

Basic Life Principles

Form and Function

Review

- * There are millions of different species on earth.
- * Different species are found virtually anywhere on earth.
- * Both abiotic and biotic factors influence the distribution of species on earth.
- * Some factors are more limiting than others.
- * Species have unique sets of adaptations that enable them to survive and reproduce in spite of abiotic and biotic challenges.

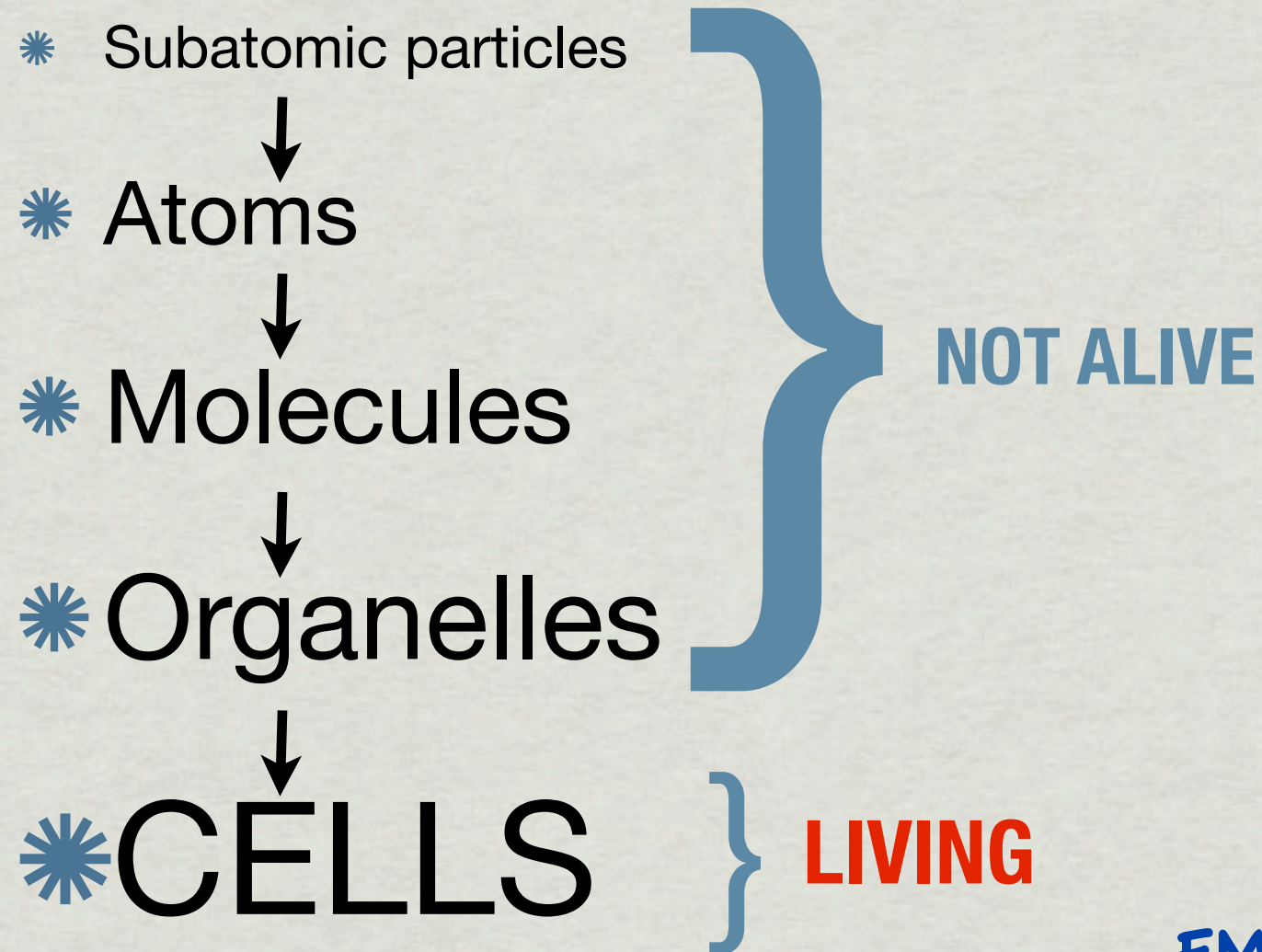
Preface

- ✱ Habitats are diverse.
- ✱ Life forms are diverse.
- ✱ **HOWEVER ALL LIFE SHARES SOME COMMON CHALLENGES AND SIMILAR SOLUTIONS EXIST DESPITE THE ENORMOUS VARIATION OF LIFE FORMS.**
- ✱ This unit will explore the challenges faced by all life and the solutions that evolved to meet these challenges.

I. SEPARATION OF ENVIRONMENTS

- * Cells are the smallest collection of matter that are alive.
- * Cells come in many different shapes and sizes.
- * However 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.

Cells are the smallest collection of matter that are alive.



LIFE ITSELF IS AN
EMERGENT PROPERTY, WHERE
THE SUM IS GREATER THAN
ITS PARTS

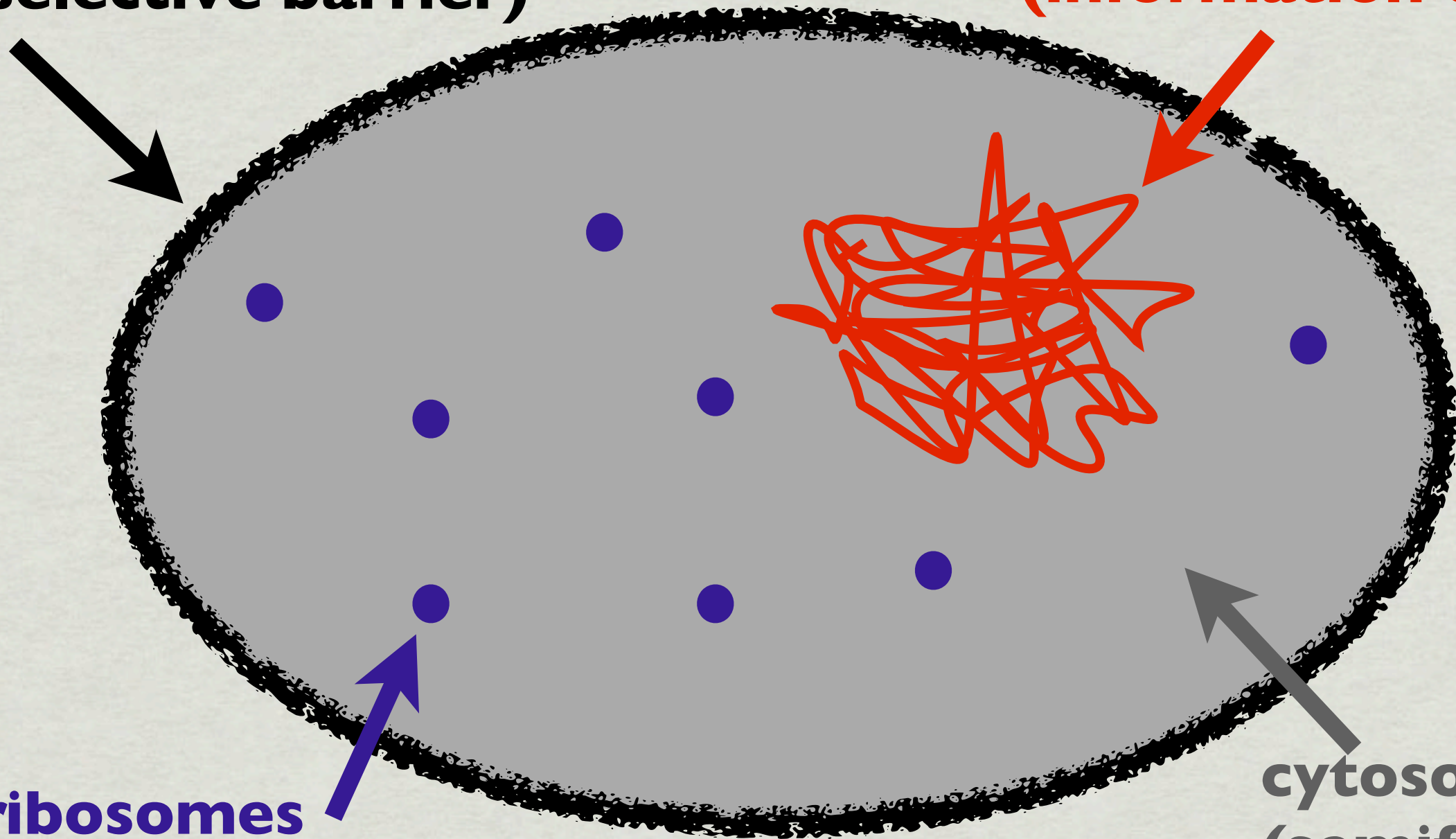
ALL Cells have 4 major features.

**plasma membranes
(selective barrier)**

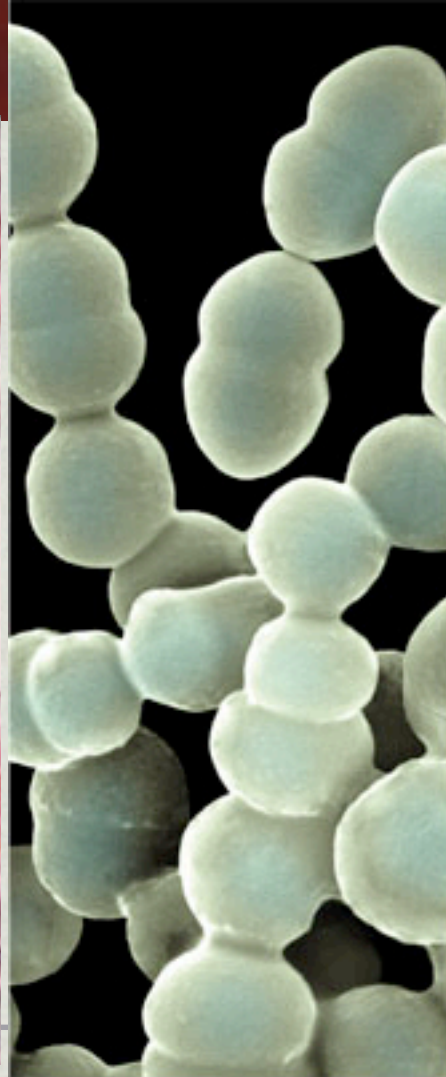
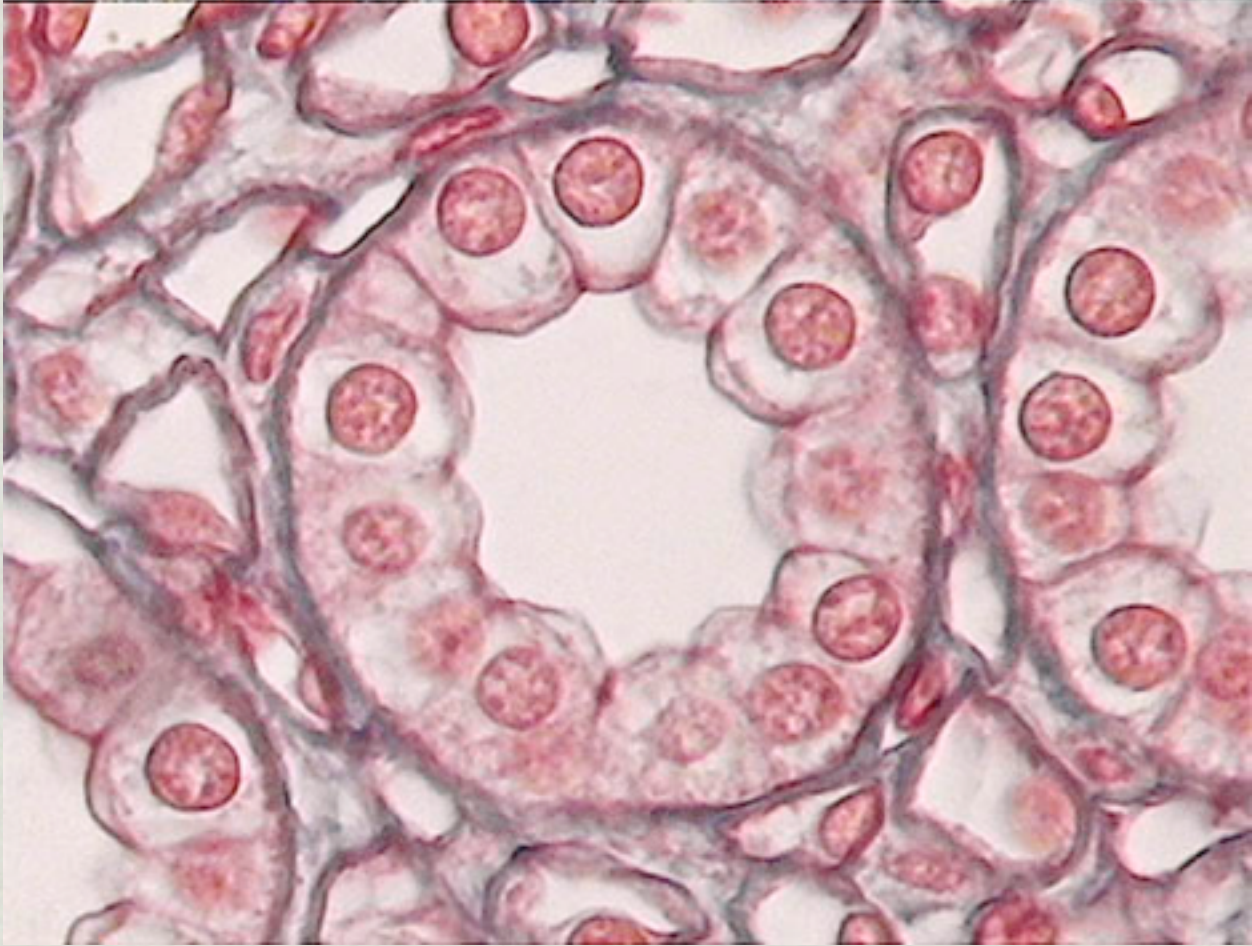
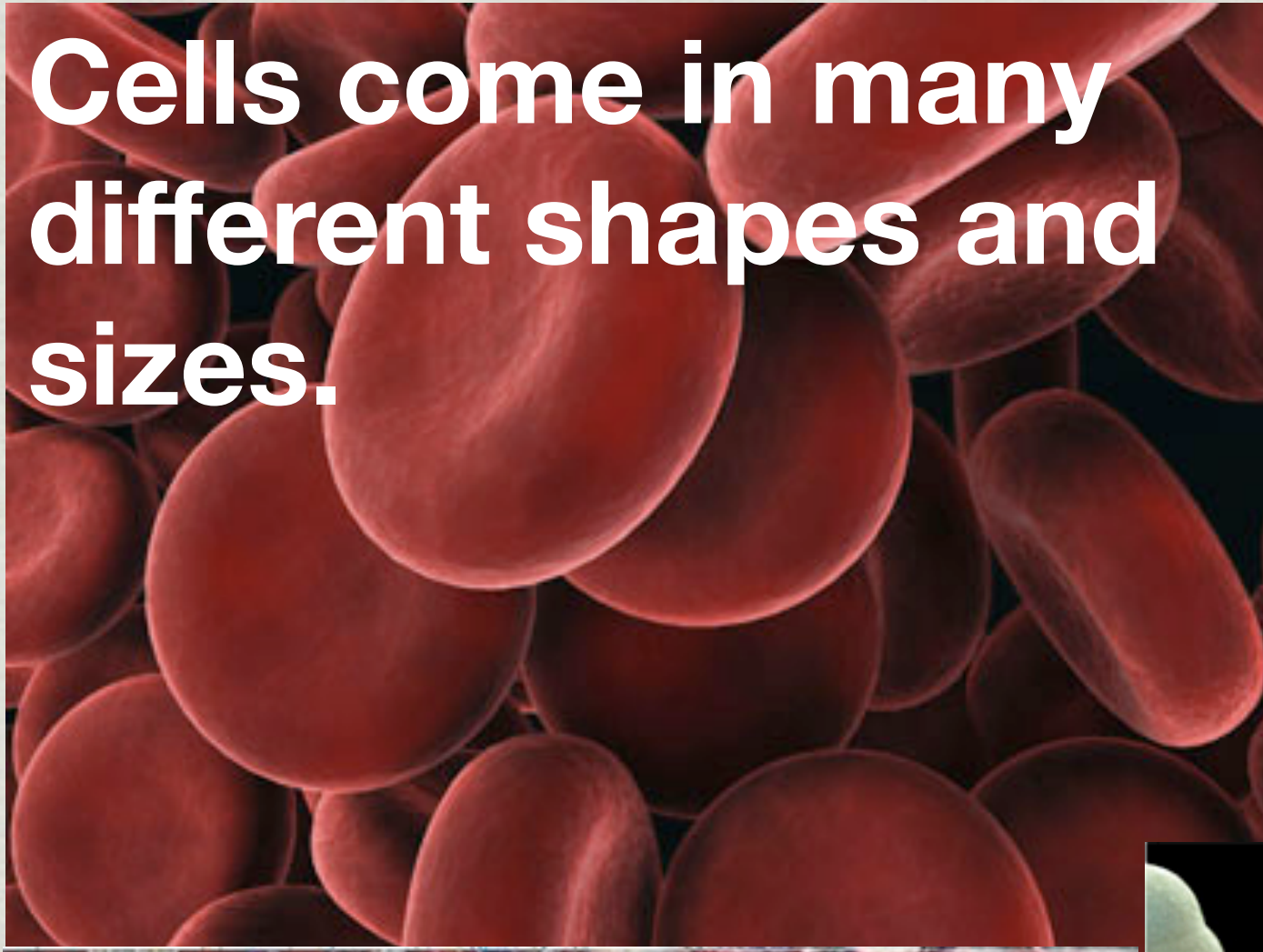
**chromosomes
(information carrier)**

