1.0 VIRUSES

The word virus is derived from the Latin language and means a poisonous liquid or poison. Viruses have been variously defined by scientists and can be regarded as living or non-living. They are the smallest and possibly the most primitive living organisms yet known to science. Bowden (1964) defined viruses as submicroscopic infective entities that multiply only intracellularly and are potentially pathogenic. Virology is an aspect of microbiology that specializes in the study of viruses.

Viruses are responsible for many common human diseases, such as colds, flu, diarrhea, chicken pox, measles, and mumps. Some viral diseases—such as rabies, hemorrhagic fevers, encephalitis, polio, yellow fever, and acquired immunodeficiency syndrome (AIDS)—can result in death. German measles and cytomegalovirus can cause serious abnormalities or death in unborn infants. Of the estimated 1000 to 1500 types of viruses, approximately 250 cause disease in humans.

1.1 Nature and Origin of Viruses

The origin of viruses is not clear because it is not easy to describe viruses since they have both living and non-living characteristics. Three theories have been put forth to explain the origin of viruses.

1. One theory suggests that viruses are derived from more complex intracellular parasites that have eliminated all but the essential features required for replication and transmission.
2. A more widely accepted theory is that viruses are derived from normal cellular components that gained the ability to replicate autonomously.
3. A third possibility is that viruses originated from self-replicating RNA molecules. This hypothesis is supported by the observation that RNA can code for proteins as well as carry out enzymatic functions.

1.2 Structure of Virus

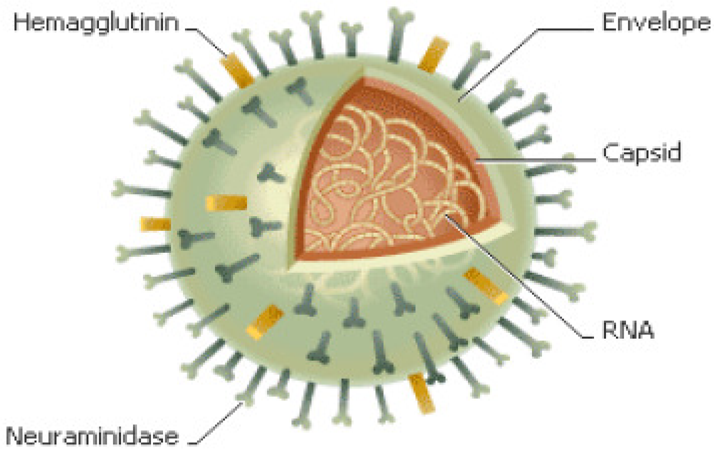
All viruses consist of two major components; a nucleic acid and protein. The nucleic acid core is surrounded by a protein sheath. The nucleic acid is only of one type in a virus ie either DNA or RNA. Viruses possessing DNA are called **Deoxyviruses** whereas those with RNA are called **Riboviruses**. The nucleic acids may be single or double stranded.

The protein sheath or coat is also called **capsid**. The capsid consists of several smaller units called **capsomeres** made up of amino acids. The functions of the capsid are;

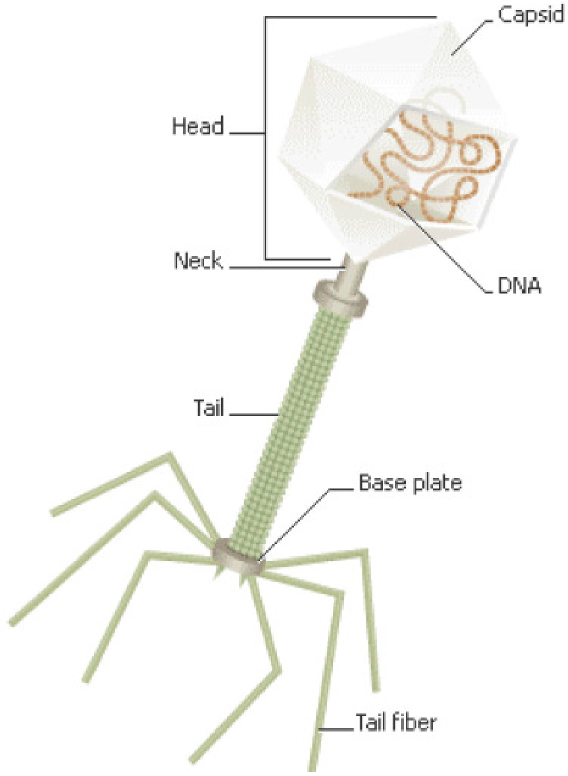
a) It provides the shape of the virus particle

b) It protects the nucleic acid

c) It is involved in the initial attachment of the virion to the host cell.



The influenza virus shown above has a relatively simple structure. A lipid (fatty) envelope surrounds the protein shell (capsid), which encloses coiled genetic material (RNA). Projecting from this envelope are two kinds of protein spikes, hemagglutinin and neuraminidase.



