

Organelles of cells:

Introduction :

- The cell is the fundamental unit of life.
- The modern 'Cell theory' states :
 - i) All living organisms are composed of cells.
 - ii) All new cells are derived from other cells.
 - iii) Cells contain the hereditary material of an organism which is passed from parent to daughter cells.
 - iv) All metabolic process take place within cells.

Microscopy :

1. Light microscope :
 - It is the most common type of microscopes.
 - The degree of detail which can be seen with a microscope is called resolution or resolving power. This measures its ability to distinguish two objects which are close together.
 - The resolving power is inversely proportional to the wavelength of light being used. This means that the resolving power of any light microscope is limited because the wavelength of light has a fixed range.
 - At best it can distinguish two points which are $0.2\mu\text{m}$ apart and magnify around 1500 times.
2. Electron microscope :
 - It works on the same principal as the light microscope except that instead of light rays, a beam of electrons is used.
 - In practice it magnifies just over 500,000 times.
 - The image produced by the electron microscope cannot be detected directly by the naked eye. Instead, the electron beam is directed onto a screen from which black and white photographs, called photoelectromicrographs, can be taken.
3. A comparison of the light and electron microscope :

Light microscope	Electron microscope
<u>Advantage</u> Cheap to purchase Cheap to operate – uses a little electricity for a light bulb. Small and portable – can be used almost anywhere. Unaffected by magnetic fields. Preparation of material is relatively quick and simple, requiring only a little expertise. Material rarely distorted by preparation Both living or dead material may be viewed. Natural colour of the material can be observed.	<u>Disadvantage</u> Expensive to purchase Expensive to operate – requires up to 100,000 volts to produce the electron beam. Very large and must be operated in special rooms. Affected by magnetic fields. Preparation of material is lengthy and requires considerable expertise and sometimes complex equipment. Preparation of material may distort it. A high vacuum is required and living material cannot be observed. All images are in black and white.
<u>Disadvantage</u> Magnifies objects up to 1500x. Can resolve objects up to 200nm apart. The depth of field is restricted.	<u>Advantage</u> Magnifies objects over 5000,000x. Has a resolving power for biological specimens of around 1nm. It is possible to investigate a greater depth of field.

The Types of Cells :

- Prokaryotic cells were probably the first forms of life on earth. There are no true nucleus and no membrane-bounded organelles within a prokaryotic cell. This occurs only in bacteria and the blue-green algae

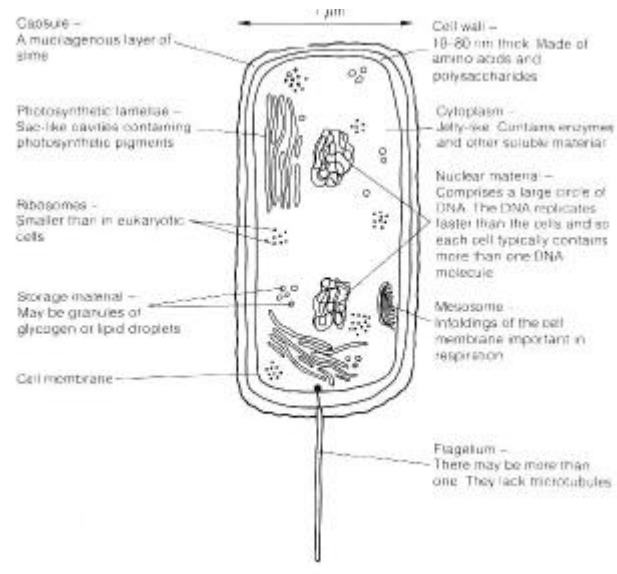


Fig. 31 Structure of prokaryotic cell, e.g. a generalised bacterial cell.

- The development of eukaryotic cells from prokaryotic ones involved considerable changes. The essential changes was the development of membrane-bounded organelles within the outer plasma membrane of the cell.
- The presence of membrane-bound organelles confers four advantages :
 - i) increase surface area for the metabolic process to take place; (enzymes are embedded in the membrane)
 - ii) contain enzymes for a particular metabolic pathway;
 - iii) control the rate of any metabolic reaction in an organelle as membrane of the organelle control the passage of reactants.
 - iv) harmful substance can be isolated inside an organelle.
- There are two main kinds of eukaryotic cells, they are plant and animal cells. Belows are the differences between them.

Plant Cell	Animal Cell
Cellulose cell wall surrounds the cell membrane	No cell wall (only a membrane surrounds the cell)
Pits and plasmodesmata present in the cell wall	Absent
Middle lamella join cell walls of adjacent cells	Cells are joined by intercellular cement
Present of plastids e.g. chloroplast	Absent
Mature cells have a 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 vacuole	Absent
Nucleus at edge of the cell	Nucleus always in the central
Lysosome not normally present	Lysosomes always present
Centrioles absent in higher plant	Centrioles present
Cilia and flagella absent in higher plant	Present
Starch grains used for storage	Glycogen granules used for storage
Only meristematic cells can divide	Almost all cells are capable of division
Few secretion are produced	Wide variety of secretions are produced

Exercise : (95 I 1)

Tabulate the major differences in cellular organization between prokaryotic and eukaryotic organisms.
 [4 marks]

Ultra-structure of the cell :

