CELL BIOLOGY

The study of cells is known as cytology. A cell is a fundamental unit of life. All organisms whatever their type or size are composed of cells.

The cell theory states that;

1. All living organisms are composed of cells.
2. All new cells are derived from other cells.
3. Cells contain the hereditary material of an organism which is passed on from parent to daughter cells.
4. All metabolic processes take place within cells.

INVESTIGATION OF THE CELL STRUCTURE

Cells are investigated using microscopes. There are 3 main types of microscopes, i.e.

- Compound light
- Electron
- Phase contact

The compound light microscope

This is a type of microscope that uses light to investigate structures. Two lenses are used i.e. objective lens and the ocular lens (eye piece lens).

Light from an object passes through the first lens (objective) and produces a magnified image which acts as the object for the second lens (eye piece lens) which further magnifies it.

The degree of detail which can be seen with a microscope is called its resolution (resolving power). This measures its ability to distinguish objects close together.

The electron microscope

It works on the same principle as the light microscope but instead of light rays, a beam of electrons is used. It magnifies objects over 500,000 times which compares with the best light microscope that magnifies only 1500 times.

Whereas the light microscope uses glass lenses to focus light rays, the electron beam of the electron microscope is focused using electron beams.

The image produced cannot be detected by a naked eye but is directed on a screen from which black and white photographs called photoelectron micrographs can be seen.

Advantages and disadvantages of the light and electron microscope

Light microscope	Electron microscope
(advantages)	**(disadvantages)**
It is easy and cheap to operate since it uses little or no electricity.	It is difficult and expensive to operate since it requires much electricity to produce an electron beam.
The natural colour of the specimen can be observed.	All images are in black and white.
It is small and portable.	It is very large and operated in special rooms.
It can view living and dead materials.	The high vacuum required kills the living materials.
Preparation of material is quick.	Preparation of material is lengthy and requires special equipment.
Materials are not changed or distorted by preparation.	Materials are changed or distorted by preparation.
Disadvantages	**Advantages**
It has a low resolving power i.e. 200nm.	Has a high resolving power of about 1nm.
It has a low magnifying power i.e. up to 1500 times.	Has a high magnifying power i.e. up to 500,000 times.

CYTOLOGY

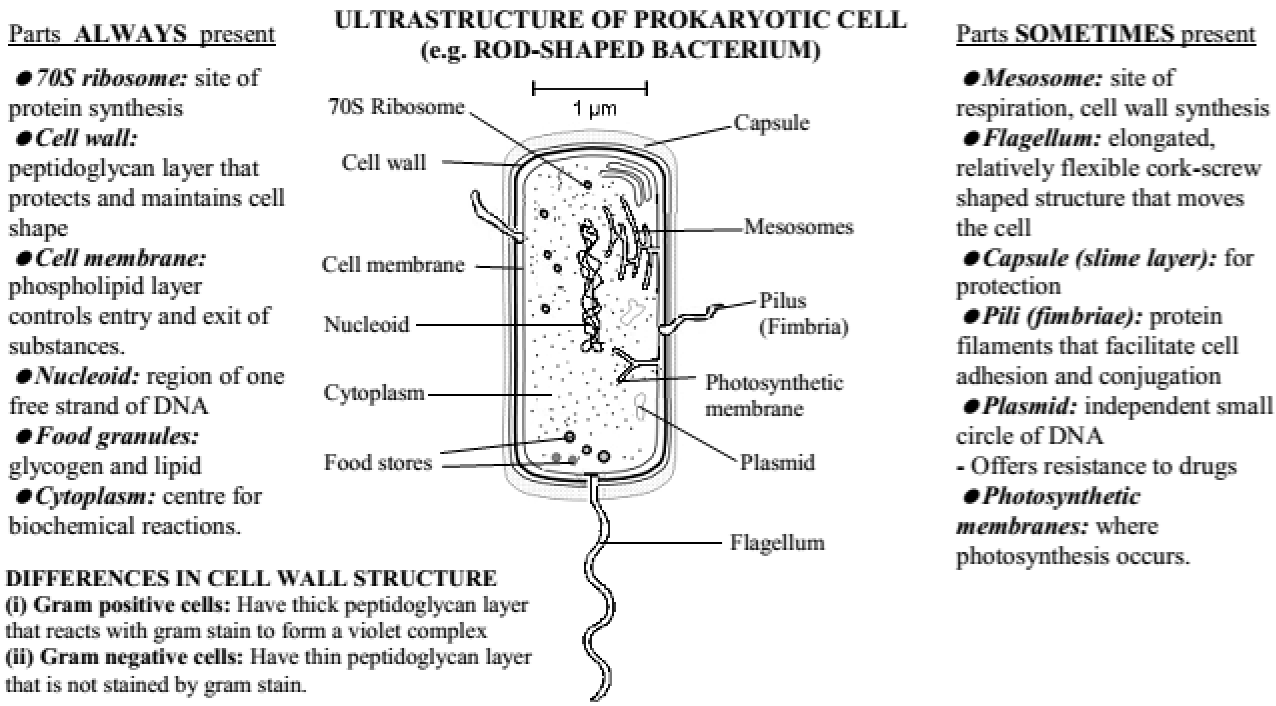
All cells are self-contained and self-sufficient units. They are surrounded by a cell membrane and have a nucleus or nuclear area.

Types of cells

There are two types of cells grouped according to their structure. They include ***prokaryotic and eukaryotic cells.***

Structure of prokaryotic cells

These are cells of bacteria. They are referred to as primitive cells because they are believed to have occurred in the earliest organisms. Their DNA (Deoxyribose Nucleic Acid) is not enclosed within a nuclear membrane therefore have no true nucleus. Such cells also have no membrane bound organelles.



