<u>Cell Wall:</u>

Discovery:
Robert Hooke (1665) discovered cell wall when he observed dead empty cells in a very thin slice of cork under his microscope.

Definition:
Cell wall is the thick, rigid, non-living, semi-elastic, transparent, specialized form of protective extra-cellular matrix that present outside the plasma lemma of cells.

Occurrence:
Found in plant cells, fungal cells, some protists and prokaryotes except a few lower plants, gametes and in animal cells.

Thickness:
The thickness varies from 0.1 to 10/µm and xylem vessels have thickest cell wall, while thinnest cell wall found in meristematic and parenchymatous cells.

Chemical composition:
In plants, cell wall composed of cellulose micro-fibrils embedded in the matrix. Matrix is the gel-like ground substance which consists of water, hemicellulose, pectin, glycoproteins and lipids. The cell wall may have lignin for hardness, silica for stillness and protection, cut in to prevent water loss and suberin for impermeability. In fungi, cell wall composed of chitin or fungal cellulose. In bacteria, cell wall composed of peptidoglycan.

Structure:
The structure of cell wall determines the architecture and function of plant cell.

A typical cell wall composed of 3-4 layers that are formed sequentially from outside to inwards are as follows: Middle lamella, Primary wall, Secondary wall & occasionally tertiary wall is present.

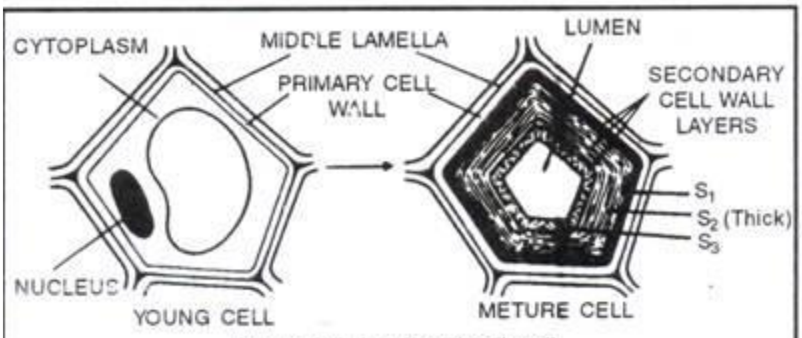


Figure 3.1 Layers of cell wall

(a) Middle Lamella.
It is a cementing layer present between adjacent cells but absent on the free surface of plant cells and in plasmadesmata region. Chemically it is composed of pectin (calcium and magnesium-pectate). Softening of fruits and fibre retting involves the dissolution of middle lamella.

(b) Primary Wall:
It is the first formed wall of the cell which is deposited inner to the middle lamella. Primary wall is usually thin (0.1-3.0/µm) and capable of extension. Its thickness increases with the growth of the plant cell. It grows by internal growth i.e. wall materials deposited into the existing primary wall. Cells engaged active division, photosynthesis, respiration and secretion have only primary walls.

(c) Secondary wall:
It is deposited inner to primary wall only in mature and non-dividing cells. It is generally seen in parenchyma, collenchyma, sclerenchyma, tracheids and vessels. The secondary wall grows by accretion i.e. deposited in layers. It is about 3 –lo/µm thick and consists of usually three layers, designated as S_1, S_2 (thickest) and S_3, sometimes even more as in latex tube of Euphorbia milli. During the formation of secondary cell wall in tracheids and vessels of xylem, its constituents are deposited unevenly inner to primary wall. As a result, various patterns of secondary thickening develop such as annular, spiral, scalariform, reticulate and pitted.

(d) Tertiary wall:
In certain plant cells there occurs another cell wall beneath the secondary cell wall which is known as tertiary cell wall. The tertiary cell wall differs from the secondary cell wall from its morphology,

chemistry and staining properties. Besides the cellulose the tertiary cell wall contains another chemical substance known as the xylan.

Ultra-structure:

The primary wall and the secondary wall have the same basic structure. In both cases cellulose macro-fibrils are found embedded in the gel-like matrix. Cellulose is the chief constituent of plant cell wall. Each cellulose chain (1 -5/µm long) consists of about 2000-25000 glucose units. Nearly 100 cellulose chains arranged parallel to form minute bundle called crystalline domain or micelle (1.0 nm thick). Micelle is the smallest structural unit of cell wall. About 20-40 micelles assemble in the matrix to form a micro fibril (2.6 nm thick).

In primary wall micro fibrils are short, wavy and loosely scattered. In secondary wall micro fibrils are long, straight, close and parallel arranged (Fig. 3.2)

Micro fibrils are synthesized on the plasma membrane by protein complexes called particle rosettes. Matrix contains a glycoprotein called expansin which causes the loosening and expansion of cell wall by the addition of cellulose molecules to the micro fibrils.

Pits:

These are the depressions in the secondary wall of plant cells.

A pit consists of:

(i) Pit chamber, the actual hole within the secondary wall;

(ii) Pit membrane, composed of middle lamella and primary walls between two adjacent pits; and

(iii) Pit aperture, an opening that communicate pit chamber with the interior of the cell.

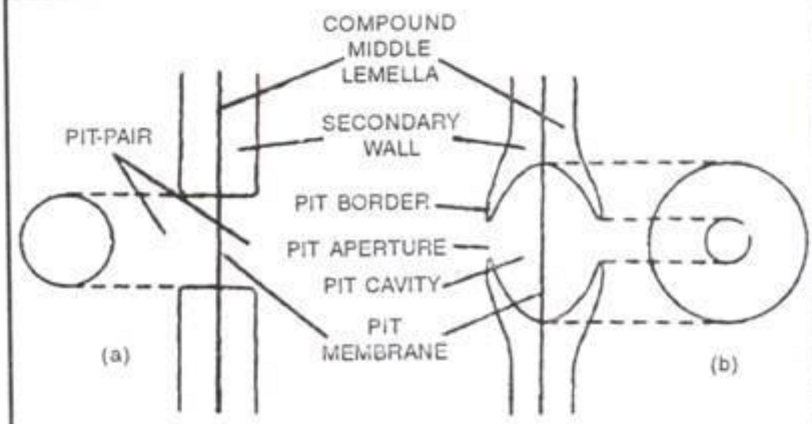


Figure 3.3 Structure of pits. (*a*) Simple pit pair in surface view and L.S. (*b*) Bordered pit-pair in L.S. and surface view.