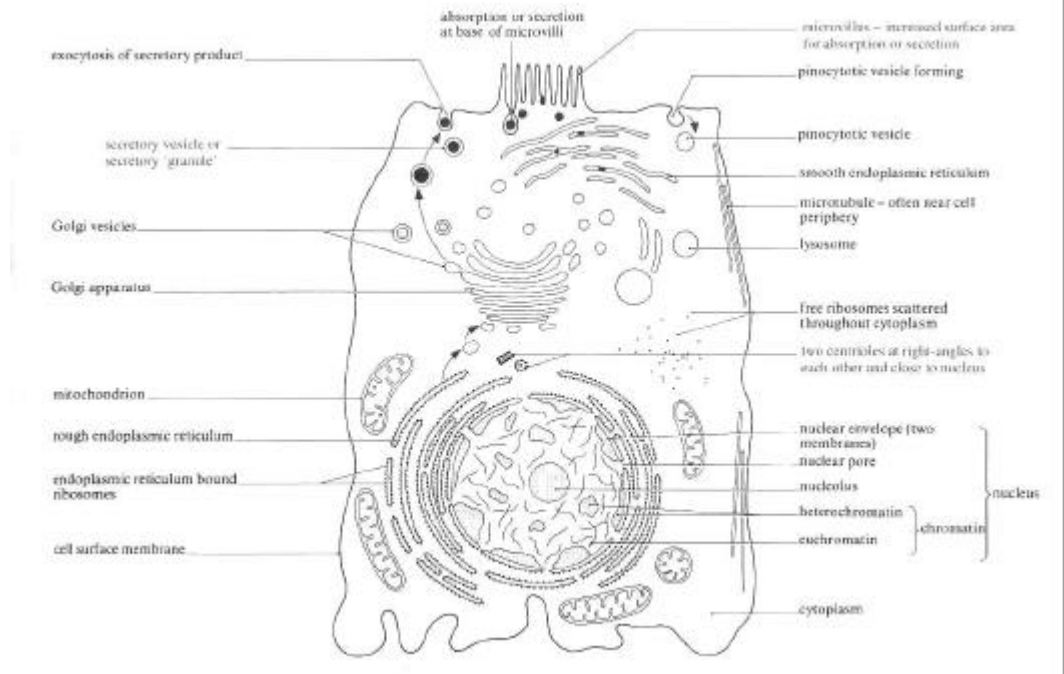


Fig. 32 Ultrastructure of a generalised animal cell as seen with the electron microscope.

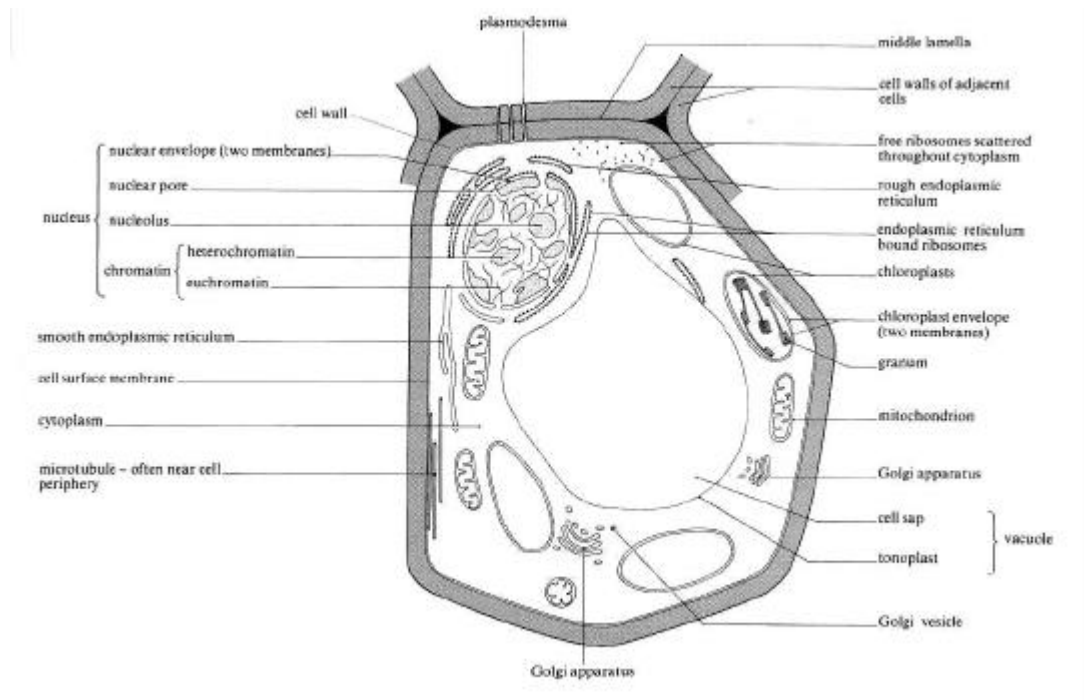


Fig. 33 Ultrastructure of a generalised plant cell as seen with the electron microscope.

