BHARATHIDASAN UNIVERSITY

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Tamil Nadu, India.

Programme: M.Sc., Botany

Course Title : CELL BIOLOGY AND BIOINSTRUMENTATION
Course Code : 22PGBOT104

Unit – I
CELL AND CELL WALL

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The Fluid Mosaic Model

Membrane

- Transport of molecules into and outside the cell
- Promotes intracellular traffic by transporting molecules from one organelle to the other.
- Barrier between the intracellular and extracellular compartment.
- Mechanical support to the cell
- Signal transduction
- Mediate cell-cell communication

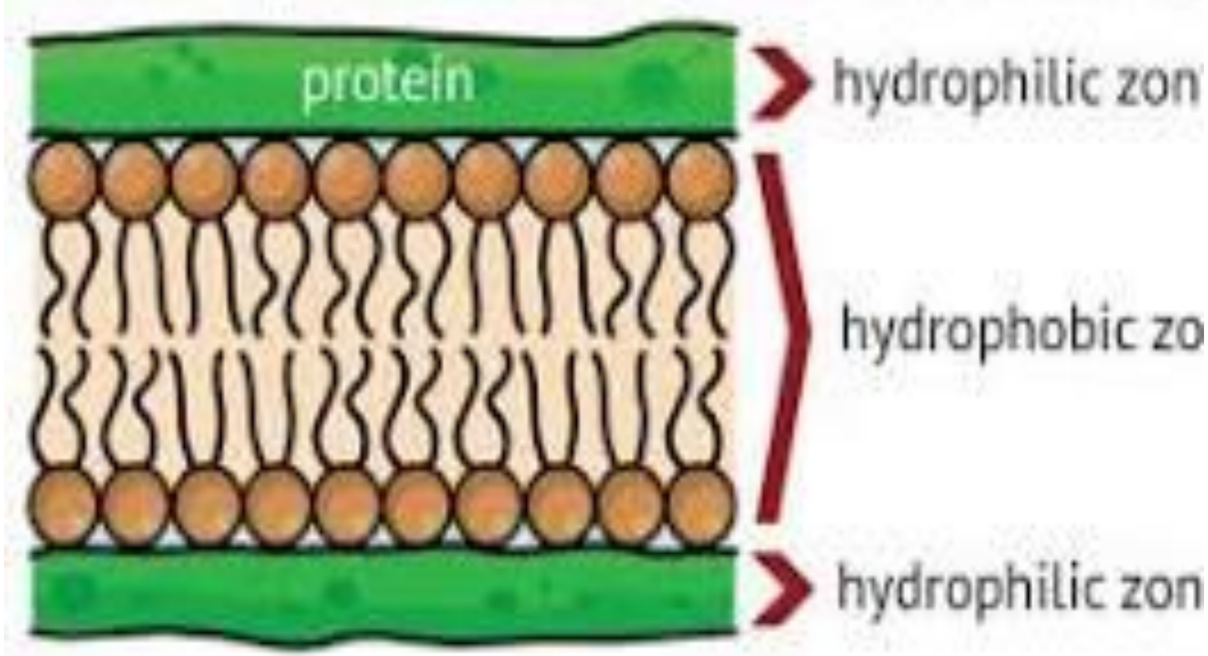
Composition

- Lipid
- Carbohydrates
- Proteins

Danielli and Davson Model

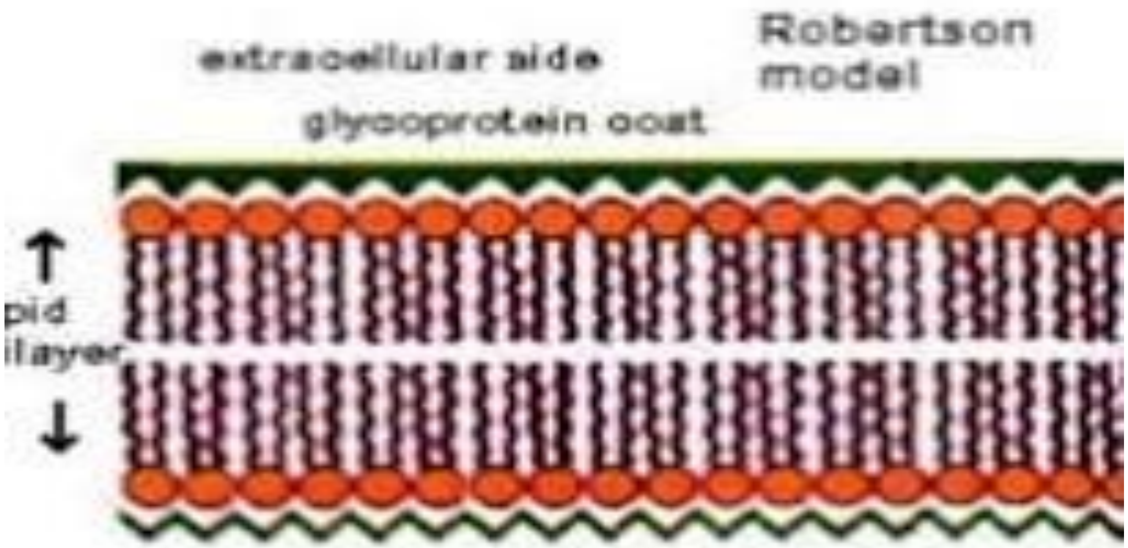
- In 1935 , Danielli and Davson studied triglyceride lipid bilayers over a water surface
- proposed that the plasma membrane consists of two layers of lipid (phospholipid) molecules.
- They found that they arranged themselves with the polar heads facing outward
- It always formed droplets (oil in water) and the surface tension was much higher than that of cells

Sandwich (Davson-Danielli) model of cell membra

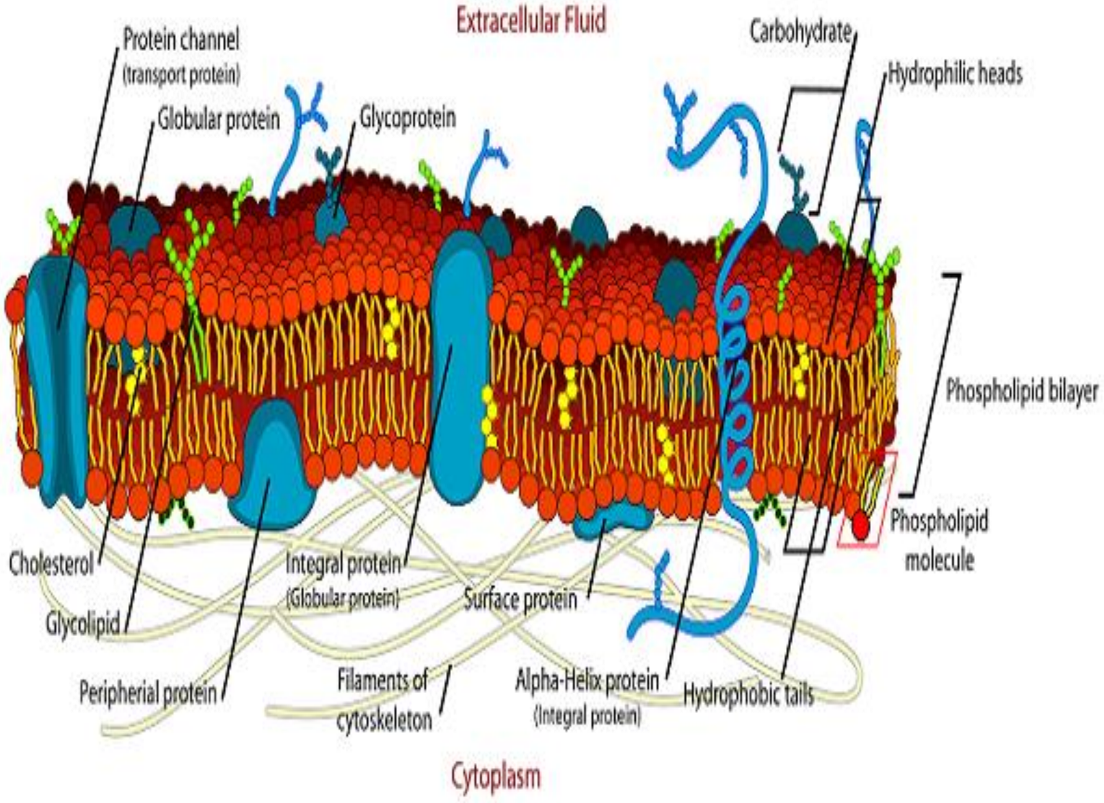


Robertson’s Model

- In 1965, Robertson noted the structure of membranes seen in the electron micrographs
- no spaces for pores in the electron micrographs
- hypothesized that the railroad track appearance came from the binding of osmium tetroxide to proteins and polar groups of lipids
- Proposed unit membrane hypothesis


Robertson
model
extracellular side
glycoprotein coat
pid
ilayer

Plasma



S.J. Singer and Garth L. Nicolson proposed the fluid mosaic model , which is widely used.
The fluid mosaic model of the plasma membrane structure describes the plasma membrane as a fluid combination of phospholipids, cholesterol, proteins, and carbohydrates.