(diagram in F.A page 30 fig 2.24)

The structure of eukaryotic cells

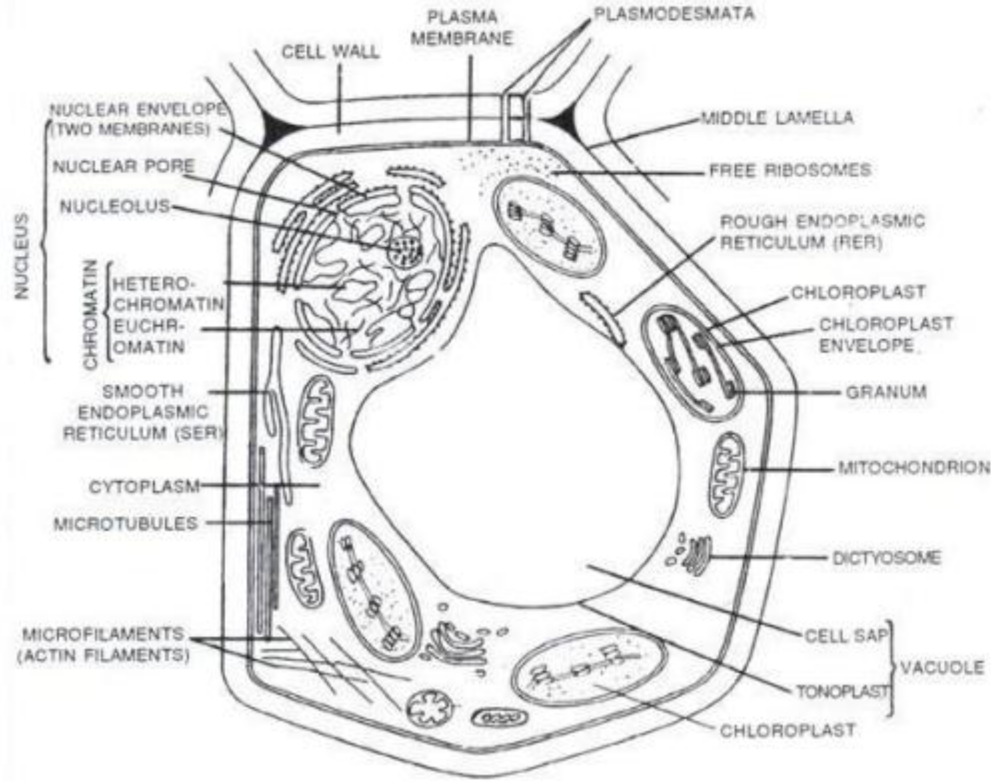
These are true cells that developed from prokaryotic cells. This development involved several stages which include:

i) Development of a nuclear membrane around the nuclear material forming a true nucleus.

ii) Development of membrane bounded organelles e.g. mitochondria and nucleus within the cytoplasm of the cell.

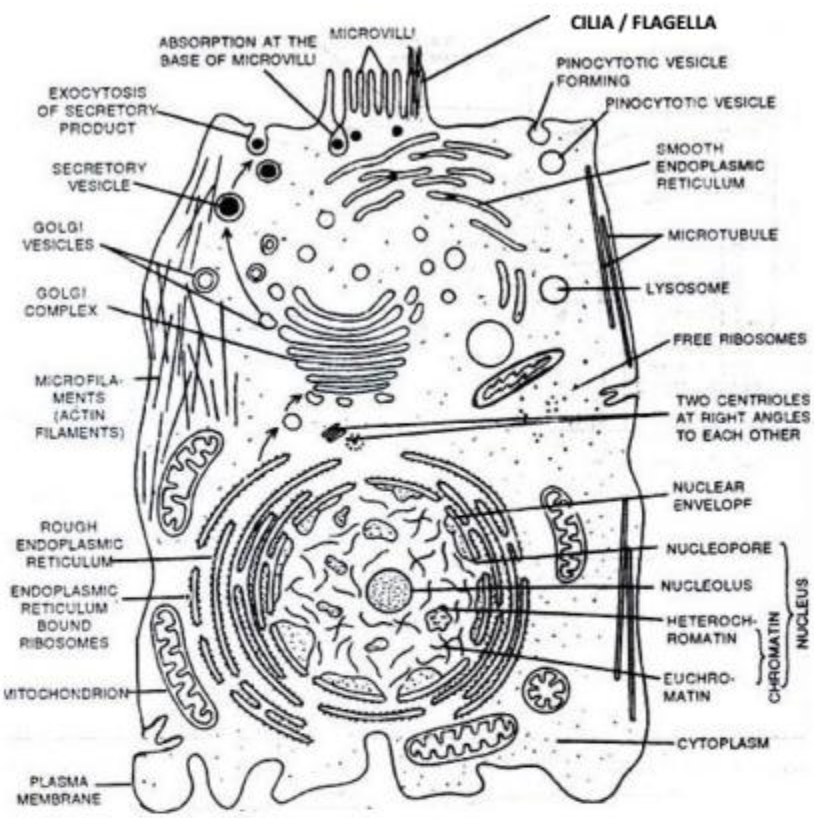
There are two main types of eukaryotic cells i.e. the plant cell and animal cell.

