First Lecture: Animal cell structure

Introduction:

Cell physiology is the biological study of the activities that take place in a cell to keep it alive. The term physiology refers to normal functions in a living organism, Animal cells, plant cells and microorganism cells show similarities in their functions even though they vary in structure.

"An animal cell is a type of eukaryotic cell that lacks a cell wall and has a true, membrane-bound nucleus along with other cellular organelles."

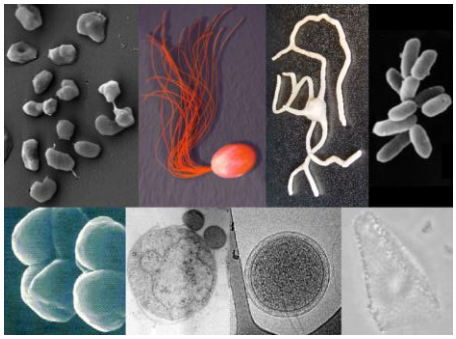
The cell is the structural and functional unit of the living matter and is capable of carrying on the processes of life independently. They provide the structure for the body's tissues and organs, ingesting nutrients and converting them to energy, and performing specialized functions. Cells also contain the body's hereditary code, which controls the substances synthesized by the cells and permits them to make copies of themselves.

Each cell has two major parts:

1. Nucleus.
2. The cytoplasm.

The different substances that make up the cell are collectively called protoplasm. Protoplasm (nucleus and the cytoplasm) is composed mainly of five basic substances—water, electrolytes, proteins, lipids, and carbohydrates.

General characteristics of cell: There are two types of cells: **prokaryotes and eukaryotes. Prokaryotes** were the first of the two to develop and do not have a self-contained nucleus. Their mechanisms are simpler than later-evolved **Eukaryotes**, which contain a nucleus that envelops the cell's DNA and some organelles.



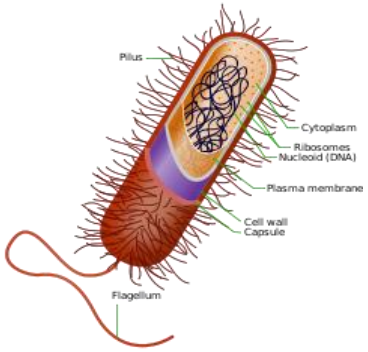
archaea

1. Prokaryotes

Prokaryotes have DNA located in an area called the nucleoid, which is not separated from other parts of the cell by a membrane. There are two domains of prokaryotes: bacteria and archaea.

Prokaryotes have fewer organelles than eukaryotes. Both have plasma membranes and ribosomes (structures that synthesize proteins and float free in cytoplasm).

Two unique characteristics of prokaryotes are fimbriae (finger-like projections on the surface of a cell) and flagella (threadlike structures that aid movement).



Bacteria

2. Eukaryotic:

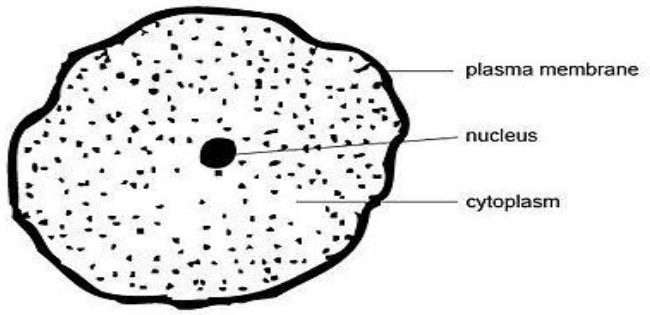
Typical eukaryotic animal cell structure

- Eukaryotes have a nucleus where DNA is contained. They are usually larger than prokaryotes and contain many more organelles. The nucleus, the feature of a eukaryote that distinguishes it from a prokaryote, contains a nuclear envelope, nucleolus and chromatin. In cytoplasm, endoplasmic reticulum (ER) synthesizes membranes and performs other metabolic activities.
- There are two types, rough ER (containing ribosomes) and smooth ER (lacking ribosomes). The Golgi apparatus consists of multiple membranous sacs, responsible for manufacturing and shipping out materials such as proteins. Lysosomes are structures that use enzymes to break down substances through phagocytosis, a process that comprises endocytosis and exocytosis. In the mitochondria, metabolic processes such as cellular respiration occur. The cytoskeleton is made of fibers that support the structure of the cell and help the cell move.

