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Programme: M.Sc., Biochemistry
Course Title : Cell biology
Course Code :BC105DCE

Unit-I
The cell

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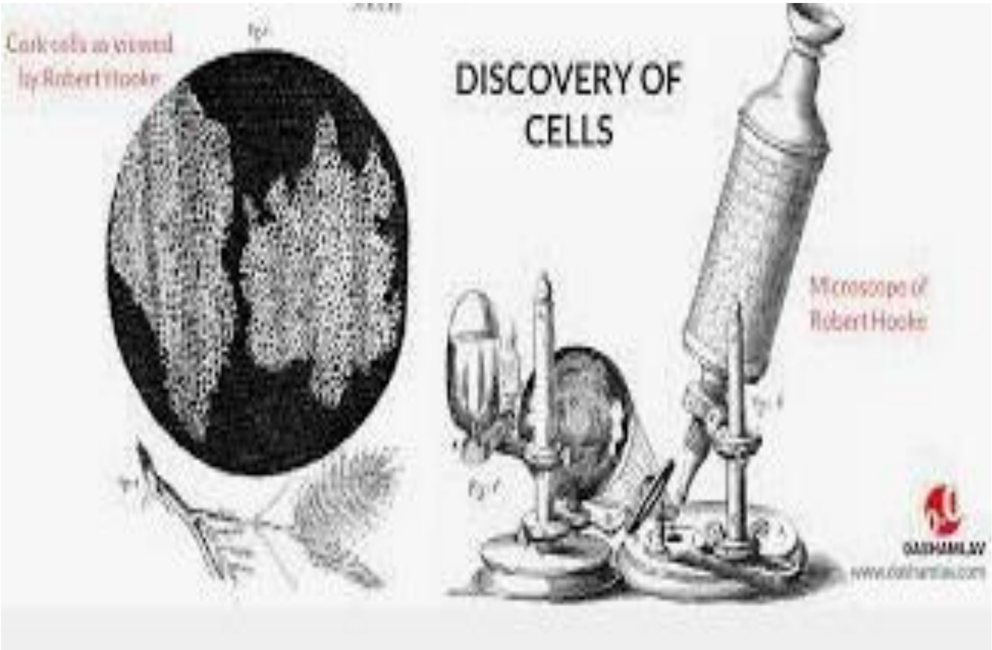
History of the Cell

- In the year of 1665, cells were first discovered by **Robert Hooke**, When he observed the cells in a cork slice with the help of first light microscope

Robert Hooke

Leeuwenhoek

- In 1674, **Leeuwenhoek** discovered the free living cells in pond water for the first time with the help of improved microscope (1 lens)



- In 1590, two Dutch lens makers by the name of **Hans and Zacharias Janssen** invented the first compound microscope when they put two of their lenses together in a tube.

- **Robert Brown** discovered the location of nucleus within the cell in 1831

Matthias Schleiden

Theodore Schwann

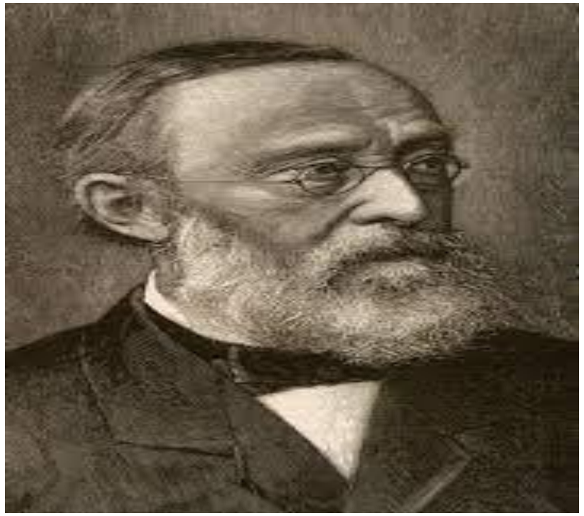
Robert Brown

Cell Theory

- In 1838 and 1839, **Matthias Schleiden** and **Theodore Schwann** viewed plants and animals under a microscope and discovered that plants and animals are both made of cells.
- In 1855, **Rudolph Virchow** collaborated his ideas with the other two scientists and they developed the Cell Theory.
- The Three main principles of cell theory.

1. All living organisms are made up of cells.
2. Cells are the most basic unit of life.
3. Cells only come from the division of pre-existing cells.

In other words, spontaneous generation of cells does not occur.



Rudolph Virchow

Protoplasm: It is defined as the organic and inorganic substances that constitute the living the nucleus, cytoplasm, plastids and mitochondria of the cell

Components and Functions Of A Protoplasm

- The cytoplasm is the initial component of protoplasm, which is found between the cell membrane and the cell nucleus in a eukaryotic cell. In the cell, a cytoplasm plays a vital role in maintaining the cell environment, maintains the shape of cells and also stores substances required by the organelle.
- The nucleus is the second component of the protoplasm, which stores the genetic information of an organism. Ribosomes are also found in the nucleus, which is essential for the production of proteins in the cell. Prokaryotes contain a nucleoid instead of a nucleus where all the genetic information is found.
- Proteins, fats, enzymes, hormones, all make up the protoplasm. These are either dissolved or suspended in the water component of the protoplasm.

- **Organismal theory** was explained by several scientists such as Reichert a morphologist stated that an organism have structured plan; Strasberger a cytologist argues that cells in an organism are connected by cytoplasmic bridges, and Sherrington and Pavlov (neurophysiologists) says cells communicate with each other and co-ordinate with their actions.
- **Several postulates of organismal theory are as following:**
- Some organisms such as fungi are non-cellular and are unable to divide into cellular compartments. plant cells have cytoplasmic bridges between each other called plasmodesmata.
- some of the cells lack some basic components such as red blood cells and nucleus. Cytoplasm in unicellular organisms does not undergo subdivision into cells.
- If any cell is removed from the multicellular organisms, it would require complete life support to be alive.
- Homeostatic control or co-ordination between unicellular or multicellular organism is must to maintain the whole organism.

Broad classification of Cell types:

- Cell: The basic unit of a living organism, consisting of a quantity of protoplasm surrounded by a cell membrane, which is able to synthesize proteins and replicate itself.
- A living thing can be composed of either one cell or many cells.
- There are two broad categories of cells: prokaryotic and eukaryotic cells.
- Cells can be highly specialized with specific functions and characteristics.

