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.1: Cell membranes are selectively permeable due to their structure.

a. Cell membranes separate the internal environment of the cell from the external environment.

PREFACE

- The plasma membrane is the edge of life.
- All cells have a plasma membrane.
- It enables and maintains an internal environment of the cell that is different from its surrounding external environment.
- The plasma membrane is **selectively permeable**, it controls the traffic of molecules into and out from the cell.

PREFACE

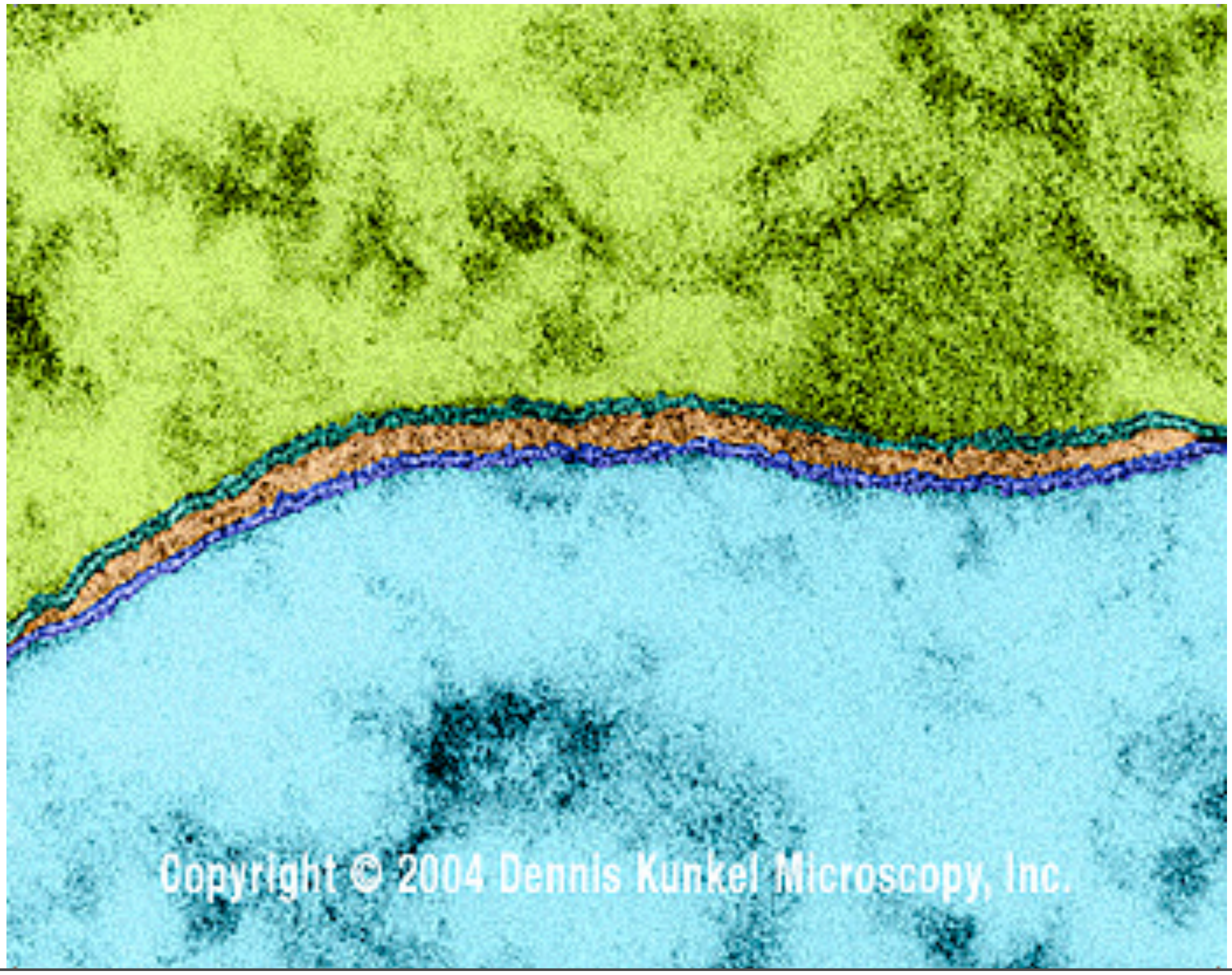
- The plasma membrane is the edge of life.
- All cells have a plasma membrane.
- It enables and maintains an internal environment of the cell that is different from its surrounding external environment.
- The plasma membrane is **selectively permeable**, it controls the traffic of molecules into and out from the cell.

All told, each one of us has enough membranes in our body to cover about 75 soccer fields!

Cell Membranes

Main Idea: Membranes are composed of primarily phospholipids which give the membrane a fluid like quality.

Main Idea: Membranes are embedded with proteins and sugars which give them a mosaic like quality.

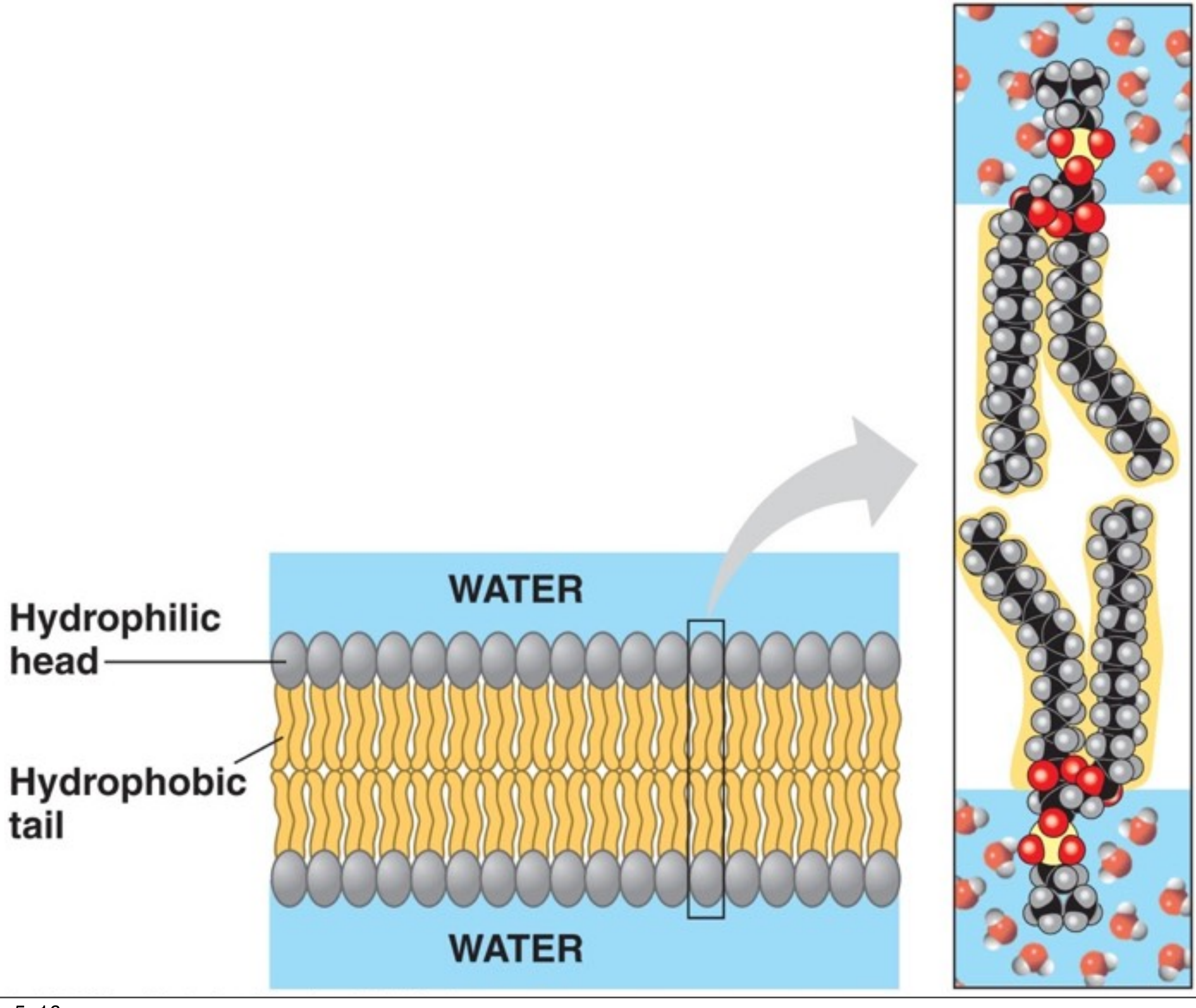


CELLULAR MEMBRANES ARE FLUID MOSAICS OF LIPIDS AND PROTEINS

- The foundation of the membrane is the phospholipid.
- Phospholipids are **amphipathic** meaning that have a hydrophilic region and a hydrophobic region.
    - They will inherently form membranes when they come together.
- The remainder of the membrane is littered with proteins and sugars.
    - Many of the proteins are themselves amphipathic
- The **fluid mosaic model** describes the structure of membranes.

Membrane Models

- As our understanding grows the fluid mosaic models are continually refined.



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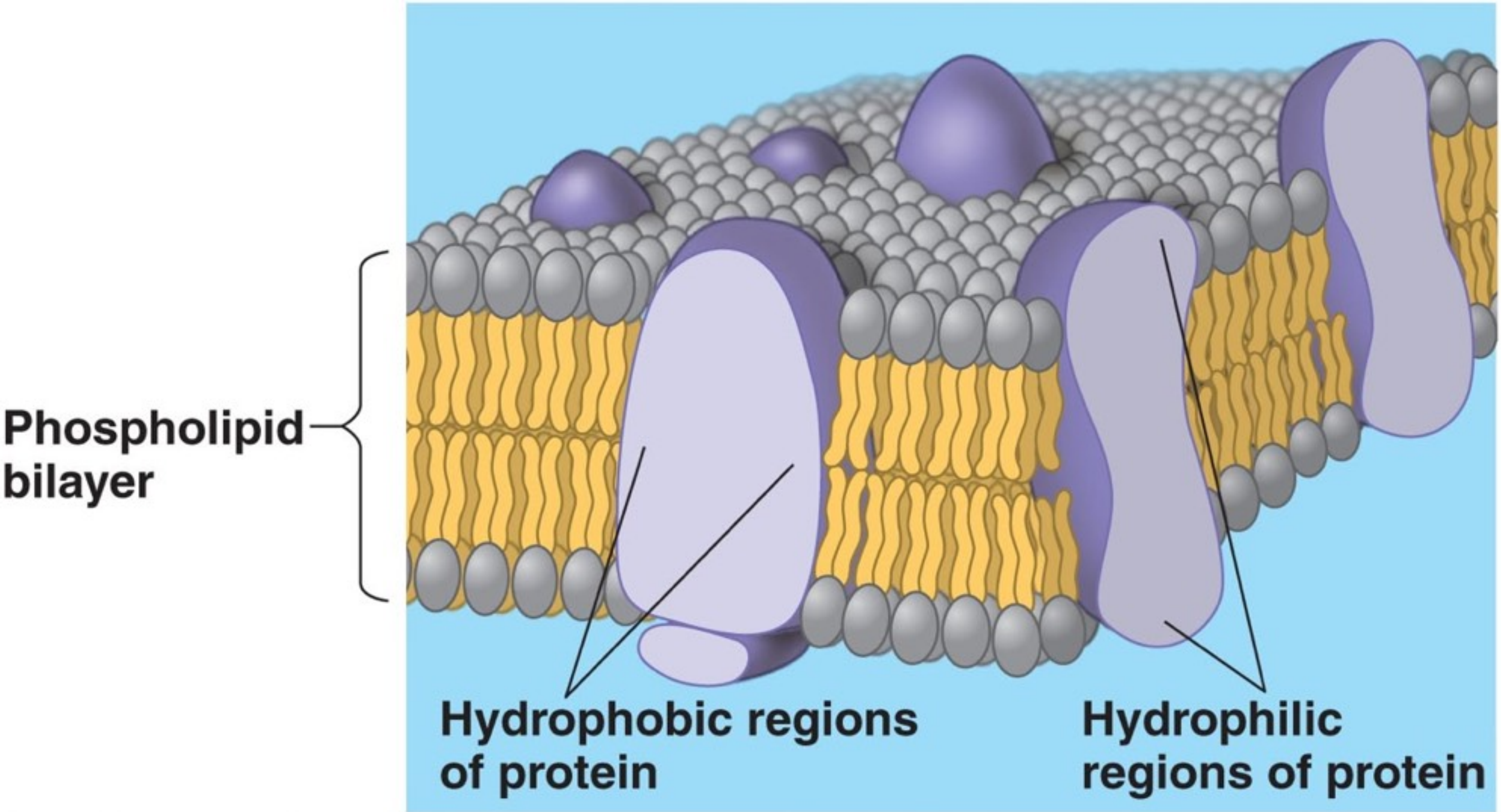

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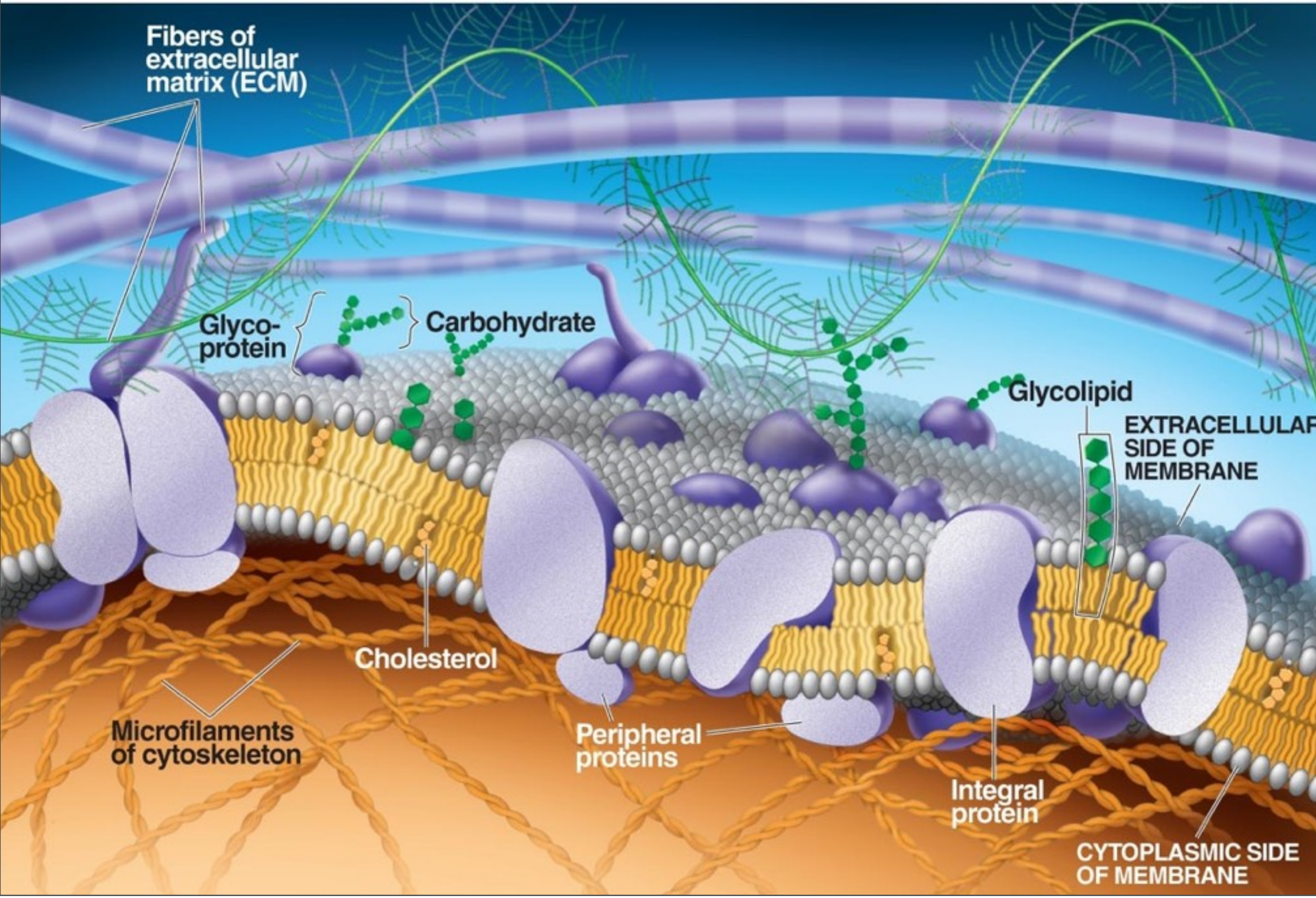

SEPARATION OF ENVIRONMENTS

- ALL cells no matter the shape or size have a selectively permeable membrane!
- Membranes have two fundamental purposes:
  - 1. Regulate the movement of materials into and out of the cell.
  - 2. Maintain an internal environment that differs from the external environment.

Maintain an internal environment that differs from the external environment

Maintain an internal environment that differs from the external environment

Essential knowledge 2.B.1: Cell membranes are selectively permeable due to their structure.

b. Selective permeability is a direct consequence of membrane structure, as described by the fluid mosaic model. [See also 4.A.1]

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

1. Cell membranes consist of a structural framework of phospholipid molecules, embedded proteins, cholesterol, glycoproteins and glycolipids.

Membrane Models

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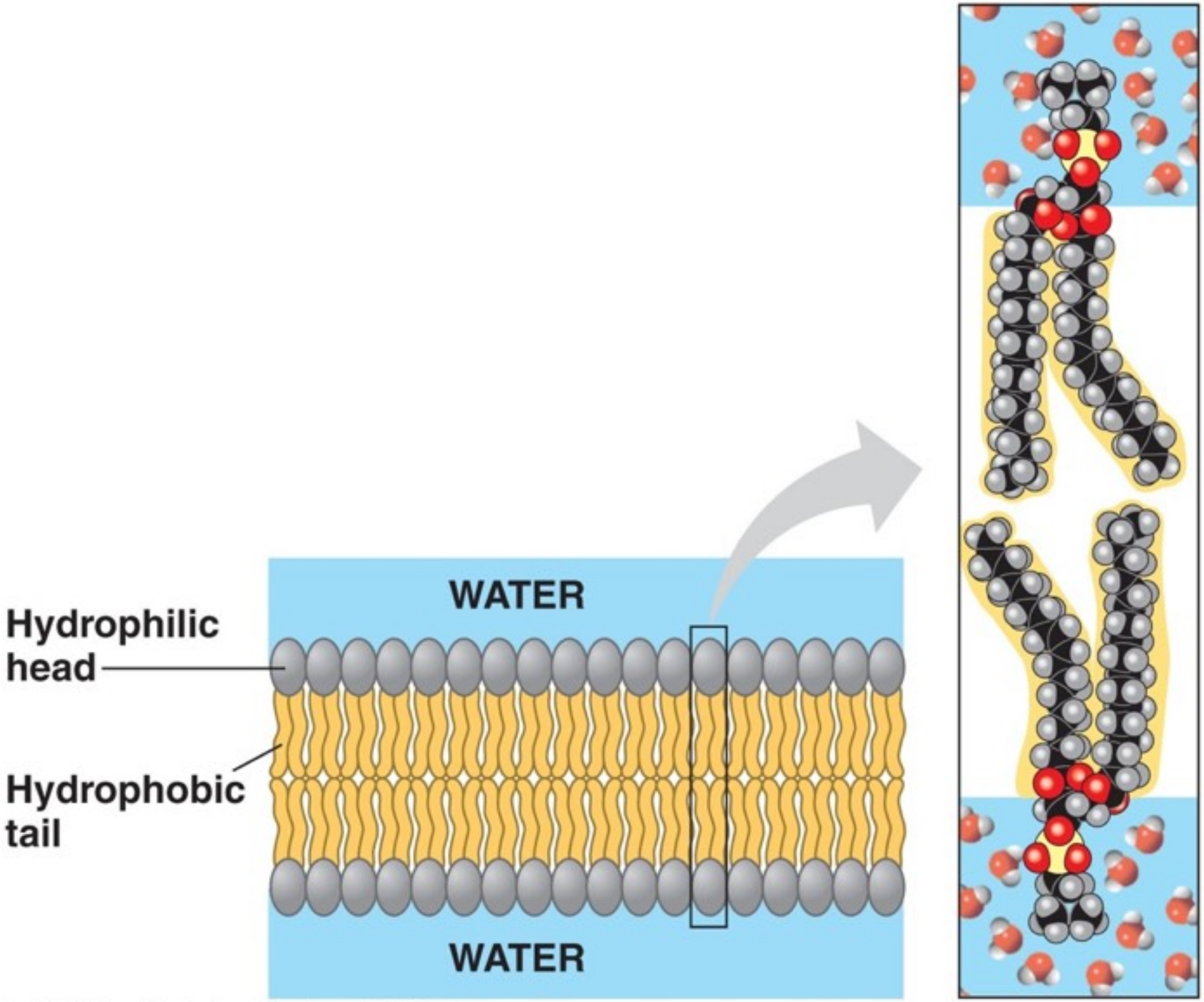

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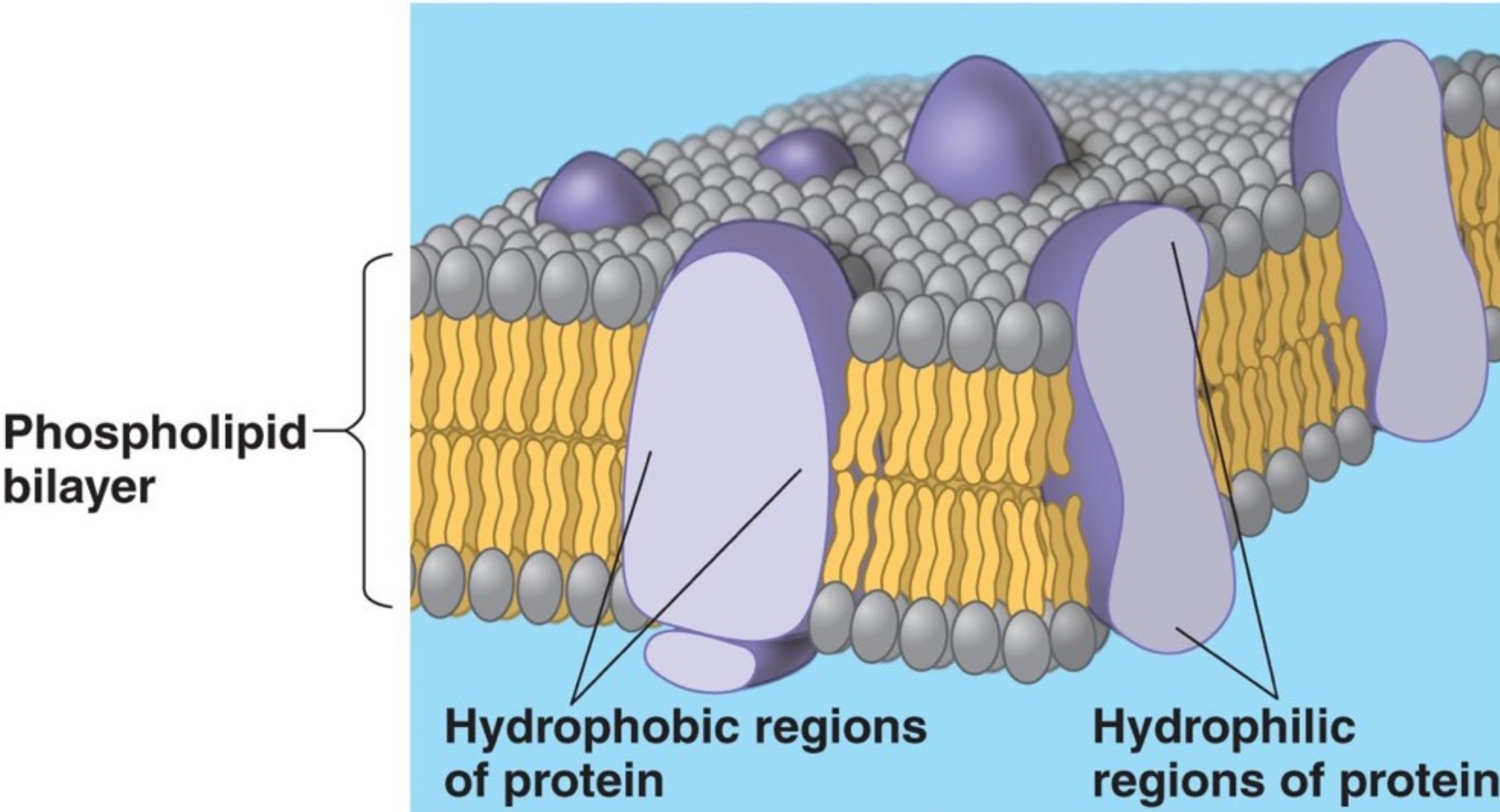