**ribosomes
(protein builders)**

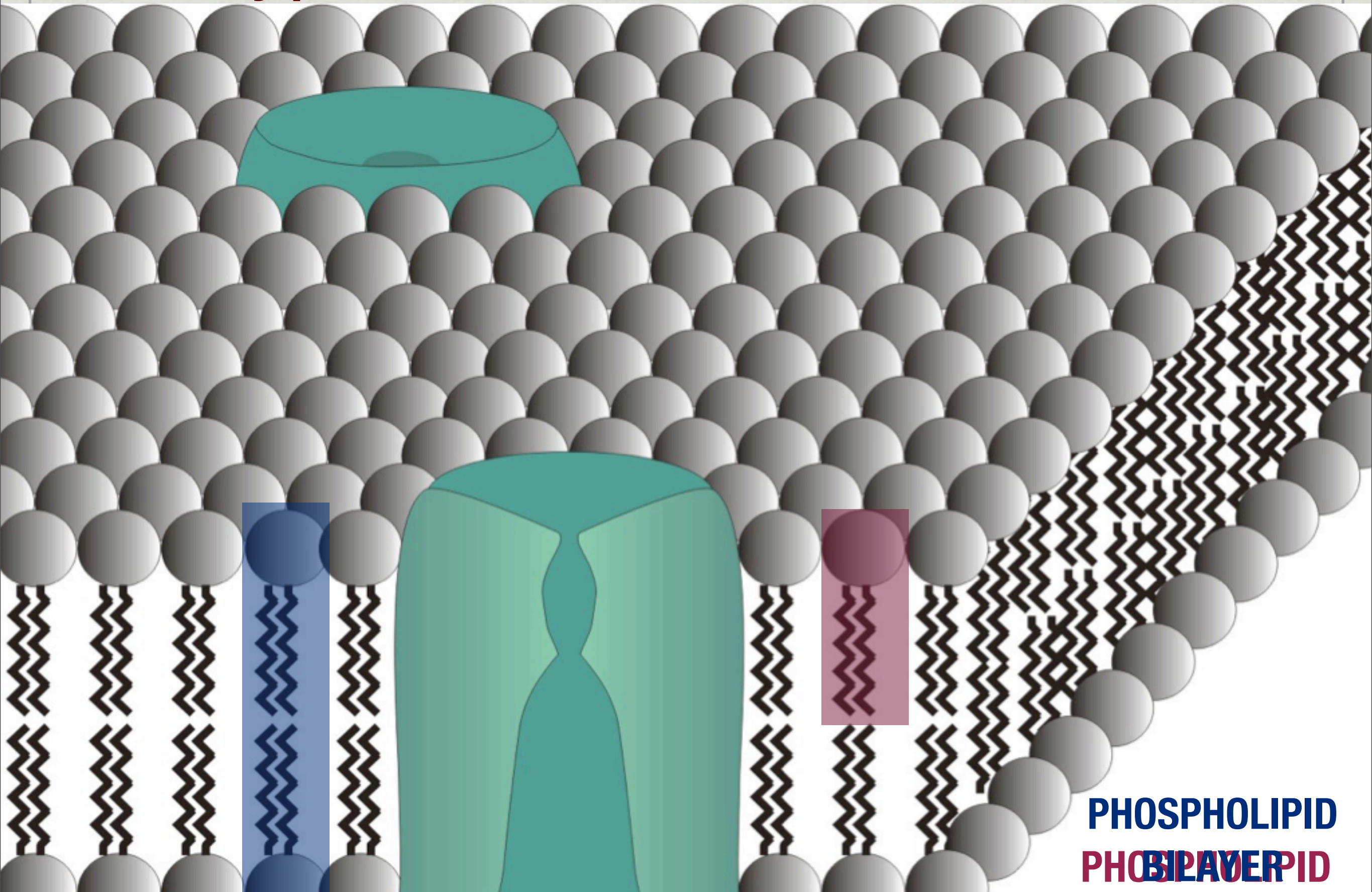
**cytosol
(semifluid
substance)**



Cells come in many different shapes and sizes.

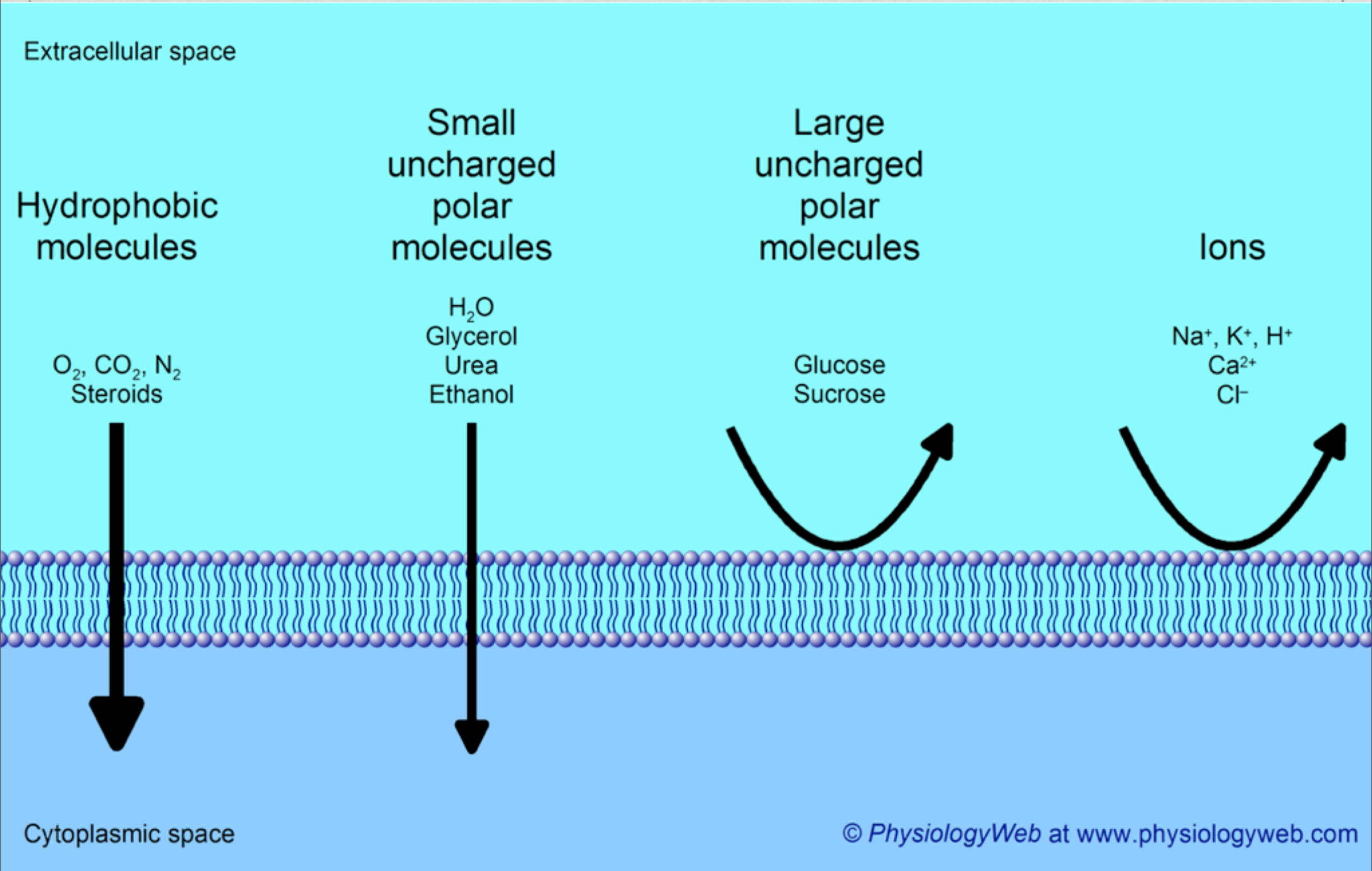


However ALL cells no matter the shape or size have a selectively permeable membrane!



**PHOSPHOLIPID
BILAYER**

Selective Permeability



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Regulate the movement of materials into and out of the cell

However
If cell permits

**Small
Molecules**

**Fat
Soluble
Molecules**

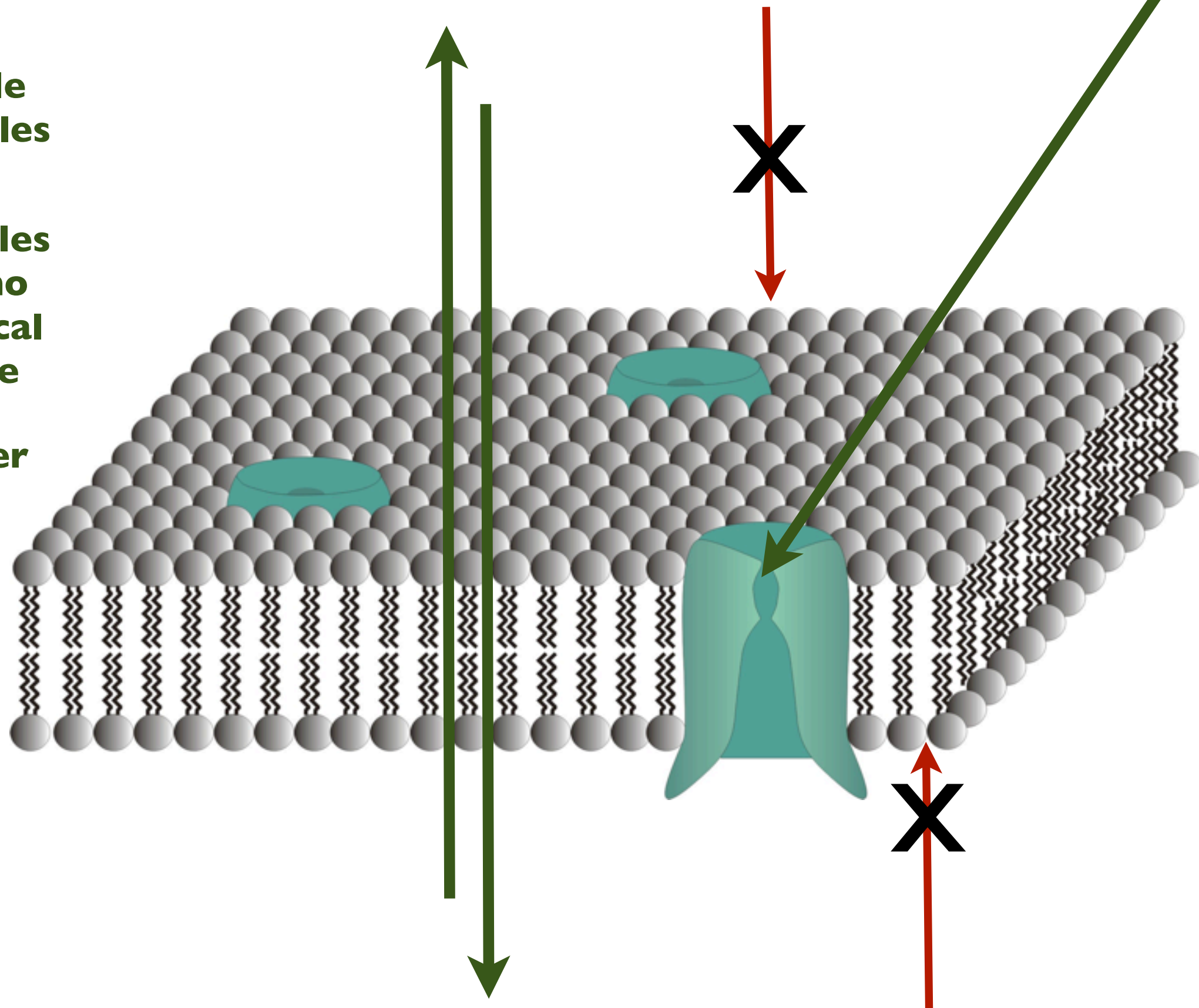
**Molecules
with no
electrical
charge**

***Water**

**Large
Molecules**

**Water
Soluble
Molecules**

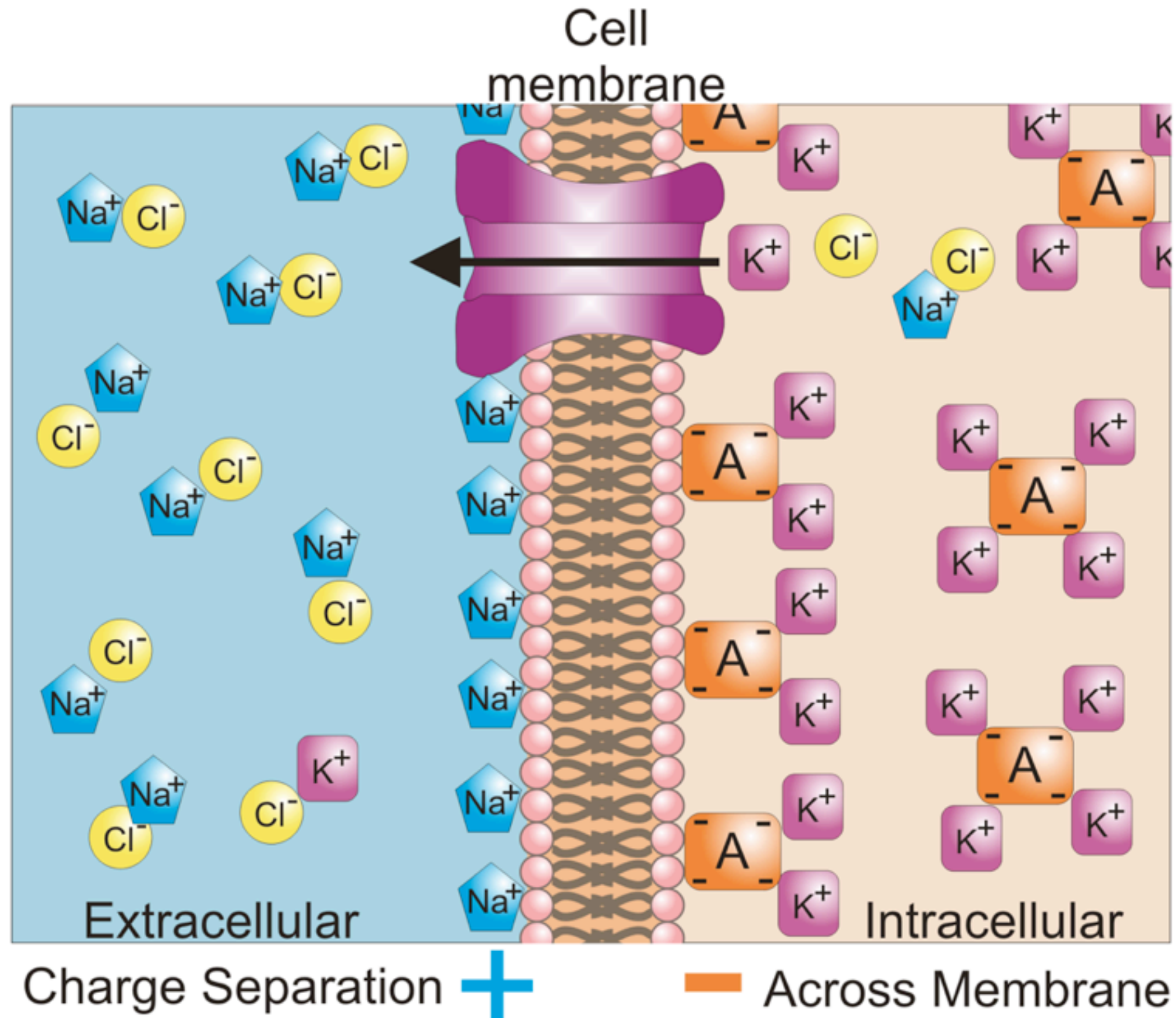
**Molecules
with
electrical
charges**



Maintain an internal environment that differs from the external environment



Maintain an internal environment that differs from the external environment



II. EXCHANGING WITH THE ENVIRONMENT

- * Molecules need to be 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.
- * Small cells can import and export molecules more efficiently than larger cells. All cells are small.

Molecules need to be imported and exported across the membrane.

FOR STARTERS

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

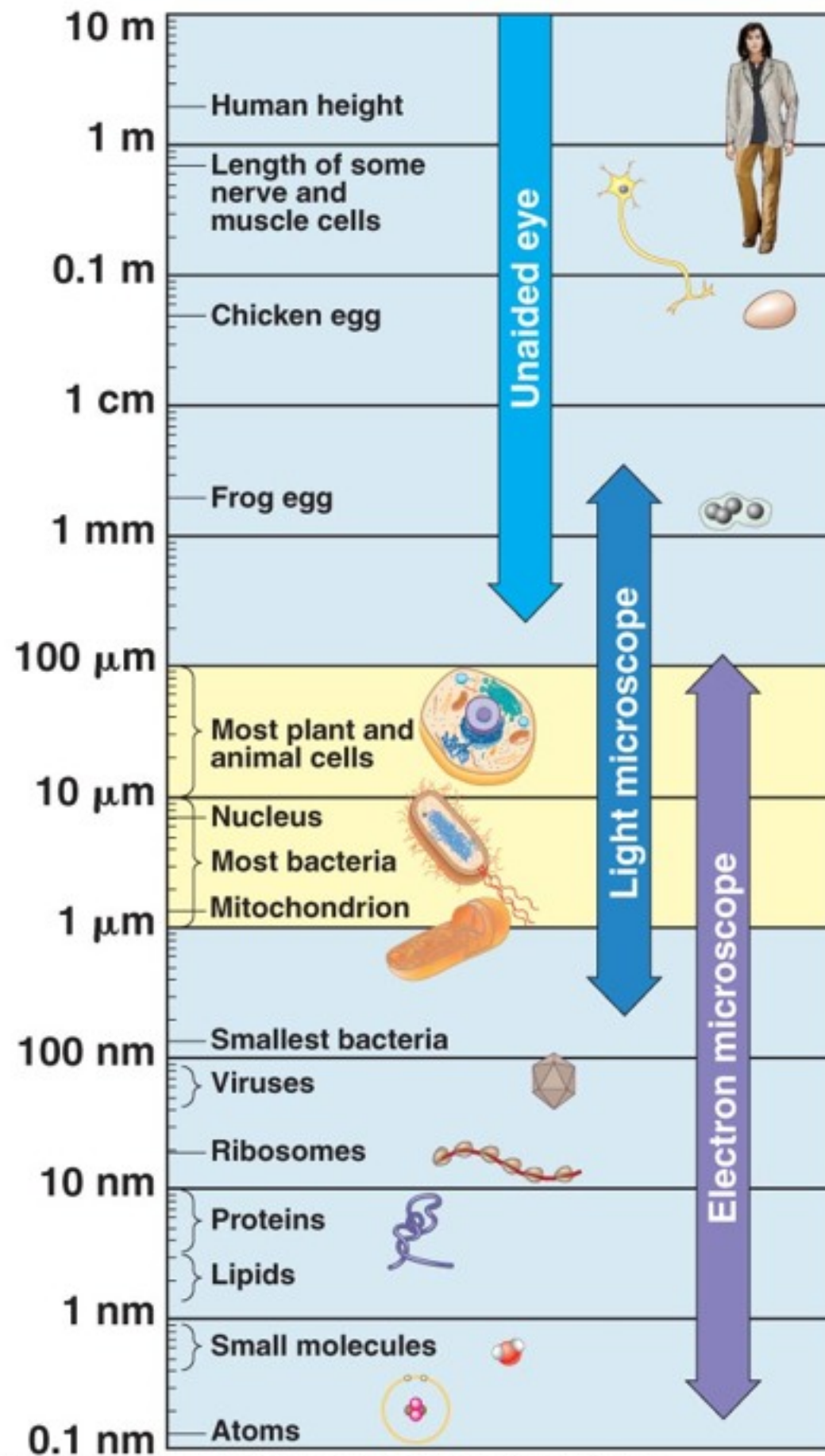
Cells are filled with water and cells are surrounded by water.

