Big Idea 2: Biological systems utilize free energy and molecular building blocks to grow, to reproduce and to maintain dynamic homeostasis.

Enduring understanding 2.B: Growth, reproduction and dynamic homeostasis require that cells create and maintain internal environments that are different from their external environments.

Essential knowledge 2.B.2: Growth and dynamic homeostasis are maintained by the constant movement of molecules across membranes.

a. Passive transport does not require the input of metabolic energy; the net movement of molecules is from high concentration to low concentration.

Evidence of student learning is a demonstrated understanding of each of the following:

1. Passive transport plays a primary role in the import of resources and the export of was

Let's review for a few slides...

EXCHANGING WITH THE ENVIRONMENT

- Molecules need to imported and exported across the membrane.
- Cells are filled with water and cells are surrounded by water.
  - Not pure water but rather a solution.
- Water is the medium that imports and exports molecules across the membrane.

Molecules need to imported and exported across the membrane.

FOR STARTERS

- Nutrients and oxygen need to be imported.
- Waste and carbon dioxide need to be exported.

Cells are filled with water and cells are surrounded by water.

- The inside of a cell is 70-95% water, more specifically called cytosol.
  - *The cytosol is a complex mixture of substances dissolved in water.*
- A unicellular organism is surrounded lives an aquatic environment.
- The cells of a multicellular organism are bathed in extracellular fluid.
  - *denotes all body fluid outside of cells*

Water is the medium that imports and exports molecules across the membrane.

- Life began in water.
- Life remains tied to water, organisms require water more than any other substance.
- Important cellular substances and molecules are dissolved in water.
- Water molecules participate in many chemical reactions necessary to sustain life.

OK, back to the topic

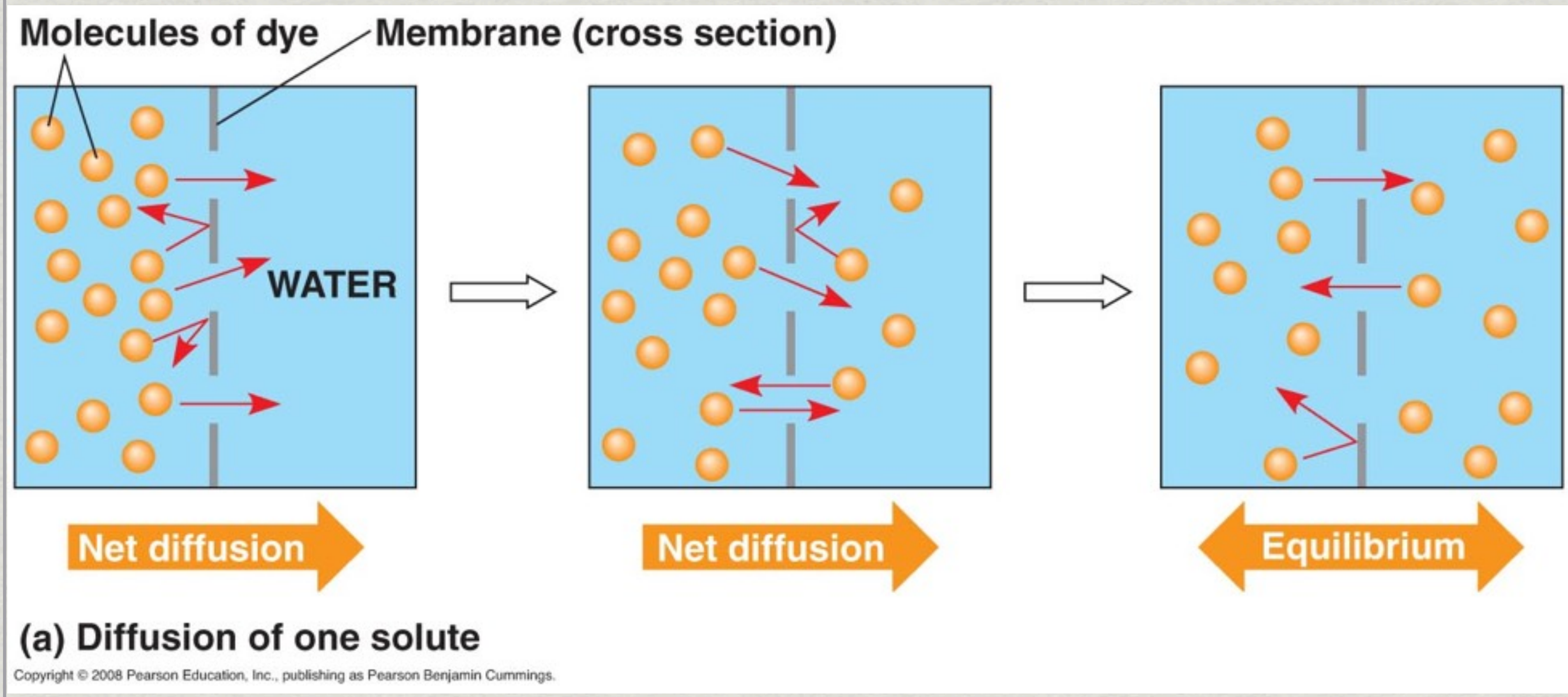
Cells Exchanging with Environment

- Cells can transport “relatively” anything across their plasma membrane.
- Cells have different mechanisms for transport depending on the nature of that which is being transported.
  - *Some substances move freely, with no input of energy.*
  - *Some substances can travel through the lipid bilayer.*

Some substances move freely, with no input of energy.

- **Passive transport** moves substances across membranes with no energy investment from the cell itself.
  - However energy is still required for any movement, where does it come from?
- The *Kinetic Molecular Theory* states that molecules are in constant random motion, these molecules therefore have their own energy.
- This motion results in **diffusion,** the movement of molecules from an area of high concentration to an area of low concentration. They “spread out”!

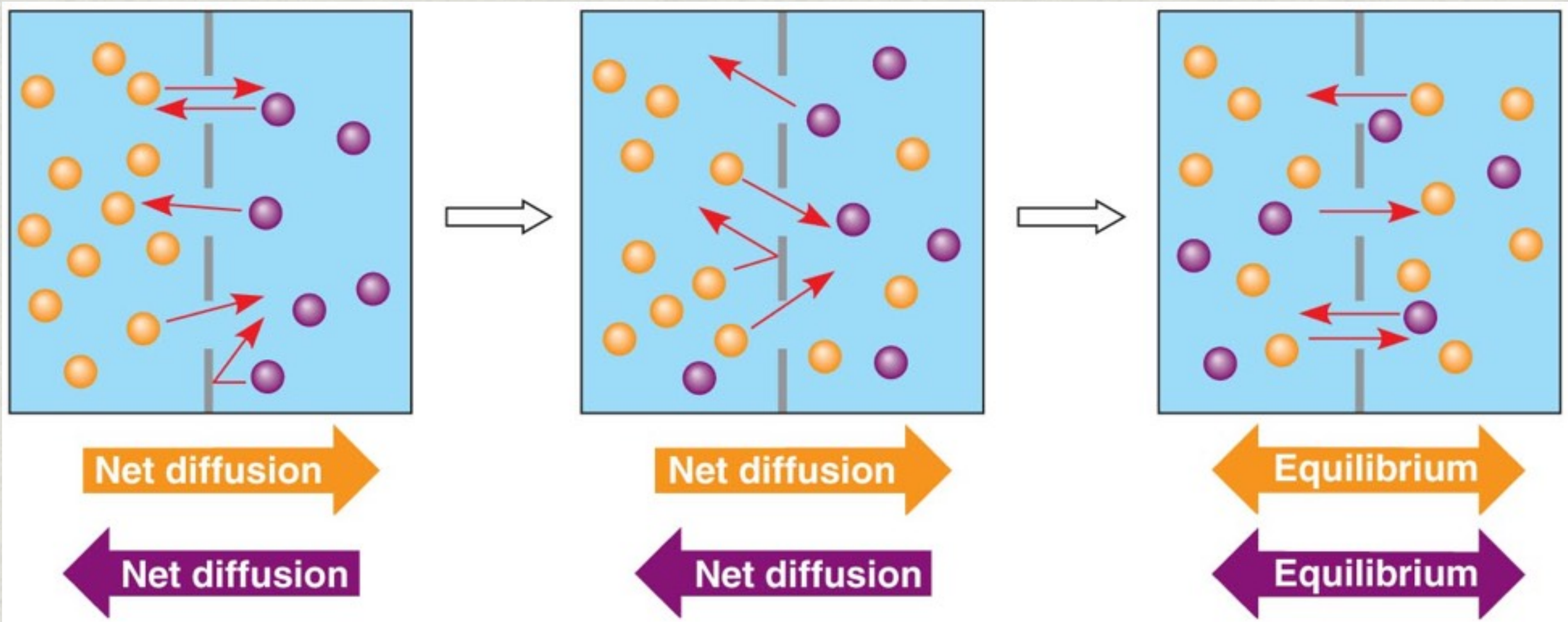
Diffusion



(a) Diffusion of one solute

THESE YELLOW CIRCLES REPRESENT EITHER SOLIDS OR GASES

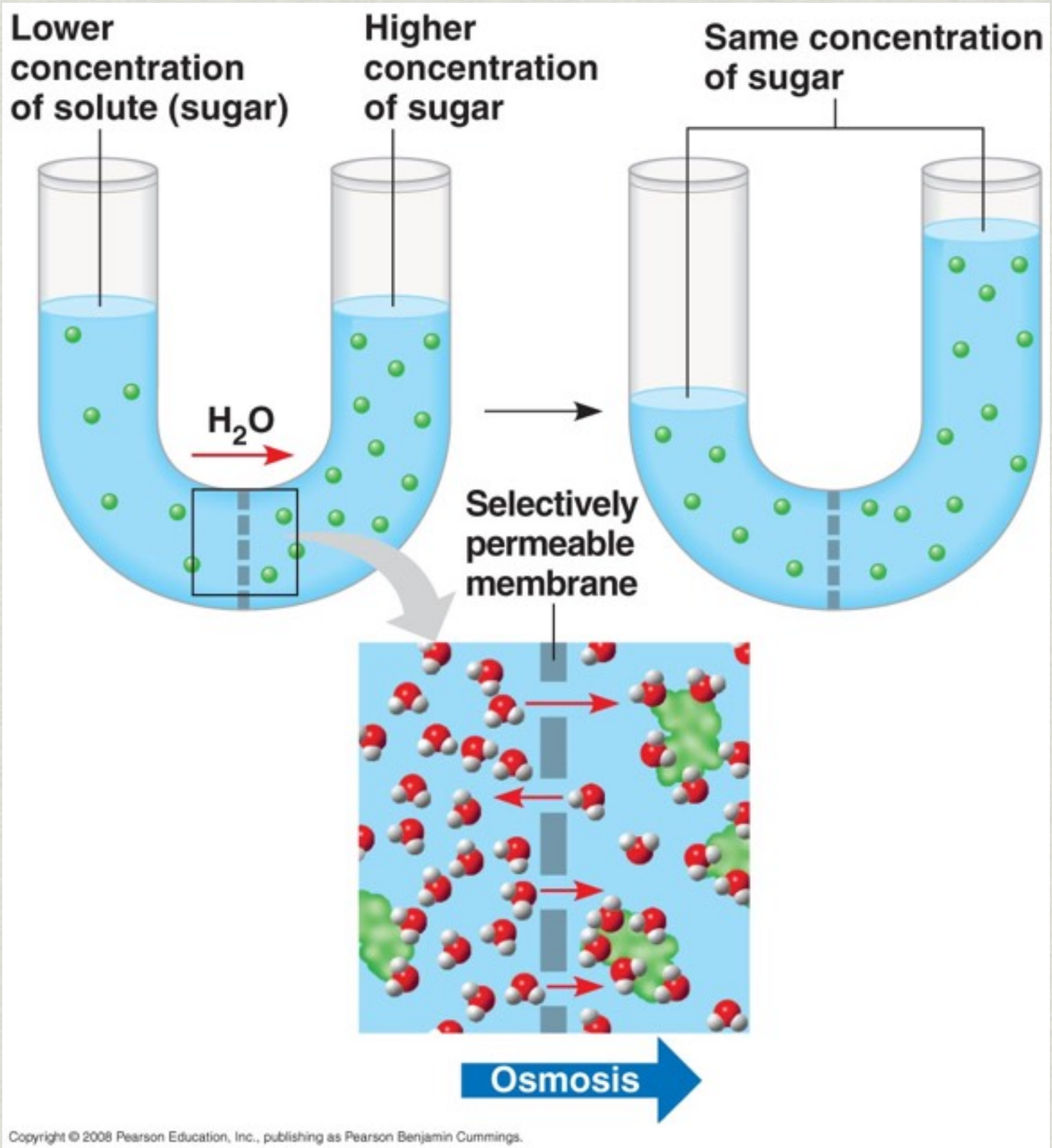
Diffusion



(b) Diffusion of two solutes

DIFFUSION OF SOLUTES IS INDEPENDENT OF OTHER SOLUTES

Diffusion of Water...



