Study questions 2013 – Topic 2 Cell membranes

Multiple choice questions (1 mark per answer)

1. A bacterium is suddenly expelled from a warm human intestine into cold water. Which of the following adjustments might the bacterium make to maintain the same level of membrane fluidity?
   a. Increase the length of the hydrocarbon tails in its membrane phospholipids.
   b. Increase the proportion of unsaturated hydrocarbon tails in its membrane phospholipids.
   c. Increase the amount of cholesterol in the membrane.
   d. Increase the proportion of hydrocarbon tails with no double bonds in its membrane phospholipids.
   e. Both (b) and (c) would be appropriate responses for the bacterium to make to maintain the same level of membrane fluidity following the change in environment.

2. The plasma membrane of an animal cell is symmetric with respect to…
   a. The distribution of different phospholipids in each leaflet of the lipid bilayer.
   b. The orientation of membrane proteins in the lipid bilayer.
   c. The distribution of cholesterol in each half of the lipid bilayer.
   d. The distribution of GPI-linked proteins in each leaflet of the lipid bilayer.
   e. All of the above

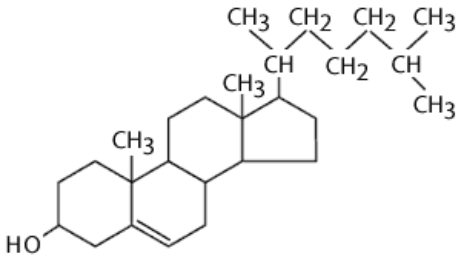
3. You are characterizing an isolated membrane protein. The protein is exposed on both sides of the membrane. Over much of the centre part of its surface, there are hydrophobic amino acids while the ends are hydrophilic. It crosses the membrane a number of times. There is an opening in the centre of this protein that is lined by hydrophilic amino acids. Which of the following statements best describes this protein and its function?
   a. It is a peripheral membrane protein that serves to stabilize the structure of the membrane.
   b. It is a multipass transmembrane protein of the P-type active transport pumps.
   c. It is a lipid-anchored protein that functions as a receptor.
   d. It is an integral protein that serves as a hydrophilic channel for the passage of charged molecules.
   e. None of a, b, c or d adequately describes the protein.

4. The lipid bilayer nature of the plasma membrane was postulated by
   a. Singer & Nicolson
   b. Watson & Crick
   c. Frye & Edidin
   d. Gorter & Grendel
   e. Schleiden & Schwann

5. A human red blood cell is placed into a clear solution. Within minutes, the once plump and rounded red cell is wrinkled and shrunken. What can you infer about the clear solution into which the red cell was placed?
   a. The solution was hypotonic with respect to the red cell.
   b. The solution contained a lower concentration of solute particles than the cytoplasm of the red blood cell.
   c. The red cell was isotonic with the solution.
   d. The cytoplasm of the red cell contained a lower concentration of solute particles than the solution.
   e. Both a and d are true.

6. Which of the following movements by a membrane protein is most likely to occur by lateral diffusion through the lipid bilayer?
   a. Movement from the outer nuclear membrane to the inner nuclear membrane.
   b. Movement from the outer mitochondrial membrane to the inner mitochondrial membrane.
   c. Movement from the outer nuclear membrane to the endoplasmic reticulum.
   d. All of the above are equally likely to occur.

7. The molecule at right is...
   a. A phosphoglyceride
   b. A sterol
   c. A glycolipid
   d. A phospholipid
   e. A sphingolipid



8. Which of the following is **not** a cell surface receptor?
   a. A ligand-gated channel
   b. A ligand-activated transcription factor
   c. A receptor tyrosine kinase
   d. A G protein-coupled receptor
   e. All of the above are cell surface receptors.

