

# History of Cell Theory

- mid 1600s – Anton van Leeuwenhoek
  - Improved microscope, observed many living cells
- mid 1600s – Robert Hooke
  - Observed many cells
- 1850 – Rudolf Virchow
  - Proposed that all cells come from existing cells

# Cell Theory

Cells were discovered in 1665 by Robert Hooke.

Early **studies of cells** were conducted by

- Mathias Schleiden (1838)
- Theodor Schwann (1839)

Schleiden and Schwann proposed the **Cell Theory**.

# Cell Theory

1. All organisms consist of 1 or more cells.
2. Cells are the smallest working units of all living things.
3. All cells come from preexisting cells through cell division.

All cells today represent a continuous line of descent from the first living cells.

# Cell Theory

Microscopes are required to visualize cells.

**Light microscopes** can resolve structures that are 200nm apart.

**Electron microscopes** can resolve structures that are 0.2nm apart.

# Cell Theory

All cells have certain structures in common.

1. genetic material – in a nucleoid or nucleus
2. cytoplasm – a semifluid matrix
3. plasma membrane – a phospholipid bilayer

# Definition of Cell

A cell is the smallest unit that is capable of performing life functions.

# General Characteristics of Cell

Each cell in the body:

1. Needs nutrition and oxygen
2. Produces its own energy necessary for its growth, repair and other activities
3. Eliminates carbon dioxide and other metabolic wastes
4. Maintains the medium, i.e. the environment for its survival
5. Shows immediate response to the entry of invaders like bacteria or toxic substances into the body
6. Reproduces by division. There are some exceptions like neuron, which do not reproduce.

# Tissue

- Tissue is defined as the group of cells having similar function.
- There are many types of tissues in the body. All the tissues are classified into four major types which are called the primary tissues.
- The primary tissues include:
  1. Muscle tissue (skeletal muscle, smooth muscle and cardiac muscle)
  2. Nervous tissue (neurons and supporting cells)
  3. Epithelial tissue (squamous, columnar and cuboidal epithelial cells)
  4. Connective tissue (connective tissue proper, cartilage, bone and blood)



# Organ

- An organ is defined as the structure that is formed by 2 or more primary types of tissues, which execute the functions of the organ.
- Some organs are composed of all the four types of primary tissues.
- The organs are of 2 types, namely tubular or hollow organs and compact or parenchymal organs.
- Some of the organs in the body are brain, heart, lungs, stomach, intestine, liver, gallbladder, pancreas, kidneys, endocrine glands, etc.

# System

- The organ system is defined as group of organs that work together to carry out specific functions of the body.
- Each system performs a specific function.
- Digestive system is concerned with digestion of food particles.
- Excretory system eliminates unwanted substances.
- Cardiovascular system is responsible for transport of substances between the organs.
- Respiratory system is concerned with the supply of oxygen and removal of carbon dioxide.

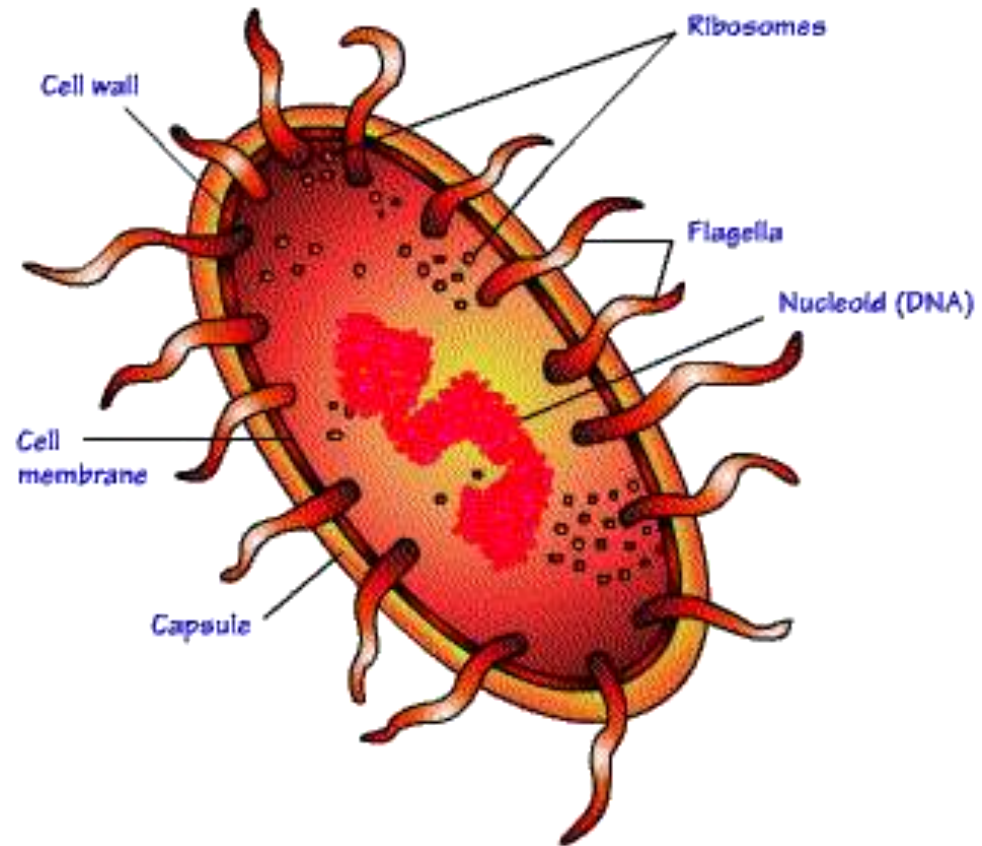
- Reproductive system is involved in the reproduction of species.
- Endocrine system is concerned with growth of the body and regulation and maintenance of normal life.
- Musculoskeletal system is responsible for stability and movements of the body.
- Nervous system controls the locomotion and other activities including the intellectual functions.

# Two Types of Cells

- Prokaryotic
- Eukaryotic

# Prokaryotic

- Do not have structures surrounded by membranes
- Few internal structures
- One-celled organisms, Bacteria



# Prokaryotic Cells

**Prokaryotic cells** lack a membrane-bound nucleus.

- genetic material is present in the **nucleoid**

Two types of prokaryotes:

- archaea
- bacteria

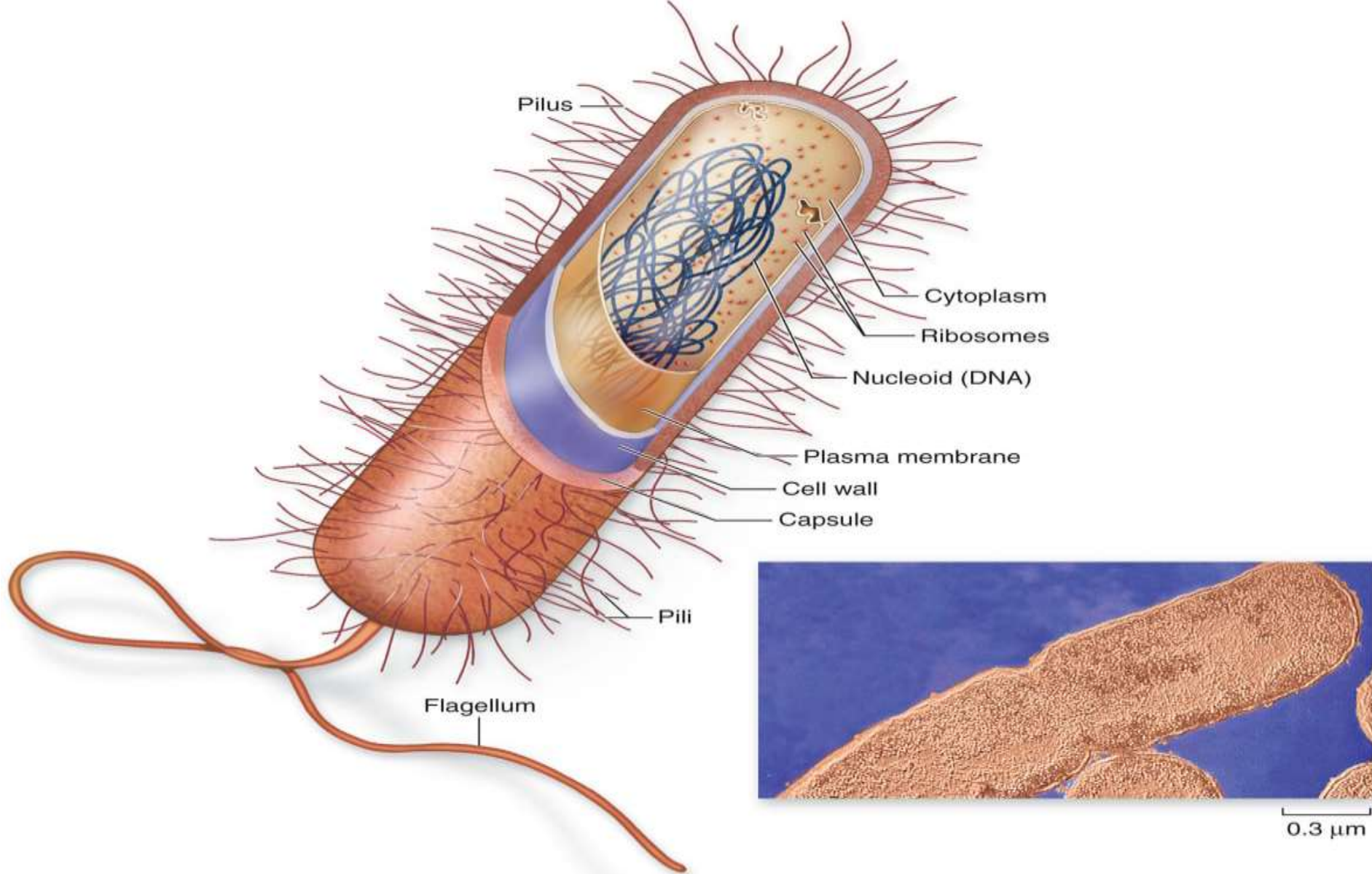
# Prokaryotic Cells

Prokaryotic cells possess

- genetic material in the nucleoid
- cytoplasm
- plasma membrane
- cell wall
- ribosomes
- no membrane-bound organelles

# Prokaryotic Cells

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# Prokaryotic Cells

Prokaryotic cell walls

- protect the cell and maintain cell shape

Bacterial cell walls

- may be composed of peptidoglycan- a rigid envelope surrounding the cytoplasmic membrane

Archaeal cell walls lack peptidoglycan.

# Prokaryotic Cells

## Flagella

- present in some prokaryotic cells
- used for locomotion
- rotary motion propels the cell

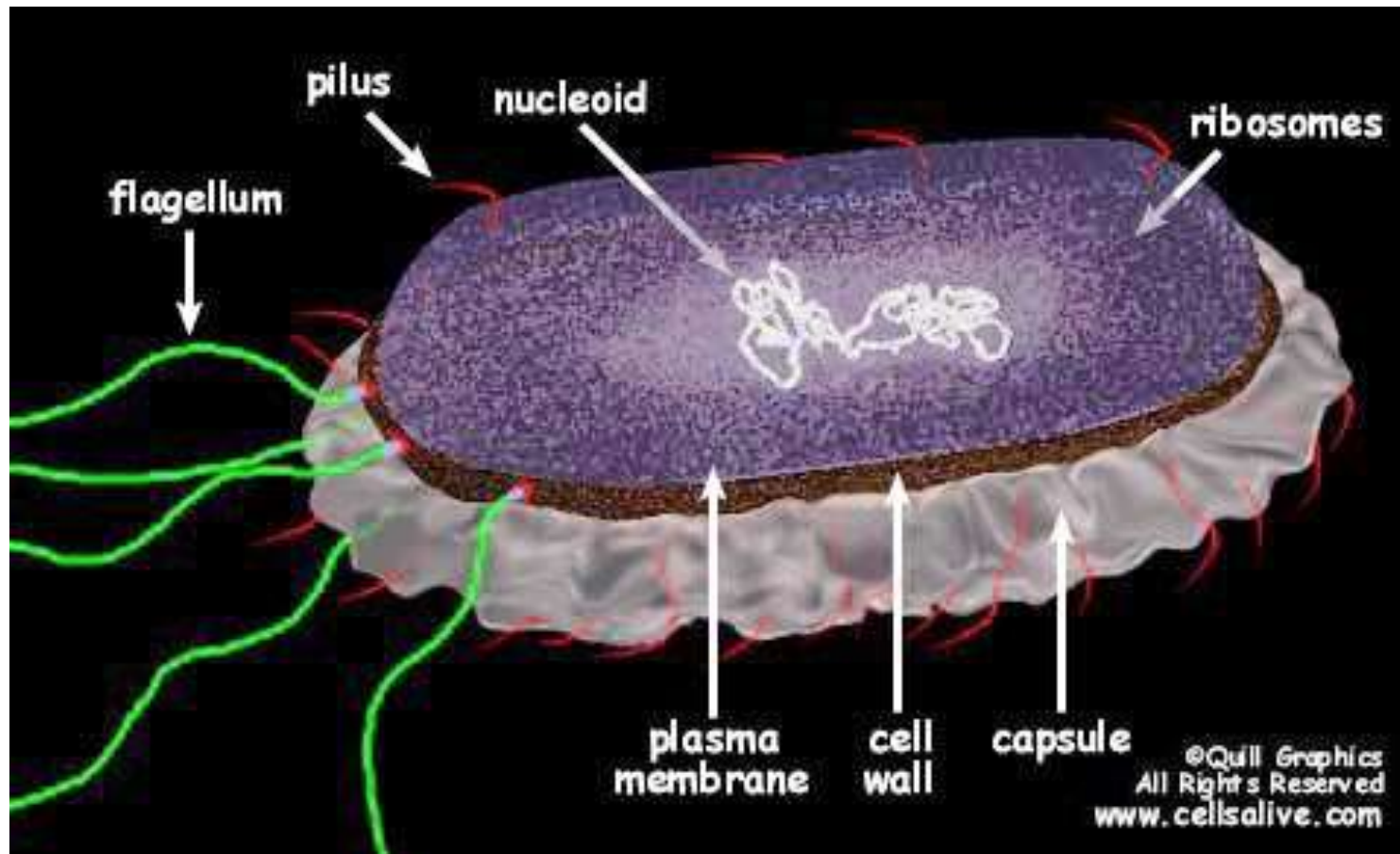
# Prokaryotic Cell Structure

- Prokaryotic Cells are smaller and simpler in structure than eukaryotic cells.

