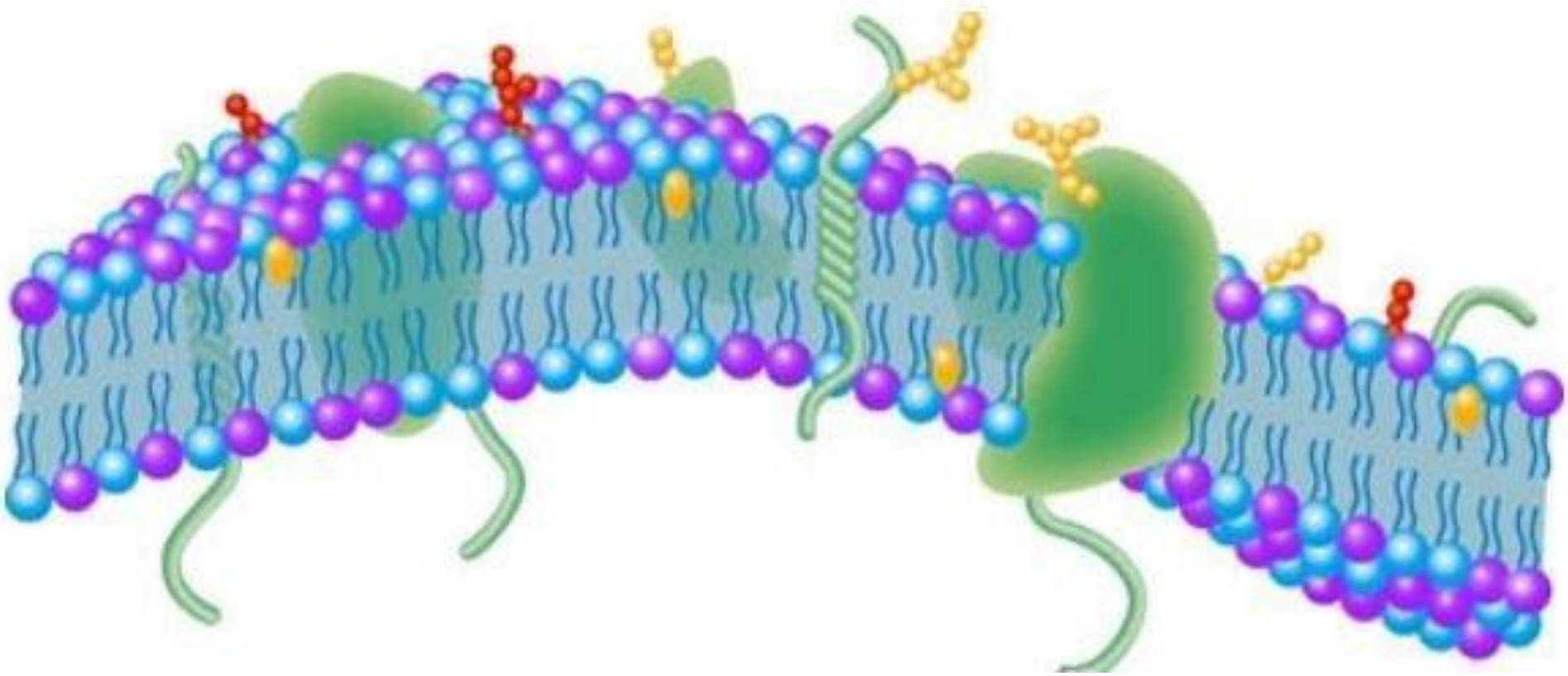
# Lecture B4: Cells and the Plasma Membrane



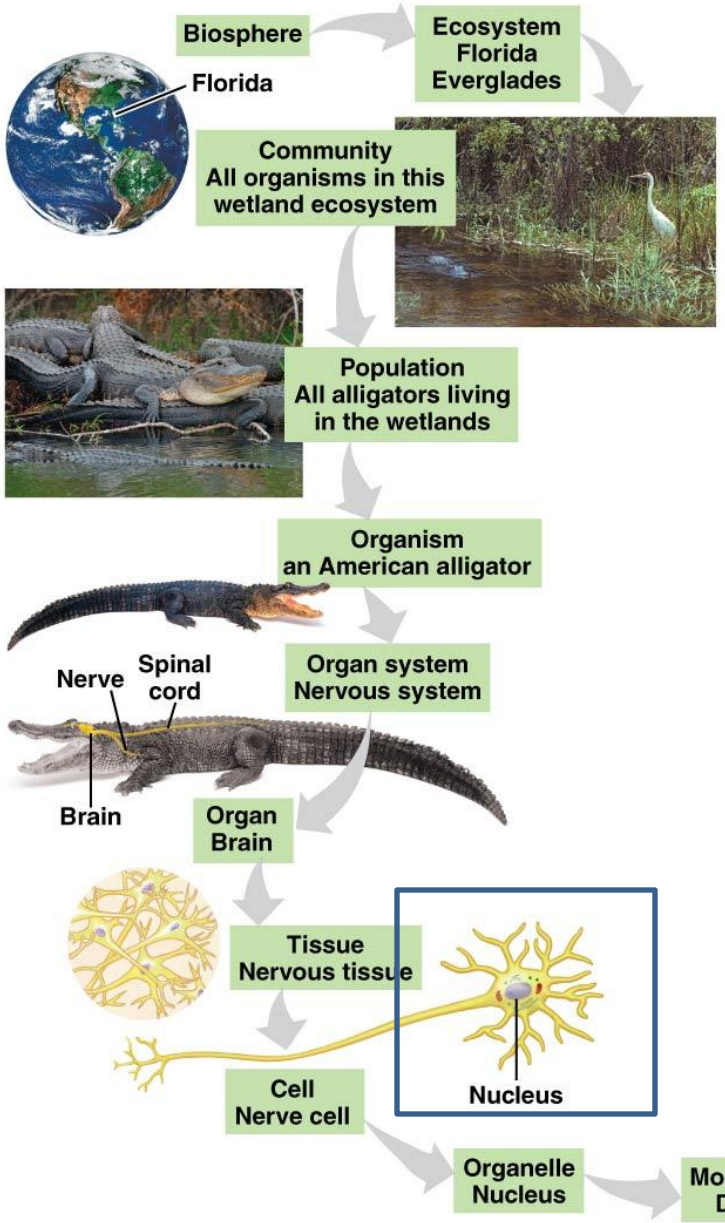
# Learning outcomes

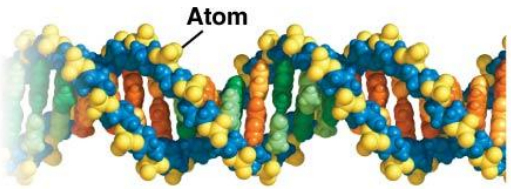
At the end of the lecture students should be able to:

- Explain the importance of membranes in cells
- Describe the fluid mosaic model of the membrane
- Identify the various membrane components and describe their functions
- Explain why the membrane is selectively permeable
- Describe how the fluidity of the membrane is maintained
- Distinguish between the different types of active and passive transport
- **Text reference:** *Campbell Concepts*, 5.1-5.9

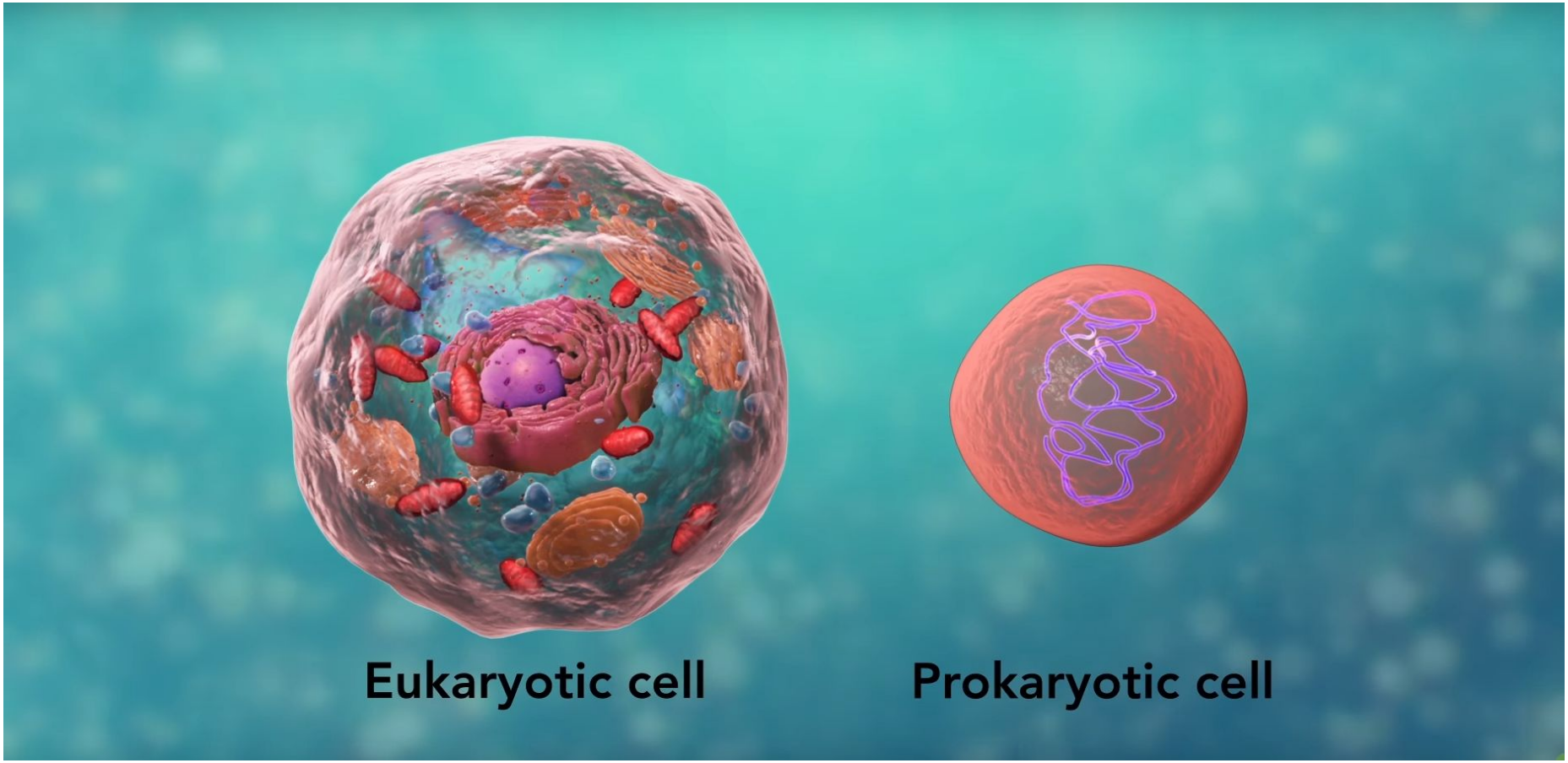
# The Cell

- The cell is the basic unit of life
- All organisms are made of cells
- In the hierarchy of biological organization, the cell is the simplest collection of matter that can be alive



# Cell types



# Cell types

Two kinds of cell which differ in size and structure

**Prokaryotic cells** "before nucleus"

- No nucleus, DNA is in unbound region called nucleoid
- No membrane-bound organelles

**Eukaryotic cells** "true nucleus"

- Have a membrane-enclosed nucleus, which houses most of their DNA
- Also have many membrane-bound organelles