Membrane Structure

The **fluid mosaic model** (Singer and Nicholson, 1972) of membrane structure - membranes consist of:

-**phospholipids** arranged in a bilayer

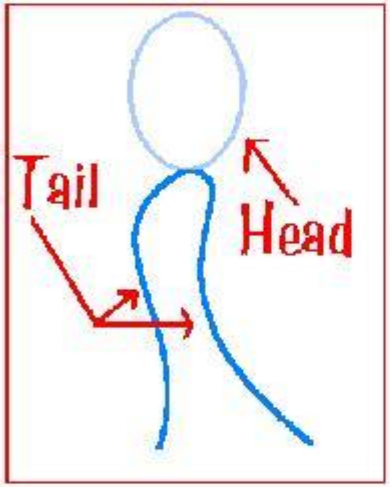
-**globular proteins** inserted in the lipid bilayer

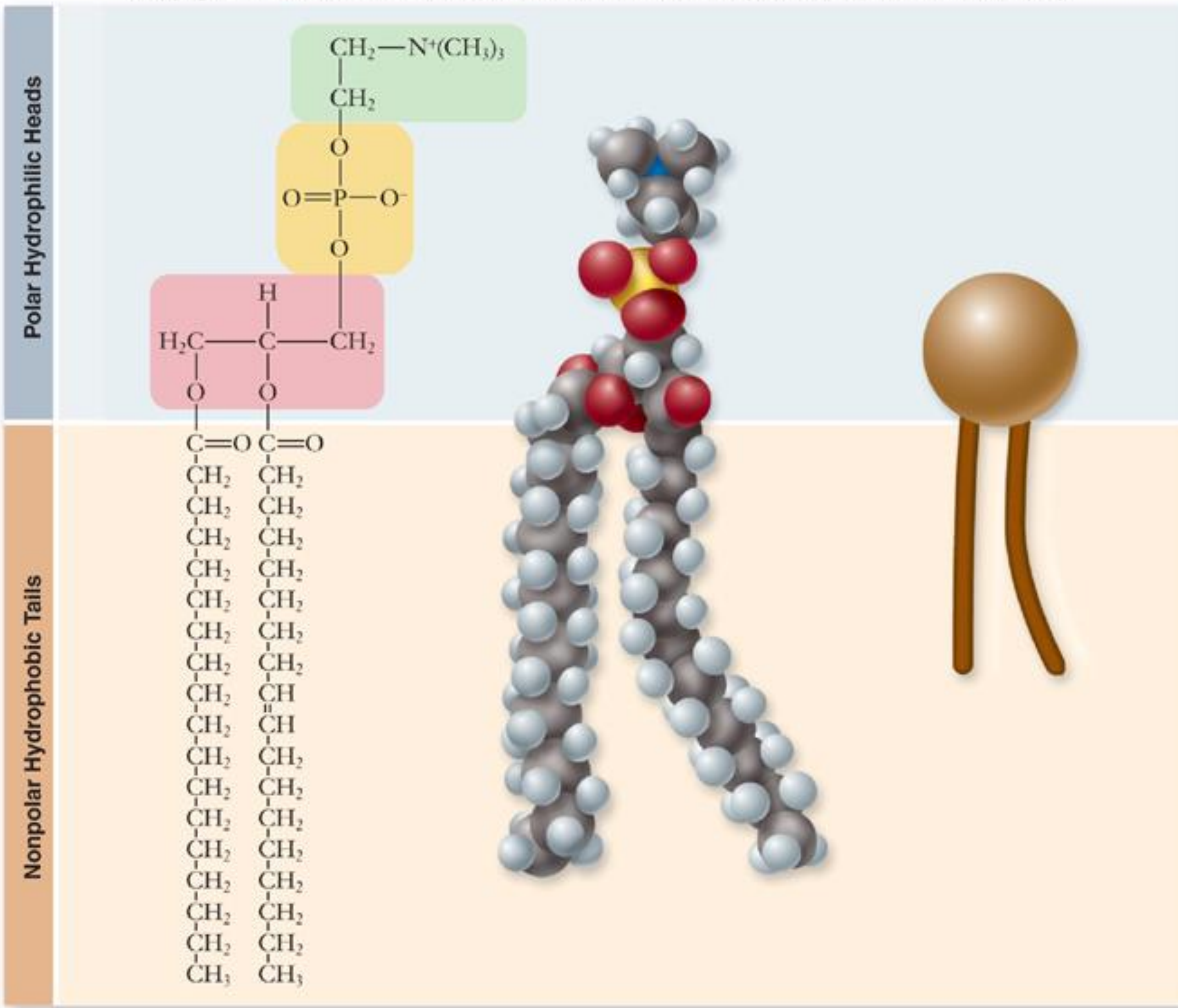
- molecules are constantly moving in two dimensions, in a *fluid* fashion, similar to icebergs floating in the ocean. The movement of the mosaic of molecules makes it impossible to form a completely impenetrable barrier.

- The membrane fluidity can be altered by changing the temperature:
- Temperature: The temperature will affect how the phospholipids move and how close together they are found. When it’s cold they are found closer together and when it’s hot they move farther apart.

- Lipids are esters of fatty acids.
- The fatty acid chain of the lipid forms a tail and it is non-polar.
- Phosphate – forms the head of lipid molecule and is **hydrophyllic and polar**.
- This contributes to the amphipathic nature of lipid.

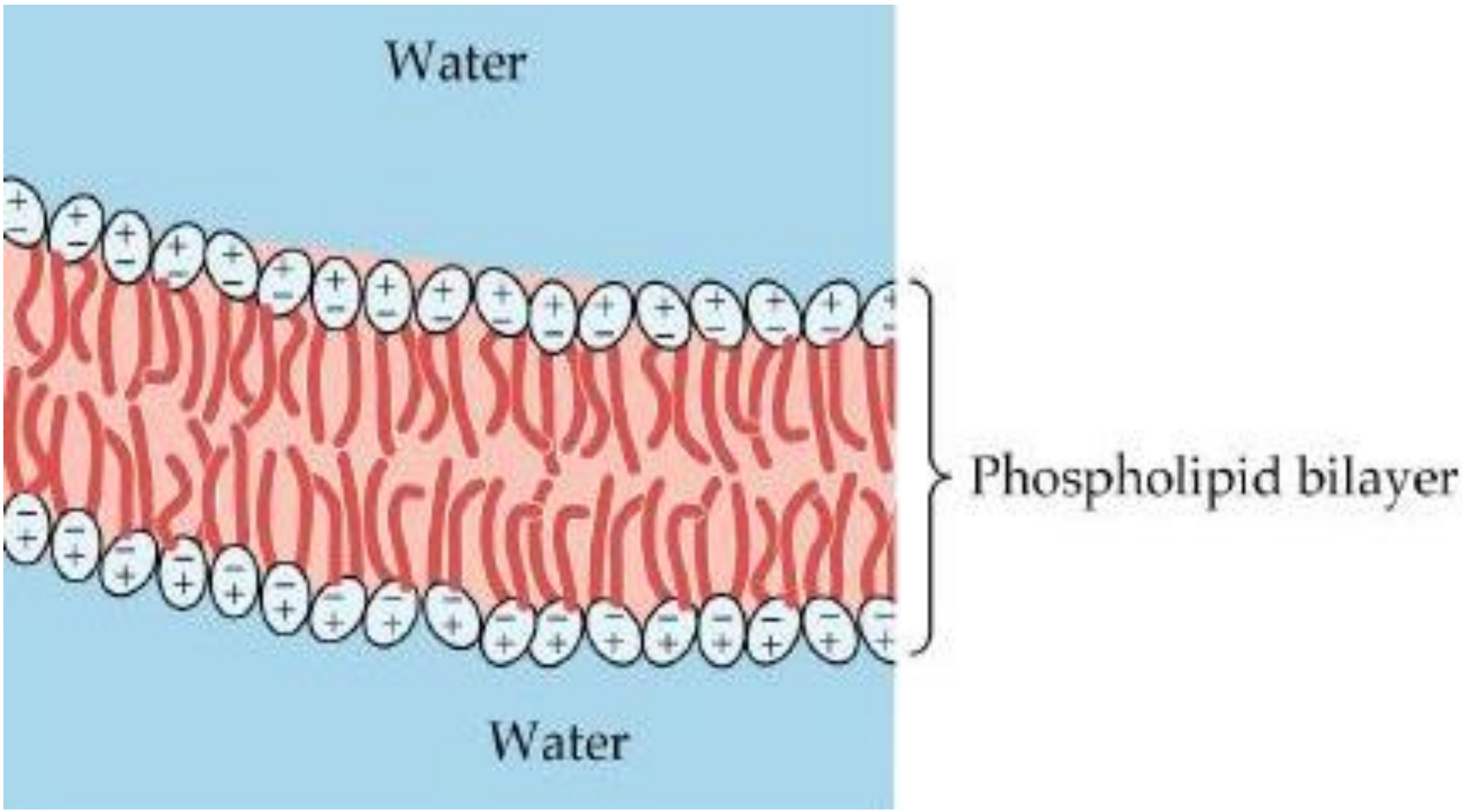
a. Phosphate head is *polar*
b. Fatty acid tails *non-polar*
c. Proteins embedded in membrane