- * 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.

Small cells can import and export molecules more efficiently than larger cells. All cells are small.



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SIZE MATTERS

The logistics to carry
out metabolism sets the
lower limit on cell size

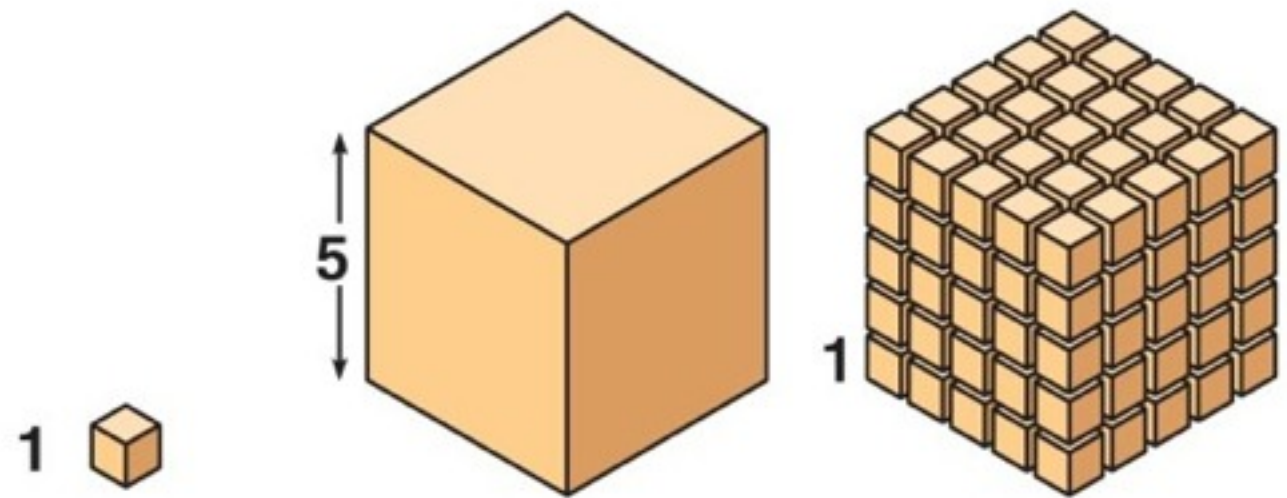
The requirements for
metabolism set the
upper limit on cell size

**The ratio of surface area
to volume is critical**

**Volume (cubed function) grows
proportionately more than its surface
area (squared function)**

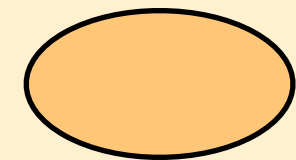
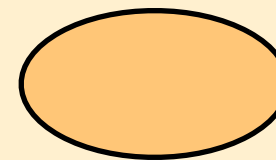
Thus a smaller object has a greater SA:V ratio

Surface area increases while total volume remains constant



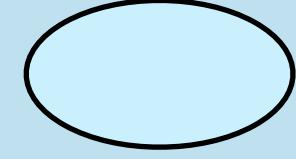
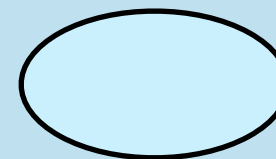
Total surface area
[Sum of the surface areas
(height \times width) of all box
sides \times number of boxes]

6



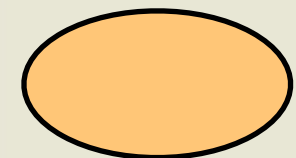
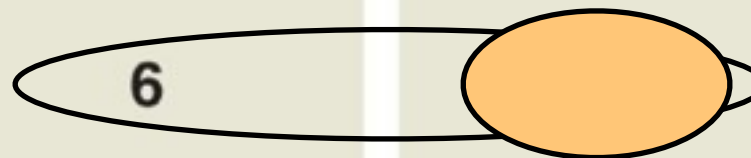
Total volume
[height \times width \times length \times
number of boxes]

1



Surface-to-volume
(S-to-V) ratio
[surface area \div volume]

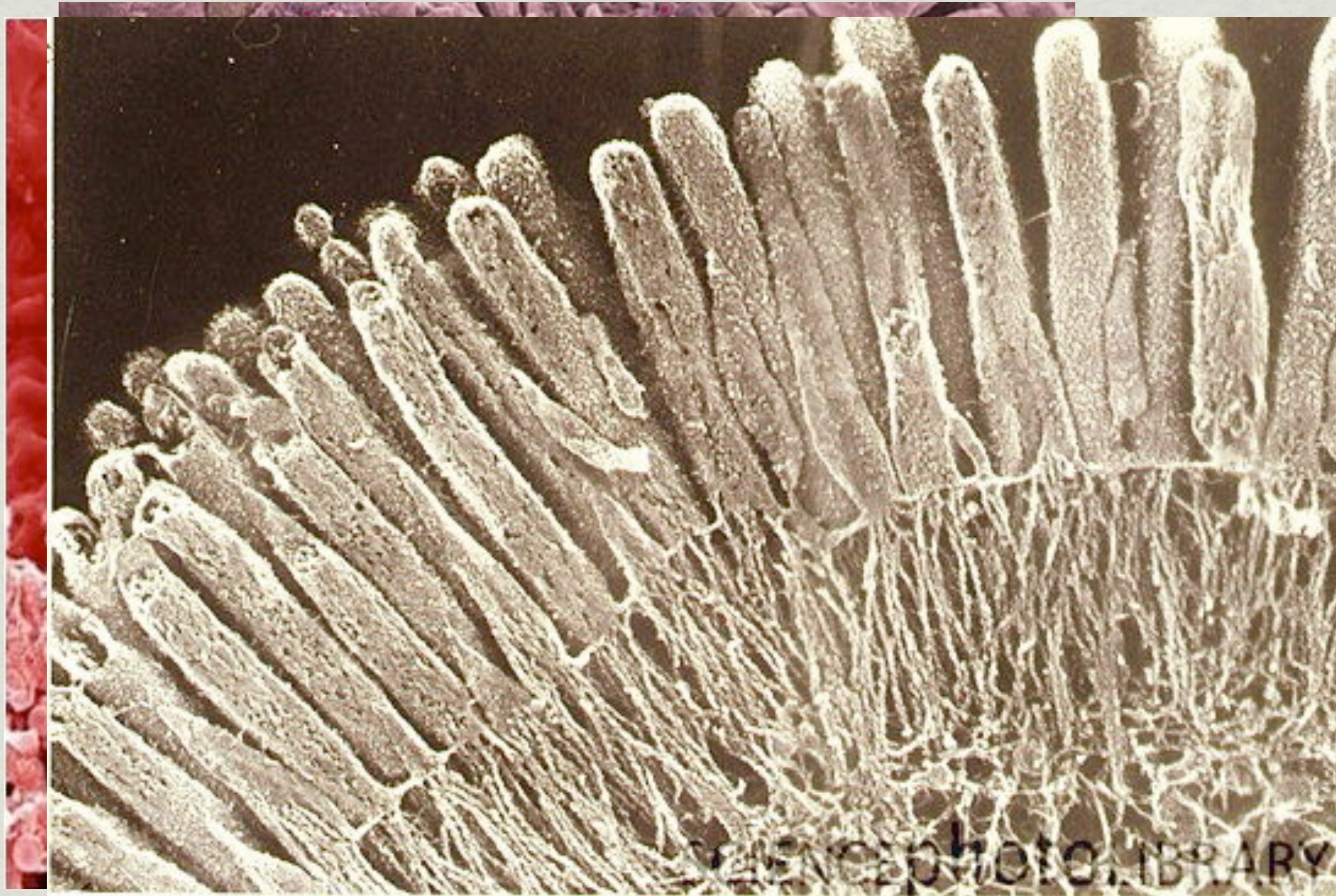
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Bigger is Better!

A Big SA:V ratio is especially important for cells that continually exchange with its surroundings

Can think of any cells or tissues that continually exchange with its environment?



Intestine

Pancreas

Alveoli

A. Unicellular & Multicellular Organisms

- * Single celled organisms exchange material with its environment in the same ways that individual cells of a multicellular organism exchange with its environment.
- * The difference often lies with the external environment itself.
 - * Single cells interact with the “outside” environment as we think of “outside”.
 - * For many cells in a multicellular organism their outside environment is extracellular fluid which lies inside of the organism as a whole.
 - * **Here in lies the crux; single celled organisms have to adapt as the outside world changes but multicellular organisms work as a whole to maintain/regulate an outside environment that is conducive for life**

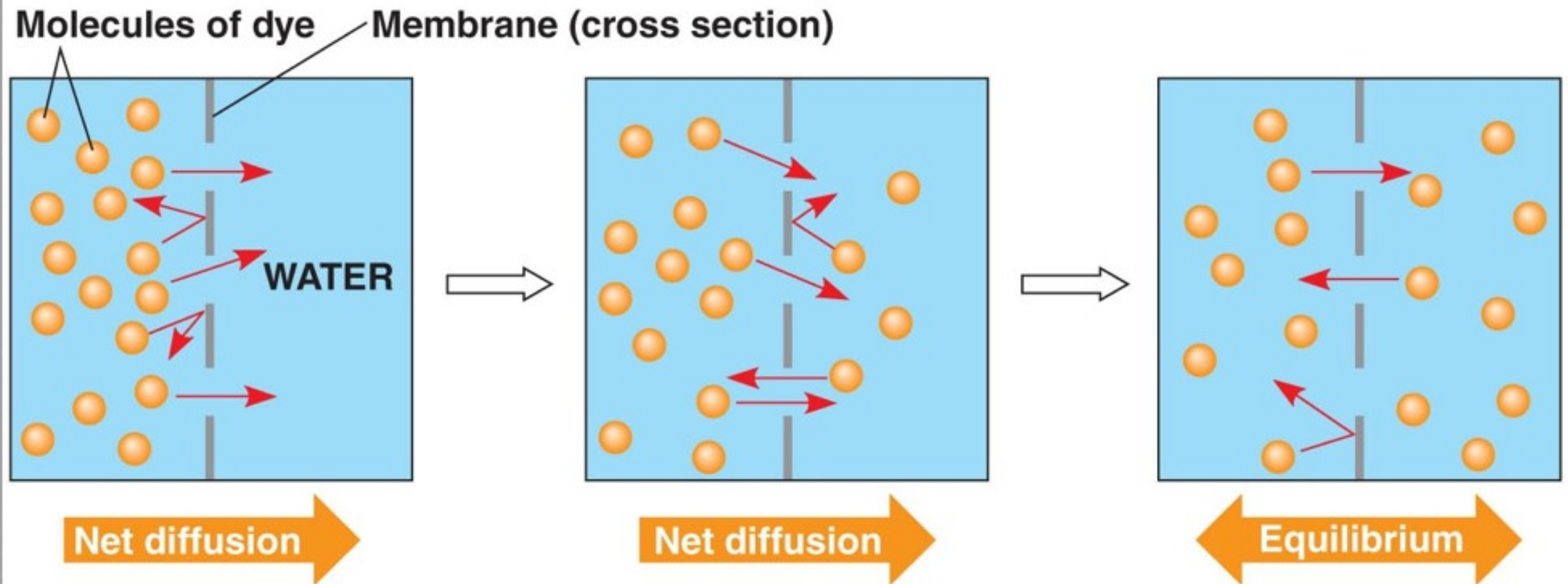
B. Cells Exchanging with Environment

- * 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.*
 - * *Others require energy source to bring them across.*
 - * *Some substances can travel through the lipid bilayer.*
 - * *Yet others can only travel through protein channels located in the membrane.*

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

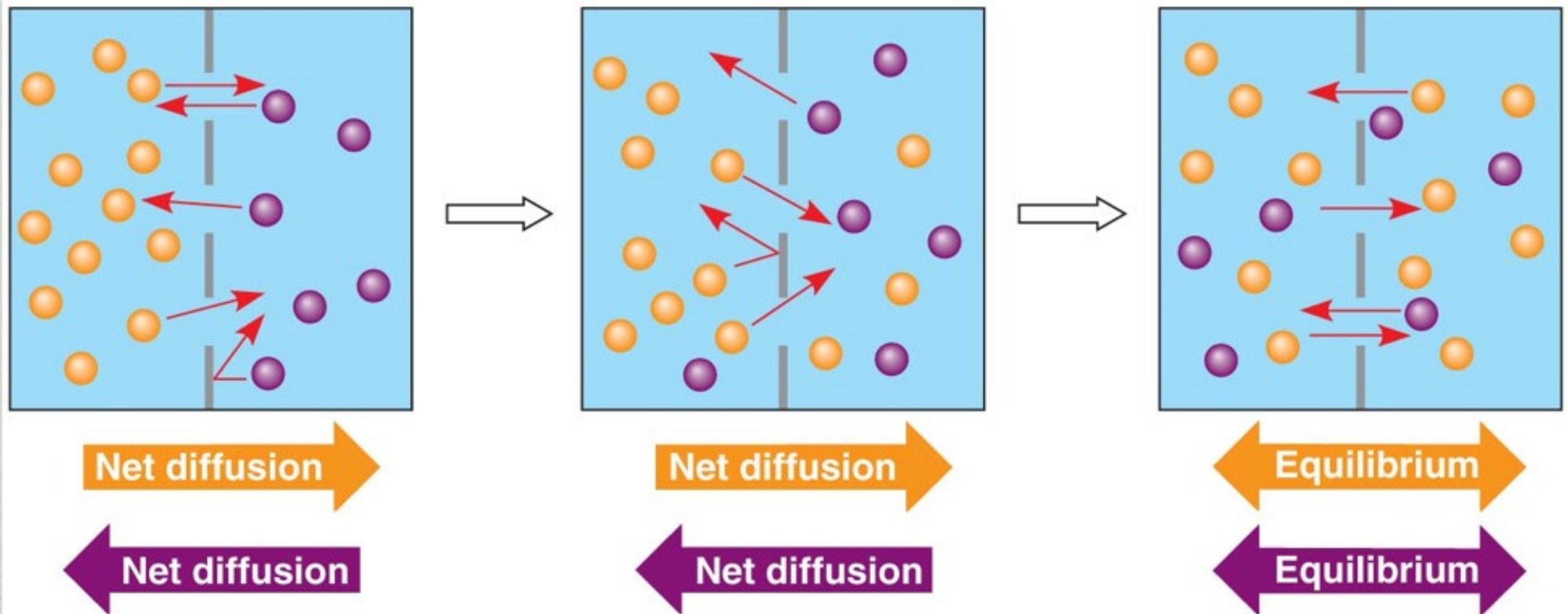


(a) Diffusion of one solute

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THESE YELLOW CIRCLES REPRESENT EITHER
SOLIDS OR GASES

Diffusion

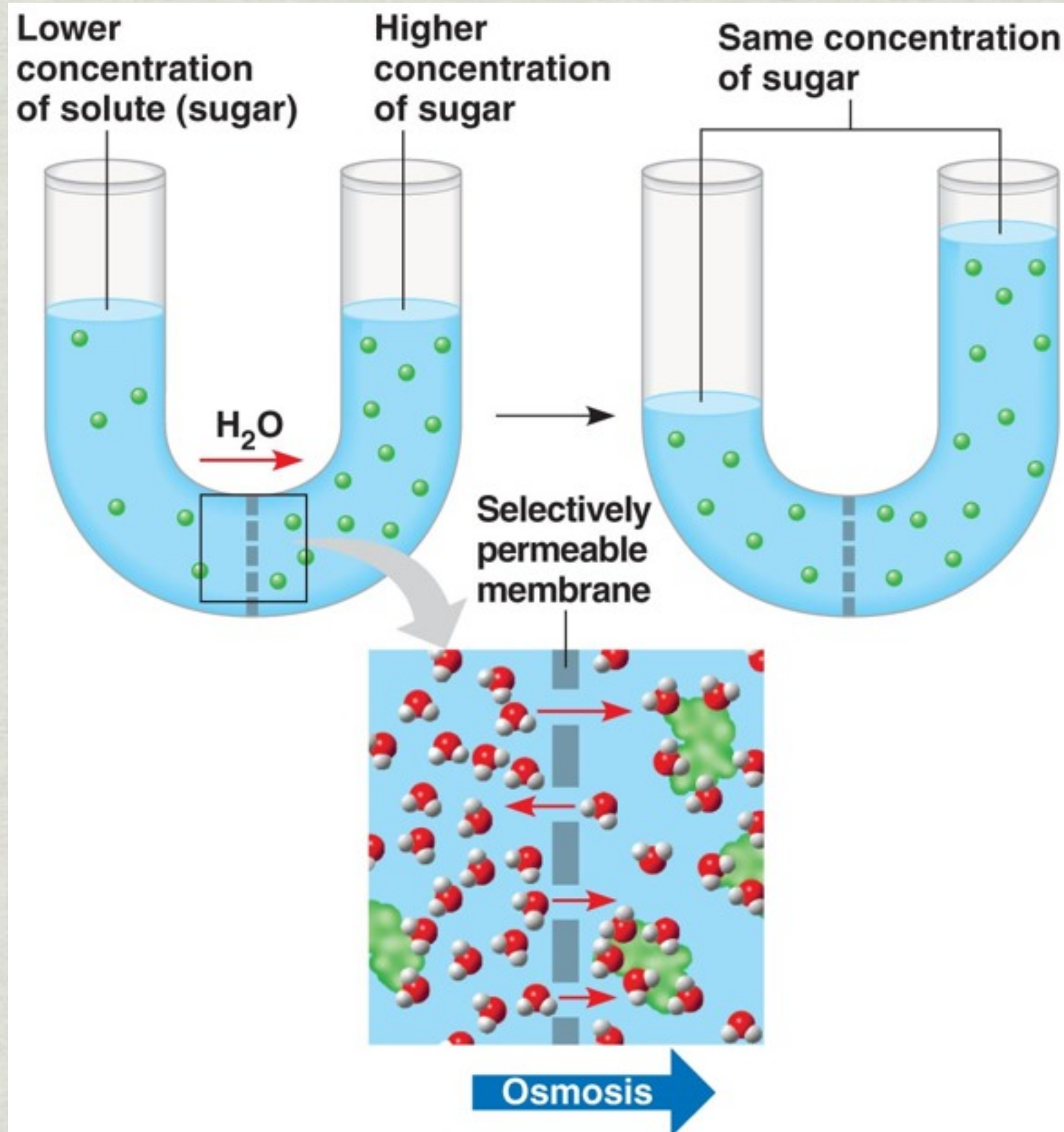


(b) Diffusion of two solutes

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DIFFUSION OF SOLUTES IS INDEPENDENT OF OTHER SOLUTES

Diffusion of Water...



