

NAME: _____

STUDENT #: _____

BIO 1140 Introduction to cell biology

MIDTERM #1

February 8th, 2014

Dr. K.M. Gilmour

MULTIPLE CHOICE QUESTIONNAIRE KK

Instructions:

1. Make sure that you have a complete test package. You should have a set of multiple choice questions with a written-answer questionnaire, and a Scantron. Both components must be returned at the end of the midterm. Please make sure that this questionnaire includes 8 pages.
2. Fill in the Scantron with your name, student number and course code **BIO 1140 KK**.
3. You will have 75 min to complete the midterm.
4. Please note that answers written in pencil cannot be submitted for re-marking.

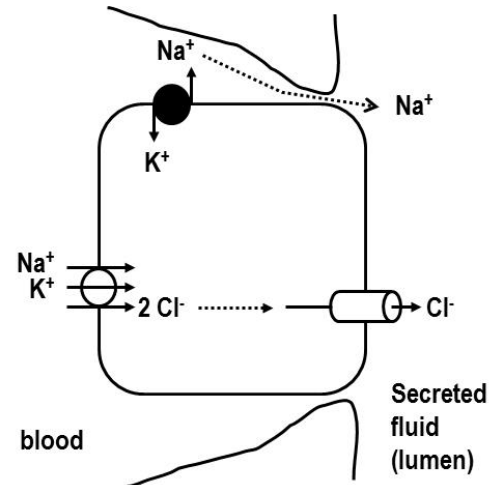
Answer the following 20 multiple choice questions **on the Scantron sheet** provided. Choose only one answer from among the choices. (20 marks)

1. The fluid mosaic model of the cell membrane was proposed by:

- a. Singer and Nicolson
- b. Rudolf Virchow
- c. Frye and Ediden
- d. Peter Mitchell
- e. Gorter and Grendel

2. In the schematic at right, Cl^- enters the cell by means of...

- a. A channel
- b. A co-transporter
- c. An exchanger
- d. A uniporter

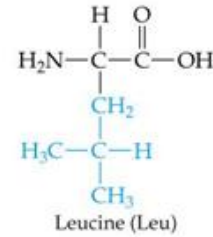
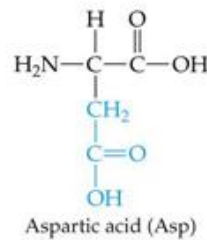
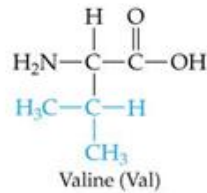
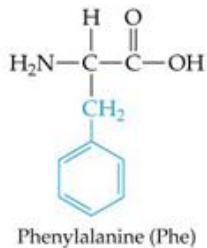


3. A mitochondrion is approximately...

- a. 2×10^{-3} m long
- b. $0.02 \mu\text{m}$ long
- c. 2×10^3 nm long
- d. 2×10^3 mm long
- e. None of the above