On the basis of the shape of pit chamber, pits are either simple or bordered. In simple pit the pit chamber has uniform width and appears one ringed in surface view. In bordered pit the pit chamber is flask-shaped with narrow pit aperture and appears bordered on surface view.

Plasmodesmata (Singl. Plasmodesma):

These are the fine protoplasmic channels (20-40 nm in diameter) that connect the protoplasts of adjacent plant cells means through which the cells of tissue maintain cytoplasmic flow with each other. Plasmodesmata were discovered by Tangle (1879) and studied in details by Strasburger (1901). Through these plasmodesmata the cytoplasm and the endoplasmic reticulum remain continued to the adjacent cells. Through the plasmodesmata the inter circulation of solutions containing nutritional products, dissolved gases, ions or other substances takes place.

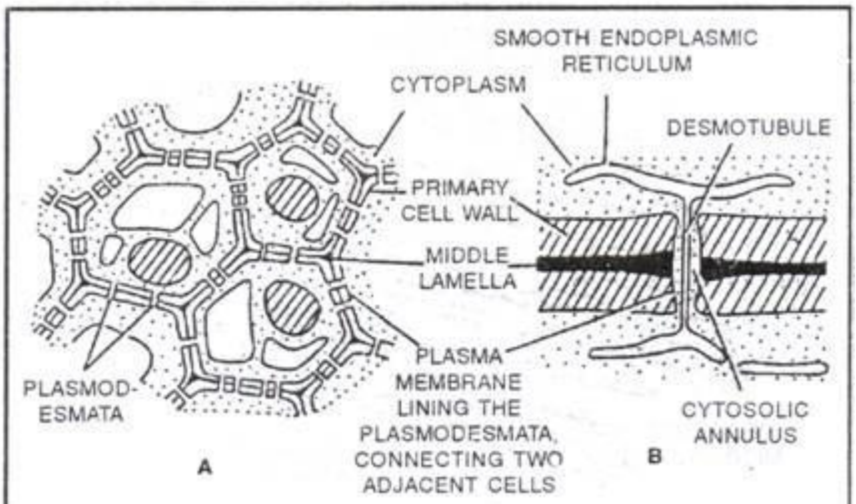


Figure 3.4 A—Cells showing plasmodesmata Plasmodesmata pierce the cell wall and connect all cells in the plant together to form symplast ; B—Details of the structure of a plasmodesma.

Functions of Cell Wall:

1. It provides definite shape and rigidity to cell.

2. It protects the cell from mechanical injury and attacks of pathogens.

3. It prevents the osmotic bursting of the cell.

4. The system of adjacent cell walls throughout the plant body constitue the apoplast.

5. Plasmodesmata in cell wall form a system of interconnected protoplasts called the symplast.

6. Cutin and Suberin deposits check water loss.

7. Phycocolloids (water holding substances) are extracted from the cell wall of marine algae, e.g., algin (brown algae), agar (red algae) and carrageen (red algae) are used commercially.

8. Particularly in higher plants, having vascular system, the cell walls provide the main supporting framework.

Endoplasmic Reticulum (ER):

It was discovered independently by Porter (1945) and Thompson (1945). The name was given by Porter in 1953. Endoplasmic reticulum is a 3-dimensional, complicated and interconnected, membrane-lined channels that run through the cytoplasm.

At places, it is connected with plasma lemma as well as nuclear envelope. Plasmodesmata contain it in the form of desmotubules. It is not visible under light microscope but can be observed under electron microscope.

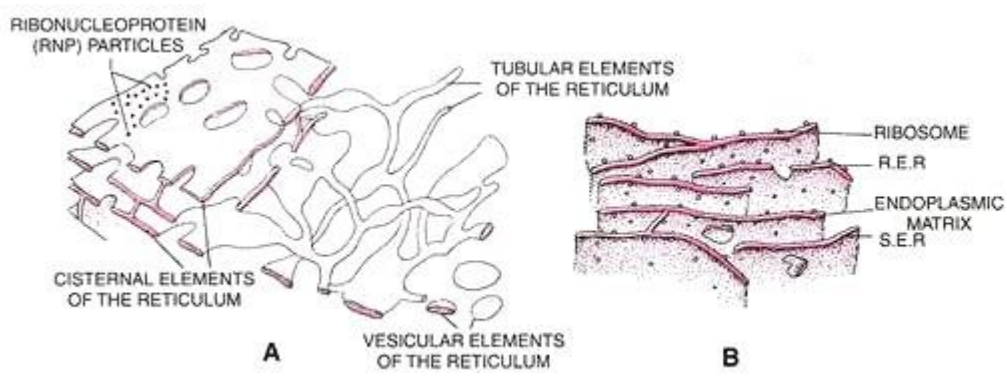


Fig. 8.30. Part of endoplasmic reticulum showing its three dimensional nature.

Endoplasmic reticulum divides the intracellular space into two compartments luminal (inside the endoplasmic reticulum) and extra-luminal (rest of cytoplasm). The extent of endoplasmic reticulum varies from cell to cell. Normally it forms 30-60% of membrane system of the cell which increases the internal surface 30-40 times as compared to external surface.

Types of Endoplasmic Reticulum:

Depending upon the nature of its membranes, endoplasmic reticulum is of two main types, smooth and rough. The two types of ER may be continuous with one another, plasma membrane and nuclear envelope. Endoplasmic reticulum may develop from pre--existing E.R., plasma lemma or nuclear envelope.

i. Smooth Endoplasmic Reticulum (SER)

It has smooth membranes which do not bear ribosomes. It is, therefore, also called agranular endoplasmic reticulum. This type of ER is found in cells engaged in the synthesis and storage of glycogen, fat and sterols but they do not found in cells which have no active participation in protein synthesis. Smooth endoplasmic reticulum is mostly made of vesicles and tubules.

ii. Rough Endoplasmic Reticulum (RER):
It has rough membranes because a number of ribosomes occur attached to their outer surfaces. RER is, therefore, also called granular endoplasmic reticulum. The membrane of the endoplasmic reticulum bears a fine pore in the area of attached ribosome to pass the synthesized polypeptide into the channel of endoplasmic reticulum for transport.

RER contains two types of glycoproteins (ribophorin I and ribophorin II) for attachment to ribosomes. On account of the presence of ribosomes, the rough ER is engaged in synthesizing proteins and enzymes.

It is, rich in cells which are actively engaged in protein synthesis and secretory activity. In conjunction with Golgi apparatus, RER helps to produce lysosomes. RER is mostly made of cistemae. Tubules are very few.