Prokaryotic cells do NOT have:

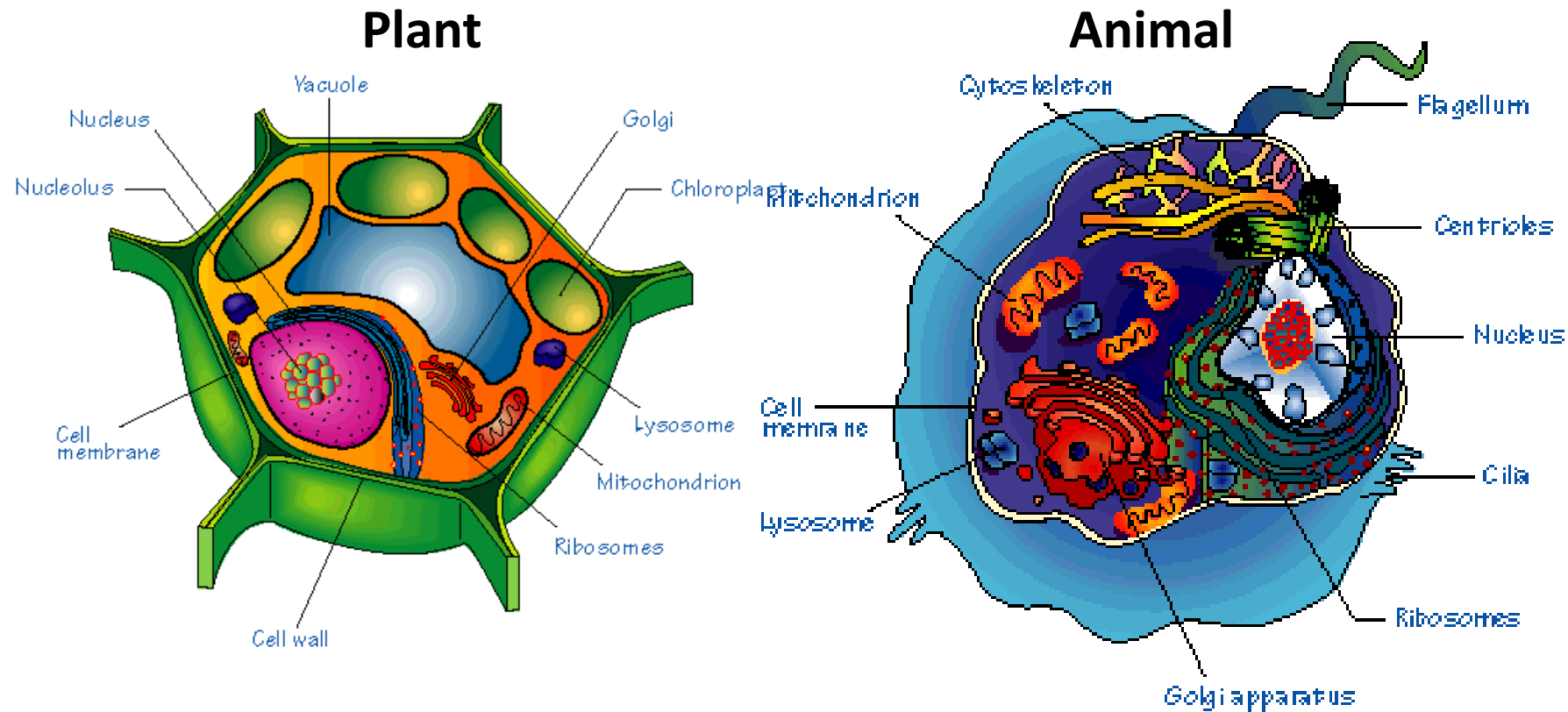
- Nucleus
- Membrane bound organelles

# Prokaryotic Cell

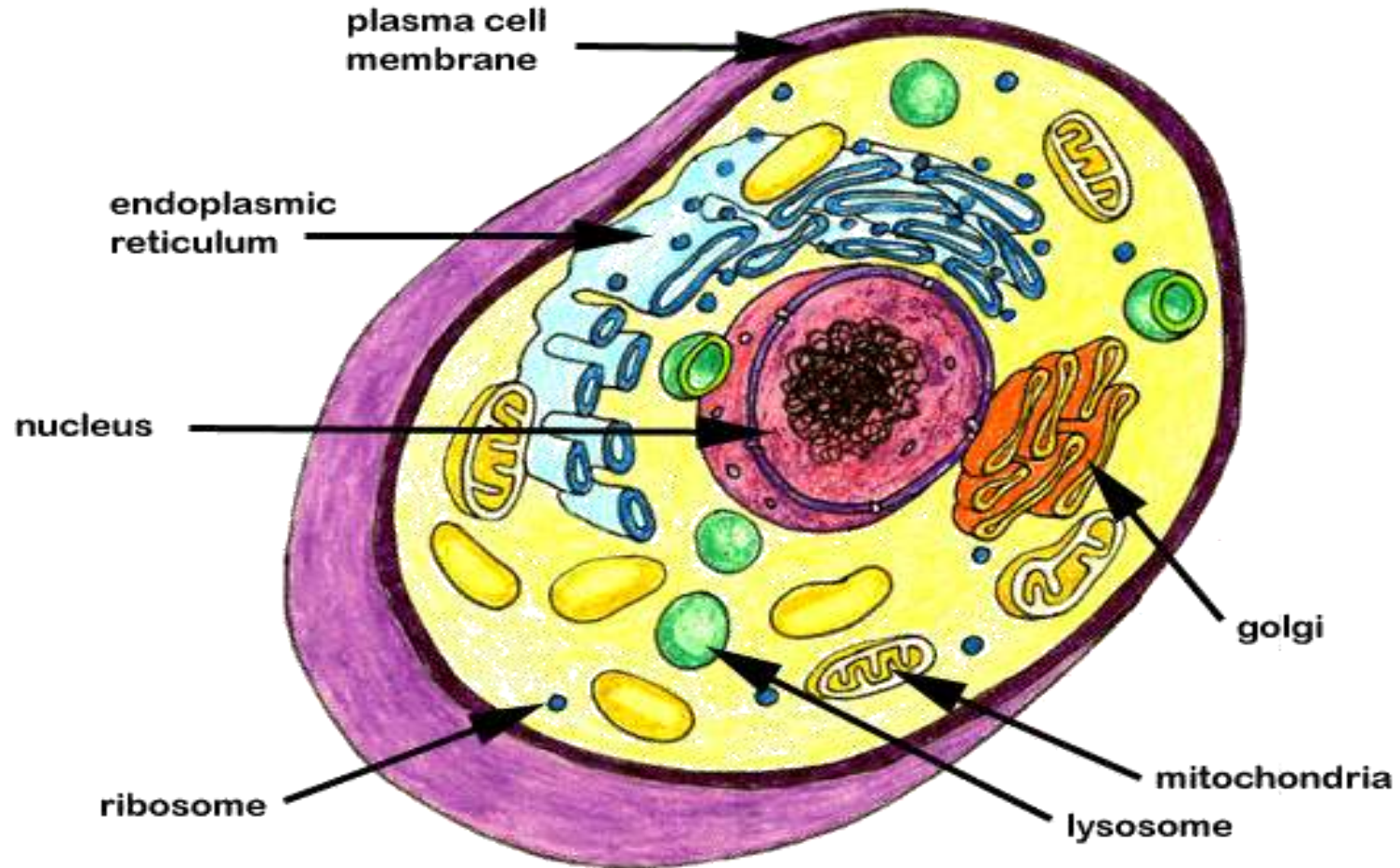


# Eukaryotic

- Contain organelles surrounded by membranes
- Most living organisms

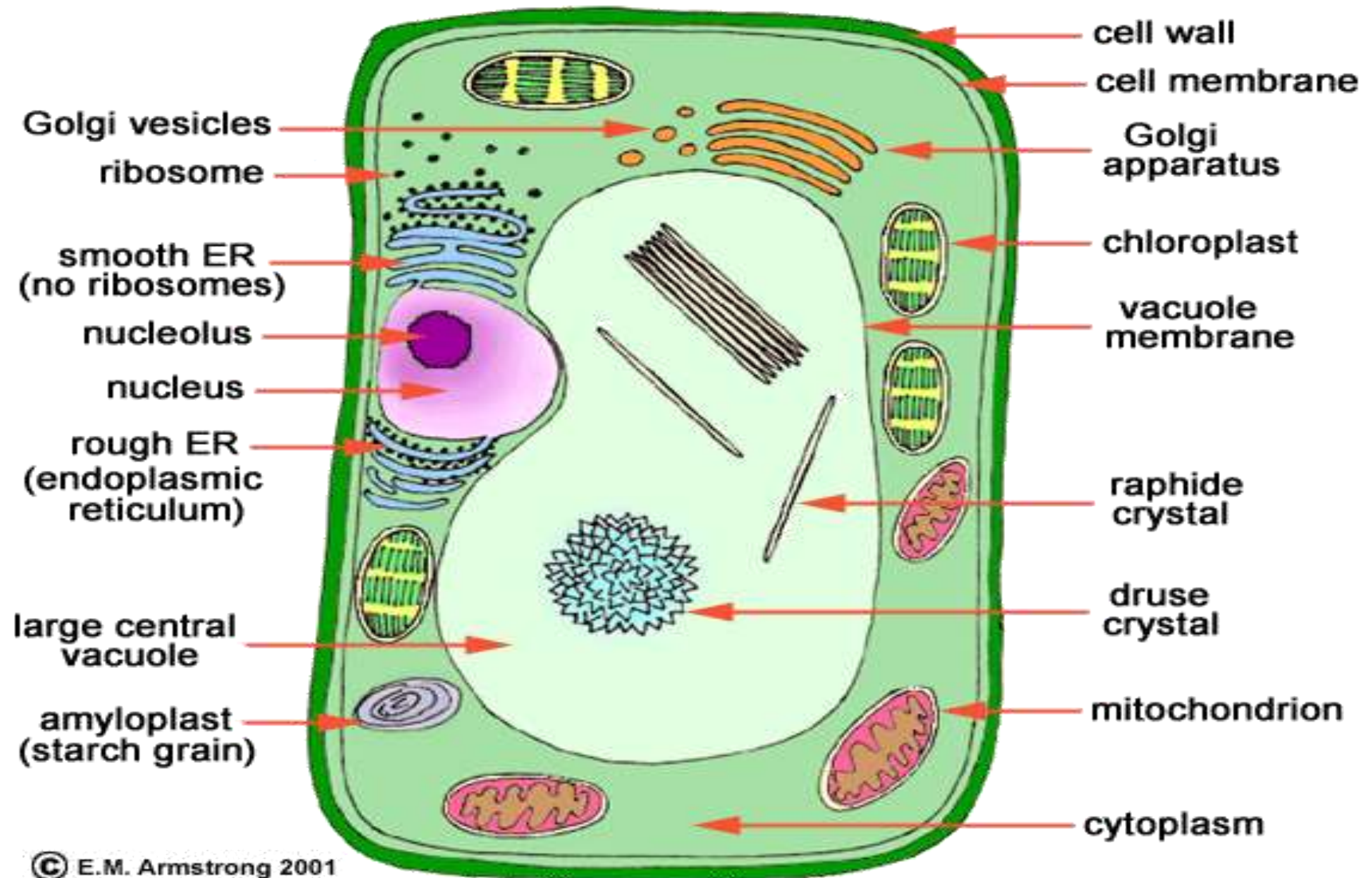


# “Typical” Animal Cell





# Plant Cell



# Eukaryotic Cells

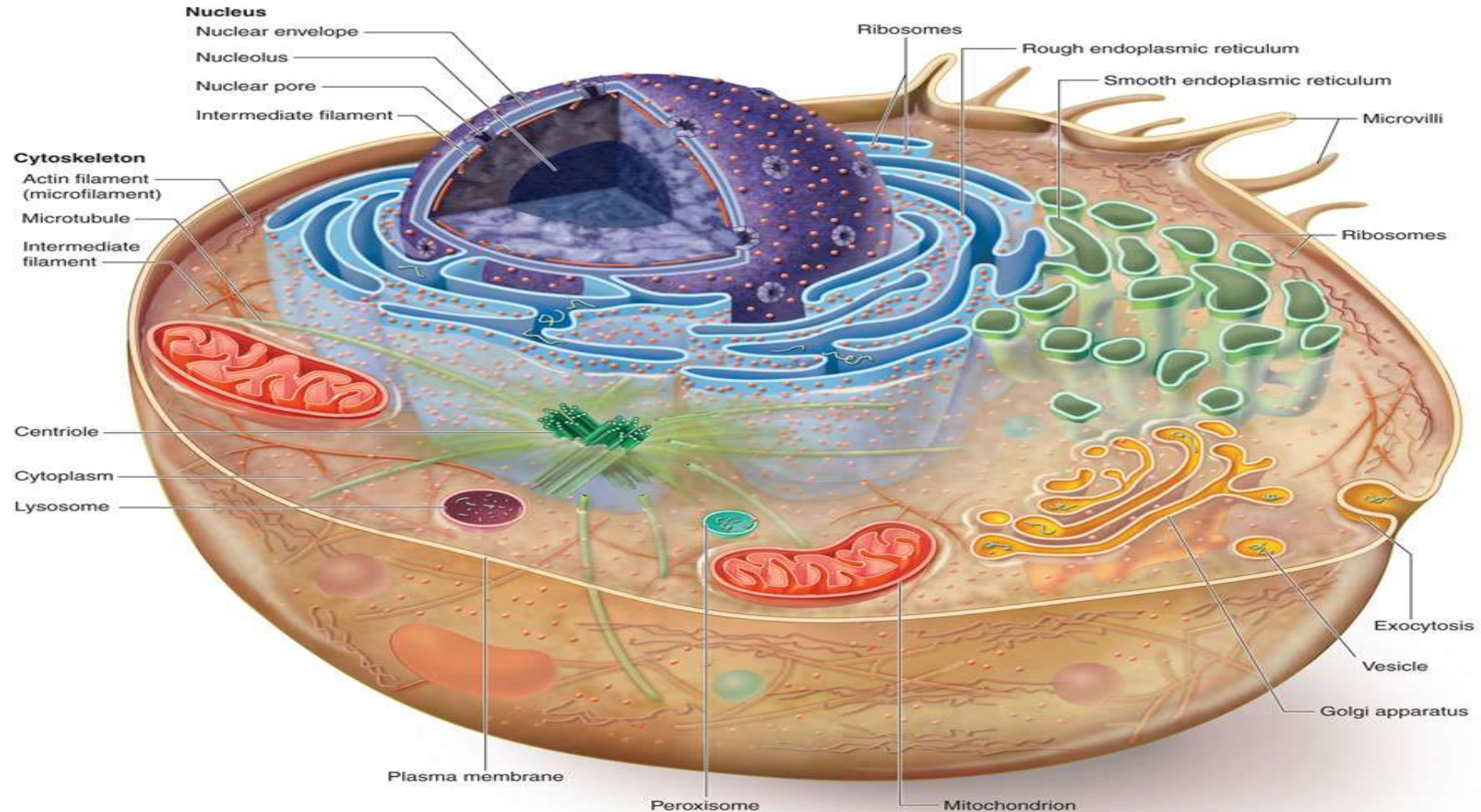
## Eukaryotic cells

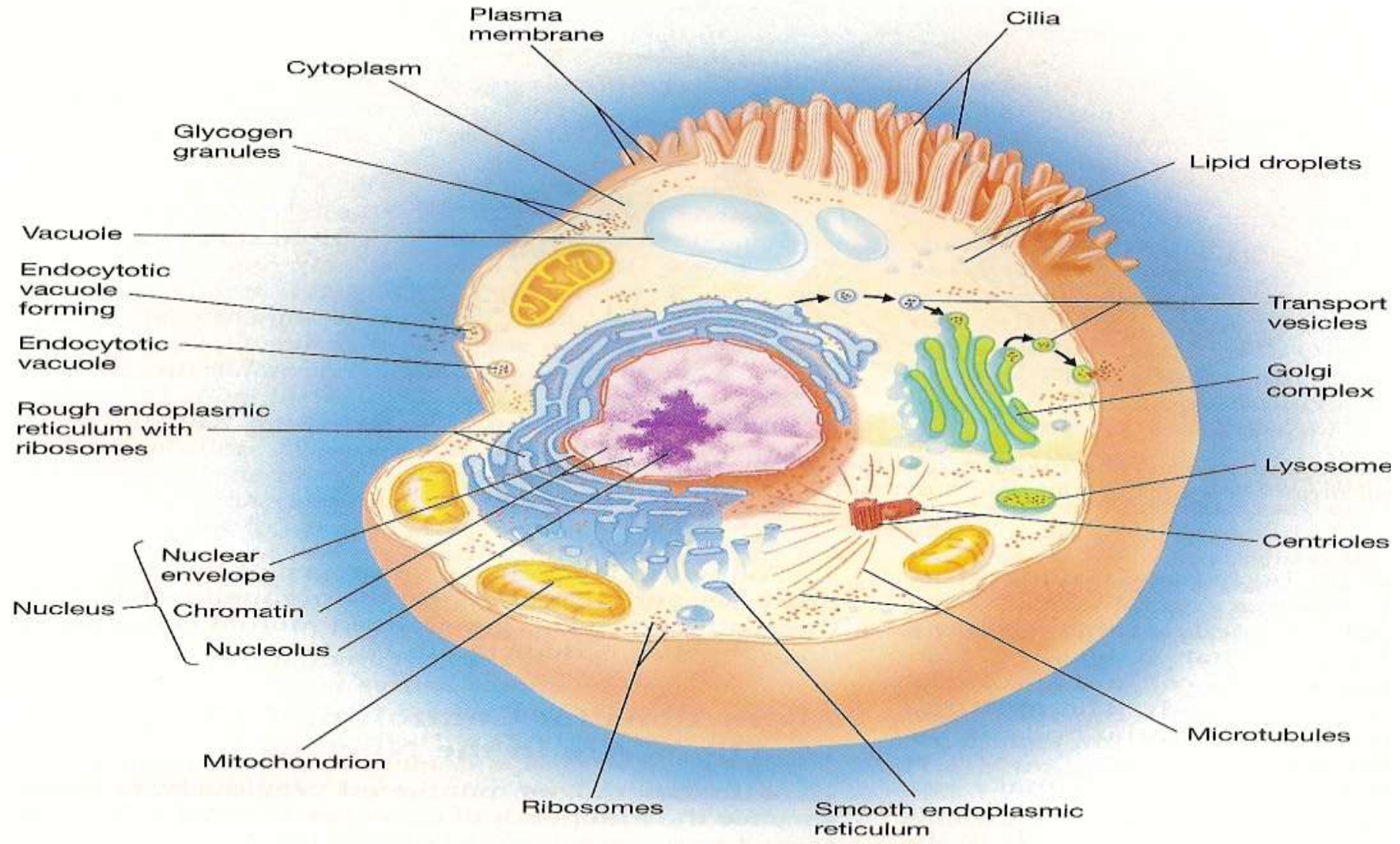
- possess a membrane-bound nucleus
- are more complex than prokaryotic cells
- compartmentalize many cellular functions within **organelles** and the **endomembrane system**
- possess a **cytoskeleton** for support and to maintain cellular structure



# Eukaryotic Cells

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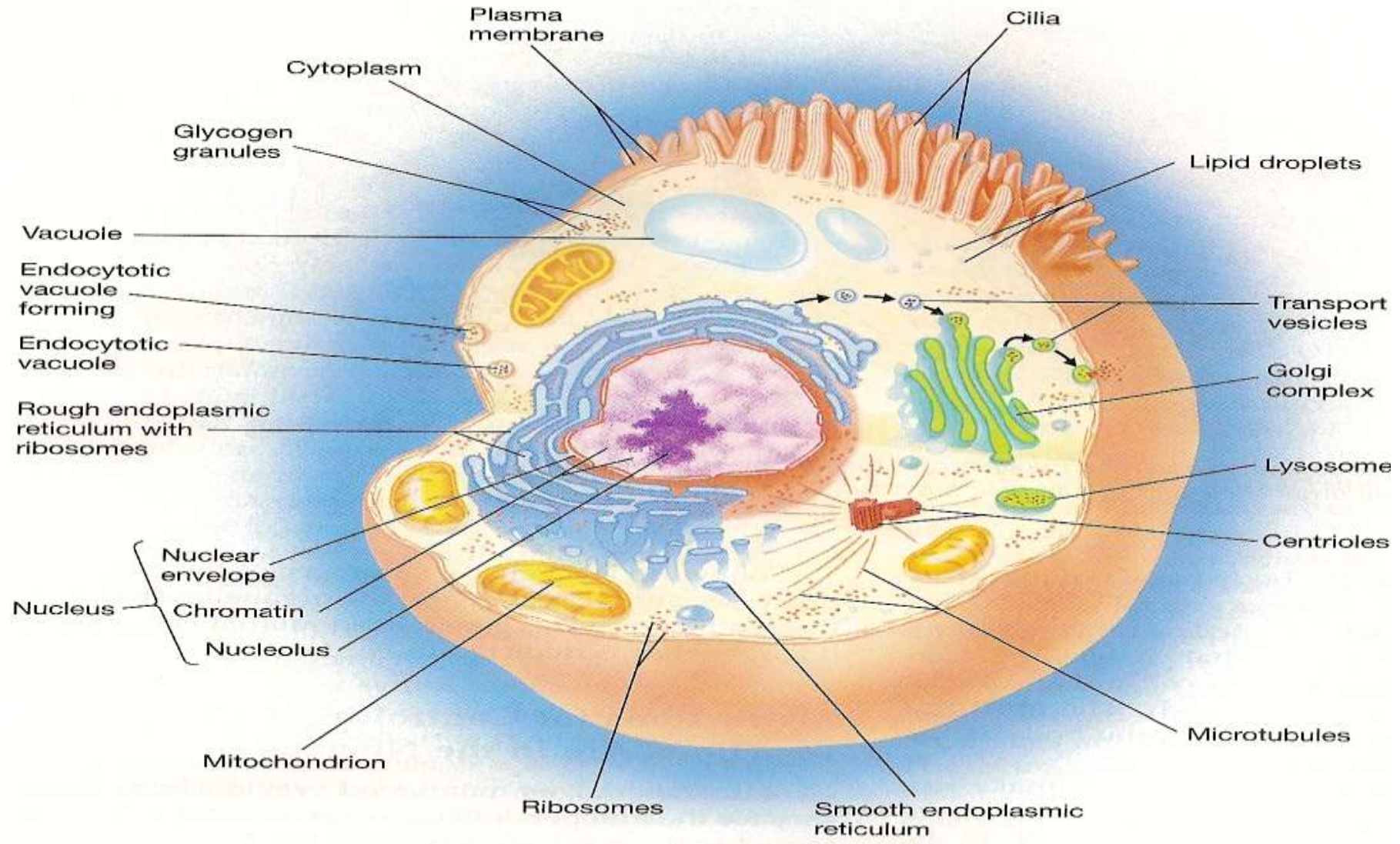




(a)

- Each cell is formed by a cell body and a membrane covering the cell body called the cell membrane.
- Cell body has two parts, namely nucleus and cytoplasm surrounding the nucleus
- Thus, the structure of the cell is studied under three headings:
  - 1. Cell membrane
  - 2. Cytoplasm
  - 3. Nucleus





(a)

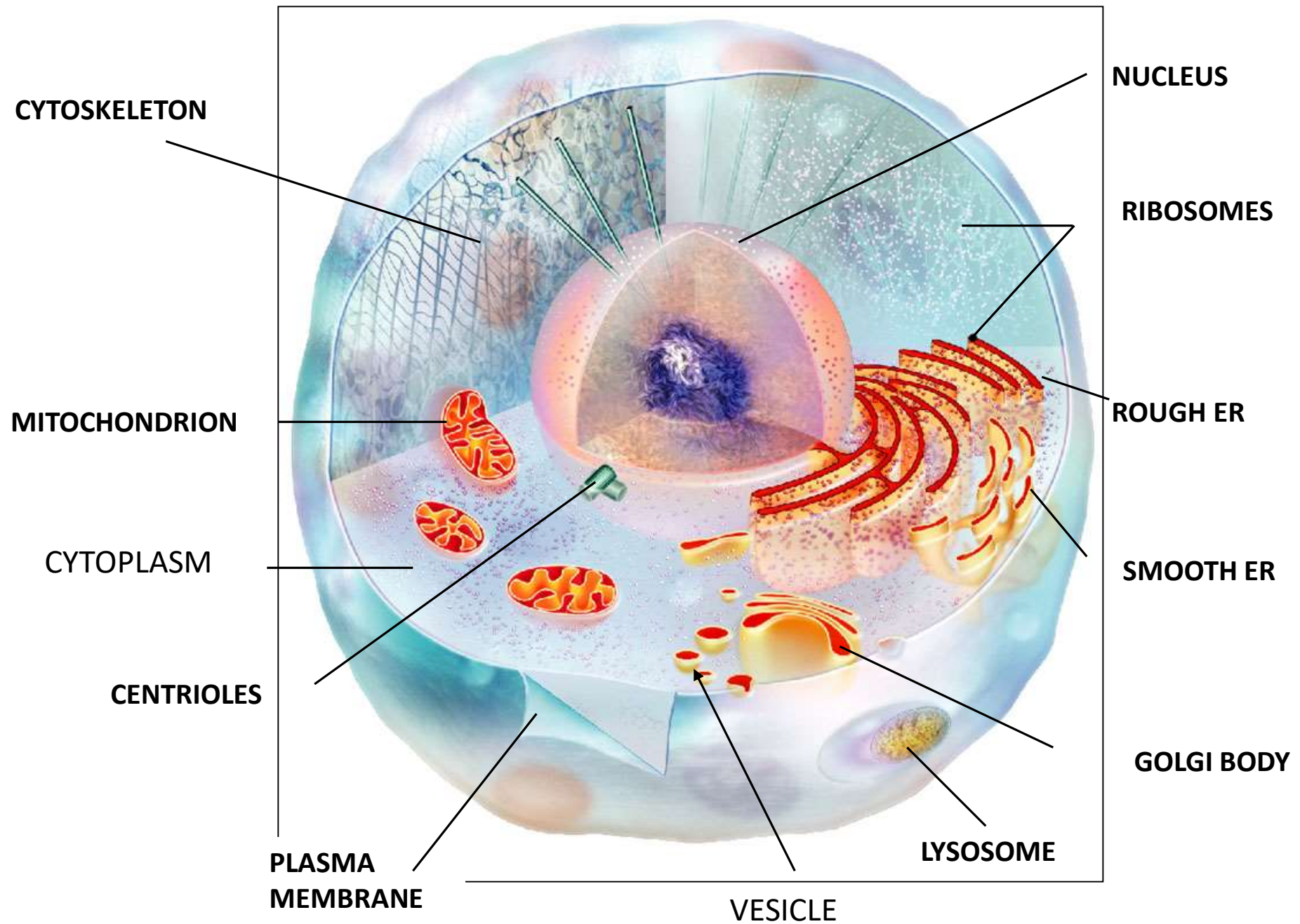


Fig. 4-15b, p.59

# CELL MEMBRANE

- Cell membrane is a protective sheath, enveloping the cell body.
- Also known as plasma membrane or