9. When a trimeric G protein is activated by a cell surface receptor…
   a. The ß subunit exchanges its bound GDP for GTP.
   b. The GTP bound to the α subunit is dephosphorylated to form bound GDP.
   c. It dissociates into a free ß subunit and an $\alpha\gamma$ subunit.
   d. It dissociates into a free α subunit to which GTP is bound and a ßγ subunit.
   e. None of the above

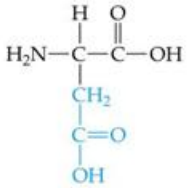
10. Acetylcholine acts at a G protein-linked receptor on heart muscle to make the heart beat more slowly. The effect is mediated by the α subunit of the G protein, which acts on a membrane K^+ channel. Which one of the following would enhance this effect of acetylcholine?
    a. A high concentration of a non-hydrolyzable analogue of GTP.
    b. Mutations in the acetylcholine receptor that weaken the interaction between the receptor and acetylcholine.
    c. Mutations in the α subunit of the G protein that resulted in a loss of GTPase activity.
    d. Mutations in the acetylcholine receptor that weaken the interaction between the receptor and the G protein.
    e. Both a and c would enhance the effect of acetylcholine in this signalling pathway.

11. Which one of the following statements is true?
    a. All hydrophilic signalling molecules bind to cell surface receptors that contain at least one transmembrane domain.
    b. All extracellular signalling molecules are transported across the plasma membrane by their receptor.
    c. A second messenger is an essential component of all signalling pathways that involve lipid-insoluble signalling molecules.
    d. All hydrophilic signalling molecules activate phosphorylation cascades that change the activity of target proteins in the cell.
    e. None of the above statements is true.

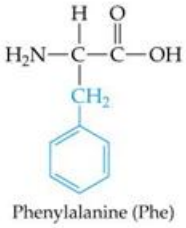
12. A phosphoglyceride:
    a. Consists of a central carbon atom to which carboxyl and amino groups as well as a hydrogen atom and a side chain are attached.
    b. Consists of a glycerol backbone to which two fatty acids are covalently attached, as well as a phosphate group linked to a hydrophilic head group.
    c. Consists of a pentose sugar to which a nitrogen-containing base and up to three phosphate groups are attached.
    d. Consists of a 4-ring hydrocarbon skeleton to which a hydroxyl group is attached at one end, and a hydrocarbon tail at the other end.

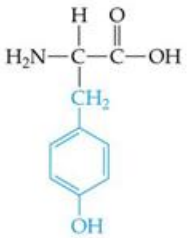
13. You observe that the heart rate of a BIO 1140 student increases dramatically immediately prior to beginning a midterm. You hypothesize that this increase in heart rate is driven by the stress hormone adrenaline acting through a G protein-coupled receptor to increase cAMP in heart cells, causing them to contract more rapidly. Which one of the following experimental approaches would allow you to test your hypothesis?
    a. Use of a non-hydrolyzable GTP analogue.
    b. Use of an adenylyl cylcase activator (e.g. forskolin).
    c. Use of a phosphodiesterase inhibitor (e.g. caffeine).
    d. All of the above are experimental approaches that would allow a G protein-coupled receptor pathway to be implicated in the control of heart rate in a BIO 1140 student.

14. Which one of the amino acids below might you expect to find in the transmembrane domain of an integral membrane protein?


Aspartic acid (Asp)


Threonine (Thr)


Phenylalanine (Phe)


Tyrosine (Tyr)

a. Aspartic acid
b. Threonine
c. Phenylalanine
d. Tyrosine
e. None of the above

15. You are investigating the mechanism through which a solute (we'll call it X), exits an animal cell across the plasma membrane. You observe that the transport of X exhibits saturation kinetics, depends on the presence of ATP but not Na^+ ions, and occurs even when a high concentration of X is present in the extracellular solution. The transport of X most likely occurs by:
a. Simple diffusion
b. Facilitated diffusion
c. Primary active transport
d. Secondary active transport

16. Membrane potential...
a. Refers to the capacity of the membrane to participate in functions such as transport, cell-to-cell signalling, formation of attachments to other cells etc.
b. Refers to the voltage gradient across the plasma membrane.
c. Is determined by the activity of the Na^+,K^+-ATPase in creating concentration gradients for Na^+ and K^+ movement, and by the passive permeability of the membrane to Na^+ and K^+ determined by voltage-gated ion channels.
d. Can be altered by opening/closing gated ion channels; such changes in membrane potential are used as communication signals by a variety of cells including blood cells, epithelial cells and cells of the immune system.
e. All of the above are true of membrane potential.