Animal Cell:

- When you look at a typical animal cell with a light microscope it seems quite simple with only a few structures visible.
- Three main parts can be seen:

1. An outer cell membrane (plasma membrane).
2. An inner region called the cytoplasm and the nucleus.



Cell constituents:

Different substances that make a cell are collectively called

Protoplasm: Protoplasm is composed of :-

1. Water -70-80% Water is present in cell.
2. Carbohydrates
3. Lipids
4. Proteins
5. Electrolyte - Sodium (Na+), Potassium (K+), Magnesium (Mg2+), Calcium (Ca2+), Phosphate , Chloride (Cl-), and Bicarbonate (HC03 -).

Major Structures Present in a cell is:-

1. Cell Membrane
2. Cytoplasm and its Organelles
3. Nucleus

Animal Cell Structure:

1. Cell Membrane (Plasma Membrane): is a thin elastic structure that envelops the cell and separate the cytoplasm from the surrounding fluids. It is composed primarily of phospholipids and proteins.

A. Lipid bilayer: It consists of :

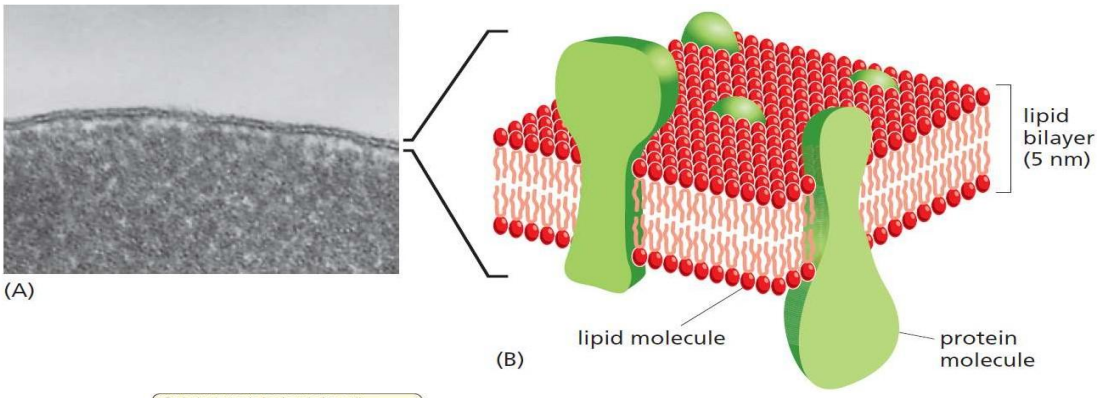
1. Phospholipids have a hydrophilic (water soluble)
2. lipid-soluble substances (e.g., O2, CO2, steroid hormones) cross cell membranes because they can dissolve in the hydrophobic lipid bilayer.
3. Water-soluble substances (e.g., Na+, Cl−, glucose, H2O).

B. proteins that are:

1. Integral Proteins.
2. Peripheral proteins.

C. Intercellular connections are:-

1. Tight junctions (zonula occludens)
2. Gap junctions



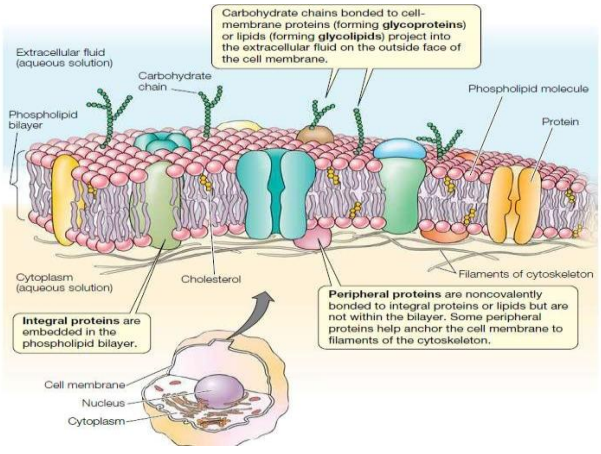


Figure: The structure of a cell membrane. The cell membrane consists primarily of twolayers of phospholipid molecules with protein molecules embedded and attached. Intracellular membranes also have a structure based on proteins embedded in a phospholipid bilayer.

Functions of the Cell Membrane:

1. Protective: - Forms outermost boundary of the cell organelles.

2. Digestive: - Takes in food and excretes waste products.

3. Selective Permeability:-

A. Non-Polar Molecules: - Gases (like O_2, CO2, N_2), Lipids, Steroid Hormones, Alcohols can dissolve in the non –polar regions of the membrane and move rapidly across the membrane.

