Lectures of Cell Biology

First Stage

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Introduction to Cell Biology

(The Cell Theory: A Brief History)

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What's Cell Biology?

Cell Biology is a branch of biology focused on the study of cell structure and function, on how cells form and divide, and how they differentiate and specialize.

Cell Biology **is** the study of the **activities, functions, properties, and structures of cells.**

The microscopes ....**1600s by** Antony van Leeuwenhoek.

In 1665, Robert Hooke .....**"cells".**

In 1670s, van Leeuwenhoek ....**discovered bacteria and protozoa.**

Later advances in lenses, microscope construction, and staining techniques.

The Cell Theory:

By the late 1830s, …..cell theory

Matthias Schleiden and Theodor Schwann

The unified cell theory states three parts:

1. states all organisms are made of cells.
2. states that cells are the basic units of life
3. new cells arise from existing cells.

Rudolf Virchow later made important contributions to this theory.

"All cells only arise from pre-existing cells".

The generally accepted portions of the modern Cell Theory are as follows:

1. The cell is the fundamental unit of structure and function in living things.

2. All organisms are made up of one or more cells.

3. Cells arise from other cells through cellular division.

The expanded version of the cell theory can also include:

1. Cells carry genetic material passed to daughter cells during cellular division

2. All cells are essentially the same in chemical composition

3. Energy flow (metabolism and biochemistry) occurs within cells

What is a cell?

All living things are made from one or more cells.

A cell is the simplest unit of life

Cells are structural units that make up plants and animals

There are many single celled organisms (**unicellular**) organism performs all the necessary functions to keep the organism alive. All species of bacteria and archaea are single-celled organisms.

large organisms like humans are made from many trillions of cells (**multicellular**) that work together to keep the organism alive.

General Structure and Chemistry of the Cell:

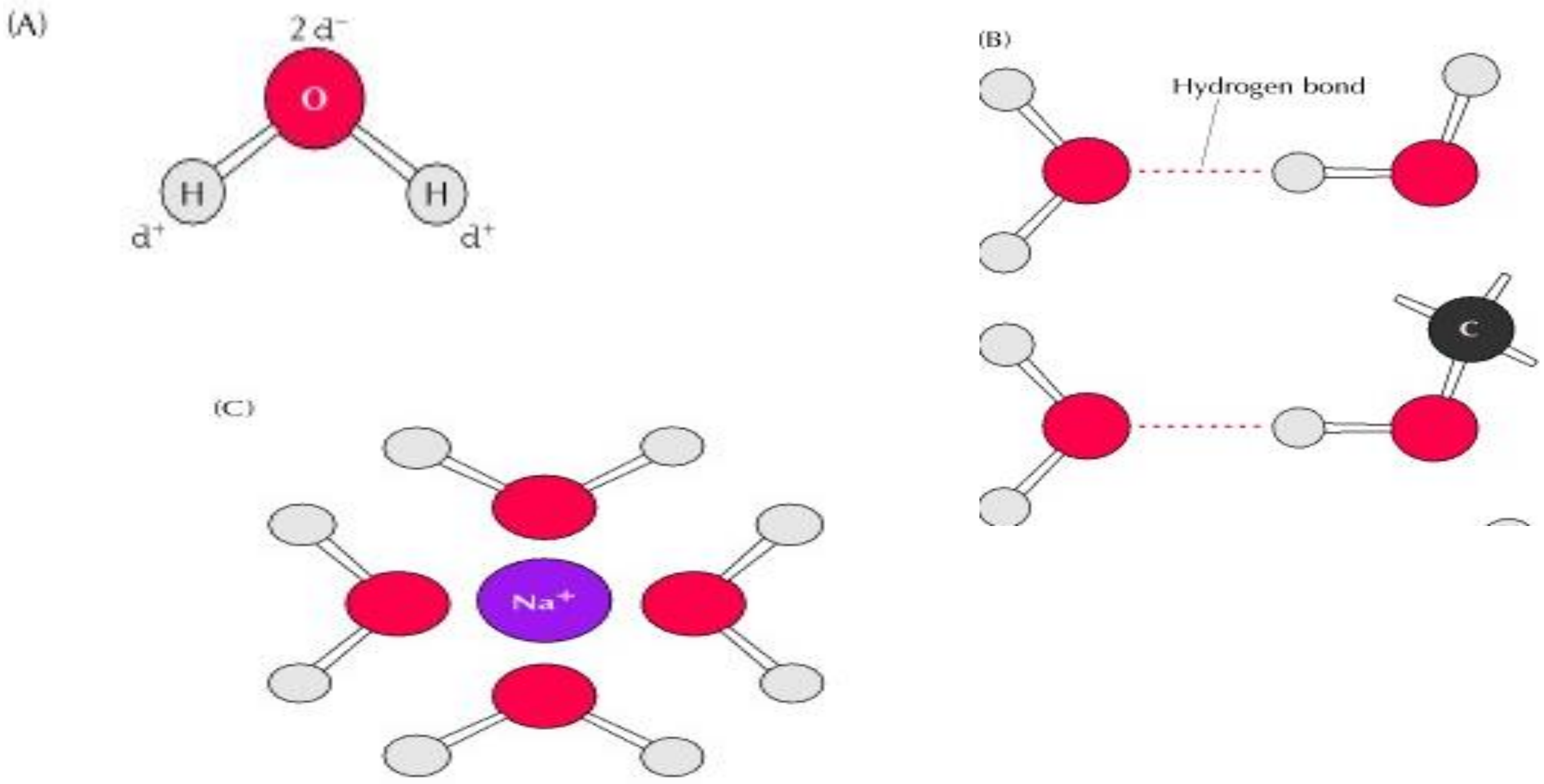
Cells are composed of water, inorganic ions, and carbon-containing (organic) molecules.

Water 70% or more of total cell mass.

water is a polar molecule.

(hydrophilic).

(hydrophobic).



(Figure.1): (A) Water is a polar molecule, with a slight negative charge (δ^-) on the oxygen atom and a slight positive charge (δ^+) on the hydrogen atoms. Because of this polarity, water molecules can form hydrogen bonds (dashed lines) either with each other or with other polar molecules (B), in addition to interacting with charged ions (C).

Physical Properties of Water

1. Water is a liquid at standard temperature and pressure, but is also found in nature in its solid (frozen) and gaseous phases.

2. Boiling point is 100° Celsius and its freezing point is 0°C.

3. Water has a high heat capacity.

4. Water is a universal solvent.

Biological Properties of Water

1. In the body, the major components of cells such as proteins, DNA and organelles are all dissolved in water .

2. Water transport into and out of the cell is strictly regulated.

3. Water's high heat capacity insulates our bodies from drastic temperature changes.

4. Water's chemical and physical properties contribute to all life on Earth at the planetary, organismal, cellular, and molecular levels.

The Macromolecules of the Cell

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large molecules are necessary for life.

These macromolecules are built from different combinations of smaller organic molecules.

1-Carbohydrates

2-Proteins

3- Lipids

4- Nucleic acids

1-Carbohydrates:

Pure carbohydrates have the formula $(CH_2O)_n$.

n is the number of carbons in the molecule

the ratio of carbon to hydrogen to oxygen is 1:2:1

Carbohydrates are classified into three subtypes:

monosaccharides,

disaccharides,

polysaccharides

A-Monosaccharides:

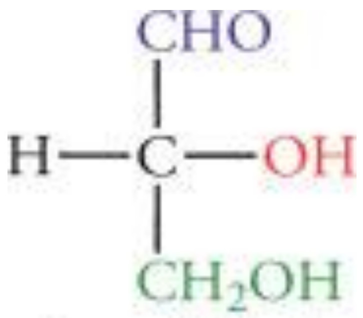
1. Monosaccharides (mono- = “one”; sacchar- = “sweet”) are simple sugars

2. the number of carbons usually ranges from three to seven.

3. Most monosaccharide names end with the suffix -ose

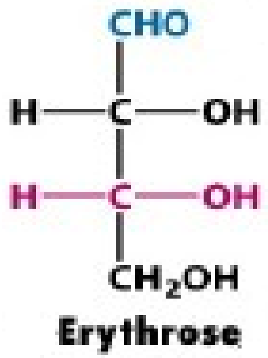
Depending on the number of carbons in the sugar:

Trioses (three carbons) like **glyceraldehyde**

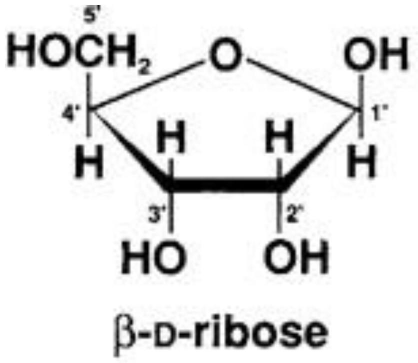


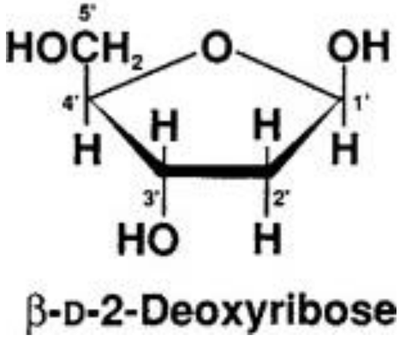
glyceraldehyde

Tetrose(four carbons) like erythrose.



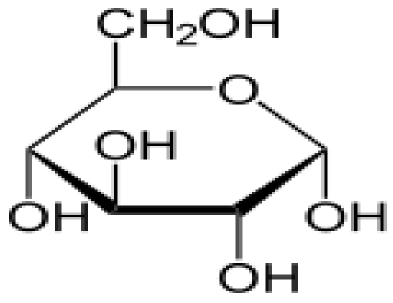
Pentose (five carbons) such as ribose and deoxyribose





Hexose (six carbons) like glucose

used as a basic source of energy by most heterotrophic cells

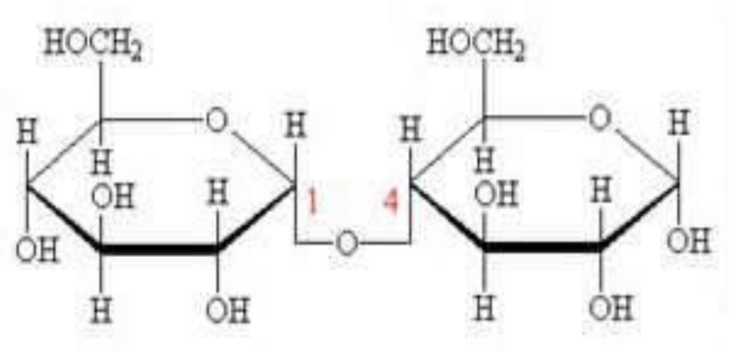


B-Disaccharides

Disaccharides (di = “two”) form when two monosaccharides connected by a glycosidic bond.

Lactose consisting of glucose and galactose.

Maltose(malt sugar), is formed of two glucose molecules.



Sucrose(table sugar), is composed of glucose and fructose

C-Polysaccharides

polysaccharide (poly- = “many”)

A long chain of monosaccharides linked by glycosidic bonds

The chain may be branched or unbranched

it may contain different types of monosaccharides

The molecular weight may be 100,000 daltons or more depending on the number of monomers joined.

Starch, glycogen, cellulose, and chitin are primary examples of polysaccharides.

Starch is the stored form of sugars in plants and is made up of a mixture of amylose and amylopectin (both polymers of glucose).

Glycogen is the storage form of glucose in humans and other vertebrates and is made up of monomers of glucose.

Glycogen is the animal equivalent of starch and is a highly branched molecule usually stored in liver and muscle cells.

Cellulose is made up of glucose monomers that are linked by β 1-4 glycosidic bonds.

Functions of Carbohydrates:

1-Living organisms use carbohydrates as a source of energy.

2-Serve as energy stores, fuels. It is stored as glycogen in animals and starch in plants.

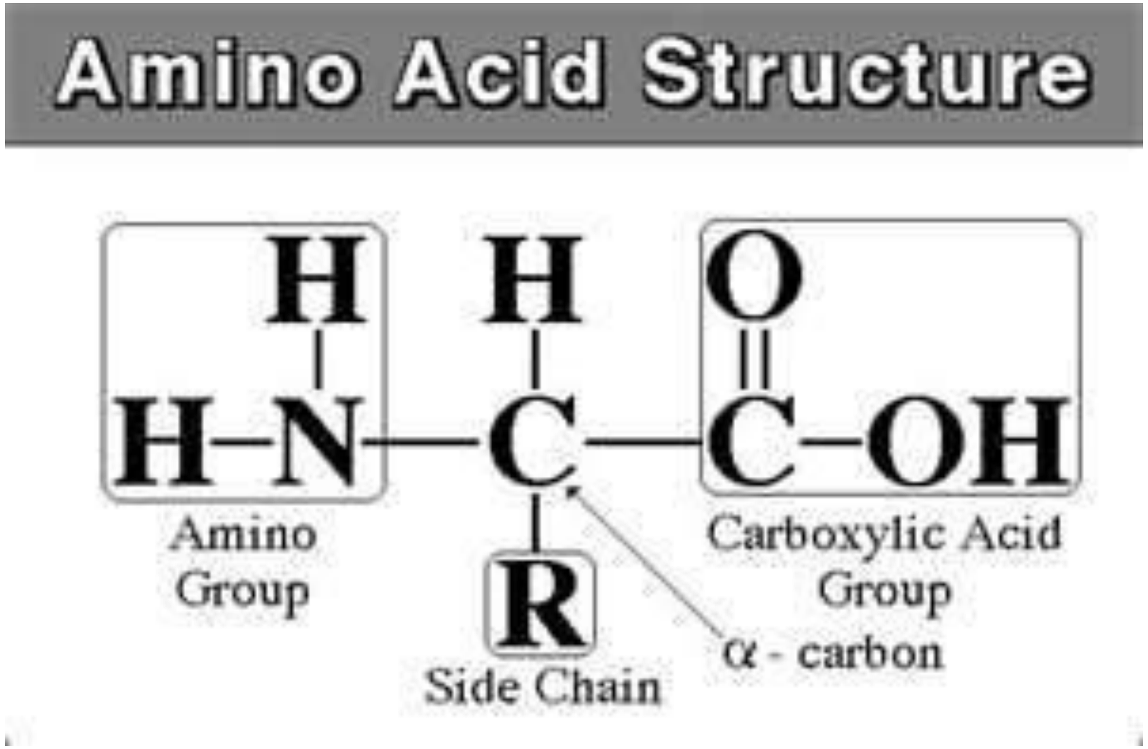
3-They form structural and protective components, like (cellulose) in the cell wall of plants and (chitin, structural elements in the cell walls of animals.