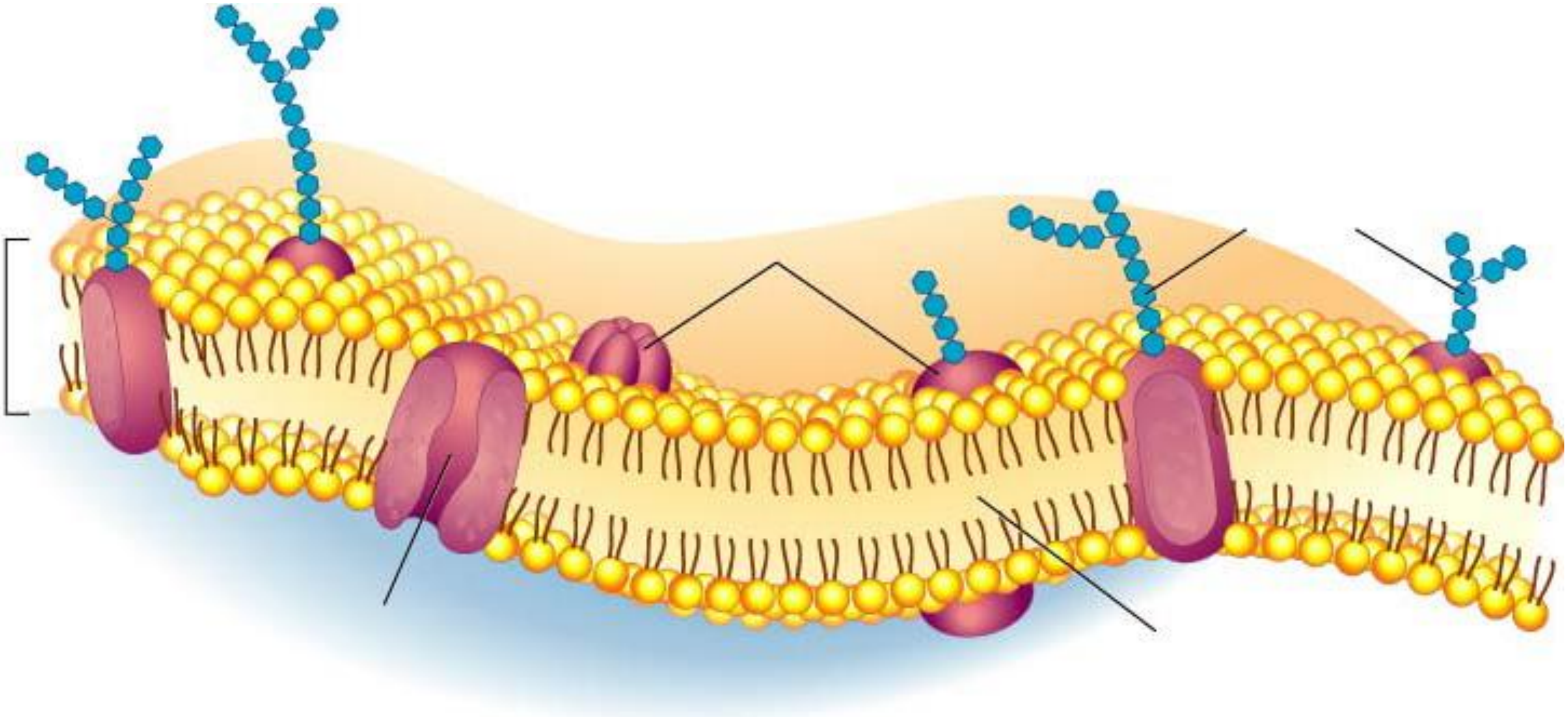




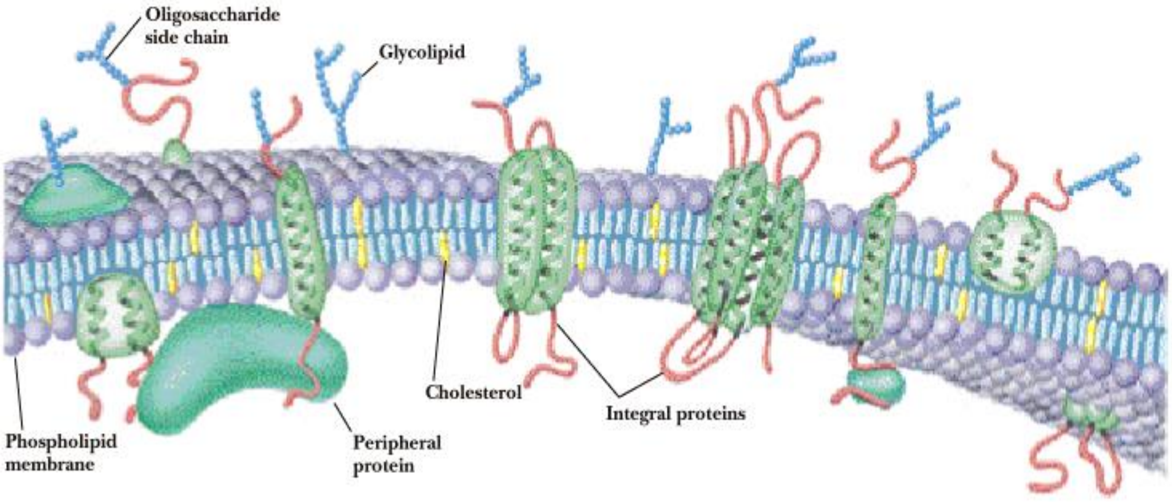
a. Formula *b.* Space-filling model *c.* Icon

- Lipid molecules arranged in a lateral fashion forming a monolayer.
- Two such monolayer’s are arranged in a tail to tail fashion forming a **bilayer.**


Water
Phospholipid bilayer
Water



Garrett & Grisham: Biochemistry, 2/e
Figure 9.6



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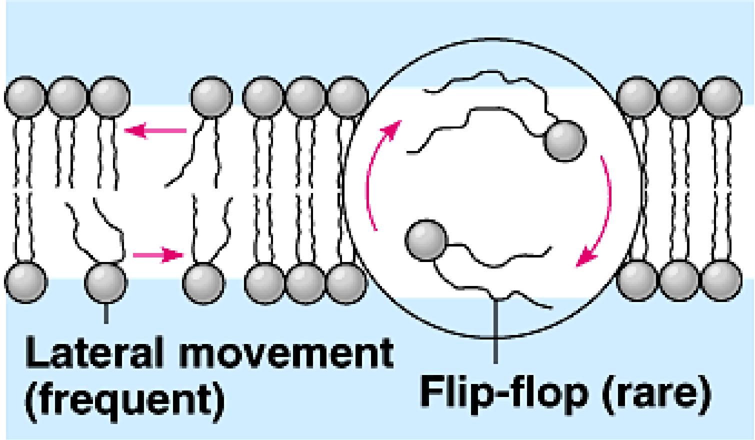
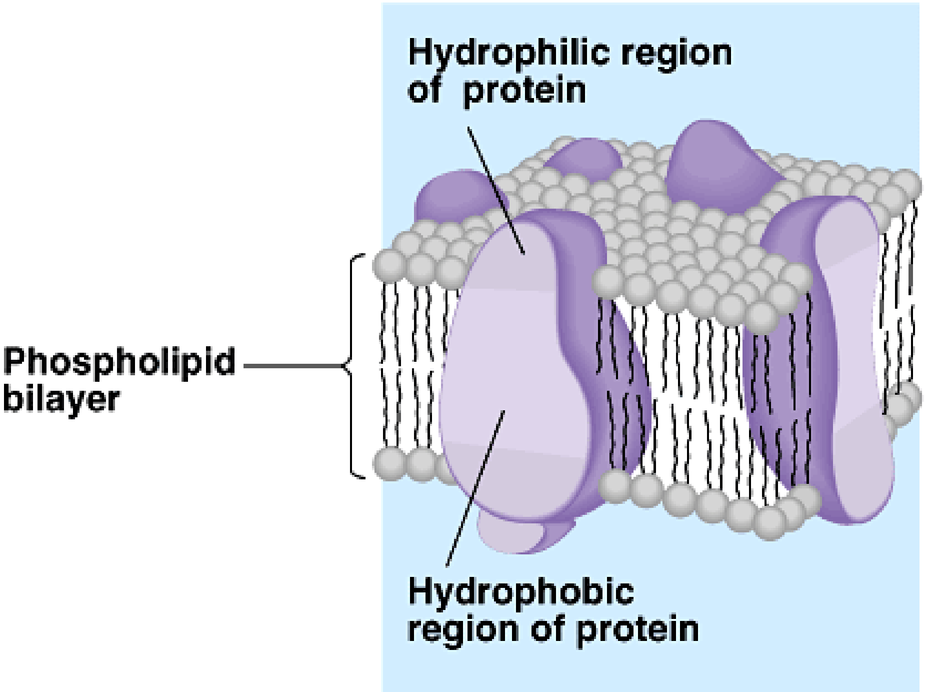
- Phopholipid bilayer is a fluid matrix
- Lipids and proteins undergo rotational and lateral movement



