Good afternoon. This is the midterm and like we discussed, it has two purposes. The first is to solidify your knowledge of the basic and oft-used concepts and information covered in this test. The second is to discern how much you know. Because you are taking the midterm, you are eligible for it to be optional pending getting a better percentage score on the final. Meaning, if the midterm helps you at the end of the quarter, we will use it in the scoring. If it hurts you... out it goes! This way, it is more about what you end up learning rather than exactly when you learn it. Sort of. Why do I insist on you taking this midterm in light of our contingency policy? Because the first purpose, solidification of knowledge, and that is the more important one, is better served by studying for and taking this exam.

My only advice is to read the whole question before you dive in, and to feel free to ask questions. That is why we are circulating around like sharks who must move to breath. Finally, please believe me when I say we are not about tricking you, fooling anyone, or trying to be all crafty-like. This is a very straightforward exam, and what we ask for is what we want. Period. Enjoy, to the extent that this is possible in a midterm...

Summation

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1 (6pts) The following pictures are amino acids.

   a) 4pt- Write the one letter code below each structure. Notice that I am not asking you to memorize structures, just recognize them...

   One Letter Code: H 
   L (or V) 
   K 
   Y

   b) 1pt- Which of these functions in the chymotrypsin catalytic triad

   ___H___

   c) 1pt- What does it do in the catalytic triad? (one sentence)

   **Accepts and donates protons in the hydrolysis of the peptide bond.**

2 (5pts) Let's talk briefly about the two terms $\Delta G^o$ and $\Delta G^\ddagger$; they are both free energy changes, but they are very different.

   a) 1pt-Write an English (not equation) definition of free energy

   **Free energy is the energy available to do work in a chemical reaction (at constant temperature and pressure)**

   b) 2pt-Draw a reaction coordinate graph showing the relationship of $\Delta G^o$ and $\Delta G^\ddagger$ for a reaction with a negative free energy change, using S and P as we do in class.

   c) 2pt-Which quantity is altered by an enzyme, and how (one sentence)

   **The $\Delta G^\ddagger$ is altered by the enzyme; it is lowered to hasten the rxn**

3 (4pts) Below are two half-cell reactions, each written like a reduction, with the corresponding half-cell potentials $E^o$ for each.

   \[
   \begin{align*}
   \text{NO}_3^- + 2H^+ + 2e^- &\rightarrow \text{NO}_2^- + H_2O \quad 0.421 \\
   \text{Fumarate}^{2-} + 2H^+ + 2e^- &\rightarrow \text{succinate}^{2-} \quad 0.031
   \end{align*}
   \]

   a) 2pt-Write the balanced redox reaction for the spontaneous case. You can use F and S for fumarate and succinate.

   The reaction will run spontaneously when the redox rxn has a positive $E^o$. This way:

   \[
   S + \text{NO}_3^- \rightarrow F + \text{NO}_2^-
   \]

   **so the S to F reaction run backwards, the NO3 to NO2 one runs forward. Redox**

   b) 2pt-What is the $E^o$ for the resulting spontaneous redox reaction?: $0.421 - 0.031 = 0.39$
4 (2pts) “An enzyme accelerates the forward reaction S to P but does not accelerate the reverse reaction P to S”. Is this true or false, and why do you say this? (one sentence)

It is a falsehood most foul, because enzymes lower the activation energy ($\Delta G^\ddagger$), thus accelerating the forward and reverse reaction to exactly the same extent

5 (11pts) The picture shows a “generic” linear metabolic pathway, in which A goes to F by 5 enzyme steps.

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a) 1pt- Suppose in cellular conditions the conversion of A to F is spontaneous. Which statement is true:

Write choice here: __2____

1) Every separate reaction has a negative free energy
2) The sum of the separate free energies is negative
3) The sum of the separate free energies is positive
4) Without enzymes, the pathway would not be spontaneous

The enzymes, E_{cd}, undergoes allosteric regulation. In fact, B and F are each allosteric regulators of E_{cd}. Answer a few questions about allosteric enzymes:

b) 2pt- What is an allosteric regulator? One sentence

An allosteric regulator binds to an enzyme at a site distinct from the active site and alters the catalytic activity of the enzyme, either increasing or decreasing the activity.

c) 2pt- How should B regulate the enzyme in order to ensure that not too much B accumulates?

