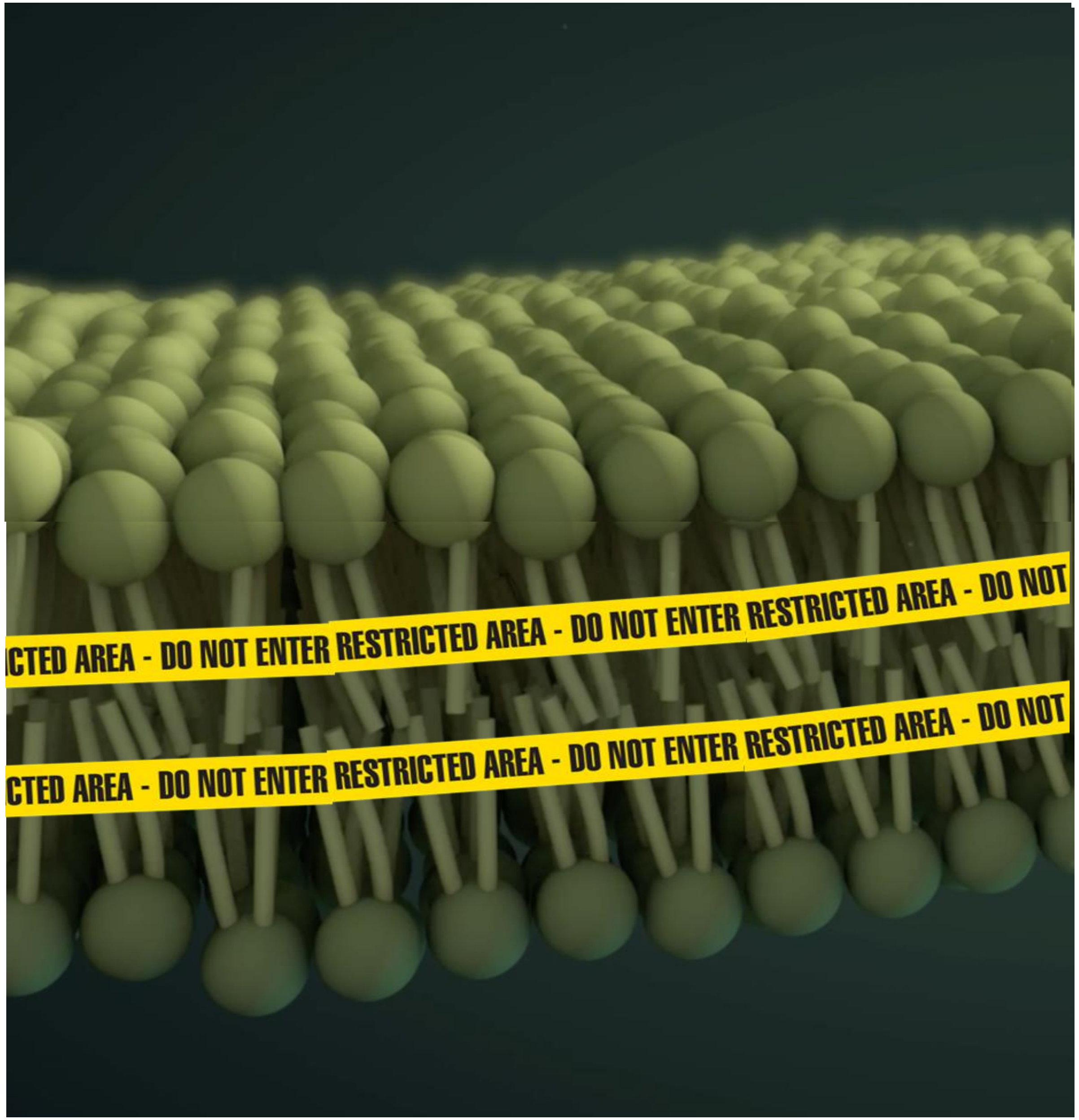
Lesson 2:
The Great Divide (and How to Cross It)

BIOL 1441

Cell & Molecular Biology



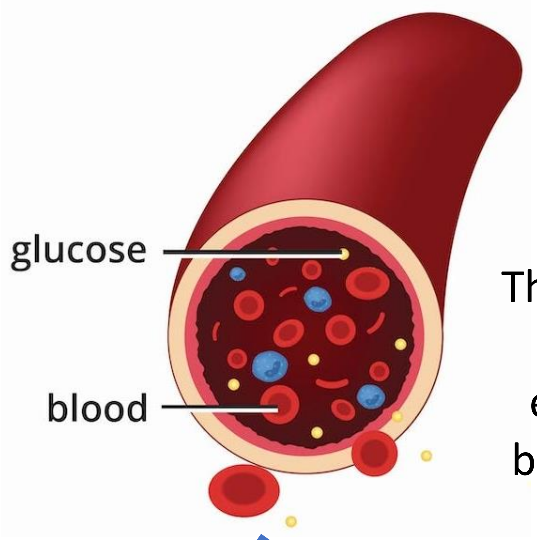
Learning Objectives
(a.k.a. Study Guide)

By the end of this lesson, students will be able to:

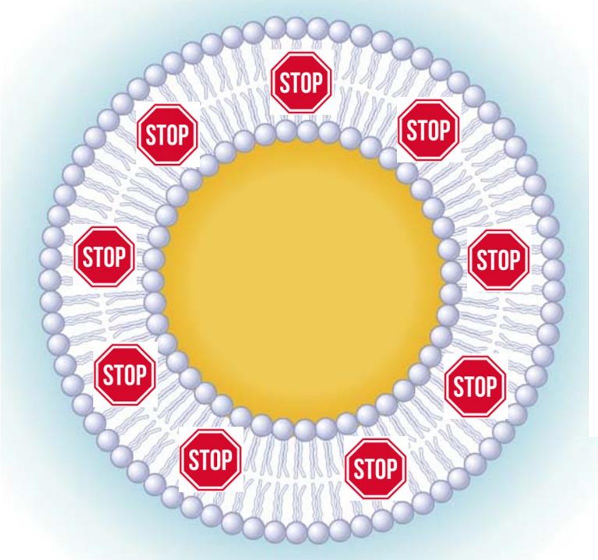
1. Explain the fundamentals of atomic structures and define a bond.
2. Explain the main function of a cell’s plasma membrane.
3. Describe the functions of phospholipids & transport proteins in the plasma membrane.
4. Identify the hydrophobic & hydrophilic regions of the phospholipid bilayer.
5. List the kinds of molecules that can & cannot diffuse across the membrane.
6. Use the chemical properties of a molecule (hydrophobic, hydrophilic, polar, nonpolar, charged) to determine whether or not it could diffuse across the membrane.
7. Explain what a concentration gradient is.
8. Use the direction of a concentration gradient to determine which way a molecule would move (into or out of a cell).
9. Explain how passive transport is different from active transport.
10. Explain why active transport is important to a cell.
11. Identify similarities & differences between these transport processes: diffusion, facilitated diffusion, osmosis, primary active transport, secondary active transport.

How do your cells get the glucose in your food?

You eat a donut.



The glucose in the donut enters your bloodstream.



The plasma membrane **won't let glucose diffuse** into the cell. (It's polar, large, & there's already A LOT inside!)

Your cells use a <u>transport protein</u> (i.e. the car), powered by the **concentration gradient** of Na^+ (i.e. the car's gas) to move glucose (i.e. the piggy bank) into your cells.

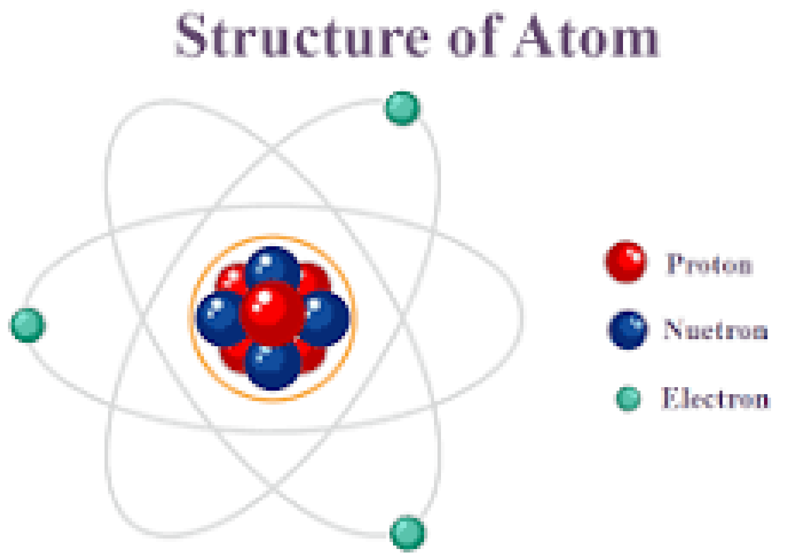
First- a brief review of atoms and chemical bonds

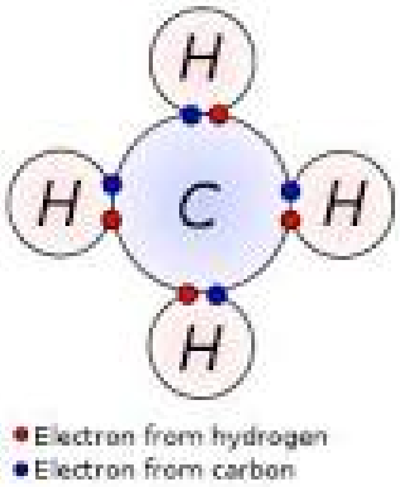
An **atom** is a particle of matter that consists of a nucleus that is surrounded by one or more negatively charged electrons.

A chemical bond is a lasting attraction between atoms or ions that enables the formation of molecules.

There are different types of bonds (some are stronger than others).

When the bonds break, **energy is released**. When new bonds are formed, energy is absorbed and stored in the bond.