Structure of Endoplasmic Reticulum:
Endoplasmic reticulum consists of membrane lined channels or spaces. The channels or spaces contain a fluid called endoplasmic matrix, which is quite different from cytoplasmic matrix present outside the reticulum. The membranes of endoplasmic reticulum are 50-60 A thick. Endoplasmic reticulum can exist in three forms-cisternae, vesicles and tubules.

1. Cisternae:
They are long, flattened, unbranched, interconnected sac-like parts of the endoplasmic reticulum which are 40-50 nm in diameter. The cisternae are found in bundles where they lie parallel to one another. They occur in the cells actively involved in synthetic activity.

2. Vesicles:
They are oval or rounded sacs of 25-500 nm in diameter. The vesicles appear as small vacuoles. They remain isolated in the cytoplasm. The vesicles are also called microsomes.

3. Tubules:

The tubules are branched structures forming the reticular system along with the cisternae and vesicles. They usually have the diameter from 50 to 190nm and occur almost in all the cells.

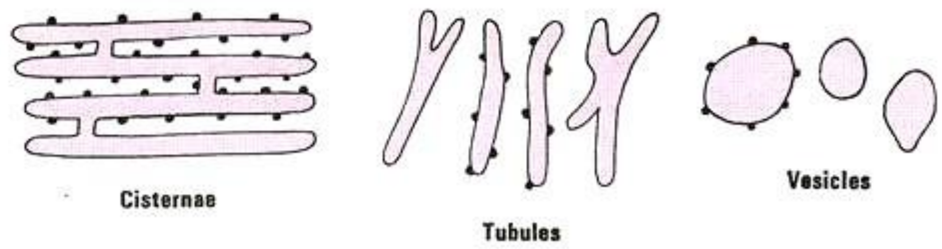


Fig. 8.31. The three components of endoplasmic reticulum.

Functions of Endoplasmic Reticulum:

Common Functions of ER:

1. It provides a large surface inside the cell for various physiological activities.

2. It functions as cytoskeleton or intracellular and ultra-structural skeletal framework by providing mechanical support to colloidal cytoplasmic matrix.

3. Endoplasmic reticulum keeps the various organelles in their position.

4. Endoplasmic reticulum (as desmotubules) controls movement of materials between two adjacent protoplasts through plasmodesmata.

5. Endoplasmic reticulum acts as a means of quick intracellular transport.

6.In cells, endoplasmic reticulum conducts information from cell exterior to inside and from one part of the cell to another, e.g., cytoplasm to nucleus and vice versa.

7. It provides membranes to nuclear envelope after telophase.

8. It provides precursors of different secretory substances to Golgi apparatus.

9. It gives membranes to Golgi apparatus for the formation of vesicles and lysosomes.

10. It gives rise to vacuoles.

11. Complexing of proteins and lipids to form lipoproteins occurs in ER.

12. The membranes of endoplasmic reticulum contain a number of enzymes (e.g., ATP- ase, reductases, dehydrogenases, phosphatases) for various metabolic activities and cytochromes that take part in electron transport.

ii. Functions of Rough Endoplasmic Reticulum (RER):

1. It contains ribophorins for providing attachment to ribosomes.

2. RER provides a large surface area to ribosomes.

3. It bears enzymes in the region of pores for modifying polypeptides synthesised by attached ribosomes, e.g. glycosylation.

4. It synthesizes serum proteins, membrane proteins and a number of other proteins.

5. Proteins and enzymes synthesised by ribosomes enter the channels of RER both for intracellular use as well as secretion.

6. It provides enzyme precursors for the formation of lysosomes by Golgi complex.

iii. Functions of Smooth Endoplasmic Reticulum (SER):

1. It is responsible for synthesis of fats, formation of sphaerosomes, synthesis of glycogen, synthesis of ascorbic acid.

3. It takes part in detoxification.

Golgi Apparatus:

Meaning of Golgi Apparatus:
Golgi complex (Golgi Apparatus) is a complex cytoplasmic structure made up of smooth membrane saccules or cisternae, a network of tubules with vesicles and vacuoles, which takes part in membrane transformation, secretion and production of complex biochemicals.

It is surrounded by an organelle free cytoplasm called zone of exclusion or Golgi ground substance. It was first seen by George (1867) but is named after Italian scientist Camillo Golgi, who in 1898 recognised the apparatus as reticular structure (apparato reticulare) near the nucleus.

Occurrence of Golgi Apparatus:
Golgi apparatus or complex is absent in prokaryotic cells (PPLO, bacteria and blue-green algae). It is present in all eukaryotic cells except sieve tubes of plants, sperms of bryophytes and pteridophytes and red blood corpuscles of mammals.

Location of Golgi Apparatus:
It generally occurs at one end between the nucleus and the periphery. In plant cells, Golgi apparatus is formed of a number of unconnected units called dictyosomes. Their number is highly variable— from one in certain simple algae to 25000 in rhizoidal cell of Chara. Commonly there are 10-20 dictyosomes per plant cell.

Structure of Golgi Apparatus:
Usually Golgi complex is made up of four parts— cisternae, tubules, vesicles and vacuoles.

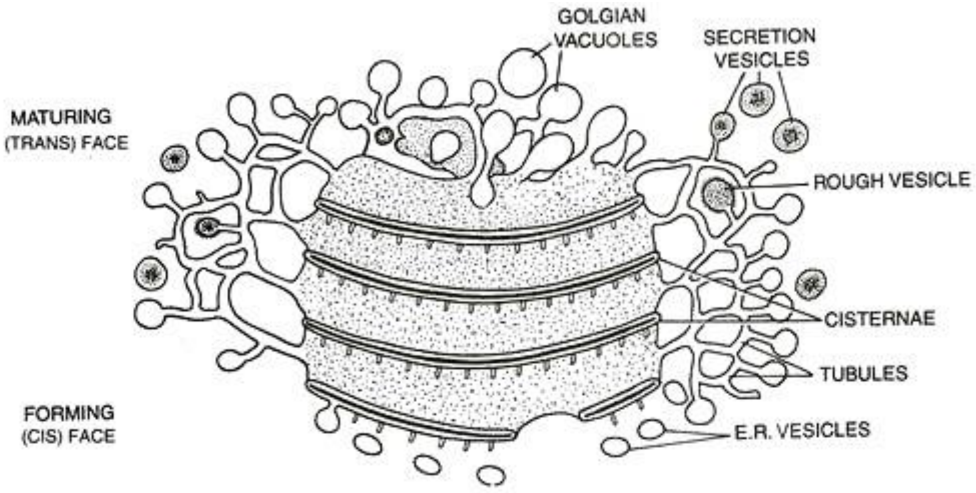


Fig. 8.32. Structure of Golgi apparatus (dictyosome)

Cisternae:

Golgi complex consists of a stack of generally 4-8 (range 3-20) membrane bound saccules or cisternae. Unicisternal dictyosomes are found in fungi.

