CELL BIOLOGY

This deals with cell structure, function and cell physiology all at the unit level of a living organism called a cell. The study of the structure of cells, **cytology**, is part of a major branch of biology known as cell biology.

The main functions of the cell include

1. Basic unit of life. The cell is the smallest part to which an organism can be reduced that still retains the characteristics of life.
2. Protection and support. Cells produce and secrete various molecules that provide protection and support of the body. For example, bone cells are surrounded by a mineralized material , making bone a hard tissue that protects the brain and other organs and that supports the weight of the body.
3. Movement. All the movements of the body occur because of molecules located within specific cells such as muscle cells
4. Communication. Cells produce and receive chemical and electrical signals that allow them to communicate with one another. For example, nerve cells communicate with one another and with muscle cells, causing them to contract
5. Cell metabolism and energy release. The chemical reactions that occur within cells are referred to collectively as cell metabolism. Energy released during metabolism is used for cell activities, such as the synthesis of new molecules,muscle contraction, and heat production, which helps maintain body temperature.
6. Inheritance. Each cell contains a copy of the genetic information of the individual. Specialized cells are responsible for transmitting that genetic information to the next generation

The cell of a living organism

The cell can be defined as the basic unit of structure and function in a living organism. This generalisation is known as the ***cell theory*** and it embraces four ideas;

A. The cell is the building block of structures in living cells
B. The cell is derived from other cells by cell division
C. The cell contains hereditary information that is passed from parent cell to daughter cell
D. The cell is the functioning unit of life i.e. the chemical reactions of life takes place within cells

The cell theory states that "***a cell is the fundamental and functional unit of*** life" i.e. the cell is the basic unit of the structure and function in living organisms.

Factors that limit cell size

1. **Surface area to volume ratio**
   Small cells have large surface area: Volume ratio (SA: V ratio) while large cells have a small SA: V ratio. A large SA: V ratio enables fast rate of diffusion while a small SA: V ratio slows the rate of diffusion.
   Small cells have low metabolic demands and form low amount of wastes while large cells have higher metabolic demands and form much amount of wastes.
   Therefore, the large SA: V ratio in small cells enables adequate supply of oxygen and nutrients and expulsion of wastes e.g. carbon dioxide via the surface of the cell by simple diffusion while the small SA: V ratio in large cells limits diffusion hence the supply of nutrients by simple diffusion is inadequate to meet the metabolic demands of the cell.
2. **Nucleocytoplasmic ratio**
   DNA in the nucleus provides instructions for protein synthesis hence controls activities of the whole cell. Each nucleus can only control a certain volume of cytoplasm.
   Specialization forms some long / large cells, therefore to overcome this limitation such cells are modified to become multinucleate / coenocyte e.g. skeletal muscle cells and fungal hyphae.
3. **Fragility of cell membrane**

As cell size increases, the risk of damage to the cell membrane also increases. This limits the maximum size of cells, especially animal cells. Hence;

(i) In animals, some large sized cells take in substances in bulk by endocytosis and expel bulk substances by exocytosis to supplement on simple diffusion.

(ii) Some animal cells increase their surface area by forming many tiny projections called microvilli.

(iii) Some cells divide when they reach a certain size to maintain suitable SA: V ratio.

Note: SA: V ratio particularly limits the size of bacterial cells, i.e. prokaryotic cells which are incapable of endocytosis and exocytosis.

4. Mechanical structures that hold the cell together

Cells with tough cell walls e.g. plant cells are larger than cells with only the fragile cell membrane e.g. animal cells because the tough walls provide support and maintain cell shape.

Cells with complex internal cytoskeleton are larger than cells with little cytoskeleton because the cytoskeleton protects and supports the cell structure and maintains cell shape.

TYPES OF CELLS

There are two fundamentally different types of cells, the prokaryote cell and eukaryote cell.

A. Prokaryote cell (Pro, before; karyon, nucleus)

Characteristics of prokaryotic cells

- These are cells that **do not have a true nucleus.**
- They have no membrane bound organelles. An **organelle** can be defined as a membrane-enclosed structure with specialised functions, suspended in the cytosol of eukaryotic cells.
- Their nuclear material lies in a free region known as a **nucleoid** e.g. in bacteria. They were probably the first organisms on earth
- The cell has no distinct nucleus. The nucleoplasm appears scattered in the cytoplasm or the nuclear materials e.g. DNA.
- The cell lacks a nuclear membrane
- Each cell has got very few cell organelles (cell parts) e.g. they do lack the chloroplasts and mitochondria.
- The cell has a single circular chromosome in the form of a ring, of Deoxyribonucleic Acid (DNA) in the cytoplasm, not contained in a nuclear membrane
- They are extremely small, ranging in size between 1-10milimetres in diameter
- Duplication of the chromosomes occurs but not on the spindle i.e. their cells are capable of multiplication
- The cell has got a unique cell wall containing a polysaccharide

Examples include bacteria and cyanobacteria i.e. first organisms on earth.

Diagram of a generalised structure of a bacterium *Fig 2.5 pg 9 Soper*

Function of the parts

Structures which are always present

1. **Cell wall**

   This lies external to the cell membrane, it's rigid and strengthened by presence of murein (a molecule consisting of parallel polysaccharide chains cross-linked at regular intervals by short amino acid chains)
   The cell wall is a physical barrier which:
   (i) protects the internal parts from mechanical damage
   (ii) prevents the cell bursting when it takes in water by osmosis
   (iii) allows entry of some substances, such as water, ions and small molecules
   The cell wall cannot grow and for growth to occur the cell wall is forts dissolved at intervals for materials to be added.

2. **Cell membrane**

   It lies immediately below the cell wall and has a **fluid mosaic structure**. It's hydrophobic and impermeable to most water soluble molecules.
   It has **enzymes** involved in the synthesis of the capsid and cell wall components. Enzymes for respiration and those which facilitate flagella mobility.
   Note: a damaged cell membrane leads to the death of the cell.

3. **Ribosomes**

   Prokaryotes have 70S ribosomes which are slightly smaller than the 80S eukaryotic ribosomes.
   Ribosomes are site of protein synthesis.

4. **DNA**

   The DNA comprises of a single circular molecule possessing the genetic information needed to replicate new cells

5. **Food reserves**

   Food reserves include lipids and glycogen

6. **Cytoplasm**

   This is enclosed by the cell membrane and is divided into three divisions (bacteria only) i.e.
   (i) Cytoplasmic area which contains ribosomes and it is also a site for protein synthesis.
   (ii) Chromatin area, a dense area which is rich in nucleic acid material. The nuclear region is called **nucleoid**. Bacteria have single circular strand of chromatin material.
   (iii) The fluid area, an area with dissolved substances. In the bacteria the rough endoplasmic reticulum is lacking. The ribosomes are generally smaller than in an eukaryotic cell and are free or attached to the cell membrane.

Structures sometimes present

7. **Flagellum** (Plural. flagella)

   This occurs in many species of bacteria. They are hair like helical appendages protruding through the cell wall. They are used for propulsion. Bacterial flagella are smaller, thinner and simpler than eukaryotic flagella. Their location and number may be used in identification of bacteria.

8. **Pili**

   Pili are numerous fine protein rods projecting from the walls of some bacteria. The pili are for attachment to specific cells or surfaces. The F.pilus is used in sexual reproduction.

9. **Capsule**

   This is an enveloping layer of viscous substances around the cell wall. This layer can be detected under the light microscope after staining the bacteria with Indian ink. Its uses include;
   (i) Protecting against infecting phages
   (ii) Resist engulfment by white blood cells
   (iii) Prevents agglutination of bacteria
   (iv) Used by bacteria to stick firmly onto substances e.g. bacteria on teeth

(v) The capsular secretions are in some cases used to unite bacteria into colonies

10. Plasmids

Plasmids are small self-replicating strands of extra DNA. Plasmids possess only a few genes, and are generally concerned with survival in adverse conditions.

Plasmids are known which;

a) Confer resistance to antibiotics
b) Confer resistance to disinfectants
c) Cause disease
d) Are responsible for fermentation of milk to cheese by lactic acid bacteria
e) Confer the ability to use complex as chemicals such as hydrocarbons as fuel

11. Mesosomes

Bacteria lack membrane bound organelles such as mitochondria and chloroplasts. Instead they have invaginations of cell membranes forming a system referred to as mesosomes. There are 2 types; the central and the peripheral mesosomes.

(i) Central mesosomes
These are invaginations which penetrate deep into the cytoplasm. They appear to be linked to the nuclear material and play a role in cell division.

(ii) Peripheral mesosomes
These are shallow invaginations formed by infoldings of the cell membrane. They are associated with export of secretions such as cellular secretions or enzymes. They are site of respiration.

12. Photosynthetic membranes

Photosynthetic bacteria possess sac-like, tubular or sheet-like infoldings of the cell surface membrane containing photosynthetic pigments, always including **bacteriochlorophyll**

13. Spores

Some bacteria form endospores (spores produced inside cells). The spores are thick-walled, long-lived, and extremely resistant (particularly to heat, drought, and shortwave radiations)

14. Membranes for nitrogen fixation

B. Eukaryotic cell (Eu, true; Karyon Nucleus)

These are cells with a true nucleus. Their nuclear materials are found inside the nucleus surrounded by two membranes. They probably evolved about 1000 million years ago, 2 million years after the prokaryotes. There are 2 main types of eukaryotic cells; the plant cell and the animal cell.

Cells as seen with the light microscope

A light microscope is a microscope that uses light as a source of radiation. Under the microscope, cells are described as a small unit of living protoplasm and always surrounded by cell surface membrane and sometimes as in plants, surrounded by a non-living cell wall made of cellulose. The most conspicuous structure is the nucleus which contains a deeply staining material know as chromatin. When loose it is referred to as chromosome. Chromosomes appear as thread like structures just before nuclear division. The living material between the nucleus and the cell surface is known as the cytoplasm which contains a variety of organelles.

A generalised cell is a cell which shows all the typical features found in a cell.

a) Animal cell

An animal cell as seen in a light microscope contains protoplasm (nucleus and cytoplasm) surrounded by a thin plasma membrane.

Each cell has a relatively large central nucleus surrounded by the cytoplasm. The nucleus contains coiled threads called chromatin. Chromatin contains DNA and proteins called histones which together condense to form chromosome during cell division. DNA carries genetic material which controls cell activities and determines the organism's characteristics. The cytoplasm contains organelles suspended within.

The structure of a generalised animal cell *Fig 5.1 a pg 129 Soper*

b) Plant cell

Many of the structures found in an animal cell also occur in the plant cell. A typical plant cell has additional specialised structures.

