

NAME: _____

STUDENT #: _____

BIO 1140 Introduction to cell biology

MIDTERM #1

February 8th, 2014

Dr. K.M. Gilmour

MULTIPLE CHOICE QUESTIONNAIRE GG

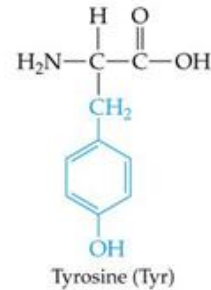
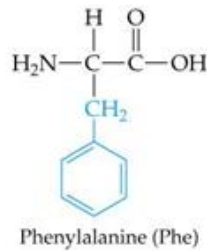
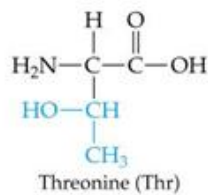
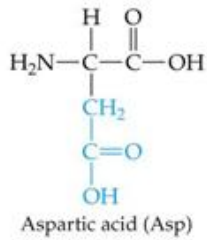
Instructions:

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 GG**.
3. You will have 75 min to complete the midterm.
4. Please note that answers written in pencil cannot be submitted for re-marking.

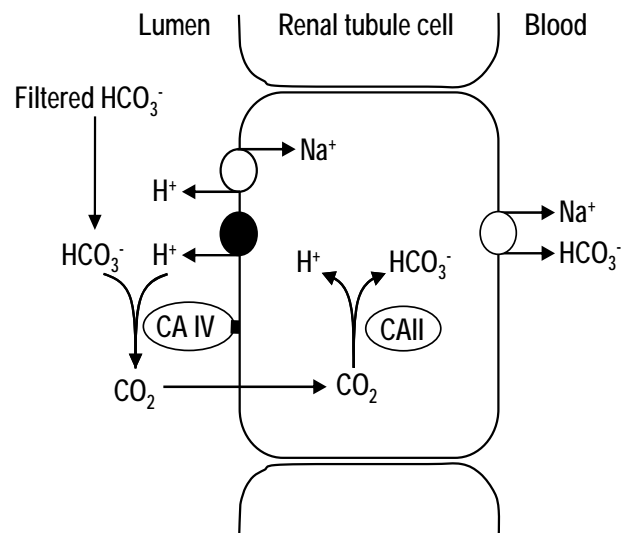
Answer the following 20 multiple choice questions **on the Scantron sheet** provided. Choose only one answer from among the choices. (20 marks)

1. 'Kleptoplasty' ...
 - a. Is observed in the sea slug *Caenorhabditis elegans*, which 'steals' chloroplasts from the algae on which it feeds.
 - b. Is a modern-day phenomenon that is often used to support the endosymbiosis hypothesis for the origins of mitochondria and chloroplasts.
 - c. Results in a 'solar-powered' or photosynthetic animal, i.e. an animal that is able to transform chemical energy into light energy.
 - d. All of the above are true of kleptoplasty.
 - e. None of the above is true of kleptoplasty.
2. A sterol ...
 - a. 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.
 - 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 hydrophilic head group linked through a phosphate group to a sphingosine molecule that is carrying a single fatty acid.
 - e. 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
3. The chemiosmotic model of ATP synthesis was proposed by:
 - a. Singer and Nicolson
 - b. Rudolf Virchow
 - c. Frye and Ediden
 - d. Peter Mitchell
 - e. Gorter and Grendel

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



- a. Aspartic acid
b. Threonine
c. Phenylalanine
d. Tyrosine
5. Which one of the following statements about the electron transport chain is **not** correct?
- a. The electron transport chain consists primarily of integral membrane proteins organized into large complexes that are freely mobile along the inner mitochondrial membrane.
b. 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.
c. Ubiquinone, a hydrophilic coenzyme localized to the nonpolar interior of the membrane, and cytochrome c, a peripheral membrane protein located on the matrix side of the membrane, play key roles in the electron transport chain by carrying electrons between the protein complexes.
d. 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 acceptor.
6. In the schematic at right, Na^+ enters the cell by means of...
- a. A channel
b. A co-transporter
c. An exchanger
d. A uniporter



7. 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:
 - a. Increasing the PUFA content of the flight muscle cell membranes to increase membrane fluidity for more rapid entry of fuels into the muscle cells during flight.
 - b. Increasing the PUFA content of the fat reserves used to provide the energy necessary to fuel the trans-oceanic flight.
 - c. Increasing the Na^+, K^+ -ATPase activity of the flight muscles to enhance ATP production.
 - d. All of the above

