0 % colchicines, which is applied by brush or with a dropper. The treatment is repeated once or twice daily for 5-7 days.
- A small cotton wool piece may also be placed at the shoot-tip meristem, which daily soaked with colchicine solution.
- Colchicine 0.5 to 1.0 % solution mixed in lanoline paste may be smeared on the shoot apex and this treatment is repeated 2 to 3 times per week.

d) **Woody plants :** 1 % colchicine is used for application on shoot buds. For better wetting and penetration, a small quantity of wetting agent is added in the colchicine solution.

e) **Special treatments:** Special methods for the treatments in cereals, grasses, pulses, oilseeds crop etc have been developed to contact the colchicines solution with shoot apical meristem.

B) **Induction of autopolyploidy using physical agents :**

- Heat or cold treatments, centrifugation, X-rays or gamma rays irradiation may also produce polyploids but with very low frequencies and are not used commercially.

C) **Induction of autopolyploidy using other chemicals :**

- Several other chemicals like acenaphthene, 8-hydroxyquinoline, nitrous oxide etc. are used to induce autopolyploid but these chemicals are much less effective than colchicines and are not commonly used.

APPLICATIONS IN CROP IMPROVEMENT

Polyploidy plays an important role in crop improvement. Both, autopolyloidy and allopolyploidy are useful in several ways. However, allopolyploidy has wider applications than autopolyloidy. Applications of allopolyploidy and autopolyloidy in crop improvement are briefly presented below :

Autoploidy

Both triploids and tetraploids have been used in crop improvement. However, their applications have been limited to few species only.

- Autotriploids have been developed in sugar beets and water melon only. The triploid sugar beets have larger roots and higher sugar content than diploids.
- The triploid water melons are seedless or have rudimentary and soft seeds like cucumber. The triploid seed is produced by using tetraploid as female and diploid as male.
- Tetraploid varieties of rye are grown in Sweden and Germany. They have larger seeds and higher protein than diploids.
- Tetraploid grapes have been developed in California USA, which have larger fruits and fewer seeds per fruit than diploids.

Alloploidy

Alloploidy is useful in four principal ways, ***viz-,*** (1) in tracing the origin of natural allopolyploids, (2) in creating new species, (3) in interspecific gene transfer, and (4) as a bridging species. These are briefly described below :

1. **Tracing the Origin of Crop Species.** Alloploidy plays an important role in tracing the origin of natural allopolyploids. Study of chromosome pairing in a cross between allopolyploid and a diploid species helps in tracing the origin of polyploid species
2. **Creation of New Species.** Alloploidy sometimes leads to the creation of new crop species. Triticale is the best example, which is alloployploid between wheat and rye. It combines desirable character of both the species ***i.e.,*** grain quality of wheat and hardiness of rye.
3. **Interspecific Gene Transfer.** When the desirable character is not found within the species, it is transferred from the related species. Interspecific gene transfer is done in two ways, *viz.,* by alien addition and alien substitution.
4. **4. Bridging Cross.** Sometimes direct cross between two species is not posssible due to sterility in F_1. In such case, first an amphidiploid is made between such species and then amphidiploid is crossed with the recipient species. Such types of bridging crosses have been made for transfer of genes from wild species particularly in crops like tobacco and cotton.

LMITATIONS OF POLYPLOIDY

1. **Limited Use.** The single species polyploidy has limited applications. It is generally useful in those crop species which propagate asexually like banana, potato, sugarcane, grapes, etc.
2. **Difficulty in Maintenance.** The maintenance of monoploids and triploids is not possible in case of sexually propagating crop species.
3. **Undesirable Characters.** In bispecies or multipecies polyploids characters are contributed by each of the parental species. These characers may be sometimes undesirable as in case of **Raphanobrassica.**
4. **Some other Defects.** Induced polyploids have several defects such as low fertility, genetic instability, slow growth rate, late maturity, etc.

GLOSSARY

Genome. A basic or monoploid set of chromosome. In a genome, each type of chromosome is represented only once.

Heteroploidy. Any change in the chromosome number from the diploid state. It is of two types, *viz.*, euploidy and aneuploidy.

Euploidy. The change in chromosome number which involves entire set. Euploidy includes, monoploids, diploids and polyploids.

Monoploids. Individuals with basic chromosome number.

Haploids. Individuals with gametic (half) chromosome number. Haploids are of different types.

Euhaploid. Haploids which develop from an euploid species. Euhaploids are of two types, *viz.*, monohaploids and polyhaploids.

Monohaploids. Haploids which develop from a normal diploid species.

Polyhaploids. Haploids which develop from a polyploid species. Polyhaploids again are of two types, *viz.*, allohaploids and auto haploids.

Allohaploids. Polyhaploids which develop from an allopolyploid species.

Autohaploids. Polyhaploids which develop from an auto polyploid species.

Dihaploid. A haploid which develops from a tetraploid species.

Aneuhaploids. Haploids which develop from an aneuploid species. Aneuhaploids are of four types, *viz.*, dihaploids, nullisomic haploids, substitution haploid and miss division haploid.

Disomic haploid. A haploid which develops from a tetrasomic species $(n + 1)$.

Nullisomic haploid. A haploid which develops from a nullisomic (n - 1).

Substitution haploid. A. haploid which develops from a substitution line (n - 1 + 1)

Mis-division haploid. A haploid which has an isochromosome.

Diploids. Individuals with 2x somatic chromosome number.

Polyploid. An individual having more than two basic or monoploid sets of chromosomes. Such conditions is known as polyploidy. Polyploidy is of two type, *viz.*, autopolyploidy and allopolyploidy.

Autopolyploids. Polyploids which develop by multiplication of the chromosome of a single species. It may include triploid (3x), tetraploid (4x), pentaploid (5x) etc.

Alloployploid. A polyploid which originates by combining complete chromosome sets from two or more species.

Amphidiploid. An allopolyploid combining genomes of two diploid species. Colchiploidy. Polyploid which is induced by colchicine treatment.

Aneuploidy. The change in chromosome number which involves one or few chromosomes of thegenome. Aneuploids are of three types, *viz.*, monosomic, nullisomic and polysomic.

Monosomic. An individual lacking one chromosome from a diploid set (2n -1).

Nullisomic. An individual lacking one pair of chromosomes from a diploid set (2n-2).

Polysomic. An individual having either single or one pair of extra chromosome in the diploid complement. Polysomics are of two types, viz., trisomic and tetrasomic.

Trisomic. Addition of one chromosome to one pair in a diploid set. Trisomies are of three types, *viz.*, primary trisomies, secondary trisomies and tertiary trisomies.

Primary trisomic. A trisomic in which the additional chromosome is normal.

Secondary trisomic. A trisomic in which the additional chromosome is isochromosome.

Tertiary trisomic. A trisomic in which the additional chromosome is translocated one.

Tetrasomic. Addition of two chromosomes to one pair or two different pairs.

Simple tetrasomic. Addition of two chromosomes to one pair (2n + 2).

Double tetrasomic. Addition of two chromosomes to two different pairs (2n + 2 + 2).

Hyperploids. Individuals having addition of one or two chromosomes to a single or two different pairs.

Hypoploids. Individuals having loss of one or two chromosomes from the diploid complements.

Alien addition. Adding one chromosome of wild species to the normal chromosome complement of a cultivated species.

Alien substitution. Replacement of one pair of chromosome in cultivated species with that of wild species.

//*//*//*//

EVOLUTION OF CROP PLANTS

A divergent process which increases genetic diversity and leads to change in allelic frequencies in a population is known as evolution. OR

A process which leads to significant deviation in the characteristic features of existing individuals as compared to their pre-existing individuals is termed evolution.

The evolution is of two types, *viz,*

1. Natural evolution: Natural selection operates
2. Man made evolution: Human selection operates

NATURAL EVOLUTION:

EVOLUTION OF WHEAT (*Triticum aestivum*) Hexaploid wheat and Tetraploid wheat (Durum wheat):

Wheat is a cereal crop of global importance. It belongs to the genus Triticum of the family Poaceae (old Gramineae). There are three types of species in the genus Triticum, *viz.*, diploid, tetraploid and hexaploid. The somatic chromosome number of these species is 14, 28 and 42, respectively. Bread wheat (Triticum aestivum) is the predominantly cultivated species, which belongs to the hexaploid group. Other cultivated species are T. monococcum in diploid group and T. turgidum in tetraploid group.

The tetraploid species developed as an **amphidiplod** between two diploid species, and hexaploid species originated from a cross between tetraploid and diploid species. It is believed that tetraploid species Triticum turgidum evolved as an amphidiploid between Triticum **monococcum** (AA) and an unknown species (now probably extinct) with BB genome. The hexaploid bread wheat originated as an amphidiploid between Triticum **turgidum** (AABB) and T. tauschii (DD). The overall process can be represented as follows

Thus, A genome of bread wheat has derived from **T. monococcum,** B genome from an unknown species which is now probably extinct, and D genome from **T. tauschii.** The F_1 was sterile at both the stages, which became fertile through chromosome doubling in nature. Thus, interspecific hybridization and polyploidy have played key role in the evolution **of** bread wheat.

Give the evolution of hexaploid wheat

It is an allohexaploid having two copies each of the genome (ABD).

Triticum monococcum X Unknown Species

2n = 14 (AA) ↓ 2n=14 (BB)

2n = 14 (AB)

↓

Chromosome doubling with colchicine

↓

Tetraploid wheat

2n=4x=28 (AABB)

Triticum turgidum

Tetraploid wheat X *Triticum tauschii*

2n = 28 (AABB) ↓ 2n=14 (DD)

3n = 21 (ABD)

↓

Chromosome doubling with colchicine

↓

Hexaploid wheat

(*Triticum aestivum*)

2n=6x=42 (AABBDD)

EVOLUTION OF COTTON:

Cotton is one of the major fibre crops of global importance. It is grown in more than sixty countries in the world. Cotton belongs to the genus **Gossypium** of the family Malvaceae. There are about 50 species in the genus Gossypium. Some of them are diploid [2n = 26] and some tetraploid [2n = 52]. Out of 50 species, only four species are cultivated, ***viz.,*** *G. arboreum, G.* ***herbaceum,*** *G.* ***hirsutum*** and *G. barbadense.*

This is generally believed by the evolutionists that **Gossypium africanum** (native of South Africa) is the ancestor or progenitor of all cultivated species of cotton. It reached India possibly by sea and over a long time branched into two species, ***viz.,*** **G. arboreum** and **G. herbaceum.** These species have 13 large chromosomes in their haploid complements. The American diploids have 13 small chromosomes in their diploid complements. Skovsted (1937) proposed that tetraploid cottons have developed from natural crossing between diploid species with small and large chromosomes and natural chromosome doubling in the long past

resulted in the evolution of present day tetraploid species. There are two opinions about the origin of upland cotton **(Gossypium hirsutum).** According to Beasley (1940) a possible origin of **G. hirsutum** is from the cross between Asiatic cultivated cotton, **G. arboreum** and American wild species, **G. thurberi** followed by chromosome doubling of F_1 in nature. According to more recent scheme **G. hirsutum** has originated from the cross between **G. africanum** and **G. raimondii** followed by chromosome doubling of F_1 in nature. Now this theory is widely accepted.

The upland cotton (*Gossypium hirsutum*) is an allotetraploid having two copies each of the genomes (AD)

G. africanum X *G. raimondii*

2n = 26 (AA) ↓ 2n = 26 (DD)

2n =26 (AD)

↓

Chromosome doubled

↓

Tetraploid cotton

Gossypium hirsutum

2n = 4x = 52 (AADD)

Short note on 'U' triangle of Brassica.

EVOLUTION OF BRASSICAS:

The genus **Brassica** belongs to the family **Crucifereae** and has several oil bearing species. There are three basic species of **Brassica** from which three different tetraploid species have originated. The tetraploid species have originated through interspecific hybridization between diploid species and chromosome doubling of the F_1 in nature.

Brassica Juncea is natural amphidiploid between B. campestris and B. nigra, **B. napus** is amphidiploid between B. oleracea and B. campestris, and **B. carinata** is amphidiploid between B. nigra and B. oleracea. The origin of different tetraploid species from three diploid basic species can be represented by triangle of U.

* short note on 'U' triangle of Brassica

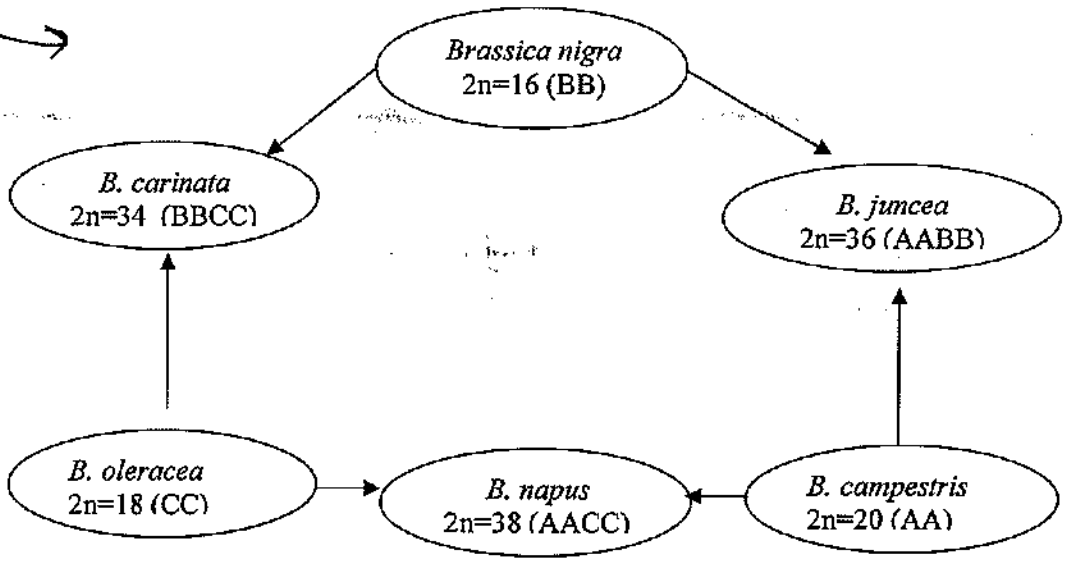


Fig. A simple diagram demonstrating origin of three tetraploid species of ***Brassica, viz., B. juncea, B. carianata* and *B. napus.***

EVOLUTION OF TOBACCO:

Tobacco is a narcotic plant which belongs to the genus Nicotiana in the family Solanaceae. It is a native of America, but now it is grown in all the countries of South and South-East Asia. There are two cultivated species of tobacco, ***viz., Nicotiana tabacum* and *N. rustica.*** Both these species are tetraploid (2n = 48). The wild species are diploids.

It is believed that ***Nicotiana tabacum*** has originated as an amphidiploid between two diploid wild species, *viz., N. sylvestris* and *N. tomentosa*. Similarly, ***N. rustica*** is believed to be an amphidiploid between wild diploid species *N. paniculata* and *N. undulata.*

N. sylvestris (n = 12) X *N. tomentosa* (n = 12)

↓

Sterile (2n = 24)

↓

Chromosome doubling with colchicine

↓

Fertile (4n = 48). *N. tabacum*

N. paniculata X *N. undulata*

(n = 12) (n = 12)

↓

Sterile

(2n = 24)

↓

Chromosome doubling with colchicine

↓

Fertile (4n = 48)

N. rustica

EVOLUTION OF TRITICALE: {MAN MADE CEREAL}

Triticum turgidum X Rye

(2n = 28) (2n=14)

AABB CC

↓

F_1 ↓ 2n = 21 (ABC)

Sterile, because A & B not pair

↓

Chromosome doubling by colchicine

↓

2n = 42 (AABBCC) Amphidiploid fertile

Triticale – A new species (Hexaploid)

//*//*//*//

MENDELIAN PRINCIPLES OF HEREDITY

Mendel's Laws

- The first systematic approach for the investigation of **mechanisms of inheritance** was made by **Gregor Johann Mendel** in the nineteenth century. Mendel was born in 1822 near Brunn in Austria, in a farmer family. He had collected commercial peas varieties from different parts of Europe.
- He had systematically worked on a crop - Garden Pea (*Pisum sativum*) and invented the **principles of inheritance** and which laid the foundation of new branch of biology that is **Genetics,** and for his pioneer work on principle of heredity, he is known as **Father of Genetics.**

Mendel's Experimental Materials:

Mendel has selected garden pea as a experimental material for his experiment, which has following advantages:

- Well defined characters
- Bisexual flowers
- Pre-dominantly self pollinated crop
- Easy hybridization
- Short crop duration

Characters studied by the Mendel: * list out the characteristic studied by Mende

Mendel had worked on garden pea and studied the **dominant and recessive behaviors** on a seven different characters.

Sr.	Character	Dominant	Recessive
1	Plant height	Tall	Dwarf
2	Position of the flower	Axial	Terminal
3	Shape of the pod	Inflated	Constricted
4	Colour of the pod	Green	Yellow
5	Seed shape	Round	Wrinkled
6	Seed colour	Yellow	Green
7	Seed coat colour	Grey	White

Based on the seven years studies (1856-1864), he discovered two important laws of heredity that is

1. Law of segregation
2. Law of independent assortment

- Mendel's had published the research work first time **(1866)** in **Natural History Society of Brunn** in form of two research papers in **Annual proceeding of the society.**
- Title of paper : **"Experiments in plants"** in German language
- Mendel's work came into light in 1900, when three scientists *viz.*, **De Vris (Holland), Correns (Germany) and Tschemark (Austria)** rediscovered the mendel's work.

Key Terminology:

- **Hereditary Determinants**: The entries which are responsible for inheritance of characters from one generation to another are called as hereditary determinants or factors. Nowadays, these factors are referred as gene.
- **Alleles** : The alternative form of the gene is called as alleles. (R and r)
- **Locus / Loci**: The position at which gene/alleles are located on the chromosome is referred as locus.
- **Gamete:** It refers to the sexual unit. Usually the sex cells are usually called as gamete.
- **Dominant character:** The character which express in F_1 generation is called as the dominant character.
- **Recessive character**: The character which cannot expressed in presence of dominant character or The character which cannot expressed in F1 generation is called as recessive character.
- **Genotype**: The genetic constitution of an organism is referred as genotype.
- **Phenotype**: The observable characteristics of an organism or the out ward appearance of an individual is referred as phenotype.
- **Homozygote**: An individual possessing both the identical alleles for a given character at corresponding loci of a homologous chromosomes is referred as homozygote. Example – TT or RR.
- **Heterozygote**: An individual possessing both the different alleles for a given character at corresponding loci of a homologous chromosomes is referred as homozygote. **Ex.** – Tt or Rr.

- **Dominant allele:** The gene express its phenotypic effects in heterozygote condition is referred as dominant allele.
- **Recessive allele:** The gene which cannot produce its phenotypic effect in heterozygote condition but produce its phenotypic effect in homozygous condition is referred as recessive allele.
- **Monohybrid**: A cross between two parents differing for a single character is referred as monohybrid.
- **Dihybrid**: A cross between two parents differing for a two different characters is referred as dihybrid.
- **Back cross:** A cross of F1 with either of its parents is referred as back cross.
- **Test cross:** A cross of F1 with homozygous recessive parents is referred as test cross.
- A test cross always considered as back cross but the back cross may or may not considered as test cross.
- **Direct cross:** A cross between two individuals is referred as direct cross. $A \times B = F_1$
- **Reciprocal cross:** when we change the order of individual in crosses by reversing the use of male and female it is referred as reciprocal cross. $B \times A = F_1$.

Que :- Explain the law of segregation with suitable example.

Law of segregation / Law of purity of gamete:

The laws states that **alleles separate from each other during gamete formation and pass into different gamete in equal number**.

In other words, when alleles of two contrasting characters come to gether in a hybrid, **they do not blend, contaminate or affect each other while to gether**. The different genes separate from each other in a pure form pass on to different gametes formed by the hybrid and then go into different individuals in the offspring of the hybrid.

Main features of the law of the segregation:

- When dominant and recessive alleles of a gene come to gether in a single hybrid, they do not mix or blend together.
- The alleles remain together in pure form without affecting each other and for this reason, the law of segregation is also referred as law of purity of gamete.
- The allele separate into different gametes in equal number.
- Separation of two alleles are take place due to separation of homologous chromosomes during meiosis (Anaphase-I).

- In case of complete dominance, for single gene the phenotypic segregation ratio in F_2 generation is 3 : 1 and for two genes it is 9 : 3 : 3 : 1.

Example: (Monohybrid Cross)

When we make a cross between round (RR) and wrinkled (rr) seed shaped plants, The seeds shape resulting in the F_1 hybrids were all round type but the F_2 generation produced from F_1 generation selfing were having two kinds of seed shape i.e round seed and wrinkle seed. Out of every four seeds, three were of round seed shape type and one was having wrinkled seed shape. The detail diagrammatically explanation is given in Figure.

Parents : Round seed shape **(RR)** X Wrinkled seed shape **(rr)**

⇩

F_1 :- **Rr** (Round seed shape)

F_2 :-

F\M	**R**	**R**
R	RR (Round seed)	Rr (Round seed)
r	Rr (Round seed)	Rr (Wrinkle seed)

Phenotypic ratio:- 3 : 1 (Round seed shape : Wrinkle seed shape)

Genotypic ratio:- 1 : 2 : 1

Ques:- Explain the law of independent assortment with example

Law of independent assortment:

The law of independent assortment states that when two pairs of gene enter in F_1 combination, **both of them have their independent dominant effect.** These genes segregate when gametes are formed but the **assortment occurs randomly and quite freely.**

Important features of law of independent assortment

- This law explains the simultaneous inheritance of two plant characters.
- In F1, when two genes controlling two different characters come together each gene exhibits independent assortment behavior without affecting or modifying the effect of other gene.

- The two gene pairs involved are segregate independently.
- The alleles of one gene pair are freely combine with the alleles of another gene. Thus, the each gene having equal chance to combine with each allele of another gene.
- Each of two gene pairs when considered separately, they exhibit typical 3 : 1 segregation ratio in F2 generation.
- Free assortment of alleles of two genes leads to formation of new gene combinations.

Example: (Dihybrid Cross)

In a garden pea, yellow round seeded (YYRR) plants crossed with green wrinkle (yyrr) seed shaped plants, The seeds resulting in the F_1 hybrids were all yellow round seed but the F_2 generation produced from F_1 generation selfing were having four kinds of seeds i.e yellow round (YR), yellow wrinkle (Yr), green round (yR) and green wrinkle seed (yr) in a proportion of 9 : 3 : 3 : 1. The detail diagrammatically explanation is given in Figure.

Parents : Yellow Round seed **(YYRR)** X Green Wrinkled seed **(yyrr)**

⇩

F_1 : **YyRr** (Yellow Round seed)

F_2 :

F\M	**YR**	**Yr**	**yR**	**Yr**
YR	YYRR Yellow Round	YYRr Yellow Round	YyRR Yellow Round	YyRr Yellow Round
Yr	YYRr Yellow Round	YYrr Yellow Wrinkle	YyRr Yellow Round	Yyrr Yellow Wrinkle
yR	YyRR Yellow Round	YyRr Yellow Round	yyRR Green Round	yyRr Green Round
yr	YyRr Yellow Round	Yyrr Yellow Wrinkle	yyRr Green Round	Yyrr Green Wrinkle

Phenotypic and Genotypic ratio:

Genotypes	Genotypic ratio	Phenotypes	Phenotypic ratio
YYRR	1	Yellow & Round	9
YYRr	2		
YyRR	2		
YyRr	4		
YYrr	1	Yellow & Wrinkle	3
Yyrr	2		
yyRR	1	Green & Round	3
yyRr	2		
Yyrr	1	Green & Wrinkle	1

Reasons of the Mendel's success:- Ans:- Give the reasons of Mendel success-

1. **Proper maintenance of record**

   Mendel have maintained separate, systematic, generation wise record of all seven characters, which help him a lot to analyze and to understand the inheritance mechanism of various characters.

2. **Study of individual character**

   At a time he had focused on a single character. So it becomes easy to understand the inheritance pattern.

3. **Choice of the materials**

   Mendel has selected garden pea as an experimental material and it has several advantages like hermaphrodite flower, self pollinated crop, short crop duration and easy hybridization. It is also possible to raise more than one generation in a year and the garden pea flower is also ideal for selfing and emasculation.

4. **Maintenance of purity**

   Mendel has maintained the purity of the material by selfing.

5. **Always used pure materials.**

6. **Knowledge of shortfall of earlier worker**

   He has also studied the work made by earlier worker, so he got proper directions and it has helped him for better planning of his experiment.

7. **Mathematical background**

   Basically the background of Mendel was Mathematics and Physics, which help him a lot to analyze the collected data.

8. **Proper choice of the characters**

   Mendel has recorded seven contrasting characters for his experiment.

★ **Reasons for The Neglect of Mendel's Findings** ★ Give the reasons of Mendel's failure

- ✓ Mendel used mathematical principles of probability and distribution (binomial) to explain a biological phenomenon. This was something new and not readily acceptable to biologists.
- ✓ Mendel's result did not match those of other scientists who also used plants to try studying heredity.
- ✓ The phenomena of fertilization and the behaviour of chromosome during cell divisions (mitosis & meiosis) were not known at the time when Mendel presented his findings. Clearly, Mendel was much ahead of his time to be understood and appreciated.
- ✓ Mendel did not publicise his findings through further writing on the subject after his initial paper.
- ✓ Mendel failed to demonstrate the validity of his conclusions in other species. He was distinctly unlucky in selecting Hieraceum (a facultative apomict) and honey bees (having haploid males) as experimental materials. As a result, he failed to verify his conclusions from pea in these organisms.
- ✓ Mendel corresponded extensively with his contemporary, the noted botanist, Carl Nageli. Mendel informed Nageli about his failure to verify his conclusions in Hieraceum and other plants. This may have created a doubt about the applicability of Mendel's conclusions to plants other than pea.

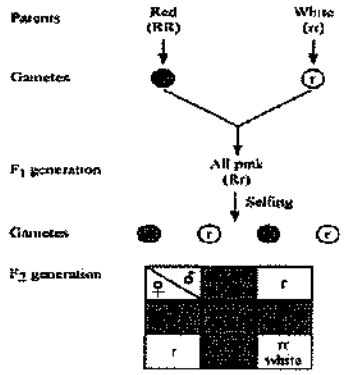
EXTENSIONS OF MENDELIAN CONCEPTS

The basic principles of heredity were initially discovered by Mendel in 1866 and rediscovered by de Vries, Correns and Tschermak in 1900. Later on these principles were clarified and confirmed by several researchers and some new concepts were investigated. Some of the new concepts were at variance with the findings of Mendel. ***These are called as Mendelian deviations or exceptions or anomalies.*** Such investigations, include

Short Note

1. Incomplete Dominance

Mendel always observed complete dominance of one allele over the other for all the seven characters which he studied in garden pea. Later on cases of incomplete dominance were reported. For example, in four 'o' clock plant (Mirabilis jalapa) there are two types of flowers, *viz.*, red and white. A cross between red and white flowered plants produced plants with intermediate flower colour, *i.e.*, pink colour in F, and a modified ratio of 1 red : 2 pink : 1 white was observed in F_2

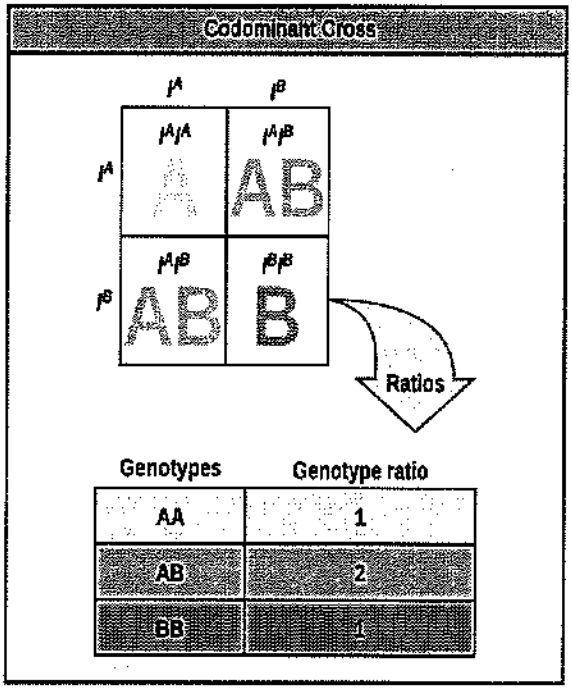


- Phenotypic Ratio – 1:2:1 that denotes Red: Pink: White
- Genotypic Ratio – 1:2:1 that denotes RR: Rr: rr

Short Note

2. Codominance

In case of codominance both alleles express their phenotypes in heterozygote. The example is AB blood group in human. The people who have blood type AB are heterozygous exhibiting phenotypes for both the I^A and I^B alleles. In other words, heterozygotes for codominant alleles are phenotypically similar to both parental types. The main difference between condominance and incomplete dominance lies in the way in which genes act. In case of codominance, both alleles arc active, while in case of incomplete dominance only one allele (dominant) is active.



3. Multiple Alleles

Mendel always observed two allelic forms of a gene. Now cases are known where a gene has more than two allelic forms, although only two can exist in a diploid cell at a time. Existence of more than two alleles for a gene is called multiple alleles. Examples of multiple alleles are ABO blood group alleles in human, coat color in rabbit and self incompatibility alleles in tobacco.

4. Linkage

Mendel always observed independent assortment of genes. Later on cases of Linkage were reported by Bateson and Punnett in 1906 in pea, Hutchinson in maize and Morgan (1910) in **Drosophila.** In a dihybrid test cross, they observed higher frequencies of parental types than recombinants instead of 1 : 1 : 1 : 1 ratio. This led to modification of the concept of independent assortment.

5. Lethal Genes

Gene which causes the death of its carrier when in homozygous condition is called lethal gene. Mendel's findings were based on equal survival of all genotypes. In the presence of lethal genes, the normal segregation ratio of 3 : 1 is modified into 2 : 1 ratio. Lethal genes have been reported in both animals as well as plants. In mice, allele for yellow coat color is dominant over grey. When a cross is made between yellow and grey, a ratio of 1:1 for yellow and grey mice was observed. This indicated that yellow mice are always heterozygous, because yellow homozygotes are never born because of homozygous lethality. Such genes were not observed by Mendel. He always got 3 : 1 ratio in F_2 for single gene characters.

6. Gene Interactions

When the expression of an allele of one gene pair depends on the presence of a specific allele of another pair, it is known as gene interaction. Mendel observed 9 : 3 : 3 : 1 ratio in F_2 from a dihybrid cross. Later on many deviations of this phenotypic ratio were observed in dihybrid crosses. The modified ratios included 9 : 7, 9 : 3 : 4, 12 : 3 : 1, 13 : 3 : 15 : 1 and 9 : 6 : 1 in different crop plants.

7. Pleiotropic Gene Effects

Mendel observed that one gene controls the expression of only one character. Later on cases were observed in which one gene was found to govern the expression of two or more characters. Example is white eye allele in **Drosophila.** This allele affects eye colour, shape of spermathica, fecundity and testicular membrane.

8. Polygenes

Mendel always observed that each character is governed by a single gene. Later on Nilsson Ehle observed that some characters are controlled by several genes and each of such gene has additive effect in the expression of character. This concept led to the foundation of polygenic inheritance. East (1916) demonstrated that polygenic characters were perfectly in agreement with Mendelian segregation and later on Fisher and Wright provided a mathematical basis for the genetic inteipretation of polygenic characters.

9. Environmental Effects

Genes can interact not only with other genes but also with the environment to produce the - final phenotype. Thus phenotype is the result of the interaction between genotype and environment. It leads directly to the concept of penetrance and expressivity. The importance of environment was first realised by Johannsen. He coined the terms genotype and phenotype.

10. Maternal Effects

Mendel did not observe any difference between direct and reciprocal crosses. Later investigations revealed the presence of significant difference in the reciprocal crosses, which led to the concept of cytoplasmic inheritance.

//*//*//*//

GENETIC MATERIAL

NUCLEIC ACID AS GENETIC MATERIAL

- There are two types of genetic materials – DNA & RNA.
- Nucleic acid found in the cells of all living organisms
- DNA found in chromosomes (Nucleus), whereas RNA mostly found in the ribosomes (cytoplasm)
- DNA is the genetic materials of all living organisms (Bacteria, animals, higher plants, human being), whereas RNA is the genetic material of some of viruses
- Nucleic acid – First isolated by Miescher (1871) and it was known as nuclein, but later on in 1899 Altmann used the term nucleic acid for nuclein

Difference between DNA and RNA

Particulars	DNA	RNA
Strands	Usually two, Rarely one	Usually one, Rarely two
Sugar	Deoxyribose	Ribose
Bases	Adenine, Guanine, Cytosine and Thymine	Adenine, Guanine, Cytosine and Uracil
Pairing	AT and GC	AU and GC
Location	Mostly in chromosomes, some in mitochondria and chloroplast	In chromosomes and ribosomes
Replication	Self replicating	Formed from the DNA. Self replicating in some form of viruses
Size	Contain 4.3 million nucleotides	Contain 12000 nucleotides
Functions	Genetic code	Protein synthesis, genetic in some viruses
Types	Several forms	Three types : mRNA, tRNA and rRNA

Structure of DNA

The molecular model of the DNA structure was proposed by Watson and Crick in 1953.This model was universally accepted and because of that contribution they got Noble prize in 1958.

Q. Enlist the characteristics of genetic material
Q. Diff. between Nucleotide & Nucleoside.

Main features of the model (Double helical model)

- The DNA has a double helical structure. Each DNA molecules consist of two strands of the DNA which are spirally arranged in clock-wise direction
- Each strand consists of deoxyribose sugar and phosphate group arranged in alternate fashion
- Two strands are connected by purines and pyrimidine bases
- A combination of deoxyribose sugar and nitrogenous base is known as nucleoside
- A combination of nucleoside and phosphate is known as nucleotide
- Total 10 nucleotides are there per turn. Thus each nucleotide consist of 3.4^0
  - **Nucleoside** = Deoxyribose sugar + nitrogenous base
  - **Nucleotide** = Deoxyribose sugar + nitrogenous base + phosphate
- A combination of several nucleotide leads to formation of polynucleotide chain. Which consist thousands pairs of nucleotide monomers
- Total number of purines are always equal to number of pyrimidines
  - **A + G = C + T**
- Base paring between purines and pyrimides taken place in a definate fashion
- Adenine always pair with Thymine and Guanine with cytosine
- Adenine are joined with Thymine by doubie hydrogen bond
- Guanine are joined with cytosine by triple hydrogen bond
- These bonds are weaker in nature, that will help DNA in separation of strands during replication
- The width of the DNA molecules is 2 nm and in one turn of two strands is completed in 3.4 nm

Nitrogenous bases of DNA :

- Two types of nitrogenous bases : Purines and Pyrimidines

<u>Pyrimidines</u> –

- Single ring structure
- Three types – Cytosine, Thymine and Uracil
- Cytosine and Thymine founds in DNA and Cytosine and Uracil in RNA

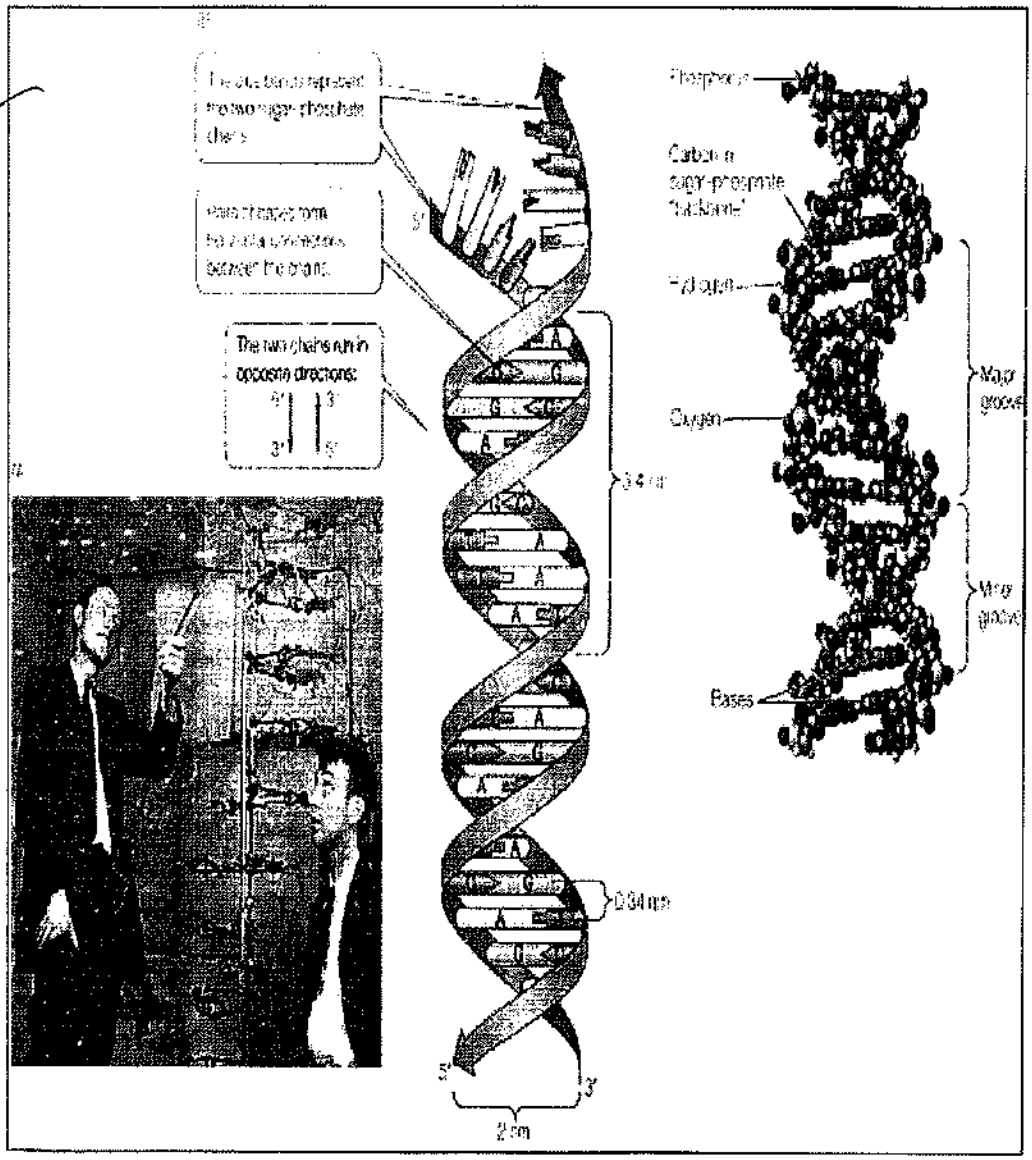
<u>Purines</u> –

- Double ring structure

- Both in DNA and RNA – Adenine and Guanine

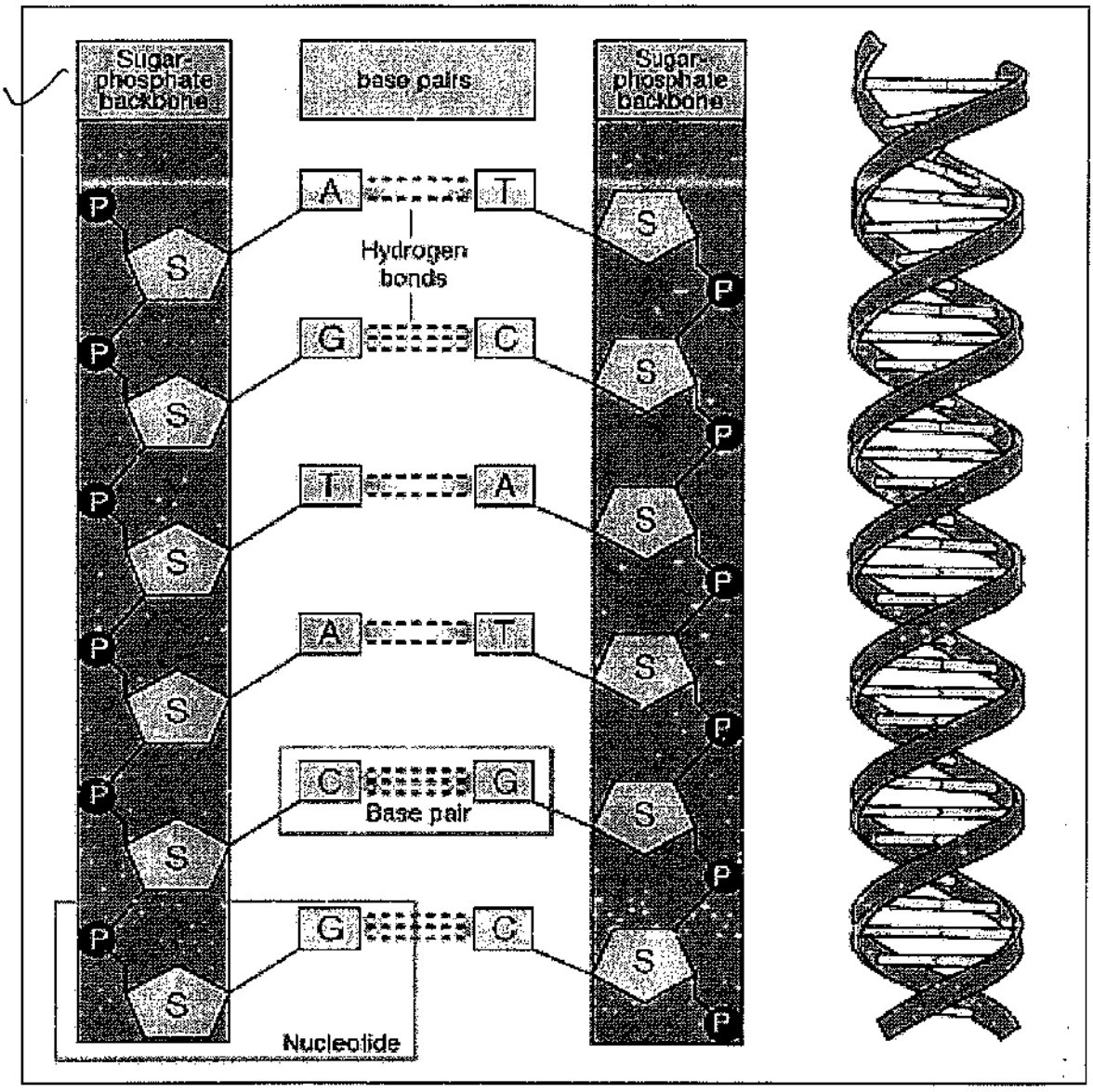
Base paring – In DNA the pairing between purines and pyrimides taken place in a definite fashion

- Adenine always pair with Thymine and Guanine with cytosine
- Adenine are joined with Thymine by double hydrogen bond
- Guanine are joined with cytosine by triple hydrogen bond
- These bonds are weaker in nature, that will help DNA in separation of strands during replication



Watson and Crick model (Double helical structure of DNA)

Clue:- Illustrate (Diagram) the DNA model proposed by Watson & Crick & mention the salient features of it.



Base pairing in double stranded DNA :

Differences between Pyrimidines and Purines :

	Pyrimidines	Purines
1	These are single ring structure	These are double ring structure
2	They are three types : Cytosine, Thymine and Uracil	They are two types : Adenine and Guainine
3	It occupy less space in DNA structure	It occupy more space in DNA structure
4	The pyrimidines is linked with deoxyribose sugar at position 3	Deoxyribose is linked at position 9 of purines

Functions of the DNA :

- DNA (Deoxyribose nucleic acid) is the act as the genetic material of majority of living organisms like in prokaryotes, eukaryotes and some of the viruses.
- DNA is the genetic code, which ensures that daughter cells inheritate the same characteristics as the parent cells
- DNA is the code from which all protein is synthesized

Types of the DNA

The DNA can be classified on the basis of

1. Number of base pair per turn
2. Coiling pattern
3. Location
4. Structure
5. Nucleotide sequences
6. Number of strands

1. Number of base pair per turn :

Depending upon the nucleotide base per turn of the helix, pitch of the helix, tilt of the base pair and humidity of the sample, the DNA can be observed in four different forms namely A-DNA, B-DNA, C-DNA & D-DNA.

2. Coiling pattern :

On the basis of coiling pattern of the helix, DNA is of two types i.e Right handed and left handed

- Right handed DNA : The coiling of the helix is in the right direction.
- Left handed DNA : The coiling of the DNA is in the left direction. The Z-DNA has left handed double helical structure.

Comparison of the different forms of the DNA molecules :

Parameters	A-DNA	B-DNA	C-DNA	D-DNA	Z-DNA
Coiling of the helix	Right handed	Right handed	Right handed	Right handed	Left handed
Sugar phosphate linkage	Normal	Normal	Normal	Normal	Zig zag
Base pair per turn	11	10	9.3	8.0	12
Pitch of the helix	2.8	3.4	3.1	--	4.5

3. Location :

Based on the location it be classified into three sub group

- Chromosomal DNA : The DNA found on the chromosome
- Cytoplasmic DNA : It indicating the Mitochondrial DNA (mtDNA) or chloroplast DNA (cpDNA)
- Promiscuous DNA : DNA segment with common base sequences of chloroplast, mitochondria and nucleus can move from one organelle to other, such DNA is referred as promiscuous DNA

4. Structure:

Based on the structure, DNA is of two types viz., linear and circular

- Linear DNA – The DNA is thread like structure with both ends free, founds in eukaryotes
- Circular DNA – The DNA having ring or circular shape and found in prokaryotes . Viruses & bacterial DNA molecules are circular.

5. Repetition of base sequence

On the basis of the copies of the nucleotide sequences, the chromosomal DNA is of two types (1) Repetitive DNA and (2) Unique DNA

Repetitive DNA : The DNA in which small sequences of bases are repeated several hundred times.

- It is also known as satellite DNA
- Several thousands of copies of this type of DNA is found in cell
- Such DNA found near the centromere in chromosomes

- Repetitive DNA is found in almost all eukaryotes
- The percentage of repetitive DNA also varies from species to species
- Example : Proportion of repetitive DNA in Humans – 30 %, Drosphilla- 25 %, Mouse – 30 %, 75 % in pea.

Unique DNA : : In DNA molecules, some of the nucleotides or segments have only single copy per genome, such type DNA is known as unique DNA.

- The unique DNA is higher in animals than in plants
- Proportion of unique DNA : 70 % in man, 17 % in wheat and 8 % in rye.
- Unique DNA plays an important role in gene regulation.

6. Number of strands:

Based on the number of strands DNA is of two types : Double stranded and single stranded DNA.

- Double stranded DNA : The DNA with two helical structure is known as a double stranded DNA. In most of the organism this kind of DNA is found.
- Single stranded DNA : The DNA with one helix is known as single stranded. Such kind of DNA is found in bacteriophases.

Que :- Prove that DNA is the genetic material by experim

EVIDENCE FOR DNA AS A GENETIC MATERIAL

There are some experimental evidence which prove that in most of the organisms DNA is the genetic material and only in some viruses RNA is the genetic material.

1. Transformation

The generic recombination in which naked DNA from one cell can enter and integrate in another cell is referred to as genetic transformation. Experiments on genetic transformation were conducted by Griffith (1920; and Avery, Macleod and Mc Carty (1944) which support that DNA is the genetic material. These experiments are discussed as follows.

Griffith's Experiment [1920]

Organism Used. Mice and pneumonia causing bacteria *Diplococcus pneumoniae.*

Principle Involved. The virulent strain causes pneumonia and death of mice, where as avirulent strain does not cause pneumonia. The experiment is based on the principle of genetic transformation.

Procedure Adopted. There are two types of strains in above bacteria, *viz.* virulent with smooth surface [having coating of polysaccharide] designated as SIII; and avirulent with rough surface [without coating] designated as RII. The virulent strain causes pneumonia and death of mice, where as avirulent strain does not cause pneumonia. Griffith injected strains of Diplococcus pneumoniae bacteria into mice in following four combinations and recorded the results.

1. Virulent strain SIII which causes pneumonia.
2. Avirulent strain RII which does not cause pneumonia.
3. Heat killed virulent strain SIII.
4. Mixture of heat killed virulent strain SIII + avirulent strain RII.

Results

S.N.	*Strain injected*	*Effect on mice*	*Recovery of SHI in mice*
1.	Virulent SIII	Mice die	SIII recovered
2.	Avirulent RII	Mice survive	SIII not recovered
3.	Heat killed SIII	Mice survive	SIII not recovered
4.	Heat killed SIII + RII	Mice die	SIII recovered

Conclusion. The results suggest that the chemical from the heat killed bacteria transformed the avirulent bacteria into virulent which caused death of the mice. However, Griffith could not conclude that the transforming chemical was DNA.

Avery, Macleod and McCarty Experiment [1944]

Organism Used. They used pneumonia causing bacteria *Diplococcus pneumonia.* These experiments provided the first evidence that DNA was the genetic material.

Principle Involved. The extract from virulent strain will lead to transformation.

Procedure Adopted. Avery, Macleod and McCarty isolated DNA from virulent strain (SIII) and applied the same in culture medium of avirulent strain [RII] in following four combinations and recorded the results.

I. DNA extract from heat killed virulent strain SIII which contains all the components *i.e.* DNA, RNA and proteins.

II. DNA extract from heat killed virulent strain SIII treated with DNAase enzyme which digests DNA, so there are RNA and proteins but no DNA.

III. DNA extract from heat killed virulent strain SIII treated with RNAase enzyme which digests RNA, so there are DNA and Proteins but no RNA.

IV. DNA extract from heat killed virulent strain SIII treated with protease enzyme which digests proteins, so there are DNA and RNA but no protein.

S.No.	*Extract applied in RII culture*	*Bacteria recovered after few hours*
1.	DNA extract from heat killed SIII	Few SIII strains in RII were recovered
2.	DNA extract from heat killed SIII treated with DNAase enzyme which digests DNA	Only RII strains were recovered
3.	DNA extract from heat killed SIII treated with RNAase enzyme which digests RNA	Some SIII strains with RII were recovered
4.	DNA extract from heat killed SIII treated with protease enzyme which digests proteins	Few SIII colonies with RII were recovered

Conclusion. They concluded that DNA was the genetic material and not the proteins. Because the transformation occurred when DNA was present in the extract and there was no transformation when DNA was digested with DNAse enzyme.

Ques:- Explain the types of DNA replication

DNA REPLICATION :

The process by which a DNA molecule makes its identical copies is known as DNA replication. There are three possible ways of DNA replication :

1. Dispersive
2. Conservative
3. Semi conservative

Dispersive Replication :

- In this method, the two strands of DNA break at several points resulting in several pieces of DNA.
- Each piece replicates and reunited randomly.
- Finally two copies of the DNA form from a single copy.
- The new DNA molecules are hybrid, which have old and new DNA in patches.
- This method is not accepted because replication could not prove experimentally.

Conservative replication :

- In conservative replication, two DNA molecules are formed.
- One molecule has both parental strands and the other contain both newly synthesized strands.
- This method is also not accepted because of no experimental proof in support of this model.

Semi conservative replication :

- Semi conservative mode of DNA replication was proposed by Watson and Crick.
- In this type of replication, both the strands of parental DNA separates from one another and from each of the old strand new strand synthesize.
- Thus each of two resulting DNA molecules has one parental and one new strand.
- This method of DNA replication was universally accepted, because so many evidence are there in support of this replication.

Steps of semi conservative method of DNA replication

Semi conservative method of DNA replication involved following steps :

1. Initiation of DNA replication :

- DNA replication is start at **a specific point** of the chromosome and this unique site is referred as **origin.**
- This origin site is differ from organism to organism.
- Some time it start with an **incision,** which is made by enzyme which is known as endonuclease.

2. Unwinding of strands :

- The two strands of the DNA double helix unwind.
- The opening of DNA strands taken place with the help of unwinding protein.

- This protein also unites together both the strands and hence this protein is also known as **DNA binding protein.**

3. Formation of RNA primers :

- RNA primer is essential for the formation of DNA synthesis.
- RNA primer is synthesized by the DNA template near the origin with the help of a special type of RNA polymerase.

4. Synthesis of DNA on RNA primer :

- After the formation of RNA primer, DNA synthesis starts on the RNA primer.
- Deoxyribose nucleotides are added to the 3" end position of RNA primer.
- The main DNA strand is synthesized on the DNA template with the help of DNA polymerase.
- The newly synthesized short pieces of DNA is known as **Okazaki** fragments
- Synthesis of new strands takes place in 5" – 3" and its other form in opposite direction.
- During replication it is possible that, the one strand of DNA can replicate continuously and other strand replicate discontinuously or in pieces.
- During replication of DNA, one strand replicate continuously is referred as **leading strand** and other strand replicate discontinuously or replicate in pieces is referred as **lagging strand.**
- The DNA replication in which, one strand replicate continuously and other discontinuously, such type of replication is referred as semi-discontinuous replication.

5. Removal of RNA primer:

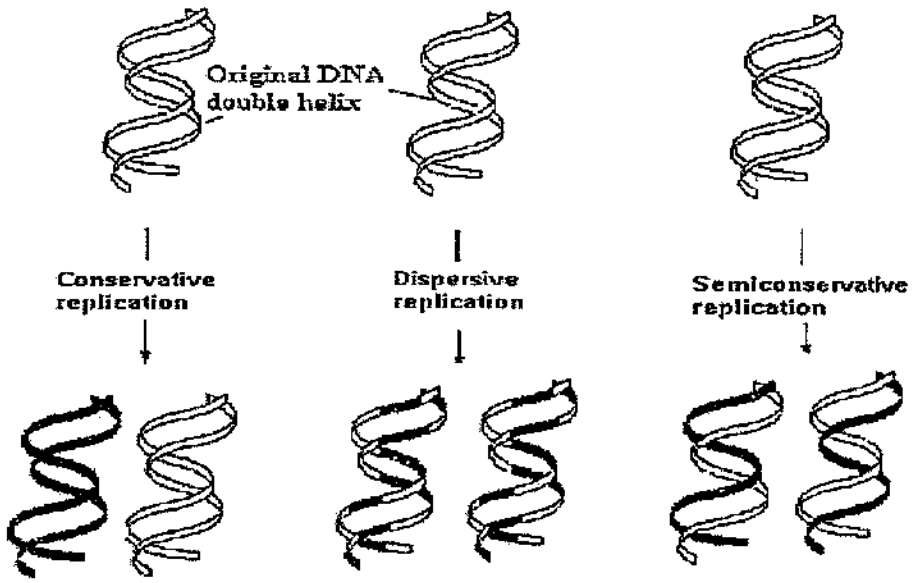
- The RNA primer is degraded by DNA polymerase-I, which activates the synthesis of short DNA segment to replace the primer.
- The newly synthesized segment is joined to the main DNA strand with the help of DNA ligase enzyme.

6. Union of Okazaki fragments:

In this process, discontinuous fragments of newly synthesized new fragments joined to make continuous strand

- The above union is take place with the help of joining enzyme called polynucleotide ligase.
- The replication may take place either in one direction or both the direction from point of origin.

- If replication of DNA in one direction it is referred as **unidirectional**, but if it is proceed in both the directions it is called as **bidirectional replication**.
- Bidirectional replications do take place in prokaryotes, drosophila and man.



Possible Models of DNA Replication

<u>RNA structure</u>

<u>Important features of RNA:</u>

1. **Location**
   - Found in the cells of all living organisms
   - Found both nucleus and cytoplasm
   - In Nucleus – Mainly found in the chromosomes
   - In Cytoplasm – present in the ribosome
2. **Chemical structure**
   - Ribosome's are composed of ribose sugar, nitrogen bases and phosphate group
   - Nitrogen bases – A, G, C & U
   - Pairing – AU & GC
3. **Synthesis**
   - RNA synthesis take place in the nucleus on DNA template

- After synthesis it moves from nucleus to cytoplasm (RNA does not having self duplication property)
- Exception of self duplicationsis found in TMV and plantango viruses

4. **Strand number**
   - RNA is usually single stranded
   - Double stranded RNA – reo virus in animals & Wound tumor virus in plants
   - Single stranded RNA folded upon itself either entirely or in some regions
   - Most of the bases in the folded regions are complementary and are joined by hydrogen bond
   - In unfolded regions bases do not have complements and due to it the purines and pyrimidine ratio are not equal
5. **Types**
   - Mainly of three types – mRNA, rRNA and tRNA or sRNA (Soluble RNA)
   - rRNA and tRNA consist 98 % of total RNA
   - All three forms of RNA synthesis on DNA templates
6. **Size**
   - RNA molecules are much in smaller size than DNA
   - RNA consist 12000 nucleotides
   - DNA consist 4.3 million nucleotides
7. **Functions**
   - The common function of RNA is to transfer genetic message from nucleus to cytoplasm.
   - Synthesis of protein in the ribosome.
   - In some form of viruses it also act as genetic materials and regulate the gene action

Types of RNA

On the basis of functions RNA is of two types:

1. Genetic RNA – One type
2. Non-Genetic RNA – Three types (m-RNA, r-RNA and t-RNA)

Genetic RNA:

- The RNA which acts as the genetic materials or like DNA is called genetic RNA.

- Such RNA found in most of plant viruses like TMV, HRV, some animal viruses, bacteriophases etc
- It may be single or double stranded.
- It is having self replicating property.

Non-Genetic RNA:

- The RNA which does act as the genetic material is referred as non genetic RNA.
- Found in the organism where DNA is the genetic material.
- Such RNA is single stranded.
- It is not having self replicating property.
- Such RNA synthesized from the DNA templates in the presence of DNA dependant RNA polymerase enzyme.

Difference between genetic RNA and Non-Genetic RNA :

Sr.	Genetic RNA	Non-genetic RNA
1	It act as the genetic material	It does not act as the genetic material
2	It found in plant viruses, in some animal viruses and in bacteriophases	It found in all the higher organisms including plant, animals and bacteria
3	It has a self replicating property	It does not having a self replicating property
4	It is found in absence of DNA	It is found in association with DNA
5	It is of one type	It is of three types (m-RNA, t-RNA and r-RNA)
6	Main functions is regulation of gene action	Main function is synthesis of proteins
7	It may be single or double stranded	It is always single stranded

Que:- Explain the types of RNA

Messanger RNA (m-RNA):

- **It carries the information for protein synthesis from DNA to ribosome** (site of protein synthesis) is called as the messenger RNA.
- It consist 5-10 % of total cellular RNA.
- Its molecular weight of an average molecule of mRNA is 5,00,000.
- Its sedimentation coefficient is 80S.

Que:- Enlist the kinds of RNAs along with their function.

- In bacteria -it is short lived, In E-coli – average half life is 2 minutes and in mammals – many hours to days.
- Each gene transcribe its own RNA, so there are many types of mRNA.
- The different types of RNA also differ in their base sequence and their length
- One gene (cistron) code for one molecules of mRNA is referred as **Monocistronic mRNA.**
- One molecules of mRNA coded by several cistrons is referred as **Polycistronic mRNA.**

Ribosomal RNA (r-RNA):

- The RNA which is found in the ribosome in the cytoplasm is called ribosomal RNA.
- It consist 80 % of the total RNA.
- Ribosomal RNA is more stable than mRNA.
- Ribosomal RNA is synthesized from nucleolar DNA in eukaryotes and form a part of DNA in prokaryotes
    - On the basis of molecular weight and sedimentation rate ribosomal RNA is of three types :With molecular weight over a million (21S-29S RNA)
    - With molecular weight below one million (12S-18S RNA)
    - With low molecular weight (5S RNA)
- The main function **of ribosomal RNA is binding of mRNA and tRNA to ribosomes**

Transfer RNA (t-RNA):

- Transfer RNA is also known as soluble RNA (sRNA)
- It constitutes about 10-15 % of the total RNA
- It has molecular weight of about 25000-30000 with sedimentation coefficient of 3.8 S.
- It contains 73 to 93 nucleotides.
- It is synthesized on the DNA templates using small section of the DNA molecule. It is synthesized at the end of the cleavage.
- The main function is to **carry various types of amino acids and attach them to mRNA template for the synthesis of protein.**
- There are 20 different types of amino acids, therefore there should be at least 20 different tRNA. (> 20 tRNA).

//*//*//*//

GENETIC CODE

★ **Genetic code :**

- Genetic code refers to the relationship between the sequence of base in RNA and the sequence of amino acids in a polypeptide chain. OR
- The relationship between the four letters language of nucleotides and twenty letter language of amino acids is known as genetic code.
- DNA transcribes for mRNA and various base sequences of RNA code for 20 amino acids.
- There are four bases in RNA, *viz*, A, G, U and C and there are 20 amino acid which take part in protein synthesis.
- Thus, more than 20 combinations are required to code for 20 amino acids and also for start and stop singles in the synthesis of polypeptide chain.
- Single of base will have $(4^1) = 4$ combinations and doublet of base have $(4^2) = 16$ combinations which are insufficient to code for 20 amino acids.
- Therefore, triplet of RNA base is required because it will give $(4^3) = 64$ combinations, which are sufficient to code for 20 amino acids as well as for start and stop singles

★ **Codon:**

- The triplet sequence of RNA base, which codes for a particular amino acid is called a **codon**
- There are **64 codons** which constitute genetic code.
- Genetic code is the set of all codons
- The codons are two types, *viz*, sense codons and ~~single~~ signal codons.

★	Sense codons	~~Single~~ signal codons
1.	Codons, which code for amino acids are called sense codons.	Codons, which code for single amino acid are called single codons.
2.	There are 61 sense codons, which code for 20 amino acids.	There are 4 codons, which code singles.
	e.g. UCU	**e.g. AUG**

Signed

Single codons:

- Singles are of two types, *viz*, start and stop single.
- There are three codons (UAA, UAG and UGA) which code for stop single.
- These codons are also known as stop codons or termination codons because they provide single for the termination and release of polypeptide chain.
- There is one codon, i.e., AUG which codes for start single. This is known as start codon or initiation codon because it starts the synthesis of polypeptide chain.

Difference

	Codons	Anticodons
1.	There are 64 codons in a genetic code.	No. of anticodons are always lesser than codons.
2.	Each codon codes for one amino acid only.	Some t-RNA molecule have to pair with more than one codon.
3.	Codons are written in 5-----3 direction	Anticodons are written in 3-----5 direction
4.	The first letter is at 5' end.	The first letter is at 3' end.

Anti codons :

- The base sequence of RNA which pair with codon of mRNA during translation is called anticodon.

Que:- Enlist the characters / features of genetic code.

Nature of genetic code or Important features of genetic code:

The genetic code is

1. **Triplets :**
   - Codons of 1 or 2 letters will be inadequate since there can be only 4 ($=4^1$) or 16 ($=4^2$) different codon to code for twenty different amino acids.
   - A three-letter code (triplet code) would produce 64 ($=4^3$) different codons, which is sufficient to code for twenty amino acids. e.g. UUU, CCC, AAA.
2. **Universal :**
   - Codon codes for the same amino acid in all the organisms e.g. codon UUU codes for phenylalanine in bacteria, mouse, man and tobacco.
3. **Commaless :**

- All the bases in a segment of polynucleotide are parts of codons and no base serves as a punctuation mark.
- When there are no intermediary nucleotides between words, UUUCCC two amino acids in triplet.

4. **Non-overlapping :** No nucleotide of code become a part of next codon.
   - It means no single base can again take part in the formation of next codon.
   - When only as many amino acids are coded as there are code under in end to end sequence (e.g. triplet code UUUCCC = phynylalanine + praline).

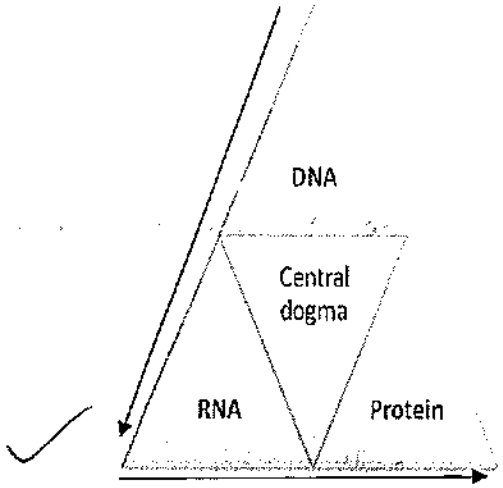
5. **Non-ambiguous :**
   - ~~When~~ one codon can code for ~~more than~~ only one amino acid e.g. ~~GGA = glycine, glutamic acid.~~

6. **Degenerate :**
   - When there is more than one codon for a particular amino acid e.g. UUU UAC = phenylalanine **Synonymous code.**

7. **Polarity :**
   - The code has a definite direction for reading of message, which is referred to as polarity.
   - Reading of code in opposite direction will specify for another amino acids due to alteration in the base sequences in the codon.

★ **Central dogma :** short note on central dogma.

- In 1958, crick proposed that the information present in DNA (in the form of base sequence) is transferred to DNA (via replication) and RNA and then from RNA it is transferred to protein (in the form of amino acid sequence); but this information does no flow in the reverse direction, that is from protein to RNA to DNA.
- DNA molecules provide the information for their own replication. This relationship between DNA; RNA and protein molecules is known as central dogma.


DNA
Central
dogma
RNA
Protein

//*//*//*//

Short Note on Protein Synthesis

OUTLINE OF PROTEIN SYNTHESIS

Transcription:

- The process of synthesis of messanger RNA (mRNA) from a DNA template is known as transcription.
- The mRNA is synthesized only from one strand of DNA in the presence of RNA polymerase enzyme.
- The RNA polymerase which catalyses the synthesis of RNA from a DNA template is called transcriptase.

This process can be represented as under:

$$\text{DNA} \xrightarrow[\text{Transcription}]{\text{Transcriptase}} \text{mRNA}$$

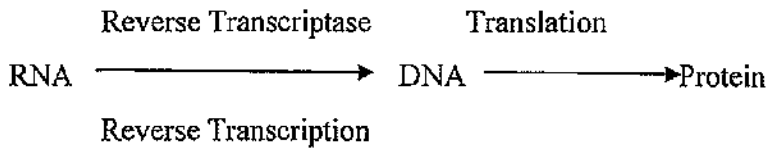
- The process of transcription requires DNA template activated precursors (ATP, GTP,Utp. And CTp) BIVALENT METAL IONS (Mg^{++} or Mn) and RNA polymerase.

The process of transcription consists of three main steps:

1. Initiation of transcription.
2. Elongation of RNA.
3. Termination of RNA chain.

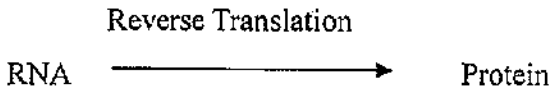
Reverse Transcription:

- It was first reported by Temin and Baltimore in 1970 for which they got nobel prize in 1975.
- It is also known as Teminism.
- Reverse transcription means synthesis of DNA from RNA in the presence of DNA polymerase.
- DNA polymerase is also known as reverse transcriptase.
- It is reported in certain tumor producing viruses.



Translation:

- The process of protein synthesis from information in mRNA is known as translation.



- The translation process requires mRNA, rRNA, ribosones, 20 amino acids kinds of the process of translation consists of five major steps:

1. Activation of amino acids
2. Transfer of amino acids to tRNA
3. Chain initiation
4. Chain elongation
5. Chain termination

Fine structure of Gene

Difference

Classical Vs Modern concept of Gene:

	Classical concept of gene	**Modern concept of gene**
1	According to this concept, the term factors for genes and reported that factors were responsible for transmission of characters.	According to this concept, a gene is a sequence of nucleotides in DNA which controls a single polypeptide chain.

2	The gene is considered as a basic unit of change or mutation, it changes form to another, but there are no smaller components within a gene that can change.	The different mutations of a gene may be due to change in single nucleotide at more than one location in the gene.
3	The gene is viewed as a fundamental unit of structures, indivisible by crossing over. Crossing over occurs between genes but not within a gene.	Crossing over can take place between the altered nucleotides within a gene.

- It was considered earlier that gene is the basic unit of function and parts of gene, if exist, cannot function.
- But based on studies on rII locus of T4 phase, Benzer (1955) concluded that there are three sub divisions of a gene, *viz,* recon, mutton and cistron.

Recon:

- Recons are the regrons (units) within a gene between which recombinations can occur, but the recombination cannot occur within a recons.

Muton:

- It is the smallest element within a gene, which can give rise to a mutant phenotype or mutation.
- This indicates that part of a gene can mutant or change.

Cistron :

- It is the largest element within a gene. Which is the unit of function.

****

Gene Structure & Gene Regulation

The hereditary units which are transmitted from one generation to the next generation are called **genes.** A gene is the fundamental biologic unit, like the atom which is the fundamental physical unit.

Mendel while explaining the result of his monohybrid and dihybrid crosses, first of all conceived of the genes as particulate units and referred them by various names such as **hereditary factors or hereditary elements**. But his concept about the gene was entirely hypothetical and he remained ignorant about the physical and chemical nature of gene.

Earlier workers proposed various hypotheses to explain the nature of genes. For instance, **De Vries** postulated **one gene one character hypothesis** according to which a particular trait of an individual is controlled by a particular gene.

Bateson and Punnett proposed the presence or absence theory. According to them, in a cross the character which dominates the other has a determiner, while, the recessive character has no such determiner.

But all the theories were discarded by **Morgan**, who produced the **particulate gene theory in 1926.** He considered **genes as corpuscles**, which are **arranged in a linear order on the chromosomes and appear like beads on a string.** The particulate theory of gene was widely accepted and supported by cytological observations.

But, the **discovery of DNA** molecule as a sole carrier of genetic informations base altogether **discarded the Morgan's theory**. Therefore, before defining the gene it will be advisable to consider both the classical as well as modern definitions of gene.

CHANGING CONCEPT OF GENE

The concept of gene has been the focal point of study from the beginning of twentieth century to establish the basis of heredity. The gene has been examined from two main angles, i.e., (1) genetic view, and (2) biochemical and molecular view. These aspects are briefly described below:

(1) A Genetic View

The genetic view or perspective of gene is based mainly on the Mendelian inheritance, chromosomal theory of inheritance and linkage studies.

- ✓ **Mendel** used the term **factors for genes** and reported that factors were responsible for transmission of characters from parents to their offspring.
- ✓ **Sutton and Boveri (1903)** based on the study of mitosis and meiosis in higher plants established **parallel behaviour of chromosomes and genes.** They reported that both chromosomes and genes segregate and exhibit random assortment, which clearly demonstrated that genes are located on chromosomes. The Sutton- Boveri hypothesis is known as chromosome theory of inheritance.
- ✓ **Morgan** based on **linkage studies in Drosophila** reported that **genes are located on the chromosome in a linear fashion.** Some genes do not assort independently because of linkage between them. He suggested that recombinants are the result of crossing over. The crossing over increases if the distance between two genes is more. The chromosome theory and linkage studies reveal that genes are located on the chromosomes. This view is sometimes called as bead theory.

Part of a Gene Can Function Short note

It was considered earlier that *gene is the basic unit of function and parts of gene, if exist, cannot function.* But this concept has been outdated now. Based on studies on **rII locus of T4 phage, Banzer (1955)** concluded that there are **three sub divisions of a gene**, viz., **recon, muton and cistron.** These are briefly described below:

Recon

Recons are the regions (units) within a gene between which recombinations can occur, but the recombination cannot occur within a recon. There is a minimum recombination distance within a gene which separates recons. The map of a gene is completely linear sequence of recons.

Muton

It is the smallest element within a gene, which can give rise to a mutant phenotype or mutation. This indicates that part of a gene can mutate or change. This disproved the bead theory according to which the entire gene was a mutate or change.

Cistron

It is the **largest element within a gene which is the unit of function.** *This also nocked down the bead theory according to which entire gene was the unit of function.* The name cistron

has been derived from the test which is performed to know whether two mutants are within the same cistron on in different cistrons. It is called cis-trans test.

(2) A Biochemical View

- ✓ It is now generally believed that a gene **is a sequence of nucleotides in DNA which controls a single polypeptide chain.**
- ✓ The different mutations of a gene may be due to change in single nucleotide at more than one location in the gene.
- ✓ Crossing over can take place between the altered nucleotides within a gene. Since the mutant nucleotides are placed so close together, crossing over is expected within very low frequency.
- ✓ When several different genes which affect the same trait are present so close that crossing over is rare between them, the term complex locus is applied to them.
- ✓ Within the nucleotide sequence of DNA, which represents a gene, multiple alleles are due to mutations at different points within the gene.

★ Fine Structure of Gene

Benzer, in 1955, divided the gene into recon, muton and cistron which are the units of recombination, mutation and function within a gene. Several units of this type exist in a gene. In other words, each gene consists of several units of function, mutation and recombination. The fine structure of gene deals with mapping of individual gene locus. This is parallel to the mapping of chromosomes. In chromosome mapping, various genes are assigned on a chromosome, whereas in case of a gene several alleles are assigned to the same locus. The individual gene maps are prepared with the help of intragenic recombination. Since the frequency of intragenic recombination is extremely low, very large population has to be grown to obtain such rare combination.

Genes can be classified in various ways. The classification of genes is generally done on the basis of (1) dominance, (2) interaction, (3) character controlled, (4) effect on survival, (5) location, (6) movement, (7) nucleotide sequence, (8) sex linkage, (9) operon model, and (10) role in mutation. A brief classification of genes on the basis of above criteria is presented

Classification of genes	A brief description
Based on Dominance	
Dominant genes	Genes that express in the F_1
Recessive genes	Genes whose effect is suppressed in F_1
Based on Interaction	
Epistatic gene	A gene that has masking effect on the other gene controlling the same trait.
Hypostatic gene	A gene whose expression is masked by anothergene governing the same trait
Based on Character Controlled	
Major gene	A gene that governs qualitative trait. Such genes have distinct phenotypic effects.
Minor gene	A gene which is involved in the expression of quantitative trait. Effect of such genes cannot be easily detected.
Based on Effect on Survival	
Lethal gene	A gene which leads to death of its carrier when in homozygous condition. It may be dominant or recessive.
Semi lethal gene	A gene that causes mortality of more than 50% of its carriers.
Sub-vital gene	A gene that causes mortality of less than 50% of its carriers.
Vital gene	A gene that does not have lethal effect on its carriers.
Based on Location	
Nuclear genes	Genes that are found in nuclear genome in the chromosomes.
Plasma genes	Genes that are found in the cytoplasm in mitochondria and chloroplasts. Also called cytoplasmic or extranuclear genes.
Based on Position	
Normal genes	Genes that have a fixed position on the chromosomes. Most of the genes belong to this category
Jumping genes	Genes which keep on changing their position on the chromosome of a genome. Such genes have been reported in maize.

Based on Nucleotide sequence	
Normal genes	Genes having continuous sequence of nucleotides which code for a single polypeptide chain.
Split gene	A gene having discontinuous sequence of nucleotides. Such genes have been reported in some eukaryotes. The intervening sequences do not code for amino acids.
Pseudo genes	Genes having defective nucleotides which are non-functional. These genes are defective copies of some normal genes.
Based on Sex Linkage	
Sex linked genes	Genes which are located on sex or X- chromosomes.
Sex limited genes	Genes which express in one sex only
Sex influenced genes	Genes whose expression depends on the sex of individual e.g., gene for baldness in humans.
Based on Operon Model	
Regulator gene	A gene found in lac operon of E.Coli which directs synthesis of a repressor
Operator gene	In lac operon, a gene which control the function of structural genes.
Promotor gene	A gene in lac operon of E.Coli which initiates mRNA synthesis
Structural genes	The genes in lac operon of E.Coli which control the synthesis of protein through mRNA.
Based on role in Mutation	
Mutable genes	Genes which exhibit higher mutation rate than others e.g., which eye gene is Drosophila.
Mutator genes	Genes which enhance the natural mutation rate of other genes in the same genome e.g., dotted gene in maize.
Antimutator genes	Genes which decrease the frequency of natural mutation of other genes in the same genome. Such genes are found in bacteria and bacteriophages.

More about Genes

There are some genes which are different from normal genes either in terms of their nucleotide sequences or functions. Some examples of such genes are split gene, jumping gene, overlapping gene and pseudo gene. A brief description of each of these genes is presented below:

✶ SPLIT GENES

Usually a gene has a continuous sequence of nucleotides. In other words, there is no interruption in the nucleotide sequence of a gene. Such nucleotide sequence codes for a particular single polypeptide chain. However, it was observed that the sequence of nucleotides was not continuous in case of some genes; the sequences of nucleotides were interrupted by intervening sequences. Such gene with interrupted sequence of nucleotides is referred to as split genes or interrupted genes. Thus, split genes have two types of sequences, viz., normal sequences and interrupted sequences.

1. **Normal Sequence.** This represented the sequence of nucleotides which are included in the mRNA which is translated from DNA of split gene. These sequences code for a particular polypeptide chain and are known as exons.
2. **Interrupted Sequence:** The intervening or interrupted sequence of split gene are known as introns. These sequences do not code for any peptide chain. Moreover, interrupted sequences are not included into mRNA which is transcribed from DNA of split genes. The interrupted sequences are removed from the mRNA during processing of the same. In other words, the intervening sequences are discarded in mRNA as they are non-coding sequences. The coding sequences or exons are joined by ligase enzyme.

The first case of split gene was reported for ovalbumin gene of chickens. The ovalbumin gene has been reported to consist of seven intervening sequences. Later on interrupted sequences (split genes) were reported for beta globin gene of mice and rabbits, tRNA genes of yeast and ribosomal genes of Drosophila.

✶ JUMPING GENES

Generally, a gene occupies a specific position on the chromosome called locus. However in some cases a gene keeps on chaining its position within the chromosome and also between the chromosomes of the same genome. Such genes are known as jumping genes or transposons or transposable elements. The first case of jumping gene was reported by Barbara Mc-Clintock in

maize as early as in 1950. However, her work did not get recognition for a long time like that of Mendel. Because she was much ahead of time and this was an unusual finding, people did not appreciate it for a long time. This concept was recognized in early seventies and McClintock was awarded Nobel Prize for this work in 1983.

Later on transposable elements were reported in the chromosome of *E. coli* and other prokaryotes. In E.coli, some DNA segments were found moving from one location to other location. Such DNA segments are detected by their presence at such a position in the nucleotide sequence, where they were not present earlier. The transposable elements are of two types, viz, insertion sequence and transposons.

1. **Insertion Sequence.** There are different types of insertion sequences each with specific properties. Such sequences do not specify for protein and are of very short length. Such sequence has been reported in some bacteria bacteriophages and plasmids.
2. **Transposons.** These are coding sequences which code for one or more proteins. They are usually very long sequences of nucleotides including several thousand base pairs. Transposable elements are considered to be associated with chromosomal changes such as inversion and deletion. They are hot spots for such changes and are useful tools for the study of mutagenesis. In eukaryotes, moving DNA segments have been reported in maize, yeast and Drosophila.

OVERLAPPING GENES

Earlier it was believed that a nucleotide sequence codes only for one protein. Recent investigations with prokaryotes especially viruses have proved beyond doubt that some nucleotide sequences (genes) can code for two or even more proteins. The genes which code for more than one protein are known as overlapping genes. In case of overlapping genes, the complete nucleotide sequence codes for one protein and a part of such nucleotide sequence can code for another protein. Overlapping genes are found in tumor producing viruses such as φ X 174, SV 40 and G4, in virus φ X 174 gene A overlaps gene B. In virus SV 40, the same nucleotide sequence codes for the protein VP 3 and also for the carboxyl – terminal end of the protein VP2. In virus G4, the gene A overlaps gene B and gene E overlaps gene D. The gene of this virus also contains some portions of nucleotide sequences which are common for gene A and gene C.

Pseudogenes

There are some DNA sequences, especially in eukaryotes, which are non-functional and defective copies of normal genes. These sequences do not have any function. Such DNA sequences or genes are known as pseudogenes. Pseudogenes have been reported in humans, mouse and Drosophila. The main features of pseudogenes are given below :

1. Pseudogenes are non functional or defective copies of some normal genes. These genes are found in large numbers.
2. These genes being defective cannot be translated.
3. These genes do not code for protein synthesis, means they do not have any significance.
4. The well known examples of pseudogenes are alpha and beta globin pseudogenes of mouse.

GENE REGULATION

Ghost Note

Gene regulation refers to the control of the rate or manner in which a gene is expressed. In other words, gene regulation is the process by which the cell determines (through interactions among DNA, RNA, proteins, and other substances) when and where genes will be activated and how much gene product will be produced.

Thus, the gene expression is controlled by a complex of numerous regulatory genes and regulatory proteins. The gene regulation has been studied in both prokaryotes and eukaryotes.

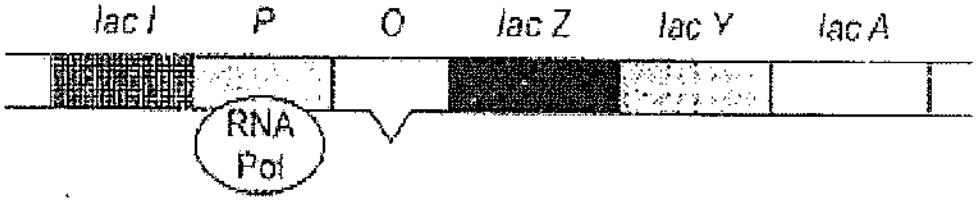
In prokaryotes, the **operon model of gene regulation** is widely accepted. This model of gene regulation was proposed by **Jacob and Monod in 1961** for which they were awarded **nobel prize in 1965.**

The operon refers to a group of closely linked genes which together code for various enzymes of a particular biochemical pathway. In other words, operon is a unit of bacterial gene expression and regulation, including structural genes and control elements in DNA recognized by regulator gene product(s). Thus operon is a model which explains the on-off mechanism of protein synthesis in a systematic manner. The main points of operon model of gene regulation are presented below.

1. **Developed By.** In prokaryotes, the operon model of gene regulation was developed by **Jacob and Monod in 1961** for which they were awarded nobel prize in 1965. Now this model of gene regulation is widely accepted.
2. **Organism Used.** The operon model was developed working with **lactose region** [lac region] of **human intestine bacteria *E. coli.*** The gene regulation was studied for degradation of the sugar lactose.
3. **Genes Involved.** In the operon model of gene regulation, four types of genes *viz.*, **(i) structural genes, (ii) operator gene, (iii) promoter gene and (iv) regulator gene** are involved. In addition, repressor, co-repressor, and inducer molecules are also involved.
4. **Enzymes Involved.** Four types of enzymes are involved in gene regulation of prokaryotes. These are beta-galactosidase, galactosidase permease, transacetylase and RNA polymerase. The-beta-galactosidase catalyses the break down of lactose into glucose and galactose. The galactosidase permease permits entry of lactose from the medium into the bacterial cell. The enzyme trans acetylase transfers an acetyl group from acetyl co-enzyme A to beta galactosidase. The enzyme mRNA polymerase controls on-off of the transcription.
5. **Type of Control.** In lac operon of *E. coli,* there are two types of control of gene regulation, *viz.*, ***(i)* negative control and *(ii)* positive control.**
6. **Types of operon.** In prokaryotes, operons are are of two types, *viz.*, **inducible** and **repressible.** The example of an **inducible operon** is the **lactose operon**, which contains genes that encode enzymes responsible for lactose metabolism. An example of **repressible operon is the Trp operon**, which encodes enzymes responsible for the synthesis of the amino acid tryptophan (trp for short).

1. Inducible Operon

Inducible Enzyme. An enzyme whose production is enhanced by adding the substrate in the culture medium is called inducible enzyme, and such system is called inducible system. The example of an inducible operon is the **lactose operon,** which contains genes that encode enzymes responsible for lactose metabolism. In bacteria, operon refers to a group of closely linked genes which act together and code for tho various enzymes of a particular biochemical pathway. The model of lac operon of *E. coli* looks like this



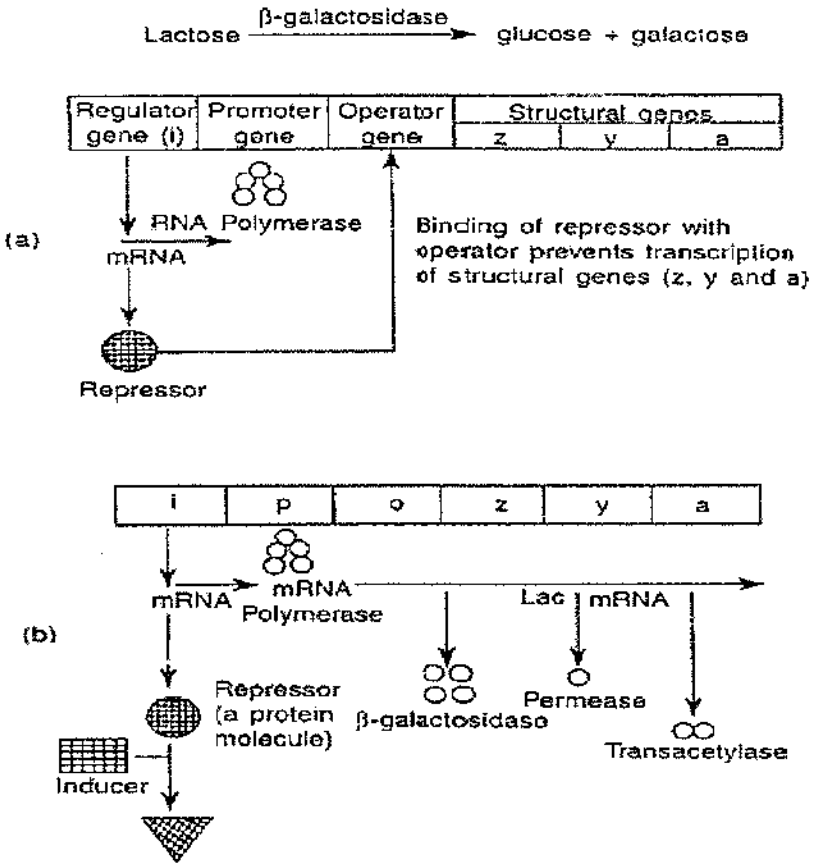
(1) **Structural Genes.** There are three structural genes of the lac operon *i.e.* ***lac* Z, lac Y and lac A.** The main **function** of structural genes is **to control of protein synthesis** through **messenger RNA.**

(2) **Promoter Gene.** The above three structural genes are under the control of the promoter gene [designated P]. In the promoter, **RNA polymerase** binds to the DNA and prepares to initiate transcription. The main function of promoter gene is to initiate mRNS transcription.

(3) **Operator Gene.** The other regulatory element in an operon is the **operator** (designated O). This is the element that determines whether or not the genes of the operon are transcribed. The main **function of operator gene is to control function of structural genes.**

(4) **Regulator Gene.** This is designated as **I.** It is expressed all the time, or constitutively and plays an important role in operon function. This is the *lac I* gene, which encodes a protein called the lac repressor.

The lac repressor has two functional domains or regions: one that binds to the DNA of the operator region, and one that binds to lactose. When the repressor binds to the operator, it prevents RNA polymerase advancing along the operon, and transcription does not occur. The regulation of the operon depends on regulating whether or not the repressor binds to the operator. The function of regulator gene is to direct synthesis of repressor, a protein molecule. Its function differs in the presence and absence of lactose as discussed below.



MECHANISM OF GENE REGULATION

The mechanism of gene regulation is of two types, *viz.* (1) negative regulation, and (2) positive regulation. The mechanism of gene regulation in *E. coli* operon and tryptophan operon are discussed below.

1. Negative Control

The first switch in the lac operon of *E. coli,* is the repressor protein. In negative control, the transcription is controlled by repressor protein, which is an allosteric protein. The repressor protein binds to operator region and prevents transcription. It prevents transcription by blocking RNA polymerase. Thus, when repressor is bound to operator, the transcription is switched off. Thus the on-off switch of protein synthesis is governed by free or occupied position of the operator gene. When the operator is free, transcription will take place and when the operator gene is blocked, the transcription is prevented. If an isomer of lactose [allolactose] is present, it will bind to repressor protein and change its shape. The changed repressor does not bind to operator and thus allows transcription.

2. Positive Control

The second switch in the lac operon of *E. coli*, is the catabolite activator protein [CAP].The CAP is an allosteric protein. The CAP binds to DNA and small molecule called cyclic adenosine mono phosphate [cAMP]. The CAP only binds to promoter region and stimulates transcription when cAMP binds to allosteric site.

Tryptophan Operon

The tryptophan operon [in short trp operon] is regulated by trp, which is the product of the metabolic pathway. The trp operon contains genes that makes enzymes in the biosynthetic pathway for the production of amino acid tryptophan. In trp operon, the negative control is associated with a repressor protein. However, the repressor protein only binds with operator gene when an allosteric effector is bound to it. The tryptophan is an allosteric effector, which is called a corepressor in trp operon also, the transcription is controlled by the free or occupied position of repressor.

If the repressor protein doesn't bind with operator gene, transcription will take place. If tryptophan is present, there is no need to synthesize enzymes. In such situation tryptophan binds to repressor protein and both these [trp and repressor] bind to operator gene preventing transcription. When trp is absent, the repressor will not bind to the operator, and transcription will take place. In the negative control, repressor protein binds DNA and stops transcription. In positive control, activator protein binds DNA and stimulates transcription. In the inducible system, allosteric effector binds and releases repressor protein from DNA resulting in transcription. In the repressible system, allosteric effector binds and causes repressor protein to bind to DNA preventing transcription.

Merits of Operon Model

1. It is a very simple yet informative model of gene regulation in prokaryotes.
2. It is a very well understood model of gene regulation in prokaryotes.
3. This model is based on empirical results and has been studied on different prokaryotes.
4. This model is of two types, *viz.*, (i) inducible operon and *(ii)* repressible.

//*//*//*//

Ques:- What is multiple allele? Explain the phenomenon of multiple allelism with suitable example *

Que:- Short note on multiple allele

MULTIPLE ALLELE

Multiple allele

Existence of more than one allele at a locus is referred as multiple allele and the phenomenon is referred as multiple allelism OR

The condition in which a particular gene occurs in three or more allelic form in population of organisms

Main features/characteristics of multiple allele

- Multiple allele always belong to the same locus and one allele is present at a locus at a time in a chromosome
- Multiple allele always control the same character of an individual. The expression of a character will differ depending upon the allele present
- There is no crossing over in multiple allele series
- In series of multiple allele wild type is always dominant.
- The cross between two mutant type will always produce mutant phenotype (intermediates). Such cross will never produce wild phenotype. In other words multiple allele do not show complementation

Examples of multiple allele :

- Fur colour in rabbit
- Wing type in Drosophila
- Eye colour in Drosophila
- Self incompatibility allele in plants
- ABO blood group in man
- Waxy gene of maize

Short Note

Self Incompatibility Alleles in Plants (Example)

The most common example of multiple alleles in plants is the series of self incompatibility alleles. Such alleles were reported in **Nicotiana** and later on they were found in several other plant species like **Brassica**, radish, tomato, potato, etc. In these species, self incompatibility is governed by a single gene S which has multiple alleles, *viz.*, S^1, S^2, S^3, S^4 and so on. Now cases

of digenic and trigenic self incompatibility have also been reported. In evening primrose 37 and in red clover 41 alleles of self incompatibility have been reported. Crosses between individuals having self incompatibility alleles will lead to three types of situations as given below :

Fully Sterile

When both male female have similar alleles, *viz.*, $S'S^2 \times S'S^2$ the cross will be incompatible and there will be no seed setting.

Partially Fertile

Such crosses are obtained when male and female plants differ for one allele, *viz.*, $S'S^2 \times S'S^3$. This cross will produces, $S'S^3$ and S^2S^3 progeny. In other words, half of the progeny will be fertile.

Fully Fertile

The fully fertile crosses are obtained when male and female plants differ in respect of both alleles, *viz.*, $S'S^2 \times S^3S^4$. This cross will produce four fertile genotypes, *viz.*, $S'S^3$, $S'S^4$, S^2S^3 and S^2S^4. Thus, plants which have self incompatibility alleles are always heterozygous for this gene.

Que:- Briefly explain ABO blood group

ABO blood group in man

- ABO blood group in man was discovered by Landsteiner (1900)
- **Antibody** : It is a type of protein which is commonly referred to as immunoglobin and found in the serum or plasma. The presence of antibody can be demonstrated by its specific reaction with antigen.
- **Antigen** : It refers to a substance or agent which introduced into the system of a vertebrate animal (like cow, goat, rabbit, man etc.) for the production of specific antibody, which binds specifically to this substance. Antigens are located in the RBC (red blood corpuscles)
- In human RBC there is two types of antigens viz., A and B
- Depending upon the presence and absence of antigen A & B, the blood group in human is of four types viz., A, B, AB & O.
- As far as antigen is concern, a person with the blood group A has antigen A on the surface of RBCs, similarly for the blood group B will have antigen B, for the blood group AB will have the antigens A & B and for the blood group O have no antigen on the surface of their RBCs

- **As far as antibody is concern**, antibodies B, A, none and AB are naturally present in the serum of individuals having A, B, AB and O blood group, respectively
- **The agglutination or coagulation of RBCs leads to clotting of blood due to interaction between common antigen and antibody**
- The blood group B can not be transferred to an individual having blood group A because in the individual having blood group A possessing antibody against antigen B
- Reverse transfusion of blood is also not possible
- The blood group AB does not have antibody against antigen A & B and because of that an individual with AB blood group can accept all types of blood viz., A, B, AB & O. So they are known as **Universal acceptors or recipients**
- The O blood group individual does not have any antigen and has antibody against antigen A & B, so it can not accept blood group other than O
- Individual with O blood group is referred as **Universal donars** because transfusion of blood group O is possible with all the four blood types.
- Likewise Rh (rhesus) factor is also important in blood transfusion
- Each blood group have two types of Rh group viz., positive and negative
- Same type of Rh is compatible for blood transfusion and opposite type of Rh blood group transfusion resulting in death of the recipient

Human blood groups, their antigen, antibody and compatible blood group for transfusion

Blood group	Genotypes	Antigen found on the surface of the RBC	Antibody present in the blood serum	Compatible blood for transfusion
A	$I^A I^A$ or $I^A i$	A	B	A and O
B	$I^B I^B$ or $I^B i$	B	A	B and O
AB	$I^A I^B$	AB	None	A, B, AB & O
O	ii	None	AB	O

PSEUDOALLELES

Pseudoalleles refer to closely linked and functionally related genes. A cluster of pseudoalleles is known as pseudoallele series or a complex locus or a complex region. Main characteristics of pseudoalleles are given below :

1. Pseudoalleles govern different expressions of the same character. In other words, they are functionally related.
2. Pseudoalleles are considered to occupy a complex locus which is divided into sub loci. Thus, they occupy different positions, but on the same complex locus.
3. They exhibit low frequency of genetic recombination by crossing over. In other words, crossingover occurs between pseudoalleles, but at a very low frequency.
4. They exhibit cis-trans position effect. In trans heterozygotes such mutants produce mutant phenotype, but in cis-heterozygotes they produce a wild phenotype.

TEST FOR ALLELISM

There are two types of tests that are used for allelism, *viz.*, recombination test and complementation test. These are briefly discussed below :

Recombination Test

Earlier it was believed that recombination can occur between two genes but not within a gene. Thus, if a cross between two mutants say tr^mi and m_2m_2 produces wild type in test cross or in F_2 then iri| and m_2 are considered as non-allelic because production of wild type is not possible without recombination. If no wild type appears in test cross or F_2 then m_1 and m_2 are considered as allelic forms. Now intragenic recombination has been reported in many organisms. Hence this concept is no more valid.

Complementation Test

Alleles may be arranged in two ways, *viz.*, **cis** position and **trans** position (Fig. 13.1). When two wild alleles are located in one chromosome and their mutant alleles in homologous chromosomes (++/ab), it is known as **cis**-arrangement. Thus, in **cis** position alleles are linked in coupling phase. On the other hand, when one wild and one mutant type alleles are located in each homologous chromosome (+a/+b), it is known as **trans** position or repulsion phase of alleles. Complementation refers to appearance of wild phenotype when two mutants are crossed. Complementation test is used to determine whether two mutant alleles belong to same gene or

two different genes. If there is complementation, the mutants are located in different genes, otherwise they are located in the same gene.

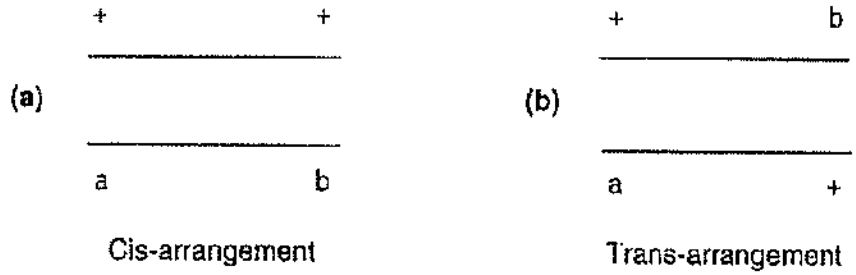


Fig.:- Arrangement of alleles : (a) Cis-arrangement, (b) Trans-arrangement

Oliver in 1940 first demonstrated that intragenic recombination occurred in Lozenge gene of Drosophila. The two mutant alleles are considered to belong to the same gene if their cis heterozygotes produce wild type and trans-heterozygotes lead to mutant type. If their both trans and cis heterozygotes lead to development of wild type, the mutant alleles are located in two different genes. Thus, cis-trans test is more reliable test of allelism.

Pleiotropism :

- A gene having more than one phenotypic effect (**manifold effects**) is called pleiotropic gene and such phenomenon is refered as pleiotropy or pleiotropism
- A pleiotropic effect may be either due to true pleiotropic gene or due to closed linked gene

Penetrance :

- The frequency with which a gene produces a phenotypic or visible effects in individuals **OR**
- Penetrance refers to the proportion of individuals which exhibit phenotypic effect of a specific gene carried by them
    1. Penetrance can calculated in percentage
    2. They are two types : Incomplete penetrance and complete penetrance
    3. When specific gene does not manifest its effect in all the individuals, which carry this gene is known as incomplete penetrance

4. When all the individuals which carry a particular gene exhibit its phenotypic effect is known as complete penetrance

- **Expressivity** :
  - The degree of phenotypic expression of a penetrant gene is called as expressivity

    Expressivity are of two types :

    1. Uniform
    2. Variable
  - When the phenotypic expression of a gene is identical or similar in all the individuals which carry such gene is known as **uniform expressivity**
  - Most of the qualitative characters exhibit uniform expressivity
  - Most of the qualitative characters exhibit uniform expressivity
  - When the phenotypic expression differs in different carriers of a gene it is known as **variable expressivity**

GLOSSORY

Allele. Alternative form of a gene. Alleles may be of two types, *viz*,, either dominant and recessive or wild and mutant.

Multiple allele. Existence of more than two alleles at a locus.

cis-position. Presence of two wild alleles in one homologous chromosome and their mutant alleles in another homologous chromosome. *(++/ab);* also called coupling phase of alleles.

Trans-position. Existence of one wild and one mutant allele in each homologous chromosome *(+ a/+b);* also called repulsion phase of alleles.

Complementation. Appearance of wild phenotype when two mutants are crossed together.

Antibody. A type of protein which is commonly known as immunoglobin.

Antigen. A substance or agent which, when introduced into a system of a vertebrate animal like cow, goat, rabbit, man, etc. induces the production of specific antibody which binds specifically to this substance.

Pseudo alleles. Closely linked and functionally related genes. A cluster of pseudo alleles in known as a complex locus or complex region. Examples are lozenge and star asteroid eyes in ***Drosophila.***

Isoallele. An allele which is similar in its phenotypic expression to that of other independently occurring allele.

Mutant isoallele. An isoallele which acts within the phenotypic range of a mutant character.

Normal isoallele. An isoallele which acts within the phenotypic range of a wild character.

Gene. A basic unit of inheritance, sequence of DNA nucleotides which codes for a functional product of RNA or a polypeptide. The term gene was coined by Johannsen in 1909. A gene consists of recon, muton and cistron.

Recons. The regions (units) within a gene between which recombination can occur, but the recombinationcannot occur within a recon.

Muton. The smallest element within a gene, which can give rise to mutant phenotype or mutation.

Cistron. The largest element within a gene which is the unit of function.

Split genes. The genes with intervening or interrupted sequences; usually found in eukaryotes.

Exons. Coding sequences of DNA in split genes.

Introns. Non coding sequences in split genes which are removed during processing of mRNA.

Jumping genes. The genes which keep on changing their position in a chromosome and also between the chromosomes in a genome. Also called transposons or transposable elements. The first case of jumping gene was reported by McClinlock in 1950 in maize.

Overlapping Genes. Genes which code for more than one protein. In such gene, the complete nucleotide sequence codes for one protein and part of such nucleotide sequence for another protein. Such genes have been reported in tumor producing viruses such as SV40 and G4.

Pseudo Genes. A non-functional sequence of DNA or a defective copy of a normal gene in eukaryotes.Such genes have been reported in humans, mouse and ***Drosophila.***

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LINKAGE & CROSSING OVER

Linkage : The tendency of two or more genes to stay together during inheritance is known as linkage.

Linkage groups :

A group of genes, which are present in one chromosome **OR** All genes which are located in one chromosome constitute one linkage group.

- Maximum number of linkage group = Haploid number of an organism. **Example** : 4 linkage group in Drosophilla (2n=8) and 23 in man (2n=46)
- Linked genes do not shown independent segregation was first reported by Bateson and Punnet in 1905 in pea.
- Effect of linkage is clearly noticeable in **test cross generation.**
- **The frequency of parental character combinations are more than expected, while new character combinations are relatively lower.**

Main features of linkage :

1. Linkage involves two or more genes which are located in the same chromosome in a liner fashion.
2. Linkage may involve either dominant genes or recessive genes or some dominant and some recessive genes.
3. Linkage usually involves those genes which are located closely.
4. Presence of linkage leads to higher frequency of parental types than recombinants in a test cross progeny. When two genes are linked the segregation ratio of a test cross progeny deviates significantly from the 1 : 1 : 1 :1 ratio.
5. Linkage may involve either two or more desirable traits or all undesirable traits or some desirable and some undesirable traits.
6. Linkage is observed for both oligogenic traits as well as polygenic traits. However, it is more common for the former than latter.
7. Besides pleiotropy, linkage is an important cause of genetic correlation between various plant characters.

★ Difference between coupling & repulsion phase

Que:- Describe in brief coupling phase & linkage with suitable example.

8. The strength of linkage depends on the distance between the linked genes. Lesser the distance higher the strength and vice versa.
9. If crossing over does not occur, all the genes located in one chromosome are expected to be inherited together. Thus the maximum number of linkage groups in an organism is equal to its haploid chromosome number.
10. Linkage can be broken by repeated intermating of randomly selected plants in segregating populations for several generations.

PHASES OF LINKAGE (Experiments of Bateson and Punnet, Morgan Estimation procedure)

There are two phases of linkage, *viz.*, coupling phase and repulsion phase. These phases were given by Bateson and Punett (1905), but they could not give proper interpretation of these terms. Later on, Morgan (1910) based on his studies with **Drosophila** explained that coupling and repulsion are the two aspects of the same phenomenon what we call linkage. The coupling and repulsion phases of linkage are briefly described below.

Coupling

The linkage between two or more either dominant (AB) or recessive (ab) alleles is referred to as coupling. A good example of coupling was reported by **Hutchinson in maize** for the genes governing colour of seed (coloured and colourless) and shape of seed (full and shrunken). The coloured seed is governed by dominant gene (C) and full seed is also governed by dominant gene (S). He made cross between plants having coloured full seeds (CCSS) and colourless shrunken seeds (ccss). The F_1 seeds were coloured full. When the F_1 was test crossed with double recessive parent the following results were obtained instead of 1 : 1 : 1 : 1 ratio.

Parents	Coloured full	**X**	Colourless shrunken
Genotype	CCSS	↓	ccss
F_1		CcSs	Coloured Full
Test Cross	CcSs	**X**	ccss
Test Cross Progeny :		↓	
1. Coloured full	(CS)	4032	Parental Type
2. Coloured shrunken	(Cs)	149	Recombinant Type
3. Colourless full	(cS)	152	Recombinant Type
4. Colourless shrunken	(cs)	4035	Parental Type

Que:- Describe in brief repulsion phase with example.

Total	8368

This indicates that parental combinations are higher than recombination's, indicating presence of linkage. The parental combinations occurred in 96.4% instead of 50% and recombination were 3.6% instead of 50% in this case. There are several other cases of coupling in other plant species.

Repulsion

The linkage of dominant allele with that of the recessive allele (Ab or aB) is known as repulsion. Hutchinson also observed repulsion phase of linkage in maize. He observed this type of linkage when he made cross between plants having coloured shrunken seeds (Cs) with those having colourless full seeds (cS). In F_1 the seeds were coloured full. By crossing of F_1 with double recessive parent the following results were obtained instead of 1 : 1 : 1 : 1 ratio.

Parents	Colourless full	X	Coloured shrunken
Genotype	ccSS	↓	CCss
F_1		CcSs	Coloured Full
Test Cross	CcSs	X	cess
Test Cross Progeny :		↓	
1. Coloured full	(CS)	639	Recombinant Type
2. Coloured shrunken	(Cs)	21,379	Parental Type
3. Colourless full	(cS)	21,906	Parental Type
4. Colourless shrunken	(cs)	672	Recombinant Type
	Total	44,595	

Again parental combinations were higher (97.1%) than expected (50%) and recombination's were lower (2.9%) than expected (50%). Thus in both cases linked genes tend to remain together during hereditary transmission. Haldane (1942) used the terms cis and trans for coupling and repulsion, respectively.

★ **Types of linkage:**

Linkage is classified on the basis of three criteria

- Presence or absence of crossing over
- Genes involved

- The chromosome involved

Based on crossing over :

1. **Complete linkage :**
    1. The linkage in which crossing over does not occur is known as complete linkage or absolute linkage.
    2. In this situation only parental types are obtained from the test cross progeny

2. **Incomplete linkage :**
    1. If some frequency of crossing over occur between linked genes, it is known as incomplete linkage
    2. In this situation, recombinants are observed in the test cross progeny along with parental combination

Based on genes involved

1. **Coupling linkage** : It refers to linkage either between dominant genes or between recessive genes
2. **Repulsion linkage** : It refers to linkage of some dominant genes with some recessive genes

Based on the chromosome involved

1. **Autosomal linkage** : it refers to linkage of such genes, which are located in other than sex chromosomes
2. **X- chromosomal linkage** : It refers to the linkage of genes which are located in sex chromosomes

Significance or practical utility of linkage :

1. Effect of selection : Linkage between two or more loci controlling different desirable character is advantageous for a plant breeder, because desirable alleles comes more frequently in segregating population than would be expected with independent assortment. Linkage is undesirable when desirable gene is linked with undesirable gene.
2. Effect on genetic variance : The estimates of genetic variance for quantitative characters are greatly influenced by presence of linkage.

3. Effect of genetic correlation : The linked characters showed high values of genetic correlation and coheritability

Crossing over :

Crossing over refers to the exchange of chromosomal segment between non sister chromatids of homologous chromosomes during meiotic prophase.

- The term crossing over was first used by Morgan and Cattell in 1912

Main features of crossing over :

1. Crossing over take place during meiotic prophase, i.e., during pachytene.
2. Crossing over occurs between non-sister chromatids. Thus one chromatid from each of the two homologous chromosomes is involved in crossing over.
3. It is universally accepted that crossing over takes place at four strand stage.
4. Each crossing over involves only two of four chromatids of two homologous chromosomes. However, double or multiple crossing over may involve all four, three or two of the four chromatids, which is very rare.
5. Crossing over leads to recombination or new combinations between linked genes. Crossing over generally yields two recombinant types or crossover types and two parental types or non-crossover types.
6. Crossing over generally leads to exchanges of equal segments of genes and recombination is always reciprocal. However, unequal crossing over has also been reported.
7. **The value of crossover or recombinants may vary from 0-50%.**
8. The frequency of recombinants can be worked out from the test cross progeny. It is expressed as the percentage ratio of recombinants to the total population (recombinants + parental types) Thus,

$$\text{Crossingover frequency (\%)} = \frac{\text{No. of recombinants}}{\text{Total progeny}} \times 100$$

Difference between linkage & crossing over

	Linkage	Crossing over
1.	It keeps the genes together	It leads to separation of linked genes.
2.	It involves individual chromosome.	It involves non-sister chromatids of homologous chromosomes.
3.	Linkages groups can never be more than haploid chromosome number.	Frequency of crossing over can never exceed 50%.
4.	It reduces variability.	It increases variability by forming new gene combinations.
5.	It do not provides equal frequency of parental and recombinant types in test cross progeny	It provides equal frequency of parental and recombinant types in test cross progeny

Types of crossing over :

Single crossing over

- It refers to formation of single chiasmata between non sister chromatids of homologous chromosomes.
- Such cross over involves only two chromatids out of four

Double crossing over

- It refers to formation of two chiasmata between non sister chromatids of homologous chromosomes.
- Such cross over involves either two strand or three or all the four stands

Multiple crossing over

- Presence of more than two cross overs between non sister chromatids of homologous chromosomes is referred as multiple crossing over.
- Frequency of such type of crossing over is extremely low

Depending upon chromatid involved, crossing over is divided into two parts :

1. **Two strand stage** : Recombination occurred between two homologous chromosomes before they divided into chromatids

2. **Four strand stage** : Recombination occurred between two chromatids, each homologous chromosome that had already divided into chromatids

Explain with any one theory.

MOLECULAR MECHANISM OF CROSSING OVER

There are two important theories *viz.*, **1.** Copy choice theory and **2.** Breakage and reunion theory to explain the mechanism of crossing over. These are briefly presented below:

1. Copy Choice Theory

This theory was proposed by Belling. This theory states that the entire recombinant section or part arises from the newly synthesised section. The non sister chromatids when come in close contact they copy some section of each other resulting in recombination. According to this theory, physical exchange of preformed chromatids does not take place. The non sister chromatids when come together during pairing, copy part of each other. Thus, recombinant chromosome or chromatids have some alleles of one chromatids and some of other. The information may be copied by one strand or both the strands. When only one strand copies, non-reciprocal recombinant is produced. If copy process involves both strands of chromosomes, reciprocal recombinants are produced. Assume, there are two chromosomes, *viz.*. AB and ab. When their chromatids come in close contact they copy each other and result in Ab and aB recombinations beside.' cental combinations (Fig.). This theory has two objections.

1. According to this theory breakage and reunion does not occur, while it has been observed cytologically.
2. Generally crossing over takes place after DNA replication but here it takes place at the same time.

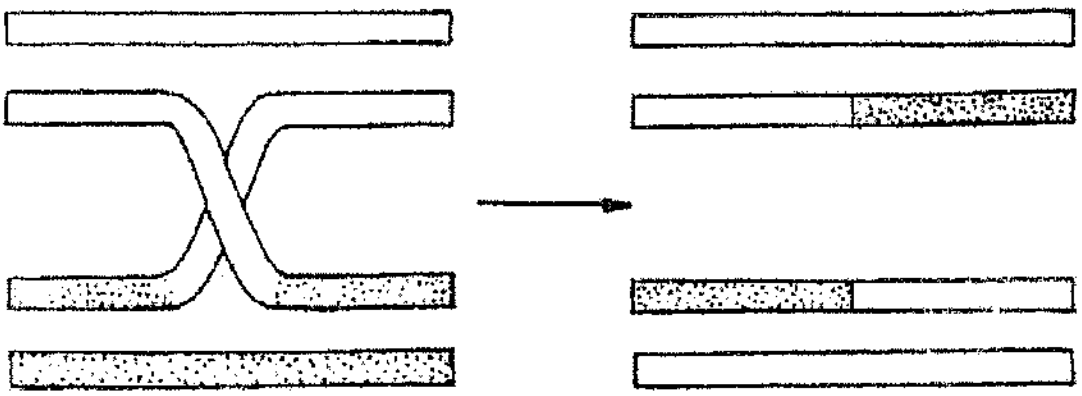


Fig: Crossing over according to Copy Choice Theory

2. Breakage and Reunion Theory

This theory states that crossing over takes place due to breakage and reunion of non-sister chromatids. The two segments of parental chromosomes which are present in recombinants arise from physical breaks in the parental chromosomes with subsequent exchange of broken segments (Fig. 9.2). The breakage results due to mechanical strains that result from the separation of paired homologous chromosomes and chromatids in each chromosome during pachytene stage. The broken ends of non-sister chromatids unite to produce chiasmata resulting in crossing over.

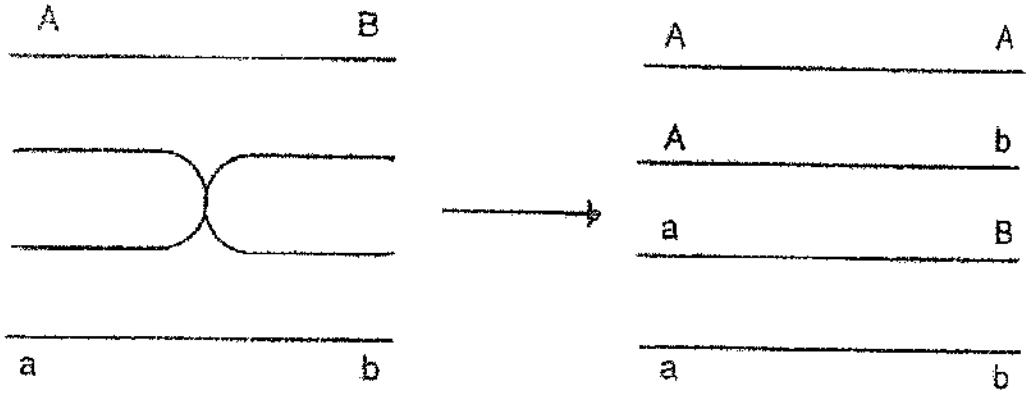


Fig: Crossing over according to Breakage & Reunion Theory

Enlist the factors affecting crossing over

★ **Factors affecting the crossing over**

1. **Distance between gene**
   - Greater the distance between genes higher is chance of crossing over and vice versa.
2. **Age of female**
   - Generally the crossing over decreases with advancement of the age in the female of Drosophila.
3. **Temperature**
   - The rate of the crossing over in Drosophila increases above and below the temperature 22 ^{0}C.
4. **Sex**
   - The rate of crossing over also differs according to sex. There is lack of crossing over in Drosophila male and female silk moth.
5. **Nutrition**

- Presence of metallic ions like calcium and magnesium in the food caused the reductions in the recombination in the Drosophila. However, removal of such chemicals from the diet increased the rate of crossing over.

6. **Chemicals**
   - Treatment with mutagenic chemicals like alkylating agents was found to increase the rate of crossing over in female of Drosophila.
7. **Irradiation**
   - Irradiation with X-rays and gamma rays was found to enhanced the rate of crossing over in female of Drosophila.
8. **Structural changes**
   - Structural changes mainly inversion and translocations reduce the frequency of crossing over in the chromosomes where such changes are involved.
9. **Centromere effect**
   - Generally the genes are located near to centromere show reduced frequency of crossing over.
10. **Cytoplasmic genes**
    - In some species, cytoplasmic genes also lead to reduction in crossing over.

Chromosome mapping

The line diagram which shows various genes present on a chromosome and recombination frequency between them such map is called as chromosome map or linkage map or genetic map. The mapping of the genes on the chromosome is done with the help of two point test cross and three point test cross

Two point test cross –

A cross between dihybrid (F_1 differing in two genes) with its homozygous recessive parent is referred as two point test cross.

- It provides information about recombination frequency between two genes. In a two point test cross, four different phenotypic classes are obtained. Out of four classes, two classes are known as **parental types** (which have maximum number of individuals or maximum frequencies). The remaining two types are known as **recombinant types** (which have lowest number of individuals or minimum frequencies).

Three point test cross –

A cross between trihybrid (F_1 differing in three genes) with its homozygous recessive parent is referred as three point test cross.