B. Polar molecules: - H_2O soluble ions, Glucose, urea etc. have much lower solubility. Therefore penetrate the membrane much more slowly.

4. Chemical and Physical Properties of membrane control the free passage of ions in and out of cell. This property helps in maintaining components in ICF and ECF.
Links adjacent cells together by junctional complexes to form tissues.

5. Insulating Properties: - It acts as dielectric material of a charged condenser, thus cell membrane have very high insulating value.

6. Transport: Substances need to pass through the membrane to enter or leave the cell and they do so in a number of ways. Some of these processes require no energy i.e. they are passive, while others require energy i.e. they are active.
Passive processes include: a) diffusion and b) osmosis, while active processes include: c) active transport, d) phagocytosis, e) pinocytosis and f) exocytosis.

2. Cytoplasm and its Organelles

A. Cytoplasm: Thick, gel-like semitransparent fluid that is found in both plant and animal cell. The constituent parts of cytoplasm are cytosol, cell organelles and cytoplasm inclusions. Bounded by the plasma membrane, and contains many organelles in a eukaryotic cell (cell containing membrane bounded nucleus).

B. cytosol:

1. The cytosol:- The cytosol consists mainly of water in which various molecules are dissolved or suspended. These molecules include proteins, fats and carbohydrates as well as sodium, potassium, calcium and chloride ions. Many of the reactions that take place in the cell occur in the cytosol. It accounts for almost 70% of the total cell volume.
2. Gelatinous substance: consisting mainly of cytoskeleton filaments, organic molecules, salt and water.

3. Chemically, the cytoplasmic matrix is composed of many chemical elements in the form of atoms, ions and molecules.

4. Cell inclusions: These are large particles of fat, glycogen and melanin that have been produced by the cell. They are often large enough to be seen with the light microscope. For example the cells of adipose tissue (as in the insulating fat layer under the skin) contain fat that takes up most of the cell.

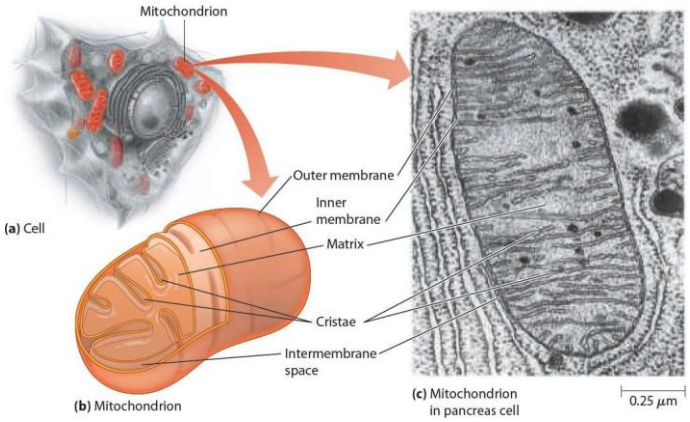
C. Organelles: are the "little organs" of the cell - like the heart, kidney and liver are the organs of the body. They are structures with characteristic appearances and specific "jobs" in the cell. Most cannot be seen with the light microscope and so it was only when the electron microscope was developed that they were discovered. The main organelles in the cell are the:

- ✓ ribosomes.
- ✓ endoplasmic reticulum.
- ✓ Mitochondrion.
- ✓ Golgi complex .
- ✓ lysosomes.
- ✓ Vacuole.
    - Each organelle is bounded by a lipid membrane, and has specific function

Mitochondria:

- The mitochondria were first observed by Kolliker in 1850 as granular structures in the striated muscles.
- Mitochondria are called the 'powerhouse of the cell'.

STRUCTURE:



- Length- 5-12µm
- Diameter- 0.5-1µm
- Filamentous or globular in shape.
- Components of Mitochondria are -
    1. Outer Membrane.
    2. Inner Membrane
- Intermediate Space- space between outer and inner membranes
- Cristae- Infoldings of inner membrane
- Matrix- The space enclosed by inner membrane
    - The membranes are made up of phospholipids and proteins

Components of Mitochondria are: -

1. Outer Membrane:

- It contains large numbers of integral membrane proteins called Porins.
- These porins form channels that allow molecules of 5000 daltons or less to pass.
- Studded with enzymes concerned with biological oxidation .
- Interior (Matrix) of the Mitochondria contains enzymes concerned with *'citric acid cycle'* and *'respiratory chain oxidation'.*
- Major metabolic pathways involved in oxidation of carbohydrates, lipids and amino acids and part of special biosynthetic pathways involving urea and heme synthesis are located in inner matrix.