4-Carbohydrates are intermediates in the biosynthesis of fats and proteins.

5-Formation of the structural framework of RNA and DNA.

2-Proteins:

The building blocks of proteins are amino acids



There are **20** amino acids that function as building blocks of proteins. **Nine** of these amino acids are considered :

Essential—they must be consumed in the diet they are: (histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine).

Non-essential amino acids, meaning they can be synthesized in sufficient quantities in the body. These five are (alanine, aspartic acid, asparagine, glutamic acid, and serine).

Conditional amino acids: being essential only at certain life stages or in certain disease states. They include (arginine, cysteine, glutamine, glycine, proline, and tyrosine)

Within a protein, multiple amino acids are linked together by **peptide bonds**, thereby forming a long chain. All proteins are made up of one or more chains of amino acids (polypeptide chains).

Classification of Proteins

(a) Simple proteins

On hydrolysis they yield only the amino acids and occasional small carbohydrate compounds. albumins, globulins, glutelins, albuminoids, histones and protamines.

(b) A conjugated protein

is a protein that functions in interaction with other (non-polypeptide)chemicalgroups. Lipoproteins, glycoproteins, Nucleoproteins, phosphoproteins, hemoproteins, metalloproteins, phytochromes, cytochromes, and chromoproteins

(c) Derived proteins:

These are proteins derived from simple or conjugated proteins by physical or chemical means. denatured proteins and peptides.

Functions of proteins

1-Antibodies

2-Contractile Proteins

3-Enzymes

4- Hormones

5- Structural proteins

6- Storage proteins

7- Transport proteins

The Macromolecules of the Cell

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3-Lipids:

compounds that are insoluble in water but soluble in organic solvents

Functions of Lipids:

1. Acting as structural components of cell membranes.
2. Serving as energy storage sources.
3. They also provide insulation to the body.
4. Act as primary compounds for some vitamins and hormones.
5. It is considered a source of essential fatty acids.

Types of Lipids

Simple Lipids

1. **Fats:** Esters of fatty acids with glycerol. Oils are fats in the liquid state.

2. **Waxes**: Esters of fatty acids with higher molecular weight monohydric alcohols.

Complex Lipids

1. **Phospholipids**: containing a phosphoric acid residue in addition to fatty acids and alcohol.

2. **Glycolipids:** containing a fatty acid, sphingosine, and carbohydrate.

3. **Other complex lipids**: sulfolipids and amino lipids. Lipoproteins may also be placed in this category

Derived Lipids

These include fatty acids, glycerol, steroids, other alcohols, fatty aldehydes, hydrocarbons, lipid-soluble vitamins, and hormones.

These compounds are produced by the hydrolysis of simple and complex lipids.

Fatty Acids:

Fatty acids are carboxylic acids (or organic acid), usually with long chains, either unsaturated or saturated.

Saturated fatty acids: Lack of carbon-carbon double bonds indicates that the fatty acid is saturated.

Unsaturated fatty acid: is indicated when a fatty acid has more than one double bond.

4. Nucleotides

is an organic molecule that is the building block of nucleic acids **DNA &RNA**

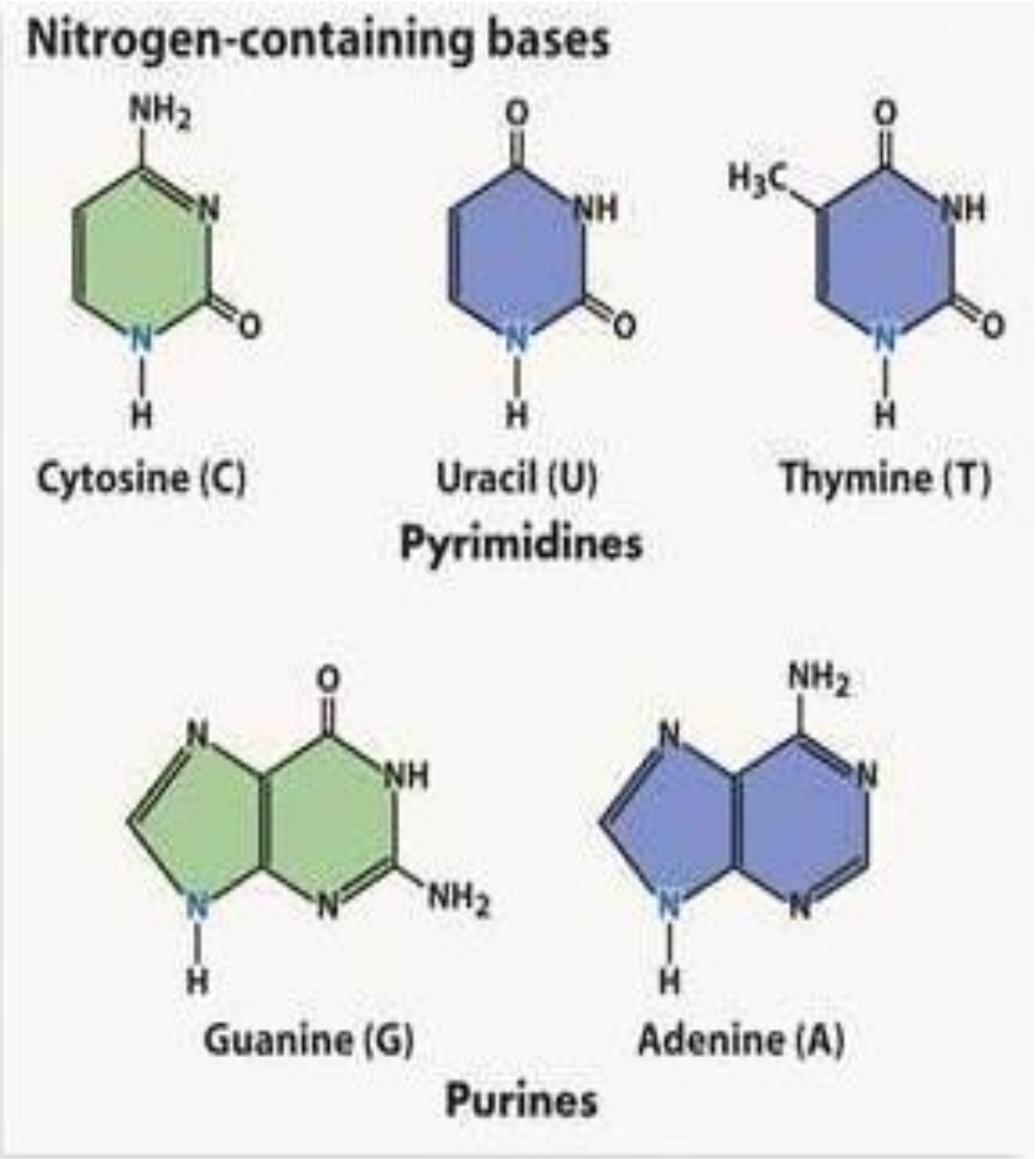
A nucleotide is made up of three parts

1. Nitrogenous base
2. Pentose sugar
3. One or more phosphate groups

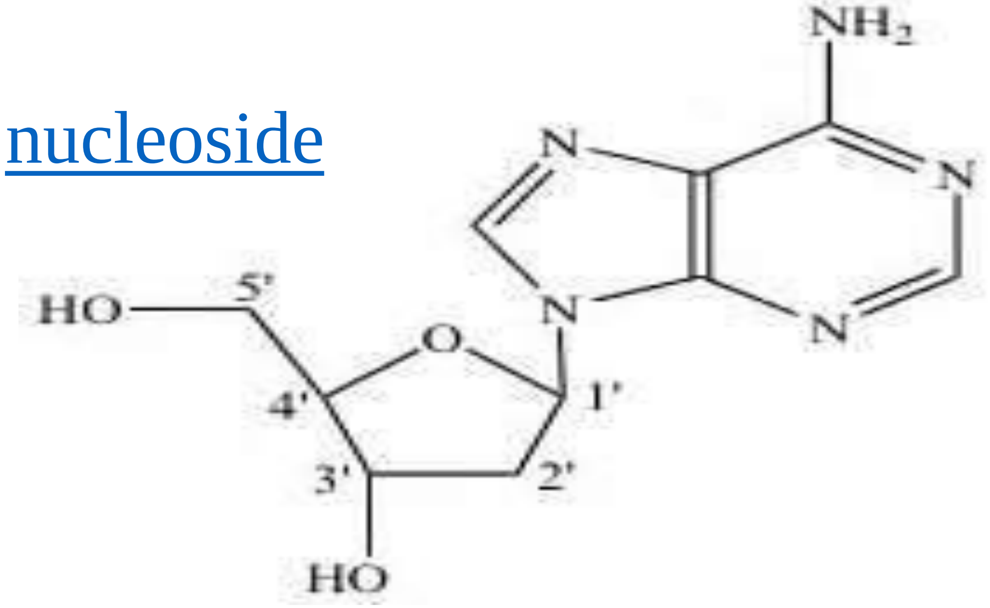
The four nitrogenous bases in DNA are adenine, cytosine, guanine, and thymine.

RNA contains uracil, instead of thymine.

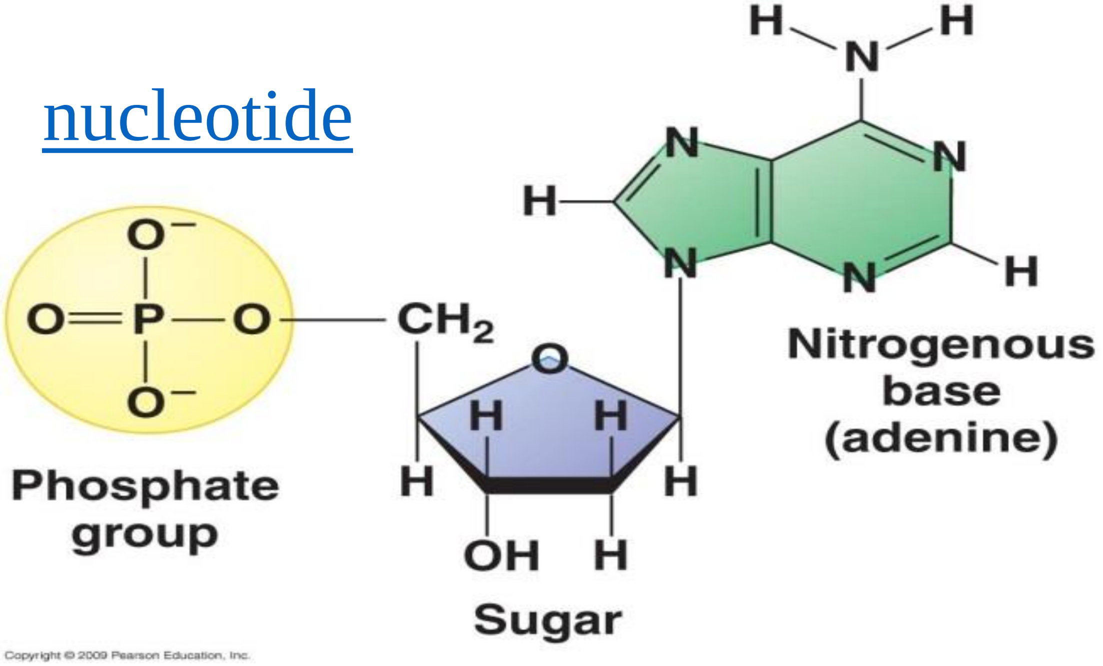
The pentose sugar in DNA (2′-deoxyribose) differs from the sugar in RNA (ribose).



nucleoside



nucleotide



Functions of nucleotides

1-They are the building block **of (DNA) and** (**RNA).**

2- Play a central role in metabolism .

3- They provide chemical energy in the form of adenosine triphosphate (ATP) .

4- Are participate in cell signaling (cyclic guanosine monophosphate or cGMP and cyclic adenosine monophosphate or cAMP).

