Scope of Anatomy & Physiology

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Human Anatomy and Physiology are the branches of biology that concerns with forms (structures) and functions of human body.

ANATOMY- Study of structure of whole body and individual parts (organs) and their correlation with each other.

Branch of biomedical science dealing with normal structure, shape, size and location of various parts of the body

The study of the structure of the body and the physical relationships involved between the body systems.

Anatomy derived from Greek words: ***ana*** means 'up' and ***tomy*** means 'cutting', and hence anatomy deals with study of structural components of body i.e. organs by means of surgical dissection.

SUBDIVISIONS OF ANATOMY

a) **Gross Anatomy** Study of body parts visible to naked eye,

b) **Microscopic Anatomy** Anatomical study by means of modern microscopes including study of cells (Cytology) and tissues (Histology),

c) **Developmental Anatomy** Study of human growth and development,

d) **Pathological Anatomy** Study of diseased body structure,

e) **Systemic Anatomy** Study of body by system (System is a group of organs that have common function e.g. bones in skeleton system and muscles in muscular system).

PHYSIOLOGY- Science deals with the functions of the living organism and its parts (i.e. functions of body parts and their synchronized working to co-ordinate the actions of whole body).

Study of how the systems of the body work, and the ways in which their integrated cooperation maintains life and health of the individual

Branch of biomedical sciences, dealing with normal functions of various organs of the body.

Physiology derived from Greek words ***physis*** means 'nature' and l***ogos*** means 'science or study', and hence physiology helps to understand how body works i.e. functioning of body.

SUBDIVISIONS OF PHYSIOLOGY

a) **Based on type of organism involved** Plant and Human Physiology,

b) **Based on organizational level** Molecular and Cellular Physiology,

c) **Based on the specific function being studied** such as Neurophysiology, Respiratory Physiology and Cardiovascular Physiology etc.

BASIC TERMINOLOGIES

Health A state of complete physical, mental, and social well being and not merely the absence of disease or infirmity (illness), according to World health Organization (WHO).

Disease An abnormal condition of the organism that impairs body functions, associated with the specific signs and symptoms. It may be caused by external factors, such as invading organisms, or it may be caused by internal dysfunctions, such as autoimmune diseases.

Syndrome The association of several clinically recognizable features, signs (observed by a physician) or symptoms (reported by the patients).

Histology The study of the microscopic anatomy of cells and tissues of plants and animals.

Pathophysiology The study of changes of normal mechanical, physical, and biomechanical functions, either caused by the disease, or resulting from an abnormal syndrome or the branch of medicine which deals with any disturbances of body functions, caused by disease or symptoms.

Pathogenesis The stepwise development of a disease and the chain of events leading to that disease due to a series of changes in the structure and/ or function of cell/ tissue/ organ being caused by a microbial, chemical or physical agent.

Homeostasis The property of system either open or closed, which regulates its internal environment and tends to maintain a stable, constant condition of human body.

Aetiology The study of why things occur or the reason behind the way that things act**.**

Histopathology The microscopic study of diseased tissue, acts as an important tool in pathological anatomy.

Acute A disease with sudden onset often requiring urgent treatment.

Acquired A disorder which develops any time after birth.

Chronic A long-standing disorder which cannot usually be cured.

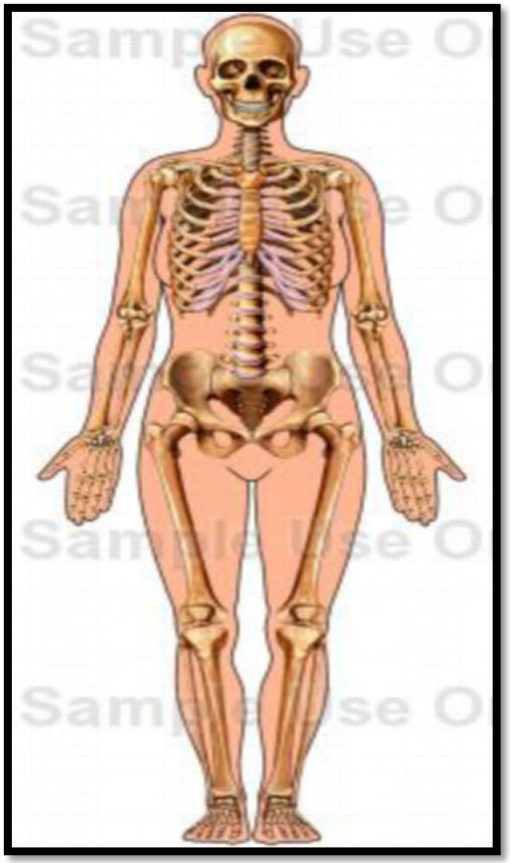
Congenital A disorder which one is born with.

Sign An abnormality seen or measured by people other than the patient.

Symptoms An abnormality described by the patient.

Bilateral symmetry An external organizational feature in humans. Humans are bilaterally symmetrical means that left and right sides of the body are mirror images of each other and only one plane can divide the body into the left and right sides.

Anatomical positions The state which discuss about the body, how it moves, its posture or the relationship of one area to other, assume that the body as a whole is in the specific position called anatomical position. The reference position in which the body is in an erect or standing, posture with the arms at the sides and palms turned forward along with head and feet.



Directional terms Terms used to describe the position of the body parts relative to each other.

- **Ipsilateral** and **contralateral** are the directional term used most frequently to designate injury to an extremity, on the same side and opposite side respectively.

- **Superior** and **Inferior** Superior means towards the head or above or upper while inferior means towards the feet or below or lower. (e.g. lungs located superior to diaphragm while stomach located inferiorly).

- **Anterior** and **posterior** Anterior means front or in front of or ventral while posterior means back or in back of or dorsal. (e.g. nose is located to anterior surface while shoulders are located on posterior surface of the body).

- **Medial** and **lateral** Medial means towards the midline of body while lateral means towards the side of the body or away from the midline. (e.g. the ulna is medial to radius bone while lungs are lateral to the heart).

- **Proximal** and **distal** Proximal means towards or nearest to trunk of the body while distal means away or farthest from the trunk. (e.g. humerus is proximal to the radius while phalanges are distal to carpals).

- **Superficial** and **deep** Superficial means nearer to the surface while deep means farther away from the body surface. (e.g. skin of the arm is superficial to the muscle below it while bone of the upper arm is deep to the muscles that surround and protect it).

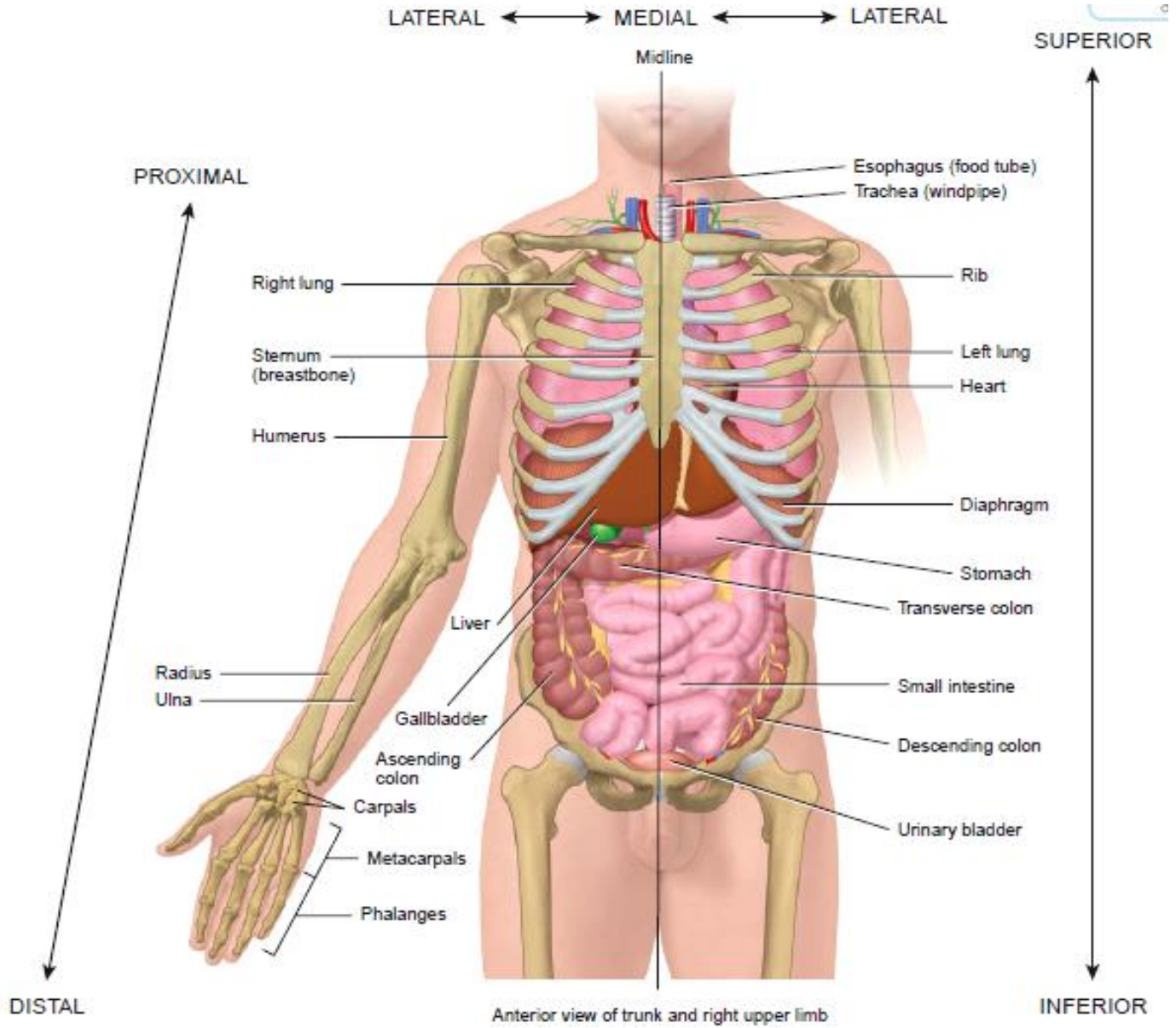


Fig. Directional terms precisely locate various parts of the body relative to one another.

Plantar Belonging to the sole of the foot.

Palmer Belonging to the palm of the hand.

Internal The relationship to the inner surface of the body.

External The relationship to the outer surface of the body.

Transverse Separates superior from inferior.

Coronal (frontal) Separates anterior from posterior.

Sagittal (median) Separates left from right.

Articulation surfaces The part of the bone that enters into the formation of joint.

Articulation A joint between two or more bones.

Bony sinus A hollow cavity within a bone.

Border A ridge of bone separating two surfaces.

Condoyle/ condyle A smooth rounded projection of bone that forms part of joint.

Facet A small, generally rather flat, articulating surface.

Fissure/ cleft A narrow slit.