The membranes of the saccules or cisternae are smooth but of variable thickness they enclose a lumen of 60-90 A. Lumen contains a fluid substance or matrix. In a stack, the adjacent cisternae are separated by a distance of 100-300 A. The intercisternal space contains thin layer of cytoplasm having parallel fibrils.

The saccules are frequently curved to give a definite polarity to the Golgi apparatus. One face of the apparatus is convex while the other is concave. The convex side is called forming (=formative, cis-face) face while the concave side of the apparatus is known as maturing face (trans-face).

Tubules:

They form a complicated network towards the periphery and maturing face of the apparatus. Actually tubules arise due to fenestrations of the cisternae. They have a diameter of 30-50 nm. The tubules interconnect the different cisternae.

Vesicles:

They are small sacs of 20-80 nm diameters. The vesicles are found attached to the tips of tubules at various levels in the network. They are of two types, smooth and coated. The coated vesicles have a rough surface. They have elaborate membrane proteins. The smooth vesicles have a smooth surface. They contain secretory substances and are hence known as secretion vesicles.

Golgian Vacuoles:
They are expanded parts of the cisternae which have become modified to form vacuoles. The vacuoles develop from the concave or maturing face. Golgian vacuoles contain amorphous or granular substance. Some of the golgian vacuoles function as lysosomes.

Functions of Golgi Apparatus:

1. Secretion:
All glandular cells depend upon Golgi complex for concentrating and packaging their products inside a soluble protein coat visible as dark staining under electron microscope. They are sent out of the cells through exocytosis or reverse pinocytosis.

2. Transformation of Membranes:
Golgi complex brings about membrane transformation, that is, converting one type of membrane (e.g., that of ER) into other types (e.g., selectively permeable plasma membrane, differentiated membrane of lysosome). The complex also takes part in the recycling of plasma membrane.

3. Glycoproteins and Glycolipids:
Proteins synthesised by the rough endoplasmic reticulum and lipids synthesized by smooth endoplasmic reticulum reach the cisternae of the Golgi apparatus. Here, they combine with carbohydrates to form glycoproteins and glycolipids.

4. Special Simple Carbohydrates:
Sialic acid and galactose are made inside Golgi complex.

5. Complex Carbohydrates:
Most of the complex carbohydrates, other than glycogen and starch, are synthesized inside the Golgi complex, e.g., pectic compounds, mucopolysaccharides, hyaluronic acid, chondroitin sulphate, hemicelluloses, etc.

13. Formation of Lysosomes:

Some of the vesicles or vacuoles of the Golgi apparatus store digestive enzymes obtained through ER in the inactive state. They act as primary lysosomes.

15. Formation of Plasma-lemma:
Membranes of the vesicles produced by Golgi apparatus join in the region of cytokinesis to produce new plasma-lemma.

16. Formation of New Cell Wall:
Pectic compounds of middle lamella and various polysaccharides of the cell wall are secreted by Golgi complex. They are brought to the area of new wall synthesis by secretion vesicles.

Mitochondria:

Mitochondria are filamentous or granular cytoplasmic organelles. Mitochondria are cell organelles of aerobic eukaryotes which take part in oxidative phosphorylation and Krebs cycle of aerobic respiration. They are called power houses of cell because they are the major centres of release of energy in the aerobic respiration.

They were first observed by Kolliker in 1850. Benda (1897) gave the present name of mitochondria (Gk. mitos- thread, chondrion-grain) to the organelles.

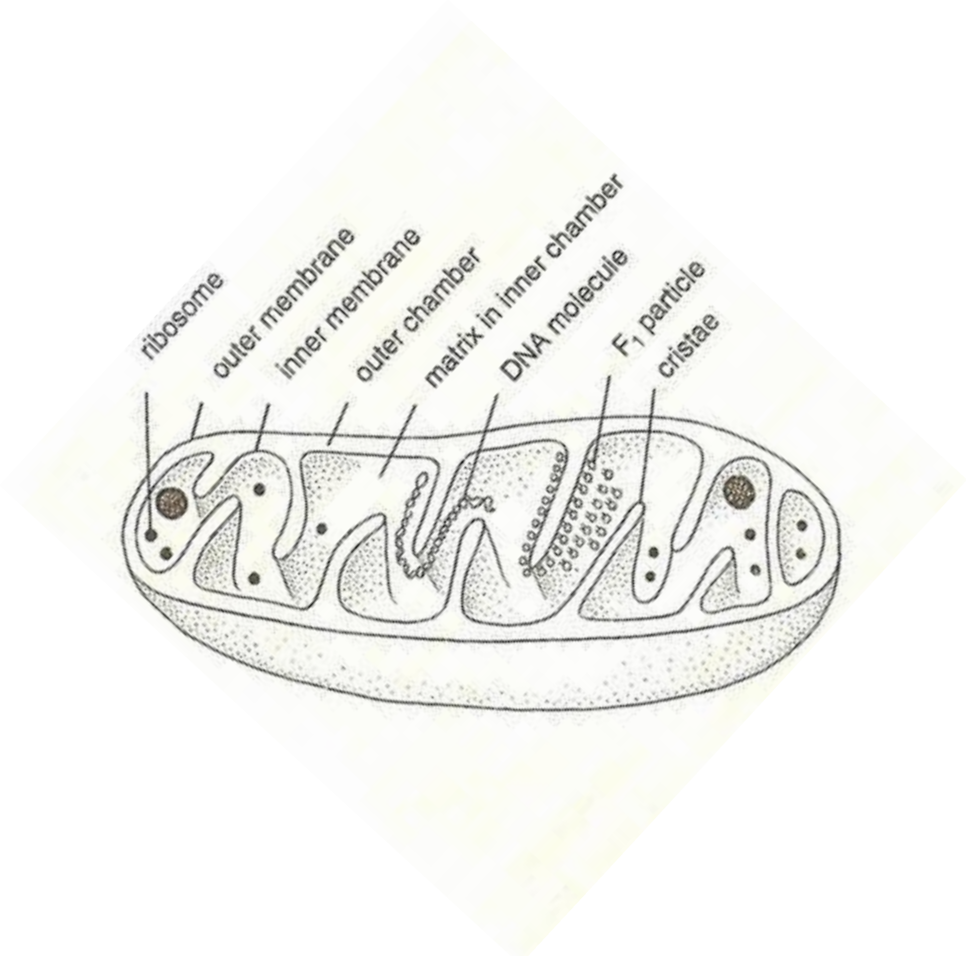
Cells of dormant seeds have very few mitochondria. Those of germinating seeds have several mitochondria. In general green plant cells contain less number of mitochondria as compared to non-green plant cells and animal cells.