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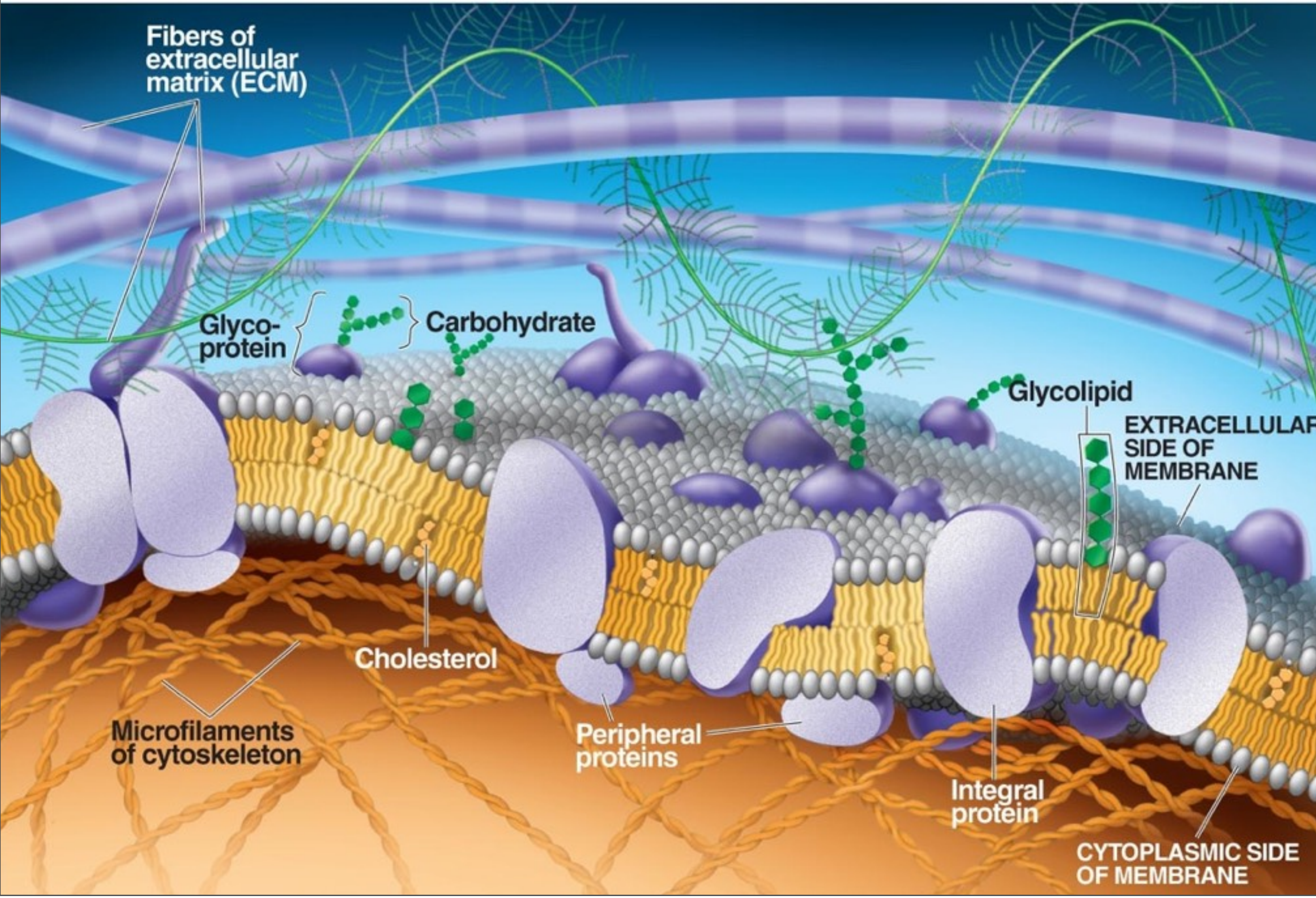


Essential knowledge 2.B.1: Cell membranes are selectively permeable due to their structure.

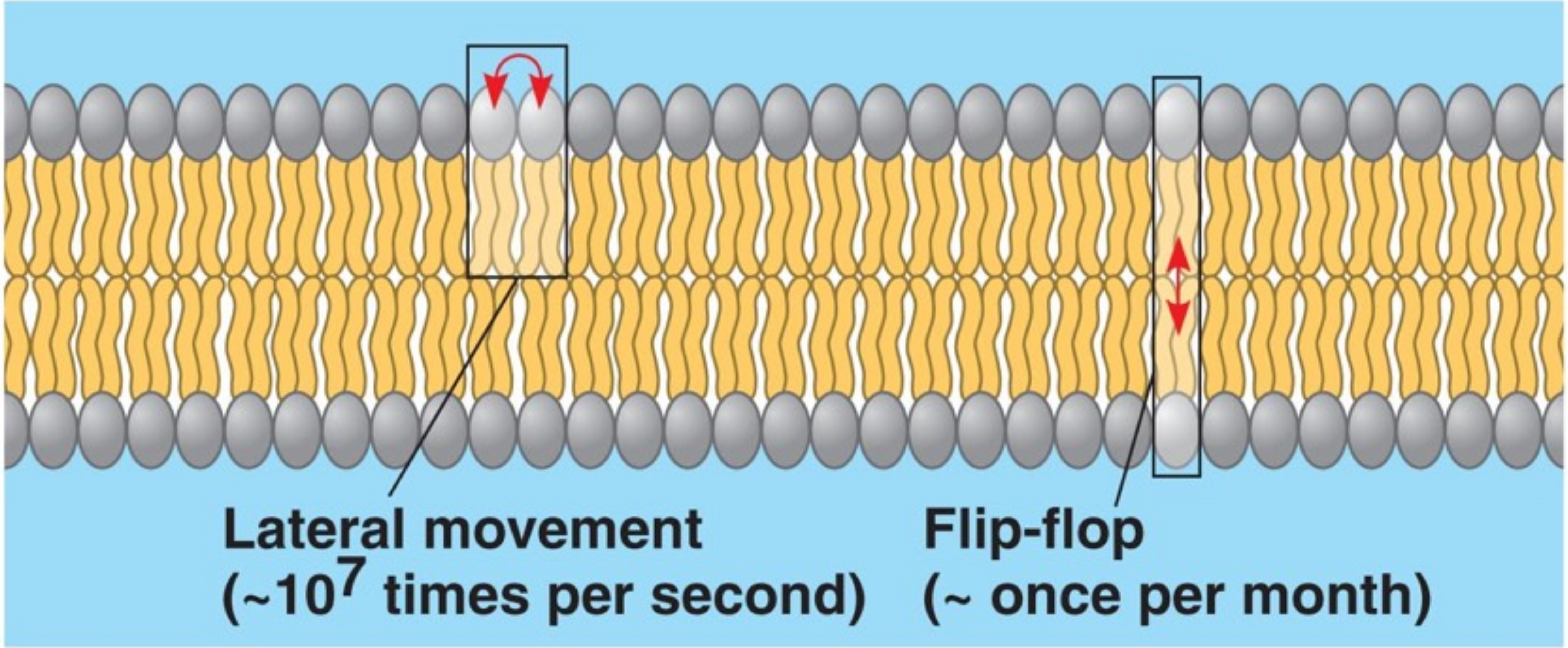
b. Selective permeability is a direct consequence of membrane structure, as described by the fluid mosaic model. [See also 4.A.1]

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

2. Phospholipids give the membrane both hydrophilic and hydrophobic properties. The hydrophilic phosphate portions of the phospholipids are oriented toward the aqueous external or internal environments, while the hydrophobic fatty acid portions face each other within the interior of the membrane itself.

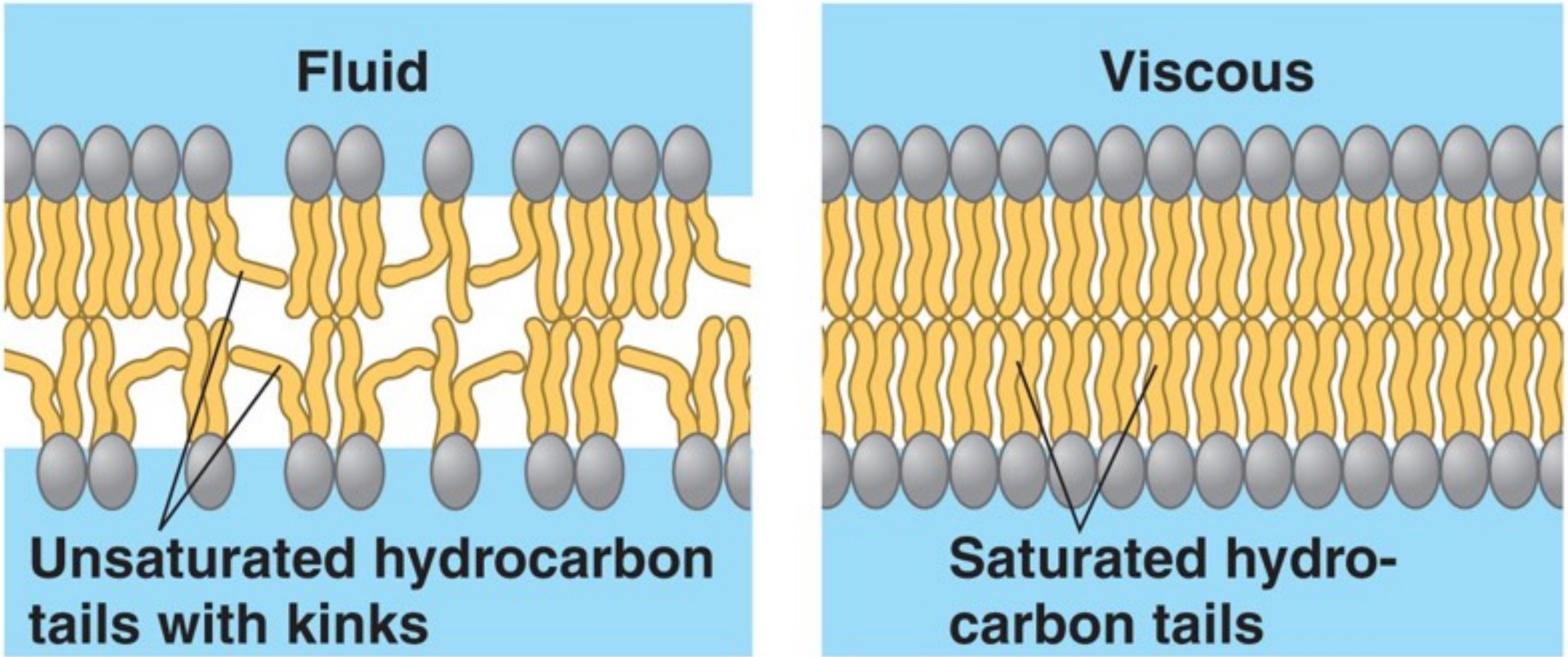
The Fluidity of Membranes

- Membranes are static sheets, they are held together by weak hydrophobic interactions.
- The lipids and proteins both move laterally although the lipids move much more freely.
    - Furthermore some proteins do not move at all because they locked into place by the ECM and cytoskeleton.



The Fluidity of Membranes

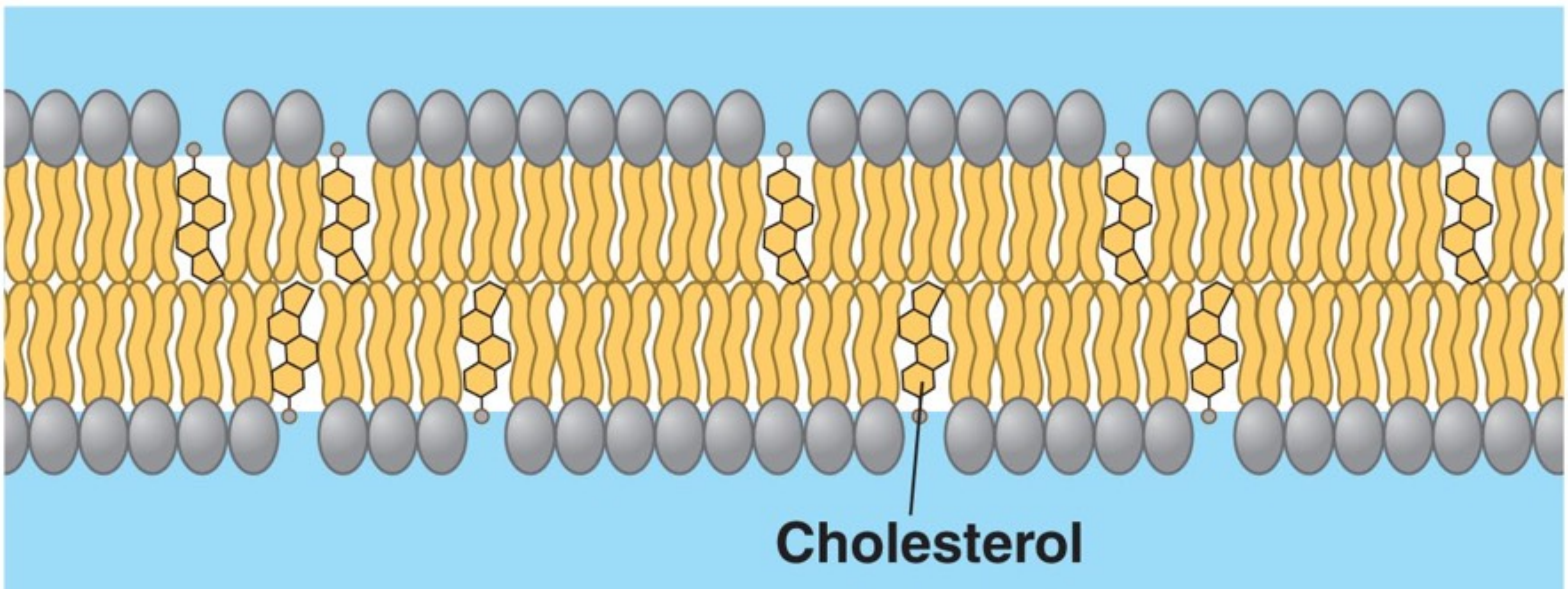
- Membrane fluidity is directly correlated with temperature.
    - The higher the temperature the more fluid the membrane
- The type of fatty acid tails in the phospholipids also effect fluidity
- Membrane fluidity is important because it effects membrane permeability



(b) Membrane fluidity

The Fluidity of Membranes

- Cholesterol acts like a membrane "fluidity buffer".
  - At higher temperatures cholesterol decreases the membrane fluidity, by restraining lipid movement.
  - At lower temperatures cholesterol increases the membrane fluidity, by hindering the close packing.



(c) Cholesterol within the animal cell membrane

On a Side Note...
In case your interested

The Evolution of Different Membrane Lipid Composition

- Variations in lipid composition appears to be an evolutionary adaptation.
  - *Fish that live in cold water have a high proportion of unsaturated fatty acids.*
  - *Bacteria living in thermal hot springs show a high proportion of saturated fatty acids.*

The Evolution of Different Membrane Lipid Composition

- The ability to adjust lipid composition appears to be an evolutionary adaptation.
    - *Winter wheat* can change its percentage of unsaturated fatty acids that make up its membrane as the seasons change.
- **Natural selection has favored organisms who have a mixture of fatty acid types and or those organisms that can adjust their membrane's permeability as necessary.**

The Speed of Life

- In general, larger the beast, the slower its metabolism and the longer its life and vice versa.
    - The explanation to this observation may reside in the plasma membrane.
- “Gunky” watertight membranes are found in elephants and whales with slow metabolisms and long lifespans.
    - *The most common unsaturated fatty acid accounts for 0.2% of an elephant’s membrane.*
- “Runny” leaky membranes allow mice and hummingbirds to live fast but these organisms have short lifespans.
    - *The most common unsaturated fatty acid accounts for 20% of an mouse’s membrane.*

Can you generate hypothesis for membrane permeability and lifespan?

Essential knowledge 2.B.1: Cell membranes are selectively permeable due to their structure.

b. Selective permeability is a direct consequence of membrane structure, as described by the fluid mosaic model. [See also 4.A.1]

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

3. Embedded proteins can be hydrophilic, with charged and polar side groups, or hydrophobic, with nonpolar side groups.

Membrane Proteins and Their Functions

- A membrane is a collage of different proteins.
  - More than 50 kinds of have been found so far in the plasma membrane.
- Proteins determine most of the membrane'd functions .
  - Different types of cells contain different sets of membrane proteins.
- However all membrane proteins fall into one of two groups

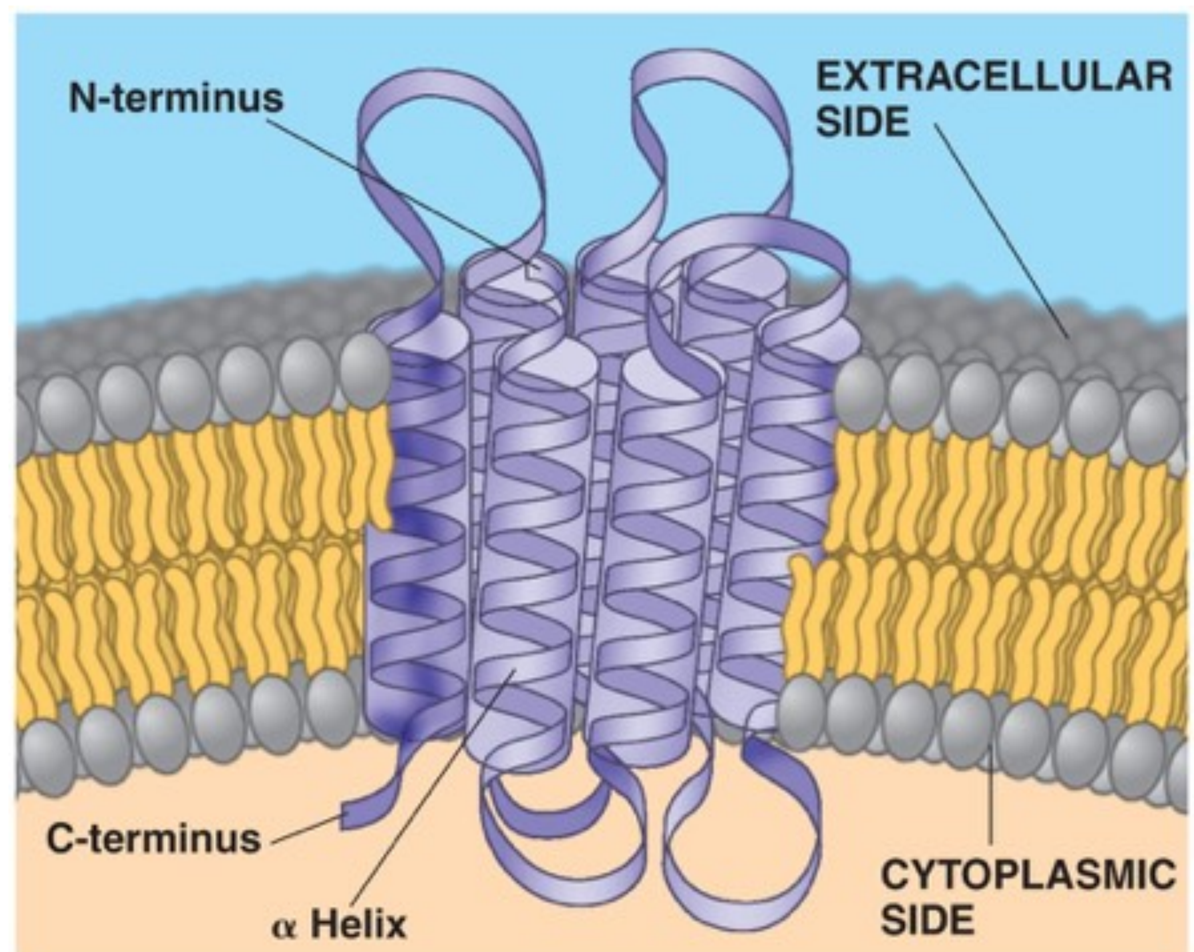
Membrane Proteins and Their Functions

- However all membrane proteins fall into one of two groups
  - **Integral proteins**, penetrate the lipid bilayer and most span the entire membrane
  - **Peripheral proteins**, do not penetrate the lipid bilayer, they are loosely bound to the surface of other proteins
- Many membrane proteins are held in place by the cytoskeleton or the fibers of the ECM

