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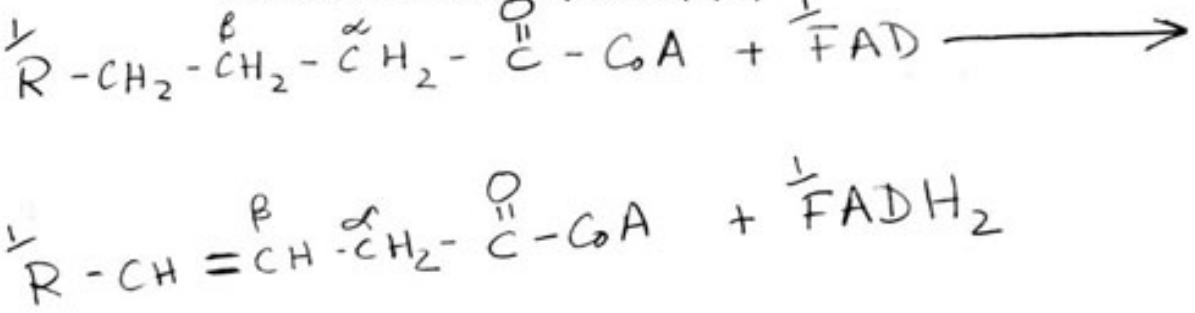
MCB 102 Exam: Metabolism
April 8, 2003

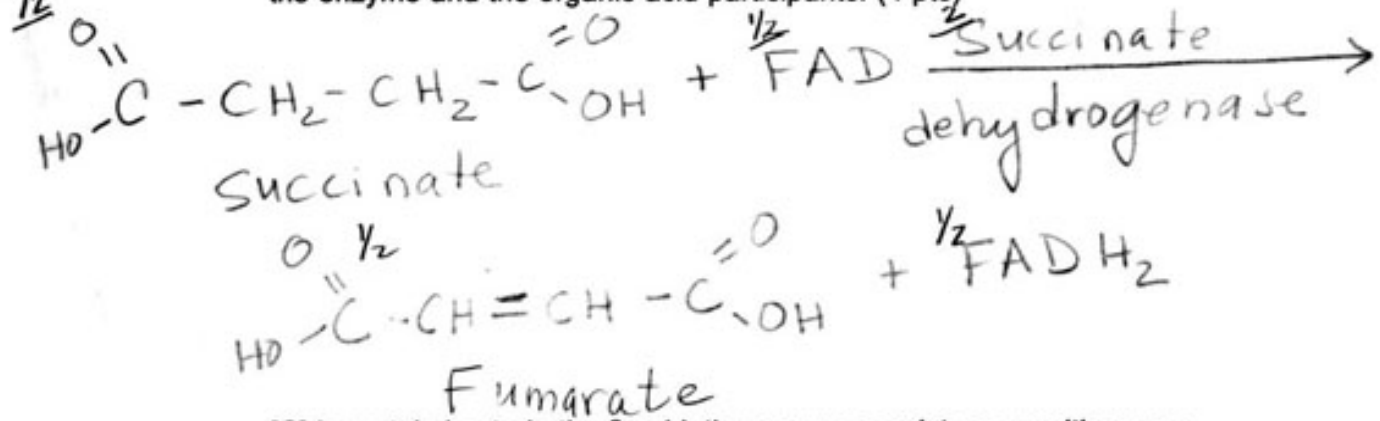
Total points = 100

1. Four enzymes catalyze the β-oxidation of saturated fatty acids to yield acetyl-CoA. (10 pts total)

[A] Write the equation for the acyl-CoA dehydrogenase step using R-COOH as the beginning fatty acid. Include structural formulas for the fatty acid derivative reactant and its product. (4 pts)



[B] Write the equation for a similar type of reaction in the citric acid cycle. Include structural formulas for the organic acid product and reactant. Name the enzyme and the organic acid participants. (4 pts)



[C] In certain bacteria the β-oxidation enzymes exist as a multienzyme complex. Give the name of the process by which such enzyme complexes facilitate the processing of fatty acids relative to counterparts that exist as four separate activities. (2 pts)