2. Inner Membrane:

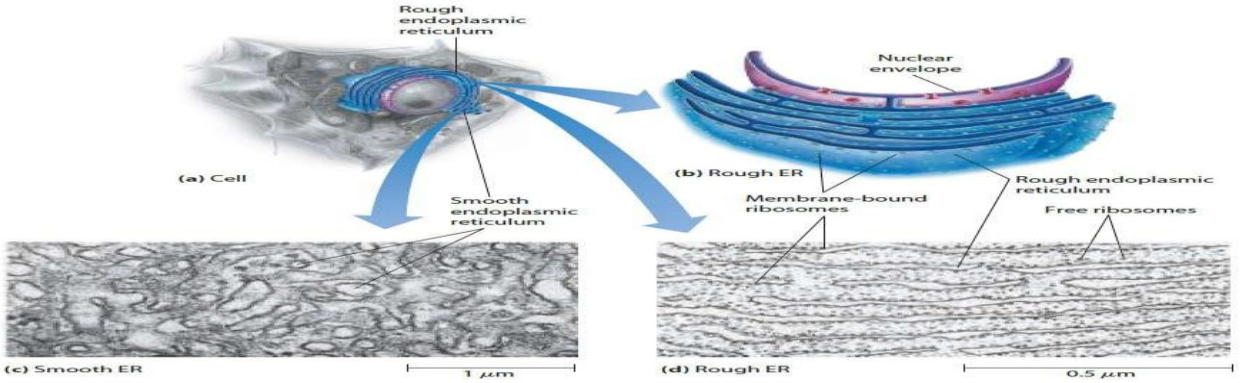
- Chemical energy produced by the mitochondria is stored in a small molecule called adenosine triphosphate (ATP).
- Contains enzymes of Electron Transport Chain.
- The ultimate purpose of these mechanisms is *oxidative phosphorylation* and *synthesis of ATP.*
- The enzymes responsible for the tricarboxylic acid cycle, one component of oxidative phosphorylation, are located in the mitochondrial matrix and the enzymes involved in electron transport, another major function of the oxidative phosphorylation process, are associated with the inner mitochondrial membrane.
- Mitochondria have some protein synthesised by Mitochondrial DNA.
- Mitochondria are self-replicative.
- The mitochondria contain DNA similar to that found in the cell nucleus.

Function of mitochondria:

1. Power generating units of the cells.
2. Important to maintain proper concentration of calcium ions within the various compartments of the cell.
3. Energy transduction through respiration.
4. Responsible for thermogenesis.

Endoplasmic Reticulum

- Network of **tubular and flat vesicular structures** in the cytoplasm.
- An extensive network of closed, flattened membrane-bounded sacs called **cisternae** Space inside the tubules
- Is filled with Endoplasmic Matrix.



Two Type:

1. Rough (Granular) Endoplasmic Reticulum: The roughness of the membrane is due to the presence of the ribosomes.

2. Smooth (Agranular) Endoplasmic Reticulum.

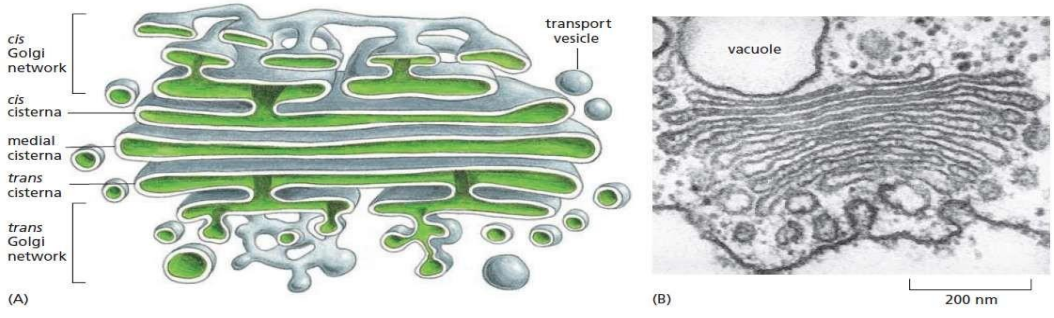
Smooth Endoplasmic Reticulum	Rough Endoplasmic Reticulum
▪ Ribosomes absent ▪ Site of synthesis of lipid and steroid hormones. ▪ Mainly present in lipid forming cells such as adipocytes, interestitial cells of testis, glycogen storing cells of liver, adrenal cortex cells, muscle cells, leucocytes etc.	▪ Contains ribosomes ▪ Site of protein synthesis,processing and packaging. ▪ Mainly present in protein forming cells such as pancreatic acinar cells ,Goblet cells ,antibody producing plasma cells, Nissl's granules of nerve cells etc.