Foramen A hole in structure.

Fossa A hollow or depression.

Meatus A tube shaped cavity within a bone.

Septum A partition separating two cavities.

Spine, spinous process or crest A sharp ridge of bone.

Styloid process A sharp downward projection of bone that gives attachment to muscle and ligaments.

Suture An immobile joint.

Tronchanter, tuberosity or tubercle Roughened bony projections, usually for attachment of muscles or ligaments.

STRUCTURE OF CELL, ITS COMPONENTS, THEIR STRUCTURE & FUNCTIONS

Cell The basic , living structural and functional unit of body or life, consists of a **cell membrane/ plasma membrane** inside which the number of **organelles** suspended in a watery fluid called **cytosol**.

Cells are **self-contained** and **self maintaining**: it can take nutrients, converts it into energy, carry out specialized functions, and reproduce as necessary. Each cell has its own instruction store to perform such activities.

cells grouped together to form tissues, each of which has specialized functions e.g. blood, muscle, bone etc., different tissues are grouped together to form organs e.g. heart, brain, stomach etc. and different organs are come together to form systems each of which perform a particular function that maintains homeostasis and contributes to the health of an individual.

Abilities or Functions of Cell

- Reproduction by cell division,
- Use of enzymes and other proteins coded by DNA genes and made via messenger RNA intermediates and ribosomes,
- Metabolism,
- Response to external and internal stimuli such as change in temperature, pH or levels of nutrients, and
- Cell contents are contained within a cell surface membrane that is made from a phospholipid bilayer with proteins embedded in it.

Definitions of eukaryotes and prokaryotes

- **Prokaryotes** (Greek ***pro***- before + ***karyon*** nut or kernel, referring to the cell nucleus), are organisms without a cell nucleus (karyon), or any other membrane-bound organelles. Most are unicellular, but some prokaryotes are multicellular.

- **Eukaryotes (**Greek **ευ**, meaning good/true, and ***karyon*** nut or kernel, referring to the cell nucleus) are organisms whose cells are organized into complex structures by internal membranes and a cytoskeleton. The most characteristic membrane bound structure is the nucleus. Animals, plants, fungi, and protists are eukaryotes.

Fig. Eukaryotic Animal Cell

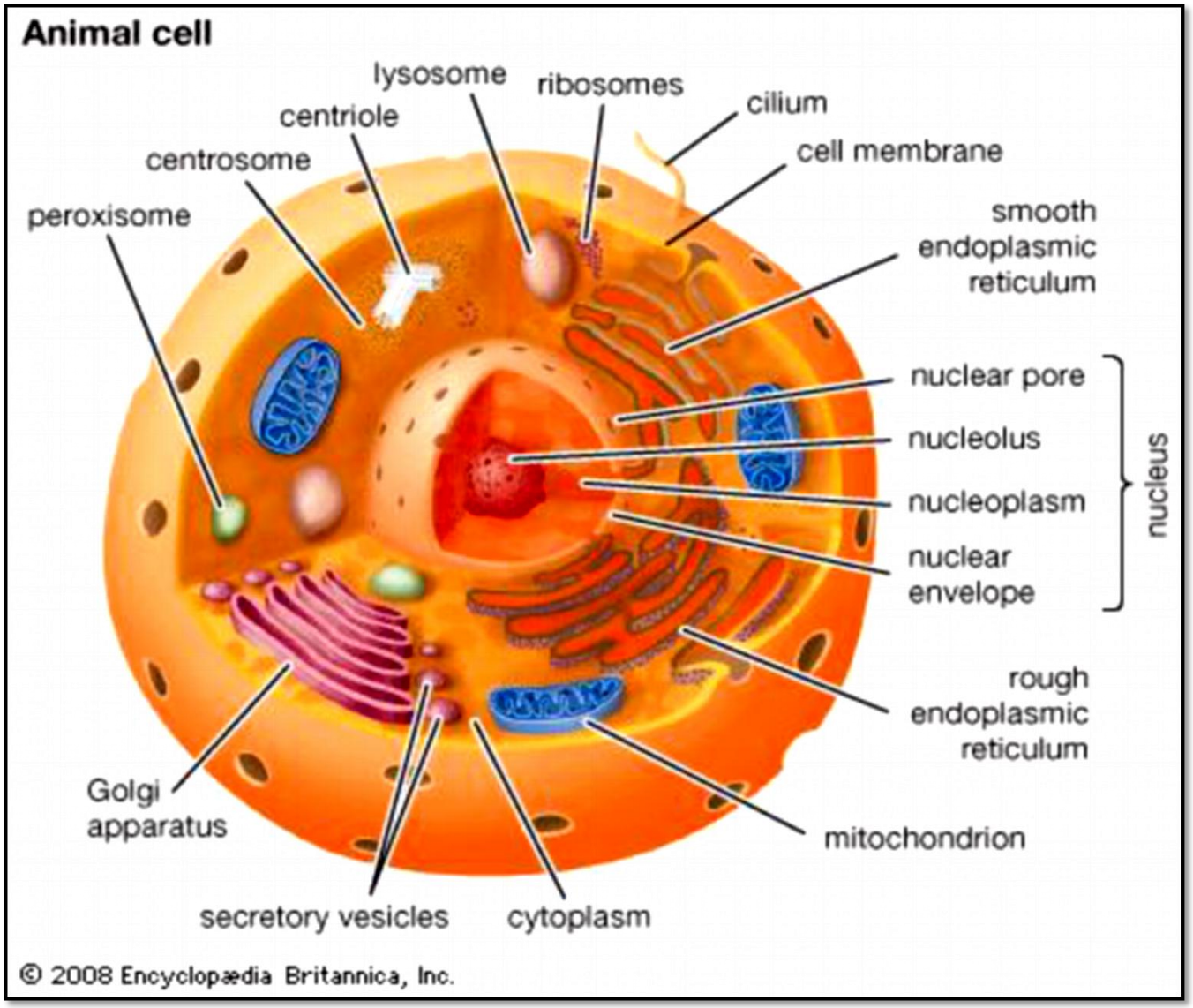
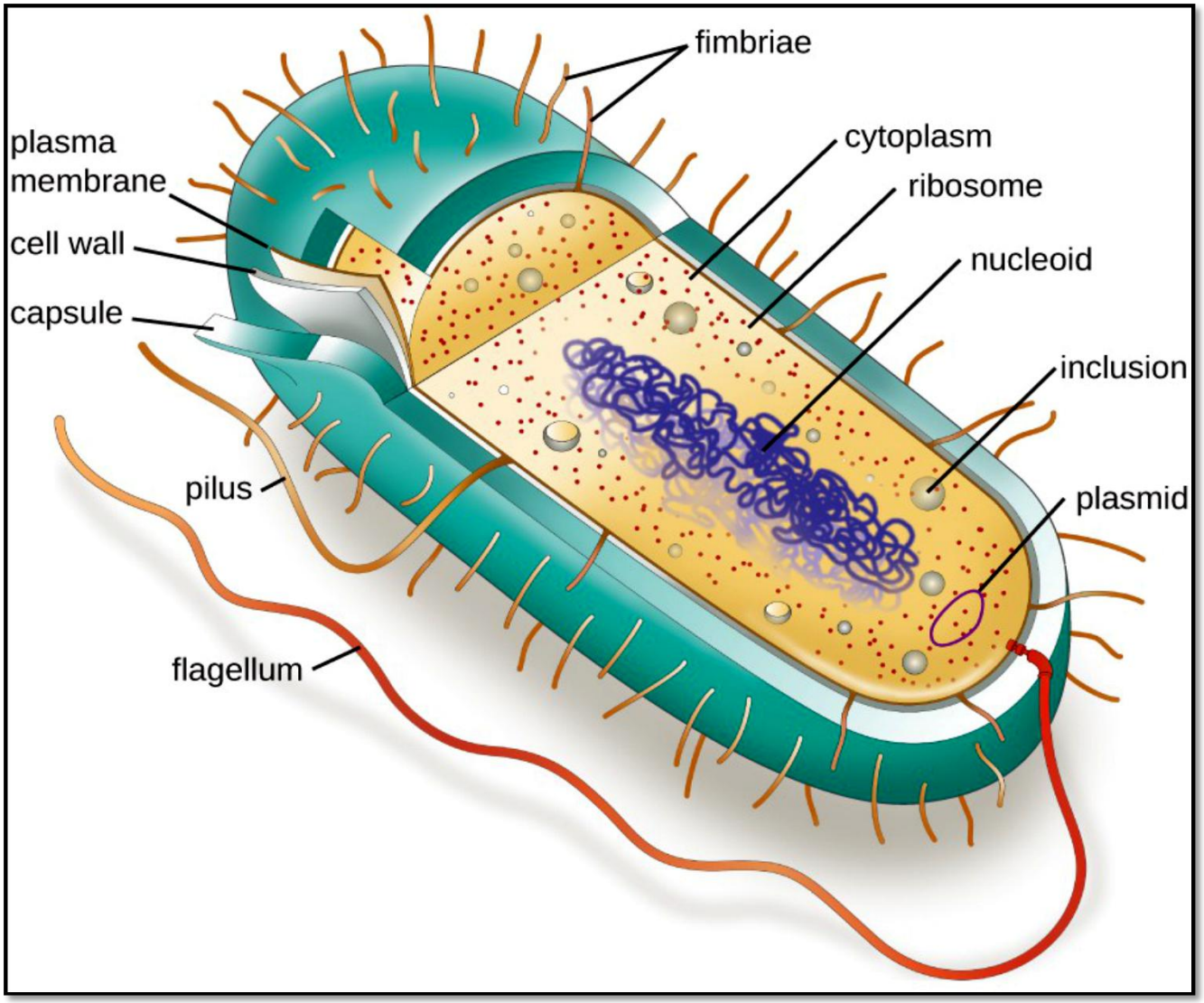


Fig. Prokaryotic Bacterial Cell



Distinguishing features of Eukaryotic and Prokaryotic Cell		
Feature	**Eukaryotic Cell**	**Prokaryotic Cell**
Nucleus	Present	Absent
Number of chromosomes	More than one	One- but not true chromosome: Plasmids
Cell Type	Usually multicellular	Usually unicellular (some cyanobacteria may be multicellular)
True Membrane bound Nucleus	Present	Absent
Example	Animals and Plants	Bacteria
Genetic Recombination	Meiosis and fusion of gametes	Partial, undirectional transfers DNA
Lysosomes and peroxisomes	Present	Absent
Microtubules	Present	Absent or rare
Endoplasmic reticulum	Present	Absent
Mitochondria	Present	Absent
Cytoskeleton	Present	May be absent

Golgi apparatus	Present	Absent
Chloroplasts	Present (in plants)	Absent; chlorophyll scattered in the cytoplasm
DNA wrapping on proteins	Eukaryotes wrap their DNA around proteins called histone	Multiple proteins act together to fold and condense prokaryotic DNA. Folded DNA is then organized into a variety of conformations that are supercoiled and wound around tetramers of the HU protein
Permeability of Nuclear Membrane	Selective	Not present
Plasma membrane with steroid	Yes	Usually no
Cell wall	Only in plant cells and fungi (chemically simpler)	Usually chemically complexed
Vacuoles	Present	Present
Cell size	10-100um	1-10um

The Cell Membrane/ Plasma Membrane

Cells flexible outer surface that separates cells internal environment from an external one.