A bacteriophage is a type of virus that destroys bacteria. It consists of a head, containing the genetic material, and a tail, which attaches to the exterior of a bacterium.

1.3 Life Cycle or Replication of Bacteriophage

Two types of life cycle are exhibited by bacteriophage;

a) Virulent or lytic

b) Temperate or lysogenic.

In virulent life cycle, the intracellular phage multiplication leads to the disintegration and release of virions while in temperate life cycle no harm is done to the cell of the host bacterium.

The major events involved in the lytic cycle of T-even phages are;

i) Attachment of phage particle to the host

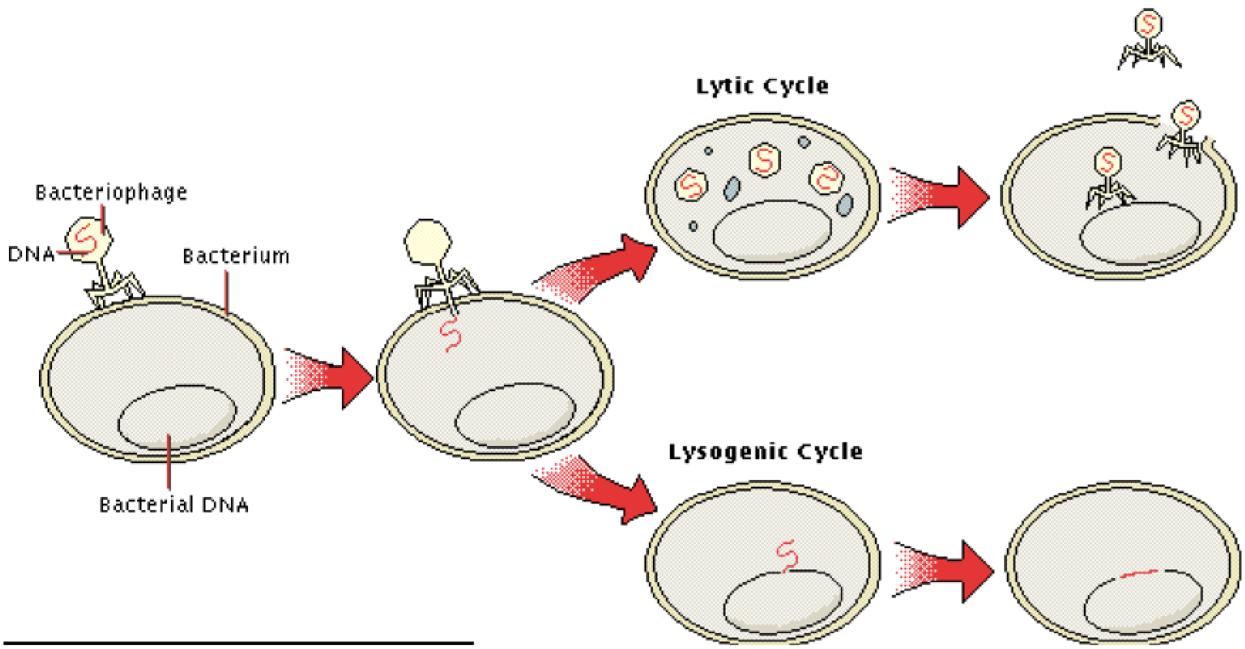
ii) Penetration into the host

iii) Replication of viral nucleic acid

iv) Protein synthesis

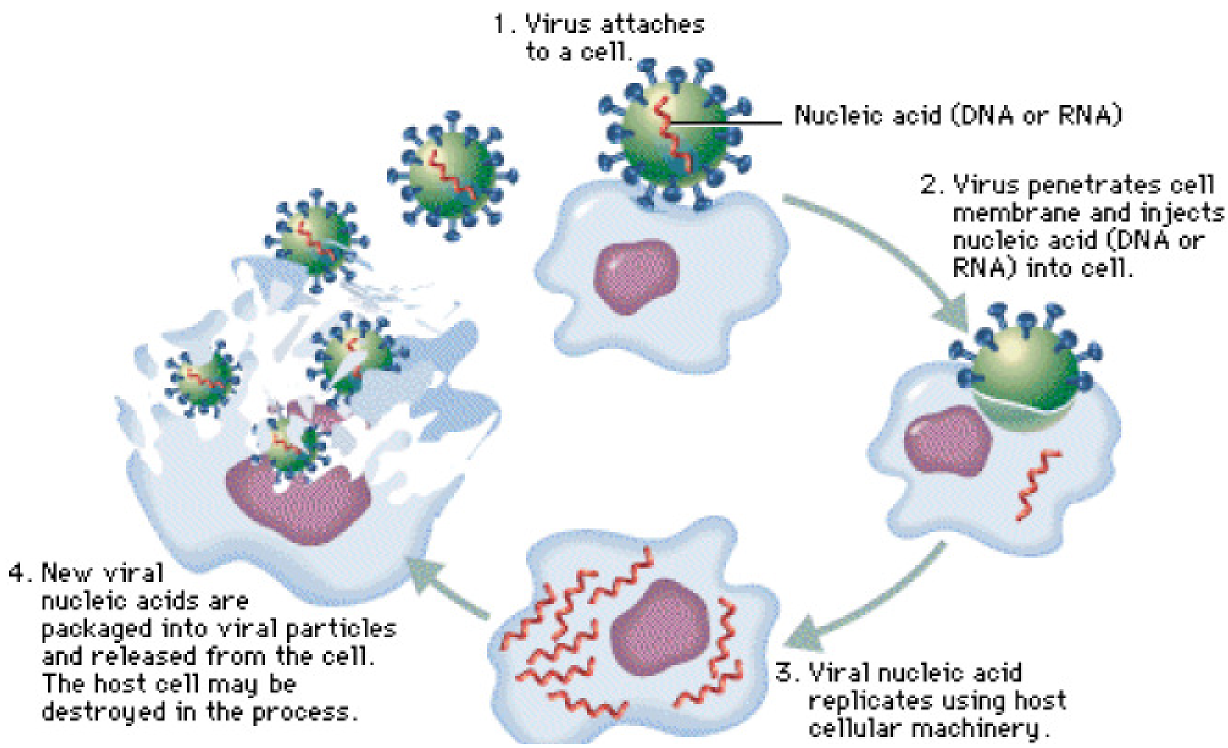
v) Assembly of new virions

vi) Release of mature viruses



Lytic and Lysogenic Cycles of a Bacteriophage

All bacteriophages (viruses that parasitize bacteria) have a lytic or infectious cycle, in which the virus, incapable of replicating itself, injects its genetic material into a bacterium. By pirating its host's enzymes and protein-building capacities, the virus can reproduce and repackage, making about 100 new copies before it bursts from and destroys the bacteria. Some bacteriophages, however, behave differently when they infect a bacterium. The injected genetic material instead integrates itself into its host DNA, passively replicating with it to be inherited by bacterial daughter cells. In about 1 in 100,000 of these lysogenic cells, the viral DNA spontaneously activates and starts a new lytic cycle.



