AP* BIOLOGY

CELL MEMBRANES, TRANSPORT, and COMMUNICATION

Teacher Packet

Cell Membranes, Transport and Communication

Objective
To review the student on the concepts and processes necessary to successfully answer questions over membranes as well as cellular transport and communication.

Standards
Photosynthesis is addressed in the topic outline of the College Board AP Biology Course Description Guide as described below.

I. Molecules & Cells
- B. Cells
  - Prokaryotic & Eukaryotic Cells
  - Membranes
  - Subcellular organization
  - Cell Cycle and its regulation

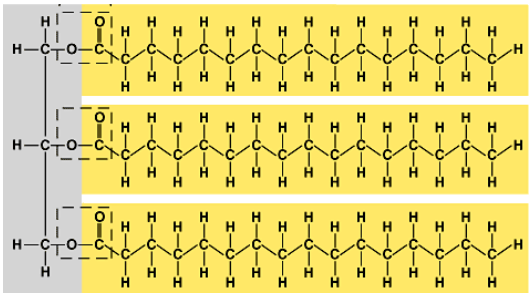
AP Biology Exam Connections
Membranes, transport, and communication are tested every year on the multiple choice and consistently make up portions the free response section of the exam. Of the topics covered in this section, membrane protein function and forms of transport seem to dominate. As with many AP Biology free response, these topics are often intertwined with other topics. Free response questions from this section also "spill over" into nervous and endocrine system as well. The list below identifies free response questions that have been previously asked over these topics. Free response questions on this topic are common. These questions are available from the College Board and can be downloaded free of charge from AP Central http://apcentral.collegeboard.com.

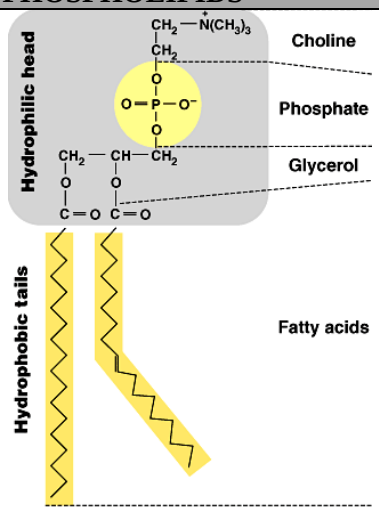
Free Response Questions	
2008- Question 1 (b)	2005- Questions 4 (lab) (form b)
2007- Question 1 (b)	
2006- Question 2 (c), (d)	
2003- Question 3 (a)	
2002- Question 4 (lab)	

Cell Membranes, Transport, and Communication

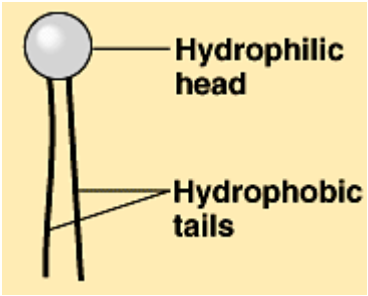
PHOSPHOLIPIDS

Triglyceride





Phospholipid



→Phospholipids containing polar phosphate heads and nonpolar lipid tails are derived from glycerol based fatty acid chains.
→Due to their amphipathic (polar and nonpolar) nature, they congregate into bilayer sheets that form spheres when placed in water.
→The inner and outer leaflets of the bilayer may be and usually are composed of different phospholipid types.
→These phospholipid bilayers are generally permeable to very small nonpolar substances.
→Membrane fluidity is different from one cell type to another, structure follows function. Membrane fluidity is primarily controlled in two ways

- The presence of cholesterol may increase or decrease fluidity depending on temperature ((high temp = more solid, low temp = less solid)
- The degree of lipid saturation. Highly saturated phospholipids tend to be more solid while the unsaturated phospholipids tend to be more liquid.

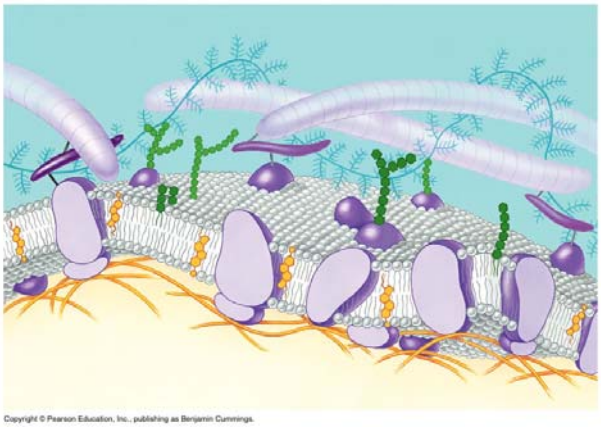
Membranes: More than a simple phospholipid bilayer, it's a fluid mosaic!