Constituents of cell membrane include phospholipids (25 %), cholesterol (03%), Proteins (55 %), carbohydrates (03 %), and other lipids (04%).

Structure

- **Phospholipids (fatty substances) bilayer** with the **protein** and **sugar molecules** embedded in them.

- **Phospholipid molecules** have an electrically charged polar, hydrophilic (water-loving) 'head' and non-polar (no charge), hydrophobic (water-hating) 'tail'.

- The phospholipid bilayer arranged like a sandwich with the hydrophilic head aligned on the **outer surface** and hydrophobic tails forms **central water-repelling layer**. The structure influences the transport of the substances across the plasma membrane.

- **Membrane proteins** are categorized as **integral** or **peripheral** proteins according to whether they are firmly embedded in membrane.

- The **integral proteins** extended into or through the lipid bilayer among the fatty acid tails and firmly embedded in it. These are **transmembrane** proteins (trans-across) which span the entire lipid bilayer and protruded into both cytosol and extracellular fluid.

The integral proteins can be differentiated as-

Channel proteins (responsible for the transfer of water- soluble substances),

Carrier proteins (responsible for the transfer of materials across the bilayer through active transport mechanism),

Receptor proteins (binds with different neurotransmitter or the chemical substance leading to the changes in intracellular reactions), and

Pumps (the proteins which actively transfer the ions across the bilayer, against concentration gradient).

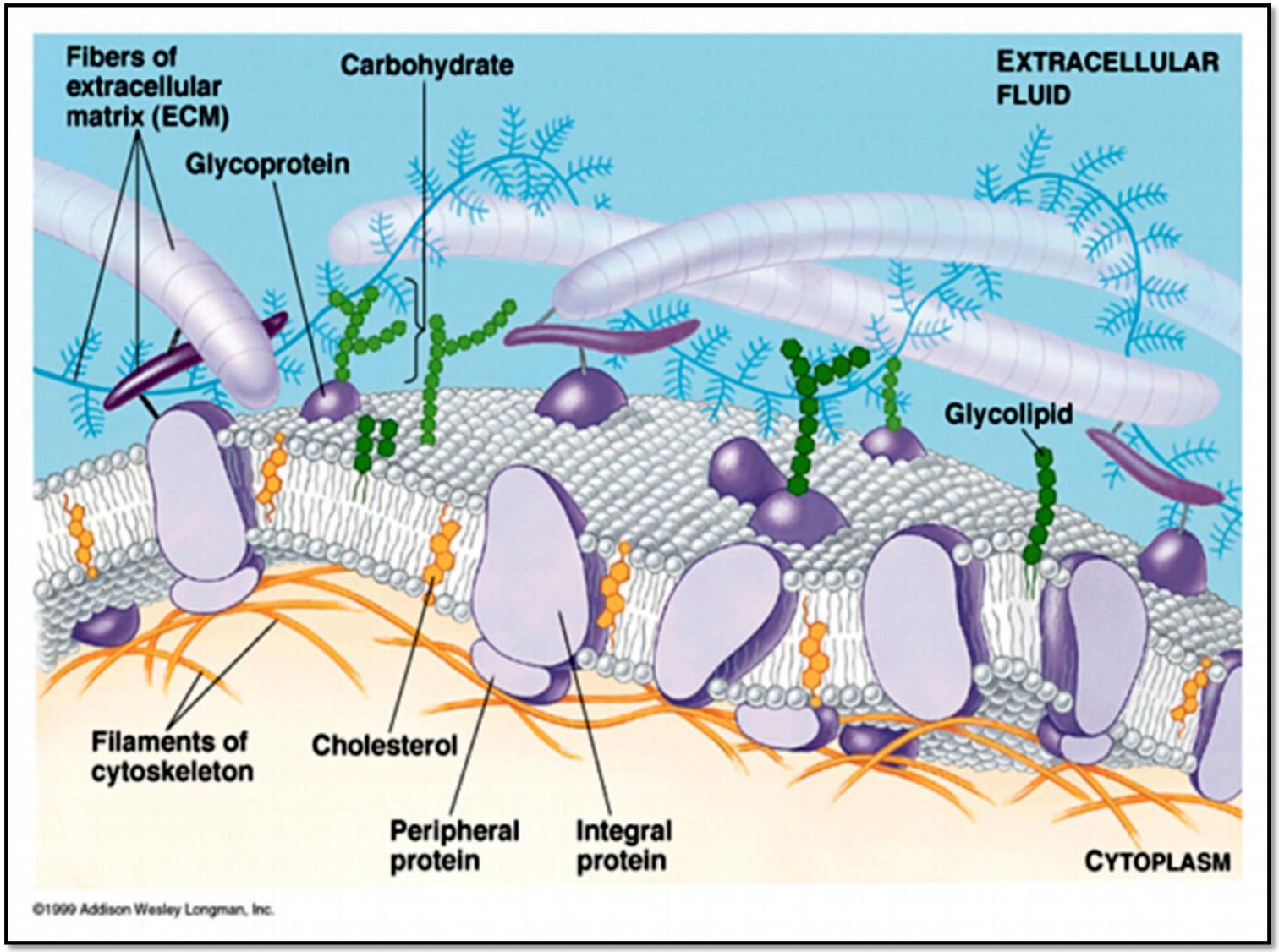
- The **peripheral proteins** are not firmly embedded/ penetrate in lipid membrane and associated more loosely with the polar head of the membrane lipids or with the integral proteins at the inner or outer surface of proteins.
- **Functions of membrane proteins**

1. Branch the carbohydrate molecules attached to the outside of some membrane proteins,
2. Give cells its immunological identity,
3. Acts as a specific receptors (recognition sites) for the hormones and specific chemical messengers,
4. Some acts as enzymes, and
5. Some are involved in the transport of substance across the plasma membrane.

Functions

- Regulate the transport of substances across the cell for regulating the normal cellular activities, and
- Role in communication among the cell and between the cell and external environment

Fig. An appearance of plasma membrane shows the presence of phospholipid bilayer with the protein and sugar moieties embedded in it and the presence of the membrane proteins i.e. integral and peripheral proteins.



Cellular Organelles (Structural Components of Cell)

A cell consists of plasma membrane inside which is number of organelles suspended in watery fluid called **cytosol (cytoplasm)**. Cytosol is a transparent, viscous gel like fluid containing 75-90% of water, and the suspended or dissolved components such as proteins, lipids, carbohydrates, different inorganic substances and salts etc.

The Major **Cellular Organelles** include-

a) Nucleus

b) Mitochondria

c) Ribosome

d) Endoplasmic reticulum

e) Golgi apparatus/ Golgi bodies/ Golgi complex

f) Lysosomes

g) Peroxisomes

h) Proteasomes

i) Centrosomes

j) Cytoskeleton

k) Cell extension

a) Nucleus

Spherical, oval shaped structure, usually acts as the most prominent feature of the cell, present in all the types of the cells.

Skeletal muscle cell and few other cells have multiple numbers of nuclei while mature RBCs are non-nucleated.

Structure & Function The nucleus consist of **nuclear envelop** and **nuclear pores** (as shown in the figure).

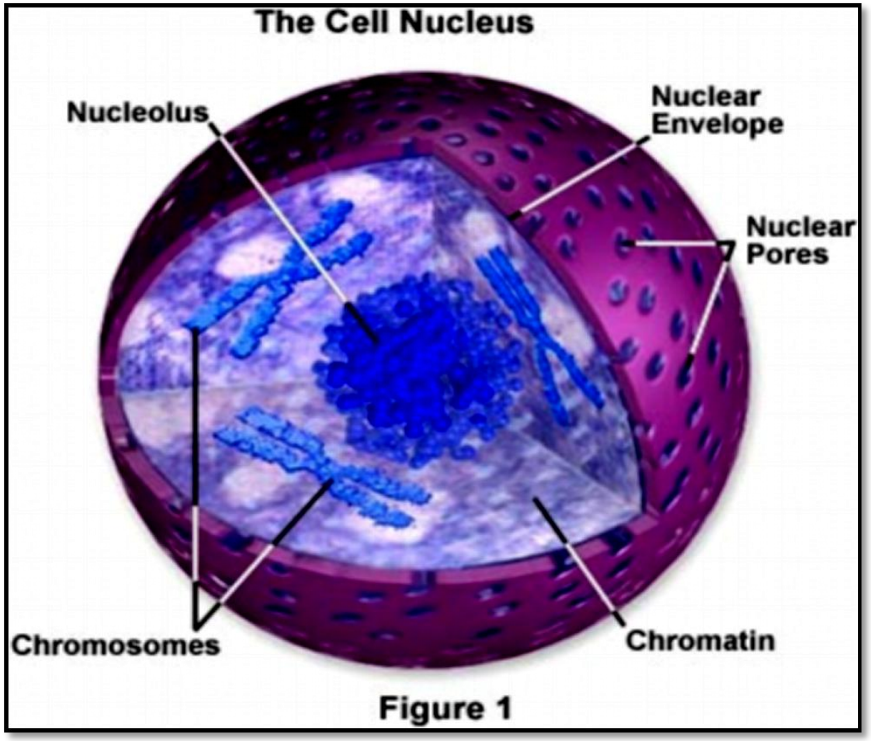


Figure 1

Nuclear envelop, a bilayer structure that separates nucleus from the cytoplasm. Both these layers of the nuclear envelop are lipid bilayer similar to the plasma membrane.

Nuclear pores are extends through the nuclear envelop consist of circular arrangement of proteins, and functioned to control the transport of the substances between the nucleus and cytoplasm.

Inside the nucleus, **nucleoli** (spherical bodies), are present which functioned in the production of ribosomes. Each nucleolus is simple clusture of protein, DNA and RNA, and is not enclosed by membrane. It also acts as the site of synthesis of ribosomal RNA (rRNA). Nucleolus get disperse and disappear during cell division and organized once new cells are formed.