- It separates the fluid outside the cell called extracellular fluid (ECF) and the fluid inside the cell called intracellular fluid (ICF).
- It is a semipermeable membrane.
- So, there is free exchange of certain substances between ECF and ICF.

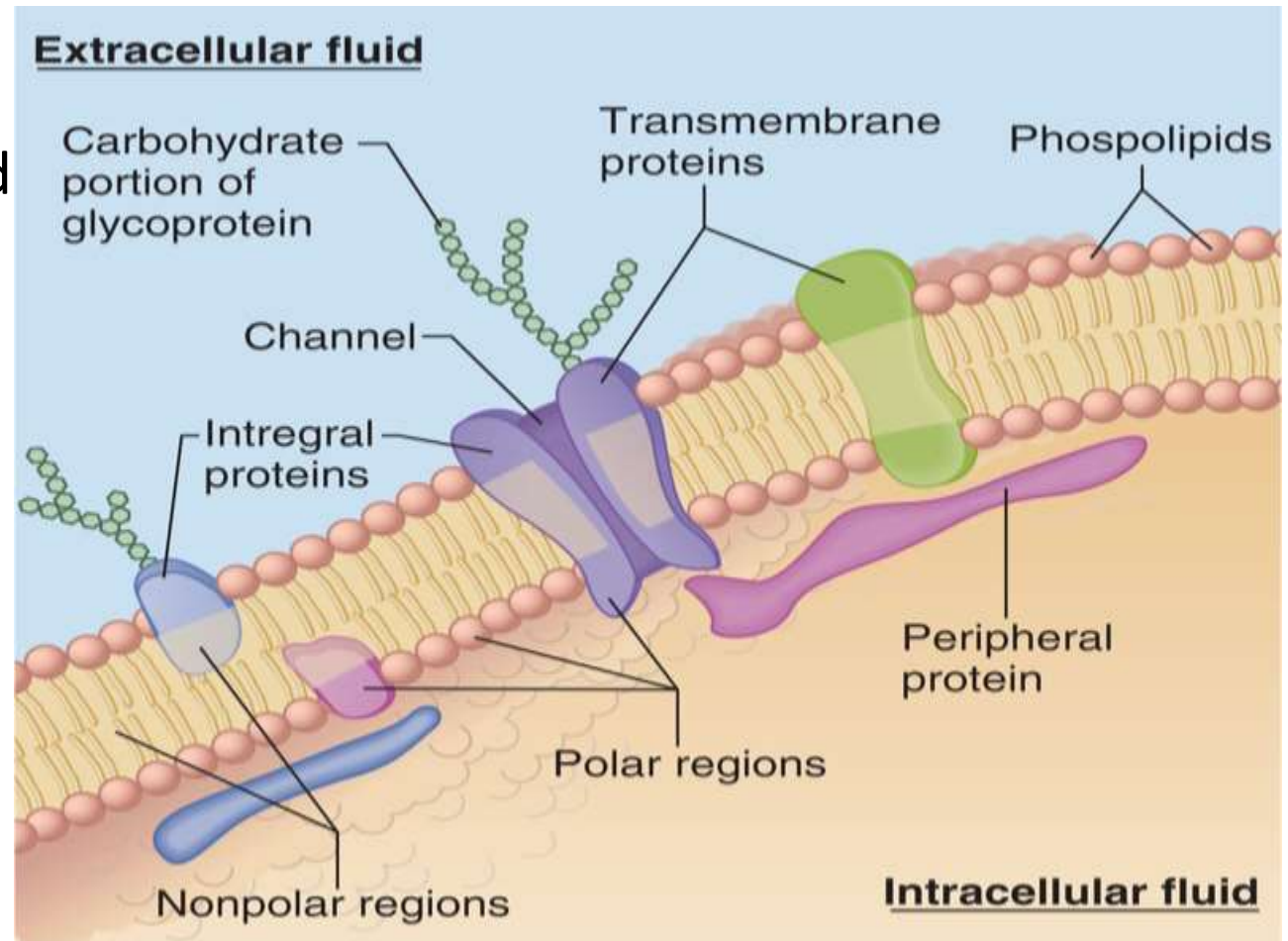
# COMPOSITION OF CELL MEMBRANE

- Cell membrane is composed of three types of substances:
- 1. Proteins (55%)
- 2. Lipids (40%)
- 3. Carbohydrates (5%).

- Cell membrane consists a lipid bilayer containing large numbers of protein molecules in the lipid, many of which penetrate all the way through the membrane
- Lipid bilayer constitutes a barrier against movement of water and water-soluble substances between the ECF and ICF
- Lipid soluble substances can penetrate through this lipid bilayer by diffusion



- All cells are surrounded by a plasma membrane.
- Cell membranes are composed of a lipid bilayer with globular proteins embedded in the bilayer.
- On the external surface, carbohydrate groups join with lipids to form glycolipids, and with proteins to form glycoproteins. These function as cell identity markers.



- protein molecules in the membrane have different properties for transporting substances.
- They interrupt the continuity of lipid bilayer, constituting an alternative pathway through the cell membrane.
- Most of these penetrating proteins function as *transport proteins*.
- Different proteins function differently.