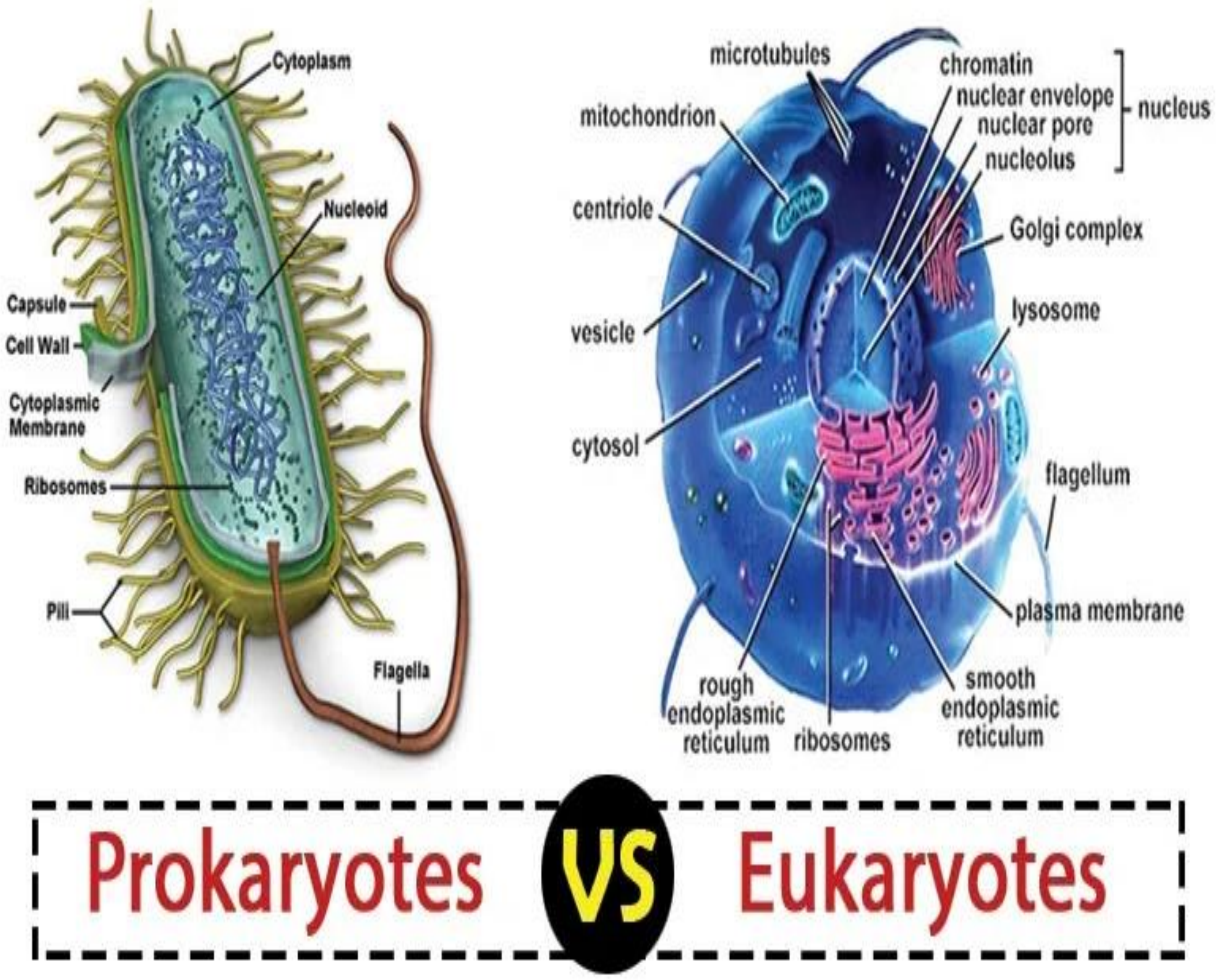


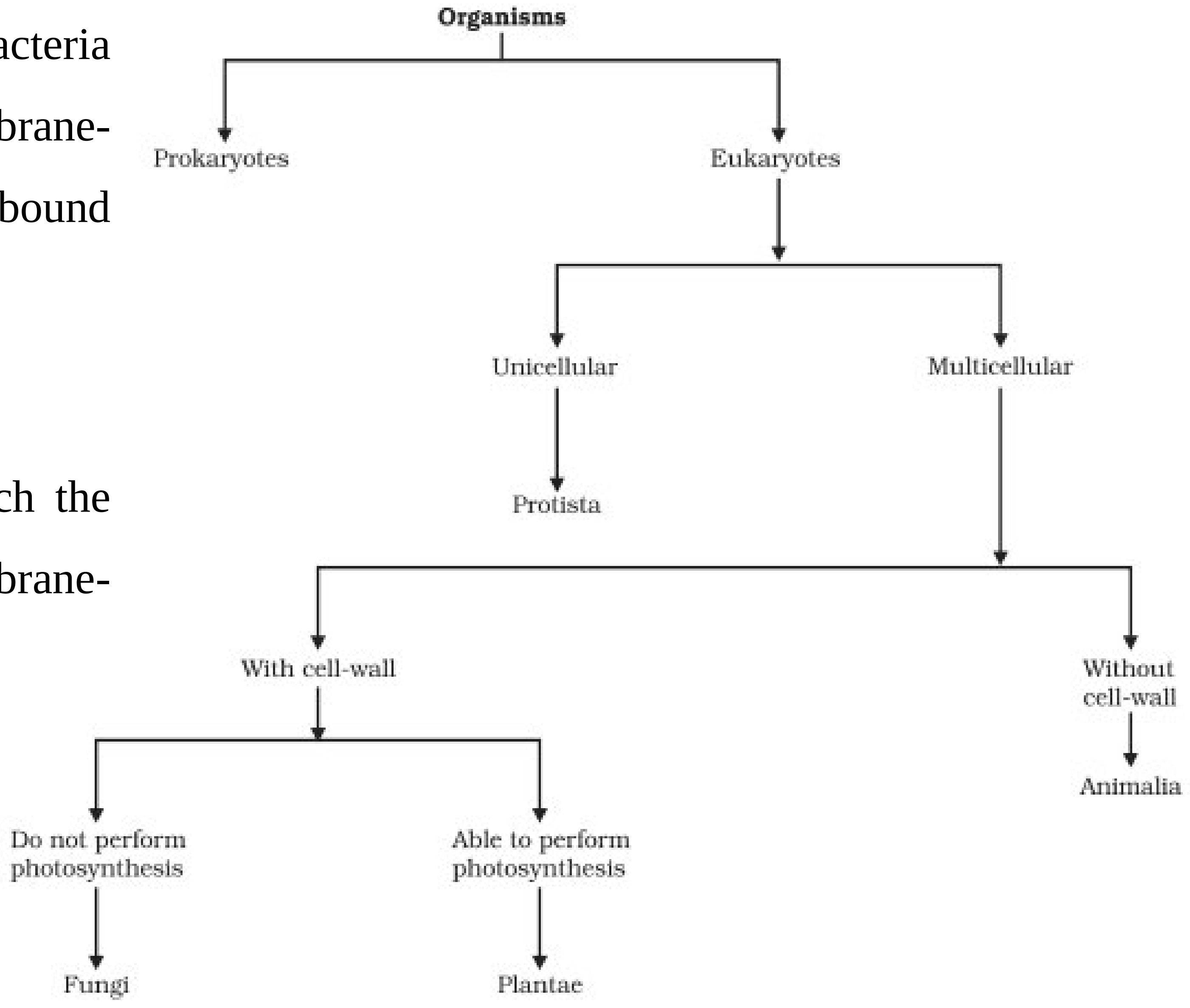
Image: Microbe notes

Comparison of Prokaryotic and Eukaryotic organisms

	Procaryotes	Eucaryotes
Organisms	bacteria and cyanobacteria	protists, fungi, plants, and animals
Cell size	generally 1 to 10 mm in linear dimension	generally 5 to 100 mm in linear dimension
Metabolism	anaerobic or aerobic	aerobic
Organelles	few or none	nucleus, mitochondria, chloroplasts, endoplasmic reticulum, etc.
DNA	circular DNA in cytoplasm	very long linear DNA molecules containing many noncoding regions; bounded by nuclear envelope
RNA and protein	RNA and protein synthesized in same compartment	RNA synthesized and processed in nucleus; proteins synthesized in cytoplasm
Cytoplasm	no cytoskeleton: cytoplasmic streaming, endocytosis, and exocytosis all absent	cytoskeleton composed of protein filaments; cytoplasmic streaming; endocytosis and exocytosis
Cell division	chromosomes pulled apart by attachments to plasma membrane	chromosomes pulled apart by cytoskeletal spindle apparatus
Cellular organization	mainly unicellular	mainly multicellular, with differentiation of many types

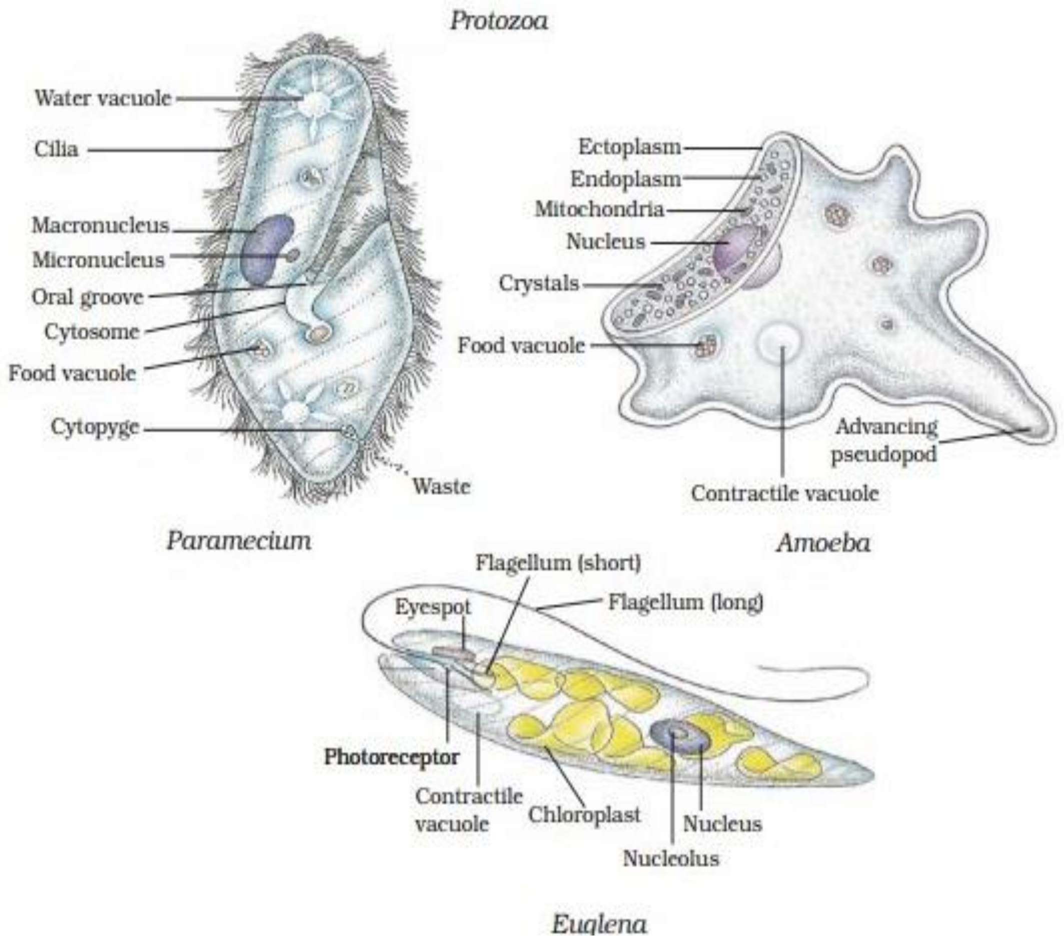
- Prokaryotic: Small cells in the domains Bacteria and Archaea that do not contain a membrane-bound nucleus or other membrane-bound organelles.

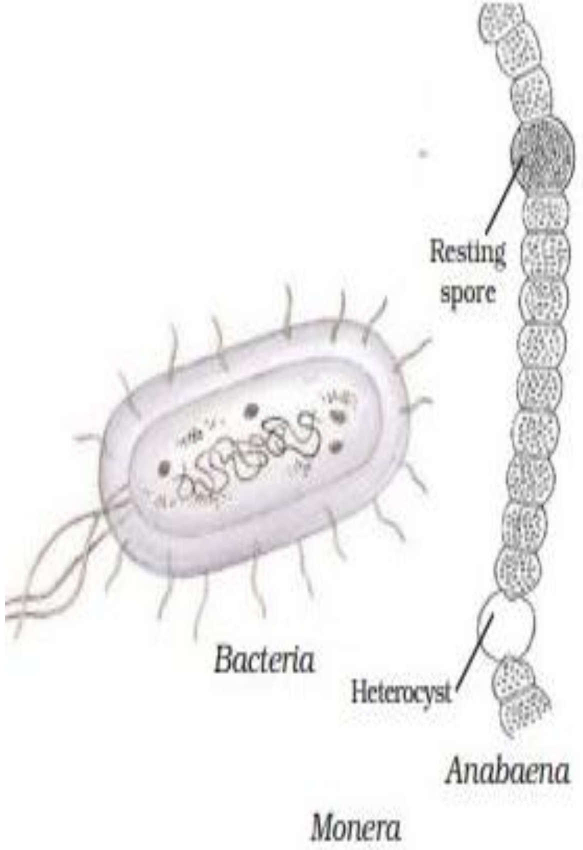
- Eukaryotic: Having complex cells in which the genetic material is contained within membrane-bound nuclei.