Viral Replication

Outside of a host cell, a virus is an inert particle. Once inside a cell, a virus can replicate many times, creating thousands of viruses that leave the cell to find host cells of their own. Viruses that cause disease do so by destroying or damaging cells as they leave them.

1.4 Classes of Viruses

Family	Virus	Disease
Adenovirus	Common cold	
Bunyavirus	Hantaan La Crosse	Kidney failure Encephalitis (brain infection)
Coronavirus	Corona	Common cold
Filovirus	Ebola	Hemorrhagic fever
Flavivirus	Hepatitis C (non-A, non-B) Yellow fever	Hepatitis Hepatitis, hemorrhage
Hepadnavirus	Hepatitis B virus (HBV)	Hepatitis, liver carcinoma
Orthomyxovirus	Influenza types A and B	Flu
Papovavirus	Human papillomavirus (HPV)	Warts, cervical carcinoma
Paramyxovirus	Measles Mumps Parainfluenza	Measles Mumps Common cold, ear infections
Poxvirus	Orthopoxvirus	Small pox (eradicated)
Retrovirus	Human immunedeficiency virus (HIV) Human T-cell leukemia virus (HTLV-I)	Acquired immune deficiency syndrome (AIDS) Adult T-cell leukemia, lymphoma, neurologic disease
Rhabdovirus	Rabies	Rabies

Checklist

* **Can you describe a bacteriophage?**
* **Can you distinguish between the virulent and temperate life cycles of a virus?**
* **Why are viruses described as living on the threshold of life?**
* **List the families in which the viruses causing the following diseases can be found; rabies, common cold, mumps ebola fever, small pox, hepatitis and measles**

2.0 BACTERIA

Bacteria belong to the kingdom Monera and they include all unicellular prokaryotic organisms