The structure of a generalised plant cell (*Fig 5.2 pg 130 Soper)*

There's a protective, rigid, cellulose cell wall surrounding the cell. Plant cells have a nucleus and cytoplasm which are usually peripheral. The cytoplasm contains chlorophyll pigments which carry out photosynthesis. A large central vacuole filled with cell sap is present in mature plant cells. The vacuole is surrounded by the tonoplast

Description of a generalised structure of a eukaryotic cell.

A cell is a small unit of living protoplasm, always surrounded by a cell surface membrane and sometimes by a non-living cell wall (as in plants and fungi).

The most conspicuous structure of the cell is the nucleus which contains chromatin. Chromatin is the loosely-coiled form of chromosomes. Chromosomes contain genetic material in the form of DNA. The nucleus is separated from the cytoplasm by its nuclear membrane

The cytoplasm contains organelles.

Comparison between prokaryotic and eukaryotic cells

Similarities	Differences	
	Prokaryotes	**Eukaryotes**
a. The protoplasm is surrounded by a membrane that is selectively permeable (protoplasm = nucleoplasm + cytoplasm) b. The binding protein is made up of lipid-protein complex c. The cells have got ectoplasmic and nuclear regions	The nuclear material is not enclosed by nuclear membrane	The nuclear material is enclosed by nuclear membrane
	Genetic material is circular double strand of DNA	Most DNA is linear and associated with histones proteins to form chromosomes
	No membrane bound organelles	Has membrane bound organelles
	No mitosis or meiosis	Mitosis, meiosis or both can occur
	No spindle formation	There's spindle formation
	Ribosomes are smaller (70S)	Ribosomes are bigger (80S)
	Rigid cell wall containing murein (peptidoglycan)	Cell walls of plants and algae contain cellulose, fungi contain chitin and animal cells have no cell walls
	No mitochondria (mesosomes in bacteria and plasma membrane of cyano bacteria contain respiratory enzymes)	Mitochondria present and function as sites for cellular respiration to produce ATP.
	Use mesosomes for respiration	No mesosomes
	Flagella if present, contain flagellin and lack microtubules	Flagella, if present, have a '9+2' arrangement of microtubules
	Average diameter of cell is 0.5-5µm	Average diameter of cell is 10-100µm
	Some bacteria have small circular DNA plasmids	Plasmids are absent
	Few organelles	Many organelles
	No chloroplasts (some prokaryotes are photoaoutotrophs with the photosynthetic membranes not stacked into grana)	Chloroplasts containing grana

NOTE: the only organelle found in animal cells which is absent from plant cells is the centriole

Advantages of having membrane bound organelles

1. Potentially harmful reactions (enzymes) can be isolated inside an organelle so that they do not harm the rest of the cell
2. The rate of any metabolic reactions inside an organelle can be controlled by regulating the rate at which the membrane allows the first reaction to occur or to enter
3. The containment of enzymes for a particular metabolic pathway within the organelle means that the products of the reaction will always be in close proximity to the next enzymes within the sequence. This increases the rate of metabolic reactions
4. Many metabolic processes which involve enzymes occur in the membrane.

MICROSCOPY

Microscopy is the science that studies structure, magnification, lenses and techniques related to the use of microscopes. A microscope is an instrument that magnifies images of very tiny objects to show great details.

Units of measurements and magnification

Magnification is the number of times that an image is larger than the specimen i.e. the ration of an object's image size to its real size and is usually given by the formula: Magnification = $\frac{size\ of\ image}{size\ of\ specimen}$

The units of measurement used in cell biology are shown in the table below

Units for measurement of a cell

Unit	Relation to a milimetre	Relation to a metre
Angstrom (Å)	10^{-7}	10^{-10}
Nanometer (nm)	10^{-6}	10^{-9}
Micrometer (μm)	10^{-3}	10^{-6}
Milietre		10^{-3}
Centimeter	10^{1}	10^{-2}

Or 1 meter = 10^2 cm = 10^3 mm = 10^6 μm = 10^9 nm = 10^{10} Å

Worked examples

1. An animal cell of 60μm length is enlarged photographically. An enlargement print is made showing the cell at 12cm. What is its magnification? 1cm = $1x10^4$ μm = 10,000μm 12 cm = 12 X 10,000 = 120,000 μm Magnification = $\frac{120{,}000}{60}$ = X2,000	2. A plant cell is magnified X2000 and the length of the chloroplast in the diagram is 16mm. Calculate the actual length of the chloroplast in μm 1mm = 1 x 10^3μm = 1,000 μm 16 cm = 16 X 1000 = 16,000 μm Magnification = $\frac{size\ of\ image}{size\ of\ specimen}$ X2000 = $\frac{16000}{size\ of\ specimen}$ Actual size of specimen = $\frac{16{,}000}{2000}$ = 8 μm

Resolution (resolving power)

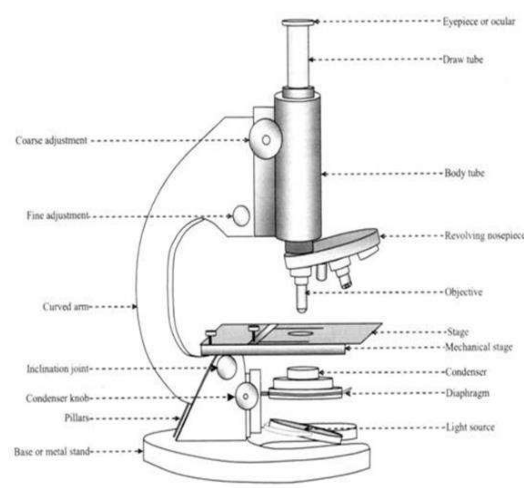
Resolution is a measure of the clarity of the image i.e. the minimum distance two points can be separated and still be distinguished as two points. For example, what appears to the unaided eye as one star in the sky may be resolved as twin stars with a telescope.

The **limit of resolution of** a microscope is the minimum distance between two points at which they are still distinguished as two separate points. If the two points cannot be resolved, they will be seen as one point. A microscope with a high resolving power will enable two small objects close together to be seen as two separate objects. A microscope with a low resolving power will cause the two small objects close together to be seen as one object.

Light microscope (LM)/optical microscope

All the microscopes you are likely to use in the labaratory are all LMs. In the LM, light rays passing through a specimen are brought to focus by a set of glass lenses. The resulting image can be seen by the human eye.

Visible light used in the LM has a wave length of about 400-700nm. The maximum resolution of an optical microscope is about 200nm, which gives a maximum magnification of about 1500 times.



Organelles such as chloroplasts (about 3000nm in diameter) are large enough to interfere with the light waves and can been seen. Ribosomes (about 20nm) are too small to interfere with the light waves and cannot be seen under a light microscope.

Phase contrast microscope

Many cell details cannot be seen using an ordinary optical microscope. This is because there is very little **contrast** between structures. They have similar transparency and are not coloured. A third important parameter in microscopy is *contrast*, which emphasizes or makes more noticeable, differences in parts of the sample. New methods of improving contrast include staining or labelling cell components to stand out visually.

Special phase contrast condensers and objective lenses are added to the optical microscope. Light rays travelling through material of different densities are bent and altered giving a better contrast (cell components having different densities show variation in the refractive index, those of a higher refractive index can bend light to greater angle than other cell components of lower refractive index).

Phase contrast microscopes enable **living, non-pigmented specimen** to be studied without fixing and staining. Phase contrast microscopes give better contrast but do not improve resolution. This is similar to the optical microscope.

Just as the resolving power of the human eye is limited, the light microscope cannot resolve detail finer than 1bout 0.2μm 0r 200nm, the size of a small bacterium, regardless of the magnification factor. The poor resolution of the LM could only be overcome by using a form of radiation with a wave length less than of light. This led to the development of the **electron microscope (EM)**. Since electrons have a shorter wavelength than light (about 0.005nm), they couple their higher magnifying power with much greater resolution and contrast. They can resolve two objects which are only about 1nm apart.

While the light microscope uses glass lenses to focus the light rays, the electron beam of the electron microscope is focused by powerful electromagnets. The image produced by electron microscopes cannot be seen by the unaided eye. Instead the electron beam is directed unto a screen giving black and white images (photographs). A photograph taken with an electron microscope is called an **electron micrograph** or **photomicrograph**.

There are two types of electron microscopes; the **Transmission Electron Microscope (TEM)** and the **Scanning Electron Microscope (SEM)**.

A TEM is an electron microscope in which the electron beam is transmitted through the specimen before viewing. The principle is the same as in the light microscope in that a beam of radiation is focused by condenser lenses through the specimen, and the image is magnified by further lenses. The TEM has a resolving power of about 1nm. It used to study the **ultrastructure** of a cell.

The electron beam is heated using a cathode and passed through ultra-thin dehydrated sections of dead specimen. Electrons are absorbed by heavily stained (due to treatment with heavy metals) parts but pass through the lightly stained parts. This provides contrast between different parts of the specimen.

Drawing of the pathway of the electron beam in the TEM (Soper pg 133)

A SEM is an electron microscope in which the electron beam is scanned to and from across the specimen. The electrons reflected from the surface are collected and used to form a TV-like image on a cathode ray tube. This enables the studying of the surfaces of structures and gives three-dimensional images. The SEM has a resolving power of about 5nm higher than that of a light microscope, but lower than that of a TEM. Larger and thicker specimens can be examined.

Note: the fine structure of the cell as seen with the electron microscope is called the **ultra-structure**.