Written answer questions (use the marks specified to gauge the content needed for your answer; in all cases, the answer must not exceed the space indicated)

1. Membrane lipids are _____amphipathic_____ molecules, composed of a hydrophilic portion and a hydrophobic portion. These molecules form a bilayer that is held together by (**select one**) covalent OR non-covalent interactions and that both forms the backbone of the membrane and acts as a permeability barrier. By contrast, the specialized functions of different membranes are largely determined by the _____proteins_____they contain. (1 mark per answer)

2. It became possible to visualize the plasma membrane during the 1950's, with the advent of electron microscopy techniques. Because all membranes (plasma, cytoplasmic or nuclear, eukaryotic or prokaryotic) examined under the electron microscope had virtually the same appearance, a "unit membrane" model of membrane structure was proposed in which all membranes were exactly alike. As an up-and-coming cell biologist, you do not agree with this model and wish to carry out experiments to test its validity. Propose such an experiment, outlining the predicted results and explaining how it would test the "unit membrane" model of membrane structure. (3 marks)

This question can be answered in a variety of different ways. For example, one possibility would be to examine the lipid:protein ratio of different membranes, or the protein complement, or the ratios of different phosphoglycerides (e.g. phosphatidylcholine to phosphatidylethanolamine ratio). To answer this question, note that demonstrating differences in lipid and/or protein composition between different membranes would invalidate the "unit membrane" model, and then outline very briefly an experiment along the lines noted above, explaining what you might expect to see.

3. Distinguish between the endosymbiont theory and the cell theory. (2 marks)

The endosymbiont theory refers to the possible origins of mitochondria and chloroplasts as prokaryotic cells (aerobic bacteria and cyanobacteria, respectively) that established stable, symbiotic relationships with a larger prokaryotic host cell. By contrast, the cell theory is a fundamental theory that shapes the way we think about life. It states that all living organisms consist of one or more cells, that the cell is the basic unit of structure for all organisms, and that all cells arise from pre-existing cells.

4. What is the structural difference between a saturated and an unsaturated fatty acid? Explain the functional consequences of this structural difference in a membrane phosphoglyceride. (3 marks)

An unsaturated fatty acid contains one or more double bonds in its hydrocarbon chain, whereas in a saturated fatty acid, the carbons of the hydrocarbon chain are linked by single bonds. This structural difference has functional consequences for membrane phosphoglycerides. Membrane phosphoglycerides normally contain one saturated and one unsaturated fatty acid to achieve the correct degree of fluidity, because the presence of double bonds does not allow the fatty acids to pack as tightly as when the fatty acids are saturated. The degree of unsaturation can be altered (e.g. by desaturase enzymes) to adjust membrane fluidity.

5. What is FRAP and why is it significant? (2 marks)

FRAP stands for fluorescence recovery after photobleaching. In this technique, membrane components are labelled with a fluorescent probe. An area of the membrane is bleached using a laser, and the rate of recovery of fluorescence in the bleached area is then monitored. It is significant as a technique that can be used to investigate the fluidity or mobility of membrane components – the rate of recovery of fluorescence after bleaching indicates how rapidly the labelled compounds can laterally diffuse within the membrane.