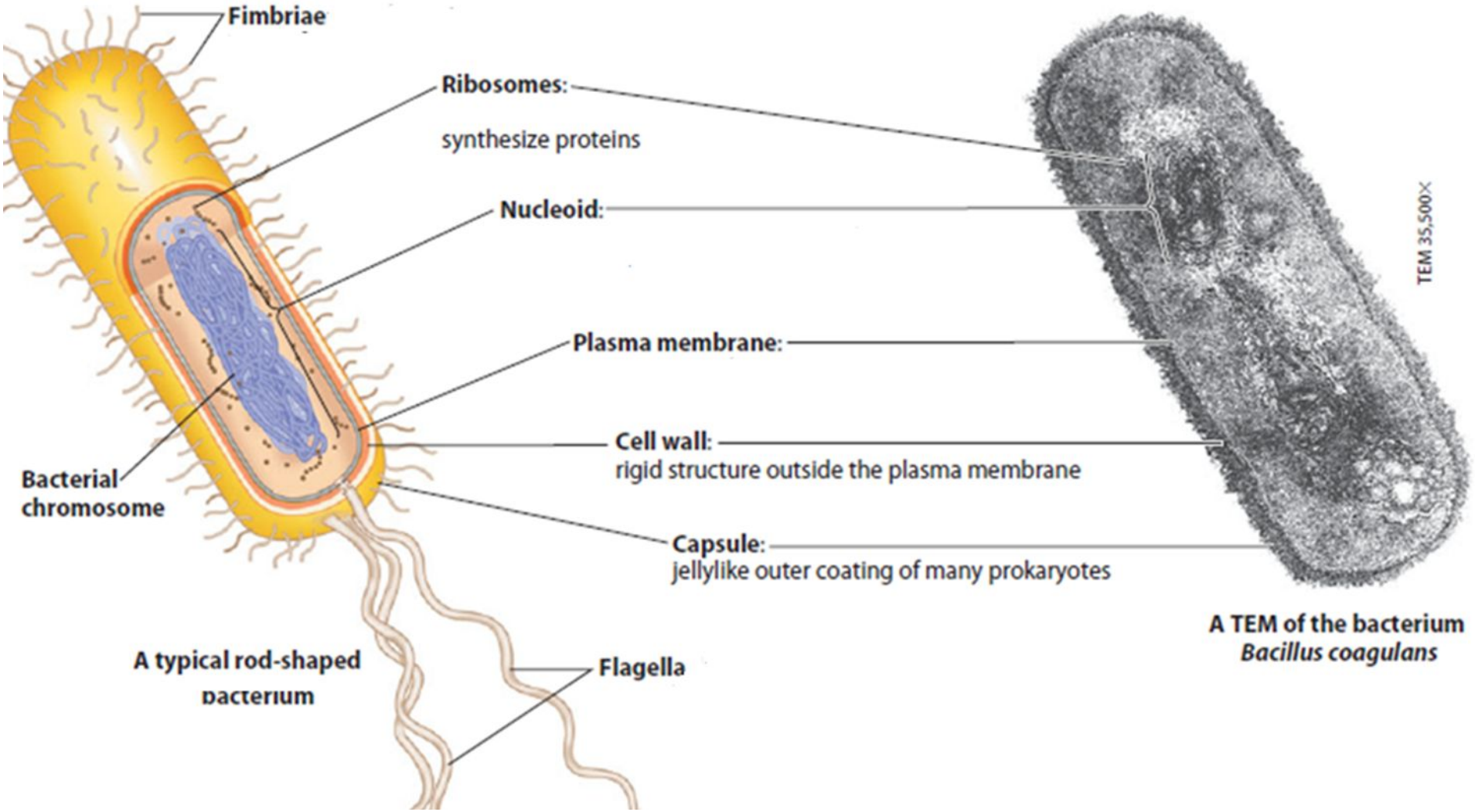
**Prokaryotic cells evolved before eukaryotic cells but because of size eukaryotic cells were observed and studied first**

# Prokaryotic Cells

- Prokaryotic cells do not have nuclei.
- In prokaryotic cells, the DNA is located within the cytoplasm in a region of the cell called the nucleoid.
- They constitute two of the three domains of life:

Bacteria and Archaea

Are unicellular organisms


Fimbriae
Ribosomes:
synthesize proteins
Nucleoid:
Plasma membrane:
Cell wall:
rigid structure outside the plasma membrane
Capsule:
jellylike outer coating of many prokaryotes
Bacterial chromosome
A typical rod-shaped bacterium
Flagella
TEM 35,500×
A TEM of the bacterium
Bacillus coagulans

# Eukaryotic Cells

- Eukaryotic cells have **nuclei**.
- A eukaryotic cell also contains various other **organelles** ("little organs"), which perform specific functions in the cell
- **Eukarya**: Plants, animals, fungi, and protists

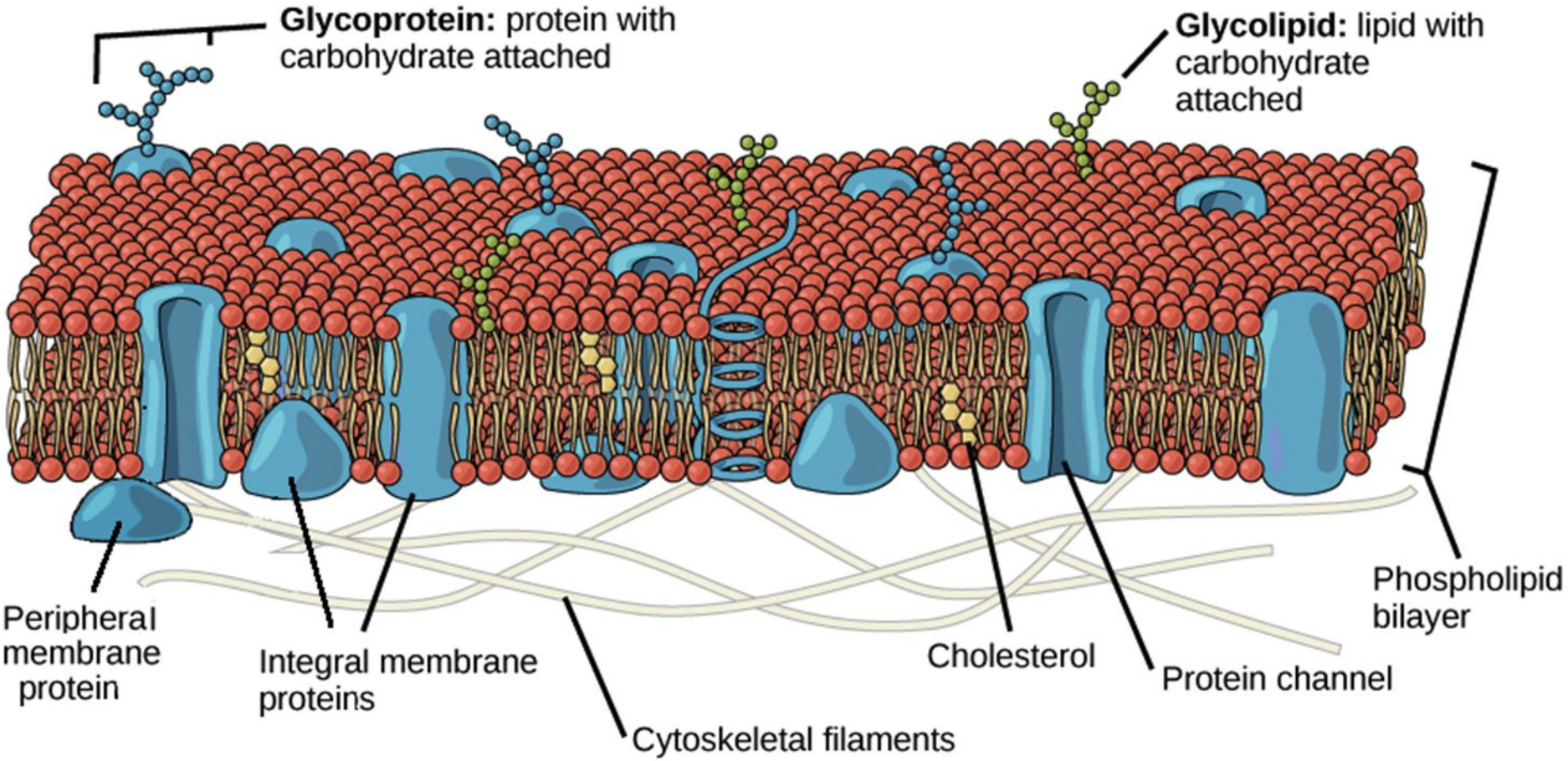
# Common Structures Of Cells

- All cells contain **deoxyribonucleic acid (DNA),** which contains the plans for how the cell is built and how it functions.
- All cells make proteins to help them function. Proteins are built on structures called ribosomes, so all cells have **ribosomes**.
- The liquid inside all cells is called **the cytoplasm**.
- All cells have a boundary that separates them from their environment - **the plasma membrane**.

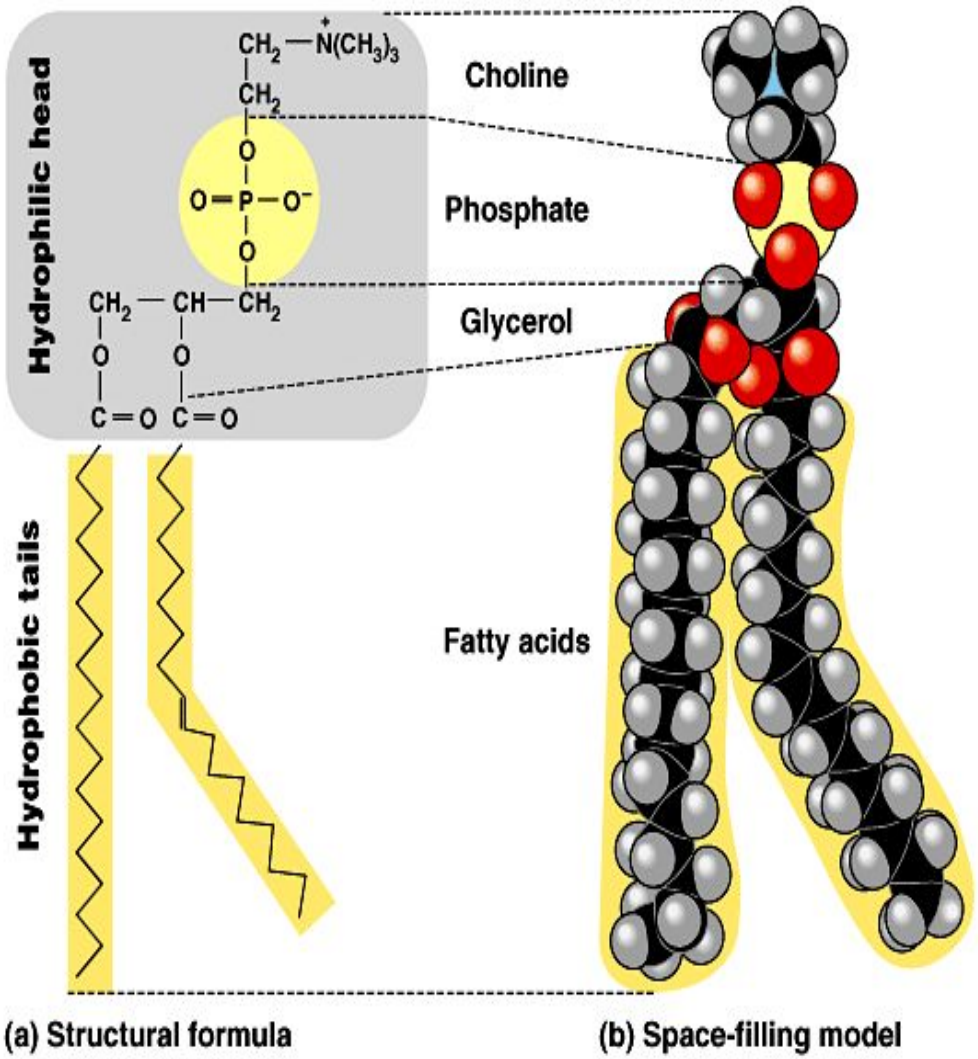
# “The edge of life”

- The plasma membrane is the boundary that separates the living cell from its surroundings and controls traffic into and out of the cell

# Fluid mosaic model



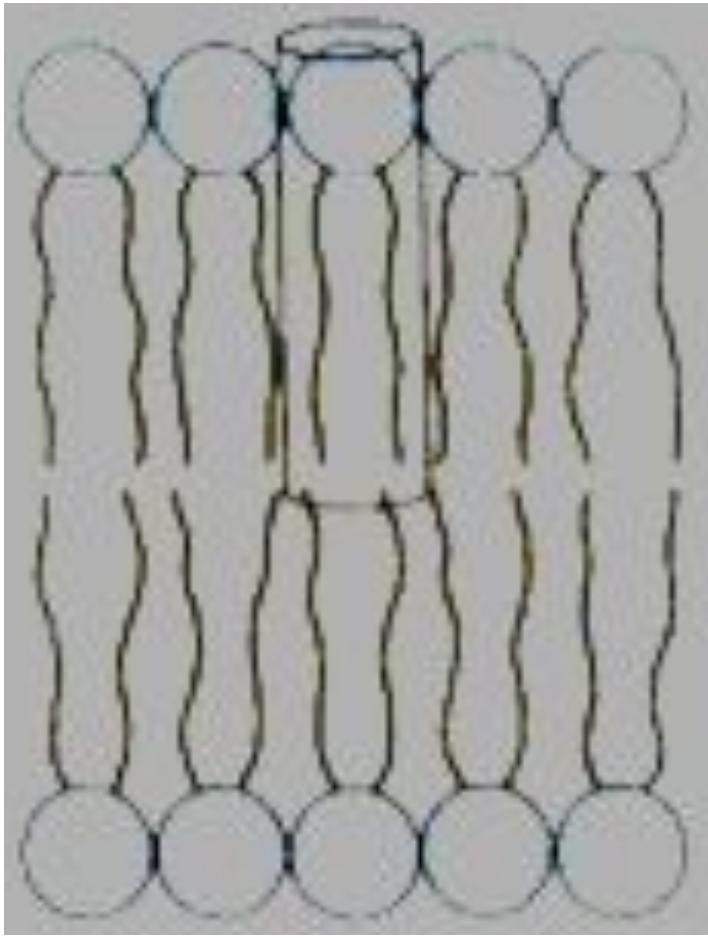
# Phospholipids (recall from Biomolecules)




- One alcohol group of glycerol bonds to phosphoric acid; the other two to fatty acids
- Phosphoric head is polar and hydrophilic
- The 2 fatty acid tails are hydrophobic.