Shape and Size of Mitochondria:
Commonly mitochondria are cylindrical in outline. The size of the mitochondria is variable. Normally, they have a length of 1.0-4.1 µm and a diameter of 0.2-1.0 µm (average 0.5 µm).

Chemical Composition. Proteins. 60-70%, Lipids 25-35%, RNA 5-7%, DNA. Small quantity. Minerals. Traces, Granules Manganese and Calcium phosphate.

Structure of Mitochondria:

A mitochondrion contains two membranes and two chambers, outer and inner. Each of them is 60-75A in thickness.



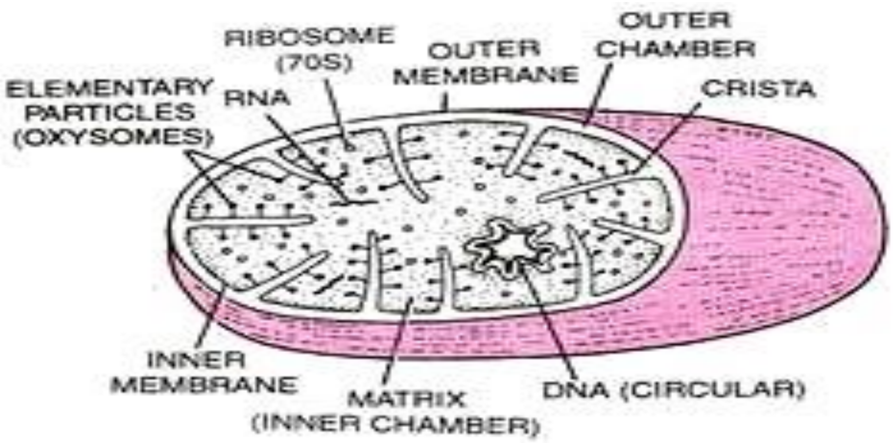


Fig. 8.34. Structure of a mitochondrion. A, mitochondrion partly cut open to show internal and external structure.

Outer Membrane:

The membrane is smooth. It is permeable to a number of metabolites. It is due to presence of protein channels called porins or minute pores. A few enzymes connected with lipid synthesis are located in the membrane. It is poorer in proteins as compared to inner membrane.

Inner Membrane:
It is permeable to only some metabolites. It is rich in double phospholipid called cardiolipin (having four fatty acids) which makes the membrane impermeable to ions. Protein content is also high, being 70—75% of total components. The inner membrane is in-folded variously to form infoldings called **cristae**. They are meant for increasing the physiologically active area of the inner membrane.

The cristae are generally arranged like baffles, at right angles to the longitudinal axis of the mitochondrion. They are tubular (most plant cells) or plate like (most animal cells) or vesicle-like (e.g., Euglena). A crista encloses a space that is continuation of the outer chamber. The density of cristae indicates the intensity of respiration.

The inner membrane as well as its cristae possess small tennis-racket like particles called elementary particles, F_o – F_1 particles or oxysomes (= oxisomes).
A mitochondrion contains 1×10^4 – 1×10^5 elementary particles.
Each elementary particle, F_o –F_1 particle or oxysome has a head, a stalk and a base. The base (F_o subunit) is about 11nm long and 1.5 nm in thickness. The stalk is 5 nm long and 3.5 nm broad.
The head (F_1 subunit) has diameter of 8.5 nm. Elementary particles function as ATP-ase. They are, therefore, the centres of ATP synthesis during oxidative phosphorylation.
At places, outer and inner mitochondrial membranes come in contact. They are called adhesion sites. Adhesion sites are special permeation regions of the mitochondrion for transfer of materials from outside to inside and vice versa.

Outer Chamber (Peri-mitochondrial Space):
The chamber is the space that lies between the outer and inner membrane of the mitochondrial envelope. Usually, it is 60-100 A

wide. It extends into the spaces of the cristae. The chamber contains a fluid having a few enzymes.

Inner Chamber:
It forms the core of the mitochondrion. The inner chamber contains a semi-fluid matrix. The matrix has protein particles, ribosomes, RNA, DNA (mitochondrial or mDNA), enzymes of Krebs or TCA cycle (except succinate dehydrogense which is membrane based), amino acid synthesis and fatty acid metabolism, crystals of calcium phosphate and manganese.

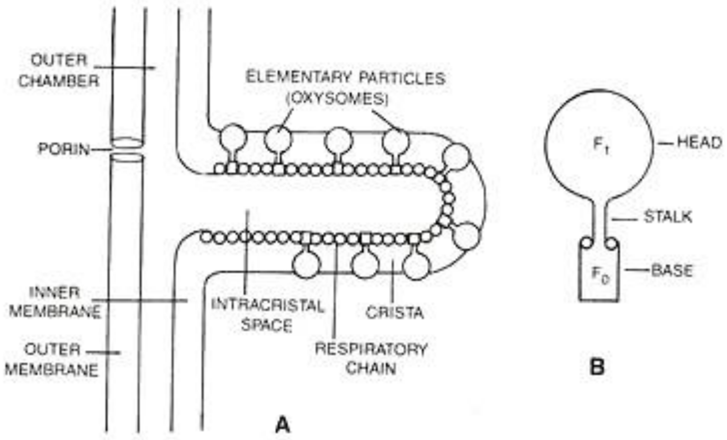


Fig. 8.35. A, inner membrane with elementary particles. B, elementary particle.

Functions of Mitochondria:
1. Mitochondria are miniature biochemical factories where food stuffs or respiratory substrates are completely oxidized to carbon dioxide and water. The energy liberated in the process is initially stored in the form of reduced coenzymes and reduced prosthetic groups.

The latter soon undergo oxidation and form energy rich ATP comes out of mitochondria and helps perform various energy requiring processes of the cell like biosynthesis, membrane transport, cell division, movement, etc. Because of the formation of ATP, the mitochondria are called power houses of the cell.