8. Isolated mitochondria treated with cyanide are unable to generate ATP. This observation...
 - a. Demonstrates that ATP synthesis relies on a proton gradient.
 - b. Demonstrates that ATP synthesis is linked to operation of the electron transport chain without specifying the nature of the linkage.
 - c. Demonstrates that isolated mitochondria are not functional; mitochondria can only operate in the cytoplasm of a cell.
 - d. Demonstrates that O_2 must be available as the final electron acceptor for ATP synthesis to occur.
 - e. All of the above are valid conclusions based on the observation that isolated mitochondria treated with cyanide are unable to generate ATP.

9. A G protein...
 - a. Is named for its glycosylphosphatidylinositol (GPI) linkage to the plasma membrane.
 - b. Consists of three different subunits, alpha (α), beta (β) and gamma (γ).
 - c. Functions as a molecular switch, binding to a response element within the promoter region of a gene and regulating transcription of that gene.
 - d. Is turned on by binding to an activated receptor, and is turned off when the alpha subunit hydrolyzes ATP to ADP.
 - e. All of the above are true of a G protein.

10. A chloroplast is approximately...
 - a. 50 nm long
 - b. $5 \times 10^6 \mu\text{m}$ long
 - c. 0.005 mm long
 - d. $5 \times 10^{-3} \text{m}$ long
 - e. None of the above

11. A groundhog emerges from hibernation on February 2nd (Groundhog Day) to look for its shadow, and its body temperature rises from 5°C to 37°C . Which of the following adjustments might occur to maintain membrane fluidity?
 - a. A decrease in the length of the hydrocarbon tails in membrane phospholipids.
 - b. An increase in the proportion of phosphatidylcholine relative to phosphatidylethanolamine (i.e. an increase in PC:PE).
 - c. An increase in the activity of desaturase enzymes.
 - d. Increased consumption of PUFA-rich foods.
 - e. Both a and c will occur to maintain membrane fluidity.

12. Organism size typically is increased by increasing cell number rather than cell size. Which one of the following statements is **not** a valid reason for this observation?
- A small cell has a higher SA:V ratio than a large cell, reducing limitations on transport in and out of the cell.
 - Diffusion is a relatively slow process – small cells keep diffusion distances small and therefore time required for diffusion low.
 - Organelles occupy a larger proportion of the volume in smaller cells, reducing diffusion distances and increasing overall membrane area for transport.
 - Maintaining adequate substrate concentrations for the biochemical reactions that support a cell is easier in smaller cells because fewer molecules are required.
 - All of the above are valid reasons why organism size is increased by increasing cell number rather than cell size.
13. Which of the following is **not** a cell surface receptor?
- A ligand-gated channel
 - A ligand-activated transcription factor
 - A receptor tyrosine kinase
 - A G protein-coupled receptor
 - All of the above are cell surface receptors
14. Which one of the following equations describes pyruvate oxidation?
- $10 \text{ NADH} + 10 \text{ H}^+ + 5 \text{ O}_2 + 30 \text{ ADP} + 30 \text{ Pi} \rightarrow 10 \text{ NAD}^+ + 10 \text{ H}_2\text{O} + 30 \text{ ATP}$
 - $\text{glucose} + 2 \text{ NAD}^+ + 2 \text{ ADP} + 2 \text{ Pi} \rightarrow 2 \text{ pyruvate} + 2 \text{ NADH} + 2 \text{ ATP}$
 - $\text{acetyl-CoA} + 3 \text{ NAD}^+ + \text{FAD} + \text{ADP} + \text{Pi} \rightarrow 2 \text{ CO}_2 + 3 \text{ NADH} + \text{FADH}_2 + \text{ATP} + \text{CoA}$
 - $\text{pyruvate} + \text{NAD}^+ + \text{CoA} \rightarrow \text{acetyl-CoA} + \text{NADH} + \text{CO}_2$
 - None of the above equations describes pyruvate oxidation.
15. To investigate the nature of a membrane protein, you tag the protein with a fluorescent marker and then measure membrane fluorescence after a variety of treatments designed to detach the protein from the membrane. The fluorescent signal was eliminated after treatment of the membrane with phospholipase C and when the membrane was disrupted by treating it with a detergent. Which 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.
 - Both a and b are consistent with your observations.
16. To maintain the cellular ratio of ATP:AMP...
- An increase in AMP should stimulate the glycolytic enzyme phosphofructokinase.
 - An increase in ATP should stimulate pyruvate dehydrogenase (PDH).
 - An increase in ADP should decrease the rate of oxidative phosphorylation.
 - An increase in NADH should increase the rate of the citric acid cycle and pyruvate oxidation.
 - All of the above should occur to maintain the cellular ratio of ATP:AMP.