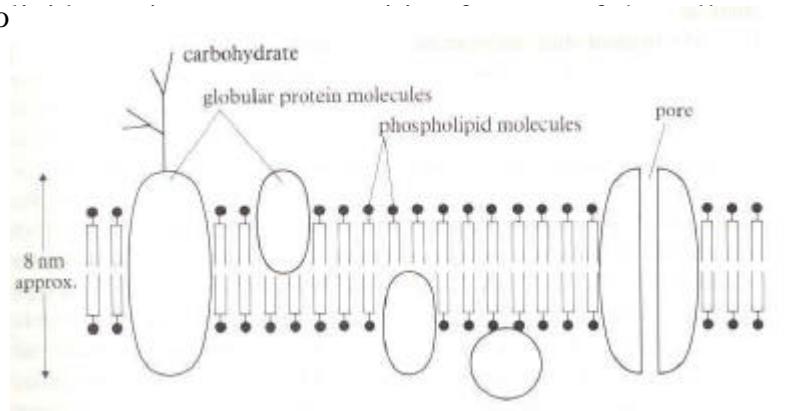
1. Cell membranes :

- They are described as selectively permeable, since apart from small molecules, such as water, larger molecule e.g. glucose, amino acids, glycerol and ions can diffuse slowly through them. And they also exert a measure of active control over what substances they allow through.
- As organic solvent (alcohol) penetrate membranes even more rapidly than water, this suggested that membranes have non-polar portions; in other words they contain lipids.
- After careful chemical analysis, it is found that membranes are comprised almost entirely of proteins and lipids (phospholipids, glycolipids and sterols).
- The fluid-mosaic model can be used to describe the detailed structure of plasma membrane.

The fluid-mosaic model (Singer-Nicholson model) :

- It was put forward in the early 1970s by S.J. Singer and G.L. Nicholson.
- The protein molecules vary in size and have a much less regular arrangement.
- Some proteins occur on the surface of the phospholipid layer, while others extend into it, some even extend completely across it.
- Viewed from the surface, the proteins are dotted throughout the phospholipid bilayer in a mosaic arrangement.
- The hydrophilic phosphate heads of the phospholipids face outwards into the aqueous environment inside and outside the cell.
- The hydrocarbon tails face inwards and create a hydrophobic interior.
- Hydrophilic molecules will be repelled by the hydrophobic tails of the phospholipid, they can pass the membrane only through the pores formed by proteins that spans the membrane or by protein carriers.
- The phospholipids are fluid and move about rapidly by diffusion in their own layers.
- Membranes also contain cholesterol which disturbs the close packing of phospholipids and keeps them more fluid. This can be important for organisms living at low temperatures when membranes can solidify. Cholesterol also increase flexibility and stability of membranes. Without it membranes break up.
- Glycoproteins and glyco

Fig. 34 The fluid-mosaic model of the plasma membrane.



- Function :

- separate contents of cells from their external environment;
- controlling exchange of substances between two cells;
- form separate compartments inside cells in which specialised metabolic pathways can take place, i.e. not interfering each other;
- as receptor sites for recognizing external stimuli;
- the glycoproteins on the surface act as cell identity markers, i.e. antigens;
- site for reaction to take place, e.g. protein on the membrane of chloroplast and mitochondria take part in the energy transfer system.

[Note] Cytoplasm = all living contents of the cell within the plasma membrane, exclude nucleus and large vacuole.

Protoplasm = cytoplasm + nucleus.

Protoplast = protoplasm + plasma membrane

Exercise : (95 II 4)

Using examples, describe the functions of cellular and subcellular membranes in living organisms. Relate these functions to the structure and composition of the membrane, whenever appropriate. [20 marks]

2. Endoplasmic reticulum (ER) :

- It is a complex network of double membranes extending throughout the cytoplasm of all eukaryotic cells
- It is an extension of the outer nuclear membrane
- Types of ER :
 - i) Rough ER : the ER lined with ribosomes; it is used for transporting the proteins synthesized from the ribosomes.
 - ii) Smooth ER : they are lacking ribosomes and concerned with the synthesis and transport of lipids.
- Functions of ER :
 - Biosynthesis : the sER may assemble fats, steroids and carbohydrates and the rER produce proteins, especially enzymes
 - Transportation : it is a complex network of passageways that extends throughout the cytoplasmic fluid, therefore, wastes and nutrients are transported intracellularly
 - Support : it forms a sort of cytoskeleton that to maintain the shape of the cell
 - Increase surface area of the cell : network-like ER provides a lot of surface area for the biochemical reactions to occur
 - Storage : in striated muscle cells, there are a highly specialized sER called sarcoplasmic reticulum which stores calcium ions and is involved in the muscle contraction
 - Detoxification : in the liver cells both rough and smooth ER are involved in detoxification of various drugs

3. Golgi apparatus :

- It is a secretory organelle
- It has a similar structure to sER but is more compact
- It consists of flattened, membrane-bound sacs called cisternae, together with a system of associated vesicles called Golgi vesicles.
- In plant cells a number of separate stacks called dictyosomes are found while in animal cells a single larger stack is thought to be more usual
- At one end of the stack new cisternae are constantly being formed by fusion of vesicles which are probably derived from buds of smooth ER. This 'outer' or 'forming' face is convex, whilst the other end is the concave 'inner' or 'maturing' face where the cisternae break up into vesicles once more (forming lysosome or secretory vesicle)

