Course No. :	BIO 111	**Credit :**	2 (1+1)
Course Title :	Introductory Biology	**Semester :**	Ist (New)

*** Theory Syllabus**

*** Teaching Schedule**

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Lecture no. 1

Introduction to the Living World. Composition and Biological Classification

Biology

Biology (bios- living, logos- study) is a scientific branch that is related with the living creatures and their body's functions. There can be seen a huge variety of living creatures on this planet.

The distinction between Living Creatures and Non-Living matter was seen by early man. Definite arrangement of identification of organisms and further their nomenclature started later. This prompted the acknowledgment of sharing similarity among life forms. Man could perceive that all the present day living beings are identified with each other furthermore to those which ever lived on this planet. The parts of this unit manage the qualities of living creatures and their characterization. Living organisms show a great biodiversity and are classified into different kingdoms- Monera, Protista, Fungi, Plantae and Animalia.

The Living World

Several type of living beings are found in various sorts of living spaces like sea, Freshwater Bodies, Backwoods, Cool Mountains, Deserts, Warm Water Springs and so on. This makes us think what is life? The answer requires separating the living and the non-living.

Fig. 1: Plant: A Living Thing

Assorted type of living beings are found in various sorts of living spaces like sea, freshwater bodies, backwoods, cool mountains, deserts, warm water springs and so on. This makes us think what is life? To find the answer for this a differentiation on living and the non-living beings is required.

What is 'Living'?

It is extremely hard to characterize "living" and traditionally different qualities common to every single living being are to be recognized. Some of them are recorded beneath:

- ✓ Cellular Association: Living things are composed of single cell (Unicellular Organisms) or many cells (Multicellular Organisms) which associate with each other to perform vital functions of the body.

- ✓ Response to Stimuli: All living things can respond and adapt themselves to any change in the environment.
- ✓ Reproduction: Living things reproduce either sexually or asexually to produce off-springs of their own kind.
- ✓ Growth: All living things grow, develop and eventually die.
- ✓ Metabolism: Living things need energy to carry out their vital life processes.

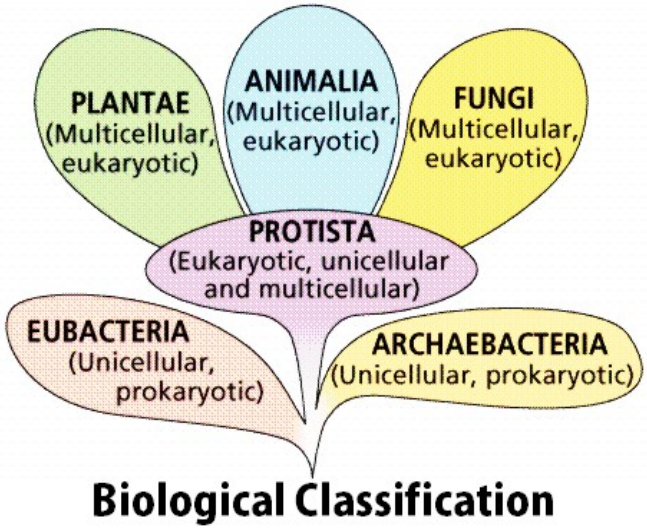
It is evaluated that more than 5 million species are available on earth. Of these around 1.7 million species are known and portrayed. Consistently a few new animal groups are portrayed and added to the rundown. Since investigation of all living beings is about incomprehensible, they are ordered into groups for the advantageous study.

Composition and Biological Classification

Biological Classification

Biological Classification is the scientific study of arranging organisms into group and subgroup on the basis of their similarities and dissimilarities and placing the group in a hierarchy of categories.

The purpose of biological classification is to organise the vast number of known plants into categories that could be named, remembered and studied.



Biological Classification

Objectives of Classification

- To identity and describe all the possible types of species.
- To arrange the species in various categories on the basis of their similarities and dissimilarities.
- To evolve a truly natural or phylogenetic system which should indicate origin and evolution of the species.
- Helping in easy identification of organisms.

Topics Covered

- Kingdom Monera
- Kingdom Protista
- Kingdom Fungi
- Kingdom Plantae and Animalia

Types of Biological Classification

There are three main types of classification- artifical, natural and phylogenetic:

1. Artificial System of Classification

It is a system of classification which uses one or two morphological character for grouping of organisms. Some artificial system have used habot and habitat for this purpose. Aristotle (c 350 BC) divided animals into two categories, enaima (with red blood) and anaima (without red blood). Aristotle also classified animals on the basis of their habitat- aquatic (e.g, fish and whale), terrestrial (e.g, reptiles, cattle) and aerial (e.g. birds, bat). Pliny the Elder (23-79 A.D.) used artificial system of classification for both plants and animals dividing them into land, air and water. Pliny distinguished animals into flight band non-flight ones. Flight animals included bats, birds and insects.

2. Natural System of Classification

It is a system of classification which takes into consideration comparable study of a number of characters so as to bring out nature similarities and dissimilarities and hence nature relationship among the organisms. The system employs those characters which are relatively constant. They include morphological characters, anatomical characters, cytological characters, physiology, ontogeny or development, reproduction, cytochemistry and biochemistry, experimental taxonomy, etc. the characteristics are helpful in bringing out maximum number of similarities in a group and comparable differences with other group of organisms. For example, mammals are characterised by the presence of mammae, birds possess wings, feathers, pneumatic bones, ovipary, 4- chambered. They are coldblooded.

Did You Know?

- Homology is the relationship of comparable structures having been derived from a common form. For example, the fore arm of different land vertebrates has the same pentadactyl constition.
- Molecular homology is the finding of relationship of comparable molecules like DNA, RNA and proteins by studying their similarities and dissimilarities. Even certain biochemicals occur in specific group, e,g. betacyanin is found in beet root and related plantes. The branch of biology that utilizes the study of chemicals in classification is called chemotaxonomy. Chromosomes or karyotypes are also important for knowing natural relationships.

3. Phylogenetic System of Classification

Classification based on evolutionary relationship of organisms is called phylogenetic system of classification. It is based on the evolutionary concept from Darwin's book- on the origin of species by means of natural selection. The preservation of favoured races in the struggle for life (1859). It reflects the true relationships among the organisms. First phylogenetic system was proposed by Engler and Prantl (1887-99). Zoologists believe that since similarity in structure represents close evolutionary relationship, their natural classification represents evolutionary and phylogenetic classification.

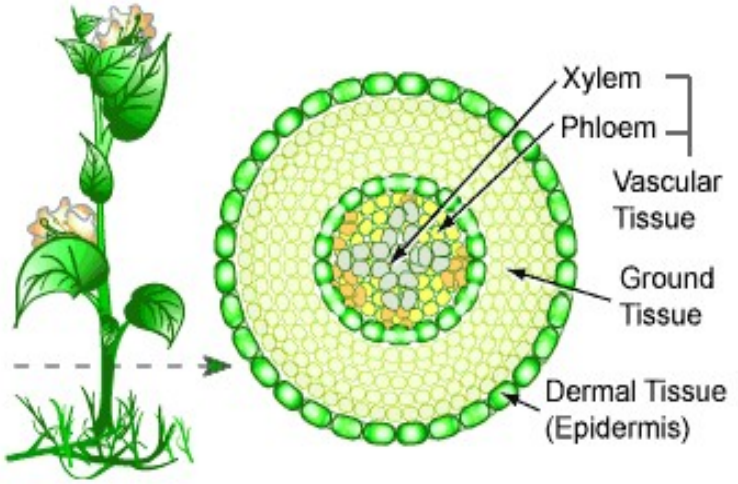
History of Classification

1. Aristotle: Father of biology & father of zoology.

2. Theophrastus:
   - ✓ He is known as father of ancient plant taxonomy and father of botany.
   - ✓ Theophrastus wrote many books on 'plants.

     Few of them are as follows:
     - Historia plantarum
     - Causes of plants
     - Enquiry into plants
   - ✓ Theophrastus gave names and descriptions of 480 plants in his book Historia plantarum.
   - ✓ Theophrastus proposes the first classification of plant kingdom. He classified plant kingdom in to four groups on the basis of growth habit. (a) Trees (b) Shrubs (c) Under shrubs (d) Herbs
3. Carolus Linnaeus: [1707 – 1778]
   - ✓ He is known as father of taxonomy, father of plant taxonomy and father of animal taxonomy.
   - ✓ Linnaeus gave the two kingdom system classification. He grouped plants and animals into kingdom plantae and kingdom Animalia respectively.
   - ✓ Linnaeus wrote many books.

     Some important books are:
     - Hortus uplandicus - First book
     - Flora lapponica
     - Philosophia botanica
     - Critica botanica
     - Systema naturae (1737)
     - Genera plantarum
     - Species plantarum -last book (1753)
4. A.P. De Candolle:
   - ✓ He wrote the book - "Theories Elementaire de la botanique".
   - ✓ He was the first to propose the significance of vascular tissue in taxonomy. On this basis of vascular tissue he classified plants into two groups



- Cellular plants (Non-vascular plants) - This group includes Thallophyta and Bryophyta

- Vascular plants - This group includes Pteridophyta, Gymnosperm and Angiosperms.

5. George Bentham (1800 -1884) and Joseph Dalton Hooker (1817 -1911):
   - ✓ Both Bentham and Hooker were related to Royal botanical garden.
   - ✓ They wrote the book "Genera plantarum" (1862 - 1883).
   - ✓ In this book, Bentham and Hooker gave the biggest and natural classification of spermatophyta i.e. plants with seeds
   - ✓ In Genera plantarum, there is description of 202 families. In it, basically the description of plants with seeds is present.
6. A. W. Eichler:
   - ✓ Syllabus de vorlesungen uber phanerogamen kunde - Book written by Eichler.
   - ✓ In this book, Eichler gave the first phylogenetic classification of plant kingdom.
   - ✓ The classification of Eichler is very little phylogenetic.
   - ✓ In this way Eichler classified plant kingdom into five divisions and arranged them in the order of evolution (Phylogeny).

7. Engler (1844 - 1930) & Pranti (1849 - 1893):
   - ✓ Book - "Die Naturlichen Pflanzen Familien".
   - ✓ He gave the phylogenetic classification of plant kingdom. This classification was more phylogenetic as compared to Eichler's classification.
8. Oswald Tippo:
   - ✓ Proposed the biggest phylogenetic classification of plant kingdom.
   - ✓ This classification is the complete classification of plant kingdom.
   - ✓ This is the most acceptable classification for books and study.
     - Cyanophyta:B.G. Alage
     - Euglenophyta:Euglenoids
     - Chlorophyta:Green algae
     - Chrysophyta:Yellow-green algae
     - Pyrrophyta:Dinoflagellates & Diatoms
     - Phaeophyta:Brown algae
     - Rhodophyta:Red algae
     - Schizomycophyta:Bacteria
     - Myxomycophyta:Slime molds (False fungi)
     - Eumycophyta:True fungi
9. Karl Menz:
   - ✓ He showed the importance of serology in taxonomy.
   - ✓ Similarities and dissimilarities in structure of proteins help to know the phylogenetic relationship of living beings. Living organisms which are phylogenetically close relatives have more similarities in their proteins.
   - ✓ Organisms which are distantly related have different proteins.

Did You Know?

(1) First tissue was originated in animal kingdom in → Coelentrata
(2) First tissues was originated "in plant kingdom in → Bryophyta
(3) Phylogenetic relationship of plants and animals can be established by animal serum. Serology indicates that chimpanzee is closest relative of man.

10. Haeckel:

- ✓ Haeckel gave the three kingdom (Protista, Plantae, Animalia) system of classification.
- ✓ Haeckel established the kingdom Protista.
- ✓ Haeckel grouped those living organisms in Protista which did not have tissues.
- ✓ Kingdom Protista: Prokaryotes, Protozoa, porifera, Algae & fungi

Five Kingdom Classification (from 1969 to 1990)

In order to develop phylogenetic classification, R.H. Whittaker (1969), an American taxonomist, divided all the organisms into five kingdoms. As the viruses are on the border line of living and non-living, they have been left out. Whittaker has used five criteria for delimiting the different kingdoms.

1. Complexity of cell structure, prokaryotic and eukaryotic.
2. Complexity of body structure or structural organization, unicellular and multicellular.
3. Mode of nutrition which is divergent in multicellular kingdoms- photoautotrophy in plantae, absorptive heterotrophy in fungi and ingestive heterotropy in animalia. Photoautotrophy totrophic nutrition is also called halophytic nutrition while ingestive heterotrophy is known as holozoic nutrition. Absorptive heterotropy is saprobiotic (saprophytic) nutrition.
4. Ecological life style like producers (plantae), decomposers (fungi) and consumers (animalia).
5. Phylogenetic relationships.

❖ **Whittaker's five kingdoms are monera, protista, plantae, fungi and Animalia.**

Table. Characteristics of five kingdom

No.	*Characters*	*Monera*	*Protista*	*Fungi*	*Plantae*	*Animalia*
1	Cell type	prokaryotic	Eukaryotic	Eukaryotic	Eukaryotic	Eukaryotic
2	Cell wall	Non-cellulosic polysaccharide+ amino acid)	Present in some (various types)	Present (non-cellulosic)	Present (cellulose)	absent
3	Chloroplast	Absent	Present in some	Absent	Present	Absent
4	Mitochondria	Absent	Present in some	Present	Present	Present
5	Nuclear membrane	Absent	Present	Present	Present	Present
6	Tissue or multicellularity	Absent	Absent	Present but limited	Present in all forms	Present in all forms

7	Motility	Bacterial flagella, gliding or nonmotile	Cilia, flagella amoeboid or contractile fibrils	Cilia, flagella in some, none in most of the forms	Cilia and flagella in lower forms, absent in most of the forms	Cilia and flagella, contractile fibrils
8	Mode of nutrition	Autotrophic-chemosynthetic and photo-synthetic, heterotrophic (saprophytic and parasitic)	Photosynthesis and heterotrophic	Heterotrophic, saprophytic and parasitic absorptive	Autotrophic by photosynthesis	Heterotrophic by ingestion
9	Reproduction/-means of genetic recombination	Conjugation transduction transformation or none	Syngamy and meiosis, conjugation or none	Fertilization and meiosis, dikaryosis or none	Fertilization and meiosis	Fertilization and meiosis
10	Nervous system	Absent	Primitive for conduction stimuli	Absent	Absent	Present, often complex

Three Domains of Life (Six Kingdom Classification) - 1990

- The three- domain system is a biological classification which was introduced by Carl Woese, a professor in the department of microbiology, university of Illinois, Urbana-Champaign in 1990 that divides cellular life forms into archaea, bacteria and eukarya domains.
- It emphasizes the separation of prokaryotes into two groups, originally called eubacteria (now bacteria) and archaebacteria (now archaea) because of their fundamental differences, Woese argued that each of the two arose separately from an ancestor with poorly developed genetic machinery, often called a progenote.
- In fact the three-domain system is loosely based on the traditional five- kingdom system but divides the monera into two ‘’domains’’, leaving the remaining eukaryotic kingdoms in the third domain.

It is actually a six kingdom classification.

(1) Archaea domain:

The domain contains prokaryotic organisms which have a monolayer core of lipids in the cell memebrane and distinct nucleotides in their 16S RNA. It contains a single kingdom.

Kingdom archaebacteria

The kingdom contain early prokaryotes which live in extreme environments,

For Example:

(a) Methanogens - metabolize hydrogen and carbon dioxide into methane.

(b) Halophiles - live in salt.

(c) Thermoacidophiles – live in acid high temperatures (upto 110 degrees Celsius).

(2) Bacteria domain:

The domain contains prokaryotes which lack membrane covered cell organelles but do have a sort of micro chambers for separating various activities. There is a single kingdom.

Kingdom eubacteria:

The domain contains diverse type of bacteria having peptidoglycan cell wall, glycogen as food reserve,naked DNA coiled to form nucleoid, absence of sap vacuoles and presence of 70S ribosomes. Some common group are bacteria, my-coplasma, ctinomycetes, rickettsiae, spirochaetes, firmicutes, and cyanobacteria.

(3) Eukarya domain.

The domain contains eukaryotic organisms which originated by endosymbiotic association between some archaebacteria and eubacteria. It has four kingdoms- protista, fungi, plantae and animalia.

Viroids (L. Virus- Point, EIos – Diminutive)

- They are the smakkest seif replicating particles which were discovered by Diener (1971).
- They are obligate parasites.
- Molecular weight of a viroid is low.
- The RNA is tightly folded to form circular or linear structure.
- Viroids are known to cuse diseases (some 20) in plants only, e,g,. Potato spindle tuber, chrysanthemum stunt. Animal or human infection is not known.
- Viroud does not production is not very clear. Viroids particle can multiply by both RNA development and DNA dependent replication.

Prions (Prusiner, 1983)

- They are highly resistant glycoprotein particles which function as infectious agents.
- They are formes due to mutation in gene PRNP.
- They can also act as catalyst converting normal protein into prion state.
- Prions are not affected by proteases, nucleases, temperature up to $800^{O}C$, UV radiations and formaldehyde.
- Prions accumulate in nervous tissue and bring its degeneration. Common diseases caused by them are scrapie of sheep, mad cow disease, cruetzfeldt-jakob disease (CJD) and kuru.

Test Your Knowledge

Question1: Trinomial nomenclature of classification was proposed by- (1) Linneaus (2) **Huxley and Stricklandt** (3) John-Ray (4) Theophrastus	Question3: Evolutionary classification is called – (1) Artificial system (2) Natural system (3) **Phylogenetic system** (4) None of the above
Question2: Most of the botanical names are drawn from the following language – (1) German (2) Greek (3) **Latin** (4) Spanish	Question4: Which system classifies a plant in more than one groups? (1) **Practical classification** (2) Artificial classification (3) Natural classification (4) Phylegenetic classification
Question5: Author of book "Flora British Indica" (1) Father Santapau (2) **J.D. Hooker** (3) William Rouxburgh (4) G. Bentham	

Lecture no. 2

Diversity and Characteristics of life

The seven characteristics of life include:

- Responsiveness to the environment;
- Growth and change;
- Ability to reproduce;
- Have a metabolism and breathe;
- Maintain homeostasis;
- Being made of cells; and.
- Passing traits onto offspring.

Building Block of Life and their Functions

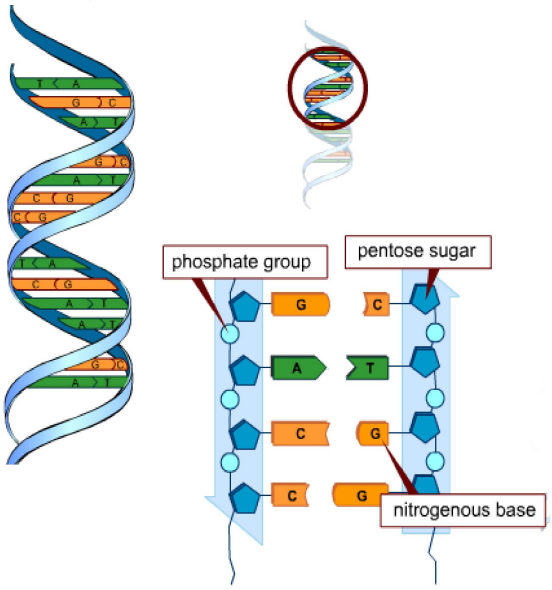
Living life form is shaped of many sorts of inorganic and also organic biomolecules. Inorganic compounds incorporate water, minerals and so on and are constantly micro biomolecules (little measured, low atomic weight, promptly dissolvable in water and diffusible) while organic particles might be smaller scale (e.g. monosugars, amino acids and so forth.) or macro biomolecules (expansive size, high sub-atomic weight, insoluble or somewhat dissolvable and non-diffusible e.g., fats, proteins, nucleic acids, and so forth.). These both sorts of biomolecules assume vital parts in digestion system:

- Role of Water: Water frames 70-90% of the cellular pool. It frames 65% (around 66%) of human body. It is framed of H and O in the proportion of 2:1. 95% of water is found in free state and 5% in consolidated shape in the cell. Water helps in supporting the life forms. Hence water is known to be a remedy or support of lip as life is impractical without water.
- Role of Oxygen: Oxygen is for the most part used in vigorous cell breath of the supplements inside the mitochondria to create energy-rich ATP particles so is fundamental forever. Without oxygen, just 5% of energy accessible is discharged.
- Role of Sodium chloride (basic salt): Sodium chloride assumes a vital part in metabolic elements of body particularly when in ionic frame.
- Role of Carbohydrates: Carbohydrates are organic compounds shaped of C, H and O for the most part in the proportion of 1:2:1. These are normally called saccharides (Gk. saccharon = sugar) Carbohydrates are the primary storage atoms and most life forms utilize starches as a vital fuel, breaking these securities and discharging energy to maintain life.
- Role of Proteins: Proteins are polymeric compounds framed by interlinking of amino acids (monomers) by peptide bonds. Out of around 100 sorts of amino acids, just 20 sorts of amino acids are of natural significance, so are called Magic 20. Proteins assume a key part in the arrangement of structures in living beings. Like starch and fat protein can be separated with the arrival of energy. Protein is not stored all things considered in the body and it is regularly just utilized as a significant wellspring of energy in states of starvation.
- Role of lipids: Lipids involve a noteworthy group of insoluble hydrocarbons having many capacities. These are polymers of alcohols (e.g. glycerol) and fatty acids interlinked by

ester bonds. Complex lipids, for example, genuine fats are critical organic atoms that are utilized to give energy. Fats in creatures likewise give security from warmth loss.

