



Faculty of Science

**Botany and Microbiology
Department**



Zagazig University

Systematic Botany and Plant Physiology

For 1st year Students

Prepared By

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2025-2026

Part One

Systematic

Botany

Systematic Botany

Systems of Classification

The Five Kingdom System of Classification

In order to suggest a better system of classification of living organisms, **Whittaker (1969)** an American Taxonomist divided all the organisms into 5 kingdoms based on their phylogenetic relationships. This classification takes into account the following important criteria.

1. Complexity of Cell structure – prokaryote to Eukaryote
2. Mode of nutrition – autotrophs and heterotrophs
3. Body organization -unicellular or multi-cellular
4. Phylogenetic or evolutionary relationship

The Five kingdoms are

Monera, Protista, Fungi, Plantae and Animalia.

1. **Monera**1. Kingdom

2. Phylum or Division

3. Class

4. Order

5. Family

6. Genus

7. Species

Species

Species is the basic unit of Classification. It is defined as the group of individuals which resemble in their morphological and reproductive characters and interbreed among themselves and produce fertile offsprings.

Major differences among five kingdoms

Property	Monera	Protista	Fungi	Plantae	Animalia
Cell type	Prokaryotic	Eukaryotic	Eukaryotic	Eukaryotic	Eukaryotic
Cell organization	Mostly unicellular	Mostly unicellular	Multicellular and unicellular	Mostly Multicellular	Mostly Multicellular
Cell wall	Present in most	Present in some; absent in others	Present	Present	absent
Nutritional class	Phototrophic, heterotrophic or chemoautotrophic	Heterotrophic and phototrophic	Heterotrophic	phototrophic	Heterotrophic
Mode of nutrition	Absorptive	Absorptive or ingestive	Absorptive	Mostly Absorptive	Mostly ingestive
Motility	Motile or non motile	Motile or nonmotile	Nonmotile	Mostly nonmotile	Mostly Motile

1-Viruses

The nature of viruses

Viruses are small particles

Are viruses living or nonliving?

Viruses belong to biology because they possess genes, replicate, evolve, and are adapted to particular hosts, biotic habitats, and ecological niches. However, they are nonliving infectious entities out their hosts. A virus is a very small, non-cellular parasite of cells. Its genome, which is composed of either DNA or RNA, is enclosed in a protein coat.

Biological position of viruses:

Viruses lack a cytoplasmic membrane and they do not have the basic component of a cell. They can only replicate inside the host cell. Outside the host cell, they are non-living. Thus, viruses show characters of both living and non-living.

(I) Non-living Characters of Viruses:

Following characters of viruses assign them as non-living:

- (a) They can be crystallized.
- (b) Outside the cell, they behave like inert chemicals.
- (c) They do not show growth, development, nutrition, reproduction, etc.
- (d) They can be precipitated.

(II) Living characters of viruses:

- (a) They multiply within host cells.
- (b) They possess genetic material, either DNA or RNA.
- (c) There are definite races or strains.
- (d) They exhibit mutations.

Because of the above reasons, viruses form unique bridge between living and non-living things

General characters common to all viruses

1. Virus is an infectious agent and obligate intracellular parasite
2. They are small size (20-300 nm in diameter) retaining infectivity after passage through filters able to hold back bacteria. ^[L]_{SEP} Cannot be seen by light microscope and can be seen by Electron microscope.
3. Virus infectious cycle includes a phase in which the agent consists of a virion. The virion consists of RNA or DNA coated with one or more proteins (capsid structure), which is sometimes coated with a membrane containing lipid and glycoproteins.
4. Compared with a cell genome, viral genomes are small, but genomes of different viruses
5. range in size by over 100-fold (c. 3000 nt to 1,200,000 bp)
6. Small genomes make small particles – again with a 100-fold size range.
7. Viral genomes are associated with protein that at its simplest forms the virus particle, but in some viruses this nucleoprotein is surrounded by further protein or a lipid bilayer.
8. Viruses can only reproduce in living cells.

9. Viruses carry genetic information in the form of RNA or DNA. This genomic nucleic acid carries information, which redirects the genetic and metabolic apparatus of the infected cell to produce virions
10. The outermost proteins of the virus particle allow the virus to recognize the correct host cell and gain entry into its cytoplasm.
11. A virus can initiate another infection when transferred to a suitable host.

Important terminology for Virologists

Virion- Morphologically complete (mature) infectious virus particle.

Pathogen- Biological disease agent.

Bacteriophage- Viruses that infect bacteria. Phage is Greek for eating, since bacteriophage produced hole on lawns of bacteria.

Virulence- the ability of an infectious agent to produce disease. Many viruses are virulent sometimes and asymptomatic at other times.

Prions are infectious agents generally believed to consist of a single type of protein molecule with no nucleic acid component.

Viroids are very small (200–400 nucleotides), circular RNA molecules with a rod-like secondary structure. They have no capsid or envelope and are associated with certain plant diseases. Their replication strategy is like that of viruses—they are obligate intracellular parasites

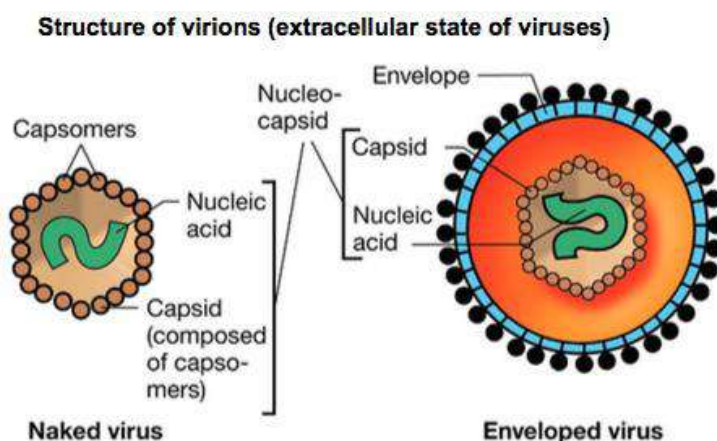
Satellites (nucleic acid molecules with or without a capsid that require a helper virus for infection and reproduction).

Defective viruses (Also known as satellites) are those that need the presence of other viruses to help them reproduce

The structure of viruses:

A complete virus particle, known as a virion, consists of nucleic acid surrounded by a protective coat of protein called a capsid. These are formed from identical protein subunits called capsomeres.

1. **Genome:** the viral nucleic acid carries the genetic information in



either DNA or RNA, which is considered

as the fingerprints of the virus. [SEP]

2. **Capsid (Protein coat):** is the protein shell, which enclose the nucleic acid. It is formed of small units called capsomeres.

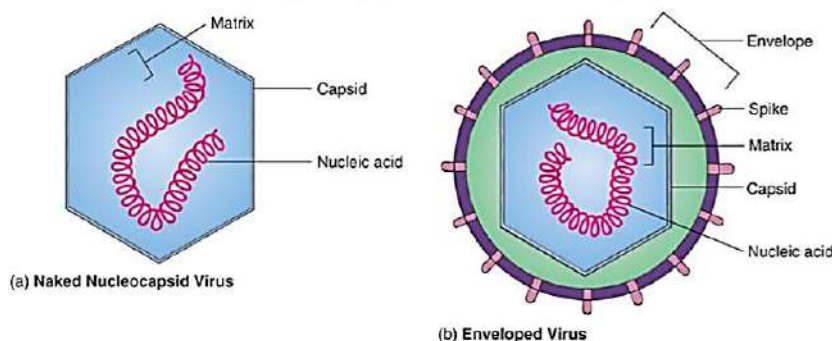
Functions of the capsid:

1. Protects the viral genome against extracellular environments.
2. It carries the viral attachment proteins (VAP), which are glycoproteins that attach the virus on specific receptors on the target cell.
3. Determine the antigenic characters of the virus.

Viral nucleic acid:

The viral nucleic acid is located internally and can be either single- or double- stranded RNA or DNA. The nucleic acid can be either linear or circular. The DNA is always a single molecule; the RNA can exist either as a single molecule or in several pieces (segmented).

- Some RNA viruses are positive polarity and others are negative polarity.
- Positive polarity is defined as RNA with same base sequence as the mRNA.
- Negative polarity has a base sequence that is complementary to the mRNA.



Viruses symmetry

Viruses come in an amazing variety of shapes and sizes. They are very small and are measured in nanometers, which is one-billionth of a meter. Viruses can range in the size between 20 to 750nm, which is 45,000 times smaller than the width of a human hair. The majority of viruses cannot be seen with a light microscope because the resolution of a light microscope is limited to about 200nm, so a scanning electron microscope is required to view most viruses.

The basic structure of a virus is made up of a genetic information molecule and a protein layer that protects that information molecule. The arrangement of the protein layer and the genetic information comes in a variety of presentations. The core of the virus is made up of nucleic acids, which then make up the genetic information in the form of RNA or DNA. The protein layer that surrounds and protects the nucleic acids is called the capsid. When a single virus is in its complete form and has reached full infectivity outside of the cell, it is known as a virion. A virus structure can be one of the following: **icosahedral, complex or helical.**

1- Icosahedral

These viruses appear spherical in shape, but a closer look actually reveals they are icosahedral. The icosahedron is made up of equilateral triangles fused together in a spherical shape. This is the most optimal way of forming a closed shell using identical protein sub-units. The genetic material is fully enclosed inside of the capsid. Viruses with icosahedral structures are released into the environment when the cell dies, breaks down and lyses, thus releasing the virions. Examples of viruses with an icosahedral structure are the poliovirus, rhinovirus, and adenovirus.

An icosahedron is a regular polyhedron with 20 equilateral faces and 12 vertices

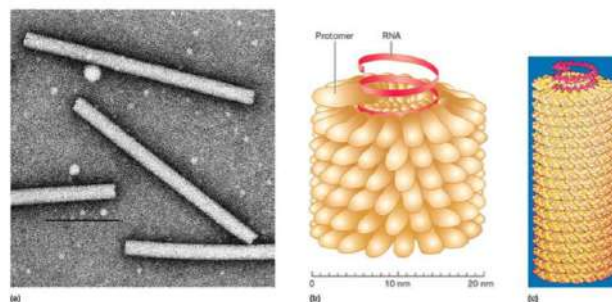
Capsomers ring or knob-shaped units made of 5 or 6 protomers – pentamers (pentons) – 5 subunit capsomers – hexamers (hexons) – 6 subunit capsomers

2- Helical symmetry

Composed of a single type of capsomer stacked around a central axis to form a helical structure, which may have a central cavity.

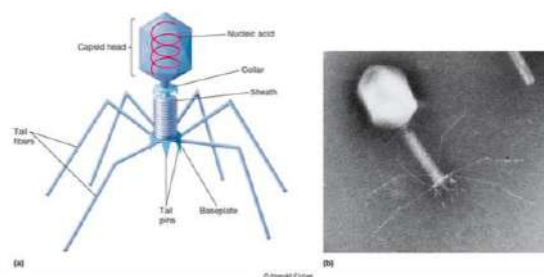
This arrangement results in rod-shaped or filamentous virions

This virus structure has a capsid with a central cavity or hollow tube that is made by proteins arranged in a circular fashion, creating a disc like shape. The disc shapes are attached helically (like a toy slinky) creating a tube with room for the nucleic acid in the middle. All filamentous viruses are helical in shape. They are usually 15-19nm wide and range in length from 300 to 500nm depending on the genome size. An example of a virus with a helical symmetry is the tobacco mosaic virus.



3- Complex

These virus structures have a combination of icosahedral and helical shape and may have a complex outer wall or head-tail morphology. The head-tail morphology structure is unique to viruses that only infect bacteria and are known as bacteriophages. The head of the virus has an icosahedral shape with a helical shaped tail. The bacteriophage uses its tail to attach to the bacterium, creates a hole in the cell wall, and then inserts its DNA into the cell using the tail as a channel.



3. Bacteria

Occurrence

Bacteria are omnipresent. They are found in all environments, where organic matter is present. They are found in air, water, soil and also in or on the bodies of plants and animals. Some of the bacteria live as **commensals** (eg. **Escherichia coli** in the human intestine) and some live as **symbionts** (eg. **Rhizobium**) in the root nodules of leguminous plants. Several of them cause diseases in plants, animals and human beings.

Size

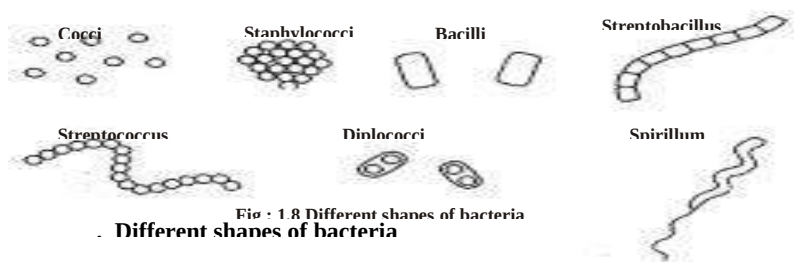
Bacteria are very small, most being approximately 0.5 to 1 micron in diameter and about 3 to 5 microns in length.

Classification of bacteria based on the shape and arrangement

The rigid bacterial cell wall determines shape of a cell. Typical bacterial cells are spherical (**Cocci**), straight rods (**Bacilli**) or rods that are helically curved (**spirilla**), some bacterial cells are **pleomorphic** ie they can exhibit a variety of shapes eg. **Arthrobacter**

Cocci bacteria appear in several characteristic arrangements depending on their plane of division.

- A. **Diplococci**: Cells divide in one plane and remain attached in pairs.
- B. **Streptococci**: cells divide in one plane and remain attached to form chains.
- C. **Tetrads**: Cells divide in two planes and form group of four cells.
- D. **Staphylococci**: cells divide in three planes, in an irregular pattern, producing bunches of cocci.
- E. **Sarcinae**: cells divide in three planes, in a regular pattern, producing a **cuboidal** arrangement of cells.

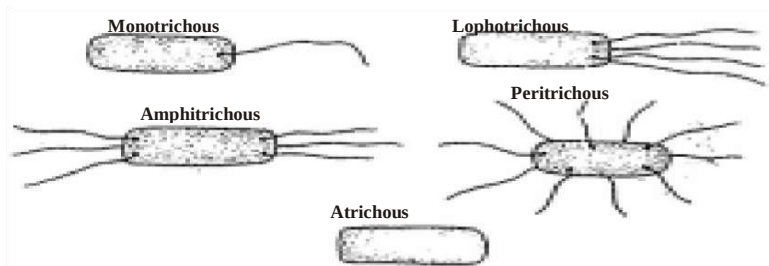


Bacilli forms occur singly or in pairs (**diplobacilli**) or form chains (**streptobacilli**). In **Corynebacterium diphtheriae** which is a bacillus species, the cells are arranged side by side like match sticks (**palisade** arrangement)

Flagellation in Bacteria

All spirilla, about half of the bacilli and a small number of cocci are flagellated. Flagella vary both in number and arrangement according to two general patterns. 1. In a **polar arrangement**, the flagella are attached at one or both the ends of the cell. Three sub types of this pattern are:

- a. **monotrichous** – with a single flagellum
 - b. **lophotrichous** – with small bunches or tufts of flagella emerging from one end
 - c. **amphitrichous** – with flagella at both poles of the cell
2. In a **peritrichous** arrangement flagella are dispersed randomly over the surface of the cell.
3. **Atrichous** bacteria lack flagellum.



Flagellar Functions

They can detect and move in response to chemical signals – a type of behaviour called **chemotaxis**. Positive chemotaxis is movement of cell in the direction of a favourable chemical stimulus (usually a nutrient). Negative chemotaxis is movement away from a repellent (potentially harmful) compound.

Nutrition in Bacteria

Autotrophic Bacteria

Some bacteria can synthesize their food and hence they are autotrophic in their mode of nutrition. They may be **photo autotrophs** (eg. **Spirillum**) or **chemoautotrophs** eg. **Nitrosomonas** or **Nitrobacter**.

Photo-autotrophic bacteria

They use sunlight as their source of energy to synthesize food. But unlike photosynthetic eukaryotic cells they do not split water to obtain reducing power. So Oxygen is not evolved during bacterial photosynthesis. Depending upon the nature of the hydrogen donor these bacteria may be

1. Photolithotrophs

In this the hydrogen donor is an inorganic substance. In green sulphur bacteria(eg. *Chlorobium*) hydrogen sulphide (H₂S) is the hydrogen donor. The chlorophyll is **bacterioviridin**

In purple sulphur bacteria (eg. *Chromatium*) thiosulphate acts as hydrogen donor. The chlorophyll is **bacteriochlorophyll**.

2. Photo-organolithotrophs

In this the hydrogen donor is an organic acid or alcohol eg. Purple non sulphur bacteria (eg. *Rhodospirillum*)

Chemo-autotrophic bacteria

They do not have photosynthetic pigments and hence they cannot use sunlight energy. Instead they obtain energy in the form of ATP by oxidising inorganic or organic compounds. The energy thus obtained is used to reduce CO₂ to organic matter. Based on the type of substance oxidized they may be

1. **Chemolithotrophs:** Inorganic compound is oxidized to release energy. eg. Sulphur bacteria (eg. *Thiobacillus*)

Iron bacteria (eg. *Ferrobacillus*), Hydrogen bacteria

eg. *Hydrogenomonas* and

Nitrifying bacteria (eg *Nitrosomonas* and *Nitrobacter*)

2. **Chemo – organotrophs:** In this type it is an organic compound that is oxidized to release energy.

eg. Methane bacteria (*Methanococcus*).

Acetobacteria and *Lactobacillus* are also examples for chemoorganotrophs.

Heterotrophic Bacteria

They depend upon other organisms (living/dead) for their food since they cannot synthesize their own food. They may be saprotrophic e.g (*Bacillus subtilis*), parasitic e.g. Plant parasite-(*Xanthomonas citrii*) animal parasite e.g.(*Bacillus anthracis*) , Human parasite e.g (*Vibrio cholerae*) or symbiotic in association with roots of the family Leguminosae. e.g. (*Rhizobium*)

Respiration in Bacteria

Aerobic Bacteria: These bacteria require oxygen as terminal acceptor of electrons and will not grow under anaerobic conditions(i.e in the absence of O₂) Some micrococcus species are **obligate aerobes** (i.e they must have oxygen to survive)

Anaerobic bacteria : These bacteria do not use oxygen for growth and metabolism but obtain their energy from fermentation reaction. eg. *Clostridium* species.

Capnophilic bacteria are those that require CO₂ for growth.

Facultative anaerobes: Bacteria can grow either oxidatively using oxygen as a terminal electron acceptor or anaerobically using fermentation reaction to obtain energy. Bacteria that are facultative anaerobes are often termed “**aerobes**”. When a facultative anaerobe such as E. Coli is present at a site of an infection like an abdominal abscess it can rapidly consume all available O₂ and change to anaerobic metabolism, producing an anaerobic environment and thus, allow the anaerobic bacteria that are present to grow and cause disease.

Endospores are structures formed in bacillus bacteria during unfavourable conditions. Fortunately most pathogenic bacteria (except tetanus and anthrax bacteria) do not form endospores.

Reproduction by binary fission is very common. It is the method by which many bacteria multiply very rapidly explaining the cause of spoilage of food stuffs, turning of milk into curd etc.

Sexual Reproduction

Typical sexual reproduction involving the formation and fusion of gametes is absent in bacteria. However, gene recombination can occur in bacteria by three different methods. They are:

1. **Conjugation:** In this method of gene transfer, the **donor** cell gets attached to the **recipient** cell with the help of pili. The pilus grows in size and forms the conjugation tube. The plasmid of donor cell which has the **F⁺** (fertility factor) undergoes replication. Only one strand of DNA is transferred to the recipient cell through conjugation tube. The recipient completes the structure of double stranded DNA by synthesizing the strand that compliments the strand acquired from the donor.
2. **Transduction** : Donor DNA is carried in a phage coat and is transferred into the recipient by the mechanism used for phage infection.

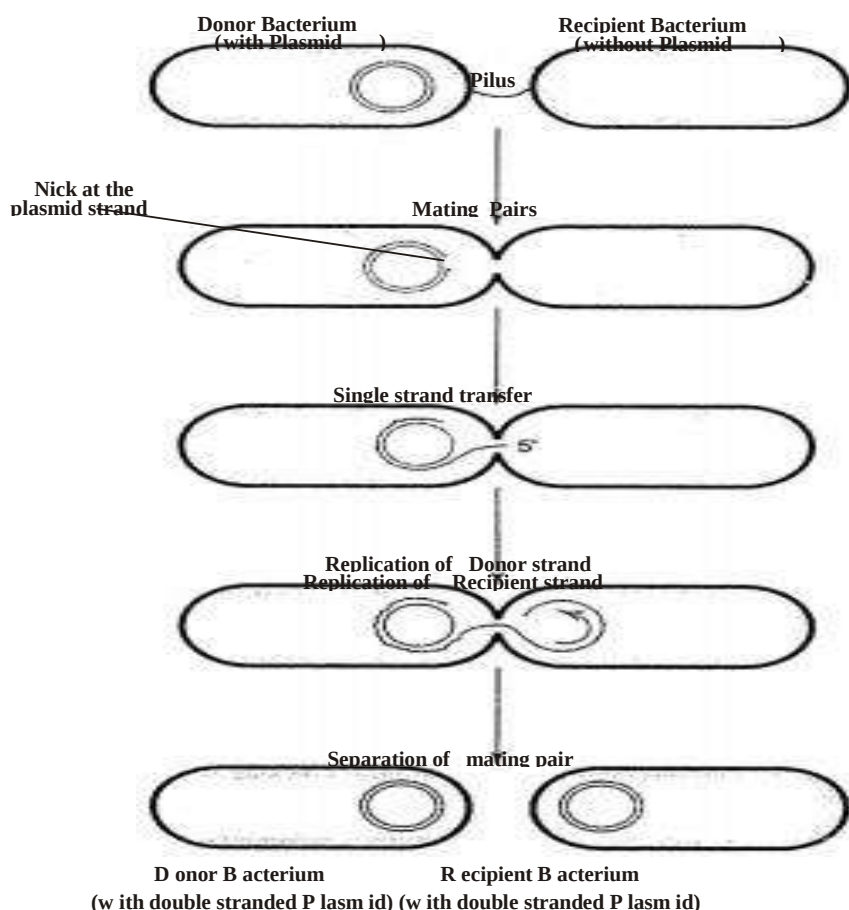


Fig: 1.9. Conjugation in Bacteria

3. **Transformation** : The direct uptake of donor DNA by the recipient cell may be natural or forced. Relatively few bacterial species are naturally competent for transformation. These species assimilate donor DNA in linear form. Forced transformation is induced in the laboratory, where after treatment with high salt and temperature shock many bacteria are rendered competent for the assimilation of extra-cellular plasmids. **The capacity to force bacteria to incorporate extra-cellular plasmids by transformation is fundamental to genetic Engineering.**

Economic Importance of Bacteria

Bacteria play an important role in day to day activities of human beings. Some of them have harmful effects and others are useful to mankind.

Harmful activities

1. Diseases caused by bacteria in plants:

Name of the host	Name of the disease	Name of the pathogen
Citrus	Citrus Canker	<i>Xanthomonas citrii</i>
Rice	Bacterial blight	<i>Xanthomonas oryzae</i>
Cotton	Angular leaf spot	<i>Xanthomonas</i>

		<i>malvacearum</i>
Pears	Fire blight	<i>Pseudomonas solanacearum</i>
Carrot	Soft rot	<i>Erwinia caratovora</i>

Beneficial Activities of Bacteria

1. **Sewage disposal** : Organic matter of the sewage is decomposed by saprotrophic bacteria.
2. **Decomposition of plant and animal remains**: Saprotrophic bacteria cause decay and decomposition of dead bodies of plants and animals. They release gases and salts to atmosphere and soil. Hence these bacteria are known as nature's scavengers.
3. **Soil fertility** :
 1. The **ammonifying** bacteria like *Bacillus ramosus* and *B. mycoides* convert complex proteins in the dead bodies of plants and animals into ammonia which is later converted into ammonium salts.
 2. The **nitrifying bacteria** such as *Nitrobacter*, *Nitrosomonas* convert ammonium salts into nitrites and nitrates.
 3. **Nitrogen fixing bacteria** such as *Azotobacter* and *Clostridium* and *Rhizobium* (a symbiotic bacterium) are capable of converting atmospheric nitrogen into organic nitrogen. All these activities of bacteria increase soil fertility.

Role of Bacteria in Industry

1. **Dairy Industry**
2. **Vinegar**
3. **Alcohols and Acetone**

Curing of tobacco,tea and coffee

Retting of fibres

Role of bacteria in medicine

1. **Antibiotics**: Antibiotics such as bacitracin (*Bacillus subtilis*), polymyxin(*Bacillus polymyxa*), Streptomycin(*Streptomyces griseus*) are obtained from bacterial sources.
2. **Vitamins**: *Escherichia coli* living in the intestine of human beings produce large quantities of vitamin K and vitamin B complex. Vitamin B₂ is prepared by the fermentation of sugar by the action of *clostridium* species.

4- Fungi

Fungi are non chlorophyllous, eukaryotic, organisms. They are a large and successful group. They are universal in their distribution. They resemble plants in that they have cell walls. But they lack chlorophyll which is the most important attribute of plants. They are ubiquitous in habitat which ranges from aquatic to terrestrial. They grow in dark and moist habitat and on the substratum containing dead organic matter. Mushrooms, moulds and yeasts are the common fungi. They are of major importance for the essential role they play in the biosphere and for the way in which they have been exploited by man for economic and medical purposes. The study of fungi is known as **Mycology**. It constitutes a branch of microbiology because many of the handling techniques used, such as sterilizing and culturing procedures are the same as those used with bacteria.