General Features

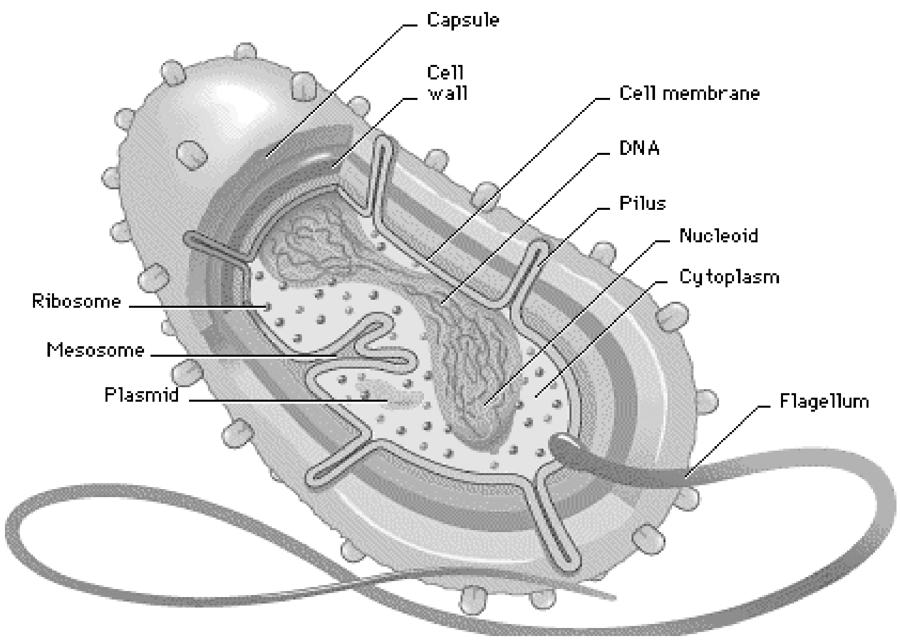
- The bacterial cell is prokaryotic lacking membrane bound organelles and a definite nucleus.
- They are surrounded by rigid cell wall composed of peptidoglycan and muramic acid that give them their characteristic shapes
- They lack nuclear envelope but each cell has long strand of DNA and some have additional small DNA fragment called plasmids
- They have independent single cells called trichomes which may occur as colonies embedded in gelatinous matrix
- Mainly non-motile, motile forms have simple whiplash flagella

2.1 Occurrence and distribution of Bacteria

Bacteria are ubiquitous organisms occurring almost everywhere. They are found in soil, water as well as air. The air we breathe is full of bacteria and they also occur as normal flora in the ear, nose and throat as well as within the stomach and intestines. They are present in and on the articles we use as food in our daily diet. Bacteria can be categorized as follows;

1. Bacteria found in soil: *Nitrosomonas, Nitrobacter, Azotobacter* and *Rhizobium.*
2. Bacteria found in water: *Salmonella typhosa, Clostridium tetani, Shigella dysentriae* and *Vibrio comma*
3. Bacteria in air: *Bacillus subtillis, Clostridium, and Sarcina lutea*
4. Bacteria in milk: Lactobacillus, *Streptococcus laciis, Escherichia coli,* and *Aerobacter cerogenes.*
5. Bacteria on meat and eggs: *Pseudomonas* and *Escherichia coli*
6. Food poisoning bacteria: *Staphylococcus aureus, Clostridium botulinum* and *Salmonella*
7. Bacteria pathenogenic to man: *Escherichia coli, Nesseria gonorhoeae, Vibrio comma,* etc.
8. Bacteria pathogenic to plants: *Agrobacterium, Erwinia, Xanthomonas, Corynobacterium, etc*.

The Bacterial Cell



- A typical bacterial cell is surrounded by an outer layer or cell envelope, which consists of two components – a rigid cell wall and beneath it a cytoplasmic or plasma membrane.
- The cytoplasm consists of inclusions like ribosomes, fat globules, vacuoles and nuclear material. Generally as prokaryotes they lack membrane-bound organelles

2.2 Morphology of Bacterial Cell

Size and shape

- Bacterial cells are recognized in one of the three conventional shapes
- rod shaped, spherical and spiral or curved.
- The smallest cocci range from 0.5µm to 1.5µm in diameter,
- the rod-shaped bacteria from 0.5µm diameter/1.5µm long to 1-1.2 µm diameter/4.8µm long,
- and some spirilli are as large as 600µm in length.

a) Rod-shaped bacteria (bacilli; singular bacillus): this is the commonest bacterial shape. The cells appear like tiny rods or hyphens (-) under microscope. They are cylindrical, straight or slightly curved, and always have rounded ends. They may occur singly or in groups of two (*diplococcus*), or in a chain (*streptobacillus*). Some rod shaped bacteria bear flagella.

b) Spherical bacteria (cocci; singular coccus): these are spherical or nearly so. They also occur in a variety of arrangements either singly, or in pairs (*diplococci*), tetrads (*tetracocci*), chains (*streptococci*), or in irregular clusters (*staphylococci*). Almost all spherical bacteria lack flagella.

c) Spiral bacteria: the least common of the three bacterial shapes is the spiral form. They are spirally curved, and therefore referred to as helicoids or curved. The spiral bacteria have two basic forms, those having a slight curve and a comma-like appearance (*Vibro comma*) and those which are spiral (*Spirillum undulum*) the body of many spiral bacteria remain spirally twisted like a cork-screw. These bacteria usually bear one or more flagella.

2.3 Nutrition in Bacteria

The basic nutritional requirement for growth and multiplication in bacteria are

- Water
- Carbon source
- Nitrogen source
- And inorganic salts

Based on nutrition, bacteria are classified into autotrophs and heterotrophs.

Autotrophic bacteria are capable of synthesizing all their organic compounds and they are capable of independent existence in soil or water. There are two types of autorophic bacteria;

a. Photosynthetic bacteria: these derive their energy from sunlight example; purple sulphur bacteria, *Rhodospirillum, Chlorobium limicola* and all *cyanobacteria.* They have specia photosynthetic pigment called bacteriochlorophyll.
b. Chemosynthetic bacteria: these obtain energy from chemical reactions and they include; nitrifying bacteria, iron bacteria, sulphur bacteria and hydrogen bacteria.

