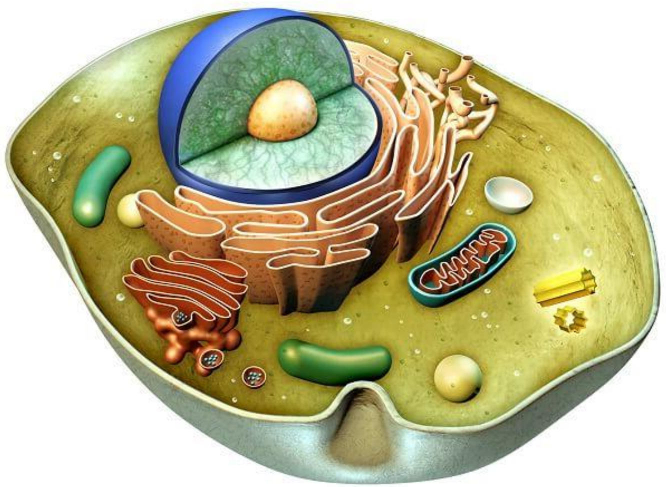
CELL BIOLOGY 2

LECTURE 1

PLASMA MEMBRANE AND CELL WALL



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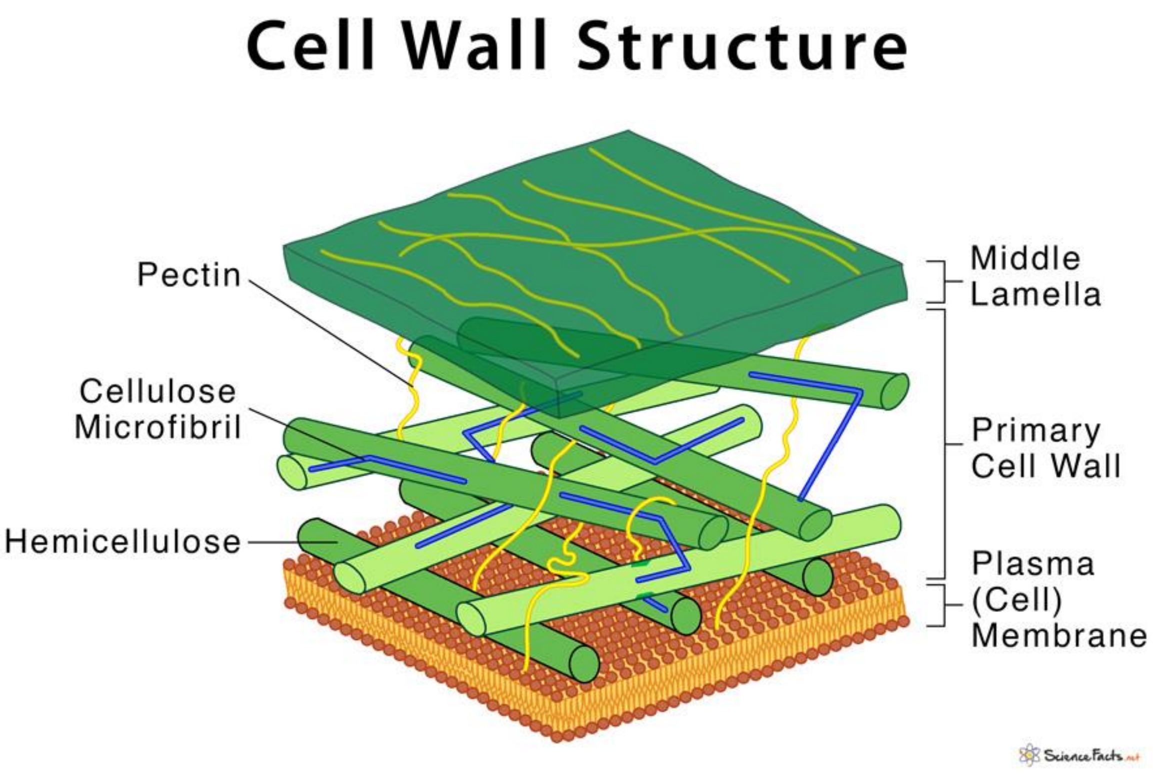
PLASMA MEMBRANE AND CELL WALL

- Plasma membrane encloses every type of cell, both prokaryotic and eukaryotic cells. It physically separates the cytoplasm from the surrounding cellular environment. Plasma membrane is a ultrathin, elastic, living, dynamic and selective transport-barrier. It is a fluid-mosaic assembly of molecules of lipids (phospholipids and cholesterol), proteins and carbohydrates. Plasma membrane controls the entry of nutrients and exit of waste products, and generates differences in ion concentration between the interior and exterior of the cell. It also acts as a sensor of external signals (for example, hormonal, immunological, etc.) and allows the cell to react or change in response to environmental signals. The cells of bacteria and plants have the plasma membrane between the cell wall and the cytoplasm. For cells without cell walls (*e.g.*, mycoplasma and animal cells), plasma membrane forms the cell surface.

PLANT CELL WALL

- The cell wall surrounds the plasma membrane of plant cells and provides tensile strength and protection against mechanical and osmotic stress. It also allows cells to develop **turgor pressure**, which is the pressure of the cell contents against the cell wall. Plant cells have high concentrations of molecules dissolved in their cytoplasm, which causes water to come into the cell under normal conditions and makes the cell's central vacuole swell and press against the cell wall.
- Plant cell walls are primarily made of **cellulose**, which is the most abundant macromolecule on Earth.
- It has two types of wall, which is primary and secondary cell wall.



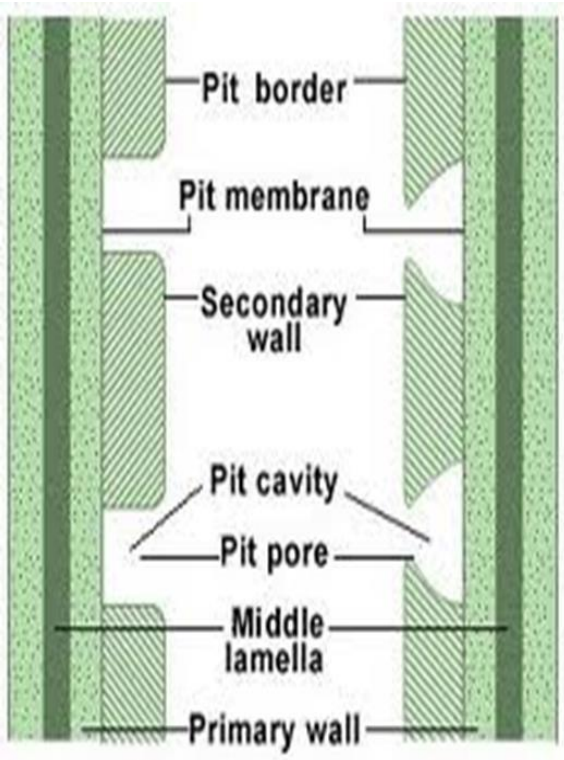
DIFFERENCES BETWEEN PRIMARY AND SECONDARY CELL WALL IN PLANTS

Primary wall

- It is formed in a growing cell
- It lies inner to the middle lamella.
- It is present in all the plant cells
- It is elastic and capable of expansion in a growing cell.
- It has relatively low cellulose conten
- It has relatively high hemicellulose, protein and lipid contents

Secondary wall

- It is formed in a mature cell
- It lies inner to the primary cell wall outside the cell membrane
- It is present in certain cells only. E.g. cells involved in mechanical support and water transportation
- It is rigid and incapable of expansion
- It has relatively high cellulose conten
- It has relatively low hemicellulose, protein and lipid content



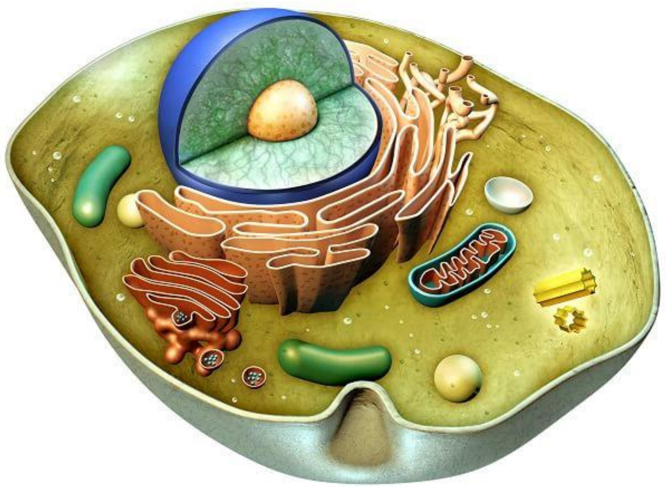
CELL MEMBRANE

- The plasma membrane is also called **cytoplasmic membrane**, **cell membrane,** or **plasma lemma** The plasma membrane is so thin that it cannot be observed by the light microscope.
- Chemically, plasma membrane and other membranes of different organelles are found to contain proteins, lipids and carbohydrates, but in different ratios). For example, in the plasma membrane of human red blood cells proteins represent 52 per cent, lipids 40 per cent and carbohydrates 8 per cent.

CELL BIOLOGY 2

LECTURE 2

STRUCTURE OF PLASMA MEMBRANE



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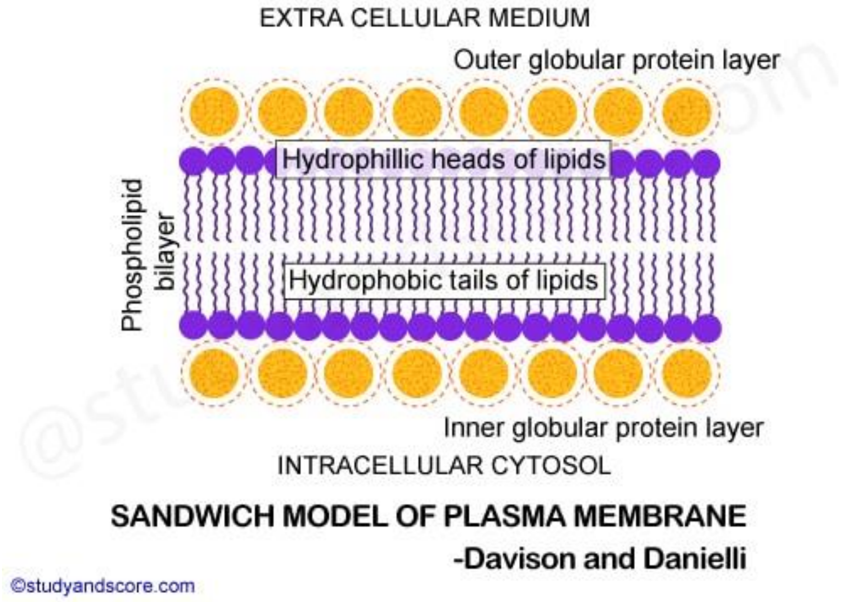
MEMBRANE MODELS - :

- The existence of the plasma membrane of the cell was difficult to prove by direct examination before 1930's (when electron microscopy was invented) because of technological limitations. The membrane is beyond the resolution of the light microscope, rendering a morphological approach of its study quite unfeasible with this instrument. Thus, most of the experimental approaches have been provided by only indirect evidences of the existence of such a membrane around the cells.

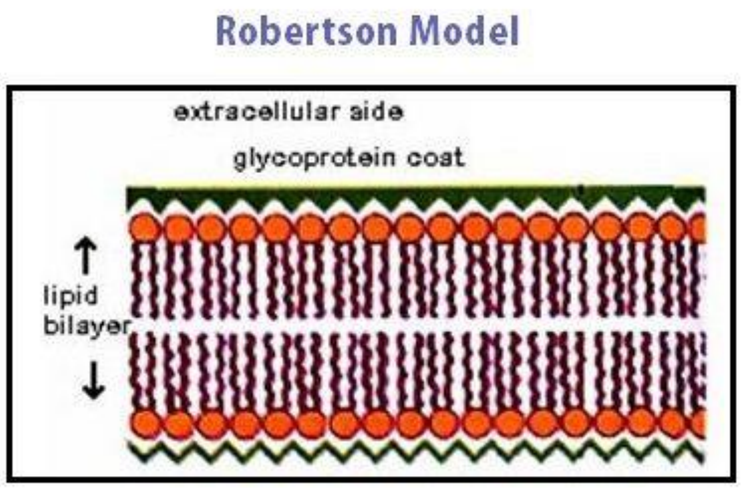
SANDWICH MODEL (PROTEIN-LIPID BILAYER-PROTEIN)

In 1935, **Danielli** and **Davson**, proposed a model, called **sandwich model**, for membrane structure in which a lipid bilayer was coated on its either side with hydrated proteins (globular proteins). Mutual attraction between the hydrocarbon chains of the lipids and electrostatic forces between the protein and the “head” of the lipid molecules, were thought to maintain the stability of the membrane. From the speed at which various molecules penetrate the membrane, they predicted the lipid bilayer to be about 6.0 nm in thickness, and each of the protein layer of about 1.0 nm thickness, giving a total thickness of about 8.0 nm.



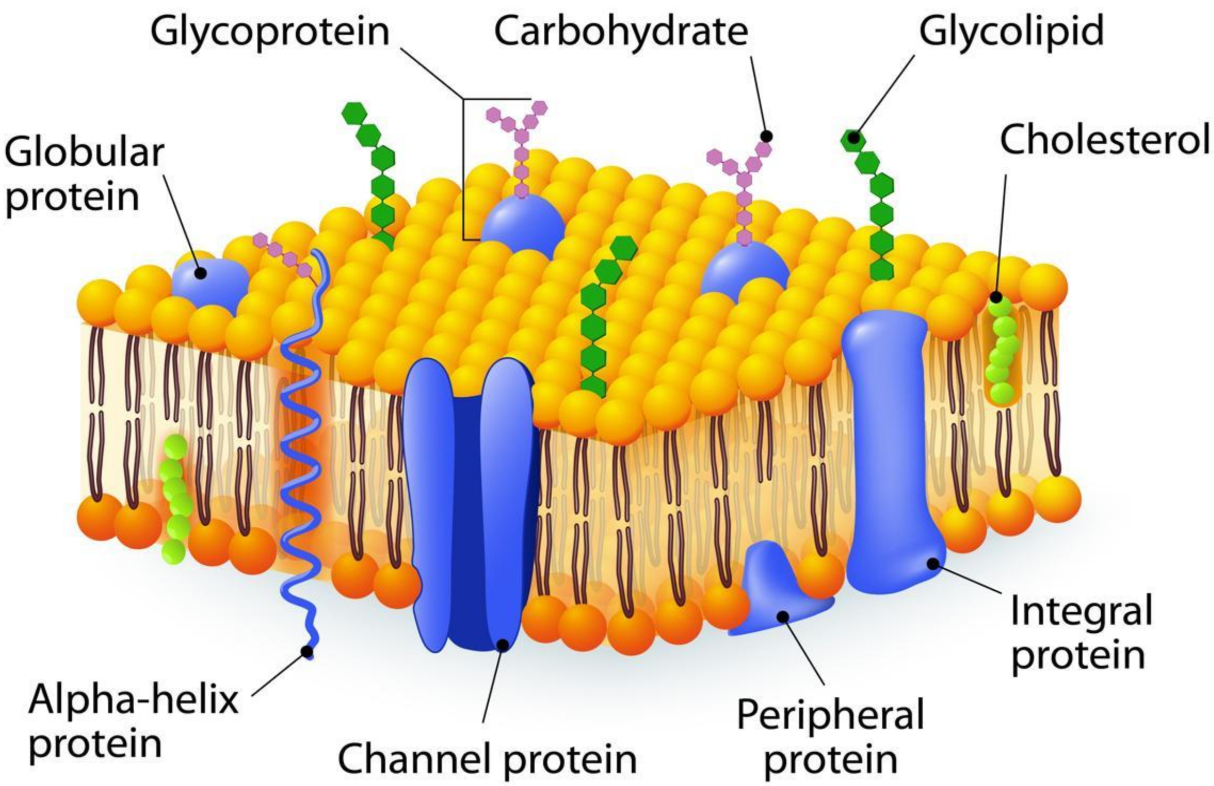
Robertson Model:

Using evidence from various electron micrographs, Robertson in 1960, proposed the unit memb-rane hypothesis . This hypothesis states that all cellular membranes have an identical trilaminar structure (or dark-light- dark or railway track pattern). However, thickness of the unit membrane has been found to be greater in plasma membrane (10 nm) than in the intracellular membranes of endoplasmic reticulum or Golgi apparatus (i.e., 5 to 7 nm).



FLUID MOSAIC MODEL

- **S.J.Singer** and **G.L.Nicolson** (1972) suggested the widely accepted **fluid mosaic model** of biological membranes. According to this model (Fig. 5.5), the plasma membrane contains a bimolecular lipid layer, both surfaces of which are interrupted by protein molecules. Proteins occur in the form of globular molecules and they are dotted about here and there in a mosaic pattern. Some proteins are attached at the polar surface of the lipid (*i.e.*, the extrinsic proteins); while others (*i.e.*, integral proteins) either partially penetrate the bilayer or span the membrane entirely to stick out on both sides (called **transmembrane proteins**). Further, the peripheral proteins and those parts of the integral proteins that stick on the outer surface (*i.e.*, ectoproteins) frequently contain chains of sugar or oligosaccharides (*i.e.*, they are glycoproteins). Likewise, some lipids of outer surface are glycolipids
- The fluid mosaic model is found to be applied to all biological membranes in general, and it is seen as a dynamic, ever-changing structure. The proteins are present not to give it strength, but to serve as enzymes catalysing chemical reactions within the membrane and as pumps moving things across it.



Glycoprotein
Carbohydrate
Glycolipid
Globular protein
Cholesterol
Integral protein
Alpha-helix protein
Channel protein
Peripheral protein

CHEMICAL COMPOSITION

1. **Proteins :**

- The amount and types of proteins in the membranes are highly variable : in the myelin membranes which serve mainly to insulate nerve cell axons, less than 25 per cent of the membrane mass is protein, whereas, in the membranes involved in energy transduction (such as internal membranes of mitochondria and chloroplasts), approximately 75 per cent is protein. Plasma membrane contains about 50 per cent protein
- **Peripheral proteins (extrinsic proteins).**
- **Integral (intrinsic proteins)**

LIPIDS:

- Four major classes of lipids are commonly present in the plasma membrane and other membranes : **phospholipids** (most abundant), **sphingolipids**, **glycolipids** and **sterols** (*e.g.*, **cholesterol**) . All of them are amphipathic molecules, possessing both hydrophilic and hydrophobic domains. The relative proportions of these lipids vary in different membranes. Phospholipids may be **acidic phospholipids** (20 per cent) such as **phingomyelin** or **neutral phospholipids** (80 per cent) such as **phosphatidyl choline**, **phosphatidylserine**, etc. Many membranes contain cholesterol. Cholesterol is especially abundant in the plasma membrane of mammalian cells and absent from prokaryotic cells. **Cardiolipin** (diphosphatidyl glycerol) is restricted to the inner mitochondrial membrane

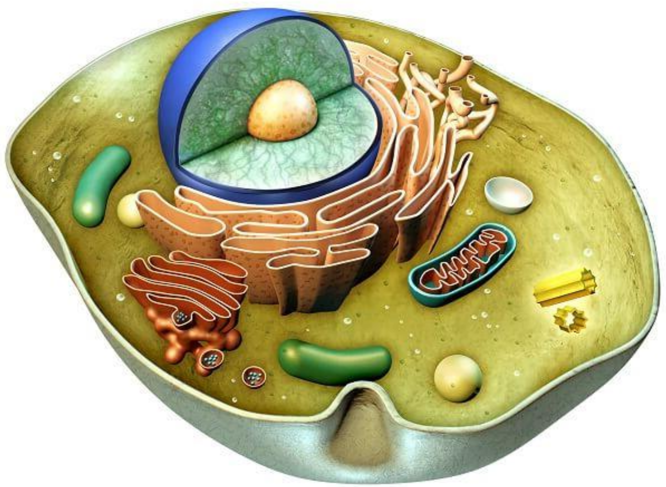
CARBOHYDRATES:

- Carbohydrates are present only in the plasma membrane. They are present as short, unbranched or branched chains of sugars oligosaccharides) attached either to exterior ectoproteins (forming glycoproteins) or to the polar ends of phospholipids at the external surface of the plasma membrane (forming glycolipids). No carbohydrate is located at the cytoplasmic or inner surface of the plasma membrane. All types of oligosaccharides of the plasma membrane are formed by various combinations of six principal sugars (all of which are glucose-derivatives) : D-galactose, D-mannose, L-fucose, Nacetylneuraminic acid (also called sialic acid), N-acetyl-D-glucosamine and N-acetyl-D-galactosamine.. The function of carbohydrates are:
- **Molecular Recognition**
- **Filtration**
- **Microenvironment**

CELL BIOLOGY 2

LECTURE 3

STRUCTURE OF PLASMA MEMBRANE



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FUNCTION ACTIVITY OF CELLULAR MEMBRANE

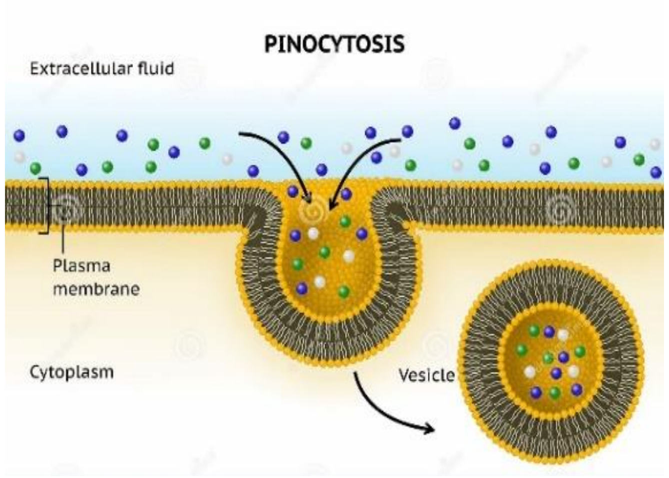
- The plasma membrane acts as a thin barrier which separates the intra-cellular fluid or the cytoplasm from the extra-cellular fluid in which the cell lives. In case of unicellular organisms (Protophyta and Protozoa) the extra-cellular fluid may be fresh or marine water, while in multicellular organisms the extra-cellular fluid may be blood, lymph or interstitial fluid. Though the plasma membrane is a limiting barrier around the cell but it performs various important physiological functions which are as follows :
- 1. Permeability. According to permeability following types of the plasma
- membranes have been recognised :
- (i) Impermeable plasma membranes.
- (ii) Semi-permeable plasma membranes.
- (iii) Selective permeable plasma membranes.
- (iv) Dialysing plasma membranes.