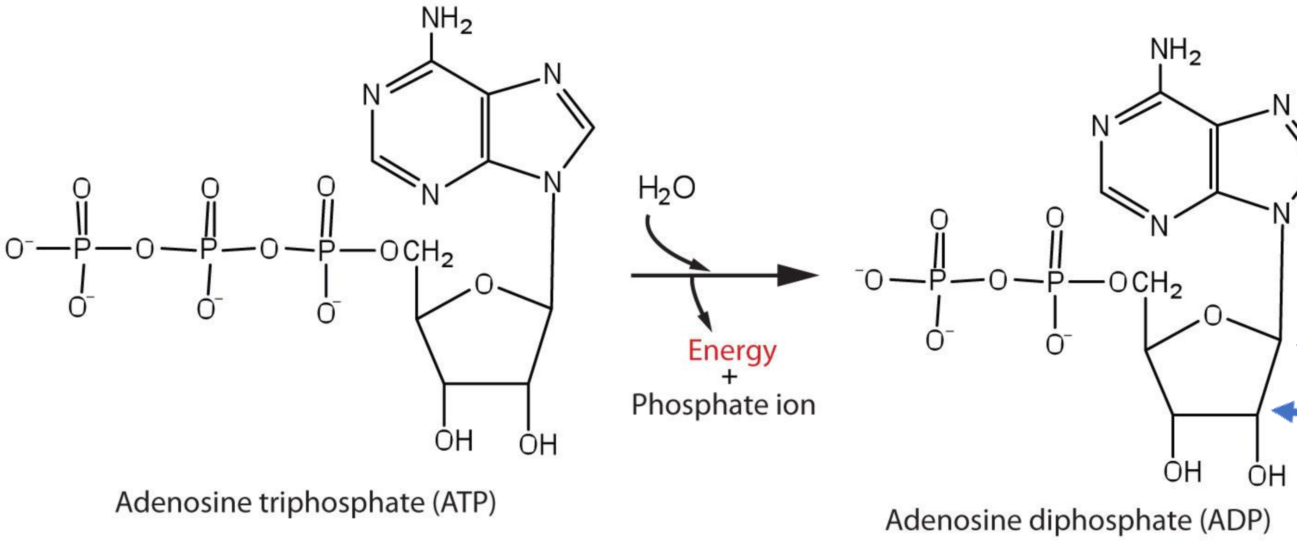




Stop & Think It Through!

We will be talking quite a bit about ATP in this course.

- Which of the following molecules would have more energy (left or right)?
- Which molecule (left or right) has more chemical bonds?
- What would be required for the reverse reaction to occur?



Side note- one line is a chemical bond, two is a double-bond!

Side note- each “point” or “corner” is a carbon atom!

Cells & the Plasma Membrane

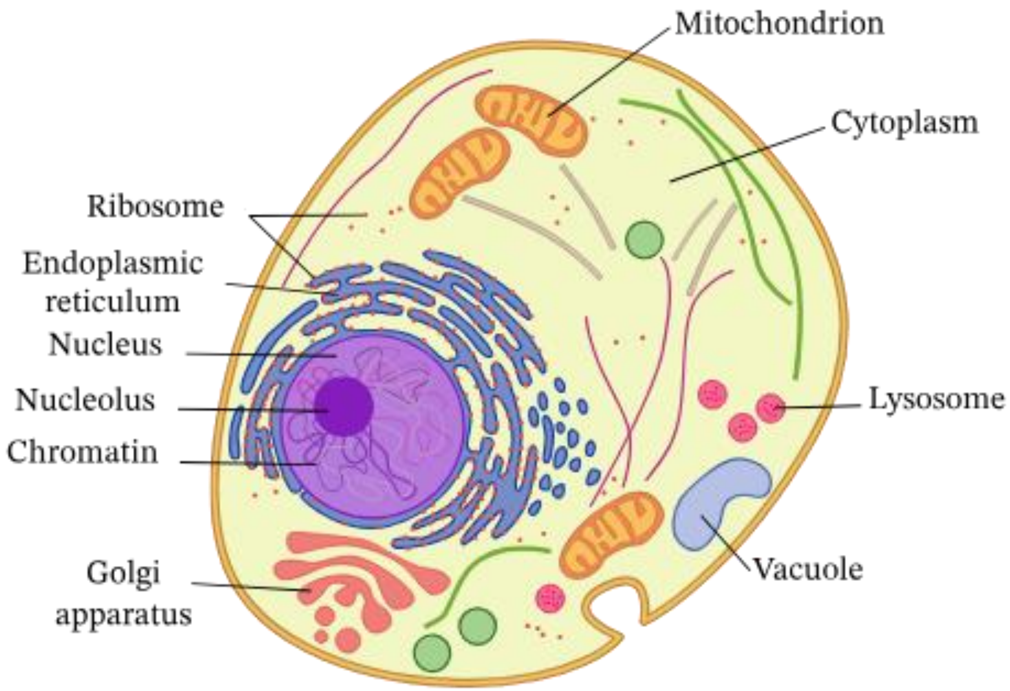
The human body is made of 30 trillion cells

Every cell has a plasma membrane

- Function: dividing the inside of a cell from its environment
- Cytosol (a.k.a. intracellular fluid) is found *inside* the cell
- Extracellular fluid is found in the *environment*

The plasma membrane is **selectively permeable**

- Definition: only certain molecules can pass straight through it
- The membrane's selective permeability is based on its structure



The Phospholipid Bilayer

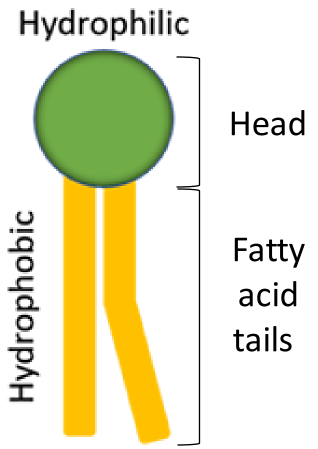
The plasma membrane (a.k.a. the phospholipid bilayer) is made of two rows of phospholipids

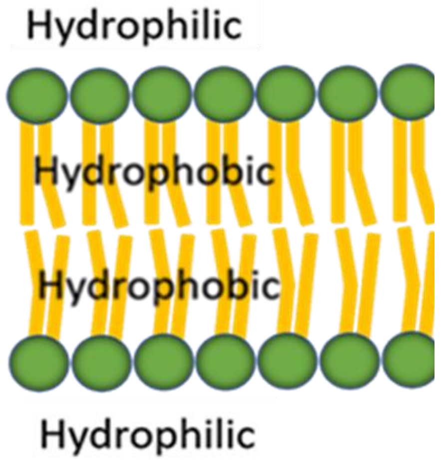
Each phospholipid has a head group & two fatty acid tails

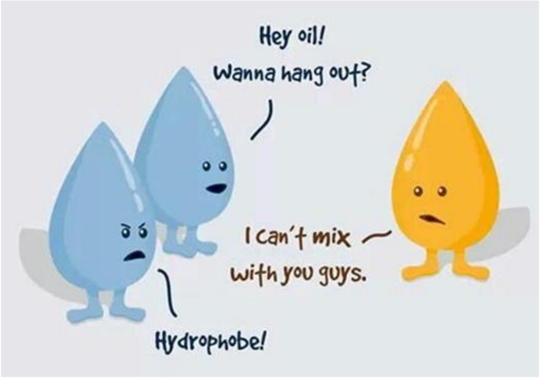
- The head group is **hydrophilic** → "water loving"
- The fatty acid tails are **hydrophobic** → "water fearing"

By grouping the fatty acid tails together in the middle of the membrane, a **hydrophobic barrier** is created between the inside & outside of the cell

- This barrier means water & water-loving molecules CANNOT easily move back & forth through the membrane







Polarity

Water is made of 2 hydrogens (H) & 1 oxygen (O)

To build water, the H's and O's share **electrons** with each other

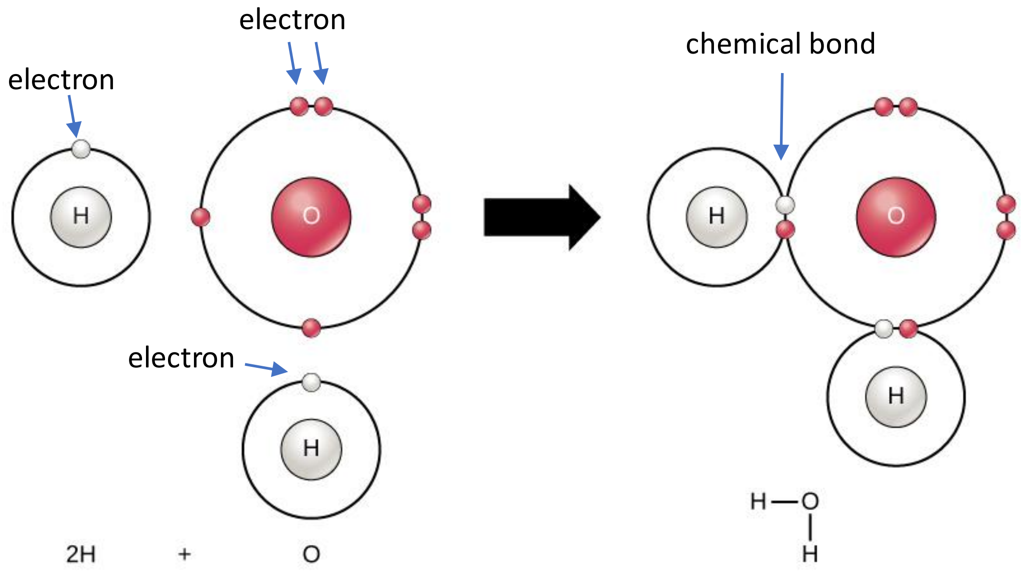
- Electrons are small particles with a negative charge
- When electrons are shared, a chemical bond is formed

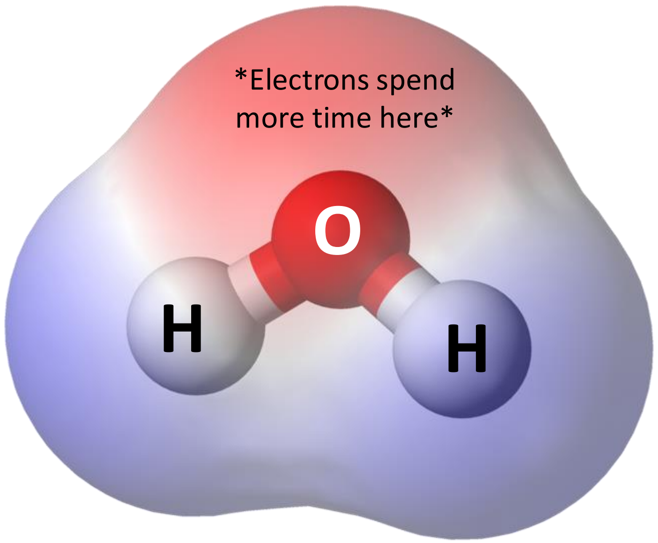
In water's chemical bonds, electrons are NOT shared equally

- Oxygen "gets" them more often, so it is slightly negative
- The hydrogens "get" them less often, so they are slightly positive

Because it has areas of partial positive & partial negative charge, water is considered a **polar** molecule

- Anything else with these partial charges (glucose, insulin, and ATP) is also considered polar





Let's Draw It!