4. The semi-palmated sandpiper feasts on PUFA-rich mudshrimp before setting off on a 3-day non-stop, 4,500 km trans-Atlantic migration flight. The PUFA-rich diet is thought to improve the bird's migratory capacity by:
- Increasing the citrate synthase activity of the flight muscles to enhance ATP production.
 - Increasing the PUFA content of the flight muscle cell membranes to enhance fatty acid entry (fatty acids are the main fuel used by the flight muscles during the trans-oceanic flight).
 - Increasing fat reserves to provide the energy necessary to fuel the trans-oceanic flight.
 - All of the above
5. Fermentation...
- Occurs in the skeletal muscle of anoxic goldfish or human athletes engaged in high-intensity exercise.
 - Functions to regenerate NAD^+ so that ATP production by glycolysis can continue in the absence of O_2 .
 - Generates energy through the production of molecules such as ethanol or lactate.
 - All of a, b and c are true of fermentation.
 - Only a and b are true of fermentation.
6. Feedback regulation refers to...
- The adjustment of membrane composition to maintain membrane fluidity as environmental temperature changes.
 - A membrane that allows selected molecules to pass while preventing or impeding the passage of other molecules.
 - The voltage difference across the plasma membrane, i.e. between the interior and exterior of a cell.
 - Regulation of the rate of a reaction by its products and substrates.
 - The generation of ATP by a proton gradient created by electron transfer.
7. Which one of the following statements about the electron transport chain is **not** correct?
- The electron transport chain consists primarily of integral membrane proteins organized into large complexes that are freely mobile along the inner mitochondrial membrane.
 - In addition to transferring electrons, complexes I, III and IV also pump protons from the mitochondrial matrix to the intermembrane space, creating a proton gradient across the inner mitochondrial membrane.
 - Ubiquinone, a hydrophobic coenzyme localized to the nonpolar interior of the membrane, and cytochrome c, a peripheral membrane protein located on the intermembrane space side of the membrane, play key roles in the electron transport chain by carrying electrons between the protein complexes.
 - The direction of transfer of electrons along the electron transport chain is determined by the affinity of the various carriers for electrons, with O_2 being the ultimate electron donor
8. Which one of the following equations describes glycolysis?
- $10 \text{ NADH} + 10 \text{ H}^+ + 5 \text{ O}_2 + 30 \text{ ADP} + 30 \text{ Pi} \rightarrow 10 \text{ NAD}^+ + 10 \text{ H}_2\text{O} + 30 \text{ ATP}$
 - $\text{glucose} + 2 \text{ NAD}^+ + 2 \text{ ADP} + 2 \text{ Pi} \rightarrow 2 \text{ pyruvate} + 2 \text{ NADH} + 2 \text{ ATP}$
 - $\text{acetyl-CoA} + 3 \text{ NAD}^+ + \text{FAD} + \text{ADP} + \text{Pi} \rightarrow 2 \text{ CO}_2 + 3 \text{ NADH} + \text{FADH}_2 + \text{ATP} + \text{CoA}$
 - $\text{pyruvate} + \text{NAD}^+ + \text{CoA} \rightarrow \text{acetyl-CoA} + \text{NADH} + \text{CO}_2$
 - None of the above equations describes glycolysis.

9. You are attempting to characterize a novel receptor. You note that the receptor includes a ligand-binding domain and a single transmembrane domain, and that dimerization occurs when the receptor is activated. The novel receptor probably belongs to the family of...
- G protein-coupled receptors
 - Steroid hormone receptors
 - Receptor tyrosine kinases
 - None of the above
10. Which one of the amino acids below would you **not** expect to find in the transmembrane domain of an integral membrane protein?



- Phenylalanine
 - Valine
 - Aspartic acid
 - Leucine
11. Organism size typically is increased by increasing cell number rather than cell size. Why?
- A single large cell has a higher SA:V ratio than many small cells.
 - The slow rate of diffusion can become limiting to cellular processes within a large cell – small cells keep diffusion distances low.
 - Maintaining adequate substrate concentrations for the biochemical reactions that support a cell becomes easier as cell size increases.
 - All of a, b and c contribute to the tendency for organism size to increase by increasing cell number rather than cell size.
 - None of a, b or c explains the tendency for organism size to increase by increasing cell number rather than cell size.
12. To investigate the nature of a membrane protein, you treat an isolated membrane with the enzyme phospholipase C and then probe the membrane with a fluorescent marker for the protein of interest. A strong fluorescent signal is observed. By contrast, membranes probed with the fluorescent marker after changes in solution pH or ionic strength show no fluorescence. Which one of the following conclusions is consistent with your observations?
- The protein of interest is linked to the membrane by a glycosylphosphatidylinositol (GPI) anchor.
 - The protein of interest is an integral protein.
 - The protein of interest behaves like a peripheral protein.
 - The protein of interest is anchored to the inner (cytosolic) leaflet of the lipid bilayer via a covalent interaction with a membrane fatty acid.