Distinguishing Features of Fungi

1. They have definite cell wall made up of **chitin** – a biopolymer made up of n-acetyl glucosamine units.
2. They are without chlorophyll, hence they exhibit heterotrophic mode of nutrition. They may be saprotrophic in their mode of nutrition or parasitic or symbiotic.
3. They are usually non – motile.
4. Their storage product is not starch but glycogen and oil.
5. They reproduce mostly by spore formation. However sexual reproduction also takes place.

Structure

The body structure of fungi is unique. The somatic body of the fungus is unicellular or multi-cellular or coenocytic. When multi-cellular it is composed of profusely branched interwoven, delicate, thread like structures called **hyphae**, the whole mass collectively called **mycelium**. The hyphae are not divided into true cells. Instead the protoplasm is either continuous or is interrupted at intervals by cross walls called **septa** which divide the hyphae into compartments similar to cells. Thus hyphae may be **aseptate** (hyphae without cross walls) or **septate** (hyphae with cross walls). When aseptate they are **coenocytic** containing many nuclei. Each hypha has a thin rigid wall, whose chief component is chitin, a nitrogen containing polysaccharide also found in the exoskeleton of arthropods. Within the cytoplasm the usual eukaryotic organelles are found such as mitochondria, golgi-apparatus, endoplasmic

reticulum, ribosomes and vacuoles. In the older parts, vacuoles are large and cytoplasm is confined to a thin peripheral layer.

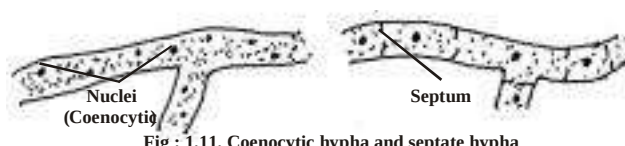


Fig : 1.11. Coenocytic hypha and septate hypha

aseptate hypha

septate hypha

Nutrition

Fungi are heterotrophic in their mode of nutrition that is they require an organic source of carbon. In addition they require a source of nitrogen, usually organic substances such as amino acids. The nutrition of fungi can be described as **absorptive** because they absorb nutrients directly from outside their bodies. This is in contrast to animals which normally ingest food and then digest it within their bodies before absorption takes place. With fungi, digestion is external using extracellular enzymes. Fungi obtain their nutrients as saprotrophs, parasites or symbionts.

Saprotrophs

A saprotroph is an organism that obtains its food from dead and decaying matter. It secretes enzymes on to the organic matter so that digestion is outside the organism. Soluble products of digestion are absorbed and assimilated within the body of the saprotroph.

Saprotrophic fungi and bacteria constitute the **decomposers** and are essential in bringing about decay and recycling of nutrients. They produce **humus** from animal and plant remains. Humus, a part of soil, is a layer of decayed organic matter containing many nutrients. Some important fungi are the few species that secrete cellulase which breaks down cellulose. Cellulose being an important structural component of plant cell walls, rotting of wood and other plant remains is achieved by these decomposers secreting cellulases.

Parasites

A parasite is an organism that lives in or on another organism, the host from which it obtains its food and shelter. The host usually belongs to a different species and suffers harm from the parasite. Parasites which cause diseases are called **pathogens**. Some parasites can survive and grow only in living cells and are called **biotrophs** or **Obligate Parasites**. Others can infect their host and bring about its death and then live saprotrophically on the remains, they are called **necrotrophs** or **facultative**

parasites. Fungal parasites may be facultative or obligate and more commonly attack plants than animals. The hyphae penetrate through stomata, or enter directly through the cuticle or epidermis or through wounds of plants. Inside the plant hosts, the hyphae branch profusely between cells, sometimes producing pectinases(enzymes) which digest the middle lamellae of the cell walls. Subsequently the cells may be killed with the aid of toxins and cellulases which digest the cell walls. Cell constituents may be absorbed directly or digested by the secretion of further fungal enzymes.

Obligate parasites often possess specialized penetration and absorption devices called **haustoria**. Each haustorium is a modified hyphal outgrowth with a large surface area which pushes into living cells without breaking their plasma membrane and without killing them. Haustoria are rarely produced by facultative parasites.

Symbiosis :

Two important types of symbiotic union are made by fungi.

1. Lichens and 2. Mycorrhizae.

Lichens

They are symbiotic association found between **algae** and **fungi**. The alga is usually a green alga or blue green alga. The fungus is an ascomycete or basidiomycete. It is believed that the alga contributes organic food from photosynthesis and the fungus is able to absorb water and mineral salts. The fungus can also conserve water and this enables some lichens to grow in extreme dry conditions where no other plants can exist.

Mycorrhizae

These are symbiotic associations between a fungus partner and roots of higher plants. Most land plants enter into this kind of relationship with soil fungi. The fungus may form a sheath around the center of the root (an **ectotrophic mycorrhiza**) or may penetrate the host tissue (an **endotrophic mycorrhiza**). The former type is found in many forest trees such as conifers, beech and oak and involve the fungi of the division **basidiomycetes**. The fungus receives carbohydrates and vitamins from the tree and in return breaks down proteins of the soil humus to amino acids which can be absorbed and utilized by the plant. In addition the fungus provides a greater surface area for absorption of ions such as phosphates.

Classification of Fungi

Traditionally fungi have been regarded as plants. At one time fungi were given the status of a class and together with the class algae formed the division

Thallophyta of the Plant Kingdom. The thallophyta were those plants whose bodies could be described as **thalli**. A thallus is a body, often flat, which is not differentiated into true roots, stem and leaves and lack a true vascular system. A modification of the scheme of classification of fungi proposed by **Ainsworth(1973)** and adopted by **Webster(1980)** is outlined below.

Myxomycota: They are fungi that lack cell wall and are quite unusual organisms. Possess either a plasmodium, a mass of naked, multinucleate protoplasm, which feeds by ingesting particulate matter and shows amoeboid movement, or pseudoplasmodium, an aggregation of separate amoeboid cells. Both are of a slimy consistency, hence they are also called “Slime moulds”. It includes three classes.

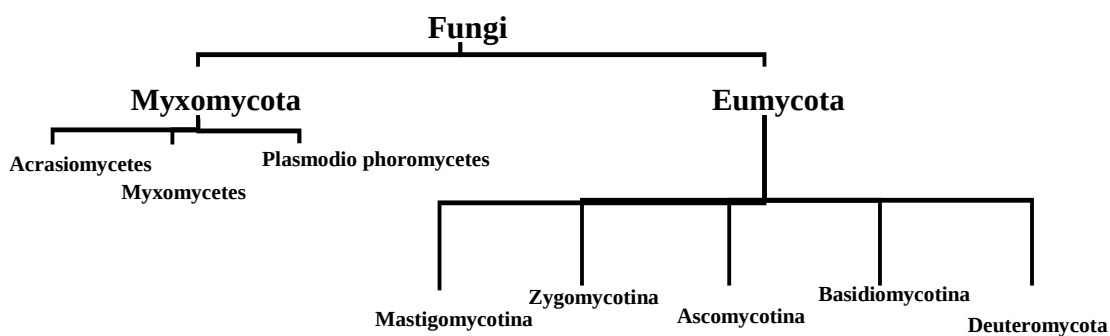


Fig.1.12.Classification of Fungi by Ainsworth

Eumycota:
They are True fungi, all with cell wall. It includes 5 phyla as follow:

- A. **Mastigomycota:** These are zoosporic fungi, many are solely aquatic. Three classes are included in this, each characterized by their distinctive type of zoospores.
- B. **Zygomycota:** Vegetative body haplophase. Asexual spores are non-motile spores. Sexual reproduction takes place by the complete fusion of two multi-nucleate gametangia producing a zygospore. Because of this the fungi of the class zygomycetes are also known as conjugation fungi. Cell wall is made up of chitin and chitosan. It includes two classes.

The common **black, bread moulds** *Rhizopus* and *Mucor* belong to this group.

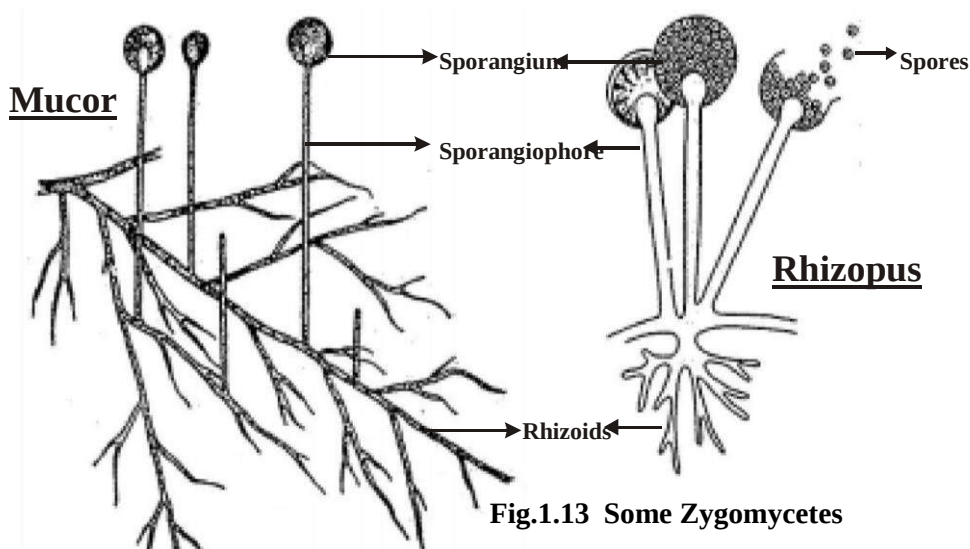
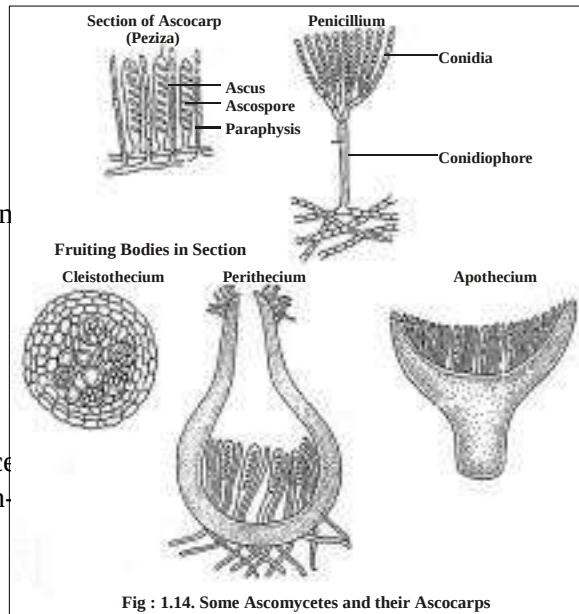


Fig.1.13 Some Zygomycetes

Rhizopus is a very common saprotroph similar in appearance to *Mucor*, but more widespread.

C. Ascomycota:

Hyphae are septate, vegetative body is haplophase. It has five classes. This subdivision includes forms such as yeasts, brown moulds, green moulds, pink moulds, cup fungi, and edible morels. In this group of fungi asexual reproduction takes place by various types of non-motile spores such as oidia, chlamydo spores and conidia. Sexual



reproduction takes place by means of gametangial copulation (yeasts). gametangial contact (***Penicillium***) and by somatogamy (***Morchella***). The ascomycetes or sac fungi are characterized by the development of spores called **ascospores**. These ascospores are enclosed in a sac like structure, the **ascus**. In primitive ascomycetes the asci occur singly. In advanced ascomycetes, groups of asci get aggregated to form compact fruiting bodies called the **ascocarps**.

The ascocarps are of three types.

1. Cleistotheecium:

These are closed and spherical ascocarps. eg. ***Eurotium***

2. Peritheecium:

These are flask shaped ascocarps. eg. ***Neurospora***.

3. Apothecium :

These are cup shaped ascocarps. eg. ***Peziza***.

D. Basidiomycota:

It includes three classes. Hyphae are septate, vegetative body is dikaryophase. It includes the highly evolved fungi. This group got its name from the **basidium**, the club shaped structure formed at the tip of the reproductive hypha. Each basidium bears four **basidiospores** at its tip. Large reproductive structures or fruiting bodies called **basidiocarps** are produced in this group of fungi. Common examples for basidiomycetes include mushrooms, toadstools, puffballs and bracket fungi . The mycelia of this group are of two types. Primary and secondary. Primary mycelium

multiplies by oidia, conidia like spores and pycnidiospores. Distinct sex organs are absent. Fusion occurs between two basidiospores or between two hyphal cells of primary mycelia. Advanced forms of basidiomycetes produce fruiting bodies called **basidiocarps**. Fruiting bodies vary in size from small microscopic to large ones.

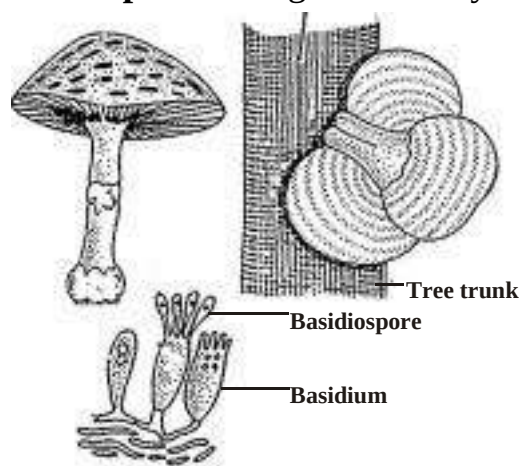


Fig : 1.15. Some Basidiomycetes and their Basidiocarps

E.Deuteromycota:

Three classes are included under this. They are the so-called “**Fungi Imperfecti**”. It is a group of fungi known only from their asexual (imperfect or anamorphic) or mycelial state. Their sexual (perfect or teleomorphic) states are either unknown or may possibly be lacking altogether.

Economic importance of Fungi

Fungi are useful to mankind in many ways. These organisms play an important role in medicine, agriculture and industry. They have harmful effects also.

Useful aspects of fungi

The antibiotic **Penicillin** was discovered in 1928 by **Alexander Fleming** of Britain from the fungus **Penicillium notatum**, which in 1940s emerged as a ‘**wonder drug**’ for the treatment of bacterial diseases. It gave another important ‘**niche**’ to fungi in the realm of biological sciences as producers of antibiotics. Many other important antibiotics are produced by moulds

Many fungi such as yeast, mushrooms, truffles, morels etc., are edible. Edible mushrooms contain proteins and vitamins. Certain species of **Agaricus** such as **A. Bisporus**, **A. arvensis** are edible. **Volvariella volvacea** and **V. dispora** are also edible mushrooms cultivated commercially.

Brewing and baking industries rely heavily on the uses of **yeast (saccharomyces)**. Yeasts ferment sugar solution into alcohol and carbon-di oxide. Alcohol is used in brewing industry and CO₂ in baking industry.

The '**biochemical genetics**' which later developed into the fascinating '**molecular biology**' was founded by studies with **Neurospora crassa**, a fungus which even dethroned **Drosophila** from the Kingdom of genetics as this fungus was especially suited for genetical analysis. Fungi like **Neurospora** and **Aspergillus** continue to be important organisms studied in genetics.

"Without fungi even death will be incomplete" said Pasteur. The dead cellulosic vegetation is decomposed into carbon and minerals by the saprotrophic fungi and these elements are returned to the same environment from where they were obtained. Thus fungi maintain the carbon and mineral cycles in nature.

Harmful aspects of Fungi

Fungi are great nuisance. They grow on everything from jam to leather and spoil them. **LSD** (d- lysergic acid diethylamide) produced from the fungus ergot (**Claviceps purpurea**) produces hallucinations. Hence this fungus is called "**hallucinogenic fungus**" and has caused greatest damage to the frustrated youth by giving an unreal, extraordinary lightness and hovering sensation.

The association of fungi with several plant diseases has now come to light. The devastating disease called '**late blight of potato**' caused by the fungus **Phytophthora infestans** in Ireland in the year 1845 has resulted in such a disaster that about one million people died of starvation and over 1.5 million people fled to other countries since potato was the staple food of Ireland. Since then '**Plant pathology**' a new science started which deals with diseases of plants caused not only by fungi but also by bacteria, viruses etc.

5. Algae

Significant Features

Algal body shows no differentiation into root, stem or leaf or true tissues. Such a plant body is called **thallus**. They do not have vascular tissues. The sex organs are not surrounded by a layer of sterile cells.

Algae are autotrophic organisms and they have chlorophyll. They are O_2 producing photosynthetic organisms that have evolved in and have exploited an aquatic environment. The study of Algae is known as **Algology** or **phycology**.

Occurrence and Distribution

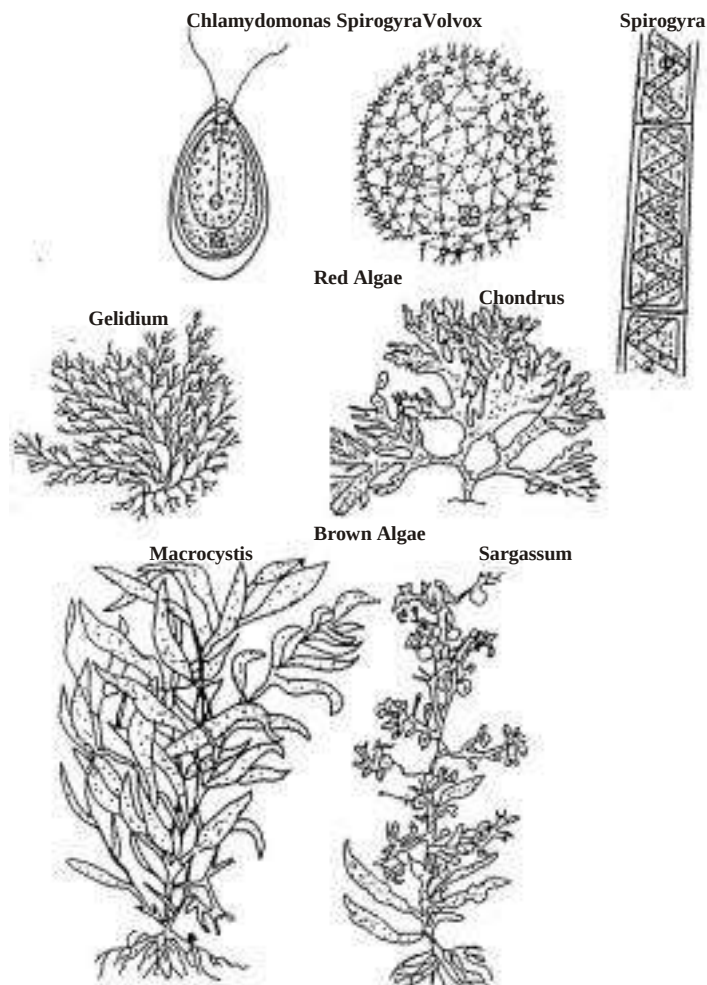
Most of the algae are aquatic either fresh water or marine. Very few are terrestrial. A few genera grow even in extreme condition like thermal springs, glaciers and snow.

The free floating and free swimming minute algae are known as **phytoplanktons**. Species that are found attached to the bottom of shallow water along the edges of seas and lakes are called **Benthic**. Some of the algae exhibit symbiotic association with the higher plants. Some species of algae and fungi are found in association with each other and they are called **Lichens**. A few species of algae are **epiphytes** (i.e they live on another plant or another alga) and some of them are **lithophytes** (i.e they grow attached to rocks)

Thallus organization

The thalli of algae exhibit a great range of variation in structure and organization. It ranges from microscopic unicellular forms to giant seaweeds like **Macrocystis** which measures up to 100 meters long. Some of them form **colonies**, or **filaments**. The unicellular form may be motile as in **Chlamydomonas** or non-motile as in **Chlorella**. Most algae have filamentous thallus. eg. **Spirogyra**. The filaments may be branched. These filamentous form may be free floating or attached to a substratum. Attachment of the filament is usually effected through a simple modification of the basal cell into a **holdfast**. Some of the Algae are macroscopic. eg. **Caulerpa**, **Sargassum**, **Laminaria**, **Fucus** etc. where the plant body is large. In **Macrocystis** it is differentiated into root, stem and leaf like structures.

The chloroplasts of algae present a varied structure. For eg. they are cup shaped in **Chlamydomonas**, ribbon-like in **Spirogyra** and star shaped in **Zygnema**.



Thallus Organization in Algae

Cell Structure & Pigmentation

With the exception of blue green algae which are treated as *Cyanobacteria*, all algae have eukaryotic cell organization. The cell wall is made up of cellulose and pectin. There is a well defined nucleus and membrane bound organelles are found.

Three types of Photosynthetic pigments are seen in algae. They are 1. **Chlorophylls** 2. **Carotenoids** 3. **Biliproteins**. While **chlorophyll a** is universal in all algal classes, **chlorophyll b,c,d,e** are restricted to some classes of algae.

The yellow, orange or red coloured pigments are called **carotenoids**. It includes the carotenes and the Xanthophylls. The water soluble biliproteins called **phycoerythrin** (red) and **phycocyanin** (blue) occur generally in the Rhodophyceae and

Cyanophyceae and the latter is now called ***cyanobacteria***. These pigments absorb sunlight at different wavelengths mainly in blue and red range and help in photosynthesis. Pigmentation in algae is an important criterion for classification.

The colour of the algae is mainly due to the dominance of some of the pigments. For example in red algae(class Rhodophyceae) the red pigment phycoerythrin is dominant over the others. The pigments are located in the membranes of chloroplasts. In each chloroplast one or few spherical bodies called **pyrenoids** are present. They are the centres of starch formation.

Nutrition and reserve food materials in Algae

Algae are autotrophic in their mode of nutrition. The carbohydrate reserves of algae are various forms of starch in different classes of Algae. For example, in Chlorophyceae, the reserve food is **starch** and in Rhodophyceae it is **Floridean starch**, in Phaeophyceae it is **laminarian starch** while in Euglenophyceae it is **paramylon**. Members of Phaeophyceae store **mannitol** in addition to carbohydrate. Members of Xanthophyceae and Bacillariophyceae store **fats, oils** and **lipids**. The nature of reserve food material is also another important criterion used in classification.

Arrangement of Flagella

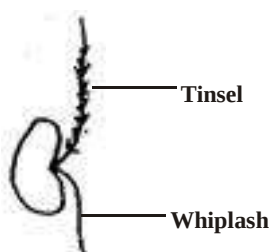


Fig: 1.17. Types of Flagella

Flagella or cilia (sing.flagellum / cilium) are organs of locomotion that occur in a majority of algal classes. There are two types of flagella namely **whiplash** (Acronematic) and **tinsel** (pantonematic).

The whiplash flagellum has a smooth surface while the tinsel flagellum has fine minute hairs along the axis. The number, insertion, pattern and kind of flagella appear to be consistent in each class of algae and it is an important criterion for classification of algae. Motile cells of the Algae are typically biflagellate. When both flagella are of equal length and appearance, they are described as **isokont**. **Heterokont** forms have dissimilar flagella with reference to their length and types. **Red algae(Rhodophyta)** and **Blue green algae(Cyanophyta)** lack flagella. Each flagellum consists of two

central microtubules surrounded by a peripheral layer of nine doublet microtubules. This is called 9+2 pattern of arrangement which is a characteristic feature of eukaryotic flagellum. The entire group of microtubules is surrounded by a membrane.

Reproduction

Three common methods of reproduction found in Algae are

1. Vegetative
2. Asexual and
3. Sexual

Vegetative reproduction

It takes place by fragmentation or by the formation of adventitious branches.

Asexual reproduction:

It takes place by means of different kinds of spores like Zoospores, Aplanospores and Akinetes. Zoospores are naked, flagellated and motile. eg. (*Chlamydomonas*) Aplanospores are thin walled and non motile (eg *Chlorella*) Akinetes are thick walled and non motile spores (eg *Pithophora*)

Sexual Reproduction

Sexual reproduction involves fusion of two gametes. If fusing gametes belong to the same thallus it is called homothallic and if they belong to different thalli it is heterothallic. Fusing gametes may be isogametes or heterogametes.

Isogamy

It is the fusion of two morphologically and physiologically similar gametes. eg. *Spirogyra* and some species of *Chlamydomonas*.

Heterogamy

This refers to the fusion of dissimilar gametes. It is of two types 1. Anisogamy 2. Oogamy

1. **Anisogamy** is the fusion of two gametes which are morphologically dissimilar but physiologically similar (both motile or both non-motile)
2. **Oogamy** refers to the fusion of gametes which are both morphologically and physiologically dissimilar. In this type of fusion the male gamete is usually referred to as **antherozoid** which is usually motile and smaller in size and the female gamete which is usually non-motile and bigger in size is referred to as **egg**. The sex organ which produces the antherozoids is called **antheridium** and the egg is produced in **oogonium**. The fusion product of antherozoid and egg is called **Zygote**. The zygote may germinate directly after meiosis or may produce **meiospores** which in turn will germinate.

Classification

F.E. Fritsch (1944-45) classified algae into 11 classes in his book “**Structure and Reproduction of Algae**” based on the following characteristics.

1. Pigmentation
2. Reserve food
3. Flagellar arrangement
4. Thallus organization
5. Reproduction.

The major groups of Algae and their characteristics are summarized in Table 1.4.

Economic Importance of Algae

Recent estimates show that nearly half the world's productivity that is carbon fixation, comes from the oceans. This is contributed by the algae, the only vegetation in the sea. Algae are vital as primary producers being at the start of most of aquatic food chains.

Algae as Food: Algae are important as a source of food for human beings, domestic animals and fishes. Species of *Porphyra* are eaten in Japan, England and USA. *Ulva*, *Laminaria*, *Sargassum* and *Chlorella* are also used as food in several countries. Sea weeds (*Laminaria*, *Fucus*, *Ascophyllum*) are used as fodder for domestic animals.