- It provides information about the sequence of genes and recombination frequency between various genes. In three point test cross, eight different phenotypic classes are obtained. These eight classes are identified in two different ways *viz.*, (1) by observing phenotypic frequencies (2) by alteration of gene sequence as a result of single crossing over or double crossing over between three linked genes. Suppose, ABC/abc are three linked genes located on two different chromosomes in F_1 of a cross between AABBCC and aabbcc parents.
  - **Parental types :** These classes have the maximum frequencies.
  - **Crossover type (R-I) :** It is a single cross over between gene A and B and it is having intermediate frequencies.
  - **Crossover type (R-II) :** It is a single cross over between gene B and C and it is having intermediate frequencies.
  - **Double crossover type :** It is the double cross over between A and C gene, which alters the position of middle gene i.e. B. Double crossover types has least frequencies.

(Two point test cross and three point test cross example – Refer practical manual)

Significance of crossing over:

1. **Creation of variability:** Crossing over leads to recombination, which is responsible for creation of genetic variation.
2. **Locating genes:** Crossing over is a useful tool for locating genes in the chromosomes.
3. **Linkage map:** Crossing over plays an important role in the preparation of chromosome maps or linkage maps. It provides information about frequency of recombination and sequences of genes located on the chromosomes.

INTERFERENCE

The term interference was coined by Muller which refers to the tendency of one crossover to reduce the chance of another crossover in its adjacent region. Interference is affected by gene d stance on the chromosome. Lesser the gene distance greater is the interference and *vice versa.*

Generally, it is observed that crossing over in one region of chromosome may check the crossing over in the second region.

Sometimes, presence of recombination in one region enhances the chance of recombination in another adjacent region. This is termed as negative interference. This type of situation has been observed in some lower organisms, *viz.*, Aspergillus and bacteriophages. Coefficient of interference is estimated as follows:

Coefficient of interference (%) = 1 - Coefficient of coincidence x 100

Positive and negative interference differ from one another in three main aspects (Table 9.2).

Differences between positive and negative interference

	Positive Interference	*Negative Interference*
1.	One crossover reduces the chance of another crossover in the adjacent region.	1. One crossover enhances the chance of another crossover in the adjacent region.
2.	Observed in both eukaryotes and prokaryotes.	2. Found in some lower organisms like Aspergillus and bacteriophages.
3.	In this case coefficient of coincidence is less than one.	3. In this case coefficient of coincidence is alwaysmore than one.

COINCIDENCE

This term was also coined by Muller to explain strength or degree of interference. The coefficient of coincidence is the percentage ratio of observed double crossovers to the expected double crossovers. The greater the coincidence, lesser will be the interference and *vice versa.* Thus,

$$\text{Coefficient of coincidence (\%)} = \frac{\text{Observed double crossovers}}{\text{Expected double crossovers}} \times 100$$

Coefficient of coincidence is a measure of the intensity of interference, because it has negative association with interference. The value of the coefficient of coincidence is less than 1 for positive interference, greater than 1 for negative interference, 1 for absence of interference and zero for complete or absolute interference.

CYTOLOGICAL PROOF OF CROSSING OVER

The first cytological evidence in support of genetic crossing over was provided by Curt Stern in 1931 on the basis of his experiments conducted with **Drosophila.** He used cytological markers in his studies. He selected a female fly in which one X-chromosome was broken into two segments. Out of these two segments, one behaved as X-chromosome. The other X-chromosome had small portion of Y-chromosome attached to its one end. Thus, both the X-chromosomes in the female had distinct morphology and could be easily identified under microscope. In female fly, the broken X-chromosome had one mutant allele (carnation) for eye colour and another dominant allele (B) for bar eye shape. The other X-chromosome with attached portion of Y chromosome had alleles for normal eye colour (red eye) and normal eye shape (oval eye). Thus, phenotype of female was barred.

A cross of such females was made with carnation male (car+). As a result of crossing over female flies produce four types of gametes, *viz.,* two parental types or non crossover types (car B and ++) and two recombinant types or crossover types (car+ and B+). The male flies produce only two types of gametes (car + and Y), because crossing over does not take place in **Drosophila** male. A random union of two types of male gametes with four types of female gametes will produce males and females in equal number, means there will be four females and four males (Fig. 9.4).

Stern examined the chromosomes of recombinant types, *viz.,* red bar and carnation normal under microscope. He observed that in carnation normal females both the X-chromosomes were of equal length.

In red bar flies, one X-chromosome was normal and other was fragmented. The fragmented X-chromosome also had attached part of Y-chromosome. Such chromosome combination in red bar is possible only through exchange of segments between non-sister chromatids of homologous chromosomes. This has proved that genetic crossing over is the result of cytological crossing over.

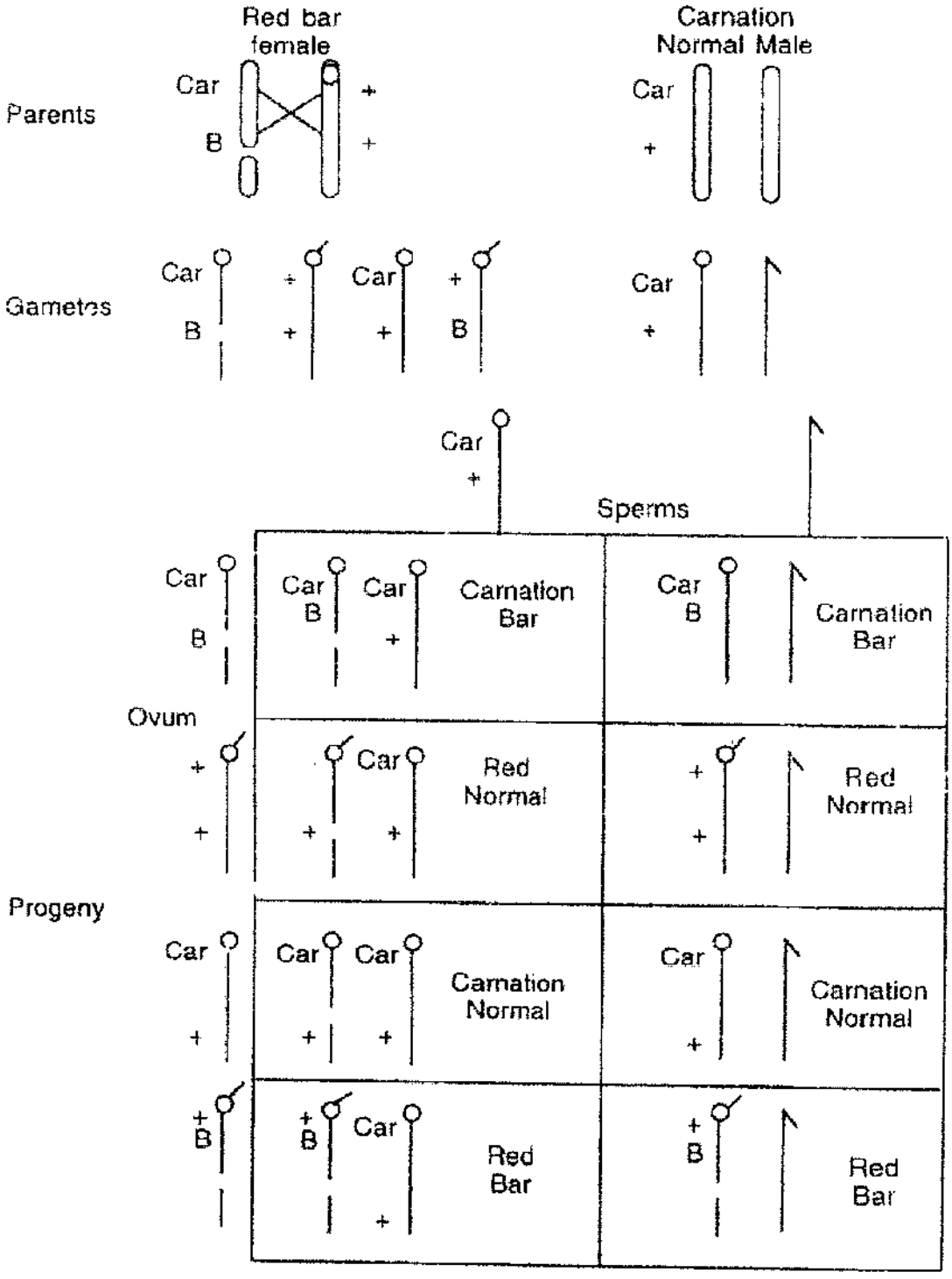


Fig.:-Cytological proof of crossing over in Drosophila

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POLYGENIC INHERITANCE

QUANTITATIVE TRAITS / QUALITATIVE CHARACTERS:

- **Quantitative traits :** The characters, which are controlled by polygenes are referred as quantitative character or **polygenic characters.** e.g. grain yield, leaf size, corolla length, maturity *etc.*
- **Qualitative traits :** The characters, which are controlled by one or two genes are referred as qualitative characters or **oligogenic characters.** e.g. fruit colour, seed colour etc.
- **Oligogene :** One or few genes governs the same character.
- **Polygene :** Several genes governs the same character.

Characteristics of Quantitative Inheritance (Polygenic Trait)

- Each quantitative character is controlled by several independent genes and each gene having small, similar and cumulative effect.
- Each quantitative character exhibits continuous variation rather than discontinuous variation. The variability observed for quantitative trait cannot be classified into distinct phenotypic classes.
- Effect of individual gene is not easily detectable in case of quantitative characters and therefore, such traits are also known as minor gene characters.
- The statistical analysis of quantitative character is based on means, variances and co-variances. Thus, quantitative characters are studied in quantitative genetics.
- Quantitative characters are highly sensitive to environmental variation.
- Classification of quantitative characters into different clear cut phenotypic classes is not possible because of continuous variation from one extreme to the other extreme.
- Generally, the expression of quantitative characters is governed by additive gene action but now the cases are known where quantitative characters are governed by dominance and epistatic gene action.
- Each quantitative character involves metric measurements like size, weight, height etc.
- Transgressive segregants are only possible from the crosses between two parents for quantitative characters.

- The transmission of quantitative characters is generally low because of high influence of environmental variation.
- If a substitution of an allele occurs in a gene locus then such allelic substitution have different effects.
- Quantitative traits are controlled by polygenes and polygenes have pleiotropic effects i.e. one gene may modify or suppress more than one phenotypic trait.

Characteristics of Qualitative Inheritance (Oligogenic Trait)

- Each qualitative character is controlled by few independent genes and each gene has its independent effect.
- Oligogenic characters exhibits discontinuous variation.
- Effect of individual gene is easily detectable in case of qualititative characters.
- The statistical analysis of the discontinuous variation can be analyzed with the help of frequencies and ratios.
- Qualitative characters are less sensitive to environmental variation.
- Qualitative characters are classified into distinct phenotypic classes.
- Generally, the expression of quantitative characters is governed by non-additive gene action (dominance and epistatic gene action).
- Transgressive segregants are not possible in case of qualitative or oligogenic inheritance.
- Qualitative characters exhibit high transmission because there is limited difference between the genotype and phenotype of such characters.

PARTITIONING OF POLYGENIC VARIABILITY (Components of Variation)

The polygenic variation or variability present in a genetic population is measured in terms of variances. The polygenic variation is of three types, *viz.,* (1) phenotypic, (2) genotypic, (3) and environmental. These are briefly described below:

1. Phenotypic Variability

It is the total variability which is observable. It includes both genotypic and environmental variation and hence changes under different environmental conditions. Such variation is measured in terms of phenotypic variance.

2. Genotypic Variability

It is the inherent or genetic variability which remains unaltered by environmental conditions. This type of variability is more useful to a plant breeder for exploitation in selection or hybridization. Such variation is measured in terms of genotypic variance. The genotypic variance consists of additive, dominance and epistatic components.

3. Environmental Variability

It refers to non-heritable variation which is entirely due to environmental effects and varies under different environmental conditions. This uncontrolled variation is measured in terms of error mean variance. The variation in true breeding parental lines and their F_1 is non-heritable. Fisher was the fust to divide in 1918, the genetic variance into additive, dominance and epistatic components.

Diff. betn

Difference between quantitative character and qualitative traits:

SN	Qualitative traits (Oligogenic Traits)	Quantitative traits (Polygenic Traits)
1.	Qualitative traits are governed by mono or oligogenes.	Quantitative traits are governed by polygenes.
2.	It deals with the inheritance of traits of kind *viz.*, form, structure, colour etc.	It deals with the inheritance of traits of degree *viz.*, height, length, girth, weight, number etc.
3.	It is less influenced by environment.	It is highly influenced by environment.
4.	It shows discontinuous variation.	It shows continuous variation.
5.	It concern with individual mating and their progeny.	It concern with a population of organisms consisting of all possible kinds of mating.
6.	It can be classified into distinct phenotypic classes.	It can be measure in terms of metrical units.
7.	Its analysis made by count and ratio.	Its analysis is made by using certain statistical methods.

Q. what is multiple factor hypothesis? Explain it with suitable example.

Multiple Factor Hypothesis / Inheritance of Quantitative Characters

The inheritance of quantitative characters was first explained by Yule (1906). In 1908, Nilson and Ehle presented experimental evidence to support the hypothesis of Yule. He studied the inheritance of seed colour in wheat and Oat. The F_2 generations from various crosses had red and white colour in the ratios of 3 : 1, 15 : 1 and 63 : 1. So from these ratios, it become clear that seed colour in these crosses was governed by one, two or three genes, respectively. However, on closer examination of the colored seeds, Nilsson-Ehle found marked difference in the intensity of their colour. On the basis of intensity of their red colour, he further classified dihybrid ratio of 15:1 into 1:4:6:4:1 (Figure).

Parents : $R_1R_1R_2R_2$ (Dark Red) X $r_1r_1r_2r_2$ (White)

Gametes : R_1R_2 r_1r_2

⇩

F_1 : $R_1r_1R_2r_2$ (Medium Red) selfing

Gametes: R_1R_2 R_1r_2 r_1R_2 r_1r_2

F_2 :

♀\♂	R_1R_2	R_1r_2	r_1R_2	r_1r_2
R_1R_2	$R_1R_1R_2R_2$ Dark Red	$R_1R_1R_2r_2$ Medium Dark Red	$R_1r_1R_2R_2$ Medium Dark Red	$R_1r_1R_2r_2$ Medium Red
R_1r_2	$R_1R_1R_2r_2$ Medium Dark Red	$R_1R_1r_2r_2$ Medium Red	$R_1r_1R_2r_2$ Medium Red	$R_1r_1r_2r_2$ Light Red
r_1R_2	$R_1r_1R_2r_2$ Medium Dark Red	$R_1r_1R_2r_2$ Medium Red	$r_1r_1R_2R_2$ Medium Red	$r_1r_1R_2r_2$ Medium Red
r_1r_2	$R_1r_1R_2r_2$ Medium Red	$R_1r_1r_2r_2$ Light Red	$r_1r_1R_2R_2$ Light Red	$r_1r_1r_2r_2$ White

Inheritance of seed colour in Wheat

F_2 Phenotypic ratio :

Phenotypes	:	Ratio
Dark Red	:	1
Medium Dark Red	:	4
Medium Red	:	6
Light Red	:	4
White	:	1

According to multiple factor hypothesis, inheritance of seed colour in this cross showing 1 : 4 : 6 : 4 : 1 ratio in F_2 may be explained as follow :

1) Seed colour in wheat is governed by two genes, R_1 and R_2 (positive alleles), r_1 and r_2 being the negative alleles of these genes.
2) The two parents having genotypes $R_1R_1R_2R_2$ and $r_1r_1r_2r_2$ will produce the gametes R_1R_2 and r_1r_2 respectively, which will unite to give rise $R_1r_1R_2r_2$ genotype in F_1.
3) Since F_1 seeds have only two positive alleles, their colour will be intermediate between those of the two parents, i.e. medium red.
4) In the F_2 generation of this cross as given in the above table, the multiple factor hypothesis is able to explain the 1: 4: 6: 4: 1 ratio for seed colour in wheat.

Explanation of 1: 4: 6: 4: 1 ratio in relation to the number of dominant alleles present in genotype of different individuals F_2 generation.

Genotype	Frequency	No. of dominant alleles	Phenotype	Frequency
$R_1R_1R_2R_2$	1	4	Dark Red	1
$R_1R_1R_2r_2$ $R_1r_1R_2R_2$	2 2	3	Medium Dark Red	4
$R_1r_1R_2R_2$ $R_1R_1r_2r_2$ $r_1r_1R_2R_2$	4 1 1	2	Medium Red	6
$R_1r_1r_2r_2$ $r_1r_1R_2r_2$	2 2	1	Light Red	4
$r_1r_1r_2r_2$	1	0	White	1

MULTIPLE FACTOR HYPOTHESIS: Continuous variation of the characters is controlled by polygene with no dominance and here each of the genes having small, similar and cumulative effect. This is the essence of the multiple factor hypothesis.

//*//*//*//

Sex Determination and Sex Linkage, Sex Limited and Sex Influenced Traits

INTRODUCTION

★ *Sex* refers to contrasting features of male and female individuals of the same species. Thus sex is usually of two types, *viz.*, male and female.

★ *Sex determination* is the process of sex differentiation, which utilizes various genetical concepts to decide whether a particular individual will develop into male or female sex.

Some important points related to sex determination are given below:

1. Applicability of Sex Determination

Majority of animals are unisexual, whereas most of the plants are bisexual or hermaphrodite. The sex determination is applicable to unisexual animals and monoecious and dioecious plant species. In case of **dioecious plants**, male and female flowers are produced on different plants such as in cucumber, papaya, asparagus, etc. On the other hand, in **monoecious plants** male and female flowers are produced on the same plant such as in maize, castor and coconut.

2. Identification of Sex

Sex is identified with the help of **sex characters**. In plants, sex is identified with the help of male and female floral parts. Thus in plants, morphological distinction of sex is possible only after flowering. In mammals, sex characters are of two types, *viz.*, primary sex characters and secondary sex characters. **Primary sex characters** include **gonads or sex organs** which are distinct since birth and take part in reproduction. **Secondary sex characters** express differently in males and females in adulthood and do not take part in reproduction. In human, such characters include voice, facial hair, mammary glands, muscles, etc.

3. Control of Sex

Sex expression is governed by **chromosomes and genes**. In some cases environment also plays an important role in the expression of sex or determination of sex. In unisexual animals, chromosomes are of two types, viz., **autosomes and allosomes**. Those chromosomes which do not differ in morphology and number in male and female sex are referred to as **autosomes**. On the other hand, those chromosomes which differ in morphology and number in male and female sex and contain genes determining sex are known as **allosomes** or **sex chromosomes**. Sex chromosomes were first discovered by **Mc Lung in 1902** in grasshopers and later on by Wilson and Stevens in 1905 in Protenor. Each unisexual diploid individual has two sex chromosomes

Short note on XX-XY method of Sex determination

Difference between

and rest autosomes. Thus autosomes and allosomes differ from one another in several aspects as follows

Autosomes		Allosomes or Sex chromosomes	
1.	Refer to other than sex chromosomes.	1.	These are sex chromosomes.
2.	Morphology is similar in male and female	2.	Morphology is different in male and female
3.	The number is same in both the sexes.	3.	The number is sometimes different in male and female sex.
4.	Generally control traits other than sex.	4.	Usually determine sex of an individual.
5.	Number of autosomes differs from species to species.	5.	Each diploid organism usually has two allosomes.
6.	Do not exhibit sex linkage.	6.	Exhibit sex linkage.

MECHANISMS OF SEX DETERMINATION

There are three important mechanisms of sex determination, *viz.*, 1. Chromosomal sex determination, 2. Monogenic sex determination, and 3. Environmental sex determination (Table 10.2). These are briefly described below :

1. CHROMOSOMAL SEX DETERMINATION

Chromosomal sex determination is again of three types, *viz.*, *(a)* Sex determination by allosomes, *(b)* the diploid-haploid system of sex determination, and *(c)* genic balance system. All these systems are briefly discussed below:

(a) ALLOSOMAL SEX DETERMINATION

Allosomes or sex chromosomes are generally of X and Y types, but in some birds they are of Z and W types. Sex with similar type of sex chromosomes (XX) is known as homogametic sex and with dissimilar type of sex chromosomes (XY) as heterogametic sex. There are four different systems of allosomal sex determination, *viz.*, 1. XX-XY female-male system, 2. XX-XO female-male system, 3. XO-XX female-male system, and 4. ZW-ZZ female-male system. These are briefly discussed below.

Short note

1. *XX-XY [Female-Male] System*

This system is found in **Drosophila,** man and some other mammals. In this system female has two X chromosomes, is homogametic and produces only one type of gamete, *i.e.*, X. The male has one X and one Y chromosome, is heterogametic and produces two types of

gametes, *viz*, X and Y. Union of X ovum with X sperm leads to development of female (XX) sex. If X ovum units with Y sperm, it produces male (XY) sex.

Table:-Mechanisms of sex determination found in animals and plants

Mechanism of sex determination			*Found in*	
			Animals	*Plants*
1.	**Chromosomal system**			
a)	Allosomal system (Female—Male)			
	i)	XX-XY System	**Drosophila**, man and some other mammals	**Melandrium, Cannabis, Coccinia, Humulus Lupulus, Salix, Bryonea** etc.
	ii)	XX-XO System	Grasshoppers, many insects of hemiptera and orthoptera.	**Dioscorea sinuata, Vallisneria spiralis**
	iii)	XO-XX System	**Fumea**	—
	iv)	ZW-ZZ System (XY-XX System)	Birds, butterflies, moths	**Fragaria**
b)	Diploid-Haploid System		Honey bee	—
c)	Genie Balance System		**Drosophila**	—
2.	**Monogenic System**		**Drosophila**, man, goats, pigs, dogs	Asparagus, maize, spinach, papaya, etc.
3.	**Environmental Effect**		**Bonellia** and **Dinophilus**	**Equisetum**, cucumber, Muskmelon, and **Cannabis.**

Sex determination in Melandrium album

In this plant pistillate plants are XX and staminate plants are XY. In this plant one dose of Y is able to produce male sex even in the presence of four X chromosomes. In other words, presence of one Y chromosome can produce male flowers in diploid, triploid and tetraploid species (Table)

Detailed investigation of the sex chromosomes of **Melandrium** revealed that Y chromosome has four regions, *viz.*, **(1) male suppression region, (2) male promoter region, (3)**

male fertility region, and (4) pairing region. Region four is common in X and Y chromosomes. Hence pairing occurs in this region (Fig. 10.1). If first region is lost a bisexual plant is produced. When second region is lost, female plant is produced, and when third region is lost, male sterile plants with abortive anthers develop.

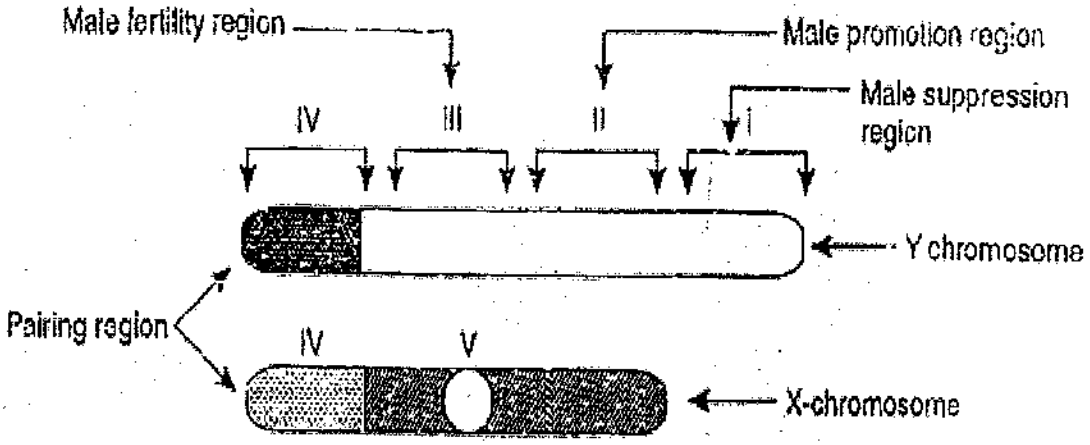


Fig. Sex chromosomes of Melandrium album. Region IV is homologous in X and Y chromosomes, hence pairing occurs in this region.

This system differs from genic balance system in **Drosophila.** In this system, the male sex is determined by the genes presented on Y chromosome, whereas in genic balance system male sex is determined by the genes located on autosomes.

Table:- Sex determination in Melandrium in relation to autosomes and sex chromosomes

Ploidy Level	*Sets of Autosomes*	*Sets of sex Chromosomes*	*X/A Ratio*	*Sex Expression*	
Diploid	2A	XX	1.00	Female	
Diploid	2A	XY	0.50	Male	
Diploid	2A	XYY	0.50	Male	
Triploid	3A	XXY	0.67	Male	
Tetraploid	4A	XXY	0.50	Male	occasional female
Tetraploid	4A	XY	0.25	Male	
Tetraploid	4A	XXXY	0.75	Male	occasional female
Tetraploid	4A	XXXXY	1.00	Hermaphrodite	occasional female

2. *XX-XO [Female-Male] System*

This type of sex determination is common in grasshoppers and many orthoptera and hemiptera insects. In this system, female has double X chromosomes (XX) and male has single X chromosome (XO). Here female is homogametic and produces all the eggs with X chromosome. The male is **heterogametic,** which produces sperms half of which have X chromosome and other have none. Union of egg with sperm having X chromosome will give rise to female sex and with sperm having none results in development of male sex. In plants, this system operates in **Dioscorea sinuata** and **Vallisneria spiralis.** Here the pistillate plants are XX and staminate plants are XO.

3. *XO-XX [Female-Male] System*

This system has been reported in very few species of insects like **Fumea.** In this system, female has only one X chromosome and hence is heterogametic. As a result of meiosis. 50% eggs of such female carry an X chromosome and remaining 50% have none. On the other hand, male has two X chromosomes and produces all the sperms with one X chromosome. Thus, male sex is homogametic. Union of X sperm with ovum having X chromosome gives rise to male sex and union of X sperm with ovum having none leads to development of female sex, **Thus, system is reverse of the system described above.** This system has not been reported in plant so far.

4 *ZW-ZZ [Female-Male] System*

This system is found in birds, butterflies and moths. In this system, the female is heterogametic and produces two types of gametes, namely Z and W types. On the other hand, male is homogametic and, as a result of meiosis, produces all the sperms of same type carrying one Z chromosome. Union of Z sperm with ovum having Z chromosome gives rise to male and union of Z sperm with ovum carrying W chromosome leads to the development of female sex. In plants, this system operates in **Fragaria.**

Short note

(b) ***DIPLOID-HAPLOID [FEMALE-MALE] SYSTEM***

This system operates in honey bees, ants and termites. In honey bees, the females have diploid (2n = 32) chromosomes and drones or males have haploid (n = 16) chromosomes. The females are of two types, *viz.,* **queen and workers.** Those females which feed on royal jelly develop into queen. **The queen is fertile and workers are sterile females.** The queen produces

haploid eggs. However, haploid male bees produce haploid sperms by mitosis rather than by meiosis. Union of egg with sperm gives rise to diploid larvae which become female. Those larvae which feed on royal jelly develop into fertile queen and others into sterile female workers. unfertilized eggs develop parthenogenetically into haploid but fertile drone or males.

(c) GENIE BALANCE SYSTEM → Short note

This system was proposed by Bridges in 1922 working with **Drosophila.** Genic balance theory states that sex determining genes are present on both X chromosome as well as autosomes. The male sex determining genes are present on autosomes and female sex determining genes on X chromosome. The sex expression is determined by the balance genes on autosomes and X chromosome. In other words, the expression of sex depends on the ratio of X chromosomes to that of autosomes (Table). This ratio is represented as X/A ratio.

The genic balance is governed by X/A index. Individuals with index of 1 develop into female and those with sex index of 0.5 into male, if the sex index is between 1 and 0.5, the resulting individual will be neither a female nor a male, but have an intermediate sex expression and is called intersex. The sex index of 1.5, which is higher than, the sex index of normal female gives to super female. A sex index of 0.33, which is lower than the sex index of normal male gives rise to super male.

Table: - Sex expression in Drosophila in relation to X/A ratio

Ratio of chromosome and autosome (X : A)	*Sex Index (X/A)*	*Expression of sex*
2X : 2A	1.00	Female
IX : 2A	0.50	Male
2X : 3A	0.67	Inter sex
IX : 3A	0.33	Super male
3X : 2A	1.50	Super female

2. MONOGENIC SEX DETERMINATION

In some animals and plants, expression of sex is influenced by a single gene. In **Drosophila,** a transformer gene (tra) which is present on autosomes plays an important role in sex expression. The gene is so named because it leads to transformation of female sex into male.

Transformer gene is recessive and hence does not have any effect in heterozygous condition (Tra/tra) on either sex, *i.e.*, male or female. In homozygous condition (tra/tra), this gene transforms the normal diploid females into sterile males.

A similar gene is found in human. The gene is probably present on autosome and transforms the normal male (XY) into female. In this case, the change is reverse as compared to **Drosophila** case. Such males have feminine characters such as breast and vagina. They also have internal degenerated testes and are sterile. This condition is known as testicular feminization. Similar effects of single recessive gene on expression of sex have been found in some other animals such as goats, pigs, dogs, etc.

Monogenic control of sex has also been reported in some plants like **asparagus, maize, papaya, spinach, etc**. In papaya, the sex is postulated to be governed by three alleles, *viz*.. m, M_1 and M_2 of a single gene. Homozygous recessive (m m) produces female plants, heterozygous, *viz.*, M_1m and M_2m produce male and hermaphrodite plants, respectively. However, combination of both dominant alleles (M_1 and M_2) produces inviable plants both in homozygous condition (M_1M_1 and M_2M_2) as well as heterozygous condition (M_1M_2), Crosses between female (mm) and male (M_1m) produce females and males in 1 : 1 ratio. Similarly, crosses between female (mm) and hermaphrodite (M_2m) will produce females and hermaphrodite in 1 : 1 ratio. Seeds obtained from hermaphrodite plants will produce hermaphrodite and female progeny in 2 : 1 ratio.

Maize being a monoecious plant bears both female (silk) and male (tassel) inflorescence on the same plant. A recessive gene ba (barren cob) in homozygous condition (ba/ba) makes the cobs barren or non-functional. Similarly, a recessive gene (ts) in homozygous condition (ts/ts) converts the male flowers of tassel into female flowers. Thus, homozygous state of gene ba (ba/ba) converts the monoecious plant into male. Similarly, gene (ts) in homozygous condition (ts/ts) converts the monoecious plant into female. Plants with both dominant genes (BaBa/TsTs) are normal monoecious, with baba/TsTs normal male, with BaBa/tsts normal female and with baba/tsts rudimentary females.

3. ENVIRONMENTAL SEX DETERMINATION

Sex determination in some organisms such as sea worm (Bonellia and **Dinophilus)** and horse tail plant **(Equisetum)** is governed by environmental conditions and also includes some hormonal effects.

In **Bonellia,** those larvae which remain free in the sea water and settle on the sea bottom are differentiated into females. On the other hand, those larvae which settle on the proboscis of female develop into tiny males. They do not have digestive organs, hence move from the proboscis to the uterus of female where they remain as parasites.

In **Dinophilus,** the determination of sex appears to depend solely on the size of egg produced by the females. Larger eggs after fertilization always develop into females and smaller eggs into male animals.

In horse tail plant **(Equisetum),** development of sex depends on growing conditions. Plants grown under good conditions develop as females and those grown under stress conditions develop into males. In some plants, sex differentiation depends on day length, temperature and hormones. For example, in cucumber **(Cucumis sativa)** and muskmelon, treatment with ethylene enhances production of female flowers.

SEX MOSAIC IN DROSOPHILA

Combination of male and female features in the body of an individual is known as sex mosaic. In **Drosophila,** flies with a very low frequency (1 in 2000) have male tissues in one part of the body and female tissues in other. Individuals with such sex mosaic are known as **gynandromorphs or gynanders.**

Three patterns of sex mosaic may be found in **Drosophila,** *viz.,* bilateral, antero/ posterior and in patches. In case of bilateral sex mosaic, one side of the fly is male and the other side is female. This is the most common type of sex mosaic found in **Drosophila.** In case of antero/posterior pattern of sex mosaic, the front half of the fly is one sex and the rear half of the other sex. Sometimes, only a quarter of the body is male and rest is female or just a small patch of tissues may be male and rest of the body is female. The last two patterns are of rare occurrence.

Gynandromorphs develop from a normal female having one pair of X-chromosomes. In the first mitotic division of zygote, one X-chromosome is lost in the cytoplasm. As a result, one of the two cells has only one X-chromosome. Thus, one cell is differentiated into male tissue. Further, division of these two types of cells results in the development of bilateral type of gynander. If such mistake occurs at the second mitosis of embryogenesis, only one cell out of four will produce male tissue. In this case only one fourth of the body will be male. If such mistake in mitosis takes place at later mitotic divisions, only a small portion of male tissues will

be produced. Gynandromorphs are detected with the help of phenotypic characters such as banding pattern of abdomen, presence or absence of sex combs on the fore legs and structure of external genitalia.

SEX REVERSAL

Sex reversal refers to transformation of one sex to another. A good example of partial sex reversal is found in chickens. In rare cases, old hens which have been good egg layers for many years start exhibiting such features which are indicative of male sex. They develop male comb and male plumage, begin to crow and try to mate with other hens. *Crew* reported such extreme case of sex reversal in hen. A normal fertile hen, after several years of egg laying changed into male, produced viable sperms and became father of two chicks. In birds, there is only one functional ovary (left sided). In the centre of this ovary a small mass of tissues similar to male testes is present. The ovary usually produces female hormone which results in full expression of female features. In some cases, the ovary is destroyed due to tubercular infection. In such cases, the testes like tissues enlarge and produce male hormone in ample quantity resulting in reversal of sex. Removal of ovary by way of surgery, and leaving the testes like portion may also result in sex reversal in hens.

HUMAN SEX ANOMALIES

There are two types of human sex abnormalities, *viz.*, 1. Klinefelter's syndrome, and 2. Turner's syndrome. These are briefly described below :

1. Klinefelter's Syndrome

Klinefelter's syndrome refers to the characteristics of an abnormal human male who has an XXY chromosome constitution. Such individuals have 47 chromosomes (44 autosomes plus XXY), whereas normal human has 46 chromosomes (44 autosomes + XX or XY). Frequency of such persons is 1 in every 5000 births.

Phenotype

Such persons have typical male sex organs, but testes are about half of the normal size, sperms are usually not produced and most of such persons are mentally retarded. Their arms are longer than average. Some degree of breast development also occurs. Hair are feminine in nature and voice is higher pitched than in normal males. Such persons are always sterile and are sex chromatin positive.

Origin

The XXY individuals may arise when an XX egg is fertilized by a Y sperm or an X egg is fertilized by XY sperm. The majority of Klinefelter's syndromes are born to mothers after the age of 32. It results mainly due to non-disjunction of the X chromosomes in the ageing oocytes than XY non-disjunction during spermatogenesis. In very rare cases, Klinefelter's syndromes have more than two X chromosomes or more than one Y chromosome. Generally, greater the number of X chromosomes greater the degree of mental retardation. Presence of one Y chromosome leads to general phenotype of male even in the presence of several X chromosomes.

2. Turner's Syndrome

It refers to the characteristics of an abnormal human female who has an XO chromosome constitution. Such individuals have 45 chromosomes (44 autosomes plus one X chromosome), their frequency is 1 in every 3000 births.

Phenotype

Such individuals are phenotypically females, but have poorly developed and sterile ovaries. They are dwarf (below 5 feet), often show some mental retardation, webbing of the neck, low set ears, broad chest and under developed breasts. They are sex chromatin negative which confirms presence of single X chromosome.

Origin

The XO individuals may arise due to non-disjunction of X and Y chromosomes in the male. In the absence of Y chromosome. the general sex phenotype is the female. Thus, union of A+X egg with A+O sperm produces AA+XO individuals.

BARR BODY OR SEX CHROMATIN

Barr body refers to relatively coiled and inactive interphase chromatin of the X chromosomes of the normal mammalian females but not the males. The Barr body was first discovered by a **geneticist, Murray Barr in nerve cells of cat.**

Barr bodies were found in the nucleus of female cats only. They take dark stain like DNA. Later on Barr bodies were found in females of many mammals including man. **Barr bodies are also known as sex chromatin.**

In humans, Barr bodies are studied in the epithelial cells, which can be easily obtained from the lining of the **mouth, vagina or urethra**. In women the Barr bodies are found near the nuclear membrane and look like a round disc. The number of Barr bodies in a female cell is always one less than the number of X chromosomes. Thus, a normal woman has two X chromosomes and one Barr body. A woman with Turner's syndrome has one X chromosome but no Barr body. Normal males have no Barr body, but males with Klinefelter's syndrome have two X chromosomes and one Barr body. Thus Barr bodies are useful tools for detection of sex abnormalities and also in the determination of sex in humans. Individuals which have Barr bodies are known as sex chromatin positive and those who do not have Barr bodies are called as sex chromatin negative.

LYONS HYPOTHESIS

This hypothesis was proposed by Lyon in 1969, which states that in a normal female only one X chromosome is active which is invisible at interphase. The other X chromosome remains inactive, takes dark stain and becomes visible in interphase nucleus.

In other words, an individual may have any number of X chromosomes, but only one remains active and others become condensed or inactive. The number of inactive chromosomes is represented by the number of sex chromatin bodies.

Though the male and female individuals in **Drosophila** and man differ from one another for dose of X chromosome, the male has one X chromosome and female has two X chromosomes. However, they do not differ in their gene products. This reveals that either one X chromosome should be inactivated in female or the efficiency of single X chromosome of male should be doubled. This phenomenon is known as **dosage compensation** which was proposed by **Muller in 1932. Discovery of Barr bodies and Lyon's hypothesis have confirmed the concept of dosage compensation.**

SEX LINKAGE

Characters for which genes are located on sex or X chromosomes are known as **sex linked traits,** such genes are called **sex linked genes** and **linkage** of such genes is referred to as **sex linkage.** Inheritance of such genes or characters is known as **sex linked inheritance.** Main features of sex linked genes are briefly discussed below:

1. Location

Sex linked genes are located on X chromosomes only. Hence, inheritance of sex linked genes follows the inheritance pattern of X chromosomes. The Y chromosome determines only sex, is usually inert, and does not contain genes for other characters.

2. Number

In a diploid organism, each homogametic sex (XX or ZZ) has two copies of linked alleles. These alleles may be either in homozygous condition (AA or aa) or in heterozygous state (Aa). The heterogametic sex (XY or ZW) has only one copy of the sex linked allele (either A or a), which may be either dominant or recessive. Thus heterozygous sex is hemizygous for a sex linked gene.

3. Expression

A recessive gene, in a homogametic sex can express only when it is in homozygous state. However, in heterogametic sex, a recessive allele can express even in a single dose (hemizygous condition) because the Y chromosome is genetically inactive. As a result, expression of recessive sex linked character is higher in heterogametic sex than in homogametic sex.

4. Transmission

Sex linked genes are transmitted from female to the male and not from the male to the male, because males receive their X chromosome from the female only. Similarly, sex linked genes are inherited from male to the female, because female receives one of its X chromosome from the male. Thus sex linked genes are first inherited from male to female in the first generation and then back to male in the second generation. This type of inheritance in which a sex linked gene is inherited from grandfather to grandson through daughter is called cris-cross inheritance.

5. Pattern of Segregation

Inheritance of sex linked characters does not follow normal segregation pattern. It exhibits several deviations from the normal segregation pattern. The deviation of sex linked inheritance from the normal one is due to location of such genes in the X chromosome and absence of such alleles in the Y chromosome.

SEX LINKED CHARACTERS

Sex linked characters are known in man (colour blindness, hemophilia, baldness, etc.), **Drosophila** (white eye, vermilion eye) and several other organisms. Some examples of sex linked genes are given below:

Sex Linkage in Man

Hemophilia is the well known example of sex linkage in humans. The hemophilic individuals lack some thing in the blood which is essential for normal clotting of blood after its exposure to the air, in hemophilic persons even a minor cut or injury leads to continuous profuse bleeding from such wounds. In case of normal persons, the clotting takes place between 2 to 8 minutes after bleeding starts. Hemophilia is a hereditary defect which is governed by recessive gene and is inherited through females. The gene is located on *X* chromosome. In case of a marriage between hemophilic woman and normal man, the disease will be transmitted to 50% of the sons even if the gene is in heterozygous condition in the carrier (Fig.)

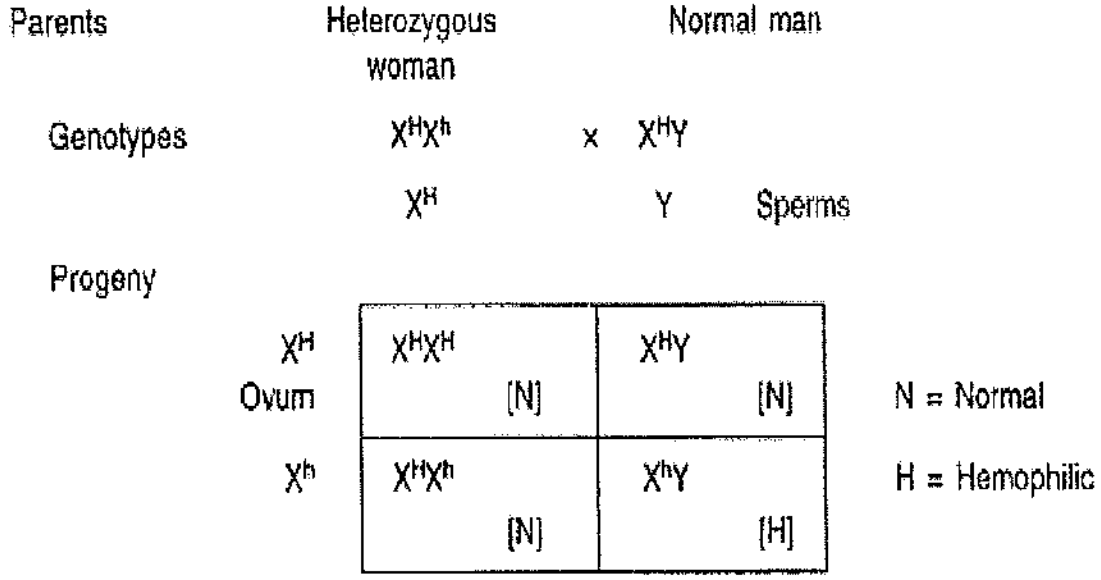


Fig. Inheritance of hemophilia in human.

The Colour blindness is another example of sex linkage in humans. This trait is governed by a recessive gene located on X chromosome. A person having such defect cannot differentiate between red and green colour. Sons from the marriage between colour blind man and normal woman will be normal, but daughters will carry such genes in heterozygous condition. Marriage of such carrier girl with colour blind boy will yield children in which both male and female children will be colour blind each in 50% cases (Fig.).

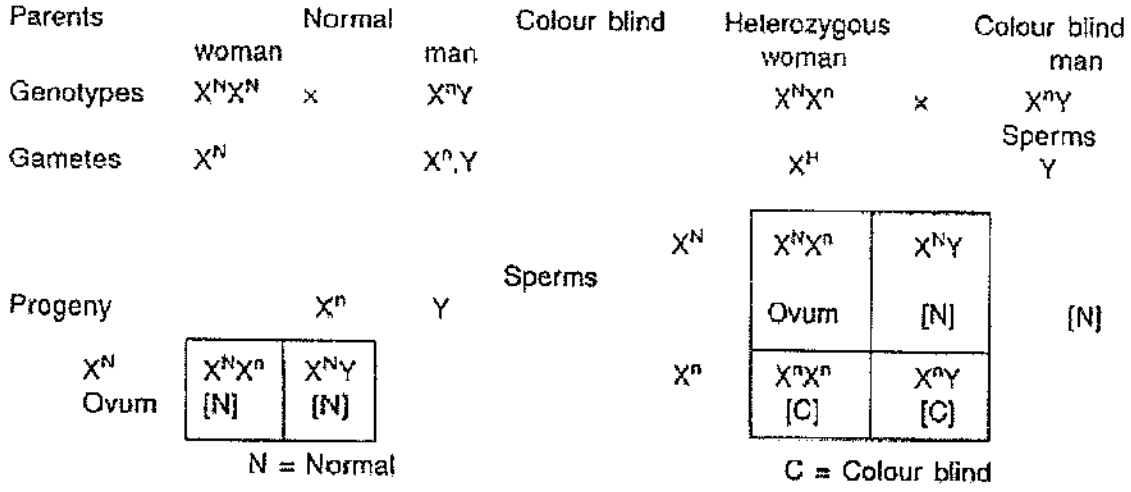


Fig. Inheritance of colour blindness in man.

Sex Linkage in Drosophila

Sex linkage was first discovered by **T.H. Morgan** in **Drosophila.** He found one mutant fly, in a population of thousands of flies, with white eye instead of normal red eye. Cross of white eyed female with red eyed male produced only white eyed males and red eyed females in F_1 generation. Intermating of F_1 females and males produced white and red eyed flies in equal proportion in both the sexes. This was an unusual pattern of inheritance known upto that time. Morgan explained inheritance of this character on the basis of two assumptions, *viz.*, (1) that the genes for eye colour was located on X chromosome, which followed the inheritance pattern of X chromosome, and (2) Y chromosome was devoid of such genes.

Inheritance of White Eye Colour

The red eye colour (R) is dominant over white (r). In a cross between white female (X^rX^r) and red male (X^RY), the female produces one type of gamete (X^r) and male produces two types of gametes (X^R and Y). Union of female gamete with two different male gametes gives rise to red female and white male in equal proportion in F_1 generation. When these F_1 flies are intermated again red females and white males are recovered in equal proportion in F_2 generation. In F_1 both male and female flies produced two types of gametes. Random union of such gametes resulted in production of red male and white female flies in equal proportion in F_2 generation (Fig. a).

In a reciprocal cross between red eyed female and white eyed male all the males and females were with red in F_1 intermating of these individuals produced all female flies with red eyes in F_2 generation. However, among male flies half were with red eyes and half with white eyes (Fig.b).

Parents	White eyed females		Red eyed Males	Red eyed females		White eyed Male
Genotypes	X^rX^r	×	X^RY	X^RX^R	×	X^rY
F_1		X^R	Y Sperms		X^r	Y Sperms
	X^r Ovum	X^RX^r [R]	X^rY [W]	X^R Ovum	X^RX^r [R]	X^RY [R]
Results	1 : 1 Ratio of red and white (Intermating)			Females and Males all red (Intermating)		

(a)

F_2		X^r	Y Sperms		X^R	Y Sperms
	X^R Ovum	X^RX^r [R]	X^RY [R]	X^R Ovum	X^RX^R [R]	X^RY [R]
	X^r	X^rX^r [W]	X^rY [W]	X^r	X^RX^r [R]	X^rY [W]
Results	(R) = Red eye Females and Males 1 : 1 Red and White			[W] = White eye Females all red Males 1/2 red, 1/2 white		

(b)

In F_1 the female will produce X^R and X^r gametes and male will produce X^R and Y gametes. Random union of these two types of gametes each of male and female flies will give rise to females with red eyes, and males with white eyes and red eyes in equal proportion.

SEX LIMITED TRAITS

Characters which are expressed in one sex only are referred to as sex limited characters. These characters have three main characteristics as given below :

1. They express in one sex only and not in the other sex.
2. Sex limited genes may be located either in sex chromosome or autosomes.
3. Sex limited genes control the expression of primary and secondary sex characters.

Difference between ↓

Table:-. Differences between sex linked and sex limited characters

	Sex Linked Characters		*Sex Limited Characters*
1.	They are located on sex or X chromosomes.	1.	They are located on sex chromosomes or autosomes.
2.	They can express in both the sexes.	2.	They express in one sex only.
3.	Include characters not related to sex.	3.	Include primary and secondary sex characters.
4.	Examples are white eye in Drosophila, hemophilia and colour blindness in man.	4.	Examples are breast development in woman and beard in man.

SEX INFLUENCED GENES

The dominance expression of some genes depends on the sex of individual. Such genes are known as sex influenced genes and characters governed by such genes are referred to as sex influenced characters. These genes have three main features as given below :

1. Such genes are located in the autosomes.
2. They express more frequently in one sex than other.
3. Expression of such characters appears to be governed by sex hormones.

The best known example of sex influenced character in pattern of baldness in humans. The gene responsible for baldness behaves as dominant in males and as recessive in females. Similarly, horns in sheep behave as dominant in males and recessive in females. The baldness character expresses in woman only when it is in dominant homozygous state, while in man it expresses even in heterozygous condition.

GLOSSARY

1. **Sex.** Contrasting features of male and female individuals of the same species.
2. **Sex determination.** The process of sex differentiation which utilizes various genetical concepts to decide whether a particular genotype will develop into male or female sex.
3. **Monoecious.** Plant species which bear male and female flowers on the same plant such as maize, caster and coconut.
4. **Dioecious.** Plant species in which male and female flowers are produced on different plants such as cucumber, papaya, asparagus, etc.
5. **Primary sex characters.** Characters which are distinct since birth and take part in reproduction such as gonads or sex organs in mammals.
6. **Secondary sex characters.** Characters which express in adulthood differently in males and females and do not take part in reproduction. In humans, such characters include voice, facial hair, mammary glands, muscles, etc.
7. **Autosomes.** Those chromosomes which do not differ in number and morphology in male and female sex.
8. **Allosomes.** Those chromosomes which differ in number and morphology in male and female sex; also known as sex chromosomes.
9. **Heterogametic.** Sex with dissimilar type of sex chromosomes such as XY, XO and ZW.
10. **Homogametic sex.** Sex with similar type of sex chromosomes such as XX or ZZ.
11. **Sex Mosaic.** Combination of male and female features in the body of an individual.
12. **Gynandromorphs.** Individuals with sex mosaic; also called gynanders.
13. **Sex reversal.** Transformation of one sex into another.
14. **Klinefelter's syndrome.** The characteristics of an abnormal human male who has XXY chromosome constitution.
15. **Turner's syndrome.** The characteristics of an abnormal human female who has XO chromosome constitution.
16. **Sex chromatin.** Relatively coiled and inactive interphase chromatin of the X chromosomes of the normal mammalian females but not the males; also called Barr Body.
17. **Lyon's Hypothesis.** This hypothesis states that an individual may have any number of X-chromosomes, but only one remains active and others become inactive or condensed.

18. **Sex linkage.** The linkage of genes which are located on sex or X chromosomes. Inheritance of such genes is known as sex linked inheritance.
19. **Sex linked traits.** Characters for which genes are located on sex- or X-chromosomes.
20. **Sex limited traits.** Characters which express in one sex only.
21. **Sex influenced genes.** Genes whose expression depends on the sex of an individual such as baldness in humans.
22. **Primary non-disjunction.** Failure of homologous chromosomes to separate at meiotic anaphase in a normal ***Drosophila*** female.
23. **Secondary non-disjunction.** Failure of chromosomes to separate in XXY individuals resulting in production of four types of egg cells, ***viz.***, XX, XY, X and Y.
24. **Hemizygous.** A recessive allele in a single dose.
25. **Cris-cross inheritance.** Inheritance of sex linked genes from grand father to grand son through daughter.

//*//*//*//

CYTOPLASMIC INHERITANCE

Cytoplasmic inheritance:

- The transmission of characters from parents to offspring is governed by cytoplasmic genes, it is known as cytoplasmic inheritance.
- Cytoplasmic inheritance is also known as **extra-nuclear inheritance** or **extra chromosomal inheritance** or **non-mendelian inheritance** or **organellar inheritance.**
- The first case of cytoplasmic inheritance was reported by **correns** in four o'clock (*Mirabillis jalaba*) for leaf colour.

Characteristics / Features of cytoplasmic inheritance:

1. **Reciprocal differences**

   Characters govern by cytoplasmic inheritance showed the marked differences in reciprocal crosses in F_1. Whereas, such kinds of reciprocal differences are not observed in case of nuclear inheritance.

2. **Maternal Effects**

   In case of cytoplasmic inheritance, distinct maternal effect is observed and it is mainly due to more contribution of cytoplasm to the zygote by female parent than male parent.

3. **Mappability**

   Nuclear genes are easily mapped on chromosomes but it is very difficult to map cytoplasmic genes.

4. **Non-Mendelian Segregation**

   In case of nuclear inheritance, typical mendelian inheritance pattern is found but in case of cytoplasmic inheritance such type of inheritance pattern is not observed.

5. **Somatic Segregation**

   Characters governed by cytoplasmic genes usually exhibits segregation in somatic tissues such as leaf variegation but such type of segregation is very rare for nuclear genes.

6. **Infection-like Transmission**

   Cytoplasmic traits in some organisms exhibit infections like transmission. They are associated with parasites or viruses present in the cytoplasm but such type of cases do not come under true cytoplasmic inheritance.

Difference between Mendelian & non-mendelian Inheritance
Diff. both mendelian & cytoplasmic inheritance

7. **Governed by Plasma Genes**

The true cases on cytoplasmic inheritance are governed by chloroplast or mitochondrial DNA. In other words, plasma genes are made up of cp-DNA or mt-DNA.

Difference between nuclear inheritance vs cytoplasmic inheritance :

Sr.	Mendelian (Nuclear) inheritance	Non mendelian (Cytoplasmic) inheritance
1.	Governed by nuclear genes	Governed by plasma genes
2.	Exhibits distinct segregation pattern	Does not exhibit distinct segregation
3.	Reciprocal differences are not observed.	Reciprocal differences are observed.
4.	Does not show maternal effects.	Exhibits maternal effects.
5.	Genes can be easily mapped on chromosomes.	Mapping of plasma genes is very difficult.
6.	Nuclear genes are associated with chromosomes.	Plasma genes are associated with either chloroplast DNA or mitochondrial DNA.

Classes of Cytoplasmic Inheritance

There are three different classes of cytoplasmic inheritance or non-Mendelian inheritance viz.,

1) **Materal effects:** e.g. coiling pattern of shell in snail.
2) **Inheritance due to infective particles:** e.g. Kappa particles in Paramecium.
3) **Cytoplasmic inheritance:**
    a. **Plastid inheritance:** e.g. Leaf color in Four o'clock
    b. **Mitochondrial inheritance:** e.g. cytoplasmic male sterility.

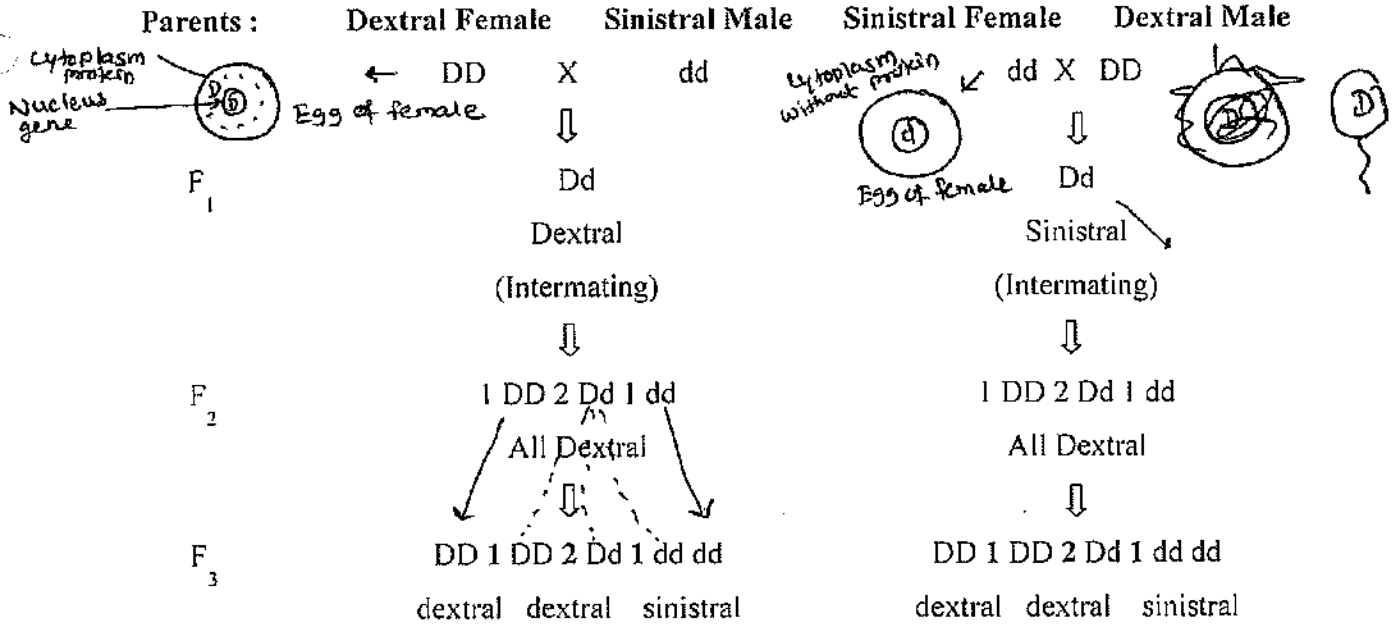
1) MATERNAL EFFECTS

short note

Coiling pattern of shell in Snail :

- The effect of maternal genotype on the coiling behaviour in water snail was studied by **Sturtevant.**
- There are two types of coiling pattern of shell in snail viz., **right handed (dextral) and left handed (sinistral).**
- The coiling behaviour is controlled by a single gene.
- The dextral coiling behaviour is governed by dominant allele D and sinistral by recessive allele d.

- When a cross is made between dextral female and sinistral male, it produces dextral snails in F_1 as well in F_2.
- However, in F_3 segregation ratio of 3 dextral and 1 sinistral is observed.
- Similarly, reciprocal cross is made, i.e., sinistral as female and dextral as male, all the snails are sinistral in F_1 and dextral in F_2. Again in F_3 ratio of 3 dextral and 1 sinistral is observed.
- **This indicates that the inheritance of coiling direction in water snail depends on the genotype of female parent and not on its own genotype.**



Maternal effect on coiling direction of water snail

2) INHERITANCE DUE TO INFECTIVE PARTICLES

In some cases, cytoplasmic inheritance is associated with infective particles like parasite, symbiont or viruses which are present in the cytoplasm of an organismSome examples of this type are given below:

(i) *Kappa Particles in Paramecium*

There are two types of strains in Paramecium. One has kappa particles in its cytoplasm and other does not have such particles. The presence of kappa particles in the cytoplasm leads to production of a toxin known as **paramecin**. This toxin can kill the strain of Paramecium which

lacks kappa particle. Thus, the strain with kappa particle is known as killer strain and that without kappa particle is called as sensitive strain.

Multiplication of kappa particles in the cytoplasm takes place by Fission. However, their multiplication is governed by a dominant nuclear gene (K). They can multiply in the homozygous dominant (KK) or heterozygous (Kk) individuals. Kappa particles cannot multiply in recessive (kk) individuals. Even if kappa particles are introduced into kk strains, they will gradually disappear due to their inability to multiply and the strain will become sensitive. **Though the multiplication of kappa particles is dependent on nuclear genes, but their action is independent of nuclear gene.** The inheritance of kappa particles can be studied by conjugation *(transfer of genetic material between bacterial cells by direct cell-to-cell contact or by a bridge-like connection between two cells)* between killer and sensitive strains. The conjugation may be of two types, *viz.*, I. short duration conjugation and 2. long duration conjugation. The consequences of such conjugations are given below :

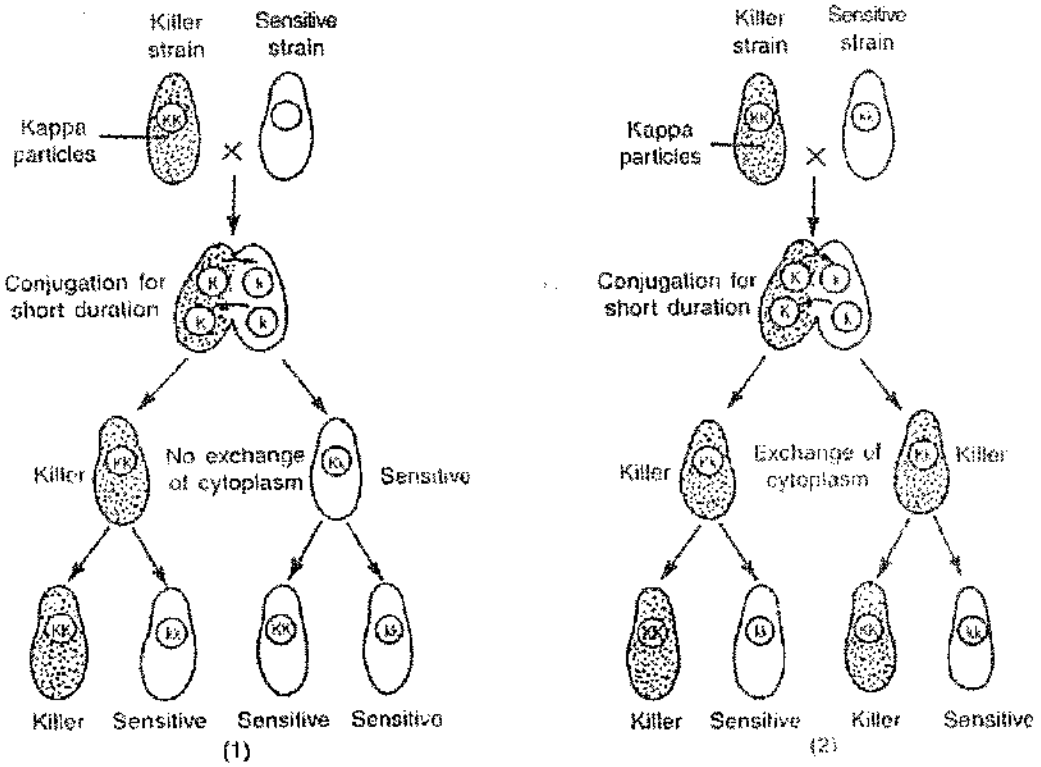


Fig. 11.3. Inheritance of kappa particles in paramecium : (1) exchange of nuclear genes, (2) exchange of both nuclear genes and cytoplasm

(a) Short Duration Conjugation. Short duration conjugation leads to exchange of nuclear genes between the killer and sensitive strains. Exchange of cytoplasm does not take place in such conjugation. Thus, the ex-conjugants (resultant strains) will be heterozygous (Kk)

for killer gene. However, the strain with killer cytoplasm produces killer (KK) and sensitive (kk) strains by further division, whereas the sensitive stain produces only sensitive strains (kk) by further division. This clearly indicates that the killer character is not governed by nuclear gene.

(b) Long Duration Conjugation. Such conjugation between killer and sensitive strains leads to exchange of both nuclear genes as well as cytoplasm. Here both the ex-conjugants are heterozygous (Kk) but killer. Autogamy of both the ex-conjugants produces killer and sensitive strains in 1 : 1 ratio. This has demonstrated that kappa particles have cytoplasmic inheritance .

3) CYTOPLASMIC INHERITANCE:

a) Plastid inheritance: e.g. Iojap in Maize, Leaf color in Four o'clock

In maize, three types of leaves are found, *viz*, green, iojap (green and white stripes) and white. Crosses between green female and iojap male produced all green individuals in F_1 and a single gene segregation ratio, *i.e.*, 3 green and 1 iojap in F_2. However, the reciprocal cross (iojap female x green male) produced individuals with all the three phenotypes, *viz.*, green, white and striped in F_1.

The iojap phenotype is governed by plastids. The green leaves have normal plastids; white leaves have mutant plastids and striped leaves have mixture of normal and mutant plastids. In a cross between iojap female and green male, there are three types of plastids, *viz.*, green, white or both in the egg cell. Depending upon the presence of these three types of plastids in the egg cell, a cross between iojap and green will produce three types of individuals, *viz.*, green, white and striped in F_1, because male parent does not contribute cytoplasm and thereby plastids to the zygote.

Parents	Green female	×	Iojap male (striped)
Genotypes	IjIj		Ij
		↓	
F_1		IjIj	
		All green	
F_2		3 green : 1 iojap 1 IjIj : 2 IjIj : 1 Ij Ij	
Reciprocal cross			
Parents	IOJAP female	×	Green male
		↓	
F_1		Green, white and striped	

Short note.

b) MITOCHONDRIAL INHERITANCE: E.G. CYTOPLASMIC MALE STERILITY.

CMS in plants

Male sterility in plants can be controlled by nuclear genes or cytoplasm or by both. There are three types of male sterility as under:

- **Genetic Male Sterility:** Male sterility is controlled by a single nuclear gene and is recessive to fertility, so that F_1 individuals would be fertile.
- **Cytoplasmic Male Sterility:** Crops like, maize cytoplasmic control of male sterility is known. If female parent is male sterile, F_1 progeny would always be male sterile, because cytoplasm is always derived from female/maternal parents.
- **Cytoplasmic genetic male sterility:** Male sterility wholly controlled by cytoplasm as well as nuclear gene. e.g. Bajara.

Cytoplasmic male sterility in maize

- Rhodes in 1933, reported the analysis of first cytoplasmic male sterile plants in maize and demonstrated that male sterility was contributed by female parent and that nuclear genes had no influence.
- He shown by crossing male sterile plants with wide range of fertile males and by observing that in sub-sequent generation all progenies were male sterile.
- **In maize, three male sterile sources (CMS) are known, which are called T, C and S.**
- **The normal male sterile cytoplasm is called N cytoplasm.**
- Each of the three CMS cytoplasms exhibits strict maternal inheritance and even when all chromosomes were replaced by a male fertile source through backcrosses.
- Cytoplasms were a great asset in production of hybrid corn seed at commercial scale.
- **T (Texas) cytoplasm was associated with susceptibility to two diseases, viz., southern corn leaf blight and yellow leaf blight, so it is not used for commercially.**

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MUTATION

Mutation in a broad sense includes all those heritable changes which alter the phenotype of an individual. Thus mutation can be defined as a sudden heritable & permanent change in the character of an organism which is not due to either segregation or recombination.

- The term mutation was first used by Hugo de Vries to describe the sudden phenotypic changes which were heritable, while working with *Oenothera lamarckiana*.
- But the earliest record of mutations dates back to 1791 when Seth Wright noticed a male lamb with unusually short legs in his flock of sheep. This lamb served as a source of short leg trait for the development of Ancon breed of sheep.
- However the systematic studies on mutations were started in 1910 by T.H. Morgan who used *Drosophila melanogaster* for his studies.
- In 1927, H.J. Muller demonstrated for the first time the artificial induction of mutations by using x-rays in *Drosophila*.
- Similarly in 1928, L.J. Stadler demonstrated an increase in the rate of mutations due to x-rays in barley and maize.
- Induction of mutations by chemicals in fungus *Aspergillus* was demonstrated by R.A. Steinberg in 1939.
- C. Auerbach and J.N. Robson in 1946 used chemicals to induce mutations in *Drosophila*.
- The first plant breeding programme using mutations (mutation breeding) was initiated in 1929 in Sweden, Germany and Russia.
- In India it was initiated in early 1930s.

Terminology

Muton: The smallest unit of gene capable of undergoing mutation and it is represented by a nucleotide.

Mutator gene: A gene which causes another gene or genes to undergo spontaneous mutation.

Mutable genes: Genes which show very high rates of mutation as compared to other genes.

Mutant: An organism or cell showing a mutant phenotype due to mutant allele of a gene.

Mutagen: A physical or chemical agent which induces mutation.

Hot spots: Highly mutable sites with in a gene.

* Diff. bet'n spontaneous and induced mutation.

Gene mutations or point mutations: The changes which alter the chemical structure of a gene at molecular level.

Que:- Enlist the types of mutation.

Classification of mutations: Mutations can be classified in several ways.

1. Based on direction of mutations :

a) Forward mutation : Any change from wild type allele to mutant allele

b) Backward mutation or reverse mutation: A change from mutant allele to wild type

2. Based on source / cause of mutations :

a) Spontaneous mutation: Mutation that occur naturally

b) Induced mutation: Mutation that originates in response to mutagenic treatment

3. Based on tissue of origin :

a) Somatic mutation: A mutation in somatic tissue

b) Germinal mutation: A mutation in germline cells or in reproductive tissues

4. Based on effect on survival :

a) Lethal mutation: Mutation which kills the individual that carries it. (survival 0%)

b) Sub-lethal mutation: When mortality is more than 50% of individuals that carry mutation

c) Sub-vital mutation: When mortality is less than 50% of individual that carry mutation.

d) Vital mutation: When all the mutant individuals survive (survival-100%)

5. Based on trait or character effected:

a) Morphological mutation: A mutation that alters the morphological features of an individual

b) Biochemical mutation: A mutation that alters the biochemical functions of an individual.

6. Based on visibility or quantum of morphological effect produce:

a) Macro-mutations: Produce a distinct morphological change in phenotype (which can be detected easily without any confusion due to environmental effects) Generally found in qualitative characters. Eg : colour of flowers, height of plant etc.

b) Micro-mutations: Mutations with invisible phenotypic changes, (which can be easily confused with effects produced due to environment). Generally observed in quantitative characters.

7. Based on the site of mutation or on cytological basis:

a) Chromosomal mutations: Mutations associated with detectable changes in either chromosome number or structure.

b) Gene or point mutations: Mutations produced by alterations in base sequences of concerned genes.

c) Cytoplasmic mutations: Mutations associated with the changes in chloroplast DNA (cpDNA) and mitochondrial DNA (mtDNA).

CHARACTERISTIC FEATURES OF MUTATIONS:

1. Mutations are mostly recessive and very rarely dominant.
2. Most mutations have harmful effects and very few (less than 0.1 %) are beneficial.
3. Mutations may be due to a change in a gene, a group of genes or in entire chromosome.
4. If gene mutations are not lethal, the mutant individuals may survive. However, chromosomal mutations are generally lethal and such mutants do not survive.
5. If mutation occurs at both loci simultaneously, the mutants can be identified in M_1 generation. However, if it is restricted to one locus only, (dominant to recessive) the effect can be seen only in M_2 generation.
6. Macro-mutations are visible and can be easily identified, while micro-mutations can not be seen with naked eye and need special statistical tests (or statistical analysis).
7. Many of the mutants show sterility.
8. Most mutants are of negative selection value.
9. Mutation for altogether new character generally does not occur.
10. Mutations are random i.e. they can occur in any tissue or cell of an organism. However some genes show higher mutation rate than others.
11. Mutations can be sectorial. The branches arising from mutated sector show mutant characters.
12. Mutations are recurrent i.e. the same mutation may occur again and again.
13. Induced mutations commonly show pleiotropy often due mutation in closely linked genes.

I. Spontaneous mutations:

Spontaneous mutations occur naturally without any apparent cause. There are two possible sources of origin of these mutations.

1. Due to error during DNA replication.
2. Due to mutagenic effect of natural environment Eg : UV rays from sunlight

Que :- Difference between spontaneous & induced mutation

The rate of spontaneous mutations is very low. 1 in 10 lakhs i.e. 10^{-6}. But different genes may show considerably different mutation rates. In crop plants some varieties were developed through spontaneous mutations. They are

Crop	Variety
1. Rice=	GEB-24, Dee-Geo-Woo-Gen
2. Wheat=	Norin
3. Groundnut=	TMV-10
4. Sorghum=	Co-4 (coimbatore 4)

II. Induced mutations:

Mutations can be induced artificially through treatment with either physical or chemical mutagens. The exploitation of induced mutations for crop improvement is called mutation breeding. The rate of induced mutations is very high. The induced mutations did not differ from spontaneous mutations in expression.

Examples of popular induced mutants in crop plants are:

Crop	Mutant variety	Original variety	Mutagen
1. Rice	Jagannath	T-141	X-rays
	Mahsuri mutant	Mahsuri	g-rays
2. Wheat	Sharbati sonara	Sonara 64	UV rays
	NP-836	NP-799	x rays
3. French Beans	Pusa Parvati	Wax podded	x-rays
	Pusa Lal Meeruti	Meeruti	x-rays
4. Tomato	S-12	Sioux	g-rays
5. Castor	Aruna	HC-6	Thermal neutrons
6. Cotton	MCU 7	1143 EE	x-rays
	MCU 10	MCU 4	g-rays

Artificial induction of mutations: Mutations can be induced artificially using

1. Physical mutagens or radiations
2. Chemical agents

Que:- Give the classification of mutagen with example.

1. Physical mutagens:

Include various types of radiations, viz., x-rays, g-rays, a-rays, ß-rays, fast neutrons, thermal or slow neutrons, UV rays etc. The physical mutagens are classified into

a) Ionizing radiations:

They work through the release of ions. They have deep penetrating capacity. Eg : x-rays, g-rays, a -particles etc.

b) Non-ionizing radiations :

They function through excitation and have a very low penetrating capacity. They are used for studies on bacteria and viruses. Eg : UV rays.

Sources of physical mutagens:

Gamma garden	X-ray machine
Gamma green house	Isotopes
Vertical gamma irradiation facility	Small portable irradiators, accelerators and cyclotrons
Horizontal gamma irradiation facility	Nuclear reactors

2. Chemical mutagens: These can be divided into four groups.

a) Alkylating agents:

This is the most powerful group of mutagens. These are the chemicals which are mainly used to induce mutations in cultivated plants. They induce mutations especially transitions and transversions by adding an alkyl group (either ethyl or methyl) at various positions in DNA. Alkylation produces mutation by changing hydrogen bonding in various ways. Eg: Dimethyl sulphonate (DMS), Ethyl methane sulphonate (EMS), Nitrosomethyl Urea (NMU), Nitrosoethyl Urea (NEU), Methyl methane sulphonate (MMS).

b) Base analogues:

These are chemicals which are very similar to DNA bases, such chemicals are sometimes incorporated in DNA in place of normal bases during replication. Thus they can cause mutation by wrong base pairing. An incorrect base pairing results in transitions or transversions after DNA replication. Eg: 5– bromouracil, 3-bromodeoxy uridine, 2-amino purine.

Que:- Define mutation and explain the ClB method of detection of mutation.

c) Antibiotics:

A number of antibiotics like mitomycin and streptomycin have been found to possess chromosome breaking properties. Their usefulness for practical purposes is very limited.

d) Acridine dyes:

Acridine dyes Eg: proflavin, acriflavin, acridine orange, etc. are very effective mutagens. These are positively charged and they insert themselves between two base pairs of DNA. This is known as intercalation. Replication of intercalated DNA molecules results in addition or deletion of one or few base pairs which produces frame shift mutations.

e) Miscellaneous:

Hydoxyl amine produce chromosomal aberrations. Nitrous acid (deaminating agent) has strong mutagenic activity in a variety of viruses and micro organisms. But not useful in higher plants.

Materials used for treating with mutagens:

Seeds, pollen, vegetative buds, whole plants, bulbils, tubers, suckers etc.

DETECTION OF MUTATION

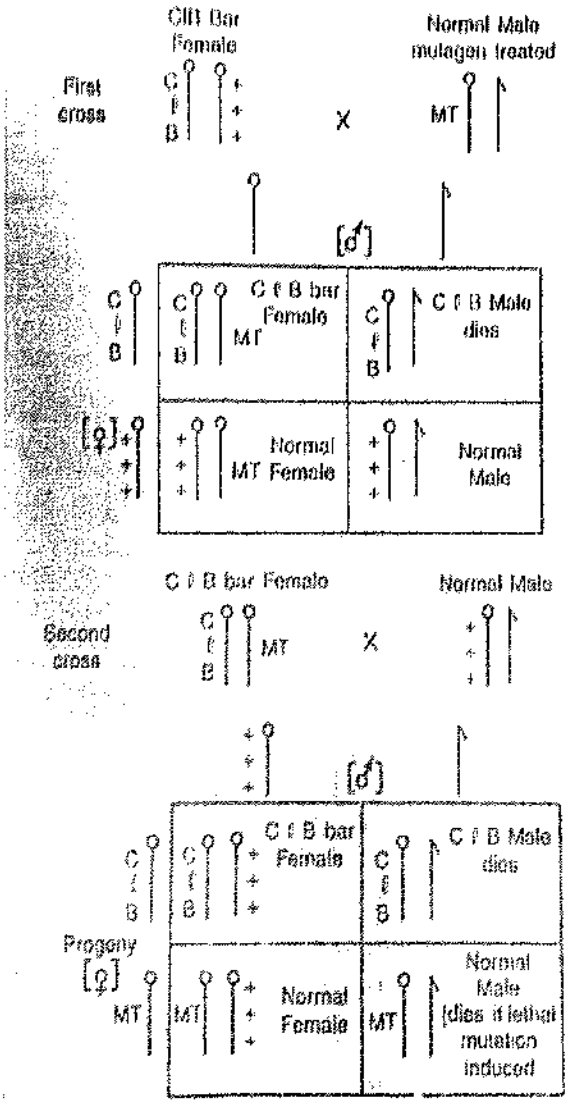
Detection of mutations depends on their types. Morphological mutations are detected either by change in the phenotype of an individual or by change in the segregation ratio in a cross between normal (with marker) and irradiated individuals. The molecular mutations are detected by a change in the nucleotide, and a biochemical mutation can be detected by alteration in a biochemical reaction. The methods of detection of morphological mutants have been developed mainly with Drosophila. Four methods, viz., (1) ClB method, (2) Muller's 5 method (3) attached X-chromosome method, and (4) curly lobe plum method are in common use for detection if mutations in Drosophila. A brief description of each method is presented below

ClB Method

This method was developed by Muller for detection of induced sex linked recessive lethal mutations in Drosophila male. In this technique, C represents a paracentric inversion in large part of X-chromosome which suppresses crossing over In the inverted portion. The l is a recessive

lethal. Females with lethal gene can survive only in heterozygous condition. The B stands for bar eye which acts as a marker and helps In identification of flies. The I and B are inherited together because C does not allow crossing over to occur between them, The males with CIB chromosome do not survive because of lethal effect. The Important steps of this methods are as follows:

(1) A cross is made between CIB female and mutagen treated male, In F_1 half of the males having normal X-chromosome will survive and those carrying CIB chromosome will die. Among the females, half have CIB chromosome and half normal chromosome (Fig.). from F_1, females with CIB chromosome and male with normal chromosome are selected for further crossing.



(2) Now a cross is made between ClB female and normal male. This time the ClB female has one ClB chromosome and one mutagen treated chromosome received from the male in earlier cross. This will produce two types of females, viz., half with ClB chromosome and half with mutagen treated chromosome (with normal phenotype). Both the progeny will survive. In case of males, half with ClB will die and other half have mutagen treated chromosome. If a lethal mutation was induced in mutagen treated X-chromosome, the remaining half males will also die, resulting in absence of male progeny in the above cross. Absence of male progeny in F_2 confirms the induction of sex linked recessive lethal mutation in the mutagen treated **Drosophila** male.

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CHAPTER: 1

INTRODUCTION TO PLANT BREEDING

Plant breeding is the applied branch of Botany which deals with the improvement of agricultural crops.

What is Plant Breeding ?

- ❖ Plant breeding means the improvement in the heredity of crop plant and production of new crop varieties which are far better than original / existing one in all aspects.
- ❖ Plant breeding is an art and science of improving the genetic pattern of plants in relation to their economic use.
- ❖ Plant breeding is the art and science of changing and improving the heredity of plant.
- ❖ Plant breeding is the genetic adjustment of plants to the service of man.

➢ Plant breeding, as a science, involve 4 basic principles:

1. Formation of hypothesis,
2. Experimentation,
3. Observation, and
4. Conclusion.

Why Plant Breeding is considered as an art and science?

In early days, when the scientific knowledge was not available, the plant breeder depends upon their skill and judgment in selecting the superior types of varieties. They do not know about

1. Inheritance of character,
2. Role of environment,
3. Basis of variation in plant, etc.

So that time the plant breeding was mainly an art.

As the knowledge of genetics and other related sciences progressed, the plant breeding become less of an art and more of a science. The modern techniques of crop improvement developed on sound scientific basis only after the rediscovery of the Mendelian laws of inheritance. So modern plant breeding is mainly based on these genetic principles. Without this precise knowledge and background, the modern plant breeder can not solve the vast range of problems.

Therefore, at this stage hybridization or crossing is considered as an art, but without the knowledge of genetics this technique of hybridization is not going to play anything in plant breeding. So that, now plant breeding is more a science and less an art.

Plant Breeding is an industry

Plant breeding can be viewed upon as an industry, where improved varieties are produced.

In this industry several units can be seen:

1. The processing Unit
2. The multiplication Unit, and
3. The research and development Unit.

1) In the Processing Unit :

- The required product is built from some raw materials.
- During this process waste products are removed.
- The raw material is formed by the varieties chosen as parents in breeding programme.
- The genotype removed during the processing from the waste products.
- The few superior genotypes selected – form the end product.

2) In the Multiplication Unit :

- Take care of this end product, which must be multiplied

3) In the Research and Development Unit :

- The research unit comprises all work directed
- As collecting scientific information,
- Improving procedures already in use, or
- Developing new procedures.
- This research can be very practically or more basically oriented

Importance of Plant Breeding

- The food grain production in India had increased from 54.92 million tones (from 99.28 million hectares) in 1949-50 to 241.00 million tonnes in 2010-11.
- This represents an increase of about 438 per cent during a period of 60 years.
- As a result, the nation became almost self-sufficient in food grains.
- But the population in India is growing at an alarming rate of around 2.5 per cent per year. This makes it necessary that the food grain production should also increase at least at the same rate or even at a faster rate in order to improve the nutritional status of the masses.
- Increased quantum and better management of inputs, such as fertilizers, irrigation water, plant protection and cultural practices, and from improved crop varieties (Fig.-1).
- It is doubtful that the net cropped area can be increased indefinitely, but there is still some scope through double and multiple cropping.

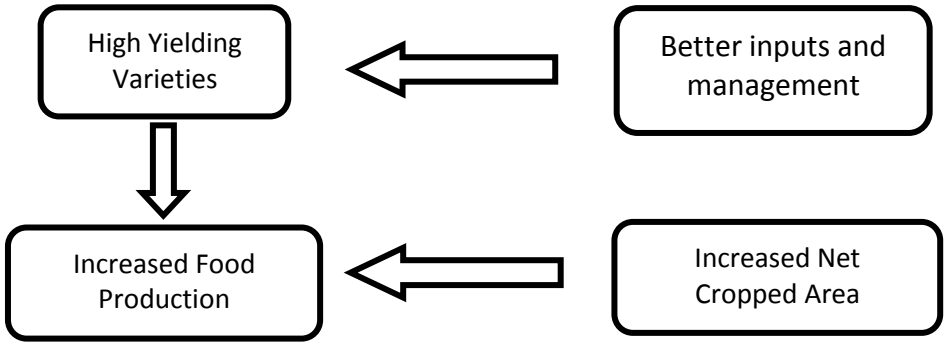


Fig. 1. Factors contributing to increased food production in India

- Improved input management practices are yet to be fully exploited, and vast tracts of cultivated lands are very poorly managed.
- In future, agricultural production is most likely to increase from providing better environment through management and from crop varieties capable of fully exploiting the environment so provided.
- Better environment alone cannot lead to better yields from inferior varieties beyond a certain limit, the limit being set by the genetic makeup of the variety.
- Improving the environment beyond a certain limit for any variety may adversely affect its performance.

- This point is illustrated by the tall and dwarf varieties of wheat. Tall wheat varieties respond to nitrogen application upto 60 kg/ha, but higher doses of nitrogen reduce yields primarily due to severe lodging.
- Dwarf wheat varieties, on the other hand, give increased yields upto, or even beyond 120 kg nitrogen per hectare.
- It is believed that the genetic makeup of the crop plants is such that it would permit considerable, perhaps endless, changes and improvements.
- Further, the changes brought about in the present varieties probably represent only a small portion of the possibilities.
- Thus, continuous favourable changes in the genotype of crop varieties are a must for increasing yields from crop plants.
- Plant breeding deals with this aspect of crop production: "***It consists of the principles and the methods required for favourably changing the genetic constitution of crop plants suited to human needs than the existing ones."***
- ***Domestication : "The process of bringing plant species under human management is referred to as domestication."***
- *Thus, domestication may be regarded as the most basic method of plant breeding.*
- *All other breeding methods become applicable to a plant species only after it has been successful1y domesticated.*
- This is likely to give rise to better types than the wild ones.
- Domestication continues till today, and is likely to continue for some time in future.
- This is particularly true in the case of timber trees, medicinal plants, microbes and plants satisfying some special requirements.
- Transfers of specific genes, *e.g.*, for disease resistances, from wild species (or even from unrelated organisms) to cultivated ones may be regarded as domestication of those genes, *i.e.*, of a part of the genome of the concerned species.
- It is likely that man also exerted some selection either knowingly or unknowingly. Movement of man from one area to another brought about the movement of his cultivated plant species.
- *The introduction into an area of new plant species or varieties from other parts of the world is an integral part of plant breeding today.*

Landmarks in plant breeding

Year	***Name of scientist***	***Outstanding contribution***
1717	Thomas Fairchild	Developed first interspecific hybrid between sweet william and carnation species of Dianthus *(Dianthus barbatus x D. caryophyllus).*
1800	Knight,T.A. (English)	First used artificial hybridization in fruit crops.
1840	John Le Couteur (English) and Patric Shirreff (Scottish)	They developed the concept of progeny test and individual plant selection in cereals.
1856	De Vilmorin (FrenchBiologist)	Further elaborated the concept of progeny test and used same in sugarbeet.
1866	Mendel, G.J. (Austria)	Discovered principles of inheritance working with garden pea
1890	Rimpu (Sweden)	First made intergeneric cross between bread wheat ***(Triticum eastvum)*** and rye ***(Secale cereal)***, which later on gave birth to ***Triticale***.
1900	DeVries(Holland) Correns(Germany) Tschermak (Austria)	Rediscovered Mendel's laws of inheritance independently.
1900	Nilsson, H. (Swedish)	Further elaborated individual plant selection method.
1903	Johannsen, W.L. (Danish botanist)	Developed the concept of pureline. In 1909 coined the terms genotype and phenotype
1908	Shull. G.H. (US) East, EM. (US)	Proposed over dominance hypothesis of heterosis independently working with maize.
1908	Hardy. G.H. Weinberg, W.	Developed concept of hardy-Weinberg law in population genetics.
1908	Davenport, C.B.	First proposed dominance hypothesis of heterosis.
1910	Bruce, A.B, Keeble,	Elaborated the dominance hypothesis of

	F and Pelles, C.	heterosis proposed by Davenport.
1914	Shull,G.H.	First used the term heterosis for hybrid vigour.
1917	Jones, D.F.	Proposed dominance of linked gene hypothesis as explanation for heterosis. He first made double cross in maize and also first used genetic male sterility in the development of maize hybrids.
1919	Hays. H. K. and Garber, R.J.	Gave initial idea about recurrent selection. They first suggested use of synthetic varieties for commercial cultivation in maize.
1920	East E.M and Jones, D.F.	Also gave initial idea about recurrent selection.
1921	Sewall Wright (English)	Gave five systems of mating namely random, genetic assortative, phenotypic assortative, genetic disassortative and phenotypic disassortative.
1925	East, E.M. and Mangelsdorf A.J.	First discovered gametophytic system of self incompatibility in *Nicotiana sanderae*
1926	Vavilov, N. J. (Russian Geneticist)	Identified 8 main centres and 3 sub centres of crop diversity. He also developed concept of parallel series of variation or law of homologous series of variation.
1927	Karpechenko (Russian Geneticist)	First developed intergeneric hybrid between radish and cabbage which had undesirable features of both species.
1928	Stadler. L.J. (US)	First used X-rays for induction of mutations in crop plants.
1935	Nagaharu. U.	Proposed the origin of tetraploid species of *Brassica* using a triangle which is popularly known as U's triangle.
1936	East, *E.M.*	Supported overdominance hypothesis of heterosis proposed by East and Shull in 1908.

1937	Harrington, J.B.	Proposed mass pedigree method of breeding which is a modification of pedigree method.
1939	Goulden, C.H.	First suggested the use of single seed descent method for advancing segregating generations of self pollinated crops.
1940	Jenkins. MT.	Described the procedure of recurrent selection.
1944	Stadler, L.J.	Proposed use of gamete selection for improvement of inbreds in maize.
1945	Hull, F.H.	Coined the terms recurrent selection and over-dominance working with maize.
1950	Hughes M B. and Babcock, E.B.	First discovered sporophytic system of self incompatibility in *Crepis foetida.*
	Gerstel, D.V.	Gerstel discovered the same independently in *Parthenium argentatum.*
1951	Painter, RH.	Gave three mechanisms, *viz*, non-preference, antibiosis and tolerance of insect resistance in crop plants.
1952	Jensen, N.F.	First suggested the use of multilines in oats.
1953	Borlaug, N.E.	First outlined the method of developing multilines in wheat.
1953	Mather, K.	Developed the concept of disruptive selection.
1956	Flor, H.H.	First developed the concept of gene for gene hypothesis in flax for flax rust caused by *Malampsora lini.*
1958	Thoday, J. M.	Further elaborated the concept of disruptive selection.
1963	VanderPlank, J.E	Developed the concept of vertical and horizontal resistance.
1964	Borlaug. N.E.	Developed high yielding semidwarf varieties of wheat which resulted in Green Revolution.

1965	Grafius, J.E.	First applied Single Seed Descent (SSD) method in oats.
1968	Donald, C.M.	Developed the concept of crop ideotype working with wheat.
1970	Patel, C.T.	Developed world's first cotton hybrid for commercial cultivation in India.
1976	Yuan Long ping *et al*.	Developed world's first rice hybrid (CMS based) for commercial cultivation in China.
1983	Fraley *et al.*	Developed first transgenic (genetically engineered) tobacco plant in USA.
1987	Monsanto, USA.	Developed first transgenic cotton plant in USA.
1991	ICRISAT, India	Developed world's first pigeon pea hybrid (ICPH 8 GMS based) for commercial cultivation in India.
1997	Monsanto, USA	First identified terminator gene, which allows germination of seed for one generation only.
1998	Monsanto, USA	Identification of traitor gene, which responds to specific brand of fertilizers and insecticides.
2002	Mahyco - Monsanto	Released three Bt cotton Hybrids (MECH 12, MECH 162 and MECH 184) for cultivation in M.P., A.P., Maharashtra, Gujarat, T.N. and Karnataka.
2005	Govt. of India	Approved cultivation of some Bt cotton hybrids in Punjab, Haryana and Rajasthan.

SOME INDIAN PLANT BREEDERS

In India remarkable contribution has made in the field of crop improvement. The significant contribution of some Indian Plant Breeders is briefly given here.

T. S. VENKATRAMAN

He was an eminent sugarcane breeder. He transferred thick stem and high sugar contents from Noble cane to North Indian canes. This process is known as Noblization of sugarcane. He developed several varieties of sugarcane having high yields and high sugar content. He was Director of Sugarcane Breeding Institute, Coimbatore.

B. P. PAL

He was an eminent Plant Breeder, known for his contributions to the breeding of superior diseases resistant N.P. varieties of wheat. He was the **first Director General** of **ICAR**.

PUSKARNATH

A famous potato breeder who developed several high yielding varieties of potato. He was the Director of **CPRI, Shimala**.

N. G. P.RAO

He is an eminent Sorghum Breeder. He developed several high yielding hybrids of grain sorghum. He was Chairman of **ASRB** and Vice-Chancellor of Marathawada Agril. University Parbhani.

K. RAMIAH

He was a renowned rice breeder. He developed several high yielding varieties of rice when he was the Director of **CRRI, Cuttack.**

K. ATHWAL

He is a famous pealmillet breeder. He worked in PAU, Ludhiana and developed several superior verieties of Pealmillet.

BOSISEN

He was an eminent maize breeder. He developed several varieties of maize for Hill region of Uttranchal. He established the **Vivekanand Parvatiya Krishi Anusandhan Shala** at **Almora**, **Uttranchal**. He was the Director of this Institute still his death.

DHARMAPAL SINGH

He is an eminent Oil-seeds breeder. He released several varieties of Oil-seeds (Rapeseed and Mustard) from Kanpur. He was Vice-Chancellor of G.B.Pant University of Agriculture and Technology, Pantnagar.

C. T. PATEL

He was a famous Cotton breeder who deevloped Worl's First Cotton hybrid in 1970 from Gujarat Agricultural University, Surat Station. He is known as **FATHER of Hybrid Cotton.**

V. SANTHANAM

He is a famous cotton breeder who developed several high yielding varieties of **Upland cotton** and two varieties of **Egyptians Cotton.** He was the first Project Coordinator for All India Coordinated Cotton Improvement Project and later worked in **FAO** as cotton consultant.

THE DISCIPLINES A BREEDER OUGHT TO KNOW

To be successful, a plant breeder must know all he can about the plants he is working with. Thus he should have an understanding of the following: (1) botany, (2) genetics and cytogenetics, (3) agronomy, (4) plant physiology, (5) plant pathology, (6) entomology, (7) bacteriology, (8) plant biochemistry, and (9) statistics.

1. Botany

A plant breeder must have a clear understanding of the morphology and the reproduction of plants he aims to improve. He should also be familiar with the taxonomy of these plants.

2. Genetics and Cytogenetics

The principles of genetics and cytogenetics provide the bases for plant breeding methods. Therefore, a thorough knowledge of these subjects is essential for a rapid and efficient improvement of a crop plant.

3. Agronomy

A good breeder is first a good agronomist. He must be able to raise a good crop in order to select and evaluate his material.

4. Plant Physiology

Adaptation of a variety is determined by its response to environmental factors like heat, cold, drought, salinity etc. Knowledge of the physiological bases of these responses would help the breeder in developing cold, drought or salinity tolerant varieties. In addition, several physiological approaches to breeding for higher yields are being developed.

5. Plant Pathology

Breeding for disease resistance is an important objective of plant breeding. For an effective breeding - for resistance, a sound knowledge of plant diseases and their pathogens is essential.

6. Entomology

Insect pests cause considerable damage to crops. Knowledge of insect pests would be necessary in order to breed insect resistant varieties, and to protect susceptible breeding materials from pest damage.

7. Bacteriology

Legumes have root nodules containing *Rhizobium* sp., which fix atmospheric nitrogen. The efficiency of this system depends upon both the host and *Rhizobium* genotypes.Therefore, in legume improvement a knowledge of *Rhizobium* would be helpful.This aspect of legumes is receiving a great deal of attention these days.

8. Plant Biochemistry

Several types of quality tests are required to determine the quality characteristic of a crop variety. These tests often involve chemical analyses, *e.g.*, protein content,

amino acid content etc. Knowledge of biochemistry would be helpful in conducting

these tests, and also in developing breeding strategies and selection techniques for such characters.

9. Statistics

For a precise comparison of performances of various entries varieties, a sound knowledge of statistical methods is a must. The breeder must be well-versed in field plot techniques, experimental designs and relevant statistical analyses and tests. The understanding of quantitative inheritance is also based on statistical principles.

10. Plant Biotechnology

Plant biotechnology is fast emerging as an extremely potent tool for crop improvement. This discipline is highly specialized and extremely sophisticated with its own array of terms, concepts and phrases. The breeder must be, at least, familiar with the basics of this discipline to enable him to communicate and interact in a meaningful manner with the experts in the subject so that this powerful tool is exploited in a profitable manner.

- In addition to the above, the breeder must be aware of the present market demands, needs of the farmer and the problems of crop production in the concerned area.
- He should also be able to see into the future to be able to meet the challenges that the farmers may face years later.
- The breeder has to plan several years ahead because it takes at least 12-15 years to develop and release a new variety.
- It is difficult for one person to be a specialist in all the above areas.
- As a result, modern plant breeding is becoming more and more of a team effort. Specialists in genetics, pathology, entomology and agronomy cooperate with the plant breeder in crop improvement.
- The Indian Council of Agricultural Research (ICAR) has formulated its All India Coordinated Crop Improvement Projects on these lines.

OBJECTIVES OF PLANT BREEDING

Plant breeding *aims to improve the characteristic of plants so that they become more desirable agronomically and economically.* Some of the main objectives of plant breeding may be summarized as follows.

1. Higher Yields

Most of the breeding programmes aim at higher crop yields. This is achieved by

developing more efficient genotypes, *e.g.*, hybrid varieties of maize (Z. *mays)*, sorghum *(S. bicolor)*, bajra *(P. glaucum), etc*.

2. Improved Quality

The quality of plant produce determines its suitability for various uses. Therefore, quality is an important aspect for plant breeders. Quality characters vary from one crop to another, *e.g.*,

- grain size, colour, milling and baking qualities in wheat *(Triticum aestivum)*,
- cooking quality in rice *(Oryza sativa)*,
- malting quality in barley *(Hordeum vulgare*,
- size, colour and flavour of fruits,
- keeping quality of vegetables,
- protein content in cereals and legumes,
- lysine content in cereals,
- methionine and tryptophan contents in pulses etc.

3. Disease and Insect Resistance

Resistant varieties offer the cheapest and the most convenient method of disease and insect management. In some cases, they offer the only feasible means of control, *e.g.*, rusts in wheat. Resistant varieties not only increase production but also stabilize it.

4. Change in Maturity Duration

It permits new crop rotations and often extends the crop area. Development of wheat varieties suitable for late planting has permitted rice-wheat rotation. Thus breeding for early maturing crop varieties or varieties suitable for different dates of planting may be an important objective in many cases.

5. Agronomic Characteristics

Modification of agronomic characteristics, such as, plant height, tillering, branching, erect or trailing habit etc., is often desirable. For example, dwarfness in cereals is generally associated with lodging resistance and fertilizer responsiveness.

6. Photo-insensitivity

Development of photo-insensitive and thermo-insensitive

Wheat and photo-insensitive rice *(O. sativa)* varieties has permitted their cultivation in new areas. Rice is now cultivated in Punjab, while wheat is a major *rabi* crop in West Bengal.

7. Synchronous Maturity

Synchronous maturity is highly desirable in crops where several pickings are necessary e.g mungbean *(Vigna radiate,)* pigeon pea *(Cajanus cajan),* cotton *(Gossypium sp.),* etc.

8. Non-shattering Characteristics

It would be of great value in a crop like mung where shattering is a major problem in case of many commercial varieties.

9. Determinate Growth

Development of varieties with determinate growth is desirable in crops like mungbean, pigeon pea *(Cajanus cajan),* cotton *(Gossypium sp.),* etc.

10. Dormancy

In some crops, seeds germinate even before harvesting if there are rains at the time of maturity, *e.g.,* mungbean, barley, Spanish groundnut, etc. A period of dormancy in such cases would check the loss due to germination. In some other cases, however, it may be desirable to remove dormancy.

11. Varieties for New Seasons

Traditionally, maize is a *kharif* crop. But scientists are now able to grow maize throughout the year. Similarly, mung is now grown as a summer crop in addition to the main *kharif* crop.

12. Moisture Stress and Salt Tolerance

Development of varieties for rainfed areas and for saline soils would be helpful in increasing crop production in India. The major proportion (about 70%) of the cropped area in the country is rainfed. The estimates of salt-affected (saline) soils in the country vary from 7 to 20 million hectares, of which about 2.8 million hectares are

alkaline soils. Most of these areas are spread in the states of Uttar Pradesh, Haryana and

Punjab.

13. Elimination of Toxic Substances

Some crops have toxic substances which must be eliminated to make them safe for consumption. For example, khesari *(Lathyruys sativus)* seeds have a neurotoxin, ß-N-oxalylarnine alanine (BOAA) that causes paralysis. Similarly, brassica oil has erucic acid, which is harmful to human health. Removal of such toxic substances would increase the nutritional value of these crops.

ACTIVITIES IN PLANT BREEDING

The desired changes in genotypes of crop species and the consequent benefits to farmers are brought about by a series of interrelated and largely interdependent activities. These activities are as follows:

(1) Creation of variation,
(2) Selection,
(3) Evaluation,
(4) Multiplication and
(5) Distribution

Refer Figure

1. Creation of variation.

- Genetic variation is a prerequisite for any improvement in a crop. Therefore, in any breeding programme, this is always the first step unless variation preexists.
- Genetic variation can be created by domestication, germplasm collection, plant introduction, hybridization (intervarieta1, distant, somatic), mutation, polyploidy, somaclonal variation and genetic engineering.

2. Selection

- The next step consists of identification and isolation of plants having the desirable combinations of characters, and growing their progeny; this is called selection.
- Selection is necessarily based on phenotype.
- The efficiency of this activity determines the success of a breeding program.

- Various breeding methods have been designed to increase the efficacy of

selection.

- Selection finally yields an improved line/strain or population.

3. Evaluation

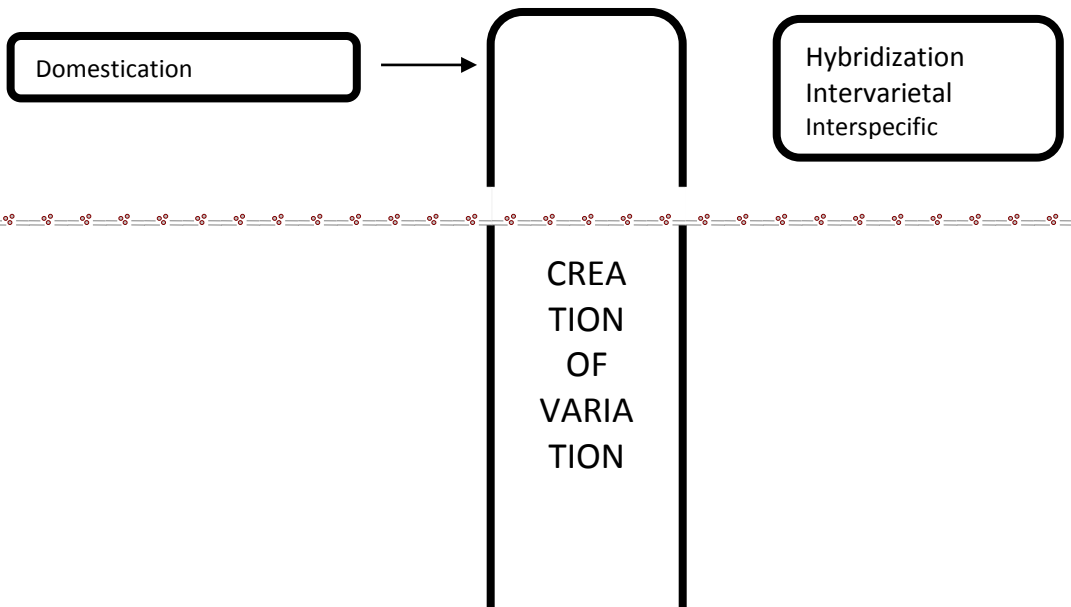
- The newly selected lines/strains/populations are tested for yield and other traits and compared with the existing best varieties called checks.
- Evaluation is a stepwise process, ordinarily conducted at several locations for 3 or more years under the concerned All India Coordinated Crop Improvement Project.
- If the new line/strain/population is superior to the checks, it is released and notified as a new variety and its seed can now be multiplied and, more importantly, certified by a seed certification agency for quality.

4. Multiplication

- This step concerns with a large scale production of certified seed of the released and notified variety.
- Seed production is usually done by seed production agencies in a step-wise manner, and the seed is certified by a seed certification agency.

5. Distribution

- Certified seed is ultimately sold to the farmers who use it for commercial crop cultivation. This activity alone makes it possible to reap the economic benefits from the above activities in form of (1) an enhanced and (2) stable production of (3) superior produce (4) often at a lower cost.



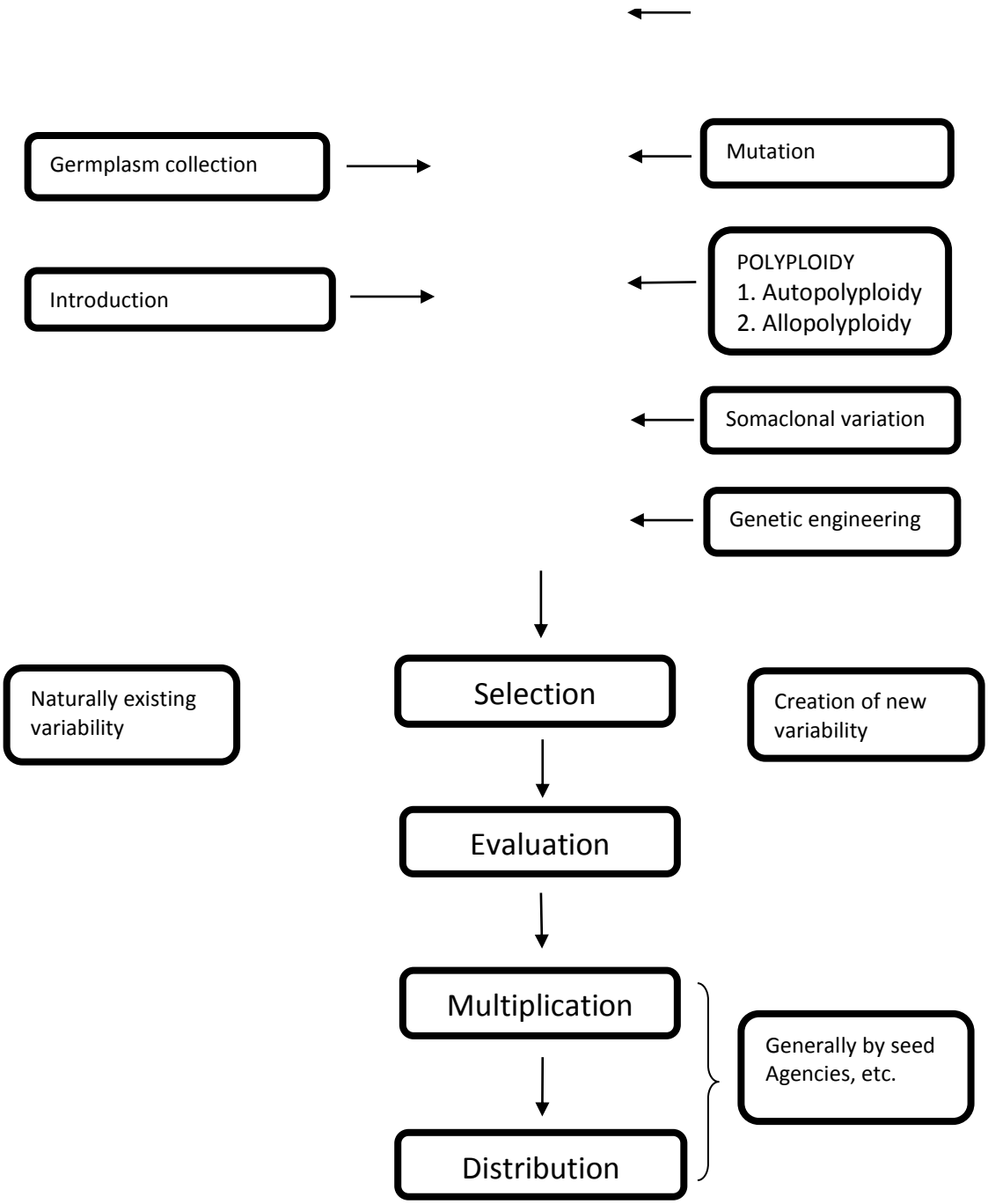


Fig. 2. Activities in plant breeding

IMPORTANT ACHIEVEMENTS

The important achievements of the plant breeding are as under

1. Semi dwarf Wheat and Rice

- One of the most important developments of modem agriculture has been the production of semi dwarf cereal varieties, particularly of wheat and rice.
- The semi dwarf wheat varieties were developed by N.E. Borlaug and his associates at **CIMMYT (International Centre for Wheat and Maize Improvement), Mexico.**
- They used a Japanese variety **Norin-10** as the source of dwarfing genes.
- In 1963, ICAR introduced several dwarf selections from CIMMYT.
- Kalyan Sona and Sonalika were selected from these materials.
- A great majority of the wheat varieties now grown in the country are semi dwarf.
- These semi dwarf wheat varieties are
  - Lodging resistant, Fertilizer responsive, High yielding Resistant to rusts and other major diseases of wheat due to the incorporation of resistance genes in their genotypes.
  - This has greatly increased and stabilized wheat production in the country.
  - These varieties are photo-insensitive and many of them are suitable for late planting.
  - This has enabled cultivation of wheat in nontraditional areas like West Bengal.
- Similarly, the development of semi dwarf rice varieties has revolutionized rice cultivation.
- These varieties were derived from **Dee-geo-woo-gen**, a dwarf, early maturing variety of *japonica* rice from Taiwan.
- **Taichung Native 1 (TN-1),** developed in Taiwan, and **IR 8**, developed at **IRRI (International Rice Research Institute), Philippines,** were introduced in India in 1966.
- They were extensively grown for few years, but were replaced by superior semi dwarf varieties developed in India, *e.g.*, Jaya, Ratna etc.
- The semi dwarf rice varieties are lodging resistant, fertilizer responsive, high yielding and photo-insensitive.
- Photo-insensitivity has allowed rice cultivation in non-traditional areas like Punjab.

- Even in traditional areas, rice-wheat rotation has become possible only due to these varieties.

2. Noblisation of Indian Canes

- Another noteworthy achievement is noblisation of sugarcane.
- The Indian canes, *Saccharum barberi* , were largely grown in North India. They were hardy, but poor in yield and sugar content.
- The tropical noble canes, *Saccharum officinarum* had thicker stem and higher sugar content. But they performed badly in North India primarily due to low winter temperatures in this region.
- C.A. Barber, T.S. Venkataraman and others at the **Sugarcane Breeding Institute (SBI), Coimbatore,** transferred the thicker stem, higher sugar content and other desirable characters from the noble canes to the Indian canes. This is commonly referred to as **noblisation of Indian canes**.
- They also crossed *Saccharum spontaneum* (vern. kans), a wild species, to transfer disease resistance and other desirable characteristics to the cultivated varieties.
- Several high yielding varieties with high sugar content and well adapted to local climate have resulted from this breeding programme.
- At present, sugarcane breeding all over the world is based on the **noblisation technique**.

3. Hybrid varieties

- The development of hybrid varieties of maize, jowar and bajra deserves a special mention.
- A programme to develop hybrid maize began in India over three decades ago in collaboration with Rockefeller and Ford Foundations. Several hybrid varieties have been released since then.
- The Ganga series of hybrids, *e.g.*, Ganga Safed 2, and Deccan, are a few examples.
- Similarly, several hybrids have been released in jowar, *e.g.*, CSH 1, CSH 2, CSH 3, CSH 4, CSH 5, CSH 6, CSH 9, CSH 10, CSH 11 etc.,
- In bajra, *e.g.*, PHB 1O, PHB 14, BJ 104 and BK 560.
- More recently, composite varieties are being developed to overcome the difficulties encountered with the hybrid varieties.
- For example, Manjari, Vikram, Sona, Vijay and Kisan are some of the notable

maize composite varieties. Some recently released composites are CO 1, NLD, Renuka, Kanchan, and Diara. **The composite varieties often yield as much as the hybrid varieties** and do not have the drawbacks of the latter. More notably, the farmers need not replace the seed every year in the case of composite varieties.

4. Hybrid Cotton

- India has achieved the distinction of commercially exploiting heterosis in cotton.
- The **first hybrid variety of cotton** was **H-4** (a hybrid from two *G. hirsutum* strains).
- It was developed by the Gujarat Agricultural University (Surat Station) and released for commercial cultivation in 1970.
- Since then, several other hybrid varieties have been released for cultivation.
- The hybrid varieties are high yielding, and have high ginning outturn and good fiber quality.
- They are becoming increasingly popular with the farmers.
- It is noteworthy that the farmers are more willing to pay the high cost of the hybrid seed produced by hand emasculation and hand pollination.
- Efforts to utilize cytoplasmic male sterility (CMS) for hybrid seed production have been successful and a hybrid based on CMS has been released.
- Hand pollination is essential for seed set on the CMS line.
- The cost of seed production is expected to be reduced to 10% of that incurred by hand emasculation and pollination technique.
- Recently, two hybrid varieties of desi cotton, *viz.*,G. cot. Dh-7 and G-cot. Dh-9, have been released.

UNDESIRABLE CONSEQUENCES

Crop improvement leads to many desirable changes in crop species, which make these crops more useful to man. However, it also generates some undesirable effects, which include (1) genetic erosion, (2) narrow genetic base and (3) increased susceptibility to previously minor diseases.

1. Genetic Erosion

Improvement in the yield of a crop species is accompanied with a reduction in variability among the cultivated varieties of that species.

This reduction is produced by two potent factors:

- Replacement of heterogeneous local varieties by few dominant, more homogeneous improved varieties.
- Use of similar/related varieties as parents in breeding programmes.
- The improved varieties are commonly purelines (self-pollinated species) or hybrids (cross-pollinated species), which are much more homogeneous than the unimproved local and open-pollinated varieties.
- A few improved varieties become predominant and rapidly replace the local varieties leading to a rapid depletion of genetic variability ***(genetic erosion)***.
- This, in turn, limits the prospects of further improvement in the species since variability is the prerequisite for any modification in the characteristics of a crop species.
- Is it not ironical that successful crop improvement has depleted the very basic resource that is so essential for its continued success?
- *Germplasm collections aim at minimizing the detrimental effects of genetic erosion by collecting and preserving the variability in crops and their related species.*

2. Narrow Genetic Base

- Many of the improved varieties have one or more parents in common with each other.
- Many semi dwarf varieties of rice have IR 8 or TN I as one of their parents.
- IR 8 and TN I are related to each other by the common parent Dee-geo-woo-gen, the source of their semi-dwarfing gene.
- The semi-dwarf wheat varieties have *Rht 1*,*Rht* 2 or both these genes for reduced height; these genes have been derived from a single wheat variety, Norin 10.
- Thus the improved varieties of a crop species are becoming increasingly similar to each other due to the commonness of one or more parents in their ancestry.
- This has led to the narrowing down of the genetic base of these varieties.
- *Genetic base* refers to **the genetic variability present among the cultivated varieties of a crop species.**
- The narrow genetic base has created *genetic vulnerability,* which refers to the susceptibility of most of the cultivated varieties of a crop species to a disease, insect pest or some other stress due to a similarity in their genotypes.
- An example of genetic vulnerability is the outbreak in epidemic proportions of

Helminthosporium (now, *Cochliobolus)* leaf blight of maize in the 1970s in U.S.A.

- This occurred due to the extreme susceptibility of most of the commercial hybrids to the leaf blight.
- This susceptibility was produced by the Texas male sterility cytoplasm (**CMS- T**) present in these hybrids.
- A similar case in India is the susceptibility of early bajra hybrids to downy mildew and ergot. This susceptibility was contributed by the male sterile parent of these hybrids, **Tift 23A** or its dwarf derivative, **Tift 23D2A**.
- But in this case, the susceptibility was due to some nuclear genes and not due to the male sterile cytoplasm itself.
- *Genetic vulnerability can be avoided by using diverse and unrelated parents in breeding programmes, and by using unrelated sources of male sterility, semi-dwarfness etc.*
- Breeders are becoming increasingly aware of this problem and they are making conscious efforts to broaden the genetic base of cultivated varieties of various crop species.

3. Increased Susceptibility to Minor Diseases

Another problem has been generated by the lopsided emphasis on breeding for resistance to major diseases and insect pests only. This has resulted in an increased susceptibility to minor diseases. As a result, these diseases have gained in importance and produced severe epidemics.

CHAPTER: 2

PLANT: DOMESTICATION AND GENETIC RESOURCES

The process of bringing wild species under human management is referred to as plant domestication.

All the present-day cultivated plants have been derived from wild weedy species. Therefore, the first step in the development of cultivated plants was their domestication.

Domestication of wild species is still being done and is likely to continue for a long time in the future. This is because the human needs are likely to change with time. Consequently, the wild species of little importance today may assume great significance tomorrow. This is particularly true for microorganisms producing antibiotics, involved in nitrogen fixation, and producing other compounds of industrial or medical interest; forest trees producing timber and other commercial products; medicinal plants; and plants fulfilling specific needs.

A notable case of recent domestication is that of several members of Euphorbiaceae producing latex. The latex of these plants may be commercially used for the extraction of petroleum products, including petrol and diesel. **Ex**- Jojoba, Jetropha, Milkweed species, etc.