- Role of Nucleic Acid: These are polymers of nucleotides interlinked by phosphodiester bonds, alleged polynucleotides. Every nucleotide is framed of 3 segments: a pentose sugar (e.g. deoxyribose in DNA and ribose in RNA), a phosphate group and an inorganic nitrogen-base (a purine or a pyrimidine).

DNA goes about as genetic material in many living beings and controls the synthesis of auxiliary and. useful proteins. RNA likewise go about as genetic material in all plant viruses that is TMV and aides in protein synthesis.



Structure of DNA: Showing the phosphate group, pentose sugar, four nitrogenous bases namely adenine, thymine, cytosine and guanine.

Diversity

'Biological diversity' means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species and of ecosystems.

Techniques, Procedures and Stored Information that are useful in Identification and classification of organisms are called taxonomic aids. They are required because taxonomic study of plants, animals and other organisms are basic to almost all branches of biological

studies for their proper identification and finding their relationships with others. Herbarium, botanical gardens, museum, zoological parks (zoos) and key are important tools used in identification of plants and animals.

Herbarium

Herbarium is a place where dried and pressed plants specimens, mounted on sheets are kept systematically according to a widely accepted system of classification. Herbarium is a repository or store house for future use. Every institute teaching botany, school college or university, has a small or large herbarium. Very large herbaria are maintained by botanical gardens and institutes connected with plant systematic.

Every student of botany is required to collect plant specimens and prepare herbarium sheets.

Equipment: Digger and pruning knife, sickle with long handle, vasculum, polythene bags, magazines or newspapers, bolting papers, plant press, field notebook, herbarium sheets, glue, labels, small transparent polythene bags.

Specimen (Herbarium Sheet) is of Different Types

- Holotype: Herbarium sheet on which the first description of plant is based.
- Lectotype: In case of holotype is lost, second herbarium sheet prepared from the original plant is called lectotype.
- Neotype: In case holotype and original plant is lost then herbarium sheet prepared from some other plant of same

- Syntype: In case holotype and original, plant is lost then many herbarium sheet prepared from many plants of same species is called syntype.
- Isotype: Duplicate of holotype - In presence of holotype a second herbarium sheet prepared from the original plant is called isotype.
- Paratype: Additional herbarium sheet used in the first description of plant is called para type. It is prepared from some other plant of same species having some variations.

Method of Specimen Collection and Mounting

An area is selected for botanical excursion. It is preferable to visit the same site in different seasons. For herbaceous species the entire plant with intact part is collected. for others, shoots having flowers, leaves and fruits are selected and cut with the help of pruning knife. Sickle with long handle is used if the desired twigs are present at a height. Diggers are used to obtain underground part like root system, tuber, bulb, corm, rhizome, etc. The collected material can be placed in polythene bags or vacuum.

Important Herbaria

Name	Number of Herbarium Specimens
Royal Botanical Gardens, Kew (London)(largest herbarium)	6.5 million
Museum of natural history (Paris)	Over 6.0 million
Conservatories at jardin botanical institute de Geneve (Geneva)	over 5.0 million
V.L. Komarov Botanical Institute of Azerbaijan	4.0million
New York botanical Garden (New York)	4.0 million
Central national herbarium (India)	2.0 million
Madras herbarium, Coimbatore (MH), India	1,50,000
Herbarium of National Botanical Research Institute, Lucknow, India	80,000

Botanical Gardens

Botanical gardens efficiently large size tract where plants of different type and areas of grown for scientific and educational purposes. The first real mechanical garden was developed by Theophrastus (370-285 B.C.). Of course, garden was part of Indian Chinese and roman cultures. “Hanging Garden” of Babylon were considered to be wonders of ancient time. Modern day Botanical Gardens contains beside outdoor plants, greenhouse, library, research laboratory herbarium with documented collections of various taxa. There is an international association of botanical gardens (established in 1962) which coordinate research and exchange of plant materials.

The important functions of botanical gardens are:

- ✓ Growing important plants of local flora.
- ✓ Keeping record of local flora.
- ✓ Providing living plant material for systematic work.
- ✓ Supplying seeds and materials for different aspect of a Botanical research.
- ✓ Growing and maintaining rare and endangered plant.

Some major botanical Gardens of the world are:
1. Main botanical garden Moscow. Largest garden, spread over an area of 900 acres. 2. Bundes garden, Vienna. It is spread over an area of 400 acres. 3. Royal Botanical Garden, Kew London: it has an area of 300 acres but grows a very large number of plants. 4. Kebun Raya (Botanical Garden) Bojor Java. Spread over an area of 200 acres, the garden has section with virgin rain forest. 5. Indian Botanical Garden Sibpur, Kolkata. it is the largest botanical garden of Asia spread over 273 acres which is famous for its Great Banyan tree, Palm house, Succulent Plants, Indian Grasses etc.

Museum

The word museum comes from the Greek word *mouseion.* In ancient Greek *mouseion* was the temple of Muses. The goddess of arts and sciences. Museum is an institution where artistic and educational materials are exhibited to the public. The materials available in exhibition for study in called collections. A Collection may include scientific specimen, works of art and exhibits and information on history of technology.

There are five main kind of museums namely art museum, history museums, applied science museums, natural science museums and general museums.

Museums

Function of Museums

Museums Performs the following functions:

- Acquisition of materials. Every new object that a museum adds to its collection is called Acquisition. Museum acquire object in several ways, of which field collection is one of the most useful. The scientific and technician go outside to gather specimens and data on particular subject which is with the scope of the museum.
- Recording of Materials. Each acquisition is listed carefully by specialist staff. As soon as objects are received, the data, the source, the method of acquisition and other available information are entered in to record register.
- Preservation of Materials. The primary purpose of museum is to preserve selected objects are received. Curators (person in charge of museum) know that no specimens will last forever. What museums undertake to do is to prolong the lifetime of the objects. Preservation in a museum consists of two steps:
  (i) Specimens must be put into a condition that that checks deterioration.
  (ii) The specimens must be protected.
- Research: One important use of museum is to extract as much knowledge as possible specimens. Many museums published scholarly journals, series of papers and books to make available result of research on collections.
- Exhibitions of Materials: Various members of museum staff prepare acquisitions for exhibitions. The specimens selected for exhibition are put on a view in numerous ways. The choice of approach and techniques depends on the purpose of exhibits.
- Education. A Number of universities conduct some courses in certain subjects as museum university advantage of the collections. Thus museums help in spreading education.

Zoological Parks (Zoos)

A Zoo is a place where are various living animals are kept within enclosures display to the public and may be used for study. Animals may also Bred.

In fact concept of ZOO has changed instead of *Zoos*, Zoological parks or zoological gardens established where high standard of care is observed and the animal live under more natural conditions.

The animal provides better recreation to the visitors.

Nehru Zoological Park (also known as Hyderabad Zoo or Zoo Park) is a zoo located near Mir Alam Tank in Hyderabad, Telangana, India.

Zoological Parks

The Role of Zoological Parks in Wildlife Conservation

The regular zoo movement in India began in the year 1885 when the first zoo was set up in Chennai. In the Zoological park animals enjoy protection, fine sun shine, fresh air and above all ample open space to play about. They have now become repositories of threatened wild life and a store house of the knowledge on animal behavior, their breeding habit, etc. zoological park is the place where they are assured of food, medical care and treatment and where they also feel safe from their natural enemies. Zoological Parks are very useful in spreading knowledge on the wildlife wealth of the country.

Taxonomy

Taxis = orderly arrangement, nomos = law

Definition: "Taxonomy is the study of principles and procedures of classification."

Taxonomy includes study of following 4 points:

(1) Identification: Identification of living organisms

(2) Nomenclature: Nomenclature of living organisms

(3) Classification: Classification of living organisms in groups

(4) Affinities: Study of inter relationship between living organisms

Systematics (Branch Related with Taxonomy)

Definition: "Systematics is a branch of Biology that deal with cataloguing plants, animals and other organisms into categories that can be named, remembered, compared and studied."

This word was proposed by **A.P. de Candolle** in his book **"Theories elementaire de la botanique''** (Theory of elementary botany)

Study of only one organism of a group provides sufficient information about the remaining members of that group. Scientists connected with the study of systematics are called systematists or taxonomists.

Simpson, (1961) has defined systematics as the branch of biology that deals with the diversity of organisms at every level of classification.

Basics of Systematic Study

- ✓ Characterization: The organism to be studied is described for all its morphological and other characteristics.
- ✓ Identification: Based on the studied characteristics, the identification of organism is carried out to know whether it is similar to any of the known group or taxa.
- ✓ Classification: The organism is now classified on the basis of its resemblance to different taxa. It is possible that the organism may not resemble any known taxa or groups. A new group or taxon is raised to accommodate it.
- ✓ Nomenclature: After placing the organism in various taxa, its correct name is determined. If the organism is new to systematics, it is given a new name based on rules and conventions of nomenclature.

Differences between Classical Taxonomy and Modern Taxonomy

❖ Classical Taxonomy / Typological concept

- It deals with morpho species.
- It has a typological concept.
- Species is considered to be static.
- It does not study evolution.
- Interrelationship of species is also not studied.

❖ Modern taxonomy / Neo-systmatics or Biosystematics

- It is also known as Neo systematic or Biosystematics:
- It deals with biological species.
- It has a population or biosystematics concept.
- Species is considered to be dynamic.
- It studies primitiveness, advancement and inter-relationships of species.

Test Your Knowledge

Question 1: The term taxon refers to – (1) Name of a species (2) Name of genus (3) Name of family (4) **A taxonomic group of any rank**	Question 3: The standard size of herbarium sheets is – (1) **11.5" × 16.5"** (2) 15.5" × 16.5" (3) 18.5" × 10.5" (4) 20.5" × 21.5"
Question 2: The herbarium specimen on whose basis a new species is described for the first time is called as (1) Syntype (2) **Holotype** (3) Paratype (4) Neotype	Question 4: Herbarium is – (1) **A garden where medicinal plants are grown** (2) Garden where herbaceous plants are grown (3) Dry garden (4) Chemical to kill plants

Lecture no. 3 & 4

Origin of life; Theories of origin of life, Evolution, Eugenics, Genetics and Mendel's Experiment

Theories of origin of life:

Various theories have been put forward to explain the phenomenon of origin of life. A few of them were only speculations while others were based on scientific grounds. These theories are

- ✓ Theory of special creation.
- ✓ Theory of spontaneous generation or Abiogenesis.
- ✓ Biogenesis
- ✓ Cosmozoic theory
- ✓ Theory of sudden creation from inorganic material.
- ✓ Naturalistic theory

Oparin-Haldane theory of chemical origin of life:

- ✓ Oparin (1924) proposed that "life could have originated from non-living organic molecules."
- ✓ He believed in Biochemical origin of life. Haldane (1929) also stated similar views. Oparin greatly expanded his ideas and presented them as a book "The origin of life" in 1936.
- ✓ According to this theory, the Earth originated about 4,500 million years ago. When the earth was cooling down, it had a reduced atmosphere. In this primitive atmosphere nitrogen, hydrogen, ammonia, methane, carbon mono-oxide and water were present. Energy was available in the form of electric discharges by lightning and ultraviolet rays. As soon as the earth crust was formed, it was very much folded. Torrential rains poured over the earth for centuries and were deposited in deep places.
- ✓ Miller's Experiment: An American scientist (Biologist) Stanley Miller (1953) performed an experiment under support Oparin's theory of origin of life. He believed that basic compounds which are essential for life can be synthesised in the laboratory by creation in the laboratory, on a small scale, the conditions which must have existed at the time of origin of life on earth.
- ✓ Miller took a flask and filled it with methane, ammonia and hydrogen in proportion of 2:1:2 respectively at 0°C. This proportion of gases probably existed in the environment at time of origin of life. This flask was connected with a smaller flask that was filled with water, with the help of glass tubes. In the bigger flask, two electrodes of tungsten were fitted. Then a current of 60,000 volts was passes, through gases containing bigger flask for seven days. At the end of seven days, when the vapours condensed, a red substance was found in the U-tube. When this red substance was analysed, it was found to contain amino acids, Glycine and nitrogenous bases which are found in the nucleus of a cell.
- ✓ The entire process of the origin of life, as proposed by Oparin, can be summarised as under

The Chemical Evolution:

- ✓ Step 1: Formation of simple molecules
- ✓ Step 2: Formation of Simple organic compounds
- ✓ Step 3: Formation of complex organic compounds
- ✓ Step 4: Formation of nucleic acids and nucleoproteins

Organic Evolution:

- ✓ Step 5: Formation of Coacervates
- ✓ Step 6: Formation of Primitive cell
- ✓ Step 7: Origin of autotrophism
- ✓ Step 8: Origin of Eukaryotic cells

Evidences of Organic Evolution

The following are the evidences in favour of Organic Evolution:

(i) Evidences from Classification
(ii) Evidences from Comparative Anatomy
  (a) Analogy and Homology
  (b) Vestigeal organs
(iii) Evidences from Physiology
(iv) Evidences from Serology
(v) Evidences from Embryology
(vi) Evidences from Palaeontology
(vii) Evidences from geographic distribution
(viii) Evidences from Genetics

Evidences of Organic Evolution

1. Evidences from Classification: All the known living animals and plants have been classified into various species, genera, families, order, classes, phyla and kingdoms. The classification of a particular animal is attempted only after its extensive study.
2. Evidences from Comparative Anatomy: In all the living animals, the basic substance of life is Protoplasm. If the species had been created separately, then there should be no relationship in the various organs and systems of animals. But on the contrary, we see that large number of animals although unlike in appearance show most of the systems and organs made on the same plan. The resemblance is very close in the members of the same group.
3. Evidences from Physiology: Various types of chemical tests exhibit many basic similarities in physiological and chemical properties that show a physiological relationship among animals.
4. Evidences from Serology: This is a method by which the reactions of blood serum are observed. From the blood are also extracted the crystals of Oxyhaemoglobin. The structure differs in different vertebrates, but in a definite order. The reaction is nearly identical in man and anthropoid monkeys, but slightly less identical with other mammals.
5. Evidences from Embryology: With the exception of a few, every multi-cellular animal originates from a zygote. The development from zygote to adult shows many similarities in various organisms. The development is termed as ontogeny
6. Evidences from Palaeontology: The study of fossils and their interpretation forms one of the great evidences of evolution. An Italian scientist, Leonardo da Vinci, was the first person to

recognize their importance and said they were either remains of organisms of their impressions on some sort of clay or rock.

7. Evidences from geographic distribution: If the study of horizontal distribution of animals on the face of this earth is made, it would be seen that animals are not evenly distributed. Two identical places with the same climate and vegetation may not have same sort of animal fauna
8. Evidences from Genetics: Johan Gregor Mendel in 1866 published his work on experimental breeding. He bred two individuals differing in certain well-defined characters, and observed the ratio in which various contrasting parental characters appeared in successive generations.

Theories of organic evolution

(i) Lamarckism: Lamarck (1744 –1829) was one of the most brilliant stars on the horizon of the history of evolution. He was the first naturalist to put forward a general theory of evolution in his famous book. Philosophic Zoologique published in 1809. His evolutionary theory may be summarised in the form of following laws:

(a) The internal forces of life tend to increase the size of an organism.
(b) The necessity in animals to produce new structures.
(c) The effect of use and disuse.
(d) Inheritance of acquired characters.

Difference between Lamarckism and Neo–Lamarckism

Lamarckism	Neo–Lamarckism
(1) It is original theory by Lamarck.	(1) It is a modification of the original theory of Lamarck in order to make it more suitable to modern knowledge.
(2) The theory lays stress on internal force, appetency and use and disuse of organs.	(2) Neo–Lamarckism does not give any importance to these factors.
(3) It believes that changes in environment bring about a conscious reaction in animals.	(3) The theory stresses on the direct effect of changed environment on the organisms.
(4) According to Lamarckism the acquired characters passes on to the next generation.	(4) Normally only those modifications are transferred to next generation which influence germ cells or where somatic cells give rise to germ cells.

(iii) Darwinism: Charles Robert Darwin was undoubtedly the first naturalist who put the idea of organic evolution on sound footing. His statements and theories were based upon practical experiences and large number of proofs which he collected directly from the nature.

His main ideas about the evolution are given below –

(a) Over – production of offspring
(b) Limited supply of food and shelter
(c) Struggle for existence:
(i) Intra –specific
(ii) Inter –specific
(iii) Environment
(d) Survival of the fittest
(e) Universal occurrence of variations

(f) Inheritance
(g) Natural selection

Difference between Darwinism and Neo–Darwinism

Darwinism (Natural Selection)	Neo–Darwinism
(1) It is the original theory given by Charles Darwin (1859) to explain the origin of new species.	(1) Neo–Darwin is a modification of the original theory of Darwin to remove its short–comings.
(2) According to this theory accumulation of continuous variations causes changes in individuals to form new species.	(2) Instead of continuous variations, mutations are believed to help form new species.
(3) It believes in the selection of individuals on the basis of accumulation of variation.	(3) Variations accumulate in the gene pool and not in the individuals.
(4) Darwinism does not believe in isolation.	(4) Neo–Darwinism incorporates isolation as an essential component of evolution.
(5) It can explain the origin of new characters.	(5) The theory can explain the occurrence of unchanged forms over millions of years.
(6) Darwinism cannot explain the persistence of certain forms in the unchanged condition.	(6) Normally only those modifications are transferred to next generation which influence germ cells or where somatic cells give rise to germ cells.

Difference amongst Lamarckism, Darwinism and Mutation Theory

Properties	Lamarckism	Darwinism	Mutation Theory
Vital force	The theory believes that every organism has an internal vital force that tends to increase its size up to a certain limit.	Darwinism does not believe in internal vital force.	No internal vital force is involved.
Conscious Reaction	Animals with well-developed nervous system react consciously to any change in environments	Darwinism does not involve any conscious reaction.	No conscious reaction is believed to take part in the process of evolution.
Appentency	The theory considers appentency or desires on the part of animals an important force in the development of modifications.	It is not a constituent of the theory.	Appentency in not involved.
Use and Disuse	The organs put to more use are believed to develop more while organs not used begin to degenerate.	The theory is silent about use and disuse of organs.	The theory is silent about it.
Inheritance of Acquired Characters	The characters acquired by an organism during its life are	According to Darwin, all the living cells produce minute	Only those variations are transferred to the offspring which

	believed to get transferred the next generation.	particles or pangenesis, which pass into germ cells for transmission to the offspring.	originate in germ cells or in the cells which form germ cells.
Struggle for Existence	The theory does not clearly spell out struggle for existence in relation to high biotic potential.	Organisms produce more offspring than the available food and space so that a struggle for existence ensues amongst them.	The theory believes in the struggle for existence.
Origin of Variations	Variations appear in organisms in response to change in environment, conscious reaction, desire r use and disuse of organs.	Variations appear automatically.	Variations appear due to change in genetic makeup.
Continuous Variations	The theory is silent about them though it believes in a continuous modification of organs in a particular direction.	It is based on the origin and selection of continuous variations.	The theory is based on discontinuous variations or mutations.
Natural Selection	The theory does not take into account natural selection or survival of the fittest.	Darwinism is based on natural selection or survival of the fittest.	Mutations theory believes in natural selection or survival of the fittest.
Progress of Evolution	Evolution is a continuous process which moves in a direction governed by environment and appentency.	Evolution is a continuous process, the direction of which is governed by nature.	Evolution is a jerky process, the direction of which is unpredictable though ultimately it is governed by nature.

Eugenics

It is branch of botany in which application of principles of genetics for improving the human being or races.

The science of improving a population by controlled breeding to increase the occurrence of desirable heritable characteristics

Genetics

Genetics is the branch of science concerned with genes, heredity, and variation in living organisms.