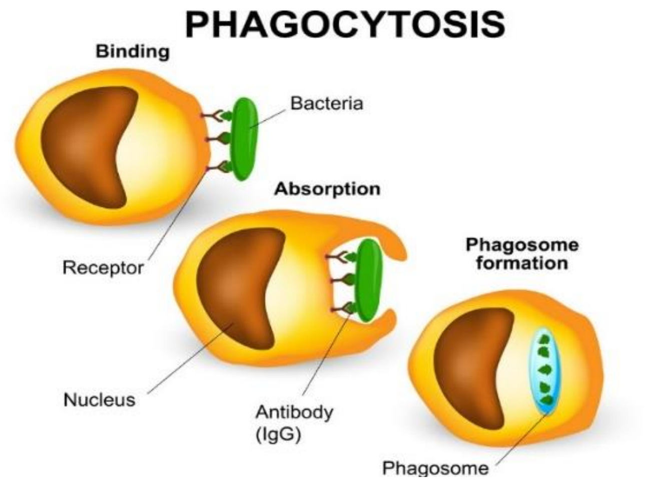
BULK TRANSPORT BY THE PLASMA MEMBRANE

- Cells routinely import and export large molecules across the plasma membrane. Macromolecules are secreted out from the cell by **exocytosis** and are ingested into the cell from outside through **phagocytosis** and **endocytosis.**

1. **Endocytosis**

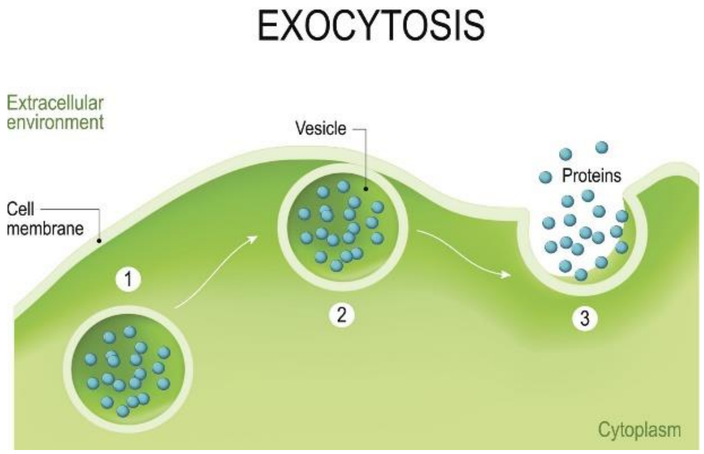
- **Phagocytosis**
- **Pinocytosis**



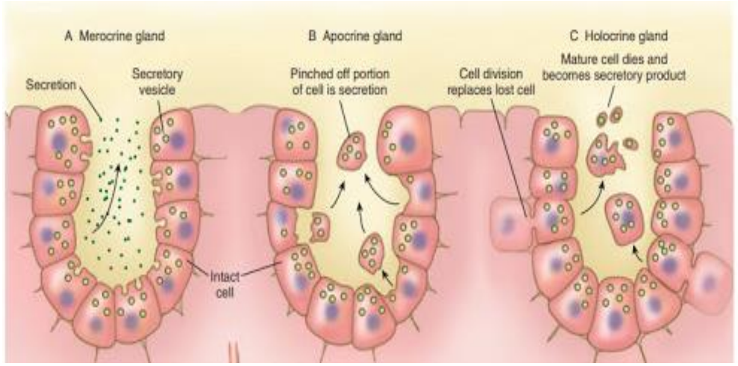


EXOCYTOSIS :

- It is also called **emeiocytosis** and **cell vomiting**. In all eukaryotic cells, **secretory vesicles** are continually carrying new plasma membrane and cellular secretions such as proteins, lipids and carbohydrates (*e.g.*, cellulose) from the Golgi apparatus to the plasma membrane or to cell exterior by the process of exocytosis. The proteins to be secreted are synthesized on the rough endoplasmic reticulum (RER). Include:

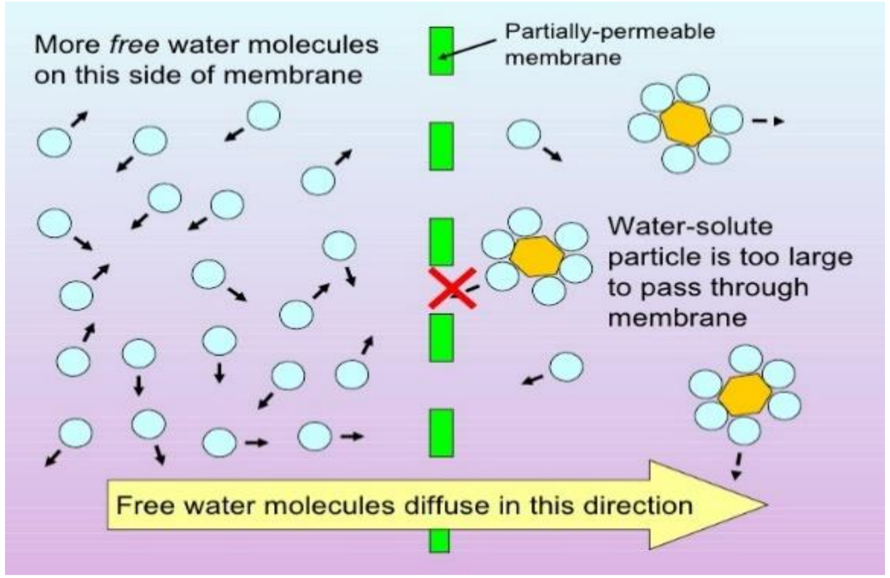


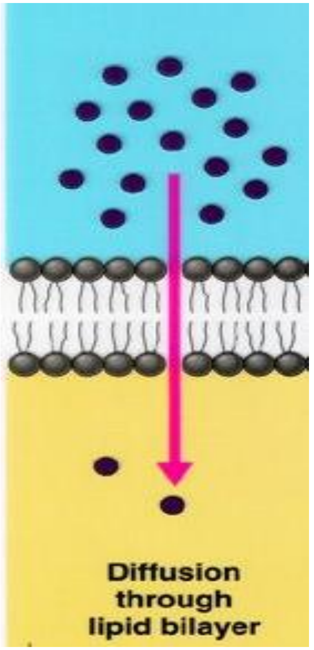
- **Eccrine (Merocrine) Secretion**
- **Apocrine secretion**
- **Holocrine Secretion**



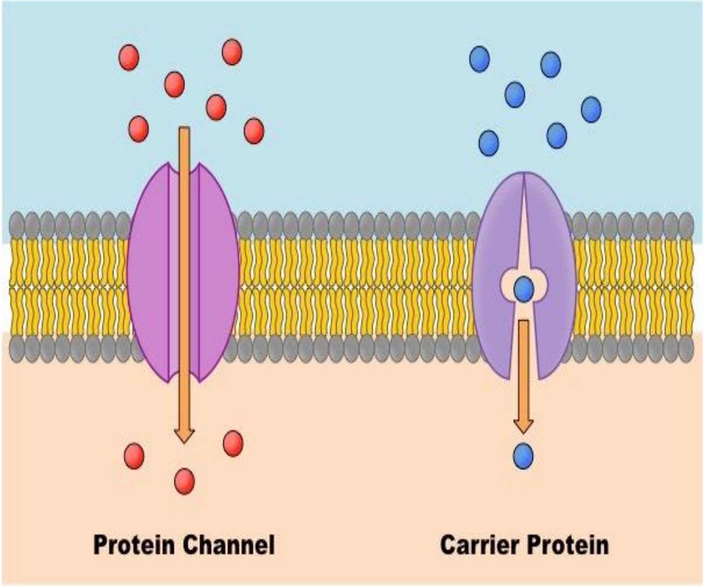
:DIFFUSION

- **Passive transport.** It is a type of **diffusion** in which an ion or molecule crossing a membrane moves down its electrochemical or concentration gradient. Materials are moving from high concentration to low concentration. No metabolic energy is consumed in passive transport. Passive transport is of following three types
- **Free Diffusion**
- **Osmosis**





Facilitated Diffusion: This is a special type of passive transport, in which ions or molecules cross the membrane rapidly because specific permeases in the membrane facilitate their crossing. Like the simple diffusion, facilitated diffusion does not require the metabolic energy and it occurs only in the direction of a concentration gradient. Facilitated diffusion is characterized by the following special features: (1) the rate of transport of the molecule Cross the membrane is far greater than would be expected from a simple diffusion. (2) This process is specific; each facilitated diffusion protein (called **protein channel**) transports only a single species of ion or molecule. (3) There is a maximum rate of transport, *i.e.*, when the concentration gradient of molecules across the membrane is low, an increase in concentration gradient results in a corresponding increase in the rate of transport. Currently, it is believed that transport proteins form the **channels** through the membrane that permit certain ions or molecules to pass across the latter



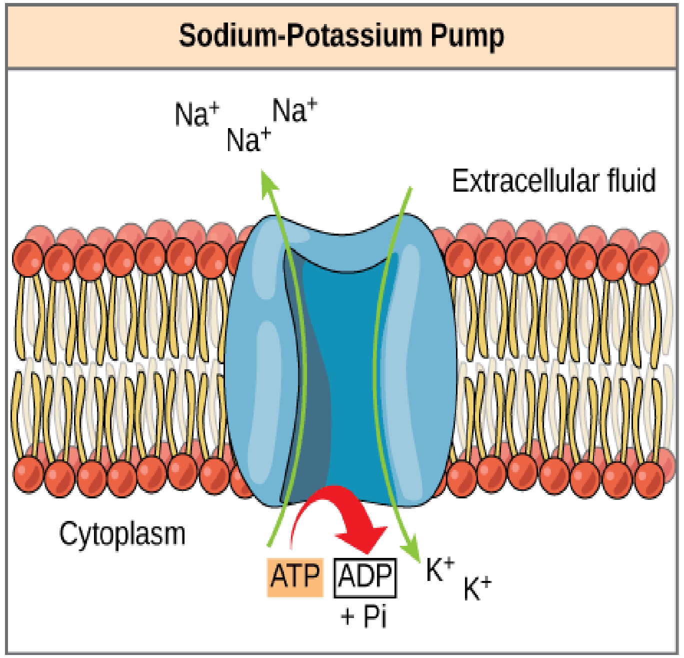
:ACTIVE TRANSPORT AND ION PUMP

- Active transport uses specific transport proteins, called **pumps**, which use metabolic energy (ATP) to move ions or molecules against their concentration gradient.

- **1. Na+- K+- ATPase pump:** It is an **ion pump** or **cation exchange pump** which is driven by energy

1. **Sodium- Potassium Pump**
2. **Electrogenic sodium pump** :

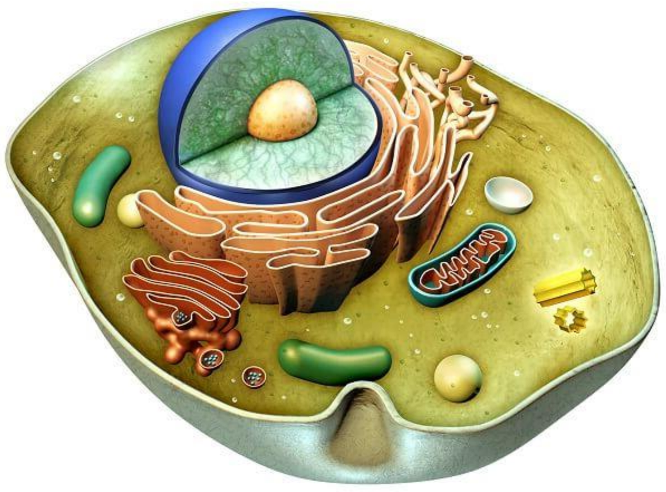
- **2. Calcium ATPase.** Calcium pump or Ca2+-ATPase pumps Ca2+-ions out of the cytosol, maintaining a low concentration of it inside the cytosol.
- **3. Proton pump or H+- pump.** The lysosomal membrane contains the ATP-dependent proton pump that transports protons from the cytosol into the lumen of the organelle,
- keeping the interior of lysosomes very acidic



CELL BIOLOGY 2

LECTURE 4

MODIFICATION OF PLASMA MEMBRANE



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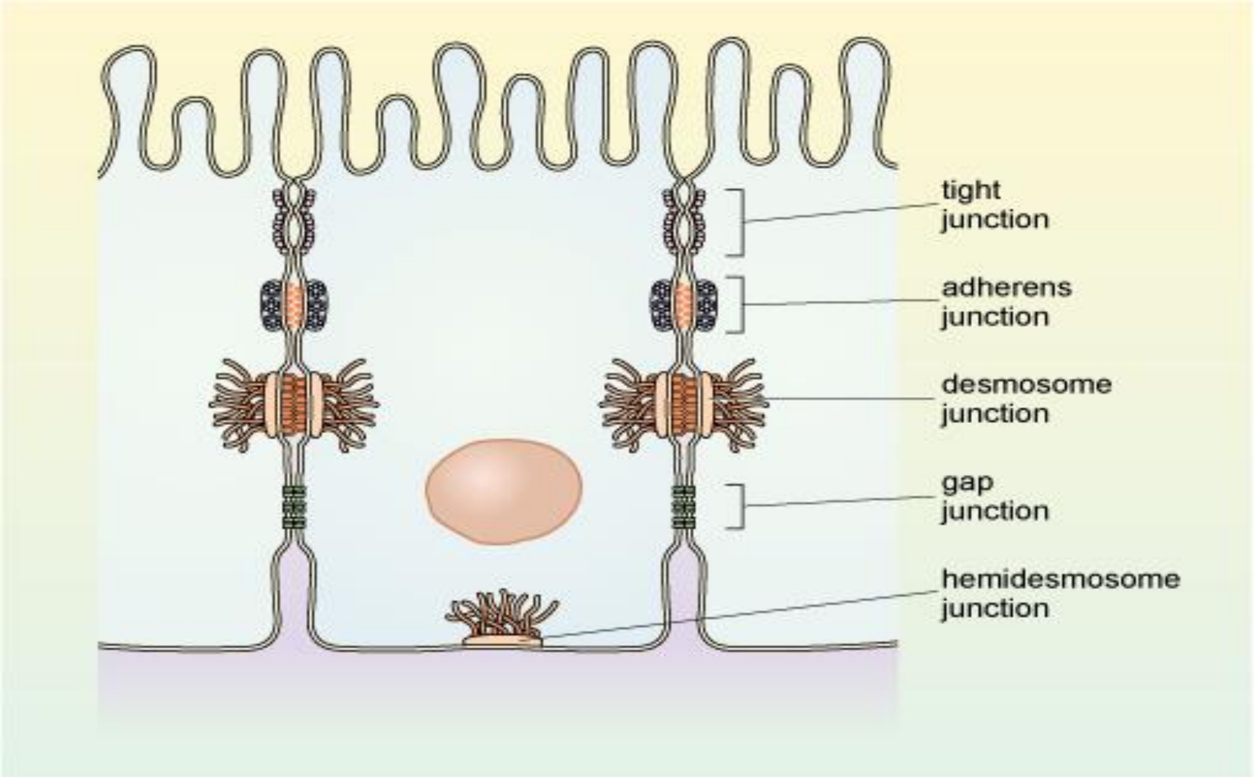
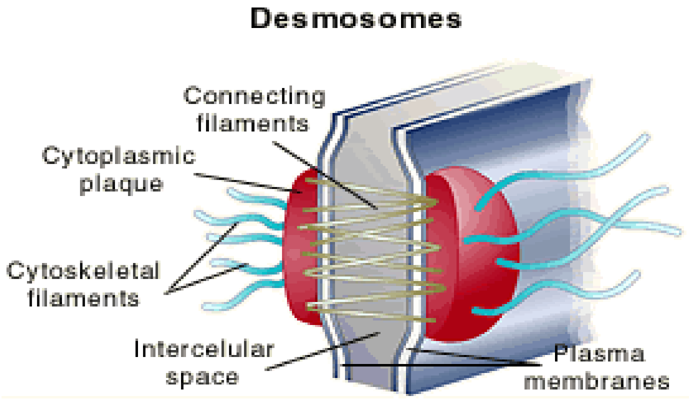
MODIFICATION OF PLASMA MEMBRANE

1. **Cell to cell Junction:**

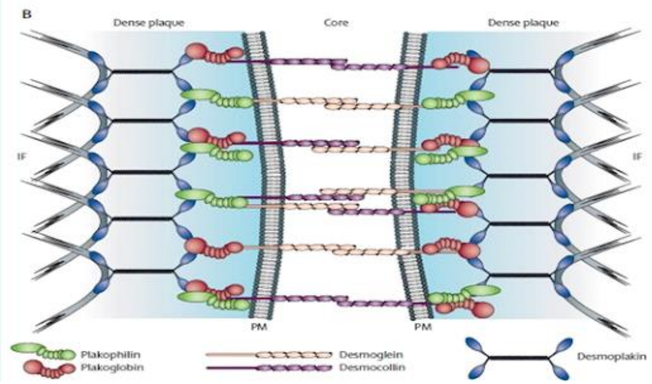
- The cell surface of certain cells performs various physiological activities such as absorption, secretion, transportation, etc. To perform such pecialized functions certain modifications are inevitable in the plasma membrane of such cells. Such cell surface differentiations may include microvilli, invagination, basement membrane and many types of cell-to-cell interconnections or junctions



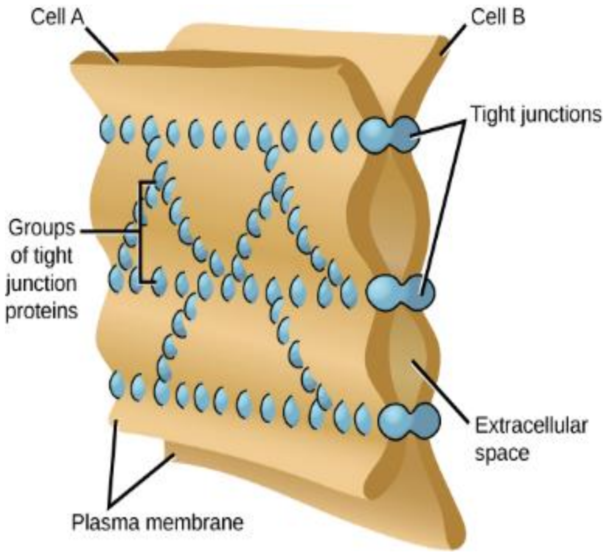
:Spot Desmosomes



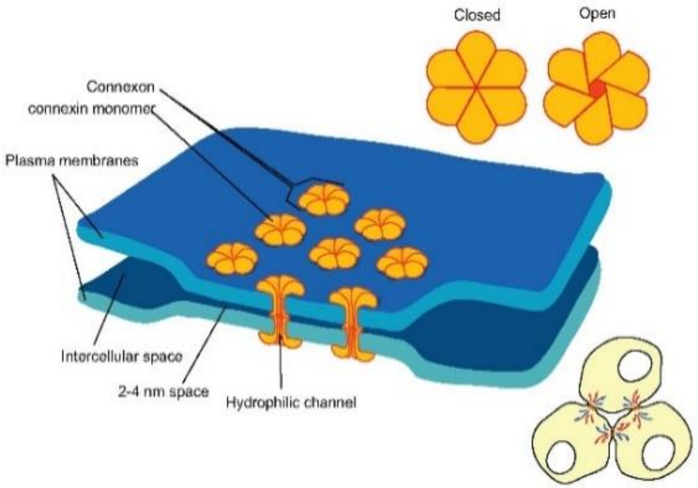
:Intermediate Junction (Adherent Junction)



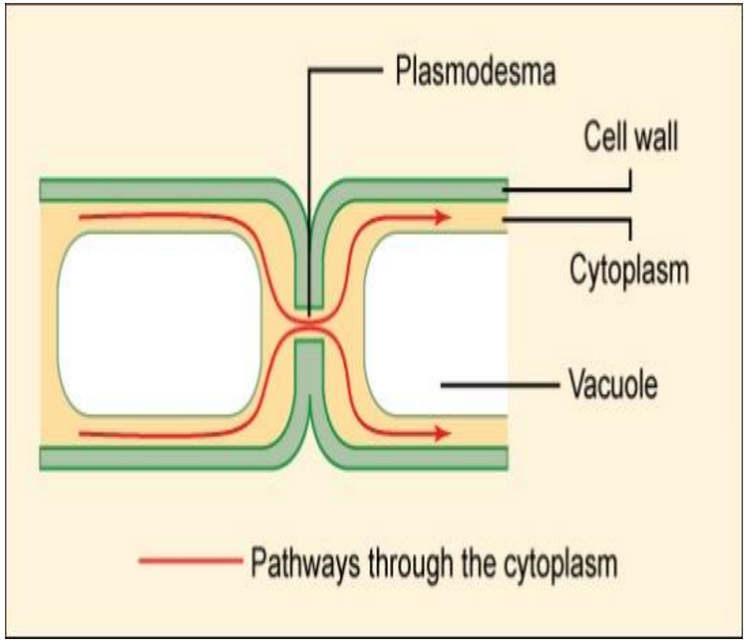
Tight Junctions



:Gap Junction

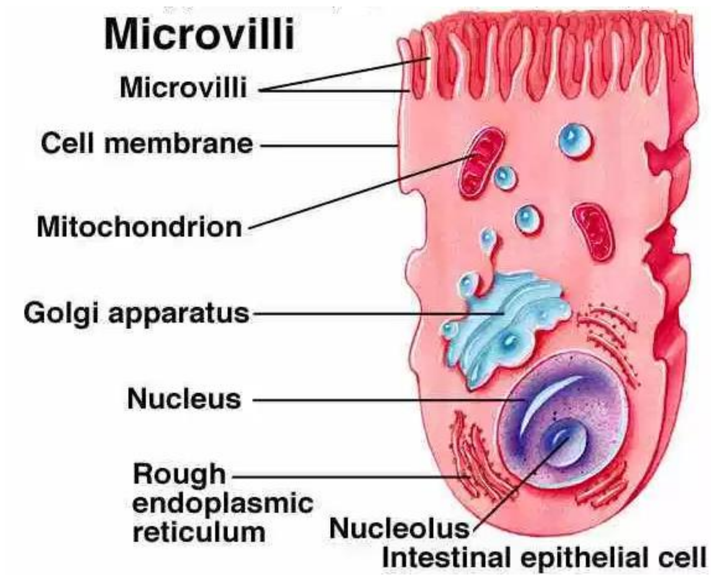


Plasmodesmata Every living cell in a higher plant is connected to its living neighbours by fine cytoplasmic channels, each of which is called a **plasmodesma**

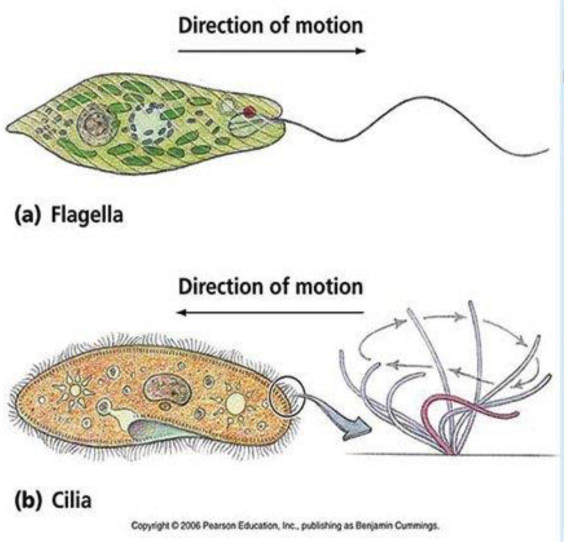


MICROVILLI:

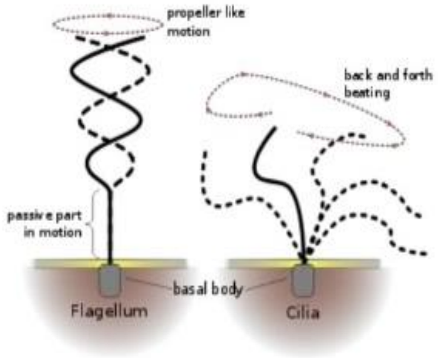
- Microvilli are nonmotile finger-like protrusions from the apical surface of plasma membrane which are found in mesothelial cells, hepatic cells, epithelial cells of intestine (**striated border**), uriniferous tubules (**brush border**), gall bladder, uterus, growing oocyte and yolk sac. Microvilli increase the effective surface of absorption

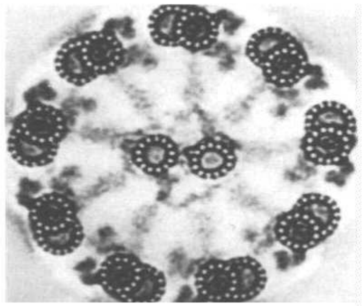


CILIA & FLAGELLA:



- Ciliary and flagellar cell motility is adapted to liquid media and is executed by minute, specially differentiated appendices, called **cilia** and **flagella**. Both of these organelles have very similar structure; they differ mainly in size and number (*i.e.*, flagella are longer and fewer in number, while cilia are short and numerous).