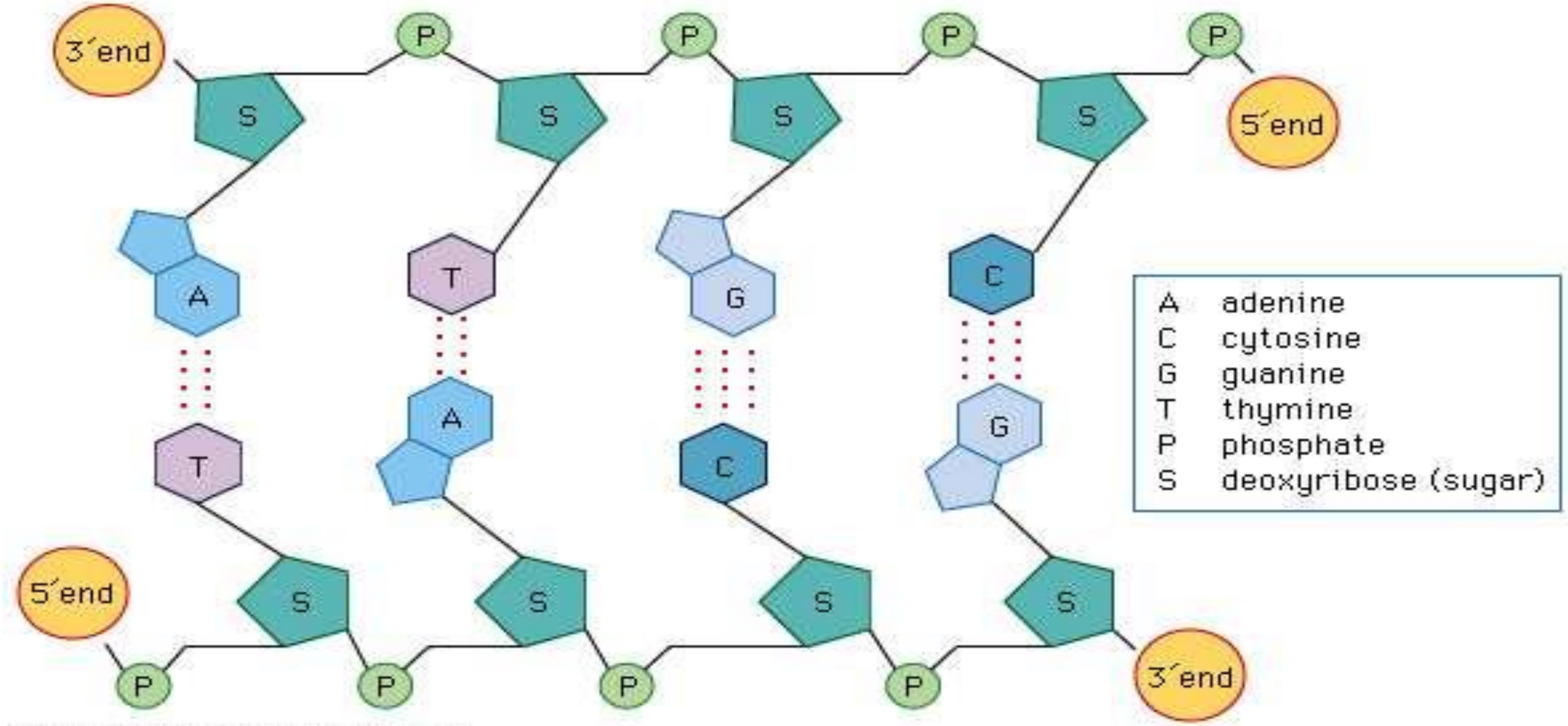
5- Are incorporated into important cofactors of enzymatic reactions (e.g. coenzyme A, FAD, FMN, NAD, and $NADP^+$).

Nucleic acids

DNA and RNA are long chains of repeated nucleotides

DNA nitrogen-containing bases (A, T,G and C)

A always pairs with T through two hydrogen bonds, and G always pairs with C through three hydrogen bonds



Ribonucleic Acid (RNA)

RNA is a single-stranded nucleic acid polymer of the four nucleotides A, C, G, and U.

Types of RNA

1-Messenger RNA (mRNA)

2-Ribosomal RNA (rRNA)

3-Transfer RNA (tRNA)

Lecture 4

Types of Cells

Cell is the basic structural and, fundamental unit of life. Various types of cells perform different functions. Based on cellular structure, there are two types of cells:

- **Prokaryotes**
- **Eukaryotes**

What is a Prokaryotic Cell?

Prokaryotic cells are single-celled microorganisms known to be the earliest on earth. Prokaryotes include Bacteria and Archaea. The photosynthetic prokaryotes include cyanobacteria that perform photosynthesis.

Characteristics of Prokaryotic Cell

Prokaryotic cells have different characteristic features as mentioned below:

1. They lack a nuclear membrane.
2. Mitochondria, Golgi bodies, chloroplast, and lysosomes are absent.
3. The genetic material is present on a single chromosome.
4. The cell wall is made up of carbohydrates and amino acids.
5. The plasma membrane acts as the mitochondrial membrane carrying respiratory enzymes.
6. They divide asexually by binary fission. The sexual mode of reproduction involves conjugation.

Examples of Prokaryotic Cells

The examples of the prokaryotic cells are mentioned below:

1-Bacterial Cells (Fig.1)

These are unicellular organisms found everywhere on earth from soil to the human body.

They have different shapes and structures.

The cell wall is composed of peptidoglycan that provides structure to the cell wall.

Bacteria have some unique structures such as pili, flagella and capsule.

They also possess extrachromosomal DNA known as plasmids.

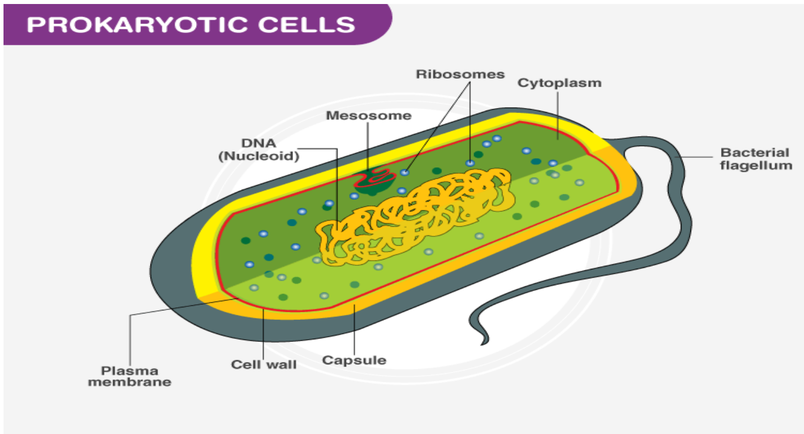


Figure 1: Bacterial Cell

2- Blue-green algae(Cyanobacteria)

Cyanobacteria are a group of photosynthetic bacteria, some of which are nitrogen-fixing, that live in a wide variety of moist soils and water either freely or in a symbiotic relationship with plants or lichen-forming fungi. They range from unicellular to filamentous and include colonial species.

Each individual cell (each single cyanobacterium) typically has a thick, gelatinous cell wall. They lack flagella. Many of the multicellular filamentous forms of *Oscillatoria* are capable of a waving motion. ***Nostoc*** is a genus of cyanobacteria found in various environments that forms colonies composed of filaments of moniliform cells in a gelatinous sheath (Fig.2).

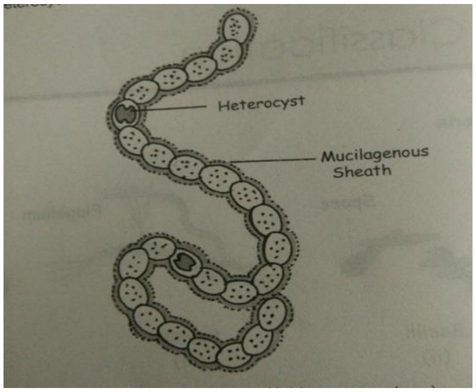


Figure 2 : ***Nostoc***

- **Eukaryotic Cell**

Eukaryotes are organisms made up of cells that possess a membrane-bound nucleus (that holds DNA in the form of chromosomes) as well as membrane-bound organelles. Eukaryotic organisms may be multicellular or single-celled organisms. All animals are eukaryotes. Other eukaryotes include plants, fungi, and protozoans . They are large cells, have cytoplasmic organelles like mitochondria golgi complex ,endoplasmic reticulum ….. etc. The nuclear envelope is present and the genetic material in the form of chromosomes consist of DNA and histone protein, the cells are dividing by mitosis or meiosis division .

A comparison showing the shared and unique features of prokaryotes and eukaryotes
All cells, whether prokaryotic or eukaryotic, share these four features:

1. DNA
2. Plasma membrane
3. Cytoplasm
4. Ribosomes

Prokaryote vs eukaryote: key differences

	Prokaryote	**Eukaryote**
Nucleus	Absent	Present
Membrane-bound organelles	Absent	Present
Cell structure	Unicellular	Mostly multicellular; some unicellular
Cell size	Smaller (0.1-5 μm)	Larger (10-100 μm)
Complexity	Simpler	More complex
DNA Form	Circular	Linear
Ribosomes	Smaller(70S) consist of a 50S large subunit and a 30S small subunit	Larger(80S) consist of a 60S large subunit and a 40S small subunit

Viruses

Viruses are microscopic parasites, generally much smaller than bacteria.

How much smaller are most viruses in comparison to bacteria? Quite a bit. With a diameter of 220 nanometers, the measles virus is about 8 times smaller than *E.coli* bacteria. At 45 nm, the hepatitis virus is about 40 times smaller than *E.coli*.

They lack the capacity to thrive and reproduce outside of a host body. Viruses teeter on the boundaries of what is considered life. On one hand, they contain the key elements that make up all living organisms: the nucleic acids, **DNA or RNA** (any given virus can only have one or the other). A minimal virus is a parasite that requires replication (making more copies of itself) in a host cell. When a virus is completely assembled and capable of infection, it is known as a virion. The structure of a simple virion comprises of an inner nucleic acid core surrounded by an outer casing of proteins known as the capsid (Fig. 3). Capsids protect viral nucleic acids from being chewed up and destroyed by special host cell enzymes called nucleases. The DNA or RNA found in the core of the virus can be single stranded or double stranded. It constitutes the genome or the sum total of a virus's genetic information. Viral genomes are generally small in size, coding only for essential proteins such as capsid proteins, enzymes, and proteins necessary for replication within a host cell.

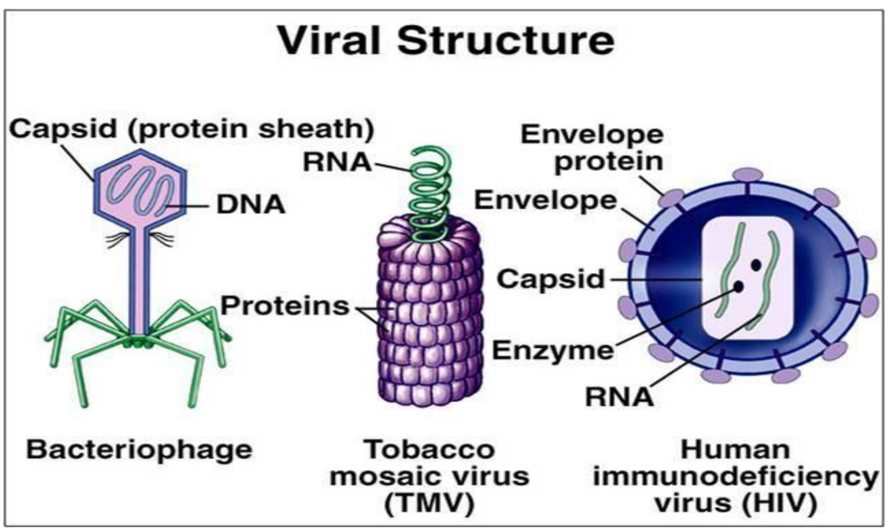


Figure 3:Virus structure

Cell Membrane

The cell membrane (also known as the plasma membrane or cytoplasmic membrane),thin membrane that surrounds every living cell, and separates the interior of a cell from its outside environment. Composed of a phospholipid bilayer with embedded proteins. The cell membrane is selectively permeable , allowing some substances to cross it more easily than others.

Cell Membrane Functions

1- The primary function of the plasma membrane is to protect the cell from its surroundings.

2- It is a barrier keeping the constituents of the cell in and unwanted substances out.

3- It contains receptors and channels that allow specific molecules, such as ions, nutrients, wastes, and metabolic products that mediate cellular and extracellular activities to pass between the cell and the outside environment.

4- The plasma membrane also plays a role in attaching to the extracellular matrix and other cells to help group cells together to form tissues.

5- The cell membrane also provides some structural support for a cell.

Cell Membrane Structure (Models or cell membrane theories)

1- Model of bimolecular phospholipid membrane Gorter and Grendel (1925).