The nucleus consists of body's **genetic material** which directs all the metabolic activities of the cell. These consist of **46 chromosomes (23 pairs)** which are made from DNA.

b) Mitochondria (Mito: thread, chondria: granules)

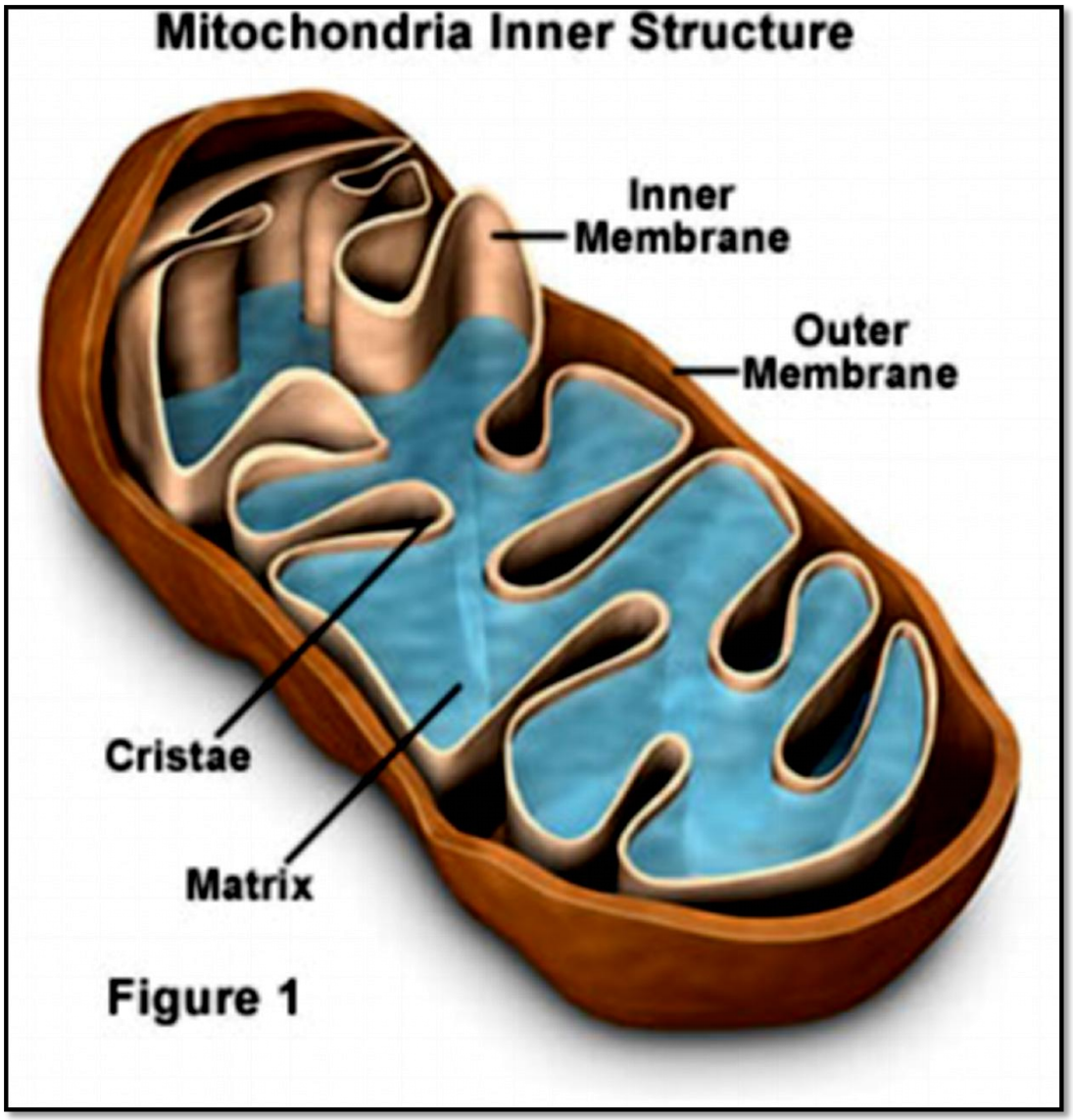
The sausage shape structure in the cytoplasm, sometime described as **'power house'** of the cell, because they generates many ATP molecules through an aerobic respiration.

Generally located within the cell where oxygen enters the cell or where the ATP is used.

The active cells, such as, those found in muscles, liver and kidneys, which use ATP at a higher rate, show numbers of mitochondria.

Structure & Function

Mitochondrion consists of **outer mitochondrial membrane**, **intermembrane space** (the space between inner and outer mitochondrial membranes) and **inner mitochondrial membrane**, with the small fluid filled space between them. Both membranes are similar in structure to the plasma membrane (as shown in figure).


Mitochondria Inner Structure
Inner Membrane
Outer Membrane
Cristae
Matrix
Figure 1

The **outer mitochondrial membrane**, which encloses the entire organelle, has a protein to phospholipid ratio similar to that of plasma membrane (about 1:1 by weight) and contains large numbers of integral protein called **porins.**

These porins forms channels that allow molecules of 5000 daltons or less in molecular weight to freely diffuse from one side of the membrane to the other.

Disruption of the outer membrane permits proteins in the intermembrane space to leak into the cytosol, leading to a certain cell death.

The mitochondrial outer membrane can associate with the endoplasmic reticulum (ER) membrane, in a structure called **mitochondria-associated ER membrane (MAM)**. This is important in ER-mitochondria calcium signaling and also involved in the transfer of lipids between ER and mitochondria.

The **intermembrane space** is basically the space between inner and outer mitochondrial membranes. As the outer membrane is freely permeable to small molecules, the concentrations of small molecules such as ions and sugars in the intermembrane space are the **same** as the cytosol. However, the concentration of large proteins in the intermembrane space and cytosol is different.

Inner mitochondrial membrane consists of series of folds called **cristae** and large fluid filled cavity of mitochondrion, enclosed by the inner mitochondrial membrane called **matrix**. Cristae provide surface area for the chemical reaction i.e. **aerobic respiration** for the production of ATPs. The enzymes that catalyses the reactions are located on the surface of cristae and in the matrix of mitochondrion.

The most prominent role of mitochondrion is the production of ATP and regulation of cellular metabolism.

c) Ribosomes

The sites of protein synthesis. It exists in much higher amount in RNA and rRNA.

Structure & Function

It consists of **two subunits**, one about half the size of others.

The **large** and **small subunits** made separately in the nucleolus, a spherical body located in the nucleus. Once produced, both the subunits exit through nucleus and come in cytoplasm.

Some ribosomes are attached to the outer membrane of nucleus and to an endoplasmic reticulum. These ribosomes synthesize protein specific for specific organelles, for insertion in the plasma membrane, or for export from the cell. Other ribosomes are free in nature or unbound to the cytoplasmic structure. Free ribosomes synthesized proteins, get utilized in cytosol. Ribosomes are also located in the mitochondria where they involved in the synthesis of mitochondrial proteins.

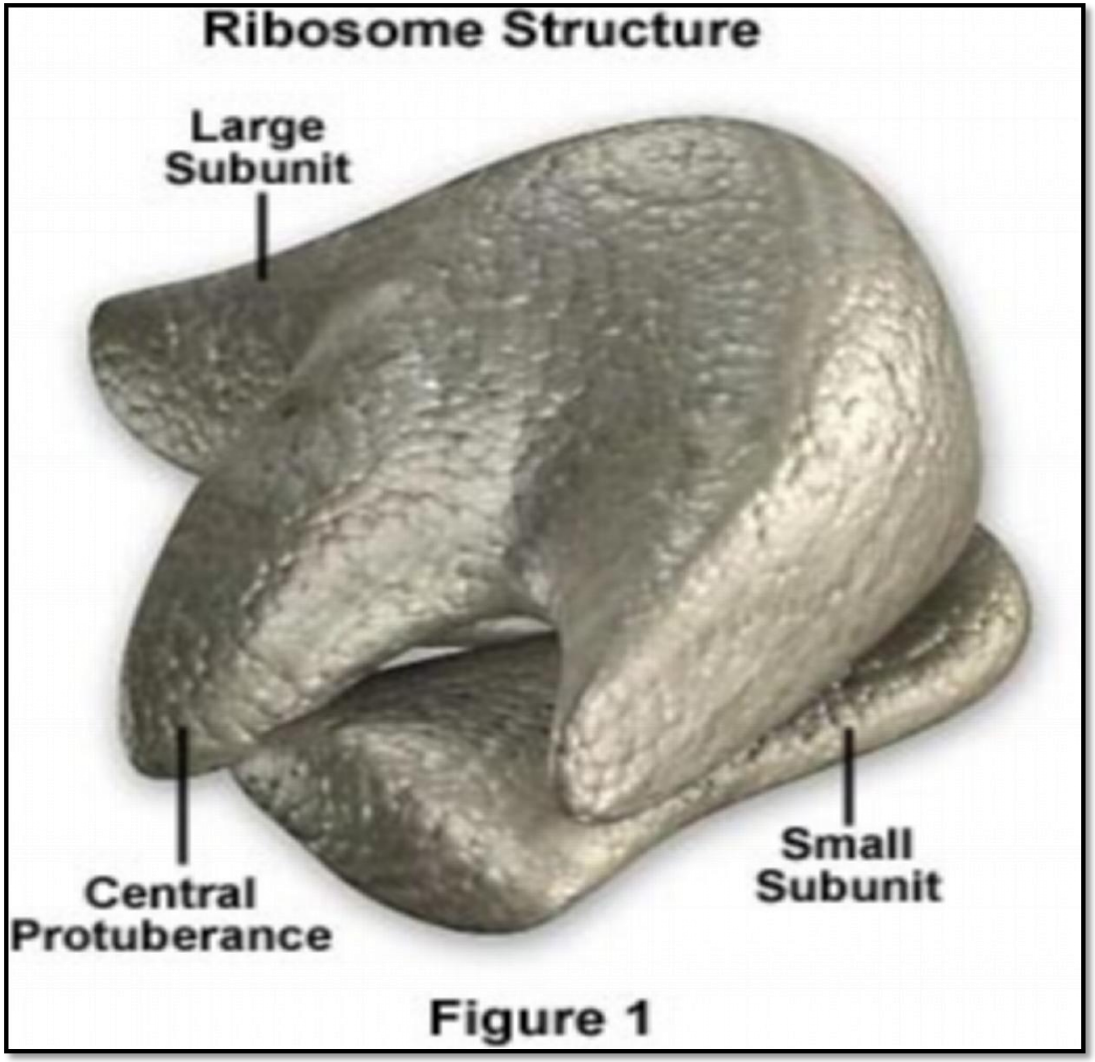

Ribosome Structure
Large Subunit
Central Protuberance
Small Subunit

Figure 1

d) Endoplasmic reticulum (ER)

(Endo: inside, plasmic: cytoplasm, reticulum: network)

The network of membrane in the form of flattened sacs or tubules, extends from the nuclear envelop to which it is connected throughout the cytoplasm, and constitutes more than half of the membrane surface in the cytoplasm.

Structure & Function

Three distinct forms of ER in the cell-

Rough ER,

Smooth ER, and

Sarcoplasmic reticulum (SR).

Rough ER (RER) is continuous with the nuclear membrane and usually is folded into a series of flattened sacs. The outer surface of ER is studded with ribosomes, the site for protein synthesis.