Selection under Domestication

When different genotypes present in a population reproduce at different rates, it is called **selection**.

Population : The group of individuals, which mate or can mate freely with each other. Thus a population consists of individuals of a single species growing in the same locality.

Selection is grouped into two types, on the basis of the agency responsible for it.

(1) Natural selection

(2) Artificial selection

1. Natural Selection : The selection that occurs due to natural forces like climate, soil, biological factors (e.g., diseases, insect, pests etc.) and other factors of the environment.

- It occurs in natural populations, *i. e.*, wild forms and wild species, and determines

the course of their evolution.

- All the genotypes of the population reproduce, plants become more adapted to the prevailing environment.
- The population retains considerable genetic variability.

2. Artificial Selection: Selection is carried out by man according to their need and uses.

- This type of selection is confined to domesticated species.
- It allows only the selected plants to reproduce, ordinarily makes plants more useful to man.
- Leads to a marked decline in genetic variability in the selected progenies/populations.
- Usually plants become less adapted to the natural environment.
- They have to be grown under carefully managed conditions.
- *Our present-day crops are the products of continued artificial selection.*

Important changes that have occurred under domestication

- *Elimination of or reduction in shattering* of pods, spikes etc. This change has taken place in most of the cultivated species.
- *Elimination of dormancy* has taken place in several crop species. Lack of dormancy has become a problem in crops like barley, wheat, mung, etc.
- *Decrease in toxins* or other undesirable substances has occurred in many crops. The bitter principle of cucurbitaceous plants provides an example of this type.
- *Plant type* has been extensively modified. The cultivated plants show altered tillering, branching, leaf characters. etc.
- In several crop species, there has been a *decrease in plant height, e.g.,* cereals, millets. This is often associated with a change from indeterminate to determinate habit.
- In some species, on the other hand, there has been an *increase in plant height* under domestication, *e.g.*, jute, sugarcane, forage grasses etc.
- *Life cycle has become shorter* in case of some plant species. This is particularly so in case of crops like cotton, arhar, etc.
- Most of the crop plants show an *increase in size of their grains or fruits.*
- *Increase in economic yield* is the most noticeable as well as desirable change under domestication. This is self-evident in every crop species.

- In many crop species, *asexual reproduction has been promoted* under domestication, *e.g.*, sugarcane, potato, sweet potato, etc.
- There has been a *preference for polyploidy* under domestication. Many of the domesticated plant species are polyploids, *e.g.*, potato, wheat, sweet potato, tobacco, etc., while diploid plants are present in nature. Thus domestication seems to have favoured polyploidy in these crop species.
- In many species, there has been a *shift in the sex form* of the species. In many dioecious fruit trees, bisexual forms have developed under domestication. Self-incompatibility has also been eliminated in many crop species. *Variability within a variety has drastically decreased* under domestication. The extreme case is that of pureline varieties, which are completely homogeneous genotypically.

PLANT GENETIC RESOURCES

The sum totals of hereditary material i.e. all the allele of various genes, present in a crop species and its wild relatives is referred to as germplasm. This is also known as genetic resources or genetic stock. Germplasm consists of the following five types of materials:

1. Land Races

These are locally adapted, traditional varieties, which had evolved over centuries through both natural and artificial selection, but without systematic and sustained plant breeding efforts. Since, they are sources of many valuable genes, their conservation is essential. The main drawbacks of land races are that they are less uniform and low yielders. Land races were first collected and studied by N.I Vavilov in rice.

2. Obsolete Cultivars

Improved varieties of recent past are known as obsolete cultivars. These varieties were developed by systematic plant breeding efforts and popular earlier but now have been replaced by new varieties.

3. Modern Cultivars

The currently cultivated varieties are referred to as modern cultivars. These varieties have high yield potential and uniform as compared to obsolete varieties and land races.

4. Wild Form

Wild forms are the wild species from which crop species were directly evolved.

CHAPTER: 3

PLANT INTRODUCTION

Plant introduction refers to "transposition of crop plants from the place of their cultivation to such areas where they were never grown earlier."

Types of Plant Introduction

1. Primary or Direct plant introduction
2. Secondary or Indirect plant Introduction

Primary or direct plant introduction:

- When the introduced variety is well suited to the new environment and it is directly released for commercial cultivation without any change in the original genotype.
- It is less common in countries having well organized crop improvement programmes.

Exotic Variety: Any foreign variety, which is directly recommended for commercial cultivation, is known as **exotic variety**.

- e.g. Semi dwarf Wheat – Sonora-64, Lerma Rojo, etc.
- Semi dwarf Rice – TN-1, IR-8, IR-28, etc.
- Tomato-Sioux, Soybean – Bragg and Lee, Clark-63, Tobacco- Delcrest & Virginia Gold.

Secondary or indirect plant Introduction:

- When the introduced variety/material may be subjected to selection to isolate a superior variety. Alternatively, it may be hybridized with local varieties to transfer one or a few characters.
- Introduced material is not used directly as a variety.
- It is much more common than primary plant introduction.
    - e.g.-KalyanSona and Sonalika wheat varieties were selected from the material introduced from CIMMYT,mexico, -Egyptian cotton variety Sujata was released after selection from the Egyptian variety Karnak.

- Similarly, new varieties have been developed through selection from the introductions in pearl millet, cowpea, radish, sweet potato and many other crops.

PURPOSES OF PLANT INTRODUCTION

The main purpose of plant introduction is to improve the plant wealth of the country. The chief objectives of the plant introduction may be grouped as follows :

1) To obtain an entirely new crop plant

Plant introduction may provide an entirely new crop species and it can be used in agriculture, forestry and industries.

e.g. -Maxican dwarf wheat & rice, maize, potato, tomato, tobbaco, soybean, etc.

Further it provides lines with new characters like M.S. lines- Tift 23A in Bajra, TSP – 10R in castor, etc.

2) To serve as a new variety

Sometimes introductions are released as a superior commercial variety. e.g. Sonora-64, Lerma Rojo in wheat, T.N.-1, IR-8 in rice.

3) To be used in crop improvement

Often the introduced material is used in hybridization with local varieties to develop improved varieties.

e.g. Pusa Ruby in Tomato – derived from Meeruty x Sioux- an introduction from USA

Cotton Hybrid –4 – derived from G-67 x American necteriless - an introduction from USA

4) For Scientific studies

Collection of plants has been used in studies on biosystematics, evolution and origin of plant species.

5) For fulfillment of aesthetic interest

Ornamental plants, shrubs and lawn grasses are introduced to satisfy the finer sensibilities of human kinds. These plants are used for decoration and great value in social life.

Advantage of Plant Introduction

1. It provides entirely new crop plants.
2. It may provide superior varieties directly/after selection/hybridization.
3. Introduction and exploration are the only feasible means of collecting germplasm and to protect variability from genetic erosion.
4. It is a very quick and economical method of crop improvement, particularly when the introductions are released as varieties directly or after simple selection.

Disadvantage of Plant Introduction

If the introductions are not done very carefully and properly, then there are chances of introducing new weeds, diseases and pests. e.g.

1. **Weeds:** *Argemone mexicana*, *Phylaris minor* (Gehunsa), *Lantana camera* (kuri), water hyacinth, etc. are some of the noxious weeds introduced in India from other countries.
2. **Diseases:** Late blight of potato from Europe, Flag smut of wheat from Australia, Coffee rust and Bunchy top of banana from Ceylon, etc diseases were also introduced in India along with plant materials.
3. **Insects:** Potato tuber moth from Italy, wolly aphis of apple, Fluted scale of citrus and very recently strip virus in groundnut.

CHAPTER: 4

MODE OF REPRODUCTION IN CROP PLANTS

Why should we know the mode of reproduction?

1. The methods of breeding depends upon the mode of reproduction, such as whether crop is sexually propagated or asexually propagated, whether it is self or cross pollinated and sterility and incompatibility involved in the mechanisms of reproduction.
2. Effect of inbreeding and out breeding depends on mode of reproduction because the genetic structure is different.
3. Genetic constituent/structure of plant and population depends on mode of reproduction.
4. Handling and management of breeding programme may depend on mode of reproduction. e.g., handling of breeding material is easy in maize, while it is difficult in alfalfa.

Therefore, it is essential for plant breeder first to know about mode of reproduction in concern crop to select proper breeding methods.

Flower: In crop plants, male and female gametes are produced in specialized structures known as **flower**. The flower contains sexual reproductive organs, therefore, it is essential to know the flower structure.

Flower normally consists of following four whorls:

Calyx	Calyx and corolla helping and protecting the sexual parts.
Corolla	
Androecium	Androecium and Gynoecium important reproductive whorls of the flower
Gynoecium	

Types of flower:

1. **Perfect/ hermaphrodite/ bisexual flowers**: A flower containing both stamens and pistil.

2. **Unisexual flowers** :
   a. **Staminate** flowers: Contains only stamens.
   b. **Pistilate** flowers : Contains only pistil

3. **Complete flowers**: Contains all four floral organs like sepals, petals, stamens and pistil. eg. Cotton, Groundnut, tobacco, rape, etc.

4. **Incomplete flowers**: Flowers lack one or more these four organs. eg. Wheat, Barley, Oat, Maize, Sorghum, Bajara, Rice, grasses, etc.

Crop Species:

- **Monoecious**: Male and female flowers are on the same plant eg. Maize, Castor, Coconut, etc.
- **Dioecious**: Male and female flowers are on the different plants eg. Papaya, Date palm, Hemp, etc.

The mode of reproduction in crop plants may be broadly grouped into two categories.

1. **Asexual reproduction**
2. **Sexual reproduction**

A) Asexual reproduction :

<table>
<tr><td colspan="2">1. Vegetative reproduction :</td></tr>
<tr><td>I. Natural</td><td>II. Artificial</td></tr>
<tr><td>i.Underground Stem :
a) Tuber- Potato
b) Bulb- Onion
c) Rhizome- Ginger
d) Corm- Arwi, Satavari, Safron</td><td rowspan="2">a) Stem cutting – Sugarcane, grape, roses
b) Layering
c) Budding
d) Grafing
e) Gootee</td></tr>
<tr><td>ii. Sub areial Stem:
a. Runner - Mint
b. Stolon - Jethimadh
c. Suckers - Datepalm</td></tr>
<tr><td colspan="2">iii. Bulbils: Bulbils are modified flowers that develop into plant directly without formation of seeds. These are vegetative bodies eg. Garlic</td></tr>
<tr><td colspan="2">2. Apomixis : Adventitious embryony, Apospory, Diplospory, Apogamy, Parthenogenesis, etc.</td></tr>
</table>

B) Sexual reproduction:

Sexual reproduction involves fusion of male and female gametes to form a zygote (i.c. the product of fusion) which develops into an embryo.

There are two principal types of sexual reproduction:

1. Isogamy Sexual reproduction
2. Heterogamy Sexual reproduction

I) Isogamy Sexual reproduction:

In this type of sexual reproduction, male and female gametes are morphologically similar. The fusion of such similar gametes is called isogamy sexual reproduction. It is found in lower plants.

II) Heterogamy Sexual reproduction:

If the gametes of both male and female sex morphologically dissimilar, they are known as heterogametes. The fusion of such dissimilar gametes is known as heterogamy. It is most common in flowering plants.

A). Androecium:

Androecium (andros = male) is male reproductive whorl of flower. Its component parts called stamens. Each stamen is consist of three parts – a) Filament b) Connective and c) Anther**.**

Pollen grains are male reproductive bodies developing within the anther.

B). Gynoecium :

Gynoecium is also known as pistil. It is female reproductive whorl of flower. Its component part is known as carpel. When the pistil is made of only one carpel, such pistil is said to be simple or monocarpellary. When pistil possesses two or more carpels then it is said to be compound or polycarpellary. Each gynoecium consists of three parts: a) Stigma b) Style and c) Ovary.

SPOROGENESIS

The production of microspores and megaspores is known as sporogenesis, and production of male and female gametes from microspores and megaspores are known as micro-gametogenesis and mega-gametogenesis, respectively.

Study of Microsporogenesis and Megasporogenesis

The production of microspores and megaspores is known as sporogenesis, and production of male and female gametes from microspores and megaspores, respectively are known as microgametogenesis and megagametogenesis.

Terminology :

- **Gamete :** A specialized cell which participates in the process of fertilization.
- **Sporogenesis :** The process of production of microspores (male gametes) and megaspores (female gametes) is known as sporogenesis.
- **Gametogenesis :** The process of production of male and female gametes in the microspores and the megaspores, respectively is known as gametogenesis.
- **Microgametogenesis :** The process of production of male gamete (sperm) is known as microgametogenesis.
- **Megagametogenesis :** The process of production of female gamete (egg cell) is known as megagametogenesis.

Process of Microsporogenesis and Microgametogenesis :

- Microspores are produced in anther i.e. microsporangium (**Fig. 2.1**).
- Each anther has four pollen sacs which contain numerous Pollen Mother Cells (PMC). These PMC's are also known as sporogenous tissue or archesporium.
- Each pollen grain undergoes meiosis to produce four haploid cells or microspores.
- The microspores mature into pollen grains by thickening of their wall.
- During the maturation of pollen, the microspore nucleus divides mitotically to produce a *generative nucleus* and a *vegetative nucleus* or *tube nucleus. This is known as binucleate pollen grain.*
- The pollens are generally released in this binucleate stage. When the pollen grain reaches the stigma of a flower, it is known as ***pollination***.
- Shortly after pollination, the pollen germinates and the pollen tube enters the stigma and grows through the style.
- The generative nucleus now undergoes a mitotic division to produce two ***male gametes* or *sperms***.
- The pollen, along with the pollen tube, is known as ***micro gametophyte*.**
- The pollen tube finally enters the ovule through a small pore (***micropyle)*** and discharges the two sperms into the embryo sac.

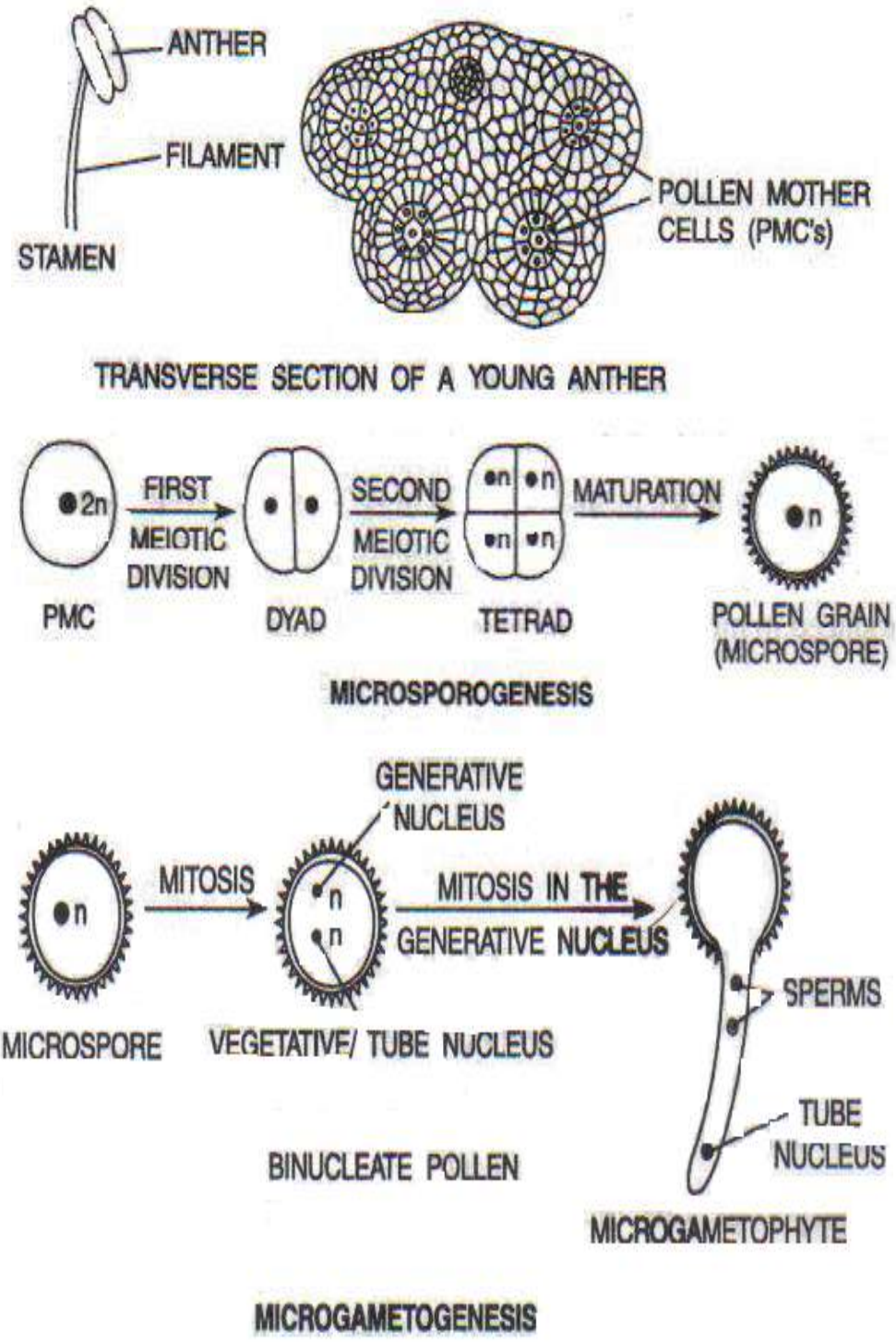


Fig. 2.1 : Process of Microsporogenesis and Microgametogenesis

Process of Megasporogenesis and Megagametogenesis:

- The embryo sac bears the embryo and develops in the ovule. Megaspores are produces in ovules, i.e. megasporangium (**Fig**. **2.2**).
- A single cell in each ovule differentiated into Megaspore Mother Cell (MMC). This MMC undergoes meiosis to produce a row of four haploid megaspores. It is known as linear tetrad.
- Three of the megaspores degenerate living one functional megaspore per ovule.
- The nucleus of the functional megaspores divides mitotically to produce four more nuclei. In most of the crop plants, megaspores nucleus undergoes three mitotic divisions to produce eight nuclei in the embryo sac, four at each end.
- The embryo sac increase in size. Then one nucleus from at each end or pole pass inwards, and the two polar nuclei fuse together somewhere in the middle forming the definitive nucleus.
- Another three nuclei remain at chalaza end or opposite end to form the antipodal cells, which have no definite function so sooner or later they get disorganized.
- They may, however, be nutritive in function. The remaining three polar nuclei at the micropyle end, each surrounded by a very thin wall form the egg apparatus, which consisted of three cells, one is female gamete known as egg cell/ovum/oospore.
- The other two are known as synergids or cooperative cells. They attract pollen tube by secreting some chemicals. One synergid degenerates to provide seat for pollen tube.

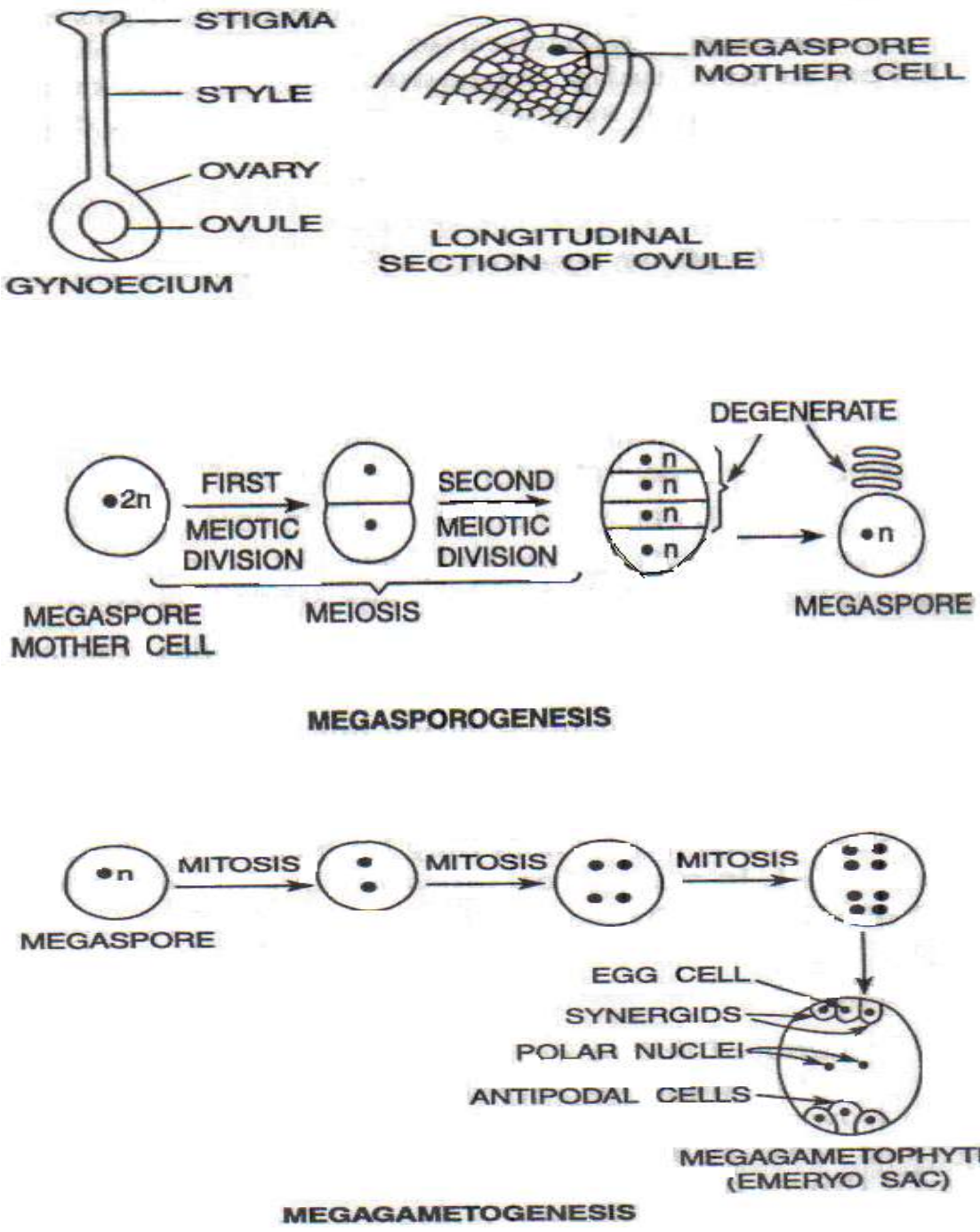


Fig. 2.2 : Process of Megasporogenesis and Megagametogenesis

Significance of sexual reproduction:

1. It is possible to combine genes from two parents into a single hybrid plant
2. Recombination among the genes produces large number of genotypes.
3. It is possible to create genetic variation through hybridization.
4. Even in asexual reproducing species, if sexual reproduction occurs, it is used to take the advantage as mentioned above eg. Sugarcane, Potato, Sweet potato etc.

Significance of vegetative reproduction:

1. A desirable plant may be used as a variety directly regards less of whether it is homozygous or heterozygous.
2. Identity of the plant can be maintained, even through it is heterozygous in nature.
3. Mutant buds, branches or seedlings, if desirable, can be multiplied and used directly as variety

MODE OF POLLINATION

Pollination: Pollination is defined as the transfer of pollen grins from anther to the stigma is called as pollination.

Types of pollination: -

1. Self pollination
2. Cross pollination

1) Self pollination: -

It is refers to the pollen from an anther may fall on to the stigma of the same flower is called as self-pollination or autogmay.

2) Cross pollination: -

It refers to the pollen grains from flower of one plant are transmitted to the stigma of flowers of another plant it is called as cross-pollination or allogamy.

3) Geitonogamy: -

When pollen from a flower of one plant falls on the stigmas of other flowers of the same plant. e.g. maize.

1) SELF POLLINATION: -

- Development of seed by self-pollination is known as autogamy or self-pollination.
- Auotogamy is the closest form of breeding.
- Auotogamy leads to homozygosity.
- Such species develop homozygous balance & do not exhibit significant inbreeding depression.
- But in most of these species, self pollination is not compete & cross-pollination may occur up to 5%.
- The degree of cross-pollination in self-pollinated species is affected by several factors. e.g. variety, environmental condition like temperature, humidity & location.

MECHANISM PROMOTING SELF POLLINATION: -

There are various mechanisms that promote self-pollination, which are generally more efficient than that cross-pollination.

Bisexuality: - Presence of male & female organs in the same flower is known as bisexuality. The presence of bisexual flowers is a must for self-pollination. All the self-pollinated plants have hermaphrodite flowers. The various mechanisms which promote self pollinations are as under

1) Homogamy: -

- Maturation of anthers and stigma of a flower at the same time is called as homogamy.
- As rule, homogamy is essential for self-pollination.

2) Cleistogamy: -

- When pollination and fertilization occur in unopened flower bud is called as cleistogamy.
- It ensures self-pollination prevents cross-pollination.
- In th is case flowers do not open at all this ensures complete self pollination since foreign pollen cannot reach the stigma of a closed flower e.g. wheat, oats, barley and other grasses.

4) Chasmogamy: -

- In plants, fertilization after opening of flower is known as chasmogamy.

- It promotes self-pollination. e.g. wheat, barley, rice, oats etc.

5) Position of anthers: -

- In some species, stigma are surrounded by anthers in such a way that self-pollination is ensured.
- Such situation is found in tomato and brinjal.
- Some legumes, the stamens and stigma are enclosed by the petals.
  e.g. green gram, black gram, soybean, chickpea and pea etc.

GENETIC CONSEQUENCES OF SELF POLLINATION:

- Self-pollination leads to a very rapid increase in homozygosity.
- Therefore populations of self-pollinated species are highly homozygous.
- Self-pollinated species do not show inbreeding depression, but may exhibit considerable heterosis.
- Therefore, the aim of breeding methods & develop homozygous varieties.

2) CROSS POLLINATION:-

- Development of seed by cross-pollination is called as allogamy.
- In cross pollination species the transfer of pollen from a flower to the stigmas of the others.

May brought about by

1) Wind (anemophily)
2) Water (hydrophily)
3) Insects (anemophly)

Many of the crop plants are naturally cross-pollinated. In many species a small amount (up to 5%)of selfing may occur.

MECHANISM PROMOTING CROSS POLLINATION: -

There are several mechanisms that facilitate cross-pollination

I) Dicliny: -

It refers to unisexual flowers. The flowers are either staminate (male) or pistilate (female).

This is of two types: viz. 1) Monoecy and 2) Dioecy

1) **Monoecy: -**

- Staminate & pistilate flowers occur in the same plant, either in the same inflorescences. e.g. castor, mango, banana, coconut, or in separate inflorescences, e.g. maize.

  Other monoecious species are cucurbits, walnut, chestnut, strawberries, rubber, grapes & cassava.

2) **Dioecy: -**

- The male & female flowers are present on different plants, i.e. the plants in such species are either male or female, e.g. papaya, datepalm, hemp, asparagus, & spinach.
- In general the sex governed by a single gene, e.g. asparagus & papaya. There are hermaphrodite plants in condition to male & female plants, & a number of intermediate forms may also occur.

II) Dichogamy: -

Stamens and pistils of hermaphrodite flowers may mature at different times. There are of two types

a) Protogyny – pistils mature before stamens. e.g. bajara
b) Protandry - stamens mature before pistils.e.g, maize and sugarbeet.

III) Heterostyly: -

When styles and filaments in a flower are different length, it is called heterostyly. e.g. linseed.

IV) Herkogamy: -

Hindrance to self-pollination due to some physical barriers such as presence of hyline membrane around the anther is called as herkogamy.eg alfalfa.

V) Self incompatibility: -

It refers to the failure of pollen from a flower to fertilize the same flower or other flowers on the same plant.

There are two types of self-incompatibility:

a) Sporophytic incompatibility: -

Self-incompatibility is controlled by the genotype of the pollen producing plant is called as sporophytic incompatibility, e.g. cabbage, cauliflower, radish.

b) Gametophytic incompatibility: -

Self-incompatibility is controlled by the genetic constitution of pollen is called as gametophytic incompatibility. e.g. potato tomato, rice.

VI) Male sterility: -

- It is refers to the absence of functional pollen grains in otherwise hermaphrodite flowers is called male sterility.
- Male sterility is not common in natural populations. But it is great value in hybrid seed production.
- It prevents self-pollination and promotes cross-pollination.

➢ **There are following three types of male sterility:**

a) Cytoplasmic male sterility: -

The pollen sterility which is controlled by cytoplsamic genes or plasma genes is called as cytoplsamic male sterility. e.g. onion .

b) Genetic male sterility: -

The pollen sterility, which is controlled by nuclear genes, is termed as genic or genetic male sterility. e.g. barley , maize, wheat , cotton , sorghum Lucerne, cucurbits, tomato and sugarbeet.

c) Cytoplasmic genetic male sterility: -

When pollen sterility, which is controlled by both cytoplamic and nuclear genes, is known as cytoplasmic genetic male sterility. E,g wheat maize , sorghum , rice, sunflower cotton, tobacco, tomato, onion, sugarbeet , carrot linseed.

GENETIC COSEQUENCES OF CROSS POLLINATION: -

- Cross pollination preserves and promotes heterozygosity in a population
- Cross-pollinated species are highly heterozygous.
- The breeding method in such a species aim at improving the crop species without reducing heterozygosity to an appreciable degree.
- Usually, hybrid or synthetic varieties are the aim of breeder wherever the seed production of such varieties is economical feasible.

3) OFTEN CROSS-POLLINATED SPECIES: -

- Cross-pollination often exceeds 5% and may reach upto 30% such a species is known as often cross-pollination. e.g. jawar cotton, arhar , safflower , etc.

DETERMINATION OF THE MODE OF POLLINATION: -

1) The first step – Determine the mode of pollination of species is to examine its flower. Mechanism like dioecy, protogyny, protandry, cleistogamy are easily detected; they clearly indicate the mode of pollination.

2) The second step: -
   - Isolate single plants and recording seed set under isolation.
   - Space isolation, i.e individual plants grown at sufficient distance to prevent cross-pollination, is preferable to isolation by bags or cages.
   - Isolation of bags and or cages may create an environment unfavorable for pollination and seed set.
   - Failure of set seed in isolation proves the spaces to be cross-pollinated.
   - However, setting of seed s only indicates of self-pollination.

   Finally, the effect of selfing (inbreeding) on the vigour of plants should be studied. Loss in vigour due to inbreeding is common in cross-pollination, but self-pollinators show to inbreeding depression.

DETERMINATION OF THE AMOUNT OF CROSS POLLINATION

The amount of cross-pollination is determined by planting two strains of the concerned species in a mixed strain.

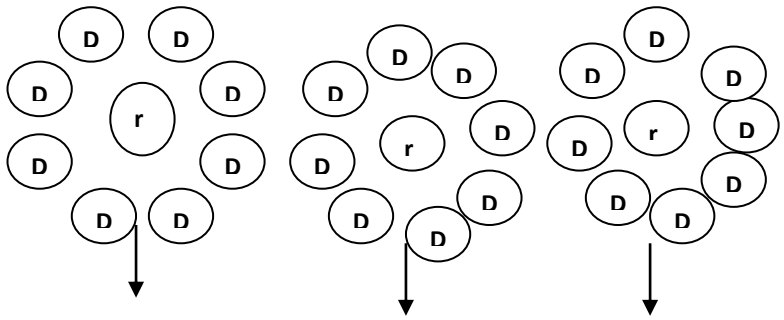
1) One strain is homozygous for a dominant character preferably an easily recognizable seed or seedling character.
2) Other strain has the recessive form of the character.
3) The two strains are planted in such a manner that each plant of recessive strain is surrounded by plants of the dominant strain to provide abundant pollen.
4) The seeds from the plants of only recessive strain are harvested.
5) The percentage of seeds carrying the dominant allele represents the percentage of crosspollination in the species.
6) The frequency of cross-pollination varies greatly with variety, weather condition.

e.g. In a study on safflower, the estimates of out crossing in different varieties grown in the same time at the same location from 0-8.7% similarly, the amount of cross pollination in a single variety grown at a several locations varied from 1.3-9.8%. Therefore such a study should include several varieties of the crop and the study should be conducted at several locations for two more years.

DETERMINATION OF THE AMOUNT OF CROSS – POLLINATION:

Crop : Castor Inbred / Varieties: 1.VI – 9 Green Stem (Recessive)

2. 48–1 Red Stem (Dominant)



Steps: 1. Sowing: Where, r = VI-9 and D = 48-1

0	0	0
0 0 0	0 0 0	
0 0 0 0	0 0 0 0	0 0 0 0
No. of Plants 100	No. of Plants 100	No. of Plants 100
Plot No.1	Plot No.2	Plot No.3

Recording of Observations:

Character	Plot No.1	Plot No.2	Plot No.3	Average
Green Stem Plant (Recessive	55	60	53	-
Red Stem Plant (Dominant)	45	40	47	-
% Cross Pollination	45	40	47	44

The average of cross-pollination is 44 %.

Significance of pollination: -

1. Gene action.
2. Genetic constitution
3. Adaptability
4. Genetic purity
5. Transfer of genes

1. GENE ACTION: -

In refers to mode of expression of genes for various characters in a population. Gene action is of two types :

1) **Additive gene action: -** It is associated with homozygosity and is more in self-pollination species.
2) **Non additive gene action or** (dominant and epitasis)**: -** It is associated with heterozygosity and therefore is more cross-pollinated species.

2. GENETIC CONSTITUTION: -

The breeding population is of four types viz. heterozygous, homozygous, homogeneous, and heterogeneous.

1) **Heterozygous: -** Individuals have dissimilar alleles at the corresponding loci and are pure types.
2) **Homozygous: -** Individuals have dissimilar alleles at the corresponding loci and are of pure types. (They do not segregate on selfing)
3) **Homogeneous: -** The genetically similar population is known as homogeneous.
4) **Heterogeneous: -**
   - Genotypically dissimilar population it is known as heterogeneous.
   - It may again the homozygous or heterozygosity and cross-pollination results in heterozygosity because in breeders have advantageous of homozygosity and outbreeders have advantage of hererozygosity.

3) ADAPTABILITY:

It refers to stable performance of a variety over a wide range of environmental conditions.

- The cross pollinating species have better adaptability (Buffering capacity) than self pollinating species, because of more heterozygosity and heterogeneity in the former case.

- The heterozygosity populations have broad genetic base. Such a populations have greater capacity to stabilize productivity over a wide range of changing environments.
- Heterogeneous population gives more stable yields over Similarly; heterozygous individuals such as F1 hybrids are more stable to environmental variations than their homozygous parents.
- Thus mode of pollination plays a key role in varieties adaptability.

GENETIC PURITY: -

- Self-pollination maintains the genetic purity of a species and the purity of a variety of a self-pollinating crop can be easily maintained for several years.
- Cross-pollination creates heterozygosity and genetic composition of a cross-pollinating variety change gradually.
- Hence, self-pollination is essential even in cross-pollinated species to maintain the purity in parental lines.

5) TRANSFER OF GENES:

Cross-pollination permits transfer of desirable genes from one species to another. Or combining of desirable genes from different sources in to a single genotype is possible through cross-pollination.

Classification of crop plants based on mode of pollination and mode of reproduction

Mode of pollination and reproduction	Example of crops
A. Autogamous species 1. Seed propagated	Wheat, rice, barley, oats, chickpea, pea, cowpea, lentil, green gram, black gram, soybean, common bean, moth bean, linseed, sesamum, khesari, sunhemp, chillies, brinjal, tomato, okra, peanut.
B. Allogamous species 1. Seed propagated	Corn pearlmillet, rye, Alfalfa, radish, cabbage, sunflower, sugarbeet, castor, red clover, white clover, safflower, spinach, onion, garlic, turnip, squash, muskmelon, watermelon, cucumber, pumpkin, oilpalm, carrot, coconut, papaya.
2. Vegetatively propagated	Sugarcane, coffee, cocoa, tea apple, peaches, pears, cherries, grapes, almond, strawberries, pine apple, banana, cashew nut, rubber, sweet potato, etc.
C. Often-allogamous species. (Seed propagated)	Sorghum, cotton, triticale, pigeonpea, Tobacco.

CHAPTER: 5

MALE STERILITY

- It is a condition in which pollen grains are non-functional or absence of functional or active pollens.
- Male sterility is caused by chromosomal aberration, gene action or cytoplasmic influences. It occurs in nature sporadically perhaps due to mutation.

Male sterility is much more useful in plant breeding because:

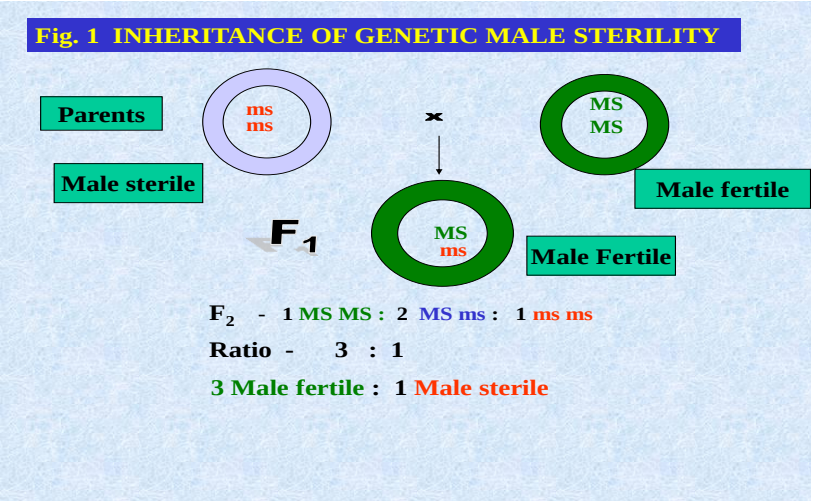
1. It acts as genetic emasculation and facilitates large scale hybrid seed production.
2. It saves the tedious and laborious work of emasculation.

Male sterility is classified into 3 groups.

1. Genetic male sterility
2. Cytoplasmic male sterility
3. Cytoplasmic-genetic male sterility

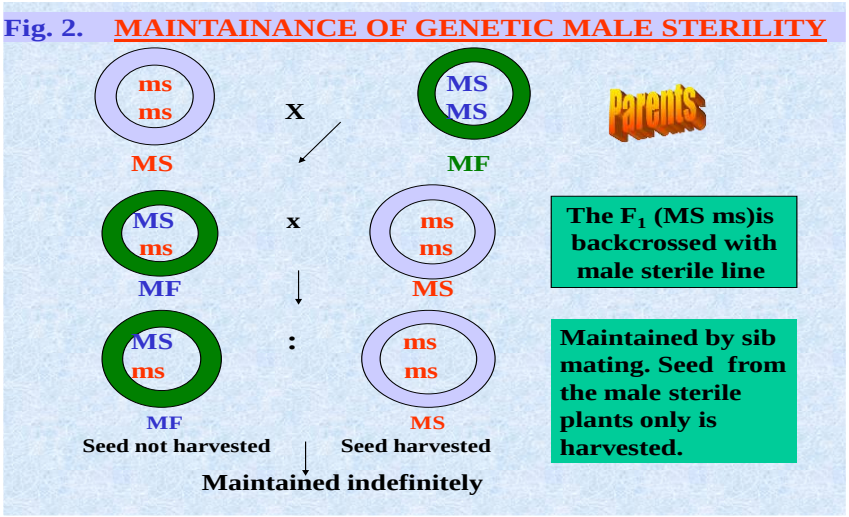
(I) Genetic Male Sterility (GMS):

1. This type of male sterility is governed by single recessive gene "ms". Therefore, it is monogenic recessive character.
2. The male sterility alleles arise spontaneously or may be artificially induced.
3. The inheritance of male sterility is as illustrated in Fig. 1.



Maintenance of Genetic Male Sterility

The male sterile line (MS) may be maintained by crossing it with heterozygous male fertile plant. Such a mating produces 1:1 male sterile and male fertile plants as demonstrated in Fig. 2.



Utilization of Genetic Male Sterility

- Genetic male sterility is used for hybrid seed production in the crop like castor and pigeon pea.
- The problem associated with genetic male sterility is that the male sterility population also contains 50% male fertile plants.
- So, in hybrid seed production programme such male fertile plants must be eliminated before flowering and this job is very tedious and laborious.
- If marker gene is available then it becomes easy to identify male fertile plants at seedling stage and can be rouged out.

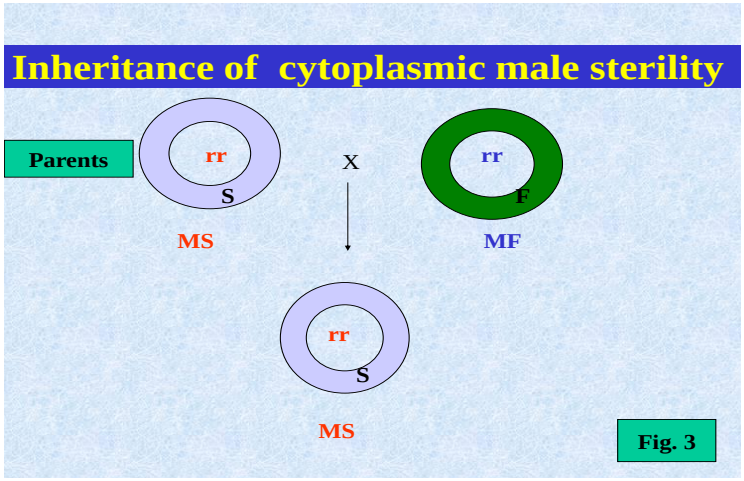
(II) Cytoplasmic Male Sterility (CMS)

This type of male sterility depends on cytoplasmic factor.

- Plants carrying particular type of cytoplasm are male sterile.
- Since the cytoplasm of a zygote comes primarily from egg cell, the progeny of such male sterile plants would always be male sterile.

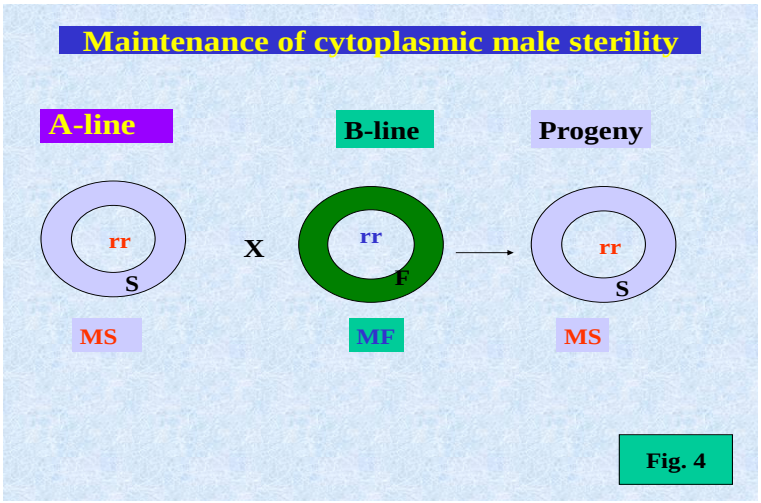
Inheritance of cytoplasmic male sterility

- The F_1 produced by the crossing between male sterile and male fertile plants would always be male sterile (Fig. 3), since their entire cytoplasm is derived from the female parent.



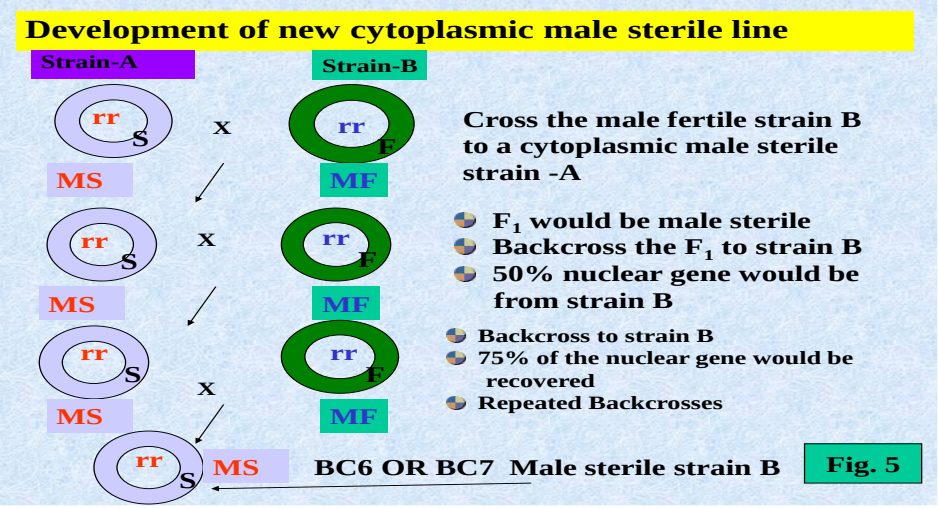
Maintenance of cytoplasmic male sterility

- The cytoplasmic male sterile line is maintained (Fig. 4) by crossing it with its male fertile counter part known as maintainer line or B-line as it is used to maintain the male sterile line.
- The male sterile line is known as A-line.



Utilization in plant breeding

- The F_1 of cytoplasmic male sterile line is always male sterile, therefore, it cannot be utilized for grain crops where seed is the economic part.
- It is useful for ornamental or vegetatively propagated crops where vegetative part is of economic value.



(III) Cytoplasmic-Genetic Male Sterility

- In this type of sterility both genetic as well as cytoplasmic factor are involved.
- This is a case of cytoplasmic male sterility where the nuclear genes are available for restoring the fertility (Restorer gene) in male sterile line.
- A gene, usually dominant, which effectively overcomes the effect of male sterile cytoplasm on pollen sterility, is known as restorer gene.
- Here, fertility restorer gene 'R' is dominant and restores the male fertility in the F_1 hybrid.
- Therefore, the cytoplasmic male sterility is converted into cytoplasmic-genetic male sterility.
- This type of male sterility is available in maize, sorghum, bajra, sunflower, rice, onion and wheat.
- The plants would be male sterile in the presence of male sterile cytoplasm if the nuclear genotype is 'rr' but would be male fertile if the genotype is 'Rr' or 'RR'.
- New male sterile lines may be developed as demonstrated in Fig. 5.
- But the condition is that the nuclear genotype **of the recurrent strain must be 'rr', otherwise fertility will be restored**

Maintenance of Cytoplasmic Genetic Male Sterility

- Fertile counterpart (B line) is used to maintain cytoplasmic male sterility (A line).
- The maintainer line or B-line is just identical to line-A, except for fertile cytoplasm.

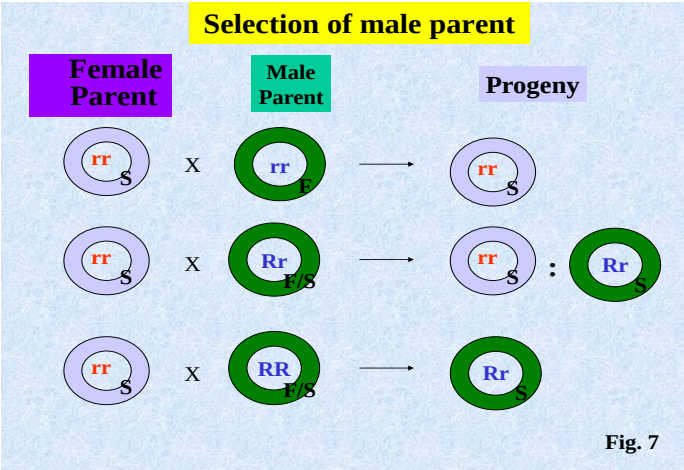


Fig. 7

Origin of male sterile cytoplasm :

1. Spontaneous mutation
   - Mutant cytoplasm have been isolated in crops like maize, bajra and sunflower
2. Interspecific hybridization
   - In wheat male sterile cytoplasm have been derived from *Triticum timopheevii or Aegilops caudata*
3. Induction through Ethidium Bromide
   - Ethidium Bromide is a potent mutagen for cytoplasmic genes
   - Generally seed treatment is applied

Limitation of Cytoplasmic Genetic Male Sterility :

1. Undesirable effects of cytoplasm
   Example – a) Texas cytoplasm of wheat (CMS-T) is highly susceptible to Helminthosporium blight, b) Tifton cytoplasm (Tift 23A) of bajra is highly susceptible of downey mildew
2. Unsatisfactory fertility restoration
3. Unsatisfactory pollination
4. Modifier genes overcome the effect of male sterility
5. Environmental effects overcome the male sterility

CHAPTER: 6

SELF INCOMPATIBILITY

It refers to condition in which pollen grains of the flowers are not in position the fertilize the same flower or the other flower of the same plant.

- Self incompatible pollen grains fail to germinate on the stigma
- If some pollen grains do germinate, pollen tubes fail to enter the stigma
- If pollen tube enter into style but they grow too slowly to effect fertilization before the flower drop
- Some time fertilization is effected but the embryo degenerates at very early stage
- Self incompatibility is a biochemical reaction but the precise nature is not clearly understood
- Lewis (1954) classified the self incompatibility as under
    1. Heteromorphic system
    2. Homomorphic system – 2 types
        a) Gametophytic control
        b) Sporophytic control

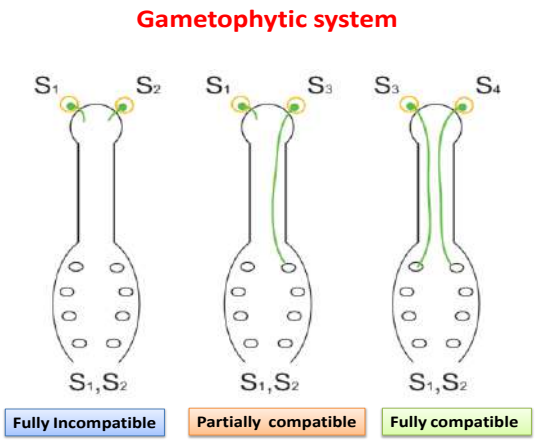
Homomorphic Incompability

- Incompatibility reaction is not associated with the morphological differences of flower
- Two types – Sporophytic and Gemetophytic
    - **Sporophytic :** Incompatibility reaction of pollen may be controlled by the genotypes of the plant on which it is produced. **Example** – Radish, diploid brassica crops
    - **Gametophytic :** Incompatibility reaction of pollen may be controlled by its own genotypes. **Example** – Pineapple, Ryegrass, diploid coffee, diploid clovers

Gametophytic System

- Gametophytic system described by East and Mangelsdorf (1925) in *Nicotiana sanderae*
- Incompatibility reaction of the pollen is determine by its own genotypes

- Incompatibility reaction of the pollen does not depend upon the genotype of the plant on which it is produced.
- It is govern by single gene having multiple alleles (Example : *Nicotiana, Lycopersicon, Solanum, Petunia*)
- Gametophytic incompatibility can be suppressed or some times eliminated by means of polyploidy induction, irridiation with x-rays and gamma rays
- In some species (Phalaris) it is govern by two loci (S & Z), while in sugarbeet and papaver three loci are involved
- In above cases polyploidy does not affect the incompatibility reaction but here pollen tube grow slowly in the style containing same S allele as in the pollen and due to slow growth it fails to effect fertilization
- In a single gene system there is three types of matings
    1. Fully incompatible – S1S2 x S1S2
    2. Fully compatible – S1S2 x S3S4
    3. Partially compatible – S1S2 x S2S3



Sporophytic System

- The sporophytic system described by Hughes and Babcock (1950) in *Crepsis foetida*
- Incompatibility reaction of the pollen is determine by the genotype of the plant on which it is produced
- Incompatibility reaction of the pollen is not depends on its own genotypes

- It is govern by single gene having multiple alleles (> 30 alleles are known in *Brassica olererecea*)
- The number of S alleles are large in gametophytic than sporophytic system
- S alleles also exhibiting dominance and codominance

1. Key characteristics –

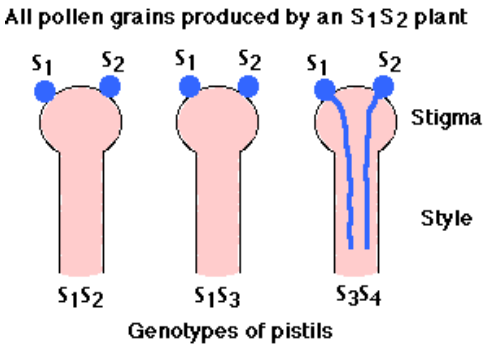
– Frequent reciprocal differences are noticed

– Incompatibility can occur with the female parent

– A family consist of three incompatibility groups

2. Polygenes (modifying genes) are known to increase as well as decrease the activities of S alleles in both systems

Sporophytic system



Mechanisms of self incompatibility

1. Pollen and stigma interaction
2. Pollen tube and style interaction
3. Pollen tube and ovule interaction

Relevance of self incompatibility

1. Hybrid seed production
   - Two self incompatible but cross compatible lines are interplanted
   - Self incompatible lines are interplanted with self compatible

Hybrid seed production problems associated with Self incompatibility system

1. Productions and maintenance of parental lines by hand pollination is tedious and costly
2. Raises the cost of hybrid seed
3. Continuous selfing/inbreeding also responsible for depression of self incompatibility
4. Extreme environmental factors overcome the effect of SI & which is responsible for high proportion of self seed (> 30 %)
5. Bees are often like to remain stay within parental lines when they are morphologically different, which also increase the proportion of self seed
6. Transfer of S – allele from one variety to another variety is tedious & complicated

Elimination of self incompatibility

1. Doubling the chromosomes numbers
2. Isolation of self fertile (S_f) mutants

How to overcome self incompatibility

1. Bud pollination
2. Surgical techniques
3. End of season pollination
4. High temperature
5. Irradiation
6. Grafting
7. Other techniques
    - Treatment of flower with carbon monoxide
    - Application of electrical potential differences
    - Phytohormone treatment
    - Treatment of some protein synthesis inhibitors
    - Steel brush pollination

CHAPTER: 7

BREEEDING METHODS OF SELF POLLINATED CROPS:

MASS SELECTION

Genetic improvement of self pollinated (autogamous) crops can be done with the help of following breeding methods:

a. Mass selection
b. Pureline selection
c. Pedigree method
d. Bulk method
e. Backcross method

} For handling segregating population

f. Other approaches
   1. Multiline varieties
   2. Population approach
   3. Diallel selective mating scheme

MASS SELECTION

- In mass selection, large numbers of plants with similar phenotypes are selected and their seeds are mixed to gather to constitute the new variety
- Selections of plants is based on easily observable characteristics (Morphological characters)

Merits of mass selection

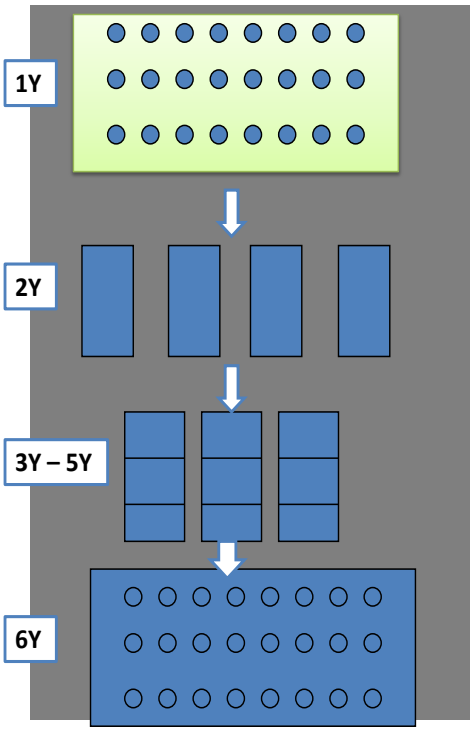
1. Variety developed thru mass selection having a wider adaptability
2. Extensive and prolonged yield trials are not required
3. Mass selection retain considerable genetic variability
4. It is less demanding method
5. Variety developed thru mass selection having a wider adaptability
6. Extensive and prolonged yield trials are not required
7. Mass selection retain considerable genetic variability
8. It is less demanding method

Demerits of mass selection

1. Varieties developed thru mass selection is not highly uniform
2. Improvement thru mass selection is generally less than pure line selection

3. Due to absence of progeny test we can't judge that selected plant is homozygous or heterozygous
4. Varieties developed thru mass selections are difficult to identify in seed certification programme
5. Varieties developed thru mass selection is not highly uniform
6. Varieties developed thru mass selection is not highly uniform
7. Improvement thru mass selection is generally less than pure line selection
8. Due to absence of progeny test we can't judge that selected plant is homozygous or heterozygous
9. Varieties developed thru mass selections are difficult to identify in seed certification programme
10. This method utilizing the variability present in the population, it does not create any new variation

General Procedure of Mass Selection



- From a heterogeneous population (200-2000) desirable plants are selected
- Selected plants are harvested in bulk
- PYT along with Std checks
- CYT with Promising selection
- If out standing, released as new variety
- Seed Multiplication for distribution

CHAPTER: 8

PURELINE SELECTION

Progeny of a single self fertilized homozygous individual of a self pollinated crop is referred to as pureline

- In this methods large numbers of plants are selected based morphological characters and are harvested separately and each progeny of them are evaluated individually
- Pureline selection also known as individual plant selection

Characteristics of Pureline

- All plants within a pureline having a similar genotypes
- The variation within a pureline is entirely due to environmental and non heritable
- Pureline become genetically variable with time

Uses of Pureline

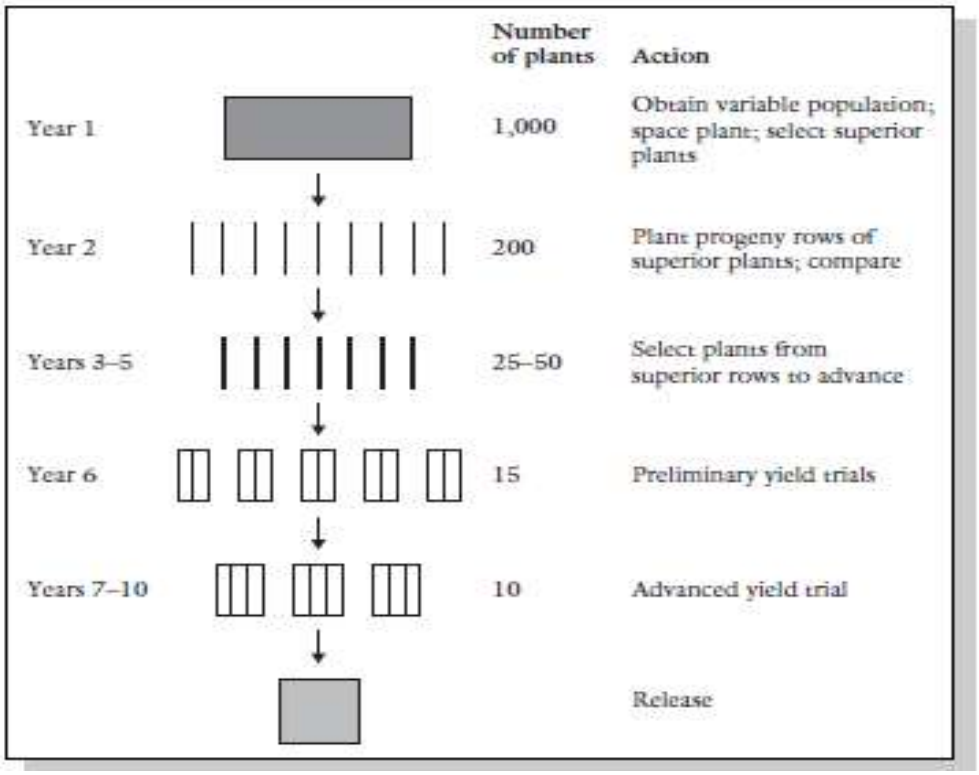
- As a variety
- As a parents in hybridization programme
- In studies of mutation
- Other scientific studies

History of pureline

- Pureline theory or Vilmorin Isolation Principles
- Vilmorin Isolation Principle is the basis for progeny test

Applications of Pureline

- Improvement of local varieties
- Improvements of old pureline varieties
- Selection for a new characteristic in a pureline
- Selection in the segregating generations from the crosses



PURELINE SELECTION METHOD

Advantages of pureline selection

1. This method provide maximum possible improvement in original variety
2. Variety developed thru pureline selection is extremely uniform, so it is more liked by farmers and consumers
3. Due to extreme uniformity, variety is easily identified in seed certification programme

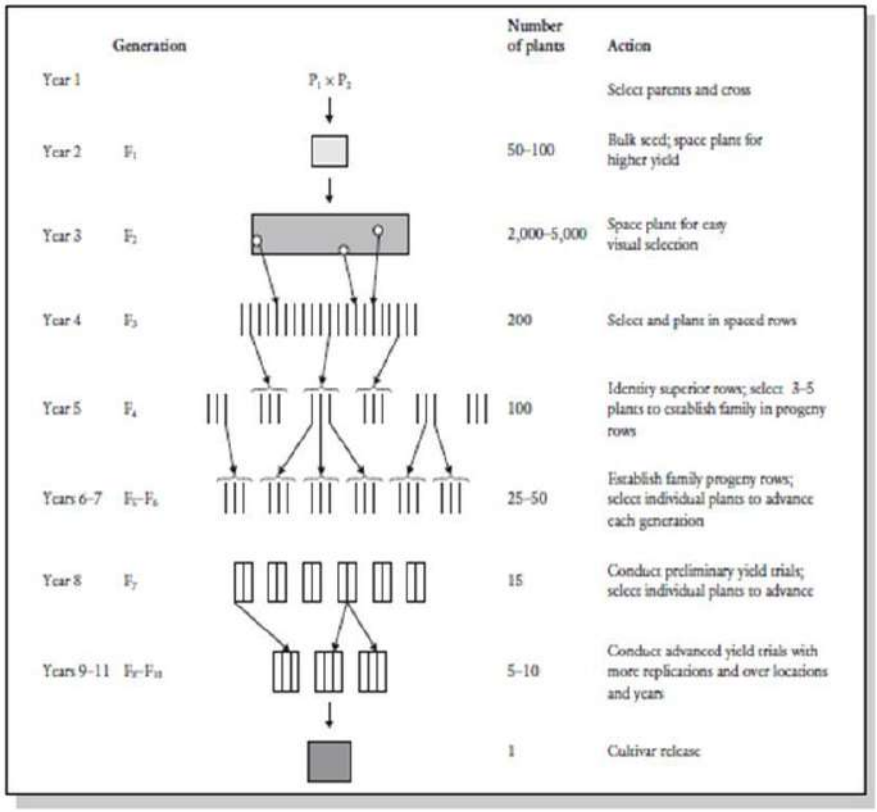
Disadvantages of pureline selection

1. Variety developed thru pureline selection do not have wider adapatation and stability
2. It require more time, labour, space and other resources than mass selection
3. The upper limit of improvement is depend upon the genetic variation present in original population
4. Breeder has to devote more time for development of new variety thru pureline method

CHAPTER: 9

PEDIGREE METHOD

- In pedigree method, individual plants are selected from F_2 and subsequent generations and their progenies are tested
- In this method, the relationship between parents and offspring are recorded and that record is known as PEDIGREE RECORD
- Pedigree record gives an idea about individual parent, grand-parent and grand-grand parent information
- Important key traits are also maintained in pedigree record
- Only promising progenies should be included in the record
- The record must be accurate



Schematic representation of pedigree method for handling segregating generations

Merits of Pedigree methods

1. Provide maximum opportunity to breeder to utilize his skill
2. Method is well suited for improvement of characters which can be easily identified and simply inherited
3. Trasgressive segregation for yield and other attributes can recovered
4. Requires less time than bulk method for development of new variety
5. Information about inheritance about qualitative characters will be available
6. Plants/progenies with visible defects are easily eliminated in early stage of breeding

Demerits of pedigree method

1. Maintenance of accurate pedigree record is tedious job
2. Selection has to be carried out between as well as within a large number of progenies in every generations
3. Success of this method depends upon the skill of the breeder
4. Selection for yield in F_2 and F_3 is ineffective

Applications of pedigree method

1. Combinations breeding
2. Trasgressive breeding

Selection approaches in pedigree method –

1. Contiguous control
   - In contiguous control check variety is planted after every two rows of F3 progenies. This ensure that each F3 progeny is located next to control variety and here the yield of F3 progenies are expressed as per cent of that of the control variety.
2. Moving average
   - In this method, F3 rogenies are planted in random order and no check variety is included in the trial. The yield of the F3 progenies is expressed as per cent of average yield of seven F3 progenies i.e F3 progeny and nearest three progenies on either side.
3. Off season crops –
   a) Wheat, Oat & Barley – Wellington (TN)
   b) Rice – Cuttak
   c) Maize – Dholi (Bihar)

CHAPTER: 10

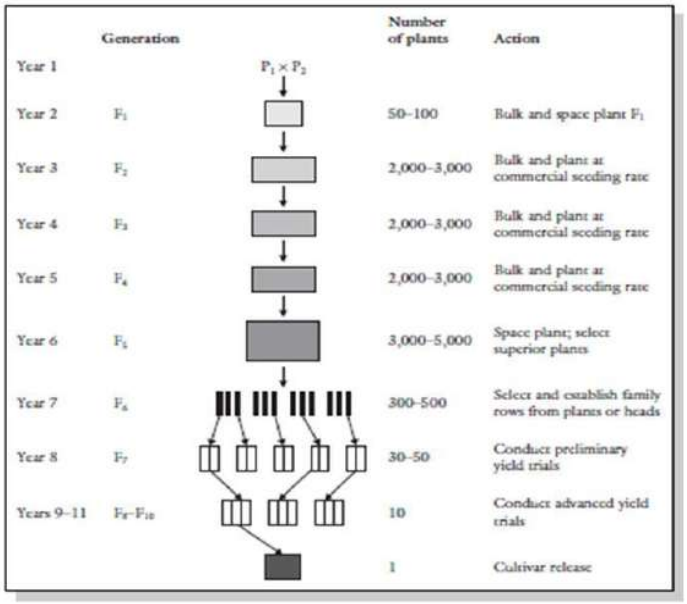
BULK METHOD

- This method first time used by Nilson-Ehle in 1908
- F_2 and subsequent generations are harvested in bulk
- Duration of bulking vary from 6 to 30 or more years depend upon the objective of the breeding program

Applications of bulk method

1. Isolation of homozygous lines
   - F_7 - > 98 % homozygosity achieved by the population
   - Different RIL_S available in F_7
2. Waiting for the opportunity for selection
   - Selection require specific type of environment
   - Aritificial selection by creating specific type of environment
3. Opportunity for the natural selection
   a. F_2 to F_6 – generation exposing to different environments

Potential genotypes survive in the population



Bulk Method

Merits of Bulk method

1. Its simple, convenient and inexpensive method
2. Artificial or natural epiphytotic eliminates the undesirable types and increase the frequency of desirable types
3. Natural selection increase the frequency of desirable types in the population
4. Breeder has to pay little attention from F_2 to F_6 (in bulking period)
5. No need to kept pedigree record, which can save the time and labour
6. Due to large population and more number of natural selection cycles frequency of getting of trasgressive segregants are much higher than pedigree method
7. Thru artificial selection increased the frequency of desirable types
8. This method is suitable to study the survival of genes and genotypes in the population

Demerits of Bulk method

1. This methods takes longer time to develop new variety
2. In short term bulk, natural selection has a little effect on the genetic composition of the population
3. This method provide little opportunity to breeder to utilize his skill
4. A large number of progenies have to selected at the end of the bulking period
5. Information on the inheritance of the character cannot be obtained
6. In some cases at least natural selection may act against the agronomically desirable types

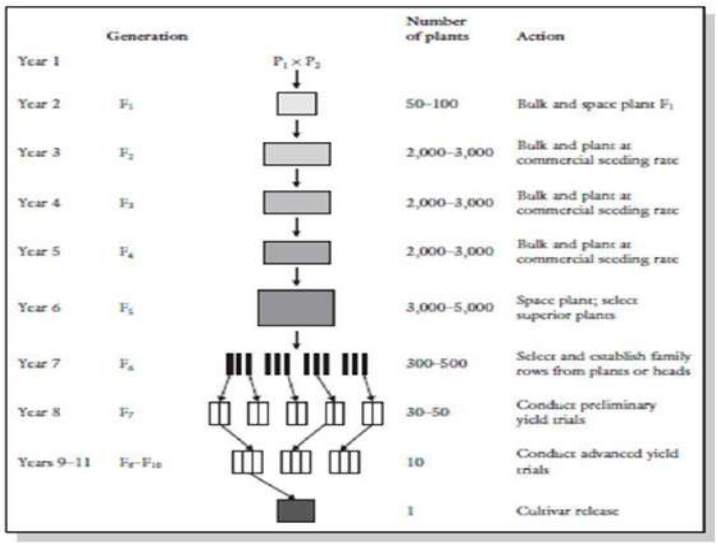
CHAPTER: 11

SINGLE SEED DESCENT METHOD

1. It is a modification of Bulk Method
2. Chief objectives of SSD method is rapidly advancing the generation of the crosses
3. F_2 to F_6 generations are grown without any sort of selection and without considering the vigour of individual plant
4. 2-3 generation may be raised using green house and off season nurseries facility

Important features of SSD

1. Lack of selection (natural or artificial till F_5 or F_6, when the population is reasonable homozygous)
2. Raising of F_3 and later generations from bulk of one seed from each F_2 and the subsequent generation plant in order to ensure that each F_2 plant is equally represented in the end population
3. Popularity of this method is due to Speed and economy



Single Seed Descent Method

Merits of single seed descent method

1. Advances the generation with the maximum possible speed in a conventional breeding method
2. Required very little space, effort and labour
3. Makes the best use of green house and off -season nursery facility
4. Ensures that the plant retain in the end population are the random sample from the F_2 population

Limitation of single seed descent method

1. This method does nor permit any forms of selection (natural or artificial) in the segregating generations
2. In each successive generation population size become progressively smaller due to poor germination and death of plants due to pest and disease problem

CHAPTER: 12

BACKCROSS METHOD

The Cross between hybrids (F_1) with either of its parents is known as **backcross**

- For transferred of simply inherited character

Test cross – The cross between F1 and its homozygous recurrent parent

- For the detection of linkage analysis

Requirements of the Backcross program

- A suitable recurrent parent which are lacking in one or two characteristics
- A suitable donar parent, which have the character in a highly intense form
- The character to be transferred must have high heritability
- Sufficient number of backcrosses should be made to transfer a specific character

Applications of backcross method

1. Intervarietal transfer of simply inherited characters
2. Intervarietal transfer of quantitative characters
3. Interspecific transfer of simply inherited characters
4. Transfer of cytoplasm
5. Trasgressive segregation
6. Production of isogenic lines
7. Germplasm conversion

Merits of Back cross method

1. The outcome of the backcross method is known beforehand
2. Extensive yield trial is not required
3. Backcross program is not dependent upon environment (Offseason nurseries and green house facilitates can be used to fasten the breeding program)
4. Much smaller population are needed
5. Easily overcome the specific defects of the variety without affecting its performance and adaptability
6. It may be modified so that easily get transgressive segregants

Demerits of Backcross method

1. The newly developed variety generally cannot be superior to the recurrent parent except for the character that is transferred
2. Sometimes undesirable closely linked gene may also transferred along with desirable gene
3. Hybridization has to be done for each backcross
4. By the time back program improve the recurrent parent, there may be chance of replacement of existing variety by other high yielding varieties

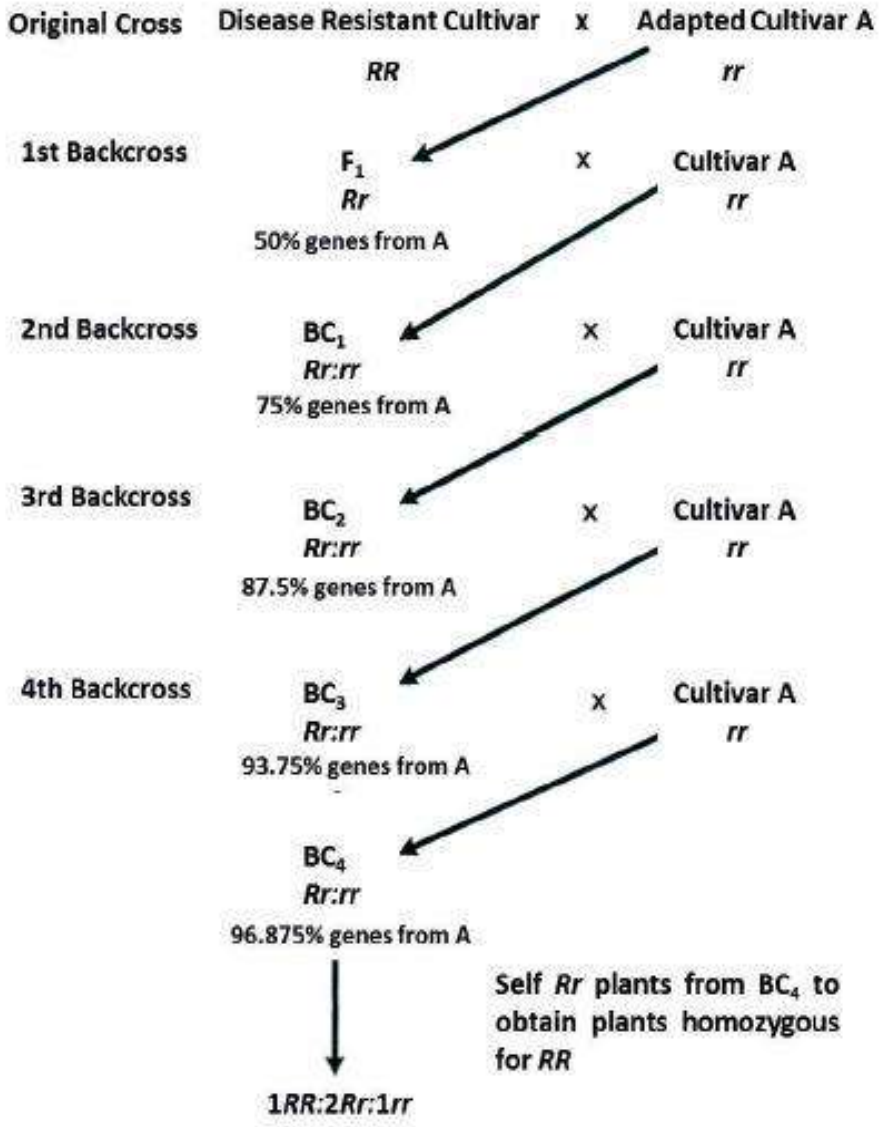
Genetic consequences of repeated backcrossing

1. Repeated backcrossing leads to homozygosity at the same rate as selfing
2. The genotype of the backcross progeny becomes similar to that of recurrent parent
3. There would be opportunity in each backcross generation for crossing over to occur between the genes being transferred and the genes tightly linked with it. When genes are tightly linked, large backcross population would have to be grown to obtain desirable recombinant type.

Achievements of backcross method

1. The backcross method has been extensively used for the transfer of disease resistance to popular- widely adapted varieties
2. This is illustrated by the popular wheat variety Kalayan Sona, which became susceptible to leaf rust
3. Rust resistance has been transferred to Kalayan Sona from several diverse sources, e.g., Robin, K1, Bluebird, Tobari, Frecor, HS19, etc. using the backcross method
4. Three multiline varieties, viz., KSML3, MLKS11 and KML7406, have been released for cultivation as a result of the above
5. Another example is provided by the hybrid bajra varieties in India. The male sterile line Tift 23A was highly susceptible to downy mildew leading to a high susceptibility of the hybrids. Tift23A was used in backcross programmes with resistant lines from India and Africa to develop downy mildew resistant male sterile lines, such as MS521, MS541A, MS570A, etc. which are now being used for producing downy mildew resistant hybrids

6. Characters other than disease resistance have been transferred by the backcross method
7. Good examples of this types are available in cotton. *G. herbaceum* varieties Vijay, Digvijay and Kalyan are some of the cotton varieties developed by the backcross method



A generalized scheme for the transfer of a dominant gene for disease resistance through the backcross in a self-pollinated species

CHAPTER: 13

MULTILINE VARIETIES

Multiline varieties are the mixture of several isogenic lines having similar agronomic characteristics but having different genes for disease resistance.

- The idea of multiline varieties was given by Jensen in 1952 for cereals
- In 1954, Borlaug suggested that several purelines with different resistance genes should be developed thru backcross programme using one recurrent parent
- Separate backcross programme is run for each donar parent using one common recurrent parent. In the end number of isogenic lines developed.
- Equal amount of seed from each isogenic lines are mixed to produce a multiline variety
- The breeder should keep several isogenic lines with different resistance genes in store for future use

Merits of multiline varieties

- Only one or two lines become susceptible at a time for the particular pathogen, so the loss to the cultivar is relatively low
- The further spread of disease is more slower
- Only small portion of the field is affected by a particular pathogen, so the yield loss is less

Demerits of multiline varieties

- The farmer has to change the seeds of multiline variety every few years depending upon the change in races of the pathogen
- There is possibility that a new race (super race) may attack all the lines of multiline variety.

Achievements –

Several rust resistance multilines in wheat developed based on this concept using different resistance genes like

- KSML-3 (mixture of 8 isogenic lines, which possesses different rust resistance genes)
- MLKS-11 (mixture of 8 isogenic lines)

CHAPTER: 14

BREEEDING METHODS OF CROSS POLLINATED CROPS: RECURRENT SELECTION

- The idea of recurrent selection was proposed by Hayes and Garber in 1919
- The basic idea of recurrent selection is to isolate superior inbreds from the population
- The recurrent selections are four different types – Simple Recurrent Selection, Recurrent selection for General Combining Ability (RSGCA), Recurrent Selection for Specific Combining Ability (RSSCA) and Reciprocal Recurrent Selection (RRS)

Simple Recurrent Selection

- Recurrent selection is effective in increasing the frequency of desirable genes of various traits in the population
- It also increase yielding ability of the population

Recurrent selection for General Combining Ability (RSGCA)

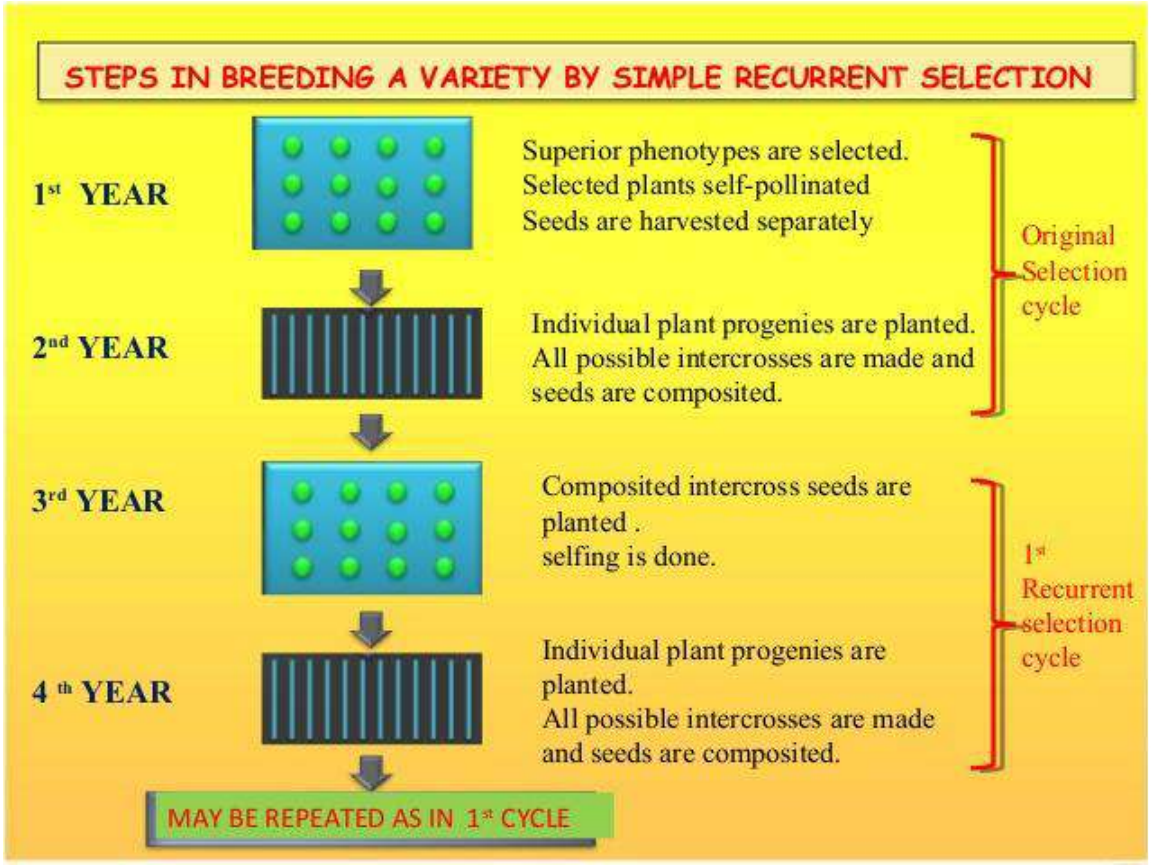
- It may be used to improve the yielding ability and the agronomic characteristics of the population
- It also increase the frequency of genes of superior GCA

Recurrent selection for Specific Combining Ability (RSGCA)

- It may be used to improve the yielding ability and the agronomic characteristics of the population
- It also increase the frequency of genes of superior SCA

Reciprocal Recurrent Selection (RRS)

- It may be used to improve the yielding ability and the agronomic characteristics of the population
- It also increase the frequency of genes of superior GCA and SCA



Schematic representation of simple recurrent selection

CHAPTER: 15

HYBRID VARIETIES

Hybrid varieties are the first generation from crosses between two pure-line, inbred, pollinated varieties, clones or other population that are genetically dissimilar

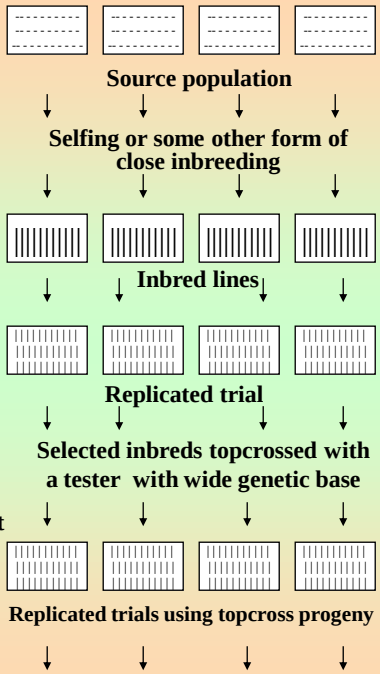
- Most of the commercial hybrid varieties are F_1 from two or more pure lines or inbred
- An **inbred** is a nearly homozygous line obtained by continuous inbreeding of a cross-pollinated species. It is maintained by close inbreeding, preferably by self-pollination
- Hybrid varieties were first commercially exploited in maize
- It is believed that hybrid varieties, on an average, gives yield increase of about 30-50%.
- The utilization of cytoplasmic-genetic male sterility is one of the significant landmarks in the development of hybrid varieties
- CGMS system used for hybrid seed productions in crops like –
    - Rice
    - Wheat
    - Bajra
    - Sorghum
    - Cotton
- GMS system used for hybrid seed productions in crops like –
    - Chilli
    - Brinjal
    - Tomato
    - Okra
    - Cotton

The operation involved in the production of hybrid varieties in such a case are :

- Development of inbred lines
- Evolution of inbreds
- Production of hybrid seed

STEP – I

Develop-ment of inbred lines



STEP – II

Evaluation of inbred line

Phenotypic evaluation

Top cross test for gca

Open pollinated plant from divers source of population are subjected to continuous inbreeding with selection after 6-7 generation of self pollination nearly homozygous inbred line is obtain.

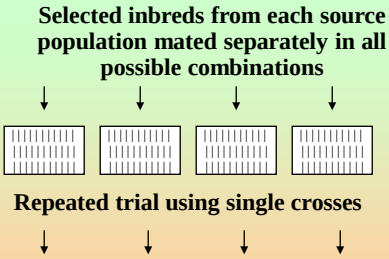
Selection amount inbreds based on phenotypic evaluation from a replicated trial. Very poor inbreds are discarded.

Inbreds tested for GCA on the basis of top cross test.

About 50% of inbred rejected on the basis of performance of top cross progeny.

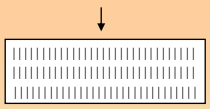
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Single cross test for sca



The remaining inbreds are subjected to single cross test of SCA. Inbreds from different source population are evaluated separately for economy .

Out standing inbreds from all the populations are mated in all possible combinations



Few outstanding inbreds form each of the population are pooled and crossed in all possible combination. Outstanding single crosses are used for estimating the performance of various double crosses.

Replicated trial using single cross progeny

STEP – III

Hybrid seed production

Outstanding inbreds used for commercial seed production.

Single and double cross

The final step consist of the production of outstanding single or double cross at a commercial scale.

Merits of hybrid variety

- Hybrid varieties exploit both GCA and SCA component of heterosis. Thus they utilize heterosis to the greatest possible extent
- The produce from hybrid, particular single cross, varieties is more uniform as compared to that from open pollinated, synthetic or composite varieties
- They can produce both in cross and self pollinated crops species
- Hybrid varieties are maintained in the form of their parental inbreds, which are grown in isolation and subjected to selfing
- In many self pollinated crops, hybrid varieties yield 25-30% more than the pureline varieties

Demerits of hybrid variety

- Farmer has to use new hybrid seed every year
- Hybrid seed production requires considerable technical skill
- The exploitation of full potential of hybrid varieties
- The large scale production of hybrid seed depends on easy emasculation of the female parent and on adequate pollen dispersal from the male parent
- In most cross-pollinated species, the requirements of isolation are rigidity and ordinarily, difficulty top fulfill expect on large farms

SYNTHETIC VARIETY

- Synthetic variety consists of all possible crosses among a number of lines that combine well with each other.
- The lines that make up a synthetic varieties may be inbred lines, clones, open pollinated varieties or other populations tested for GCA or for combining ability with other.

The operations involved in the production of synthetic varieties are illustrated as below.

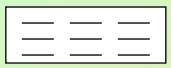
1. Evaluation of lines for GCA
2. Production of synthetic varieties
3. Multiplication of synthetic varieties

Step 1: Evaluation of lines for GCA



Inbreds, short term inbreds, synthetics, open pollinated populations

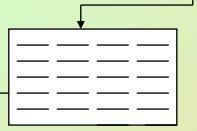
X



TESTER (open pollinated variety)

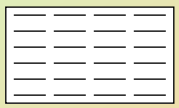
Topcross or polycross test for GCA; outstanding lines selected as parents

Step 2: Production of the synthetic



Method 1: Composited seed of all lines

Method 1: Equal seed from all the lines mixed and planted in isolation. Open pollinated seed harvested as the synthetic variety (*Syn*$_1$).

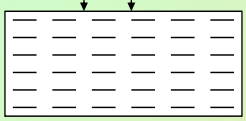


Method 2: Crossing block

Method 2: The parental lines are planted in a crossing block. All possible intercrosses are made. Equal seed from all the crosses mixed to produce the synthetic variety (*Syn*1).

Equal seed from all crosses composited

Cont……



Step 3:

Seed multiplication

Seed multiplication (open pollination in isolation)

Seed of the synthetic variety may be multiplied for one or two generations before distribution. Open pollination in isolation. (*Syn*$_2$ or *Syn*$_3$)

Merits of Synthetic variety

- The farmer can use the grain produced from synthetic variety as seed to raise the next crop.
- In variable environment, synthetic variety is likely to do better than hybrid varieties.
- The cost of synthetics varieties is relatively lower than that of hybrid varieties.
- Seed production of varieties is a more skilled operation than that of synthetic varieties.
- Synthetic varieties are good reservoir of genetic variability.
- There is good evidence that the performance of synthetic varieties can be considerably improved through population improvement without appreciably reducing variability.

Demerits of Synthetic variety

- The performance of synthetic varieties is usually lower than that of the single or double cross hybrids.
- The performance of synthetic varieties is adversely affected by lines with relatively poorer GCA.
- Synthetic varieties can be produced and maintain only in the cross pollinated crop

Synthetic variety	**Composite variety**
1) Synthetic variety produced by crossing in all possible combination a number of lines that combines well with each other	1) That is produced by open pollination among a number of outstanding stains
2) It exploit only GCA test	2) Without test of GCA and SCA
3) Improvement is better in synthetic variety in comparison to composite variety	3) Improvement is lesser in comparison to synthetic variety

CHAPTER: 16

BREEDING FOR RESISITANCE TO BIOTIC STRESSES

- **Disease**- Disease is an abnormal condition produced by an organism, e.g., fungi, bacteria, viruses, nematodes and insects
- **Pathotype**: A strain of pathogen virulent toward a specific resistance gene in the host (similar in meaning to physiological race, but not the same)
- **Host**: The plant affected by a disease
- **Pathogen**: The organism that produces the disease
- **Pathogenicity**: Ability of the pathogen to infect the host and produce disease. It is genetically controlled.
- **Resistance**: The ability of the host to prevent the pathogen from producing disease
- Different crops are attacked to different degrees by the different kinds of pathogens, but it may be emphasized that all the crop species are attacked by them
- For example
    - Cereals suffer from epidemics of air-borne fungi
    - Solanaceous crops are infected severely by viruses
    - Cotton is damaged by many insects
- In the order of their importance (based on the damage caused by them), the pathogens may be listed as : **Fungi > bacteria > viruses > nematodes = insects**

LOSSES DUE TO DISEASES

- Diseases reduce total biomass (dry matter) production by the crop in one or more of the following ways:
    - Killing of plants,
    - Killing of branches,
    - General stunting,
    - Damage to the leaf tissues
    - Damage to the reproductive organs including fruits and seeds

MECHANISM / MODES OF DISEASE RESISTANCE:

1. **DISEASE ESCAPE**:

The freedom of susceptible host plant varieties from a disease due purely to the environmental factors. Disease escape occurs primarily by avoiding contact, but unfavorable weather conditions may prevent infection. It may be achieved by

I. Early varieties: Early varieties often escape a disease since they mature before the disease epidemic occurs, *e.g.*, early groundnut varieties generally escape 'tikka' disease and early potato varieties may escape late blight.

II. Changed date of planting: A changed date of planning may successfully avoid a pathogen. For example, virus-free seed potato is produced by sowing the crop in October instead of November, the normal planting time. The October-planted crop escapes aphid infestation and, consequently, virus infection since during October-January the aphid population is very low.

III. Change in the site of planting:
In case of soil borne fungi, *e.g.*, root rots, wilts etc., and other soil-borne disease, it is highly effective to change the site of planting.

IV. Use of resistant root stocks:
Resistant root stocks to soil borne diseases have been successfully used in many fruit trees to grow otherwise susceptible, but desirable, varieties.

V. Balanced application of NPK:
A balanced application of NPK is of some usefulness as potassium is known to enhance the ability of a host to resist diseases, while N is known to increase succulence and susceptibility.

VI. Control of the disease carrier:
Some diseases, particularly viral diseases, are transmitted by insects; the control of insect vector in such cases is extremely useful in controlling the disease. The control of yellow mosaic in mung bean (V. radiata) is based on the control of white fly, the vector for the yellow mosaic virus.

2. DISEASE RESISTANCE

Host varieties are classified as susceptible or resistant according to their response to the concerned pathogen. The disease resistance reactions of the hosts to the various pathogens may be grouped into the following types:

- Susceptible,
- Immune,
- Resistant and
- Tolerant

Susceptible Reaction

- Disease development is profuse and is presumably not checked by the genotype of host. The susceptible reaction is classifiable in relative terms only, that is, in relation to the reactions of other host varieties available and the prevailing environment.
- Wheat variety Agra Local is generally taken as the susceptible standard in scoring of wheat rusts (all the three rusts).

Immune Reaction

- When the host does not show the symptoms of a disease, it is known as immune reaction.
- Immunity may result from the **prevention of pathogen to reach the appropriate parts** of the host, e.g., exclusion of the spores of ovary infecting fungi by closed flowering habit of wheat and barley.
- But more generally, it is produced by **hypersensitive reaction** of the host, usually, immediately after the infection has occurred.
- In **hypersensitive reaction**, a group of host cells around the point of infection dies. This severely restricts the establishment of pathogen and eliminates its reproduction. Thus in immune reaction, the rate of reproductions of the pathogen is zero, ($r = 0$).

Resistance

- Resistance denotes less disease development in a genotype than that in the susceptible variety and is a relative attribute.

- Infection and establishment do take place, but growth of the pathogen in the host tissue is restricted. This results in smaller spots or pustules than in the susceptible variety.
- Generally, the rate of reproduction is considerably reduced, which limits the spread of disease. In case of resistance disease symptoms do develop and the rate of reproduction is never zero, i.e., r> 0, but it is sufficiently lower than 1 (1 is the rate of reproduction on the susceptible variety) to be useful.
- The imbibitions of growth of pathogens are believed to be nutritional in nature, and in some cases chemical growth inhibitors may be involved.

Tolerance

- Tolerance implies that the host is attacked by the pathogen in the same manner as the susceptible variety, but there is little or no loss in biomass production or yield.
- Generally, tolerance is difficult to measure since it is confounded with partial resistance-and disease escape.
- To estimate tolerance, the loss in yield or some other trait of several host varieties having the same amount of disease, e.g., leaf area' covered by the disease etc., is compared.
- Virologists use the term tolerance to denote a lack of symptoms even in the presence of the virus. The lack of symptoms, however, may be strain-specific, and it does not necessarily mean a tolerance in terms of damage caused by the disease.
- Plant breeders inevitably select for tolerance whenever yield is the basis for selection.

VERTICAL AND HORIZONTAL RESISTANCE

The terms vertical and horizontal resistance were introduced by Vander Plank and are widely used:

1. **Vertical Resistance**
   - It is also known as race-specific, pathotype-specific or simply specific resistance.
   - Vertical resistance is generally determined by major genes.
   - It is characterized by pathotype-specificity.

- Pathotype-specificity: The host carrying a gene for vertical resistance is attacked by only that pathotype, which is virulent towards that resistance gene. To all other pathotypes, the host will be resistant.
- Thus an avirulent pathotype will produce an immune response, i.e., r = 0 or close to 0, but the virulent pathotype will lead to the susceptible reaction, that is, r= 1.
- Immune or susceptible response in the case of vertical resistance depends on the presence of virulent pathotype.
- When the virulent pathotype becomes frequent epidemics are common in the case of vertical resistance

2. Horizontal Resistance

- It is also known as race-nonspecific, pathotype-nonspecific, and partial or general resistance.
- Horizontal resistance is generally controlled by polygenes and is pathotype-nonspecific. That is why it is also known as 'general resistance'.
- Reproduction rate of the pathogen is never zero, but it is less than one, *i. e.*, $r > 0$ but <1.
- ***Horizontal resistance does not prevent the development of symptoms of the disease, but it slows down the rate of spread of the disease in the population***.
- Polygenes governing horizontal resistance (HR) operate on gene-for-gene basis in a way similar to the oligogenes of vertical resistance (VR), but often this is not evident due to the small effects of the individual genes and due to the small interaction (resistance x virulence) effects.
- It is very difficult to separate HR from VR.
- Further, HR may not always be more stable than VR.

Comparison between vertical and horizontal resistance

Resistance	Vertical	Horizontal
Pathotype- specificity	Specific	Nonspecific
Nature of gene action	Oligogenic	Polygenic; rarely oligogenic
Response to pathogen	Usually, hypersensitive	Resistant response
Phenotypic expression	Qualitative	Quantitative
Stage of expression	Seedling to maturity	Expression increases as plant matures
Selection and evaluation	Relatively easy	Relatively difficult
Risk of 'boom and bust'	Present (rarely durable)	Absent (durable)
Suitable for **1. Host**	1. Annuals but not perennials	Both annuals and perennials
2. Pathogen	2. Immobile pathogens,	All pathogens
Need for specific deployment of resistant varieties	Critical for success with mobile pathogens	None
Need for other control measures	Likely	Much less likely
Host-pathogen interaction	Present	Absent
Commonly used, but not strict synonyms	Major gene, race-specific, seedling, monogenic, differential specific, pathotype-specific, races specific resistance	Polygenic, race nonspecific, pathotype-nonspecific, mature plant, adult plant, field, uniform resistance
Efficiency	Highly efficient against specific race	Variable, but operates against all race

MECHANISM OF DISEASE RESISTANCE

The various mechanisms of disease resistance are as follows:

(1) Mechanical

(2) Hypersensitivity

(3) Nutritional

(1) Mechanical

- Certain mechanical and/or anatomical features of the host may prevent infection. For example, closed flowering habit of wheat and barley prevents infection by the spores of ovary infecting fungi.

(2) Hypersensitivity

- Immune reaction is due to the hypersensitive reaction of the host
- This mechanism is found in case of biotrophic organisms or obligate parasites
- Immediately after infection, several host cells surrounding the point of infection die. This leads to death of the pathogen or at least prevents its spore production

(3) Nutritional

- The reduction in growth and in spore production is generally supposed to be due to an unfavourable physiological conditions within the host
- Most likely, a resistant host does not fulfill the nutritional requirements of the pathogen and thereby limits its growth and reproduction
- However, a more precise information is not available on this aspect

(4) Antibiosis

- These kinds of resistance reaction are because of presence of some toxic substances ex. Phenolic or polyphenolic components are responsible for it.

Gene-For-Gene- hypothesis/relationship

- The gene-for-gene relationship between a host and its pathogen was postulated by Flor in 1951 on linseed rust.
- Subsequent studies have shown that the gene-for-gene relationship holds true in most of the cases studied extensively, and is now widely accepted.
- It has been found that for every resistance gene present in the host, the pathogen has a gene for virulence. Susceptible reaction would result only when the pathogen is able to match all the resistance genes present in the host with appropriate virulence genes. If one or more resistance genes are not matched by the pathogen with the appropriate virulence genes, resistance reaction is the result.
- In most of the pathogen, virulence is recessive to avirulence.

- *The gene-for-gene relationship is the consequence of specific interactions between the products of genes governing host resistance, and those, conditioning pathogenecity*

SOURCES OF DISEASE RESISTANCE

Resistance to diseases may be obtained from the

- A known variety
- Germplasm collection
- Related species
- Mutations
- Somaclonal variation
- Unrelated organisms

METHODS OF BREEDING FOR DISEASE RESISTANCE

The following breeding methods have been commonly used:

- Selection
- Introduction
- Mutation
- Hybridization
- Somaclonal variation
- Genetic engineering

TESTING OF DISEASE RESISTANCE

Three types of fungal diseases

1. Soil-borne diseases
2. Air-borne diseases
3. Seed-borne diseases
4. Insect transmitted diseases

Soil borne diseases – Here fungal pathogens are survived inside the soil. **Example** – Root rot, wilt and damping off. Screenings of such diseases are to be carried out with the help of sick plot techniques.

Air-borne diseases - Here fungal pathogens are transfer along with wind. Example – Rust, smut, mildews, blights and leaf spots etc. Screenings of such diseases are to be carried out with the help of infector row techniques. In wheat for rust screening highly susceptible agra local variety is used.

Seed borne diseases – In seed borne diseases fungal pathogens are survived inside the seed. Example – smut, bunt etc. Here disease screening carried out after providing sufficient inoculums load to the seeds. Some time spore suspension prepared in water or dry spore directly dusted on seeds and then open field or artificial screening is carried out.

Insect transmitted diseases – Most of viral diseases they are transmitted by insect vector. Example – Leaf Curl Viral diseases in chilli transmitted by white fly, Groundnut bud necrosis virus in chilli is transmitted by thrips & okra yellow vein mosaic virus transmitted by white fly. So for screening insect transmitted diseases infector row/spreader row techniques are used. Artificial screening in glass house condition is also carried out by releasing virulent vector.

BENEFITS OF BREEDING DISEASE AND INSECT RESISTANCE

- It is difficult to quantify the financial benefits which have resulted from the use of resistant varieties, but some potentially important pests and diseases have been rendered economically unimportant solely because resistant varieties have been widely grown.
- Resistant varieties reduce pest damage at all levels of infestation.
- Do not cost more to grow in tenors of time and labour than susceptible varieties.
- Generally non-toxic to man, live- stock and wildlife.
- Do not pollute the environment.
- Plant breeding for pest and disease resistance is a slow and expensive process and it has often taken 10-15 years to develop agronomically acceptable varieties, even when sources of resistance were readily available.
- The development and manufacture of new pesticides can take even longer, and cost much more, than the breeding of a new variety.
- Resistant varieties can generally be maintained at a very small extra cost, whereas new supplies of pesticides have to be manufactured each year.

DRAWBACK/LIMITATION OF BREEDING DISEASE & INSECT RESISTANCE

- Failure of resistant varieties after sometime
- Appearance of new pathogen and races (super race)
- Resistant varieties usually give only a partial control

BREEDING FOR INSECT RESISTANCE

Why insect resistance is more important

- Major proportion of crop losses is due to insect
- Wide range of insect-pests (Sucking and chewing type)
- Polyphagous in nature
- Extensive pesticide application creates problems like
  - Increases the cost of production of crops,
  - Reduces the population of natural enemies (predators and parasites) of insect pests
  - Leads to the development of pesticide-resistant races of insects
  - Pollutes the environment (the most tragic and horrifying example is the Bhopal Gas Tragedy of December, 1984)

Insect pests may be grouped into two classes **on the basis of their mode of feeding:**

1) ***Sucking pests****:* suck the cell sap, *e.g.* aphids, jassids, thrips, white fly, mites etc.
2) ***Tissue feeders***: feed on the various plant parts, *e.g.,* stem or shoot borer, root borer, fruit borer, leaf hoppers, weevils, beetles etc.
   Above both the types of insects reduce the quality as well as the quantity of crop yields.

<u>Direct damages</u>

1) Reduced plant growth or stunting,
2) Damage to leaf, stem, branch, flower buds, flower, vegetative buds, fruits and seeds
3) Premature defoliation of leaves,
4) Wilting of plants.

Indirect damage

- Many insects *e.g.*, aphids, mites, white fly etc. transmit plant viruses, *i.e.*, serve as vectors of pathogens. Further, injuries caused by insects make the plants more vulnerable to attacks by fungal and bacterial pathogens.

DEGREE OF INSECT RESISTANCE

The degree of insect resistance grouped into the following FIVE categories:

(1) Immunity (2) High resistance (3) Low resistance (4) Susceptibility

1) **Immunity:** A host-insect relationship in which the insect will not consume the plant under any conditions.
2) **High Level of Resistance:** The host plant possesses such traits that result in a small level of damage by a specific insect under a given environment.
3) **Low Level of Resistance / Partial Resistance:** The level of resistance is such that the host suffers less than average damage by an insect. The average damage is assessed on the basis of a number of varieties of the crop in question.
4) **Susceptible Response:** The level of damage or infestation is average or more than average.
5) **High Susceptible Response:** The level of damage or infestation is much more than the average for the crop.

MECHANISMS OF INSECT RESISTANCE OR TYPES OF INSECT RESISTANCE

Insect resistance is grouped into four categories:

1) Non-preference,
2) Antibiosis
3) Tolerance
4) Avoidance

Insect resistance may exhibit one, more often, two or more of these mechanisms

1. Non-preference:

- Host varieties exhibiting this type of resistance are unattractive or unsuitable for colonization, oviposition or both by an insect pest.
- This type of resistance is also termed as ***non-acceptance*** and ***antixenosis***.

- In some cases, the expression is so strong that the insects walk-off the resistant plants, *e.g.*, aphid resistance in raspberry.
- In some cases the insects do not walk-off the resistant plants, but they feed for a comparatively shorter period and are generally restless on the resistant plants as compared to on susceptible ones, *e.g.*, aphid resistance in sugarbeet.
- Non-preference involves various morphological and biochemical features of host plants.

2. Antibiosis:

- *Antibiosis refers to* ***an adverse effect of feeding on a resistant host plant on the development and or reproduction of the insect pest.***
- *In severe cases, it may even lead to the death of the insect pest.*
- Antibiosis may involve morphological, physiological or biochemical features of the host plant.

3. Tolerance:

- An insect tolerant variety *is* ***attacked by the insect pest to the same degree as a susceptible variety. But at the same level of infestation, a tolerant variety produces a larger yield than a susceptible variety.***
- In some cases, tolerant varieties show greater recovery from pest damage than do susceptible varieties, *e.g.*, in the case of shoot borer in sorghum.
- In other cases, tolerance may be due to **the ability of host to suffer less damage by the pest,** *e.g.*, aphid tolerance in sugarbeet and *Brassica* sp., and greenbugs tolerance in cereals.

4. Avoidance:

- *Pest avoidance* is the same as disease escape.
- It is often as, or even more, effective as true resistance in protecting a crop from insect pest damage.
- Most cases of insect avoidance result from the host plants being at a much less susceptible, developmental stage when the pest population is at its peak.
- For example, early maturing cotton varieties escape pink bollworm infestation, which occurs late in the season.
- The crop may be grown in a season when the pest population is very low, *e.g.*, seed-plot technique in potato to avoid aphid infestation.

NATURE OF INSECT RESISTANCE

Insect resistance may involve

1) Morphological features
2) Physiological features
3) Biochemical features of the host plant

Morphological Features:

A number of morphological factors, *e.g.,* hairiness, colour, thickness and toughness of tissues etc., are known to confer insect resistance.

- **Hairiness:** Hairiness of leaves is associated with resistance to many insect pests, e.g., in cereals to cereal leaf beetle, in cotton to jassids and in turnip to turnip aphid.
- **Colour of Plant:** Plant colour may contribute to non-preference in some cases. For example, red cabbage and red-leaved Brussels's sprouts are less favoured than green varieties by butterflies and certain other lepidoptera for oviposition. Similarly, bol1worrns prefer green cotton plants to red ones.
- **Thickness and Toughness of Plant Tissues:** Thick and tough plant tissues present mechanical obstruction to feeding and oviposition and thereby lead to non-preference as wel1 as antibiosis. For example, thick leaf lamina in cotton contributes to jassid resistance, while solid stem leads to a resistance to wheat stem sawfly.
- Similarly, thick and tough rind of cotton boll makes it difficult for the bollworm larvae to bore holes and enter the bolls.

Other Characters:

- **Narrow-lobed and leathery leaves:** *Gossypium arboreum* varieties with **narrow-lobed and leathery leaves** are more resistant to jassids than are those with broad-lobed and succulent leaves.
- **Longer pedicels:** Cotton varieties with **longer pedicels** are more resistant to bollworms than those with shorter ones. A longer pedicel makes the movement of larvae from one boll to another more difficult.
- **Leaves of nectariless:** cotton varieties are devoid of nector glands; as a result, they are visited by insects less frequently than are the normal plants.

Physiological features

Some of the physiological factors like osmotic concentration of cell sap, various exudates may be associated with insect resistance

- In some of the solanum species secrete gummy exudates in which aphids and some beetles get trapped.
- In cotton high osmotic consentration of cell sap is associated with jassid tolerance

Biochemical features

Some of biochemical features like presence of some form of chemical are imparting resistance for certain insect-pests like

- A high concentration of gossypol (phenolics component) which is responsible for sucking pest as well as bollwarm resistance
- In rice high silica content is responsible for shoot borer tolerance
- In maize high DIMBOA content is responsible for corn borer tolerance
- In tomato high ethanol component is highly toxic to tomato fruit worm

CHAPTER: 8

DISTANT HYBRIDIZATION IN PLANT BREEDING

Distant Hybridization: It is the cross between two different individuals belonging to the two different species or genus. Interspecific and intergeneric crosses are known as distant cross or wide cross

1) **Intervarietal hybridization** – It is cross between two different individuals belonging to the same species. Example: In wheat a cross between Kalyansona and Sonalika.
2) **Interspecific hybridization** – It is cross between two different individuals belonging to the two different species. Example : In okra a cross between Abelmoschus esculentus and Abelmoschus manihot
3) **Intergeneric hybridization** – It is cross between two different individuals belonging to the two different genus. Example – Tritical & Raphanobrassica
4) **Introgressive hybridization** – The process of transfer of specific gene from wild species to cultivated species is called as Introgressive hybridization

Distant hybridization also known as wide crosses because taxonomically they are more distantly related than varieties of the same species

History of distant hybridization

- **Thomas fairchild (1717)** : The first distant hybrid was the cross between carnation x sweet willian
- **Karpechenko (1928**) : prepared Raphanobrassica
- **Rimpau (1890**) : prepared Triticale by crossing Wheat & Rye

Barriers to the production of distant hybrids

1. Failure of zygote formation
   - Dry stigma surface
   - Bigger pollen size
   - Thick stigma layer
   - Pollen tube brust inside the style Example –Datura
   - Longer style – Maize x Tripsacum
   - Slow pollen tube growth in polyploid individuals (Diploid x Polyploid – slow)

2. Failure of zygote development
    - Fertilization do take place and zygote formation is taken place
    - Lethal genes
    - Genotypic disharmony between two parental genome
    - Chromosome elimination
        - *Triticum aestivum* x *Hordeum bulbosum*
    - Incompatible cytoplsm
    - Endosperm abortion

3. Failure of hybrid seedling development
    - Lethal gene
    - Genetic imbalance
    - Cytoplasmic incompatibility

Techniques for the production of the distant hybrids

- Double pollination
- Mixed pollination (mix cultivated and wild plant pollen)
- Used of short style lines as a female
- Polyploidization –
    - B. oleracea x B. compestris (diploid level fail to cross)
- Ploidy level difference (High F & Low M)
- Doubling of the chromosome number of interspecific hybrid
- Use of bridge species
    - A. ventricose x T. turgidum ---- F1 x T. aestivum
- Use of growth regulator like IAA, 2 4-D, NAA
- Embryo rescue

Applications of distant hybridization in crop improvement

1. Creation of new crop species
2. For development of alien addition line
    - **Alian addition line** carries one chromosome pair from a different species in addition to normal diploid chromosome of the parent species
    - If instead of pair only one chromosome complement is additional than it is alian addition monosome.Example : Wheat, Oat, Tobacco
    - The purpose of alien addition line is to transfer of disease resistance line
        - Tobacco mosaic resistance

- Little agriculture importance

3. For development of alien substitution line
    - **Alian substitution line** carries one chromosome pair from a different species in place of one chromosome pair of the racipient species
    - Alian addition monosome
    - Example : Wheat, Oat, Tobacco, Cotton
    - The purpose of alien addition line is to transfer of disease resistance line
        - Tobacco mosaic resistance
    - It has more undesirable side effects than alian addition line
    - Both above types lines are developed by backcross method
4. Transfer of small chromosome segment
5. Disease resistance
    - Okra YVMV : **A. manihot**
6. Wider adaptation
    - Heat and cold tolerance
7. Quality improvement
    - Cotton fibre strength improved by using *G. hirsutum*
8. Yield
9. Transfer of cytoplasm
    - *G. harkensii*
    - *T. timopheevii*
10. Utilization as new crop varieties
    - Varalaxmi is an interspecific hybrid
11. Development of new crop species
    - Triticale, Raphanobrassica

Limitation of Distant hybridization

1. Incompatible crosses
2. F_1 sterility
3. Problem in creating new crop species
4. Lack of homology between the chromosome of the parent species
5. Undesirable linkages
6. Lack of flowering in F_1
7. Dormancy

CHAPTER: 18

HETEROSIS AND INBREEDING DEPRESSION

The heterosis term was given by Shull in 1914. The heterosis is may be defind as the superiority or inferiority of an F_1 hybrid over both its parents in terms of yield and some other characteristics.

Types of heterosis – 3 types

1. Superiority of F_1 over mid parental value is known as **heterosis or average Heterosis**
   - Heterosis (%) =[(F_1 – MP)/MP] x 100
     - F_1 = F_1 mean
     - MP = mid parental value

2. Superiority of F_1 over better parental value is known as h**eterobeltiosis**
   - Heterobeltiosis (%) =[(F_1 – BP)/BP] x 100
     - F_1 = F_1 mean
     - MP = mid parental value

3. Superiority of F_1 over standard check or commercial variety is known as **economic or standard heterosis**. This type of heterosis has commercial importance
   - Standard Heterosis (%) =[(F_1 – SC)/SC] x 100
     - F_1 = F_1 mean
     - SC : mean value of standard check

Hybrid Vigour

- It is used as the synonym of the heterosis
- Hybrid vigour only indicating the superiority of hybrids over their parents, whereas heterosis describe both superiority as well as inferiority

Luxuriance

- Luxuriance is the increased vigour and size of interspecific hybrid
- The main difference between luxuriance and heterosis is in the reproductive ability of the hybrids
- Hybrids is with increased fertility, whereas the luxuriance is expressed by interspecific hybrids that may be sterile or poorly fertile
-

Genetic bases of Heterosis and Inbreeding depression

- Two hypothesis
    1. Dominance hypothesis
    2. Over dominance hypothesis

Dominance hypothesis

- Hypothesis was proposed by Davenport (1908)
- Later on it was expanded by Bruce, Keeble and Pellew (1910)
- As per this hypothesis at each locus the dominant allele has favorable effect, while recessive allele has unfavorable effects
- In heterozygous state the deleterious effect of recessive alleles are masked by their dominant alleles.
- So, the heterosis is resulting due to the masking effect of recessive allele by dominant allele, whereas inbreeding depression produced by harmful effect of recessive alleles, which become homozygous due to inbreeding

Over dominance hypothesis

- Hypothesis was proposed by East and Shull (1908)
- Also known as single gene heterosis, super domiance, cumulative action of divergent alleles or stimulation of divergent alleles
- As per this hypothesis, heterozygote's (Aa) at some the loci are superior to both the homozygotes (AA & aa)
- Heteozygosity is the essential and cause of heterosis, while homozygosity resulting from inbreeding produced inbreeding depression

INBREEDING

- Mating between individuals related by descent or ancestry is known as inbreeding or
- Mating between closely related individuals like brother sister mating or sib mating

Inbreeding depression – The severe reduction or loss in vigour and fertility due to inbreeding is known as inbreeding depression

- Concept of inbreeding depression was given by East and Shull (1909)

- Marriages between individuals related by ancestory are resctricted in early times in Hindu society
- Inbreeding depression is more common in cross pollinated crop
- The chief effect of inbreeding is increase in homozygosity in the progeny

Effects of inbreeding

- Appearance of lethal and sub lethal alleles
    - Lethal – leading to death
    - Sub lethal and sub vital – reduce survival and reproduction rate
    - Example – rootless seedling, defects in flower structure, chlorophyll deficiency
- Reduction in vigour
- Reduction in reproductive ability
- Separation of the population into distinct lines
- Increase in homozygosity
- Reduction in yield

Degree of inbreeding depression

1. High inbreeding depression
    - Alfalfa, carrot
    - Selfing produced lethal characteristics
    - > 25 % yield reduction
2. Moderate inbreeding depression
    - Maize, Jowar, Bajra
    - Proportion of lethal characteristics are relatively very low
3. Low inbreeding depression
    - Onion, cucurbits, sunflower, rye
    - Smaller proportion of lethal characteristics
4. No inbreeding depression
    - Self pollinated crops, showing homozygous balance

CHAPTER: 19

MUTATIONS IN CROP IMPROVEMENT

Mutation – It is a sudden heritable change in the characteristics of an organism is called mutation

Types of mutation

1. **Gene mutation/Point mutation** – Mutation produced by the changes in the base sequences of the gene is called gene or point mutation
    - Changes in the base sequences taken place as a result of deletion, duplication or transversion
2. **Chromosomal mutation -** Mutation produced by changes in the chromosome structure as well as number is termed as chromosomal mutation
3. **Cytoplasmic mutation** – When the mutant character shows cytoplasmic or extranuclear inheritance it is known as cytoplasmic inheritance
4. **Bud mutation/Somatic mutation -** The mutation occur in buds or somatic tissues is called bud mutation or somatic mutation. Bud mutation or somatic mutation is used for propagation purpose

History

- The term mutation was introduced by **Hugo de Vries** in 1900
- In earlier days short legged sheep was discovered by English farmer in breed named **Ancon**
- Mutagenic action of X-rays was discovered by Muller in 1927 in Drosophilla and for that he was awarded with Noble prize in 1946

1. **Spontaneous mutation** – Mutation occur in natural population (without any treatment) at a low rate is known as spontaneous mutation
    - It occurs at the rate of 1×10^{-6}
2. **Induced mutation –** If mutation induced artificially with certain physical or chemical agents such mutation is called as induced mutation.

