TRASK
Zool 3200: Cell Biology
Exam 3
3/18/16

Answer each of the following questions in the space provided; circle the BEST answer or answers for each multiple choice question, and circle either True or False when asked a True/False question. For every question, explain your answers when requested to do so. Kick butt! (70 points total)

1. How is it possible that β-sheets (beta sheets) exist in thousands of different proteins regardless of their primary structure? Explain. (2 points)
   β-sheet structures are maintained by non-covalent chemical bonds between atoms in a polypeptide’s backbone rather than by bonds between atoms in side chains. Therefore, because side chains are not involved in the maintenance of these structures, their composition does not matter.

2. In the diagram of a protein shown below right, which of the identified protein strands are likely to associate together in the form of a β (beta) sheet? Are the β (beta) strands in this protein oriented in a parallel or antiparallel manner? (2 points)
   Strands b, c and f likely form a β-sheet; these strands run antiparallel to each other.

3. Consider a eukaryotic protein with the amino acid sequence:
   Ala-Ser-Gly-His-Val-Tyr-Ile-Arg-Phe-Glu-Met-Asp-Leu-Thr-Trp-Gln-Gly

   If this sequence were to form a beta-strand within a beta-sheet, what might you be able to say about the sheet if you assume that each of the other strands in the sheet had the same type of amino acid distribution? (2 points)
   If this sequence formed a strand in a β-sheet, the strand (and possibly the sheet) would be amphipathic because every other amino acid is hydrophobic in nature. Because the strand/sheet is amphipathic, the hydrophobic “face” of the sheet would not interact well with the polar environment inside or outside of the cell. Rather, this non-polar, hydrophobic face of the sheet would either interact with a second strand/sheet that is also hydrophobic (like prion proteins or β-amyloid) or interact with the non-polar lipids in a biological membrane. If the latter is true, the β-sheet may be part of a channel-forming protein.
4. Which of the following structures could the following polypeptide form? Use the helix wheel projection if you think that it will be helpful. (1 point)
Gly-Leu-Asp-Glu-Ile-Ala-Lys-Ser-Val-Arg-His-Phe-Cys-His-Ala-Ile

a.) A hydrophobic α helix
b.) an amphipathic α helix
c.) a hydrophilic α helix
d.) a hydrophobic β sheet
e.) an amphipathic β sheet

5. True / False. The following sequence could form an alpha helix that serves as the transmembrane region of an integral membrane protein. (1 point)
Gly-Leu-Ile-Gly-Ile-Ala-Leu-Pro-Val-Trp-Val-Phe-Cys-Val-Ala-Ile

6. In the protein shown below, the highlighted region represents the ATP-binding domain of a tyrosine kinase. This is only one of a large group of proteins with similar ATP-binding regions. What do we call a collection of proteins with similar domains? Would this be a structural or functional domain? Explain. After binding ATP, what does the protein do (specifically) with the trinucleotide? (4 points)

We collectively call proteins with similar regions a protein family. Because this region of similarity is responsible for performing a function (i.e., ATP binding), it is a functional domain. However, since function depends upon structure, it’s likely that the ATP binding domain in other family members have similar structures as well. After binding ATP, because this is a kinase, the protein will transfer the terminal phosphate from ATP to a tyrosine side chain on another protein.
7. Consider the following scenario for the next two questions: the movement of a ciliate protozoan is controlled by a protein called Racer X. When this binds to another protein found at the base of the cilia, it stimulates the cilia to beat faster and the protozoan swims faster. This ciliary protein, Speed, can be phosphorylated and only binds to Racer X in its phosphorylated form. You have identified the threonine residue at which Speed is phosphorylated and have changed it to an alanine residue.

How would you expect the mutant protozoan to behave? (1 point)
   a. Sometimes swims fast.
   b. Always swims fast.
   c. Never swims fast.
   d. Alternates between swimming fast and slow.
   e. Unable to move at all.

8. Which of the following mutant protozoa would swim fast all of the time? (1 point)
   a. One lacking the protein kinase that phosphorylates the Speed protein.
   b. One lacking the Speed protein.
   c. One lacking the Racer X protein.
   d. One in which the protein phosphatase that dephosphorylates the speed protein is produced in much greater amounts than normal.
   e. One lacking the protein phosphatase.