Functions of Endoplasmic Reticulum:

1. Synthesis of proteins.
2. Protein segregation.
3. Un saturation of fatty acid.
4. Muscle contraction.
5. ER is commonly known as Sarcoplasmic Reticulum in muscle fibers.

Golgi apparatus:

- Golgi Bodies is a collection of membrane enclosed sacs composed of four or more stacked layers of thin, flat enclosed vessels lying near the side of the nucleus.
- Consist of multiple discrete compartments.
- Consist of four functionally distinct regions:
- The cis Golgi network
- Golgi stack –which is divided into
    1. The medial and
    2. Trans sub compartments
    3. The Trans Golgi network.



4. Function of Golgi apparatus:

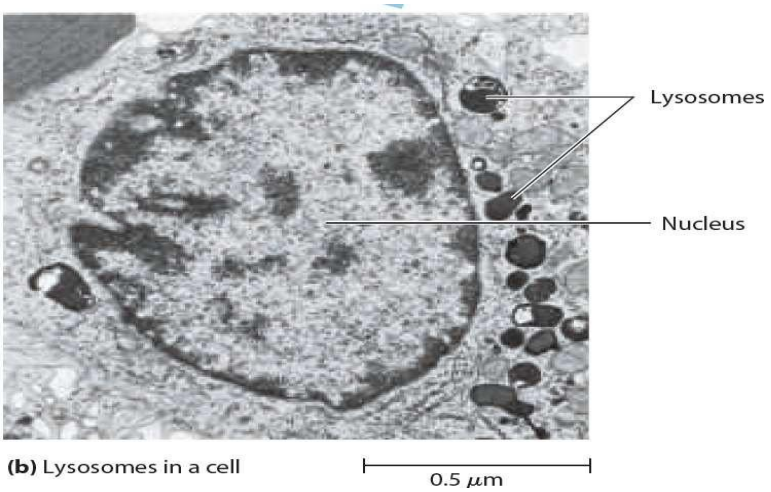
1. Wrapping and Packaging department of the cell.
2. Produces secretion granules i.e. membrane enclosed complexes, which store hormones and enzymes in the protein secreting cells, it packages proteins.
3. Site of formation of lysosomes i.e. large irregular structures surrounded by membrane which are present in the cytoplasm.
4. It adds certain carbohydrates to form glycoproteins, which play an important role in the association of the cells to form tissues

Lysosomes:

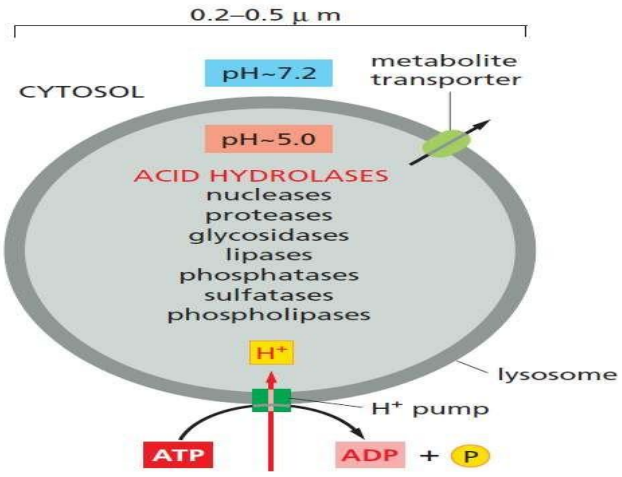
- They are vesicular organelles that form by breaking off from the Golgi apparatus.
- These are the irregular structures surrounded by the unit membrane.
- They act as intracellular digestive system of the cell, serving both to degrade materials taken up from outside the cell and to digest obsolete components of the cell itself.
- They contain hydrolytic enzymes.
- More acidic than rest of the cytoplasm and external bacteria as well as worn out cell components.
- The interior is kept acidic (near pH5.0) by the action of proton pump or H+ or ATPase.
- Lysosomes are cell hydrolases and they function best at the acidic pH.

