MCAT Biochemistry and Biology 1 Homework

Passage 1 (Questions 1-6)

Passage Outline

Paragraph 1: Background information about oxidative phosphorylation.

Paragraph 2: Experiment 1- mitochondria isolated; ADP added.

Figure 1: Exp. 1 Results- effect of amount of ADP added on oxygen consumption.

Paragraph 3: Experiment 2- oligomycin inhibits oxidative phosphorylation; DNP dissipates H^+ gradient.

Figure 2: Exp. 2 Results- effect of oligomycin on oxygen consumption.

Q1.

Assess: Figure 1 represents oxygen consumption. Elicit- what is Acetyl-CoA and how does it relate to oxygen consumption? Acetyl-CoA is the product of pyruvate decarboxylation and is necessary if the cell is undergoing aerobic respiration (i.e. no Krebs cycle means no pyruvate decarboxylation).

Plan: Ask the class if we would expect Acetyl-CoA to be lowest when oxygen levels are high or low, then analyze Figure 1 to determine which time frame represents this case.

Execute: Acetyl-CoA production will be low when undergoing anaerobic respiration, thus it will be low when oxygen levels are low. Looking at Figure 1, we see that oxygen consumption ceases (when oxygen availability is depleted) somewhere between 5.5 and 6.8 minutes. Scanning the answer choices, Choice D is the only answer that fits.

Answer: D

Q2.

Assess: The question stem provides quantitative values for oxygen and ADP, so we need to find a way to relate the two.

Plan: Elicit- Where in the passage is the relationship between amount of ADP present and oxygen consumption discussed? Use the data in Figure 1 to make quantitative approximations for this relationship and calculate an answer.

Execute: In P2, the author explains that the amount of ADP present is directly proportional the amount of oxygen taken up. Looking at Figure 1, we can approximate that when 0.3 µmoles of ADP were added, about 0.14 µmoles of oxygen were consumed. It does not matter whether we use this value or the approximately 0.28 µmoles consumed when 0.6 µmoles of ADP were added. the remainder of the question is arithmetic: 0.3 µmoles of ADP uses 0.14 µmoles, so 1.2 µmoles of ADP (4 times that amount) will use 0.56 µmoles of oxygen (again, 4 times the amount as before). Therefore, the amount left over will be 1.5 µmoles – 0.56 µmoles = 0.94 µmoles of oxygen.

Answer: C

Q3.

Assess: Although the passage states that ADP is an essential substrate in the process of oxidative phosphorylation, there really is no information needed from the passage to answer this question.

Plan: Elicit- What is oxidative phosphorylation? Move through the answer choices and consider if removing each would inhibit the process. Keep in mind we are looking for the one that would NOT limit oxidative phosphorylation if removed.

Execute: Recall that oxidative phosphorylation is the flow of electrons from one substrate to another (through a series of reductions and oxidations) until it is given to oxygen (the final electron acceptor). Also recall that NADH and $FADH_2$ are oxidizable substrates used in oxidative phosphorylation. Considering the answer choices, starting with Choice A, NAD^+ is already oxidized and so it has already "given up" its electrons to the cycle; thus, it is not expected to limit the rate of oxidative phosphorylation. Here we already have our correct answer choice, but continue through the rest with the class as a brief review. Next, Choice B--oxygen is clearly needed for oxidative phosphorylation. Moving on, Choice C $FADH_2$ is a much needed electron carrier required to propagate the cycle. Lastly, Choice D, inorganic phosphate will be needed to build ATP from ADP.

Answer: A

Q4.

Assess: In order to answer the question presented, we must also consider the first statement and why the oligomycin halted oxygen consumption.

Plan: Elicit- Does the passage tell us anything about the effects of oligomycin and DNP on oxygen consumption that would explain the trends in the Figure? What effect must DNP then have when added after oligomycin in regards to the normal process of oxidative phosphorylation?

Execute: P3 says that oligomycin inhibits oxidative phosphorylation and that DNP dissipates the proton gradient in mitochondria. Since the Figure shows us that DNP restored oxygen consumption, we can conclude that something about its effect on the protons is what allowed oxidative phosphorylation to continue. Under normal circumstances, protons are brought across the inner mitochondrial membrane into the matrix to generate a potential energy gradient that drives ATP production from ADP. Look for an answer choice that connects DNP with this normal role of protons in oxidative phosphorylation.