If B ACTIVATES enzyme Ecd, this will enhance B usage when it accumulates

d) 2pt- How should F regulate the enzyme in order to ensure that not too much F gets made? If F inhibits Ecd, this will limit the production of F when it is already abundant

e) 3pt- Draw a rate graph with three curves: the action of E_{cd} alone, E_{cd} with added B, and E_{cd} with added F. Use the axes provided:

f) 1pt- Without knowing anything about the enzyme E_{cd}, what can you say about the structure of the E_{cd} protein with great certainty?

In all likelihood, E_{cd} will have quaternary structure, that is, multiple subunits.
6 (6pts) Yo! M & M! The Michaelis-Menten (M-M) equation describes the relationship of reaction rate and substrate concentration \( S \) for many types of enzymes. Here is the equation, with two constants, and the enzyme concentration \( E_T \). I’ve written it in a most informative way.

a) 1pt- Which constant indicates the saturation behavior of the enzyme \( \text{Km} \)

b) 1pt- What is the meaning of the \( k_{cat} \)? One sentence

\[ k_{cat} \text{ is the maximum number of reactions that a molecule of enzyme can catalyze. Or the maximum rate per mole. Or the normalized maximum rate of enzyme reaction.} \]

c) 1pt- What part of the M&M equation describes the fraction of saturation as a function of \( S \)? Write that part on the right

You and your lab partner run identical test of the rate of the same M-M enzyme. For the total enzyme concentration (\( E_{tot} \)) you use 1mM and she uses 3mM.

d) 1pt- What is the concentration of \( \frac{1}{2} \) saturation in each experiment? Use the constants and the concentrations as needed.

Yours __ \text{Km} ____  

T theirs__ \text{Km} ______

e) 1pt- What is the saturated enzyme rate for each?

Yours__ \text{1} \text{mM} \times k_{cat}______  

T theirs__ \text{3} \text{mM} \times k_{cat}______

f) 1pt- Which will have a larger Y-intercept on a Lineweaver-Burke plot? __________

7 (5 pts) The structure show below is \( \alpha \)-glucose. A solution of pure \( \alpha \)-glucose changes over time to become a mixture of two types of glucose.

a) 2pt- What is the other type of glucose? Draw it:

b) 1pt- What are these two forms of glucose called? ________anomers; \( \alpha \) and \( \beta \) glucose____

c) 2pt- Fructose does the same thing, but a 5-membered ring is involved. Why? (one sentence) (I meant “why is a five membered ring formed”) because the carbonyl is now on the 2 carbon, so the resulting anomeric rings are five-membered. Anything remotely like that is acceptable.
8 (5pts) **Coat hanger!!** Below is the coat hanger version of glycolysis, with separate segments described as A, B and C, to help you answer. Use single sentences for each.

a) 1pt- In which segment is ATP consumed, and how many for one molecule of glucose?
Segment A includes consumption of 2 molecules of ATP

b) 1pt- In which segment is PEP produced, and what is the enzyme that does this?
PEP is produced in segment C, and enolase is the enzyme

c) 1pt- What does PEP do in the reaction once it is made? (one sentence)
It phosphorylates ADP to produce ATP; substrate level phosphorylation; written out rxn is also acceptable

d) 1pt- How many ATP are produced in one run along segment C? 2 per run. The segment is used twice in full glycolysis of glucose since 2 G3P are produced per glucose.

e) 1pt- What is the glycolytic metabolite required for the first ATP produced? 1, 3 bis phosphoglycerate, 1,3bPG

9(4pts) A cell is missing the gene for triose phosphate isomerase (TPI) enzyme, so it does not make this enzyme. Suppose the cell still does glycolysis with this deficiency.