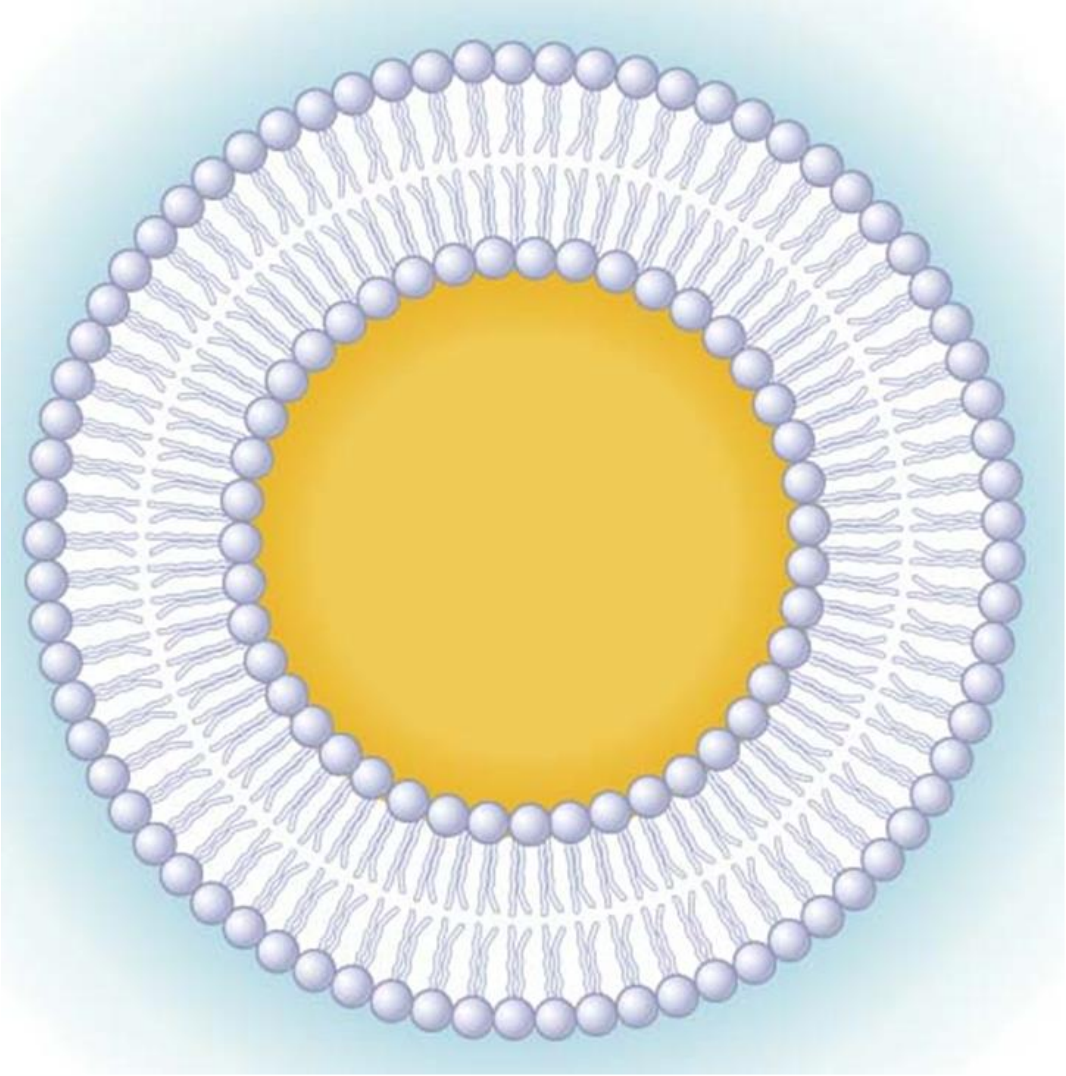
On the image, label these regions of the plasma membrane:

- ❑The hydrophilic regions
- ❑The hydrophobic regions

Then, label the locations where water would be found.

Based on your picture, which parts of phospholipids are touching water?

The hydrophilic parts The hydrophobic parts



Selective Permeability

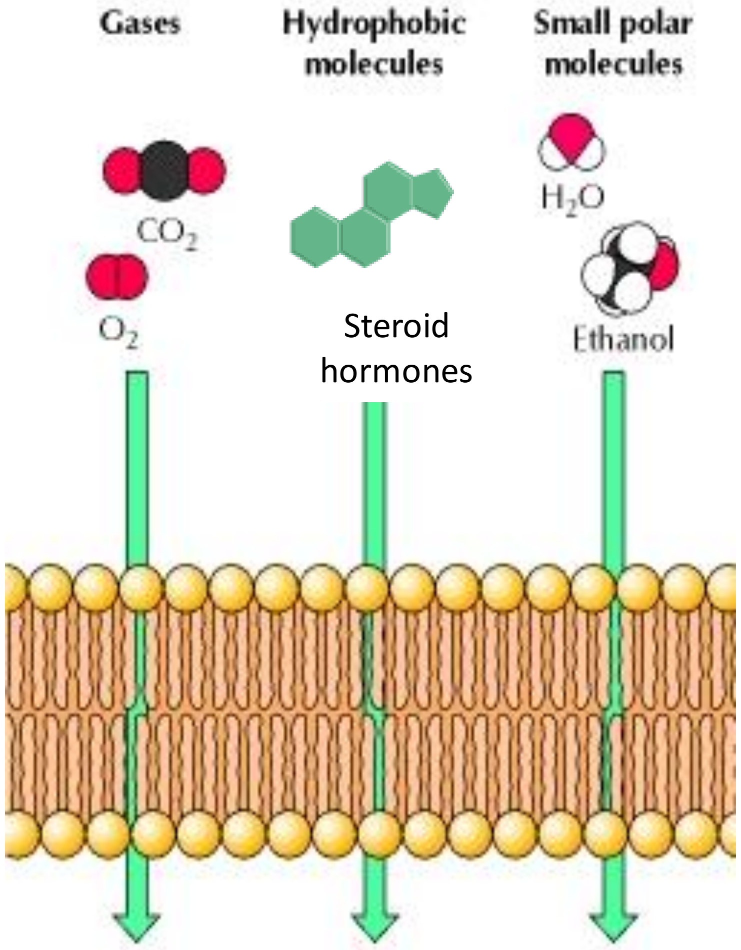
Only molecules that "match" the chemical properties of the fatty acid tails can diffuse across the membrane

Things that do "match"

- Hydrophobic molecules, like steroid hormones
- Gases, which are **nonpolar**
    - Nonpolar molecules share their electrons equally
    - Nonpolar molecules have NO positive or negative regions

Polar molecules don't match, but some can diffuse through the membrane

- Polar molecules have partial positive & partial negative regions
- <u>Small</u> polar molecules can squeeze between the fatty acid tails, but NOT large ones

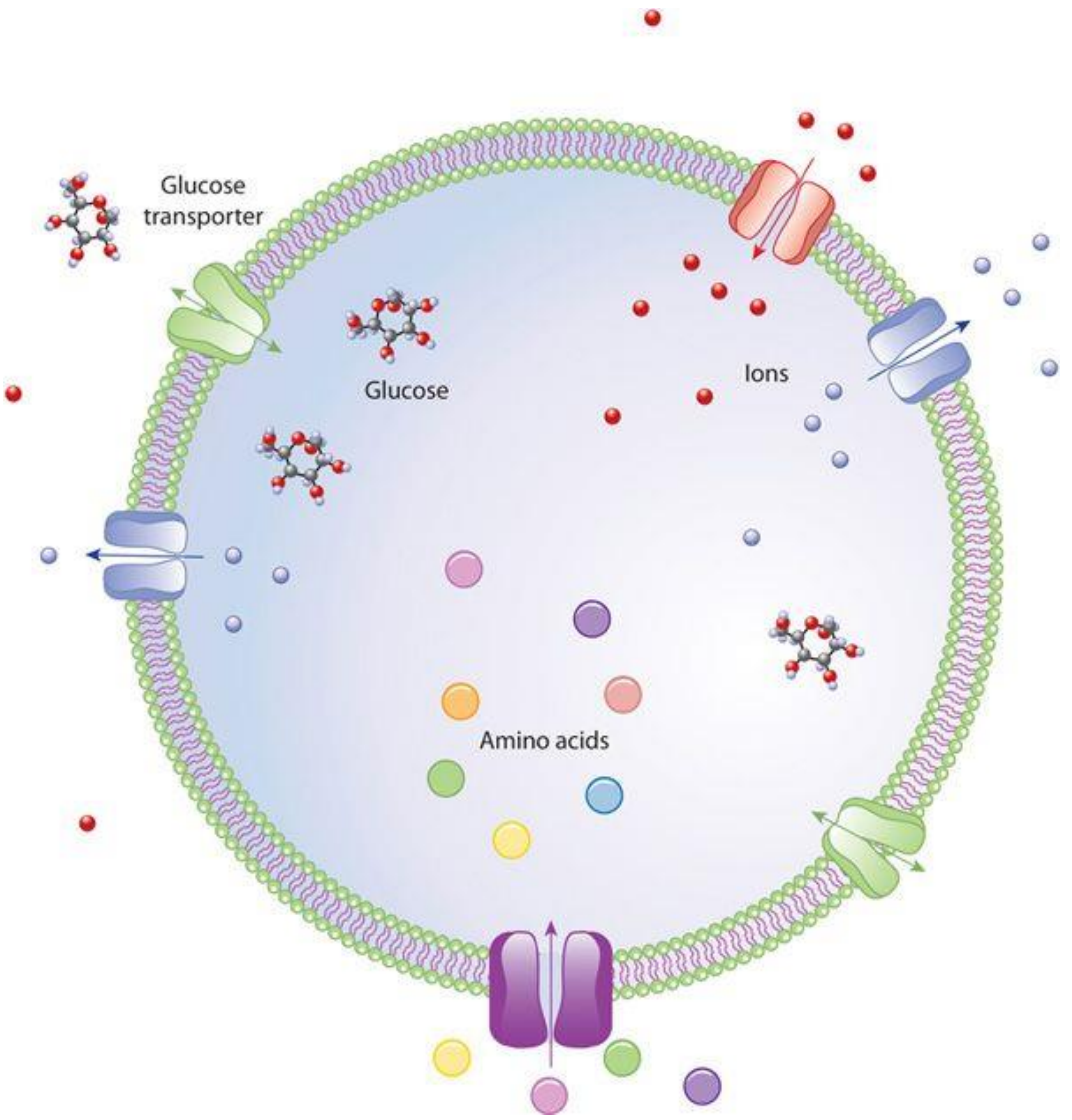


Transport Proteins

For most things that don't "match" the fatty acid tails, a transport protein is required to move in or out