9. Phosphatases can act to turn proteins _____ on or off _____ (on/off). GAPs, on the other hand, can act to turn proteins _____ off _____ (on/off; identify the correct answer[s] for each blank; 3 points)

10. The activity of ‘your favorite protein’ (YFP) is carefully regulated by two other proteins, a guanine nucleotide-exchange factor (GEF) and a GTP-ase activating protein (GAP) that stimulates the rapid hydrolysis of GTP by YFP. The activities of both GNEF and GAP are in turn also regulated. Which of the following changes in GAP and GEF protein activity might cause YFP to be active less often? (2 points)
    a. A permanently active GNEF.
    c. A permanently active GAP.
    d. A non-functional GAP.

11. The activation of many proteins, including those involved in blood clotting, is dependent upon a proteolytic cleavage. In these cases, inactive precursor proteins (called zymogens) remain ready for action, but inactive until signaled. When required, a proteinase cuts off a segment of the inactive zymogen; removal of this protein segment results in activation of it. What advantage would a protein activation model like this have? Explain how removal of a part of a protein might result in an increase in its activity. What step(s) is/are necessary to inactivate such a protein? (3 points)
One major advantage of this method is that the protein can be activated very quickly. Removal of a portion of the protein results in a shape change; the shape change results in a change (increase) in activity. Sometimes, however, cleavage of a segment results in the un-shielding of an active site in the protein. To inactivate a protein that is activated by cleavage, the protein must be degraded.

12. The lipid portion of biological membranes is comprised of mostly phospholipids and cholesterol. Why is this true? Why are other biological lipids such as tri-glycerides not used to make biological membranes? (3 points)
   Both phospholipids and cholesterol are amphipathic lipids and, as such, are able to form a bilayer in the polar environment of the water that all cells inhabit. The amphipathic nature, with the polar ends aligned with the polar water and the non-polar ends aligned with each other, allows for membrane formation. Triglycerides do not have this amphipathic property (they are completely non-polar/hydrophobic), which precludes their ability to interact with water in the same way that amphipathic lipids do. Thus, they are not used to make biological membranes.

13. Predict which one of the following organisms will have the highest percentage of unsaturated fatty acid chains in their membranes. (1 point)
   a. Antarctic fish
   b. Desert iguana
   c. Polar bear
   d. Humans
   e. Thermophilic bacteria

14. It is true that, in the legs of a reindeer, the membranes of the cells near the hoof have a higher proportion of unsaturated fatty acids than the membranes of cells in the rest of the leg. Does this make any sense? Explain. (2 points)
   Yes, it makes sense. Reindeer live in cold environments in which their lower limbs are often covered with snow. The cells in reindeer legs still have to function even in this cold environment—and environment that would normally result in fairly rigid lipid bilayers (think of a stick of butter that has just been taken out of the refrigerator). In order to allow for their function, the cells have to combat the cold environment that would normally make their membranes less fluid. To do that, the cells in reindeer legs have to incorporate more unsaturated fatty acids (and possibly also less cholesterol and more lipids with short-chain fatty acids)
15. A small membrane vesicle containing a transmembrane protein is shown in the figure to the right. Assume that this membrane vesicle is in the cytoplasm of a cell and will eventually undergo fusion with a lysosome. Which side of the vesicle’s membrane (the solid line or the dotted line) will be associated with the cytosol? Which end of the transmembrane protein (N-end or C-end) will be exposed to the lumen of the lysosome? (2 points)

The solid line is associated with the cytosol, and the N-terminal end of the protein will be exposed in the lumen of the lysosome.
16. When a lipid bilayer is torn, why doesn’t it “repair itself by forming a ‘hemi-micelle’ cap at the edges as shown in the figure below? (2 points)

In the hemi-micelle pictured, there is too much space between the phospholipids—the spacing would allow for exposure of the fatty acid tails to the polar aqueous environment and this exposure would be energetically unfavorable. The more favorable option is to re-seal the tear by allowing the bilayer to reform.

