BIOLOGY 200 Name_____

Part IV: Cellular Respiration Accounting & Worksheet Problems

Problem sets: ATP Production under standard conditions: Using the worksheets from Part I, II, and III of today's lab, fill in the table below. Under standard conditions, the model cell is estimated to produce the following from 1 molecule of glucose under standard conditions.

Pathway	CO_2	NADH	$FADH_2$	Net ATP made by substrate level phosphorylation	ATP eventually made by oxidative phosphorylation
Glycolysis	0	2	0	(4ATP – 2ATP) = 2 ATP	(2 NADH x 1.5) = 3ATP
Linking Step	2	2	0	0	(2 NADH x 2.5) = 5 ATP
Krebs Cycle	4	6	2	2 ATP	(6 NADH x 2.5) + (2 $FADH_2$ x 1.5) = 18
TOTALS	6	10	2	4	26

Total number of ATP molecules per molecule of glucose =	30

NOTES: Under standard conditions, the model cell is estimated to produce the following: Remember, if you know the # of molecules produced per molecule of pyruvate, then you will need to double the number when considering yield per molecule of glucose.

For calculating ATP yield from oxidative phosphorylation:

Each $FADH_2$ yields 1.5 molecules of ATP
Each NADH generated in the cytosol yields 1.5 molecules of ATP
Each NADH generated in the mitochondria yields 2.5 molecules of ATP

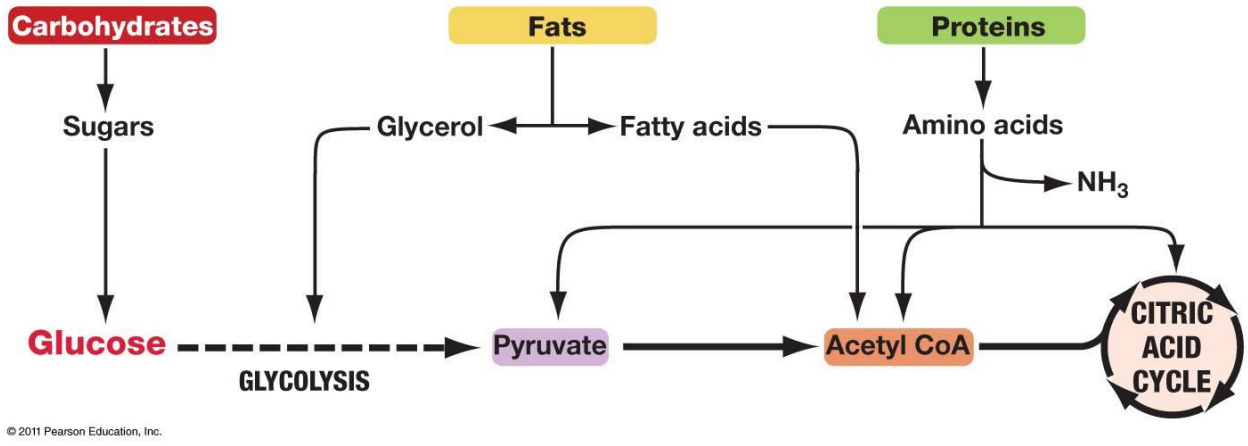
Problem sets: ATP Production under non-standard conditions: For the following problems please use the provided tables. For each chemical write "↑" if production increases, "↓" if production decreases, write "none" if the chemical is not produced in that step, or write "no change" if no change in production occurs.

1. Subject 504V56 is a research animal (dog), she was diagnosed with Pyruvate Kinase Deficiency (PKD). PKD is a genetic metabolic disease that causes pyruvate kinase to be absent or greatly reduced. Pyruvate kinase is the enzyme in the 10th and final step of glycolysis.

   a. Use the provided table to express how this disease will affect cellular respiration in the dog.

Pathway	CO_2	NADH	$FADH_2$	ATP
Glycolysis	*None*	*No Change (2 produced)*	*None*	↓
Linking Step	*None*	*None*	*No Change (None)*	↓ *(None)*
Krebs Cycle	↓ *(None)*	↓ *(None)*	↓ *(None)*	↓ *(None)*
Electron Transport Chain	↓ *(None)*	↓ *(None)*	↓ *(None)*	↓ *(None)*
TOTALS	↓	↓	↓	↓

   b. After learning about 504V56's diagnosis the Primary Investigator asks you, "Why isn't this dog dead yet?" Lab records show that 504V56 was being fed a high protein diet. Use the graphic below to explain how this animal has survived this long.



Proteins are ingested in the diet and are digested into Amino acids. Amino acids can be biotransformed into Pyruvate, Acetyl CoA, or chemicals of the Krebs cycle. As long as cells have functional mitochondria, the dog will continue to be able to conduct cellular respiration, although glycolysis will not produce a net gain of ATP and will also not produce Pyruvate.

c. PKD is fatal in dogs; the average life expectancy is 4 years. PKD most commonly produces anemia (low red blood cell counts), yet other cells are minimally affected. Most animals with PKD die due to complications of anemia. Please explain why red blood cells are strongly affected, while other cells are not. *[Hint: Look up respiration in mammalian red blood cells]*

Mammalian Red Blood Cells (RBC's) do not have mitochondria. Red blood cells start out as pluripotent stem cells, as they mature into RBC's they lose most organelles. The average life span for dog RBC's is about 100 days, and they can survive just fine without a mitochondria using glycolysis alone for cellular fuel.