Function of lysosomes:

1. Acts as a form of digestive (lytic) system or the cell, because enzymes present in it can digest essentially macromolecules.
2. Engulf worn out components of the cells in which they are located.
3. Engulf exogenous substances e.g. bacteria and degrade them.
4. When a cell dies, lysosomal enzymes causes autolysis of the remnant. That's why lysosomes are called as Suicidal Bags.

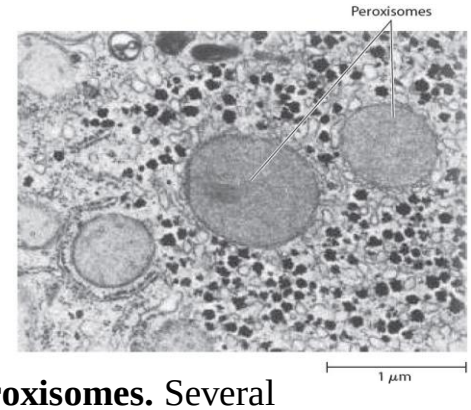


(b) Lysosomes in a cell



Peroxisomes:

- Peroxisomes are physically similar to lysosomes.
- They are formed by self-replication or by budding off from the smooth endoplasmic reticulum.
- They contain oxidases.
- A major function of peroxisomes is to catabolize long-chain fatty acids.
- About half the alcohol that a person drinks is detoxified into acetaldehyde by the peroxisomes of the liver cells.
- In animals, peroxisomes are found in most cell types but are especially prominent in liver and kidney cells. Beyond their role in detoxifying hydrogen peroxide, animal peroxisomes have several other functions, among them detoxifying other harmful compounds (such as methanol, ethanol, formate, andformaldehyde) and catabolizing unusual substances (such as d-amino acids).
- Animal peroxisomes also play an important role in the oxidative breakdown offatty acids.



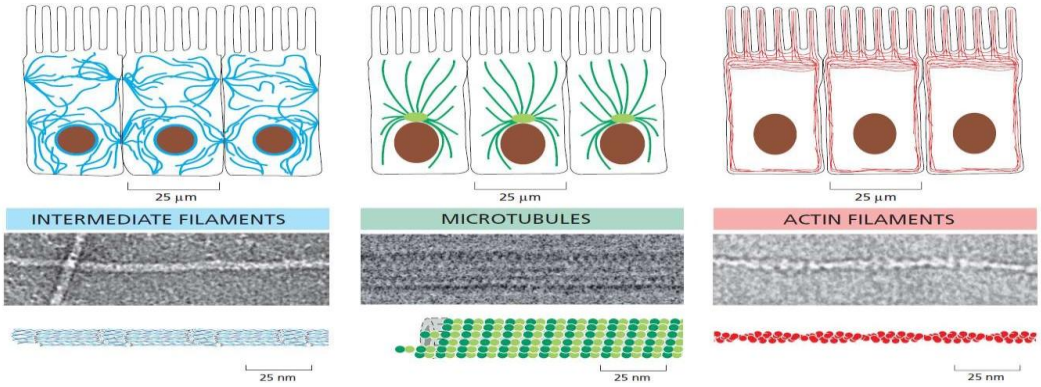
Animal Peroxisomes. Several peroxisomes can be seen in this cross section of aliver cell (TEM).

Functon of Peroxisomes:

1. H_2O_2 metabolism and detoxification
2. Helps in Photorespiration in plants
3. Biosynthesis of lipids .
4. Cholesterol and dolichol are synthesized in animals.
5. Synthesis of bile acids in liver.
6. Synthesis of plasmalogens
7. (myelin sheath).