Structure of a plant cell



(diagram in B.S page 135 fig. 5.11)

Structure of the animal cell



(diagram in B.S page 135 fig. 5.10)

Differences between prokaryotic and eukaryotic cells

Prokaryotic cells	Eukaryotic cells
They lack a true nucleus since the genetic material is naked with scattered areas of nucleoplasm with no nuclear membrane.	Have a true nucleus with a membrane binding the genetic material.
There are no chromosomes but only circular strands of DNA.	Chromosomes are present on which DNA is located.
No mitosis or meiosis occurs.	Mitosis and meiosis occur.
Lack the membrane bounded organelles e.g. chloroplast, mitochondria.	Have membrane bounded organelles.
Flagella if present lack the 9+2 fibril arrangement.	Flagella have the 9+2 internal fibril arrangement.
Ribosomes are smaller.	Ribosomes are larger.

Differences between plant and animal cells

Plant cells	Animal cells
Cell wall present in addition to the cell membrane.	Cell wall absent, only cell membrane surrounds the cell.
Pits and plasmodesmata present.	Pits and plasmodesmata absent.
Plastids e.g. chloroplasts and leucoplasts are present.	Plastids absent.
Mature cells have large single central vacuole filled with cell sap.	Vacuoles e.g. contractile vacuoles if present are small and scattered throughout the cell.
Tonoplast present around the vacuole.	Tonoplast absent.
Cytoplasm confined to a thin layer at the edge of the cell.	Cytoplasm present throughout the cell.
Nucleus at the edge of the cell.	Nucleus anywhere in the cell but often central.
Lysosomes absent.	Lysosomes present.
Cilia and flagella absent.	Cilia and flagella present.
Starch granules used for storage.	Glycogen granules used for storage.
Middle lamella present.	Middle lamella absent.
Only meristematic cells are capable of division.	All cells are capable of division.
Few secretions released.	A variety of secretions released.

PARTS OF A CELL

1. Cytoplasm.

All cell organelles are contained within the cytoplasmic cell known as cytoplasm.
It is an aqueous material which is a solution of many cellular chemicals including simple ions like sodium, phosphates, chlorides, etc. and organic molecules e.g. ATP (Adenosine Tri Phosphate) and nucleotides.
It also contains storage materials like oil droplets.
Many important bio-chemical processes e.g. glycolysis occurs within the cytoplasm.
It is not static but capable of mass flow which is known as cytoplasmic streaming.

2. Cell membrane.

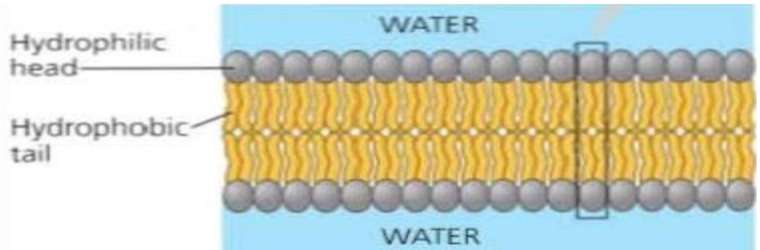
Its main function is to serve as a barrier between the cell and its environment.
It can permanently exclude certain substances from the cell while permanently retaining others.
Some substances can pass freely in and out of the membrane yet others can be excluded at one moment only to pass freely across at another occasion. Due to this, the membrane is said to be partially or semi permeable.
It is believed that the cell membrane is made up of two chemical groups i.e. proteins and phospholipids. There are two theories to explain the arrangement of these chemicals i.e.

i) The protein phospholipid sandwich theory (Davson Daniel model).
ii) The fluid mosaic model (Singer-Nicholson model)

The protein phospholipid sandwich theory

Phospholipids comprise of a hydrophilic (water loving) head and a hydrophobic (water repelling) tail. With this in mind, Davson and Daniel proposed a model of the cell membrane in which the phospholipid molecules formed a bi-molecular layer. The hydrophobic tails associated with each other at the center of the membrane with the hydrophilic heads extending towards the surface. At each side of the phospholipid was a layer of protein molecules.

The Daniel model of the structure of the cell membrane



Adopted from biology by Campbell and Reece

(Check diagram in F.A page 27 fig 2.21)

The fluid mosaic model

Singer and Nicholson suggested a modified structure of the cell membrane. The bimolecular phospholipid layer with its inwardly directed hydrophobic tails remained unchanged. However they suggested that the protein molecules vary in size and have a much less regular arrangement. They suggested that some proteins occur on the surface of the phospholipid layer while others extended into it and some even extended completely across.

They further noted that when viewed from the surface, the proteins are dotted throughout the phospholipid layer in a mosaic arrangement.

They further suggested that some proteins and lipids have short branching carbohydrate chains forming glycoproteins and glycolipids respectively.

Note: in this model, it is thought that protein also assist in the active transport of materials across the membrane.

The fluid mosaic model of the cell membrane

(**diagram in F.A page 27 fig 2.22A**)

Functions of the membranes

The phospholipid bi-layer provides the basic structure of membranes. It also restricts entry and exit of polar molecules and ions. The other molecules have a variety of functions.

1) The channel proteins and carrier proteins.
   These are involved in the selective transport of polar molecules and ions across the membrane.
2) Enzymes.
   Proteins sometimes act as enzymes e.g. the microvilli on epithelial cells lining some parts of the gut contain digestive enzymes in their cell surface membrane.
3) Receptor molecules.
   Proteins have very specific shapes. This makes them ideal as receptor molecules for chemical signaling between the cells e.g. hormones are chemical messages which circulate in blood but only bind to specific target cells which have the correct receptor sites.
4) Neural transmitters, the chemicals which enable nerve impulses to pass from one nerve cell to the next, also fit into specific receptor proteins in nerve cells.
5) The antigens

These act as cell identity markers or 'name tags'. They are glycoproteins that are proteins with branching carbohydrate side chains like antennae. There are an anonymous number of possible shapes to these side chains, so each type of cell can have its own specific markers. This enables cells to recognize other cells and to behave in an organized way. E.g. during the development of tissues and organs in multicellular organisms. It also means that foreign antigens can be recognized and attacked by the immune system.