♦ The agents which used for induction of mutation is called as **mutagen** and the used of induced mutation for crop improvement is called as **mutation breeding**

Characteristics of Mutation

- Mutations which are observed mostly recessive: It is not observed in the same generation as it is conceated by other dominant gene i.e. heterozygous condition. It take time to express and hence get chance to adjust.
- Mutations may have pleiotropic effects: Means it may be affecting more than one character.
- Most of the mutations are deleterious: Because particular genotype is adjusted to particular environment and it is disturbed their survival is disturbed. So, it is deleterious.
- Mutations are random: Means result cannot be predicted. May occur in any gene.
- Mutations are recurrent: That is the same mutation may occur again and again.
- Micro mutations are difficult to identify.
- Variability produced through mutation is same that occur in nature**.**

Effects of Mutation

- Four types of effects of mutation

❖ **Lethal** – Lethal mutation kill each and every individuls carries it.
- There effects can not be studied because they are nor surviving in the nature

❖ **Sublethal and subvital** – Sublethal and subvital mutation reduced the viability but they do not kill all the individual carrying them
- Sublethal kill more than 50 % individuals
- Subvital kill less than 50 % individuals
- Most of all mutation are lethal, sublethal and subvital types

❖ **Vital** – Vital mutation does not kill as well as reduced the viability

Classification of mutagen

1. **Physical mutagens :**

A. **Ionising radiations :**

a) Particulate radiation – α rays, β rays, fast neutrons and thermal neutrons

b) Non particulate radiation – X-rays, Y-rays

B. **Non-ionising radiations** : ultraviolet radiation (UV)

2. **Chemical mutagens :**

A. **Alkylating agents** : EMS (Ethylmethane sulphonate), MMS (Methylmethane sulphonate), EI (Ethylene imine)

B. **Acridine dyes** : Ethidium bromide, acridine yellow, acridine orange

C. **Base analogues** : 5 –bromouracil, 5-cholorouracil

D. **Others** : Nitrous acid, hydroxyl amine, sodium azide

Parts of the plants to be treated

- Seeds – mostly used
- Pollen grains – rarely used
  - Collection of lage ammount is difficult
  - Survival rate is very less
  - Hand pollination of treated pollen is also difficult
- Vegetative propagules – used mainly in case of asexully propagated crops

Dose of mutation

❖ An optimum dose which produced the maximum frequency of mutations and causes minimum amount of killing (LD_{50})

Applications of mutation breeding

1. When breeder does not having any source of variability at time for creation of new variability breeder using this tool
2. It is useful for the improving the specific characteristics of a well adapted high yielding varieties
3. Mutation breeding is useful in improving various quantitative characters
4. Intraspecific and interspecific hybrid is treated with mutagen for increasing the genetic variability

Limitations of mutation breeding

1. The frequency of desirable mutations are very low i.e 0.1 of total mutation
2. The breeder has to screen large populations to select desirable mutations
3. Desirable mutations are commonly associated with undesirable side effects due to other mutation or chromosomal abberrations
4. Most of the mutations are recessive, so they are not easily detected unless they comes into homozygous stage

Achievements of mutation breeding

Crop	**Variety**	**Mutant**
Tomato	S12	X-rays
Tomato	Pusa Lal Meevuti	30 krd gamma rays
Pea	Stral-art	15krd X-rays
Pea	Navy pea bean	X-rays

CHAPTER: 20

CLONAL SELECTION AND HYBRIDIZATION

In sexual reproduction, progeny differ from their parents in genotypes and phenotypes due to segregation and recombination. However in asexual reproduction progeny remain same in genotype and phenotype because progeny derived from vegetative cell/somatic cells. Example – Banana, potato, sweet potato, turmeric

Characteristics of asexually propagated crops

- Majority of them are perrenial
- Reduced flowering and seedset
- They are invariably cross-pollinated
- They are highly heterozygous and show severe inbreeding depression
- They are polyploid in nature (S. cane, potato, sweet potato)
- Many of them are interspecific hybrids (Banana, Sugarcane)
- The crop consist of large number of clones

Clone

A group of plants produced from a single plant through asexual reproduction is known as clone

- Characteristics of clone :
    1. All the individuals belonging to a single clone are identical in genotypes
    2. The phenotypic variation within a clone is due to environment only
    3. The phenotype of clone is due to effect of G X E
    4. Theoretically clones are immortal
    5. Clones are highly heterozygous and show the loss in vigour due to inbreeding

Genetic variation within a clone

1) **Mutation**
    - Somatic mutation/bud mutation is commonly occur in asexually propagated crops at the rate of 1×10^{-6} P. Here only dominant mutation can express its effects in next generation.

2) **Mechanical mixture**
   - It produced the genetic variation in the same manner as pureline

3) **Sexual reproduction**
   - Sexual reproduction followed by segregation and recombination

Difference between Clone, Purelie and Inbred

Particulars	Clone	Pureline	Inbred
Mode of pollination	Cross pollination	Self pollination	Cross pollination
Mode of reproduction	Asexual	Sexual	Sexual
Genetic makeup	Heterozygous	Homozygous	Heterozygous
Obtained through	Asexual reproduction	Natural self pollination	Inbreeding/sib mating
Maintained through	Asexual reproduction	Natural self pollination	Artificial self pollination
All the plants in a single entity	Identical	Identical	Almost identical
Used directly as a variety	Yes	Yes	No
Genetic makeup within an entity	Heterozygous	Homozygous	Almost homozygous
Organism where found	Plants	Plants	Plants, Animals

Clonal Degeneration

The loss in vigour and productivity of clones with time is known as clonal degeneration

- The clonal degeration is taken place due to
  1. Mutation
  2. Viral and Bacterial diseases

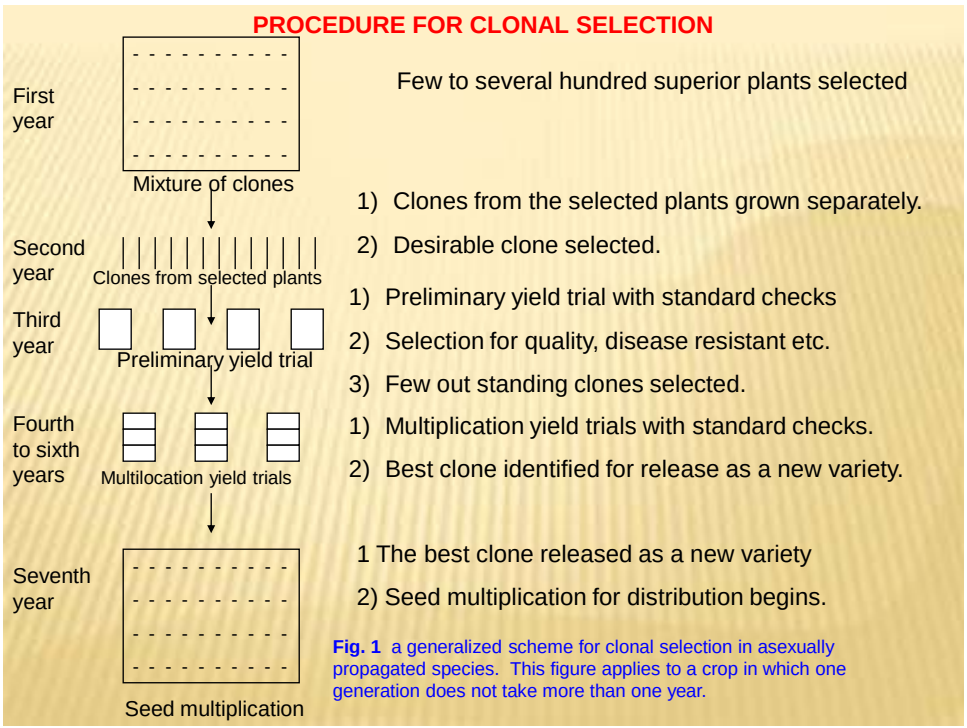


Fig. 1 a generalized scheme for clonal selection in asexually propagated species. This figure applies to a crop in which one generation does not take more than one year.

Merits of clonal selection

1. It is the only method of selection applicable to clonal crops. It avoids inbreeding depression, and preserves the gene combinations present in the clones.
2. Clonal selection, without any substantial modification, can be combined with hybridization to generate the variability necessary for selection.
3. The selection scheme is useful in maintaining the purity of clones.

Demerits of clonal selection

1. This selection method utilizes the natural variability already present in the population; it has not been devised to generate variability.
2. Sexual reproduction is a prerequisite for the creation of variability through hybridization.

Problems in the breeding asexually propagated crops

- Reduced flowering and fertility
    - Polyploid crop
    - Complex interspecific hybridity
    - Cytoplasmic male sterility
- Difficulties in genetic analysis
- Perrenial life cycle

Achievement of clonal selection

- **Clonal selection** – Varieties developed are
    - Kufri Red potato is a clonal selection from Darjeeling Red Round
    - Kufri safed potato variety is a selection from phulwa
    - Bombay green banana is a bud selection from dwarf cavendish
- **Hybridization** – Varieties developed by hybridization followed by clonal selections
    - Kufri alankar, Kufri kuber, Kufri sindhuri, Kufri kundan, Kufri jyoti
    - CO 1148, CO 1158, COS 510, CO 975, COS 109, CO 541

CHAPTER: 21

BIOMETRICAL TECHNIQUES IN PLANT BREEDING

Biometry or Biometrics: It is the science that deals with the applications of the statistical procedure for the study of biological problems

- Biometrical techniques are useful to the plant breeder in four different ways
    - **For the assessment of genetic variability**
        - Range, variance, standard deviation, coefficient of variation, standard error, D2 statistics, Meteroglyph analysis
    - **In the selection of elite genotypes**
        - Correlation and path analysis
        - Discriminant finction analysis
    - **For the choice of parents and breeding procedure**
        - Diallel and Partial diallel analysis
        - Line x Tester analysis
        - Generation mean analysis
        - Triallel, Quadriallel, Biparental cross, TTC
    - **For the determination of varietal adaptation**
        - Stability analysis

Phenotypic variability – it is an observable variation present in a population is called phenotypic variability

$$P = G \times E$$

Where, P= Phenotypic variance
G = Genotypic variance
E = Environmental variance

Genotypic variation/Genotypic variance – It is due to genotypic differences among individuals within population. It is mainly important to the plant breeder. Fisher (1918) divided genotypic variance into three components

1. **Additive variance** – The component of variance arise by taking difference between two homozygote is referred as additive variance

2. **Dominance variance** – The deviation of heterozygote from the average of the two homozygote is referred as dominance variance. It is also called as Intra-allelic interaction
3. **Epistatic variance** – The deviations arises as a consequences of interallelic interaction is called epistatic variances. It also include additive x additive, additive x dominance and dominance x dominance interaction

Heritability – It is the ratio of genotypic variance to total variance is referred as heritability

$$\text{Heritability (H)} = Vg/Vp,$$

Where, $Vp = (Vg + Ve)$

Vp= Phenotypic variance

Vg = Genotypic variance

Ve = Environmental variance

They are two types

Broad sense heritability: Its ratio of genotypic variance to total variance

- Its estimates are valid when homozygous lines are studied
- It is less useful in plant breeding

Narrow sense heritability – it is the ratio of additive variance to total variance

- When we are dealing with segregating generations, it is estimated
- It is more useful in plant breeding

Heritability estimates are useful for the plant breeder because

- Based on heritability estimate breeder can differentiate the proportion of heritable/non heritable as well as fixable variation
- He can also understand about the kinds of correspondence between genotype and phenotype, which is useful for doing the further selection

COLLEGE OF AGRICULTURE, BHARUCH

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Theory Notes on

"Principles of Seed Technology"

Course No. GPG 4.4 **Credit- 3 (2+1)**





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PBG 4.4 “Principles of Seed Technology” (2+1=3)

❖ **Theory Syllabus:-**

- Seed and seed technology: introduction, definition and importance;
- Deterioration causes of crop Varieties and their control;
- Maintenance of genetic purity during seed production,
- seed quality; Definition, characters of good quality seed and different classes of seed ; Foundation and certified seed production of important cereals, pulses, oilseed, fodder and vegetables;
- Seed certification, phases of certification, procedure for seed certification, field inspection;
- Seed Act and Seed Act enforcement,
- Duty and powers of seed inspector, offences and penalties,
- Seeds control order 1983;
- Varietal identification through grow out test and electrophoresis, molecular and biochemical test;
- Detection of genetically modified crops, transgene contamination in non-GM crops,
- GM crops and organic seed production;
- Seed drying, processing and their steps;
- Seed testing for quality assessment, its importance, method of application and seed packing;
- Seed storage- general principles, stages and factors affecting seed longevity during storage, measures for pest and disease control during storage;
- Seed marketing-structure and organization, sales generation activities, promotional media.
- Factors affecting seed marketing,
- Role of WTO and OECD in seed marketing

Reference books

- Agarwal, R.L. 1996. *Seed Technology. Oxford and IBH Publication Co., New* Delhi.
- Bhale, M. S., Khare, D. *Seed Technology* 2ND REVISED & ENLARGED EDITION (2018)
- N. C.Singhal *Seed Science and Technology* Kalyani Publishers, New Delhi. 2nd Revised Edition, 2016.

PRINCIPLES OF SEED TECHNOLOGY

INTRODUCTION:

The history of agricultural progress from the early days of man has been the history of seeds new crops and crop varieties. In the early days progress, achieved through the cultivation of indigenous useful plants and introduction of new crop species. The second stage of progress was due to selection of superior types from the cultivated plants, many useful selections were made, and there was gradual but steady progress. Later on, using well-known techniques of selection and hybridization many new and better varieties were made available. However, the pace of progress remained slow. In the mid sixties, a revolution took place in Indian agriculture, with development of dwarf varieties, better responsive to high fertilizer doses in self pollinated crops rice and wheat and exploitation of heterosis in cross pollinated crops and development of hybrids of maize sorghum, Bajra, which made significant, advances in yield.

However, to the farmer, all this scientific research would be of little value unless he gets genetically pure seeds with desirable qualities high germination percentage, high purity, more vigour and better seed health. This laid down the need of seed technology. Good agriculture depends upon good seeds. The pace of progress in food production there fore depend upon the speed with which we are able to multiply and market good quality seeds of high yielding varieties.

Seed is a crucial and basic input to increase crop yield per unit area and to improve the agricultural economy of the country.

What is seed?

- Any part of plant used for propagation is called a seed.
- It may be a true seed or any vegetatively propagating material such as seedlings, cuttings, bulbs, tubers rhizomes, root etc.
- Seed have a life.
- True seed is an embryo, a living organism embedded in the supporting and food storage tissue.
- A true seed is defined as "***a fertilized mature ovule consisting of embryo, storage material and protective coats***."
  - It can be clearly seen from the above that seed pertaining to material meant for sowing/planting purpose; the essential function being the reproduction.
  - The business of Seed Technology is to protect this biological entity and look after its 'welfare',
  - While the focus of Food Technology is on the second component – the supporting tissue.

What is a grain?

A grain is used for consumption as a food by human beings and feed by animals. If it have a life it can also be used for sowing. Grain may or may not have life.

The major differences between scientifically produced seed and the grain (when use as seed) are as under.

	Scientifically produced seed		Grain (used as seed)
(1)	It is the result of well planned seed programme.	(1)	It is the part of commercial produce, saved for sowing or planting purposes.
(2)	It is the result of sound scientific knowledge organized efforts, investment on processing, storage and marketing facilities	(2)	No such knowledge or efforts are required.
(3)	The pedigree of seed is ensured. It can be related to the initial breeders seed.	(3)	Its varietal purity is not known.
(4)	During production, efforts are made to rogue out off types diseased plants, objectionable weeds and other crops plants at appropriate stages of crop growth which ensures satisfactory seed purity and health.	(4)	No such effort is made so the purity and health status may be poor.
(5)	The seed is scientifically processed treated and packed and labeled with proper lot-identity.	(5)	It is manually cleaned. Not properly treated, labeled and packed.
(6)	The seed is tested for planting quality namely germination, purity, mixtures of weed seeds and other crop seeds, seed health and seed moisture content.	(6)	Routine seed testing is not done.
(7)	The seed quality is supervised by seed Certification agency.	(7)	There is no quality control.
(8)	The seed must meet the quality standards prescribed. The quality is well known.	(8)	No such standard is applied here hence the quality is unknown.
(9)	The labels/tags on the seed containers serves as quality marks.	(9)	There is no such label or tag which ensure quality of seed.

What is Seed Technology?

- Seed technology can be defined as techniques comprises of seed production, seed processing, seed storage, seed testing, seed certification, seed marketing, distribution and the related research of these aspects.
- Feistritzer (1975), defined seed technology as "The method through which the genetic and physical characteristics of seeds could be improved.
- According to Cowan (1973), Seed Technology is "a discipline of study having to do with seed production, maintenance, quality and preservation."

Thus, Seed Technology is essentially an interdisciplinary science, which surrounded by a broad range of subjects.

In broadest sense, "Seed Technology includes

- The development of superior crop plant varieties, their evaluation and release,
- Seed production, processing,
- Seed storage, seed testing, seed certification,
- Seed quality control, seed marketing and
- Seed distribution, and

- Research on seed physiology, seed production and seed handling based on modern botanical and agricultural sciences."

The relationship of seed technology to other sciences

1) **Genetics and Plant Breeding :** The Plant Breeders and Geneticists develop new crop varieties which are high yielding and superior in resistance to diseases and pests as compared to existing ones. They are also associated with the maintenance of nucleus and breeder seeds and grow out tests etc.
2) **Agronomy :** The agronomist provide suitable package of practices for growing, harvesting and handling of seed crops in order to obtain maximum seed yields and best possible seed quality.
3) **Horticulture :** The horticulturist provide the suitable package of practices for growing, harvesting and handling vegetable, flower and other horticultural crops to ensure maximum seed yields and best possible seed quality.
4) **Plant Pathology :** The role of plant pathologist in seed production is to produce and distribute disease free seed and hence they provide package in regard to seed treatment and plant protection measures, to be adopted in order to produce disease free seeds. They are also involved in the development of the Seed Health Testing Techniques for detection of seed borne disease and plant quarantine.
5) **Entomology :** The entomologist provide the package with regard to pest control during seed production and seed storage to ensure good seed quality and minimum losses due to storage. They are also involved in the development of seed health testing techniques for the detection and determination of insect, pests infestation and plant quarantine.
6) **Taxonomy :** The taxonomist provide information necessary for identification of various crops and weed seeds and cataloguing of Germplasm, varieties etc.
7) **Plant Physiology :** The physiologist help in understating various planting seed quality problems, seed development and maturation, and seed storage problem and their possible solutions. They are associated with the development of techniques for seed germination, seed vigour, seed viability testing.
8) **Agricultural Economics** : They provide necessary guidance in relation to seed marketing problems and helps in devising suitable marketing and distribution system. They are also concerned with the management aspects and in the determination of cost/benefit ratio, seed price fixation etc.

9) **Agricultural engineering :** The agriculture engineers are associated with the development of suitable seed planting, harvesting machinery for seed crops and also the seed drying, seed processing machinery, seed handling and seed testing equipments.

10) **Agricultural extension :** The extension agencies are involved in popularizing the use of high quality seeds of high yielding varieties amongst the farming community and also gave feedback to the researcher for the problems of farmers.

Role of seed technology/ Importance of Seed production

Feistrizer (1975) outlined the following roles of Seed Technology

1. Improved seed – a carrier of new technology
2. Improved seed – a basic tool for secured food supply
3. Improved seed – the principal means to secure crop yield in less favourable production areas.

4. Improved seed – a medium for rapid rehabilitation of agriculture in cases of natural sudden great failure.

Improved seed – a carrier of new technology:

- The introduction of quality seeds of new varieties wisely combined with other inputs significantly increases yield levels e. g.
- In India, for instance the cultivation of high yielding varieties have helped to increase food production from 52 million tones to nearly 180 million tones in last four decades. Thus the introduction of new high yielding varieties boosted the food production.
- Yields increased to the extent of 112% in Cereals, 124% in Potatoes and 142% in Sugarbeet in Central Europe through the use of improved seeds and agricultural inputs.
- In the USA, the results achieved were still better.

Improved seed – a basic tool for secured food supply:

The successful implementation of the high yielding varieties programme in India has lead to a remarkable increase in production and to a new assessment of future development potential. As a result, food import from other countries have substantially brought down in spite of the rapid population increase.

Improved seed – the principal means to secure crop yields in less favourable area of production:

The supply of good quality seeds of improved varieties suitable to these areas is one of the few important continuations that Seed Technology can make to secure higher crop yields.

Improved seed – a medium for rapid rehabilitation of agriculture in cases of natural disaster:

Widespread floods and droughts in various parts of the country and elsewhere have focused attention to these recurrent crises. The relief operations by FAO show that it would be much more economical of the Government have National Seed Research Stocks at their disposal. The establishment of National Seed Reserve Stocks should receive high priority for meeting natural calamities.

National Seed Stocks would have a two-fold role to play:

1. They would provide improved seeds in emergency periods to production area for rapid production of food grains.
2. They would supply seeds to disaster regions for re-sowing; as no seed would normally be available in such regions.

Goals of seed technology

The major goal of seed technology is to increase agriculture production through the spread of good quality seeds of high yielding varieties. The goals of The goals of seed technology could be fulfilled in the manner as under.

(1) Rapid multiplication of seeds of improved high yielding varieties. The seed should be made available to the farmers in the quickest possible time.
(2) Timely supply of improved seeds of new varieties to the farmers well in time so that they may get timely planting and harvest the benefit of quality seeds.
(3) Assured high quality seeds : In order to obtain the expected dividends from the use of seeds of improved variety the seeds must ensure high quality.

(4) Reasonable price : The cost of high quality seed should be within the reach of the average farmers i.e. price should be so reasonable that average farmer can easily buy it.

Characteristics of good seeds

The features or characteristics that determine the quality of seed are as under :

(1) High genetic purity
(2) High germination percentage
(3) Higher vigour that give effective plant stand in the field
(4) High physical purity i.e. it should be free from other crop seeds and weed seeds.
(5) Sound seed health : free from insect, pests and organism that causes disease, free from seed borne disease
(6) Wider adaptability : It can be grown and perform better under wide environmental and soil conditions.
(7) Always possess high yielding ability.
(8) Quality for special characters : should maintain its superiority for the characters/traits for which bred.
(9) Response to fertilizers and other inputs :should give higher response to high fertilizer dose and able to give higher yield.
(10) Possess uniform seed size, weight, seed colour and specific gravity.

➢ Seed certification

Seed certification is legally sanctioned system for quality control of seed multiplication and production. Its consists of following control measures

1. An administrative check on the origin of propagating material for the purpose of determining varietal purity (Genetic purity)
2. Field inspection of varietal purity, isolation to prevent cross pollination, mechanical mixtures, crop conditions as regards to disease, pest disease and weed control.
3. Supervision of agricultural and commercial operations like harvesting, threshing, storage, transport and processing to preserve the identity of seed lots.
4. Sample inspection : Drawing samples from the lot for laboratory testing like germination, moisture content, weed seed content, mixtures and purity.
5. Bulk inspection in order to check homogeneity of the lot as compared to sample drawn.
6. Control plot testing : Comparative field testing of samples drawn from the source seed or final seed production and standard sample to determine the varietal purity and seed health of the seeds produced.

Objectives

According to Douglas (1971) the three primary objective of seed certification are :

1. The systematic increase of superior varieties.
2. Identification of new varieties and their rapid increase under appropriate names.
3. Provision of continuous supply of comparable material by careful maintenance.

Basic (Fundamental) concepts of seed certification

The rapid loss of identity and genetic purity of varieties was a major problem in early years of 20th century. Hence, in 1919 the International Crop Improvement Association (ICIA) was formulated to solve the problem. In 1969 the ICIA changed its name to Association of Official Seed Certifying Agencies (AOSCA). This association laid the beginning of modern day seed certification system and explained the basic concepts of seed certification as under :

1. Pedigree of all certified crops must be based on lineage i.e. The Race.
2. The integrity (Honesty) of certified seed growers must be recognized
3. Field inspection must be made by qualified inspectors.
4. Field verification trials must be conducted to identify varieties/strains
5. Proper records must be kept to maintain pedigree of seed stocks.
6. Seed certification standards must be established for genetic purity and germination.
7. The principle of sealing of seeds must be approved to protect seed grower and the users.
8. Species of farm weeds must be identified and defined as a inert matter.

Seed certification agency :

Statutory regulations regarding establishment of seed certification agency have been discussed and broad principles have been framed as under.

1. A seed certification agency should not be involved in production and marketing of seeds.
2. The agency should have autonomy.
3. The seed certification standards for various crops and procedure to be adapted by seed certification agency should be uniform throughout the country.
4. The agency should be associated with technical institutes in order to have latest know how.
5. The agency should operate on basis of principle of no profit no loss.
6. The agency should have adequate trained staff updated by proper training.
7. The agency should have adequate facilities for timely and thorough inspection.
8. The agency should serve the interest of seed producer and seed users.

➢ Duties and responsibilities of seed certification officers :

1. He should arrange for suitable application, inspection and report forms.
2. He should identify the authentic source of seed for further multiplication.
3. He should ensure that certified seed should be produced form acceptable breeder or foundation seeds.
4. He should ensure through field inspections that minimum standards for isolation, planting ratio, roguing, etc are maintained as per the prescribed standards.
5. To assist the seed producer at the time of harvesting, threshing, drying and processing to prevent any type of mixture.
6. To issue appropriate seed certification tags for seed lots which fulfills all the criteria inspections.
7. To sample and inspect seed lots and submit such samples to the seed testing laboratory.
8. To carryout educational programme to promote the use of certified seeds.
9. To maintain adequate record so that the eligibility of specific lot can be determined.
10. To investigate violation of prescribed standards or complaints from users of certified seed and to take appropriate action.

➢ Procedure for certification of seeds :

As per the provision of seeds act, 1966 and seed rules, 1968, the certification of seeds is done in the following manner :

1. **Application for seed certification :** All those interested in certified seed production are required to submit an application in prescribed performa to the concerned state seed certification agency along with an application fee Rs. 25/-. The seed certification agency upon receipt of the application will verify the following conditions :
   - I. That the variety/varieties are notified and eligible for seed certification.
   - II. That the source of seed is authentic and in accordance with the conditions laid down in the minimum seed certification standards.
   - III. That there would be no difficulties in reaching the field for carrying out timely field inspections.
   - IV. That the seed producer is able to provide requisite isolation and the seed field meets the land requirement as per minimum seed certification standards.
   - V. That the seed processing facilities are available to the seed producer.
   - VI. That the requisite application fee has been paid. If the applicant fulfills the above conditions than certification agency would undertake the certification.

2. **Seed certification fees :** The application on the basis of above verification is accepted by the agency then the applicant has to pay certification fees as under :

   Inspection fees includes field inspection, supervision during seed processing, seed treatment, packing, seed sampling, sealing and issue of certificate.

   a) Self pollinated crop — Rs. 325/ ha.
      Hybrid, vegetable crops — Rs. 175/ha.
   b) Seed testing : — Rs. 600/sample
   c) Re processing : — Rs.250/quintal
   d) Re testing : — Rs. 600/sample
   e) Re validation fee : — Rs.20/quintal

3. **Inspection of seed fields :** Staff of seed certification agency make field inspection at appropriate stages of growth to ensure that the minimum standards for isolation, preceding (previous) crop requirement, roguing are maintained at all the times and will maintain the records of inspections.
4. **Rejecting the field :** After completion of inspection season, the staff submits the report of field inspection and problems to the Director of Seed Certification Agency. The board of Directors review the cases and if found not in accordance with the minimum certification standards then officially reject the seed field.
5. **Inspection of seed processing :** The representative of seed certification agency makes the visit of processing unit as may be required to check the mechanical admixture, seed is cleaned and graded in satisfactory manner, seed is suitably dried, seed treatment is given and seed lot is made homogenous (uniform).
6. **Seed sampling** : The staff of the agency take samples of all the seed lots which are required to carry the tags. These seed samples are then sent to seed testing laboratory for evaluation of genetic purity, germination and moisture content. If seed lots fail to meet the requisite standard then re-sampling and re-testing is done.
7. **Tagging and sealing** : After receiving the satisfactory report from official seed testing laboratory, tagging and sealing of seed lots is done under the supervision of

the agency staff. Fixing of tags and seals on the seed container will complete the certification process.

8. **Control plot testing :** The seed certification agency arrange for a post season grow out test (GOT) and concern the plant breeder to check the genetic purity.
9. Extension of validity period : The extension of validity period of certified seeds shall be for a period of six months and at each subsequent validation as long as the seed confirms the prescribed standards.
10. **Revocation of certification :** If the certification agency is satisfied that the certificate granted by the agency has been obtained by mis-representation by the seed producer, the agency will give grower a chance to submit causes and if grower does not satisfy the situation then agency will revoke (withdraw) the certificate.
11. **Appeal against certification agency :** Any seed producer aggrieved by a decision of a certification agency may appeal against the certification agency to the appellate authority specified by the state government within 30 days from receiving the rejection letter from agency. The appellate authority will discuss the matter critically and pass the necessary order. The decision of the authority is final.

➢ Seed legislation and seed law enforcement :

The basic purpose of seed legislation and its subsequent enforcement is to regulate the quality of seed sold to farmers. So long as agriculture remains traditional and static, there is little justification for regulating seed quality. However, with technological advancement and the systematic application of science to agriculture, it becomes imperative to regulate the quality of seeds through seed legislation and its subsequent enforcement to ensure that the seed buyers are not made to run undue risks.

Types of seed legislation :-

Seed legislation can broadly be divided into two groups.

1. **Sanctioning legislation :**
   Such legislation authorizes, establishes or otherwise legally sanction the activities like formation / establishment of advisory bodies, seed certification agencies, seed testing laboratories, foundation and certified seed programmes, recognition of seed certification agencies of foreign countries, appellate authority, etc..

2. **Control legislation :**
   Such legislation regulates the quality of seed sold in the market and includes the establishment of suitable agencies for regulating the seed quality.

Seed legislation in India :

In India until mid-sixties (except in Jammu and Kashmire where an Act in respect of legislation of vegetable seeds was in force), there was no legislation governing the quality of seeds sold by farmers. The rapid development of agricultural production with the introduction of hybrid varieties of maize, jowar (sorghum) and pearlmillet (pearlmillet), dwarf varieties of wheat and paddy, however, necessitated the enactment of seed legislation on 29th December, 1966, the Seeds Act was passed. It came into force throughout the country on 2nd October, 1969.

The main features of the Seeds Act, 1966 are as under :

1. Applicability : It is applicable only to notified varieties of seed and vegetatively propagating materials used for sowing.
2. Sanctioning legislation : The Act provides for the formation of an apex advisory body viz., Central Seed Committee, Central Seed Certification Board, establishment of Seed Certification Agencies and State Seed Testing Laboratories etc.
3. Regulatory legislation : The Act provides for the provisions for notification of kinds/varieties to be brought under the purview of the Seed Act regulation regarding the sale of seed and the establishment of suitable seed enforcement machinery. Under the Act, the Central Govt. is empowered to make rules to carry out the purposes of the Act and to give necessary directions to State Govt. for execution of provisions of the Act or Rules in the state.

Statutory Bodies and Agencies established in India under the Seeds Act, 1966.

1. **Central Seed Committee :** The Central Seed Committee set up under the Act is the main source of advice to the Central Govt. on the administration of the Act and any other matter related to seeds. The committee consists of a chairman, two representatives of seed growers, eight representatives of other interests nominated by the Central Govt. and one representative of State Govt., Director (Seeds), GOI acts as secretary of the committee.

The main function of the committee as envisaged in the Act and Rules are :

a) To advise Central and State Govts. on all matters related to seeds.
b) To advise Govt. regarding notification of such kinds/varieties for which it thinks it has become necessary or expedient to regulate the quality of seeds.
c) To advise Govt. of the minimum limits for germination and purity for those kinds/varieties brought under the preview of the Seeds Act.
d) To recommend the procedure and standards for certification, grow out tests and analysis of seeds.
e) To recommend the suitability of any seed certification agency established in any foreign country to the Central Govt. for the purpose of this Act.
f) To recommend the rate of fees to be charged for analysis of samples by the Central and State Seed Testing Laboratory and for certification by certification agencies.
g) To advice the Central and State Govts. regarding suitability of seed testing laboratories.
h) To send its recommendations and other proposals related to Act to the Central Govt.
i) To carry out such other functions as are supplemental, incidental or consequential of any of functions conferred by the Act or Rules.

2. Central Seed Certification Board (CCSB) :

The Govt. of India has also constituted the Central Seed Certification Board to deal with all problems related to Seed Certification and to co-ordinate the work of State Seed Certification Agencies. The membership consists of (i) Chairman, (ii) 3 members representing interests as the Govt. thinks fit, (iii) Directors of Research of Agril. Universities, (iv) Directors of Agriculture in State nominated by the Central Govt. besides a nominated secretary.

3. State Seed Certification Agencies (SSCA) :

The act provides for the establishment of state and certification agencies by notification in the official gazette of state government/central government in consultation with the state government. The governing body consists of person from state government, seed producing agency, farmers, subject specialist and seed law enforcement agencies. The governing body lays down the broad policy while the inspections, seed certification and seed analysis is the responsibility of the executive wing.

The specified functions for the seed certification agency under Seed Act are :

1) Certify seeds of any notified varieties.
2) Outline the procedure for submission of applications and for growing, harvesting, processing, storage and labeling of seeds intended for certification till the seed lots finally approved for certification meet prescribed standards for certification under the Act.
3) Maintain a list of recognized breeders of seeds.
4) Verify that the variety is eligible for certification, seed source used for planting was authentic, the record of purchase is in accordance with the rules and the fees have been paid.
5) Take sample and inspect seed lots, produced under the procedure laid down by the certification agency and such samples tested should confirm to the prescribed standards of certification.
6) Inspect seed processing plants to see that there should not be any admixture of other kinds or varieties.
7) Insure that field inspection, seed processing plant inspection, analysis of sample taken and issue of certificates including tags, marks, labels and seals is taken expediously.
8) Undertake educational programmes to promote the use of certified seed, publishing list of certified seed growers and source of certified seed.
9) Maintain records which may be necessary to verify that seed fields used for the production of certified seed were in accordance with the rules.
10) Inspect fields to ensure that the minimum standards for isolation, roguing, use of male sterility (wherever applicable) are maintained at all the times and that seed borne diseases are not present in the field to a greater extent than those prescribed in the certification standard.

4. Central Seed Testing Laboratory (CSTL) :

The seed testing laboratory located at I.A.R.I, New Delhi has been notified as central seed testing laboratory. The functions of this laboratory are as under.

I. Initiate testing programme in collaboration with state seed testing labs. to promote uniformity in test results of all seed laboratories.
II. Collect data continuously on the quality of seeds found in the market and make this data available to the committee.
III. Act as referee laboratory in testing seed samples for achieving uniformity in seed testing. The state seed testing laboratories are required to send five percent samples to the central seed testing laboratory along with their analysis results.

5. **State Seed Testing Laboratory :**

The Act envisages the establishment of state seed testing laboratory in each state by notification in the official Gazette. The function of state seed testing laboratory is to carry out the seed analysis work of the state in a prescribed manner.

6. **Appellate authority**

The Act envisages appointment of an appellate authority through an official notification in the Gazette, to look in to the grievances of certified seed producers against a seed certification agency and that of seed traders against seed law enforcement officials.

7. **Recognition of seed certification agencies of foreign countries**

The central government on the recommendations of the central seed committee recognizes or notifies the agency established in any foreign country for the purpose of the Indian Seeds Act, 1966

Seed Law Enforcement

Execution of rules and regulations of Seed Act is known as Seed Law Enforcement. The responsibility of enforcing such regulations rests with seed inspectors.

Duties of seed inspector

1. Investigate all the places used for grading, storage or sale of any seed of any notified varieties or planting material.
2. Examine the conditions of certificates, labels, tags, etc..
3. Procure and send for analysis, the samples of any seeds found doubtful as being produced, stocked, sold or exhibited for sale.
4. Investigate any complaint made to him in writing regarding violation of seed rules.
5. May detain the containers of imported seeds which are prohibited.
6. May admit prosecution in respect of breaches of the act and rules.

➢ The Seed Control Order, 1983

The Seed Control Order came into force on 30th Dece. 1983

Activities about the seed control order,1983:-

(A) Dealers in Seed to be licensed:-

(i) Dealers to obtain licence.
(ii) Application for licence
(iii) Grant and refusal of licence
(iv) Period of validity of licence
(v) Renewal of licence
(vi) Dealers to display stock and price list
(vii) Dealers to give memorandum to purchaser
(viii) Power to distribute seeds.
(ix)

(B) Seed control Order gave rules to Enforcement Authority:-

(i) Appointment of licensing authority
(ii) Appointment of inspectors
(iii) Inspection and punishment
(iv) Time limit for seed analysis
(v) Cancellation of licence
(vi) Appeal

➢ Classes of seeds :

The seed of a released and popular variety produced by scientific method is referred to as improved seed or quality seed. Variety refers to a genotype, which has been released for commercial cultivation either by state variety release committee or central variety release committee.

Improved seed results in (1) better production (2) vigorous seedling growth (3) higher crop stand (4) better quality of produce and (5) higher crop yield.

Thus production of improved seed is an important aspect of seed technology. There are four classes of improved seed viz.,

1. **Nucleus seed :** It is the initial seed of an improved variety which is always limited in quantity. It is produced by the original plant breeder of a variety. It is produced at research farm of the concerned crop under the supervision of original plant breeder. It is genetically and physically 100 % pure. There is no need of seed certification for nucleus seed. Nucleus seed is used for the production of the breeder seed.
2. **Breeder seed :** It is the progeny of nucleus seed produced under the strict supervision of original plant breeder at the research farm of the concerned crop research station. It is produced in isolation from other varieties. The isolation distance differ from species to species. It is also genetically and physically100 % pure. The genetic purity is maintained by proper roguing. Seed certification is not necessary for breeder seed. However, the seed plot is inspected by monitoring team lead by original plant breeder and representative form NSC and state seed certification agency. Breeder seed is used for the production of foundation seed.
3. **Foundation seed** :It is the progeny of breeder seed. It is produced by the NSC or State Seed Corporation under the strict supervision of research scientist. Its production is taken up at the seed multiplication farms of Govt, or research farm of ICAR institute or University farm or on progressive farmer's field. Proper isolation distance is the pre-requisite for the production of foundation seed, which varies from crop to crop. Genetically foundation seed is 100 % pure while permissible physical purity is 98 %. In case of foundation seed, certificaton is under taken by State Seed Certification Agency. Foundation seed is used for the production of certified seed.
4. **Certified seed :** It is the progeny of the foundation seed. It is produced on the field of progressive farmers under strict supervision of State Seed Certification Agency. Proper isolation is adopted for its production which varies from crop to crop. It has 100 % genetic purity and 98 % physical purity. The other crops seeds and weed seed should not be more than prescribed standards which vary from species to species. Seed certification from the State Seed Certification Agency is required for certified seed to meet the requirements of purity and germination of certified seed.

Principles of Seed Production

Production of genetically pure seed and quality seeds is an important task which requires profound technical skills. During seed production, strict attention must be given to maintain genetic purity and other qualities of seeds in order to get benefit of new improved variety. Seed production involves genetic and agronomic principles to preserve genetic purity of seeds which ultimately leads to higher seed yields.

➢ Deterioration causes of crop Varieties and their control:

Genetic principles :

Genetic purity of a variety can deteriorate due to several factors during production cycles. Kadam (1942) listed out some important factors which deteriorate the genetic purity of seeds as under :

1. Developmental variations

   When the seed crop are grown under different soil and fertility conditions or under various agro climatic conditions or under different photoperiods or at different elevations for several consecutive generations, the developmental variations may arise due to differential growth response and there will be a genetic shift to the changed agro-climatic conditions. This change in genetic shift causes deterioration of variety. To minimize such type of variations it is advisable to grow seed crops in their areas of adaptation and growing seasons.

2. Mechanical mixtures

   This is the important source of variety deterioration during seed production. Mechanical mixture may occur at the time of sowing, if more than one variety is sown with the same seed drill, through volunteer plants of the same crop or through different varieties grown side by side in the same field get mixed at the time of harvesting or threshing. Sometimes the seed produce of all the varieties are kept in the same thresher for the processing which may result in deterioration of variety. Sometimes gunny bags, seed bins used for packing the seeds may contaminate the seeds. To avoid such type of mechanical mixtures it is necessary to rogue the seed fields. Care should be taken at every stage of seed production, harvesting, threshing, processing and packing of seeds.

3. Mutations:

   Natural mutation is the continuous process in nature and it is difficult to identify or detect minor mutations, however, such mutant plant is observed in the seed field then it should be rogued out to avoid the contamination hence, constant inspection of seed plot is to be made rigorously.

4. Natural crossing:

   Most of the field crops sexually propagate, hence natural out-crossing is another important source of contamination and varietal deterioration, due to introgression of genes from unrelated stocks through natural crossing. According to Bateman (1947), the extent of genetic contamination in seed fields due to natural crossing depends on following factors.

   A. The breeding system of species (nature of pollination, self or cross)
   B. Isolation distance: It is the minimum separation required between two or more varieties of the same crop species for the purpose of keeping seed genetically pure.
   C. Varietal mass i.e. no. of varieties grown at a time in field.
   D. Pollinating agents – Insects, predator's, wind and wind direction.

E. Climatic factors – Humidity, temperature, wind velocity at the time of anthesis and pollination.

5. Residual or Minor genetic variability :

   Sometimes, minor genetic variation may exist even in the varieties appearing uniform and homogenous at the time of release. During later cycle of seed production, these variations may affect the yield and quality of the variety and deteriorate the variety. Therefore, it is essential to take precautions during maintenance of nucleus and breeder seed.

6. Disease infestation :

   Sometimes, an improved variety deteriorates because it is infested by a disease to which it was considered resistant at the time of its release. This may result either due to absence of such disease in the area where the variety was tested or due to formation of new pathogenic race of a disease.

7. Techniques of plant breeder :

   Cytological irregularities may cause instability in variety, if it is not properly assessed by the breeder at the time of its release. Premature release of variety may segregate for undesirable characters, which may deteriorate the variety. Therefore, proper care is required in testing the variety before its release.

   Other factors, such as breakdown of male sterility and heritable variations arise due to environmental conditions considerably deteriorates the genetic purity of variety.

Maintenance of genetic purity during seed production

Different workers have made suggestions to maintain the genetic purity of seeds during seed production. Notable among them are of Horne (1953) and Hartmann and Kester (1968)

Suggestions made by Horne (1953)

1. Seeds approved by competent authority and inspected by the competent agency before planting.
2. The seed field should be approved and inspected by the competent agency before planting.
3. Inspection of seed field and approval of growing crops at critical stage for verification of genetic purity, detection of mixtures, weeds and seed borne diseases should be made.
4. Proper care should be taken at the time of sampling and sealing of cleaned seed lots.
5. A comparison of potentially approved stock should be made with authentic stock by growing the samples.

Suggestions made by Hartmann and Kester (1968)

1. Adequate isolation should be provided to the seed field to prevent contamination by natural crossing or mechanical mixtures.
2. Roguing of seed field should be carried out prior to the stage at which they could contaminate the seed crop.
3. The variety should be tested periodically for its genetic purity.
4. The seed crop should be grown only in the areas of its adaptation to avoid genetic drift.
5. The seed crop should be certified by the agency to maintain genetic purity and quality of seeds.

6. The seed production should be restricted to three generation only i.e. starting from breeder seeds, it should only be multiplied up to foundation and certified class.
7. Variety grown for seed production should be tested for genetic purity by grow out test to make sure that it is being maintained in its true breeder form.

Agronomic principles of seed production :

In seed production programme in addition to genetic principles certain agronomic principles are to be followed to preserve good quality and abundant seed yields which are as under.

1. Selection of a suitable agro-climatic region : Regions or areas with moderate rainfall and humidity are more suitable for seed production. Most of the field crops require a dry sunny periods and moderate temperatures for flowering and pollination. The crops pollinated through wind require bright sunny weather with gentle wind velocity which results in to good seed setting. Thus, regions with extreme summer heat and very cold winter with excessive rainfall should be avoided for seed production.
2. Selection of seed plot : The plot selected for seed crop must have following characteristics
    I. Soil texture and fertility of plot should be according to the requirement of seed crop.
    II. The soil of the plot should be free from weeds, volunteer plants, insect, pests and soil borne diseases.
    III. The plot selected for seed production purpose should have not been used to grow the same crop in the previous season.
    IV. The plot should be well leveled and it should be feasible to isolate it from other side as per requirement of seed certification.
3. Isolation of seed crop : The seed crop must be isolated from other nearby fields of the same crop and other contaminating crops. Enough isolation distance should be provided as per seed certification standard. For nucleus and breeder seed production isolation may be provided by enclosing plants or group of plants in cage or by removing male flower parts and then artificial pollination.
4. Preparation of land : Good land preparation helps in improved germination, good stand establishment and eradication of weed plants, it also helps in water management and uniform irrigation. So land preparation is an important aspect.
5. Selection of variety : The variety selected should be adapted to the agro-climatic conditions. It should be higher yielder and possess desirable attributes like resistance to disease, insect, and pest, earliness and good grain quality.
6. Seed : The seed to be used for raising the seed crops should be obtained from an official authorized agency having known genetic purity and appropriate class. The tag and seal of seed bag purchased should be intact and the validity period of seed should not be expired.
7. Seed treatment : Appropriate seed treatment must be given to the seeds before sowing. For seed borne diseases and pests the seeds should be treated with fungicides, insecticides and pesticides. In case of legume crops the seeds must be inoculated by the bacterial culture for higher nodulation, water soaking treatment for softening the hard seed coat and mechanical scarification or acid treatment for breaking dormancy of hard seed.

8. Time of planting : The seed crop should be sown as per the recommended time of sowing. In hybrid seed production programme, staggered planting may be adjusted in order to have synchronized flowering (flowering of male and female plant at the same time). There should be sufficient moisture at the time of sowing to have good germination.

9. Seed rate : Recommended seed rate for different crops should be followed in order to carry out roguing and inspection of seed crop.

10. Method of sowing : In order to take effective plant protection measures, roguing operations and field inspection, line (row) sowing is appropriate method to be followed in seed production programme. In case of hybrid seed production, female and male parents should be planted in definite proportion of 4:2 or 6:2 rows.

11. Depth of sowing : The seed crop having small seeds should be planted at shallow depth while those having bigger seed size may be planted at deeper level.

12. Roguing : Roguing means removal of off type, diseased plants, weed plants, volunteer plants or plants differing in the characteristics form the seed crop variety. Timely and adequate roguing is important in order to maintain genetic purity of seed crop. Generally roguing is practiced at (1) vegetative or pre-flowering state, (2) flowering stage and (3) at maturity state. Roguing at flowering and maturity stages is more important because the undesirable plants which were not identified at vegetative stage may be removed from the seed crop to avoid the genetic contamination.

13. Supplementary pollination : If the seed crop is pollinated by insects then provision of honey bee and other beneficial insects may be made in nearby the seed crop field to ensure good pollination and setting.

14. Weed control : Efficient weed control is a basic requirement of seed crop in producing good quality seed and obtaining higher yield. Therefore, seed field should be free from weed plants or either it should be at minimum level. In no case, the weed plants should be allowed to flower or seed setting.

15. Plant protection measures : The quality of seeds may be poor if damaged by insects, pests or disease and there will be reduction in yield, so proper plant protection measures should be taken up at appropriate time as per recommendations.

16. Fertilizer application : For proper growth and development of seed crop application of fertilizers at proper time and as per recommended doses is important. Hence, it is necessary to have knowledge of nutritional requirement of seed crop.

17. Irrigation : Irrigation is important to ensure good and uniform germination at planting time so it is advisable to irrigate the seed crop as per its requirements. Irrigations should be stopped two to three weeks before seed maturity to allow the soil and plants to dry.

18. Harvesting of seed crops : Early or late harvesting will affect the yield and quality of seed hence, the seed crop should be harvested at the optimum time to allow maximum yield. Moisture content below 20 per cent is the optimum time to harvest the seed crop.

19. Drying of the seeds: In order to preserve seed viability and vigour, it is necessary to dry seeds to safe moisture content. Seeds of the field crops are dried to a room temperature.

20. Storage of raw seeds : The best method of storing seeds for a short period is gunny bags. After sun drying the seed should be filled in neat and clean bag. The stacks of bags should not be made directly on the floor but arrange them on wooden platform in dry, cool, clean and rat proof store house or godowns. The store house should be fumigated time to time to protect seed from stored grain pests.

Maintenance of Nucleus and Breeder seeed

The nucleus or breeder seed should be produced in such a manner that it strictly satisfy the genetic purity and identify the quality of seeds and subsequently maintain the quality of foundation and certified seed produced / multiplied from it.

Maintenance of Nucleus and Breeder in self pollinated crops

The variety of self-pollinated crops should be completely homogenous (uniform). However, in practice some amount of variation may occur during seed production cycle due to natural crossing. Therefore, purification of such variety during maintenance of nucleus/breeder seed is necessary. The methods of maintaining nucleus/breeder seed can be divided in two groups.

(1) Maintenance of newly released variety
(2) Maintenance of established variety.

Harrington (1952) outlined the procedure for maintenance of **nucleus seed** of newly released variety as under.

(A) Sampling of the variety to obtain nucleus seed :

The selected plants or lines which are highly promising in yield trials or breeding nurseries should be sampled for seed purification. Maximum fifteen such promising line at a research station should be sampled in one year. Approximately 200 plants from the central rows should be selected. To avoid shattering of the seeds, these plants should be pulled 4 to 5 days before the grains are fully mature. To prevent breakage or loss, these plants should be tied in a bundle and wrapped in a cloth or paper. Store properly these bundles till final yield results are available. Discard any of these bundle found inferior in yield and quality based on the results.

(B) Table examination of samples :

The two hundred plants of each sample should be threshed separately, clean the seeds and examine in piles on the table. Discard the pile found off type, diseased or not uniform. The seed of these selected two hundred plants is called nucleus seed, which is to be sown in a variety purification nursery.

(C) Locating and seeding of nucleus seed:

Each nucleus seed should be grown on clean fertile land at the research farm in the region or area for which it is to be released. The land to be used for sowing the nucleus seed must not had the same crop sown in the previous year. The 200 progenies of a nucleus should be sown in 50 double rows plots in four series. To facilitate examination of rows during different growth stage the plot to plot distance should be at least 45 cm. It should be isolated properly to prevent contamination by natural crossing.

(D) Inspection of two rows plot and removal of off types :

From seedling stage up to maturity, the plot should be examined critically. Differences in early plant growth, rate of growth, time of heading, plant height, head characters and disease reaction should be observed if any plot differs from the average in such traits, it should be removed. From flowering to maturity, roguing should be done based upon ear-head characters.

(E) Harvesting and threshing of nucleus :

Each plot of the nucleus should be harvested separately, tied in bundle with proper labeling. Thresh the bundle individually, clean the seeds taking care that it should not get mixed with seeds of another plot. The seeds should be treated with fungicide and insecticide, bagged and labeled properly and stored as "Breeder's stock seed".

(II) Maintenance of **Breeder seed** of newly released variety :

1. Breeder's stock seed obtained from nucleus should be sown on clean fertile land. The land to be used for sowing should not have a crop of the same kind grown in the previous year. The land requirement varies with the crop. e.g. In case of wheat about 1.2 ha. while, in case of transplanted paddy the land requirement is 3 hectare.
2. The seed should be properly isolated as per the seed certification standard.
3. The field should be produced at research farm of university and in the area or region for which the variety has been bred.
4. The sowing should be done in rows keeping sufficient spacing between rows so as to permit examination of plants for mixtures or off type.
5. Roguing should be critically done before flowering i.e. during growth period and after flowering i.e. during reproductive stage.
6. Harvesting, threshing, drying, cleaning, bagging and labeling should be carried out with most care to avoid contamination.
7. A portion of breeder seed should be retained by the plant breeder to multiply the stock with 100 % genetic purity.

Maintenance of **Breeder seed** of **established variety** :

The breeder seed of established variety can be maintained by two ways.

1. By raising the crop in isolation : The breeder seed of established variety can be maintained by growing it in isolated plots and by rigorous roguing during various stages of crop growth by observing plant characters.
2. By Bulk selection : In this method 2000 to 2500 plants representing typical plants characters of the variety are selected, harvested and threshed separately. The seeds from each selected plant are examined by table examination making piles of the individual plant and if seeds of any pile found off type or dissimilar than it is discarded The remaining piles are bulked to constitute the breeder seed.

How long a particular method should be used depends on the rate of deterioration in a variety either through natural crossing or mutation or mechanical mixture. If enough care is taken while production, we can maintain the genetic purity for several generations.

Carry over seed : A portion of breeder seed retained by the plant breeder for continuation of a variety is called carry over seed. The breeder must retain enough quantity of seeds to

safeguard against the loss of variety if there is complete failure during the foundation seed multiplication phase.

Methods of maintaining nucleus and breeder seed in cross pollinated crop :

The maintenance of variety of cross pollinated crops is complicated because it involves the maintenance of parental material and the method of breeding the variety.

Maintenance of nucleus and breeder seed of newly released variety :

Maitenance of nucleus seed of inbred lines ;

It involves self pollination, sib pollination or combination of both the procedures. Generally, sibbing (mating between the siblings) is preferred because it does not reduce the vigour excessively. However, a change in breeding behavior is observed then selfing should be used as a means of stabilizing the inbred lines. Alternate selfing and sibbing is generally practiced to maintain the parent material. The individual ear head obtained through selfing or sibbing is carefully examined and those appearing off type or inferior in any characters like texture, color, seed size, seed shape, and shape and size of ear head are discarded. The remaining ear heads are then threshed separately and are planted in ear to row method or all ear heads of an inbred are bulked for increase in the next season.

Seed multiplication is carried out in isolation. Roguing is carried out at different growth stages. Harvesting is done at physiological maturity. Generally, ear to row line (Progeny rows) is harvested, separately. Threshing or shelling is carried out in bulk or individually and then composited by examining the seeds.

Maintenance of Breeder seed of inbred :

The breeder's stock obtained from nucleus seed is planted in an isolated field. Attention is paid to land, isolation, roguing, harvesting, shelling and drying so as to maintain maximum possible genetic purity.

Maintenance of breeder seed of established variety :

The breeder seed of established variety can be maintained in two ways :

1. By raising the crop in isolation and roguing the off types thoroughly at various stages of crop growth right from sowing to maturity.
2. By mass selection: The crop is grown under isolation and roguing is carried out at different growth stages. At maturity 2000 to 2500 true to type plants are selected. The selected plants are harvested separately and after careful examination they are bulked to constitute the breeder seed.

➢ Seed marketing:

Seed marketing is one of the most vital components of seed technology. In broad sense it includes such activities as production, processing, storage, quality control and marketing of seeds. In the narrow sense, seed marketing refers to the actual acquisition and selling of packed seeds, intermediate storage, delivery of seeds and sales promotional activities. Thus seed marketing comprises of the following aspects.

1. Demand forecast (Assessment of effective demand).
2. Marketing structure.
3. Seeds storage infrastructure.
4. Sales promotional activities.
5. Post-sales service.
6. Economics of seed production and seed pricing.

1. Demand forecast : The assessment of effective seed requirements is critical to any planned seed programme. The demand forecast should be that the seed supply keeps pace with seed demand in terms of quantity, quality, price, place and time.
2. Marketing structure : The key to success in seed marketing is the establishment of effective channel of distribution. The simplest and most efficient system is to establish a central marketing cell and regional offices in end-use areas. The retail sale should be organized either by appointing distributors/ dealers such as private dealers, co-operatives, agro sales service centers etc. or by opening owned sales points of seed company or seed corporation.
3. Seed storage infrastructure : Transportation of seeds from production areas to end use areas is important and time consuming task. Availability of seeds to the dealers/consumers in time is essential. Therefore, buffer godowns, with good storage conditions are to be established in end use areas.
4. Sales promotional activities : These activities reflect on the over all distribution of seeds as well as the impact on the consumer. The seed company and the dealers should jointly share in the publicity efforts. The seed company should provide basic materials such as photographs, technical reports, posters, charts, leaflets which the dealer can adopt to specify uses. A sound and effective sales programme must be based on the judicious use of three basic tools i.e. advertising, publicity and public relations.
5. Post sale services : It includes educating the farmers, technical help as and when desired by the farmers and quick follow up on the complaints about seed sold.
6. Economics of seed production and seed pricing : The seed production cost must be kept as low as possible. The farmers or seed producer will not be interested in seed production unless the prices they receive have reasonable profit.

Factors affecting seed marketing :

Seed marketing is greatly affected by the following factors :

1. Clear-cut policy :A clear cut policy regarding duties and responsibilities of the official, semi-officials and private economic sectors is necessary for the development of seed marketing on sound basis.
2. Availability of well identified and adapted varieties : A seed programme would not have any impact unless superior varieties are regularly supplied for the seed programme. Current official information on new varieties that have been recommended for crop production helps in accelerating the programme.

3. Adequate production, storage and testing facilities : These are necessary for producing and maintaining seed qualities and quantities in accordance with the established standards for the development of sound marketing.
4. Official programme : State government has to take the initiative and promote the supply arrangement of new varieties or hybrids are when first time introduced among the small scale farmers. The important role of government is to provide market information, to set targets and to regulate and control agencies and enter prices dealing with seeds.
5. Demand forecast : Real assessment and targets of seed demand are very essential. Excess quantity of seed may result in large carry over stocks and losses in storage while short supply would deprive the seed dealers of profits they could have made.
6. Market intelligence : A market intelligence systems should be so developed to provide reliable information regarding the needs of farmers, location of production areas and size of market demands as well as marketing cost to keep official and private institution up to date on production and supply patterns.
7. Transport and storage arrangement : Adequate transport arrangement for timely supply of seeds and their proper storage in end use areas / dealers or storage buffer godowns are also important in order to maintain seed germination and viability for a long period.
8. Nature of product : Seeds are perishable commodity and easily get damaged if handling is not proper at any stage of marketing so proper handling is required.
9. Quality control programme : Legally enforced effective quality control procedure should be strictly followed to ensure uniform quality levels as per the prescribed standard which may help in reducing the unhealthy competition with bonafide seed companies.
10. Publicity : A high level publicity on value, availability and returns from certified seed of the recommended varieties is important tool for increasing seed sales.
11. Financial rewards : A well-defined policy of financial rewards to those dealers who make out standing records as salesmen is of considerable importance and goes a long way in development of seed marketing.

Seed pricing policy

The seed pricing policy is the most effective and delicate management tool for regulating the flow of seeds in the market. The price fixed for sale should be reasonable enough, so that a large number of farmers could purchase certified seeds.

Seed production costs involves following expenses.

1. In raising a seed crop :
    a) Cost of foundation seed
    b) Cost of specialized planting (in hybrids and vegetables)
    c) Roguing costs
    d) Cost of other special operations (Detasseling etc)
    e) Cost of additional supervision required in raising a seed crop.
    f) Seed certification fee
    g) Other expenses not covered above e.g. construction of separate threshing floors, extra cleaning of equipments etc.
2. At the time of seed harvesting, drying and processing :
    a) Separate harvesting of lodged or rejected portions of field and disposing the produce as commercial.
    b) Losses incurred due to drying to 10-12 % moisture content as compared to 12-14 % for a commercial crop

c) Sorting and rejection of undesirable ears of maize, ear heads of pearlmillet or sorghum, root or shoot of vegetables etc
d) Separate handling in order to maintain lot identity
e) Additional transportation costs
f) Losses in seed processing
g) Loss, that is, difference in sale price of underside, shriveled and rejected seed (roughly, 10-20 % of the seed supplied) as compared to upgraded produce.
h) Seed processing and testing charges

3. Seed marketing costs :
    a) Storage and transport expenses
    b) Interest on capital investment
    c) Distribution and sales promotion costs

Factors (components) affecting the final marketing price

1. Input costs
    a) Price paid to seed producers for raw seed or fully processed seed depending upon the marketing scheme
    b) Storage and transportation costs
    c) Distribution costs
    d) Wholesale margin (if applicable)
    e) Retail margin (Dealer's commission)
    f) Sales promotion
    g) Risks costs
    h) Profit (if applicable)
2. Supply and demand : Total supply available and total demand generated also influence the seed price. If the supply is short the sale price is relatively high, if supply is abundant the price is less and profit margin is low.
3. Prices of other farm products and time trend should also be taken in to consideration while fixing the price.

Seed processing

Seed processing is necessary in order to dry the seeds to safe moisture level, remove or reduce the various undesirable material, weed seeds, other crop seeds, deteriorated or damaged seeds, uniform size grading and seed treatment to upgrade the overall seed quality. In its common usage in India, seed processing refers to all the steps necessary for preparation of harvested seed for marketing, handling, drying, shelling, preconditioning, cleaning, size grading, treating and packaging etc. The following factors should be considered in planning and designing a seed processing plant :

1. Kinds of crop seeds to be handled, kinds of contaminating crop and weed seeds usually present in the seed lots.
2. Size of operation
3. Whether drying facilities should be required
4. Selection of suitable equipment
5. Location of plant
6. Source of power for running machinery
7. System of seed delivery to processing plant
8. Availability of labour

Analysis of operation

a) Processing sequence : After identifying the machines needed for processing, the next step is to determine proper processing sequence. The seed separators, elevators, conveyors and storage bins should be so arranged that seeds flow continuously from beginning to end.
b) Matching capacity : Equipment size of capacity must be carefully planned to prevent bottlenecks. When the overall operating capacity needs to be determined, all machines must be able to handle that capacity with some reserve capacity for problem lots. Either large models or more than one machine installed in parallel flow must be used to maintain uninterrupted flow.
c) Conveying : (Transport system) : The type of conveying system is also very important factor. The conveying system must be able to handle the capacity needed in particular spot and it must be carefully adapted to the seed handled.

Seed drying

In order to maintain seed viability and vigour drying of seed lots i.e. lowering down the seed moisture content to safe moisture limits is very important, otherwise viability and vigour deteriorates fast due to mold growth, heating and increased micro-organism activity.

Methods of seed drying

The drying of seeds is done by the following methods

(1) **Sun drying :** The moisture content of seeds have to be reduced in the field before harvest and later by sun drying on the threshing floor. The system involves harvesting of crops when they are fully dried in the field, leaving the harvested produce in field for a couple of days to sun dry and later spreading the threshed and winnowed produce in thin layers on threshing floors to sun dry. The main advantage of sun drying is that it required no additional expenditure. The disadvantages are delayed harvests, risks of weather damage and increased likelihood of mechanical mixtures.

If sun drying is to be done, the following precautions should be taken :

(a) Do not spread the produce on wet, dirty and kuchha threshing floors,
(b) Only one crop variety and produce from one plot should be handled on threshing floor, in order to maintain lot identity and to avoid mechanical admixtures.

(2) **Forced air drying :** In this system air (natural or heated) is forced into seeds. The air passing through damp seeds picks up water. The evaporation cools the air and the seed. The heat necessary for evaporating the water comes from the temperature of the air. This is the most fundamental principle of forced air seed drying.

There are three main drying methods for drying with forced air.

1. Natural air drying : Natural air is used in this type of drying method.
2. Drying with supplemental heat : Heat is provided to raise the temperature about 10 to 20°C for reducing relative humidity so that drying can take place.
3. Heated air drying : In this method the drying air is heated considerably, as much as
   110° F.

The first two methods may require 1-3 weeds or even more to reduce the seed moisture content to safe levels. They are generally used in western countries to dry

grains/seeds which will be stored on farm for some period. The third method i.e. heated air drying is universally favoured for drying the seeds. The usual practice in heated air drying is to dry the seed either in a special drying bin or in wagons. From the drying bins the seed is moved either in to processing assembly or to storage bins.

Cleaning of seeds

Principles of cleaning seeds : In the cleaning process, the separation of undesirable material viz., inert matter, weed seeds, other crop seeds, light and chaffy seeds, off-size, damaged or deteriorated seed from desirable material is done on the basis of differences in physical properties of desirable seed and undesirable matter.

The main physical differences found in seeds are seed size, length, width, thickness, density, shape, surface texture, colour, affinity for liquids and seed conductivity. If the differences between desirable and undesirable material in regard to any of these properties exist, separation of undesirable material could be done with the help of suitable machine designed for the purpose.

Seeds of different species and inert matter widely differ in regard to the physical properties. Length, width, shape, weight and surface texture differences are quite common in crop species and form the basis of seed cleaning operations.

Methods of cleaning seeds

Cleaning of seeds can be done in the following groups

1. Pre-conditioning and pre-cleaning : Pre-conditioning refers to such operations as shelling etc. that prepare seed lots for basic seed cleaning, while pre-cleaning means removal of particles, larger in size than desirable crop seed from seed lots.
2. Basic seed cleaning : Basic seed cleaning refers to actual cleaning and grading of seeds. Unlike pre-cleaning/pre-conditioning, which may or may not be required, basic seed cleaning is an essential process in the seed cleaning operations. Many kinds of seeds can be completely cleaned and made into a finished product by basic cleaning. An air screen machine, commonly referred to as an air screen cleaner is used for basic seed cleaning. It is also the basic equipment in seed processing plant.
3. Upgrading the quality of cleaned seed : The various processing operations conducted after the basic cleaning to further improve seed quality are regarded as upgrading operations. The choice of upgrading operation, however, depends upon the type of contaminants and crop. The types of upgrading operations are as under.

    1. Sizing and grading (Dimensional sizing)
        a. Width and thickness sizing and grading
        b. Length sizing and grading
    2. Gravity or weight separations
    3. Air separations
    4. Surface texture separation
    5. Electronic separation
    6. Other separations

Seed packaging, handling and storage

After processing and treating are completed, seeds are packaged into containers of specified net weight. Packaging or bagging is essentially the last operation in which seeds are handled in bulk flow. The packaging consists of the following operation.

1. Filling of seed bags to an exact weight.

2. Placing leaflets in the seed bags mentioning improved cultivation practices
3. Attaching labels, certification tags on the seed bags and sewing of the bags.
4. Storage/shipment of seed bags.

Equipments used for packaging of seeds

The bagger and weigher : These are small machines which when properly mounted beneath a bin will fill and weigh a bag accurately in a single operation. Bagger weigher and bagging scales used in seed packaging may be manual, semi-automatic or automatic.

Bag sewing machine : After an open-mouth bag is filled, the bag top must be sewed with a bag sewing machine. Bag sewing machines are precision, high speed machines and must be operated and maintained properly to prevent frequent breakdowns and short operating life.

Attaching labels : At the time of placing seed into bags, a label must be placed on each bag to maintain positive identity of the seed. When bags are closed with a bag sewing machine, a label or tag can be sewn to the bag.

Maximum lot size : Each seed lot will be assigned a seed lot no. in the following manner specified in the Indian Minimum Seed Certification Standards.

First part – Month – year code
Second part – Production location code
Third part – Processing plant code
Fourth part – Seed produce code

All the four parts of the lot number shall be written in series which a dash '(-)' between first, second, third and fourth parts to distinctly indicate the code number of each part. An example is show below :

Lot No. – May 88-06-01-01

May-88	: Seed harvested in May-1988
06	: Seed crop raised in Gujarat
01	: Seed processed in a processing plant identified as number 01 by the Gujarat state seed certification agency
01	: Seed produce code which will trace to the particular unit of Certification

➢ Seed storage :

Purpose of seed storage : The purpose of seed storage is to maintain the seed in good physical and physiological condition from the time they are harvested until the time they are planted.

Stages of seed storage :

The seeds are considered to be in storage from the moment they reach physiological maturity until they germinate or until they are thrown away because they are dead or otherwise worthless. The storage period of seeds can be divided into following six stages.

1. Storage on plants (physiological maturity to harvest)
2. Harvest, process and storing in a warehouse
3. Storages in a warehouse
4. In transit (from warehouse to retailer)
5. Retail dealers storage

6. On the user's farm

The seed quanlity i.e. germination and vigour can be considerable affected during above storage periods if the seeds are not properly handled and proper storage is not followed.

➢ Factors affecting seed longevity (long life span of seed) in storage

Seed ageing and loss of germination during storage cannot be stopped completely but it can be minimized by providing good storage conditions. Important factors which affect the longevity of seeds are as under.

1. Kind / variety of the seed : The genetic makeup of the lines / varieties influence the storage period.
2. Initial seed quality : Seed damage during transit period at various stages due to mechanical injury may reduce the longevity.
3. Moisture content : Moisture content of seeds to be stored determines the seed viability and germination. If the moisture content is high, the quality will deteriorate rapidly. 8-10 % moisture content is very safe to maintain good germination and vigour for longer period.
4. Relative humidity and temperature during storage : Increase in relative humidity and temperature adversely affect the storage life of seeds. The relative humidity should not exceed 50 % and temperature should be around room temperature. A 10°F decrease in temperature nearly doubles the storage period. Similarly 1 % decrease in moisture content doubles the storage life. So good seed storage is achieved when the percentage of relative humidity in storage environment and the storage temperature in degree Farenhit add up to one hundred.

General principles of seed storage

a) Seed storage conditions should be dry and cool.
b) Storage must have effective pest control
c) The seed stores must have proper sanitation
d) The seeds should be dried to a safe moisture limit required for storage system.
e) The seeds should be well cleaned, treated with proper insecticides, pesticides, fungicide and should have high germination percent and vigourous.

➢ Seed Treatments

Seed treatment is the application of protective fungicides, insecticides or a combination of both to seeds prior to planting so as to disinfect and disinfest them from seed borne or soil borne pathogens and even storage insects. It also refers to the subjecting of seeds to solar energy exposure, immersion in conditioned water etc.

After green revolution, the treatment of seeds with protective chemicals prior to planting has become a standard and widely accepted practices.

The ideal seed treatment chemical should be

a) Highly effective against pathogenic organisms.
b) Relatively non-toxic to plants
c) Harmless to humans and livestock, even if misused
d) Stable for relatively longer periods of time during seed storage.
e) Easy to use
f) Economically competitive

Benefits of seed treatments

1. Prevention of spread of plant diseases
2. Protects the seed against soil borne and seed borne organisms.
3. It improves germination
4. Provides protections against storage insects
5. It controls soil insects and pests.

➢ Types of seed treatments :

1. **Seed disinfections :** Seed disinfections refers to the eradication of fungal spores that have established within the seed coat or in deep-seated tissues. For effective control, the fungicidal treatment must actually penetrate the seed in order to kill the fungus present inside the seeds.
2. **Seed disinfestations :** refers to the destruction of surface borne organisms that have contaminated the seed surface but not infected the seed surface.
3. **Seed protection** : To protect the seed and young seedlings from organisms in the soil which might otherwise cause decay of the seed before germination.

Equipments for seed treatment :

The equipments used to apply chemicals in any form (slurry, a liquid form or a dust) to seed are referred to seed treaters and can be divided into two broad categories.

1. Slurry treaters : The slurry treatment principle involves suspension of wettable powder material in water. The treatment material applied as slurry is accurately prepared through a simple mechanism composed of a slurry cup into a mixing chamber where they are blended.

   The slurry treaters are adaptable to all type of seeds and rate of treating. The small amount of moisture that is added to the seeds does not affect seed in storage, since the moisture is added to the seed surface and is soon lost.

2. Direct treaters : Direct treaters are the most recent development and include the "Panogen" and "Mist-o-matic" treaters. Of these two, the Mist-o-matic" treater is being used more widely. It applies treatment as a mist directly to the seed.

   Coloring of seed : Most of the treatments contain dyes and some companies add their own "color brand" dye to seed treatments.

   Dyes served two purposes :
   1. As a warning that the seeds have been treated to prevent contamination as food or feed and
   2. As a visible means of evaluating the completeness of treatment coverage.

   The dyes, if used for treating formulation of dry seed are mixed with fungicide / insecticide treatment.

Acronyms

1. AOSA : Association of Official Seed Analysis
2. AOSCA : Association of Official Seed Certifying Agencies.
3. CSCB : Central Seed Certification Board
4. IBPGR : International Board for Plant Genetic Resources
5. ISST : Indian Society of Seed Technology
6. NBPGR : National Bureau of Plant Genetic Resources
7. NSDC : National Seed Development Council
8. NSSL : National Seed Storage Laboratory
9. NSC : National Seed Corporation
10. SSCA : State Seed Certification Agency
11. UPOV : Union for the Protection of New Varieties of Plants
12. ISTA : International Seed Testing Association
13. IMSCS : Indian Minimum Seed Certification Standard
14. GSSCA : Gujarat State Seed Certification Agency
15. GSSC : Gujarat State Seed Corporation

➢ Detection methods for GMOs/LMOs

➢ Definition

Any living organism that possesses a novel combination of genetic material obtained through the use of modern biotechnology

❖ Transgenic plants

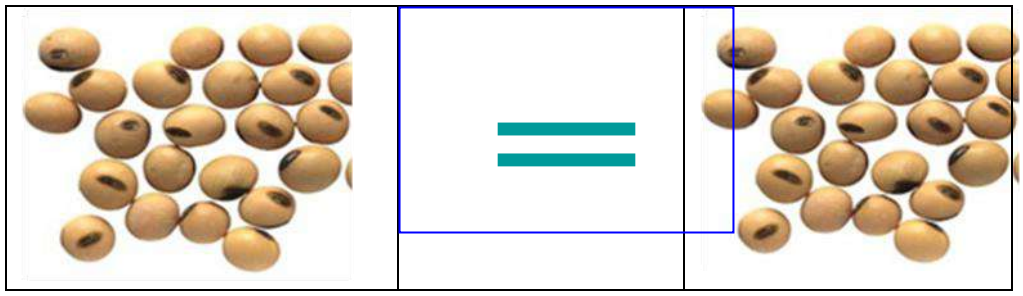
•Characterized by the insertion of a new gene or sets of genes into their genome
•The new genes translate and new protein expressed
•This gives the plant new characteristic

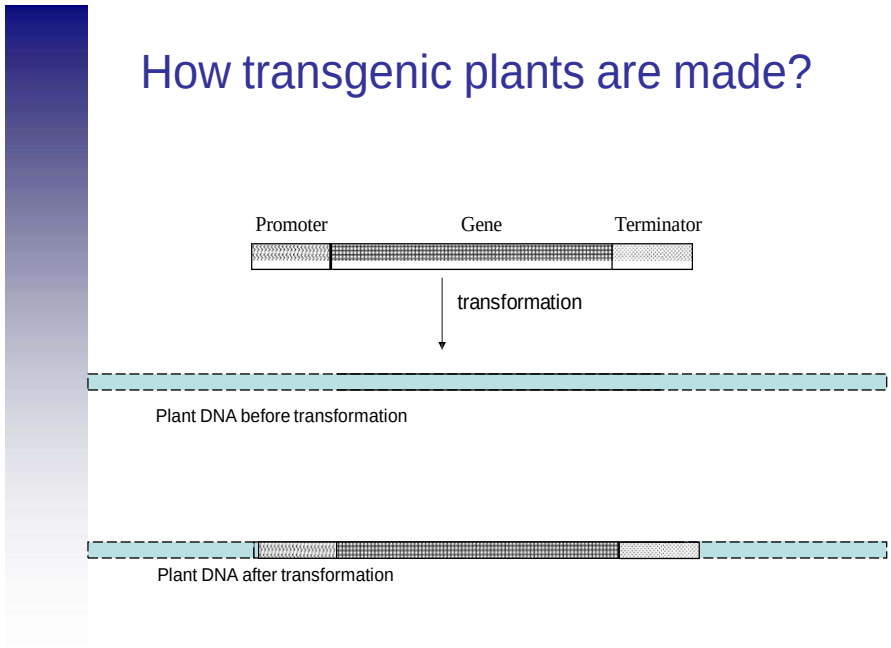
➢ Transgenic plants – Examples

- Bt cotton
  Cotton plants resistant to lepidopteran insects
- Round-up ready soybean
  Soybean resistant to glyphosate
- Golden rice
  Rice grains with beta-carotene & Vitamin -A

		
➢ **Bt cotton**	**Round-up ready soybean**	➢ **Golden rice**

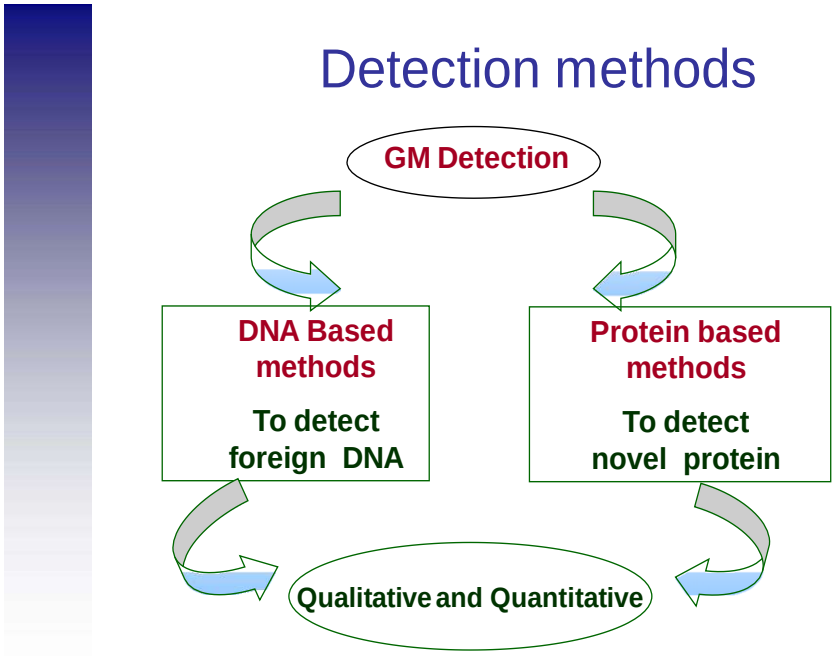
➢ Detection Methods



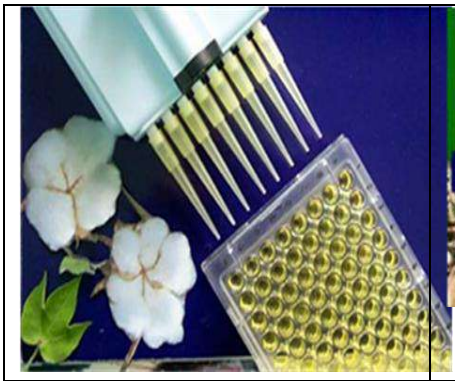


➢ General Procedure:

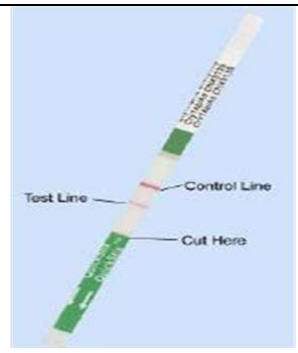
- **Detection:** to determine whether a product is GM or not. For this purpose, a general screening method can be used. The result is a positive/negative statement.
- **Identification:** to find out which GM crop or product are present and whether they are authorized or not in the country.
- **Quantification:** If a crop or its product has been shown to contain GM varieties, then it become necessary to assess compliance with the threshold Regulation by the determination of the amount of each of the GM variety present.

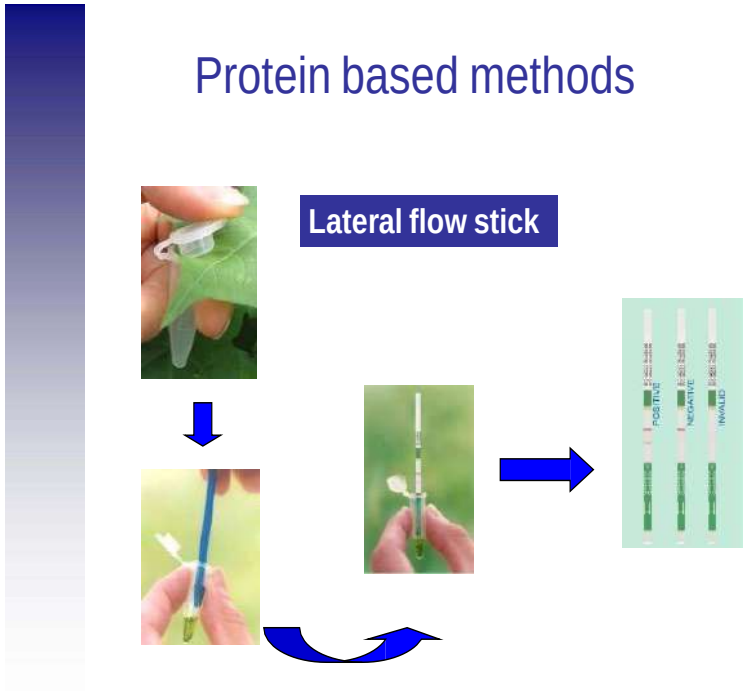


- **DNA based methods:**
  - Highly sensitive - can detect trace amounts GM- DNA
  - Work with most product types - both processed and unprocessed products
  - Can test for multiple GM varieties simultaneously
  - Takes a number of days to perform - typically 3-5 days
  - Requires highly skilled personnel and laboratory analysis
  - More expensive than Protein Based Methods
- **Protein based methods**
  - Relatively cheap to perform
  - Rapid turnaround - 5 to 20 mins for strips; 24 hours for ELISA
  - Strips do not require trained personnel
  - Limited to one or a small number of varieties per test
  - Not appropriate for processed products
  - Not appropriate for some GM varieties - in certain crops the GM protein is only produced in the leaves or stems and not in the actual grain. Protein tests on the grain are therefore not informative.
  - Not very sensitive (~1% of GM protein)

	
• **ELISA**	• **Lateral flow strip**

➢ **Lateral flow stick**

• Collect leaf and extract sample • Place the strip into the extraction tube • The sample will travel up the strip • Allow the strip to develop for 10 minutes • To retain the strip, cut off and • Discard bottom section of the strip	



➢ Transgenic contamination in non-GM crops:

The coexistence of genetically modified (GM) crops and non-GM crops is a myth because the movement of transgenes beyond their intended destinations is a certainty, and this leads to genetic contamination of organic farms and other systems. It is unlikely that transgenes can be retracted once they have escaped, thus the damage to the purity of non-GM seeds is permanent. The dominant GM crops have the potential to reduce biodiversity further by increasing agricultural intensification. There are also potential risks to biodiversity arising from gene flow and toxicity to nontarget organisms from herbicide-resistant (HT) and insect-resistant (Bt) crops. Unless whole regions are declared GM agriculture free, the development of distinct systems of agriculture (GM and non-GM) will be impossible as GM agriculture emerges at the expense of all other forms of production.

➢ The movement of transgenes follows many different routes:

- By pollon
- By wind or pollinators
- By humans transport crop seeds over huge distances
- By hybridize with non-crop species
- By volunteer plants
- By isolation distance
- **By** accidental release of unapproved transgenes into commercial seed
- **By** violations of safety protocols during field trials of GM crops

➢ GM crops and organic seed production:

- Genetically modified (GM) crops cannot be released into the environment and used as food, feed, medicines or industrial processing before they have passed through a rigorous and internationally recognized regulatory process designed to protect human and animal health, and the environment.
- The UK body that oversees standards in organic farming, the United Kingdom Register of Organic Food Standards (UKROFS), has ruled that genetically modified (GM) crops have no role to play in organic farming systems. They, therefore, have concerns about the possibility and consequences of the mixing of GM crops with organic crops.
- The two main sources of mixing are through pollen and seed. Pollen from GM crops may pollinate an organic crop. Seed from a GM crop, or plants established from them, may become mixed with organic crops or their products.
- Minimizing genetic mixing is an important feature of the production of all high quality seed samples of plant varieties supplied to farmers.
- Extensive experience has been obtained over many decades in the production of high purity seed samples. Crop isolation distances, and crop rotational and management practices are laid down to achieve this. These procedures for the production of seed of high genetic purity could be used for the production of organic crops.

- No system for the field production of seed can guarantee absolute genetic purity of seed samples. Very rarely long distance pollination or seed transfer is possible, so any criteria for organic crop production will need to recognise this.
- There has always been the possibility of hybridization and seed mixing between organic crops and non-organic crops.
- Organic farming systems acknowledge the possibility of spray or fertilizer drift from non-organic farming systems, and procedures are established to minimize this.
- In practice, detecting the presence of certain types of GM material in organic crops, especially quantification, is likely to be difficult.
- Some seed used by organic farmers are currently obtained from abroad.
- Organic farmers and/or GM crop producers will need to ensure that their crops are isolated from one another by an appropriate distance or barrier to reduce pollen transfer if the crop flowers. To reduce seed mixing, shared equipment will need to be cleaned and an appropriate period of time allowed before organic crops are grown on land previously used for GM crops. Responsibility for isolation will need to be decided before appropriate measures can be implemented. The report highlights the need for acceptable levels of the presence of GM material in organic crops and measures identified to achieve this.

➢ Seed production technologies in different field crops

Wheat

(1) Selection of seed plot : The plot to be used for seed production of wheat shall be free from weeds and volunteer plants. The plot should be well drained. Prepare the land with deep ploughing, followed by harrowing and leveling. Pre-sowing irrigation should be given for uniform germination.

(2) Isolation distance : Wheat is normally a self-pollinated crop, however, natural cross-pollination to the extent of 1 to 4 percent occurs. So an isolation distance of 3 meter should be kept in all the side of seed plot to avoid natural crossing. If a variety of the seed plot is likely to get infected by loose smut then isolation distance of 180 meters between seed field and other field of wheat is recommended.

(3) Planting time and seed rate :

1) Long duration (late maturing) varieties may be sown during the first fortnight of November.
2) Short (early) and medium duration varieties may be sown during second fortnight of November.
3) The seed crop should be sown in rows at spacing of 20 to 22.5 cm to a depth of 5 cm.
4) The recommended seed rate for seed crop is 85 to 100 kg /ha.

(4) Cultural practices :

1) Fertilizer: The recommended doses of fertilizer is 80 kg nitrogen, 60 kg phosphorous and 40 kg potash per hectare. Apply all the quantity of phosphorous and potash fertilizers at the time of sowing while 50 % quantity of nitrogen at time of sowing and remaining 50 % nitrogen at the crown root initiation stage i.e. 30 to 35 days after sowing.
2) Irrigation: Depending upon the soil texture and structure about 4 to 6 irrigations are sufficient. 1st irrigation at 30 to 35 days after sowing and other irrigations at late tillering, panicle emergence, flowering, milk and dough stages should be given
3) Inter-culturing and weeding: Periodically inter culturing and weeding should be carried out to keep the crop free from weeds. Chemical weedicides like 2,4-D @ 0.5 kg a.i. per hectare and pendimethalin @ 1 kg a.i. per hectare in 750 litres of water should also be used for effective control of weeds.
4) Plant protection :
    I. For the control of termites, use chlorpyriphos 20 EC @ 2.3 litres/ha with irrigation water.
    II. For control of stem borer apply carbofuran 3 G @ 25 kg/ha two weeks after germination or spray the crop with endosulfan 35 EC @ 1.5 litres per hectare.
    III. Seed treatment with systemic fungicide should be given for control of loose smut.

(5) Roguing : Two to three roguing are sufficient
    1) 1st roguing may be done at the time of heading to remove off types and plants infected with loose smut.
    2) 2nd roguing should be done just after flowering to remove off types plants with late flowering based upon ear head (panicle) characters.
    3) 3rd roguing should be done at the time of maturity based upon variation in ear head color. Color of awns and ear head types as well as volunteer plants and weed plants should be removed.

(6) Harvesting and threshing : Harvesting may be done by sickle and threshing with thresher. Care should be taken to avoid mechanical mixture.

(7) Processing : Wheat seeds should have 9 to 10 percent moisture content for storing purpose. To maintain good quality of seeds, it should be cleaned, treated with fungicide and should be properly bagged. The seed should be stored in a dry, clean and rodent proof warehouse.

(8) Yield : The average seed yield should be between 30 to 40 qtls per hectare.

Minimum seed certification standard

	Foundation seed	Certified seed
Germination (%)	85	85
Genetic purity (%)	98	98
Inert matter (%)	2	2
Other crop seeds (No./kg)	10	10
Weed seeds (No./kg)	10	10
Diseased seeds (%)	0.05	0.25
Moisture (%)	10	10

Rice (Paddy)

1. Selection of seed plot : The plot should be free from weeds and volunteer plants and should have not been used for growing the same crop in previous year or season. Prepare the land with deep ploughing followed by harrowing so that the transplanted seedlings establish quickly. A plot should be kept flooded for a week or ten days before transplanting.
2. Isolation chamber : The extent of cross pollination in rice varies from 0 to 6.8 % hence it is necessary to keep the plot isolated atleast by 3 meters from other rice plot for pure seed production.
3. Cultural practices : The paddy crop must be grown by direct sowing or by transplanting. For seed production transplanting method is desirable.

I. Raising nursery : Land selected for paddy nursery should not have paddy as previous crop to avoid varietal mixture due to volunteer plant. The appropriate time of sowing nursery for early duration varieties is from 10^{th} to 25^{th} June and for late duration varieties, it is 25^{th} May to 10^{th} June. Long and narrow nursery beds (1 m x 10 m) are more ideal. Prepare raise bed to facilitate drainage of excess water and also to irrigate the nursery uniformly. About 80 to 90 beds of the size 10 m x 3 m are sufficient for raising seedlings to transplant one hectare of land.

II. Seed rate : 20 -25 kg for fine grain varieties, 30-35 kg for coarse grain varieties

Seed should be obtained from the source approved by the seed certification agency. The sowing of seeds in nursery may be carried out in row (line) sowing or broadcasting may be done. Irrigate the nursery after sowing the seeds. Recommended plant protection measures and fertilizer application may be made to raise the seedlings successfully. Keep the nursery free of weeds.

III. Uprooting of seedlings and transplanting : Seedling are ready for transplanting after 3 to 4 weeks of sowing. Uproot the seedling gently, discard weak, diseased or those seedlings differing in any way from the original variety. The land should be puddled either by tractor or by bullock pair and flood it with appropriate water level to transplant the seedlings. Fertilizer may be applied based on soil test, however, the fertilizer recommendation is 120-60-00 kg N:P:K for later varieties and 100-50-00 kg N:P:K for early and mid-late varieties. Apply whole amount of phosphorus and potash as basal dose at the time of puddling. 50 % nitrogen may be applied as basal dose while 25 % of nitrogen at tillering stage and 25 % at panicle initiation stage. If the land is deficient in zinc, apply 15 kg zinc sulphate per hectare at puddling stage. Spacing should be kept at 20 cm x 15 cm. Maintain a water level of 2.5 to 5 cm of water till milking stage. Drain excess water when the crop does reach to physiological maturity.

IV. Weed control. : Keep the crop free from weeds by hand weeding or using chemical herbicides. Butachlor or benthiocarb @ 1.5 kg a.i./ha 5 to 7 days after transplanting.

V. Plant protection : Stem borer, brown plant hopper, leaf roller and Gundhi bug are the major pests of paddy.

a) For the control of stem borer use carbofuran 3 % granules @ 20 kg/ha or phorate 10 % granules @ 10 kg/ha.
b) For the control of brown plant hopper and leaf roller spray endosulphan 35 EC @ 1 litre per hectare
c) Disease : Blast, bacterial leaf blight, bacterial leaf streak and brown spot are the important disease of paddy.

i. For control of blast Hinosan 625 ml per hectare in 625 litres of water one or two times before panicle emergence and once after panicle emergence.
ii. For the control of bacterial leaf blight spray 75 g agrymycine + 500 g copper oxychloride in 500 litres of water per hectare 3 to 4 times at an interval of 10 to 15 days.
iii. For control of bacteria leaf streak spray 12 g of streptocycline or 75 g agromycin in 50 litres of water per hectare at an interval of 10 to 15 days.
iv. For the control of brown spot spray 0.25 percent dithane M-45 or Zineb after 6 weeks of transplanting at an interval of 10 to 12 days.

4. Roguing : Roguing of off types and volunteer plants should be done once before flowering and then at flowering and maturity stage. Roguing of wild rice or plants infested by pests and diseases may be done from time to time as required
5. Harvesting and threshing : It is important to harvest the crop when the seed is ripe. The moisture content at this stage varies between 17 to 23 percent. Harvest the crop by sickle or combined harvester. Allow the crop to dry for two to three days till the moisture content reduce to 12 to 13 percent. Clean the seeds to remove chalf, durt, empty husks and light seds by winnowing. Store in a gunny bags in a cool and dry place on wooden racks.
6. The average paddy seed yield should be from 50 to 60 quintals per hectare depending upon the varieties.

Minimum Seed Certification Standard

	Foundation seed	Certified seed
Germination (%)	80	80
Genetic purity (%)	98	98
Inert matter (%)	2	2
Other crop seeds (No./kg)	10	20
Weed seeds (No./kg)	10	20
Diseased seeds (%)	0.01	0.05
Moisture (%)	13	13

Seed production of hybrid rice

The successful development and use of hybrid rice technology in china during 1970s led the way for development and release of rice hybrid. In India 14 rice hybrids have been bred and released for commercial cultivation by some the state agricultural universities and private seed companies. Hybrid rice can be produced in the following ways.

(1) Three line system : This involves multiplication of cytoplasmic genetic male sterile line (A line), maintainer line (B line) and a restorer line (R line). Finally production F_1 hybrid seed (A x R)
(2) Two line approach : This involves the use of photoperiod sensitive genetic male sterile (PSMS) and any normal line can serve as a restorer.
(3) By using chemical emasculators : Chemicals which act as male gametocytes have been developed which can sterilize the stamen without affecting the normal functioning of pistil. These chemicals are used to emasculate female parent for hybrid rice production. In this method, two varieties are planted in alternate strips and one is chemically sterilized and pollinated by the other.

Steps involved in seed production :

(1) Selection of seed field : The field should be free of volunteer plant, well leveled, should have fertile soil with good physical properties and well drainage facilities.
(2) Isolation : The hybrid rice field should be isolated from other paddy fields by 200 meters for foundation seed and 200 meters for hybrid seed production (A x R)
(3) Synchronization of flowering : Synchronizing of flowering of both parents is the key factor to increase the yield. Technical measure such as staggered planting of female and male parents may be adjusted to ensure synchronizing the flowering time. In addition, one or two extra planting of male parents may be done to extend the time of availability of pollens. Flowering time can be manipulated by additional fertilizer application and regulation of water in the field.
(4) Methods of improving seed setting :
    a) Supplementary pollination : This can be done by pulling the nylon rope back and forth on the restorer line and panicles of restorer lines are shaken which helps in transfer of pollen grains.
    b) Leaf clipping : Clipping of leaves prior 1-2 days of panicle emergence will increase the probability of pollination and out crossing so blade of the flag leaf may be clipped.
    c) GA_3 application : Spraying of 60 ppm (60 mg/l) solution of GA_3 on the female parent two to three times at the time of panicle emergence will increase quick exertion of panicle and helps in seed setting.
(5) Roguing : The seed field should be free of rogues (off type plants). Remove off type plants in the male and female parents. First before panicle initiation and then soon after emergence of panicles. Rogue out the plants of maintainer lines or semi-sterile plants from the female parent plot as and when required.
(6) Harvesting and processing : Harvest male rows first to avoid chances of mechanical mixture. Moisture percentage in the grain at the time of harvesting should be less than 18 percent for combine harvester or harvested by hand and must be sun dried to 12 percent for storing purpose. Cleaning of seeds should be done taking enough care to avoid mixture. Store the seed in cool and dry place.

Minimum seed certification standard

	Foundation seed	Certified seed
Isolation distance (m)	200	100
Germination (%)	90	90
Genetic purity (%)	98	98
Other crop seeds (No./kg)	10	20
Weed seeds (No./kg)	10	20
Diseased seeds (%)	0.01	0.02
Moisture (%)	13	13

Seed production of composite and synthetic varieties in Pearlmillet (Bajara)

1. Land preparation : One ploughing followed by two harrowing and leveling. Land should have well drainage capacity. It should be free from volunteer plants and weeds
2. Time of sowing :

Kharif : 2nd fortnight of July
Rabi : Mid October to mid December

3. Isolation : Foundation seed – 400 m
   Certified seed – 200 m
4. Source of seed : Obtain foundation seeds from the source approved by the certification agency.
5. Seed rate, method of sowing and spacing :
   a) Direct sowing : 3.5 kg to 5.0 kg, keeping 50 cm spacing between rows. Thinning should be done at a distance of 10 to 15 cm.
   b) Transplanting : 1.5 kg/ha, Spacing : 45 cm between the rows
6. Fertilizer : 50 kg NPK as basal, 25 kg N after 25-30 days of sowing and 25 kg N after 40-45 days of sowing.
7. Irrigation : Irrigate the crop as and when required. If rain is inadequate, 1-2 irrigation may be given.
8. Weed control : Pre-emergence application of Propazine or Atrazine @ 1 kg/ha and one hand weeding would be effective to control weeds. One or two inter-culturing would be sufficient to keep the crop weed-free.
9. Plant protection :
   a) White grub and shoot fly : Apply 10 % phorate granules 10-15 kg/ha as soil application at the time of sowing. Spraying of carbaryl @ 2 kg in 500 litres of water per hectare would be effective.
   b) Red hairy caterpillar, leaf roller, hopper and army worms : Thiodan 35 EC, 1.25 litre/ha in 600 to 800 litres of water.
   c) Sucking pests like aphids, jassids can be controlled by Dimethoate 30 percent @ 250 ml in 500 litres of water per hectare.
   d) Earhead midge and blister beetles : Carboryl 50 % @ 3 kg/ha or Malathion 2 % dust @ 15 kg/ha.
   e) Smut : Seed treatment with Agrosan 3 gm/one kg seed.
   f) Rust : Spray zineb 50 % w.p. 1 kg/ha in 600 litre of water.
   g) Ergot : Spray the ears with Ziram (Cuman) 0.15 % or mixture of copper oxichoride (fytolan) and zineb (Dithane-Z-78) in 1:2 ratio
10. Roguing : Remove off types and volunteer plants identified on the basis of plant characteristics like stem color, hairiness, plant height, peduncle shape, colour etc.
11. Harvesting : Seed crop should be harvested when it is fully matured. Remove diseased or damaged ear-head at the time of harvest. Threshing can be done by thresher. Dry the seed to 10 % moisture before storage.

Production of hybrid seed in Pearlmillet :

The hybrid seed is produced by using cms line and restorer (CGMS concept) as similar to other cereals.

Important steps are :

a) Maintenance of parental lines, i.e. male sterile line, B line and restorer line.
b) Production of hybrid seed i.e. (A x R)

Planting ratio : Female : male , 4 : 2 rows. Eight border rows of parent should be provided on all sides of the field or sufficient availability of pollen grains.
Spacing : 75 cms between rows adjust planting by sowing early or late.
Seed rate :

Direct sowing - Female : 1.5 kg/ha and male : 0.75 kg/ha
Transplanting : female : 400 g/ha, male : 200 g/ha

Isolation : 200 meters from other field

Roguing :

a) Start roguing before flowering
b) All off type plants and volunteers must be cut from the ground level or pulled out to prevent re-growth.
c) Remove off types both from the seed parent and pollinator parents.
d) Remove pollen shedding plants at the time of flowering from the rows of female (seed parent).
e) Seed (female) parent should be rogued at least once a day.
f) Remove diseased plants at the time of harvest.

Harvesting : Harvest male rows first. Keep it separately. Female rows should be harvested after completion of male rows. The seed should be dried, threshed and cleaned before storage

Seed yield : 3 to 4 qtls/ha
Minimum seed certification standard :

	Foundation seed	Certified seed
Isolation distance (m)	75	75
Inert matter (%)	2	2
Genetic purity (%)	98	98
Other crop seeds (No./kg)	10	10
Weed seeds (No./kg)	20	20
Diseased seeds (%)	0.02	0.04
Moisture (%)	12	12

Hybrid seed production in maize

Production of hybrid maize seed involves three steps

1. Maintenance of parental lines (Inbreds)
2. Production of single cross
3. Production of commercial hybrids
    a) Production of three way cross : (A X B) X C
    b) Production of double cross : (A X B) X (C X D)

Maintenance of parental lines and production of single cross are called as foundation seed production while production of three way cross or double cross is known as certified seed.

Maintenance of inbred lines :

(1) Land requirement (Selection of seed plot) : The soil should be well aerated and suitable for maize growing. Selected field should be free from volunteer plants and weed plants. It should have good drainage capacity as maize is sensitive to excess water as well as drought conditions.
(2) Isolation distance : The seed field of an inbred line must be isolated by not less than 400 m. from any maize field with the same kernel colour and texture and 600 m. from maize field with different colour and texture.
(3) Seed rate : Female parent : 10 kg/ha, male parent : 5 kg/ha
Ratio - Female : male row ratio should be 4 : 2
Planting time : 2nd week of June to Mid July.
(4) Roguing : Start roguing the distantly tall and vigorous plant when the crop is at knee light stage. At pre-flowering stage, rogue off plants which are easily identified on the basis of plant characteristics such as leaf shape, size, plant height etc. Continue

roguing during flowering stage to remove plants differing in tassel or silk character. Final roguing should be done to remove stalk-rot affected plants.

(5) Harvesting : Maze ears can be harvested when the seed moisture content is around 15 per cent. The male rows are harvested first so as to avoid mixing of male ears with female ears. After compilation of harvesting of male rows, harvesting of female rows is carried out. After harvest, sort out all off type maize ears, particularly those showing different colours and torture and infested by disease.

(6) Processing : Before shelling of maize ears they are once again examined and any off-type or diseased ear is found, it is removed immediately. Processing for kernel is carried out at processing plant under the supervision of staff of seed certification agency.

Minimum seed certification standard

	Foundation seed
Germination (%)	90
Genetic purity (%)	98
Inert matter (%)	2
Other crop seeds (No./kg)	5
Weed seeds (No./kg)	none
Diseased seeds	none
Moisture (%)	12

Hybrid seed production in sorghum

The hybrid sorghum seed is produced by utilizing cytoplasmic genetic male sterility. The steps involved in hybrid seed production are as under.

1. Maintenance of parental lines i.e. line A carrying cytoplasmic genetic male sterility. Line B male fertile (maintainer lines of A) and R line i.e. restorer line used as male parent for the purpose of producing hybrid seed male fertile, pollen restoring line.
2. Production of hybrid seed : This involves crossing of male sterile line A with restorer line (R line) to produce hybrid seeds. The maintenance of parental lines is known as foundation seed production and the production of hybrid seed is known as certified seed production.

<u>Maintenance of male sterile lines (Line A)</u>

I. The male sterile line (line A) carried male sterility due to cytoplasmic genetic factors. It is maintained by crossing with male fertile non-pollen restoring line (non-restorer line) in an isolated plot. The isolation distance kept is 400 meters. In a crossing field the planting ratio of line A and B is 4 : 2. Four to six border rows of line B are planted all around the seed plot. The seed harvested from line A is male sterile and is used for hybrid seed production as a female parent and for further maintenance of line A. The seed harvested from line B is pollen fertile and may be used in further maintenance of line A.

II. Seed rate, spacing and planting ratio :

Seed rate	:	Female line (Line A) 8 kg/ha
		Male line (Line B) 4 kg/ha
Spacing	:	75 x 10 cm
Ratio	:	Female line to male line ratio is 4 : 2.

III. Roguing : It is very important for quality seed production. Before flowering remove all off type plants from both seed parent and pollinator parent. Roguing may be strated before off type, volunteers and pollen shedders in female rows start shedding pollens. At flowering roguing should be done every day to remove pollen shedding plants in the female rows. Pre-harvest roguing i.e. the field should be thoroughly rogued before harvesting and after the seed has matured to the stage when we can identify the true plant and seed characters easily. The roguing of diseased heads should also be done critically.

IV. Harvesting : Harvest male rows (B lines) first and keep their ear heads separate. The female rows (A line) should be harvested after completion of harvesting of B lines.

Production of hybrid seed :

Hybrid seed is produced by crossing male sterile line (line A) with specified restorer line (line R) in an isolated field. This is hybrid seed that is to be sold to farmers.

i. Selection of seed plot : The land should be free from volunteer plants and weed plants. There should be no Johnson grass in the seed field or within the isolation distance. The field should be well drained.

ii. Isolation distance :

	Foundation seed	Certified seed
From field of other sorghum varieties	200 m	100 m
Johnson grass	400 m	400 m
Forage sorghum	400 m	400 m

iii. Spacing , planting ratio, seed rate :

Spacing : 75 to 90 x 10 cm

Planting ratio : Female to male rows ratio 4 : 2, and four border rows of male parent in all the sides of the field

Seed rate : female parent 8 kg/ha
Male parent 4 kg/ha

iv. Synchronization flowering time in male and female parent. : Perfect synchronization of flowering time between male and female parent is most important. Differential flowering time may result in non-synchronization of the parents which may result into poor seed set, hence knowledge regarding flowering habit of the parent is very useful for planning of suitable staggering to ensure nicking and there by maximum seed set.

v. Roguing : During vegetative growth stage, before flowering remove all off type plants from the rows of both female and male parents. Start roguing before off type plants, volunteer plants and pollen shedders in female rows start shedding pollens. At flowering and during flowering period roguing should be done every day to remove pollen shedding plants from the female rows. Pre-harvest roguing before harvesting and after maturity roguing should be done thoroughly and ear heads infested with the disease should be removed.

vi. Harvesting and threshing : Harvest male rows any time after the maturity prior to harvest the female rows. Remove the produce of the male parent from the seed field before harvesting the female rows to avoid the mixture. The threshing machine may be thoroughly cleaned before threshing the female ear heads to avoid mechanical mixture.

vii. Seed yield : Average seed yield of 4 to 6 quintals per hectare.

Minimum Seed Certification Standard

	Foundation seed	Certified Seed
Germination (%)	75	75
Genetic purity (%)	98	98
Inert matter (%)	2	2
Other crop seeds (No./kg)	5	10
Weed seeds (No./kg)	5	10
Diseased seeds	0.02 %	0.04 %
Moisture (%)	12	12

Seed Production In pulses crops:

➢ Pigeon pea:

(1) **Selection of seed plot** : The plot to be used for seed production of pigeon pea shall be free from weeds and volunteer plants. The plot should be well drained. Prepare the land with deep ploughing, followed by harrowing and leveling.

(2) **Isolation distance** : Pigeon pea is normally a Often cross-pollinated crop, however, natural cross-pollination to the extent of 65 percent occurs. So an isolation distance of 200 meter should be kept for foundation seed class and 100 meter for certified class side of seed plot to avoid natural crossing.

(1) **Planting time and seed rate** :

Sowing of seed crop in first week of June is recommended for obtaining higher yields.

Seed crop should be sown in rows at spacing of Row to Row- 60 to 75 cm
Plant to plant- 25 to 30 cm
a depth of 5 cm.

The recommended **seed rate** for seed crop is 12 to 15 kg /ha.

(2) **Cultural practices** :

(a) Fertilizer: The recommended doses of fertilizer is 25 kg nitrogen, 50 kg phosphorous per hectare. All the quantity of nitrogen and phosphorous should apply in drilled at time of sowing of seed.

(b) **Irrigation**: one to two light irrigation prior to onset of monsoons may be necessary.if rain disturibution is irregular and weather remains dry for prolonged periods, one irrigation at flowering time and subsequent irrigation after flowering are necessary.

(c) **Inter-culturing and weeding**: Periodically inter culturing and weeding should be carried out to keep the crop free from weeds. Chemical weedicides like 2,4-D @ 0.5 kg a.i. per hectare and pendimethalin @ 1 kg a.i. per hectare in 750 litres of water should also be used for effective control of weeds.

(d) **Plant protection** :

For the control of pod fly spray endosulphan 1.25 liters per hectare or monocrotophos at 750 ml per hectare in 250 liters of water.

For the control of pod bug or plume moth and gram catter piller, spray, 750 ml of monocrotophos or dust 25 kg malathion 5 % dust per hectare.

(3) **Roguing** : rogue the off-type plants and diseased plants affected by wilt, leaf spot and stem canker, YVMV and sterility virus from seed field from time to time as required.

(4) **Harvesting and threshing** : Harvesting may be done by sickle and threshing with sticks. Care should be taken to avoid mechanical mixture.

(5) **Processing** : Pigeon pea seeds should have 8 to 10 percent moisture content for storing purpose. To maintain good quality of seeds, it should be cleaned, treated with fungicide and should be properly bagged. The seed should be stored in a dry, clean and rodent proof warehouse.

(6) **Yield** : The average seed yield should be between 20 to 25 qtls per hectare.

Minimum seed certification standard

	Foundation seed	Certified seed
Germination (%)	85	85
Genetic purity (%)	98	98
Inert matter (%)	2	2
Other crop seeds (No./kg)	10	10
Weed seeds (No./kg)	10	10
Diseased seeds (%)	0.05	0.25
Moisture (%)	9	9

➢ Chickpea

(1) Selection of seed plot : The plot to be used for seed production of chickea shall be free from weeds and volunteer plants. The plot should be well drained. Prepare the land with deep ploughing, followed by harrowing and leveling.

(2) Isolation distance : chickea is normally a Self-pollinated crop, however, natural cross-pollination to the extent of 1 percent occurs. So an isolation distance of 10 meter should be kept for foundation seed class and 5 meter for certified class side of seed plot to avoid natural crossing.

(3) Planting time and seed rate :

Sowing of seed crop in third and fourth week of October is recommended for obtaining higher yields.

Seed crop should be sown in rows at spacing of Row to Row- 45 to 60 cm
Plant to plant- 10 to 15 cm
a depth of 7-10 cm.

The recommended **seed rate** for seed crop is 55 to 100 kg /ha.

(4) Cultural practices :

(a) **Fertilizer**: The recommended doses of fertilizer is 15-20 kg nitrogen, 50 kg phosphorous per hectare. All the quantity of nitrogen and phosphorous should apply in drilled at time of sowing of seed.

(b) **Irrigation**: one to two light irrigation prior to onset of monsoons may be necessary.if rain disturibution is irregular and weather remains dry for prolonged periods, one irrigation at flowering time and subsequent irrigation after flowering are necessary.

(c) **Inter-culturing and weeding**: Periodically inter culturing and weeding should be carried out to keep the crop free from weeds. Chemical weedicides like 2,4-D @ 0.5 kg a.i. per hectare and pendimethalin @ 1 kg a.i. per hectare in 750 litres of water should also be used for effective control of weeds.

(d) **Plant protection** :

For the control of pod fly spray endosulphan 1.25 liters per hectare or

monocrotophos at 750 ml per hectare in 250 liters of water.
For the control of pod bug or plume moth and gram catter piller, spray, 750 ml of monocrotophos or dust 25 kg malathion 5 % dust per hectare.

(5) Roguing : Rogue the off-type plants and diseased plants affected by wilt and blight, from seed field from time to time as required.

(6) Harvesting and threshing : Harvesting may be done when the seeds are fully matured. At the leaves are reddish brown by sickle and threshing with

sticks. Care should be taken to avoid mechanical mixture.

(7) Processing : Chick pea seeds should have 8 to 10 percent moisture content for storing purpose. To maintain good quality of seeds, it should be cleaned, treated with fungicide and should be properly bagged. The seed should be stored in a dry, clean and rodent proof warehouse.

(8) Yield : The average seed yield should be between 15to 20 qtls per hectare.

Seed Production in Major Oil seed Crops

➢ Castor

Foundation seed production

Seed production male and female parents and their maintenance is known as foundation seed production.

1. Land requirement & preparation : Castor seed production can be successfully taken up on any type of soil provided they are fairly deep, fertile and well drained. Medium to deep sandy loam and heavy loam soils are ideally suited for seed production. Since, castor is a deep rooted crop, deep ploughing has been very useful. One deep ploughing followed by two to three harrowing is sufficient to bring the field to the desired tilth.
2. Isolation : Castor is monoecious and highly cross pollinated crop. The cross pollination by wind varies from 5 to 40 % depending upon the climatic condition. The seed field must be isolated from other variety field atleast 300 m from foundation seed class and 150 meters for certified seed class.
3. Source of seed : Obtain nucleus/breeder/ foundation seed from authentic source approved by seed certification agency.
4. Time of sowing : For *kharif* season first fortnight of July, for *rabi* mid of September to mid of October.
5. Method of sowing : The crop is planted in rows either by drill or in furrows opened by plough or by transplanting the seedlings
6. Spacing : 120 to 90 x 90 to 45 cm
7. Seed rate : 15 5o 20 kg/ha. Seed rate varies according to seed size spacing and method of sowing.
8. Fertilizer : 80 : 40 : 00, NPK kg/ha. Of these, 50 % nitrogen plus all the amount of phosphorus and potash is given as basal dose at the time sowing. Remaining 50 % nitrogen is given in two equal split, first at 40 to 60 days after sowing and second after first picking.
9. Irrigation : The number of irrigations required varies with the rainfall received. However, usually 2 to 3 irrigations during the entire crop season may be sufficient to

avoid moisture stress. Adequate moisture in soil at time of flowering is necessary otherwise moisture stress at this stage may lead to high proportion of male flowers in monoecious varieties.

10. Weed control : The castor field must be kept weed free up to 60 days after planting. 2 to 3 hand weeding / hoeing are sufficient to keep the field clean.

11. Plant protection :
    a) Phytophthora blight and Cercospora leaf spot are the major disesase. Spraying of Bordeaux mixture at 15 days interval or 2 to 3 spray of 0.25 % dithan M-45 may be effective.
    b) 1) Semilooper : 0.35 % thiodan, 0.03 % dimecron
       2) Pod borer : 0.35 % thiodan
12. Roguing : Remove all off type plants before flowering. Rogue out diseased plants as soon as they are noticed in the field and take plant protection measures to check the spread of disease. For male parent two rounds of roguing are required, first about 10 days prior to flowering and the second at flowering. As soon as flower initiation is noticed in primary raceme, reduce the population to 50 % of initial plant stand by roguing of variants in respect to number and the spread of male flowers beyond lower two whorls. After second round of roguing maintain the node number up to primary raceme.

    For female parent there will be four field inspections viz., before flower initiation (35-45 DAS), full flowering in primary raceme (60-65 DAS). Besides the routine two rounds of roguing for removal of off-types based on stem colour, internodes type, leaf shape, nodes up to primary raceme, sex expression, branching etc. inspect every female plant regularly for any possible reversion to monoecism at secondary, tertiary and quarternary orders. These plants should be removed and destroyed.
13. Harvesting and threshing : Start harvesting when all the capsules in primary spikes and 1 to 2 secondary spikes start turning light yellow. The picking continues till 2 to 3 months, because the capsules mature unevenly due to sequential development of racemes. Keep picking-wise seed lot separately, sun dry them, thresh them separately for drawing representative seed samples. Before storage, the seed must be dried to 8 % moisture content.
14. Seed yield : 8-10 qtl under rainfed condition, 15-20 qtl under irrigated condition.

Minimum seed certification standard :

	Foundation seed	Certified seed
Isolation distance for hybrid seed production (m)	1500	1000
Germination (%)	60	60
Genetic purity (%)	98	98
Inert matter (%)	2	2
Other crop seeds (No./kg)	5	10
Weed seeds (No./kg)	none	None
Objectionable weed seeds (No./kg)	none	None
Moisture (%)	8	8

➢ SUNFLOWER

- Sunflower is second most important oilseed crop after soybean because of its non-cholesterol and anticholesterol properties. The sunflower head is made up of 1,000 to 2,000 individual flowers joined at a common receptacle. The flowers around the circumference are ligulate ray flowers without stamens or pistils; the remaining flowers are perfect flowers. Anthesis (pollen shedding) begins at the periphery and proceeds to the center of the head. It is highly cross pollinated. It is protandrous (androecium matures before gynoecium), since many sunflower varieties -self-incompatibility, insects and bee colonies have generally increased yields. Pollens are sticky, heavy, only transferred by insect (Honey bees). Hybrid seed produced A, B and R line utilizing CGMS concept.

