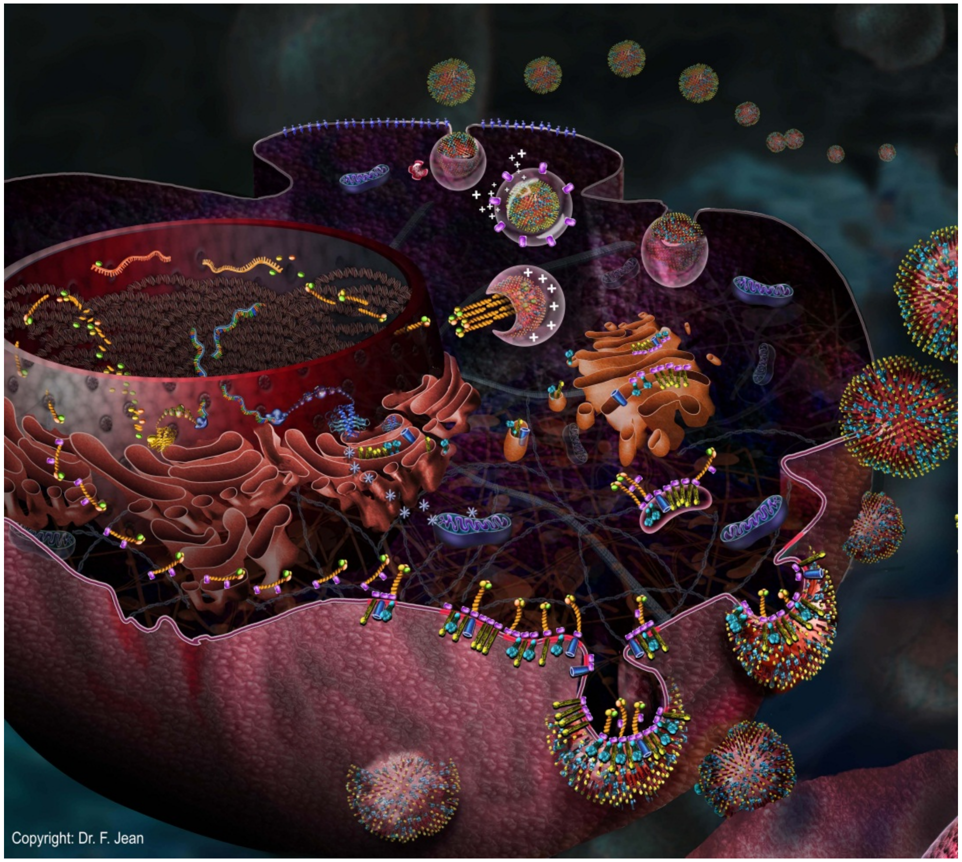
Week 3 - Biology 112



Replicating thing criteria:

Generate a container ⇒	***Membranes (wall)***
Gather raw material Gather or make parts Gather and transform energy ⇒	*Proteins*
Have a set of instructions ⇒	*DNA*
Pass instructions to replicas ⇒	*Proteins and DNA*
Mechanism to read the instructions ⇒	*RNA and proteins*

First, let's talk about "stability"

- Stability and change are related. Something is stable if it does not change.
- Stability arises if there is no potential for change.
- A chemical change has the potential to occur only if it leads to an increase in stability of the chemical system.

Stability

- Two kinds of stability

Enthalpic

- Stability associated with chemical bonds (all types)

Entropic

- Stability associated with molecular motion (eg. types of motion and their intensities)

Entropy is NOT about (dis)order or chaos

High and Low Stability

	High	Low
Enthalpic Stability (Bonding)	Strongly bonded	Weakly bonded
Entropic Stability (Motional Freedom)	Motionally free	Motionally constrained

Changes (differences) in Stability

- Mathematically, the total difference in stability (ΔG) between 2 states of a chemical system is given by:

Difference in enthalpic (bonding) stability ↓

Total difference in stability →

$$\Delta G = \Delta H + (-T\Delta S)$$

↑ Difference in entropic (motional freedom) stability

Changes in Stability

	Increases	Decreases
Enthalpic Stability (Bonding)	Bonding strength increases	Bonding strength decreases
Entropic Stability (Motional Freedom)	More freedom to move	Less freedom to move

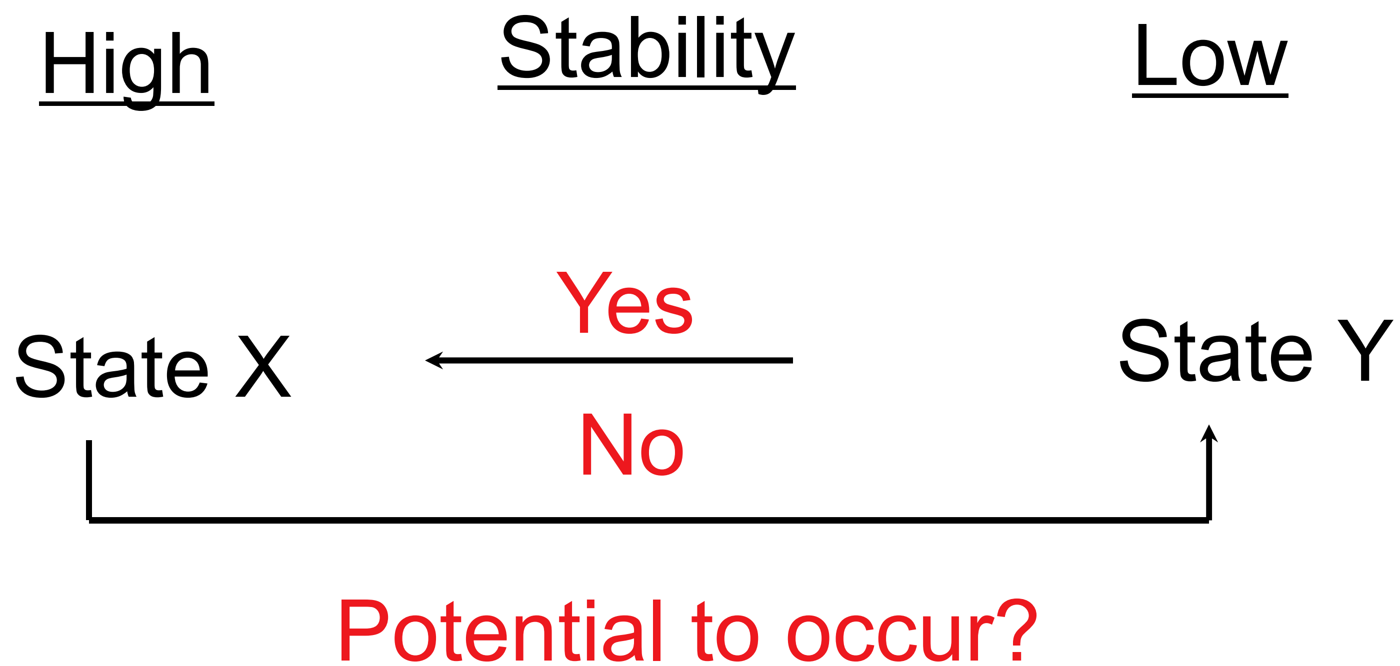
Changes in Stability

- Sign conventions

	Increases	Decreases
Overall Stability	$\Delta G < 0$	$\Delta G > 0$
Enthalpic stability (Bonding)	$\Delta H < 0$	$\Delta H > 0$
Entropic stability (Motional Freedom)	$T\Delta S > 0$	$T\Delta S < 0$

ΔG as a criterion for "spontaneity"

- A chemical change has the potential to occur only if it leads to an increase in stability of the chemical system.



- Chemical process (eg. reaction) with the potential occur is called spontaneous = favourable = permissible ($\Delta G < 0$)
- Chemical process (eg. reaction) with no potential occur is called nonspontaneous = unfavourable = prohibited ($\Delta G > 0$)

Important

Spontaneous ≠ fast! Spontaneous process can occur very quickly to very slowly depending on the process.

Stability

- We will be using the concept of stability a lot in this course, so take some time to become familiar with it.

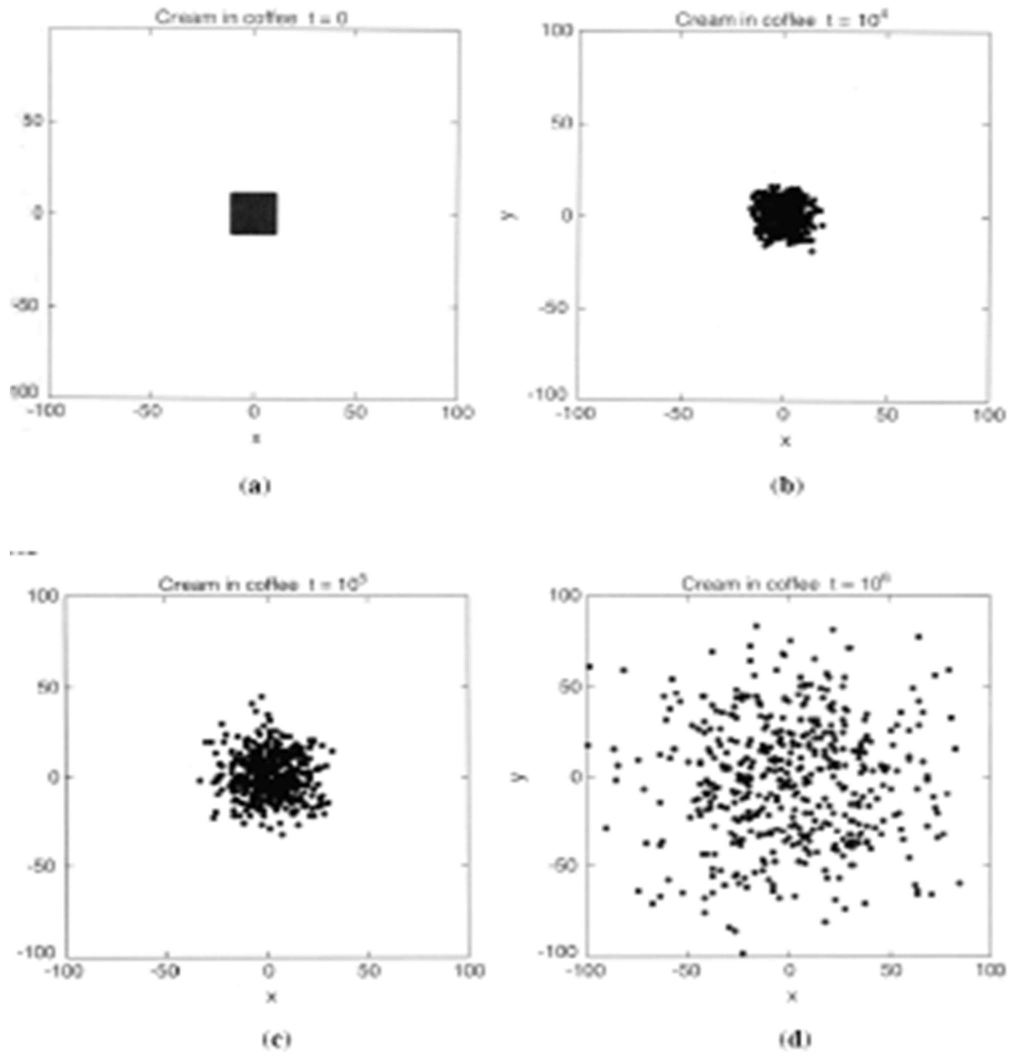
- Note that stability is closely linked to the concept of ***Free Energy***, which will be discussed later in the course.

Let’s Talk Diffusion

Two properties are at work:

1. The molecules are moving (kinetic energy).

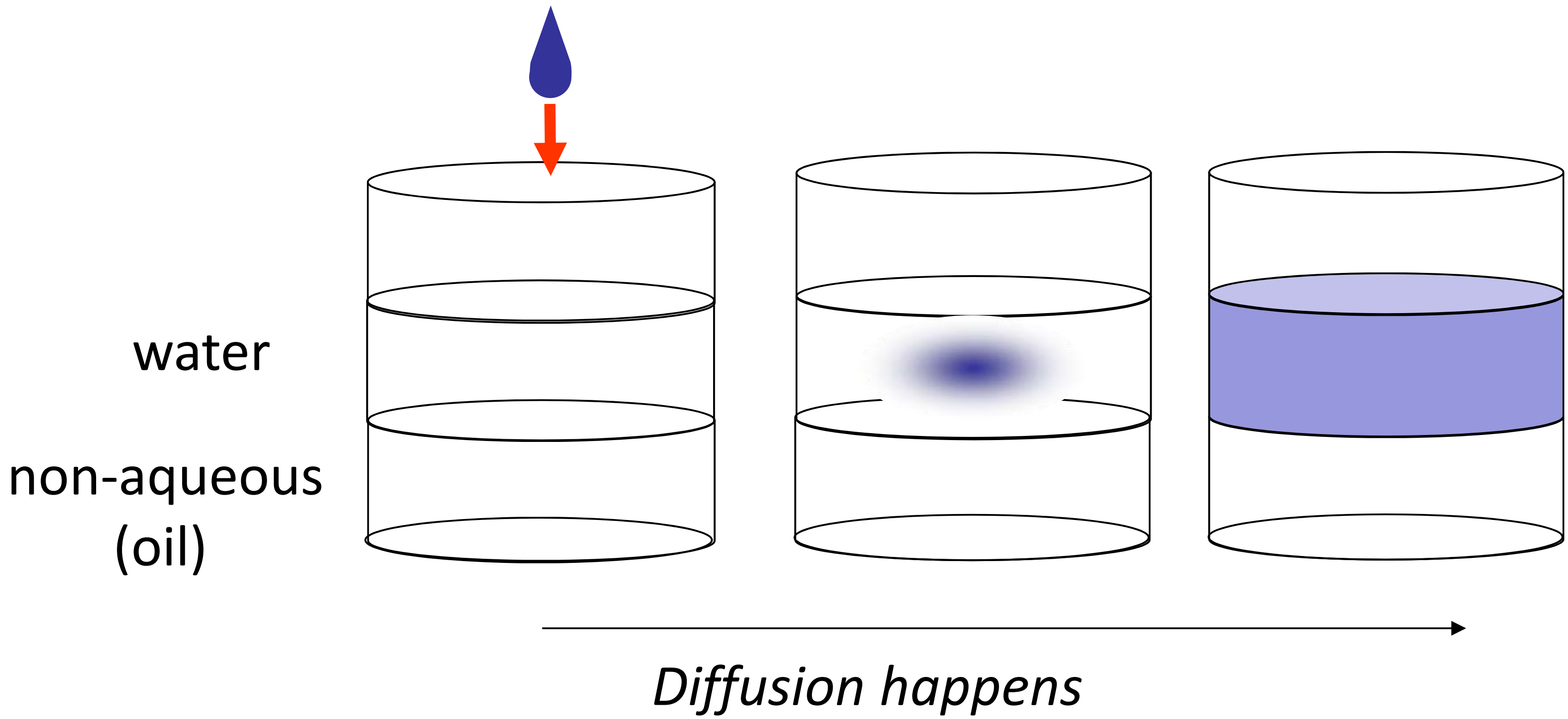
2. The system will spontaneously tend towards more arrangements (more motional freedom), which is more stable.



http://chemistry.illinoisstate.edu/standard/che38056/lecture_notes/380.56chapter13-S06.pdf

Clicker Question

Add a drop of *water soluble* dye to the water layer

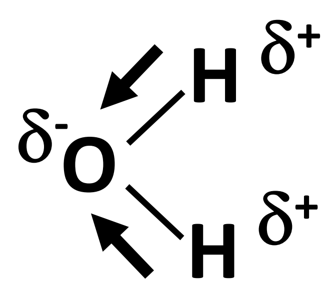


What's the barrier?

Solubility depends on the ability to form intermolecular interactions between the solute and the solvent.

The water soluble dye stays in the water because it is interacting strongly with water molecules (stronger interactions, therefore more stable).

Water is a molecule with polar bonds and so will easily interact with other molecules that are charged or have polar groups.