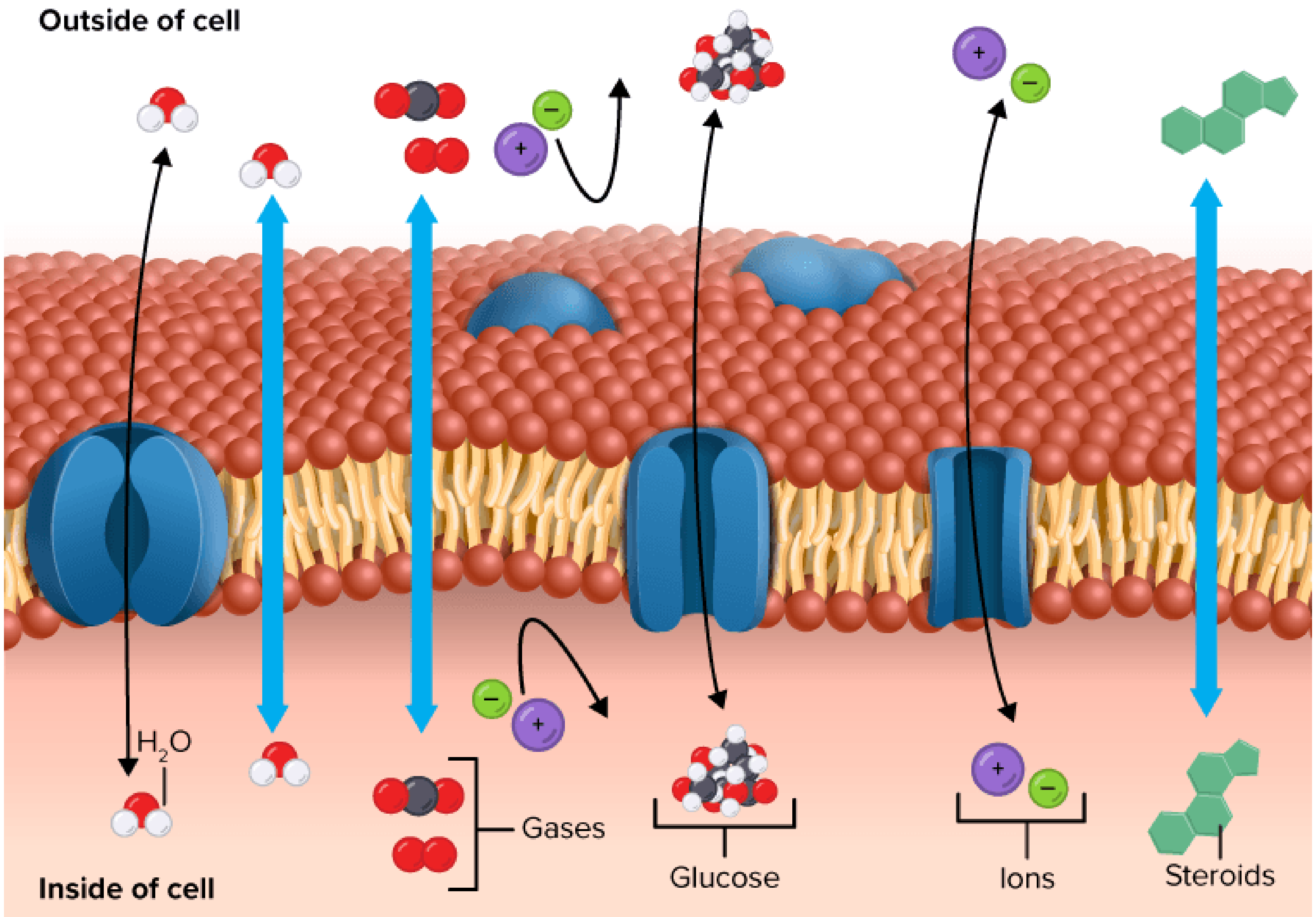
Examples of things that require transport proteins:

- **Glucose**, a cell's "favorite food"
  - Glucose is <u>polar</u> and too large to sneak between the fatty acid tails
- **Amino acids**, the monomers of proteins
  - Amino acids are <u>too large</u> to squeeze between fatty acid tails
- **Ions**, which are <u>fully</u> positive or <u>fully</u> negative
  - Having an extra electron makes one ion negative
  - Having one less electron makes the other ion positive



Summary of Membrane Permeability

Blue arrows show molecules can diffuse straight across the plasma membrane.



Black arrows show that a transport protein is required to move the molecule across the plasma membrane.

Stop & Think It Through!

Which of these molecules could diffuse straight through the plasma membrane of your cells?

More than one may be correct!

A. Aspartic acid, a negatively-charged amino acid
B. Carbon dioxide, a hydrophobic gas
C. Chloride, a negatively-charged ion
D. Propofol, a nonpolar anesthesia medication
E. Sucrose, a hydrophilic molecule
F. Tetracycline, a large polar antibiotic

Types of Passive Transport

Passive transport is any kind of movement across the plasma membrane that does NOT require energy.

Passive transport includes:

(Simple) diffusion

Facilitated diffusion

Osmosis

Diffusion (a.k.a. simple diffusion): molecules travel straight through the plasma membrane

- Hydrophobic & nonpolar molecules cross the membrane via diffusion

Facilitated diffusion: molecules use transport proteins to travel through the plasma membrane

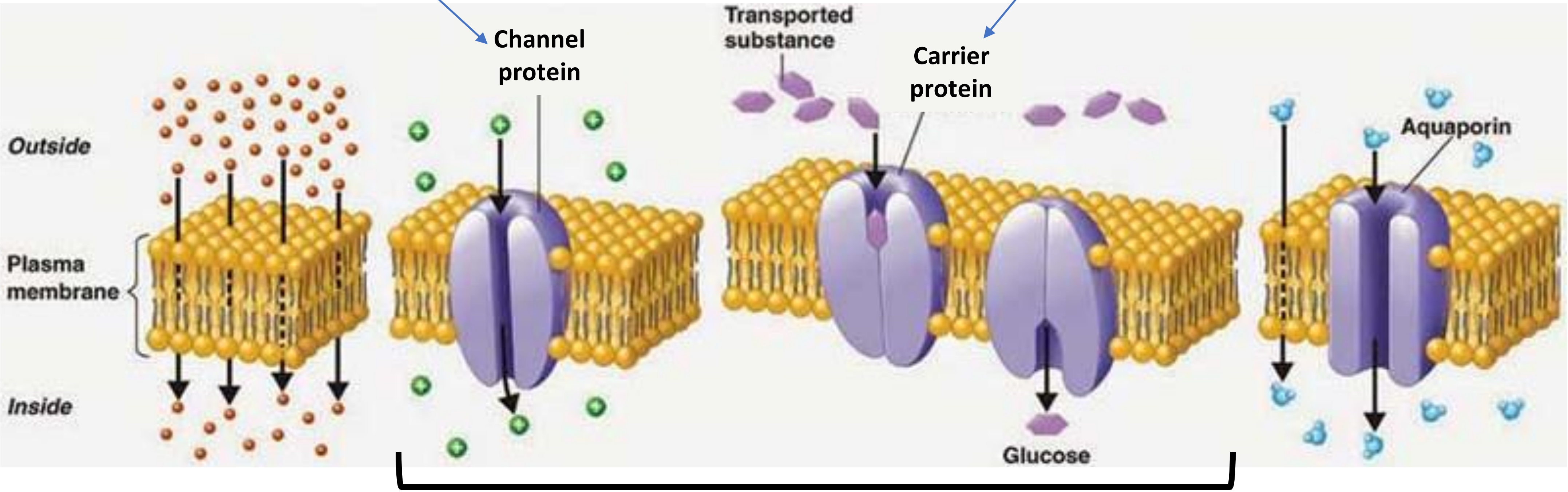
- Hydrophilic, polar, & large molecules cross the membrane via facilitated diffusion

Osmosis: water travels through the plasma membrane

Types of Passive Transport

Channel proteins are open on both sides of the membrane at the same time.

Carrier proteins change their shape to move things across the membrane.



(Simple) Diffusion

In (simple) diffusion, molecules move ***straight across*** the plasma membrane.

Facilitated Diffusion

In facilitated diffusion, molecules use ***a transport protein*** to move across the plasma membrane.

Osmosis

In osmosis, <u>water</u> uses ***a transport protein*** to move across the plasma membrane.

Stop & Think It Through!

Which specific transport process would each of these molecules use to move across the plasma membrane?

(Simple) diffusion *Facilitated diffusion* *Osmosis*

A. Aspartic acid, a negatively-charged amino acid
B. Carbon dioxide, a hydrophobic gas
C. Chloride, a negatively-charged ion
D. Propofol, a nonpolar anesthesia medication
E. Water, a hydrophilic molecule
F. Tetracycline, a large polar antibiotic

Concentrations

The fluids of the body are solutions

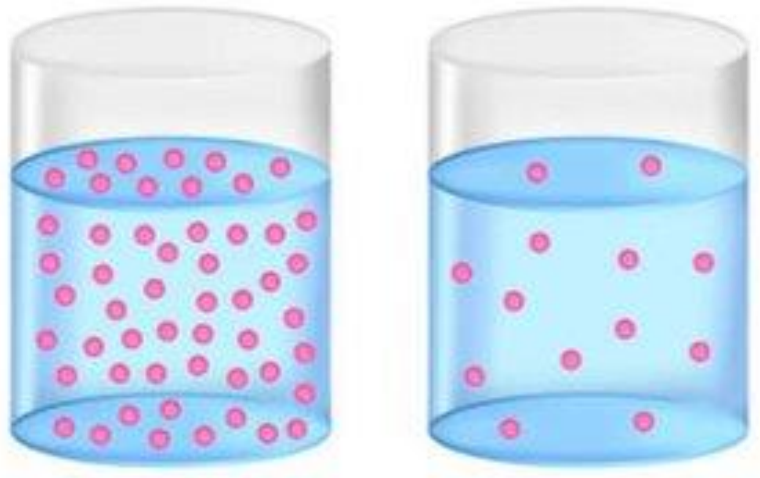
- Definition: liquids with dissolved things in them
- The liquid part of a solution is called the **solvent**
  - In the body, the solvent is water
- The dissolved things in a solution are called the **solutes**

The **concentration** of a solution represents the number of solutes dissolved in it

- Solutions with a high concentration have A LOT of solutes (dissolved things)
- Solutions with a low concentration have A FEW solutes (dissolved things)