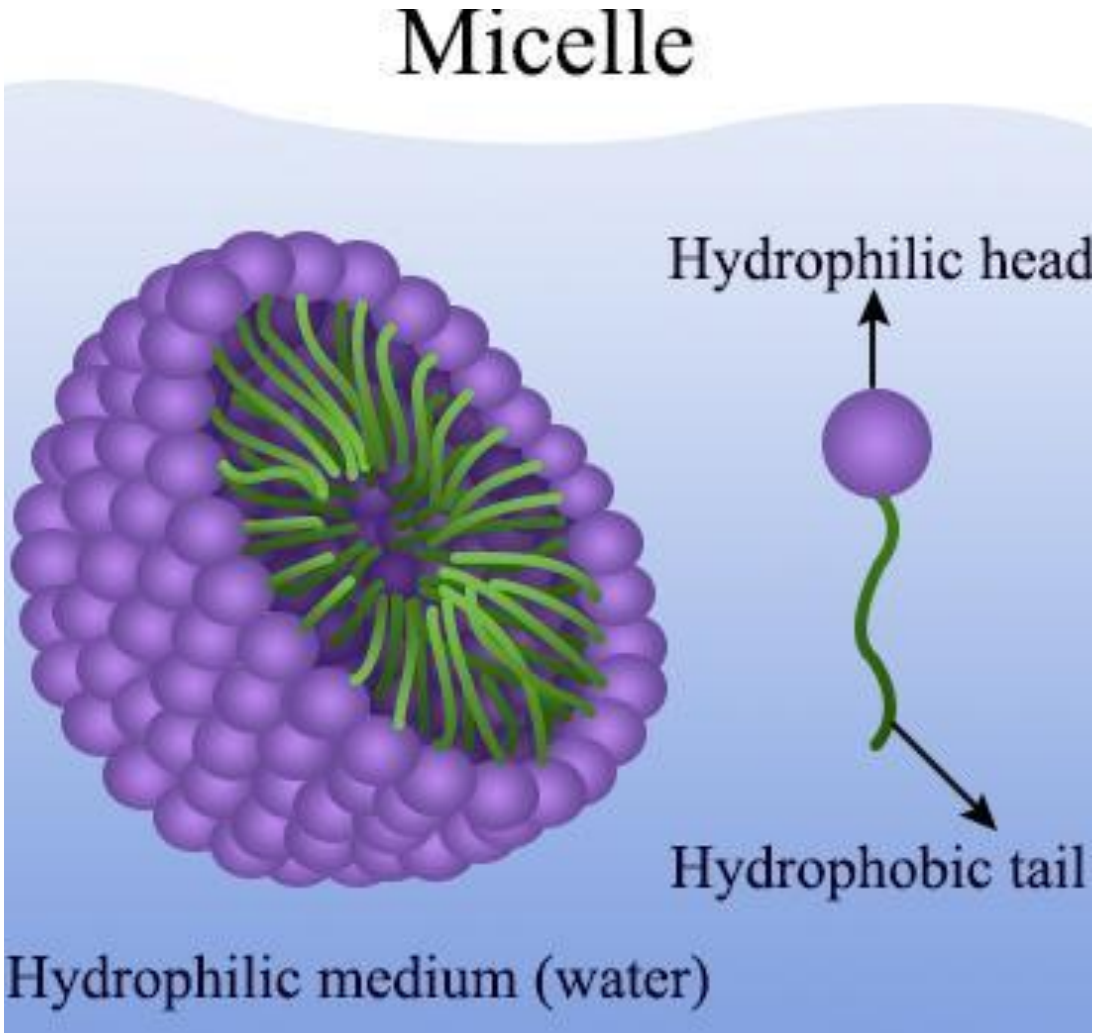
# Phospholipid bilayer

- Composed of two lipid layers that contain **hydrophilic** heads and **hydrophobic** tails
- **Amphipathic**: able to both attract and repel water
- If layered onto water, phospholipids line up so that their polar heads are next to water and their hydrophobic chains are protected from water internally



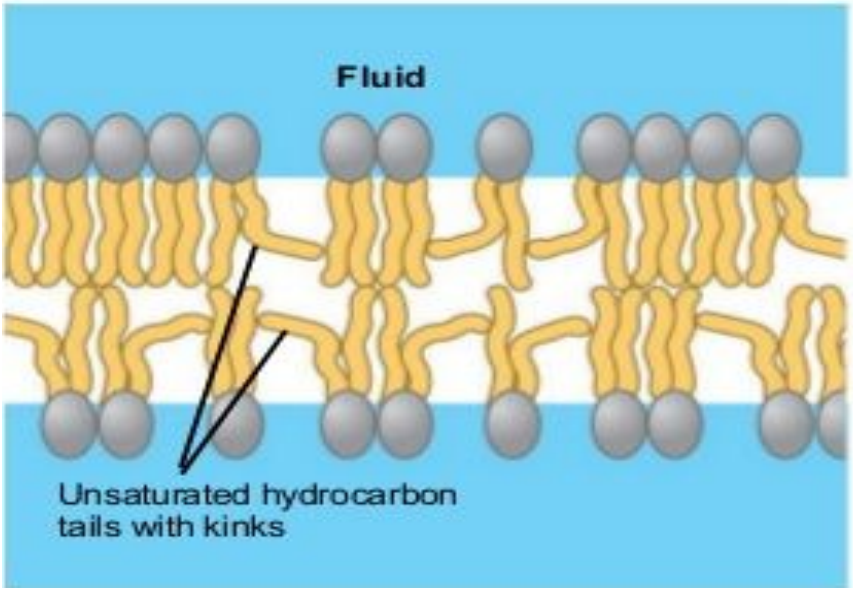
**Phospholipid bilayer**

# Phospholipid bilayer is amphipathic

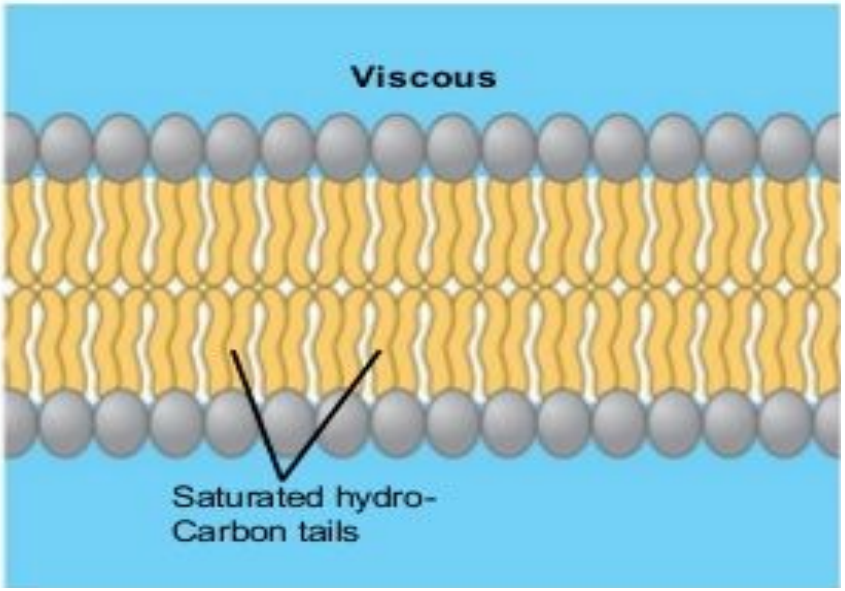


# Membrane fluidity

- Membrane is fluid in nature
- The type of hydrocarbon (fatty acid) tails in phospholipids affects the fluidity of the plasma membrane



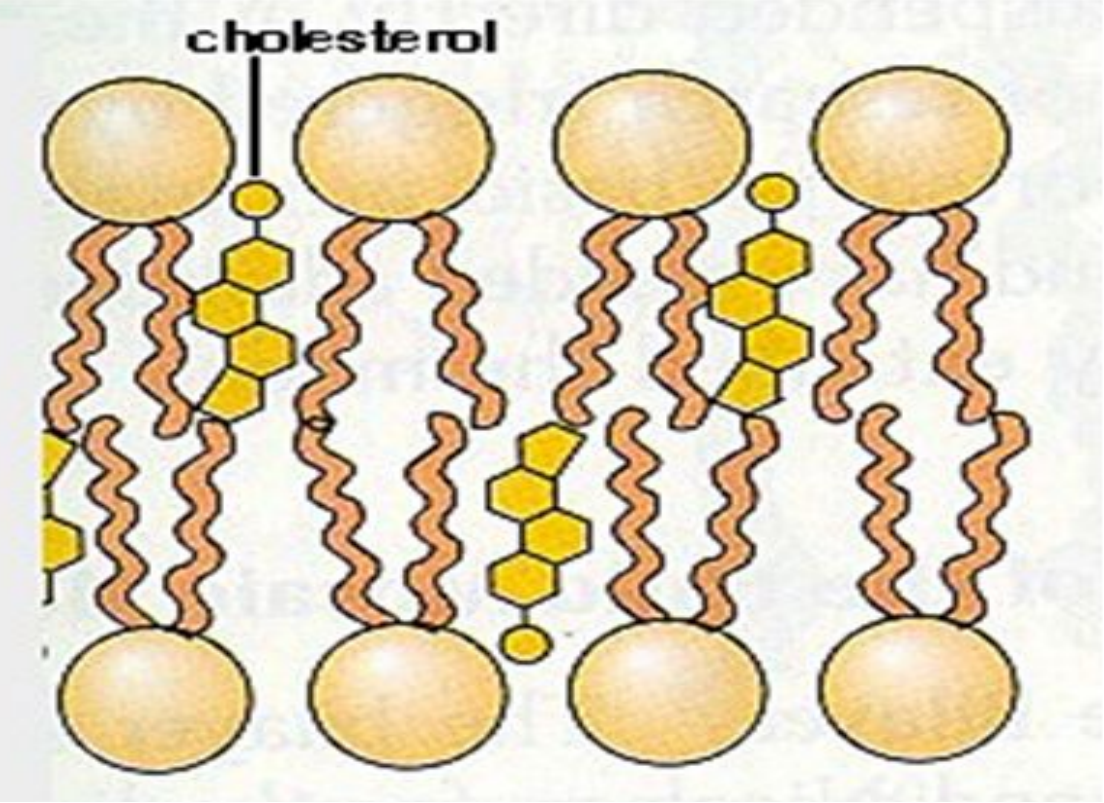

Unsaturated tails prevent packing, enhance fluidity




Saturated tails pack together, increase viscosity

# Membrane fluidity

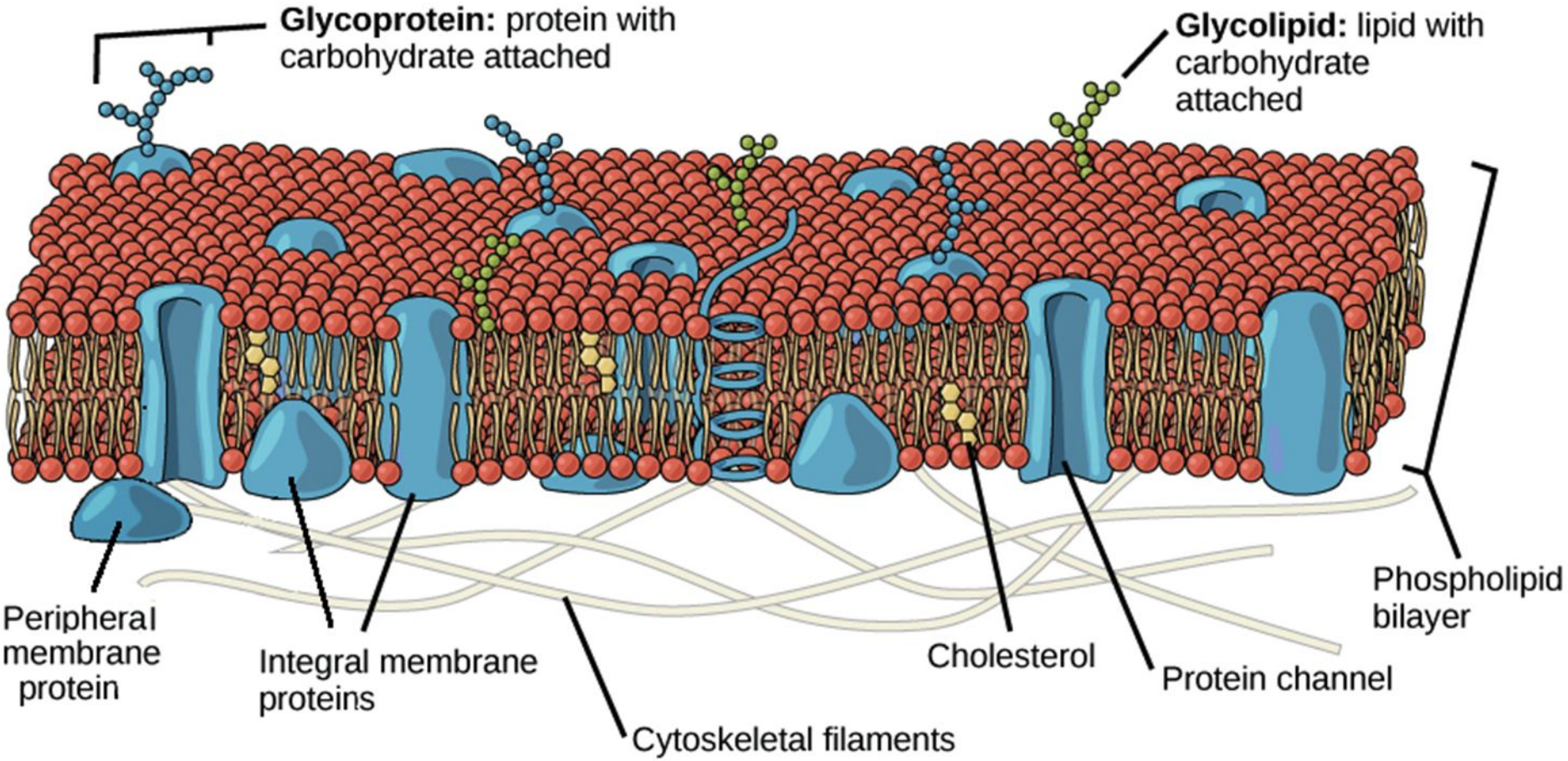
- **Cholesterol** -plays an important role in membrane fluidity within a range of physiological temperatures.
- Warm temperature – restrains movement
- Cool temperature - maintains fluidity by preventing tight packing.