Answer: C

Q5.

Assess: This problem requires us to apply new information presented in the question stem to our understanding of oxidative phosphorylation.

Plan: Elicit- If there is a movement of K^+ into the mitochondria, what effect will this have on the organelle? How will this effect impact the rate of ATP synthesis carried out by oxidative phosphorylation?

Execute: The introduction of K^+ into the mitochondria will create a net positive charge within the organelle. We discussed in the previous question how an important part of the ATP synthesis process is the generation of a proton gradient across the inner mitochondrial membrane. Since like charges will repel each other, we can expect that with the addition of an extra positive charge created by the presence of excess K^+, there would be a disruption to the formation of that proton gradient. Find the answer choice that best matches this idea.

Answer: B

Q6.

Assess: The question is basically asking the role of ADP and oxygen in oxidative phosphorylation.

Plan: Elicit- How is oxygen consumed in oxidative phosphorylation? What is the role of ADP in this process?

Execute: As has already been reviewed in previous questions from this passage, oxygen is the final electron acceptor in the generation of ATP. Previous to this step, ADP is converted to ATP by the enzyme ATP-synthase as it pulls protons across the inner mitochondrial membrane into the matrix. If there is no ADP available, the earlier step by the ATP-synthase will not be active and thus, protons will not flow into the matrix. Oxygen will therefore not be required as a later step to accept electrons.

Answer: A

Passage 2 (Questions 1-5)

Passage Outline

Paragraph 1: Immune system introduction

Paragraph 2: Response = recognition, cytokine production; dendritic cells

Paragraph 3: Experiment set-up; RNA for cytokines from normal and FIV cats measured

Paragraph 4: Results showed no difference in cytokine expression

Figure 1: Cytokine levels in normal and FIV-infected cells

Q1.

Assess: The question is pretty open-ended. Turning to the answer choices will help guide our thoughts as we come up with an answer.

Plan: Move through each of the answer choices and identify the one that provides an accurate and plausible explanation.

Execute: First, Choice A is a false statement, since RNA can also form triple bonds (between cytosine and guanine), so it must be incorrect. Next, Choice B offers a plausible reason--since P3 specifically told us the RNA was converted to cDNA prior to going through PCR, it makes sense this was a calculated move to maintain the integrity of the molecules because the DNA was more stable in the process than RNA would be. So far, this is looking like our correct answer, but let's check the rest. Moving on to Choice C, we have another false (and therefore incorrect) statement, since both DNA and RNA carry genetic information. Lastly, Choice D does not make sense and can be eliminated because DNA routinely interacts with RNA during transcription; it could not do so if unstable.

Answer: B

Q2.

Assess: This question really tests understanding of molecular genetics.

Plan: Elicit- What did the passage tell us about cytokines? How would this relate to levels of RNA?

Execute: P2 told us that cytokines are proteins that signal an immune response to take place. Proteins are produced by the translation of RNA, so more RNA would mean the

cell is more active in producing protein. Find the answer choice that matches this reasoning.

Answer: C

Q3.

Assess: This is a fairly straightforward question asking what holds the nucleotide pairs of DNA together.

Plan: Elicit- What types of bonds hold nucleotide pairs together in DNA?

Execute: Hydrogen bonds.

Answer: A

Q4.

Assess: Another straightforward question testing understanding of the transcription process.

Plan: Elicit- What post-transcriptional modifications are made to mRNA?

Execute: Addition of the poly-A tail and 5’ guanosine cap, as well as the splicing of introns.

Answer: D

Q5.

Assess: This problem requires a conclusion to be drawn based on the experimental results from the passage.

Plan: First, make sure that the class understands the purpose of the experiment. Elicit- Where in the passage do we get a description of the scientist's intent? How do the results answer the question asked?

Execute: P3 told us the scientist wanted to determine which cytokines (not cells!) are affected by FIV. The results are only for an experiment done on dendritic cytokines. Since the results showed no difference in the expression of dendritic cytokines in an infected cell versus that of an uninfected cell, we can only conclude that it was not this particular type of cytokine that FIV affected. Identify the answer choice that reflects this conclusion.