Algae in Agriculture: Various blue green algae such as *Oscillatoria*, *Anabaena*, *Nostoc*, *Aulosira* increase the soil fertility by fixing the atmospheric nitrogen. In view of the increasing energy demands and rising costs of chemically making nitrogenous fertilizers, much attention is now being given to nitrogen fixing bacteria and blue green algae. Many species of sea weeds are used as fertilizers in China and Japan.

Table : 1.4. Characteristics of Major Groups of Algae

Class	Pigments	Flagella	Reserve food
Chlorophyceae (green algae)	Chlorophyll-a,b Carotene Xanthophyll	Two identical flagella per cell	Starch
Xanthophyceae	Chlorophyll-a, b Carotene Xanthophyll	Heterokont type, one whiplash type and other tinsel	Fats and Leucosin
Chrysophyceae (diatoms, golden algae)	Chlorophyll-a, b Carotenoids	One,two or more unequal flagella	Oils and Leucosin
Bacillariophyceae	Chlorophyll-a, c Carotenes	Very rare	Leucosin and fats

Cryptophyceae	Chlorophyll-a, c Carotenes and xanthophylls	Heterokont type one tinsel and other whiplash	Starch
Dinophyceae (Dinoflagellates)	Chlorophyll-a, c Carotenoids Xanthophyll	Two unequal lateral flagella in different plane.	Starch and oil
Chloromonadineae	Chlorophyll-a, b Carotenes Xanthophyll	Isokont type	Oil
Euglenophyceae (Euglenoids)	Chlorophyll-a, b	One, two or three anterior flagella.	Fats and paramylon
Phaeophyceae (brown algae)	Chlorophyll-a Xanthophyll	Two dissimilar lateral flagella	Laminarin, fats
Rhodophyceae (Red algae)	Chlorophyll-a Phycocyanin Phycocerythrin	Non-motile	Starch
Myxophyceae	Chlorophyll-a, carotene, phycocyanin, phycocerythrin	Non-motile	Cyanophyce an starch

Algae in Industry

- Agar – agar** : This substance is used as a culture medium while growing bacteria and fungi in the laboratory. It is also used in the preparations of some medicines and cosmetics. It is obtained from the red algae ***Gelidium*** and ***Gracillaria***.
- A phycocolloid **Alginic acid** is obtained from brown algae. Algin is used as emulsifier in ice creams, tooth pastes and cosmetics.
- Idodine**: It is obtained from kelps (brown algae) especially from species of ***Laminaria***.
- Diatomite** : It is a rock-like deposit formed on the siliceous walls of diatoms (algae of **Chrysophyceae**). When they die they sediment, so that on the seabed and lake bottom extensive deposits can be built up over long periods of time. The resulting '**diatomaceous earth**' has a high proportion of silica. Diatomite is used as a fire proof material and also as an absorbent.

It is used in sound and fire proof rooms. It is also used in packing of corrosive materials and also in the manufacture of dynamite.

Algae in space travel: ***Chlorella pyrenoidosa*** is used in space travel to get rid of CO₂ and other body wastes. The algae multiplies rapidly and utilizes the CO₂ and

liberate O_2 during photosynthesis. It decomposes human urine and faeces to get N_2 for protein synthesis.

Single cell protein (SCP): *Chlorella* and *Spirulina* which are unicellular algae are rich in protein and they are used as protein source. Besides, *Chlorella* is a source of vitamin also. The rich protein and amino acid content of *chlorella* and *Spirulina* make them ideal for single cell protein production. An antibiotic **Chlorellin** is extracted from *Chlorella*.

Sewage Disposal: Algae like *Chlorella* are grown in large shallow tanks, containing sewage. These algae produce abundant oxygen by rapid photosynthesis. Microorganisms like aerobic bacteria use these oxygen and decompose the organic matter and thus the sewage gets purified.

6. Bryophytes

There are fossil records of blue green algae (Cyanobacteria) living 3000 million years ago and many eukaryotic organisms have existed for more than 1000 million years. However the first organisms to colonize the land, primitive plants did so only 420 million years ago. The greatest simple problem to overcome in making the transition from water to land is that of desiccation. Any plant not protected in some way, for example, by a waxy cuticle, will tend to dry out and die very soon.

Salient features of Bryophyta

Bryophyta are the simplest group of land plants. They are relatively poorly adapted to life on land, so they are mainly confined to damp, shady places. These are **terrestrial non-vascular plants** (no vascular tissue namely xylem and phloem) which still require moist environment to complete their life-cycle. Hence these are called **amphibians** of plant kingdom. They are more advanced than algae in that they develop special organs. The male sex organ is called **antheridium** and the female sex organ is called **archegonium**. Bryophytes show distinct alternation of generation in their life cycles. Bryophytes include mosses, liverworts and hornworts.

Distinguishing features of Bryophytes

1. They are small terrestrial plants.
2. They are without a distinct root system but are attached to the substratum by means of thin, filamentous outgrowth of the thallus called rhizoids.
3. Water and mineral salts can be absorbed by the whole surface of the plant body, including the rhizoids. So the main function of rhizoids is anchorage, unlike true

roots (true roots also possess vascular tissues, as do true stems and leaves). Thus the “stems” and “leaves” found in some Bryophytes are not homologous with stems and leaves of vascular plants. The plant body is called thallus.

4. They do not possess true vascular tissues.
5. Male sex organ is called antheridium and female sex organ is called archegonium.
6. Sex organs are multi-cellular and they have a protective jacket layer of sterile cells.
7. Sexual reproduction is of oogamous type.
8. Bryophytes show distinct alternation of gametophytic generation with sporophytic generation.
9. Gametophyte generation is dominant and independent.
10. Sporophyte generation is very small, microscopic and dependent on the gametophyte phase.

Alternation of Generations

In common with all land plants and some advanced algae such as *Laminaria*, bryophytes exhibit alternation of generations. Two types of organism, a **haploid gametophyte** generation and a **diploid sporophyte** generation, alternate in the life cycle. The cycle is summarized in the fig below.

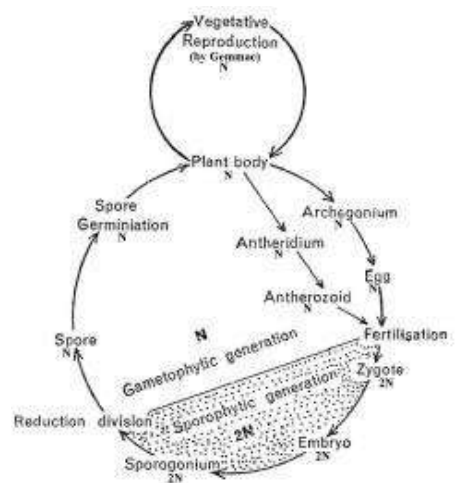


Fig : 1.18. Generalised life cycle of a Bryophyte plant showing alternation of generations

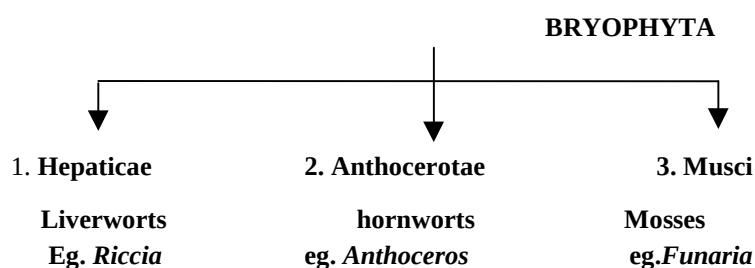
The haploid generation is called the gametophyte because it undergoes sexual reproduction to produce gametes. Production of gametes involves **mitosis**, so the gametes are also haploid. The gametes fuse to form a **diploid zygote** which grows into the next generation, the diploid sporophyte generation. It is called sporophyte because it undergoes asexual reproduction to produce spores.

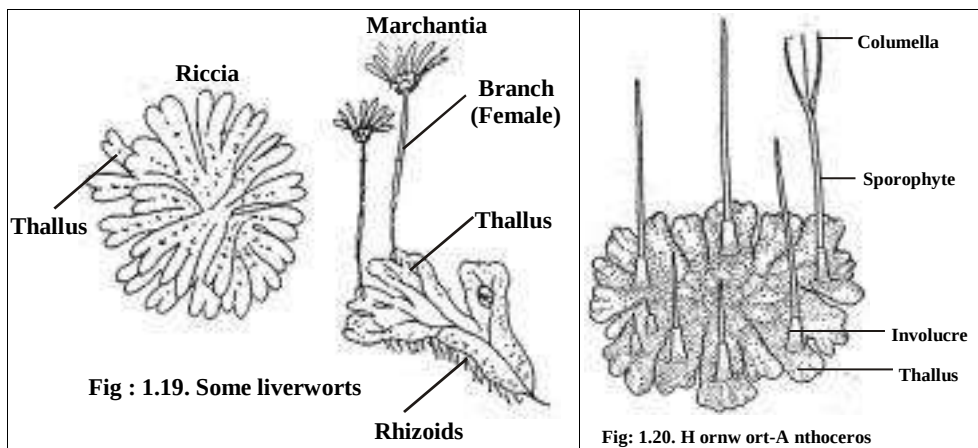
Production of spores involves **meiosis**, so that there is a return to the haploid condition. The haploid spores give rise to the gametophyte generation.

One of the two generations is always more conspicuous and occupies a greater proportion of the life cycle. This generation is called as the dominant generation. **In all Bryophytes the gametophyte generation is dominant. In all other land plants the sporophyte generation is dominant.** It is customary to place the dominant generation in the top half of the life cycle diagram. The figure given above summarises the life cycle of a typical Bryophyte. One point that must be remembered here is that gamete production involves mitosis and not meiosis as in animals. Meiosis occurs before the production of spores.

Classification

Bryophyta is divided into three major classes.





1. Class Hepaticae

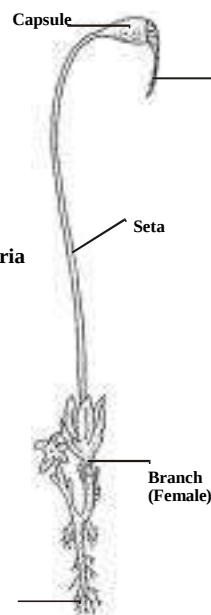
These are lower forms of Bryophytes. They are more simple in structure than mosses and more confined to damp and shady habitats. They have an undifferentiated thallus. Protonemal stage is absent. Sporophyte is very simple and short lived. In some forms sporophyte is differentiated into foot, seta and capsule. Eg. *Marchantia*. In some the foot and seta are absent. Eg. *Riccia*.

2. Class Anthocerotae

Gametophyte is undifferentiated thallus. and unbranched. Protonemal stage is absent. Sporophyte is differentiated into foot and capsule and no seta.

3. Class Musci

They have a more differentiated structure than liverworts. They often form dense cushions. These are higher forms in which the gametophyte is 'stem' like and 'leaf' like parts and the former showing radial symmetry. Rhizoids are multi-cellular and protonemal stage is present. Sporophyte is differentiated into foot, seta and capsule Eg. *Funaria*.



Rhizoids are unicellular. Sporophyte is differentiated into foot, seta and capsule. Eg. *Anthoceros*.

than liverworts. They

are differentiated into 'stem' like and 'leaf' like parts and the former showing radial symmetry. Protonemal stage is present. Sporophyte is differentiated into foot, seta and capsule.

Economic Importance

1. Bryophytes form dense mat over the soil and prevent soil erosion.
2. **Sphagnum** can absorb large amount of water. It is extensively used by gardeners in nursery to keep seedlings and cut plant parts moist during propagation.
3. Peat is a valuable fuel like coal. Mosses like *Sphagnum* which got compacted and fossilized over the past thousands of years have become peat.
4. Mosses are good sources of animal food in rocky areas.

7. Pteridophytes

This division includes club mosses, horsetails and ferns. The oldest known pteridophytes are fossils from the end of the silurian period, 380 million years ago. Pteridophyta constitutes the earliest known vascular plants. Vascular plants are those plants that contain the vascular tissue that is the conducting tissues of xylem and phloem. Sometimes all vascular plants are included in one division the **Tracheophyta**. This is to emphasise the advance nature of vascular tissue over the simple conducting cells of some Bryophytes and Algae. Tracheophyta includes **pteridophytes** and the more advanced **spermatophytes** (seed bearing plants) as two subdivisions.

Presence of vascular tissue is a feature of the sporophyte generation, which in the bryophytes is small and dependent on the gametophyte. The occurrence of vascular tissue in the the sporophyte is one reason why sporophyte generation has become the dominant one in all vascular plants. The vascular tissue of pteridophytes shows certain primitive features compared with flowering plants. The xylem of pteridophytes contains only tracheids rather than vessels and the phloem contains sieve cells rather than sieve tubes.

Vascular tissue has two important roles to perform. Firstly it forms a transport system, conducting water and food around the multi- cellular body, thus leading to the development of large, complex bodies. Secondly, xylem, one of the vascular tissues, supports these large bodies since xylem contains lignified cells of great strength and rigidity.

Significant features of Pteridophytes

Pteridophytes are the **vascular Cryptogams**. They are **seedless** and they are the simplest plants among the Tracheophytes (Plants having vascular tissues). Pteridophytes were world wide in distribution and abundant in the geological past. Today, they are best represented by the **ferns**. The non-fern pteridophytes are comparatively less in number. These plants are mostly small and herbaceous. They grow well in moist, cool and shady places where water is available.

Distinguishing characters of Pteridophytes

1. The life cycle shows distinct heteromorphic alternation of generation.
2. Plant body of Sporophyte is dominant phase.
3. Sporophyte is differentiated into true root, stem and leaves.
4. Vascular tissue i.e xylem and phloem are present. Xylem lacks vessels but tracheids are present. In phloem sieve tubes and companion cells are absent.
5. Asexual reproduction takes place by spores.
6. Most pteridophytes are **homosporous** i.e they produce one type of spores. A few show **heterospory** i.e they produce two types of spores **microspores** and **megaspores**.
7. Spores are produced from spore mother cells after meiosis in multi-cellular sporangia.
8. Sporangia bearing leaves are called **sporophylls**.
9. Spores on germination develop into gametophyte which is haploid, multi-cellular, green and an independent structure.

The gametophyte develops multi- cellular sex organs. The male sex

organ is called **antheridium** and the female sex organ is called **archegonium**.

11. Sex organs have a sterile jacket.
12. Antherozoids are spirally coiled and multiflagellate.
13. Fertilization takes place inside archegonium.
14. Opening of sex organs and transfer of male gametes to archegonium for fertilization are dependent on water.
15. Fertilized egg i.e zygote develops into embryo.

Some common examples of microphyllous pteridophytes are ***Psilotum***, ***Lycopodium***, ***Selaginella***, ***Isoetes***, ***Equisetum*** etc.

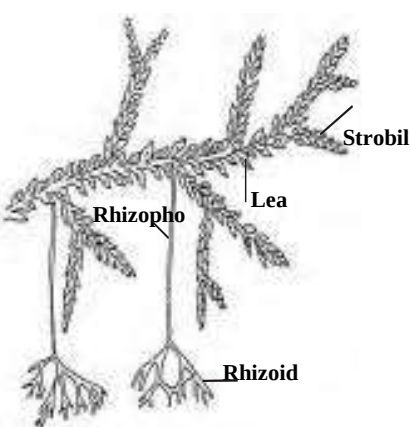
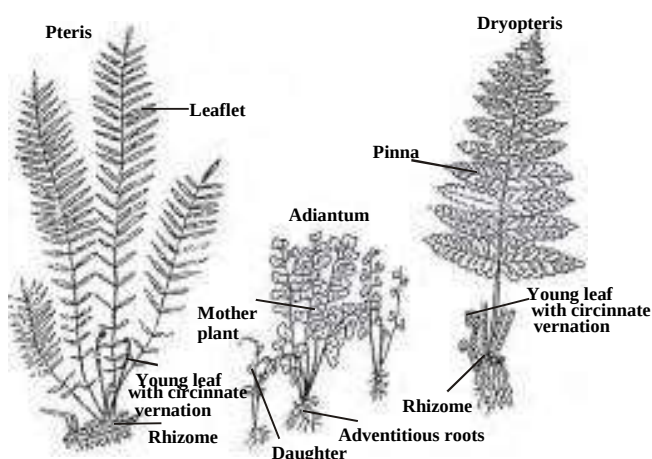


Fig: 1.22. Microphyllous Pteridophyte -



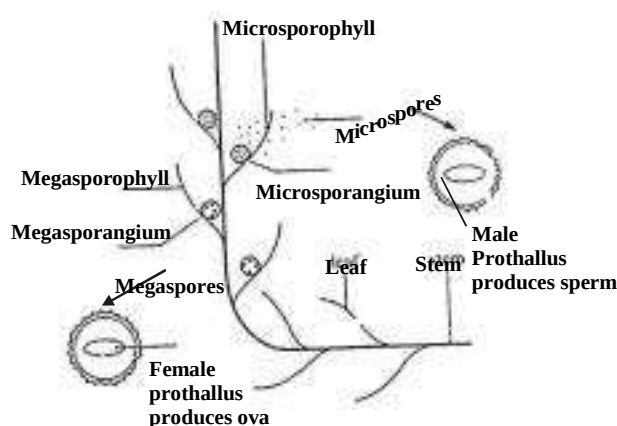
Ferns represent a more specialized group of higher pteridophytes with larger leaves (**megaphyllous**). They are world wide in distribution and grow luxuriantly in forests, mountains, valleys etc. Some common examples of ferns are *Nephrolepis*, *Ophioglossum*, *Osmunda*, *Pteris*, *Adiantum*, *Marsilea*, *Azolla*, *Salvinia* etc.

Characteristics of Pteridophytes

Heterospory

In some pteridophytes the gametophyte is protected by remaining in the spores of the previous sporophyte generation. In such cases there are two types of spore and the plants are therefore described as **heterosporous**. Plants producing only one type of spore, like the Bryophytes, are described as **homosporous**.

Diagram atic representation of heterospory



In heterosporous plants two types of spores are produced. 1. large spores called **megaspores** and 2. small spores called **microspores**. Megaspores give rise to **female gametophytes** (prothalli). Female gametophyte bears the female sex organs namely archegonia. The microspores give rise to **male gametophytes** (Prothalli). This bears the male sex organs namely antheridia. Sperms (antherozoids) produced by the antheridia travel to the female sex organ namely archegonium found in female gametophyte. Both male and female gametophytes remain protected inside their respective spores. The microspore is small and they are produced in large numbers and they are dispersed by wind from the parent sporophyte, the male gametophyte that the microspore contains within is therefore dispersed with it. The evolution of heterospory is an important step towards the evolution of seed bearing plants.

Economic importance of pteridophytes

1. Ferns are grown as ornamental plants for their beautiful fronds.
2. The rhizomes and petioles of the fern *Dryopteris* yield a vermifuge drug.
3. The sporocarps of *Marsilea* (a water fern) are used as food by certain tribal people.

8. Spermatophytes (Gymnosperms)

The most successful and advanced group of land plants are the **spermatophytes (sperma – seed)**. One of the main problems that had to be faced by plants living on land was the vulnerability of their gametophyte generation. For example in ferns the gametophyte is a delicate prothallus and it produces the male gametes (sperms) which are dependent on water for swimming to reach the female gamete in archegonia. In seed plants, however, the gametophyte generation is protected and very much reduced. Three important developments have been made by seed plants.

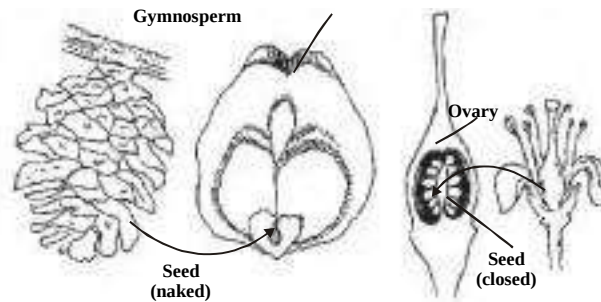
1. **The development of heterospory.**
2. **The development of seeds.**
3. **The development of non-swimming male gametes.**

Table : 1.5. Differences between class Gymnospermae & Angiospermae

Class Gymnospermae (Cycads Conifers, and Ginkgos)	Class Angiospermae (flowering plants)
1. No vessels in xylem, only tracheids(except Gnetales) no companion cells in phloem.	xylem has vessels, phloem contains companion cells
2. Usually have cones on which sporangia and spores develop.	Produce flowers in which sporangia and spores develop
3. Seeds are naked that is the seeds are exposed; they are not enclosed in ovary.	Seeds are enclosed in ovary.
4. No fruit because no ovary	After fertilization, ovary develops into fruit.

Classification and Characteristic of Spermatophytes

Division : Spermatophyta (seed bearing plants)



General Characteristics

Seeds of Gymnosperm and Angiosperm compared

Heterosporous– microspore = pollen grain, megaspore = embryo sac. The embryo sac remains completely enclosed in the ovule; a fertilized ovule is a seed. Sporophyte is the dominant generation, gametophyte is very much reduced. Water is not needed for sexual reproduction because male gametes do not swim, complex vascular tissues in roots, stem and leaves are present. It includes two classes namely Gymnospermae and angiospermae.

GYMNOSPERMS

Significant features of Gymnosperms

G y m n o s p e r m s represent a primitive group of seed bearing plants (Spermatophytes) in which the **seeds are naked** i.e. they are not covered by the fruit wall as in Angiosperms (The word **Gymnos** means naked and **spermos** means seed) This is because in Gymnosperms the ovules are exposed and they are not covered by ovary. Instead the ovules are borne directly on open carpellary leaves called megasporophylls and hence they are naked and they develop into naked seeds after fertilization.

Gymnosperms were most abundant during the Mesozoic era (225 million years) ago. However, they form only a small part of the present day vegetation. There are about 70 genera and 900 species of gymnosperms distributed in tropical and temperate regions. Most of them are Conifers mostly evergreen, with needle like leaves. They are found in the form of **coniferous forests** in the Himalayas in the Indian sub-continent. The common conifers are species of **pine, fir, spruce, Cedar, Cupressus, Sequoia gigantia**, (red wood tree which measures more than 100 meters in height).

Distinguishing features of Gymnosperms

1. Gymnosperms are woody perennial which are mainly trees and rarely shrubs.
2. The life cycle of gymnosperms shows **heteromorphic** alternation of generations.

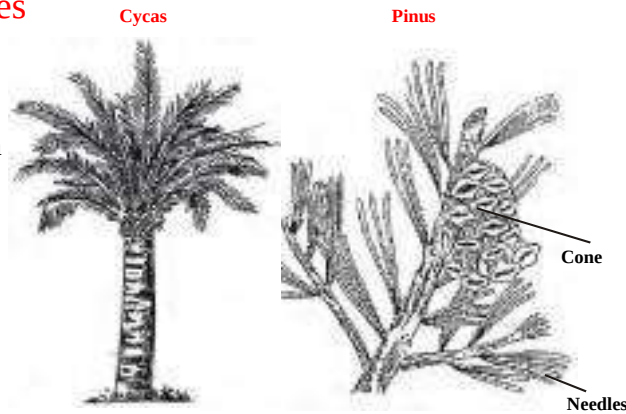


Fig : 1.26. Gymnosperms

3. They form an intermediate group between pteridophytes and Angiosperms i.e they are more advanced than pteridophytes but are primitive than angiosperms.
4. The plant body is the **sporophyte (diploid)** mostly a tree with well developed roots, stem and leaves.
5. The sporophyte bears two types of fertile leaves, the microsporophyll that produces microspores and megasporophyll that produces megaspores.
6. Mostly the spores are grouped into compact **cones** or **strobili**.
7. Spores on germination develop into gametophytes which are very much reduced, microscopic and dependent on sporophyte.
8. Ovules are naked.
9. Pollination is mostly by wind (**anemophilous**).
10. Fertilization involves only one fusion. Female gametophyte provides nutrition to the developing embryo. The endosperm (female gametophyte) is a prefertilization tissue and is haploid.
11. Seeds are naked and not embedded in fruit.
12. Vessels are absent in xylem (except **Gnetales**)

Classification of Gymnosperms

Chamberlain has classified gymnosperms into two classes 1. class **Cycadophyta**
2. Class **Coniferophyta**. The class Cycadophyta consists of plants with simple stem, thick cortex but thin wood and simple sporophylls. The class Coniferophyta consists of plants with profusely branched stem, thin cortex, thick wood and complex sporophylls.

Economic importance of Gymnosperms

1. Woods of many conifers is used in the manufacture of paper. eg. ***Pinus***. Conifers are the source of soft wood for construction, packing and ply wood industry eg. ***Cedrus, Agathis***
2. Turpentine is obtained from the resin of ***Pinus***. It is used as solvent in paint and polishes. It is also used medicinally for pain, bronchitis etc.
3. Seeds of ***Pinus gerardiana*** are edible.
4. **Ephedrine** is an alkaloid obtained from ***Ephedra***. It is used in curing asthma and respiratory problems.
5. Saw dust of conifers is used in making linoleum and plastics.
6. *Pinus* species yield a resin called rosin which is used in water proofing and sealing joints.
7. ***Araucaria*** is an ornamental plant.