- It is proposed that the cell membrane has a fluid mosaic model’.
- This implies that the membrane is a fluid with mosaic of proteins (mosaic means pattern formed by arrangement of different colored pieces of stone, tile, glass or other such materials).
- In this model, the proteins are found to float in the lipid layer instead of forming the layers of the sandwich-type model.

# Lipid Layers of the Cell Membrane

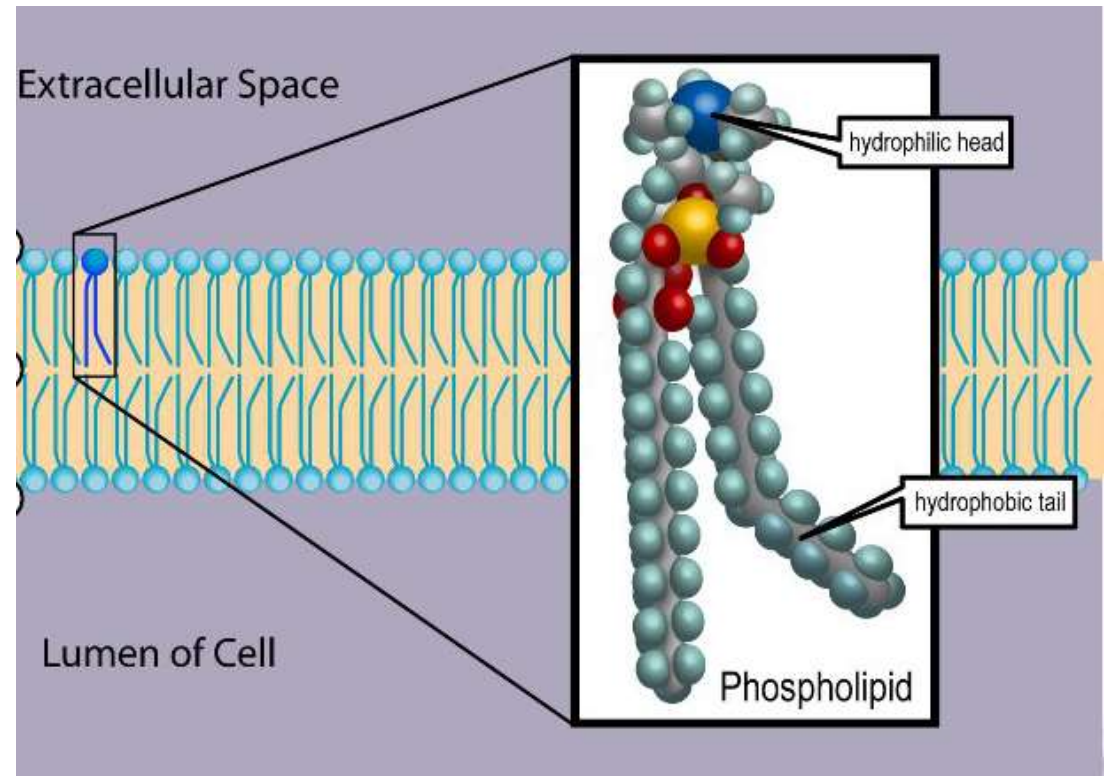
- The central lipid layer is a bilayered structure.
- Formed by a thin film of lipids.
- The characteristic feature of lipid layer is that, it is fluid in nature and not a solid structure.
- So, the portions of the membrane move from one point to another point along the surface of the cell.
- The materials dissolved in lipid layer also move to all areas of the cell membrane.

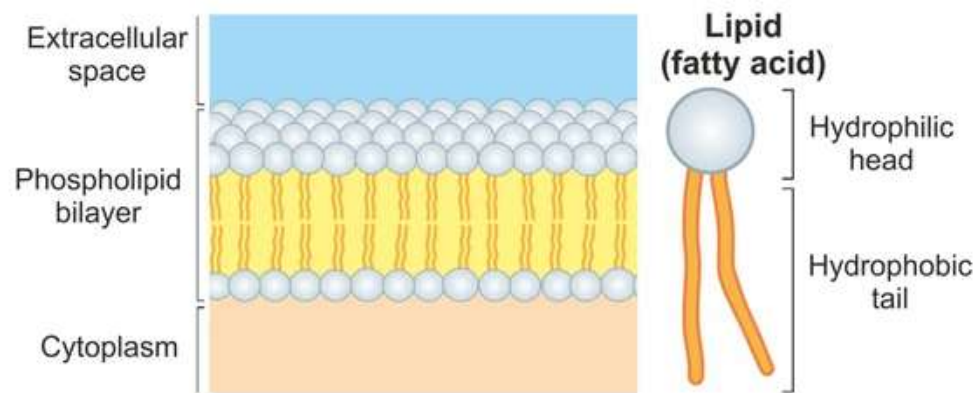
Major lipids are:

- 1. Phospholipids
- 2. Cholesterol.

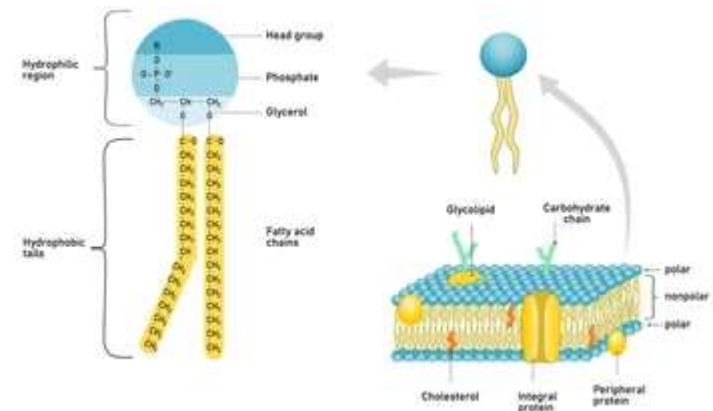
# 1. Phospholipids

- These are the lipid substances containing phosphorus and fatty acids.
- Are arranged in 2 layers
- Each phospholipid molecule resembles the headed pin in shape.
- The outer part of the phospholipid molecule is called the head portion and the inner portion is called the tail portion





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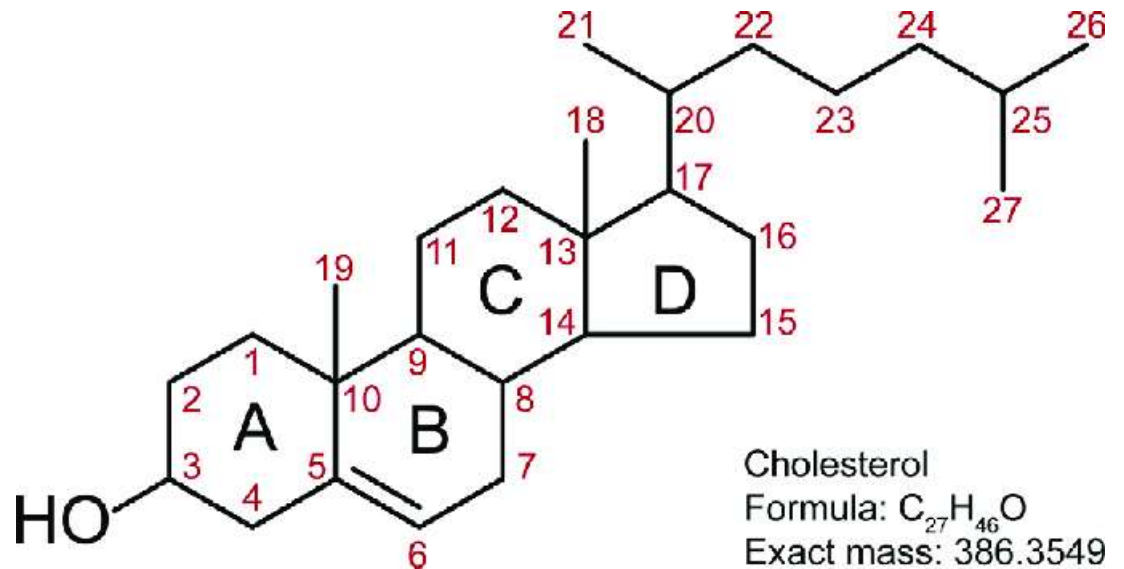


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- Head portion is the polar end ( $\text{PO}_4$  with a charge of -3)
- It is soluble in water and has strong affinity for water (hydrophilic).
- Tail portion is the non-polar end ( $(\text{CH}_3(\text{CH}_2)_n-)$ ).
- It is insoluble in water and repelled by water (hydrophobic).
- 2 layers of phospholipids are arranged in such a way that the hydrophobic tail portions meet in the center of the membrane.
- Hydrophilic head portions of outer layer face the ECF and those of the inner layer face ICF (cytoplasm).

## 2. Cholesterol

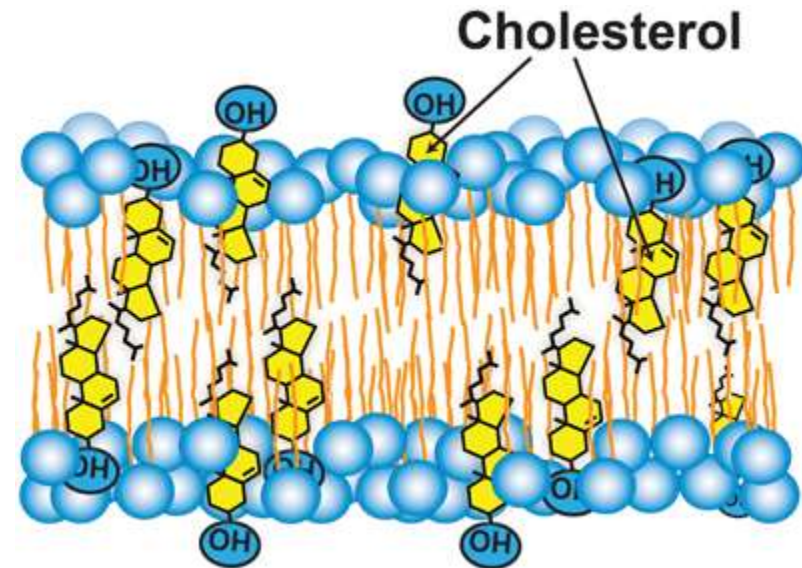
- Cholesterol molecules are arranged in between the phospholipid molecules.
- Phospholipids are soft and oily structures and cholesterol helps to 'pack' the phospholipids in the membrane.
- So, cholesterol is responsible for the structural integrity of lipid layer of the cell membrane.



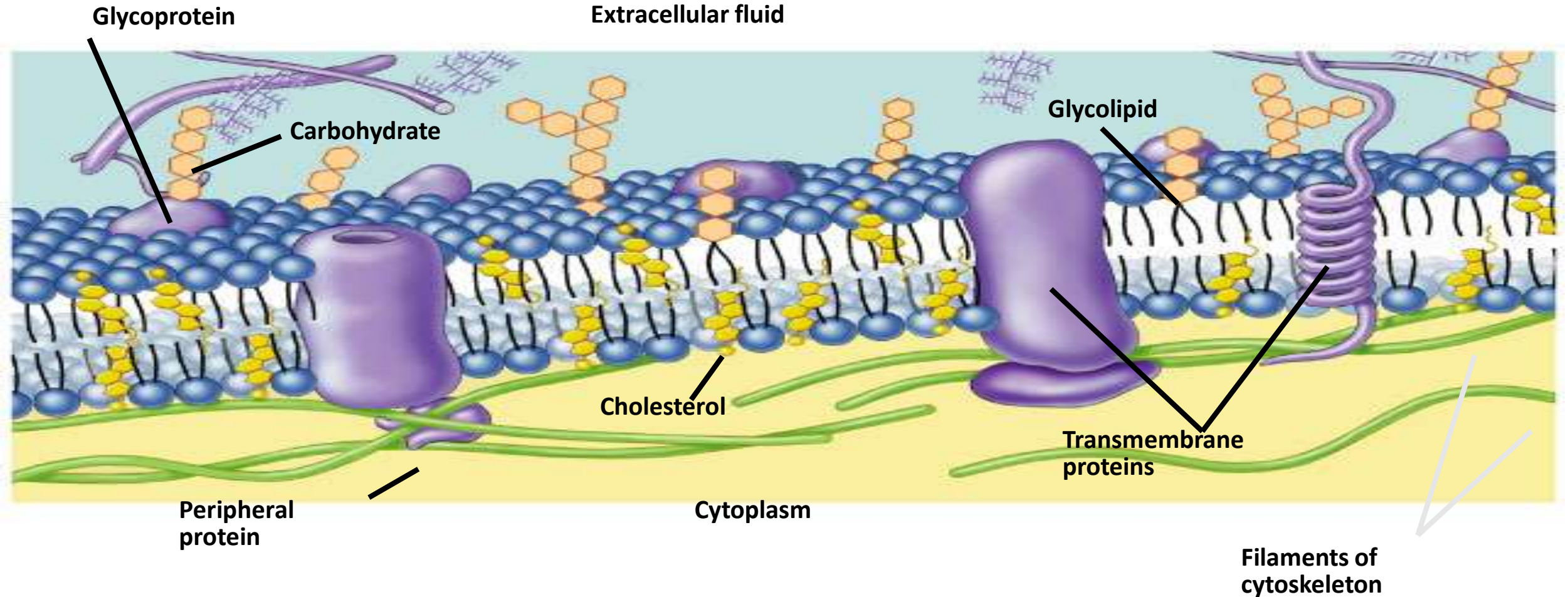


## Functions of Lipid Layer in Cell Membrane

- Lipid layer of the cell membrane is a semipermeable membrane and allows only the fat-soluble substances to pass through it.
- Thus, the fat-soluble substances like  $O_2$ ,  $CO_2$ , and alcohol can pass through
- this lipid layer with ease
- Water-soluble substances such as glucose, urea and electrolytes cannot pass through this layer



# Fluid Mosaic Model

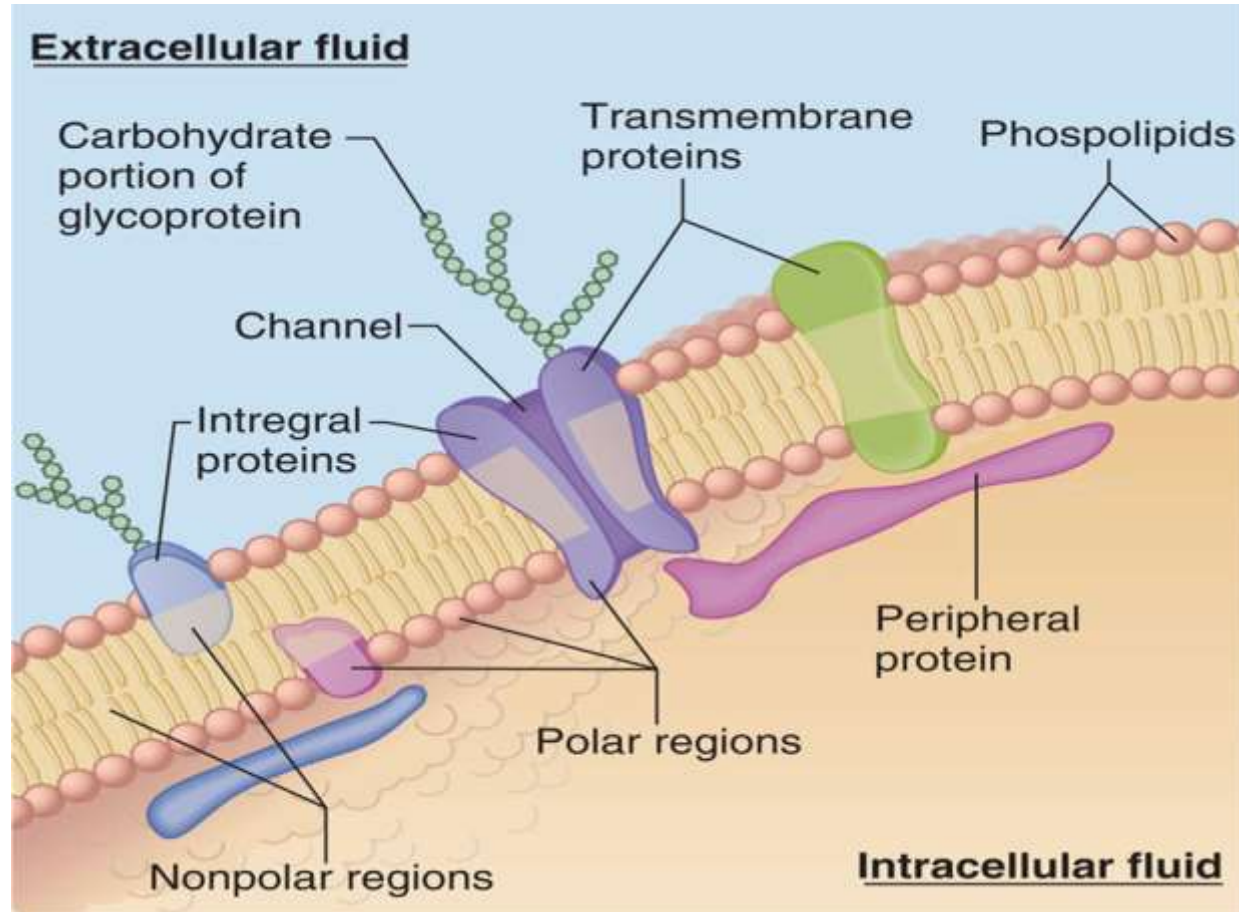


# Protein Layers of the Cell Membrane

- These layers cover the two surfaces of the central lipid layer.
- They give protection to the central lipid layer.
- The protein substances present in these layers are mostly glycoproteins
- Protein molecules are classified into 2 categories:
  - 1. Integral proteins or transmembrane proteins.
  - 2. Peripheral proteins or peripheral membrane proteins.