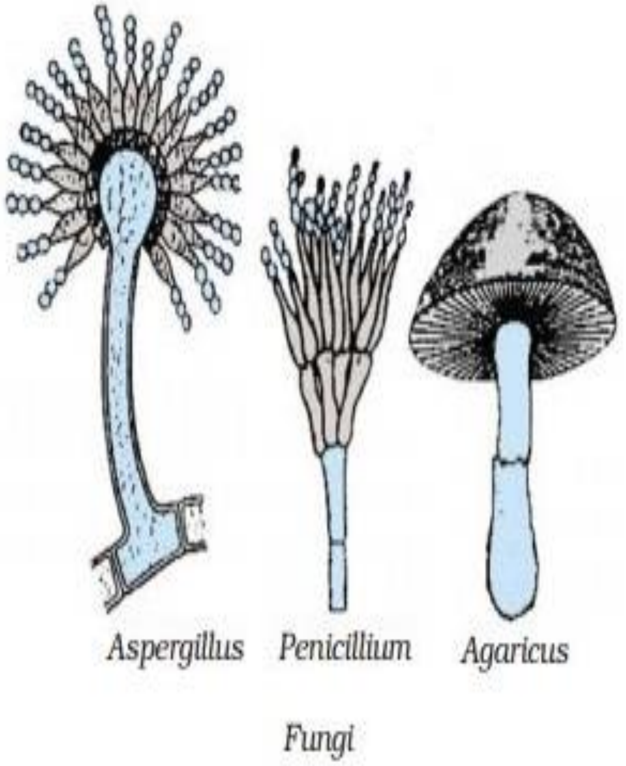


The Five Kingdom classification

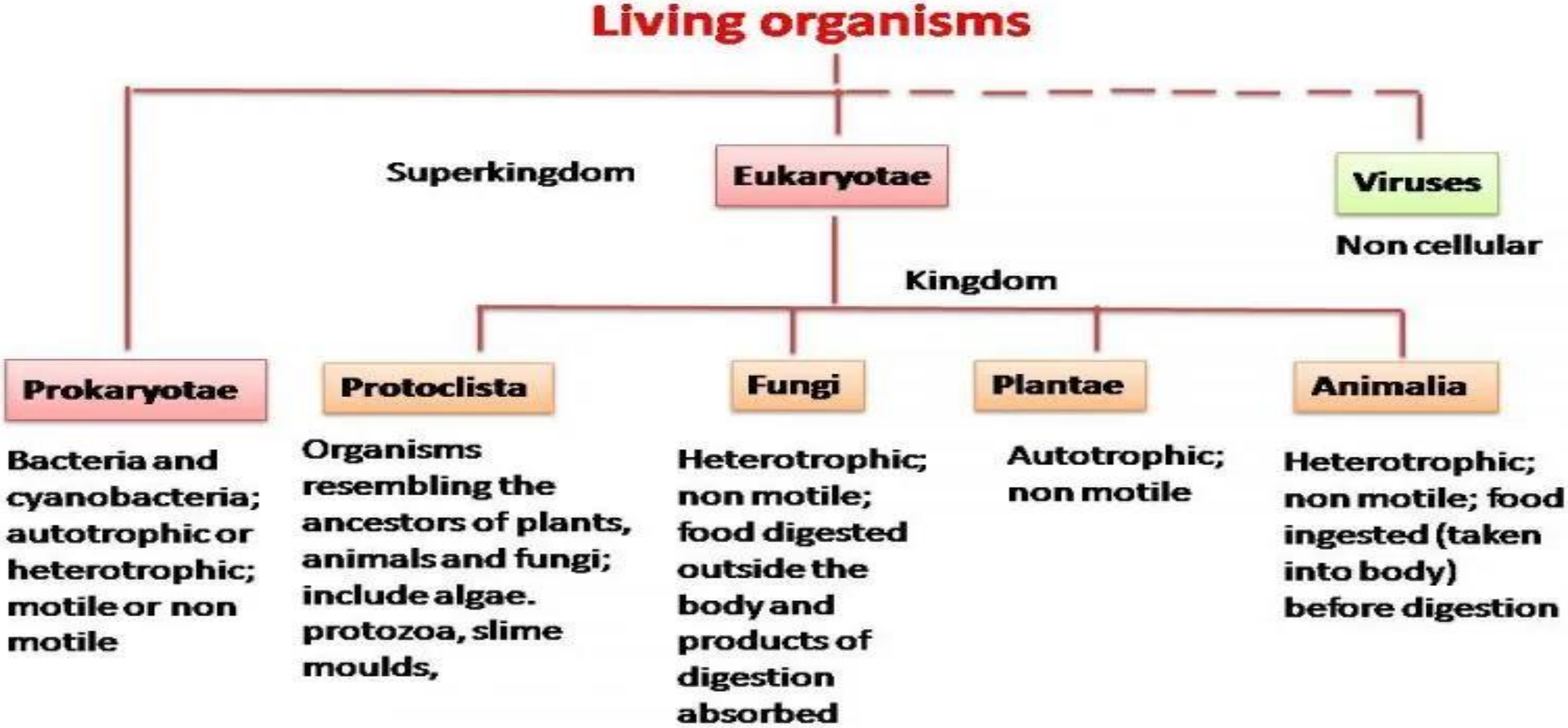
- Eukaryotes is further classified into Unicellular and Multicellular
- Unicellular: Protoctista
- Multicellular: Plantae, Animalia, Fungi







The five kingdom classification of organisms (according to Margulis and Schwartz)



Universal features of cells

A. All Cells Store Their Hereditary Information in the Same Linear Chemical Code (DNA)

B. All Cells Replicate Their Hereditary Information by Templated Polymerization

C. All Cells Transcribe Portions of Their Hereditary Information into the Same Intermediary Form (RNA)

D. All Cells Use Proteins as Catalysts

E. All Cells Translate RNA into Protein in the Same Way

F. The Fragment of Genetic Information Corresponding to One Protein Is One Gene

G. Life Requires Free Energy

H. All Cells Function as Biochemical Factories Dealing with the Same Basic Molecular Building Blocks

I. All Cells Are Enclosed in a Plasma Membrane Across Which Nutrients and Waste Materials Must Pass

J. A Living Cell Can Exist with Fewer Than 500 Genes

The Diversity of Genomes and the Tree of Life

Cells Can Be Powered by a Variety of Free Energy Sources:

- Living organisms obtain their free energy in different ways. Some organisms get it by feeding on other living things or the organic chemicals they produce *organotrophic (trophe*- food*)*

  Eg. bacteria that live in the human gut

- energy directly from the nonliving world. These fall into two classes:

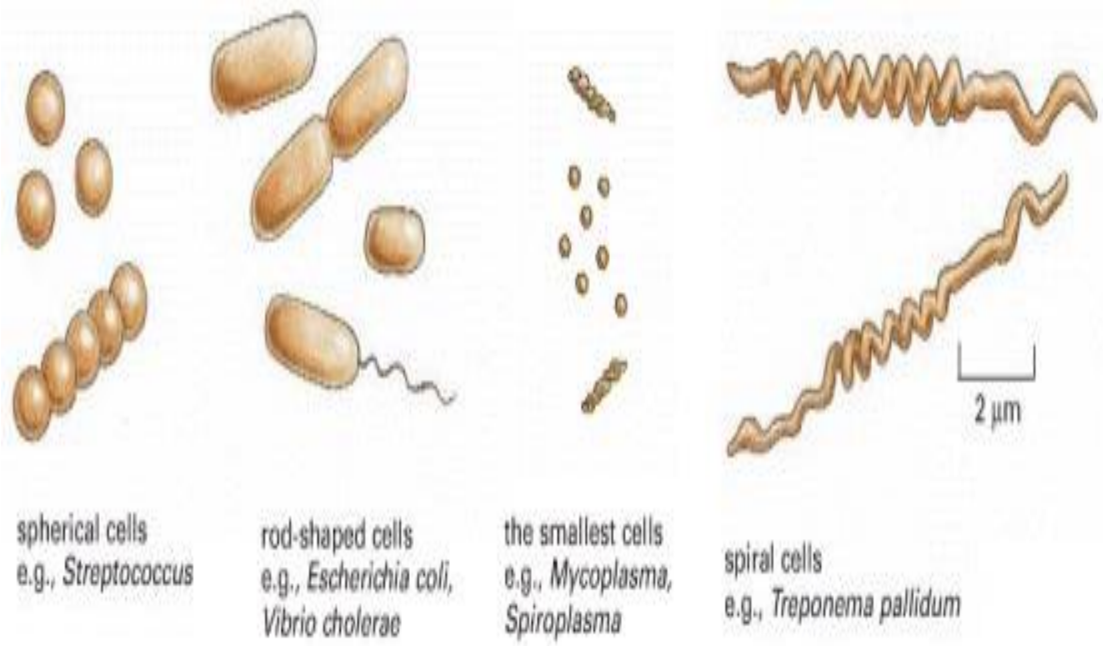
  -*phototrophic* (feeding on sunlight)

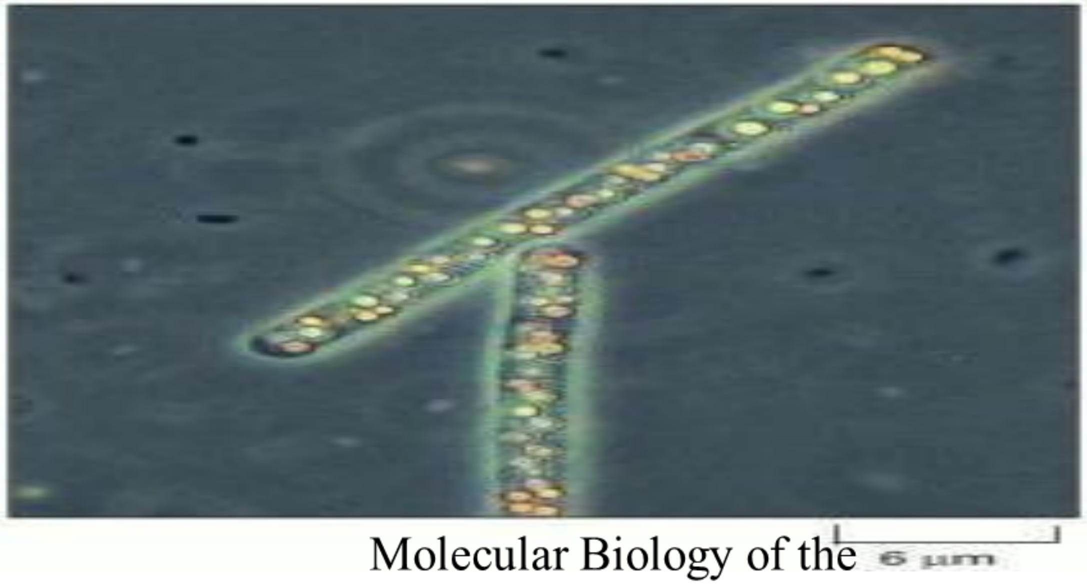
  Eg.Plants and algae

  -*lithotrophic* (feeding on rock)

- Microorganisms found in deep ocean, surface of earth crust, Volcano surface etc., get fueled from geochemical energy directly. They are aerobic and anaerobic in nature

- Some Cells Fix Nitrogen and Carbon Dioxide for Others. Atmospheric N2 and CO2, in particular, are extremely unreactive, and a large amount of free energy is required to drive the reactions that use these inorganic molecules to make the organic compounds needed for further biosynthesis—that is, to fix nitrogen and carbon dioxide, so as to make N and C available to living organisms.
- The Greatest Biochemical Diversity Is Seen Among Procaryotic Cells





