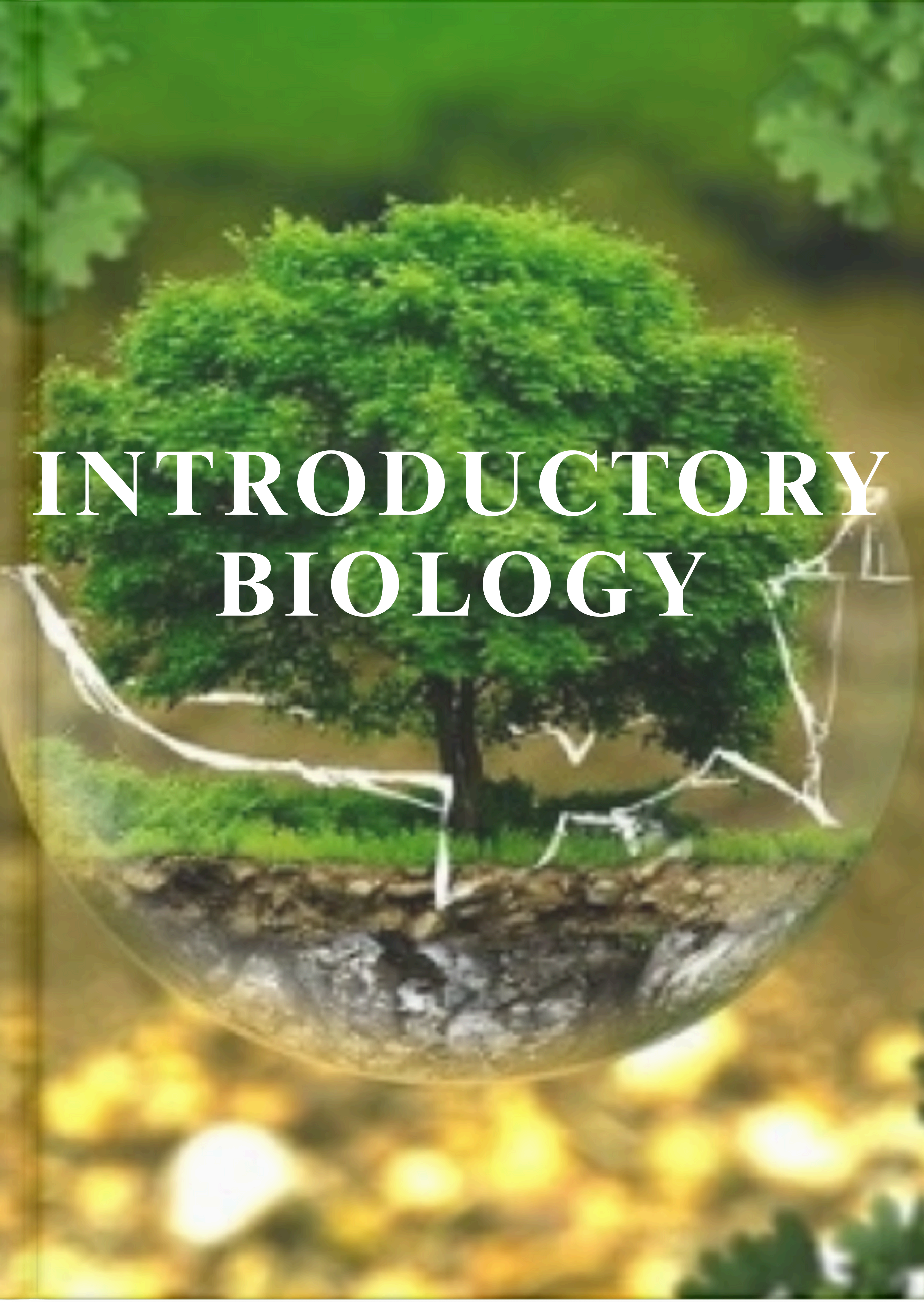
INTRODUCTORY BIOLOGY



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INTRODUCTORY BIOLOGY

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Tittle

1. Introduction to the living world, diversity and characteristics of life

Biology is the science of life forms and non-living processes. The living world comprises an amazing diversity of living organisms. In order to facilitate the study of kinds and diversity of organisms, biologists have evolved certain rules and principles for identification, nomenclature and classification of organisms. The branch of biology dealing with these aspects is referred to as Taxonomy.

Life is a characteristic that distinguishes objects that have signaling and self-sustaining processes from those that do not, either because such functions have ceased (death), or else because they lack such functions and are classified as inanimate. Biology is the science concerned with the study of life.

Characteristics features of Living things / Differences between living and non-living things:

a) Growth
b) Reproduction
c) Metabolism
d) Response to stimuli

Biodiversity: Range of organisms present on earth (1.7 – 1.8 million)

Identification: Comparing similarities and differences with already known ones.

Nomenclature: Naming of organisms. The names are unique and universal.

Rules for nomenclature are provided by;

a) ICBN – International Code for Botanical Nomenclature
b) ICZN – International Code for Zoological Nomenclature

Binomial Nomenclature:
Carolous Linnaeus – Father of Taxonomy
Name with two parts: - Generic name (**Genus**) & Specific epithet (**Species**)
Guidelines and Principles for Nomenclature

a) It should be in Latin / derived from Latin.
b) If it is written in Italics when types and underlined when handwritten.
c) It contains two parts, first word is Genus ; second word is Species.
d) Genus name starts with Capital while species name starts with small letters.

e) Name should be short, precise & easy to pronounce.
f) Name of the author is written is an abbreviated form after the species name.

Ex. *Mangifera indica* Linn.

Example:
Mangifera indica (Mango)
Homo sapiens (Human)
Panthera pardus (Leopard)
Felis domestica (Cat)

Classification – Grouping of organisms in to categories based on observable characters. (category –taxa)
Taxonomy - Characterization, identification , classification and nomenclature are the process of taxonomy.
Systematics - Different kinds of organisms and their relationships Linnaeus – *Systema Naturae* (evaolutionary relationships among organisms).
Taxonomical Hierarchy – Similarities decreases/ Differences increases
Species à Genus à Family à Order àClass àPhylum àDivisions àKingdom

1. Species -*Panthera leo, Panthera pardus, Panthera tigris*.
2. Genus- Panthera (Lion, Leopad,Tiger)
3. Family- Panthera and Felis together into Felidae
4. Order - Felidae (cat family) , Canidae (dog family) - Carnivora
5. Class - Carnivora (tiger, cat, dog), Primates (monkeys)- Mammalian
6. Phylum – Pisces, Amphibian, Reptilian, Aves & Mammals
7. Kingdom – Plantae, Animalia.

Taxonomical Aids :

1. Herbarium
2. Botanical garden- NBRI (Lucknow) & IBG (Howrah)
3. Museum
4. Zoological parks.
5. Key (analytical in nature)
6. Monograph (1 family / genera at a time.)
7. Manuals (particular area , family/ genus/ species)
8. Flora (habitat & description of plants in a given area)

Taxonomical aids

- These are the procedures and techniques used to store and preserve information as well as specimens of various plants and animals.
- These help in identification, naming, and classification of organisms.

Herbarium

- It is the storehouse of collected plant specimens.

- Collected plant specimens are dried, pressed, and preserved on sheets and then arranged systematically according to the universally accepted system of classification.
- Herbarium sheet contains label regarding date, place of the collection, scientific name, family, collector‘s name, etc. of the specimen.

Botanical gardens

- It has the collection of living plant species that are grown for identification and reference.
- Each plant contains labels indicating their scientific name and family.
- Some famous botanical gardens are Indian Botanical Garden, Calcutta (largest in India), Royal Botanical Garden, Kew (largest in world till date) and National Botanical Research Institute.

Museum

- It is the repository that has a collection of various plant and animal specimens that are preserved for study and reference.
- The organisms are preserved either in preservative solution or in the form of dry specimen
- It often has a collection of skeletons of animals also.

Zoological parks

- Wild animals are kept in protected environments.
- Provides opportunity for studying the behaviour and food habits of the animals

Key

- Keys are used for identification of plants and animals based on similarities and dissimilarities.
- Manuals, monographs, and catalogues are other means of recording descriptions.
- Manuals help in the identification of names of various species of organisms in a given area.
- Monograph is a detailed and well-documented work on any particular taxon.

Organisms with their Taxonomic categories:

Man : *Homo sapiens* – Homo – Hominidae – Primate – Chordate - Mammalia
Housefly : *Musca domestica* - Musca – Muscidae – Diptera - Insecta -Arthropoda
Mango : *Mangifera indica* – Mangifera - Anacardiaceae - Sapindales- Dicotyledonae - Angiospermae
Wheat : *Triticum aestivum* – Triticum – Poaceae – Poales - Monocotyledonae –

Angiospermae

Biology, the study of life, is a human endeavor resulting from an innate attraction to life in its diverse forms (E.O. Wilson's biophilia).

The science of biology is enormous in scope.

- It reaches across size scales from submicroscopic molecules to the global distribution of biological communities.
- It encompasses life over huge spans of time from contemporary organisms to ancestral life forms stretching back nearly four billion years.

As a science, biology is an ongoing process.

- As a result of new research methods developed over the past few decades, there has been an information explosion.
- Technological advances yield new information that may change the conceptual framework accepted by the majority of biologists.

With rapid information flow and new discoveries, biology is in a continuous state of flux. There are, however, enduring unifying themes that pervade the science of biology:

- A hierarchy of organization
- The cellular basis of life
- Heritable information
- The correlation between structure and function
- The interaction of organisms with their environment
- Unity in diversity
- Evolution: the core theme
- Scientific process: the hypothetico-deductive method

I. Life's Hierarchical Order

A. The living world is a hierarchy, with each level of biological structure building on the level below it

A characteristic of life is a high degree of order. Biological organization is based on a hierarchy of structural levels, with each level building on the levels below it.

In multicellular organisms similar cells are organised into Large scale communities classified by

predominant vegetation type and distinctive combinations of plants and animals

The sum of all the planet's ecosystems

Atoms

Complex biological molecules

Subcellular organelles

Cells

Tissues

Organs

Organ systems

Complex organism

There are levels of organization beyond the individual organism:

Population =

Community =

Ecosystem =

Biomes =

Biosphere =

B. Each level of biological organization has emergent properties

Emergent property = Property that emerges as a result of interactions between components.

• With each step upward in the biological hierarchy, new properties emerge that were not present at the simpler organizational levels.

• Life is difficult to define because it is associated with numerous emergent properties that reflect a hierarchy of structural organization.

Some of the emergent properties and processes associated with life are the following:

1. Order. Organisms are highly ordered, and other characteristics of life emerge from this complex organization.

An energy-processing system of community interactions that include abiotic environmental factors such as soil and water

Populations of species living in the same area

Localized group of organisms belonging to the same species

2. Reproduction. Organisms reproduce; life comes only from life (biogenesis).

3. Growth and Development. Heritable programs stored in DNA direct the species-specific pattern of growth and development.

4. Energy Utilization. Organisms take in and transform energy to do work, including the maintenance of their ordered state.

5. Response to Environment. Organisms respond to stimuli from their environment.

6. Homeostasis. Organisms regulate their internal environment to maintain a steady-state, even in the face of a fluctuating external environment.

7. Evolutionary Adaptation. Life evolves in response to interactions between organisms and their environment.

Because properties of life emerge from complex organization, it is impossible to fully explain a higher level of order by breaking it into its parts.

Holism = The principle that a higher level of order cannot be meaningfully explained by examining component parts in isolation.

• An organism is a living whole greater than the sum of its parts.

• For example, a cell dismantled to its chemical ingredients is no longer a cell.

It is also difficult to analyze a complex process without taking it apart.

Reductionism = The principle that a complex system can be understood by studying its component parts.

• Has been a powerful strategy in biology

• Example: Watson and Crick deduced the role of DNA in inheritance by studying its molecular structure.

The study of biology balances the reductionist strategy with the goal of understanding how the parts of cells, organisms, and populations are functionally integrated.

C. Cells are an organism‟s basic units of structure and function The cell is an organism's basic unit of structure and function.

• Lowest level of structure capable of performing all activities of life.

• All organisms are composed of cells.

• May exist singly as unicellular organisms or as subunits of multicellular organisms.

The invention of the microscope led to the discovery of the cell and the formulation of the cell theory.

• Robert Hooke (1665) reported a description of his microscopic examination of cork. Hooke described tiny boxes which he called "cells" (really cell walls). The significance of this discovery was not recognized until 150 years later.

• Antonie van Leeuwenhok (1600's) used the microscope to observe living organisms such as microorganisms in pond water, blood cells, and animal sperm cells.

• Matthias Schleiden and Theodor Schwann (1839) reasoned from their own microscopic studies and those of others, that all living things are made of cells.

This formed the basis for the cell theory.

• The cell theory has since been modified to include the idea that all cells come from preexisting cells.

Over the past 40 years, use of the electron microscope has revealed the complex ultrastructure of cells.

• Cells are bounded by plasma membranes that regulate passage of materials between the cell and its surroundings.

• All cells, at some stage, contain DNA.

Based on structural organization, there are two major kinds of cells: prokaryotic and eukaryotic.

Prokaryotic cell = Cell lacking membrane-bound organelles and a membrane-enclosed nucleus.

• Found only in the archaebacteria and bacteria
• Generally much smaller than eukaryotic cells
• Contains DNA that is not separated from the rest of the cell, as there is no membrane-bound nucleus
• Lacks membrane-bound organelles
• Almost all have tough external walls

Eukaryotic cell = Cell with a membrane-enclosed nucleus and membrane-enclosed organelles.

• Found in protists, plants, fungi, and animals
• Subdivided by internal membranes into different functional compartments called organelles
• Contains DNA that is segregated from the rest of the cell. DNA is organized with proteins into chromosomes that are located within the nucleus, the largest organelle of most cells.
• Cytoplasm surrounds the nucleus and contains various organelles of different functions
• Some cells have a tough cell wall outside the plasma membrane (e.g., plant cells). Animal cells lack cell walls.

Though structurally different, eukaryotic and prokaryotic cells have many similarities, especially in their chemical processes.

D. The continuity of life is based on heritable information in the form of DNA

Biological instructions for an organism's complex structure and function are encoded in DNA.

• Each DNA molecule is made of four types of chemical building blocks called nucleotides.
• The linear sequence of these four nucleotides encode the precise information in a gene, the unit of inheritance from parent to offspring.
• An organism's complex structural organization is specified by an enormous amount of coded information.
Inheritance is based on:
• A complex mechanism for copying DNA.
• Passing the information encoded in DNA from parent to offspring.
All forms of life use essentially the same genetic code.
• A particular nucleotide sequence provides the same information to one organism as it does to another.
• Differences among organisms reflect differences in nucleotide sequence.
E. Structure and function are correlated at all levels of biological organization
There is a relationship between an organism's structure and how it works. Form fits function.
• Biological structure gives clues about what it does and how it works.
• Knowing a structure's function gives insights about its construction.
• This correlation is apparent at many levels of biological organization.
F. Organisms are open systems that interact continuously with their environments
Organisms interact with their environment, which includes other organisms as well as abiotic factors.
• Both organism and environment are affected by the interaction between them.
• Ecosystem dynamics include two major processes:
1. Nutrient cycling
2. Energy flow
G. Regulatory mechanisms ensure a dynamic balance in living systems
Regulation of biological processes is critical for maintaining the ordered state of life.
Many biological processes are self-regulating; that is, the product of a process regulates that process (= feedback regulation; see Campbell, Figure 1.8).
• Positive feedback speeds a process up
• Negative feedback slows a process down
Organisms and cells also use chemical mediators to help regulate processes.
• The hormone insulin, for example, signals cells in vertebrate organisms to take up glucose. As a result, blood glucose levels go down.
• In certain forms of diabetes mellitus, insulin is deficient and cells do not take up glucose as they should, and as a result, blood glucose levels remain high.

II. Evolution, Unity, and Diversity

A. Diversity and unity are the dual faces of life on Earth
Biological diversity is enormous.
• Estimates of total diversity range from five million to over 30 million species.

• About 1.5 million species have been identified and named, including approximately 260,000 plants, 50,000 vertebrates, and 750,000 insects.

To make this diversity more comprehensible, biologists classify species into categories.

Taxonomy = Branch of biology concerned with naming and classifying organisms.

• Taxonomic groups are ranked into a hierarchy from the most to least inclusive category: domain, kingdom, phylum, class, order, family, genus, species.

• A six-kingdom system recognizes two prokaryotic groups and divides the Monera into the Archaebacteria and Eubacteria.

• The kingdoms of life recognized in the traditional five-kingdom system are Monera, Protista, Plantae, Fungi, and Animalia

There is unity in the diversity of life forms at the lower levels of organization. Unity of life forms is evident in:

• A universal genetic code.

• Similar metabolic pathways (e.g., glycolysis).

• Similarities of cell structure (e.g., flagella of protozoans and mammalian sperm cells).

B. Evolution is the core theme of biology

Evolution is the one unifying biological theme.

• Life evolves. Species change over time and their history can be described as a branching tree of life.

• Species that are very similar share a common ancestor at a recent branch point on the phylogenetic tree.

• Less closely related organisms share a more ancient common ancestor.

• All life is connected and can be traced back to primeval prokaryotes that existed more than three billion years ago.

In 1859, Charles Darwin published On the Origin of Species in which he made two major points:

1. Species change, and contemporary species arose from a succession of ancestors through a process of "descent with modification."

2. A mechanism of evolutionary change is natural selection.

Darwin synthesized the concept of natural selection based upon the following observations:

• Individuals in a population of any species vary in many inheritable traits.

• Populations have the potential to produce more offspring than will survive or than the environment can support.

• Individuals with traits best suited to the environment leave a larger number of offspring, which increases the proportion of inheritable variations in the next generation. This differential reproductive success is what Darwin called natural selection.

Organisms' adaptations to their environments are the products of natural selection.

• Natural selection does not create adaptations; it merely increases the frequency of inherited variants that arise by chance.

• Adaptations are the result of the editing process of natural selection. When exposed to specific environmental pressures, certain inheritable variations favor the reproductive success of some individuals over others.

Darwin proposed that cumulative changes in a population over long time spans could produce a new species from an ancestral one.

Descent with modification accounts for both the unity and diversity of life.

• Similarities between two species may be a reflection of their descent from a common ancestor.

• Differences between species may be the result of natural selection modifying the ancestral equipment in different environmental contexts.

III. Science as a Process

A. Testable hypotheses are the hallmarks of the scientific process

As the science of life, biology has the characteristics associated with science in general.

Science is a way of knowing. It is a human endeavor that emerges from our curiosity about ourselves, the world, and the universe. Good scientists are people who:

- Ask questions about nature and believe those questions are answerable.
- Are curious, observant, and passionate in their quest for discovery.
- Are creative, imaginative, and intuitive.
- Are generally skeptics.

Scientific method = Process which outlines a series of steps used to answer questions.

- Is not a rigid procedure.
- Based on the conviction that natural phenomena have natural causes.
- Requires evidence to logically solve problems.

The key ingredient of the scientific process is the hypothetico-deductive method, which is an approach to problem-solving that involves:

1. Asking a question and formulating a tentative answer or hypothesis by inductive reasoning.
2. Using deductive reasoning to make predictions from the hypothesis and then testing the validity of those predictions.

Hypothesis = Educated guess proposed as a tentative answer to a specific question or problem.

Inductive reasoning = Making an inference from a set of specific observations to reach a general conclusion.

Deductive reasoning = Making an inference from general premises to specific consequences, which logically follow if the premises are true.

• Usually takes the form of If...then logic.

• In science, deductive reasoning usually involves predicting experimental results that are expected if the hypothesis is true.

Some students cannot make the distinction between inductive and deductive reasoning. An effective teaching strategy is to let them actually experience both processes. To illustrate inductive reasoning, provide an every day scenario with enough pieces of information for student to hypothesize a plausible explanation for some event. Demonstrate deductive reasoning by asking students to solve a simple problem, based upon given assumptions.

Useful hypotheses have the following characteristics:

- Hypotheses are possible causes. Generalizations formed by induction are not necessarily hypotheses. Hypotheses should also be tentative explanations for observations or solutions to problems.
- Hypotheses reflect past experience with similar questions. Hypotheses are not just blind propositions, but are educated guesses based upon available evidence.
- Multiple hypotheses should be proposed whenever possible. The disadvantage of operating under only one hypothesis is that it might restrict the search for evidence in support of this hypothesis; scientists might bias their search, as well as neglect to consider other possible solutions.
- Hypotheses must be testable via the hypothetico-deductive method. Predictions made from hypotheses must be testable by making observations or performing experiments. This limits the scope of questions that science can answer.
- Hypotheses can be eliminated, but not confirmed with absolute certainty. If repeated experiments consistently disprove the predictions, then we can assume that the hypothesis is false. However, if repeated experimentation supports the deductions, we can only assume that the hypothesis may be true; accurate predictions can be made from false hypotheses. The more deductions that are tested and supported, the more confident we can be that the hypothesis is true.

Another feature of the scientific process is the controlled experiment which includes control and experimental groups.

Control group = In a controlled experiment, the group in which all variables are held constant.

- Controls are a necessary basis for comparison with the experimental group, which has been exposed to a single treatment variable.
- Allows conclusions to be made about the effect of experimental manipulation.
- Setting up the best controls is a key element of good experimental design.

Variable = Condition of an experiment that is subject to change and that may influence an experiment's outcome.

Experimental group = In a controlled experiment, the group in which one factor or treatment is varied.

Science is an ongoing process that is a self-correcting way of knowing. Scientists:

- Build on prior scientific knowledge.
- Try to replicate the observations and experiments of others to check on their conclusions.

- Share information through publications, seminars, meetings, and personal communication.

What really advances science is not just an accumulation of facts, but a new concept that collectively explains observations that previously seemed to be unrelated.

- Newton, Darwin, and Einstein stand out in the history of science because they synthesized ideas with great explanatory power.
- Scientific theories are comprehensive conceptual frameworks which are well supported by evidence and are widely accepted by the scientific community.

B. Science and technology are functions of society Science and technology are interdependent.

- Technology extends our ability to observe and measure, which enables scientists to work on new questions that were previously unapproachable.
- Science, in turn, generates new information that makes technological inventions possible.
- Example: Watson and Crick's scientific discovery of DNA structure led to further investigation that enhanced our understanding of DNA, the genetic code, and how to transplant foreign genes into microorganisms. The biotechnology industry has capitalized on this knowledge to produce valuable pharmaceutical products such as human insulin.

We have a love-hate relationship with technology.

- Technology has improved our standard of living.
- The consequence of using technology also includes the creation of new problems such as increased population growth, acid rain, deforestation, global warming, nuclear accidents, ozone holes, toxic wastes, and endangered species.
- Solutions to these problems have as much to do with politics, economics, culture and values as with science and technology.

A better understanding of nature must remain the goal of science. Scientists should:

- Try to influence how technology is used.
- Help educate the public about the benefits and hazards of specific technologies.

C. Biology is a multidisciplinary adventure

Biology is a multidisciplinary science that integrates concepts from chemistry, physics and mathematics. Biology also embraces aspects of humanities and the social sciences.

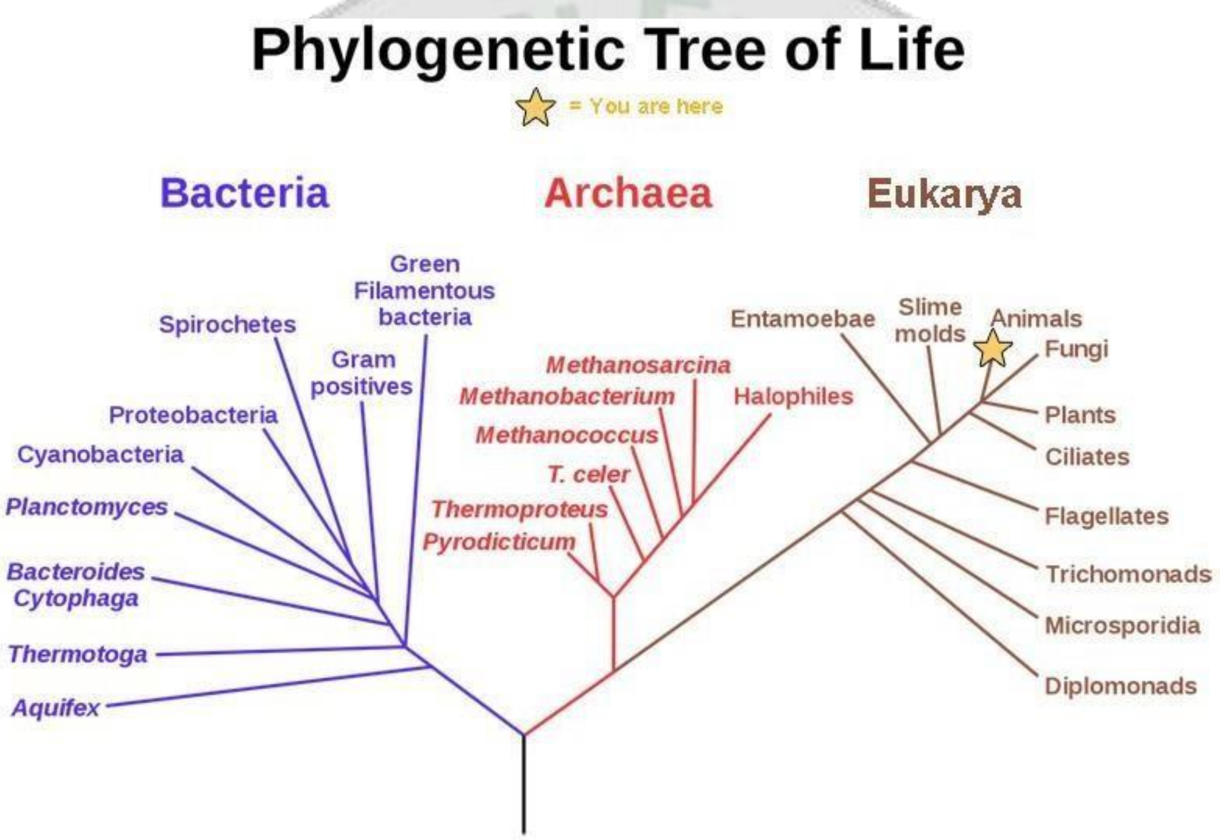
The Diversity of Life

The fact that biology, as a science, has such a broad scope has to do with the tremendous diversity of life on Earth. The source of this diversity is evolution, the process of gradual change during which new species arise from older species. Evolutionary biologists study the evolution of living things in everything from the microscopic world to ecosystems.

The evolution of various life forms on Earth can be summarized in a phylogenetic tree using phylogeny . A phylogenetic tree is a diagram showing the evolutionary relationships among biological species based on similarities and differences in genetic or physical traits or both. A phylogenetic tree is composed of nodes and branches. The internal nodes represent ancestors and are points in evolution when, based on scientific evidence, an ancestor is thought to have diverged to form two new species. The length of each branch is proportional to the time elapsed since the split.

Phylogenetic Tree of Life

This phylogenetic tree was constructed by microbiologist Carl Woese using data obtained from sequencing ribosomal RNA genes. The tree shows the separation of living organisms into three domains: Bacteria, Archaea, and Eukarya. Bacteria and Archaea are prokaryotes, single-celled organisms lacking intracellular organelles.



Carl Woese and the Phylogenetic Tree

In the past, biologists grouped living organisms into five kingdoms: animals, plants, fungi, protists, and bacteria. The organizational scheme was based mainly on physical features, as opposed to physiology, biochemistry, or molecular biology, all of which are used by modern systematics. The pioneering work of American microbiologist Carl Woese in the early 1970s has shown, however, that life on Earth has evolved along three lineages, now called domains—Bacteria, Archaea, and Eukarya . The first two are prokaryotic cells with microbes that lack membrane-enclosed nuclei and organelles. The third domain contains the eukaryotes and includes unicellular microorganisms together with the four original kingdoms (excluding bacteria). Woese defined Archaea as a new domain, and this resulted in a new taxonomic tree . Many organisms belonging to the Archaea domain live under extreme conditions and are called extremophiles. To construct his tree, Woese used genetic relationships rather than similarities based on morphology (shape).

Woese's tree was constructed from comparative sequencing of the genes that are universally distributed, present in every organism, and conserved (meaning that these genes have remained essentially unchanged throughout evolution). Woese's approach was revolutionary because comparisons of physical features are insufficient to differentiate between the prokaryotes that appear fairly similar in spite of their tremendous biochemical diversity and genetic variability. The comparison of homologous DNA and RNA sequences provided Woese with a sensitive device that revealed the extensive variability of prokaryotes, and which justified the separation of the prokaryotes into two domains: bacteria and archaea. DNA, the universal genetic material, contains the instructions for the structure and function of all living organisms and can be divided into genes whose expression varies between organisms. The RNA, which is transcribed from DNA, varies between organisms as well based on the expression of specific genes. Thus, to examine differences at this molecular level provides a more accurate depiction of the diversity which exists.

2.Evolution

The theory of evolution by natural selection, first formulated in Darwin's book "On the Origin of Species" in 1859, is the process by which organisms change over time as a result of changes in heritable physical or behavioral traits. Changes that allow an organism to better adapt to its environment will help it survive and have more offspring.

Evolution by natural selection is one of the best substantiated theories in the history of science, supported by evidence from a wide variety of scientific disciplines, including paleontology, geology, genetics and developmental biology. The theory has two main points, said Brian Richmond, curator of human origins at the American Museum of Natural History in New York City. "All life on Earth is connected and related to each other," and this diversity of life is a product of "modifications of populations by natural selection, where some traits were favored in and environment over others," he said.

More simply put, the theory can be described as "descent with modification," said Briana Pobiner, an anthropologist and educator at the Smithsonian Institution National Museum of Natural History in Washington, D.C., who specializes in the study of human origins. The theory is sometimes described as "survival of the fittest," but that can be misleading, Pobiner said. Here, "fitness" refers not to an organism's strength or athletic ability, but rather the ability to survive and reproduce.

Natural selection

To understand the origin of whales, it's necessary to have a basic understanding of how natural selection works. Natural selection can change a species in small ways, causing a population to change color or size over the course of several generations. This is called "microevolution."

But natural selection is also capable of much more. Given enough time and enough accumulated changes, natural selection can create entirely new species, known as "macroevolution." It can turn dinosaurs into birds, amphibious mammals into whales and the ancestors of apes into humans. Take the example of whales — using evolution as their guide and knowing how natural selection works, biologists knew that the transition of early whales from land to water occurred in a series of predictable steps. The evolution of the blowhole, for example, might have happened in the following way:

Random genetic changes resulted in at least one whale having its nostrils placed farther back on its head. Those animals with this adaptation would have been better suited to a marine lifestyle, since they would not have had to completely surface to breathe. Such animals would have been more successful and had more offspring. In later generations, more genetic changes occurred, moving the nose farther back on the head.

Other body parts of early whales also changed. Front legs became flippers. Back legs disappeared. Their bodies became more streamlined and they developed tail flukes to better propel themselves through water.

Darwin also described a form of natural selection that depends on an organism's success at attracting a mate, a process known as sexual selection. The colorful plumage of peacocks and the antlers of male deer are both examples of traits that evolved under this type of selection.

But Darwin wasn't the first or only scientist to develop a theory of evolution. The French biologist Jean-Baptiste Lamarck came up with the idea that an organism could pass on traits to its offspring, though he was wrong about some of the details. And around the same time as Darwin, British biologist Alfred Russel Wallace independently came up with the theory of evolution by natural selection.

Modern understanding

Darwin didn't know anything about genetics, Pobiner said. "He observed the pattern of evolution, but he didn‘t really know about the mechanism." That came later, with the discovery of how genes encode different biological or behavioral traits, and how genes are passed down from parents to offspring. The incorporation of genetics and Darwin's theory is known as "modern evolutionary synthesis."

The physical and behavioral changes that make natural selection possible happen at the level of DNA and genes. Such changes are called mutations. "Mutations are basically the raw material on which evolution acts," Pobiner said.