Osmosis

It has been said that water moves down its concentration gradient, from a high to low

However it is more accurate and helpful if focus on solute concentration and remember that water moves from a less concentrated side to a more concentrated side. OR That water moves from a low solute concentration to a high solute concentration.

Essential knowledge 2.B.2: Growth and dynamic homeostasis are maintained by the constant movement of molecules across membranes.

a. Passive transport does not require the input of metabolic energy; the net movement of molecules is from high concentration to low concentration.

Evidence of student learning is a demonstrated understanding of each of the following:

2. Membrane proteins play a role in facilitated diffusion of charged and polar molecules through a membrane.

To foster student understanding of this concept, instructors can choose an illustrative example such as:

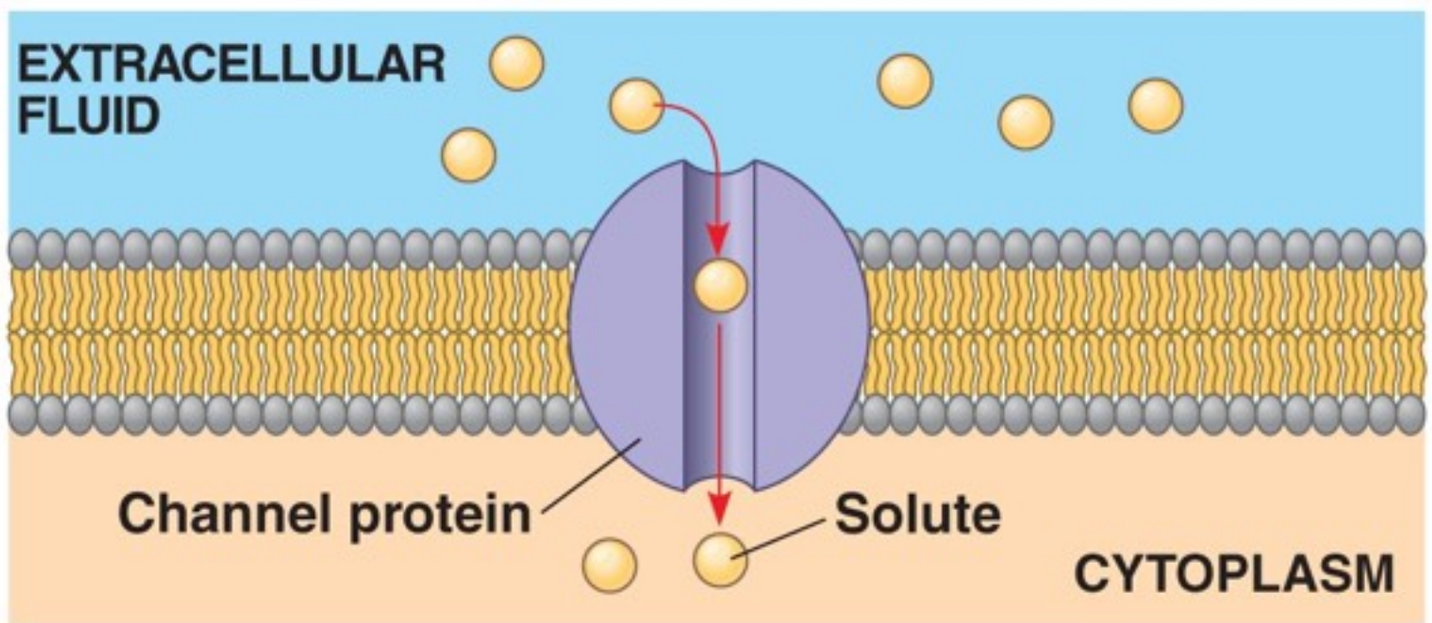
Glucose transport
Sodium/Potassium Transport

✘ There is no particular membrane protein that is required for teaching this concept.

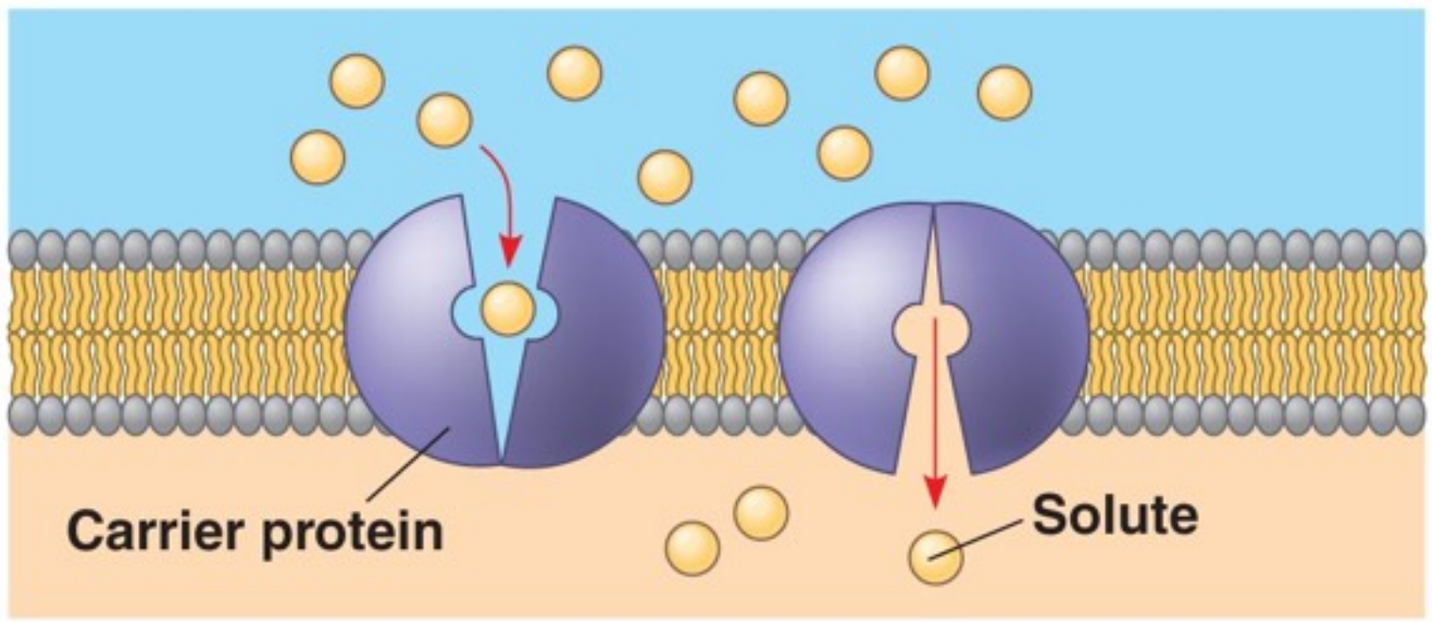
Cells Exchanging with Environment

- Cells can transport “relatively” anything across their plasma membrane.
- Cells have different mechanisms for transport depending on the nature of that which is being transported.
  - *Some substances move freely, with no input of energy.*
  - *Some substances can only travel through protein channels located in the membrane.*

Facilitated Diffusion



(a) A channel protein



(b) A carrier protein

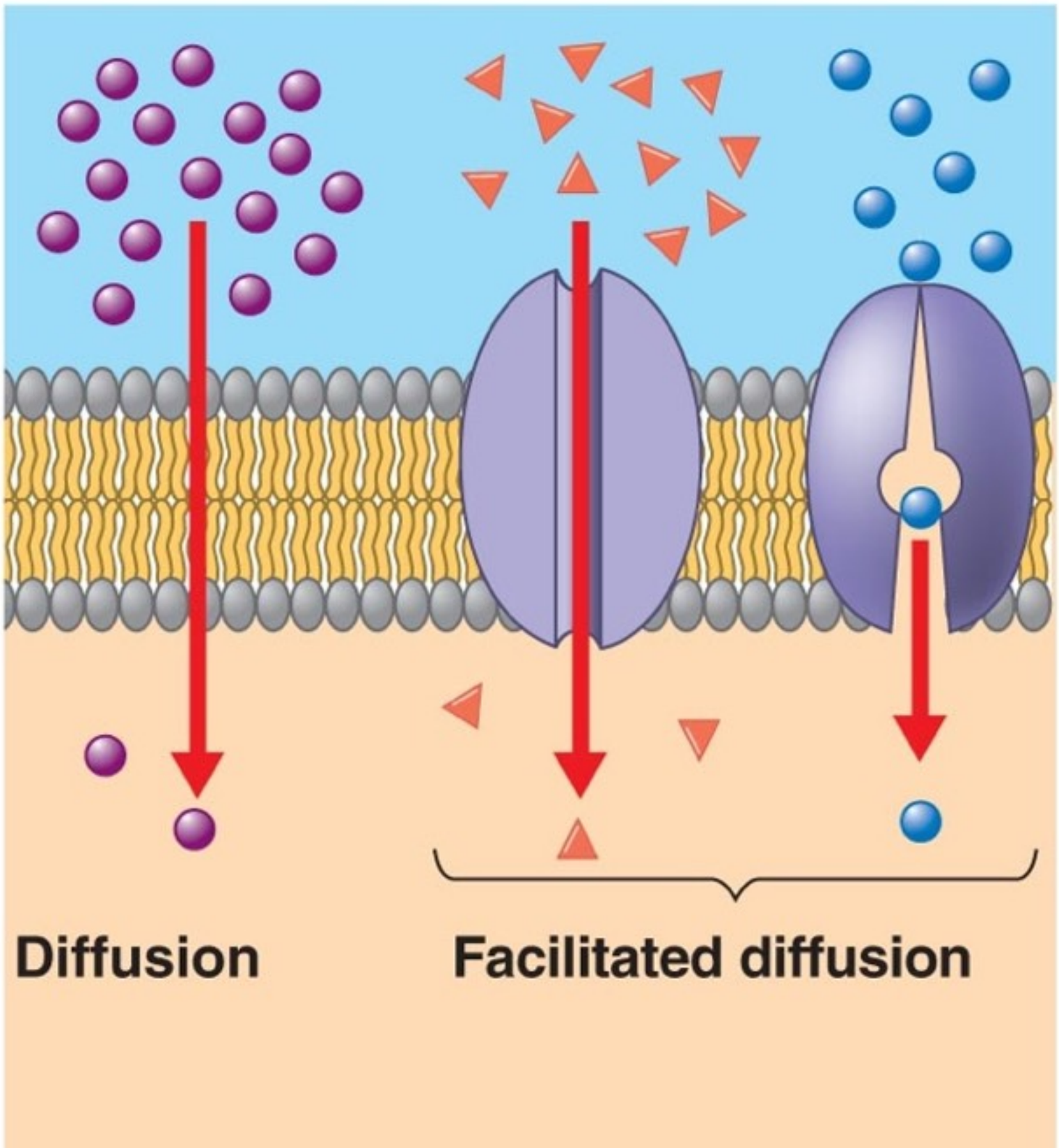
THE ONLY DIFFERENCE BETWEEN THIS AND REGULAR DIFFUSION IS THE ROUTE...IN SIMPLE DIFFUSION MOLECULES MOVE THROUGH THE LIPID BILAYER BUT HERE MOLECULES MOVE THROUGH A CHANNEL OR CARRIER PROTEIN INSTEAD. (STILL HIGH TO LOW, STILL NO ENERGY NEEDED BY CELL)