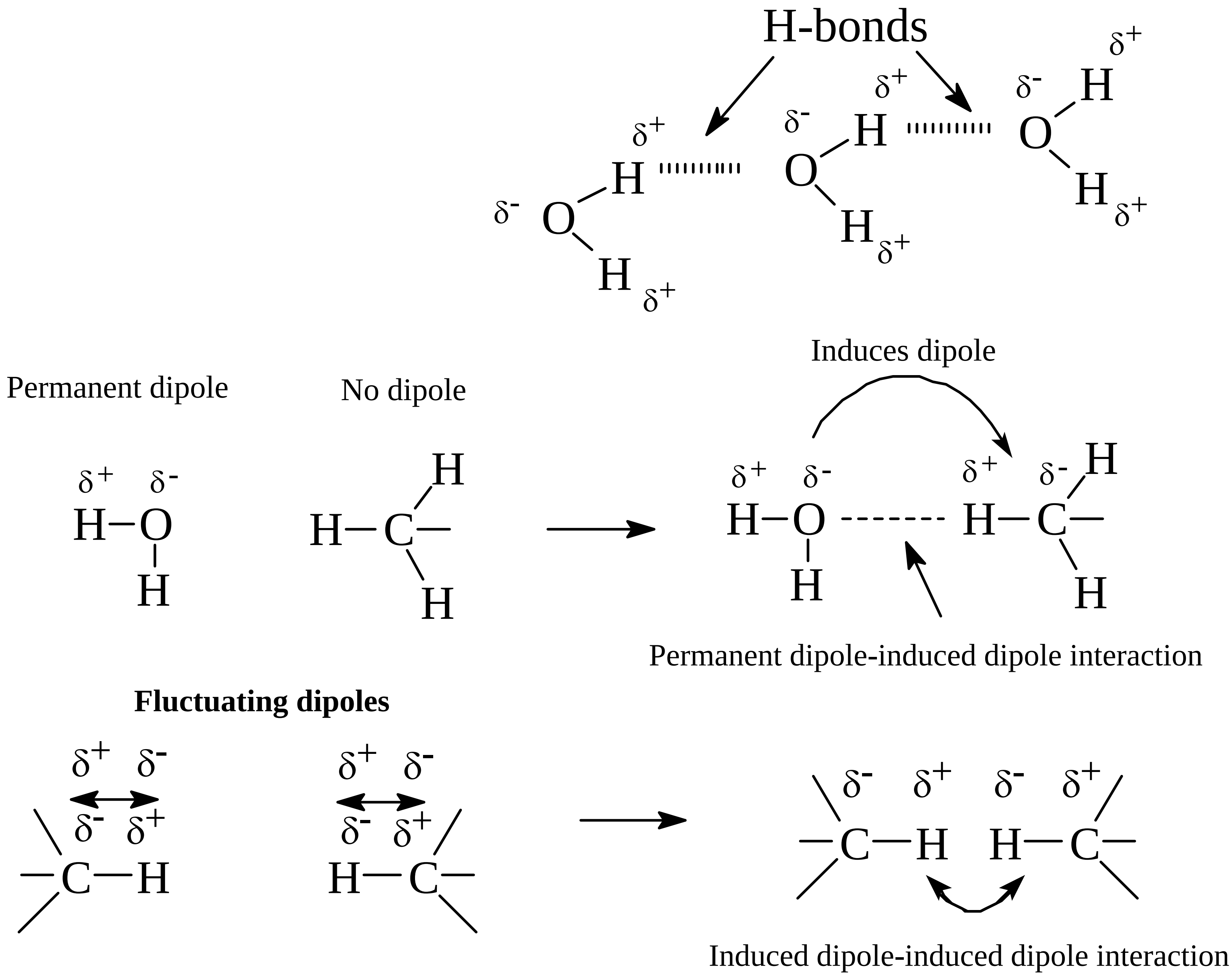


Electrons pulled towards O

Electronegativity

High **O > N > S = C ~ H = P** **Low**

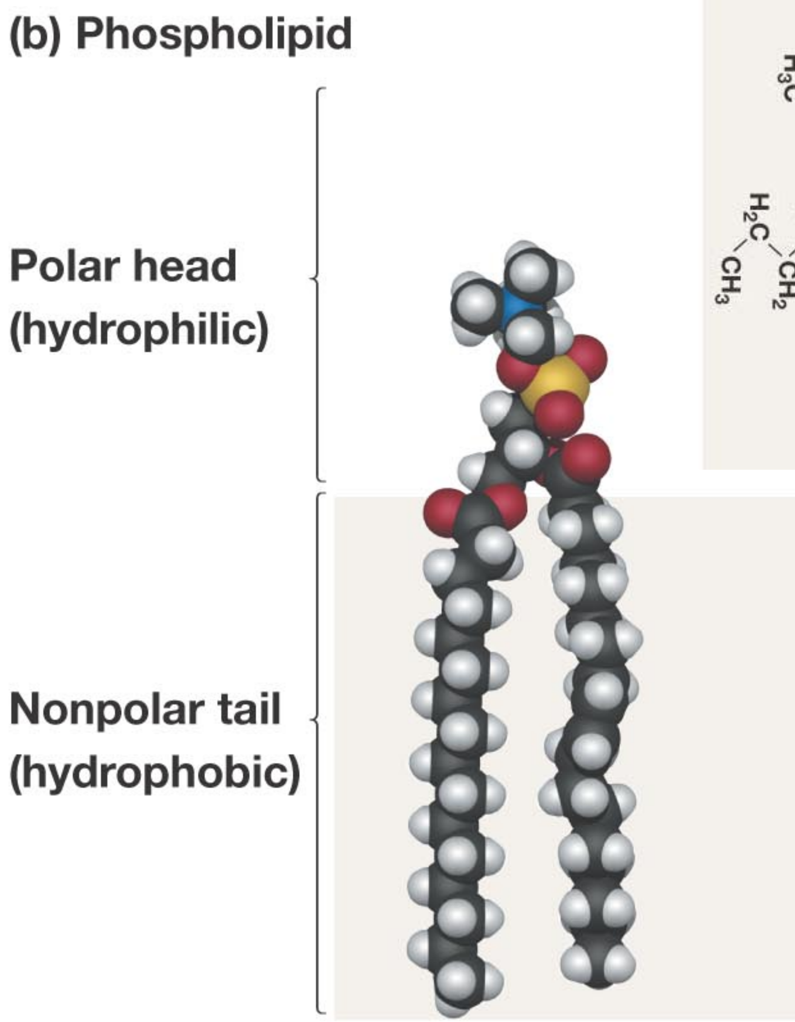
Clicker Question


H-bonds
Permanent dipole
No dipole
Induces dipole
Permanent dipole-induced dipole interaction
Fluctuating dipoles
Induced dipole-induced dipole interaction

In the aqueous environment of the cell, the bond energies (amount of energy required to break the bond or intermolecular interaction) decrease in the following order. This is an indication of bond or interaction strength.

Strongest	**Covalent bonds** (polar and non-polar)
↑	**Ionic bonds (**fully charged ion-fully charged ion)
	Ion–permanent dipole interactions
	Permanent dipole–permanent dipole interactions (*e.g.* H-bond)
↓	**Permanent dipole–induced dipole interactions**
Weak	**Induced dipole–induced interactions**

Cytoplasmic membranes are made from molecules called phospholipids



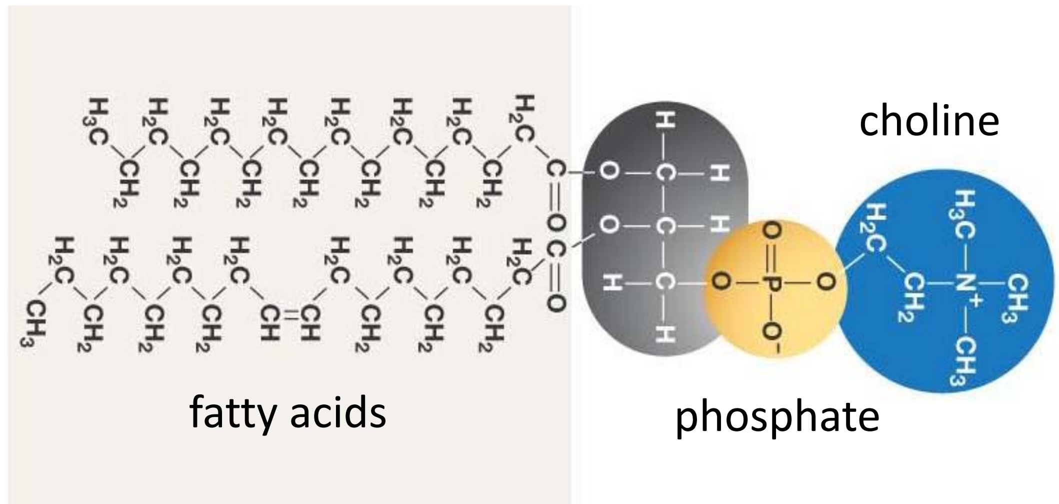


Fig 6.4b Biological Sciences

Molecules can have polar and non-polar groups.

In cases where the regions are separated and distinct, the molecules are called **amphipathic**

Phospholipids are Amphipathic Molecules

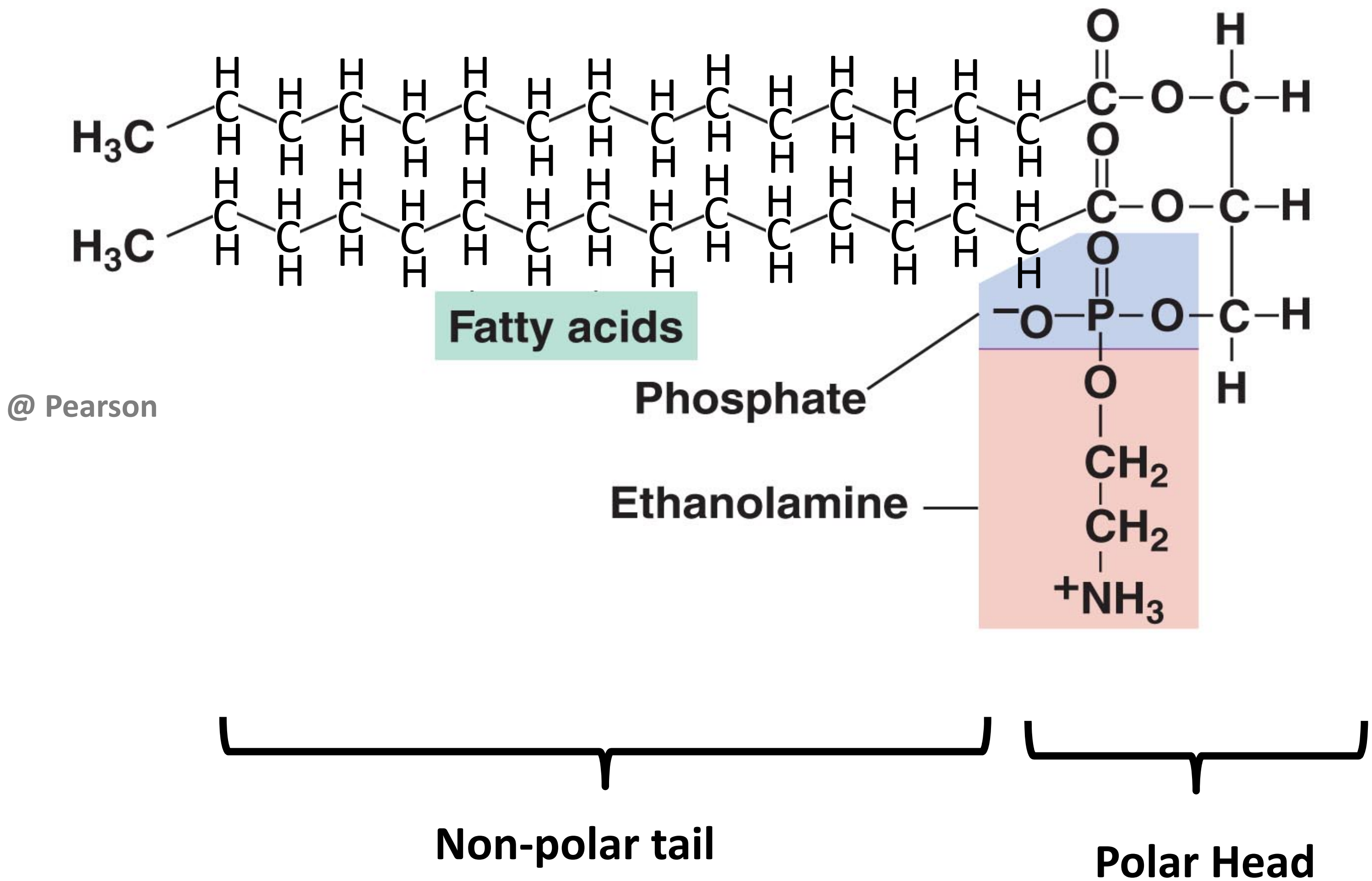
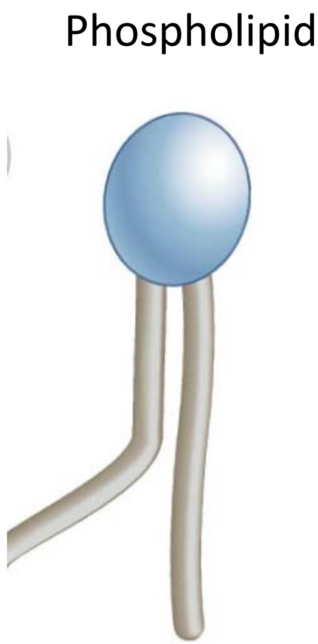
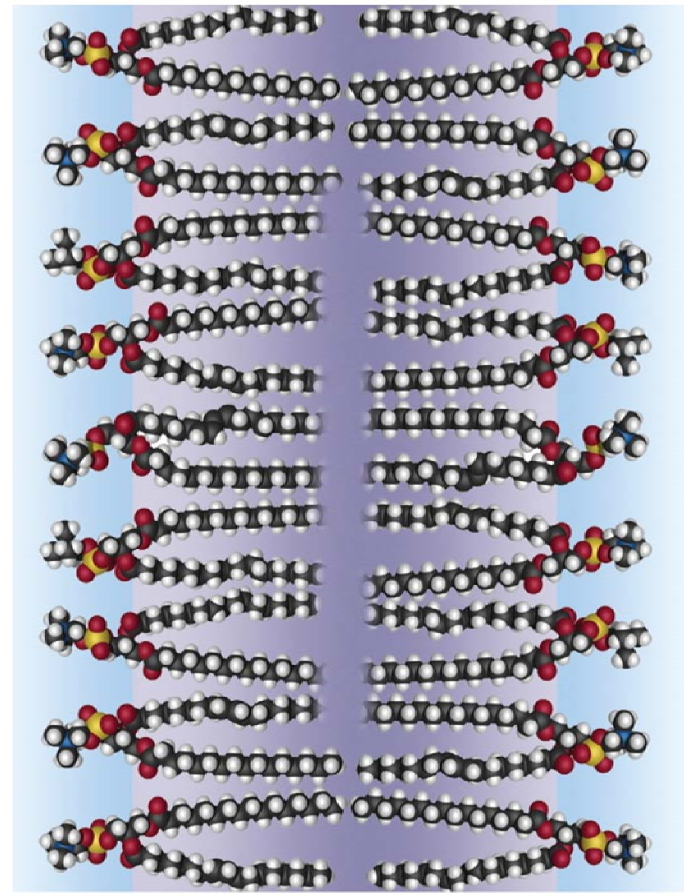


Fig 3.7c Brock "Biology of Microorganisms"

Clicker Question





Phospholipids form bilayers that are non-polar in the middle.

Left: Fig 6.9 Biological sciences
Right: Fig 6.5 Biological sciences

What sort of barrier is a this bilayer?

We can use a dual-chamber container separated by a membrane to test the permeability of a membrane to different molecules.

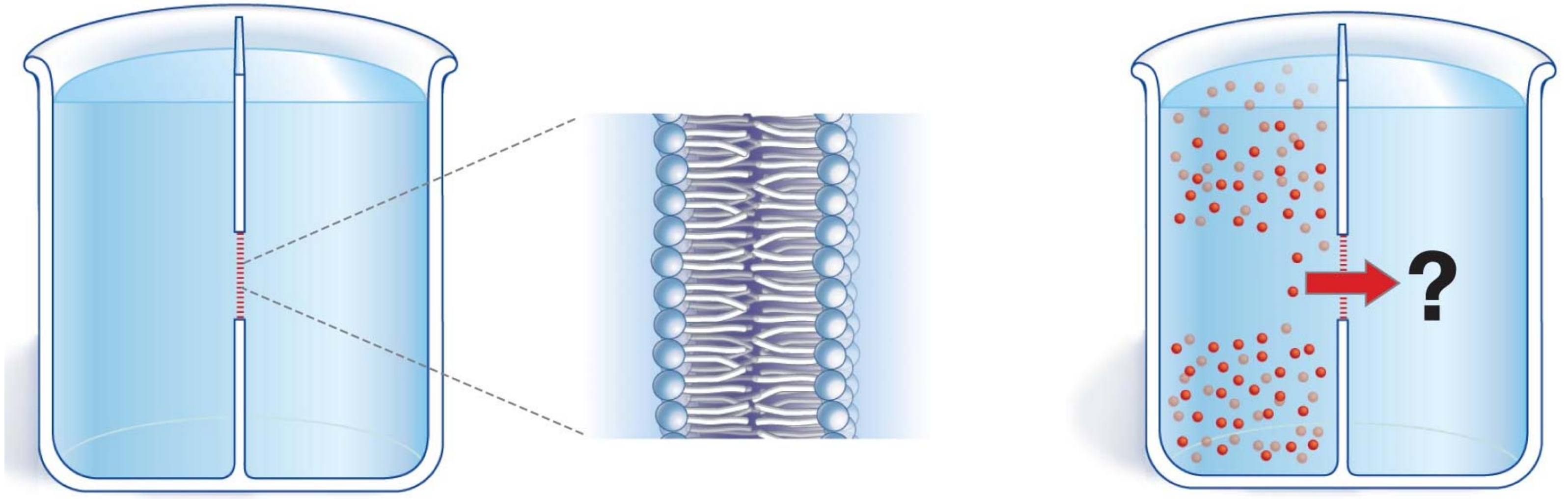
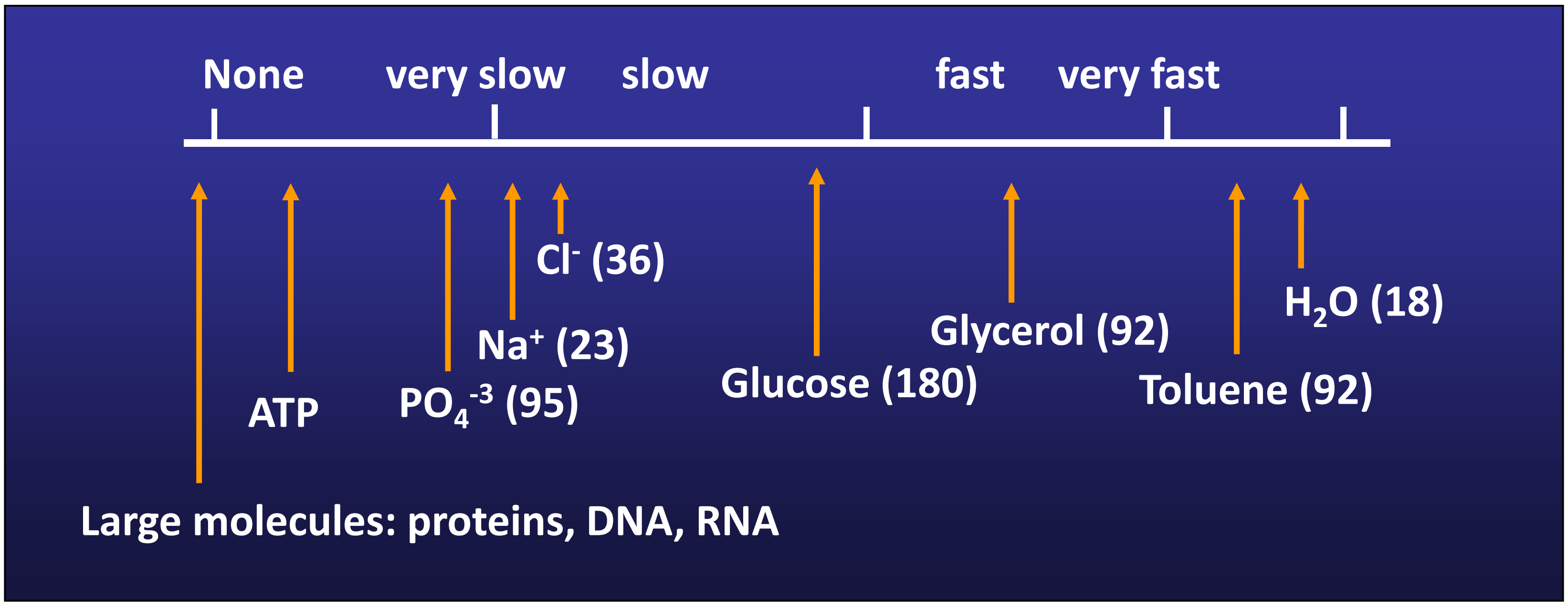


Fig 6.7b and Fig 7.6c Biological Sciences

Permeability for the phospholipid bilayer of a membrane.