Differences between the light and electron microscopes

TEM	Compound light microscope
1. Source of radiation are electrons	1. Source of radiation is light
2. Electrons have a shorter wavelength of about 0.005nm	2. Light has a longer wave length of about 400-700nm
3. Maximum resolution is greater (about 0.5nm)	3. Maximum resolution is lower (about 20nm)
4. Maximum useful magnification on screen is higher (about X250,000)	4. Magnification is low (about X1500)
5. Uses powerful electromagnets as lenses	5. Uses glass lenses
6. The specimen is dead, dehydrated and relatively small or thin	6. The specimen maybe living or non-living
7. The specimen is supported on a small copper and in a vacuum	7. The specimen is supported on a glass slide
8. The stains used contain heavy metals to reflect electrons	8. The stains used are coloured dyes
9. The image is black and white	9. The image is usually coloured

A comparison of radiation pathways in light and transmission electron microscopes

A comparison of the relative advantages and disadvantages of the light and electron microscopes

Light microscope	Electron microscope
Advantages	**Disadvantages**
1. Cheaper to produce and operate	1. Much more expensive to purchase and operate
2. Smaller and more portable; thus can be used almost anywhere	2. Much larger and fixed, and must be operated in special rooms
3. Not affected by magnetic fields	3. Affected by magnetic fields
4. Preparation of material is relatively quicker and simpler, and requires only a little expertise and simpler equipment	4. Preparation of material is lengthier and requires more expertise and more complex equipment
5. Material rarely distorted by preparation	5. Material is usually distorted by the preparation (preservation and staining may change or damage the structure)
6. The natural colour of the material can be observed	6. All images are in black and white
7. The specimen may be living	7. The specimen must be dead because it is viewed in a vacuum
8. The specimen does not deteriorate easily, allowing more study time	8. The specimen gradually deteriorates in the electron beam, and thus photomicrographs must be taken and observed on the screen
Disadvantages	**Advantages**
1. Lower magnification of up to X1,500	1. Higher magnification of up to X250,000
2. Has a restricted depth of field	2. Enables investigation of a greater depth of field
3. Lower resolution of about 200nm	3. Higher resolution of about 0.5nm

CELL STRUCTURE

Differences between plant and animal cells

Plant cells	Animals cells
1. Have tough slightly elastic cellulose cell wall outside the cell surface membrane	1. Have no cell wall, only a cell surface membrane surrounds the cell
2. Have pits and plasmodesmata in the cell wall	2. Have no cell wall, and therefore have no pits and plasmodesmata
3. Have middle lamellae joining the cell walls of adjacent cells	3. Middle lamellae are absent, the cells are joined by intercellular cement
4. Possess plastids, such as chloroplasts	4. Lack plastids
5. Mature cells possess a large single, central vacuole filled with cell sap	5. Possess only small vacuoles scattered throughout the cells
6. The cell vacuole is enclosed by a tonoplast	6. Vacuoles lack tonoplasts
7. Have a thin layer of cytoplasm confined to the edge of the cell	7. Have much cytoplasm spread throughout the cell
8. The nucleus is located at the edge of the cell	8. The nucleus is usually placed centrally in the cell
9. Higher plant cells lack centrioles	9. Possess centrioles
10. Higher plant cells lack cilia and flagella	10. Often possess cilia and flagella
11. Store food as starch grains	11. Store food as glycogen granules

12. Only some cells are capable of division	12. Almost all cell are capable of division
13. Plant cells produce secretions	13. Animal cells produce a wide variety of secretion
14. Have a regular shape	14. Have an irregular shape

a) The ultra-structure of a generalised animal cell (Soper fig 5.10 page 135)

b) The ultra-structure of a generalised plant cell (Soper fig 5.11 page 135)

Detailed study of animal and plant cells.

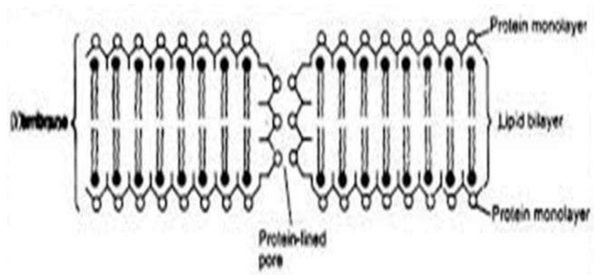
Cell membrane

The cell membrane is invisible with a light microscope.

Danielli and **Davison** proposed a membrane structure in which a lipid bilayer was coated on either side with a protein so as to provide the mechanical strength (elasticity and surface tension properties) to the cell membrane. This hypothesis proposes that the plasma membrane is made up of three layers: a bimolecular layer of lipid **sandwiched** between two layers of protein, the lipid molecules being set at right angles to the surface i.e. the **sandwich model** of the cell membrane

Diagram of the cell membrane based on the Danielli-Davison hypothesis

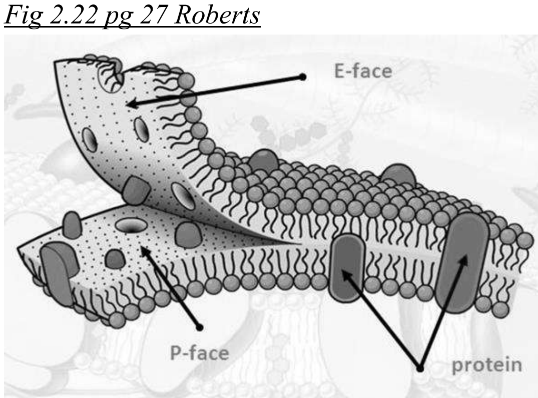
Fig 2.21 pg 27 Roberts



From the speeds at which various molecules penetrate the membrane, they predicted the lipid layer to be about 6.0nm in thickness, and each of the protein layers about 1.0nm giving a total thickness to the membrane of about 8.0nm.

Robertson (1960) used an electron microscope to observe a cell membrane and proposed that a cell membrane is actually **a unit membrane**. According to his proposal, all membranes have the same structure. A unit membrane has protein molecules with lipid molecules inside. The head of the lipid molecules are in mutual electrostatic attraction with the protein molecules, this increases on the mechanical strength of the unit membrane.

Fig 2.22 pg 27 Roberts



The unit membrane has pores that are lined with protein molecules which enable water soluble substances to enter or leave the membrane. Such substances include, water molecules, mineral salts, simple sugars, vitamins, gasses and excretory products. The membrane has got lipid layers which enable the lipid molecules to enter and leave the membrane.

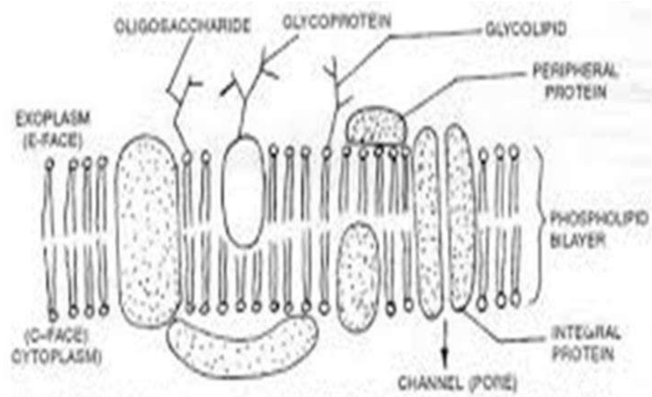
Most of the proteins on the cell membranes are called carrier proteins i.e. they enable the transport of substances across the membrane. Other proteins are enzymes in nature i.e. they catalyse biochemical reactions at the cell surface

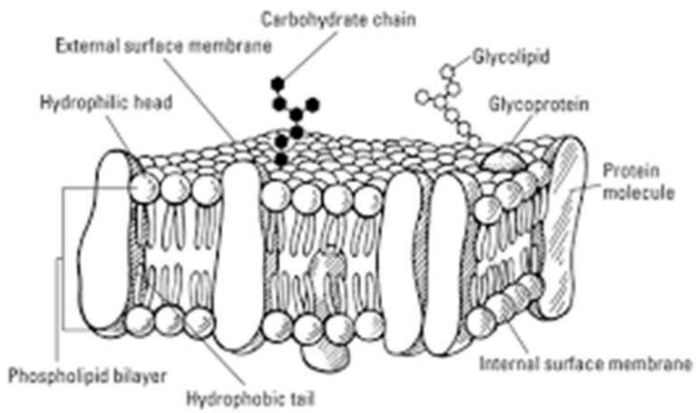
In 1972 **Singer** and **Nicolson** suggested that the unit membrane has a **fluid mosaic model**

- The fluid mosaic model proposes that the basic structure for the unit membrane is a phospholipid bilayer with various protein molecules embedded and attached to it.
- The hydrophilic phosphate heads of the phospholipids face outwards into the aqueous environments inside and outside the cell and form hydrogen bonds with water molecules.
- The hydrocarbon tails face inwards and create a hydrophobic interior through Van der Waal forces and hydrophobic interactions. The phospholipids are fluid and move about rapidly by diffusion in their own layers. Some of the fatty acid tails are saturated and some are unsaturated. Unsaturated tails are bent and fit together more loosely. Therefore the more unsaturated the tails are, the more fluid the membrane is.
- Most protein molecules float about in the phospholipid bilayer forming a fluid mosaic pattern and these proteins stay in the membrane because they have regions of hydrophobic amino acids which interact with
- the fatty acid tails to exclude water.

- The membrane proteins most of which float individually in the fluid bilayer, forming the mosaic part of the fluid mosaic model. The rest of the protein is hydrophilic and faces into the cell or out into the external environment, both of which are aqueous. Some proteins penetrate only part of the way into the membrane (extrinsic proteins) while others penetrate all the way through (intrinsic proteins).
- Some proteins and lipids (phospholipids) have short branching carbohydrate (oligosaccharides) chains forming glycoproteins and glycolipids respectively, more glycoproteins are formed than glycolipids. These are important for cell recognition.
- Membranes also contain cholesterol which disturbs the close parking of phospholipids and regulates membrane fluidity. This is important for organisms living at low temperatures where membranes can solidify. Cholesterol also increases flexibility and stability of membranes, without it, membranes break up.