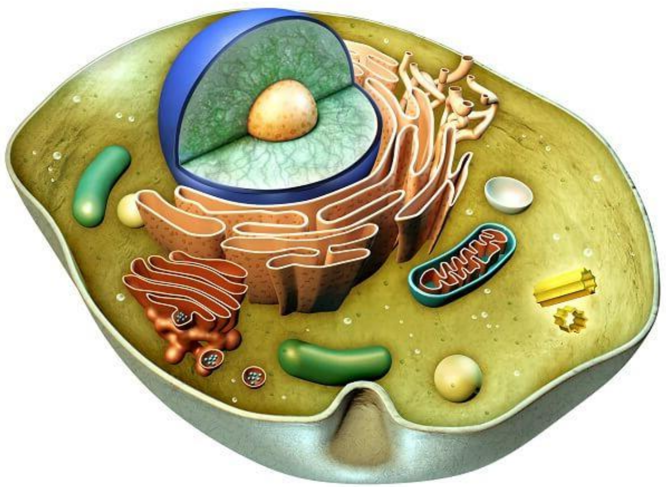




CELL BIOLOGY 2

LECTURE 5

ENDOPLASMIC RETICULUM ER



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ENDOPLASMIC RETICULUM ER -:

The endoplasmic reticulum is the main component of the **endomembrane system**, also called the **cytoplasmic vacuolar system** or **cytocavity network**. This system comprises following structures:

(1) The **nuclear envelope**, consisting of two non-identical membranes, one opposed to the nuclear chromatin and other separated from the first membrane by a perinuclear space (both forming a cisternae), the two membranes being in contact at the nuclear pores

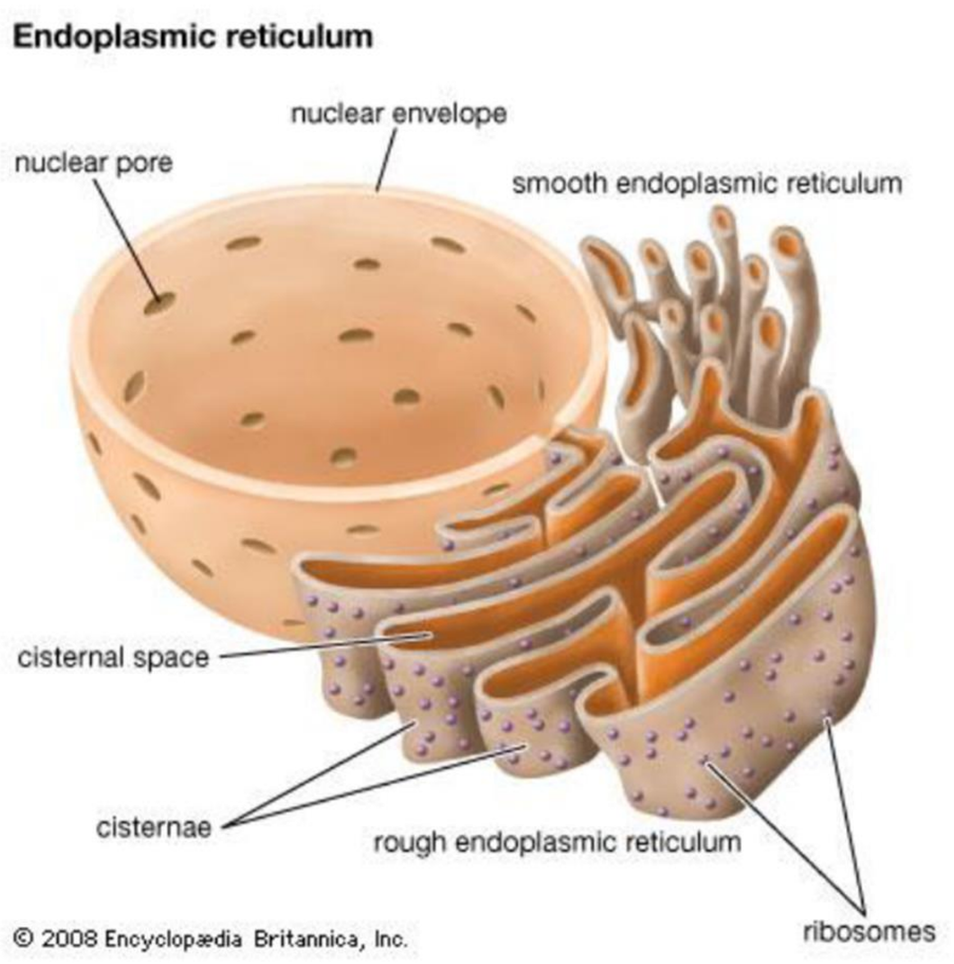
(2) The **endoplasmic reticulum**;

(3) The **Golgi apparatus,** which is mainly related to some of the terminal processes of cell secretion. **GERL** (or Golgi, ER and lysosome) refers to a special region of endomembrane system, which is more related to the Golgi apparatus and is involved in the formation of lysosomes.

MORPHOLOGY

Morphologically, the endoplasmic reticulum may occur in the following three forms :

1. Lamellar form or cisternae (A closed, fluid-filled sac, vesicle or cavity is called **cisternae**)
2. vesicular form or vesicle
3. tubular form or tubules.



TYPES OF ENDOPLASMIC RETICULUM

Two types of endoplasmic reticulum have been observed in same or different types of cells which
are as follows:

1. Agranular or Smooth Endoplasmic Reticulum
2. Granular or Rough Endoplasmic Reticulum

FUNCTIONS OF ENDOPLASMIC RETICULUM

Granular and Agranular Endoplasmic Reticulum

1. The endoplasmic reticulum provides an ultrastructural skeletal framework to the cell and gives mechanical support to the colloidal cytoplasmic martix.
2. The exchange of molecules by the process of osmosis, diffusion and active transport occurs through the membranes of endoplasmic reticulum. Like plasma membrane, the ER membrane has permeases and carriers
3. The endoplasmic membranes contain many enzymes which perform various synthetic and metabolic activities
4. The ER membranes form the new nuclear envelope after each nuclear division.

Smooth Endoplasmic Reticulum

1. Synthesis of lipids. SER performs synthesis of lipids (e.g., phospholipids, cholesterol, etc.) and lipoproteins.
2. Glycogenolysis and blood glucose homeostasis.
3. Sterol metabolism
4. 4. Detoxification.

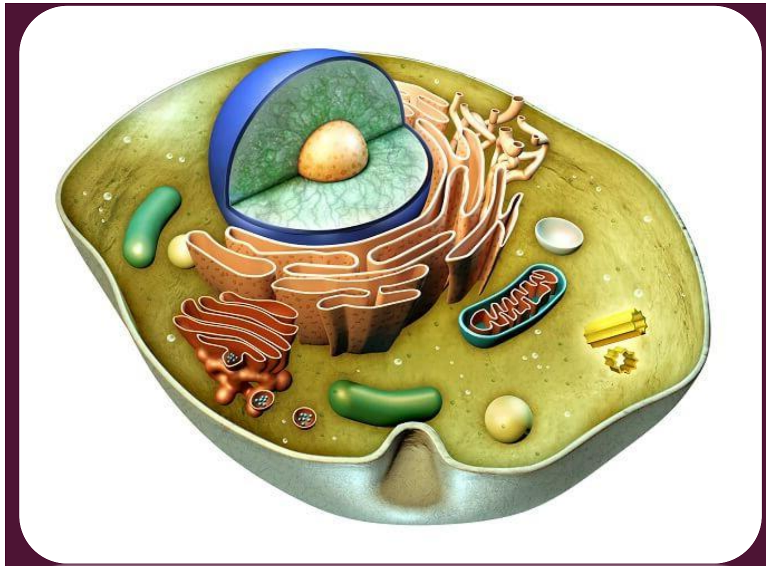
Rough Endoplasmic Reticulum

The major function of the rough ER is the synthesis of protein. It has long been assumed that proteins destined for secretion (i.e., export) from the cell or proteins to be used in the synthesis of cellular membranes are synthesized on rough ER-bound ribosomes, while cytoplasmic proteins are translated for the most part on free ribosomes

CELL BIOLOGY 2

LECTURE 6

GOLGI APPARATUS OR BODY



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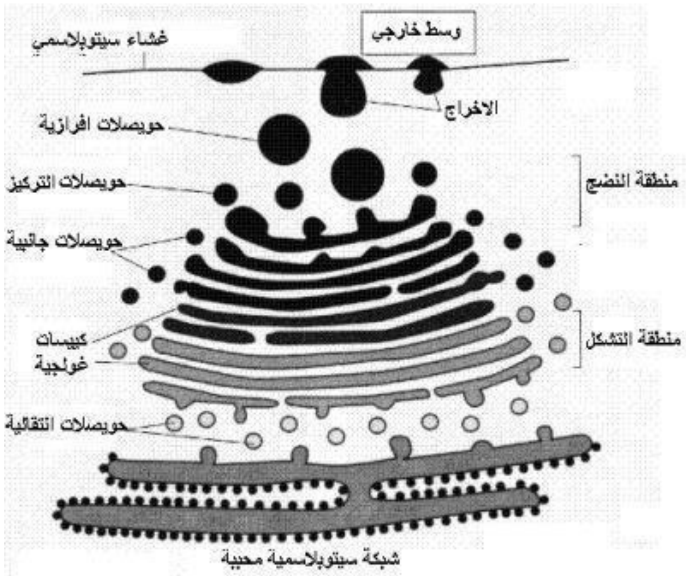
GOLGI APPARATUS OR BODY

- **Golgi** apparatus find in the cytoplasm of animal and plant cells. The Golgi apparatus, like the endoplasmic reticulum, is a canalicular system with sacs, but unlike the endoplasmic reticulum it has parallely arranged, flattened, membrane-bounded vesicles which lack ribosomes and stainable by osmium tetraoxide and silver salts.
- The Golgi apparatus occurs in all cells except the prokaryotic cells (*viz*., mycoplasmas, bacteria and blue green algae) and eukaryotic cells of certain fungi, sperm cells of bryophytes and pteridiophytes, cells of mature sieve tubes of plants and mature sperm and red blood cells of animals In animal cells, there usually occurs a single Golgi apparatus, however, its number may vary from animal to animal and from cell to cell.

MORPHOLOGY

The Golgi apparatus is morphologically very similar in both plant and animal cells. However, it is extremely **pleomorphic** : in some cell types it appears compact and limited, in others spread out and reticular (net-like). Its shape and form may vary depending on cell type. Typically, however, Golgi apparatus appears as a complex array of interconnecting *tubules*, *vesicles* and *cisternae*. The detailed structure of three basic omponents of the Golgi apparatus can be studied as follows

1. Flattened Sac or Cisternae (cis-face and trans-face)
2. Tubules
3. Vesicles (Transitional vesicles, Secretory vesicles, Clathrin-coated vesicles



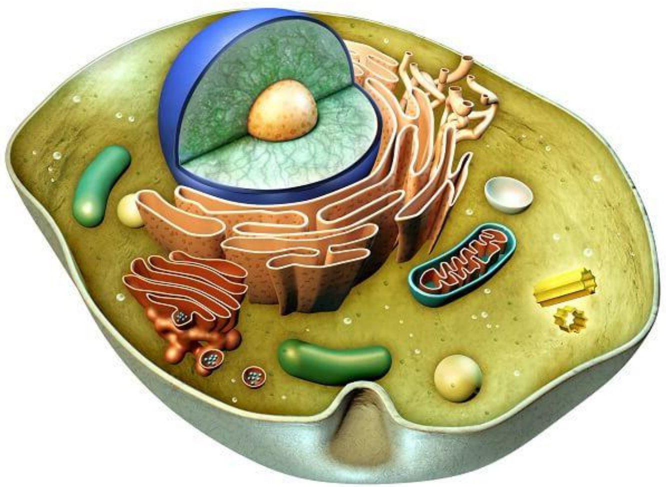
FUNCTIONS

- Thus, Golgi apparatus is a centre of *reception*, *finishing*, *packaging*, and *dispatch* for a variety of materials in animal and plant cells:
- **1. Golgi Functions in Plants**
- In plants, Golgi apparatus is mainly involved in the secretion of materials of primary and secondary cell walls (e.g., formation and export of glycoproteins, lipids, pectins and monomers for hemicellulose, cellulose, lignin, etc.)
- **2. Golgi Functions in Animals**
- In animals, Golgi apparatus is involved in the packaging and exocytosis of the following materials :
- 1. Zymogen of exocrine pancreatic cells;
- 2. Mucus (=a glycoprotein) secretion by goblet cells of intestine
- 3. Lactoprotein (casein) secretion by mammary gland cells (Merocrine secretion) ;
- 4. Secretion of compounds (thyroglobulins) of thyroxine hormone by thyroid cells;
- 5. Secretion of tropocollagen and collagen
- 6. Formation of melanin granules and other pigments;
- 7. Formation of yolk and vitelline membrane of growing primary oocytes

CELL BIOLOGY 2

LECTURE 7

MITOCHONDRIA



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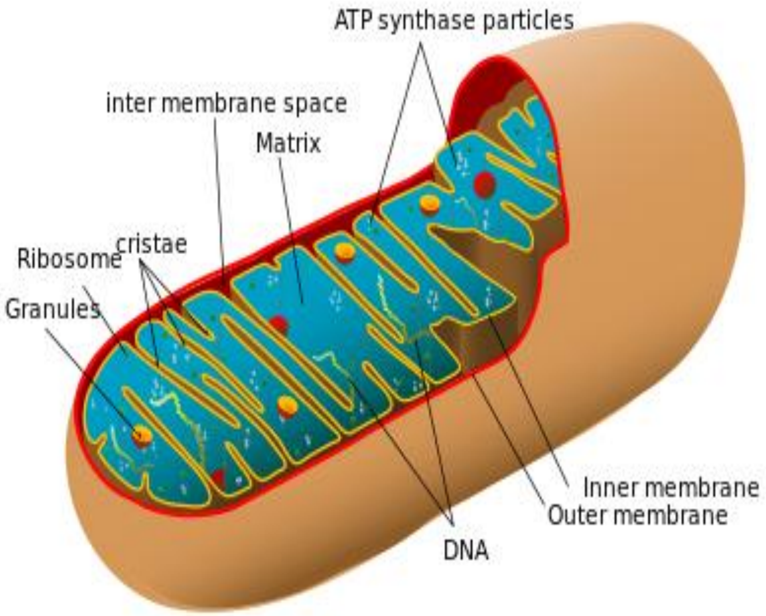
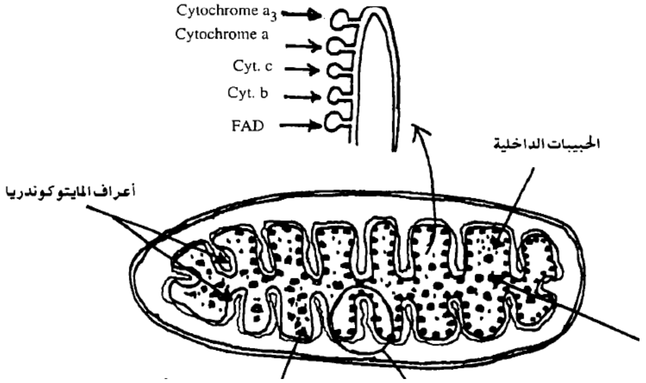
MITOCHONDRIA

- The mitochondria (Gr., *mito*=thread, *chondrion* =gran ule) are filamentous or granular cytoplasmic or ganelles of all aerobic cells of higher animals and plants and also of certain micro-organisms including Algae, Protozoaand Fungi. These are absent in bacterial cells. The mitochondria have lipoprotein framework which contains many enzymes and coenzymes required for energy metabolism. They also contain a specific DNA for the cytoplasmic inheritance and ribosomes for the protein synthesis.
- The mitochondria move autonomously in the cytoplasm, so they generally have uniform distribution in the cytoplasm, but in many cells their distribution is very restricted. The distribution and number of mitochondria (and also of mitochondrial cristae) are often correlated with type of function the cell performs. Typically mitochondria with many cristae are associated with mechanical and osmotic work situations, where there are sustained demands for ATP and where space is at a premium, e.g., between muscle fibres, in the basal infolding of kidney tubule cells, and in a portion of inner segment of rod and cone cells of retina.

MORPHOLOGY

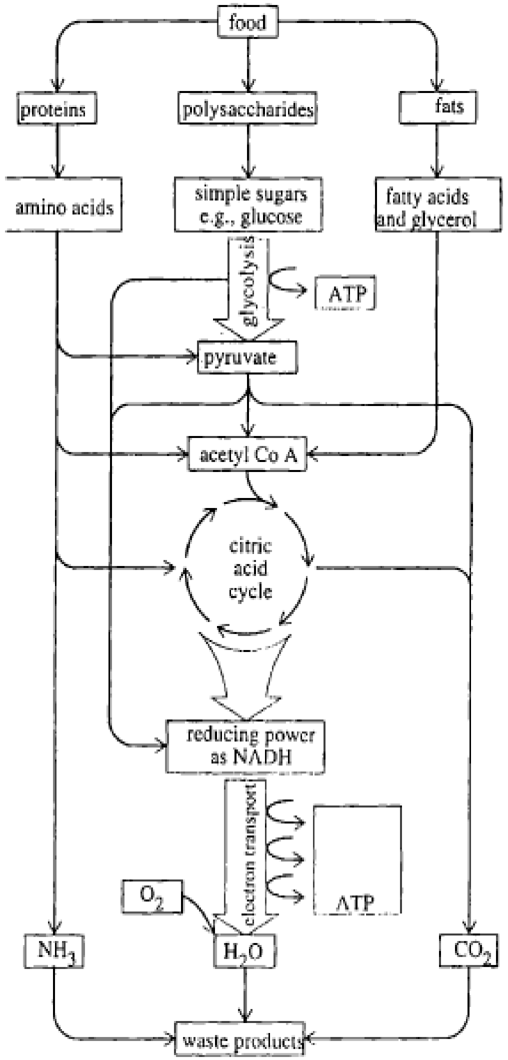
- **Number.** The number of mitochondria in a cell depends on the type and functional state of the cell. It varies from cell to cell and from species to species.
- **Shape.** The mitochondria may be filamentous or granular in shape and may change from one form to another depending upon the physiological conditions of the cells. Thus, they may be of club, racket, vesicular, ring or round-shape.
- **Size.** Normally mitochondria vary in size from 0.5 µm to 2.0 µm and, therefore, are not distinctly visible under the light microscope.
- **Structure.** Each mitochondrioa is bound by two highly specialized embranes that play a crucial part in its activities.
- **outer membrane**
- **inner membrane**
- **Cristae**
- **Matrix** (lipids, proteins, mtDNA)
- **granules**





CHEMICAL COMPOSITION

- 1. Enzymes of outer membrane
- 2. Enzymes of intermembrane space.
- 3. Enzymes of inner membrane
- 4. Enzymes of mitochondrial matrix.