Heterotrophic bacteria are unable to manufacture their own food but depend on pre-formed organic compounds. They are also of two types;

a. Saprophytic; they grow on dead or decomposing organic materials and break down complex organic compounds to simpler inorganic compounds by secreting enzymes. The process of break down of proteins is known as putrefaction while carbohydrate breakdown is fermentation.
b. Parasitic; they grow on or within living organisms. The harmless ones are termed non-pathogenic, whereas the disease causing ones are called pathogenic bacteria.

2.4 Reproduction in Bacteria

Bacteria cells reproduce asexually by binary fission. They also produce different types of spores namely;

- Endospore
- Myxospores
- Cysts and
- Conidia

There is no clearly observed sexual reproductive mode of reproduction in bacteria as they lack both gametes and gametangia. Genetic recombination however occurs in bacteria.

2.5 GRAM Reaction

Gram stain is the most commonly used bacterial stain, named after its founder, Christian Gram (1884), a Danish bacteriologist. He made a smear on a microscope slide, soaked it in a violet dye, treated it with iodine and then washed with alcohol and counter-stained with safranine. Gram-positive bacteria retained the violet dye and appeared blue to purple. In Gram-negative bacteria, the alcohol washed the violet stain off and the bacteria retained safranine counter stain and appeared pink to red. This formed the basis for identification of bacteria.

2.6 Classification of Bacteria

The kingdom Monera consists of two sub-kingdoms; Archaebacteribionta and Eubacteriobionta

Sub-kingdom Archaebacteribionta consists of the Division Archaebacteria made up of bacteria that are anaerobic, have cell walls of unusual composition and live in extreme environments. They include;

1) Methanogens or methane bacteria (found in sediments, swamps, sewage treatment and animal intestinal tract)
2) Halobacteria (found in salt ponds and saline waters)
3) Sulpholobus or thermoacidophiles (found in acidic, sulphur hot springs)

Sub-kingdom Ebacteriobionta are the true bacteria which have cell walls made up of mucopeptide (murein) formed by N-acetyl glucosamine and N- acetyl muramic acid molecules. There are four divisions in this kingdom namely;

1) Division Eubacteria; usually unpigmented, purple and green-purple bacteria (coccus, bacillus, spilillum). The bulk of both pathogenic and beneficial bacteria belong to this division and examples include; *Trponema pallidum* and *Neisseria gonorrhea* responsible for syphilis and gonorrhea diseases in man; *Clostridium tetani* (tetanus), *Mycobacterium tuberculosis* (tuberculosis), *Escherichia coli* food-borne infections etc.
2) Division Actinomycetes; mold-like bacteria example *Actinomyces israelli, Streptomyces venezuelae, Mycobacterium leprae* (causes leprosy) etc.
3) Division Cyanobacteria; prokaryotes and formally classified as blue-green algae examples, *Nostoc*, *Anabaena*, *Gloecapsa quarternata* etc.
4) Division Chloroxybacteria; prokaryptic organisms also known as Prochlorons with bright green cells and live in small invertebrate animals called sea squirts. They have similar pigment compliments with higher plants (chlorophyll a and b, and accessory carotenoids)

2.7 Economic Importance of Bacteria

1. Bacteria beneficial to man.

a) Antibiotics, enzymes and vitamins e.g. streptomycin, aureomycin, neomycin, erythromycin and terramycin (all antibiotics) are produced by *Streptomyces*. The enzyme amylase is produced by *Bacillus* and vitamin B is produced by the fermentation of sugars and starch by *Clostridium acetobutilicum*.

b) Gas and Acids production.

c) Role in carbon, oxygen, nitrogen and sulfur cycles. Bacteria and fungi are very important in the geochemical cycling of these elements.

d) Sewage treatment. The domestic and industrial organic wastes are first treated by microbial mineralization before their final disposal.

e) Bacteria and genetic engineering. The use of isolated genes or segments of DNA in various manipulative processes is done in the field of research called genetic engineering or biotechnology.

2. Bacteria harmful to mankind

a) Plant diseases. Bacteria cause many serious diseases in almost all groups of plants. E.g. rot of maize caused by *Erwinia carotovora*, potato wilt (*Pseudomonas solanacearum* and blight of beans (*Xanthomonas phaseoli*).

b) Animal diseases. Some common bacterial diseases of man and their causative agents include; typhoid (*Salmonella typhi*), diphtheria (*Corynebacterium diphtheriae*), tuberculosis (*Mycobacterium tuberculosis*), syphilis (*Traponema pallidum*), cholera (*Vibro cholerae*), plague (*Yersinia pestis*) gonorrhea (*Neisseria gonorrhoeae*) and anthrax (*Bacillus anthracis*).

c) Bacteria and pollution. Many mercury compounds released in rivers and other water channels by industries are converted into methyl mercury by bacterial activity. Methyl mercury is a powerful nerve toxin for man. Such compounds in water also pollute the environment for fishes and other aquatic animals.

d) Biological warfare. Microbiologists are working to use bacteria as a biological weapon by attacking the enemy by producing infections in him, his animals and plants.