In 1925, Gorter and Grendel used acetone to extract lipids from a known quantity of red blood cells and, after evaporating the solvent, measured the area that the extracted lipids occupied .They concluded that: chromocytes are covered by a layer of fatty substances that is two molecules thick"(Fig.1)

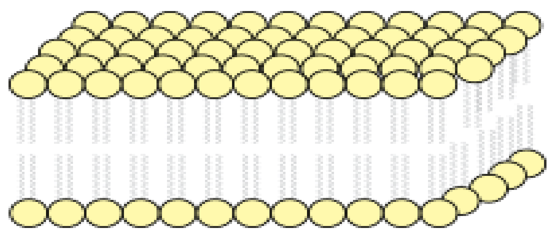
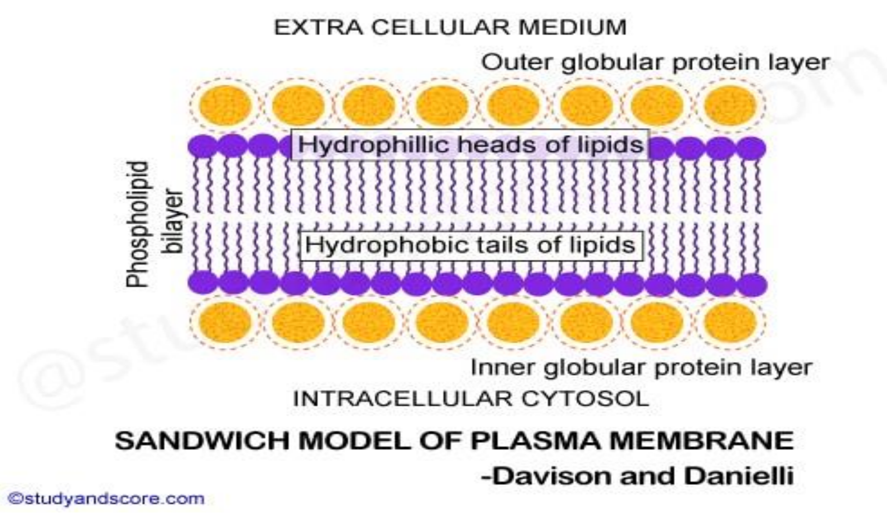


Figure 1: Model of bimolecular phospholipid membrane Gorter and Grendel (1925).

2- Sandwich model (Danielli and Davson in 1935)

The unit membrane concept that says all membranes have an underlying bilayer composed of phospholipids was originally proposed by Danielli and Davson in 1935. Davson and Danielli postulate the presence of two films of globular proteins. protein associated with the polar head groups at each side of the bimolecular lipid leaflet, their model was illustrated as a "sandwich" of protein-lipid-protein. (Fig. 2).

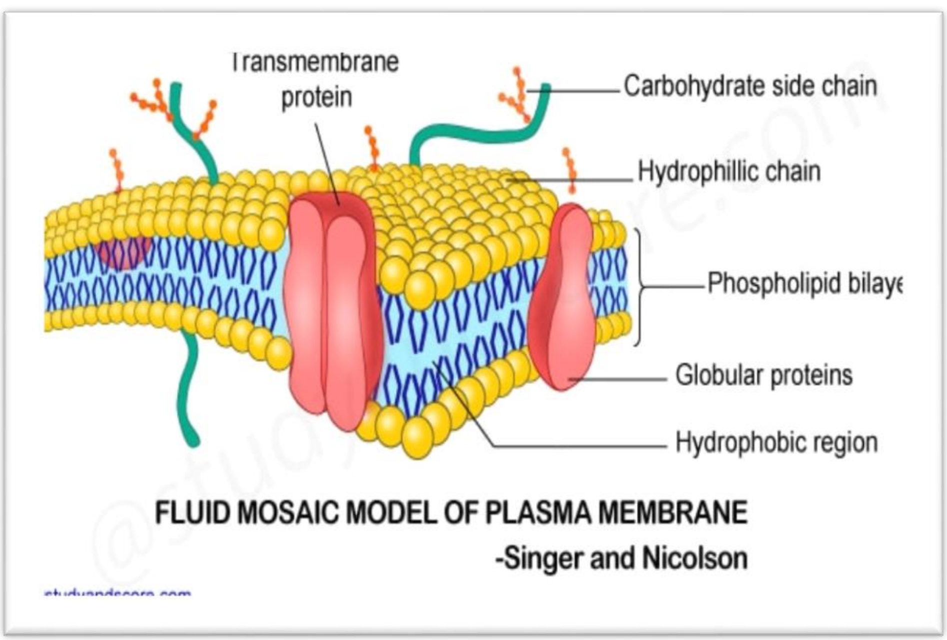


3- Unit membrane model

In 1950s David Robertson used electron microscope to propose the unit membrane model. Basically, he suggested that all cellular membranes share a similar underlying structure, the unit membrane. he suggested that the membranes consist of a lipid bi-layer covered on both surfaces with thin sheets of proteins. The image appears as two dark lines, each about 25–30 Å thick, sandwiching a lighter zone This suggestion was a great boost to the proposal of Davson and Danielli.

4- Fluid mosaic model

In 1972, Singer and Nicolson developed new ideas for membrane structure. Their proposal was **the fluid mosaic model**, which is the dominant model now. It has two key features—a mosaic of proteins embedded in the membrane, and the membrane being a fluid bi-layer of lipids. The lipid bi-layer suggestion agrees with previous models but views proteins as globular entities embedded in the layer instead of thin sheets on the surface (Fig. 3). As for the fluid nature of the membrane, the lipid components are capable of moving parallel to the membrane surface and are in constant motion. Many proteins are also capable of that motion within the membrane. However, some are restricted in their mobility due to them being anchored to structural elements such as the cytoskeleton on either side of the membrane.



Transport across cell membrane

The biological membranes are semi-permeable in nature that is their permeability properties ensure that the specific molecules and ions readily enter the cell and the waste products leave the cell. The movement of a substance across the selectively permeable plasma membrane can be either "passive"—i.e., occurring without the input of cellular energy—or "active"—i.e., its transport requires the cell to expend energy.

Types of transport process:

Two types of transport process occur across the membrane.

1. Non-mediated transport
2. Mediated transport

Non-mediated transport occurs through the simple diffusion process and the driving force for the transport of a substance through a medium depends on its chemical potential gradient. Whereas **mediated transport** requires specific carrier proteins. Thus, the substance diffuses in the direction that eliminates its concentration gradient; at a rate proportional to the magnitude of this gradient and also depends on its solubility in the membrane's non-polar core. **Mediated transport** is classified into two categories depending on the thermodynamics of the system:

1. **Passive-mediated transport,** or **facilitated diffusion:** In this type of process a specific molecule flows from high concentration to low concentration.

2. **Active transport:** In this type of process a specific molecule is transported from low concentration to high concentration, that is, against its concentration gradient. Such an endergonic process must be coupled to a sufficiently exergonic process to make it favorable (ΔG <0).

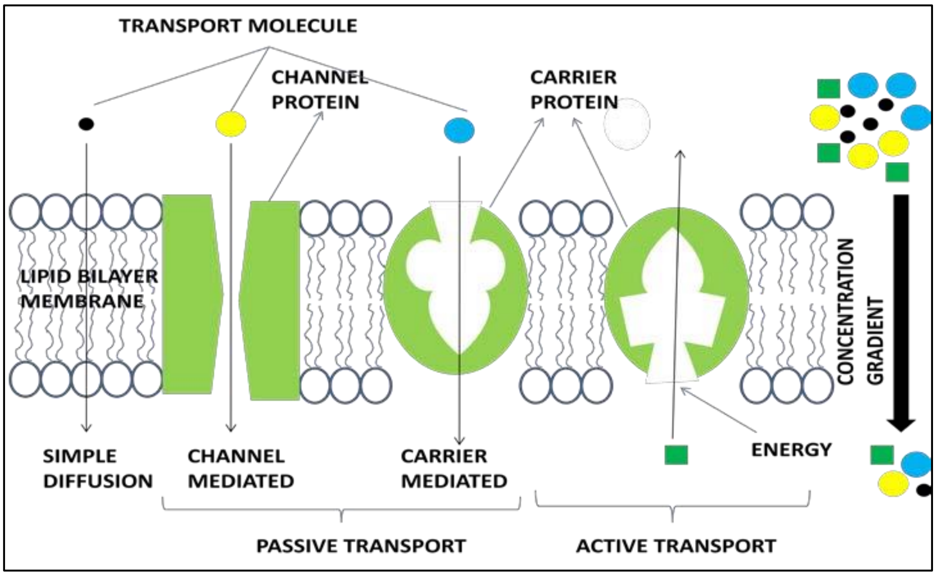


Fig.1: Types of transport process

1. Diffusion:

- Spontaneous phenomenon where small, hydrophobic molecules movefrom a higher concentrated area to lower concentrated area.
- All molecules have motion called **Brownian Movement,** and a **concentration gradient** (the difference in two concentrated areas) will always move molecules to the less concentrated area.
- No external energy is required.
- Diffusion stops when **equilibrium** is achieved (no concentration gradient).
- Factors that affect diffusion rate includes temperature, concentration, molecular size, and diffusion distance.

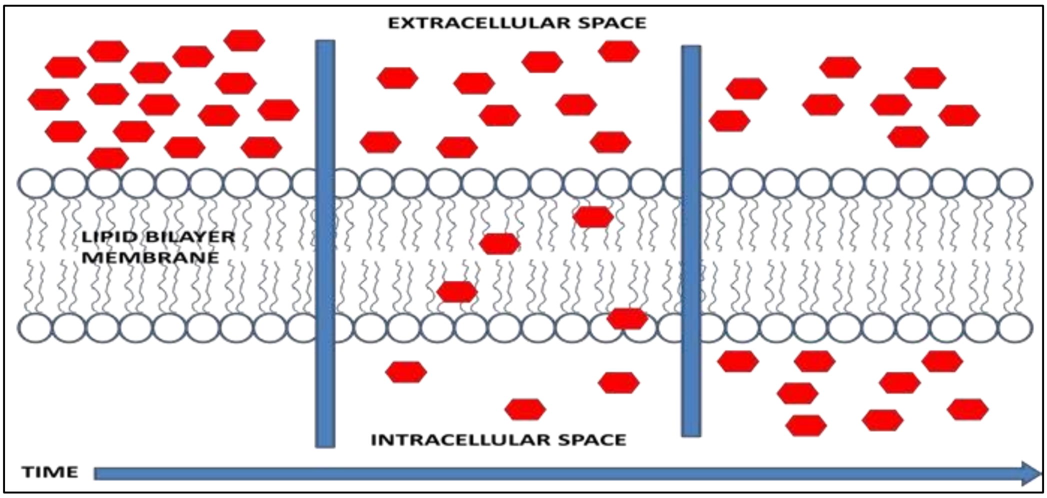


Fig.2: Diffusion: Extracellular space contains high concentration of solutes than intracellular space and hence the solutes move from extracellular space to intracellular space till there is no concentration gradient between the spaces.

2. Facilitated diffusion:

- Allow large, hydrophilic molecules to cross the cell membrane.
- Molecules bind with a specific **protein carrier** at the cell membrane. The combined molecule is now fat soluble and can diffuse to the other side.
- Movement is from a higher concentrated area to a lower concentrated area.
- No external energy is required.

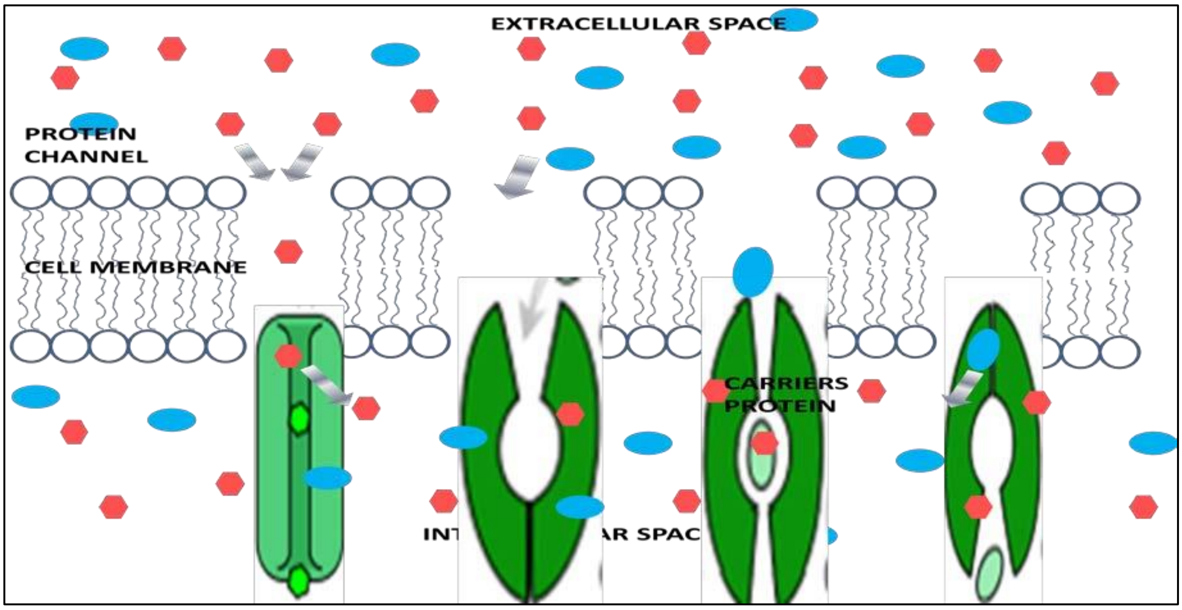


Fig.3: Facilitated transport. Movement of the solutes from extracellular space to intracellular space via carrier proteins and down its concentration gradient.

3. Active transport:

Active transport is the movement of a substance against its concentration gradient (i.e. from low to high concentration). It is an endergonic process that, in most cases, is coupled to the hydrolysis of ATP.