(a) Movement of phospholipids

- Most membrane lipids and some proteins can drift **laterally** within the membrane
- Molecules **rarely flip transversely** (flip-flop) across the membrane, because hydrophilic parts would have to cross the membrane’s hydrophobic core.

- A membrane is a fluid mosaic of lipids, proteins and carbohydrates.
- Two classes of proteins:
- Peripheral proteins (Extrinsic Proteins)
- Integral proteins (Intrinsic proteins)



(b) Current fluid mosaic model

Membrane lipids

- Variety of lipids – all are amphipathic i.e they contain both hydrophobic and hydrophilic regions
- 3 types:
- Phophoglycerides
- Spingolipids
- Cholestrol
- Fatty acid/lipid ratio varies from cell to cell and organism to organism.

- Phosphoglycerides:
- Membrane lipids contains phosphate group – phopholipids
- Because most membrane phospholipids are built on a glycerol backbone –called phosphoglycerides eg. diglycerides

Phospholipids

Phospholipid structure consists of

-**glycerol** – a 3-carbon polyalcohol acting as a backbone for the phospholipid

-2 **fatty acids** attached to the glycerol

-**phosphate group** attached to the glycerol

- Sphingolipids
- Derivatives of spingosine, an amino alcohol-contains a long hydrocarbon chain.
- Spingosine linked to fatty acid by its aminogroup.

- Cholestrol
- Sterol – which in certain animal cell constitute up to 50% of lipid molecules in the plasma membrane
- Cholestrol absent from plasma membrane - most plant and all bacterial cell
- They interfere with the movements of the fatty acid tails of the phospholipids.
- Plant – phytosterol, stigmatosterol, sitosterol etc.,

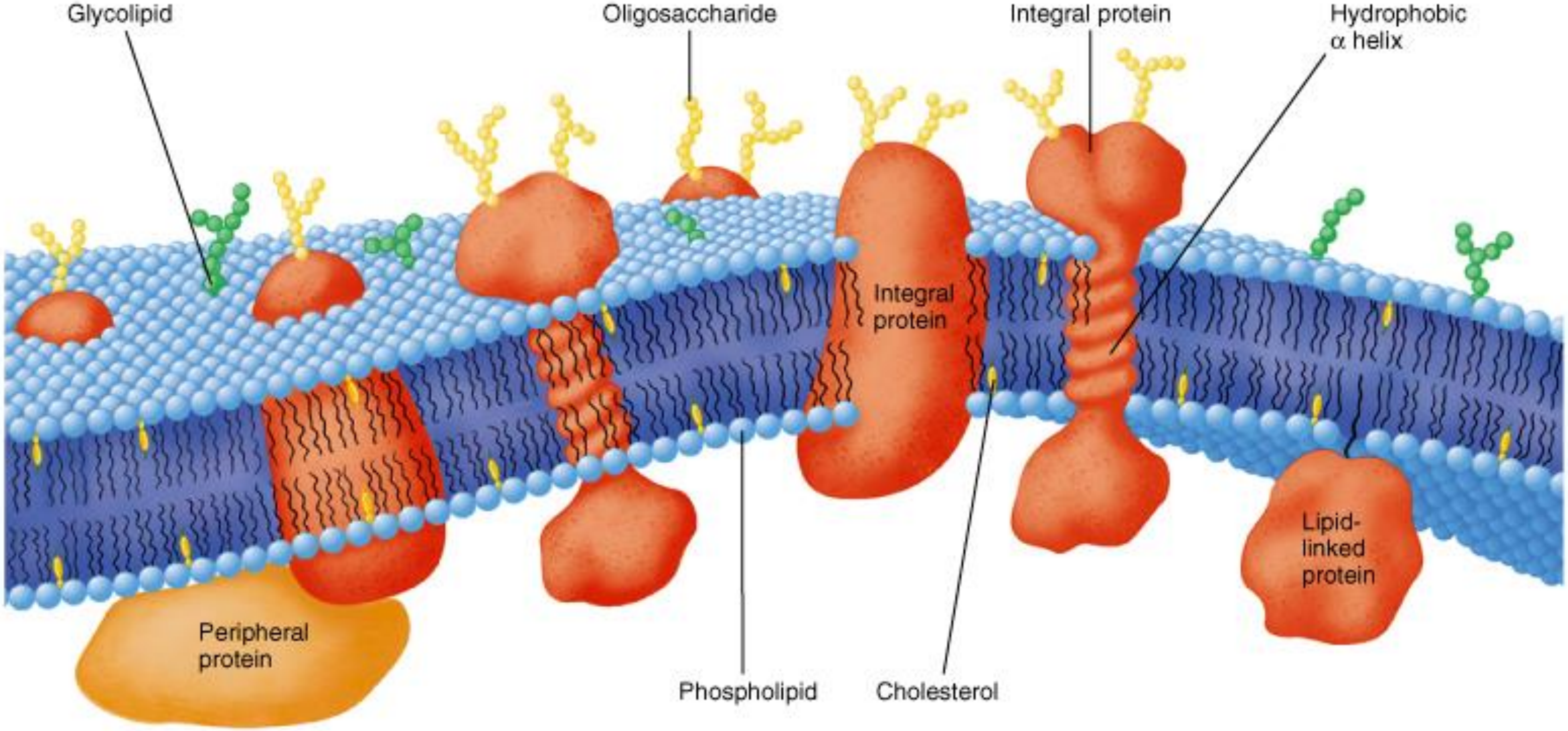
Membrane carbohydrates

- Plasma membrane of eukaryotic cells also contain carbohydrates
- Species and cell type – content range from 2-10%
- Membrane carbohydrates – covalently linked to lipids to form glycolipids
- Oligosaccharides of 15 sugar/chain

Membrane carbohydrates

- Cell-cell recognition : The ability of the cell to distinguish one type of neighboring cell from another.
- Sorting of cell into tissues and organs in animal
- Rejection of foreign cells by the immune system.

- Usually branched oligosacharides -15 sugar units
- Covalently Bond to lipids – glycolipids
- Covalently bond to proteins – glycoproteins
- Vary from cell to cell, species to species among cells within the same individual.



Glycolipid
Oligosaccharide
Integral protein
Hydrophobic
α helix
Integral
protein
Peripheral
protein
Phospholipid
Cholesterol
Lipid-
linked
protein

- These carbohydrate projections play an important role in mediating the interactions of a cell with its environment and sorting of membrane proteins to different cellular compartments.
- Carbohydrate of red blood cell plasma membrane determine whether person’s blood type is A, B,AB or O.

- A antigen – enzyme adds N-acetylgalactosamine to the end of the chain.
- B antigen – enzyme adds galactose to the chain terminal
- AB antigen – both enzyme
- O – lack enzymes capable of attaching either terminal sugar.