Hydrophilic

Hydrophobic

Hydrophilic



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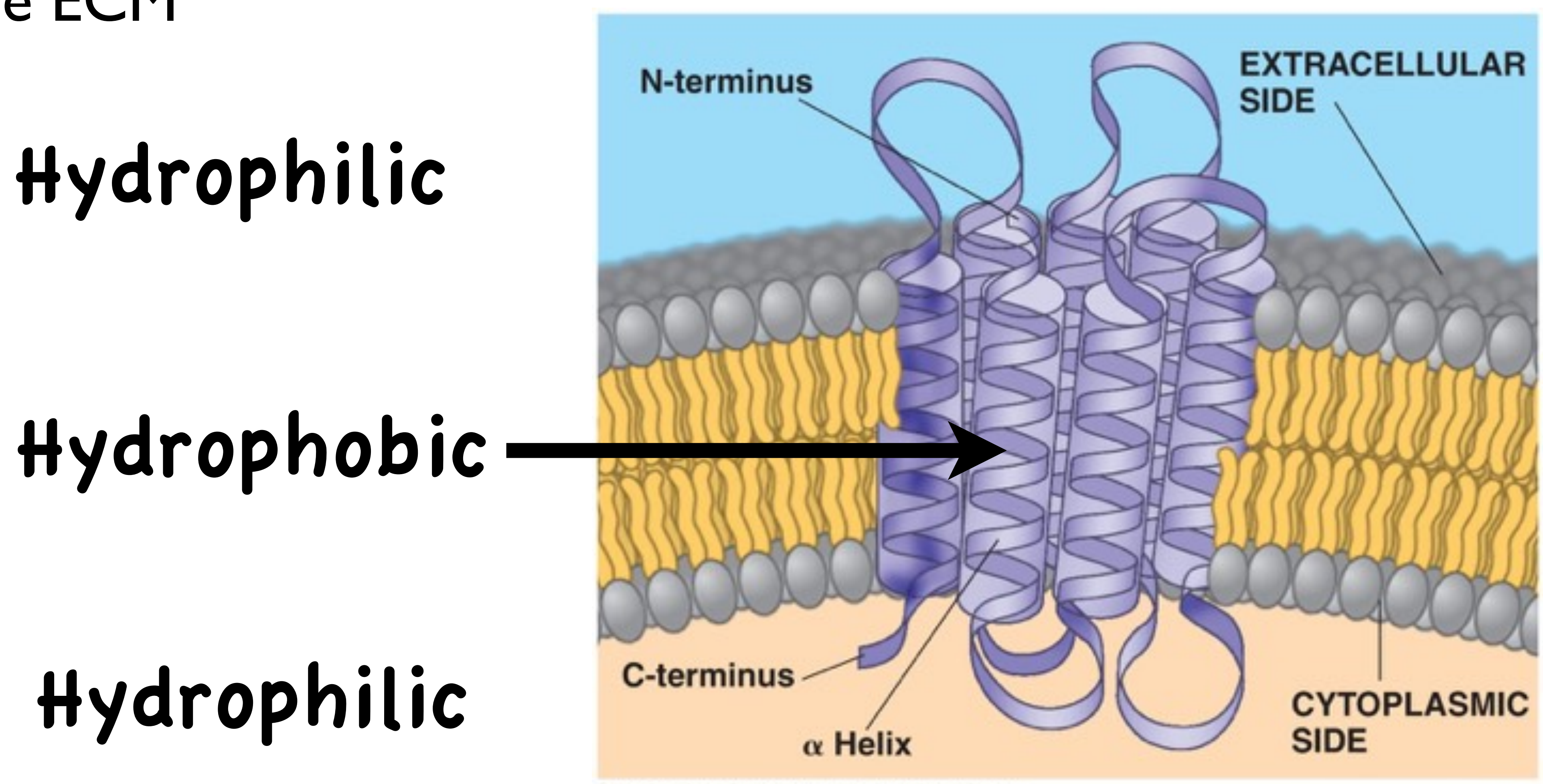

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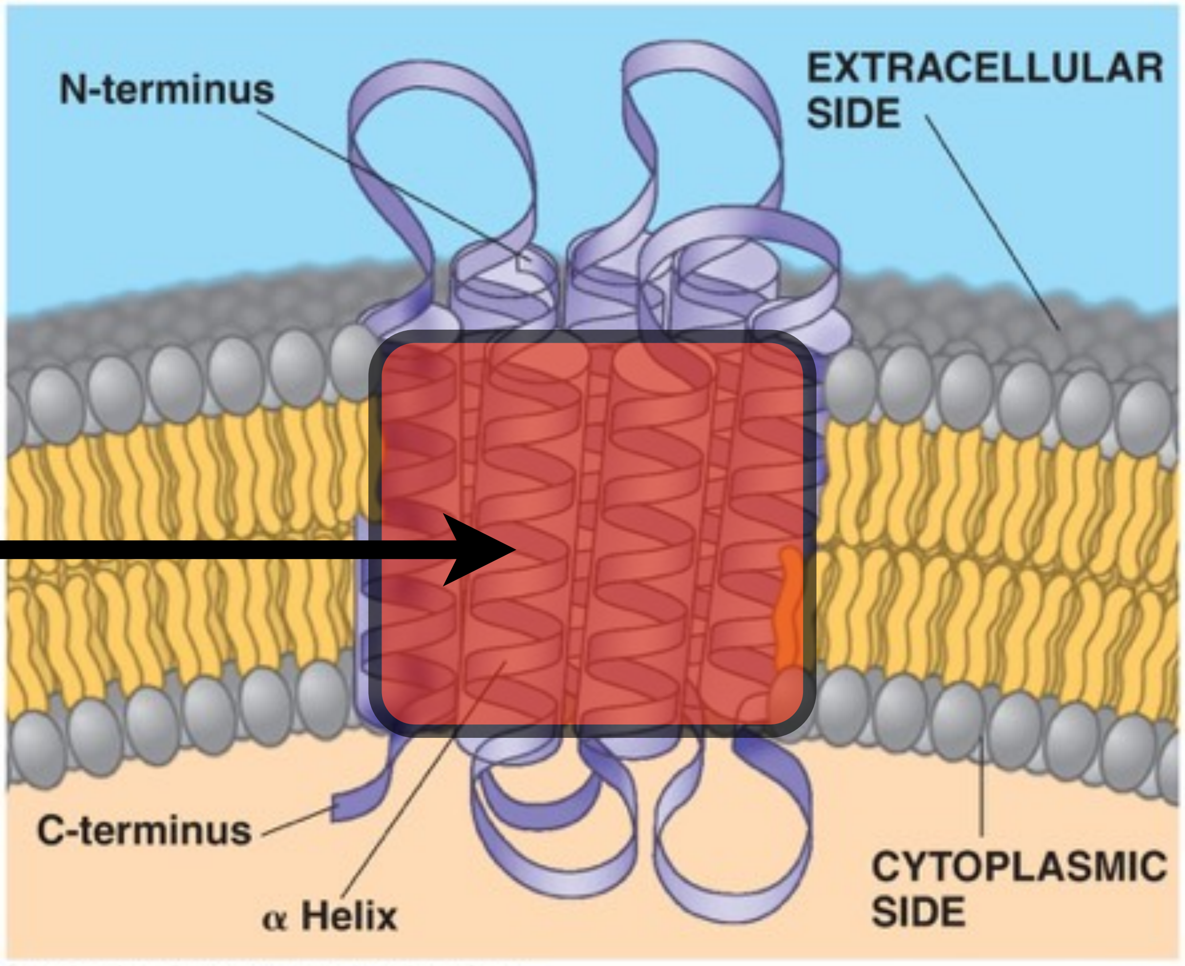

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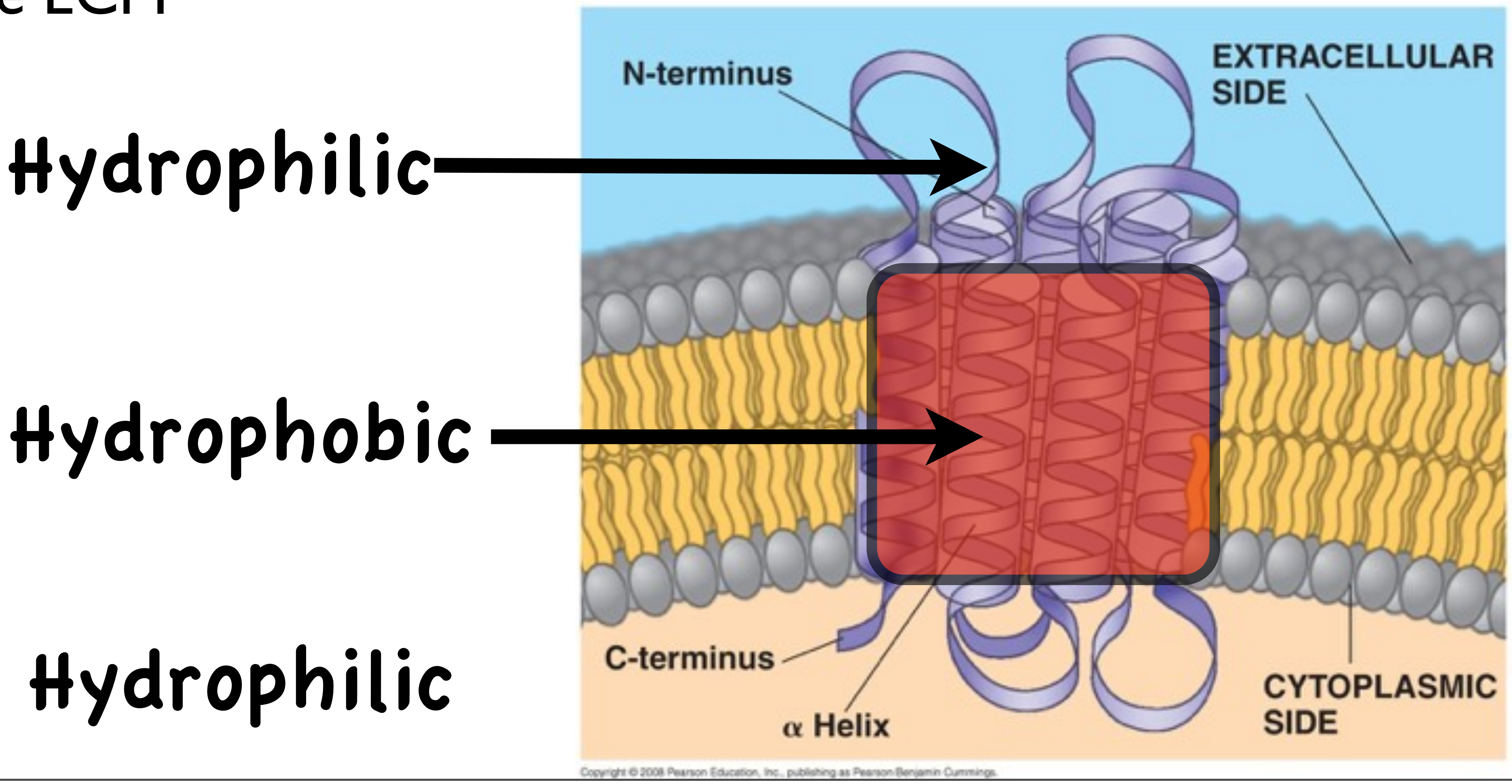

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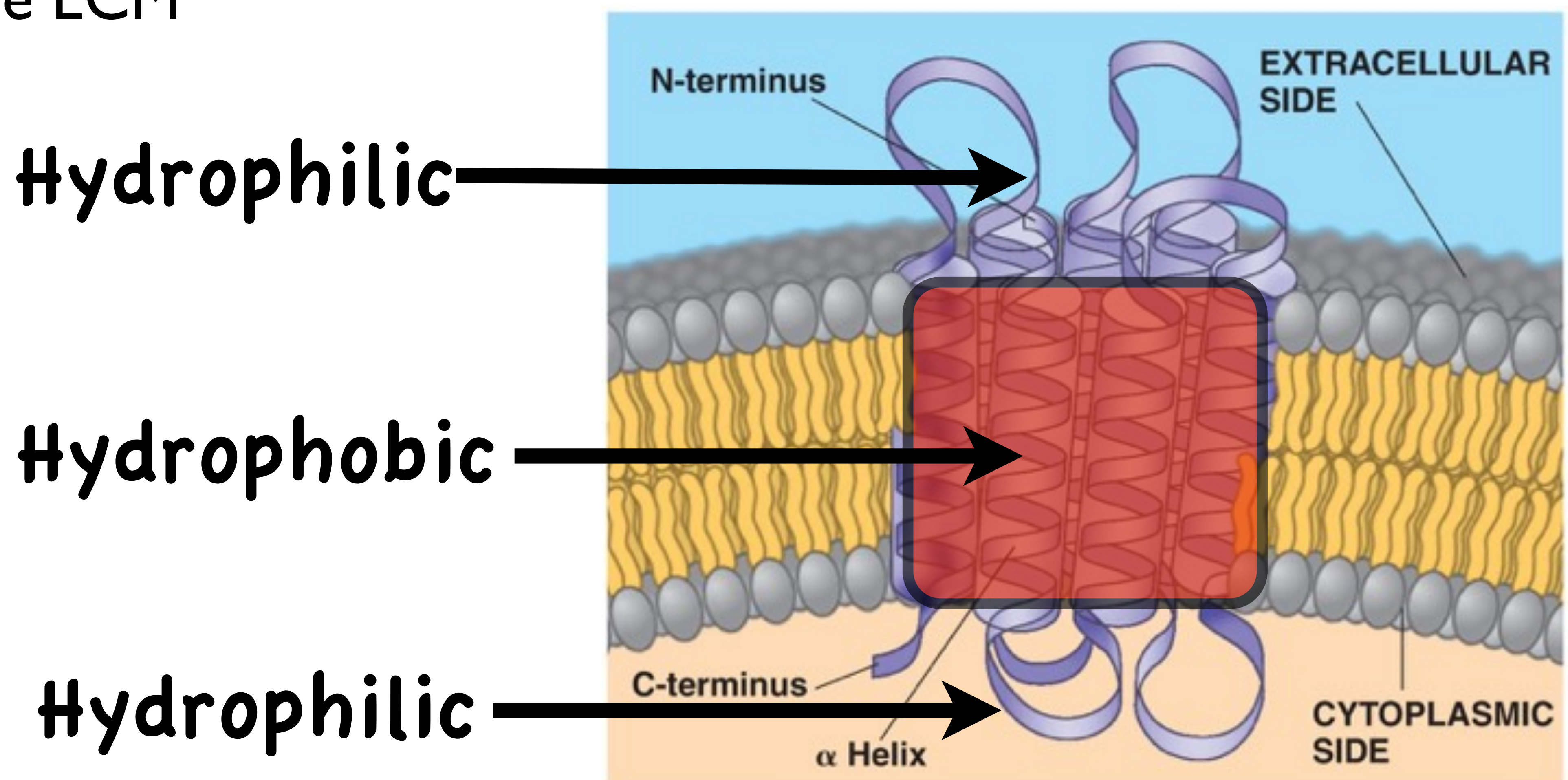

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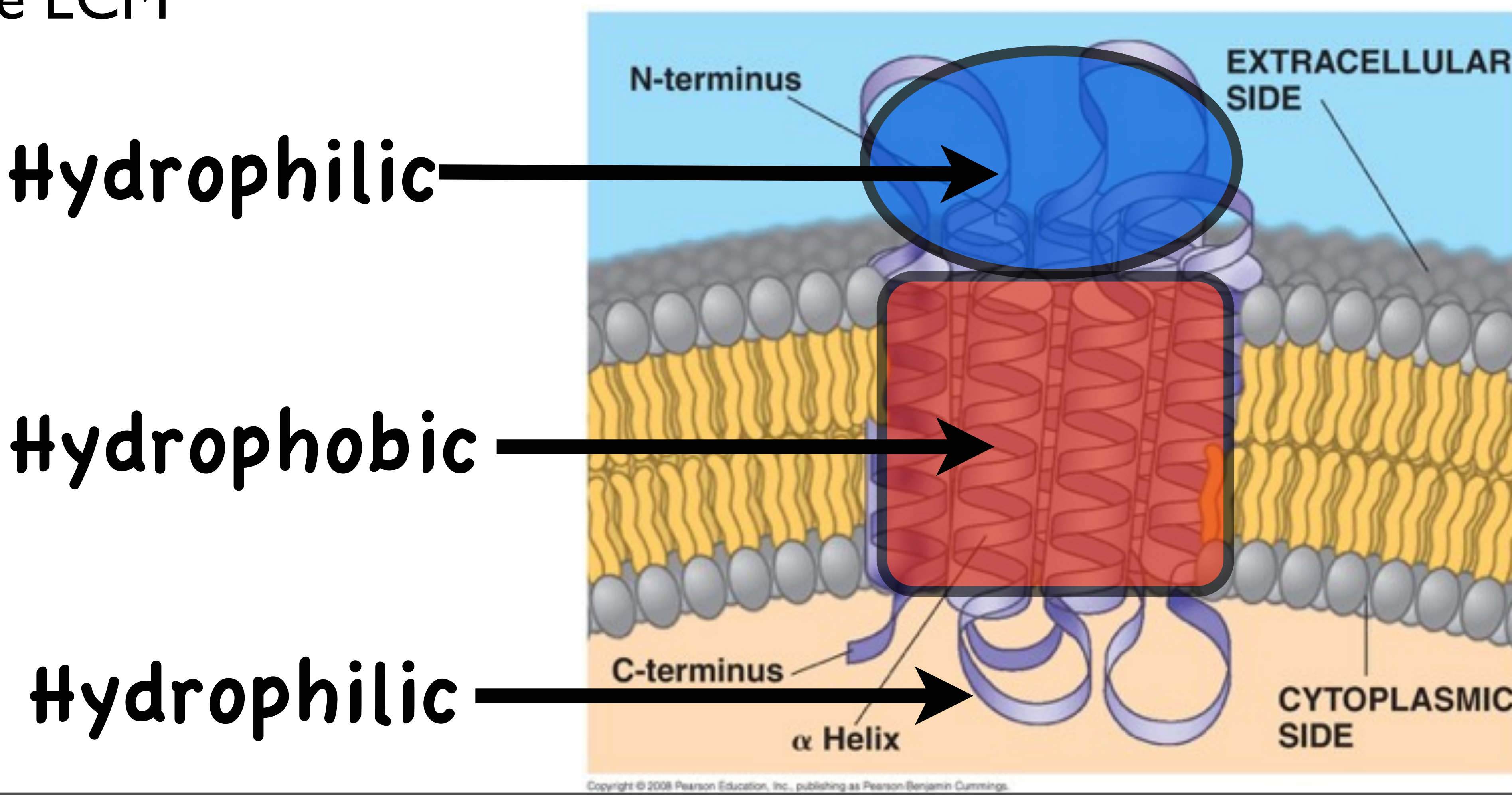

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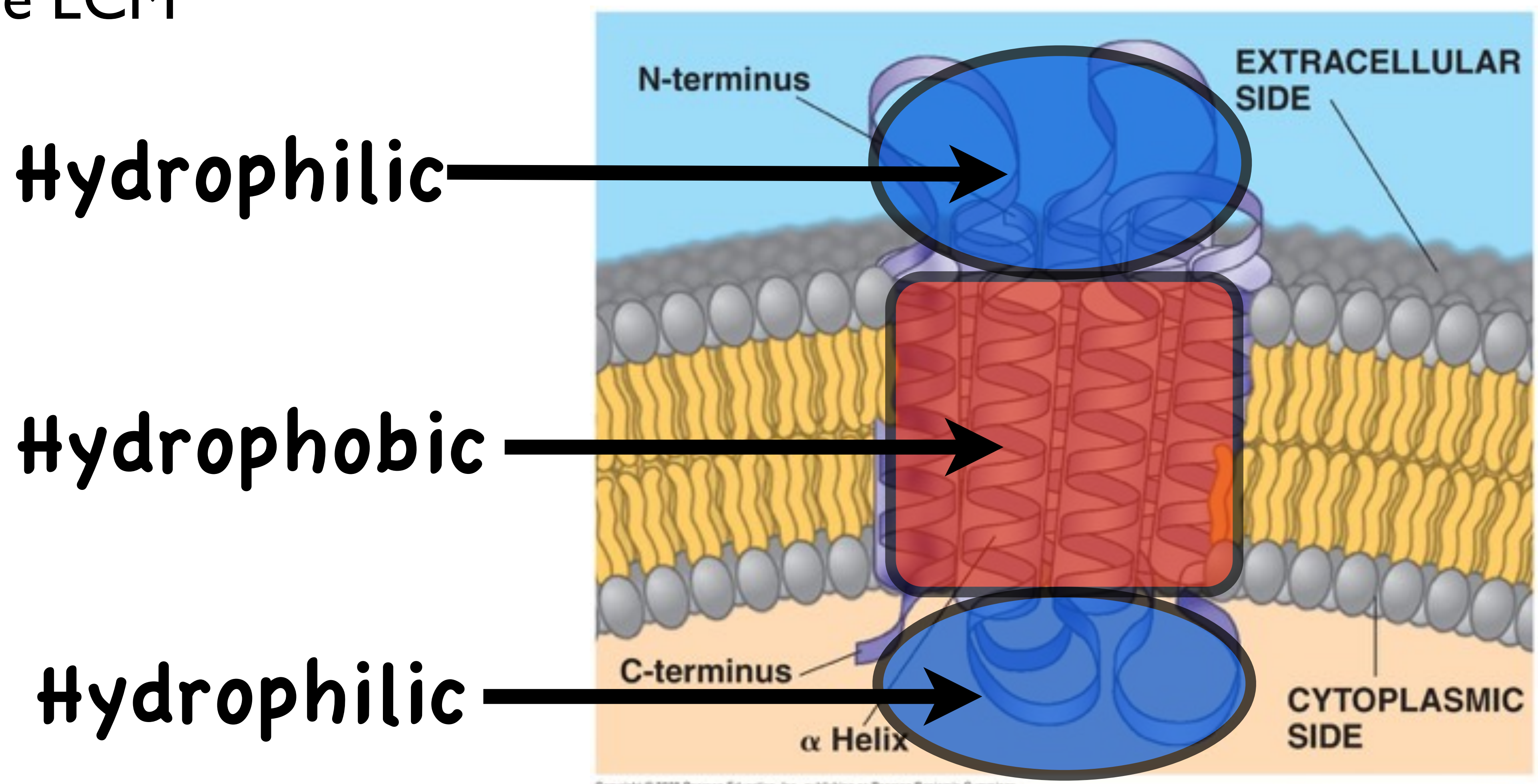