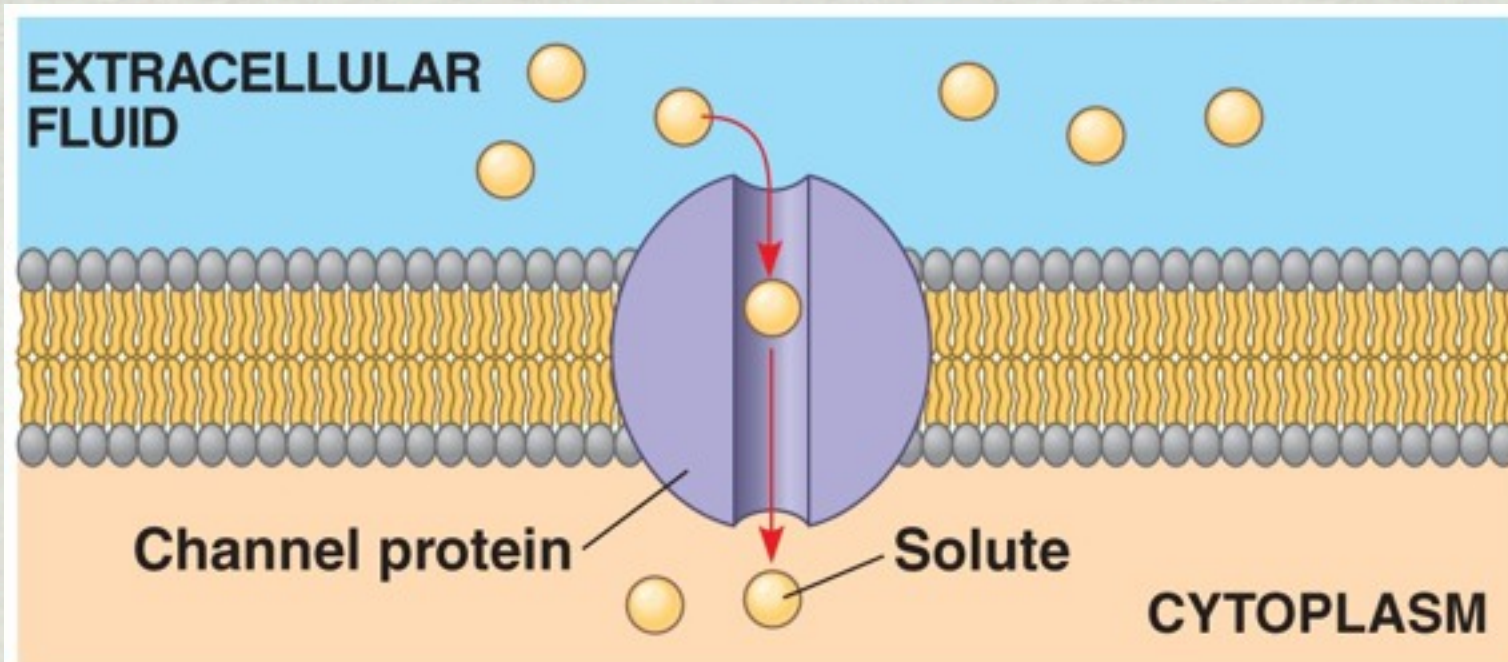
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Osmosis

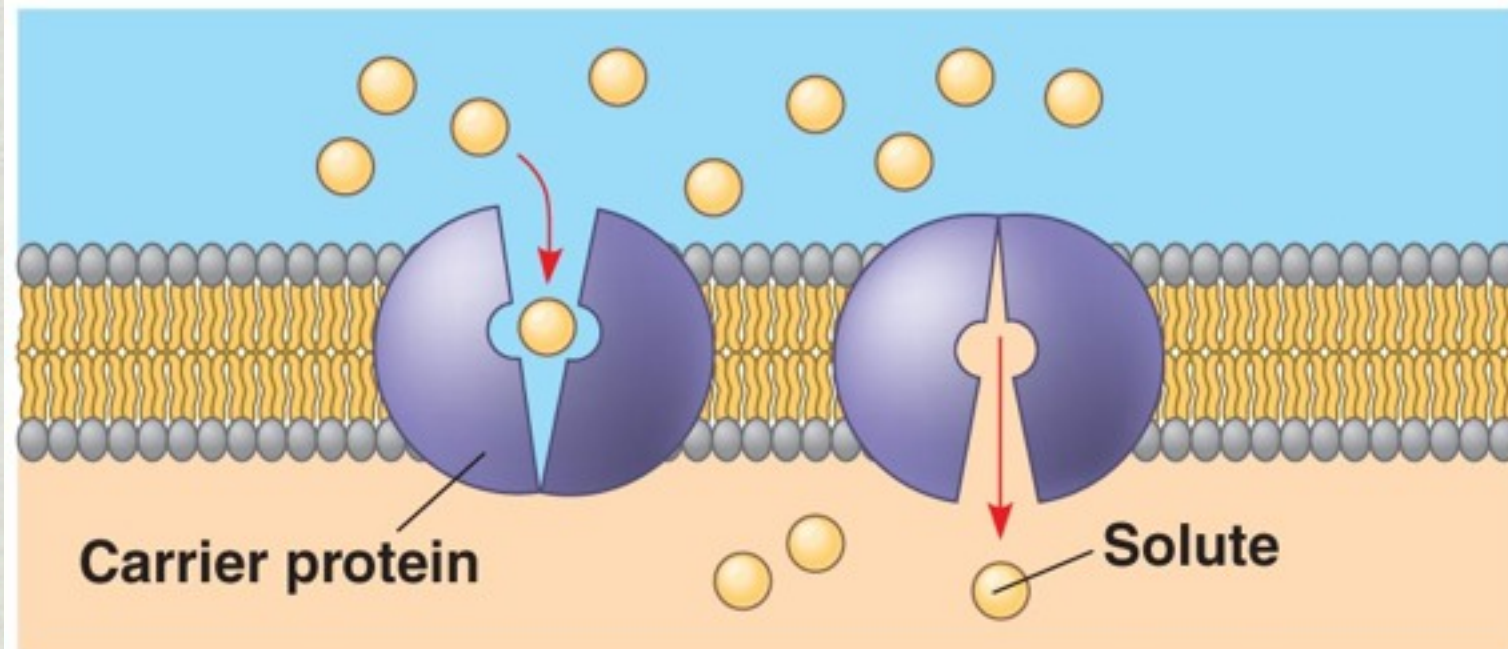
It has been said that water moves down its concentration gradient, from a high to low

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.

Facilitated Diffusion



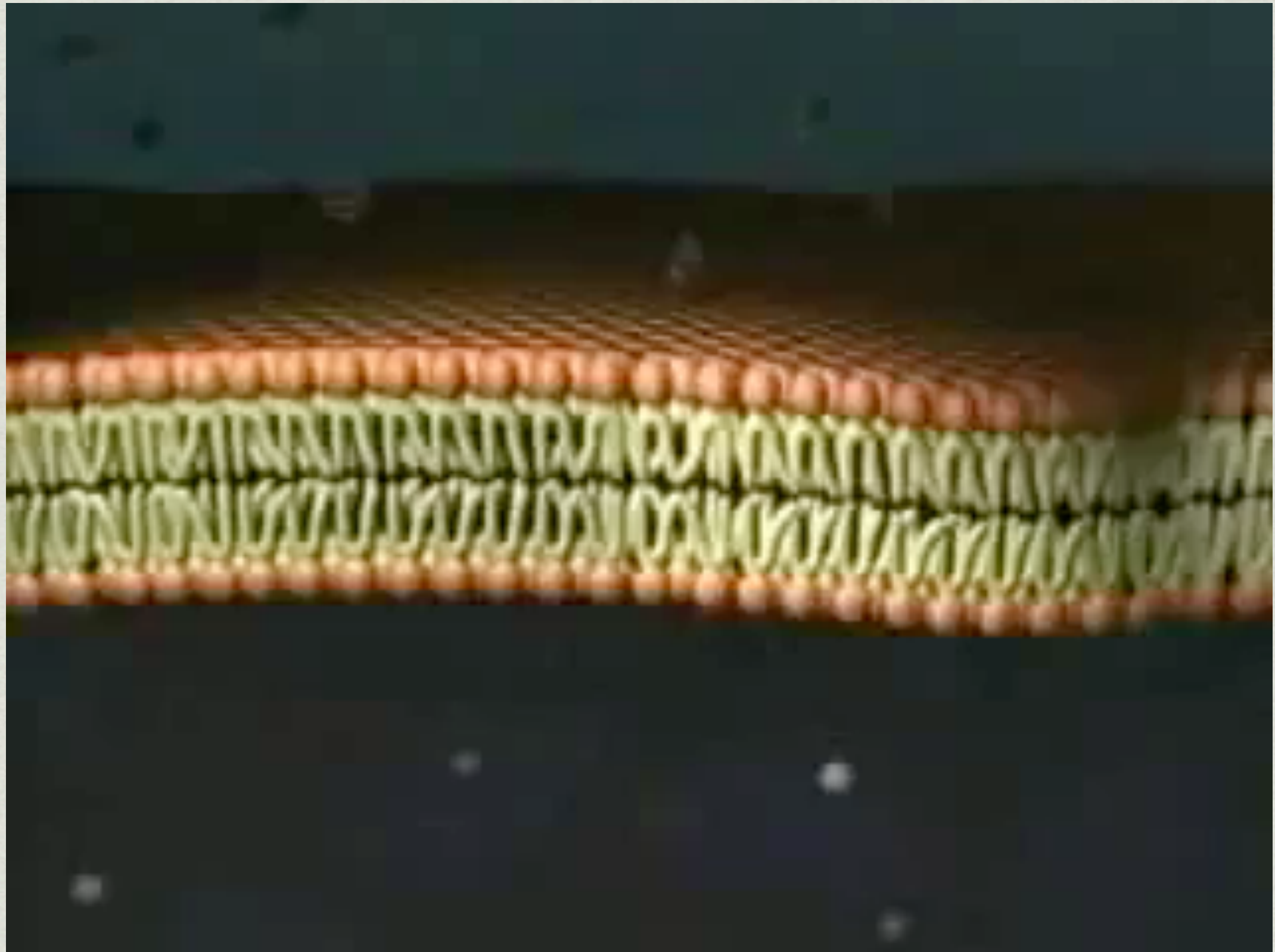
(a) A channel protein



(b) A carrier protein

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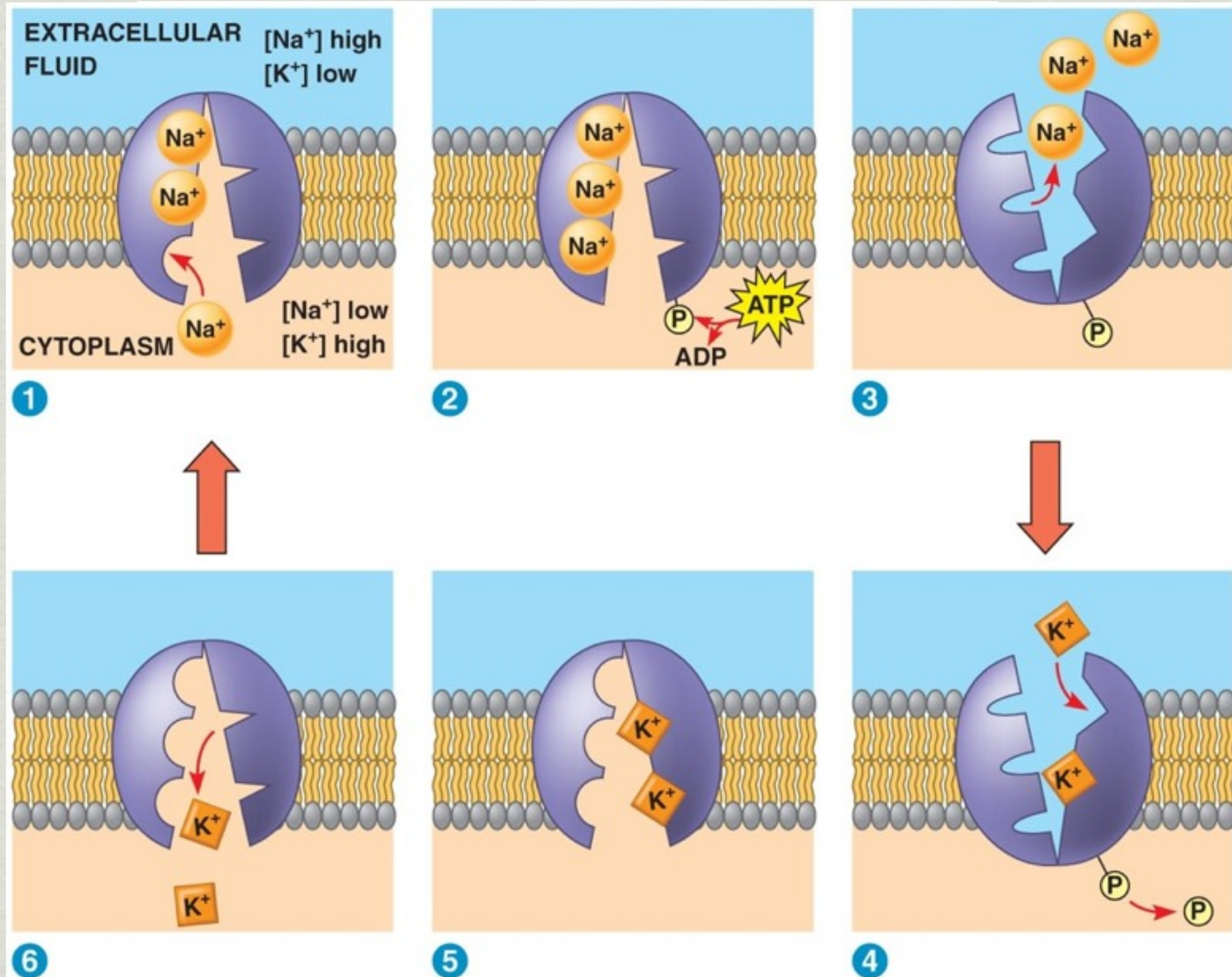
THE ONLY DIFFERENCE BETWEEN THIS AND REGULAR DIFFUSION IS THE ROUTE...IN SIMPLE DIFFUSION MOLECULES MOVE THROUGH THE LIPID BILAYER BUT HERE MOLECULES MOVE THROUGH A CHANNEL OR CARRIER PROTEIN INSTEAD. (STILL HIGH TO LOW, STILL NO ENERGY NEEDED BY CELL)



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.

Sodium/Potassium Pump



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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!