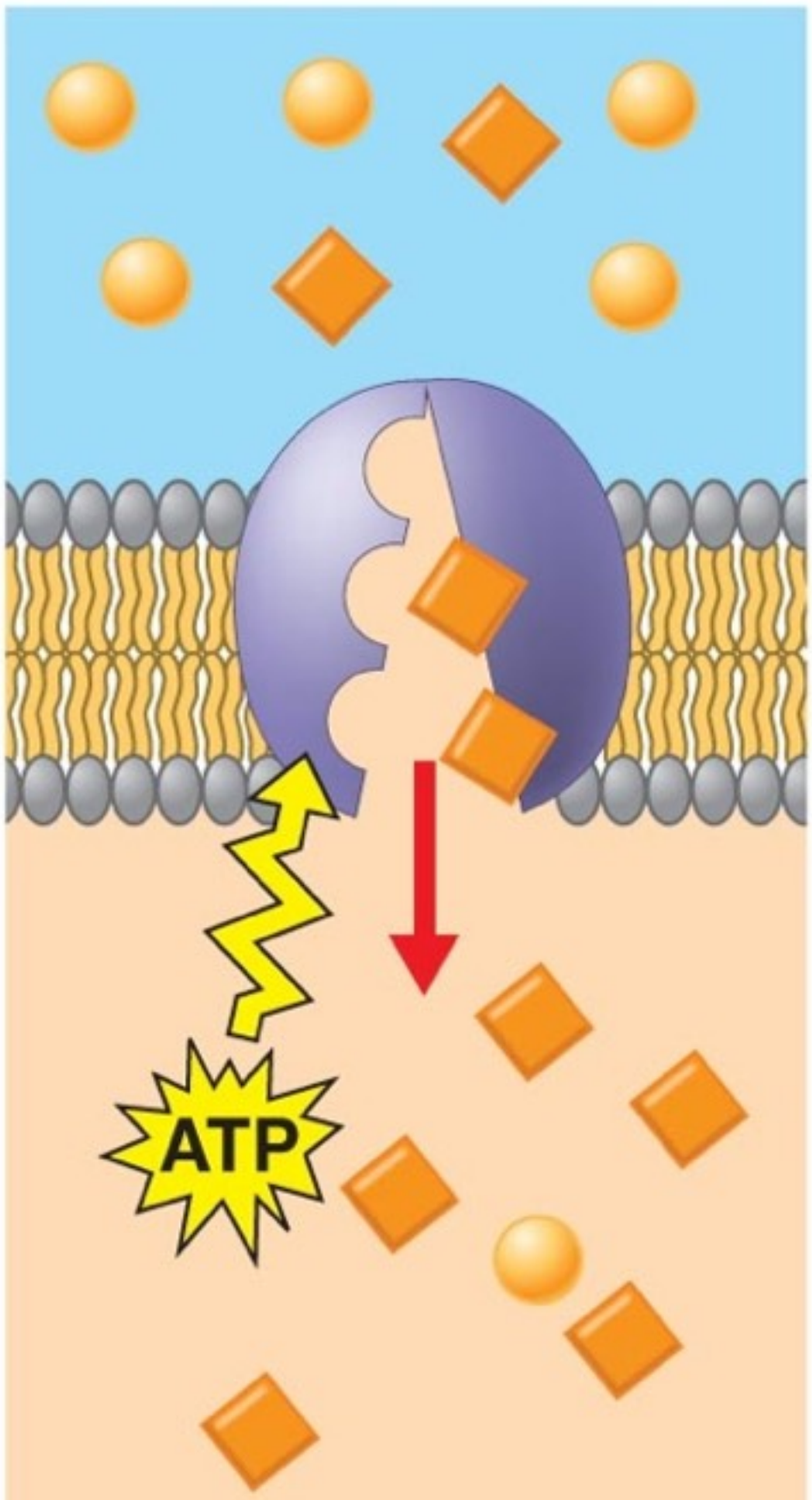
Passive transport

Review

Active transport

Learn about later





Essential knowledge 2.B.2: Growth and dynamic homeostasis are maintained by the constant movement of molecules across membranes.

a. Passive transport does not require the input of metabolic energy; the net movement of molecules is from high concentration to low concentration.

Evidence of student learning is a demonstrated understanding of each of the following:

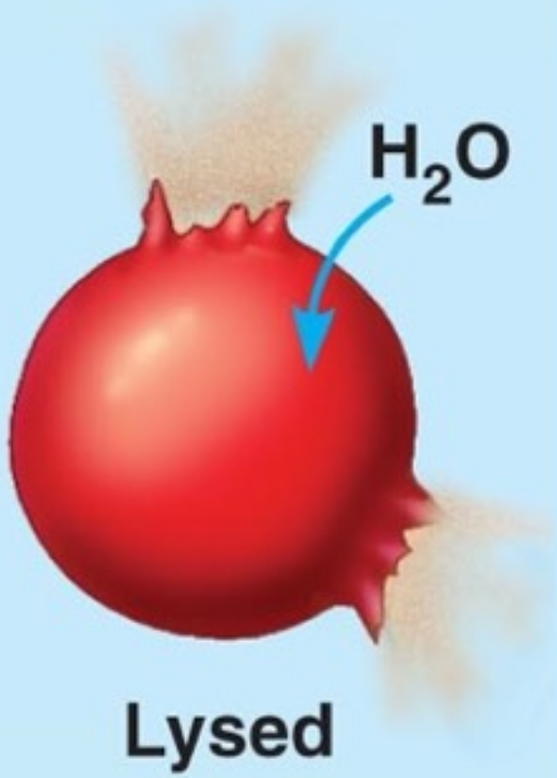
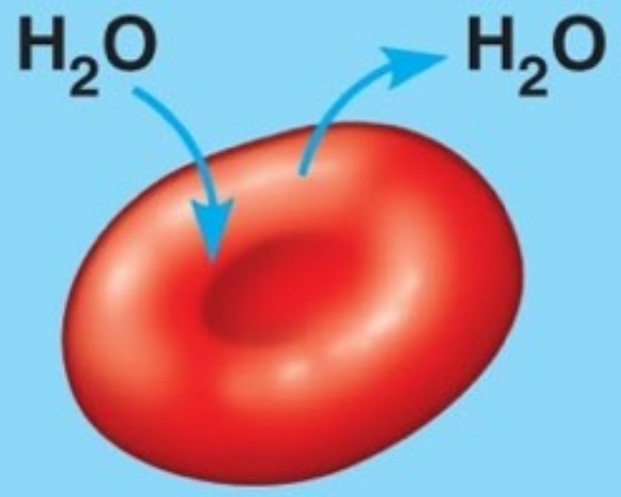
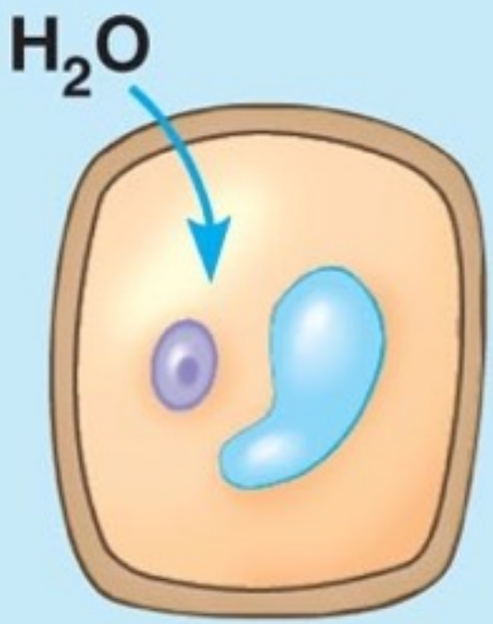
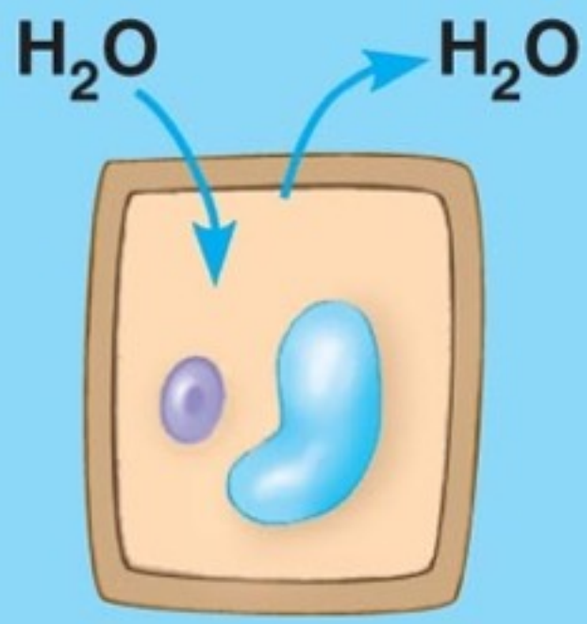
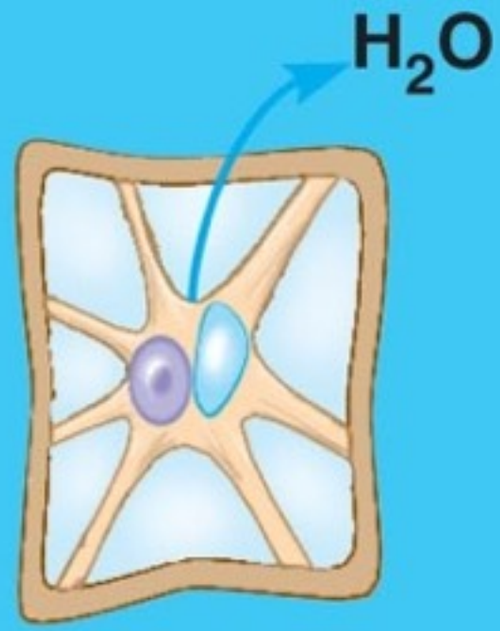
3. External environments can be hypotonic, hypertonic or isotonic to internal environments of cells.

Water Balance of Cells Without Walls

- **Tonicity** is the ability of a surrounding solution to cause a cell to gain or lose water.
  - The key is the "non-penetrating solutes" relative to cell's interior
  - **Iso**tonic solutions are **same** as cell's solution thus no net movement of water.
  - **Hyper**tonic solutions have **more** than a cell's solution thus a net movement of water out of the cell.
  - **Hypo**tonic solutions have **less** than a cell's solution thus a net movement of water into the cell.

Water Balance of Cells With Walls

- Because these cells have rigid walls they can not burst.
- As water moves in the cell wall pushes back (*turgor pressure*) which opposes further water uptake
  - **Isotonic** solutions cause these cells to be *flaccid* (limp).
  - **Hypertonic** solutions cause a net loss of water, which results in *plasmolysis* (membrane pulls away from cell wall)
    - This causes a plant to wilt and die
  - **Hypotonic** solutions cause these cells to be *turgid* (stiff).
    - This is a healthy state for plants.

	Hypotonic solution	Isotonic solution	Hypertonic solution
Animal cell	 Lysed	 Normal	 Shriveled
Plant cell	 Turgid (normal)	 Flaccid	 Plasmolyzed

Essential knowledge 2.B.2: Growth and dynamic homeostasis are maintained by the constant movement of molecules across membranes.

b. Active transport requires free energy to move molecules from regions of low concentration to regions of high concentration.