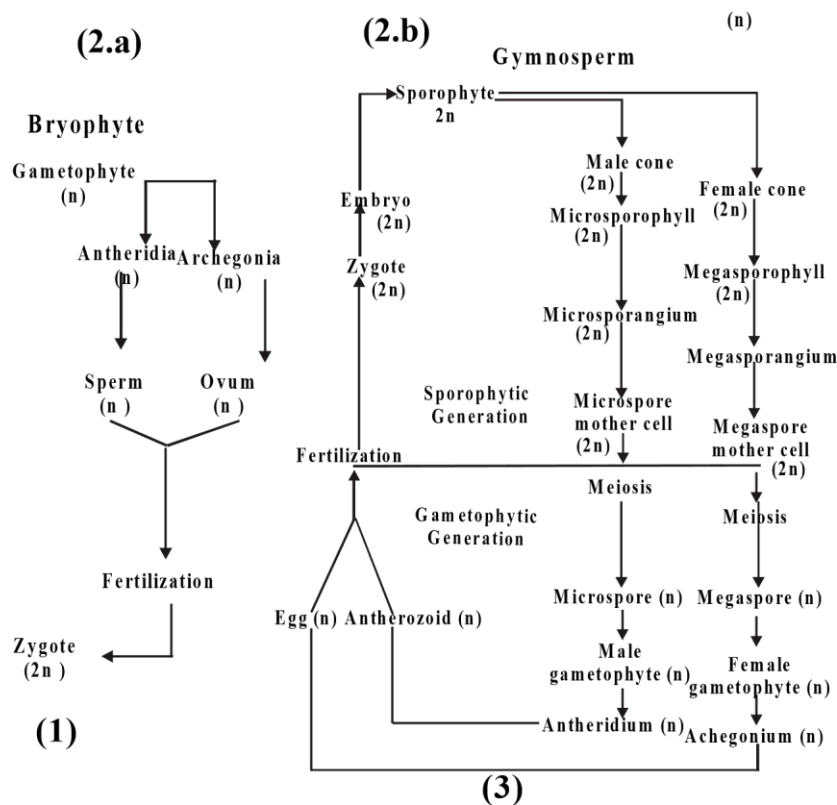


Fig : 1.26. Graphical representation of life cycles of various plant groups.

SELF EVALUATION

Choose the correct answer

1. The basic unit of classification is
a. genus b. species c. family d. taxon
2. Unicellular plants found floating in oceans and freshwater are called
a. A. algae b. zooplanktons c. phytoplanktons d. epiphytes
3. Carolus Linnaeus proposed the following system of classification
a. Phylogenetic b. Two kingdoms c. Five Kingdoms d. Natural

Fill in the blanks

1. "Systema Naturae" is written by _____
2. Father of Ayurveda is _____
3. _____ introduced the term species for the first time.
4. The author of "Species Plantarum" is _____
5. _____ coined the word Taxonomy.

Match the following

Fossil records	- Five kingdom System
Whittaker	- Species
Carolus Linnaeus	- Taxonomy
John Ray	- Phylogenetic studies
Augustin de Candolle	- Species Plantarum

1. Define biodiversity.
2. What are the aims of classification?
3. Define Taxonomy.
4. Define species.
5. Write the hierarchy of the units of classification.
6. Define phylogeny.
7. Give any two reasons why phylogenetic classification is not always possible?
8. What is meant by phylogenetic classification?
9. What is meant by artificial system of classification? Give example.
10. What are Archaeobacteria?
11. Define systematics.

1. List the differences between plants and animals.
2. How do you justify a separate kingdom status for fungi.
3. What are the difficulties encountered in classifying Euglena?

1. Discuss the Five kingdom system of classification. List its merits and demerits. 2. Discuss the Two kingdom system of classification. List its merits and demerits.

Choose the correct answer

1. The chlorophyll pigment found in green sulphur bacteria is
a. bacteriochlorophyll b. bacterioviridin c. phycocyanin d. phycoerythrin
2. Cell which keeps changing its shape is called
a. Spirilla b. Pleomorphic c. Symbiont d. Gram – negative

Fill in the blanks

1. _____ proposed germ theory of disease .
2. _____ bacteria require CO₂ for growth .
3. _____ is a type of movement of cells in response to chemical signals.
4. _____ is not evolved during bacterial photosynthesis.

Two Marks

1. What are commensals?
2. What are Gram-Positive bacteria?
3. What are Gram-Negative bacteria?
4. What are Chemoautotrophs?
5. What is transduction/ transformation.
6. Name any four plant diseases / human diseases caused by bacteria?
7. Give reason: Bacteria are also known as nature's scavengers.
8. Name some antibiotics obtained from bacteria

Five Marks

1. Describe the various steps in Gram's staining procedure?
2. What are the different shapes found in bacteria? Give examples.
3. Describe the various types of flagellation found in bacteria.
4. Discuss the role of bacteria in industry?
5. Discuss the role of bacteria in soil fertility.

Ten Marks

1. Write an essay on sexual reproduction in bacteria.
2. Discuss the economic importance of bacteria.
3. Write an essay on nutrition in bacteria.

One Mark

Choose the correct answer

1. The study of Fungi is called
a. phycology b. plant pathology c. systematics d. mycology
2. The fungal cell wall is made up of
a. chitin b. cellulose c. pectin d. peptidoglycan

Fill in the blanks

1. The storage products of fungi are _____ and _____
2. Haustoria are rarely produced by _____ parasites.

Two Marks

1. What is a coenocytic mycelium?
2. What is meant by septate hypha?
3. Distinguish obligate parasite from facultative parasites.
4. What are haustoria?
5. What are mycorrhizae?
6. Name some fungal diseases of plants.
7. Name some edible fungi.
8. Justify the statement by Pasteur: "Without fungi even death will be incomplete"
9. Which fungus is called hallucinogenic fungus and why? **Five Marks**
1. Write about the symbiotic mode of nutrition as seen in fungi.
2. Give the salient features of the subdivision Ascomycotina / Basidiomycotina / Zygomycotina

Ten Marks

1. Write an essay on the mode of nutrition in fungi.
2. Give a concise account on the economic importance of fungi.

One Mark

Choose the correct answer

1. Phycology is the study of
a. plants b. virus c. Algae d. bacteria

Fill in the blanks

1. _____ is the red colour pigment found in algae.
2. _____ is the blue colour pigment found in algae.
3. _____ algae lack motile cells.

Match

Macroscopic	- Attached to the bottom of shallow water
Epiphyte	- Laminaria
Benthic	- Spirogyra
Lithophyte	- Growing on another plant
Filamentous	- Grow attached to the rocks.

Two Marks

1. Define: thallus
2. What is a Lichen?
3. Name the three types of photosynthetic pigments found in algae?
4. Differentiate a whiplash flagellum from a tinsel flagellum.
5. What are pyrenoids?
6. Differentiate isokont from heterokont type of flagella?
7. Define isogamy / heterogamy/ anisogamy/ oogamy.
8. What is agar-agar?
9. What is diatomite?
10. Write any two uses of diatomite.
11. How are the algae used in space travel?
12. What is SCP?
13. How are algae used in sewage disposal?

14. What is algal bloom. How does it affect the lakes?
15. Algae are not associated with diseases unlike many fungi and bacteria. What is the reason for this?

Five Marks

1. What is eutrophication? What is its significance?
2. Write notes on: Nutrition and reserved food materials in algae.
3. Write about the pigmentation in algae.

Ten Marks

1. Write an essay on the economic importance of algae.
2. Write an essay on reproduction in algae.

One Mark

Fill in the blanks

1. The process of evolution of the seed habit is associated with the origin of _____
2. The dominant phase changed from _____ to _____ as in all Pteridophytes, Gymnosperms and Angiosperms.

Two Marks

1. What is meant by Tracheophyta?
2. Justify: the vascular tissue of pteridophyte is primitive when compared with flowering plants.
3. What are the functions of vascular tissue?
4. What are the advantages of seed development in Phaenerogams?
5. Name any two economically important products of Pteridophytes.

Five Marks

1. What are the salient features of Pteridophytes?
2. What is heterospory? What is its significance?

Ten Marks

1. List the strategies that the plants had to develop in order to survive on land.

One Mark

Fill in the blanks

1. The most successful and advanced group of land plants
2. are _____
3. All seed plants are _____
4. The most extreme reduction of gametophyte has taken place in _____.
5. The equivalent structure to a megasporangium, in a seed plant is called an _____.
6. The equivalent structure to a microsporangium, in a seed plant is called _____

Two Marks

1. Name the three important developments that have been made by the seed plants.
2. Define heterospory.
3. Justify the statement: a seed is a complex structure containing cells from three generations.
4. Why do we call the seeds of gymnosperms as naked?
5. Name the two classes of Gymnospermae.

Five Marks

1. Discuss the advantages associated with seed habit.
2. List the differences between Gymnospermae and Angiospermae.
3. Write the salient features of Gymnosperms.
4. Write about the economic importance of gymnosperms.

Part Two

Plant

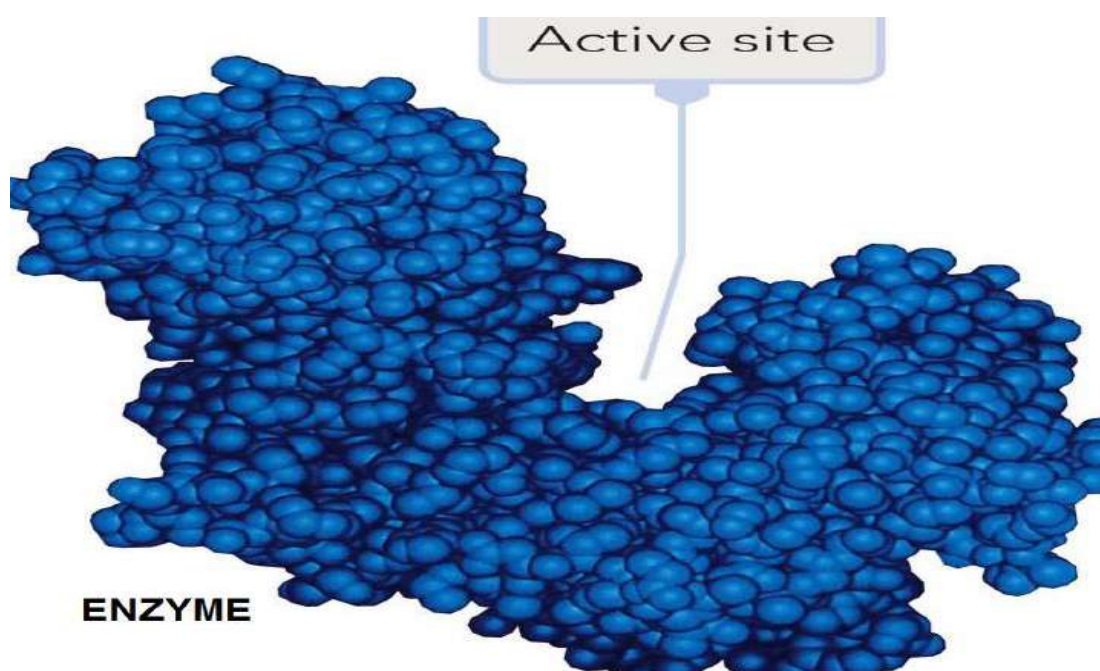
Physiology



Botany and Microbiology department
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Bot.102 1st year Sc

Introduction to Plant Physiology



Prepared and Collected
by
Botany and Microbiology department
(Plant Physiology and Tissue Cultures)

2026

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Introduction

The plant by most definitions: is multicellular; has eukaryotic cells, has cell walls comprised of cellulose, is autotrophic and exhibits alternation

of generations - has a distinctive diploid (sporophyte) and haploid (gametophyte) phase.

The Plant Kingdom includes the angiosperms (flowering plants), gymnosperms (cone-bearing plants), ferns, and bryophytes (mosses & liverworts). Recent classification systems suggest that these organisms, in addition to the red algae and green algae, should be classified in the Plant Kingdom (Plantae).

The plant physiology is the study of: the functions and processes occurring in plants, the vital processes occurring in plants, and how plants work.

In essence, plant physiology is a study of the plant way of life, which include various aspects of the plant lifestyle and survival including: metabolism, water relations, mineral nutrition, development, movement, irritability (response to the environment), organization, growth, and transport processes.

Plant physiology is a lab science, is an experimental science, and relies heavily on chemistry and physics.

Importance of studying of plant physiology:

1. Food - plants are the route by which solar energy enters ecosystems.
2. Economically important products - plants produce countless products from fibers to medicines to wood.
3. Applications to other disciplines (i.e. agriculture, forestry, horticulture).
4. Understanding of plant behavior and performance.
5. Understanding of plant-microorganism relationships.

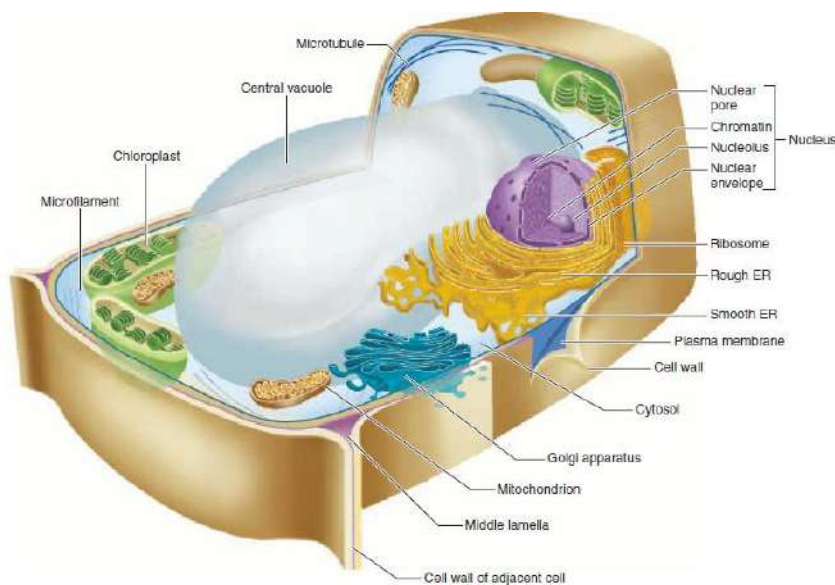
Cell as a Physiological Unit

Plants are made up of structural and functional units called cells. Every cell is made up of several biomolecules and organelles. The organelles are membrane-bound structures involved in specific functions. The plant cell can be referred to as a physiological unit as it has the capabilities of carrying out physiological functions as a single entity.

Plant cell consists of:-

- 1- The cell wall is a permeable, non-living outer limiting layer of the plant cell which provides shape and rigidity to the cell
- 2- plasma membrane or cell membrane ; which lies inward the cell wall; has selectively permeable involved in the absorption of water by osmosis, and other substances like ions and low molecular weight biomolecules.

- 3- The protoplasm which is *the physical basis of life* includes cytoplasm, nucleus and cellular organelles which are involved in the various physiological processes taking place within the cell. The protoplasm is a water retentive colloid holding 90% of water which is a universal solvent.
- 4- The plant cells are characterized by a prominent vacuole holding the cell sap and functioning as an osmo-regulatory organelle of the cell.



Thus the cell is the principal seat of metabolic events and the following examples will explain this meaning:-

Nutrition

Among the cell organelles, the Chloroplast is the most important structure unique to plant cells and involved in the most important physiological process called Photosynthesis. This process is the source of food for life on earth.

Respiration

The organelle of the plant cell involved in cellular respiration is the mitochondrion. This organelle is concerned with the oxidation of food

substances to release CO₂, water and energy in the form of Adenosine Triphosphate (ATP).

Protein Synthesis

The synthesis of proteins and their transport is carried out by the ribosomes and the endoplasmic reticulum.

Secretion

Cell secretion takes place by the organelle called the Golgi body which is referred to as the dictyosome in plants.

The plant is thus able to co-ordinate the physiological activities of the various organelles and behaves as a perfect physiological unit. Thus the cell *is the seat of important physiological functions*.

The Physical Nature of Protoplasm

The protoplasm forms a colloidal system composed of a water phase in which mineral matter is dissolved, also having a protein phase, a fat phase and many minor phases. So it is said to be a polyphase colloidal system.

Colloids

A solution is a mixture of one substance dissolved in another so the properties are the same throughout. A solution is composed of a solute and the solvent. The solute is the *substance being dissolved* and the solvent is the part of the solution that *does the dissolving*. The solute is of molecular size.

According to the diameter of solute particles there are three types of solutions

- 1- **True solution** (diameter less than 1 nm) is always transparent; light passes through with no scattering from solute particles which are molecule in size. The solution is homogeneous and does not settle out. A solution cannot be filtered but can be separated using the process of distillation.
- 2- **Suspension and Emulsion** (diameter larger than 1000 nm) is cloudy and heterogeneous. If the dispersed particles are solid the system is called a suspension, but if it is a liquid, the system is called an emulsion. A suspension larger particle allows them to be filtered. If a suspension is allowed to stand the particles will separate out.

3- Colloid (diameter ranged between 1 nm and 1000 nm) is intermediate between a solution and a suspension. While a suspension will separate out a colloid will not. Colloids can be distinguished from solutions using the Tyndall effect. Light passing through a colloidal dispersion, such as smoky or foggy air, will be reflected by the larger particles and the light beam will be visible. According to the affinity between solute and solvent, there are two types of colloids

a- Lyophilic colloid. In which there is an affinity between solute (dispersed medium) and solvent (dispersion medium), e.g. starch or gelatin in water.

b- Lyophobic colloid. In which there is no affinity between solute (dispersed medium) and solvent (dispersion medium), e.g. clay or ferric chloride in water.

Difference between Lyophobic and Lyophilic.

Property	Lyophilic Colloids	Lyophobic Colloids
Nature	reversible	irreversible
Visibility	non visible	relatively visible
Stability	relatively stable	less stable
Viscosity	more viscous (higher than that of dispersion medium).	less viscous (same as that of dispersion medium).
Tyndall effect	less distinct	more distinct.
Electrophoresis	the particles may or may not show electrophoresis.	the particles show electrophoresis.

Properties of colloidal solution

1- Viscosity

Viscosity is the resistance of fluid to flow, it is decrease with rises of temp. The lyophilic colloids are highly viscous in nature and have higher viscosity than that of the medium. The Lyophobic colloids have almost same viscosity as that of medium.

2- Solation and Gelation (Phase reversal of colloid)

The protoplasm exists mostly as a sol (which is semi-liquid) but sometimes it becomes rigid and is viewed as a gel (which is sem-solid).

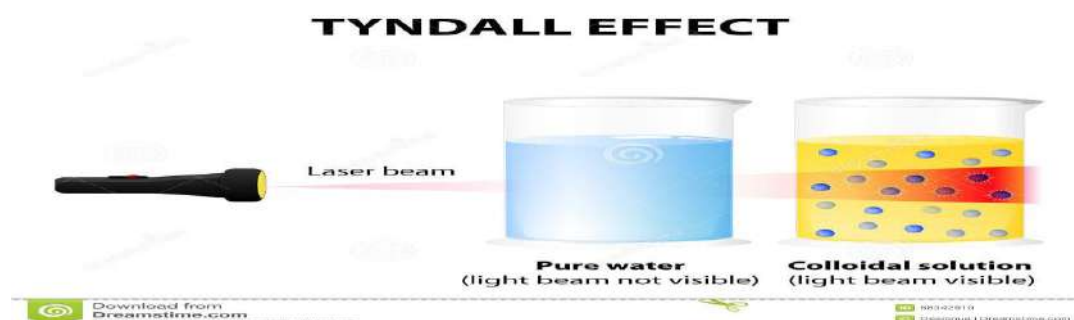
Gelation is the conversion of a sol to a gel while solation is the conversion of a Gel to a Sol. It depends on temperature.

3- Brownian Movement

There are continuous collisions between the colloidal particles and molecules of dispersion medium which are in constant motion and passes kinetic energy to colloidal particles by striking it from all sides. This results into zigzag movement of colloidal particles. This zigzag movement of colloidal particles is known as Brownian movement. The Brownian movement explains the force of gravity acting on colloidal particles. This helps in providing stability to colloidal sols by not allowing them to settle down.

4- Tyndall Effect

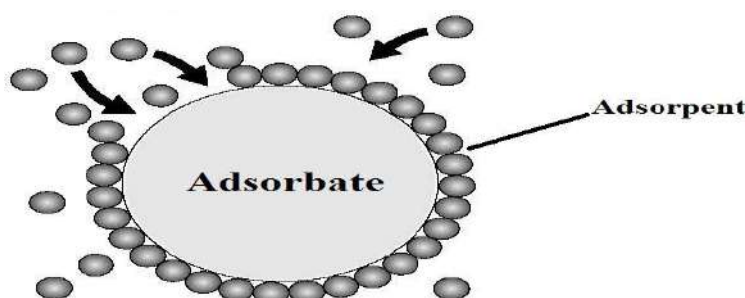
Tyndall observed this phenomenon in 1869. He observed that when a beam of light is allowed to pass through a colloidal solution, the path of light gets illuminated. This phenomenon is known as Tyndall Effect. It occurs because light is scattered by particles present in colloidal solution. The intensity of the scattered light depends on the difference between the refractive indices of the dispersed phase and the dispersion medium. Greater is the difference, greater the intensity of light. In case of lyophilic solution, the colloidal particles are highly solvated, which results into lower difference in refractive index of two phases. In lyophilic solution, Tyndall effect is not pronounced. In case of lyophobic solution, the difference is quite large and it shows Tyndall effect. The Tyndall effect confirms the heterogeneous nature of the colloidal solution. The Tyndall effect has also been observed by an instrument called ultra-microscope.



5- Adsorption

Adsorption is the ability of colloidal particle to attract and collect other molecules to their surface. So colloids are good catalysts. The substance adsorbed on the surface is called adsorbate and the substance on which it

is adsorbed is called adsorbent. The surface where the process takes place is called interface. Adsorption may be mechanical, electrical and chemical.



6- Ultrafiltration

The particles of the protoplasm cannot be filtered through ordinary filter paper but can be filtered through ultra filters such as millipore filters.

7- Electrical Properties

The particles of the colloid carry a uniform electric charge either +ve or -ve. The movement of colloidal particles under the influence of electric field is called Electrophoresis. When an electric field is applied across the colloidal solution, the colloidal particles migrate to oppositely charged electrode where they get neutralized. This phenomenon is known as electrophoresis. The reverse of electrophoresis is called Sedimentation potential or Dorn effect. The sedimentation potential is setup when a particle is forced to move in a resting liquid. This phenomenon was discovered by Dorn and is also called Dorn effect.

8- Flocculation or Co-agulation

When the particles of a colloid lose their charges they tend to aggregate and increase in size. As a result they fall out and get precipitated. In other words protoplasm loses its living property.

Examples of Colloids

Colloids are important chemicals which are used extensively used to produce commercial products. Many familiar products of daily use are examples of colloids. Based on physical state of dispersion medium and dispersed phase, different types and examples of colloids are arranged below. For each state of dispersion medium all possible states of dispersed phase are discussed.

Case 1: Dispersion Medium is Solid

When dispersion medium is solid, the dispersed phase can be solid, liquid or gas. Based on the state of dispersed phase, colloids are called Solid Sols or Gels. Different types of colloids and examples of each type are given below.

Dispersed Medium	Dispersed Phase	Types Of Colloids	Examples of Colloids
Solid	Solid	Solid Sol	Gemstones, Pearls, Some Coloured Glass
Solid	Liquid	Gels	Cheese ,Butter, Jellies, Jam, Shoe Polish
Solid	Gas	Solid Sol	Pumice Stone, Foam Rubber

Case 2: Dispersion Medium is Liquid

When dispersion medium is liquid, the dispersed phase can be solid, liquid or gas. Based on the state of dispersed phase, colloids are called Sols, Emulsions or Foam. Different types of colloids and examples of each type are given below.

Dispersed Medium	Dispersed Phase	Types Of Colloids	Examples of Colloids
Liquid	Solid	Sols	Paints, Gum, Muddy Water
Liquid	Liquid	Emulsion	Milk, Hair Cream, Cod-Liver Oil
Liquid	Gas	Foam	Froth, Soap Lather , Whipped Cream

Case 3: Dispersion Medium is Gas

When dispersion medium is gas, the dispersed phase can be solid or liquid but not the gas.

It is important to note that colloid is a heterogeneous mixture. When gas is mixed with another gas, it forms a completely miscible homogeneous mixture and not a colloidal solution. Though 3 states (solid , liquid or gas) each for dispersed medium and dispersed phase can form 9 (=3+3+3) different combinations, we only have 8 colloidal states. Colloids of gas with dispersed phase as solids or liquids are called Aerosols.

Different types of colloids and examples of each type are given below.

Dispersed Medium	Dispersed Phase	Types Of Colloids	Examples of Colloids
------------------	-----------------	-------------------	----------------------

Gas	Solid	Aerosol	Smoke, Dust
Gas	Liquid	Aerosol	Insecticide Spray, Fog, Clouds



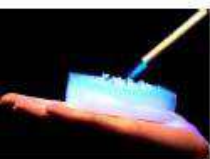
Foams



Milk



Fog, smoke



Aerogel



Blood

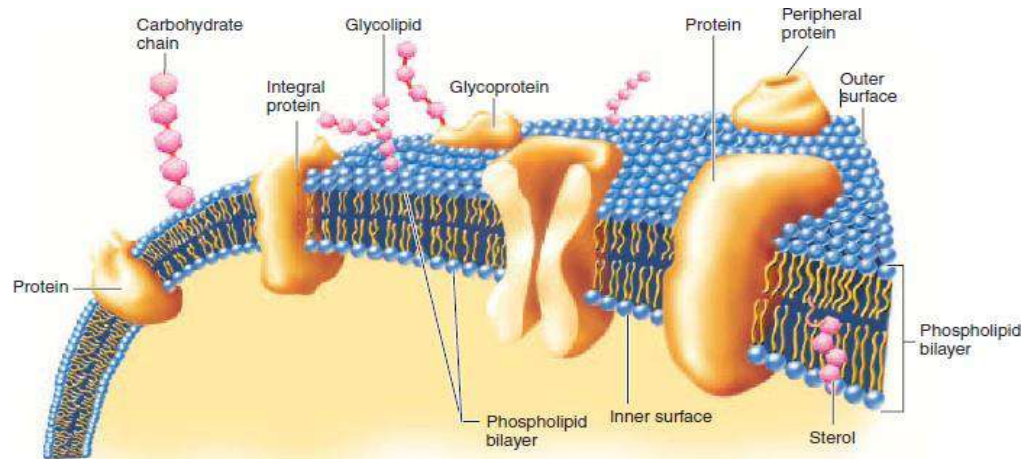


Paints

PERMEABILITY

It is important to remember that cell wall is permeable while cell membranes are selective semi-permeable. That is, while the membrane is permeable to water and impermeable to mannitol or sorbitol, other solutes must be permeant (able to cross the membrane). The property of membrane to allow of passage of substances is known as permeability. Cell wall with upper cutin and superin or other waxy layer is

i m p e r m e a b l e .