Answer: D

Passage 3 (Questions 1-5)

Passage Outline

Paragraph 1: Leigh Syndrome introduction

Paragraph 2: LS = DNA mutation; mitochondrial DNA = passed maternally; heteroplasmy

Paragraph 3: LS gene mutations affect ETC = less ATP per NADH/$FADH_2$

Case 1: Transcription rate test of pregnant woman with LS family history

Figure 1: Transcription rate of Case 1 mutated gene

Case 2: Gel electrophoresis test pregnant woman with LS paternal grandfather

Figure 2: Gel analysis of Case 2 LS gene sites

Q1.

Assess: This question is melding knowledge of DNA makeup and microbiology. Elicit- For what types of contamination could the scientist be looking? It could be presence of RNA, bacterial DNA, or viral DNA.

Plan: Examine the data given. Ask the class what signs would indicate whether there were any of the previously mentioned contamination were present or not.

Execute: The DNA is indeed DNA (no uracil, which would indicate RNA) and the percentages support double-stranded DNA. Adenine binds to thymine so their percentages should be the same and the same is true for guanine and cytosine. However, remember that bacterial DNA is double-stranded and circular, while viral DNA can be single or double-stranded. Therefore, the presence of dsDNA does not indicate anything and another test must be performed.

Answer: D

Q2.

Assess: The first thing to think of for this question is, “What affects the transcription rate of a gene?” Some possibilities include enhancers, silencers, or promoters, among some others.

Plan: Review the information presented in Case 1 if necessary then consider the data shown in Figure 1. Ask the class what is indicated by these results and which DNA sites could account for this observation.

Execute: The graph indicates that the child will be born with a lower transcription rate than either the mother or sibling. Thus, Choices C and D can be ruled out since (amongst the choice given) only either an enhancer or a promoter will affect

transcription rate. In general, enhancers have the effect of increasing gene transcription, while promoters are often needed in order to produce the mRNA at all. Thus, knocking out a promoter will have a more drastic effect on lowering transcription than knocking out an enhancer.

Answer: B

Q3.

Assess: The story of a paternal grandfather having the condition points to the possibility of an autosomal recessive trait (see also P3) reappearing now in the fetus.

Plan: Review the information presented in Case 2 if necessary then consider the data shown in Figure 2. Ask the class what is indicated by these results with regards to the LS gene, specifically lanes 2/3, and how this would impact ATP production based on information in the passage.

Execute: The gel shows that the mother has 1 copy of the gene that is mutated and one that is not. We know this because lanes 4/5 are characteristic of a homozygote (likely the unaffected sibling), because upon digestion, there are no pieces of DNA left that are the same length as the undigested strand. Thus, lanes 2/3 are characteristic of a homozygous recessive individual that has no restriction enzyme marker sites due to mutation. Enzyme digestion will not change the DNA strand length in this case. As a result, complex II electron transport activity will be affected as well as ATP production from both NADH and $FADH_2$. Though complex II does not contribute to the proton gradient, it is essential for transporting electrons to the other complexes which do pump protons into the intermembrane space. The normal ratios are 3 ATP/mol for NADH and

2 ATP/mol for $FADH_2$, so ask the class which answer choice represents a drop in both of these ratios.

Answer: A

Q4.

Assess: This problem requires a mix of information from the passage and outside understanding of the electron transport chain.

Plan: Elicit- Where in the passage do we have information about the complexes of the electron transport chain? What else do we already know about these complexes and their part in this process?

Execute: As stated in the passage, complex II is encoded for entirely by the nucleus. The other complexes have varying components of mitochondrial genome in them. Complex I, however, is fed electrons only from NADH, while the other complexes get electrons from a mix of the electron carriers NADH and $FADH_2$.

Answer: A

Q5.

Assess: This problem is asking for “the most likely explanation” for the results described. This means we can only use the information presented in the question stem coupled with known hard facts to make a conclusion and cannot use any other assumptions we come up with on our own.

Plan: Move through the answer choices one by one, keeping in mind the details given in the question stem, and identify the one best explanation while ruling out implausible choices.