→ Proteins may be classified based on location or function

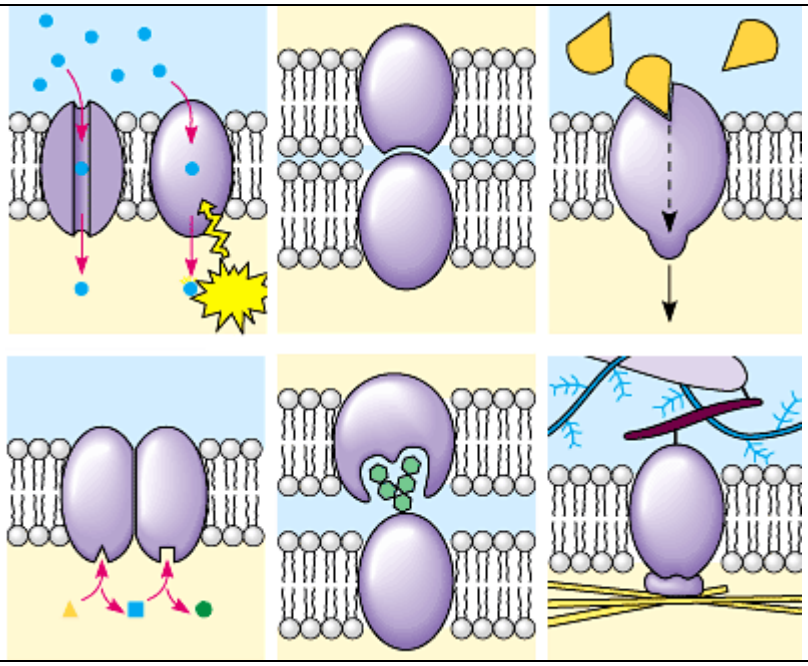
→Location

- Integral or transmembrane proteins are embedded in and typically traverse the entire membrane.
- Peripheral proteins are associated with the inner or outer leaflet only.

→The order of amino acids will determine the placement of polar and nonpolar regions. The completed protein will have regions complimentary to the phospholipids around it (primarily polar periphery + primarily nonpolar central regions).
→The appearance of these large proteins "floating" among the phospholipids is the reason for the "fluid mosaic" designation.



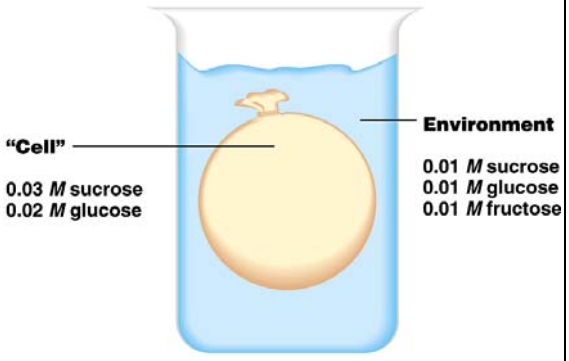
→Function (more in later sections)
- Carriers, Channels/Pores
- Receptors
- Enzymes
- Anchor (anchoring cytoskeletal elements for example or cell to cell)
- Cell to cell recognition sites (glycoproteins)



Osmosis, Diffusion, & Tonicity

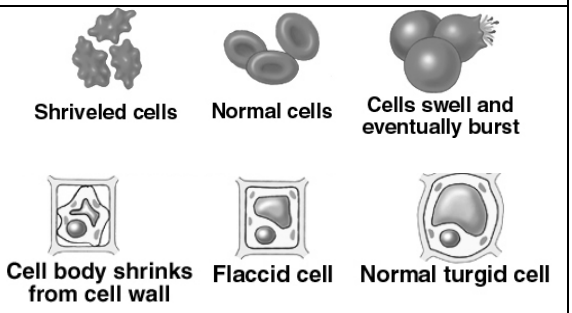
→The passage of substances along the concentration gradient (from [high] to [low]) is the passive process of **diffusion**. If the substance happens to be H_2O, the process is **osmosis**. These processes are passive and therefore do not require cellular energy.
→Cell tonicity is named based on solute concentration. These terms are relative, when one location is hypertonic another location must be hypotonic
- Hypertonic- higher solute concentration, Hypotonic-lower solute concentration, Isotonic- equal solute concentrations
- Significance: H_2O can move passively between phospholipids and through aquaporins. Solute concentrations will determine which way that H_2O will move.