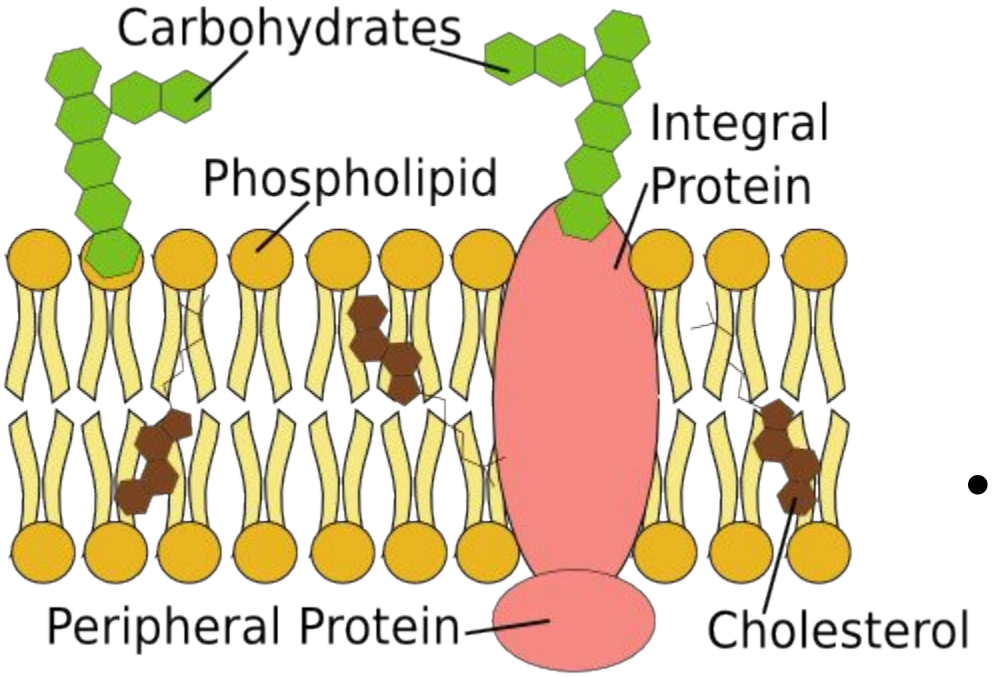
# Membrane proteins

- There are two major populations of membrane proteins
- **Integral** – transmembrane proteins that span the membrane.
- **Peripheral proteins**- not embedded in the lipid bilayer; are loosely bound to the surface of the membrane

# Fluid mosaic model



# Glycocalyx



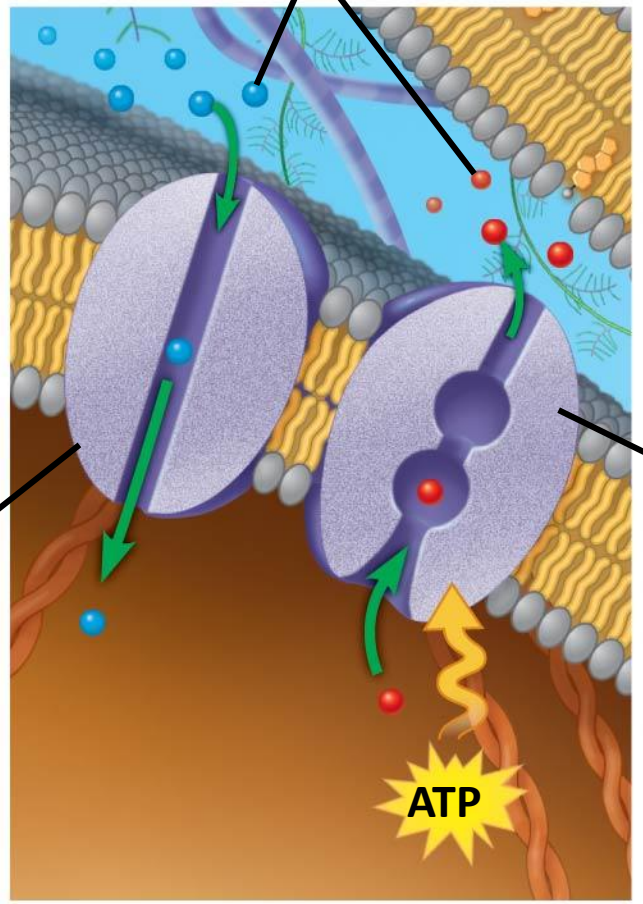

- Carbohydrates attached to membrane lipids or proteins also referred to as **glycolipids** or **glycoproteins**, respectively

- Provide protection of the membrane and also cell recognition and attachment.

# Function of membrane proteins

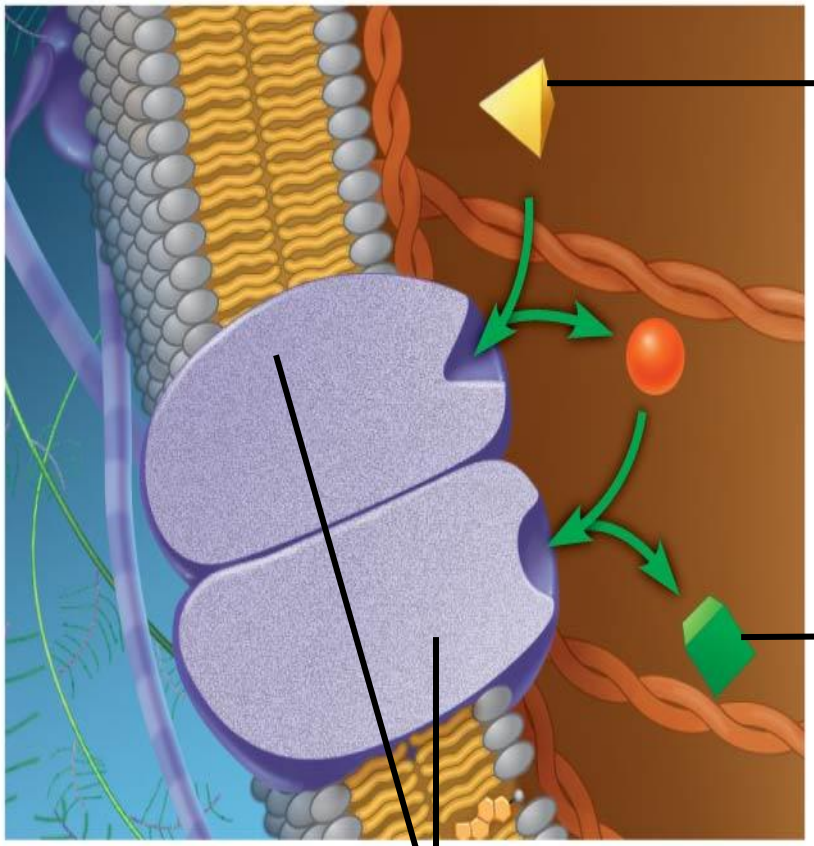
## Transport proteins

- Allow specific ions or molecules to enter or exit the cell.
- Ion channels (can be gated or always open)
- Carrier proteins



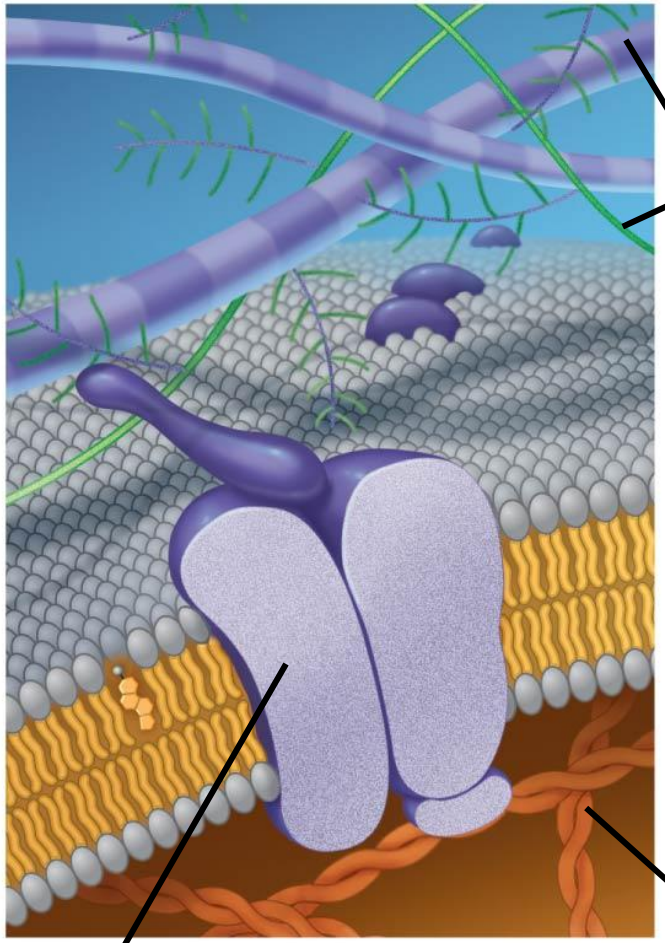
# Enzymes

- Some membrane proteins are enzymes.
- Enzymes may be grouped to carry out reactions in sequence.

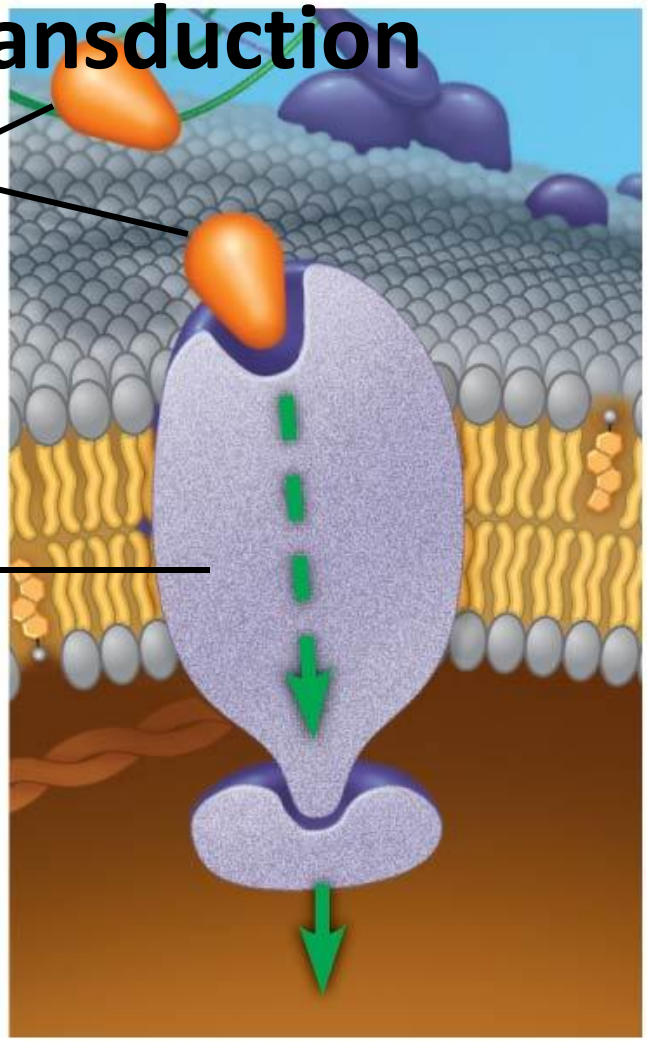


# Attachment Proteins

- Attach to the extracellular matrix and cytoskeleton.
- Help support the membrane.
- Maintain cell shape and stability.