2. Mitochondria provide important intermediates for the synthesis of several bio-chemicals like chlorophyll, cytochromes, pyrimidine’s, steroids, alkaloids, etc.

3. The matrix or inner chamber of the mitochondria has enzymes for the synthesis of fatty acids.

4. Synthesis of many amino acids occurs in the mitochondria. The first formed amino acids are glutamic acid and aspartic acid. They are synthesized from a-ketoglutaric acid and oxaloacetic acid respectively.
5. Mitochondria may store and release Calcium when required.

Plastids:

1. Meaning of Plastids:
The term plastid was introduced by E. Haeckel in 1866. Plastids are semi-autonomous organelles having DNA and double membrane envelope which store or synthesise various types of organic compounds.

With the exception of some protistans, (e.g., Euglena, dinophyceae, diatoms) plastids are restricted to plants only. Plastids develop from colourless precursors called pro-plastids. Pro-plastids have the ability to divide and differentiate into various types of plastids.

2. Types of Plastids:

Depending upon their colour, plastids are of three main types— leucoplasts, chromoplasts and chloroplasts.

(i) Leucoplasts (Gk. leucos- white, plastos- moulded).
They are colourless plastids which generally occur near the nucleus in non-green cells and possess internal lamellae. Grana and photosynthetic pigments are absent. Leucoplasts have variable size and form, e.g., rounded, oval, cylindrical, filamentous, etc.

There are three types of special leucoplasts:
(a) Amyloplasts:
They are the starch containing leucoplasts. An amyloplast is several times larger than the original size of leucoplast. It contains a simple

or compound starch grain covered by a special protein sheath, e.g., Potato tuber, Rice, Wheat,

(b) Elaioplasts (Lipidoplasts, Oleoplasts):
The colourless plastids store fat, e.g., Tube Rose,

(c) Aleuroplasts, Proteoplasts or Proteinoplasts:
The plastids contain protein in the amorphous, crystalloid or crystallo- globoid state (e.g., aleurone cells of Maize grain, endosperm cells of Castor).

(ii) Chromoplasts (Gk. chroma- colour, plastos- moulded):
The plastids are yellow or reddish in colour because of the presence of carotenoid pigments. Chlorophylls are absent. Chromoplasts are formed either from leucoplasts or chloroplasts. Lamellae degenerate partially or completely during chromoplast formation. Change of colour from green to reddish during the ripening of Tomato and Chili is due to transformation of chloroplasts to chromoplasts.

The orange colour of Carrot roots is due to chromoplasts. The pigments are often found in crystallized state so that the shape of the plastids can be like needles, spindles or irregular,

(i) Chromoplasts provide colour to many flowers for attracting pollinating insects.

(ii)They provide bright red or orange colour to fruits for attracting animals for dispersal.

(iii)They are also the site of synthesis of membrane lipids.

(iii) Chloroplasts (Gk. chlorosgrass green, plastos- moulded).
They are greenish plastids which possess photosynthetic pigments, chlorophylls and carotenoids, and take part in the synthesis of food from inorganic raw materials in the presence of radiation energy. Chloroplasts of algae other than green ones are called chromatophores (e.g. rhodoplasts of red algae, phaeoplasts of brown algae).

Number:
The number of chloroplasts per cell of algae is usually fixed for a species. The minimum number of one chloroplast per cell is found in green alga Ulothrix and several species of Chlamydomonas.

However, different species of a genus may have different number of chloroplasts, e.g., 1 in Spirogyra indica and 16 in S. rectospora. A photosynthetic leaf chlorenchyma cell has 20-40 chloroplasts. An inter nodal cell of Chara (an alga) has several hundred chloroplasts.

---

3. Shape of Plastids:

In algae the chloroplasts have various shapes. They may be plate like (e.g., Ulothrix), cup-shaped (e.g., Chlamydomonas), ribbon-like (e.g., Spirogyra), polygonal or stellate (e.g., Zygnema) and reticulate (e.g., Oedogonium). The chloroplasts of higher plants are generally disc-shaped with oval or circular outline. Rarely, they may be lens-shaped, rounded or club-shaped.

4. Size of Plastids:

Like shape, the size of the chloroplasts is different in different species. The discoid chloroplasts of higher plants are 4—10 mm in length and 2-4 mm in breadth.

5. Chemical Composition of Plastids:

Protein- 50-60%. Lipids- 25-30%. Chlorophyll- 5-10%. Caro-tenoids (carotenes and xanthophylls)- 1—2%. DNA- upto 0.5%. RNA- 2-3%. Vitamins K and E, quinones, Mg, Fe, Co, Mn, P, etc.- in traces.

6. Structure of Plastids:

A chloroplast has three parts— envelope, matrix and thylakoids. Pyrenoid and stigma are two additional structures present in the chloroplasts of some algae.

Chloroplast Envelope:

A chloroplast is covered by an envelope made up of two smooth membranes. Each membrane is about 90—100 A thick. It has trilaminar lipoprotein structure. The two membranes are separated by an inter-membrane space of 100-200 A width.

The outer membrane may be attached to endoplasmic reticulum. At places the inner membrane is connected to thylakoids. As in mitochondria, the outer membrane is more permeable than the inner membrane. The inner membrane has more of proteins including carrier proteins.

Matrix:
The ground substance of a chloroplast is known as matrix or stroma. It is semifluid colloidal complex that is made of 50% soluble proteins. The remaining is DNA, RNA, ribosomes, plastoglobuli and enzymes.

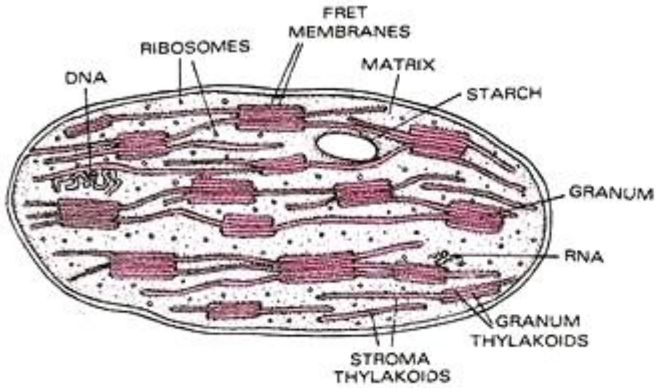


Fig. 8.36. Internal structure of chloroplast of higher plants as seen under electron microscope.