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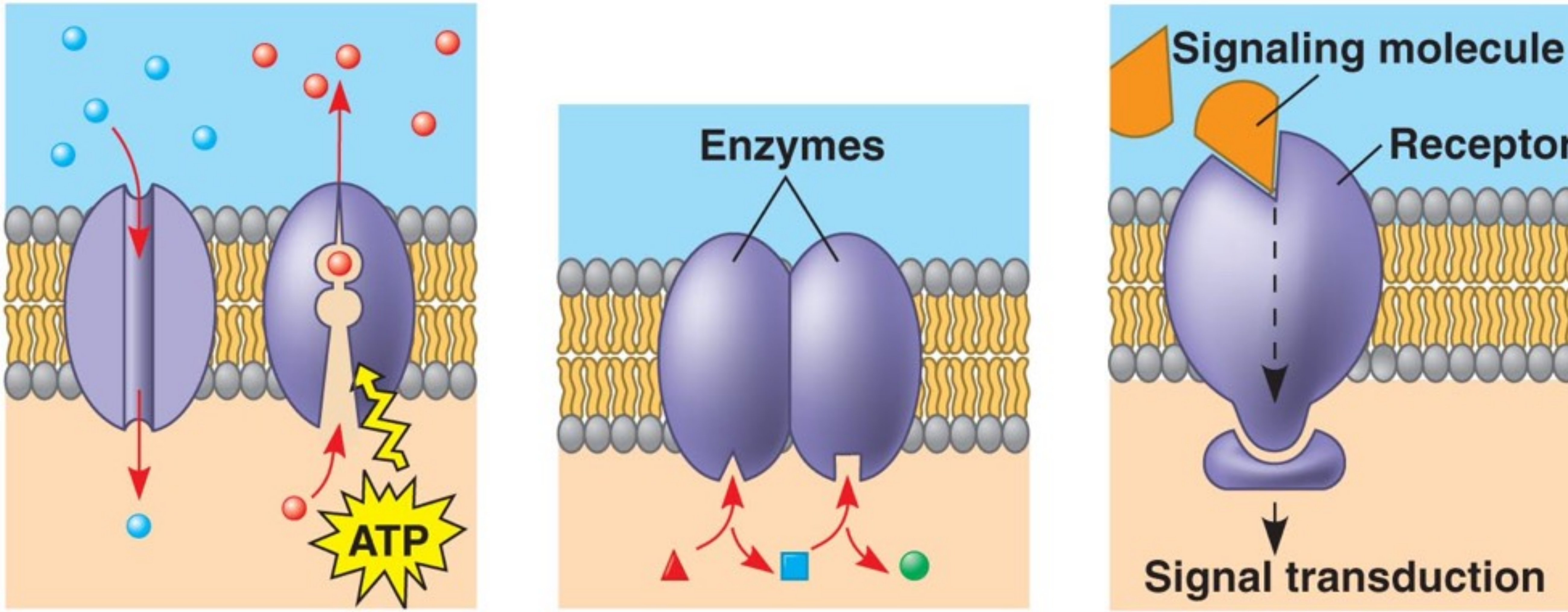
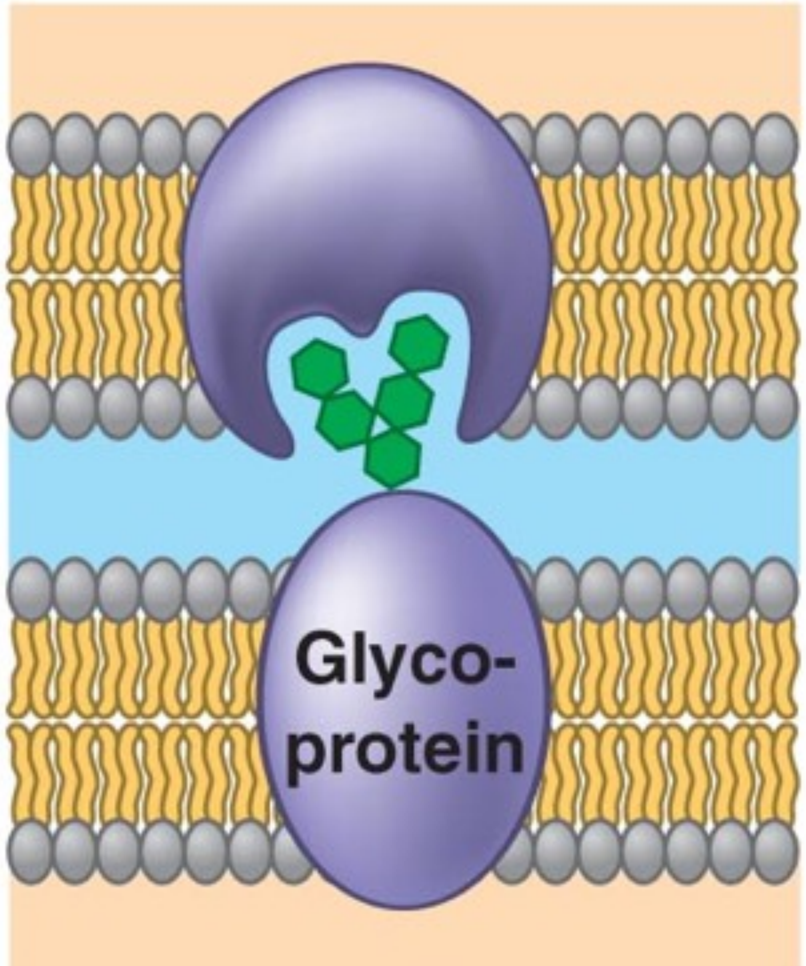
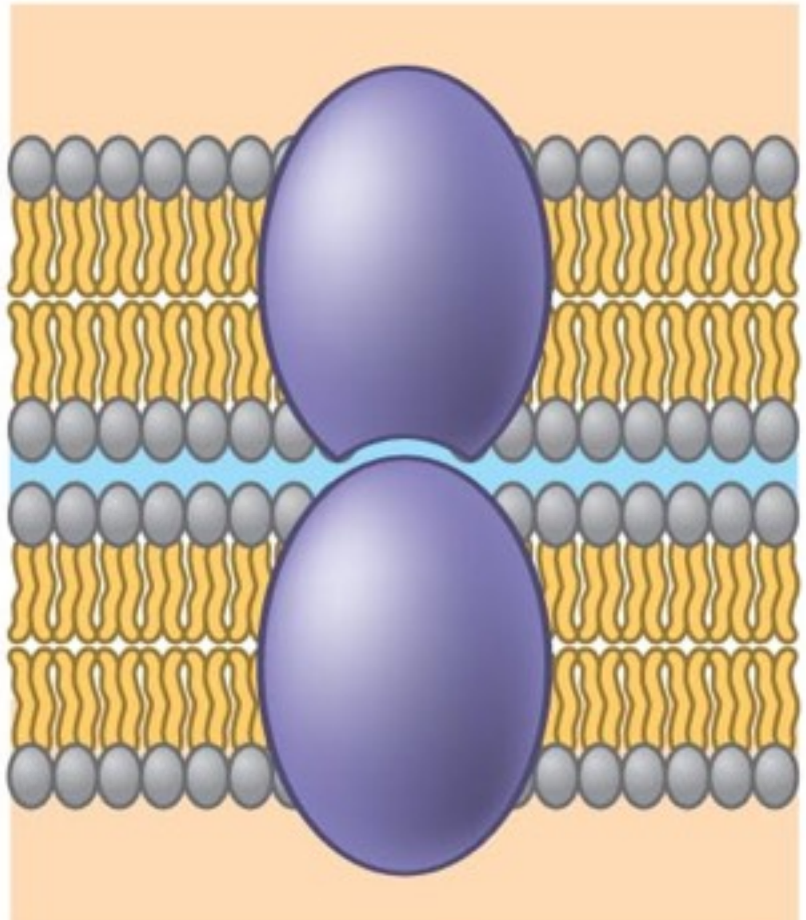


(a) Transport (b) Enzymatic activity (c) Signal transduction

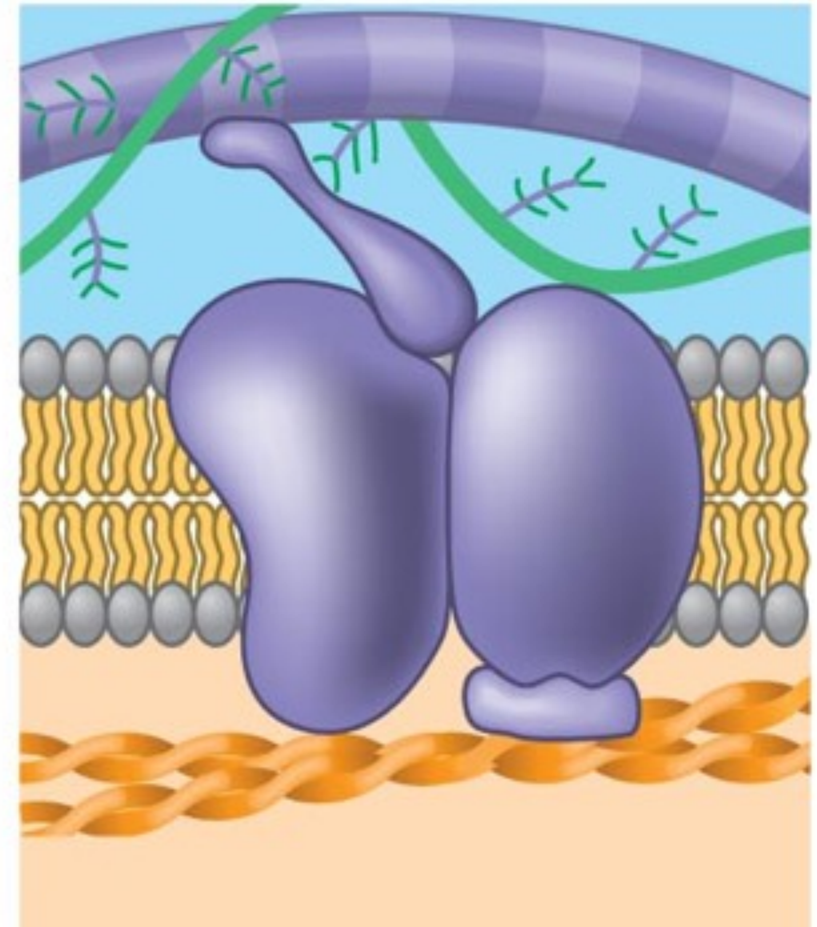
Membrane Proteins and Their Functions



(d) Cell-cell recognition



(e) Intercellular joining



(f) Attachment to the cytoskeleton and extracellular matrix (ECM)

The Role of Membrane Carbohydrates in Cell to Cell Recognition

- Carbohydrates play a critical role in cellular identification.
  - Very short (~15 units) sugars serve as cellular "ID tags".
  - **Glycolipids** are sugars bound to lipids
  - **Glycoproteins** are sugars bound to proteins
- These carbs are located on the extracelluar side.
  - *They vary from species to species*
  - *They vary among individuals of the same species*
  - *They vary among the cells of the same individual.*

Essential knowledge 2.B.1: Cell membranes are selectively permeable due to their structure.

b. Selective permeability is a direct consequence of membrane structure, as described by the fluid mosaic model. [See also 4.A.1]

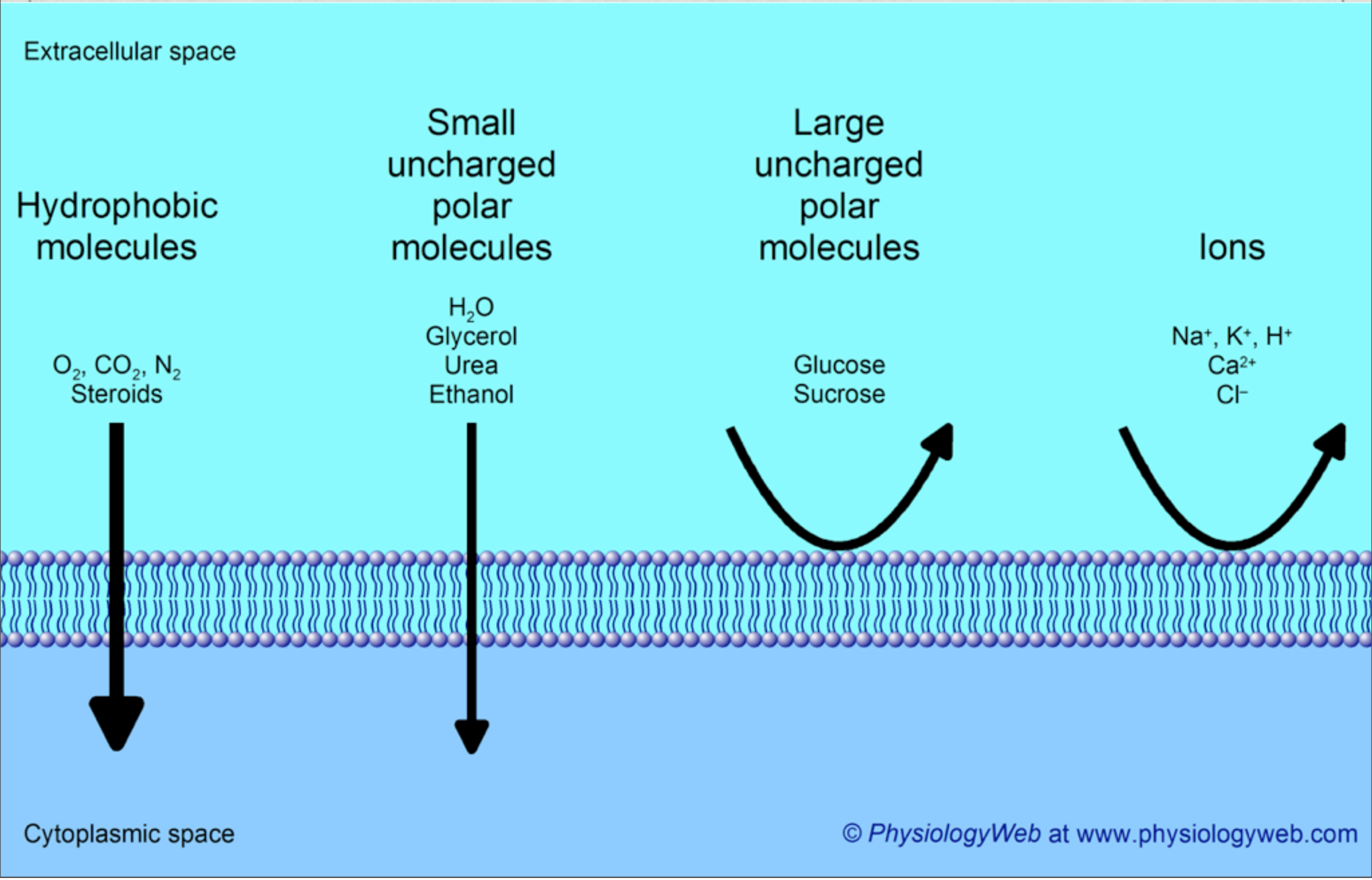
Evidence of student learning is a demonstrated understanding of each of the following:

4. Small, uncharged polar molecules and small nonpolar molecules, such as N_2, freely pass across the membrane. Hydrophilic substances such as large polar molecules and ions move across the membrane through embedded channel and transport proteins. Water moves across membranes and through channel proteins called aquaporins.

MEMBRANE STRUCTURE RESULTS IN SELECTIVE PERMEABILITY

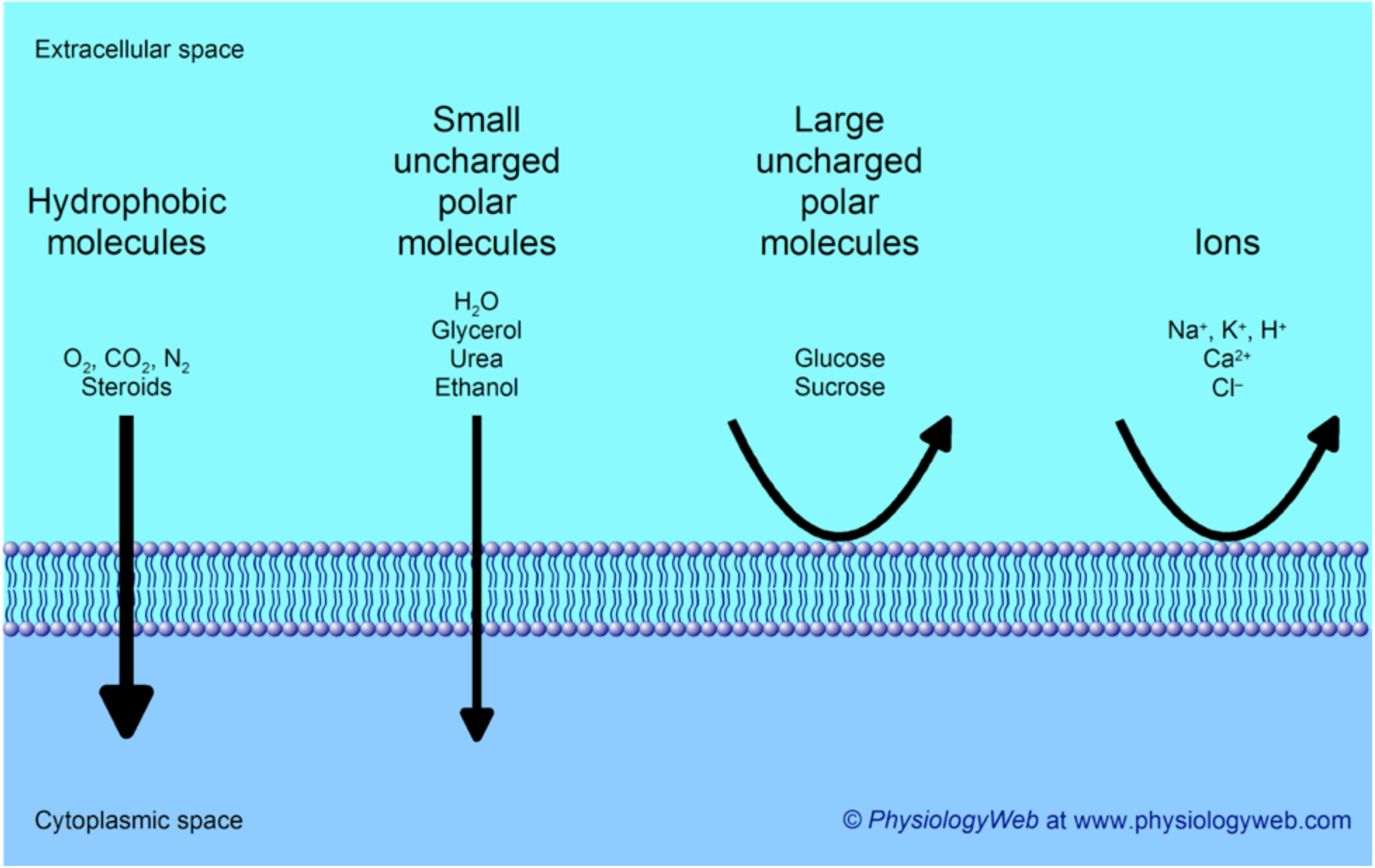
- Substances do not pass through the membrane indiscriminately
- The cell is able to take up some molecules while excluding others.
  - Nutrients need to enter the cell and wastes need to leave the cell
- Also, substances move through the membrane at different rates

Selective Permeability



Something else to think about...

The permeability of the Lipid Bilayer



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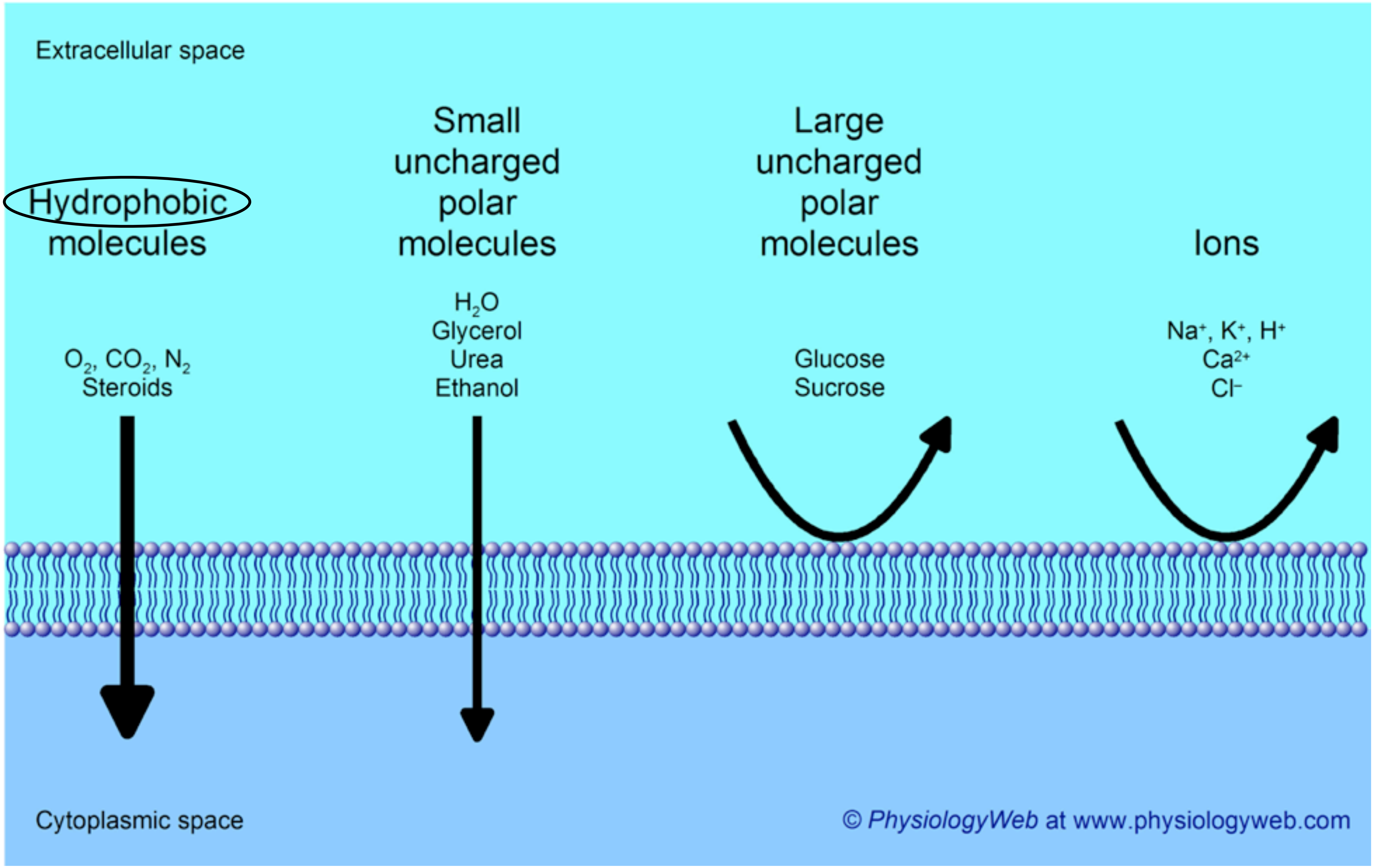

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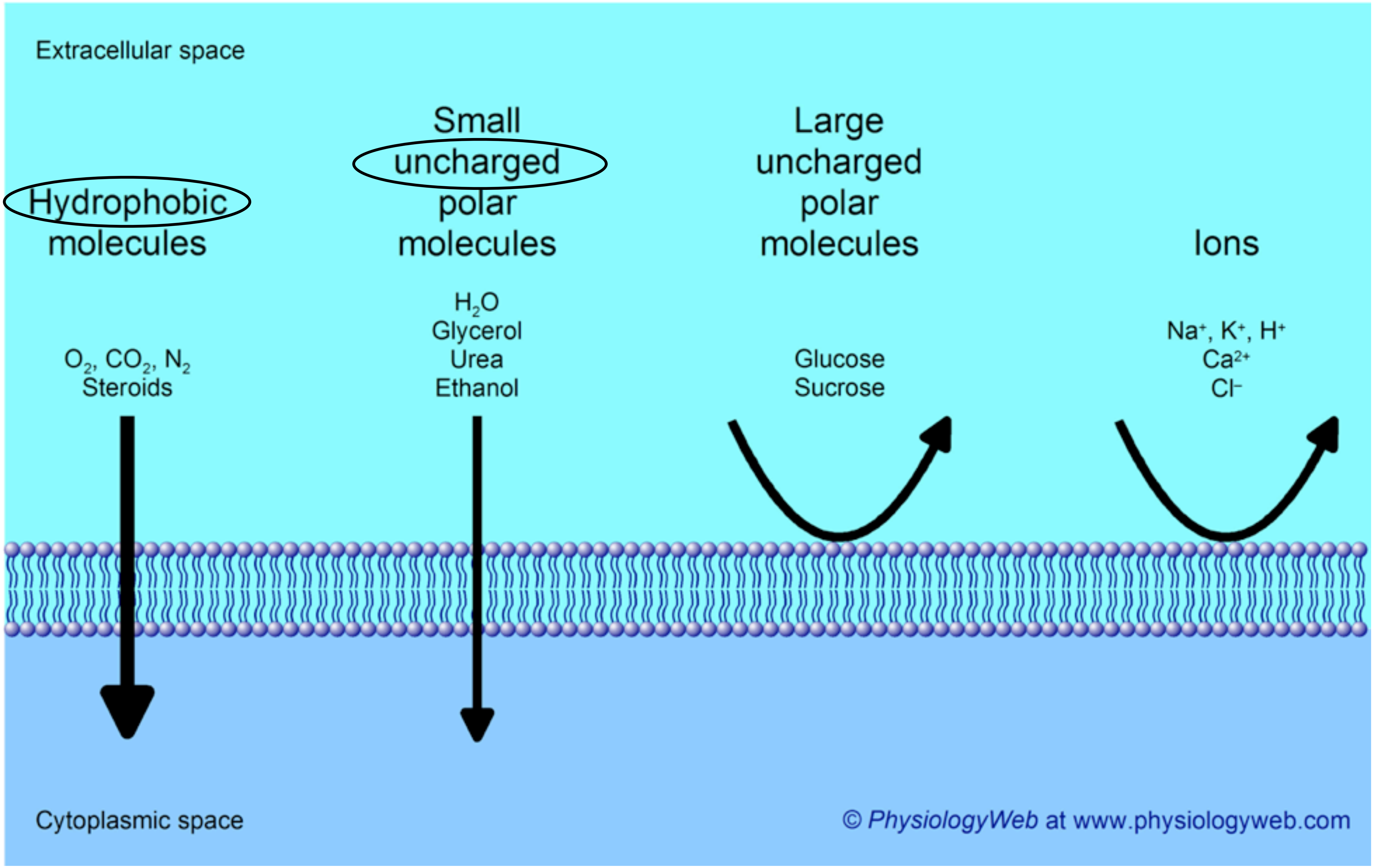