Genetics is the study of genes, genetic variation, and heredity in living organisms. Genetics is the study of genes, genetic variation, and heredity in living organisms.

Branches of Genetics

- ✓ Cytogenetics
- ✓ Biochemical Genetics
- ✓ Molecular Genetics
- ✓ Quantitative Genetics
- ✓ Qualitative Genetics
- ✓ Mendelian Genetics
- ✓ Population Genetics

Mendel's Experiment

For thousands of years farmers and herders have been selectively breeding their plants and animals to produce more useful hybrids. It was somewhat of a hit or miss process since the actual mechanisms governing inheritance were unknown. Knowledge of these genetic mechanisms finally came as a result of careful laboratory breeding experiments carried out over the last century and a half.

Gregor Mendel
1822-1884

By the 1890's, the invention of better microscopes allowed biologists to discover the basic facts of cell division and sexual reproduction. The focus of genetics research then shifted to understanding what really happens in the transmission of hereditary traits from parents to children. A number of hypotheses were suggested to explain heredity, but Gregor J. Mendel, a little known Central European monk, was the only one who got it more or less right. His ideas had been published in 1866 but largely went unrecognized until 1900, which was long after his death. His early adult life was spent in relative obscurity doing basic genetics research and teaching high school mathematics, physics, and Greek in Brno (now in the Czech Republic). In his later years, he became the abbot of his monastery and put aside his scientific work.

While Mendel's research was with plants, the basic underlying principles of heredity that he discovered also apply to people and other animals because the mechanisms of heredity are essentially the same for all complex life forms.

Common edible peas

Through the selective cross-breeding of common pea plants (*Pisum sativum*) over many generations, Mendel discovered that certain traits show up in offspring without any blending of parent characteristics. For instance, the pea flowers are either purple or white-intermediate colors do not appear in the offspring of cross-pollinated pea plants. Mendel observed seven traits that are easily recognized and apparently only occur in one of two forms:

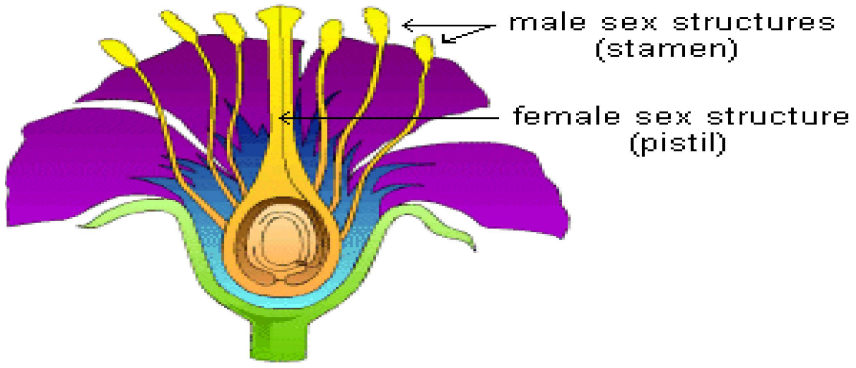
1. flower color is purple or white
2. flower position is axil or terminal
3. stem length is long or short
4. seed shape is round or wrinkled
5. seed color is yellow or green
6. pod shape is inflated or constricted
7. pod color is yellow or green

This observation that these traits do not show up in offspring plants with intermediate forms was critically important because the leading theory in biology at the time was that inherited traits blend from generation to generation. Most of the leading scientists in the 19th century accepted this "blending theory." Charles Darwin proposed another equally wrong theory known as "pangenesis". This held that hereditary "particles" in our bodies are affected

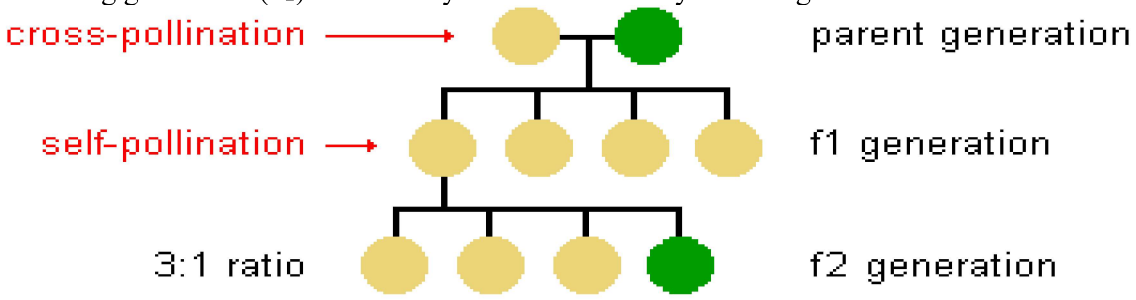
by the things we do during our lifetime. These modified particles were thought to migrate via blood to the reproductive cells and subsequently could be inherited by the next generation. This was essentially a variation of Lamarck's incorrect idea of the "inheritance of acquired characteristics."

Mendel picked common garden pea plants for the focus of his research because they can be grown easily in large numbers and their reproduction can be manipulated. Pea plants have both male and female reproductive organs. As a result, they can either self-pollinate themselves or cross-pollinate with another plant. In his experiments, Mendel was able to selectively cross-pollinate purebred plants with particular traits and observe the outcome over many generations. This was the basis for his conclusions about the nature of genetic inheritance.

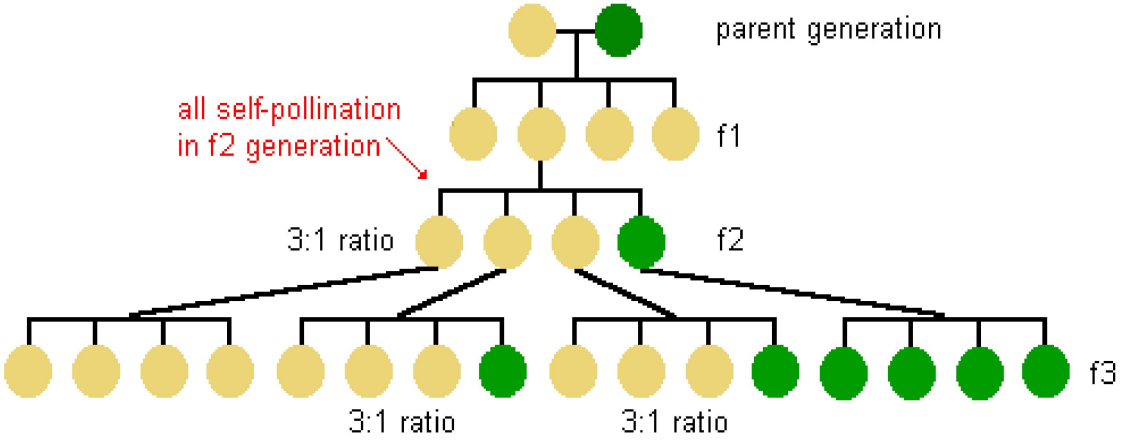
Reproductive structures of flowers



In cross-pollinating plants that either produce yellow or green pea seeds exclusively, Mendel found that the first offspring generation (f1) always has yellow seeds. However, the following generation (F_2) consistently has a 3:1 ratio of yellow to green.



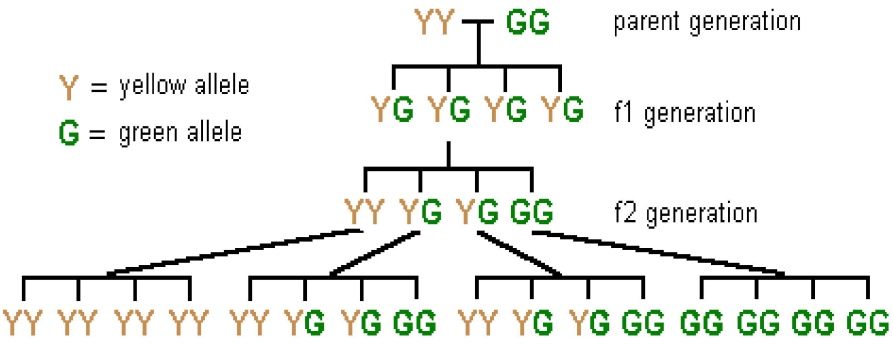
This 3:1 ratio occurs in later generations as well. Mendel realized that this underlying regularity was the key to understanding the basic mechanisms of inheritance.



He came to three important conclusions from these experimental results:

1. That the inheritance of each trait is determined by "units" or "factors" that are passed on to descendants unchanged. (these units are now called genes)
2. That an individual inherits one such unit from each parent for each trait.
3. That a trait may not show up in an individual but can still be passed on to the next generation.

It is important to realize that, in this experiment, the starting parent plants were **homozygous** for pea seed colour. That is to say, they each had two identical forms (or **alleles**) of the gene for this trait--2 yellows or 2 greens. The plants in the f1 generation were all **heterozygous**. In other words, they each had inherited two different alleles-one from each parent plant. It becomes clearer when we look at the actual genetic makeup, or **genotype**, of the pea plants instead of only the **phenotype**, or observable physical characteristics.



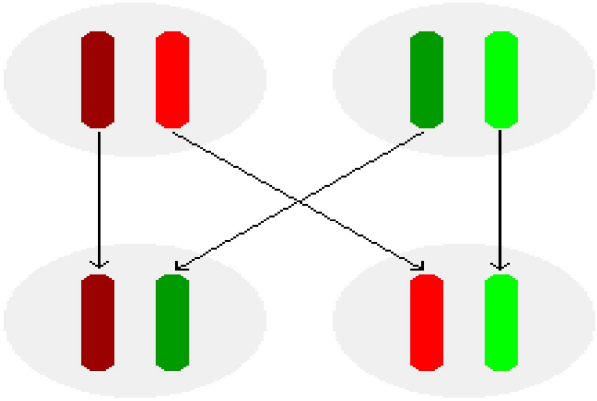
Note that each of the F_1 generation plants (shown above) inherited a Y allele from one parent and a G allele from the other. When the f1 plants breed, each has an equal chance of passing on either Y or G alleles to each offspring.

With all of the seven pea plant traits that Mendel examined, one form appeared **dominant** over the other, which is to say it masked the presence of the other allele. For example, when the genotype for pea seed color is YG (heterozygous), the phenotype is yellow. However, the dominant yellow allele does not alter the **recessive** green one in any way. Both alleles can be passed on to the next generation unchanged.

Mendel's observations from these experiments can be summarized in two principles:

1. The principle of segregation
2. The principle of independent assortment

According to the **principle of segregation**, for any particular trait, the pair of alleles of each parent separate and only one allele passes from each parent on to an offspring. Which allele in a parent's pair of alleles is inherited is a matter of chance. We now know that this segregation of alleles occurs during the process of sex cell formation (i.e., meiosis).



Segregation of alleles in the production of sex cells

According to the **principle of independent assortment**, different pairs of alleles are passed to offspring independently of each other. The result is that new combinations of genes present in neither parent are possible. For example, a pea plant's inheritance of the ability to produce purple flowers instead of white ones does not make it more likely that it will also inherit the ability to produce yellow pea seeds in contrast to green ones. Likewise, the principle of independent assortment explains why the human inheritance of a particular eye color does not increase or decrease the likelihood of having 6 fingers on each hand. Today, we know this is due to the fact that the genes for independently assorted traits are located on different chromosomes.

These two principles of inheritance, along with the understanding of unit inheritance and dominance, were the beginnings of our modern science of genetics. However, Mendel did not realize that there are exceptions to these rules. Some of these exceptions will be explored in the third section of this tutorial and in the Synthetic Theory of Evolutiontutorial.

By focusing on Mendel as the father of genetics, modern biology often forgets that his experimental results also disproved Lamarck's theory of the inheritance of acquired characteristics described in the Early Theories of Evolution tutorial. Mendel rarely gets credit for this because his work remained essentially unknown until long after Lamarck's ideas were widely rejected as being improbable.

What is Evolutionary Genetics?

Evolutionary genetics is defined as how genetic variation leads to evolutionary change. It includes, evolution of structure of genome, genetic basis of adaptation and specification and genetic changes in response to selection within the population. Evolutionary genetics is the sum of population genetics and evolution.

Genome Evolution

Genome evolution is defined as the process by which genome changes in structure and size with time.

Lecture no. 5

Binomial Nomenclature and Classification

Nomenclature

Frequently, the living beings around us are identified by local names which vary from spot to spot and dialect to dialect. Consequently there is a need to institutionalize naming them. Researchers have figured certain strategies to allot scientific name to every creature. International Code for Botanical Nomenclature (ICBN) and International code for Zoological Nomenclature (ICZN) were advanced to appoint scientific names for animals and plants separately. The investigative name has two segments Generic Name and the Particular Sobriquet. This arrangement of naming is called Binomial Nomenclature. It was given via Carolus Linnaeus and is utilized by scientists everywhere throughout the world. Examples: *Mangifera indica* (Mango); *Homo sapiens* (Man). In this case, *Mangifera* and *Homo* are the generic names; *indica* and *sapiens* are specific epithets.

1. Polynomial system:

According to this system name of any plant consists of many words.

For Example: Caryophyllum-Cqryophyllum saxatilis folis gramineus umbellatis corumbis.

2. Binomial system:

Binomial system was first proposed by Gaspard Bauhin in his book - "Pinax Theatre Botanica".

Principle of Priority: The nomenclature is done by principle of priority. If two names are proposed for any plant after the 1753, the valid name is the earlier name proposed just after 1 May, 1753.

ICBN - "International Code of Botanical Nomenclature"

Did You Know?

- ICBN - Book of rules of nomenclature
- Collection of rules regarding scientific nomenclature of plants is known as ICBN
- ICBN was firstly proposed by Sprague, Hitchcock, Green (1930).
- ICBN was first accepted in 1961.
- 12th International congress, Leningrade, revised ICBN in 1975.
- After revision it was republished in 1978. So that ICBN was published two times:
  (1) 1961
  (2) 1978

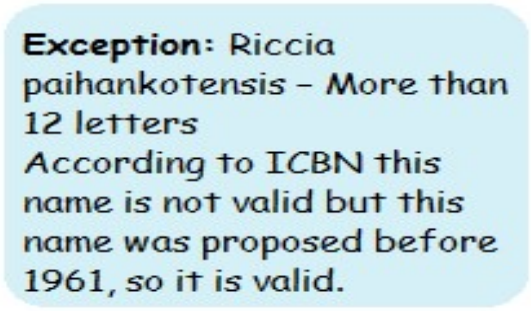
Main Rules of ICBN

1. According to binomial system name of any species consists of two names
   (i) Generic name - Name of genus
   (ii) Specific name - Trival name

Example: Specific Name: Mango; Generic Name: *Mangifera indica*

2. In plant nomenclature (ICBN), tautonyms are not valid i.e. generic name and specific name should not be same in plants. Example: *Mangifera mangifera*

But tautonyms are valid for animal nomenclature (ICZN-International Code of Zoological Nomenclature)
Example: *Naja naja* (Indian cobra), *Raitus rattus* (Rat)



3. Length of generic mime or specific name should not be less than 3 letters and not more than 12 letters.
Example: *Mangifera indica*
4. First letter of generic name should be in capital letter and first letter of specific name should be in small letter. Example: *Mangifera indica*
But if specific name is based on the name of some person, its first letter should be in capital letter ego lsoetes Pantii
5. When written with free hand or typed, then generic name and specific name should be separately underlined. But during printing, name should be italized.
6. Name of scientist (who proposed nomenclature) should be written in short after the specific name Example: *Mangifera indica* Lin.
7. Name of scientist should be neither underlined nor written in italics, but written in roman, letters (simple alphabets)
8. If any scientist has proposed wrong name then his name should be written in bracket and the scientist who corrected the name should be written after the bracket.
Example: *Tsuga canadensis* (Lin.) Salisbury
Note: Linnaeus named this plant as *Pinus canadensis*
9. Scientific names should be derived from Latin or Greek languages because they are dead languages.
10. Type specimen (Herbarium Sheet) of newly discovered plant should be placed in herbarium (Dry garden).
11. Standard size of herbarium sheet is 11.5 × 16.5 inches
ICNB = International Code of Nomenclature 'for Bacteria
ICVN = International Code of Viral Nomenclature
ICNCP = International Code of Nomenclature for Cultivated Plants

3. Trinomial System:

Proposed by Huxley and Stricklandt. According to this system name of any plant or species is composed of three names

(i) Generic name
(ii) Specific name
(iii) Subspecifie name (Name of variety)

When members of any species have large variations then trinomial system is used. On the basis of dissimilarities this species is classified into subspecies

Example: *Brassica oleracea* var. *botrytis* (Cauliflower)
Brassica oleracea var. *capitata* (Cabbage)
Brassica oleracea var. *caulorapa* (Knol-Khol)

Types of Classification

There are three main types of classification- artifical, natural and phylogenetic:

1. Artificial System of Classification

It is a system of classification which uses one or two morphological character for grouping of organisms. Some artificial system have used habot and habitat for this purpose. Aristotle (c 350 BC) divided animals into two categories, enaima (with red blood) and anaima (without red blood). Aristotle also classified animals on the basis of their habitat- aquatic (e.g, fish and whale), terrestrial (e.g, reptiles, cattle) and aerial (e.g. birds, bat). Pliny the Elder (23-79 A.D.) used artificial system of classification for both plants and animals dividing them into land, air and water. Pliny distinguished animals into flight band non-flight ones. Flight animals included bats, birds and insects.

2. Natural System of Classification

It is a system of classification which takes into consideration comparable study of a number of characters so as to bring out nature similarities and dissimilarities and hence nature relationship among the organisms. The system employs those characters which are relatively constant. They include morphological characters, anatomical characters, cytological characters, physiology, ontogeny or development, reproduction, cytochemistry and biochemistry, experimental taxonomy, etc. the characteristics are helpful in bringing out maximum number of similarities in a group and comparable differences with other group of organisms. For example, mammals are characterised by the presence of mammae, birds possess wings, feathers, pneumatic bones, ovipary, 4- chambered. They are coldblooded.

3. Phylogenetic System of Classification

Classification based on evolutionary relationship of organisms is called phylogenetic system of classification. It is based on the evolutionary concept from Darwin's book- on the origin of species by means of natural selection. The preservation of favoured races in the struggle for life (1859). It reflects the true relationships among the organisms. First

phylogenetic system was proposed by Engler and Prantl (1887-99). Zoologists believe that since similarity in structure represents close evolutionary relationship, their natural classification represents evolutionary and phylogenetic classification.

Test Your Knowledge

Question 1: Which of the following is a correct name -

(1) *Solanum tuberosum*

(2) Solanum Tuberosum

(3) ***Solanum tuberosum*** **Linn**

(4) All the above

Question 2: Taxonomy refers to –

(1) Plant classification

(2) Plant nomenclature

(3) Plant affinity

(4) **All the above**

Question 3: ICBN was first revised in –

(1) 1961

(2) 1964

(3) **1975**

(4) 1753

Question 4: Systematics deals with –

(1) Classification

(2) Nomenclature

(3) **Plant description**

(4) Plant exploration

Question 1: Artificial system of classification classifies plants on the basis of-

a. **One or two characters**

b. Phylogenetic trends

c. Many naturally existing characters

d. None of the above

Question 2: The term new systematics was introduced by –

a. Linnaeus

b. Bentham

c. Hutchinson

d. **Huxley**

Question 3: Group of organisms that closely resemble each other and freely interbreed in nature, constitute a-

a. **Species**

b. Genus

c. Family

d. Taxon

Question 4: The scientific naming of plants began with publication of Linnaeus book –

a. Genera plantarum

b. Systema naturae

c. **Species plantarum**

d. Charaka sanhita

Question 5: The basic unit of classification is –

a. Genus

b. **Species**

c. Order

d. All of the above

Lecture no. 6 & 7

Cell and cell division

Cell

The Cell (from Latin *cella,* meaning "Small Room") is the basic Structural, Functional, and Biological unit of all known Living Organisms. A cell is the Smallest Unit of life that can replicate independently, and cells are often called the "Building Blocks of Life". The study of cells is called Cell Biology.

Cell is the fundamental structural and functional unit of all living organisms.

Discovery of a cell

Anton Von Leeuwenhoek first saw and described a Live Cell. *Robert Brown* discovered the cork cell. *Robert Brown* later discovered the Nucleus.

Types of Cells

There are different types of cells present in human body. The largest cell in the human body is Ovum in females. And the smallest cell in the human body is Sperm.

Apart from these, brain contain nerve cell or neurons, liver cells are known as Hepatocytes, Kidney cells are known as Nephron etc.