Channeling

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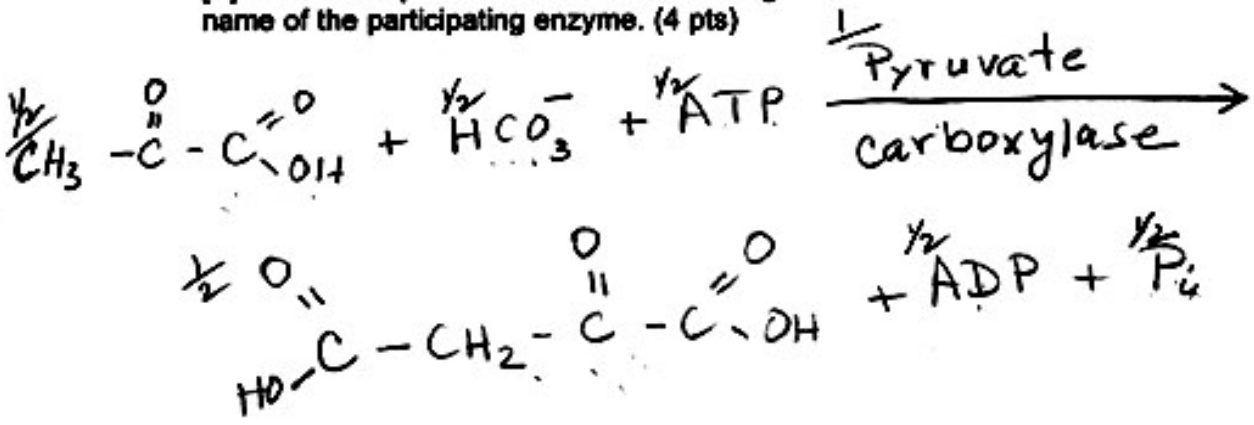
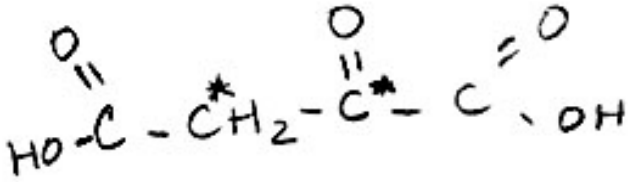
2. Assume that oxaloacetate is generated from $^{14}C_2$-pyruvate by an anapleurotic reaction in liver by an enzyme that requires biotin. (10 pts total)

[A] Write the equation for this reaction using structural formulas. Include the name of the participating enzyme. (4 pts)



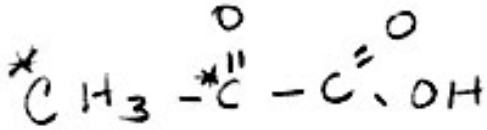
[B] Which carbon atom(s) would be labeled in the oxaloacetate formed from $^{14}C_2$-pyruvate after one turn of the citric acid cycle using unlabeled acetyl-CoA? Include the structural formula for the oxaloacetate. Use reverse side of this page for formulating your answer. (4 pts)

2 pts/carbon



[C] Which carbon atom(s) would be labeled in pyruvate formed if the oxalacetate in [B] fed into the gluconeogenic pathway? Show the structural formula for the labeled pyruvate. (2 pts)

1 pt/carbon



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3. Glucagon regulates two enzymes of gluconeogenesis. (10 pts total)

[A] Give the names of these two enzymes ~~and identify the final chemical change that the glucagon signal causes on each~~. (2 pts)

½ Fructose 1,6-bisphosphatase or FBPase

½ Glycogen synthase

[B] Indicate whether either of these enzymes is activated or deactivated as a result of glucagon? (2 pts)

FBPase activated

Glycogen synthase deactivated

[C] Give the name or abbreviation of the signaling molecule that acts between glucagon and the target enzyme. (1 pt)

c-AMP

[D] An enzyme of the opposing pathway of glycolysis is also regulated by glucagon. Write the equation (using words) and give the name of the enzyme for this reaction. Include cofactor(s). (3 pts)

½ Fructose 6-P + ½ ATP —½ Phosphofructokinase-1 (or PFK), ½ Mg^{++}→ ½ Fructose 1,6-bisphosphate + ½ ADP

[E] Name the four metabolites that regulate [D] directly in the presence or absence of glucagon (2 pts)

½ ADP, ½ citrate, ½ AMP, ½ ATP

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4. We have studied the transfer and conversion of radiant energy in photosynthesis in MCB 102. Answer the following questions using a "T" (True) or "F" (False). (5 pts total, 1 pt each)

[A] F Energy is transferred from chlorophyll a to chlorophyll b.

[B] T In energy transfer light is first absorbed by blue-absorbing pigments and then transferred to red-absorbing pigments.

[C] F Mn^{++} is essential for the oxidation of plastocyanin in electron transport.

[D] T Photosystems functional in anaerobic photosynthetic bacteria appear to be the evolutionary precursors of photosystems of chloroplasts.

[E] F P700 participates in the reduction of plastoquinone (PQ).