Fig 5.16 b pg 142 Soper OR Fig 7.15 pg 159 Cross-sectional view Clegg





A comparison of the sandwich model (Daniel-Danielli) and the fluid-mosaic model (Singer-Nicholson) of the cell membrane

a) **Similarities**
   (i) Both comprise of a bimolecular layer of phospholipids
   (ii) Both contain protein molecules
   (iii) In both, the phospholipids possess hydrophilic heads and hydrophobic tails
   (iv) In both, the phospholipid tails extend inwards, while the heads lie at the periphery
   (v) In both, the main structural skeleton of the membrane comprises lipids and proteins

b) **Differences**

Sandwich model	**Fluid-mosaic model**
1. Proteins regularly arranged to form a continuous layer covering both sides of the membrane 2. Proteins lie on the surface, and do not get in the membrane 3. Lipids and proteins are rigid and cannot move 4. Protein molecules are of the same size 5. Proteins lack pores 6. All proteins offer structural support only	1. Proteins arranged irregularly in a mosaic pattern 2. Some globular proteins lie on the surface, some extend into the lipid layer to varying degrees, and others extend through it 3. Lipids and proteins capable of much movement like a fluid 4. Proteins molecules are of different sizes 5. Some proteins have pores 6. Proteins may be structural, carrier proteins or enzymes

How phospholipid properties maintain cell membrane structure

1. Hydrophilic / hydrophobic layers restrict entry/ exit of substances.
2. Phospholipids are held together by hydrophobic interactions
3. Phospholipid layers are stabilized by interaction of hydrophilic heads and surrounding water
4. Phospholipids with short fatty acids and those with unsaturated fatty acids are more fluid. Fluidity is important in breaking and remaking membranes (e.g. endocytosis / exocytosis)
5. Phospholipids can move about / move laterally (horizontally) / "flip flop" (move transversely) to increase fluidity
6. Phospholipids allow for membrane fluidity/ flexibility. Fluidity/ flexibility enables membranes to be functionally stable

Membrane fluidity

Membranes are fluid, dynamic structures whose fluidity/viscosity is affected by their composition.

a) An increase in temperature increases the fluidity of the membrane. Low temperature decreases membrane fluidity because lipids are laterally ordered, the lipid chains pack well together, mobility reduces to allow many stabilising interactions. Increase in temperature increases membrane fluidity because lipids acquire thermal energy to become mobile and reduce stabilising interactions.
b) At moderate warm temperatures, the cholesterol molecules reduce the free movement of phospholipid molecules and make the membranes less fluid. At low temperatures, cholesterol molecules prevent the close packing of phospholipid molecules and slow down solidification of the membrane.
c) Lipid chains with double bonds (unsaturated fatty acids) are more fluid because the kinks caused by double bonds make it harder for the lipids to pack together. Lipids that have single bonds only (saturated fatty acids) have straightened hydrocarbon chain which pack together to reduce membrane fluidity.
d) Lipids with shorter chains are more fluid because they quickly gain kinetic energy due to their smaller molecular size and have less surface area for Van der Waals interactions to stabilise with neighboring hydrophobic chains. Lipids with longer chains are less fluid because their large surface area enables more Van der Waals interactions hence increasing the melting temperature.

Functions of the unit membrane

1) Surface membrane forms a protective barrier between cell contents and external environments, and determines the shape of the cell.
2) They form membrane organelles e.g. mitochondria, chloroplasts e.t.c.
3) Membranes are selectively permeable and regulate movement of substances in and out the cell
4) Some membrane proteins act as enzymes e.g. ATP synthase
5) Cell surface receptor proteins are involved in signal-transduction
6) Some membrane proteins act as electron carriers in the electron transport chain
7) Glycoproteins with branching oligosaccharides act as antigens
8) Glycolipids are involved in cell-cell recognition
9) Folding of cell membranes enables the cell to carry out phagocytosis and pinocytosis which enables the cell to obtain nutrients or to engulf and destroy foreign particles.
10) Folding of membranes also increases the surface area for reactions e.g. the epithelium villus of the ileum
11) Cell adhesion proteins join cells together forming tissues which carry out specific functions
12) Cholesterol molecules stabilise the membrane structure and reduce entry or exit of polar molecules through the membrane

Note; the various membranes of an eukaryotic cell are different because only certain proteins are unique to each membrane.

Molecules and ions can pass through the plasma membrane in four ways:

a) **Directly through the phospholipid membrane**. Molecules that are soluble in lipids, such as oxygen, carbon dioxide, and steroids, pass through the plasma membrane readily by dissolving in the lipid bilayer. The phospholipid bilayer acts as a barrier to most substances that are not lipid-soluble; but certain small, nonlipid-soluble molecules, such as water, carbon dioxide, and urea, can diffuse between the phospholipid molecules of the plasma membrane.

b) **Membrane channels**. There are several types of protein channels through the plasma membrane. Each channel type allows only certain molecules to pass through it. The size, shape, and charge of molecules determines whether they can pass through a given channel. For example, sodium ions pass through sodium channels, and potassium and chloride ions pass through potassium and chloride channels, respectively. Rapid movement of water across the cell membrane apparently occurs through membrane channels.

c) **Carrier molecules**. Large polar molecules that are not lipidsoluble, such as glucose and amino acids, cannot pass through the cell membrane in significant amounts unless they are transported by carrier molecules. Substances that are transported across the cell membrane by carrier molecules are said to be transported by carrier-mediated processes. Carrier proteins bind to specific molecules and transport them across the cell membrane. Carrier molecules that transport glucose across the cell membrane do not transport amino acids, and carrier molecules that transport amino acids do not transport glucose.

d) **Vesicles**. Large nonlipid-soluble molecules, small pieces of matter, and even whole cells can be transported across the cell membrane in a vesicle, which is a small sac surrounded by a membrane. Because of the fluid nature of membranes, the vesicle and the cell membrane can fuse, allowing the contents of the vesicle to cross the cell membrane.

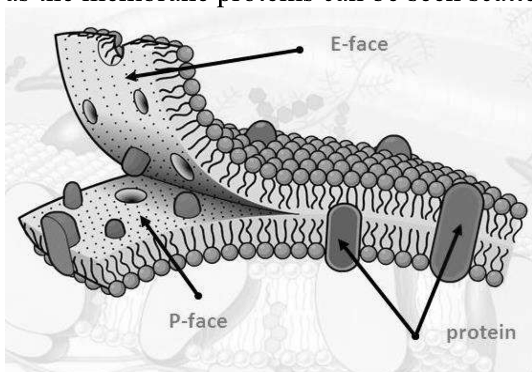
Role of proteins within the plasma membrane

1. Anchoring cells. Membrane proteins anchor cells to the cuticle membrane, and also to microfilaments within the cell.
2. Transport. Membrane proteins form channels that allow selective passage of ions or molecules, for example carrier proteins during facilitated diffusion.
    - Some carrier proteins pump solutes across membranes by active transport
3. Enzyme activity. Some membrane proteins are enzymes that catalyse reactions that are placed within or along the surface of the membrane.
4. Signal transduction. Receptor proteins bind with signal molecules such as hormones and neurotransmitters, and transmit information into the cell
5. Cell recognition. Proteins function as identification tags for cells
6. Junction between cells. Cell adhesion proteins of different cells together
7. Energy transducers and electron carriers. In photosynthesis and respiration, membrane proteins take part in energy transfer
8. Structural support. The various proteins dotted throughout the biphospholipid layer provide structural support to the cell membrane.

Evidence for the fluid-mosaic model of the cell membrane

a. Pieces of the cell membrane treated from one side with chemicals which react with the proteins but cannot pass through the membrane behave differently.
In some cases, the reactions are confined to the side of the membrane to which the chemicals are applied, while in other cases they occur on both sides, suggesting that this particular proteins span the entire membrane.

b. Using freeze-fracture technique, a piece of the cell membrane is frozen, then split down the middle longitudinally. If there's inner surface is then viewed in the electron microscope, globular structures of the same size as the membrane proteins can be seen scattered about as shown below



c. Experiments on membrane viscosity suggest that it is of a fluid consistency rather like oil, and shows considerable side movements of the lipid and protein molecules within it.

The cytoplasm

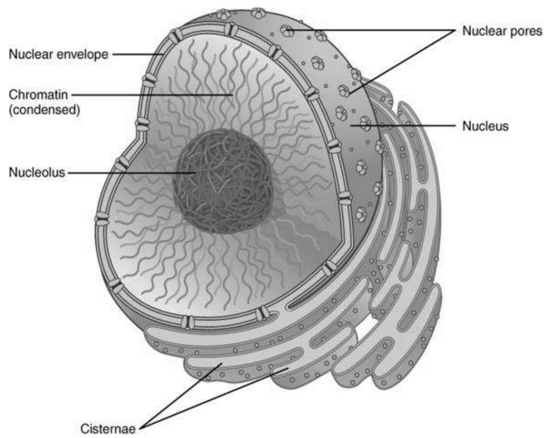
The cell organelles are contained within the cytoplasmic matrix (cytoplasm). The cytoplasm is an aqueous material forming a solution or colloidal suspension of many fundamental biochemicals of life, including ions such sodium, phosphates and chlorides; organic molecules such as amino acids, ATP, fatty acids, nucleotides, vitamins; dissolved gases and storage material such as oil droplets.

The cytoplasm is capable of mass flow in a process cytoplasmic streaming. The cytoplasm is important for important biochemical processes.

The nucleus

This is the central region in both plant and animal cells with a diameter of 4-10µm. In this region, all the cell activities are directed e.g. cell division and protein synthesis. A nucleus can be seen with the ordinary microscope. The nuclei have got various shapes depending on the cells e.g. oval, spherical or lobed Mammalian red blood cells (erythrocytes) and phloem sieve tube elements don't have a nucleus.
A distinct nucleus is present at some stage in the cells of all forms except in bacterial cells, blue green- algae and viruses.

- The nucleus has a double layered nuclear membrane (unit membrane). The outer membrane is continuous with the endoplasmic reticulum. The perinuclear space occurs between the two membranes.
- The nuclear membrane has got nuclear pores, which regulate exchange of substances between the nucleoplasm and the cytoplasm. The nuclear membrane pores are routes for the passage of large molecules such as mRNA, from the nucleus to the cytoplasm and this happens during protein synthesis. The nuclear pores can only be seen using an electron microscope.
- Inside the nuclear membrane, we find nucleic acids (DNA and RNA) and proteins. The nuclear DNA is bonded to a number of proteins which are called histones which appear as chromatin in a non-dividing cell. During nuclear division, the chromatins become visible as chromosomes and the nuclear membranes disappear. During Interphase, some of the chromatin strands are tightly coiled and are called heterochromatin. The remaining loosely coiled chromatin is called euchromatin. Inside the nucleus, there is a nucleolus which makes ribosomes and ribosomal RNA.
- The nucleus contains one or more small spherical bodies called nucleoli which manufacture ribosomal RNA (rRNA) and assemble ribosomes. A nucleolus contains RNA and DNA.



Functions of a nucleus

1. Chromosomes in a nucleus contain the genetic material of the cell
2. The nucleus acts as the centre to control cell activities and cell division
3. Production of ribosomes and RNAs needed for protein and enzymes synthesis
4. Formation of the ribosomal RNA by nucleolus.
5. Nuclear division gives rise to cell division hence reproduction.