6) Glycolipids
Also have branching carbohydrate side chains and are involved in cell-cell recognition. They may act as receptor sites for chemical signals. With glycoproteins they are also involved in sticking the correct cells together in tissues.

7) Energy transfer
In photosynthesis and respiration proteins take part in the energy transfer systems that exist in the membranes of the chloroplasts and mitochondria respectively.t

8) Cholesterol
Act like a plug, reducing even further the escape or entry of polar molecules through the membrane.

MEMBRANOUS ORGANELLES

(refer to table in B.S on pages 137 and 139)

1. NUCLEUS

This is the most prominent feature of the cell. Its shape, size, position and its chemical composition of the cell vary from cell to cell but its functions are always the same, mainly to control the cell's activities and to retain the organism's hereditary materials (chromosomes). It's bounded by a double membrane known as the nuclear membrane (nuclear envelope).

It possesses many large pores which permit the passage of large molecules e.g. RNA between it and the cytoplasm.

The cytoplasm-like material within the nucleus is called nucleoplasm which contains chromatin but it is made up of coils of RNA bound to proteins. During cell division, the chromatin condenses to form chromosomes.

Within the nucleus, are one or two small round bodies, each known as the nucleolus which is the one responsible for the manufacture of RNA?

Functions of the nucleus

- ✓ It contains the genetic material of the cell in form of chromosomes.
- ✓ It is the control center for the chemical activities of the cell
- ✓ The DNA in the nucleus carries the instructions of synthesis of proteins.
- ✓ It's involved in the production of ribosomes and RNA
- ✓ It is essential for the cell division.

(Diagram in BS page 137)

2. CHLOROPLASTS

They belong to the large group of organelles known as plastids. Chloroplasts are bounded by a double membrane known as the chloroplast membrane or envelope.

Within the chloroplast envelope, there are some distinct regions.

Stroma

This is a colourless structure or matrix in which other structures are embedded. Such structures involve the grana. Each granum is made up of 2 to 100 closed fattened sacks called thylakoids, within the thylakoids are located at the photosynthetic pigments called chlorophyll. Some of the thylakoids are tubular extensions which interconnect adjacent grana.

Also present within the stroma are a series of starch grains which act as temporary stores for the products of photosynthesis. It also contains a small amount of DNA and oil droplets.

The structure of the chloroplast

(Structure in BS on page 201 fig. 7.7)

3. MITOCHONDRIA

These are found within the cytoplasm of all eukaryotic cells. Though in some cells like in the red blood cells, they may be absent. They are double bounded by a double membrane.

The outer of which controls the entry and exit of chemicals. The inner one is folded inwards to give rise to extensions called cristae.

The cristae increase the surface area on which the respiratory processes take place.

The surfaces of the cristae have stalked granules along their length. The remainder of the mitochondrion is the matrix which is a semi liquid material containing proteins, lipids and traces of DNA.

Mitochondria serve as signs for some stages of respiration. The numbers of mitochondria in the cell therefore vary with the metabolic activities of the cell. This means that highly active cells have more mitochondria than less active ones. Similarly the number of cristae increases according to how active the cell is.

Respiratory enzymes are also located on the cristae. This means that the muscle cells have more mitochondria than the red blood cells

Transverse section of the mitochondria

(Diagram in B.S page 276 fig. 9.12)

Stalked particles/granules contain ATPase enzyme which increases surface area over which respiration occurs.

4. ENDOPLASMIC RETICULUM (E.R)

The ER is the system of membranes found out on the nucleus forming a cytoplasmic skeleton. The ER is an extension of the outer nuclear membrane with which it is continuous. The membranes form a series of sheets which enclose flattened sacks called cisternae when the membranes are lines with ribosomes; they are called rough endoplasmic reticulum (R.E.R). The RER is concerned with protein synthesis and it is most abundant in those cells which are rapidly growing or secrete enzymes.

In the same way, damage to a cell often results into increased formation in order to produce the proteins necessary for the cell repair.

Where the membranes lack ribosomes, they are known as smooth endoplasmic reticulum (S.E.R). The SER is concerned with lipid synthesis and is consequently in those cells producing lipid related secretions e.g. the sebaceous glands of the mammalian skin.

The general functions of the ER thus are:

- Providing a large surface for chemical reactions.
- Providing a pathway for the transport of the materials in the cell.
- Producing proteins especially enzymes (RER)
- Producing lipids and steroids (SER)
- Collecting and storing synthesized materials
- Providing a structural skeleton to maintain cellular shape. E.g. the SER of the rod cell of the eye retina.

5. GOLGI APPARATUS/DICTYOMES

The Golgi apparatus has the same structure with the smooth ER but it's more compact. It is composed of stacks of flattened sacks made of membranes.

The stacks are fluid filled and pinch off small membranous sacks called vesicles at their ends.

There is always one Golgi apparatus on each animal cell but plant cells have large number of stacks known as dictyomes.

The Golgi apparatus is more developed in secretory cells and neurons and is small in muscle cells. This suggests that the Golgi apparatus plays some role in the production of secretory materials.

The apparatus plays the following functions:

- Produces glycoproteins e.g. Mucin required for the secretion by adding the carbohydrate part of the protein.
- Produces secretory enzymes e.g. digestive enzymes of the pancreas.
- Secretes carbohydrates such as those involved in the production of new cell wall.
- Transports and stores lipids.
- Forms lysosomes.