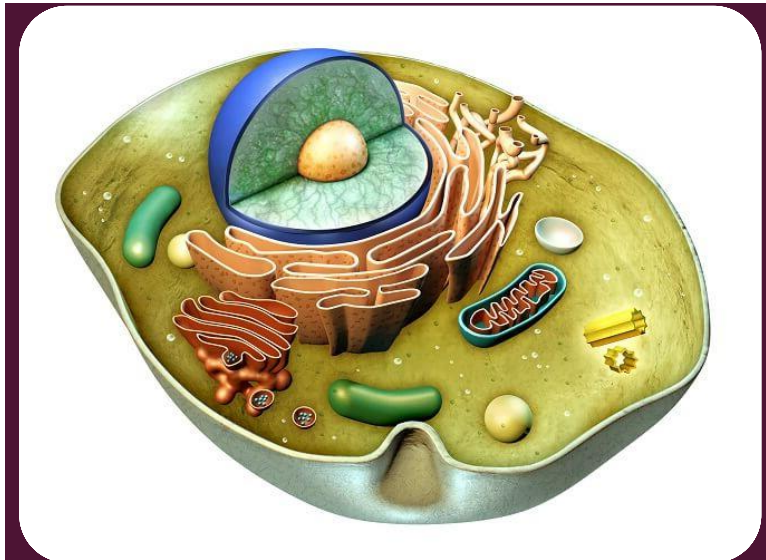
FUNCTIONS

- The mitochondria perform most important functions such as oxidation, dehydrogenation, oxidative phosphorylation and respiratory chain of the cell. Their structure and enzymatic system are fully adapted for their different functions. They are the actual respiratory organs of the cells where the foodstuffs, *i.e.*, carbohydrates and fats are completely oxidised into CO2 and H2O. During the biological oxidation of the carbohydrates and fats large amount of energy is released which is utilized by the mitochondria for synthesis of the energy rich compound known as **adenosine triphosphate** or **ATP**. Because mitochondria synthesize energy rich compound ATP, they are also known as "power houses" of the cell. In animal cells mitochondria produce 95 per cent of ATP molecules, remaining 5 per cent is being produced during anaerobic respiration outside the mitochondria. In plant cells, ATP is also produced by the chloroplasts.

CELL BIOLOGY 2

LECTURE 8

PLASTIDS



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PLASTIDS

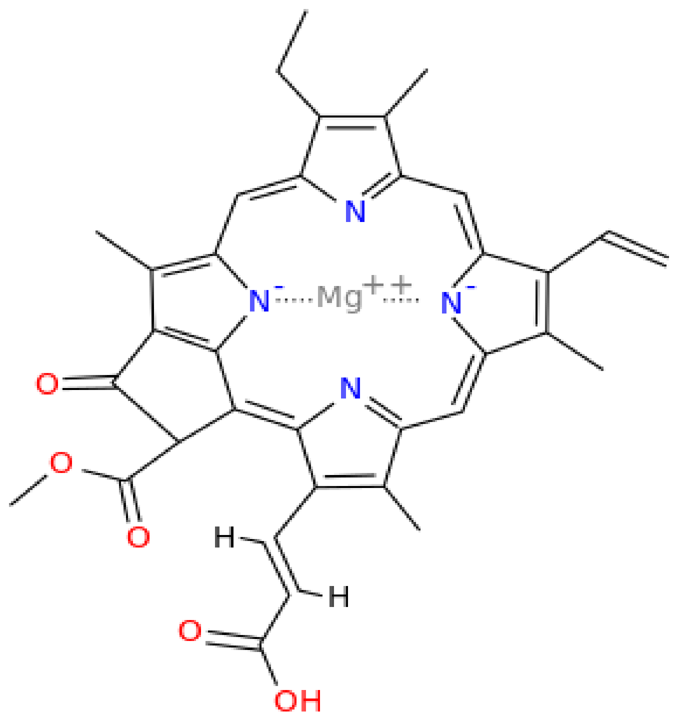
- Plastids are present in all living plant cells and in *Euglena* (a protozoan). They are small bodies found free in the cytoplasm. Plastids are often more or less spherical or disc-shaped (1 µm to 1 mm in diameter), but may be elongated or lobed or show amoeboid characteristics. Their other identifying features are their double bounding membranes, the possession of **plastoglobuli** (spherical lipid droplets; store of lipids surplus to current requirements) and an internal membrane fretwork of many discrete internal vesicles. All plastids in a particular plant species contain multiple copies of same relatively small genome (DNA) and 70S-type ribosomes They are self-replicating organelles containing a protein-synthesizing capacity comparable to that of mitochondria. They perform most important biological activities as the synthesis of food and storage of carbohydrates, lipids and proteins. Plastids are absent in the cells of fungi, bacteria, animals and male sperm cells of certain higher plants.

TYPES OF THE PLASTIDS

- **Chromoplasts (Phaeoplast., Rhodoplast.)**
- **Leukoplasts (Amyloplasts. Elaioplasts., Proteinoplasts)**
- **Chloroplasts**
- **Carotenoids ,Carotens , Xanthophylls , Anthocyanin.**

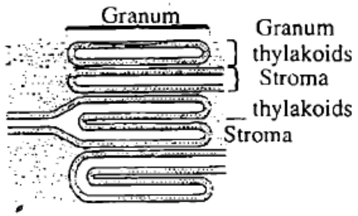
CHLOROPLASTS

- They are most common plastids of many plant cells and they perform the photosynthetic activity of greatest biological importance. By the process of photosynthesis the chloroplast synthesizes the carbohydrates which contain energy in the form of chemical energy. The chemical energy is utilized by all living beings to perform various life activities.



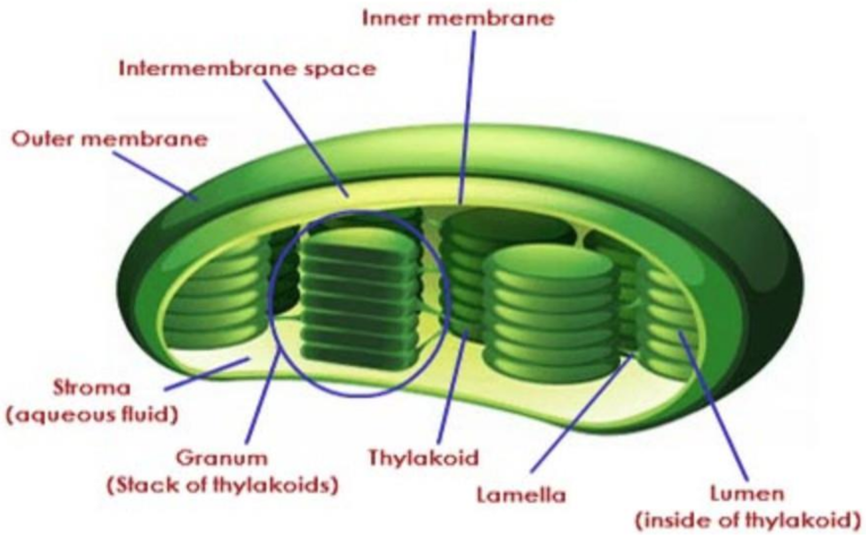
MORPHOLOGY

Shape. Higher plant chloroplasts are generally biconvex or plano-convex. However, in different plant cells, chloroplasts may have various shapes, *viz*., filamentous, saucer-shaped, spheroid, ovoid, discoid or club-shaped. They are vesicular and have a colourless centre.



Size. The size of the chloroplasts varies from species to species. The chloroplasts measure 2–3µm in hickness and 5–10µm in diameter (*e.g*., *Chlamydomonas*). Generally, chloroplasts of plants grown in the shade are larger and contain more chlorophyll than those of plants grown in sunlight.

Number. The number of the chloroplasts varies from cell to cell and from species to species and is related with the physiological state of the cell, but it usually remains constant for a particular plant cell. The algae usually have a single huge chloroplast. The cells of the higher plants have 20 to 40 chloroplasts



Structure A chloroplast comprises the following three main components

1. Envelope
2. 2. Stroma
3. 3. Thylakoids

4. DNA of chloroplast.
5. Ribosomes of chloroplasts.
6. Protein synthesis.

FUNCTIONS OF THE CHLOROPLAST : PHOTOSYNTHESIS

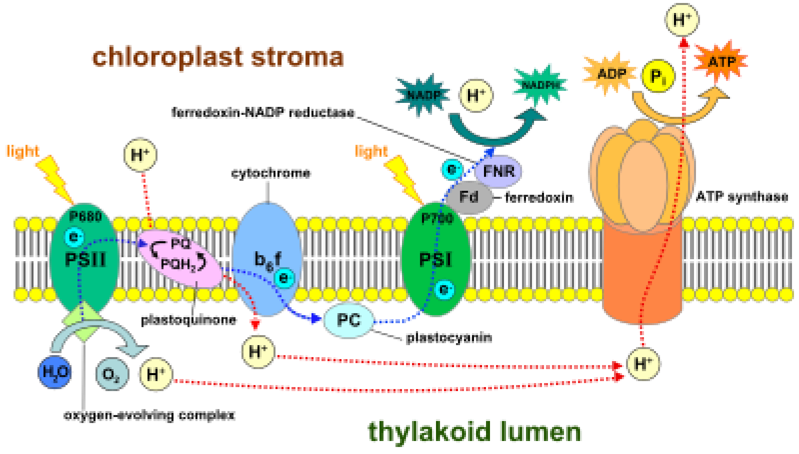
- 1. **Light reaction**.

It is also called Hill reaction, photosynthetic electron transfer reaction or photochemical reactions :

- (i) Light absorption by photosynthetic pigment
- (ii) Electron transport systems and oxidation of water.
- 2. Dark Reaction

The dark reaction is completed by passing through following three main phases:

- (i) Phase I : Carboxylation
- (ii) Phase 2 : Glycolytic reversal
- (iii) Phase 3 : Regeneration of RuBP

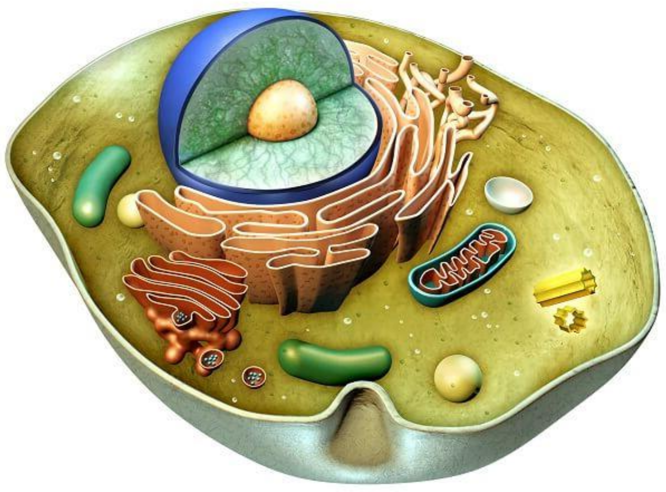


CELL BIOLOGY 2

LECTURE 9

RIBOSOMES

LYSOSOMES



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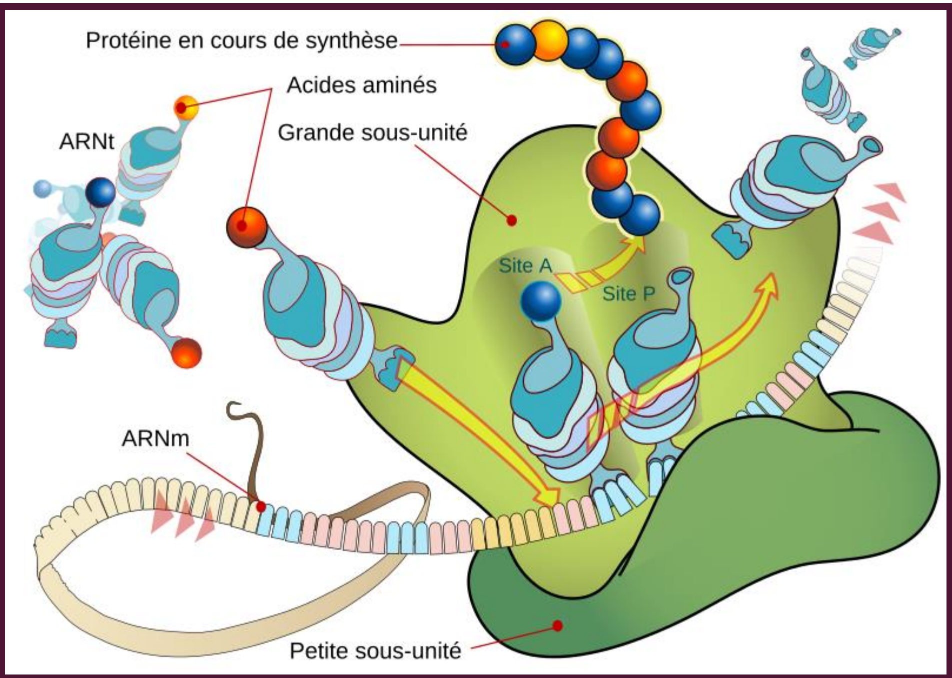
Level- 1

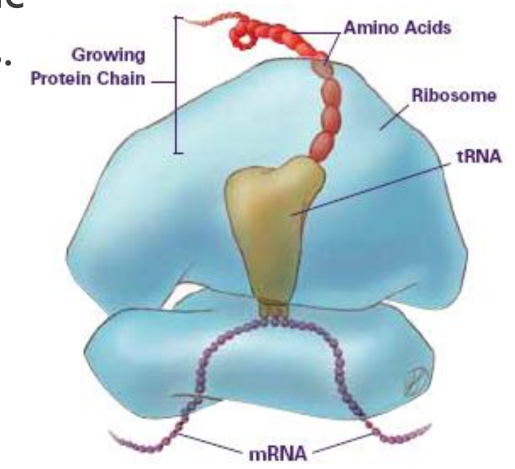
RIBOSOMES



Protéine en cours de synthèse
Acides aminés
ARNt
Grande sous-unité
Site A
Site P
ARNm
Petite sous-unité

The ribosomes are small, dense, rounded and granular particles of the ribonucleoprotein. They occur either freely in the matrix of mitochondria, chloroplast and cytoplasm (*i.e.*, cytoplasmic matrix) or remain attached with the membranes of the endoplasmic reticulum and nucleus. They occur in most prokaryotic and eukaryotic cells and are known to provide a scaffold for the ordered interaction of all the molecules involved in protein synthesis.
The ribosomes occur in cells, both prokaryotic and eukaryotic cells. In prokaryotic cells the ribosomes often occur freely in the cytoplasm. In eukaryotic cells the ribosomes either occur freely in the cytoplasm or remain attached to the outer surface of the membrane of endoplasmic reticulum.

- The yeast cells, reticulocytes or lymphocytes, meristamatic plant tissues, embryonic nerve cells and cancerous cells contain large number of ribosomes which often occur freely in the cytoplasmic matrix. The cells in which active protein synthesis takes place, the ribosomes remain attached with the membranes of the endoplasmic reticulum. Such cells are the pancreatic cells, plasma cells, hepaticparenchymal cells, Nissls bodies, osteoblasts, serous cells, or the submaxillary gland, chief cells of the glandular stomach, thyroid cells and mammary gland cells. The cells which synthesize specific proteins for the intracellular utilization and storage often contain large number of free ribosomes. Such cells are the erythroblasts, developing muscle cells, skin and hair



CHEMICAL COMPOSITON

The ribosomes are chemically composed of RNA and proteins as their major constituents ; both occurring approximately in equal proportions in smaller as well as larger subunit.
There is no lipid content in ribosomes.

TYPES OF RIBOSOMES

Recently accroding to the size and the sedimentation coefficient (S) two types of ribosomes have been recognized

1. 70S Ribosomes. The 70S ribosomes are comparatively smaller in size and have sedimentation coefficient 70S and the molecular weight 2.7× 106 daltons.

2. 80S Ribosomes. The 80S ribosomes
have the sedimentation coefficient of 80S and the molecular weight 40 × 106 daltons. The 80S ribosomes occur in eukaryotic cells of the plants and animals.

NUMBER OF RIBOSOMES

An *E. coli* cell contains 10,000 ribosomes, forming 25 per cent of the total mass of the bacterial cell. In contrast, ammalian cultured cells contain 10 million ribosomes per cell, each of which is about twice as large as a prokaryotic ribosome.

STRUCTURE OF RIBOSOMES

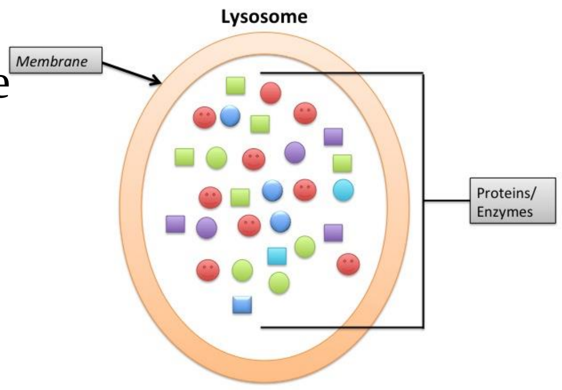
The 70S ribosome consists of two subunits, *viz*., 50S and 30S. The 50S ribosomal subunit is larger in size and has the size of 160 A_o to 180 A_o. The 30S ribosomal subunit is smaller in size and occurs above the 50S subunit like a cap .

The 80S ribosome also consists of two subunits, *viz*., 60S and 40S. The 60S ribosomal subunit is dome-shaped and larger in size. In the ribosomes which remain attached with the membranes of endoplasmic reticulum and nucleus, etc., the 60S subunit remains attached with the membranes. The 40S ribosomal subunit is smaller in size and occurs above the 60s subunit forming a cap-like structure. Both the subunits remain separated by a narrow cleft

Lysosomes

- The lysosomes (Gr., lyso=digestive + soma=body) are tiny membrane-bound vesicles involved in intracellular digestion. They contain a variety of hydrolytic enzymes that remain active under acidic conditions. The lysosomal lumen is maintained at an acidic pH (around 5) by an ATP-driven proton pump in the membrane. Thus, these remarkable organelles are primarily meant for the digestion of a variety of biological materials and secondarily cause aging and death of animal cells and also a variety of human diseases such as cancer, gout, Pompe's disease, silicosis and I-cell disease.

The lysosomes occur in most animal and few plant cells (Table 8-1). They are absent in bacteria and mature mammalian erythrocytes. Few lysosomes occur in muscle cells or in acinar cells of the pancreas. Leucocytes, especially granulocytes are a particularly rich source of lysosomes. Their lysosomes are so large-sized that they can be observed under the light microscope. Lysosomes are also numerous in epithelial cells of absorptive, secretory and excretory organs (*e.g.*, intestine, liver, kidney, etc.). They occur in abundance in the epithelial cells of lungs and uterus. Lastly, phagocytic cells and cells of reticuloendothelial system (*e.g.*, bone marrow, spleen and liver) are also rich in lysosomes.

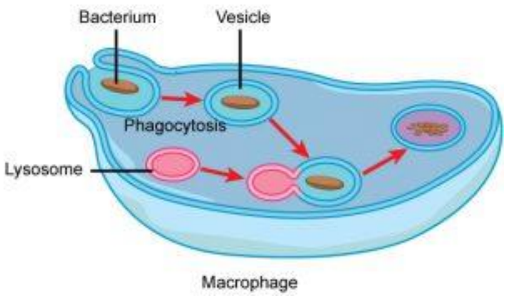


STRUCTURE

- The lysosomes are round vacuolar structures which remain filled with dense material and are bounded by single unit membrane. Their shape and density vary greatly. Lysosomes are 0.2 to 0.5µm in size. Since, size and shape of lysosomes vary from cell to cell and time to time (*i.e.* they are polymorphic), their identification becomes difficult. However, on the basis of the following three criteria, a cellular entity can be identified as a lysosome:
- (1) It should be bound by a limiting membrane
- (2) It should contain two or more acid hydrolases
- (3) It should demonstrate the property of enzymelatency when treated in a way that adversely affects organelle's membrane structure.

Lysosomal Enzymes

They include proteases (*e.g.*, cathepsin for protein digestion), nucleases, glycosidases (for digestion of polysaccharides and glycosides), lipases, phospholipases, phosphatases and sulphatases. All lysosomal enzymes are acid hydrolases, optimally active at the pH5 maintained within lysosomes.



KINDS OF LYSOSOMES (POLYMORPHISM IN LYSOSOMES

Lysosomes are extremely dynamic organelles, exhibiting polymorphism in their morphology. Following four types of lysosomes have been recognized in different types of cells or at different times in the same cell. Of these, only the first is the primary lysosome, the other three have been grouped together as secondary lysosomes.

1. **Primary Lysosomes (**called **storage granules**, **protolysosomes** or **virgin lysosomes)**

2. **Heterophagosomes (heterophagic vacuoles**, **heterolysosomes** or **phagolysosomes)**

3. **Autophagosomes (**called **autophagic vacuole**, **cytolysosomes** or **autolysosomes**.)

4. **Residual Bodies (**called **telolysosomes** or **dense bodies)**

FUNCTIONS OF LYSOSOMES

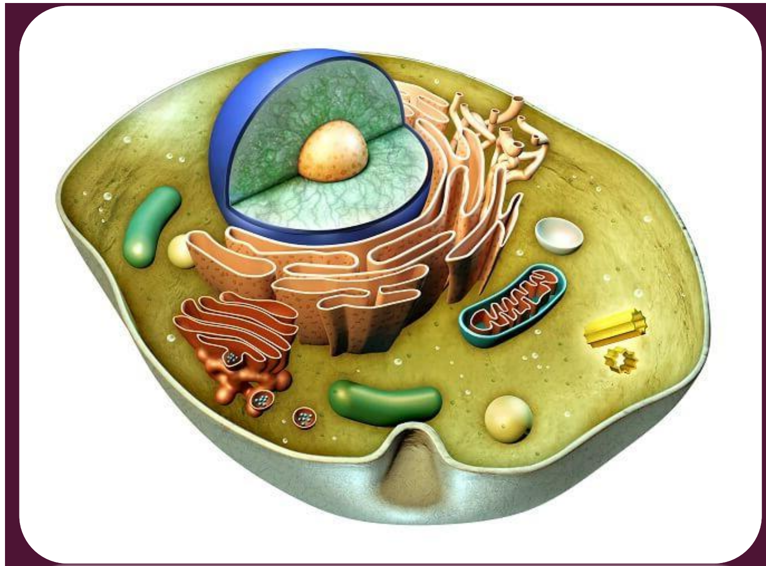
- **1. Digestion of large extracellular particles.** The lysosomes digest the food contents of the phagosomes or pinosomes. The lysosomes of leucocytes enable the latter to devour the foreign proteins, bacteria and viruses.
- **2. Digestion of intracellular substances.** During the starvation, the lysosomes digest the stored food contents, *viz*., proteins, lipids and carbohydrates (glycogen) of the cytoplasm and supply to the cell neccessary amount of energy.
- **3. Autolysis.** In certain pathological conditions the lysosomes start to digest the various organelles of the cells and this process is known as **autolysis** or **cellular autophagy**.
- **4. Extracellular digestion.** The lysosomes of certain cells such as sperms discharge their enzymes outside the cell during the process of fertilization

CELL BIOLOGY 2

LECTURE 10

PEROXISOMES

MICROFILAMENT & MICROTUBULES



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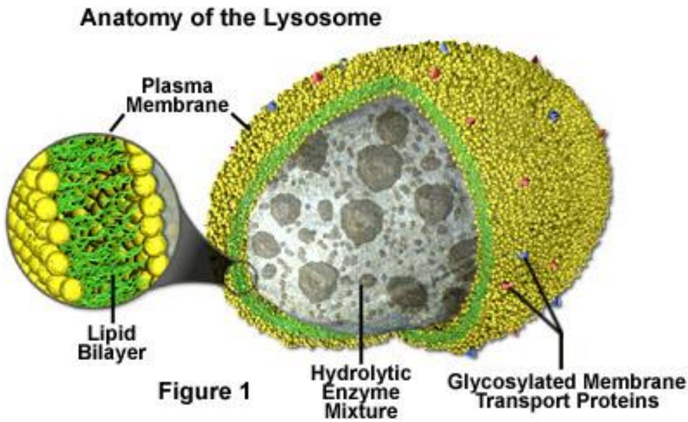
PEROXISOMES

- Peroxisomes occur in many animal cells and in a wide range of plants. They are present in all photosynthetic cells of higher plants in etiolated leaf tissue, in coleoptiles and hypocotyls, in tobacco stem and callus, in ripening pear fruits and also in Euglenophyta, Protozoa, brown algae, fungi, liverworts, mosses and ferns.