Fluid mosaic model of the plasma membrane. The plasma membrane is composed of a phospholipid bilayer with embedded proteins.

So membranes are divide into following type on the basis of permeability.

- 1) Permeable membrane:** - Such membrane permeable for both solute and solvent. e.g. Cellulose cell wall, lignified cell wall, cell wall of bacteria, fungi, diatoms.
- 2) Impermeable membrane:** - Such membrane impermeable for both solute and solvent e.g. cutinized cell wall and subrised cell wall.
- 3) Semipermeable membrane:** - Such membrane allows only diffusion of solvent molecules egg membrane, parchment paper and copper ferrocyanide membrane.
- 4) Selectively permeable membrane:** - Such membrane allows some solute to pass through them along with the solvent molecules e.g. cell membrane, tonoplast (vacuolar membrane) membrane surrounding cell organelles.

Transport across Membrane:-

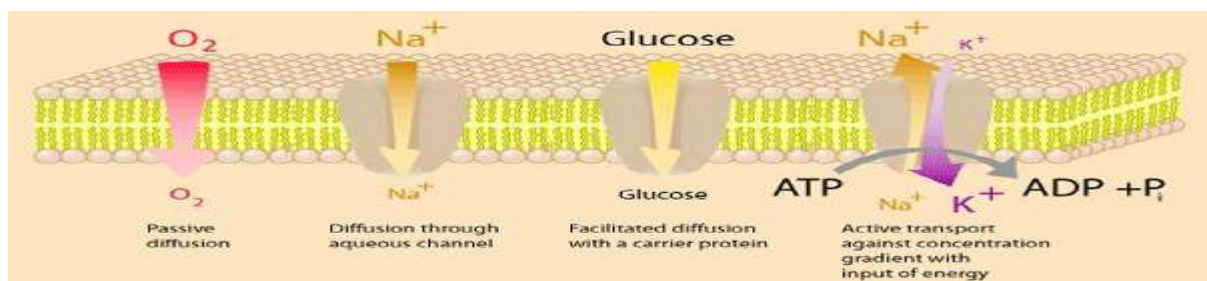
a- Passive Transport:-

Moving molecules according to the concentration gradient, which does not require energy. It includes:

1-Simple Diffusion - water, oxygen and other molecules move from areas of high concentration to areas of low concentration, down a concentration gradient. **2-Facilitation Diffusion**- diffusion that is assisted by proteins (channel or carrier proteins). **3-Osmosis** - diffusion of water solutions.

b- Active Transport:-

Moving molecules against the concentration gradient, which requires energy (ATP).



Factors affecting permeability of plant cells

1- Temperature

Permeability of plasma membrane increases reversibly at temp. up to 40 $^{\circ}C$ gradually because of increasing in kinetic energy of diffused particles and decreasing of the viscosity of protoplasm. Permeability of plasma membrane increases irreversibly at higher temp. than 50 $^{\circ}C$, due to accumulation of components of plasma membrane and finally its rupture.

2-Light

Permeability of plasma membrane increases in light and decreases in darkness because of increasing in kinetic energy of diffused particles. Permeability of plasma membrane increases in short wave length light (as blue or violet) than short wave length light (as red).

3- Alkalies and acids

Permeability of plasma membrane increases reversibly in low concentration of alkalies whereas it decreases in case of acids. Permeability of plasma membrane increases irreversibly in higher conc. of both due to dissolution of plasma membrane and some cell organelles.

4- Anesthetics

Permeability of plasma membrane increases reversibly in low concentration of anesthetics. Permeability of plasma membrane increases irreversibly in higher conc. due to dissolution of lipid of plasma membrane.

5- Carbon dioxide

Permeability of plasma membrane decreases in higher conc. of CO₂. CO₂ dissolves in water forming of carbonic acids giving the same effects of low conc. of acids.

6- Composition of the external dissolved solvent

Salts of monovalent cations as NaCl increase permeability of plasma membrane due to decrease the binding forces of plasma membrane components and its liqification. Salts of divalent cations as CaCl₂ increase permeability of plasma membrane due to increase the binding forces of plasma membrane components and its soldfication. So both cations are harmful to plasma m. when used separately whereas by mixing both cations together one cation antagonize the harmful effect of other (Antagonism) which as the same as in see water. Synergism is opposite to antagonism : the harmful effect of mixed solutions is canceled in case of separated one as sodium citrate and sod. sulphate solns and accelerated by mixing.

Diffusion

Diffusion: It is a random movement of molecules of substance from the region of higher concentration to the region of lower concentration due to their kinetic energy until equilibrium.

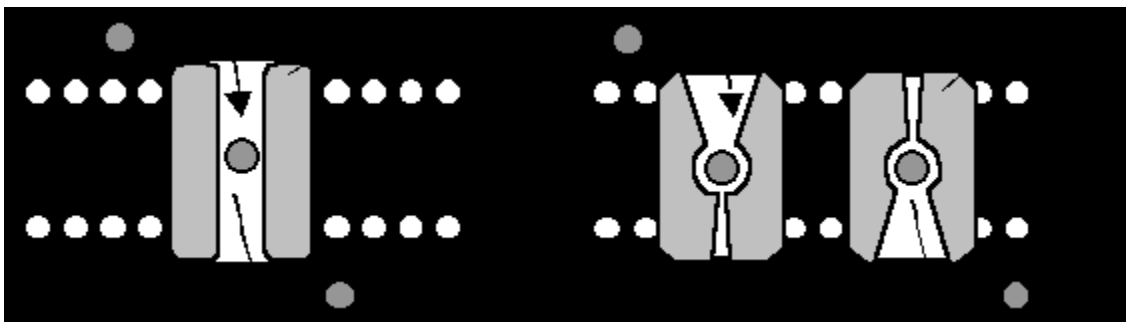
Imagine opening a bottle of perfume containing volatile essential oils in a very, very still room. Initially, the essential oils are concentrated in a corner of the room. As the molecules move randomly, in every different direction, over time they will eventually appear throughout the room. Ultimately the essential oils will reach a point, dynamic equilibrium, at which they are evenly distributed throughout the room. At this point the molecules are still moving. They continue to move randomly in every direction. The only difference is that there is no net change in the overall distribution of the perfume in the room.

Now imagine that the room is divided by a partition with holes (which is analogous to a membrane). If we place a drop of perfume on one side of the partition and then count at intervals the number of essential oil molecules on either side of the partition and graph the results:

We will observe that the number of molecules on one side will decrease while the other will increase until they reach dynamic equilibrium. At equilibrium the molecules continue to move randomly, back and forth from one side of the partition to the other. Hence the number of molecules on either side of the partition at any given time is simply chance. The number oscillates about the midpoint.

Diffusion occurs in fluids (liquids and gases). It does not happen in solids because solids have fixed points and they are held together by the force of attraction which prevents them from moving freely. In liquids and gases however, their molecules are constantly moving randomly and spread through any available space until they are evenly distributed. Diffusion in gases is faster than in liquids. This is because there is almost no force of attraction in gas molecules and this makes gas molecules free to move in every direction.

Facilitated diffusion: Some larger molecules, such as glucose, need help by way of a transport protein to help carry glucose into a cell and this requires no energy.



During the movement of molecules all the molecules collide themselves and produce a pressure in the medium called **diffusion pressure**, which is directly proportional to the concentration and temperature of diffusing molecules. Diffusion pressure of pure water is maximum and when solutes are added in it, diffusion pressure of the solution is reduced.

Importance of diffusion in plants includes: The exchange of O_2 and CO_2 in the atmosphere through stomata, and during stomata transpiration the water vapors from intercellular spaces diffuse in the atmosphere through stomata.

Factors influencing the rate of diffusion

1-Size and mass of diffusing particles:

The rate of diffusion is inversely proportional to the size and mass of the diffusing particles. *for examples: H and Cl^- mol. diffuse faster than glucose and Fe^{+3} .*

2- Concentration Gradient:

As previously stated, solutes move from an area of high concentration to one of lower concentration; in other words, in response to a concentration gradient (ΔC). Although this is true for most solutes, it is not important for water. The concentration of water ($55.2 - 55.5 \text{ mol L}^{-1}$) is nearly constant under all conditions (*i.e.*, $MW = 18 \text{ g/mol}$, and 1000 g/liter ; thus, $1000/18 = 55.5 \text{ mol/L}$).

Fick's Law - is an equation that relates the rate of diffusion to the concentration gradient ($Conc1 - Conc2$) and resistance or length (r or l). Diffusion rate, also called flux density (J_s , in units of $\text{mol m}^{-2} \text{ s}^{-1}$) can be expressed in the simplified version of Fick's equation as:

$$\text{Diffusion rate or } J_s = (C1 - C2) / r \text{ or } l$$

The take lessons from this equation are that:

1. the rate of diffusion is directly proportional to the concentration gradient.
2. the rate of diffusion is indirectly proportional to resistance; and

3. the rate of diffusion is inversely proportional to distance traveled (also a function of resistance).

3-Molecular weight and density:

Rate of diffusion is inversely related to square root of molecular weight (MW) and relative density (RD).

$$\text{diffusion rate} = 1 / \sqrt{\text{MW or RD.}}$$

RD of gases = MW of certain volume of this gas/ MW of same volume of H₂ gas

Independent diffusion of mixed substances is depend on the difference in conc. of the diffused substances separately, e.g. diffusion of CO₂, O₂ and water vapor in and out of plant.

4- Molecular Speed:

The rate of diffusion is directly proportional with molecular speed, according to kinetic theory.

5- Temperature - increases the rate of molecular movement, therefore, increases the rate of diffusion due to increase of kinetic energy

6- Pressure - increases speed of molecules, therefore, increase the rate of diffusion

7-Solubility of the diffusing particles-The rate of diffusion is directly proportional to solubility of the diffusing particles in the medium of diffusion.

Osmosis

The process of osmosis can account for the net movement of water from a region of high conc. of water to a region of low conc. of water across semipermeable membrane. In brief, the presence of a solute in an aqueous solution lowers the chemical potential of the water in the solution. Thus, water will move from a region that contains a low concentration of the solute (relatively higher chemical potential of water) to a region that contains a high concentration of the solute (relatively lower chemical potential of water).

There are no well-documented cases of active transport of water into plant cells. Instead, water appears only to cross the differentially-permeable cell membrane by a process analogous to diffusion (the passive movement of chemicals from an area of greater

concentration to an area of less concentration). This movement of water is called **osmosis**.

Since osmosis does not require expenditure of energy, it must be an energetically "downhill" process. The measure of the energy involved in osmosis is called **water potential** (ψ) expressed in a variety of units (atm, bar, MPa). In this exercise we will use MPa as the proper SI unit for pressure. Since the water must lose energy as it moves by osmosis, water must move from an area of **greater** water potential to an area of **less** water potential. At **equilibrium**, there is no **net** movement of water.

- If the water potential is greater inside the cell than outside the cell, then there will be a net movement of water **out** of the cell (Exo-osmosis).
- If the water potential is greater outside the cell than inside the cell, then osmosis will be a spontaneous net movement of water **into** the cell (Endo-osmosis).
- If the water potential on each side of a cell membrane is the same, there is **no net movement** of water across the membrane (No-osmosis).

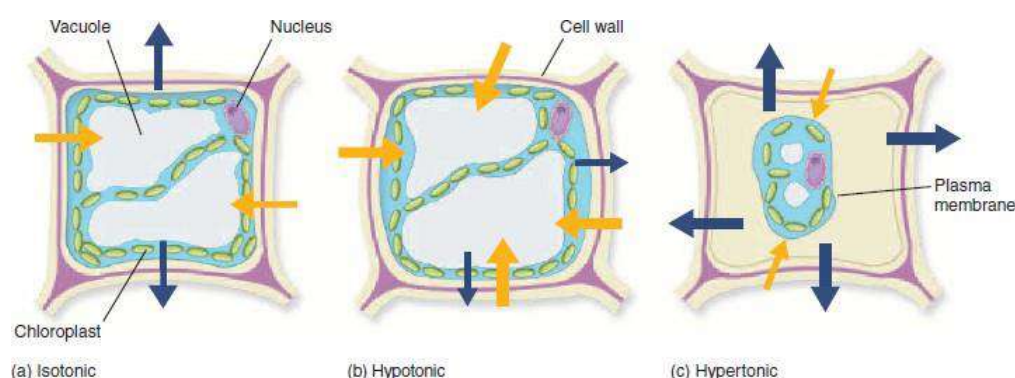
Osmosis in plant cells.

In plants, osmosis is just as important as plants with too little water will wilt. This happens when water moves out of the cells by osmosis. Without this water there is little pressure inside the cells and the plant can no longer support itself against the pull of gravity. However, after watering the plant, the cells become reinflated with water and the plant stands upright.

Plant cell consists of an osmotic system as :-

- 1- Cell wall is a permeable, non-living outer limiting layer of the plant cell which provides shape and rigidity to the cell
- 2- Plasma membrane or cell membrane ; which lies inward the cell wall; has selectively permeable involved in the absorption of water by osmosis, and other substances like ions and low molecular weight biomolecules.
- 3- Vacuole holding the cell sap and functioning as an osmo-regulatory organelle of the cell.

The effect of water loss on plant cells is shown in the diagram below.



The direction of the arrows indicates the direction of the water movement; the size of the arrow indicates the relative amount of water moving into or out of the cell. (a) In an isotonic solution, the cell neither gains nor loses water; water flows equally both into and out of the cell, so no change in cell size. (b) In a hypotonic solution, the cell gains water because more water enters the cell than leaves, so the cell size will increase and the cell become turgid. (c) In a hypertonic solution, the cell loses water because more water leaves the cell than enters, so the cell size will decrease and the cell become flaccid.

An isotonic solution is a same salt concentration solution and in which the concentration of solutes is the same both inside and outside of the cell.

A hypotonic solution is a low salt concentration solution and in which the concentration of solutes is greater inside the cell than outside of it

A hypertonic solution is a high salt concentration solution and one where the concentration of solutes is greater outside the cell than inside it.

Importance of osmosis in plants

- 1- It helps in water absorption by plants.
- 2- The turgidity of plant organs is dependent on water, which is absorbed due to osmosis.
- 3- It helps in movement of water from one cell to another.
- 4- It also maintains the resistance of plants during drought and frost.
- 5- It helps in opening and closing of stomata.
- 6- The expansion of cells is dependent upon turgidity.

Osmotic Pressure (OP)

A pressure is required to stop the osmosis is osmotic pressure. Solute is directly proportional to concentration of solution and this is directly proportional to osmotic pressure. In osmosis, the water molecule is always moving from low osmotic pressure to high osmotic pressure. Osmotic pressure of pure water is always zero because osmotic pressure is due to presence of solute in the solution.

Turgor Pressure (TP)

The pressure that develops in a cell from time to time due to osmotic diffusion of water molecule into a cell that causes stretching of cell wall is called turgor Pressure (TP).

Wall Pressure (WP)

Due to Turgor Pressure rigid cell wall offers resistance. This resistance which works in a direction opposite to the turgor pressure but is equal in strength to TP is called WP.

Diffusion Pressure Deficit (DPD) or Suction Pressure (SP)

Diffusion Pressure of a pure solvent is maximum, by the addition of solute the DP of the solvent decreases. Thus the deficit develop in the diffusion pressure of a pure solvent by the addition of solute is called a DPD of the solvent.

Water Potential

According to principal of thermodynamic, every component of system is having definite amount of free energy for doing their work. The pure water has greater free energy i.e. maximum (it will be zero). The free energy lowers down by addition of solute. The difference between the free energy of molecule of pure water and free energy of the solution is called water potential or chemical free energy.

Water potential (ψ) = free energy of pure water – free energy of solution

Water potential is a measure of the energy state of water. This is a particularly important concept in plant physiology because it determines the direction and movement of water.

$$\Psi_w = \Psi_p + \Psi_s$$

where Ψ_w = water potential; Ψ_p = pressure potential; Ψ_s = solute or osmotic potential.

1. Solute potential (Ψ_s): It represents the amount of solute present.

2. Pressure potential (Ψ_p): Pressure potential which is denoted as Ψ_p is equivalent to either the wall pressure or turgor pressure. In turgid plant cells it usually has a positive value.

Water potential of protoplasm is equal to DPD but opposite in sign.

Movement of water is from higher water potential to lower water potential.

$$\text{DPD} = \text{OP} - \text{TP}$$

$$\Psi = \Psi_s + \Psi_p$$

Plasmolysis and deplasmolysis

Plasmolysis is the shrinkage of cell membrane away from cell wall when the cell is present in a hypertonic solution, because of **exosmosis**. Plasmolysis may be temporary (when the cell present in 10% glycerin or urea) or permanent (when the cell present in a conc. sucrose soln.).

Deplasmolysis is ability of plasmolysed cell to recover its turgidity when the cell is present in a hypotonic solution, because of **endosmosis**.

Transpiration

I. Definitions

- Transpiration - evaporation of water from a plant surface
- Evapotranspiration - evaporation of water from a plant surface and soil (including abiotic surroundings).
- Plants lose a lot of water by transpiration.

Importance of transpiration

- A. Transport in plants. This is important to a small degree. Transpiration is certainly not a necessity.
- B. Heat loss (latent heat of vaporization)
- C. Carry nutrients in the soil to the plant
- D. Perhaps plant cells need to maintain some optimal level of turgidity and this helps them do so.

The movement of water through a plant is called the **transpiration stream**. This pathway begins at the root epidermis and continues symplastically and apoplastically to the endodermis. The path continues

in the vascular cylinder of the root. The water and mineral solution accumulated by the endodermal transport proteins is conducted up the xylem of the root, the stem, and the leaf. In the leaf the solution coats the mesophyll cells apoplastically, evaporates into the gas spaces between the cells, and escapes the leaf through the stomata and into the atmosphere. Thus water passes through (trans-) the plant and exits by small pores (-spira-) in this process (-tion).

Guttation

A process in which liquid water is forced out through openings at the margins of leaves (Hydathodes) due to root pressure.

Guttation occurs only under conditions of high atmospheric humidity and Plentiful water in the soil, which occur most commonly at night.



Bleeding

Exudation of sap from injured parts of the plants is called bleeding.

Examples: Exudation of milky latex from euphorbia.

Types of transpiration:-

1. Cuticular Transpiration

Cuticular transpiration takes place through outer covering of the epidermis called cuticle made up of substance called cutin. Only a very little part of transpiration takes place by this process. (10-20%).

2. Lenticular Transpiration

Lenticels are regions on the bark having loosely arranged cells called complementary cells. A very little amount of water is lost by transpiration through lenticels (0.1%).

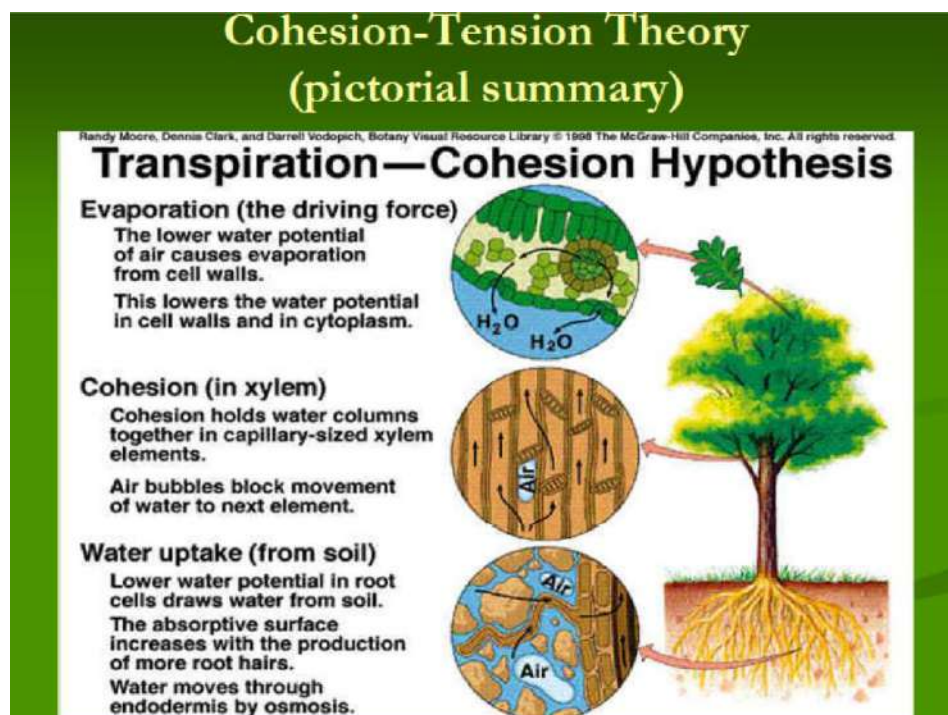
3. Stomatal Transpiration

Stomata are minute openings on the epidermis of leaves and stems. Most of the water lost by transpiration (about 95%) takes place through the stomata.

Mechanism of Transpiration

Transpiration is supported by four critical factors.

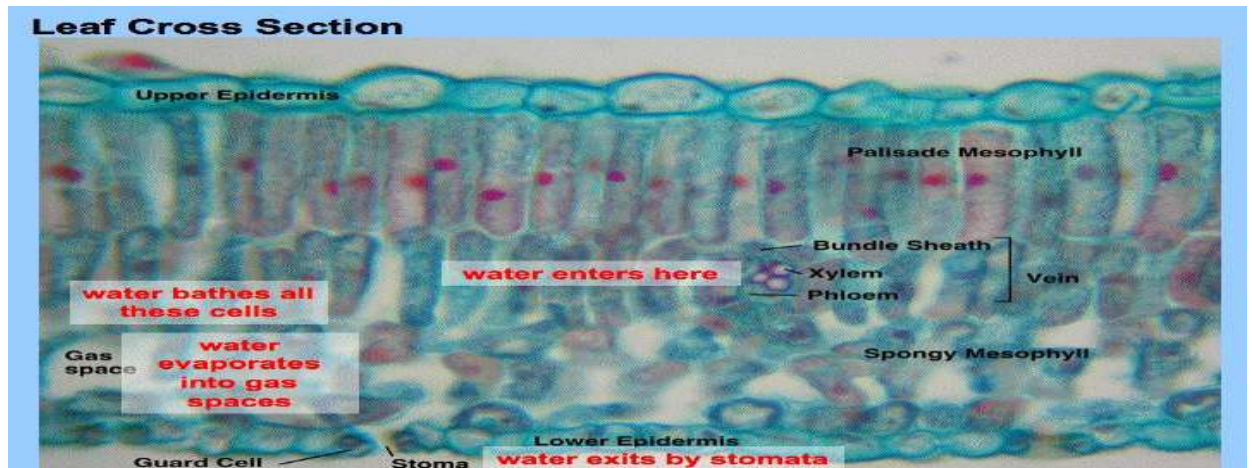
- 1-Root pressure pushes water up the xylem
- 2-Capillarity allows water to climb up the xylem
- 3-Cohesion in the column of water prevents cavitation



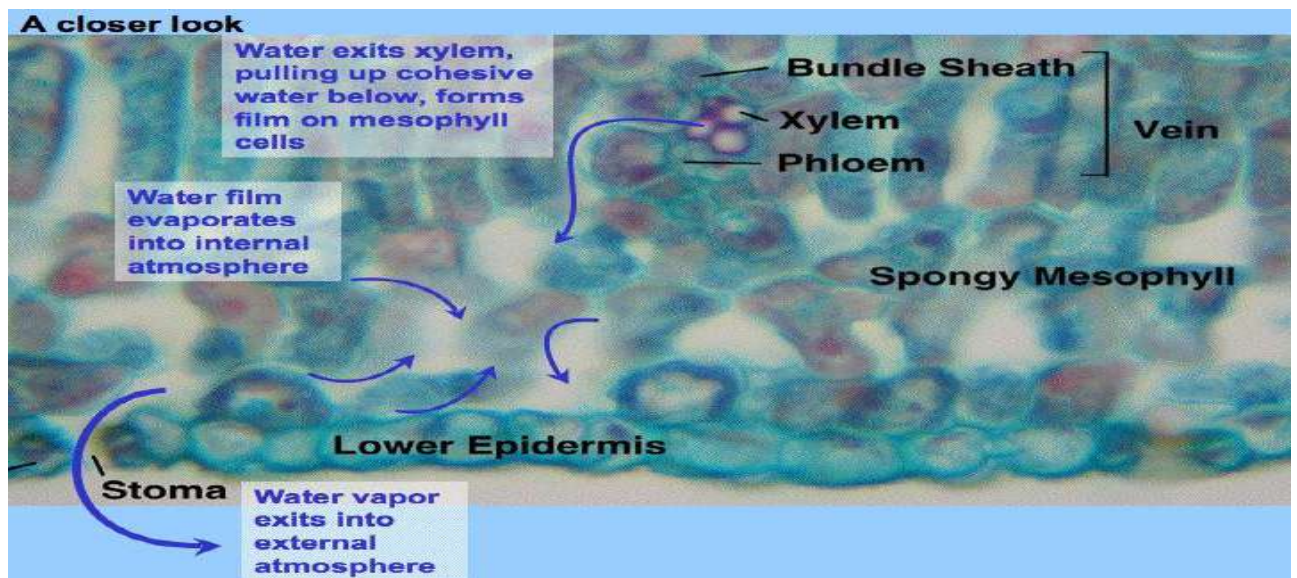
4-Evaporation from the leaves pulls water up the xylem

Evaporation from the intercellular spaces in the leaf into the atmosphere is a strong pull that removes water from the top of the column of water in the xylem. This process generates sufficient force to lift the column of water up against the gravity vector in tall trees. This evaporative pull should not be underestimated.