Adaptations of the nucleus to its function

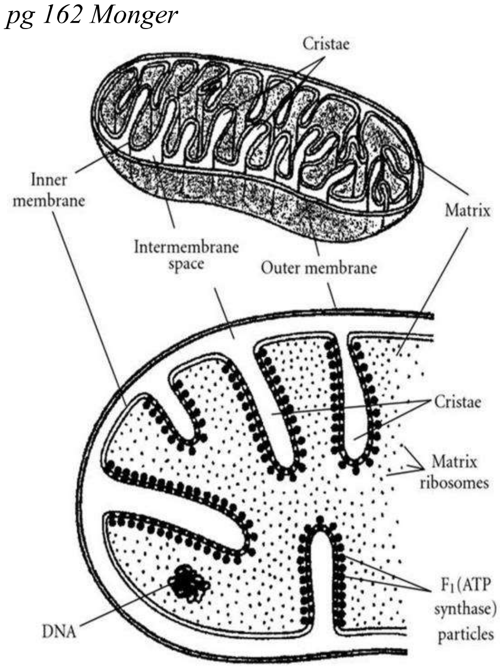
1) DNA is long to store many genes
2) Nuclear membrane has pores for exchange of DNA and RNA between the nucleus and cytoplasm
3) Presence of nucleolus that produces ribosomes which are protein factories
4) Nuclear envelope that isolates nucleus from interference by processes in cytoplasm
5) Nuclear pores are narrow to regulate entry and exit of substances

Mitochondria

Mitochondria appear as rod-shaped or cylindrical organelle, although occasionally they are more variable in shape with a length of about 2.5-5µm and a diameter of 1µm.

Each mitochondrion is bound by a double membrane, the outer layer being a continuous smooth boundary. Between the two membranes is the intermembrane space. The inner membrane is extensively in folded to form partitions called Cristae (consisting of a head piece, stalk and base piece), which partially divide the interior. The Cristae in plants are commonly tubular and villus-like; in animal cells they are sheet-like plates. The inner membrane holds the oxysome and encloses are fluid filled space called the matrix. The matrix contains enzymes and DNA, the DNA directs or codes the synthesis of proteins within the mitochondria i.e. mitochondria multiply during cell division.

Fig 7.21 pg 163 Clegg OR Fig 162 B & C pg 162 Monger



Functions

1. They are sites of ATP formation
2. They are sites of aerobic respiration

NOTE; Mitochondria are prominent in organs where there's a lot of metabolic activity e.g. kidney nephron, muscle fibres, neurone axons, tail of the sperm and root hairs.

Adaptations of the mitochondria to its function (energy production)

1. The double membranes separate the mitochondrion from interference by processes in the cytoplasm
2. small size gives a large surface are to volume ratio for the rapid uptake / release of materials
3. matrix contains enzymes of the Krebs cycle
4. inner membrane invaginates (in-folds) forms cristae to increase the surface area for electron transport chain (oxidative phosphorylation)
5. inner membrane has cristae with oxysomes that contain ATP synthetase (ATPase) on stalked particles that make ATP

6. narrow intermembrane space (gap between inner and outer membranes) enables pH / H^+ / proton concentration gradient to be rapidly established / steeper chemiosmosis therefore more efficient / chemiosmosis can occur
7. inner membrane contains molecules for electron transport pathway
8. DNA is present to act as genetic material for synthesis of some protein / control of metabolism
9. Presence of many ribosomes for protein synthesis to reduce on importation of some proteins
10. Phosphate used in glycolysis thru protein carriers (not clear)

Comparison between the structure of the nucleus and the mitochondria

a. Similarities

- Both contain DNA
- Both contain RNA
- Both contain ribosomes
- Both contain enzymes
- Both are bound by a double membrane

b. Differences

Nucleus	Mitochondrion
1. Liner DNA	1. Circular DNA
2. DNA contained in chromosomes	2. DNA not contained in chromosome
3. Larger 80S ribosomes	3. Smaller 70S
4. Membrane has pores	4. Membrane has no pores
5. Inner membrane not folded	5. Inner membrane folded to form cristae
6. Oval or spherical	6. Sausage shaped, spiral or cup-shaped
7. Outer membrane continuous with endoplasmic reticulum	7. Outer membrane not continuous with any organelle
8. Ribosomes may be attached to outer membrane	8. Ribosomes not attached on outer membrane

Chloroplast

Chloroplasts are members of a group of organelles known as **plastids**. Plastids normally contain pigments such as chlorophylls and carotenoids and bound by 2 membranes. They develop from small bodies called protoplastids found in the meristematic regions. There are mainly two types of plastids and they are both found in plant cells.

The ***leucoplasts*** are colourless and are found in plant parts which are not exposed to sunlight; these parts include roots and underground stems. They are the food storage organelles. There are three types of leucoplasts;

1. In the amyloplasts, sugar is converted into starch
2. In the elaioplasts, there's synthesis and storage of lipids
3. In the aleuroplast, there's synthesis and storage of proteins

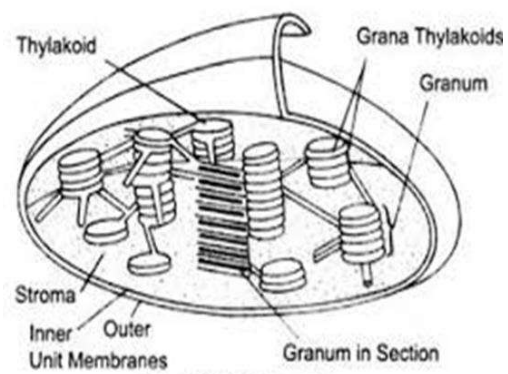
Chromoplasts are coloured pigments containing non-photosynthetic pigments, common in fruits, carrot root tissue and in flower petals

Structure

- Chloroplasts are biconvex in shape, 4-10µm in diameter, 2-3µm thick.
- They are bound by a double unit membrane, like chloroplasts, but in addition chloroplasts have a third membrane called the thylakoid membrane. This is folded into thin vesicles (the thylakoids), enclosing small spaces called the thylakoid lumen (lamellae). The thylakoid vesicles are often layered in stacks called grana, which contain photosynthetic pigments. The thylakoid membrane contains the same ATP synthase particles found in mitochondria.

- The interior of the chloroplast is divided into the grana which are surrounded by an aqueous matrix called stroma, into which the lamella is suspended.
- Chloroplasts contain DNA, tRNA and ribosomes, and they often store products of photosynthesis as starch grains and lipid droplets.

Fig 4.5 a & b pg 56 Toole.



Adaptations of chloroplasts to their function

1. Chloroplasts of flowering plants have a biconvex shape which increases the surface area for the exposure of the photosynthesis pigments.
2. It has a double membrane with an outer membrane (surface) membrane which prevents the photosynthetic reactions from mixing with those in the cell cytoplasm.
3. The surface membrane is permeable to gases like carbon dioxide which is a raw material for photosynthesis.
4. The internal membrane also contains electron transport systems which synthesize ATP.
5. It contains chlorophyll for trapping sunlight energy.
6. It has thylakoids that increase the surface area for holding chlorophyll molecules.
7. The thylakoid granum is connected by intergrana membranes thus maintaining the thylakoids and chlorophyll stationary in position.
8. The stroma of the chloroplast has DNA and ribosomes for protein synthesis.
9. The stroma contains the necessary enzymes for protein synthesis.

Comparison of chloroplast and mitochondrion

Similarities:	**Differences**	
Both: a. are enclosed by double membrane b. contain DNA c. contain 70S ribosomes d. have electron transport chain e. produce ATP by chemiosmosis f. contain ATP synthase /ATPase	**Chloroplast**	**Mitochondrion**
	Site of photosynthesis	Site of respiration
	Contains thylakoid membranes	Lacks thylakoid membranes
	Contains photosynthetic pigments that absorb light	Lacks photosynthetic pigments
	There is light generated ATP production	ATP production by oxidation of organic molecules
	H+ gradient across thylakoid membrane	H+ gradient across inner membrane
	Cristae absent	Cristae present
	Larger size	Smaller size

Microvilli

Microvilli are tiny finger-like extensions of the cell surface membrane or certain animal cells, such as those of the intestinal epithelium. Microvilli are massed together forming a brush bonder at the edge of cell bearing them.

Each microvillus contains bundles of actin and myosin filaments, causing the microvilli to contract.

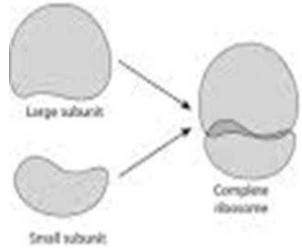
Microvilli provide a large surface area for absorption and digestion.

Ribosomes

Ribosomes are tiny organelles with a diameter of about 20nm, made of ribosomal RNA and protein. They carry out protein synthesis. Each ribosome consists of two sub-units, one large and one small. There are two types of ribosomes: 70s are found in prokaryotes, mitochondria, chloroplasts and are the slightly larger 80s ribosomes occur in the cytoplasm of eukaryotes.

When several ribosomes occur along a common strand of mRNA, the whole structure is known as a polysome or a polyribosome.

Bound and free ribosomes are structurally identical, and ribosomes can alternate between the two roles.



Ribosomes lying free in the cytoplasm are the site of synthesis of proteins that are retained within the cells, e.g. enzymes that catalyse the first steps of sugar breakdown and haemoglobin in young red blood cells. Ribosomes bound to endoplasmic reticulum produce proteins that are subsequently secreted outside the cell e.g. proteins inserted into membranes for packaging within certain organelles (lysosomes) or for export from the cell.

Cells that specialise in protein synthesis have a high proportion of bound proteins and a prominent nuclei e.g. cells of the pancreas that secrete digestive enzymes.

Endoplasmic reticulum

Endoplasmic reticulum (ER) consists of a network of folded membranes forming sheets, tubes or flattened sacs in the cytoplasm. It forms a cytoplasmic skeleton called a cytoskeleton. The tubules and sacs are called cisternae.

ER is flexible and mobile since it occupies much of the cytoplasm of many cells, including those in which streaming movements of the cytoplasm occur. *It therefore forms an intracellular transport system and a cytoplasmic skeleton of the cell*.

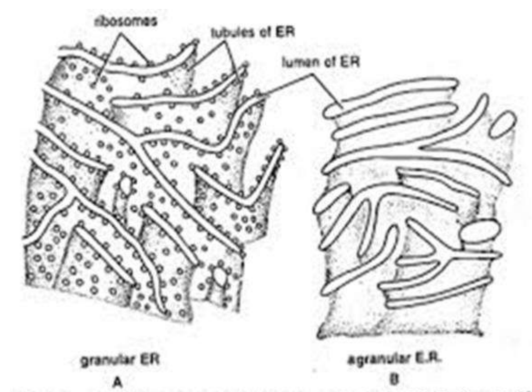


Fig. 298. Structure of endoplasmic reticulum. A, Rough ER; B, Smooth ER.

Functions of ER

1. Offer increased surface area for cellular reactions.
2. Form part of the cell's skeletal framework
3. Transporting proteins and carbohydrates to other organelles like lysosomes, Golgi apparatus, and plasma membrane.
4. Form the nuclear membrane during cell division.