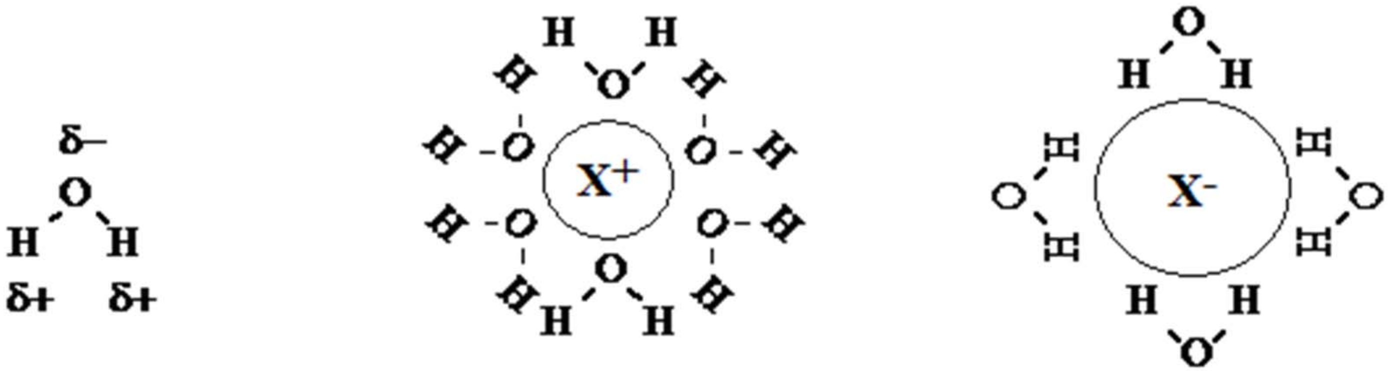
Clicker Question

Clicker Question

Clicker Question

Clicker Question

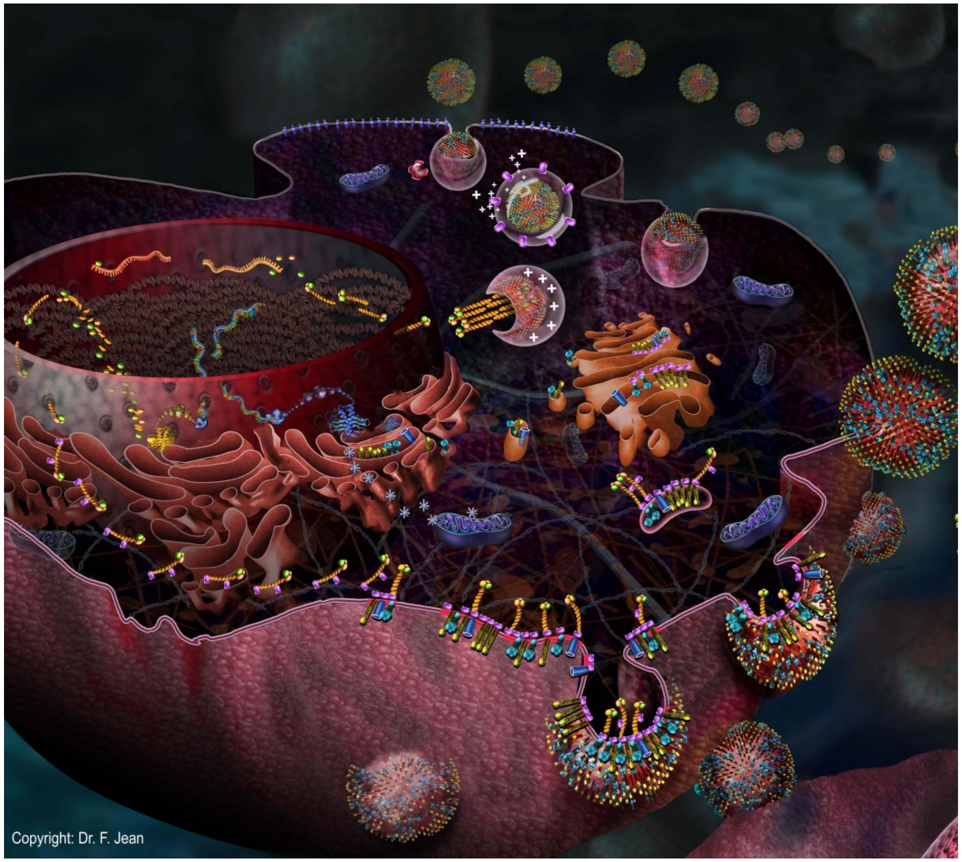
Charged Molecules

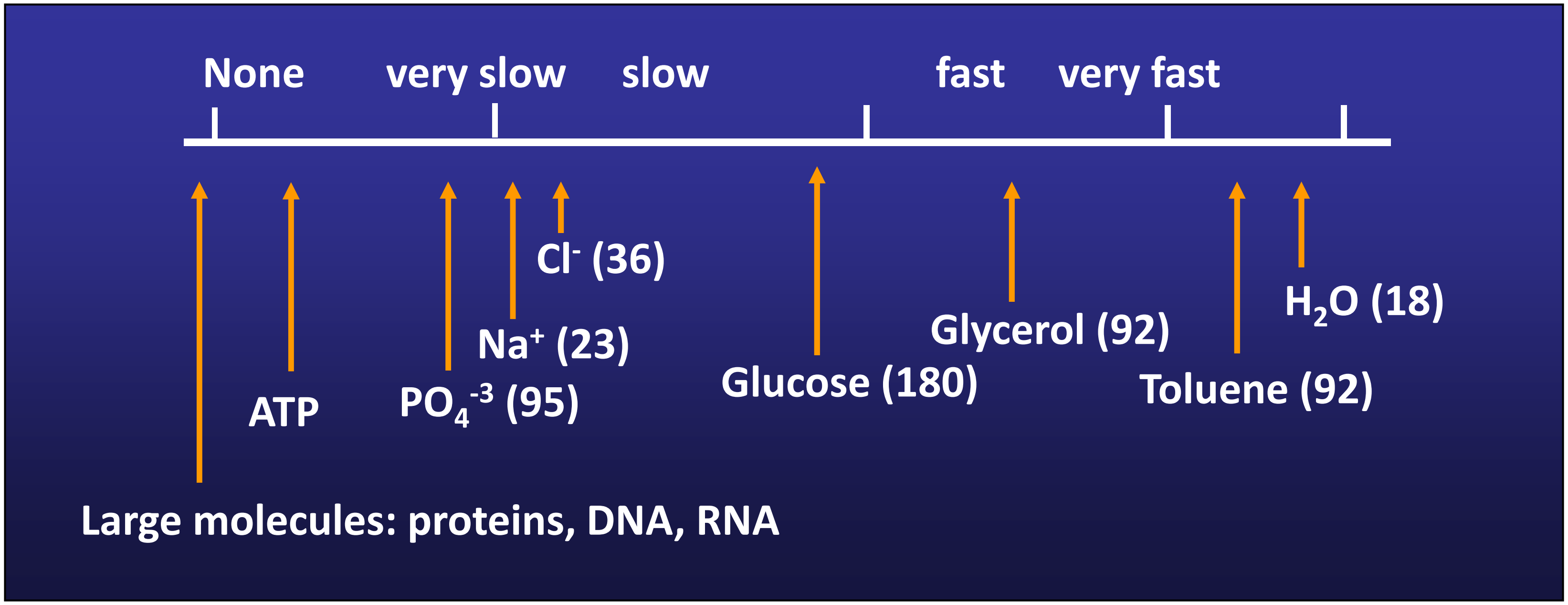


A hydration shell surrounding a charged molecule (X^+ or X^-).

Charged molecules, regardless of their size, do NOT readily permeate lipid bilayers because they are surrounded by a shell of water molecules (called a “hydration shell”).

Week 3 - Biology 112





The molecules that can rapidly pass through the phospholipid bilayer are uncharged, non polar and relatively small.

Water appears to break this rule. Discuss.

How do phospholipids form membrane bilayers?

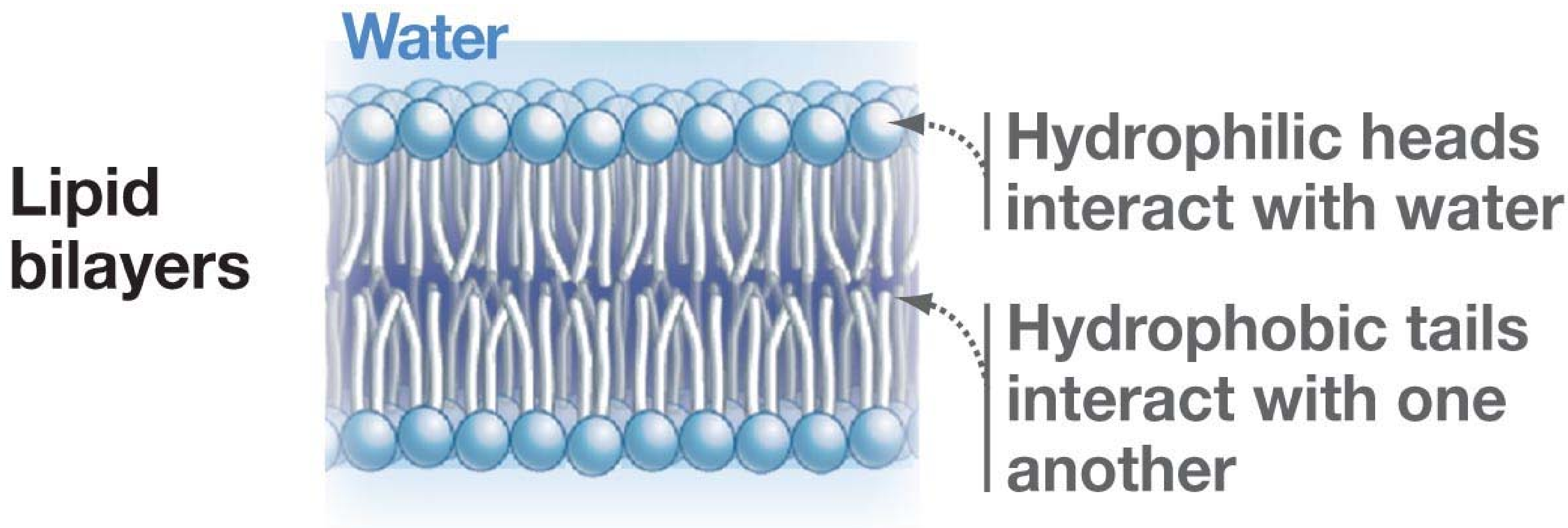
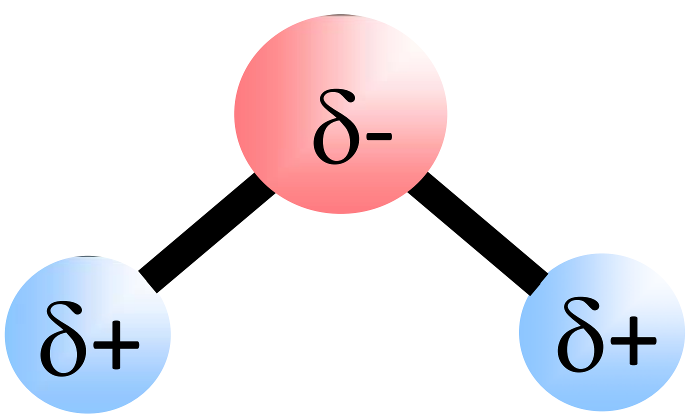
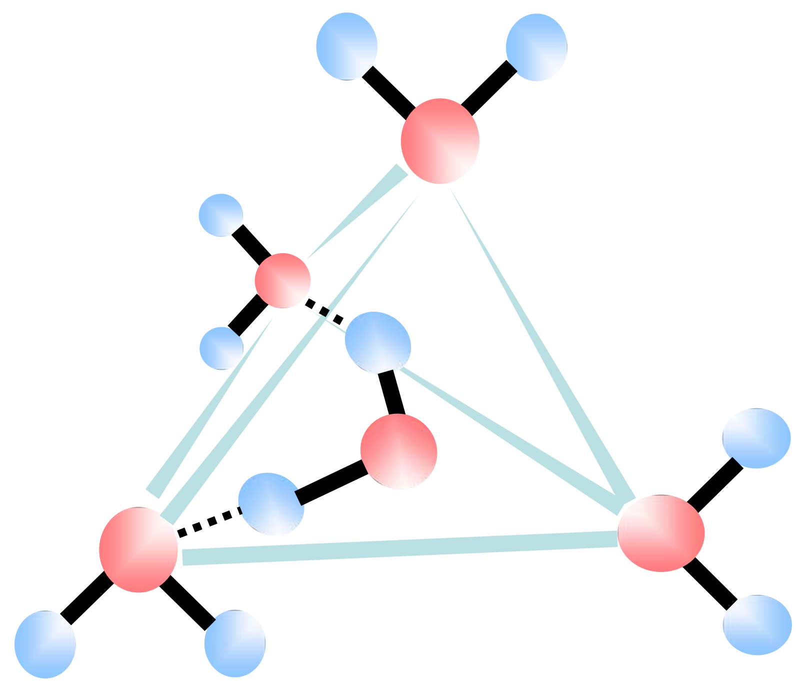


Fig 6.7b Biological Sciences

Water makes strong polar interactions.

As a result it forms hydrogen bonds with other polar molecules, including itself. A water molecule surrounded by four other water molecules can make hydrogen bonds in multiple ways. The position of the water molecule is not fixed.