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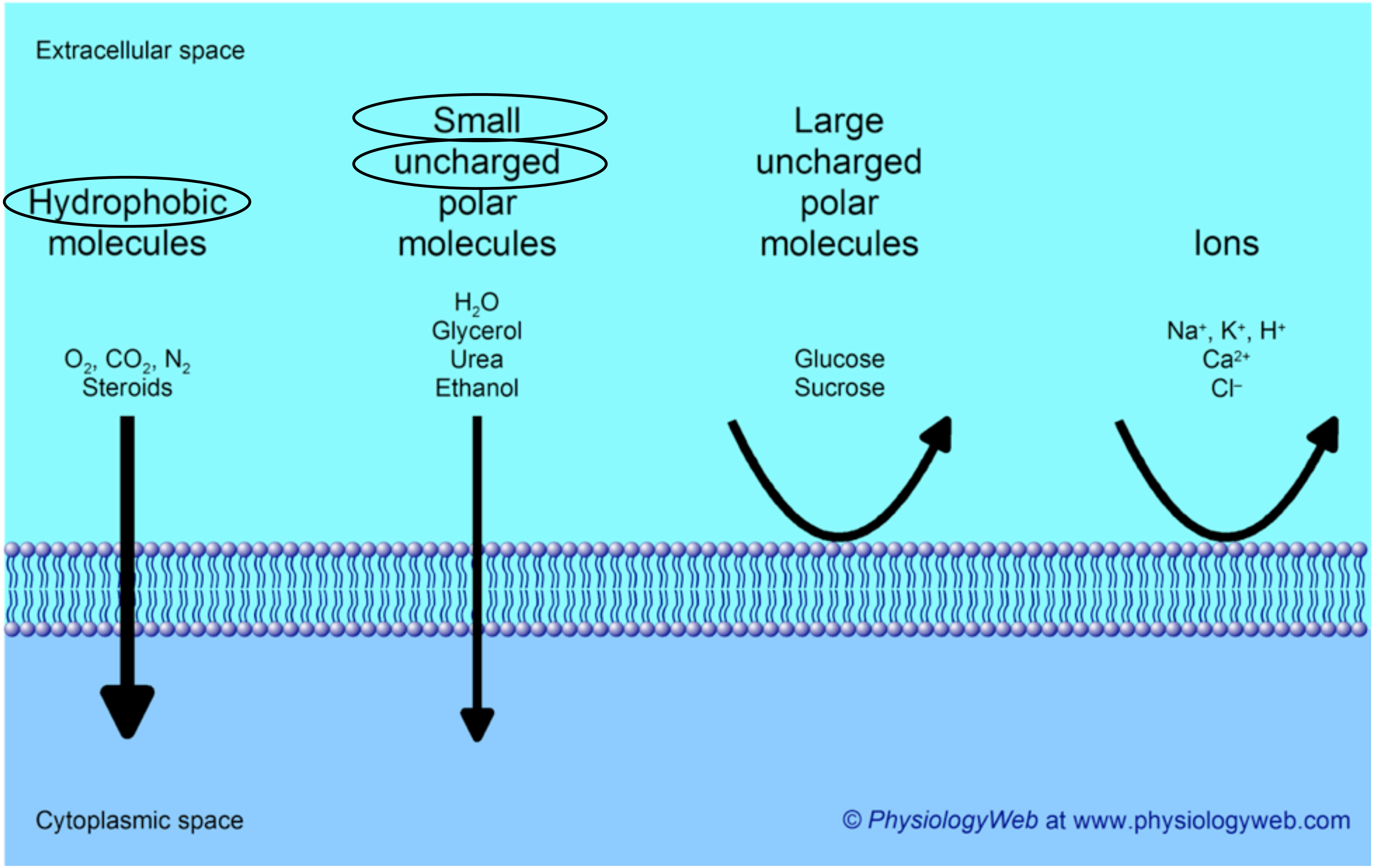

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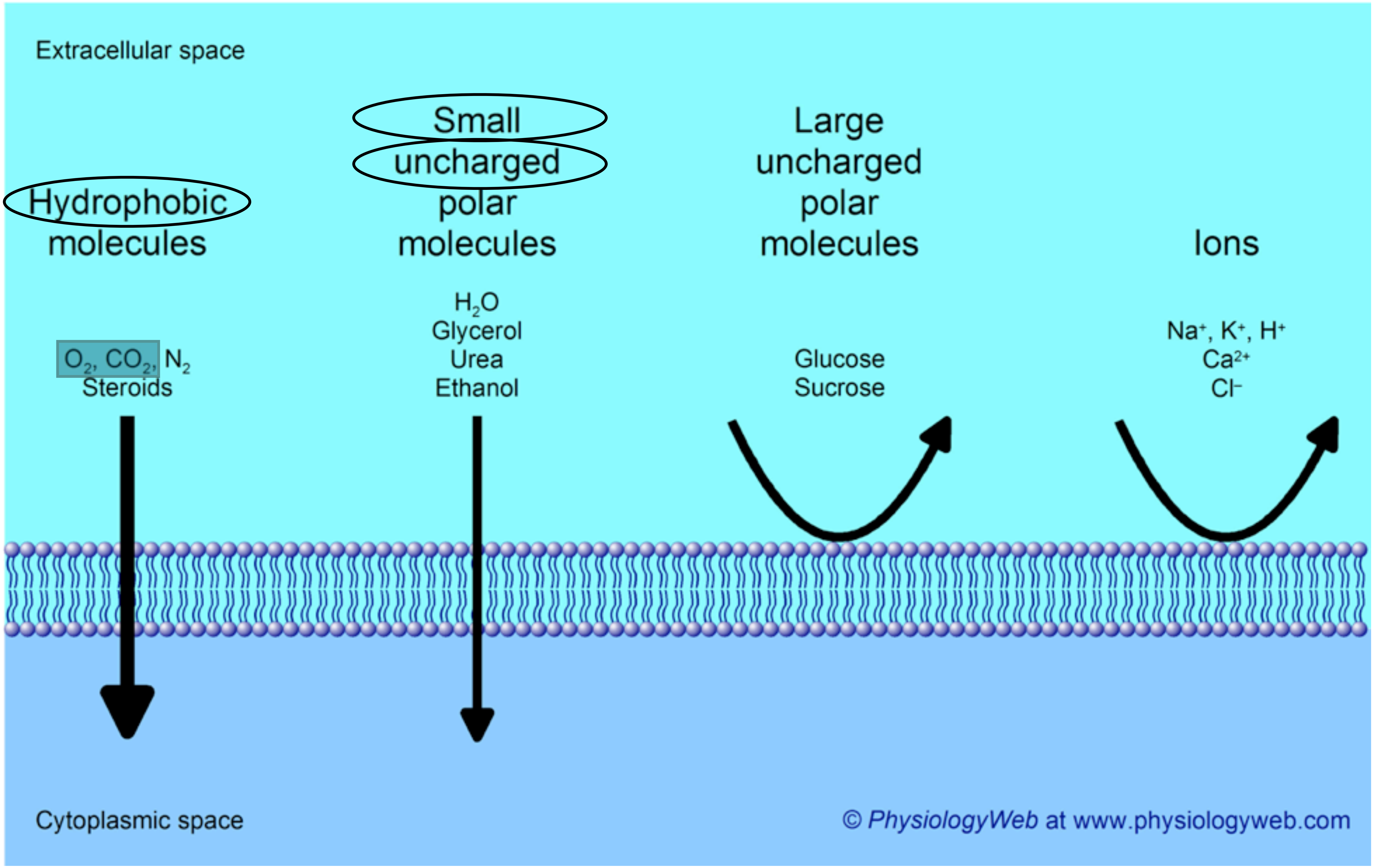

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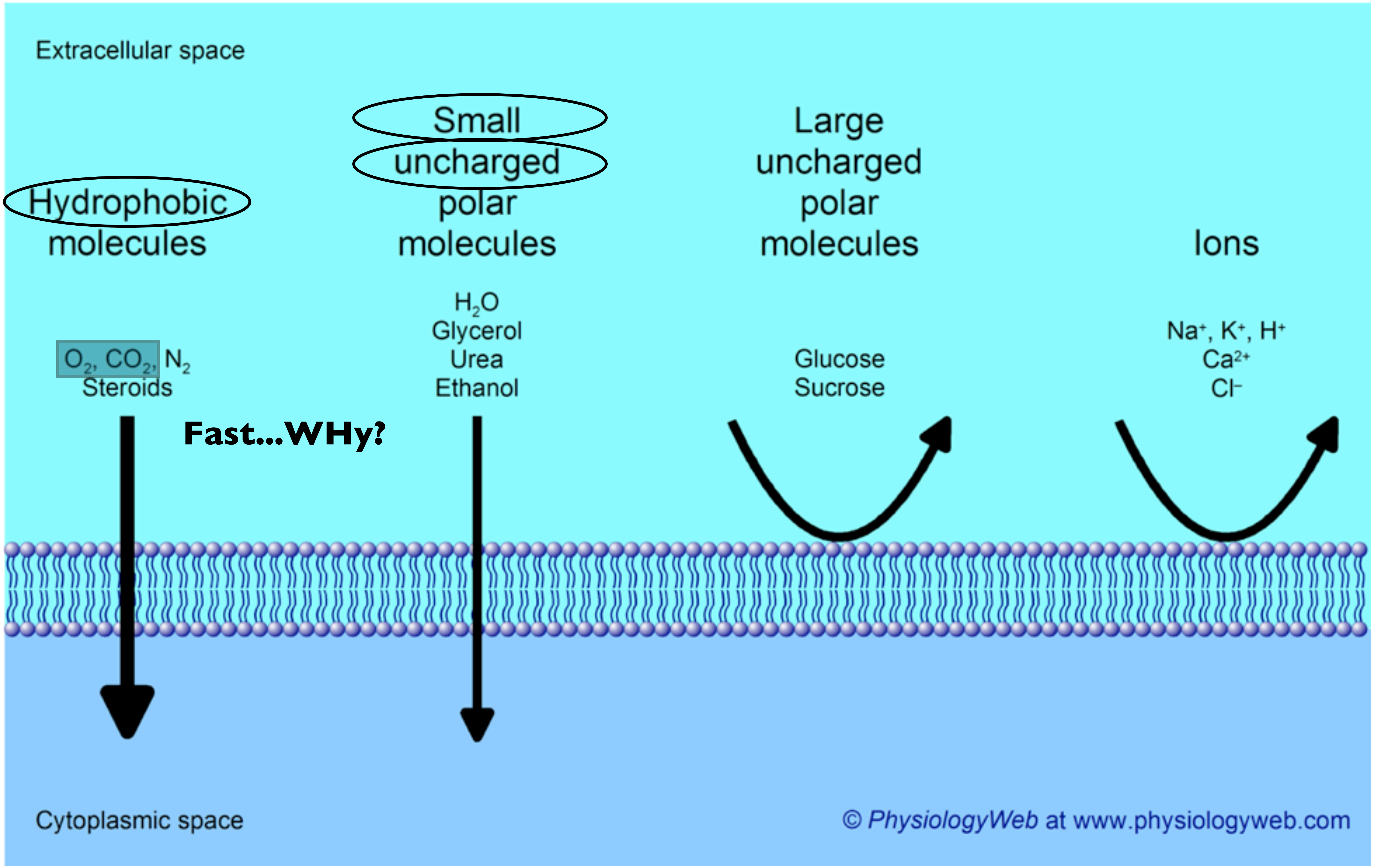

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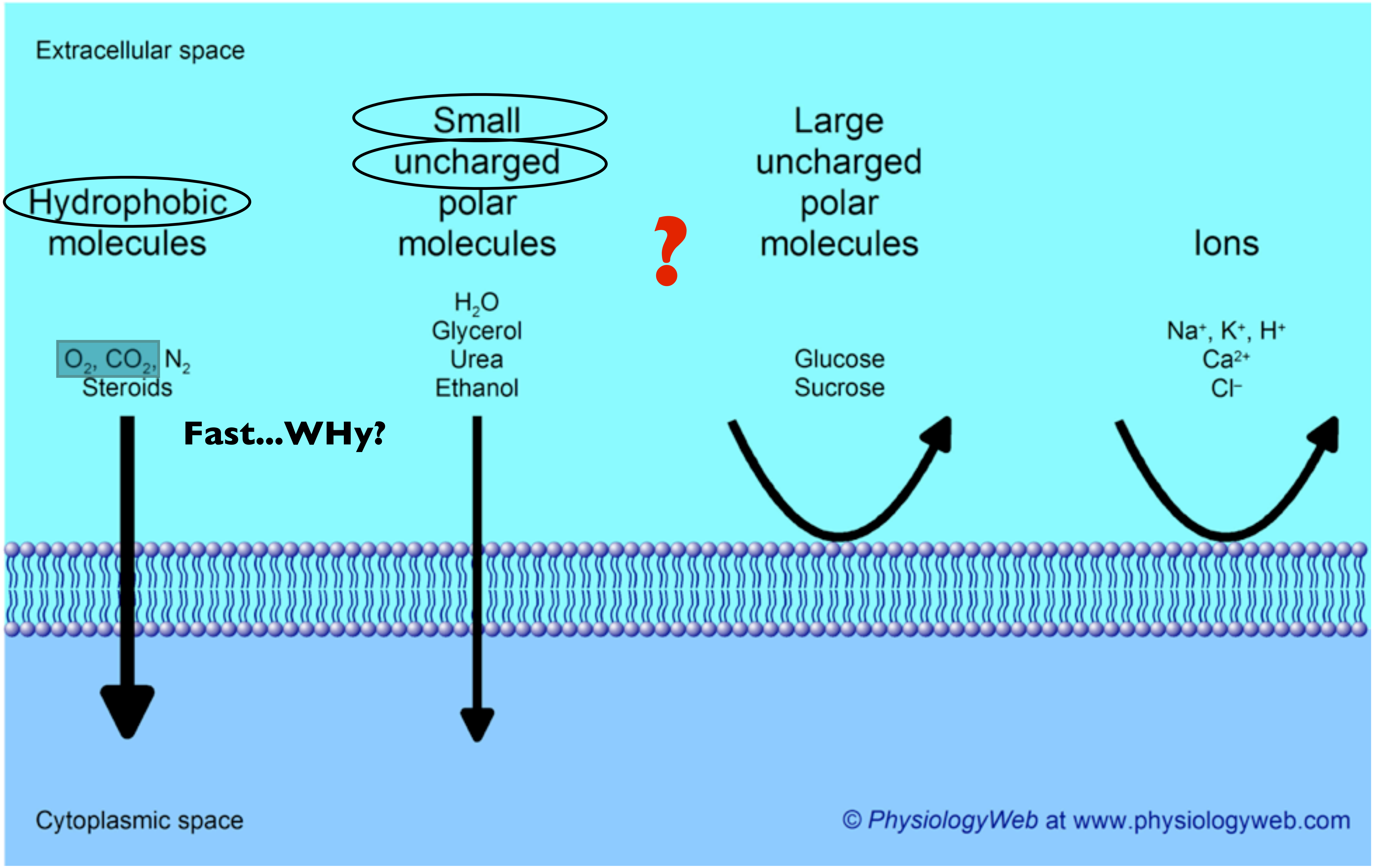

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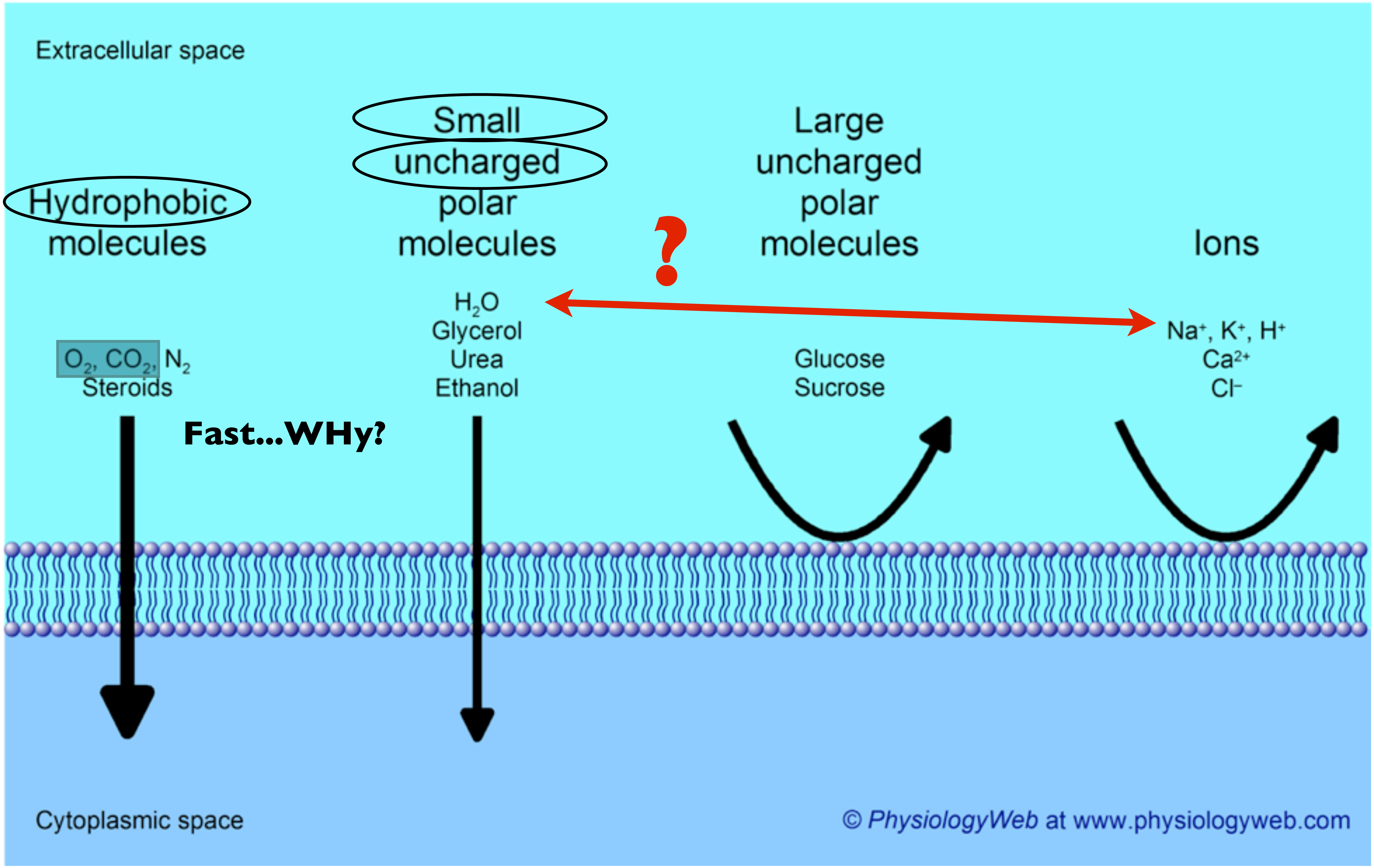

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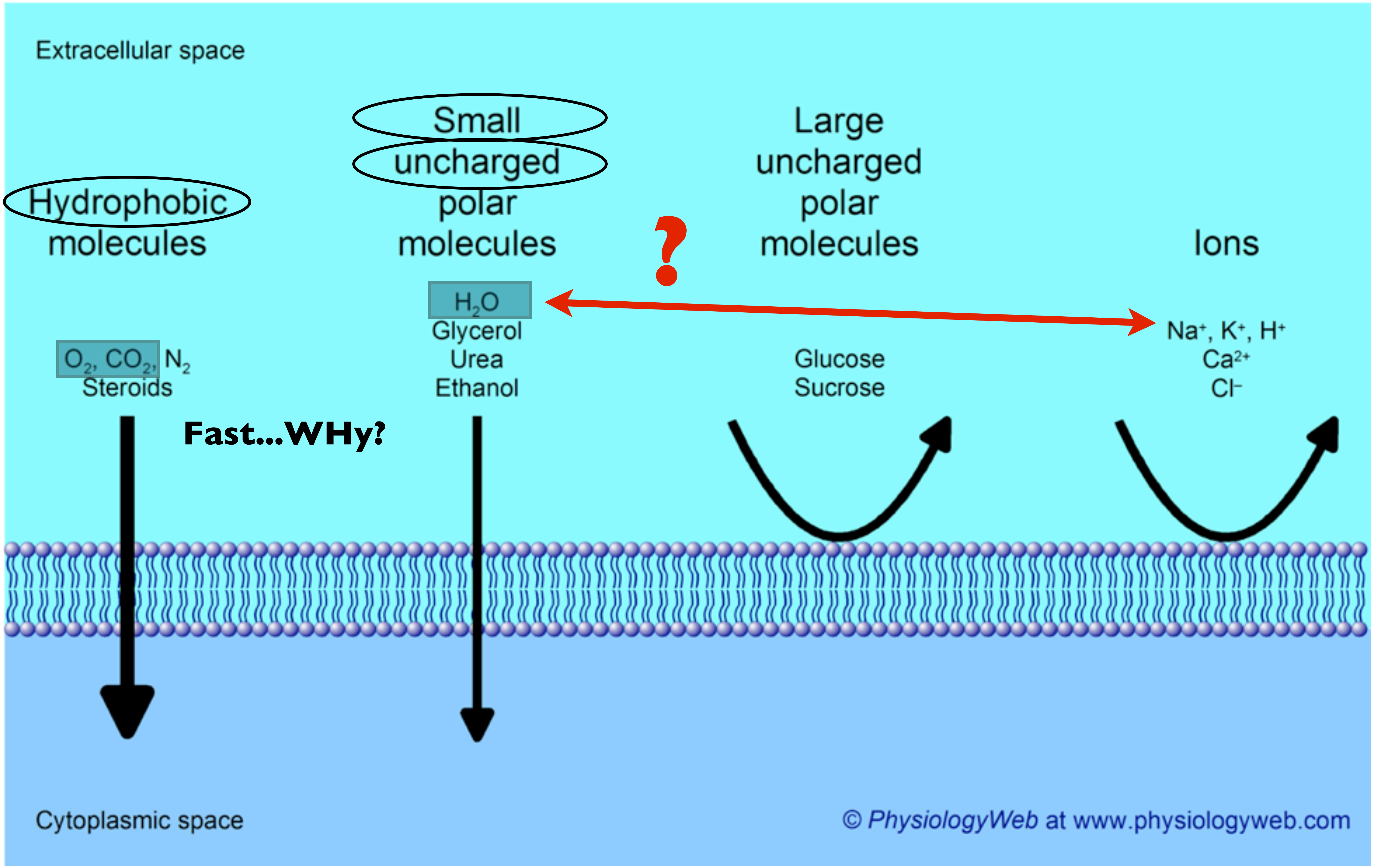