With the help of ribosomes the chloroplast is able to synthesize most of the enzymes required by it. The important enzymes present in chloroplast are those that take part in synthesis of photosynthetic pigments, photolysis of water, photophosphorylation, dark assimilation of CO_2, synthesis and degradation of starch, synthesis of lipids, etc.
Plastoglobuli are lipid droplets of 10-500 nm diameters. They may contain some enzymes, vitamin K and quinones.

The chloroplast matrix of higher plants may store starch temporarily, as starch grains. It is known as assimilation starch. In green algae (e.g., Spirogyra, Ulothrix), the chloroplasts possess special starch storing structures called pyrenoids.

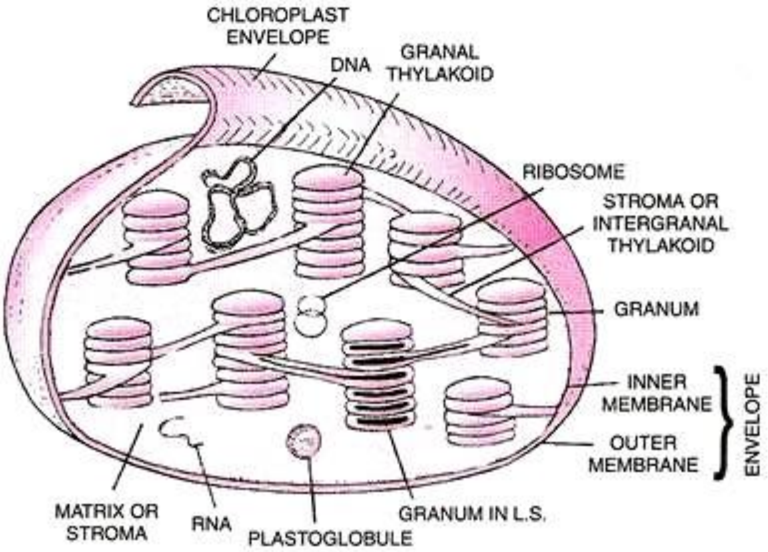


Fig. 8.37. Schematic 3-dimensional structural diagram of a chloroplast.

Thylakoids:

They are membrane lined flattened sacs which run throughout the stroma or matrix of the chloroplast. Since, they take part in photosynthesis, they are also called photosynthetic thylakoids. Thylakoids are thus the structural elements of the chloroplast. They generally run parallel but may show interconnections. Thylakoids may also be attached to the inner membrane of chloroplast envelope.

In the chloroplasts of higher plants, thylakoids are stacked at places to form grana. 40- 60 grana may occur in a chloroplast. Each granum has 2—100 thylakoids.

Because of the presence of grana, thylakoids are differentiated into two— granal thylakoids and stroma or interregnal thylakoids. A granum is attached to only a few stroma or nongranal thylakoids, though it is made up of upto 100 thylakoids. It is, therefore, believed that the thylakoids get folded and bifurcated in the region of grana.

Thylakoid membranes possess photosynthetic pigments and coupling factors. Coupling factors are involved in ATP synthesis.

Photosynthetic pigments include chlorophyll a, chlorophyll b, carotenes and xanthophylls.

They occur in specific groups called photosystems (previously quantasomes). There are two photosystems, I and II. Photosystem II occurs in appressed parts of granal thylakoids while photosystem I am found in stromal thylakoids and nonappressed parts of granal thylakoids.

Functions of Plastids:

1. Photosynthesis:

Chloroplasts are the centers of photosynthesis or formation of organic compounds from inorganic raw materials. The organic substances, thus synthesised, not only provide body building material to autotrophic plants themselves but also to all heterotrophic plants as well as animals.

2. Energy Transduction:

Chloroplasts are able to trap sun energy and change it into chemical energy. The chemical energy is used by all living organisms to perform their life activities.

3. Consumption of Carbon Dioxide:

Chloroplasts pick up carbon dioxide and use the same in photosynthesis. This keeps the percentage of this gas balanced in the atmosphere as carbon dioxide is being constantly added to it through combustion and respiration.

4. Liberation of Oxygen:

Chloroplasts liberate oxygen which is passed into the atmosphere. This keeps the balance of oxygen constant in the atmosphere, as oxygen is being consumed in respiration and combustion.

5. Storage of Starch:

They store starch either temporarily (in higher plants) or permanently (in several algae).

6. Photosensitivity:

Chloroplasts of some algae provide photosensitivity because of the presence of stigma or eye spot.

7. Reducing Power:
The reducing power produced during light reaction (NADPH) is used in the reduction of nitrate and synthesis of amino acids.

8. Synthesis of Fatty Acids:
Murphy and Leech (1978) have reported the synthesis of fatty acids in Spinach chloroplasts.

9. Storage of Lipids:
Chloroplasts store fat in the form of plastoglobuli.

10. Formation of Chromoplasts:
They can be changed into the chromoplasts to provide colour to many flowers and fruits for attracting animals.

Ribosomes:

Definition:
Ribosomes are sub-microscopic, smallest, dense, membrane-less granular ribonucleoprotein organelles found in all living cells.

History:
A. Claude (1941), first observed ribosomes and called them as microsomes which were actually fragments of RER.

Robinson and Brown (1953) first discovered ribosomes, in plant cells. R.B. Roberts (1958) coined the term ribosome.

Distribution and Number:
The ribosomes are present in both prokaryotic and eukaryotic cells. In prokaryotic cells, they are found freely scattered in the cytoplasm, but in eukaryotic cells they occur free in the cytoplasmic matrix and also attached to the outer surface of the rough endoplasmic reticulum and nuclear envelope. The ribosomes are also found in the matrix of mitochondria and the stroma of plastids

in the eukaryotic cells. These ribosomes are called organellar ribosomes to distinguish them from the cytoplasmic ribosomes.

Ribosomes occur singly (monosomes) or in cluster (polysomes). At the time of protein synthesis 6-8 ribosomes temporarily join with a mRNA to form a cluster called poly ribosome or polysome or ergosome. The number of ribosomes in a cell depends upon the active protein synthesis.

Types:
On the basis of sedimentation coefficient, measured in Svedberg Units or S units two types of ribosomes have been recognized – 70 S ribosomes and 80 S ribosomes.

1.70 S Ribosomes:
These types of ribosomes are found in prokaryotic cell such as bacteria and cyanobacteria, mitochondria and chloroplasts of eukaryotic cells. Their sedimentation coefficient is 70 S and molecular weight 2.7 x 10^6 Daltons. Each 70S ribosome is made up of two subunits the smaller 30 S subunit remains attached with larger 50S subunit like a cap.