Evidence of student learning is a demonstrated understanding of each of the following:

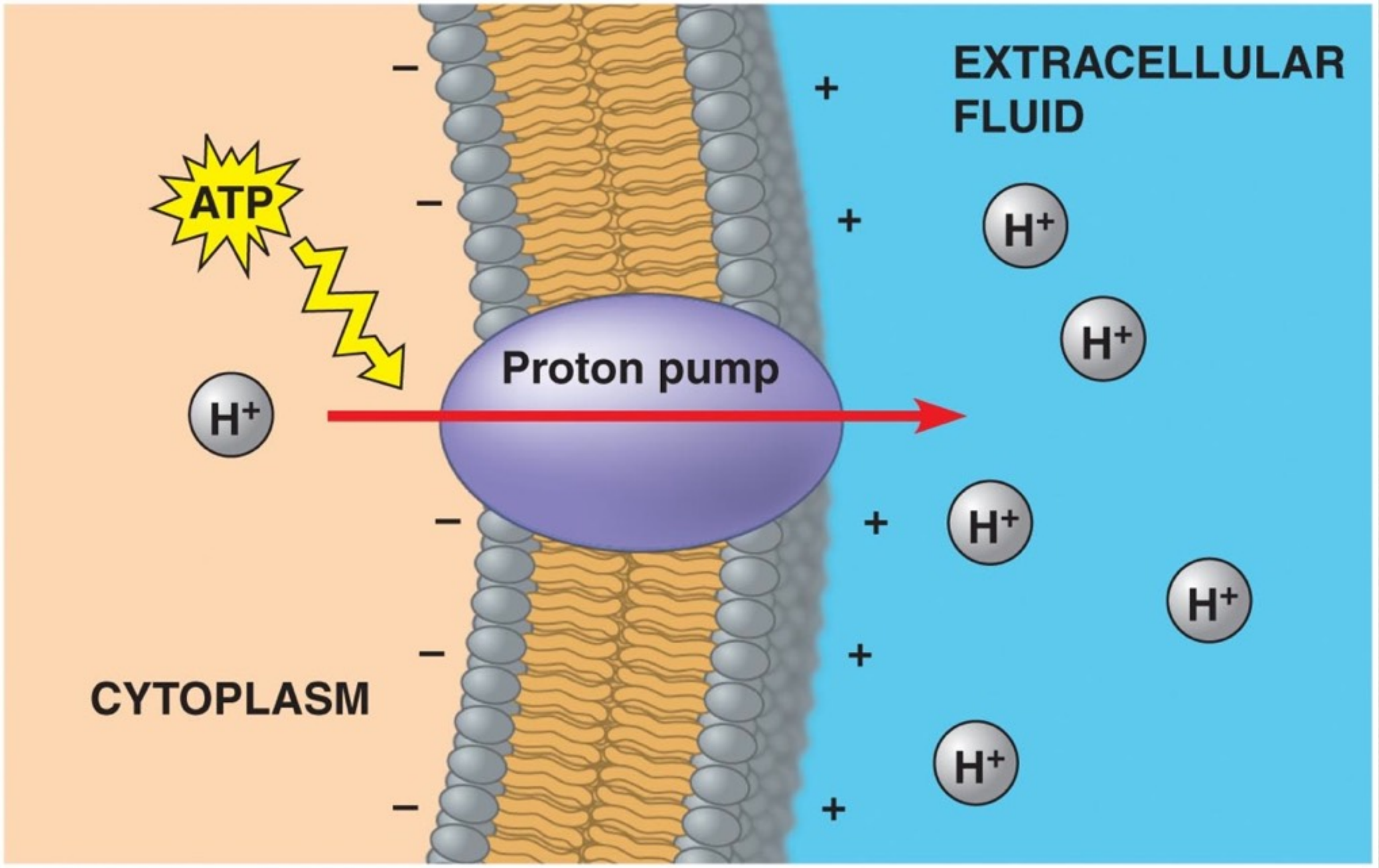
1. Active transport is a process where free energy (often provided by ATP) is used by proteins embedded in the membrane to “move” molecules and/or ions across the membrane and to establish and maintain concentration gradients.

Cells Exchanging with Environment

- Cells can transport “relatively” anything across their plasma membrane.
- Cells have different mechanisms for transport depending on the nature of that which is being transported.
  - *Some substances require energy source to bring them across.*

Other substances require an input of energy to across a membrane.

- **Active transport** moves substances across membranes and requires an energy investment from the cell.
  - The cellular fuel is adenosine triphosphate or ATP?
- These molecules are “pumped” against their concentration gradient *(low to high or “uphill”)*
- These molecules will never travel through the lipid bilayer directly. This transport requires a *carrier protein* to “pump” the molecule across.



How Ion Pumps Maintain Membrane Potential

- ALL cells have *voltage* across their membrane, ***voltage*** is electrical potential energy
  - The voltage across a membrane is called ***membrane potential***
  - The cytoplasmic side is negative relative to the positive outside.
  - Acts like a battery!

How Ion Pumps Maintain Membrane Potential

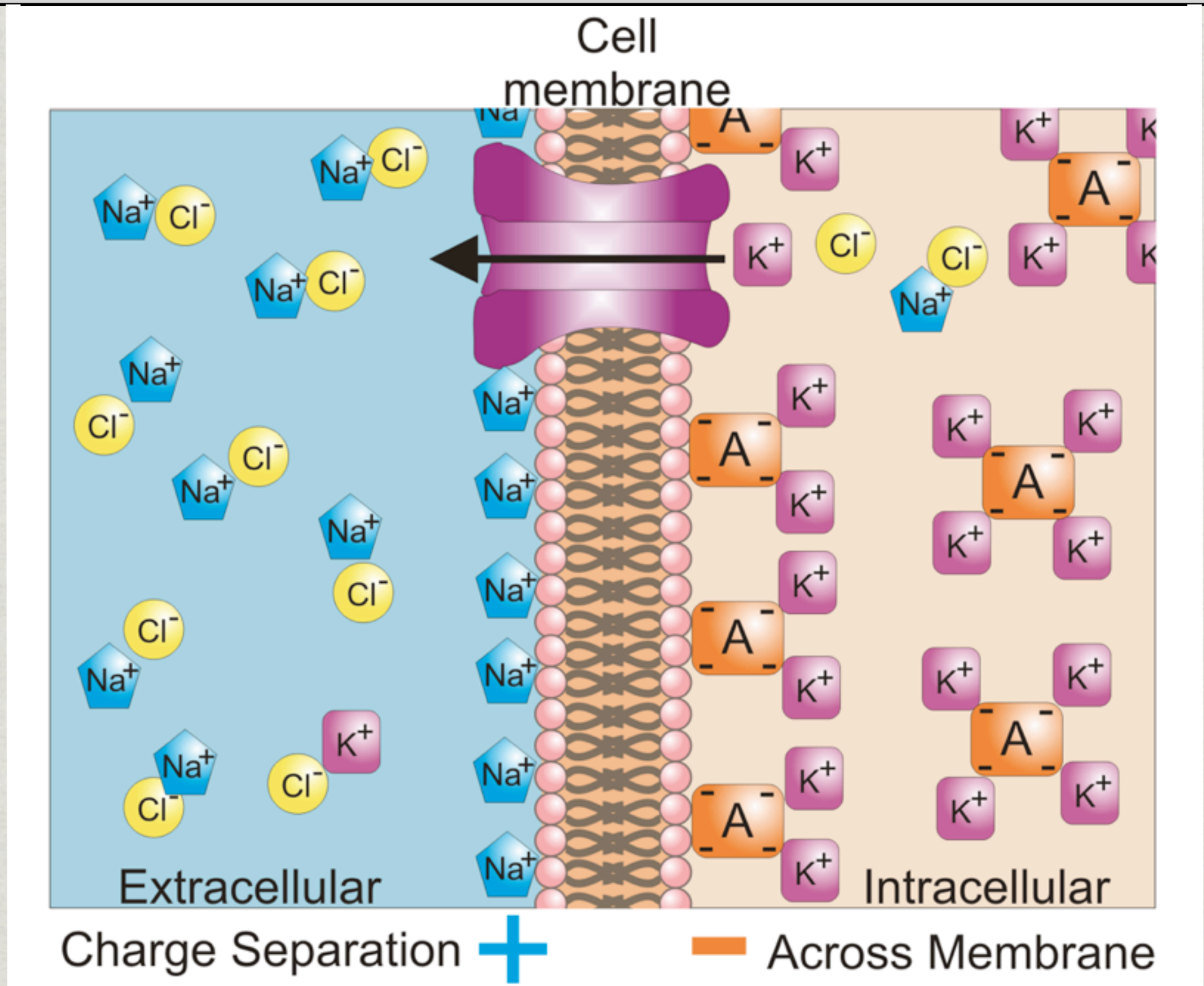
- ALL cells have *voltage* across their membrane, ***voltage*** is electrical potential energy
  - The voltage across a membrane is called ***membrane potential***
  - The cytoplasmic side is negative relative to the positive outside.
  - Acts like a battery!

How Ion Pumps Maintain Membrane Potential

- ***THUS two forces drive diffusion of ions across a membrane***
  - *A Chemical Force (concentration gradient)* *AND*
  - *An Electrical Force (membrane potential)*
- *The combination of forces is called the* ***electrochemical gradient***
  - *As a result we must refine our definition of diffusion*
  - *Molecules (at least those with charges) diffuse down their electrochemical gradient.*

Maintain an internal environment that differs from the external environment

Maintain an internal environment that differs from the external environment



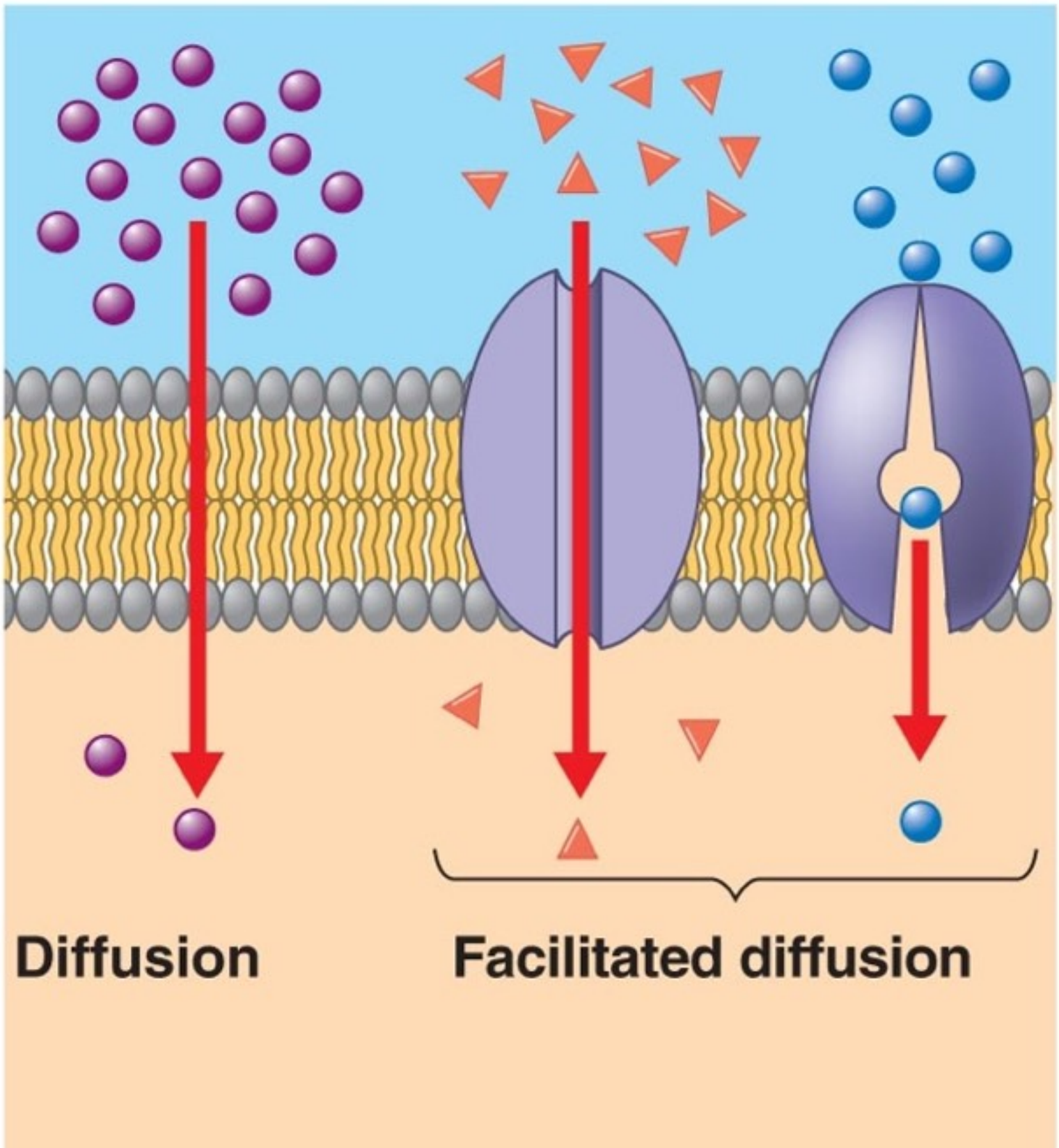
How Ion Pumps Maintain Membrane Potential