3.0 EUKARYOTIC PLANT CELL AND ORGANELLES

Eukaryotic plant cell is composed of a rigid cell wall composed primarily of cellulose and the inner living portion called protoplasm. The protoplasm id bounded by the cell membrane in the outside and the nuclear membrane inside. There is a definite nucleus within which lies the chromosomes and nucleolus and all eukaryotic cells separate many of the metabolic processes into discrete membrane-bound, organized, protoplasmic particles called **organelles**.

3.1 Mitochondria

These occur as small rods or granules in the cytoplasm and visible when cells are stained with certain dyes or observed with electron microscope. They are the “power house” of the cell.

Endoplasmic reticulum

This is an interconnected system of membrane-bound cavities ramifying the cytoplasm and in is continuous with the nuclear envelope. They are of two types, the rough endoplasmic reticulum (RER) and smooth endoplasmic reticulum (SER). The RER are associated with ribosomes and are the sites of protein synthesis in the cell; while the SER lack ribosomes.

3.2 Plastid

This the pigment bearing organelle found in the cytoplasm of plant cells. It is spherical, ovoid or lens shaped (usually 4-10µm in diameter and about 1-2 µm thick) and clearly visible without staining.

3.3 Dictyosomes

These are found in all cells. The central portion of this organelle consists of series of stacked discs, each composed of a flattened sack bounded by two membranes. Dictyosomes are also called GOLGI BODIES, and the term GOLGI APPARATUS refers collectively to all the golgi bodies, or dictyosomes of a given cell. The dictyosome is involved in formation of new wall when cells divide and in the general synthesis of wall materials.

3.4 Microbodies and microtubules

Present in the cytoplasm are small structures of definite length and about 25nm in diameter known as microtubules. They are found in the spindle fibers during mitosis, at the expanding margin of the cell plate and in cilia and flagella. They also participate in conduction of materials through the cell and in the orderly growth of cell wall by controlling alignment of cellulose microfibrils. They are also responsible for the orientation of other cytoplasmic components (e.g. nucleus, plastid, and mitochondrion).

3.5 Vacuoles

Within the vacuole is a fluid, cell sap, composed of water and a variety of dissolved materials (sugars, organic acids, pigments, alkaloids and various water soluble materials). The vacuole is the storehouse of food materials and deposit of waste products. The vacuoles also maintain cell turgidity by the presence of the differential permeable vacuolar membrane (tonoplast), which in actual sense is the inner membrane of the cytoplasm.

3.6 Crystals and stored food

In the cells of various parts of the plant may be found crystals, differing considerably in size and shape, being waste products or excretory products of the protoplast.

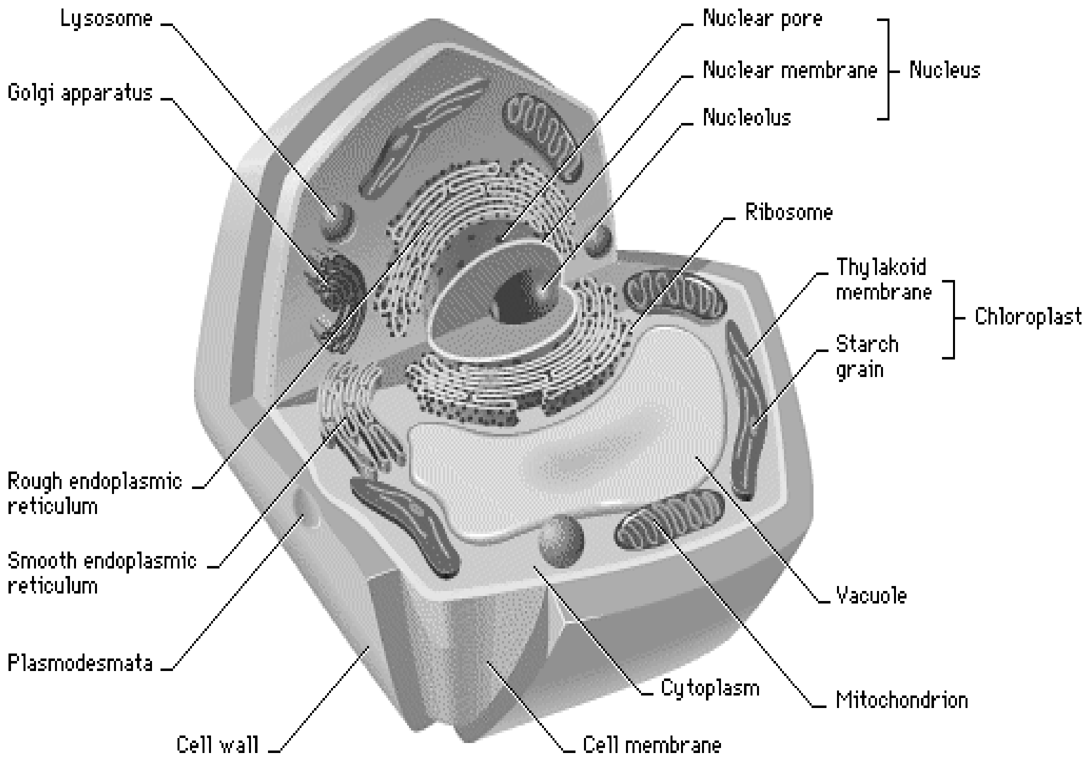


DIAGRAM OF A PLANT CELL SHOWING ORGANELLES

4.0 FUNGI

What is a fungus?