17. Which of the following could be isolated from a biologic membrane via significantly altering the pH? (1 point)
   a. An integral membrane protein
   b. A transmembrane protein
   c. A lipid-linked protein
   d. A peripheral membrane protein

18. If an ion for which the cell membrane does not have a transport protein is injected into the blood in significant amounts, which of the following would occur? (1 point)
   a. The cell would swell and eventually burst.
   b. The volume of the blood would decrease.
   c. Blood proteins would diffuse into the cells to compensate.
   d. The cells would shrivel due to osmotic movement of water out of the cell.
   e. The speed of blood flow through the vessels would increase.

19. To rectify the condition described in the question above, intravenous administration of which of the following solution(s) would be necessary? (1 point)
   a. A solution containing a low concentration of ions (lower than what is inside a typical cell).
   b. A solution containing a high concentration of ions (higher than what is inside a typical cell).
   c. An isotonic solution containing the same concentration of ions that is inside of a typical cell.

20. Which of the following would most likely move into a cell (across the cell membrane) by simple diffusion? (1 point)
   a. A K⁺ ion.
   b. A molecule of polyethylene glycol.
   c. A steroid hormone.
   d. A glycerol molecule.
   e. glucose molecule.
21. Which of the following would most likely move into a cell (across the cell membrane) by facilitated diffusion? (1 point)
   a. A K⁺ ion.
   b. A molecule of polyethylene glycol.
   c. A steroid hormone.
   d. A protein
   e. A glucose molecule.

22. Water most easily moves through cell membranes via: (1 point)
   a. Facilitated diffusion
   b. Simple diffusion
   c. Active transport
   d. Co-transport
   e. Symport
   f. Both d and e.
   g. C, d and e.

23. Three phospholipids X, Y, and Z are distributed in the plasma membrane as indicated in the figure below. For which of these phospholipids does a flippase most likely exist? (1 point)
   a. X
   b. Y
   c. Z
   d. Both X and Y
   e. Both Y and Z
   f. Both X and Z
   g. None of them; phospholipids rarely flip between membrane leaflets.

24. The cell cortex underlies a cell membrane to provide structural support to an otherwise fragile plasma membrane. The exterior surface of a cell membrane is “decorated” with carbohydrates that surround the cell in what is called a ______glycocalyx_______. The function of this “decoration” is: _____________________________ (3 points)
   The glycocalyx has several potential functions including adhesion, protection and to attract water for hydration.
25. Refer to the diagram to the left when answering the following questions:

(2 points) The cell-cell junctions identified by the #2 are mediated by what two proteins? This type of junction located at the apical surface of epithelial cells functions to: Claudins and occludins. These tight junctions function to prevent molecular movement between adjacent cells.

26. (1 point) The cell-cell junctions depicted in #s 3 & 4 both depend upon transmembrane cadherins proteins that associate via extracellular “homotypic” interactions.

27. (2 points) The cell-cell junctions identified by the #5 are made up of connexin proteins, and function to: allow small communication molecules (e.g., ions) to quickly convey information to an adjacent cell without the possibility of being diluted in the extracellular space.

28. True / False: Although cholesterol is a hydrophobic molecule, it has a hydrophilic head group like all other membrane lipids. (1 point)

29. True / False: Phosphatidylserine is the most abundant type of phospholipid found in cell membranes. (1 point)

30. True / False: Phospholipids will spontaneously form liposomes in nonpolar solvents. (1 point)

31. True / False: Membrane lipids diffuse within the plane of the membrane. (1 point)

32. Cierto / Falso: Glycolipids are occasionally flipped between the two leaflets of the cell membrane. (1 point)

33. True / False: CO₂ and O₂ are water-soluble molecules that are able to simply diffuse across cell membranes. (1 point)

34. True / False: Transporters are similar to channels, except that they are larger, allowing large molecules such as folded proteins, as well as smaller organic molecules to pass through them. (1 point)
35. True / False: Carrier proteins undergo transitions between different conformations, depending on whether the substrate-binding pocket is empty or occupied. (1 point)