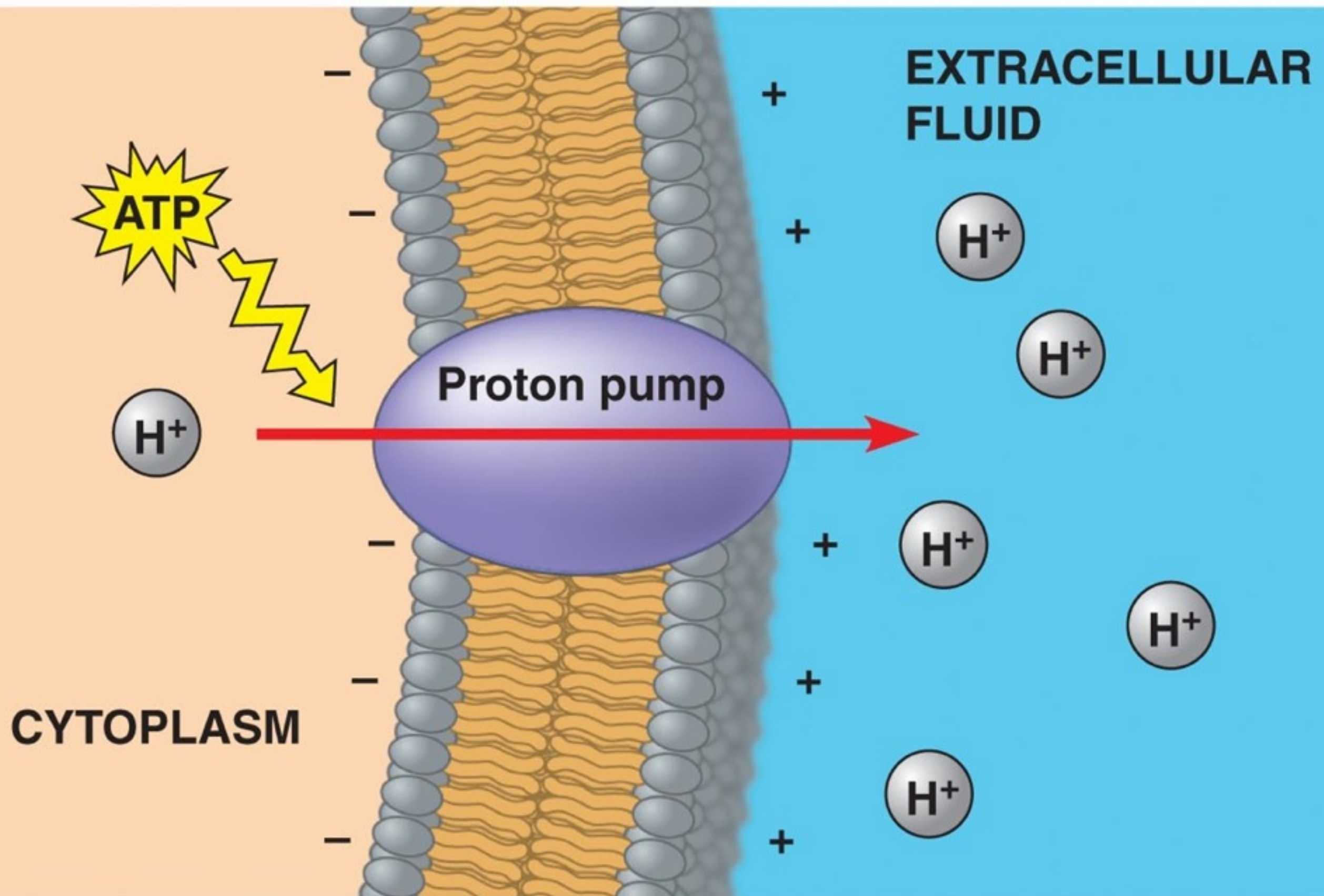


How Ion Pumps Maintain Membrane Potential

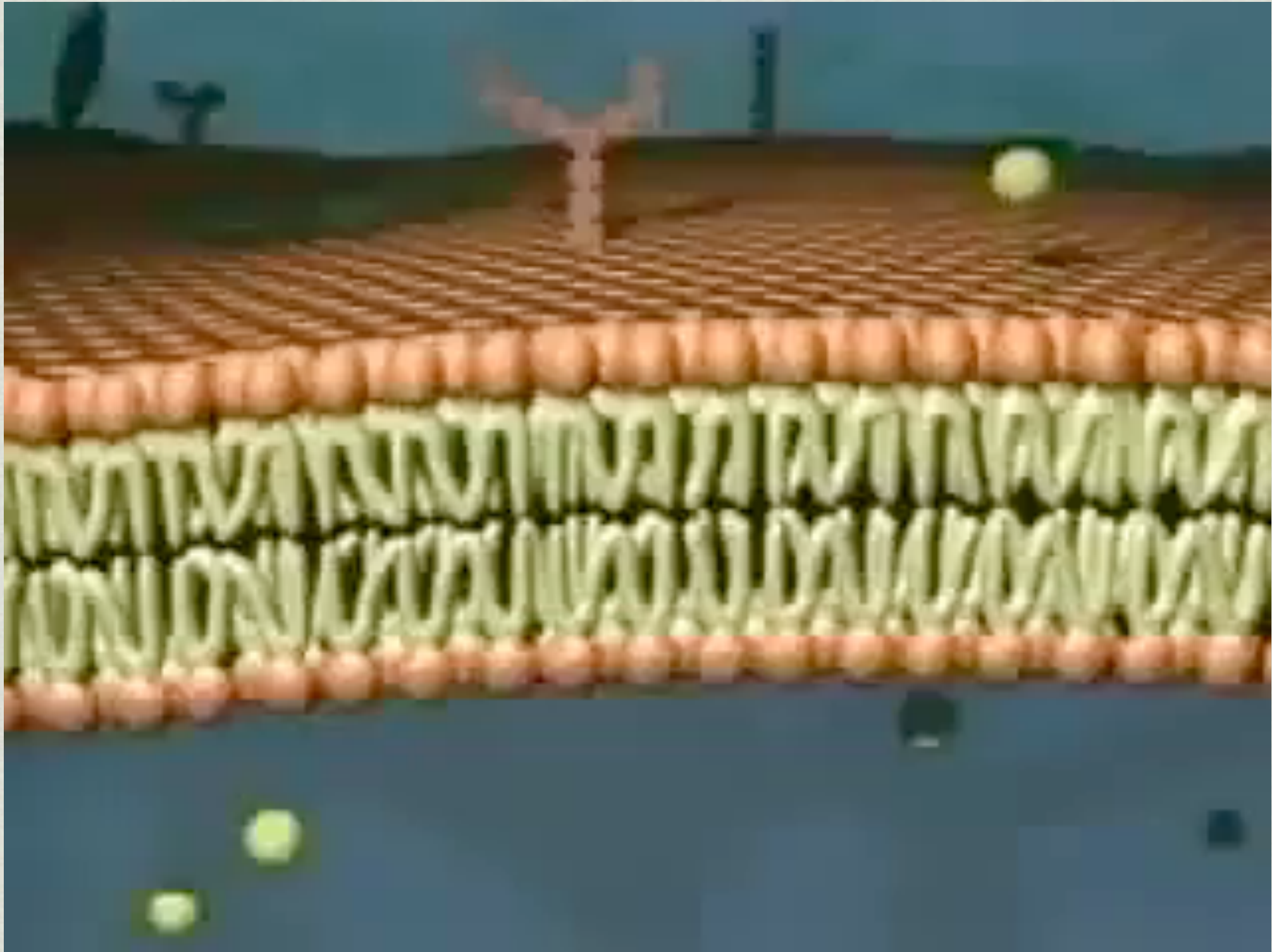
- ***THUS two forces drive diffusion of ions across a membrane***
- A **Chemical Force** (concentration gradient) AND
- An **Electrical Force** (membrane potential)
- The combination of forces is called the **electrochemical gradient**
- *As a result we must refine our definition of diffusion*
- *Molecules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

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!**

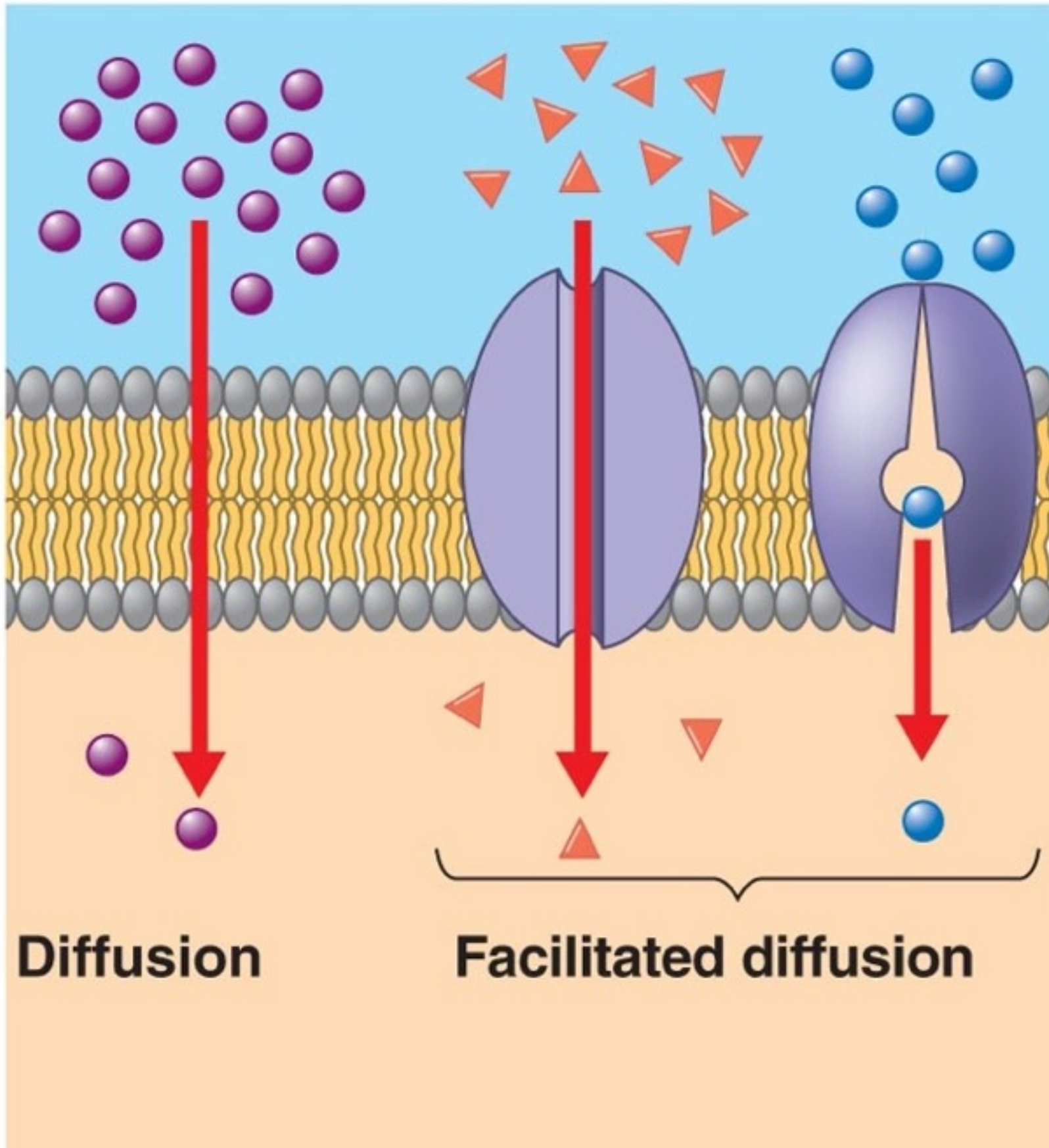


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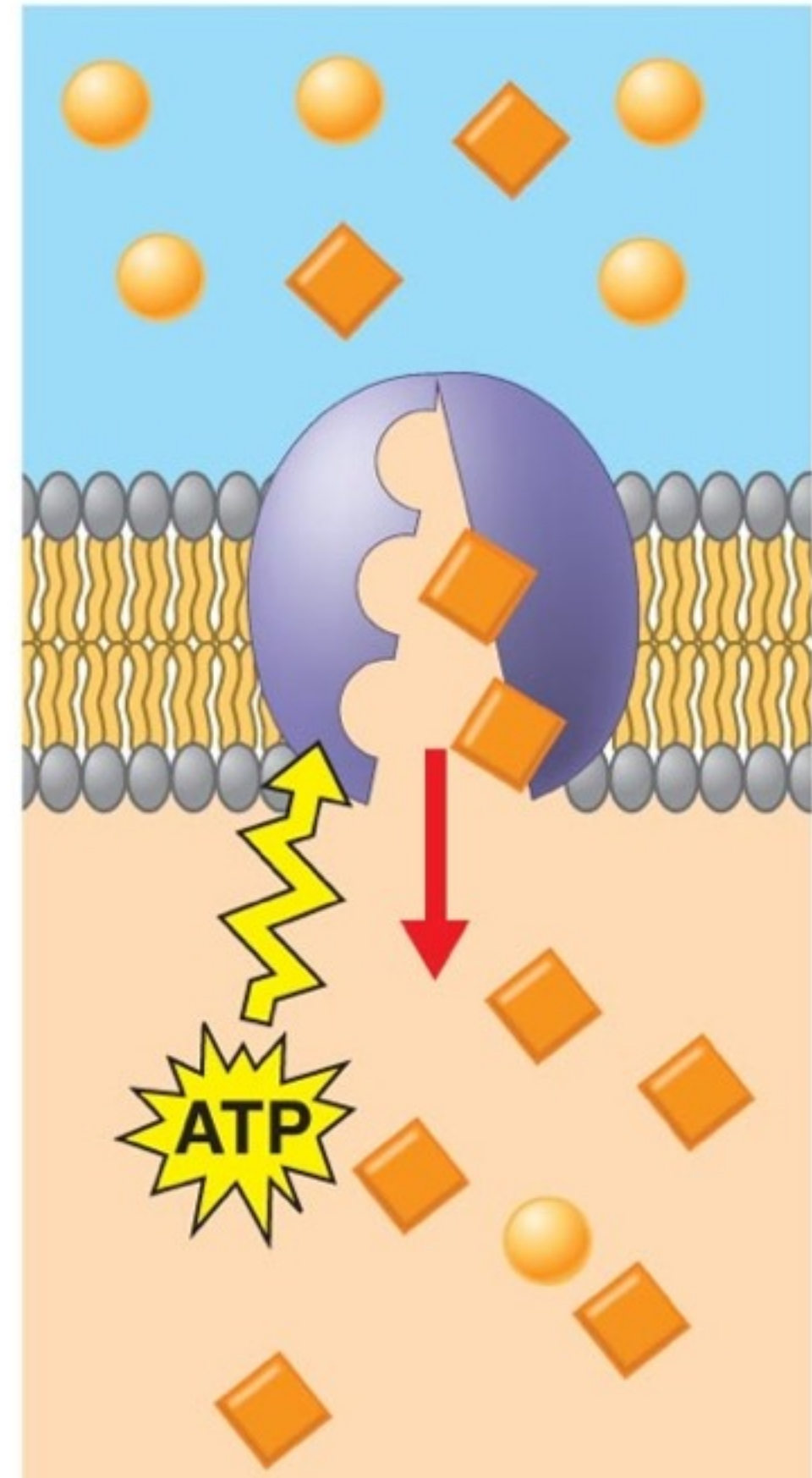
Passive transport

Review



Active transport

Review

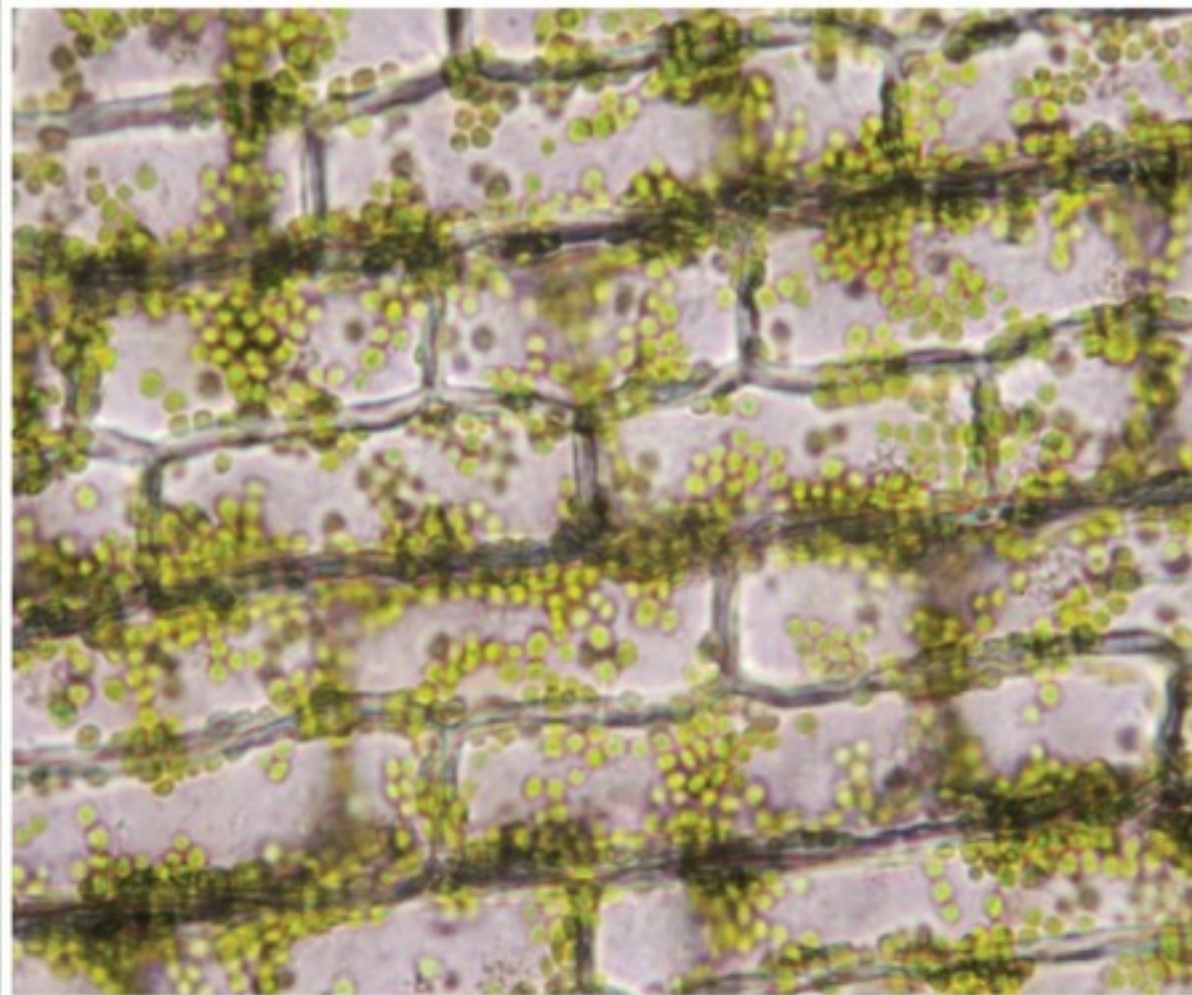


IV. Control, Communication and Coordination

- * Multicellular organisms are composed of two or more cells and usually a multitude of different cell types.**
- * Each cell type has a unique structure and function.**
- * The collection of cells together control the organism.**
- * For these cells to work together their actions must be coordinated.**
- * Coordinating so many cells requires communication.**
- * Cells communicate through chemical and electrical messages**

Multicellular organisms are composed of two or more cells and usually a multitude of different cell types.