Mutations can be caused by random errors in DNA replication or repair, or by chemical or radiation damage. Most times, mutations are either harmful or neutral, but in rare instances, a mutation might prove beneficial to the organism. If so, it will become more prevalent in the next generation and spread throughout the population. In this way, natural selection guides the evolutionary process, preserving and adding up the beneficial mutations and rejecting the bad ones. "Mutations are random, but selection for them is not random," Pobiner said.

But natural selection isn't the only mechanism by which organisms evolve, she said. For example, genes can be transferred from one population to another when organisms migrate or immigrate, a process known as gene flow. And the frequency of certain genes can also change at random, which is called genetic drift.

A wealth of evidence

Even though scientists could predict what early whales should look like, they lacked the fossil evidence to back up their claim. Creationists took this absence as proof that evolution didn't occur. They mocked the idea that there could have ever been such a thing as a walking whale. But since the early 1990s, that's exactly what scientists have been finding.

The critical piece of evidence came in 1994, when paleontologists found the fossilized remains of *Ambulocetus natans*, an animal whose name literally means "swimming-walking whale." Its forelimbs had fingers and small hooves but its hind feet were enormous given its size. It was clearly adapted for swimming, but it was also capable of moving clumsily on land, much like a seal. When it swam, the ancient creature moved like an otter, pushing back with its hind feet and undulating its spine and tail. Modern whales propel themselves through the water with powerful beats of their horizontal tail flukes, but *Ambulocetus* still had a whip-like tail and had to use its legs to provide most of the propulsive force needed to move through water.

In recent years, more and more of these transitional species, or "missing links," have been discovered, lending further support to Darwin's theory, Richmond said.

Controversy

Despite the wealth of evidence from the fossil record, genetics and other fields of science, some people still question its validity. Some politicians and religious leaders denounce the theory, invoking a higher being as a designer to explain the complex world of living things, especially humans. School boards debate whether the theory of evolution should be taught alongside other ideas, such as intelligent design or creationism.

Mainstream scientists see no controversy. "A lot of people have deep religious beliefs and also accept evolution," Pobiner said, adding, "there can be real reconciliation." Evolution is well supported by many examples of changes in various species leading to the diversity of life seen today. "If someone could really demonstrate a better explanation than evolution and natural selection, [that person] would be the new Darwin," Richmond said.

3.Eugenics

Eugenics from Greek *eugenes* "well-born" from *eu*, "good, well" and *genos*, "race, stock, kin") is a set of beliefs and practices that aims at improving the genetic quality of the human population. It is a social philosophy advocating the improvement of human genetic traits through the promotion of higher rates of sexual reproduction for people with desired traits (positive eugenics), or reduced rates of sexual reproduction and sterilization of people with less-desired or undesired traits (negative eugenics), or both. Alternatively, gene selection rather than "people selection" has recently been made possible through advances in gene editing (e.g. CRISPR). The exact definition of *eugenics* has been a matter of debate since the term was coined. The definition of it as a "social philosophy"—that is, a philosophy with implications for social order—is not universally accepted, and was taken from Frederick Osborn's 1937 journal article "Development of a Eugenic Philosophy"

While eugenic principles have been practiced as far back in world history as Ancient Greece, the modern history of eugenicsbegan in the early 20th century when a popular eugenics movement emerged in the United Kingdom and spread to many countries, including the United States, Canada and most European countries. In this period, eugenic ideas were espoused across the political spectrum. Consequently, many countries adopted eugenic policies meant to improve the genetic stock of their countries. Such programs often included both "positive" measures, such as encouraging individuals deemed particularly "fit" to reproduce, and "negative" measures such as marriage prohibitions and forced sterilization of people deemed unfit for reproduction. People deemed unfit to reproduce often included people with mental or physical disabilities, people who scored in the low ranges of different IQ tests, criminals and deviants, and members of disfavored minority groups. The eugenics movement became negatively associated with Nazi Germany and the Holocaust when many of the defendants at the Nuremberg trials attempted to justify their human rights abuses by claiming there was little difference between the Nazi eugenics programs and the US eugenics programs. In the decades following World War II, with the institution of human rights, many countries gradually abandoned eugenics policies, although some Western countries, among them the United States, continued to carry out forced sterilizations.

Since the 1980s and 1990s when new assisted reproductive technology procedures became available, such as gestational surrogacy (available since 1985), preimplantation genetic diagnosis (available since 1989) and cytoplasmic transfer (first performed in 1996), fear about a possible future revival of eugenics and a widening of the gap between the rich and the poor has emerged.

A major criticism of eugenics policies is that, regardless of whether "negative" or "positive" policies are used, they are vulnerable to abuse because the criteria of selection are determined by whichever group is in political power. Furthermore, negative eugenics in particular is considered by many to be a violation of basic human rights, which include the right to reproduction. Another criticism is that eugenic policies eventually lead to a loss of genetic diversity, resulting in inbreeding depression instead due to a low genetic variation.

History of eugenics

The idea of eugenics to produce better human beings has existed at least since Plato suggested selective mating to produce a guardian class. The idea of eugenics to decrease the birth of inferior human beings has existed at least since William Goodell (1829-1894) advocated the castration and spaying of the insane.

However, the term "eugenics" to describe the modern concept of improving the quality of human beings born into the world was originally developed by Francis Galton. Galton had read his half-cousin Charles Darwin's theory of evolution, which sought to explain the development of plant and animal species, and desired to apply it to humans. Galton believed that desirable traits were hereditary based on biographical studies; Darwin strongly disagreed with his interpretation of the book. In 1883, one year after Darwin's death, Galton gave his research a name: *eugenics*. Throughout its recent history, eugenics has remained a controversial concept.

Eugenics became an academic discipline at many colleges and universities and received funding from many sources. Organisations formed to win public support, and modify opinion towards responsible eugenic values in parenthood, included the British Eugenics Education Society of 1907, and the American Eugenics Society of 1921. Both sought support from leading clergymen, and modified their message to meet religious ideals. Three International Eugenics Conferences presented a global venue for eugenists with meetings in 1912 in London, and in 1921 and 1932 in New York City. Eugenic policies were first implemented in the early 1900s in the United States. It has roots in France, Germany, Great Britain, and the United States. Later, in the 1920s and 30s, the eugenic policy of sterilizing certain mental patients was implemented in other countries, including Belgium, Brazil Canada Japan and Sweden.

The scientific reputation of eugenics started to decline in the 1930s, a time when Ernst Rüdin used eugenics as a justification for the racial policies of Nazi Germany. In addition to being practised in a number of countries, eugenics was internationally organized through the International Federation of Eugenics Organizations. Its scientific aspects were carried on through research bodies such as the Kaiser Wilhelm Institute of Anthropology, Human Heredity, and Eugenics, the Cold Spring Harbour Carnegie Institution for Experimental Evolution, and the Eugenics Record Office. Its political aspects involved advocating laws allowing the pursuit of eugenic objectives, such as sterilization laws. Its moral aspects included rejection of the doctrine that all human beings are born equal, and redefining morality purely in terms of genetic fitness. Its racist elements included pursuit of a pure "Nordic race" or "Aryan" genetic pool and the eventual elimination of "less fit" races.

As a social movement, eugenics reached its greatest popularity in the early decades of the 20th century. At this point in time, eugenics was practiced around the world and was promoted by governments and influential individuals and institutions. Many countries enacted various eugenics policies and programmes, including: genetic screening, birth control, promoting differential birth rates, marriage restrictions, segregation (both racial segregation and segregation of the mentally ill from the rest of the population), compulsory sterilization, forced abortions or forced pregnancies, and genocide. Most of these policies were later regarded as coercive or restrictive, and now few jurisdictions implement policies that are explicitly labelled as eugenic or unequivocally eugenic in substance. The methods of implementing eugenics varied by country; however, some early 20th century methods involved identifying and classifying individuals and their families, including the poor, mentally ill, blind, deaf, developmentally disabled, promiscuous women, homosexuals, and racial groups(such as the Roma and Jews in Nazi Germany) as "degenerate" or "unfit", the segregation or institutionalization of such individuals and groups, their sterilization, euthanasia, and their mass murder. The practice of euthanasia was carried out on hospital patients in the Aktion T4 centers such as Hartheim Castle.

By the end of World War II, many of the discriminatory eugenics laws were largely abandoned, having become associated with Nazi Germany. After World War II, the practice of "imposing measures intended to prevent births within [a population] group" fell within the definition of the new international crime of genocide, set out in the Convention on the Prevention and Punishment of the Crime of Genocide. The Charter of Fundamental Rights of the European Union also proclaims "the prohibition of eugenic practices, in particular those aiming at selection of persons". In spite of the decline in discriminatory eugenics laws, government practices of compulsive sterilization continued into the 21st century. During the ten years President Alberto Fujimori led Peru from 1990 to 2000, allegedly 2,000 persons were involuntarily sterilized. China maintained its coercive one-child policy until 2015 as well as a suite of other eugenics based legislation in order to reduce population size and manage fertility rates of different populations. In 2007 the United Nations reported coercive sterilisations and hysterectomies in Uzbekistan. During the years 2005–06 to 2012–13, nearly one-third of the 144 California prison inmates who were sterilized did not give lawful consent to the operation.

Developments in genetic, genomic, and reproductive technologies at the end of the 20th century are raising numerous questions regarding the ethical status of eugenics, effectively creating a resurgence of interest in the subject. Some, such as UC Berkeley sociologist Troy Duster, claim that modern genetics is a back door to eugenics. This view is shared by White House Assistant Director for Forensic Sciences, Tania Simoncelli, who stated in a 2003 publication by the Population and Development Program at Hampshire College that advances in pre-implantation genetic diagnosis (PGD) are moving society to a "new era of eugenics", and that, unlike the Nazi eugenics, modern eugenics is consumer driven and market based, "where children are increasingly regarded as made-to-order consumer products". In a 2006 newspaper article, Richard Dawkins said that discussion regarding eugenics was inhibited by the shadow of Nazi misuse, to the extent that some scientists would not admit that breeding humans for certain abilities is at all possible. He believes that it is not physically different from breeding domestic animals for traits such as speed or herding skill. Dawkins felt that enough time had elapsed to at least ask just what the ethical differences were between breeding for ability versus training athletes or forcing children to take music lessons, though he could think of persuasive reasons to draw the distinction.

Some, such as Nathaniel C. Comfort from Johns Hopkins University, claim that the change from state-led reproductive-genetic decision-making to individual choice has moderated the worst abuses of eugenics by transferring the decision-making from the state to the patient and their family. Comfort suggests that "the eugenic impulse drives us to eliminate disease, live longer and healthier, with greater intelligence, and a better adjustment to the conditions of society; and the health benefits, the intellectual thrill and the profits of genetic bio-medicine are too great for us to do otherwise." Others, such as bioethicist Stephen Wilkinson of Keele University and Honorary Research Fellow Eve Garrard at the University of Manchester, claim that some aspects of modern genetics can be classified as eugenics, but that this classification does not inherently make modern genetics immoral. In a co-authored publication by Keele University, they stated that "[e]ugenics doesn't seem always to be immoral, and so the fact that PGD, and other forms of selective reproduction, might sometimes technically be eugenic, isn't sufficient to show that they're wrong."

In October 2015, the United Nations' International Bioethics Committee wrote that the ethical problems of human genetic engineering should not be confused with the ethical problems of the 20th century eugenics movements; however, it is still problematic because it challenges the idea of human equality and opens up new forms of discrimination and stigmatization for those who do not want or cannot afford the enhancements.

Meanings and types

Karl Pearson (1912)

The term eugenics and its modern field of study were first formulated by Francis Galton in 1883, drawing on the recent work of his half-cousin Charles Darwin. Galton published his observations and conclusions in his book *Inquiries into Human Faculty and Its Development*.

The origins of the concept began with certain interpretations of Mendelian inheritance, and the theories of August Weismann. The word*eugenics* is derived from the Greek word *eu* ("good" or "well") and the suffix *-genēs* ("born"), and was coined by Galton in 1883 to replace the word "stirpiculture", which he had used previously but which had come to be mocked due to its perceived sexual overtones. Galton defined eugenics as "the study of all agencies under human control which can improve or impair the racial quality of future generations" Galton did not understand the mechanism of inheritance.

Historically, the term has referred to everything from prenatal care for mothers to forced sterilization and euthanasia. To population geneticists, the term has included the avoidance of inbreeding without altering allele frequencies; for example, J. B. S. Haldanewrote that "the motor bus, by breaking up inbred village communities, was a powerful eugenic agent." Debate as to what exactly counts as eugenics has continued to the present day.

Edwin Black, journalist and author of *War Against the Weak*, claims eugenics is often deemed a pseudoscience because what is defined as a genetic improvement of a desired trait is often deemed a cultural choice rather than a matter that can be determined through objective scientific inquiry. The most disputed aspect of eugenics has been the definition of "improvement" of the human gene pool, such as what is a beneficial characteristic and what is a defect. This aspect of eugenics has historically been tainted with scientific racism.

Early eugenists were mostly concerned with perceived intelligence factors that often correlated strongly with social class. Some of these early eugenists include Karl Pearson and Walter Weldon, who worked on this at the University College London. Eugenics also had a place in medicine. In his lecture "Darwinism, Medical Progress and Eugenics", Karl Pearson said that everything concerning eugenics fell into the field of medicine. He basically placed the two words as equivalents. He was supported in part by the fact that Francis Galton, the father of eugenics, also had medical training.

Eugenic policies have been conceptually divided into two categories. Positive eugenics is aimed at encouraging reproduction among the genetically advantaged; for example, the reproduction of the intelligent, the healthy, and the successful. Possible approaches include financial and political stimuli, targeted demographic analyses, *in vitro* fertilization, egg transplants, and cloning. The movie Gattaca provides a fictional example of positive eugenics done voluntarily. Negative eugenics aimed to eliminate, through sterilization or segregation, those deemed physically, mentally, or morally "undesirable". This includes abortions, sterilization, and other methods of family planning. Both positive and negative eugenics can be coercive; abortion for fit women, for example, was illegal in Nazi Germany.

Jon Entine claims that eugenics simply means "good genes" and using it as synonym for genocide is an "all-too-common distortion of the social history of genetics policy in the United States." According to Entine, eugenics developed out of the Progressive Era and not "Hitler's twisted Final Solution".

Implementation methods

According to Richard Lynn, eugenics may be divided into two main categories based on the ways in which the methods of eugenics can be applied.

1. Classical Eugenics
    1. Negative eugenics by provision of information and services, i.e. reduction of unplanned pregnancies and births.
        1. "Just say no" campaigns.
        2. Sex education in schools.
        3. School-based clinics.
        4. Promoting the use of contraception.
        5. Emergency contraception.
        6. Research for better contraceptives.
        7. Sterilization.
        8. Abortion.
    2. Negative eugenics by incentives, coercion and compulsion.

1. Incentives for sterilization.
2. The Denver Dollar-a-day program, i.e. paying teenage mothers for not becoming pregnant again
3. Incentives for women on welfare to use contraceptions.
4. Payments for sterilization in developing countries.
5. Curtailment of benefits to welfare mothers.
6. Sterilization of the "mentally retarded".
7. Sterilization of female criminals.
8. Sterilization of male criminals.

3. Licences for parenthood.
4. Positive eugenics.
    1. Financial incentives to have children.
    2. Selective incentives for childbearing.
    3. Taxation of the childless.
    4. Ethical obligations of the elite.
    5. Eugenic immigration.

2. New Eugenics
1. Artificial insemination by donor.
2. Egg donation Prenatal diagnosis of genetic disorders and pregnancy terminations of defective fetuses.
3. Embryo selection.
4. Genetic engineering.
5. Gene therapy.
6. Cloning.

Doubts on traits triggered by inheritance

The first major challenge to conventional eugenics based upon genetic inheritance was made in 1915 by Thomas Hunt Morgan, who demonstrated the event of genetic mutationoccurring outside of inheritance involving the discovery of the hatching of a fruit fly (*Drosophila melanogaster*) with white eyes from a family of red-eyes. Morgan claimed that this demonstrated that major genetic changes occurred outside of inheritance and that the concept of eugenics based upon genetic inheritance was not completely scientifically accurate. Additionally, Morgan criticized the view that subjective traits, such as intelligence and criminality, were caused by heredity because he believed that the definitions of these traits varied and that accurate work in genetics could only be done when the traits being studied were accurately defined. In spite of Morgan's public rejection of eugenics, much of his genetic research was absorbed by eugenics.

Ethics

A common criticism of eugenics is that "it inevitably leads to measures that are unethical". Historically, this statement is evidenced by the obvious control of one group imposing its agenda on minority groups. This includes programs in England, Germany, and America targeting various groups, including Jews, homosexuals, Muslims, Romani, the homeless, and those with intellectual disabilities. Original position, a hypothetical situation developed by American philosopher John Rawls, has been used as an argument for *negative eugenics*.

Many of the ethical concerns from eugenics arise from the controversial past, prompting a discussion on what place, if any, it should have in the future. Advances in science have changed eugenics. In the past, eugenics has had more to do with sterilization and enforced reproduction laws (i.e. no inter-racial marriage and marriage restrictions based on land ownership). Now, in the age of a progressively mapped genome, embryos can be tested for susceptibility to disease, gender, and genetic defects, and alternative methods of reproduction such as in vitro fertilization are becoming more common. In short, eugenics is no longer ex post facto regulation of the living but instead preemptive action on the unborn.

With this change, however, there are ethical concerns which lack adequate attention, and which must be addressed before eugenic policies can be properly implemented in the future. Sterilized individuals, for example, could volunteer for the procedure, albeit under incentive or duress, or at least voice their opinion. The unborn fetus on which these new eugenic procedures are performed cannot speak out, as the fetus lacks the voice to consent or to express his or her opinion. The ability to manipulate a fetus and determine who the child will be is something questioned by many of the opponents of, and even proponents for, eugenic policies.

Societal and political consequences of eugenics call for a place in the discussion on the ethics behind the eugenics movement. Public policy often focuses on issues related to race and gender, both of which could be controlled by manipulation of embryonic genes; eugenics and political issues are interconnected and the political aspect of eugenics must be addressed. Laws controlling the subjects, the methods, and the extent of eugenics will need to be considered in order to prevent the repetition of the unethical events of the past.

Most of the ethical concerns about eugenics involve issues of morality and power. Decisions about the morality and the control of this new science (and the subsequent results of the science) will need to be made as eugenics continue to influence the development of the science and medical fields.

Losing genetic diversity by classifying traits as diseases

Eugenic policies could also lead to loss of genetic diversity, in which case a culturally accepted "improvement" of the gene pool could very likely—as evidenced in numerous instances in isolated island populations (e.g., the dodo, *Raphus cucullatus*, of Mauritius)—result in extinction due to increased vulnerability to disease, reduced ability to adapt to environmental change, and other factors both known and unknown. A long-term species-wide eugenics plan might lead to a scenario similar to this because the elimination of traits deemed undesirable would reduce genetic diversity by definition.

Edward M. Miller claims that, in any one generation, any realistic program should make only minor changes in a fraction of the gene pool, giving plenty of time to reverse direction if unintended consequences emerge, reducing the likelihood of the elimination of desirable genes. Miller also argues that any appreciable reduction in diversity is so far in the future that little concern is needed for now.

While the science of genetics has increasingly provided means by which certain characteristics and conditions can be identified and understood, given the complexity of human genetics, culture, and psychology there is at this point no agreed objective means of determining which traits might be ultimately desirable or undesirable. Some diseases such assickle-cell disease and cystic fibrosis respectively confer immunity to malaria and resistance to cholera when a single copy of the recessive allele is contained within the genotype of the individual. Reducing the instance of sickle-cell disease genes in Africa where malaria is a common and deadly disease could indeed have extremely negative net consequences.

However, some genetic diseases such as haemochromatosis can increase susceptibility to illness, cause physical deformities, and other dysfunctions, which provides some incentive for people to re-consider some elements of eugenics.

Autistic people have advocated a shift in perception of autism spectrum disorders as complex syndromes rather than diseases that must be cured. Proponents of this view reject the notion that there is an "ideal" brain configuration and that any deviation from the norm is pathological; they promote tolerance for what they call neurodiversity. Baron-Cohen argues that the genes for Asperger's combination of abilities have operated throughout recent human evolution and have made remarkable contributions to human history. The possible reduction of autism rates through selection against the genetic predisposition to autism is a significant political issue in the autism rights movement, which claims that autism is a part of neurodiversity.

Many culturally Deaf people oppose attempts to cure deafness, believing instead deafness should be considered a defining cultural characteristic not a disease. Some people have started advocating the idea that deafness brings about certain advantages, often termed "Deaf Gain."

Heterozygous recessive traits

The heterozygote test is used for the early detection of recessive hereditary diseases, allowing for couples to determine if they are at risk of passing genetic defects to a future child. The goal of the test is to estimate the likelihood of passing the hereditary disease to future descendants.

Recessive traits can be severely reduced, but never eliminated unless the complete genetic makeup of all members of the pool was known, as aforementioned. As only very few undesirable traits, such as Huntington's disease, are dominant, it could be arguedfrom certain perspectives that the practicality of "eliminating" traits is quite low.

There are examples of eugenic acts that managed to lower the prevalence of recessive diseases, although not influencing the prevalence of heterozygote carriers of those diseases. The elevated prevalence of certain genetically transmitted diseases among the Ashkenazi Jewish population (Tay–Sachs, cystic fibrosis, Canavan's disease, andGaucher's disease), has been decreased in current populations by the application of genetic screening.

Pleiotropic genes

Pleiotropy occurs when one gene influences multiple, seemingly unrelated phenotypic traits, an example being phenylketonuria, which is a human disease that affects multiple systems but is caused by one gene defect. Andrzej Pękalski, from the University of Wrocław, argues that eugenics can cause harmful loss of genetic diversity if a eugenics program selects for a pleiotropic gene that is also associated with a positive trait. Pekalski uses the example of a coercive government eugenics program that prohibits people with myopia from breeding but has the unintended consequence of also selecting against high intelligence since the two go together.

At its peak of popularity, eugenics was supported by a wide variety of prominent people, including Winston Churchill, Margaret Sanger (the founder of Planned Parenthood), Marie Stopes, H. G. Wells, Norman Haire, Havelock Ellis, Theodore

Roosevelt, Herbert Hoover, George Bernard Shaw, John Maynard Keynes, John Harvey Kellogg, Robert Andrews Millikan, Linus Pauling, Sidney Webb, and W. E. B. Du Bois.

In 1909 the Anglican clergymen William Inge and James Peile both wrote for the British Eugenics Education Society. Inge was an invited speaker at the 1921 International Eugenics Conference, which was also endorsed by the Roman Catholic Archbishop of New York Patrick Joseph Hayes. In 1925 Adolf Hitler praised and incorporated eugenic ideas in *Mein Kampf* and emulated eugenic legislation for the sterilization of "defectives" that had been pioneered in the United States.

Early critics of the philosophy of eugenics included the American sociologist Lester Frank Ward, the English writer G. K. Chesterton, the German-American anthropologist Franz Boasand Scottish tuberculosis pioneer and author Halliday Sutherland. Ward's 1913 article "Eugenics, Euthenics, and Eudemics", Chesterton's 1917 book *Eugenics and Other Evils*, and Boas' 1916 article "Eugenics" (published in *The Scientific Monthly*) were all harshly critical of the rapidly growing movement. Sutherland identified eugenists as a major obstacle to the eradication and cure of tuberculosis in his 1917 address "Consumption: Its Cause and Cure", and criticism of eugenists and Neo-Malthusians in his 1921 book *Birth Control* led to a writ for libel from the eugenist Marie Stopes. Several biologists were also antagonistic to the eugenics movement, including Lancelot Hogben. Other biologists such as J. B. S. Haldane and R. A. Fisher expressed skepticism that sterilization of "defectives" would lead to the disappearance of undesirable genetic traits.

Some supporters of eugenics later reversed their positions on it. For example, H. G. Wells, who had called for "the sterilization of failures" in 1904, stated in his 1940 book*The Rights of Man: Or What are we fighting for?* that among the human rights he believed should be available to all people was "a prohibition on mutilation, sterilization, torture, and any bodily punishment".

Among institutions, the Catholic Church was an opponent of state-enforced sterilizations. Attempts by the Eugenics Education Society to persuade the British government to legalise voluntary sterilisation were opposed by Catholics and by the Labour Party. The American Eugenics Society initially gained some Catholic supporters, but Catholic support declined following the 1930 papal encyclical *Casti connubii*. In this, Pope Pius XI explicitly condemned sterilization laws: "Public magistrates have no direct power over the bodies of their subjects; therefore, where no crime has taken place and there is no cause present for grave punishment, they can never directly harm, or tamper with the integrity of the body, either for the reasons of eugenics or for any other reason."

4. Binomial nomenclature and classification

Binomial nomenclature (also called **binominal nomenclature** or **binary nomenclature**) is formal system of naming species of living things by giving each a name composed of two parts, both of which use Latin grammatical forms, although they can be based on words from other languages. Such a name is called a **binomial name** (which may be shortened to just "binomial"), a **binomen** or a **scientific name**; more informally it is also called a **Latin name**. The first part of the name identifies the genus to which the species belongs; the second part identifies the species within the genus. For example, humans belong to the genus *Homo* and within this genus to the species *Homo sapiens*. The *formal*introduction of this system of naming species is credited to Swedish natural scientist Carl Linnaeus (author abbrv. L.), effectively beginning with his work *Species Plantarum* in 1753. But Gaspard Bauhin, in as early as 1623, had introduced in his book *Pinax theatri botanici* (English, *Illustrated exposition of plants*) many names of genera that were later adopted by Linnaeus.

The application of binomial nomenclature is now governed by various internationally agreed codes of rules, of which the two most important are the *International Code of Zoological Nomenclature* (*ICZN*) for animals and the *International Code of Nomenclature for algae, fungi, and plants* (*ICN*). Although the general principles underlying binomial nomenclature are common to these two codes, there are some differences, both in the terminology they use and in their precise rules.

In modern usage, the first letter of the first part of the name, the genus, is always capitalized in writing, while that of the second part is not, even when derived from a proper nounsuch as the name of a person or place. Similarly, both parts are italicized when a binomial name occurs in normal text. Thus the binomial name of the annual phlox (named after botanist Thomas Drummond) is now written as *Phlox drummondii*.

In scientific works, the "authority" for a binomial name is usually given, at least when it is first mentioned, and the date of publication may be specified.

In zoology:

- "*Patella vulgata* Linnaeus, 1758". The name "Linnaeus" tells the reader who it was that first published a description and name for this species of limpet; 1758 is the date of the publication in which the original description can be found (in this case the 10th edition of the book *Systema Naturae*).
- "*Passer domesticus* (Linnaeus, 1758)". The original name given by Linnaeus was *Fringilla domestica*; the parentheses indicate that the species is now considered to belong in a different genus. The ICZN does not require that the name of the person who changed the genus be given, nor the date on which the change was made, although nomenclatorial catalogs usually include such information.

In botany:

- "*Amaranthus retroflexus* L." – "L." is the standard abbreviation used in botany for "Linnaeus".
- "*Hyacinthoides italica* (L.) Rothm. – Linnaeus first named this bluebell species *Scilla italica*; Rothmaler transferred it to the genus *Hyacinthoides*; the ICN does not require that the dates of either publication be specified.

History

Carl Linnaeus (1707–1778), a Swedish botanist, invented the modern system of binomial nomenclature. Prior to the adoption of the modern binomial system of naming species, a scientific name consisted of a generic name combined with a specific name that was from one to several words long. Together they formed a system of polynomial nomenclature. These names had two separate functions. First, to designate or label the species, and second, to be a diagnosis or description; however these two goals were eventually found to be incompatible. In a simple genus, containing only two species, it was easy to tell them apart with a one-word genus and a one-word specific name; but as more species were discovered the names necessarily became longer and unwieldy, for instance *Plantago foliis ovato-lanceolatus pubescentibus, spica cylindrica, scapo tereti* ("Plantain with pubescent ovate-lanceolate leaves, a cylindric spike and a terete scape"), which we know today as *Plantago media*.

Such "polynomial names" may sometimes look like binomials, but are significantly different. For example, Gerard's herbal (as amended by Johnson) describes various kinds of spiderwort: "The first is called *Phalangium ramosum*, Branched Spiderwort; the second, *Phalangium non ramosum*, Unbranched Spiderwort. The other ... is aptly termed *Phalangium Ephemerum Virginianum*, Soon-Fading Spiderwort of Virginia". The Latin phrases are short descriptions, rather than identifying labels.

The Bauhins, in particular Caspar Bauhin (1560–1624), took some important steps towards the binomial system, by pruning the Latin descriptions, in many cases to two words. The adoption by biologists of a system of strictly binomial nomenclature is due to Swedish botanist and physician Carl von Linné, more commonly known by his Latinized name Carl Linnaeus (1707–1778). It was in his 1753 *Species Plantarum* that he first began consistently using a one-word "trivial name" together with a generic name in a system of binomial nomenclature. This trivial name is what is now known as a specific epithet (*ICN*) or specific name (*ICZN*). The Bauhins' genus names were retained in many of these, but the descriptive part was reduced to a single word.

Linnaeus's trivial names introduced an important new idea, namely that the function of a name could simply be to give a species a unique label. This meant that the name no longer need be descriptive; for example both parts could be derived from the names of people. Thus Gerard's *phalangium ephemerum virginianum* became *Tradescantia virginiana*, where the genus name honoured John Tradescant the younger, an English botanist and gardener. A bird in the parrot family was named *Psittacus alexandri*, meaning "Alexander's parrot", after Alexander the Great whose armies introduced eastern parakeets to Greece. Linnaeus' trivial names were much easier to remember and use than the parallel polynomial names and eventually replaced them.

Value

The value of the binomial nomenclature system derives primarily from its economy, its widespread use, and the uniqueness and stability of names it generally favors:

- Economy. Compared to the polynomial system which it replaced, a binomial name is shorter and easier to remember. It corresponds to the widespread system of family name plus given name(s) used to name people in many cultures.

- Widespread use. The binomial system of nomenclature is governed by international codes and is used by biologists worldwide. A few binomials have also entered common speech, such as *Homo sapiens*, *E. coli*, and *Tyrannosaurus rex*.
- Clarity. Binomial names avoid the confusion that can be created when attempting to use common names to refer to a species. Common names often differ from one country to another, or even from one part of a country to another. In English-speaking parts of Europe, the bird called a "robin" is *Erithacus rubecula*. In English-speaking North America, a "robin" is *Turdus migratorius*. In contrast, the scientific name can be used all over the world, in all languages, avoiding confusion and difficulties of translation.
- Uniqueness. Provided that taxonomists agree as to the limits of a species, it can have only one name that is correct under the appropriate nomenclature code, generally the earliest published if two or more names are accidentally assigned to a species. However, establishing that two names actually refer to the same species and then determining which has priority can be difficult, particularly if the species was named by biologists from different countries. Therefore, a species may have more than one regularly used name; these names are "synonyms".
- Stability. Although stability is far from absolute, the procedures associated with establishing binomial names, such as the principle of priority, tend to favor stability. For example, when species are transferred between genera (as not uncommonly happens as a result of new knowledge), if possible the second part of the binomial is kept the same. Thus there is disagreement among botanists as to whether the genera *Chionodoxa* and *Scilla* are sufficiently different for them to be kept separate. Those who keep them separate give the plant commonly grown in gardens in Europe the name *Chionodoxa siehei*; those who do not give it the name *Scilla siehei*. The *siehei* element is constant. Similarly if what were previously thought to be two distinct species are demoted to a lower rank, such as subspecies, where possible the second part of the binomial name is retained as the third part of the new name. Thus the Tenerife robin may be treated as a different species from the European robin, in which case its name is *Erithacus superbus*, or as only a subspecies, in which case its name is *Erithacus rubecula superbus*. The *superbus* element of the name is

constant. Since taxonomists can legitimately disagree as to whether two genera or two species are distinct or not, more than one name can be in use The only reason a specific epithet may need to be changed is if that by transferring it to a new genus it becomes a junior homonym of an older specific epithet for a different species in the same genus.