1. Isolation distance : Foundation seed – 1.5 km, Certified seed – 1.0 km
2. Sowing time : November to October
3. Spacing : 60 x 30 cm
4. Seed rate : A line– 4 kg/ha and R line – 1.25 kg/ha
5. Planting ratio : Female : Male ratio should be 3 : 1, staggered planting can be adopted for synchronization of flowering.
6. Fertilizer : 80 : 90 : 60 kg/ha NPK, Remaining Nitrogen – 2 splits – 30 & 55 DAS
7. Roguing : Pollen shedders in cms lines (A lines) should be rogued out. Other traits like plant type, stem, leaf, height, hairiness, leaf size etc. should be considered for roguing purpose.
8. Pollination : This crop has heavy pollens. Artificial pollination by muslin cloth or by collected the pollens in mugs and spreading on female plant using brush will be helpful to increase the seed set and overall production.
9. Field inspection : 1st a vegetative, 2nd and 3rd at flowering, 4th at maturity.
10. Harvesting : When capitulum turns to lemon yellow color.
11. Yield : 7 to 8 qtls/ha

Minimum Seed Certification Standard

	Foundation seed	Certified Seed
Isolation distance (m)	1500	1000
Germination (%)	70	70
Genetic purity (%)	98	98
Inert matter (%)	2	2
Other crop seeds (No./kg)	None	None
Weed seeds (No./kg)	5	10
Objectionable weed seeds (No./kg)	None	None
Moisture (%)	9	9

➢ Seed production in cotton

Selection of seed plot : The land to be used for seed production must be free of volunteer plants and weeds. The soil should be deep, well drained and should be retentive of moisture and fertile. Plough the land with deep ploughing and harrow two to three times followed by leveling to make it well pulverized.

1. Isolation distance : Cotton is mainly a self pollinated crop but natural cross pollination to the extent of 1 to 10 % in *G. arboretum* and *G. barbadense* while 10 to 50 % in *G. hirsutum* has been recorded, so a minimum isolation distance of 50 meters for foundation class and 30 meters for certified class is recommended.
2. Planting time :
   Seed rate : American cotton : 20-25 kg/ha
   Deshi Cotton : 12-15kg/ha
   Spacing : American Cotton : 90 x 30 cm
   Deshi Cotton : 75 x 30 cm
3. Stage wise roguing : Roguing for off type and diseased plants should start at vegetative growth stage, subsequent roguing should be done at square initiation and flowering time.
4. Picking : The time of picking is important for maintaining seed quality. The picking should start when the cotton is fully mature. Since maturing (ripening) of balls is continuous process several picking may be done. Seeds obtained from initial two to three picking give better germination but planting seeds will be best when collected at the peak of the harvest. The seed cotton picked from last picking should not be kept for seeds or dew. Balls damaged due to insect pest may be discarded for seed purpose.
5. Ginning and delinting : Ginning of cotton seed should be done on the gins approved by certification agency. The machinery must be thoroughly cleaned before the ginning. Gin only those cotton seed with a moisture content of 6 to 8 percent and the ginning rate should not exceed 4.5 to 5.5. kg of lint cotton per hour. Removal of seed coat hairs and short fiber that remains after ginning is called delinting. This may be done with the help of either machine, acid or flame.
6. Seed cotton yield : Average seed cotton yield varies from 6 to 10 quintals per hectare depending upon the yield potential of the variety.
7. Minimum seed certification standard

	Foundation seed	Certified Seed
Germination (%)	65	65
Genetic purity (%)	98	98
Inert matter (%)	2	2
Other crop seeds (No./kg)	5	10
Weed seeds (No./kg)	5	10
Diseased seeds	None	None
Moisture (%)	8-10	8-10
Minimum purity in GOT (%)	90	90

➢ Hybrid seed production in cotton

The hybrid cotton seed is produced by hand emasculation. The individual bud emasculation of the female parent is done in the evening of the previous day and the same is pollinated in the morning of next day with the pollens of male parent. The emasculated bud is covered either with butter paper bag or a soda straw tube after emasculation and pollination.

1. Selection of seed plot : The land selected for seed production must be free from volunteer plants and weeds. The plot should not have cotton crop in the previous year or season. It should be well drained, moisture retentive and well fertile. Prepare the land with deep ploughing followed by 2 to 3 harrowing and leveling.
2. Isolation distance : 50 meters from other cotton crop variety.
3. Planting ration, time, seed rate and spacing

   Female to male ration is 4 : 1.

   The flowering period in cotton is spread over a long time. So sowing of male parent should be done in 2 to 3 installments at an interval of eight to ten days in order to get sufficient pollens for pollination of female flower.

Time : onset of monsoon or one week earlier than usual date of onset of monsoon
Seed rate : Female parent : 3.75 kg/ha., male parent : 2,5 kg/ha.
Spacing : Female parent : 150 cm between rows, 100 cm within row.
: Male parent : 150 cm between row and 50 cm within row.

Precautions to be taken during crossing programme :

1. Rogue out all off type plants before starting of the crossing programme.
2. Emasculate and pollinate, all buds appearing during the first seven weeks of the reproductive phase duration to ensure good seed setting and better development of balls.
3. Emasculate the flower bud in the evening time i.e. 2 to 6 pm only and pollinate them in the next morning between 9 to 13 pm.
4. Emasculate the flower bud i.e. remove all the anthers carefully.
5. Remove un-emasculated flower if any found open.
6. Do not choose very young or old buds for emasculation.
7. Cover the buds of male parent with paper bags in the previous evening for their use in the next day.
8. Emasculated bud may be covered with coloured butter paper bag or soda straw tube to identify for pollination in the next morning.
9. Tie a thread to the pedicel of the bud after pollination. Cover crossed buds with soda straw tube.
10. Close the crossing programme after 11^{th} week and remove all buds and flowers appearing subsequently to facilitate better development of crossed balls. Nip the top end shoots to stop further vertical or horizontal growth.
11. Give light irrigation as and when required during the crossing programme.

4. Stage wise roguing : Roguing for off type and diseased plants should start at vegetative growth stage. Subsequent roguing should be done at square initiation and flowering time.
5. Picking of hybrid seeds : Pickup the ripe and completely opened balls along with threads on and collect in basket for a second sorting. Collected crossed balls should be sorted to verify that they are actually crossed seeds. Sundry for one to two days and store in gunny bags till supplied to processing unit. Care should be taken to avoid mechanical mixture during and after picking.

6. Ginning and delinting : Ginning cotton seed should be done on the gins approved by certification agency. The machinery must be thoroughly cleaned before ginning. Gin only those seed cotton with a moisture content of 6 to 8 % and the ginning rate should not exceed 4.5 to 5.5. kg lint cotton per hour. Delinting may be done using machine, acid or flame.

7. Seed cotton yield : Average seed cotton yield varied from 8 to 10 quintals per hecature.

Minimum seed certification standard (MSCS)

	Foundation seed	Certified seed
Germination (%)	65	65
Genetic purity (%)	98	98
Inert matter (%)	2	2
Other crop seeds (No./kg)	5	10
Weed seeds (No./kg)	5	10
Diseased seeds (%)	None	None
Moisture (%)	8	8

➢ Seed Production in Vegetable Crops

➢ Brinjal, Chilli and Tomato

- Nucleus, breeder and foundation seeds are produced by selfing in brinjal, chilli and tomato. Hybrids seed is produced by hand emasculation and hand pollination. Anthers form cone around bilobed stigma. In chilli, CGMS system is utilized to produce hybrid where, as usual, A line is maintained by B line (maintainer, non-restorer line), B line and R line (restorer) by selfing and hybrid seed is produced by crossing A line with R line.
- During the certified seed production, isolation distance remains 200 m for foundation seeds and 100-200 m for certified seeds. Though these are self pollinated crops, some aount of cross pollination occurs by insects. Inspections are made during vegetative, flowering and maturity stages.

	Tomato		Brinjal	
	Foundation	Certified	Foundation	Certified
Isolation distance (m)	200	200	200	100
Germination (%)	70	70	70	70
Genetic purity (%)	98	98	98	98
Inert matter (%)	2	2	2	2
Other crop seeds (No./kg)	None	None	5	10
Weed seeds (No./kg)	None	None	None	None
Moisture (%)	8	8	8	8

➢ Cucurbits (bottle gourd and ridge gourd)

Bottle gourd and ridge gourd are monoecious crops (separate male flower and female flowers on same plant) and so high amount of cross pollination occurs. Female flowers can be visualized on plant as ovary with rudimentary anthers (pistillate) and in male flowers ovary is absent (staminate) but 3 anthers are present. To prevent selfing male flowers are plucked off at bud stage and hand pollination is done for crossing. Isolation distance is

1500m for foundation seeds and 1000m for certified seeds. Four inspections are made, 1st during vegetative stage, 2nd and 3rd during flowering stage and 4th during maturity stage.

	Foundation seed	Certified Seed
Isolation distance (m)	1500	1000
Germination (%)	60	60
Genetic purity (%)	98	98
Other crop seeds (No./kg)	5	10
Weed seeds (No./kg)	None	None
Objectionable weed seeds (No./kg)	None	None
Moisture (%)	7	7

- **Onion**

In onion seed is not economic unit, bulbs are consumed which are vegetative tissue of the plant.

Method of reproduction :

(1) Bulb to seed : It requires two season. In first seasons bulbs are obtained from seeds and in the next season these bulbs are planted and seed are harvested at the end of the second season.

(2) Seed to seed (Bolting) : In this method only one season is required to produce seed. Seeds are planted in nursery and seedlings are transplanted. In onion occasional bolting (appearance of flowering) occurs and if allowed to mature, these flowers will bear seeds taking food material from developing bulb under the soil surface.

Onion is highly cross pollinated crop having protandrous nature and pollinated by bees, flies and other insects. Cms lines (cytoplamsic male sterility) available for hybrid seed production. Cytoplasmic male sterility is utilized to produce hybrids viz Arka lalima and Arka Kirtiman. Inbreds are produced by selfing or sibmating covered with net. In onion restorer line is not required because seed is not economic material. Restorer lines are required to restore the fertility in other crops like rice, bajara, sorghum, sunflower etc. where seed is the economic material. Onion hybrid seed production includes maintenance of A line and crossing of this A line with any other parent. Recall that in other crops R line (restorer lines) are utilized as male parent to restore the fertility in F_1 hybrid.

Isolation distance :

	Foundation seed	Certified seed
Bulb	5 m	5 m
Seed	1000 m	500 m

Male and female ratio is 2:8 for hybrid seed production. The planting ratio depends upon the pollen production ability of male and pollinating agents especially *Apis melifera.* Staggered planting can be done for synchronization. The seed harvested from female rows is used as hybrid seed. Harvest the crop when 5-10 % capsule shows black seeds. Umbel (type of inflorescence in onion flower) is harvested keeping 10-15 cm seed stalk along with it. Mature heads are harvested 2-3 times after proper drying of umbel. Onion seeds are stored at < 8 % moisture.

WORLD TRADE ORGANISATION AND ITS ROLE IN INTERNATIONAL TRADE:

Introduction:

This paper calls for the meaning of international trade, a look at the international organisation known as World Trade Organisation and its role as far as international trade is concerned.

International Trade.

International trade may be defined as a contract of buying and selling goods and services entered into between parties whose places of business are in different countries or trade in goods and services that cut across international borders or boundaries or between nationals of different countries. This involves imports from one country to another and or exports to one country from another country or trans boundary trade. An international sale or export trade contract can also be described as an agreement for the sale and delivery of goods across international borders or boundaries and for all other things incidental to it.

- **Five essentials of such international trade are:**

- A contract of sale of goods.
- A contract of carriage of goods.
- The contract of insurance for the goods.
- The compliance with formalities and documentation requirements stipulated by the exports and imports' authorities.
- The mechanism for payment set up by the buyer.

Since no nation can produce all it needs by itself alone, international trade has become not only a means by which nations source those goods and services they lack or do not have in sufficient quantities but also a subject of international politics either for achieving, promoting or maintaining peace between international trading partners or countries and a source of national insecurity as a result of external developments in countries with which it inter-depends or depends on for essential products and sometimes wars are fought to preserve that national security. For instance it has been argued that one of the reasons for US' going into the Gulf Wars on the side of Kuwait against Iraq was US' intention to preserve the vulnerability (weakness) of its economy to oil crisis if it is cut off from oil purchases from the Gulf by the hostile Iraq that had annexed the oil-rich portions of Kuwait.

➢ The Role of WTO:

The role of WTO in international trade is as stipulated in the Agreement establishing it and includes:

1. facilitating the implementation, administration and operation and furthering the objectives of the agreement establishing it and other Multilateral Trade Agreements and providing the framework for the implementation, administration and operation of the Plurality Trade Agreements,
2. Providing the forum for negotiations among its Members concerning their multilateral trade relations in matters dealt with under the agreements in the Annexes to the Agreement setting it up and for the results of such negotiations as may be decided by the Ministerial Conference,
3. Administering the Understanding on Rules and Procedures Governing the Settlement of Disputes or the Dispute Settlement Understanding which is Annex 2 to the agreement setting it up,
4. Administering the Trade Policy Review Mechanism in Annex 3 of the agreement setting it up, and
5. Cooperating as appropriate with the International Monetary Fund and the International Bank for Reconstruction and Development [the World Bank] with a view to achieving greater coherence in global economic policy making.

LIST OF ABBREVIATIONS

AOSA	Association of Official Seed Analysts
AOSCA	Association of Official Seed Certifying Agencies
ECOWAS	Economic Community of West African States
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GPA	Global Plan of Action
IP	Identity Preserved
IPPC	International Plant Protection Convention
ISF	International Seed Federation
ISTA	International Seed Testing Association
MLS	Multilateral System of Access and Benefit-Sharing
NDA	National Designated Authority
OAPI	Organisation africaine de la propriété intellectuelle
OECD	Organisation for Economic Co-operation and Development
OIC	Orange International Seed Lot Certificate
PGRFA	Plant Genetic Resources for Food and Agriculture
QA	Quality Assurance
QDS	Quality Declared Seed
RPPO	Regional Plant Protection Organization
SADC	Southern African Development Community
SMTA	Standard Material Transfer Agreement
SPS	Sanitary and Phytosanitary
TRIPS	Trade-Related Aspects of Intellectual Property Rights
UPOV	International Union for the Protection of New Varieties of Plants
WTO	World Trade Organization

OECD- Organisation for Economic Co-operation and Development (OECD)

The OECD Schemes for the Varietal Certification or Controlling of Seed traded internationally was established in 1958. Membership is open to OECD, UN and WTO countries, and there are currently 61 member countries. The principal aim of all eight Seed Schemes in place is to encourage the production and use of high quality seed. Each Scheme is defined according to a group of species of cultivated plants; at present, 200 agricultural and vegetable species are covered..

The OECD Schemes for the Varietal Certification or the Control of Seed Moving in International Trade include Rules and Regulations applicable to eight groups of species constituting the following Schemes:

- Grasses and Legumes
- Crucifers and other Oil or Fibre species
- Cereals
- Maize
- Sorghum
- Sugar and Fodder Beet
- Subterranean clover and similar species
- Vegetables.

The OECD is known for its evidence-based advice and standards, as well as for being a forum where national experts from different areas can meet and jointly develop common standards and procedures. This and the involvement of highly qualified seed experts in the standard setting process ensure the wide acceptance of the OECD seed varietal certification system, and its value to the global seed and agricultural sectors.

I. INTRODUCTION

- World population will increase from 6.9 billion in 2010 to 9.3 billion people in 2050; and agriculture will play a fundamental role in meeting the world‟s growing demand for food, feed and fibre. In order to feed the world population in 2050, agricultural production will have to almost double, and most of the incremental output will have to come from increases in yields (FAO, 2009).[1]

- High-quality seed is a pre-requisite to achieve maximum outputs and good returns for farmers.

- To strengthen the seed sector, it is crucial that seed growers and companies adhere to policies that guarantee quality standards and appropriate regulatory features. Many countries have adopted seed laws.

- A number of international organisations, conventions and treaties deal with the regulation of seed trade, ranging from access to delivery of quality seeds to growers. Together they provide an international regulatory framework by overseeing the interests of breeders, producers and consumers. Among these organisations are the Organisation for Economic Co-operation and Development (OECD), whose Seed Schemes are globally recognized for the certification of seed moving in international trade.

- International regulatory framework for related aspects of seed trade, including plant health and phytosanitary measures, access and benefit-sharing for plant germplasm and use of pesticides..

- An appropriate regulatory framework helps to promote competitive seed markets and lowers barriers to trade. Special attention is paid to the OECD Seed Schemes and their contribution to the development of an international seed certification framework as well as their links to other international organizations.
- The plan aims to further strengthen the work of the Schemes and its value to Member countries.
- This document is intended as an information document for policy-makers in Member countries of the OECD Seed Schemes and in countries interested in joining the Schemes.

The OECD Seed Schemes: A globally recognized seed certification system

1. The OECD Seed Schemes provide an international framework for the certification of seed. They aim to facilitate seed trade by reducing technical barriers, improving transparency and lowering transactions costs.
2. The Seed Schemes authorise the use of labels and certificates for seed produced and processed for international trade according to agreed principles. One of the main principles is that OECD certification is applied only to those varieties that are officially recognised as distinct and having an acceptable value in at least one participating country.
3. An OECD list of varieties eligible for seed certification is regularly published and available online and in hard copy. For a country to use the OECD labels, it is required to register the species and varieties in the OECD list of varieties. The list contains most internationally traded varieties, and it has grown progressively over the last 30 years. There are currently 49 899 varieties and 200 species listed.
4. The rules of the Seed Schemes cover seven groups of species, constituting seven distinct and independent Schemes. In response to the needs of Member countries, the rules are regularly amended.
5. In order for a country to participate in the OECD Seed Schemes, several criteria must be met: The country must provide a description of the national seed certification scheme and a copy of the national rules and procedures governing variety registration and seed certification.

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-:INTRODUCTION TO IPR:-

Topic Contents

- Introduction and meaning of intellectual property and IPR.
- Brief introduction to GATT, WTO, TRIPs and WIPO.
- Treaties for IPR protection: Madrid protocol, Berne Convention, Budapest treaty, Nagoya protocol etc. (Only Brief information)

The property refers to **wealth or valuable things earned by a person.** It is estimated in terms of **land, house, garden, industries, animals, gold, silver, diamond, money** etc. accumulated by a person. Each person wants to earn property for four **main purposes** as given below:

1. **To get a better or higher status** in the society, because of a person is measured in terms of property accumulated by him or her. On the basis of property, the person is called as rich, middle class or poor.
2. To lead a **better quality of life** in the society.
3. To get a **name and fame** in the society. In the society, rich people get more respect than others.
4. For better **financial security** of life for himself and for his children.

Types of Property

The various valuable belongings of a person are broadly classified into two groups, ***viz.*** (i) immovable property, and (ii) movable property. These are defined below:

Immovable Property

It refers to **fixed types of properties which can not move from one place to other.** Such properties include **land, buildings, house, flat, bungalow, farm houseand gardens**. Such properties are protected by laws of land in each country.

Movable Property

It refers to the **property which can be easily shifted from one place to other**. Such property includes **animals, farm machines, furniture, fixtures, gold, silver, diamond and money.** Such properties are also protected by public laws.

Intellectual Property (IP)

There is third type of property what we call intellectual property. It is the " property created by application of human mind".

OR

Intellectual property is a term referring to a number of distinct types of creation of the mind for which property rights are recognized in the corresponding fields of law

OR

The product / process / idea which is outcome of the brain of a person and can be used on commercial scale for benefit of human kind is called intellectual property.

OR

Intellectual property refers to creations of the mind; inventions, literary and artistic works, and symbols, names, images, and designs used on commercial Scale.

The main features of intellectual property are given below:

- It is measured in terms of new ideas, processes, products, inventions and innovations developed by a person.
- It requires lot of intellectual inputs in terms of thinking, planning and fine tuning of new ideas/products/processes etc.
- It requires considerable amount of funds and other resources to develop new products/processes.
- The main problem with intellectual property is that it can be copied, reproduced and used by others resulting in loss of inventor. Hence protection of intellectual property is essential so that the inventor can derive maximum benefits from his invention.

What are intellectual property rights (IPR)?

Intellectual property rights are the rights given to persons over the creations of their minds. They usually give the creator an exclusive right over the use of his/her creation for a certain period of time.

OR

Intellectual property rights are like any other property right. They allow creators, or owners, of patents, trademarks or copyrighted works to benefit from their own work or investment in a creation.

Forms of Intellectual Property Rights

The Intellectual Property Rights are broadly divided into two groups, *viz.,* Primary Rights and Sui-generis Rights. These are briefly discussed below:

1. Primary Rights

Primary rights include, Copyrights, Patents, Trademarks, Trade Secret, Trade names, Domain names, Industrial Designs, Geographical Indications etc.

2. Sui-generis Rights

Sui-generis refers to things of their own kind or things with unique characteristics. Such rights include Database Rights, Mask work, Plant Breeders Rights, Traditional Knowledge, Moral Rights and Supplementary Protection Certificate.

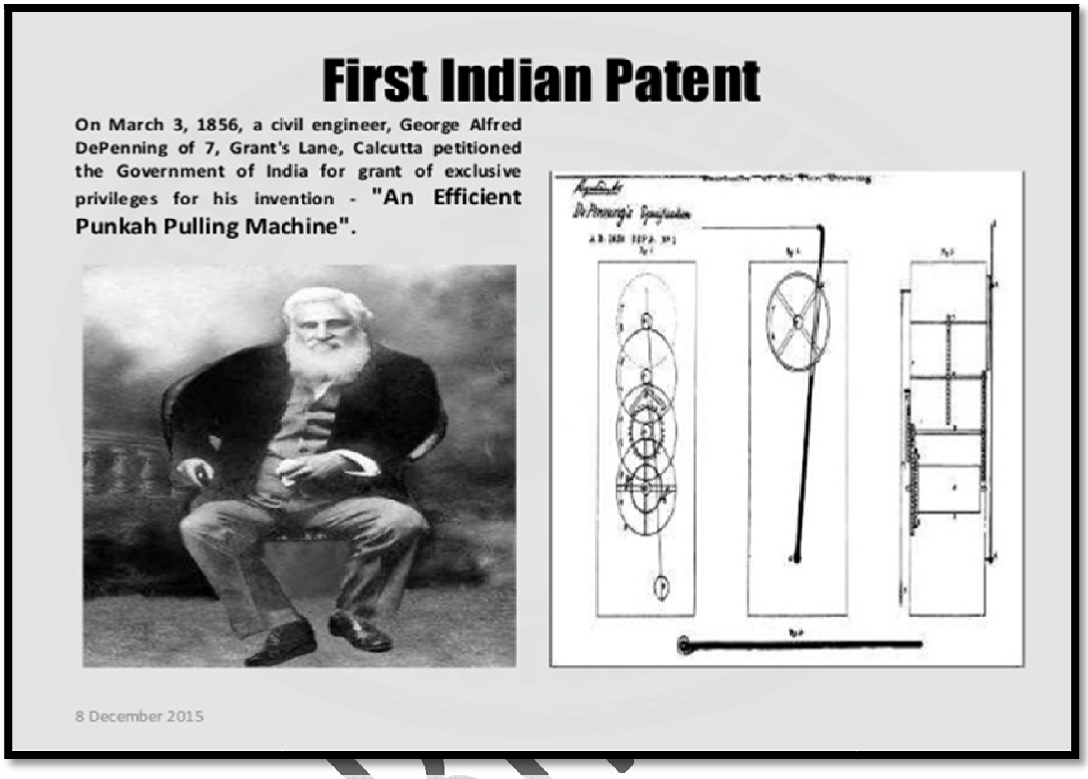
Who are Responsible for Administration of IPRs in the Country?

- Patents, designs, trademarks and geographical indications are administered by the Controller General of Patents, Designs and Trademarks which is under the control of the Department of Industrial Policy and Promotion, Ministry of Commerce and Industry.
- Copyright is under the charge of the Ministry of Human Resource Development.
- The Act on Layout-Design of Integrated Circuits is administered by the Ministry of Telecommunication and Information Technology.
- Protection of Plant Varieties and Farmers' Rights Authority, Ministry of Agriculture administers the Act on Plant Variety.

What is History Behind Intellectual Property Rights?

- The first low of patent was passed in 1474 in Venice, which gave monopoly rights to artisans for their inventions.
- In 1623,the house of commons of U. K. passed the act of Proprietorship.
- George Alfred De Penning is supposed to have made the first application for a patent in India in the year 1856.
- On February 28, 1856, the Government of India promulgated (Circulated) legislation to grant what was then termed as "exclusive privileges (rights/freedom) for the encouragement of inventions of new manufactures" *i.e.* the Patent Act.
- On March 3, 1856, a civil engineer, George Alfred De Penning of 7, Grant's Lane, Calcutta petitioned (appealed/requested) the Government of India for grant of exclusive privileges for his invention- "An Efficient Punkah Pulling Machine".

- On September 2, De Penning, submitted the Specifications for his invention along with drawings to illustrate it's working. These were accepted and the invention was granted the first ever Intellectual Property protection in India.



- 1847: Copyright low enactment during the East India company's regime
- 1856: First legislation in India related to Patents was Act VI of 1856
- 1856: Government of India introduced the Act of Protection
- 1872: Patents and Design Protection Act
- 1883: The Protection of Invention Acts
- 1888: Inventions and Designs Act
- 1947: Indian patents and Designs Act on 15-8-1947
- 1970: The Indian Patents Act(amended in 1999, 2002 and 2005)
- 1911: The Indian patent and Design Act (amended in 1978, 1985)
- 1958: Indian Trade and Merchandise Marks Act
- 1957: The Indian copyright act. (amended in 1999)

What is Intellectual Property act in India?

- There is **no Intellectual Property Act in India**. In India, Intellectual Property Rights are governed by specifically.
- **Intellectual Property Rights include Trademark, Copyright, Patent, Geographical Indications and Design**.

- **Each of them is governed by different legislative framework**.

Different Acts Under IPR

For Patent

1. The Patents Act, 1970
2. The Patents (Amendment) Act, 1999, 26 March, 1999
3. The Patents (Amendment) Act, 2002,25 June, 2002
4. The Patents (Amendment) Act, 2005

For Trademarks

1. Trademarks Act, 1999
2. Trademarks (Amendment) Rules, 2013
3. Trademarks (Amendment) Act, 2010

For Geographical Indications

1. The Geographical Indications of Goods (Registration & Protection) Act, 1999

For Design

1. Design Act, 2000

For Copyright

1. Copyright Act, 1957
2. Copyright Rules, 2013

What is the Scope of the Intellectual Property Law in India?

- Scope can have different interpretation in this question. India has always been and has been more active in terms of IPR be it patents, copyrights, designs, trademarks, geographical indications and others.
- **SCOPE OF PATENTS:** Protects ideas/inventions for a period of 20 years from date of filing of application
- **SCOPE OF COPYRIGHT:** Protects EXPRESSION of ideas, this includes literary, dramatic, artistic works including software. Tenure of copyright is life of author + 60 years.
- **SCOPE OF TRADEMARK:** Protects the name, logo, colour, sound, smell that helps any person differentiate products/services of one company from the other. Tenure is lifetime, it needs to be renewed every 10 years.
- **SCOPE OF DESIGN:** Protects the artistic feature or shape of the product. Tenure is 15 years from date of registration.

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GATT AND WTO

Timeline of GATT and the WTO

- **1944:** At the **Bretton Woods Conference**, which created the **World Bank and International Monetary Fund (IMF)**, there is talk of a **third organization**, the **International Trade Organization (ITO).**
- **1947:** As support for another international organization wanes in the U.S. Congress, the **General Agreement on Tariffs and Trade (GATT) is created.** The **GATT treaty creates a set of rules to govern trade among 23 member countries** rather than a formal institution.
- **1951–86:** Periodic negotiating rounds occur, with occasional discussions of **reforms of GATT**. In the 1980s, serious problems with dispute resolutions arise.
- **1986–94:** The Uruguay Round, a new round of trade negotiations, is launched. This culminates in a 1994 treaty that establishes the **World Trade Organization (WTO).**
- **1995:The WTO is created at the end of the Uruguay Round, replacing GATT.**
- **2003:** The **WTO consists of 146 members**, accounting for **approximately 97 percent of world trade.**

What is Structure of GATT?

- **General Agreement on Tariffs and Trade (GATT)** was **a legal agreement between many countries, whose overall purpose was to promote international trade by reducing or eliminating trade barriers such as tariffs or quotas.**
- According to its preamble, **trade barriers and the elimination of preferences (weakness/partialities), on a reciprocal and mutually advantages basis.**
- It was **first discussed during the United Nations conference on Trade and Employment** and was the out come if the failure of negotiating governments to create the International Trade Organization (ITO).
- **GATT was signed by 23 nations in Geneva on October 30, 1947** and **took effect on January 1, 1948**, as remained in effect on January 01, 1948.
- It **remained in effect until the signature by 123 nations in Marrakesh on April 14, 1994 of the Uruguay Romed Agreements**, **which established the World Trade Organization (WTO) on January 1, 1995.**

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- The **WTO is some ways a successor to GATT**, and the **original GATT text (GATT 1947) is still in effect under the WTO framework, subject to the modifications of GATT 1994.**

What is Purpose of GATT

- The **purpose of GATT** was to **eliminate harmful trade protectionism.** That had sent **global trade down 65 percent during the Great Depression.**
- **GATT restored economic health to the world after the devastation of the depression and World War II.**

Three Main Provisions of GATT

FIRST

- The most important requirement was that **each member must confer most favored nation status to every other member.**
- **All members must be treated equally when it comes to tariffs (prices/rates/charges).**
- **It permitted tariffs if their removal would cause serious injury to domestic producers.**

SECOND

GATT prohibited restriction on the number of imports and exports. The exceptions were:

- When a government had a **surplus of agricultural products**.
- If a country needed to **protect its balance of payments because its foreign exchange reserves were low.** In **addition**, **countries could restrict trade for reasons of national security**. These included protecting patents, copyrights, and public morals.

Third

- That was because **more developing countries joined GATT**, and it **wished to promote them.**
- **Developed countries agreed to eliminate tariffs on imports of developing countries to boost their economies.**
- It would **increase the number of middle-class consumers throughout the world.**

What is the Uruguay Round of GATT?

- The Uruguay round of GATT (1986-94) gave birth to **World Trade Organization.**

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- The **members of GATT** singed on an agreement of Uruguay round in April 1994 in **Morocco** for establishing a new organization named **WTO**.
- It was **officially constituted** on **January 1, 1995** which took the place of GATT as an **effective formal** organization. **GATT was an informal organization** which regulated world trade since 1948.
- Contrary to the **temporary nature of GATT**, **WTO is a permanent** organization which has been established on the **basis of an international treaty** approved by participating countries.
- It **achieved the international status like IMF** (International Monetary Fund) and **IBRD** (The International Bank for Reconstruction and Development), but it is not an agency of the United Nations Organization (UNO).
- **The WTO has nearly 153 members accounting for over 97% of world trade. Around 30 others are negotiating membership.**
- **Decisions are made by the entire membership. This is typically by consensus (by the consent).**
- **A majority vote is also possible but it has never been used in the WTO and was extremely rare under the WTO's predecessor, GATT.**
- **The WTO's agreements have been ratified (approved/sanctioned) in all members' parliaments.**
- **The WTO's top level decision-making body is the Ministerial Conferences which meets at least once in every two years.**
- **Below this is the General Council (normally ambassadors and heads of delegation in Geneva, but sometimes officials sent from members' capitals) which meets several times a year in the Geneva.**
- **The General Council also meets as the Trade Policy Review Body and the Disputes Settlement Body.**
- **Contrary to the temporary nature of GATT, WTO is a permanent organization which has been established on the basis of an international treaty approved by participating countries.**
- **It achieved the international status like IMF and IBRD**, but it is not an agency of the United Nations Organization (UNO).
- At the next level, the **Goods Council, Services Council and Intellectual Property (TRIPs) Council report to the General Council.**

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- **Numerous specialized committees**, **working groups and working parties** deal with the individual agreements and other areas such as, the environment, development, membership applications and regional trade agreements.

What is the Composition of the WTO Secretariat?

- **The WTO secretariat, based in Geneva, has around 600 staff and is headed by a Director-General.** Its annual budget is roughly 160 million Swiss Francs. It does not have branch offices outside Geneva.
- Since **decisions are taken by the members themselves**, the **secretariat does not have the decision making role** that other international bureaucracies are given.
- **The secretariats main duties is to supply technical support** for the various councils and committees and the ministerial conferences, to provide technical assistance for developing countries, **to analyze world trade and to explain WTO affairs to the public and media.**
- **The secretariat also provides some forms of legal assistance in the dispute settlement process and advises governments wishing to become members of the WTO.**

What are the Objectives of WTO?

- To improve the standard of living of people in the member countries.
- To ensure full employment and broad increase in effective demand.
- To enlarge production and trade of goods.
- To increase the trade services.
- To ensure optimum utilization of world resources.
- To protect the environment.
- To accept the concept of sustainable development.

What are the Main Functions of 'WTO'?

- To implement rules and provisions related to trade policy review mechanism.
- To provide a platform to member countries to decide future strategies related to trade and tariff.
- To provide facilities for implementation, administration and operation of multilateral and bilateral agreements of the world trade.
- To administer (manage/controls) the rules and processes related to dispute settlement.
- To ensure the optimum use of world resources.

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- To assist international organizations such as, IMF and IBRD for establishing coherence (link/compatibility/consistency/relevance) in Universal Economic Policy determination.

Difference between GATT & WTO

GATT	**WTO**
General Agreement of Trade & Tariffs	World Trade Organization
Created in 1947	Established on January 1, 1995
GATT was an informal organization	WTO is an formal organization
Nature of GATT is temporary	WTO is a permanent organization
Just a multi-lateral treaty, an agreement	An international organization with membership
Applied on provisional basis	No provisional application
Concerned with tariff barriers in trade of goods	Non-tariff barriers, trade in services, Intellectual property right
Very weak dispute settlement mechanism	Strong dispute settlement mechanism

TRIPs (Trade Related Intellectual Property Rights)

- ✓ The **TRIPs** (Trade Related Intellectual Property Rights) agreement forms a part of the **Uruguay Round to GATT** (General Agreement on Tariffs and Trade; signed by India and other countries).
- ✓ It is to date the **most comprehensive multilateral agreement on IPR**; it became **effective on January 1, 1995.**

What is Trade Related Intellectual Property Rights (TRIPs)?

- ❖ The Agreement on TRIPS is an **international legal agreement between all the member nations of the World Trade Organization (WTO).**
- ❖ **TRIPS was negotiated at the end of the Uruguay Round** of the General Agreement on Tariffs and Trade (GATT) between 1989 and 1990 and is **administered by the WTO.**
- ❖ TRIPs provide **minimum standards in the form of common set of rules for the protection of intellectual property globally under WTO system.**

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- ❖ The TRIPs agreement gives set of provisions deals with domestic procedures and remedies for the enforcement of intellectual property rights.
- ❖ TRIPs cover **eight areas for IPRs** legislation including **patent, copyright and geographical indications etc.**

World Intellectual Property Organization (WIPO)?

- Established in 1970.
- An **international organization dedicated to helping & ensure that the rights of creators and owners of intellectual property are protected worldwide, and that inventors and authors are therefore recognized and rewarded for their ingenuity.**
- This international protection **acts as a spur (encourages) to human creativity, pushing back the limits of science and technology and enriching the world of literature and the arts.**
- By providing a **stable environment for marketing products** protected by intellectual property, it also oils the wheels of international trade.
- **WIPO** works **closely with its Member States and other constituents** to **ensure the intellectual property system remains a supple (flexible/ not stiff) and adaptable tool** for **prosperity and well-being**, crafted to help realize the full potential of created works for present and future generations.

How does WIPO promote the protection of intellectual property?

- ✓ As part of the United Nations system of specialized agencies, WIPO serves as a forum for its Member States to establish and harmonize rules and practices for the protection of intellectual property rights.
- ✓ WIPO also services global registration systems for trademarks, industrial designs and appellations of origin, and a global filing system for patents.
- ✓ These systems are under regular review by WIPO's Member States and other stakeholders to determine how they can be improved to better serve the needs of users and potential users.
- ✓ Many industrialized nations have intellectual property protection systems that are centuries old. Among newer or developing countries, however, many are in the process of building up their patent, trademark and copyright legal frameworks and intellectual property systems.

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- ✓ With the increasing globalization of trade and rapid changes in technological innovation, WIPO plays a key role in helping these systems to evolve through treaty negotiation; legal and technical assistance; and training in various forms, including in the area of enforcement.
- ✓ WIPO works with its Member States to *make available information on intellectual property and outreach tools for a range of audiences – from the grassroots level through to the business sector and policymakers* –to ensure its benefits are well recognized, properly understood and accessible to all.

How is WIPO funded?

- WIPO is a largely **self-financed organization**.
- Generating more than **90 percent of its annual budget through its widely used international registration and filing systems, as well as through its publications and arbitration and mediation services.**
- The remaining funds come from contributions by Member States.

Treaties for IPR protection:

Industrial Property Treaties

- The Paris Convention for the Protection of Industrial Property (1883)
- The Madrid Agreement Concerning the International Registration of Marks (1891) and the Protocol Relating to that Agreement (1989)
- The Madrid Agreement for the Repression of False or Deceptive Indications of Source on Goods (1891)
- Hague Agreement Concerning the International Registration of Industrial Designs (1925)
- Nice Agreement Concerning the International Classification of Goods and Services for the Purposes of the Registration of Marks (1957)
- The Lisbon Agreement for the Protection of Appellations of Origin and their International Registration (1958)
- Locarno Agreement Establishing an International Classification for Industrial Designs (1968)
- The Patent Cooperation Treaty (PCT) (1970)
- The Strasbourg Agreement Concerning the International Patent Classification (1971)

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- The Vienna Agreement Establishing an International Classification of the Figurative Elements of Marks (1973)
- The Budapest Treaty on the International Recognition of the Deposit of Microorganisms for the Purposes of Patent Procedure (1977)
- The Nairobi Treaty on the Protection of the Olympic Symbol (1981)
- The Trademark Law Treaty (TLT) (1994)
- The Patent Law Treaty (PLT) (2000)
- The Singapore Treaty on the Law of Trademarks (2006)

MADRID PROTOCOL

MADRID SYSTEM FOR THE INTERNATIONAL REGISTRATION OF MARKS

The Madrid System is a centrally administered system by the International Bureau of the *World Intellectual Property Organization*(**WIPO**) **for obtaining a bundle of trademark registrations** in separate jurisdictions, creating in effect a basis for an **"*international registration*" of marks.**

Registration of trademarks in multiple jurisdictions around the world is Governed by two independent treaties:

- the **Madrid Agreement** (the Agreement) and
- the **Madrid Protocol** (the Protocol)

Together, the Agreement and the Protocol AKA the Madrid System.

THE MADRID AGREEMENT (established in 1891, 56 members)

- **1900 - 1967**: revised 6 times and amended once on **September 28,1979**
- **Single and inexpensive international trademark registration** to eliminate the need for filing, prosecuting or maintaining separate registrations in multiple countries

FEATURES OF THE MADRID AGREEMENT

- Should be first registered at the national level in the country of origin. The first registration is called **"basic registration"**
- International filing only **through Office of origin** to IB
- Country of origin has to be a **member state**
- **"Central Attack"** feature of the Agreement
- **Complementary fees**

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THE MADRID PROTOCOL

- was **adopted in 1989** to **correct the perceived deficiencies in the Agreement (80 members)**
- **Entry into force 1st Jan, 1995**
- Entered into **operation on 1st April, 1996**to create a system of simple and inexpensive international trademark registration

INNOVATIONS INTRODUCED BY MADRID PROTOCOL

- No need for **"Basic registration"**
- **Facilitates priority claim**
- Transforms an international registration into national application -**Remedies Central Attack Provision**
- Individual fee system

Difference between Mandrid Agreement & Protocol

CERTAIN DIFFERENCES	AGREEMENT	PROTOCOL
Accession	States	States and IGOs
Basic mark	Basic registration	Basic application/registration
Languages	French	French/English/Spanish
Fee system	Basic Complementary Supplementary	Basic Complementary Supplementary or Individual
Refusal period	12 months	12 months/18 months/18+ months
Dependency	5 years	5 years with possibility of transformation
Remedy to central attack	No recourse for the owner of IR	IR may be transformed into national application in each contracting party
Validity	20 years	10 years
Choice of office of origin	Real or effective industrial or commercial establishment	Establishment, domicile or origin

PROCEDURE FOR AN INTERNATIONAL APPLICATION

1. Filing international application of trademark
2. Check for minimum requirements by the Office of Origin

3. Certify the date of International Application and **conformity to the basic application/registration by the Office of Origin**
4. Transfer of the International Application to the International Bureau by the Office of Origin
5. Formality check by the International Bureau
6. Registration and Publication by the International Bureau

ADVANTAGES OF THE MADRID SYSTEM

- One application
- In one place
- One set of documents
- One fee
- One language
- No legalization necessary
- Resulting in one registration with one registration number and term
- Covering many countries
- One renewal date /only one renewal application necessary
- Simplified recordal of assignments, name changes, licenses, etc
- Filing under the Madrid is less time consuming

DISADVANTAGES OF MADRID SYSTEM

- **Expensive** (if more than a very limited number of countries)
- IR dependent on the basic mark for **5 years**
- **Central attack** – Possibilities of opposition or infringement actions in the country of origin
- **Specification of goods and services** – If the National Office is demanding

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THE BERNE CONVENTION

The **Berne Convention for the Protection of Literary and Artistic Works**, usually known as the **Berne Convention**, is an **international agreement governing copyright**, which was first accepted in **Berne, Switzerland, in 1886**

INTRODUCTION

- ✓ The Berne Convention for the Protection of Literary & Artistic Works, Adopted on **09 September 1886** is the **Oldest Comprehensive Multilateral Treaty in the Field of Copyright.**
- ✓ Initially the Berne Convention was **Signed by 8 Countries** and in 2004, it had **156 Members** therefore a Great Number of Nations have Formulated their own National Copyright Rules, by Broadly Conforming to the Norms Set by the Berne Convention.
- ✓ The Convention has **laid down Minimum Standards of Protection which have bound all Member States.**
- ✓ The World Intellectual Property Organization **(WIPO) has been created to administer this Instrument Universally.**

PRINCIPLES

- ***The Principle of National Treatment***

According to the Principle of ***National Treatment***, Works Originating in one of the Member States is to be Given the Same Protection in each of the Member States as they Grant to Works of their own Nationals.

- ***The Principle of Automatic Protection***

According to the Principle of ***Automatic Protection***, Such National Treatment is not dependent on any Formality that Protection is Granted Automatically, by Mere Creation of the Work and is Not Subject to the Formality like Registration/Deposit.

- ***The Principle of Independence of Protection***

According to the Principle of ***Independence of Protection***, Enjoyment & Exercise of the Rights Granted in a Member State to an Eligible Foreign Author is Independent of the Existence of protection in the Country of Origin of the Work.

- ***The Principle of Minimum Standards of Protection***

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According to the Principle of ***Minimum Standards of Protection***, each Country is required to Grant to Foreign Eligible Authors the Minimum Standards of Protection that are provided for in the

MINIMUM STANDARDS

The minimum standards of protection related **to the works and rights to be protected, and to the duration of protection:**

(a) **As to works**, protection must include "every production in the literary, scientific and artistic domain, whatever the mode or form of its expression" (Article 2(1) of the Convention).

(b) **The rights to be protected (recognized as exclusive rights of authorization):**

- the **right to translate**,
- the **right to make adaptations and arrangements of the work,**
- the **right to perform** in public dramatic, dramatico-musical and musical works,
- the **right to recite (deliver/perform)** literary works in public,
- the **right to communicate** to the public the performance of such works,
- the **right to broadcast**
- the **right to make reproductions** in any manner or form.
- The **right to use the work** as a basis for an audiovisual work, and the right to reproduce, distribute, perform in public or communicate to the public that audiovisual work.
- The Convention also provides for **"moral rights",** that is, the **right to claim authorship of the work** and the right to object to any mutilation, deformation or other modification of, or other derogatory (offensive) action in relation to, the work that would be prejudicial (harmful/hurtful) to the author's honor or reputation.

(c) As to the **duration of protection**,

- The general rule is that protection must be **granted until the expiration of the 50th year after the author's death**.
- In the case of audiovisual (cinematographic) works, the minimum term of protection is 50 years after the making available of the work to the public ("release").
- In the case of works of applied art and photographic works, the minimum term is 25 years from the creation of the work.

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LIMITATIONS

- The **Berne Convention allows certain** cases in which **protected works may be used without the authorization of the owner of the copyright, and without payment of compensation.**
- These limitations are commonly referred to as **"free uses"** of protected works, and are set forth in Articles 9(2) (reproduction in certain special cases), 10 (quotations and use of works by way of illustration for teaching purposes), 10*bis* (reproduction of newspaper or similar articles and use of works for the purpose of reporting current events) and 11*bis* (3) (ephemeral recordings for broadcasting purposes).

BUDAPEST TREATY

- The **Budapest Treaty on the International Recognition of the Deposit of Microorganisms for the Purposes of Patent Procedure**
- **Budapest Treaty**, is an international treaty signed in Budapest, Hungary, on **April 28, 1977.**
- It entered into force on August 9, 1980, and was later amended on September 26, 1980.
- The treaty is administered by the World Intellectual Property Organization (WIPO).
- **The proposal for International treaty on deposits of microorganisms was first put forward by United Kingdom.**
- At that time **18** countries ratified this treaty such as France, USA, UK, Italy etc.
- The **main objective** of this treaty is to **deposit live microorganisms for their patent purpose.**
- **To deposit live microorganisms in one place, member country has to develop IDA (International depositary authority)** where depositors can safely deposit live microorganisms.
- Today more than **80 countries** are part of this treaty and there are **39 IDAs in 22 countries.**
- To **get the membership** of Budapest treaty, each **country has to ratify Paris convention** which is related to protection of work having industrial application.
- **Budapest treaty is not only restricted to microorganisms** but plant and animal cells, hybridoma cell, cell lines, RNA, plasmids etc., can also be deposited in IDA.

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- **In 2001, India became part of Budapest treaty and currently there are two IDAs**, **Microbial Culture Collection (MCC) in National Centre for Cell Science (NCCS), Pune** and **Microbial Type Culture Collection and Gene Bank (MTCC) at Institute of Microbial Technology (IMTECH), Chandigarh respectively.**
- Along with **two IDAs**, **India has thirteen more culture collection centers known as designated repositories**, storing different kinds of biological resources and are recognized by National Biodiversity Authority

What is an IDA (International depositary authority)?

Any culture collection center can become IDA but it has to give assurance to members of Budapest treaty and World Intellectual Property Organization (WIPO) that…

- It will deposit microorganism from any depositors.
- It will accept and store microorganism in safe and proper manner and furnish the sample to any authorized person as per the requirement in strict manner
- Obeying all the rules and regulations of Budapest treaty.

Main functions of IDA:

1. **Storage of microorganisms** for patent purpose;
2. **Long term storage** of microorganisms in **safe manner**;
3. **Furnishing of samples** as **per the requirement**;
4. **Creates an environment of good microbiological practices**;
5. **Identification and characterization of samples**;
6. **Gives accession number to samples**;
7. **Maintain secrecy** of deposited microorganisms;
8. Provides human resource work such as **training program related to microbial techniques;**
9. **Protection of environment**;
10. **Proper transport of sample**.

Depositable subject matter

The range of materials able to be deposited under the Budapest Treaty includes:

- cells, for example, bacteria, fungi, eukaryotic cell lines, plant spores;
- genetic vectors (such as plasmids or bacteriophage vectors or viruses) containing a gene or DNA fragments;
- organisms used for expression of a gene (making the protein from the DNA).

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Main or Key Features of the Budapest Treaty

1) **IDA formation and recognition of single deposition of microorganisms for patent purpose:**

- Budapest treaty has given **clear rules and regulations of creating and maintenance of IDA, daily working protocol of IDA and guidelines to depositor.**
- It was decided that **each member country will make IDA** for microorganisms deposition with **full infrastructure facility,** also the **IDA will accept microorganisms from depositors of native country as well as outside from country.**
- **One of the burning issue** that was **solved in this treaty was to stop multiple deposition of sample in more than one IDA for patent purpose.**
- The treaty says that **single deposition of sample for patent purpose in IDA will be enough to give recognition by other member countries of Budapest treaty**

2) Broad definition of microorganisms:

Budapest treaty has not defined the definition of microorganisms; because of this situation **today not only microorganisms but plasmid, cell lines, fungi, yeast, RNA, plant and animal cells etc., can also be deposited.**

3) Safe deposition of microorganisms:

It is the **duty of IDA to safely deposit microorganisms without affecting its viability and purity.**

4) Deposition and furnishing of samples:

A brief rule and regulation is given for deposition of samples. Further, sample can be **stored up to 5 to 30 years in IDA**. Also, IDA has to furnish samples to depositor or concern authority as per the requirement.

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NAGOYA PROTOCOL

What is the Nagoya Protocol and what is its objective?

- The *Nagoya Protocol on* ***Access to Genetic Resources*** *and* ***the Fair and Equitable Sharing of Benefits Arising from their Utilization to the Convention on Biological Diversity*** is a supplementary agreement to the Convention on Biological Diversity.
- The Nagoya Protocol was adopted on **29 October 2010 in Nagoya, Japan** and entered into force on 12 October 2014,
- **Its objective** is the **fair and equitable sharing of benefits arising from the utilization of genetic resources**, **thereby contributing to the conservation and sustainable use of biodiversity.**

Why is the Nagoya Protocol important?

The Nagoya Protocol will **create greater legal certainty and transparency** for both **providers as well as users of genetic resources** by:

- **Establishing more predictable (probable) conditions for access to genetic resources**.
- H**elping to ensure benefit-sharing**, the Nagoya Protocol **creates incentives (encouragement/supports) to conserve and sustainably use genetic resources, and therefore enhances the contribution of biodiversity to development and human well-being.**

What does the Nagoya Protocol cover?

- The Nagoya Protocol **applies to genetic resources that are covered by the CBD**, and **to the benefits arising from their utilization.**
- The Nagoya Protocol also **covers traditional knowledge (TK) associated with genetic resources** that are covered by the CBD and the benefits arising from its utilization.

What are the core obligations (duties / responsibilities) of the Nagoya Protocol with respect to genetic resources?

The Nagoya Protocol sets out core obligations for its contracting parties to take measures in relation to **access to genetic resources, benefit-sharing and compliance (obedience).**

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1) Access obligations: Domestic-level access measures are to:

- **Create legal certainty, clarity and transparency**
- **Providefair (neutral) and non-arbitrary (fix) rules and procedures**
- **Establish clear rules and procedures** for prior informed consent and mutually agreed terms
- Provide for **issuance of a permit** when access is granted
- Create conditions to **promote and encourage research** contributing to biodiversity conservation and sustainable use
- **Consider the importance of genetic resources for food and agriculture for food security**

2) Benefit-sharing obligations

- Domestic-level benefit-sharing measures are to provide for the **fair and equitable sharing of benefits arising from the utilization of genetic resources** with the contracting party providing genetic resources.
- **Utilization includes research and development on the genetic or biochemical composition of genetic resources**, as well as **subsequent applications and commercialization**. Sharing is subject to **mutually agreed terms**. **Benefits may be monetary or non-monetary** such as royalties and the sharing of research results.

3) Compliance obligations

- **Take measures providing that genetic resources utilized within their jurisdiction have been accessed in accordance with prior informed consent**, and that **mutually agreed terms** have been established, as required by another contracting party
- **Cooperate in cases of alleged violation of another contracting party's requirements**
- **Encourage dispute resolution in mutually agreed terms**
- **Monitor the use of genetic resources after they leave** a country by designating effective checkpoints at every stage of the value-chain: **research, development, innovation, pre-commercialization, or commercialization**

Tools and mechanisms to assist implementation

The Nagoya Protocol's success will require effective implementation at the domestic level. A range of tools and mechanisms provided by the Nagoya Protocol will assist contracting Parties including:

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- **Establishing national focal points (NFPs) and competent national authorities (CNAs) to serve as contact points for information, grant access or cooperate on issues of compliance** (obedience)
- **An Access and Benefit-sharing Clearing-House to share information**, such as domestic regulatory requirements or information on NFPs and CNAs
- **Awareness-raising**
- **Technology Transfer**
- **Targeted financial support for capacity-building and development initiatives through the Nagoya Protocol's financial mechanism, the Global Environment Facility (GEF).**

The Paris Convention

- The Paris Convention for the Protection of Industrial Property (1883).
- The Paris Convention applies to industrial property in the widest sense, including patents, trademarks, industrial designs, utility models (a kind of "small-scale patent" provided for by the laws of some countries), service marks, trade names (designations under which an industrial or commercial activity is carried out), geographical indications (indications of source and appellations of origin) and the repression of unfair competition.

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-:Types of IPR and legislations covering IPR in India:-

What are the Legislations Covering IPRs in India?

- **Patents:** The Patents Act, 1970 as amended in 1999, 2001 and 2005
- **Design:** The Designs Act, 2000
- **Trade Mark:** The Trade Marks Act, 1999
- **Copyright:** The Copyright Act, 1957 as amended in 1983, 1984 and 1992, 1994, 1999
- **Layout Design of Integrated Circuits:** The Semiconductor Integrated Circuits Layout Design Act, 2000.
- **Protection of Undisclosed Information (Trade Secret):** No exclusive legislation exists but the matter would be generally covered under the Contract Act, 1872.
- **Geographical Indications:** The Geographical Indications of Goods (Registration and Protection) Act, 1999
- **Plant Varieties:** The Protection of Plant Variety and Farmers' Rights Act, 2001.

REGISTRATION:

- IP can be either registered or unregistered.
- With unregistered IP, you automatically have legal rights over your creation.
- Unregistered forms of IP include copyright, unregistered design rights, common law trade marks and database rights, confidential information and trade secrets.
- With registered IP, you will have to apply to an authority, such as the Intellectual Property Office in the UK, to have your rights recognised.
- If you do not do this, others are free to exploit your creations.
- Registered forms of IP include patents, registered trade marks and registered design rights. Copyright is also registerable.

TREATIES AND RECIPROCAL AGREEMENTS:

India is also a signatory to the following international IP agreements:

- The Paris Convention – under this, any person from a signatory state can apply for a patent or trade mark in any other signatory state, and will be given the same enforcement rights and status as a national of that country would be;

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- The Berne Convention – under this, each member state recognises the copyright of authors from other member states in the same way as the copyright of its own nationals.
- The Madrid Protocol – under this, a person can file a single trade mark application at their national office that will provide protection in multiple countries;
- The Patent Cooperation Treaty – this is a central system for obtaining a 'bundle' of national patent applications in different jurisdictions through a single application.

India is not a signatory to the Hague Agreement, which allows the protection of designs in multiple countries through a single filing.

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-:PATENTS:-

A patent is the right granted by a government to an inventor to exclude others from imitating (copying/duplicating/reproducing), manufacturing, using or selling the invention in question for commercial use during the specified period.

- It is an official document which grants sole rights to the inventor for manufacturing and marketing his product/process/invention to derive benefit.
- In other words, it is legal document issued by a government that grants exclusive rights for the production, sale and profit from the invention of a product or process for a specific period of time.
- Patent is a set of exclusive rights granted by government to a patentee for a fixed period of time.
- This right allow the patent owner to prevent others from manufacturing, using or selling the invention protected by the patent.

Patents are granted for

- **An invention**
- **Innovation/Improvement in an invention**
- **The process/product of an invention**
- **A concept.**

Patent Requirements

The chief requirements for the grant of patent are as follow:

1. **Novelty**
2. **Inventiveness**
3. **Industrial application and Usefulness**
4. **Patentability**
5. **Disclosure**

1. Novelty:

The invention must be **new** and should **not already known to the public.**

2. Inventiveness:

The invention should not be obvious to a person skilled in the art and **should represent an innovation**.

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3. Industrial application and Usefulness:

The subject matter of the patent must have an **industrial application**, **either immediate or in the future**, that is useful to the society/nation.

4. Patentability

- The **subject matter of a patent must be patentable** under the existing law and its current interpretation.
- **The Indian patent act does not permit the patenting of any contrary to natural laws, existing laws or morality or injurious to public health.**
- Further a **scientific principle, an abstract theory, a discovery of new property, new use for known substance, method of agriculture or horticulture and inventions relating to atomic energy are not patentable.**
- The **patentability** of subject matter **depends** not only on the **patent laws of a country** but also on their **currently accepted interpretation.**
- The implication and interpretations of the various provisions of patent act of any country require specialist patent attorneys, who are helpful in filing of patent applications, contesting/defending such applications and in enforcing the rights accruing from patents to the inventors.

5. Disclosure

- The **inventor is required to describe his invention in sufficient detail** so that a **person of normal skill is able to reproduce it**.
- In **case of biological entities**, **already known organisms may be simply named.**
- In **case of organism has been genetically modified**, **the nature and method of modification has to be described fully.**
- **A sample of the microorganism, cell line etc.** being patented may be required to be **deposited in the designated culture collection**.
- The deposited material serves the following two purpose.

a) **As a reference** in cases of disputes concerning its novelty or unauthorized use

b) **As a source** for the microorganisms, cell lines etc. to the authorized users.

- The disclosure of an invention gives an opportunity to other inventors to improve upon the various features of the invention so that it becomes more efficient and useful.

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Limits of Patent

There are two basic limitations of patent.

1. **Limitation of Time:** A patent is **valid for a specified period, 15-20 years** from the date of its awarded in most countries.
2. **Limitation of Space:** A patent is **valid only in the country** of its award and not in other countries.

A group of nations may agree to honor the patents awarded by any member country. **WTO has similar provision, that patent awarded by WTO will be valid in all member countries.**

Indian Patent System

- **1858**: The **Act VI of 18**56 protection of inventions based on the British Patent law of 1852. **Certain exclusive privileges granted to inventions of new manufactures for a period of 14 years**.
- **1859**: The **Act VI was notified as Act XV**, patent monopolies called **exclusive privileges (making, selling and using inventions in India and authorizing to others to so for 14 years from date of filing specification.**
- **1872: The Patents and Designs protection Act was enacted.**
- **1883: The protection of invention Act was created**.
- 1888: The **Act was consolidated as the inventions and Design Act.**
- **1911: The Indian Patents and Designs Act was created.**
- 1970: **The Patents Act (Act 39 Of 1970) came into force on 20 April, 1972.**
- 1999: The Patents (Amendment) Act, 1999 came into force on 26 March.
- 2002: The Patents (Amendment) Act, 2002 came into force from 20 May, 2003.
- 2005: The Patents (Amendment) Act, 2005 effective from 1 January, 2005.
- 2006: The Patent (Amendment) Act, 2006, **focused on the introduction of reduced time and a fee structure** based on specification size and number of claims, in addition to a basic fee.
- 2012: The Patents (Amendment) Act, focused on **change in marks of patent Agent Examination.**
- 2014: The Patents (Amendment) Act, 2014, **adding a clause "small entity" and revised fees structure.**

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- 2016: The Patents (Amendment) Rules, 2016, the **Government announced India's first IPR Policy and amended patents rules in effect from 16 May, 2016.**

The Patent Act, 1970

- **The patent Act, 1970** is **a landmark in the industrial development of India**. The **basic philosophy of the Act** is that **patents are granted to encourage "invention and to ensure that these inventions are worked on commercial scale without undue delay**.
- "**An invention** means **a new product or process involving an inventing step and capable of industrial application"**
- The **world "Invention"** has been **defined under the Patent Act 1970** as amended from the time to time as
- "**New invention**" is defined **as any invention or technology which has not been anticipated by publication in any document or used in the country or elsewhere in the world before the date of filing of patent application with complete specification, i.e. the subject matter has not fallen in public domain or that it does not from part of the state of the art.**
- The patent is an exclusive right granted by a country to the owner of an invention to make, use, manufacture and market the invention, provided the invention satisfies certain condition stipulated in the law.
- The law may relate to health, safety, food, security etc. Further, existing patents in a similar area may also come in the way.
- A patent in the law is a property right and hence, can be gifted, inherited, assigned, sold or licensed.
- As the right is conferred by the state, it can be revoked by the state under very special circumstances even if the patent has been sold or licensed or manufactured or marketed in the meantime.
- The patent right is territorial in nature and inventors/ their assignees will have to file separate patent applications in countries of their interest, along with necessary fees, for obtaining patents in those countries.
- By virtue of the grant of a patent, patentee gets the exclusive rights in his favour that prevent the third parties (not having his consent) from making, using, offering for sale, selling or importing the patented product or process within the territory of grant.

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- The basic obligation in the area of patent is that, invention in all branches of technology whether products or process shall be patentable if they meet the three test of: being new, involving an inventive step and being capable of industrial applications. In addition to the general security exemption which applies to the entire TRIPS Agreement.
- The TRIPS Agreement provides for a minimum term of protection of 20 years counted from the date of filing.
- India has already implemented its obligations under Articles 70.8 and 70.9 of TRIPS Agreement.
- A comprehensive review of the Patent Act 1970 was also made and a bill to amend the Patent Act, 1970 was introduce in Parliament on 20th December 1999 and notified on 25.6.2002 to make the Patents law TRIPS compatible.
- India amended its patents Act again in 2002 to meet the second set of obligations (Term of Patent etc.) which had to take effect from 1.1.2000.
- This amendment, which provides for 20 years term of the patent, reversal of burden of proof etc; came into force on 20th May, 2003.
- The third amendment of the patent Act, 1970, by way of the patents (amendment) ordinance 2004 came into force on 1St January, 2005 incorporating the provisions for granting product patent in all fields of Technology including chemicals, food, drugs and agrochemicals and this ordinance has been replaced by the Patents (Amendment) Act, 2005 which has been force now with effect from 1.1.2005.

Patentable inventions under the patent Act, 1970

- Art, process, method or manner of manufacture
- Machine, apparatus or other article, substances produced by manufacture, which include any new and useful improvement of any of them and alleged invention.
- However, inventions claiming substance intended for use, or capable of being used, as food or as medicine or drug or relating to substances prepared or produced by chemical process (including alloys, optical glass, semi conductors and inter-metallic compounds) are not patentable.

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Types of Inventions which are not Patentable in India

An invention may satisfy the condition of novelty, inventiveness and usefulness but it may not quality for patent under the following situations:

- An invention which is frivolous (perky) or which claim anything obviously contrary to well established natural laws e.g. different types of perpetual motion machines.
- An invention the primary or intended use of which would be contrary to law or morality or injurious to public health e.g. a process for the preparation of a beverage which involves use of a Carcinogenic substances, although the beverage may have higher nourishment value.
- The mere discovery of a scientific principle or formulation of an abstract theory e.g. Raman Effect.
- The discovery of any new property or new use of known substance or the mere use of a known process, machine or apparatus unless such known process results in a new product or employs at least one new reactant.
- A substance obtained by a mere admixture resulting only in the aggregation of the properties of the compounds thereof or a process for producing such substance.
- The mere arrangement or rearrangement or duplication of future known devices each functioning independently of one another in a known way.
- A method of agriculture or horticulture
- Any process for medical, surgical, curative, prophylactic or other treatment or human beings, or any process for a similar treatment of animal and plants.
- Inventions relating to Atomic energy.

Process and Product Patent

- There is strict divergence between product and process patent regimes.
- The developed countries follow product patent system.
- On the other, process patent system is preferred by the developing world.
- The two systems are known for their different levels of protection to inventors.

<u>In the case of PROCESS PATENT</u>

Under a process patent, the patent is granted for a particular manufacturing process and not for the product itself.

- Any other person can produce the same product through some other PROCESS, modifying the various parameters.

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- The implication is that there will be more than one producer for the same product because of the possibility of different process for the manufacturing of the product.
- Weakness of the process patent regime is that it gives less protection for the inventor. There is high tendency for competitors to reengineer the original invention by discovering a new process with less strain and investment.
- Benefit of process patent regime is that it reduces the element of monopoly.

In the case of PRODUCT PATENT,

- It is an **exclusive right given to the original inventor of a product**. This means that **no other manufacturer can provide the same product through the same or any other process.**
- The implication is that **there will not be a competitor for the producer as it is the product which is patented.**
- Product patent system **gives higher level of protection to the inventor as there will not be any other patent holder.**
- **TRIPs follow the product patent regime.**
- **India's 1970 Patent Act allowed only process patent before it was amended in 2005** to comply with WTO's TRIPs provisions under which there is only product patents.

PATENT FILING

- **The term patent application** refers to **the legal and administrative proceedings of requesting the issuance of a patent for an invention,** *as well as to the physical document and content of* the *description and claims of the invention, including its procedural paper work.*
- **The forms can be submitted online through website http://ipindiaonline.gov.in/epatentfiling/goForLogin/doLogin) if you have a class 3 digital certificate.**
- **Alternatively, you can send true copies (hard copies) to the patent office. The patent office charges 10% additional fee if applications are filed offline.**
- Please note that, the **most important factor in filing a patent application is preparing a patent specification.**
- **Drafting a patent specification is a highly skilled job**, which can be **only preformed by persons who have both technical as well as patent law expertise**.

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- If a person or company is serious about protecting their intellectual property, it is **highly recommended to use the services of professional patent practitioners**.
- **Indian patent offices are located at Delhi, Kolkata, Mumbai and Chennai.**
- The patent application has to be filed in the appropriate office based on your/your company's location.

What is the Cost of Filing a Patent Application in India?

No.	Action	Limits, conditions and timelines	Official Fees	
			Individual	Legal entity
1.	Filing of patent application along with complete/provisional specification	For maximum number of pages 30 and maximum number of claims 10	Rs.1000/-	Rs.4000/-
		For each additional sheet	Rs.100/-	Rs.400/-
		For each additional claim	Rs.200/-	Rs.800/-
2.	Request for examination of patent		Rs.2,500/-	Rs.10,000/-
3	Request for early publication		Rs.2,500/-	Rs.10,000/-
4.	Renewal fee (every year)	2nd year to 6th year	Rs.500/-	Rs.2,000/-
		7th year to 10th year	Rs.1500/-	Rs.6000/-
		11th year to 15th year	Rs.3000/-	Rs12,000/-
		16th year to 20th year	Rs.5000/-	Rs.20000/-

Forms are required to be filled for filing of a patent application in India

- Form-1*: Application for grant of a patent
- Form-2*: Provisional/Complete Specification
- Form-3*: Statement and undertaking foreign applications
- Form-5 : Declaration as to inventor ship
- Form-8: Request or claim regarding mention of inventor as such in a patent
- Form-9: Request for early publication
- Form-18*: Request for examination of a patent application
- Form-26: Form of authorization of a Patent Agent

Note:- * indicates this forms are mandatory for filling of patent

PATENT SPECIFICATION

Provisional Specification

- A provisional specification is usually filed to establish priority of the invention in case the disclosed invention is only at an early stage and a delay is expected in giving final shape to the invention.
- Although, a patent application accompanied with provisional specification does not confer any legal patent rights to the applicant, it is, however, a very important document to establish the earliest ownership of an invention.
- The provisional specification is a permanent and independent scientific cum legal document and no amendment is allowed in this.
- **No patent is granted on the basis of a provisional specification**. It has to be followed by a complete specification for obtaining a patent for the said invention. **Complete specification must be submitted within 12 months of filing the provisional specification.**
- This period is non-extendible. **It is not necessary to first file an application with provisional specification and then the complete specification.**
- **An application with complete specification can be filed right at the first instance.**

Complete Specification

- Title of the invention.
- Field to which the invention belongs.
- Background of the invention including prior art giving drawbacks of the known inventions & practices.
- Complete description of the invention along with experimental results.
- Drawings etc. essential for understanding the invention.
- Claims, which are statements related to the invention on which legal proprietorship is being sought. Therefore, the claims have to be drafted very carefully.
- Abstract of the invention.
- If a biological material is mentioned in a specification; then the source and geographical origin of the same is to be disclosed in the specification.
- For new biological material, registration number of the same given by an International Depositary Authority (IDA) is to be included in the specification along with its

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address. [Institute of Microbial Technology (IMTech), Chandigarh is a recognized IDA in India]

PATENT CLAIMS

- In simple terms, **the claims define the actual area of exclusivity or protected features of an invention or the patent.**
- **The claim includes the features or aspects of the invention which the patentee can stop others from making, using and selling without his/her permission.**
- A claim is a statement of **novel technical features expressed in terms which define the scope of the invention sought to be protected.**
- As stated above the **claims are the defining boundary of a patent, tells third parties what they can and cannot do where the said invention is concerned.**
- **Therefore, in an application for patent, the claims are of paramount importance** in patent prosecutions at the Patent Office and in a patent litigation before the courts.
- This is the **most important section of a Patent.** Claims are set with a boundary of the invention.

PATENT OPPOSITIONS

- **Patent opposition in India can be done**, either before the patent is granted, by filing **pre-grant opposition** by representation, or after the grant of the patent **within a year, by filing a post grant opposition.**
- **Pre-grant opposition can be filed after the publication of patent application and before the grant of patent.**
- **Post-grant opposition** *can be filed within one year of the grant of the patent.*
- An opposition board will be constituted for each of the opposition notifications accepted by the Controller for the post grant opposition proceedings.

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GROUND FOR PATENT OPPOSITIONS

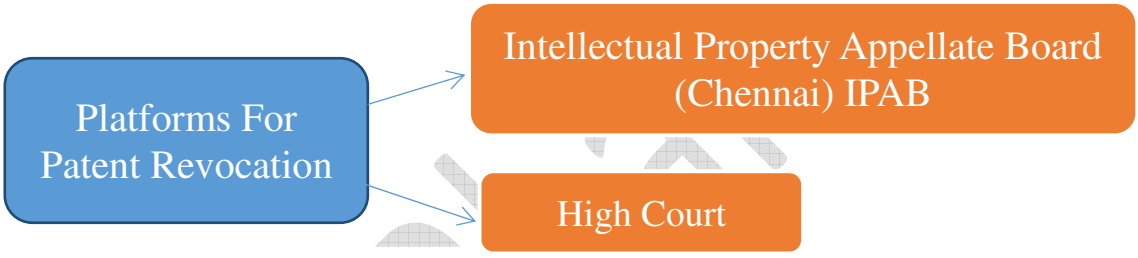
- **The grounds of opposition are provided under section 25 (1) of the Indian Patent Act 1970**
- Claimed invention or its part **wrongfully obtained;**
- **Claimed invention** is **published in a patent or any other document** before the priority date;
- Claimed invention is published in a patent after the priority date having earlier priority date;
- Claimed invention was **publicly known or publicly used before the priority date;**
- Claimed invention is **obvious (understandable) and does not involve clearly any inventive step**, as regards to the matter published or used (in India) before the priority date;
- Claimed invention is **not an invention within the meaning of the Patents Act or is not patentable under the Patents Act;**
- **The complete specification does not sufficiently and clearly describe the invention or the method by which it is to be performed;**
- The **applicant has failed to disclose** to the Controller the **information regarding foreign applications filed by him for the same invention** or has furnished the information which in any material particular was **false to his knowledge**;
- **In case of convention (agreement/settlement) application if the application is not filed before the expiry of 12 months from the date of first application in convention country;**
- **The complete specification does not disclose or wrongly mentions the source and geographical origin of biological material used in the invention;**
- Claimed invention was anticipated having regard to the knowledge, oral or otherwise available within any local or indigenous community in India or elsewhere.

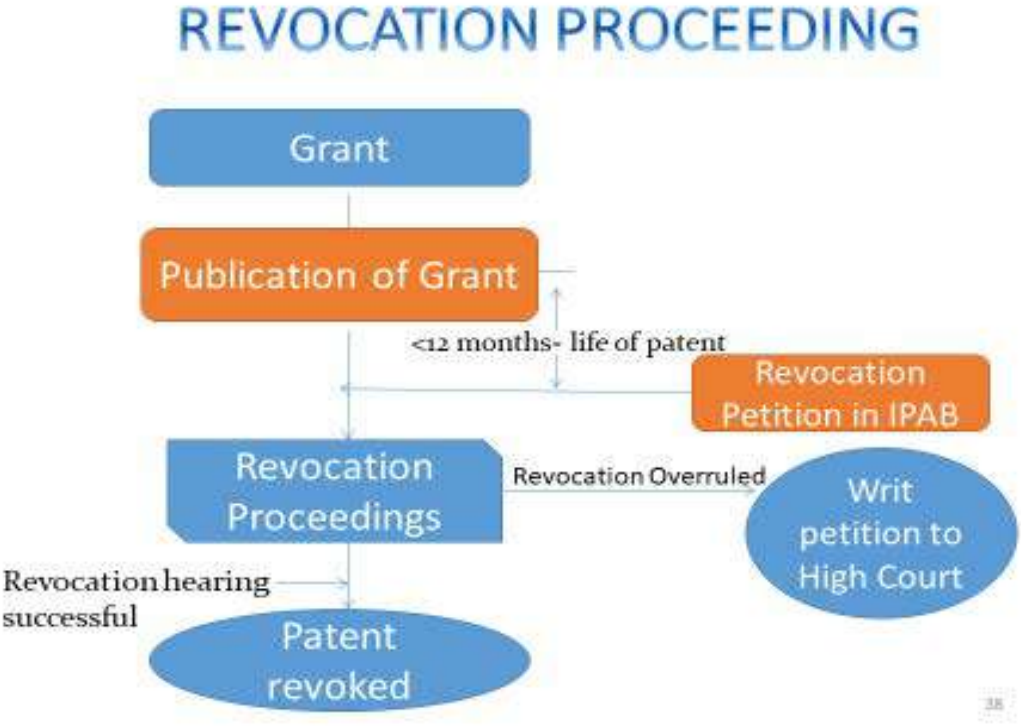
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PATENTS REVOCATION

- Revocation of patents can be made under Section 64 of the Indian Patents Act 1970.
- Revocation means: Cancellation of the rights granted to a person by the grant of a patent.
- The patent can be revoked on petition of any person interested or of the Central Government or on a counter claim in a suit for infringement of the patent by the High Court or on the basis of the grounds mentioned in section 64.

PATENT REVOCATION PLATFORMS





REVOCATION PROCEEDING CONTD...



Ground for Patents Revocation

- The Claims are invalid;
- The Patentee is not entitled for the patent;
- Wrongful obtainment of patent;
- The subject of any claim is not an invention;
- The subject of the invention is not new;
- The subject claimed is obvious;
- The subject claimed is not useful;
- The description of the invention as disclosed in the specification is not elaborate;
- The scope of invention disclosed in claims is insufficient;
- The patent was obtained on a false suggestion or representation;
- The subject in claim not patentable matter;
- The invention was secretly used in India before the priority date;
- The details under section 8 not been disclosed or wrongfully disclosed;
- Secrecy direction has been issued against the invention;

- The amendment of patent application stands outside the section 57 or section 58;
- The origin of biological material was wrongfully disclosed or not disclosed;
- The invention claimed is anticipated (expected/known earlier) by prior knowledge in any local community;

Initiation of Patents Revocation Proceeding

1. Central Government

- Central Government directs the Controller to revoke the patent,

✓if the invention relates to defense purposes,

✓if the patent is for an invention relating to atomic energy, and

✓if the Central Government feels that the patent or the manner in which it is exercised is prejudicial (harmful / detrimental) to public

2.Revocation of patents in the High Court as counter claim in an infringement suit

3. Controller

- If a compulsory license has been granted for a patent, and if a person applies to the Controller on the ground that the patented invention is not worked at the optimum to meet the requirements of the public.
- If an independent patent has been granted for any modification or improvement on the main invention, the Controller on the patentee's request may revoke the independent patent on modification of that invention and grant him patent of addition. {S.54(2)}
- If the patentee surrenders the patent the Controller may revoke the patent.

PATENTS INFRINGEMENT

Patent infringement is the commission of a prohibited act with respect to a patented invention without permission from the patent holder.

An invention is considered to be infringed when:

- Any immaterial (irrelavant) variation in the invention
- Mechanical equivalents
- Colorable imitation of an invention
- Imitation (copying/misuse) of essential features of the invention

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An act is considered to be an infringement when:

- The patented product is made, used, distributed, sold or imported
- The patented process has been used, or used, offered for sale, sold or imported the product directly obtained by that process

Procedure for filling suit for infringement

- A suit for infringement has to be **filed in a District or High court within whose territorial jurisdiction the cause of action has arisen,**
- However as soon as a counter claim for revocation of patent is filled against the suit for infringement of patent,
- **Only high court has the jurisdiction of entertain the matter and the matter has to be transferred to high court for decision.**

COMPULSORY LICENSING

- Compulsory licensing is when a government allows someone else to produce a patented product or process without the consent of the patent owner or plans to use the patent-protected invention itself.
- In essence, under a compulsory license, an individual or company seeking to use another's intellectual property can do so without seeking the rights holder's consent and pays the rights holder a set fee for the license.
- This is an exception to the general rule under intellectual property laws that the intellectual property owner enjoys exclusive rights that it may license – or decline to license – to others.
- It is one of the flexibilities in the field of patent protection included in the WTO's agreement on intellectual property — the TRIPS (Trade-Related Aspects of Intellectual Property Rights) Agreement.

PATENT COOPERATION TREATY

- The Patent Cooperation Treaty (PCT) is a multilateral treaty entered into force in 1978.
- Through PCT, an inventor of a member country (Contracting State) of PCT can simultaneously obtain priority for his/her invention in all the member countries,

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without having to file a separate application in those countries, by filing of PCT application, which is popularly known as International Application.

- India joined the PCT on December 7,1998.
- All activities related to PCT are coordinated by the World Intellectual Property Organization (WIPO) situated in Geneva.

Which is the appropriate office in India in relation to PCT applications?

- A PCT application can be filed in any of the Branch Offices of the Patent Office located at New Delhi, Chennai, Mumbai and Kolkata (Head Office).
- Any of these Offices shall function as a receiving office, designated office and elected office for the purpose of international applications filed under the Treaty.
- An international application shall be filed in the Patent Office which would process the application in accordance with these rules and the provisions under the PCT.

Cost of filing a PCT application

The cost of filing a PCT application by an Indian Applicant is as follows:

1.	Transmittal Fees	Rs.8,000/- for legal entity and Rs.2000/- for individuals
2.	International Filing Fee	US$ 1,367 (will be increased to US$1,520 w.e.f. 01.09.2011
3.	Fee per sheet over 30 sheets	US$15 (will be increased to US$17 w.e.f. 01.09.2011)
4.	Search Fee	US$ 314 to US$ 2,443 depending on the International Searching Authority (ISA) selected by the applicant

PATENT SEARCH

- A patent search is prudent (practical) and cost effective process of searching for all issued patents or published patent applications related to your invention.
- Based on the patent search results, you can determined whether your invention is patentable and to what degree it is patentable.
- It is primarily focused on determining what similar inventions are already patented.

- There is no cost for doing a patent search in India**.** A patent search can be done through the Patent database of India available at: **http://ipindiaservices.gov.in/publicsearch**.
- A search may not only help inventors decide whether to pursue a patent but also to modify their efforts to improved the probability of getting a patent.
- Knowing the prior art related to your invention guides the patent applicant in drafting the patent application necessary to properly disclose applicant's novel invention.
- We need to conduct a search of issued patents, published patent applications or other published or public information to evaluate whether any part of your invention or idea has been patented, published or disclosed previously.
- A patent gives its owner the right to prevent others from making, using, importing or selling the invention without approval. Before such a right is granted, there obviously is a rigorous check on whether the process or product is inventive (i.e. isn't obvious), novel (hasn't been anticipated in any published document) and industrially applicable (possesses utility).
- It involves a search of the database of the intellectual property regulator of India to check whether there exists an object or invention that is the same as or similar to applicant's invention. This is also known as a prior art search.

Importance of Patent Search

- Before filing a patent application, a patent search can help with different objectives like:
- **Determining the probability of having a patent** granted to a proposed invention.
- Determining the **claims to be filed in the patent application.**
- Determining the **freedom to operate.**
- Determining **whether a granted patent can be invalidated.**
- **Knowing more about similar inventions and status of similar patent filings.**

Patent Database

A database is a collection of information that is organized so that it can easily be accessed, managed, and updated. In one view, databases cam be classified according to types of content: bibliographic, full-text, numeric and images

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Importance of Patent Database:

Patent information is commonly not available in developing countries. There are significant obstacles to identifying the patent status of any particular even in rich countries. There are many patents filed on various products. Patent application may be easily searchable.

PATENT DATABASES:

1. **PatentScope (WIPO)**
2. **EKASWA**
3. **EPIDOS-INPADOC**
4. **Canadian Patents Database (CIPO)**

1. PatentScope (WIPO)

- Patent Scope is the public database of record for Primary Care Trust (PCT) international patent application published by the World Intellectual Property Organization (WIPO).
- It contains approximately 1.7 million international application published from 1978 forward.
- In 2009, WIPO extended PatentScope to include national patent application collection from the African Regional Intellectual Property Organization, Cuba, Israel, Korea, Mexico, Singapore, South Africa and Vietnam.
- The largest of these are Korea (1.3 million documents from 1973-2007), Mexico (1,80,000 documents from 1991-2009) and Israel Mexico (1,44,000 documents from 1990-1999).
- WIPO also introduced a new search interface with simple, structures and browse function, and the option to display search results as table or graphs.

2. EKASWA

EKASWA is India's first patent database hosted by technology information and forecasting Assessment Council (TIFAC). As a first step in this direction a Patent Facilitating Centre (PFC) was set up by Department of Science and Technology Information Forecasting and Assessment Council (TIFAC). In 1995.

The patent search involves three levels

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1. A bibliographic report on patents granted/published in US, Europe, PCT and India are provided to the client.
2. Providing the abstracts of the relevant patents as requested by the client.
3. Providing full text document of the patents

3. EPIDOS-INPADOC

- EPIDOS-INPADOC is complete database under the National Informatics Centre (NIC). It is one of the most comprehensive database on the patent bibliography.
- This database is known as EPIDOS (European Patent Information & Document Service). European Patent Office (EPO) publishes this database.
- EPO has been receiving the bibliography of all the patents filed and granted in approximately 71 countries since 1968 onwards.
- Almost 3 million references are added each year. Awe live in the age of the information technology (IT).
- The universal acceptance of the power of IT to transform and accelerate the development process, especially in developing economies is indisputable.

4. Canadian Patents Database (CIPO)

- The Canadian Patents Database, which is maintained by the Canadian Intellectual Property Office, contains more than two millions Canadian Patens and published application from 1869 to present.
- This database lets you access 92 years of patents descriptions and images. You can search, retrieve and study more than 21,10,000 patent documents. Full text images are available from 1920 onwards. Recent improvements includes a few aesthetic changes to search interface and the inclusion of a representative drawing (if available) displayed in the bibliographic record. In addition, as of January 2,92,010 abstracts in both English and French are available for application field under the PCT

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-:GEOGRAPHICAL INDICATION:-

A geographical indication is a **sign used on goods that have a specific geographical origin and often possess qualities or a reputation that are due to that place of origin.**

Main points about geographical indication are given below

1. Geographical indication may be an **agricultural, natural or manufactured goods or product.**
2. About **170 geographical indication have been registered by Lisbon Agreement** members up to 1997. Now this number would much more.
3. In **past, wines, spirits, cheeses, tobacco**, which account for 88 per cent, have been registered as GI.

- According to TRIPS agreement of GATT(1994), GIs are indication which identify a good as originating in the territory of a member or a region are a locality in that territory, where a given quality, reputation or characteristics of the goods is essentially attributable to its geographical origin.
- Suitable laws have to be enacted by concerned countries to avail protection under the provisions of geographical indications.
- Such a legislation clearly specifies the products that have been accepted in terms of quality and other characteristics to have originated from given specific localities.
- The GIs, once enforced by legislation, exclude others from using GI as trademark for particular product because such use is likely to mislead to consumer about the place of origin of the product.
- GIs cover agricultural goods, natural products, manufactured products, goods of handicraft and even food product, but they do not apply to intellectual property.
- India has enacted the Geographical Indications of Goods Act (1999), which came into force on Sept. 15, 2003.

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India's famous GIs

- Darjeeling tea became the first GI tagged product in India, in 2004-05, since then by September 2010, 184 had been added to the list.

- *Banarasi* silks
- *Paschmina* shawls
- *Kashmir* carpets
- *Basmati* rice
- *Darjeeling* tea
- *Assam* tea
- *Bengal* Cotton
- *Alphonso* Mangoes
- *Pochampalli* silk
- *Chanderi* silk
- Hyderabad pearls
- Kerala Nendran bananas
- Jaipur silver jewellery
- *Nilgiri* tea
- *Coorg* coffee
- *Mysore* sandal products
- *Mysore* silk
- *Malabar* pepper
- *Kancheepuram* silks
- *Lonawala chikis* (food stuff)
- *Nilgiri* tea
- Coir products from *Kerala*
- Cardamom from *Kerala*
- *Aranmula* mirrors
- Nagpur oranges
- Phulkari embroidery work

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GEOGRAPHICAL INDICATIONS - INDIA

GI tags give trademarks to different states for indigenous or unique goods that they produce

State	No. of GI tags (Until April 2017)	Examples
Karnataka	39	Mysore Silk, Mysore Sandal Soap, Coorg Green Cardamom
Uttar Pradesh	23	Patan Patola, Lucknow Zardozi, Firozabad Glass
Odisha	15	Ikat, Konark Stone Carving, Pattachitra
West Bengal	14	Darjeeling Tea, Nakshi Kantha, Baluchari Saree
Gujarat	13	Agates of Cambay, Kutch Embroidery, Gir Kesar Mango
Rajasthan	13	Kathputlis of Rajasthan, Blue Pottery of Jaipur, Makrana Marble
Himachal Pradesh	7	Kullu Shawl, Kangra Tea, Chamba Rumal

ThePrint

Geographical Indications

granted by Indian Patent Office in 2017-18



Banaganapalle Mangoes of Andhra Pradesh

Tulapanji Rice of West Bengal



Tirupathi Laddu



Darjeeling Tea





Kashmir Pashmina

Nagpur Orange





Kangra Paintings

Other 5 products that received this tag this year

- **Pochampally Ikat** of Telanganal
- **Gobindobhog Rice** of West Bengal
- **Durgi** Stone Carvings
- **Etikoppaka Toys** of Andhra Pradesh
- **Chakshesang Shawl** of Nagaland



A Geographical Indication (GI) is primarily an agricultural, natural or a manufactured product (handicrafts/industrial goods) originating from a definite geographical territory

2016-17: 33 items got GI registration

GRAPHICS

Geographical indications of Gujarat

Kutch Embroidery







Gir Kesar Mango







Patan Patola







What rights cover under Geographical indications of Goods Act

- A geographical indication right enables those who have the right to use the indication to **prevent its use by a third party whose product does not conform to the applicable standards.**
- For example, in the jurisdictions in which the Darjeeling geographical indication is protected, **producers of Darjeeling tea can exclude use of the term "Darjeeling" for tea not grown in their tea gardens or not produced according to the standards set out in the code of practice for the geographical indication.**
- However, **a protected geographical indication does not enable the holder to prevent someone from making a product using the same techniques** as those set out in the standards for that indication.
- **Protection for a geographical indication is usually obtained by acquiring a right** over the sign that constitutes the indication.

Condition must be meet to obtain GI protection

- **A sign must qualify** as a geographical indication under the applicable law and **not be subject to any obstacles to registering a geographical indication (GI).**
- Generally, an **important requirement under the definition, is that the good identified by the GI needs to have a link to the geographical origin.**
- **This link may be determined by a given quality, reputation or other characteristic essentially due to the geographical origin.**
- **In many legislation a single criterion attributable to geographical origin is sufficient**, be it a quality or other characteristic of the product, or only its reputation.

What is the term of GI protection?

The registration of a GI shall be for a **period of ten years** but may be **renewed from time to time for an unlimited period by payment of the renewal fees.**

What is the cost of registering a GI in India?

Some important fees are given below:-

Sr. No	Action	Official fee
1.	On application for the **registration of a geographical indication** for goods included in **one class**	Rs.5000/-

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2.	On a single application for the registration of a geographical indication for goods in **different classes**	Rs.5000/- for each class
3.	On application for the **registration of an authorized user** of a registered geographical indication	Rs.500/-
4.	For **renewal** of an **authorized user**	Rs.1,000/-

Who can apply for GI's registration?

Any association of persons or producers or any organization or authority established by or **under any law for the time being in force representing the interest** of the producers of the concerned goods, who are desirous of registering geographical indication in relation to such goods can apply for GI's registration.

Who is a registered proprietor of a geographical indication?

Any association of persons or of producers or any organisation or authority established by or under the law can be a registered proprietor. Their name should be entered in the Register of Geographical Indication as registered proprietor for the Geographical Indication applied for.

Who can use the registered geographical indication?

An authorised user has the exclusive rights **to the use of geographical indication** in relation to goods in respect of which it is registered.

Who is an 'authorised user'?

'Authorised user' is **any person claiming to be the producer of the goods in respect of which a geographical indication has been registered.** For becoming an authorized user the person has to apply in writing to the Registrar in prescribed manner and by paying requisite fee.

Who can be considered a 'producer' for the purposes of this act?

'Producer' in **relation to goods**, means any person who :-

(a) Produces, processes or packages agricultural goods

(b) Exploits natural goods

(c) Makes or manufactures handicraft or industrial goods.

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What is the punishment in the Act for falsifying GI?

A **sentence of imprisonment** for a term between **six months to three years** and a **fine between fifty thousand rupees and two lakh rupees** is provided in the Act. The court may reduce the punishment under special circumstances.

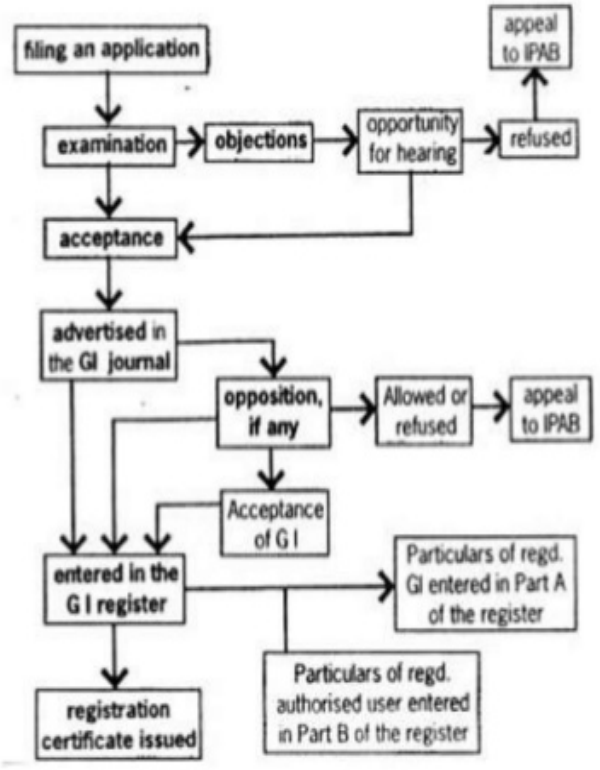
Can all geographical indications be registered?

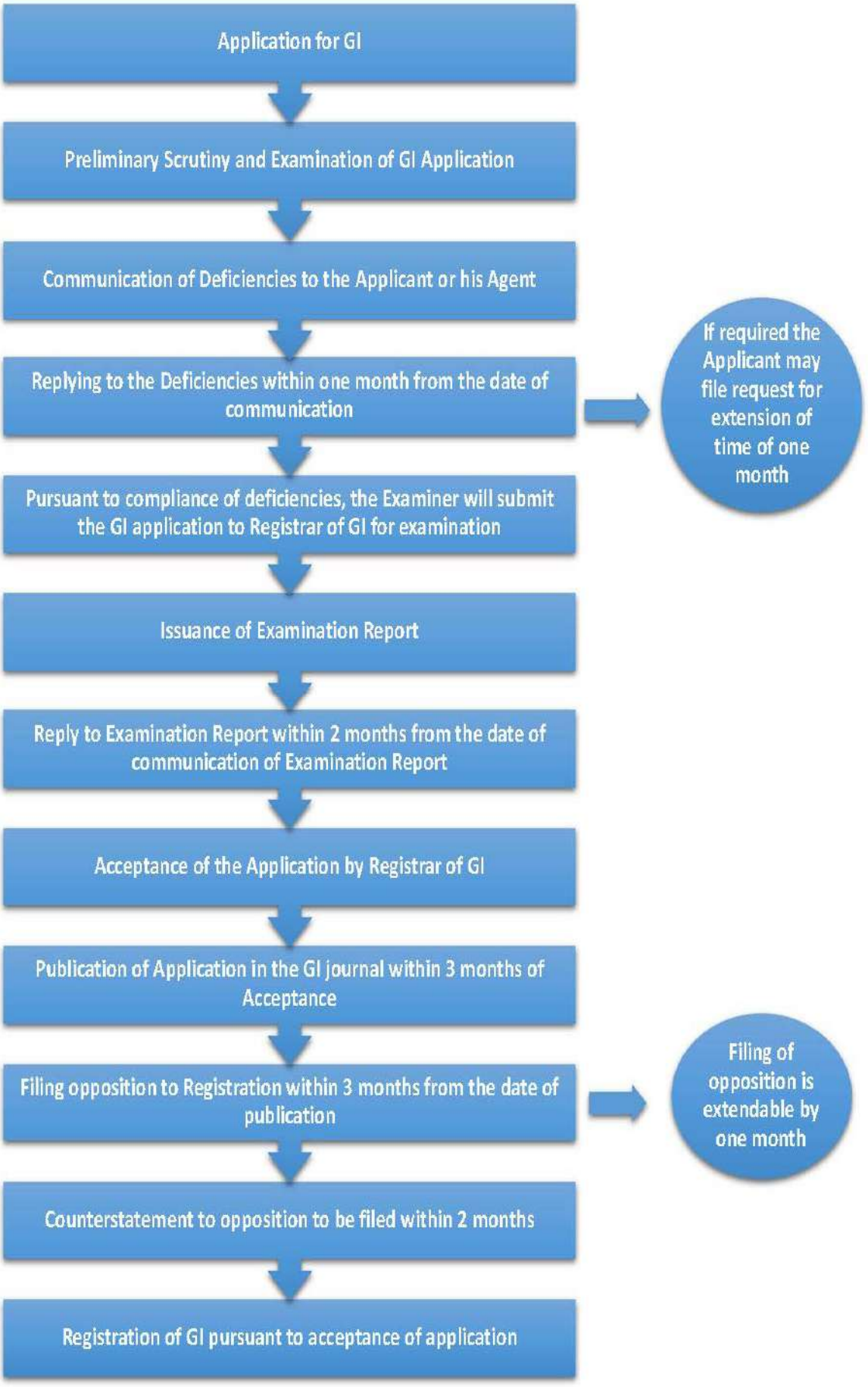
No, a GI cannot be registered if :-

- **signs** that **do not qualify as geographical indications** under the applicable law
- its use is **likely to deceive (mislead) or cause confusion or be contrary to any law**;
- it comprises or **contains scandalous (shameful/immoral) or obscene (offensive) matter or any matter likely to hurt religious susceptibilities** of any class or section of the citizens of India.

Indian GI registry system

- The Geographical Indications Registry (GIR) is situated at Chennai.
- Its main function is registration of Geographical Indications under the Act
- Whether a particular product is registerable or not is determined by the Registrar of Geographical Indications, on receipt of the application




Application for GI
Preliminary Scrutiny and Examination of GI Application
Communication of Deficiencies to the Applicant or his Agent
Replying to the Deficiencies within one month from the date of communication
If required the Applicant may file request for extension of time of one month
Pursuant to compliance of deficiencies, the Examiner will submit the GI application to Registrar of GI for examination
Issuance of Examination Report
Reply to Examination Report within 2 months from the date of communication of Examination Report
Acceptance of the Application by Registrar of GI
Publication of Application in the GI journal within 3 months of Acceptance
Filing opposition to Registration within 3 months from the date of publication
Filing of opposition is extendable by one month
Counterstatement to opposition to be filed within 2 months
Registration of GI pursuant to acceptance of application

STEP 1 : Filing of application

- Application must be made in **triplicate.**
- The application shall be signed by the applicant or his agent and must be accompanied by a statement of case.
- Details of the **special characteristics** and how those standards are maintained.
- **Three certified copies of the map of the region** to which the GI relates.
- Give **details of all the applicant** together with address.

STEP 2 and 3: Preliminary scrutiny and examination

- The Examiner will scrutinize the application for any deficiencies.
- The applicant should within one month of the communication in this regard, remedy the same.
- The content of statement of case is assessed by a consultative group of experts
- They will ascertain the correctness of particulars furnished.
- There after an Examination Report would be issued.

STEP 4: Show cause notice

- If the Registrar has any objection to the application, he will communicate such objection.
- The applicant must respond within two months or apply for a hearing.
- The decision will be duly communicated. If the applicant wishes to appeal, he may within one month make a request.
- The Registrar is also empowered to withdraw an application, if it is accepted in error, after giving on opportunity of being heard.

STEP 5: Publication in the geographical indications Journal

- Every application, within three moths of acceptance shall be published in the Geographical Indications Journal.

STEP 6: Opposition to Registration

- Any person can file a notice of opposition within three months (extendable by another month on request which has to be filed before three months) opposing the GI application published in the Journal.
- The registrar shall serve a copy of the notice on the applicant.

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- Within two months the applicant shall sent a copy of the counter statement.
- If he does not do this be shall be deemed to have abandoned his application. Where the counter-statement has been filed, the registrar shall serve a copy on the person giving the notice of opposition.
- Thereafter, both sides will lead their respective evidences by way of affidavit and supporting documents.
- A date for hearing of the case will be fixed thereafter.

STEP 7: Registration

- When an application for a GI has been accepted, the registrar shall register the geographical indication. If registered the date of filing of the application shall be deemed to be the date of registration.
- The registrar shall issue to the applicant a certificate with the seal of the Geographical indications registry.

STEP 8: Renewal

- A registered GI shall be valid for 10 years and can be renewed on payment of renewal fee.

Trademark	**Geographical indication**
Trademarks inform consumers about the source of a good or service.	Geographical indications identify a good as originating from *a particular place*.
They identify a good or service as originating from a *particular company*.	Based on its place of origin, consumers may associate a good with a particular quality, characteristic or reputation.
A trademark often consists of a fanciful or arbitrary sign that may be used by its owner or another person authorized to do so.	In contrast, the sign used to denote a GI usually corresponds to the name of the place of origin of the good, or to the name by which the good is known in that place.
A trademark can be assigned or licensed to anyone, anywhere in the world, because it is linked to a specific company and not to a particular place.	GI cannot be assigned or licensed to someone outside that place or not belonging to the group of authorized producers

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Obstacles for protecting GI

From a legal point of view, potential obstacles to successfully registering a geographical indication (GI) may include the following:

1. Conflict with a prior mark

A GI may be refused protection in a particular territory if the authority in that territory considers that the GI is identical or similar to a trademark previously applied for, registered or acquired through use, in good faith, and that use of the GI would result in a likelihood of confusion with the trademark.

2. Generic character

A GI may be refused protection if the competent authority considers that the sign constitutes the common name for the kind of product or service to which it applies

3. Homonymous geographical indications

- Homonymous GIs are those that are spelled or pronounced alike, but which identify products originating in different places, usually in different countries.
- A GI may be refused protection if, due to the existence of another homonymous indication, its use would be considered potentially misleading to consumers with regard to the product's true origin.

4. The indication is the name of a plant variety or animal breed

In certain jurisdictions, protection may be refused to a GI if it conflicts with the name of a plant variety or an animal breed and may, as a result, mislead the consumer as to the true origin of the product.

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-:TRADE MARK:-

How is "Trademark" defined?

A trademark or trade mark is a distinctive sign of some kind which is used by an individual, business organization or other legal entity to uniquely identify the source of its products and/or services to consumers, and to distinguish its products or services from those of other entities.

Main features of trademarks are briefly presented below:

1. A trademark can be a word, name, symbol, device or mark which is used to identify and distinguish the goods or services of one company from goods or services of another.
2. It is the name of a product made by a particular person or company.
3. The period of protection for a trademark varies, but can renewed indefinitely.
4. A consumer associates some level of quality/price/prestige with the goods of a particular trademark. In other words the consumer uses the trademark for making a choice while buying a particular product.
5. There are so many examples in our day to day life such as TATA, BATA, Liberty, Brooke Bond, Dabur, Baidyanath, Park Avenue, SAIL and so on.

Types of Trademark

- Trademark
- Servicemark
- Collectivemark
- Certification Mark

What are "Well-known Trademarks"?

The term "well-known trade mark“ (famous mark) has been defined in the Trade Marks Act, 1999 and refers to a mark which has become so to the substantial segment of the public which uses such goods or receives such services that the use of such mark in relation to other goods or services would be likely to be taken as indicating a connection in the course of trade or rendering of services between those goods or services and a person using the mark in relation to the first mentioned goods or services.

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A well-known trademark is a popular mark, logo or a symbol that represents a brand and also it's hard earned goodwill and reputation.

A trademark becomes a well-known mark depending on:

- The degree of recognition it receives in the relevant sector;
- The duration of recognition;
- The extent & geographical area of recognition; and
- The value associated with it.
- Well-known marks are usually protected, irrespective of whether they are registered or not, in respect of goods and services which are identical with, or similar to, those for which they have gained their reputation.
- 7 O'CLOCK for shaving razors, AIWA, BAJAJ, Bata, Bisleri, Benze etc.
- AIWA is a well-known trademark in India in respect of electronic goods. Use of this mark without due cause for any other products would be likely to deceive or cause confusion, unfair advantage and be detrimental to the distinctive character and repute of mark.

Service mark

- A service mark or servicemark is a trademark used in the United States and several other countries to identify a service rather than a product.

OR

- A trade or service mark is a distinctive sign which identifies certain products or services as those produced or provided by a specific person, enterprise or a group of persons/enterprises allowing the consumer to distinguish them from goods or services of others
- When a service mark is federally registered, the standard registration symbol ® or "Reg U.S. Pat & TM Off" may be used (the same symbol is used to mark registered trademarks).

Certification Trademarks

Certification trademark means a mark capable of distinguishing the goods or services in connection with which it is used in the course of trade which are certified by the proprietor of the mark in respect of origin, material, mode of manufacture of goods or performance of services, quality and accuracy.

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Collective Marks

Collective Mark means a trademark distinguishing the goods or services of an association of persons (not being a partnership within the meaning of the Indian Partnership Act, 1932).

What is the cost of filing trademarks application in India?

Some important fees are given below:

No	Action	Official fee
1.	Application to register a trade mark for a specification of goods or services included in one class	Rs.2500/-
2.	Application to register a textile trade mark consisting exclusively of numerals or letters or any combination thereof for specification goods included in one item	Rs.2500/-
3.	Application to **register a collective mark** for a specification of goods or services included in one class	Rs.10,000/-
4.	Application to **register a certification trade mark** for specification of goods or services included in one class	Rs.10,000/-
5.	**Renewal of registration**	Rs.5,000/-
6.	Application for approval of Registrar (i) For first mark (ii) For every additional mark	Rs.2500/- Rs.500/-
7.	Application under Geographical Indications of Goods (Registration and Protection) Act, 1999 to refuse or invalidate registration of a trade mark consisting of Geographical Indication etc.	Rs.3,000/-

What is the term of a registered trademark?

The initial registration of a trademark shall be for a period of ten years but may be renewed from time to time for an unlimited period by payment of the renewal fees.

Register and unregistered trade marks

Registered Trademark:

A "registered trademark" confers a bundle of exclusive rights upon the registered owner, including the right to exclusive use of the mark in relation to the products or services. Registration of a trade mark is not a mandatory requirement in India. A trade mark is

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registered for a period of 10 years and is subject to renewal. The Trademarks Act 1999 governs the whole process of registration.

Registration is required for the following reasons:

- It identifies the origin of goods and services;
- Advertises goods and services;
- Guards the commercial goodwill (reputation) of a trader; and
- Protects the innocent public from buying the second rate quality goods.

Unregistered trademark

- Unregistered marks are defined as marks which are not registered in relation to goods or services (that is names, marks or logos used in relation to a business) under the Trademark Act 1999.
- An "unregistered trademark" is one which does not possess legal benefits.
- But in some cases, an unregistered trademark may get common law benefits.

Difference between register and unregistered trade marks

Registered trademark	**Unregistered trademark**
It confers a bundle of exclusive rights upon the registered owner.	It does not possess legal benefits
Protection given under Trade marks Act 1999	Protection not available.
It has a statutory remedy.	It has a common law remedy.
A registered trademark is represented by the symbol ®	An unregistered trademark is represented by the trademark symbol ™.
It possesses a statutory right of infringement (violation)	It does not possesses a statutory right of infringement.

How is the Trademarks Act 1999 Different from the Trade and Merchandising Marks Act 1958?

Enactment of the Trademarks Act 1999 is a big step forward from the Trade and Merchandise Marks Act 1958 and the Trademark Act 1940. The newly enacted Act has some features not present in the 1958 Act and these are:

- Registration of service marks, collective marks and certification trademarks.
- Increasing the period of registration and renewal from 7 years to 10 years.

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- Allowing filing of single application for registration in more than one class.
- Enhanced punishment for offences related to trademarks.
- Simplified procedure for registration of registered users and enlarged scope of permitted use.
- Constitution of an Appellate Board for speedy disposal of appeals and rectification applications which at present lie before High Court.

Is Registration Mandatory?

No, but it is advisable.

Why Hire a Trademark Agent?

- **Trademark registration can be a complex process;** an **experienced agent can save your time and money by avoiding pitfalls** such as **poorly prepared applications and Improper research.**
- However the **prime reason** for **hiring an experienced Agent** is his **ability to address concerns of the Trade Marks office**. If you fail to respond correctly, your application will likely tail.

Who can Register a Trademark?

Companies, individuals, partnerships, trade unions or lawful associations, provided they meet the requirements of the Trademarks Act.

Who should Register a Trademark?

There has always been a debate over who should own marks. As a rule, trademarks denote the source of goods. Therefore the owner of the mark should be the party who derives benefit from the goodwill attached to the goods.

How Long is Registration Effective?

Depending on the country registration is valid for **10 to 17 years and is renewable,** upon payment of a fee into perpetuity.

How do I Register a Trademark?

You must file, an Application with the Trademarks Office.

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Does Registration in one County Protect my Rights in other countries?

No. If your products are sold in other countries, **you should consider applying for foreign registration.** Contact a trademark agent or the embassy of the country in question to find out about procedures.

What is the Difference Between a Trademark and a Trade Name?

A trade name is the name under which you conduct business. It can be registered as a trademark, but only if it is used as such, that is, used to identify wares or services.

May I Register my Own Name as a Trademark?

Normally, you may not register a proper name neither yours, nor anyone else's, as a trademark.

An exception may be made **if you can demonstrate that the name has become identified in the minds of the public with your specific wares or services.**

What Other Kinds of Marks May not be Registered?

- Words that are **clearly descriptive** ***(e.g.*** "delicious" ice cream),
- Terms that are **misleading**,
- words that **designate a place of origin** ***(e.g.*** "Atlantic" cod),
- **Terms or symbols that are too similar to an existing trademark**, and **terms and symbols that are expressly prohibited under the Trademarks Act.**

What are the Steps of Trademark Registration?

Trademark registration usually involves following steps:

1. A **preliminary search** of existing trademarks;
2. **an application**;
3. **examination** of your application by the Trademarks Office;
4. **publishing** of the application in the Trademarks, Journal;
5. **time for opposition** to the application;

allowance and registration (if there is no opposition).

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-:TRADE SECRET:-

A trade secret is anything a formula, process, method, mechanism, tool, pattern or device which the disclosing party desires to keep secret. Trade secrets usually include such things as the manufacturing details for a product, variations or alternative uses.

The main points about trade secret are briefly presented as follows:

1. There is **no specific period for trade secret**. It **may continue life long or for generations together.**
2. There is **no need of registration for trade secret.**
3. It does **not provide opportunity to others for improvement of innovation.**
4. It is **not applicable to books, equipments, plant varieties, designs** which are openly used.

What are the requirements of trade secret protection?

For the protection of trade secret, **conditions vary from country to country**, **some general standards exist** which are referred to in Art. 39 of the Agreement on Trade-Related Aspects of Intellectual Property Rights **(TRIPS Agreement):**

- ✓ **The information must be secret** (i.e. it is not generally known among, or readily accessible to, circles that normally deal with the kind of information in question).
- ✓ It **must have commercial value** because it is a secret.
- ✓ It **must have been subject to reasonable steps** by the rightful holder of the information to keep it secret (e.g., through confidentiality agreements).

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Trade Secrets

Difference between trade secret, copy rights, trade mark and patent

	Copyright	Trademark	Patent	Trade Secret
Protects:	Creative works	Brand identifiers	Inventions	Confidential business information
Protection Begins:	Upon fixation	Upon use in commerce	Upon registration	Upon creation
Length of Protection:	Life + 70 years (WFH: 95/120 years)	For as long as in use	20 years (14 for designs)	For as long as kept secret
Registration:	Gives extra protection	Gives extra protection	Required	None
Example:	Books, paintings, recorded music	"Coca-Cola" 	Incandescent light bulb, Coca-Cola bottle shape	KFC's 11 herbs and spices

		Protects	Infringement	Registration Process	Term	Comparative Costs
Patent	Utility Patent	Functional Aspects	Make, Use, Offer, Sale, Import	Yes	20 years upon filing	Expensive
	Design Patent	Ornamental Features	Make, Use, Offer, Sale, Import	Yes	15 years upon filing	Moderate
Trademarks		Brands	Used in commerce	Optional	Potentially indefinite, limited by use	Inexpensive
Copyrights		Works of Authorship	Copying, etc.	Optional	Life Plus 70 Years	Inexpensive
Trade Secrets		Information	Misappropriation	No	Potentially indefinite, limited by secrecy	Depends

	Trade secret	**Copyright**	**Trademark**	**Design patent**	**Utility Patent**
What is protected?	Know-how	Original expression of an idea	Customer's notion of your good or service's source.	Visible appearance	Products, processes, compositions, functions
Typical things protected	how to make Coca-cola, hidden high-tech methods, & etc.	written material: computer programs, books, plays, poems; art: sculptures, paintings, photographs, etc.	names, logos, internet domainnames, designs, & etc.	unique shape/styling of articles like product packaging, figurines, etc.	tools, devices, machines, computer programs, games, processes, formulas, internet, electronic, chemical and business methods etc.
What are others prohibited from doing?	Unauthorized use or dissemination by someone who has been let in on the secret.	Copying the expression	Confusing the consumer.	Making something looking the same or similar..	Using the claimed invention.
How is the right established?	Use in trade	Authorship	Use in trade	Examination	Examination

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What is needed to get protection?	Know-how must be well defined, not publicly known, and protected.	Tangible use of the expression.	Mark must distinctive, and not confusingly similar to another.	Visible appearance must be new and not obvious.	Invention must be new, useful and not obvious, and you must teach how to make and use it.
Geographic coverage	country of origin or by other countries by treaty	Worldwide	Country filed in	Country filed in	Country filed in, or worldwide if PCT filing
What is the duration of protection?	Until disclosed to the public.	life of author plus 50 years	10 years, or as long as it is in use.	14 years (US) from filing	At most 20 years from filing.

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-:INDUSTRIAL DESIGN & LAYOUT DESIGN OF IC:-

DESIGN

A Design refers to the features of shape, configuration, pattern, ornamentation or composition of lines or colours applied to any article, whether in two or three dimensional (or both) forms.

This may be applied by any industrial process or means (manual, mechanical or chemical) separately or by a combined process, which in the finished article appeals to and judged solely by the eye.

Industrial Design

An industrial design is the ornamental (decorative/attractive/patterned) or aesthetic (artistic/appealing) aspect of an article produced by industry or handicraft.

Main points about industrial designs are given below

1. Industrial designs include any original shape, picture, or some combination applied to a useful article of manufacture.
2. Registration is essential to get protection.
3. Registration can be done from 5 to 15 years.
4. The owner has the right to transfer right to any other person.
5. Protection is valid only in the country where the design has been registered

What is the object of registration of Designs?

- The essential purpose of design law it to promote and protect the design element of industrial production.
- It is also intended to promote innovative activity in the field of industries.
- The Designs Act, 2000 and the Designs Rules, 2001 presently govern the design law in India. The Act came into force on 25th May 2000 while the Rules came into effect on 11th May 2001.
- The object of the Designs Act to protect new or original designs so created to be applied or applicable to particular article to be manufactured by Industrial Process or means.
- Sometimes purchase of articles for use is influenced not only by their practical efficiency but also by their appearance.

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Essential requirements for registration of Designs

A design should –

- ✓ Be new or original
- ✓ Not be disclosed to the public anywhere by publication in tangible form or by use or in any other way prior to the filling date, or where applicable, the priority date of the application for registration.
- ✓ Be significantly distinguishable from known Designs or combination of known designs.
- ✓ Not comprise or contain scandalous or obscene matter.
- ✓ Not be a mere mechanical contrivance.
- ✓ Be applied to an article and should appeal to the eye.
- ✓ Not be contrary to public order or morality.
- ✓ The design should not include any trade mark or property mark or artistic work.

Duration and fees for registration of Designs

- The term of a registered design is 15 years.
- Initially the right is granted for a period of 10 years, which can be extended, by another 5 years by making an application and paying a fee of Rs. 2000/- to the Controller before the expiry of initial 10 years period.
- The proprietor of design may make application for such extension as soon as the design is registered.

What is the cost of filing design application in India?

The fee for filing application for registration of design in India is Rs.1,000/-.

What is not registrable as IC layout design?

An IC layout design is not registrable if it is: -

1. Not original;
2. Commercially exploited anywhere in India or in a convention country;
3. Inherently not distinctive;
4. Inherently not capable of being distinguishable from any other registered layout design

Note: Design not exploited commercially for more than 2 years from date of registration of application shall not be treated as commercially exploited for the purpose of this Act.

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What is the term of an IC layout design protection?

The term is 10 years from the date of filing or from the date of first commercial exploitation anywhere in any country whichever is earlier.

SEMICONDUCTOR INTEGRATED CIRCUITS LAYOUT-DESIGN (SICLD)

Semiconductor Integrated Circuit

Semiconductor Integrated Circuit means a product having transistors and other circuitry elements, which are inseparably formed on a semiconductor material or an insulating material or inside the semiconductor material and designed to perform an electronic circuitry function.

The layout-design of a semiconductor integrated circuit

The layout-design of a semiconductor integrated circuit means a layout of transistors and other circuitry elements and includes lead wires connecting such elements and expressed in any manner in semiconductor integrated circuits.

The layout of transistors on the semiconductor integrated circuit or topography of transistors on the integrated circuit determines the size of the integrated circuit as well as its processing power.

That is why the layout design of transistors constitutes such an important and unique form of intellectual property fundamentally different from other forms of intellectual property like copyrights, patents, trademarks and industrial designs.

Semiconductor Integrated Circuits Layout-Design (SICLD) Act, 2000

- The Semiconductor Integrated Circuits Layout-Design Act, 2000 was passed to fulfils India's obligations as a TRIPS signatory.
- It provides protection for semiconductor Integrated Circuit layout designs.
- The main purpose of the Act is to provide for routes and mechanism for protection of IPR in Chip Layout Designs created and matters related to it.

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Major provisions of SICLD Act, 2000

The important provisions of the Act are –

- ✓ Jurisdiction to the whole of India;
- ✓ SICLD Registry - where the layout-designs of integrated circuit chips can be registered;
- ✓ Defines layout-designs of integrated circuits which can be registered under the Act;
- ✓ Duration of registration of layout-designs;
- ✓ Rights conferred by registration;
- ✓ Infringement of layout-designs;
- ✓ Procedure for assignment and transmission of registered layout- design;
- ✓ Appellate Board as a forum of redressal;
- ✓ Treatment of Royalties;
- ✓ Provisions in case of national emergency or extreme public urgency;
- ✓ Penalties;
- ✓ Provision for agents;
- ✓ Reciprocity provision with other recognized countries.