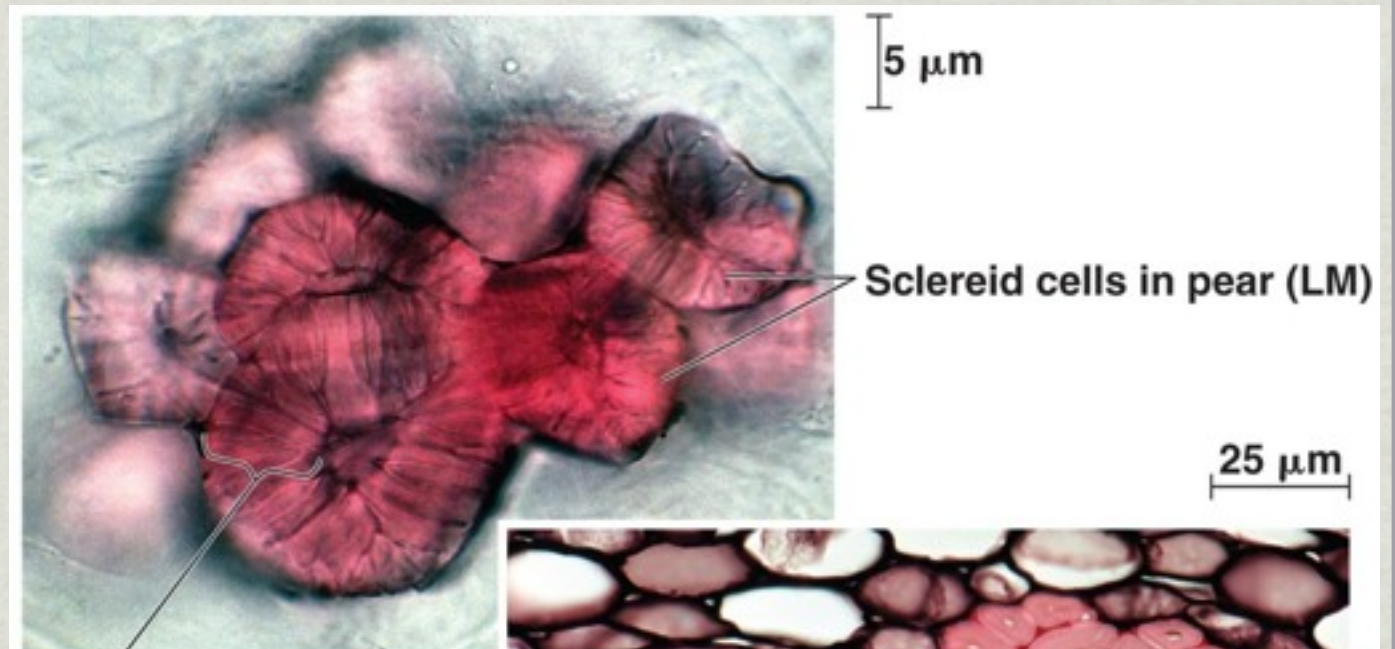
- ✱ Case in Point: Humans have 210 distinct cell types and over 50 trillion cells.
- ✱ Below are some different plant cell types



Parenchyma cells in *Elodea* leaf, with chloroplasts (LM)

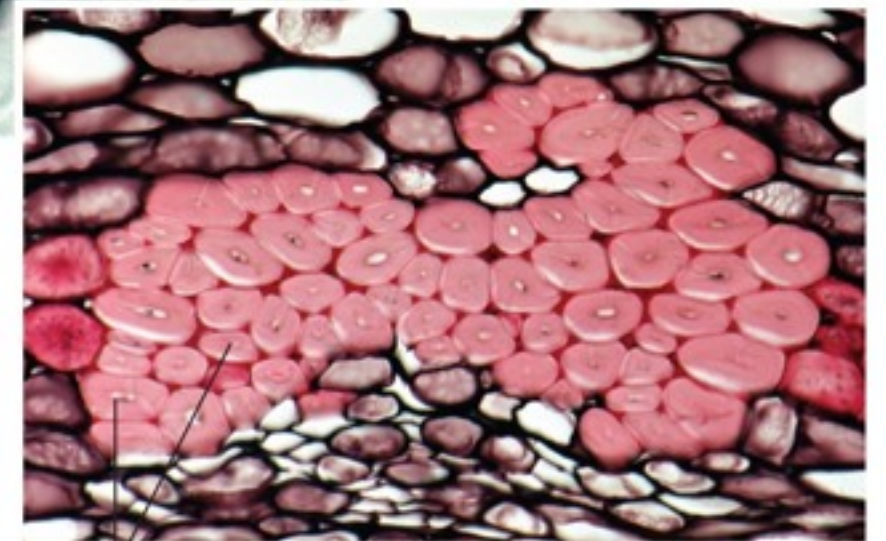
60 μm

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Cell wall

25 μm



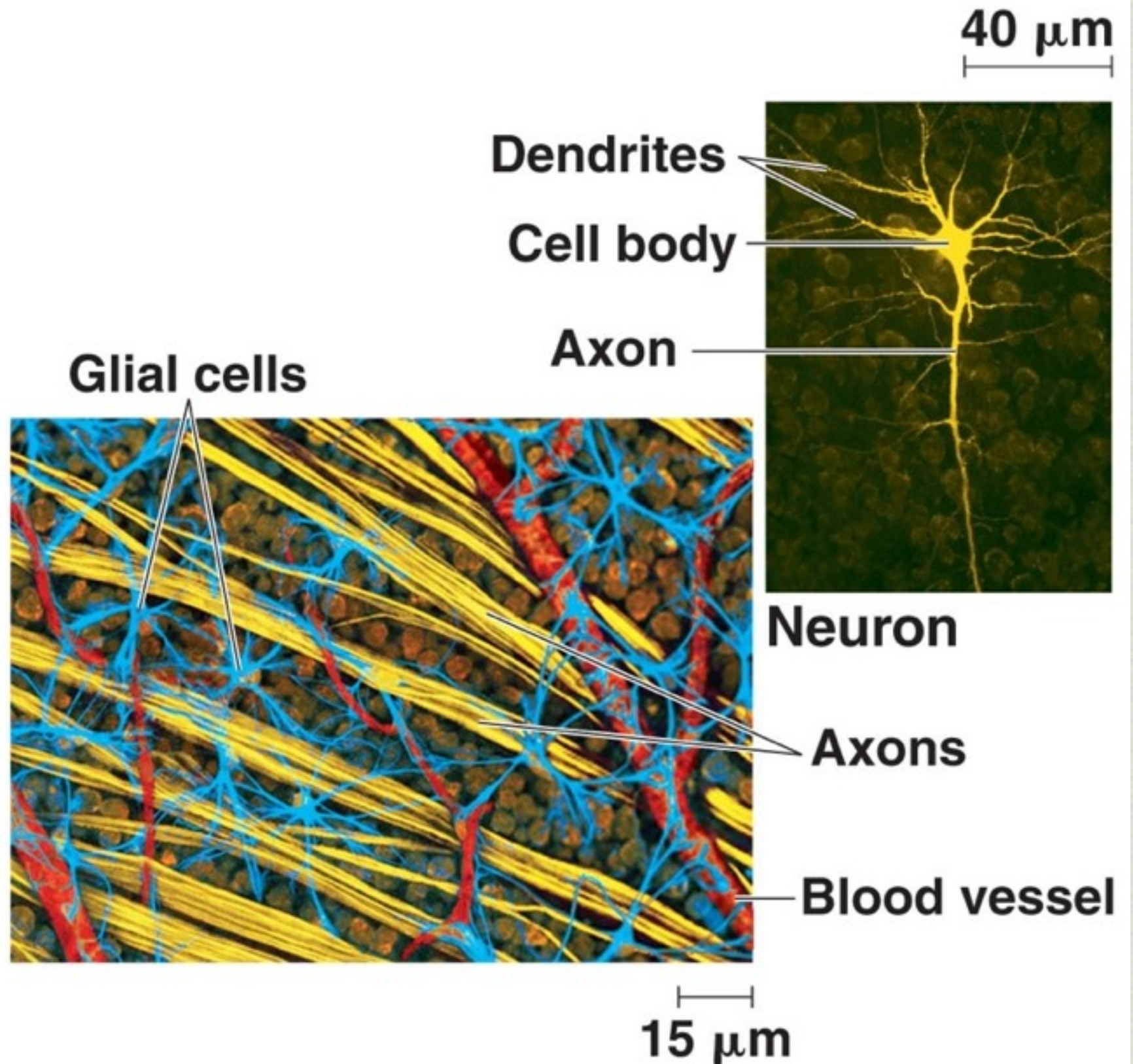
Fiber cells (cross section from ash tree) (LM)

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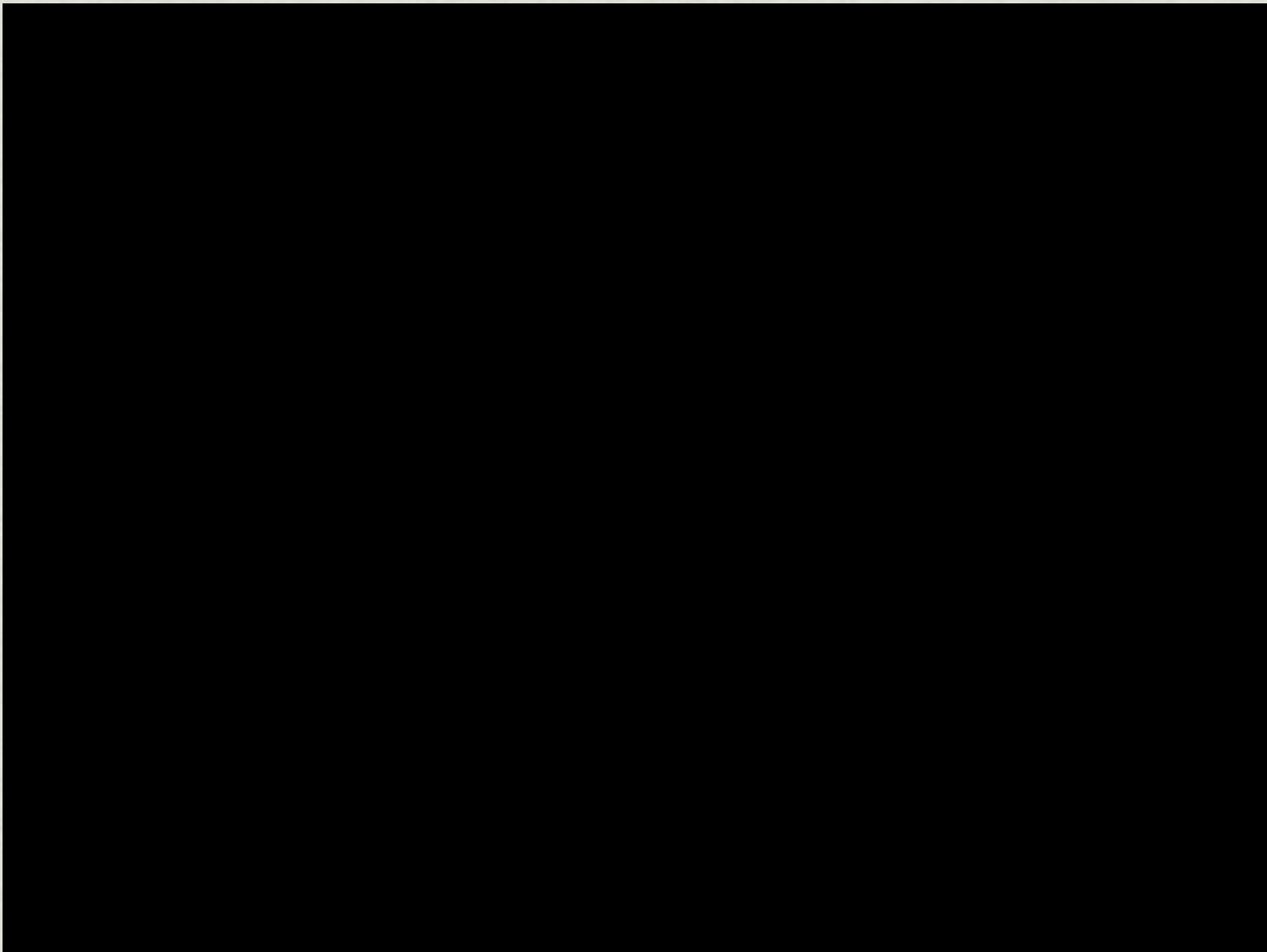
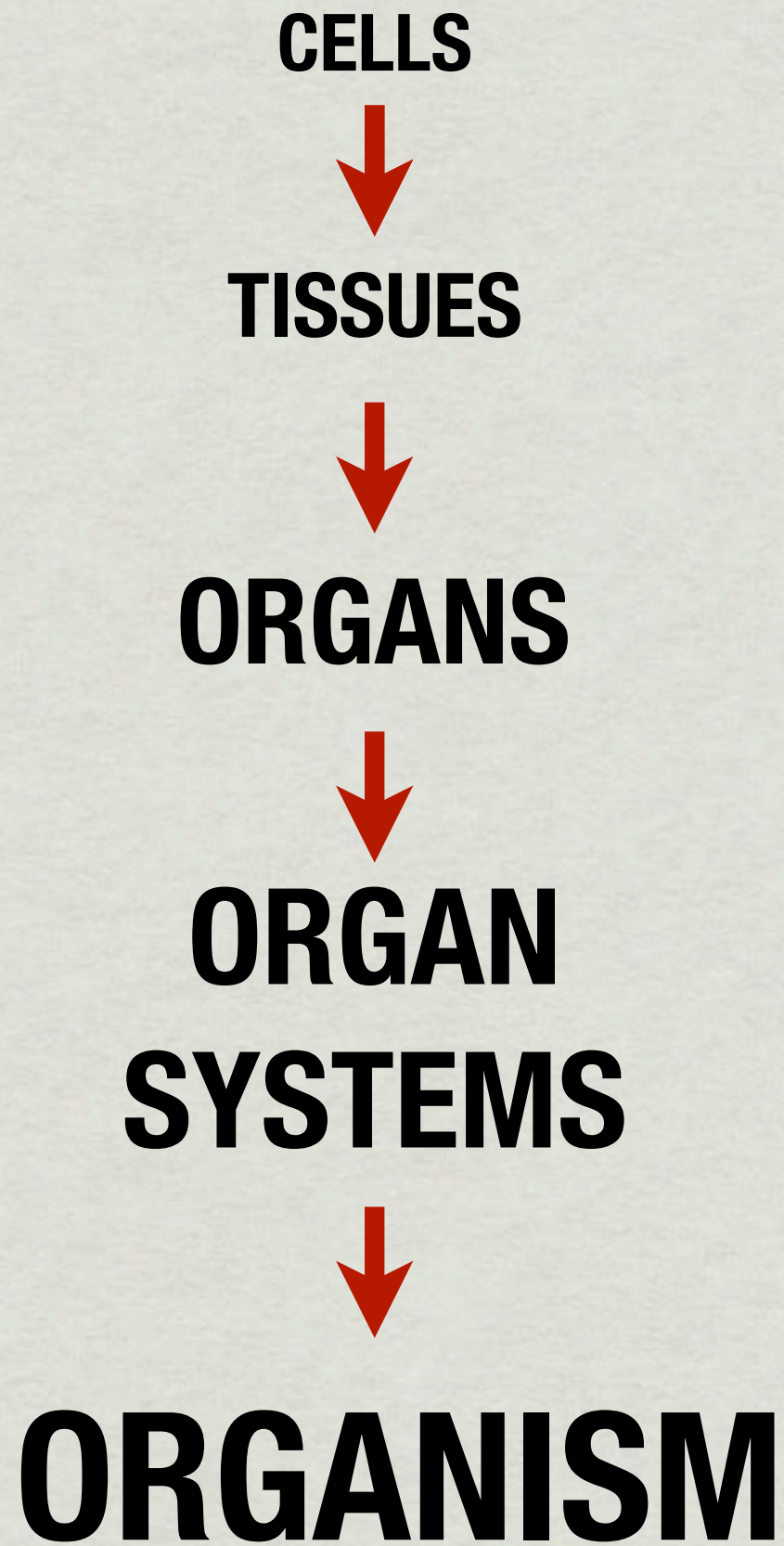
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Each cell type has a unique structure and function.

Nervous Tissue



The collection of cells together control the organism.