13. *Escherichia coli* are suddenly expelled from a warm human intestine into cold water. Which of the following adjustments might occur to maintain membrane fluidity?
- Increase the proportion of unsaturated hydrocarbon tails in its membrane phospholipids.
 - Increase the amount of cholesterol in the membrane.
 - Increase the length of the hydrocarbon tails in its membrane phospholipids.
 - Increase the proportion of phosphatidylcholine relative to phosphatidylethanolamine (i.e. increase PC:PE).
 - Both a and b would be appropriate responses to maintain membrane fluidity following the change in temperature.
14. A sphingolipid...
- Consists of a central carbon atom to which carboxyl and amino groups as well as a hydrogen atom and a side chain (or 'R' group) are attached.
 - 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.
 - Consists of a pentose sugar to which a nitrogen-containing base and up to three phosphate groups are attached.
 - Consists of a hydrophilic head group linked through a phosphate group to a sphingosine molecule that is carrying a single fatty acid.
 - 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
15. If the cellular concentration of ATP falls...
- Cellular AMP levels will decrease, stimulating the glycolytic enzyme phosphofructokinase.
 - The low ATP levels will stimulate pyruvate dehydrogenase (PDH).
 - Cellular ADP levels will fall, increasing the rate of oxidative phosphorylation.
 - NADH levels will increase, increasing the rate of the citric acid cycle and pyruvate oxidation.
 - All of the above should occur if the cellular concentration of ATP falls.
16. The Cell Theory states...
- That all animals consist of one or more cells.
 - That the cell is the basic unit of structure for all animals.
 - That all cells arise only from pre-existing cells.
 - All of the above are tenets of the Cell Theory.
 - None of the above is a tenet of the Cell Theory.
17. Which one of the following statements is true?
- Extracellular signalling molecules are transported across the plasma membrane by their receptor.
 - Lipophilic signalling molecules activate phosphorylation cascades that change the activity of target proteins in the cell.
 - Hydrophilic signalling molecules bind to cell surface receptors that contain at least one transmembrane domain.
 - A second messenger is an essential component of all signalling pathways that involve lipid-insoluble signalling molecules.
 - None of the above statements is true.

18. Which one of the following statements about ATP synthase is correct?
- a. ATP synthase is found in the plasma membrane of prokaryotic cells.
 - b. The F_0 component of ATP synthase functions as a proton translocator, hydrolyzing ATP to move H^+ across a membrane.
 - c. ATP synthase is a P-type pump that is transiently phosphorylated as part of its pumping mechanism.
 - d. ATP synthase is a peripheral membrane protein.
 - e. The movement of $10 H^+$ through ATP synthase hydrolyzes approximately 3 ATP.
19. An allosteric activator...
- a. Increases the activity of an enzyme by catalyzing the addition to the enzyme of an inorganic phosphate group.
 - b. Increases the activity of an enzyme by facilitating binding of the substrate to the active site of the enzyme.
 - c. Increases the activity of an enzyme by binding to a regulatory site that is distinct from the active site of the enzyme.
 - d. Alters the activity of one or more enzymes in a pathway so as enhance activity of the pathway.
 - e. None of the above adequately describes an allosteric activator.
20. Based on the chemiosmotic model of ATP synthesis, treatment of isolated mitochondria with the H^+ ionophore 2,4-dinitrophenol would be predicted to...
- a. Inhibit ATP production by blocking the electron transport chain.
 - b. Lower the pH of the incubation solution by allowing protons to escape through the outer mitochondrial membrane.
 - c. Increase ATP production by increasing the proton supply in the mitochondrial matrix.
 - d. Inhibit ATP production by dissipating the proton gradient across the inner mitochondrial membrane.
 - e. None of the above describes the results expected from treatment of isolated mitochondria with 2,4-dinitrophenol.

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Answer the following questions **on the questionnaire in the space** provided (and only in the space provided – answers written on the back of the page will not be marked). (20 marks)

1. Complete the following statements. (1 mark per answer)

- a. *Elysia chlorotica* exhibits kleptoplasty (1 mark); that is, it “steals” chloroplasts from the algae on which it feeds.
- b. Membrane asymmetry (1 mark) refers to the differential distribution of lipids and/or proteins into the two halves of the lipid bilayer.
- c. A molecule that has both hydrophobic and hydrophilic regions is said to be amphipathic (1 mark).
- d. ATP synthesis in which a phosphate group is transferred from a phosphorylated intermediate to ADP is termed substrate-level phosphorylation (1 mark).