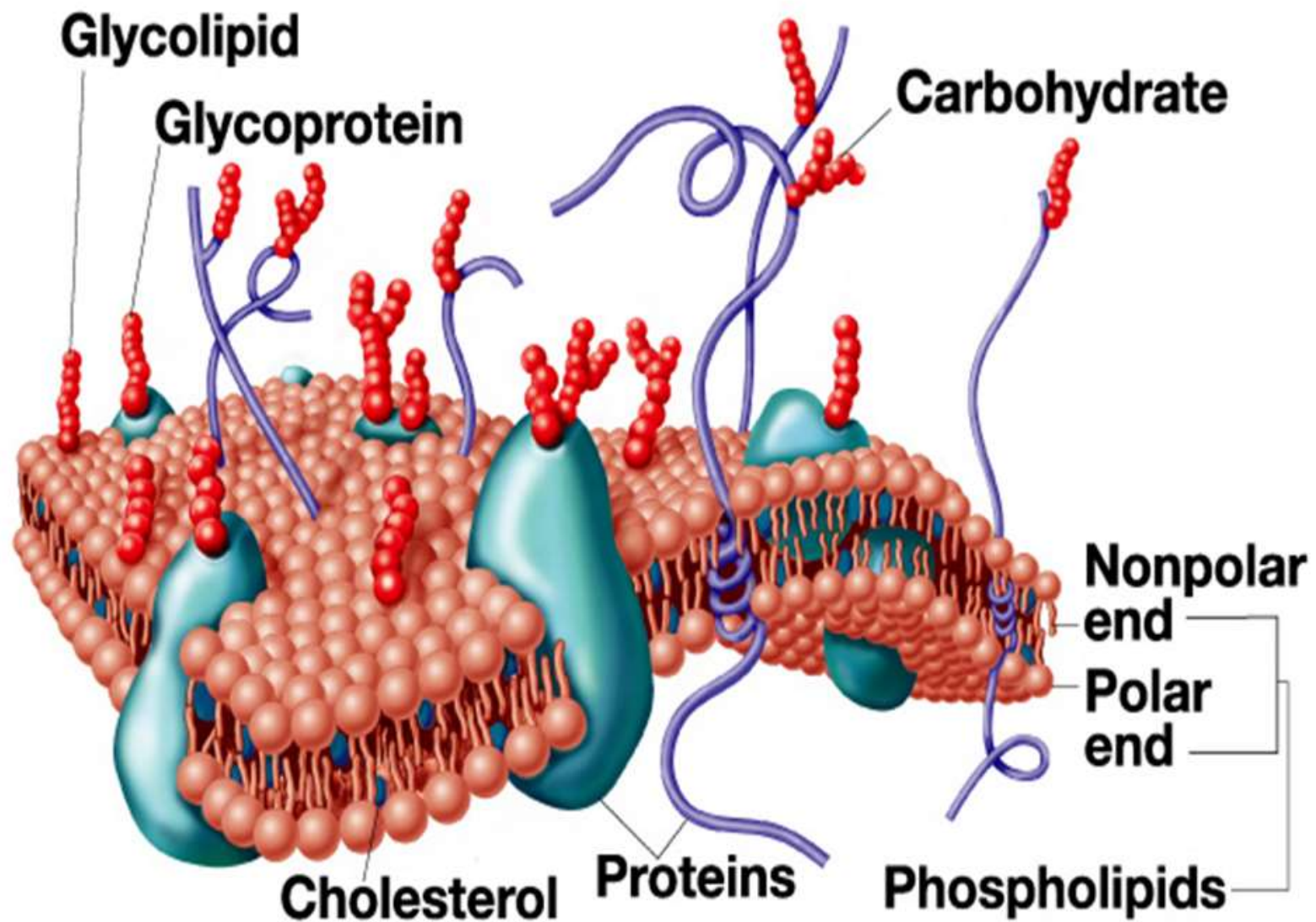
# 1. Integral proteins

- Are the proteins that pass through entire thickness of cell membrane from one side to the other side.
- Are tightly bound with the cell membrane.
- Examples of integral protein:
  - i. Cell adhesion proteins
  - ii. Cell junction proteins
  - iii. Some carrier (transport) proteins
  - iv. Channel proteins
  - v. Some hormone receptors
  - vi. Antigens
  - vii. Some enzyme





## Extracellular side



## Intracellular side

## 2. Peripheral proteins

- Are the proteins which are partially embedded in the outer and inner surfaces of the cell membrane
- Do not penetrate the cell membrane.
- They are loosely bound with integral proteins or lipid layer of cell membrane.
- They dissociate readily from the cell membrane.
- Examples of peripheral proteins:
  - i. Proteins of cytoskeleton
  - ii. Some carrier (transport) proteins
  - iii. Some enzymes

# Functions of Proteins in Cell Membrane

1. Integral proteins provide the structural integrity of the cell membrane
2. Channel proteins help in the diffusion of water soluble substances like glucose and electrolytes
3. Carrier or transport proteins help in the transport of substances across the cell membrane by means of active or passive transport
4. Pump: Some carrier proteins act as pumps, by which ions are transported actively across the cell membrane
5. Receptor proteins serve as the receptor sites for hormones



6. Enzymes: Some of the protein molecules form the enzymes and control chemical (metabolic) reactions within the cell membrane

7. Antigens: Some proteins act as antigens and induce the process of antibody formation

8. Cell adhesion molecules or the integral proteins are responsible for attachment of cells to their neighbors or to basal lamina

# Carbohydrates of the Cell Membrane

- Some of the carbohydrate molecules present in cell membrane are attached to proteins and form glycoproteins (proteoglycans).
- Some are attached to lipids and form glycolipids.
- Carbohydrate molecules form a thin and loose covering over the entire surface of the cell membrane called glycocalyx

## **Functions of Carbohydrates in Cell Membrane**

1. Carbohydrate molecules are negatively charged and do not permit the negatively charged substances to move in and out of the cell

2. Glycocalyx from the neighboring cells helps in the tight fixation of cells with one another
3. Some carbohydrate molecules function as the receptors for some hormones

# FUNCTIONS OF CELL MEMBRANE

1. Protective function: Cell membrane protects the cytoplasm and the organelles present in the cytoplasm
2. Selective permeability: Cell membrane acts as a semipermeable membrane, which allows only some substances to pass through it and acts as a barrier for other substances
3. Absorptive function: Nutrients are absorbed into the cell through the cell membrane
4. Excretory function: Metabolites and other waste products from the cell are excreted out through the cell membrane

5. Exchange of gases: Oxygen enters the cell from the blood and carbon dioxide leaves the cell and enters the blood through the cell membrane

6. Maintenance of shape and size of the cell: Cell membrane is responsible for the maintenance of shape and size of the cell.

# CYTOPLASM

- Cytoplasm of the cell is the jellylike material formed by 80% of water.
- Contains a clear liquid portion called cytosol and various particles of different shape and size.
- These particles are proteins, carbohydrates, lipids or electrolytes in nature.
- Also contains many organelles with distinct structure and function.

# ORGANELLES IN CYTOPLASM

- Cytoplasmic organelles are the cellular structures embedded in the cytoplasm.
- Organelles are considered as small organs of the cell.
- Some organelles are bound by limiting membrane and others do not have limiting membrane
- Each organelle is having a definite structure and specific function

## Organelles with limiting membranes

1. Endoplasmic reticulum
2. Golgi apparatus
3. Lysosome
4. Peroxisome
5. Centrosome and centrioles
6. Secretory vesicles
7. Mitochondria
8. Nucleus

## Organelles without limiting membranes

1. Ribosomes
2. Cytoskeleton



# ENDOPLASMIC RETICULUM

- It is a network of tubular and microsomal vesicular structures which are interconnected with one another.
- It is covered by a membrane which is formed by proteins and bilayered lipids.
- Forms the link between nucleus and cell membrane by connecting the cell membrane with the nuclear membrane
- 2 types: Rough and smooth endoplasmic reticulum.
- Both the types are interconnected and continuous with one another.
- Depending upon the activities of the cells, the rough endoplasmic reticulum changes to smooth endoplasmic reticulum and vice versa.

- Rough Endoplasmic Reticulum
- Rough appearance is due to the attachment of granular ribosomes to its outer surface.
- Hence, it is also called the granular endoplasmic

## **Functions of Rough Endoplasmic Reticulum**

### **1. Synthesis of proteins**

- Concerned with the synthesis of proteins in the cell.
- It is involved with the synthesis of mainly those proteins which are secreted from the cells such as insulin from  $\beta$ cells of islets of Langerhans in pancreas and antibodies from B lymphocytes

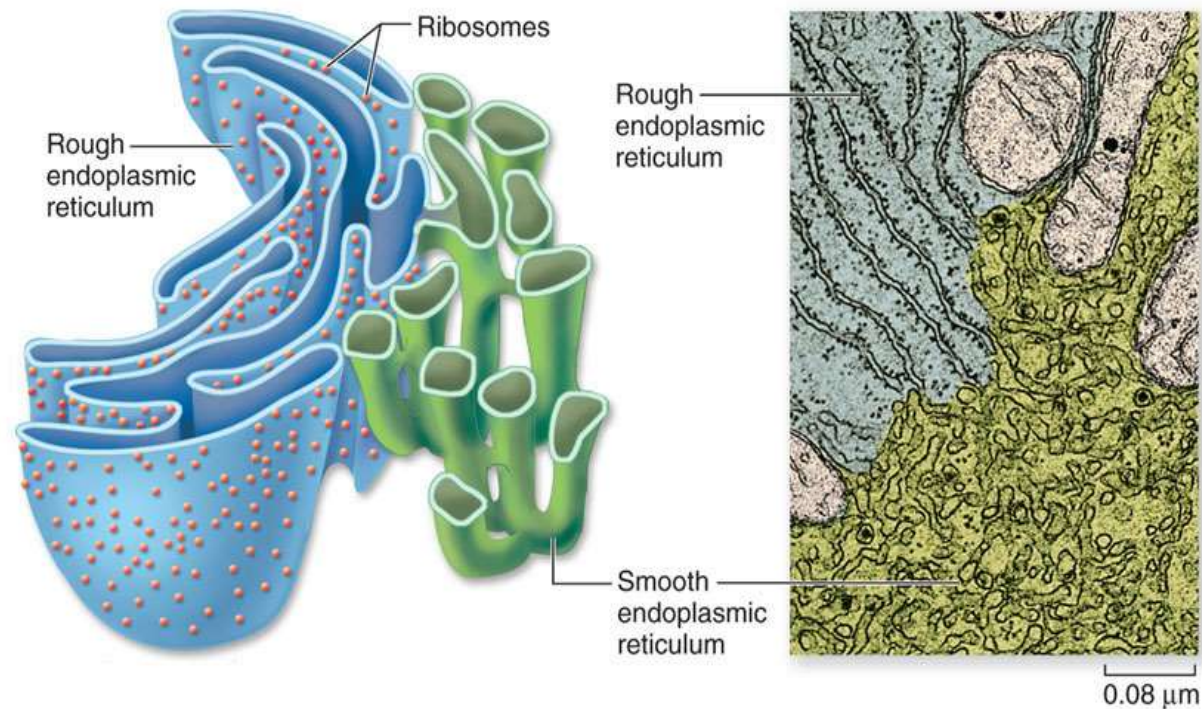
- Ribosomes arrange the amino acids into small units of proteins and transport them into the rough endoplasmic reticulum.
- Here, the carbohydrates are added to the protein units forming the glycosylated proteins or glycoproteins, which are arranged in the form of reticular vesicles.
- These vesicles are transported mainly to Golgi apparatus for further modification and processing.
- Few vesicles are transported to other cytoplasmic organelles.

## 2. Degradation of worn-out organelles

- Also plays an important role in the degradation of worn-out cytoplasmic organelles like mitochondria.
- It wraps itself around the wornout organelles and forms a vacuole which is often called the autophagosome.
- Autophagosome is digested by lysosomal enzymes

# Endomembrane System

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# Smooth Endoplasmic Reticulum

- It is the endoplasmic reticulum with smooth appearance. Also called agranular reticulum.
- It is formed by many interconnected tubules.

## **Functions of Smooth Endoplasmic Reticulum**

- 1. Synthesis of non-protein substance
- Smooth endoplasmic reticulum is responsible for synthesis of non-protein substances such as cholesterol and steroid.
- Is very abundant in cells involved in synthesis of lipids, phospholipids, lipoprotein substances, steroid hormones etc.
- In most of the other cells, smooth endoplasmic reticulum is less extensive than the rough endoplasmic reticulum.

## 2. Role in cellular metabolism

- Outer surface of smooth endoplasmic reticulum contains many enzymes which are involved in various metabolic processes of the cell

## 3. Storage and metabolism of calcium

- It is the major site of storage and metabolism of calcium.
- In skeletal muscle fibers, it releases calcium which is necessary to trigger the muscle contraction.