(Diagram in F.A page 19 fig. 2.10)

6. LYSOSOMES

This is a simple spherical sac bounded by a single membrane and containing digestive enzymes (hydrolytic enzymes). It has no internal structures which are visible. The word lysosome comes from two words 'lysis' meaning splitting, 'soma' meaning body. Therefore lysosomes are connected with the destruction of cells and their structures.

Lysosomes are bound by a single membrane and contain digestive hydrolytic enzymes like hydrolases in acid solutions.

They isolate these enzymes from the remainder of the cell and in so doing they prevent them from acting upon other chemicals and organelles within the cell.

Functions of lysosomes

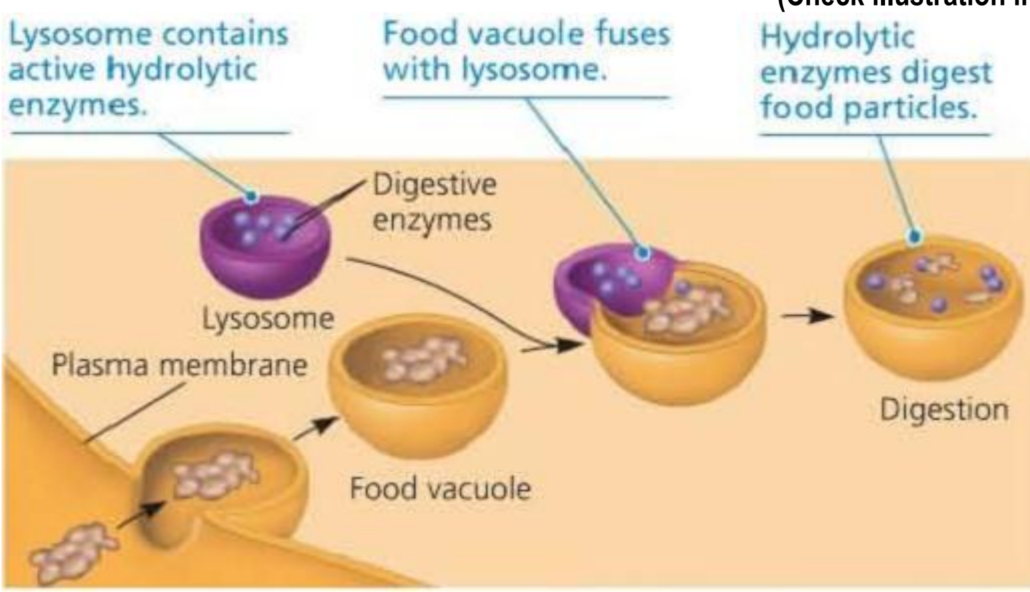
They digest materials which the cell consumes from the environment. In case of white blood cells, the material may be bacteria. In protozoa it is the food which has been consumed by phagocytosis. In either case, food is broken down within the lysosome, useful chemicals absorbed into the cytoplasm and wastes ingested by a cell.

They digest parts of the cell e.g. worn out organelles. After death of the cell, they are responsible for its complete breakdown a process called autolysis.

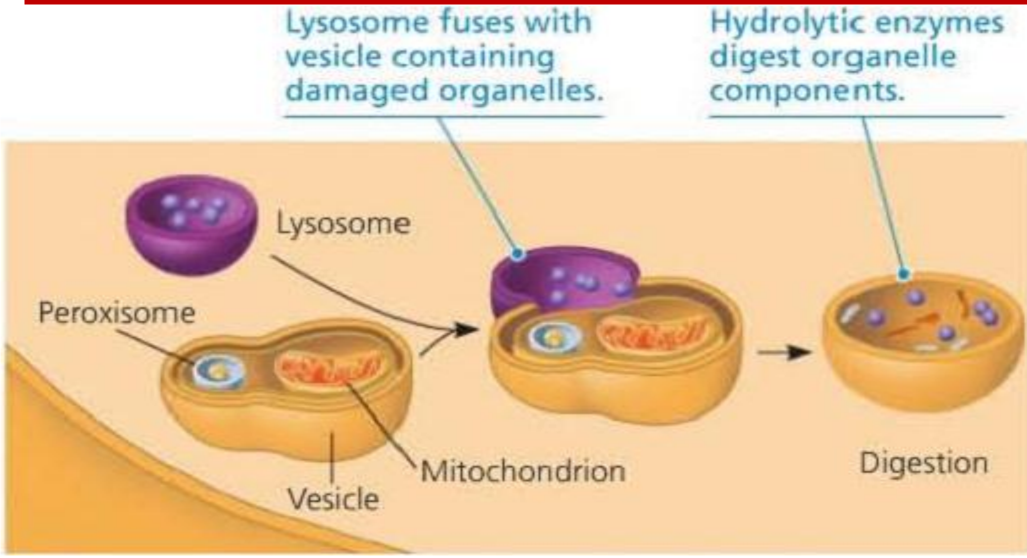
They release enzymes outside the cell (exocytosis) in order to break down other cells e.g. in the re absorption of tad pole tails during frog metamorphosis.

Functioning of lysosomes

(Check illustration in F.A page 21 fig 2.12)



Lysosome digesting food



Lysosome breaking down damaged cell organelles

7. MICROBODIES (PEROXOSOMES)

These are small roughly spherical organelles bounded by single membrane. They contain metabolic enzymes mainly catalase enzyme which catalyzes the breakdown of hydrogen peroxide which is a toxic bi-product of many chemical reactions within organisms.

Peroxides containing catalase are therefore more in metabolic reactions like those in the liver i.e.