Structure

Peroxisomes are variable in size and shape, but usually appear circular in cross section having diameter between 0.2 and 1.5µm (0.15 to 0.25 µm diameter in most mammalian tissues; 0.5 µm in rat liver cells). They have a single limiting unit membrane of lipid and protein molecules, which encloses their granular matrix



FUNCTIONS OF PEROXISOMES

- Peroxisomes are found to perform following two types of biochemical activities :
- **A. Hydrogen peroxide metabolism** $RH_2 + O_2 \rightarrow R + H_2O_2$
- **B. Glycolate cycle.** $CH_2OH.COOH + O_2 \rightarrow CHO - COOH + H_2O_2$

$CHO - COOH + H_2O_2 \rightarrow HCOOH + CO_2 + H_2O$

C. β-oxidation.

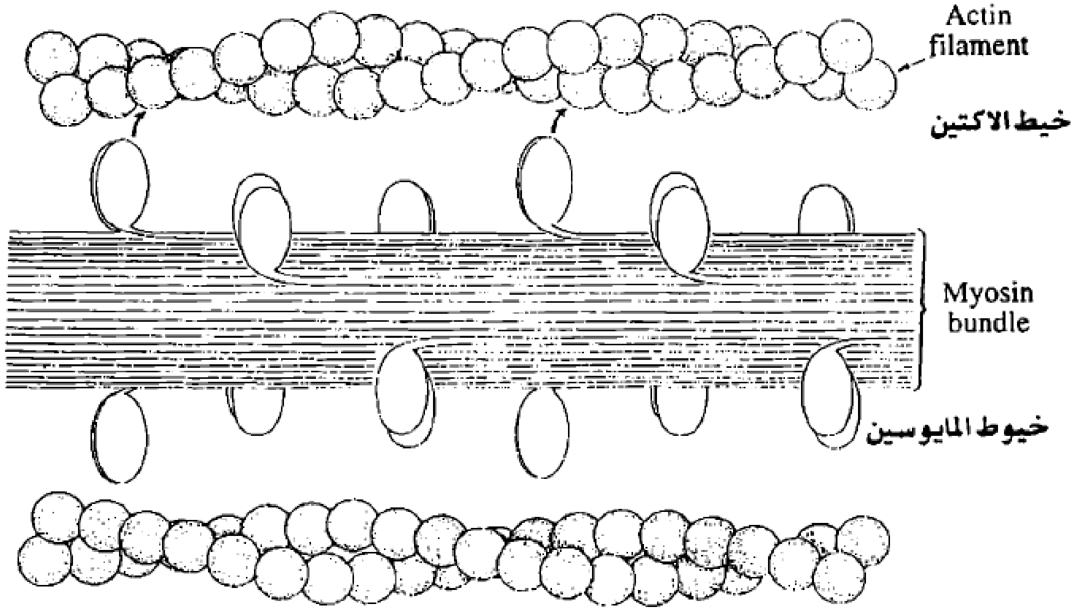
MICROFILAMENT

- microfilaments are a thin, solid actin protein, ranging between 5 to 7 nm in diameter and indeterminate length, represent the active or motile part of the cytoskeleton. They appear to play major role in cyclosis and amoeboid motion. With high voltage electron microscopy a three-dimensional view of microfilaments has been obtained (*i.e.*, an image of crotrabecular lattice). These microfilaments are sensitive to cytochalasin-B, an alkaloid that also impairs many cell activities such as beat of heart cell, cell migration, cytokinesis, endocytosis and exocytosis. It is generally assumed that the cytochalasin-B-sensitive microfilaments are the contractile machinery of non-muscle cells.

Chemical Composition

Actin is the main structural protein of microfilaments. The concentration of actin in non-muscle cells is surprisingly high ; it may account up to 10 per cent of total cell protein.

It can be extracted and *in vitro* settings will undergo polymerization reactions from Gactin monomer state to F-actin. In fact, the globular (=G actin) – fibrillar (=F-actin) transition is the basis of the classical sol-gel transition in the cytoplasm of moving cells



Function

Microfilaments are found to be involved in movement associated with furrow formation in cell division, cytoplasmic streaming in plant cells (*e.g.*, *Nitella* and *Chara*) and cell migration during embryonic development.

MICROTUBULES

- Microtubules were fisrt of all observed in the axoplasm of the myelinated nerve fibres by **Robertis** and **Franchi** (1953). They called them **neurotubules**. The exact nature of microtubules was brought into light when **Sabatini**, **Bensch** and **Barnett** (1963) made use of the glutarldehyde fixative in the electron microscopy. Microtubeles of plant cells were first described in detail by **Ledbetter** and **Porter** (1963).
- microtubules are found in all eukaryotic cells, either free in the cytoplasm or forming part of centrioles, cilia and flagella.

Structure

Microtubules constitute a class of morphologically and chemically related filamentous rods which are common to both plant and animal cells. A microtubule consists of a long, unbranched, hollow tubules 24–25 nm in diameter, several micrometers long and with 6 nm thick wall having 13 subunits or protofilaments. Thus, the wall of the microtubule consists of 13 individual linear or spiraling filamentous structures about 5 nm in diameter, which in turn, are composed of tubulin. These protofilaments have a centre-to-centre spacing of 4.5 nm. Application of negative staining techniques has shown that microtubules have a lumen 14 nm wide and a protofilament or subunit structure in the wall

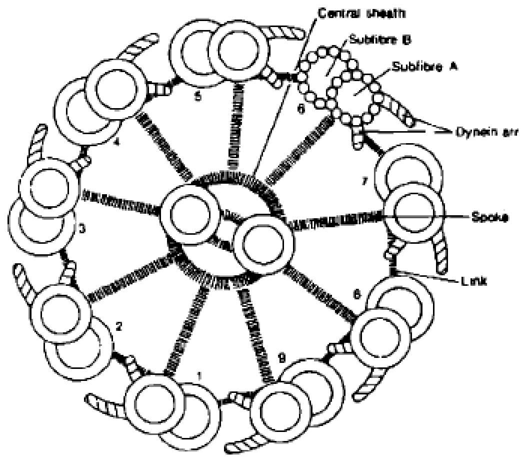
Chemical Composition

Biochemically, a protofilament of microtubule is made of a protein called **tubulin**. Tubulin is an acidic protein with a molecular weight of 55,000 and a sedimentation constant of 6S. It occurs in two different forms, called α**-tubulin** and β**-tubulin**, each containing about 450 amino acids. Both of these proteins have a distinct, though closely related, amino acid sequences and are thought to have evolved from a single ancestral protein.

Functions of Cytoplasmic Microtubules

Microtubules have several functions in the eukaryotic cells such as follows

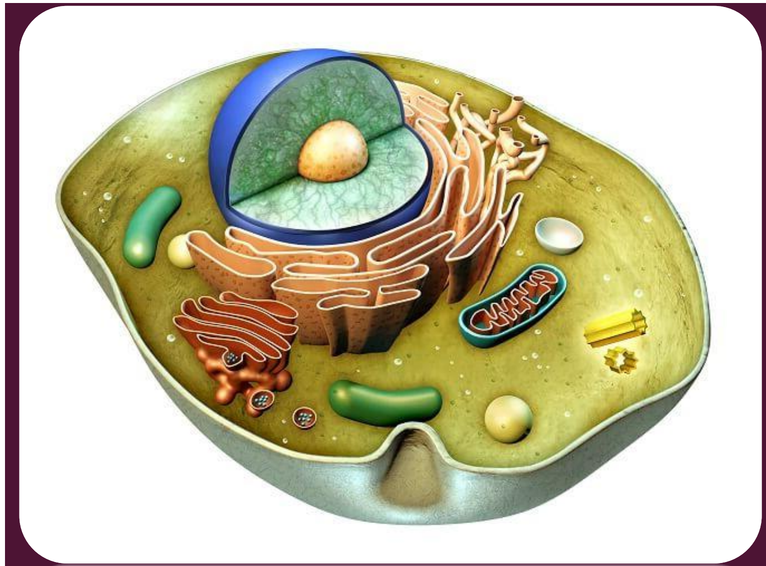
1. **Mechanical function**
2. **Morphogenesis**
3. **Cellular polarity and motility**
4. **Contraction**
5. **Circulation and transport**



CELL BIOLOGY 2

LECTURE 10

NUCLEUS



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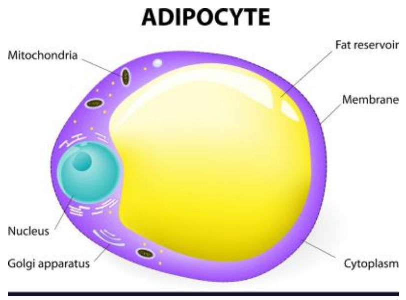
The nucleus (L.,*nux*= nut) is the heart of the cell. It is here that almost all of the cell's DNA is confined, replicated and transcribed. The nucleus, thus, controls different metabolic as well as hereditary activities of the cell. A synonymous term for this organelle is the Greek word **karyon**. Nucleus serves as the main distinguishing feature of eukaryotic cells, *i.e.*, this is the true nucleus as opposed to the nuclear region, prokaryon or nucleoid of the prokaryotic cells

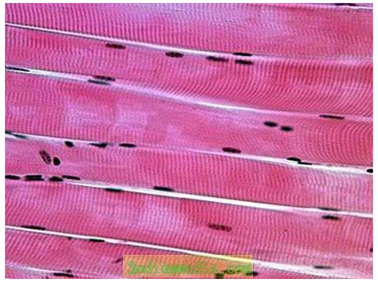
The nucleus is found in all the eukaryotic cells of the plants and animals. However, certain eukaryotic cells such as the mature sieve tubes of higher plants and mammaliam erythrocytes contain no nucleus. In such cells nuclei are present during the early stages of development. Since mature mammalian red blood cells are without any nuclei, they are called red blood "corpuscles" rather than cells

The prokaryotic cells of the bacteria do not have true nucleus, *i.e.*, the single, circular and large DNA molecule remains in direct contact with the cytoplasm. The position or location of the nucleus in a cell is usually the characteristic of the cell type and it is often variable. Usually the nucleus remains located in the centre. But its position may change from time to time according to the metabolic states of the cell.

MORPHOLOGY

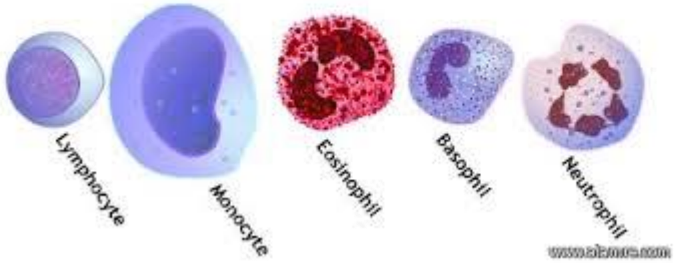
- **Number**
- Usually the cells contain single nucleus but the number of the nucleus may vary from cell to cell. According to the number of the nuclei following types of cells have been recognised :
- **1. Mononucleate cells**
- **2. Binucleate cells.**
- **3. Polynucleate cells.**





Shape

The shape of the nucleus normally remains related with the shape of the cell, but certain nuclei are almost irregular in shape. The spheroid, cuboid or polyhedral cells (isodiametrical cells) ontain the **spheroid** nuclei. The nuclei of the cylindrical, prismatic or fusiform cells are **ellipsoid** in shape. The cells of the squamous epithelium contain the **discoidal** nuclei.



Size

Generally nucleus occupies about 10 per cent of the total cell volume. Nuclei vary in size from about 3 ⌠m to 25 ⌠m in diameter, depending on cell type and contain diploid set of chromosomes.

STRUCTURE

NUCLEAR ENVELOPE

NUCLEOPLASM
NUCLEOLI
CHROMATIN

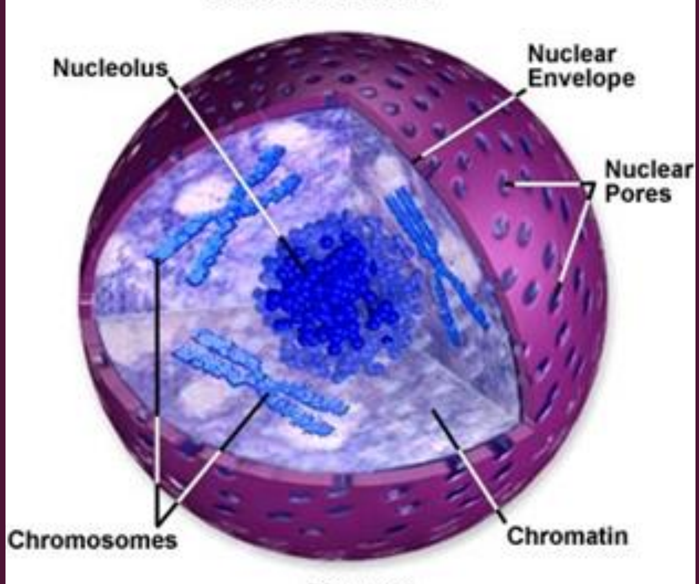


Figure 1

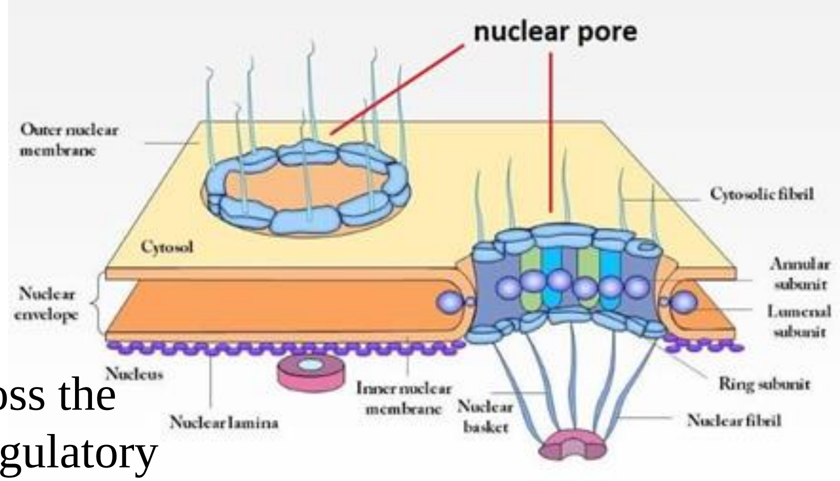
NUCLEAR ENVELOPE

- The nuclear envelope (or perinuclear cisterna) encloses the DNA and defines the nuclear compartment of interphase and prophase nuclei. It is formed from two concentric unit membranes, each 5–10 nm thick. The spherical **inner nuclear membrane** contains specific proteins that act as binding sites for the supporting fibrous sheath of ntermediate filaments (IF), called **nuclear lamina**. Nuclear lamina has contact with the chromatin (or chromosomes) and nuclear RNAs.

1. Nuclear pores and nucleocytoplasmic traffic.

1. Structure of nuclear pores: Nuclear pores appear circular in surface view and have a diameter between 10nm to 100 nm

2. Number of nuclear pores (Pore density). In nuclei of mammals it has been calculated that nuclear pores account for 5 to 15 per cent of the surface area of the nuclear membrane.



3. Arrangement of nuclear pores on nuclear envelope. In somatic cells, the nuclear pores are evenly or randomly distributed over the surface of nuclear envelope

4. Nucleo-cytoplasmic traffic. Quite evidently there is considerable trafficking across the nuclear envelope during interphase. Ions, nucleotides and structural, catalytic and regulatory proteins are imported from the cytosol (cytoplasmic matrix); mRNA, tRNA and ribosome subunits are exported to the cytosol

NUCLEOPLASM

The space between the nuclear envelope and the nucleolus is filled by a transparent, semi-solid, granular and slightly acidophilic ground substance or the matrix known as the **nuclear sap** or **nucleoplasm** or **karyolymph**. The nucleoplasm has a complex chemical composition. It is composed of mainly the nucleoproteins but it also contains other inorganic and organic substances

1. **Nucleic acids**
2. **Proteins ((i) Basic proteins , (ii) Non-histone or Acidic proteins.**
3. **Enzymes (DNA polymerase, RNA polymerase, NAD synthetase, nucleoside triphosphatase, adenosine diaminase, nucleoside phosphorylase, guanase, aldolase, enolase, 3-phosphoglyceraldehyde dehydrogenase** and **pyruvate kinase)**
4. **Lipids.**
5. **Minerals**

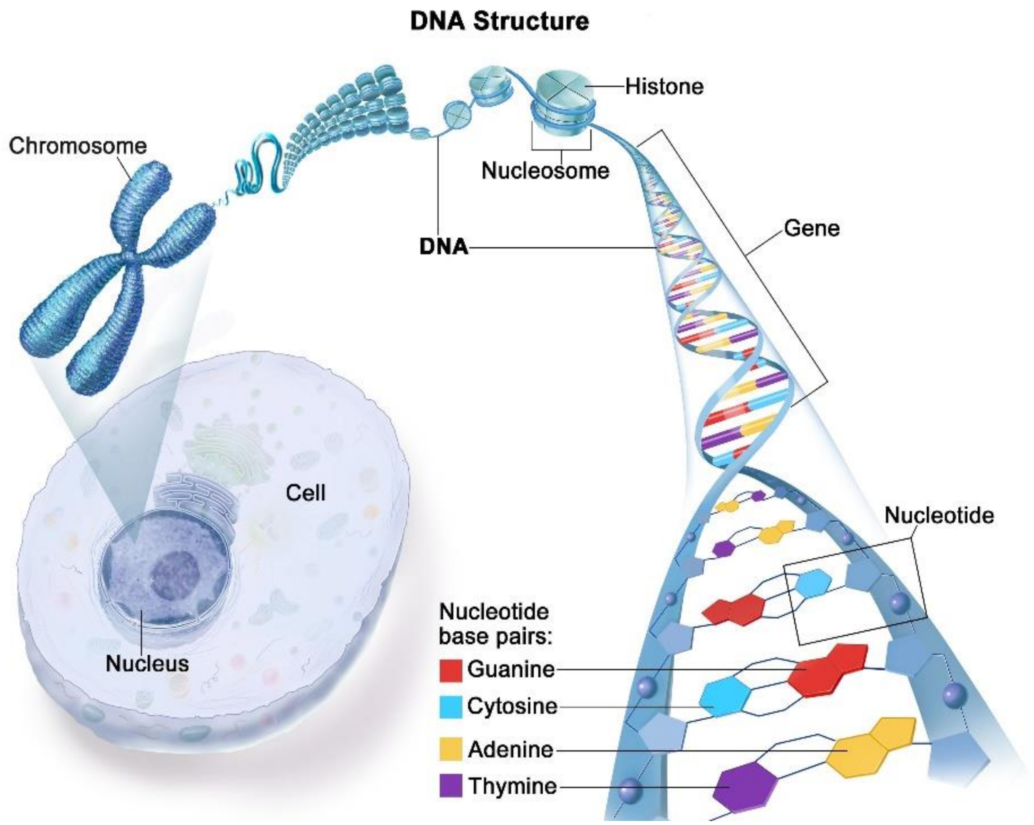
NUCLEOLUS

- Most cells contain in their nuclei one or more prominent spherical colloidal acidophilic bodies, called nucleoli. However, cells of bacteria and yeast lack nucleolus. The size of the nucleolus is found to be related with the synthetic activity of the cell. Therefore, the cells with little or no synthetic activities, e.g., sperm cells, blastomeres, muscle cell, etc., are found to contain smaller or no nucleoli, while the oocytes, neurons and secretory cells which synthesize the proteins or other substances contain comparatively large-sized nucleoli. The number of the nucleoli in the nucleus depends on the species and the number of the chromosomes. The number of the nucleoli in the cells may be one, two or four. The position of the nucleolus in the nucleus is eccentric.

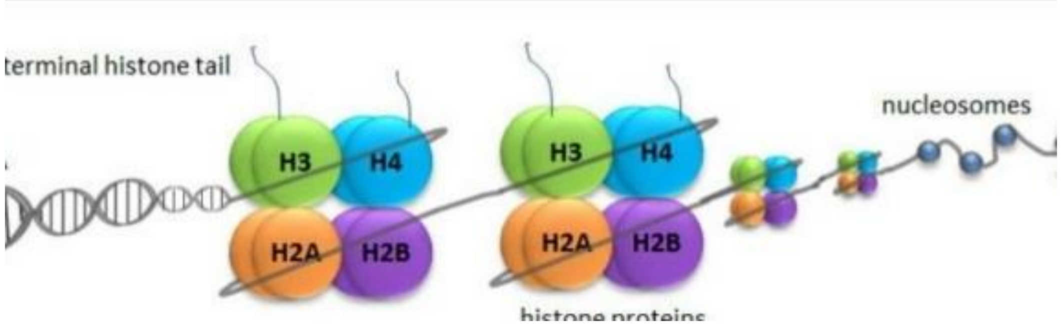
Chemically, nucleolus contains DNA of nucleolar organizer, four types of rRNAs, 70 types of ribosomal roteins, RNA binding proteins (*e.g.*, nucleolin) and RNA splicing nucleoproteins (U_1, U_2......U_{12}). It also contains phospholipids, orthophosphates and Ca^{2+} ions. Nucleolus also contains some enzymes such as acid phosphatase, nucleoside phosphorylase and AD^{+}synthesizing enzymes for the synthesis of some coenzymes, nucleotides and ribosomal RNA

CHROMATIN

- The nucleoplasm contains many thread-like, coiled and much elongated structures which take readily the basic stains such as the basic fuchsin. These thread-like structures are known as the **chromatin** (*Gr., chrome*=colour) **substance** or **chromatin fibres**. Such chromatin fibres are observed only in the interphase nucleus. During the cell division (mitosis and meiosis) chromatin fibres become thick ribbon-like structures which are known as the **chromosomes**.
- Chemically, chromatin consists of DNA and proteins. Small quantity of RNA may also be present but the RNA rarely accounts for more than about 5 per cent of the total chromatin present. Most of the protein of chromatin is histone, but "nonhistone" proteins are also present.