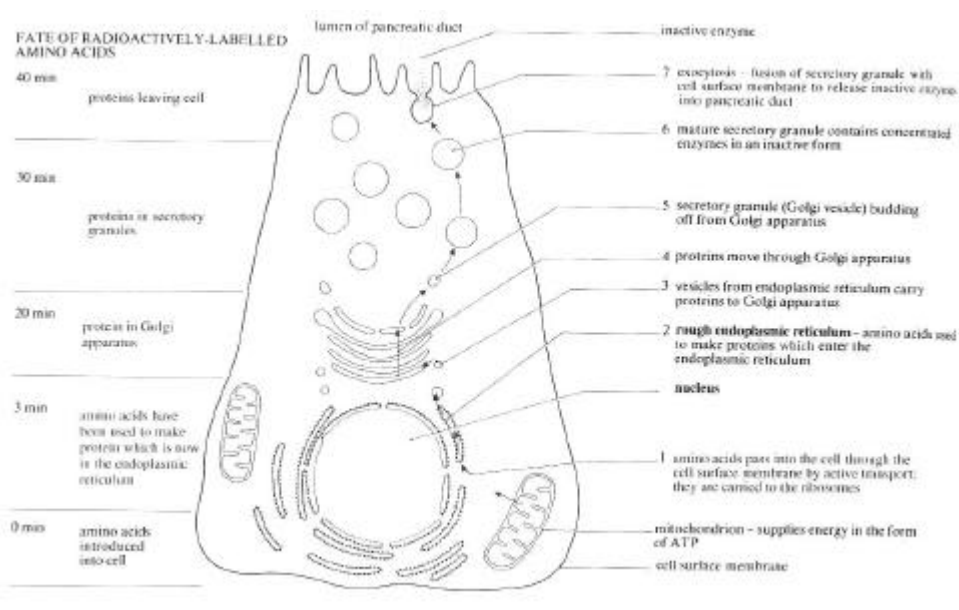
- Function :

- **Packaging** : materials that are manufactured elsewhere in the cell move along the ER into Golgi apparatus where they are packaged and being pushed to the ends of the organelle and pinched off into small bubble-like secretion vesicles
- **Glycosylation** : many cell secretions are in the form of glycoproteins and, although considerable glycosylation (adding carbohydrates) takes place in ER, the finishing touches is a Golgi function
- **Concentration** : dilute secretion is firstly concentrated in the Golgi apparatus before discharged

Transportation : when digested, lipid are absorbed as fatty acids and glycerol in the small intestine, they are resynthesised to lipids in the sER, coated in protein and then transported through the Golgi apparatus to plasma membrane where they leave the cell, mainly to enter the lymphatic system

- **Lysosome formation**
- **Membrane differentiation** : many membrane is synthesized at the ER, transferred to the Golgi apparatus where modification occur and fully modified is then added to the plasma membrane by fusion of Golgi vesicles during exocytosis
- **Enzyme production** e.g. the digestive enzymes of pancreas
- **Making cell wall** : secretes carbohydrates, those involved in cell wall formation.

Fig. 35 Diagram of synthesis and secretion of a protein (enzyme)



4. Lysosomes :

- Size are similar to mitochondria, being 0.2-0.5 μ m in diameter
- Functions :
 - **endocytosis** : process whereby extracellular materials are brought into cells and then included inside the lysosome for digestion.
 - **exocytosis** : the release of their enzymes outside the cell in order to break down other cells
 - **autolysis** : the self- destruction of cell by release of the contents of lysosomes within the cell
 - **autophage** : special type of controlled autolysis in which constituents are selectively degraded by inclusion within a specialised lysosome

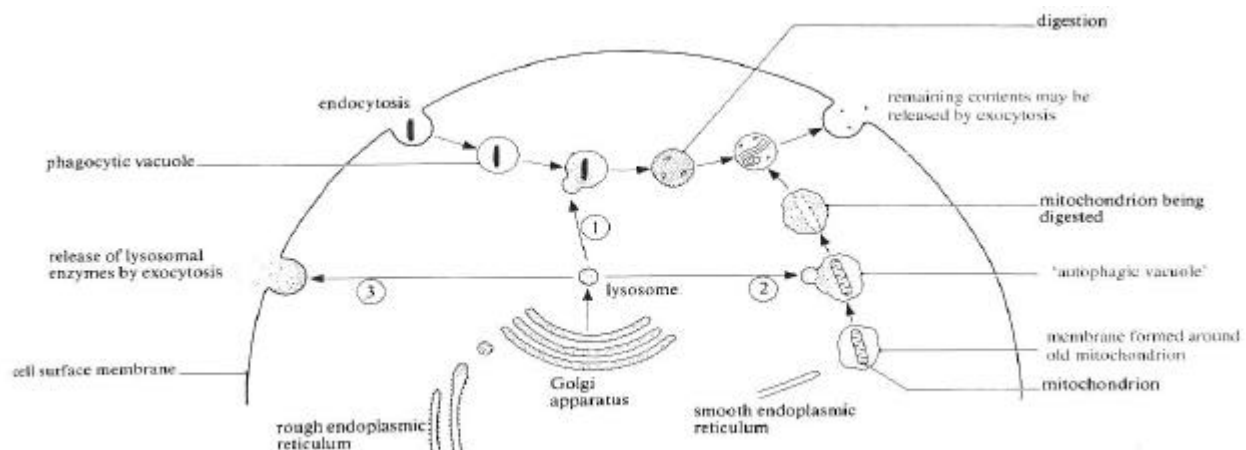


Fig. 36 Three possible uses of a lysosome. 1 endocytosis ; 2 autophagy; 3 exocytosis.