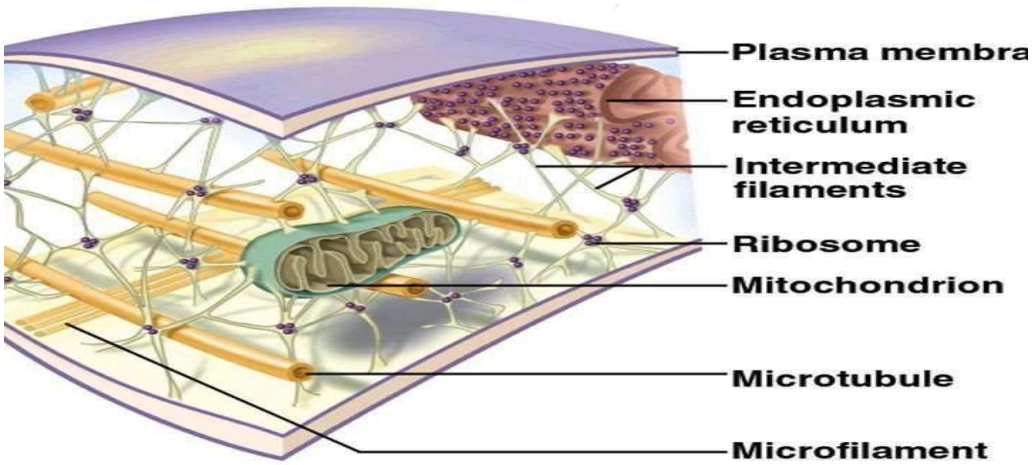
Cytoskeleton:

- System of fibers that not only maintains the structure of the cell but also permit it to change shape and move.
- The cytoskeleton is made up primarily of:-
  1. Microtubules
  2. Intermediate Filaments
  3. Microfilaments and along with protein that anchor tie them together.



Function of the cytoskeleton: They are involved in the:-

1. Movement of the chromosomes
2. Cell movement.
3. Processes that move secretion granules in the cell.
4. Movement of proteins within the cell membrane.



Nucleus:

- Nucleus has an internal structure that organizes the genetic material and localizes nuclear functions.
- The nucleus is the control center of the cell and sends messages to the cell to grow and mature, replicate, or die.
- The nucleus contains large quantities of DNA, which comprise the genes.

➢ **Nuclear Membrane (nuclear envelope):**

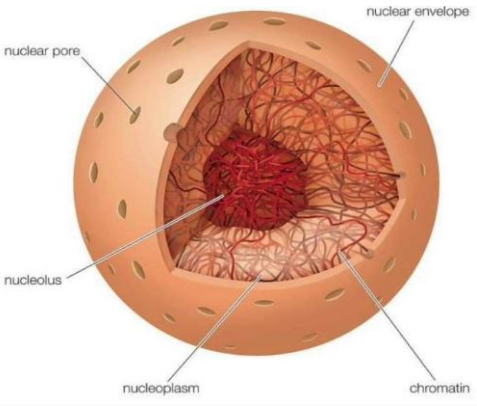
- Surrounds the nucleus.
- The nuclear membrane is penetrated by several thousand nuclear pores which
- permit passage of molecules from the nucleus to the cytoplasm.

➢ **Nucleolus:**

- The nucleus is responsible for the synthesis of messenger RNA (mRNA) which carries the genetic information in code through the pores in the nucleus.

CONTD. Of the nucleus:

- These lamins serve as sites of chromatin attachment and organize other proteins into functional nuclear bodies.
- Chromatin within the nucleus is organized into large loops of DNA, and specific regions of these loops are bound to the lamin matrix by lamin-binding proteins in the chromatin.



nuclear envelope:

- Complex structure consisting of two nuclear membranes, an underlying nuclear lamina, and nuclear pore complexes.
- **Two concentric membranes, called the:**

1. inner and outer nuclear membranes .
2. The outer membrane is continuous with the endoplasmic reticulum, so the space between the inner and outer nuclear membranes is directly connected with the lumen of the endoplasmic reticulum.

CONTD. Of nuclear:

- Nuclear membrane is permeable only to small nonpolar molecules.
- Underlying the inner nuclear membrane is the nuclear lamina, a fibrous meshwork that provides structural support to the nucl

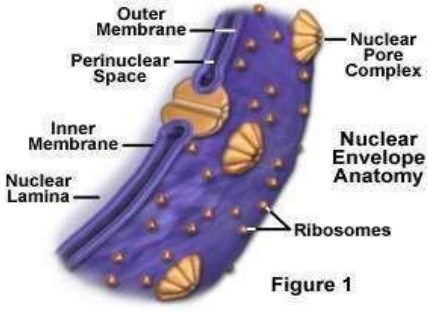
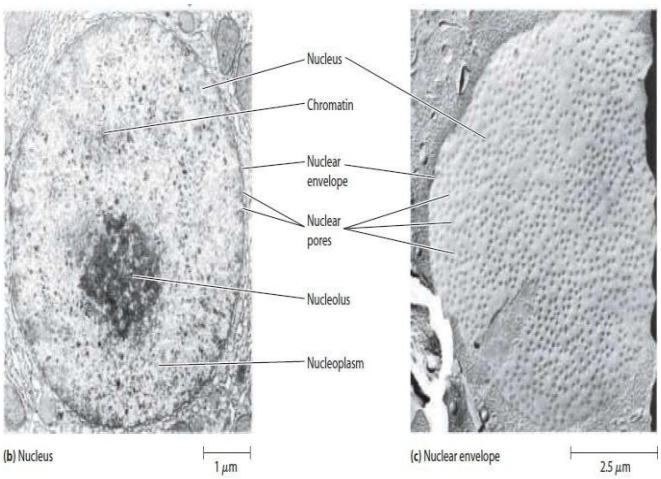