- The fibres of the chromatin are twisted, finely anastomosed and uniformly distributed in the nucleoplasm. Two types of chromatin material have been recognised, e.g., heterochromatin and euchromatin.
- **A. Heterochromatin.** The darkly stained, condensed region of the chromatin is known as heterochromatin. The condensed portions of the nucleus are known as **chromocenters** or **karyosomes** or **false nucleoli**. The heterochromatin occurs around the nucleolus and at the periphery. It is supposed to be metabolically and genetically inert because it contains comparatively small amout of the DNA and large amount of the RNA.
- **B. Euchromatin.** The light stained and diffused region of the chromatin is known as the euchromatin. The euchromatin contains comparatively large amount of DNA.

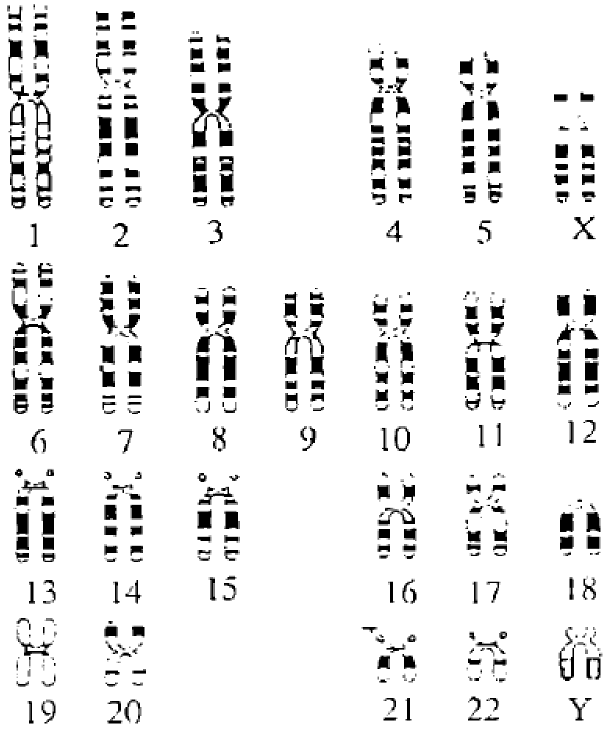


CHROMOSOMES

- The chromosomes are the nuclear components of special organisation, individuality and function. They are capable of self-reproduction and play a vital role in heredity, mutation, variation and evolutionary development of the species.

CHROMOSOME NUMBER

The member of the chromosomes is constant for a particular species. Therefore, these are of great importance in the determination of the phylogeny and taxonomy of the species. The number or set of the chromosomes of the gametic cells such as sperms and ova is known as the gametic, reduced or **haploid** sets of chromosomes. The haploid set of the chromosomes is also known as the **genome**. The somatic or body cells of most organisms contain two haploid set or genomes and are knows as the **diploid cell.** The number of chromosomes in each somatic cell is the same for all members of a given species.

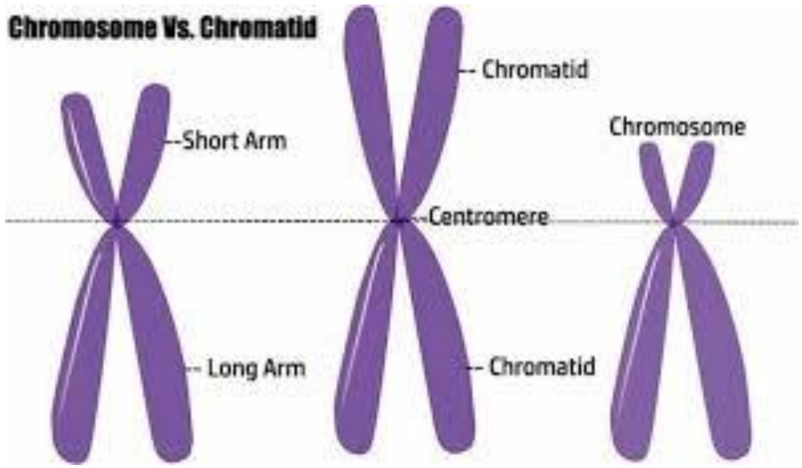


Size

The size of chromosome is normally measured at mitotic metaphase and may be as short as 0.25 µm in fungi and birds, or as long as 30 µm in some plants such as Trillium

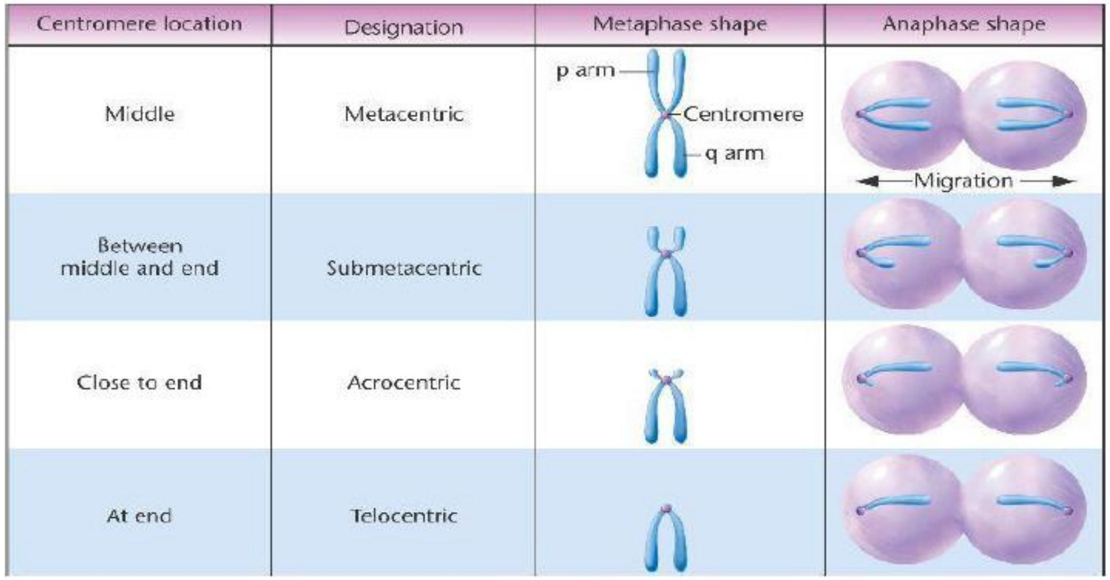
Shape

The shape of the chromosomes is changeable from phase to phase in the continuous process of the cell growth and cell division. In the resting phase or interphase stage of the cell, the chromosomes occur in the form of thin, coiled, elastic and contractile, thread-like stainable structures, the chromatin threads. In the metaphase and the anaphase, the chromosomes become thick and filamentous. Each chromosome contains a clear zone,known as centromere or kinetocore, along their length. The centromere divides the chromosomes into two parts, each part is called hromosome arm



The position of centromere varies form chromosome to chromosome and it provides different shapes to the latter which are following

1. Telocentric
2. Acrocentric.
3. Submetacentric
4. Metacentric.

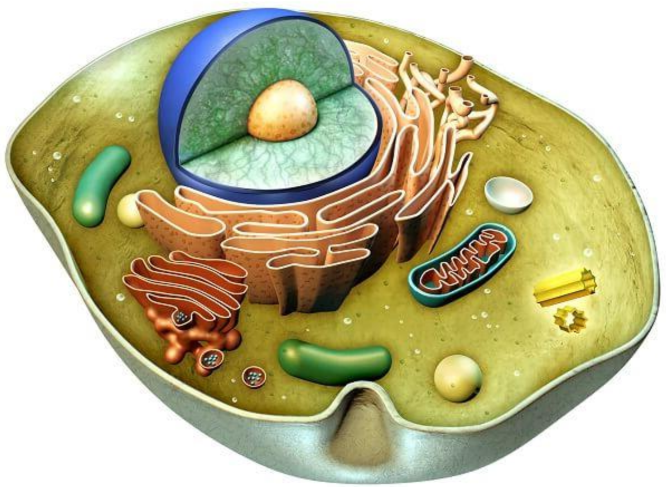


Centromere location	Designation	Metaphase shape	Anaphase shape
Middle	Metacentric	p arm, Centromere, q arm	Migration
Between middle and end	Submetacentric		
Close to end	Acrocentric		
At end	Telocentric		

CELL BIOLOGY 2

LECTURE 11

GENETIC MATERIALS (DNA AND RNA)



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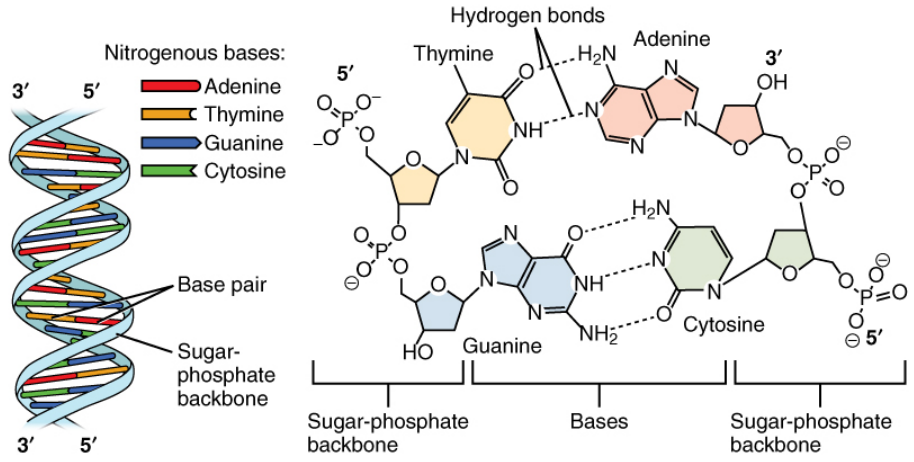
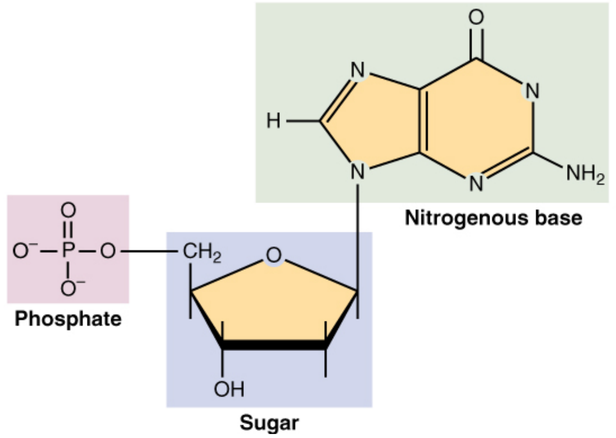
DEOXYRIBONUCLEIC ACID

- DNA (deoxyribonucleic acid) and RNA (ribonucleic acid), the principal genetic materials of living organ isms, are chemically called **nucleic acids** and are complex molecules larger than most proteins and contain carbon, oxygen, hydrogen, nitrogen and phosphorus.
- Each deoxyribonucleotide is made up of three moieties: a **phosphoric acid molecule** (biologically called phosphate); a pentose sugar called **2 deoxyribose**; and **pyrimidine** and **purine** nitrogenous bases. Four major kinds of nitrogenous bases have been found in four kinds of deoxyribonucleotides of DNA : two are heterocyclic and two-ringed purines, **adenine** (**A**) and **guanine** (**G**), and two are one ringed pyrimidines, **cytosine** (**C**) and **thymine** (**T**).





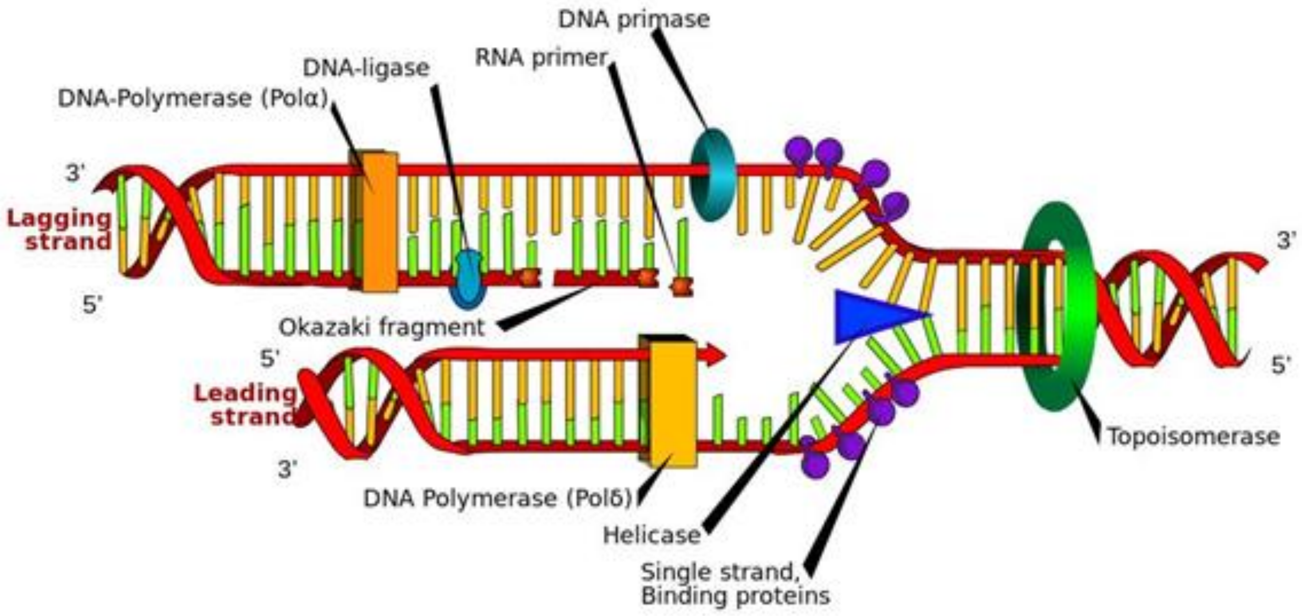
RIBONUCLEIC ACID (RNA)

- RNA is polymeric nucleic acid of four monomeric **ribotids** or **ribonucleotids**. Each ribonucleotide contains a pentose sugar (**D-ribose**); a molecule of phosphate group and a nitrogen base. The nitrogen bases of RNA are two purines, **adenine** and **guanine** and two pyrimidines, **cytosine** and **uracil**.
- **Replication of Genetic RNA**
- The genetic RNA of viruses is self-replicating, that is, it can produce its own replica by itself. So, its mode of replication is called **RNA-dependent RNA synthesis**. The genetical research on genetic RNA has revealed the following facts about it. (1) The viral RNA functions directly as a messenger RNA which, in association with the ribosomal apparatus of the host, directs the synthesis of both the **RNA polymerase enzyme** (required for RNA replication) and the proteins of the viral coat. (2) With the mediation of RNA polymerase and on the standard base-pairing principles, the viral RNA serves as a template in the synthesis of a complementary RNA chain, and thus a double stranded structure is produced.

Roles of RNA Primers in DNA Replication

No known DNA polymerase can initiate synthesis of DNA without the availability of a **primer RNA strand.** So, before actual DNA replication starts, short RNA oligonucleotide segments, called **RNA primers** or simply the **primers,** have to be synthesized by **DNA primase** enzyme utilizing ribonucleoside triphosphates. This RNA primer is synthesized by copying a particular base sequence from once DNA strand and differs from a typical RNA molecule in that after the synthesis the primer remains hydrogen-bonded to the DNA template

The primers are about 10 nucleotides long in eukaryotes and they are made at intervals on the lagging strand where they re elongated by the DNA polymerase enzyme to begin each okazaki fragment. These RNA primers are later excised and filled with DNA with the help of DNA repair system in eukayrotes (or DNA polymerase I in *E.coli).* In bacteria, two different enzymes are known to synthesize primer RNA oligonucleotides – **RNA polymerase** (on the leading strand) and **DNA primase** (on the lagging strand).

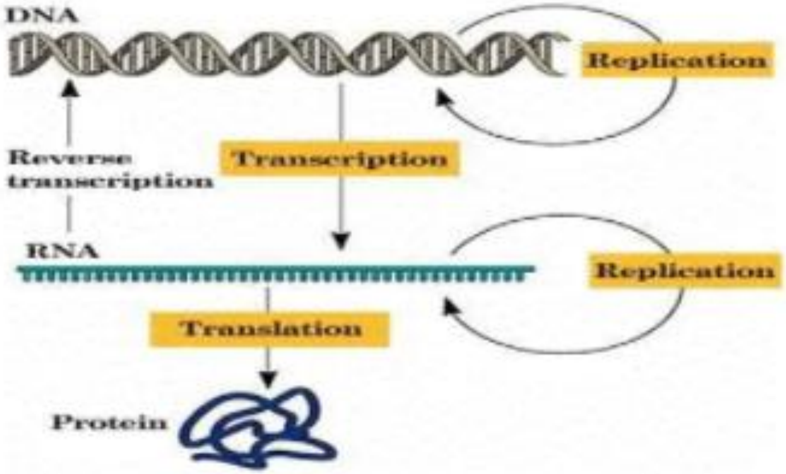


DNA REPLICATION

- DNA replication is the process of producing two identical replicate of DNA from one DNA molecule.
- DNA replication occur during the S Phase of interphase of cell cycle.

Types of Replication:

- **Conservative :**
  Both parental strands stay together after DNA replication
- **Semi-conservative :**
  The double-stranded DNA contains one parental and one daughter strand following replication
- **Dispersive:**
  Parental and daughter DNA are interspersed in both strands following replication



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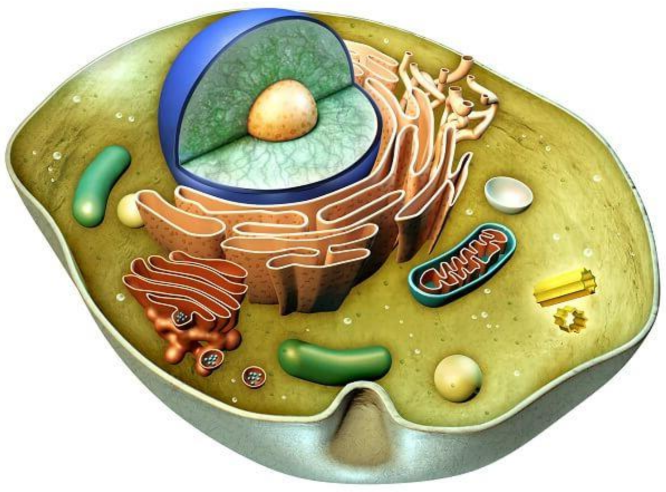
LECTURE 12

TRANSCRIPTION



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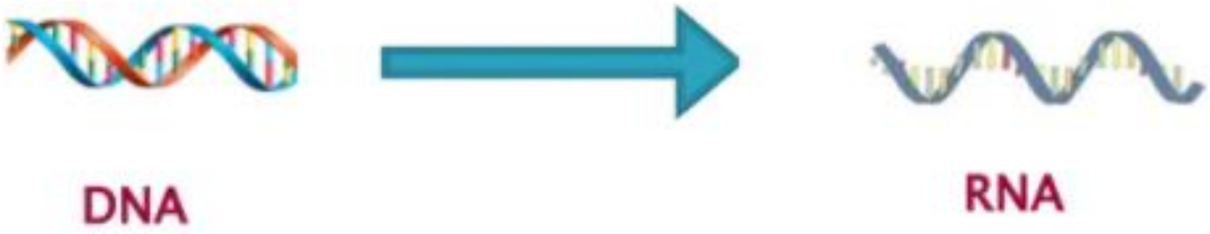
:TRANSCRIPTION

Definition

Cellular process in which RNA is synthesized using DNA as a template known as TRANSCRIPTION.



RNA

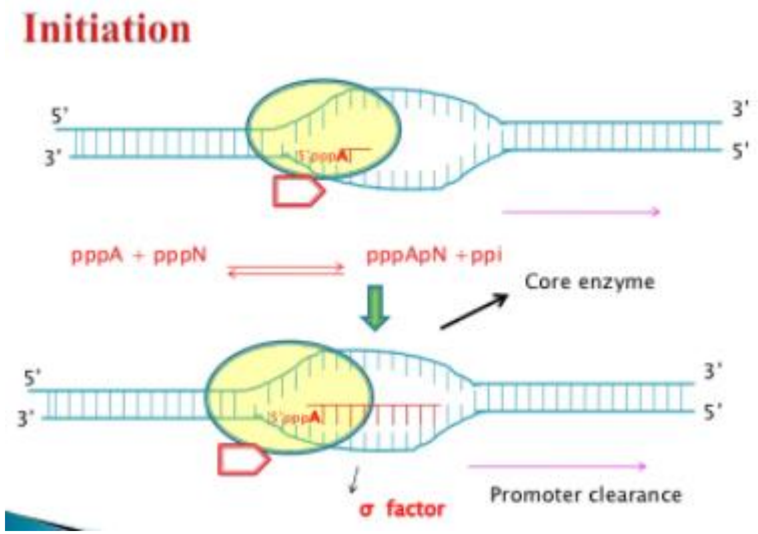
- Polymer of ribonucleotide held together by 3'→ 5' phosphodiester bridge & are single stranded.
- Is the only molecule known to function both in the storage & transmission of genetic information & in catalysis.
- All RNAs except the RNA genomes of certain viruses derived from information which is stored permanently in DNA.