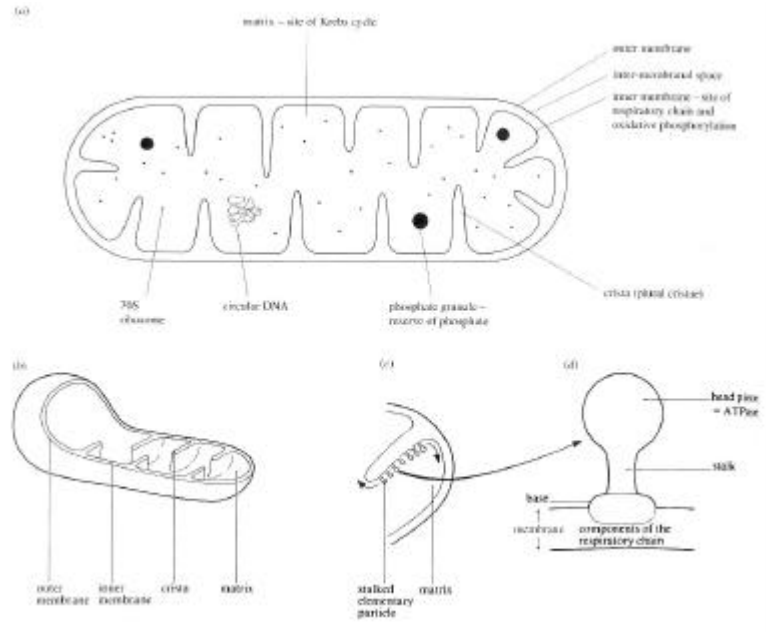
5. Vacuoles :

- It is a fluid-filled sac bounded by a single membrane (called tonoplast in plant cell)
- It contains a solution of mineral salts, sugar, amino acids, wastes and sometimes also pigments, these substance are collectively called 'cell sap'
- Animal cells contain small vacuoles but plant cells have large central vacuole
- Functions:
 - Support and cell growth : water enters the concentrated cell sap by osmosis, so turgor pressure builds up within the cell; osmotic uptake of water is also important in cell expansion during cell growth
 - Store pigments : it sometimes contain pigments that responsible for the colours in flower, fruit, buds and leaves. This is important in attracting insects, birds and other animals for pollination and seed dispersal
 - As lysosome : sometimes it may contain hydrolytic enzymes, after cell death the tonoplast losses its differential permeability and the enzymes escape causing autolysis
 - Temporary stores for wastes and food

6. Mitochondria :

- They are spherical or rod shaped scattering throughout the cytoplasm of all eukaryotic cells
- Double membrane bounded, the outer of which controls the entry and exit of chemicals and the inner membrane is folded inwards, giving rise to cristae as to increase the surface area on which respiratory processes take place
- Stalked elementary particles are spherical bodies located on the inner membrane. They contains enzymes for the phosphorylation of ADP (ATP formation process)
- The remainder of the mitochondrion is the matrix, it is a semi-rigid material containing protein (include all the soluble enzymes of the Kreb's cycle and those involved in the oxidation of fatty acids), lipids and traces of DNA.
- Functions:
 - Energy metabolism and respiration : the major function of mitochondrion is produce chemical energy (ATP) from food stuffs via Kreb's cycle and respiratory chain. Mitochondria are the site of the terminal catabolism of foods (the preliminary degradation of these compounds occurs in the cytoplasm)
 - Heat production : energy of oxidation is dissipated as heat instead of being converted into ATP, so mitochondrion is the site to produce heat to maintain body temperature.
 - Amine metabolism : some amines are metabolized in mitochondria

Fig. 37 Structure of mitochondria. (a) Diagram ; (b) 3-D structure; (c) Diagram of crista showing inner membrane particles; (d) Structure of inner membrane particle



Exercise : (99 II 2a)

Illustrate the structure of a mitochondrion as seen under the electron microscope with a labelled diagram. [3 marks]

7. Ribosome :

- It is a small (20nm in diameter) and non-membranous structure
- It consists of two subunits, one large (called 70S) and one small (called 80S)
- It present in large numbers in both prokaryotic and eukaryotic cells
- It may occur in groups called polysomes and may be associated with ER to form rER or occur freely within the cytoplasm.
- It is made of roughly equal amounts of ribosomal ribonucleic acid (rRNA) and proteins
- Functions :
 - it acts as a binding site for protein synthesis

8. Nucleus :

- Found in all eukaryotic cells except in mature phloem sieve tube elements and mature red blood cells of mammals.
- The shape of the nucleus is sometimes related to that of the cell, but it may be completely irregular.
- Almost all cells are mono-nucleate, but bi-nucleate cells (some liver and cartilage cells) and poly-nucleate cells (some white blood cells) also exists.
- It is bounded by a double membrane (nuclear envelope). The envelope possesses many large pores which permit the passage of large molecules, such as RNA.
- The cytoplasm-like material within the nucleus is called nucleoplasm. It contains chromatin which is made up of coils of DNA bound to proteins. The chromatin are the genetic materials of the cell. In a resting cell (interphase), it appears as a network of tiny granules. During cell division the chromatin granules are re-organized into filaments called chromosomes.