→If the "cell" on the right is permeable only to water, which way will water flow?

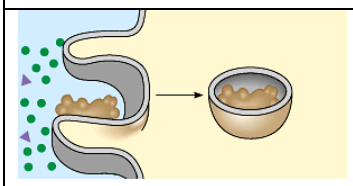
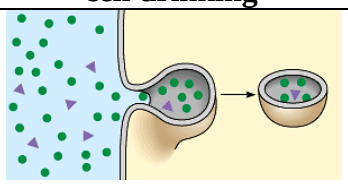
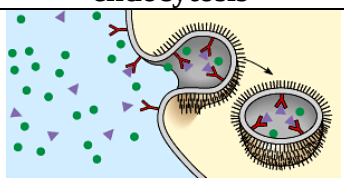
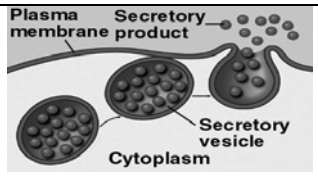


→Be it the need for turgor pressure in plants or the maintenance of a particular chemical environment in an animal cell, osmosotic balance is important to homeostasis.

→Protists may extrude H_2O through contractile vacuoles while other eukaryotes may use channels and pumps.



Bulk Transport

ENDOCYTOSIS: Phagocytosis "cell eating"	ENDOCYTOSIS: Pinocytosis "cell drinking"	ENDOCYTOSIS: Receptor mediated endocytosis	EXOCYTOSIS: "exiting" the cell
			

Functional significance

→Phagocytosis and Pinocytosis are quick ways to bring in large quantities of materials. Receptor mediated endocytosis (with the aid of clathrins) adds a layer of specificity. For additional specificity a mode of selective transport must be used

→Exocytosis allows the cell to excrete waste, hormones such as insulin, and other substances.

Selective Transport

→Facilitated diffusion: "helped" diffusion
- Carriers are specific, passive, and saturable
- Carriers have an arrangement of amino acids unique to a specific substance
- Example: aquaporin

→Active transport
- Carriers are specific, active (require energy), and saturable
- Often have "pump" in the name
- Examples: Na+/K+ pumps found in neurons, proton pumps found in the ETC.

→Advantage: Selective transport mechanisms are more accurate than bulk transport mechanisms.

→Disadvantage: Selective transport mechanisms are slower than bulk transport mechanisms

Cell Signaling

TYPES OF SIGNALING

→direct contact: cell / cell recognition, gap junctions

→paracrine signaling: local only
- example: growth factors

→synaptic signaling: neurons only
- neurotransmitters

→endocrine signaling: long distances
- example: hormones

THREE STAGES OF A SIGNAL-TRANSDUCTION CASCADE

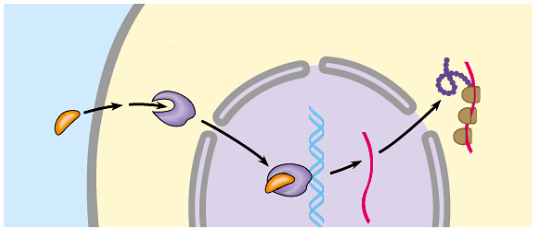
1. Reception- signal molecule (ligand) binding to receptor
2. Transduction- usually a change in shape, getting signal into form that can illicit response
3. Response

Receptor Types: Mechanisms of Cell Signaling

Intracellular Receptors

→Location- The receptor is located inside the cell.

→Operating procedures- Nonpolar ligands (such as steroid based hormones) can diffuse through the lipid bilayer to reach the internal receptor. The activated receptor will eventually (directly or indirectly) effect transcription or translation.

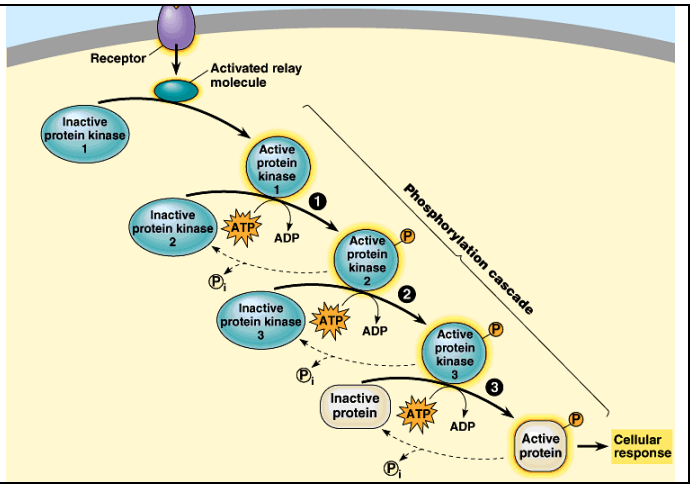


Cell Surface Receptors

→Location- The receptor is located on the cell surface.
→A signal transduction cascade ensues.
Why a cascade?