Fungi are nucleated, achlorophyllous organisms which typically reproduce sexually and asexually, and whose usually filamentous branched somatic structures are surrounded by cell walls and found in the air, water and land.

General Features

- The cell wall is made up of chitin combined with cellulose and other complex carbohydrates like ß-glucan. Fungi are heterotrophic and their stored food reserve is glycogen.
- Most fungi are filamentous and cells which are tubular, whitish or colorless joined end to end.
- The vegetative filament is known as hypha and a mass of hypha is called mycelium.
- Hyphae show apical growth and grow indefinitely under favorable conditions.
- Hyphae of most fungi are divided by cross walls (septa) and are termed septate. Hypae lacking cross walls are non septate and referred to as coenocytic.
- Septate hyphae may be uninucleate or binucleate.
- Non septate hyhae are also multi nucleate – meaning many nuclei within a common cytoplasm comprising the filament.
- Fungi absorb nutrients through the cell wall and cell membrane. To do this, they secrete digestive enzymes into their immediate environment and absorb the liquefied nutrient produced by the secreted enzymes.
- Thus fungi are important decomposers, aiding the breakdown of dead matter and the recycling of inorganic as well as organic molecules in an ecosystem.
- Many species of fungi are either decomposer (saprobes) or symbionts (i.e live with another organism). As symbionts, they may be parasitic and harm the host; they may be beneficial to their host or may cause no mutual harm or benefit.

4.1. Classification of Fungi

Fungi classification is a very dynamic area and usually depends on a number of criteria we shall consider the following groups in details; Chytridiomycota, Oomycota, Zygomycota, Ascomycota, Basidiomycota and Deuteromycota. The myxomycetes were previously classified as fungi. They are currently not regarded as true fungi as they have both fungi-like and animal characteristics. Their vegetative cells are amoeboid but they bear spores and fruiting structures with cellulose walls. They are now classified in kingdom protista.

4.1.1 Class Chytridiomycota

Member of this group are also known as chytrids and they bear motile, flagellated cells (spores and gametes). They are aquatic and have coenocytic hyphae. Some are parasitic on fresh water plants and animals, terrestrial plants and as saprobes on a wide variety of plants and animals. Examples are; *Synchytrium*, *Chytrium*, *Saprolegnia*, *Phytophthora*, *Pythium* and *Albugo*.

4.1.2 Class Zygomycota

Members do not have motile cells during their life cycle and their sexual spores are thick-walled resting spores called zygospores. They are mainly saprophytic and the parasitic forms produce profusely branched, well developed mycelia that ramify and immerse the host. The mycelia are mostly coenocytic, coarse, grey or whitish in color. One of the best known and most widespread member of this group is *Rhizopus stolonifera* – the common bread mold, *Entomorphthora*, is a common insect pathogen and *Pilobolus*.

4.1.3 Class Ascomycota

The most famous of this class are the brewers or baker's yeast, bread molds, truffles and morels. Asco- means 'sac', which refers to the sac-like filamentous structures where spores form in ascomycetes. The spore sacs are called asci (singular ascus). They are found in a variety of habitats including in soil, on dung, in marine as well as freshwater, as saprophytes of animal and plant remains, and also as parasites on plants and animals. The mycelium is well developed, profusely branched and septate, however, yeasts are unicellular. Ascomycetes are of interest because they cause plant diseases like Dutch elm disease, apple scab, and stem rot of strawberry, powdery mildew and brown rot disease of peach, plum and apricot. They are also the most common fungi that appear in lichens. Examples are Yeasts – *Saccharomyces, Aspergillus*, *Peziza*, *Claviceps*, *Penicillium*, *Neurospora* and *Taphrina.*

4.1.4 Class Basidiomycota

Like the ascomycetes, the basidiomycetes are filamentous with uninucleate or multinucleate hyphae. They form spores on structures called basidia; and such spores are known as basidiospores. Members are mostly terrestrial and saprophytic or parasitic. Saprophytic are mostly responsible for wood decay. The most developed type of fruiting structure is the basidiocarp and commonly identified as mushrooms, puff-ball, bird's nest, stink-horn, bracket fungi, jelly fungi, coral fungi etc. basidiomycetes also include rusts and smuts which cause plant diseases.