Higher concentration

Lower concentration

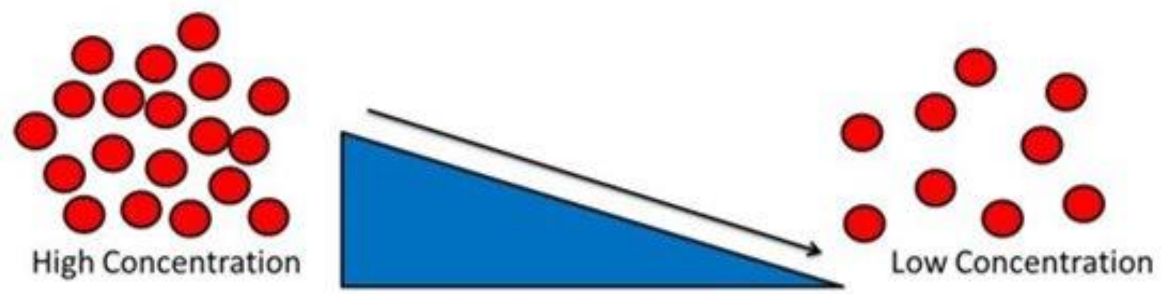


Many solutes (dissolved things)

Fewer solutes (dissolved things)

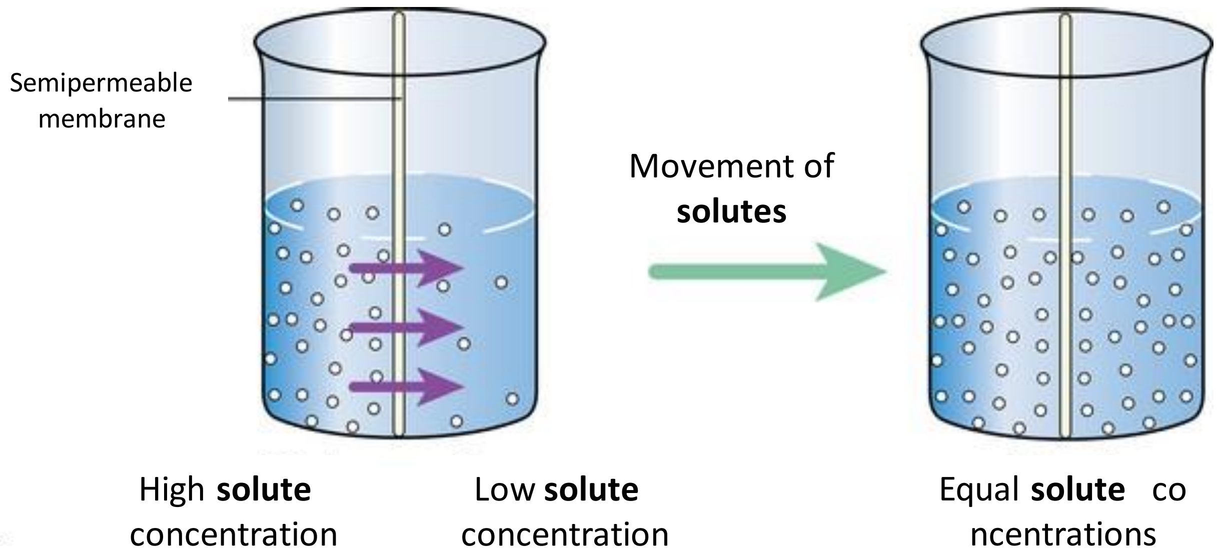
Concentration Gradients & Movement

When two solutions have different concentrations, there is a **concentration gradient** (difference) between them



Molecules naturally move DOWN (a.k.a. with) their concentration gradient

- Meaning: they move ***out of*** a solution with a high concentration and ***into*** a solution with a low concentration
- Moving DOWN a concentration gradient (from high to low) does NOT require energy



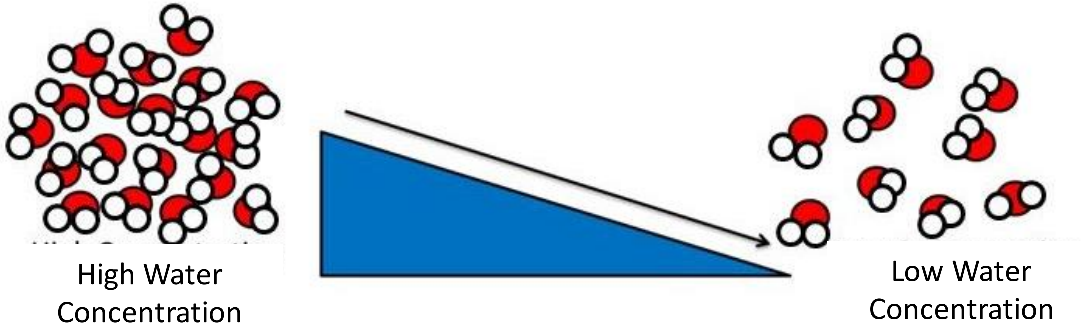
When solutes (dissolved things) move DOWN their concentration gradient, this is known as (simple) diffusion or facilitated diffusion

- These are **passive** transport processes

Concentration Gradients & Movement

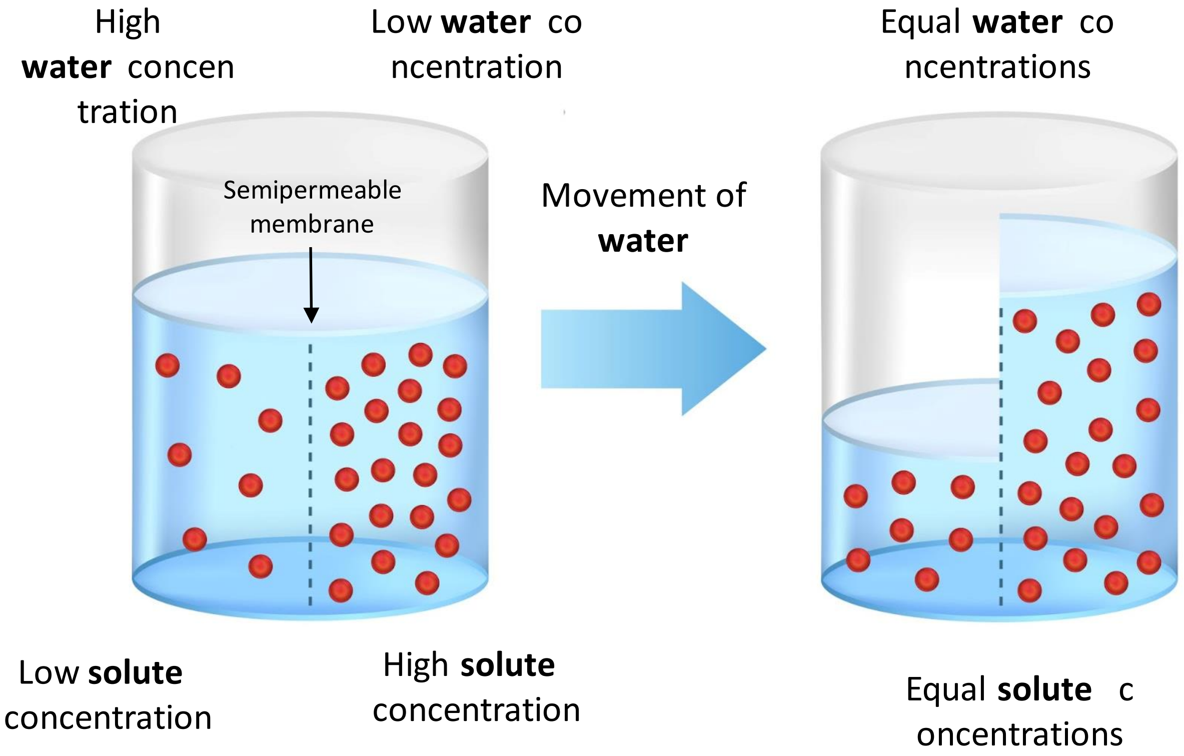
Water can also move down its concentration gradient

- Meaning: water moves from where there is A LOT of water to where there is a little water
- This movement is called osmosis



To determine the concentration gradient of water, consider this:

- A solution with A LOT of water has *a little* solute (a low solute concentration)
- A solution with *a little* water has A LOT of solute (a high solute concentration)



Hint: remember "water follows solute"

Osmosis & The Human Body

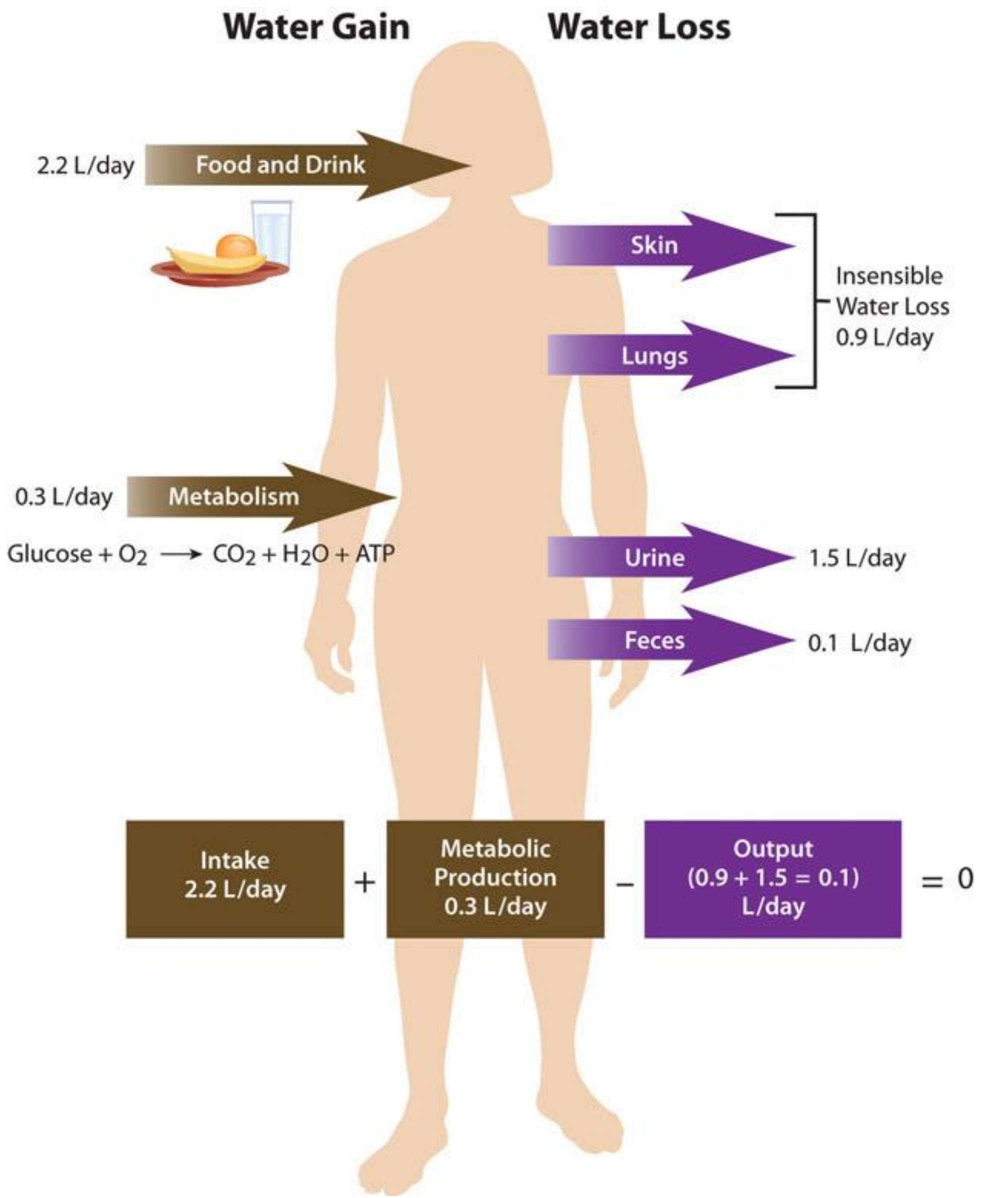
The level of water in your body is constantly changing