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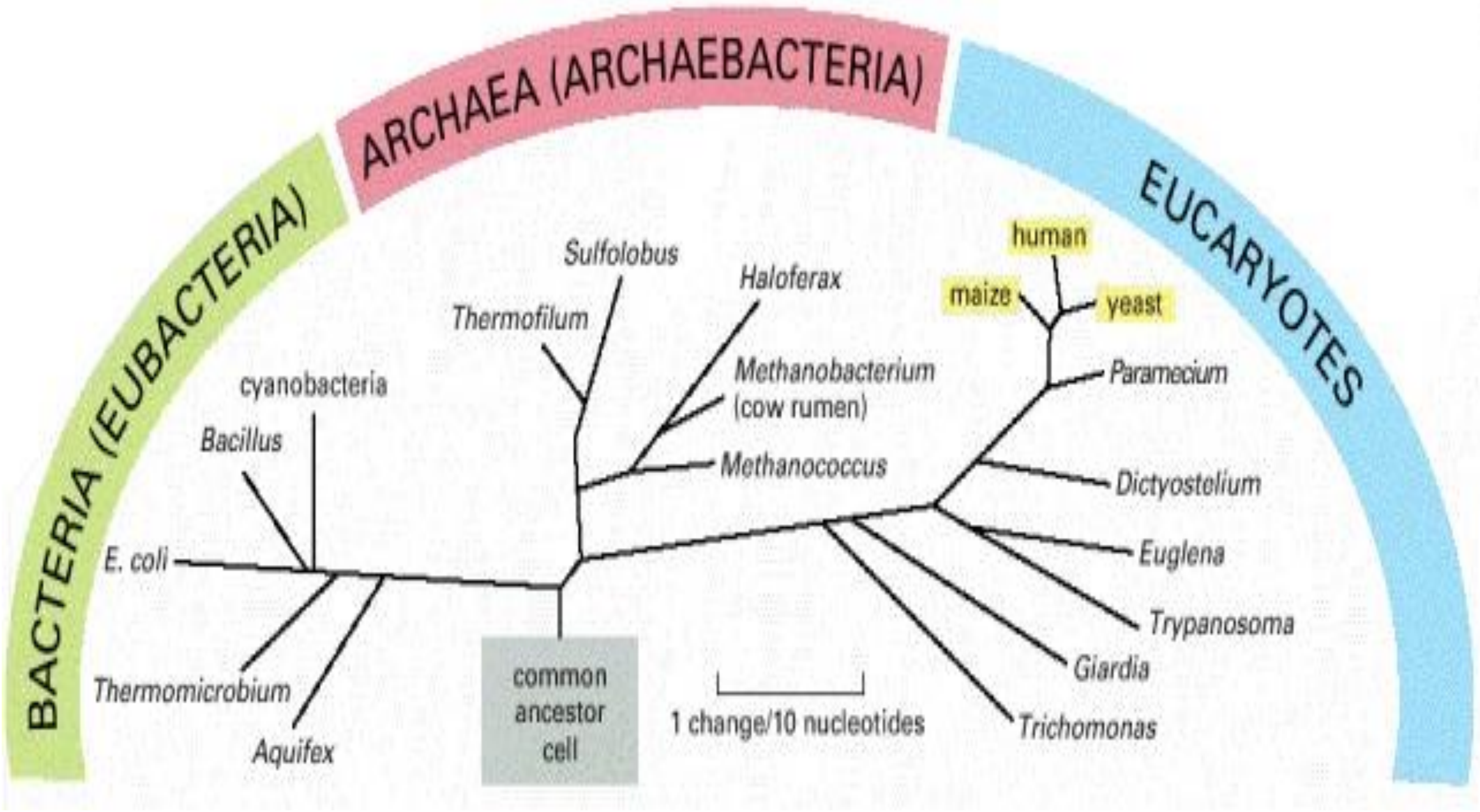
Tree of Life



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Key points in Tree of Life

- Some Genes Evolve Rapidly; Others Are Highly Conserved
- Most Bacteria and Archaea Have 1000–4000 Genes
- New Genes Are Generated from Preexisting Genes
- Gene Duplications Give Rise to Families of Related Genes Within a Single Cell
- Genes Can Be Transferred Between Organisms, Both in the Laboratory and in Nature
- Horizontal Exchanges of Genetic Information Within a Species Are Brought About by Sex
- The Function of a Gene Can Often Be Deduced from Its Sequence
- More Than 200 Gene Families Are Common to All Three Primary Branches of the Tree of Life
- Mutations Reveal the Functions of Genes
- Molecular Biologists Have Focused a Spotlight on *E. coli*

Cell Membranes

Basic Properties of Cell Membrane:

(1)Cell membranes are thin enclosures that form closed boundaries

(2) Cell membranes are made up of lipids, proteins and carbohydrates

(3) Cell membranes consists of a phospholipid bilayer

(4) Cell membranes are held together by non-covalent interactions

(5) Membranes are fluid-like structure

(6) Proteins diversify the functionality of cell membranes

(7) Membranes have polarity

(8) Membranes are asymmetrical structures

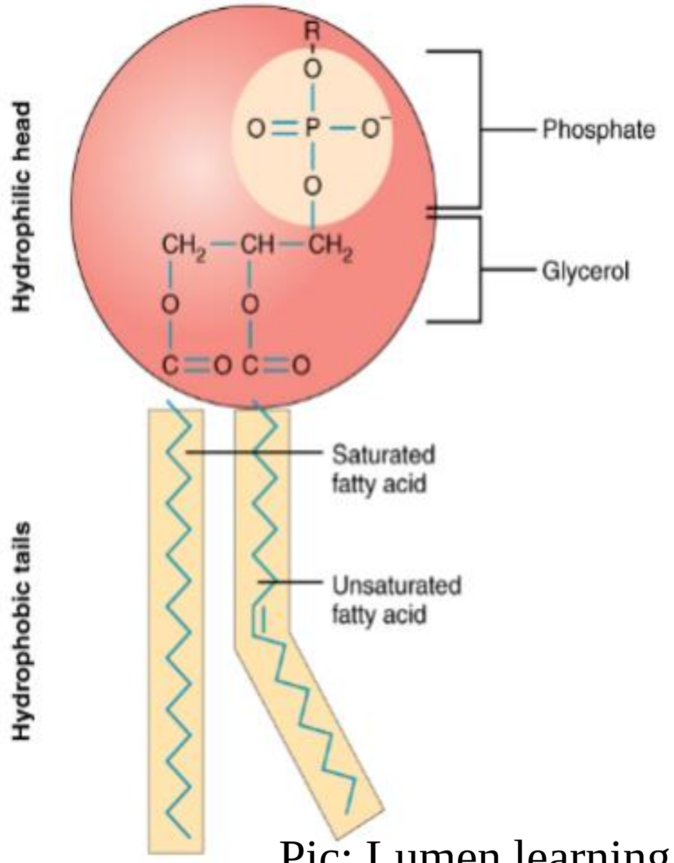
The lipid Bilayer

Composition and Structural Organization:

- Cell membrane is extremely flexible composed of back to back phospholipids
- Cholesterol is present which makes fluidity to the membrane
- A single phospholipid molecule has a phosphate group on one end, called the “head,” and two side-by-side chains of fatty acids that make up the lipid tails
- Phosphate group is negatively charged which makes it polar and hydrophilic head

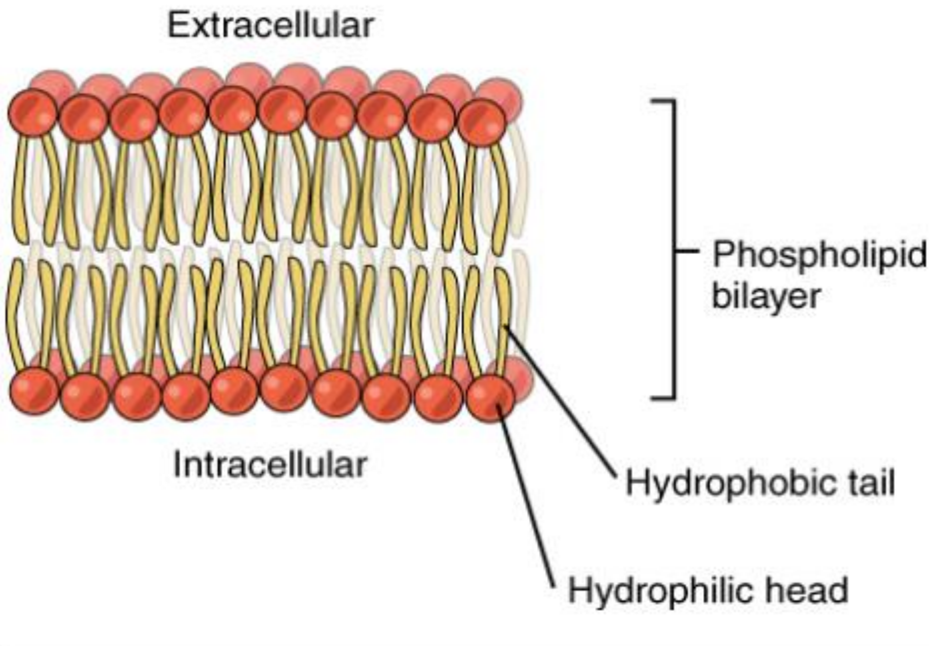
Hydrophobic:

- Molecules that repels water. Some lipids tails consists of Saturated and Un saturated fatty acids. This combinations adds fluidity to the tails and it will be in motion



Pic: Lumen learning

- An **amphipathic** molecule is one that contains both a hydrophilic and a hydrophobic region
- A **hydrophilic** molecule (or region of a molecule) is one that is attracted to water
- The cell membrane consists of two bilayer of phospholipids
- Lipid tail faces the other lipid tail and head of phospholipid face the interior and exterior surface of the cell
- Phosphate group of head attracts to intercellular fluid and Extracellular fluid
- **Interstitial fluid (IF)** is the term given to extracellular fluid not contained within blood vessels
- Because the lipid tails are hydrophobic, they meet in the inner region of the membrane, excluding watery intracellular and extracellular fluid from this space
- The cell membrane has many proteins, as well as other lipids (such as cholesterol), that are associated with the phospholipid bilayer
- An important feature of the membrane is that it remains fluid; the lipids and proteins in the cell membrane are not rigidly locked in place



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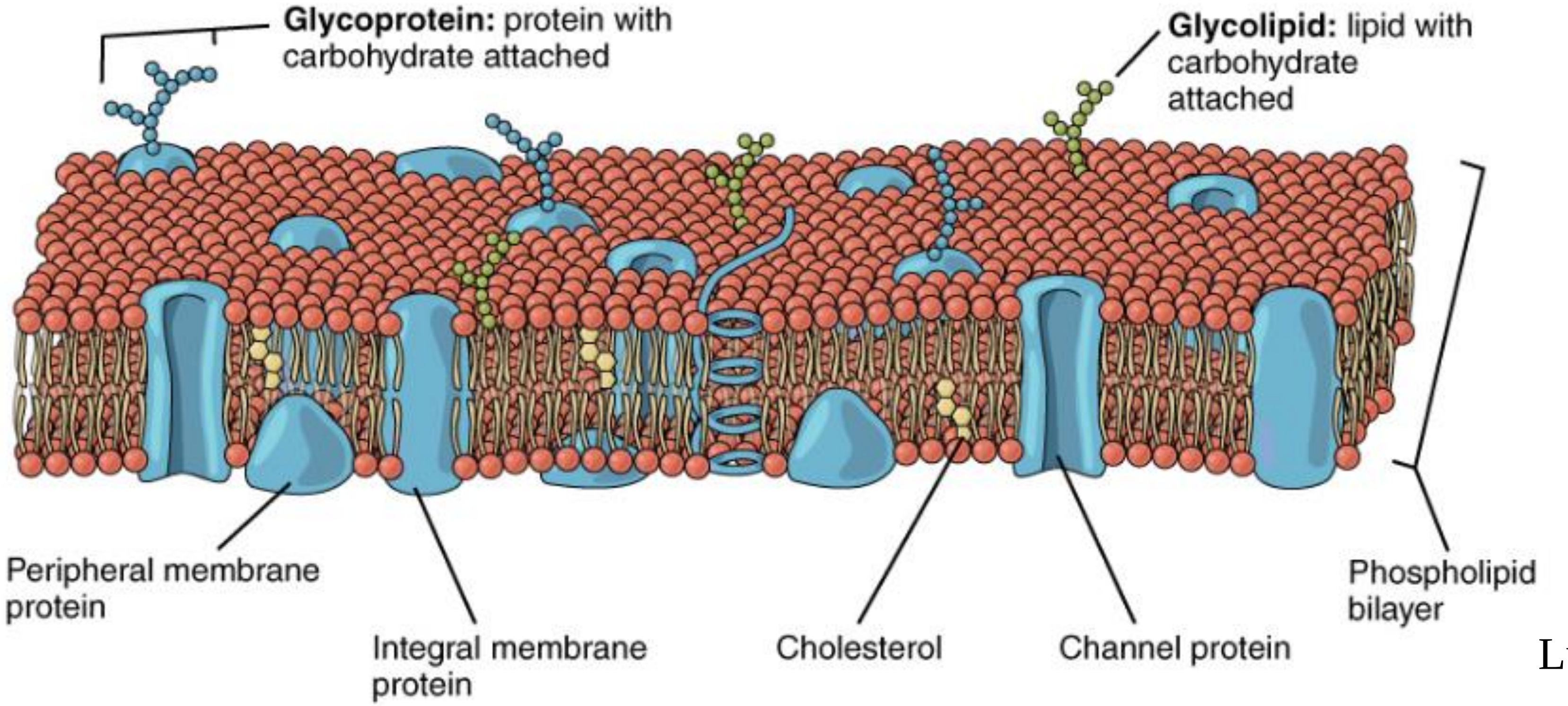
Membrane Proteins