The Role of Membrane Carbohydrates in Cell-Cell Recognition

- Cells recognize each other by binding to surface molecules, often carbohydrates, on the plasma membrane

- Carbohydrates covalently bonded to lipids (glycolipids) or more often to proteins (glycoproteins)

- Much variability of extracellular carbohydrates among species, individuals, cell types in an individual

Membrane proteins

- Integral proteins
- Peripheral proteins
- Lipid-anchored proteins

Peripheral proteins

- Located outside the lipid bilayer on either the cytoplasmic or extracellular side.
- Peripheral proteins are not strongly bound to the membrane (by weak electrostatic bonds)
- They can be dissociated with mild detergent or with high salt concentration.
- Provide mechanical strength for the membrane and function as an anchor of integral membrane proteins

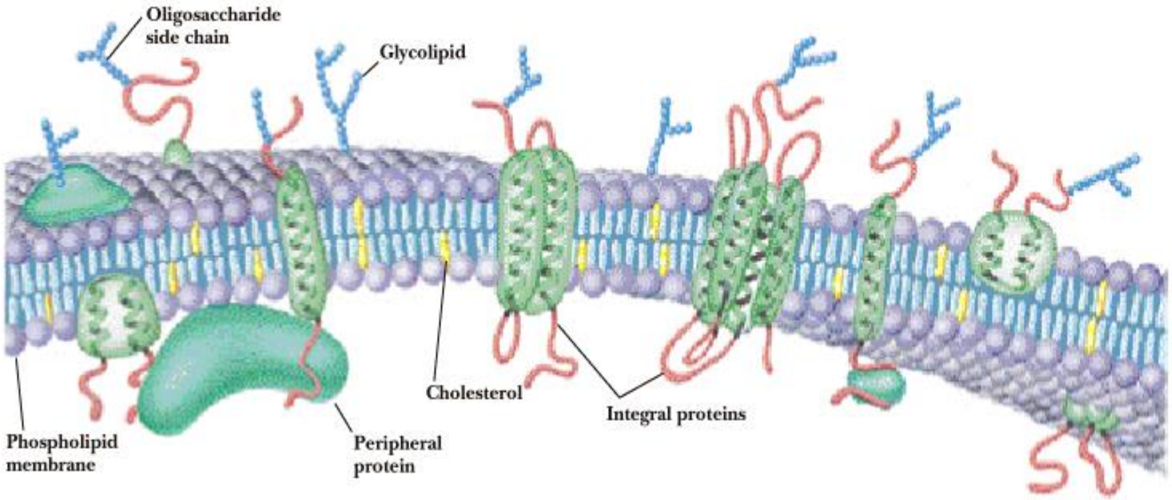
Peripheral membrane proteins

-anchored to a phospholipid in one layer of the membrane

-possess nonpolar regions that are inserted in the lipid bilayer

-are free to move throughout one layer of the bilayer

Garrett & Grisham: Biochemistry, 2/e
Figure 9.6



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Membrane Proteins

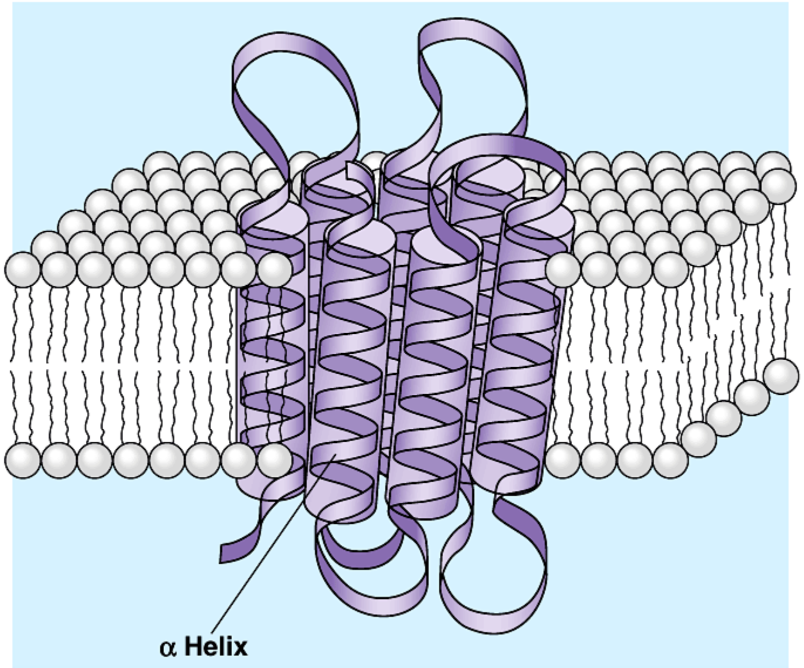
Membrane proteins have various functions:

1. transporters
2. cell surface receptors
3. cell surface identity markers
4. cell-to-cell adhesion proteins
5. attachments to the cytoskeleton

Integral membrane proteins

- Strongly imbedded in the bilayer.
- They can be removed from the membrane by denaturing the membranes (Organic solvents or strong detergents)
- Transmembrane protein
- Eg. Glycophorin, bacterio

  -rhodopsin



- Integral proteins
  - Pass entirely through lipid bilayer and have domains that protrude from both extracellular and cytoplasmic side.
  - hydrophobic regions consist of one or more stretches of nonpolar amino acids
  - often coiled into alpha helices

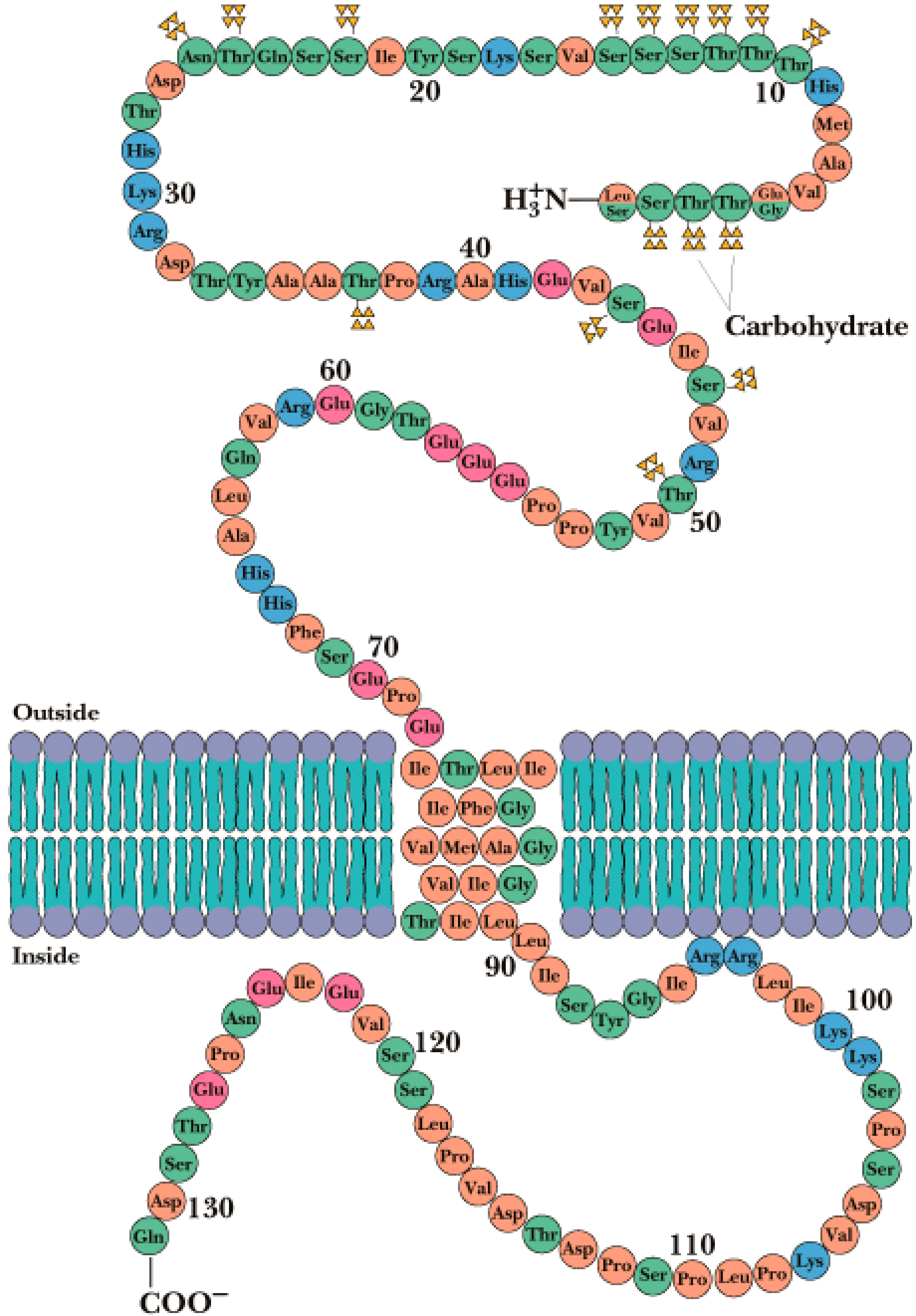
Integral membrane proteins

-span the lipid bilayer (transmembrane proteins)

-nonpolar regions of the protein, embedded in the interior of the bilayer

-polar regions of the protein protrude from both sides of the bilayer

- Six major functions of membrane proteins:
  - Transport
  - Enzymatic activity
  - Signal transduction
  - Cell-cell recognition
  - Intercellular joining
  - Attachment to the cytoskeleton and extracellular matrix (ECM)


H$_3^+$N
Carbohydrate
10
20
30
40
50
60
70
Outside
Inside
90
100
110
120
130
COO$^-$

- Function as receptors – bind specific substances at the membrane surface
- as channels/ transporters involved in movement of ions and solutes across the membrane
- As agents that transfer electrons during the processes of photosynthesis/ respiration
- Resides within the lipid bilayer have hydrophobic characters

Lipid-anchored proteins

- Located outside the lipid bilayer on either side or extracellular side – covalently linked to lipid molecule.
- Proteins present external face of plasma membrane are bound to membrane by a oligosaccharide linked to phosphatidyl ionositol – embedded in outer side of lipid bilayer.