Types of active transport:

a) **Primary active transport:** Primary active transport, also called direct active transport, directly uses energy to transport molecules across a membrane. Example: Sodium-potassium pump, which helps to maintain the cell potential.

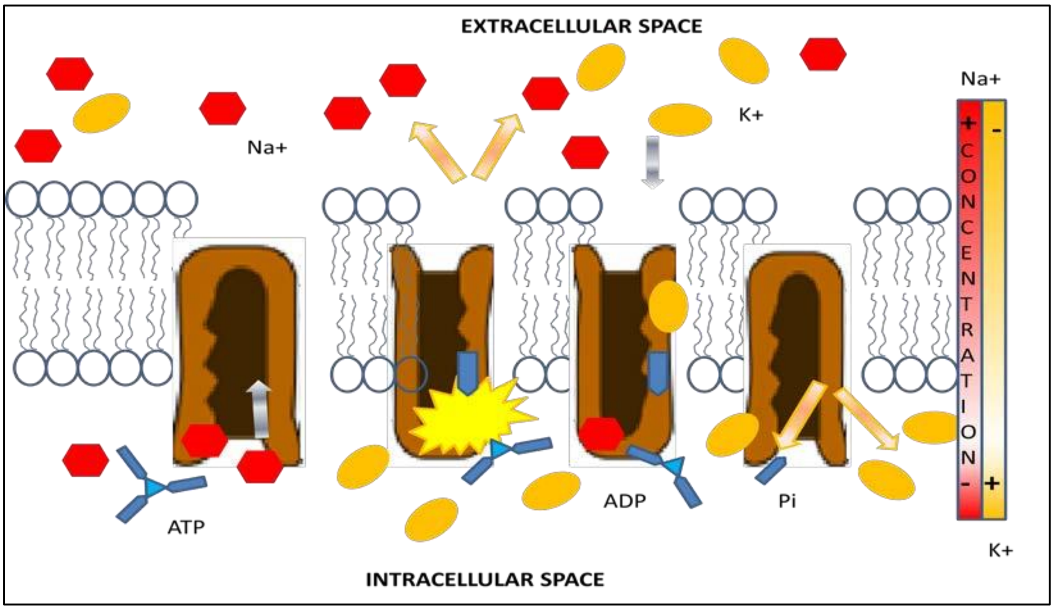


Fig.4: Primary active transport. The action of the sodium-potassium pump is an example of primary active transport.

b) **Secondary active transport:** Secondary active transport or co-transport, also usesenergy to transport molecules across a membrane; however, in contrast to primaryactive transport, there is no direct coupling of ATP; instead, the electrochemical potential difference created by pumping ions out of the cell is instrumental.

This pump is widespread in many living cells, and in it the external pumping of sodium ions is not equal to the internal pumping of potassium ions as a ratio of 1:1. Thus potassium ions accumulate, which compensates for the decrease in sodium ions (or hydrogen ions in bacteria). These are two biological processes that require high concentrations of the first potassium ions are **the protein building process** in the ribosomes, while the second is one of the important enzymatic steps during the process of **glycolysis.**

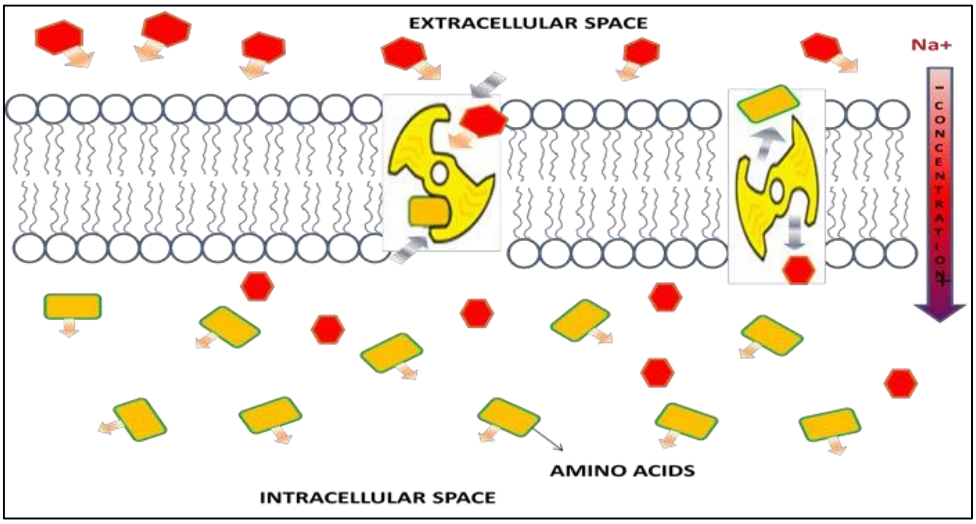


Fig.5: Secondary active transport.

4. Transport by vesicle formation:

a) Endocytosis: allows large molecule that cannot be transported by other methods to enter the cell by membrane vesicles.

- **Pinocytosis**: transports liquid substances.
- **Phagocytosis:** transports solid substances. Divided into 3 main phases – adhesion, ingestion, and digestion.
- **Receptor-mediated endocytosis:** the molecules initially bind to specific receptors on the cell membrane.

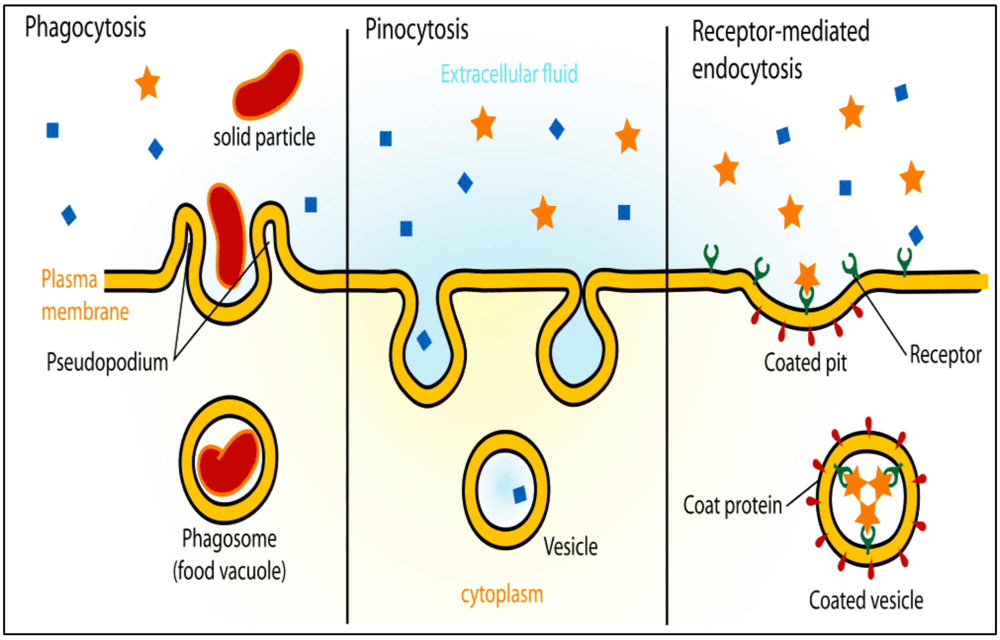


Fig.6: Types of endocytosis

b) Exocytosis Allows large molecule that cannot be transported by other methods to exit the cell membrane.

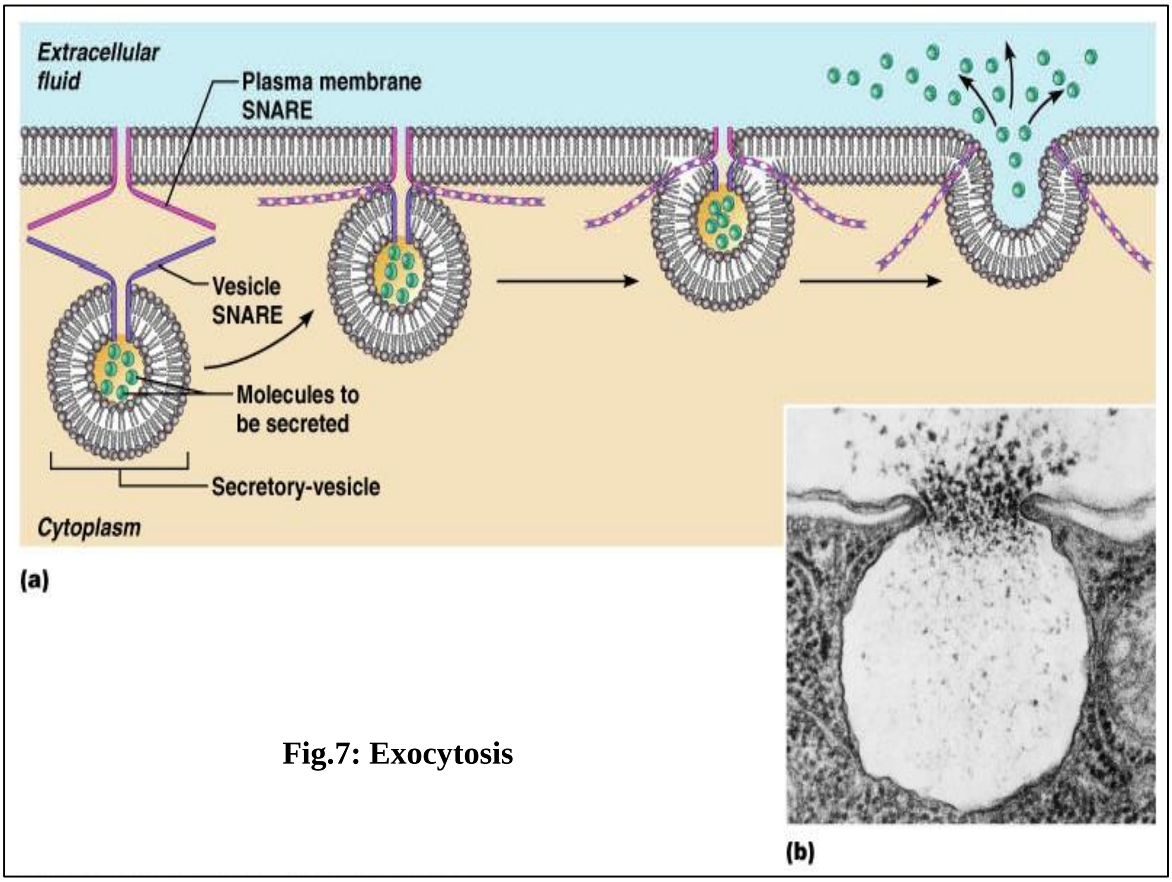


Fig.7: Exocytosis

Endomembrane system

The **endomembrane system** (*endo-* = “within”) is a group of membranes and organelles in eukaryotic cells that works together to modify, package, and transport lipids and proteins. It includes a variety of organelles, such as the nuclear envelope, lysosomes, the endoplasmic reticulum and Golgi apparatus.

1. The endoplasmic reticulum

The endoplasmic reticulum (ER) plays a key role in the modification of proteins and the synthesis of lipids. It consists of a network of membranous tubules and flattened sacs. Cisternae are tubular in structure and form a three-dimensional polygonal network. The discs and tubules of the ER are hollow, and the space inside is called the lumen. There are two forms of endoplasmic reticulum:

A. Rough E. R.

The **rough endoplasmic reticulum** (**rough ER**) gets its name from the bumpy ribosomes attached to its cytoplasmic surface. As these ribosomes make proteins, they feed the newly forming protein chains into the lumen. Some are transferred fully into the ER and float inside, while others are anchored in the membrane.

If the modified proteins are not destined to stay in the ER, they will be packaged into **vesicles**, or small spheres of membrane that are used for transport, and shipped to the Golgi apparatus. The rough ER also makes phospholipids for other cellular membranes, which are transported when the vesicle forms.

B. Smooth E. R.

The **smooth endoplasmic reticulum** (**smooth ER**) is continuous with the rough ER but has few or no ribosomes on its cytoplasmic surface.

Functions of the ER include:

1. **Protein Synthesis and Folding:** Protein synthesis occurs in the rough endoplasmic reticulum. Although translation for all proteins begins in the cytoplasm, some are moved into the ER in order to be folded and sorted for different destinations. Proteins that are translocated into the ER during translation are often destined for secretion. Initially, these proteins are folded within the ER and then moved into the Golgi apparatus where they can be dispatched towards other organelles.

2. **Lipid synthesis:** The smooth endoplasmic reticulum plays an important role in cholesterol and phospholipid biosynthesis. Therefore, this section of the ER is important not only for the generation and maintenance of the plasma membrane but of the extensive endomembrane system of the ER itself.

3. **Storage of calcium ions:** The SER is an important site for the storage and release of calcium in the cell. A modified form of the SER called **sarcoplasmic reticulum** forms an extensive network in contractile cells such as **muscles fibers**. Calcium ions are also involved in the regulation of metabolism in the cell and can change cytoskeletal dynamics.

4. **Synthesis of carbohydrates, lipids, and steroid hormones**
5. **Detoxification of medications and poisons.**
6. **Exchange:** ER plays an important role in the exchange of materials between the cytoplasm and the inner cavity of the network.
7. **Mechanical support.**
8. **Circulation system of the cell.**
9. **Glycogenolysis.**
10. **Ionic Gradients:** the ionic gradient and the electric potential occur across the membranes of SER.