2. What is *Saccharomyces cerevisiae* and why does it matter (i.e. why is it significant within the context of cell biology)? (1 mark)

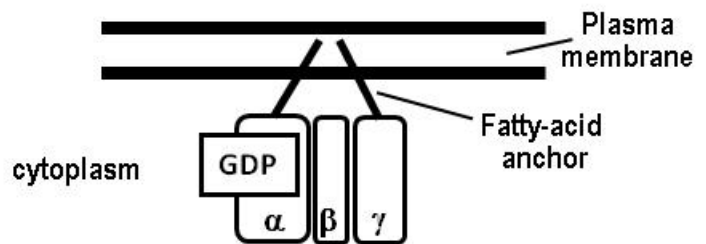
Saccharomyces cerevisiae is a model organism, specifically, a fungus. **(0.5 marks)**

It matters within the context of cell biology because it is a small, simple eukaryote that is easy to grow or culture in the lab (so experimentally advantageous) but that nevertheless exhibits many similarities to more complex eukaryotes (so can be used to provide insight into them). **(0.5 marks)**

3. Sketch and label a G protein. Use your sketch to explain how the G protein functions as a molecular switch in signal transduction. (4 marks)

With GTP bound to the α subunit, the G protein is activated and splits into α and $\beta\gamma$ subunits, each of which can carry out signalling activities. **(1 mark)**

When the α subunit hydrolyzes GTP to GDP, the protein is inactivated and adopts the conformation illustrated in the sketch. **(1 mark)**



- 1 mark for showing/labelling three different subunits and indicating GTP or GDP binding
- 0.5 marks for showing/labelling fatty-acid anchorage
- 0.5 marks for showing or implying location (anchored to membrane on cytosolic side)
- Note that either the inactive or active form can be used for the sketch.

4. Distinguish between a ligand-gated channel and a ligand-activated transcription factor. (2 marks)

A ligand-gated channel is activated by a water-soluble (or polar, or hydrophilic) signalling molecule, whereas a ligand-activated transcription factor is activated by a lipid-soluble (non-polar, hydrophobic, lipophilic) signalling molecule. **(1 mark)**

A ligand-gated channel is a membrane protein receptor, whereas a ligand-activated transcription factor is an intracellular protein receptor. **(1 mark)**

When activated by a signalling molecule, a ligand-gated channel opens or closes (to change membrane potential), whereas a ligand-activated transcription factor binds to (response elements within the promoter regions of genes in) DNA, increasing or decreasing the rate of transcription. **(1 mark)**

Two points needed for 2 marks.

5. The figures at right present data generated in experiments designed to identify the mechanism through which glucose enters an intestinal cell in a goldfish. What can be concluded from these data? Please explain your reasoning. (3 marks)

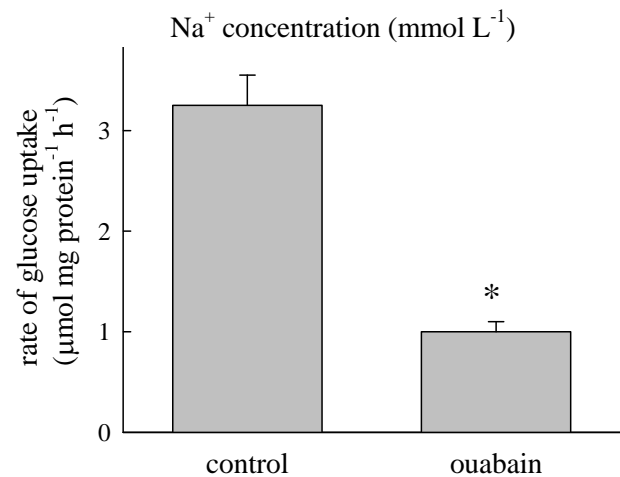
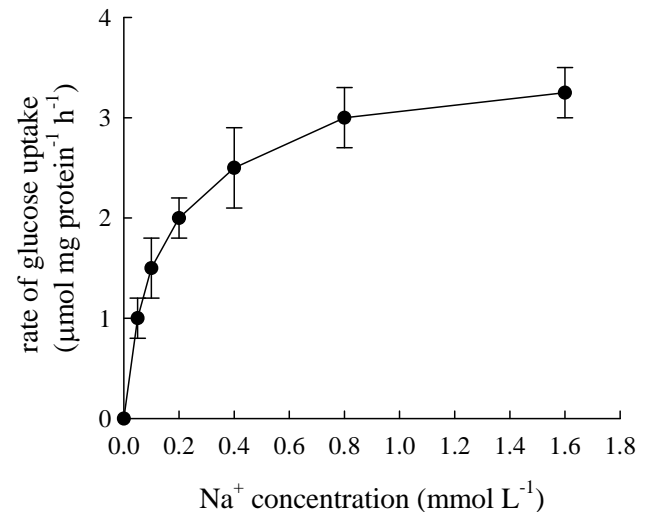
The conclusion derived from these data is that glucose enters an intestinal cell in a goldfish via a secondary active transport mechanism. **(1 mark)**