**TAIL MUSCLES CONTRACT
BODY TEMP LOWERS
HEART RATE SLOWS
LUNGS COLLAPSE**

THIS COORDINATION REQUIRES COMMUNICATION

Coordinating so many cells requires communication

THERE ARE TWO SYSTEMS OF COMMUNICATION

✱ Endocrine System

✱ Chemical Messages

✱ Slower acting

✱ Long lasting response

✱ Messages reach all the cells

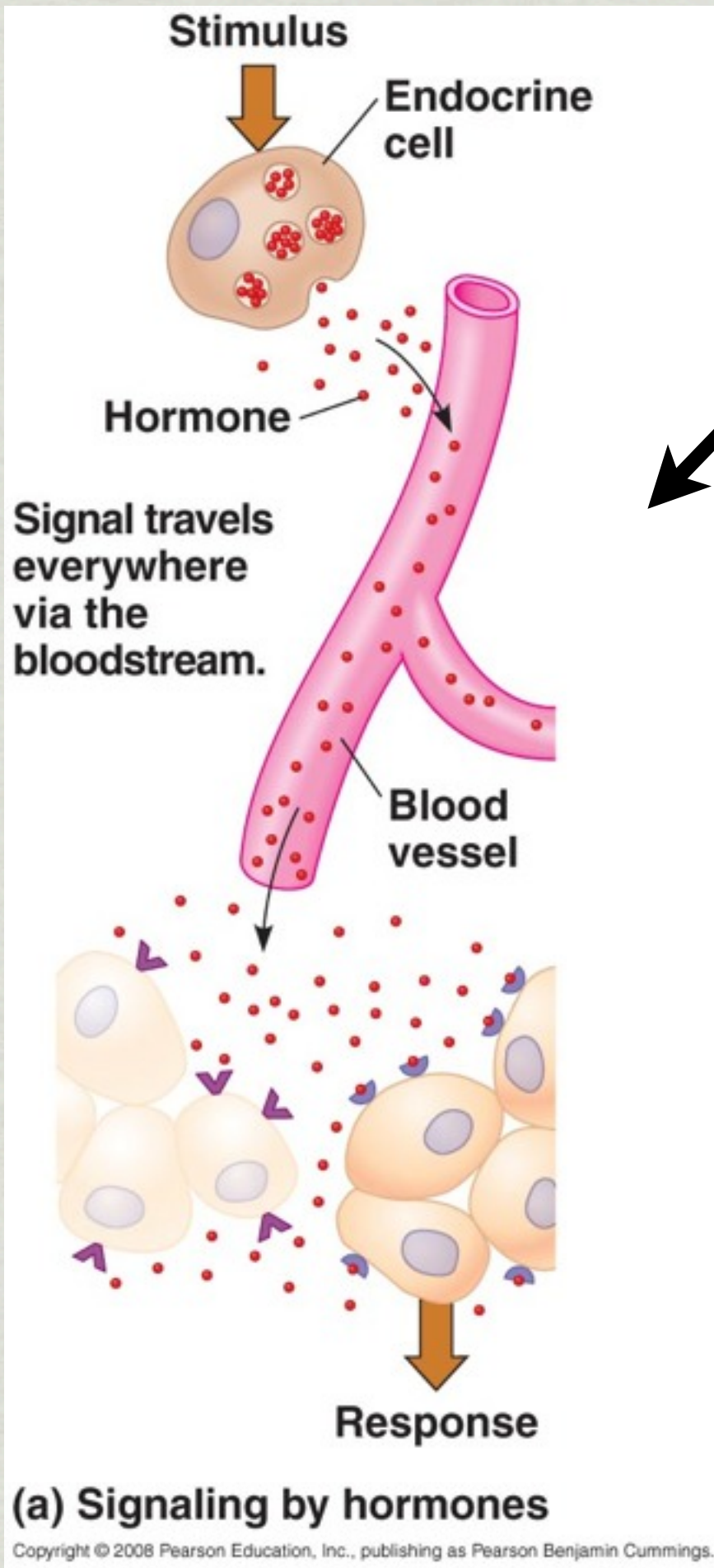
✱ Nervous System

✱ Electrical Messages

✱ Fast acting

✱ Short lived response

✱ Messages reach specific cells

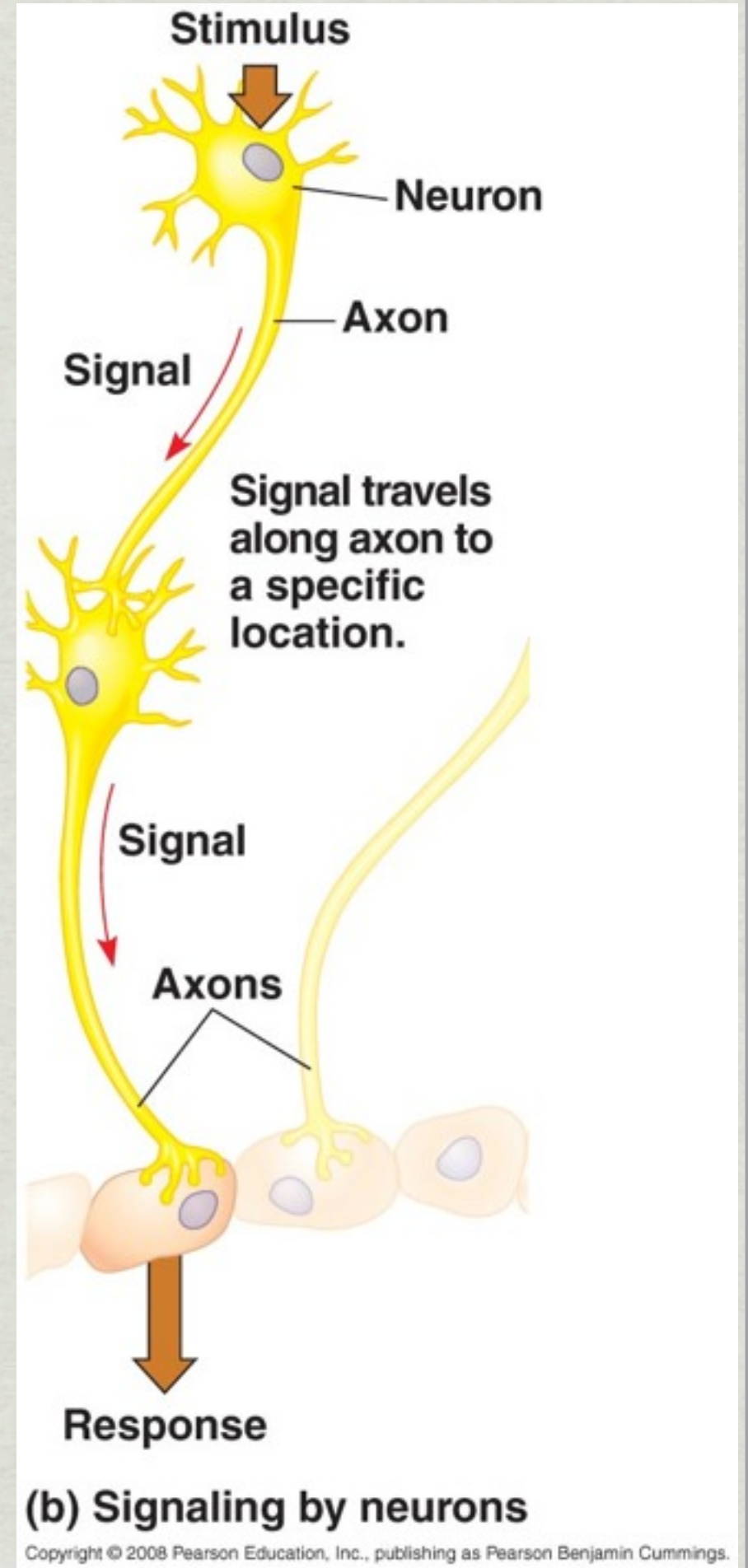


Cells communicate through chemical and electrical messages

DIFFERENT

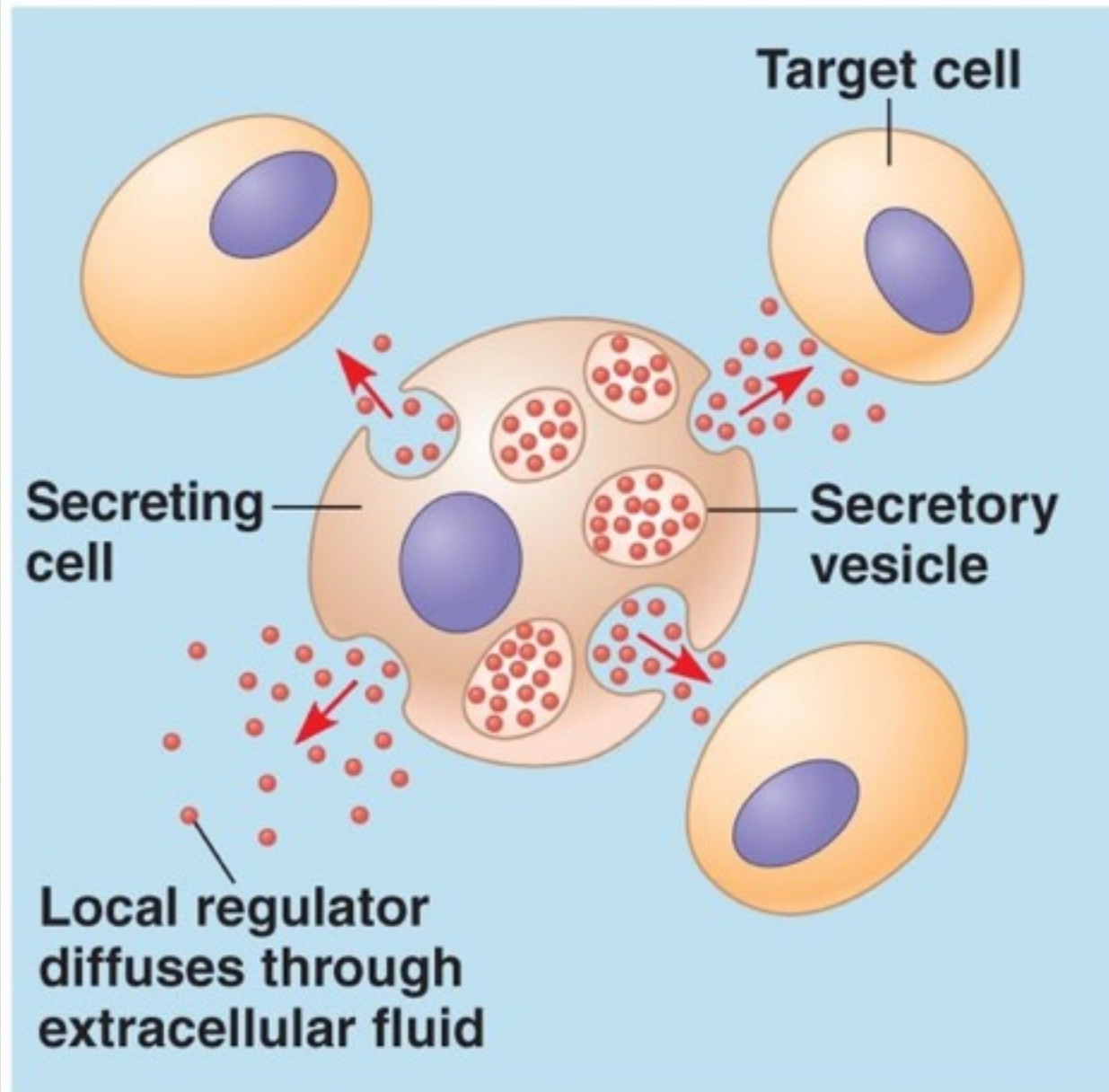
- SIGNAL TYPE**
- TRANSMISSION**
- SPEED**
- DURATION**

THEY ARE ADAPTED FOR DIFFERENT FUNCTIONS

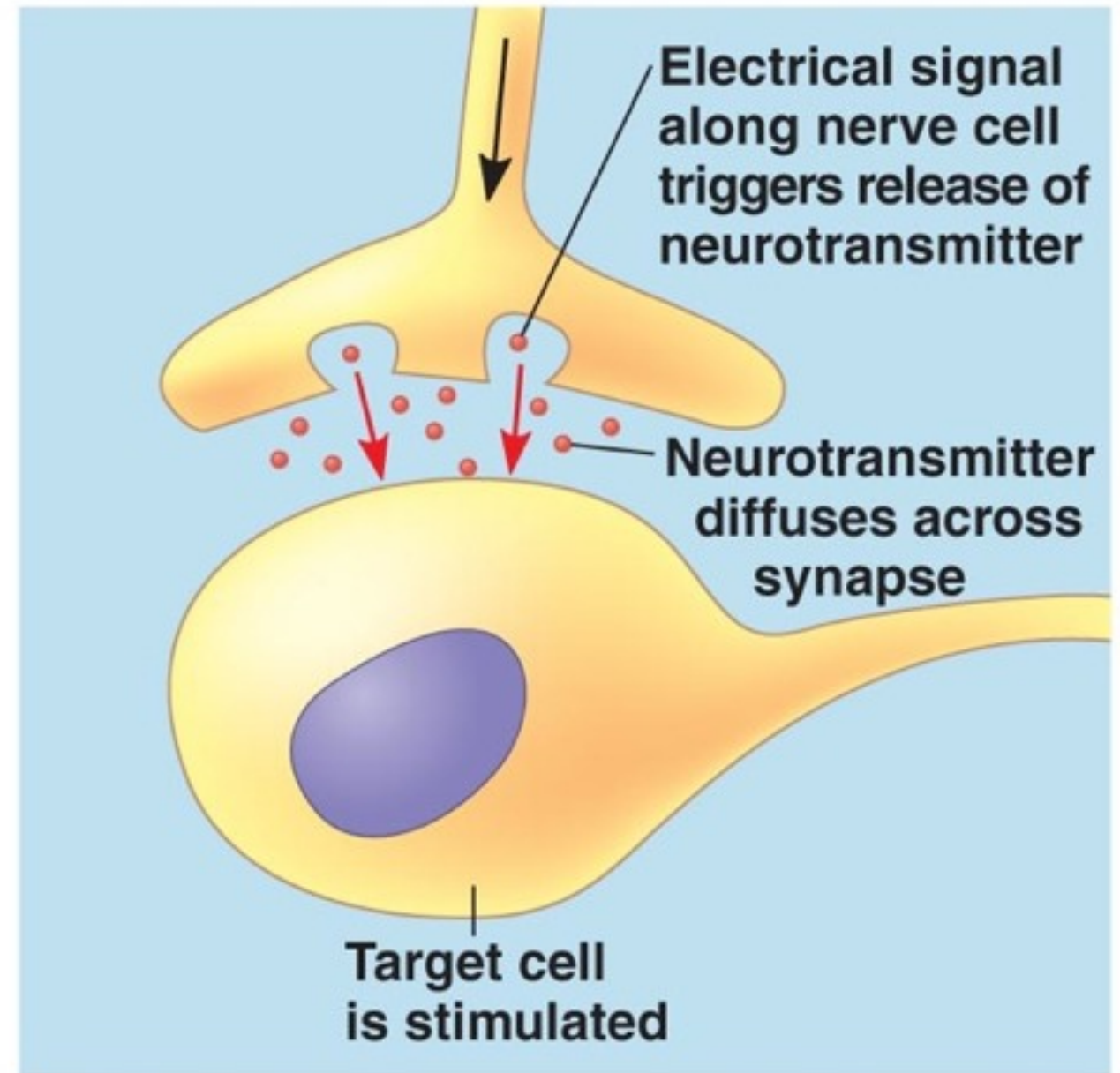


SHORT DISTANCE CHEMICAL MESSAGING

Local signaling

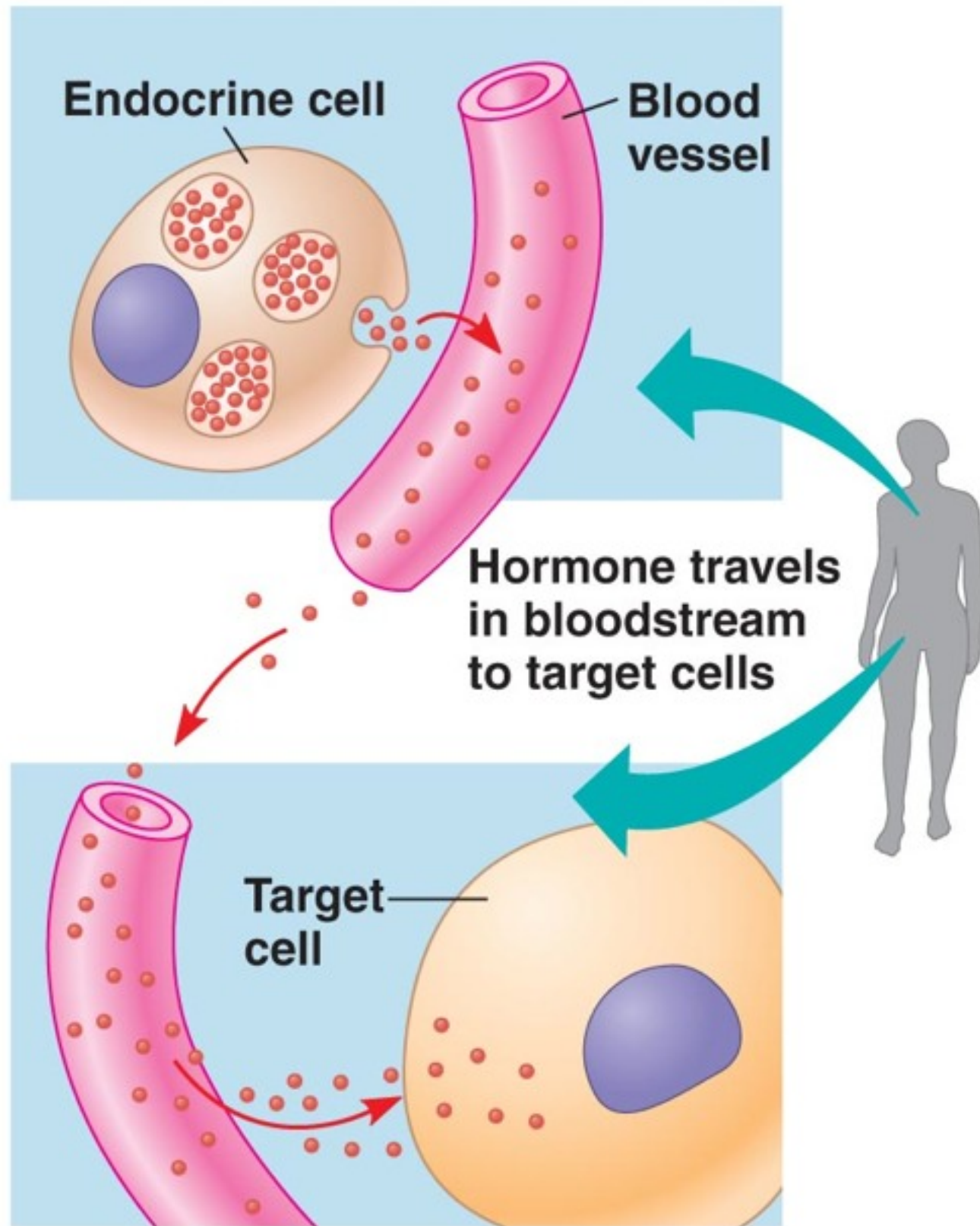


(a) Paracrine signaling



(b) Synaptic signaling

Long-distance signaling

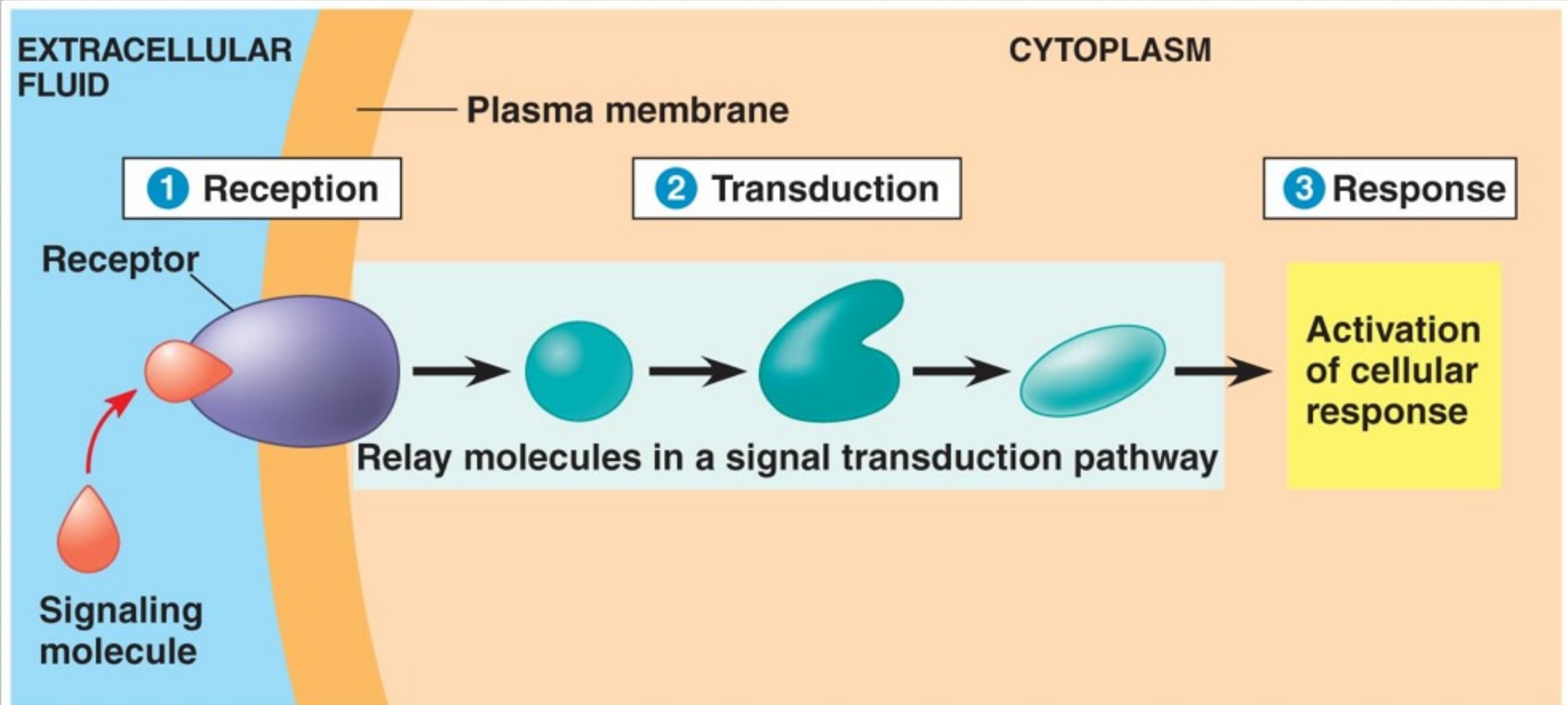


(c) Hormonal signaling

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**THESE CHEMICAL
MESSAGES TRAVEL
THROUGH THE
ENTIRE BODY
BINDING ONLY TO
TARGET CELLS**