- Lipid bilayer forms the cell membrane , but it is also contains various protein
- There are two types of Protein commonly associated with cell membrane (1) Integrin Proteins

(2) Peripheral Proteins

- Integral proteins are embedded in the cell membrane. Eg. Channel Protein which allows selective

particles such as some ions



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- Other important integral protein is recognition protein, it marks an cell's identity, so that other cell recognize and binds
- A **receptor** is a type of recognition protein that can selectively bind a specific molecule outside the cell, and this binding induces a chemical reaction within the cell
- Ligand is a specific molecule which binds to receptor
- Example for Receptor – Ligand Interaction

When a dopamine molecule binds to a dopamine receptor protein, a channel within the transmembrane protein opens to allow certain ions to flow into the cell

- Some integral membrane proteins are glycoproteins
- **Glycoprotein** is a protein that has carbohydrate molecules attached, which extend into the extracellular matrix
- Carbohydrate attached in cells are aid in cell recognition
- Carbohydrate which extends from cell membrane and lipids from some membrane will collectively for **Glycocalyx**

- The **glycocalyx** is a fuzzy-appearing coating around the cell formed from glycoproteins and other carbohydrates attached to the cell membrane
- It has various roles . Example :it may have molecules that allow the cell to bind to another cell, it may contain receptors for hormones, or it might have enzymes to break down nutrients
- These are the products of person's genetic makeup
- This is the primary way that a person' immune cells refuse to attach its own cell
- It is also the reason for organ from other persons gets rejected

Peripheral proteins are typically found on the inner or outer surface of the lipid bilayer but can also be attached to the internal or external surface of an integral protein

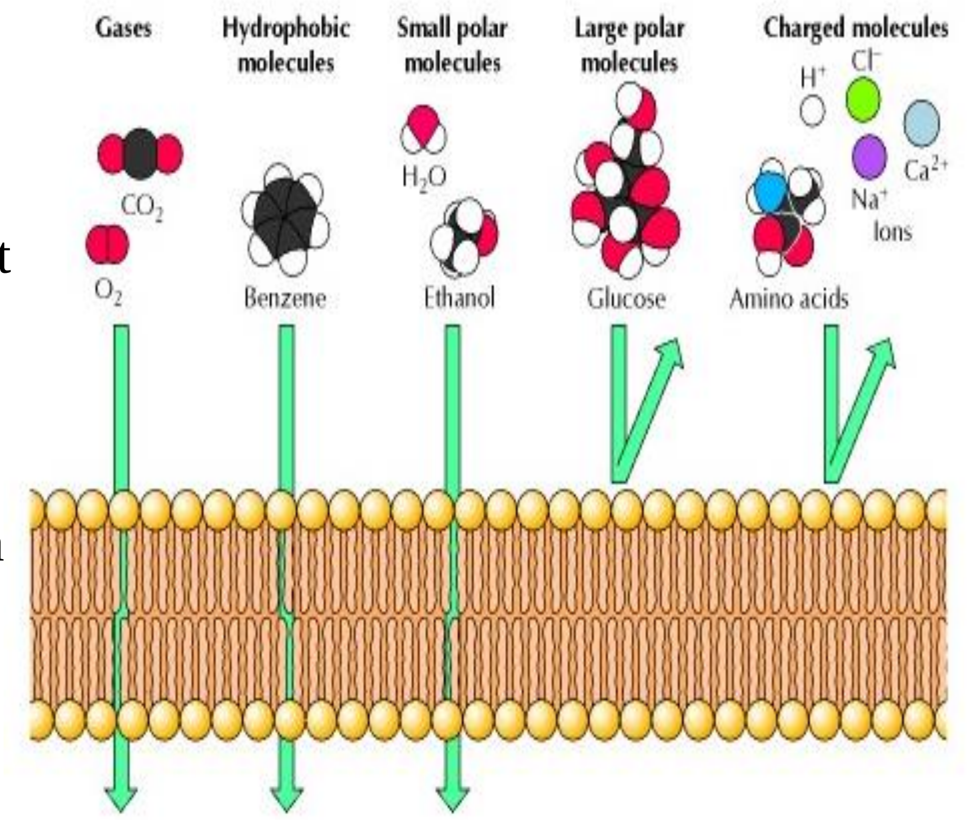
- Some peripheral proteins on the surface of intestinal cells, for example, act as digestive enzymes to break down nutrients to sizes that can pass through the cells and into the bloodstream.

Membrane transport of small molecules

- The internal composition of the cell is maintained because the plasma membrane is selectively permeable to small molecules
- Most biological molecules are unable to diffuse through the phospholipid bilayer, so the plasma membrane forms a barrier that blocks the free exchange of molecules between the cytoplasm and the external environment of the cell
- Specific transport proteins (carrier proteins and channel proteins) then mediate the selective passage of small molecules across the membrane, allowing the cell to control the composition of its cytoplasm.

Passive Diffusion:

- It is simplest mechanism in which any molecule can cross the plasma membrane
- Molecule simply dissolves in lipid bilayer and diffuse across it and dissolves in the aqueous solution of the other side of the membrane
- The net flow of molecules is always down their concentration gradient—from a compartment with a high concentration to one with a lower concentration of the molecule



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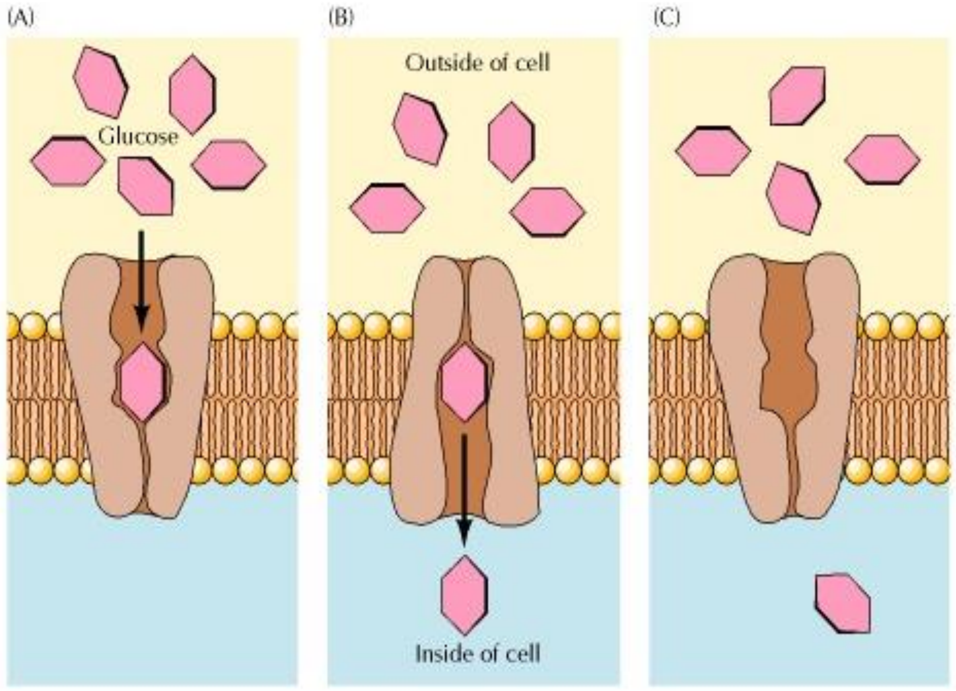
Facilitated Diffusion and Carrier Proteins

- It is like passive diffusion, the movement of the molecules is determined by their concentration inside and outside of the cell
- No external energy required, It differs from passive diffusion in that the transported molecules do not dissolve in the phospholipid bilayer
- Instead, their passage is mediated by proteins that enable the transported molecules to cross the membrane without directly interacting with its hydrophobic interior
- Facilitated diffusion therefore allows polar and charged molecules, such as carbohydrates, amino acids, nucleosides, and ions

- Two types of protein that mediates facilitate diffusion (1)Carrier proteins (2)Channel proteins
- Carrier proteins bind specific molecules to be transported on one side of the membrane
- They then undergo conformational changes that allow the molecule to pass through the membrane and be released on the other side
- In contrast, channel proteins form open pores through the membrane, allowing the free diffusion of any molecule of the appropriate size and charge



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Ion Channels

- Channel proteins simply form open pores in the membrane, allowing small molecules of the appropriate size and charge to pass freely through the lipid bilayer