a) 1pt- How many ATP are consumed per glucose molecule in the altered pathway?
Still 2 ATP are consumed, since that happens in segment A

b) 1pt- How many ATP are produced per glucose molecule in the altered pathway?
only 2 ATP are produced, since there is only one molecule of G3P that goes down segment C when the DHAP can not be converted into G3P by the blocked, vertical arrow.

c) 1pt- Is NADH still produced in this altered version of glycolysis? How many per molecule of glucose?
One NADH is produced instead of two, because there is only one run down segment C

d) 1pt- What molecule would we expect to build up as glycolysis proceeds in these mutant cells?
We would expect DHAP to build up, because TPI normally converts it into the second G3P, which is then consumed by going down segment C.

10 (4pts) We talked about another glucose consuming process: the pentose phosphate pathway.

a) 1pt- Briefly describe the function of the first, or oxidative phase of this alternate pathway:
The PPP produces five carbon ribose and reducing equivalents from glucose oxidation.

b) 1pt- What electron-rich molecule is produced in the course of this reaction? NADPH

c) 1pt-What happens to the 1-carbon of glucose in this pathway?
It is lost as CO₂ (the structure in the rogues gallery shows the -CO₂- form right before it gets lost in oxidative decarboxylation)

d) 1pt-What pentose is produced in this oxidative phase? ribose-5-phosphate; ribose-
11 (6pts) In glucose metabolism, pyruvate participates in the restoration of NAD⁺ when there is no oxygen available.
   a) 1pt- What is the general name for this type of process _fermentation_

   b) 2pt- Describe (one sentence each, no need for reactions) the two ways we spoke about by which pyruvate participates in NAD⁺ restoration
   _Production of lactate from pyruvate, production of ethanol from pyruvate; each requires NADH as a substrate, thus restoring NAD⁺_

   c) 1pt- Why are these processes essential when oxygen is unavailable to the cell?  
   _Glycolysis will not run without NAD⁺, since it is a substrate of the GAPDH reaction_

   d) 2pt- Complete the reaction for lactate dehydrogenase, filling in the needed structures. Cofactors, if needed, can be abbreviated.
   \[
   \text{CH}_3\text{C}(-\text{O}_2^-) + \text{NADH} + \text{H}^+ \rightleftharpoons \text{CH}_3\text{C}(-\text{O}_2^-) + \text{NAD}^+
   \]

12 (8pts) This question pertains to the beautiful multiprotein machine the Pyruvate Dehydrogenase (PDH) complex. Ready!?  
   a) 1pt- What is the function of the PDH (one sentence)?
   _It catalyzes transfer of the CH₃-CO- acetyl group of pyruvate to CoA; to produce AcCoA from pyruvate; to produce AcCoA_

   b) 1pt- Where does the PDH function in the cell? _mitochondrial matrix_

   c) 1pt- What product of the PDH delivers carbon to the Krebs cycle? _AcCoA_

   The picture shows one of the cofactors of the PDH.

   d) 1pt- What is this cofactor’s name _lipoic acid; lipoate_

   e) 2pt- What are the two ways this cofactor functions in the PDH reaction? (one sentence)
   _It accepts the CH₃-CO acetyl group from pyruvate and it also accepts a pair of electrons produced in the oxidation of that molecule_.

   f) 1pt- The PDH is regulated by many inputs. When citrate is abundant, what happens to PDH activity, and why does this make sense?
   _ARRRG! Despite this sounding good, it turns out not to be true, and so we give credit to all. My bad…_

   h) 1pt- Which Krebs cycle enzyme is very similar to the PDH complex? _αKGD; alpha ketoglutarate dehydrogenase complex_
13 (9pts) Krebs Schmebs! You knew we were gonna talk about the Krebs cycle. Here we go. Suppose you have a single Krebs cycle operating in a teeny tiny beaker. So there is a single molecule of OAA, the substrate of the first reaction, from which your single cycle runs. Answer the following questions:

a) 1pt- Your lone Krebs cycle turns 1000 times. How many Ac-CoA are consumed __1000__

b) 1pt- How many molecules of CO₂ are produced? __2000__

c) 1pt- At the end of your 1000 turns, how many molecules of OAA are there? ____1____

d) 2pt- Draw the structure of OAA, and indicate the carbon that forms a covalent bond with the incoming acetyl group with an arrow.