- Functions :
 - contain genetic materials (chromatin)
 - act as a control centre for the activities of a cell
 - the nuclear DNA carries the instructions for the synthesis of proteins
 - it is involved in the production of ribosomes and RNA
 - it is essential for cell division

9. Nucleolus :

- Appears as a rounded, darkly stained structure inside the nucleus.
- One or more nucleoli may be present in a cell.
- It stains intensely because of the large amounts of DNA and RNA it contains.
- During nuclear division nucleoli seem to disappear, but this is because the DNA disperses. They reassemble after nuclear division.
- Functions :
 - making ribosomes

Exercise : (90 I 2)

Describe the relationships between the following pairs of cell organelles :

(a) the nucleolus and the ribosomes [2 marks]

(b) the endoplasmic reticulum and the Golgi apparatus [4 marks]

10. Cellulose Cell Wall :

- It is a characteristic feature of plant cells
- Consist of cellulose microfibrils embedded in a matrix
- The matrix is usually composed of polysaccharides, e.g. pectin or lignin.
- Functions:
 - provide support in herbaceous plants.
 - provide mechanical strength, the strength may be increased by the presence of lignin in the matrix between the cellulose fibres
 - permit movement of water through the plant, in particular in the cortex of root
 - cell walls develop a coating of waxy cutin, the cuticle, to decrease water loss and risk of infection
 - give shape of the cell
 - sometimes cell walls are modified to act as food reserves, e.g. hemicellulose in some seeds
 - cell walls possess minute pores through which plasmodesmata can pass, for living connections between cells, and allow all the protoplasts to be linked in a system called symplasm

11. Chloroplast :

- It is the most common plastid (double membrane bounded organelle) in plant cells
- It is bounded by double membrane, the chloroplast envelope.
- The stroma is a homogenous matrix which contains enzymes for the carbon dioxide fixation processed (dark reaction) in photosynthesis.

- Grana are scattered within the stroma. Each granum consists of membrane-bounded disc-shaped vesicles (thylakoids) arranged like a pile of coins. The grana connected with each other by intergranal lamella. Both are the site for light reaction of photosynthesis.
- The thylakoids are formed by double layers of thylakoid membrane. Such membranes contain all of the energy-generating system e.g. chlorophyll, electron transport chain and ATP synthetase.
- A small amount of DNA is present within the stroma. This suggests that the chloroplasts are also a kind of semi-autonomous organelles. The chloroplasts might be the residue of primitive algae once lived symbiotically in the cells of non-green organisms.
- Functions :
 - Photosynthesis
 - Synthesis of fatty acid : in the stroma, carbohydrates are converted to fatty acid in the aid of ATP and NADPH
 - Reduction of nitrite to ammonia.

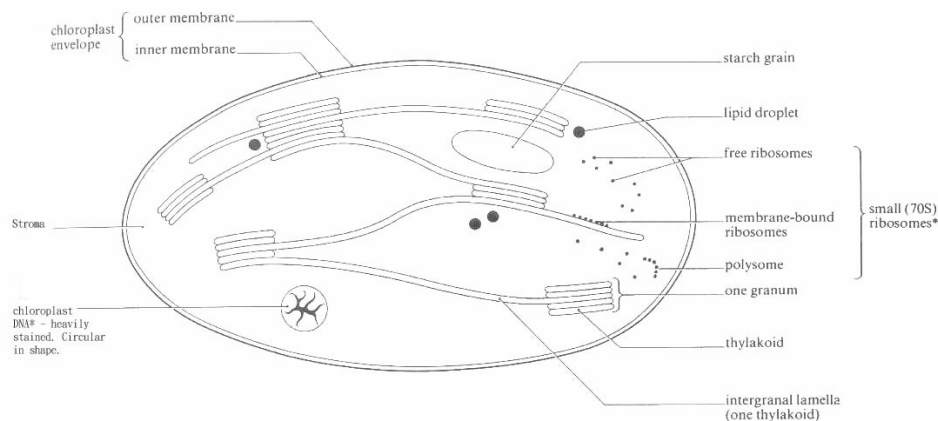


Fig. 38 Chloroplast structure. The membrane system has been reduced in extent to make the diagram simpler.

Exercise :

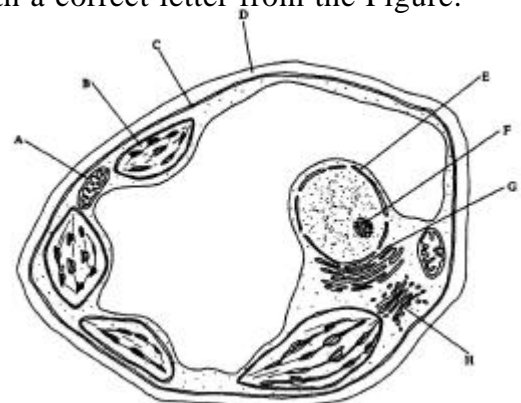
(92 I 2)

Match each of the functions from the following list with a correct letter from the Figure.

- (a) protein synthesis
- (b) Krebs cycle
- (c) electron transport (respiratory chain)
- (d) protein/ carbohydrate complex formation
- (e) generation of ATP
- (f) ribosome production

Name each of the structures you have selected.