Why the Cell is the basic Unit of Life?

Every living organism such as plants and animals are made up of cells. So, cell is considered as the basic unit of life.

Functions of Cell

Cells perform different functions in different parts of the body. For Example: Neuron transmits information from brain to different parts of the body. Nephron is a structural and functional unit of kidney. Nephron helps in removal of nitrogenous waste from the body. Cells perform variety of metabolic reactions such as breakdown of complex molecules to release energy. Cells also synthesizes new molecules required by the body.

Cell theory

In 1838, *Matthias Schleiden*, a German botanist, examined that plants are made up of large number of cells. Theodore Schwann (1839), a British Zoologist, examined that animals are also made up of cells.

Later on, Rudolf Virchow explains that cells arise from pre-existing cell. This is known as *Omnis cellula-e cellula.*

Characteristics of Cell Theory

- Cell is the structural and functional unit of life
- All organisms: plants and animals are made up of cells.
- All cells arise from the pre-existing cells.

Types of Cell

1. Prokaryotes

Bacteria, blue green algae, mycoplasma and PPLO (Pleuro Pneumonia like Organisms) represents prokaryotes. The cell of prokaryotes is known as Prokaryotic Cells. These cells are small in size and multiply at a faster rate. Prokaryotes have outermost covering known as Cell Wall, except in mycoplasma.

2. Eukaryotes

It includes protists, plants, fungi and animals. They have cell organelles separated by a membrane. They have well developed nucleus separated by a nuclear membrane.

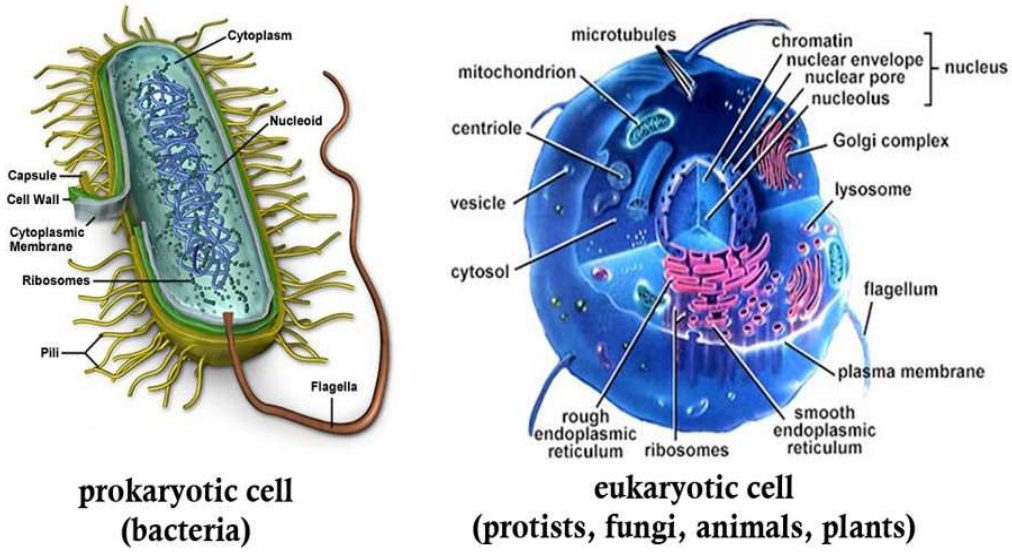


Fig.2. Prokaryotic and Eukaryotic Cell

Parts of cell/ Human cell/ Human cell structure

Plasma Membrane

In eukaryotes (higher organisms), cell is surrounded by a membrane known as Plasma Membrane or Cell Membrane. Plasma membrane is made up of lipids and protein. This membrane is selective or semi-permeable in nature, that is, it allows only certain molecules to enter the cell while remaining left outside the cell.

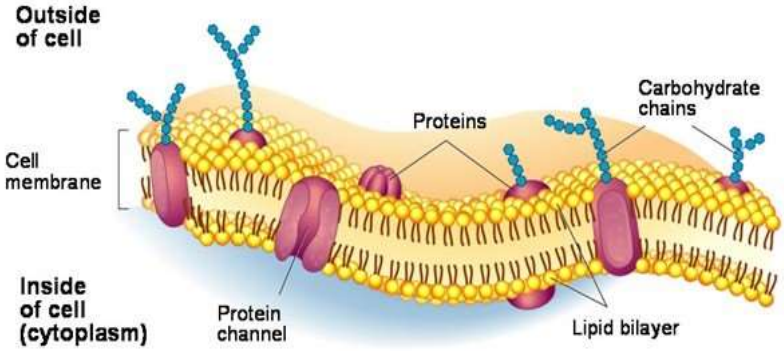


Fig.3. Structure of Plasma Membrane

Plant cell is surrounded by cell wall. Cell wall is made up of polysaccharide known as Cellulose. Cellulose provides strength and rigidity to the cell.

There are certain modification of Plasma Membrane such as:

Bacteria have outermost envelope known as Glycocalyx. Glycocalyx is followed by cell wall and then plasma membrane. It is protective in nature. According to cell envelope or staining procedure, bacteria is classified as gram negative and gram positive. Bacteria that can be stained using gram stain are known as Gram Positive bacteria whereas those which are not stained are considered Gram Negative bacteria.

If glycocalyx is a loose sheath, then it is known as Slime Layer whereas if it is thick and tough it is known as Capsule.

Fluid Mosaic Model

According to this model, plasma membrane is composed of phospholipids, cholesterol, and proteins and exists in fluid state. The outer face of membrane contains glycoproteins ad glycolipids.

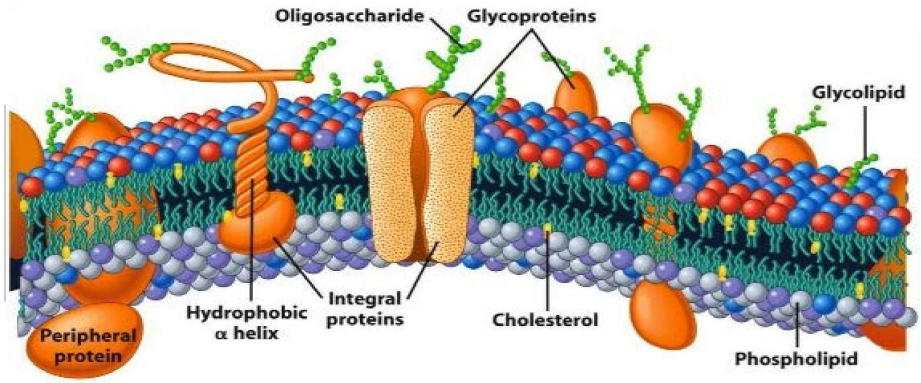


Fig.4. Fluid mosaic model

Glycolipids are carbohydrates attached to lipids whereas glycoproteins are carbohydrates attached to carbohydrates.

Ribosomes

These are the sites of protein synthesis. They are composed of two subunits- 50S and 30S subunit. These subunits together form 70S unit. 70S ribosome is present in bacteria. Eukaryotes contain 80S ribosome. The subunit of eukaryotic ribosomes is 60S and 40S. In prokaryotes, reserve material is stored in cytoplasm is the form of inclusion bodies.

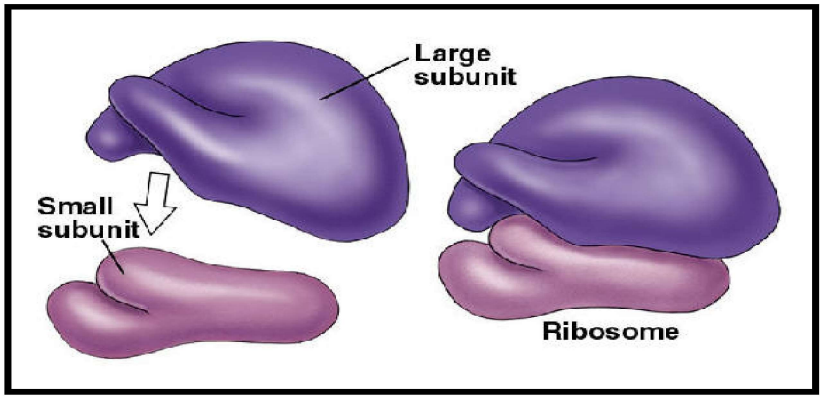


Fig.5. Subunits of Ribosomes

Endomembrane System

It includes nucleus, Endoplasmic Reticulum, Mitochondria, Lysosomes, Golgi apparatus, Plastids in plants and vacuole.

Endoplasmic Reticulum

A network of tubules spread in a cytoplasm is known as Endoplasmic Reticulum or ER. Inside of the ER is known as Lumen whereas outside the lumen is known as Extra Luminal. There are two types of ER- Rough ER and Smooth ER. Rough ER is covered by ribosomes whereas smooth ER do not contain ribosomes.

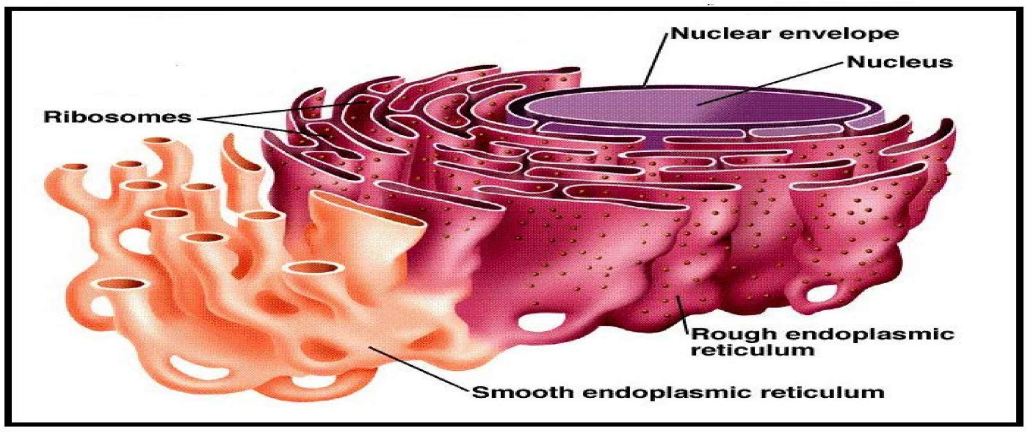


Fig.6. 3D Structure of ER

Rough ER is involved in protein synthesis and smooth ER is involved in fatty acid synthesis and detoxification.

Golgi apparatus

Camillo Golgi first observed this structure. They consist of many flat, disc-shaped sacs or cisternae of 0.5µm to 1.0µm diameter. They are arranged near the nucleus. The side facing the nucleus is known as Cis Face whereas side away from the nucleus is known as Trans Face. It is primarily involved in secretion process.

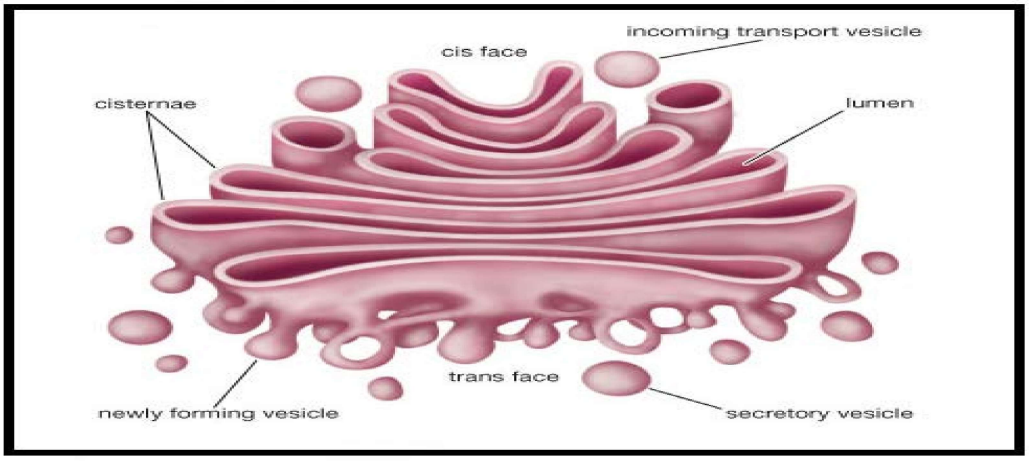
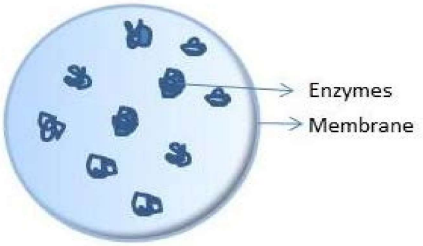


Fig.7. Structure of Golgi apparatus

It packages the materials in vesicles and helps in transportation to different cell organelles as well as outside the cell organelle.



Lysosomes

It is a membranous structure formed from golgi apparatus. It is garbage collector of the cell. It contains various hydrolytic enzymes such as lipases, proteases which works at acidic environment. They help in digestion of lipids, Proteins and Carbohydrates.

Vacuoles

These are more prominent in plant cells as compared to animal cells. It contains water, sap and excretory product. The vacuole is bound by a membrane known as Tonoplast.

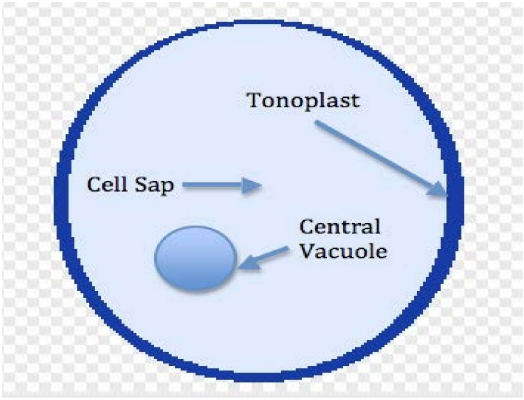
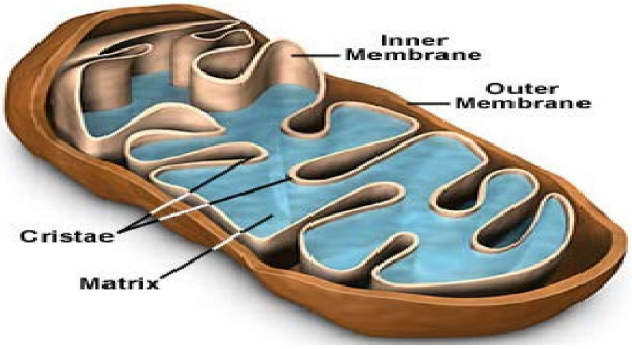


Fig.9. Structure of Vacuole

Amoeba contain vacuole-like structure known as Contractile Vacuole. This is essential for excretion.



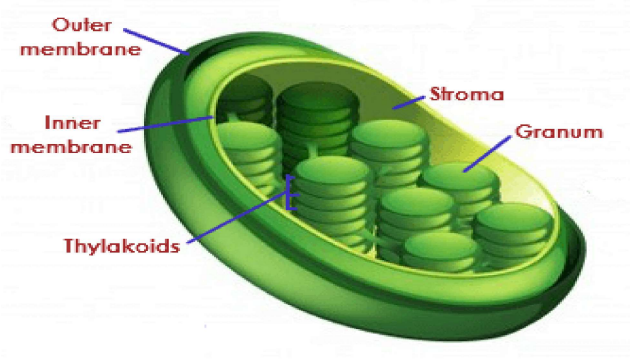
Mitochondria

It has a double membrane structure – The Outer membrane and Inner membrane. The inner membrane is folded to form a structure known as Cristae. It is a site for ATP synthesis. The outer membrane and inner membrane is separated by intermembrane space. The inner

compartment is known as Matrix. DNA and ribosomes are present in the matrix of the mitochondria.

Plastids

These are found in plant cells. There are three types of plastids- Chloroplast, Chromoplast and Leucoplast.



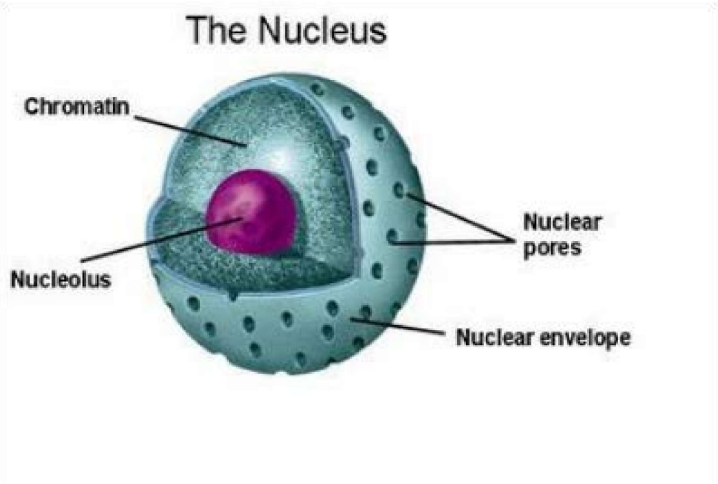
Chloroplast contain a green pigment known as Chlorophyll. The leaves appear green due to the presence of chlorophyll in it. The central atom present in chlorophyll is magnesium ion. Chlorophyll is essential for photosynthesis.

Chloroplast is double membrane structure-inner membrane and outer membrane. The space limited by the inner membrane of the chloroplast is called the stroma. Stroma contain flattened sac-like structure known as Thylakoids.

It is site of photosynthesis. Thylakoids are stacked upon each other to form grana. Each granum is connected with another granum by a lamella. Similar to mitochondria, chloroplast contain DNA and ribosomes.

Chromoplast provides color to flower and fruits. The pigment present in chromoplast are carotene which provides red color and xanthophyll which provides yellow-orange color.
Leucoplast are of different types such as amyloplast for storage of starch, aleuroplast store proteins and elaioplast stores oil and fats.

Nucleus



It is a double membrane structure. The outer membrane is continuous with the ER and contain ribosomes on it. The space between the two membranes is known as Perinuclear Space. The two nuclear membrane are interrupted by minute pores known as Nuclear Pores, which allow only certain molecules of particular size to enter the nucleus. The nuclear matrix is known as Nucleoplasm.

Nucleoplasm is composed of chromatin and nucleolus.

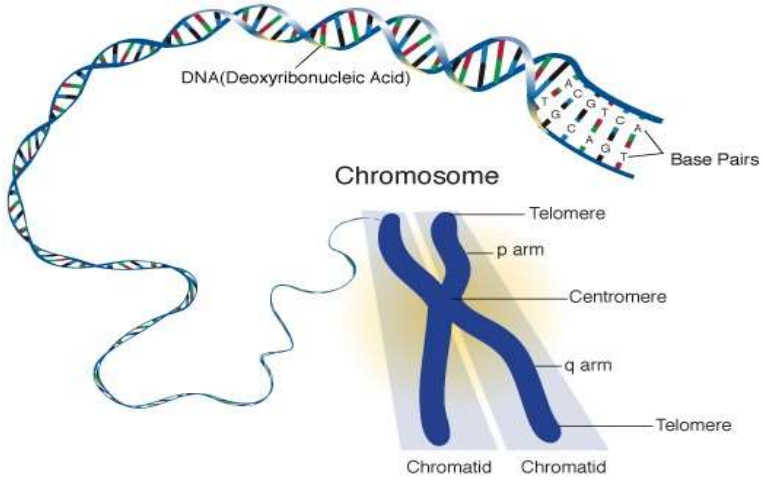
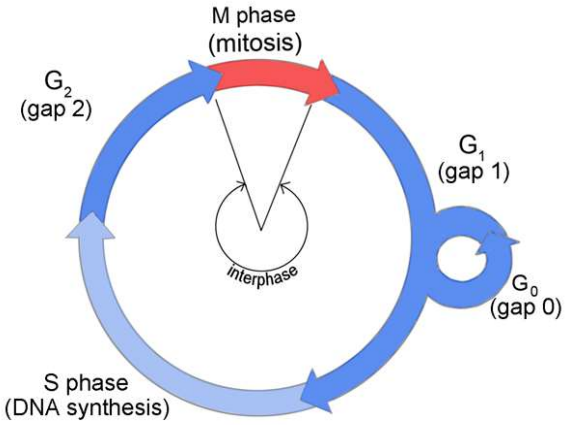


Fig.13. Structure of Chromosome and DNA

Chromatin is a network of DNA surrounded by proteins known as Histone Proteins. During interphase (no cell division), the genetic material exists in the form of chromatin. At the time of cell division, the chromatin becomes compact and forms chromosomes. Chromosomes contain constriction known as Centromere. RNA synthesis occurs in the nucleolus.