What is Register of Layout Designs?

- The Register of Designs is a document maintained by the Patent Office, Kolkata as a statutory requirement.
- It contains the design number, date of filing and reciprocity date (if any), name and address of proprietor and such other matters as would affect the validity of proprietorship of the design.
- It is open for public inspection on payment of prescribed fee and extract from register may also be obtained on request with the prescribed fee.

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-:COPYRIGHT:-

Copyrights

Copyrights refer to the legal right granted to an author, composer, playwright, Publisher, or distributor to exclusive publication, production, sale, or distribution of a literary, musical, dramatic, or artistic work is called copyright.

Main features of copyrights are briefly presented below:

1. It provides protection for a specific duration.
2. It is applicable in all countries.
3. The copyright holder has the rights to authorize others to use the protected work.
4. It is applicable to books, movies, music, paintings, photographs and software's.
5. The information cannot be reproduced as such without written permission. However, the information or idea can be used by any one.

History of copyright in India

The history of copyright law in India can be traced back to its colonial era under the British Empire.

- **The first law of copyright was introduced in India during the control of the British Rule in India via the British Copyright Act, 1911.** According to this law the **term of the Copyright was life time of the author plus seven years after the death of the author.** However the **total term of copyright cannot exceed the period of forty-two years**. **Registration of Copyright with the Home Office** was mandatory for enforcement of rights under the Act.
- **In 1914, Indian legislature under the British Raj enacted the Copyright Act of 1914.** It was almost **similar to the British Copyright Act of 1911**. **However the major change** that was brought in this Act was the **criminal sanction for infringement**. The 1914 Act was **constantly amended a number of times.**
- **In 1957, the introduction of the Indian Copyright Act, 1957** which was enacted in order to suit the provisions of the **Berne The Act is applicable from 21 January 1958.**
- **The Copyright Act 1957 was the first post-independence copyright legislation in India** and the law has been **amended six times since 1957**.
- The **most recent amendment was in the year 2012**, through the Copyright (Amendment) Act 2012.

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- ***India is a member of most of the important international conventions governing the area of copyright law***, including the **Berne Convention of 1886 (as modified at Paris in 1971), the Universal Copyright Convention of 1951, the Rome Convention of 1961 and the Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS).**
- ***But India is not a member of the WIPO Copyright Treaty (WCT) and the WIPO Performances and Phonograms Treaty (WPPT).***

Types of work subject to copy rights

1. Literary, dramatic and musical work. Computer programs / software are covered within the definition of literary work;
2. Artistic work;
3. Cinematographic films which include sound track and video films;
4. Record-any disc, tape, perforated roll or other device.

What are the Rights of a Copyrights holder?

(a) In the case of literary, dramatic or musical work:-

i. To reproduce the work in any material form including the storing of it in any medium by electronic means;
ii. To issue copies of the work to the public not being copies already in circulation;
iii. To perform the work in public, or communicate it to the public;
iv. To make any cinematography film or sound recording in respect of the work;
v. To make any translation of the work; to make any adaptation of the work;
vi. To do, in relation to a translation or an adaptation (alternatation / editing) of the Work, any of the acts specified in relation to the work in Sub-clauses (i) to (vi);

(b) In the case of computer program -

i. To do any acts specified in clause (a);
ii. To sell or give on hire, or offer for sale or hire any copy of the computer program, regardless of whether such copy has been sold or given on hire on earlier occasions;

(c) In the case of an artistic work –

i. To reproduce the work in any material form including depiction (illustration / picture / representation) in three dimensions of a two dimensional work or in two dimensions of a three dimensional work;

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ii. To communicate the work to the public;
iii. To issue copies of the work to the public not being copies already in circulation;
iv. To include the work in any cinematography film;
v. To make any adaptation of the work;
vi. To do, in relation to a translation or an adaptation of the work, any of the acts specified in relation to the work in sub-clauses (i) to (vi);

(d) In the case of a cinematography film -

i. To make a copy of the film including a photograph of any image forming part thereof;
ii. To sell or give on hire or offer for sale or hire, any copy of the film, regardless of whether such copy has been sold or given on hire on earlier occasions;
iii. To communicate the film to the public;

(e) In the case of sound recording –

i. To make any other sound recording embodying (representing/expressing) it;
ii. To sell or give on hire or offer for sale or hire, any copy of the, sound recording, regardless of whether such copy has been sold or given on hire on earlier occasions;
iii. To communicate the sound recording to the public;

Terms of copyrights

a) If published within the life time of the author of a literary work, the term is for the life time of the author plus 60 years.
b) For *cinematography films, records, photographs, posthumous (after death) publications, anonymous (unnamed) publication, works of government and international agencies*, the term is 60 years from the beginning of the calendar year following the year in which the work was published.
c) For broadcasting, the term is 25 years from the beginning.

Rules for the transfer of copyrights

The owner of the copyright in an existing work or prospective (probable) owner of the copyright in a future work may assign to any person the copyright, either wholly or partially in the following manner.

i. For the entire world or for a specific country or territory; or
ii. For the full term of copyright or part thereof ; or
iii. Relating to all the rights comprising the copyright or only part of such rights.

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Cost of filing Copyrights Application in India

Some important fees are given below :-

S. No	Action	Official fee
1.	For an application for registration of copyright in a- (a) literary, dramatic, musical or artistic work (b) literary or artistic work which is used or is capable of being used in relation to any goods	Rs.50 per work Rs.400 per work
2.	For an application for registration of copyright in a Cinematograph Film	Rs.600 per work
3	For an application for registration of copyright in a sound recording	Rs.400 per work

Powers of Copyrights Board

The Chairman of the Copyright Board is of the level of a judge of a High Court. The Board has the power to:

1. Hear appeals against the orders of the Registrar of Copyright;
2. Hear applications for rectification of entries in the Register of Copyrights;
3. Adjudicate (Umpire / referee) upon disputes on assignment of copyright;
4. Grant compulsory licenses to publish or republish works
5. Grant compulsory license to produce and publish a translation of a literary or dramatic work in any language after a period of seven years from the first publication of the work;
6. Hear and decide disputes as to whether a work has been published or about the date of publication or about the term of copyright of a work in another country;
7. Fix rates of royalties in respect of sound recordings under the cover-version provision;
8. Fix the resale share right in original copies of a painting, a sculpture or a drawing and of original manuscripts of a literary or dramatic or musical work.

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-:PROTECTION OF PLANT VARIETIES:-

Origin and history including a brief introduction to UPOV for protection of plant varieties.

- **An act to provide patent on plant was first introduced in Germany in 1866.**
- Subsequently, during the **beginning of 20th century, legislation for patenting plants** were introduced in **other countries.**
- **The international organization for plant variety protection was established in 1928** with the **objective of establishing an efficient system for the protection of new plant varieties**.
- The **issue of Plant variety Protection** has been brought into focus under the provisions of **Trade Related Aspects of Intellectual Property (TRIPs) Right** which is a part of **Agreement on Agriculture (AoA) under World Trade Organization (WTO)** for which India is signatory and a founding member.
- **Different forms of Protection of New Plant Varieties** have **been existing in the developed countries through** the system of **Plant Breeder's Rights (PBRs).**
- The **most significant event in the development of PBR systems** was the effort to **harmonize PBR laws** of different countries through **UPOV(International Union for Protection of New Plant Variety).**
- **UPOV constituted in 1961 in Geneva, Switzerland** and **first convention** of UPOV was **held and sign in 1961 in Paris.**
- Therefore, 1961 year is declared as **"World Seed Year"**
- Initially UPOV law was constitute as **UPOV 1978 act** which is **now revised** as **UPOV 1991** act with effect from 24, April 1998.
- In 1993, UPOV had 24 member countries while **at present 74 countries** are member of UPOV(up to October 2, 2015).
- **In India UPOV act come into forced with effect from January, 2006.**

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Comparison of UPOV 1978 Act and UPOV 1991 Act

	UPOV 1978 Act	UPOV 1991 Act
Minimum scope of coverage	Increasing number of genera or species required to be protected is 5 accession at time and 24 accession eight years later.	Increasing number of genera or species required to be protected is 15 accession at time and all accession 10 years later.
Eligibility Requirements	Novelty, distinctness, uniformity and stability.	Novelty, distinctness, uniformity and stability.
Minimum exclusive rights in propagating material	Production for purposes of commercial marketing; Offering for sale; Marketing; Repeated use for the commercial production of another variety.	Production or reproduction; Conditioning for the purposes of propagation; Offering for sale; Selling or other marketing; Exporting; Importing or stocking for any of these purposes.
Minimum exclusive rights in harvested material	No such obligation, except for ornamental plants used for commercial propagating purposes.	Same acts as above if harvested material obtained through unauthorized use of propagating material and if breeder had no reasonable opportunity to exercise his or her right in relation to the propagating material.
Prohibition on dual protection with patent	Yes, for same botanical genus or species.	No, dual protection is possible
Breeders' exemption	Mandatory. Breeders free to use protected variety to develop a new variety.	Permissive, but breeding and exploitation of new variety "essentially derived" from earlier variety require right holder's authorization.
Farmers' privilege	Implicitly allowed under the definition of minimum exclusive rights.	Allowed at the option of the member state within reasonable limits and subject to safeguarding the legitimate interests of the right holder.
Minimum term of protection	18 years for vines and trees; 15 years for all other plants.	25 years for grapevines and trees; 20 years for all other plants.

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INTRODUCTION PPV&FR

- As the **existing UPOV models of plant variety protection were not suitable for our requirements**, the **Government of India** enacted our own legislation on the **Protection of Plant Varieties and Farmers Rights Act (PPV&FR) in 2001**, which is a **unique model in the world** as **it provides equal rights to farmers along with breeders**. For the purpose of implementation of this act, central Govt. of India established PPV&FR authority.
- **PPVFR Act, 2001** was passed on **August 9, 2001 by the LokSabha.**
- The **AIM** of this act is **"to establishment of an effective system for protection of plant variety, the right of farmers as well as plant breeders and encourage the development of new varieties of plants".**

Objective of PPVFR, 2001

- Establishment of an effective system for protection of plant varieties, the rights of farmers and plant breeders.
- To stimulate investment for research and development, both in the public and private sector, for the development of new plant varieties.
- Facilitate the growth of the seed industry in the country which will ensure the availability of high quality seeds and planting material to the farmers.
- Provides the exclusive right to produce, sell, market, distribute, import, or export the variety.

Main Features of PPV & FR

The main features of PPV & FR Act 2001 in relation to purpose, legislative structure, headquarters, registration, period of registration, farmers' rights, plant breeders' rights, exclusion, compensation and penalties are briefly presented below.

Purpose (Objectives).

a) **Toestablish an effective system** for protection of plant varieties, farmers' rightsand plant breeders' rights.
b) **Torecognize and protect farmers' rights** for their contribution in **conserving, improving and making available plant genetic resources for development of new plant varieties.**

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c) **Tostimulate investment for research and development** both public and privatesector for **development of new plant varieties.**

d) **Topromote the growth of seed industry** in the country to **ensure availability of high quality seeds** to the farmers.

Legislative Structure.

The Authority consists of a chair person called as authority and 15 persons as members. The members of the Authority include

1. **Agricultural Commissioner - GOI**
2. DDG Crop Science-ICAR
3. Joint Secretary Seeds- GOI
4. Horticulture Commissioner - GOI
5. Director, NBPGR
6. One member each [not below the rank of Joint Secretary] from DBT
7. Ministry of Environment and forests - GOI
8. Ministry of Law Justice and Company Affairs-GOI
9. One representative each [nominated by central government] from farmers
10. Tribal organization
11. Seed industry
12. An Agricultural University
13. Women organization
14. Two nominated representative of state government.

Headquarters

The headquarters of Protection of Plant Varieties and Farmers Rights Authority is located in **Pusa Campus, [National Agricultural Science Complex], New Deulhi.**

Plant Material Protected:

Various types of crop cultivars can be protected under PPV & FR Act. The following breeding material can be protected.

1. **All new varieties of self pollinated** species such pure line and multi line varieties.
2. **New varieties of cross pollinated** species such as open pollinated variety, synthetics and composites
3. **New varieties of vegetatively / clonally propagated species**.

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4. **Single, three-way and double cross hybrids**.
5. **Inbred parental lines of hybrid varieties.**
6. **Trees, fruits, ornamental plants and vines, etc.**

REGISTRATION

The PPV & FR Act Authority **establishes a Plant Varieties Registry, which maintains a National Register of Plant Varieties.** Specifies details under which a variety may be registered such as a complete passport data of the parental lines from which a variety has been derived have to be furnished by the breeder. A new variety will be registered under the act if it conforms to the **criteria of novelty, distinctiveness, uniformity and stability.**

1) **Novelty.** It refers to **newness of a variety**. A variety which has not been grown for more than one year prior the application for registration can be protected. .
2) **Distinctiveness.** The variety should be clearly **distinguishable** from previouslyavailable varieties at least for one characteristics.
3) **Uniformity.** It refers to **same type of population of a variety**, in cross pollinated species, the range of variation should be within the tolerable limit
4) **Stability.** It means that the **variety should give stable performance** alter repeated reproduction or propagation. Moreover, a variety should have a designation.

For registration of a variety, an application has to be filed with the Registrar, PPV & FR Act. No fee is charged if a variety is registered by a farmer.

Period of Protection

The PPV & FR Authority has accepted UPOV Act 1978. According to this Act, the period of protection is **15 years for annual and biennial Crops** and **18 years for perennial plants such as trees and vines**. The registration is renewable after its expiry for a similar term of duration.

Farmers' Rights

A farmer is entitled to **save, use, sow, resow, exchange, share or sell his farm produce** including seed of a variety protected under the Act in the same before this Act came into force. **He cannot sell branded seed of a variety protected under the Act.**

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Plant Breeders' Rights

A certificate of registration for a variety issued by this act, shall confer **an exclusive right on the breeder or his successor, his agent or licensee, to produce, sell, market, distribute, import or export seed of his variety.** The breeder has **right to authorize** any other person for production and marketing of his variety.

Exclusion

Those **techniques which are harmful to animals and the environment** such as **terminator technology and traitor technology are excluded** and **not allowed by the protection of Plant Varieties and farmers' Rights Act 2001.**

Compensation (Reward)

If a breeder of a propagating material of a variety registered under the Act sells his product to a farmer, he has to disclose the expected performance under given conditions. **If the propagating material fails to perform, the farmer can claim compensation** in the prescribed manner before the Protection of Plant Varieties and Farmers' Rights Authority.

Penalty

Penalty for applying false denomination to a variety is imprisonment up to two years and/or a fine between 50,000 and 5 lakh. Penalty for falsely representing a variety as registered is imprisonment up to three years and/or a fine between 1 lakh and 5 lakh or both. Penalty for subsequent offence is imprisonment up to three years and/or a fine between '2 lakh and 20 lakh'.

MERITS OF PPV&FR ACT 2001

- ✓ It **provides an effective system for protection** of **plant varieties, farmers' rights and plant breeders' rights**
- ✓ It **recognizes the contribution of farmers** in **conserving, improving and making available plant genetic resources for development of new plant varieties.**
- ✓ It **provides rights to farmers** to **save, use, sow, resow, exchange, share or sell his farm produce** including seed of a variety protected by PPV & FR Act.
- ✓ It **confers an exclusive right on the breeder or his successor**, **his agent or licensee, to produce, sell, market, distribute, import or export seed of his variety.** Thus it

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gives recognition to breeders for their contribution and encourage them to breed still better varieties.

- ✓ **It encourages investment in plant breeding research and development** both by **public and private sectors** for **development of superior plant varieties.** It will **lead to fast development of seed industry and improvement in seed quality** due to competitions among breeders.
- ✓ It **promotes the growth of seed industry** in the country to ensure availability of high quality seeds to the farmers.
- ✓ It involves representatives of farmers, women and seed industry in its legislative structure who will look to the interest of these sectors.
- ✓ **The Act has provision for compensation**. If the seed gives poor performance than the declared by the breeder, farmer can claim compensation in the prescribed manner before the Protection of Plant Varieties and Farmers' Rights Authority
- ✓ **The Act has provision for rewarding farmers** for their role in conserving plant genetic resources. Such **expenditure can be met out from the gene fund available with PPV & FR Act Authority.**
- ✓ **The act has provision of benefit sharing**. The farmers can get share from the benefits arising from cultivation of farmers varieties and knowledge.
- ✓ **The act has provision to impose penalties to curb unhealthy practices.**

DEMERITS OF PPV&FR ACT 2001

1. The PPV & FR Act will promote cultivation of new high yielding varieties which are **highly uniform.** This will result in **reduction in genetic diversity leading to narrow genetic base and danger of uniformity.**
2. This will **encourage monopoly of some breeders** or **seed companies for genetic material with special traits**
3. The **holders of plant breeders rights will produce less seed than market demand and hike price to earn more profit.** The high price can not be afforded by small and marginal farmers. Thus *all farmers can not take advantage of new varieties.*
4. **It will inhibit free exchange of seed material and encourage unlawful practice.**

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COMPARISON OF SEED ACT 2004 AND PPVFR ACT 2001

Sr. No.	Particulars	Seeds Act 2004	PPV & FR Act 2001
A.	**SIMILARITIES**		
1.	**Registration**	Compulsory	Compulsory
2.	**Period of registration**	15 years for annual and biennial crops and 18 years for perennials	15 years for annual and biennial crops. 18 years for Perennials
3.	**Renewal of registration**	Permitted for similar period	Permitted for similar period
4.	**Farmers Rights**	Allowed	Allowed
5.	**Plant breeders' Rights**	Available	Available
6.	**Disclosure of variety's performance**	Compulsory	Compulsory
7.	**Sale of branded seeds by fanners**	Not permitted	Not permitted
8.	**Involvement of Private Sector**	Yes	Yes
B.	**Dissimilarities**		
1.	**Record Maintained**	National Register of Seeds	National register of plant varieties
2.	**Compensation**	Through consumer court	Through PPV & FR Authority
3,	**Disclosure of variety's parentage**	Not required	Required
4.	**Variety's performance to be declared by**	Seed producer, distributor or vendor	Breeder of the variety
5.	**Penalty for violation of the Act**	5,000-50,000/	50,000-20 lakh
6.	**Imprisonment for**	Up to six months	From 2-3 years

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- **Essentially derived variety.** is a **variety which is predominantly derived from another variety (protected)** and conformed to the initial variety in all aspect excepts for the differences which result from the act of derivation, and yet is clearly distinguishable from such initial variety
- **Extant variety. All released and notified varieties which have not been protected**
- **Candidate Variety.** A variety that has to be protected,
- **Reference variety.** All **released and notified extant varieties** that are under study production chain.
- **Example variety.** A **variety that is used for comparison of a particular character**.
- **Farmers' Variety.** A **variety that has been developed by a farmer** and used for commercial cultivation for several years.

Registration procedure Under PPV&FR ACT 2001

Plant Variety Protection Application Form:

- **Form I** - for **registration of new variety, extant variety and farmer's variety and**
- **Form II** - for **essentially derived varieties (EDVs) and transgenic varieties**.
- **Technical Questionnaire attached with Form I and Form II** – for detailed information of the concerned variety

Attachments submitted along with complete registration form:

1. Document of authorization in Form PV-1
2. Document of assignment in Form PV-2
3. Documents in support of 1 and 2 given above.
4. **Affidavit that the Terminator Technology and the Genetic Use Restriction Technology is not involved;**
5. Copy of document on filing date
6. Copy of letter of agreement
7. **Technical Questionnaire** for the Candidate variety
8. In case of Convention Country applicant attach complete details on the variation in the important trait with respect to first filing as enclosure;

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9. In case of Convention Country applicant provide information whether the variety has been sold or otherwise disposed of within or outside the convention Country with details thereof;
10. In **Case of transgenic** relevant **Genetic Engineering Approval Committee clearances and approvals**.

Filing of application for the registration:

To,

Registrar,

Protection of Plant Varieties and Farmers' Rights Authority,

Govt. of India, Ministry of Agriculture, NASC Complex, DPS Marg, Opposite Todapur, New Delhi– 110 012.

Cost of registering a plant variety

A.	**Application Form Charges**	**200/-**
B.	**DUS test fee*** Rice, Wheat, Maize, Sorghum, Pearl millet, Pigeon pea, Mungbean, Urdbean, Chickpea, Field pea, Lentil, Rajmah	20,000/-
C.	**Annual Fee** The Authority shall notify the amount separately in the official Gazette (in the PVJ of India).	
II.	**Other charges**	
A.	**Registration Charges**	
1.	For Extant Variety of Common Knowledge where no DUS test is needed.	2,000/-
2.	Registration Certificate charges	5,000/-
B.	DUS test site visit charges/person/visit	500/-

DUS test under PPVFR:

- **Application along with sufficient quantity of seed should be submitted to the Registrar.**

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- **Evaluate Seeds of a variety along with parental material** to conform the standards as may be prescribed.
- Keep safe to unaltered viability and quality of seeds.
- **Applicant shall deposit the fees**. (DUS + special test) (except farmer)
- **A part of the seed sample** - to **conduct of DUS tests.**
- **Remaining part** – To **Maintain seed samples** at **National gene bank** for their entire period of protection by the Authority.

Type of variety	**Type of test**	**No. of location**	**No. of season**
New	**DUS**	**2**	**2**
Variety of common knowledge	**DUS**	**2**	**1**
Farmers	**Grow out test**	**2**	**1**
Essentially Derived Variety	**Manner of testing EDV shall be decided by authority on case to case basis.**		

<u>Acceptance of application and amendments:</u>

- **Registrar** will **accept / reject** the application depending upon the **DUS test performance.**

If Registrar has any doubt,

- Applicant has to amend the application to clarify the doubts or
- Reject the application.

Advertisement of application :

- **Registrar will advertise** the application after fulfillment of criteria by DUS testing.
- **Any person having objection**, can apply in written form to the Registrar within 3 months along with prescribed fee.
- ***Plant Variety Journal of India.***

Opposition to registration if:

- **Any person claiming** the breeder's variety.
- **Variety not registrable** under this act.

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- Registration may **not be in public interest**.
- Variety may have **adverse effect on environment.**

Steps to be taken if opposed during registration:

- **Registrar send the copy of opposition to the applicant**
- Applicant shall send the **counter statement for defending the variety**.
- **If applicant don't reply or defend**, application for **registration will be rejected**.
- **A copy of counter statement** will be **sent to the opponent by Registrar.**
- The Registrar shall give **opportunity to both applicant and opponent**. **Finally, Registrar will decide** the Rights of applicant or opponent based on the evidences produced.

Time limitation for registration:

- If registration process is not completed **within 12 months** from date of application by any reason related to applicant.
- Registrar will send notice to the applicant, if **not replied within the prescribed time**, the application is abandoned.
- Registrar can protect the *Breeder's Right* in case of any abusive act committed by any third party during the period between filing of application and final decision.

Registration of EDV under PPVFR :

- EDV must fulfill NDUS criteria.
- Registrar will forward the application for EDV registration to the Authority.
- Authority will decide on the basis of examination / test, whether the variety is derived from the initial variety or not.
- If Authority is satisfied, Registrar will register the variety. If not satisfied, application will be refused.
- The rights of the breeders of initial variety and EDV are protected and depends upon mutual agreement between these two.

Issue of the certificate if…

- When an **application for the registration of a variety (other than EDV) has been accepted.**
- The application **has not been opposed.**
- **Opposition has been rejected.**
- **Time of notice of opposition has expired**

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PLANT BREEDER'S RIGHTS

- The Plant Breeders' Rights program was first established in 1987 under the Plant Variety Rights Act [PVRA], which was succeeded by the current Plant Breeders' Rights Act 1994. [PBRA].
- Plant breeders' rights [PBR], also known as **plant variety rights (PVR),** are intellectual property rights **granted to the breeder of a new variety of plant.**
- Plant Breeders Rights are granted to **novel plant varieties that are distinctive, uniform, and stable***(e.g.,* cultivars breed true-to-type for desired traits).
- The legal protection of a new plant variety is granted to the **breeder or his successor**.
- The effect of PBR is that **prior authorization is required before the material can be used for commercial purposes.**

Main Features of Breeder's Right

1. **Registration.**

Registration is essential to get legal rights. There is **no protection without registration.** The registration consists of following steps :

a. **Filing application** in the prescribed form.
b. **Payment of prescribed processing fee along with application.** The registration fee varies from country to country. In USA, after registration annual renewal fee [300 Dollars] is payable.
c. **Examination of the application by the experts**, and
d. **Issue of protection certificate**, if application is found to meet the desired requirements.
e. Normally the registration takes about 2.5 years for most of the species.

2. Duration. The **period of protection varies with plant species**.

- **For Trees and Vines.** Initially for nine years and maximum for **18 years.**
- **For extant varieties**. Initially six years and maximum for **15 years** from the date of registration of the variety.
- **In other cases**. **Initially six years and maximum for 15 years** from the date of registration of the variety.

Thus breeders" rights allow plant breeders to get benefit of their variety for a **limited period.** When the **PBR period is over, the variety reverts to the public domain and is**

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available to every body. The limited duration of Plant Breeders' Rights ensure a balance between private and public interest.

3. Validity.

The protection of the Plant Breeders Rights is **valid only in the country** where it has been registered. The protection in other countries can be obtained by filling separate application in each country.

4. Matters Covered.

The protection right can be **granted for varieties of all botanical genera and species**. The variety should have a designation [name] as per the rule of International Code of Nomenclature.

5. Requirements.

There are four basic requirements for protection of a variety under PBR. *viz.,* **(i) novelty, (ii) distinctiveness, (iii) uniformity, and (iv) stability.**

6. Transfer.

An authorized plant breeder has **right to authorize other** interested persons for commercial production and marketing of his variety on royalty basis.

7. Control.

The authorized plant breeder has **right to prevent others from commercial production and marketing of his variety without permission.**

8. Enforcement.

The Plant Breeders' Rights **come into force immediately after registration of the variety.**

9. Other Points.

There are some other **points which are taken into account for granting PBR**. These are as follows :

- PBR can be **granted only to the owner of a new variety.**
- The plant breeders rights **protect the variety but not the standard breeding procedures** that are used to develop new variety.
- The main purpose of PBR is to **encourage breeders to develop better plant varieties.**
- The **PBRs provide monopoly of new varieties to breeders for a limited period**
- The **gene technology or gene sequences** can be **patented and the end product that is the plant variety can be protected under PBR.**

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- **A person growing protected variety cannot sale its seed on commercial scale**. But he can use the **produce of such seed for planting purpose on his farm.**
- **PBR coexists with other legislation**. It is not independent of other laws of the land.
- **The protected variety can be used to breed new varieties.**
- **A variety cannot be registered under trademarks**. It **comes under Sui generic rights**, hence it can be registered under PBR only.

Requirements for Registration of Plant breeder's rights

The PBR cannot be granted to any variety. There are **four basic requirements for protection of a variety under Plant Breeders' Rights. These are (i) novelty, (ii) distinctiveness, (iii) uniformity, and (iv) stability.**

- **Novelty.** It refers to newness of a variety. A variety which has not been grown for more than one year prior the application for registration can be protected. .
- **Distinctiveness**. The variety should be clearly distinguishable from previously available varieties at least for one characteristics.
- **Uniformity**. It refers to same type of population of a variety, lit cross pollinated species, the range of variation should be within the tolerable limit
- **Stability**. It means that the variety should give stable performance alter repeated reproduction or propagation. Moreover, a variety should have a designation.

RIGHTS PROTECTED

The *Plant Breeders' Rights Act* provides plant breeders the exclusive right to produce and sell new plant varieties which they have developed. In other words, it **provides exclusive rights to the breeder for commercial production and marketing of his variety.** The important Plant Breeders' Rights are as follows :

- **Rights for commercial Seed production.** PBR provide legal right to the breeder of a variety for large scale seed production. This he can do either on his own farm or on the farms of authorized farmers on payment basis.
- **Rights for Marketing.** The breeder or owner of a variety has exclusive rights to regulate marketing of his variety.
- **Rights to export and import.** The breeder or owner of a variety has full rights to regulate export and import of his or her variety.
- **Rights of Authorization.** The breeder or owner of a protected variety has rights to authorize other interested persons for commercial production, marketing, export and

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Import of his variety. However, prior authorization of the breeder or owner of a variety's required for such purpose.

- **Rights to prevent Infringement.** The breeder or owner of a variety has rights to prevent others from **unauthorized commercial production and marketing of his variety.**

Advantages

- ✓ **Breeders get benefit of their variety.**
- ✓ PBR help in **faster development of seed industry.**
- ✓ PBR lead to **improvement in quality because of competition**.
- ✓ PBR are **useful in procurement of good material on payment basis**.
- ✓ PBR help in **enrichment of genetic resources.**

Disadvantages

- ✓ It will **promote monopoly**.
- ✓ It will encourage **unhealthy practices**.
- ✓ It may lead to **increase in prices.**
- ✓ There will be **reduction in genetic variability**.
- ✓ There will be **compulsion to purchase fresh seed every year.**

RESEARCHERS' RIGHTS

- **The legal rights granted to any breeder/scientist/person to used protected variety for research purpose.**
- **The use of a protected variety by any person as an initial source of variety for the purpose of creating other varieties.**
- **However, authorization of the breeder is required where repeated use of such variety as a parental line is necessary for commercial production of such other newly developed variety.**
- **Permitted one time use of registered variety.**
- **Can use any of the registered variety** (initial source) for conducting experiments to develop another variety.

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FARMER'S RIGHTS

Farmers' rights refer to the rights arising from the past, present and future contributions of farmers in conserving, improving and making available plant or animal genetic resources, particularly those in the centres of origin/diversity.

In other words, the legal rights provided to farmers to save, use, sow, replant, exchange, share or sell his farm produce including seed of a variety protected under Plant Variety Protection Act refer to Farmers Rights. The purpose of these rights is to ensure full benefits to farmers and support the continuation of their contributions.

The FAO Conference held in Rome from 11-29 November, 1989 endorsed the concept of Farmers Rights with a view to :

i. Ensuring global recognition of the need for conservation and the availability of sufficient funds for these purposes;

ii. Assisting farmers and farming communities throughout the world, especially those in areas of original diversity of plant genetic resources, in the protection and conservation of their PGR and of the natural biosphere; and,

iii. Allowing the full participation of farmers, their communities and countries in the benefits derived, at present and in the future, from the improved use of PGR.

Main Features of Farmers Right

1. Registration.

A farmer who has bred or developed a new variety shall be entitled for registration and protection of his variety like a breeder. The registration process consists of the following steps :

i. ***Filing of application.*** The **application is to be filed in the prescribed form and submitted** in the office of the registrar of Plant Variety Protection and farmers' Rights Act. The application should contain all the desired documents and information.

ii. ***Examination of the application.*** The **application is examined by experts in the registrar office**. If found correct, it is advertised for opposition. Three months time is given for filing opposition.

iii. ***Registration.*** **If there is no opposition, and the registrar and Authority are satisfied**, the variety is registered and the registration certificate is issued to the breeder, farmer or other owner of the variety.

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2. Requirements.

The farmers; variety shall be entitled for registration if it meets the following requirements :

a) It should have a **denomination [name] assigned by the applicant**.
b) **An affidavit** that the **variety does not contain terminator gene.**
c) **A complete passport data of parental lines** from which the variety has been derived.
d) The **contribution of any** farmer, village community, institution or organization in the development of the variety.
e) **The source of genetic material used** in developing the variety and the parental material used in developing new variety was **lawfully acquired.**
f) A brief description of the variety about its **novelty, distinctiveness, uniformity and stability**.
g) A proof of the right to make the application.

3. Exemption From Fee.

A farmer or group of farmers or village community shall not be liable to pay any fee in any proceeding before the Authority or Registrar or the Tribunal or the High Court under Plant Variety Protection and Farmers' Rights Act or the rules made there under.

4. Rights Covered.

The Farmers' Rights Act provide following **rights to the farmers in India even for the variety protected under PPV and FR Act.**

- Rights to **save, use, sow or replant seeds of his farm produce**.
- Rights to **exchange or share his farm produce.**
- Rights to **sell seeds of his farm produce**
- However, the **farmer cannot sell the seeds or planting material under a brand name.**

5. Rights of Communities.

In India, any of the following can file application for registration on behalf of any village or community.

- **Any person or group of persons** [whether actively engaged in farming or not],
- **Any governmental or non-governmental organization**.

6. Authorization of Farmers' Variety.

The authorization for an **essentially derived variety from farmers variety cannot be given by the breeder of such farmers variety except with the consent of the farmers**

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or group of farmers or community of farmers who have made contribution in the preservation or development of such variety

7. Materials Covered

Farmers' Rights include **new varieties of all self pollinated, cross pollinated and asexually propagated varieties.**

8. Duration

The protection is provided for a **definite period.** The duration of protection for different plant species is as follows'

i. **For Trees and Vines**. Initially for nine years and maximum for **18 years.**
ii. **For extant varieties**. Initially six years and maximum for **15 years** from the date of registration of the variety.
iii. **In other cases**. Initially **six years** and maximum for **15 years** from the date of registration of the variety.

9. Validity: The protection is **valid only in the country** where the variety has been registered.

10. Benefit Sharing. If the variety has been developed by a particular farmer, he can get benefits of his variety. In **case of community rights**, **the sharing of benefits becomes difficult and the money is deposited in the gene fund.**

11. Gene Fund.

The central government has constituted a Fund called National Gene Fund. The money earned from following will be deposited in this fund;

- The **benefit sharing** received from the **breeder of a variety.**
- The **annual fee** payable to the Authority in the form of royalty.
- The **amount of compensation** received by the Authority.
- **Contribution received from any National or International Organization and other sources**. **The gene fund may be utilized for benefit sharing, rewards and other expenditure related to Plant Variety Protection and Farmers' Rights Act.**

12. Rewards.

A farmer who is **engaged in the conservation of genetic resources of land races and wild relatives** of economic plants and their improvement through selection shall be **entitled for recognition and reward**. The **expenses toward rewards will be met out from the National Gene Fund.**

13. Acknowledgement by Breeders.

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It is compulsory for the breeder of a variety to reveal the origin of the parental lines & plant genetic resources used in the development of a variety. It will help in deciding the share of different persons, *viz.,* farmers and other communities in benefits earned by breeder of such variety.

14. Infringement

If a farmer was not aware of the PPV and FR Act at the time of using any protected variety, he will be exempt from the infringement and will be asked not to do such act in future. This right has been provided to Indian farmers by PVP and FR Act 2001.

COMPARISON OF PBR AND FARMERS' RIGHTS

S.N.	Particulars	Plant Breeders* Rights	Farmers' Rights
A.	**Similarities**		
1.	Registration	Essential	Essential
2.	Duration		
	a) Trees and vines	18 years	18 years
	b) Extant varieties etc.	15 years	15 years
3.	Enforcement	After Registration	After Registration
4.	Requirements	Novelty, Distinctiveness, uniformity & stability	
5.	Validity	In country of registration	In country of registration
B.	**Dissimilarities**		
1.	Registration Fee	Charged	Not charged
2.	Annual renewal fee	Charged	Not charged
3.	Penalty for infringement	Charged	Not charged
4.	Community Rights	Not covered	Covered
5.	Authorization	Easy	Not permitted

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ADVANTAGES OF FARMERS' RIGHTS

- **Provide recognition** to farmers, communities or village **for their role in conserving Plant Genetic Resources** and Provide respect to farmers.
- **Provide opportunities to farmers** to participate in the policies, projects and programs related to plant Genetic Resources [PGR].
- **Lead to benefit sharing** when farmers material is used in developing new variety by breeders.
- **Farmers permission** is required to use their plant material.
- **Provide rewards** to those farmers who are actively engaged in conserving Plant Genetic Resources.

LIMITATIONS OF FARMERS' RIGHTS

- Mostly farmers' rights are of **collective nature.**
- The **benefit sharing is difficult.**
- Farmers do not get any financial support from government for the conservation of Plant Genetic Resources.
- Farmers' Rights are of **territorial nature.**

ROLE OF FARMERS RELATED TO PGR

- ✓ **Farmers both men and women have conserved plant genetic resources** over the past thousands of years.
- ✓ **Farmers are rightly called as on site managers of plant genetic resources.**
- ✓ **Farmers have in depth knowledge of the land races and wild relatives of cultivated plant species**.
- ✓ **All modern plant varieties contain only those genes that have originated from farmers' traditional varieties (landraces) or wild crop relatives.**
- ✓ The women and men have **historically provided the germplasms upon which scientific plant breeding is based.**
- ✓ Generally, **germplasms is provided by small-scale subsistence farmers** to plant breeders whose varieties are then adapted/developed for medium to large scale commercial farmers (Spillane, 1996).
- ✓ **Women's special knowledge of the value and diverse uses of plants for nutrition, health and income has important implications for the conservation of plant genetic resources.**

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- ✓ **The women have played significant role not only in terms of labor and skills, but also their decision-making about how natural resources are used to satisfy the multiple needs of rural households.**
- ✓ In much of the developing world, the **on-farm and in-situ conservation and use of plant genetic resources begins with women.**
- ✓ **It is estimated that ninety per cent of the planting materials used in developing countries is produced by the farmers themselves, *i.e.* from saved seed (Spillane, 1996).**
- ✓ The **selection of wild genetic resources for home planting**, **of seeds for conserving for next year's planting** and of **asexually propagated material is usually carried out by women**.

TERMINOLOGY

- **Biodiversity.** The totality of genes, species and ecosystem in a region or the world. Cultivar. Cultivated variety of plants.
- **Domestic biodiversity,** the genetic variation existing among the species, breeds, animal, plant and microbial species **that have been domesticated**, often including their immediate wild relatives.
- ***Ex-situ* conservation.** The conservation of biological diversity outside their natural habitats.
- **Farmers' rights.** Rights arising from the past, present and future contributions of farmers in conserving, improving and making available plant or animal genetic Resources.
- **Genetic Resources.** The genetic material of actual or potential value.
- ***In-situ*.** The conservation of biological diversity in the original location.
- ***In-situ*conditions.** The conditions where genetic resources exist within ecosystem and natural habitats.

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Traditional knowledge and Rights of TK holders.

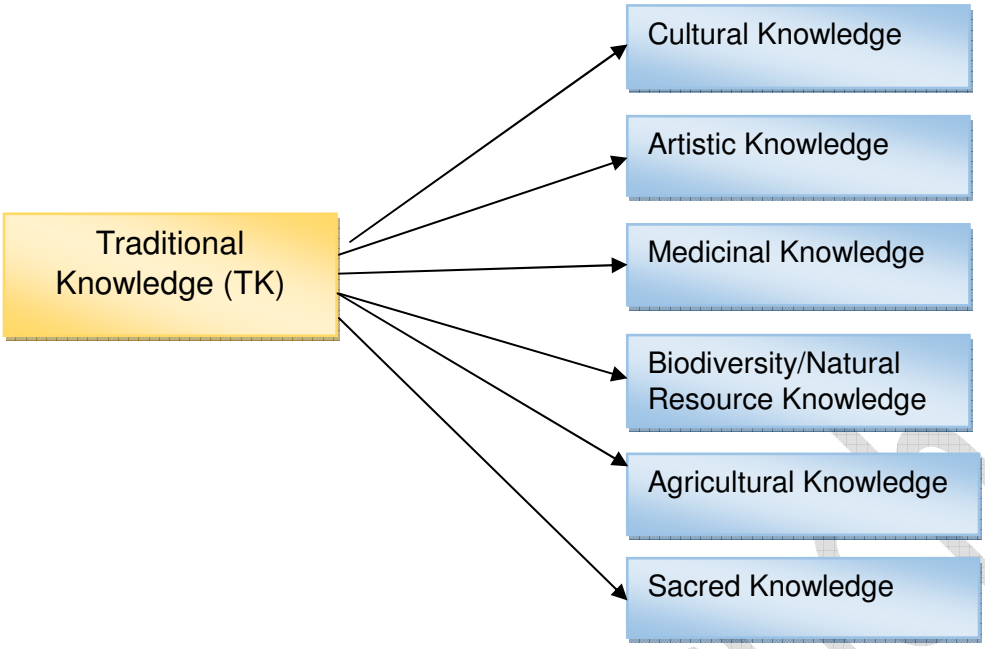
Indigenous Knowledge or Traditional Knowledge [TK] **refers to the knowledge, innovations and practices of indigenous people and local communities.**

In other words, **it is the: knowledge gained through tradition from ancestors about plants and animals, medicines, agricultural practices and other matters.**

Main points about traditional knowledge are listed below:

- Traditional knowledge can be **protected by sui-generic rights**
- **Traditional knowledge** is also known as **indigenous knowledge** or **local knowledge** or **traditional ecological knowledge.**
- It **covers** the matured long-standing **traditions and practices of certain regional, indigenous, or local communities.**
- It **includes knowledge about plants, animals, indigenous treatment of diseases through herbal medicines, cultural practices etc.**
- Traditional knowledge is **based on teachings and experiences** and is **orally passed on from generation to generation to some persons only**.
- **Some forms of traditional knowledge are expressed through stories, folklore, rituals, songs and even laws,**
- It is **collectively owned by the people or natives of an ecosystem or region.**
- Traditional knowledge **incorporates knowledge of ecosystem and code of ethics governing appropriate use of environment.**
- **The ecological knowledge is composed of both traditional knowledge and experiential knowledge.**
- **Traditional knowledge is very important almost in every sphere of life. Hence, its protection is very necessary otherwise this valuable knowledge will be gradually lost.**

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Types of Traditional Knowledge

The traditional knowledge has been classified into six major fields such as traditional knowledge of

1. Agriculture: Traditional knowledge related to agriculture includes following aspects.

- It includes knowledge of plant and animal genetic resources and their conservation.
- Knowledge of production practices including development of plant varieties and animal breeds.

2. Horticulture: Traditional knowledge related to horticulture includes:

- Knowledge of horticultural plant genetic resources and their conservation.
- Knowledge of production and improvement of horticultural plant species.

3. Forestry: It includes knowledge of timber yielding and other useful forest plants and their conservation.

4. Medicines: It include knowledge of medicinal plant species which are used for treating human and animal diseases.

5. Fisheries: It includes in depth knowledge about fish genetic resources and their conservation.

6. Human Culture:

It includes traditional knowledge which is expressed through stories, legends, folklore, rituals, songs and even laws. Moreover, local people have better knowledge of environment such as snow, ice, weather, resources and the relationship between things.

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Main Features of Traditional Knowledge

Registration:

Registration of traditional knowledge **is not essential however, registration will provide legal rights** to the people of focal communities to protect their traditional knowledge.

Duration:

The traditional knowledge can be protected for **indefinite period** by the local communities. In other words, **there is no limit for conservation of TK.**

Validity:

The traditional knowledge is generally used in the area of its conservation by local people.

Areas Covered:

The traditional knowledge is **mainly of *practical* nature,** particularly in such fields as **agriculture, horticulture, forestry, fisheries, animals and herbal medicines**. **It also includes *cultural* matters such as stories, songs, folklore, proverbs, beliefs, cultural values, rituals, community laws and local language, etc.**

Transmission:

The **knowledge is directly transmitted from individual to individual**. Generally, it is **passed on from father to son and mother to daughter generation after generation**.

Local people or natives possess both collective and individual traditional knowledge. The traditional knowledge is **passed on by elders to the young**. As the elders die, the some knowledge which has not been passed on is lost.

Control.

The Native people have the rights to prevent use of their traditional knowledge by others without permission.

Rights of T.K.

The local people or natives, who have conserved the knowledge for centuries together, own the intellectual property rights to their traditional knowledge.

No one has the right to document or use traditional knowledge without permission. In other words, the following things are required for use of traditional knowledge:

(i) **Prior permission of natives**

(ii) The **source of traditional knowledge** should be **acknowledged**

(iii) It should be **properly interpreted**.

(iv) There should **respect for traditional knowledge**.

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Bio-piracy:

The illegal collection of indigenous plants by corporations who patent them for their own use is called bio-piracy. There is bio-piracy of traditional knowledge which needs to be prevented.

Sharing of T.K.:

Local people possess both collective and individual traditional knowledge. Most traditional knowledge is shared among community members. But some traditional knowledge may be specific to an individual. This type of traditional knowledge is kept secret by some people who are engaged in treating some human animal diseases. Moreover, it **depends on the individual *to* decide whether he wishes to share his knowledge with outside parties or not.**

Main reason need to protect Traditional Knowledge

1) Equity:

Traditional farmers are not paid for their value addition. The plant breeder and seed companies are also not charged for the samples they take, hence the **inequality inherent in the current system of intellectual property rights (IPRs).**

2) Conservation of biodiversity:

Knowledge, innovations and practices of indigenous peoples and local communities are a show of their cultures. **Protecting a people's culture, therefore, entails preserving the link between the people and natural features including plants and animals.**

3) Preservation of traditional practices:

Preservation of TK **helps to preserve the self- identification of a people and can ensure the continuous existence of indigenous and traditional people.**

4) Prevention of biopiracy:

An example is the **US patent number 5, 401, 5041 granted for wound healing properties of turmeric acid. The innovation had been used in India for centuries prior to the registration of the patent**. The Council of Scientific and Industrial Research (CSIR) from India successfully applied for its revocation.

5) Promotion of the use and importance of TK in development

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Advantages of TK

- There is **no need of registration.**
- **Native people have the right** to their traditional knowledge.
- It **will help natives in profit sharing for benefits by users.**
- It is **useful in sustainable use of resources**.
- It **brings respect and reputation to the local people.**
- It is **holistic approach to knowledge**.

Disadvantages of TK

- **Non sharing of TK will promote monopoly.**
- It is **some times lost due to non-disclosure**.
- It is **passed on orally to next generation**.
- It is **based on personal experience.**
- Explanations are **based on examples, stories and myth.**

TABLE 31.3. A comparison among UPOV Act (1978), UPOV Act (1991), PPVFR Act (2001) and Patents

Feature	*UPOV Act (1978)*	*UPOV Act (1991)*	*PPVFR Act (2001)**	*Patent*
Protection coverage	Plant varieties of nationally defined plant species	Plant varieties of all plant genera and species	Varieties of nationally specified genera and species	Inventions
Requirements for protection	1. Distinctness 2. Uniformity 3. Stability	1. Novelty 2. Distinctiveness 3. Uniformity 4. Stability	1. Novelty** 2. Distinctiveness† 3. Uniformity 4. Stability	1. Novelty 2. Inventiveness 3. Non-obviousness 4. Industrial application and usefulness
Duration of protection	Minimum 15 yr	Minimum 20 yr	15 yr for extant varieties and new varieties of crops; 18 yr for varieties of trees and vines	17-20 yr (OECD)††
Scope of protection	Commercial use of the ***reproductive*** material of protected variety	Commercial use of ***all material*** of the protected variety	Commercial use of ***all material*** of the protected variety	Commercial use of protected subject matter
Breeder's exemption	Yes	Yes, ***except for essentially-derived varieties and parents of hybrids***	Yes, except for ***essentially-derived varieties, and use as parents of hybrid varieties***	No
Farmer's privilege	Yes (in practice)	Optional; left to the national laws	Yes, as 'farmer's right'; more extensive than in UPOV Act (1978)	

* PPVFR Act, 2001, The Protection of Plant Varieties and Farmers' Right Act, 2001.
** A variety not in commercial use for more than one year in India, or 4 years (6 years in case of trees and vines) outside India.
† In case of extant varieties; distinctiveness, uniformity and stability.
†† OECD, Organization for Economic Cooperation and Development.

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-:BIODIVERSITY & IPR:-

- **The biodiversity refers to the variety of life in all forms, levels and combinations.**
- The, term **Biodiversity** includes **genetic diversity, species diversity, and ecosystem diversity.**
- **Crop biodiversity** refers to **the variety of genes and genotypes found in crop plants.**
- Biodiversity is a modern term which simply means **"the variety of life on earth".** This variety of life can be measured in several ways.

1. Genetic Diversity

Genetic diversity refers to **the variation between individuals of the same species**. This includes genetic variation between individuals in a single population, as well as variations between different populations of the same species. The main points related to genetic diversity, are listed below.

- ✓ It represents **variation between individuals of the same species.**
- ✓ It represents the **variation at gene level.**
- ✓ It can be **measured at population, species and community levels**.
- ✓ **Sophisticated techniques** are required for its measurement.
- ✓ It represents the **raw material for evolution and adaptation**.
- ✓ It is **effected by the environment and competition with other species.**

2. Species Diversity

Species diversity refers to **the variety of species in a given region or area.** This can be either be **determined by counting the number of different species present** or by determining **taxonomic diversity**. **Taxonomic diversity is more precise** and considers the relationship of species to each other. For example, an area containing three species of wheat and two species of barley, is more diverse than an area containing five Species of wheat, even though they both contain the same number of species. The main points related to species diversity are listed below.

- ✓ It **represents variety of species in a given region or area.**
- ✓ Its **identification is easy by naked eye** in the field.
- ✓ It can be **determined simple by counting the number of different species**.
- ✓ **Species are distinct units of diversity.**

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3. Ecosystem Diversity

Ecosystem diversity refers **to communities of plants and animals, together with the physical characteristics of their environment** *(e.g.* geology, soil and climate). Ecosystem diversity is **more difficult to measure** because there are **rarely clear cut boundaries** between different ecosystems and they grade into one another. However, if consistent criteria are chosen to define the limits of an ecosystem, then their number and distribution can also be measured. The main points related to ecosystem biodiversity are given below.

- ✓ It **represents communities of plants and animals together with physical structures of their environment**.
- ✓ The **measurement of ecosystem diversity is more difficult than genetic diversity and species diversity**.
- ✓ The **assessment of ecosystem diversity needs many complex measurements to be taken over a long period of time.**
- ✓ It is a **time consuming task and completion of such work requires adequate staff and financial support.**

ADVANTAGES OF CROP BIODIVERSITY

There are several advantages of crop biodiversity. Some important advantages or benefits of crop biodiversity are briefly presented as follows.

- ❑ The **crop biodiversity provides choice of items for food, fiber, oil, fuel, fodder to animals, timber and medicines.**
- ❑ It **provides protection from biotic** [disease and insects] and **abiotic** [drought, soil salinity, soil alkalinity, soil acidity, cold temperature, heat etc.] **stresses** and also **provides wider adaption and broad genetic base to the populations.**

LOSS OF CROP BIODIVERSITY

There are **two main reasons of depletion of biodiversity in crop plants**, *viz.,* **extinction and genetic erosion.**

Extinction refers to **permanent loss of a crop species due to various reasons**.

Genetic erosion refers to the **gradual reduction in genetic variability**, **in population of a species, due to elimination of various genotypes.**

There are five main reasons of genetic erosion, viz.,

(i) **Replacement of land races by modern cultivars,**

(ii) **Industrial agriculture and mechanization,**

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(iii) **Farming into wild habitat,**

(iv) **Clean cultivation and**

(v) **Developmental activities.**

CONSERVATION OF BIODIVERSITY

Conservation refers to protection of genetic diversity of crop plants from genetic erosion.

There are two major methods of conserving viz.,

(i) ***In-situ* conservation and**

(ii) ***Ex-situ* conservation.**

(i) *In-situ* Conservation

***In-situ* (= on-site) conservation and use refers to the maintenance and use of wild plant populations in the habitats where they naturally occur and have evolved without the help of human beings.**

In other words, **it refers to conservation of biodiversity under natural habitats**. In this method, the **wild species and the complete ecosystems are preserved together**.

The main focus of Biodiversity's work is on the **maintenance of the genetic diversity of the wild species and wild relatives of crop plants in the protected areas [national parks and nature reserves].**

Advantages.

- The **biodiversity is conserved under natural habitats**.
- It **improves of the populations**.
- It **conserves complete ecosystem** means **several species together**.
- It **protects endangered species** in their original habitats.

Disadvantages.

- It requires **establishment of gene sanctuaries and national parks.**
- **Several areas have to be conserved** to protect a single species.
- The **management of protected areas poses several problems**.
- It is **costly method** of biodiversity conservation,

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(ii) *Ex-situ* Conservation

- ✓ ***Ex-situ* (= off-site) conservation** of **germplasm takes place outside the natural habitat or outside the production system, in facilities specifically created for this purpose.**
- ✓ Depending on the type of species to be conserved, different *ex-situ* conservation methods may be used. **The gene banks are used for *ex-situ* conservation of biodiversity.**
- ✓ In **gene banks**, **biodiversity is conserved for its sustainable use by breeders, farmers and researchers for agricultural development**

Advantages.

- One species can be conserved at **one place.**
- The biodiversity is conserved either in seed gene banks or in field gene banks.
- **Handling of material is easy.**
- It **requires less space** for conservation.

Disadvantages.

- It requires **establishment of seed gene banks and field gene banks.**
- It requires **regular funding for maintenance of gene banks.**
- It involves **high technical man power**.
- It requires **periodical rejuvenation in case of seed crops.**

CONVENTION ON BIOLOGICAL DIVERSITY [CBD]

The Convention (agreement/treaty) on Biological Diversity is also known as the Biodiversity Convention. It is an **international treaty** that was **adopted in Rio de Janeiro in June 1992.** The Invention was **opened for signature** at the Earth Summit in Rio de Janeiro on 5 June, 1992 and **entered into force** on 29 December, 1993. The biodiversity agreement has been signed by **189 countries**. *The Convention has following three main goals:*

1. **Conservation of biological diversity (or biodiversity);**
2. **Sustainable use of its components; and**
3. **Fair and equitable sharing of benefits arising from genetic resources.**

1. **Conservation of Biodiversity**

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- The **convention recognized for the first time in international law** that **the conservation of biological diversity is "a common concern of humankind"** and is an integral part of the development process.
- Its **objective** is **to develop national strategies for the conservation and sustainable use of biological diversity.**
- The **Convention recognizes** that **ecosystem, species and genes must be used for the benefit of humans.** However, **this should be done in a way and at a rate that does not lead to the long-term decline of biological diversity.**
- The **convention states** that **if there is a threat of significant reduction or loss of biological diversity, immediate measures must be taken up to avoid or minimize such a threat.**
- The **conservation of biodiversity**, though requires substantial investments, **will bring us significant environmental, economic and social benefits in return.**

2. Sustainable Use

- The agreement covers all ecosystems, species, and genetic resources.
- It links traditional conservation efforts to the economic goal of using biological resources sustainably.
- **The convention reminds decision-makers that natural resources are not infinite and sets out a philosophy of sustainable use.**

3. **Equitable Benefit Sharing**

It sets principles for the fair and equitable sharing of the benefits arising from the use of genetic resources, notably those destined for commercial use.

The main points are as follows:

1. **Measures and incentives** for the conservation and sustainable use of biological diversity.
2. **Regulated access** to genetic resources and traditional knowledge, including prior informed consent of the party providing resources.
3. **Sharing**, **in a fair and equitable way**, the results of research and development and the benefits arising from the commercial and other utilization of genetic resources.
4. **Access to and transfer of technology**, including biotechnology, to the governments and/or local communities that provided traditional knowledge and/or biodiversity resources.
5. **Technical and scientific cooperation**,
6. **Impact assessment**.

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7. **Education and public awareness**.
8. **Provision of financial resources**.
9. National reporting on efforts to Implement treaty commitments,

CARTAGENA PROTOCOL

- **The Cartagena Protocol on Biosafety of the Convention**, also known as the **Biosafety protocol, was adopted in January 2000.**
- **The Biosafety Protocol seeks to protect biological diversity** from the potential risks posed by living modified organisms resulting from modern bio-technology.
- **The Biosafety Protocol makes clear** that **products from new technologies must be based on the precautionary principle** and allow developing nations to balance public health against economic benefits.
- It will **for example** let **countries ban imports of a genetically modified organism if they feel there is not enough scientific evidence the product is safe** and requires exporters to label shipments containing genetically altered commodities such as corn or cotton.

INDIAN BIODIVERSITY LEGISLATION / BIOLOGICAL DIVERSITY ACT 2002.

In India the **Biological Diversity Act** [also called **Biodiversity act**] was passed by the **Central Government in 2002**.

The salient features of the Biodiversity Legislation are briefly presented below.

1. Purpose.

The purpose of the Biodiversity Act-2002 is to protect *India's rich biodiversity [genetic resources] and associated knowledge* against their use by foreign individuals, institutions or companies **without sharing the benefits arising out of such use, and check bio-piracy.**

2. Structures of Biodiversity Act-2002.

The biodiversity Act provides for establishment of a **three tiered structure** at the **national, state and local level as given below.**

(i) National Biodiversity Authority (NBA).

All matters relating **to requests for access** by **foreign** individuals, institutions or companies, and all matters relating **to transfer of results of research** to any foreigner will be dealt with by the National Biodiversity Authority.

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(ii) State Biodiversity Boards (SBB).

- **All matters relating to access by Indians** for commercial purposes will be under the purview of the State Biodiversity Boards (SBB).
- **The Indian industry will be required to provide prior intimation** to the concerned SBB about the **use of biological resource.**
- The State Board will have **the power to restrict any such activity, which violates the objectives of conservation, sustainable use and equitable sharing of benefits.**

(iii) Biodiversity Management Committees (BMCs).

- **Institutions of local self government will be required to set up Biodiversity Management Committees** in their respective areas for conservation, sustainable use, documentation of biodiversity and chronicling of knowledge relating to biodiversity.
- **NBA and SBBs are required to consult the concerned BMCs on matters related to use of biological resources and associated knowledge within their jurisdiction.**

3. Research on Biological Resources.

There is no requirement under the legislation for seeking permission of the National Biodiversity Authority for carrying out research, if it is carried out in India by Indians, as well as under collaborative research projects that have been drawn within the overall policy guidelines formulated by the Central Government.

The only situations that would require permission of the NBA are

(i) When the **results of any research** which has made use of the country's biodiversity is **sought to be commercialized,**

(ii) When the results of research are **shared with a foreigner or foreign institution**, and

(iii) **When foreign institution wants access** to the country's biodiversity for undertaking research.

4. Exemptions.

The legislation provides for the following exemptions,

(i) Exemption to **local people and community of the area for free access to use of biological resources within India.**

(ii) Exemptions to **growers and cultivators of biodiversity and to Vaids and Hakims to use biological resources.**

(iii) Exemption through notification of normally traded commodities from the purview of the Act.

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(iv) **Exemption for collaborative research through government sponsored or government approved** institutions subject to overall policy guidelines and approval of the Central Government.

(v) **The value added products** have been excluded from the definition of biological resources.

(vi) **The Indian researchers neither require prior approval nor need to give prior intimation to SBB** for obtaining biological resource for conducting research in India.

5. Indian industry and Biodiversity Act.

The Indian industry is required to give prior intimation to the concerned SBB about obtaining the biological resources for commercial purposes. The SBB will have the power to prohibit or restrict any such activity, which violates the objectives of conservation, sustainable use and equitable sharing of benefits.

6. Ayurvedic Industry.

The Act does not aim at banning the use of medicinal plants. It provides that for commercial use of resources and related knowledge by Indians only, prior intimation to the State Biodiversity Board is required. Hakims and vaids will continue to have free access to resources and knowledge.

7. Biodiversity Bill and Plant Varieties Protection Act.

There is **no overlap** between Biodiversity Bill and Plant Varieties Protection (PVP) Act. The **scope and objectives** of these two legislations are **different**.

- **The PVP legislation** accords intellectual property **rights to a person for developing a new plant variety.**
- On the other hand, the **biodiversity legislation** is **primarily aimed at regulating access to biological resources and associated knowledge** so as to ensure equitable sharing of benefits arising from their use

8. Heritage sites.

The Act [Section 37] provides for designating heritage sites. **These are areas of biodiversity importance, which harbor rich biodiversity, wild relatives of crops, or areas, which lie outside the protected area network.** The purpose is not to cover the already designated protected areas such as national parks and wildlife sanctuaries.

9. Threatened species.

The Act [Section 38] provides for notifying threatened species and prohibits or regulates their collection. It also provides for taking appropriate steps to rehabilitate and preserve those species, thereby ensuring their conservation and management.

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10. Repositories.

The Act [Section 39] **provides for designating some premier Institutions of the country** (e.g. Botanical Survey of India, Zoological Survey of India, National Bureau of Plant Genetic Resources etc.) **as repositories** for keeping differed Categories of biological resources for **safe custody and posterity.**

11. Check on Bio-piracy.

To check biopiracy, the proposed legislation provide that access to biological resources and associated knowledge is **subject to terms and conditions, which secure equitable sharing of benefits.** Further, **it would be required to obtain the approval of the National Biodiversity Authority before seeking any IPRbasedon biological material and associated knowledge obtained from India.**

12. Benefit Claimers.

- **The benefit claimers are conservers of biological resources, creators and holders of knowledge and information relating to the uses of biological resources.**
- While granting approvals, **NBA will impose conditions, which secure equitable share in the benefits arising out of the use of biological resources occurring in India or knowledge relating to them.**
- **These benefits could include monetary gains, grant of joint ownership of IPRs, transfer of technology,** association of Indian Scientists in R & D setting up of venture capital fund etc.
- **In cases where specific individuals, or group of individuals are identifiable, the monetary benefits will be paid directly to them**. Otherwise, the amount will be deposited in the National Biodiversity Fund.

National Biodiversity Authority (NBA).

The National Biodiversity Authority (NBA) was established by the Central Government in 2003 to implement India's Biological Diversity Act (2002). The NBA is a Statutory Body and it performs facilitative, regulatory and advisory functions for the Government of India on issues of conservation, sustainable use of biological resources and fair and equitable sharing of benefits arising out of the use of biological resources.

The head office of the National Biodiversity Authority shall be at Chennai and the National Biodiversity Authority may, with the previous approval of the Central Government, establish offices at other places in India.

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The NBA with its headquarters in Chennai, Tamil Nadu, India delivers its mandate through a structure that comprises of the Authority, Secretariat, SBBs, BMCs and Expert Committees. Since its establishment, NBA has supported creation of SBBs in 29 States and facilitated establishment of around 72,304 BMCs

FUNCTIONS AND POWERS OF THE NATIONAL BIODIVERSITY AUTHORITY

(1) It shall be the duty of the National Biodiversity Authority to regulate activities referred to in sections 3, 4 and 6 and by regulations issue guidelines for access to biological resources and for fair and equitable benefit sharing.

(2) The National Biodiversity Authority may grant approval for undertaking any activity referred to in sections 3, 4 and 6.

(3) The National Biodiversity Authority may-

(a) advise the Central Government on matters relating to the conservation of biodiversity, sustainable use of its components and equitable sharing of benefits arising out of the utilization of biological resources;

(b) advise the State Governments in the selection of areas of biodiversity importance to be notified under sub-section (1) of section 37 as heritage sites and measures for the management of such heritage sites;

(c) Regulate activities, approve and advice the government of India on research, commercial, bio-survey and bio-utilization.

(d) Certain persons not to undertake -biodiversity related activities without approval of national-biodiversity authority (section 3).

(e) Results of research not to be transferred to certain persons without approval of national-biodiversity authority (section 4).

(f) Application for IPR rights not to be made without approval of national-biodiversity authority (section 6).

(g) Perform such other functions as may be necessary to carry out the provisions of this act

(4) The National Biodiversity Authority may, on behalf of the Central Government, take any measures necessary to oppose the grant of intellectual property rights in any country outside India on any biological resource obtained from India or knowledge associated with such biological resource which is derived from India.

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State Biodiversity Boards (SBBs)

State Biodiversity Boards (SBBs) are to be established under Section 22 of the Act. Accordingly, in all the 29 States, SBBs have been established..

The Functions of State Biodiversity Boards are as under:

1. Advise the State Governments, subject to guidelines issued by the Central Government, on matters relating to conservation of biodiversity, sustainable use of its components and equitable sharing of benefits arising out of utilization of biological resources.
2. Regulate by granting approvals or otherwise request for commercial utilization or bio-survey and bio utilization of any biological resource by Indians;
3. Perform such other functions as necessary to carry out the provisions of this Act or as prescribed by the State Governments.

Biodiversity Management Committees

Every local body shall constitute a Biodiversity Management Committee within its area for the purpose of promoting conservation, sustainable use and documentation of biological diversity including preservation of habitats, conservation of land races, folk varieties and cultivars, domesticated stocks and breeds of animals and microorganisms and chronicling of knowledge relating to biological diversity.

Explanation. - For the purposes of this sub-section,-

(a) "cultivar" means a variety of plant that has originated and persisted under cultivation or was specifically bred for the purpose of cultivation;

(b) "folk variety" means a cultivated variety of plant that was developed, grown and exchanged informally among farmers;

(c) "landrace" means primitive cultivar that was grown by ancient farmers and their successors.

The National Biodiversity Authority and the State Biodiversity Boards shall consult the Biodiversity Management Committees while taking any decision relating to the use of biological resources and knowledge associated with such resources occurring within the territorial jurisdiction of the Biodiversity Management Committee.

The Biodiversity Management Committees may levy charges by way of collection fees from any person for accessing or collecting any biological resource for commercial purposes from areas falling within its territorial jurisdiction.

The functions of BMCs are as under:

1. Prepare, maintain and validate People's Biodiversity Register (PBR) in consultation with the local people. The BMC is to maintain a Register giving information about the details of biological resources and traditional knowledge available within the jurisdiction of BMC.
2. Advice on any matter referred to it by the State Biodiversity Board or Authority for granting approval, to maintain data about the local vaids and practitioners using the biological resources

TERMINOLOGY

1. **Accession**.

   A sample of a crop variety collected at a specific location and time; may be of any size.
2. **Adaptation**.

   The fitness of a genotype to a particular environment.

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THE INTERNATIONAL TREATY ON PLANT GENETIC RESOURCES FOR FOOD AND AGRICULTURE (ITPGRFA)

The International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), popularly known as the International Seed Treaty, is a comprehensive international agreement in harmony with the Convention on Biological Diversity, which aims at guaranteeing food security through the conservation, exchange and sustainable use of the world's plant genetic resources for food and agriculture (PGRFA), as well as the fair and equitable benefit sharing arising from its use.

The International Treaty on Plant Genetic Resources for Food and Agriculture was adopted by the 31st Session of the Conference of the Food and Agriculture Organization of the United Nations on 3 November 2001.

***It also recognizes farmers' rights, subject to national laws to*:**

a) The protection of traditional knowledge relevant to plant genetic resources for food and agriculture;
b) The right to equitably participate in sharing benefits arising from the utilization of plant genetic resources for food and agriculture; and
c) The right to participate in making decisions, at the national level, on matters related to the conservation and sustainable use of plant genetic resources for food and agriculture.

The Treaty establishes the Multilateral System of Access and Benefit-sharing to facilitate plant germplasms exchanges and benefit sharing through Standard Material Transfer Agreement (SMTA).

The goals of ITPGRFA

To support food security and sustainable agriculture

- Through continuous conservation and utilization of the plant genetic resources for food and agriculture;
- The benefit sharing arising out their use should be fair and equitable in accordance with the Convention on Biodiversity (CBD)

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To Protect Farmer's Rights

- Based on the contribution from farmer, local society in the centre of plant genetic resources for the conservation and the development of plant genetic resources as the basis of food production and agricultural in the world.

What makes PGRFA different?

- Importance of PGRFA for food security (1960- Green revolution and post green revolution-saved one billion people from starvation)
- Importance of PGRFA for breeding - Over the last 60 years it has been estimated that half the yield gains in major crops is attributable to the introduction of new cultivars
- Interdependence of countries on PGRFA.

History: Evolution of the Treaty

- **The conservation and sustainable use of plant genetic resources for food and agriculture** are **key to ensuring that the world will produce enough food to feed its growing population in the future.**
- **In 1983,** the **Commission on Genetic Resources for Food and Agriculture** was established, and the voluntary **International Undertaking on Plant Genetic Resources** was adopted.
- Another major step was taken in **1996 with the adoption of the Global Plan of Action** at the **Leipzig International Technical Conference on Plant Genetic Resources**.
- All this work **culminated (concluded/finished) in 2001** with the **historic adoption of the legally binding International Treaty on Plant Genetic Resources for Food and Agriculture.** The Treaty entered into force on **29 June 2004.**

Genesis of IPTGFRA & MLS

1992 - Adoption of CBD

1994 - Beginning of negotiations

2001 - Adopted by the FAO Conference

2006 - 1st Session of the GB (Madrid) SMTA& Funding Strategy adopted

June 2009 –3rd Session of the GB (Tunis)

March 2011 –4th Session of the GB (Bali)

September 2013 – 5th Session of the GB (Muscat, Oman)

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- The International Treaty was adopted on 3 November 2001 by the Thirty-first Session of the FAO Conference.
- Enforced on 29th June 2004.
- July 2016: 139 Contracting Parties (138 states and EU)

International Seed Treaty

Signed	2001
Location	Madrid
Effective	2004
Depositary	Secretary-General of the United Nations
Languages	Arabic, Chinese, English, French, Russian and Spanish

Objectives of ITPGRFA

The objectives of this Treaty are

- **The conservation (Article 5) and sustainable use (Article 6) of plant genetic resources for food and agriculture.**
- **Recognizing the enormous contribution of farmers** to the diversity of crops that feed the world;
- Establishing a **global system** to provide farmers, plant breeders and scientists with **access to plant genetic materials;**
- **Fair and equitable sharing (Article 13) of the benefits arising out of their use, in harmony with the Convention on Biological Diversity, for sustainable agriculture and food security.**
- These objectives will be attained by closely linking this Treaty to the Food and Agriculture Organization of the United Nations and to the Convention on Biological Diversity.

Use of terms

- **"In situ conservation"** means the conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings and, in the case of domesticated or cultivated plant species, in the surroundings where they have developed their distinctive properties.
- **"*Ex situ* conservation"** means the conservation of plant genetic resources for food and agriculture outside their natural habitat.
- **"Plant genetic resources for food and agriculture"** means any genetic material of plant origin of actual or potential value for food and agriculture.
- **"Genetic material"** means any material of plant origin, including reproductive and vegetative propagating material, containing functional units of heredity.
- **"Variety"** means a plant grouping, within a single botanical taxon of the lowest known rank, defined by the reproducible expression of its distinguishing and other genetic characteristics.
- **"Centre of origin"** means a geographical area where a plant species, either domesticated or wild, first developed its distinctive properties.
- **"Centre of crop diversity"** means a geographic area containing a high level of genetic diversity for crop species in *in-situ* conditions.

Head quarters of ITPGRFA

- **FAO head qurter= Viale delle Terme di Caracalla, Rome, Italy**

Aims of Treaty

- **Recognizing the enormous contribution of farmers** to the diversity of crops that feed the world
- **Establishing a global system** to provide farmers, plant breeders and scientists with access to plant genetic materials
- **Ensuring that recipients share benefits** they derive from the use of these genetic materials with the countries where they have been originated.

Why to implement ITPGRFA & MLS?

1. **Scope - This legally binding Treaty covers all PGRFA relevant for food and agriculture.** (Article 3)

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2. Each country that **ratifies will then develop the legislation and regulations** it needs to implement the Treaty (Article 4).
3. The Treaty is vital in **ensuring the continued availability of the plant genetic resources that countries will need to feed their people.**

Treaty's Objectives

1. **Conservation(Article 5).**
2. **Sustainable use** of PGRFA for food and Agriculture **(Article 6).**
3. **Fair and equitable sharing of benefits** derived from their use **(Article 13).**

Major activities of ITPGRFA

General Provisions

Article 4 - General Obligations

Each Contracting Party shall ensure the conformity of its laws, regulations and procedures with its obligations as provided in this Treaty.

Article 5 - Conservation, Exploration, Collection, Characterization, Evaluation and Documentation of Plant Genetic Resources for Food and Agriculture

Each Contracting Party shall, subject to national legislation, and in cooperation with other Contracting Parties where appropriate, promote an integrated approach to the exploration, conservation and sustainable use of plant genetic resources for food and agriculture and shall in particular, as appropriate

The Contracting Parties shall, as appropriate, take steps to minimize or, if possible, eliminate threats to plant genetic resources for food and agriculture.

Article 6 - Sustainable Use of Plant Genetic Resources

The Contracting Parties shall develop and maintain appropriate policy and legal measures that promote the sustainable use of plant genetic resources for food and agriculture.

Article 7 - National Commitments and International Cooperation

Each Contracting Party shall, as appropriate, integrate into its agriculture and rural development policies and programme, for the conservation and sustainable use of plant genetic resources for food and agriculture and cooperate with other Contracting Parties, directly or through FAO and other relevant international organizations.

Article 8 - Technical Assistance

The Contracting Parties agree to promote the provision of technical assistance to Contracting Parties, especially those that are developing countries or countries with economies in transition, either bilaterally or through the appropriate international organizations, with the objective of facilitating the implementation of this Treaty.

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Farmers' Rights (Article 9 - ITPGRFA)

Farmers' Rights include:

- Protection of traditional knowledge;
- Participate equitably in benefit sharing
- Participate in decision making process , at the national level, on matters related to PGRs
- Save, use, exchange, and sell farm-saved seed/propagating material subject to national law.
- Compensation for losses due to use of new breeders' protected varieties.

The Multilateral System of Access and Benefit-sharing

- The Treaty establishes a multilateral system, both to facilitate access *to plant genetic resources for food and agriculture*, and to share, *in a fair and equitable way, the benefits arising from their use.*
- It applies to a list of crops established according to criteria of food security and interdependence
- These provide about 80% of our food from plants

Multilateral System of Access and Benefit-sharing

- In their relationships with other States, the Contracting Parties recognize the sovereign (paramount/topmost/prime) rights of States over their own plant genetic resources for food and agriculture, including that the authority to determine access to those resources rests with national governments and is subject to national legislation.
- In the exercise of their sovereign rights, the Contracting Parties agree to establish a multilateral system, which is efficient, effective, and transparent, both to facilitate access to plant genetic resources for food and agriculture, and to share, in a fair and equitable way, the benefits arising from the utilization of these resources, on a complementary and mutually reinforcing basis.

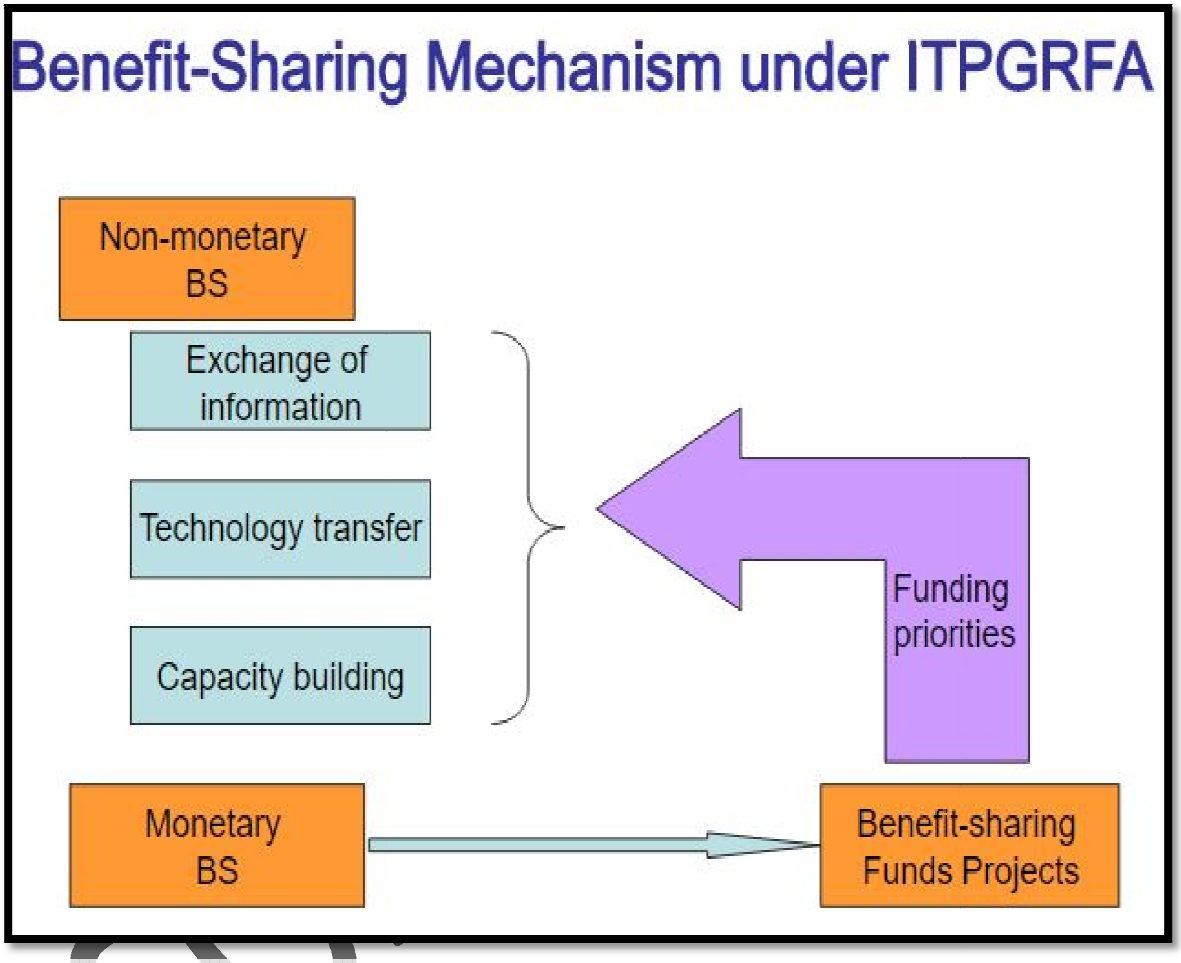
The Multilateral System "pools" these crucial plant genetic resources

- They are available under a Standard Material Transfer Agreement (SMTA)
- There is no tracking of individual accessions
- Recipients must continue to make the materials received available
- "Intellectual property or other rights that limit access to the plant genetic resources for food and agriculture, or their genetic parts and components, in the form received from the Multilateral System" may not be claimed

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Benefit-sharing

- Because these genetic resources are pooled, there is no individual owner with whom individual contracts for access and benefit-sharing must be negotiated
- This means there are very low transaction costs, to the benefit of farmers, plant breeders and researchers, and ultimately of consumers
- It also means that benefits must be shared in a pooled, multilateral way



Benefits of the MLS

- MLS now a day-to-day operational system;
- Access itself
- Low transaction costs
- Overcomes market failure
- Provides public and private breeders with a wide range of resources
- Contributes to food security
- Provides the industry with a clear framework in which to plan investment

Standard Material Transfer Agreement (SMTA)

- Contracting Parties beginning to applyit;
- Toolkitsplanned for application of SMTA
- Establishment of information technology infrastructure
- SMTA being applied worldwide by CGIAR;
    - 89,000 transfers within 8 months;
    - Increasing private sector interest & involvement

Experts Welcome International Seed Treaty

- Implications of ITPGRFA, are yet to be pursued debatable, While many have welcomed the treaty as a step forward in fulfilling the Millennium Development Goals in ensuring farmers' rights, food security and biodiversity. Others have suggested a similar global treaty for protection of interests of livestock keepers.
- ITPGRFA is a binding agreement that gives legal force to the conservation and sustainable use of 64 food crops from 35 genera and 29 forges.
- This treaty was initiated by the UN Food and Agriculture Organization (FAO) and comes into force 90 days after the 40th ratification by UK and other European countries on March 31, 2004.
- But the treaty has an ambiguity (doubt) in Article 12.3.d, which is being interpreted by countries as allowing changes to intellectual property rights (IPRs) on changes made to genetic resources held in the multi-lateral system (MLS).
- This would mean patenting of seeds and restricting farmers' access and defeating the basic purpose of the treaty.

The Treaty aims at:

- **Recognizing the enormous contribution of farmers to the diversity of crops that** feed the world;
- Establishing a global system to provide farmers, plant breeders and scientists with access to plant genetic materials;
- Ensuring that recipients share benefits they derive from the use of these genetic materials with the countries where they have been originated.
- The ITPGRFA will facilitate germplasm exchange in designated crops. Also, bilateral agreements with different countries can be made for introduction of need-based trait-oriented germplasm.
- Technical inputs were provided at the international negotiations of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), the Global

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Plan of Action (GPA) for PGRFA, International Standards for phytosanitary Measures (ISPMs).

- For crops not covered under ITPGRFA, appropriate national programmes need to be identified and followed with the needful germplasms requirements to overcome yield barriers or for value addition and development of bilateral agreements to facilitate the import of desired germplasms accessions.

The Importance/Benefits of ITPGRFA in relations to IPR

- The International Treaty on Plant Genetic Resources for Food and Agriculture is crucial in the fight against hunger and poverty and essential for the achievement of Millennium Development.
- No country is self-sufficient in plant genetic resources; all depend on genetic diversity in crops from other countries and regions.
- International cooperation and open exchange of genetic resources are therefore essential for food security.
- The fair sharing of benefits arising from the use of these resources has for the first time been practically implemented at the international level through the Treaty and its Standard Material Transfer Agreement

What is special about plant genetic resources for food and agriculture?

- PGRFA "means any genetic material of plant origin of actual or potential value for food and agriculture''. (Article-2)
- Historically, plant genetic resources were relatively freely exchanged in accordance with the idea that these resources were the common heritage of humankind.
- Farmers have been involved in collective system of conservation and utilization, openly sharing these since the earliest time of crop domestications.
- Relatively open flows of plant germplasms resulted the spread of PGRFA from its center of origin to the centers of domestication.

Who benefits from the Treaty and how?

All benefit, in many ways

- Farmers and their communities, through Farmers' Rights
- Consumers - of a greater variety of foods, and of agriculture products, as well as increased food security;
- The scientific community, through access to the plant genetic resources crucial for research and plant breeding;

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- International Agricultural Research Centers, whose collections the Treaty puts on a safe and long-term legal footing
- Both the public and private sectors, which are assured access to a wide range of genetic diversity for agricultural development; and
- The environment, and future generations, because the Treaty will help conserve the genetic diversity necessary to face unpredictable environmental changes, and future human needs.

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-:ABBREVIATIONS:-

1.	IPRs	:	Intellectual Property Rights
2.	ITO	:	International Trade Organization
3.	IBRD	:	The International Bank for Reconstruction and Development
4.	IMF	:	International Monetary Fund
5.	UNO	:	United Nations Organization
6.	GATT	:	General Agreement on Tariffs and Trade
7.	TLT	:	Trademark Law Treaty
8.	PLT	:	Patent Law Treaty
9.	WIPO	:	World Intellectual Property Organization
10.	NCCS	:	National Centre for Cell Science
11.	MCC	:	Microbial Culture Collection
12.	MTCC	:	Microbial Type Culture Collection and Gene Bank
13.	GEF	:	Global Environment Facility
14.	NFPs	:	National Focal Points
15.	CNAs	:	Competent National Authorities
16.	PCT	:	Patent Cooperation Treaty
17.	TIFAC	:	Technology Information and Forecasting Council
18.	PFC	:	Patent Facilitating Centre
19.	NIC	:	National Informatics Centre
20.	EPIDOS	:	European Patent Information & Document Service
21.	EPO	:	European Patent Office
22.	IT	:	Information Technology
23.	CIPO	:	Canadian Patents Database
24.	IDA	:	International Depositary Authority
25.	GI	:	Geographical indication
26.	TM	:	Trademark
27.	SICLD	:	Semiconductor Integrated Circuits Layout-Design
28.	WCT	:	WIPO Copyright Treaty
29.	WPPT	:	WIPO Performances and Phonograms Treaty
30.	TRIPs	:	Trade Related Aspects of Intellectual Property Right
31.	WTO	:	World Trade Organization
32.	UPOV	:	International Union for the Protection of New Varieties of Plants
33.	ICAR	:	Indian Council of Agricultural Research
34.	NBPGR	:	National Bureau of Plant Genetic Resources
35.	PPV&FR	:	Protection of Plant Varieties and Farmers' Rights
36.	EDV	:	Essentially Derived Variety
37.	PVR	:	Plant Variety Rights
38.	PBRA	:	Plant Breeders' Rights Act
39.	PVRA	:	Plant Variety Rights Act
40.	NDUS	:	Novelty Distinctiveness Uniformity Stability
41.	FR	:	Farmers Right
42.	PBR	:	Plant Breeders Right
43.	PGR	:	Plant Genetic Resources
44.	CSIR	:	Council of Scientific and Industrial Research
45.	TK	:	Traditional Knowledge

Copyright

46.	CBD	:	Convention on Biological Diversity
47.	PVP	:	Plant Varieties Protection
48.	NBA	:	National Biodiversity Authority
49.	SBB	:	State Biodiversity Boards
50.	BMC	:	Biodiversity Management Committees
51.	IPAB	:	Intellectual Property Appellate Board
52.	PGRFA	:	Plant Genetic Resources for Food and Agriculture
53.	ISPMs	:	International Standards for phytosanitary Measures
54.	FAO	:	Food and Agriculture Organization
55.	MLS	:	Multi-Lateral System
56.	SMTA	:	Standard Material Transfer Agreement
57.	CGIAR	:	Consultative Group on International Agricultural Research
58.	IST	:	International Seed Treaty
59.	GURT		Genetic use restriction technology
60.	IPEA		International Preliminary Examining Authority
61.	ITPGRFA	:	The International Treaty on Plant Genetic Resources for Food and Agriculture

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COLLEGE OF AGRICULTURE, BHARUCH

NAVSARI AGRICULTURAL UNIVERSITY (GUJARAT)

Theory Notes on

"Crop Improvement-1"

Course No. GPG 5.6 **Credit- 2 (1+1)**





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Crop Improvement – I (*Kharif* crops)

GPB 5.6 Credit hours: (1+1=2)

Course content

Theory

Botanical Name, family, chromosome number, centre of origin, nature of pollination, list of wild relatives (donor parents for different characters), distributions of species of 18 selected crops (rice, maize, sorghum, pearl millet, pigeon pea, mungbean, soybean, groundnut, sesame, castor, cotton, tobacco, okra, bottle gourd, bitter gourd, ridge gourd, smooth gourd and cucumber); Floral biology as well as study of genetics of qualitative and quantitative characters of rice, maize, sorghum, pearl millet, pigeon pea, mungbean, soybean, groundnut, sesame, castor, cotton, tobacco, okra, bottle gourd, bitter gourd, ridge gourd, smooth gourd and cucumber; Breeding methods of rice, maize, sorghum, pearl millet, pigeon pea, mungbean, soybean, groundnut, sesame, castor, cotton, tobacco, okra, bottle gourd, bitter gourd, ridge gourd, smooth gourd and cucumber; Major breeding objectives (including quality parameters) of rice, maize, sorghum, pearl millet, pigeon pea, mungbean, soybean, groundnut, sesame, castor, cotton, and tobacco, okra, bottle gourd, bitter gourd, ridge gourd, smooth gourd and cucumber; Ideotype concept for Rice, Pigeon pea, and Cotton. International, National and State level research station and varieties/hybrids released of rice, maize, sorghum, pearl millet, pigeon pea, mungbean, soybean, groundnut, sesame, castor, cotton, tobacco, okra, bottle gourd, bitter gourd, ridge gourd, smooth gourd and cucumber.

Practical

Emasculation and hybridization techniques rice, maize, sorghum, pearl millet; Emasculation and hybridization techniques in pigeon pea and mungbean; Emasculation and hybridization techniques in soybean, groundnut, sesame, castor, cotton; Emasculation and hybridization techniques in tobacco and okra; Emasculation and hybridization techniques in bottle gourd, bitter gourd, ridge gourd, smooth gourd and cucumber; Maintenance breeding of different *kharif* crops; Detailed procedure of hybrid seed production of maize, pearl millet and cotton and castor etc.; Visit to seed production plots and submission of report; Visit to AICRP plots of different field crops and submission of report.

- **Reference books:**
  - Breeding field crops
    by V.L.Chopra
  - Breeding field crops
    by Dr.B.N.Bhardwaj

RICE BREEDING



- Rice is a staple food of more than 60% of the world's population. Maximum area under rice is in Asia. Among rice growing countries, India has the largest area of about 40.2 million-hectare followed by China and Bangladesh.
- Rice is India's predominant crop and is the staple food for people of the eastern and southern parts of India.

1. Name of Crop	:	Rice
2. Botanical Name	:	*Oryza sativa* L.
3. Family	:	Poaceae
4. Chromosome No .	:	2n = 24
5. Centre of Origin	:	Orissa and South-East Asia
6. Mode of pollination	:	Self pollination
7. Out crossing %	:	0 - 3 % with an average 0.5 %
8. Isolation distance	:	3 m for breeder & foundation seed

RELATED SPECIES:

Sr. No.	Species	Chro. No. (2n)	Remarks
1.	*Oryza sativa*	2n=2x=24	Cultivated
2.	*Oryza glaberrima*	2n=2x=24	Cultivated
3.	*Oryza rufipogon*	2n=2x=24	Wild
4.	*Oryza nivara*	2n=2x=24	Wild
5.	*Oryza latifolia*	2n=2x=48	Wild
6.	*Oryza alata*	2n=2x=48	Wild

Cultivated Species of Rice:

(A) Asian Rice: (*Oryza sativa* L.)

It is predominant species which has spread to different part of word.

(B) African Rice: (*Oryza glaberrima* L.)

It is still confined to tropical Africa.

The Asian rice grouped into three ecological forms based on morphological and physiological characteristics and geographical adaptation:

1. Indica: Grown in Tropical climate: India, Sri- Lanka, China, Thailand, Malaysia, Taiwan
2. Japonica: Temperate climate: Japan, Korea
3. Javanica: Intermediate between Indica and Japonica

Classification

- Family: Graminaea
- Tribe: Oryzeae
- Genus: *Oryza*

Types:
- Indica type
- Japonica type
- Javanica type





Distinguishing characteristics of three ecological forms of rice

	Character	*Indica*	*Japonica*	*Javanica*
1	Tillering	Profuse	Moderate to fewer tillering	Low
2	Leaves	Broad, Light, Green, droopy (Bended) leaves	Narrow, deep green	Broad,stiff (unblended), light green
3	Photoperiod response	Sensitive	Often-sensitive	Insensitive
4	Seed dormancy	Present	Absent	Absent
5	Response to N2 fertilizers	Rarely responsive	Responsive	Moderately responsive
6	Seed Shattering	Present	Absent	Absent
7	Grain	Thin, narrow, flat	Short, roundish	Broad, thick
8	Awn	Awn less	Awn less to long awn	Long awn
9	Hairs on glumes	Thin and short	Dense & long	Long

Type of cultivation in rice:

1. Upland rice
2. Irrigated flooded rice
3. Rainfed or low land rice
4. Deep water and floating rice
5. Vegetatively propagated rice

- **Breeding objectives:**
  - (1) Higher yield
  - (2) Adaptability and stability
  - (3) Early maturity
  - (4) Lodging resistance
  - (5) Disease and pest resistance
  - (6) Grain quality
    - (a) Shape, Size and translucency of grain
    - (b) Texture of Endosperm and quality of starch
    - (c) Aroma & Cooking quality (Basmati type)
    - (d) Milling quality
    - (e) Seed dormancy
  - (7) Breeding for improved nutritional quality (Golden Rice)
  - (8) Awnness

Floral biology:

1. The rice inflorescence is a panicle that bears single flowered spikelets, having 6 stamens instead of 3 in other cereals.
2. The flower is surrounded by the lemma, palea and glumes.
3. The blooming of rice normally occurs between 8.00 am to 11.00 pm. The flowers in a single panicle bloom over a period of 7-10 days, but most of the flowers bloom between 2nd and 4th days after emergence of the panicle from boot leaf. Blooming of the spikelet starts at the top of the panicle and proceeds downwards.
4. Pollen shedding begins at the time of flower opens with blooming of the spikelet.

5. High day temperature, high solar radiation and low night temperature promote panicle production.

Fig. Rice panicle showing its branching pattern & attachment of spikelets



Fig. Rice opened spikelet

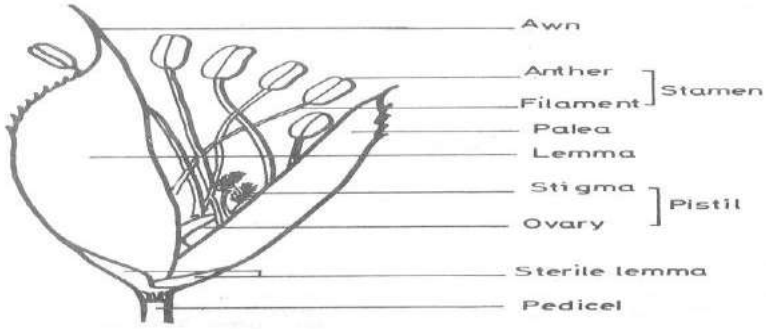
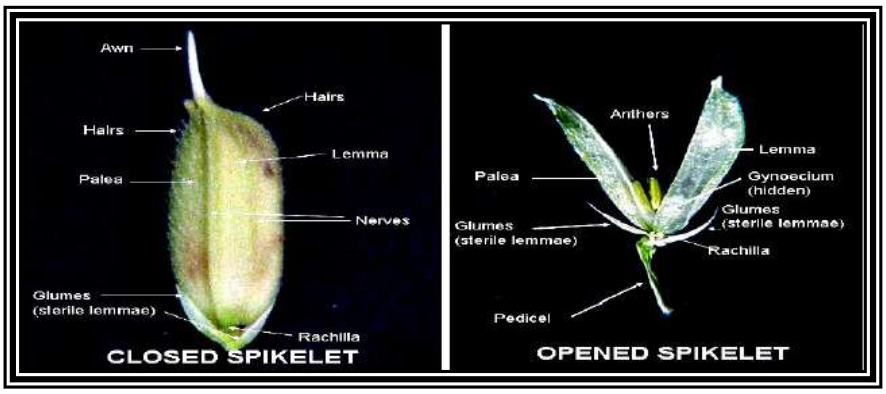


Fig. Rice closed spikelet and opened spikelet



- Spikelets: The spikelets are single-flowered, each with a short stalk.
- Glumes: There are two small glumes at the base of each spikelet.
- Floret: The floret consists of the lemma, the palea, two lodicules, the androecium and the gynoecium.
- Lemma: The lemma is large and hairy. It is awned 5-nerved structure.
- Palea: The palea is hairy, smaller than the lemma and is present opposite to it. It is three-nerved structure. After maturity, the lemma, the palea and the glumes remain attached on the seed as a cover called husk.
- Flower: The flower is bisexual, zygomorphic and bracteate. Main axisSecondary branch Spikelets Tertiary branch

Androecium:

- The androecium consists of six stamens arranged in two whorls whose filaments are short in earlier stage.
- The filament elongates immediately after floret opening and brings anther to the level of stigma.
- The total number of pollen grains per anther is reported to be directly correlated with anther size.

- Normally 2-3 pollen grains are required per stigma to fertilize one egg cell.

Gynoecium:

- The gynoecium is monocarpellary and has a superior ovary, with two feathery stigmas on a style.

- Receptivity of stigma is maximum during the first 3 days after opening of spikelet and then is gradually lost after 7 days.
- Stigma exertion, large stigmatic area and its receptivity, all play a major role in determining high seed set in CMS parent.

Anthesis and Mode of Pollination:

The flower may open from 7 a.m. to 4 p.m., depending upon the season. Most of the flowers start opening at the apex and the flowering proceed downward in the panicle, but in the branches, it is not strictly so.

In rice three types of pollination are possible:

- The usual process is that the anther burst as they emerge and pollinate the stigma (leading to self-pollination).
- The anthers burst open and pollination takes place before blossoming, generally at high temperature and under low humidity (leading to self-pollination).

- Under certain temperature and humidity conditions, the anthers may emerge from the flower without bursting and such flower is generally cross pollinated.

Emasculation:

Several methods have been used for emasculating rice:

(a) Standard method:

- This is most widely used method of emasculation in rice.
- Remove all the immature and mature spikelets from the panicle.
- Separate the glumes with the help of a pair of forceps and gently remove all the six stamens.
- To speed up the emasculation, suction may be used.
- Emasculation is generally performed in the evening and the pollination is done next morning.
- After emasculation, cover the female with butter paper bags. Tagging is also done.

(b) Hot water treatment:

This method of emasculation is commonly used in Japan. The immature spikelets are cut off. The panicles are dipped in hot water containing constant temperature of 42-44 0C for 5-10 min.

Pollination:

- Collect the pollens just before anther dehiscence.
- To apply pollens, the anthers from the derived male parents are shaken over the emasculated florets.
- If pollens are not available in plenty then repeat the above process.
- After pollination, bagged and labeled it.
- If two panicles on the same plant are to be pollinated by the same male parent, they are brought together by wrapping the two clums and are tied with a clip. The other bag is also placed over both panicles.

Crossing technique:

Hot water is also used to open the florets of rice before crossing. Panicles in the 2nd and 3rd days of blooming are selected for emasculation. Open and immature florets are removed. Then this panicle is immersed in water having temperature 42-44 °C for 5-10 minutes. Pollinate the emasculated panicle and then bagged and labeled it.

➢ Breeding Methods:

Genetic improvement of rice can be achieved by

A. **General Breeding Methods** i.e. Introduction. Pure line selection, Bulk, Backcross and Pedigree Methods.

1. Introduction :

All the IRRI Rice varieties from IR 8 to IR 72. Other Examples are Basmati from Punjab, Ponni (mahsuri) from Malaysia, CR 1009 (Ponmani) from Orissa.

2. Pure line selection :

3. Hybridization and Selection :

(a) Pedigree method

(i) Inter varietal:

(ii) Inter-racial

Japonica x indica cross ADT 27 (Norin 10 x GEB 24)

Ponni (Mashuri) (Taichung 65 x ME 80)

(iii) Inter specific crosses

Co 31 (*O.perennis x GEB 24) Drought resistance.*

IR 34 Complex cross, one of the parent is *O.nivara*

(b) Back Cross Method of breeding

B. Special Methods: Mutation breeding, Heterosis breeding and distance hybridization.

4. Mutation breeding:

Mutation breeding has played significant role in the rice improvement.

a) Spontaneous mutation

GEB 24, ADT 41 - Dwarf mutant of Basmati 370.

b) Induced mutation :

Jagannath rice from Orissa.

Parbhani - from Maharastra

5. Heterosis Breeding (Rice Hybrids)

APHR – 1 (IR 58025A X Vajram),APHR – 2 (IR 62829A X MTU9992),

KRH-1 (IR 58025A X IR 9761-10-IR) CORH – 2 (IR 58025A X C 20R)

➢ Ideotype Breeding :

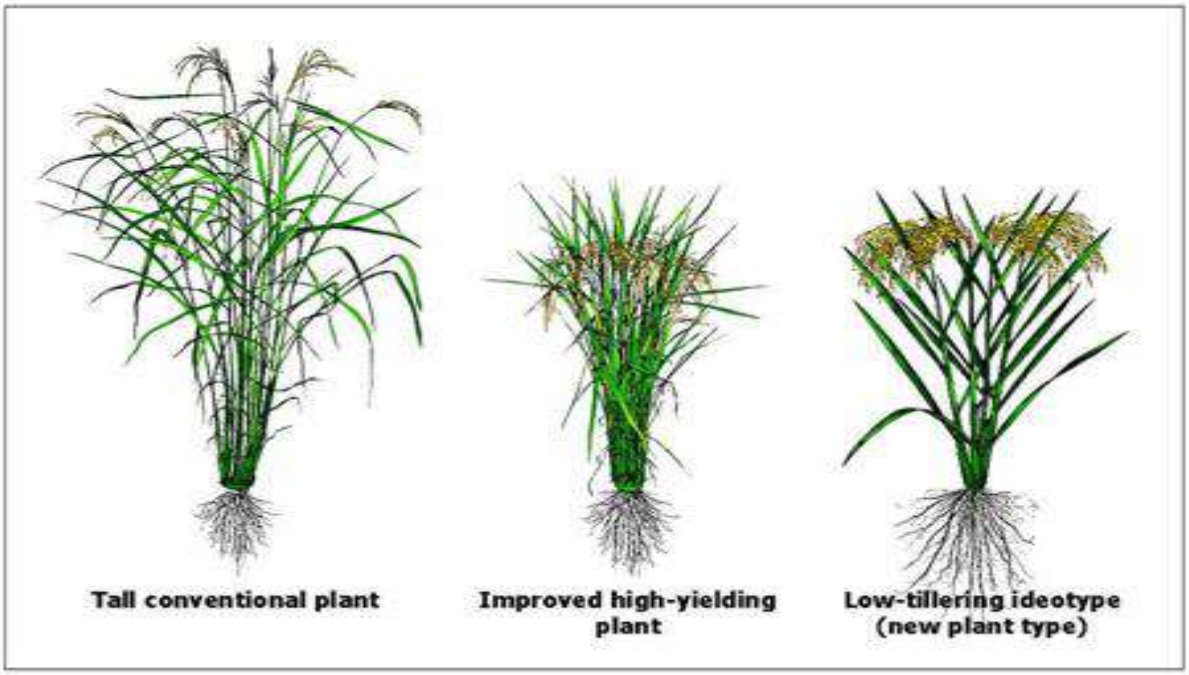
Physiological features of crop **ideotype** are expected to differ for irrigated cultivation or rainfed cultivation. The **concept** of plant type was introduced in **rice** breeding by **Jennings in 1964**, while the term **ideotype** was coined **by Donald in 1968.**

Ideotype breeding, aimed at modifying plant architecture, is also a time-tested strategy to increase yield potential. Selection for short-statured cereals such as rice and wheat resulted in a doubling of their yield potential.

Rice

- Shorter Culm length. (100 cm or less)
- Greater Culm diameter.
- High tillering capacity
- High (55% or more) harvest index
- Lower relative internodes elongation





HYBRID RICE

- Heterosis in rice was reported by Jones in USA as early in 1926 and Ramaiah in 1933.
- But the research work on hybrid rice was initiated in 1964, in China by Yuan Long Ping (Father of hybrid Rice).
- The identification of 'Wild Abortive' or 'WA' type cytoplasmic male sterility in 1970 was a breakthrough in hybrid rice breeding.
- In 1971 China accepted Hybrid Rice Research as a national cooperative project and in the year 1976, hybrid rice became a reality in China, for the first time in world, by the release of commercial rice hybrids.

- Since then many commercial rice hybrids were released in countries like Vietnam, Korea; besides these countries, research on hybrid rice is progressing in countries like Philippines, Indonesia, Malaysia, Thailand, United States, Egypt, Colombia and Brazil.
- Although research on the commercial utilization of heterosis in rice has made tremendous gains during the last 20 years, it is still in its infancy stage because the high yield potential of hybrid rice has not been fully tapped yet and hence various approaches are adopted in major rice growing countries of the world to maximize the yield potential advancements of hybrid rice production.

Breeding techniques for developing hybrid rice involve the following:

(a) Three -line method or CGMS system:

- This system involving three lines *viz.,* cytoplasmic, genic male sterile line (A), maintainer line (B) and restorer line (R) is the most commonly used method in China and outside.
- CMS system like –WA, GA (Gambiaca), Di (Disi), DA (Dwarf wild rice), BTC (Chinsurah Boro II) and IP (Ido Paddy 6) has been identified.
- Long experience had undoubtfully proved that the CGMS system involving sporophytic and gametophytic male sterility is an effective way of developing hybrid rices and will continue to play an important role in the next decade.
- However, there are some constraints and problems in such a system. The most serious is that yields of existing hybrid rice varieties including newly developed ones have stagnated (Yuan, 1994). They have already reached their yield plateau, and are unable to increase the yield potential through this approach and hence new methods and materials were adopted.
- In this regard, two-line hybrids are promising ones, to raise the yield ceiling in hybrid rice.

(b) Two-line method of rice breeding:

- Two-line hybrids can be evolved through

(1) Mechanical means
(2) Application of gametocides
(3) Use of CMS
(4) Use of GMS
(5) Use of environmentally induced genic male sterility (EGMS)

- EGMS lines are made use of *viz.,* PGMS (Photosensitive Genic Male Sterility) and TGMS (Thermosensitive Genic Male Sterility) which had been developed successfully in China. In rice EGMS system is commonly used.

  Developing hybrid rice varieties with these system has the following advantages over the classical CMS system,

  - Maintainer lines are not needed.
  - The choice of parents for developing heterotic hybrids is greatly broadened.
  - No negative effect due to sterile cytoplasm
- In 1991, China had released hybrid combinations using this approach, and some of these combinations out yielded the best existing hybrids by 10-20%
- Work is progressing in India and International Rice Research Institute, in Philippines to identify best suited rice hybrids through this approach, for commercial exploitation.
- TGMS system is considered useful in tropical and subtropical regions where as PGMS system is useful in temperate regions.
- Other possible approaches to develop two-line hybrid breeding system includes identification of a genic male sterility system which would revert to male fertility, in

response to application of growth regulators and also the chemical induction of male sterility.

(c) One -line method of rice breeding:

Rice hybrids can be developed and popularized through the following concepts

- Vegetative propagation
- Micro propagation
- Anther culture hybrids
- Apomictic lines

Among the above, apomictic lines and anther cultured materials will be economical for large scale cultivation.

Tissue culture, particularly Anther culture has been utilized in rice improvement by China and also developed several varieties.

Practical Achievement:

Several semi dwarf and high yielding varieties has been developed by IRRI. The Dee Geo-woo-gen has been used as source of dwarfing gene in evolving semi dwarf rice varieties.

Improved varieties: GR-3, GR-4, GR-5, GR-103, GR-6, GR-7, Ambica, Gurjari and Jaya
Hybrid varieties: APHR1, APHR 2, COHR 1, KRH 1, KRH 2, DRRH 1, CNHR 3, PHB 71, MPH 516, MPH 517, MPH 518, PRS 1 and VRH 4

Research stations:

A. International:
International Rice Research Institute (IRRI), Los banos, Laguna, Philippines

B. National:
Central Rice Research Institute (CRRI), Cuttack, Orissa
DRR: Directorate of Rice Research Hyderabad. (A.P)

C. State level:
Main Rice Research Station, AAU, Navagam (Kheda), Gujarat

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MAIZE BREEDING



- Maize is the important crop next to rice and wheat with regard to total area and production.
- It is studied to a much wider range of climatic conditions than rice and wheat, because of its greater adoptability.
- Corn is most important grain crop in the United States which produces nearly one-half of the total world production.
- The next largest corn-producing countries are China and Brazil.
- The important maize growing states are Karnataka, Andhra Pradesh, Bihar, Punjab and Himachal Pradesh.
- It has worldwide significance as human food, animal feed and as a raw material for the manufactures of hundreds of industrial products**.**
- The edible product include corn oil, corn starch, corn syrup, maltodextrins and products of fermentation and distillation industries.
- Refined maize oil content is more which can be used in bakery products, cooking oil, salad dressing, pharmaceuticals and preparation of soups.
- Unsaturated fatty acids in oil are essential for growth, pregnancy, lactation, maintenance of normal skin, liver and kidney functions.
- Maize oil is also useful for preparation of soap, chemicals, paint, varnish, rubber and textiles industries.
- **Fact file:**

- Corn is QUEEN OF ALL CEREALS
- From average yield view points, maize occupies first rank among all cereals.
- Corn having C_4 photosynthetic pathway which is more efficient than C_3 pathway under high temperature and dry-land condition.
- C_4 plants are the most productive in terms of food nutrients produced (per unit land area, per unit water transpired and per unit time).
- Morphologically, corns shows a greater diversity of phenotype the perhaps any other grain crops.
- Architecturally, the plants has many desirable characteristics like sparse leaf arrangement-maximum light interception and minimum mutual shedding.
- Multiplication ratio is very high: 1 seed---400 to 1000 kernels.
- 1 hectare ---- 60000 seeds
- Seed production is easy-mechanical detesseling.

1.	Name of Crop	:	Maize
2.	Botanical Name	:	*Zea mays* L.
3.	Family	:	Poaceae
4.	Chromosome No.	:	2n = 20
5.	Center of Origin	:	Central America
6.	Progenitors:	:	*Zea tunicate, Z. Teosinte*
7.	Mode of pollination	:	Cross polination
8.	Out crossing percentage	:	95%
9.	Related wild species	:	*Zea maxicana* (2n=2x=20), Annual teosinte *Zea diplorerenni* (2n=2x=20), Perennial teosinte *Zea perennis* (2n=4x=40), Perennial teosinte

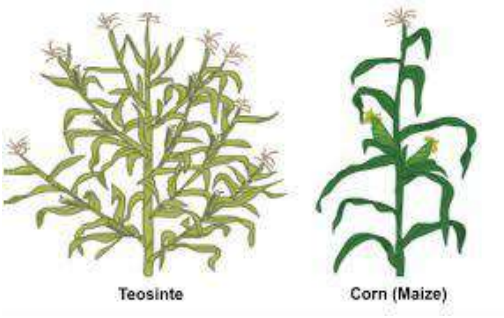
➢ *Teosinte*:

- *Teosinte* is nearest known relative of corn, has been its progenitor.
- There are three species of teosinte, of which *Zea mexicana* is annual diploid (2n = 20) like maize.
- It crosses readily with corn and produce fertile hybrids.
- *Teosinte* is similar to maize in flowering habit, but it differs from maize in that the pistillate spikes bear 6-12 kernels in hard, triangular shell like structures.
- Like corn, it is a monoecious and produced 6 to 12 dispersable seeds.
- The seeds break apart and shatter when mature, forming natural means of seed dispersal, prolific habit-multi cob and tillers.

Teosinte cob (closest wild relative of maize)







➢ *Tripsacum*:

- The genus, *Tripsacum* is a close relative of Zea.
- Gamma grass belongs to genus Tripsacum
- There are five diploid (2n=2x=36) and four tetraploid (2n=4x=72) species of *Tripsacum*, which are perennial.

***Tripsacum* (gama grass)**	**Flower of *Tripsacum* (gama grass) Anthers are come out from flowers**
	

- It is bisexual in nature. The lower section of each inflorescence branch is female and upper part is male.
- *Tripsacum* has been suggested as a potential donor of genes for disease and insect resistance that may be used in improving maize.

❖ Groups of maize:

1. Dent: Depression on seed, hard starch grown in America
2. Flint: Hard seed, grown in Asia, America, and Europe
3. Sweet corn: Wrinkled seeds, one recessive gene prevent conversion of sugar into starch
4. Flour corn: Soft starch
5. Pop corn: Extremely flint
6. Pod corn: Each seed enclosed in pod

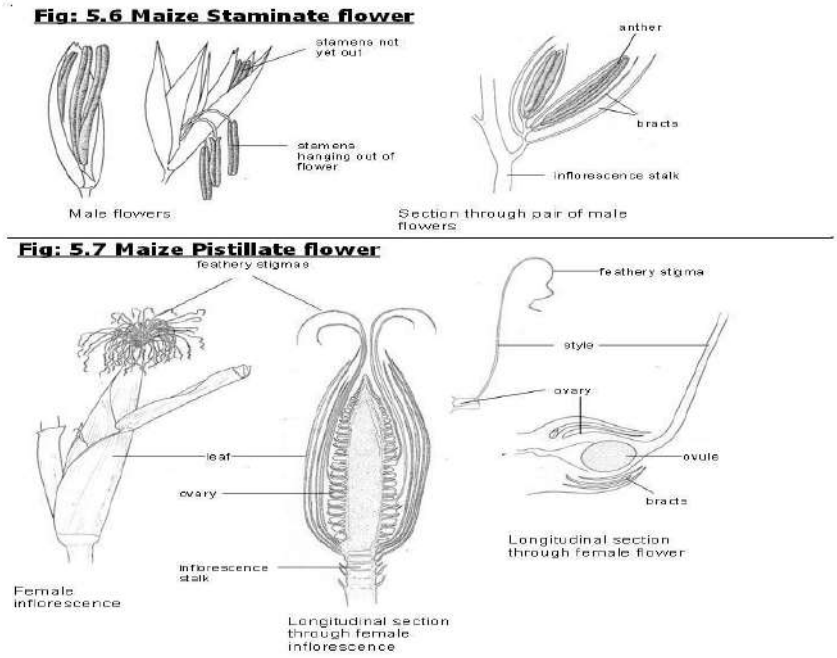


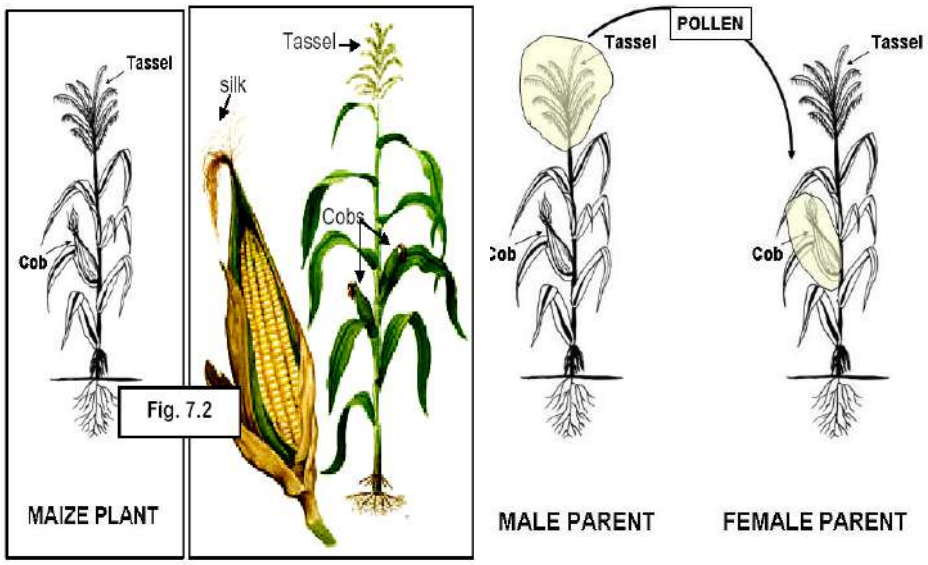
- **Floral biology:**

- Maize bears monoecious flowers.
- Staminate flowers are produced in tassel and
- Pistillate flowers are on the shoot in the axil of leaf.

➢ Staminate flower (tassel):

- The main stem of the maize plant terminates in a tassel, bearing two flowered staminate spikelets.
- Each staminate flower having lemma, palea and three stamens.
- As the tassel flower opens, the anthers are pushed-out by the elongating filaments and pollen grains are come out from the extruded anthers.
- Pollen shedding usually brings 1-3 days before the silk have emerged from the shoots of the same plant (protandry nature) and usually continues for a period of 3-4 days after the silks on the plants are ready to be pollinated.





- **Pistillate flowers (silk / spadix):**

- The shoots arise as branches from nodes about mid-way of the stalk. Each shoot is composed of a shank from which the husk arises and terminates in the ear on which the pistillate flowers are borne .
- The spikelets are borne in pairs. Each spikelet normally contains one fertile and one sterile ovule. This results in an even number of rows of kernels on the ear.
- Fresh silks functions both as a stigma and style, being receptive to fresh pollen throughout their entire length
- Fertilization of the ovule usually occurs within 12-28 hours after the silk have been pollinated.

- **Selfing technique:**
  1. Select the plant that silk will emerge within 1-2 days
  2. The ears should cut about 1" below the tip of husk in evening and covered with butter paper bag.
  3. The tassel of the same plant is also covered with a brown paper bag for collection of pollen dust.
  4. By the following 1-2 days equal size of the silk (1 - 1.5") will grow. Pollen collected in the tassel bag will be dusted on silk in the morning. Bag the silk quickly to avoid contamination with foreign pollens. Label the ear shoot.
- **Crossing technique:**

  As the maize is a monoecious plant, detesseling of male inflorescence from plant ensure the process of emasculation and desire pollen from selected inbred line is dusted on female inflorescence previously protected with paper bags.