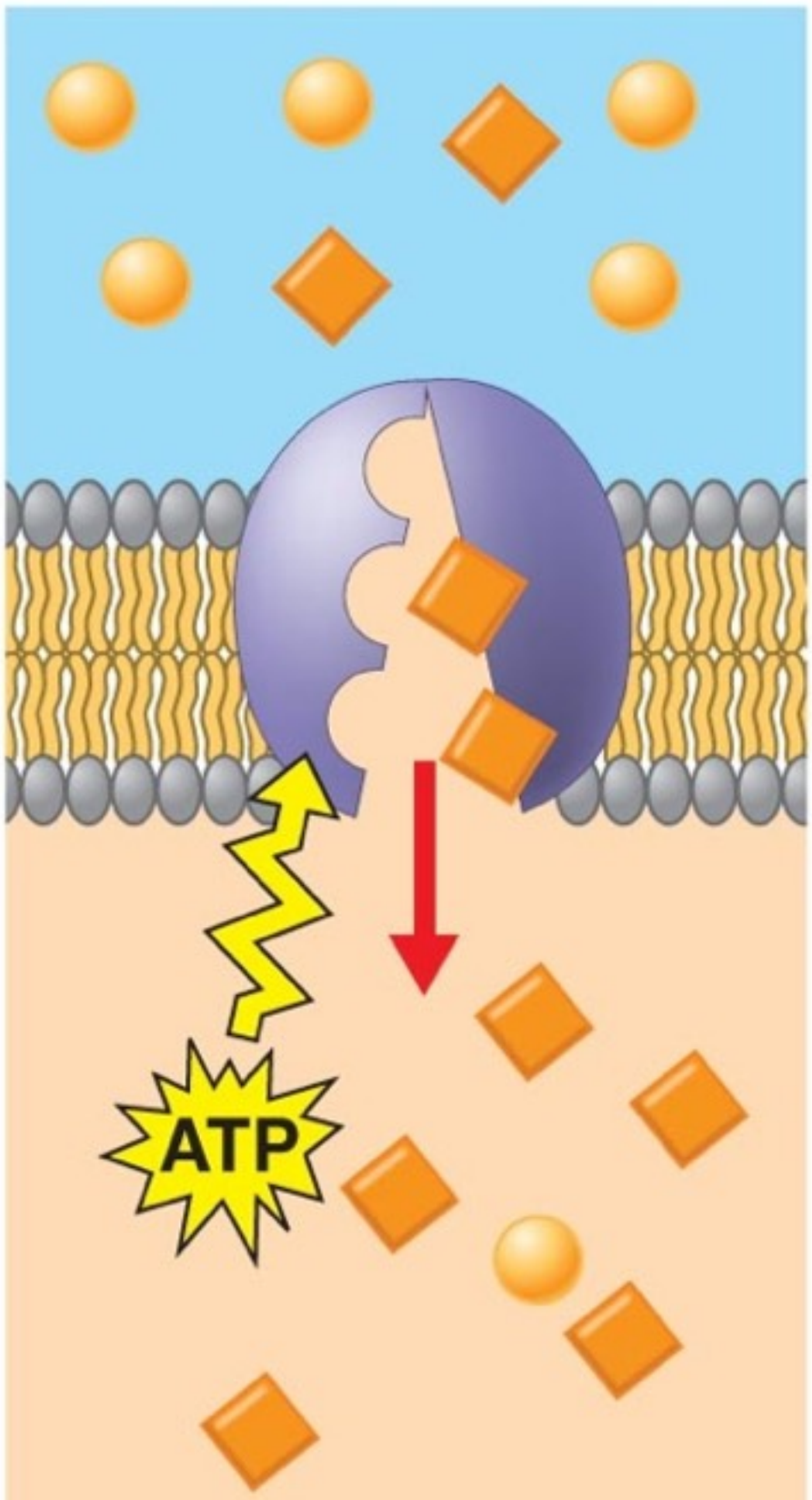
- Membrane proteins actively transport ions in a way that establishes a membrane potential
  - The **Na+/K+ pump** is the main pump used in animal cells
  - The **proton pump** is the main pump used by plants, fungi and bacteria.
- **ALL cells use about 20% of their energy budget for each of these pumps thus cells use nearly half of their total energy setting up membrane potentials!**

Passive transport

Active transport

Review





Essential knowledge 2.B.2: Growth and dynamic homeostasis are maintained by the constant movement of molecules across membranes.

b. Active transport requires free energy to move molecules from regions of low concentration to regions of high concentration.

Evidence of student learning is a demonstrated understanding of each of the following:

2. Membrane proteins are necessary for active transport.

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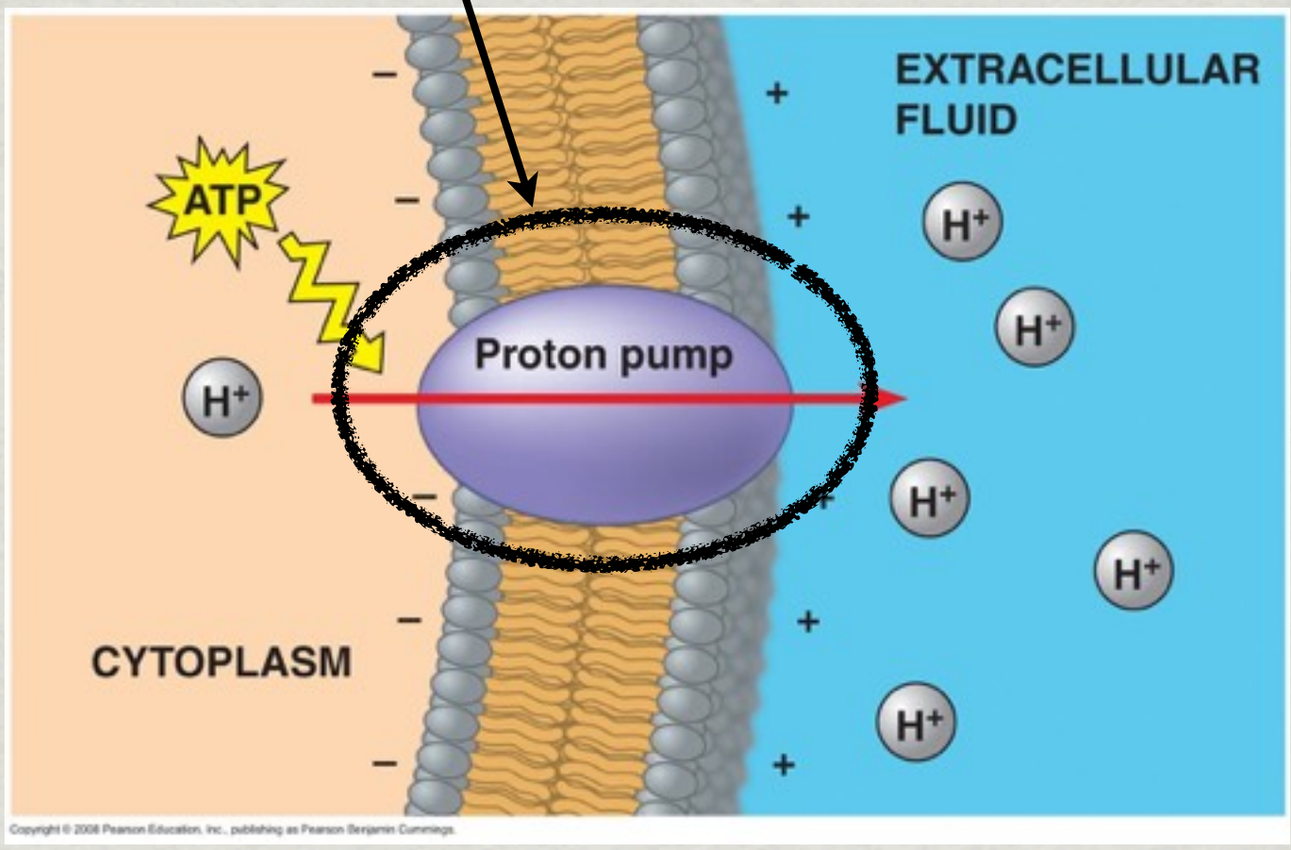
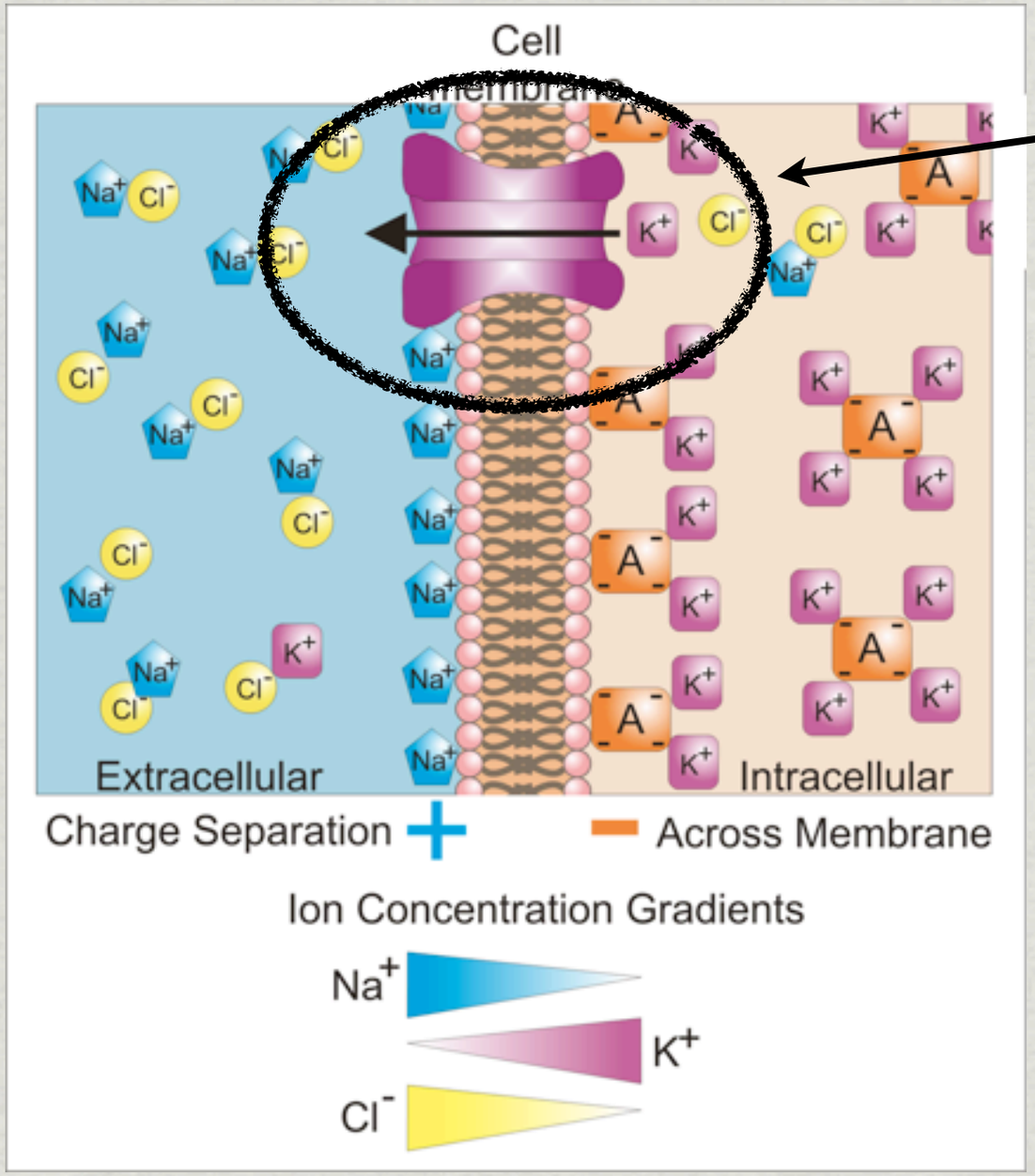
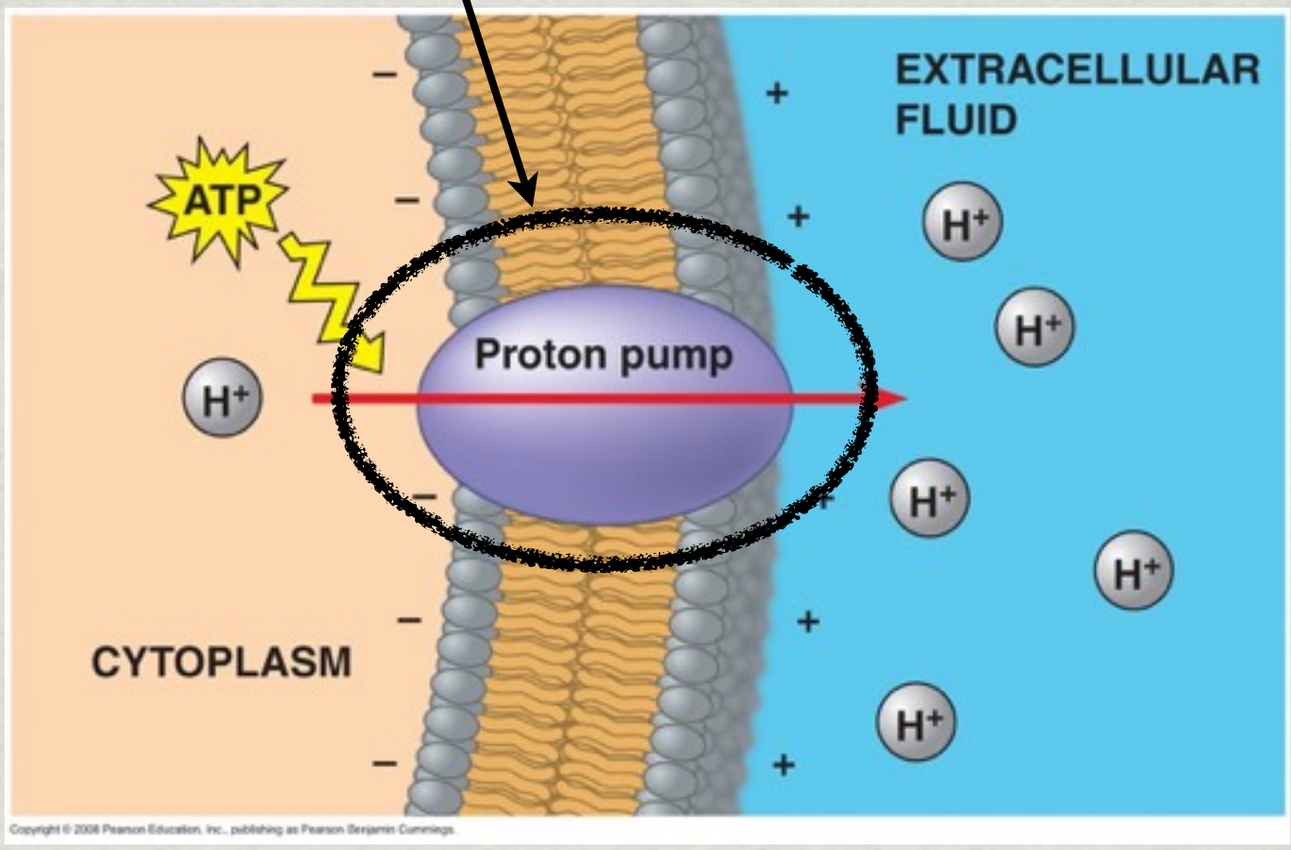