5. [A] The synthesis of glucose from pyruvate is achieved by bypassing 3 irreversible reactions of glycolysis. Name the enzymes for each glycolysis reaction bypassed. (3 pts)

Hexokinase
Phosphofructokinase
Pyruvate kinase

[B] Unlike animals and plants, bacteria can convert acetyl-CoA and CO_2 jointly to pyruvate.

[a] Name the enzyme catalyzing the reaction of animals and plants that these bacteria are able to bypass. (1 pt)

Pyruvate dehydrogenase

[b] Name the electron carrier that these bacteria use to achieve this bypass. (1 pt)

Ferredoxin

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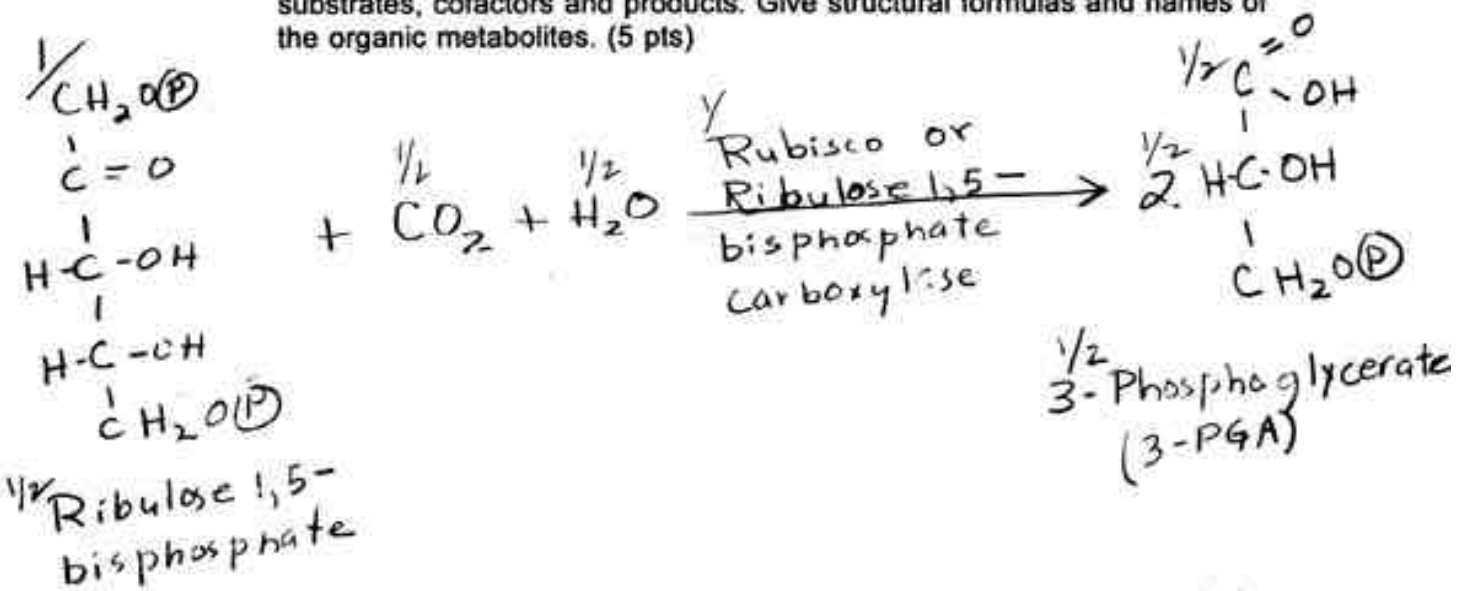
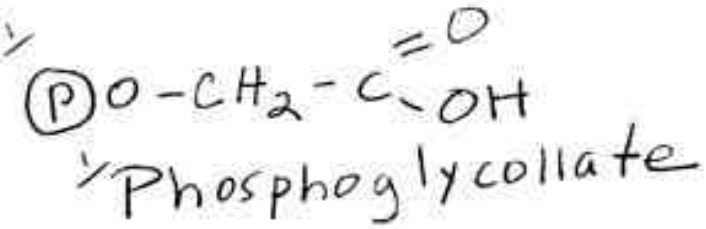
6. Early investigators of $^{14}CO_2$ assimilation by algae showed that the first stable product formed was labeled in the #1 carbon. (10 pts total)

[A] Write the enzyme reaction that forms this product, identifying enzyme, substrates, cofactors and products. Give structural formulas and names of the organic metabolites. (5 pts)



[B] Name and write the formula of the product formed by this enzyme in the presence of O_2. (2 pts)



[C] The path leading from the product in [A] to starch shows both similarities and differences from the parallel pathway leading to glycogen in animal cells.