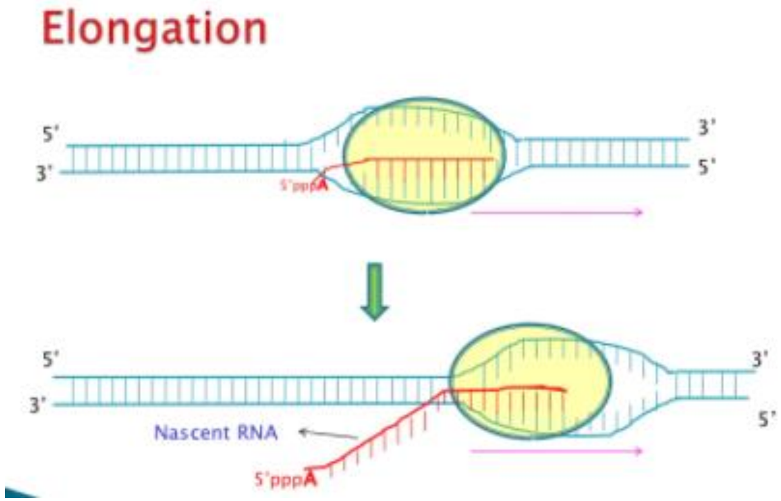
- Three major kinds of RNAs
- mRNA (5-10%)→ transfer information of gene to ribosome i.e. encodes the amino acids sequence .
- tRNA (10-20%) → reads codes on mRNA and transfers appropriate AA to mRNA.
- rRNA (60-80%) → constituents of ribosome.
- Many additional specialized RNAs which has catalytic activity or regulatory functions are present in the cell.

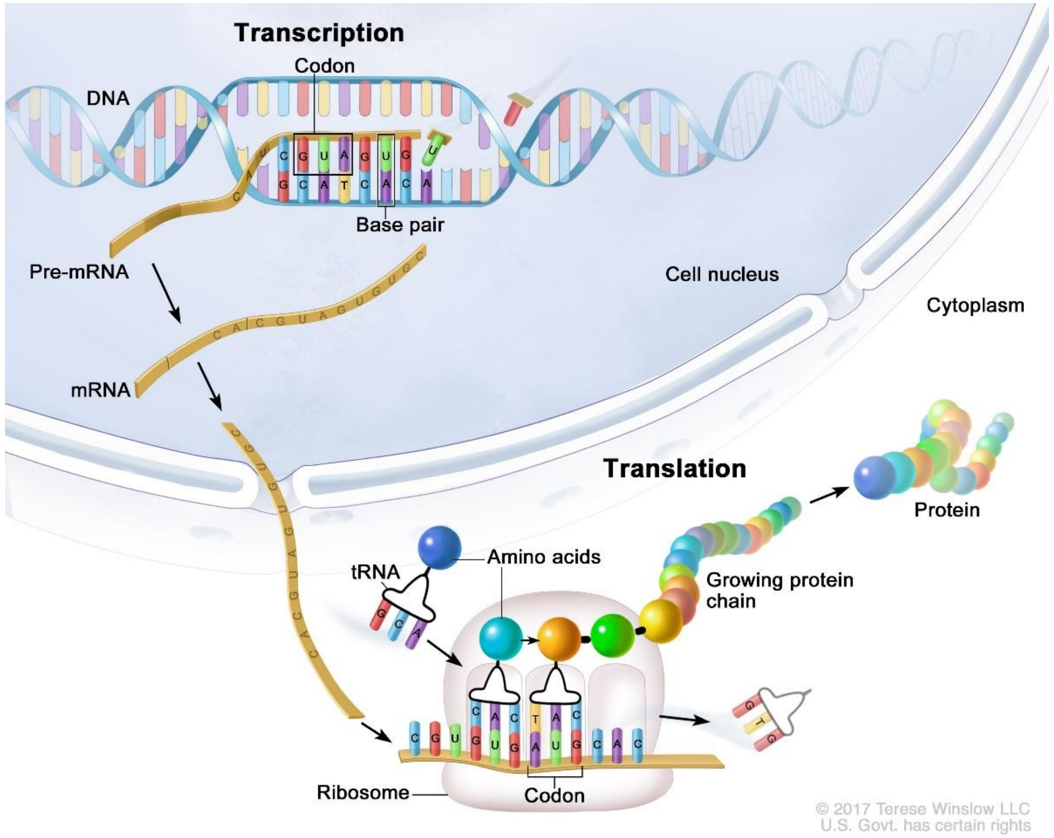
Transcription in Prokaryotes

Three stages

- Initiation phase: RNA-polymerase recognizes the **promoter** and starts the transcription.
- Elongation phase: the RNA strand is continuously growing.
- Termination phase: the RNA-polymerase stops synthesis and the nascent RNA is separated from the DNA template.







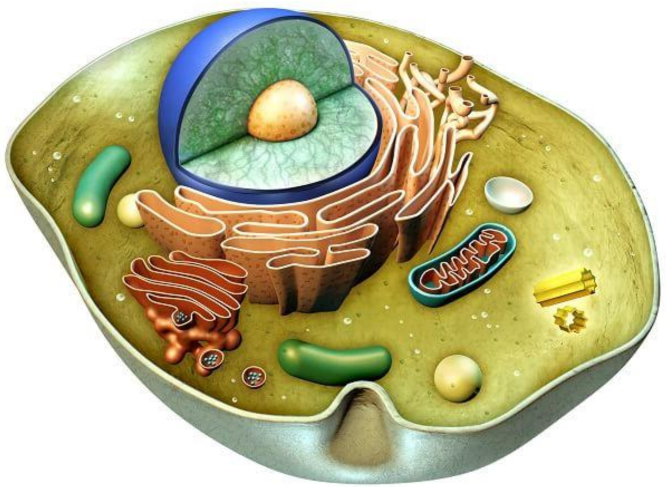
Differences between replication and transcription

	Replication	Transcription
Template	Both strand whole genome	single strand small portion of genome
Primer	yes	no
Enzyme	DNA polymerase	RNA polymerase
Product	dsDNA	ssRNA
Base pair	A-T, G-C	A-U, T-A, G-C
Proof reading	yes	no

CELL BIOLOGY 2

LECTURE 13

CELL DIVISIONS



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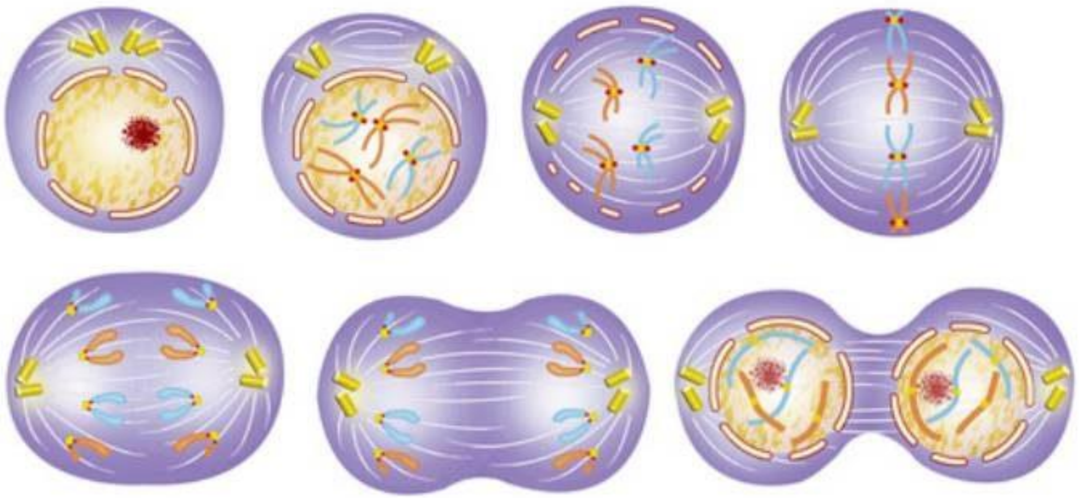
Growth— an increase in size or mass of a developing/ living system— is an irreversible process that occurs at all organizational levels. Often, it is difficult to define, because, it is. multifactorial, that is, growth embodies following three interacting growth patterns : (1) **auxetic growth**— an increase in cell mass or **auxesis** ; (2) **multiplicative growth—** an increase in cell number due to cell division; and (3) **accretionary growth**— growth due to accumulation of extracellular products (accretion means increase by addition on the surface of the material of same nature as that is already present, *e.g.*, the manner of growth of crystal). Generally, when rate of anabolism (*i.e.*, photosynthesis, protein synthesis, etc.) far exceeds the rate of catabolism (*i.e.*, respiration), the growth of protoplasm (*i.e.*, auxetic growth) takes place.

CELL CYCLE

- All cells are produced by divisions of pre-existing cell. Continuity of life depends on cell division. A cell born after a division, proceeds to grow by macromolecular synthesis, reaches a species-determined division size and divides. This cycle acts as a unit of biological time and defines life history of a cell. **Cell cycle** can be defined as the entire sequence of events happening from the end of one nuclear division to the beginning of the next. The cell cycle involves the following three cycles

- **1. Chromosome cycle.** In it **DNA synthesis** alternates with **mitosis** (or karyokinesis or nuclear division).
- **2. Cytoplasmic cycle.** In it **cell growth** alternates with **cytokinesis** (or cytoplasmic division).
- **3. Centrosome cycle.** Both of the above cycles require that the **centrosome** be inherited reliably
- and duplicated precisely in order to form the two poles of the mitotic spindle

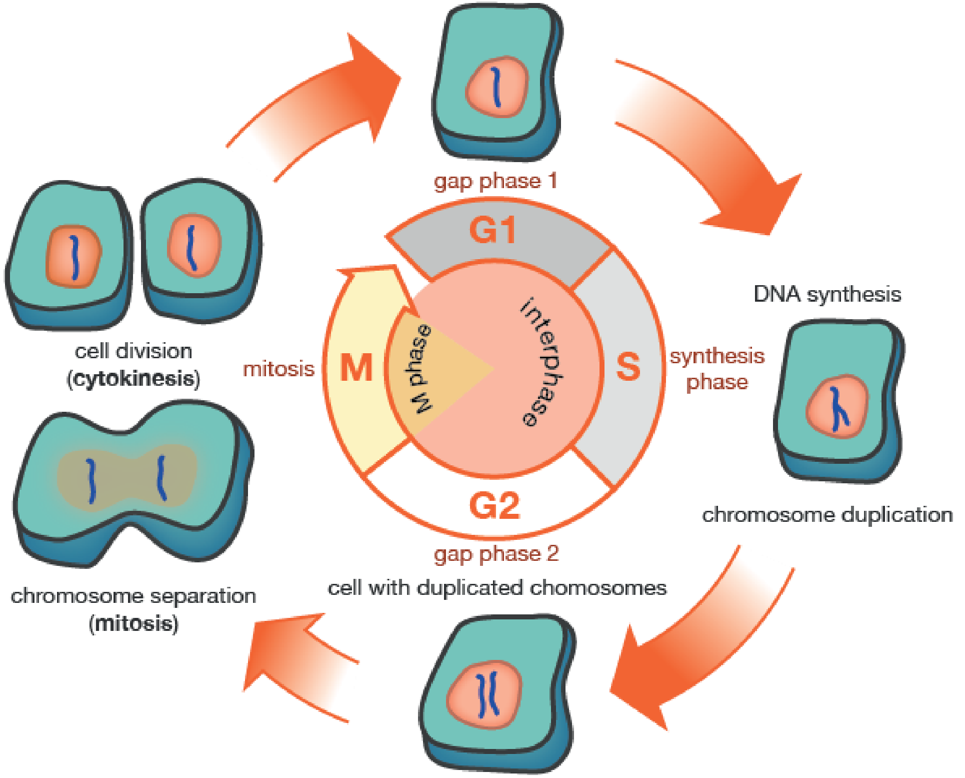


Howard and **Pelc** (1953) have divided cell cycle into four phases or stages : G_1, S, G_2 and M phase. The G_1 phase, S phase and G_2 phase are combined to from the classical **interphase**. **1. G_1 Phase.** After the M phase of previous cell cycle, the daughter cells begin G_1 of interphase of new cell cycle. G_1 is a resting phase. It is called **first gap phase**, since no DNA synthesis takes place during this stage; currently, G_1 is also called **first growth phase**, since it involves synthesis of RNA, proteins and membranes which leads to the growth of nucleus and cytoplasm of each daughter cell towards their mature size

2. S phase. During the S phase or **synthetic phase** of interphase, replication of DNA and synthesis of histone proteins occur. New histones are required in massive amounts immediately at the beginning of the S period of DNA synthesis to provide the new DNA with nucleosomes.

3. G_2 phase. This is a **second gap** or **growth phase** or resting phase of interphase. During G_2 phase, synthesis of RNA and proteins continues which is required for cell growth. It may occupy 10 to 20 per cent time of cell cycle. As the G_2 phase draws to a close, the cell enters the M phase.

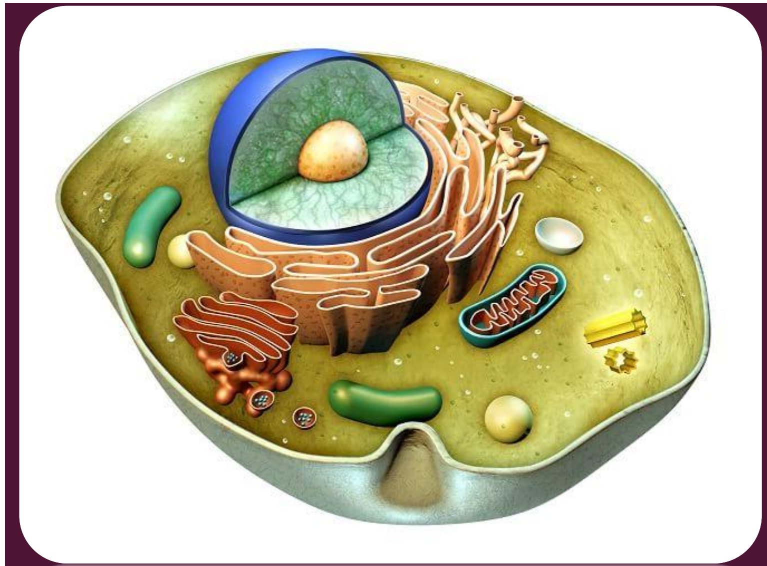
4. M phase or Mitotic phase. The mitosis (Gr., *mitos*=thread) occurs in the somatic cells and it is meant for the multiplication of cell number during embryogenesis and blastogenesis of plants and animals. Fundamentally, it remains related with the growth of an individual from zygote to adult stage.



CELL BIOLOGY 2

LECTURE 14

CELL DIVISIONS



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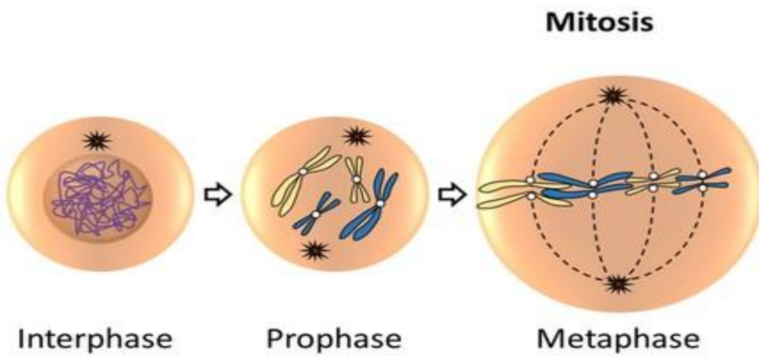
MITOSIS

1-Prophase:

- The appearance of thin-thread like condensing chromosomes marks the first phase of mitosis, called **prophase.** The cell becomes spheroid, more refractile and viscous.



2-Metaphase:

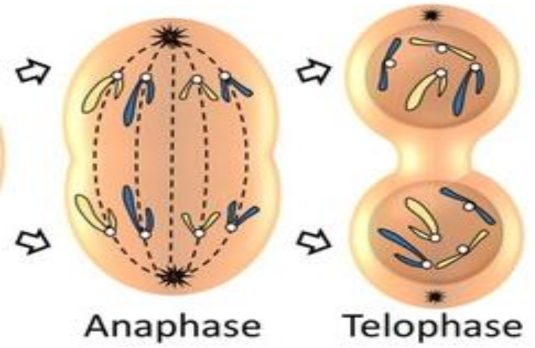
- During metaphase : the chromosomes are shortest and thickest. Their centromeres occupy the plane of the equator of the mitotic apparatus (a region known as the **equatorial** or **metaphase plate**. although the chromosomal arms may extend in any direction. At this stage the sister chromatids are still held together by centromere and the kinetochores of the two sister chromatids face opposite poles

3-Anaphase

- begins abruptly with the synchronous splitting of each chromosome into its sister chromatids, called **daughter chromosomes**, each with one kinetochore. Synchronous splitting of each centromere during prophase is evidently caused by an increase in cytosolic Ca2+
- **(i) Anaphase A**.
- **(ii) Anaphase B.**

4-Telophase

- The end of the polar migration of the daughter chromosomes marks the beginning of the telophase ; which in turn is terminated by the reorganization of two new nuclei and their entry into the G1 phase of interphase



MEIOSIS:

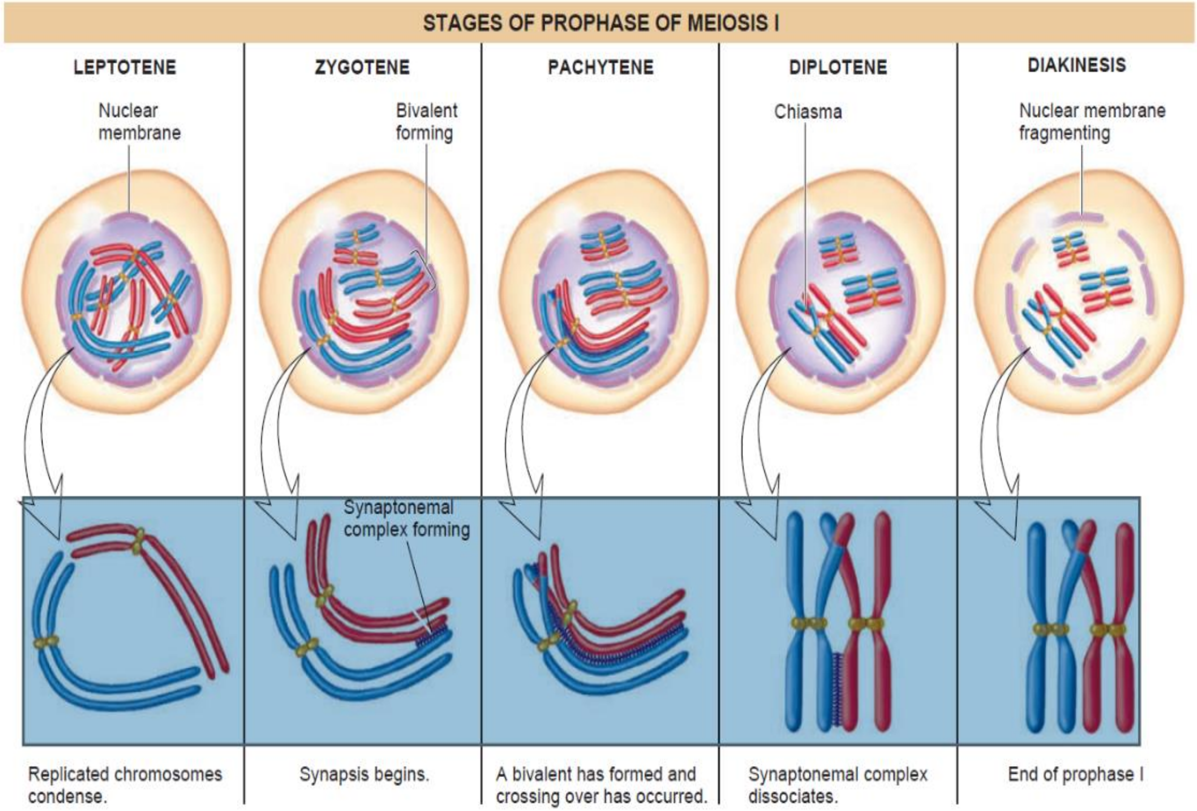
- Meiosis produces a total of four haploid cells from each original diploid cell. These haploid cells either become or give rise to gametes, which through union (fertilization) support sexual reproduction and a new generation of diploid organisms. The zygote undergoes reduction division (*i.e.*, meiosis) resulting in the formation of haploid spores In higher plants, however, the reproductive cycle includes a long dominant diploid and multicellular generation
- In both animals and plants, male and female gametes unite during fertilization to produce a **zgote** in which the diploid chromosome number is restored. In animals and simpler plants, the zygote matures to a new diploid organism. Thus, reproductive cycle includes alternation of two generations : haploid and diploid and involves meiosis.

MEIOSIS I

Prophase I

The first prophase is the longest stage of the meiotic division. It includes following substages :

1. **Proleptotene or Prolepto-nema**
2. **Leptotene or Leptonema**
3. **Zygotene or Zygonema.**
4. **Pachyteneor Pachynema**
5. **Diplotene or Diplonema**
6. **Diakinesis**



Metaphase I

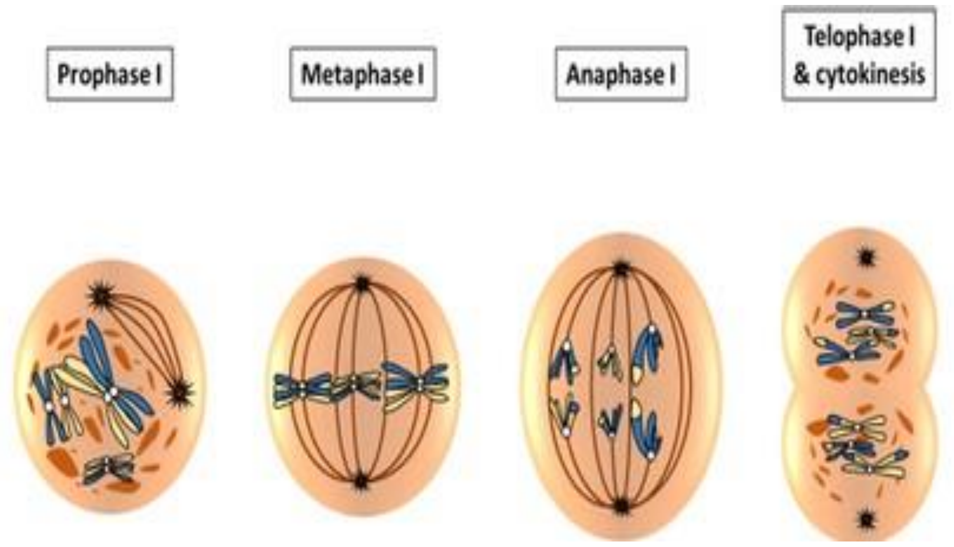
Metaphase I consists of spindle fibre attachment to chromosomes and chromosomal alignment at the equator. During metaphase I, the microtubules of the spindle are attached with the centromeres of the homologous chromosomes of each tetrad. The centromere of each chromosome is directed towards the opposite poles

Anaphase I

At anaphase I homologues are freed from each other and due to the shortening of chromosomal fibres or microtubules each homologous chromosome with its two chromatids and undivided centromere move towards the opposite poles of the cell

Telophase I

The arrival of a haploid set of chromosomes at each pole defines the onset of telophase I, during which nuclei are reassembled. The endoplasmic reticulum forms the nuclear envelope around the chromosomes and the chromosomes become uncoil.