Cell Cycle and Cell Division

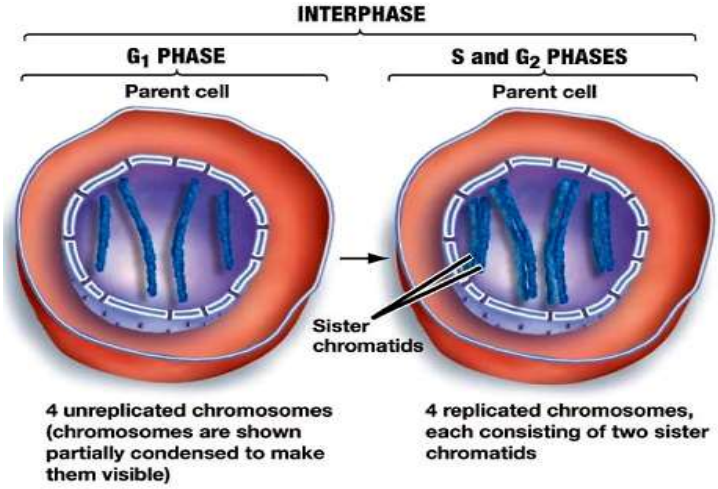
- Rudolf Virchow (1855 - 1859) was the first to suggest that new cells are formed from the division of the pre-existing cells- omnis cellula e cellula (every cell is derived from a cell).
- In 1873, Strasburger similarly proposed that nuclei are formed from pre-existing ones. Boveri (1879) and Flemming (1879, 1880) studied details of somatic cell division.
- It is the process by which a mature cell divides and forms two nearly equal daughter cells which resemble the parental cell in a number of characters.
- "Continuity of life" is an important intrinsic characteristic of living organisms and is achieved through the process of reproduction. The reproduction may be asexual or sexual. Both of these involve the division and replication of cells. Even the growth and development of every living organism depends on the growth and multiplication of its cells.
- In unicellular organisms, cell division is the means of reproduction by which the mother cell produces two or more new cells. In multicellular organism also, new individual develop from a single cell. The zygote, by the cell division. Cell division is central to life of all cells and is essential for the perpetuation of the species.
- A cell divides when it has grown to a certain maximum size which disturb the karyoplasmic index (KI)/ Nucleoplasmic ratio (NP)/ Kernplasm connection. Two processes take place during cell reproduction.



(a) Cell growth : (Period of synthesis and duplication of various components of cell).
(b) Cell division : (Mature cell divides into two cells).
(3) Cell cycle : Howard and Pelc (1953) first time described it. The sequence of events which occur during cell growth and cell division are collectively called cell cycle. Cell cycle completes in two steps:
(i) Interphase
(ii) M-phase/Dividing phase

G_1 Phase/Post Mitotic/Pre-DNA Synthetic Phase/Gap Ist

In which following events take place:



- ✓ Intensive cellular synthesis.
- ✓ Synthesis of rRNA, mRNA ribosomes and proteins.
- ✓ Metabolic rate is high.
- ✓ Cells become differentiated.
- ✓ Synthesis of enzymes and ATP storage.
- ✓ Cell size increases.
- ✓ Decision for a division in a cell occurs.
- ✓ Substances of G stimulates the onset of next S – phase.
- ✓ Synthesis of NHC protein, carbohydrates, proteins, lipids.
- ✓ Longest and most variable phase.

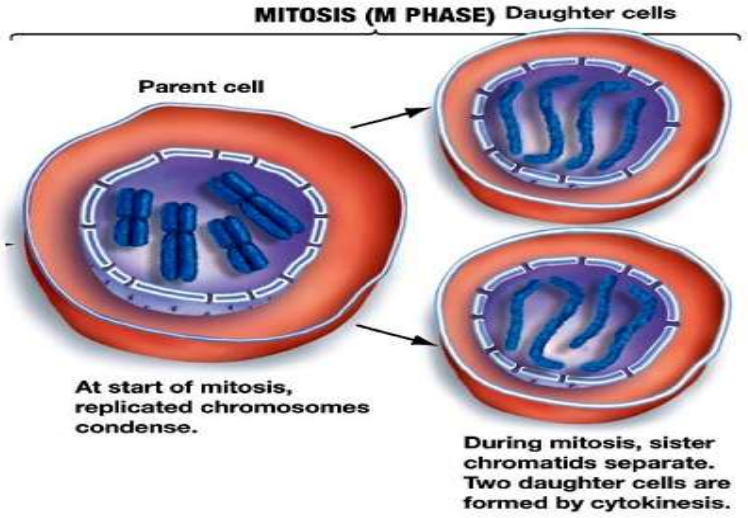
- ✓ Synthesis of enzyme, amino acids, nucleotides etc. but there is no change in DNA amount.

S-phase/Synthetic Phase

- ✓ DNA replicates and its amount becomes double (2C - 4C).
- ✓ Synthesis of histone proteins.
- ✓ Euchromatin replicates earlier than heterochromatin.
- ✓ Synthesis of NHC (non-histone chromosomal proteins).
- ✓ Each chromosome has 2 chromatids.

G_2-Phase/Pre Mitotic/Post Synthetic Phase/Gap-IInd

- ✓ Intensive cellular synthesis.
- ✓ Increase in energy store.
- ✓ Mitotic spindle protein (tubulin) synthesis begins.
- ✓ Chromosome condensation factor appears.
- ✓ Synthesis of 3 types of RNA and NHC proteins.
- ✓ Synthesis of ATP molecule and storage.
- ✓ Duplication of mitochondria, plastids and other cellular macromolecular complements.
- ✓ Damaged DNA repair occur.



M-Phase/Dividing Phase/Mitotic Phase

- ✓ M –phase is the final phase of cell cycle.
- ✓ It represents the phase of actual division.
- ✓ Prior to it, the cell components have undergone duplication.
- ✓ M – Phase is, therefore, the stage of separation of already duplicated components.
- ✓ It consists of karyokinesis (division of nucleus) and cytokinesis (division of cell protoplast.).

G_0 – Phase (Quiescent Stage)

- ✓ It is the stage of inactivation of cell cycle due to non-availability of mitogens and energy rich compounds.

- ✓ The cells remain metabolically active.
- ✓ They do not grow or differentiate.
- ✓ The cells function as reserve cells which can join cell any time.

Differences between G_1 and G_2 phases		
S.No.	G_1 phase	G_2 phase
1.	It is the first substage of interphase.	It is the last substage of interphase.
2.	Available factors determine its fate, entry in G 0, differentiation or continuity of cell cycle.	There is very little choice for the cell except to proceed further in cell cycle.
3.	Cell organelles do not increase in number.	Cell organelles increase in number.
4.	Cell grows in size but growth of nucleus is little.	Both cell and nucleus grow in size.
5.	It synthesizes RNAs, proteins and other biochemicals for cell growth and subsequent replication of DNA.	It synthesizes RNAs, proteins and other biochemicals for spindle formation and M- phase division.

Differentiation Phase

- ✓ Most of the cells leave the G_1-phase midway.
- ✓ They grow in size, assume particular shape and come to have a particular function. The phenomenon is called cell differentiation.

Duration of Cell Cycle

It depends on the type of cell and external factors such as temperature, food and oxygen. Time period for G_1, S, G_2 and M-phase is species specific under specific environmental conditions. E.g. 20 minutes for bacterial cell, 8-10 hours for epithelial cell, and onion root tip cells may take 20 hours.

Regulation of Cell Cycle

Stage of regulation of cell cycle is G_1 phase during which a cell may follow one of the three options.

- It may start a new cycle, enter the S-phase and finally divide.
- It may be arrested at a specific point of G_1 phase.
- It may stop division and enter G_0 quiescent stage. But when conditions change, cell in G_0 phase can resume the growth and renter the G_1 phase.

Did You Know?

- Generation time: Period between 2 successive generation (range 8 hr – 100 days).
- Mitogens : Chemicals which enhance or stimulate cell division e.g. lymphokinase (in man)
- Cell cycle duration: 20 minutes in bacteria, 20 hrs in root tip of onion, 2-3 hrs in yeast, 24 hrs in man.
- G_0 phase: Cell only starts dividing when the period is favourable otherwise, it remain viable for months or years as such in G_0 phase.

- During the mitosis of He-La cells, the longest period is gap I phase or G_1.
- DNA replication occurs in S-phase.
- In a cell cycle the condensation of chromosome with visible centromere occurs during M-phase.
- Sequence in cell cycle is G_1, S, G_2, and M.
- M-phase is of shortest duration of cell cycle.
- In G_2, the damaged DNA is repaired.
- Histone protein and RNA synthesis occurs in S-phase.
- Duplication of chromosome occurs at S- phase.

Test Your Knowledge

Q.1 Which one connected with the cell division (a) ER (b) Peroxysomes (c) Ribosomes (d) **Microtubules**	Q.6 Duplication of chromosomes take place in (a) G_1 phase (b) G_2 phase (c) **S phase** (d) In all of the above
Q.2 Cell division is initiated by (a) **Centrosome** (b) Centriole (c) Centromere (d) Chromomere	Q.7 The number of DNA in chromosome at G_2 stage of cell cycle (a) One (b) **Two** (c) Four (d) Eight
Q.3 Cell division in blue-green algae is more or less similar to that in (a) Red algae (b) Green algae (c) Brown algae (d) **Bacteria**	Q.8 The decision for division occurs in a cell at (a) S phase (b) G_2 phase (c) **G_1 phase** (d) None of these
Q.4 Which one of the following forms the spindle apparatus during cell division (a) Chromosome (b) Centrosome (c) Ribosome (d) **Kinetosome**	Q.9 During interphase, RNA and proteins are synthesized in (a) S phase (b) G_1 phase (c) G_2 phase (d) **In both G_1 and G_2 phases**
Q.5 The replication of nuclear DNA occurs in (a) G_1 phase (b) G_2 phase (c) **S phase** (d) M phase	Q.10 Mitosis results in (a) Reduction in chromosome number (b) Doubling of chromosome number (c) **Constant chromosome number** (d) Increase in cell volume

Mitosis

(Gk. Mitos = thread; osis = state)

1. Definition : It is also called indirect cell division or somadtic cell division or equational division. In this, mature somatic cell divides in such a way that chromosomes number is kept constant in daughter cells equal to those in parent cell, so the daughter cells are quantitatively as well as qualitatively similar to the parental cell. So it is called equational division
2. Discovery : Mitosis was first observed by Strasburger (1875) and in animal cell by W.Fleming (1879) term mitosis was given by Fleming (1882).

3. Occurrence : Mitosis is the common method of cell division. It takes place in the somatic cells in the animals. Hence, it is also known as the somatic division. It occurs in the gonads also for the multiplication of undifferentiated germ cells. In plants mitosis occurs in the meristematic cells e.g. root apex and shoot apex.
4. Duration : It ranges from 30 minutes to 3 hours' time is species-specific but also depends upon type of tissues, temperature.
5. Process of mitosis : Mitosis is completed in two steps
6. Karyokinesis: (Gk. karyon = nucleus; kinesis = movement) Division of nucleus. Term given by Schneider (1887).
7. Cytokinesis: (Gk. kitos = cell; kinesis = movement) Division of cytoplasm, Term given by Whitemann (1887).

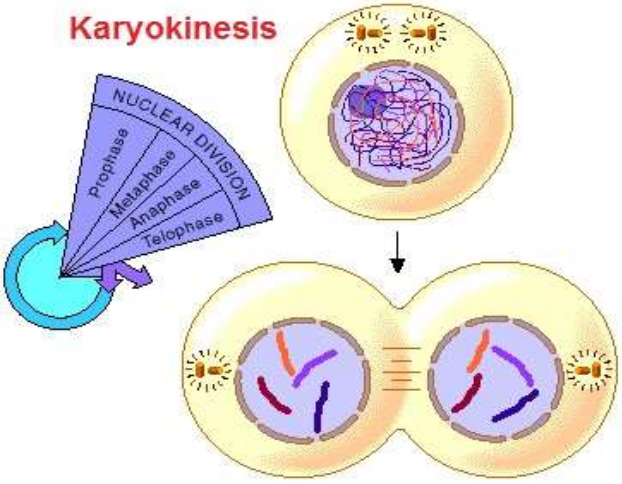
Karyokinesis

It comprises four phases i.e. Prophase, Metaphase, Anaphase, Telophase.

Prophase

It is largest phase of karyokinesis.

- ✓ Chromatin fibres thicken and shorter to form chromosomes which may overlap each other and appears like a ball of wool. i.e. Spireme stage.
- ✓ Each chromosome divides longitudinally into 2 chromatids which remain attached to centromere.
- ✓ Nuclear membrane starts disintegrating except in dinoflagellates.
- ✓ Nucleolus starts disintegrating.
- ✓ Cells become viscous, refractive and oval in outline.
- ✓ Spindle formation begins.
- ✓ Cell cytoskeleton, Golgi complex, ER, etc. disappear.
- ✓ In animal cells, centrioles move towards opposite sides.
- ✓ Lampbrush chromosomes can be studied well.
- ✓ Small globular structure (beaded) on the chromosome are called chromomeres.



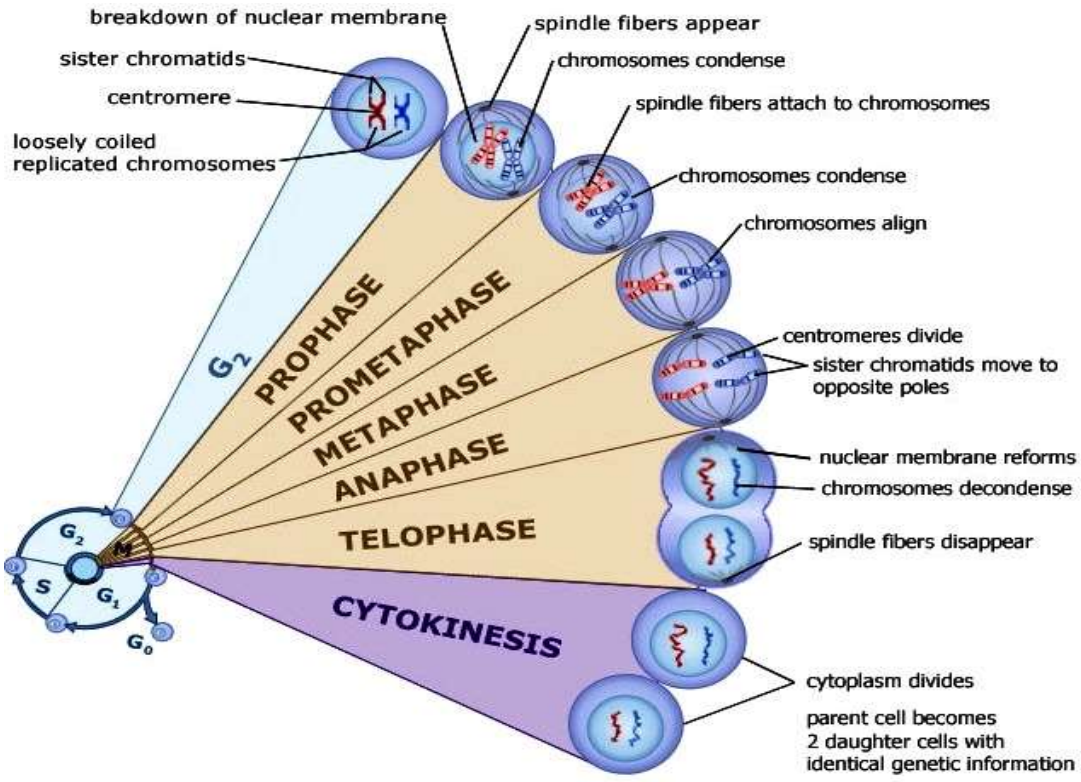
Metaphase

- Chromosomes become maximally distinct i.e. size can be measured.
- A colourless, fibrous, bipolar spindle appears.

- Spindle is formed from centriole (in animal cells) or MTOC (microtubule organising centre) in plant cells successively called astral and anastral spindle.
- Spindle has 3 types of fibres.
  - ✓Continuous fibre (run from pole to pole).
  - ✓Discontinuous fibre (run between poles to centromeres).
  - ✓Interzonal fibre (run between 2 centromere).
- Spindle fibre are made up of 97% tubulin protein and 3% RNA.
- Chromosomes move towards equatorial plane of spindles called congression and become arranged with their arms directed towards pole and centromere towards equator.
- Spindle fibres attach to kinetochores.
- Metaphase is the best stage for studying chromosome morphology.

Anaphase

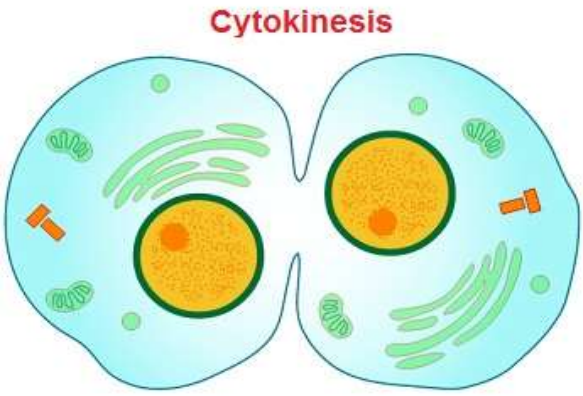
- ✓ Centromere splits from the middle and two chromatids gets separated.
- ✓ Both the chromatids move towards opposite poles due to repulsive force called anaphasic movement.
- ✓ Anaphasic movement is brought about by the repolymerisation of continuous fibres and depolymerisation of chromosomal fibres.
- ✓ Different shape of chromosomes become evident during chromosome movement viz. metacentric acrocentric etc.
- ✓ Chromosomes takes V, J, I or L shapes.
- ✓ The centromere faces towards equator.
- ✓ The chromatids are moved towards the pole at a speed of 1 mm/minute. About 30 ATP molecules are used to move one chromosome from equator to pole.



Telophase

- ✓ Chromosomes reached on poles by the spindle fibers and form two groups.
- ✓ Chromosomes begin to uncoil and form chromatin net.
- ✓ The nuclear membrane and nucleolus reappear.
- ✓ Two daughter nuclei are formed.
- ✓ Golgi complex and ER etc., reform.

Cytokinesis



It involves division of cytoplasm in animal cells, the cell membrane develops a constitution which deepens centripetally and is called cell furrow method.
In plant cells, cytokinesis occurs by cell plate formation.

Significance of Mitosis

- ✓ It keeps the chromosome number constant and genetic stability in daughter cells, so the linear heredity of an organism is maintained. All the cells are with similar genetic constituents.
- ✓ It helps in growth and development of zygote into adult through embryo formation.
- ✓ It provides new cells for repair and regeneration of lost parts and healing of the wounds.
- ✓ It helps in asexual reproduction by fragmentation, budding, stem cutting, etc.
- ✓ It also restores the nucleo-plasmic ratio.
- ✓ Somatic variations when maintained by vegetative propagation can play important role in speciation.

Did You Know?

- Pericentriolar cloud : A clear cytoplasmic area with no cell organelle between the centriole pair and astral rays.
- Root tips of onion are best material for studying mitosis.
- Kinetochore : A discoidal area on each chromatid and is the site of attachment of spindle fibres.
- In mitosis, plectonemic coiling takes place, in which sister chromatids are tightly coiled upon each other and are not easily separable. Paranemic coiling found in meiosis.
- Chromosomal fibres are also called tractile fibres, while continuous fibres are also called interpolar fibres.

- Mitogens : The agents which stimulate cell division e.g., cytokinins, auxins, gibberllins, insulin, temperature, steroids.
- Mitotic poision : The agents which inhibit cell division.
- Azides and Cyanides : Inhibit prophase.
- Colchicine : Inhibits spindle formation at metaphase.
- Mustard gas : Agglutinates the chromosomes.
- Chalones : These were first reported by Laurence and Bullough (1960). They are peptides and glycoproteins secreated by extracellular fluid of healthy cells and inhibit cellular division.
- Karyochoriosis : A type of mitosis in fungi in which is intranuclear nucleus divides by furrow formation.
- C-mitosis : Colchicine induced mitosis.
- After undergoing certain divisions, cells die. This is called as “Hayflick limit”.
- Actinomycin D and tetracyclin inhibit cell division.
- 7 mitotic divisions occur to form embryosac in angiosperms.
- Mitosis index is the ratio of dividing and non-dividing cells.