- **Why TMS source of cytoplasm not used for hybrid seed production?**
  - The Texas cytoplasm of maize carries two cytoplasmically inherited traits, **male sterility** and **disease susceptibility.**
  - The two traits are **inseparable** and are associated with an **unusual mitochondrial gene, T-*urf13***, which encodes a **13-kilodalton polypeptide (URF13).**
  - An interaction between **fungal toxins** and **URF13**, which results in permeabilization of the inner mitochondrial membrane, accounts for the specific susceptibility to the fungal pathogens, **Southern Leaf Corn Blight.**

- **XENIA EFFECT:**
- **Effect of pollen grains on the phenotypic development of seeds:**



XENIA CAN BE DEFINED as the effect of the genes from the male parent on the development of the fruit or the seeds.

Effect of pollen grains on the phenotypic development of seeds.

- **HYBRID SEED PRODUCTION IN MAIZE:**

- **Steps for the maize hybrid seed production**
  1. Development of inbreds
  2. Evaluation of inbreds
     - Phenotypic evaluation

- Top-cross tests for GCA
- Production of single cross hybrids
- Predication the performance of double cross hybrids

3.Hybrid seed production

(A) SINGLE CROSS HYBRID:

A single cross is the progeny produced by making cross between two different inbred lines.

The inbred lines that are found to be superior in top-cross combinations are crossed in all possible combinations.

A X B -→ F_1 Single cross hybrid.

The possible number of single crosses = [n(n-1)] /2

Where, n= number of inbred lines

- Female: male row ratios of 3 : 1 is to be maintained in seed production plot.The female parents are detasseled or male sterile lines are to be used.
- Double cross hybrids are superior to Single cross hybrids because they are more uniform and more productive. It is more vigorous than parents.

(B) DOUBLE CROSS HYBRIDS:

- A double cross is the progeny produced by making cross between two single crosses. e.g. (A x B) F_1 x (C x D) F_1.
- The possible number of double crosses =[n (n-1)(n-2)(n-3)] / 8
  Where, n= number of inbred lines.
- 5(5-1)(5-2)(5-3)/8 = 5(4 x 3 x 2)/8 =120/8 = 15 double crosses.
- In maize double cross seed is generally produced because

a. Seeds are uniform in size and appearance
b. More seeds per hectare can be produced as compared to single cross
c. Due to more seed production double cross hybrid seed is cheap.

➢ Research stations:

A. International:

The International Maize and Wheat Improvement Center (**CIMMIT)**,Maxico

B. National:

All India Co-ordinated Maize Improvement Project (AICMIP), IARI, New Delhi.

C. State level:

Main Maize Research Station, AAU, Godhara.

➢ Improved varieties :

Guj. Maize -1, Guj. Maize -2, Guj. Maize -3, Guj. Maize -4, Guj. Maize -6

Hybrid varieties :

Ganga safed-2, Ganga-5, Ganga-9, Ganga-11, Deccan, Deccan-103 and Sartaj.

Synthetic and Composite varieties :

Protina, Shakti, Ratan, Vijay, Kisan, Vikram, Tarun, Prabhat, Navjot, Mansar, Arun, Renuka, Kiran and Surya.

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SORGHUM BREEDING



- Sorghum is one of the most important cereal crop in the world with significant acreage in Africa, South Asia, and Central America.
- It is grown as an animal feed in the USA and Australia.
- Sorghum is widely used as a staple food in rural areas and is fed as fodder to the cattle.
- Sorghum is C4 plant and, therefore has high photosynthetic efficiency.
- It can tolerate heat, drought, salt and aluminium toxicity. It can be easily grown on soil with low fertility.

1.	Name of Crop	:	Sorghum
2.	Botanical Name	:	*Sorghum bicolor L.*
3.	Family	:	Poaceae
4.	Chromosome No.	:	2n = 2x = 20
5.	Centre of Origin	:	Tropical Africa
6.	Mode of pollination	:	Often cross pollinated
7.	Out crossing percentage	:	5 – 47%
8.	Related wild species	:	As per below Table

- *S.halapense* : Both *2n = 20* and *2n = 40* forms are available utilized for forage sorghum improvement.
- *S.sudanense* : for improvement of forage sorghum.
- *S.nitidum* : Possesses shoot fly resistance and dormancy.
- *S.staffii* : Utilized for inducing dormancy.

Table: List of wild relatives of sorghum along with chromosome number

Sr. No.	Scientific Name	Chromosome number	Remarks
1	*S. arundinaceum*	2n=2x=20	Wild
2	*S. propinquum*	2n=2x =20	Wild
3	*S. halepense*	2n=4x =40	Cross between *S. arundinaceum* x *S. propinquum* and is commonly known as Johanson grass
4	*S. almum*	2n=4x=40	Cross between *S. bicolor* x *S. halepense* and is commonly known as Columbus grass.

Types of sorghum:

The commercial types of sorghum are as under:

1. Grain sorghum
2. Sweet or Sorgos sorghum
3. Grass sorghum:
   (i) Sudan grass (annual)
   (ii) Johnson (perennial) grass.
4. Special purpose sorghum:
   Broom corn, waxy sorghum, pop sorghum.

- **Differences Between Grain Sorghum and Sweet Sorghum**

	1.Grain Sorghum		2.Sweet or Sorgos Sorghum
1	It is used for grain production with good quality flour.	1	Preparation of sweet juice, silage, fodder, syrup & molasses.
2	The seeds are relatively large and palatable.	2	The seeds are small, white or colored; often bitter and unpalatable
3	The seeds thresh free from glumes	3	The seeds do not thresh clean from glumes
4	The stalk is moderately juicy and slightly or no sweet.	4	The stalk is very juicy and sweet.
5	The grain sorghum is divided into variety groups like , Kafir, Hegari, Feterita, Durros, Shallu etc.	5	No varietal groups in sweet or sorgos sorghum.

3. Grass sorghum:

The grass sorghum is grown for forage.

Two types of grass sorghums are grown

(i) Sudan grass (annual) and

(ii) Johnson grass (perennial) both have slender stem, open heads and vigorous tillering capacity.

4. Miscellaneous:

Special purpose sorghum indicates miscellaneous types such as broom corn, waxy sorghum, pop sorghum etc.

- **CHARACTERISTICS / FEATURES OF SORGHUM**

- Sorghum resembles maize in its vegetative characters but differs in having narrower leaves and a waxy bloom covering the leaves and stem.
- It has a well-developed root system which is twice as efficient.
- It is a coarse, erect, annual grass with slender, prominently jointed culms which are 1-4 m or more in height.
- Stilt roots occasionally appear from the lower nodes.
- The crop is more drought-resistant than maize, wheat and barley.
- It has tendency to roll its leaves, closure of stomata in hot and more silica in the root endodermis which may prevent root from collapsing.
- The dried grains contain about
  - 68-74 % carbohydrates, 3% fat, and 9-12 % protein.
- Sorghum proteins contain some cystine and vitamin B_1 but deficient (lacking) lysine and methionine. Unfortunately these proteins cannot be digested by the human system.

- **UTILIZATION OF SORGHUM**
  - 1. It is used as stock feed in the semi-arid tropics Africa and Asia.
  - 2. White grained varieties that yield white flour used to make tortilla—like cake leavened bread (in Asia) or porridge, cooked either in water or fat (in Africa). The flour is unfit for bread-making as it lacks gluten.
  - 3. Sorghum Starch: It used as in adhesive, for chewing and for making syrups.
  - 4. The crop is also quite valuable for forage or silage.
  - 5. The young shoots and leaves and the germinating seeds of some cultivars contain a toxic cyanogenic glycoside, which when eaten hydrolyses to yield poisonous hydrocyanic acid. If the plants are injured the enzymes react with the glycoside to form HCN.
  - 6. The plant dried stalks or stems are used as a fuel, fencing, thatching (straw are use for roofing), and for making baskets, fish-traps and mats.
  - 7. The leaves may be used as mulching material.
  - 8. In West Africa, a red dye is obtained from sorghum leaves and stems and is used for dyeing leather.
  - 9. A wax can be extracted from the sorghum hulls.

- **Useful genes in breeding for Sorghum millet:**
  - ***Zera-zera*** landraces from Ethiopia and Sudan
    Useful sources of grain quality, tan plant, resistance to leaf diseases, tolerance to grain weathering and desirable plant type.
  - ***Durra:*** resistance to drought, shoot fly, stem borer.
  - ***Kafir:*** nuclear cytoplasmic male-sterility system
  - ***Guinea:*** Resistance to grain mold
  - ***Bicolor :*** Forage traits

- **Inflorescence:**

The inflorescence is a panicle (called arrow) with a central rachis from which primary branches arise. They give rise to secondary and sometimes tertiary branches which carry the racemes of spikelets.

Panicle:

The central axis of panicle the rachis may be striated and it may be hairy or glabrous.

Raceme:

A raceme always consists of one or several spikelet. Raceme may vary in length according to number of nodes and length of internodes.

The spikelet generally occurs in pairs, one being sessile which is bisexual, perfect and fertile, the second born on short pedicel which may be sterile or staminate.

Flower:

- Perfect flower consist of two glumes, one hairy lemma, a small palea, small awn, three stamens, two lodicules and one pistil.
- Ovary has two styles with feathery stigmas.
- Sorghum is short day plant and flowering is hastened by short day length and higher temperature.

Anthesis:

- The sorghum flowers bloom just prior to sunrise.
- Blooming starts from apex and moves downward.
- Anthers and stigma pushed out as the glumes open.

- Pollen remain viable for 3-6 hrs. while stigma remain receptive for 7 days but are most receptive up to 3 days after emergence.

Mode of Pollination:

Sorghum is an often cross pollinated crop like pigeonpea and cotton.

The extent of out crossing ranges from 5-47 per cent, on account of the exposure of the stigma before the dehiscence of the anthers.

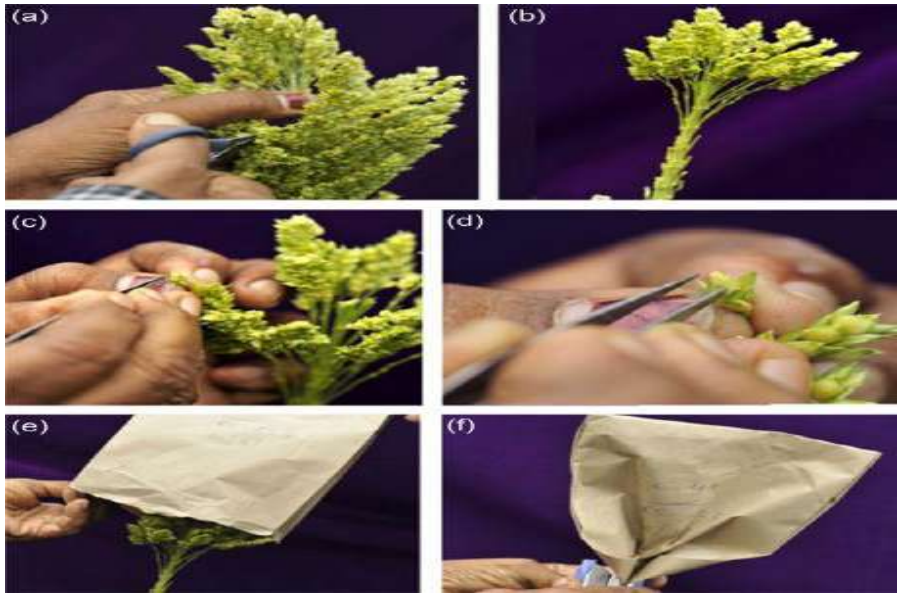
Fig. Emergence of stigmas and dehiscence of anthers from sorghum florets



Emasculation:

Hand Emasculation:

Remove all the open spikelets with fine blade scissors. Remove all the three stamens with the help of forceps. Care must be taken that there is no injury to stigma.



Hot water treatment:

The panicle is inserted for about 10 min. in 48^0C hot water.

Male Sterility:

- ✓ Genetic (GMS) and cytogenetic male sterlity (CMS) are available in sorghum.
- ✓ These types of male sterility may be used for the production of hybrid seed on a large scale.
- ✓ MSCK 60 (male sterile combine Kafir 60) is a male sterile variety of sorghum. It contains the Kafir chromosomes and Milo cytoplasm.

- ✓ One phenomenon which has been observed by the seed producer is the occurrence of female sterility in male sterile parent resulting in poor seed set. Mainly observed in K 60A, 2071 A and 2219 A verities.

Pollination:

- ✓ For pollination, the pollen is collected in the morning from the desired male parent panicle which is flowering.
- ✓ Dust the pollen on the emasculated spikelet and cover is again with pollinated bag.

Fruit:

- ✓ Fruit of sorghum is caryopsis (Kernel), it may be naked or covered.
- ✓ The individual grains are small- about 3-4 mm in diameter.
- ✓ They vary in colour from pale yellow through reddish brown to dark brown depending on the cultivar.

➢ Breeding objectives:

1. Higher Grain and Fodder yield:

   Dual purpose genotypes with high grain and fodder biomass potential per unit time.

2. Breeding for Grain Quality:
   - (i) Nutritional value of the grain
   - (ii)Taste- Sweet/bitter due to tannins
   - (iii) Size and appearance
   - (iv) Protein, lysine and sugar content
   - (v) Puffing quality- Bread making

3. Breeding for Fodder quality:

- High sugar content (sweetness)
- juicy and sweet stalks (juiciness),
- Ability to retain green colour
- leafiness, vigorously growing capacity,
- More number of tillers with high nutritive value
- Low hydro cyanic (HCN) content

4. Breeding drought resistant varieties with low HCN content in the early stages of growth

- ✓ 75% of sorghum is grown under rainfed condition.
- ✓ It is highly essential to breed varieties, which can withstand initial as well as terminal drought.
- ✓ In dry land varieties there will be high HCN content in the stem during early vegetative phase. This limits the use of varieties as green cattle feed.
- ✓ To overcome this, it is essential to breed varieties with low HCN content.

  Low HCN content exhibits partial dominance reaction. More than one gene involved in controlling this trait

5. Breeding for sweet sorghum:

- ✓ Because of self sufficiency in rice, use of sorghum as human food is fast dwindling.
- ✓ So to find out alternate uses for sorghum, breeding sweet sorghum is one strategy.
- ✓ From the stem juice, ethanol can be produced which is a renewable source of energy. Brazil stands first in this.
- ✓ There are two types of sweet sorghums.
- ✓ Syrup varieties - Syrup for table purpose can be produced from this. This is also suitable for ethanol production.

- ✓ Sugar varieties: Contains more of sugars and less of combustible organics. Not suitable for ethanol production compared to syrup varieties.

6. Breeding for non-lodging sorghums.
7. Early maturity
8. Resistance to biotic stresses (diseases like grain mold, downy mildew, rusts, leaf blight, leaf spots etc.
9. Resistance / Tolerance to insects like shoot fly, stem borer, gall midge etc.
10. Resistance to abiotic stresses like salinity, drought with resistance to low HCN content
11. Breeding for quality characters like bread making, redgrain for biscuit making protein and lysine content.
12. Breeding for special traits like sweet sorghums and striga resistance.
13. To isolate alternate sources of cytoplasmic genic male sterile lines

➢ Breeding Procedure :

1. Introduction :

Varieties of milo and kafir sorghum introduced from USA are used in conversion programme to convert the local long duration photo sensitive varieties to short duration, non-photo sensitive lines.

2. Selection :

Old varieties like Co1, Co2, Co4 are all selection made from local land races.

3. Hybridization and selection

(a) Inter varietal

- Three way cross derivative Co 25
  (IS 4283 x Co 21) x CS 3541,
- Single cross derivative Co 26
  (MS 8271 x IS 3691)

(b) Inter specific

- Co 27 Sorghum.
  (Co11 x *S.halapense)*

4. Heterosis breeding :

- Use of CMS lines. CSH 5 2077 A x CS 3541

5. Mutation breeding :

- X ray mutant from CSV 5 (148)
- Co 19 is a natural mutant from Co 2

6. Back cross method :

- ❖ The long duration photosensitive germplasm was converted in to photo insensitive short duration sorghums through backcross method.
- ❖ This was done at USA Similar programme was done at ICRISAT also.

7. Population improvement :

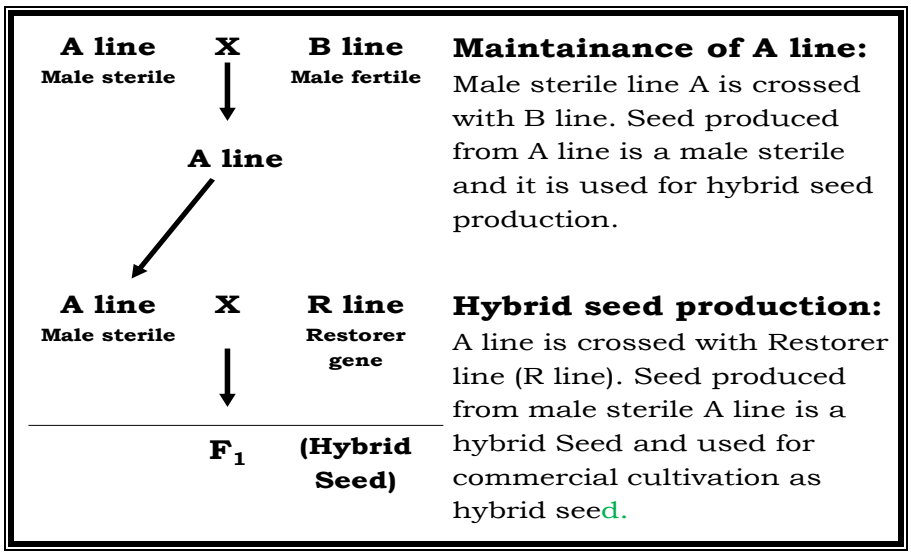
- ❖ Population improvement can be done with the use of cytoplasmic genetic male sterility as well as genic male sterility.
- ❖ Superior inbred can be develop through recurrent selection.

8. Use of Apomictic lines :

- ❖ Some apomictic lines have been identified which can be utilized in breeding programme and by vegetative propagation we can fix up heterosis. E.g. R473 from Hyderabad.

➢ Hybrid seed production in Sorghum:

- ✓ For any large-scale seed production of hybrid sorghum, cytoplasmic male sterile lines are required.
- ✓ Cytoplsmic male sterile lines like CK-60, MSCK-60A, MS-2219, MS-2077A, PMS-1063A etc. are available which can also be introduced into the local varieties through repeated backcrossing.
- ✓ In sorghum, Stephen and Holland (1954) discovered cytoplasmic male sterility (CMS) designated as milo cytoplasm in the progenies of a cross between two cultivars, milo and combine kafir, with milo as the female and kafir as the male.



- ➢ **Research stations:**

A. International:

International Crop Research Institute for Semi Arid Tropics (ICRISAT), Patancheru, Patancheru, Hydrabad

B. National:

Directorate of Sorghum Research (DSR), Hyderabad, Andhra Pradesh.

C. State :

Main Sorghum Research Station, NAU, Surat

Improved varieties: GJ-36, GJ-37, GJ-38, GJ-39, GJ-40, GJ-41, GJ-108 and GFS-4

Hybrid varieties: CSH-1 (first CGMS hybrid), CSH-6, CSH-8R and GSH-1.

Fodder sorghum: GFS-4, GFS-5 and CSV-21F

PEARL MILLET BREEDING



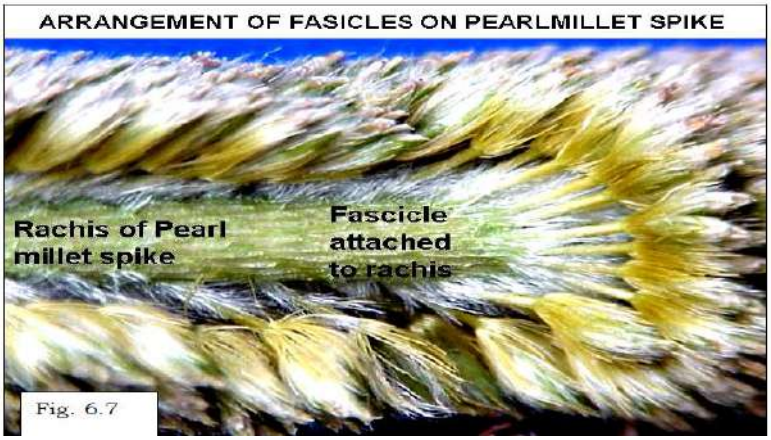
- ✓ Pearl millet, popularly known as bajara, is the 4th most extensively cultivated cereal after rice, wheat, and sorghum.
- ✓ It is robust, quick growing, rainy season cereal grass with large stems, leaves and heads, being tall and vigorous, with exceptional grain and fodder yielding potential.
- ✓ Pearl millet is an important food crop of semi arid tropics. It is also grown as fodder crop
- ✓ It is also grown in arid and semi-arid region of our country with limited rainfall.
- ✓ It is one of the most dual-purpose crops.
- ✓ The main pearl Millet growing countries are Africa, India, Pakistan and East Asia. In USA, Australia and Europe it is primarily grown as forage crop.
- ✓ In India, Rajasthan, Maharashtra, Gujarat, Haryana and Utter Pradesh are the leading states of pearl millet.
- ✓ The nutritive value of grains of pearl millet is fairly high and used for human consumption.
- ✓ It contains protein (9 to 15%), fat (5%) and mineral matters (2 to 7%).
- ✓ It is also rich in vitamin-A and B, thiamin and riboflavin contents and imparts substantial energy to the body with easy digestibility.

1.	Name of Crop	:	Bajara, Cattail millet, Spiked millet, bulrush millet
2.	Botanical Name	:	*Pennisetum glaucum* (L.) R. Br.
3.	Family	:	Poaceae
4.	Chromosome No.	:	2n = 14
5.	Centre of Origin	:	West Africa
6.	Mode of pollination	:	Cross pollination
7.	Percent cross pollination	:	80 % (Protogynous condition)
8.	Related wild species	:	(1)*Pennisetum pupureum* (2) *Pennisetum squamulatum*

Floral biology:

- The inflorescence is a cylindrical spike tapering towards the end.
- Each spikelet contain two types of flowers, staminate and bisexual protected by glumes and a whorl of bristles.
- Pattern of emergence of stigma is from top to bottom.

- Stigma begins to appear 2-3 days after emergence of spike, attain full length after 36-48 hrs and remain receptive for 1-2 days.
- The anthers emerges after the stigma dry up, thus it is protogynous in nature which induce cross pollination even though bisexual flower.



Anthesis:

- The stigmas begin to appear two to three days after emergence of the spike.
- Stigma attains full length after 36 to 48 hours and remains receptive for one to two days.
- The anthers emerge after stigmas dry up.

- The anthers of the bisexual flowers appear two to three days before those of the staminate flowers.
- Style divides in two branches in its upper part and possesses stigmatic hairs to admit pollen grains.
- Stigma takes 12 to 24 hours to protrude and open out, and remains receptive for one to two days.

Fig.: Various stages of spike initiation to ear development

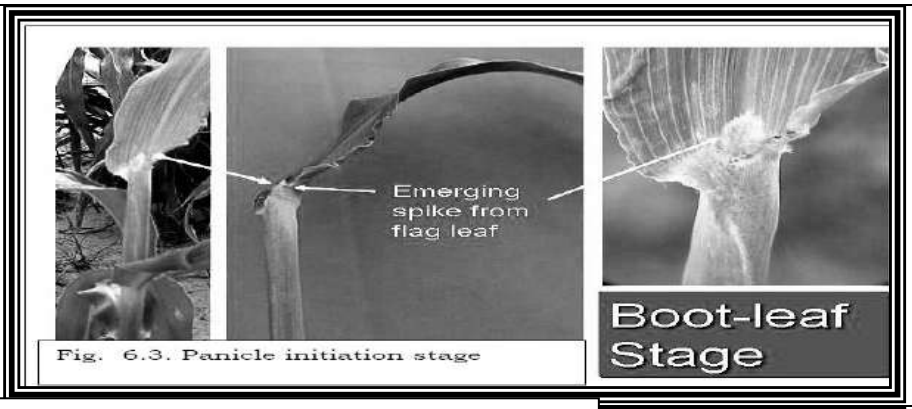


Fig. Boot leaf / Penicle initiation stage

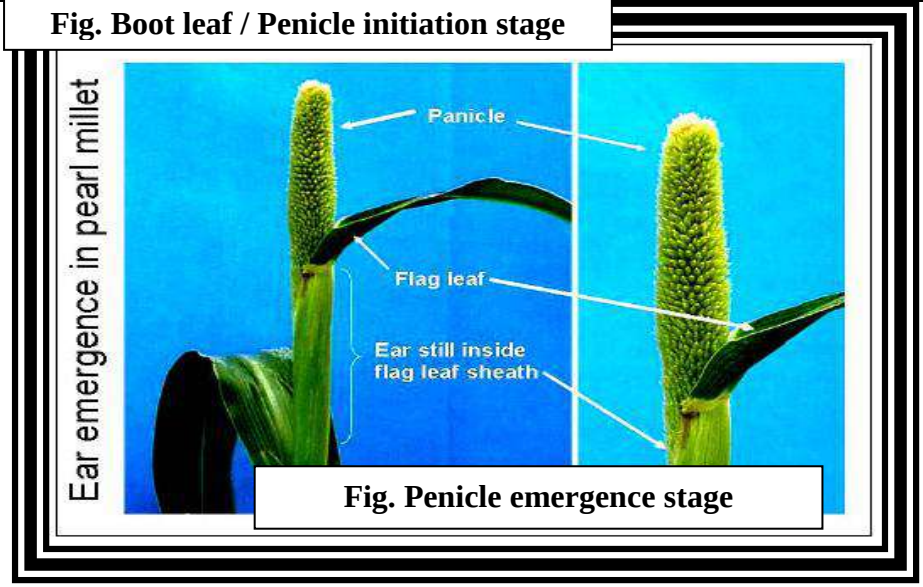


Fig. Penicle emergence stage

Fig. Spikelets, Florests and Stemens

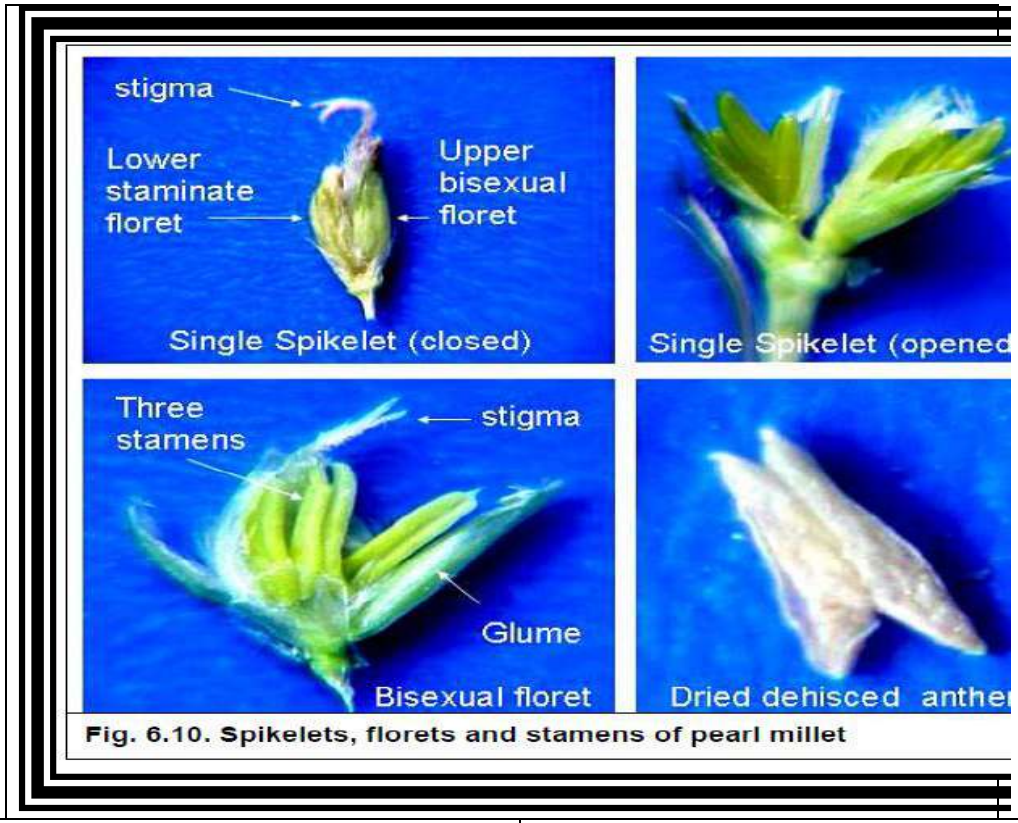


Fig. 6.10. Spikelets, florets and stamens of pearl millet

Fig: Earhead of pearl millet



Fig: Emergence of receptive stigma from bajara flower



Emasculation:

- ❖ Emasculation is not required in pearl millet due to its protogynous nature
- ❖ The head is covered with glassine bag before style appears.
- ❖ The exerted style can be watched through the glassine bag.

- ❖ When styles are exerted then pollination is performed with desired male parent.
- ❖ However, the emergence of the stigmas before emergence of the anthers is used for artificial cross-pollination.

➢ Pollination:

Self Pollination:

- ❖ Bag the spikes before the emergence of stigma.
- ❖ Length of bag must be such that lower most spikelets, which will be emerging later, could be covered.

- Alternate way is that two spikes from the same plant may be enclosed within the same bag.
- These spikes are such that the older one sheds Pollen when the stigma emerges in the second spike.
- Label it with lead pencil.

Cross-Pollination:

- Crossing can be done without the necessity of emasculation with the advantage of protogynous condition of bajra.
- Being sure that anthers of a spike will not ripen at the time of stigma receptivity we can select a spike
- About four-fifth of the upper spikelets of the inflorescence are removed.
- The remaining spike of spikelets is enclosed in a bag before the stigma emergence. Upper spikelets bloom a day prior to lower spikelets.
- Bag the spikes to be used as pollen parents and collect the shedding pollen dust.
- In the morning dust the pollen grains on the stigmas.
- Bag the spike after gross pollination has taken place.
- Label the necessary information.

➢ **Other methods:**

- **Use of male sterility:**
- Male sterility (CGMS) may be incorporated for genetic emasculation of bajra:
- The male sterility conditioned by recessive genes is introduced in to plants to be used as females by back crossing and the genetic emasculation is completed.

- **Hot water treatment:**
- Dip the spike in hot water having a desired temperature of 45-50oC for 1 to 10 minutes depending up on the variety.
- The hybrid pearl- millet seed is produced by utilizing cytoplasmic genetic male sterility.

The various steps involved in the production of hybrid pearl-millet seed are: maintenance of parental lines namely:

- Male sterile lines (A-lines).
- Maintainer lines (B-lines).

- Restorer lines (R-lines).
- The maintenance of parental lines is referred to as foundation seed production, whereas the hybrid seed production is known as certified seed production.

- **Maintenance of Male sterile lines:**
- It is maintained by crossing male sterile line (Line A) with a male fertile, non-pollen restoring maintainer (Line B) in an isolated plot.
- This B line is a sister strain of line A and is essentially similar to line A in genetic constitution except that it carries fertile pollen.
- In a crossing field, the usual planting ratio of line A and Line B is 4:2. In addition 4-8 border rows are planted with line B around the field.
- The seed harvested from line A would be male sterile and is used for hybrid seed production.
- The field for producing the foundation seed of male sterile line A must be isolated by 1000 m from other pearl-millet fields.

Maintenance of maintainer line:

- The seed of maintainer line is produced by sowing B lines in isolated plot or B lines sown in the field for production of A-seed can be harvested separately to get B-seed.

Maintenance of restorer line:

- The seeds of restorer line (Line R) are produced by multiplying the seed in an isolated plot having a distance of 1,000 m from nearby pearl-millet.
- Production of Hybrid seed using CGMS: (HHB-67)
- The hybrid seed is produced by crossing male sterile line (Line A) with a specific restorer line (Line R) in an isolated plot.
- Isolation distance are 200 m from fields of other varieties.
- The hybrid seed is produced by growing 6 rows of male sterile line A alternated by 2 rows of restorer line (Line R).
- The 2:6 proportion of male rows (Line R) and female rows (Line A) can be increased safely to 2:10 depending upon the pollinating vigour of the restorer parent.
- The seed harvested from the female rows (A-lines) is the hybrid seed.

Useful genes in breeding for Bajra millet

1. ***Pennisetum glaucum ssp. Monodii-*** rust and leaf spot resistance and cytoplasmic male sterility.

2. Pennisetum pupureum:

Rhizomatus perennial Most closely related to pearl millet, known as Napier grass used in developing perennial fodder varieties. greater stalk strength and male fertility restorer genes. Famous perennial fodder variety Cumbu napier hybrid = BN1.

(3) *Pennisetum squamulatum:*

It has been used in breeding programme to develop draught and cold resistant cultivers.

(4) P. orientale : *Used for transferring apomixis.*

(5) P. setaceum P. violaceum : *To transfer male sterile genes to P.glaucum*

Planning a Breeding programme

1. Pollination behavior of the crop
   a. To understand the genetic constitution of a species
   b. The ease in pollination control
   c. The stability of varieties after release
2. Types of cultivar- varieties or hybrids
3. Objective of the breeding program

Breeding objectives:

1. **Breeding for high grain yield:**

To get high yields the following plant characters are necessary

a) More number of tillers
b) well filled, compact, long panicle.
c) heavy grains.
d) Uniformity of ripening.

2. Breeding for improved grain quality.

✓ Grain colour: gray, pearly

- ✓ Grain size: bold, lustrous, pearly and amber grain
- ✓ Protein and Vitamin content: highest protein (14-17 %) than any major cereals .

It can be achieved by incorporating
-- yellow endosperm to improve vitamin A content
-- white endosperm to improve protein content

3. Breeding for high forage value :

The forage cultivars must have following characters.

(i) Increased number of tillers
(ii) Increased number of leaves
(iii) high sugar content in the stem juice
(iv) Ability to retain green colour
(v) Nutritive value of fodder and Digestibility

4. Breeding for drought tolerance:

This can be achieved through evolving early maturing lines so that they can escape drought.

The lines with more adventitious roots, high leaf water potential and high chlorophyll stability index are to be evolved.

5. Early maturity and Photo-insensitivity

Under irrigated conditions photo insensitivity and early maturity are essential for multiple and relay cropping.

6. Breeding for disease resistance

- Downy mildew is the major disease. Ergot and smut comes next. Rust at late stage is also becoming a major problem.
- Lines having Local Bellary cytoplasm (732 A) are observed to be downy mildew resistant.

7. Breeding for bird resistance: Variety with bristle

8. Breeding for alternate source of cytoplasm in male sterile lines.

- Original Tift 23 A evolved at Tifton, Georgia is highly susceptible to downy mildew. Because of this the HB series went out of cultivation.
- The indigenous Bellary cytoplasm (732 A) is resistant.
- Similarly L 111A of Ludhiana is also tolerant.
- A_1, A_2, A_3 and A_4 are there 732 A belongs to A_4 cytoplasm.

9. Lodging resistance

Breeding Procedures:

1. Introduction : Tift 23 A from USA

2. Selection : Pure line selection : Co 2, Co 3**,**

3. Heterosis breeding : Hybrid bajra

- In earlier days before the identification of male sterile lines, hybrids were released by utilising the protogynous nature.

- After the discovery of cytoplasmic genic male sterile line Tift 23A by Burton led to development of hybrids.But due to susceptibility to downy mildew they went out of cultivation.
- To over come the problem of downy mildew, male sterile lines L 111A and 732 A were isolated and at present used in breeding programme.

4. Population improvement :

ICRISAT entry WCC 75 and ICMV 155 is an example for population improvement

5. Synthetic varieties :

Synthetics are produced by crossing in isolation a number of lines tested for their GCA.

E.g. ICMS 7703.

6. Mutation breeding

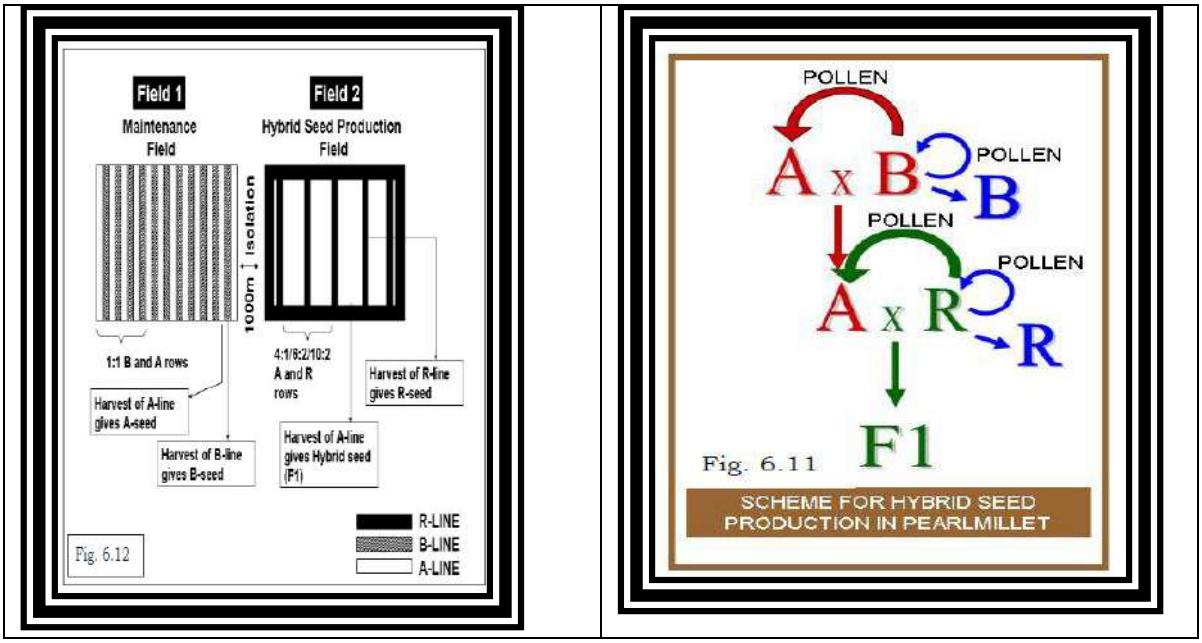
At IARI Tift 23 A was gamma irradiated and male sterile line 5071 A resistant to downy mildew was evolved. With this the hybrid NHB 3 was evolved.

Production of Hybrid seed using CGMS: (HHB-67)

→ The hybrid seed is produced by crossing male sterile line (Line A) with a specific restorer line (Line R) in an isolated plot.

→ The isolation distance for foundation seed and certified seed production are 200 and 400m, respectively.

→ **Fig.: Schematic diagram of Production of Hybrid seed using CGMS:**



→ The hybrid seed is produced by crossing male sterile line (Line A) with a specific restorer line (Line R) in an isolated plot.

→ The isolation distance for foundation seed and certified seed production are 200 and 400m, respectively.

→ The hybrid seed is produced by growing 6 rows of male sterile line A alternated by 2 rows of restorer line (Line R).

→ The 2:6 proportion of male rows (Line R) and female rows (Line A) can be increased safely to 2:10 depending upon the pollinating vigour of the restorer parent.

→ The seed harvested from the female rows (A-lines) is the hybrid seed.

→ The hybrid seed is produced by growing 6 rows of male sterile line A alternated by 2 rows of restorer line (Line R).

→ The 2:6 proportion of male rows (Line R) and female rows (Line A) can be increased safely to 2:10 depending upon the pollinating vigour of the restorer parent.

→ The seed harvested from the female rows (A-lines) is the hybrid seed.

Certified seed production programme

- It is taken on farmers field and is supervised and certified by GSSCA.
- Isolation distance of 200 m is maintained
- Line A and Line R are planted in the ratio of 4:2, two pollinator lines should be grown surrounding the field.
- Rouging should be carried out at

1. One month after sowing,
2. At the time of flowering and
3. At the time of maturity

Practical achievements:

FIREST HYBRIDES:

1. HB1: Tift 23A x BIL3b (Ludhiana)
2. HB2: Tift 23A x J88 (Jamnagar)
3. HB3: Tift 23A x J104 (Jamnagar)
4. HB4: Tift 23A x K560 (Kanpur)
5. HB5: Tift 23A x K599 (Kanpur)

Recent Hybrids :

From Jamnagar: GHB-526, GHB-558, GHB-538, GHB-577, GHB-732, GHB-744. GHB-719 and GHB-905 with bristle.

From Hissar: HHB 45, HHB 50

From IARI: PUSA-23, PUSA-605 and NHB 3

Composite variety : ICTP-8203

Synthetic varieties : ICMS 7703.

Research stations:

A. International:

International Crop Research Institute for Semi Arid Tropics (ICRISAT), Patancheru, Patancheru, Hydrabad

B. National:

All India Co-ordinated Research Project on Pearl millet, Mandoor, Jodhpur, Rajasthan.

C. State :

Main Millet Research Station, JAU, Jamnagar

PIGEONPEA / REDGRAM BREEDING



- ✓ Pigeon pea / Red gram is an important pulse crop next to chickpea in India.
- ✓ The major pigeonpea growing countries are India, Uganda, Kenya, West Indies, Puerto Rico, Dominican Republic in the Caribbean region and Burma.
- ✓ India is a largest producer i.e. 90% of the world's production. It is grown in kharif season.
- ✓ In India it is mainly cultivated in Gujarat, Maharashtra, Madhya Pradesh, Uttar Pradesh, Karnataka and Andhra Pradesh.

1.	Name of Crop	:	Pigeonpea, Redgram, Arhar
2.	Botanical Name	:	*Cajanus cajan* L.

3.	Family	:	Fabaceae
4.	Chromosome Number	:	2n = 22
5.	Center of Origin	:	India
6.	Mode of pollination	:	Often cross pollination
7.	Percent cross pollination	:	5 - 48 %
8.	Related wild species	:	*C. acutifolius, C. albicans, C. cajanifolius, C. conferiflorus, C. scarabaeoides*

Classification of Pigeonpea:

1. **On the basis of flowering pattern:** It is classified into two habit groups

Determinate type: Flowering duration is short and flowers are borne more or less at the same level. e.g. GT-100

Indeterminate type: Flowering duration is longer and flowers borne at several point along the branches. e. g. BDN-2

2. **On the basis of maturity**: It is classified in to five groups as under.

Sr. No.	Types	Maturity Days	Name of variety
1	**Extra early**	100 to 120	ICPL-88039, APK-1, CO-5
2	**Early**	120 to 150	GT-100, UPAS-120, GTH-1 (Hybrid)
3	**Medium**	150 to 175	BDN-2, GT-1, BSMR-736, ICPL-87119
4	**Medium late**	175 to 200	Bahar, JA-3
5	**Late**	Above 200	Type-7, Type-17, T-15-15

Floral structure:

Inflorescence:

The flowers are borne on short axially or terminal racemes and are vary in colors.

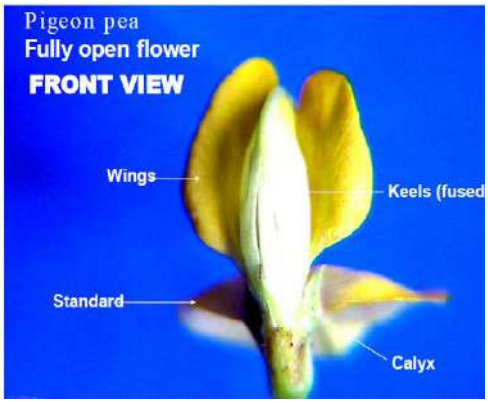
Pigeonpea has typical papilionaceous, bracteate bracteolate flowers consisting of 5 sepals (gamosepalous), 5 pleats (polypetalous) and one carpel with the style born laterally on the ovary.

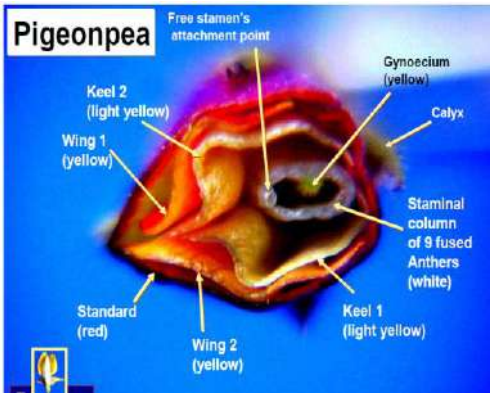
Petals and Sepals:

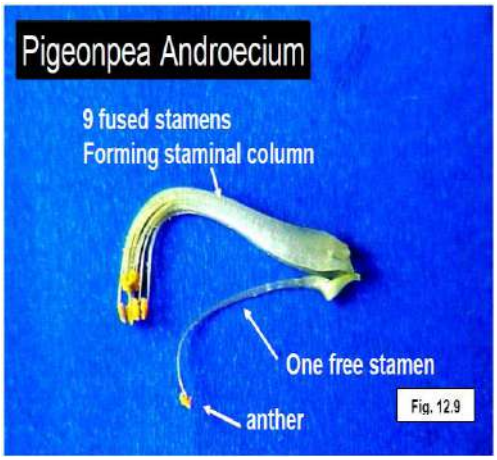
The petals are large and brightly colored and 5 in number, comprised of one standard, two wings and two keels.

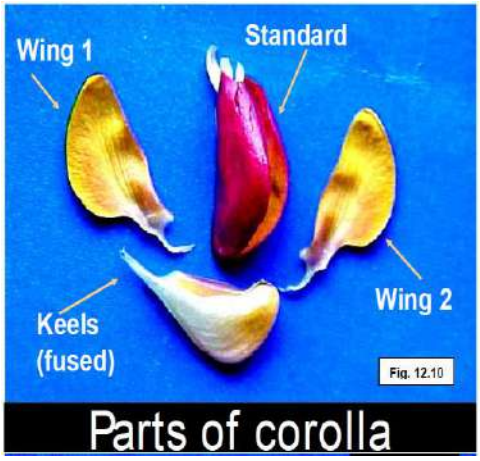
Sepals are also 5 in number.

Papilionaceous. Five free petals are unequal in size (Zygomorphic) and arranged in butterfly like manner - one large posterior bilobed petal called standard (or vexillum) which over-laps two small lateral petals called wings (or alae). The wings further overlap the two innermost smallest and fused petals forming a boat, called Keel (or carina). Examples - plants of family Papilionaceae or Fabaceae (Pea, chickpea, pigeonpea etc.).









Bracteate:
Flowers having bracts.

Bracteole : A secondary bract at the base of an individual flower.
Bracteolate : Flower having bracteoles.

Stamen:
It consists of a slender stalk or filament, which supports an anther. These are 10 in number, 9 fused to form a staminal column and one is free i.e. are in diadelphous condition.

Pistil:
The ovary is unicarpellary, unilocular, superior, sub-sessile with 2-9 ovules; style long, filiform, much upcurved; stigma capitate and glandular papillate.

Anthesis and Mode of pollination:

- Pigeonpea flowers can be self-pollinated or cross-pollinated.
- Self-pollination occurs in bud before the flower opens.
- Although the stigma is completely covered with the pollen of its own flower, considerable outcrossing occurs in pigeonpea.
- The foreign pollen has an advantage over native pollen in affecting fertilization.
- It has been proven by pollinating the flower buds by foreign pollen. It was observed that the percentage of 'self' was negligible when flower buds were pollinated with foreign pollen without emasculation.

- It is due to delayed germination and slow pollen tube growth of the native pollen. Such mechanism provides sufficient gap for foreign pollen to be introduced into the stigma and thus it favours cross-pollination.
- Among the insects involved in cross-pollination are Apis florea, Apis dorseta and Megachile spp.
- Anthesis normally occurs between 8.00 a.m. and 5.00 p.m. and flowers may remain open for 6 to 48 h.
- Flowering period is influenced by weather conditions.

Emasculation and Pollination:

- Flowers are generally emasculated in the evening and pollinated in the next morning.
- For emasculation, flowers that will open one or two days later are selected, and the rest of the flowers and the buds in a branch are removed.
- The stamens of the selected buds are removed with a pair of a fine forceps by gently pushing the keels apart. The emasculated floral branch is then bagged.

Self pollination:

- To ensure selfing the flowers need to be bagged. This is because insects may sometimes carry pollen to the stigma and bring about cross-pollination.

Seed Production:

- Seed production is done in isolation using dhencha as a border crop to protect the seed crop from contamination through foreign pollen.
- CMS lines are also available and are under test for use in seed production programmes.

Classification of Pigeonpea:

1. On the basis of flowering pattern: It is classified into two habit groups.

Determinate type: Flowering duration is short and flowers are borne more or less at the same level. e.g. GT-100.

Indeterminate type: Flowering duration is longer and flowers borne at several point along the branches. e. g. BDN-2.

2. On the basis of maturity: It is classified in to five groups as under.

Sr	Types	Maturitys	Name of variety
1	Extra early	100 to 120	ICPL-88039, APK-1, CO-5
2	Early	120 to 150	GT-100, UPAS-120, GTH-1 (Hybrid),GT-105
3	Medium	150 to 175	BDN-2, GT-1, BSMR-736, ICPL-87119, GT-104, GNP-2, GT-106 (2020)
4	Medium late	175 to 200	Bahar, JA-3, GJP-1, AGT-2, GT-103
5	Late	Above 200	Type-7, Type-17, T-15-15

➢ Breeding objectives:

1. High yield
2. Shattering resistant
3. Early and synchronous maturity
4. High harvest index
5. Adaptation
6. Efficient nitrogen fixing ability
7. Resistant to drought
8. Resistant to disease and pest
9. Breeding for quality:
   (i) Grain colour (ii) Grain shape (iii) Grain size (iv) Protein content
10. Breeding for vegetable purpose

❖ Breeding procedures

- 1. **Introduction :**
  E.g. Prabhat short duration variety from IARI, ICPL 87 from ICRISAT.
- **2. Pure line selection:**
  Earlier breeding work was based on the assumption that Redgram is a self pollinated crop. However it was later found to be often cross pollinated crop.
- **3. Hybridization and selection :**
  Inter varietal : VBN 1 (Prabath x NY 34)
  Inter generic : *C. cajan x Cajanus lineata, C. cajan x C. scaraboides are being attempted.*
- **4. Mass selection :**
- **5. Population improvement :**
- **6. Mutation breeding:**
  LRG-30 variety was susceptible to wilt was irradiated and wilt resistant variety was developed as ICPL-270
- **7. Heterosis breeding:**

➢ RESEARCH STATIONS:

A. International:
International Crop Research Institute for Semi Arid Tropics (ICRISAT), Patancheru, Hydarabad

B. National:
Indian Institute of Pulses Research (IIPR), Kanpur, Uttar Pradesh

C. State level:
Main Pulses Research Station, SDAU, Sardarkrushinagar

Improved varieties:
T-15-15, GT-1(Vegetaable), BDN-2, GT-100, GT-101, GT-102, GT-103, GT-104, GT-105, GNP-2 (Dual purpose) , GJP-1, AGT-2, AVPP-1, BSMR-856, BSMR-736, ICPL-87119, ICPL-87

Hybrid varieties:

World first GMS based hybrid, ICPH-8 = MS Prabhat DT x ICPL 161 (ICRISAT, Hyderabad), World first CGMS based hybrid, GTH-1 = GT 288A x GTR-11 (GAU, Sardarkrushinagar)

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GREENGRAM / MUNGBEAN BREEDING



- Greengram, popularly known as mungbean, is primarily grown in India, Pakistan, Bangaladesh, Sri Lanka, the Phillipines, Taiwan, Thailand, Nepal and other Southeast Asian countries.
- It is consumed mainly as a food legume.
- It is the third important pulse crop after chickpea and pigeonpea in India.
- The states accounting for the major area under cultivation are Rajasthan, Maharastra, Madhya Pradesh, Andhra Pradesh and Orissa.
- The green gram forms a very nutritious diet.
- It is consumed in the form of whole dried seeds and in the form of dal prepared by splitting the seeds in a mill.
- The sprouted mung beans are a highly nutritious food. There is an amazing increase in nutrients in sprouted beans when compared to their dried embryo.

1. **Name of crop** : Mungbean, Moong, Green gram, Chikasaw pea, Oregon pea

2.	**Botanical name**	**:**	*Vigna radiata* L. Wilczek
3.	**Family**	**:**	Fabaceae
4.	**Chromosome number**	**:**	2n = 22
5.	**Center of origin**	**:**	India
6.	**Mode of pollination**		Self pollination
7.	**Out crossing percentage**	**:**	0.5% (2.8 to 3.0 per cent cross pollination reported)
8.	**Related wild species**	**:**	*Vigna angularis*



Mungbean flower



Single flower



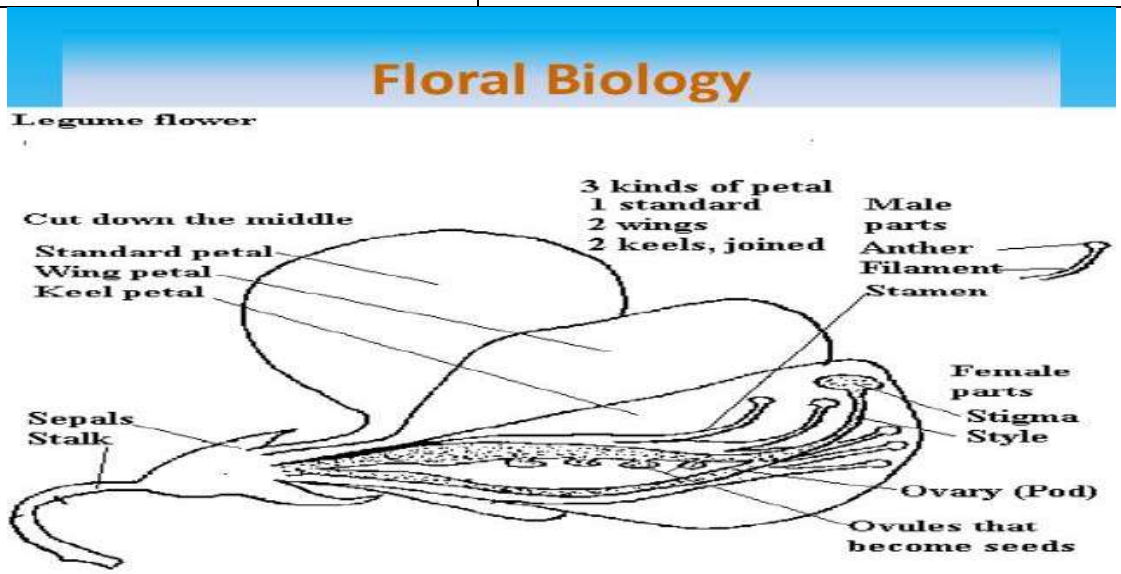
Open flower



Mungbean pod



Mungbean seeds



- **Flower biology:**

- Flowers are in an axillary or terminal receme, peduncle up to 13 cm in length with clusters of 10 to 20 flowers.
- Corolla is yellow in colour and papilionaceous, sometimes curved 5-10 cm long. Small flowers are borne in capitates clusters on the end of long hairy peduncles.

- Petals are five in numbers, three kinds of petals, 1 standard, 2 wings and 2 keels.
- **Androecium:** male reproductive part stamen has got two parts anther and filament.
- **Gynoecium** : Female reproductive part made up of stigma, style and ovary. Gynoecium is monocarpellary with a superior unilocular ovary.
- The stigma is hairy and placentation is marginal.
- Keel encloses reproductive organs, 10 stamens and one gynoecium.

➢ **Anthesis and pollination:**

- Pollination occurs a night prior to opening of the flowers.
- Anthers start dehiscing from 9 a.m. and complexly dehisced by 3 a.m.
- A stigma is by then receptive and is thoroughly covered with pollen.
- Flower open between 6 a.m. and 8 a.m. and remain open till 11 a.m. later they close between 2 p.m. and 4 p.m.
- Pollen shedding takes place long before the petals open.
- Cleistogamy occurs to an extent of 40 %.
- Pollination is effected in the bud stage on the night previous to the opening of the flower.

➢ **Shivashankar's Methods:**

- Followed in pulse crop
- On the evening previous to the day of pollen shedding, transverse cut is made in flower bud.
- Facilitates removal of upper portion of the corolla like a cap without causing injury to the gynoecium.
- Anthers are clipped off automatically and remains inside the corolla cap which is removed.
- The stigma is then pollinated with desired pollen on the next morning.

➢ **Breeding objectives:**

1. High yield
2. Maturity:
   (i) Early, 60-70 days (ii) Mid-late, 90 days (iii) Late, 90-120 days
3. Adaptation
4. Resistance to shattering
5. Insects pests and diseases resistance
6. Breeding for quality: Cooking quality and nutritional value, seed size, seed colour etc.

➢ **Breeding Methods:**

1. **Introduction -** Pusa baisakhi
2. **Pure line selection -** Co1
3. **Hybridisation and selection**
   Inter Varietal :
   Inter specific - To transfer high methionine content from black gram to green gram.
   V. radiata x V.umbellata rice bean to transfer resistance to bean fly crossing with V.radiata var. sublobata resistance to bruchids
5. **Mutation breeding**
   Co4 - mutant of Co1
6. **Embryo culture :**

Green gram x Black gram

Ideal plant type

- 60 - 65 days duration with determinate habit for irrigated conditions
- 80 days duration with indeterminate type for dry land condition
- Plants with more pods and seeds, increased branches poding from base of main stem
- synchronized maturity non - shattering habit.

➢ **Research Stations:**

A. National:

Indian Institute of Pulses Research (IIPR), Kanpur, Uttar Pradesh

B. State level:

Main Pulses Research Station, SDAU, Sardarkrushinagar

➢ **Improved varieties:**

Gujarat Mungbean-1, Gujarat Mungbean-2, Gujarat Mungbean-3, Gujarat Mungbean-4, K-851, Gujarat Mungbean-5, Gujarat Mungbean-6, Gujarat Mungbean-7, Meha

Breeding for Soybean, groundnut and sesame

SOYBEAN BREEDING



- Soybean, a "Golden Nugget of the Orient", is recognized worldwide as a miracle crop, which experienced phenomenal expansion.
- It is an efficient producer of the two scarcest items in the world food economy, i.e., high quality protein and oil.
- The whole bean contains about 40 per cent protein, 20 per cent oil, 22 per cent carbohydrate, 5 per cent crude fiber, 4 per cent ash and 9 per cent moisture.
- This versatile plant serves as a natural soil fertilizer by fixing 50 kg nitrogen per hectare.

- Soybean is also an excellent source of good quality unsaturated oil.
- The five most important soybean based foods are miso (soy paste), shoyu (soy sauce), tofu (soy curd), soy milk (fluid extracted from soybeans) and tem peh (a fermented, cake-like product).
- Soybean cultivation originated in the North China Plain and spreading through East and Southeast Asia, reached to the United States of America, which is the leading country in soybean production.

1.	Name of Crop	:	Soybean
2.	Botanical Name	:	*Glycine max* L. Merr.
3.	Family	:	Fabaceae
4.	Chromosome Number	:	2n = 40
5.	Center of Origin	:	China
6.	Mode of pollination	:	Self pollination
7.	Out crossing percentage	:	< 1%
8.	Related wild species: *G. soja, G. albicans, G. arenaria, G. argyrea, G. canescens, G. clandestine, G. curvata, G. cyrtoloba, G. falcate,G. hirticaulis*		

Breeding objectives:

1. High yield
2. Early maturity
3. Suitability for different agro-climatic zones
4. Resistance to lodging and shattering
5. High germinability and longivity
6. Tolerance to abiotic stresses
7. Resistance/tolerance to diseases and insect pests
8. Seed quality
9. Breeding for vegetables or for culinary purpose
10. Protein and oil quantity and quality

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BOTANY AND STRUCTURE OF SOYBEAN PLANT

Inflorescence

- Soybean has a typical papilionaceous flower.
- It consists of a tabular calyx with five sepal lobes; a corolla made up of a standard petal, two lateral wing petals, and two anterior keel petals.
- Nine of the ten stamens are fused leaving the posterior one separate
- The pistil is made of an ovary that contains 1-5 ovules, a style that accrues towards the standard and a capitate stigma.
- Pollination occurs before the flower opens

Soybean flowers



Contd...

The corolla begins to emerge from the sepals.

The are five petals,one standard, two keel and two wing petals.

The keel petals encloses the pistal and the stamen.

Stamens are 10 in number and diadelphous,nine are united to form a tube around the ovary and the tenth is free.



FLORAL BIOLOGY

- Soybean belongs to family legumioseae and it is highly self pollinated.
- Soybean has perfect flower consistig of calyx,
- Corolla, pistil and stamens.
- There are 5sepals, green,hairy sepals.

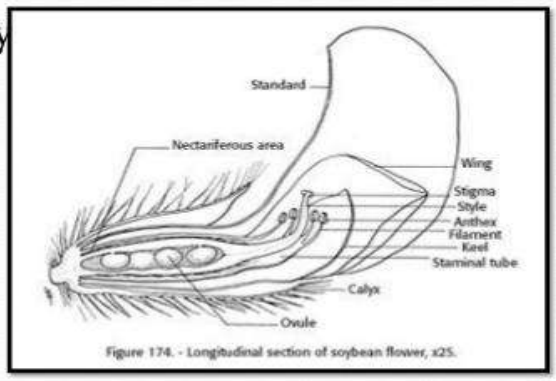
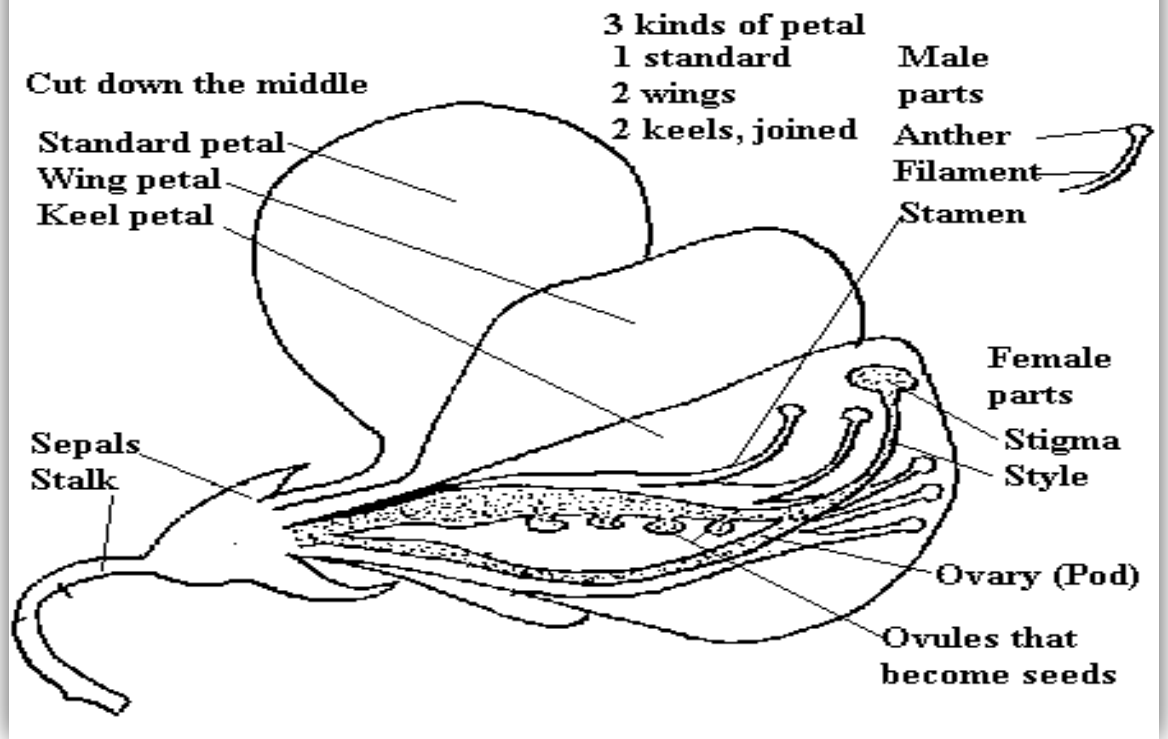
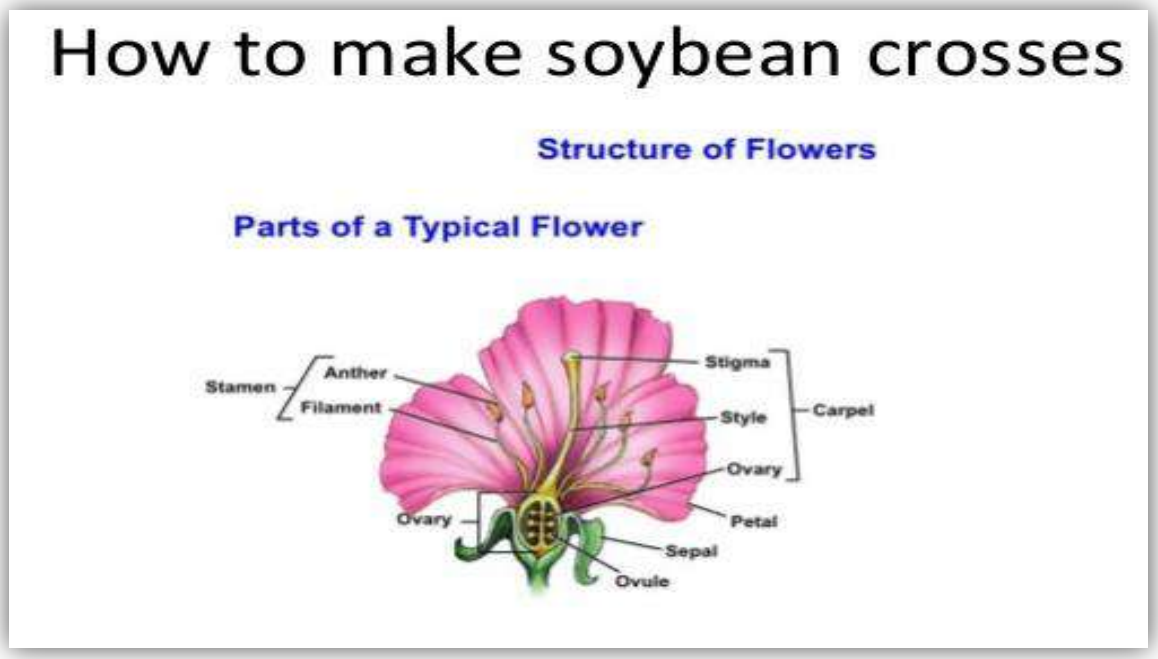


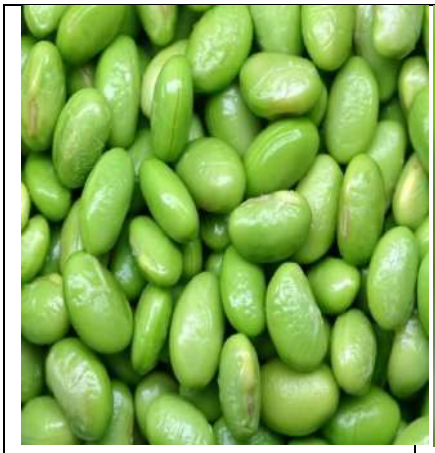
Figure 174. - Longitudinal section of soybean flower, x25.

9.72.2 Legume flower

Winged bean *Psophocarpus tetragonolobus*











- **Research stations:**

A. **National:**
Directorate of Soybean Research (DSR), Indore, M.P.

B. **State:**
Oilseed Research Station, JAU, Amreli

- **Improved varieties :**

Gujarat Soybean-1,
Gujarat Soybean-2,
Gujarat Soybean-3

Groundnut Breeding



Groundnut is a herbaceous either a perennial or an annual unpredictable legume. It is one of theprincipal edible oilseed crop of the world, ranking 13th among the food crops. Groundnut occupies 45 per cent of the total oilseeds area and contributes about 55 per cent of the total oilseeds production. Eighty per cent groundnut are and 84 per cent production confined to the five states *viz*., Gujarat, Andhra Pradesh, Tamil Nadu, Karnataka and Maharashtra.

Peanut is having 46-55 per cent oil and 25-30 per cent protein. Out of the total groundnut production, 12 per cent used for seed purpose, 6 per cent for for domestic purpose, 81 per cent for oil extraction and 1 per cent is exported to other countries. Plant is used as a fodder and the oilcake as feed for cattle or as a manure.

1.	**Name of crop**	**:**	Groundnut, pea nut, monkey nut, goose nut, Manila nut, Jack nut, Earth nut
2.	**Botanical name**	**:**	*Arachis hypogaea* L.
3.	**Family**	**:**	Fabaceae
4.	**Chromosome number**	**:**	2n = 40
5.	**Center of origin**	**:**	South America (Bolivia) and Brazil
6.	**Mode of pollination**		Self pollination
7.	**Out crossing percentage**	**:**	< 1 %
8.	**Related wild species**	**:**	*A.monticola, A. glabrata, A. villosa, A. pusilla,A.duranensis, A. batizocoi, A. cardenasii*

Groundnut has basically indeterminate growth habits.

Three types viz., bunch, semi-spreading and spreading are recognized in varietal classification.

- In spreading form, the main axis is very short and erect and the primary branches spread horizontally along the ground.
- In the bunch types, the main axis is long and erect and the primary branches are oblique to the main axis.

The indeterminate forms between these two types are classified as semi-spreading

Types of groundnut

The cultivated *Arachis hypogaea* have two-sub species, ***hypogaea*** **(Virginia types)** and ***fastigiata*** **(Spanish and Valencia types).**

- Sub-species *hypogaea*, var. *hypogaea* includes both Virginia bunch (semi-spreading) and Virginia runner (spreading) types
- Sub-species *fastigiata* var. *fastigiata* (Valencia) and var. vulgaris (Spanish) commonly known as bunch-types.

Difference between bunch and spreding types of groundnut:

Sr. No.	Character	Bunch	Spreading
1.	Botanical group	Spanish and Valencia	Virginia
2.	Plant growth habit	Erect	Spreading
3.	Branching pattern	Sequential	Alternate
4.	Lateral branches	Reproductive	Always vegetative
5.	Flowers on main stem	Present	Absent
6.	Foliage colour	Light green	Dark green
7.	Leaflet size	Large and oblong	Smaller and pointed
8.	Pod arrangement	Cluster in base of the plant	Scattered along with branches
9.	Pod size	Small to medium	Medium to bold
10.	Seed size	Smaller	Large and heavier
11.	Seed dormancy	Usually absent	Present
12.	Maturity	Early	Late
13.	Growing season	*Kharif* and *summer*	*Kharif*
14.	Oil per sent	Less (42-46%)	Higher (48-55%)

The genetical reasons for low productivity in groundnut

1. Success in hybridization is very less due to small and complex flower structure, low flower to pod ratio (7 : 1) few seeds per pod etc.
2. Transferring desirable traits like disease, pest, drought resistance, etc., from wild species is very difficult.
3. Flowering is not synchronous, which is essential for maximum pod filling.
4. Absence of seed dormancy in bunch and prolonged dormancy in spreading types.
5. Poor response to high dose of fertilizers and number of irrigations.
6. Weak peg attachment, which causes maximum pod losses during harvesting.
7. Linkage map of genes not available
8. Seed multiplication ratio is very less i.e. 1:5.
9. Low harvest Index.

General constraints for low productivity in groundnut:

1. Periodic droughts (early season, mid season and late season drought).
2. Occurrence of pests and diseases.
3. Difficulties in implementing the recommended moisture conservation practices.
4. Poor economic status of the farmers.
5. Lack of drought tolerant cultivars.
6. Inadequate and untimely supply of inputs.
7. Poor response to high dose of fertilizers.

Origin of cultivated groundnut

Arachis villosa X *Arachia lignosa*
2n=20 2n=20

↓

2n=20, Chromosome Doubling

↓

2n=40 Allptetraploid
Arachis hypogaea

❖ Groundnut is an unpredictable Crop

- Since the pods are borne below ground positively geotropic, we cannot predict its performance before harvest as in the case of other crops.
- Further Groundnut is highly influenced by environment.

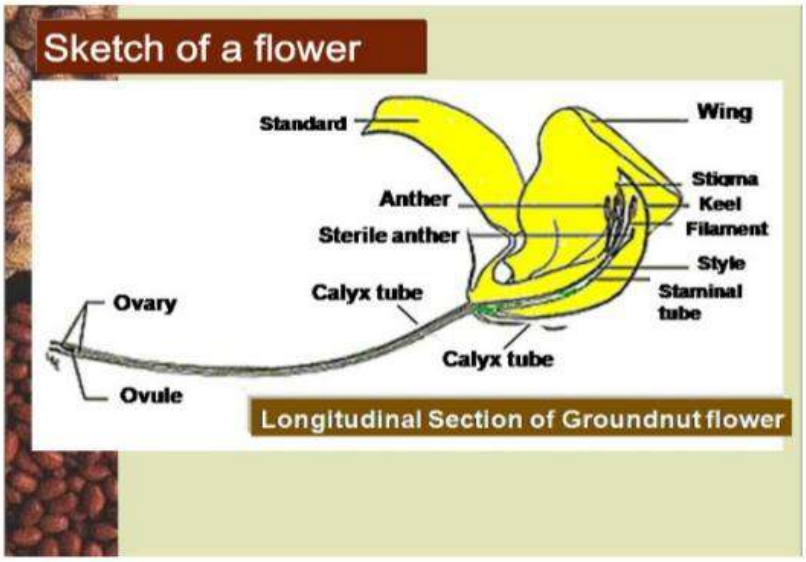
The unfavorable environment influence not yield alone but also affected the quality characters.

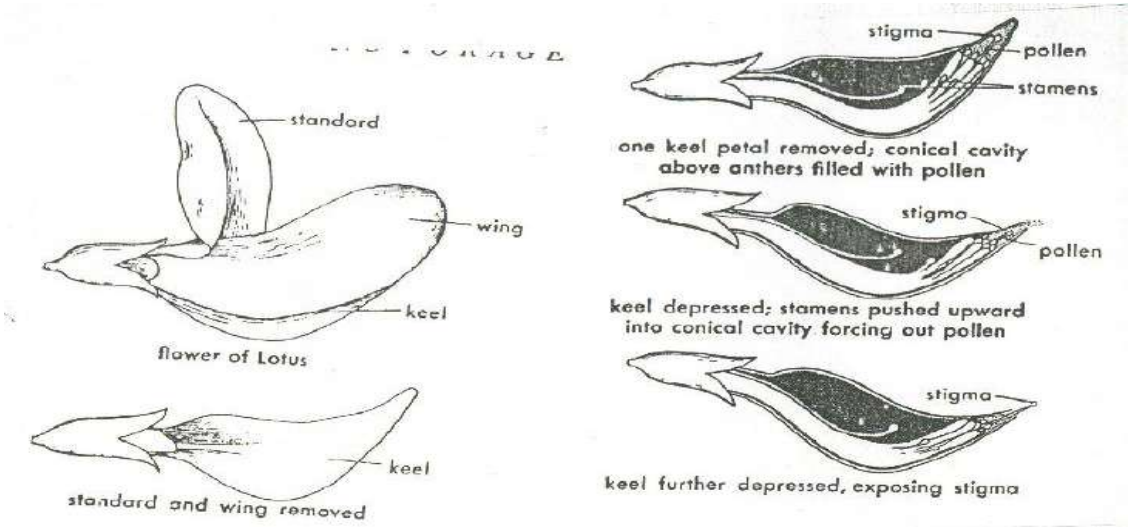
- ❖ Less boron leads to low shelling % and
- ❖ Moisture stress at immature seed stage leads to lower yield as well as reduction in well developed kernels.
- ❖ Excess moisture leads to more vegetative growth and reduction in yield
- ❖ Oil percentage is also influenced by environment.
- ❖ Compared to any other crop, The G x E interaction is more pronounced in groundnut.
- ➢ **In groundnut though the flowers are above ground level, peg formation take place below ground level.**

- Because after fertilization, in response to auxin formation, ovary stalk elongates and shows positive geotropic movement towards the soil.
- Subsequent to penetration of the peg in the soil, pod development takes place due to darkness, mechanical stimulus and Ca and nutrients uptake by the developing pod.
- One of the bottlenecks in the spread of improved varieties in groundnut is low Seed multiplication ratio that is 1:5.

➢ Floral biology

- The flowers are borne in the axils of the leaves, mostly near the base of the plant.
- Sepals are 5 and form a green colored tube
- Petals are 5 and yellow in color, **one standard, two wings and two keels.**
- The stamens are **10 monoadelphous** with the **staminal column** surrounding the ovary. **Two of them are usually sterile.**
- Long style, **club shaped stigma** with hairy end, which is enclosed in keel.
- Stalk of the ovary elongate to form a **peg and curves towards soil.**
- Flowers open between 6.00 to 8.00 am. Anthers dehisce about 1-2 hrs before opening of the flowers and fertilization completes before mid-day (6 hours after pollination)





Though flowers are above ground level in groundnut, peg formation take place below ground level.

Because after fertilization, in response to auxin formation, ovary stalk elongates and shows positive geotropic movement towards the soil, subsequent to penetration of the peg in the soil, pod development takes place due to darkness, mechanical stimulus and Ca than nutrients uptake by the developing pod.

Selfing technique

The whole plant is covered with muslin cloth bag to ensure the cent percent self-pollination.

Crossing technique

- Select a bud of the female parent, which is fully matured and very nearer to the soil during 1.30 - 6.00 p.m. (mature bud is pink or light purple in color)

- Except the selected bud in the inflorescence all other buds should be removed. Care should be taken to see that any developing peg resulted from self-pollination is not in axils of the leaf.
- Hold the bud very gently with your thumb and index finger.

Pull down a little part of the calyx with the help of forceps.

- Open the whole flower by forceps and holds its standard and wings with thumb and index finger.
- Pull down the keel by forceps and remove all anthers in down-wards movement very carefully. Do not touch the stigma by forceps during the whole procedure.
- Leave the flower, it will close automatically.
- On the next day at 6.00 to 10.00 a.m. pollinate the emasculated flowers by pollen of the desired male parent.
- After 5-7 days of pollination successfully crosses will produce pegs. A small wire-ring of 4 mm diameter will kept on the pegs with code number of receptive crosses.

Breeding objectives

1. **Breeding for higher yield**
   The different yield components traits viz., Seed size (Virginia types have larger kernels than Spanish type), Number of pods per plant, Shelling per cent**.**

2. **Breeding for fresh seed dormancy**

   Problem more persists in Spanish cultivars. The Spanish types cultivars grown during kharif may faced early N.E. monsoon rains which results in germination of varieties. So it is necessary to breed varieties having dormancy. Semi spreading varieties are dormant TMV 7 and slightly dormant varieties, BSR.1, ALR 2 dormant for 15 days.

3. **Breeding resistance to biotic stresses**

   Disease: Rust and leaf spot (early and late) are major diseases; varieties having multiple disease resistance are Girnar-1, ALR-2, GPBD-4, etc. Tomato spotted wilt virus or Bud necrosis of late gaining importance. NCAC 17090 -resistant.

   Pest: Red hairy caterpillar, leaf miner are major pests.

4. **Breeding resistance to abiotic stresses**
   Different stress viz., drought (K 134, ICGS-1, ICGS-5, ICGS-37, etc. are tolerance to drought), salinity, high temperature, Aluminum toxicity.

5 **Breeding for earliness:** Suitable to escape drought, disease, and prevent germination due to early monsoon.

6 **Breeding for quality**

   a. **High oil content:** More than 50 percent, the semi spreading variety TMV 10 is having 52 percent oil. Generally oil content is highly influenced by environment.
   b. **Oil quality:** Low iodine value-long shelf life, high value: high level of unsaturation may good for health purpose. Higher oleic to linoleic acid ratio.
   c. **High shelling percentage: More than 75 percent. The variety having** Thin shelled shows high shelling percentage.
   d. **High sound mature kernel** (SMK): This is also influenced by environment. Increased boron application results in high shelling percentage and high SMK %
   e. **Table purpose varieties:** large seeded or confectionary types- good for table purpose.

f. **Aflatoxin resistance:** A toxin produced by fungi *Aspergillus flavus and A. parasiticus*. Aflatoxin causes various disease in animal including human *i.e.*, Cancer, affects on immune system.

7. Resistance to diseases and insect pests

8. **Breeding for high Biological Nitrogen Fixation (BNF) efficiency**

➢ Breeding Methods:

1. Introduction:

All the groundnut lines are introduced ones.

2. Selection :

a) Pure line selection: TMV 2 - from local Gudiyatham bunch.

b) Mass selection: JL 24 from Taiwan variety.

3. Hybridization and Selection

a) **Inter varietal:** Bunch x Bunch - VRI 2 (Co2 x JL 24)

b) **Inter specific:** For transfer of disease resistance.

A.monticola - for thin shelled conditions

A.villoulicarpa for increased number of pods.

5. Mutation breeding

TG 1 to TG 6 (Vikaram) from BARC Trombay.

GNLM - Gujarat Narrow Leaf Mutant.

6. Embryo rescue technique :

A.puscilla x A.hypogaea crosses. But not much successful. Cotyledon culture is a success.

7. Transgenic plants

Transgenic plants for disease resistance.

➢ Research stations

A. International

International Crop Research Institute for Semi Arid Tropics (ICRISAT), Patancheru, Hydrabad, Andhra Pradesh

B. National

Directorate of Groundnut Research (DGR) [National Research Center for Groundnut (NRCG)], Junagadh, Gujarat

C. State level

Main Oilseeds Research Station, JAU, Junagadh, Gujarat

➢ Improved Varieties

Spreading types: GAUG-10, GG-11, GG-12, GG-13, GJG-17

Semi-spreading types: GG-20, GJG-22

Bunch type: GG-2, GG-4, TG-26, GG-5 and GG-7

➢ Recent Released Variety

- GJG-HPS-1 Groundnut (HPS)
- GG-17 Groundnut (Spreading)
- GJG-22 Groundnut (Semi Spreading)
- GJG-9 Groundnut (Bunch)

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Sesame Breeding



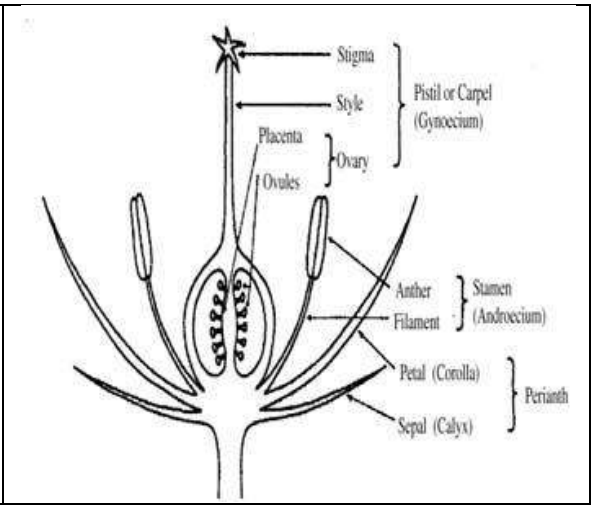
1.	Name of crop	:	Sesamum, til, gingely
2.	Botanical name	:	*Sesamum indicum* L.
3.	Family	:	Pedaliaceae
4.	Chromosome number	:	2n = 26
5.	Center of origin	:	East Africa or Asia
6.	Mode of pollination	:	Self pollination
7.	Out crossing percentage	:	<1%
8.	Related wild species	:	*S. alatum, S. carpense, S. schenckii,* *S. malabaricum* (2n=26). *S. prostratum, S. laciniatum, S. angolense,* *S. angustifolium* (2n=32). *S. radiatum, S. occidentale* (2n=64)

➢ Flower Biology

- ❖ The flowers are zygomorphic, solitary, occasionally two or three together, axillary, short-pedicelled, borne on the upper part of the stem or branches.
- ❖ The tube bent downward and is dialated above the oblique base.
- ❖ The calyx is small and five sectioned.
- ❖ The corolla is tubular and campanulate.
- ❑ There are four functional stamens and often one is sterile, didynamous. (Di - two, dynamis – strength): Out of four stamens, two are long and two are short.)
- ❑ The ovary is superior, bilocular but may be subdivided by false internal walls.

The fruit is a capsule, erect and oblong. The capsule contains numerous small ovate seeds. The testa may be smooth or reticulate and may be white, yellow, reddish-brown or black





BREEDING OBJECTIVES

- The objectives are dynamic rather than static and change with the requirement of time.
- The general breeding objectives in sesame are similar to those applicable in other crops and include higher yield, improved plant architecture, reduced length of growing season and resistance to diseases and pests whereas, whereas the specific objectives vary with the level of technology and local conditions.
- Sesame fits into cropping systems either as a main crop or a second crop.
- Furthermore, it is grown often in mixed stands with diverse companion crops like groundnut, pigeon pea, cotton, pearl millet and soybean to mention a few.

Non-shattering cultivars are needed for combine harvesting in advanced countries and shattering types are preferred where manual labour is readily available and prevailing the traditional systems.

Marketing and quality aspects:

- The confectionery market or the oil mills have different requirements.
- Seed size, shape, and coat texture, colour and sweet taste are not so important to the oil industry, but these characters are very critical for the confectionery market which is increasing globally with the growing health concerns.
- In India, white seeded is preferred for export as well as for domestic use in northern plains and plateau region.
- Whereas brown seeded or black seeded are preferred by domestic consumers in eastern coastal region and black seeded in southern coastal region. Specific breeding objectives in sesame are summarized below.

Seed characters:

Large or medium-large, well filled, shape and colour to satisfy market demands, especially for confectionery use.

- Seed coat, rough or brittle, easily removed by dry decortication; Short term (a few months) seed dormancy, appropriate for local cropping systems; Higher oil content above 50%; Higher lignans content for longer shelf life.

Seedling characters:

- Fast, vigorous germination and emergence, with strong hypocotyl elongation to assure better emergence; Rapid growth in the early stages to overcome weeds and to give good stand establishment; Ability to germinate and withstand lower temperatures in early stages of growth in temperate production areas.

Breeding method

1. **Plant Introduction**
2. **Selection :**
   - G.Til-1:Selection MT-6752
   - G.Til-10:Selection from TNAU-17
3. **Pedigree method**
   - G.Til-2:Gujarat Til-1 x TC-25
   - G.Til-3:G Til-1 x AHT -85

- **Research stations**

A. **National:** Directorate of Oilseeds Research (DOR), Hyderabad, Andhra Pradesh
B. State: Main Oilseeds Research Station, JAU, Amreli, Gujarat

- **Improved varieties:** Purva-1, Gujarat Til-1, Gujarat Til-2, Gujarat Til-3, Gujarat Til-4, Gujarat Til-5 and Gujarat Til-10 (Black seeded)
- **Hybrid varieties:**

Yeti No. 9 (ms 86-1 x Danback, GMS based hybrid in China) developed by Tu in 1995

CASTOR BREEDING



- ✓ Castor is a non-edible oil-yielding crop, it requires warm climate, grown in tropical, sub-tropical and temperate regions.
- ✓ Crop is widely grown in India, Brazil, China, Thailand, USSR and USA. India, Brazil and China contribute about 90 % of world production.
- ✓ India is the largest producer and exporter of castor oil in the world.
- ✓ Gujarat, Rajasthan, Andhra Pradesh, Tamil Nadu, Madhya Pradesh, Uttar Pradesh, Bihar and Orissa, are the major castor growing states in India.
- ✓ There is a wide range of uses of castor oil. It is mainly used as lubricant, in industry or as a medicinal purpose.
- ✓ It is also used in the adhesives, plastics, soaps, printing ink, waxes, rubber substitutes, drying oil for enamels, paints, varnishes and cosmetics.
- ✓ Large quantity of castor oil is used in paints and varnish industry.
- ✓ The plant is used as a source of pulp for cellulose, cardboards and newsprint. The oil cake is used as manure.
- ✓ The viscosity of oil changes very little with temperature, hence it is considered to be one of the best lubricants for high-speed engines like aeroplane.
- ✓ Castor is monotypic because all varieties of castor from giant perennials to short internode dwarf have the same chromosome number.

1.	**Name of crop**	**:**	Castor
2.	**Botanical name**	**:**	*Ricinus communis* L.
3.	**Family**	**:**	Euphorbiaceae
4.	**Chromosome number**	**:**	2n = 4x = 20
5.	**Center of origin**	**:**	Abyssinia (Ethiopia)
6.	**Mode of pollination**		Cross polination
7.	**Out crossing percentage**	**:**	5-46 %
8.	**Related wild species**	**:**	*R. perciens, R. chinesis, R. maxicanus*

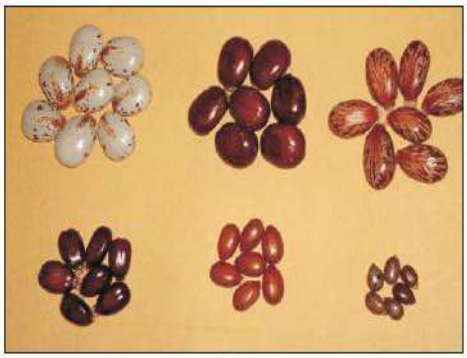
Types of dehiscence of capsules in castor:

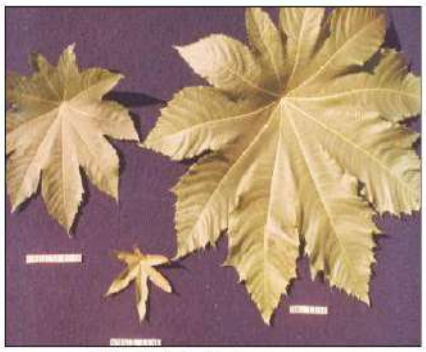
•Non-dehiscent type: Capsule is difficult to open
•Dehiscent type: Capsules open but the seeds are not shed
•Popper type: The capsule burst with force and the seeds are thrown at a considerable distance



Diversity in spike compactness in castor core.
a: Very loose; b: Loose; c: Firmly compact; d: Compact


Diversity in capsule colour in castor core


Diversity in seed traits in castor core


Diversity in leaf size in castor core

Types of blooming (waxy coat):

1. Zero bloom: White powder is not observed on stem and leaf.
2. Single Bloom: The white powdery coat on the stem and petiole of leaves.
3. Double bloom: The white powdery coat on stem + lower side of leaves.
4. Triple bloom: The white powdery coat on stem + both sides of leaves.

Floral biology:

- Flower inflorescence (raceme) is terminal on branch or main shoot.
- This species is clearly monoecious with separate male and female flowers on the same individual.

• About 30-50 per cent female flowers in the upper portion of raceme and 50-70 per cent male flowers at the bottom (lower part).
• The percentage of staminate and pistillate flowers varies and can be altered by selection procedure.

Flowering pattern:

There are four types of flowering pattern in castor
• Racemes with pistillate and staminate flowers inter-spread through out inflorescence
• Raceme with 70-90 per cent pistillate flowers
• Raceme with 100 percent pistillate flowering
• Racemes with a few hermaphrodite (bisexual) flowers

Differential sex expression in F_1 of a cross between complete pistillate and complete male.
a: Complete pistillate; b: Complete male; c: Interspersed staminate; d: Intersperse pistillate; e: Monoceious



a) Complete pistillate

Female Flower:

• Female flowers are conical shaped having three-carpalled ovary, short style and feathery, bifurcated red stigma.
• The pistillate flowers starts opening at 11.00 a.m. but peak opening period is from 4.30 to 5.00 p.m.
• The pistillate flowers are mature and become receptive even 2 hrs before opening of the flowers and remain receptive for 2-3 days.

Male flowers (staminate flower):
• Male flowers are greenish, splitting to 3-5 valvate segments with many stamens.
• It opens at 5.00 a.m. and pollen remains viable for about 60 hours.

Anthesis and Mode of Pollination:
• Castor is a cross pollinating plant but unlike other cross pollinating plant, it is inclined towards some amount of self-pollination.
• The female flowers open before the male flowers and hence there is large degree of cross-pollination.
• The flowering period of one flower lasts for one to two days. The period of opening of male flower is longer than that of female flower.

- The pollen of castor retains its viability for a long time i.e. for about 60 hrs. The viability of fresh collected pollen is around 80 %; within two days of storage under room condition & it is lowered to 75 %; within five days it is 50 % and after 20 days it becomes 25%.

Selfing technique

- **Crossing technique:**
  - Select the desire healthy plants and removes all the male flowers either by rubbing the fingers/thumb or by using forceps
  - 100 per cent pistillate line can also be used to avoid the emasculation
  - Cover the emasculated inflorescence by cloth/paper bag.
  - On the next day, during anthesis, collect pollen grains and apply it on the receptive stigmas of female inflorescence with hair brush or may be dusted.
  - The raceme is covered with a bag immediately after pollen is applied and labeled it. If the exceptionally hot or wet weather not follows pollination, the seed set should be nearly 100%.
  - When the capsule setting is complete, remove the bag.
- **Breeding objectives**

1. Higher yield
2. Higher Oil content
3. Early and medium duration varieties.
4. Dwarf and medium tall plant types
5. Disease and insect resistance
   - Semi looper, jassid. Hopper burn - serious in dry land varieties.
   - Wilt. GCH-7 is resistance
   - Triple bloom - TMV 5. - Triple bloom condition gives resistance.
6. Breeding varieties suitable for mechanical and efficient harvesting.
7. Breeding varieties with low ricin content
8. Breeding non shattering, spineless varieties
   - Baker variety of USA Non - Shattering.

- **Breeding methodology**

1. Introduction: TSP-10R
2. Selection:
   - Mass selection: Kavkazskaya from NVIIMK, IAC-38 from Brazil, CP-1 from interbreeding of different lines viz., JI 35, HC-6, HC-8.
3. Mutation breeding: e.g., Aruna. SA 2 is short duration types identified as spontaneous mutant from TMV-1
4. Population improvement: Recurrent selection method.
5. Hybridization and selection
   - Pedigree method of selection; method generally used to improve polygenic trait, long duration and tall plant type variety e.g., HC 8, Junagadh-1, MC 1 developed.
   - TMV-1 to TMV-5 series was developed at Tindivanam centre.
6. Heterosis breeding: For developing hybrid pistilate and inbred lines are used

- **Research stations:**

A. **National:** Indian Institute of Oilseeds Research (IIOR), Rajendranagar, Hyderabad.
B. **State level:** Castor-Mustard Research Station, SDAU, Sardarkrushinagar, Gujarat.

- **Improved varieties:** GAUC-1, GC-2 and GC-3

Table :- Hybrids developed by Gujarat Agricultural University

Character	GAUCH 1	GCH 2	GCH 4	GCH 5	GCH 6	GCH 7
Parents	VP 1xVI 9	VP 1 x JI 35	VP1x48-1	Geeta x SH72	JP65xJI96	SKP84xSKI215
Year of released	1973	1985	1986	1996	1997	2007
Stem colour	Mahogany	Green	Light red	Mahogany	Red	Mahogany
Bloom	Triple	Triple	Triple	Double	Double	Triple

GCH-8 by SDAU for all India

GCH-9 by JAU for irrigated areas in Gujarat

Emasculation is not necessary for hybrid seed production of castor.

Because in castor hybrid seed production, generally 100% pistillate line is used as female. So, there is no need to do emasculation**.**

COTTON BREEDING



India ranks first in terms of area among cotton growing nation. Cotton constitutes about 85 per cent of raw material of our textile industries. The major cotton growing states in India are Maharashtra, Gujarat, Karnataka, Punjab, Madhya Pradesh, Andhra Pradesh, Rajasthan and Tamil Nadu. Genus Cossypium contains 39 species of which 33 are diploid and 6 are tetraploid. Ninety per cent of the world cotton production comes from *G. hirsutum* followed by *G. barbadense* (8%).,*G.herbaceum and G. aeboreum* is mainly cultivated in India.

1. Name of crop : Cotton

2.	Botanical Name	:	*Gossypium* spp.
3.	Family	:	Malvaceae
4.	Chromosome Number	:	As per Table
5.	Center of Origin	:	As per Table
6.	Mode of pollination	:	Often cross pollination
7.	Out crossing percentage	:	5 – 25 %
8.	Related wild species	:	As per Table

Genetic origin of tetraploid cotton

African linted species *(G. africanum) reached America through pacific ocean and after* crossing with American lintless wild diploid species *G. rarimondii gave birth to tetraploid* cotton. The chromosome doubling took place in nature resulting in the development of fertile amphidiploids

G. Herbaceum Var africanum linted X ***G. rarimondii lintless***

Old world cotton -Diploid (2n=2x=26) AA Large chromosome

American cotton -Diploid (2n=2x=26) DD Small chromosome

F1 hybrid-Diploid
2n=2x=26 AD Sterile

Doubling of chromosomes

G. hirsutum: New world cotton: Amphidiploid
2n = 4x = 52 AA DD Large & small chromosome

This can be crossed with cultivated species and produces fertile hybrids

Table: Details of cultivated species and wild relatives along with chromosome number, center of origin and common name.

Sr. No.	Particulars	No. of Chromo.	Chromo. Size	Center of origin	Common name
	A. Cultivated species				
1	*Gossypium arboreum*	2n = 26	Large	India	Deshi/ Diploid/ Old world
2	*G. herbaceum*	2n = 26	Large	Africa	Deshi/ Diploid/ Old world
3	*G. hirsutum*	2n = 52	26-Large 26-Small	South America	New world/ Tetraploid
4	*G. barbadense*	2n = 52	26-Large 26-Small	North America	New world/ Tetraploid
	B. Wild species				
1	*G. anomalum*	2n = 26	Medium	Africa	Diploid/Old world
2	*G. thurberi*	2n = 26	Small	America	Diploid/New world
3	*G. tomentosum*	2n = 52	26-Large 26-Small	Hawaii	Tetraploid/ New world
4	*G. caicoense*	2n = 52	26-Large 26-Small	Brazil	Tetraploid/ New world

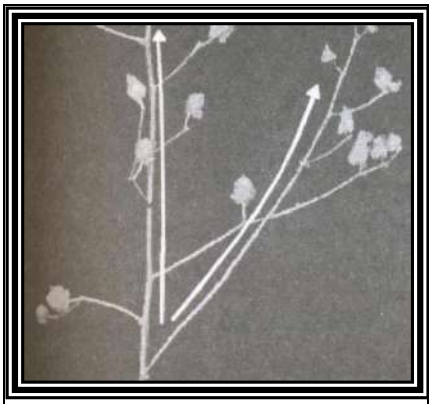
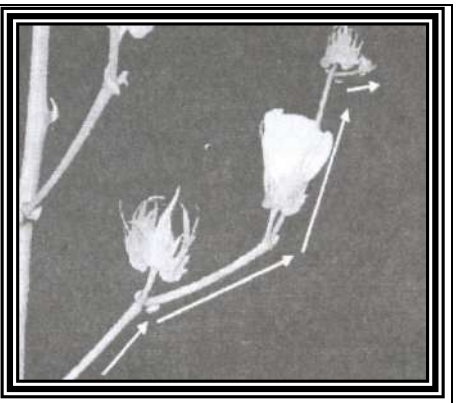
Growth and development in cotton: The branch forms in the axil above a main stem leaf. The leaves and stems on nodes above and below the one illustrated have been removed.

Fig. 1 Growth of a fruiting branch from the main stem



Development of fruiting and vegetative branches:-

The branches on a cotton plant are classified as either vegetative branches (monopodia) or fruiting branches (sympodia). Vegetative branches, like the main stem, are referred to as monopodia (meaning "single foot") since they have only one meristem. Because vegetative branches have only one meristem, they grow straight and erect, much like the main stem (Fig. 2). Vegetative branches can also produce fruiting branches.

	
A cotton plant (with leaves removed) shows the straight growth habit.	**A fruit Branch (with leaves) removed shows its zig-zag growth**

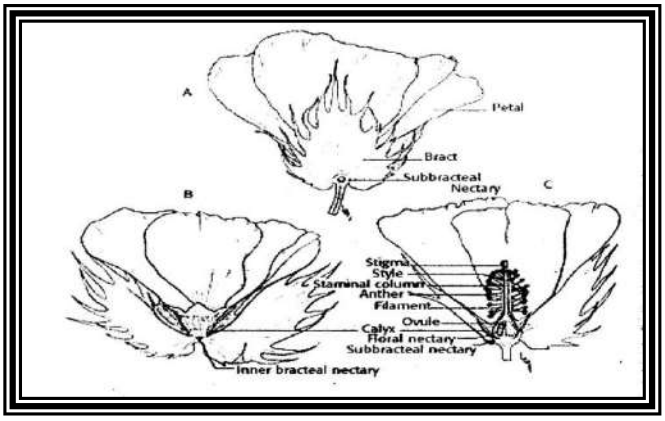
Habit of the main stem and the vegetative Branch:

The branches from which fruiting buds arise are called fruiting branches, or sympodia (meaning" multiple feet"), because each fruiting branch contains multiple meristems. Fruiting branches have a 'zig-zag' growth habit of the vegetative branches. The initial growth of a fruiting branch is terminated once a fruiting bud forms. The fruiting branch, however, initiates a new growing point, called an axillary meristem. The axillary meristem is located at the base of a leaf that subtends the newly formed fruiting bud. The "zig-zag" growth habit is a consequence of the stop - and - go growth of the fruiting branch (Fig. 3).

Floral biology:

- The base of cotton flower is surrounded by leaf like triangular bracts that is commonly known as squares.
- On the day before pollination the twisted corolla emerges from the bracts.

- When the corolla first opens the petals may be white, cream, yellow or purple in the different varieties. The following day the corolla turns pink gradually changes to red and finally falls from the plant.



Flower of cotton showing subbracteal nectarines and longitudinal section

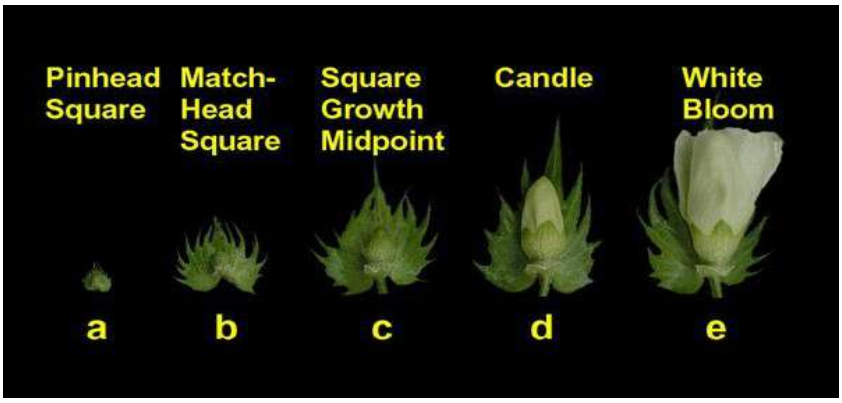
- The stamens are numerous, forming a tube like staminal column around the style which is united with the inside base of the corolla.
- Pistil is formed 3-5 carpel's corresponding to the number of locks in the ball (Fig. 4)
- Pollen is shed directly on the stigma when the anthers open or it may be carried to the stigma by insects may in considerable (5-25%) cross pollination.

Formation of the cotton bud from square to bloom:

During the 21-day period from square to bloom, there are several recognized developmental stages of the cotton flower bud (Fig. 5). A "pinhead" square is the first stage at which the square can be identified. The next stage of square growth is "match-head" or "one-third grown". Once the cotton begins to bloom, it is said to be

"flowering". A cotton plant typically blooms or flowers for about 6 weeks. Thus, until the cotton begins to produce fruit, the stage of development is discussed in terms of leaves or nodes. Once fruiting begins, the stage of cotton development is discussed in terms of square development and the number of nodes. Once blooms are present, the stage of cotton development is discussed in terms of weeks of bloom.

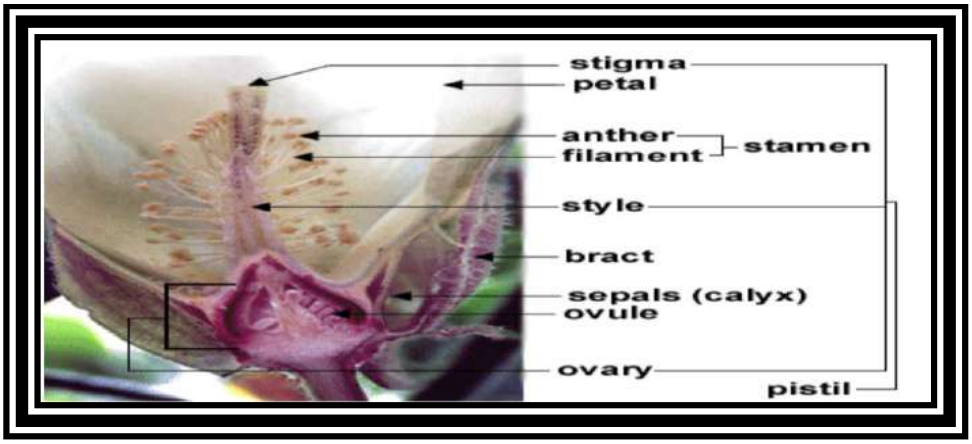
Development of the bud from match head square (a) to flower (e) involves both a size increase and petal development.



Two bracts have been removed from each square, candle and bloom to show this development.

Stages of flowering:

Flowering is important to cotton production because pollinated flowers from cotton bolls. The bloom process takes several days, and bloom age can be estimated by the bloom characteristics



On the day a flower opens it is white in colour. Pollination of that flower usually occurs within a few hours after the white flower opens.

On the second day, the flower will have a pink-like color and a red color on the third day. Approximately 5 to 7 days after a flower appears it usually dries and falls from the plant exposing the developing boll. Occasionally a flower will stay attached to the developing boll for a longer period of time. This is referred to as a bloom tag

Selfing technique:

The flowers, which are expected to open next day morning either, should be covered with the proper size of paper bag or tide with the rubber ring, mud or wire ring.

Crossing technique:

- Emasculate the young bud in the afternoon. Buds, which are likely to flower next day, are selected for emasculation.
- Remove the corolla with staminal from the base of the buds with the help of nail of the thumb without injuring the ovary. Emasculated flower is labeled and bagged.
- Collect the male flower in the dish and exposed it to sunshine to stimulate the anthers.
- Rub the male flower on the stigma of emasculated flower then labeled and bagged.
- Pollination should be completed in the morning 8:00 to 10:00 am.

Stages of flowering:

- Flowering is important to cotton production because pollinated flowers form cotton bolls.
- The bloom process takes several days, and bloom age can be estimated by the bloom characteristics.
- On the day a flower opens it is **white in color.**
- Pollination of that flower usually occurs within a few hours after the white flower opens.
- On the second day, the flower will have a **pink-like color, and a red color on the third day.**
- Approximately 5 to 7 days after a flower appears, it usually dries and falls from the plant exposing the developing fruit (boll).
- Occasionally a flower will stay attached to the developing boll for a longer period of time. This is referred to as a **bloom tag.**

BREEDING OBJECTIVES:

1. **Yield of line fiber:**

More bolls and high lint percentage, Small bolled varieties having small seeds and a high lint turnout.

2. **Early maturity**
3. **Mechanical picking**
4. **Fiber quality:** Fiber quality is depends on (i) Fiber length (staple length) (ii) Fiber strength and (iii) Fiber weight (fiber fineness)

* Cotton fiber is borne in bolls consist 3-5 locks. The fiber developing on the cottonseed may be separated into two groups according to length.

(a) Lint: the outlay is composed of long fibers separated from the seed in ginning and used in spinning cotton yarn.

$$\text{Lint Index (Absolute weight of lint/seed)} = \frac{100 \text{ seed weight x Ginning per cent}}{100 - \text{Ginning per cent}}$$

$$\text{Lint percent (Ginning percent)} = \frac{\text{Weight of lint}}{\text{Weight of seed cotton}}$$

(b) Linter (fuzz): The inner layer is composed of short fibers that remain attached to the seed after ginning are used in marketing rayon and various cellulose products.

5. **Resistance to biotic and abiotic stresses**
6. **Glandless cotton:** The cotton plant normally produces pigmented glands in leaves, stems and seed, which contain Gossypol (undesirable toxic substance) in the seed causes
   - Discoloration in cotton seed oil
   - Reduce availability of lysine and other essential amino acids in cotton seed protein
   - Male sterility in humans through cotton seed oil. Three genes viz., gl1, gl2 and gl3 are controlling this character.

➢ **Research Stations:**

A. National:

Central Institute for Cotton Research (CICR), Nagpur, Maharashtra.

B. State level:

Main Cotton Research Station, Navsari Agricultural University, Surat, Gujarat.

➢ **Improved varieties:** GAU Cot-10, GAU Cot-100, G.Cot-101, G.Cot-11, G. Cot- 12, G. Cot-13, G. Cot-14, G. Cot-16, G. Cot-18, G. Cot-20, G. Cot-22, G. Cot-24

Hybrid varieties: GCH-4, GCH-6, GCH-7 (Deshi), GCH-8, GCH-9 (Deshi), GCH-10 , GCH-12, GCH-14,

Bt hybrids: Boll Guard-I, Boll Guard-II and Fusion Bt

Genetic Engineering Approval Committee (GEAC) approved following variety for Cultivation.

- RCH-2, RCH-138, RCH-118, RCH-144 (Rasi Seeds, Attur, Tamil Nadu)
- MECH 12, MECH 162, MECH 184, MRC 6301 (MAHYCO), Jalana, Maharashtra.
- Ankur-651, Ankur 09 (Ankur seeds, Nagpur, Maharashtra)

• Bunny and Mallika (Nuziveedu seeds, Hyderabad, Andhra Pradesh)

Hybrid seed production is feasible in cotton due to…

Hand emasculation and pollination is very easy and become practically possible because of large flower size, More number of seeds per cross, Low seed rate for sowing.

➢ **Procedure for hybrid seed production in cotton:**

For example, Gujarat Cotton Hybrid-4

Gujarat – 67 x American Nectariless (AN)

↓

Hybrid – 4

The male and female parents are grown separately but near to each other. Isolation distance should be maintained 50m for foundation seed and 30m for certified seed.

A) Sowing of the female parent (Gujarat - 67):-

Sowing is done in last week of May to 2nd week of June at a distance of 1.5 m x 1.5m or 2.0 m x 2.0 m. the seed rate of 1.5 – 2.0 kg seed per hectare is needed to grow approximately 2500 – 3600 plantlets per hectare. Extra seeds may be raised in bags for gap filling.

B) Sowing of male parent (American Nectariless):

About 0.2 ha male plot is enough for one hectare of female parent. The spacing required is 1.0 x 0.6 m proportion of female: Male is 5 : 1 rows.

C) Time of sowing:

American Nectariless is early in maturity. So that male parent should be sown 20-25 days after the female parent sowing. The male parent is usually sown in 2-3 different dates like.

(i) With female parent sowing
(ii) 10 days after female parent sowing
(iii) 25 days after female parent sowing

D) Period of Sowing:

• The crossing begins from September onwards and continues up to 15th December. The seed setting is good during September – October.
• For emasculation of flower buds Doak's method is used. In this method, bracts, petals and anthers removed by Thumbnail without damaging the ovary.
• Emasculation is carried out from 2.00 to 6.00 pm. Unemasculated open flowers should be removed.
• After emasculation the flower buds should be covered by RED colored tissue paper bag or round straw tube and tide with a thread or tag or price label. Red colour bag is useful for identification of emasculated buds for pollination.

E) Pollination:

• From male flowers, which are about to open, bracts and petals are removed and flower is kept in sunlight in trays or dishes. The anthers burst at 10.00 a.m.
• The red tissue bag from the emasculated female flower bud is removed and male flower bud is rubbed all around the surface of the stigma.

- One male flower is sufficient for 3 to 5 female flowers.
- The pollinated female flowers are covered by white tissue paper bags.

F) Picking of crossed bolls:

- When the bolls open, picking should be done along with the tissue paper bags. The cotton is then taken out and filled in gunny bags after drying.
- On an average, 700-1000 kg of hybrids seed can be produced per hectare.

****

Tobacco Breeding



Tobacco belongs to the family of plants called solanaceae or the night shade family and the genus Nicotiana. Tobacco was introduced into India by Portuguese traders during AD 1600. Its use and production proliferated to such a great extent that today India is the second largest producer of the tobacco in the world.

Dried tobacco leaves are mainly used for smoking in cigarettes and cigars, as well as pipes and shishas. They can also be consumed as snuff, chewing tobacco, dipping tobacco and snus.

Tobacco contains nicotine, a highly addictive drug that makes it difficult for smokers to kick the habit. Tobacco products also contain many poisonous and harmful substances that cause disease and premature death.

1	**Name of Crop**	**:**	**Tobacco**
2	**Botanical Name**	**:**	*Nicotiana tabacum* *Nicotiana rustica*
3	**Family**	**:**	Solanaceae
4	**Chromosome No.**	**:**	2n = 4x= 48 (Tetraploid)
5	**Mode of pollination**	**:**	Often- cross pollination

IMPORTANT RELATED SPECIES

N. Affinis		Ornamental tobacco
N. glutinosa		Resistant to mosaic virus

N. repanda		
N. longiflora		Resistant to wild fire and black fire disease
N. debneyi		Resistant to blue mould black root rot, wild fire and fusarium wheat
Nicotine		Botanical pesticide **40% Nicotine sulphate**
		Drugs/Tobacco cessation products **Pure nicotine**
Protein		Feed supplement **crude protein**
Seed oil		Paint and soap industry **crude oil**
		Edible oil **refined oil**

Tobacco type	Type of curing	Nicotine (%)
Burley	Air-curing	0.5-1.0
FCV	Flue-curing	2-3
Lanka/Natu	Sun-curing	3-4
Hookah/chewing	Air curing	4-6
Bidi	Sun-curing	6-10

NICOTINE

- Nicotine ($C_{10}H_{14}N_2$) is the principal alkaloid synthesized in roots and accumulated in the leaf.
- Nicotine is known for its insecticidal property in the form of 40% Nicotine sulphate.
- Further, tobacco decoction is used for controlling several pests in cereals and vegetables in many countries.

ORIGIN AND EVOLUTION

Nicotiana sylvetries X *Nicotiana tomentosa*
2n=24 2n=24

F_1(sterile)
Natural doubling of Chromosome
Nicotiana tabacum
2n=2x=48

Nicotiana paniculata X *Nicotiana undulatea*
2n=24 2n=24

F_1(sterile)
Natural doubling of chromosome
Nicotiana rustica
2n=4x=48

- India grows both the species, but by far the largest area is under *N. tabacum.* Since *N. rustica* requires cooler climate, its cultivation is confined mainly to the northern and north-eastern areas of the country, i.e., U.P., West Bengal, Bihar and Assam.
- The *N. tabacum* varieties known as desi types have tall plants with broad leaves and have usually pink flowers.
- The *N. rustica* varieties known as `vilayati' and `calcuttia' are characterised by short plants with round puckered leaf and yellow flowers.
- Specific varieties in *N. tabacum* have been developed for cigarette, cigar and cheroot, bidi, hookah and snuff tobaccos.
- The varieties developed in *N. rustica* are used for only chewing, hookah and snuff tobaccos.

➢ **Comparision between *N. rustica* and *N. tabacum***

N. rustica	***N. tabacum***
Also known as vilayati, cullcuttia type	Also known as desi types
leaves of are usually petiolate and of regular ovate or cordate shape with a dark green, shiny surf	leaves are mostly sessile, ovate or oblong-lanceolate shaped.
N. rustica types are dwarf than rustica types	*N. tabacum* types are taller than rustica types
Chewing type	Used for cigarette, cigar and cheroot, bidi, hookah and snuff tobaccos.
Flower colour is yellow.	Flower colour is pink.



N. tabacum



N. rustica

➢ **FLORAL BIOLOGY**

- The inflorescence of tobacco is a terminal raceme
- The flowers are pedicellate and hermaphrodite
- Calyx contain five sepals
- Corolla contain five petal
- The stamens are five in number
- It has superior ovary
- It is self pollinated crop but; 4-10; of cross pollination occurs due to insects. Therefore, it is grouped into often cross pollinated crop.
- Pollens are viable for 24hrs
- Stigma is receptive one day before and after flower opening

SELFING TECHNIQUE

Covering entire inflorescence with paper bag will ensures the self pollination.