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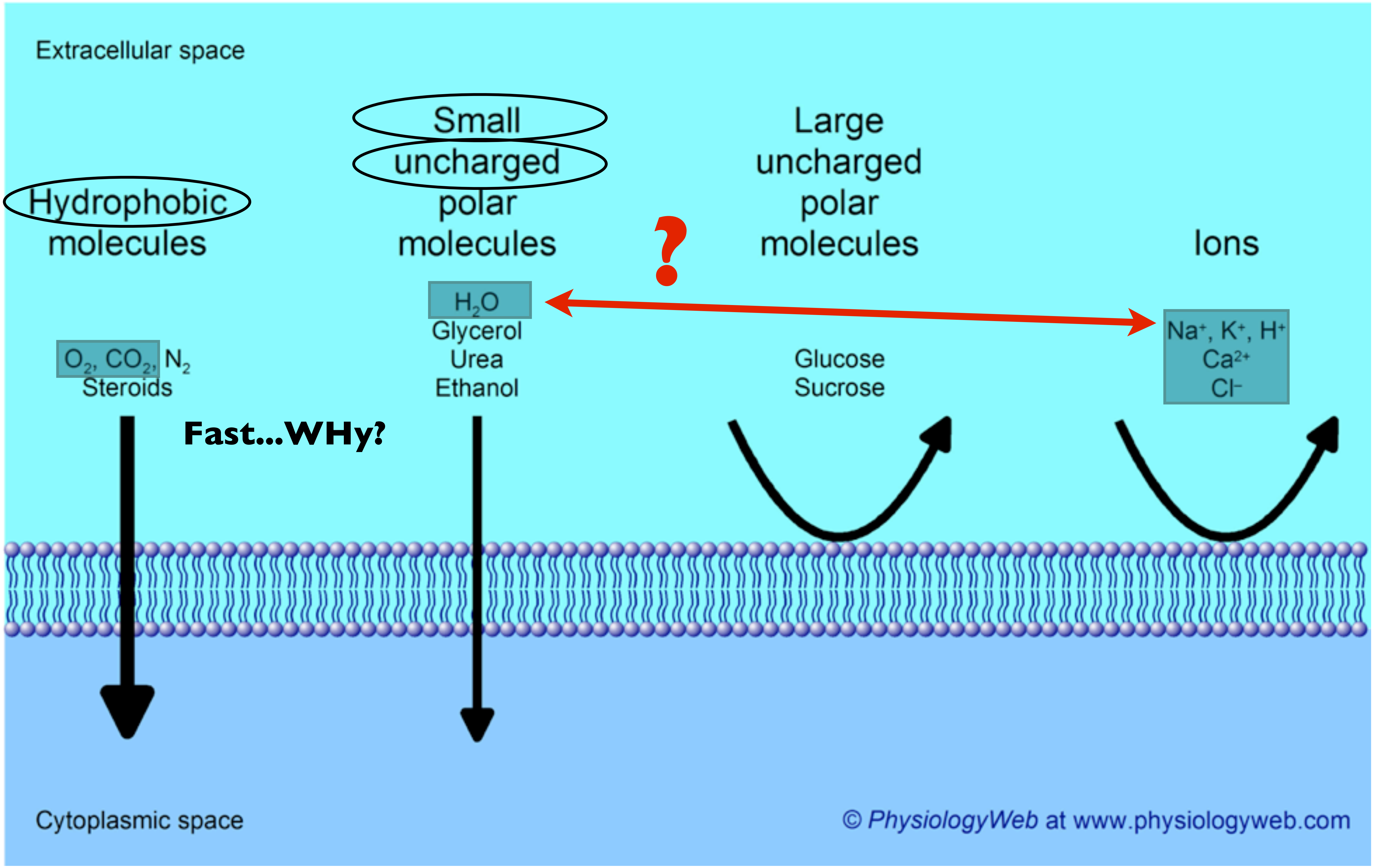

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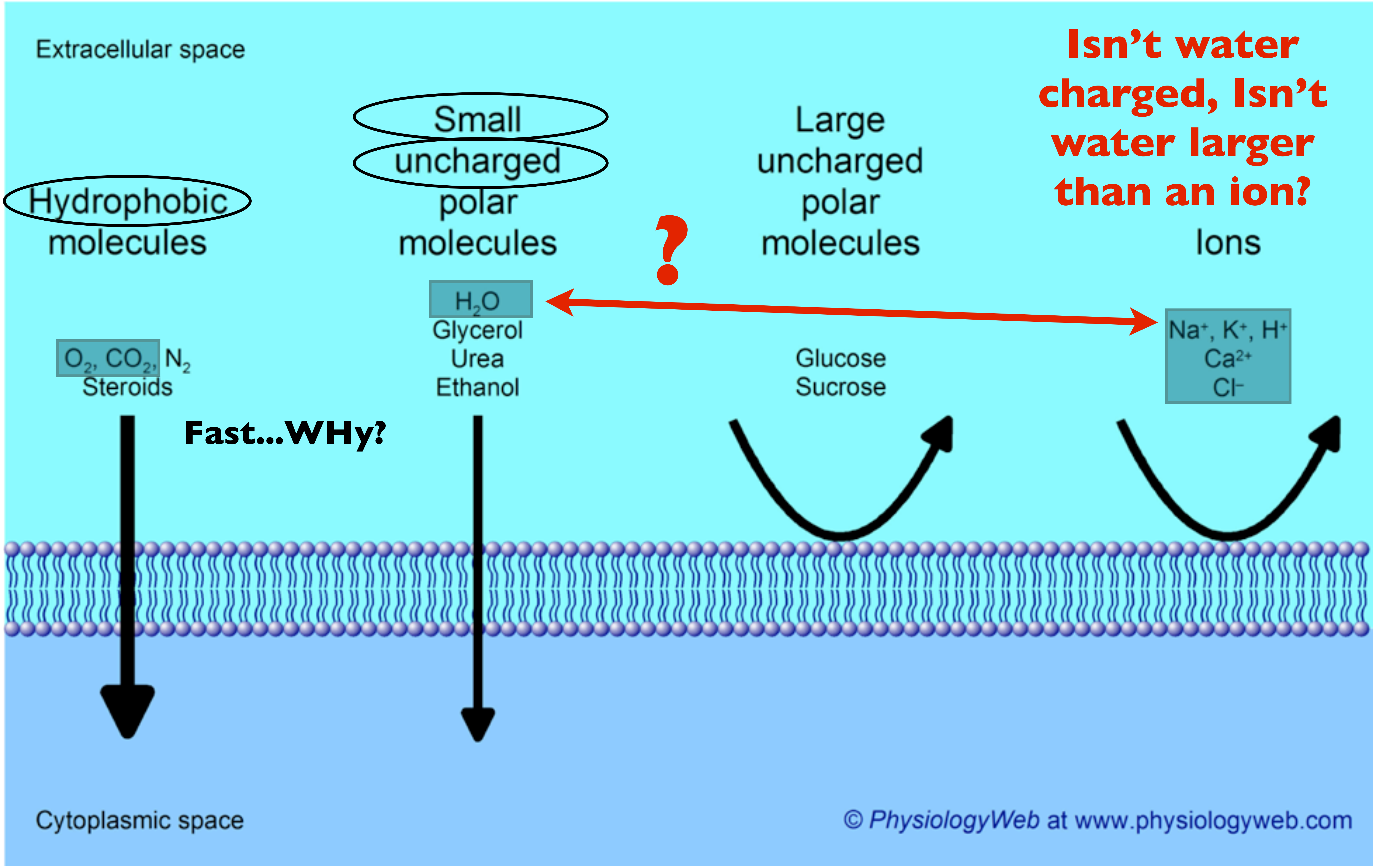

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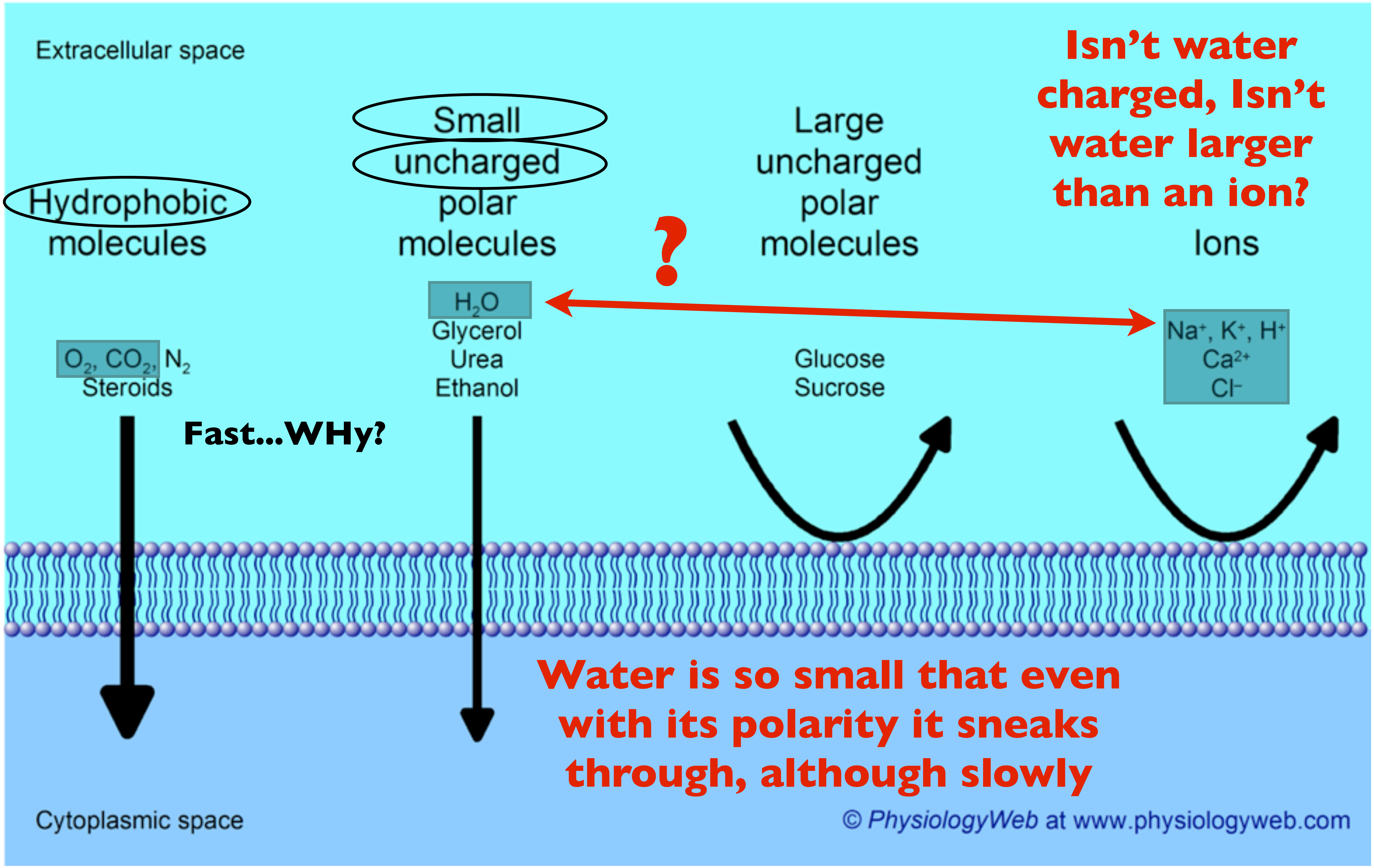

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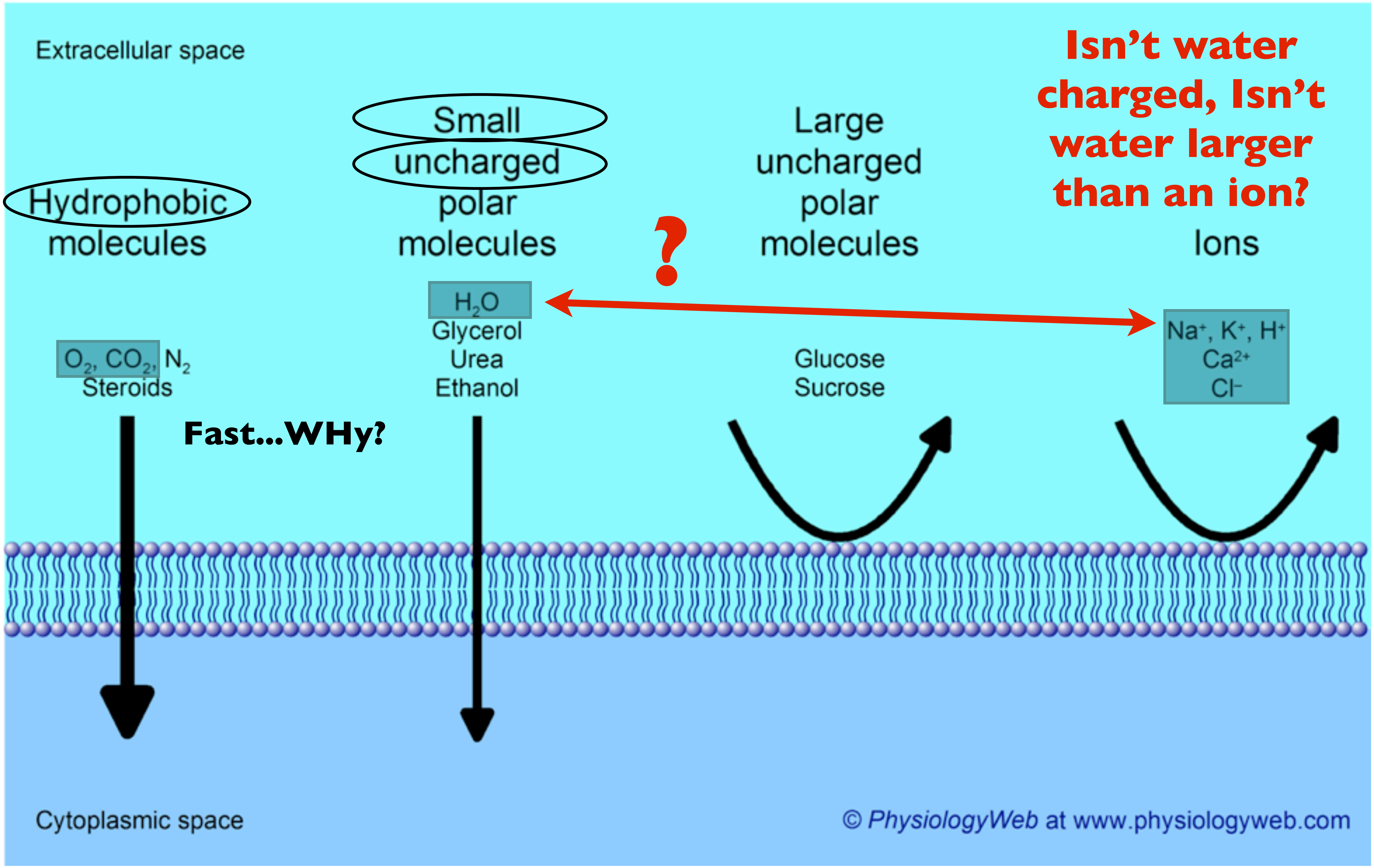

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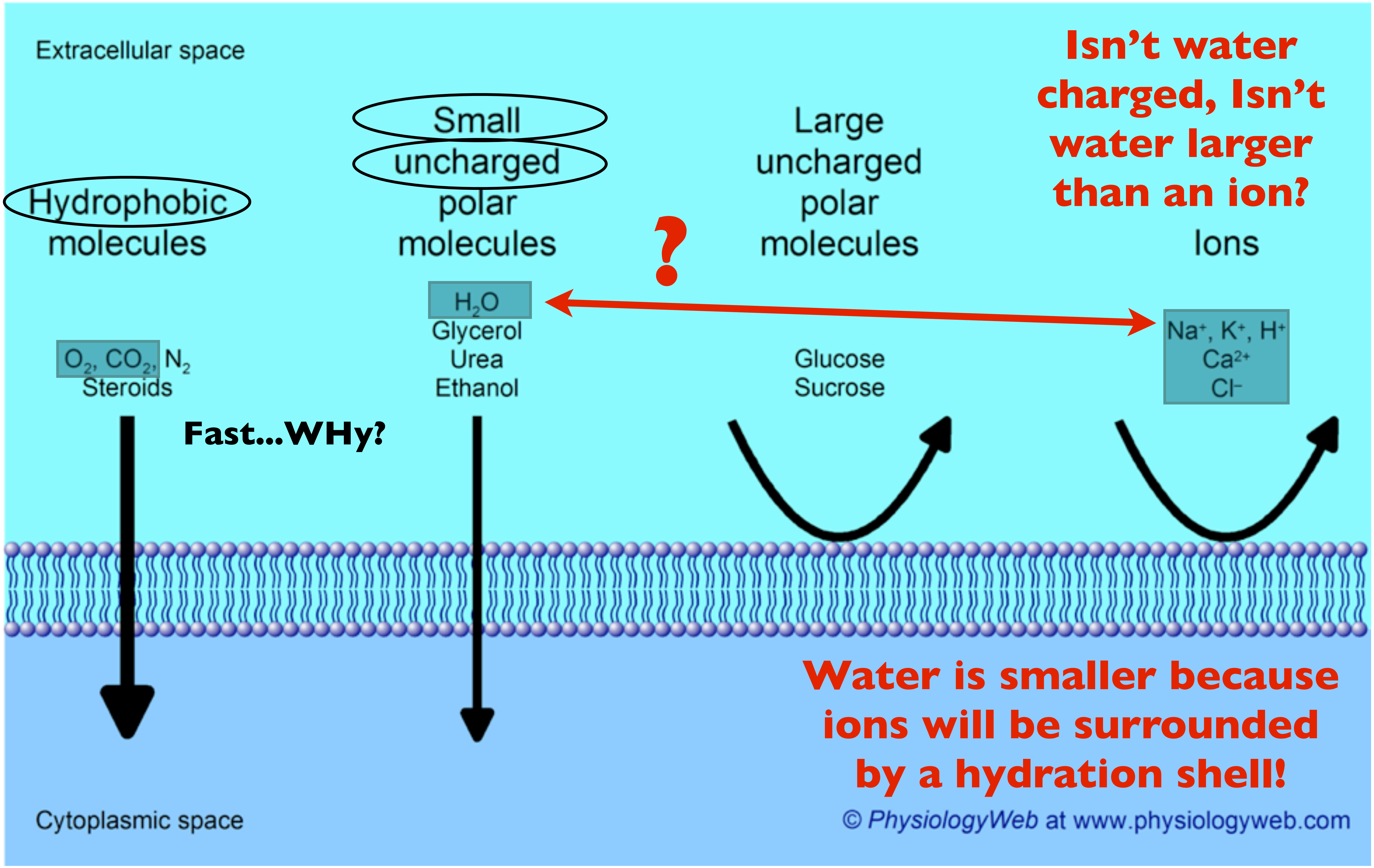

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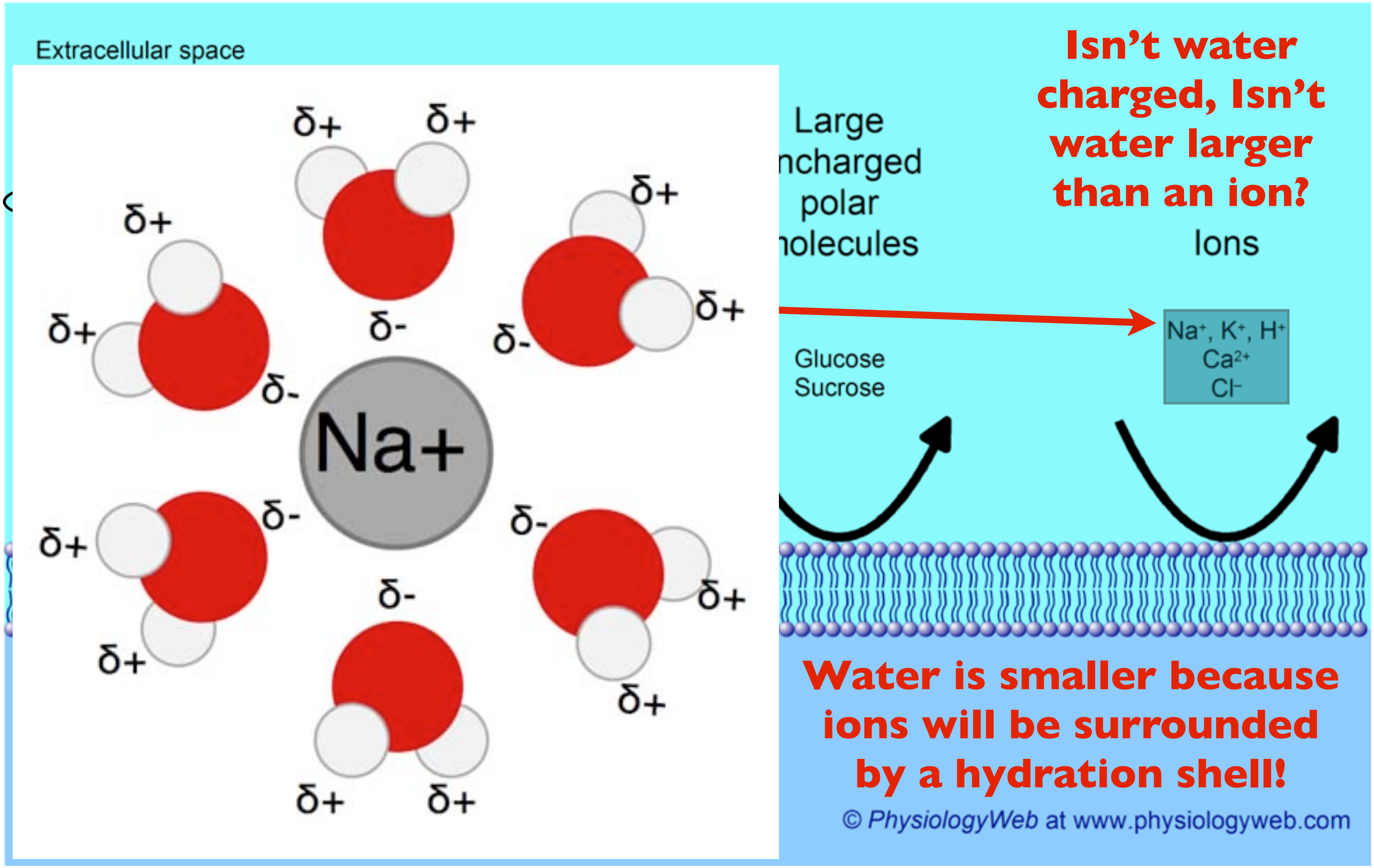

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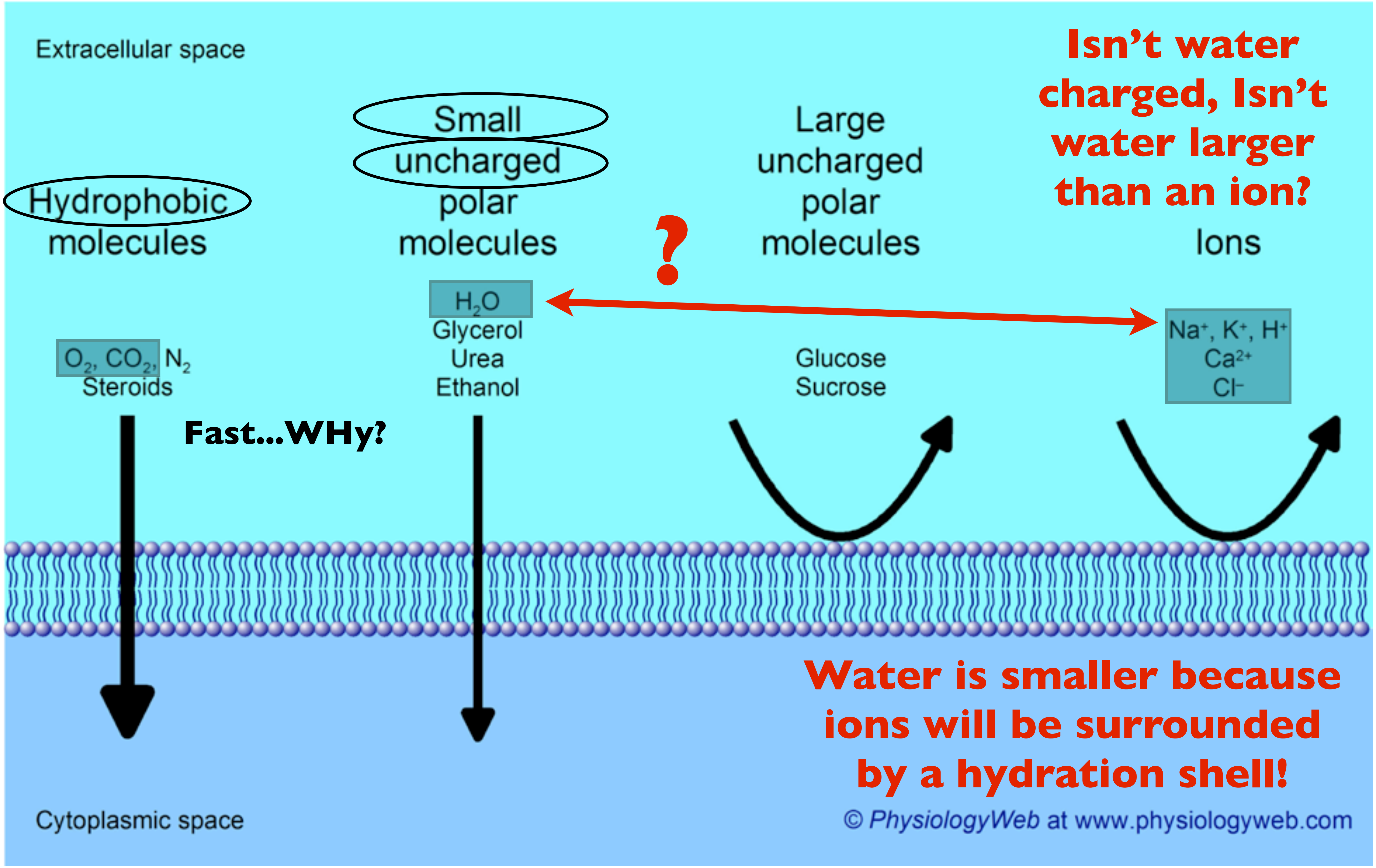


Isn't water charged, Isn't water larger than an ion?