Garrett & Grisham: Biochemistry, 2/e
Figure 9.20

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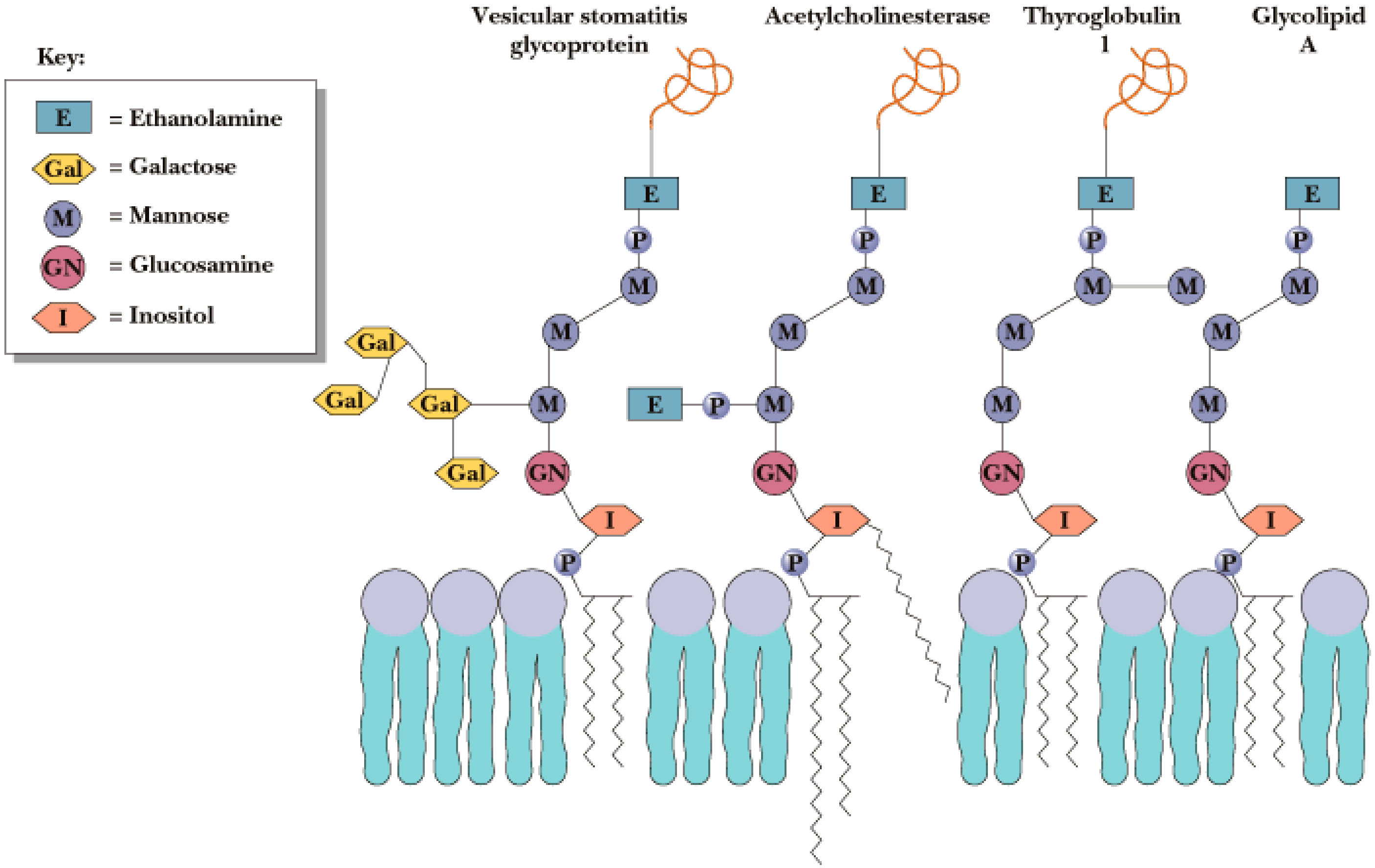

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- They are transient in nature
- Reversible anchoring and de-anchoring can control signaling pathways.
- Proteolytic cleavage triggers signaling

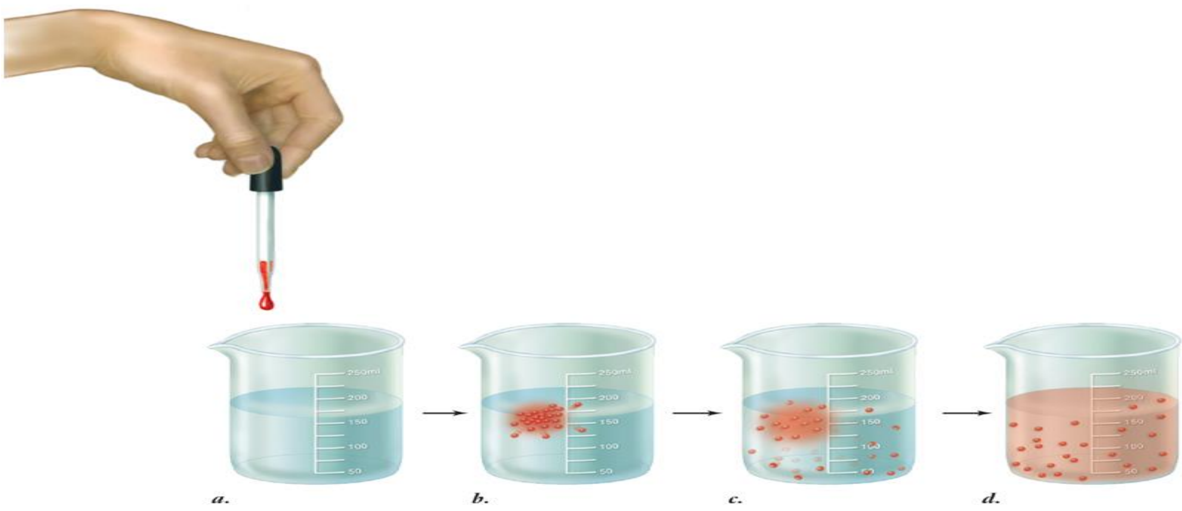
- Thank You

Transport

- Passive transport
  - -Simple diffusion
  - -Facilitated diffusion
- Active transport
- Group translocation

- In eukaryotes – no group translocation/ only endocytosis

- Simple and facilitated diffusion – movement of molecules down concentration gradient.
- Other two – against concentration gradient
- Diffusion - Higher to lower eg. Glycerol



- Simple diffusion
- Movement of molecules from region of higher concetration to lower concentration (diffusion of solutes towards equilibrium eg. Glycerol transport to cell. No energy is required.

- Facilitated Diffusion (carrier mediated) – Membrane bound carriers called permeases (transport proteins) attach to substrates to which they have an affinity. Energy is not required for this movement. Because this is aided by carrier – facilitated diffusion. Carrier proteins- selective in nature and transport closely related solutes.
- Common in Eukaryotes than in prokaryotes

Passive Transport

Selective permeability: integral membrane proteins allow the cell to be selective about what passes through the membrane.

Channel proteins have a polar interior allowing polar molecules to pass through.

Carrier proteins bind to a specific molecule to facilitate its passage.