Chemical structure of the ER:

The membranes of ER are found to contain many enzymes, triglycerides, phospholipids and cholesterol. Most important ER enzymes include stearates, NADH-cytochrome C reductase, NADH-diaphoresis, glucose-6-phosphatase, glycosyl transferase and Mg^{++} activated ATPase. The various enzymes have different topologies with respect to the luminal or cytoplasmic surfaces of the ER.

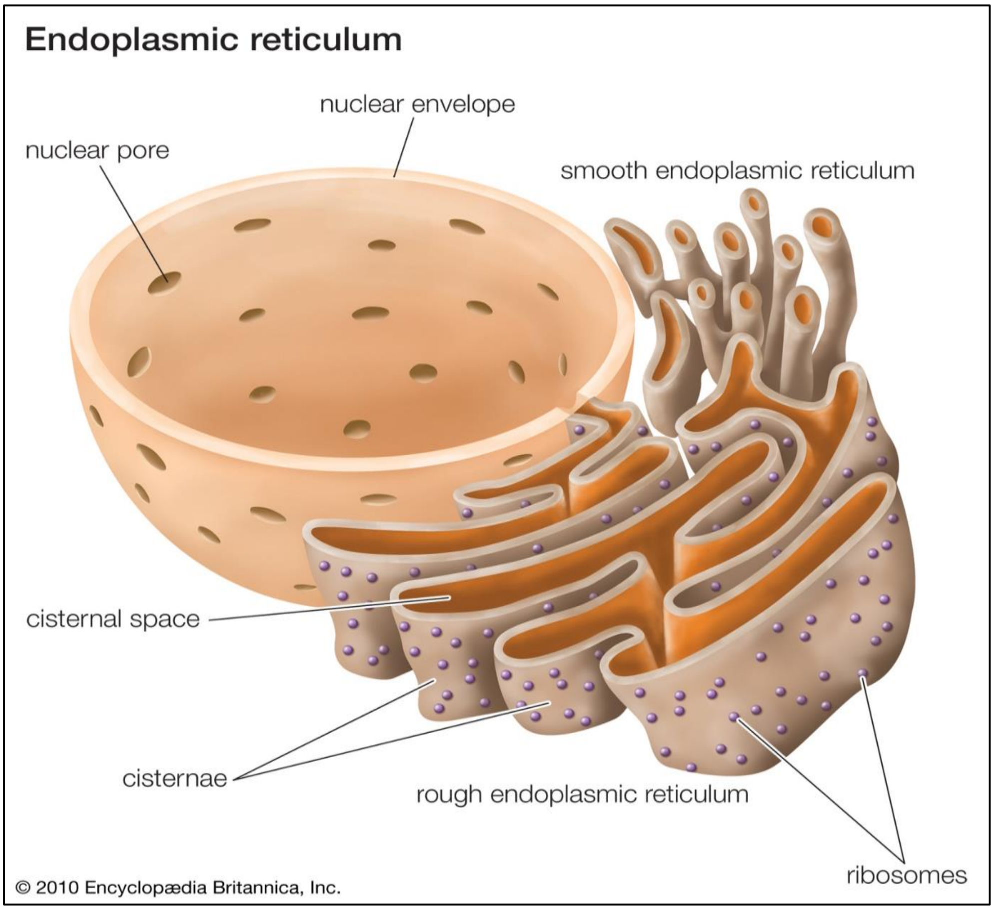


Fig. 1: Diagram gives a 3D representation of rough ER and smooth ER along with the cell nucleus.

2. The Golgi apparatus

Golgi apparatus, also called **Golgi complex** or **Golgi body**, and also called **Dictyosomes** in plant cells. membrane-bound organelle of eukaryotic cells that is made up of a series of flattened, stacked pouches called **cisternae**.

The Golgi apparatus is responsible for transporting, modifying, and packaging proteins and lipids into vesicles for delivery to targeted destinations. It is located in the cytoplasm next to the endoplasmic reticulum and near the cell nucleus. While many types of cells contain only one or several Golgi apparatus, plant cells can contain hundreds.

Structure:

The receiving side of the Golgi apparatus is called the ***cis*** **face** is closest to the endoplasmic reticulum and the opposite side is called the ***trans*** **face** is the side furthest from the nucleus, which secretes vesicles to various parts of the cell. Further, **there are a number of lumens and cisternae** through which products flow. These appear as a series of flattened sacs stack on each other, much like the endoplasmic reticulum. Transport vesicles from the ER travel to the *cis* face, fuse with it, and empty their contents into the lumen of the Golgi apparatus.

Chemical structure of Golgi apparatus:

Golgi complex from different plant and animal cells show marked differences in its chemical composition. The Golgi, isolated from rat liver consists of about 60% protein and 40% lipid. In animal cells, Golgi complex contains phospholipids in the form of phosphatidylcholins, whereas that of plant cells contains phosphatidic acid and phosphatidyl- glycerol.

The Golgi apparatus also contains a variety of enzymes, such as glycosyl trans-ferases (e.g., sialyl transferases), oxireductases (e.g., NADH-cytochrome C-reductase), phosphatases (G-6-phophatase), phospholipase (phospholipase A), kinases (casein phosphokinases) etc.

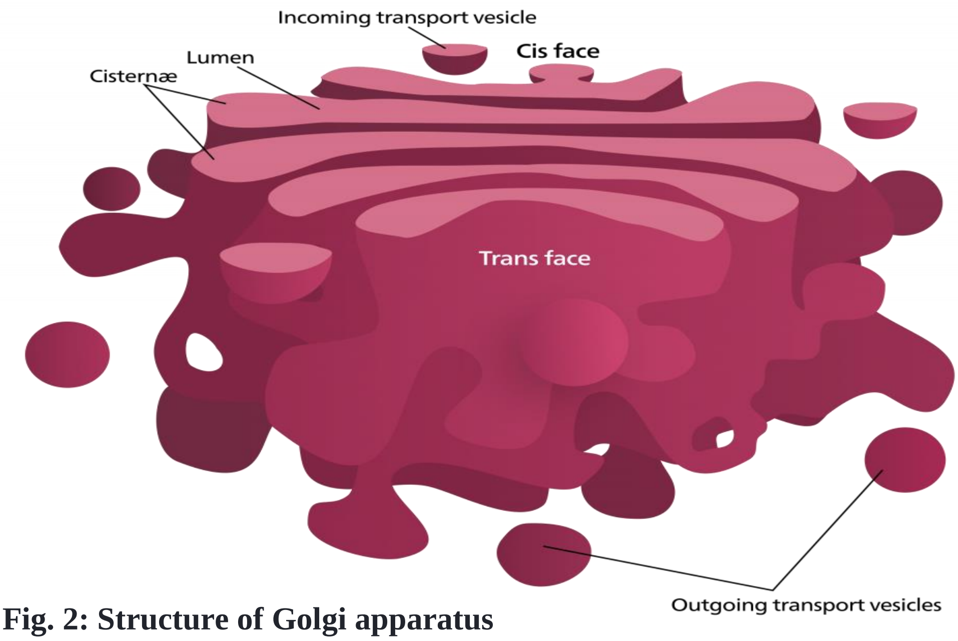


Fig. 2: Structure of Golgi apparatus

Finally, the modified proteins are sorted (based on markers such as amino acid sequences and chemical tags) and packaged into vesicles that bud from the *trans* face of the Golgi. Some of these vesicles deliver their contents to other parts of the cell where they will be used, such as the lysosome or vacuole. Others fuse with the plasma membrane, delivering membrane-anchored proteins that function there and releasing secreted proteins outside the cell.

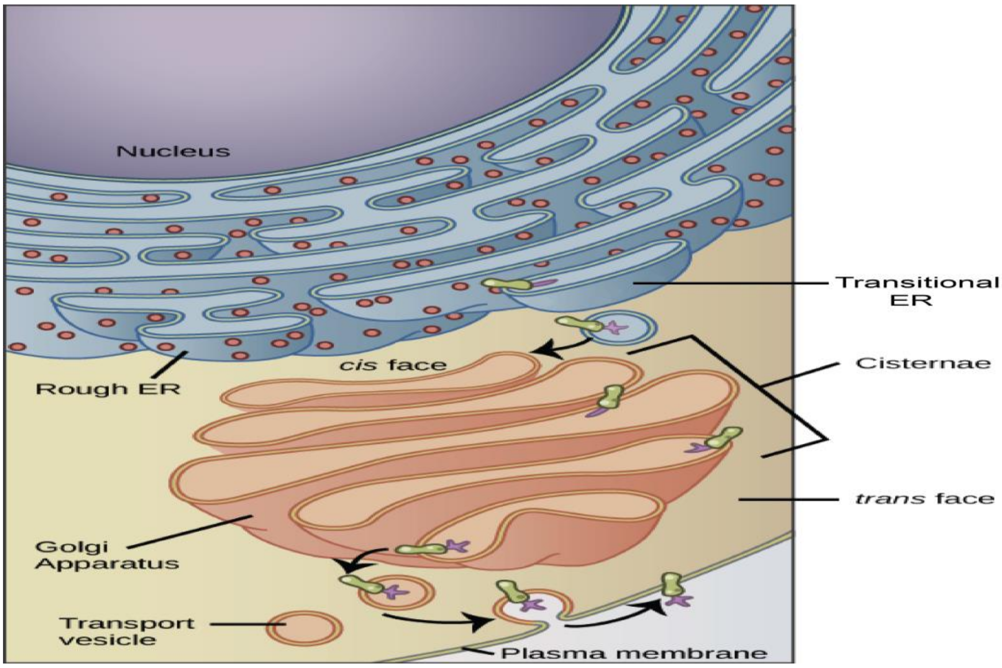


Fig. 3: Image showing transport of a membrane protein from the rough ER through the Golgi to the plasma membrane. The protein is initially modified by the addition of branching carbohydrate chains in the rough ER; these chains are then trimmed back and replaced with other branching chains in the Golgi apparatus.

Functions:

In general Golgi complex is of vital importance and serves many functions:

1. **Absorption of compounds:** These products may be lipids, yolk, bile compounds, enzymes and hormones, etc. Golgi membranes may remove water from the products of synthesis during the formation of secretory granules.

2. **Formation of secretory vesicles and secretion:** The principal function of Golgi complex is secretion. In several types of cells, synthetic products from the rough endoplasmic reticulum are transferred to Golgi region, from where they are liberated from the cell through plasma membrane by pinocytosis.

3. **Helps in enzyme formation:** Golgi body helps in the production of follicular fluid from granulosa cells of ovary. And it may release zymogen granules (inactivated pancreatic enzymes) which arise from cisternae into secretory vesicles.

4. **Production of hormones:** Golgi body in endocrine cells helps in secretion of hormones.

5. **Storage of protein:** Vacuoles and vesicles which are the main components of Golgi complex become filled with protein-lipoid material for storage. These stored products help in secretory action.

6. **Formation of acrosome:** It forms the acrosome of sperm during sperm maturation

7. **Formation of intracellular crystals:** In the marine isopod, Limnaria ligmorum, which is a burrowing form, whose cells consist of crystals.

8. **Milk protein droplet formation:** In lactating mammary gland of mice are produced protein droplets which are related with Golgi complex.

9. **Formation of plant cell wall:** Golgi bodies of plant cells synthesize all polysaccharides such as pectin, hemicellulose and microfibrils of a-cellulose. These are packaged in secretory vesicles to form the plant cell wall.

10. **Glycoproteins secretion:** Glycoproteins are formed in the Golgi complex by the attachment of carbohydrate to the protein products of the endoplasmic reticulum.

Lysosomes

- The word “lysosome” is made up of two words “**lysis**” meaning breakdown and “**soma**” meaning body.
- The **lysosome** is an organelle that contains digestive enzymes and acts as the organelle-recycling facility of an animal cell. It breaks down old and unnecessary structures so their molecules can be reused. Lysosomes are part of the endomembrane system, and some vesicles that leave the Golgi are bound for the lysosome.
- Lysosomes can also digest foreign particles that are brought into the cell from outside. As an example, a class of white blood cells called macrophages, which are part of the human immune system.
- Lysosomes are membrane-bound, dense granular structures containing hydrolytic enzymes responsible mainly for intracellular and extracellular digestion.
- They are more commonly found in animal cells while only in some lower plant groups and saprophytic fungi.
- They are found in most abundant numbers in cells related to enzymatic reactions such as liver cells, pancreatic cells, kidney cells, spleen cells, leucocytes, macrophages, etc.

Structure of lysosome

- Lysosomes are without any characteristic shape or structure i.e. they are pleomorphic
- They are mostly globular or granular in appearance.
- It is 0.2-0.5 μm in size and is surrounded by a single lipoprotein membrane unique in composition.

- The membrane contains highly glycosylated **lysosomal associated membrane proteins (LAMP)** and **Lysosomal integral membrane proteins (LIMP)**. LAMPs and LIMPs form a coat on the inner surface of the membrane. They protect the membrane from attack by the numerous hydrolytic enzymes retained inside.
- Inside the membrane, the organelle contains enzymes in the crystalline form.