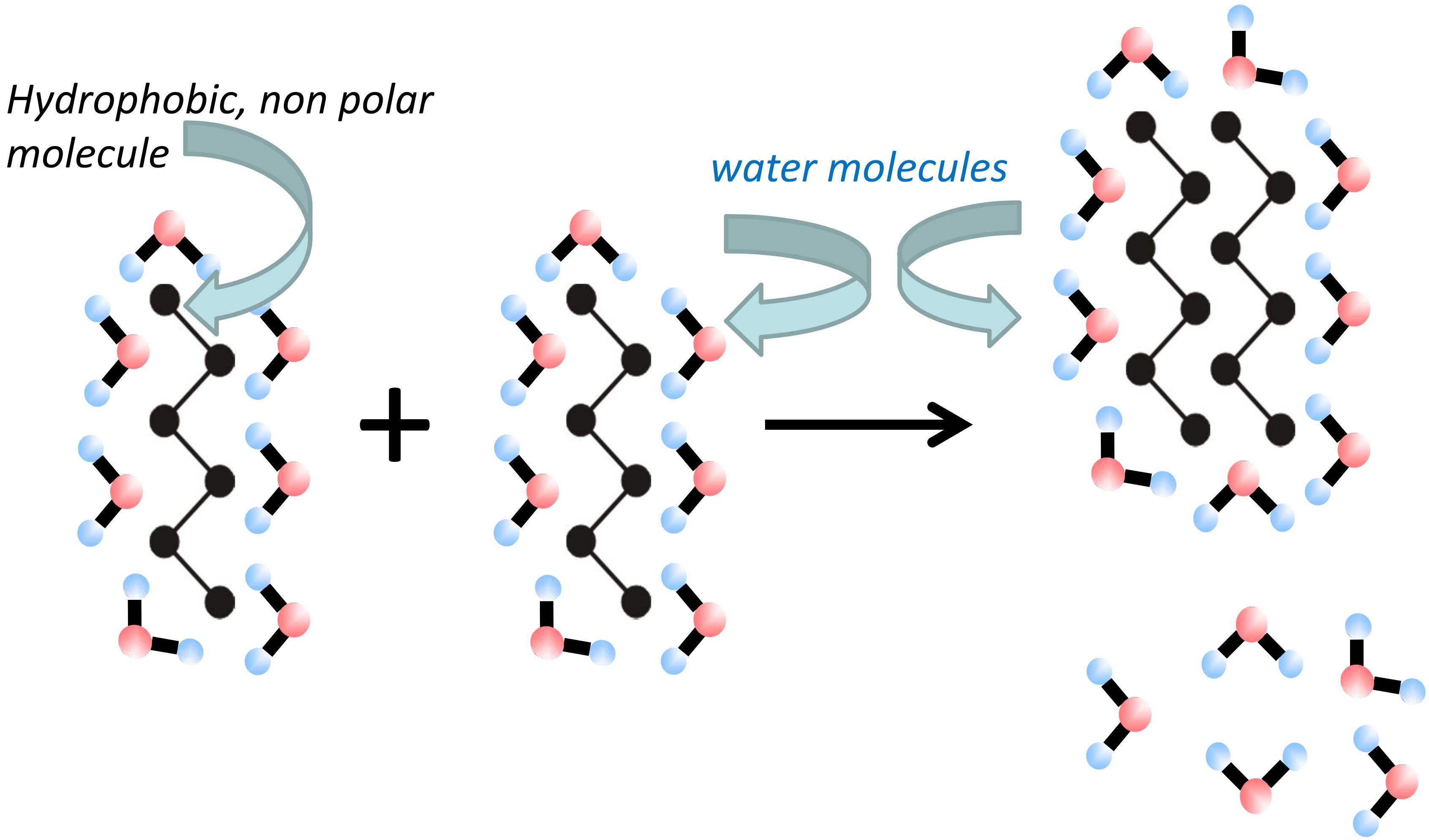




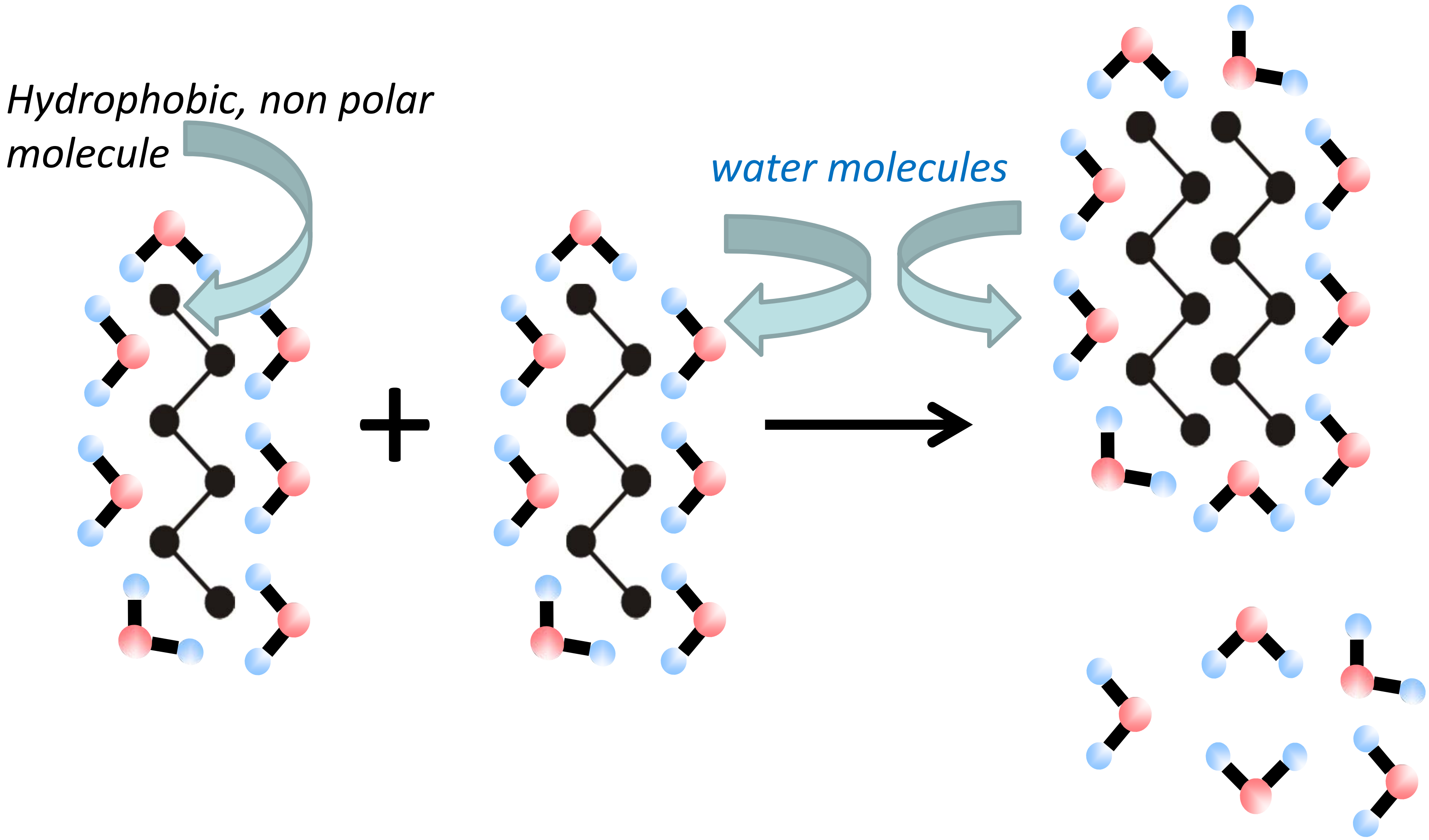
Clicker Question

Clicker Question

Clicker Question



In a mixture of water and hydrophobic molecules, the hydrophobic molecules “clump” together. Why?



This maximizes the entropy (motional freedom) of the water and therefore contributes to the stability of the system.

The clumping of the hydrophobic molecules is known as the **hydrophobic effect**. What drives the process is maximizing the entropy of the system.

The hydrophobic effect

The term hydrophobic effect is simply a name for the observation that burying nonpolar groups away from water increases system stability.

Nature uses this phenomenon to help build and a stabilize biological structures

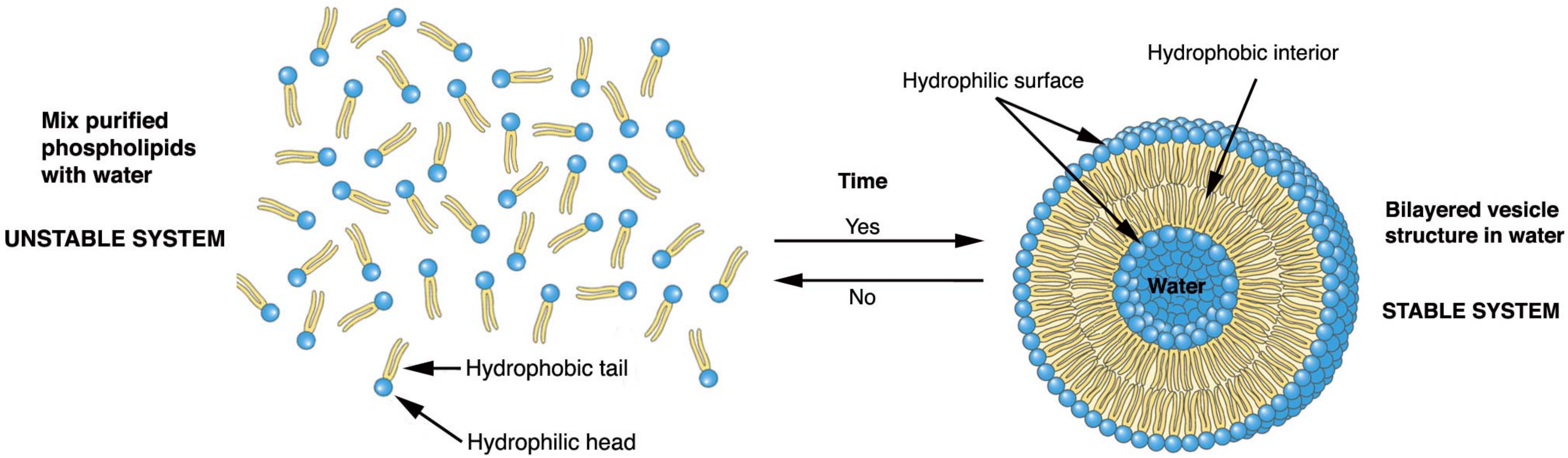
eg. Lipid bilayers

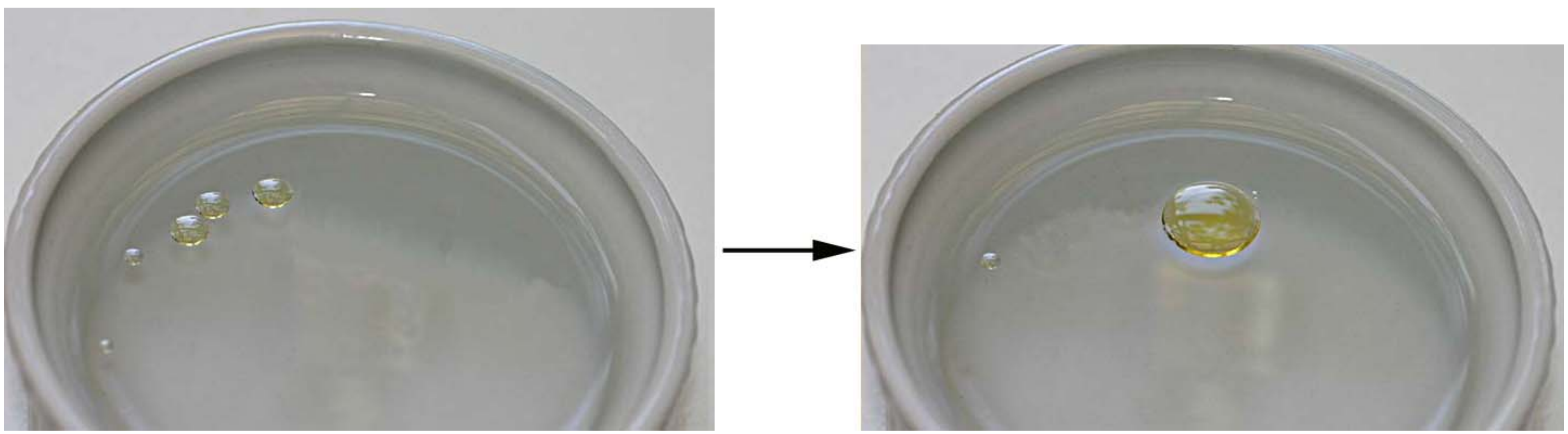
Folded polypeptides

Quaternary structure of proteins

Clicker Question

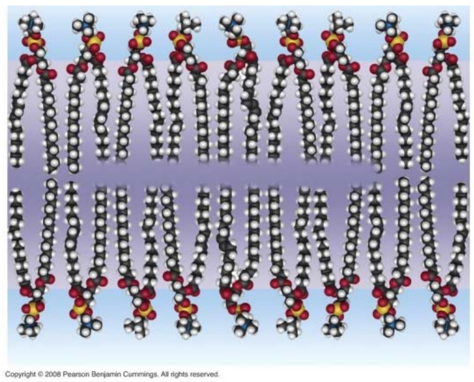
Lipid bilayer asssembly: a macroscopic analogy



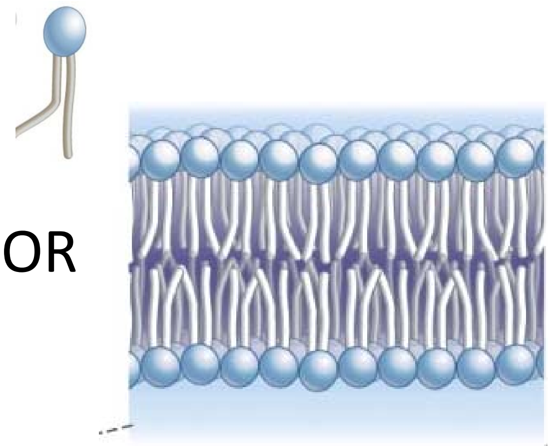


- **Which state is more stable, i.e. which state has the least potential for change?**

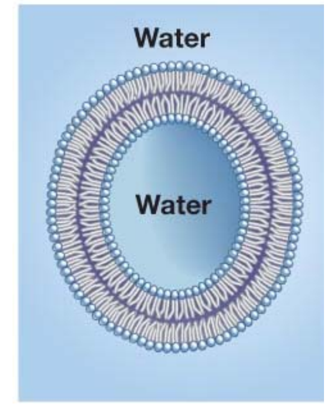
Bilayers and Micelles Form Spontaneously



OR

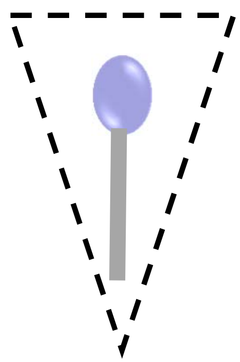


(b) Lipid bilayers

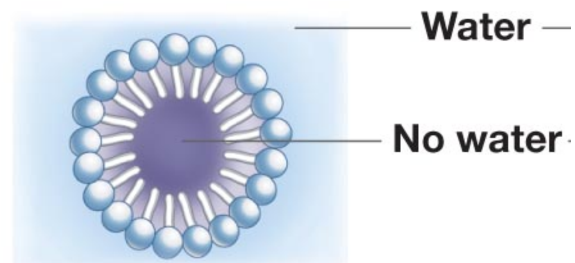


This would be the expected process

single-tailed lipids are wedge-shaped



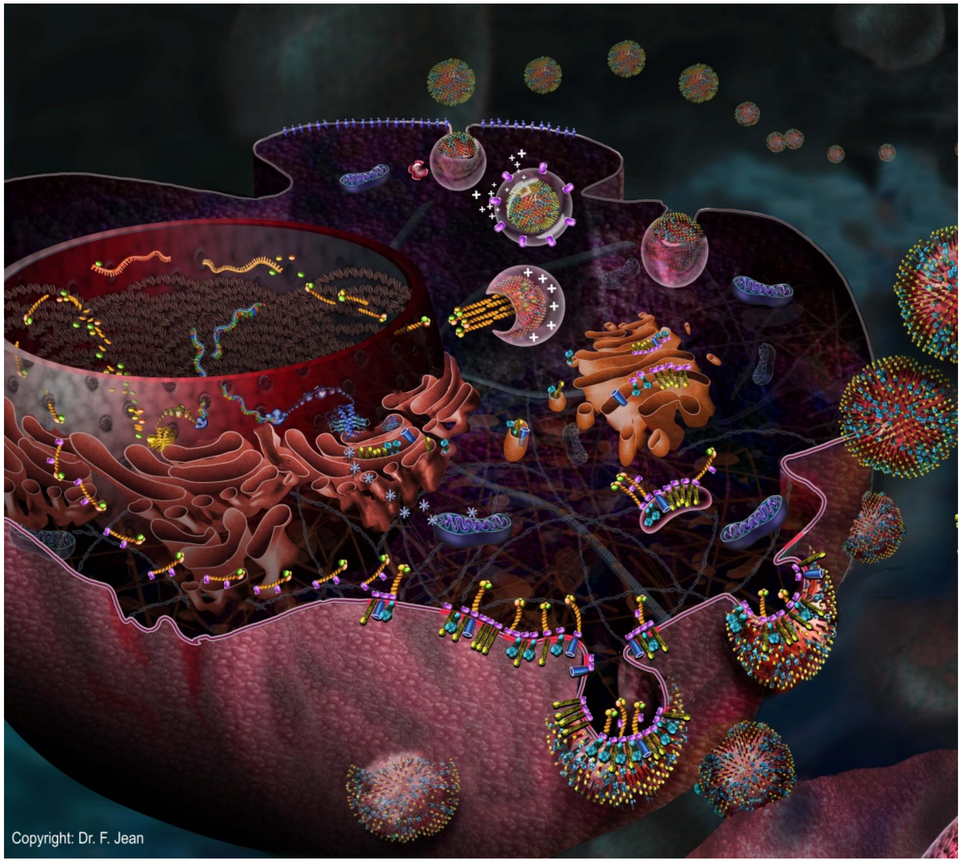
(a) Lipid micelles



no aqueous cavity

Fig 6.5 and 6.7 Biological Sciences

Week 3 - Biology 112



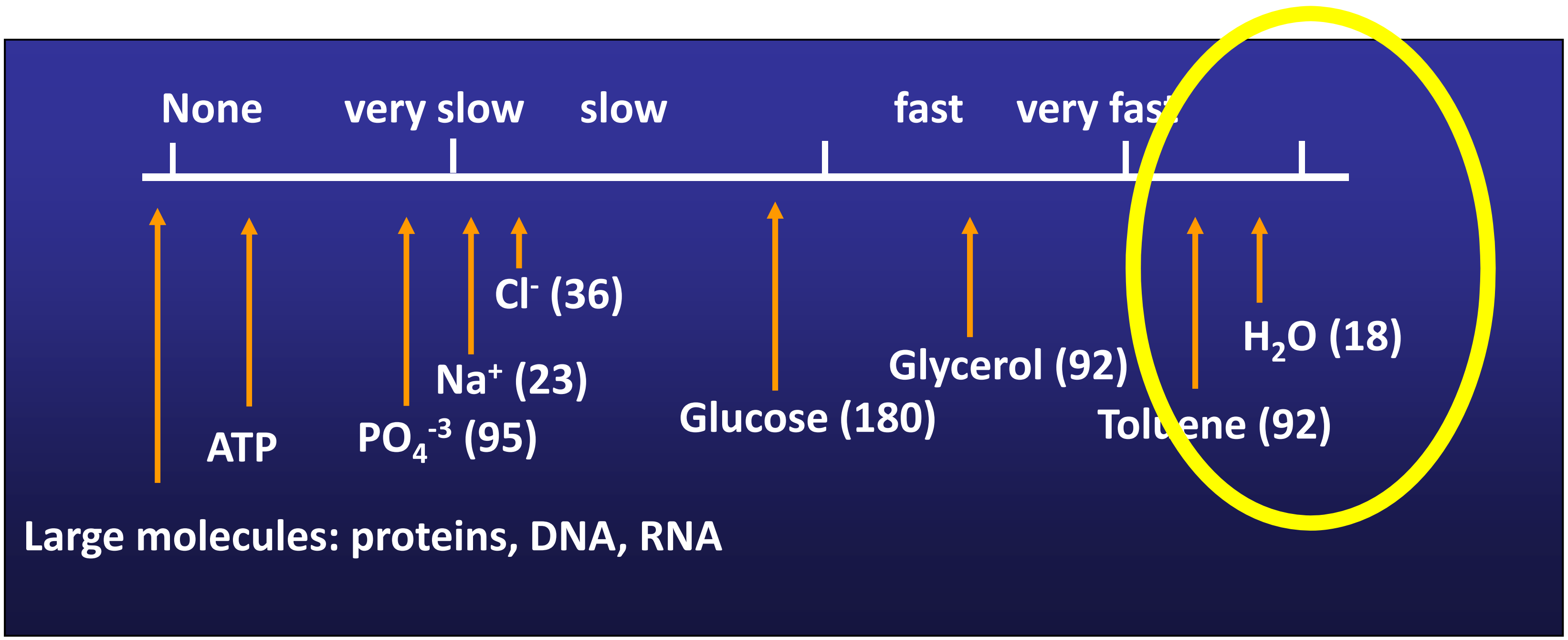
PeerWise

Multiple Choice (M/C) Database

- Create your login and password- see instructions on VISTA.
- Prior to **Midterm 1** for 1% of your grade
  - ❖ submit 1 multiple choice question (by Fri, Jan 25, midnight)
  - ❖ answer 2 questions from other students (by Mon, Jan 28, midnight).