e) 1pt- Aconitase moves an OH from a symmetrical position on the citrate molecule to a new position. The structure of citrate is shown. The top acetyl is the one added from AcCoA. Indicate where the OH ends up from this reaction from the aconitase reaction with an arrow.

f) 1pt- Circle which carboxyl group gets lost during the alpha keto glutarate dehydrogenase reaction.

g) 1pt- Krebs cycle oxidizes carbon. Does it require oxygen to do this? ____NO____

h) 1pt- We have referred to the Krebs cycle as "amphibolic". Why is this term appropriate for this metabolic process? (One sentence)

It is both an anabolic and a catabolic pathway; amphibolic refers to this dual role in metabolism

14 (5pts) Pyruvate carboxylase is not a Krebs cycle enzyme, but it is important Krebs cycle function. It is one of the anapleurotic reactions.

a) 1pt- What is an anapleurotic reaction? One sentence

It is one of a group of reactions used to replenish Krebs cycle molecules lost to anabolism or other fates; reactions to “refill” the Krebs cycle

b) 2pt- Write the pyruvate carboxylase reaction. You can use abbreviations, no need for structures.

\[
\text{Pyr} + \text{HCO}_3^- + \text{ATP} \leftrightarrow \text{OAA} + \text{ADP}
\]

The “business end) of the cofactor needed for the pyruvate carboxylase is shown to the right

c) 1pt- What is the name of this cofactor __biotin__

d) 1pt- What does this cofactor do? (one sentence)

It forms an adduct with CO₂ allowing carboxylation reactions; participates in carboxylations; mobilizes CO₂
15 (5pts; 1 each) The glyoxalate cycle is a variation of the Krebs cycle that functions in anabolism.

a) In one sentence, what does the glyoxalate cycle do?

It allows formation of molecules of the Krebs cycle from AcCoA without loss of CO₂

b) How much CO₂ is produced in glyoxalate cycle per AcCoA added? ___none_____

c) Give an example of a biological situation where the glyoxalate cycle is used (one sentence)

When a seed germinates, much of the carbohydrate produced to make structural elements is produced from fats stored in the seed and processed by the glyoxalate cycle

d) The glyoxalate cycle uses two enzymes that are distinct from the Krebs cycle. Name one of them below (two possible answers)

isocitrate lyase malate synthase

e) Why can’t the Krebs cycle be used to convert acetate carbon into anabolic products like starch or structural carbohydrates? One sentence

For every acetate put into Krebs, 2CO₂ are released; thus, no net production of carbon-containing molecules can be accomplished using Krebs fed AcCoA

16 (5pts; 1 each) Describe where in the cell the following pathways occur:

This was an oldie: directly from the 2009 exam…

a) Glycolysis: cytosol

b) Pentose phosphate pathway: cytosol

c) Pyruvate dehydrogenase reaction: mitochondrial matrix

d) Krebs Cycle: mitochondrial matrix

e) Electron transport chain: mitochondrial inner membrane
17 (10 pts) Rogue’s Gallery! For each structure, write it’s name and the pathway where it arises in the spaced provided.

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<tr>
<th>Name</th>
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<tbody>
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<td>glycolysis</td>
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<tr>
<td>2-phosphoglycerate 2PG</td>
<td>glycolysis</td>
</tr>
<tr>
<td>succinyl-CoA (not AcCoA)</td>
<td>Krebs cycle</td>
</tr>
<tr>
<td>6-phosphogluconate</td>
<td>pentose phosphate</td>
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<tr>
<td>isocitrate</td>
<td>Krebs cycle, also accept glyoxalate cycle</td>
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