- Things like eating & drinking *increase* water levels in the body
- Things like sweating, defecating, & urinating *decrease* water levels in the body

With changing water levels, the concentrations of your body fluids also change

- Low water levels leads to increased fluid concentrations
- High water levels leads to decreased fluid concentrations

Water constantly moves into & out of your cells based on the **concentration gradient** between your cytosol & other body fluids

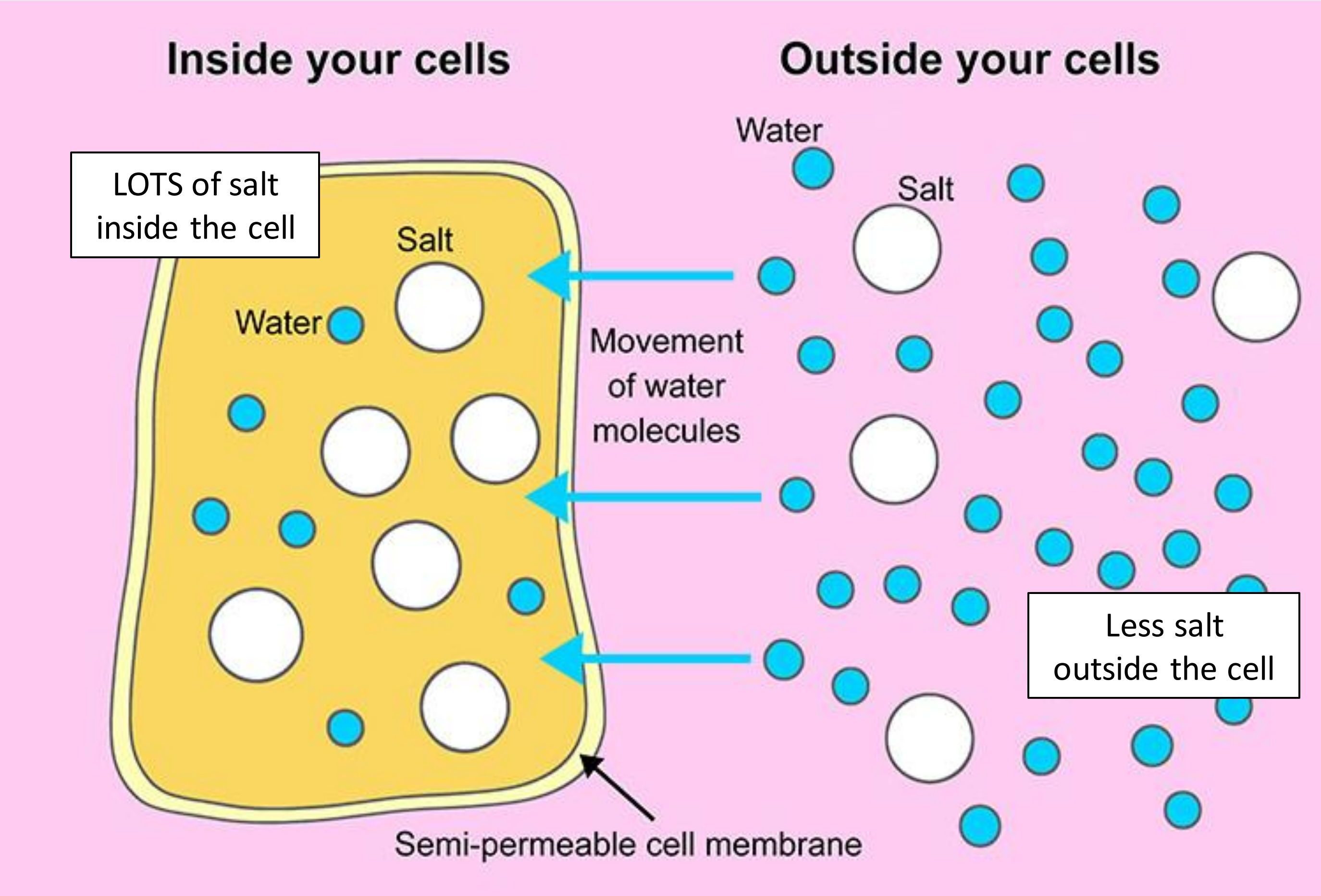


Osmosis on a Cellular Level

#2

With increased water outside a cell, the **salt** concentration of the cytosol appears higher.

Higher **salt** concentration means lower **water** concentration.



#1

When you drink water, the salt concentration of the fluids outside your cells decreases.

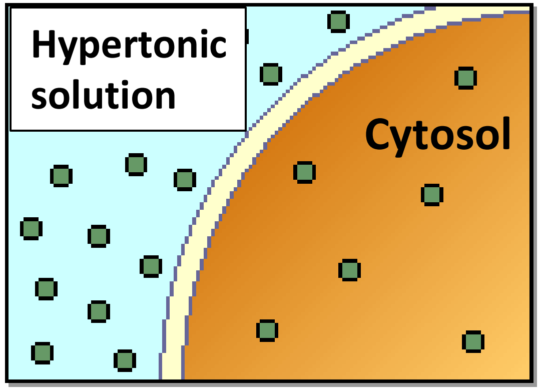
Low **salt** concentration means higher **water** concentration.

#3

When **water** <u>enters</u> the cell, it is moving from a region of HIGH **water** concentration to a region of low **water** concentration.

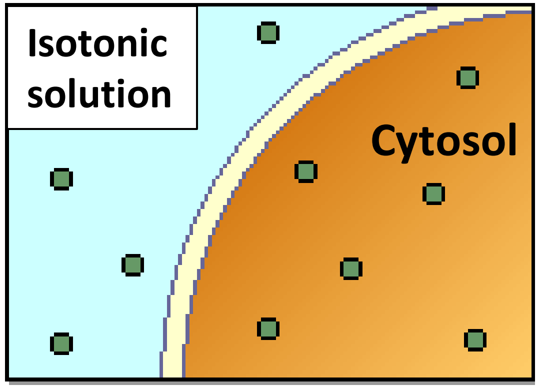
-tonic Words

When comparing the concentration of a fluid to the concentration of cytosol, -tonic words can be used



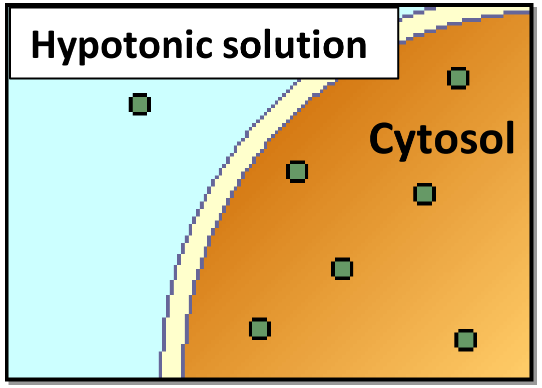
A **hyper**tonic solution has a HIGHER concentration of solutes than cytosol

- This means it has a *LOWER* concentration of **water**



An **iso**tonic solution has THE SAME concentration of solutes as cytosol

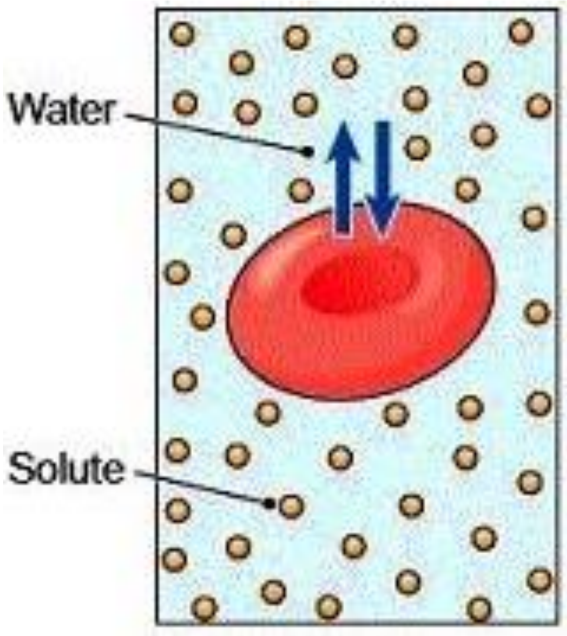
- This means it has *the same* concentration as **water**



A **hypo**tonic solution has a LOWER concentration of solutes than cytosol

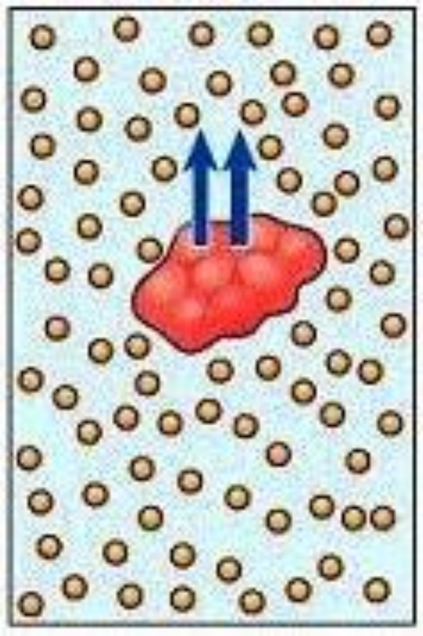
- This means it has a *HIGHER* concentration of **water**

Osmosis in Action



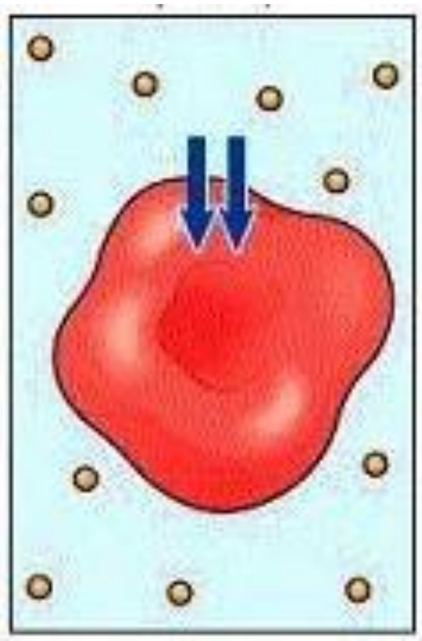
In "normal" conditions, the fluid outside your cells is **isotonic** to cytosol

This means there is the same amount of water inside & outside your cells, so water enters & leaves your cells at the same rate in isotonic solutions



When you are dehydrated, the fluid outside your cells can become **hypertonic** to cytosol.