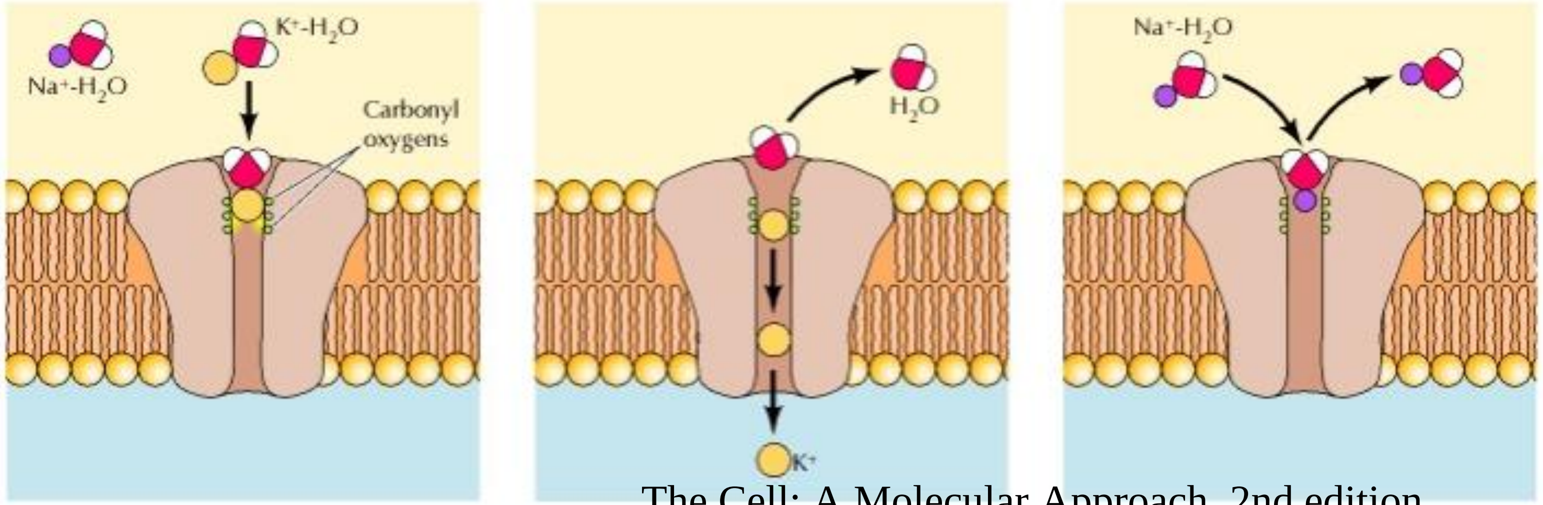
- The plasma membranes of many cells also contain water channel proteins (aquaporins), through which water molecules are able to cross the membrane much more rapidly than they can diffuse through the phospholipid bilayer

- Three properties of ion channels

(1) Transport through channels is extremely rapid

(2) ion channels are highly selective

(3) most ion channels are not permanently open



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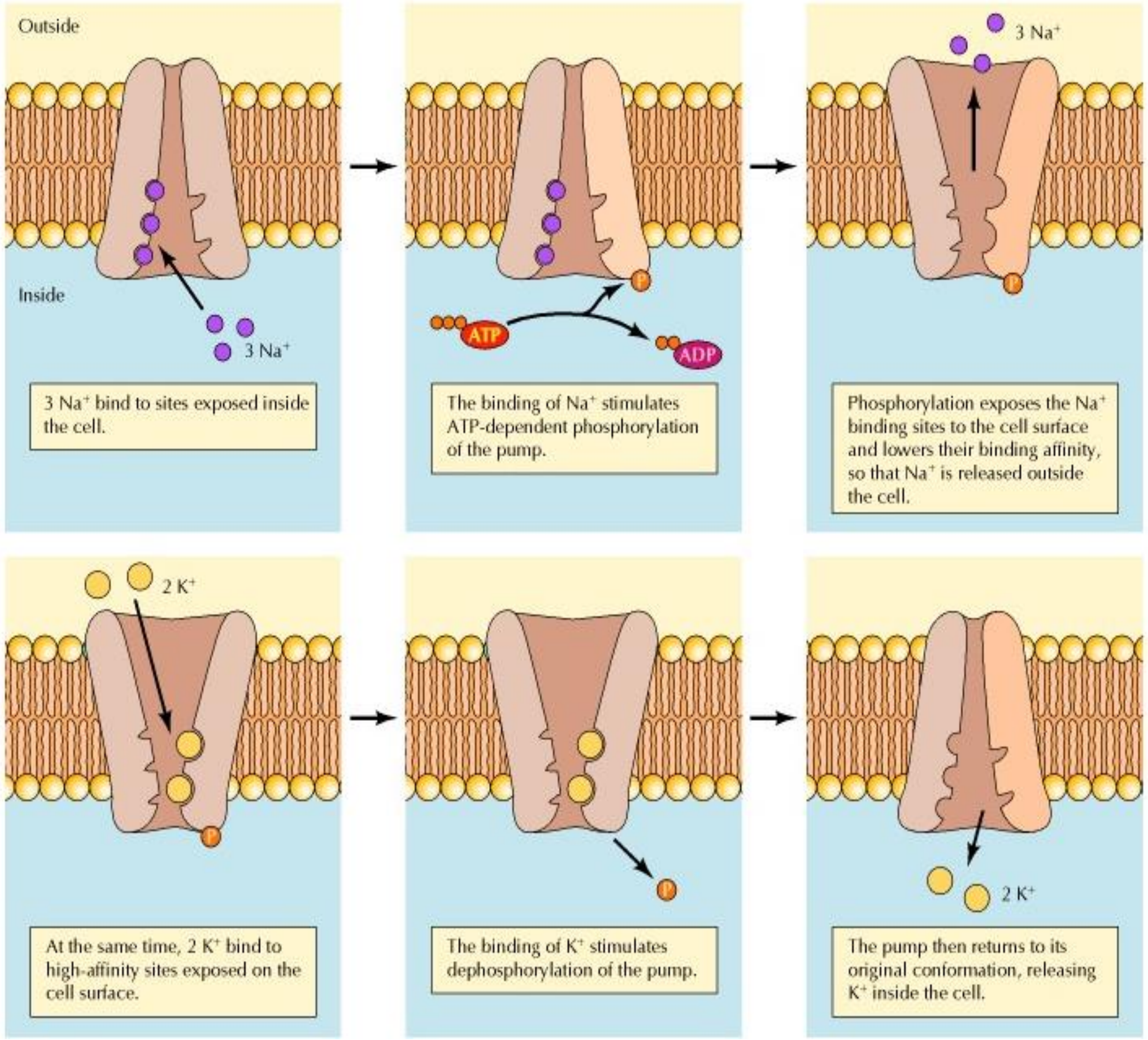
- the opening of ion channels is regulated by “gates” that transiently open in response to specific stimuli
- **ligand-gated channels-** open in response to the binding of neurotransmitters or other signaling molecules
- **voltage-gated channels-** open in response to changes in electric potential across the plasma membrane

Active Transport Driven by ATP Hydrolysis

- The largest family of membrane transporters consists of the ABC transporters, so called because they are characterized by highly conserved ATP-binding domains or *A*TP-*b*inding *c*assettes
- In bacteria, ABC transporters utilize energy derived from ATP hydrolysis to transport a wide range of molecules, including ions, sugars, and amino acids
- In eukaryotic cells, the first ABC transporter was discovered as the product of a gene (called the multi drug resistance, or *mdr*, gene) that makes cancer cells resistant to a variety of drugs used in chemotherapy



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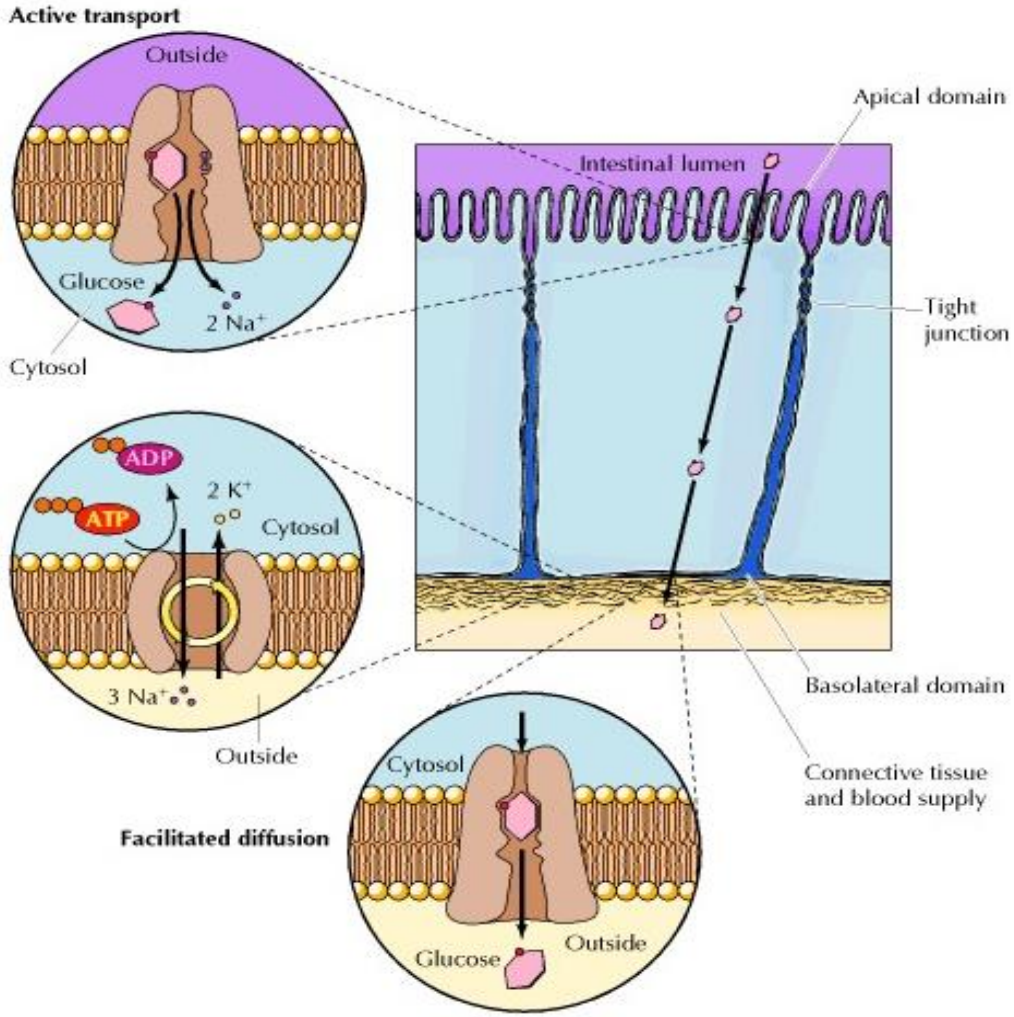
- The ion pumps and ABC transporters utilize energy derived directly from ATP hydrolysis to transport molecules against their electrochemical gradients
- molecules are transported against their concentration gradients using energy derived not from ATP hydrolysis but from the coupled transport of a second molecule in the energetically favorable direction



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Electrical Properties of Membranes

- Channel proteins form hydrophilic pores across the cell membrane
- Some channel proteins form gap junction between two adjacent cells, Each plasma membrane

equally contributes which connects the cytoplasm of each cell

Two properties of ion channel which distinguish it from aqueous protein

(1)Ion Channels Are Ion-Selective and Fluctuate Between Open and Closed States

The permeating ions have to shed most or all of their associated water molecules to pass, often in single file, through the narrowest part of the channel, which is called the *selectivity filter*