Water is smaller because ions will be surrounded by a hydration shell!

Transport Proteins

- Hydrophilic substances can pass through protein pores called ***transport proteins*** more specifically ***channel proteins*** whose channel is also hydrophilic.
  - **Aquaporins** for example greatly facilitates the rate of water transport.
- Other ***transport proteins*** hold on called ***carrier proteins*** hold onto their passengers, change shape and release to the other side

Essential knowledge 2.B.1: Cell membranes are selectively permeable due to their structure.

c. Cell walls provide a structural boundary, as well as a permeability barrier for some substances to the internal environments.

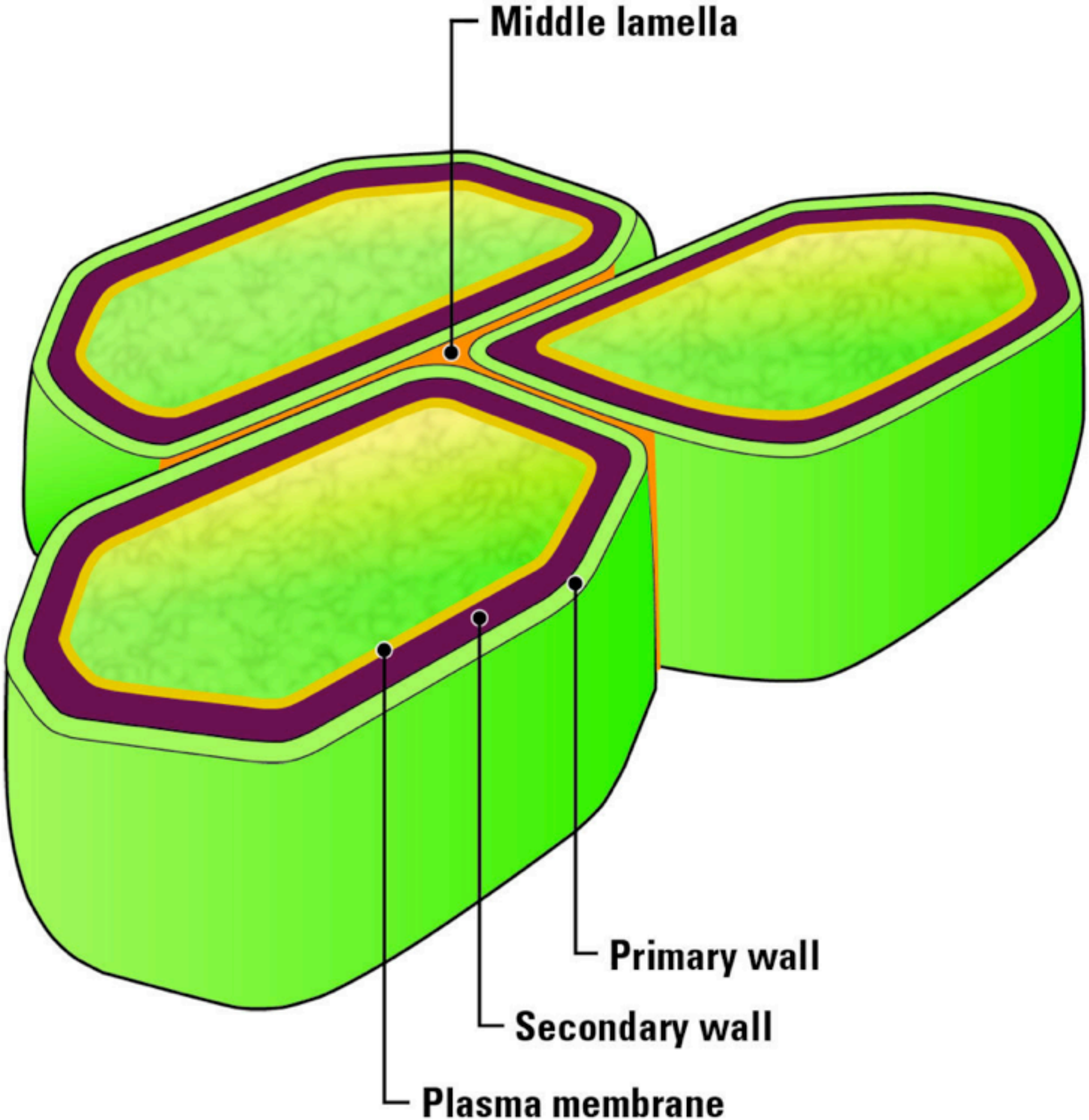
Evidence of student learning is a demonstrated understanding of each of the following:

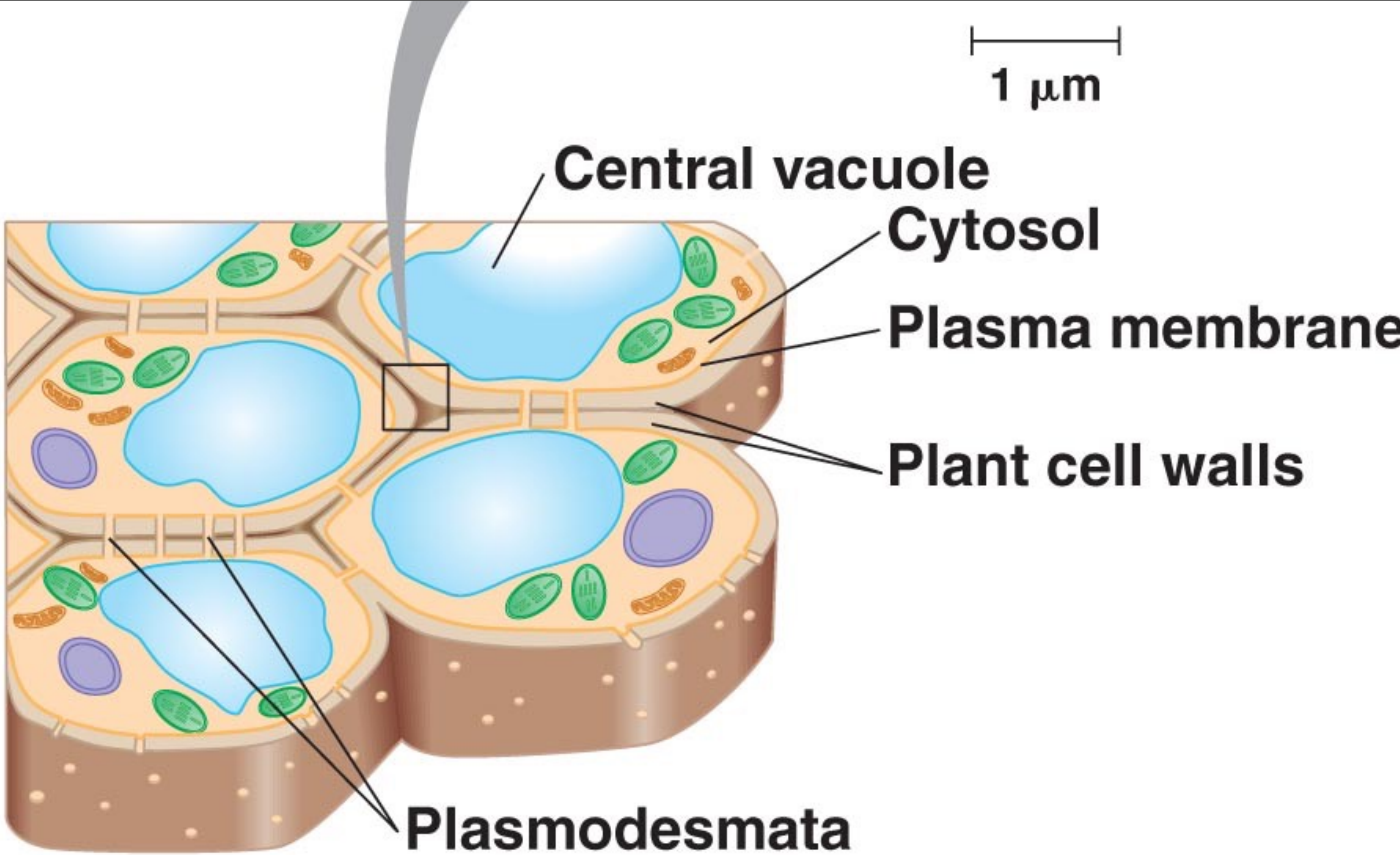
1. Plant cell walls are made of cellulose and are external to the cell membrane.

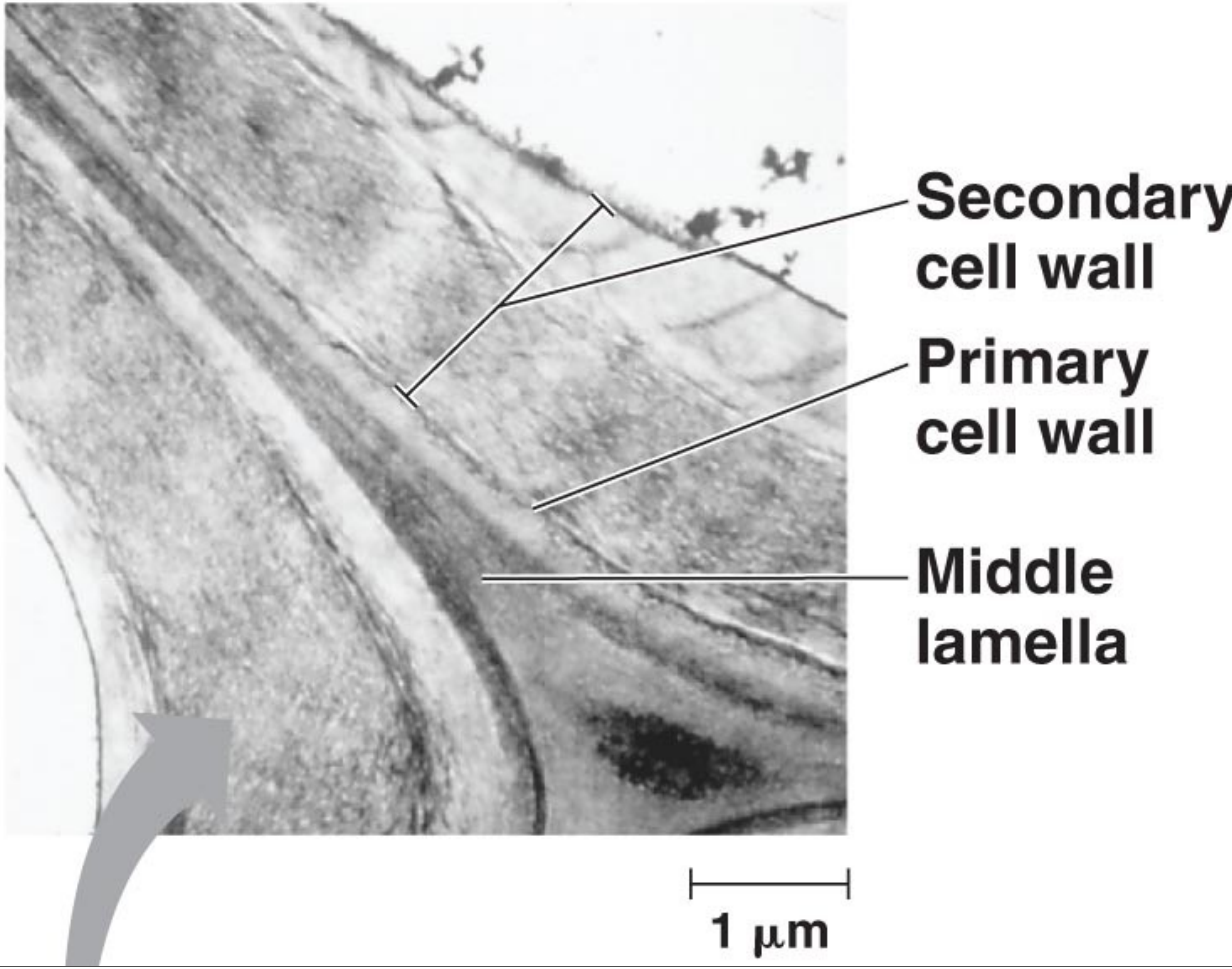
EXTRACELLULAR COMPONENTS AND CONNECTIONS BETWEEN CELLS HELP COORDINATE CELLULAR ACTIVITIES

A. Cell Walls of Plants

- Cell wall lies <u>outside</u> plasma membrane
- It <u>protects</u>, <u>shapes</u> and <u>prevents excess water intake</u>.
- They are found in *plants*, *bacteria*, *fungi* and some *protists*.


Middle lamella
Primary wall
Secondary wall
Plasma membrane


1 µm
Central vacuole
Cytosol
Plasma membrane
Plant cell walls
Plasmodesmata


Secondary
cell wall
Primary
cell wall
Middle
lamella
1 μm

Essential knowledge 2.B.1: Cell membranes are selectively permeable due to their structure.

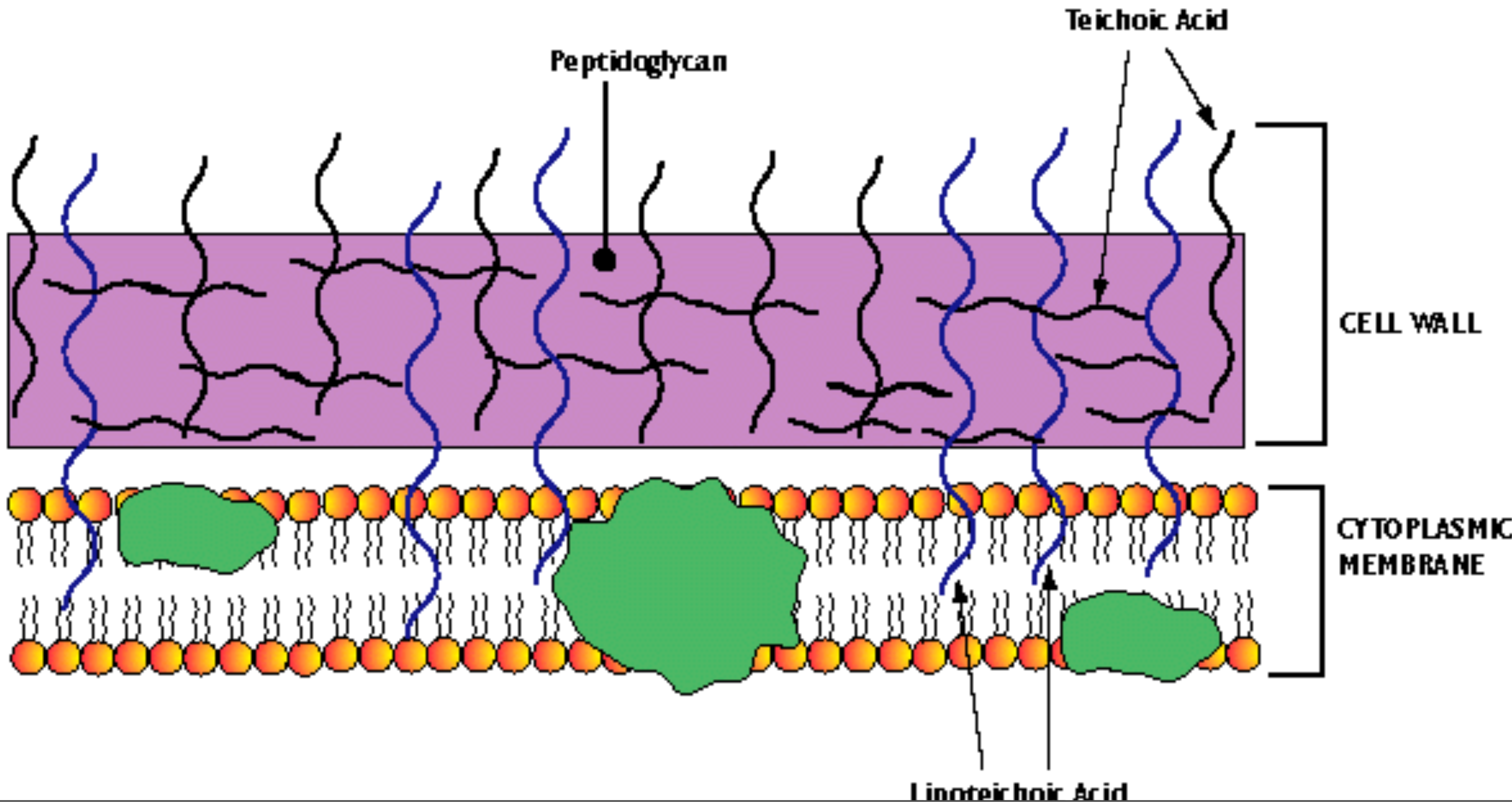
c. Cell walls provide a structural boundary, as well as a permeability barrier for some substances to the internal environments.

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

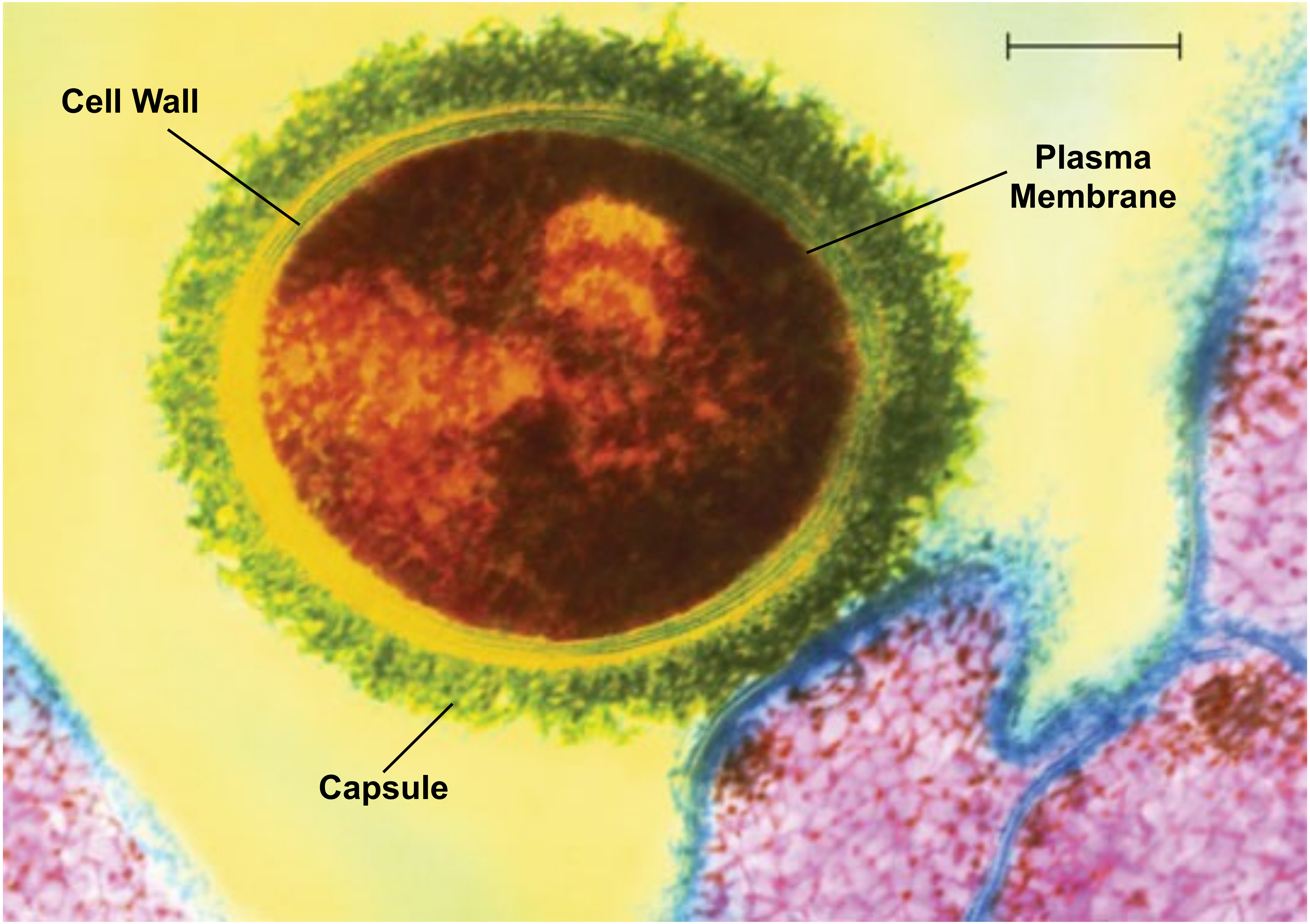
2. Other examples are cells walls of prokaryotes and fungi.