Passive Transport

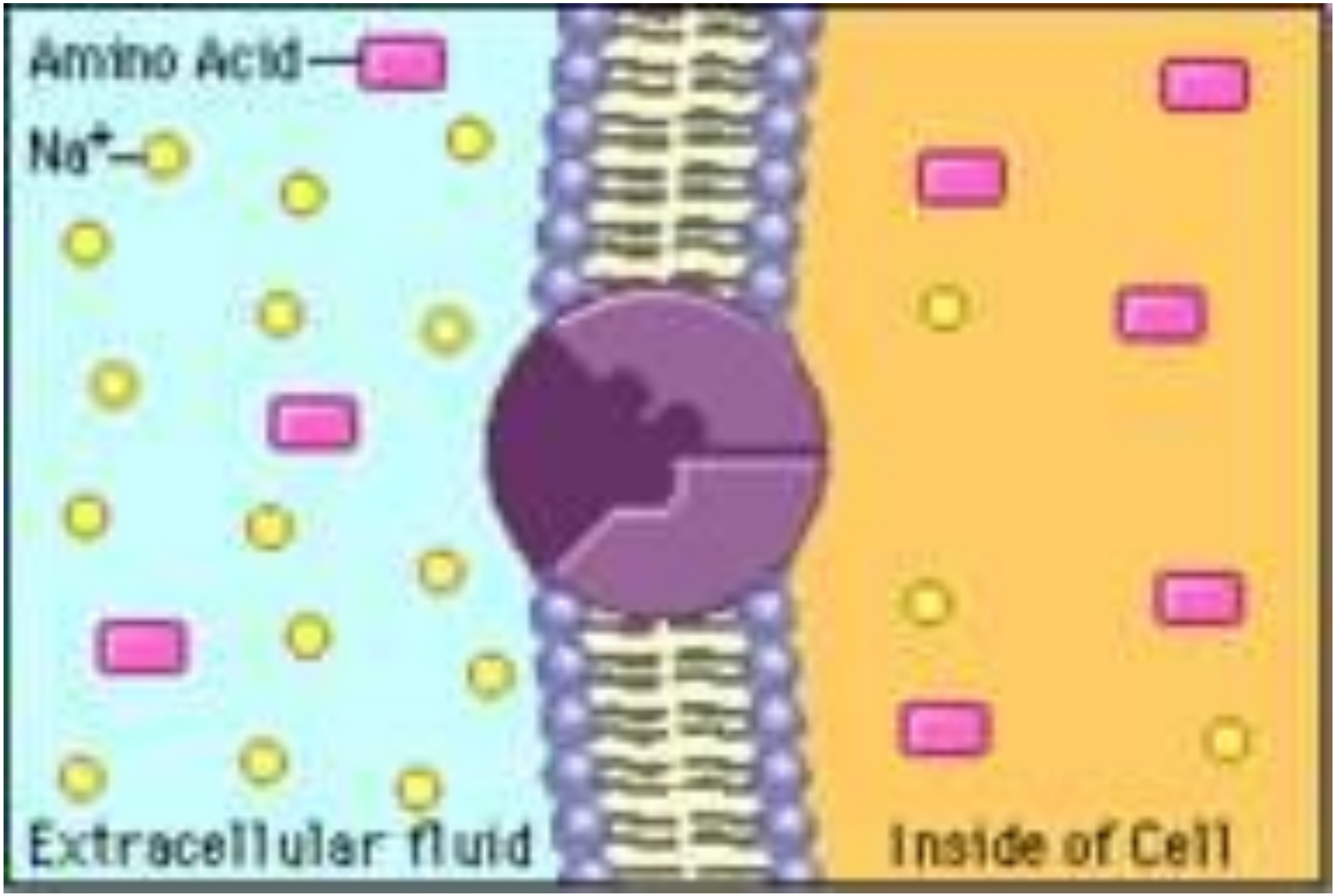
Channel proteins include:

-**ion channels** allow the passage of ions (charged atoms or molecules) which are associated with water

-**gated channels** are opened or closed in response to a stimulus

-the stimulus may be chemical or electrical

- Carrier proteins bind one or more solute molecule on one side of membrane and then undergo confirmational changes that transfer solute to other side of the membrane.
- In bacteria – channel through membrane and allow passage of solutes without any confirmational changes in protein. These channels appear as pores – outer membrane porin.
- Carrier proteins carry either one or two solutes.

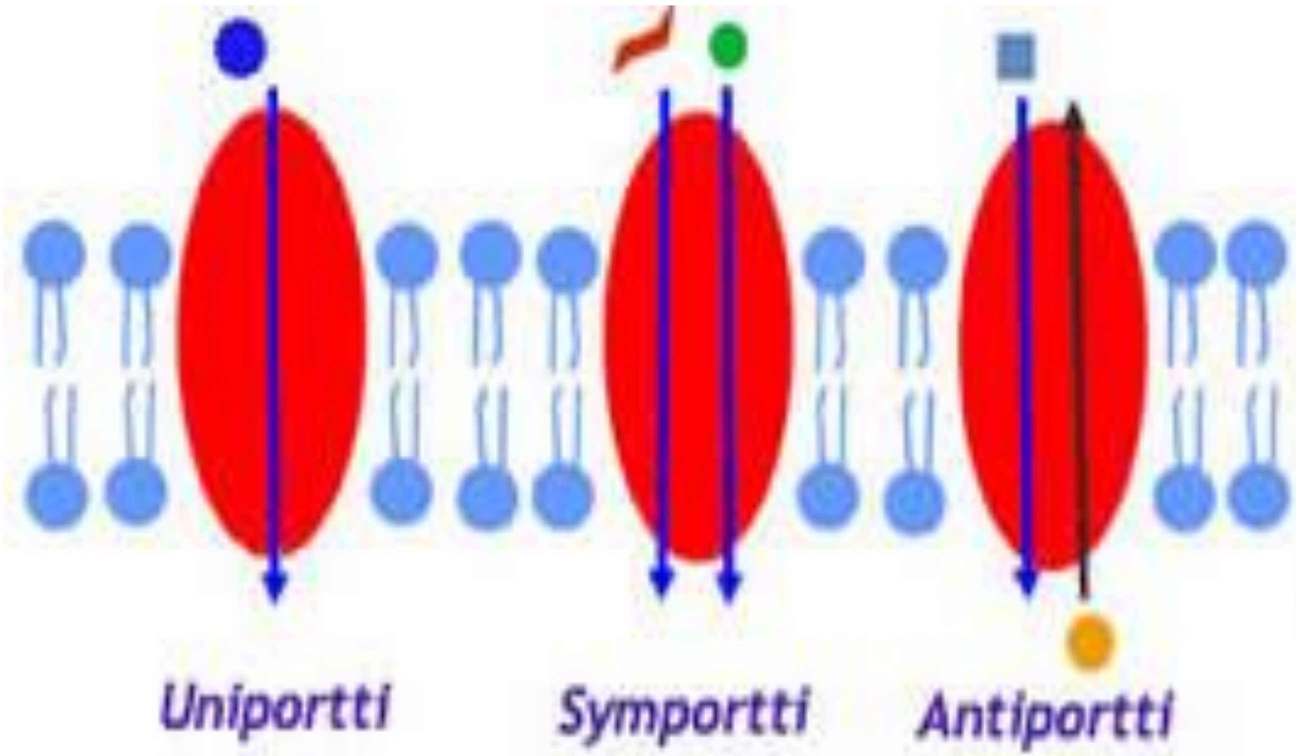

Amino Acid
Na+
Extracellular fluid
Inside of Cell

- Fac.diffusion – Uniporter

  Co-transporter

- Uniporter - carry one substance at a time
- Co-transporter - more than one substance at a time - Symport
- Antiport

- Symport - two substances carried across the membrane in same direction
- Antiport - substances transported across the membrane in opposite direction


Uniportti
Symportti
Antiportti

Active Transport

Active transport

-requires energy – ATP is used directly or indirectly to fuel active transport

-moves substances from low to high concentration

-requires the use of carrier proteins

- Active transport
- Protein mediated movement up the gradient – require energy.
- Energy might be used to reversibly modify the confirmation of the protein carrier, which spans the membrane, when this occurs the carrier accepts the substance, opens a channel through the membrane and extrudes the substrate on the other side.
- Allows secretary products, waste materials to be carried/ removed from cell – even when concentration outside is greater.

- Group translocation – Here molecules are transported into cell while being chemically altered.
- Eg. Sugar phosphorylation to enter the cell in E.coli – which occurs in two steps.