[a] Name the enzyme(s) that are unique to this part of the starch biosynthesis pathway. (2 pts)

ADP-glucose pyrophosphorylase
Starch synthase

[b] What is the main structural difference between the glycogen and starch products formed? (1 pt)

Glycogen is more branched

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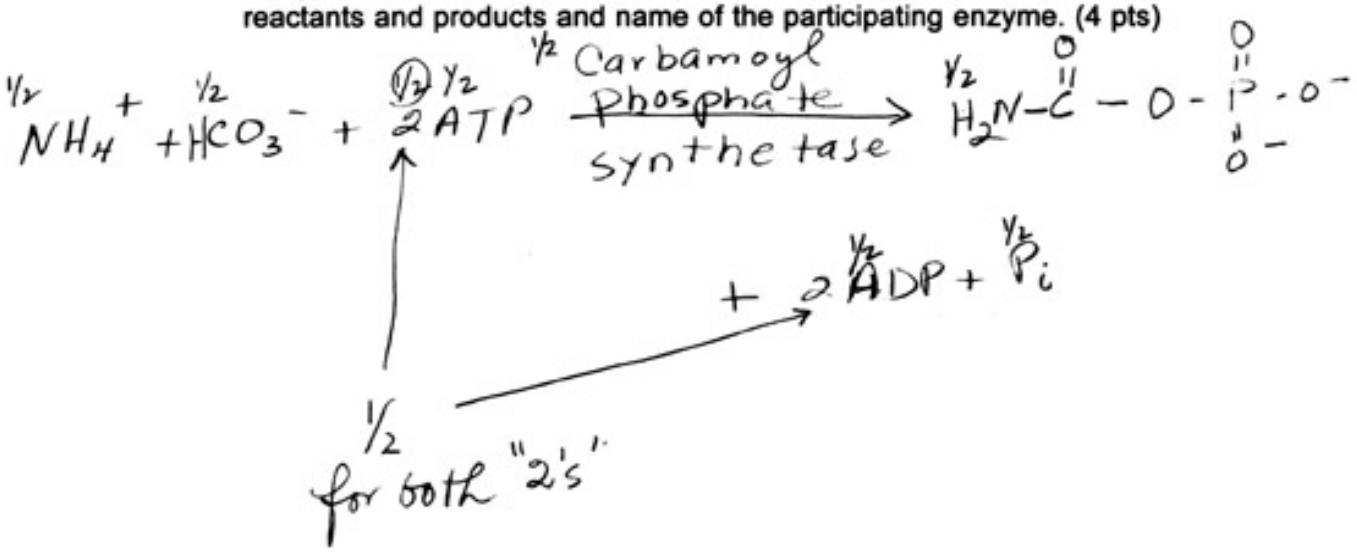
7. Unlike birds and reptiles, mammals excrete excess nitrogen as urea synthesized via the urea cycle. (10 pts total)

[A] Write the equation by which animals convert excess nitrogen to the compound that enters the urea cycle. Give the structural formulas of reactants and products and name of the participating enzyme. (4 pts)



[B] Fill in the blanks. (6 pts)

The above product is converted to citrulline which receives the second nitrogen equivalent from aspartate yielding the intermediate arginosuccinate which is converted to fumarate and Arginine. The latter, in turn, yields urea in a reaction catalyzed by the enzyme Arginase.

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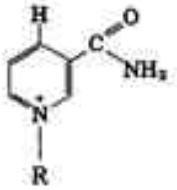
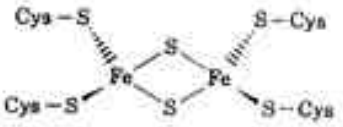
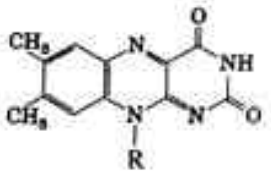
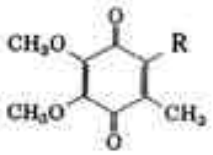
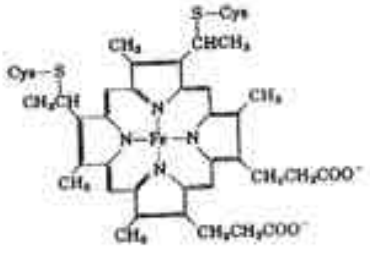
2. ~~This site, in turn, determines the number of ATPs generated~~. Identify the following coenzymes and prosthetic groups that feed electrons into the mitochondrial electron transport pathway. Write full names of cofactors; do not use abbreviations. (10 pts total; 1 pt for each part)

[A]  1/ Nicotinamide adenine dinucleotide 1/2 (NAD) [OR NADP]

[B]  1/ Iron-sulfur 1/2 (FeS)

[C]  1/ Flavin mononucleotide or Flavin adenine dinucleotide 1/2 (FMN/FAD)

[D]  1/ Ubiquinone

[E]  1/ Cytochrome or Heme 1/2 Porphyrin (need not specify "c")

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[F] Give the number of ATPs resulting from the transfer of 2 e^- from [A] to O_2.