See deadlines on CONNECT.

Permeability for the phospholipid bilayer of a membrane.



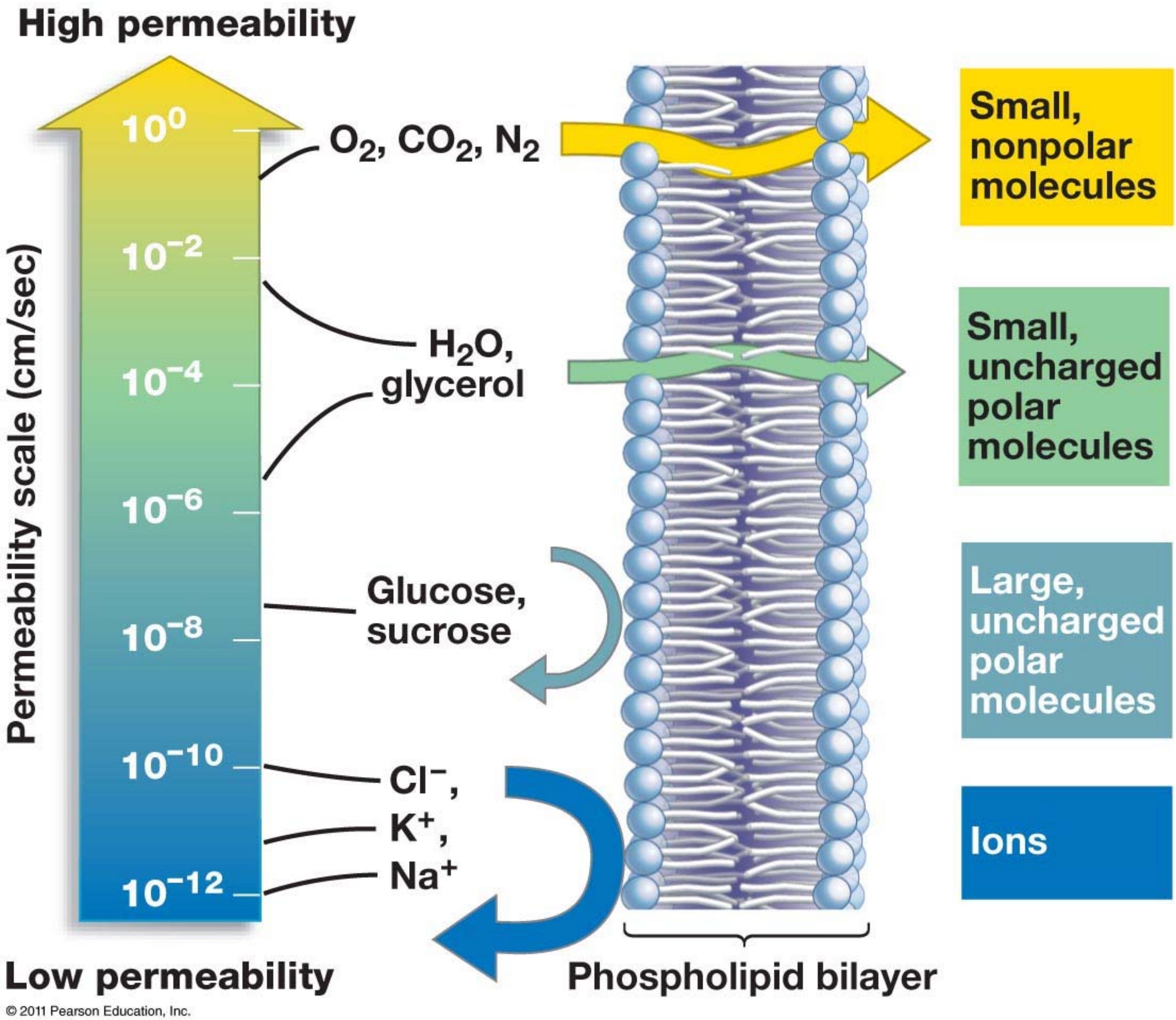
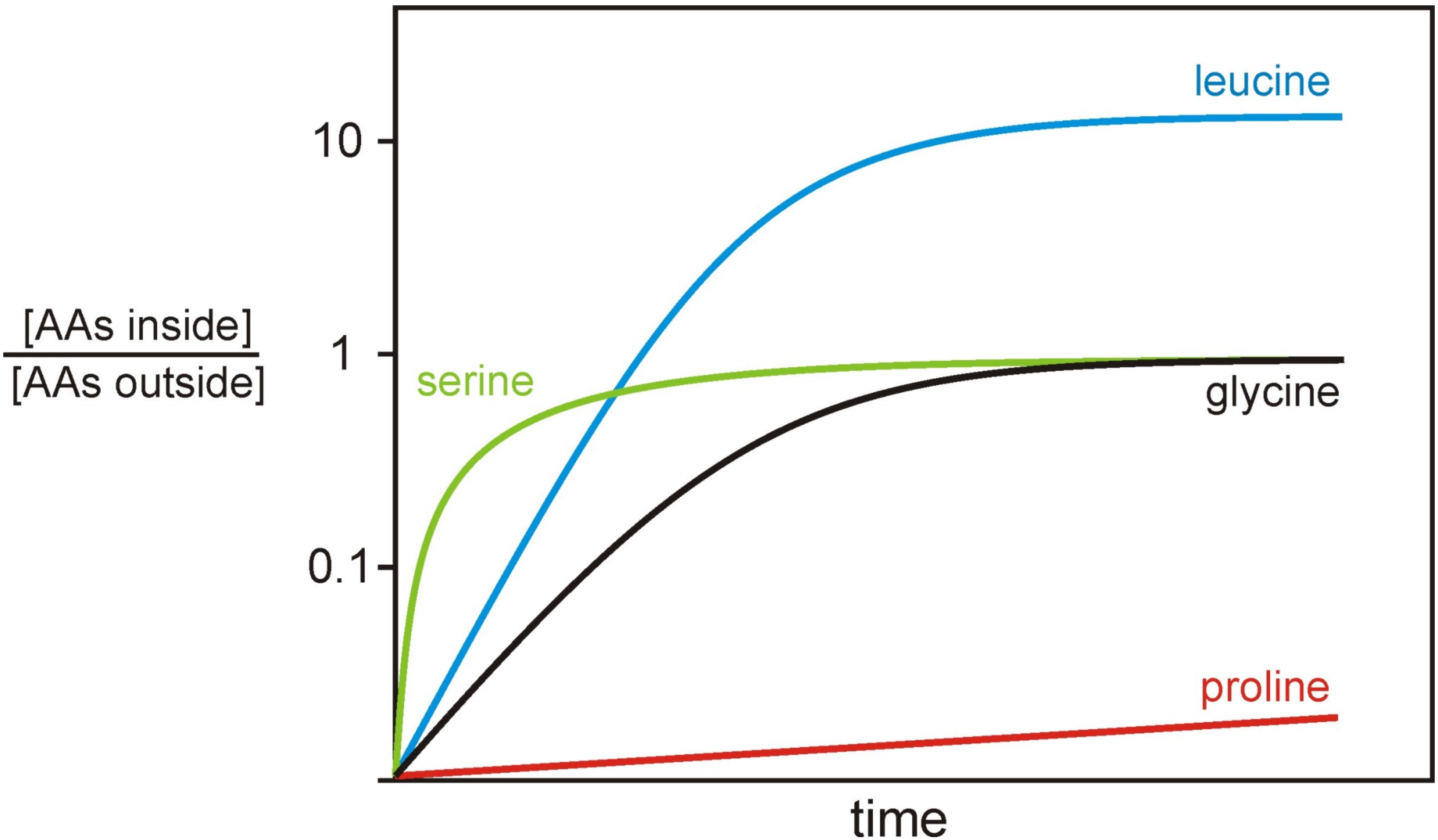


Fig 6.8 Biological Sciences

How does the cell get nutrients?



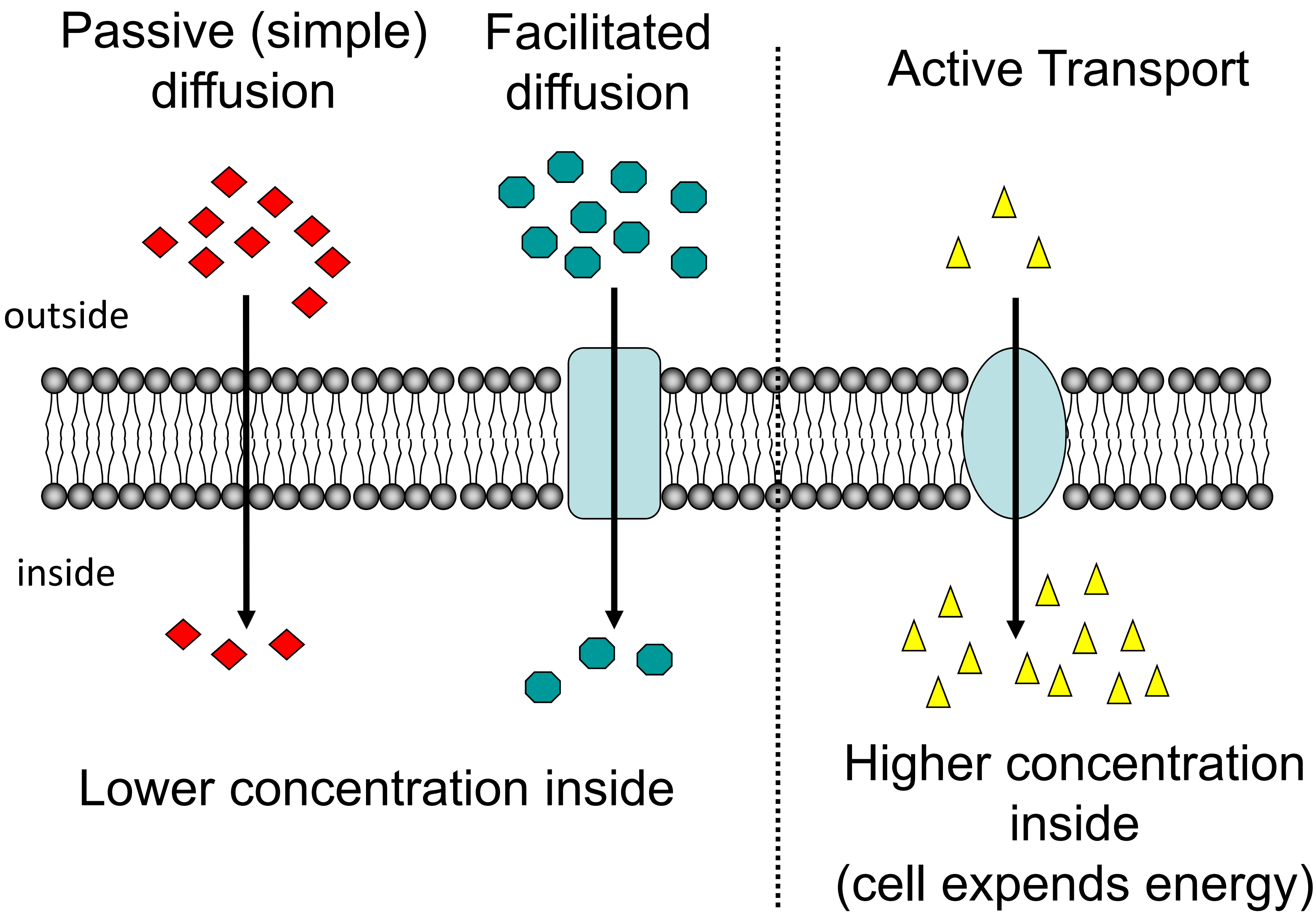
Recall the clicker questions from the rodent invention activity.

What we are looking at is different forms of membrane transport.

Clicker Question

Clicker Question

Getting things across the membrane: Transport



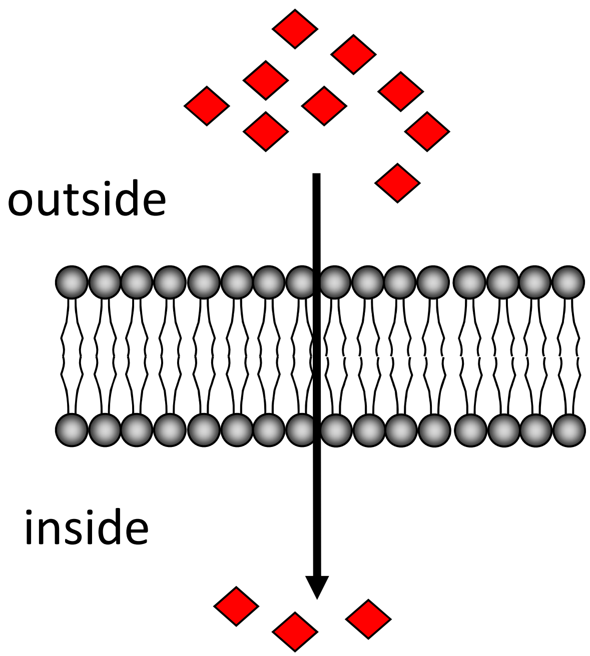
Materials can move across the cell membrane in different ways.

1. Passive transport does not require an input of energy.

   Forms of passive transport are (a) simple diffusion and (b) facilitated diffusion

2. Active transport requires energy to move substances across the membrane.

1.(a) Simple Passive Diffusion



Small molecules and ions in solution are called **solutes**, have thermal energy, and are in constant, random motion.

The movement of solute molecules through the phospholipid bilayer from a region of high solute concentration to low solute concentration is called **diffusion**.

Diffusion is a form of passive transport.

A difference in solute concentrations creates a concentration gradient.

Molecules and ions move randomly when a concentration gradient exists, but there is a *net movement* from high-concentration regions to low-concentration regions.

Diffusion along a concentration gradient increases entropy and is thus spontaneous.