[6 marks]



(93 I 2)

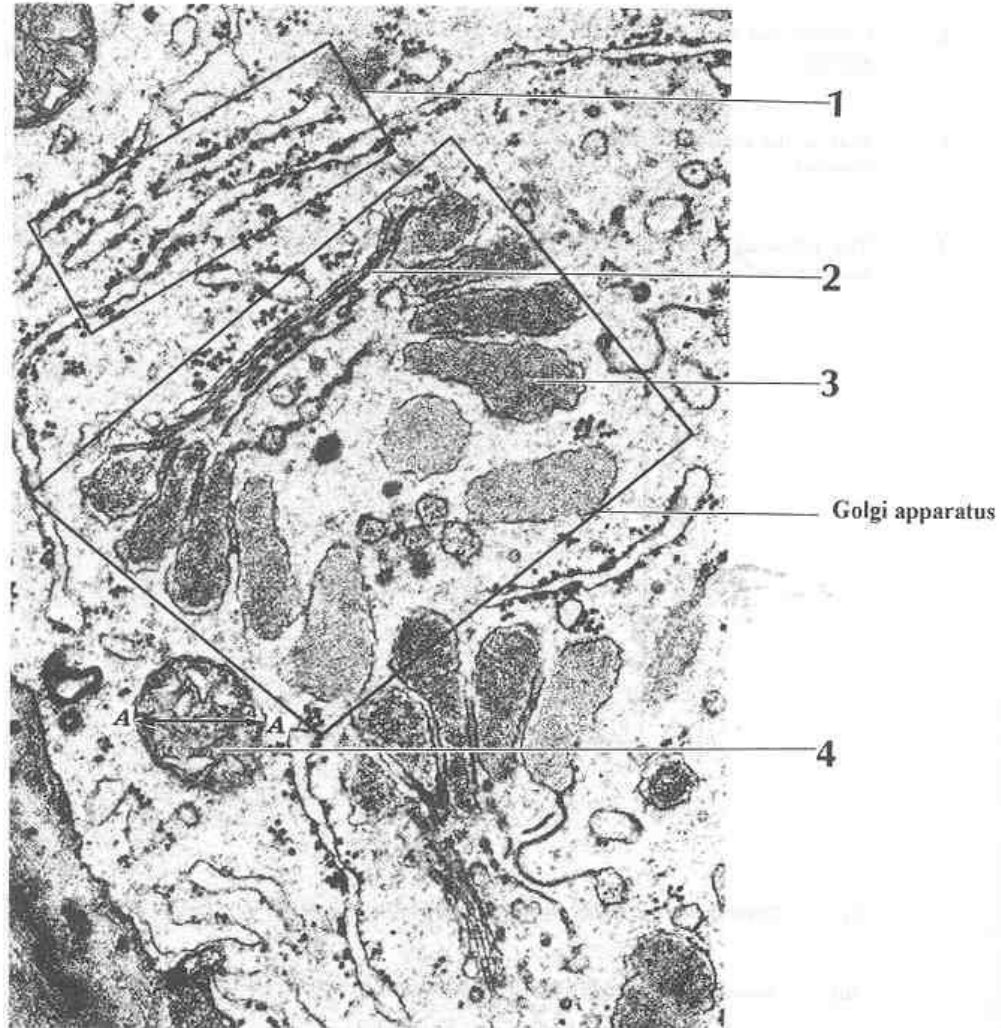
- (a) Name all the cellular organelles which are surrounded by two layers of membrane.
- (b) One of these organelles is concerned with energy production. Draw a simple labelled diagram to show the structure of this organelle.
- (c) How is the structure of the organelle in (b) related to its function in cellular metabolism ?

[7 marks]

(97 I 5)

The electron micrograph below shows a portion of a cell.

- (a) Name organelle 1 and state the event occurring in it. [2 marks]
(b) What is the functional relationship between organelle 1 and the Golgi apparatus? [1 mark]
(c) Structures 2 and 3 are parts of the Golgi apparatus. What is the relationship between structure 2 and 3? How does 3 perform its role in cellular activity? [2 marks]
(d) Calculate the diameter of organelle 4 at A-A. Show your working [2 marks]



Summary :-


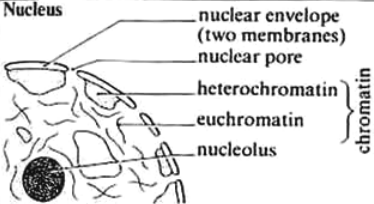
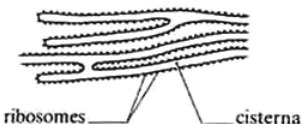
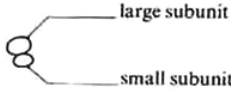
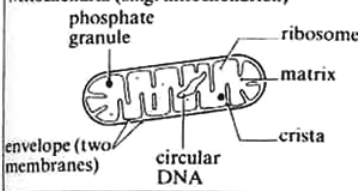