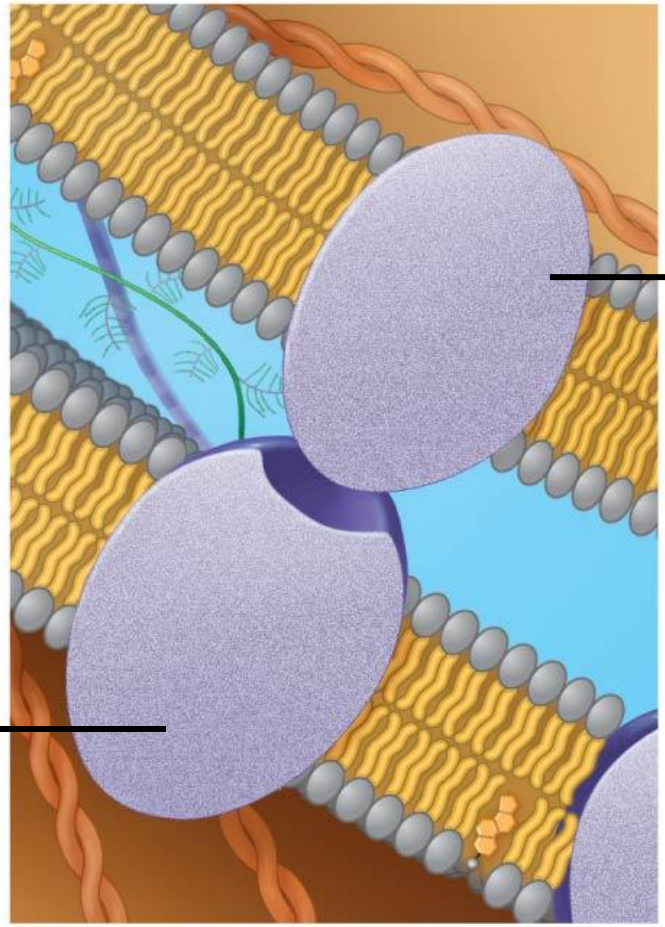
# Receptor Proteins/ Signal transduction




- Signalling molecules bind to receptor proteins.
- Receptor proteins relay the message by activating other molecules inside the cell.

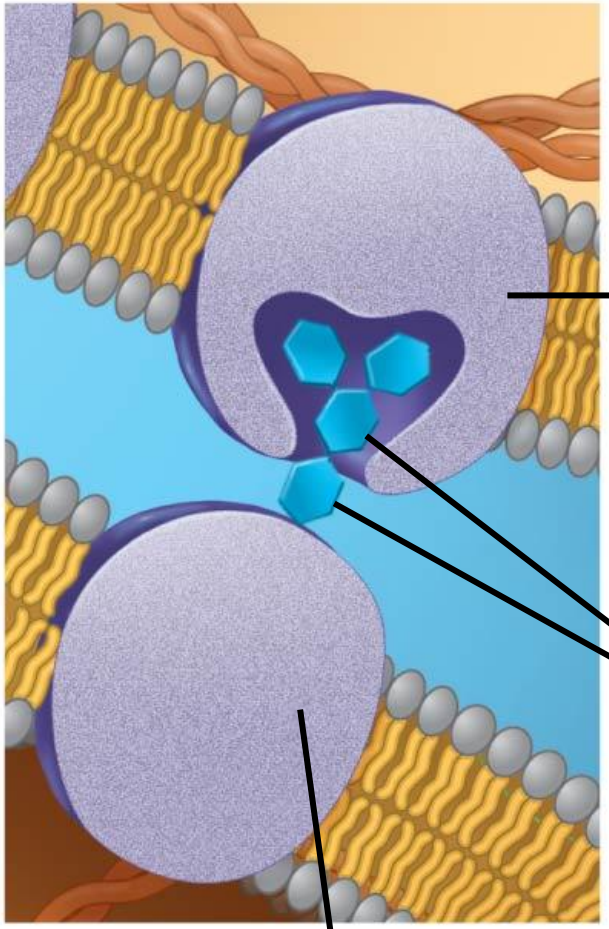
# Junction Proteins

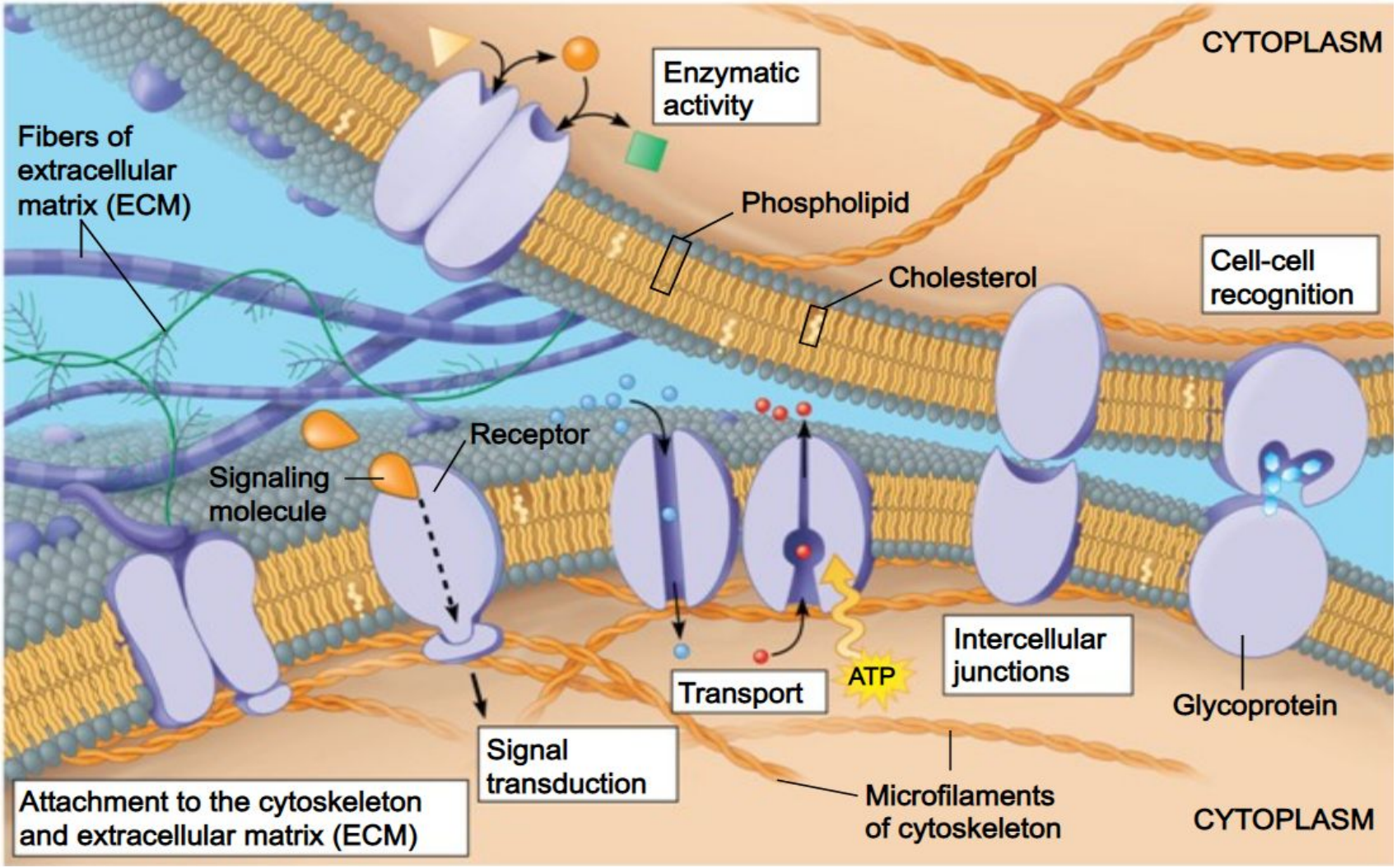
- Adjacent cells may be joined together by anchoring, gap or tight junctions



# Glycoproteins

- Some glycoproteins serve as identification tags recognized by membrane proteins of other cells e.g. in HIV infection.




CYTOPLASM
Enzymatic activity
Fibers of extracellular matrix (ECM)
Phospholipid
Cholesterol
Cell-cell recognition
Receptor
Signaling molecule
Intercellular junctions
Transport
ATP
Glycoprotein
Signal transduction
Attachment to the cytoskeleton and extracellular matrix (ECM)
Microfilaments of cytoskeleton
CYTOPLASM

# Functions of membrane proteins

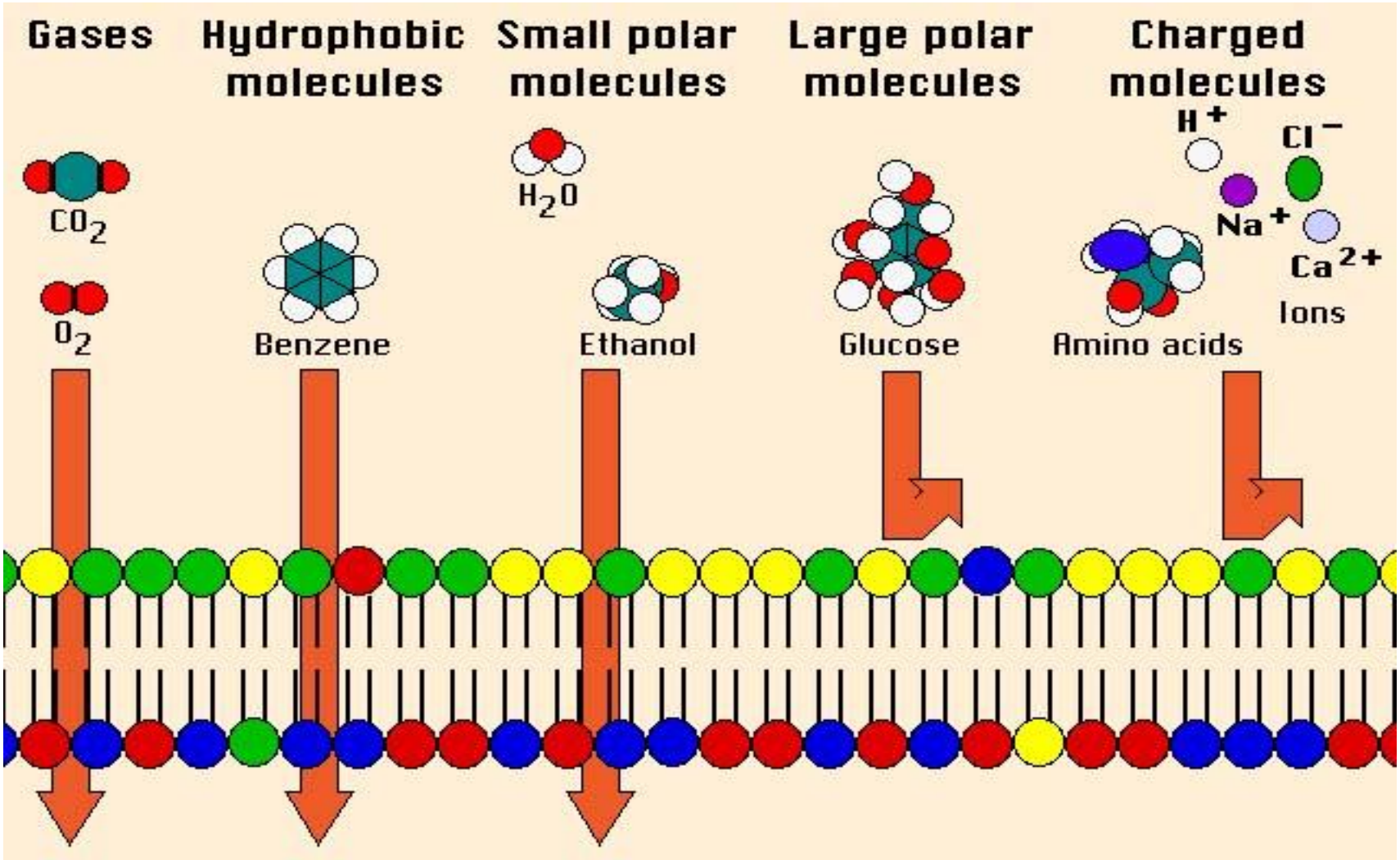
- **NB!!** A single cell may have surface membrane proteins that carry out multiple functions e.g. transport, enzymatic activity or attachment to a neighbouring cell.