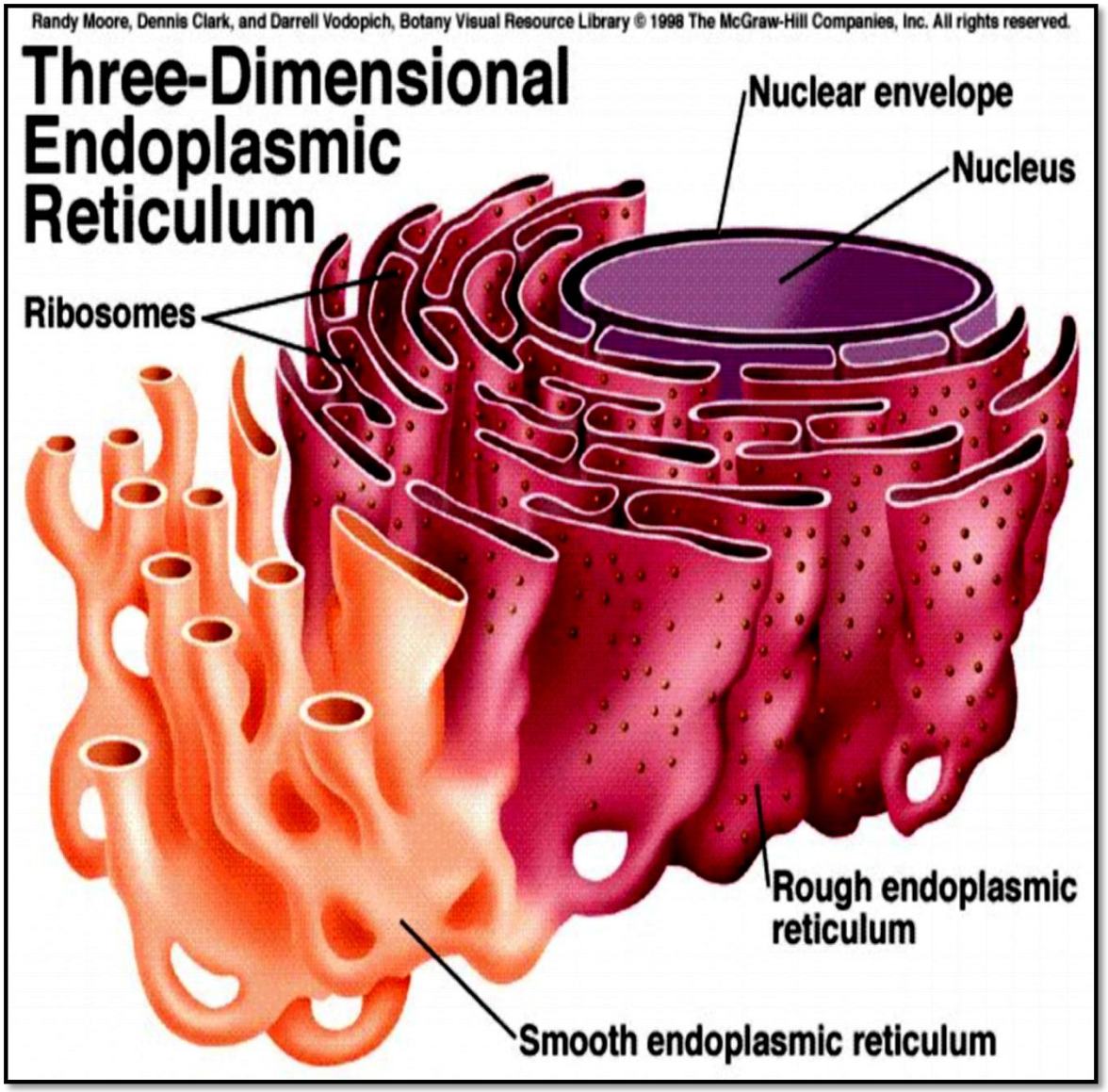
RER has **function** in the synthesis of proteins includes secretary proteins, membrane proteins and many organelles proteins.

Smooth ER (SER) is extends from the rough ER to form a network of membrane tubules. It does not show the presence of ribosomes.

SER has **function** in several metabolic processes, including synthesis of lipids and steroids, metabolism of carbohydrates, regulation of calcium concentration, detoxification of drugs, attachment of receptors on cell membrane proteins, and steroid metabolism. It also contains the enzyme glucose-6-phosphatase which converts glucose-6-phosphate to glucose, a step in gluconeogenesis.

Sarcoplasmic reticulum (SR) is a special type of smooth ER found in smooth and striated muscle.

The only structural difference between SR and SER is the **variety of proteins** they have. This fundamental difference is indicative of their functions, the SER synthesizes molecules while SR stores and pumps calcium ions. The SR contains large stores of calcium, which it sequesters and then releases when the muscle cell is stimulated. The SR's release of calcium upon electrical stimulation of the cell plays a major role in excitation-contraction coupling.



e) Golgi apparatus or Golgi complex or Golgi bodies

Consists of stacks of closely folded flattened membranous sacs, called as **cisternae** (singular- cisterna) and present in all the cells but is larger on those areas that synthesize and export proteins.

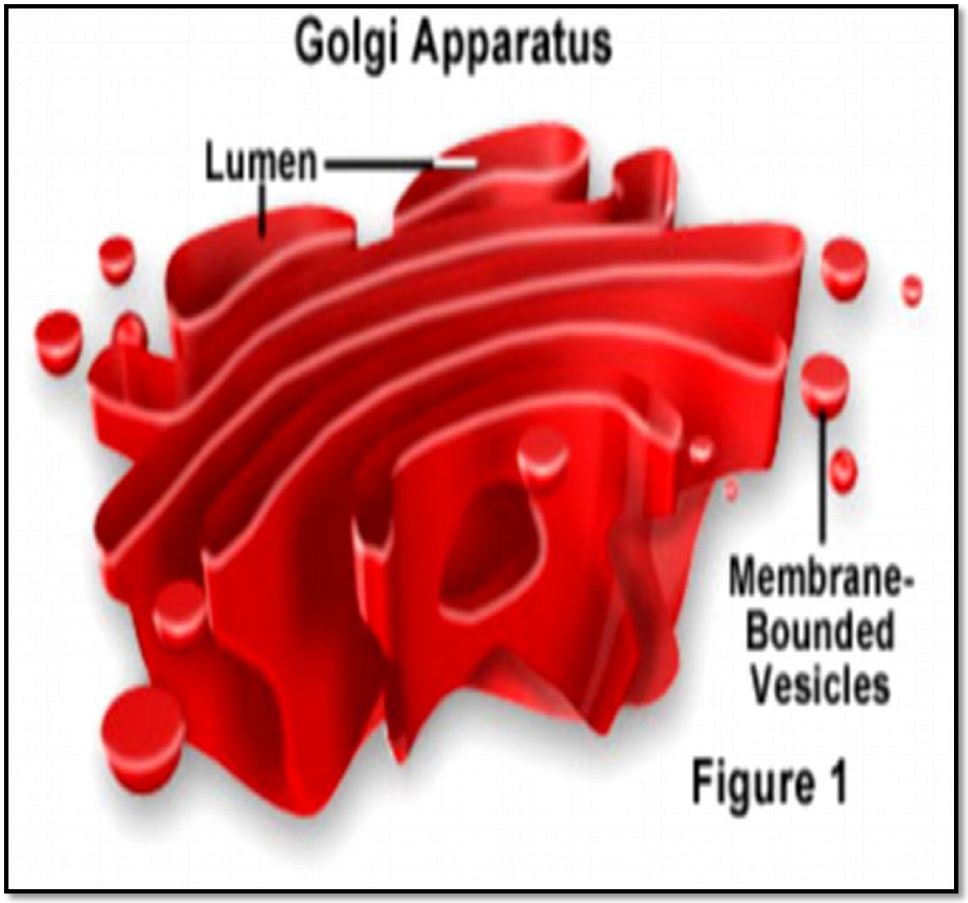
Structure & Function

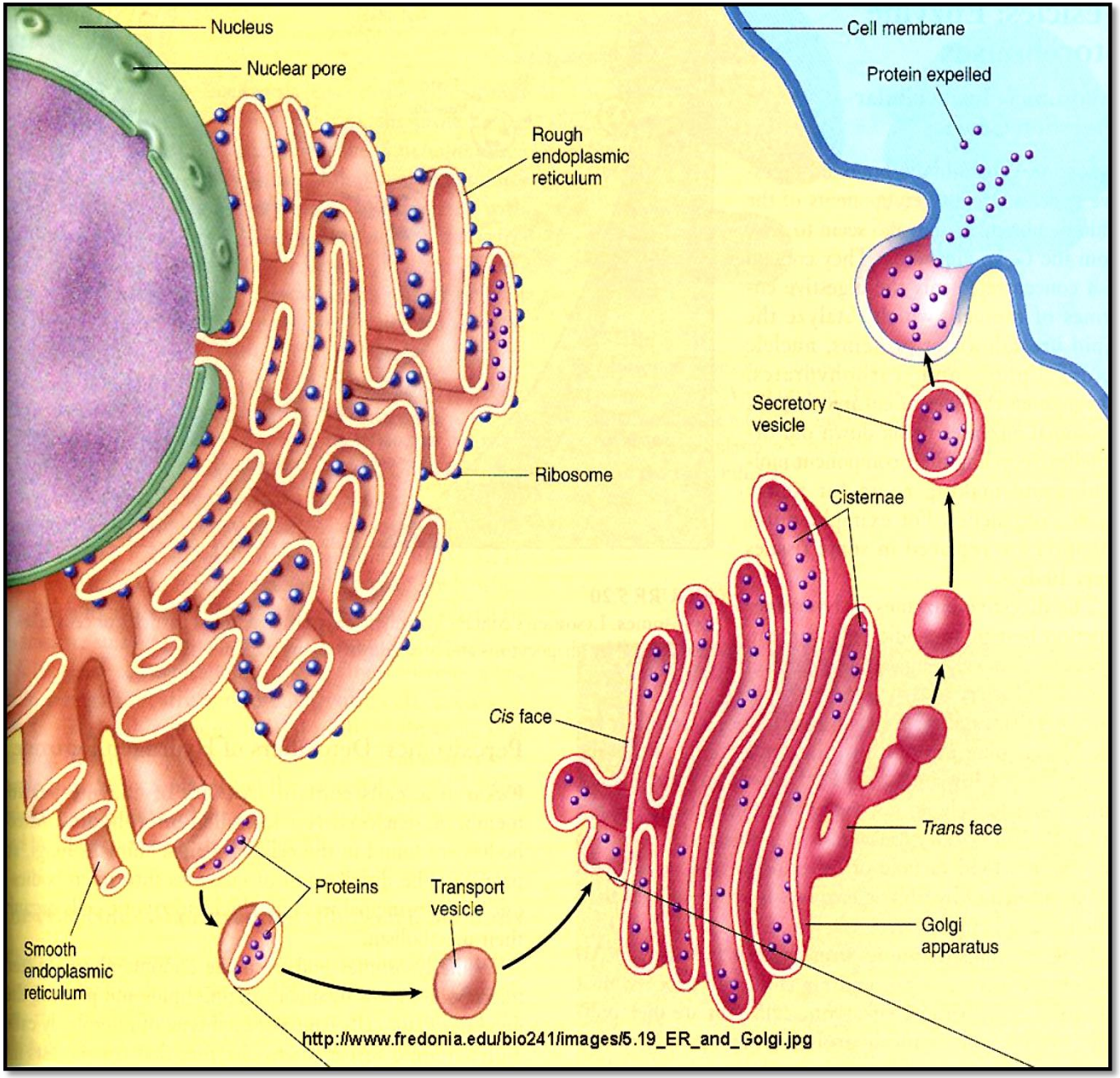
It consists of 3 to 20 cisternae (cavities), the small flattened membrane sacs with bulging edges. The cisternae are often curved, giving the Golgi complex, a cuplike shape. The cisternae at the opposite ends of a Golgi complex differ from each others in size, shapes and enzymatic activities.