This means there is more water *INSIDE* your cells than *outside* your cells, so water leaves your cells.



When you drink a lot of water, the fluid outside your cells can become **hypotonic** to cytosol.

This means there is more water *OUTSIDE* your cells than *inside* our cells, so water enters your cells.

Passive Transport: A Review

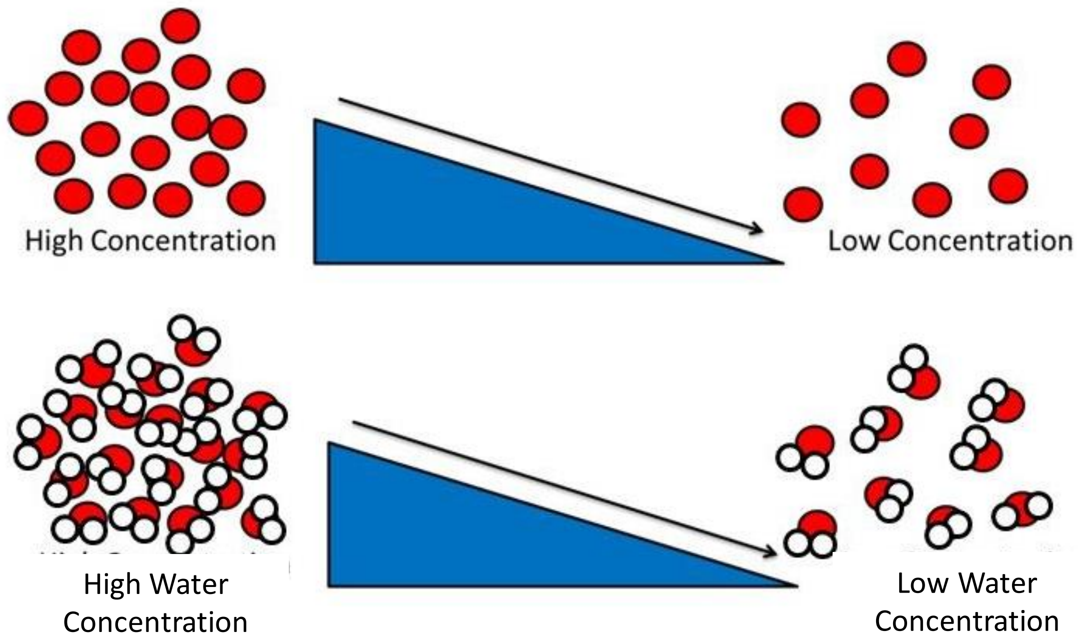
Passive transport does NOT require energy

- It moves molecules (solutes or solvents) from areas of HIGH concentration to areas of low concentration

Types of passive transport

- Diffusion: molecules move *directly across* the plasma membrane
- Facilitated diffusion: molecules use *a transport protein* to move across the plasma membrane
- Osmosis: *water* moves across the membrane

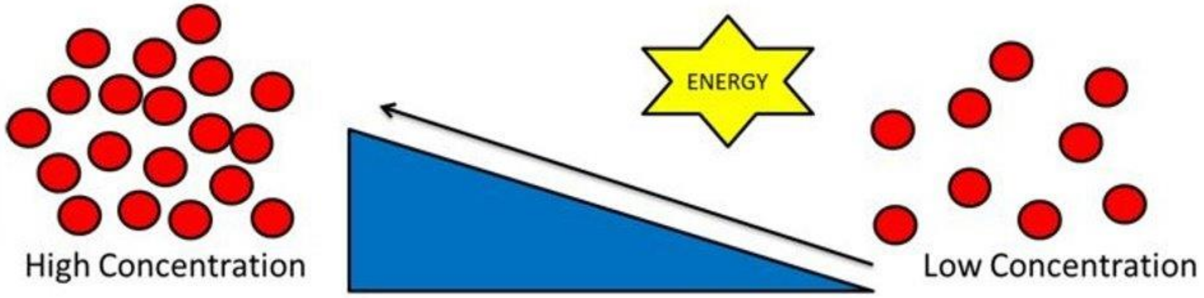
Remember: passive transport can only move molecules DOWN (a.k.a. with) their concentration gradient!



Active Transport

Sometimes a cell needs to move a molecule UP (a.k.a. against) its concentration gradient

- Example: concentrating a molecule inside the cell
- When a cell does this, it's moving that molecule from where there is *a little* to where there is already *A LOT*
- This movement requires **energy**



Two kinds of energy can be used in **active** transport :

- #1: ATP
  - ATP stores energy in its chemical bonds
  - Break ATP's bonds & energy is released
- #2: A concentration gradient
  - As one molecule moves down its concentration gradient, that movement pushes a different molecule up its own gradient

Primary Active Transport

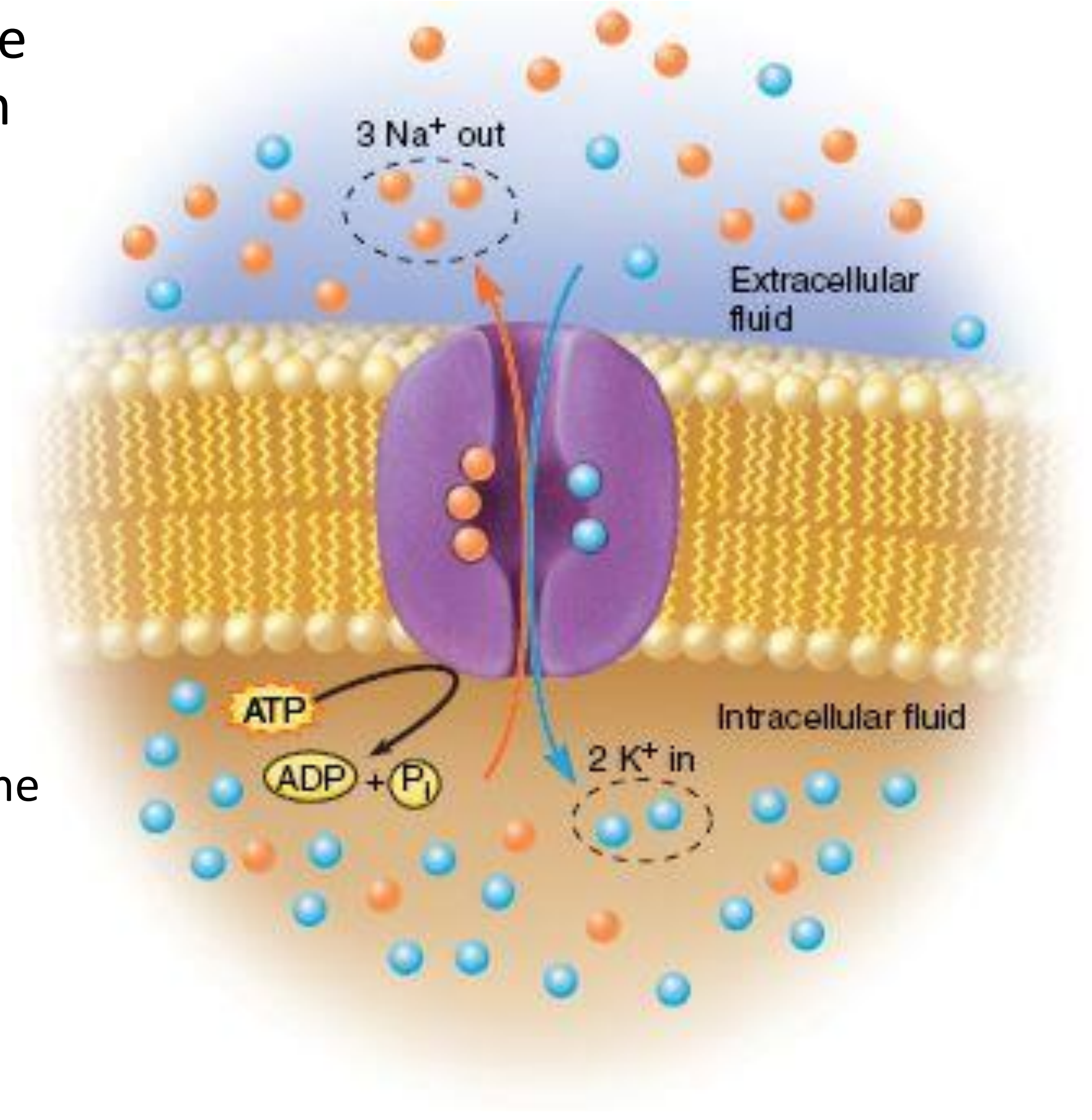
In **primary active transport**, **ATP** is the energy source for the movement UP (a.k.a. against) a concentration gradient

Example: the sodium-potassium pump

- Sodium (Na^+) is pumped *out* of the cell, where there is already A LOT
- Potassium (K^+) is pumped *into* the cell, where there is already A LOT

Why use ATP to do this?