$2H_2O_{2\,(aq)}$ $\qquad$ $2H_2O_{\,(l)} + O_{2(g)}$

8. VACUOLES

These are fluid filled sacs bounded by a single membrane. Within mature plat cells, there is usually one large central vacuole with a single membrane called a tonoplast.

The vacuole contains a solution of mineral salts, sugars, amino acids, wastes e.g. tannins and pigments like anthocyanin.

Functions of vacuoles

- Sugars and amino acids which act as temporary food stores are stored within the vacuole.
- It stores anthocyanin which is of many colours and therefore may colour the petals to attract pollinating insects or fruits to attract animals for dispersal.
- They are temporary stores of organic wastes e.g. tannins. They accumulate in vacuoles of cells and are removed during leaf fall.
- They contain hydrolytic enzymes therefore perform functions similar to those of lysosomes.
- They support herbaceous plants and woody plants by providing the osmotic system which creates turgidity.

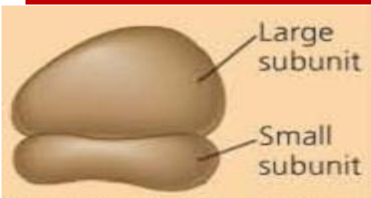
In animal cells, vacuoles are small, temporary and occur in large numbers. Common types include; food vacuoles, phagocytic vacuoles and contractile vacuoles which are important in osmoregulation in protozoa.

NON MEMBRANOUS ORGANELLES

RIBOSOMES:

These are small cytoplasmic granules found in cells.

- They occur in groups called polysomes.
- They are made up of RNA molecules and protein.
- They are important in protein synthesis.



STORAGE GRANULES

Every cell contains a limited store of energy. The store may be in form of soluble material e.g. the sugar found in the vacuoles of plant cells. It may also occur in colloidal form as grains within the cell.

Starch grains occur within chloroplast and in the cytoplasm of plant cells. Starch may also be stored in specialized leucoplasts called amyloplasts.

Food energy is stored as glycogen in glycogen granules in the cytoplasm of animal cells.

Oil/lipid droplets are also found within the cytoplasm of both plant and animal cells.

MICRO TUBULES

These are slender unbranched tubes occurring throughout living cells. Their functions are:

- They provide an internal skeleton to the cells thereby determining their shape.
- They aid in transporting materials within cells by providing routes.
- They form a frame work along which cellulose cell wall in plants is laid.
- They are major components of the cilia and flagella where they contribute to their movement.
- They are found in spindle fibres during cell division and within centrioles from which spindles are formed.

CILIA AND FLAGELLA

These are almost identical except that cilia are shorter and more numerous than flagella.

Both are 0.2 micrometers in diameter.

They are out-growth from cells and can beat either in one direction or both (cilia).

Their function is to move the whole organism e.g. cilia in paramecium or to move materials within an organism e.g. cilia lining the respiratory tract move mucus towards the throat.

Cross sections of a cilium shows that it contains a bundle of micro tubules which run longitudinally along its length arranged in a way that there are two in the center surrounded by a ring of 9 paired ones called doublets. This arrangement is described as the 9+2 pattern.

The transverse section of the cilium

(Diagram in F.A page 23 fig. 2.16B)

CENTRIOLES

These are small hollow cylinders about 0.3-0.5 μm long and about 0.2 μm in diameter. They occur in pairs in most animal cells. Each contains a triplet of micro tubules.

They arise from a distinct region of the cytoplasm called centrosome. Each centrosome has two centrioles. As cell division proceeds, the centrioles migrate to opposite poles of the cell where they synthesize the microtubules of the spindle.

MICROFILAMENTS

These are very thin strands about 6 nm in diameter. They are made up of a protein called actin and a smaller proportion of myosin since these are the two proteins involved in muscle contraction. It means that microfilaments play a role in movement within cells and of the cell as a whole.

MICROVILLI

These are tiny finger-like projections about 0.6 micro meters in length on the membranes of certain cells e.g. those lining the intestines and kidney tubules.

The microvilli are massed together and appear similar to bristles of a brush hence the term brush border given to the age of cells basing microvilli.

Each microvillus contains bundles of actin and myosin filaments hence allowing them to contract which along with their large surface area facilitate absorption.

CELLULOSE CELLWALL

It is found in plant cells made up of cellulose micro fibrils embedded in an amorphous polysaccharide matrix.
The matrix has polysaccharides e.g. pectin or lignin.

Functions of a cell wall

i) It provides support in herbaceous plants. As water enters the cell osmotically, the cell wall resists expansion and internal pressure is created which provides turgidity of the cell and the plant as a whole.
ii) It gives direct support to the cell and the plant by providing mechanical strength. The strength may be increased by presence of lignin in the matrix between the cellulose fibres.
iii) It allow movement of water through and along it hence contributing to movement of water in the plant as a whole especially in the cortex of the root.
iv) It stops loss of materials from the cell to the outside since it is less permeable than the cell membrane.
v) The arrangement of the cellulose fibrils in the cell wall gives the overall shape of the cell.
vi) It is a store of some food reserves.

THE DIVERSITY OF CELLS

(refer to F.A pages 28 and 29)

This diversity is seen between different species and within a single species. Structures like the chromosomes, mitochondria, endoplasmic reticulum and ribosomes are common in all cells but the shape, form and contents in individual cells show much variation.
Thus the cells of hydra differ from those of human though they share the same basic features and some perform the same function.
Within the body of a hydra, there are seven types of cells and these include:

1. Epithelial cells:
These possess a shape suitable for lining the surface of the body, organs and cavities within it.

2. Glandular cells:
These are suitable for producing a secretion e.g. mucus.

3. Erythrocytes (red blood cells):
These convey oxygen around the body since they are loaded with a red pigment haemoglobin.