Meiosis

(Gk. meioum = to reduce, osis = state)

1. Definition : It is a special type of division in which the chromosomes duplicate only once, but cell divides twice. So one parental cell produces 4 daughter cells; each having half the chromosome number and DNA amount than normal parental cell. So meiosis is also called reductional division.
2. Discovery : It was first demonstrated by Van Benden (1883) but was described by Winiwarter (1900). Term “meiosis” was given by Farmer and Moore (1905).
3. Occurrence : It is found in special types and at specific period. It is reported in diploid germ cells of sex organs (e.g. primary spermatocytes of testes to form male gametes called spermotozoa and primary oocytes to form female gametes called ova in animals) and in pollen mother cells (microsporocytes) of anther and megasporocyte of ovule of ovary of flowers in plant to form the haploid spores. The study of meiosis in plants can be done in young flower buds.

Process of Meiosis

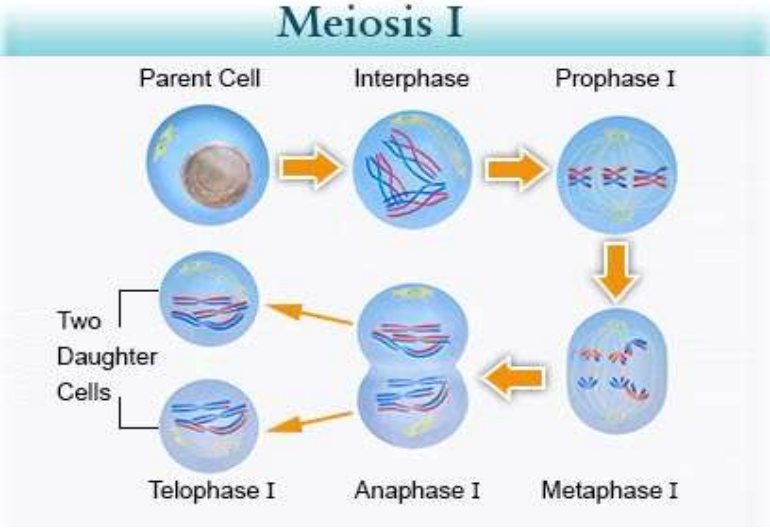
Meiosis is completed in two steps, meiosis I and meiosis II

Meiosis I

In which the actual chromosome number is reduced to half. Therefore, meiosis I is also known as reductional division or heterotypic division. It results in the formation of two haploid cells from one diploid cell. It is divided into two parts, karyokinesis I and cytokinesis I.

Karyokinesis I

It involves division of nucleus. It is divided into four phases i.e. prophase, metaphase, anaphase and telophase.



Prophase I

It is of longest phase of karyokinesis of meiosis. It is again divisible into five subphases i.e. leptotene, zygotene, pachytene, diplotene and diakinesis.

Leptotene/Leptonema

(a) Chromosomes are long thread like with chromomeres on it.

(b) Volume of nucleus increases.

(c) Chromatin network has half chromosomes from male and half from female parent.

(d) Chromosome with similar structure are known as homologous chromosomes.

(e) Leptonemal chromosomes have a definite polarization and forms loops whose ends are attached to the nuclear envelope at points near the centrioles, contained within an aster. Such peculiar arrangement is termed as bouquet stage (in animals) and syndet knot (in plants).

(f) E.M. (electron microscope) reveals that chromosomes are composed of paired chromatids, a dense proteinaceous filament or axial core lies within the groove between the sister chromatids of each chromosome.

(g) Lampbrush chromosome found in oocyte of amphibians is seen in leptotene.

Zygotene / Zygonema

- Pairing or "synapsis" of homologous chromosomes takes place in this stage.
- Synapsis may be of following types.
  - Procentric : Starting at the centromere.
  - Proterminal : Starting at the end.
  - Localised random : Starting at various points.
- Paired chromosomes are called bivalents, which by further molecular packing and spiralization becomes shorter and thicker.
- Pairing of homologous chromosomes in a zipper-fashion. Number of bivalents (paired homologous chromosomes) is half to total number of chromosomes in a diploid cell. Each bivalent is formed of one paternal and one maternal chromosome (i.e. one chromosome derived from each parent).
- Under EM, a filamentous ladder like nucleoproteinous complex, called synaptinemal. Complex between the homologous chromosomes which is discovered by "Moses" (1953).

Pachytene/Pachynema

- In the tetrad, two similar chromatids of the same chromosome are called sister chromatids and those of two homologous chromosomes are termed non-sister chromatids.
- Crossing over i.e. exchange of segments between non-sister chromatids of homologous chromosome occurs at this stage.
- It takes place by breakage and reunion of chromatis segments. Breakage called nicking, is assisted by an enzyme endonuclease and reunion termed annealing is added by an enzyme ligase. Breakage and reunion hypothesis proposed by Darlington (1937).
- Chromatids of pachytene chromosome are attached with centromere.
- A tetrad consists of two sets of homologous chromosomes each with two chromatids. Each tetrad has four kinetochore (two sister and two homologous).
- A number of electron dense bodies about 100 nm in diameter are seen at irregular intervals within the centre of the synaptonemal complex, known as recombination nodules.
- DNA polymerase is responsible for the repair synthesis.

Diplotene/Diplonema

- At this stage the paired chromosomes begin to separate (desynapsis).
- Cross is formed at the place of crossing over between non-sister chromatids.
- Homologous chromosomes move apart they remain attached to one another at specific points called chiasmata.
- At least one chiasma is formed in each bivalent.
- Chromosomes are attached only at the place of chiasmata.
- Chromatin bridges are formed in place of synaptonemal complex on chiasmata.
- This stage remains as such for long time.

Diakinesis

- Chiasmata moves towards the ends of chromosomes. This is called terminalization.
- Chromatids remain attached at the place of chiasma only.
- Nuclear membrane and nucleolus degenerates.
- Chromosome recondense and tetrad moves to the metaphase plate.
- Formation of spindle.
- Bivalents are irregularly and freely scattered in the nucleocytoplasmic matrix.

When the diakinesis of prophase-I is completed than cell enters into the metaphase-I.

Metaphase I

It involves;

i. Chromosome come on the equator.
ii. Due to repulsive force the chromosome segment get exchanged at the chiasmata.
iii. Bivalents arrange themselves in two parallel equatorial or metaphase plates. Each equatorial plate has one genome.
iv. Centromeres of homologous chromosomes lie equisdistant from equator and are directed towards the poles while arms generally lie horizontally on the equator.
v. Each homologous chromosome has two kinetochores and both the kinetochores of a chromosome are joined to the chromosomal or tractile fibre of same side.

Anaphase-I

i. It involves separation of homologous chromosomes which start moving opposite poles so each tetrad is divided into two daughter dyads. So anaphase-I involves the reduction of chromosome number, this is called disjunction.
ii. The shape of separating chromosomes may be rod or J or V-shape depending upon the position of centromere.
iii. Segregation of Mendelian factors or independent assortment of chromosomes take place. In which the paternal and maternal chromosomes of each homologous pair segregate during anaphase-I which introduces genetic variability.

Telophase-I

i. Two daughter nuclei are formed but the chromosome number is half than the chromosome number of mother cell.
ii. Nuclear membrane reappears.
iii. After telophase I cytokinesis may or may not occur.
iv. At the end of Meiosis I either two daughter cells will be formed or a cell may have two daughter nuclei.
v. Meiosis I is also termed as reduction division.
vi. After meiosis I, the cells in animals are reformed as secondary spermatocytes or secondary oocytes; with haploid number of chromosomes but diploid amount of DNA.
vii. Chromosomes undergo decondensation by hydration and despiralization and change into long and thread like chromatin fibres.

Interphase

Generally there is no interphase between meiosis-I and meiosis-II. A brief interphase called interkinesis, or intermeiotic interphase. There is no replication chromosomes, during this interphase.

Cytokinesis-I

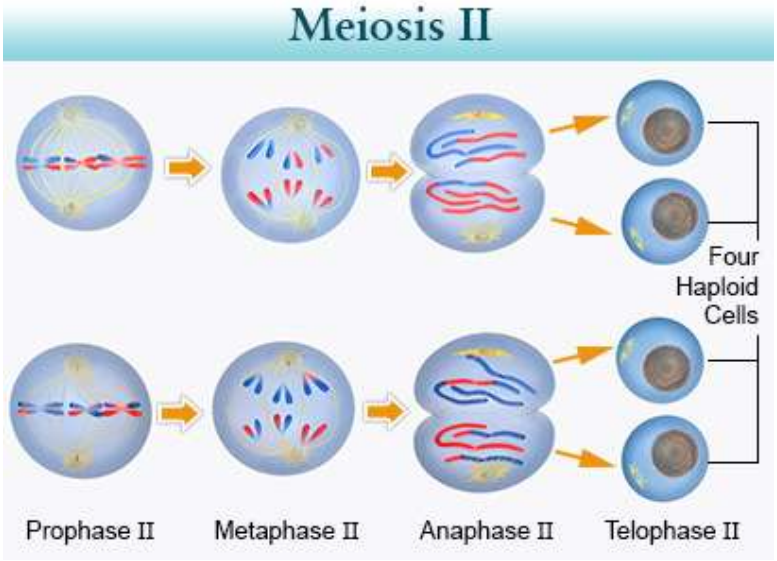
It may or may not be present. When present, it occurs by cell-furrow formation in animal cells and cell plate formation in plant cells.

Significance of meiosis-I

- ✓ It separates the homologous chromosomes to reduce the chromosome number to the haploid state, a necessity for sexual reproduction.
- ✓ It introduces variation by forming new gene combinations through crossing over and randon assortment of paternal and maternal chromosomes.
- ✓ It may at times cause chromosomal mutation by abnormal disjunction.
- ✓ It induces the cells to produce gametes for sexual reproduction or spores for asexual reproduction.

Meiosis-II

It is also called equational or homotypical division because the number of chromosomes remains same as after meiosis-I. It is of shorter duration than even typical mitotic division. It is also divisible into two parts, Karyokinesis-II and Cytokinesis-II.



Karyokinesis-II

It involves the separation of two chromatids of each chromosome and their movement to separate cells. It is divided in four phases i.e., Prophase-II, Metaphase-II. Anaphase-II and Telophase-II.

Almost all the changes of Karyokinesis-II resembles to mitosis which involves.

- ✓ It starts just after end of telophase I.
- ✓ Each daughter cell (nucleus) undergoes mitotic division.
- ✓ It is exactly similar to mitosis.
- ✓ At the end of process, cytokinesis takes place.
- ✓ Four daughter cells are formed after completion.
- ✓ The sister kinetochores of one chromosome are separated.
- ✓ The four daughter cells receive one chromatid each of the tetravalent.
- ✓ Centromere divide at anaphase II.
- ✓ Spindle fibres contract at prophase II.

Cytokinesis-II

It is always present and occurs by cell furrow formation in animal cell and cell plate formation in plant cell.

So by meiosis, a diploid parental cell divides twice forming four haploid gametes or sex cells, each having half the DNA amount than that of the parental cell and one-fourth of DNA present in the cell at the time of beginning of meiosis.

Significance of Meiosis

- ✓ Constancy of chromosome number in successive generation is brought by process.
- ✓ Chromosome number becomes half during meiosis.
- ✓ It helps in introducing variations and mutation.
- ✓ It brings about gamete formation.
- ✓ It maintains the amount of genetic informative material.
- ✓ Sexual reproduction includes one meiosis and fusion.
- ✓ The four daughter cells will have different types of chromatids.

Why the necessity of Meiosis-II

The basic aim of meiosis is to reduce the number of chromosomes to half. The chromosomes that separate in the anaphase of meiosis-I are still double. Each consist of two chromatids and has 2n amount of DNA. Thus reduction of DNA content does not occur in meiosis-I. Truly haploid nuclei in terms of DNA contents as well as chromosome number are formed in meiosis-II. When the chromatids of each chromosome are separated into different nuclei. Thus meiosis-II is necessary.

Difference between Mitosis and Meiosis

No.	Characters	Mitosis	Meiosis
I. General			
(1)	Site of occurrence	Somatic cells and during the multiplicative phase of gametogenesis in germ cells.	Reproductive germ cells of gonads.
(2)	Period of occurrence	Throughout life.	During sexual reproduction.
(3)	Nature of cells	Haploid or diploid.	Always diploid.
(4)	Number of divisions	Parental cell divides once.	Parent cell divides twice.
(5)	Number of daughter cells	Two.	Four.
(6)	Nature of daughter cells	Genetically similar to parental cell. Amount of DNA and chromosome number is same as in parental cell.	Genetically different from parental cell. Amount of DNA and chromosome number is half to that of parent cell.
II. Prophase			
(7)	Duration	Shorter (of a few hours) and simple.	Prophase-I is very long (may be in days or months or years) and complex.
(8)	Sub phases	Formed of 3 sub phases: early-prophase, mid-prophase and late-prophase.	Prophase-I is formed of 5 subphases: leptotene, zygotene, pachytene, diplotene and diakinesis.
(9)	Bouquet stage	Absent.	Present in leptotene stage.
(10)	Synapsis	Absent.	Pairing of homologous chromosomes in zygotene stage.
(11)	Chiasma formation and crossing over.	Absent.	Occurs during pachytene stage of prophase-I.
(12)	Disappearance of nucleolus and nuclear membrane	Comparatively in earlier part.	Comparatively in later part of prophase-I.

(13)	Nature of coiling	Plectonemic.	Paranemic.
III. Metaphase			
(14)	Metaphase plates	Only one equatorial plate	Two plates in metaphase-I but one plate in metaphase-II.
(15)	Position of centromeres	Lie at the equator. Arms are generally directed towards the poles.	Lie equidistant from equator and towards poles in metaphase-I while lie at the equator in metaphase-II.
(16)	Number of chromosomal fibres	Two chromosomal fibre join at centromere.	Single in metaphase-I while two in metaphase-II.
IV. Anaphase			
(17)	Nature of separating chromosomes	Daughter chromosomes (chromatids with independent centromeres) separate.	Homologous chromosomes separete in anaphase-I while chromatids separate in anaphase in anaphase-II.
(18)	Splitting of centromeres and development of inter-zonal fibres	Occurs in anaphase.	No splitting of centromeres. Inter-zonal fibres are developed in metaphase-I.
V. Telophase			
(19)	Occurrence	Always occurs	Telophase-I may be absent but telophase-II is always present.
VI. Cytokinesis			
(20)	Occurrence	Always occurs	Cytokinesis-I may be absent but cytokinesis-II is always present.
(21)	Nature of daughter cells	2N amount of DNA than 4N amount of DNA in parental cell.	1 N amount of DNA than 4 N amount of DNA in parental cell.
(22)	Fate of daughter cells	Divide again after interphase.	Do not divide and act as gametes.
VII. Significance			
(23)	Functions	Helps in growth, healing, repair and multiplication of somatic cells. Occurs in both asexually and sexually reproducing organisms.	Produces gametes which help in sexual reproduction.
(24)	Variations	Variations are not produced as it keeps quality and quantity of genes same.	Produces variations due to crossing over and chance arrangement of bivalents at metaphase-I.
(25)	In evolution	No role in evolution.	It plays an important role in speciation and evolution.

Did You Know?

- Brachymeiosis : Failure of meiosis-II. It is characteristic feature of fungi.
- Meiosis-II is not mitosis as it occurs haploid number of chromosomes and chromatids formed may not be similar to each other.
- Restitution nucleus: A colchicine treated cell has the nucleus with double sets of chromosomes.
- In cyperus, one meiosis produce only one pollen instead of four so that meiotic division required to produce fruits will be = number of fruits ´ 2.
- Chiasmata first observed by Janseens (1909).
- When sister chromatids are loosely arranged and are easily separate. It is found in meiotic chromosomes.
- Mitosis ends in 1- 2 hours while meiosis may take 24 hrs to few years.
- Neuron cells are always in interphase.
- When the chromosome duplicates but karyokinesis does not take place the number of chromosome per cell will increases, it is called endomitosis or endoduplication.
- Process of inducing mitosis into a cell – mitogenesis.
- To study mitosis root tips are fixed in 1: 3 acetic acid and methanol.
- Colchicine inhibits spindle formation and enhance duplication in number of chromosomes.
- At the time of cell division electrostatic force is responsible for terminalization.
- Mitotic crossing over takes place in parasexual cycle.

Test Your Knowledge

Q.1 Meiosis was discovered by (a) **Strasburger** (b) Hofmeister (c) Sutton (d) Amici	Q.6 Repulsion of homologous chromosomes takes place in (a) Zygotene (b) Leptotene (c) Diakinesis (d) **Diplotene**
Q.2 In which of the following meiosis takes place (a) Pollen grains (b) Pollen tube (c) **Pollen mother cells** (d) Generative cells	Q.7 Chiasmata formation occurs during (a) **Diplotene** (b) Leptotene (c) Pachytene (d) Diakinesis
Q.3 The significance of meiosis lies in (a) Reduction of the diploid number of chromosomes to haploid (b) Maintaining constancy in the number of diploid chromosomes during sexual reproduction (c) Production of genetic variability in the population of a species (d) **All of the above**	Q.8 In pachytene stage of meiosis the chromosomes appear (a) Single stranded (b) Double stranded (c) Three stranded (d) **Four stranded** Q.9 Pachytene occurs during (a) **Meiosis** (b) Mitosis (c) Growth of a cell (d) Formation of endosperm
Q.5 When during the meiotic division, do the homologous chromosomes pair with each other (a) Leptotene (b) Pachytene (c) **Zygotene** (d) Metaphase-I	Q.10 Chromonemata start associating into bivalent chromosomes during **(a) Zygotene** (b) Leptotene (c) Pachytene (d) Diplotene
Q.4 The correct chronological sequence Prophase of reduction division is (a) **Leptotene – pachytene – zygotene – diplotene – diakinesis** (b) Leptotene – diplotene – pachytene – zygotene – diakinesis (c) Leptotene – zygotene – diplotene – pachytene – diakinesis (d) Leptotene – zygotene – pachytene – diplotene– diakinesis	

Lecture no. 8, 9, 10 & 11

Morphological studies on flowering plants

Morphology

Morphology is the branch of science which deals with the study of external structural of the plants. The flowering plant consists of an axis, root system and shoot system.

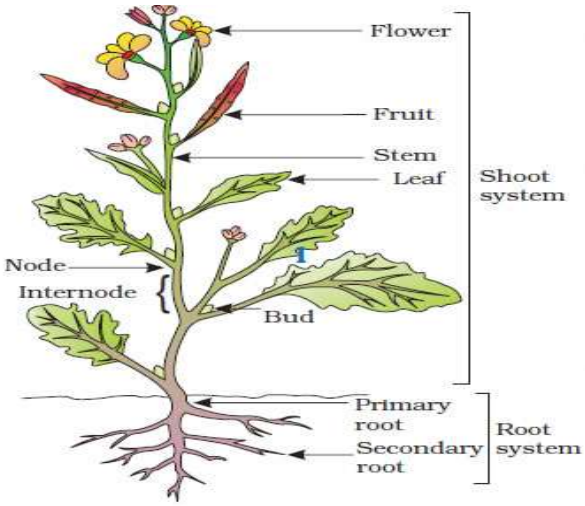


Figure 5.1 Parts of a flowering plant

Root System

The flowering plants consist of a long cylindrical axis which is differentiated into an underground root system. Root is the descending, non-green, underground part lacking nodes, internodes, leaves and buds. In Dicotyledonous plants, the elongation of radicle leads to the formation of primary root. The primary root grows inside the soil. Primary root bears lateral roots known as Secondary Roots, Tertiary Roots etc.

Types of Root System

The primary root along with its branches forms a Tap Root system. For Example: Mustard. Primary roots have short life span and are replaced by large roots later on.

The root which arises from the base of the stem is known as Fibrous Root system. For Example: Grasses. This type of system is common in Monocotyledonous plants. The root which arises from the part other than the radicle is known as Adventitious Roots. For Example: Banyan Tree, *Monstera.*

Regions of the Root

The root has five main regions which are as follows:

- Root Cap is the structure that covers the apex/tip of the root. It helps in protecting the apex of the root.
- Region of Meristematic Activity located few millimeters above the root cap. The cell of this region has the property of repeated divisions which is needed for the growth of the plant.
- Region of Elongation is located proximal to the region of meristematic activity. This is required for the elongation of root.
- Region of Maturation is located proximal to region of elongation. These cells gradually differentiate and mature.

- Root Hairs arise from the region of maturation which helps in absorption of water and minerals from the soil.