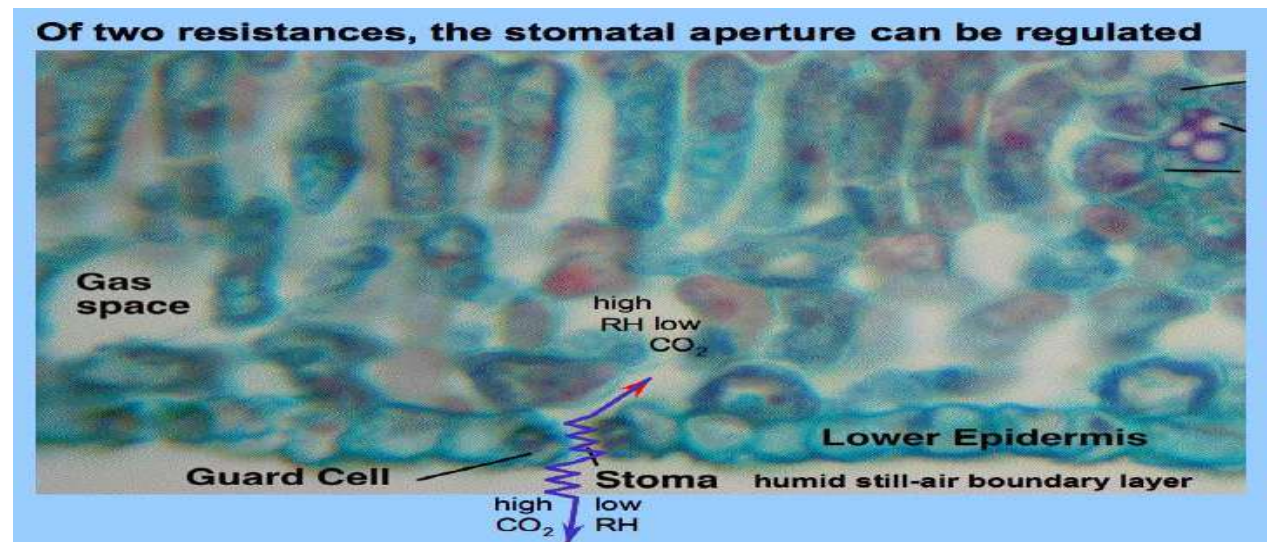
The first evaporation occurs from the leaf mesophyll cells into the humid atmosphere inside the leaf:



Let's take a closer look to see the path of water through a leaf



The pull is assisted by some capillary action in microscopic pits in the surfaces of the cell wall:



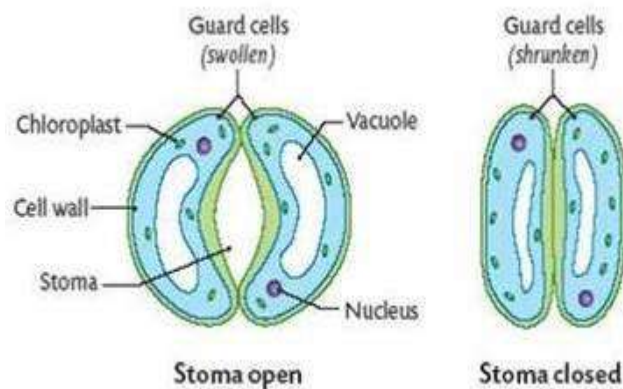
You might notice that the arrows have a "wiggly" edge as they pass through the epidermis via the stomata. These are meant to show a resistance to water movement caused by the small stomatal aperture and the boundary layer of "dead air." These two factors determine how rapidly the water will move from the interior atmosphere to the external atmosphere.

The rate of transpiration obviously will be a function of the size of the stomatal pore and the thickness of the boundary layer.

Opening and closing of stomata:-

Opening and closing of stomata takes place due to changes in turgor pressure of guard cells. During the day, water from subsidiary cells enters the guard cells making the guard cells fully turgid. As a result, the thin elastic convex outer walls are bulged out causing the thick and rigid concave inner walls to curve away from each other causing the stoma to open.

During night time, water from guard cells enters the subsidiary cells and as a result, the guard cells become flaccid due to decrease in turgor pressure. This causes the inner concave walls to straighten up and the stoma closes.



Mechanics of Guard Cell Action

Guard cells of stomata open in light because of the osmotic entry of water into the GC. In turn, this increases the turgidity (water pressure) in the GC and causes them to elongate. The radial orientation of cellulose microfibrils prevents increase in girth. Since GC are attached at the ends and because the inner wall is thicker, the guard cells belly out with the outer wall moving more pulling open the guard cell. Guard cell closure essential involves reversing this process. We can summarize the mechanics of GC action as follows:

stoma closed (*GC flaccid*) → water uptake (osmosis) → increase pressure → stoma open (*GC turgid*)

Or : stoma closed (*GC flaccid*) → add solute → lower Ψ_s → decrease Ψ_w → water uptake (osmosis) → increase pressure → stoma open (*GC turgid*)

Factors Affecting Rate of Transpiration:

a-External Factors:

1- Temperature

The rate of transpiration increases with rise of temp. due to increase of kinetic energy and hence the rate of diffusion of water vapor. Also temp. caused hydrolysis of starch into sugars which leads to turgidity of guard cell to open.

2- Relative humidity (RH)

The rate of transpiration increases with decrease of RH, due to decrease of vapor pressure between stomata and air.

3- Light

The rate of transpiration increases in light due to stomata open in light and closed in dark. Light has heating effects and increase permeability of plasma membrane.

3-Wind

The rate of transpiration increases by increases of wind velocity due to rapid removal of water vapour from leaf surface.

b- Internal Factors:

1- Stomatal number and distribution

The number and distribution of stomata per leaf unit area are vary with plant type. The rate of transpiration increases with increase of stomatal number and distance among stomatal pores.

2- Diameter of stomatal pores

The rate of transpiration increases with increase of diameter of stomatal pores.

3- Modification of plant structure

Modification of plant structure occurs to reduce the rate of transpiration in desert and arid plants (xerophytes) as: reduction of leaf size, developing a thick cuticle, presence of hairs and sunken stomata.

Enzymes

Enzymes are the complex protein molecules, often called biocatalysts, which are produced by living cells. Kuhne (1878) was explored trypsin catalyzed reactions and introduced of word '**enzyme**'. Enzyme are highly specific both in the reactions that they catalyze and in their choice of reactants, which are known as substrates. An enzyme typically catalyzes a single chemical reaction or a set of closely related reactions.

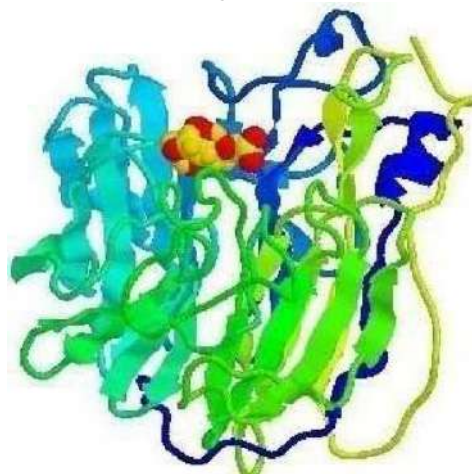
Side reactions resulting in the wasteful formation of by-products are rare in enzyme catalyzed reactions, in comparison to uncatalyzed ones. Enzymes can also be defined as soluble, colloidal and organic catalysts that are produced by living cells, but are capable of acting independently of the cells. Enzymes are currently being used in diverse areas in the

food, feed, paper, leather, agriculture and textiles industries, resulting in major cost reductions.

(En=In : Zyme=Yeast)

Enzyme Characters

1. High turnover number (make lots of product per unit enzyme)
2. Almost all enzymes are proteins
3. Catalysis occurs at the active site
4. Enzymes do not change equilibrium: $E + S \rightleftharpoons E + P$
5. Enzymes exhibit specificity due to unique form of active site.
6. Enzymes do not consume during reactions: $E + S \rightleftharpoons E + P$
7. Enzyme is coagulated (due to its protenic nature) at high temperatures hence loss its activity.

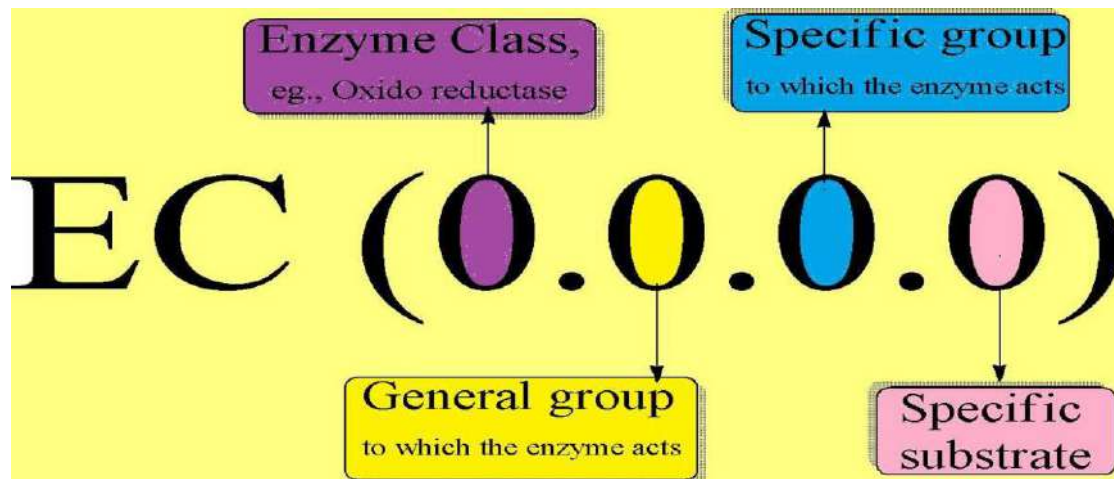


ES Complex

Enzyme nomenclature

- One of systems of nomenclature is that, enzymes are named depending on the reaction they catalyse by addition of suffix -ase.

The latest systematic nomenclature system known as the International Enzyme Commission (IEC) system is based upon the type of reaction catalyzed.



Naming of enzyme according to 'International Union of Biochemistry' formed a 'Commission on Enzyme Nomenclature'

Structure of enzyme:

Enzymes are of two types:

1- Simple enzymes: they are composed only of protein, e.g. *amylase*

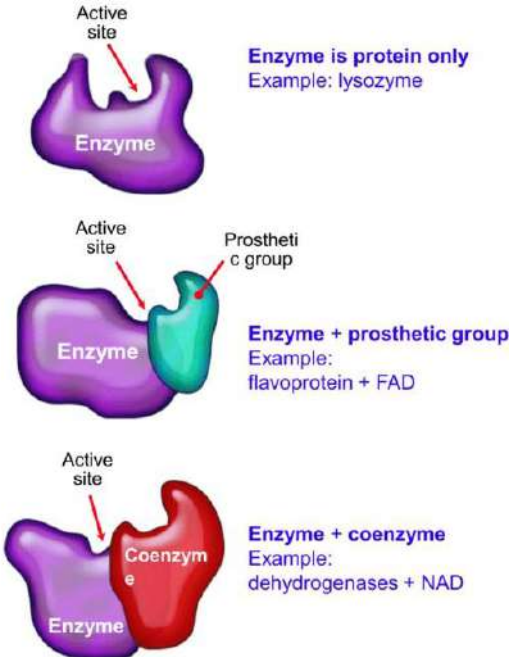
1- Compound or conjugated enzymes: they are composed of protein portion and non-protein portion; hence they consist of two parts:

$$\begin{array}{ccccc}
 \textbf{Holoenzyme} & = & \textbf{Apoenzyme} & + & \textbf{Cofactor} \\
 \textbf{(Total enzyme)} & & \textbf{(Protein)} & & \textbf{(Non-protein)}
 \end{array}$$

a- Apoenzyme: is the protein portion of enzyme and consists of polypeptide chains in the 4th structural form of protein. Each of polypeptide chain consists of a number of amino acids linked together by peptide bounds.

Enzyme Cofactors

- Some enzymes require **cofactors** to be active.
- Cofactors are a **nonprotein** component of an enzyme. Cofactors can be:
 - organic molecules** (coenzymes).
 - inorganic ions** (e.g. Ca^{2+} , Zn^{2+}).
- Cofactors may be:
 - Permanently attached**, in which case they are called **prosthetic groups**.
 - Temporarily attached coenzymes**, which detach after a reaction, and may participate with another enzyme in other reactions.



α - Cofactor: is the non-protein portion of enzyme and consists of organic molecules or inorganic ions, Cofactors may be **permanently attached calling a prosthetic group** which signifies a covalently bound cofactors, **or temporarily attached coenzyme** which detach after reaction . According to reports, co-enzymes and metal ions are stable under heating, while the protein part of an enzyme (the apoenzyme), is denatured by heat.

Cofactors may be classified functionally into two major classes: coenzymes and activators:

1- Activators: Other enzymes, such as carboxypeptidase, require metal ions as co-factors, the divalent cations Mg^{2+} , Zn^{2+} and Mn^{2+} being the most common; these are often called **enzyme activators**.

1- Co-enzymes may be considered to be biosynthetically related to the vitamins, such as the co-enzyme nicotinamide adenine dinucleotide (NAD) which is vital for cellular energy metabolism and integrates the vitamin niacin into its chemical makeup.

Types of Coenzymes

Coenzymes for transfer Phosphorus and Energy: e.g. AMP (Adenosine Mono Phosphate), ADP(Adenosine Di Phosphate) and ATP(Adenosine Tri Phosphate). e.g. *kinase*

Coenzymes for transfer of Hydrogen: e.g. NAD (Nicotinamide Adenine Dinucleotide, also called CoI), NADP (Nicotinamide Adenine Dinucleotide Phosphate, also called CoII), FMN (Flavin Mono Nucleotide), FAD (Flavin Adenine Dinucleotide). e.g. *dehydrogenase*

Specificity of Enzymes:-

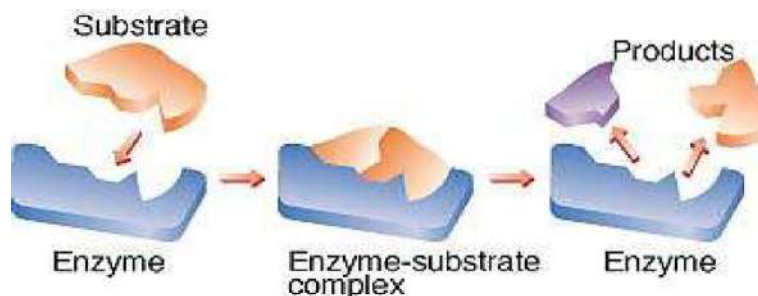
Enzymes are the most remarkable and highly specialized proteins, they have a high degree of specificity for their substrates, and they accelerate chemical reactions tremendously. In general, four types of behavior can be described:

1. Absolute specificity - Catalyze only one reaction e.g. Urease.
2. Group specificity – catalyses a particular type of functional group, which can occur in a variety of substrate e.g. Transaminase.
3. Linkage specificity - Catalyses a particular type of chemical bond regardless of the rest of the molecular structure e.g. Proteases and Glycosidase.
4. Stereochemical specificity - the enzyme will act on a particular steric or optical isomer e.g. Isomerase.

MECHANISM OF ENZYME ACTION

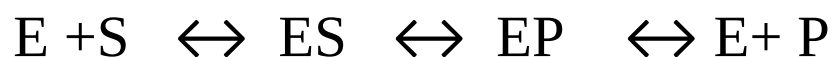
Enzymes are macromolecules that help to accelerate (catalyze) chemical reactions in biological systems. Some biological reactions in the absence of enzymes may be as much as a million times slower. Any chemical reaction converts one or more molecules, called the **substrate**, into different molecule(s), called the **product**.

Enzymes are usually proteins – each has a very specific shape or conformation. Within this large molecule is a region called an **active site**, which has properties allowing it to bind tightly to the substrate molecule(s).



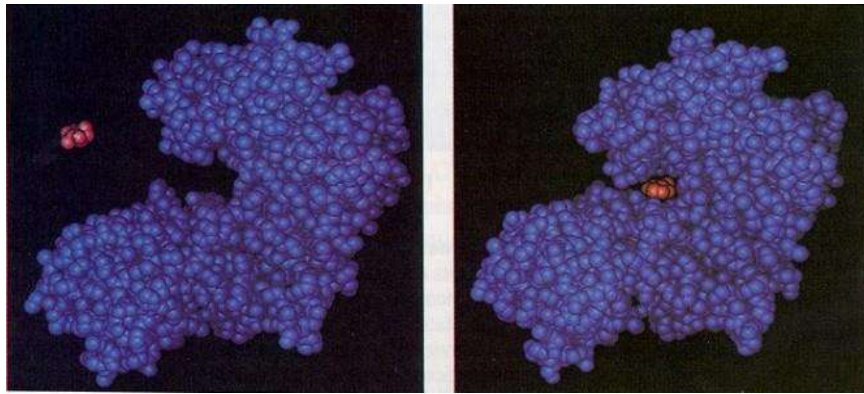
The active site encloses a substrate and catalyzes its chemical transformation. The enzyme substrate complex was first discovered in 1880, is central to the action of enzymes.

So a simple enzymatic reaction can be written as,



Where E, S, and P represent the enzyme, substrate, and product respectively; ES and EP are transient complexes of the enzyme with the substrate and with the product respectively.

The active site is typically a pocket or groove created by some of the amino acids of the enzyme.

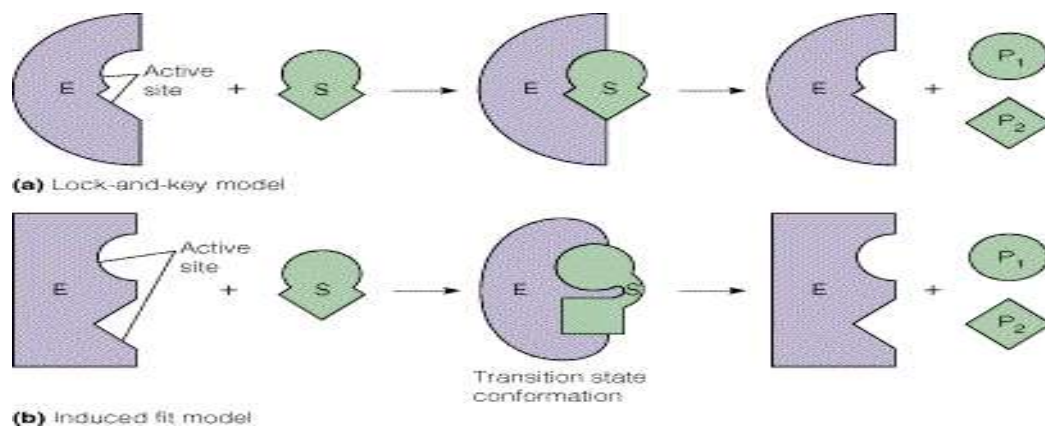


The binding of the substrate (glucose) to the groove that makes up the active site of *hexokinase*

The enzyme–substrate interactions can be explained by the following theories.

1 Lock and key model

In "lock and key" model the active site of the enzyme is complementary in shape to that of the substrate. The substrate is held in such a way that its conversion to the reaction products is more favorable. It was thought that the substrate exactly fitted into the active site of the enzyme molecule like a key fitting into a lock.



2. Induced fit

Lock and key model does not explain the stability of the transition state for it would require more energy to reach the transition state complex. To explain this concept Koshland in 1958, first proposed the induced-fit model, this suggests that the enzyme active site is conformationally fluid.

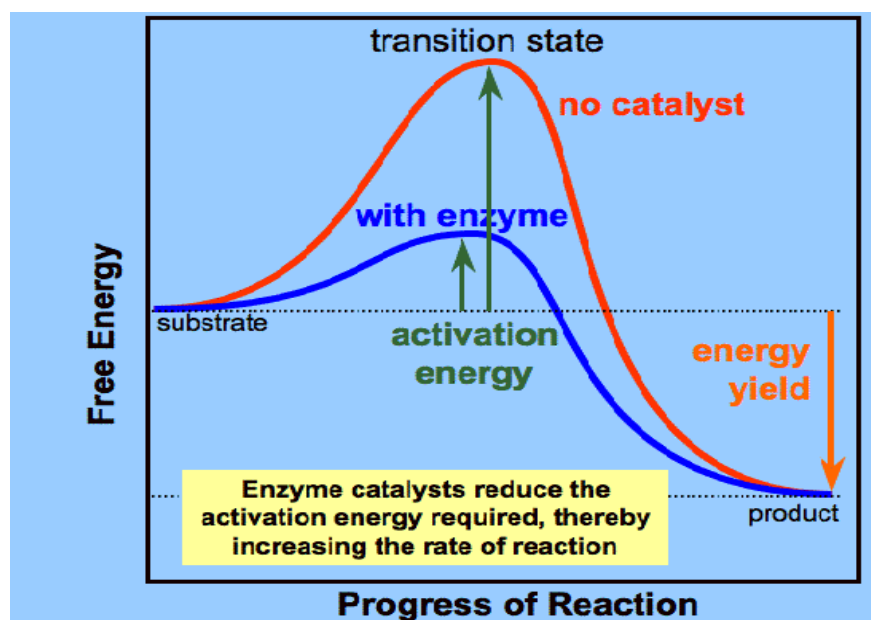
Enzyme itself usually undergoes a change in conformation when the substrate binds, induced by multiple weak interactions and hydrophobic characteristics on the enzyme surface mold into a precise formation .

3. Transition state theory

According to this theory when an enzyme catalysis, the enzyme binds more strongly to its *"transition state complex rather than its ground state reactants."* This indicates, the transition state is more stable.

The difference between the energy levels of the ground state and the transition state is the activation energy (Activation energy = E_A); the rate of a reaction reflects this activation energy: higher activation energy corresponds to slower reaction. Reaction rates can be increased by raising the temperature, thereby increasing the number of molecules with sufficient energy to overcome the energy barrier. Alternatively, the activation energy can be lowered by adding a catalyst-enzyme.

To overcome the activation energy requires energy input. For some chemical reactions, this can be accomplished by heating. Cells can be damaged by heat, therefore they use enzyme catalysts to lower the activation energy.

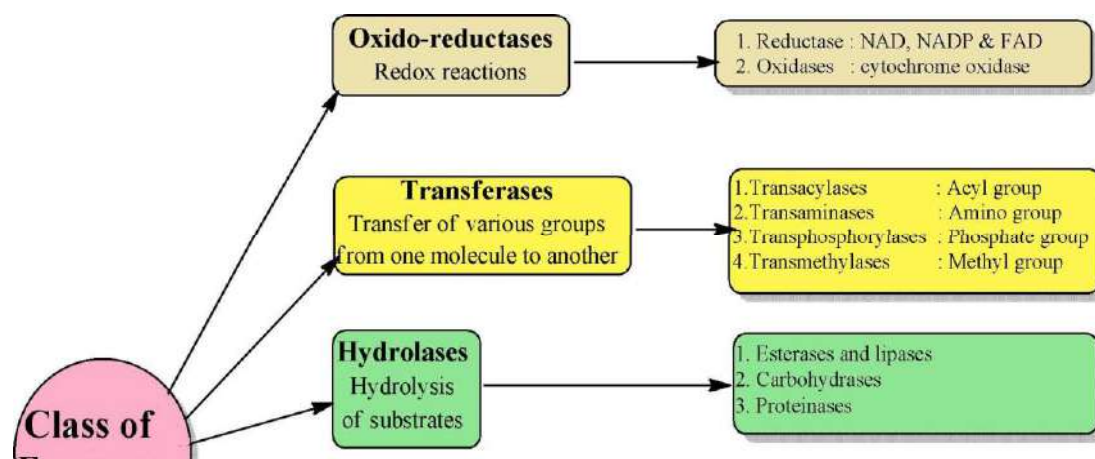
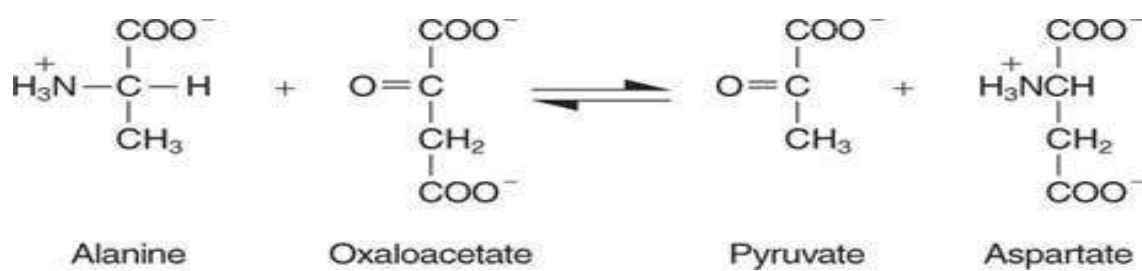


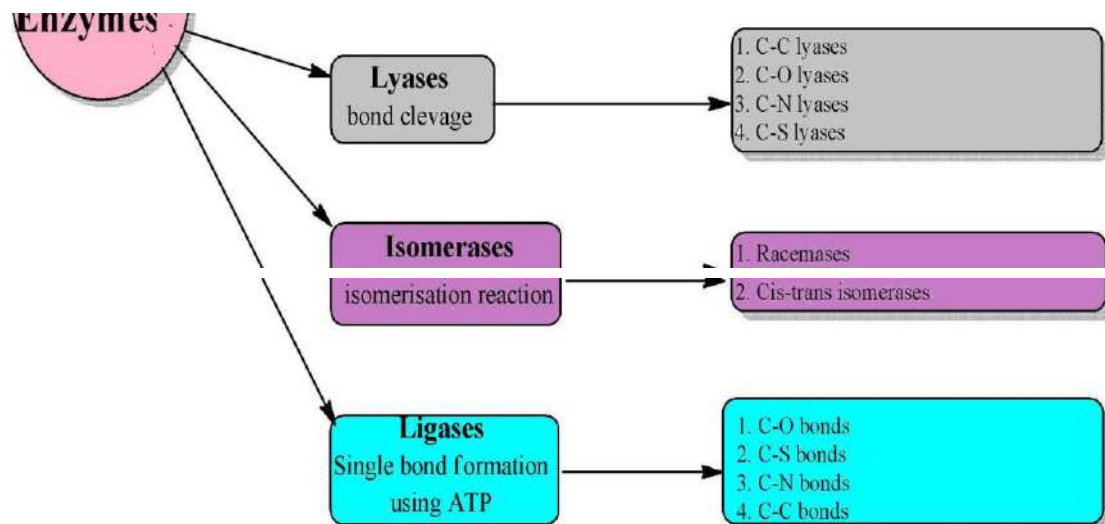
Classification of Enzymes:

- 1) **Oxidoreductases** : Oxido-reduction reactions

2) **Transferases** : Transfer active groups or particles between different molecules.