4. Leucocytes (white blood cells):
These defend the body against diseases.

5. Nerve cell/neuron:
These contain slender arm-like processes that transmit electrical impulses through the nervous system.

6. Sensory cells:
These are capable of electrical activity which is generated by specific kinds of stimulation like light, sound, touch, etc.

7. Muscle fibres:
These are capable of movements since the electrical activity is accompanied by contraction since they are elongated.
Other cells found in animals below the level of mammals i.e. skin of animals include the following;

8. Flame cells:
These are found in flatworms and play an important role in osmoregulation.

9. Nematoblast/stinging cells:
These are found in sea anemones, hydra and jelly fish for piercing and poisoning prey due to their toxic fluid.

10. Musculo-epithelial cells:
These contain one side that contributes to the lining of the body whilst.
Other cells found in plants include;

11. Photosynthetic cells:
These build up complex molecules
Others include parenchyma cells, epidermal cells, guard cells and collenchyma cells.

MOVEMENT IN AND OUT OF CELLS

The various organelles and structures within a cell require a variety of substances in order to carry out their reactions. In turn they form products which are useful and some are wastes.

Most of these substances pass in and out of the cell in the following ways;

- Diffusion
- Osmosis
- Active transport
- Phagocytosis
- Pinocytosis

DIFFUSION

This is the movement of gaseous molecules from a region of high concentration along a concentration gradient.

Concentration gradient refers to the difference in concentration between two points of a diffusing particle.

Diffusion occurs because the molecules are in a random motion e.g. if molecules are closed in a vessel occupying one side and are in random motion, they collide with each other and the sides of the vessel.

Some particles on the side of high concentration start to move to the side of low concentration meaning that movement is in one direction only at the beginning hence a large concentration gradient and therefore rapid diffusion.

After a short time, particles spread themselves evenly in the vessel and at this point the rate of movement from one side to another is equal thus no concentration gradient and no net diffusion hence the particles are said to be in a dynamic equilibrium.

Factors affecting the rate of diffusion

1) **Temperature:**
   Increase in temperature increases the rate of diffusion since temperature increases the kinetic energy of the molecules hence more collisions and vice versa.
2) **Size of diffusing particles:**
   The larger the particles the lower the rate of diffusion and the smaller the particles the higher the rate of diffusion.
3) **Surface area over which diffusion occurs:**
   The larger the surface area the greater the rate of diffusion and vice versa.
4) **Concentration gradient:**
   The greater the concentration gradient, the higher the rate of diffusion and vice versa.
5) **Density of the diffusing particles/molecules:**
   The denser the diffusing particles, the lower the rate of diffusion and vice versa.
6) **Distance over which diffusion occurs:**
   The larger/bigger the distance the lower the rate of diffusion and vice versa.

Question: ***with examples, discuss the factors affecting the rate of diffusion.***

Types of diffusion

1. **Simple diffusion:**
   This is a type of diffusion where molecules and ions do not need carrier molecules to be carried across the membrane.
2. **Facilitated diffusion:**
   This is the diffusion where by molecules/ions are connected to other molecules to carry them across the membrane. The carrier molecules are mainly protein molecules, e.g. glucose molecules are not able to diffuse quickly through the membrane on their own. Therefore they combine with globular proteins in the cell membrane to carry them across.

OSMOSIS

This is the movement of water molecules from a region of their high concentration to a region of their low concentration across a semi-permeable membrane. OR

It is the movement of water molecules from a dilute solution to a concentrated solution across a semi-permeable membrane.

If the solution is separated from its pure solvent e.g. water, different forces act on these solution causing water molecules to come in a particular direction.

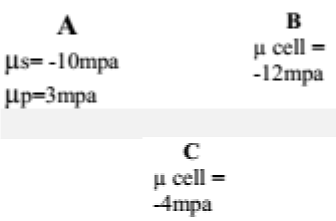
Terms used in osmosis

1) **Osmotic potential:**
   This is the capacity of a solution to allow in water molecules by osmosis. Therefore a concentrated solution has a higher osmotic potential than a dilute one.
2) **Osmotic pressure:**
   This is the force that must be applied to stop water molecules from entering that solution, i.e. a dilute solution has a higher osmotic pressure than a concentrated solution.
3) **Water potential of a cell (μ_{cell}):**
   This is the ability of water molecules to move out of a cell by osmosis. A dilute solution has a higher water potential than a concentrated one. ***It has a negative value.***
4) **Solute potential (μ_s):**
   It is a measure of the amount of solute in the solution. It is also defined as the degree of lowering the water potential. ***It always has a negative value***.
5) **Pressure potential (μ_p):**
   This is a force extended on the cell contents by the cell wall as a result of reaching the cell wall after water absorption. ***It has a positive value.***

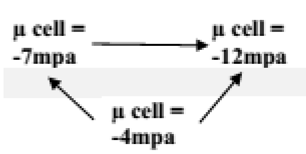
Water potential, solute potential and pressure potential all act on a cell at the same time in the following way;

$$\underset{\mu\ \text{cell}}{\text{Water potential (Negative)}} = \underset{\mu\ \text{s}}{\text{Solute potential (Negative)}} + \underset{\mu\ \text{p}}{\text{Pressure potential Positive)}}$$

For example: the diagram below shows 3 adjacent cells



a) Calculate the water potential of cell A.
b) By means of arrows, show the direction of water movement between the cells.



c) Explain why water potential of sucrose solution has a negative value.
   This is because water has a water potential of zero therefore sucrose having a negative value (lower water potential) enables water molecules to move into sucrose solution by osmosis and cannot move out of the solution.