Rough ER (RER) consists of an interconnected system of membrane-bound flattened sacs. It is continuous with the outer membrane of the nucleus and has many minute globular bodies called ribosomes. The RER isolates and transports proteins manufactured by ribosomes, mainly secreted proteins for export i.e. those that the cell does not need but are needed elsewhere e.g. enzymes and hormones. RER is abundant in cells which are rapidly growing or secretory cells e.g. pancreatic cells.

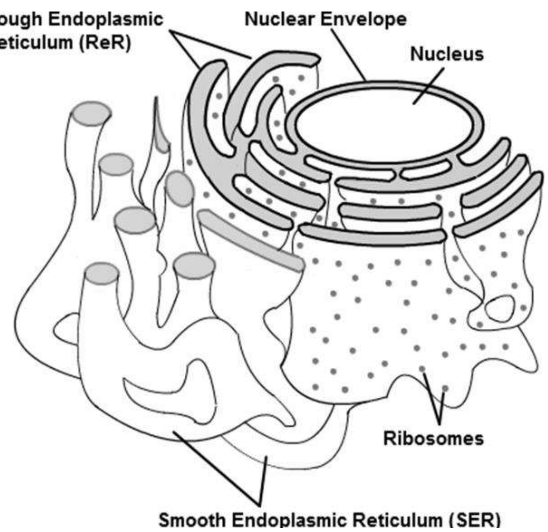
Functions of RER

1. Rough ER is concerned with the transport of proteins which are made by ribosomes on its surface
2. The protein is extensively modified as it passes through the cisternae e.g. converting it into a glycoprotein.
3. Checks the quality of proteins formed, especially correct ordering and structure.

Smooth ER (SER) is a system of interconnected tubules and it lacks ribosomes. SER is abundant in cells involved in lipid and steroid hormone synthesis e.g. cells in the testes and ovaries or cells involved in detoxification e.g. liver cells.

Functions of SER

1. Enzymes of SER are important in the synthesis of lipids including oils, phospholipids and steroids e.g. lipids from fatty acids and glycerol in the epithelium of the intestine. Testes and ovaries are rich in SER because they secrete steroid hormones
2. Other enzymes of SER detoxify drugs, alcohol and poisons, especially in the liver
3. SER becomes modified to form the sarcoplasmic reticulum surrounding the muscle myofibrils
4. SER attaches receptors to cell membrane proteins in plant cells



5. Synthesis and repair of membranes by producing cholesterol and phospholipids
6. For metabolism of glycogen in the liver e.g. glucose-6-phosphatase enzyme in SER converts glucose-6-phosphate to glucose.
7. Contains enzymes that detoxicate lipid soluble drugs, alcohol and metabolic wastes from the liver
8. The SER also stores calcium ions
9. Pathway for the transport of materials through the cell

Adaptations of ER to its function

1. The interconnected network provides the cell with skeletal framework.
2. Forming an extensive network increases the surface area for metabolic reactions e.g. protein synthesis at RER.
3. The endoplasmic reticulum membrane compartmentalizes the cytoplasm (isolates lumen from cytosol), which;
    - Enables transporting soluble and well packaged substances to their specific destinations.
    - Prevents interference of different metabolic processes taking place in the cell at the same time.
4. Contains a variety of enzymes for performing diver roles in cell metabolism.
5. The SER is modified into sarcoplasmic reticulum storage and release of calcium ions.
6. The membrane has a variety of proteins that offer unique properties including signal reception.
7. The RER membrane has sites for attachment of many ribosomes for protein synthesis

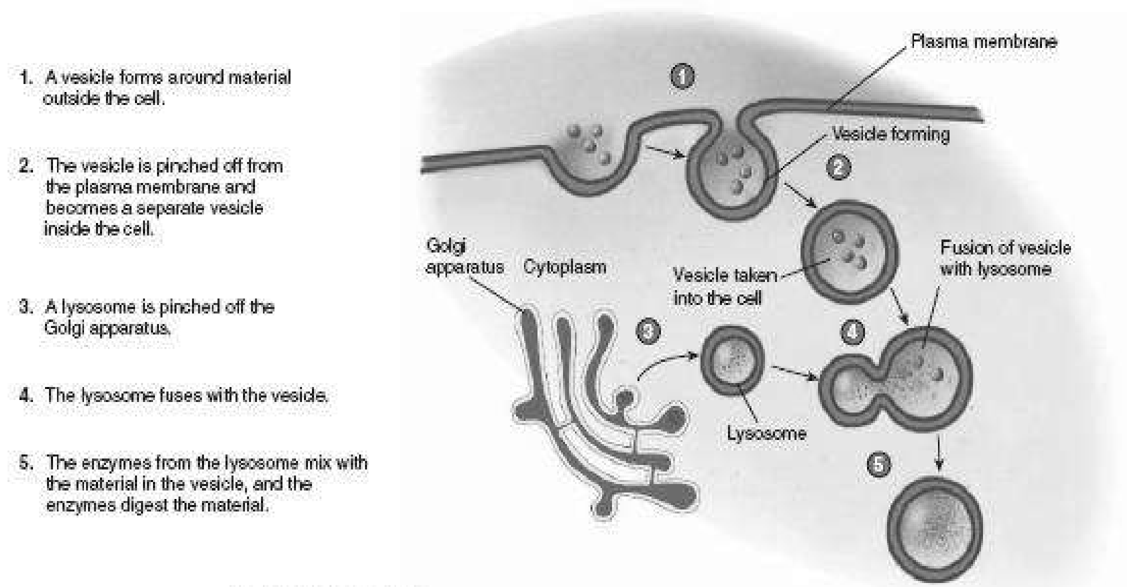
Lysosomes (suicide bag)

These are tiny membrane bound organelles that contain hydrolytic enzymes. Lysosomes occur only in animal cells and there are primary and secondary lysosomes. The primary lysosomes are tiny vesicles from the Golgi body while the larger secondary lysosomes are formed when the primary lysosomes fuse with small vacuoles of the animal cells.

They are usually absent in plants except insectivorous plants e.g. *Nepenthes, Dionaea.*

Lysosomal enzymes work best in the acidic environment found in lysosomes. If a lysosome breaks open or leaks its contents, the released enzymes are not very active because the cytosol has a neutral pH. However, excessive leakage from a large number of lysosomes can destroy a cell by *autodigestion.*

Particles taken in by cells or made in the cell are digested on the lysosome. Lysosomes contain enzymes e.g. lipase which hydrolyses lipids to fatty acids and glycerol, carbohydrases which hydrolyse carbohydrates to simple sugars, peptidases which hydrolyse peptides to amino acids, RNA-ase, DNA-ase, and others.



Action of Lysosomes

Fig 5.32 pg 155 Soper OR Fig 7.20 pg 162 Clegg

Functions

1. Digestion of materials taken in by endocytosis. The digestion may be for nutrition or defensive purposes. After its action, the products of digestion are absorbed, assimilated and the vacuole migrates to the cell surface membrane and releases its contents.
2. Release of enzymes outside the cell. This occurs during replacement of cartilage by bone during development or bone remodeling after injury.
3. On the sperm head is an organelle called acrosome which is actually a lysosome, it contains enzymes that enable the sperm to penetrate the ova.
4. Autolysis. This is the process by which the lysosome releases its contents into the cell i.e. a suicide bag. Autolysis occurs during reabsorption of the tail of a tadpole and returning the nucleus to its normal size after delivery

5. Autophagy. This is the process by which unwanted structures within the cell are engulfed and digested within the lysosomes.

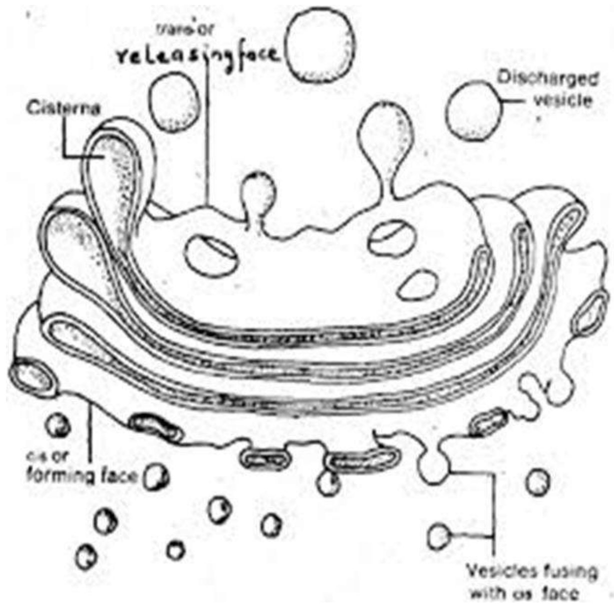
Golgi apparatus/body

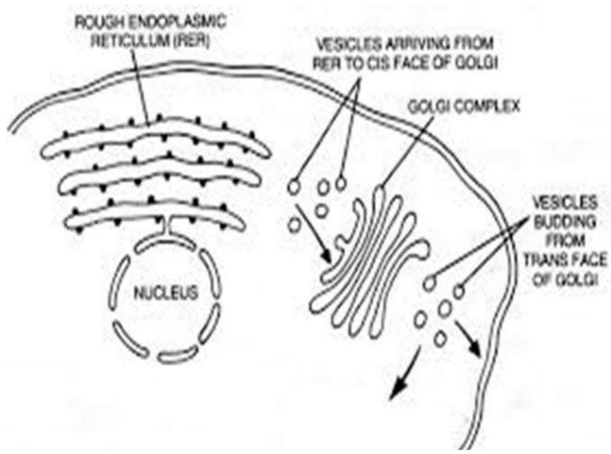
It is called a dictyosome in plants.
Golgi consist of a stack of flattened, membrane bound sacs called cisternae, together with a system of associated vesicles called Golgi vesicles. They are abundant in secretory cells and in rapidly dividing cells e.g. pancreatic cells, goblet cells, cells in testes and ovaries.
NOTE: at one end of the stack, new cisternae are constantly being formed by vesicles from the SER.

Mode of action of the Golgi

i. Proteins made at RER have, as part of their amino acid sequence, a signal that directs them where to go:
ii. Proteins arriving at cis-Golgi but having RER retention signal (were wrongly sent), are repackaged into vesicles then returned to RER.
iii. Soluble or properly folded macromolecules (proteins, lipids and polysaccharides) from RER enter cis-Golgi network via transport vesicles
iv. Within cis-cisternae, macromolecules are partly modified i.e. carbohydrates are added to proteins (glycosylation), phosphate is added to protein (phosphorylation) e.t.c.
v. After partial modification, coated vesicles bud (pinch) off the swollen ends of cis-cisternae and fuse with ends of medial cisternae.