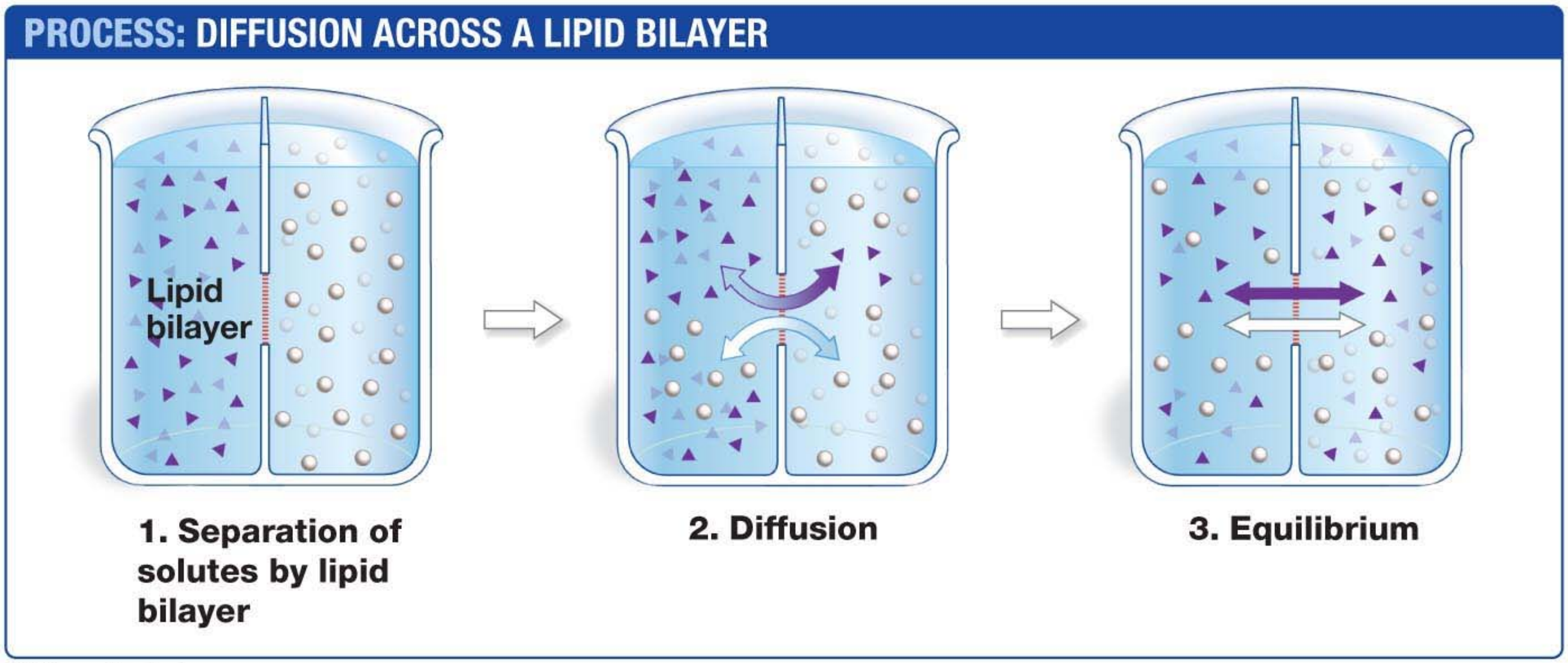


Fig 6.14 Biological Sciences

Equilibrium is established once the molecules or ions are randomly distributed throughout a solution

Molecules are still moving randomly but there is no more *net* movement

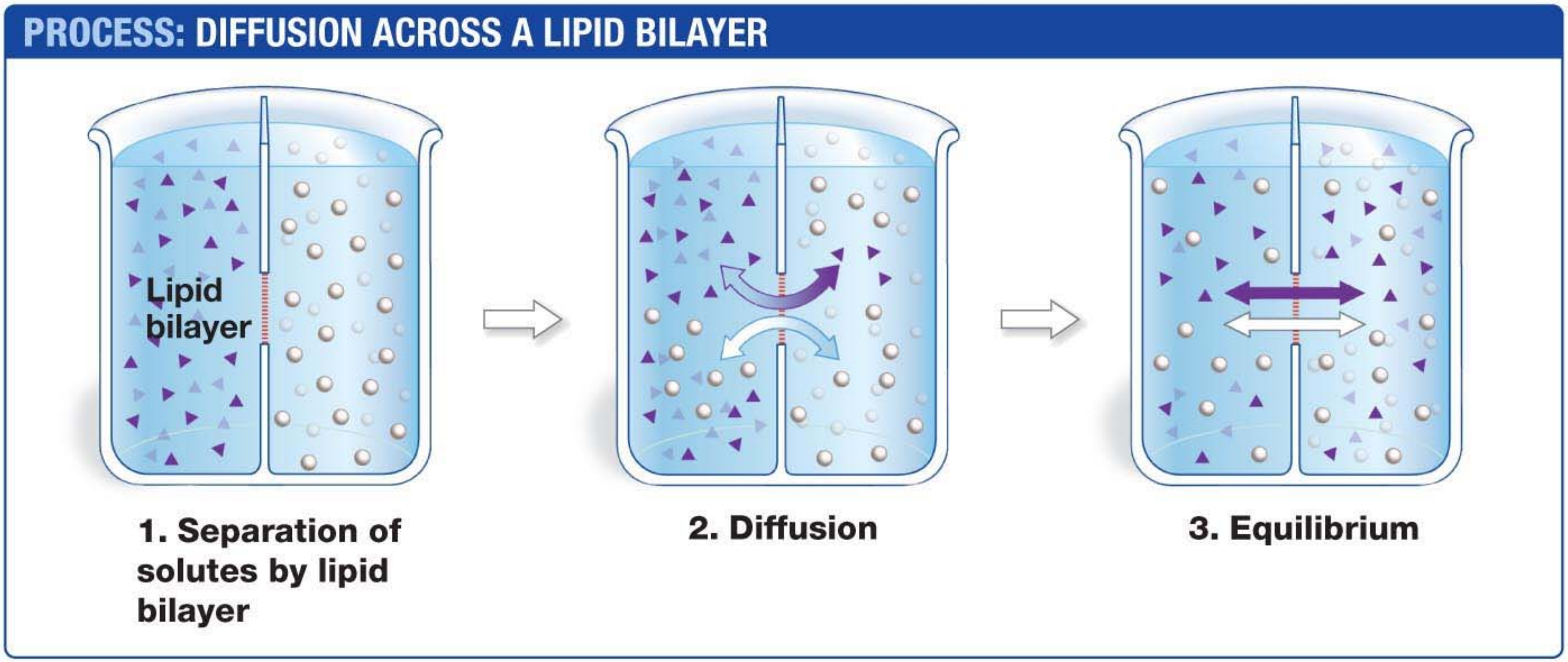
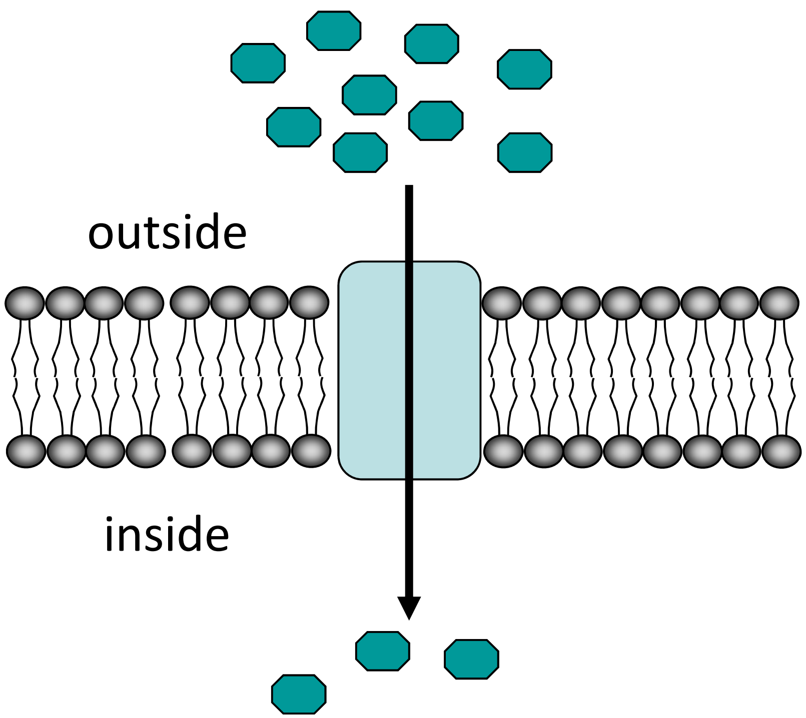


Fig 6.14 Biological Sciences

1(b). Facilitated Diffusion via Carrier Proteins



Some carrier proteins, or permeases increase the permeability of the cytoplasmic membrane and do not require the input of energy hence "facilitating"diffusion.

Facilitated diffusion by permeases occurs only down a concentration gradient.

Facilitated diffusion occurs via:

(I) Protein channels:

Ion channels are specialized membrane proteins which circumvent the plasma membrane’s impermeability to small, charged compounds

Additional proteins that will not be discussed in this course:

Porins *are water filled membrane proteins in the outer membrane of Gram negative bacteria.*

Aquaporins *are proteins channels that allow water molecules to move across the membrane.*

(II) Carrier proteins called permeases

Facilitated Diffusion via Ion Channels

When ions build up on one side of a plasma membrane, they establish both a concentration gradient and a charge gradient, collectively called the electrochemical gradient.

The ions diffuse through channels down their electrochemical gradients.

This passive transport decreases the charge and concentration differences between the cell's exterior and interior.

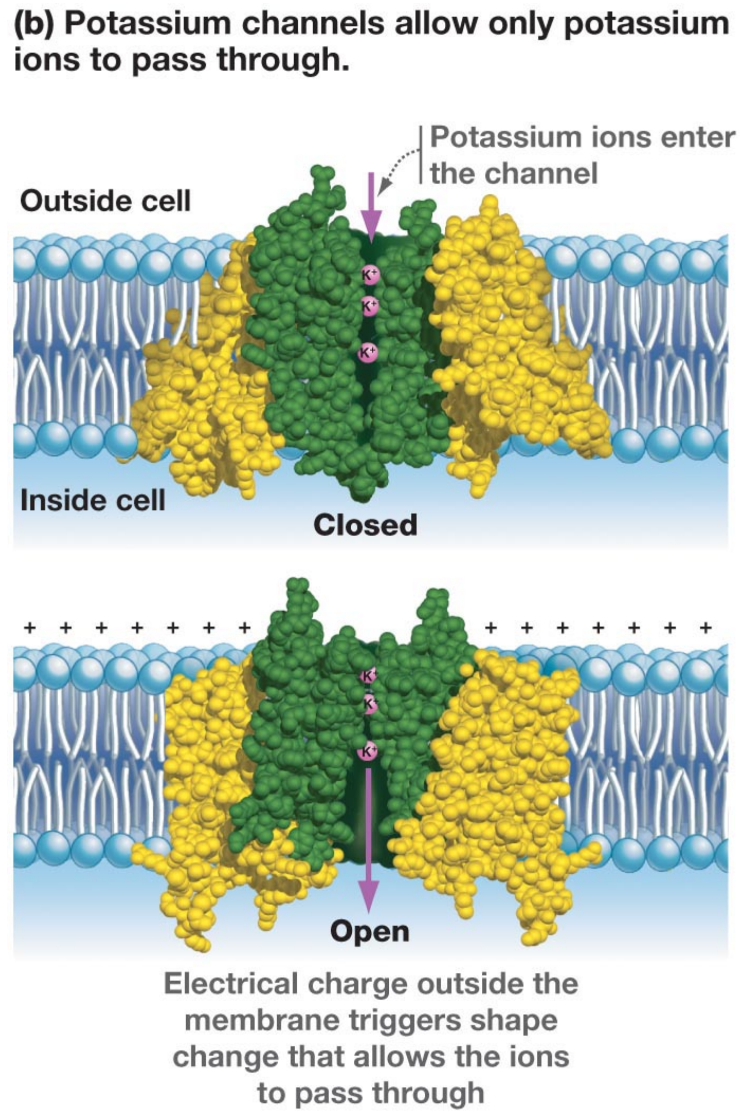


Fig 6.25b Biological Sciences

Carrier proteins (permeases) positioned in the membrane allow transport of some molecules the bilayer, alone, will not allow through.

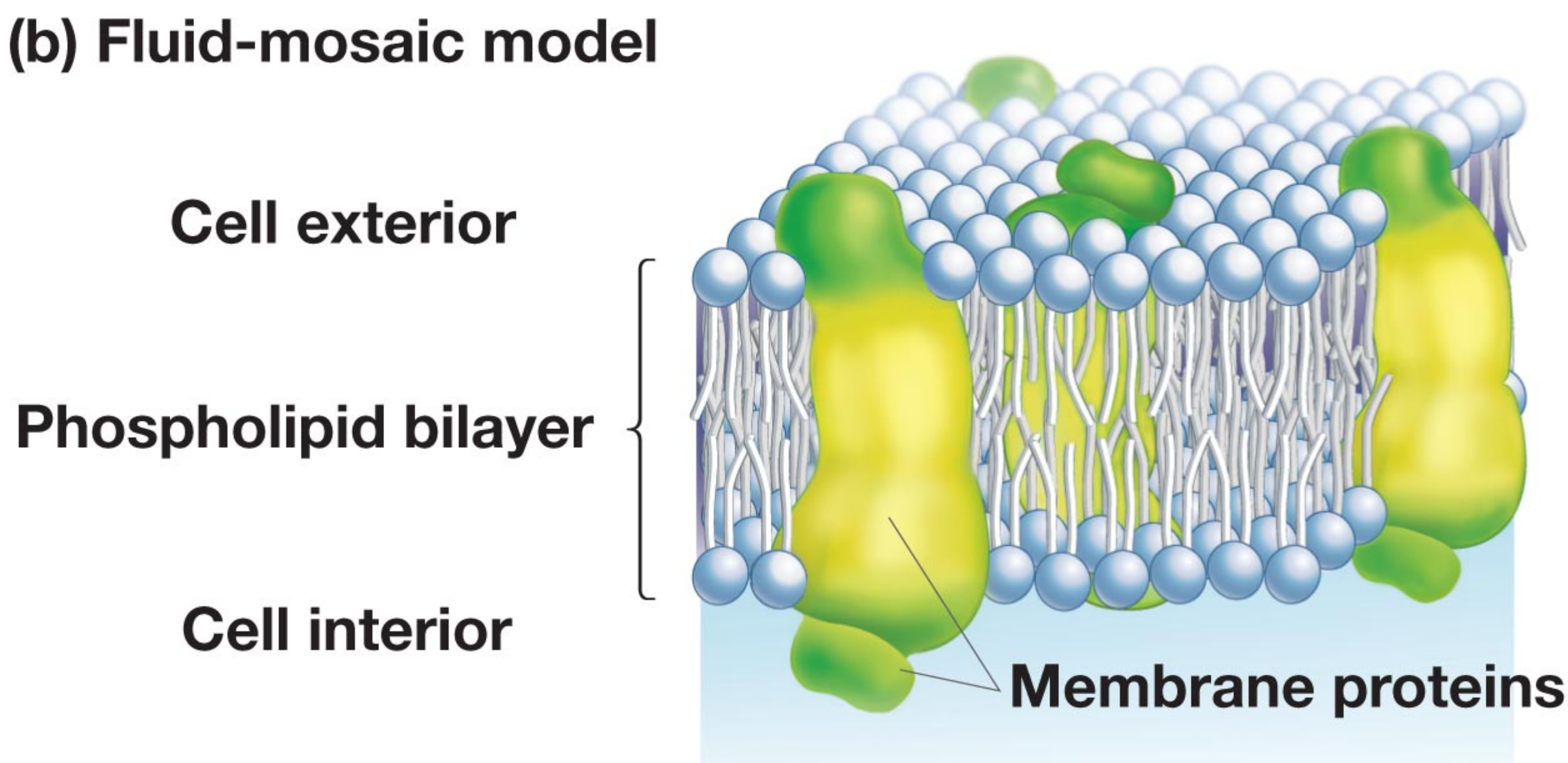


Fig 6.18b Biological Sciences

Glucose is a building block for important macromolecules and a major energy source, but lipid bilayers in eukaryotic cells such as erythrocytes are only moderately permeable to glucose.

The eukaryotic glucose permease called GLUT-1 increases membrane permeability to glucose.

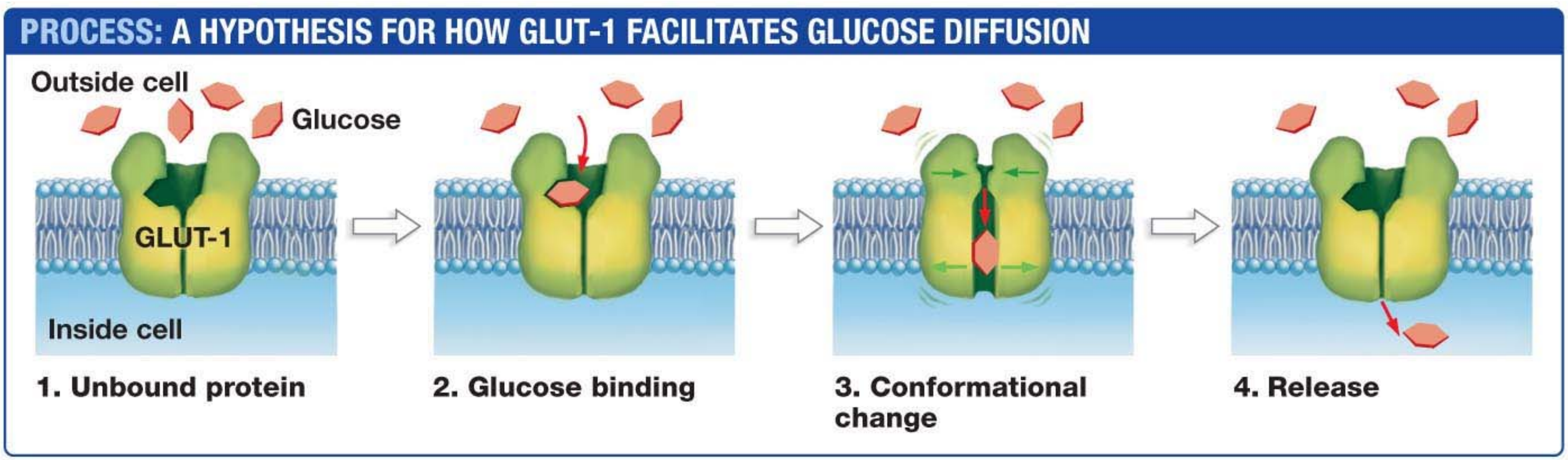
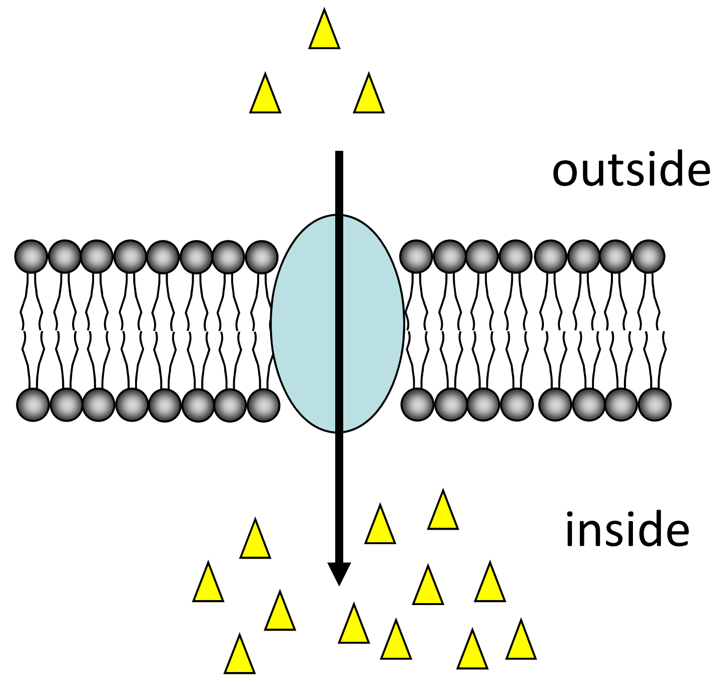


Fig 6.27 Biological Sciences

2. Active Transport

Cells can transport molecules or ions *against* an concentration gradient. **This process requires energy in the form of ATP and is called active transport.**

Pumps are membrane proteins that provide active transport of molecules across the membrane



The sodium-potassium pump, Na^+/K^+-ATPase, uses ATP to transport Na^+ and K^+ against their concentration gradients (1-4).