2. 80 S Ribosomes:
They are larger in size than 70S ribosomes. Their sedimentation coefficient is 80 S, and molecular weight 40 x 10^6 Daltons. Like 70 S ribosomes, it is also made up of two subunits – 60 S and 40 S; with 40 S placed over 60 S subunit.

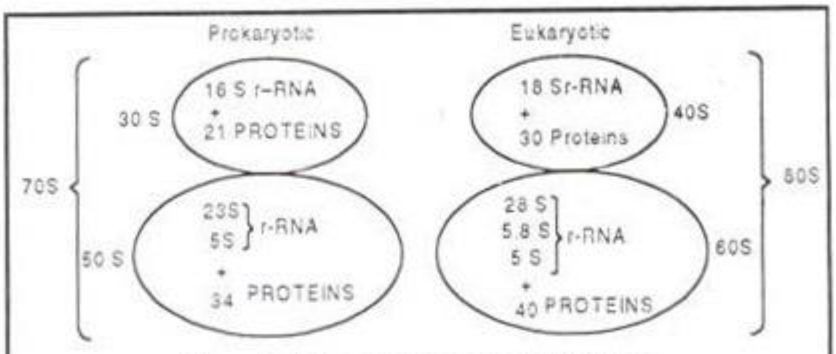


Figure 3.37 The components of prokaryotic and eukaryotic ribosomal sub units.

Ultrastructure:

Ribosomes are smallest and most abundant organelles of a cell. Each ribosome is porous, hydrated and composed of two unequal sub-units, larger one dome- shaped and the smaller one oblate – ellipsoid. The large subunit has a protuberance, a ridge and a stalk. The smaller subunit has a platform, cleft, head and base. It is about half the size of larger subunit. The smaller subunit fits over the larger one at one end like a cap.

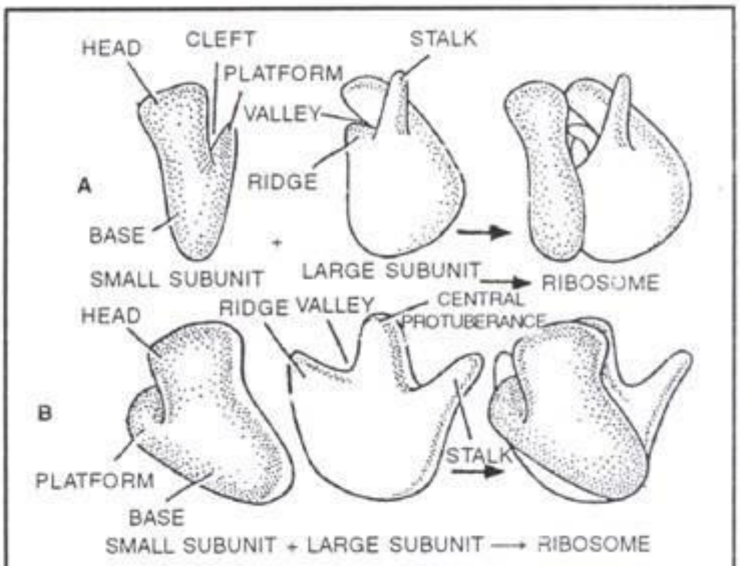


Figure 3.38 70S ribosome. Note the three dimensional structure of the ribosome in two different orientations.

The two subunits usually remain separated and come together only at the time of protein synthesis. For the union of two subunits require 0.001M of Mg^{2+} subunits dissociated below it. When Mg^{2+} concentration is above 0.0001M non-functional dimmers are formed. Each ribosome has four sites for specific functions in protein synthesis.

They are:

(i) mRNA binding site in smaller sub-unit

(ii) A-site or amino acyl-tRNA site,

(iii) P-site or peptidyl-tRNA site and

(iv) E-site or exit site to which uncharged t-RNA come before leaving the ribosome.

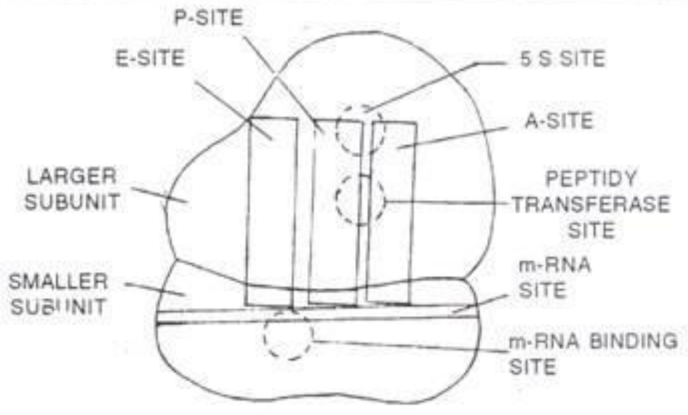


Figure 3.39 A ribosome showing different active sites.

"Chemically ribosomal," subunit consists of highly folded ribosomal RNA, (rRNA) and many attached proteins. The ratio of rRNA to protein in prokaryotic and eukaryotic ribosomes is 60:40 and 50:50 by weight respectively. The ribosomal proteins maybe basic, structural or enzymatic in function. The larger subunit of ribosome contains an important enzyme – peptidyl transferase, which brings about the formation of peptide bond. Inside the ribosome, the rRNA remains fully covered with proteins. The ribosomes are therefore, ribonucleoprotein particles (RNP).

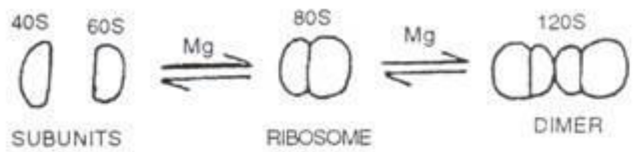


Figure 3.40 Association of ribosomal subunits or ribsosome depend on Mg^{2+} ion concentration.

Functions:

(a) As protein factories:

The ribosomes are the site of protein synthesis and also provide necessary enzymes for the same. Hence these are called "Protein Factories".

(b) Free and attached Ribosomes:

Free ribosomes synthesize structural and enzymatic proteins for use inside the cell. The attached ribosomes synthesize proteins for transport (i.e. transport proteins).

(c) Enzymes and Factors:

Ribosomes provide enzymes (e.g. peptidyl transferase) and factors for condensation of amino acids to form polypeptide.

(d) rRNA:
Ribosome contains rRNAs for providing attachment points to mRNA and tRNAs (transfer RNA).

(e) mRNA.
Ribosomes has tunnel for mRNA so that it can be translated properly.