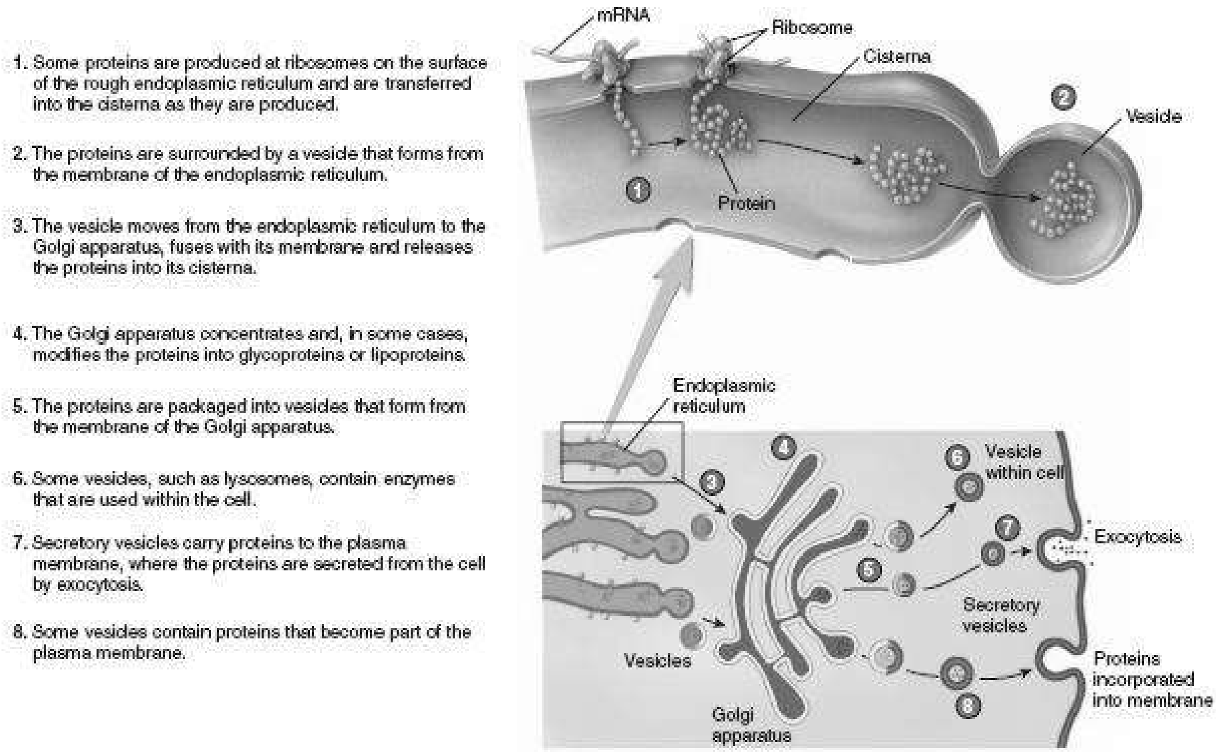
Fig 4.10 pg 60 Toole OR Fig 2.10 pg 19 Roberts OR Fig 2.19 pg 162 Clegg





From trans-cisternae, the transformed macromolecules exit the Golgi and are sorted into different transport vesicles destined for lysosomes, plasma membrane or storage vesicles for secretion.
Within medial-cisternae, different enzymes further transform macromolecules differently, depending on their structures and destination i.e. some are modified for secretion, others for the membrane, and some for lysosomes.
After further modification within the medial-cisternae, coated vesicles bud (pinch) off the swollen ends of the medial-cisternae and fuse with the ends of trans-cisternae for further transformation

a) Vesicles containing hydrolase enzymes fuse with membranes of growing lysosomes so that the contents of both structures fuse.
b) Vesicles containing hormones e.g. insulin remain until when signaled by the cell, the vesicles then fuse with plasma membrane to release (secrete) the hormone outside the cell by exocytosis.
c) Vesicles containing membrane proteins fuse with the cell membrane and some of the modified proteins become part of the cell membrane e.g. protein receptors.



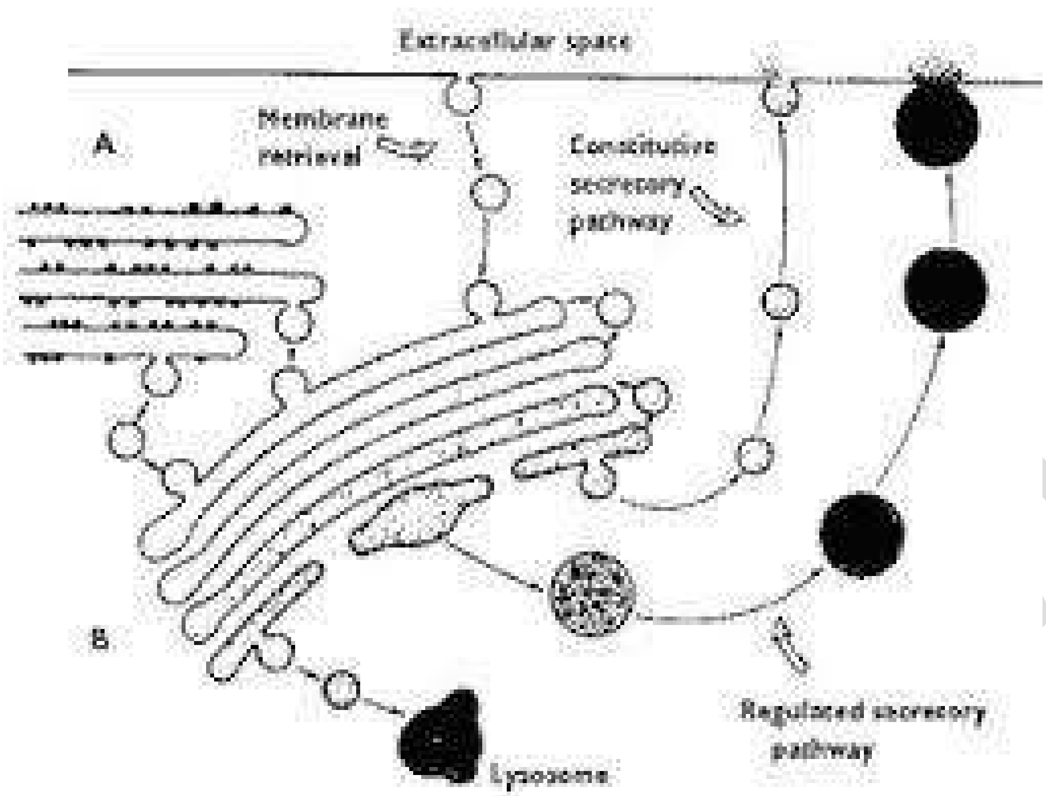
Function of the Golgi Apparatus

Functions

1. The function of the Golgi apparatus is to transport and chemically modify the materials contained within it.
2. Golgi apparatus forms lysosomes containing hydrolytic enzymes
3. Golgi is involved in the formation of peroxisomes
4. Golgi apparatus in the leaf glands of some insectivorous plants e.g. sundews secrete a sticky slime and enzymes which trap and digest insects
5. The membranes of the vesicles from the Golgi apparatus for the first layer of the new cell wall that develops between the two daughter cells as they divide.
6. Golgi is sometimes involved in the secretion of carbohydrates e.g. polysaccharides are attached to a protein to form proteoglycans present in the extracellular matrix of the animal cell
7. To form carbohydrates.
8. Transport of lipid molecules around the cell.
9. Secretory vesicles produced by Golgi contain a variety of important substances e.g. neurotransmitters, hormones, mucin, zymogen e.g. pepsinogen, etc.
10. Fusion of Golgi vesicles with cell membrane maintains the membrane which is used to form phagocytic vacuoles and Pinocytic vesicles
11. They form lysosomes if or when they contain digestive enzymes

Adaptations of the Golgi

a) Cisternae are enclosed by permeable membranes, which isolate the inside cavity from cytosol for efficient functioning.
b) Tubular structure enables transportation of soluble protein and lipids from the endoplasmic reticulum for modification.
c) Variety of enzyme systems for modifying proteins by adding carbohydrates and phosphate by the process of glycosylation and phosphorylation respectively.
d) Many cisternae increase the surface area for modifying synthesised macromolecules.
e) There are many compartments at the cis, located at the beginning of the Golgi apparatus to facilitate passage of proteins through the Golgi apparatus



Plant cell wall
It has fibres of cellulose that contain several units of glucose cellulose fibres. Each fibre has several microfibrils. These are strands of cellulose in a crystalline state and these cellulose molecules are held in a matrix by hydrogen bonds. The matrix consists of pectic acid, calcium and magnesium pectate and hemicelluloses. Hemicelluloses are polymers of various pectose and hexose sugars. Pectic substances also make up most of the middle lamella. The middle lamella binds adjust plant cells to one another. The cell wall is interrupted by pores which carry strands of cytoplasm called plasmodesmata. This cytoplasm facilitates the movement of substances between adjacent cells as well as the deposition of cellulose during the thickening of secondary cell wall.
The young plant cells are made up of the primary wall. These cells are usually found in the growing regions of plants i.e. the meristems e.g. the shoot and root apex. The primary wall is thin, plastic and it allows the cell to grow. Inside the primary wall develops the secondary wall which is thicker due to more cellulose fibres being laid down as the cell grows. The cellulose fibres are closely packed and are laid down in an orderly way.
The secondary wall is impregnated with lignin which is an alcohol polymer and this lignin gives strength to cells of the xylem and the sclerechyma. The secondary cell wall tends to be rigid and tangile. This characteristic brings about the death of the cell because the essential nutrients from the cytoplasm can no longer move across the pores through the cell wall.

In the cork tissue, the tissue between primary and secondary wall, is a fatty substance called suberin. The cork (phloem) cells are formed by the cork cambium (phellogen) prevents the passage of water and gases into and out of the woody plants.

The outer walls of the leaves and young stems are made up of cells called epidermal cells. These cells are covered by a waxy polymer called cutin. Which is secreted by the cytoplasm and it passes through the primary wall and the middle lamella to appear on the epidermis. Cutin provides a water proof covering to the aerial surface of the plant.