Figure 1

Function of the nucleus:

1. Serves both as the repository of genetic information and as the cell's control center.
2. The presence of a nucleus thus allows gene expression to be regulated by posttranscriptional mechanisms, such as alternative splicing.
3. The nuclear envelope provides novel opportunities for the control of gene expression at the level of transcription.



Energy Production:

- The principal substances from which cells extract energy are foods that react chemically with oxygen—carbohydrates, fats, and proteins.
- In the Animal body, essentially all carbohydrates are converted into glucose by the digestive tract and liver before they reach the other cells of the body.
- Similarly, proteins are converted into amino acids, and fats are converted into fatty acids.
- Inside the cell, they react chemically with oxygen under the influence of enzymes that control the reactions and channel the energy released in the proper direction.
- Briefly, almost all these oxidative reactions occur inside the mitochondria, and the energy that is released is used to form the high-energy compound ATP. Then, ATP, not the original food, is used throughout the cell to energize almost all the subsequent intracellular metabolic reactions.

Uses of ATP for Cellular Function:

Energy from ATP is used to promote three major categories of cellular functions:

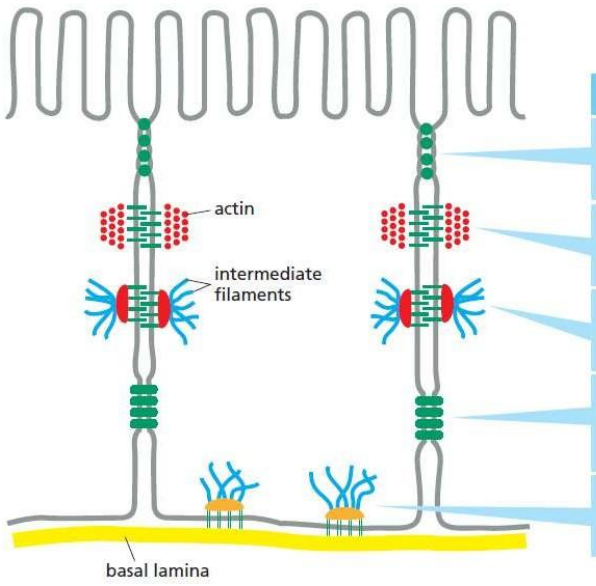
1. transport of substances through multiple membranes in the cell,
2. synthesis of chemical compounds throughout the cell, and
3. supply energy for special cells to perform mechanical work.

These uses of ATP are :

1. to supply energy for the transport of sodium through the cell membrane,
2. to promote protein synthesis by the ribosomes.
3. to supply the energy needed during muscle contraction.

CELL-CELL JUNCTIONS:

- Cells do not exist in isolation, but rather exert multiple influences on one another.
- Four types of intercellular junctions are commonly encountered in vertebrate tissue: (1) **tight junctions**; (2) **gap junctions**; (3) **adherens junctions**; and (4) **desmosomes**.
- Epithelial layers such as seen in small intestine display a rather stylized **"junctional complex"** that consists of the four junctional types arranged in a sequence from the luminal (apical) surface down to the basal surface; in order, the complex goes tight junction/adherens junction/ desmosome/gap junction



name	function
tight junction	seals neighboring cells together in an epithelial sheet to prevent leakage of extracellular molecules between them; helps polarize cells
adherens junction	joins an actin bundle in one cell to a similar bundle in a neighboring cell
desmosome	joins the intermediate filaments in one cell to those in a neighbor
gap junction	forms channels that allow small, intracellular, water-soluble molecules, including inorganic ions and metabolites, to pass from cell to cell
hemidesmosome	anchors intermediate filaments in a cell to the basal lamina