The first figure illustrates saturation kinetics, indicating that a transport protein is involved. **(0.5 marks)**

This figure also indicates that glucose movement is Na^+ dependent, which is characteristic of secondary active transport in an animal cell, which is driven by the Na^+, K^+ -ATPase (NKA). **(0.5 marks)**

The second figure demonstrates that glucose movement is dependent upon NKA, because ouabain, an inhibitor of NKA, inhibits glucose transport. **(1 mark)**

Thus, movement of glucose is dependent upon the Na^+ gradient established by NKA, a primary pump. This fits the description of secondary active transport.



6. Discuss the structure of the mitochondrion with reference to its endosymbiotic origin and its function as the 'energy powerhouse' of the cell. (6 marks)

The structure of the mitochondrion reflects both its endosymbiotic origins and its function as the 'energy powerhouse' of the cell.

According to the endosymbiont theory, mitochondria originated by the incorporation of an aerobic prokaryote into a larger prokaryotic host cell. The aerobic prokaryote was engulfed by the host cell but not digested; instead, it formed a stable symbiotic association. If the endosymbiont theory is correct, then the mitochondrion should possess the structure of a prokaryotic cell. **(1 mark)**

A number of structural features of mitochondria are very similar to structural features of prokaryotes:

- Their basic dimensions are similar (a few microns in the longest dimension) **(1 mark)**
- Both possess genetic material consisting of a single, circular chromosome of naked DNA (i.e. DNA that is not associated with protein) **(1 mark)**
- The size and structure of their ribosomes are similar (smaller and simpler than eukaryotic ribosomes) **(1 mark)**
- The absence of sterols from the inner mitochondrial membrane and the prokaryotic cell plasma membrane is another similarity **(1 mark)**
- Porins are found in the outer mitochondrial membrane and in the plasma membrane of some prokaryotic cells **(1 mark)**
- Mitochondrial ribosomal RNA (rRNA) is similar to prokaryotic/bacterial rRNA **(1 mark)**
- Mitochondria are surrounded by two membranes; the inner is derived from the plasma membrane of the endosymbiont, the outer from the host cell **(0.5 marks)**
- Note: binary fission is not a structure **(so no marks)**

The mitochondrion is where pyruvate oxidation, the citric acid cycle and oxidative phosphorylation take place. Since these processes yield the bulk of the ATP generated from glucose catabolism, the mitochondrion is considered to be the 'energy powerhouse' of the cell. **(1 mark)**

Several structural features of the mitochondrion are essential to its role in ATP generation.

- The presence of porins in the outer mitochondrial membrane is a structural feature that is critical to allowing molecules to enter (e.g. pyruvate) or exit (e.g. ATP) the mitochondrion. **(1 mark)**
- The inner mitochondrial membrane lacks such non-selective transport routes and therefore functions as a permeability barrier. This is important in, for example, allowing a proton gradient between the mitochondrial matrix and the intermembrane space to be established. **(1 mark)**
- The inner membrane is highly folded into cristae that greatly increase surface area. High SA is important to provide space for the protein complexes needed for electron transport and ATP synthesis (the inner membrane is ~75% protein). **(1 mark)**
- The mitochondrial matrix is rich in the enzymes required for pyruvate oxidation and the citric acid cycle. **(1 mark)**
- The lack of sterols in the inner mitochondrial membrane results in higher fluidity, which facilitates protein complex (electron transport chain) movement in membrane. **(1 mark)**

- The inner mitochondrial membrane contains transport proteins that function in allowing substrates to enter the mitochondrion (e.g. pyruvate, ADP, Pi) and in transporting products (ATP) out. **(1 mark)**

Total marks to a maximum of 6. For full marks, mitochondrial structure must be explicitly compared to prokaryotic structure (in at least one way) AND mitochondrial structure must be explicitly linked to mitochondrial function (in at least one way).