17. Which one of the following statements is **not** true of the Na^+, K^+ -ATPase (the 'sodium pump')?
- The Na^+, K^+ -ATPase is found in the plasma membrane of animal cells.
 - The Na^+, K^+ -ATPase is responsible for creating the Na^+ and K^+ concentration gradients that contribute to membrane potential.
 - The Na^+, K^+ -ATPase phosphorylates ADP to move 3 Na^+ out of a cell and 2 K^+ into a cell.
 - The Na^+, K^+ -ATPase is transiently phosphorylated as part of the pumping mechanism.
 - The Na^+, K^+ -ATPase is an integral transmembrane protein.
18. Alcoholic fermentation...
- Occurs in the skeletal muscle of human athletes performing high-intensity exercise.
 - Regenerates NAD^+ by transferring electrons from NADH to pyruvate.
 - Results in CO_2 production, useful in making bread rise or beer fizz, because a 3-C pyruvate molecule is decarboxylated.
 - All of a, b and c are true of alcoholic fermentation.
 - None of a, b or c is true of alcoholic fermentation
19. Membrane potential refers to...
- A molecule that includes both hydrophobic and hydrophilic regions.
 - 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.
20. If binding of the signal molecule to a surface receptor is what triggers the cellular response, i.e. the signal molecule itself does not enter the cell, then...
- Metabolic poisons such as cyanide should prevent the cellular response.
 - The cellular response should not be triggered by injection of the signal molecule into the cytoplasm of the cell.
 - Non-hydrolyzable analogues of GTP such as $\text{GTP}\gamma\text{S}$ should enhance the cellular response.
 - All of the above are true.
 - Only b and c are true.

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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)

- Complete the following statements. (1 mark per answer)
 - The **fluid mosaic model (1 mark)** describes a membrane as a lipid bilayer studded with a unique complement of proteins; this lipid-protein assembly is held together by non-covalent bonds.
 - The activation of pyruvate dehydrogenase by dephosphorylation is an example of **covalent (1 mark)** regulation of enzyme function.
 - The adjustment of membrane composition to maintain membrane fluidity as environmental temperature changes is termed **homeoviscous adaptation (1 mark)**.
 - Voltage-gated (1 mark)** ion channels open or close in response to a change in membrane potential.
- What is *Escherichia coli* and why does it matter (i.e. why is it significant within the context of cell biology)? (1 mark)

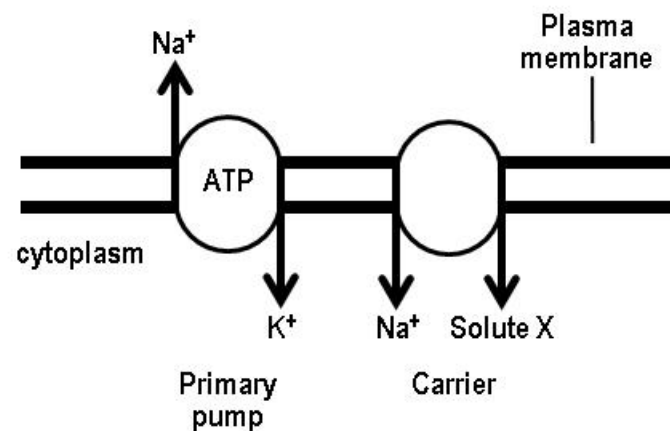
Escherichia coli is a model organism, specifically, a prokaryote (bacterium). **(0.5 marks)**

It matters within the context of cell biology because it is easily cultured in a lab setting with a standard culture medium and a 37°C incubator, and grows and divides rapidly (so is experimentally advantageous) allowing it to be used easily to gain insight into the molecular and cellular biology of prokaryotic organisms. **(0.5 marks)**