Functions

1. Mechanical strength and skeletal support is provided for individual cells and for the plant as a whole
2. Cell walls are fairly rigid and resistant to expansion and therefore allow development of turgidity when water enters by osmosis
3. Orientation of cellulose microfibrils limits and controls cell growth and shape because the cell's ability to stretch is determined by their arrangement
4. The system of interconnected cell wall (apoplast) is a major pathway of movement for water and dissolved salts
5. Cell walls develop a coating of waxy cutin, the cuticle, on exposed epidermal surfaces reducing water loss and risk of infection
6. The walls of xylem vessels and sieve tubes are adapted for long distance translocation of materials through the cells
7. The cell wall of root endodermal cells are impregnated with suberin that forms a barrier to water movement
8. Some cells walls are modified as food reservoirs as in storage of hemicelluloses in some seeds.
9. The cell walls of transfer cells develop an increased surface area and the consequent increase in surface area of the cell surface membrane increases the efficiency of transfer by active transport
10.

Adaptation of the cell wall to its function

a) The cell wall has cellulose polymers associate through very many H-bonds whose cumulative bonding energy provides high tensile strength of the cell wall for providing support and preventing rupturing
b) The cell wall has relatively thick multiple wall layers provide mechanical support
c) The cell wall has secondary walls which may be cutinized / suberinised for preventing water loss
d) The variety of functional proteins like oxidative enzymes (peroxidases), hydrolytic enzymes (pectinases, cellulases) enable performing several functions like protection against pathogens, cell expansion, cell wall maturation
e) The cell wall has extremely rigid secondary walls that provide compression strength
f) Deposition of cellulose fibrils in alternating layers enables some degree of flexibility
g) The cell wall is semi-permeable in nature to allows exchange of water, dissolved salts and small protein molecules

Comparison between pant cell wall and plasma membrane		
Similarities	**Differences**	
(Group assignment)	**Cell wall**	**Plasma membrane**
	Number of main layers / regions varies (2 or 3)	Number of main layers / regions constant
	Skeleton mainly made of carbohydrates / polysaccharides	Skeleton mainly made of phospholipids
	More permeable to molecules	Less permeable to molecules
	Lacks transmembrane proteins	Transmembrane proteins present
	Plasmodesmata present	Plasmodesmata absent
	May be lignified and suberinised	Lacks lignification and suberinisation
	Has middle lamella	Lacks middle lamella
	Secondary thickening occurs	Lacks secondary thickening

Flagella and cilia

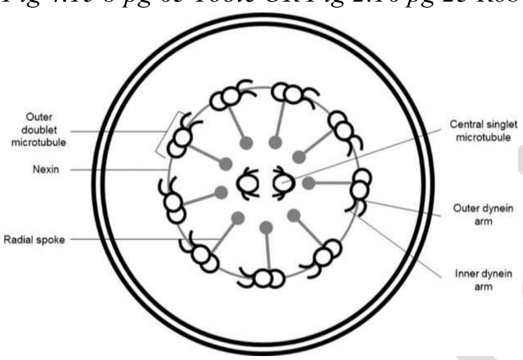
These are organelles that project from the surface of cells but are connected to a basal body just below the membrane.

Flagella occur singly or in small numbers, whereas cilia occur in large numbers on larger cells, and are typically shorter than flagella.

Flagella and cilia are enclosed by a plasma membrane. Internally, they consist of microtubules arranged in an outer ring of nine pairs surrounding two central pairs (‘9 + 2’ arrangement).

Flagella and cilia move by means of sliding movements of one member of a microtubule pair relative to the other.

Fig 4.15 b pg 63 Toole OR Fig 2.16 pg 23 Roberts



Functions

1. In moving cells e.g. sperm, chlamydominas spp e.t.c.
2. To propel fluids across cells of ciliated cells that move mucus along the brachial lining
3. To acquire food e.g. the feeding current generated by paramecium in its oral groove
4. To sense the environment e.g. sensory hair cells

Centrioles

Centrioles are found in animal cells. The centrioles are located outside the nucleus in a material of poorly defined structure called the centrosome. Centrioles are paired cylinders of about 0.3-0.5µm long and 0.24µm in diameter which are held at right angle to each other. Each cylinder consists of nine triplets of microtubules in a ‘9+0’ arrangement.

Functions

a. Centrioles act as organizers of spindle fibres and are involved in the separation of chromosomes or chromatids during cell division
b. In some cells, centrioles divide to produce basal bodies from which flagella and cilia develop.

Microfilaments

These are long fibres of about 6-7nm in diameter. They are made up of two actin protein strands intertwined together.

Functions

1. Component of cytoskeleton; give support and maintain cell shape
2. Actin and myosin filaments are needed for muscle contraction
3. Constriction of filaments causes cleavage and furrow formation in cytokinesis of animal cells
4. They play a role in cellular movements e.g. cytoplasmic streaming, cell motility, involved in phagocytosis and pinocytosis.

Microbodies

These are small spherical membrane-bound bodies of 0.5-1.5µm in diameter. The two common types of microbodies are peroxisomes and glyoxysomes.

Peroxisomes contain oxidative enzymes e.g. catalase. Glyoxysomes are found in the fat tissues of germinating seedling such as those of peanut plants. Glyoxysomes contain enzymes that catalyse the conversion of fats and oils into sugars until the germinating seedlings can produce their own sugars through photosynthesis.

Middle lamella

This is a membrane that holds adjacent plant cells together. It is called the basement membrane in animal cells to form a tissue. The middle lamella is made up of calcium pectate.

Vacuoles

Vacuoles are fluid cavities bound by a single membrane. They are formed either by infolding or pinching off of part of the cell membrane, or by enlargement of a vesicle cut off by the Golgi apparatus.

Young plant cells usually contain several small vacuoles which, in the mature cell, have united to form a large permanent, central vacuole. The plant vacuole is filled with a liquid known as a cell sap, an aqueous solution

of dissolved food materials, ions, waste products and pigments. The membrane around this type of vacuole is known as the tonoplast.
The vacuoles of animal cells are usually very small and less permanent, called vesicles. They may contain engulfed solids or liquids.

Functions of vacuoles

1. In plants, the vacuole functions to store food substances e.g. sugars
2. The concentrated cell sap causes water to enter by osmosis and the cell becomes turgid. Turgidity brings about support in herbaceous plants and plays a role in enlargement and growth of young plant cells
3. Vacuoles of come plant cells e.g. petals of flowers; contain coloured pigments to attract insects for pollination.
4. Vacuoles in leaves accumulate waste products e.g. tannins and are removed when the leaves fall
5. Food vacuoles formed by endocytosis enable bulk intake of large food particles
6. Contractile vacuoles in unicellular organisms e.g. amoeba and paramecium, regulate water content in the cell.

Protoplasm

This is the living material that comprises of the cytoplasm and the nucleoplasm. The cytoplasm is the protoplasm outside the nucleus and it has all other organelles e.g. mitochondria, RER and other cell contents e.g. glycogen in animal cells, liquid droplets, starch granules in plant cells, salts e.g. NaCl.
The nucleoplasm is the cytoplasm bound by the nuclear membrane. Chromatins are found within the nucleoplasm and later form the chromosomes.
The protoplasm is a colloidal system i.e. a solution with suspended particles in it e.g. cell organelles and food nutrients

Microtubules

These are straight unbranched hollow cylinders, 25nm wide and usually short in strength. They are made of protein and constantly being built up and broken down.

Functions

1. They are involved in the movement of cytoplasmic components within the cell.
2. Microtubules appear to direct the passage of Golgi vesicles to deposition sites.
3. Along with the microfilaments, the microtubules constitute the cytoskeleton, which controls the shape and movement of the cell
4. They are used in cell wall formation
5. They also occur in basal bodies, centrioles, in the spindle, in cilia and flagella

Distribution and function of membranes of cells

a) Membranes of cells is not limited only to the cell membrane (plasma membrane), which forms the cell boundary plus its various modifications, it also includes all other membranes enclosing some organelles and some cytoplasmic inclusions within cells.
b) Plasma membrane: Forms a protective barrier between the cell inside and outside. Determines cell shape and provides cell stability. Selectively regulates entry and exit of substances.
c) Nuclear envelope: Separate nuclear contents from cytoplasm hence limits DNA within the nucleoplasm but allows exit of RNA. Controls flow of information to nucleus and DNA that are carried by the macromolecules.
d) Outer mitochondrial membrane: Allows entry of ATP, NADH and from glycolysis
e) Inner mitochondrial membrane: Contains electron carriers in electron transport chain
f) Rough Endoplasmic Reticulum: Intracellular transport and sites for ribosome attachment
g) Smooth Endoplasmic Reticulum: intracellular transport
h) Outer chloroplast membrane: Allows photosynthetic products out and substrates in

i) Thylakoid membranes of chloroplasts: Store photosynthetic pigments e.g. chlorophyll. Contains electron carriers
j) Golgi complex membrane. Storage of glycoprotein. Synthesis of polysaccharides e.g. cellulose in plants
k) Lysosomes. Isolates autolytic enzymes from unnecessary digestion of cell components
l) Tonoplast. Limits cell sap within the vacuole
m) Membranes surrounding vesicles: Limit the contents of the vesicles within until when ready for exit e.g. calcium ions and neurotransmitters in neurones, undigested materials in phagocytic vesicles, etc.
n) Neurilemma of neurones. Contains protein pumps for Na+ and K+ which bring about impulse propagation
o) Myelin sheath membrane. Insulates nerve fibre to increase transmission speed.

Advantages of having membrane-bound organelles (importance of possession of numerous internal membranes)

1. Internal membranes maintain pH and temperature of internal membranes for reactions to proceed optimally
2. Increases proportion of membrane area to cell volume, increasing surface area over which metabolic reactions occur, for metabolic pathways with membrane-embedded enzymes.
3. Internal membranes partition the cell into compartments, providing different local environments for specific metabolic pathways so that incompatible processes can proceed simultaneously inside the same cell
4. Inner membranes provide attachment sites for specific enzymes, metabolites and molecules, regulating the occurrence of specific metabolic processes.
5. Enzymes and metabolites for particular metabolic pathways are enclosed within organelles, causing close proximity of products of one reaction to the next enzyme in the sequence, thereby increasing the rate of metabolic reactions
6. Internal membranes regulate the entry of metabolites into the organelle, controlling the rate of metabolic activity
7. Potentially harmful metabolites and enzymes are isolated inside organelles, preventing damage to the rest of the cell, such as lytic enzymes in lysosomes.
8. Internal membranes provide a supporting cytoskeleton to the cell, and serve as an intracellular transport system
9. Internal membranes protect the genetic material (DNA) from digestion and chemical alternation, preventing harmful mutations
10. Internal membranes maintain optimal conditions in specific organelles for specific metabolic pathways to proceed optimally