Problems

Binomial nomenclature for species has the effect that when a species is moved from one genus to another, not only is its genus name changed but sometimes its species name must be changed as well (e.g. because the name is already used in the new genus, or to agree in gender with the new genus). Some biologists have argued for the combination of the genus name and specific epithet into a single unambiguous name, or for the use of uninomials (as used in nomenclature of ranks above species)

Relationship to classification and taxonomy

Nomenclature (including binomial nomenclature) is not the same as classification, although the two are related. Classification is the ordering of items into groups based on similarities and/or differences; in biological classification, species are one of the kinds of item to be classified. In principle, the names given to species could be completely independent of their classification. This is not the case for binomial names, since the first part of a binomial is the name of the genus into which the species is placed. Above the rank of genus, binomial nomenclature and classification are partly independent; for example, a species retains its binomial name if it is moved from one family to another or from one order to another, unless it better fits a different genus in the same or different family, or it is split from its old genus and placed in a newly created genus. The independence is only partial since the names of families and other higher taxa are usually based on genera

Taxonomy includes both nomenclature and classification. Its first stages (sometimes called "alpha taxonomy") are concerned with finding, describing and naming species of living or fossil organisms. Binomial nomenclature is thus an important part of taxonomy as it is the system by which species are named. Taxonomists are also concerned with classification, including its principles, procedures and rules.

Derivation of binomial names

A complete binomial name is always treated grammatically as if it were a phrase in the Latin language (hence the common use of the term "Latin name" for a binomial name). However, the two parts of a binomial name can each be derived from a number of sources, of which Latin is only one. These include:

- Latin, either classical or medieval. Thus, both parts of the binomial name *Homo sapiens* are Latin words, meaning "wise" (*sapiens*) "human/man" (*Homo*).
- Classical Greek. The genus *Rhododendron* was named by Linnaeus from the Greek word ῥοδόδενδρον, itself derived from *rhodos*, rose, and *dendron*, tree. Greek words are often converted to a Latinized form. Thus coca (the plant from which cocaine is obtained) has the name *Erythroxylum coca*. *Erythroxylum* is derived from the Greek words*erythros*, red, and *xylon*, wood. The Greek neuter ending -ον (-on) is often converted to the Latin neuter ending -um.
- Other languages. The second part of the name *Erythroxylum coca* is derived from *kuka*, the name of the plant in Aymara and Quechua. Since many dinosaur fossils were found in Mongolia, their names often use Mongolian words, e.g. *Tarchia* from *tarkhi*, meaning "brain", or *Saichania* meaning "beautiful one".
- Names of people (often naturalists or biologists). The name *Magnolia campbellii* commemorates two people: Pierre Magnol, a French botanist, and Archibald Campbell, a doctor in British India.
- Names of places. The lone star tick, *Amblyomma americanum*, is widespread in the United States.
- Other sources. Some binominal names have been constructed from anagrams or other re-orderings of existing names. Thus the name of the genus *Muilla* is derived by reversing the name *Allium*. Names may also be derived from jokes or puns. For example, Ratcliffe described a number of species of Rhinoceros beetle, including *Cyclocephala nodanotherwon*.

The first part of the name, which identifies the genus, must be a word which can be treated as a Latin singular noun in the nominative case. It must be unique within each kingdom, but can be repeated between kingdoms. Thus *Huia recurvata* is an extinct species of plant, found as fossils in Yunnan, China, whereas *Huia masonii* is a species of frog found in Java, Indonesia.

The second part of the name, which identifies the species within the genus, is also treated grammatically as a Latin word. It can have one of a number of forms.

- The second part of a binomial may be an adjective. The adjective must agree with the genus name in gender. Latin has three genders, masculine, feminine and neuter, shown by varying endings to nouns and adjectives. The house sparrow has the binomial name *Passer domesticus*. Here *domesticus* ("domestic") simply means "associated with the house". The sacred bamboo is *Nandina domestica* rather than *Nandina domesticus*, since *Nandina* is feminine whereas *Passer* is masculine. The tropical fruitlangsat is a product of the plant *Lansium parasiticum*, since *Lansium* is neuter. Some common endings for Latin adjectives in the three genders (masculine, feminine, neuter) are *-us*, *-a*, *-um* (as in the previous example of *domesticus*); *-is*, *-is*, *-e* (e.g. *tristis*, meaning "sad"); and *-or*, *-or*, *-us* (e.g. *minor*, meaning "smaller"). For further information, see Latin declension: Adjectives.

- The second part of a binomial may be a noun in the nominative case. An example is the binomial name of the lion, which is *Panthera leo*. Grammatically the noun is said to be in apposition to the genus name and the two nouns do not have to agree in gender; in this case, *Panthera* is feminine and *leo* is masculine.

- The second part of a binomial may be a noun in the genitive (possessive) case. The genitive case is constructed in a number of ways in Latin, depending on the declension of the noun. Common endings for masculine and neuter nouns are *-ii* or *-i* in the singular and *-orum* in the plural, and for feminine nouns *-ae* in the singular and *-arum* in the plural. The noun may be part of a person's name, often the surname, as in the Tibetan antelope *Pantholops hodgsonii*, the shrub *Magnolia hodgsonii*, or the olive-backed pipit*Anthus hodgsoni*. The meaning is "of the person named", so that *Magnolia hodgsonii* means "Hodgson's magnolia". The *-ii* or *-i* endings show that in each case Hodgson was a man (not the same one); had Hodgson been a woman, *hodgsonae* would have been used. The person commemorated in the binomial name is not usually (if ever) the person who created the name; for example *Anthus hodgsoni* was named by Charles Wallace Richmond, in honour of Hodgson. Rather than a person, the noun may be related to a place, as with *Latimeria chalumnae*, meaning "of the Chalumna River". Another use of genitive nouns is in, for example, the name of the bacterium *Escherichia coli*, where *coli* means "of the colon". This formation is common in parasites, as in *Xenos vesparum*, where *vesparum* means "of the wasps", since *Xenos vesparum* is a parasite of wasps.

Whereas the first part of a binomial name must be unique within a kingdom, the second part is quite commonly used in two or more genera (as is shown by examples of*hodgsonii* above). The full binomial name must be unique within a kingdom.

Codes

From the early 19th century onwards it became ever more apparent that a body of rules was necessary to govern scientific names. In the course of time these becamenomenclature codes. The *International Code of Zoological Nomenclature* (*ICZN*) governs the naming of animals, the *International Code of Nomenclature for algae, fungi, and plants* (*ICN*) that of plants (including cyanobacteria), and the *International Code of Nomenclature of Bacteria* (*ICNB*) that of bacteria (including Archaea). Virus names are governed by the *International Committee on Taxonomy of Viruses* (*ICTV*), a taxonomic code, which determines taxa as well as names. These codes differ in certain ways, e.g.:

- "Binomial nomenclature" is the correct term for botany, although it is also used by zoologists. Since 1953, "binominal nomenclature" is the technically correct term in zoology. A binominal name is also called a binomen (plural binomina).

- Both codes consider the first part of the two-part name for a species to be the "genus name". In zoological code (*ICZN*), the second part of the name is a "specific name", or in the botanical code (*ICN*) a "specific epithet". Together, these two parts are referred to as a "species name" or "binomen" in the zoological code; or "species name", "binomial", or "binary combination" in the botanical code.

- The *ICN*, the plant *Code*, does not allow the two parts of a binomial name to be the same (such a name is called a tautonym), whereas the *ICZN*, the animal *Code*, does. Thus the American bison has the binomial *Bison bison*; a name of this kind would not be allowed for a plant.

- The starting points, the time from which these codes are in effect (retroactively), vary from group to group. In botany the starting point will often be in 1753 (the year Carl Linnaeus first published *Species Plantarum*). In zoology the starting point is 1758 (1 January 1758 is considered the date of the publication of Linnaeus's *Systema Naturae*, 10th Edition, and also Clerck's *Aranei Svecici*). Bacteriology started anew, with a starting point on 1 January 1980.

Unifying the different codes into a single code, the "*BioCode*", has been suggested, although implementation is not in sight. (There is also a code in development for a different system of classification which does not use ranks, but instead names clades. This is called the *PhyloCode*.)

Writing binomial names

By tradition, the binomial names of species are usually typeset in italics; for example, *Homo sapiens*. Generally, the binomial should be printed in a font style different from that used in the normal text; for example, "*Several more* Homo sapiens *fossils were discovered*." When handwritten, each part of a binomial name should be underlined; for example,Homo sapiens.

The first part of the binomial, the genus name, is always written with an initial capital letter. In current usage, the second part is never written with an initial capital. Older sources, particularly botanical works published before the 1950s, use a different convention. If the second part of the name is derived from a proper noun, e.g. the name of a person or place, a capital letter was used. Thus the modern form *Berberis darwinii* was written as *Berberis Darwinii*. A capital was also used when the name is formed by two nouns in apposition, e.g. *Panthera Leo* or *Centaurea Cyanus*.

When used with a common name, the scientific name often follows in parentheses, although this varies with publication. For example, "The house sparrow (*Passer domesticus*) is decreasing in Europe."

The binomial name should generally be written in full. The exception to this is when several species from the same genus are being listed or discussed in the same paper or report, or the same species is mentioned repeatedly; in which case the genus is written in full when it is first used, but may then be abbreviated to an initial (and a period/full stop). For example, a list of members of the genus *Canis* might be written as "*Canis lupus*, *C. aureus*, *C. simensis*".

In rare cases, this abbreviated form has spread to more general use; for example, the bacterium *Escherichia coli* is often referred to as just *E. coli*, and *Tyrannosaurus rex* is perhaps even better known simply as *T. rex*, these two both often appearing in this form in popular writing even where the full genus name has not already been given.

The abbreviation "sp." is used when the actual specific name cannot or need not be specified. The abbreviation "spp." (plural) indicates "several species". These abbreviations are not italicised (or underlined). For example: "*Canis* sp." means "an unspecified species of the genus *Canis*", while "*Canis* spp." means "two or more species of the genus*Canis*". (The abbreviations "sp." and "spp." can easily be confused with the abbreviations "ssp." (zoology) or "subsp." (botany), plurals "sspp." or "subspp.", referring to one or more subspecies. See trinomen (zoology) and infraspecific name.)

The abbreviation "cf." (i.e. *confer* in Latin) is used to compare individuals/taxa with known/described species. Conventions for use of the "cf." qualifier vary. In paleontology, it is typically used when the identification is not confirmed. For example, "*Corvus* cf. *nasicus*" was used to indicate "a fossil bird similar to the Cuban crow but not certainly identified as this species". In molecular systematics papers, "cf." may be used to indicate one or more undescribed species assumed related to a described species. For example, in a paper describing the phylogeny of small benthic freshwater fish called darters, five undescribed putative species (Ozark, Sheltowee, Wildcat, Ihiyo, and Mamequit darters), notable for brightly colored nuptial males with distinctive color patterns, were referred to as "*Etheostoma* cf. *spectabile*" because they had been viewed as related to, but distinct from, *Etheostoma spectabile* (orangethroat darter). This view was supported in varying degrees by DNA analysis. The somewhat informal use of taxa names with qualifying abbreviations is referred to as open nomenclature and it is not subject to strict usage codes.

In some contexts the dagger symbol ("†") may be used before or after the binomial name to indicate that the species is extinct.

Authority

Main articles: Author citation (zoology) and Author citation (botany)

In scholarly texts, at least the first or main use of the binomial name is usually followed by the "authority" – a way of designating the scientist(s) who first published the name. The authority is written in slightly different ways in zoology and botany. For names governed by the *ICZN* the surname is usually written in full together with the date (normally only the year) of publication. The *ICZN* recommends that the "original author and date of a name should be cited at least once in each work dealing with the taxon denoted by that name." For names governed by the *ICN* the name is generally reduced to a standard abbreviation and the date omitted. The International Plant Names Index maintains an approved list of botanical author abbreviations. Historically, abbreviations were used in zoology too.

When the original name is changed, e.g. the species is moved to a different genus, both *Codes* use parentheses around the original authority; the *ICN* also requires the person who made the change to be given. Some examples:

- (Plant) *Amaranthus retroflexus* L. – "L." is the standard abbreviation for "Linnaeus"; the absence of parentheses shows that this is his original name.
- (Plant) *Hyacinthoides italica* (L.) Rothm. – Linnaeus first named the Italian bluebell *Scilla italica*; Rothmaler transferred it to the genus *Hyacinthoides*.
- (Animal) *Passer domesticus* (Linnaeus, 1758) – the original name given by Linnaeus was *Fringilla domestica*; unlike the *ICN*, the *ICZN* does not require the name of the person who changed the genus to be given.

Binomial nomenclature, as described here, is a system for naming species. Implicitly it includes a system for naming genera, since the first part of the name of the species is a genus name. In a classification system based on ranks there are also ways of naming ranks above the level of genus and below the level of species. Ranks above genus (e.g., family, order, class) receive one-part names, which are conventionally not written in italics. Thus the house sparrow, *Passer domesticus*, belongs to the family Passeridae. Family names are normally based on genus names, although the endings used differ between zoology and botany.

Ranks below species receive three-part names, conventionally written in italics like the names of species. There are significant differences between the *ICZN* and the *ICN*. In zoology, the only rank below species is subspecies and the name is written simply as three parts (a trinomen). Thus one of the subspecies of the olive-backed pipit is *Anthus hodgsoni berezowskii*. In botany, there are many ranks below species and although the name itself is written in three parts, a "connecting term" (not part of the name) is needed to show the rank.

Thus the American black elder is *Sambucus nigra* subsp. *canadensis*; the white-flowered form of the ivy-leaved cyclamen is *Cyclamen hederifolium* f. *albiflorum*.

Diversity in living organisms

There is a great diversity among living organisms found on the planet earth. They differ in their structure, habit, habitat, mode of nutrition, and physiology. The Biodiversity of the earth is enormous. Current estimates suggest that the earth may have anywhere from 10 to over 40 million species of organisms, but only about 1.7 million have actually been described including over 7,50,000 insects, about 2,50,000 flowering plants and 47,000 vertebrate animals. We call such diversity among living organisms as **Biodiversity**. Even though there is such a variety and diversity among them, the living organisms show a lot of similarities and common features so that they can be arranged into many groups. In order to understand them and study them systematically, these living organisms, mainly the plants and animals are grouped under different categories. The branch of biology dealing with identification, naming and classifying the living organisms is known as **Taxonomy**. Taxonomy in Greek means rendering of order. The word **Systematics** means to put together. It was **Carolus Linnaeus** who used this word first in his book **_Systema Naturae‟**. Systematics may be defined as the systematic placing of organisms into groups or **taxa** on the basis of certain relationships between organisms.

Need for Classification

It is not possible for anyone to study all the organisms. But if they are grouped in some convenient way the study would become easier as the characters of a particular group or a family would apply to all the individuals of that group. Classification allows us to understand diversity better.

The plant kingdom is divided into the following sequence as shown **Plant kingdom**: several divisions are placed to form plant kingdom.

Divisions: Taxon characterised by aggregation of characters rather than by any single infalliable one.

Sub-divisions: Taxon composed of several classes form sub divisions.

Classes: the class is the next full category subordinate in rank to the sub-divisions. The name of a class particularly ends in *eae* and each is sub-divided into orders.

Orders: This taxon comprises of one or more families. The name of orders usually ends in *ales* as in Geraniales, Umbellales, etc.

Families: many similar genera grouped together forms a family. The name of a family usually ends in *aceae*. The family generally represents a more natural unit than any of higher categories because usually more is known about the components of the family and correlation between a greater numbers of characters naturally exists.

Genus: the genus is subordinate to the family and in one family there exists many genera. The generic name of any plant is the first of the two latin words which comprise of the binomial system of classification e.g., *Geranium lucidum* where the generic name is *Geranium*.The Latin names of Genera are always adjectives used as such, always capitalised and always in singular number.

Species: A genus is subdivided into many species. This taxon forms the basic unit of classification. Genetically species are distinct and their progeny have the same parental characteristics. Species are the population capable of interbreeding among themselves.

Varieties: Due to change in climate, soil, or any change in external conditions the plant may exhibit variations in colour, shape, size, form or any other minor characters said as varieties. A species may have many varieties or none of them.

Systems of classification:

Different systems of classification had been proposed from time to time. All such classifications fall under one of the following categories-

1. **Artificial system**: It is an arbitrary arrangement of groups based on incomplete knowledge or mere convenience. I gave equal weightage to the vegetative and sexual characteristics; this is not acceptable as we know that vegetative characters are more easily affected by environment.
2. **Natural system**: This was based on natural affinities among the organisms and it considered not only the morphological characters but also the internal features like anatomy, embryology, ultrastructure and phytochemistry etc. Such a system for flowering plants was proposed by George Bentham and Joseph Dalton Hooker.

3. **Phylogenetic system**: at present phylogenetic system is much focused based on phylogeny (evolutionary relationships) between the various organisms. It is acceptable and assumes that organisms belonging to same taxa share a common ancestor.

Numerical Taxonomy which is now easily carried out using computers is based on all observable characteristics. Number and codes are assigned to all the characters and the data are then processed. In this way each character is given equal importance and at the same time hundreds of characters can be considered**. Cytotaxonomy** that is based on cytological information like chromosome number, structure, behaviour and **chemotaxonomy** that uses the chemical constituents of the plant to resolve confusion are also used by taxonomists these days.

Chapter 5. Cell and Cell Division

The plant is made up of innumerable structural and functional units - the cell. The cell is a unit of protoplasm surrounded by a membrane. A cell is a dynamic and highly organised system of interdependent and interacting components. The protoplasm weighs 5-90% or more of water forming the viscous fluid region.

In this semi fluid substance which is in a sol or gel state at different times and in different regions, are suspended a large number of various inclusions (cell organelles). Some of the significant components are mitochondria (cell respiration); golgi apparatus/dictyosomes (role in secretory activities); chloroplasts (entrapment of light energy and synthesis of carbohydrates; photosynthesis);ribosomes (protein synthesis site); nucleus controlling the entire cellular metabolism).

The protoplasm with much of colloidal phase in nature hydrophilic and hydrophobic colloidal complexes. Hydrophilic sol is formed mainly of amino acids, sugars, and inorganic ions while hydrophobic system comprises of fats and oils which remain suspended as droplets. The fats and oils due to their property to repel water molecules tend to collect in interfacial films of cytoplasm.

The protoplasm of the cell exhibits cyclosis (constant movement), a characteristic of plant cells. The cessation of this movement is one of the first signs of cell death.

Nearly all cells possess a cell wall around the plasma membrane. The cell wall is a rigid structure providing skeletal support and protection against osmotic pressure. The cell membrane (plasmalemma) regulates the continuous movement of substance into and out of the cell. It is a selectively permeable membrane allowing certain substances to pass through it more easily than others.

A cell is a structural and functional unit of all living organisms. It is microscopic and capable of independent existence. All living things are made up of cells. The outward differences among the various biological forms may bewilder us. But underlying these differences is a powerful uniformity. That is all biological systems are composed of same types of molecules and they all employ similar principles of organization at the cellular level. We shall see for example, that all living organisms employ the same genetic code and similar machinery for protein synthesis. Organisms contain organs, organs composed of tissues, tissues are made up of cells; and cells are formed of organelles and organelles are made up of molecules. However, in all living organisms, the cell is the functional unit. All of biology revolves around the activity of the cell. **Loewy** and **Siekevitz** defined cell as a unit of an organism delimited by a plasma membrane in animal cells and cell wall and plasma membrane in plant cells. Thus cell forms the basic unit of life.

A brief history about the discovery of cells

The study of cell is impossible without microscope. **Anton van Leewenhoek** (1632-1723) studied the structure of bacteria, protozoa spermatozoa, red blood cells under the simple microscope which he examined under a simple microscope that was designed by him. The word cell was first coined by **Robert Hooke** in 1665 to designate the empty honey-comb like structures viewed in a thin section of bottle cork which he examined. In 1838, the German botanist **Schleiden** proposed that all plants are made up of plant cells. Then in 1839 his colleague, the anatomist **Theodore Schwann** studied and concluded that all animals are also composed of cells. Even at that time the real nature of a cell was a big question. Cell theory was again rewritten by **Rudolf Virchow** in 1858. **Robert Brown** in 1831 discovered the presence of nucleus in the cells of orchid roots. This was an important discovery. **Purkinje** coined the term protoplasm for the slimy substance that is found inside the cells. In the 20th century, various modern micro techniques have been employed in cytological investigation. With the invention of electron microscope in the year 1932 more and more information about the cell and various organelles of the cells become available to us. On the basis of the structure, the cells are classified into **prokaryotic** and **eukaryotic** cells.

Eukaryotic cells vary very much in shape and size. The smallest cells are found among bacteria (0.2 to 50 microns). The largest plant cell is the ovule of ***Cycas*.** The shape of the cells also varies considerably. It may be spherical, polygonal, oval, rectangular, cylindrical, ellipsoidal etc.

Dynamic nature of cell

A cell in an adult organism can be viewed as a steady - state system. The DNA is constantly read out into a particular set of **mRNA (transcription)** which specifies a particular set of proteins **(translation)**. As these proteins function they are being degraded and replaced by new ones and the system is so balanced that the cell neither grows, shrinks, nor changes its function. Considering this static view of the cell, however, one should not miss the all-important dynamic aspect of cellular life. The dynamics of a cell can be best understood by examining the course of a cell‘s life. A new cell is formed when one cell divides or when two cells, (a sperm and an egg) fuse. Both these events start a cell-replication programme. This usually involves a period of cell growth, during which proteins are made and **DNA** replicated, followed by cell division when a cell divides into two daughter cells. Whether a given cell will grow and divide is a highly regulated decision of the body, ensuring that adult organism replaces worn out cells or makes new cells in response to a new need. The best example for the latter is the growth of muscle in response to exercise or damage. However, in one major and devastating disease namely cancer, the cells multiply even though there is no need in the body.

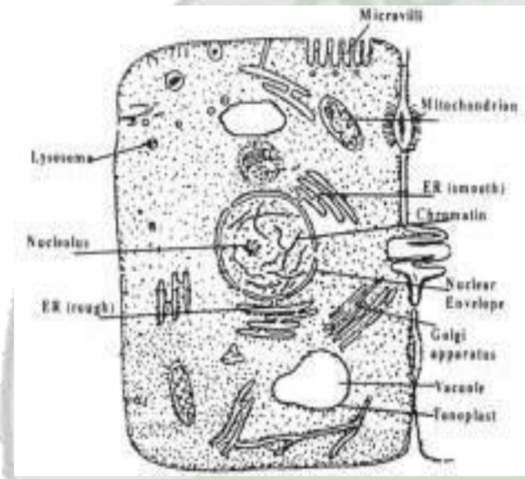


Fig 25. Prokaryotic cell

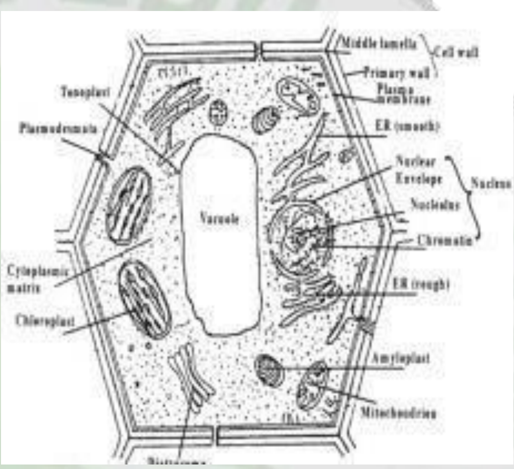


Fig 26. Eukaryotic cell

Cell Cycle

The cell cycle follows a regular timing mechanism. Most eukaryotic cells live according to an internal clock, that is they proceed through a sequence of phases, called **cell cycle.** In the cell cycle **DNA** is **Duplicated** during **synthesis (S) Phase** and the copies are distributed to daughter cells during **mitotic (M) phase.** Most growing plant and animal cells take 10-20 hours to double in number and some duplicate at a much slower rate. The most complicated example of cellular dynamics occurs during **differentiation** i.e when a cell changes to carry out a specialized function. This process often involves changes in the morphology of a cell based on the function it is to perform. This highlights the biological principle that **“form follows function”** Unchecked cell growth and multiplication produce a mass of cells, a tumor. Programmed Cell Death (**PCD**) plays a very important role by balancing cell growth and multiplication. In addition, cell death also eliminates unecessary cells. Plant cells differ from animal cells in many ways.

2. Cell Theory

In the year (1839) **Schleiden** and **Schwann** have jointly proposed the **"Cell Theory"** It states that all living organisms are made up of cells and cells are the structural and functional units of all organisms.

Development of Cell Theory

If we study the step by step development of cell theory we will understand how scientific methodology operates. It includes the following steps 1.observation 2.Hypothesis 3.Formulation of theory 4.modification of theory (if it warrants). Observations were made by Schleiden (1804 - 1881) a German botanist. He examined a large variety of plants and found that all of them were composed of cells. In 1838 he concluded that cells are the ultimate structural units of all plant tissues. Schwann, a German Zoologist studied many types of animals and found that animal cells lack a cell wall and they are covered by a membrane. He also stated that animal cells and plant cells were basically identical but for the cell wall. He observed that both contain nucleus and a clear substance around it. He defined the cell as a membrane bound nucleus containing structure. He proposed a hypothesis that the bodies of animals and plants are composed of cells and their products. Schleiden and Schwann both together discussed Schwann's hypothesis and they formulated **cell theory.** The important aspects of cell theory are:

1. All living organisms are made up of minute units, the cells which are the smallest entities that can be called living.
2. Each cell is made up of protoplasm with a nucleus and bounded by plasma membrane with or without a cell wall.
3. All cells are basically alike in their structure and metabolic activities.
4. Function of an organism is the sum total of activities and interaction of its constituent cells.

Exception to cell Theory

1. Viruses are biologists' puzzle. They are an exception to cell theory. They lack protoplasm, the essential part of the cell.
2. Bacteria and **cyanobacteria** (Blue Green algae) lack well organized nucleus.
3. Some of the protozons are acellular.
4. The coenocytic hyphae of some fungi eg. ***Rhizopus*** have undivided mass of protoplasm, in which many nuclei remain scattered.

5. Red Blood Corpuscles (**RBC**) and mature sieve tubes are without nuclei.

A cell may grow, secrete, divide or die while its adjacent cells may lie in a different physiological state. Many of the subsequent findings about the cell like this had necessitated modification in cell theory. The modified form of cell theory has been given the higher status as cell principle or cell Doctrine.

Cell Principle or Cell Doctrine

The important features of cell doctrine are:

1. All organisms are made up of cells.
2. New cells are produced from the pre-existing cells.
3. Cell is a structural and functional unit of all living organisms.
4. A cell contains hereditary information which is passed on from cell to cell during cell division.
5. All the cells are basically the same in chemical composition and metabolic activities.
6. The structure and function of the cell are controlled by DNA.
7. Sometimes the dead cells may remain functional as tracheids and vessels in plants and horny cells in animals.

3. Prokaryotic and Eukaryotic Cell (Plant Cells)

All living things found on the planet earth are divided into two major groups namely, prokaryotes and Eukaryotes based on the types of cells these organisms possess. Prokaryotic cells lack a well defined nucleus and have a simplified internal organization. Eukaryotic cells have a more complicated internal structure including a well defined, membrane - limited nucleus. Bacteria and Cyanobacteria are prokaryotes. Fungi, plants and animals are eukaryotes.

Prokaryotes

In general, Prokaryotes consist of a single closed compartment containing the **cytosol** and bounded by the plasma membrane. Although bacterial cells do not have a well defined nucleus, the genetic material, DNA, is condensed into the central region of the cell. In all prokaryotic cells, most of or all the genetic information resides in a single circlular DNA molecule, in the central region of the cell. This region is often referred ot as **incipient nucleus** or **nucleoid.** In addition, most ribosomes, the cell‘s protein synthesizing centres are found in the DNA-free region of the cell. Some bacteria also have an invagination of the cell membrane called a mesosome, which is associated with synthesis of DNA and secretion of proteins. Thus we cannot say that bacterial cells are completely devoid of internal organization. Bacterial cells possess a cell wall which lies adjacent to the external side of the plasma membrane. The cell wall is composed of layers of peptidoglycan, a complex of proteins and oligosaccharides. It protects the cell and maintains its shape. Some bacteria (eg ***E.coli***) have a thin cell wall and an unusual outermembrane separated from the cell wall by the periplasmic space. Such bacteria are not stained by Gram staining technique and thus are classified as Gram-negative bacteria. Other bacteria (eg.***Bacillus polymyxa***) that have a thicker cell wall without an outer membrane take the Gram stain and thus are classified as Gram positive bacteria.

Ultra structure of a prokaryotic cell

The bacterium is surrounded by two definite membranes separated by the periplasmic space. The outer layer is rigid, serves for mechanical protection and is designated as the cell wall. The chemical composition of the cell wall is rather complex; it contains peptidoglycan, polysaccharides, lipid and protein molecules. One of the most abundant polypetides, porin, forms channels that allow for the diffusion of solutes. The plasma membrane is a lipoprotein structure serving as a molecular barrier with the surrounding medium. the plasma membrane controls the entry and exit of small molecules and ions. The enzymes involved in the oxidation of matabolites (i.e. the respiratory chain) as well as the photosystems used in photosynthesis, are present in the plasma membrane of prokaryotes. The bacterial chromosome is a single circular molecule of naked DNA tightly coiled within the nucleoid which appears in the electron microscope as a lighter region of the protoplasm. It is amazing to note that the DNA of ***E.coli*** which measures about 1 mm long when uncoiled,contains all the genetic information of the organism. In this case, there is sufficient information to code for 2000 to 3000 different proteins.

The single chromosome or the DNA molecule is circular and at one point it is attached to the plasma membrane and it is believed that this attachment may help in the separation of two chromosomes after DNA replication. In addition to a chromosome, certain bacteria contain a small, extrachromosomal circular DNA called **plasmid.** The plasmid is responsible for the antibiotic resistance in some bacteria. These plasmids are very much used in genetic engineering where the plasmids are separated and reincorporated, genes (specific pieces of DNA) can be inserted into plasmids, which are then transplanted into bacteria using the techniques of genetic engineering. Surrounding the DNA in the darker region of the protoplasm are 20,000 to 30,000 particles called ribosomes. These are composed of RNA and proteins and are the sites of protein synthesis. Ribosomes exist in groups called **polyribosomes** or **polysomes.** Each ribosome consists of a large and a small sub unit. the remainder of the cell is filled with H2O, various RNAs, protein molecules (including enzymes) and various smaller molecules. Certain motile bacteria have numerous, thin hair like processes of variable length called flagella. Flagella are used for locomotion. In contrast with the flagella of eukaryotic cells which contain 9+2 micortubles each flagellum in bacteria is made of a single fibril. It was Fox *et al* who divided the living organisms into two kingdoms Prokaryota and Eukaryota. Prokaryotes are in turn classified into two major sub Ggroups 1) ***Archae bacteria*** and 2) ***Eubacteria.*** Cyanobacteria are included in the group Eubacteria. The Cyanobacterial prokaryotes, commonly called bluegreen algae, are photosynthetic. In cyanobacterial cells, the photosynthetic, respiratory and genetic apparatuses are present but not delimited from each other by any bounding membrane of their own. No sharp boundaries divide the cell into special regions. But, there are several cell components with characteristic fine structure. These are distributed throughout the cell in patterns varying from species to species and also in different developmental stages in the same species. These cyanobacterial cells have an elaborate photosynthetic membrane system, composed of simple thylakoids and a central nucleoplasmic area which is usually fibrillar or granular or both. The cell also includes various kinds of granular inclusions, a rigid, several layered cell wall and a fibrous sheath over the cell wall.The characteristic collective properties of Cyanobacteria include oxygenic photosynthesis, chromatic adaptation, nitrogen fixation and a capacity for cellular differentiation by the formation of heterocysts, akinetes and hormogonia.