The **convex entry** or **cis-face** is the cisterna that faces the **rough ER** while the **concave exit** or **trans-face** is a cisterna that faces the **plasma membrane**.

The sacs between the entry and exit faces are called as **medial cisternae**. The proteins moves from the ER to the Golgi complex, where they packaged into the membrane bound vesicles called secretary granules or transport vesicles. The vesicles are stored and when needed moves to the plasma membrane through which the proteins are exported.

The primary **function** of the Golgi apparatus is to process and package macromolecules, such as proteins and lipids, after their synthesis and before they make their way to their destination; it is particularly important in the processing of proteins for secretion. It forms a part of the cellular endomembrane system.




Nucleus
Nuclear pore
Rough endoplasmic reticulum
Ribosome
Cell membrane
Protein expelled
Secretory vesicle
Cisternae
Cis face
Trans face
Golgi apparatus
Proteins
Transport vesicle
Smooth endoplasmic reticulum
http://www.fredonia.edu/bio241/images/5.19_ER_and_Golgi.jpg

f) Lysosomes (Lyso: dissolving, somas: body)

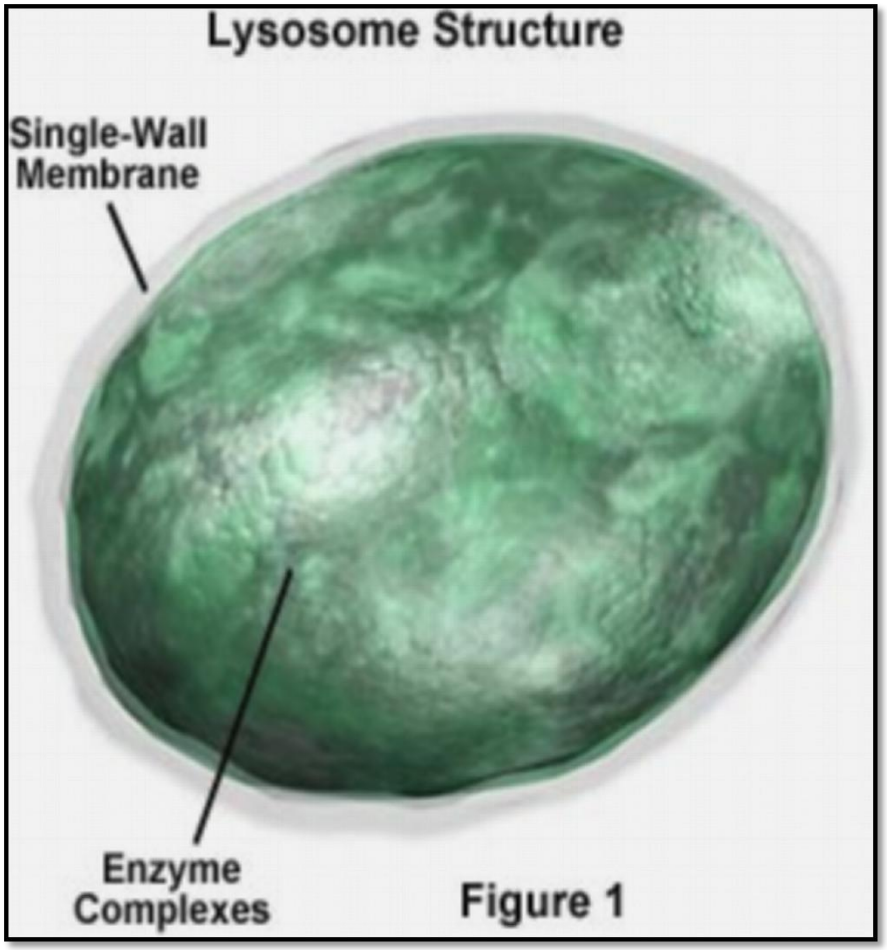
The membrane enclosed vesicles formed from the Golgi complex, contains variety of enzymes involved in the breakdown fragments of organelles and macromolecules (RNA, DNA, carbohydrates and proteins) into the smaller particles that are either recycled or extruded from the cell as the waste material.

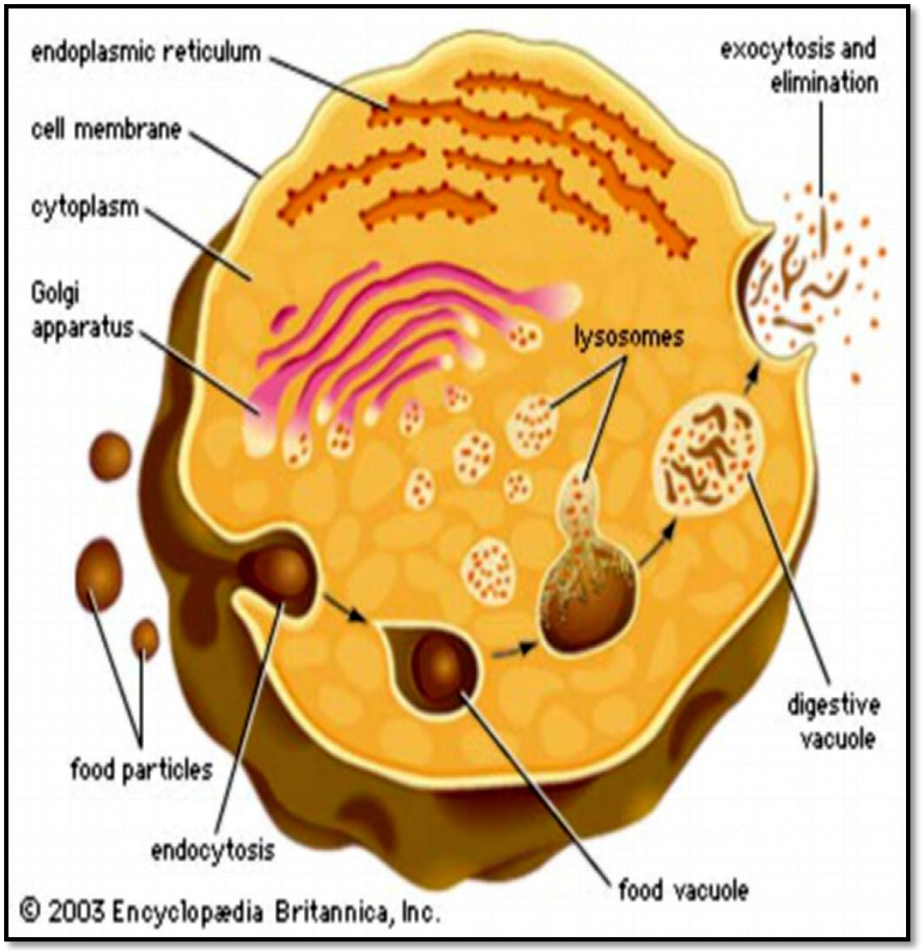
Lysosomes that are located in the WBCs are involved in breakdown or digestion of foreign materials such as microbes.

Autophagy (Auto: self, phagy: eating)- the process in which lysosomes can engulf another organelles, digest it and returned the digested components to the cytosol for reuse.

Autolysis- the process in which the entire of cell is gets destroyed by lysosomal enzymes.

Figure- Structure of Lysosome and Its Involvement in the Process of Digestion of Food Particles.





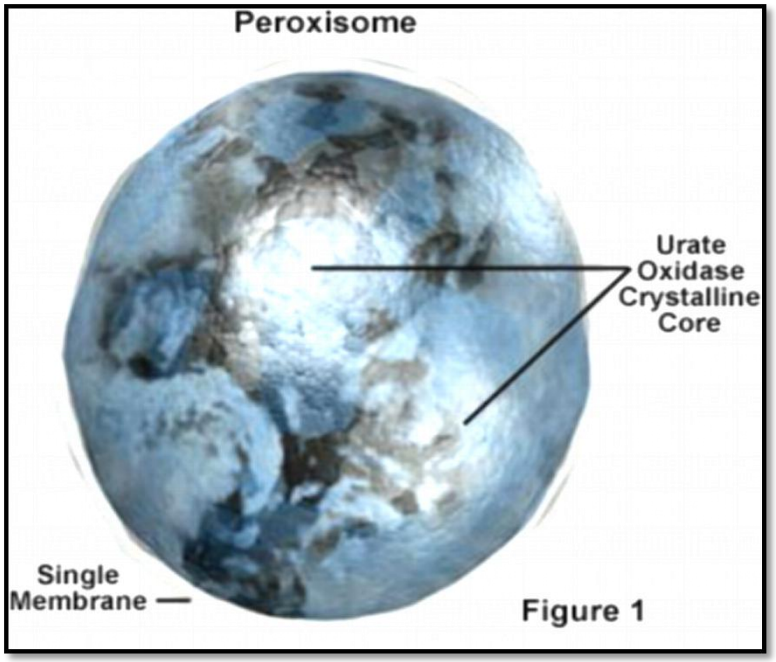
g) Peroxisomes (Peroxi: peroxide, somas: body)

Shows the similar structure to lysosomes but smaller than lysosomes, and are very abundant in liver- the site of detoxification process.

Shows the presence of several **oxidases**, enzymes that can oxidizes (remove hydrogen atom from various organic substances) amino acids, fatty acids, toxic substances such as alcohol.

The by-product of oxidative reaction is hydrogen peroxide (H_2O_2), which is decomposed by an enzyme- catalase already present in peroxisomes.