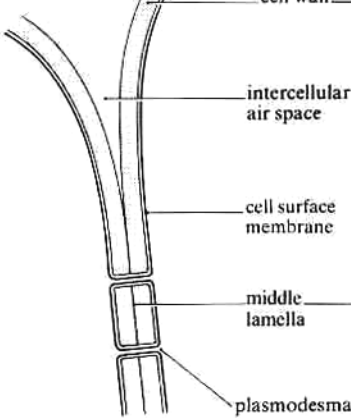

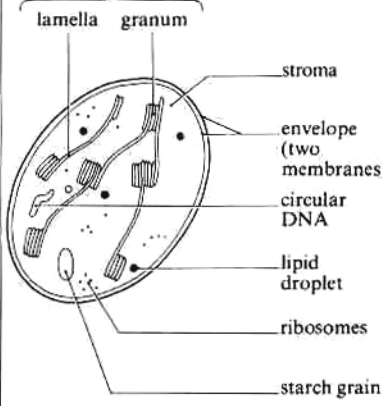
Diagram	Structure	Functions
Cell surface membrane 	'Trilaminar' appearance (3 layers), a pale layer sandwiched between 2 dark layers	A partially permeable barrier controlling exchange between the cell and its environment
Nucleus 	Largest cell organelle, enclosed by an envelope of two membranes that is perforated by nuclear pores. It contains chromatin which is the extended form taken by chromosomes during interphase. It also contains a nucleolus.	Chromosomes contain DNA, the molecule of inheritance. DNA is organised into genes which control all the activities of the cell. Nuclear division is the basis of cell replication, and hence reproduction. The nucleolus manufactures ribosomes.
Endoplasmic reticulum (ER) 	A system of flattened, membrane-bounded sacs called cisternae, forming tubes and sheets. It is continuous with the outer membrane of the nuclear envelope.	If ribosomes are found on its surface it is called rough ER , and transports proteins made by the ribosomes through the cisternae. Smooth ER (no ribosomes) is a site of lipid and steroid synthesis.
Ribosomes 	Very small organelles consisting of a large and a small subunit. They are made of roughly equal parts of protein and RNA. Slightly smaller ribosomes are found in mitochondria (and chloroplasts in plants).	Protein synthesis. They are either bound to the ER or lie free in the cytoplasm. They may form polysomes (polyribosomes), collections of ribosomes strung along messenger RNA.
Mitochondria (sing. mitochondrion) 	Surrounded by an envelope of two membranes, the inner being folded to form cristae. Contains a matrix with a few ribosomes, a circular DNA molecule and phosphate granules.	In aerobic respiration cristae are the sites of oxidative phosphorylation and electron transport, and the matrix is the site of Krebs cycle enzymes.
Golgi apparatus 	A stack of flattened, membrane-bounded sacs, called cisternae, continuously being formed at one end of the stack and budded off as vesicles at the other.	Internal processing and transport system. Processing of many cell materials takes place in the cisternae, e.g. proteins from the ER. Golgi vesicles transport the materials to other parts of the cell or to the cell surface membrane for secretion. Makes lysosomes.
Lysosomes 	A simple spherical sac bounded by a single membrane and containing digestive (hydrolytic) enzymes. No internal structure visible.	Many functions, all concerned with breakdown of structures or molecules. For example, get rid of old organelles, digest bacteria taken in by phagocytosis.

Diagram	Structure	Functions
<p>Cell wall, middle lamella, plasmodesmata (sing. plasmodesma)</p>  <p>cell wall</p> <p>intercellular air space</p> <p>cell surface membrane</p> <p>middle lamella</p> <p>plasmodesma</p> <p>Detail of plasmodesma</p>  <p>ER</p> <p>tubular core</p>	<p>A rigid cell wall surrounding the cell, consisting of cellulose microfibrils running through a matrix of other complex polysaccharides. May be secondarily thickened in some cells.</p>	<p>Provides mechanical support and protection. It allows a pressure potential to be developed which aids in support. It prevents osmotic bursting of the cell. It is a pathway for movement of water and mineral salts. Various modifications, such as lignification, for specialised functions.</p>
	<p>Thin layer of pectic substances (calcium and magnesium pectates).</p>	<p>Cements neighbouring cells together.</p>
	<p>A fine cytoplasmic thread linking the cytoplasm of two neighbouring cells through a fine pore in the cell walls. The pore is lined with the cell surface membrane and has a central tubular core, often associated at each end with ER.</p>	<p>Enables a continuous system of cytoplasm, the symplast, to be formed between neighbouring cells for transport of substances between cells.</p>
<p>Chloroplast</p> <p>photosynthetic membranes with chlorophyll</p>  <p>lamella</p> <p>granum</p> <p>stroma</p> <p>envelope (two membranes)</p> <p>circular DNA</p> <p>lipid droplet</p> <p>ribosomes</p> <p>starch grain</p>	<p>Large plastid containing chlorophyll and carrying out photosynthesis. It is surrounded by an envelope of two membranes and contains a gel-like stroma through which runs a system of membranes that are stacked in places to form grana. It may store starch. The stroma also contains ribosomes, a circular DNA molecule and lipid droplets.</p>	<p>It is the organelle in which photosynthesis takes place, producing sugars from carbon dioxide and water using light energy trapped by chlorophyll. Light energy is converted to chemical energy</p>
<p>Large central vacuole</p> <p>(Smaller vacuoles may occur in plant and animal cells such as food vacuoles, contractile vacuules.)</p>	<p>A sac bounded by a single membrane called the tonoplast. It contains cell sap, a concentrated solution of various substances, such as mineral salts, sugars, pigments, organic acids and enzymes. Typically large in mature cells.</p>	<p>Storage of various substances including waste products. It makes an important contribution to the osmotic properties of the cell. Sometimes it functions as a lysosome.</p>