## 4. Catabolism and detoxification

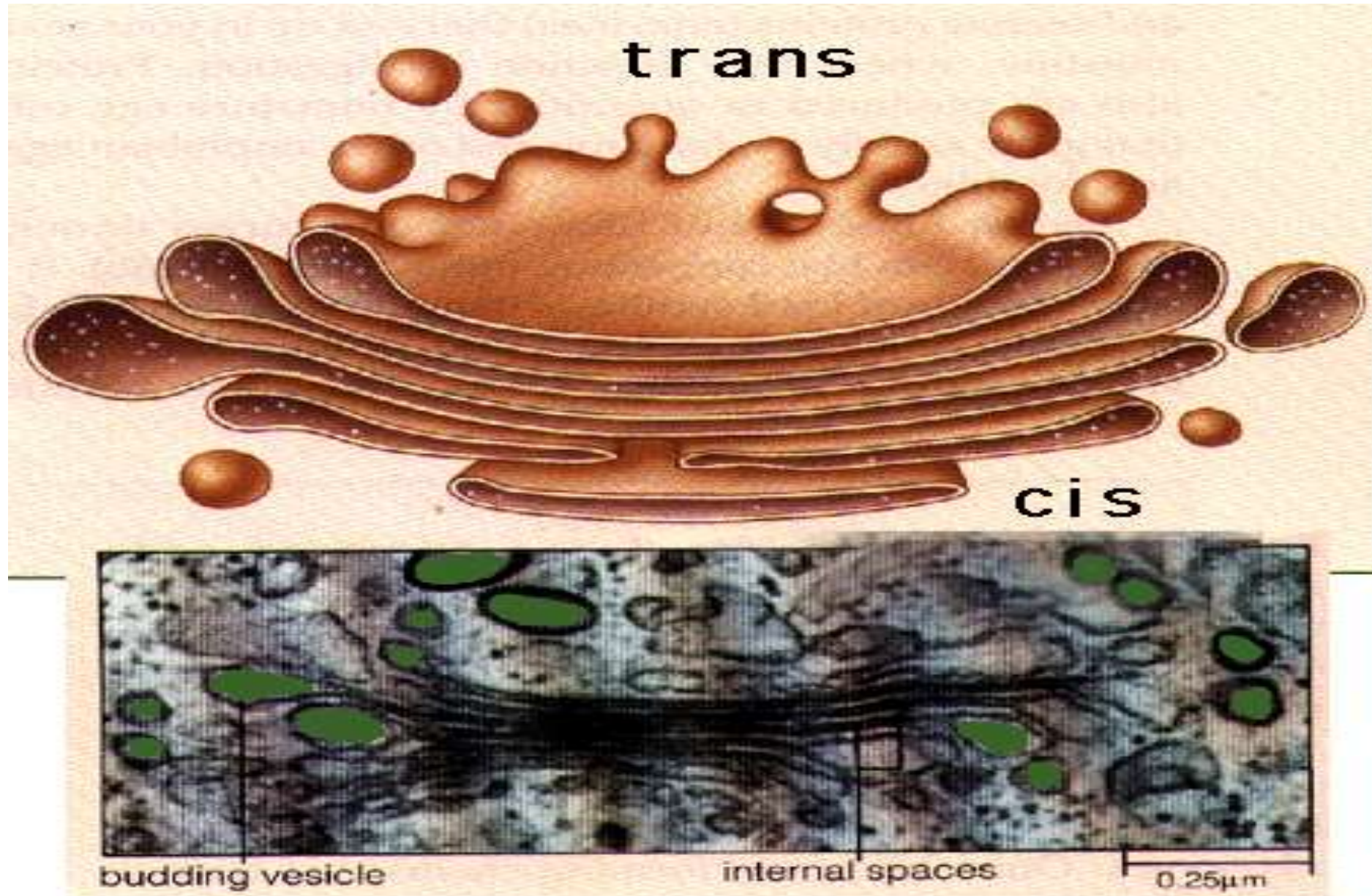
- Also concerned with catabolism and detoxification of toxic substances like some drugs and carcinogens in the liver.

# Golgi apparatus

- Is a membrane-bound organelle, involved in the processing of proteins.
- Present in all cells except red blood cells.
- Each Golgi apparatus consists of 5 to 8 flattened membranous sacs called the cisternae.
- Golgi apparatus is situated near the nucleus.
- It has two ends or faces, namely cis face and trans face.
- The cis face is positioned near the endoplasmic reticulum.
- Reticular vesicles from endoplasmic reticulum enter the Golgi apparatus through cis face.
- The trans face is situated near the cell membrane.
- The processed substances make their exit from Golgi apparatus through trans face



# Golgi Apparatus



# Functions of Golgi Apparatus

- Major functions of Golgi apparatus are processing, packing, labeling and delivery of proteins and other molecules like lipids to different parts of the cell.

## **1. Processing of materials**

- Vesicles containing glycoproteins and lipids are transported into Golgi apparatus.
- Here, the glycoproteins and lipids are modified and processed.

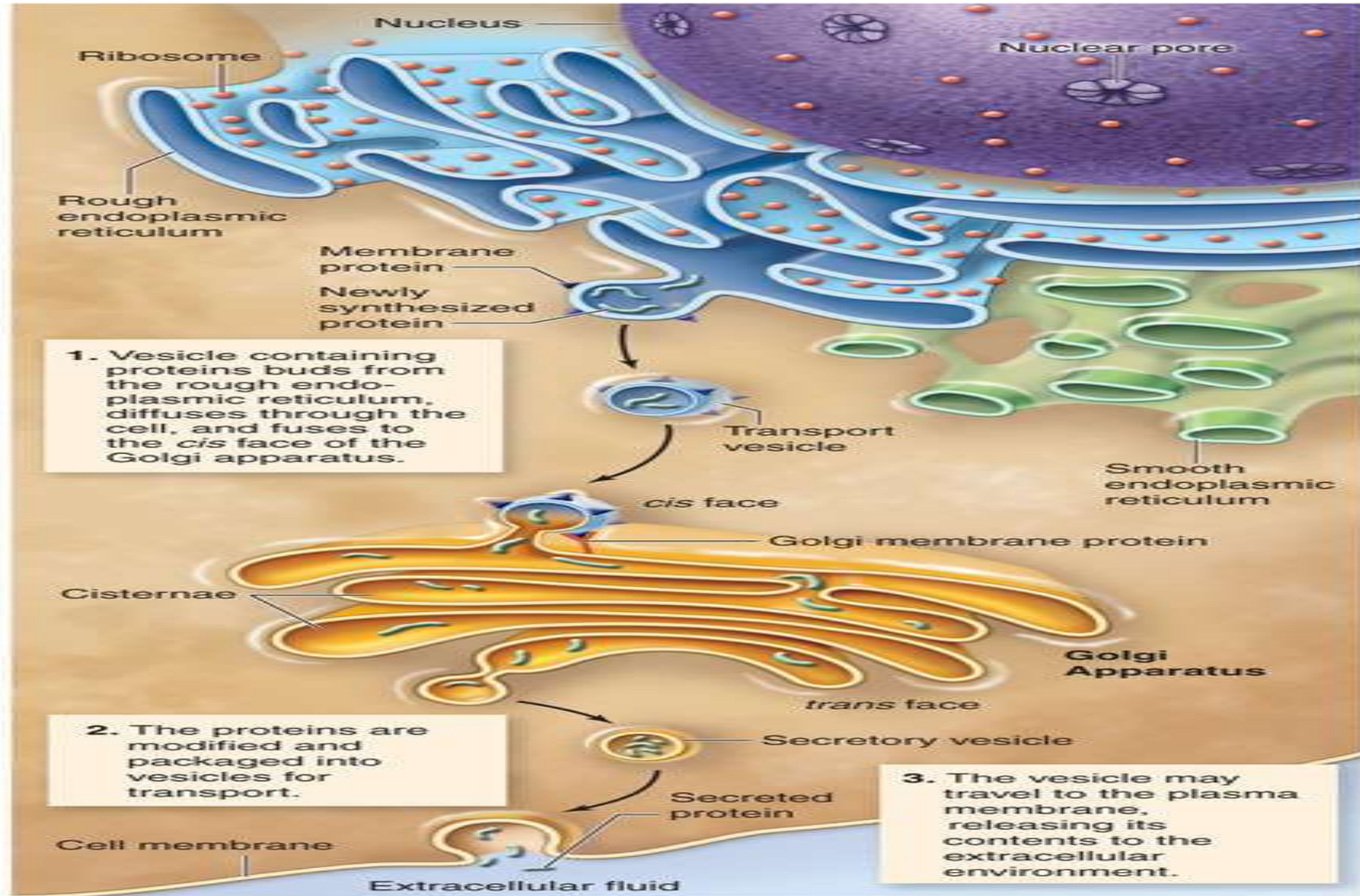
## **2. Packaging of materials**

- All the processed materials are packed in the form of secretory granules, secretory vesicles and lysosomes, which are transported either out of the cell or to another part of the cell.
- Because of this, Golgi apparatus is called the 'post office of the cell'.

- **3. Labeling and delivery of materials**

- Finally, the Golgi apparatus sorts out the processed and packed materials and labels them (such as phosphate group), depending upon the chemical content for delivery (distribution) to their proper destinations.
- Hence, the Golgi apparatus is called 'shipping department of the cell'.





# LYSOSOMES

- These are the membrane-bound vesicular organelles found throughout the cytoplasm.
- Are formed by Golgi apparatus.
- The enzymes synthesized in rough endoplasmic reticulum are processed and packed in the form of small vesicles in the Golgi apparatus.
- Then, these vesicles are pinched off from Golgi apparatus and become the lysosomes.
- Among the organelles of the cytoplasm, the lysosomes have the thickest covering membrane.
- It has many small granules which contain hydrolytic enzymes.

# Functions of Lysosomes

- Lysosomes are often called 'garbage system' of the cell because of their degradation activity.
- About 50 hydrolytic enzymes, called acid hydroxylases are present in the lysosomes, through which they execute their functions.

## Important lysosomal enzymes

- 1. Proteases, which hydrolyze the proteins into amino acids
- 2. Lipases, which hydrolyze the lipids into fatty acids and glycerides
- 3. Amylases, which hydrolyze polysaccharides into glucose
- 4. Nucleases, which hydrolyze the nucleic acids into mononucleotides.

# Lysosome

- Digestive 'plant' for proteins, fats, and carbohydrates
- Transports undigested material to cell membrane for removal
- Cell breaks down if lysosome structure is disrupted.



Lysosomal functions involve two mechanisms:

1. Heterophagy: Digestion of extracellular materials engulfed by the cell via endocytosis
2. Autophagy: Digestion of intracellular materials such as worn-out cytoplasmic organelles.



# Specific functions of lysosomes

## 1. Degradation of macromolecules

- Macromolecules are engulfed by the cell by endocytosis (phagocytosis, pinocytosis or receptor mediated endocytosis)
- The macromolecules such as bacteria, engulfed by the cell via phagocytosis are called phagosomes or vacuoles.
- The other macromolecules taken inside via pinocytosis or receptor-mediated endocytosis are called endosomes.
- The primary lysosome fuses with the phagosome or endosome to form the secondary lysosome.
- The pH in the secondary lysosome becomes acidic and the lysosomal enzymes are activated.

- The bacteria and the other macromolecules are digested and degraded by these enzymes.
- The secondary lysosome containing these degraded waste products moves through cytoplasm and fuses with cell membrane.
- Now the waste products are eliminated by exocytosis.

## **2. Degradation of worn-out organelles**

- The rough endoplasmic reticulum wraps itself around the worn-out organelles like mitochondria and form the vacuoles called autophagosomes.
- One primary lysosome fuses with one autophagosome to form the secondary lysosome.
- The enzymes in the secondary lysosome are activated.
- Now, these enzymes digest the contents of autophagosome.

### 3. Removal of excess secretory products in the cells

- Lysosomes in the cells of the secretory glands remove the excess secretory products by degrading the secretory granules.

- 4. Secretory function – secretory lysosomes
- Recently, lysosomes having secretory function called secretory lysosomes are found in some of the cells, particularly in the cells of immune system.
- The conventional lysosomes are modified into secretory lysosomes by combining with secretory granules (which contain the particular secretory product of the cell).
- Lysosomes in the cytotoxic T lymphocytes and natural killer (NK) cells secrete perforin and granzymes, which destroy both viral-infected cells and tumor cells. Perforin is a pore-forming protein that initiates cell death

# PEROXISOMES

- Are the membrane limited vesicles like the lysosomes.
- Unlike lysosomes, peroxisomes are pinched off from endoplasmic reticulum and not from the Golgi apparatus.
- They contain some oxidative enzymes such as catalase, urate oxidase and D-amino acid oxidase.

## **Functions of Peroxisomes**

- i. Breakdown the fatty acids by means of a process called beta-oxidation: This is the major function of peroxisome
- Degrade the toxic substances such as hydrogen peroxide and other metabolic products by means of detoxification.

- iii. Form the major site of oxygen utilization in the cells
- iv. Accelerate gluconeogenesis from fats
- v. Degrade purine to uric acid
- vi. Participate in the formation of myelin
- viii. Play a role in the formation of bile acids.

# CENTROSOME AND CENTRIOLES

- Centrosome is the membrane-bound cellular organelle situated almost in the center of cell, close to nucleus.
- It consists of two cylindrical structures called centrioles which are made up of proteins.
- Are responsible for the movement of chromosomes during cell division



# SECRETORY VESICLES

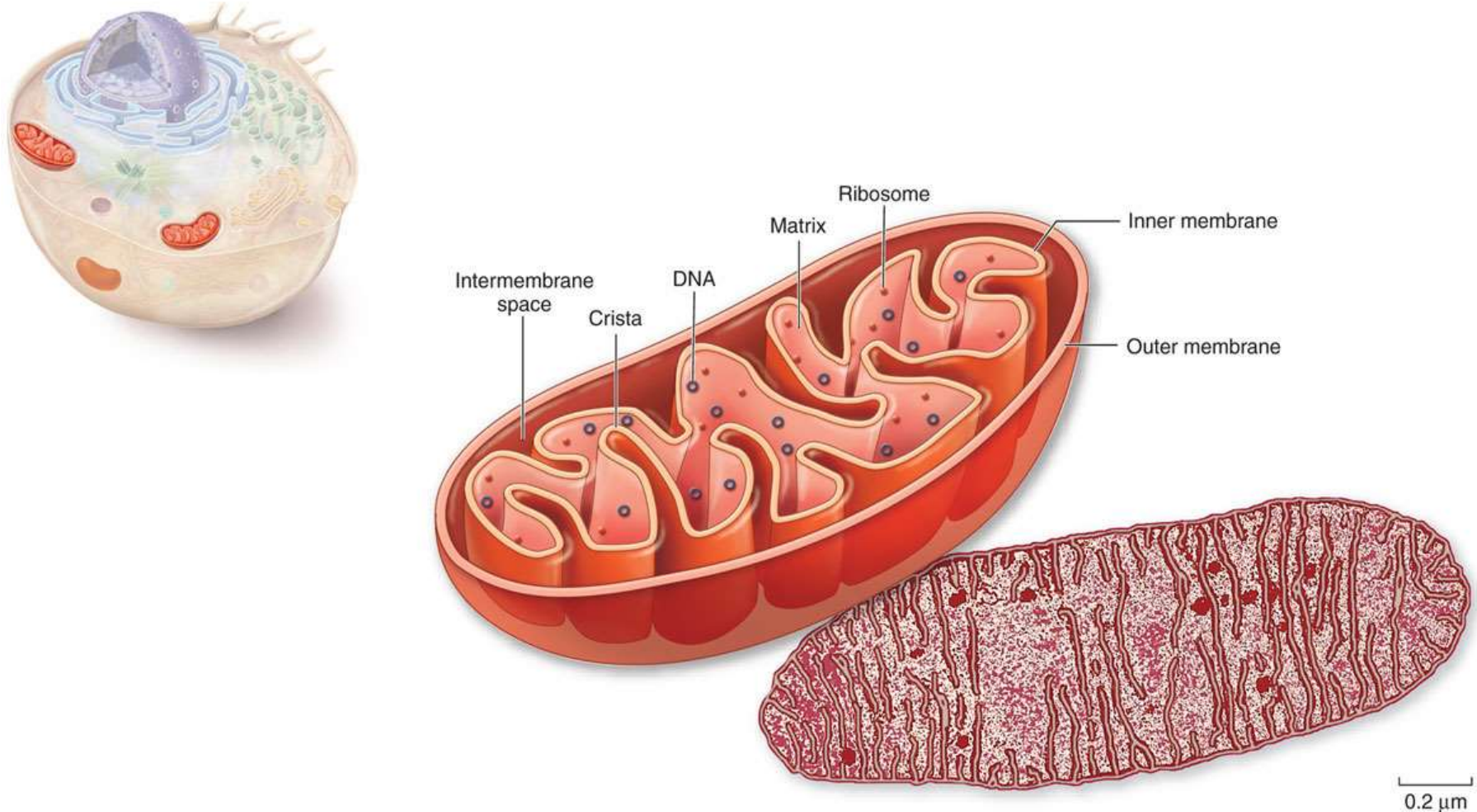
- Are the organelles with limiting membrane and contain the secretory substances.
- These vesicles are formed in the endoplasmic reticulum and are processed and packed in Golgi apparatus.
- Secretory vesicles are present throughout the cytoplasm.
- When necessary, these vesicles are ruptured and secretory substances are released into the cytoplasm.