- The sodium-potassium pump **polarizes** the cell membrane
  - This means the charges inside & outside are different
- A polarized membrane allows cells to perform complex tasks (like neuron signaling & muscle contraction)



Secondary Active Transport

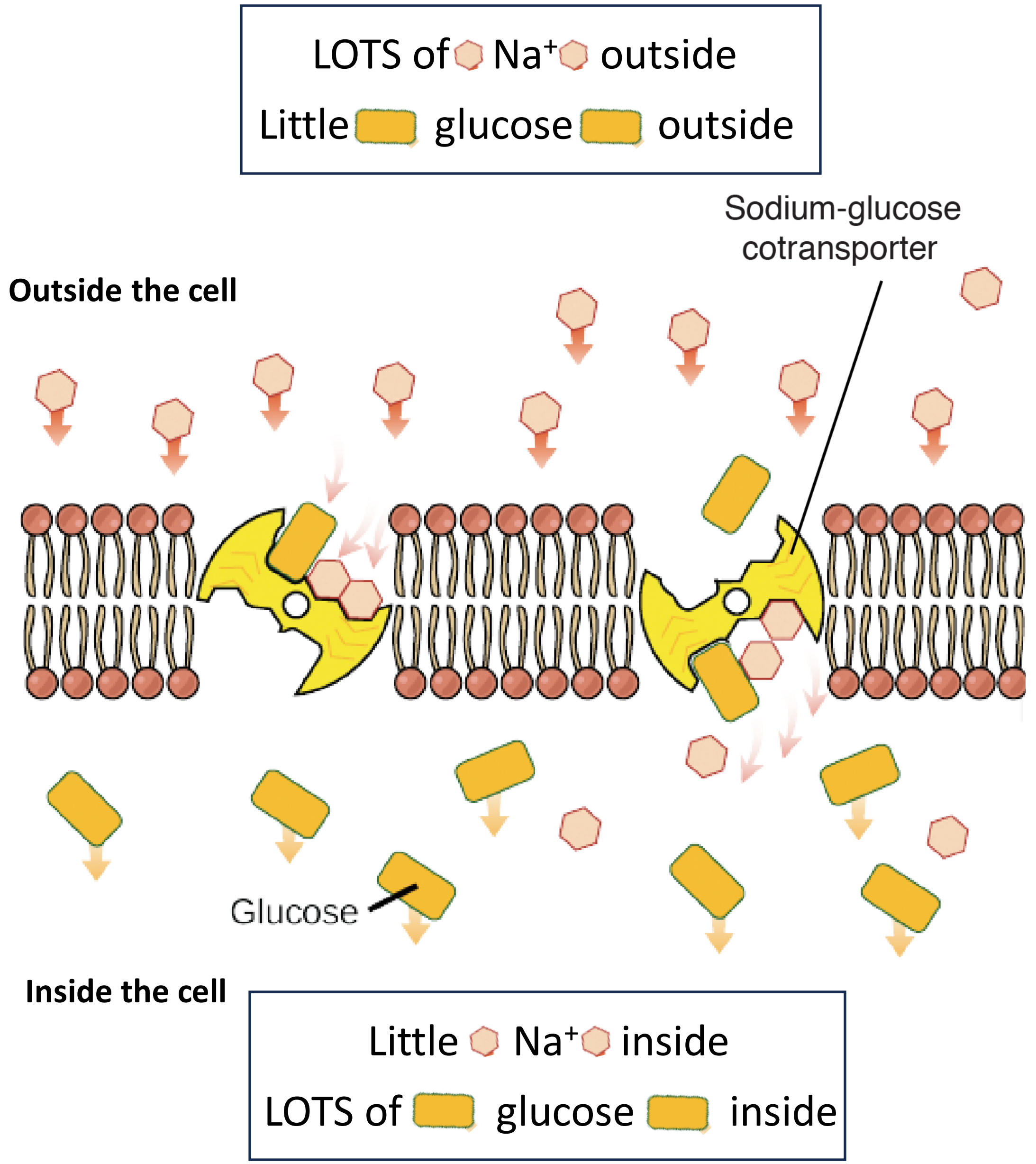
In **secondary active transport**, **movement down** one concentration gradient is used to power movement up a different concentration gradient

Example: the sodium-glucose cotransporter

- Sodium (Na^+) rushes *into* the cell, where there is *a little*
  - This means Na^+ is moving DOWN its concentration gradient
- As Na^+ enters the cell, glucose "sneaks" *into* the cell with it, where there is already A LOT
  - This means glucose is moving UP its concentration gradient

Why use energy to do this?

- The sodium-glucose cotransporter helps a cell get **glucose,** its favorite food
- While cells already have a lot of glucose inside, they continue to "hoard" as much as they can from their environment

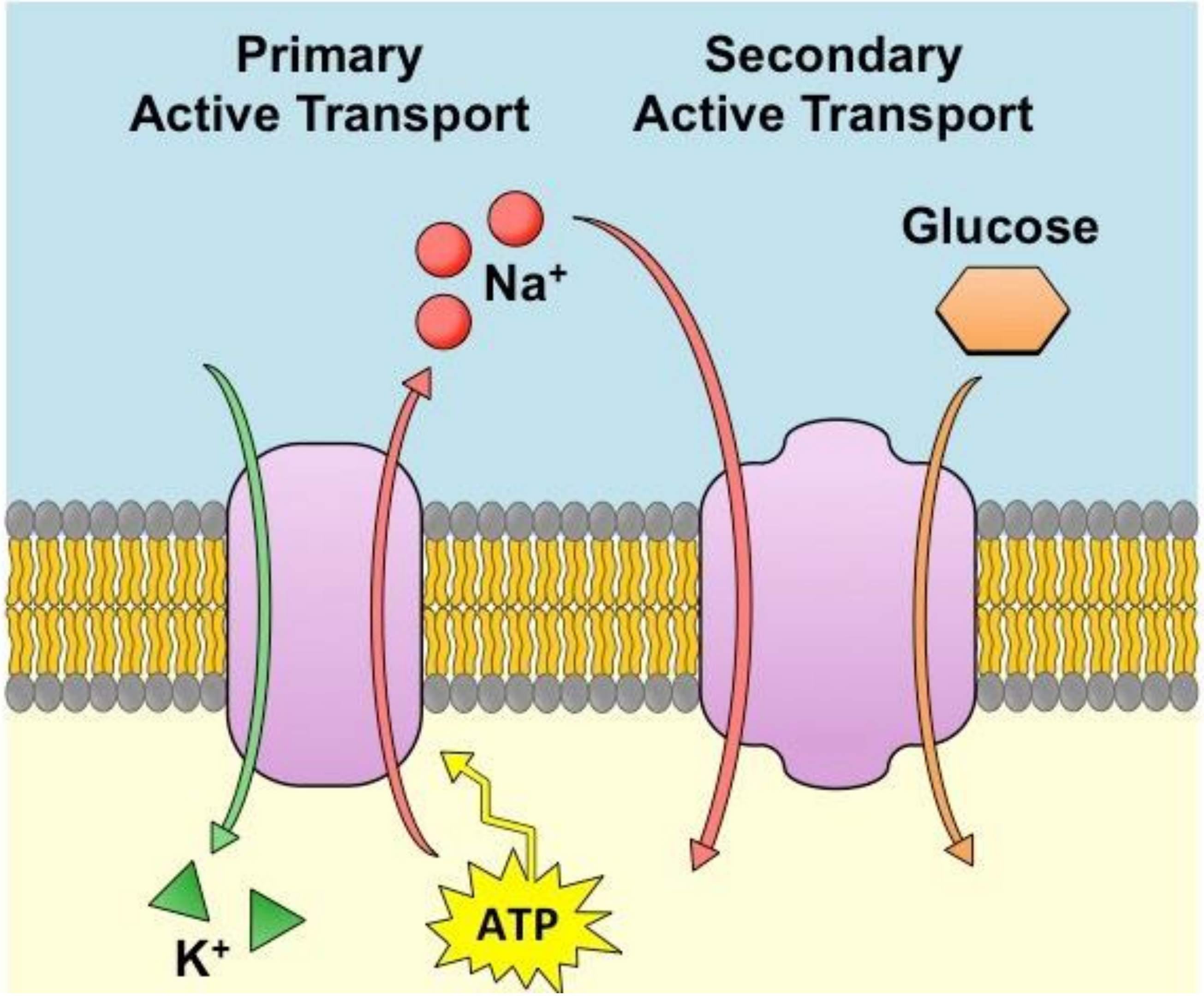


Tying the Processes Together...

First:

Cells use **ATP** to pump sodium (Na^+) out of the cell.

This creates a strong concentration gradient that favors Na^+ movement back *into* the cell.



Then:

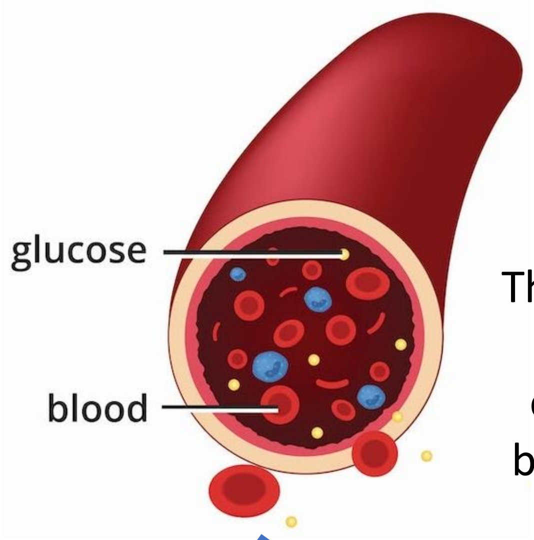
Cells use sodium's (Na^+) **concentration gradient** to "sneak" glucose into the cell.

Glucose is already concentrated inside the cell, so it is moving UP its concentration gradient.

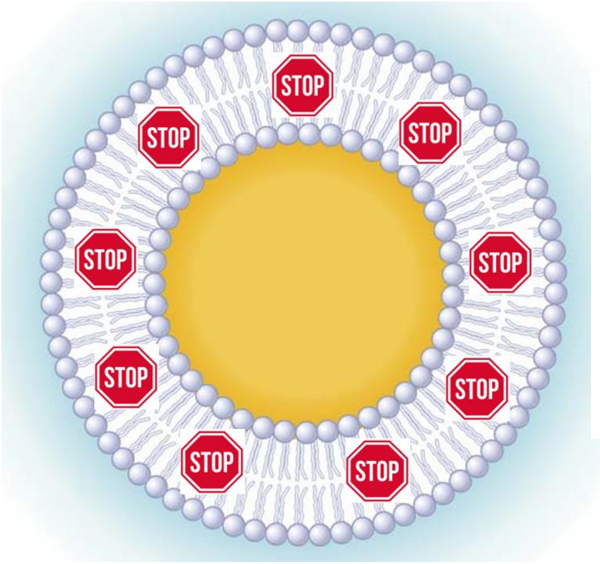
Result: the cell builds a stockpile of its "favorite food"

So… how do your cells get the glucose in your food?

You eat a donut.



The glucose in the donut enters your bloodstream.



The plasma membrane **won't let glucose diffuse** into the cell. (It's polar, large, & there's already A LOT inside!)

So… your cells use a transport protein (i.e. the car), powered by the **concentration gradient** of Na^+ (i.e. the car's gas) to move glucose (i.e. the piggy bank) into your cells.

To Prepare for Next Class…

- ❑ Review your class notes
  - Use the eTextbook & Other Helpful Resources to supplement your lecture notes

- ❑ Complete the homework assignment and use it to direct your studying

- ❑ Print the slides for Lesson #3 – Teamwork Makes the Dream Work