Membrane proteins are necessary for active transport.



Essential knowledge 2.B.2: Growth and dynamic homeostasis are maintained by the constant movement of molecules across membranes.

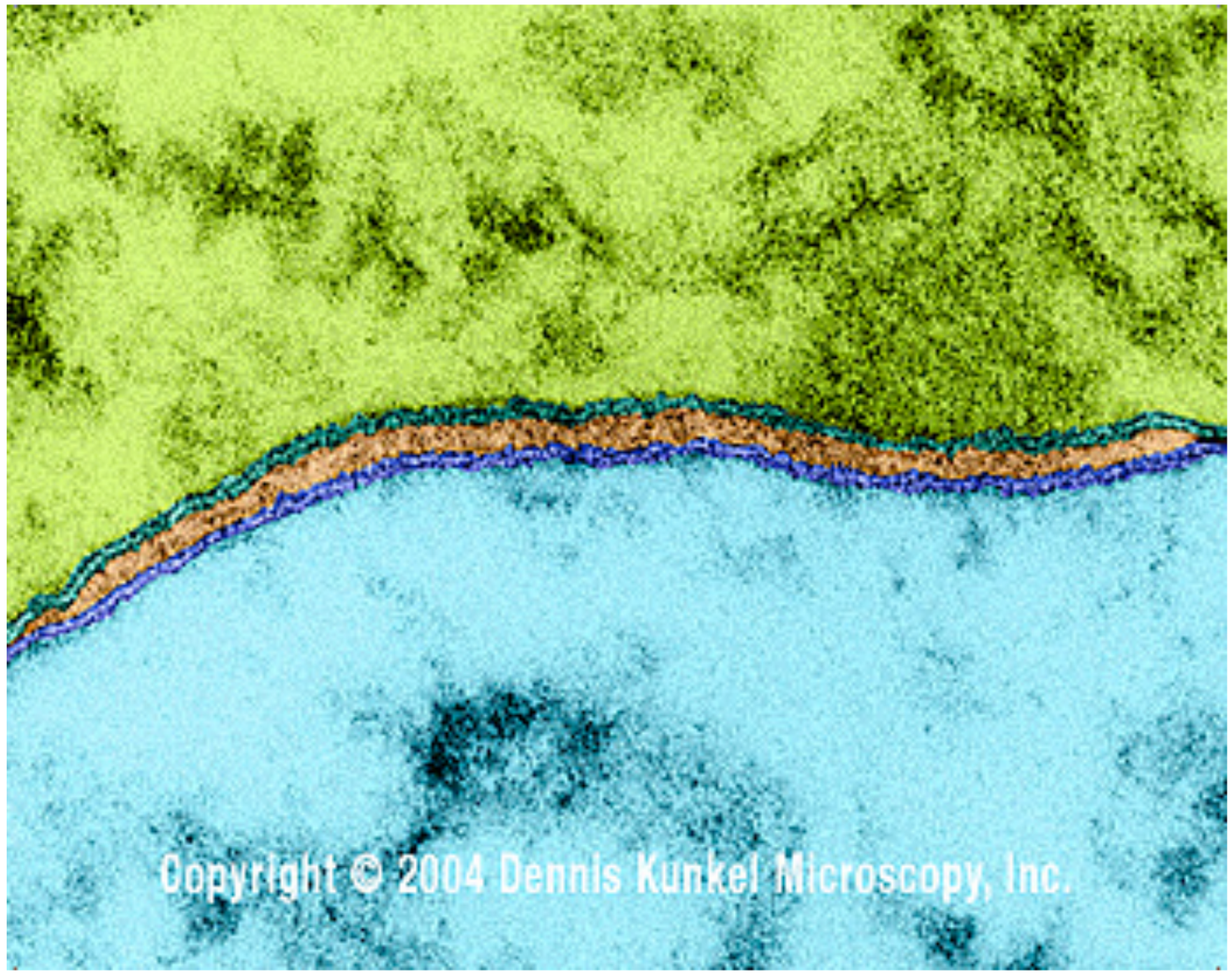
c. The processes of endocytosis and exocytosis move large molecules from the external environment to the internal environment and vice versa, respectively.

Evidence of student learning is a demonstrated understanding of each of the following:

1. In exocytosis, internal vesicles fuse with the plasma membrane to secrete large macromolecules out of the cell.

Cell Membrane

Main Idea: Very large molecules can be moved across the membrane however it requires energy and a special mechanism.

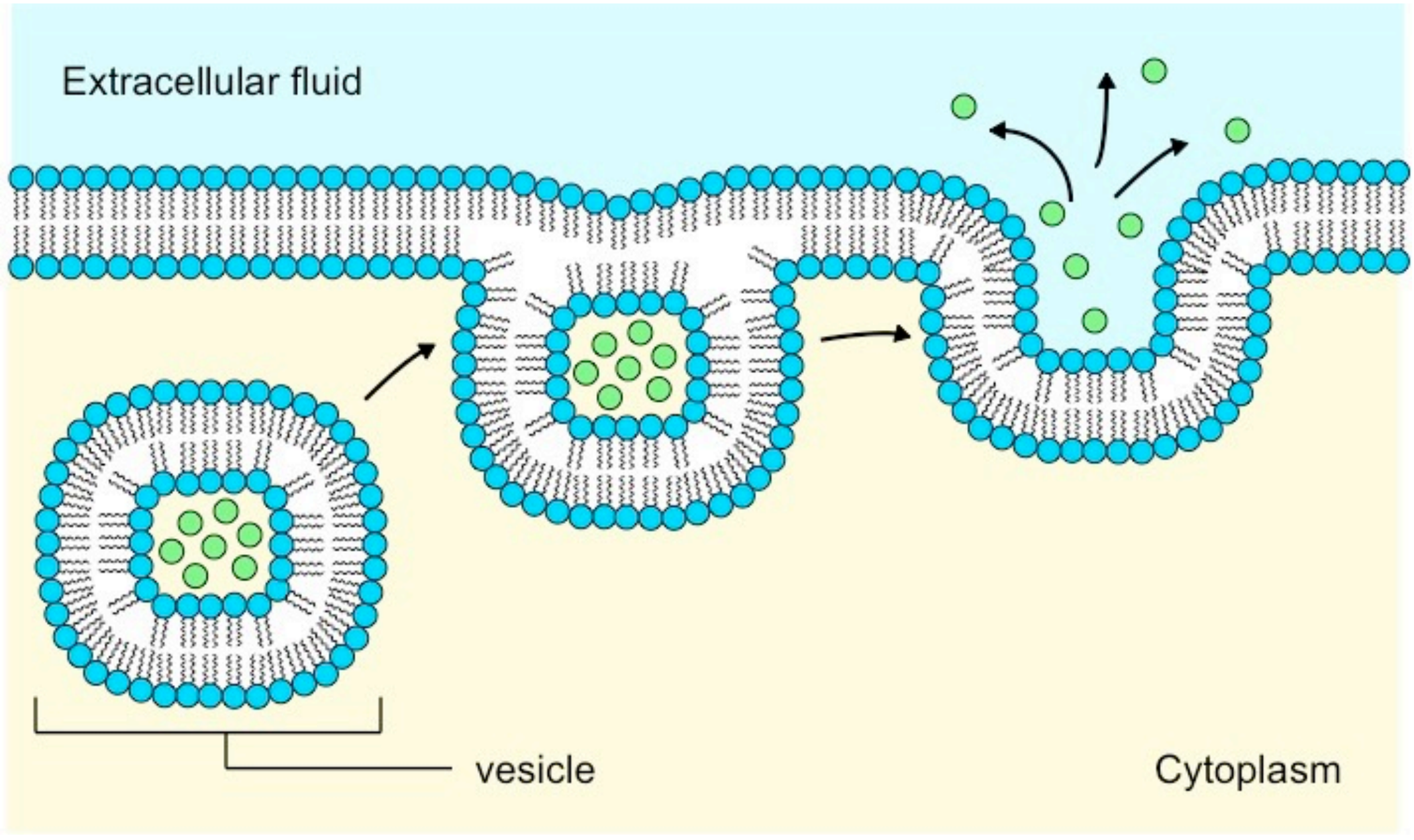


BULK TRANSPORT ACROSS THE PLASMA MEMBRANE OCCURS BY EXOCYTOSIS AND ENDOCYTOSIS

Exocytosis

- **Exocytosis** involves the fusion of vesicles with the plasma membrane
- Pancreas secretes insulin in this way
- Neurons secrete acetylcholine in this way

Exocytosis



Essential knowledge 2.B.2: Growth and dynamic homeostasis are maintained by the constant movement of molecules across membranes.