# MITOCHONDRION

- Mitochondrion (plural = mitochondria) is a membrane bound cytoplasmic organelle concerned with production of energy.
- It is a rod-shaped or oval-shaped structure
- Covered by a bilayered membrane
- It contains various enzymes in production of ATP

# Mitochondria

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# Mitochondria

- Produces energy through chemical reactions – breaking down fats & carbohydrates
- Controls level of water and other materials in cell
- Recycles and decomposes proteins, fats, and carbohydrates



- Functions of Mitochondrion
- 1. Production of energy
- Mitochondrion is called the 'power house' or 'power plant' of the cell because it produces the energy required for cellular functions.
- The energy is produced during the oxidation of digested food particles like proteins, carbohydrates and lipids by the oxidative enzymes in cristae.
- During the oxidative process, water and carbon dioxide are produced with release of energy.
- The released energy is stored in mitochondria and used later for synthesis of ATP.

# RIBOSOMES

- They are the organelles without limiting membrane.
- They are granular and small dot-like structures
- Are made up of 35% of proteins and 65% of ribonucleic acid (RNA).
- RNA present in ribosomes is called ribosomal RNA (rRNA).
- Ribosomes are concerned with protein synthesis in the cell.

- 2. Synthesis of ATP
- The components of respiratory chain in mitochondrion are responsible for the synthesis of ATP by utilizing the energy by oxidative phosphorylation.
- ATP molecules diffuse throughout the cell from mitochondrion.
- Whenever energy is needed for cellular activity, the ATP molecules are broken down

# CYTOSKELETON

- Cytoskeleton is the cellular organelle present throughout the cytoplasm.
- It determines the shape of the cell and gives support to the cell.
- It is a complex network of structures with varying sizes.
- Also essential for the cellular movements and the response of the cell to external stimuli.
- Cytoskeleton consists of three major protein
- components:
  - 1. Microtubule
  - 2. Intermediate filaments
  - 3. Microfilaments



# 1. Microtubules

- Microtubules are the straight, hollow and tubular structures of the cytoskeleton.
- No membrane
- Are arranged in different bundles.
- Each tubule has a diameter of 20 to 30 nm.
- Length of microtubule varies and it may be 1000 times more than the thickness.
- They are formed by bundles of globular protein called tubulin
- Tubulin has two subunits, namely  $\alpha$ subunit and  $\beta$ subunit.

# Functions of microtubules

- Microtubules may function alone or join with other proteins to form more complex structures like cilia, flagella or centrioles and perform various functions.
- Microtubules:
  - i. Determine the shape of the cell
  - ii. Give structural strength to the cell
  - iii. Act like conveyer belts which allow the movement of granules, vesicles, protein molecules and some organelles like mitochondria to different parts of the cell
  - iv. Form the spindle fibers which separate the chromosomes during mitosis
  - v. Are responsible for the movement of centrioles and the complex cellular structures like cilia.

## 2. Intermediate Filaments

- Intermediate filaments are the structures that form a network around the nucleus and extend to the periphery of the cell.
- Diameter of each filament is about 10 nm.
- They are formed by ropelike polymers, which are made up of fibrous proteins
- **Functions of intermediate filaments**
- Intermediate filaments help to maintain the shape of the cell.
- These filaments also connect the adjacent cells through desmosomes

### 3. Microfilaments

- Microfilaments are long and fine threadlike structures with a diameter of about 3 to 6 nm.
- These filaments are made up of non-tubular contractile proteins called actin and myosin.
- Actin is more abundant than myosin.
- Microfilaments are present throughout the cytoplasm.

#### **Functions of microfilaments**

- i. Give structural strength to the cell
- ii. Provide resistance to the cell against the pulling forces
- iii. Are responsible for cellular movements like contraction, gliding and cytokinesis (partition of cytoplasm during cell division).

# NUCLEUS

- Nucleus is the most prominent and the largest cellular organelle.
- Occupies about 10% of total volume of the cell.
- It is present in all the cells in the body except RBC's
- The cells with nucleus are called eukaryotes and those without nucleus are known as prokaryotes.
- Presence of nucleus is necessary for cell division.
- Most of the cells have only one nucleus (uninucleated cells).
- Few types of cells like skeletal muscle cells have many nuclei (multinucleated cells).
- Generally, the nucleus is located in the center of the cell.
- It is mostly spherical in shape but the shape and situation of nucleus may vary in some cells.

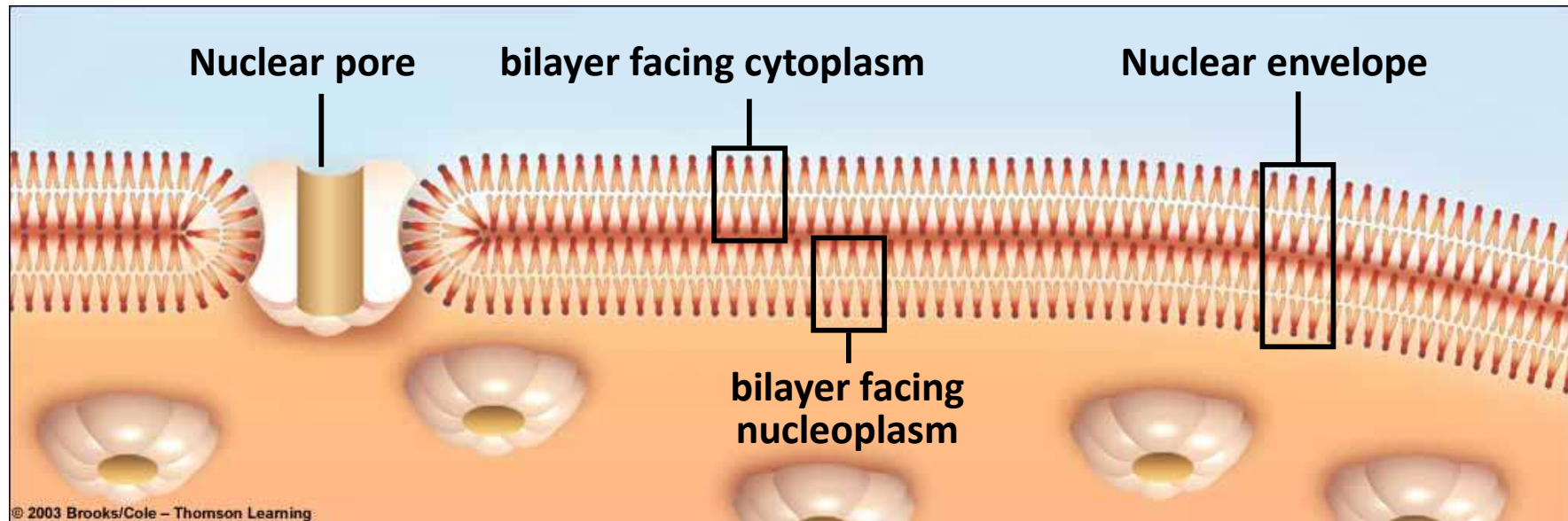
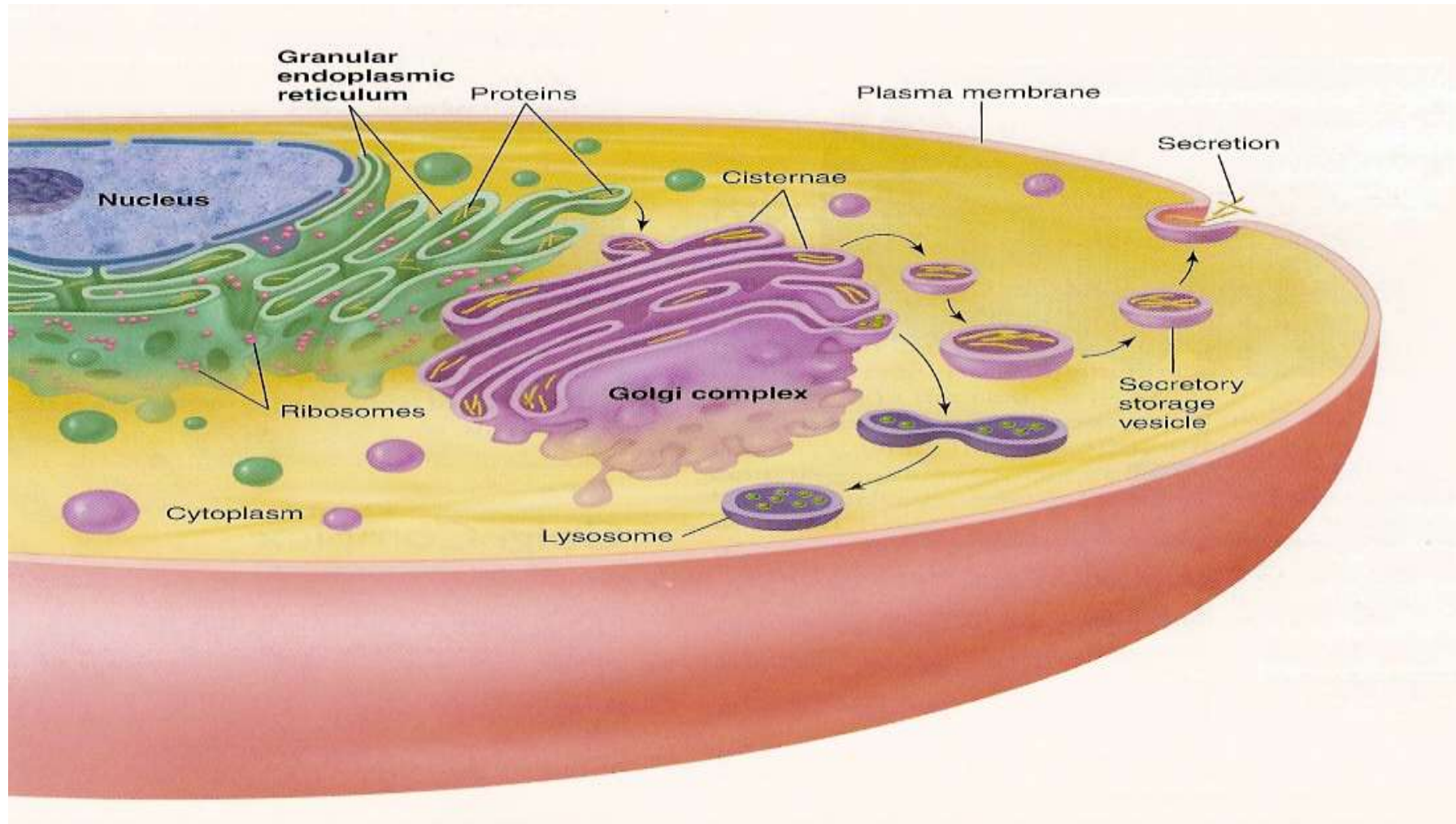


Fig. 4-17, p.61

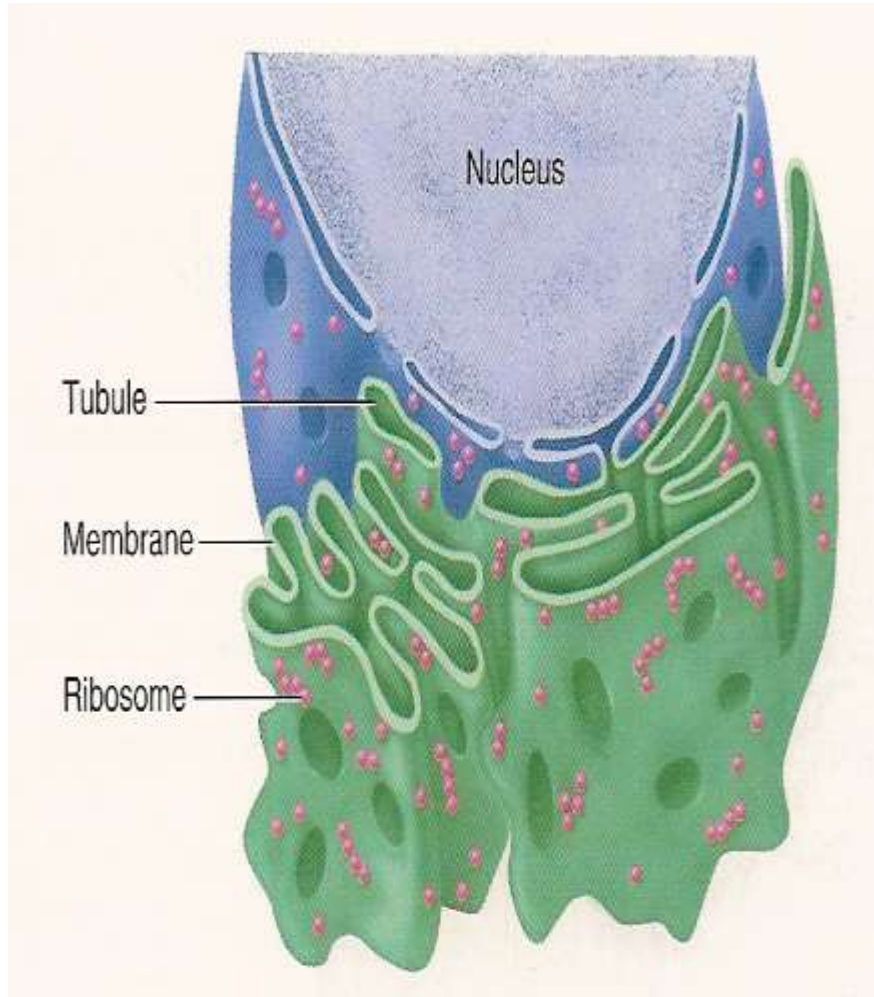
- Pores of the nuclear membrane are guarded (lined) by protein molecules
- Exchange of materials between nucleoplasm and cytoplasm occurs through these pores.
- Nucleoplasm is a highly viscous fluid that forms the ground substance of the nucleus and is similar to cytoplasm
- Nucleoplasm surrounds chromatin and nucleolus.
- It contains dense fibrillar network of proteins called the nuclear matrix and many substances such as nucleotides and enzymes.

- An illustration of the processing of proteins by the granular endoplasmic reticulum & Golgi complex. Notice the formation of vesicles at the ends of some of the flattened sacs of the Golgi complex.