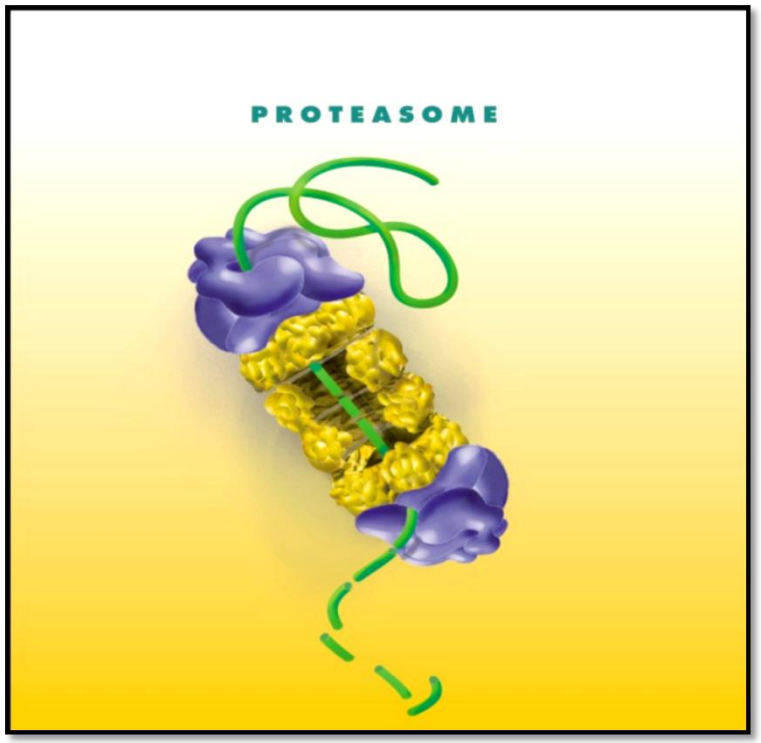
New peroxisomes are formed from the older or pre-existing one.



h) Proteasomes

Tiny, barrel shape structure present in numerous, both in the nucleus and cytosol and are involved in the continuous destruction of unneeded, damaged or faulty proteins.

Proteasomes, named because it contains **protease-** an enzyme responsible for the breakdown of protein into the smaller fragments: peptides. Once peptides get formed, other enzymes break those peptides into amino acids, which then again recycled in the synthesis of proteins.



i) Cytoskeleton

The network of protein filaments that extends throughout the cytosol.

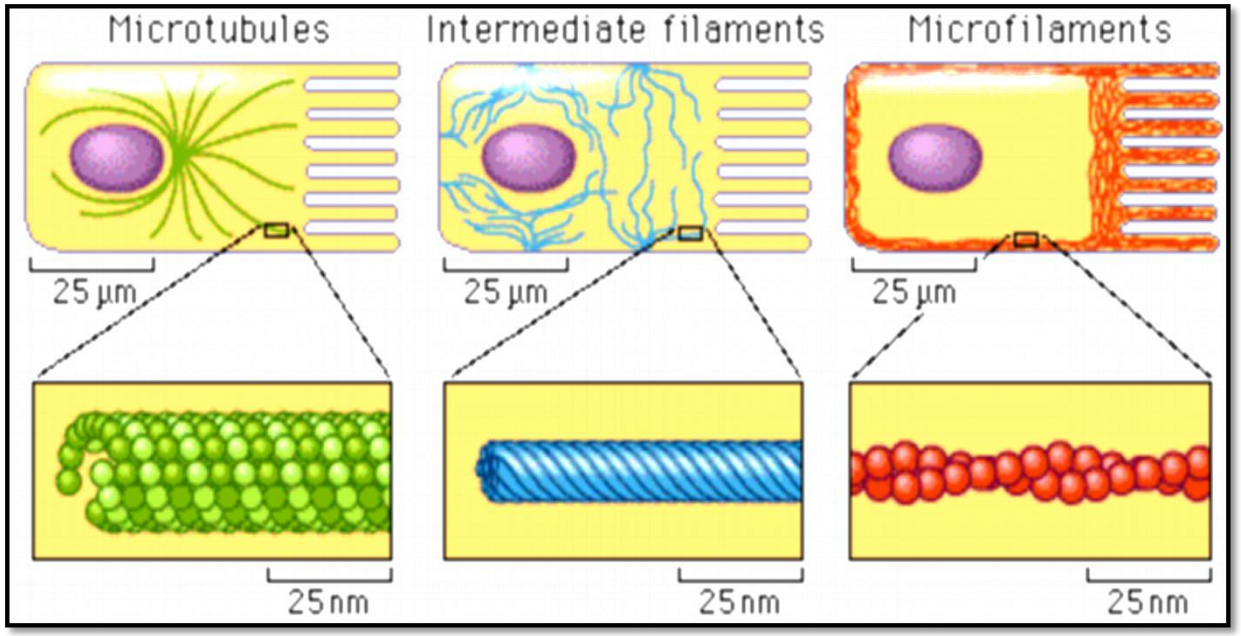
Types of the filamentous proteins- **Microfilaments**, **Intermediate Filaments** and **Microtubules**, in order of their increasing diameter.

1) Microfilaments are thinnest of the cytoskeleton, made up of protein- **actin**, and located at peripheral parts of cell.

Its **functions** includes movements (muscle contraction, cell division and cell locomotion), and provides the mechanical support to cell (responsible for the basic strength and shape of cells). They also provides supports to the extension, called microvillus (non-motile, microscopic finger-like projection of plasma membrane) which are abundant on cells involved in absorption, such as epithelial cells, that lines the small intestine.

2) **Intermediate filaments** are thicker than microfilaments but thinner than microtubules. They are found in the parts of cells subject to mechanical stress, help to attach the cells to one another and also help to stabilize the organelles like nucleus.

3) **Microtubules** are the largest cytoskeleton component, long, unbranched, hollow tubes, composed of protein- **tubulin**. Microtubules are larger contractile protein fibers that are involved in the movement of organelles within the cell, chromosome during cell division, and cell extension.



j) Centrosomes

Are located near the nucleus, consists of two components, **a pair of centrioles** and **peri-centriolar material**.

The two centrioles are cylindrical structure, each composed of nine clusters of three microtubules **(triplets)** arranged in circular pattern.

Surrounding the centriole, pericentriolar material which contains number of ring shape complexes composed of protein- **tubulin,** acts as the organizing centers for the growth of mitotic spindles which plays an important role in the cell division and for the microtubule formation in the non-dividing cell.

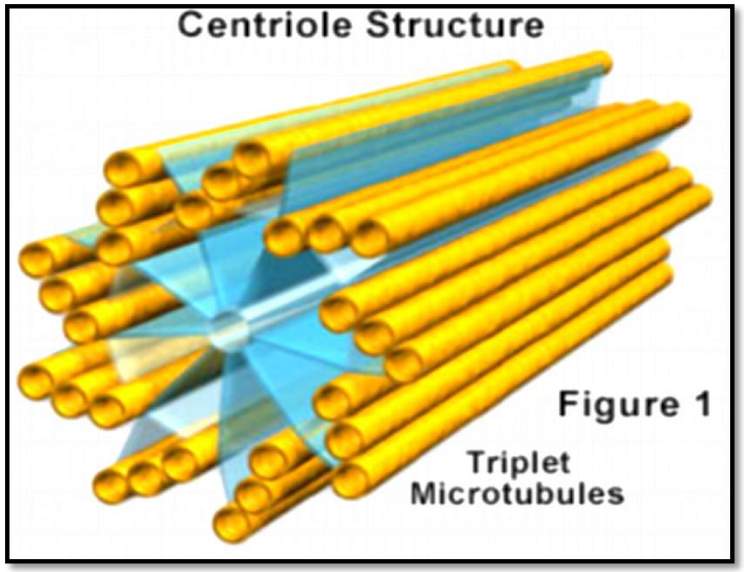
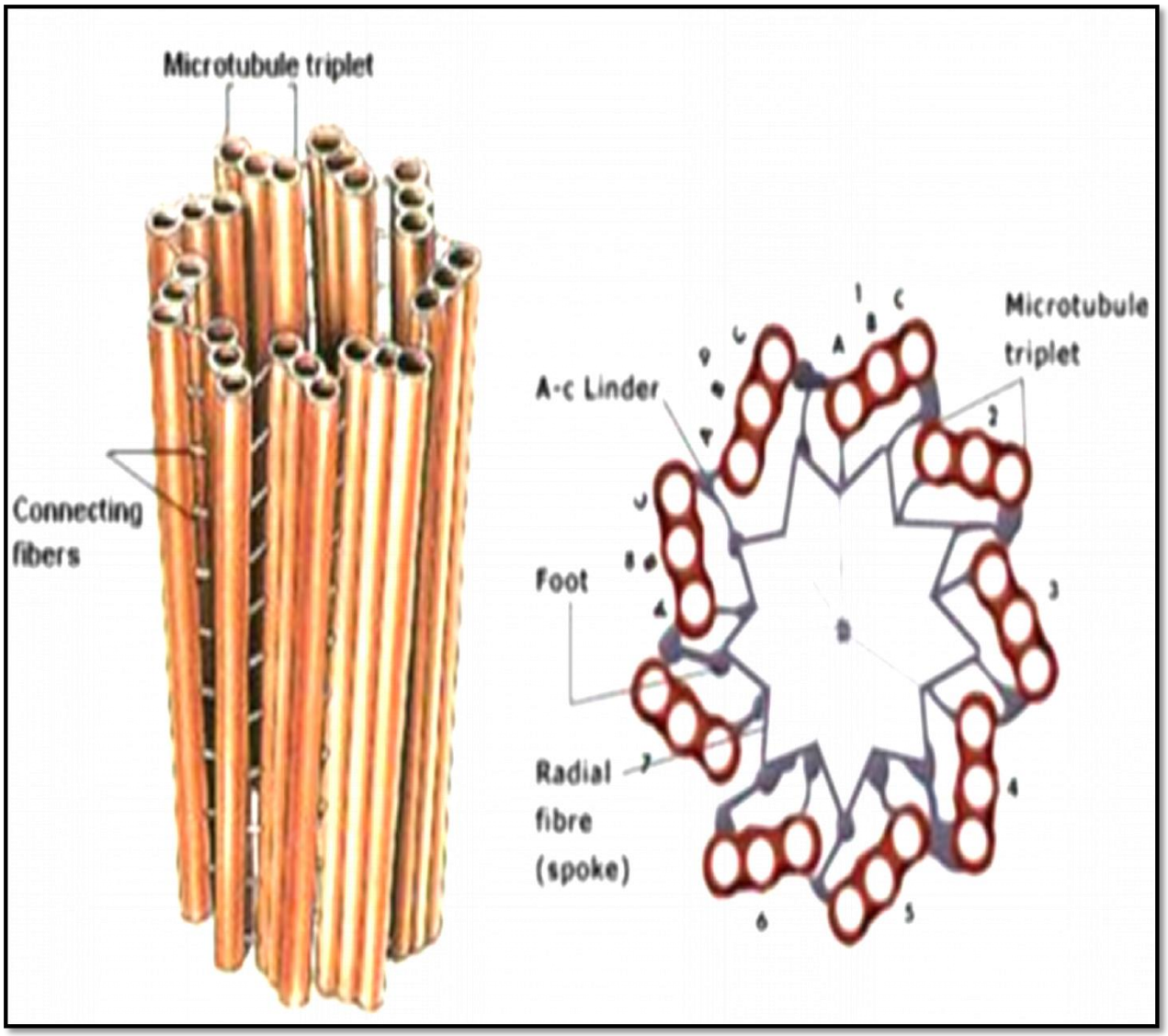