- Therefore the membrane is not only structurally mosaic but also **functionally mosaic.**

# Membrane is semi-permeable

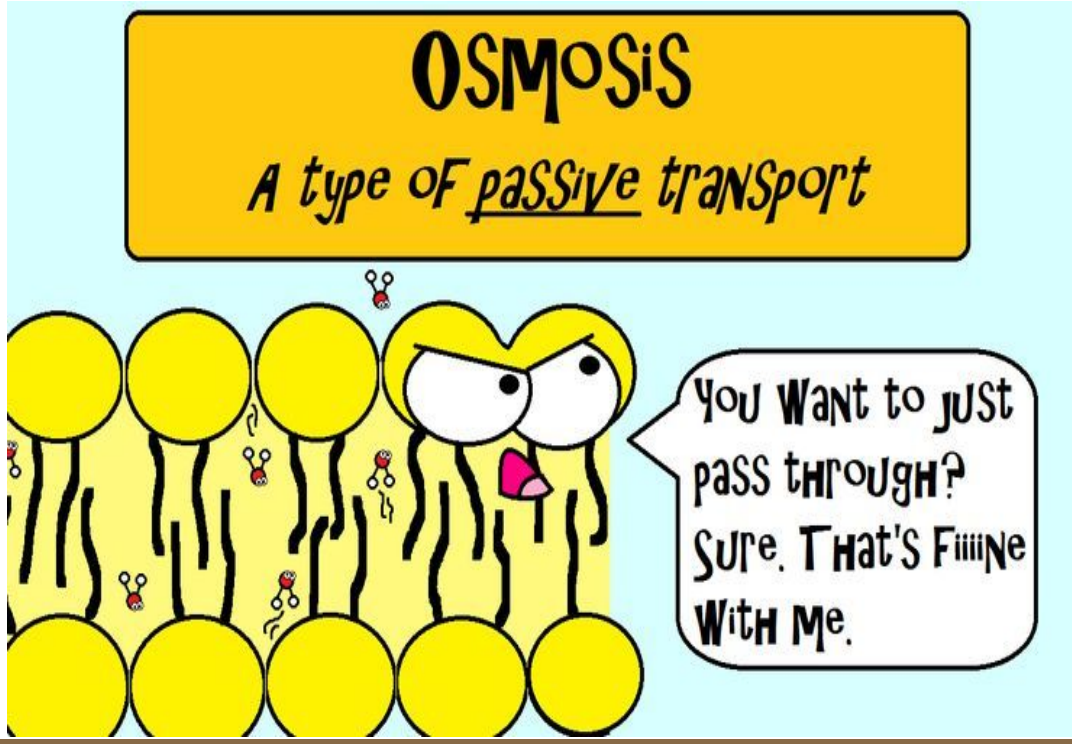
- Membranes are **semi-permeable** (also called **selectively permeable**) – some molecules can pass through them easily, while others cannot
- The ability of a molecule to pass through the membrane depends on its **size** and **polarity**

# Permeability of the Cell Membrane



# Modes of transport across the membrane

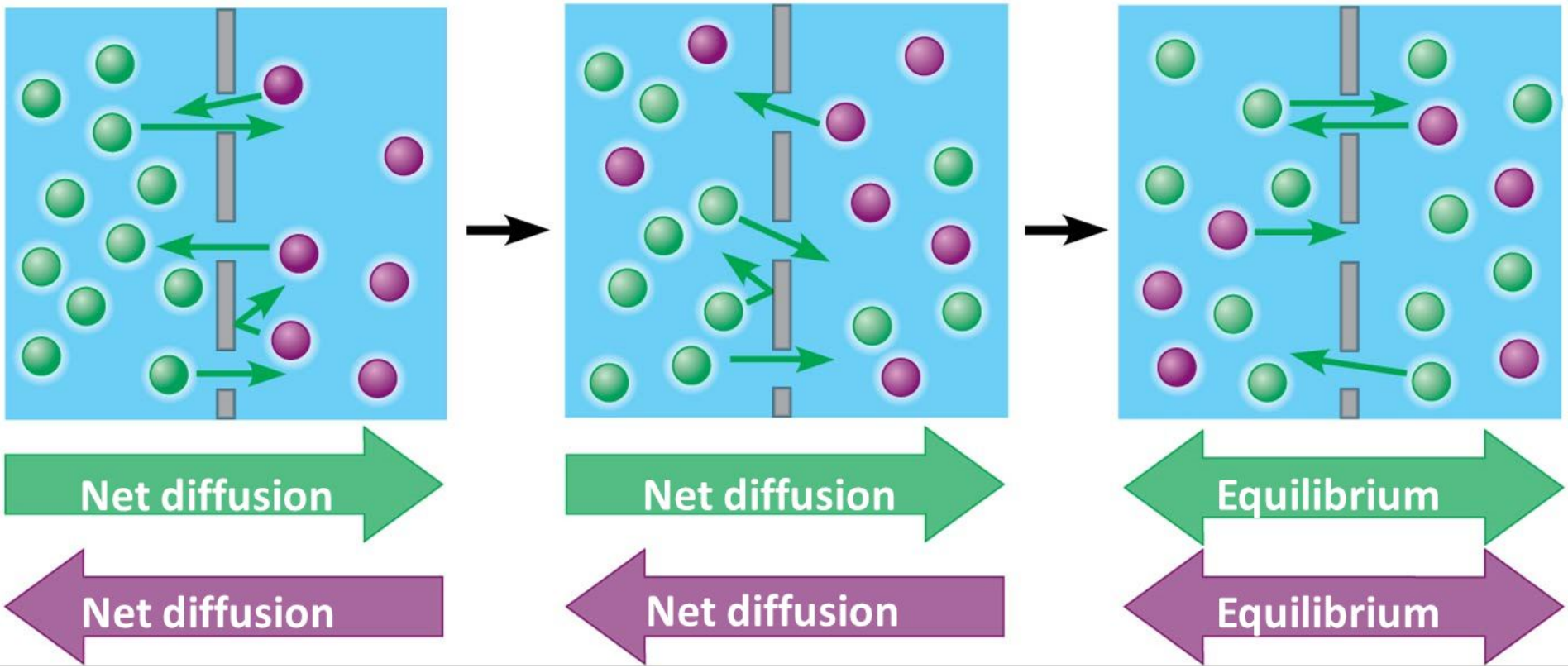
- **Passive transport**: involves movement of substance down a **concentration gradient** with no use of energy
  - Simple diffusion
  - Osmosis
  - Facilitated diffusion.



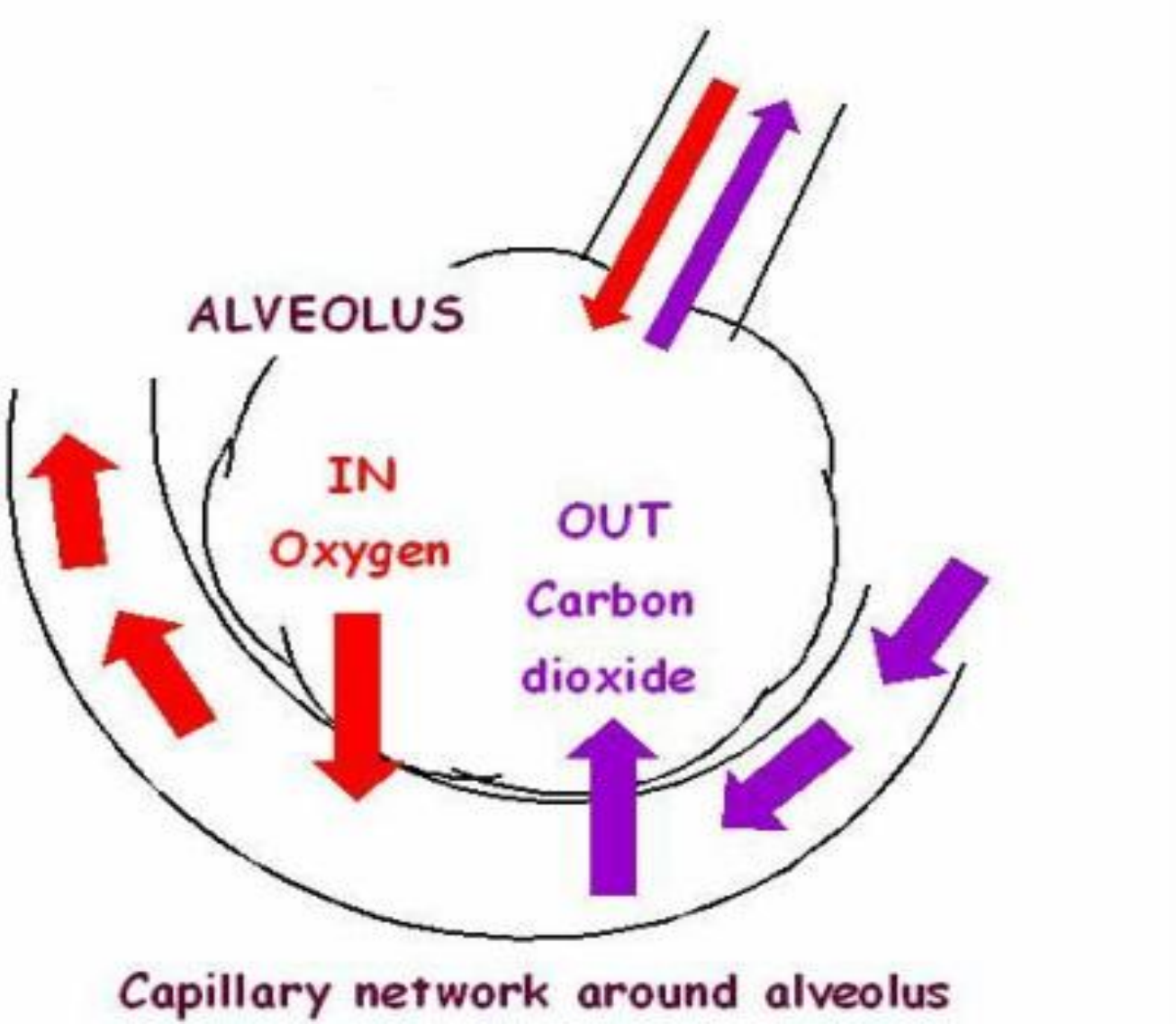
# Diffusion

- Simple diffusion
  - the **passive** movement of molecules from a higher to a lower concentration until *equilibrium* is reached.
  - Gases move through plasma membranes by diffusion.
- Osmosis– A special case of diffusion.
- Facilitated diffusion- carrier proteins for transport of specific molecules that cannot move through the membrane by themselves

# Passive transport: diffusion of two types of molecules across a membrane

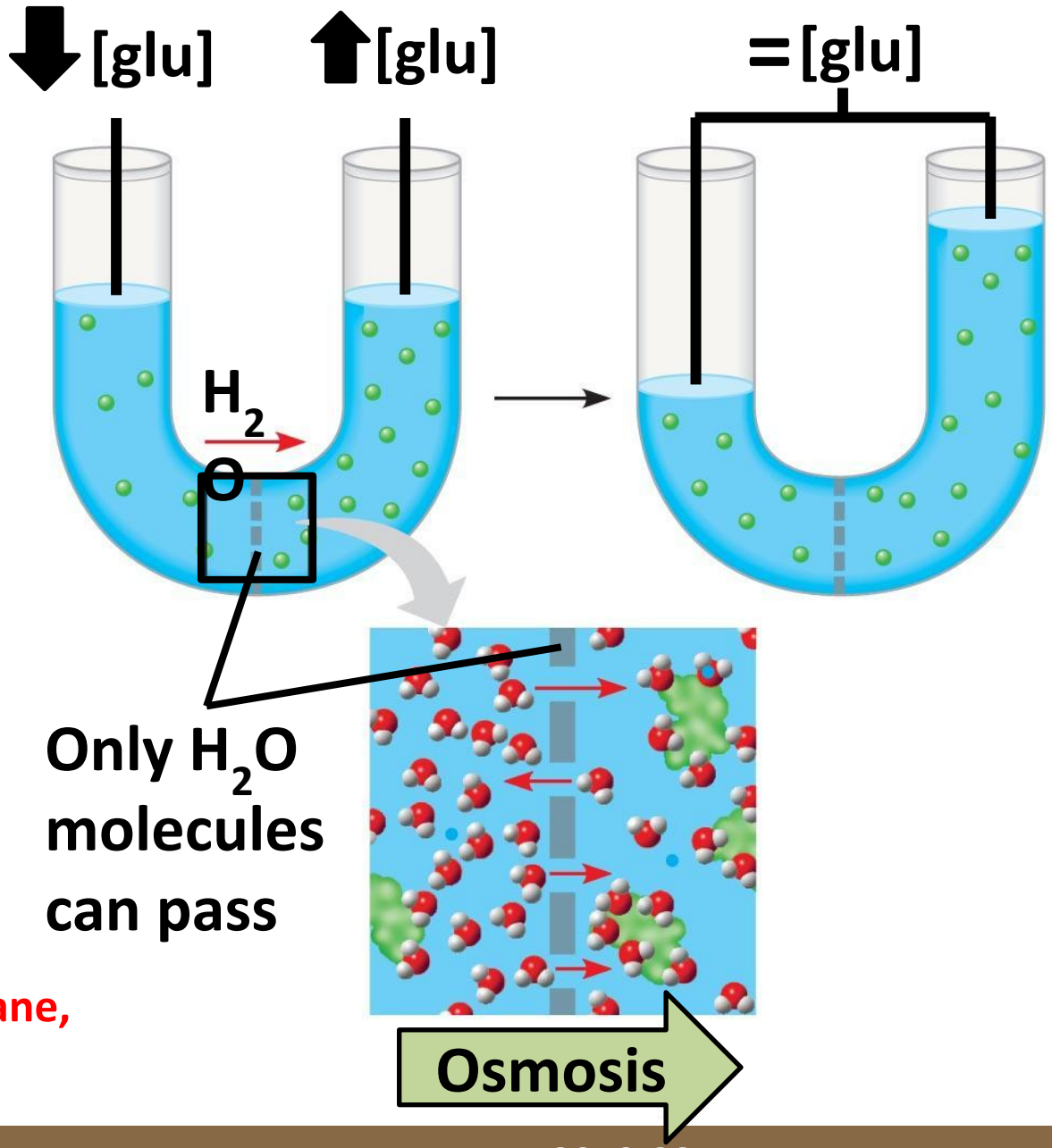


# Gas exchange in lungs by diffusion



# Osmosis

Diffusion of water across a differentially or selectively permeable membrane due to concentration differences.