CROSSING TECHNIQUE

- It involves emasculation followed by pollination
- For emasculation select the unopened flowers with pink colour tip and anthers are removed with five pointed forceps after tearing petals
- Collect the pollen grain from matured flowers and dust it on the emasculated flower
- Bag the pollinated flower and then tag it

BREEDING METHODS

- Introduction
- Selection
- Pedigree method

- Back cross method
- Ploidy breeding
- Mutation breeding
- Genetic engineering

MAJOR BREEDING OBJECTIVES

- To develop drought tolerant, high yielding, better quality tobacco varieties.
- Breeding variety for multiple resistances to diseases and insect pests.
- Breeding tobacco for less health risk factors.
- Tailoring the genotypes suitable for alternate uses.
- Heterosis breeding for developing high yielding commercial hybrids
- Development of genotypes suitable for multiple and intercropping systems.

Physical traits

- Body appearance
- spangling score
- Colour
- Leaf thickness

Chemical traits

- Nicotine content
- Reducing sugar content
- Total nitrogen content
- Potash content
- Chloride content
- Aroma

Smoke quality traits

- Tar content
- Total phenol content
- Carbon monoxide content

Number of puff per bidi

Oganoleptic traits

- Chewing taste
- Elasticity
- Pungency

RESEARCH STATION

- **National level:-** Central Tobacco Research Institute, Rajahmundry, Andhra Pradesh
- **State level:-** Bidi Tobacco Research Station (BTRS) - AAU, Anand

➢ VARIETIES / HYBRIDS RELEASED

Tobacco type	**Varieties released**
Flue-cured tobacco	Chatam, Delcrest, Kanakaprabha, Dhanadayi, CTRI Special,Jayasri, CTRI Spl. (MR), 16/103, FCV special, Godavari Spl., Swarna, Mc Nair 12, Jayasri (MR), Hema, Bhavya, Gauthami, CM 12 (KA), VT 1158, Kanchan, Thrupthi, Rathna, Kanthi, Hemadri, Siri, Sahyadri, FCH 222, LT Kanchan, CH-1, N-98, CH-3, CTRI Sulakshana (TBST-2)

Bidi tobacco	GT 4, NPN 190, Anand 119, Anand 2, Spoorthy (PL 5), GT 5, GT 7, GTH1, Bhavyasree, GT 9, NBD 43, MRGTH- 1, ABT 10, Vedaganga 1, GABT-11, Nadyala Pogaku-1, NBD 209
Chewing tobacco	Chama, Podali, DP 401, GandakBahar, Sona, Vairam, Thangam Bhagyalakshmi, Maragadham, Prabha, PT 76, Meenakshi Vaishali Special, Lichchavi, Manasi, Abirami, Kaviri, Meenakshi (CR), Sangami, Kamatchi, Abirami (CR),
Hookah and Chewing tobacco	DD 437, Sonar Motihari, GC 1, GT 6, GCT 2, GT 8, GCT 3, Dharla, Azad Kanchan
Cigar-wrapper tobacco	S 5, Krishna

OKRA BREEDING



Okra is a fast growing annual herb, the young seed capsules are used for vegetable purpose in tropical and sub-tropical regions. It is commonly grown in Asia, Southern Europe, northern Africa and USA. In India, okra is commercially grown in the states Gujarat, Maharashtra, Andhra Pradesh, Utter Pradesh, Tamil Nadu, Karnataka, Haryana and Punjab.

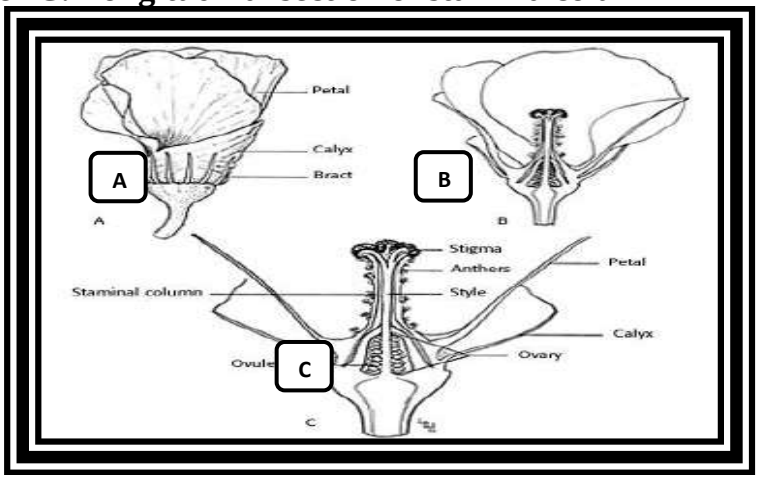
The okra is low in saturated fat, cholesterol and sodium and high in dietary fiber, vitamin A, vitamin C, vitamin K, thiamine, B6, folate, calcium, magnesium, phosphorus, potassium, manganese, iron, zinc and copper.

1.	Name of crop	:	Okra, Lady's finger
2.	Botanical Name	:	*Abelmoschus esculentus* L.
3.	Family	:	Malvaceae
4.	Chromosome Number	:	2n = 130
5.	Center of Origin	:	India, Pakistan and Burma
6.	Mode of pollination	:	Often cross pollination
7.	Out crossing percentage	:	4-42%
8.	Related wild species	:	A. manihot, A. fluculnes, A. crinitus with variable chromosomes number (2n = 80 to 130)

Floral biology:

- Flowers are solitary and axillary having long peduncle.
- Epicalyxes are 5 to 8 in number with gamosepalous calyx.
- Petals are five having yellow colour with crimson spot.
- Stamens are numerous and are united to the base of petals and form a staminal coloum (monoadalphous).
- Stigmas are 5 to 9 in number, deep red in colour.

Fig. 13. Okra flower A. Side view. B. Longitudinal section of flower C. Longitudinal section of stamina column



- Flowers open during 8.00 and 10.00 a.m. The pollen viability is maximum in the period between an hour before and an hour after opening of the flower. It takes 2 to 6 hours for fertilization after pollination.
- The stigma is receptive at opening of the flower and hence pollination at bud stage is not possible.

- **Selfing and Crossing technique:**
  As per cotton breeding (Prac. No. 9)

- **Breeding objectives:**

1. Higher green fruit yield
2. Early and prolonged harvest
3. Dark green, tender, thin, medium long, smooth, 4-5 ridged fruits
4. Pods free from conspicuous hairs
5. Short plants with more number of nodes and short internodes
6. Optimum seed setting ability
7. Resistance to Yellow Vein Mosaic Virus (YVMV), fusarium with, cercospora leaf spot and fruit rot
8. Resistance to insect-pests viz., Fruit and shoot borer, jassids and white fly
9. Tolerance to abiotic stress

- **RESEARCH STATION:**

A.International:
Asian Vegetable Research and Development Center (AVRDC), Shanhua, Taiwan.

B. National:
Indian Institute of Vegetable Research (IIVR), Varansi, Uttar Pradesh

C. State level:
Vegetable Research Station, JAU, Junagadh, Gujarat.

- **Improved varieties:** Gujarat Okra-2, Parbhani Kranti, Arka Abhay, Arka Vikas, Hissar Unnat and Varsha Uphar.

Hybrid varieties: Gujarat Okra Hybrid-1, DVR-2 and DVR-3.

BREEDING FOR BOTTLE GOURD, BITTER GOURD, RIDGE GOURD, SMOOTH GOURD AND CUCUMBER

BOTTLE GOURD BREEDING



1.	**Name of Crop**	:	**Bottle gourd**
2.	**Botanical Name**	:	*Lagenaria siceraria* (Molina.) Stadl.
3.	**Family**	:	Cucurbitaceae
4.	**Chromosome No.**	:	2n = 2x= 22
6.	**Progenitors**		Unknown
7.	**Mode of pollination**		Cross pollination
8.	**Out crossing percentage**	:	95%
9.	**Related species**	:	The genus Lagenaria contains five other wild species, namely: *L. breviflora* (Benth.) Roberty, *L. abyssinica* (Hook f.) Jeffrey, *L. rufa* (Gilg.) Jeffrey, *L. sphaerica* (Sonder) Naudin and *L. guineensis* (G. Don) Jeffrey

BOTANICAL DESCRIPTION

- Bottle gourd is a monoecious, annual vine pubescent herb with five angled stem, stem is profusely branched.
- The flowers are large, unisexual, white, solitary, showy. The flower has five petals (Pentamerous).
- The staminate flower are on long pedicels than female and hermaphrodite flower & exceeding the foliage.
- The pistilate flowers are single with short peduncle and hairy ovary.
- Ovary may be round, ovate long or cylindrical.
- There are three stamens, two as compound and one as single.
- The spiny, sticky pollen is not windborne and the plants therefore require pollinators to move pollen from male to female flowers.
- The ratio of male & female flower may vary from 5 : 1 to 15 : 1 in common type.
- The fruits are essentially a berry, it is called because of its hard and tough rind at maturity.
- Tendrils are borne in the axils of leaves

GENETICS OF QUALITATIVE AND QUANTITATIVE CHARACTERS.

- Very little is known about genes following simple inheritance in this crop.
- **Kalloo (1993)** has mentioned fruit colour to be monogenically determined.
- **Pathak and Singh (1950)** have demonstrated a single dominant gene for bitterness in *Lagenaria leucantha* (Duchs.). They also reported that two genes have major effects on fruit shape, and a single gene pair determines patchy vs white fruit colour in *L. leucantha.*
- **Singh (1996)** obtained an andromonoecious sex form (staminate and hermaphrodite flowers on same plant) in a segregating progeny during the course of selfing in a monoecious local collection of bottlegourd. F_2 and BC_1 generations derived from the crosses between a stable monoecious line and the andromonoecious form indicated monogenic recessive inheritance for andromonoecious sex form.

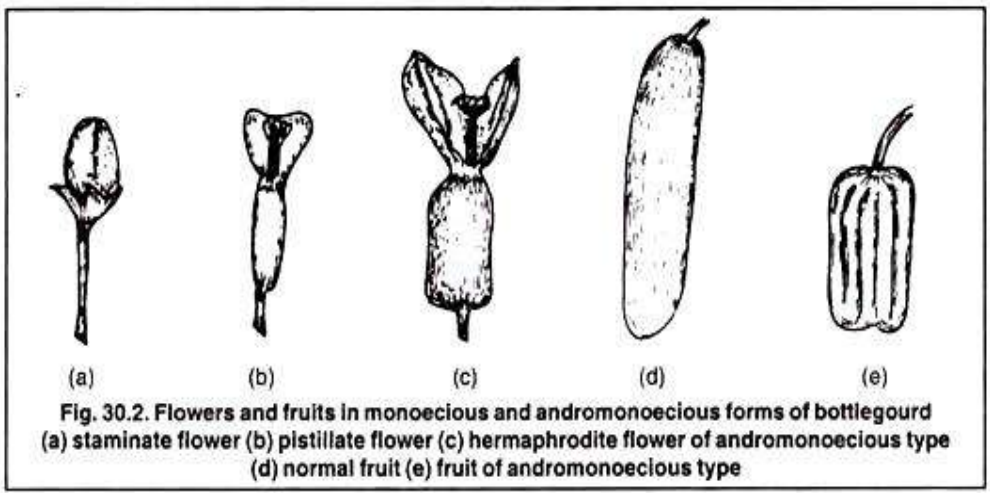


Fig. 30.2. Flowers and fruits in monoecious and andromonoecious forms of bottlegourd (a) staminate flower (b) pistillate flower (c) hermaphrodite flower of andromonoecious type (d) normal fruit (e) fruit of andromonoecious type

SEX PHENOTYPES

- Bottle gourd is a monoecious species with male and female flowers found separately on the leaf axils of the same plant.
- Though monoecious, bottle gourd is a highly cross pollinating crop.
- Dioecious (i.e Male and female flowers found on different plants) and andromonoecious sex forms (i.e Sex forms bearing male and perfect flowers) also exist in wild, non-cultivated species (Singh *et al.*, 1996).
- An andromonoecious sex form bearing hermaphrodite flower and male flower in the same plant have been isolated and named Andromon-6 by Singh *et al.* (1996). The male flowers of Andromon-6 are similar to normal monoecious, however; the hermaphrodite flowers exhibit a few distinguishing characteristics compared to normal female flowers.
- The expression of monoecious and andromonoecious sex form in bottle gourd is genetically controlled (Singh et al., 1996).
- The expression of sex form, flower, fruit morphology and seed characteristics in the F_1 generation demonstrated that monoecious sex form is completely dominant over andromonoecious sex form, normal size corolla dominant over large size corolla, long fruit shape dominant over drum-shaped oval fruit, small blossom scar dominant over large blossom scar and normal seed development dominant over abnormal seed development.
- Even though more than one sex form has been reported in bottle gourd, there is generally little sex phenotypes reported in this crop compared to other cucurbits.

MALE AND FEMALE FLOWERS IN BOTTLE GOURD

- Male flowers in bottle gourd are borne on longer pedicels than female and hermaphrodite flowers.
- Both male and female flowers generally have large and white corolla with five petals.
- However, male flowers have larger petals than female flowers.
- In male flowers, stamens are apparently 3, two are 2–celled and one is 1–celled (Singh, 2008). Female flowers have small prominent ovary, which may be round, ovate, long or cylindrical. Female flowers also have three stigmatic lobes with many ovules, generally between 400 to 700 (Morimoto *et al.*, 2004; Singh, 2008). Petals and sepals are fused. (Morimoto *et al.*, 2004).

SELFING TECHNIQUE IN BOTTLE GOURD

- For selfing, use the staminate flowers to pollinate the pistillate flower of the same vine to ensure self pollination.
- Cover the pistillate flower after performing the selfing to avoid foreign pollens.

CROSSING TECHNIQUE IN BOTTLE GOURD

- Being a monoecious plant, hybrid seed is produced by hand pollination without emasculation.
- The female flowers of female parents and male flowers of male parents are tied with butter paper bags about 24h before they open.
- It is less time consuming and also profitable if, corolla of the buds of male flowers of male parents is covered with non-absorbent cotton instead of covering them with butter paper bags.
- The following day, when the flower open, the male flower are collected after removing cotton or butter paper bags and their pollen grains are dusted directly on the stigmas of the female flowers after removing the butter paper bags.
- After completing the hand pollination, the female flowers are covered again by butter paper bags and tags with small labels.
- After 4 to 5 days of pollination, remove butter paper bags for better fruit sets.
- The success of controlled pollination may be enhanced by removal of any previously set fruit as first fertilized flower inhibits the development of subsequent fruits. Therefore, controlled pollination should be done as soon as possible after flowering begins.

BREEDING OBJECTIVES OF BOTTLE GOURD

1. High yield
2. More number of fruits per plant
3. **Fruit size, shape and weight as per market demand**
4. Earliness (appearance of pistillate flowers at early node number)
5. Immature seeds for longer period during green edible stage
6. **High female: male flower ratio**
7. Sparse hairs persisting on skin
8. Non-fibrous flesh at edible stage
9. Non-bitter fruit
10. Attractive green fruit with long colour retention
11. Identification of cultivars suitable for canning and dehydration (Value addition)

BREEDING METHODS

- Mass selection,
- Pedigree method
- Back cross method
- Bulk population method
- Heterosis breeding
-

GRAFT HYBRIDIZATION

- Intergeneric grafting is used in the production of many cucurbits, i.e. cucumber grafted on pumpkin and water melon on bottle gourd.
- When watermelon tops are grafted onto **bottle gourd root stock**, they are found to be resistant to **Fusarium wilt.**
- It's a non-genetic approach of crop improvement.
- Its better to assess graft compatibility before performing graft hybridization

VARIETIES / HYBRIDS RELEASED

Varieties
• Pusa Naveen • PSPL • ABG-1 • Arka Bahar • Punjab Komal
Hybrids
• Pusa Hybrid-3 • Pusa Meghdoot • NDBH-7 • GABGH-1

CUCUMBER BREEDING



Cucumber is one of the Asiatic species and member of the cucurbitaceae Family which has 90 genera and 750 species. Cucumber is grown throughout the world to be consumed as fresh fruits, as slicing and as pickles in immature stage. Cucumber is regarded the fourth most important vegetable crop after tomato, cabbage and onion.

Genetic of Sex:- Following main types are reported in cucumber.

1. Monoecious Plants: Staminate and pistillate flowers
2. Androecious plants: Only staminate flowers
3. Gynoecious plants: Only pistillate flowers
4. Hermaphrodite plants: Only hermaphrodite flowers
5. Andomonoecious plants : Staminate and hermaphrodite flowers

Floral biology

Cucumber is an annual day neutral plants. Flowers are Monoecious. The staminate flowers are in cluster with short, slender pedicels. The pistillate flowers are usually solitary with stout, short pedicels. The calyx and corolla of staminate and even hermaphrodite flowers have locales each and the third is unilocular. Filaments are free, but the stamens are more or less united by their anthers.

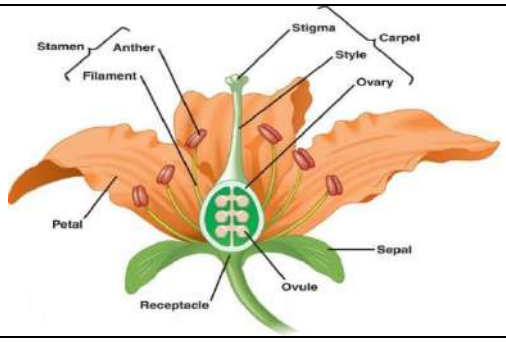
Anthesis takes place from 5.30 a.m. to 7.00 a.m. Dehiscence occurs around 4.30 a.m. to 5.00 a.m. Pollen viability remains up to 14 hours. The pistillate flowers are epigynous and hermaphrodite and hermaphrodite flowers are perigynous. The pistil consists of one to five (but usually three) carpels which in turn, produce ovaries with a corresponding number of locales.

The following are the cultivated cucurbits crops mainly grown in India.

No	Common Name	Local Name	Botanical Name	Ch.No (2n)
1.	Cucumber	Kakri, Khira	*Cucumis sativus* L.	14
2.	Bitter gourd	Karela	*Momordica charantia* L.	22
3.	Bottle gourd	Lauki	*Lagenaria siceraria* (mol) Stndyl	22
4.	Ridge gourd	Kali tori	*Luffa acutangula* (Roxb.) L.	26
5.	Sponge gourd	Ghia tori	*Luffa cylindrica* Roem	26
6.	Snap melon	Phoot	*Cucumis melo* var.*momardica*	24
7.	Musk melon	Kharbuza	*Cucumis melo* L.	24
8.	Squash	Chappan	*Cucurbita pepo* L.	40
9.	Pumpkin	Kaddu	*Cucurbita maxima* Dutch	40
10.	Water melon	Tarbuz	*Citrullus lanatus* (Thumb)	22
11.	Snake gourd	Chichinda	*Tricosanthes cucumerina*	24
12.	Pointed gourd	Parwal	*Tricosanthes dioica* Roxb.	24
13.	Ash gourd	Safed kaddu	*Benineasa hispida* (Thumb.) dessert.	24
14.	Ivy gourd	Kundsru	*Coccinia cordifolia*	24



Flower



Parts of flower

Selfing techniques:-

For Selfing use the staminate flowers to pollinate the pistillate flowers of the same vine to ensure self pollination.

Crossing technique:- Being a Monoecious plant, hybrid seed is produced by hand pollination without emasculation. The female flowers of female parents and male flowers of male parents are tide with butter paper bags about 24 hours befor the open. It is less time consuming and also profitable if, corolla of the buds of male flowers of male parents is covered with non-absorbent cotton instead of covering them with butter paper bags. The following day, when the flower open, the male flower are collected after removing cotton or butter paper bags and their pollen grains are dusted directly on the stigma of the female flowers after removing the butter paper bags. After completing the hand pollination, the female flowers are covered again by butter paper bags and tags with small labels. After completing the hand pollination, the female flowers are covered again by butter paper bags tags and tags with small labels. After 4 to 5 days of pollination, remove butter paper bags for better fruit sets. The success of controlled pollination may be enhanced by removal of any previously set fruit as first fertilized flower inhibits the development of sub sequent fruit. Therefore, controlled pollination should be done as soon as possible after flowering begins.

BITTER GOURD



1	**Name of crop**	**Bitter gourd**
2	**Botanical name**	*Momordica charantia* L.
3	**Family**	Cucurbitaceae
4	**Chromosome number**	2n = 22
5	**Center of origin**	Indo-Malayan
6	**Mode of pollination**	Cross pollination

Bitter ground is an important cucurbit fruit vegetable grown in tropics. The crop is of Asiatic origin either China or India. It is cultivated in Malaysia, China, Philippines, tropical Africa and North and South America. Immature fruits is good source of vitamin-C and also contain vitamin-A, phosphorous and iron. The tender vine tips are an excellent source of vitamin-A, protein, thiamin and vitamin –C. Leaf juice is used for curing cough, as a purgative, anti-helminthic to expel intestinal parasites, for healing wound and also act against lowering blood sugar. The bitter taste is caused by a group of tetracyclic triterpenes called cucurbitacins which are found in many gourd species.

Floral biology:-

Bitter ground is monoecious having both male and female flowers are in same plant. The anthesis and anther dehiscence take place early in the morning from 7.30 to 9.30 a.m. The stigma remains receptive 24 hours before and 24 hours after anthesis. Pollen losses viability as the day advanced and may be fully non-viable by midday.

Selfing and crossing technique: As per cucumber

SELFING AND CROSSING TECHNIQUE

Same as <u>Bottle gourd.</u>

Breeding objectives (Cucumber, Bitter gourd and Bottle gourd):

1. Higher fruit yield
2. Earliness
3. High female: male flower ratio
4. Fruits free from carpel separation without hollow spots
5. Immature seeds for longer period during green edible stage
6. Resistance to diseases, insects and pests
7. Attractive green or dark green fruits with smooth surface and without prominent spines or prickles (cucumber)
8. Uniform, long, club shape without crook neck (cucumber)
9. Round, long, club shape fruit (bottle gourd)
10. Sparse hairs persisting on skin (bottle gourd)
11. Whitish green to glossy green fruit (bitter gourd)
12. Less ridged fruit surface (bitter gourd and ridge gourd)
13. Thick fruits particularly suitable for stuffing (bitter gourd)

BREEDING METHODS

- Single plant selection
- Mass selection
- Pedigree method
- Back cross method
- Bulk population method
- Heterosis breeding

VARIETIES / HYBRIDS RELEASED

- VK 1 Priya
- Pusa vishesh
- Punjab 14
- C 96
- Pusa Do Mousmi
- Arka Harit
- Coimbatore Long
- Kalyanpur barahmasi,
- Kalyanpur sona,
- Pant karela-1
- Coimbatore green

Table 12.1: Cucurbitaceous crops: At a glance

1.	**Name of crop**	:	**Cucumber**	**Bitter gourd**	**Bottle gourd**	**Loofah**
2.	**Botanical name**	:	*Cucumis sativus*	*Momordica charantia*	*Lagenaria siceraria*	Ridge gourd - *Luffa acutangula* Smooth gourd - *Luffa cylindrica*
3.	**Family**	:	Cucurbitaceae	Cucurbitaceae	Cucurbitaceae	Cucurbitaceae
4.	**Chromosome number**	:	2n = 14	2n = 22	2n = 22	2n = 26
5.	**Center of origin**	:	India	Indo-Malayan	South Africa and India	India
6.	**Mode of pollination**	:	Cross pollination	Cross pollination	Cross pollination	Cross pollination
7.	**Related wild species**	:	*Sicyos angulatus, Marah macrocarpus*	*M. dioca, M. cochinchinensis*	*L. sphaerica*	*L. echinata, L. graveolens*
8.	**Improved varieties**	:	Straight eight, Japanese long green, Poinsette, Pusa sanyog, Pant Khira-1	Pusa do mausami, Priya, Arka harit, Pusa vishesh, Kalyanpur barahmasi, Kalyanpur sona, Pant karela-1, Coimbatore green	Pusa summer prolific long and round, Pusa meghdoot, Pusa manjari, Pusa naveen, Punjab komal, Arka bahar	**Ridge gourd:** Co-1, Pusa nasdar, Pusa sadabahar, Satputia (hermaphrodite), Pant torai-1 **Sponge gourd:** Pusa chikni, Kalyanpur chikni, Pusa Supriya, Gujarat Sponge gourd-1
9.	**Hybrid varieties**	:	Pant sankar khira-1	--	Pant sankar lauki-1	--

RESEARCH STATIONS FOR BOTTLE GOURD AND BITTER GOURD

A. International: Asian Vegetable Research and Development Center (AVRDC), Shanhua, Taiwan

B. National: Indian Institute of Vegetable Research (IIVR, Varanasi, Uttar Pradesh

State: Main vegetable Research Station, AAU, Anand, Gujarat

Improved varieties:

Ridge gourd: Co-1, Pusa nasdar, Pusa sadabahar, Satputia (hermaphrodite), Pant torai-1

Sponge gourd: Pusa chikni, Kalyanpur chikni, Pusa Supriya, Gujarat Sponge gourd-1

Improved varieties Bottle gourd

Pusa summer prolific long and round, Pusa meghdoot, Pusa manjari, Pusa naveen, Punjab komal, Arka bahar

Hybrid varieties

Pant sankar lauki-1

Improved varieties Bitter gourd

Pusa do mausami, Priya, Arka harit, Pusa vishesh, Kalyanpur barahmasi, Kalyanpur sona, Pant karela-1, Coimbatore green

Improved varieties Cucumber

Straight eight, Japanese long green, Poinsette, Pusa sanyog, Pant Khira-1

Hybrid varieties

Pant sankar khira-1

SUPPLIMENTARY EXERCISE

Q.1 Describe floral biology of cucumber, bitter gourd, bottle gourd and Loofah with suitable diagram.

Q.2 How selfing and crossing is done in cucumber, bitter gourd, bottle gourd and Loofah?

Q.3 Enlist the important wild relatives of cucumber, bitter gourd, bottle gourd and Loofah.

Q.4 List out breeding methods adopted for improvement of cucumber,

BREEDING CEREAL CROP I:
WHEAT



Wheat is the one of the leading cereal crops of the world. It is a major crop of the America, Canada, Europe and Asia. It ranks third in area and second in production among the cereals grown in India. The most important wheat producing states of India are Uttar Pradesh, Haryana, Madhya Pradesh, Punjab, Rajashthan, Maharastra, Bihar and Gujarat.

Wheat contains a substance called gluten, which make possible the production of loaf bread. This property is only present in wheat and to some extent in rye. Wheat is used to make bread, biscuits, pastry and semolina products. In India, it is mainly used for making *chapattis.*

1.	**Name of Crop**	:	Wheat
2.	**Botanical Name**	:	*Triticum aestivum* Bread Wheat (Irrigated) *Triticum durum* Durum Wheat or Macronic Wheat (Irrigated or rainfed)
3.	**Family**	:	Poaceae
4.	**Chromosome Number**	:	As per Table No. 3.1
5.	**Center of Origin**	:	South West Asia
6.	**Mode of pollination**	:	Self of pollination
7.	**Out crossing percentage**	:	< 1 per cent
8.	**Related wild species**	:	As per Table No. 3.1

Mode of origin of tetraploid and hexaplaiod wheat:

Teraploid: *Triticum monococcum* x Unknown

2n= 14 (AA) ↓ 2n= 14 (BB)

F_1 (AB) Diploid in nature

↓

Chromosome doubling

2n= 4x = 28 (AABB) Tetraploid

(*Triticum turgidum*–durum wheat)

Hexaploid: *Triticum turgidum* x *T. tauchii*

2n= 28 (AABB) 2n= 14 (DD)

↓

F_1(ABD) 2n= 21

Chromosome doubling

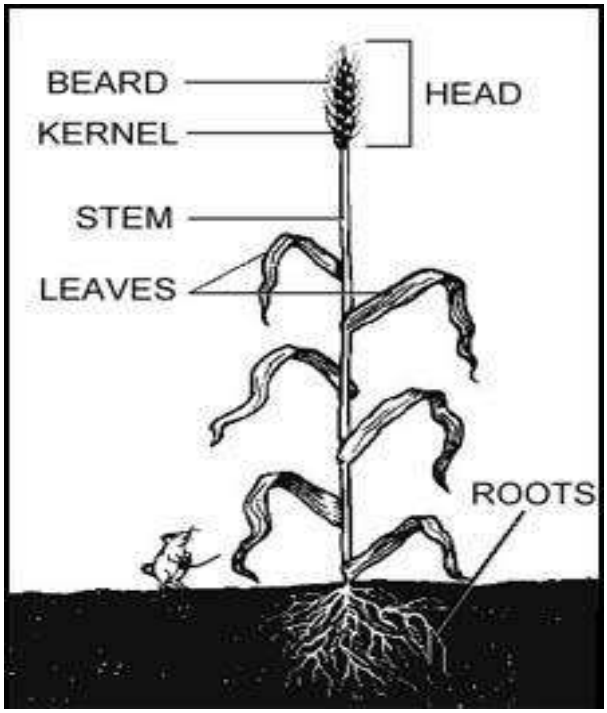
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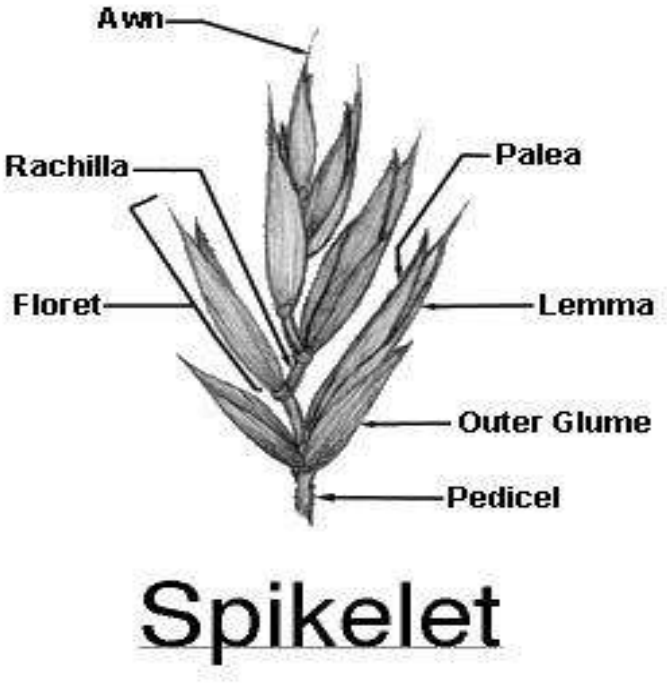
2n= 6x= 42, AABBDD, Hexaploid *(Triticum aestivum)*

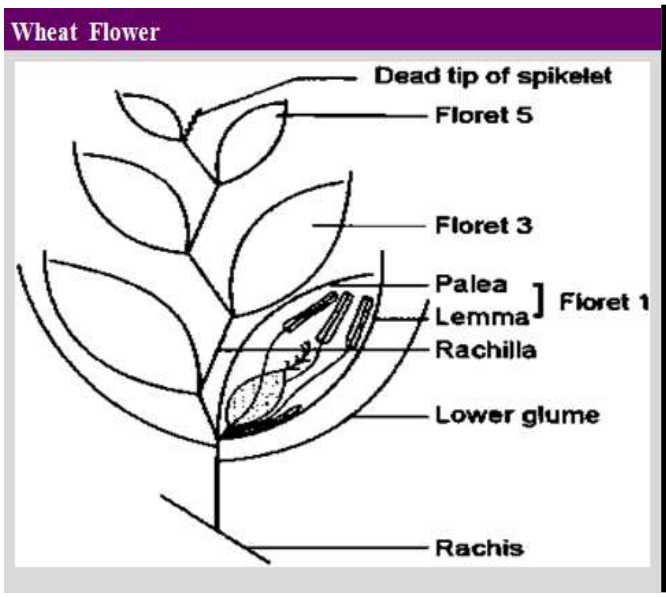
In nature, this wheat performs as diploid due to a mutation in 'ph' gene (dominant gene) on chromosome 5B, which inhibits pairing between homologous chromosomes.

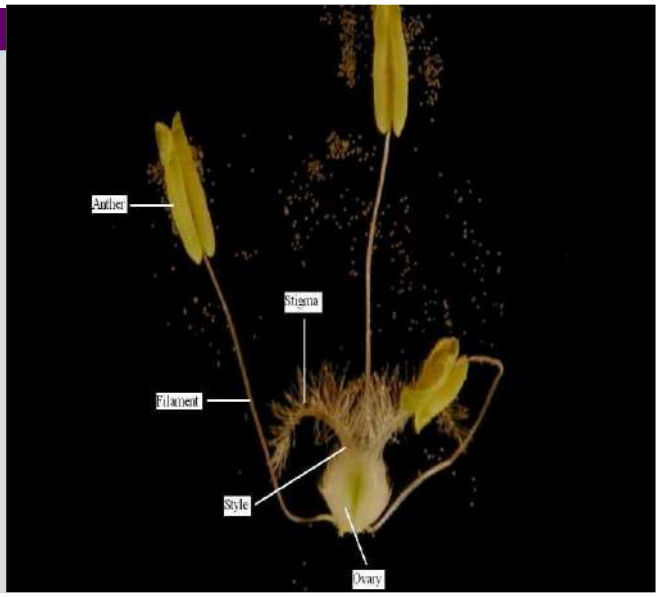
Table 3.1: Wild relatives of wheat along with chromosome number, genome formula, common name and use(s)

Sr. No.	Species	Chro. No. (2n)	Genome Formula	Common Name	Use
Diploid species					
1.	*T. monococcum*	14	AA	Einkorn	Cultivated
2.	*Aegilops speltoids*	14	SS	_	Wild
3.	*Triticum dichasians (Aegilops caudate)*	14	CC	_	Wild
4.	*Triticum tauchii (Aegilops squarrosa)*	14	DD	_	Wild
5.	*Secale cereale*	14	EE	Rye	Cultivated
Tetraploid speices					
1.	*Triticum dicoccoides*	28	AABB	Wild emmer	Wild
2.	*T. dicoccum*	28	AABB	Emmer	Cultivated
3.	*T.durum*	28	AABB	Durum wheat	Cultivated
4.	*T. polonicum*	28	AABB	Durum wheat	Cultivated
5.	*T. timopheevi*	28	AAGG	Timpopheevi	Wild
6.	*Aegilops cylindrica*	28	CCDD	Goat grass	Wild
Hexaploid species					
1.	*Triticumcompactum*	42	AABBDD	Culb wheat	Cultivated
2.	*T. spelta*	42	AABBDD	Spelt wheat	Cultivated
3.	*T. aestivum*	42	AABBDD	Bread wheat	Cultivated









Floral biology:

- Wheat inflorescence (spike) contains 13-23 spikelets. Inflorescence is a spike of spikelets, which are sessile. Each spikelet contains 3-7 florets. Each floret consists of outer parianth called the ***lemma*** and thin two-keeled parianth called the ***palea*** **(Fig. 3.1).**
- These lemma and palea enclose the sexual organs. The lemma covers the outer portion of the matured kernel and in the awn varieties it terminates in awn.
- Sexual organs consist of single pistil and 3 stamens.
- Pistil consists of monocarpellary superior one ovary bearing two short styles bifurcated feathery stigmas.

- Blooming starts several days after the wheat spike emerges. The flowers on the main stem (culm) bloom first and those on the tillers later, in order of the tiller formation.
- Flowering starts in the upper part of the spike and proceeds in both directions.
- Flowering continues throughout the day takes 2-3 days for a spike to finish blooming.
- The glumes normally open during the flowering process. The anthers protrude (emerge) from the glumes and part of the pollens shed outside the flowers.
- If the conditions are unfavorable for the opening of the glumes the anthers may shed their pollen without being extruded (emerged).
- Pollen remains viable for a very short period, usually not more than 1-3 minutes. Therefore, fresh pollen is essential for obtaining good seed set when making crosses.

- **Breeding objectives:**

(1) Higher yield
(2) Early maturity
(3) Lodging resistance
(4) Winter hardiness
(5) Drought resistance
(6) Disease and insect resistance
(7) Breeding for quality

(a) Market quality

(i) Seed size-uniform, well filled, bold and lustrous grain
(ii) Seed texture-hard
(iii) Seed must be pure, clean and sound
(iv) High kernel weight

(b) Milling and backing quality

- **BREEDING METHODS:**

1. Introduction:

Semi dwarf wheat from Mexico, Sonara 63, Sonara 64, Mayo 64, Lerma Roja 64

2. Pure line selection:

Earlier varieties like P4, P6, P12 evolved at Pusa institute are result of pure line selection from local population.

3. Hybridization and selection:

a) Inter varietal:

A crossing between two varieties of the same crop is called inter varietal hybridization. A number of successful derivatives were developed at IARI New Delhi and Punjab. However all these varieties were lodging and poor yielders when compared to other countries.

Introduced variety Sonara 63, Sonara 64 Mayo 64 and Lerma Roja 64 were utilised in our breeding programme and amber colour wheat varieties like Kalyan Sona, Safed Lerma, Sharbati Sonara were released, these are double gene dwarfs.

b) Inter specific crosses:

A crossing between two species of same genera is called inter specific hybridization.E.g. To get Hessian fly and rust resistance resistance.

b) Inter generic crosses:

A crossing between two genera of same family is called inter generic hybridization. E.g. Triticale: *Triticum aestivum* X *Secale cereale* to confer winter hardiness and drought resistance.

d) Back cross method of breeding:

Rust resistance in Chinese spring from Thatcher variety.

4. Hybrid wheat:

At Kansas Agri. Expt. Station USA male sterile lines were identified by crossing *T.timophevi* x *T. aestivum* Bison variety. By repeated back crossing a male sterile line resembling Bison was evolved. At present USA and Canada are doing work.

5. Mutation breeding:

Dr. M. S. Swamina did extensive work on this with gamma rays. Sharbati Sonara with increased protein content was evolved.

6. Development of multilines:

Borlaug developed multilines against rust. MLKS 15 was developed at IARI. Multiline is a deliberate mixture of pure lines which are phenotypically similar but genotypically dissimilar. Each line is produced by separate back cross method of breeding. Each line has resistance against particular races of a disease.

- **Wheat Ideotypes:**
  - A. Short and stiff straw
  - B. Photo insensitivity
  - C. High response to nitrogen application
  - D. Few small leaves
  - E. Larger and erect ear
  - F. Presence of awn
  - G. High harvest index
  - H. Resistance to various rusts

Research stations:

A. International: International Maize and Wheat Improvement Center (CIMMYT), Mexico.

B. National: Directorate of Wheat Research (DWR), Karnal, Haryana.

C. State level: Main Wheat Research Station, SDAU, Vijapur, Gujarat.

Improved varieties:

***Triticum aestivum group*:** Lok-1, GW-496, GW-503, GW-190, GW-173, GW-273, GW-322,GW-366,GW-415(2015) and GW-499 (2019)

***Triticum durum group*:** GW-1, GW-2, Raj-1555, H1-8498, GW-1139 and GW-1339(2019).

SUPPLIMENTARY EXERCISE

Q-1 Describe floral biology of wheat with suitable diagram.

Q-2 Enlist the five important wild relatives of wheat.

Q-3 How tetraploid and hexaploid wheat is originated?

Q-4 List out breeding methods adopted for improvement of wheat.

Q-5 Enlist important breeding objectives of wheat.

Q-6 Mention International, National and State level research stations of wheat.

Q-7 Write the improved varieties of *T. estivum* and *T. durum* group.

BREEDING OILDSEED CROPS II: MUSTARD AND SUNFLOWER

MUSTARD



Of the nine annual oilseed crops grown in India, mustard is the second crop in area and production, next to groundnut. It is grown in as many as twenty three states in India. Indian mustard is a quantitatively photosensitive and basically temperate crop and requiring cool temperature, below 25^{o}C (within agro-climatic conditions) during growth period. Therefore, this crop grown extensively in northeastern and central parts of our country.

Mustard oil is considered to be oil that has low saturated fat as compared to other cooking oils. This pungent tasting oil is mostly used for cooking in parts of Uttar Pradesh, Bengal, Assam, Bihar, Orissa, Haryana and some other parts of India. It has

antioxidant and cholesterol reducing properties. It is also loaded with essential vitamins. Though this oil is nutty tasting, it is good for heart and also has many other benefits.

1. **Name of Crop** : Mustard
2. **Botanical Name** : *Brassica juncea* L.
3. **Family** : Brassicaceae (Cruciferae)
4. **Chromosome Number** : 2n = 36
5. **Center of Origin** : China
6. **Mode of pollination** : Cross pollination
7. **Out crossing percentage** : 4 to 14 %
8. **Related wild species** : *B. japonica, B. nigra* (2n=16). *B. oleracea* (2n=18), *B. carinata* (2n=34), *B. carica*, *B. napus* (2n=38), *B. compestris*(2n=38)

- **Constraints /causes for low yield potential in mustard:**

1. Mustard is grown in unproductive marginal lands with low levels of inputs and aberrant weather conditions.
2. Continuous adaptation of the traditional package of practices.
3. Susceptibility to disease (white rust), pests (aphids) and frost.
4. Inadequate production and poor supply of quality seeds of improved varieties.
5. The unhealthy fluctuating marketing trends with poor support price.
6. Poor water management and inadequate use of fertilizers.

Genetic origin of mustard:

Brassica nigra **x** ***Brassica campestris***

2n=16 (BB) 2n=20(AA)

F_1, 2n=2x = 18 (AB)

(Chromosome doubling)

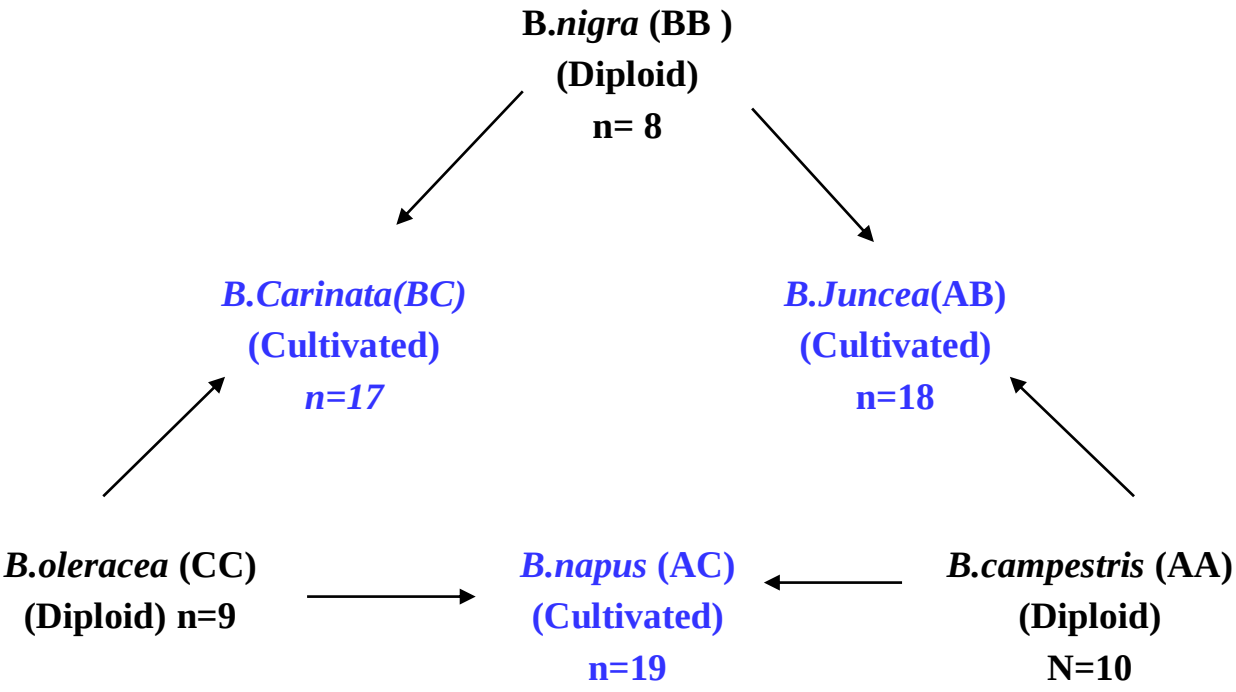
Brassica juncea, 2n = 4x = 36 (AABB)

Allotetraploid or Amphidiploid

The “Triangle of U” diagram, showing the genetic relationships between the six species of the genus *Brassica.* Nagaharu U (1935). “Genome analysis in Brassica with special reference to the experimental formation of B. napus and peculiar mode of fertilization”. *Japan. J. Bot.,* 7: 389-452.

➢ **Brassica Triangle**

The genetical relationship between the oilseed brassicas are represented as follows.



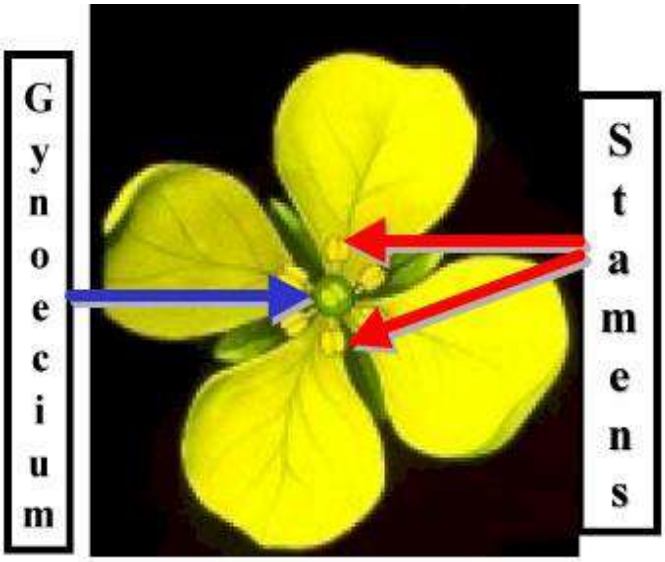
Botanical name	**2n**	***Economic characters***
Rape seed		
1. Brassica compestris	**20**	Indian Rape Seed. Self sterile in nature. Important oil seed crop of North India. 3 Cultivated types. B.*campestris* var. Brown sarson B.*campestris* var. Yellow sarson B.*campestris* var. toria
2. B.*napus*	**38**	European Rape Seed. Self fertile.
Mustard		
1. *B.nigra*	**16**	**Black mustard** : Native of Eurasia. Used as medicine pungent due to glucoside sinigrin.
2. *B.alba*	**24**	**White mustard** : Young seedling used as Salad, yellowish seed
3. *B.juncea*	**36**	**Indian mustard**. **RAI**. Leaves used as herb contains sinigrin.

Floral biology:

The inflorescence is a corymb raceme, sepals are united and green which turn yellow before falling. Petals are narrow and pale yellow to cream in colour.

Androecium:

1. The stamens are six, four with long and two with short filaments teradynamous condition.
2. During bud stage, the immature stamens are always below the stigma.
3. Just before the opening of the flower the four stamens, which have long filaments carry the anthers up to the stigma and the anthers are introse.





Emasculated flower



Pollination

Gynoecium:

1. The flower bears a hypogynous, syncarpous ovary, which is bicapellary with a very large number of ovules and parietal placentation.
2. Before the flower opens, the style often increases in length. Generally, the stigma remains in flush with the opening of the tube formed by the corolla.

Anthesis and pollination:

1. The flowers begin to open from 8.00 a.m. to 12.00 noon.
2. The flowers continue to open till 3-4 days, fading gradually every day and on the 4^{th} to 5^{th} day, the petals and sepals are shed.
3. As the flowers open, the anthers begin to dehisce from the apex downwards.
4. At the time of dehiscence, the pollen liberating sides of the anthers remain towards the stigma and slightly of the flowers by wind etc. is sufficient to

accomplish the transfer of pollen. Large numbers of bees visit the flowers soon after they open and certain amount of cross-pollination takes place.

Breeding objectives:

1. Higher seed yield per unit area
2. Early maturity
3. Shattering resistance
4. Resistance to biotic and abiotic stress
5. Higher oil content (45 per cent) and oil quality

   The important characteristics of oil quality are

   (i) Oil content of the seed

   (ii) Taste

   (iii) Colour of the oil: It is related with the colour of the seed

   (iv) Pungency in the oil: It is preferred in North – eastern India

   (v) Low Erucic acid and linolenic acid and low glucosinolate in meal

   - High content of long chain fatty acid, erucic acid up to 50 per cent is desirable in oil, which is used as lubricant. But for the edible purpose is should be low.
   - Glucosinolate: A group of compounds that give the characteristics flavor to vegetable and condiment. In meal, it is relatively high, therefore, restricted to use in cattle feed.
   - Linolenic acid should be reduced (<3%) as it very unstable and is easily oxidized to give unpleasant smelling substance in oil.

Research stations:

A. National: National Research Centre for Rape Seed and Mustard (NRCRM), Sewar, Bharatpur, Rajasthan.

B. State level: Main Mustard Research Station, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Gujarat.

Improved varieties: Gujarat Mustard-1, Gujarat Mustard-2, Varuna and Pusa Jay Kisan (Developed by somaclonal variation, IARI, New Delhi)

SUPPLIMENTARY EXERCISE

Q-1 Describe floral biology of mustard with suitable diagram.

Q-2 Give the genetic origin of mustard.

Q-3 Enlist the important wild relatives of mustard.

Q-4 Enlist important breeding objectives of groundnut, sesamum and mustard.

Q-5 Mention National and State level research stations of mustard.

Q-6 Write the improved varieties of mustard.

SUNFLOWER



Sunflower is one of the important oilseed crops grown in India. Its genetic name 'Helianthus' is derived from the Greek word 'halio' meaning 'sun' and 'anthos' meaning 'flower'. Although it is a crop of the temperate region, it has spread to all the continents of the world like Russia, Bulgeria, Romania, Canada and USA.

In India, it is extensively grown in Karnataka, Maharastra, Tamil Nadu and Andhra Pradesh. Its seed contains 40-20 per cent edible oil with low cholesterol content. The oil is also suited for soap making and for preparation of a number of other allied products. The oil cake contains 40-44 per cent protein. Sunflower meal is used as a bird and animal feed.

1.	**Name of Crop**	: Sunflower
2.	**Botanical Name**	: *Helianthus annus* L.
3.	**Family**	: Astreraceae
4.	**Chromosome Number**	: 2n = 34
5.	**Center of Origin**	: Central America
6.	**Mode of pollination**	: Cross pollination
7.	**Percent cross pollination**	: >90%
8.	**Related wild species**	: *H. agrestis, H. angustifolius, H. anomalus, H. arizonensis, H. atrorubens, H. bolanderi, H. californicus, H. petiolaris*

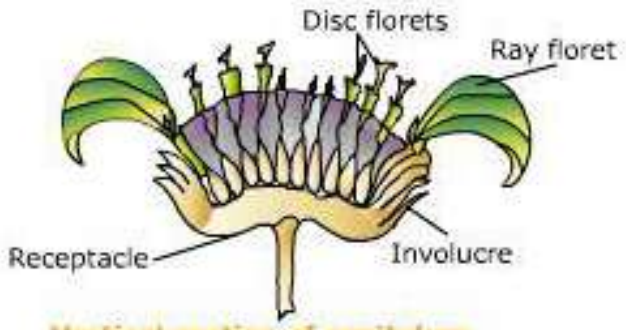
Reasons for spread of sunflower in India:

1. Wider adaptability over varying soil and climatic condition.
2. High yield potential.
3. Short duration and day neutral crop.
4. Assured marketing facility and fixed support price.
5. Easy crushing and oil extraction procedure.
6. High seed multiplication ratio.
7. Availability of varieties/hybrids with diverse duration periods to fit into multiple and inter-cropping systems.
8. Ideal crop for contingency cropping plans.

9. Drought tolerance capacity and rapid revivability after prolonged periods of drought.

Floral biology:

- The inflorescence is a capitutum or head, surrounded by green bracts, which protect the unopened head **(Fig.9.1)**
- The capitutum consists of two types of flower, ray florets and disc florets.
- The outer single row of ray florets, which are female and sterile.
- The inner disc florets are arranged in concentric circles on the receptacle which are hermaphrodite and fertile.
- Each disc floret consists of inferior ovary, two pappus scales, which are modified to sepals, and a tubular corolla, formed by the fusion of five petals, except at the apex.



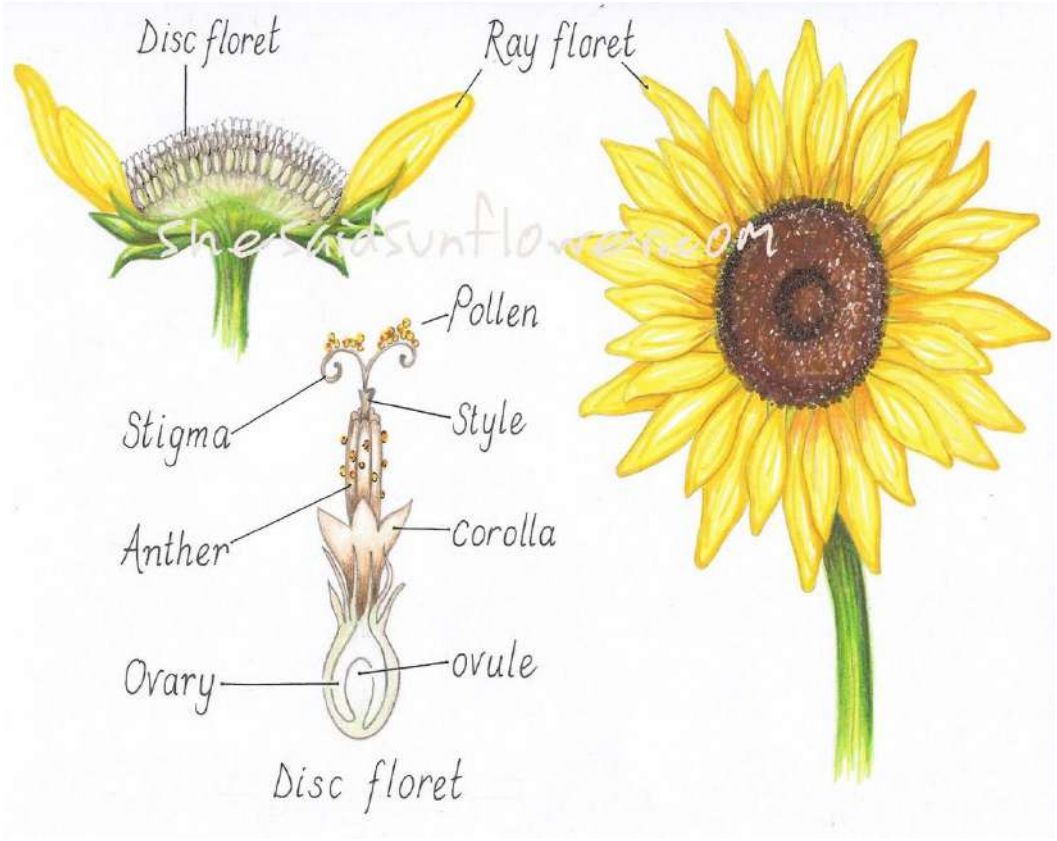




The five anthers are also fused to form a tube with filaments attached to the base of the corolla tube.

- Anthesis takes place in the morning between 6 a.m. and 8.a. m. The pollen grains remain viable for 12 hours.
- The style is inside the anther tube and the stigma is bilobed.
- The flowering process begins with the unfolding of outer ray florets.
- The outer whorl of the disc flower opens first and then proceeds towards the centre of the head.
- The stigma becomes receptive the following day and continues to be receptive for 2-3 days.

- The flowering is completed within 5-10 days, depending upon the size and season.



Selfing technique:

Self pollination is achieved by placing a muslin cloth bag over the head before anthesis. Seed set can be increased by rubbing pollen from the newly opened inner florets on the stigma of outer florets with a cotton pad or with a soft brush. Seed setting under bags without rubbing with brush indicates the extent of self fertility.

Crossing techniques:

- Sunflower is protoandrous, in which the androecium matures earlier than the gynoecium. There is a time lag of 18-24 hours in the maturity of male and female parts. Because of this, cross-pollination is favoured by insects, particularly bees which play an important role in pollination and fertilization.
- A single head produces 350 to 2000 seeds. The seed is called achene and consists of outer pericarp, thin and papery inner seed coat and embryo.
- For attempting crossing in sunflower, the heads must be covered with bags prior to flowing to prevent natural cross-pollination.
- For emasculation, the anthers of the disc florets of the female parent are removed with the help of forceps early in the morning before they have dehisced and before the stigmas have extended far enough into the anther tubes.
- Pollination is carried out the day after emasculation when the stigmatic lobes have separated and the receptive surfaces are exposed. For this purpose, the pollen is

collected from the heads covered with bags before flowering and applied with a brush or a piece of cotton to the female parent.

Breeding objectives:

1. Higher yield
2. Early maturity
3. Lodging resistance and dwarf type plants
4. High oil percentage
5. Tolerance to abiotic stress
6. Resistance to bird damage
7. Resistance to insect, pest and diseases

Improved varieties: Modern, Surya, TNAU-SUF-7, GAU-SUF-1, EC-68413, EC-68414, EC-68415, and EC-69874

Hybrid varieties: BSH-1, KBSH-1 and KBSH-11

Research stations:

A. National: All India Coordinated Research Programme on Sunflower, UAS, Bangalore, Karnataka.

B. State: Main Oilseeds Research Station, JAU, Amreli, Gujarat.

CHICKPEA



→ Chick pea is the third most important pulse crop in the world.

→ It is mainly confined to Indian Subcontinent where India alone contributes about 70% to the global chickpea production.

→ The important chickpea growing states of India are Rajasthan, Madhya Pradesh, Maharashtra, Uttar Pradesh and Haryana.

→ Rajasthan and Madhya Pradesh together contribute about 68% to the Indian and about 50% to the global chickpea production.

→ Chickpea is a **winter crop in the tropics** and a **summer or spring crop in the temperate region** of the world.

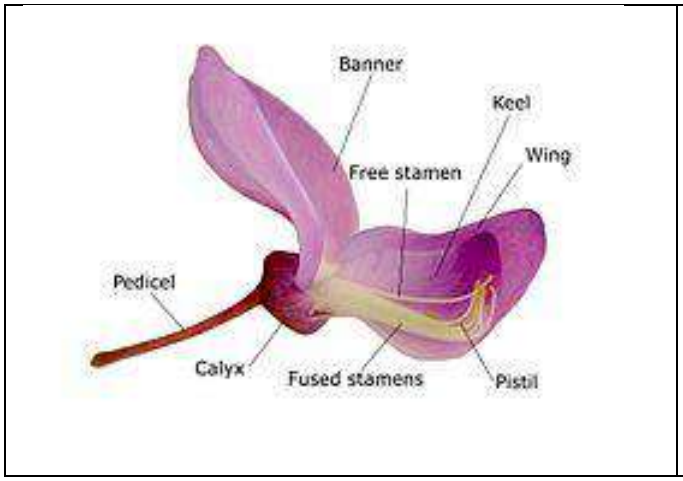
→ It requires **cool, dry and bright weather. Temperature, day length and availability of moisture** are the three major factors affecting flowering in chickpea.

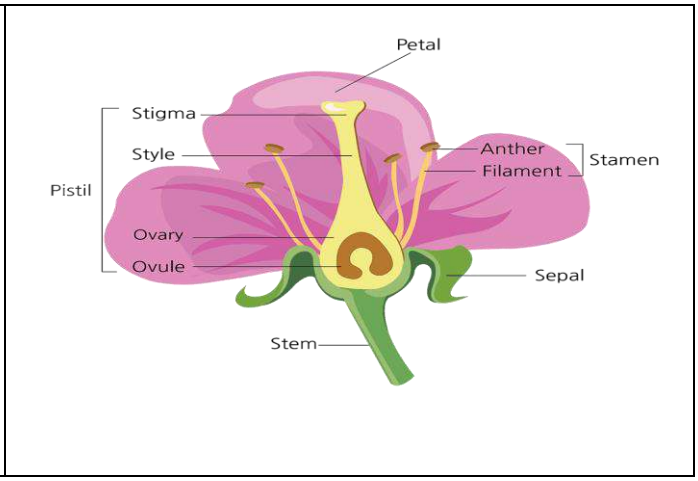
→ In general, flowering is delayed under low temperatures but more branching occurs. Progress towards flowering is rapid during long day

→ Chickpea is valued for its nutritive seeds with high protein content (25.3-28.9%).

1.	**Name of crop**	**:**	Chickpea, gram, Bengal gram, garbanzo bean, Indian pea, Ceci bean
2.	**Botanical Name**	**:**	*Cicer arietinum* L.
3.	**Family**	**:**	Fabaceae
4.	**Chromosome Number**	**:**	2n = 16
5.	**Center of Origin**	**:**	South eastern Turkey and adjoining Syria
6.	**Mode of pollination**	**:**	Self pollination
7.	**Out crossing percentage**	**:**	< 1 %
8.	**Related wild species**	**:**	*C. bijugum, C. Reticulatum, C. pinnatifidum, C echinospermum.*

- Chickpea is predominantly a self-pollinated crop, perhaps, obligatory since pollination takes place at the hooded bud stage.
- Pollen is most viable when the flower is half opened, and pollination occurs 12 to 24 h before the flower is fully expanded.
- During the early stages of green bud development and enlargement, the style elongates and the stamens remain clustered at the base of the ovary.





- The corolla consist of five petals (1+2+2), one big standard, two side wings and two keels are united
- The androecium is composed of ten stamens (9+1). The anthers are bi celled, orange and basifixed.
- The gynoecium consists of a superior ovary with a terminal slightly curved style and blunt knot like stigma.
- Anthesis occurs from 6 to 10 a.m. and may continue up to 3 p.m. The flowers remain open for two days. The anthers dehisce about 40 hours before the opening of the flowers. Cleistogamy has also been reported in this species.

Types of chickpea:

There are two main kinds of chickpea.

- **Desi**: It has small, darker seeds and a rough coat, cultivated mostly in the Indian subcontinent, Ethiopia, Mexico and Iran.

	
Desi chickpea	**Kabuli chickpea**

- **Kabuli**: It has lighter colored, larger seeds and a smoother coat, mainly grown in Southern Europe, Northern Africa, Afghanistan and Chile, also introduced during the 18th century to the Indian subcontinent.

➢ **Breeding objectives:**

1. High yield
2. Early maturity
3. Increased biomass, Medium tall, erect and compact cultivars
4. Resistance to diseases and insect pests: Pod borer, Root rot.
5. Tolerance to stress environments i.e. cold, heat, drought and saline and alkaline soil.

➢ **Breeding Methods:**

- Introduction

  i.e. G-109-1 Turkish variety introduced in India
- Pure line selection

  i.e. Chaffa, Jyoti, Pragati, Ujjain etc
- Hybridization

  i.e.Gaurav, Radhe, Vishal,Vijay etc
- Mutation Breeding

  i.e.Ajay, Atul, Girnar etc.
- Transgenic Technology

  Not available

➢ **Ideal plant type in chickpea**

1. Compact plant type

2. Medium tall are preferred
3. Optimum number of primary and secondary and minimum number of tertiary branches
4. Determinate growth habit for harvesting uniform produce
5. Well developed nodules

Research stations:

A. International: International Crop Research Institute for Semi Arid Tropics (ICRISAT), Patancheru, Hyderabad, Andhra Pradesh

B. National: Indian Institute of Pulses Research (IIPR), Kanpur, Uttar Pradesh

C. State: Main Pulses Research Station, JAU, Junagadh, Gujarat

Improved varieties:

Dahod yellow, Chaffa, ICCC-4, Gujarat Gram-1, Gujarat Gram-2, Gujarat Junagadh Gram-3, Gujarat Gram-4, Gujarat Gram-5 (2017) and Gujarat Junagadh Gram-6 (2016).

ASSIGNMENTS:

Q– 1.	**Justify the following**
(i)	Chickpea flowers are didelphous.
(ii)	Chickpea is predominantly self pollinated crop.
(iii)	The white bud stage is most suitable for crossing in chickpea.

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BREEDING VEGETABLE CROPS I:
POTATO,TOMATO, BRINJAL, CHILLI AND ONION

POTATO



Potato (*Solanum tuberosum* L.) is one of the most important non-cereal food crops cultivated *worldwide* under various environmental conditions. Today potato has become an integral part of human diet and is the world's fourth largest food crop, after rice, wheat and maize. Fresh potatoes contain about 78% water, 18.5% carbohydrates, 2.1% protein, 0.1% fat and 1.7% fiber. Nutritionally, it is superior food in term of supply of carbohydrates, proteins, minerals, and vitamin C and high quality dietary fiber. Potato is staple food in European countries and North America and a vegetable in the developing world including India. It is also used in the manufacturing of adhesives, paper and cosmetics and in pharmaceuticals. Keeping in view the importance of potatoes, the United Nations officially declared the year 2008 as the International Year of the Potato. Worldwide, about 329.58 million tones of potatoes were produced during 2009 from an area of 186.352 million ha with average productivity of 17.67 t/ha.

1.	**Name of Crop**	:	Potato
2.	**Botanical Name**	:	*Solanum tuberosum* L.
3.	**Family**	:	Solanaceae
4.	**Chromosome Number**	:	2n = 48
5.	**Center of Origin**	:	Central & South America
6.	**Mode of pollination**	:	Cross pollination
7.	**Percent cross pollination**		>90%
8.	**Cultivated Species**	: :	**Diploid:***S.stenotomum,S.goniocalyx,* *S. ajanhuiri, S.phureja* **Triploid:***S. x chaucha, S. x juzepczukii* **Tetraploid:***S.tuberosum ssp. andigena.* *S.tuberosum ssp. Tuberosum. S.hygrothermicum* **Pentaploid:** *S.curtilobum*
9.	**Related wild species**	:	*S. sparsipilum, S. leptophyes,* *S. megistacrolobum* (2n=24),*S. acaule (2n=48)*

➢ Floral biology:

- The inflorescence may be simple or compound.
- In simple inflorescence, the peduncle divide into secondary axis usually two in number.each of which forms amonochasial cyme.
- In compound inflorescence, the secondary axis divides again to form amonochasial cyme.
- The difference between simple and compound inflorescence lies in the degree of sub divisions of the main peduncle(short, medium or long).
- Potato flowers are bisexual and possess all the four part of a flower.



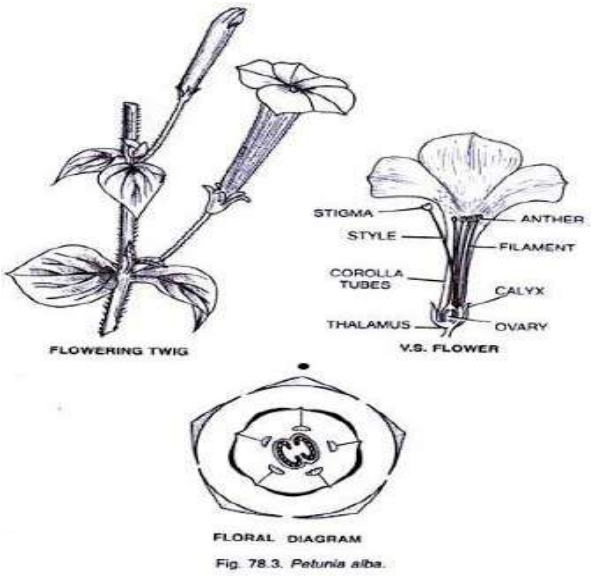
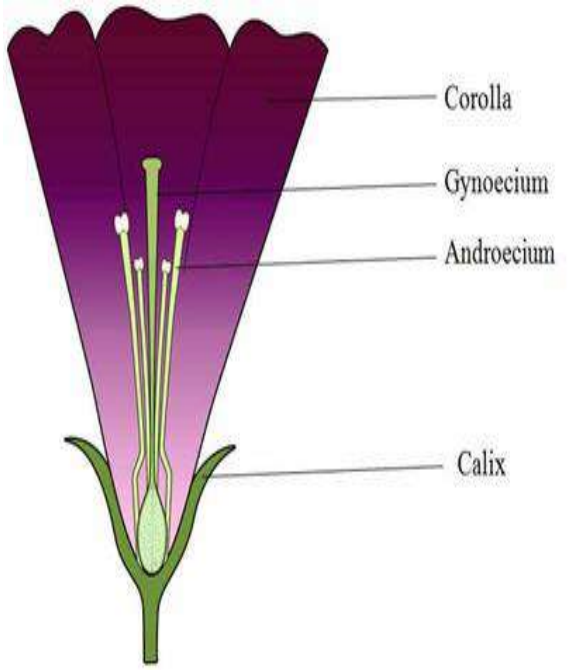
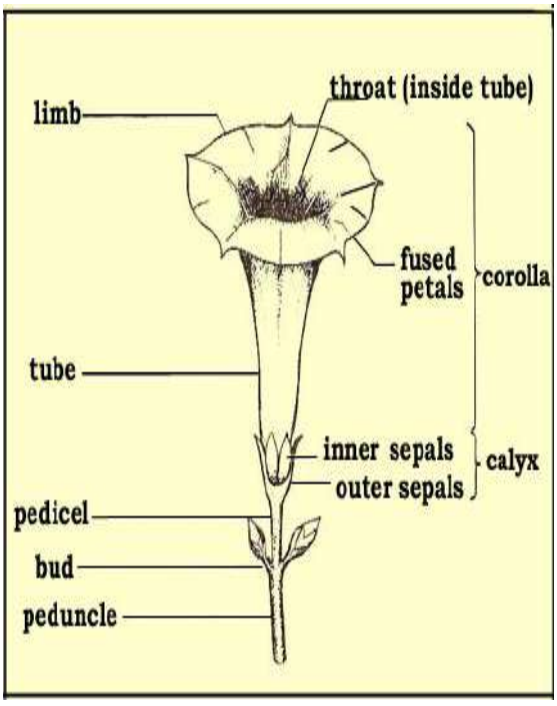


Fig. 78.3. *Petunia alba.*





- The calyx is composed of five sepals united at their base to form a bell-shaped structure below the corolla. The colour of calyx may be green, red, purple or in combination.
- The corolla consists of petals joined at the base and forms a short tube with a flat five lobed surface. Each lobe ends is a triangle point (acumen).the shape of corolla is generally round (rotate). However, pentagonal or star shaped. The colour of corolla may be white, light blue, blue, red or purple with different combination.
- Androecium consists of five stamens. The stamens are composed of anther and filament joined to the corolla tube. Pollon dehiscence is through the pores.
- The gynoecium of the flower is very well developed and pistil has three parts *viz*; the basal swollen region (ovary), the middle thin long region (style) and the flat tip (the stigma).the overy is superior, bilocular with axile placentation. The style is an elongated portion of the pistil connecting the sigma and ovary. The stigma is receptive portion of the pistil, where the pollen grains germinate to grow down the style for fertilization.

➢ **Breeding objectives:**

1. Higher yield, good keeping quality, combining resistance to late blight, viruses and insects.
2. Biotic stress tolerance (water and temperature stress).
3. Developing varieties for processing into chips, French fries and starch.
4. Widely adaptable.
5. Varieties should produce attractive, mediumsized, shallow eyed with good keeping and nutritional quality.

➢ **Breeding methods:**

- Conventional breeding approaches
- Hybridization
- Mutation breeding
- Innovative breeding approaches likes; embryo culture, anther culture for haploid production, somaclonal variation, somatic hybridization, marker assisted selection, genetic transformation.

➢ **Improved varieties:** Kufri sinduri, K. chandramukhi, Kufri Badshah, Kufri Badshah, JH-222 (Kufri Jawahar), Kufri Pukhraj, K. Pushkar , K. Surya and K. Chipsona-3, K. Garima and K. Gaurav, K. Mohan, K. Lima and K. Ganga, K. fryoM, Kufri Khyati (2019).

➢ **Research stations:**

1. **National:** Central Potato research Statiuon, Kufri, Shimla-171012 (HP)
2. **State:** Potato Research Station, Sardarkrushinagar Dantiwada Agricultural University, Deesa, Dist- Banaskantha, Gujarat.

TOMATO



Tomato is the second most important vegetable crop after potato. Its genetics is much studied among vegetable crops, resulted in the recognization of its commercial exploitation of hybrid vigor since last hundred years. The leading tomato growing countries in the world are the America, European countries, Japan and China. In India, tomatoes are grown in almost every state, out of doors in season and in glass and polyhouses for off-season markets. Tomato is a rich source of vitamins and minerals.

The plant is grown for its fruit, a fleshy berry, which is consumed fresh, canned or used to produce juice, sauces, pastes or powder. The seed yields 24 per cent oil, which is used in salad oil, margarines and soap. The number of seeds in a fruit may vary from 73 to 346.

1.	**Name of Crop**	:	Tomato
2.	**Botanical Name**	:	*Lycopersicon esculentum* L.
3.	**Family**	:	Solanaceae
4.	**Chromosome Number**	:	2n = 24
5.	**Center of Origin**	:	Peru, Equador and Bolivia
6.	**Mode of pollination**	:	Self pollination
7.	**Out crossing Percentage**	:	5-7%
8.	**Related wild species**	:	*L. cheesmanii, L. parviflorum, L. chmielewskii, L. pennellii, L. hirsutum, L. chilense, L. peruvianum*

Floral biology:

- The inflorescence may arise terminally, opposite or between the leaves.
- The flower is hermaphrodite, hypogynous and regular.







- The individual flower is about three-quarters of an inch in diameter with a 5 to 10 part green calyx that clings to the fruit until it matures.
- There are usually six golden yellow petals that re-curve as they expand.
- There are usually six stamens, which are united with their yellow anthers to form a tube or cone about one-half inch long that surrounds the pistil and with the re-curved petals, gives the pendant flower a shooting star or rocket appearance.
- Depending upon cultivars and environmental conditions, the style may range from slightly shorter than the tip of the anthers to as much as 2 mm beyond the tip, terminating with a capitate, simple, narrow or somewhat bulbous stigma.
- The style elongates about the time the anthers begin to split at the terminal end and release their pollen into the styler tube.
- The stigma is receptive to its own or other pollen 1 or 2 days before anther dehiscence, which favors cross-pollination. The stigma remains receptive for 4 to 8 days. The construction of the anthers, delicately united with the filament, permits them to vibrate at the slightest touch and send a rain of pollen down the cone outlet and around the stigma. The pollen is more attractive to wild bees than honey bees.

Selfing techniques:

Entire plants or branches of plant are covered with muslin cloth bags to ensure cent percent self pollination.

Crossing techniques:

- There are four to eight flowers in each compound inflorescences.
- Stigma is cover with light protective anther cone.
- Emasculation is carried out one day prior to anthesis/flower opening. At this stage, the sepals have stated to separate and the anthers and corolla are beginning to change from light to dark yellow. The stigma is fully receptive at this stage allowing for pollination even immediately after emasculation.
- Anthers are removed as a group with or without the surrounding corolla, by inserting forceps between the sepals to grip the base of the anthers and/or petals which are then removed by a firm but steady pull.
- Emasculated flower are pollinated with pollen grains next morning
- Protect pollinated flower with small cotton bags or pollination bags.

Breeding objectives:

1. Higher fruits yield
2. Early maturity
3. Indeterminate cultivars for green house production
4. Resistance to diseases and insects
5. Resistance to abiotic stresses

6. Breeding for fruit quality
   (i) Appearance (ii) Colour (iii) Texture and firmness (iv)Flavor (v) Nutritional value (vi) Processing quality (vii) Fruit pH (viii) Titrable acidity (ix) Total Soluble Solids (TSS) (x) Viscosity (Consistency)

Improved varieties: Gujarat Tomato-1, Gujarat Tomato-2, Junagadh Tomato-3, Pusa early dwarf, Pusa gaurav, Arka vikash and Arka saurabh

Hybrid varieties: Pusa Hybrid-1 and Pusa Hybrid-2

Research Stations:

A. International: Asian Vegetable Research and Development Center (AVRDC), Shanhua, Taiwan.

B. National: Indian Institute of Vegetable Research (IIVR), Varansi, Uttar Pradesh.

C. State: Vegetable Research Station, JAU, Junaghadh, Gujarat.

BRINJAL



The brinjal also known as "Egg plant" is a member of the nightshade family, along with the tomato, pepper and potato. Brinjal is grown commonly in almost all the parts of the country and liked by both poor and rich. It is a main vegetable to the plains and is available more or less throughout the year. It is primarily used as cooked vegetable and popular for the preparation of various dishes in different regions of the country. It is supposed to contain certain medicinal properties in ayurvedic medicines. It is rich in Vitamin A and B.

Country and state

1.	**Name of Crop**	: Brinjal, Egg plant, Guinea squash
2.	**Botanical Name**	: *Solanum melongena* L.
3.	**Family**	: Solanaceae
4.	**Chromosome Number**	: 2n = 24
5.	**Center of Origin**	: Central Asia
6.	**Mode of pollination**	: Often cross pollination
7.	**Out crossing Percentage**	: 30-40%
8.	**Related wild species**	: *S. khasianum, S. aviculare*

Botanical varieties under the species *S. melongena* :

No.	Variety Group	Fruit shape/Plant type
1	*S. melongena var. esculentum*	Round or egg shape
2	*S. melongena var. sorpentium*	Long and cylindrical
3	*S. melongena var. depressum*	Dwarf type

Floral biology:

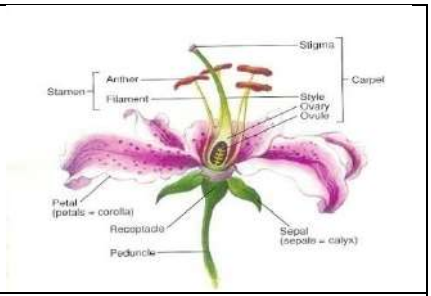
- ✓ The flower is bisexual and it contains stamens that dehisce at the same time when the stigma is receptive, thus, self pollination is the rule. However, upto 30-40 per cent cross-pollination is reported.
- ✓ Inflorescence is often solitary but sometimes it constitutes a cluster of 2-5 flowers. Flower is complete, actinomorphic and hermaphrodite.
- ✓ Calyx is five lobbed, gamosepalous and persistence. It forms a cup like structure at the base.



Flower bud



Open flower



Parts of flower

- ✓ Corolla is five lobbed gamopetalous with margin of lobes incurved.
- ✓ Anthers are cone shaped, free and with apical dehiscence (**Fig.11.3**).
- ✓ Pollen remains viable for 8-10 days.
- ✓ Anthers starts dehiscence from 7.30 a.m. to 11.00 a.m.
- ✓ Ovary is hypogynous, bicarpellary, syncarpous and with basal placentation.
- ✓ **Four types of flowers are found depending upon the length of the style**
  1. Long style with big size ovary
  2. Medium styled with medium sized ovary
  3. Pseudo-short styled with rudimentary ovary, which do not producing fruits
  4. True short styled with very rudimentary ovary, which do not producing fruits.
- ✓ Stigma receptivity is highest during anthesis i.e. flower opening. The receptivity of stigma can be observed from its plump and shiny appearance which gradually becomes brown with the loss of receptivity.
- ✓ Stigma becomes receptive until about four days to flower opening.

Selfing technique:

For effective and cent per cent selfing, entire plant or branches of plants are covered with muslin cloth bags.

Crossing technique:

- ✓ A healthy long or medium styled, well developed bud from the central portion of the plant is selected.
- ✓ The bud is opened gently with the help of fine pointed forceps one or two days before the opening of the bud and all the five anthers are carefully removed.
- ✓ Freshly dehiscing anthers are picked up and are slit vertically with fine needle to get sufficient pollen at the tip of the needle.
- ✓ Collected pollens are applied on stigma of emasculated flower.
- ✓ Pollinated flowers are labeled and covered with small pollination bag.

Breeding objectives:

1. Higher yield
2. Earliness
3. Fruit shape, size and colour as per consumer preference
4. Low portion of seed
5. Soft flesh
6. Lower solanine content
7. Upright sturdy plant free from lodging
8. Resistance to bacterial wilt, phomopsis blight, little leaf, root knot nematode, shoot and fruit borer, jassids

Research stations:

A. International: Asian Vegetable Research and Development Centre (AVRDC), Shanhua, Taiwan.

B. National: Indian Institute of Vegetable Research (IIVR), Varansi, Utter Pradesh.

C. State level: Vegetable Research Station, JAU, Junagadh, Gujarat.

Improved varieties: PLR-1, KS-224, Junagadh Ravaiya, DBSR-91, Gujarat Brinjal Long-1, Gujarat Brinjal Oblong-1, Pusa Purple long, Pusa Purple Cluster, Pusa Purple Round, Pusa Kanti and Pusa Bhairav.

Hybrid varieties: Gujarat Brinjal Hybrid-1 and Gujarat Brinjal Hybrid-2

CHILLI AND BELL PEPPER



Bell pepper and chilli are important vegetable crops. It is a constituent of many foods, add flavor, colour, vitamin-C and pungency to world food basket. Top

chilligrowing countries are India, China, Turkey, Nigeria, Mexico, Spain, USA, Indonesia, Italy, Korea, Bulgeria, Netherlands, Egypt, Romania and Tunisia.

Red chilli contains high amounts of vitamin C and carotene (provitamin A). Yellow and especially green chilli contains a considerably lower amount of both substances. In addition, peppers are good source of vitamin B complex, and vitamin B_6 in particular. They are very high in potassium, magnesium and iron. There high vitamin C content can also substantially increase the uptake of non-heme iron from other ingredients in a meal, such as beans and grains.

1. **Name of Crop** : Chilli, Bell pepper
2. **Botanical Name** : *Capsicum* spp.
3. **Family** : Solanaceae
4. **Chromosome Number** : 2n = 24
5. **Center of Origin** : As per Table
6. **Mode of pollination** : Often cross pollination
7. **Out crossing Percentage** : Up to 80%
8. **Related wild species** : *C. eximum, C. minimum, C.cardenasii*

Table: Major species of genus *Capsicum*, their origin and plant description

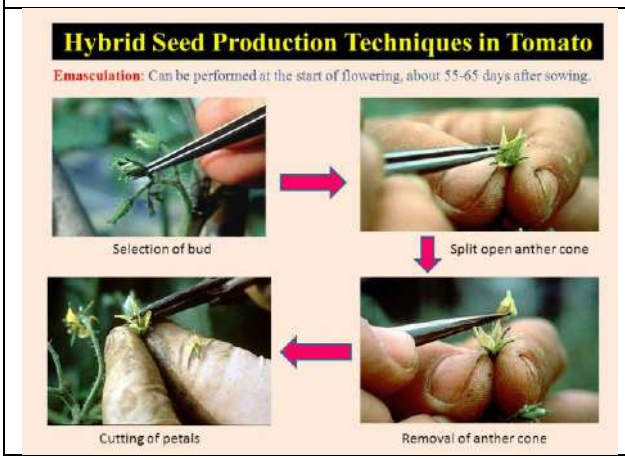
Sr. No.	Botanical name	Centre of origin	Plant description
1.	*C. annuum*	Mexico	White flowers, blue to purple anthers, a toothed calyx and typically single-fruited nodes with the possible exception of an occasional double flowered axil in a lower main fork.
2.	*C. chinense*	Amazonia	White or greenish white flowers, blue anthers, a constricted, toothed calyx, and typically form one to three fruits per nodes.
3.	*C. frutescens*	Amazonia	Grennish flowers, a non-toothed, non-constricted calyx that encloses the fruit base, blue anthers and mostly single fruited nodes but with a few double flowered nodes on each plant.
4.	*C. pendulum*	Peru and Bilivia	White flowers with the yellow corolla throat spots, yellow anthers, and the long, curved, characteristically pendant fruits pedicels and leaf petioles.
5.	*C. pubescens*	Peru and Bilivia	Larger, showy purple flowers, soft pubescens leaves, yellow orange fruits, and black seeds are unique.

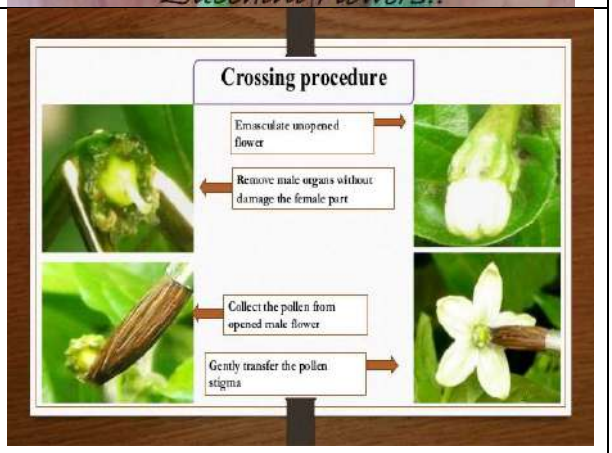
➢ **Floral biology:**

1. Flowers are small, solitary in leaf axils or 2-3 or more together at the tip of branches and long pedicelled. Pedicels are erect, nodding at the tip, light green shortly pubescent, terete and 1.5 to 2.5 cm long and pentamerous.
2. Calyx is minute, companulate, minutely abstrusely 5-toothed or sub truncate, yellowish green, glabrous and not or hardy enlarged under the fruit.
3. Corolla is gamopetalous, patent, flat, yellowish or grayish white deeply 5-partite and 0.5 to 1.0 cm in diameter
4. Stamens are five and erect. Anthers are bronze-green in colour.









Selfing technique:

To ensure cent percent selfing branch or entire plant are covered with muslin cloth bags, net or cotton bag.

Crossing technique:

- Crosses can be made any time during the day morning hours are preferable.
- Flowers are emasculate in bud stage just prior to anther dehiscence.
- Emasculation is beginning with removal of petals from the flowers. Then carefully remove anthers with the help of forceps or needle without damaging the pistil.
- Once petal should be removed bees usually do not visit the flowers so there is no need to cover emasculated flower.
- If more than two flowers are present at a node, only one flower are kept and others are snipped off to reduce competition for food and space.
- Mark emasculated flower with a clip for easy location the next day.

- Stigma receptivity to pollen is highest on the day of anthesis, when fully developed anthers are still closed.
- Pollen for crossing can be obtained at any time of day, with the most abundant and viable pollen coming from freshly dehisced anthers. Freshly dehisced anthers can be picked from the male parents and used to make the pollination.

Breeding objectives:

1. Higher green fruit yield
2. Earliness
3. Desirable fruit shape and size
4. High oleoresin content
5. Resistance to diseases like leaf curl virus, fruit rot, cercospora leaf spot, powdery mildew, bacterial leaf spot, phytophthora root rot, root knot etc.
6. Resistance to insects like thrips, mites, aphid and fruit borer
7. Resistance to abiotic stresses (heat, water stress, salinity)
8. Breeding for superior fruit quality: (i) Pleasing flavor (ii) High sugar-acid ratio (iii) High pigment content and vitamin C (iv) High capsaicin

Research stations:

A. International: Asian Vegetable Research and Development Center (AVRDC), Shanhua, Taiwan.

B. National: Indian Institute of Vegetable Research (IIVR), Varansi, Utter Pradesh.

C. State level: Vegetable Research Station, JAU, JUnagadh, Gujarat.

Improved varieties:

Chilli: Pusa Jwala, Pusa Sadabahar, Pant Chilli-1, Jawahar-218, Gujarat Chilli-1 and Gujarat Chilli-2

Bell Pepper: California Wonder, Arka Mohini, Arka Gaurav, Arka Basant and Pusa Deepti

Hybrid varieties: ACH-15 and ACH-30

ONION



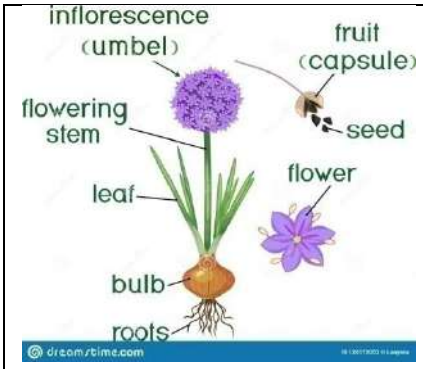
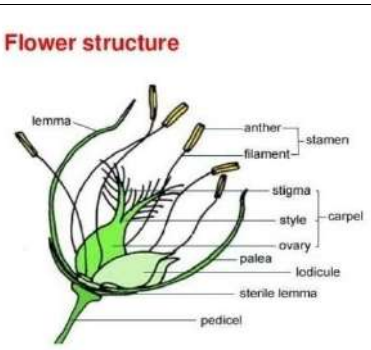
Onion is one of the oldest vegetables grown throughout the world. A global review of major vegetables show that onion ranks second after tomato in area. The leading onion growing countries are China, India, USA, USSR, Japan, Spain, Brazil, Italy, Egypt and Pakistan. In India, It is grown in Mahrastra, Gujarat, Andhra Pradesh, Bihar, Kanataka, Madhya Pradesh, Oriss, Tamil Nadu and Uttar Pradesh.

Onion is used in a large number of recipes and preparations spanning almost the totality of the world's cultures. It is now available in fresh, frozen, canned, caramelized, pickled, powdered, chopped, and dehydrates forms. Onion can also be used, usually chopped or sliced, in almost every type of food, including cooked foods and fresh salads and as a spicy garnish.

1.	**Name of Crop**	: Onion
2.	**Botanical Name**	: *Allium cepa* L.
3.	**Family**	: Alliaceae (liliaceae)
4.	**Chromosome Number**	: 2n = 16
5.	**Center of Origin**	: Central Asia (Pakistan, Iran)
6.	**Mode of pollination**	: Cross pollination
7.	**Out crossing Percentage**	: 95 to 100%
8.	**Related wild species**	: *A.vavilovii, A. galanthum*

Floral biology:

- The flowers are protandrous and cross-pollination is mainly achieved by honey bess.
- The flowering stalk of onion is an apical extension of the stem but without nodes and internodes.
- The flowering stalk of onion is an apical extension of the stem but without nodes and iternodes.
- The growth of flower stalk ceased when umbels starts to flower.
- Spherical umbel which terminates the stalk may have 50 to 2000 flowers. Each flower is attached to a slender pedicel.
- Each individual flower contains 6 stamens, 3 carpels united into one pistil and 6 perianth segments.

		
Plant parts	**Inflorscence**	**Flower structure**

- The pistil contains 3 locules each of which has 2 ovules
- Anthers shed pollen over a period of 3-4 days prior to time when full length of style attained. Thus stigma becomes receptive 3-4 days after shedding of pollen grains.
- The flower also contain nectarines which secrete nectar to attract insects for cross pollination.

Selfing technique:

Onion is a self-incompatible crop so selfing induces reduction in vigour and appearance of sterile plants in the populations. Therefore, sufficient amount of seeds cannot be produced. Thus, selfing in onion is done only on a limited scale as it becomes difficult to maintain the inbred lines beyond S_2 generation.

Putting individual cages over the plants carries out Selfing. Honey bees are generally used to ensure pollination within cages. Sometimes it is convenient to enclose 2-3 umbels of the same plant in a muslin cloth bag before anthesis. After anthesis, the umbels are rubbed with soft puff against each other daily for a few days to ensure self pollination.

Crossing technique:

- As soon as few buds in an umbel open, the whole umbel of the female parent is bagged in a muslin cloth bag.
- The flowers are removed daily for a few days until the peak flowering has reached after which buds are emasculated as they open and when sufficient buds have been emasculated. The remaining young flower buds are removed.
- The umbel of pollen parents covered by a muslin cloth bag is cut off and its stalk placed in glass bottle filled with water. This bottle is fasted to a bamboo/wooden stake and fixed in soil close to the female parent.
- Female parent umbel and the pollen parent umbel are now enclosed in the same common bag.

- For a few days in the morning, the male umbel is gently rubbed over the emasculated umbel to ensure pollen shedding and cross pollination. A few common house flies can also be introduced into the bag for pollen transfer.

Breeding objectives:

1. Higher bulb yield
2. Early maturity
3. Self-topping habit and more storage life (Shelf life)
4. High Total Soluble Solid (TSS) content
5. Breeding varieties for dehydration purpose
6. Resistance to diseases (Purple blotch, Basal rot, Stemphylum blight, Bacterial storage rot)
7. Resistance to insect pests (Thrips and Jassids)
8. Resistance to abiotic stresses (Moisture stress, High temperature, Salinity)
9. Bulb quality: (Bulb size, shape and colour, bulb weight, bulb pungency, bulb firmness etc.)

Research stations:

A. International: Asian Vegetable Research and Development Center (AVRDC), Shanhua, Taiwan.

B. National: National Research Center for Onion and Garlic, Rajgurunagarm, Pune, Maharastra.

C. State level: Vegetable Research Station, JAU, Junagadh, Gujarat.

Improved varieties:

Kharif: Agrifound Dark Red, N-53, Agrifound White and Phule Safed,

Rabi: Agrifound Light Red, Pilipatti, Talaja Red, Arka Niketan, Gujarat White Onion-1 and Agrifound White.

Hybrid varieties: Arka Lalima and Arka Niketan

SUPPLIMENTARY EXERCISE

Q-1 Describe floral biology of tomato, brinal, chilli, okra and onion with suitable diagram.

Q-2 How selfing and crossing is carried out in tomato, brinal, chilli, okra and onion**?**

Q.3 Enlist the important wild relatives of tomato, brinal, chilli, okra and onion**.**

Q-4 List out breeding methods adopted for improvement of tomato, brinal, chilli, okra and onion.

Q-5 Enlist important breeding objectives of tomato, brinal, chilli, okra and onion**.**

Q-6 Mention International, National and State level research stations of tomato, brinal, chilli, okra and onion**.**

Q-7 Write the improved varieties/hybrids varieties of tomato, brinal, chilli, okra and onion**.**

****

BREEDING SUGAR CROP: SUGARCANE



Sugarcane is an important sugar crop in all the countries of tropical Asia. Sugarcane is grown in more than 110 countries. The world's largest producer of sugarcane is Brazil, followed by India, China, Thailand, Pakistan, Mexico, Columbia, Australia, America and Phillipines. The state having substantial sugarcane are in India are, Utter Pradesh, Maharastra, Haryana, Andhra Pradesh, Tamil Nadu, Karnataka, Bihar and Punjab. The sugar industry is the second largest agro-based industry in India in terms of economic gains and employment potential.

Sugarcane products include table sugar, falernum, molasses and ethanol. The bagasse that remains after sugarcane crushing may be burned to provide heat and electricity. Because of its high cellulose content, serve as raw material for making paper and cardboard. In Brazil, ethanol extracted from sugarcane is blend with petrol for running vehicle.

1.	**Name of Crop**	:	Sugarcane
2.	**Botanical Name**	:	*Sachharum officinarumum* L.
3.	**Family**	:	Poaceae
4.	**Chromosome Number**	:	2n = 80
5.	**Center of Origin**	:	(1) New Guinea and (2) North India
6.	**Mode of pollination**	:	Cross pollination
7.	**Out crossing Percentage**	:	42-50 per cent
8.	**Related wild species**	:	*As per* Table

Table: Cultivated and wild relatives of sugarcane with chromosome number

No.	Name of species	No. of Chromosome	Remarks
1.	*Saccharum officnarum*	2n=80	Cultivated
2.	*Saccharum sinense*	2n=116, 118	Cultivated
3.	*Saccharum barberi*	2n=82 to 114	Cultivated
4.	*Saccharum spontaneum*	2n=40,58,120	Wild type
5.	*Saccharum robustum*	2n=60 to 148	Wild type

Sugarcane is highly heterozygous due to high chromosome number and complex ploidy levels (due to hybridization of several genomes)

S. sinense ***S. barberi*** ***S. spontaneum***





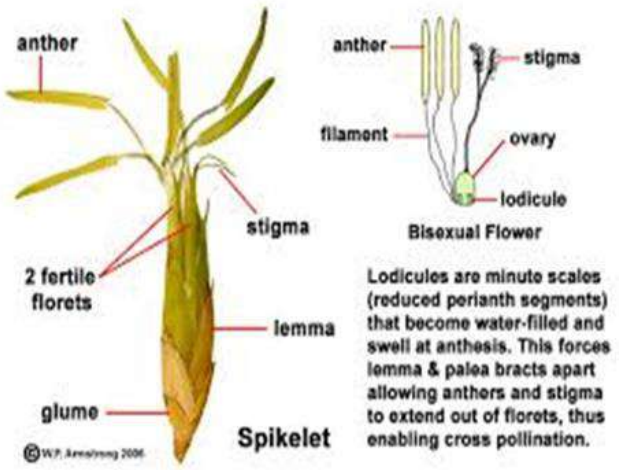


Origin of sugarcane:

Two geographic centres of origin are (1) New Guinea and (2) North India. The Indian sugarcane *S. sinense* and *S. barberi* might have originated by natural hybridization between *Saccharum officinarum* and *Saccharum spontanem.* The large barreled, tropical species of *S. officinarum* originated from *S. robustum* in new Guinea. It migrated from its centre of origin to other places and was modified by natural hybridization with a species of related genus, either *Erianthus maximum* (2n=60 to 100) or *Sclerostachya fusca* (2n=30).

Floral biology:

Photoperiod is an important factor for flowering sugarcane. It flowers all the year round at equator, where day length is constant for 12 hours. Warm nights, humid conditions and high rainfall favours flowering, while cool weather and high altitude where the day length varies affecting the flowering.

	
Sugarcane flowers	**Parts of Flower**

- The inflorescence is a panicle called arrow, contains many flowers (about 10,000 to 50,000 individual spikelets)
- The flowers are in pair, one sessile (without petiole) and one pedicellate (with petiole). The sessile spikelet flowers before the pedicellate spikelet.
- The stamens are three and stigma is feathery and bifurcated.
- The flowers open in the morning between 5 and 6 a.m. About 7 to 14 days are required for an arrow to complete the flowering
- The flowers show a wide range of fertility, rangimg from male sterility to high pollen fertility. Generally, the flowers are protogyny in nature.
- The seeds produced are extremely small in size, often poorly developed and invisible.

Selfing technique:

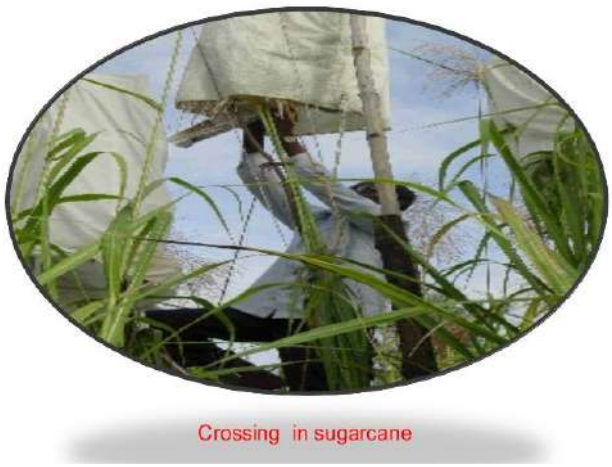


Lantern method of raising of Sugarcane seed

Covering the arrow in a lantern (A bamboo frame work or cage like structure which covered a muslin cloth bag or a polyethylene) before anthesis to ensure selfing.

Crossing technique:

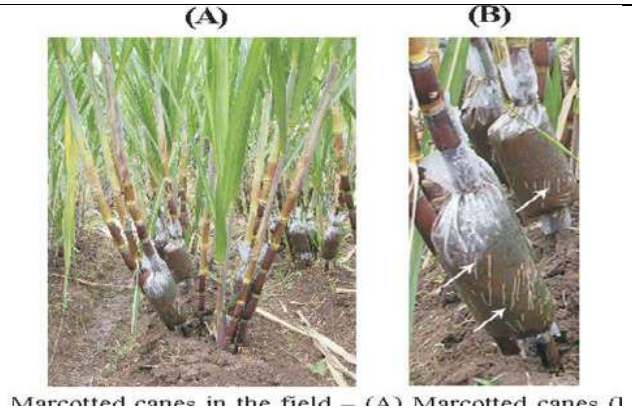
- Due to small size and large number of flowers on arrows and tall plant height emasculation is not practicable.
- The female parent is selected on the basis of protogyny, male sterility or late pollen shading.



Crossing in sugarcane

- The crossing is attempted by any of the following three methods.
  1. The male and female parent is planted closely. The male and female arrows are enclosed in a single lantern.
  2. The arrows from male parent are cut-off and cut end of arrow is kept in weak sulphur dioxide solution (arrow can be kept alive) and then these arrows are dusted on female arrows.
  3. **Marcotting procedure (technique):**

This procedure was first used in India and now it is adopted by several countries. The procedure in which a plastic sleeve containing a growth medium is secured about 2 to 3 nodes above the base of the stalk to induce rooting is called marcotting. In this technique, healthy female clones are selected.

 Marcotted canes in the field – (A) Marcotted canes (I	
Marcotting procedure	**Root Development**

1. Just prior to flowering, a polyethylene strip containing a mixture of moist potting soil is wrapped around a bud of the sugarcane stalk about two nodes above the ground level.
2. Roots will develop on the stalk within 10 days where the bud has been marcotted.
3. The cane is cut below the rooted portion and taken to the crossing area, where they are transplanted in a big plots containing soil.
4. Clusters of such 3-4 female arrows are usually kept in a lantern and pollination is carried out either by enclosing male and female arrows under same lantern or by dusting the pollen.

Flowering is undesirable in commercial canes:

1. Plant stops growing and matures rapidly after the appearance of the flowering stalk.
2. Reduction in cane and sugar yield as the food is diverted towards growing inflorescence.
3. Sugarcane stalk becomes hollow.

Breeding objectives:

1. Higher cane yield
2. High sucrose content
3. Early to full season maturity
4. Resistance to lodging
5. Resistance to abiotic stresses (forst, drought and water logging)
6. Resistance to diseases and pests.
7. Breeding for quality: (i) Sugar content of juice (ii) Quality of juice and (iii) Milliability

Millability: It refers to the characteristics of the canes that make it possible to recover the sucrose from the stalk by normal methods of extraction.

Desirable characteristic for good milliability:

(i) Moderate hardness of rind (dark)
(ii) Good length of fibers
(iii) Long internodes
(iv) Low- fiber: sucrose ratio
(v) Good fiber quality for paper making

Research stations:

A: National: 1. Sugarcane Breeding Institute (SBI), Coimbatore, Tamil Nadu.
2. Indian Institute of Sugarcane Research, Lucknow, Uttar Pradesh.

B: State level: Sugarcane Research Station, JAU, Kodinar, Gujarat.

Improved varieties: Co-791, Co-775, Co-6806, Co-6304, Co-7602, CoC-671, Co-7527, Co-62175, Co-8338, Co-87263, Gujarat Sugarcane-1, Gujarat Sugarcane-2 Gujarat Sugarcane-3, Gujarat Sugarcane-4, Gujarat Sugarcane-5, Gujarat Sugarcane-6, Gujarat Sugarcane-7

SUPPLIMENTARY EXERCISE

Q-1 Describe floral biology of sugarcane with suitable diagram.
Q-2 How selfing and crossing is done in sugarcane?
Q.3 Enlist the important wild relatives of sugarcane.
Q-4 List out breeding methods adopted for improvement of sugarcane.
Q-5 Enlist important breeding objectives of sugarcane.
Q-6 Mention National and State level research stations of sugarcane.
Q-7 Write the improved varieties sugarcane.
Q-8 What is marcotting procedure. Give in detail.
Q-9 Why flowering in commercial cane is undersirable?

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BREEDING FOR FORAGE CROP: LUCERNE



- Cultivated alfalfa (Medicago sativa L., 2n = 4x =32), often called " queen of the forage"
- Lucerne or alfalfa (*Medicago sativa*) is a deep-rooted, temperate, perennial pasture legume
- It is most productive and nutritious forage crop grown for silage.
- Lucerne is allogamous (Cross pollination) plant, generally self-incompatible and pollinated by various insect species.

➢ General characteristics:

- Rabi fodder crop
- Perennial forage
- Nitrogen-fixer

- Fast growing
- Highly palatable and digestive
- High nutrient value
- Drought and frost tolerant

1.	**Name of Crop**	:	Lucerne
2.	**Botanical Name**	:	*Medicago sativa* L.
3.	**Family**	:	Fabaceae
4.	**Chromosome Number**	:	2n = 32
5.	**Center of Origin**	:	South-central Asia
6.	**Mode of pollination**	:	Cross pollination
7.	**Out crossing Percentage**	:	-
8.	**Related wild species**	:	As per table

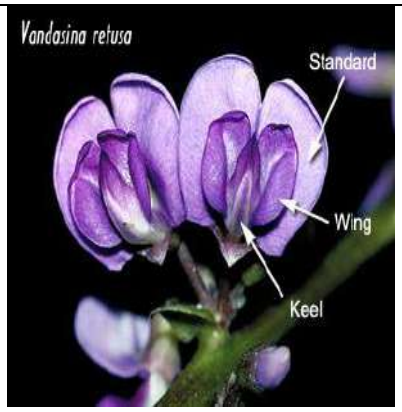
➢ **Chromosome number and wild relatives:**

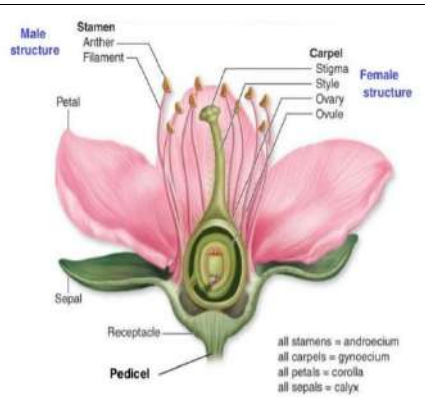
Sr. no.	Cultivated spp	No. of Chromosome	Remarks
1	Medicago sativa	2n = 32	Cultivated, perenial
2	Medicago falcate	2n =16	Diploid wild, perenial
3	Medicago coerulea	2n =16, 32	Diploid wild, perenial

➢ **Floral biology**

- Flowers are generally purple.
- They are typical pea shaped, 12-15 mm long.
- They developed in dense clusters of 20-30 flowers at the tips of the branches.
- The inflorescence is pyramidal branched panicle, flowers are sessile form spikes, spikelets often with stamens 3 and gynoecium is superior one called ovary, bifid stigma.
- Blooming normally begins near the apex of the inflorescence and progresses more or less regularly towards the base. Blooming favoured at temperature 20 to 25^0C.
- There is wide variations in anthesis of flowers.
- The flowers are typical legume types; Calyx 5 united; Corolla 5 – Standard 1, Wing 2, keel 2 free, stamens 10 (9+1 or 8+2, Staminodes in few), Gynoecium superior, monocarpellary.
- The petals partially joined and enclose the stamens and pistil.
- In alfalfa or lucerne (*Medicago sativa*) pollen is dispersed by an explosive action commonly known as ***tripping***.







- **Problems in forage crops:**

1. Most forage species are cross *pollinated*, makes it difficult to propagate and maintain the identity of lines due to heterozygous in nature.
2. *Self incompatibility*
3. Small floral parts. This makes difficult in hybridization.
4. *Apomixis*
5. Poor seed production and low viability of seeds
6. Difference in performance in wider and close (normal) spacing, grazing management etc.,
7. *Polyploidy*
8. Variation in different reproductive systems
9. Since most of them are perennials, require many years to evaluate the genotypes.
10. Many of forage produce weak seedlings and hence crop establishment is not satisfactory.

- **Crossing technique**

1. Hand emasculation and pollination (as in sorghum).
2. Bagging inflorescence of parent clones following emasculation of the seed parent. Paper covers are used for covering the inflorescence.
3. Mutual pollination by bagging together the inflorescence of the parent clones without emasculation.
4. By hot water method: panicle is immersed in hot water with temperature around 40 to 45^0C for about 5 minutes.

- **Breeding Objectives:**

  - Forage yield
  - Nutritive value
  - Seed yield
  - Cold tolerance
  - Drought tolerance
  - Salinity tolerance
  - Disease and Insect Resistance

- **Breeding Procedure:**

  - Individual plant selection
  - Mass selection

- Inbreeding and hybridization
- Recurrent selection
- Synthetic varieties
- Composite varieties

➢ **Research station:**

- **National:** ICAR- Indian Grassland and Fodder Research Institute Gwalior Road, Jhansi-284003, Uttar Pradesh
- **State:** Main Forage Research Station, Anand

➢ **Released varieties:** AL-3, AL-4

BREEDING FOR GARLIC



Garlic is the second most widely used cultivated Allium after onion. It has long been recognized all over the world as a valuable spice for foods and a popular remedy for various ailments and physiological disorders. It is grown throughout Pakistan and consumed by most of the people. It is used all over the world for flavouring various dishes.

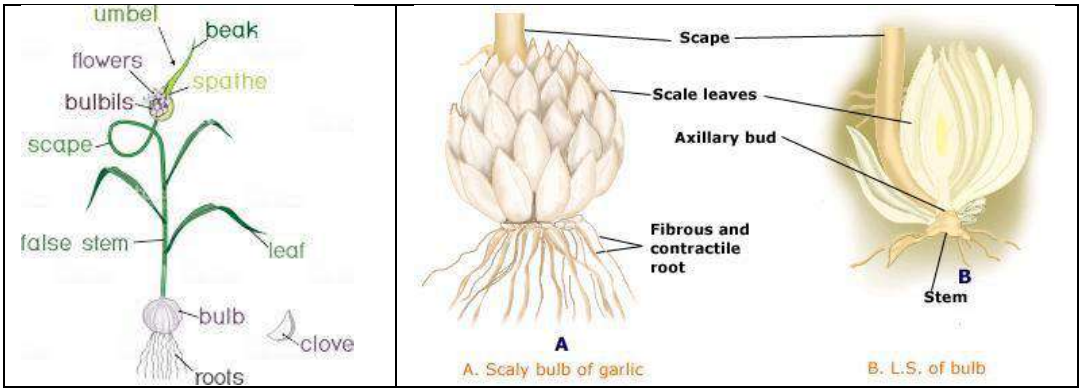
They have a characteristic pungent, spicy **flavor** that mellows and sweetens considerably with cooking. The distinctive **aroma** is mainly due to organosulfur compounds including allicin present in fresh garlic cloves and ajoene which forms when they are crushed or chopped.

The bulb is **made up of** many smaller bulbs covered with a papery skin known as cloves. Although **garlic** is known as the "stinking rose" it is actually a member of the lily family. The most active components of fresh **garlic** are an amino acid called alliin and an enzyme called allinase.

1.	**Name of Crop**	:	Garlic
2.	**Botanical Name**	:	*Allium sativum* L.
3.	**Family**	:	Amaryllidaceae
4.	**Chromosome Number**	:	2n = 16
5.	**Center of Origin**	:	Central Asia and northeastern Iran
6.	**Mode of pollination**	:	Self and Cross pollination

7.	**Out crossing Percentage**	:	-
8.	**Related wild species**	:	-

Garlic plants grow about 60 cm (2 feet) tall. Depending on the variety, the long leaves typically arise from a short hard stem above the bulb or emerge from a softer pseudostem made up of overlapping leaf sheaths. The bulb is covered with membranous skin and encloses up to 20 edible bulblets called cloves. The spherical flower cluster is initially enclosed in a pair of papery tapered bracts; the bracts split open when the green-white or pinkish flowers bloom. Flower stalks sometimes arise bearing tiny bulbils (tiny secondary bulbs that form in place of flowers) and sterile blossoms. Garlic is usually grown as an annual crop and is propagated by planting cloves or top bulbils, though seeds can be also be used.



➢ Breeding Objectives :

- High yield
- Bulb quality
- Size, shape, color, pungency, ...
- Resistance to abiotic stresses (moisture stress, high temperature, salinity and alkalinity)
- Resistance to pests(thrips)
- Resistance to diseases (purple blotch, basal rot, stem phyllium blight, bacterial storage rot)
- Longer bulb storage life

➢ Research Station:

- **National:** Directorate Of Onion and Garlic Research (DOGR), Rajgurunagar, Maharashtra
- **State:** Vegetable Research Station, JAU,Junagadh, AAU, Anand

➢ Released variety:

Bhima super, Bhima Dark red, Bhima red,Bhima Sweta, Bhima Shubhra Gujarat Garlic-2,3,4 and 5.

BREEDING FOR CUMIN



- Cumin is a drought-tolerant, tropical, or subtropical crop.
- Cultivation of cumin requires a long, hot summer of three to four months.
- At low temperatures, leaf colour changes from green to purple.
- The main producers of cumin are China and India, which produces 70% of the world supply and consumes 90% of that (which means that India consumes 63% of the world's cumin).
- Mexico is another major producer. In total, around 300,000 tons of cumin per year are produced worldwide.
- Cumin oil which is used for a variety of flavors, perfumes, and essential oil. Cumin oil may be used as an ingredient in some cosmetics.

1.	**Name of Crop**	:	Cumin
2.	**Botanical Name**	:	*Cuminum cyminum* L.
3.	**Family**	:	Apiaceae
4.	**Chromosome Number**	:	2n = 14
5.	**Center of Origin**	:	Egypt and the **Middle** East.
6.	**Mode of pollination**	:	Cross pollination
7.	**Out crossing Percentage**	:	2.34 %
8.	**Related wild species**	:	*Bunium persicum*, *Bunium bulbocastanum* and *Nigella sativa* are sometimes called black cumin

➢ **Floral biology:**

- Flowers arranged in umbels. The umbel is a type of inflorescence, similar to an inverted umbrella, which is formed because all the **flower** stalks are joined to the stem by the same point.
- The flowers are so small that artificial emasculation and cross-pollination is extremely difficult. As the artificial hybridization could not be done, the genetic studies are limited only to the study of segregating generations of chance hybrids between pink and white flowers
- The study of such crosses revealed that flower color is a single gene controlled character, pink being dominant over white.

	
Cumin seed	**Cumin flower**

- **Breeding objectives:**
  - Resistance to blight
  - Resistance to powdery mildew
  - Breeding for high yield
  - Volatile oil content
  - Seed size, colour and luster

- **Research Station:**
  - **National:** Indian Institute of Spices Research, Calicut, Kerala.
  - **State:** Spices Research Station , Jagudan (Gujarat)

- **Released varieties:**

  Guj. Cumin-1, 2 & 3, RZ-19, MC- 43, RZ -223

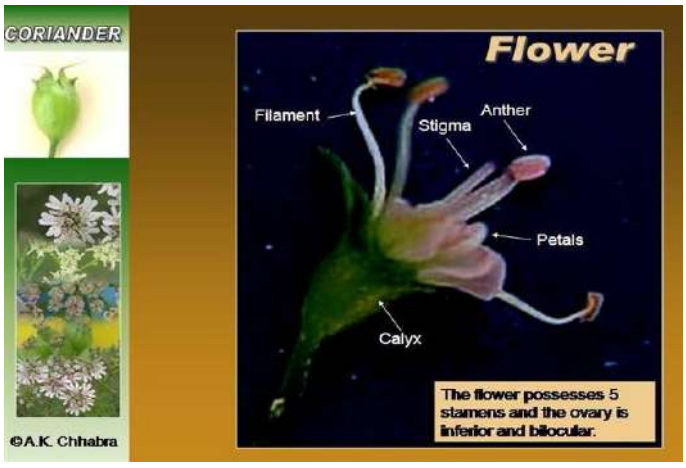
BREEDING FOR CORIANDER



1.	**Name of Crop**	:	Coriander
2.	**Botanical Name**	:	*Coriandrum sativum* L.
3.	**Family**	:	Apiaceae
4.	**Chromosome Number**	:	2n = 22
5.	**Center of Origin**	:	Mediterranean region
6.	**Mode of pollination**	:	Cross pollination
7.	**Out crossing Percentage**	:	-
8.	**Related wild species**	:	*Coriandrum tordylium*.

➢ Flower Biology:

The flowers are borne in small umbels, white or very pale pink, asymmetrical, with the petals pointing away from the center of the umbel longer (5–6 mm) than those pointing toward it (only 1–3 mm in long).





➢ Breeding objectives:

- High yield
- Volatile oil content
- Powdery mildew resistance
- Stem gall resistance
- Seed size, shape and luster

- **Research Station:**

  National: Indian Institute of Spices Research, Calicut, Kerala.
  State: Spices Research Station , Jagudan (Gujarat)

- **Varieties released:**
  CO. 1, 2 & 3, CS-287, Guj. Coriander-1 & 2, Rajendra Swathi, Rajendra Swathi, RCr-41, Sadhana, Swathi, Sindhu, RCr-20, RCr-435, RCr-436, RCr-684, Hisar Anand, UD-446, Hisar Sugandh, DH-246

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