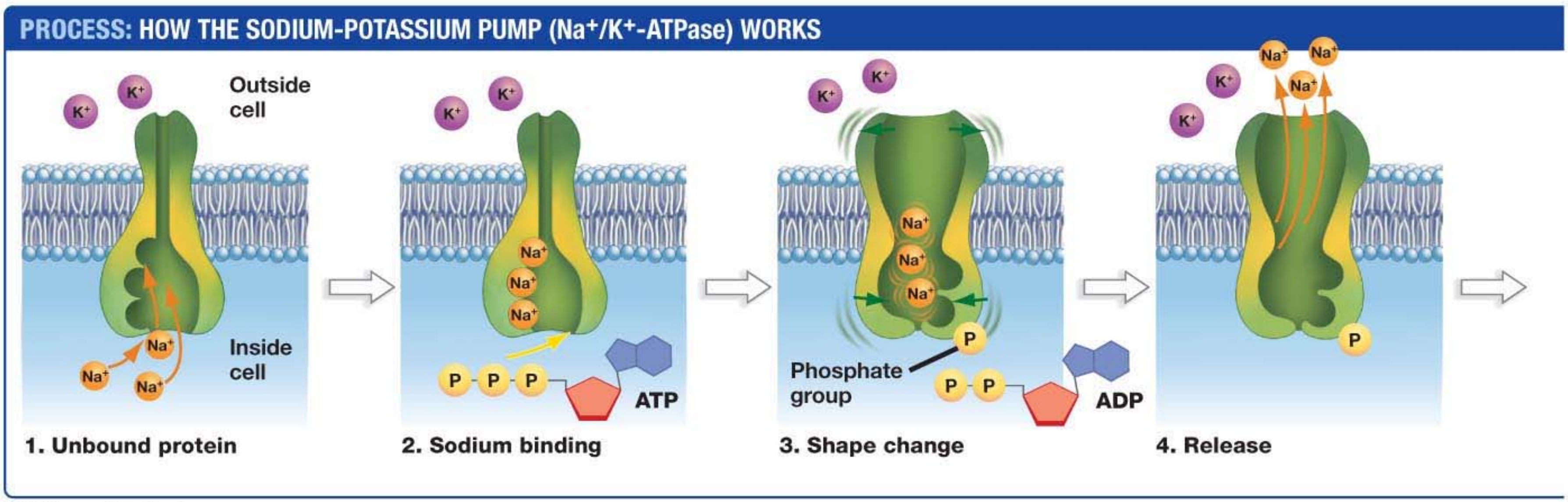
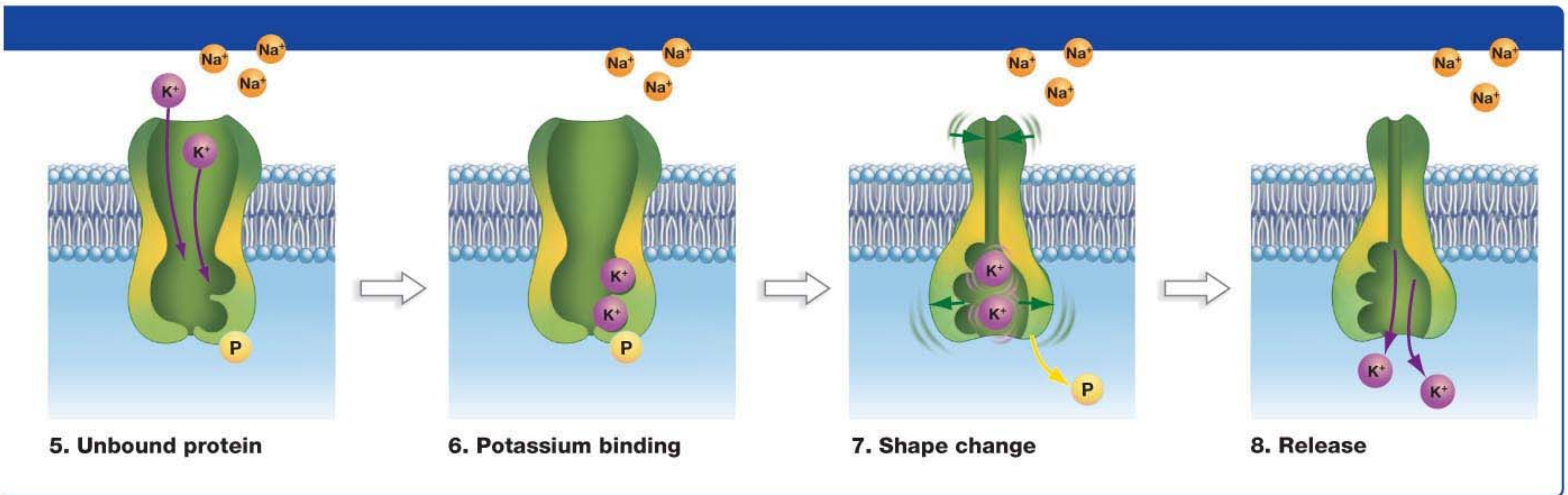


Fig 6.28 Biological Sciences

The sodium-potassium pump, Na^+/K^+-ATPase, uses ATP to transport Na^+ and K^+ against their concentration gradients (5-8).

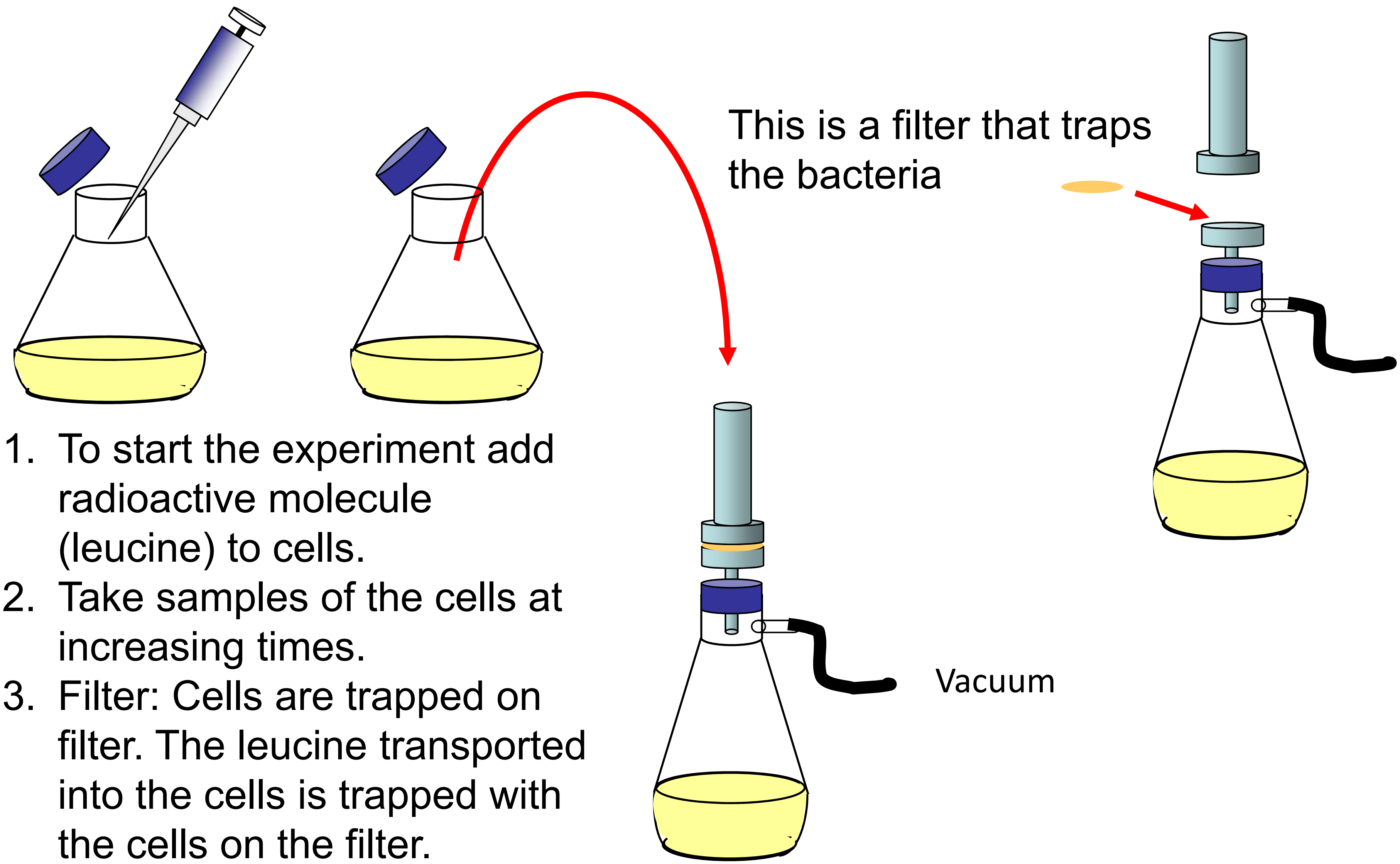


Freeman 6.28

Fig 6.28 Biological Sciences

Clicker Question

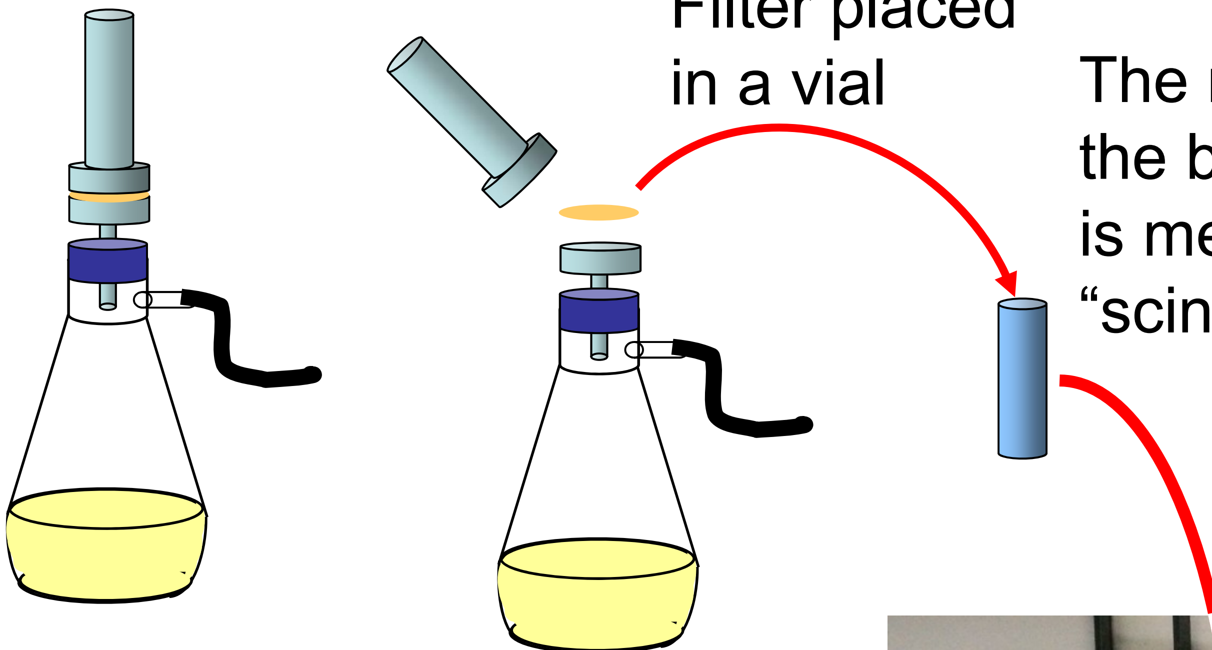
Experimental set up for measuring uptake of molecules



1. To start the experiment add radioactive molecule (leucine) to cells.
2. Take samples of the cells at increasing times.
3. Filter: Cells are trapped on filter. The leucine transported into the cells is trapped with the cells on the filter.
4. Leucine that is free goes into flask with the culture medium.

Experimental for measuring uptake of molecules

Filter placed in a vial



The radioactivity inside the bacteria on the filters is measured in a "scintillation counter"

Clicker Question

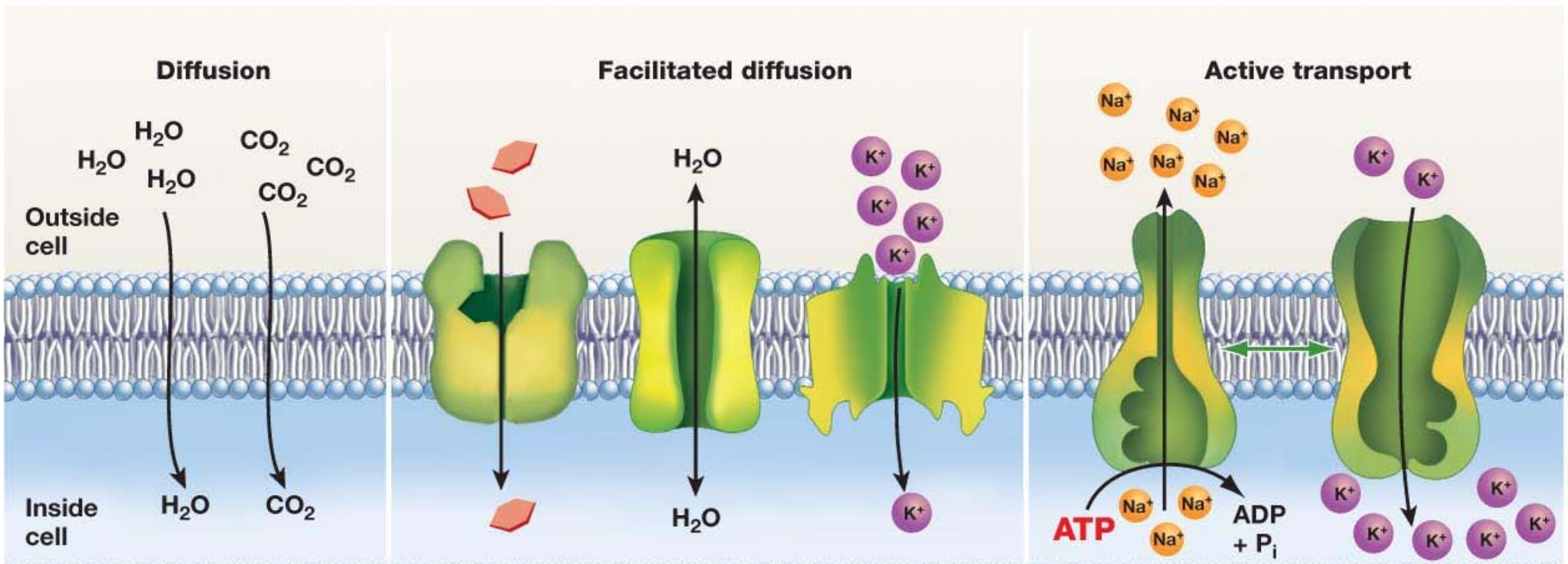
Clicker Question

Summary of Membrane Transport

- There are three mechanisms of membrane transport:
  1.(a) Diffusion
  1.(b) Facilitated diffusion
  2. Active transport

- Diffusion and facilitated diffusion are forms of passive transport and thus move materials down their concentration gradient and do not require an input of energy.

- Active transport requires energy provided by the cell (as ATP or an electrochemical gradient) and allows the cells to transport materials against their concentration gradient.



	Diffusion	Facilitated diffusion	Active transport
Description:	Passive movement of small, uncharged molecules along an electrochemical gradient, through a membrane	Passive movement of ...	Active movement of ...
Protein(s) involved:	None		

Fig 6.29 Biological Sciences

Osmosis

Water moves quickly across lipid bilayers. The movement of water is a special case of diffusion called osmosis.

Water moves from regions of low *solute* concentration to regions of high *solute* concentration.This movement dilutes the higher concentration, thus equalizing the concentration on both sides of the bilayer.