36. True / False: The net negative charge on the cytosolic side of the membrane contributes to an increase in the rate of glucose import into the cell by a symporter. (1 point)

37. A hungry yeast cell lands in a vat of grape juice and begins to feast on the sugars there, producing carbon dioxide and ethanol in the process:

\[
C_6H_{12}O_6 + 2ADP + 2P_i + H^+ \rightarrow 2CO_2 + 2CH_3CH_2OH + 2ATP + 2H_2O
\]

Unfortunately, the grape juice is contaminated with proteases that attack some of the transport proteins in the yeast cell membrane, and the yeast cell dies. Which of the following could account for the yeast cell’s demise? (1 point)
   a. toxic buildup of carbon dioxide inside the cell
   b. toxic buildup of ethanol inside the cell
   c. diffusion of ATP out of the cell
   d. inability to import sugar into the cell

38. The stimulation of auditory nerves depends on the opening and closing of channels in the auditory hair cells. Which type of gating mechanism do these cells use? (1 point)
   a. voltage-gated
   b. extracellular ligand-gated
   c. intracellular ligand-gated
   d. mechanically-gated

39. In what state would the voltage-gated sodium channels of an axon be at each of the following times/events? Use the diagram of an action potential provided if you think that it would help. (4 points)
   1.) initial stimulus –closed
   2.) at + 40 mV –either open (immediately before reaching -40mV) or inactivated (at exactly +40mV)
   3.) When voltage-gated potassium channels are open –inactive
   4.) Threshold –open
40. Studies on the squid giant axon were instrumental in our current understanding of how action potentials are generated. You decide to do some experiments on the squid giant neuron yourself. You isolate this neuron, and then place it in a NaCl solution with double the amount of extracellular Na\(^+\) (double the extracellular to 300mM NaCl versus the usual 150mM). Recall that typical intracellular sodium concentrations are around 10mM. First, use the Nernst equation to calculate the $V_m$ at which Na\(^+\) will reach equilibrium given the altered extracellular solution. (3 points)

$$V_m = 62 \log \frac{C_o}{C_i}$$
$$V_m = 62 \log \frac{300}{10}$$
$$V_m = 62 \times \log 30$$
$$V_m = 62 \times 1.477$$
$$V_m = 91.6 \text{ mV}$$

41. Secondly, how do you expect that this change in extracellular sodium might affect an action potential in this neuron should a depolarizing stimulus be received at the neuron cell body? (2 points)

Assuming that the cell is not very permeable to sodium while it’s at rest (similar to a typical cell), this change in extracellular sodium will establish an even larger gradient (electrical and chemical) than is usual. When the cell receives a depolarizing stimulus, sodium will still rush in—possibly even faster than usual, though this depends upon whether the channels are already saturated at physiologic sodium concentrations. If sodium influx is, indeed, faster, the slope of the depolarization may be steeper than usual. Since the sodium inactivation gates close via a “timer” of sorts, a steeper curve may result in an even higher than normal $V_m$ peak before the inactivation gates close.

42. Since you went to so much trouble to isolate the squid neuron, you decide to do an additional experiment. After completing your Na\(^+\) experiment, you restore the extracellular fluid with a physiologic one (including all the usual extracellular ions) and allow the squid neuron to equilibrate so that its resting $V_m$ is restored to normal. You then decide to see what happens if you electrically stimulate the squid axon in the middle, directly between the cell body and the axon terminus. Which direction(s) will the depolarization ‘signal’ travel down the axon? Explain (3 points)

The signal will travel in both directions, toward the cell body and toward the axon terminus. This is because when the axon is at rest, the voltage-gated sodium channels will be in their closed conformation all along the axon’s length. When the stimulus is received in the center of the axon the activation gate will open and sodium will rush in, depolarizing the axon and opening adjacent voltage-gated channels—on either side of the stimulus. The reason that the signal normally travels only one direction, toward the axon terminus, is that voltage gated sodium channels “upstream” of where the signal is at any given time have already been activated and subsequently inactivated. The channels are in their inactivated states and unable to open in the “backward” direction. In this scenario, no channels are inactive when the signal is received, so all channels can be responsive to the stimulus.