Bulk Transport

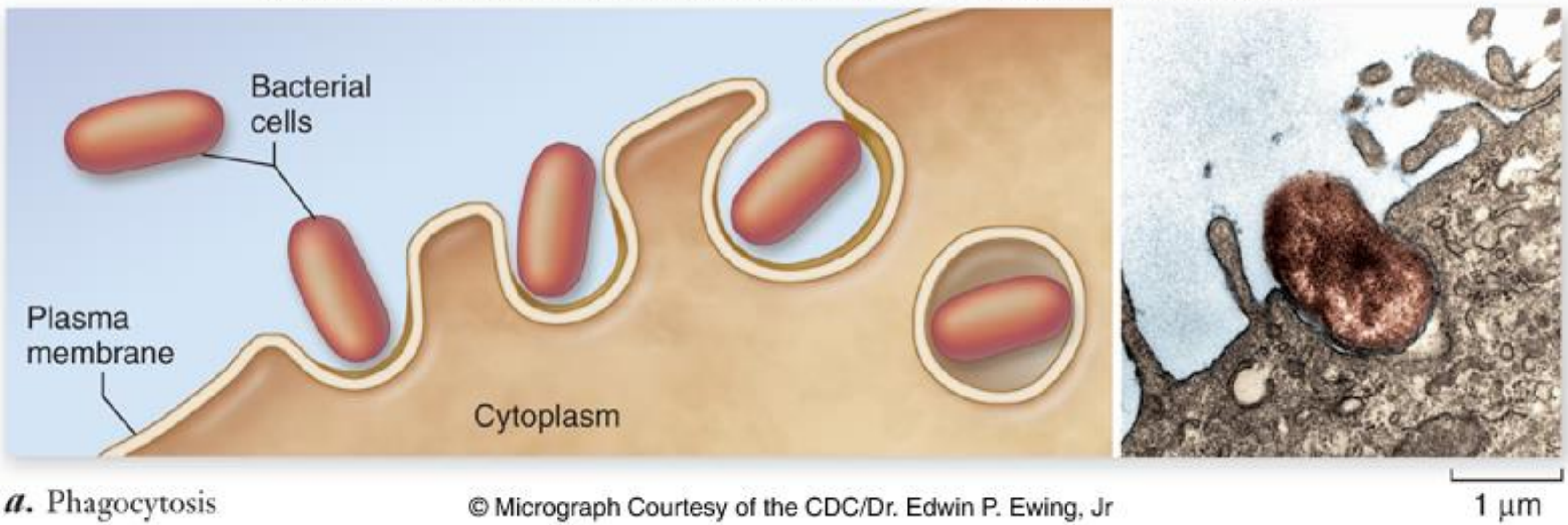
Bulk transport of substances is accomplished by

1. **endocytosis** – movement of substances into the cell
2. **exocytosis** – movement of materials out of the cell

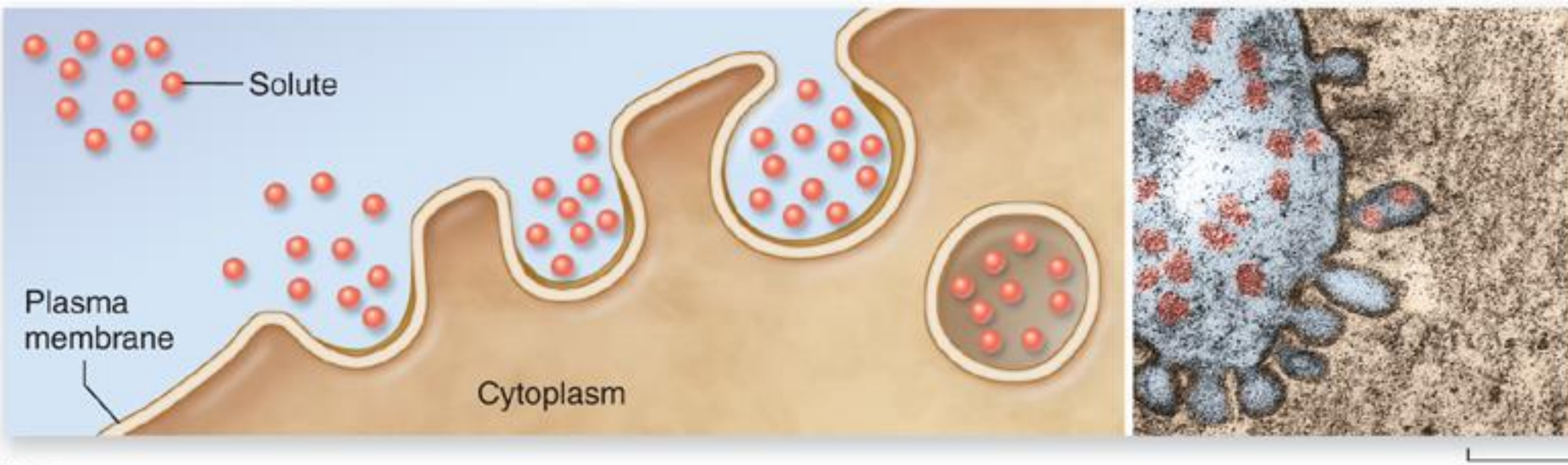
Bulk Transport

Endocytosis occurs when the plasma membrane engulf food particles and liquids.

1. **phagocytosis** – the cell takes in particulate matter
2. **pinocytosis** – the cell takes in only fluid
3. **receptor-mediated endocytosis** – specific molecules are taken in after they bind to a receptor



a. Phagocytosis



b. Pinocytosis

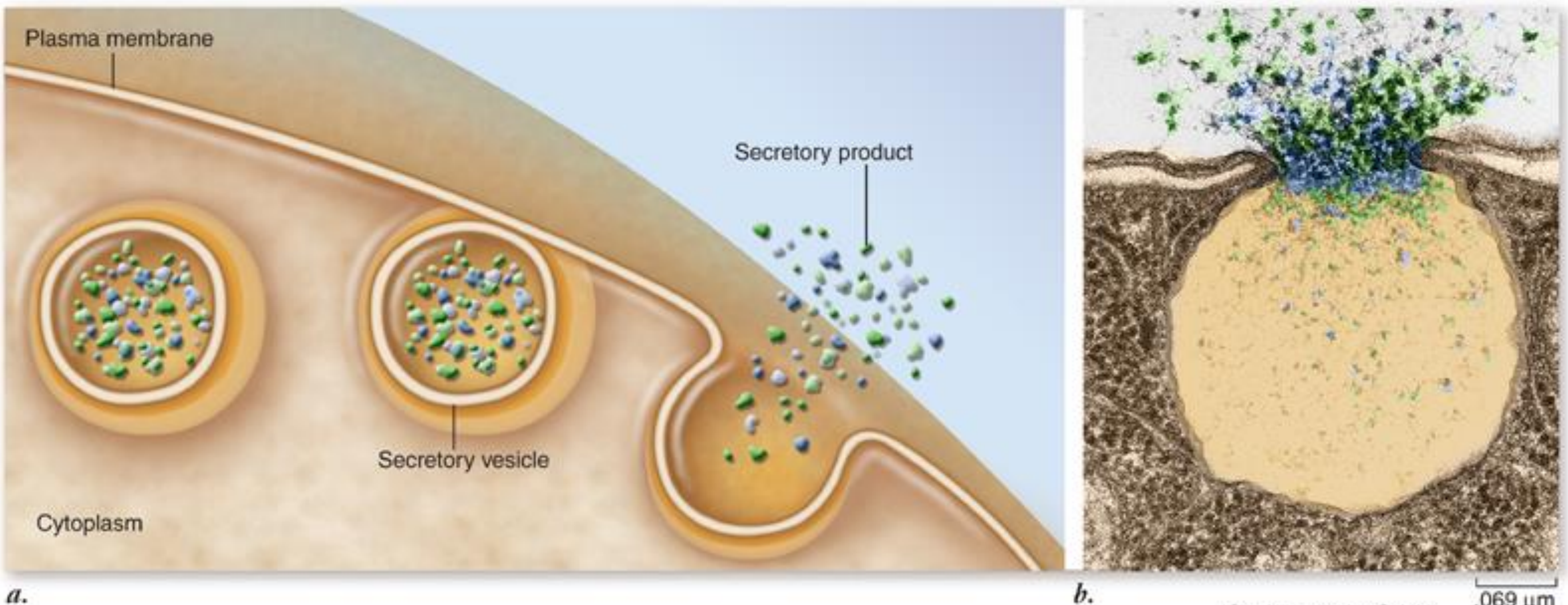
Bulk Transport

Exocytosis occurs when material is discharged from the cell.

-vesicles in the cytoplasm fuse with the cell membrane and release their contents to the exterior of the cell

-used in plants to export cell wall material

-used in animals to secrete hormones, neurotransmitters, digestive enzymes


Plasma membrane
Secretory product
Secretory vesicle
Cytoplasm
a.
b.
.069 µm