Eukaryotes

Eukaryotes comprise all members of Plant Kingdom, Fungi and Animal Kingdoms, including the unicellular fungus Yeast, and protozoans. Eukaryotic cells, like prorkaryotic cells are surrounded by a plasma membrane. However, unlike prokaryotic cells, most eukaryotic cells contain internal membrane bound organelles. Each type of organelle plays a unique role in the growth and metabolism of the cell, and each contains a set of enzymes that catalyze requisite chemical reactions. The largest organelle in a eukaryotic cell is generally the **nucleus,** which houses most of the cellular DNA. The DNA of eukaryotic cells is distributed among 1 to about 50 long linear structures called **chromosomes.**

The number and size of the chromosomes are the same in all cells of an organism but vary among different species of organisms. The total DNA (the genetic information) in the chromosomes of an organism is referred to as its **genome.** In addition to the nucleus, several other organelles are present in nearly all eukaryotic cells, the **mitochondria** in which the cell's energy metabolism is carried out, the rough and smooth **endoplasmic reticula,** a network of membranes in which proteins and lipids are synthesized and **peroxysomes,** in which fatty acids and amino acids are degraded. **Chloroplasts**, the site of photosynthesis are found only in plants and some single celled organisms. Both plant cells and some single celled eukaryotes contain one or more **vacuoles**, large, fluid – filled organelles in which nutrients and waste compounds are stored and some degradative reactions occur. The cytosol of eukaryotic cells contains an array of fibrous proteins collectively called the **cytoskeleton**. Cytosol is the soluble part of the cytoplasm. It is located between the cell organelles. The plant cell has a rigid **cell wall** composed of cellulose and other polymers. The cell wall contributes to the strength and rigidity of plant cell.

Some familiar prokaryotes are: Bacteria, filamentous bacteria (Actinomycetes) and Cyanobacteria.

Some familiar eukaryotes are: Fungi, plants and animals.

Cell Wall

The cells of all plants, bacteria and fungi have a rigid, protective covering outside the plasma membrane called **cell wall**. The presence of cell wall in plant cells distinguishes them from animal cells. Among the vascular plants only certain cells connected with the reproductive processes, are naked, all other cells have walls. The cell wall was first observed by **Hooke** in the year 1865 in cork cells. Originally it was thought that the cell wall was a non-living secretion of the protoplasm, but now it is known to be metabolically active and is capable of growth and at least during its growth, contains protoplasmic material.

Formation of the cell wall

During the telophasic stage of mitosis, the **phragmoplast** widens and becomes barrel shaped. At the same time, on the equatorial plane the cell plate i.e the first evident partition between the daughter protoplasts, begins to form inside the phragmoplast. In the area where the cell

plate forms, the fibres of the phragmoplast become indistinct and are restricted to the circumference of the cell plate. When
the cell plate is completely formed the phargmoplast disappears completely. At this stage thin lamellae are laid down by the daughter protoplasts on both the sides of the cell plate. The cell plate gradually undergoes changes to form the intercellular substances referred to as the **middle lamella.**

Structure of the cell wall

A typical plant cell has the following three parts. 1. **Middle lamella** 2.**Primary wall** 3.**Secondary Wall**

Chemical Composition

The chemical composition of cell wall varies in different kingdoms. In bacteria the cell wall is composed of **peptidoglycan,** in Fungi it is made up of **chitin.** The plant cell wall is made up of **cellulose.** Besides cellulose certain other chemicals such as hemicellulose, pectin, lignin, cutin, suberin, silica may also be seen deposited on the wall.

Middle lamella

It is a thin amorphous cement like layer between two adjacent cells. Middle lamella is the first layer, which is deposited at the time of cytokinesis. It is optically inactive (isotropic). It is made up of calcium and magnesium pectates. In addition to these substances proteins are also present.

Primary wall

It is the first formed wall of the cell which is produced inner to the middle lamella. It is thin, elastic and extensible in growing cells. It is optically active (anisotropic). It grows by addition of more wall material within the existing one. Such a growth is termed as **intussusception.** Some cells like the parenchymatous cells and meristematic cells have only the primary wall. The primary wall consists of a loose network of cellulose **microfibrils** embedded in a gel like matrix or ground substances. In most of the plants the micro fibrils are made up of cellulose. The micro fibrils are oriented variously according to shape and thickness of the wall. The matrix of the primary wall in which the micro fibrils are embedded is mainly composed of water, hemicellulose, pectin and glycoprotein. Pectin is the filling material of the matrix. Hemicellulose binds the microfibrils with the matrix and the glycoproteins control the orientation of the microfibrils.

Secondary Wall

A thick secondary wall is laid inner to the primary wall after the cell has reached maturity. It is laid down is succession of at least three layers often named **S1, S2** and **S3.** It grows in thickness by accretion (apposition) i.e deposition of materials over the existing structures. The central layer (**S2**)is usually the thickest layer. In some cells however, the number of layers may be more than three. The formation of secondary wall is not uniform in all the cells. This results in the differentiation of various types of cells, such as parenchyma, collenchyma, fibres and tracheids.

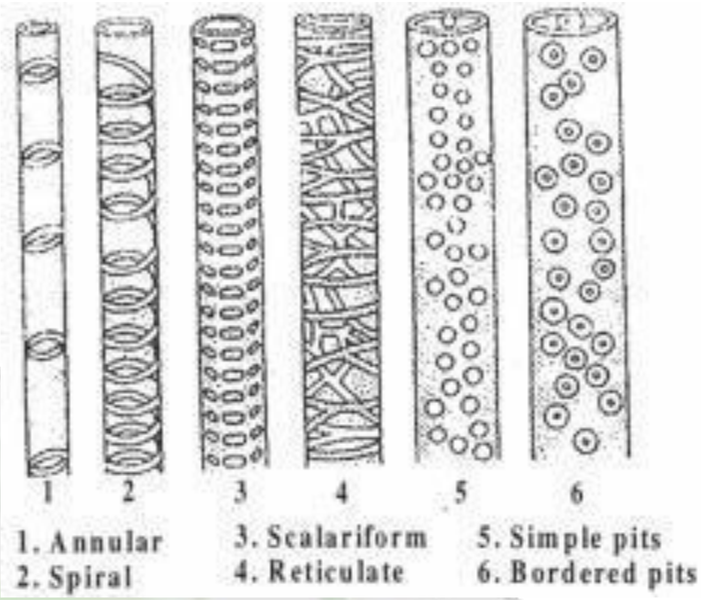


Fig 27. Various types of thickenings in cell wall

The micro fibrils of secondary wall are compactly arranged with different orientation in different layers embedded in a matrix of pectin and hemicellulose. Substances like lignin, suberin, minerals, waxes, tannins, resins, gums, inorganic salts such as calcium carbonate, calcium oxalate, silica etc may be deposited in the secondary wall. The secondary wall is very strongly anisotropic and layering can be observed in it. Fine structure of the cell wall particularly that of the secondary wall, has been intensively studied. This study was stimulated because of its importance to the fibre, paper and other industries.

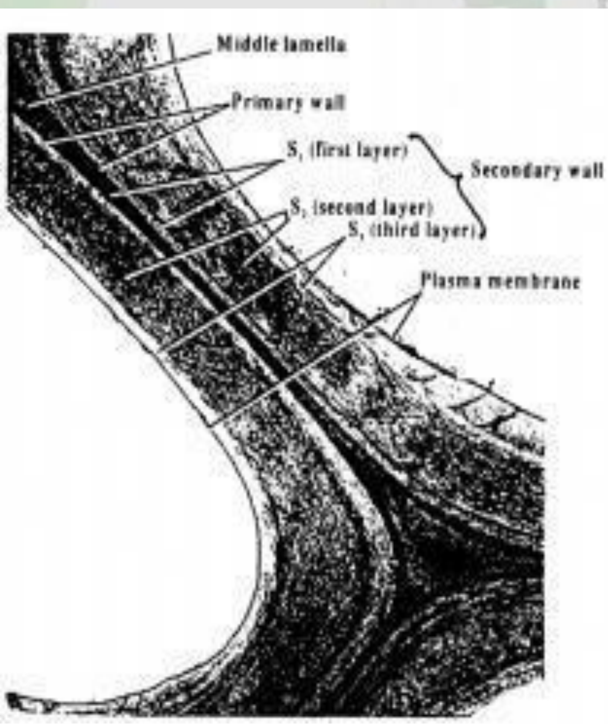


Fig 28. Electron micrograph of a thin section showing parts of the cells separating three cells

Cell wall is built of a system of microscopic threads the micro fibrils, which are grouped together in larger bundles. the layering seen in the secondary wall is often the result of the different density of the micro fibrils. The secondary wall consists of two continuous interpenetrating systems one of which is the **cellulose micro fibrils** and the other, the continuous system of **microcapillary spaces.** These spaces may the filled with lignin, cutin, suberin, hemicellulose and other organic substances and sometimes even some mineral crystals. The cellulose molecules consist of long chains of linked glucose residues. The chain molecules are arranged in bundles which are generally termed **micellae.** The hypothesis of the presence of micellae was proposed by **Nageli.** According to Frey-wyssling and Muhlethaler the thread like cellulose molecules are arranged in bundles. Each such bundle which forms an **elementary fibril** consists of about 36 cellulose molecules. The elementary fibril is mostly crytalline.

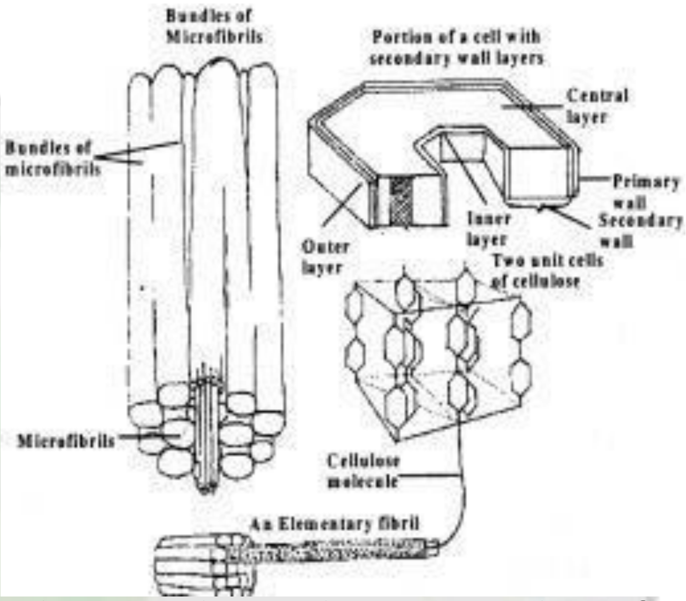


Fig 29. Diagramatic representation of ultrastructure of the cell wall

Plasmodesmata

The cell wall is not totally complete around the cell. It is interrupted by narrow pores carrying fine strands of cytoplasm, which interlink the contents of the cells. They are called **plasmodesmata.** They form a protoplasmic continuum called **symplast.** It consists of a canal, lined by plasma membrane. It has a simple or branched tubule known as **desmotubule.** Desmotubule is an extension of endoplasmic reticulum. Plasmodesmata serves as a passage for many substances to pass through. It is also believed that they have a role in the relay of stimuli.

Pits

Pits are the areas on the cell wall on which the secondary wall is not laid down. The pits of adjacent cells are opposite to each other. Each pit has a **pit chamber** and a **pit membrane.** The pit membrane consists of middle lamella and primary wall. Pit membrane has many minute pores and thus they are permeable. Pits are of two types 1.**Simple pits** 2.**Bordered pits.** In simple pits the width of the pit chamber is uniform. There is no secondary wall in the simple pit. In bordered pit the secondary wall partly overhangs the pit. Pits help in the translocation of substances between two adjacent cells. Generally each pit has a **complementary pit** lying exactly opposite to it in the wall of the neighbouring cell.

Such pits form a morphological and functional unit called the **pit pair.**

Functions of cell wall

1. It gives definite shape to the cell.
2. It protects the internal protoplasm against injury.
3. It gives rigidity to the cell
4. It prevents the bursting of plant cells due to endosmosis.
5. The walls of xylem vessels, tracheids and sieve tubes are specialized for long distance transport.
6. In many cases, the cell wall takes part in offense and defense.

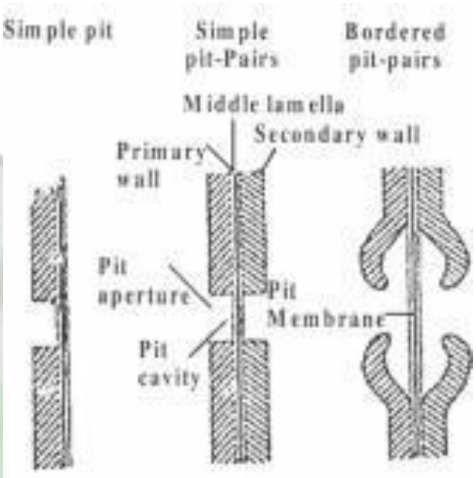


Fig 30. Structure of pits

Cell Membrane

All the prokaryotic and eukaryotic cells are enclosed by an elastic thin covering called **plasma membrane.** It is selectively permeable since it allows only certain substances to enter or leave the cell through it. In addition to this eukaryotic cells possess intracellular membranes collectively called cytoplasmic membrane system, that surround the vacuole and cell organelles. Plasma membrane and the sub-cellular membranes are together known as **biological membranes.**

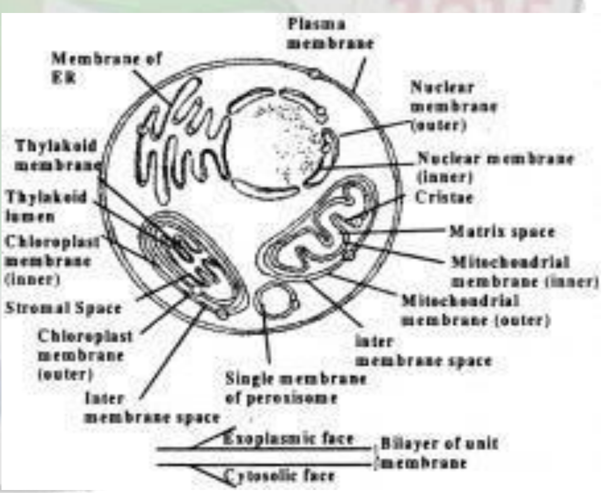


Fig 31. Two faces of biomembrane

Ultra structure of the cell membrane

Cell membranes are about 75A° thick. Under the electron microscope they appear to consist of 3 layers. 1. an outer electron dense layer of about 20A° thick 2. an inner electron dense layer of about 20A° thick. 3. a middle pale coloured layer about 35A° thick.

The outer and inner layers are formed of protein molecules whereas the middle one is composed of two layers of phospholipid molecules. Such a trilaminar structure is called ―Unit membrane‖ which is a basic concept of all membranes.

Fluid mosaic Model

Many models have been proposed to explain the molecular structure of plasma membrane. Fluid mosaic model was proposed by **Singer and Nicholson** (1972) and it is widely accepted by all. According to this model the cell membrane has **quasifluid** structure. All cellular membranes line closed compartments and have a **cytosolic** and an **exoplasmic** face. Membranes are formed of lipids and priteins. According to this model the membrane is viewed as a two dimensional mosaic of phospholipids and protein molecules.

Lipids

The lipid molecules form a continuous bilayer. The protein molecules are arranged as **extrinsic proteins** on the surface of lipid bilayer and as **intrinsic proteins** that penetrate the lipid bilayer either wholloy or partially. The lipid bilayer is formed of a double layer of phospholipid molecules. They are **amphipathic** molecules i.e. they have a hydrophilic and hydrophobic part. The arrangement of

phospholipids forms a water resistant barrier. So that only lipid soluble substances can pass through readily but not water soluble substances. The phospholipid bilayer forms the basic structure of all biomembranes which also contain proteins, glycoproteins, cholesterol and other steroids and glycolipids. The presence of specific sets of membrane proteins permits each type of membrane to carryout distinctive functions.

Proteins

Proteins are arranged in two forms.

1. **Extrinsic or peripheral proteins:**These are superficially attached to either face of lipid bimolecular membrane and are easily removable by physical methods.

2. **Intrinsic or Integral proteins**:These proteins penetrate the lipid either wholly or partially and are tightly held by strong bonds. In order to remove them, the whole membrane has to be disrupted. The integral proteins occur in various forms and perform many functions.

Functions of plasma membrane

In all cells the plasma membrane has several essential functions to perform. These include transporting nutrients into and metabolic wastes out of the cell preventing unwanted materials from entering the cell. In short, the intercellular and intra cellular transport is regulated by plasma membrane. The plasma membrane maintains the proper ionic composition pH(~7.2) and osmotic pressure of the cytosol. To carry out all these functions, the plasma membrane contains specific transport proteins that permit the passage of certain small molecules but not others. Several of these proteins use the energy relaeased by **ATP** hydrolysis to pump ions and other molecules into or out of the cell against concentration gradients. Small charged molecules such as ATP and amino acids can diffuse freely within the cytosol but are restricted in their ability to leave or enter it across the plasma membrane. In addition to these universal functions, the plasma membrane has other important functions to perform. Enzymes bound to the plasma membrane catalyze reactions that would occur with difficulty in an aqueous environment. The plasma membranes of many types of eukaryotic cells also contain **receptor proteins** that bind specific **signalling molecules** like hormones, growth factors, neurotransmitters etc. leading to various cellular responses. Like the entire cell, each organelle in eukaryotic cells is bounded by a unit membrane containing a unique set of proteins essential for its proper functioning.

Membrane Transport

Based on the permeability a membrane is said to be:

1. **Permeable**: If a substance passes readily through the membrane
2. **Impermeable**: If a substance does not pass through the membrane
3. **Selectively permeable**: If the membrane allows some of the substances to pass through but does not allow all the substances to pass through it.

The permeability of a membrane depends on

1) the size of pores in the Plasma membrane.
2) The size of the substance molecules
3) The charge on the substance molecules.

All the biological membranes are selectively permeable. Its permeability properties ensure that essential molecules such as glucose, amino acids and lipids readily enter the cell, metabolic intermediates remain in the cell and waste compounds leave the cell. In short it allows the cell to maintain a constant internal environment.

Substances are transported across the membrane either by:

1. **Passive Transport** or 2. **Active Transport**

Passive Transport

Physical processes

Passive Transport of materials across the membrane requires no energy by the cell and it is unaided by the transport proteins. The physical processes through which substances get into the cell are 1.**Diffusion** 2.**Osmosis**

Diffusion

Diffusion is the movement of molecules of any substance from a region of it's higher to a region of it's lower concentration (down its own concentration gradient) to spread uniformly in the dispersion medium on account of their random kinetic motion.

The rate of diffusion is directly proportional to

1. the concentration of the substance
2. temperature of the medium
3. area of the diffusion pathway

The diffusion is inversely proportional to

1. the size of the substance molecules
2. the molecular weight of the substance molecule
3. the distance over which the molecules have to diffuse

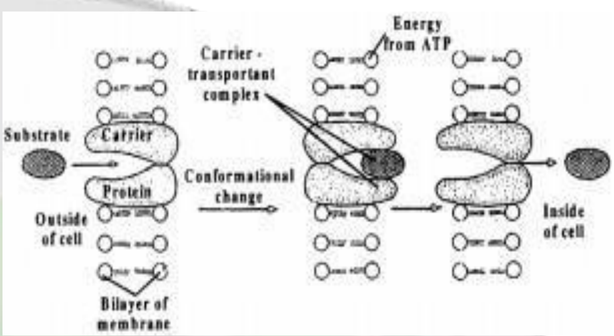


Fig 32. Role of carrier proteins in active membrane transport – a schematic representation

Diffusion through Biomembranes

Gases and small hydrophobic molecules diffuse directly across the phospholipid bilayer at a rate proportional to their ability to dissolve in a liquid hydro carbon. Transport of molecules takes place **along the concentration gradient** and no metabolic energy is expended in this process. This can be described as **„down hill transport"**. Diffusion through the bio membrane takes place in two ways.

1. Diffusion of fat-soluble substances through plasma membrane simply by dissolving in the lipid bilayer.
2. Diffusion of water soluble substances and ions: This takes place through pores in the membranes.

Diffusion of charged particles water soluble substances and ions such as K+ Cl– and HCO3 – diffuse through the pores in the membranes. An ion diffuses from the side richer in like charges to the side with an excess of opposite charges. The difference of electrical charges between the two sides of a membrance is called electro chemical gradient. The integral proteins of the membrane act as protein channels extending through the membrane. The movement of gas molecules occurs down its pressure gradient.

Osmosis

It is the special type of diffusion where the water or solvent diffuses through a selectively permeable membrane from a region of high solvent concentration to a region of low solvent concentration.

Role of Osmosis

1. It helps in absorption of water from the soil by root hairs.
2. Osmosis helps in cell to cell movement of water.
3. Osmosis helps to develop the turgor pressure which helps in opening and closing of stomata.

Uniporter Catalyzed Transport

The plasma membrane of most cells (animal or plant) contains several uniporters that enable amino acids, nucleosides, sugars and other small molecules to enter and leave cells down their concentration gradients. Similar to enzymes, uniporters accelerate a reaction that is thermodynamically favoured. This type of movement sometimes is referred to as **facilitated transport** or **facilitated diffusion.**

Three main features distinguish uniport transport from passive diffusion.

1. the rate of transport is far higher than predicted

2.transport is specific

3.transport occurs via a limited number of transporter proteins rather than through out the phospholipids bilayer.

Active transport

It is vital process. It is the movement of molecules or ions **against the concentration gradient.** i.e the molecules or ions move from the region of lower concentration towards the region of higher concentration. The movement of molecules can be compared with the **uphill movement** of water. Energy is required to counteract the force of diffusion and the energy comes from ATP produced by oxidative phosphorylation or by concentration gradient of ions. Thus active transport is defined as the energy dependent transport of molecules or ions across a semi permeable membrane **against the concentration gradient.**

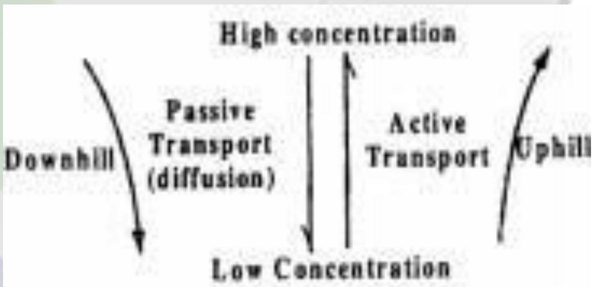


Fig 33. Active transport- a scheme

Active transport takes place with the help of **carrier proteins** that are present in the plasma membrane. In the plasma membrane there are a number of carrier molecules called **permeases** or **translocases** present. For each type of solute molecule there is a specific carrier molecule. It has got two binding sites; one for the **transportant** and other for **ATP** molecule. The carrier proteins bind the
transportant molecule on the outer side of the plasma membrane. This results in the formation of **carrier-transportant-complex.** As the ATP molecule binds itself to the other binding site of the carrier protein it is hydrolysed to form ADP and energy is released. This energy brings **conformational change** in the carrier transportant-complex and the transportant is carried through the channel on the other side of the membrane. The carrier molecule regains its original form and repeats the precess. There are two forces which govern the movement of ions across selectively permeable membranes, the **membrane electric potential** and **the ion concentration gradient.** ATP driven ion pumps generate and maintain ionic gradients across the plasma membrane.

Endocytosis and exocytosis

Endocytosis and exocytosis are active processes involving bulk transport of materials through membranes, either into cells(endocytosis) or out of cells (exocytosis). Endocytosis occurs by an in folding or extension of the plasma membrane to form a vesicle or vacuole or vauole. It is of two types.

1. Phagocytosis:(cell eating)-Substances are taken up in solid form. Cells involving in this process are called phagocytes and said to be phagocytic. (eg.) some white blood cells. A phagocytic vacuole is formed during the uptake.

2. Pinocytosis (cell drinking)-Substances are taken up in liquid form. Vesicles which are very small are formed during intake. Pinocytosis is often associated with amoebiod protozozns, and in certain kidney cells involved in fluid exchange. It can also occur in plant cells. Exocytosis is the reverse of endocytosis by which materials are removed from cells such as undigested remains from food vacuoles.

Cell Organelles

The internal architecture of cells and central metabolic pathways are similar in all plants, animals and unicellular eukaryotic organisma (eg. Yeast) All eukaryotic cells contain a membrane bound nucleus and numerous other organelles in their cytosol. Unique proteins in the interior and membranes of each type of organelle largely determine it‘s specific functional characteristics. A Typical plant cell contains the following organelles and parts:

1. Mitochondria

They are bounded by two membranes with the inner one extensively folded. Enzymes in the inner mitochondrial membrane and central matrix carry out terminal stages of sugar and lipid oxidation coupled with ATP synthesis.

2. Chloroplasts

They are the sites of Photosynthesis. They are found only in plant cells. They are surrounded by an inner and outer membrane, a complex system of **thylakoid** membranes in their interior contains the pigments and enzymes that absorb light and produce ATP.

3. Nucleus

It is surrounded by an inner and outer membrane. These contain numerous pores through which materials pass between the nucleus and cytosol. The outer nuclear membrane is continuous with the rough endoplasmic reticulum. The nuclear membrane resembles the plasma membrane in its function. The nucleus mainly contains DNA organized into linear structures called **chromosomes.**

4. Endoplasmic reticulum

These are a network of inter connected membranes. Two types of Endoplasmic Reticulum are recognised. 1.**Rough E.R** 2. **Smooth E.R**

Rough ER

In this kind of ER, ribosomes are present on the surface. The endoplasmic reticulum is responsible for protein synthesis in a cell. Ribosomes are sub organelles in which the amino acids are actually bound together to form proteins. There are spaces within the folds of ER membrane and they are known as **Cisternae.**

Smooth ER

This type of ER does not have ribosomes.

5. Golgi Body or Golgi Apparatus(G.A.) (Dictyosomes)

Golgi body is a series of flattened sacs usually curled at the edges. Proteins which were formed on ribosomes of rough endoplasmic reticulum are processed in G.A. After processing, the final product is discharged from the G.A. At this time the G.A. bulges and breaks away to

form vesicle known as **secretory vesicle.** The vesicles move outward to the cell membrane and either insert their protein
contents in the membrane or release these contents outside the cell.

6. Vacuoles

The Vacuoles form about 75% of the plant cell. In the vacuole the plant stores nutrients as well as toxic wastes. If pressure increases within the vacuole it can increase the size of the cell. In this case the cell will become swollen. If the pressure increases further the cell will get destroyed.

7. Ribosomes

Ribosomes are found in cells, both prokaryotic and eukaryotic except in mature sperm cells and RBCs. In eukaryotic cells they occur freely in the cytoplasm and also found attached to the outer surface of rough ER. Ribosomes are the **sites of protein synthesis**

8. Plasma Membrane

In all the cells the plasma membrane has several functions to perform. These include transporting nutrients into and metabolic wastes out of the cell. It is formed of lipids and proteins.

9. Microbodies

These are spherical organelles bound by a single membrane. They are the sites of glyoxylate cycle in plants.

10. Cell wall

The cells of all plants have cell wall. It has three parts. 1. Middle lamella 2. Primary wall 3. Secondary wall.It gives definite shape to the
plant cell.

Nucleus

Nuclus is the largest organelle in eukaryotic cells. It is surrounded by two membranes. Each one is a phospholipid bilayer containing many different types of proteins. The inner nuclear membrane defines the nucleus itself. In many cells the outer nuclear membrane is continuous with the rough ER and the space

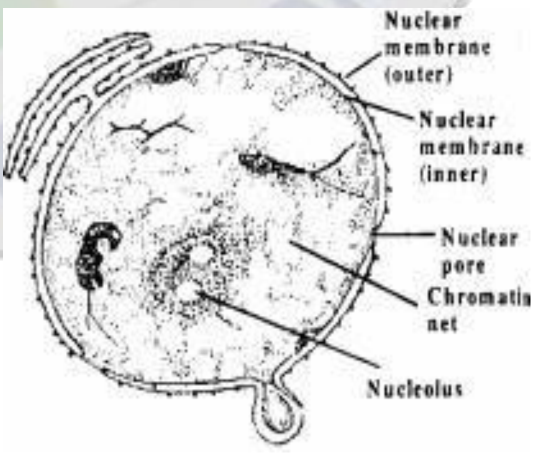


Fig 34. Structure of nucleus

between the inner and outer nuclear membrane is continuous with the lumen of the rough ER The two nuclear membranes appear to fuse at the nuclear pores. These ring like pores are constructed of a specific set of membrane proteins and these act like channels that regulate the movement of substances between the nucleus and the cytosol.

In a growing of differentiating cell, the nucleus is metabolically active, producing DNA and RNA. The RNA is exported through nuclear pores to the cytoplasm for use in protein synthesis. In 'resting' cells, the nucleus is inactive or dormant and minimal synthesis of DNA and RNA takes place.

In a nucleus that is not dividing, the chromosomes are dispersed and not thick enough to be observed in the light microscope. Only during cell division the chromosomes become visible b y light microscopy. **Chromosomes** form the physical basis of heredity. **Genes,** the chemical basis of heredity, are arranged in linear fashion on the chromosomes. A sub organelle of the nucleus, the **nucleolus** is easily recognized under light microscope. Most of the ribosomal RNA of a cell is synthesized in the nucleolus. The finished or partly finished ribosomal sub units pass through a nuclear pore into the cytosol. The non nucleolar regions of the nucleus is called the **nucleoplasm.** It has very high DNA concentration. Fibrous proteins called lamins form a two dimensional network along the inner surface of the inner membrane giving it shape and apparently binding DNA to it. During the early stages of cell division breakdown of this network occurs.

Functions of Nucleus

1. It controls all the metabolic activities of the cell by controlling the synthesis of enzymes required.
2. Nucleus controls the inheritance of characters from parents to offspring.
3. Nucleus controls cell division.

Mitochondria

A Mitochondrion is also called as the **"Power house of the cell"** because it stores and releases the energy of the cell. The energy released is used to form ATP (Adenosine T r i p h o s p h a t e)

Mitochondria are the principal sites of ATP

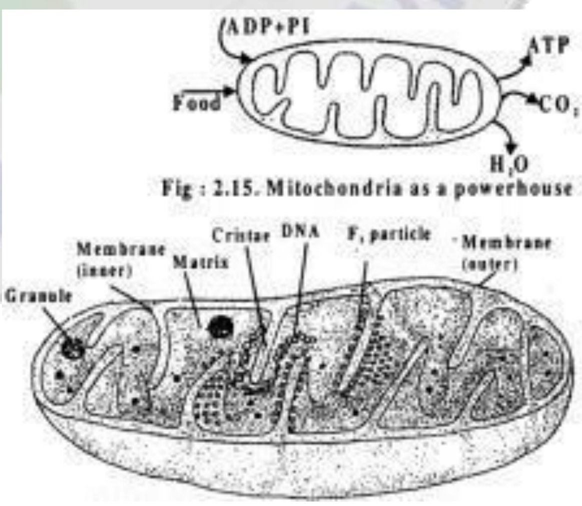


Fig 35. Ultra structure of mitochondria

production in aerobic cells. Most eukaryotic cells contain many mitochondria, which occupy up to 25 percent of the volume of the cytoplasm. These complex organelles are among the largest organelles generally exceeded in size only by the nucleus, vacuoles and chloroplasts. Typically the mitochondria are sausage-shaped but these may be granular, filamentous, rodshaped, spherical or thread like. Mitcohondria contain two very different membranes an outer one and an inner one, separated by the inter membrane space. The outer membrane is composed of about half lipid and half protein. The inner membrane is less permeable. It is composed of about 20 percent lipid and 80 percent protein. The surface area of the inner membrane is greatly increased by a large number of infoldings, or **cristae** that protrude into the matrix.