Since RBC's have no Mitochondria, when glycolysis is disrupted, it severely effects the RBC's ability to produce cellular energy. Other cells that have mitochondria are able to rely on other dietary molecules (Proteins and Lipids) to be biotransformed into molecules that can be used inside the mitochondria in the Linking Step, Krebs, or ETC/ Oxidative Phosphorylation.

d. 504V56 is currently enrolled in a pharmaceutical trial that is investigating a new diet pill. The experimental drug causes ATP synthase to produce less ATP per proton.

i. Why would this drug work as a diet pill?

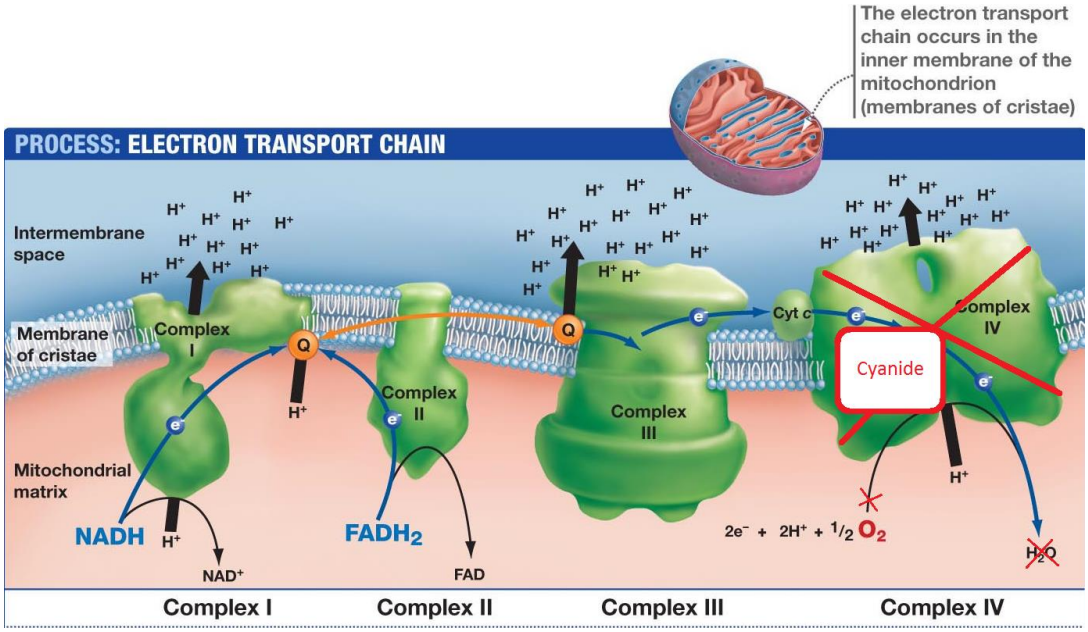
If less ATP is produced per proton, then MORE glucose (or other foods) would be needed to be consumed to produce the same amount of energy for cell function. That means that if you eat the SAME amount of food, the body will turn to fat stores to make up the needed ATP. The body will also less likely have surplus food it could store as fat.

ii. In order to get the most accurate idea of the efficacy of this drug, should 504V56 be allowed to continue in the study? Briefly explain why or why not.

No – This dog has a disease of cellular respiration, and is therefore respiring in an abnormal way. This makes this dog a poor model organism. Researchers will not be able to know for certain if results are due to the dog's disease or the drug.

2. The golden bamboo lemur (*Hapalemur aureus*) was recently discovered in Madagascar. This primate exclusively eats a plant that has high cyanide content. Cyanide is a toxin that binds to iron within the fourth complex of the electron transport chain. As a result cyanide prevents oxygen from accepting electrons. Researchers have found that all parts of the giant bamboo plant *(Cathariostachys madagascariensis*, the primary diet of *H. aureus*) contain cyanide

   a. How would this influence ATP production?
   [Please draw a picture and describe your illustration with 2 or 3 sentences.]



Complex 4 is disabled, and oxygen is no longer able to accept electrons. This means that hydrogens will not continue to be pumped into the intermembrane space by complex 4. This also means that the electron transport chain will "back up" – with all of the complexes eventually being reduced with 2 e-. As a result, no more H+ will be pumped into the intermembrane space. H^+ will be able to pass through ATP synthase until it reaches equilibrium across the inner mitochondrial membrane, at which time all ATP synthesis will stop.

b. Recent quantification shows that an average lemur ingests plant material containing 12 times the lethal dose for a mammal of similar size. Cyanide was also detected in the lemur's urine and feces, yet they appear to be unaffected by the toxic effects of cyanide. Researchers do not yet understand the mechanism that protects cellular respiration in golden bamboo lemurs. Use what you know about the electron transport chain and chemistry to propose a hypothesis that might explain how the golden bamboo lemur is not poisoned by the cyanide in its natural diet. *[Hint 1. look at a periodic table, locate iron. 2. Think about what happens inside each complex of the ETC]*

Scientists don't know, however some possible hypothesis may include:

- *Alternative metals may be used in the heme group in complex 4. Invertebrates sometimes use copper instead of iron as a respiratory pigment.*
- *Protective chemicals: Maybe they produce a protein/enzyme that guards complex 4 and protects it from cyanide?*
- *Detoxifying chemical: Maybe they make a chemical that interacts with cyanide before it reaches the mitochondria?*
- *Many other correct answers exist beyond the few listed here.*