**Water will cross the membrane,**

# Water balance between cells and their surroundings

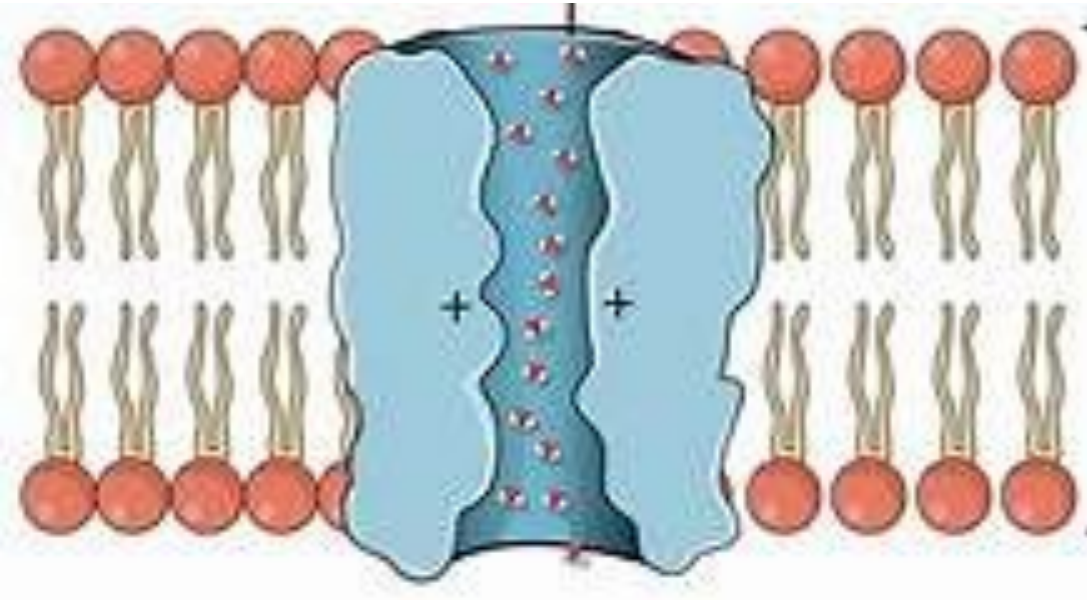
- **Tonicity** - describes the ability of a surrounding solution to cause a cell to gain or lose water.
- The tonicity of a solution mainly depends on its concentration of solutes relative to the concentration of solutes inside the cell.

# Facilitated diffusion

- Polar or charged particles cross the membrane with the help of carrier proteins e.g. water re-absorption by the kidneys or glucose and amino acids uptake by cells from the blood.
- It does not require energy – the diffusion of the molecules is **facilitated**
- Relies on the concentration gradient
- NB! The proteins are specific for the substances they carry
- https://www.youtube.com/watch?v=IX-kLh34KcQ

# Facilitation of osmosis

- Because water is polar, its diffusion through a membrane's hydrophobic interior is relatively slow.
- The very rapid diffusion of water into and out of certain cells is made possible by a protein channel (**aquaporin**).



# Active transport

- Substances are transported against a concentration gradient with use of energy
  - Primary and secondary active transport
  - Endocytosis and exocytosis.

# Active transport

- **Primary active-** directly utilizes energy from ATP hydrolysis e.g. the $Na^+/K^+$ ATPase pump

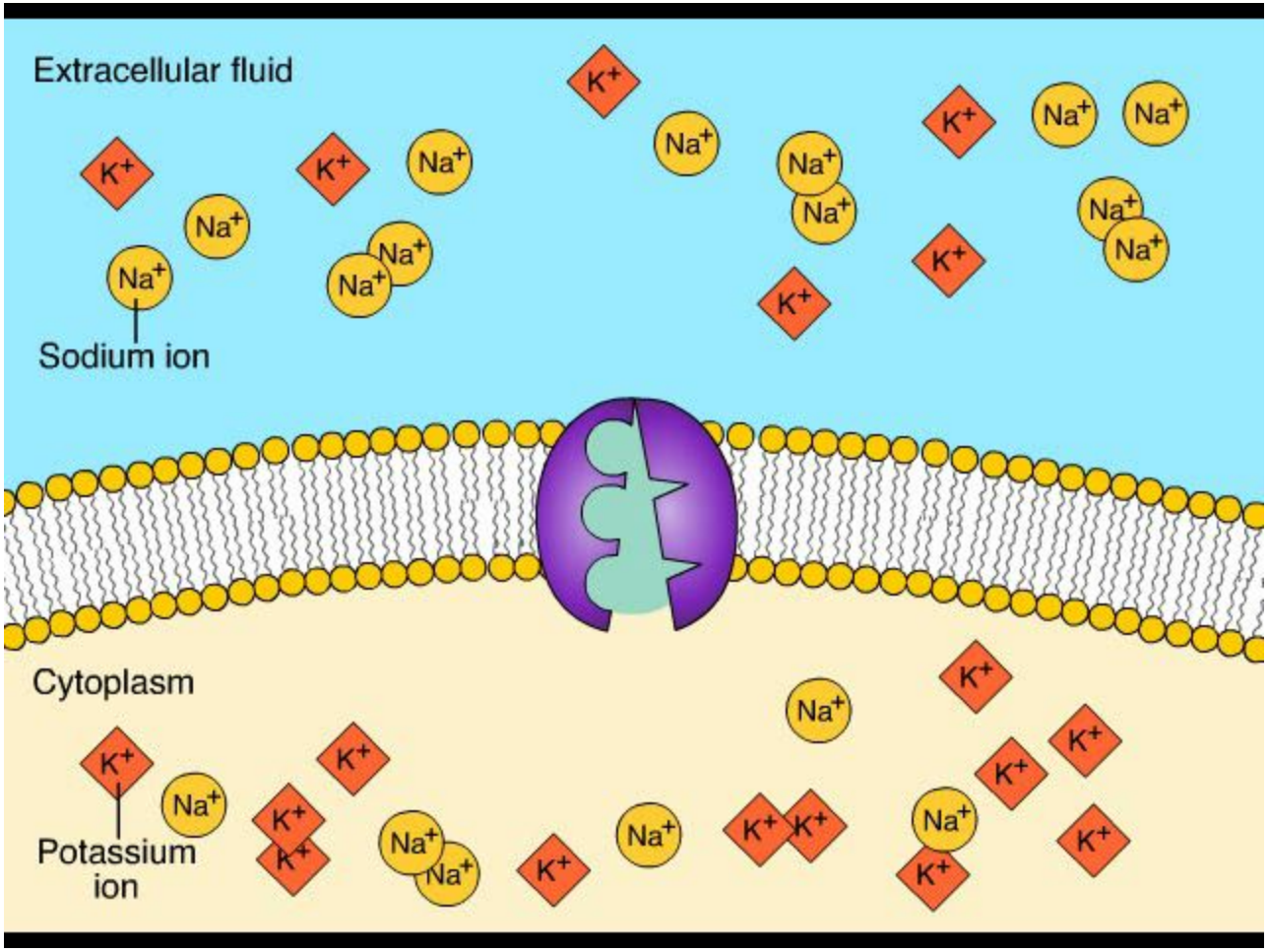
- **Secondary active-** uses energy contained in concentration gradients of another substance to transport a molecule against its concentration gradient
  - Does NOT involve ATP directly

  e.g. sodium glucose co-transport in the gut

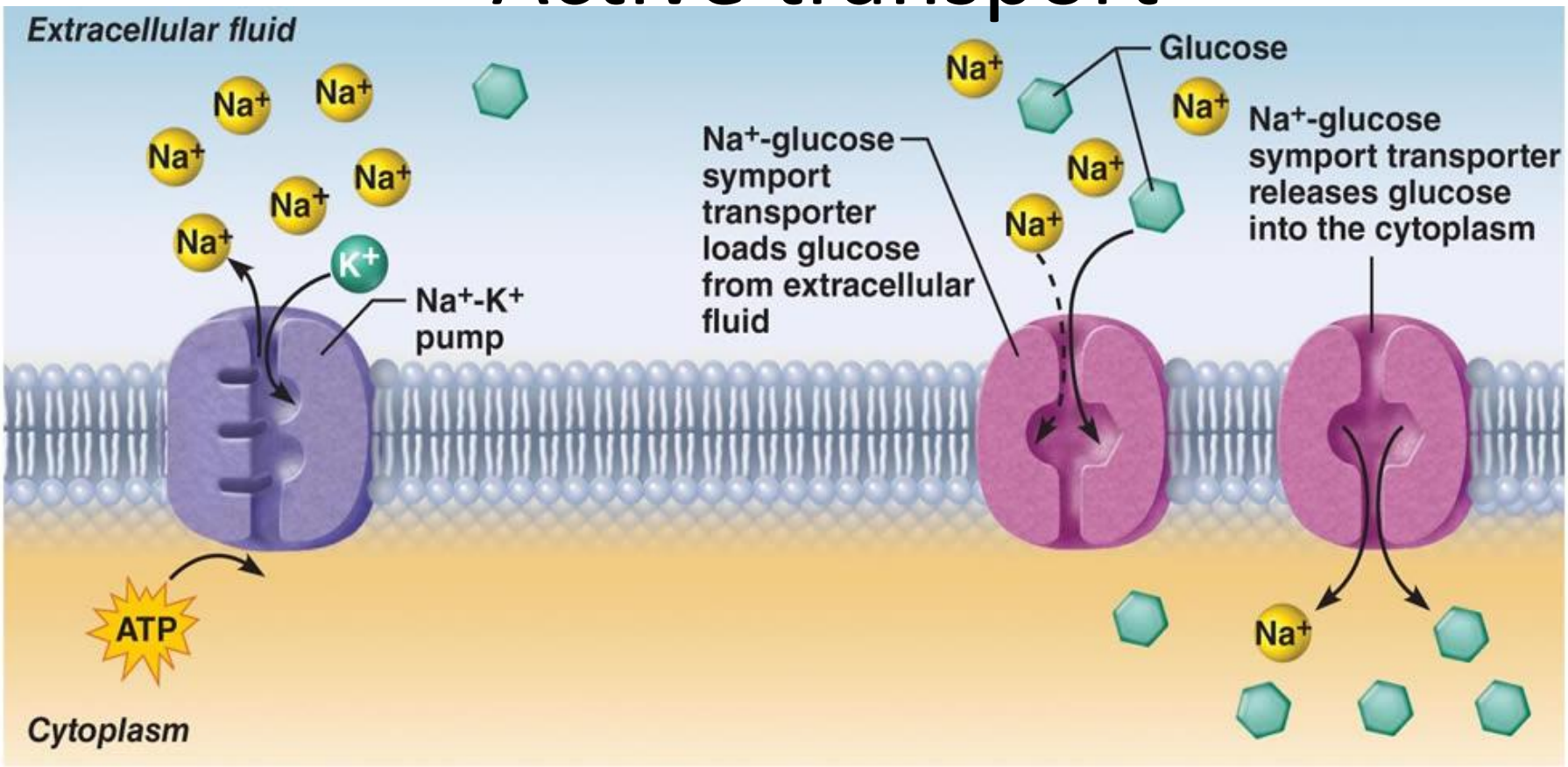
# $Na^+/K^+$-ATPase pump

- Pumps 3 $Na^+$ out and 2 $K^+$ in against their concentration gradients.
- Creates a voltage across the membrane with negative inside and positive outside
- Important across neuronal membranes for nerve impulse transmission

# Animation: Active Transport



# Active transport




**(1) Primary active transport**
The ATP-driven $Na^+$-$K^+$ pump stores energy by creating a steep concentration gradient for $Na^+$ entry into the cell.