Modifications of the Root

Roots modify in structure to perform different functions as explained below:

- Fusiform root is a modified form of tap root. The root is swollen from the middle and tapers at both the ends. For Example: Radish
- Napiform roots are also a modified tap root. They have swollen base and then it tapers abruptly. For Example: Turnip
- Prop roots are roots which are modified for aerial support. For Example: Corn
- Stilt roots are modified roots for support. For Example: Maize
- Pneumatophores are roots modified for respiration. They grow in swampy area and grow vertically upwards. For Example: *Rhizophora*

Functions of the Root

- To absorb water and minerals from the soil.
- To provide proper anchorage to the plants.
- To store reserve food materials
- Synthesis of plant growth regulators

Shoot System

It is an aerial system, usually above the soil and originates from the plumule. It consists of stem, branches, leaves, flowers and fruits.

Stem

It facilitates conduction of water, mineral and food material. The flowers, fruits and seeds form the reproductive parts of the plants. The stem bears the nodes and internodes. The point from where the leaf arises is known as node and the part between the two nodes are known as internodes.

Modification of Stems

Similar to roots, the stem is also modified to perform different functions:

- Tendrils are slender, twining strands that allow the plant to climb and help in support. For Example: Cucumber.
- Thorns are modified stem for protection of the plant. They are hard, woody and sharp outgrowths from the plant. For Example: Rose.
- Cladodes are modified stem that perform the function of photosynthesis.
- Bulbils are modified stem that becomes fleshy and store food.

Leaf

Leaf is a green dorsoventrally flattened exogenous lateral outgrowth that arises from a node of the stem or a branch. The leaf is a specialized organ of photosynthesis, transpiration and gaseous exchange.

Parts of Leaf

The point of origin of leaf is known as Node. It bears bud in its axil. The leaves are attached to the stem by the leaf base and have two lateral leaf like structures called Stipules. In monocots, the leaf base is swollen to form pulvinus. The stalk of the leaf is known as Petiole. The green exposed part of the leaf is known as lamina. Lamina bears the veins or veinlets. The arrangement of veins on the leaf is known as Venation.

There are basically two types of Venation: Parallel Venation and Reticulate Venation.

Parallel venation is observed when veins run parallel to each other. For Example: Monocots
Reticulate venation is observed when veinlets form network. For Example: Dicots

Flower

The modified shoot is known as Flower. The arrangement of flower on the floral axis is known as Inflorescence.

There are two major types of Inflorescence- Racemose and Cymose.

In racemose type of inflorescence, new flowers are generated at the tip of the inflorescence. For Example: Snapdragon

In cymose type of inflorescence, new flowers are generated at the base of the inflorescence.

Structure of the Flower

Each flower has four whorls- sepals, petals, stamens and the carpels. Sepals are a green leafy structure that covers the flower bud. Petals are bright colored to attract insects for pollination. Gynoecium are female reproductive structures whereas Androecium is the male reproductive structure.

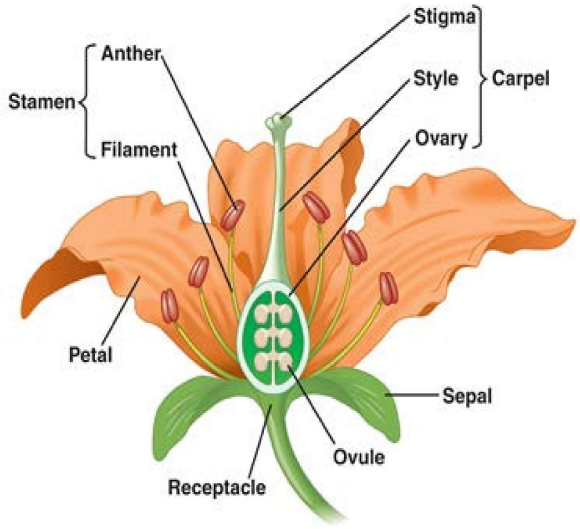


Fig.5. Structure of the Flower

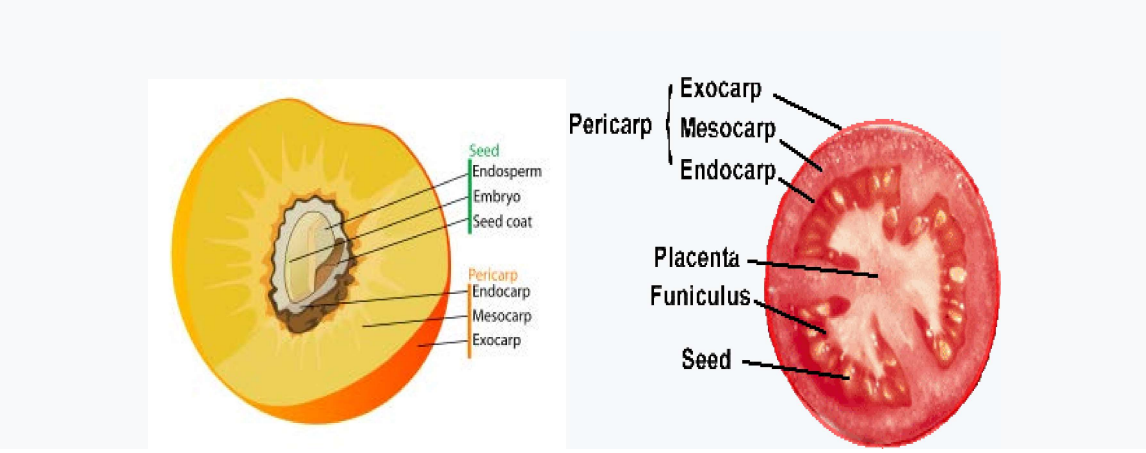
Gynoecium is composed of carpels. Carpels comprises of three structures ovary, style and stigma. Ovary comprises of ovules that forms the seed, whereas stigma is the place of landing of pollen at the time of pollination. Ovary finally forms the fruit. The male part of the flower is known as Androecium. Androecium is composed of stamens. Stamen is composed of anther and the filament. Anthers contain the pollen grains, the male gamete.

Fruits

Fruits are the mature ovary or ovaries of one or more flowers.

In fleshy fruits, the outer layer (which is often edible) is the pericarp, which is the tissue that develops from the ovary wall of the flower and surrounds the seeds. But in some seemingly pericarp fruits, the edible portion is not derived from the ovary.

Anatomy of simple fruits



1. Pericarp layers

The pericarp is typically made up of three distinct layers: the epicarp, which is the outermost layer; the mesocarp, which is the middle layer; and the endocarp, which is the inner layer surrounding the ovary or the seeds. In a citrus fruit, the epicarp and mesocarp make up the peel. Exocarp, the outermost layer often consisting of only the epidermis Mesocarp, or middle layer, which varies in thickness Endocarp, which shows considerable variation from one species to another

2. Epicarp

Epicarp (from Greek: epi-, "on" or "upon" + -carp, "fruit") is a botanical term for the outermost layer of the pericarp (or fruit). The epicarp forms the tough outer skin of the fruit, if there is one. The epicarp is sometimes called the exocarp, or, especially in Citrus, the flavedo.

Flavedo is mostly composed of cellulosic material but also contains other components, such as essential oils, paraffin waxes, steroidsand triterpenoids,fatty acids,pigments (carotines, chrophylls, flavonoids), bitter principles (limonin) and enzymes.

3. Mesocarp

The mesocarp (from Greek: meso-, "middle" + -carp, "fruit") is the fleshy middle layer of the pericarp of a fruit; it is found between the epicarp and the endocarp. It is usually the part of the fruit that is eaten. For example, the mesocarp makes up most of the edible part of a peach, and a considerable part of a tomato. "Mesocarp" may also refer to any fruit that is fleshy throughout.

In a hesperidium, as is found in citrus fruit, the mesocarp is also referred to as albedo or pith. It is the inner part of the peel and is commonly removed before eating. In citron fruit, where the mesocarp is the most prominent part, it is used to produce succade.

4. Endocarp

Endocarp (from Greek: endo-, "inside" + -carp, "fruit") is a botanical term for the inside layer of the pericarp (or fruit), which directly surrounds the seeds. It may be membranous as in citrus where it is the only part consumed, or thick and hard as in the stone fruits of the family Rosaceae such as peaches, cherries, plums, and apricots.

In nuts, it is the stony layer that surrounds the kernel of pecans, walnuts, etc., and that is removed prior to consumption.

In citrus fruits, the endocarp is separated into sections, which are called segments. These segments are filled with juice vesicles, which contain the juice of the fruit.

Lecture no. 12

Seed and Seed Germination, Structure of monocot and dicot seed, Types and factors affecting Seed Germination

Seed

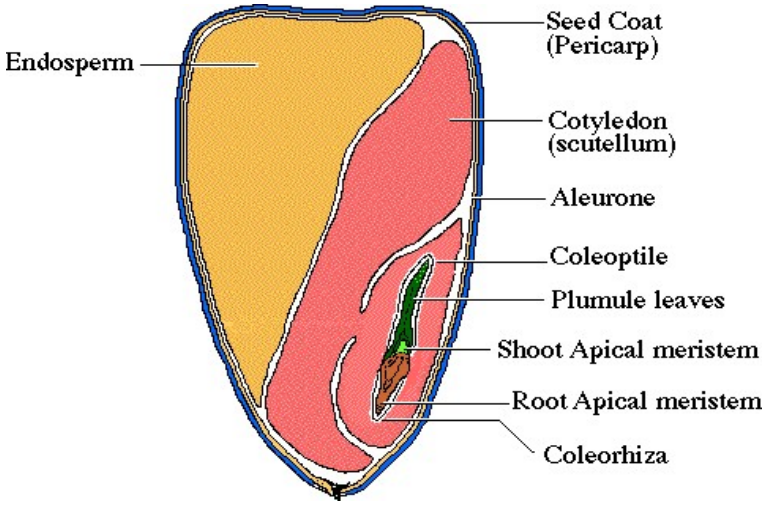
It is the fertilized, matured ovule of a flowering plant, containing an embryo or rudimentary plant.

Seed The fertilized and mature ovule containing the embryo is called the seed.

Seed Germination

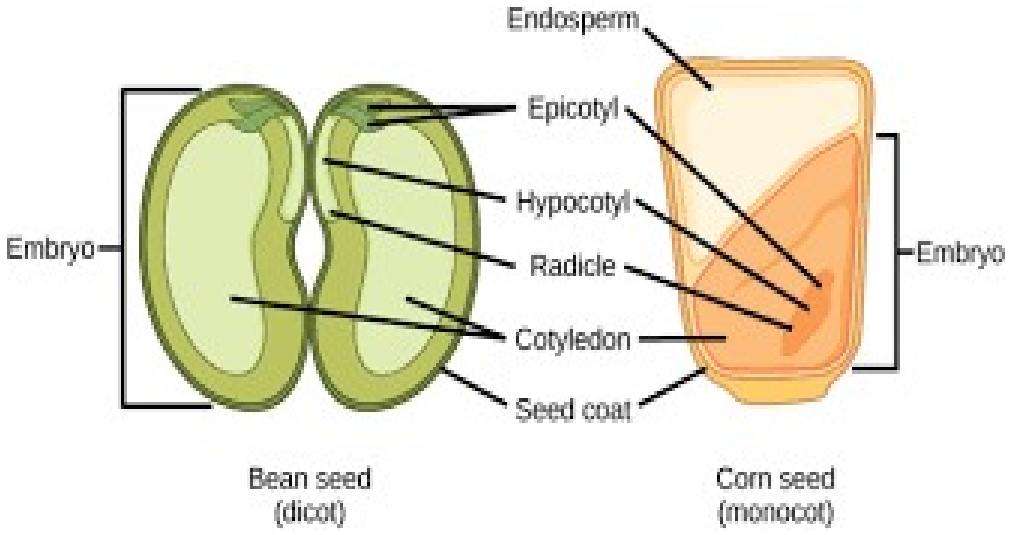
Seed Germination is the process of reactivation of metabolic machinery of the seed resulting in the emergence of radicle and plumule.

Structure of monocot seed



Monocot seed

Structure of dicot and monocot seed



Types of germination

1. **Hypogeal Germination:**

In this kind of germination, the cotyledons do not come out of the soil surface. In such seeds the epicotyl (i.e., part of embryonic axis between plumule and cotyledons) elongates pushing the plumule out of the soil. All monocotyledons show hypogeal germination. Among dicotyledons, gram, pea, groundnut are some common examples of hypogeal germination.

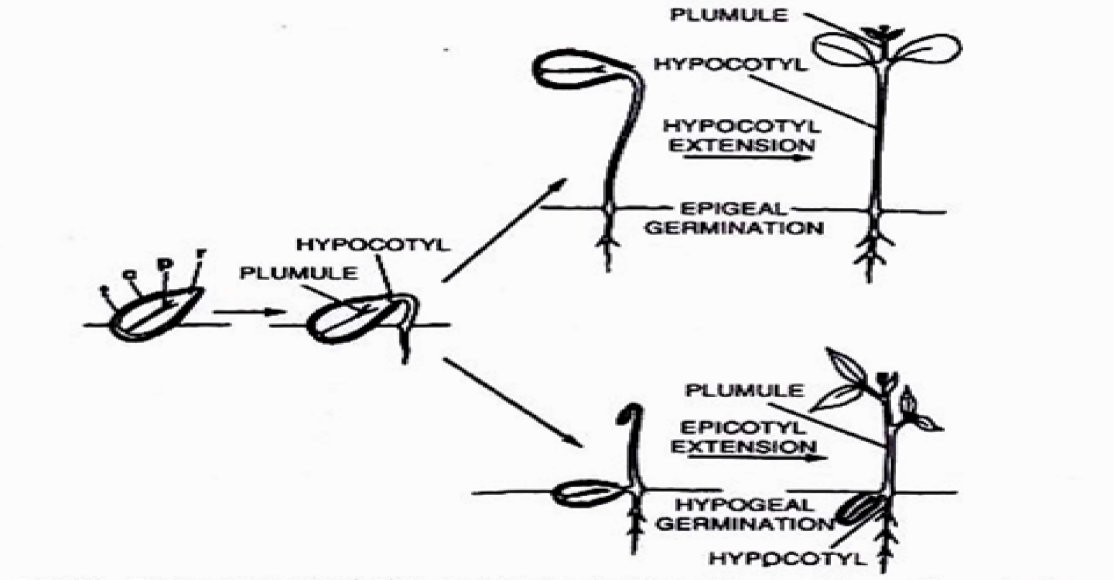


Fig. 4.1. Figure sowing distinction between epigeal and hypogeal type of germination.

In monocotyledons (e.g., wheat, maize, rice, coconut) radicle and plumule come out by piercing the coleorhiza and coleoptile respectively. The plumule grows upward and the first leaf comes out of the coleoptile. The radicle forms the primary root which is soon replaced by many fibrous roots.

2. **Epigeal Germination:**

In seeds with epigeal germination, the cotyledons are brought above the soil due to elongation of the hypocotyl. In castor, cotton, papaya, onion (Figs. 4.7., 4.8), flat green leaf like cotyledons can be seen in the young seedlings. Here the cotyledons, besides food storage, also perform photosynthesis till the seedling becomes independent. In some other plants like bean, the cotyledons being thick, do not become leaf-like; they shrivel and fall off after their food reserves are consumed by the seedling.

3. **Vivipary (Viviparous Germination):**

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.

The embryo of the seed (present inside the fruit) continues growth while the latter is attached to the parent plant. Hypocotyl elongates and pushes the radicle out of the seed and the fruit. Growth continues till the hypocotyl and radicle become several centimetres long (more than 70 cm in *Rhizophora*). The seedling becomes heavy.

As a result it breaks its connection with the fruit and falls down in the salt rich muddy water in such a position that the plumule remains outside the saltish water while the tip of the radicle gets fixed in the mud. This protects the plumule. The radicle quickly forms new roots and establishes the seeding as a new plant (Fig. 4.9).

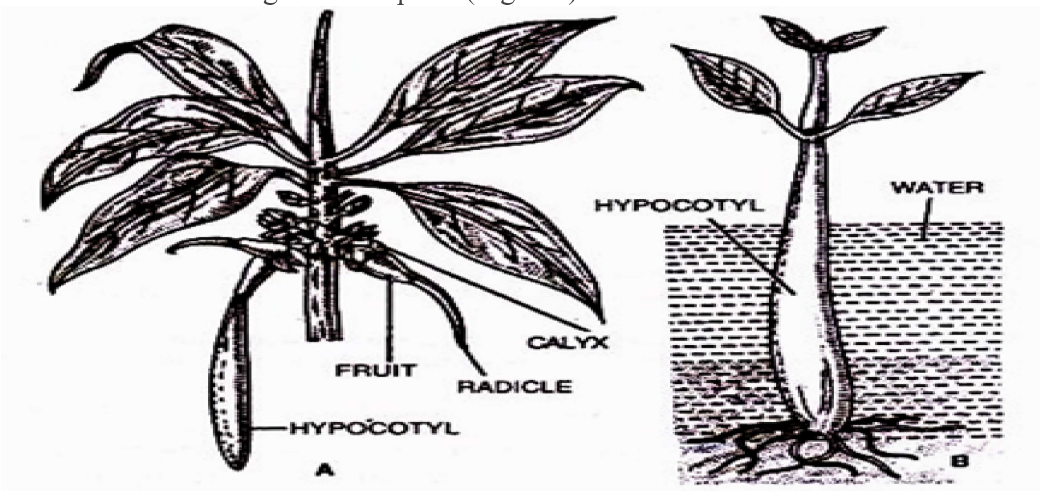


Fig. 4.9. Vivipary. A. twig of *Rhizophora* showing viviparous germination. B. A seedling has become established on tidal soil.

Factors affecting seed germination

Germination is depends on availability of water, health of the seeds, time, temperature and heat, presence of oxygen, and exposures to light play an important role in the germination process.

- ✓ Temperature: Extremely low or cold temperature is not favourable 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 undergoes a resting time through which they stay dormant and germinate when conditions are favourable. Presence of growth inhibitors like abscisic acid induce dormancy in seeds.
- ✓ Thinness or thickness of seed coat: 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.

Lecture no. 13, 14 & 15

Plant Systematic – Study of families

A) Cruciferae (Brassicaceae)

Systematic position

Division	**Angiospermae**
Class	**Dicotyledonae**
Subclass	**Polypetalae**
Series	**Thalamiflorae**
Order	**Parietales**
Family	**Cruciferae (Brassicaceae)**

Habit : Annual, biennial or perennial herbs. *Farsetia jacquemontii* is an undershrub. The plants possess pungent juice having sulphur-containing glucosides.

Root : Tap root alongwith hypocotyl is swollen in Radish (*Raphanus sativus*) and Turnip (*Brassica rapa*).

Stem : Erect, cylindrical, hairy or glabrous, herbaceous or rarely woody. It is reduced in the vegetative phase in Radish and Turnip. The stem is swollen in Kohlarabi (Knol-Kohl = Ganthgobi, *Brassica, oleracea* var. Gonglylodes). Axillary buds enlarged in Brussel's Sprouts (= Button gobhi) or *Brassica oleracea* var. *gemmifera*. *Brassica oleracea* var. *capitata* (Cabbage) has the largest terminal bud.

Leaves : Radical, cauline and ramal, alternate or sub-opposite but forming rosettes when radical, exstipulate with sheathing leaf base, sessile simple or rarely compound (e.g., *Nasturium officinale*), hairy. Bulbils occur in the leaf axils of *Dentaria bulbifera*and on the leaves of *Cardamine pratensis*.

Inflorescence : Flowers are usually arranged in racemose racemes. Occasionally they are in corymbs (candtuft).

Flower : Ebracteate or rarely bracteate (e.g., *Rorippa montana*), pedicellate, complete, perfect, regular, actinomorphic, rarely zygomorphic (e.g., *Iberis, Teesdalia*), tetramerous or bimerous, hypogynous (perigynous in *Lepidium*), cyclic, cruciform.

Calyx : Sepals 4, polysepalous, aestivation imbricate, generally arranged in two whorls, outer of antero-posterior sepals and inner of lateral sepals, lateral sepals generally saccate or pouched at the base, green or petaloid, inferior.

Corolla : Petals 4, polypetalous, arranged in one whorl and alternate with sepals, often with long claws and spread out in the form of a Greek cross. This arrangement of petals which

is characteristic of the family is known as the cruciform arrangement and corolla is described as cruciform corolla, valvate aestivation. Petals reduced or absent in *Lepidium* and *Rorippa*.
Androecium : Stamens 6, (four in *Cardamine hirsuta*, two in *Coronopus didymus*, 16 in *Megacarpaea*), free (polyandrous), tetradynamous, arranged in two whorls, outer of two short lateral stamens while the inner whorl is made up of 4 long stamens arranged in two median pairs, anthers basifixed or dorsifixed, dehiscence longitudinal, inferior. Green nectaries are often associated with the bases of stamens.
Gynoecium : Bicarpellary (tricarpellary in species of *Lepidium*, tetracarpellary in *Tetrapoma* and *Tropidocarpum*), syncarpous, carpels placed transversely, ovary superior, placentation parietal, ovary bilocular due to the presence of a false septum called replum, style short, stigma capitate, simple or lobed.
Fruit : Siliqua of silicula, lomentaceous siliqua occurs in radish.
Seed : Non-endospermic, often oily.