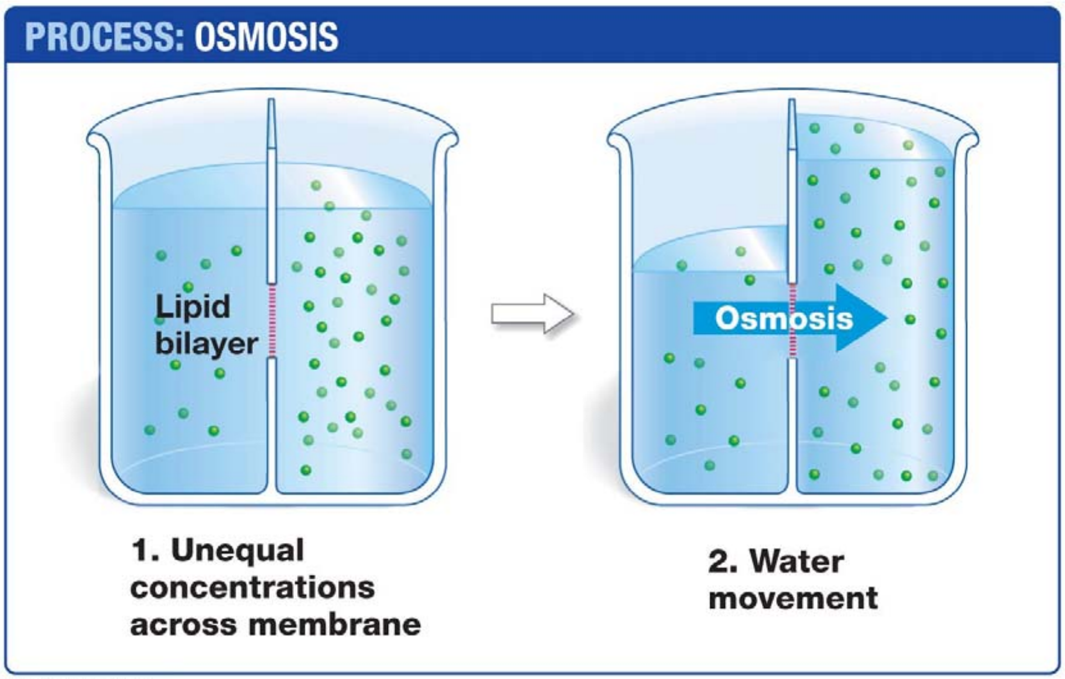
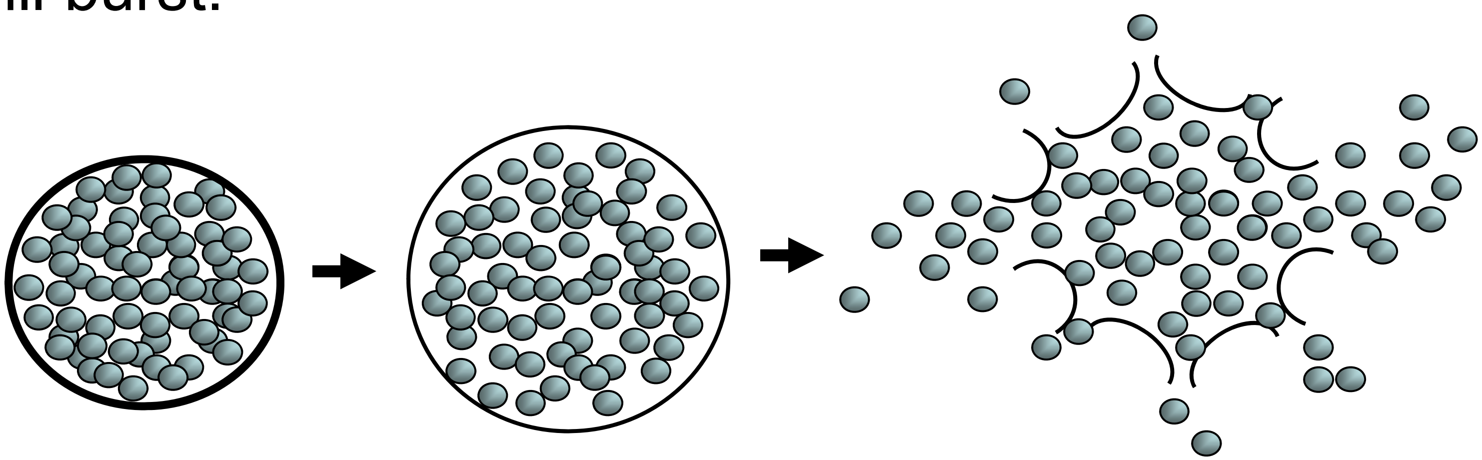


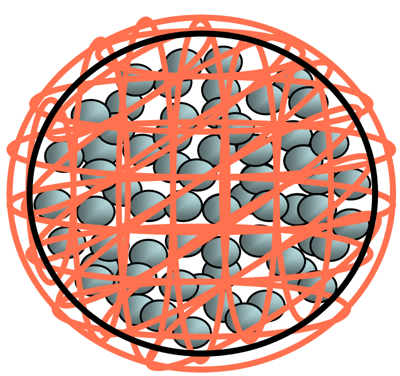
Fig 6.15 Biological Sciences

Clicker Question

For cells living in ‘natural water’ (lakes, oceans), the concentration of water is lower concentration inside the cell than it is outside the cell. The diffusion of water across the cell membrane results in “osmotic pressure”.

The cell membrane might be able to expand a little. But then it will burst.

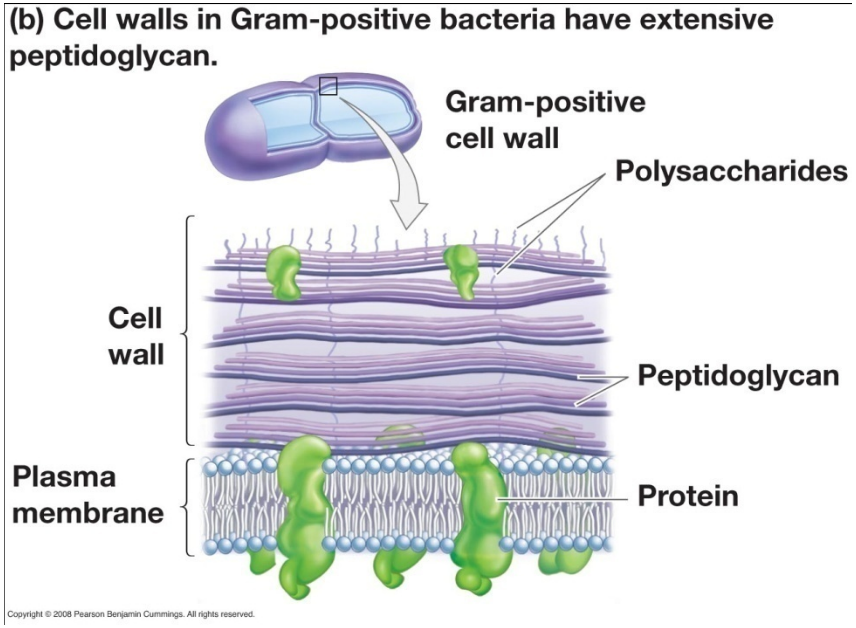




To combat osmotic pressure, Bacteria use a ‘net’ to surround the cytoplasm, and in some cases another barrier.

Two Basic Types of Bacterial Cells

Gram-positive bacteria



Gram-negative bacteria

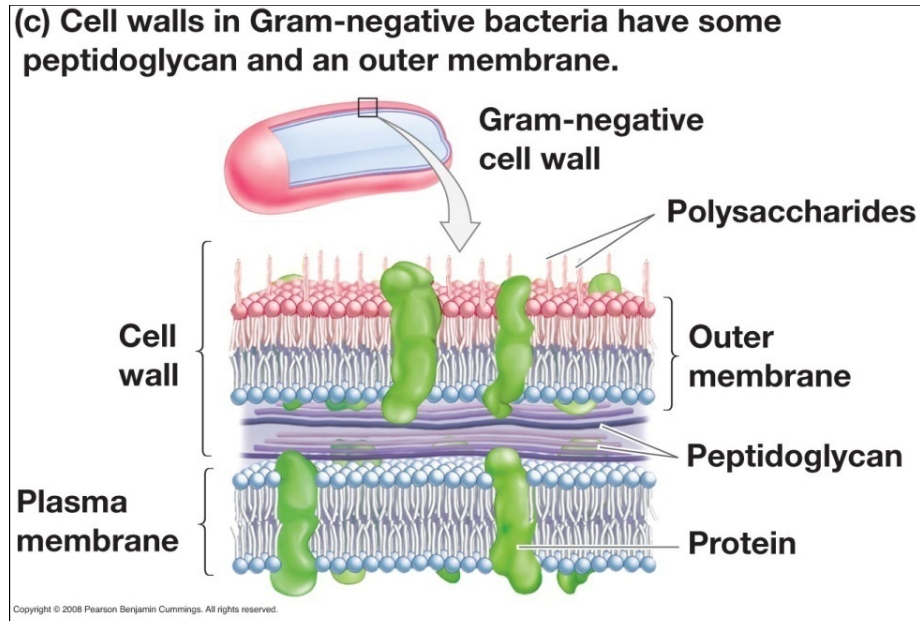
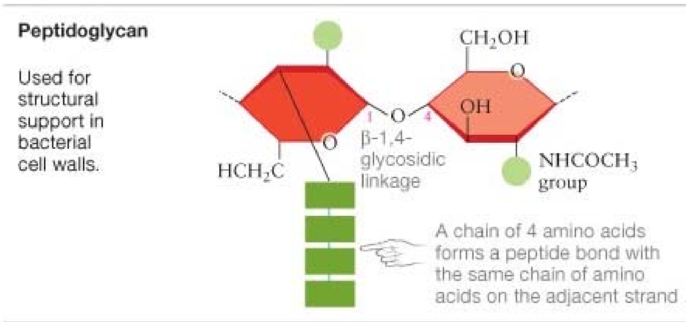


Fig 28.14b and Fig 28.14c Biological Sciences

The Bacterial Net: Peptidoglycan



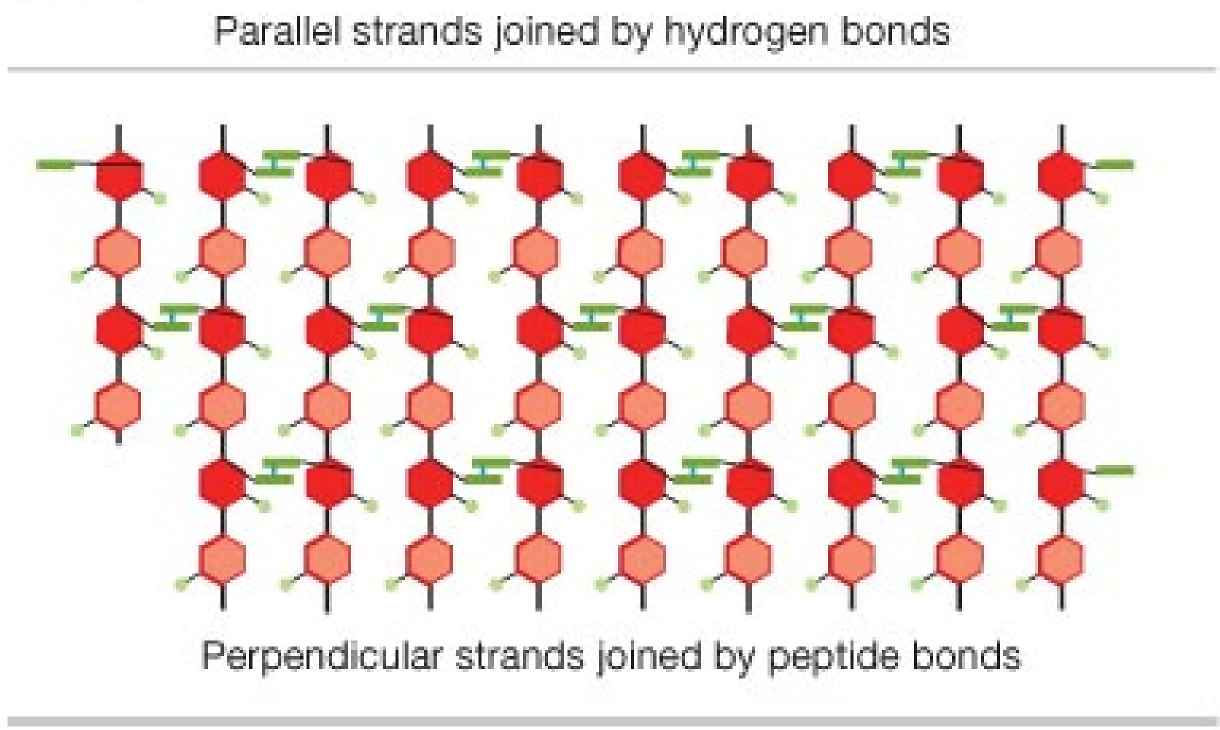
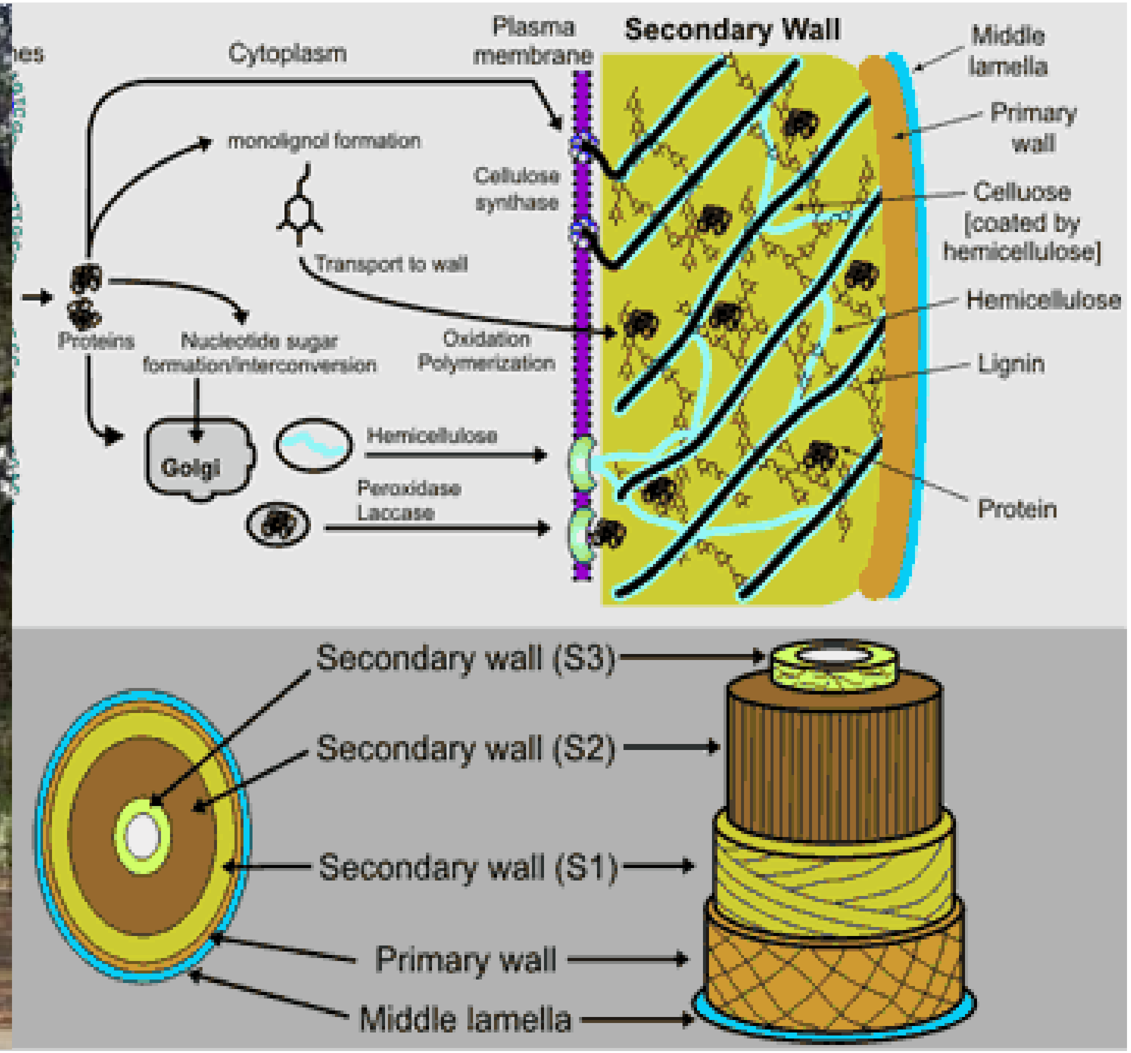


Table 5.1 Biological Sciences

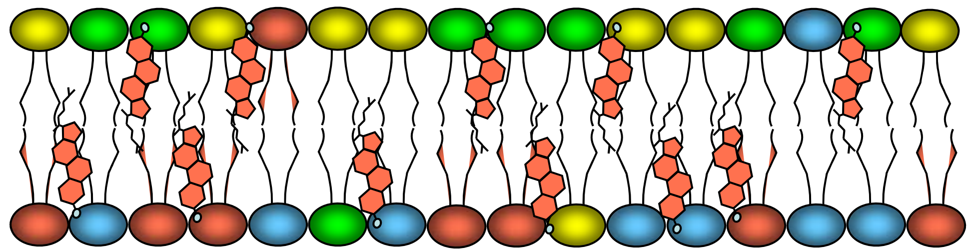
Plant cell walls



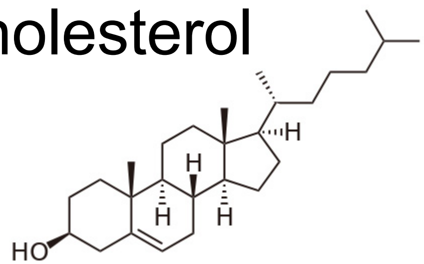
Left: http://tinka.net/category/texas/page/28/

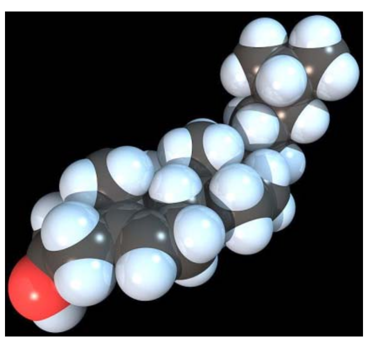
Right: http://www.ccrc.uga.edu/~mao/intro/ouline.htm

Other Eukaryotic membranes have several types of phospholipids. They are not the same on the inside and outside! Also, cholesterol stabilizes the membrane *making it less permeable to water.*

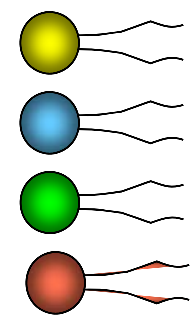


Structure of cholesterol





Phosphatidylcholine
Phosphatidylserine
Sphingomyelin
Phosphatidylethanolamine



Top: http://en.wikipedia.org/wiki/File:Cholesterol.svg
Bottom: http://en.wikipedia.org/wiki/File:Cholesterol_Spacefill.jpeg (author: RedAndr)

Many eukaryotes do not have cell walls, but live in aqueous environments.

How might these cells deal with osmotic pressure?