6. A molecule normally enters a cell by means of a carrier protein. You wish to determine whether the carrier protein involved in this transport is functioning in facilitated diffusion or primary active transport. How might you distinguish between these possibilities? (5 marks)

To answer this question, focus on the differences between facilitated diffusion and primary active transport. For example, facilitated diffusion occurs in the direction of the diffusion gradient and the direction of transport can be reversed by reversing the diffusion gradient. By contrast, primary active transport has an intrinsic directionality that is independent of the diffusion gradient. Primary active transport requires ATP whereas facilitated diffusion does not; a cell deprived of ATP will not be able to carry out primary active transport but is still capable of facilitated diffusion. Craft your answer around these points, explaining how you would use these differences to differentiate between a facilitated diffusion mechanism and a primary active transport mechanism.

7. A rainbow trout red blood cell and a lamprey red blood cell are fused together. Rainbow trout red blood cells possess the band 3 Cl^-/HCO_3^- exchange protein, a multipass transmembrane protein that is linked to a network of proteins underlying the red cell membrane by a peripheral protein named ankyrin. Lamprey red blood cells lack the band 3 protein. The band 3 protein of the trout red blood cell is labelled with a fluorescent marker. When examined by fluorescence microscopy, what appearance would the cells have immediately after fusion? What about an hour later? Please explain your answers. (4 marks)

The key point in answering this question is to note that because band 3 is anchored to cellular structures, it is not free to move around in the membrane. Thus, following fusion with a cell that lacks band 3, band 3 will remain in the trout part of the hybrid cell. A top notch answer might contrast this situation with the results obtained by Frye and Edidin.

8. What do protein kinase A and receptor tyrosine kinase have in common? (1 mark)

Both are kinases, i.e. they phosphorylate proteins.

9. Contrast and compare the signalling pathways involving ligand-gated ion channels and G protein-coupled receptors. (4 marks)

To address this question, point out the similarities and differences between these pathways. Similarities would include the involvement of a cell-surface receptor that binds the primary messenger; in both cases the receptor would be a transmembrane protein that undergoes a conformational change upon binding of the messenger. There are, however, many differences. For example, activation of one receptor alters ion transport across the plasma membrane directly, whereas activation of the other stimulates a series of steps involving a G protein, an enzyme, a second messenger etc. In this type of question it is important to directly compare the two pathways as opposed to describing one and then the other.

10. Explain the steps involved in the activation of a cellular response by the interaction of an extracellular signal with a receptor tyrosine kinase. (3 marks)

Describe the steps in the pathway, i.e. the signal binds to the ligand-binding domain of the receptor, activating it so that it forms a dimer with another activated receptor. This step leads to phosphorylation of the receptor; the kinase of the activated receptor adds phosphate groups to tyrosine residues. The activated receptor can now build a signalling complex by phosphorylating and/or binding target proteins.

11. Design an experiment to test the hypothesis that urea excretion in a toadfish gill cell involves a G protein-coupled receptor and signalling pathway. (4 marks)

The key here is to implicate a G protein by manipulating G protein activity, thereby changing the response (which is urea excretion, and is what should be measured – you should predict the impact of your experimental manipulations on urea excretion). For example, providing the cell with a GTP analogue that cannot be hydrolyzed will permanently activate the G protein (because G proteins are inactivated by hydrolyzing GTP to GDP) and would, if urea excretion involves a G protein-coupled receptor and signalling pathway, increase urea excretion. Having come up with an experiment, explain the rationale for your experiment and the predicted results, explaining how they would support (or refute) the hypothesis.

12. Explain how the structure of a G protein is related to its function. (4 marks)

Describe the structure of a G protein, e.g. note that it is a fatty-acid anchored membrane protein, that it is a heterotrimer and that it binds GTP or GDP, then explain how these structural features enable it to function as part of a signal transduction pathway. For example, its membrane anchorage is important in linking it to an activated receptor. It functions as a molecular switch because it is active when GTP is bound and inactive with GDP bound. When active, it splits into two components (the α subunit and the ßγ subunit), each of which can carry out activities in the cell. And so on…