- Each step of signal transduction may activate many proteins in the next step amplifying the signal.
- Each step is a "yes/no" point of control

→Second messengers may be used as well. These are soluble nonproteins (cAMP, Ca^{2+}).
→G linked proteins are a "diffusible signal in the cytoplasm"; however, they still stay near the cell surface and usually activate a cell surface enzyme. G linked proteins are activated by GTP, hence the name.



Multiple Choice

1. The membrane of an animal cell would be impermeable to all of the following EXCEPT

I. a large and primarily polar protein
II. a small lipid based molecule
III. starch

(A) I only
(B) II only
(C) III only
(D) I and II only
(E) I and III only

B	Small lipid soluble substances are able to traverse the phospholipid bilayer. Large substances and polar substances are typically not able to cross with the aid of proteins.

2. The passive transport of an ion through a protein carrier into a cell represents which of the following?

(A) facilitated diffusion
(B) osmosis
(C) exocytosis
(D) phagocytosis
(E) active transport

A	Of the options listed, only A & B are passive. The movement of an ion cannot be osmosis (diffusion of water). In this case, a protein carrier helps (facilitates) the passive movement (diffusion) of ions.

3. All of the following statements regarding membranes are correct EXCEPT

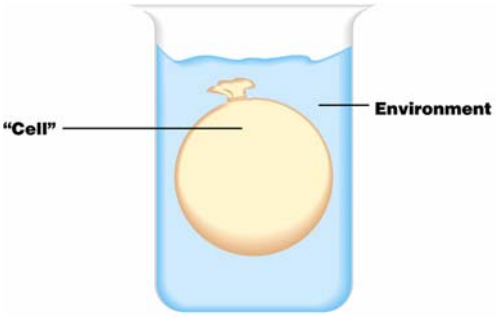
(A) Polar heads of phospholipids are located on the periphery of the cell membrane.
(B) Cell surface receptor proteins transfer small polar substances into the cell.
(C) Peripheral proteins may display enzymatic functions.
(D) Phospholipids are amphipathic.
(E) Glycoproteins are involved in cell-to cell recognition.

B	Receptor proteins transfer information into a cell, but unlike carriers they do not transfer an actual molecule into the cell.

4. Which of the following signaling mechanisms represent a correctly matched pair?
(A) endocrine- neural communication
(B) synaptic- intravenous communication
(C) paracrine- communication with nearby, surrounding cells
(D) gap junction- communication via hormones
(E) receptor- substrate communication

C	Paracrine signaling involves nearby cells.

Question 5 and 6 refers to the data table and picture of the membrane experiment below



"Cell"	Environment
0.1 M sucrose	0.2 M sucrose
0.2 M glucose	0.1 M glucose
5% starch	2% starch

5. Assume that the "cell" above is permeable to sucrose, glucose, and water but impermeable to starch. Which of the following statements is correct?

(A) Starch will diffuse into the cell.
(B) Starch will diffuse out of the cell.
(C) There will be no net movement of glucose
(D) Glucose will diffuse into the cell
(E) Sucrose will diffuse into the cell

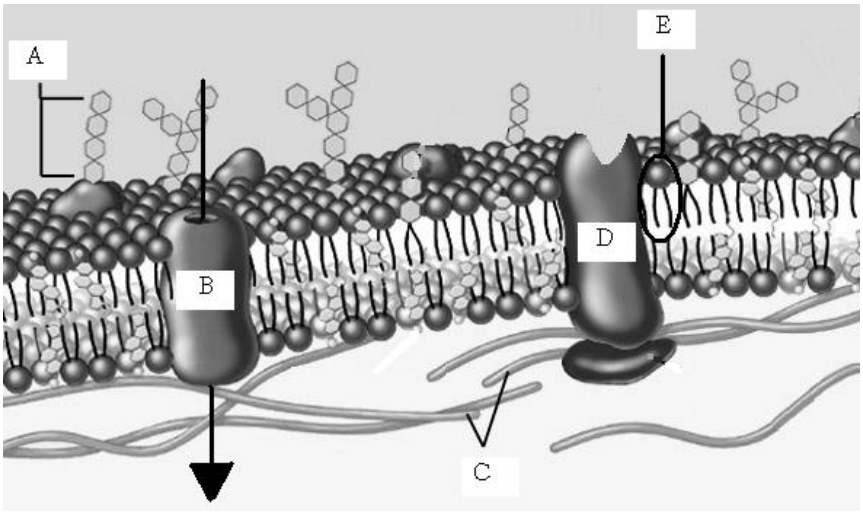
E	The question stem tells the reader that the "cell" is impermeable to starch. The concentration gradient is such that sucrose will move from higher [0.2M] concentration outside of the cell to lower [0.1M] inside the cell