For example, Alanine Aminotransferase transfers the alpha-amino group between alanine and aspartate:





Classification of enzyme and examples of related enzyme classes

3) **Hydrolases:** These catalyze the hydrolysis of their substrates by adding constituents of water across the bond they split. The substrates include ester, glycosyl, ether, peptide, acid-anhydride, C—C and P—N bonds.

Examples: **-Proteases/ Peptidases** cleave peptide bonds between amino acids in order to breakdown proteins into free amino acids.

-Lipases break down lipids into fatty acids and glycerol by cleaving ester bonds.

4) **Lyases:** cleavage in the absence of water

e.g. ATPase (Phosphatase)

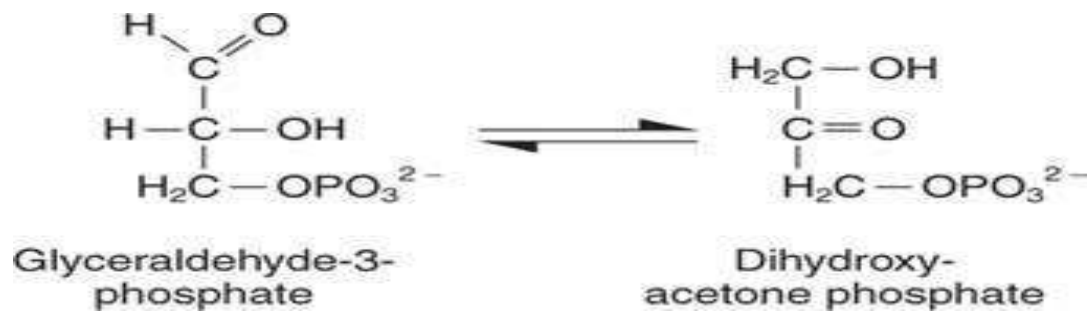


$\text{P}_i = \text{H}_3\text{PO}_4$

$\text{PP}_i = \text{Pyrophosphate (i.e. } 2\text{P}_i\text{)}$

5) **Isomerases :** These catalyze interconversions of optical, geometric or positional isomers by intramolecular rearrangement of atoms or groups. i.e Transfer active groups or particles in the same molecules.

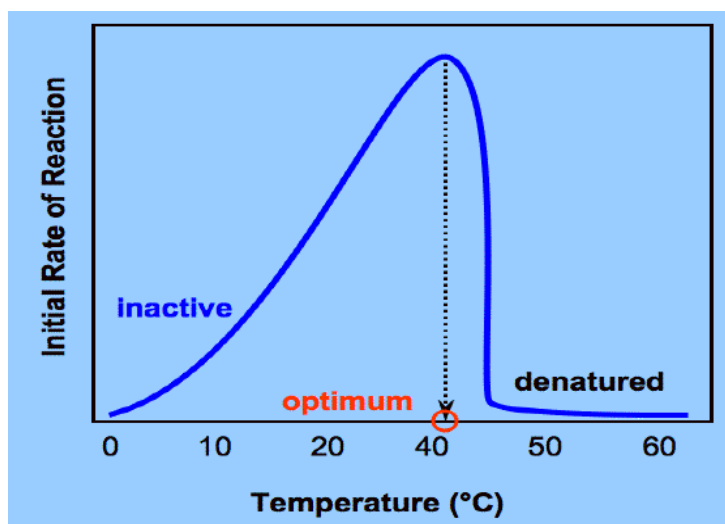
For example, Triosephosphate Isomerase,



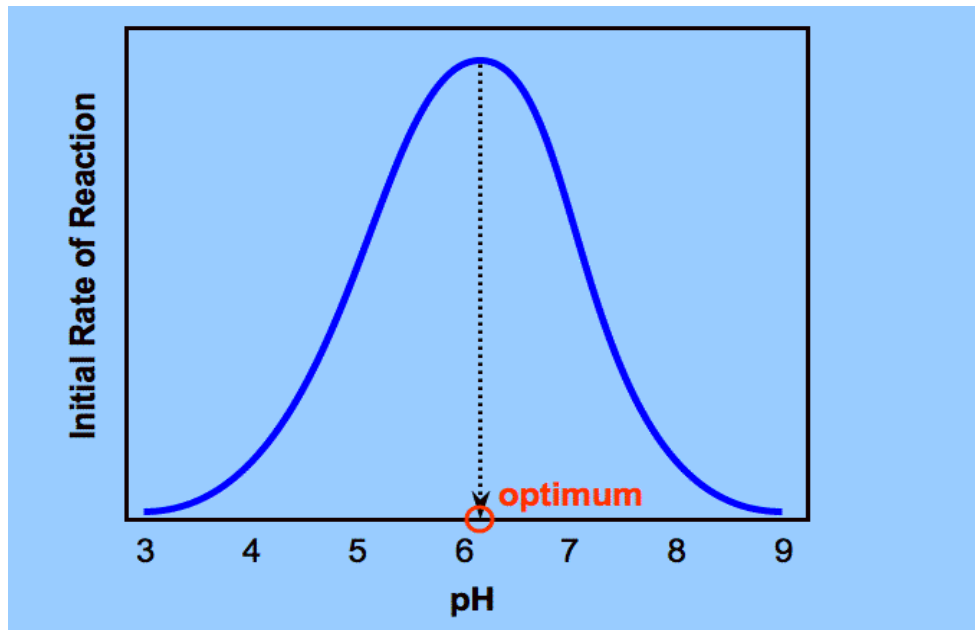
6) Ligases or Synthetases. These are the enzymes catalyzing the linking together of two compounds utilizing the energy made available due to simultaneous breaking of a pyrophosphate bond in ATP or a similar compound. This category includes enzymes catalyzing reactions forming C—O, C—S, C—N and C—C bonds.

FACTORS THAT AFFECT ENZYME ACTIVITY

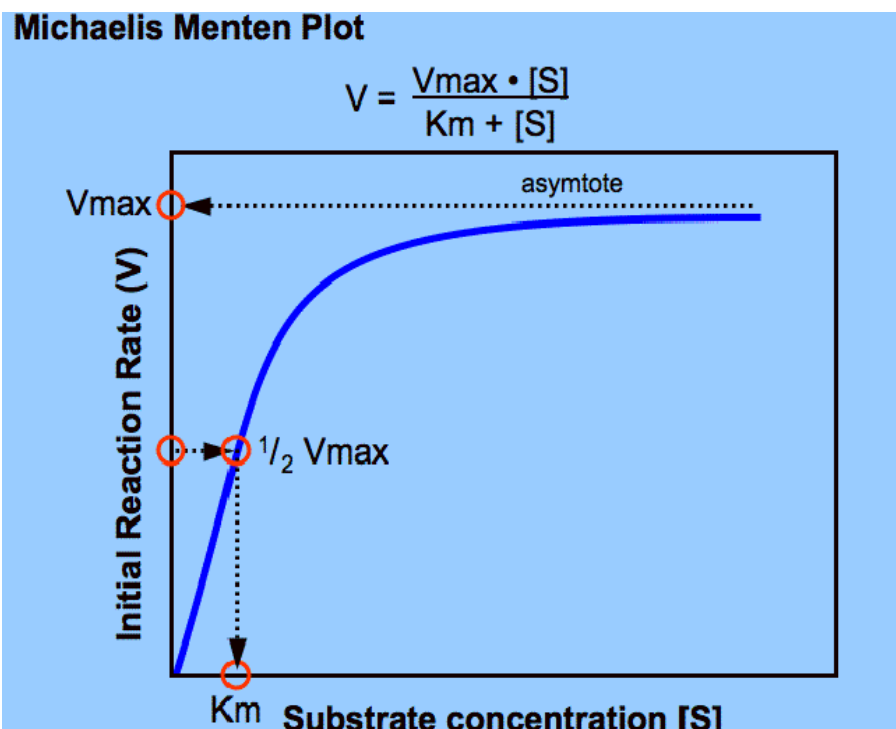
1-Temperature: Rate of enzyme activity increases with increase in temperature up to a maximum and then declines. A bell-shaped curve is usually observed. The optimum temperature for most of the enzymes is between 40°C-45°C. Enzymes from thermophilic organisms (as bacteria) may have optimal activity at 70°C. Denaturation (Coagulation) will occur when the enzymes are exposed to a temperature above 50°C, Majority of the enzymes become inactive at higher temperature (above 70°C).



2- pH: Increase in the hydrogen ion concentration (pH) considerably influences the rate of enzyme activity and a bell-shaped curve is normally obtained. Most enzymes have optimal activity around pH 7.

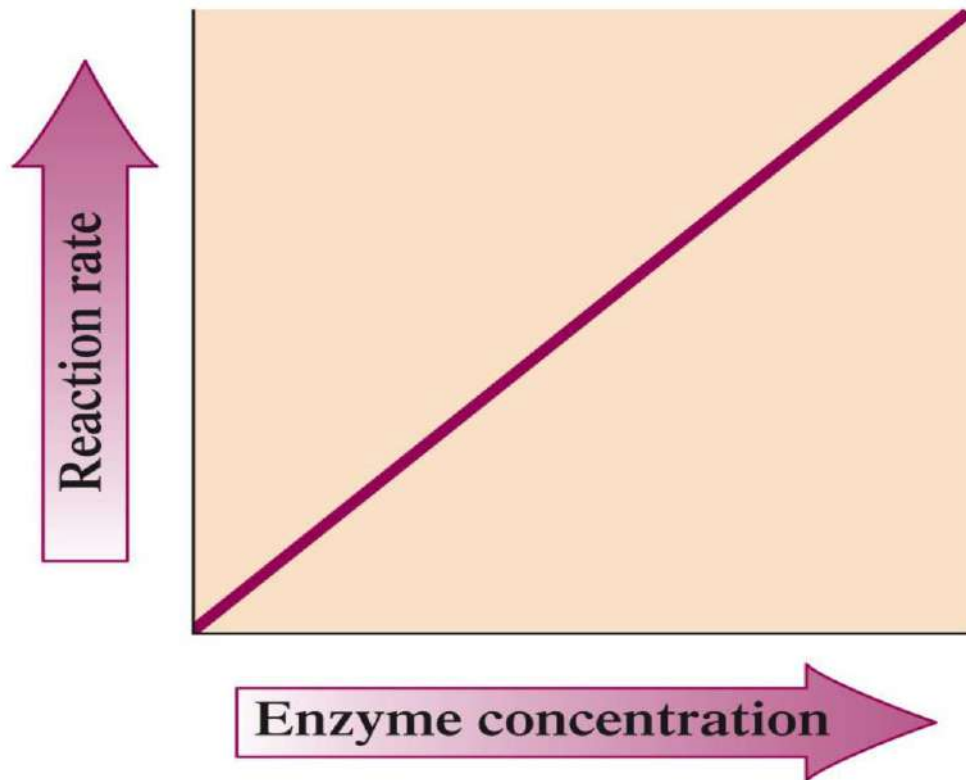


3- **Substrate Concentration:** Most enzymes activity increased proportionally with the substrate concentration until all substrate molecules reacted with all Enzyme particles. Then any increase in substrate not affect on enzyme activity.



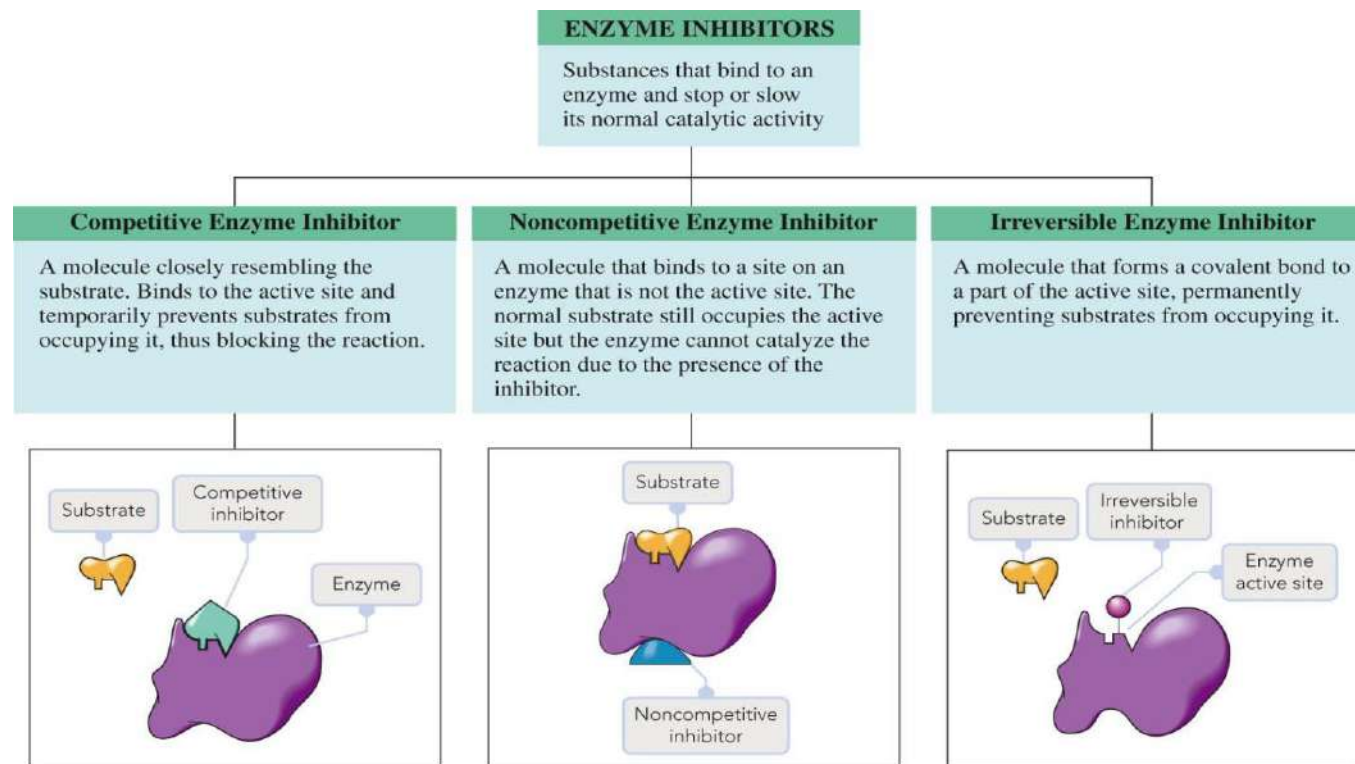
4- Enzyme Concentration:

The rate of enzyme activity directly proportional with its concentration, because there are more enzyme molecules (more active sites), available to catalyse the reaction.



5- **Cofactors:** Ions or coenzymes that are required by the enzyme for catalytic activity.

6- **Inhibitors:** Chemicals that slow or stop the action of enzymes. compares two types of inhibitors.



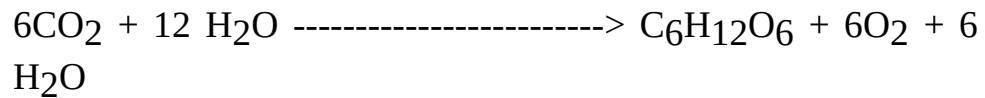
Plant Metabolism

Plant metabolism is all biochemical reactions occur inside the plant cell which may be: ***anabolism*** which is a synthetic reactions as photosynthesis with absorption of energy, and ***catabolism*** which is a degradation reactions as respiration with release of energy
 Also plant metabolism may be: Primary or secondary.

Photosynthesis

- Photosynthesis - The process which occurs in the chloroplasts of green plants in which simple sugars are formed from carbon dioxide and water in the presence of light and chlorophyll.
- The essential formula for photosynthesis which you learned in general biology is

light energy/chlorophyll



A. Two major parts of photosynthesis

It was clear that photosynthesis consists of many reactions that can be divided into two pathways :

I. First - pathway is light dependent and is called light reactions . This reaction is driven by light energy. It produces ATP and a reduced electron carrier (NADPH + H⁺).

II. Second pathway is light independent and is called dark reactions or Calvin-Benson Cycle. It does not use light directly. It uses ATP, NADPH + H⁺ and CO₂ to produce sugar.

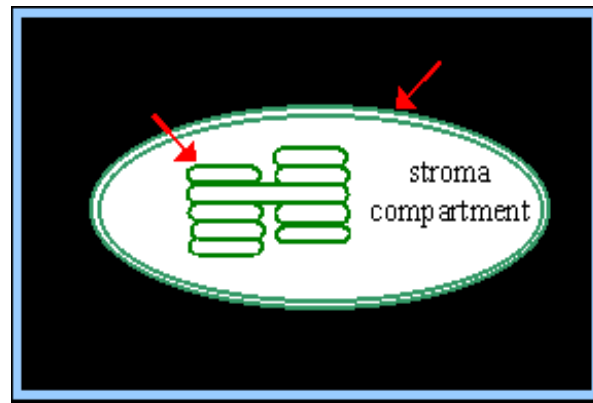
B. Purpose of photosynthesis

- 1) Main biosynthetic pathway by which carbon and energy enter the web of life
- 2) Nearly the only source of O₂
- 3) Reduce the CO₂ conc. in the atmosphere.

III. Where it occurs

Chloroplast

1. Light reactions - granum (several thylakoids) and thylakoid membranes
2. Dark reactions –stroma



LIGHT REACTIONS

- 1- Chlorophyll absorbs light and released electrons
2. One Electron (e^-) used by photolysis to split one molecule of water into OH and H
3. O_2 is released and H^+ goes into thylakoid to reduce $NADPH^+$ into $NADPH+H$
4. Another one Electron (e^-) used to produce one ATP molecule.
5. The products of light reaction (ATP – energy and $NADPH+H$) are used for organic compounds synthesis in Photosynthesis process (Dark Reactions).

DARK REACTIONS (CO₂ FIXATION)

Major purpose is use energy from light reactions to fix CO_2 into organic molecules.

C3 and C4 plants.

C 3 plants , are those in which the first product of CO_2 fixation is the 3-carbon molecule 3Phosphoglyceladehyde (3-PGA), they are called C3 plants . Photorespiration occurs under this condition. **C3** plants have

one main pathway known as **Calvin - Benson Cycle**. **C3** plants are most of Dicots.

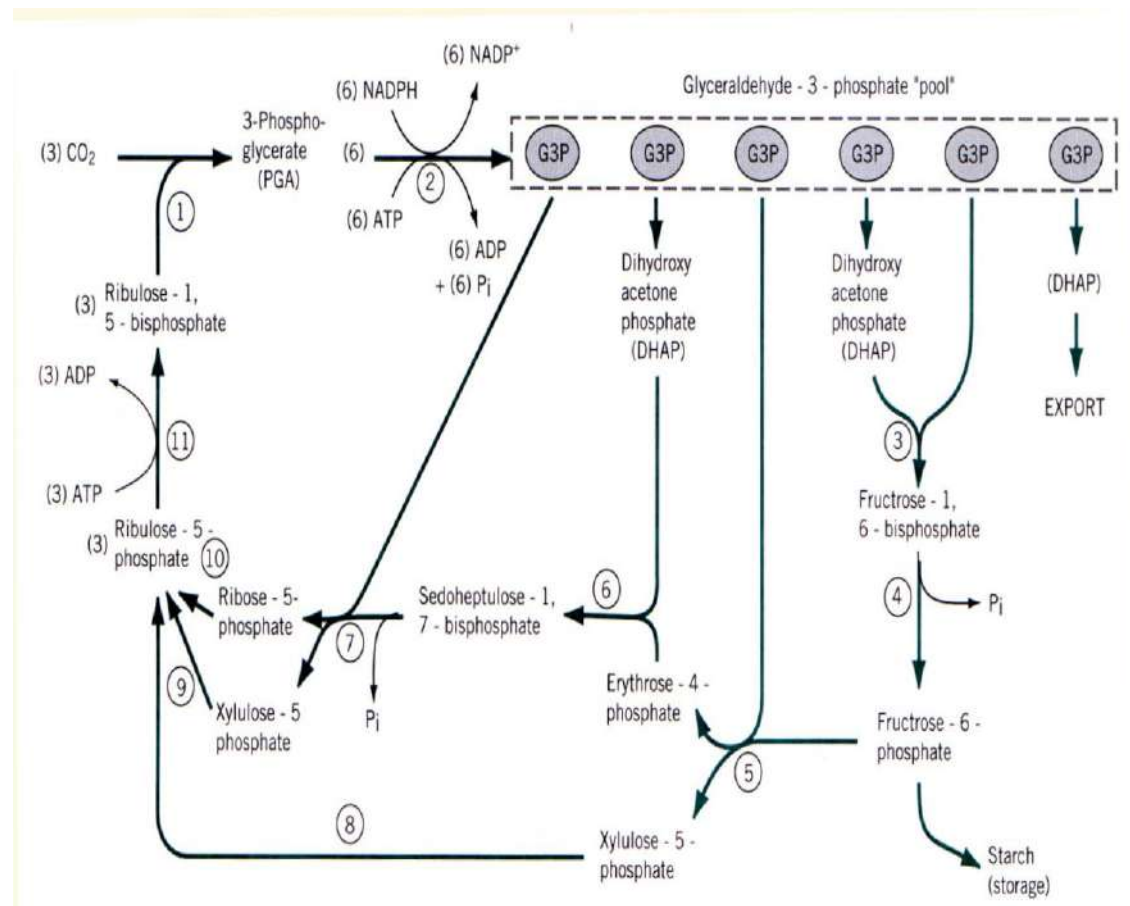
C4 plants, are those in which having a 4-carbon compound , oxaloacetate, as the first product of CO₂ fixation, and Photorespiration occurs. C4 plants have two main pathways known as **Hatch - Slack pathway** in addition to **Calvin - Benson Cycle**. **C4** plants are most of Monocots. such as corn , sugarcane , and other tropical grasses.

C3 plants carbon fixation (Dark reaction)

Steps of CO₂ fixation:

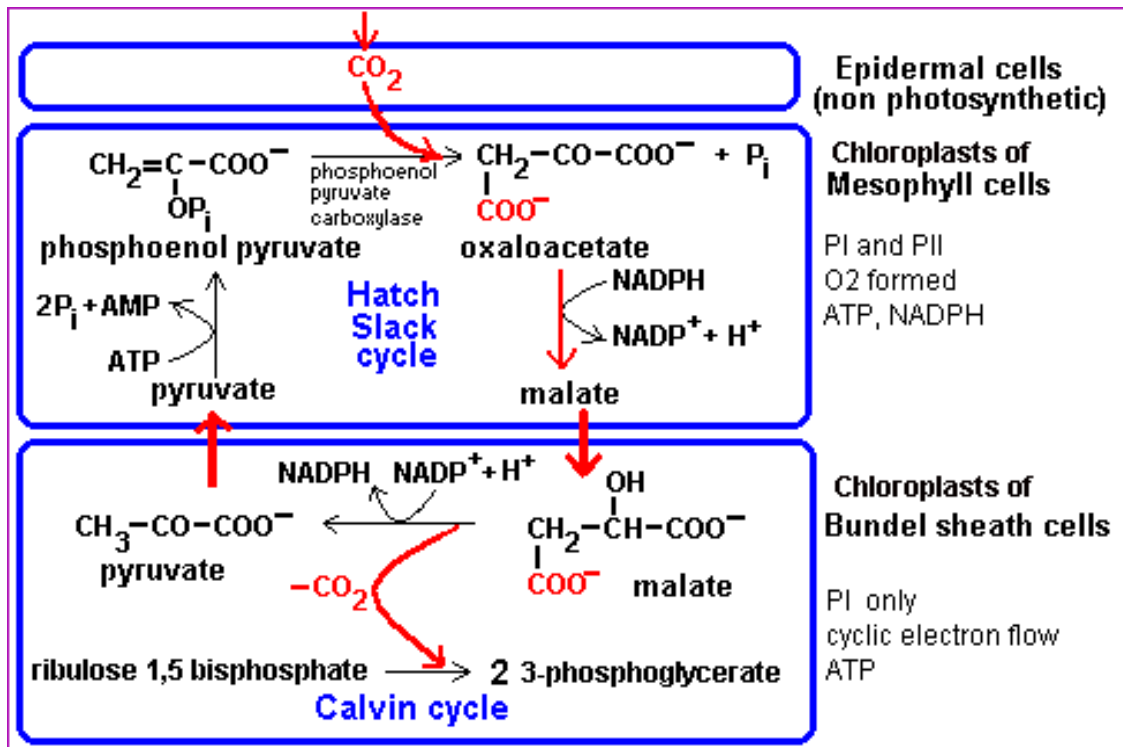
1. CO₂ and H₂O (1 carbon) are added to ribulose bisphosphate (5 carbons) to form two molecules of 3-phosphoglyceric acid (3-PGA) (total of 6 carbons)
2. Catalysis of this reaction by the enzyme activity.
3. 3-PGA is reduced to 3-PGAL with the help of NADPH and ATP
4. 3-PGAL is converted to either fructose diphosphate or, eventually ribulose bisphosphate
5. Fructose diphosphate goes to other aspects of metabolism and ribulose bisphosphate goes back to the original cycle of CO₂ fixation.