Structure of the cristae membrane

The inner of the cristae membrane (i.e the surface towards the matrix) is covered with numerous (infinite) stalked particles. These are called **F1 Particles, elementary particles** or **sub units.** These particles project into the matrix. Each F1 particle has 3 parts, viz, the head piece, the stalk and the base piece. The respiratory chain consists of enzymes and co-enzymes which constitute the **Electron Transport System, (ETS)** in the mitochondrion. These enzymes and co-enzymes of the ETS act as the electron acceptors in the aerobic respiration reaction. (Oxidative Phosphorylation). In non photosynthetic cells the principal fuels for ATP synthesis are fatty acids and glucose. The complete aerobic degradation of glucose to CO2 and H2O is coupled to synthesis of as many as 38 molecules of ATP. In eukaryotic cells, the initial stages of glucose degradation occur in the cytosol, where 2 ATP molecules per glucose molecule are generated. The terminal stages including those involving phosphorylation coupled to final oxidation by oxygen are carried out by exzymes in the mitochondrial matirix and cristae. As many as 36 ATP molecules per glucose molecule are generated in mitochondria although this value can vary because much of the energy released in mitochondrial oxidation can be used for other purposes (e.g heat generation and the transport of molecules into or out of the mitochondrion) making less enery available for ATP synthesis. Similarly, virtually all the ATP formed during the oxidation of fatty acids to CO2 is generated in the mitochondrion. Thus the mitochondrion can be regarded as the **“Power plant”** of the cell.

Mitochondria as semi-autonomous organelles

Mitochondria are self perpetuating semi autonomous bodies. These arise new by the division of existing mitochondria. These are also regarded as intra cellular parasitic prokaryotes that have established symbiotic relationship with the cell. The mitochondrial matrix contains DNA molecules which are circular and 70s ribosomes, tRNA and enzymes for functioning of mitochondrial genes.

Plastids

Plastids are the largest cytoplasmic organelles bounded by double membrane. These are found in most of the plant cells and in some photosynthetic protists. These are absent in prokaryotes and in animal cells. Plastids are of three types namely **chloroplasts, chromoplasts** and **leucoplasts.** Chromoplasts are coloured plastids other than green. They are found in coloured parts of plants such as petals of the flower, pericarp of the fruits etc. Leucoplasts are the colourless plastids. These colourless plastids are involved in the storage of carbothydrates, fats and oils and proteins. The plastids which store carbohydrates are called amyloplasts. The plastids storing fats and oils are called elaioplasts. The plastids storing protein are called proteinoplasts.

Chloroplast

Chloroplasts can be as long as 10ìm and are typically 0.5 - 2.0 ìm thick, but they vary in size and shape in different cells, especially among the algae. Like mitochondrion, the chloroplast is surrounded by an outer and inner membrane. In addition to this, chloroplasts contain an internal system of extensive inter connected membrane-limited sacs called **thylakoids** which are flattened to form disks. These are often grouped in stakes of 20-50 thylakoids to from what are called **grana** and embedded in a matrix called **stroma**.

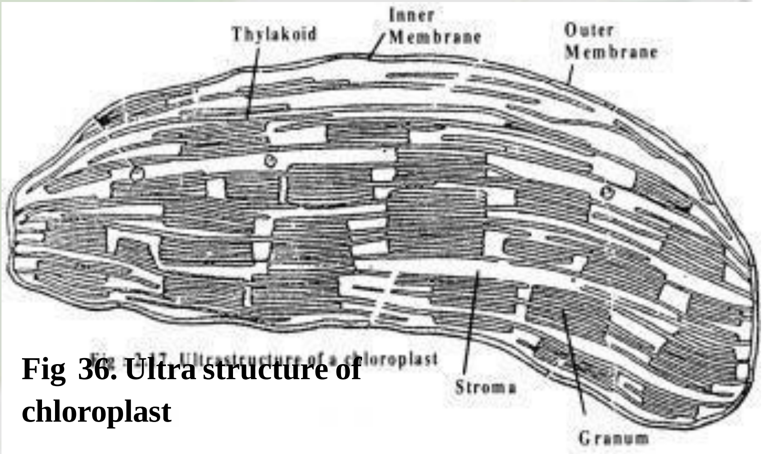


Fig 36. Ultra structure of chloroplast

Stroma, a semi fluid, colourless, colloidal complex contains DNA, RNA, ribiosomes and several enzymes. The DNA of chloroplast is circular. The ribosomes are of 70s type. The matrix of higher plant's chloroplasts may contain starch as storage product. Thylakoids may occur attached to the inner membrane of the chloroplast envelop. About 40-100 grana may occur in a chloroplast. Many membranous tubules called stroma lamellae (intergranal thylakoids) interconnect thylakoids of different grana. Thylakoid membrane contains photosynthetic pigments. The thylakoid membrane contains green pigments (Chlorophylls) and other pigments and enzymes that absorb light and generate ATP during photosynthesis. Part of this ATP is used by enzymes located in stroma to the convert CO2 into three carbon (3C) intermediates which are then exported to the cytosol and converted to sugars. The molecular mechanism by which ATP is formed is very similar in mitochondria and chloroplasts. Chloroplasts and mitochondria have other features also in common. Both migrate often from place to place within cells and both contain their own DNA which code for some of the key organellar proteins. These proteins are synthesized in the ribosomes within the organelle. However, most of the proteins in each of these organelles are encoded in the nuclear DNA and are synthesized in the cytosol. These proteins are then incorporated into the organelles.

Ribosomes

Ribosomes are small subspherical granular organelles, not enclosed by any membrane. They are composed of ribonucleo proteins and they are the site of protein synthesis.

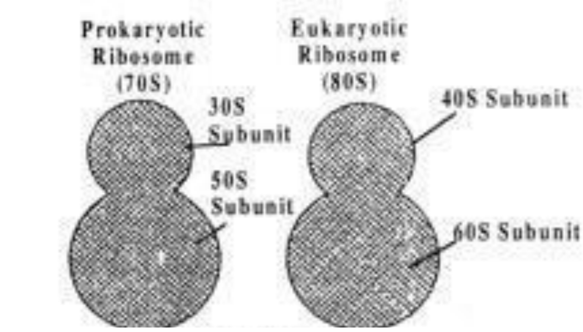


Fig 37. Ribosome

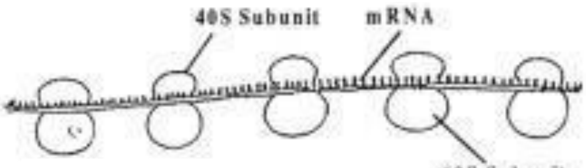


Fig 38. Polyribosome

They occur in large number. Each ribosome is 150-250A in diameter and consists of two unequal sub units, a larger dome shaped and a smaller ovoid one. The smaller sub unit fits over the larger one like a cap. These two subunits occur separately in the cytoplasm and join to form ribosomes only at the time of protein synthesis. At the time of protein synthesis many ribosomes line up and join an mRNA chain to synthesise many copies of a particular polypeptide. Such a string of ribosomes is called **polysome.** Ribosomes occur in cytoplasmic matrix and in some cell organelles. Accordingly, they are called cytoplasmic ribosomes or organelle ribosomes. The organelle ribosomes are found in plastids and mitochondria. The cytoplasmic ribosomes may remain free in the cytoplasmic matrix or attached to the surface of the endoplasmic reticulum. The attached ribosomes generally transfer their proteins to cisternae of endoplasmic reticulum for transport to other parts both inside and outside the cell. Depending upon size or sedimentation coefficient(s), ribosomes are of two types. **70s** and **80s. 70s** type of ribosomes are found in all prokaryotic cells and **80s** type are found in eukaryotic cells. **S** is Svedberg unit which is a measure of particle size with which the particle sediments in a centrifuge. In eukaryotic cells, synthesis of ribosomes occurs inside the nucleolus. Ribosomal RNA are synthesized in the nucleolus. The ribosomal proteins are synthesized in the cytoplasm and shift to the nucleolus for the formation of ribosomal sub units by complexing with rRNA. The sub units pass out into the cytoplasm through the nuclear pores. In prokaryotic cells, both ribosomal RNAs and proteins are synthesized in the cytoplasm. Thus the ribosomes act as the **protein factories** of the cell.

Cell Division

Cell Cycle

As we have discussed in the earlier chapter, the cell cycle amazingly follows a regular timing mechanism. Most eukaryotic cells live according to an internal clock, that is, they proceed through a sequence of phases, called the cell cycle. During the cell cycle DNA is duplicated during the **synthesis(S)** phase and the copies are distributed to the daughter cells during **mitotic(M)** phase. Most growing plant and animal cells take 10-20 hours to double in number and some duplicate at a much slower rate. A multi cellular organism usually starts it‘s life as a single cell (zygote). The multiplication of this single cell and it‘s descendants determine the growth and development of the organism and this is achieved by cell division. Cell division is a complex process by which cellular material is equally divided between daughter cells. Cell division in living things are of three kinds. They are 1.**Amitosis** 2.**Mitosis**
3. **Meiosis.**

Amitosis

It is a simple type of division where the cell contents including nucleus divide into two equal halves by an inwardly growing constriction in the middle of the cell. This type of cell division is common in prokaryotes.

Mitotic cell cycle

It is represented by DNA duplication followed by nuclear division (Karyokinesis) which in turn is followed by cytokinesis. Mitotic cell division was first described by **W. Flemming** in 1882. In the same year, mitosis in plants was described by **Strasburger.** In plants, active mitotic cell division takes place in apices. In higher animals mitotic cell division is said to be diffused, distributed all over the body. Mitotic cell cycle consists of long **interphase**(which is sub divided into **G1, S and G2** phases), a short **M stage** (or mitotic stage, subdivided into prophase metaphase, anaphase and telophase) and **cytokinesis**. The duration of interphase and M-phase varies in different cells.

Interphase

It is the stage in between two successive cell divisions during which the cell prepares itself for the process by synthesizing new nucleic acids and proteins. Chromosomes appear as chromatin network. Interphase consists of the following three sub stages.

i) G1 or Gap-1 phase

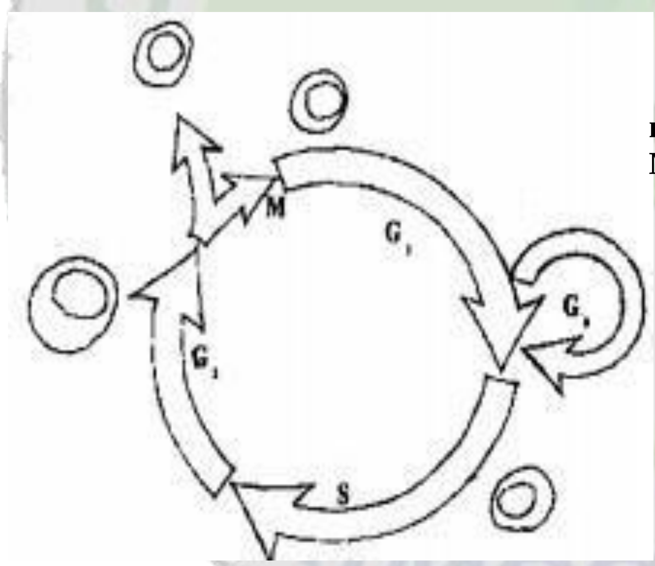
This phase starts immediately after cell division. The cell grows in size and there is synthesis of new proteins and RNA needed for various metabolic activities of the cell. A non-dividing cell does not proceed beyond G1 phase. The differentiating cells are said to be in **G0** stage.

ii) S-or Synthetic Phase

During this phase there is duplication of DNA. Thus each chromosome now is composedof two sister chromatids.

iii) G2 or Gap-2Phase

The proteins responsible for the formation of spindle fibres are synthesised during this stage.



ig 39. Eukaryotic cell cycle
nterphase (G1, S, G2)
Mitotic stage (M)
Non dividing stage (G0)

Mitosis

Mitosis is divided into the following 4 sub stages.

1.Prophase 2. Metaphase 3.Anaphase 4. Telophase

1. Prophase

The chromatin network begins to coil and each chromosome becomes distinct as long thread like structure. Each chromosome at this stage has two chromatids that lie side by side and held together by centromere. The nucleus gradually disappears. The nuclear membrane also starts disappearing.

2. Metaphase

The disappearance of nuclear membrane and nucleolus marks the beginning of metaphase.The chromosomes become shorter by further coiling. Finally, the chromosomes become distinct and visible under compound microscope. The chromosomes orient themselves in the equator of the cell in such a way that all the **centromeres** are arranged in the equator forming metaphase plate or equatorial plate. Out of the two chromatids of each chromosome, one faces one pole and the other one faces the opposite pole. At the same time spindle fibres arising from the opposite poles are seen attached to the centromeres. The fibres are made up of proteins rich in sulphur containing amino acids. At late metaphase, the **centromeres divide** and now the chromatids of each chromosome are ready to be separated.

3. Anaphase

Division of centromere marks the beginning of anaphase. The spindle fibres start contracting and this contraction pulls the two groups of chromosomes towards the opposite poles. As the chromosomes move toward opposite poles they assume **V or J** or **I** shaped configuration with the centromere proceeding towards the poles with chromosome

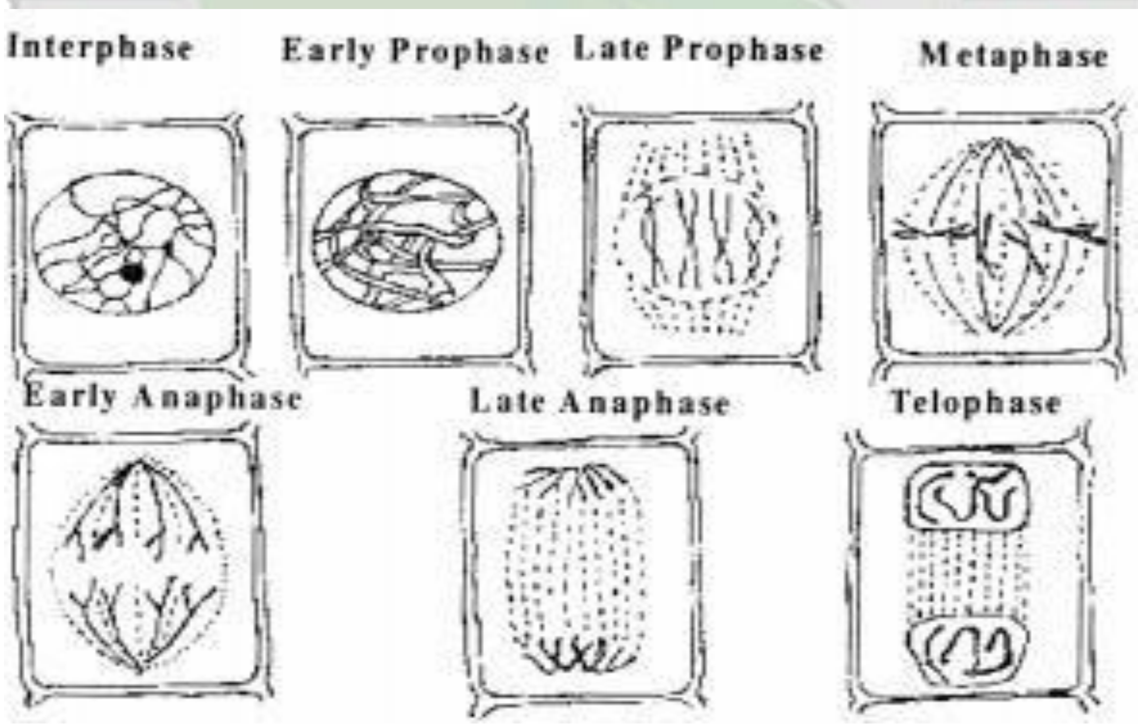


Fig 40. Stages of mitosis

arms trailing behind. Such variable shapes of the chromosomes are due to the variable position of centromere.

Telophase

At the end of anaphase, chromosomes reach the opposite poles and they uncoil, elongate and become thin and invisible. The nuclear membrane and the nucleouls reappear. thus, two daughter nuclei are formed, one at each pole.

Cytokinesis

The division of the cytoplam is called cytokinesis and it follows the nuclear division by the formation of cell wall between the two daughter nuclei. The formation of cell wall begins as a cell plate also known as **phragmoplast** formed by the aggregation of vesicles produced by Golgi bodies. These vesicles which contain cell wall materials fuse with one another to form cellmembranes and cell walls. Thus, at the end of mitosis, **two identical** daughter cells are formed.

Significance of Mitosis

1. As a result of mitosis two daughter cells which are identical to each other and identical to the mother cell are formed.
2. Mitotic cell division ensures that the daughter cells possess a genetical identity, both quantitatively and qualitatively.
3. Mitosis forms the basis of continuation of organisms.
4. Asexual reproduction of lower plants is possible only by mitosis.
5. Vegetative reproduction in higher plants by grafting, tissue culture method are also a consequence of mitosis.
6. Mitosis is the common method of multiplication of cells that helps in the growth and development of multi-cellular organism.
7. Mitosis helps in the regeneration of lost of damaged tissue and in wound healing.
8. The chromosomal number is maintained constant by mitosis for each species.

Meiosis

Meiosis is a process of cell division of the reproductive cells of both plants and animals in which the diploid number of chromosomes is reduced to haploid. Meiosis is also known as **reduction division (RD)** since the number of chromosomes is reduced to half. It takes place only in the reproductive cells during the formation of gametes. Meiosis consists of two complete divisions. As a result of this a diploid cell produces four haploid cells. The two divisions of meiosis are

meiosis I or heterotypic division and **meiosis II** or homotypic division. The first division is **meiotic** or reductional in which the number of chromosomes is reduced to half and the **second division** is **mitotic** or **equational**. In all the sexually reproducing organism the chromosome number remains

constant generation after generation. During sexual reproduction the two gametes male and female, each having single set oof chromosomes (n) fuse to form a zygote.The zygote thus contains twice as many chromosome as a gamete (**n+n=2n**). In these two sets of chromosomes one set is derived from the male parent and the other set from the female parent. This is how diploids come to possess tow identical sets of chromosomes called **homologous chromosomes** Meiosis may take place in the life cycle of a plant during any one of the following events.

1. At the time of spore formation ie. During the formation of pollen grains in anther and megaspores in ovules.

   2. At the time of gamete formation
   3. At the time of zygote germination.

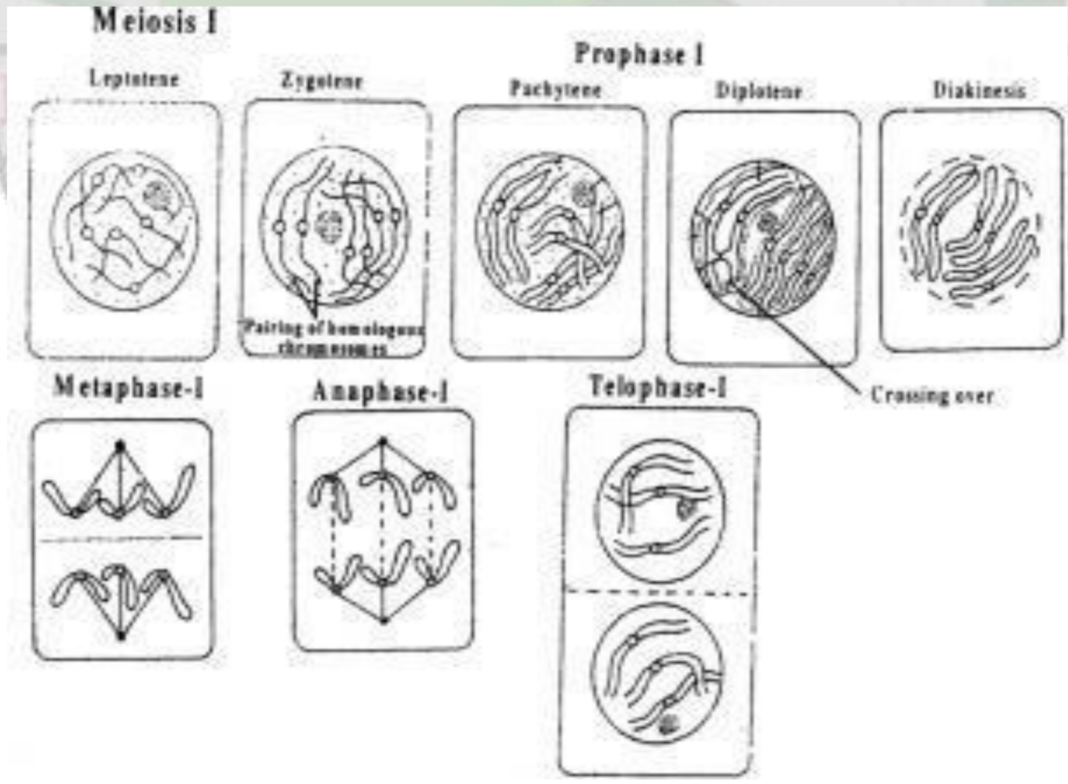


Fig 41. Stages of meiosis I

Each meiotic division cycle is divided into same four stages as in mitosis.

Prophase, Metaphase, Anaphase and Telophase. The name of each stage is followed by **I** or **II** depending on which division of cycle is involved.

Meiosis I

It consists of four stages namely.

1. Prophase I

2. Metaphase I

3. Anaphase I

4. Telophase I

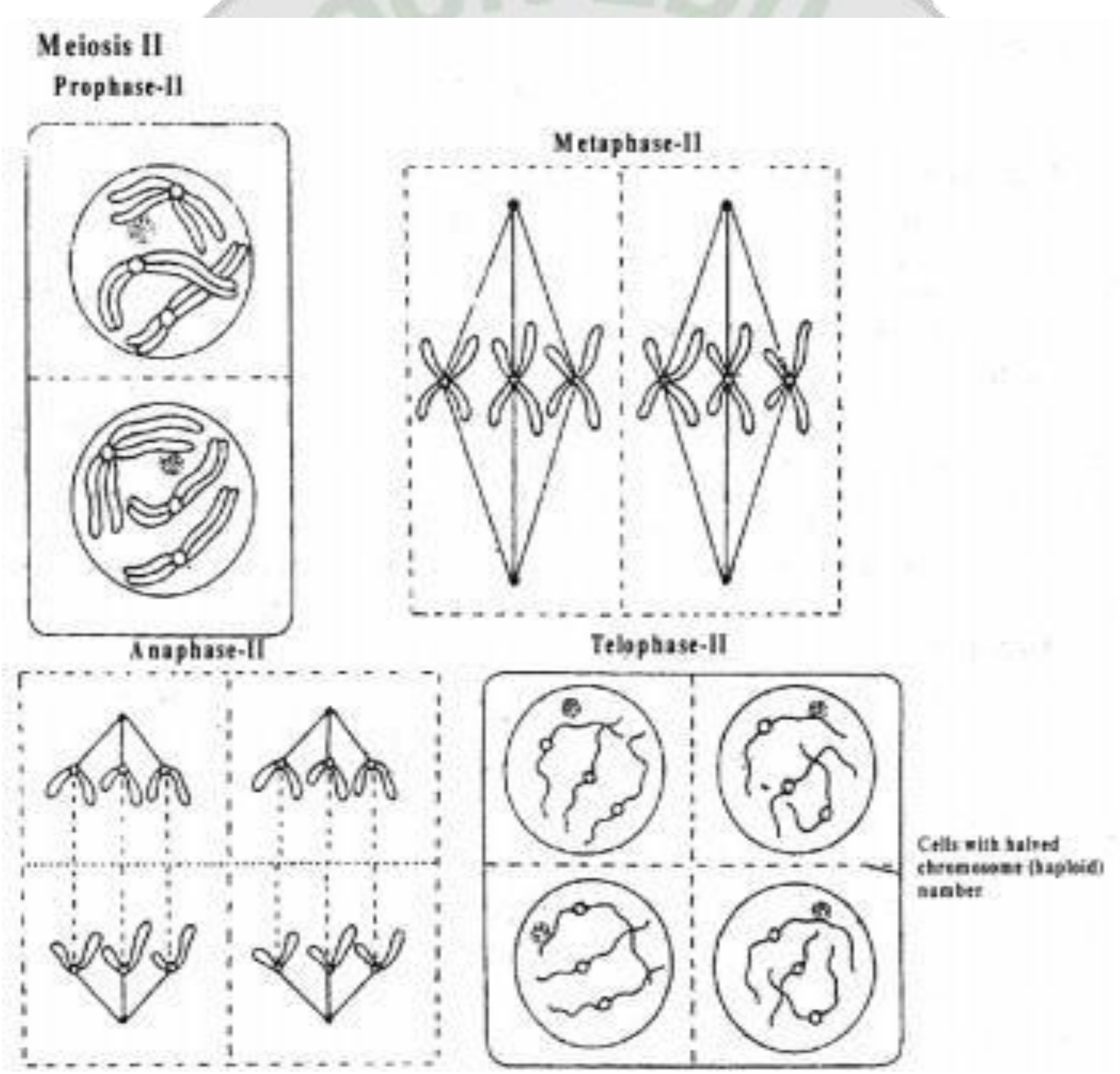


Fig 42. Stages of meiosis II

Prophase I

It is the first stage of first meiosis. This is the longest phase of the meiotic division. It includes 5 sub stages namely

1.Leptotene 2.Zygotene 3.Pachytene 4.Diplotene 5.Diakinesis

1. Leptotene

The word leptotene means **„thin thread"**. The chromosomes uncoil and become large and thinner. Each chromosome consists of two chromatids.

2. Zygotene

Homologous chromosomes come to-gether and lie side by side throughout heir length. This is called **pairing** or **synapsis.** The paired chromosomes are now called **bivalents.** The adjacent non-sister chromatids are joined together at certain posints called **chiasmata.**

3. Pachytene

The chromosomes condense further and become very shorter and thicker. They are very distinct now. The two sister chromatids of each homologous chromosome become clearly visible. The bivalent thus becomes a **tetrad** with four chromatids. In the region of chiasmata, segments of non-sister chromatids of the homologous chromosomes are exchanged and this process is called **crossing Over.**

4. Diplotene

The homologous chromosomes condense further. They begin to separate from each other except at the chiasmata. Due to this separation the dual nature of a bivalent becomes apparent and hence the name **diplotene.**

5. Diakinesis

The Chromosomes continue to contract. The separation of chromosome becomes complete due to **terminalisation**. The separation starts from the centromeres and goes towards the end and hence the name terminalisation: The nucleolus and nuclear membrane disappear and spindle formation starts.

Metaphase I

The spindle fibres become prominent. The bivalents align on the equatorial plane. Spindle fibres from opposite poles get attached to the centromeres of homologous chromosomes.

Anaphase I

The two chromosomes of each bivalent (with chromatids still attached to the centromere) separate from each other and move to the opposite poles of the cell. Thus, only one chromosome of each homologous pair reachers each pole. Consequently at each pole only half the number of chromosomes (haploid) is received. These chromosomes are, however not the same as existed at the beginning of prophase. Each chromosome consists of one of its original chromatids and the other has a mixture of segments of its own and a segment of chromatid from its homologue (due to crossing over).

Telephase I

This is the last stage of meiosis I. Reorganization of the chromosomes at poles occurs to form two haploid nuclei. Nuclear membrane and nucleolus re-appear. The spindle disappears. There is no cytokinesis after meiosis I. The second meiotic division may follow immediately or after a short inter phase. The DNA of the two haploid nuclei does not replicate.

Meiosis II

The second meiotic division is very much similar to mitosis.

Prophase II

The events of prophase II are similar to mitotic prophase. Nucleolus and nuclear membrane disappear. Spindle fibres are formed at each pole.

Metaphase II

Chromosomes move to the centre of the equatorial plane. They get attached to spindle fibres centromere.

Anaphase II

The sister chromatids separate from one another and are pulled to opposite poles of the spindle due to contraction of the spindle fibres.

Telophase II

The chromosomes begin to uncoil and become thin. They reorganize into nucleus with the reappearance of nucleolus and nuclear membrane in each pole. Cytokinesis follows and **four haploid daughter cells** are formed and thus the meiotic division is completed.

Significance of Meiosis

1. Meiosis helps to maintain the **chromosome number constant** in each plant and animal species. In meiosis four haploid daughter cells are formed from a single diploid cell. This is very important in sexual reproduction during the formation of gametes.
2. The occurrence of crossing over results in the **recombination of genes.**
3. The recombination of genes results in **genetic variation.**
4. The genetic variations form raw materials for **evolution**

Plant Tissue

A cellular organization between a single cell and a complete organism is controlled by the tissue. They are the collection of similar cells, with specific function. A collection of tissue gives rise to an organ. A tissue is a simple, which may be single celled type or a complex cell type.

Definition of Plant Tissue

A plant tissue can be defined as a cell or a group of cells dividing, to give rise to large number of cell, which is collectively referred as tissues. They are structurally and functionally similar to these cells.

Plant Tissue Systems

Plants do have a higher level of structure called plant tissue systems. A plant tissue system can be defined as a functional unit, which connects all organs of a plant. Like animal tissue system, plant tissue system is also grouped into various tissues based on their functions.

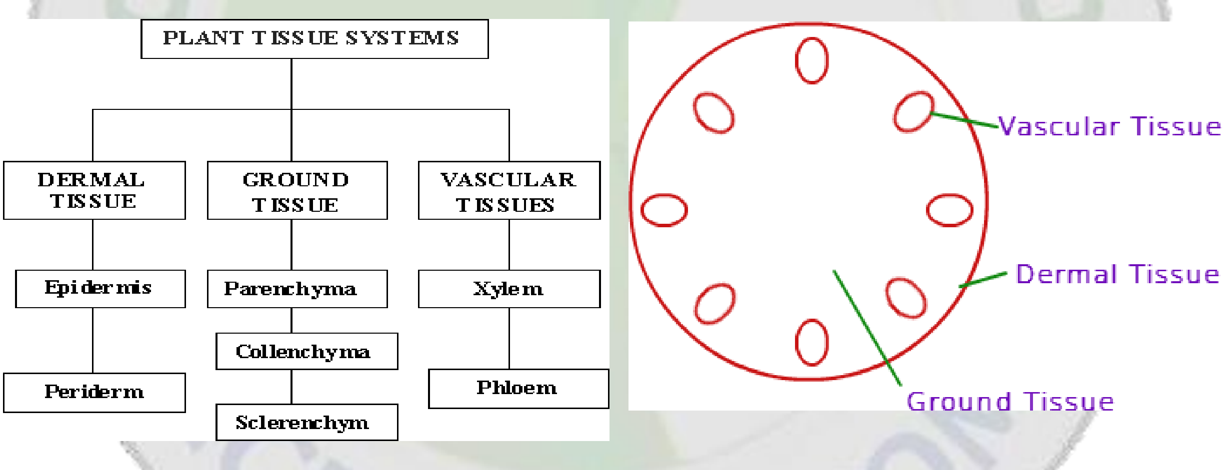


Fig 44. Plant tissue system

Types of Plant Tissue Systems

There are three types of tissue systems.

Dermal Tissue

- They are the tissues, which covers the external part of the herbaceous plants.
- They are composed of epidermal cells, which secrete the waxy cuticle.
- Waxy cuticles are responsible for protecting plants against water loss.
- Dermal tissue consists of Epidermis and periderm.

Epidermis

- They are the outermost layer of the primary plant body, which covers roots, stems, leaves, floral parts, fruits and seeds.
- They are one layer thick with cuticle.
- They are composed mostly of unspecialized cells- parenchyma and sclerenchyma.
- They include trichomes, stomata, buIIiform ceIIs, etc.

Periderm

- They are the outermost layer of stems and roots of woody plants such as trees. They are also called as barks.
- They replace epidermis in plants that undergo secondary growth.
- They are multilayered structures.
- They include cork cells, which are nonliving cells that cover the outside of stems and roots.
- The periderm protects the plant from injuries, pathogens and also from excessive water loss.

Ground Tissue

- They synthesize the organic compounds and support the plants by storing the produced products.
- They are composed of parenchyma cells and also include collenchyma and sclerenchyma cells.

Parenchyma

- They are the general cells of plants, which are circular in shape and have very thin wall.
- They are present in all plant cells.
- They have very large vacuoles and are frequently found in all roots, stem, leaves and in fruits
- Parenchyma cells help in synthesizing and storage of synthesized food products.
- Parenchyma cells also controls plant's metabolism like photosynthesis, respiration, protein synthesis.
- They also play a vital role in wound healing and regeneration of plants.

Collenchyma

- Collenchymas are a specialized parenchyma tissue, which are found in all green parts.
- Collenchyma cells are elongated with unevenly thickened walls.
- They are alive during the cell maturity.
- Collenchyma cells controls the functions of young plants.
- A collenchyma cell provides a support to plants by not restraining growth, which is caused due to their absence of secondary walls and hardening agent in their primary walls.