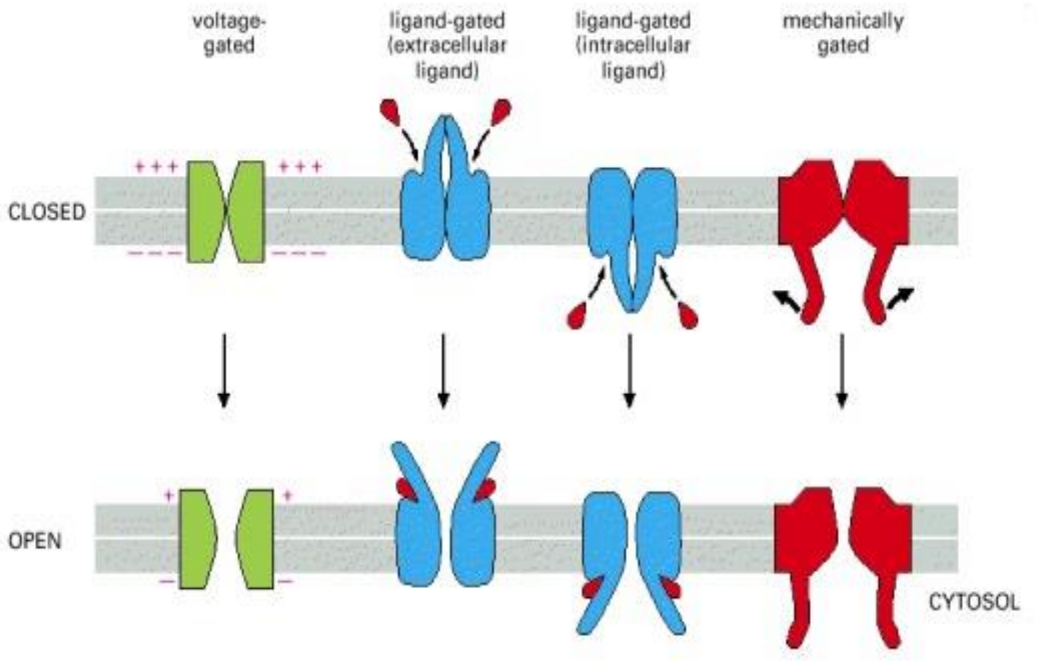
(2) ion channels are not continuously open, they are *gated*, which allows them to open briefly and then close again

- In most cases, the gate opens in response to a specific stimulus

  (1) voltage-gated channels- Open when there is change in voltage

  (2) ligand-gated channels- Opens when ligand binds intracellular or extracellular

  (3) Mechanically gated



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Endocytosis and Exocytosis

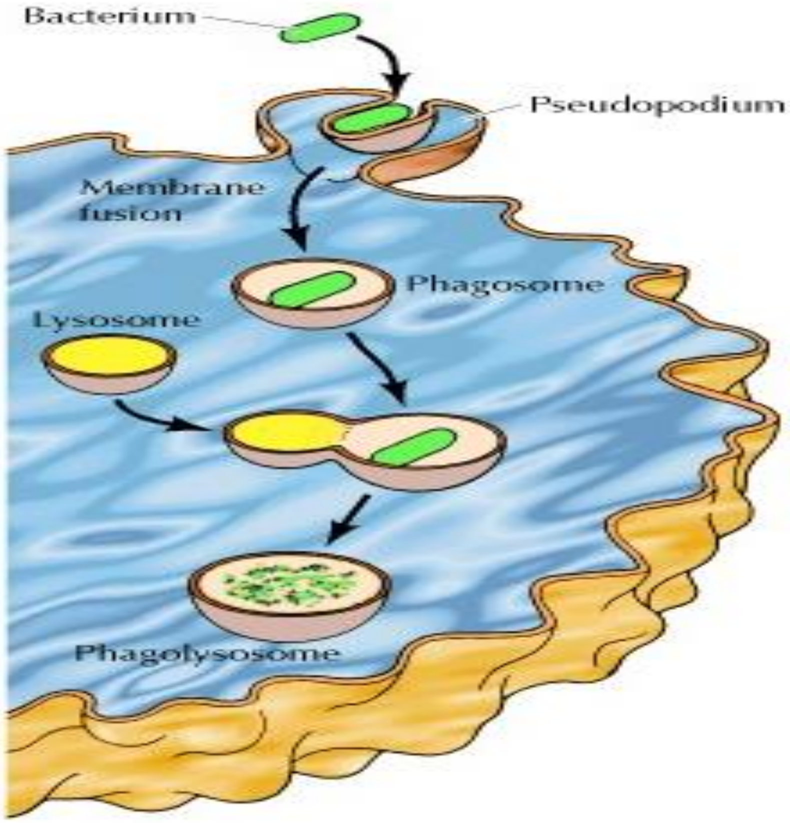
- Eukaryotic cells are also able to take up macromolecules and particles from the surrounding medium by a distinct process called **endocytosis**
- Phagocytosis(cell eating)

(1) The pseudopodia eventually surround the particle and their membranes fuse to form a large intracellular vesicle (>0.25 µm in diameter) called a phagosome

(2) The phagosomes then fuse with lysosomes, producing phagolysosomes in which the ingested material is digested by the action of lysosomal acid hydrolases

- pinocytosis (cell drinking)

The uptake of fluids or molecules into a cell by small vesicles



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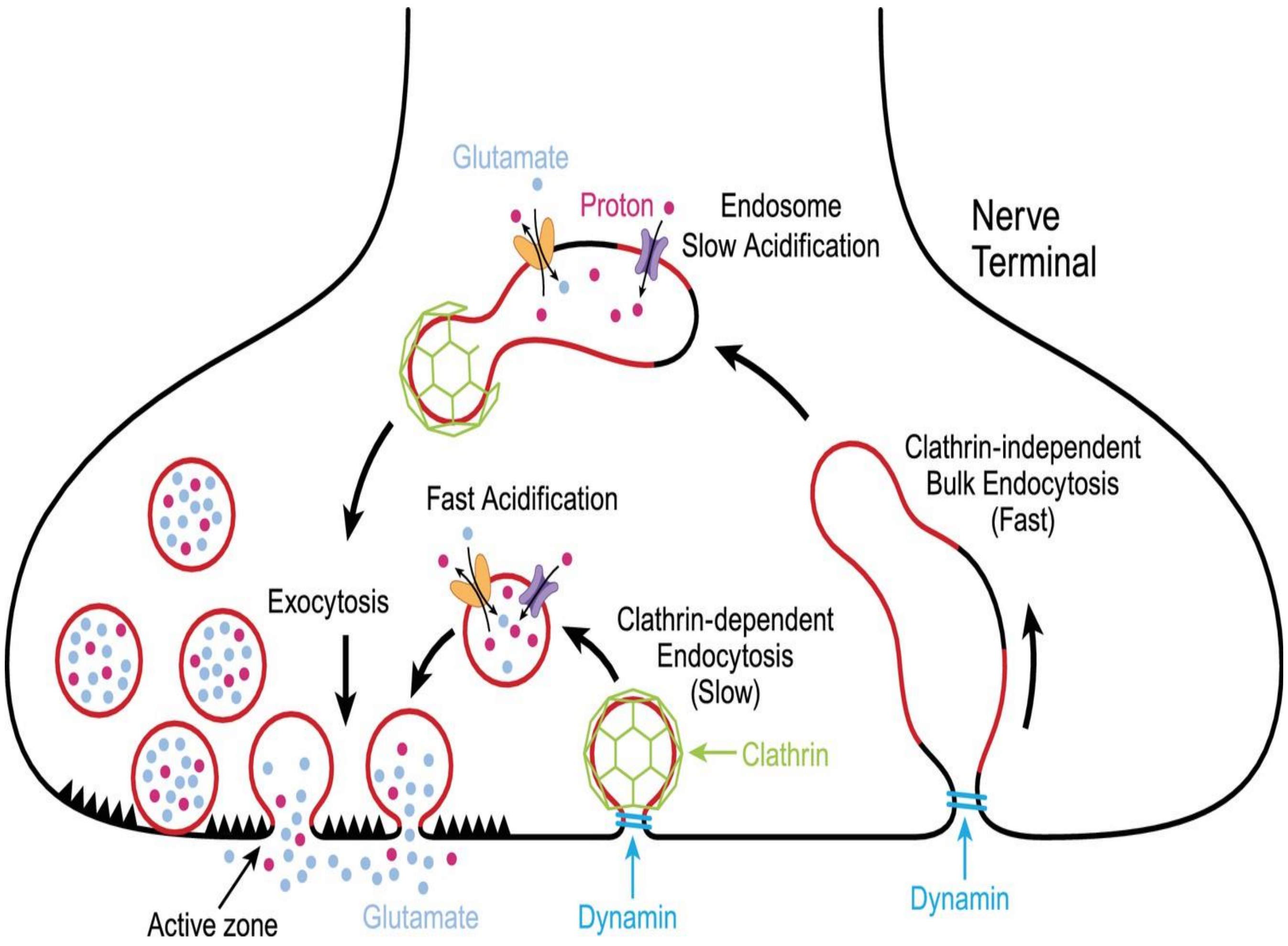
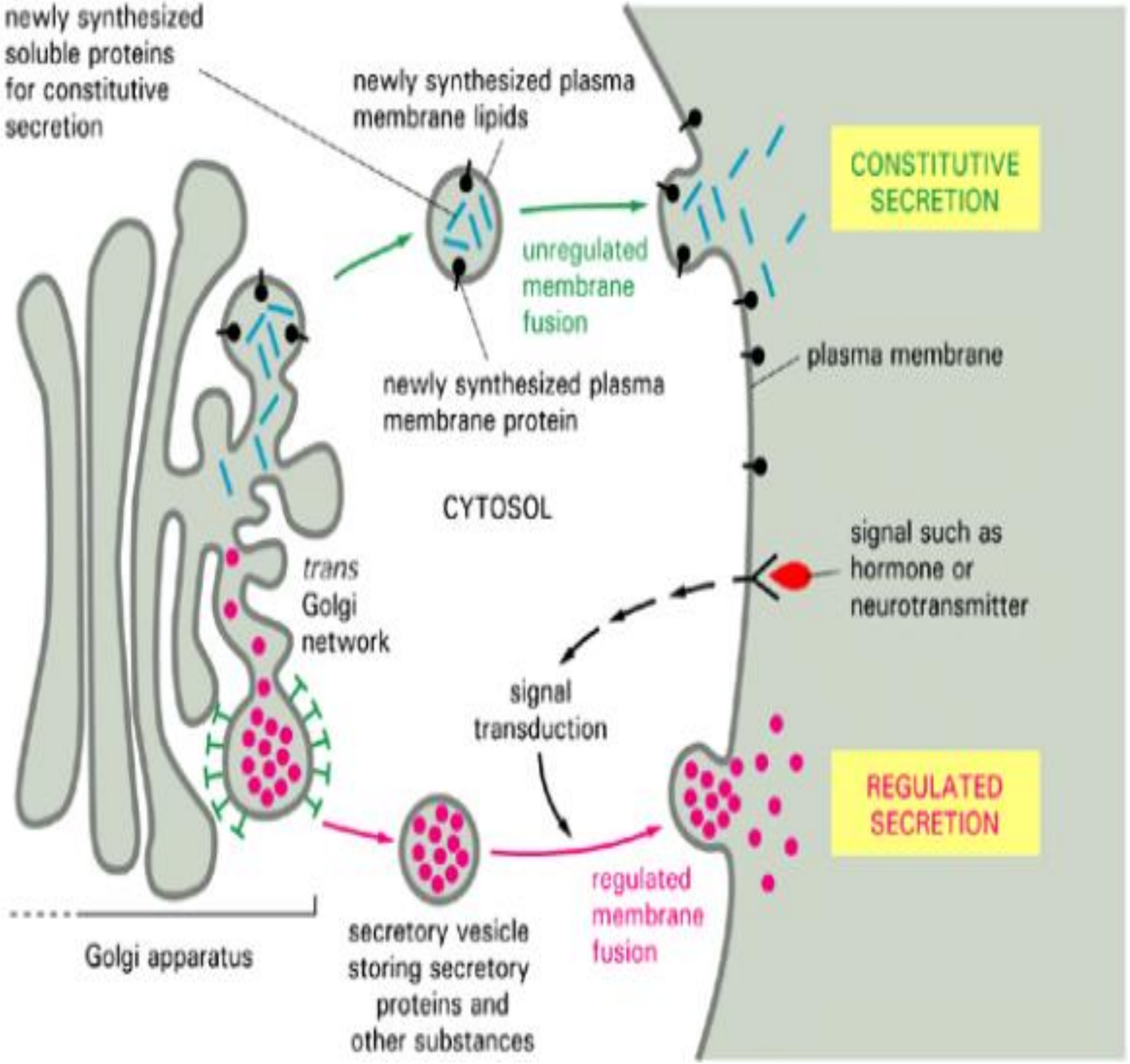
Exocytosis