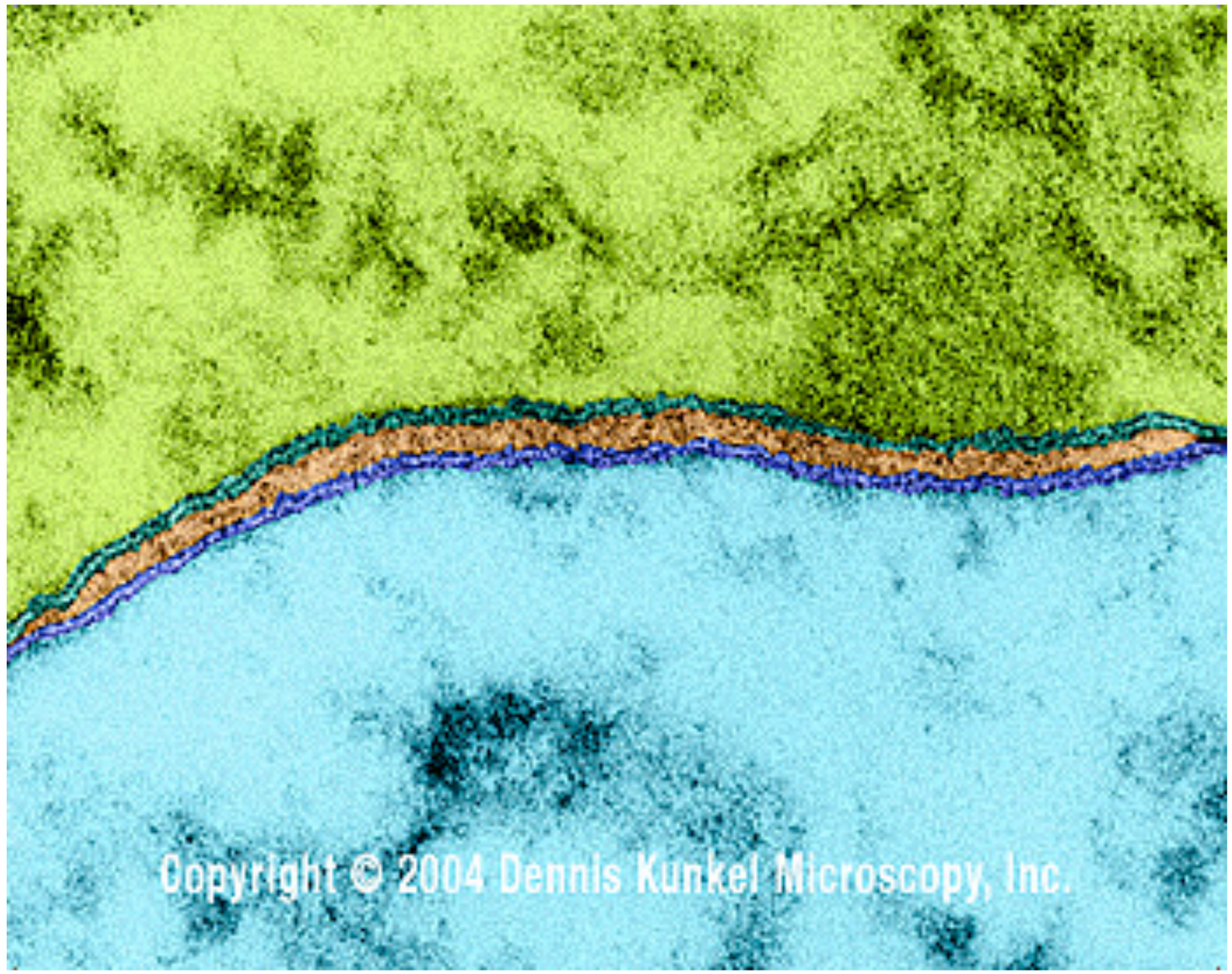
c. The processes of endocytosis and exocytosis move large molecules from the external environment to the internal environment and vice versa, respectively.

Evidence of student learning is a demonstrated understanding of each of the following:

2. In endocytosis, the cell takes in macromolecules and particulate matter by forming new vesicles derived from the plasma membrane.

Cell Membrane

Main Idea: Very large molecules can be moved across the membrane however it requires energy and a special mechanism.

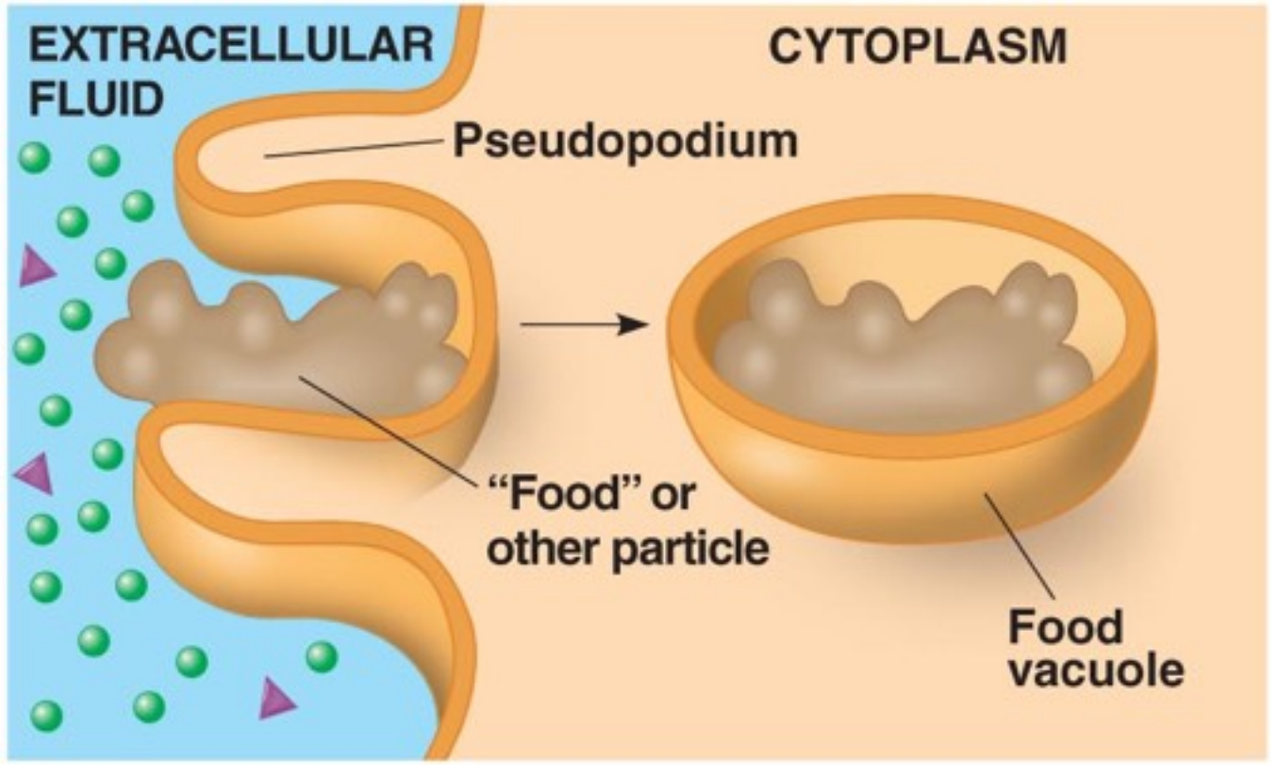


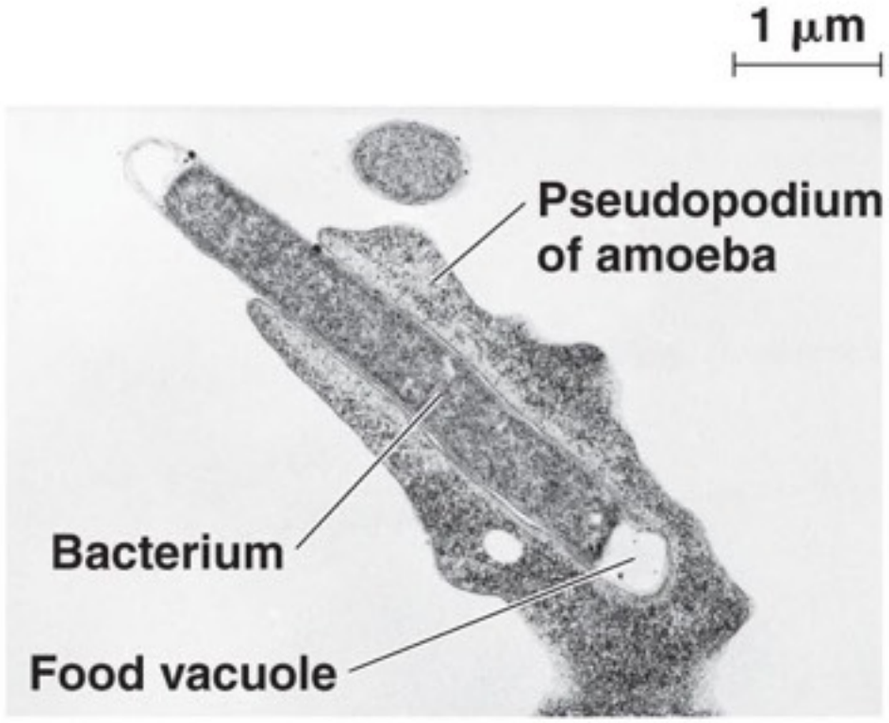
Endocytosis

- **Endocytosis** involves taking in substances by forming vesicles plasma membrane invaginates and pinches off
- There are three types of endocytosis:
  - *Phagocytosis* ("cell eating")
  - *Pinocytosis* ("cell drinking")
  - *Receptor Mediated Endocytosis* (like phagocytosis but a **ligand** must bind to a receptor in order for the process to continue)
    - Cholesterol is absorbed this way by cells
      - A **ligand** is describes any molecule that binds specifically to a receptor site on another molecule

Both endocytosis and exocytosis are important for membrane remodeling

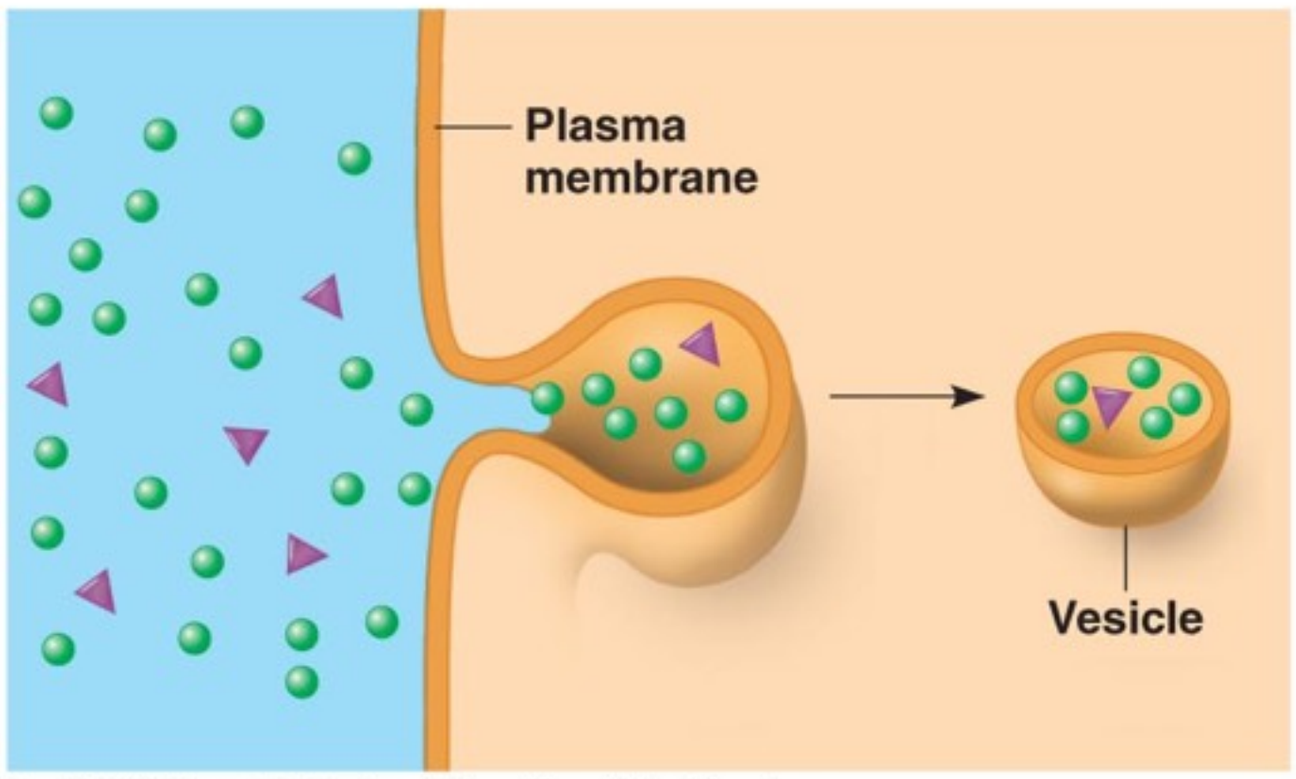
PHAGOCYTOSIS

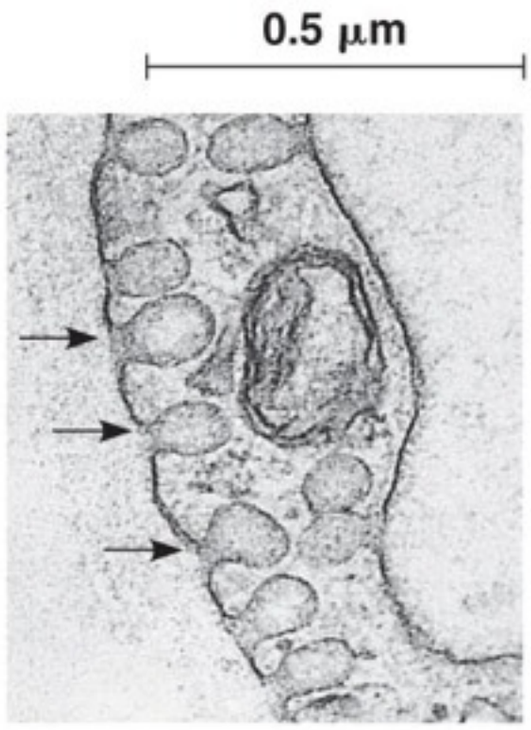




An amoeba engulfing a bacterium via phagocytosis (TEM)