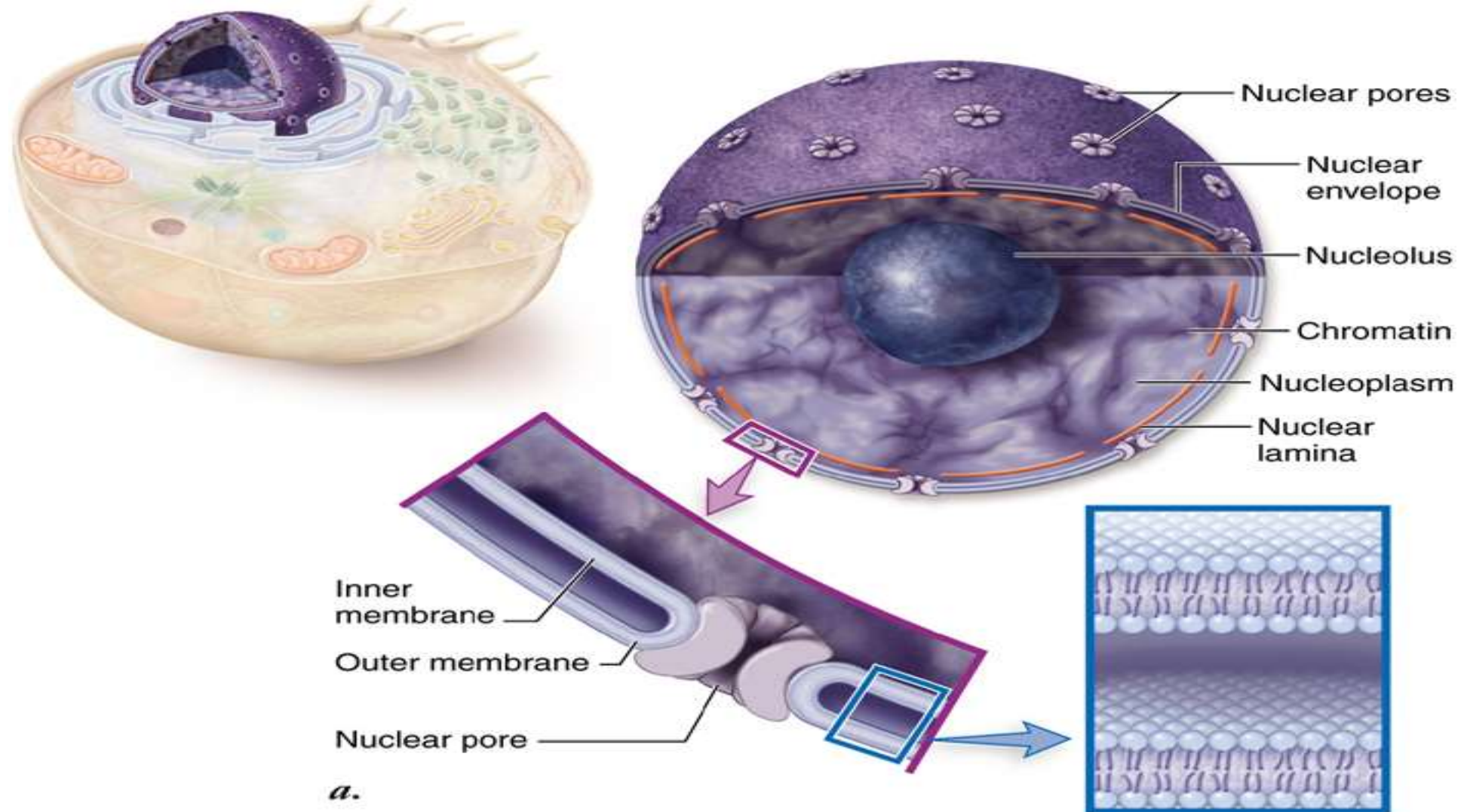


- The endoplasmic reticulum. Agranular ER has ribosomes attached to its surface, whereas granular ER lacks ribosomes.



# Eukaryotic Cells

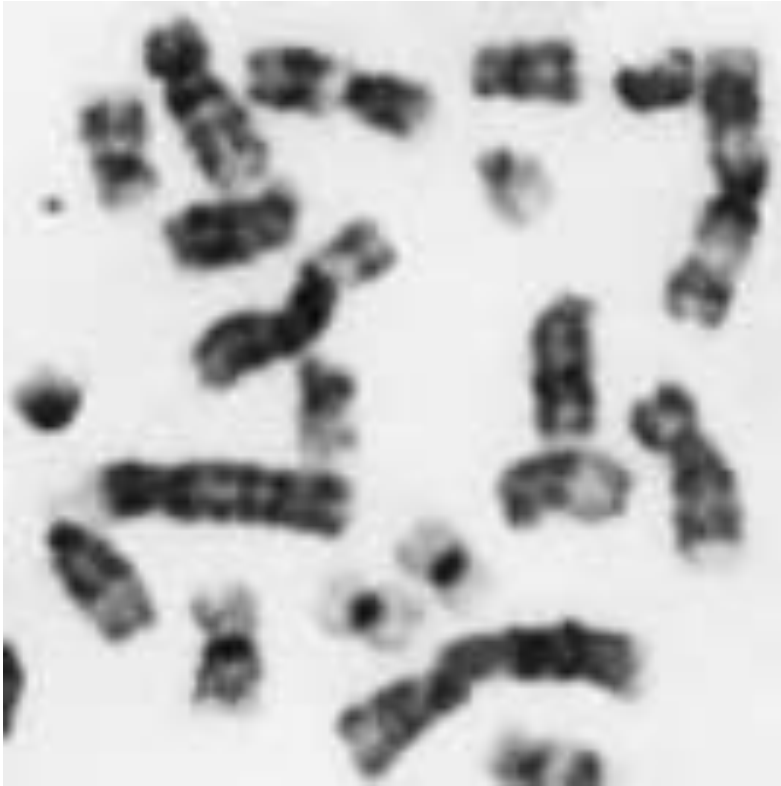
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- Chromatin
- This is a thread-like material made up of large molecules of DNA.
- The DNA molecules are compactly packed with the help of a specialized basic protein called histone.
- So, chromatin is referred to as DNA-histone complex and forms the major bulk of nuclear material.
- DNA is a double helix which wraps around a central core of eight histone molecules to form the fundamental packing unit of chromatin called nucleosome.
- Nucleosomes are packed together tightly with the help of a histone molecule to form a chromatin fiber.
- Just before cell division, the chromatin condenses to form a chromosome.

- Chromosomes
- Chromosome is the rod-shaped nuclear structure that carries a complete blueprint of all the hereditary characteristics of that species.
- A chromosome is formed from a single DNA molecule coiled around histone molecules.
- Each DNA contains many genes.
- Normally, the chromosomes are not visible in the nucleus under microscope but they do become visible during cell division.
- This is because DNA becomes more tightly packed just before cell division, which makes the chromosome visible during cell division.

# Chromosomes



- In nucleus
- Made of DNA
- Contain instructions for traits & characteristics

- All the dividing cells of the body except reproductive cells contain 23 pairs of chromosomes.
- Each pair consists of one chromosome inherited from mother and one from father.
- The cells with 23 pairs of chromosomes are called diploid cells.
- The reproductive cells called gametes or sex cells contain only 23 single chromosomes and are called haploid cells

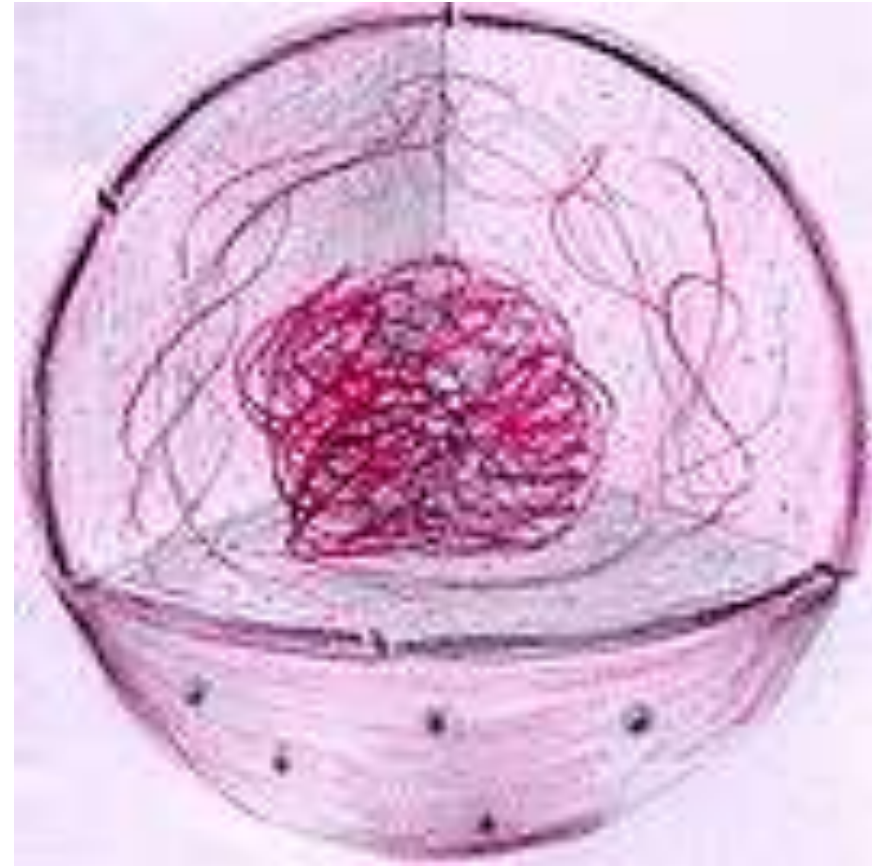
# Nucleolus

- Nucleolus is a small, round granular structure of the nucleus.
- Each nucleus contains one or more nucleoli.
- The nucleolus contains RNA and some proteins, which are similar to those found in ribosomes.
- The RNA is synthesized by five different pairs of chromosomes and stored in the nucleolus.
- Later, it is condensed to form the subunits of ribosomes.
- All the subunits formed in the nucleolus are transported to cytoplasm through the pores of nuclear membrane.
- In the cytoplasm, these subunits fuse to form ribosomes, which play an essential role in the formation of proteins.



# Nucleolus

- Inside nucleus
- Contains RNA to build proteins





# FUNCTIONS OF NUCLEUS

- Major functions of nucleus are the control of cellular activities and storage of hereditary material.
- Several processes are involved in the nuclear functions.

## **Functions of nucleus:**

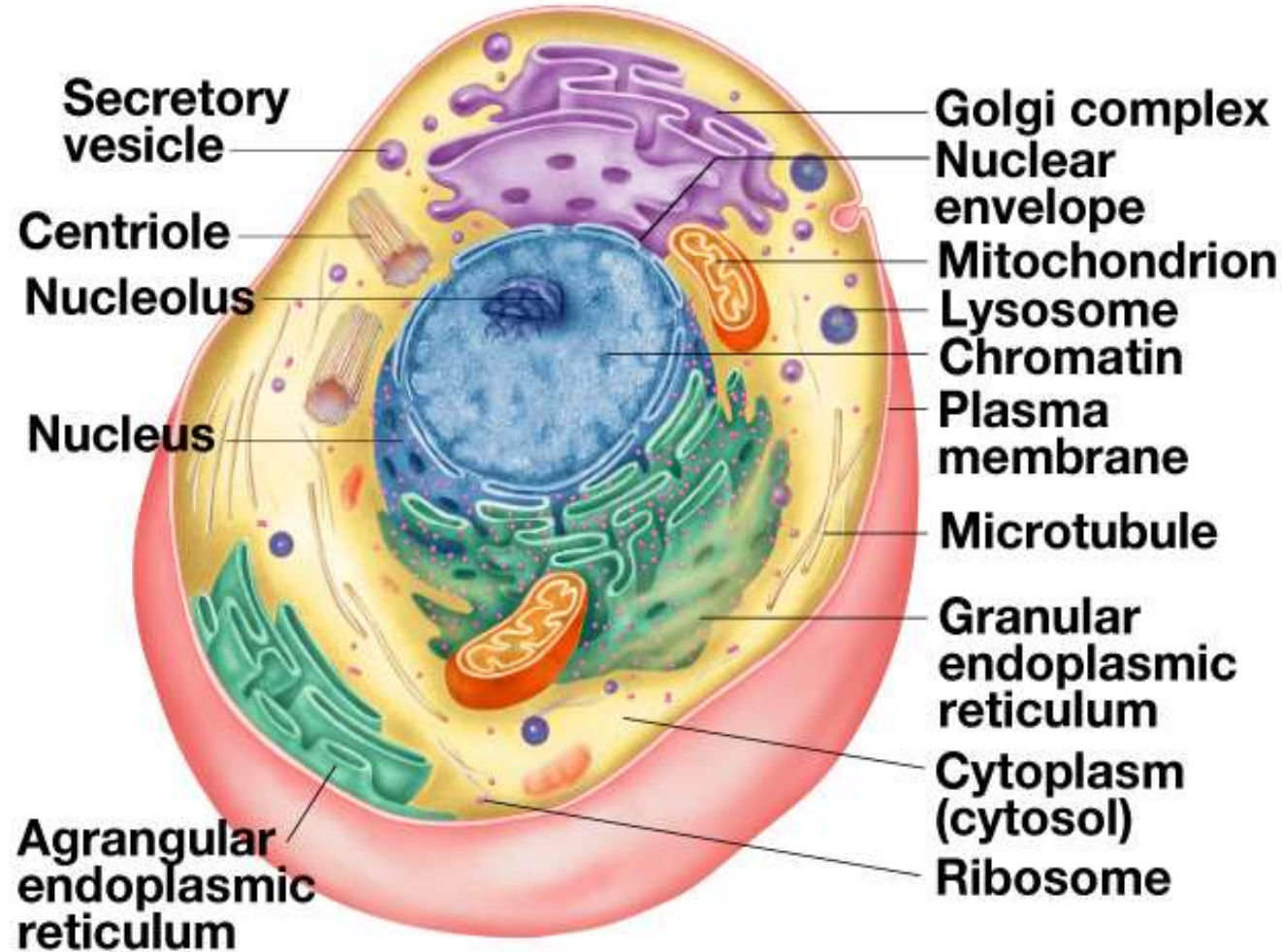
1. Control of all the cell activities that include metabolism, protein synthesis, growth and reproduction (cell division)
2. Synthesis of RNA
3. Formation of subunits of ribosomes
4. Sending genetic instruction to the cytoplasm for protein synthesis through messenger RNA (mRNA)

5. Control of the cell division through genes

6. Storage of hereditary information (in genes) and transformation of this information from one generation of the species to the next.

# Cytoplasm, Organelles, Nucleoli (continued)

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# Endomembrane System

- Putting it all together
  - DNA directs RNA synthesis → RNA exits nucleus through a nuclear pore → ribosome → protein is made → proteins with proper code enter RER → **proteins** are modified in **RER** and **lipids** are made in **SER** → vesicles containing the proteins and lipids bud off from the ER

# Endomembrane System

- Putting it all together
  - ER vesicles merge with Golgi body → proteins and lipids enter Golgi → each is fully modified as it passes through layers of Golgi → modified products are tagged, sorted and bud off in Golgi vesicles → ...

# Water.

- Main component upto 80% of cell
- Many cellular chemicals are dissolved or suspended in the water.
- Others suspended as solid particulates.
- Chemical rxns take place among the dissolved chemicals or at the surfaces of the suspended particles or membranes.

# ions

- Most important ions in cell are potassium, *phosphate*,  $SO_4$  and  $HCO_3$  *with small quantities of Na, Ca and Chloride*
- provide inorganic chemicals for cellular rxns
- Also necessary for operation of some of the cellular control mechanisms such as transmission of impulses in nerves and muscle

# proteins

- Most abundant substance after water in cells
- 10 – 20% of cell mass
- 2 types- structural & functional proteins
- *Structural* present mainly in the form of long filaments that are polymers of many individual protein molecules