Execute: Starting with Choice A, the question stem told us that the vector was non-viral and so an infection is not likely. An immune process could still occur because it is foreign but it is less likely, but this would be more of an assumption on our part (and is thus less likely than Choice D). Next, Choice B is a distortion--the creation of a stop codon could explain complete loss of function, but UGG is not a stop codon. Only UAA, UGA, and UAG are stop codons. Moving on, Choice C is an opposite statement--the presence of more adenine-uracil interactions decreases hydrogen bonding compared to cytosine-guanine interactions (2 hydrogen bonds for adenine-uracil; 3 hydrogen bonds for cytosine-guanine). Lastly, we are left only with Choice D. Based on the information in the question, the vector introduced is not solving the missense mutation and potentially is doing something worse. Since it is non-viral, it is less likely to be infectious as compared to it being an error-prone vector.

Answer: D

Discrete Question Practice (Questions 1-6)

Q1.

Assess: This problem requires us to connect the new information presented about DNP to our understanding of oxidative phosphorylation.

Plan: Elicit- What is the role of a proton passing through ATP-synthase? How would this not happening affect the process of oxidative phosphorylation?

Execute: The passing of a proton through ATP-synthase into the inner mitochondrial matrix facilitates the conversion of ADP to ATP. If the protons were entering the matrix

through another means, this conversion would not be taking place and ATP synthesis would be inhibited.

Answer: A

Q2.

Assess: This question is basically asking the role of ATP-synthase in oxidative phosphorylation, then asking us to take it one step further to make a conclusion about its environment.

Plan: Elicit- What is the role of ATP-synthase in oxidative phosphorylation? How would this function influence the environment immediately surrounding it?

Execute: ATP-synthase converts ADP into ATP by pulling protons across the inner mitochondrial membrane. During a high rate of oxidative phosphorylation, ATP-synthase would be highly active in moving these protons, so we would expect a high concentration of protons immediately surrounding it. This high concentration of protons would create an acidic environment with a low pH.

Answer: B

Q3.

Assess: The basic principle here is a coupling of prokaryotic/eukaryotic differences with an understanding of oxidative phosphorylation.

Plan: Ask the class for some differences between prokaryotes and eukaryotes. With these differences and the process of oxidative phosphorylation in mind, scan through each answer choice to find one that would account for the difference in ATP production.

Execute: First, Choice A is far too generalized and makes an inaccurate conclusion--all types of prokaryotes do not have longer life spans than all eukaryotes and ATP production is not a determinant factor in life span. Next, Choice B is a distortion statement. Prokaryotes lack membrane-bound organelles and will thus have no lysosomes at all. NADH would also play an interactive role with mitochondria, not lysosomes, in ATP synthesis. Moving on to Choice C, we have another slight distortion--prokaryotes do not have mitochondria at all into which they would need to transfer NADH. Lastly, we have D, which represents the most plausible choice of those listed.

Answer: D

Q4.

Assess: This is a fairly straightforward question about the process of DNA replication and PCR.

Plan: Elicit- What is the happening during the polymerase reaction? How would lowering the temperature affect this?

Execute: Polymerase enzymes work to create daughter strands of DNA by assembling nucleotides to the unwound, separated parent strands. Lowering the temperature enough could allow the parent strands to reconnect with one another, preventing the polymerase enzyme from being able to continue building new strands. Find the answer choice that matches this thinking.

Answer: B

Q5.

Assess: Previewing the answer choices shows that we must determine how the loss of spliceosomes affects post-transcriptional processing and splicing ability.

Plan: Elicit- What occurs during post-transcriptional processing? What is splicing? What role do spliceosomes play?

Execute: Post-transcriptional processing includes the mechanisms of capping, addition of the poly-A tail, splicing, and other modifications to the mRNA prior to its exiting the nucleus. Splicing itself is the removal of introns and joining of exons. Spliceosomes are the complexes that facilitate most, but not all, forms of the splicing process. Other forms are much rarer, but include self-splicing (introns that form ribosomes and perform the functions of a spliceosome alone) and tRNA splicing (a set of mechanisms that perform a splicing reaction in tRNA). Find the answer choice that best embodies these ideas.

Answer: C

Q6.

Assess: The underlying principle here is an understanding of molecular genetics and protein synthesis.

Plan: Elicit- What does it mean if we increase the usage of an mRNA molecule? How would this relate to gene expression?

Execute: mRNA is used as the template for creating a protein through the process of translation. Increasing the use of a strand of mRNA means we are translating it repeatedly to create more protein product. Gene expression is the manifestation of DNA code through transcription to RNA and translation into proteins and the effects those

proteins have on the development and various processes of the body. Find the answer choice that best aligns with these facts.

Answer: A