6. Assume the "cell" is permeable to water only. If the cell contains a 0.3 M solution of glucose and the environment contians a 0.1 M solution of glucose, which of the following statements would be true?

(A) The cell will decrease in volume.
(B) Glucose will enter the "cell."
(C) Pinocytosis will occur.
(D) There would be a net movement of water into the "cell."
(E) There would be no net movement of water.

D	Water will move in to "dilute" the higher concentration of glucose inside the "cell."

Questions 7-10 refer to the diagram of a cell membrane below.



7. Contains both polar and nonpolar regions while lacking sulfur

E	Phospholipids contain polar heads and nonpolar tails

8. Responsible for maintaining the shape of the cell.

C	The cytoskeleton contributes to the shape of the cell.

9. Allows information to pass through the membrane without actually allowing substances to penetrate the membrane.

D	Receptors allow information to pass without allowing the ligand to actually enter the cell.

10. Primarily responsible for cell-to-cell recognition

A	Glycoproteins are involved in cell-to cell recognition (immune system, etc.)

Free Response

1. The cell membrane is much more than a passive barrier of the cell.
(A) Describe in detail the fluid mosaic model of the cell membrane.
(6 pt maximum)

__phospholipid description (polar head, nonpolar tails)
__phospholipid bilayer (must explain significance with reference to polarity)
__cholesterol: effects membrane fluidity
__transmembrane proteins span the entire membrane
  __role of a transmembrane protein (carrier, receptor, etc.)
__peripheral protein
  __role of a peripheral protein (anchor, enzyme, etc.)
__glycolipid OR cell surface marker
  __role of glycolipid (identify cell as "self" to the immune system, etc)

(B) Describe and give an example for each of the following:
i) a bulk transport mechanism *(2 pt maximum)*

__phagocytosis: cell "eating" OR taking in larger solutes
__pinocytosis: cell "drinking" OR taking in smaller solutes
__receptor mediated endocytosis: receptor coated invaginations
__valid example #1: such as immune system phagocytosis description
__valid example #2: cell taking fluids in to maintain osmotic balance

ii) facilitated diffusion *(2 pt maximum)*

__passive OR movement from high to low concentration with the aid of a protein or carrier/channel
__usually a water filed pore to allow polar molecules to pass through
__example: aquaporins or other valid example

iii) active transport *(2 pt maximum)*

__transporting against the concentration gradient OR so that "stockpiling" of molecules can take place
__requires energy or ATP
__example: proton pumps, Na^+/K^+ pumps, etc

*must earn a point all 3 sections of part B in order to earn a 10 overall.

Free Response

2. Cell receptors play an integral role in cellular communication.

A. Briefly list and describe the steps of a signal transduction cascade

__Reception- ligand binding
__Transduction- change in shape of proteins or activation or phosphorylation of proteins
__Response- cellular response to the message (ie cell division if the "message" was a growth factor)

B. Describe and discuss the mechanism by which a cell surface receptor sends a message to the interior of the cell.

__ligand is typically NOT lipid soluble, so it must bind to a cell surface receptor
__receptor is often linked to a peripheral protein
__receptor will create a biochemical cascade (signal transduction cascade) activating many proteins
__second messengers may be involved (Ca^{2+}, cAMP, etc.)
__each step of the cascade is a "control" step where the process may be halted by other proteins
__each step may result in amplification: 1 signal activates 10 proteins which each activate 10, etc.
__mention of G proteins in proper context (associated with membrane, GTP dependent, etc.)

C. Describe and discuss the role of a receptor located in the cytosol with respect to cellular communication.

__Nonpolar ligands are able to diffuse into the cytosol
__receptors are activated and usually enter the nucleus to effect transcription