Sclerenchyma

- They are rigid, non-living cells.
- They have thick, lignified secondary walls and lack protoplasts at maturity.
- They provide strength
- A sclerenchyma cell also provides a support to plants with the help of hardening agent present in their cells.

Sclerenchyma cells are of two types:

- Sclereids: They are short, irregular in shape and have thick, lignified secondary walls
- Fibers: They are long, slender and are arranged in threads.

Vascular Tissues

- They are specialized cells with transport of water, hormone and minerals throughout the plant.
- They contain transfer cells, fibers in addition to xylem, phloem, parenchyma, cambium and other conducting cells.
- They are located in the veins of the Leaves.

Xylem

- The term Xylem• is derived from the Greek word meaning Wood• .
- They are dead with hollow cells, which consist of only cell wall.
- They play a vital role in transporting water and dissolved nutrients from the roots to all parts of a plant.

- They transport the nutrients in the upward direction .i.e. from the root to the stem, leaves and flower.
- Xylem is also called as water-conducting cells.

Phloem

- The term phloem• is derived from the Greek word meaning Bark• .
- They are live cells, which lack nucleus and other organelles.
- They transports dissolved organic food materials (sugars) from the leaves to all parts of a plant.
- They transport the nutrients in the downward direction .i.e. from the leaves to the different parts of the plant.
- Phloem is also called as sugar-conducting cells.

There are two types of tissue systems in plants based on their ability to divide.

Meristematic Tissues

Meristematic tissues are group of cells, which have the ability to divide. This tissue consists of small, cubodial densely packed cells, which keeps on dividing to form new cells. These tissues are capable of stretching, enlarging and differentiate into other types of tissues as they mature. Meristematic tissues give rise to permanent tissues.

General characteristics of Meristematic tissues

- They have very small cells with thin cell walls.
- Their cells have large nuclei.
- Their cells have very small vacuoles and they lack intercellular spaces.
- They remain young forever and divide actively throughout the life of the plant.
- In plants, these tissues are found in the -Tips of roots, stems, nodes of stems, buds, in between the xylem and phloem, under the epidermis of dicotyledonous plants and also producing branch roots.

Kinds of Meristematic tissues

- Apical meristems : They are found at the tip of stems and roots. During the cell division, this meristem helps in cellular enlargement and also it influence the shapes of the mature plants.

- Lateral meristems : They are found along the sides of roots and stems .They play a vital role in increasing the width or diameter of stems and roots.
- Intercallary meristems : They are found at the bases of young leaves and internodes. They are mainly responsible for further lengthening of stems and leaves.

Permanent Tissues

The tissues, which are derived from the Meristematic tissues, are called as permanent tissues. They are the tissues, which have lost their ability to divide as they have attained their mature form.

Kinds of Permanent Tissues

- Simple permanent tissue: They are the tissues, which are similar in function and are called as simple because they are composed of similar types of cells, which have common origin and function.
- Complex permanent tissue: They are the tissues, which are composed of two or more types of cells but contribute to a common function are called complex tissues.

Plant Tissue Functions

Different types of plant tissue have their own respective functions.

The plant tissue helps in providing mechanical strength to both the internal and external organs.

- They also help in rendering the elasticity and flexibility to the organs.
- The tissue also helps in easy bending in various parts of a plant like- leaf, stem and branches without causing any damages to main plant.
- The tissue also helps transportation of materials thorough out the plants and prevents water loss.
- They divide to produce new growth and build the mass of the plants.
- They are involved in various cellular metabolisms like photosynthesis, regeneration, respiration, etc.

Histological study of a dicot root (Ficus, Banyan)

The section appears almost circular in transverse plane

Rhizodermis: outermost layer composed of single row of almost rectangular cells.

A thick cuticle is present over this layer.

Periderm: This forms a wide zone of phellem **(cork),** phellogen **(cork cambium)** and phelloderm **(secondary cortex).**

Phellem or cork consists of mainy layers of thick suberised cells. The cells show characteristic arrangement. A few lenticles may also be present.

Phellogen or cork cambium forms a continuous layer of tangentially elongated and thin walled cells.

Phelloderm or secondary cortex comprises a few layers of parenchymatous cells. A few cells of this region consists of numerous chloroplasts and while a few others show thick walled fibres. Tannin filled cells are also abundant.

Endodermis: A single layer endoderm is distinguishable in young roots. It becomes indistinguishable with the advance of secondary growth.

Pericycle: In old roots it forms discontinuous patches of thick walled and pitted stone cells.

Vascular tissue system:

- It consists of primary phloem, secondary phloem, cambium, secondary xylem and primary xylem.
- Primary phloem is small in amount and appears crushed in roots with sufficient secondary growth.
- Secondary phloem forms a large zone comprising sieve tubes, companion cells, phloem parenchyma and phloem fibres.
- **Cambium is unistratose** and separate the zone of phloem forming the underlying zone of xylem.
- Secondary xylem that follows the cambium consists of large vessels, tracheids, and xylem parenchyma. These tissues are dispersed amongst thin and thick walled prosenchyma.
- **Medullary rays** run from the primary phloem to primary xylem. Tannin cells are abundant.

- Primary xylem is situated close to secondary xylem near the pith. It shows the exarch condition.

Pith: A small, parenchymatous pith is present in centre. It becomes completely obliterated in older roots being occupied by the secondary xylem.

Histological study of monocot root (Zea mays)

Outline of the section is almost circular.

Epiblema or piliferous layer: this is the outermost layer of barrel shaped and thin walled cells. Unicellular hairs arising as outgrowth are present.

Cortex: it is several layers deep occupying a large part of the section. The cells are thin walled and parenchymatous with numerous intracellular space present. In an old root, when the epiblema gets disorganised a few outer layers of the cortex undergo suberisation and thus outer layer becomes thick walled **(exodermis**). Exodermis is a protective layer protecting the internal delicate tissues.

Endodermis: Innermost cortical layer that separates underlying vascular tissue from the cortex.

It forms a definite ring around the stele.

The cells are barrel shaped, compactly arranged with **Casparian strips** present.

A few cells opposite to protoxylem cells are thin walled called as passage cells.

Pericycle follows the endodermis. The cells are thin walled forming a complete ring.

Vascular tissue system: V.Bundles are radial and exarch.

Many groups of xylem and phloem are located on alternate radii.

Protoxylem is close to pericycle and hence exarch.

Xylem elements consist of tracheids and xylem parenchyma. Protoxylem is annularly or spirally thickened.

Phloem consists of sieve tubes and companion cells.

Conjunctive tissue (thick walled parenchyma) occurs in between and around the vascular tissues.

Pith: present in centre of axis.

The cells are parenchymatous, sometimes the cells become thick walled and lignified.

Histological study of a dicot stem (Luffa).

The outline of the section shows ridges and furrows.

Epidermis: Consists of single layer of cell. A few multicellular hairs are present. A thin cuticle covers the epidermis.

Cortex: Few to many layered consisting of collenchyma and parenchyma.

Collenchyma lies below epidermis in ridges. It is several layers deep . In the furrows it is two-three layered or sometimes absent.

Chlorenchyma lies both in ridges and furrows below the collenchymas.

This is two or three layers deep and the cells bear numerous chloroplasts.

Endodermis(starch sheath): this layer separates cortex from the vascular tissues. The cells lack casparian strips but show starch. Thus called as starch sheath.

Pericycle: it follows endodermis and is a few layers deep. These cells are sclerenchymatous due to lignification.

The Ground Tissue: it extends from the pericycle to the centre of the section.

The cells are parenchymatous with large intercellular spaces present.

Vascular bundles: There are about 10 vascular bundles in two rows.

Each vascular bundle is conjoint, bicollateral, endarch and open.

The vascular bundles are larger in size. In a bicollateral vascular there is a centrally located mass of xylem. On both of its faces are cambial strips (inner and outer cambia) and on outer side of cambia on either sides phloem groups are present.

The xylem contains wide pitted vessels, tracheids, fibres and xylem parenchyma with protoxylem facing the inner cambium. The phloem occupies both the extremes of vascular bundle. It is composed of sieve tubes, companion cells and phloem parenchyma.

Pith: The central part of section is occupied by the parenchyma.

Identification

Stem: Vascular bundles are conjoint and bicollateral

Protoxylem endarch

Dicot stem:

- Cortex well differentiated
- Endodermis and pericycle distinguishable.
- Vascular bundles in a ring and open.
- Pith well developed.

Histological studies of a monocot stem (Zea mays).

Transverse section is almost circular in outline.

Epidermis: Outermost layer of single row of cells covered by thin cuticle.

The epidermal hairs are absent.

Hypodermis: It lies below the epidermis consisting of 2-3 layers of sclerenchymatous cells.

Ground Tissue: It extends from hypodermis to the centre of the axis.

The cells are parenchymatous and numerous large inter cellular spaces are present. Cortex, endodermis and pericycle are not differentiated.

Vascular tissue system:

Numerous vascular bundles scattered in the ground tissue. The vascular bundles near the periphery are smaller than in centre. Each bundle is **conjoint, collateral, endarch and close**. The xylem is almost Y shaped and consists of very large and pitted metaxylem elements. The protoxylem is situated near the centre of axis. Surrounding and just below the protoxylem is a large water cavity formed by the breaking of protoxylem elements **(lysigenous cavity).**

Phloem is composed of sieve tubes and companion cells only phloem parenchyma being absent. Protophloem present. Metaphloem lies just below the protophloem and extends upto Y shaped xylem, consisting of very prominent sieve tubes and companion cells.

Identification:

Stem: Vascular bundles conjoint, collateral and endarch.

Monocot stem:

- Endodermis and pericycle absent
- Cortex undifferentiated, presence of ground tissue.
- Closed vascular bundle (cambium absent), numerous and scattered.
- Bundle sheath prominent.

Chapter 6. Morphology of Flowering plants (Roots)

A matured plant is composed of roots, stem, leaves, flower, fruits etc (Fig.1)

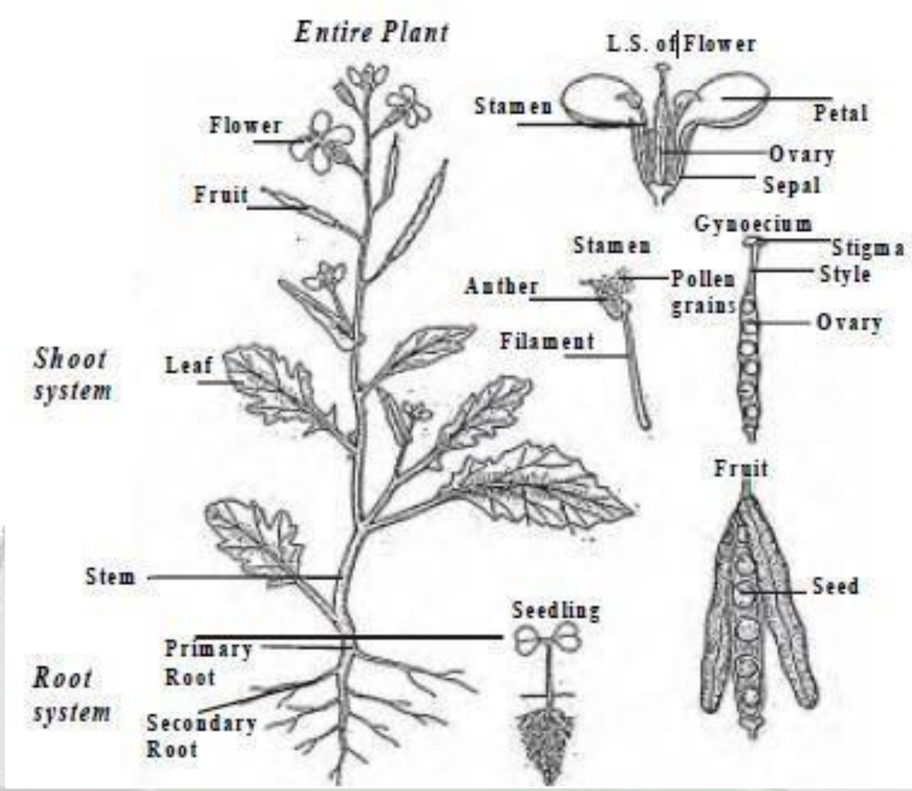


Fig 1. Different parts of a matured plant

Root: the underground part of plant axis developing from the radicle is called the root. It is positively geotropic, negatively phototropic and positively hydrotropic lacking chlorophyll.

There are two groups of roots: Tap root and Adventitious roots.

(a) Tap root

The root directly arises from the seed is called tap root. The first root which is formed by the elongation of radical is called primary tap root. It gives rise to secondary and tertiary roots. The deep feeder plants have a long net work of tap root system. The surface feeder plants have short tap roots. There are following forms of tap roots:

I. Fibrous tap roots: The long and slender tap root with slender branches is called fibrous tap root. It is found in many herbs like bean, pea etc. In some leguminous plants, the tap roots form nodules. Bacteria live in these nodules and fix atmospheric nitrogen.

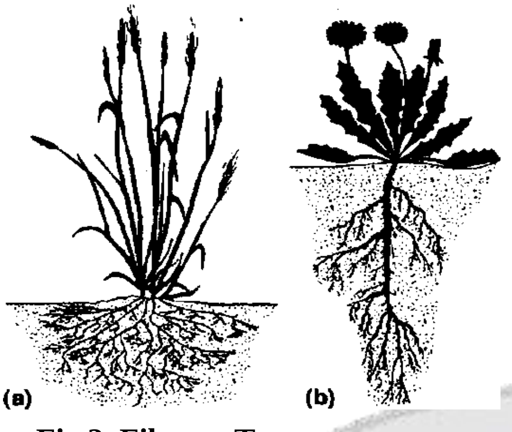


Fig 2. Fibrous Tap roots

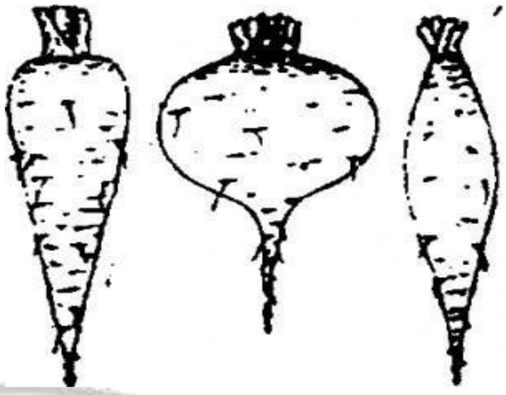


Fig 3. Tuberous Tap roots

2. Tuberous tap roots: The thick or swollen tap roots with reserve food are known as tuberous tap roots.

Such roots occur in biennial plants like carrot, turnip, radish etc. The biennial plants live in two seasons. In first season (before winter) they store food in the roots. They use this food in the second season (after winter). Tuberous roots may be:

- **Conical:** These roots are swollen towards tipper end but taper towards the lower end. Examples: carrot, radish.
- **Fusiform:** These tap roots are spindle shape i.e. swollen in the middle. Examples: English carrot
- **Napiform:** These tap roots are very much swollen above but abruptly tapers towards the lower end. Examples: turnip and beet.

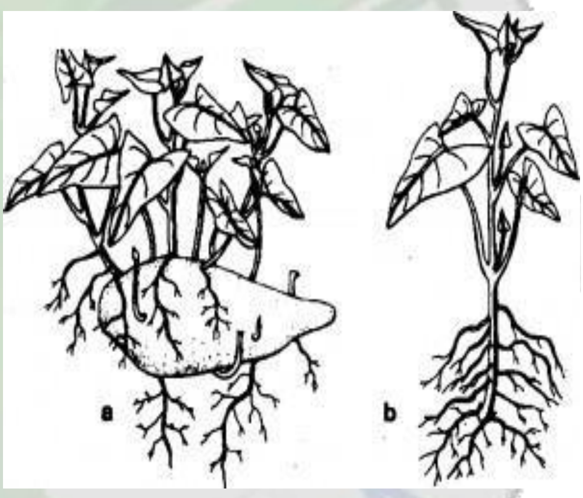


Fig 4. Tuberous adventitious roots (a) and Fibrous adventitious roots

(b) Adventitious roots

The roots arised from the stems or sometimes leaves are called adventitious roots. It has following forms:.

1. Underground or subterranean adventitious roots: These roots arise from some part of stem which is in contact with the soil. They may be fibrous or tuberous.

- **Fibrous adventitious roots:** These are long and slender roots. These commonly develop on creeping and underground sterns like grasses.
- **Tuberous adventitious roots:** These are swollen and fleshy roots. These roots contain stored food material. Examples: Asparagus, sweet potato

2. Partly subterranean adventitious roots:

These roots are partly above and partly below the ground. These roots may be stilt roots, prop roots and aerating roots.

(a) **Stilt roots:** In this case, adventitious roots arise from the lower portion of stem and grow into soil. Such types of roots are found in corn, stig:if cane, bamboo etc.

(b) Prop roots: In this case, roots hangs down in the air from the aerial branches of stern. These roots absorb moister of air. Example: bayan rubber tree etc.

(c) **Aerating roots or pneumatophores:**

These roots grow vertically upward and projects above the soil surface. These roots have openings kir the entry of air. Such roots are:

3. Aerial roots: These roots are entirely exposed in air. These roots perform special functions. There are two kinds of aerial roots.

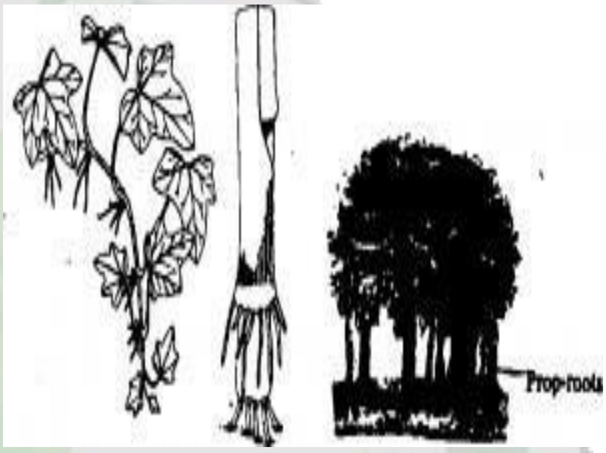


Fig 5. Partly subterranean adventitious roots

a. Climbing roots: These roots are developed by stein in climbing plants. These roots firmly attach the plants with some support like wall, tree trunk. These roots secrete sticky fluid for attachment. Examples: These roots are developed in long pepper etc.

b. Absorbing roots: Some epiphytes develop long roots in air for absorption of moisture. These roots are called absorbing roots. These roots hang freely in the atmosphere. These roots are developed in orchids.

4. Parasitic roots or Haustoria: These roots are developed in parasitic plants like Cuscut Stem develops these roots for absorption of food from host. These roots penetrate into the host tissues.

5. Aquatic roots: These roots are developed in water plants. These roots arise form stem and spread in water. Example: Hydrilla.

Physiological functions of root:

- The roots **fix** the plant to the soil providing **architectural support**.
- **Absorption** of water & nutrients from the soil and transport it to various parts of plants through conducting cells.
- To **store the prepared food** by plants as in case of Radish, Turnip, Beet and sweet potato.
- In climber & twine plants, adventitious roots are developed from nodes & internodes of the stem that helps the plant in **climbing.**
- In certain cases carry **out photosynthesis** (*Tinospora*).
- Helps in breathing of mangroves which develops in water logged condition of soil as in *Rhizospora, Avicennia* etc.
- Symbiotic roots provide habitat & nutrition to the bacteria and in return gets absorbable salts of nitrogen through **nitrogen fixation** (root nodules).
- An adventitious root contains an adventitious bud that is responsible for **reproduction** of plants like *sweet potato.*

Morphology of Flowering plants (Stem)

Characteristics of stem

The main characteristics of stem are as follows:

1. Stem is an aerial part of plant which develops from the plumule.
2. Stem are usually **positively phototropic, negatively geotropic and negatively hydrotropic.**
3. Stem bears a terminal bud for growth.
4. The stem is differentiated into nodes and internodes.
5. The nodes posses appendages, i. e. , leaves, branches and flowers.
6. Leaves and stem branches develop exogenously.
7. The young stem is green and capable of performing photosynthesis.
8. Axillary buds are found in the axis of leaves on the stem.
9. Multi cellular hairs are found on the surface of stem.
10. The branches of stem may end in a vegetative or floral bud.
11. Stem exposes leaves, flowers and fruits to their most suitable position in the aerial environment for optimum function

According to the position on soil, there are three types of stems:

1. *Aerial stems:* All those stems which grow above the soil level are known as aerial stem.
2. *Sub aerial stems:* Some stems are found beneath the soil surface in such a way that stem remains in contact with both the soil and the air.
3. *Underground stems:* Stems of some plants remain underground and help in perennation, storage of food. Stems may be distinguished from the roots by the presence of scales, leaves and buds at the nodes.

Some of the most important types of modifications of stem are as follows:

I. Underground modifications of Stem
II. Subaerial modifications of Stem
III. Aerial modifications of Stem.

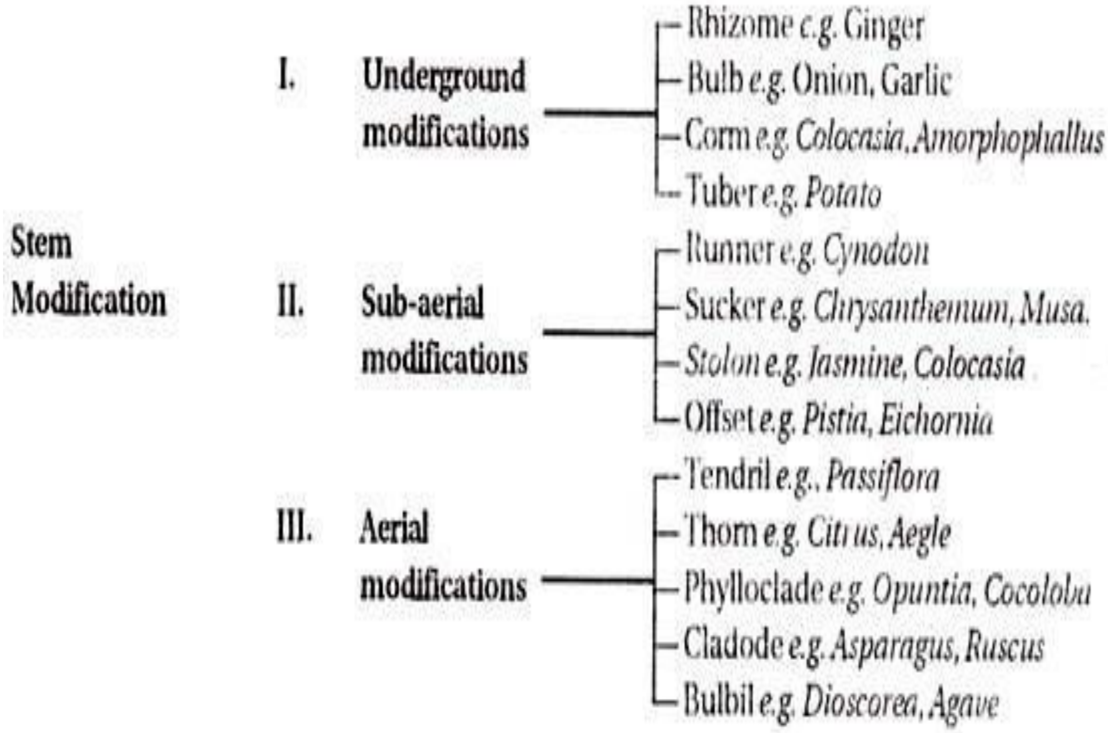


Fig 6. Modification of stems

I. Underground modifications of Stem:

Many plants produce underground stems for perennation and food storage. They produce aerial shoots annually.

Although they resemble roots superficially but can be; distinguishable from roots by the presence of following features:

(i) Presence of nodes and internodes

(ii) Presence of scale leaves, buds and adventitious roots at the nodes.

(iii) Internal structure resembles that of aerial stem and not of root

Some underground modified stems are as:

1. Rhizome:

It is fleshy, non-green underground stem. It has distinct nodes and internodes. The nodes bear dry scale leaves with axillary buds. Terminal buds also present. Adventitious roots arise from the lower side. The rhizome that grow obliquely is called root stock rhizome (e..g., Alocasia, Dryopteris, Banana etc.) and when grow horizontally is called straggling rhizome [e.g. Ginger, termeric, Cannaetc.).

2. Bulb:

It is a highly condensed discoid stem its upper surface a terminal bud and many fleshy scale leaves are present. A cluster of adventitious roots arise from the base of the bulb. The bulbs may be tunicated or scaly. A tunicated bulb is covered by a sheath of dry membranous scale leaves called tunic, e.g., onion and garlic. In case of garlic, the bulb consists of an aggregate of bulblets or

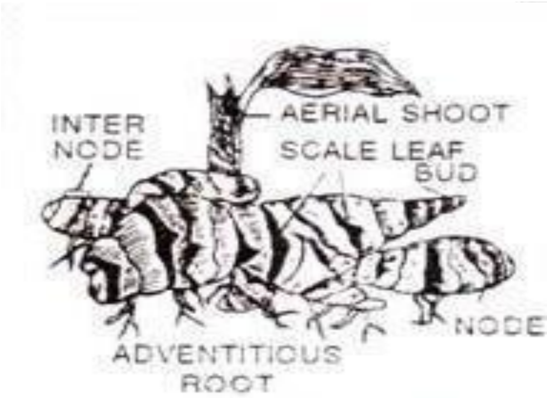


Fig 7. Straggling of ginger

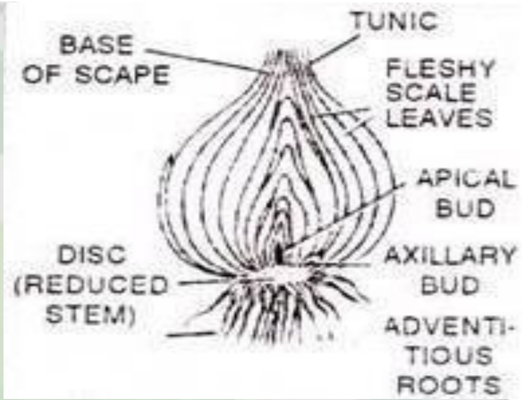


Fig 8. V.S. of tunicated bulb of onion

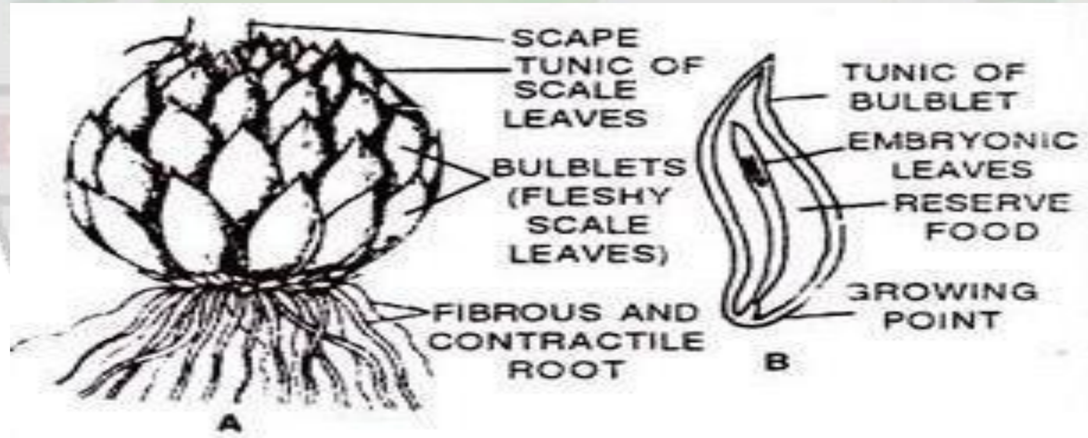


Fig 9. Compound tunicated bulb of garlic

cloves, each covered by its individual tunic. A scaly bulb is without any tunic, e.g., Lily.

3. Corm:

It is a condensed form of rhizome growing in vertical direction. It is more or less spherical with a flattered base. The corm has distinct circular nodes and in ternodes. The n ides bear scale leaves and axillary buds. Adventitious roots arise either from its base or all over the body. Examples- colocasia, corcus, Amorphophallus.

4. Tuber:

Stem tuber is a swollen tip of an underground lateral Stem (Stolon). It is covered by a corry Skin with a number small depressions called eyes‘. Each eye represents a node, bearing one or more buds subtended by a leaf scar (= scale leaf). A big scar at one end (heel end) of a potato marks its attachment to the stolon. Adventitious roots are usually absent e.g., Potato.

II. Subaerial modifications of Stem:

In subaerial modifications, the stem is partly aerial and partly underground. Short aerial branches and adventitious roots develop at the nodes. Detachment of entire branch or a node can develop into a new plant. The plants are commonly known as creepers and their subaerial stem modifications meant for vegetative propagation.

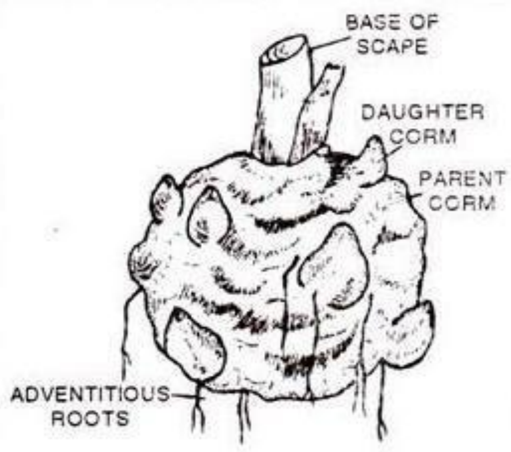


Fig 10. Corm of Amorphophallus

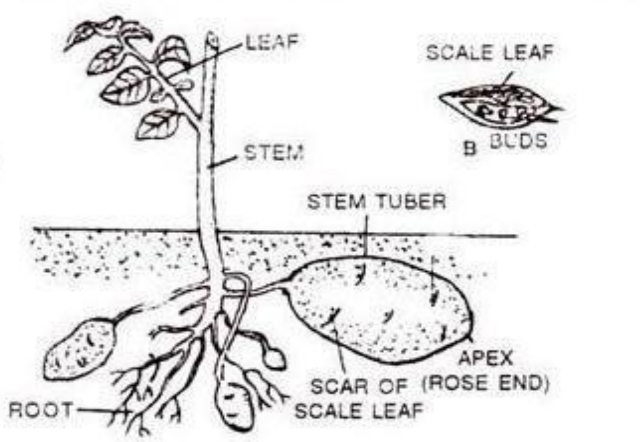


Fig 11. Stem tuber of potato, an eye magnified roots

The weak sub-aerial stems are modified into following four types:

1. Runner:

It is a creeping stem with long internodes, running horizontally on the soil surface. The nodes bear axillary buds, scale leaves and adventitious roots. Runner arises from an axillary bud. A mother plant o0.ften produces a number of runners in all direction. Runners break off and grow into individual plants, and thus help in vegetative propagation. Examples – C-Cynodon (Lawn grass), Oxalis (Wood sorrel), Centella (Or. Thalkudi) etc. An underground runner is called sobole, e.g. Agropyron.