Fig. Details of Centrosome and Arrangement of Microtubule in Centrioles



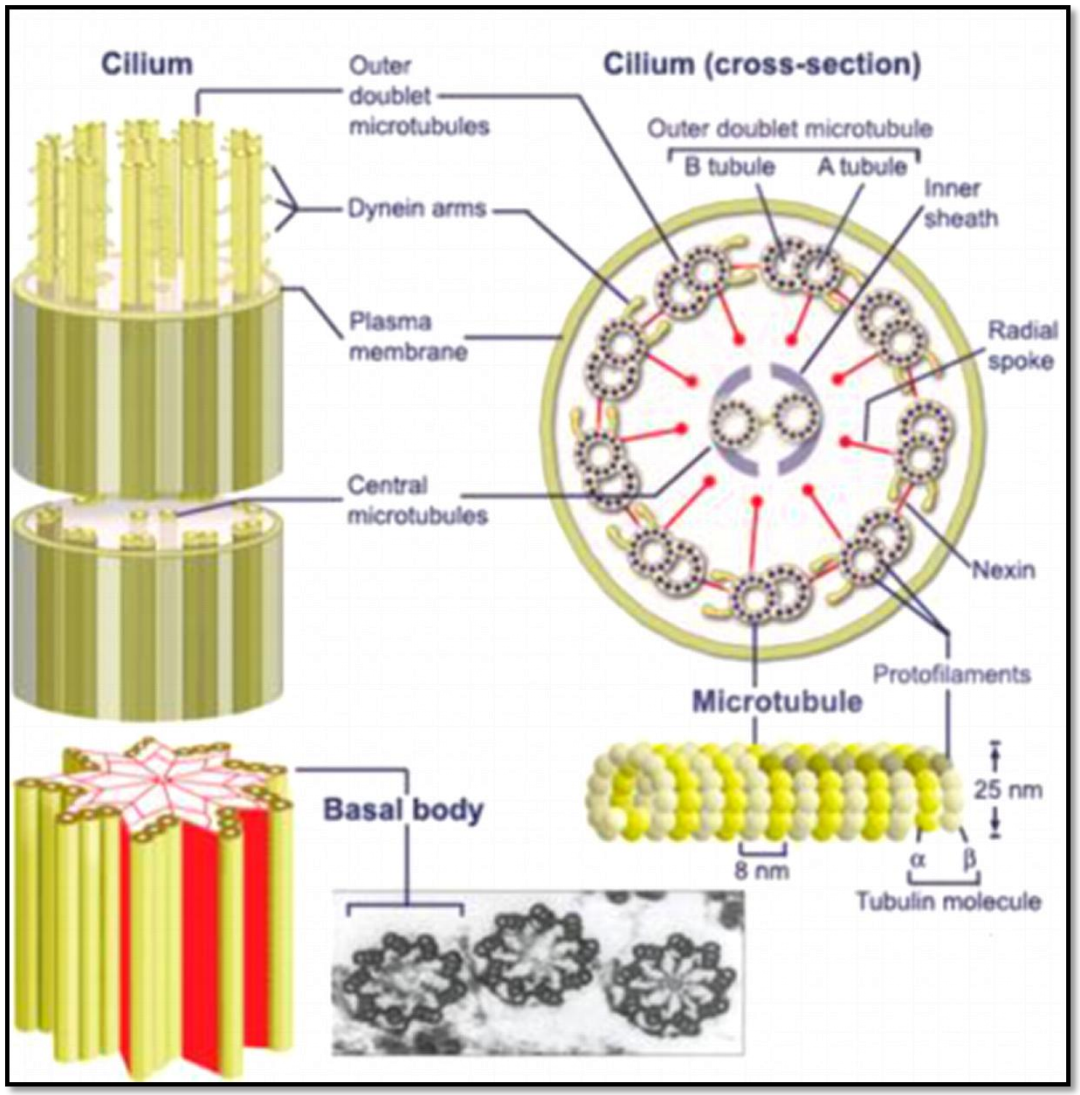
k) Cell extensions

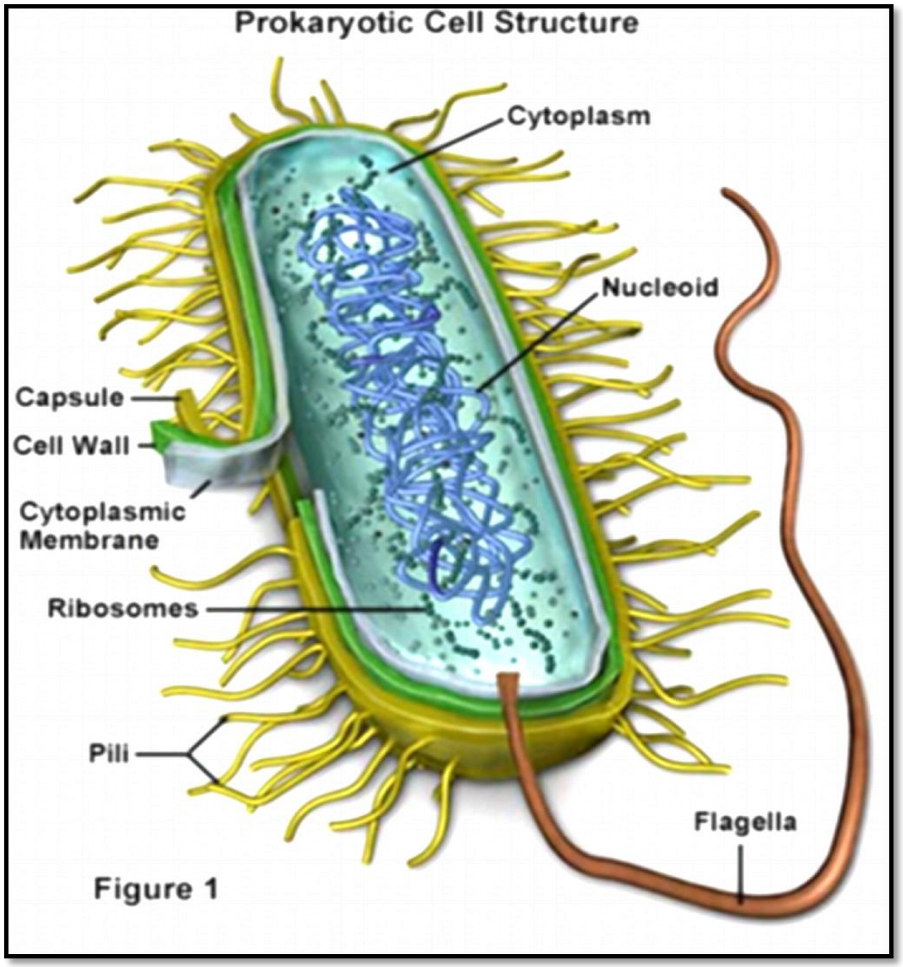
Projected from the plasma membrane and their main components are microtubules which allow the movement. These include-

1) Cilia Small, hair-like projections, lying along the free borders of some cell, contains the core of 20 microtubules surrounded by the plasma membrane. The coordinated movement of many cilia on the surface of the cell causes the steady movement of fluid along the cell surface. (e.g. many cells of the respiratory tract have hundreds of cilia, that sweep foreign particles trapped in mucus away from the lung., cells that lines the uterine- fallopian tubes also have cilia that sweeps oocytes- egg cell towards the uterus).

2) Flagella Similar in structure to cilia but are typically much longer. Flagella are usually moves an entire cell. Flagella generate forward motion along its axis by rapidly wiggling in wave-like pattern. (e.g. the only example of flagellum in human body is sperm cells tail, which propels the sperm towards its binding with oocytes).

Fig. Cross section of Cilium





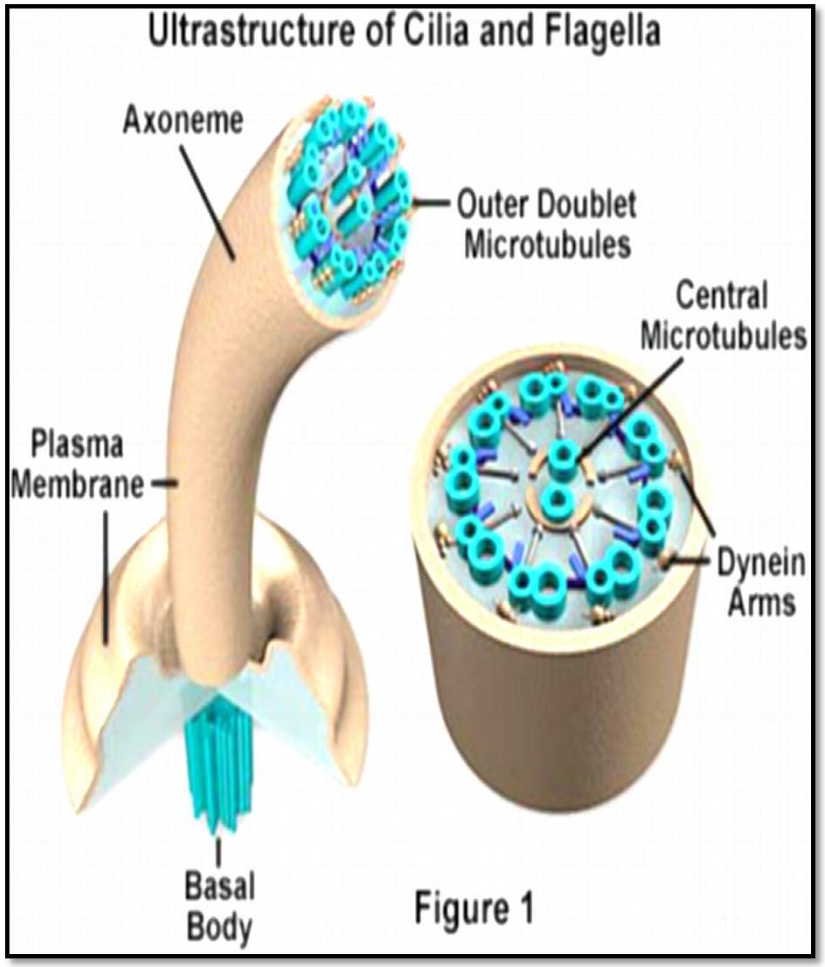


Fig. Flagellum and The Ultrasturcture of Cilium & Flagellum