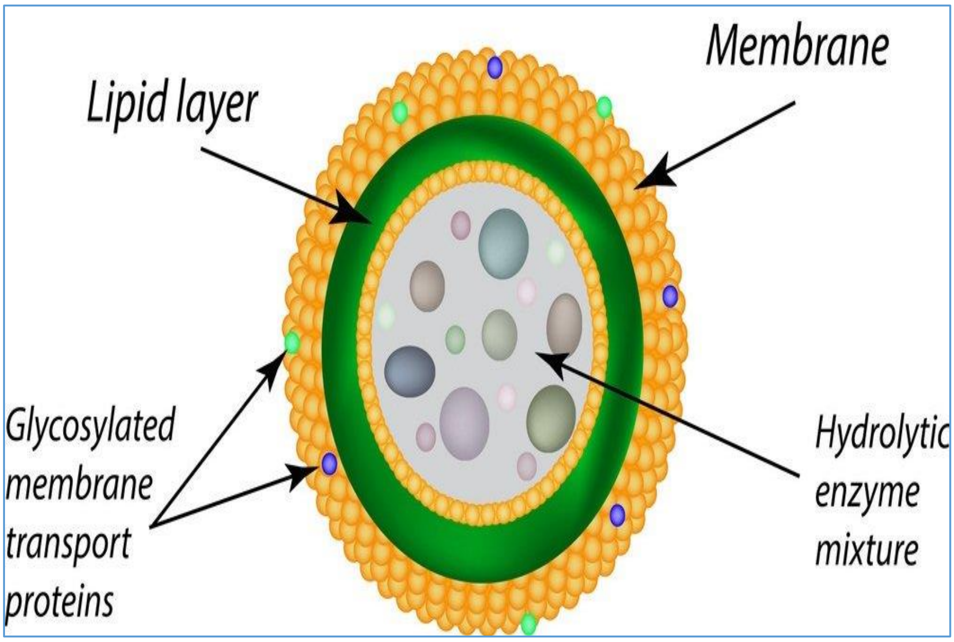


Fig.1: Structure of Lysosome

Lysosome enzymes

Lysosomes filled with enzymes called hydrolases. It contains about 40 varieties of enzymes which are classified into the following main types, namely:

- **Proteases**, which digest proteins
- **Lipases,** which digests lipids
- **Amylase**, which digests carbohydrates
- **Nucleases,** which digest nucleic acids
- **Phosphoric acid monoesters**

Collectively the group of enzymes is called hydrolases which cause cleavage of substrates by the addition of water molecules. Most of the lysosomal enzymes function in the acidic medium.

Types of Lysosomes:

1. Primary Lysosomes:

They are newly pinched off vesicles from the Golgi apparatus which generally fuse with some endosomes to become fully functional. The primary lysosomes are small in size. They contain hydrolytic enzymes in the form of granules.

2. Secondary Lysosomes:

They are also called heterophagosomes or digestive vacuoles. A secondary lysosome is formed by the fusion of food containing phagosome with lysosome (having hydrolytic or digestive enzymes). The digested food passes out into the cytoplasm. Finally, the secondary lysosome is left with undigested food.

3. Residual Bodies (Tertiary Lysosomes):

They are those lysosomes in which only indigestible food materials have been left. These lysosomes pass outwardly and fuse with the plasma membrane to throw out the debris into externalenvironment by exocytosis.

Sometimes, residual bodies remain inside the cells due to failure of exocytosis and absence of some hydrolytic enzymes. This leads to pathological diseases (storage diseases).

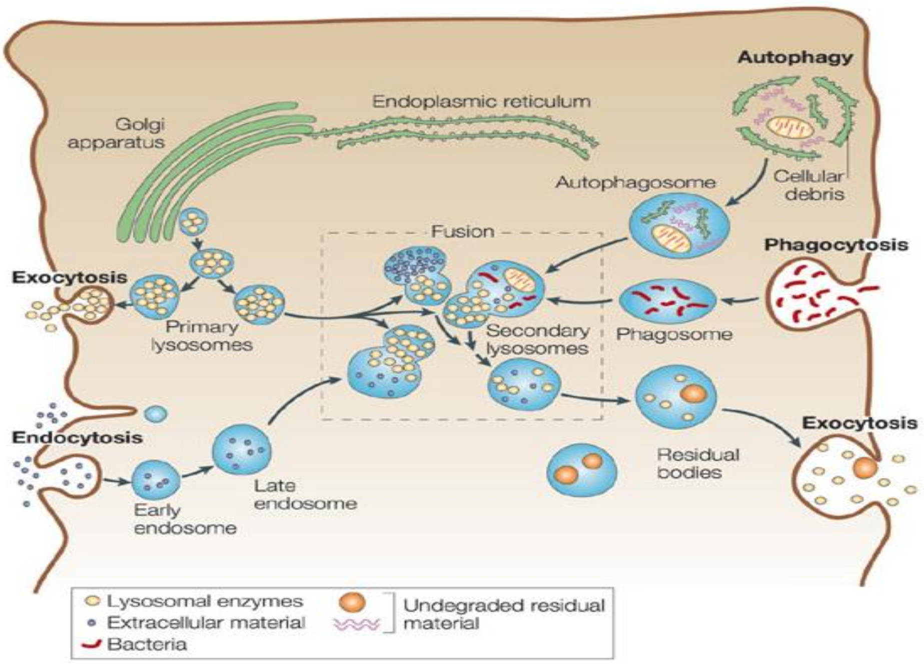
4. Autophagic Vacuoles (Auto-phagosomes, Auto-lysosomes):

They are produced by the fusion of a number of primary lysosomes around worn out or degenerate intracellular organelles. The latter are first wrapped over by one or two membranes from endoplasmic reticulum before being recognized by lysosomes.

The cell debris is digested the phenomenon is also called autophagy or auto digestion. It helps in disposal of cell debris. The worn out, aged orinjured cells are also disposed of similarly (apoptosis). Therefore, lysosomes are also called disposal bags or disposal units.

Functions of Lysosomes:

1. **Intracellular Digestion:** Individual cells may obtain food through phagocytosis. The same isdigested with the help of lysosomes.
2. **Extracellular Digestion:** For this the lysosomes release enzymes in the external environmentthrough exocytosis.
3. **Body Defence:** Lysosomes of leucocytes devour foreign proteins, toxic substances, bacteria and other microorganisms. They thus take part in natural defence of the body.
4. **Autophagy:** In the metamorphosis of many animals (e.g. amphibians) certain embryonic parts like tail, gills, etc. are digested through the agency of lysosomes.
5. **Intracellular Scavenging:** In long lived cells the lysosomes perform intracellular scavenging byremoving old or useless organelles.
6. **Sperm Lysins:** They are lysosomal enzymes which are used for breaking limiting membrane of eggs.
7. **Disposal of Useless Cells:** They cause breakdown of ageing and dead cells.
8. **Storage Diseases:** In certain regions due to some malfunction, the residual bodies do notundergo exocytosis.
9. **Formation of Thyroxine.**
10. **Cell Division.**
11. **Genetic Changes:** It may result in mutations, breakage of chromosomes and other abnormalities. Blood cancer may be result of such an activity.
12. **Carcinogenesis:** Lysosomes remove carcinogens by engulfing and separating them.
13. **Leucocyte Granules:** Leucocyte granules are derived from lysosomes.
14. **Osteogenesis.**



Types of Lysosomes

Vacuoles

Plants cells are unique because they have a lysosome-like organelle called the **vacuole**. The large central vacuole stores water and wastes, isolates hazardous materials, and has enzymes that can break down macromolecules and cellular components, like those of a lysosome. Plant vacuoles also function in water balance and may be used to store compounds such as toxins and pigments (colored particles).

Microbodies

A microbody is a cell organelle present in both plant and animal cells. Glyoxysomes, peroxisomes are included in the microbodies family. In Vertebrates, microbodies are prevalent in the kidney and liver cells.

Structure

Microbodies are present in the cytoplasm of a cell so they are known as cytosomes. They are very small in size ~0.2-1.5 µm and can be seen under the electron microscope.

Some of the common characteristics of microbodies are:

- They are vesicular and mostly spherical in shape
- They are enclosed in a single membrane of a phospholipid bilayer
- The intracellular matrix contains proteins and enzymes
- They do not contain separate DNA

Function

Different types of microbodies perform various specific functions.

- Microbodies take part in various biochemical reactions in the cell
- The enzymes present in microbodies facilitate various essential reactions, e.g. breakdown of fats, amino acids, alcohol, etc.
- They are involved in the photorespiration in plants
- Detoxification of peroxides occurs in microbodies

Peroxisomes

Peroxisomes are a membrane-bound organelle present in the eukaryotic cells. They take part in various oxidative processes. They take part in lipid metabolism and catabolism of D-amino acids, polyamines and bile acids. The reactive oxygen species such as peroxides produced in the process is converted to water by various enzymes like peroxidase and catalase.

In plants, photorespiration occurs in peroxisomes.

Glyoxysomes

Glyoxysomes are specialized peroxisomes. Their main function is to convert fatty acid to carbohydrate. They are present in plants and fungi. They are prevalent in the germinating seeds in their fat-storing tissues

Mitochondria and Chloroplast

1) Mitochondria and chloroplasts are the powerhouses of the cell.
2) Mitochondria appear in both plant and animal cells as elongated cylindrical bodies.
3) Mitochondria oxidize the products of cytoplasmic metabolism to generate ATP.
4) Chloroplasts are the photosynthetic organelles in plants and some algae; they partly convert light energy into ATP.

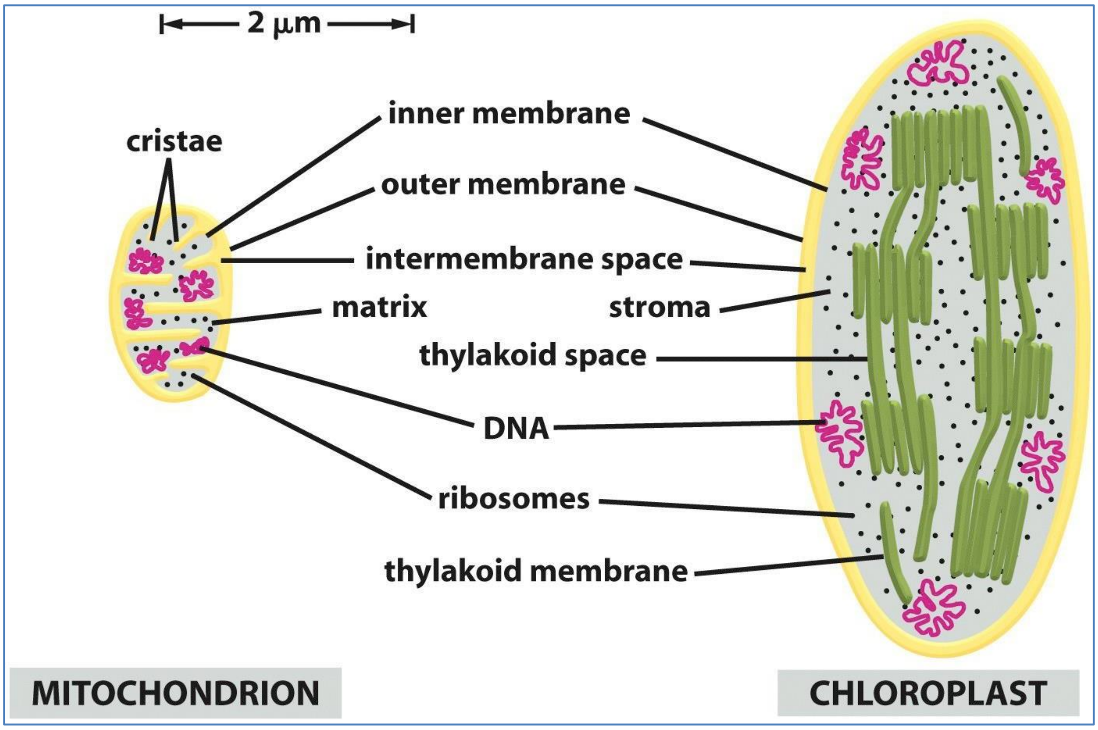
• Structure of mitochondria and chloroplast

☒ Structural similarities

1) Both organelles are bounded by an inner and external membrane.
2) Inner membrane impermeable to small ions, while external membrane impermeable to cytoplasmic proteins.
3) The space between inner and external membrane is filled with a fluid containing a rich mixture of metabolic products, enzymes, and ions.

☒ Structural differences

1) In mitochondria, the inner membrane is elaborately folded into structures called cristae that dramatically increase the surface area of the membrane.
2) In contrast, the inner membrane of chloroplasts is relatively smooth and has a series of folded membranes that form a set of flattened, disk-like sacs called thylakoids.
3) The space enclosed by the inner membrane is called the matrix in mitochondria and the stroma in chloroplasts.
4) The space inside each thylakoid is thought to be connected with that of other thylakoids to form the thylakoid space, which isseparate from the stroma.