2. Sucker: It arises from the basal, underground part of the main stem. It grows horizontally for a distance under the soil and then emerges obliquely upwards. It develops a leafy shoot and

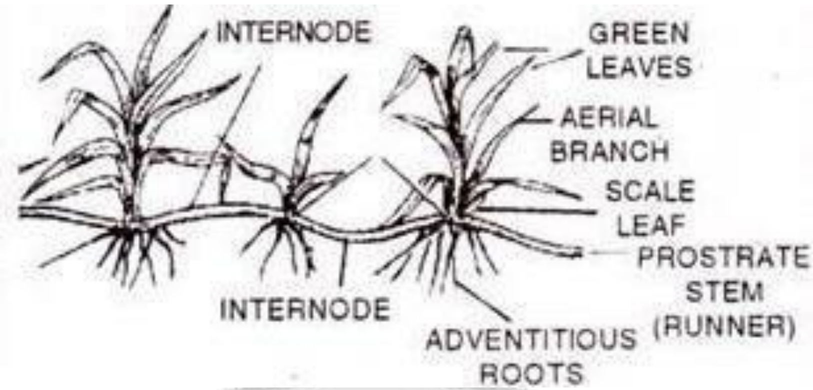
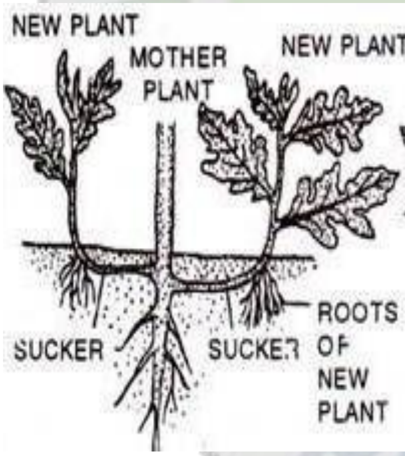


Fig 12. Runner of lawn grass (Cynodon

adventitious roots before separating from the mother plant. The common sucker-bearing plants are Chrysanthemum (Or. Sebati), Musa (banana), Mentha (Or podina), strawberry, pineapple etc.

3. Stolon:

It is a weak lateral branch that arises from the base of main stem. After growing aerially for some time it bends downwards to touch the ground, where its terminal bud gives rise to a new shoot and adventitious roots. The common stolon bearing plants are Jasmine, Colocasia, and Vellisneria etc.



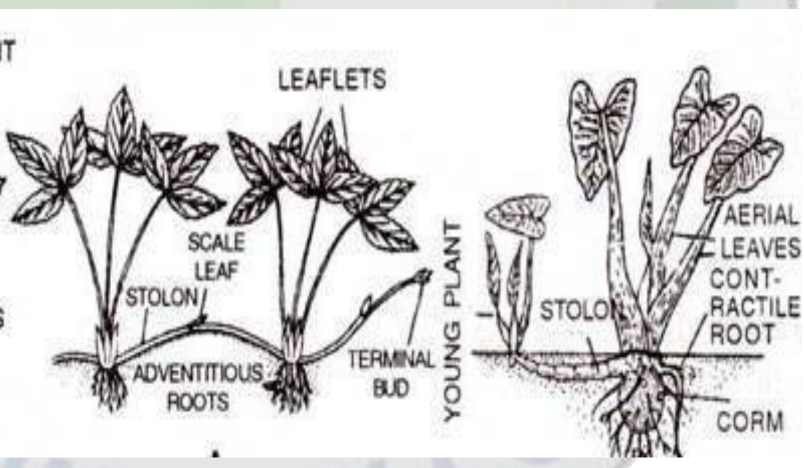


Fig 13. Suckers of Chrysanthemum **Fig 14. Stolon of Strawberry and Colocasia**

4. Offset:

It is a short runner with one internode long. It originates from leaf axil, grows as a short horizontal branch. It produces a rosette of leaves above and adventitious roots below. Offsets art generally found in aquatic plants like Pistia (water lettuce), Eichomia (water hyacinth), Houseleek etc.

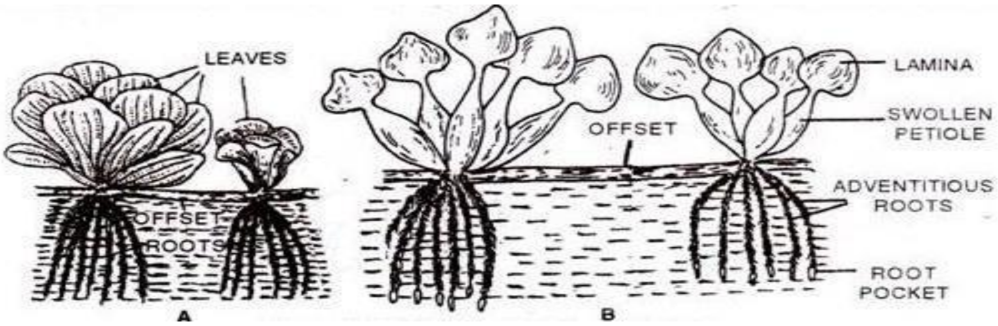


Fig 15. Offset in Pistia and Eichornia

III. Aerial modifications of Stem:

In certain plants, the aerial stem or buds get modified to perform special functions like climbing, protection, food storage, vegetative propagation etc.

The various aerial modifications are as follows:

1. Stem tendrils:

Stem or its branches get modified into green thread like leafless structures called tendrils which are meant for climbing. These may be branched or un-branched. A scale leaf is always present at the point of branching of the tendril.

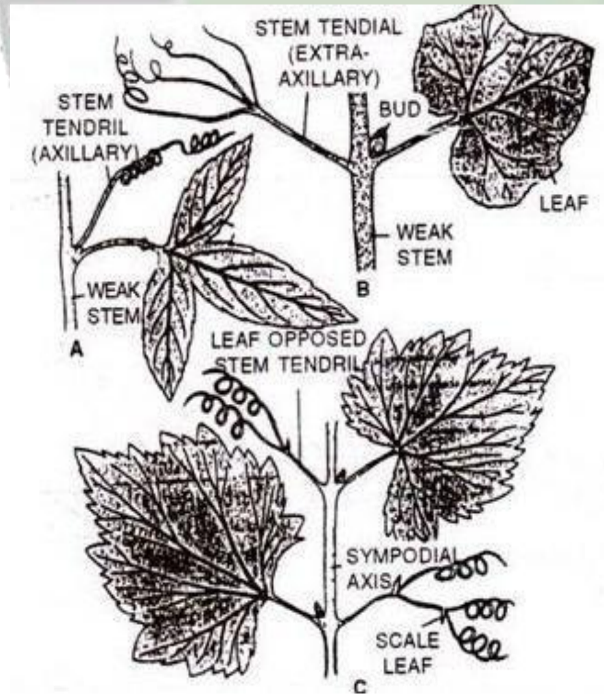


Fig 16. Stem tendrils. A. Passflora B. Luffa C. Grape Vine

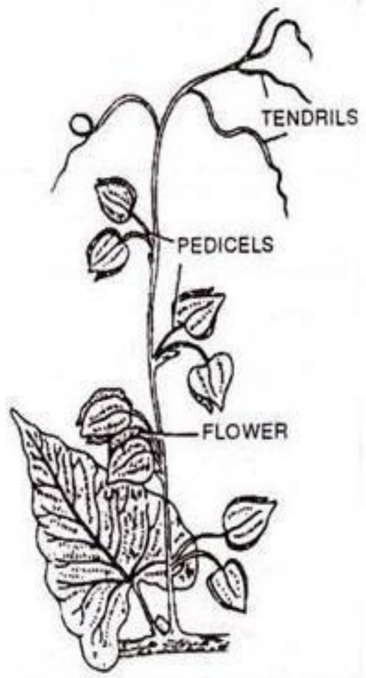


Fig 17. Floral bud tendrils of Antigonon

Stem tendrils are of four types:

(a) Axillary tendrils-e.g., Passiflora

(b) Extra-axillary tendrils-e.g., Cucurbita, Luffa

(c) Leaf-opposed or Apical bud tendrils, e.g., Grapevine (Vitis)

(d) Floral bud or Inflorescence tendrils – e.g., Antigonon, Cardiospermum (Balloon vine

2. Thorns:

These are straight, pointed, hard or woody structures sometimes they bear leaves, flowers or even may be branched. In Citrus, Duranta and Aegel thorns are modified axillary buds; in Carrissa (Or. Khirkoli) terminal bud gets modified into thorn. Thorns are used as organs of defence or climbing (e.g. Bougainvillea) and check transpiration.

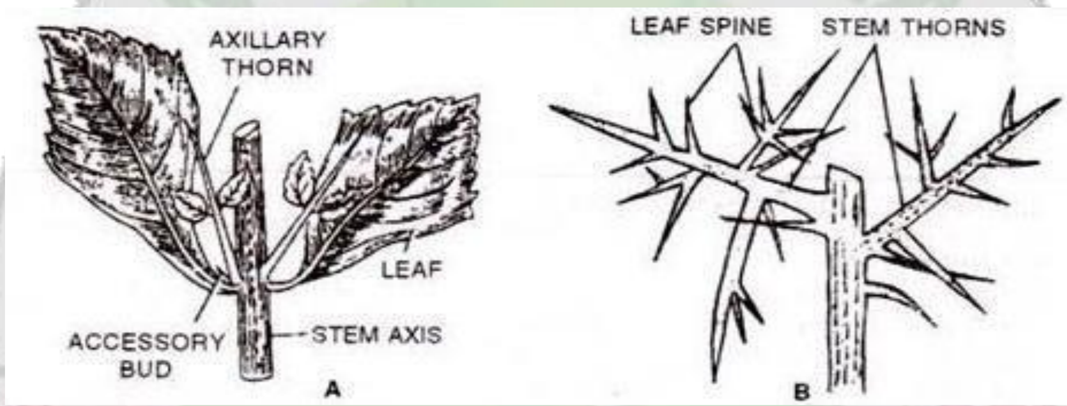


Fig 18. Stem thorn of duranta (A) and Stem thorn and leaf spine of *Ulex*

3. Phylloclades:

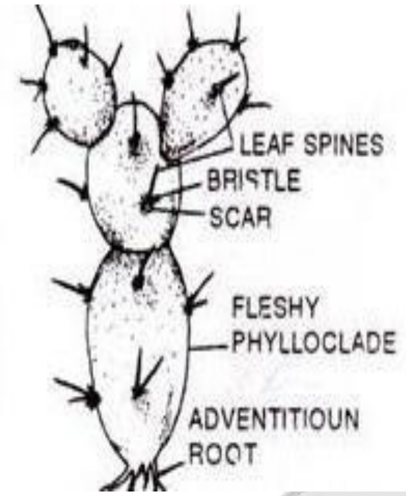
These are fleshy, green flattened or cylindrical branches of unlimited growth. The leaves are modified into spines or scales to check transpiration. They take part in photosynthesis and store water. These are seen in xerophytic plants like Opuntia, Euphorbia, Casuarina, Cocoloba etc.

4. Cladodes or Cladophylls;

These are green cylinderical or flattened leaf-like branch of limited growth. In Asparagus, the cladodes are one internode long and in Ruscus the cladodes are two internode long. They help in photosynthesis.

5. Bulbil:

These are modified vegetative or floral buds with stored food and meant for vegetative



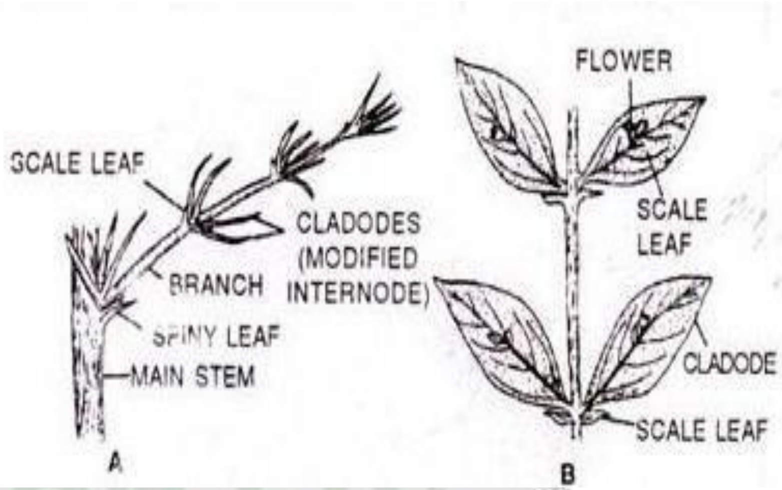
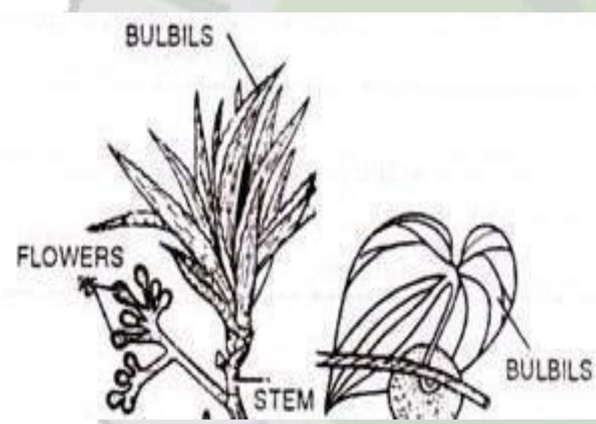


Fig 19. Phylloclade of Opuntia

Fig 20. Cladodes of Asparagus (A) and Ruscus (B)

propagation. In Dioscorea, bulbils are condensed axillary buds while in Agava and lily the floral buds develop into bulbil. They detach to become new plants.



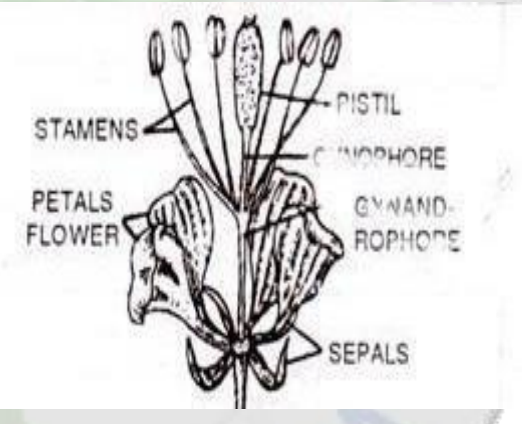


Fig 21. Bulbils of Agave and Dioscirea

Fig 22. Gynardropsis showing nodes and internodes.

6. Thalamus (= Receptacle or torus):

It is a condensed stem axis that bears words of floral organs -calyx, corolla, androecium and gynoecium. In Gynandropsis, Cleomeand Silene the thalamus exhibits clear nodes and internodes.

Morphology of Flowering plants (Leaf)

Leaf is a thin, dorsi- ventrally flattened, photosynthetic machinery of a vascular plant and the principal lateral appendage of the stem. The term _foliage‘ is used collectively for mass of leaves.

Morphological characters

A structurally complete leaf of an angiosperm consists of a petiole (leaf stalk), a lamina (leaf blade), and stipules (small structures located to the either side of base of a petiole). Not all species exhibit these characters. A petiole may be absent, or the leaf blade may not be flattened. The petiole mechanically links the leaf to a plant, providing a route for transfer of water and sugar to and from leaf. The lamina is typically the location for majority of photosynthesis.

- Leaves have determinate growth .They grow to a specific shape and pattern and then stops.
- Morphologically leaves may be of single type (monomorphic). Some species do produce more than one type of leaf (di or polymorphic).
- Most leaves have distinctive upper (adaxial) and lower (abaxial) surfaces, that differ in colour, hairiness, the number of stomata present.
- Leaves are covered with a thin protecting film of cuticle their epidermal layer.
- Other morphological characters may include leaf shape, margin and venation of leaves.

Types of leaves:

Broadly it may be categorised as Simple and Compound leaf

Simple leaf: a leaf which may be entire or incised to any depth but not down to the mid rib or the petiole (Mango).

Compound leaf: A leaf in which the leaf blade is incised upto its midrib or petiole, thus dividing it into two or more segments called as leaflets (Sweet pea, Gold mohur). Compound leaves may be either palmately compound or pinnately compound leaves.

1. **Palmately compound** leaves- A compound leaf with the leaflets attached at the tip of petiole, and thus, seem to be radiating from a common point *(Cleome gynandra).* Palmately compound leaves further may be

- Unifoliate: a single leaflet articulated to petiole *(citrus).*
- Bifoliate: two leaflets articulated to the petiole *(Prinsepia*).
- Trifoliat : Three leaflets articulated to the petiole *(Medicago , Oxalis*).
- Quadrifoliate: Four leaflets are articulated to the petiole *(Paris quadrifolia, Marsilea).*
- Multifoliate (Digitate): Five or more leaflets are articulated to the petiole and spreading like fingers from the palm *(Bombax, Cleome).*

2. **Pinnately compound** leaf: A compound leaf with its leaflets arranged along the sides of common axis, the rachis (Tamarind). Further a pinnately compound leaf may be
   - Unipinnate: A pinnately compound leaf bearing the leaflets directly on rachis (Cassia).
   - Bipinnate : A twice pinnate compound leaf i.e., the mid rib produces secondary axes on which leaflets are borne *(Acacia,Mimosa pudica)*
   - Tripinnate : a thrice pinnate compound leaf i.e., secondary axes produces tertiary axes bearing the leaflets *(Moringa).*
   - Decompound : A compound leaf which is more than a thrice pinnate *(Coriandum*).

Functions:

a) Photosynthesis: leaves are the major photosynthesising machinery of plant system. This essentially involves absorption of light by chlorophyll molecules, and absorption of CO2 via the stomatal pores thereby cleaving the water molecules to generate free oxygen being released into atmosphere.

b) Transpiration: losing water from aerial parts in the form of vapour. Stomatal transpiration is far more dominant than the cuticular transpiration.Transpiration produces cooling effect and the transpirational pull is responsible for the continuous ascent of water and nutrients from root to the plant body.

c) Floral induction: The plant leaves synthesize and translocate florigen (a flower inducing hormone).

d) Food storage: leaves serve as the food storage organ of plants both temporarily and on long term basis. During the daytime sugar accumulates in the leaves and starch is synthesised and stored. At night, the stored starch is hydrolyzed to glucose and respired or converted to transportable forms like sucrose.

e) Special uses: In banana, the leaf sheaths provide physical support often called pseudostem. In few insectivorous plants (pitcher plant or venus fly-trap) the leaves are so modified to aid in trapping insect and releasing enzymes and digesting them. In certain plants like Kalanchoe and Bryophyllum the leaves are used for asexual reproduction.

Study of modified leaves

In many plants leaves get modified to perform special functions while sometimes these modifications are in response to certain environmental conditions. Some important modifications are given below

I. Storage leaves: some xerophytic plants and members of Crassulaceae family generally posses highly thickened and succulent leaves for water storage purpose.this kind of adaptations helps to conserve restricted supply of water and resists dessication.

II. Leaf tendrils : In weak stemmed plants, leaf or a part of leaf gets modified into thread like structures (tendrils) that helps in clinging around the support (Lathyrus *aphaca, Naravelia).*

III. Leaf spines: leaves of certain plants become wholly or partially modified for defensive purposes into sharp, pointed structures called spines (Opuntia, Argemone).

IV. Scale leaves: typically these are thin,dry,stalkless, membranous structures,to protect the axillary bud they bear in their axils. Sometimes scale l eaves are thick and fleshy (as in onion) to store up water and food as well.scale leaves are common in saprophytes, underground stems, etc. They are also found in Asparagus and Casurina.

V. Leaflet hooks: in Bignonia the terminal leaflets get modified into claws like hook that helps in climbing.

VI. Phyllode: In Australian Acacia the petiole of any part of rachis becomes flattened, turning green in colour taking the shape of a leaf. This winged petiole/rachis is called phyllode that functions as the normal leaf, where the pinnately compound natural leaf soon falls off.

VII. Insect catching leaves: In insectivorous plants the leaves are especially adapted to trap and digest insects to fulfil their nitrogen. These adaptations include leaf Pitcher (Nepenthes) where lamina is modified into pitcher like structure; leaf bladder (Utricularia).

Venation and its types

The arrangement of vascular bundles or veins in a leaf is called as venation. The single middle prominent is being the mid-rib (primary vein). The veins other than primary veins are called as secondary veins. The leaf vein consists of vascular bundle that helps in transport of mineral nutrient and water from the roots to the leaves and carry the material produced by leaves to the rest of plant .The pattern of venation is important in identification of a plant. Leaf venation is basically of two types

a) **Reticulate venation**:- herein the veinlets are randomly distributed in leaf blade forming a network. Other types of reticulate venation may be

- Unicostate – Having only one principal vein that gives off many lateral veins which proceeds towards margin or apex of leaf (Mango, Banyan).
- Multicostate : having many principal veins arising from the tip of petiole and proceeding upwards or outward. It may be of

✓ Convergent type: many principal veins arising from the tip of petiole run in a curved manner and converge towards apex of leaf blade (Cinnamonum).

✓ Divergent type: many principal veins arising from the tip of petiole diverge from one another toward the margin of leaf blade (Castor,Cucumber).

b) **Parallel venation**: the pattern of venation where the veins run parallel to each other. In this type of venation no veinlets are formed and no network is produced. Parallel venation may also be

- Unicostate: having only one principal vein that gives off many lateral veins, which proceed towards the margin or apex of leaf blade in a more or less parallel manner (Canna, Banana).
- Multicostate: having many principal veins arising from the tip of petiole and proceeding upwards or outwards. Multicostate parallel venation may be of following types –
  - ✓ Convergent type: many principal veins arising from the base of leaf blade converge towards its apex in a more or less parallel fashion (Grass, Bamboo, Wheat).
  - ✓ Divergent type: many principal veins arising from the tip of petiole diverge towards the margin of leaf blade in a more or less parallel manner (Palms).

Stipules:

Appendages on the either sides of basal part of a leaf in some species are the stipules. There are different types of stipules as listed below

i. Scaly – Small dry scales, usually two in number, borne on the two sides of the leaf *base (Spergula, Desmodium).*

ii. Adnate: two lateral stipules that grow adhering to the petiole upto a certain height thus making it winged *(Rose).*

iii. Interpetiolar: two stipules lying between the petioles of opposite or whorled leaves *(Ixora, Mussaenda*).

iv. Intrapetiolar: stipules situated between the petiole and the axis *(Tabernaemontana).*

v. Ochreate: stipules that form a hollow tube encircling the stem from the node upto a certain height of internode in front of petiole *(Polygonum).*

Modifications of stipules

Stipules may be modified to serve the purpose of protection by forming different structures. These include

Spinous stipules: stipules modified into hard spines one on each side of the leaf base (*Barlelia prionitis, Acacia, Zizyphus*).

Tendrillar stipules: stipules modified into thread like structures called the tendrils, one on each side of the petiole *(Smilax*).

Convolute or ventral stipules: these occur on the ventral side of the petiole. The margins after meeting serve as the bud scales *(Ficus, Magnolia, Ricinus).*

Morphology of Flowering plants: Phyllotaxy

Phyllotaxy refers to the arrangement of leaves on a plant stem.The word has been derived from the ancient Greek word (*phyllon* ―leaf‖ and taxis ―arrangement‖).

Types of phyllotaxy

Three major types of leaves arrangement are described as follows

1. **Alternate or spiral** : In this type of arrangement a single leaf arises from each node.the cosecutive leaves are produced in a spiral manneraround the stem (Ipomoea).
    - ½ or two ranked : Third leaf stands over the first and there is one spiral between the two leaves *(Graminiae, Ginger, Ravenala).*
    - 1/3 or three ranked : fourth leaf stands over the first and there is one spiral between the two leaves *(Cyperus rotundus).*
    - 2/5 or five ranked : Sixth leaf stands over the first and there are two spirals between the two leaves (China rose).This being the **most common** type of alternate phyllotaxy.
    - 3/8 or eight-ranked: Ninth leaf stands over the first and there are three spirals between the two leaves (Papaya).

2. **Opposite**: Here the leaves arearranged in pairs at each node (*Ixora*).
   Further types of opposite arrangement may be classified as-
    - Decussate:- when each opposite pairs of leaves are at right angles to each other it is said to be opposite decussate *(Calotropis, Mussaenda, Tabernaemontana).*
    - Superposed:- a pair of leaves that stands directly over a pair in the same plane its opposite superposed arrangement (Guava, Quisqualis, Carissa)

3. **Whorled** : Such arrangement of leaves where more than two leaves at each node is arranged in a circle or a whorl *(Alstonia).*

Morphology of Flowering plants: Inflorescence

Inflorescence may be defined as the **arrangement of flowers in a specific pattern on its floral axis.** It comprises of a stem holding the whole inflorescence commonly called as **peduncle** and the major axis where flowers are borne within the inflorescence called as the **rachis**.

Types : Several types of inflorescence may be categorised as under

A. **Racemose** : An inflorescence where the main axis never terminates to form a flower (indeterminate), but continues to grow and form flowers laterally in an acropetal succession.Different such types of inflorescence are detailed as follows

Raceme :- Simple, elongated, interdeterminate inflorescence with stalked flowers (*Radish*,*Mustard*,*Delphinium* etc).

Panicle :- When the axis of raceme is branched, it is called a panicle *(Gold Mohur).*

Spike :- Usually unbranched,elongated,simple,with sessile flowers *(Adathoda,Piper longum).*

- Compound spike :- Branched axis where the flowers are arranged in a spike like manner *(Amaranthus).*
- Strobile :- Type of spike where each flower is borned in the axil of persistent membranous bract (*Humulus lupulus*).
- Spikelet :- the unit of compound inflorescence of grasses composed of a cluster of one or more flowers and their associated bracts (Grasses).
- Catkin :- A pendant spike of unisexual flowers found only in woody plants (*Morus, Salix*).
- Spadix :- A thick or fleshy spike subtended by a spathe (*Maize or Corn*).

Corymb :- Indeterminate inflorescence with shortened main axis in which the lower flowers have much longer pedicels than the upper ones so that the flowers areborne more or less on the same level (Candytuft).

- Compound corymb :- A branched corymb (Pyrus torminalis).

Umbel :- An inflorescence where the stalks of the flowers, of more or less of equal length arise from the same point, like the ribs of an umbrella. At the base of flower stalks there is whole of bracts forming the involucre (*Hydrocotyl asiatica*).

- Compound umbel :- An umbel with the branched axis bearing the flowers. These are known as umbellules (*Coriander,Fennel,Anise*).

Capitate :- When a large number of sessile flowers arise from suppressed axis forming a globose structure as in *Acacia,Mimosa*. It differs from capitulum in the absence of of a receptacle.

Capitulum :- A dense inflorescence comprising an aggregation of usually sessile flowers arranged on a convex receptacle formed by the axis, and having one or more whorls of bracts forming involucre (Compositae family).

B. **Cymose :** An inflorescence where the growth of main axis is soon checked by the development of a flower at its apex, and the lateral axis which develops below the terminal flower also ends in a flower, thus its growth is also checked.Different kinds of cymose inflorescence are

- Uniparous (monochasial) :- the main axis ending in a flower producing only one lateral branch at a time ending in a flower.This includes the following

1. Scorpioid – A uniparous cyme in which the lateral branches develop on alternate sides evidently forming zig-zag (*Ranunculous bulbosus*).
2. Helicoid – Uniparous cyme in which the lateral branches develop successively on the same side , evidently forming a helix like structure (*Juncus,Begonia,Heliotropium*).

- Biparous (Dichasial) :- A determinate inflorescence where the main axis ends in a flower after producing two daughter axes or flowers (*Ixora*, *Saponari*, *Mussaenda*).
- Multiparous (Polychasial) :- A determinate inflorescence where the main axis terminates in a flower after producing a number of daughter axes or flowers around. This looks like an umbel but can be distinguished from it by the opening of middle flower first (*Calotropis).*

Study of special types of inflorescence

- **Cyathium** : A type of inflorescence (characteristic of Euphorbia) in which a cup shaped involucre,often provided with nectary , encloses a single female flower (reduced to pisti)in centre and a number of male flowers (each reduced to solitary stamen) around it.
- **Thyrsus** : A panicle like cluster with main axis indeterminate and the lateral axes determinate. *(Lilacs).*

- **Verticillaster** : It consists of a series of nodes.At each node there is a condensed dichasial cyme with a cluster of almost sessile flowers arranged opposite to one another in the axils of opposite bracts or leaves *(Ocimum).*
- **Hypanthodium** : The fleshy receptacle forms a cup like cavity with an apical opening (ostiole)guarded by scales and bearing flowers on the inner wall of cavity (Fig, Peepal).

Morphology of Flowering plants: Flower

A metamorphosed shoot essentially meant for the reproduction. A typical flower consists of the following parts:

- Calyx (the outermost whorl of a flower, composed of sepals). Sepal or the unit of calyx is the usually green and foliaceous structure enclosing the flower.
- Corolla (the second whorl of flower composed of petals). Petals are the brightly coloured attractive and showy parts of a flower.
- Androecium (the male reproductive whorl of a flower, composed of stamens). Stamens are the pollen producing structures composed of an anther, connective and a filament.
- Gynoecium or the pistil (the female reproductive whorl of a flower composed of one or more carpels). Carpels are the ovule bearing structures composed of stigma, style and ovary.

Cohesion and adhesion of different parts of a flower

Cohesion in calyx

- Polysepalous: when the sepals are free from each other (Geranium).
- Gamosepalous: when the sepals are fused together (Dianthus).

Cohesion in corolla

- Polypetalous: when the petals are free as in *Mustard.*
- Gamopetalous: condition where the petals are united as in *Ipoemoea.*

Cohesion of stamens

- Polyandrous: In an androecium where the stamens are free (anthers as well as filaments); as in Papaver.
- Monadelphous: stamens united in one group by connation of their filaments (anthers being free) are called monoadelphous stamens *(Achyranthus, Abutilon).*
- Diadelphous: Stamens united in two bundles by connation of their filaments but the anthers are free, as in Pea.
- Polyadelphous: Here the stamens are united in many bundles by connation of their filaments but anthers remain free *(Citrus, Bombax malabarica).*

- Syngenesious: in this case the stamens connate by their anthers (filaments being free) to form a cylinder about the style as in Compositae e.g, *Sonchus.*
- Synandrous: stamens united throughout their whole length both by the filaments and anther (Cucurbita).

Adhesion of stamens

- Epipetalous: Stamens adhering to the corolla wholly or partially by their filaments (anthers remaining free) e.g., *Ocimum* , *Solanum*
- Epitepalous: stamens adhering to the perianth as in aforesaid manner.
- Gyanandrous: Stamens adhering to the carpels either throughout their whole length or by their anthers only *(Calotropis).*

Cohesion of carpels

- Apocarpous: A pistil of two or more carpels which are free *(Clematis).*
- Syncarpous: A pistil of two or more carpels which are fused together *(Melia).*

Aestivation

Aestivation refers to the positional arrangement of the parts of a flower within a flower bud before it has opened. Different types of aestivation patterns are:

Valvate - petals meeting by the edges without overlapping ; e.g., *Solanum.*

Induplicate valvate – a form of valvate in which the margins of the petals are folded inwards on themselves ; e.g.; *Ipomoea*.

Twisted (contorted) - one margin of the petal overlaps that of the next one, and the margin is overlapped by the third one *(China rose).*

Imbricate – out of the five petals one internal, one external and the other three partly internal, partly external *(Callistemon).*

Quincuncial – a form of imbricate where there are five petals, two internal, two external and one partly internal, partly external *(Melia,Murraya).*

Vexillary – out of the five petals the posterior one is the largest and covers the two lateral petals and the latter in turn overlaps the two anterior and smallest petals. This is a characteristic of Papilionaceae.

Position of the ovary & its relation with different floral parts within a flower.

According to the position occupied by the ovary within a flower there may be three cases. These are

Superior: When the ovary occupies the highest position on thalamus and stamens, petals and sepals are successively inserted below it *(Citrus, Stellaria).*

Semi-inferior: when the thalamus grows around the ovary to form a cup and bears sepals, petals and stamens on the rim of cup (Peach, Plum, Rose).

Inferior: when the thalamus completely covers the ovary getting fused with it, and bears sepals, petals and stamens on the top of ovary (Coriandrum, Guava, Cucurbita).

Placentation and its types

The arrangement of placentae and ovules within the ovary is defined as placentation. Types of placentation may be dealt as follows:

- **Marginal**: placentae developing along the junction of two margins of the carpels, in monocarpellary and one chambered ovary (Pea).
- **Axile**: placentae bearing ovules developed from the central axis, of a compound ovary corresponding to the confluent margins of the carpels. The ovary here is many chambered usually as many as the number of carpels *(Citrus, Solanum).*
- **Parietal:** placentae bearing the ovules on the inner wall of the ovary and their position corresponds to the confluent margin of the carpels. The number of placentae being equal to the number of carpels and the ovary is mono chambered *(Argemone).*
- **Lamellate**: ovules borne on plate like lamella within the ovary. It is a modification of parietal placentation *(Papaver).*
- **Free central**: the ovules are borne on central column without any septa, the ovary is unilocular *(Stellaria).*

- **Basal:** The ovules are few reduced to one and are borne on the base of ovary, the ovules when solitary often filling the cavity the ovary is unilocular *(Sonchus).*
- **Superficial**: ovary is multilocular, carpels being numerous as in axile type but placentae in this case develop all around the inner surface of partition wall *(water lily).*

Morphology of Flowering plants: Pollination

Pollination is the process of transfer of pollen grains from the stamens to the ovules of the ovary. The process of pollination is an interchange between flower and agent. This was first introduced in the 18th century by Christian Konrad Sprengel. The process of pollination is important in agriculture as fruits are a product of fertilization, which is a result of pollination.