Floral formula: Ebr ⊕ ⚥ K_{2+2} C_4 A_{2+4} $\underline{G}_{(2)}$

B) Papilionaceae (Fabaceae)

Family Fabaceae is large family including plants which are economically important. The family Fabaceae also was known as Leguminosae or Papilionaceae since it is the pea or legume family. It consists of around 5000 species of dicotyledons which are widely distributed all over the world.

Systematic position

Division	**Angiospermae**
Class	**Dicotyledonae**
Subclass	**Gamopetalae**
Series	**Bicarpellatae**
Order	**Polimoniales**
Family	**Solanaceae**

Root: Dicotyledons with taproot with root nodules.
Stem: Erect or climber; Fabaceae include shrubs, herbs, trees and majorly climbers.
Leaves: Petiolate, pinnately compound or simple; pulvinus leaf base, stipulate; reticulate venation.
Inflorescence: Racemose or solitory axillary

Flower: Bracteate or ebracteate rarely bracteolate (e.g., *Arachis*), pedicellate or sessile, complete, irregular, zygomorphic, perigynous or occasionally hypogynous, pentamerous.

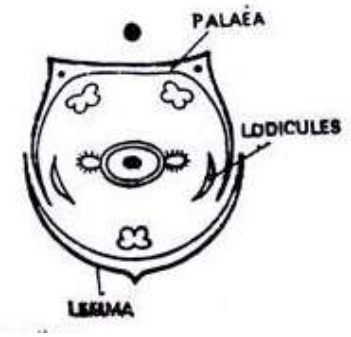
Calyx: Sepals 5, gamosepalous, usually companulate, lobe unequal, rarely tubular (e.g, *Cyamopsis*), odd sepal anterior, may be persistent inferior.
Corolla: Petals 5, polypetalous, papilionaceous, descending imbricate aestivation, one posterior long standered, two lateral short wings, and two anterior petals jointed to each other forming keel.
Androecium: Stamens 10, usually diadelphous (9+1 in *Lathyrus*, 5+5 in *Aeschynomene*) or monadelphous (9 in *Dalbergia*, 10 in *Arachis* and *Erythrina indica*), rarely free (e.g., *Sophora*), nectar gland often present on the inner bases of filaments, anther lobes bilocular, dorsifixed, introse.
Gynoecium: Monocarpellary, ovary superior, unilocular with marginal placentation ovary covered by staminal tube, style bent, stigma simple or capitate.
Fruit: Legume or lomentum.
Floral formula:

$$\% \, ♂ \; K_{(5)} \, C_{1+(2)+2} \, A_{(9)+1} \, \underline{G_1}$$

C) Poaceae (Gramineae)

Systematic position

Division	**Magnoliophyta**
Class	**Monocotyledonae**
Subclass	**Commelinidae**
Series	**Monocarpellatae**
Order	**Poales**
Family	**Poaceae**



Habit: Herbs, annuals or perennials or shrubs, sometimes tree like (*Bambusa, Dendrocalamus*).
Root: Adventitious, fibrous, branched, fascicled or stilt (*Zea mays*).
Stem: Underground rhizome in all perennial grasses, cylindrical, culm with conspicuous nodes and internodes, internodes hollow, herbaceous or woody, glabrous or glaucous, vegetative shoots are arising from the base of aerial stem or from underground stems are called tillers.
Leaves: Alternate, simple, distichous, exstipulate, sessile, ligulate (absent in *Echinochloa*), leaf base forming tubular sheath, sheath open, surrounding internode incompletely, ligule is present at the junction of the lamina and sheath, entire, hairy or rough, linear, parallel venation.

Inflorescence: Compound spike which may be sessile or stalked. Each unit of inflorescence is spikelet. The spikelets are arranged in various ways on the main axis called rachilla. A compound inflorescence may be spike of spikelets (*Triticum*), panicle of spikelets (*Avena*).
The spikelet consists of a short axis called rachilla on which 1 to many sessile or short stalked flowers are borne. The florets may be arranged in alternate or opposite manner on the central axis.

At the base of rachilla two sterile scales, called glumes, are present. The glumes are placed one above the other on opposite sides. The lower one is called first glume and the upper is called second glume. Both the glumes are boat shaped and sterile. Above the glumes a series of florets are present. Each floret has an inferior palea or lemma and above it a superior palea. The lemma frequently bears a long, stiff hair called awn.

Flower: Bracteate and bracteolate, sessile, incomplete, hermaphrodite, or unisexual (Zea mays), irregular, zygomorphic, hypogynous, cyclic.

Perianth: Represented by membranous scales called the lodicules. The lodicules are situated above and opposite the superior palea or may be absent, or many (*Ochlandra*), or 2 or 3.

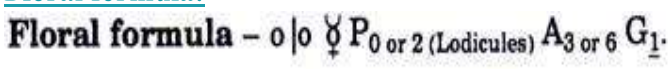
Androecium: Usually stamens 3, rarely 6 (*Bambusa, Oryza*) and one in various species of Anrostis, Lepturus; polyandrous, filaments long, anthers dithecous, versatile, linear, extrorse; pollen grains dry.

Gynoecium: Monocarpellary, according to some authors carpels 3, of which 2 are abortive, ovary superior, unilocular with single ovule, basal placentation, style short or absent; stigmas two feathery or papillate and branched.

Fruit: Caryopsis (achene with pericarp completely united or adherent with the seed coat) or rarely nut (*Dendrocalamus*) or berry (*Bambusa*).

Seed: Endospermic and containing a single cotyledon called scutellum, which is shield shaped and pressed against the endosperm.

Floral formula:



Lecture no. 16

Role of Animals in Agriculture

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Taxonomic categories

It is also called Linnaean hierarchy or taxonomic hierarchy or Taxonomic classification. It was first proposed by Linnaeus. Hierarchy of categories is the classification of organism in a definite sequence of categories (taxonomic categories) in a descending order starting from kingdom. The number of similar characters of categories decreases from lowest rank to highest rank. The hierarchy includes seven obligate categories – kingdom, division or phylum, class, order, family, genus and species. The categories are arranged in descending sequence keeping the kingdom at the top. In order to make taxonomic position of species more precise, certain categories have been added to this list. They are called intermediate categories.

Types of Taxonomic Categories

There are 7 main taxonomic categories. They are obligate categories i.e, they are strictly used at the time of any plant classification.

1. **Species:** Species (used both as singular and plural) is a natural population of individuals or group of population which resemble one another in all essential morphological and also reproductive characters so that they are able to interbreed freely and produce fertile offspring. Mango is species *indica* of genus *mangifera* (*Mangifera indica*). Potato is species *tuberosum* of genus *solanum* (*Solanum tuberosum*).
2. **Genus:** It is a group or assemblage of relate species which resemble one another in certain correlated characters. Correlated Characters are those similar or common features which are used in delimitation of a taxon above the rank of species. All the species of genus are presumed to have evolved from a common ancestor.
3. **Family:** It is taxonomic category which contains one or more related genera. All the genera of a family have some common features or correlated characters. They are separable from genera of a related family by important and characteristic differences in both vegetative and reproductive features. Thus the genera of cats (felis) and leopard (panther) are included in the family felidae.
4. **Order:** The category includes one or more related families. Thus the family solanaceae is placed in the order polemonialesalong with four other related families (convolvulaceae, boraginaceae, hydrophyllaceae and polemoniaceae). Similarly, the families' fekidae and

canidae are included under the order carnivore alongwith hyaenidae (hyaenas) and ursidae (bears).

5. **Class:** A class is made of one or more relates order. For example, the class dicotyledoneae (dicotyledonae, dictoyledons) of flowering plants contains all dicots which are grouped into several orders (e,g. Rosales, passiflorales, polemoniales, sapindales, ranales, etc.) likewise, class mammalian of animals includes all mammals which range from bats (order chiroptera),kangaroos (order marsupialia). Rodents (order rodentia), whales (order cetacean), carnivores (order cornivora) to great apes and man (order primate).
6. **Division or phylum:** It is a category higher than that of class. The term phylum is used for animals while division is commonly employed for plants. A division or phylum is formed of one or more classes. The phylum chordate of animals contains not class mammalian but also aves (birds), reptilian (reptiles), amphibian (amphibians), cyclostomata, chondrichthyes, osteichthyes (fishes) etc.
7. **Kingdom:** It is the highest taxonomic category. All plants are included in kingdom plantae while all animals belong to kingdom animalia.

There are some extra categories like sub division, sub order, sub family, tribe, sub tribe, etc. They are not regularly used. They are used only when they are needed.

Did You Know?

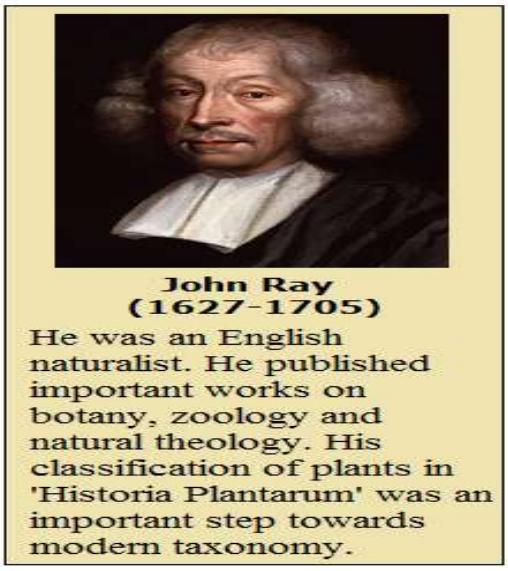
Taxon: Plant groups or animal groups included in categories are called taxon.
Adolf Mayer - First proposed the term 'Taxon" - for animals.
H. J. Lan: First proposed the term "Taxon" - for plants.
Hierarchy - Descending arrangement of taxonomic categories is known as hierarchy.
Species: Smallest taxonomic category: It is basic unit of classification.'

Species Concept

John Ray: Proposed the term and concept of species.
To explain the species, different concepts were proposed, which are as follows:
(A) Biological concept of species:

- ✓ Mayer proposed the biological concept of species.
- ✓ Mayer defined the "species" 'in the form of biological concept.
- ✓ According to Mayer "All the members that can interbreed. Among themselves and can produce fertile off springs are the members of same species"
- ✓ But this definition of Mayer was incomplete because this definition is applicable to sexually reproducing living beings because there are many organisms that have only asexual mode of reproduction. Example: Bacteria, Mycoplasma, BGA
- ✓ The main character in determination of any species is interbreeding. But this, character is not used in taxonomy. In taxonomy, the determination of species is based on other characters. Example: Mainly morphological characters.
- ✓ In higher plants, the determination of species is mainly based on the morphology of flower (floral morphology). Because floral (reproductive) characters are more conservative as compared to vegetative (Root/Stem, Leaf) characters i.e. they do not shows any major changes.

- ✓ When the species is determined on the basis of interbreeding then it is called as biological species. Example: All the 'humans in this world can interbreed among themselves. So all the humans are the members of one biological species.
- ✓ When the determination of species is based on other characters then it is' called as taxonomic species. Example: These 3 have same morphological characters. Therefore they belong to same taxonomic species i.e. one taxonomic species. But these three cannot interbreed among themselves. Therefore on the basis of interbreeding these are three biological species.



(B) Static concept of species:

- ✓ The static concept of species was proposed by Linnaeus. According to Linnaeus "species is unchangeable" i.e. there is no change in the character of species. The species of present day are same as they were in past and they will remains same in future.
- ✓ Linnaeus believed in the "Theory of Special creation".
- ✓ Father Suarez - gave the principle of special creation. According to this theory "All the living organisms are created by God (Every life is created 'by God) and God gave the basic size and shape of all living organisms, they are still present in their actual former form. But Lamarck rejected this hypothesis.

(C) Dynamic concept of species:

- ✓ It was proposed by "Lamarck".
- ✓ According to this concept "Species is always changeable". Changes always occur in the characters of species from one generation to next generation. And these changes are known as "evolution".

(D) Typological concept:

- ✓ It was proposed by "Aristotle" and "Plato".
- ✓ According to this concept 'There is a definite type or pattern of characters in the each species of every living organisms and all the members of species show maximum resemblance with this pattern. (Typological concept is based on single individual of species)The species in which a fixed pattern of characters is present are called as monotypic species. Example: Bacteria, blue green algae.

- ✓ In many species, more than one type' or pattern of characters are present. These are called "Polytypic species" or "Macrospecies". Example: *Brassica oleracea* → Cauliflower, Cabbage, Knolkhol

Polytypic Species are of three types:

- Biotype: Members of same species inhabiting similar environment and having some genetic variations are known as biotypes. Variations found in these members are permanent. These members cannot interbreed among themselves. Example: Cauliflower, Cabbage, Knol-Khol are three biotypes of one species
- Eeotypes: Members of same species inhabiting different environment and having some genetic variations are known as ecotypes. Variations are permanent. These members can interbreed among themselves but due to geographical barrier they cannot interbreed. Example: Crow (Corvus splendense) found in different regions are ecotype of one species
  - ✓ *Corvus splendense splendense* - Indian crow
  - ✓ *Corvus splendense insolence* - Myanmar crow
  - ✓ *Corvus splendense protegatus* - Srilankan crow
- Eeads or Ecophenes: Members of same species having some non-genetic variations due to environment is called Ecads. These variations are temporary. Example: Every living being

This hypothesis is believed to be most acceptable.

Some definition related to species:

- Linneon species: Those taxonomic species whose determination is based on morphology. They are called as linneon species. They are also called morpho-species or taxonomic species.

  Example: Most of species in taxonomy are linneon species
- Microspecies or Joardan's species: Those species in which variations are very less are called Joardan's species. They reproduce asexually so they have very less variations.
- Sibling species or Cryptic species: Members of species which are morphologically similar but reproductively isolated are known as Sibling species i.e. they cannot interbreed among themselves.

  Sibling species is one taxonomic species (because these members have similar morphology) but they are different biological species. [Because they cannot interbreed]. Example: *Brassica oleracea*
- Allopatric species: Those species that are found in different geographical regions and have geographical barriers between them are known as allopatric species.

  Geographical barriers are hills, oceans, Himalayan Mountains.
- Sympatric species: The species found in similar geographical regions are sympatric species.
- Allochronk species: The species found in different time periods.

  Example: Man and Dinosaurs.
- Synchronic species: Those species that are found in same era.

  Example: Dinosaurs and Archaeopteryx.
- Palaeo species: Those species that are extinct now and are found in the form of fossils.

Example: Dinosaurs

Types of Taxonomy

1. Alpha taxonomy or classical taxonomy: It is based on external morphology, origin and evolution of plants.
2. Beta taxonomy or Explorative taxonomy: Besides external morphology, it also includes internal characters' like embryological, cytological, anatomical characters etc.
3. Omega taxonomy or Encyclopaedic taxonomy: Omega taxonomy has widest scope. It is based on all the information or data available about plants.
4. Cytotaxonomy: The use of cytological characters of plants in classification or in solving taxonomic problems is called cytotaxonomy. Cytological characters constitute an important aid to plant taxonomy, especially in determining affinities at the generic and infrageneric levels.
5. Chemotaxonomy: The uses of chemical characters of plants in classification or in solving taxonomic problems is called chemotaxonomy or chemical taxonomy. It is based on the chemical constitution of plants. The fragrance and taste vary from species to species.

   The basic chemical compounds used in chemotaxonomy are alkaloids, carotenoids, tannins, polysaccharide, nucleic acids, fatty acids, amino acids, aromatic compounds etc.
6. Karyotaxonomy: Based on characters of nucleus and chromosomes. Pattern of chromosomal bands (dark bands and light bands) is most specific characters.

Biodiversity and Conservation

(1) The vast array of species of micro-organisms, algae, fungi, plants and animals occurring on the earth either in the terrestrial or aquatic habitats and the ecological complexes of which they are a part.

(2) Diversity ranges from macromolecules to biomes.

(3) Biodiversity on earth exists in three levels of organization:

(i) Genetic diversity

(ii) Species diversity

1. Genetic diversity

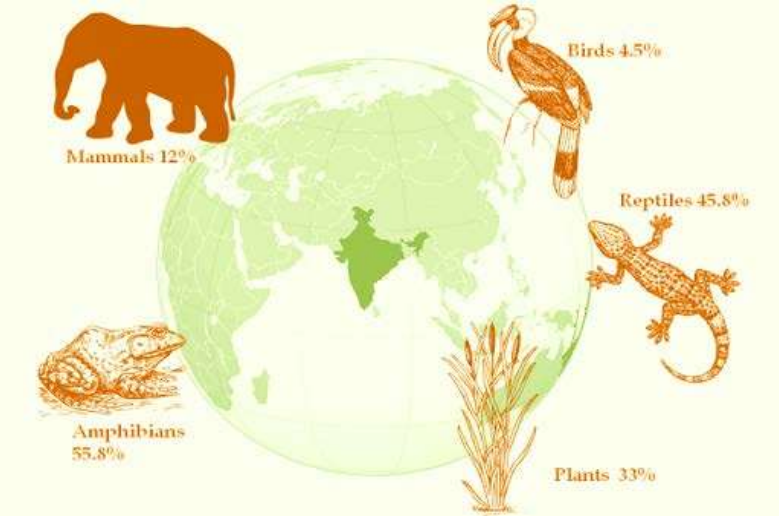
- ✓ It is related to the variations of genes within species.
- ✓ The variations may be in different variants of same genes (alleles), in entire genes or in chromosomal structures.
- ✓ Greater the genetic diversity among organisms of a species, more sustenance it has against environmental perturbations.
- ✓ Genetically uniform populations are highly prone to diseases.

2. Species diversity

- ✓ It is related to the variety of species within a region.
- ✓ Species richness refers to the number of species per unit area.
- ✓ Species Evenness refers to the relative abundance with which each species is represented in an area.

Biodiversity in India

- ✓ Out of the twelve mega biodiversity counties, India is one.
- ✓ India has 10 biogeographical regions, 89 national parks, 500 wild life sanctuaries, 14 biosphere reserves, 6 westlands and 35 world heritage sites.
- ✓ There are about 45,000 species of plants and about 90,000-1, 00,000 species of animals.



Patterns of Biodiversity

- Biodiversity changes with change in latitude or altitude.
- It is minimum at the poles and maximum near or at equator. Similarly, as one moves down from higher to lower altitudes, biodiversity is increased.

Loss of bio-diversity:

- Caused by three factors - Population, Urbanisation and Industrialisation.
- The colonisation of tropical Pacific Islands by human has led to the extinction of more than 2000 species of native birds.
- Loss of bio-diversity in a region leads to:
  (i) Decrease in plant production.
  (ii) Less resistance to environmental disturbances such as droughts.
  (iii) Increase in variability in ecosystem processes like plant productivity, water use, pest and disease cycles etc.

Biodiversity Conservation

In situ conservation

(1) The most appropriate method to maintain species of wild animals and plants in their natural habitats. This approach includes conservation and protection of the total ecosystems and its biodiversity through a network of protected areas.

(2) The common natural habitats (protected areas) that have been set for in-situ conservation of wild animals and plants include:
  (i) National parks
  (ii) Wild life sanctuaries
  (iii) Biosphere reserves

(iv) Several wetlands, mangroves and coral reefs.

(v) Sacred grooves and lakes.

(3) Hot spot of biodiversity are those regions of rich biodiversity which have been declared sensitive due to direct or indirect interference of human activities.

(4) There are 25 terrestrial hot spots in the world including two from India.

Ex situ conservation

(1) Threatened animals and plants are taken out from their natural habitat and placed in special setting where they can be protected and given special care.

(2) Ex situ conservation includes the following:

(i) Sacred plants and home gardens

(ii) Seed banks, field gene banks, cryopreservation.

(iii) Botanical gardens, Arborata, Zoological gardens, Aquaria.

Convention on Biodiversity:

(1) "The earth Summit" held in Rio de Jeneiro in 1992 called upon all nations to take appropriate measures for conservation of biodiversity and sustainable utilization of its benefits.

(2) Second international Conference on Sustainable development held in 2002 in Johannesburg, South Africa, 190 countries pledged their commitment to achieve by 2010 a significant reduction in the current rate of biodiversity loss at global, regional and local level.