MEIOSIS II:

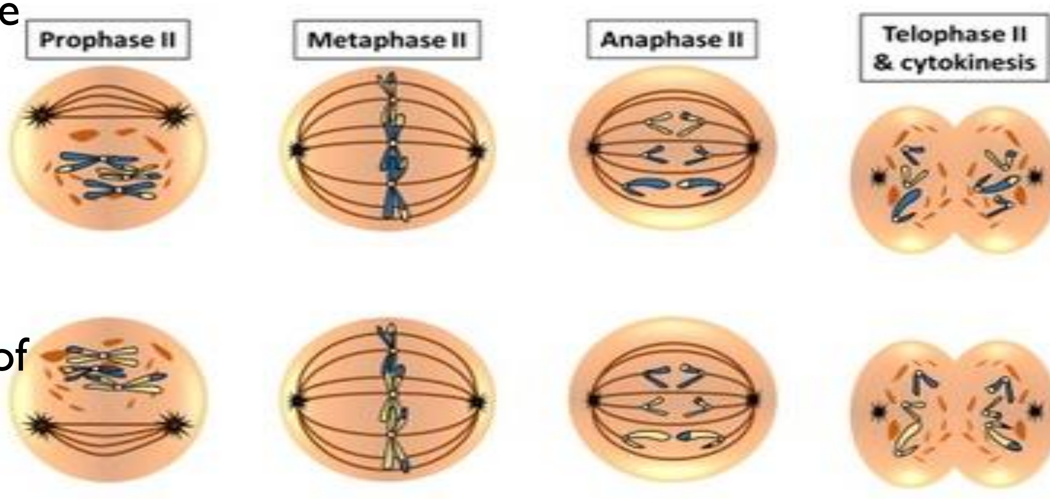
- **Prophase II**
- In the prophase second, each centriole divides into two and, thus, two pairs of centrioles are formed. Each pair of centrioles migrates to the opposite pole. The microtubules get arranged in the form of spindle at the right angle of the spindle of first meiosis.
- **Metaphase II**
- During metaphse II, the chromosomes get arranged on the equator of the spindle. The centromere divides into two and, thus, each chromosome produces two monads or daughter chromosomes. The microtubules of the spindle are attached with the centromere of the chromosomes.

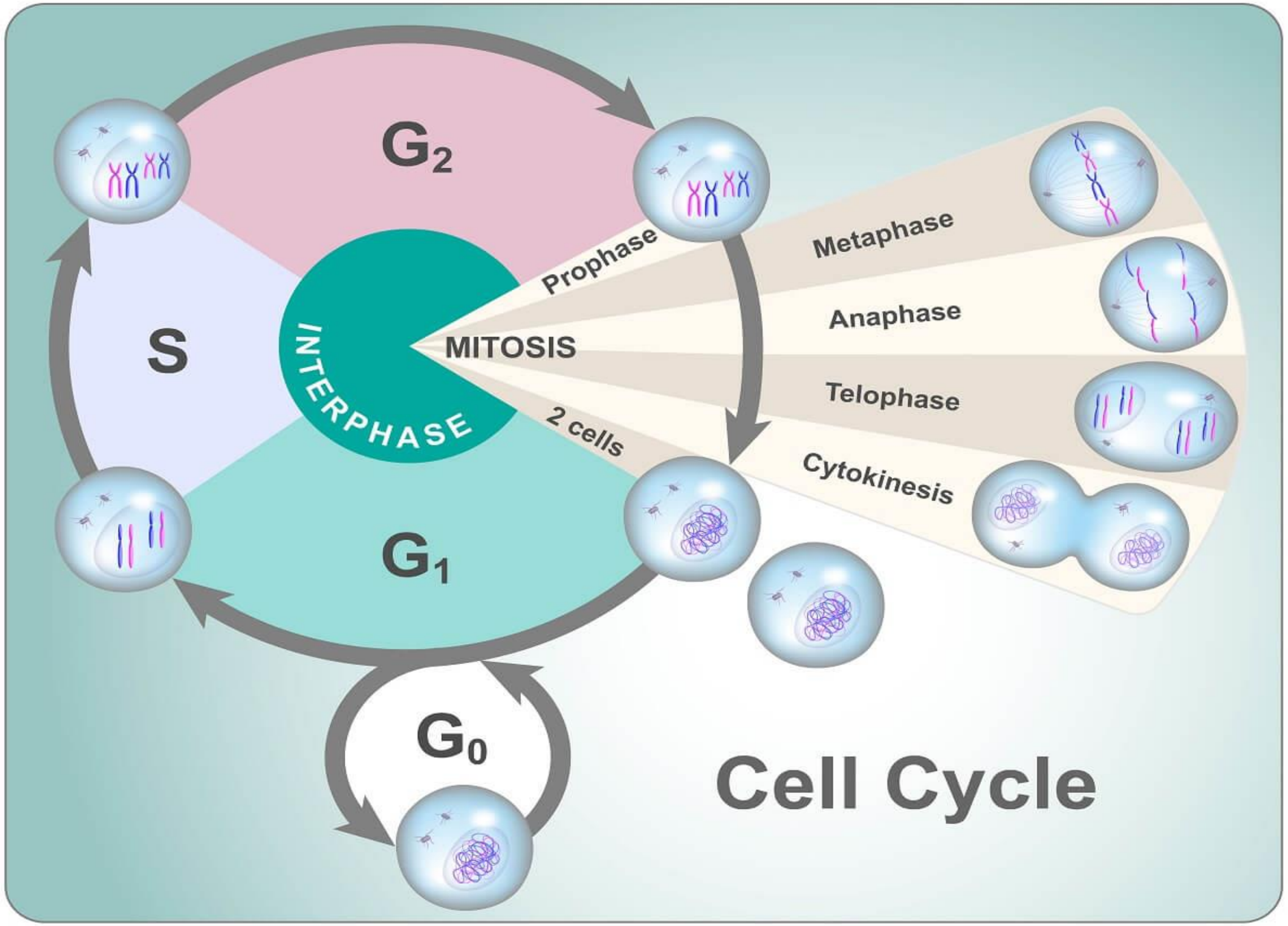
Anaphase II

The daughter chromosomes move towards the opposite poles due to the shortening of chromosomal microtubules and stretching of interzonal microtubules of the spindle

Telophase II

The chromatids migrate to the opposite poles and now known as chromosomes. The endoplas- mic reticulum forms the uclear envelope around the chromosomes and the nucleolus reappears due to synthesis of ribosomal RNA (rRNA) by rDNA and also due to accumulation of ribosomal proteins



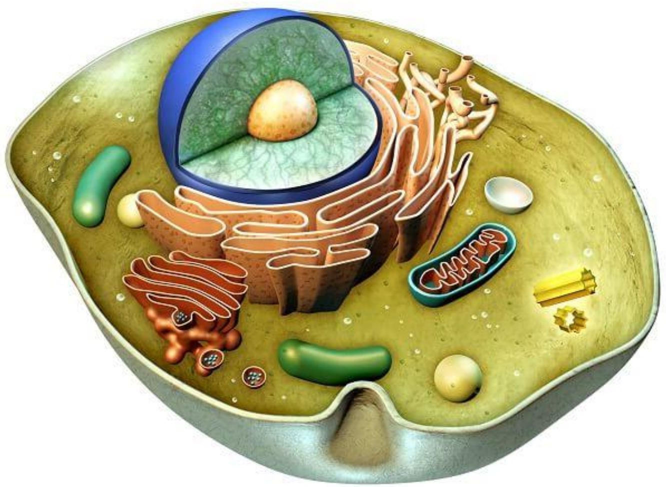


G_2
S
G_1
G_0
INTERPHASE
MITOSIS
Prophase
Metaphase
Anaphase
Telophase
Cytokinesis
2 cells
Cell Cycle

CELL BIOLOGY 2

LECTURE 15

ENZYMES



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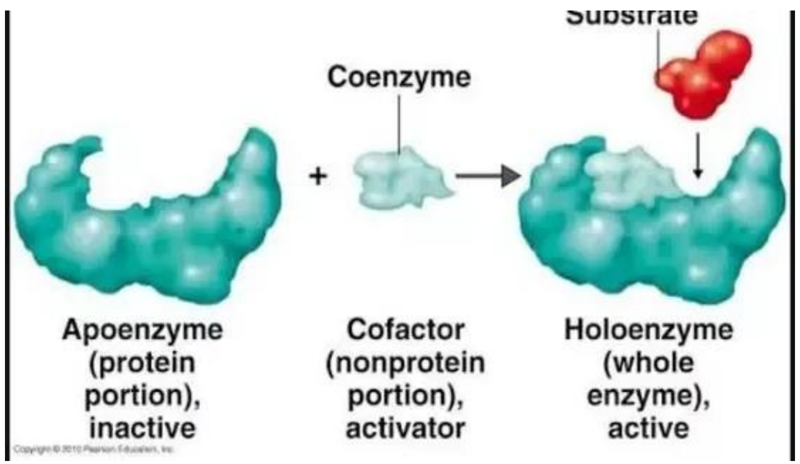
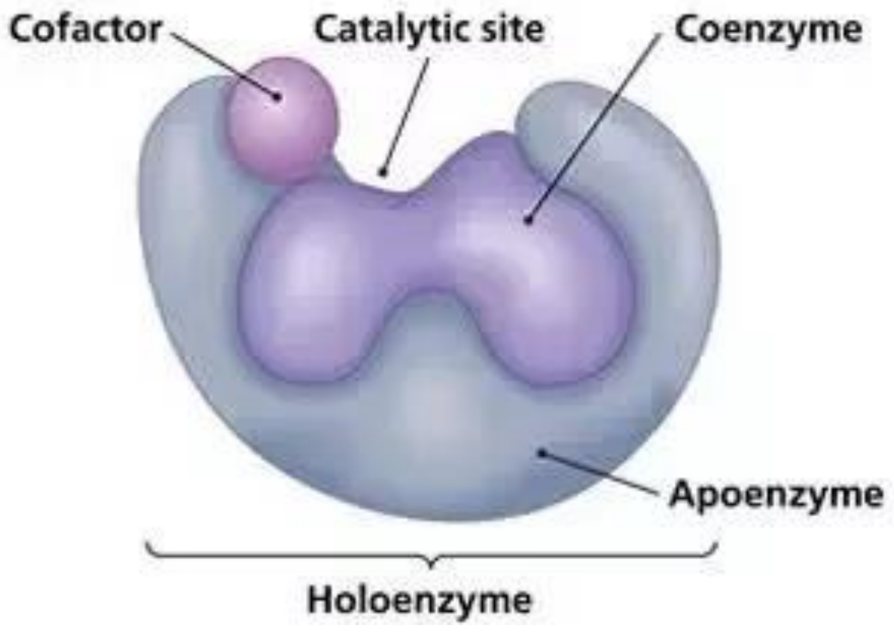
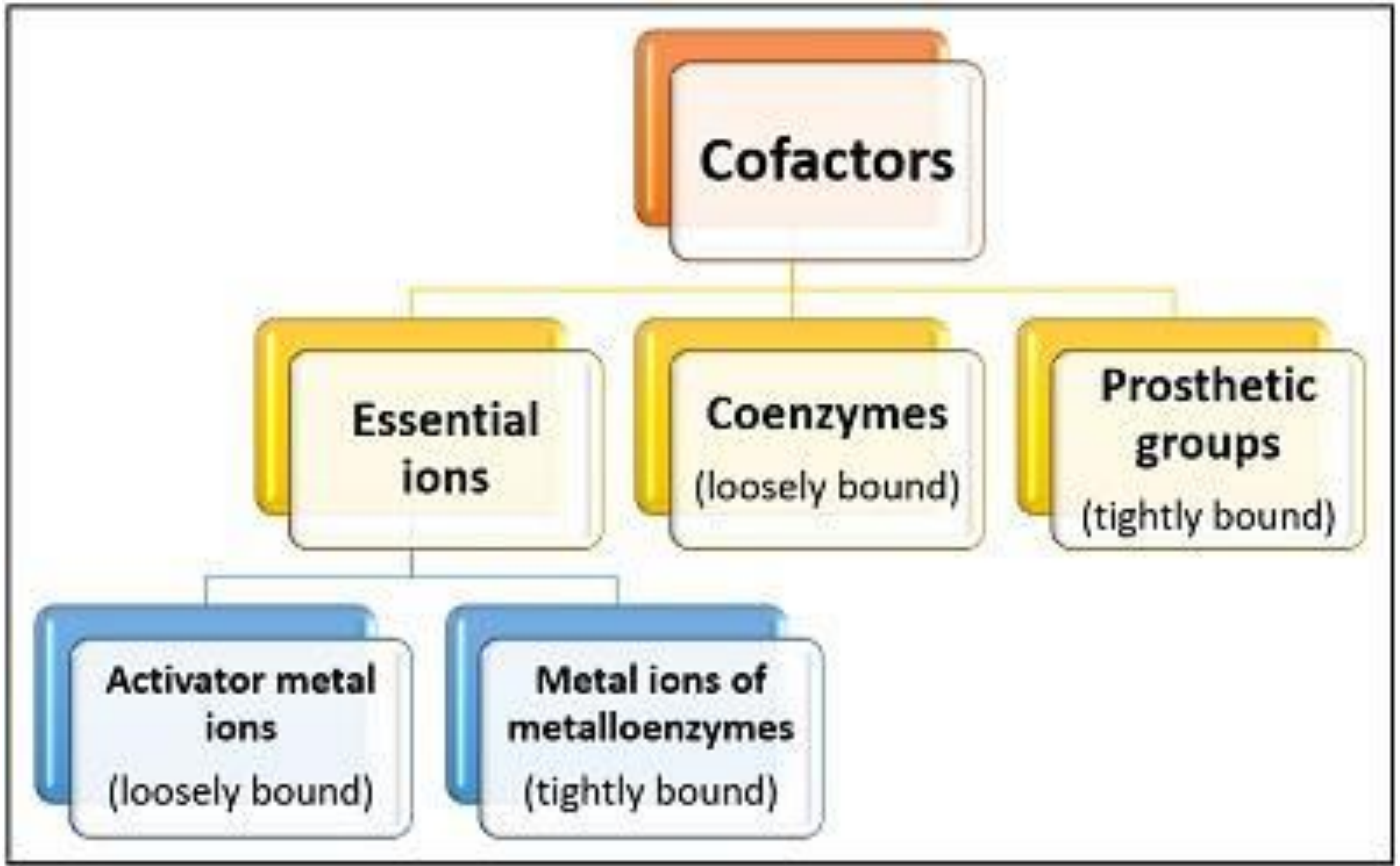
The cytoplasmic matrix and many cellular organelles contain very important organic compounds known as the **enzymes**. The word enzyme (Greek. "in yeast") had been proposed by **Kuhne** in 1878. The enzymes are the specialized proteins and they have the capacity to act as catalysts in chemical reaction. Like the other catalysts of chemical world, the enzymes are the catalysts of the biological world and they influence the rate of a chemical reaction, while themselves remain quite unchanged at the end of the reaction. The substance on which the enzymes act is known as **substrate**. The enzymes play a vital role in various metabolic and biosynthetic activities
of the cell such as synthesis (anabolism) of DNA, RNA and protein molecules and catabolism of carbohydrates, lipids, fats and other chemical substances.

An **enzyme** is a protein that functions as a biological **catalyst** – a substance that speeds up a chemical reaction without being changed by the reaction



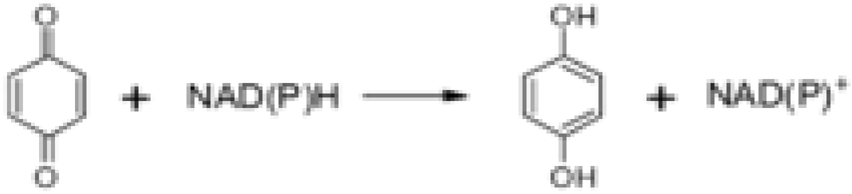




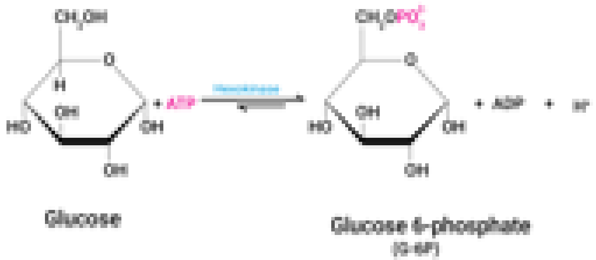
Types of Cofactors

ENZYME TYPES

- **1. Oxireductases.** The enzymes catalyzing the oxidation and reduction reaction of the cell are known as oxireductases. These enzymes transfer the electrons and hydrogen ions from the substrates, *e.g.*, hydrogenases or reductases, oxidases, oxygenases and peroxidases



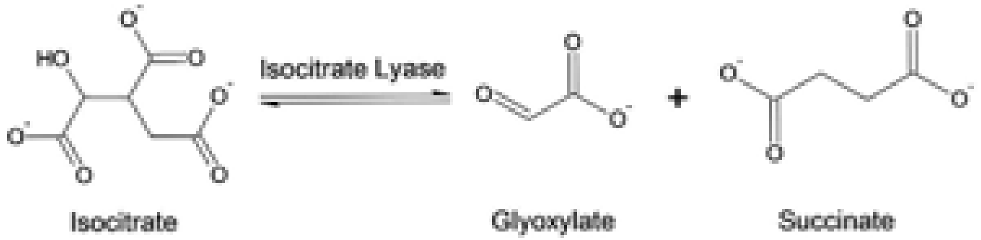
- **2. Transferases.** The enzymes which transfer following groups from one molecule to other are known as transferases : one carbon, aldehydic or ketonic residues, acyl, glycosyl, alkyl, nitrogenous, phosphorus containing groups and sulphur containing groups.



3. Hydrolases. These enzymes hydrolyse a complex molecule into two compounds by adding the element of the water across the bond which is cleaved. These enzymes act on the following bonds– ester, glycosyl, ether, peptide, other C–N bonds, acid anhydride, C–C, halide and P–N bonds. Certain important hydrolase enzymes are the proteases, esterases, phosphatases, nucleases and phosphorylases

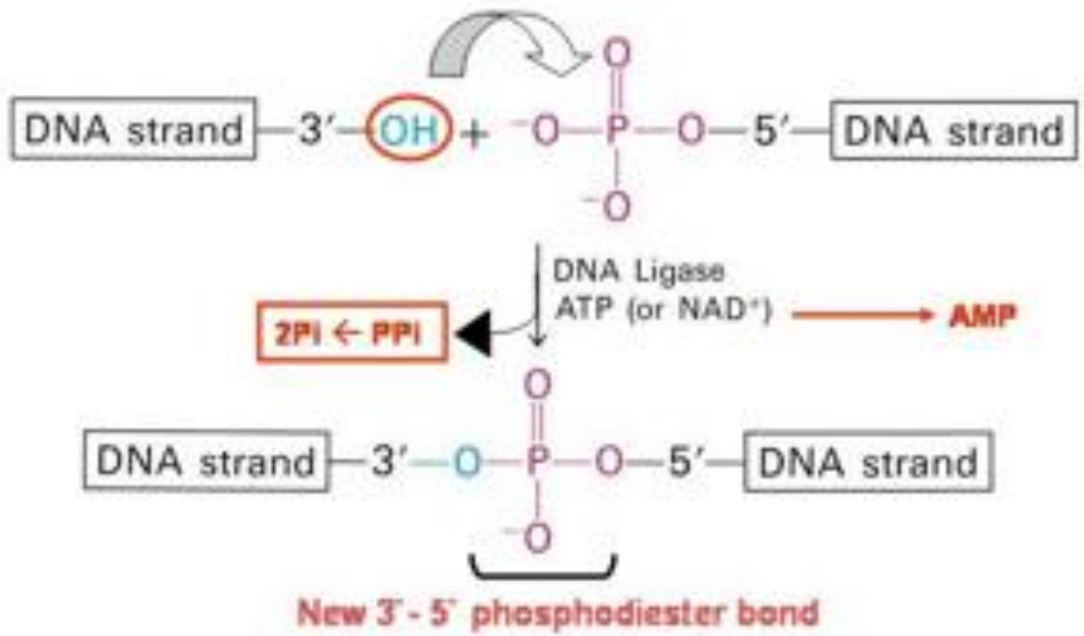
$$\underset{\text{Sucrose}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow[\text{Hydrolase enzyme (Sucrase)}]{H^+} \underset{\text{(Glucose)}}{C_6H_{12}O_6} + \underset{\text{(Fructose)}}{C_6H_{12}O_6}$$

4. Lysases. The lysase enzymes add or remove group to or from the chemical compounds containing the double bonds. The lysases act on C–C, C–O, C–N, C–S and C–halide bonds.



5. Isomerases. These enzymes catalyse the reaction involving in the isomerization or intramolecular rearrangements in the substrates, *e.g.*, intramolecular oxidoreductases, intramolecular transferases, intramolecular lysases, cis-trans-isomerases, racemases and epimerases.

6. Ligases or synthetases. These enzymes catalyze the linkage of the molecules by splitting a phosphate bond. The synthetase enzymes form C–O, C–S, C–N and C–C bonds.



ENZYME HYPOTHESIS

- **Lock and key model**
- Enzymes are folded into complex shapes that allow smaller molecules to fit into them. The place where these molecules fit is called the **active site**.
- In the **lock and key model**, the shape of the active site matches the shape of its **substrate** molecules. This makes enzymes highly **specific** – each type of enzyme can catalyse only one type of reaction (or just a few types of reactions).
- The diagram shows how this works. In this example, the enzyme splits one molecule into two smaller ones, but other enzymes join small molecules together to make a larger one.