4.1.5 Class Deuteromycota

These are also known as fungi imperfecti (imperfect fungi). They are defined by the absence of sexual reproduction. The sexual stage remains unknown, if it exists. They reproduce almost exclusively by conidia. They are mostly free-living and terrestrial, but some are parasitic.

4.2 Lichen

Lichens are fungi and photosynthetic organisms living together. They are symbiotic relationships consisting of a fungus and a green alga, a fungus and a cyanobacterium or a fungus with both. Within the symbiosis, the fungus gets carbohydrate from both the alga and fixed nitrogen from the cyanobacterium, while the photosynthetic organisms receive nutrients and a place for protected growth within the surrounding fungal mycelia. Lichens tolerate environmental conditions that are too extreme for most other life forms. They live on bare rocks, in the blazing sun and extreme cold in deserts, in both Arctic and Antarctic regions, on trees etc.

4.3 Economic Importance of Fungi

Fungi are both beneficial and destructive to man, animals, plants and the environment generally.

Beneficial aspects

1. Industrial usefulness.
   a) Bread making. Yeast facilitates the rising of dough in bread making.
   b) Wine and beer brewing. Yeast is also essential in fermentation process.
   c) Cheese making and coloration using *Penicillium.*
   d) Production of organic acids.
   e) Antibiotic production.
   f) Cocoa fermentation.
   g) Vitamin synthesis.
2. Fungi are decomposers and just as critical to existence of our world as producers because with bacteria they break down dead organisms and release nutrients and minerals to the soil and carbon dioxide into the air.
3. Fungi also serve as food, e.g. edible mushrooms and truffles.
4. Fungi are very useful research tools because of the rapidity with which they grow and reproduce.

Negative aspects of fungi

1. Diseases of man. The most fungal infections are of skin, outer respiratory tract, lungs, bones, kidney, corneal tissues of the eye etc.
2. Diseases of animals
3. Spoilage of food and stored produce
4. Poisonous fungi and toxins
5. Wood rotting.

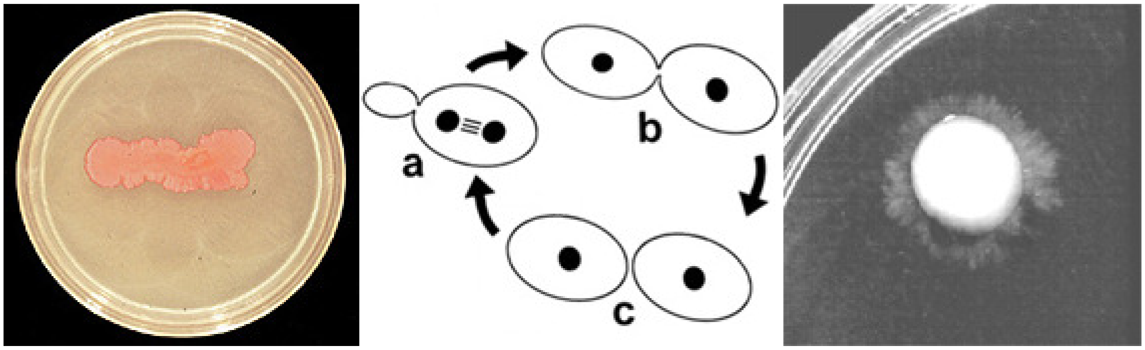


Fig. 4a. Yeast colony of *Rhodotorula* (right), Fig. 4b. Yeast cell undergoing budding (middle) and Fig. 4c. Dimorphic species having both mycelium and yeast.

Figure 4c: Zoospore of Chytridiomycota (left) and *Allomyces* gametangia

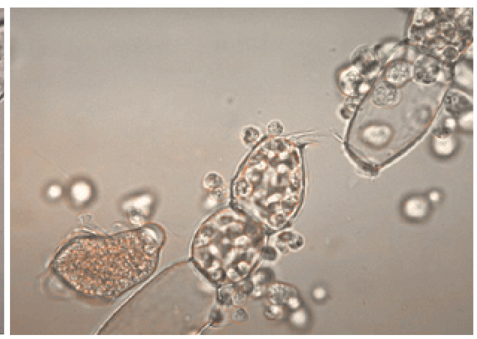


Figure 4d: Male and female gametes released from *Allomyces* gametangia

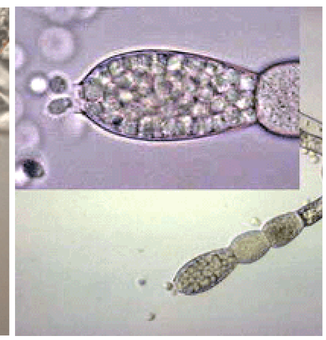


Figure 4e: Zoospores of Allomyces released from Zoosporangium

Figure 4f: *Pencillium* conidia

Figure 4g: *Cortinarius clelandii* mushroom. basidiospores and basidia are borne on the lamella of mushrooms.

Figure 4h: *Lycogala* is another genus with much larger sporangia.