Bacterial Cell walls

Bacterial cell walls are different from eukaryotic cell walls like those found in fungi and plants. Plants and fungal cell walls are composed of cellulose or chitin. Bacterial cell walls are composed of **peptidoglycan**, a sugars crossed linked with polypeptides.

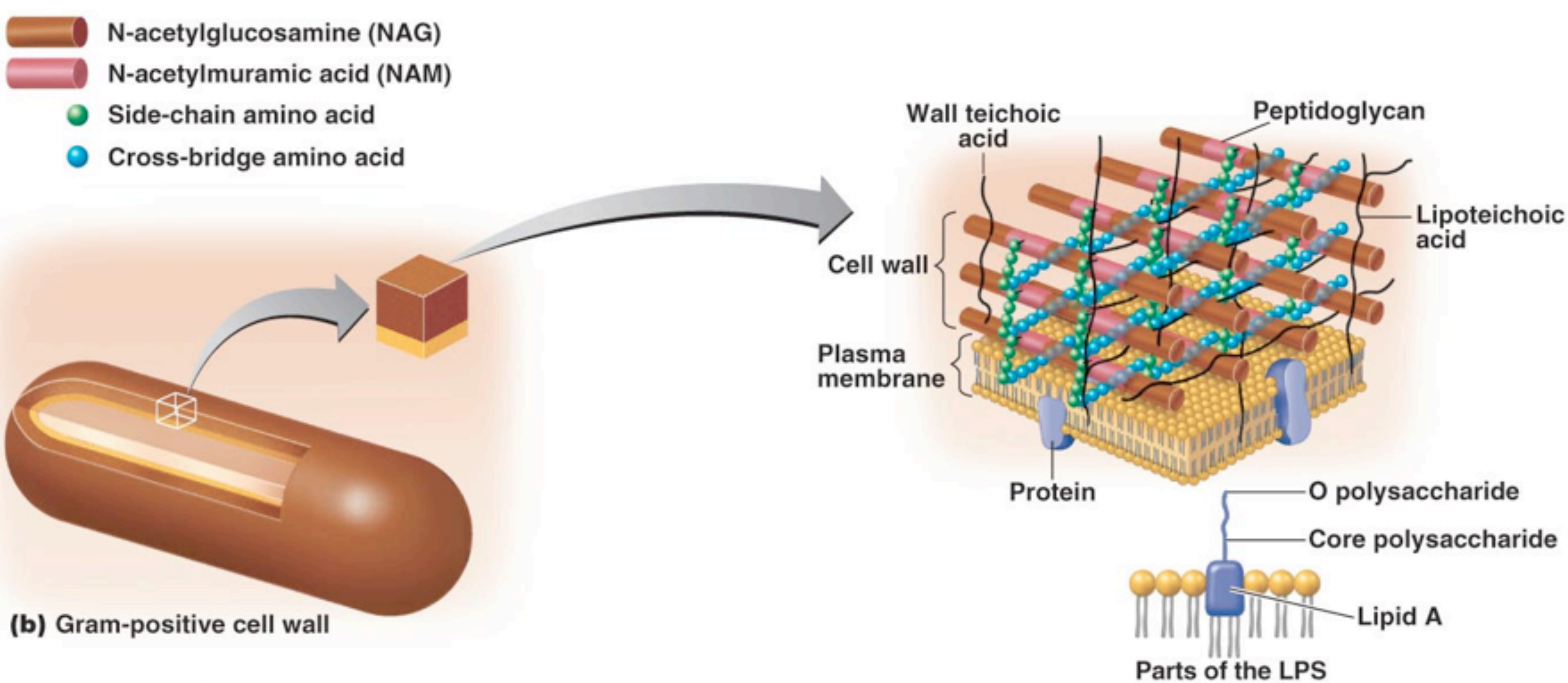


Bacterial Capsules



Bacterial Barriers- 3 Forms

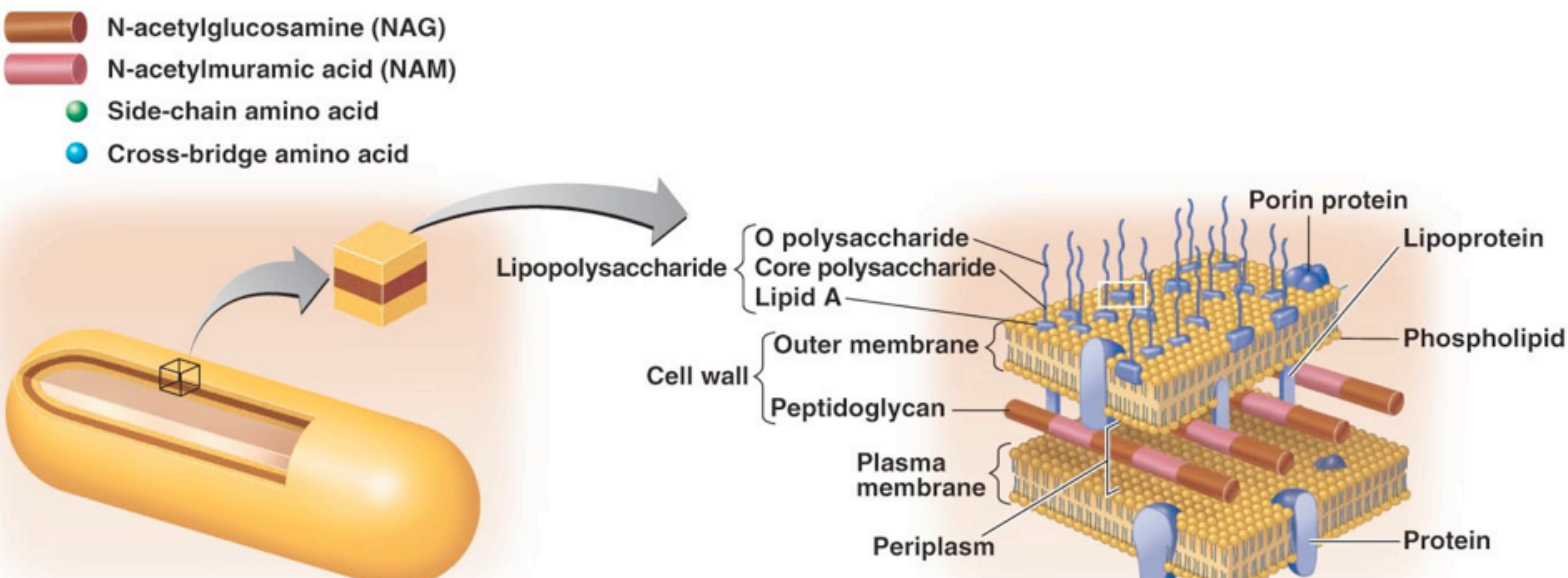
- Bacteria come in three forms in terms of these barriers and how they are used.
- **2. Gram Positive Bacteria**
  - Thick cell wall and a plasma membrane.



(b) Gram-positive cell wall

Bacterial Barriers- 3 Forms

- Bacteria come in three forms in terms of these barriers and how they are used.
- **3. Gram Negative Bacteria**
  - Outer membrane, thin cell wall and a plasma membrane.

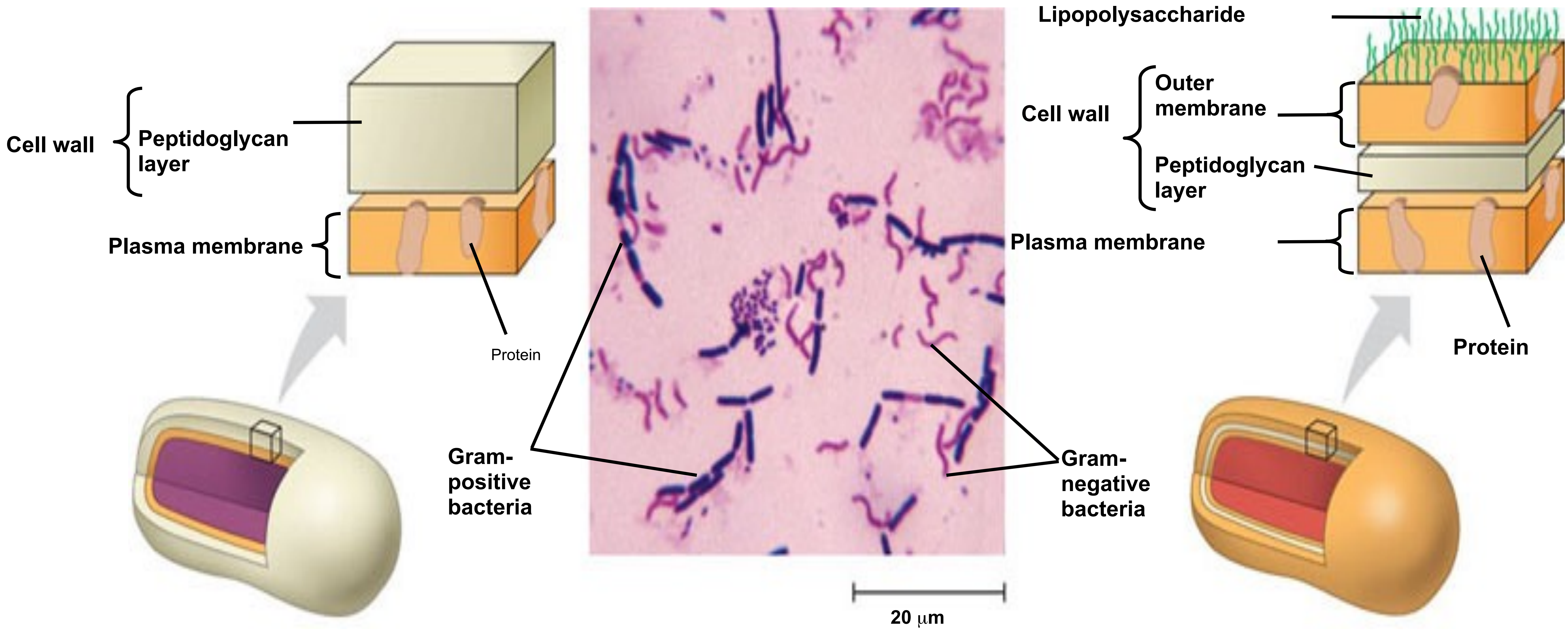


(c) Gram-negative cell wall

Gram Staining

Gram staining separates bacteria into two groups based upon the structure of their cell walls.

Valuable diagnostic tool used in medicine, helps determine type of infection.



Gram-positive.

Gram-negative.

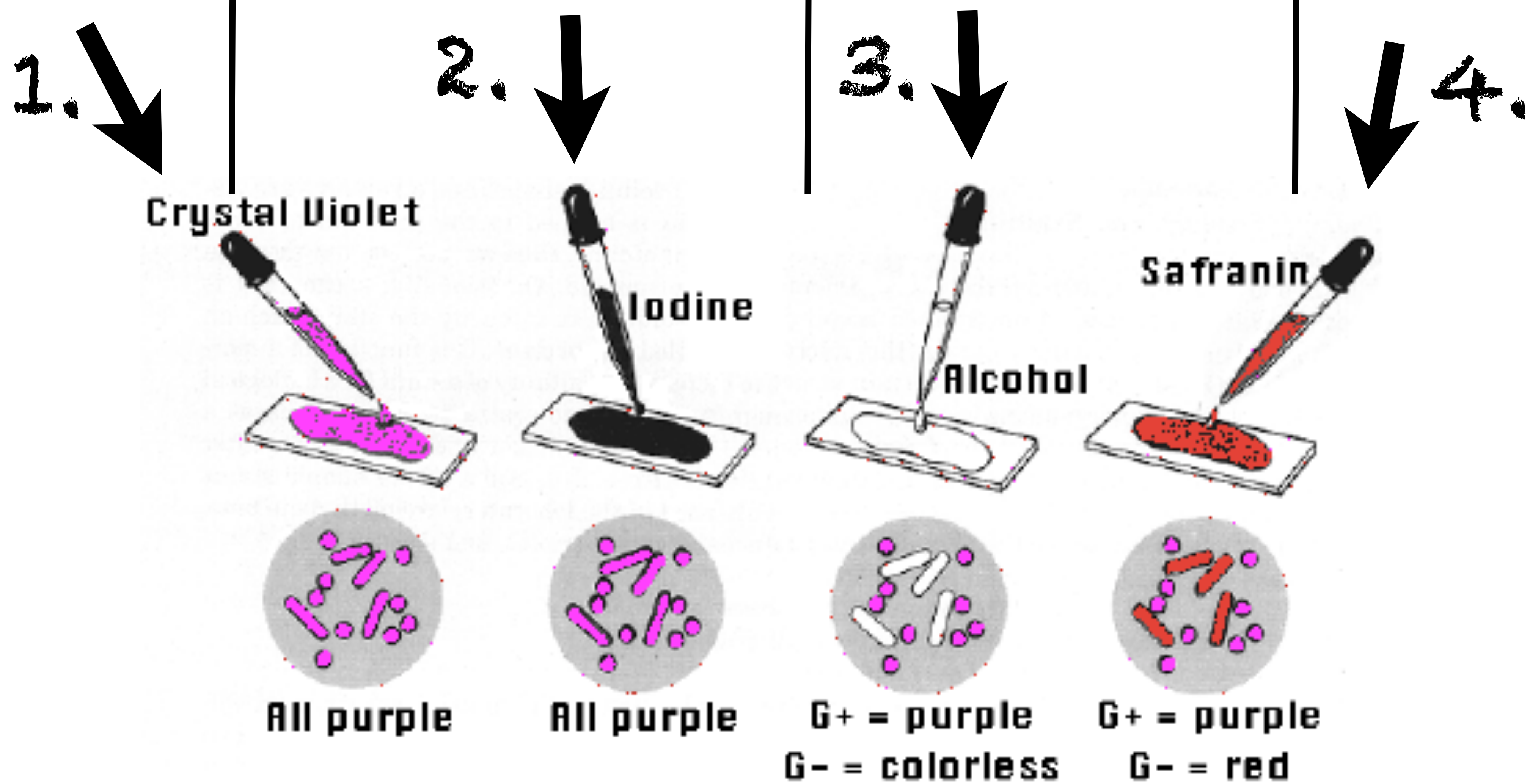
Gram Staining

Crystal Violet (CV) penetrates cell wall of all bacteria

Iodine penetrates cell wall, binds to CV and locks it into the cell

Alcohol rinses the CV/iodine complex out of gram negative bacteria because cell wall is so thin

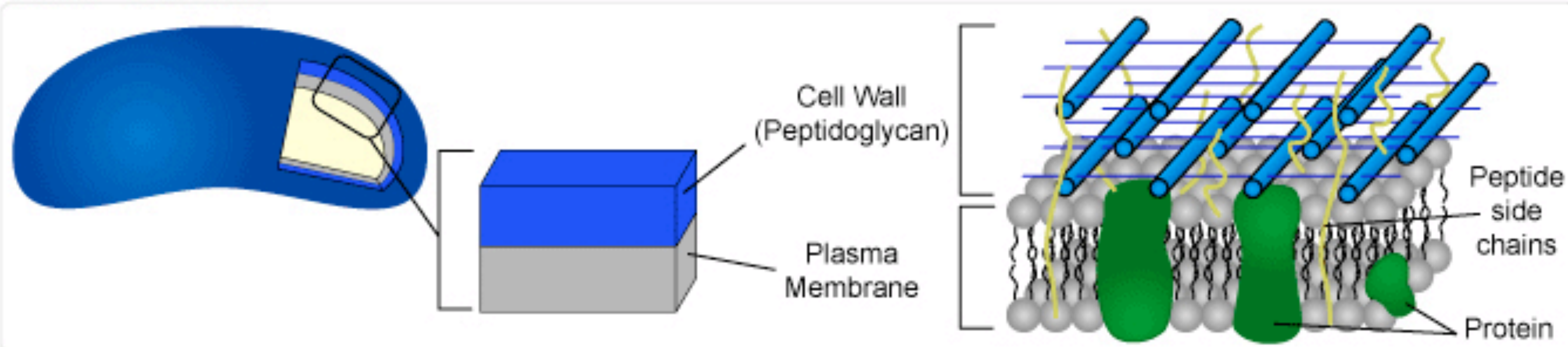
A red dye is used to stain the gram negative bacteria that lost their purple color



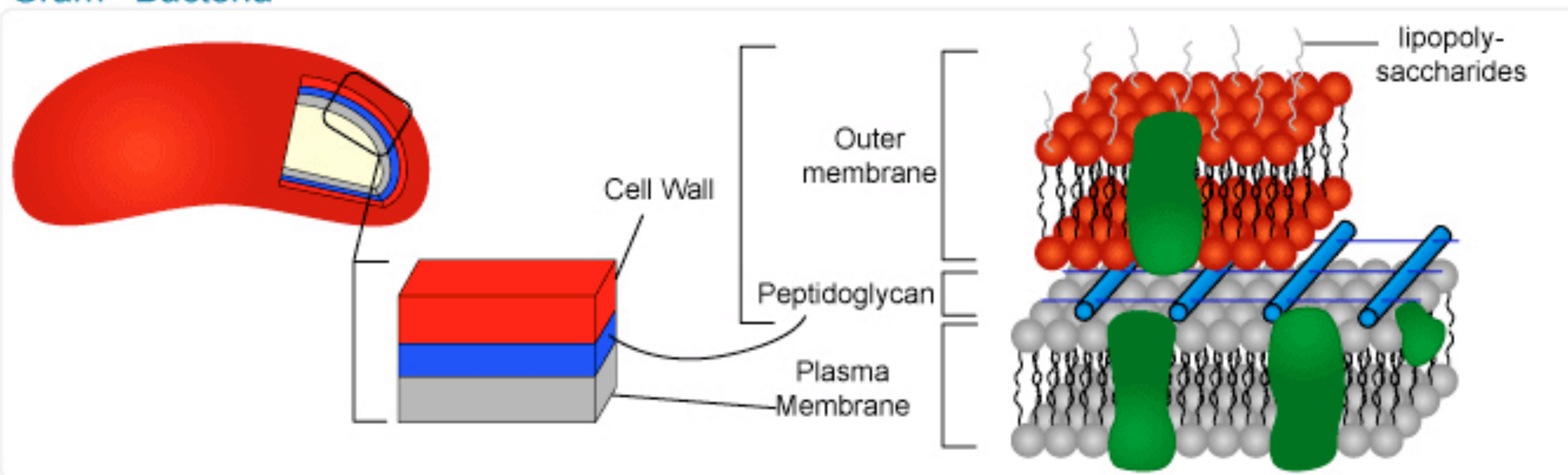
COMPARISON OF GRAM NEGATIVE AND GRAM POSITIVE BACTERIA

CHARACTERISTIC	GRAM POSITIVE	GRAM NEGATIVE
GRAM STAINED COLOR	Purple	Pink to Red
CELL SHAPE(S)	Rods and Cocci	Mostly rods, few cocci, spirilli; some pleomorphic
ENDOSPORE PRODUCTION	Common in 2 Genera	Virtually Unknown
CELL WALL COMPOSITION	1-4% Lipid (low); Thick, Multilayered Peptidoglycan (up to 30 layers)	11-22% Lipid (high); 3 Separate Layers (inner one is Peptidoglycan - 1 to 2 layers only)
CELL WALL NATURE	Rigid, Strong	Flexible
PENICILLIN SENSITIVITY	High (penicillin interferes with peptidoglycan synthesis)	Low
LYSOZYME SENSITIVITY	Wall is Dissolved (protoplast formed)	Wall is Weakened (spheroplast formed)
INHIBITION BY BASIC DYES (e.g. C.V.)	High	Low
PHYSICAL DISRUPTION SENSITIVITY (heat, alcohol)	Low	High
EXOTOXINS	Common (e.g. *Clostridium botulinin, Clostridium tetani*)	Rare (e.g. *Pseudomonas, E. coli*)
ENDOTOXINS	Unknown	Common (*Salmonella, Shigella*)

Gram+ Bacteria

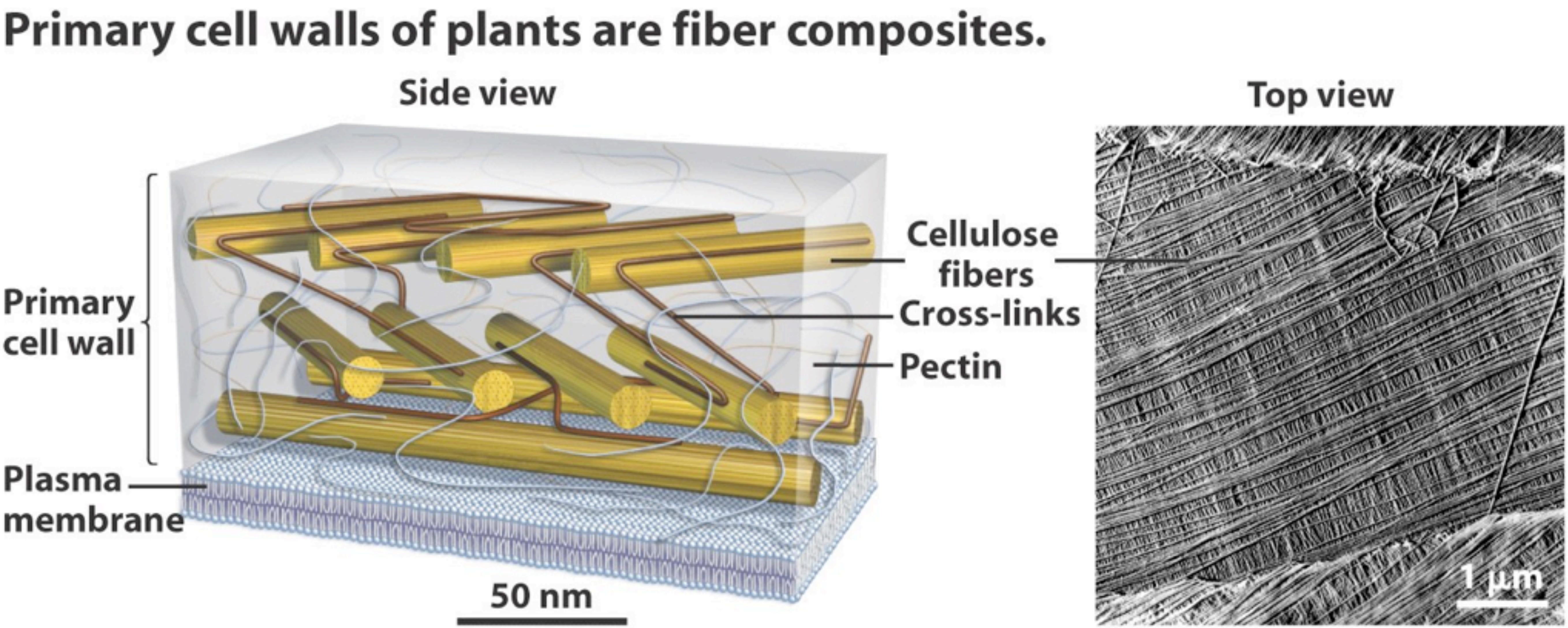


Gram- Bacteria



Cell Walls of Plants

- Cell wall is much <u>thicker</u> than the plasma membrane
- The exact <u>chemical composition varies</u> between species
- The basic <u>design</u> is however <u>consistent</u>
    - *microfibrils are embedded in a matrix of sugars and proteins*



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Learning Objectives:

LO 2.10 The student is able to use representations and models to pose scientific questions about the properties of cell membranes and selective permeability based on molecular structure. [See SP 1.4, 3.1]

LO 2.11 The student is able to construct models that connect the movement of molecules across membranes with membrane structure and function. [See SP 1.1, 7.1, 7.2]