½ 2.5 ok/ 3.0

[G] Give the number of ATPs resulting from the transfer of 2 e^- from [C] to O_2.

½ 1.5 ok/ 2.0

[H] In what form is the energy released in the absence of ATP synthesis during the transport of e^- from [A] or [C] to O_2?

½ Heat

[I] Based on your reading of Lehninger, give an example of how an organism can benefit from [H].

½ Hibernation
or ½ Germination (plant growth)

[J] What is the effect on the rate of electron transport from [A] to O_2 if ADP and Pi are absent?

½ slow down

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9. As you have learned in MCB 102, muscles of competitive runners draw on all available sources of energy in times of demand during a race. (5 pts total; 1 pt each part)

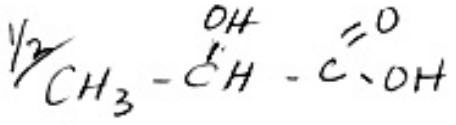
[A] Which system for generating ATP from ADP and Pi becomes limiting first?

1/ Oxidative phosphorylation

[B] Which system for generating ATP from ADP and Pi is accelerated in [A]?

1/ Glycolysis

[C] Name the metabolite that accumulates as a result of [B] and draw its structure.

1/2 

1/2 Lactate

[D] Name the final product to which the metabolite in [C] is converted when running has ceased.

1/ Glycogen

[E] In what tissue does the conversion in [D] mainly take place?

1/ Liver

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10. ATP is synthesized in chloroplasts by two electron transport pathways. (5 pts total; 1 pt each)

[A] Name the two electron transport pathways that result in phosphorylation of ADP.

½ Noncyclic photophosphorylation
½ Cyclic photophosphorylation

[B] Name the by-product of one of these electron transport pathways that is essential for almost all eukaryotes.

1 O_2

[C] What effect does net electron transport via one of these pathways have on the activity of regulatory enzymes of the Calvin cycle?

1 Activation

[D] Name the enzyme in [C] with a counterpart in liver gluconeogenesis that acts in a potential futile cycle.

1 Fructose 1,6- bisphosphatase
or (FBPase)

[E] Is the enzyme in [D] regulated by electron transport as the enzyme in [C]?

No

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11. Suppose human food intake is switched to a diet consisting mainly of fat. (10 pts total; 2 pts each part)

[A] What class of essential compounds we have studied would the body be unable to synthesize from fat?

2/ Sugars
OK (carbohydrates)

[B] Name the type of compounds serving as an energy source that would be enriched in the blood?

2/ Ketone bodies

[C] Name the primary tissue to which these compounds would be targeted.

2/ Brain

[D] Name the immediate biochemical intermediate from which these compounds are synthesized.

2/ Acetyl - CoA

[E] Identify the clinical condition resulting from a genetic defect in which the compounds in ~~[A]~~ B are also observed.

2/ Diabetes (mellitus)
(type I)
↖ not necessary

1/2 pt for Type II

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12. In photosynthetic electron transport, A_o carries electrons that are ultimately transferred to $NADP^+$. (10 pts)

[A] The standard reduction potential of the electron acceptor chlorophyll $A_{o,reduced}$ and $A_{o,oxidized}$ and the $ferredoxin_{oxidized}$/$ferredoxin_{reduced}$ pairs are, respectively, -1.12V and –0.42V. Using these values, calculate the kJ/mol released in this reaction. Assume that Faraday's constant is 100 kJ/V*mol. (5 pts)

1½ $\Delta E = E'_{o(oxidant)} - E'_{o(reductant)}$

½ $= -0.42V - (-1.12V) = +0.70V$

1½ $\Delta G = -n\mathcal{F}\Delta E$

$= -(1)(100\ kJ/V \cdot mol)(0.7V)$

½ $= -70\ kJ/mol$

[B] Using a $\Delta G'_o = -30$ kJ/mol for the hydrolysis of ATP, approximately how many ATPs could theoretically be formed in this reaction? (2 pts)

$\frac{70}{30} = \sim 2$ 2/2

[C] How many ATPs are experimentally detected in this electron transfer reaction? (2 pts) 2/0

[D] What happens to any energy that is not used for ATP synthesis? (1 pt)

½ Heat