The pollen grains produced by the male gametes and the ovules borne by the female gametes are produced by different structures. Hence, it is necessary for the union of the gametes, the pollen must be transferred to the stigma. The transfer and deposition of pollen grains from the anther to the surface of the stigma of the flower is called pollination.

Pollination are of two types:

- Self Pollination.
- Cross Pollination.

Self Pollination:

It is the transfer of pollen grains from the anther of a flower to the stigma of either the same or genetically similar flower. Accordingly, self pollination is of two types, autogamy and geitonogamy.

1. Autogamy (Gk. autos- self, gamos- marriage):

It is a type of self pollination in which an intersexual or perfect flower is pollinated by its own pollen. Autogamy is possible only when anther and stigma are close together and there is synchrony in pollen release and stigma receptivity. Autogamy occurs by three methods.

(a) Homogamy:

The anthers and stigmas of chasmogamous or open flowers are brought together by growth, bending or folding. In Catharanthus (= Vinca), the growth of style brings the stigma in contact of ripe anthers present on the mouth of corolla tube (Fig. 2.17A). In Mirabilis (Four O'clock), the bending of filaments brings the ripe anthers in contact with stigma (Fig. 2.17B). Potato flowers show curling of style for carrying stigma to ripe anthers (Fig. 2.17 C). When cross pollination fails in Sunflower, the bifid bent style stigma curls back so as to pick the pollen sticking to the surface of style (Fig. 2.17 D, E). It is fail safe mechanism of self pollination.

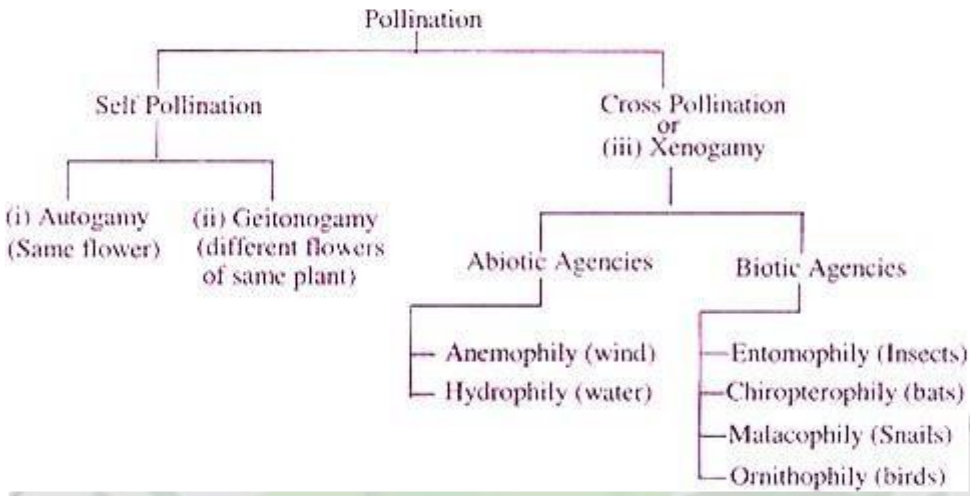


Fig 14. Types of pollination

(b) Cleistogamy (Gk. kleistos-closed, gamos-marriage; Fig. 2.18):

The flowers are intersexual. They remain closed causing self pollination. Cleistogamy occurs late in the flowering season in some plants, e.g., Commelina bengalensis, Balsam, Oxalis, Viola. These plants, therefore, possess both chasmogamous and cleistogamous flowers. In cleistogamous flowers, the anthers dehisce inside closed flowers. Growth of style brings the pollen grains in contact with stigma. Pollination and seed set are assured. Pollinators are not required.

(c) Bud Pollination:

Anthers and stigmas of intersexual or perfect flowers ripen before the opening of the buds so that self pollination takes place as a rule, e.g., Pea, Wheat, and Rice

2. Geitonogamy (Gk. geiton- neighbour, gamos- marriage):

It is a type of pollination in which pollen grains of one flower are transferred to the stigma of another flower belonging to either the same plant or genetically similar plant. In geitonogamy, the flowers often show modifications similar to ones found in xenogeny or cross pollination.

Advantages and Disadvantages of Self Pollination

Advantages of self pollination are:

- Plants that are self pollinating spend less energy in the production of pollinator attractants.

Fig 14. Offset in Pistia and Eichornia

- They can grow in areas where organisms that might help pollination like insects and other animals could be absent or very scarce like in Arctic regions or at regions of high elevations.
- Self pollination allow plants to spread beyond the range of suitable pollinators or produce offspring in regions where there is reduction the population of the pollinators or they are naturally variable.
- There is less chance of failure of pollination and hence help maintain the purity of race.

Disadvantages of Self Pollination are:

- New species are not produced due to self pollination.
- Progeny shows less vigor due to continuous self pollination.
- New characters are not introduced.
- Characters that are undesirable cannot be eliminated.
- Capacity to resistant to diseases becomes less.
- Self pollination does not help in evolution.

Cross Pollination

Definition: Cross pollination is also known as allogamy. Cross Pollination occur when pollen grains are transferred to a flower from a different plant. The plants that undergo cross pollination often have taller stamens than their carpels. They use mechanisms to ensure that the pollen grains are spread to other plants' flowers. The process of cross pollination requires the help of **abiotic or biotic** agents like wind, water, insects, birds, bats, snails and other animals as pollinators.

Abiotic Pollination

Abitoic pollination is a process where the pollination is carried out without the involvement of other organisms. About only 10% of plants are pollinated without animal agents.

Anemophily

Anempophily is the most common form of abiotic pollination, it is pollination by wind. The flowers that are pollinated by wind show the following characters:

- They are usually unisexual flowers.
- Stamens are exposed freely with versatile anthers.
- The pollen grains are light, smooth, dry and not easily wetted by rain.
- Pollen are produced in enormous quantities.
- The stigma is large and well exposed to receive the pollen grains.
- The flowers are small, inconspicuous with no color, odor or nectar.

Examples of wind pollinated plants are coconut, palm, maize, grasses etc.

Hydrophilly

Hyrdophily is the pollination by water and it occurs in aquatic plants as they release pollens directly into the surrounding water medium. Not all aquatic plants are pollinated by water, most of them bear flowers above the water surface and are pollinated by wind or insects.

Biotic Pollination

Biotic pollination is the process of pollination that requires pollinators like some organisms that transfer the pollen grain from the anther to the receptive part or the stigma of the carpel or pistil.

Entimophily or Insect Pollination

Entimophily is the pollination carried out by insects. This process of pollination occurs in plants where they have colored petals and a strong odor to attract insects like bees, wasps and some ants, beetles, moths and butterflies.

The insects visit flowers in order to collect nectar, edible pollen, during this visit the pollen grains gets dusted on the body. When the insect visits the another flower the body brushes against the stigma and transfers the pollen to bring about pollination. Example: Rose, Poppy, etc.

Some features seen in insect pollinated flowers are:

- The flowers are large, and brightly colored.
- The flowers usually have pleasant fragrance and sweet nectar.
- The pollen grains are usually rough and sticky and they show spiny outgrowths.

Zoophily

It is the pollination performed by vertebrates like birds and bats. Plants that get pollinated by bats and moths are usually have white petals and a strong scent. Plants that are pollinated by birds usually develop red petals and rarely have any odor.

Example: Species of *Arctium* (burdock), *Acaena* and *Galium aparine*

Ornithophily or Bird Pollination

Humming birds, sun birds and honey eaters are common bird pollinators. Bird obtain nectar from flowers. Flowers that are pollinated by birds have funnel shaped or tubular corollas and are brightly colored. The floral parts of these plants are leathery and produce large amount of nectar and pollen grains which are sticky.

Chiroperophily or Bat Pollination

Pollination by bats happens in the tropics. Bats visit flowers that are large and that emit strong odor. The flowers pollinated by bats produce more nectar and have large number of stamens.

Anthropophily

Anthropophily is pollination performed by humans, it is usually artificial pollination used

Anthropophily is pollination performed by humans, it is usually artificial pollination used in hybridization techniques.

Open Pollination

Open Pollination is the pollination performed by insects, birds, wind or other natural mechanisms. Open pollination ensures that all seeds of a crop are descended from parents with known traits and have desired traits. In open pollination the breeding is uncontrolled and the pollen source is unknown it may result in plant variety that may vary widely in genetic traits. Open pollen may increase biodiversity. Bigger challenges in open pollination is maintaining the strain by avoiding pollination by introduction of pollen from other strains. Examples of plants produced by open pollination are heirloom tomatoes.

Cleistogamy

- Cleistogamy is also known as automatic self pollination, it describes the trait of certain flowering plant where the plants propagate by using non-opening, self pollinating flowers.
- Cleistogamy is seen in peanuts, peas and beans and this trait is also seen in grass family.
- Cleistogmay requires less plant resources as development of petals, nectar and large amount of pollen are not required.
- This makes cleistogamy useful for production of seeds in unfavorable sites or adverse conditions.
- The disadvantage of cleistogamy is self fertilization may suppress the creation of genetically improved plants.

Examples of Cleistonagamy plants are: peas, beans plants of genus Viola and some grasses.

Chasmogamy

- Chasmogamy botanically describes a type of flower.
- A flower which is chasmogamous opens at maturity, exposing stamens and style to allow the fertilization process.
- The process of fertilization in chasmogamous flowers depends on the reception of appropriate pollen but often is failure.
- The structure of chasmogamous flowers are usually maximized to favor reception of pollen and are generally large and have nectar guides to facilitate insect pollination.
- These flowers produce nectar and also scented to attract pollinating organisms.
- This mechanism of chasmogamy increases exchange of genes between individuals.

Examples of Chansmogamy plants are: Hibiscus, viola, oxalis, etc

Morphology of Flowering plants: Fruit

A fruit is a matured or ripened ovary.

Types of fruits

Simple fruit: a single fruit developing from the single ovary of a single flower with or without accessory parts.

A. Dry fruits:

Dehiscent or capsular fruit: which bursts automatically on ripening and discharge their seeds.

- Legume: a type of dry fruit developed from a simple, superior and one chambered pistil which opens along both the sutures (Pea,Beans etc).
- Follicle: a dry fruit derived from superior and one chambered pistil and opening along ventral suture only (Calotropis).
- Siliqua: a dry two chambered, long narrow, many seeded fruit developing from a bicarpellary, syncarpous, superior ovary and dehiscing from below upwards by both the sutures and seeds remaining attached to replum (Mustard).
- Silicula: a much shorter and flattened siliqua containing only a few seeds (Candytuft,Capsella).
- Capsule: a many seeded dry fruit that develops from compound, generally superior, one to many chambered pistil and opens in various ways, allowing seeds to escape (Datura,Cotton).
- Utricle: a one seeded fruit with a thin wall often dehiscent by a lid (Amaranthus, Chenopodium).

Indehiscent or achenial fruit: fruits that do not split open at maturity and hence the seeds are liberated only by the destruction of pericarp.

- Caryopsis: A very small, dry, indehiscent one seeded fruit developing from a monocarpellary superior ovary with the pericarp fused with the seed coat (wheat).
- Achene: a small, indehiscent, one seeded fruit developing from monocarpellary superior ovary and the seed coat is not adherent to the pericarp (Mirabilis, Phagopyrum).
- Cypsela: A dry, indehiscent, one seeded fruit developing from bicarpellary, syncarpous, inferior unilocular ovary with the pericarp and seed coat free (Sonchus).

- Nut: A dry, indehiscent, one seeded fruit, developing from a superior bi or polycarpellary ovary and where the fruit wall is hard, stony or woody at maturity (Chestnut, Cashewnut, Litchi)
- Samara: a dry indehiscent, one or two seeded, winged fruit developing from a superior ovary (Hiptage, Acer, Holoptelia).

B. Fleshy fruit:

- Drupe: a fleshy, generally one seeded fruit with pericarp differentiated into epicarp (skin), mesocarp (fleshy and edible) and the endocarp (hard and stony) as in Mango, Peach, Coconut, Almond.
- Pome: A fleshy fruit surrounded by thalamus and developing from two or more carpellary, syncarpous, inferior ovary (Apple,Pear).
- Berry: a pulpy, few or many seeded fruit developing commonly from a syncarpous, superior or sometimes inferior ovary (tomato, Banana, Guava).
- Pepo: a pulpy many seeded fruit like berry but developing from an inferior, tricarpellary, unilocular ovary with parietal placentation (Cucurbita, Cucumber).
- Hesperidium: A fleshy fruit developing from many carpellary, syncarpous, superior ovary with axile placentation and with endocarp projecting inward from distinct chambers, and the epicarp and the mesocarp fused to form rind of the fruit as in Lemon, Orange etc.
- Balausta: a many chambered and many seeded, inferior fruit like the berry. The pericarp is tough with two rows of carpels one above the other bearing seeds irregularly. Calyx is persistent and succulent testa is edible (Pomegranate).
- Amphisarca: a fleshy fruit with woody pericarp developing from syncarpous, superior many seeded ovary. The edible portion is the placenta and inner pulpy layers of pericarp.

Aggregate fruits: Fruits developed from a flower having a number of free carpels, all of which ripen together and are more or less coherent at maturity.

- Etaerio of drupes : Aggregate of drupes (Rubus).
- Etaerio of achenes: Aggregate of achenes (Strawberry, Naravelia).
- Etaerio of follicles: aggregate of follicle (Michelia champaca, Magnolia grandiflora).
- Etaerio of berries: an aggregate of berries (Artabotrys, Anona squamosa).

Multiple or composite fruits: fruits composed of a number of closely associated fruits derived from the entire inflorescence and forming one body at maturity (Jackfruit).

- Sorosis: a fruit developing from a spike or spadix in which the flowers fuse by their succulent tepals and axis bearing them becomes fleshy or woody thus forming a compact mass (Pineapple,Mulberry).
- Syconus: A fruit developing from hypanthodium inflorescence characteristically having a hollow, pear shaped fleshy receptacle.

Chapter 7. Seed and Seed Germination

A seed is a mature ovule, which is formed after the fertilization. The outer covering of a seed is called seed-coat which is a protective covering and is known as testa. Seeds contain a small opening called micropyle through which water enters into the seed.

The inner layer below the testa is called tegmen. Inside, seeds contain embryo which consists of cotyledons, radicle and plumule. Seed contains endosperm. However the endosperm is absent in some seeds. Hilum is a scar, where the seed breaks from the stalk of the ovule wall.

Types of Seeds According to the Number of Cotyledons:

Seeds are of two types according to the number of cotyledons.

A. Monocotyledonous Seeds: These seeds contain only one cotyledon; for example, wheat, bajra, maize and rice.

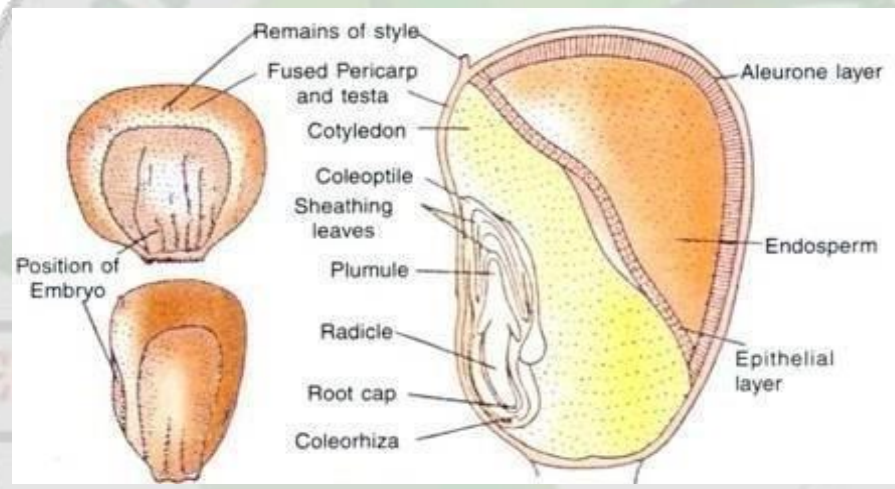


Fig 23. Maize seed

B. Dicotyledonous Seeds: These seeds contain two cotyledons; for example, mango, gram and pea.

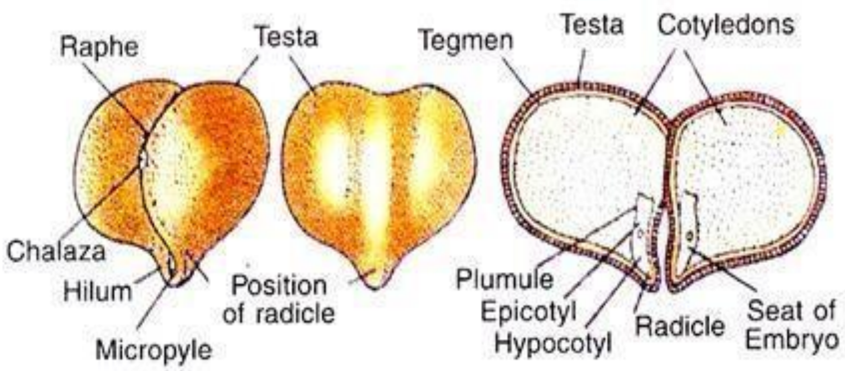


Fig 24. Gram seed

Types of Seeds According to the Food Storage Tissue

There are two types of seeds according to the food storage tissue.

A. Endospermic Seeds (Albuminous):

Endospermic seeds are those in which food is stored in endosperm, e.g., wheat, rice and bajra.

B. Non-Endospermic Seeds (Exalbuminous):

Non-endospermic seeds are those in which food is stored in cotyledons, e.g., pea and gram.

Germination:

Germination is a process by which the embryo in the seed becomes activated and begins to grow into a new seedling.

Seed germination is a process by which a seed embryo develops into a seedling. It involves the reactivation of the metabolic pathways that lead to growth and the emergence of the radicle or seed root and plumule or shoot. The emergence of the seedling above the soil surface is the next phase of the plant's growth and is called seedling establishment. Three fundamental conditions must exist before germination can occur. (1) The embryo must be alive, called seed viability. (2) Any dormancy requirements that prevent germination must be overcome. (3) The proper environmental conditions must exist for germination.

Seed viability is the ability of the embryo to germinate and is affected by a number of different conditions. Some plants do not produce seeds that have functional complete embryos, or the seed may have no embryo at all, often called empty seeds. Predators and pathogens can damage or kill the seed while it is still in the fruit or after it is dispersed. Environmental conditions like flooding or heat can kill the seed before or during germination. The age of the seed affects its health and germination ability: since the seed has a living embryo, over time cells die and cannot be replaced. Some seeds can live for a long time before germination, while others can only survive for a short period after dispersal before they die.

Seed vigor is a measure of the quality of seed, and involves the viability of the seed, the germination percentage, germination rate and the strength of the seedlings produced.

The **germination percentage** is simply the proportion of seeds that germinate from all seeds subject to the right conditions for growth. The **germination rate** is the length of time it takes for the seeds to germinate. Germination percentages and rates are affected by seed viability, dormancy and environmental effects that impact on the seed and seedling. In agriculture and horticulture quality seeds have high viability, measured by germination percentage plus the rate of germination. This is given as a percent of germination over a certain amount of time, 90% germination in 20 days, for example. 'Dormancy' is covered above; many plants produce seeds with varying degrees of dormancy, and different seeds from the same fruit can have different degrees of dormancy. It's possible to have seeds with no dormancy if they are dispersed right away and do not dry (if the seeds dry they go into physiological dormancy). There is great variation amongst plants and a dormant seed is still a viable seed even though the germination rate might be very low.

Environmental conditions affecting seed germination include; water, oxygen, temperature and light.

Three distinct phases of seed germination occur: **water imbibition; lag phase; and radicle emergence.**

In order for the seed coat to split, the embryo must imbibe (soak up water), which causes it to swell, splitting the seed coat. However, the nature of the seed coat determines how rapidly water can penetrate and subsequently initiate germination. The rate of imbibition is dependent on the permeability of the seed coat, amount of water in the environment and the area of contact the seed has to the source of water. For some seeds, imbibing too much water too quickly can kill the seed. For some seeds, once water is imbibed the germination process cannot be stopped, and drying then becomes fatal. Other seeds can imbibe and lose water a few times without causing ill effects, but drying can cause secondary dormancy.

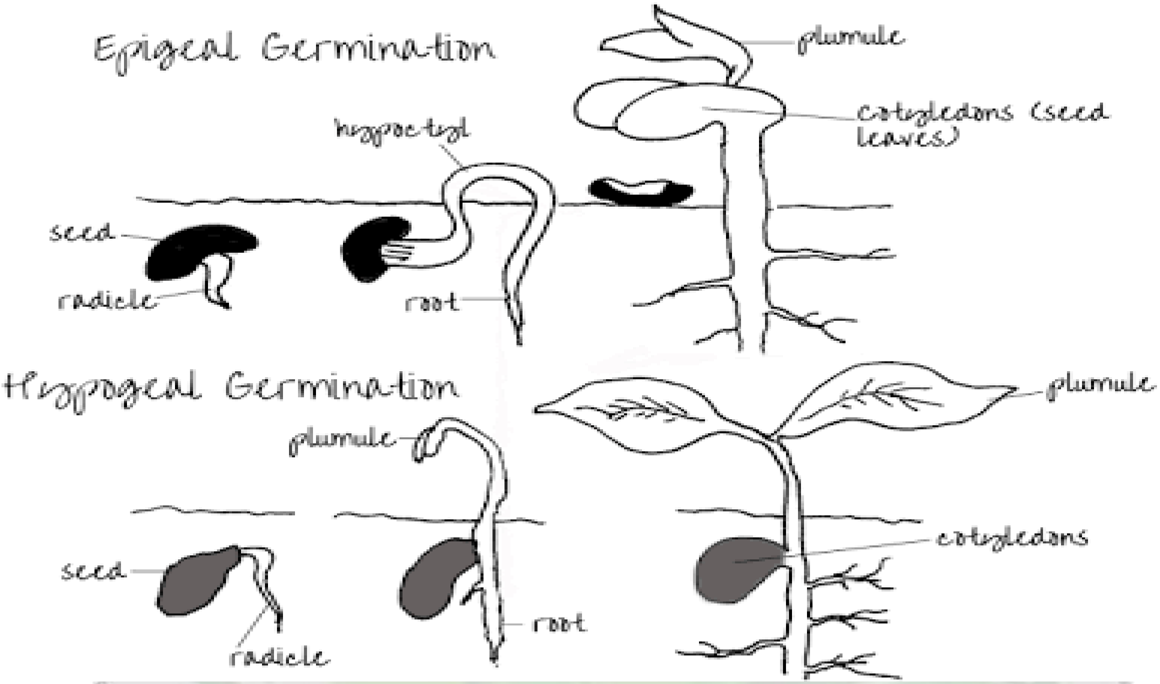
Types of Germination:

There are two types of germination:

1. Epigeal Germination:

In this type of germination, the hypocotyl elongates rapidly and arches upwards pulling the cotyledons which move above the soil. Bean, cotton, papaya, gourd, castor and onion have germination of this kind.

2. Hypogeal Germination: In this type of germination, the epicotyl elongates and the cotyledons remain below the soil. Pea, mango, maize, rice, gram and groundnut have germination of this type.



3. Viviparous germination: In this type of germination, the embryo of seed undergoes development without any resting period with the fruit still attached to and nourished by the parent plant. In species of Rhizophora the embryo grows out not only from seed but emerges out from the fruit, so that the hypocotyls and the radical grow and project out to a considerable length from the fruit.

8. Plant Systamatics: Brassicaceae, fabaceae and Poaceae

A. Brassicaceae: eg (*Brassicaceae campestris* Linn. Var. Sarso).

Stem: Herbaceous, aerial, erect, cylindrical, branched, solid, smooth and green.

Leaf: Cauline and ramal, alternate, exstipulate, simple, sessile, lower leaf lyrate with deeply cut margins, acute, glaborous, unicostate, reticulate.

Inflorescence: Racemose raceme

Flower: Ebracteate, pedicillate, complete, actinomorphic, hermaphrodite, tetramerous, hypogynous, cyclic and yellow.

Calyx: Sepals 4 in two whorls of 2 each, polysepalous, slightly petaloid.

Corolla: Petals 4, polypetalous, cruciform. Each petal is distinguished into a claw and a limb, valvate.

Androecium: Stamens 6 in two whorls (2+4), polyandrous, tetradynamous, 4 inner long and 2 outer short, dithecous, basifixed and introrse, glands are present at the base of 4 longer stamens.

Gynoecium: Bicarpellary, syncarpous, ovary superior, unilocular but becomes bilocular later on due to the development of a false septum (replum), ovules many in each locule, placentation parietal, style short and stigma is bilobed.

Fruit: siliqua.; **Floral formula**: Ebr, $\oplus$, ⚥, K_{2+2}, C_4, A_{2+4}, $G_{(2)}$

Classification and Identification:

Dicotyledons

1. Venation reticulate
2. Flowers pentamerous.

Polypetaleae

1. Petals free

Thalamifloreae

1. Flowers hypogynous and ovary superior.

Parietales

1. Carpels united to form an unilocular ovary with parietal placentation.

Crucifereae

1. Herbs with alternate exstipulate leaves
2. Corolla cruciform
3. Stamens tetradynamous
4. Ovary bicarpellary, syncarpous, unilocular but becomes bilocular due to the development of false septum; fruit Siliqua.

B. Gramineae: (*Triticum aestivum* Linn.)

Habit: herb

Root: Adventitious, fibrous.

Stem: herbaceous, aerial, erect, cylindrical, branched, branching is only at the basal region of stem and is known as tillering, culm smooth and green.

Leaf: Alternate, exstipulate, simple, sessile, leaf distinguished into a linear leaf blade and a leaf sheath and at the junction of two small, membranous ligule is present, lamina lancoelate, entire, acute, minutely hairy, multicostate parallel.

Inflorescence: Spike of spikelets. Each spikelet consists of the following parts-

1. A pair of glumes present at the base, outer one is called the first glume and the inner as second glume. These glumes are barren
2. After glume, is present lemma or inferior palea.
3. There is present superior palea or pale. The essential organs of flower lie between superior palea or lemma and inferior palea or pale.

Flower: Sessile, complete, zygomorphic, hermaphrodite, hypogynous and cyclic.

Perianth: Represented by two rudimentary free tepals known as lodicules.

Androecium: Stamen 3, polyandrous, filaments long, dithecous, versatile and introsed.

Gynoecium: monocarpellary, ovary superior, unilocular, with one marginal ovule, style absent, stigma 2 and feathery.

Fruit: Caryopsis.

Floral diagram: Br, Φ ⚥, P_2, A_3, $G_{\underline{1}}$

Classification & Identification:

Monocotyledons:

1. Venation parallel.
2. Flowers trimerous.

Glumaceae:

1. Flowers solitary, sessile in the axil of bract.
2. Perianth of scales or none.
3. Ovary usually unilocular and one ovuled.

Gramineae:

1. Joint stems with alternate 2 ranked leaves with split sheath and ligule.
2. Inflorescence: Spikelet and each begins with one or two empty glumes then palea with axillary flowers.
3. Stamens usually 3.
4. Gynoecium superior with one ovule.

Fruit: Caryopsis.

C. Fabaceae or Leguminaceae or Paplionaceae (e.g. *Sesbania sesban* (Linn.). Merr.

Stem. Herbaceous**,** Lower portion woody, aerial , erect, cylindrical, branched, solid, glabrous, green

Leaf. Cauline and ramal, alternate, stipulate, stipules free lateral, leaf base pulvinus, compound, unipinnate and paripinnate, oblong, entire, mucronate, glabrous, unicostate, reticulate.

Inflorescence. Axillary racemose raceme.

Flower. Bracteate,bracteolate,pedicellate,complete,zygomorphic,hermaphrodite,pentamerous, hypogynous and cyclic.
Calyx. Sepals 5, gamosepalous,valvate,persistent,odd sepals anterior.
Corolla. Petals 5, polypetalous, vexillary aestivation, corolla papilionaceous, yellow.
Androcium. Stamens10, diadelphous (9)+1, dithecous, dorsifixed and introrse.
Gynocium. Monocarpellary, ovary superior, unilocular, marginal placentation, style long and curved , stigma capitates
Fruit. Pod.
Floral formula: Br, Ebr, ⦶, ⚥, $K_{(5)}$, $C_{1+2+(2)4}$, $A_{(9)+1}$, $G_{\underline{1}}$

Classification and identification.
Dicotyledons
(i) Venation reticulate (ii) Flowers pentamerous.
Polypetalae
(i) Petals free.
Calyciflorae
(i)Thalamus cup-shaped. (ii) Ovary inferior or semi inferior
Rosales
(i) Alternate, stipulate leaves. (ii) Carpel one or more.
Papilionaceae
(i) Flowers zygomorphic. (ii) Gynocium usually one. (iii) Corolla papilionaceous with descending imbricate type of activation. (iv) Ovary monocarpellary.

9. Role of animal in agriculture

Solving the problems and overcoming the obstacles to sustainable food security, although daunting, are not options, because food security is critical not only to national security but also to global stability. Feeding the world s rapidly expanding population can therefore rightly be viewed as the main global challenge of the 21st century. Animals will play an important role in meeting this challenge.

Importantly, although often overlooked, meat, milk, eggs, and other animal products, including fish and other sea foods, will play an important role in achieving food security for several reasons. First, animal products are an important source of high quality, balanced, and highly bio-available protein and numerous critical micronutrients, including iron, zinc, and vitamins B-12 and A, many of which are deficient in a large portion of the world's population (10–12). Thus, moderate consumption of animal-sourced foods plays an important role in achieving a nutritionally balanced diet, especially in the developing world.

Second, because they are recognized as high-quality foods, global demand for animal products is almost certain to continue to increase dramatically. The drivers of the increased demand for animal products include not only population growth but also increased affluence, especially in the developing world, where most of the increase in population will occur.

Third, farm animals are critical to a sustainable agricultural system and especially for smallholders who comprise most of the world's farmers. Farm animals contribute not only a source of high-quality food that improves nutritional status but also additional resources such as manure for fertilizer, on-farm power, and other by-products, and, in addition, provide economic diversification and risk distribution.

Moreover, increased efficiencies in the past several decades through genetic selection and improved management technologies has saved a large amount of resources, including water and land, and have substantially reduced the carbon footprint of animal production.

Fourth, ruminants such as buffalo, cattle, goats, and sheep, efficiently convert the forages from grasslands into high-quality animal products, and grazing also can promote the health and biodiversity of grasslands if managed appropriately. This is important because grassland pastures cover >25% of the Earths land surface and, despite being home to nearly a billion people, comprise primarily marginally or non-arable land.

However, sustainable farm animal production will also require a more complete understanding of their impact on the environment. For example, a report by the FAO of the

UN estimated that livestock, and especially ruminants, contribute as much as 18% of greenhouse gas emissions, but others have suggested that this is a gross overestimate and that the actual value may be as low as 3%. Regardless, as farm animal production continues to increase, we need to be concerned with not only greenhouse gases but also the impact of farm animals on soil, water, and biodiversity. We also need to better understand the specific role of animal products in the diet in the global increase in non-communicable diseases such as type 2 diabetes, obesity, and cardiovascular disease, because non-communicable diseases are now responsible for more deaths worldwide than all other causes. In this regard, recent reports from the National Research Council and from the Office of Disease Prevention and Health Promotion, Department of Health and Human Services, argue strongly for renewed focus, including additional research, on these controversial and critical issues.