Osmotic relations in cells

Cells owe most of their properties due to the permeability of their cell membrane. In case a cell is surrounded by pure water or a solution whose solute concentration is lower than that of the cell's contents, water flows into

the cell by osmosis and this brings about the swelling of the cell. In this case, the solution is said to be hypotonic since the osmotic pressure of the external solution is lower than that of the cell.
And if the cell is surrounded by a solution whose solute concentration and osmotic pressure exceeds that of the cell, water flows out of the cell hence it shrinks. In this case the external solution is said to be hypertonic.
If the solute concentration of the cell and its surrounding medium are the same, there is no net flow in either direction and the external solution is said to be isotonic with the cell.
The osmotic flow of water into a cell is called endosmosis. The osmotic flow of water out of a cell is called exo-osmosis.

(Check B.S page 431 fig. 13.4)

From the above illustration, the potential energy of the water molecules on the left is greater than the potential energy of the water molecules on the right. Hence this potential energy is called water potential.

Note: check point:

Which cell has the higher (less negative) water potential? Cell B
In which direction will water move by osmosis? From cell B to A
At equilibrium the two cells will have the same water potential, which will be the average of the two, namely -1000kpa. Assuming that Us does not change significantly, what would be Up at equilibrium in cell A and cell B?
Cell A at equilibrium: Up =U-Us
Up=1000kpa
Cell B at equilibrium: Up=U-Us
Up=400kpa

Water flows from a region of high water potential to a region of low water potential. At s.t.p. water is given an osmotic potential of zero. The presence of solute molecules due to the component of the water potential is called osmotic or solute potential.

Osmosis and plant cells

Plant cells have a solute concentration higher than that of the surrounding region. Since they are surrounded by a weak solution, water is drawn into the surrounding by osmosis bringing about the swelling of the cell.

Summary of plant cells placed in hypotonic and hypertonic solutions

(Check F.A page 52 fig. 4.5)

As water flows into the vacuole by osmosis, an internal hydrostatic pressure develops which presses the protoplasm against the cell wall. This is called turgor pressure and it is opposed by a back pressure exerted by the cell wall against the cell contents. This back pressure tends to force water out of the cell and is called water potential.
When turgor pressure reach its maximum and the cell wall can no more be stretched, full turgor is said to be achieved i.e. the cell becomes fully turgid.

Importance of turgidity

- It supports plants and maintains their shape and form.
- Holds stems erect i.e. the herbaceous plants.
- Holds leaves in flat, horizontal position.

When a cell is immersed in a higher solute concentration solution, its volume decreases hence the protoplast shrinks to an extent of pulling away from the cell wall. This shrinkage is called plasmolysis.
Plasmolysis usually happens to plants exposed to extremely salty water.
Wilting is the phenomenon where the stems and leaves of a plant loose more water by evaporation than they can absorb.

Plant water relations

Here, we consider 3 forces i.e.

i) Water potential of the whole cell
ii) Osmotic potential of the sap
iii) Pressure potential

In case the plant cell is plasmolysed (placed in a strong sucrose solution) and then placed in pure water, water immediately enters the sap vacuole by osmosis and the protoplast begins to expand.

As the influx of water continues, the protoplast goes on expanding until it comes into contact with the cellulose wall. When this point is reached, the influx of water starts being opposed by the inward pressure of the cell wall i.e. pressure potential.

The water potential of the cell now becomes less negative than the osmotic potential of the sap by the amount of the pressure potential. As this continues, full turgor is reached, where the cell can expand no more, water potential of the cell reaches zero and osmotic potential of the sap is exactly counter balanced by the pressure potential.

Below is a graph illustrating the relationship between the water potential of the cell (µcell), osmotic potential of the sap (µs) and pressure potential (µp) of a plant cell at different states of turgor and plasmolysis

(F.A page 54 fig. 4.6)

Water potential (Negative) µ cell	=	Solute potential (Negative) µ s	+	Pressure potential Positive) µ p

In a cell which is plasmolysed to the extent that the protoplast loses contact with the cell wall;

µp = 0 and µcell = µs

At full turgor, µp is equal and opposite of µs, so µcell = 0.

ACTIVE TRANSPORT

This is the movement of molecules and ions from a region of low concentration to a region of high concentration against a concentration gradient.

Active transport only takes place in a living system that is actively producing energy by respiration. Temperature and oxygen concentration which affect the rate of respiration also affect active transport. Active transport takes place by means of carriers in the cell membrane i.e. protein in nature. These carriers act as one way valves.

PHAGOCYTOSIS (Cell-eating)

This is the process by which cells take in large particles. Examples of cells include white blood cells which take up bacteria and amoeba which feeds on a variety of small organisms.

Process of phagocytosis

i) The plasma membrane invaginates to form a flask-like depression enclosing the particles.
ii) The neck of the flask then closes and invagination becomes sealed off as a phagocytic vessel or food vacuole which migrates towards the centre of the cell.
iii) The particles are now digested by enzymes secreted into the vesicle from lysosomes which fuse it.
iv) The soluble products of digestion are then absorbed into the surrounding cytoplasm.

PINOCYTOSIS (Cell drinking)

Tiny pinocytic channels are continually being formed at the cell surface by invagination of the plasma membrane.

Pinocytic channel provide a means by which liquids can be brought into the body of the cell, and their breaking up into numerous vacuoles aids distribution and increases the surface area across which absorption can take place.

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"If you want to change the fruits, you will first have to change the roots. If you want to change the visible, you must first change the invisible." Harv Eker. T. 2005