- Explain how a secondary active transport mechanism operates. Illustrate your explanation with a labelled sketch. (4 marks)

In secondary active transport, either Na^+, K^+ -ATPase (NKA, in animal cells) or H^+ -ATPase (proton pump, in other cell types) creates an ion gradient (Na^+ or H^+) across the plasma membrane of the cell. **(1 mark)**

A second carrier then uses this gradient to move the solute of interest (X) across the plasma membrane. That is, the second carrier transports Na^+ or H^+ across the membrane with its diffusion gradient while simultaneously transporting X across the membrane against its concentration gradient. **(1 mark)**



- 1 mark for showing/labelling the primary pump (NKA or H^+ -ATPase); must indicate ATP use and Na^+ or H^+ must exit the cell.
- 1 mark for showing/labelling a second transport protein that is a carrier; it must carry either Na^+ (if NKA is the pump) or H^+ (if H^+ -ATPase is the pump) into the cell, and indicate carriage of a second solute.

4. Distinguish between substrate-level phosphorylation and oxidative phosphorylation. (2 marks)

Whereas substrate-level phosphorylation occurs in the cytoplasm of the cell or the mitochondrial matrix, oxidative phosphorylation takes place at the inner mitochondrial membrane. **(1 mark)**

Substrate-level phosphorylation involves the transfer of a phosphate group from a phosphorylated intermediate to ADP, whereas oxidative phosphorylation relies on the creation of a proton gradient (by the electron transport chain) that drives ATP synthase. **(1 mark)**

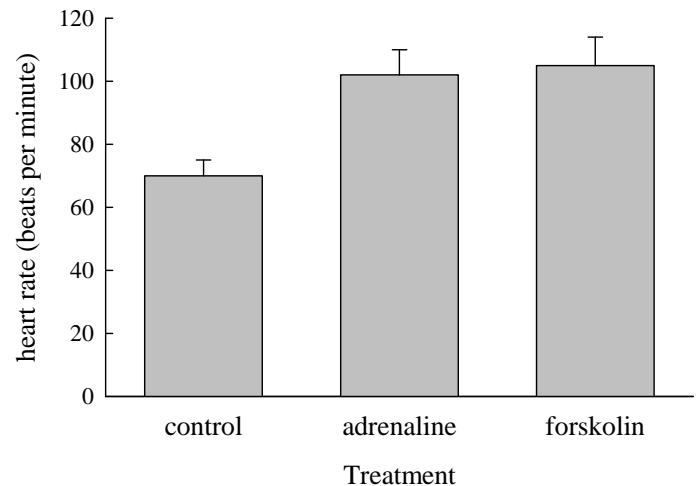
Substrate-level phosphorylation can occur without O_2 (e.g. during glycolysis), whereas oxidative phosphorylation is dependent upon O_2 . **(1 mark)**

Substrate-level phosphorylation occurs during glycolysis and the citric acid cycle, whereas oxidative phosphorylation occurs as an independent process involving creation of a proton gradient (by the electron transport chain) that drives ATP synthase. **(1 mark)**

Two points needed for 2 marks.

5. The figure at right presents data generated in experiments designed to identify the mechanism through which heart rate is increased during a “fight-or-flight” response. The compound forskolin acts as an adenylyl cyclase activator. What can be concluded from these data? Please explain your reasoning. (3 marks)

The conclusion derived from these data is that heart rate during a “fight-or-flight” response is increased through a cAMP-mediated pathway, which therefore is likely to be a G protein-coupled receptor pathway. **(1 mark)**



The compound forskolin acts as an adenylyl cyclase activator. Because adenylyl cyclase is the enzyme that catalyzes the conversion of ATP to cAMP, forskolin will increase cellular cAMP levels. **(1 mark)**

Forskolin increased heart rate to the same extent as adrenaline, supporting the hypothesis that the effects of adrenaline are mediated by cAMP. **(0.5 marks)**

In the cell, cAMP increases are (often) achieved through activation of a G protein-coupled receptor that activates a G protein that, in turn, activates adenylyl cyclase. The resulting increase in cAMP activates protein kinase A (PKA), which activates other effectors in the cell. **(0.5 marks)** It is likely that this pathway is responsible for the increase in heart rate during a “fight-or-flight” response.

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).