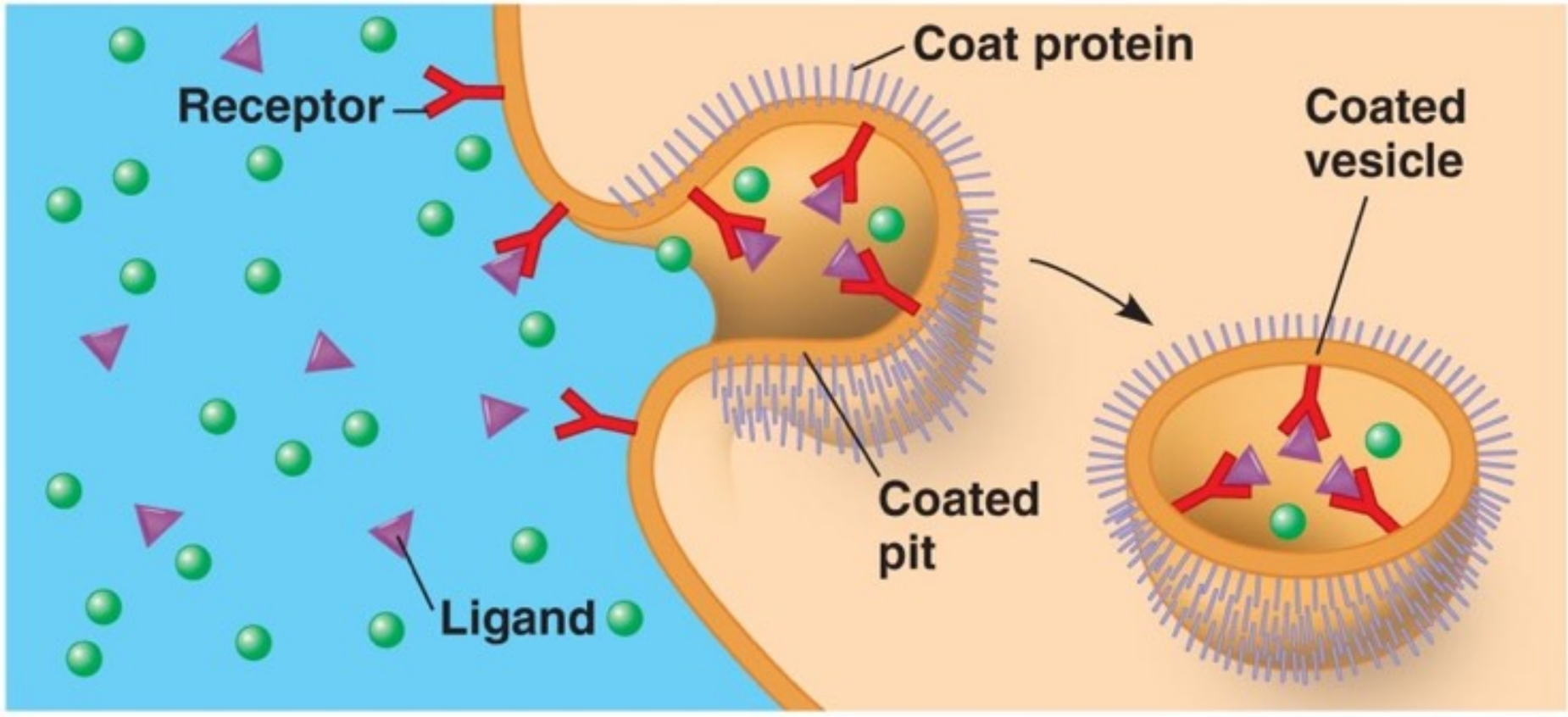
PINOCYTOSIS

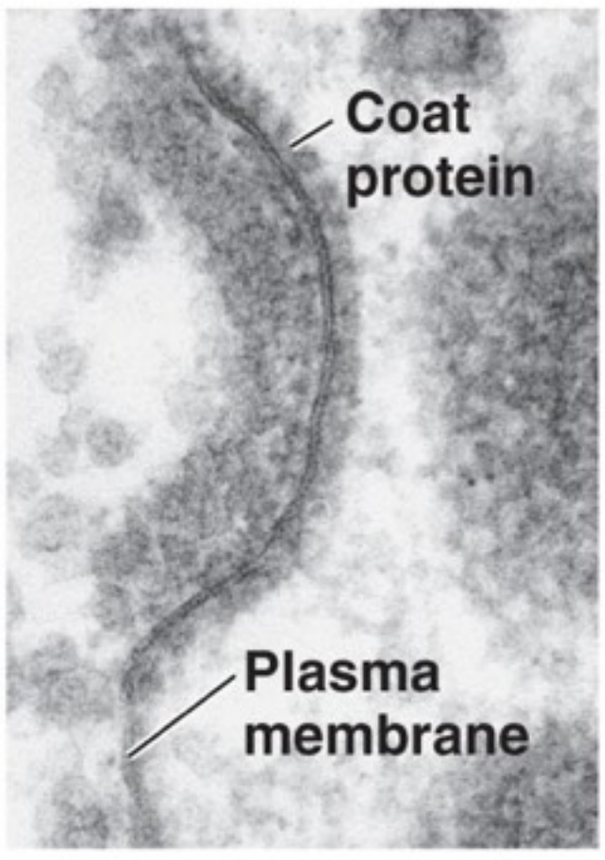


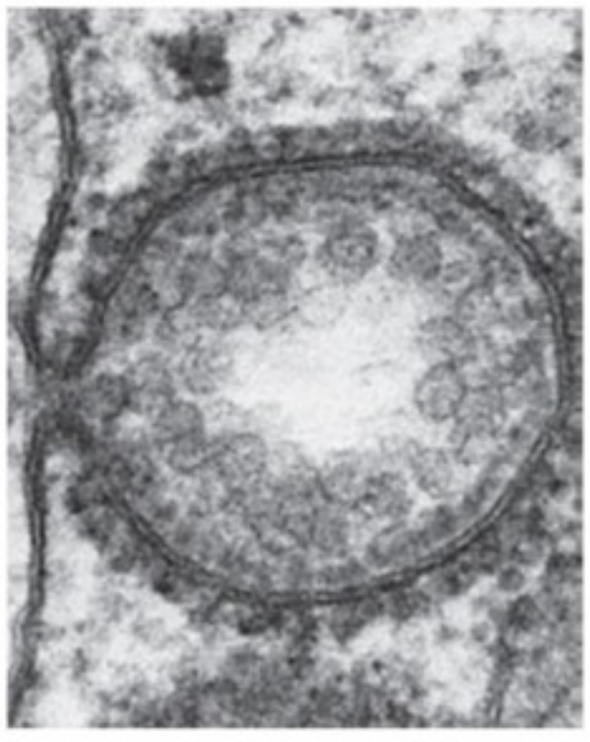


Pinocytosis vesicles forming (arrows) in a cell lining a small blood vessel (TEM)

RECEPTOR-MEDIATED ENDOCYTOSIS

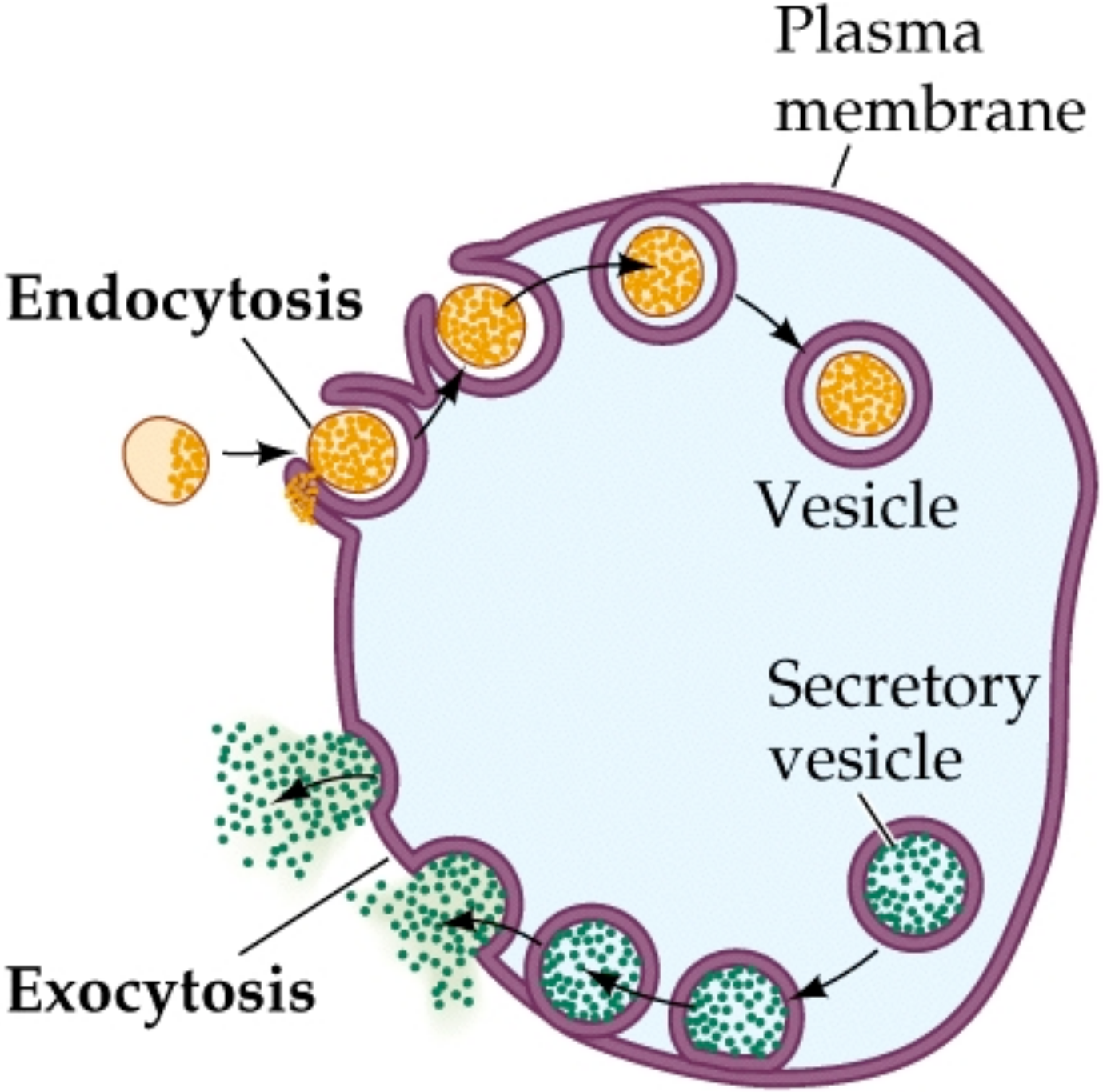






A coated pit and a coated vesicle formed during receptor-mediated endocytosis (TEMs)

Comparison Overview



Learning Objectives:

LO 2.12 The student is able to use representations and models to analyze situations or solve problems qualitatively and quantitatively to investigate whether dynamic homeostasis
is maintained by the active movement of molecules across membranes. [See SP 1.4]