OVERVIEW OF CELL COMMUNICATION



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V. SENSING THE ENVIRONMENT

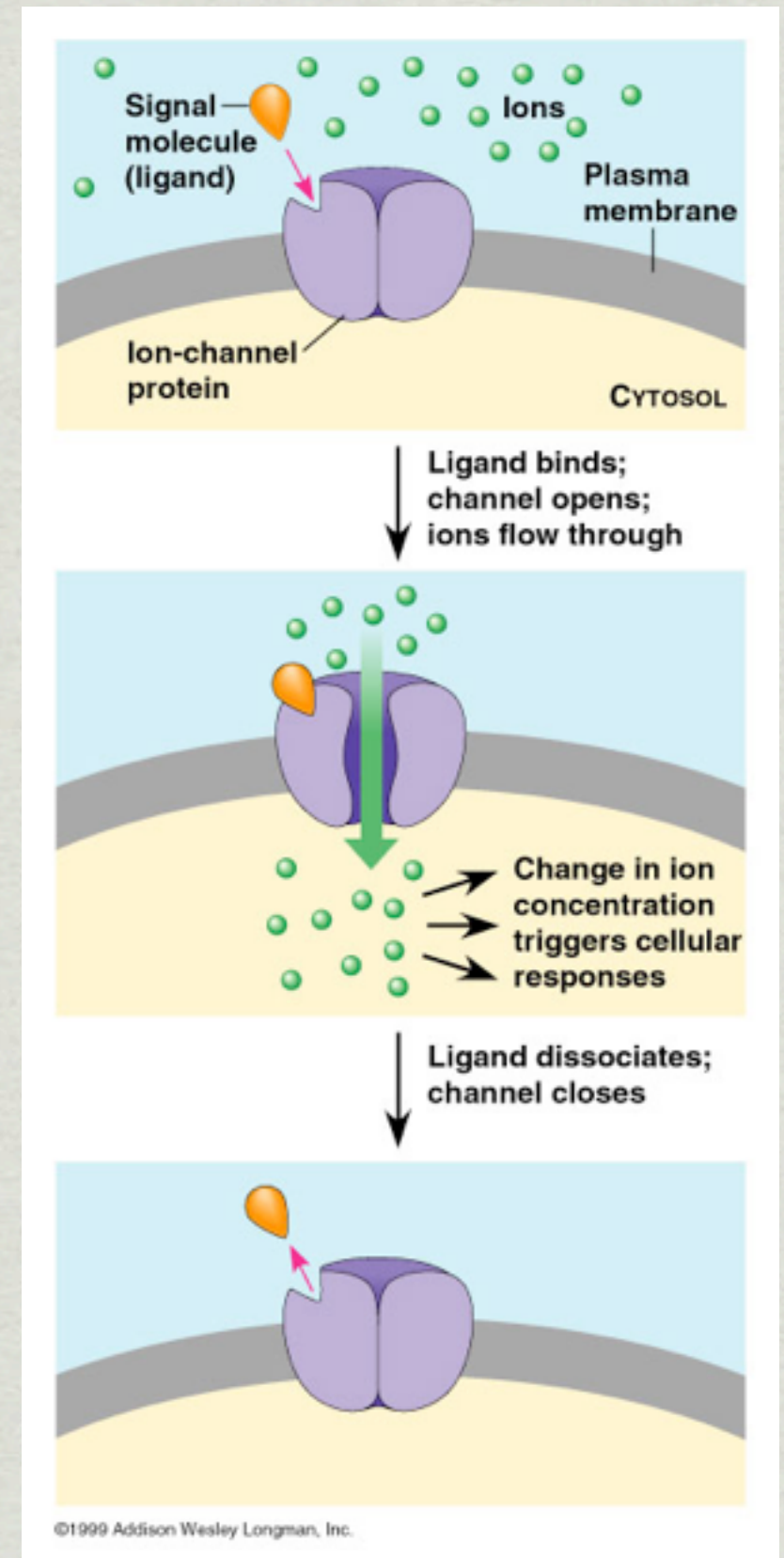
- * The first step in interacting with the environment is detecting stimuli.
- * All stimuli represent forms of energy
- * Sensory pathways have in common four basic functions: sensory reception, transduction, transmission, and perception.
- * Although sensory pathways vary from unicellular organisms to complex animals the four basic functions loosely hold true

SENSORY RECEPTION

- ✱ Begins with the detection of stimulus by sensory cells (multicellular organism)
- ✱ These sensory cells have sensory receptors that detect the stimuli directly. (unicellular and multicellular organisms)
- ✱ The type of stimuli regularly detected include:
electromagnetic radiation, pressure, temperature, chemicals

SENSORY TRANSDUCTION

- ✱ The conversion of a physical or chemical stimulus to change in membrane potential of the cell with the sensory receptor.
- ✱ This is necessary for both unicellular and multicellular organisms



SENSORY TRANSMISSION

- ✱ Changing the membrane potential of the sensory cell initiates the action potential (electrical impulse) to the central nervous system.
- ✱ In other words the sensory cell must tell the brain that it received the stimulus
- ✱ Obviously this would not need to take place in a unicellular organism because the changing potential would be the message itself.

SENSORY PERCEPTION

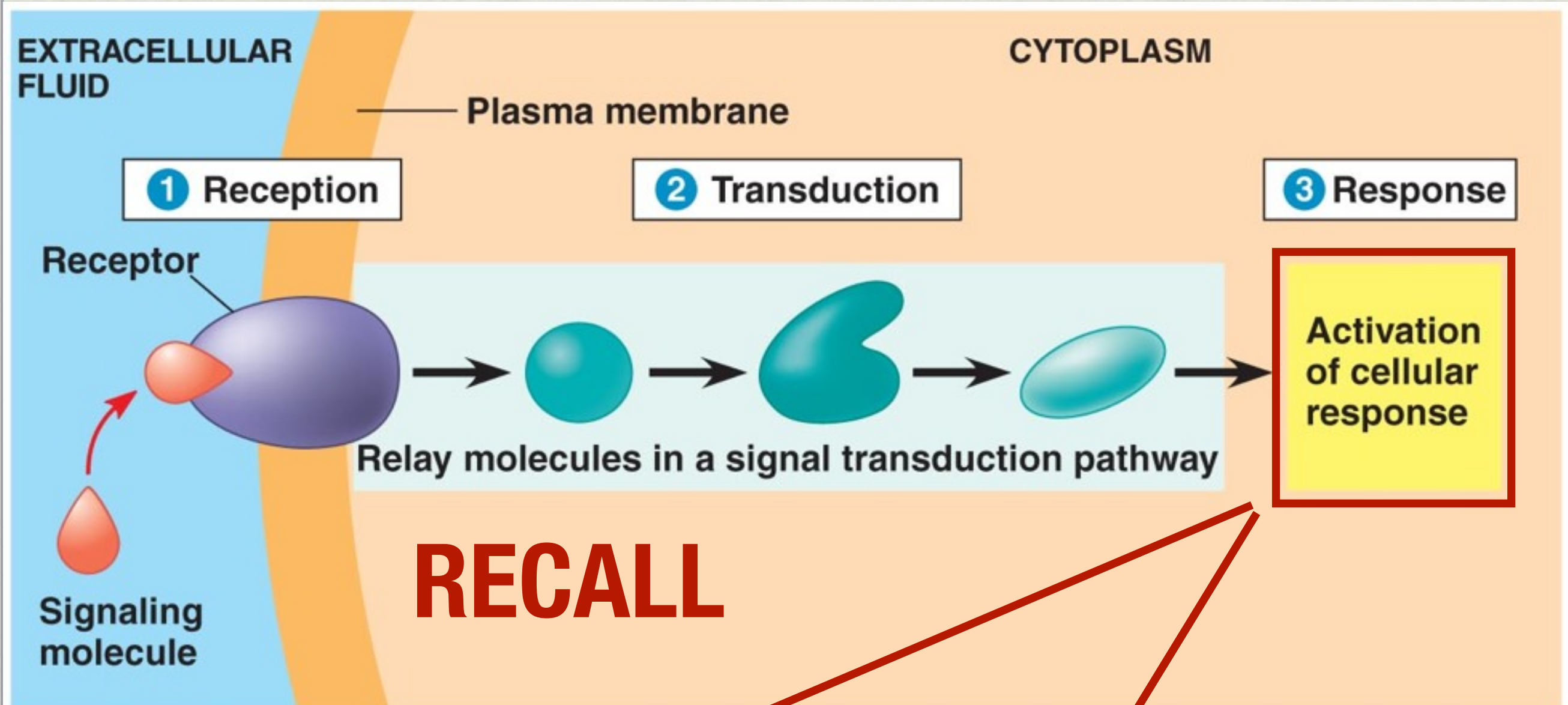
- * When the electrical impulse from the sensory cell(s) reaches the brain the neuronal circuits interpret this information and generate a perception.
- * Perceptions include colors, sounds, tastes, smells
- * **Perceptions are constructions formed in the brain and do not exist outside it!**

WEIRD ...RIGHT

V. RESPONDING TO THE ENVIRONMENT

- * Responses at the intracellular level involve proteins.
 - * Responses at this level, usually comes down to some change in protein activity or synthesis.
- * Responses at the organismal level involves taxes and tropisms.
 - * Mobile organisms move towards or away from stimuli.
 - * Stationary organisms change their pattern of growth or development in response to stimuli
- * Responses by animals are characterized as regulation or conformation.

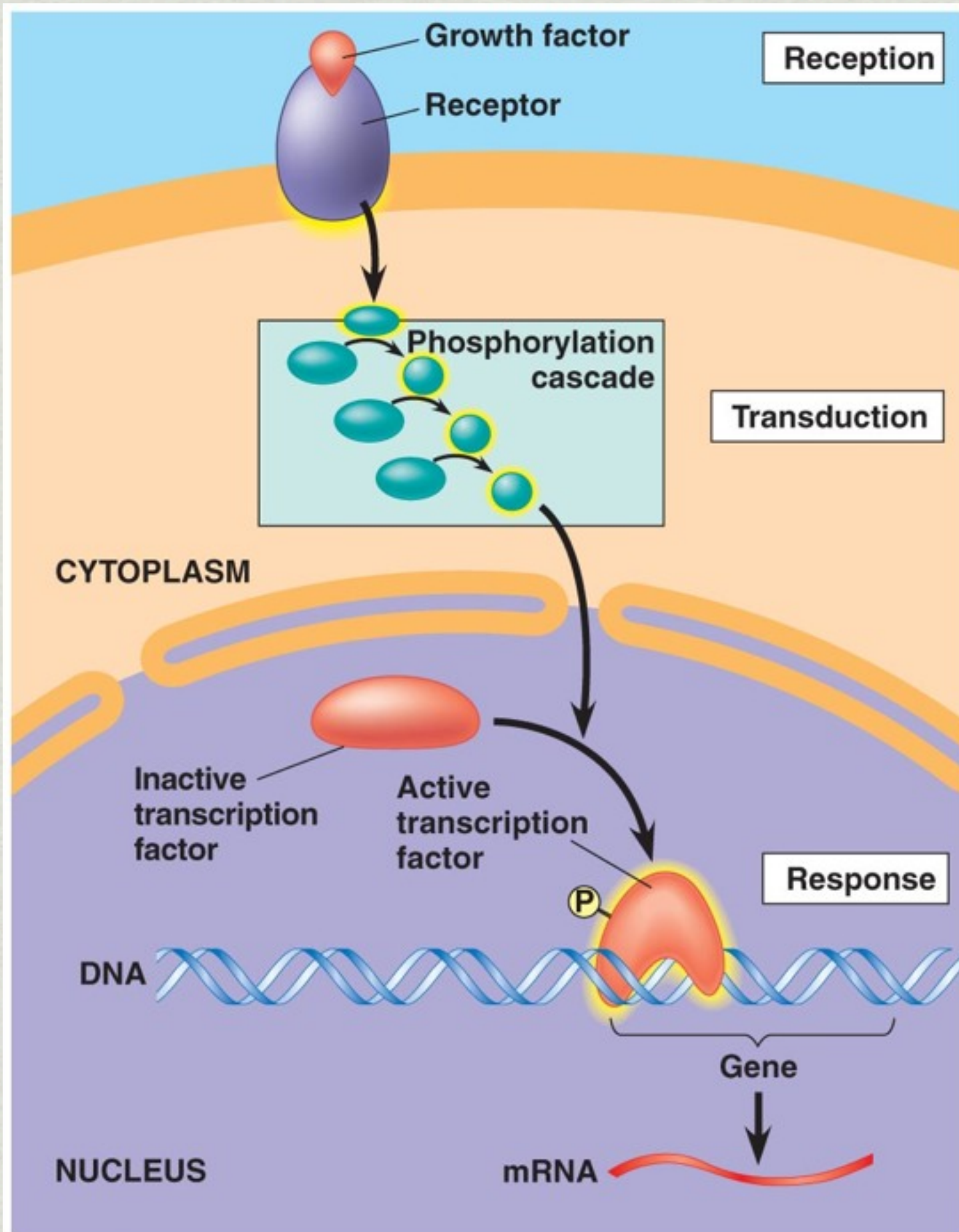
Responses at the intracellular level involve proteins



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#1. Genes in the DNA will be turned “on” to start the production of some protein, or turned “off” to stop the production.

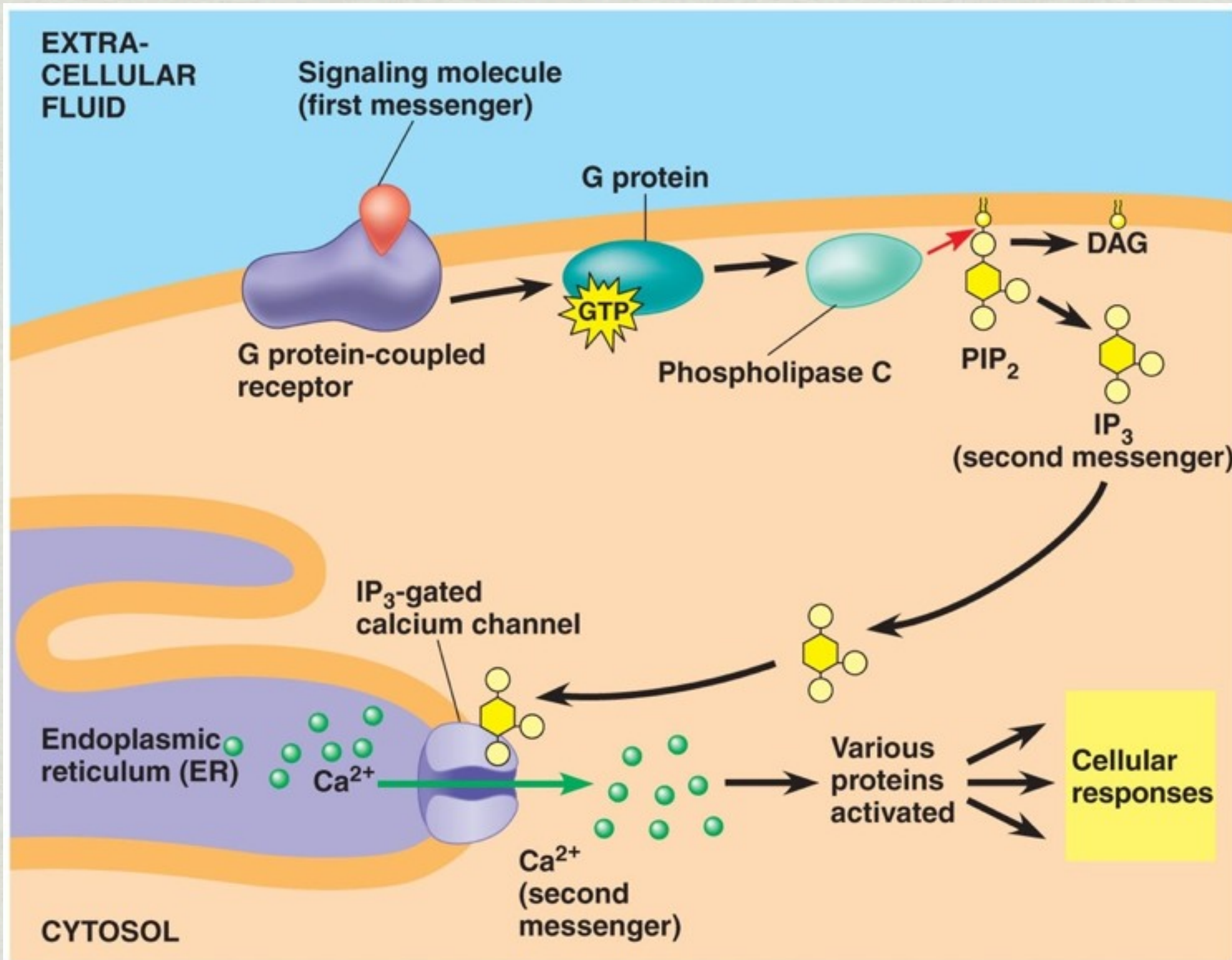
#2. Existing proteins will either be turned “on” or “off”.



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**YOU ARE NOT
RESPONSIBLE FOR
THIS INFORMATION**

**THIS IS ONLY
AN EXAMPLE
TO SHOW YOU
HOW GENES
MIGHT BE
TURNED "ON"
OR "OFF"**



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YOU ARE NOT RESPONSIBLE FOR THIS INFORMATION

THIS IS ONLY AN EXAMPLE TO SHOW YOU HOW PROTEINS MIGHT BE TURNED “ON” OR “OFF”

Responses at the organismal level involve taxes and tropisms

- ✱ **Taxis:** is an innate behavioral response by an organism with motility towards or away from a stimulus, positive taxes move toward stimulus while negative taxes are away from the stimulus..
- ✱ **Tropisms:** growth of an organism (usually a plant) in response to a stimulus, positive tropisms show growth toward stimulus while negative tropisms are away from the stimulus.

Responses by animals are characterized as regulation or conformation.

- ✱ **Regulator:** an animal that uses internal mechanisms to control internal change in face of external environmental fluctuations.
- ✱ **Conformer:** an animal that allows its internal condition to change in accordance with external changes in the variable.
- ✱ *Regulating and conforming represent extremes on a continuum. An animal may regulate some internal conditions while allowing others to conform to the environment.*

Homeostasis

- ✱ **Homeostasis:** “steady state” refers to the maintenance of an internal environment.
- ✱ It means that an internal environment stays relatively constant in spite of external environmental fluctuations some of which may be extreme.
- ✱ Human examples
 - ✱ Blood pH 7.4 (+/- .1)
 - ✱ Temperature 98.6° F
 - ✱ Blood Glucose Concentration 70-110mg/100ml

VI. COMMON CHALLENGES

✱ Involve the following variables

✱ **Water**

✱ **Food**

✱ **Oxygen**

✱ **Temperature**

✱ **Wastes**

✱ **Defense**

✱ **Moving**

✱ **Reproducing**