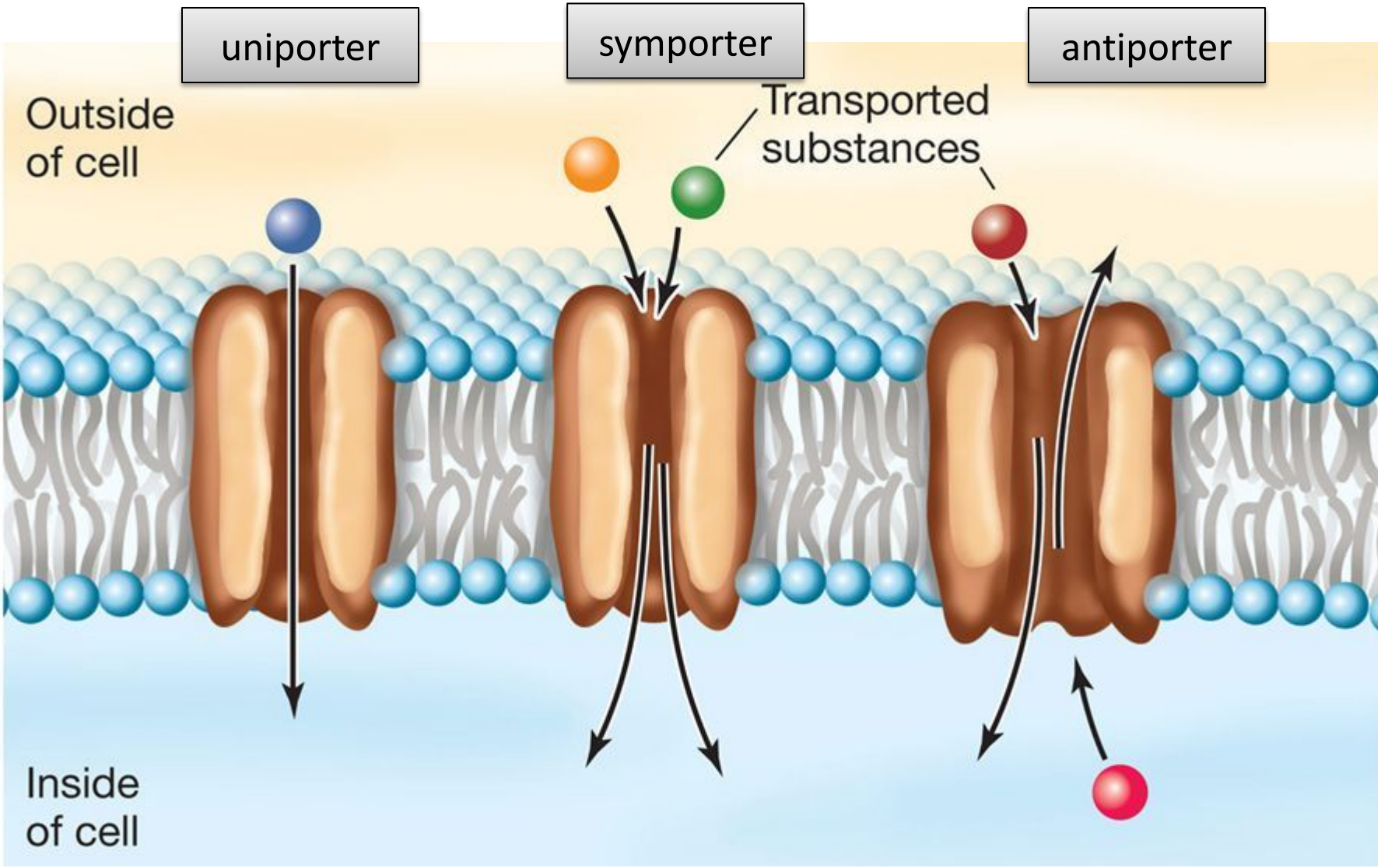
**(2) Secondary active transport**
As $Na^+$ diffuses back across the membrane through a membrane cotransporter protein, it drives glucose against its concentration gradient into the cell.

https://www.youtube.com/watch?v=nYC3_3hb54Q

# Active transport is directional

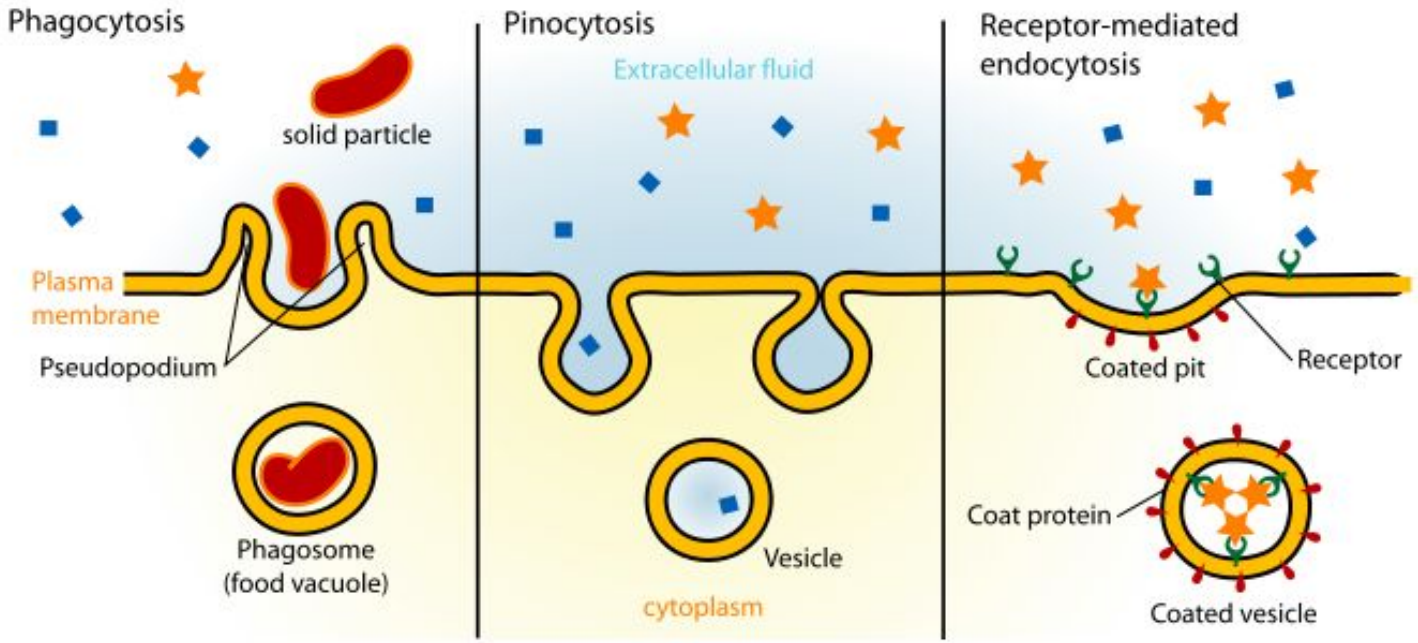
- A **uniporter** moves a single substance in one direction.
- A **symporter** moves two substances in the same direction.
- An **antiporter** moves two substances in opposite directions, one into the cell and the other out of the cell.

# Active transport is directional



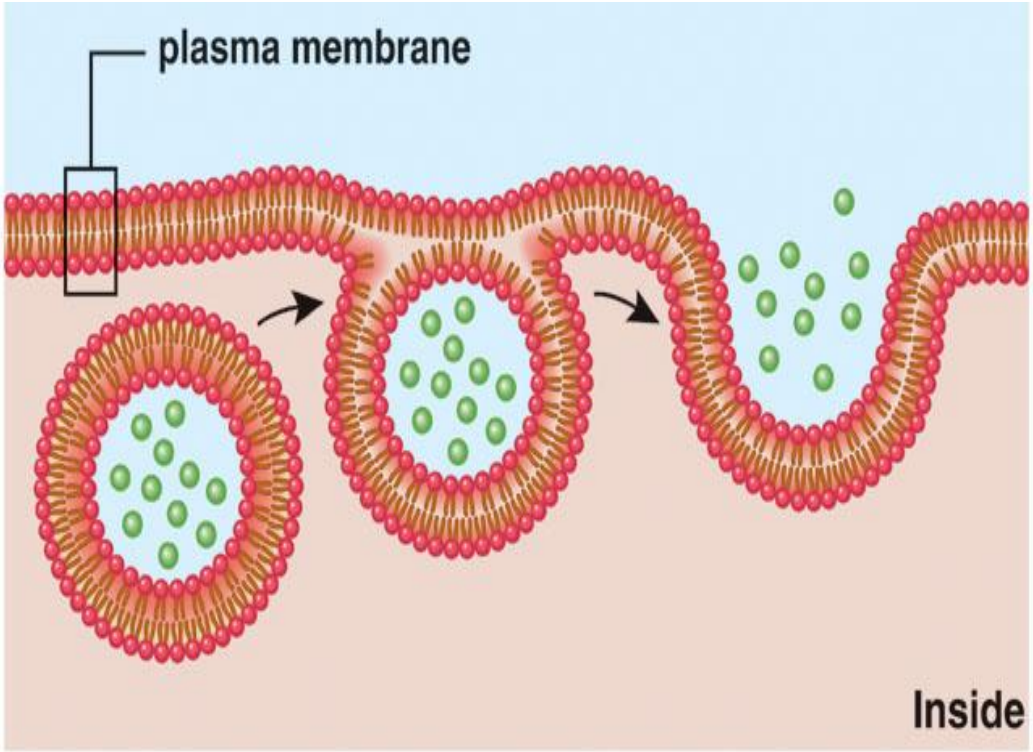
# Endocytosis

- **Phagocytosis**— "Cell eating"
  - Process is specific e.g. white blood cells engulfing bacteria
- **Pinocytosis**– "Cell drinking/fluid endocytosis"
  - Non-specific e.g. in the re-absorption of extracellular fluid
- **Receptor-mediated endocytosis**-specific particles, recognition.



# Exocytosis

- Cellular secretion
  - e.g. in the transport of bulky materials such as proteins or carbohydrates
  - Vesicles bulging off from the Golgi apparatus



# Summary

- Membrane is fluid and mosaic in nature and fluidity varies with temperature and lipid saturation
- It is selectively permeable therefore not all things can pass through freely
- Depending on polarity, size and charge substances can cross passively or actively
- Active transport uses energy of some kind to move substances against their concentration gradients; passive transport moves substances along their concentration gradients
- The plasma membrane is important in osmoregulation/ tonicity
- Additional links:
- https://www.youtube.com/watch?v=LKN5sq5dtW4
- https://www.youtube.com/watch?v=2-icEADP0J4
- https://www.youtube.com/watch?v=xweYA-IJTqs

# Glossary

- **Prokaryotic cell:** a cell that lacks all membrane-bound organelles
- **Eukaryotic cell:** a cell that has a nucleus and other membrane-bound organelles; more complex than a prokaryotic cell
- **Organelle:** "little organ" – a structure that performs a specific function in the cell
- **Nucleus (pl. nuclei):** a membrane bound organelle that holds the DNA of the cell
- **Cytoplasm:** the liquid content of the cell
- **Plasma membrane:** the boundary separating a cell from its environment
- **Integral protein:** a membrane-associated protein that is embedded in the lipid layer of the membrane
- **Peripheral protein :** a membrane-associated protein that is loosely associated with the surface of the membrane
- **Glycolipid:** a membrane phospholipid with a carbohydrate chain attached
- **Glycoprotein:** a membrane protein with a carbohydrate chain attached
- **Glycocalyx:** the combination of glycolipids and glycoproteins present in the outside half of the membrane
- **Semi-permeable:** a membrane (or barrier) that allows some substances to move through easily while not allowing other substances to move through at all
- **Passive transport:** movement of substance down a **concentration gradient** (from high concentration to low concentration) with no use of energy
- **Diffusion:** the **passive** movement of molecules from a higher to a lower concentration until the concentrations are equal
- **Osmosis:** Diffusion of water across a semi-permeable membrane due to concentration differences between the solutions
- **Facilitated diffusion:** Diffusion of polar or charged substances across the membrane with the help of carrier proteins
- **Tonicity:** the ability of a surrounding solution to cause a cell to gain or lose water
- **Aquaporin:** a protein channel that helps water move rapidly across the membrane
- **Active transport:** the movement of a substance against its concentration gradient using energy, either in the form of ATP **(primary transport)** or stored in the concentration gradient of another substance **(secondary transport)**
- **Uniporter:** a transport protein that moves a single substance in one direction
- **Symporter:** a transport protein that moves two substances in the same direction
- **Antiporter:** a transport protein that moves two substances in opposite directions
- **Endocytosis:** large scale uptake of substances into the cell, it involves movement of the plasma membrane
- **Phagocytosis:** "cell eating", where the cell surrounds a large particle with membrane and takes it inside the cell
- **Pinocytosis:** "cell drinking", non-specific absorption of surrounding fluid by membrane movement
- **Receptor-mediated endocytosis:** endocytosis of specific particles, triggered by binding to cell membrane-bound receptors
- **Exocytosis:** cellular secretion, where cellular products are expelled from the cell into the surrounding fluid