Calvin - Benson Cycle



C4 plants. Carbon fixation (Dark reaction)

Hatch - Slack pathway

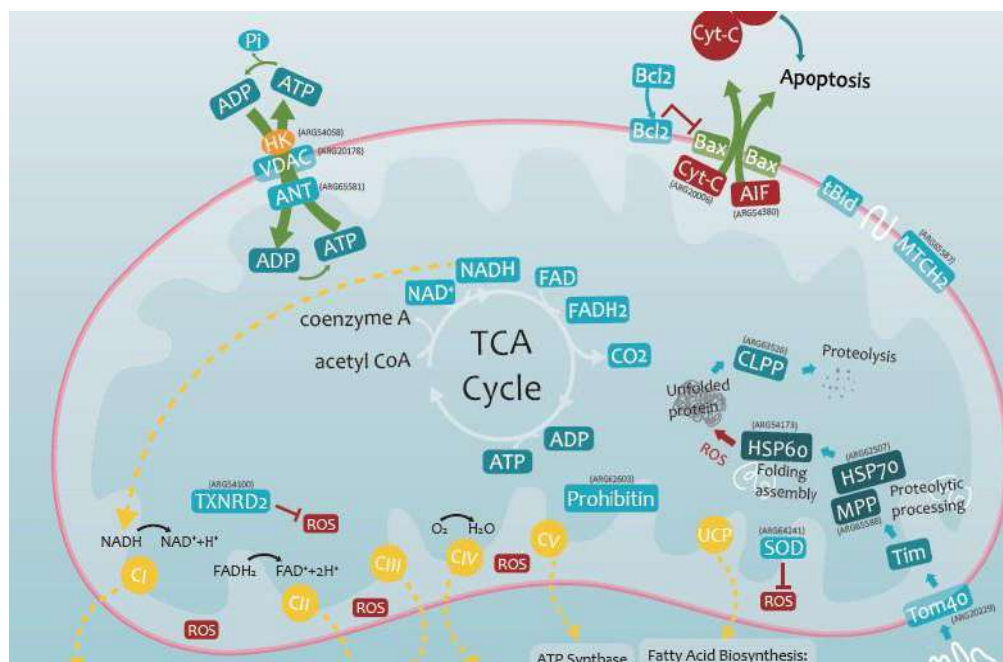
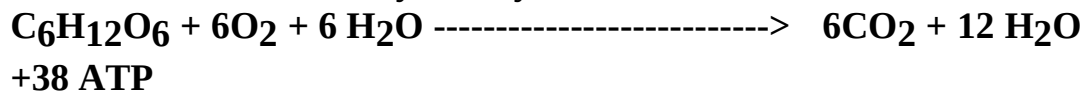


Respiration

The breakdown of complex molecules to yield energy takes place in the cytoplasm and in the mitochondria. The breaking of the C-C bonds of complex compounds through oxidation within the cells, leading to release of considerable amount of energy is called **respiration**. The compounds that are oxidized during this process are known as **respiratory substrates**.

Types of respiration: aerobic with O₂ and anaerobic without O₂

Enzymes/Cytosol and Mitochondria



Mitochondrion

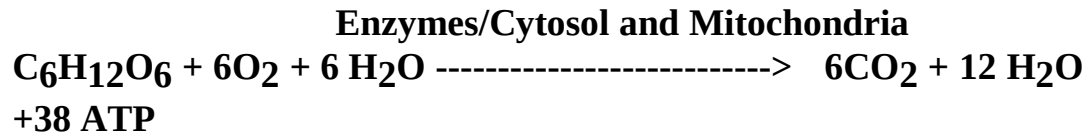
Aerobic respiration

Aerobic respiration is the process that leads to a complete oxidation of organic substances in the presence of oxygen, and releases CO₂, water and a large amount of energy present in the substrate. This type of respiration is most common in higher organisms. We will look at these processes in the next section.

Mechanism of Aerobic respiration

Mechanism of respiration includes following steps: glycolysis, krebs (TCA) cycle, electron transport and oxidative phosphorylation.

The essential formula for aerobic respiration which you learned in general biology is

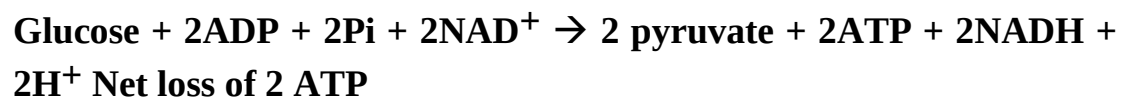


Glycolysis (Embden-Meyerhof Pathway)

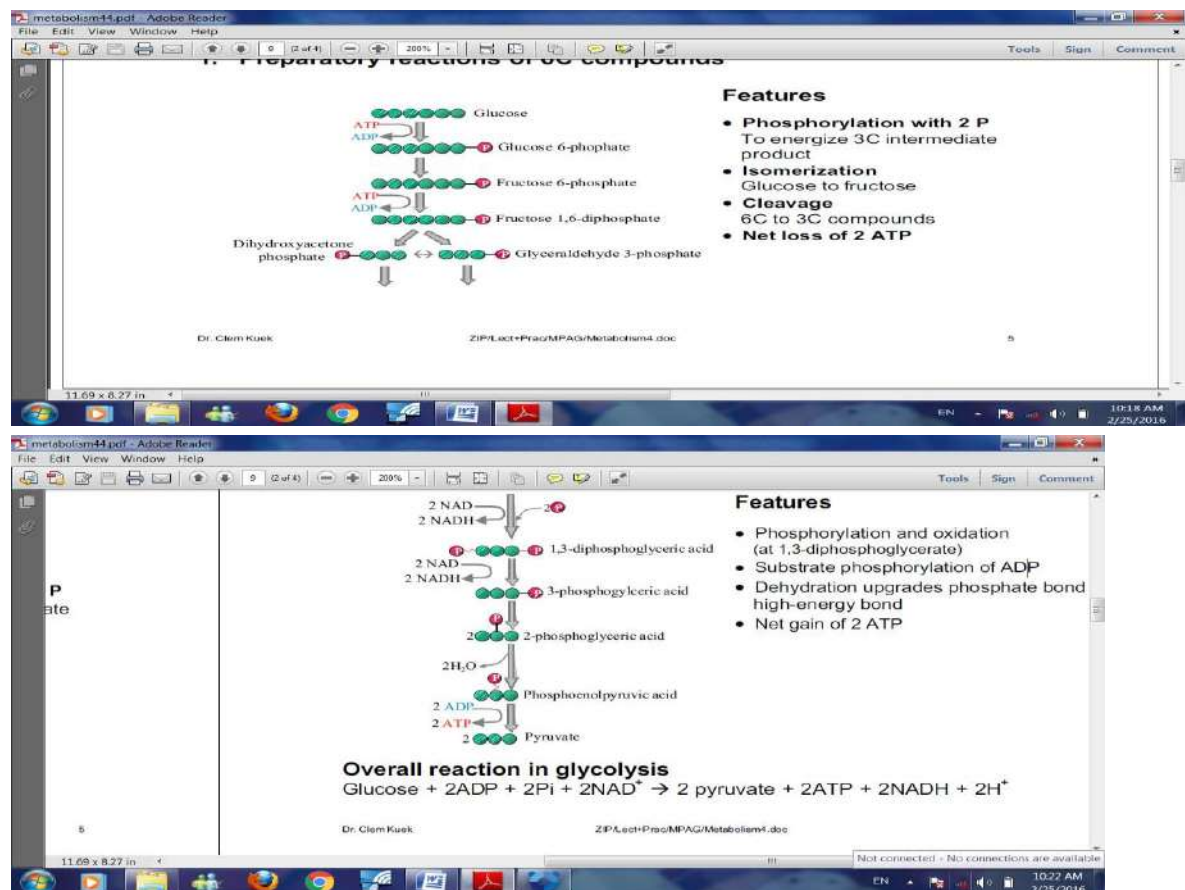
Oxidation of glucose to pyruvate

- Reduces carbon number from 6 to 3, • Releases energy for anabolism and fermentation in ATP and NADPH molecules.
- Several amphibolic (catabolic and anabolic) pathways
Embden-Meyerhof in eukaryotes and bacteria, Others found in bacteria
- Glucose derived from polysaccharides and other sugars
- Carbon compounds derived from amino acids and lipids may enter glycolytic pathways at various stages.

Overall reaction in glycolysis



Glycolysis Pathway



The Krebs/TCA/Citric Acid cycle

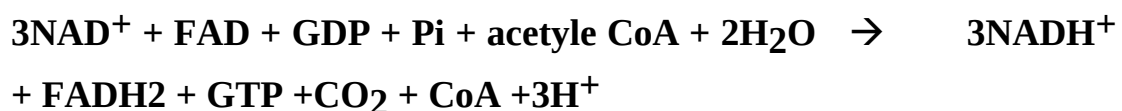
Oxidation of acetyl-CoA to CO₂ with production of NADH, FADH₂ and some ATP: 4 NADH+H, 1 FADH+H and 1GTP per pyruvate molecule, 4, 5 and 6C compounds available for biosynthesis.

Carbon skeletons supplied for amino acid biosynthesis by α-ketoglutarate, succinate and oxaloacetate.

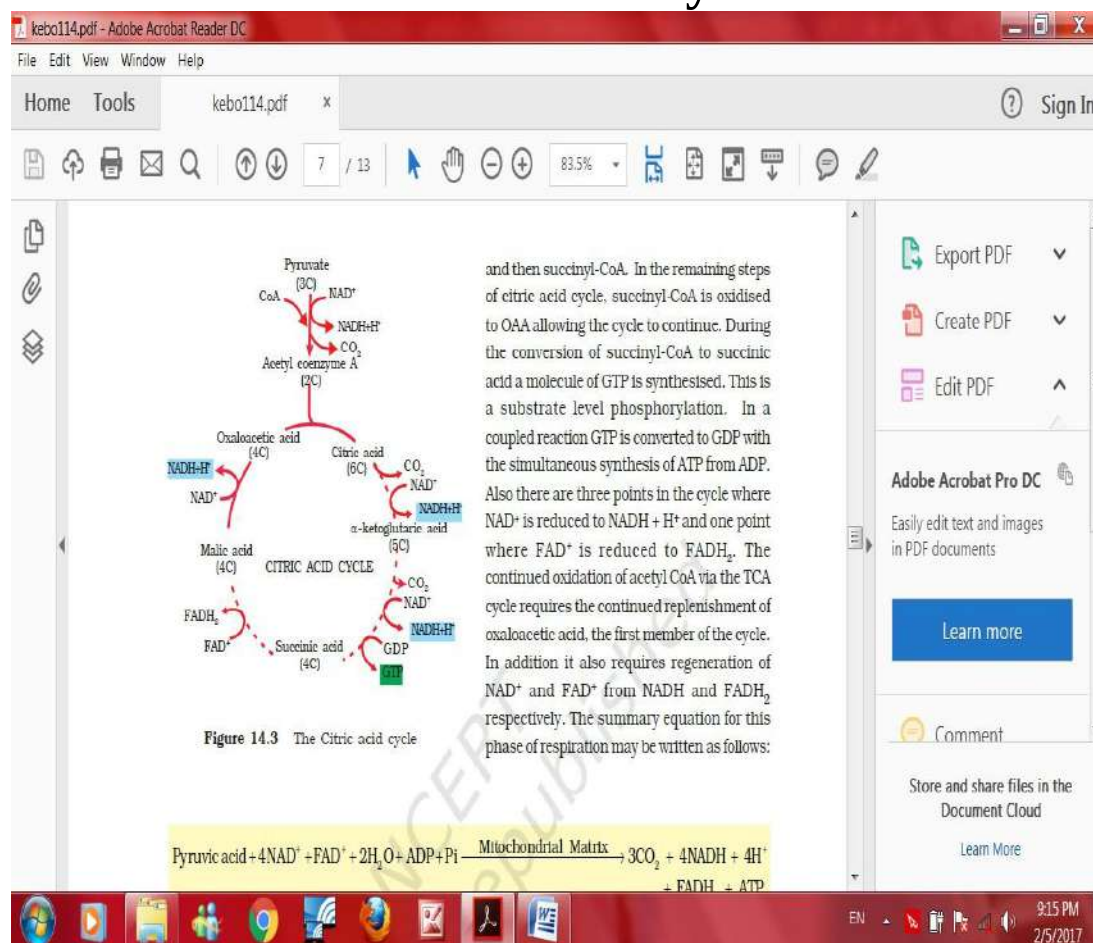
Glucose biosynthesis (gluconeogenesis) from malate/oxaloacetate

Present in organisms with aerobic respiration in Mitochondria

The net reaction of citric acid cycle is



The Krebs/TCA/Citric Acid cycle



Anaerobic Respiration

In Anaerobic Respiration (fermentation), say by yeast, the incomplete oxidation of glucose is achieved under anaerobic conditions by sets of reactions where pyruvic acid is converted to CO₂ and ethanol. The enzymes, pyruvic acid decarboxylase and alcohol dehydrogenase catalyse these reactions. Other organisms like some bacteria produce lactic acid from pyruvic acid. The steps involved are shown in Figure. In animal cells also, like muscles during exercise, when oxygen is inadequate for cellular respiration pyruvic acid is reduced to lactic acid by lactate dehydrogenase. The reducing agent is NADH+H⁺ which is reoxidised to NAD⁺ in both the processes.

The screenshot shows a PDF document titled 'kebo114.pdf' in Adobe Acrobat Reader DC. The document contains a diagram of anaerobic respiration pathways and a text block with a question.

Figure 14.2 Major pathways of anaerobic respiration

The diagram illustrates the following pathways:

- Glycolysis:** Glucose is converted to Glyceraldehyde 3-Phosphate, then to 3-Phosphoglyceric acid, and finally to Phosphoenolpyruvic acid.
- Lactic Acid Fermentation:** Glyceraldehyde 3-Phosphate is converted to Lactic acid, with NAD^+ being reduced to $NADH+H^+$.
- Alcoholic Fermentation:** Phosphoenolpyruvic acid is converted to Pyruvic acid, which is then converted to Ethanol- CO_2 , with $NADH+H^+$ being oxidized to NAD^+ .

Text Block:

fermentation not much energy is released; less than seven per cent of the energy in glucose is released and not all of it is trapped as high energy bonds of ATP. Also, the processes are hazardous – either acid or alcohol is produced. What is the net ATPs that is synthesised (calculate how many ATP are synthesised during glycolysis) when one molecule of glucose is fermented to alcohol or lactic acid? Yeasts poison themselves to death when the concentration of alcohol reaches about 13 per cent. What then would be the maximum concentration of alcohol in beverages that are naturally fermented? How do you think alcoholic beverages of alcohol content greater than this concentration are obtained?

What then is the process by which organisms can carry out complete oxidation of glucose and extract the energy stored to synthesise a larger number of ATP molecules

References by author as web sites , Physiological books and preparation efforts .

Mauseth, James D. 2003. *Botany: An Introduction to Plant Biology*, 3rd Edition. Jones and Bartlett, Sudbury, MA.

Koning, Ross E. 1994. Osmosis. *Plant Physiology Information Website*. file:///E:/plant%20physiology/Osmosis.htm. (1-1-2002).

Bugg, T. D. (2012): *Introduction to enzyme and coenzyme chemistry*: John Wiley & Sons.

Biochemistry enzymes and coenzymes:

http://highered.mheducation.com/sites/0073522732/student_view0/chapter4/animation_-_enzyme_action.html

=====

WITH BEST WISHES=Y.H.2020=

ACTIVITY QUIZZES

Name:

- 2020- Student ID:

Answer the following questions:=Plant Physiology=

Part One: True or False questions

- 1) In lyophilic colloid there is no affinity between dispersed phase and dispersion phase.
- 2) The rate of diffusion is directly proportional to the size and mass of the diffusing particles.
- 3) Permeability of plasma membrane is inversely proportional with the rise in temperature.
- 4) The main difference between osmosis and diffusion is that the movement of molecules in diffusion across membrane.
- 5) When the water potential is greater inside the cell than outside the cell, and then there will be a net movement of water into of the cell.
- 6) The most amount of water lost from plant is through cutical transpiration.
- 7) Lyophobic colloid is more stable than lyophilic one.
- 8) The most amount of water lost from plant is through cutical transpiration.
- 9) In Alcoholic fermentation 2 mols. pyruvate give 2ethanol and 2CO₂.
- 10) Enzyme have high turnover number and high activation energy.
- 11) $E + S \leftrightarrow ES \text{ complex} \rightarrow P1 + P2$.
- 12) Photons is trapped by CO₂ receptor in photosynthesis.
- 13) Electron transfer and oxidative phosphorylation occur in matrix of mitochondria.
- 14) Receptor of CO₂ in C₄ plants is Ribulose 1,5biP.

15) Hexokinase catalyze the reaction of { $ATP \rightarrow cAMP + PPi$ }.

Part Two: MCQ questions

- 1) Cell secretion takes place by the organelle called -----
a- Mitochondrion b- Ribosomes c- Golgi body
d- plastids
- 2) In a hypertonic solution, more water ----- the cell.
a- enters b- stays in c- Leaves d- penetrate
- 3) Solubility of the diffusing particles ----- the rate of diffusion.
a- Increase b- Decrease c- Not affect d- nill
- 4) Solation is the conversion of a Gel to a Sol, It needs on ----- temperature
a- Change in b- cool c- ice d- high
- 5) A piece of potato when placed in a solution and swells. The solution is:
a- Hypotonic b- Hypertonic c- Isotonic d- saline water
- 6) Transport of molecules against concentration gradient using energy is
a- active, b- passive, c- permeability, d- transpiration.
- 7) Stomata in light.
a- opened, b- closed, c- not changed, d- flaccid
- 8) Wall pressure of the cell is turgor pressure.
a- less than, b- more than, c- equal to d- nill
- 9) Chlorophyll absorbs light and release :

a- hydrogen, b- photon, c- electron, d- proton.

10) Receptor of CO₂ in C₃ plants is:

a- Ribulose-5P, b- Glyceraldehyde-3P, c- Ribulose 1,5biP,
d- Phospenol pyruvate.

11) Enzyme for Alcoholic fermentation is :

a- Lyase, b- Dehydrogenase, c- Oxidas, d- Hydrolase.

12) Coenzyme I is :

a- NADP, b- FAD, c- NAD, d- NADH₂

13) The active site of enzyme is a pocket created by :

a- Substrates, b- Oxalic acid, c- Amino acids, d-
Polypeptides

14) Linkage specificity enzyme is explained by a theory of

a- Absolute, b- Functional bound, c- Induced fit, d- Key and
lock

15) Polypeptide chains consists of numbers of amino acids linked by

a- Ester bound, b- Peptide bound, c- Amino bound, d- Protein
bound



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Course specification

Program on which the course is given:	1 st year-Science
Major or Minor element of Program	Major
Department offering the Program:	Botany and Microbiology Department
Department offering the course:	Botany and Microbiology
Academic year / Level:	1 st year 2 nd semester
Date of specification approval:	26- 8 -2025

a-Basic Information

Title: Systematic Botany and Plant Physiology **Code:** B.102

Lecture: 2 h/week **Practical:** 1h/week **Total:** 3 h/week

b-Professional Information

1 - Overall Aims of Course

The main aim of the course is to ensure that the student has the necessary knowledge and understanding the followings:

1- Systematic Botany:

- a- Classification of Plant kingdom.
- b- The evolutionary steps among their different order and families.
- c- Characters of each plant subkingdom and life cycles of different members of each division.

2- Plant Physiology:

- a- Solutions and Colloidal state.



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- b- Protoplasm diffusion and permeability.
- c- Osmosis and Transpiration
- d- Plant Enzymes.
- e- Photosynthesis and Respiration.

2 - Intended Learning Outcomes of Course (ILOs)

a- Knowledge and Understanding:

- a1- Study classification of Plant kingdoms.
- a2- Recognize the evolutionary steps among their different order and families.
- a3- Describe the characters of each plant subkingdom and life cycles of different members of each division.
- a4- Recognize about types of solutions, colloidal state, permeability and protoplasm diffusion.
- a5- Know of osmosis and transpiration.
- a6- Study plant enzymes, photosynthesis and respiration.

b- Intellectual Skills

- b1- Characterize of the systematic and features of each plant division.
- b2- Develop methods for studying of the characters of each plant division.
- b3- Discuss of the evolutionary steps among the different order and families of embryonic plants.
- b4- Characterize of types of solutions, colloidal state, permeability and protoplasm diffusion,
- b5- Design of the different methods and equipments used in studying of plants-water relationships.
- b6- Discuss the plant enzymes, photosynthesis and respiration.

c- Professional and Practical Skills

- c1- Explain the basis of the systematic and features of plant kingdom,
- c2- Practice characters of the plant communities.
- c3- Explain the evolutionary steps among the different order and families of embryonic plants.
- c4- Demonstrate many technical methods for studying the plant enzymes, colloids and plants-water relationships.



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c5- Examine the chemistry of enzymes and plant metabolism.

d- General and Transferable Skills

d1-Communicate the different knowledge sources.

d2-Get the different training methods for the modern technology resources and information technology skills.

d3- Practical learning for experimental control and problem solving skills.

d4-Activate continuous self learning process and the teamwork cooperation.

3- Contents

Topic	No. of hours	Lecture	Practical
Systematic and classification of Plant kingdom.	9	6	3
The evolutionary steps among their different order and families.	3	2	1
Characters of each plant division	9	6	3
Protoplasm diffusion and permeability	4	2	2
Types of solutions and colloidal state.	4	2	2
Osmosis and transpiration	3	2	1
Plant Enzymes	3	2	1
Photosynthesis and respiration	3	2	1



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4-Teaching and Learning Methods

- 4.1-Teaching in the lecture halls.
- 4.2- Self learning process.
- 4.3-Preparation of some assays.
- 4.4- Activating the cooperation between the students (team work).
- 4.5- Regular student seminars.

5- Student Assessment Methods

- 5.1) Oral test during lectures to assess the skills of the student during the lectures.
- 5.2) Questionnaires during practical courses to assess the benefits from the practical experiments.
- 5.3) Student small researches to assess the skills of the students in collecting knowledge.
- 5.4) Written exams to assess the final outcome from the learning process.

Assessment Schedule

Assessment 1: extends from week (1-13) followed by a final practical exam by week 14

Assessment 2: Written mid-term test (week 7).

Assessment 3: Final first term examination; practical, oral & written (after week 15)

Weighting of Assessments

Mid-Term Examination	10 %
Oral Examination.	10 %
Practical Examination	20 %
Final-term Examination	60 %
Total	100%



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6- List of References

6.1- Course Notes: Notes on **Systematic Botany and Plant Physiology**, Botany Dept.

6.2- Essential Books (Text Books): **Advanced Plant Physiology** , Malcolm B. Wilkins ;**The Plant Community**, Herbert C. Hamson;
Ecology and Metabolism of Plant Lipids, Glenn Fuller.

6.3-Periodicals, Web Sites: google.com, wikipedi.com.

7- Facilities Required for Teaching and Learning:

Overhead projector, Computers, Data Show Projectors

Lecturer: Prof. Dr. Hanan Abdallah, Dr. Asmaa Hussein, Dr Hoda Ali and Dr.Nabil Zkaria.

Course coordinator: Prof. Dr. Hanan Abdallah

Head of Department: Prof. Dr. Fifi Reda

Date of council : 26/8/2025.



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Course Matrix (B.102)

Title: Systematic botany and General Plant Physiology

Code: B. 102

Course Matrix (B.102)																						
Title: Systematic botany and General Plant Physiology																Code: B. 102						
Topics	Knowledge and Understanding						Skills															
							Intellectual						Professional and Practical					General and Transfer				
	a1	a2	a3	a4	a5	a6	b1	b2	b3	b4	b5	b6	c1	c2	c3	c4	c5	d1	d2	d3	d4	
1- Classifiaction of Plant kingdom.	x						x							x					x	x	x	x
2- The evolutionary steps among their different order and families.		x						x							x				x	x	x	x
3- Chracters of each plant subkingdom and life cycles of different members of each division.			x						x							x			x	x	x	x
4- Solutions and Colloidal state.				x						x							x		x	x	x	x
5- Protoplasm, diffusion and permeability.					x						x						x		x	x	x	x