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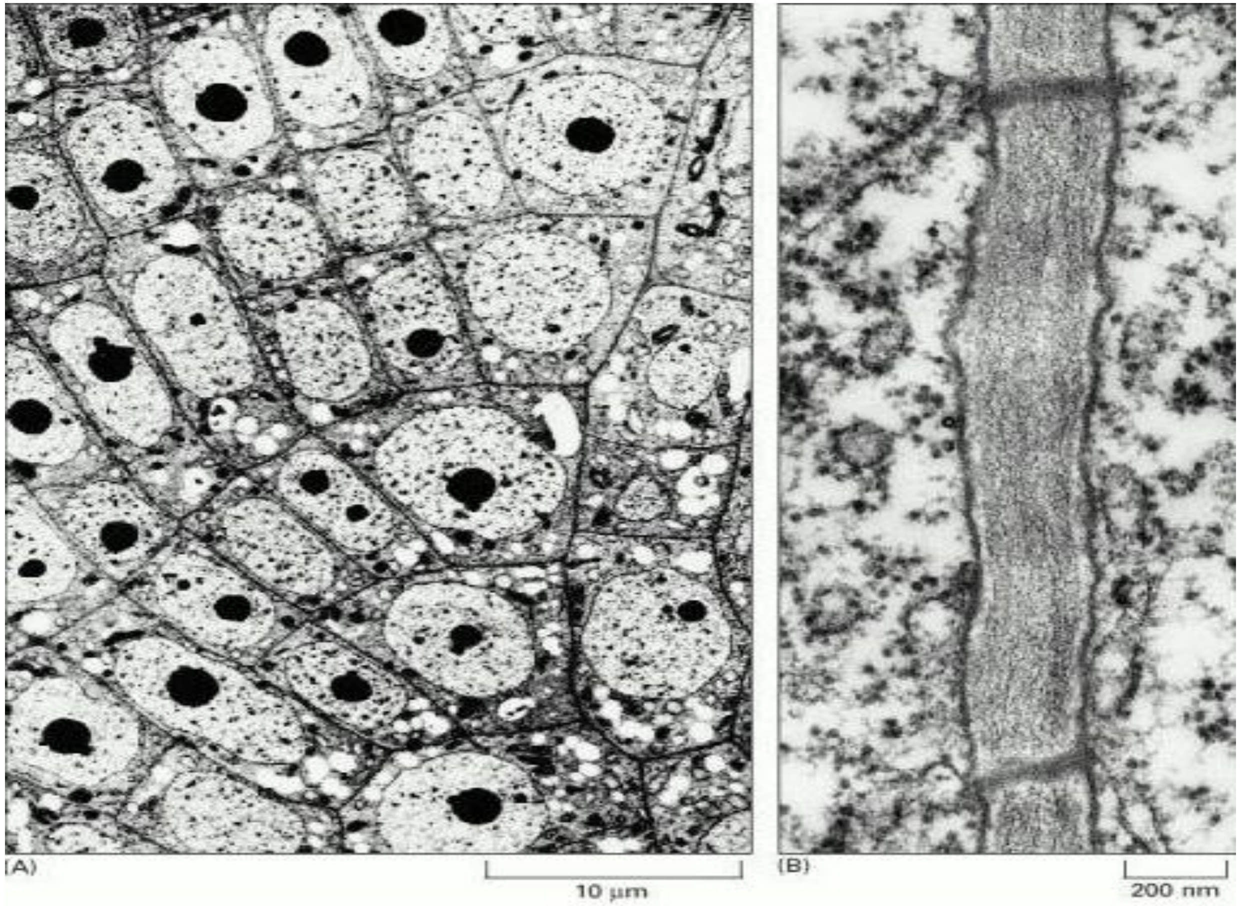
The Plant Cell Wall

- It is an elaborate extracellular matrix that encloses each cell in a plant. It was the thick cell walls of cork, visible in a primitive microscope, that in 1663 enabled Robert Hooke to distinguish and name cells for the first time

Figures A) Electron micrograph of the root tip of a rush, showing the organized pattern of cells that results from an ordered sequence of cell divisions in cells with relatively rigid cell walls. In this growing tissue, the cell walls are still relatively thin, appearing as fine black lines between the cells in the micrograph.

(B) Section of a typical cell wall separating two adjacent plant cells.



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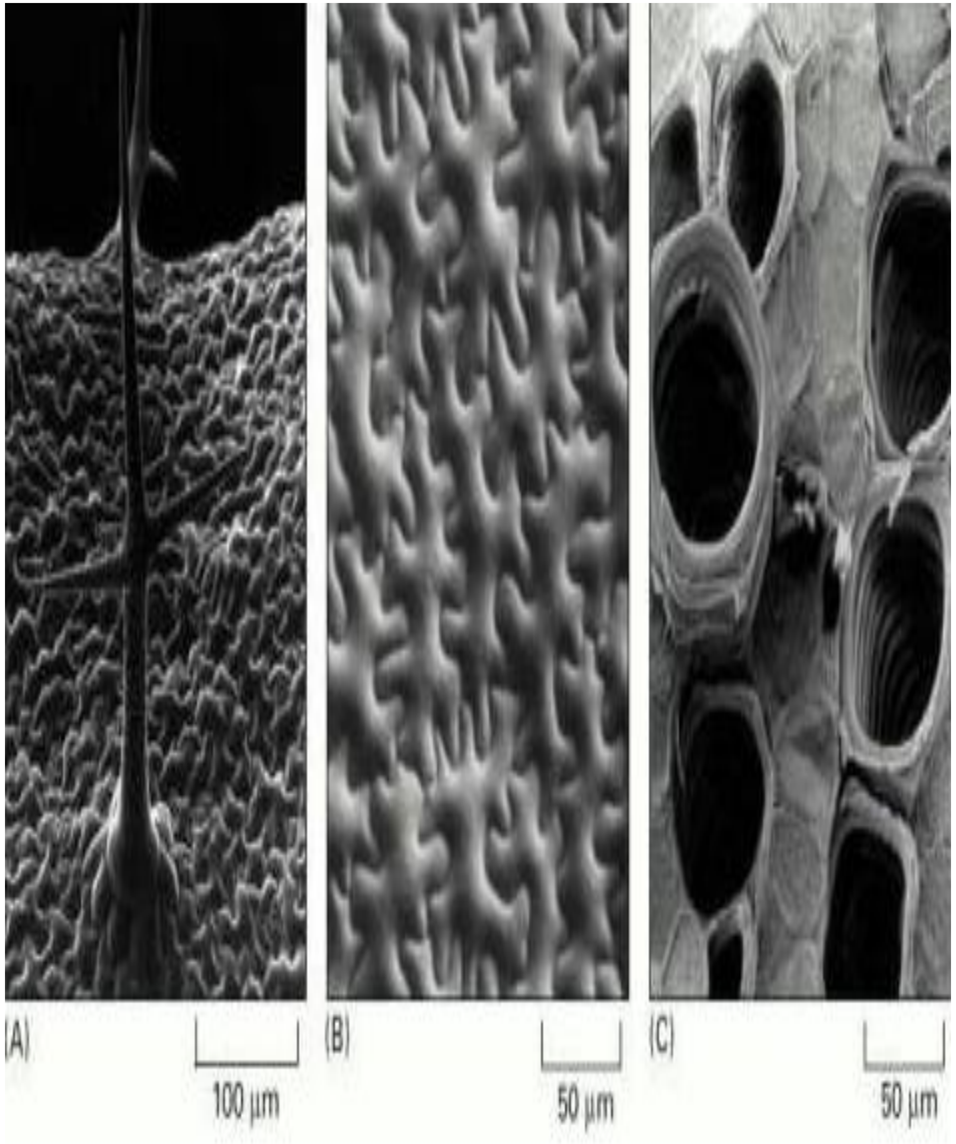
The Composition of the Cell Wall Depends on the Cell Type

- All cell walls in plants have their origin in dividing cells, as the cell plate forms during cytokinesis to create a new partition wall between the daughter cells
- The new cells are usually produced in special regions called *meristems*
- To accommodate subsequent cell growth, their walls, called **primary cell walls**, are thin and extensible, although tough
- Once growth stops, the wall no longer needs to be extensible: sometimes the primary wall is retained without major modification, but, more commonly, a rigid, **secondary cell wall** is produced by depositing new layers inside the old ones
- polymer in secondary walls is **lignin**, a complex network of phenolic compounds found in the walls of the xylem vessels and fiber cells of woody tissues

- (A) A trichome, or hair, on the upper surface of an *Arabidopsis* leaf. This spiky, protective single cell is shaped by the local deposition of a tough, cellulose-rich wall.
- (B) Surface view of tomato leaf epidermal cells. The cells fit together snugly like the pieces of a jigsaw puzzle, providing a strong outer covering for the leaf. The outer cell wall is reinforced with a cuticle and waxes that waterproof the leaf and help defend it against pathogens. (C) This view into young xylem elements shows the thick, lignified, hoop-reinforced secondary cell wall that creates robust tubes for the transport of water throughout the plant



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Reference

- Molecular Biology of the Cell. 4th edition, Bruce Alberts, Alexander Johnson.
- The Cell: A Molecular Approach , Geoffrey M. Cooper
- Lumen learning