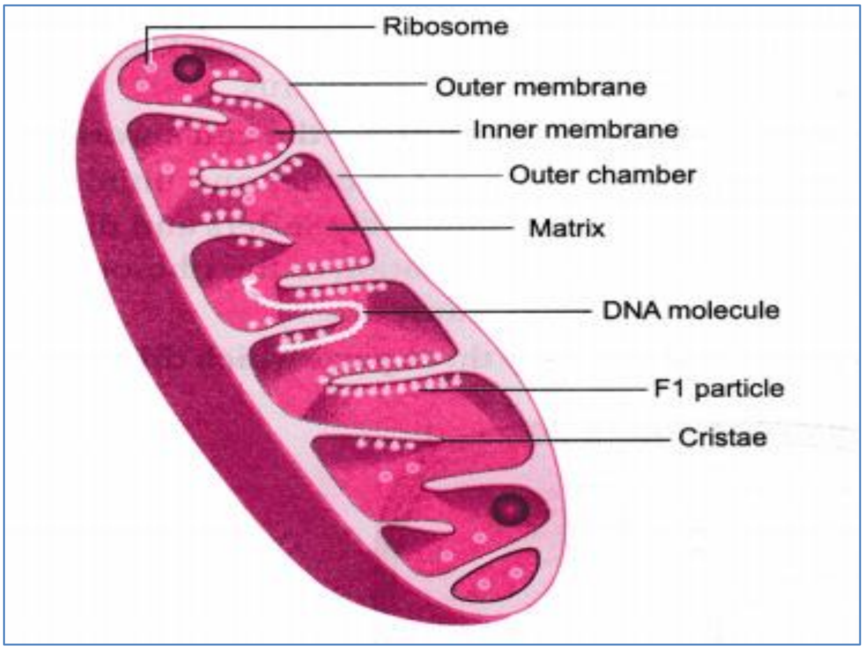


Mitochondria and chloroplasts share many of their features

Ultrastructure of mitochondria

- A mitochondria contains outer and inner membranes composed of phospholipid bilayers and proteins.
- The two membranes, however, have different properties. Because of this double-membraned organization, there are five distinct compartments within the mitochondrion.

1. The outer mitochondrial membrane
2. The intermembrane space (the space between the outer and inner membranes)
3. The inner mitochondrial membrane
4. The cristae space (formed by infoldings of the innermembrane)
5. The matrix (space within the inner membrane).



Ultrastructure of Mitochondria

Outer membrane

- The outer mitochondrial membrane, which encloses the entire organelle, has a protein-to-phospholipid ratio similar to that of the eukaryotic plasma membrane.
- It contains large numbers of integral proteins called *porins*.
- These porins form channels that allow molecules 5000 Daltons orless in molecular weight to freely diffuse from one side of the membrane to the other.

Intermembrane space

- The intermembrane space is the space between the outermembrane and the inner membrane.
- Because the outer membrane is freely permeable to small molecules, the concentrations of small molecules such as ions and sugars in the intermembrane space is the same as the cytosol.

Inner membrane

- The inner mitochondrial membrane contains proteins with five typesof functions:

  1-Those that perform the redox reactions of oxidativephosphorylation

  2-ATP synthase, which generates ATP in the matrix

  3-Specific transport proteins that regulate metabolite passage intoand out of the matrix.

4-Protein import machinery.

5-Mitochondria fusion and fission protein

- The inner membrane is home to around 1/5 of the total protein in a mitochondrion.
- The inner membrane is rich in an unusual phospholipid, cardiolipin

Cristae

- The inner mitochondrial membrane is compartmentalized into numerous cristae, which expand the surface area of the inner mitochondrial membrane, enhancing its ability to produce ATP.
- In typical liver mitochondria, for example, the surface area, including cristae, is about five times that of the outer membrane.
- Mitochondria of cells that have greater demand for ATP, such asmuscle cells, contain more cristae than typical liver mitochondria.
- These folds are studded with small round bodies known as F_1 particles or oxysomes.

• Mitochondria and cellular respiration

1) Cellular respiration is the harvesting of energy (for ATP synthesis) from the degradation of food molecules (carbohydrates, lipids, and proteins).
2) Cellular respiration is a metabolic reactions which includes four steps or processes

   a) Glycolysis

   b) Transition reaction (Acetyl-CoA reaction)

   c) Krebs cycles (TCA cycle or citric acid cycle)

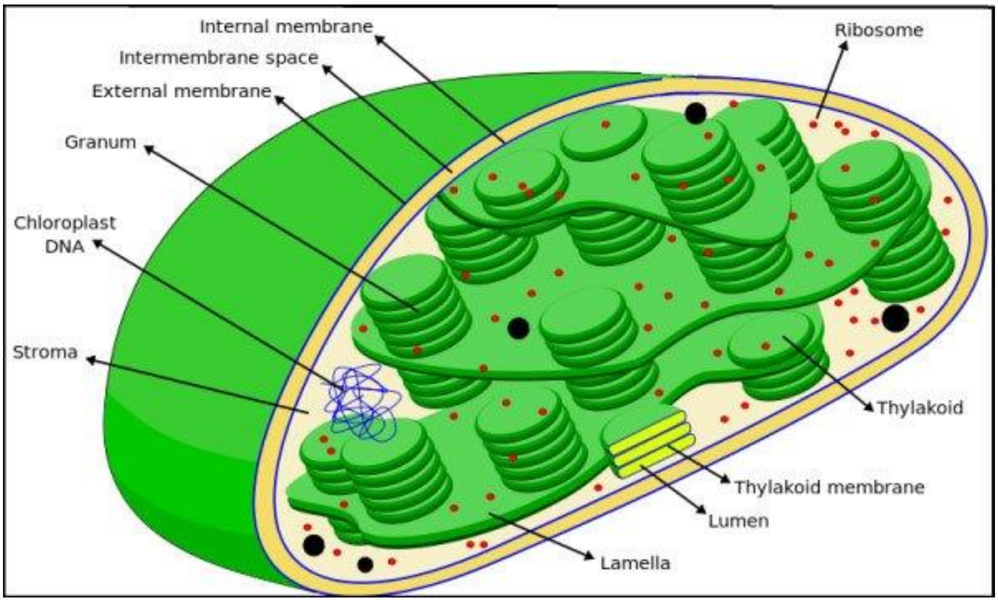
   d) Oxidative phosphorylation

Ultrastructure of chloroplast

- The chloroplast is bounded by two lipoprotein membranes, an outer and an inner membrane, with an intermembrane space between them.
- The inner membrane encloses a matrix, the stroma which contains small cylindrical structures called grana. Most chloroplasts contain 10-100 grana

The Grana and Thylakoids

- Each granum has a number of disc-shaped membranous sacs called grana lamellae or thylakoids (80-120Å across) piled one over the other.
- The grana are interconnected by a network of anastomosing tubules called inter-grana or stroma lamellae.
- Single thylakoids, called stroma thylakoids, are also found in chloroplasts.
- Electron dense bodies, osmophilic granules along with ribosomes (70S), circular DNA, RNA and soluble enzymes of Calvin cycles are also present in the matrix of the stroma.
- Chloroplasts thus have three different membranes, the outer, the inner and the thylakoid membrane.



Ultrastructure of plastid

▪ Chloroplast and photosynthesis

1) Photosynthesis is the series of light-driven reactions that creates organic molecules from atmospheric carbon dioxide (CO_2).
2) Plants, algae, and photosynthetic bacteria such as Cyanobacteria use electrons from water and the energy of sunlight to convert atmospheric CO_2 into organic compounds.
3) Water molecules are split, releasing vast quantities of O_2 gas into the atmosphere.
4) This oxygen in turn supports oxidative phosphorylation not only in animals but also in plants and aerobic bacteria.
5) In plants, photosynthesis is carried out in a specialized intracellular organelle called chloroplast, which contains light-capturing pigments such as the green pigment chlorophyll.
6) For most plants, the leaves are the major sites of photosynthesis.
7) Photosynthesis can be divided into two processes; first occurs only during the daylight hours which producing ATP and NADPH.
8) These activated carriers can then be used, at any time of day, to convert CO_2 into sugar inside the chloroplast a process called carbon fixation (sometime called dark reactions).

Cytoskeleton

The cytoskeleton is a network of filaments and tubules that extends throughout a cell, through the cytoplasm, which is all of the material within a cell except for the nucleus. It is found in all cells, though the proteins that it is made of vary between organisms. The cytoskeleton supports the cell, gives it shape, organizes and tethers the organelles, and has roles in molecule transport, cell division and cell signaling.

Structure of the Cytoskeleton

All cells have a cytoskeleton, but usually the cytoskeleton of eukaryotic cells is what is meant when discussing the cytoskeleton. Eukaryotic cells are complex cells that have a nucleus and organelles. Prokaryotic cells are less complex, with no true nucleus or organelles except ribosomes, The cytoskeleton of prokaryotic cells was originally thought not to exist; it was not discovered until the early 1990s.

The eukaryotic cytoskeleton consists of three types of filaments, which are elongated chains of proteins: microfilaments, intermediate filaments, and microtubules.

Microfilaments

Microfilaments are also called **actin filaments** because they are mostly composed of the protein actin; their structure is two strands of actin. They are about **7 nanometers thick**, making them the thinnest filaments in the cytoskeleton. Microfilaments have many functions. **They aid in cytokinesis**, which is the division of a cytoplasm of a cell when it is dividing into two daughter cells. **They aid in cell motility** and allow single-celled organisms like amoebas to move. **They are also involved in cytoplasmic streaming**, which is the flowing of cytosol (the liquid part of the cytoplasm) throughout the cell. **Microfilaments are also part of muscle cells and allow these cells to contract**, along with myosin. **Actin and myosin** are the two main components of muscle contractile elements.

Intermediate Filaments

Intermediate filaments are about **8-12 nm wide**; they are called intermediate because they are in-between the size of microfilaments and microtubules. Intermediate filaments are made of different proteins such as **keratin** (found in hair and nails, and also in animals with scales, horns, or hooves), **vimentin, desmin, and lamin**. All intermediate filaments are found in the cytoplasm except for lamins, which are found in the nucleus and help support the nuclear envelope that surrounds the nucleus. The intermediate filaments in the cytoplasm maintain **the cell's shape**, **bear tension**, and **provide structural support to the cell**.

Microtubules

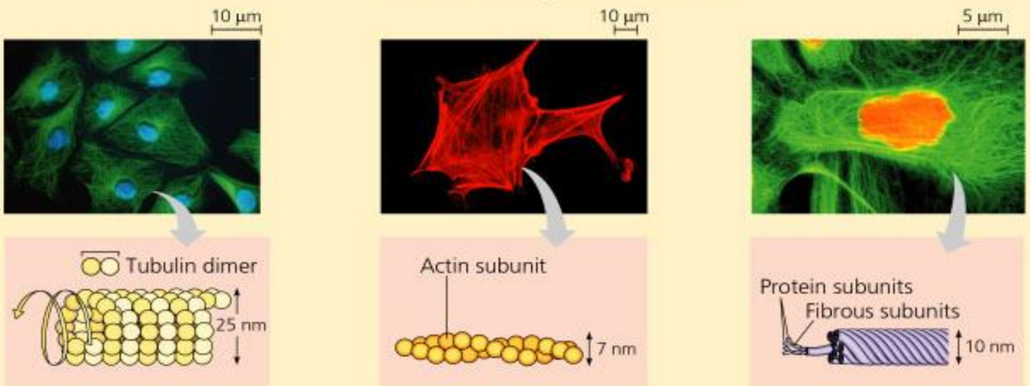
Microtubules are the largest of the cytoskeleton's fibers at about **23 nm**. They are **hollow tubes** made of **alpha and beta tubulin**. Microtubules form structures like flagella, which are "tails" that propel a cell forward. They are also found in structures like cilia, which are appendages that increase a cell's surface area and in some cases allow the cell to move. Most of the microtubules in an animal cell come from a cell organelle called the centrosome, which is a **microtubule organizing center** (**MTOC**). The centrosome is found near the middle of the cell, and microtubules radiate outward from it. Microtubules are **important in forming the spindle apparatus** (or mitotic spindle), which separates sister chromatids so that one copy can go to each daughter cell during cell division. They are also **involved in transporting molecules within the cell and in the formation of the cell wall in plant cells.**

Function of the Cytoskeleton

1. **It gives the cell shape.** This is especially important in cells without cell walls, such as animal cells, that do not get their shape from a thick outer layer.

2. **It can also give the cell movement.** The microfilaments and microtubules can disassemble, reassemble, and contract, allowing cells to crawl and migrate, and microtubules help form structures like cilia and flagella that allow for cell movement.
3. **The cytoskeleton organizes the cell and keeps the cell's organelles in place,** but it also aids in the movement of organelles throughout the cell. For example, during endocytosis when a cell engulfs a molecule, microfilaments pull the vesicle containing the engulfed particles into the cell.
4. **Similarly, the cytoskeleton helps move chromosomes during cell division.**
5. **The cytoskeleton is the "frame" of the cell, keeping structures in place, providing support, and giving the cell a definite shape.**

Property	Microtubules	Microfilaments (Actin Filaments)	Intermediate Filaments
Structure	Hollow tubes; wall consists of 13 columns of tubulin molecules	Two intertwined strands of actin	Fibrous proteins supercoiled into thicker cables
Diameter	25 nm with 15-nm lumen	7 nm	8–12 nm
Protein subunits	Tubulin, consisting of α-tubulin and β-tubulin	Actin	One of several different proteins of the keratin family, depending on cell type
Main functions	Maintenance of cell shape (compression-resisting "girders") Cell motility (as in cilia or flagella) Chromosome movements in cell division Organelle movements	Maintenance of cell shape (tension-bearing elements) Changes in cell shape Muscle contraction Cytoplasmic streaming Cell motility (as in pseudopodia) Cell division (cleavage furrow formation)	Maintenance of cell shape (tension-bearing elements) Anchorage of nucleus and certain other organelles Formation of nuclear lamina



Differences between types of cytoskeleton filaments