Name Key (Final)
SID:
GSI Name:
Section:

MCB 102 Exam: Metabolism
April 6, 2005

Total points = 100

1. The degradation of fatty acids takes place via a series of reactions we studied this semester. Three of these reactions are mechanistically the same as those of another pathway we discussed (we will designate the unidentified pathway as "Pathway A"). **Total 10 pts.**

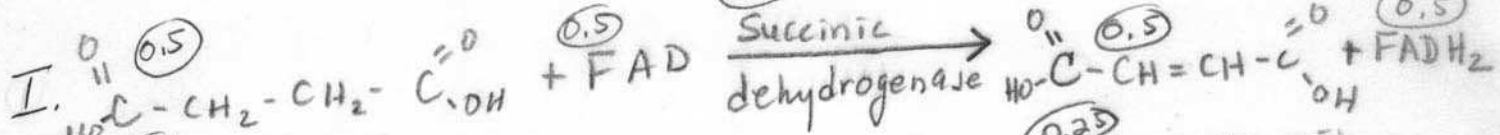
A. Give the name of the pathway by which fatty acids are degraded to C_2 units. **(0.5 pt)**

(0.5) β-oxidation

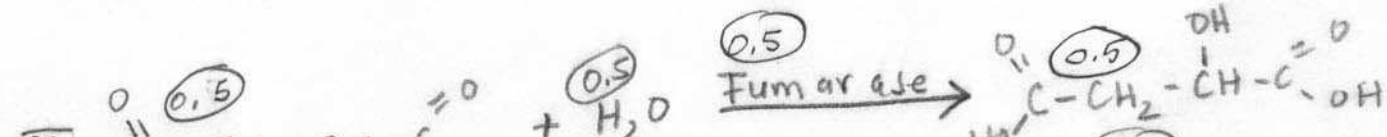
B. Give the name of Pathway A. **(0.5 pt)**

(0.5) Citric acid cycle

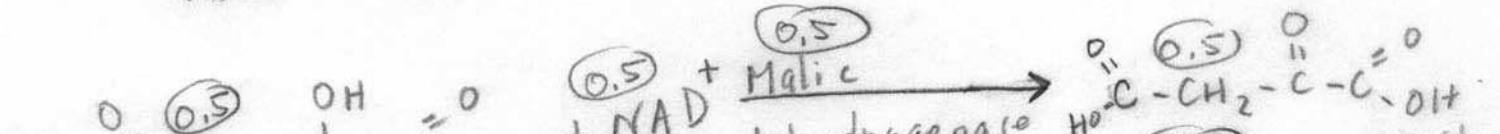
C. Write equations for the three reactions of Pathway A that are of the same type as three members of the pathway by which fatty acids are degraded. Include structural formulas and names of metabolites and enzymes. Identify cofactor(s) using abbreviations. **(9 pts)**

I. 

Succinic acid
Fumaric acid

II. 

Fumaric acid
Malic acid

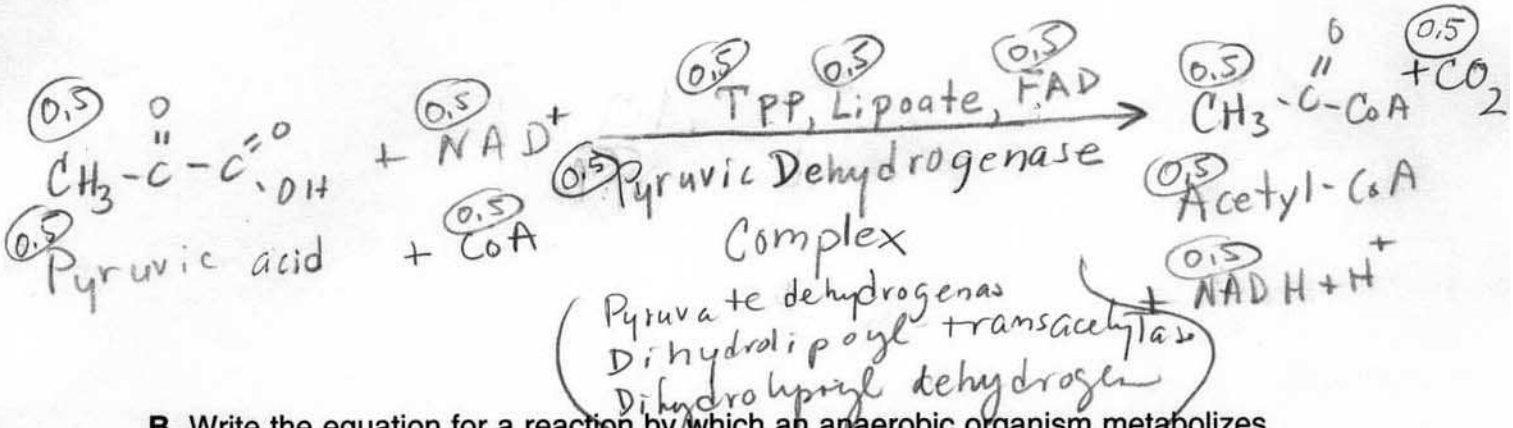
III. 

Malic acid
Oxaloacetic acid
+ NADH + H+

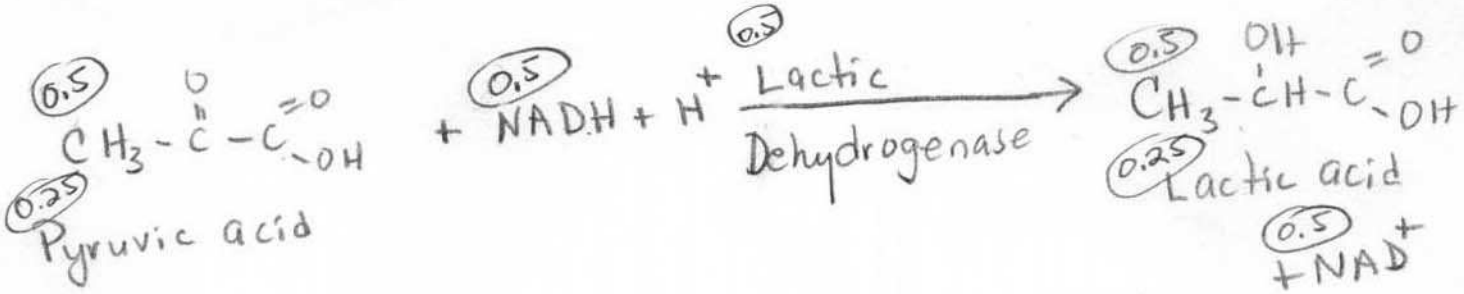
Name Key
SID:
GSI Name:
Section:

2. We have seen that glycolysis is a pathway fundamental to most organisms. Yet organisms metabolize the products of glycolysis in a manner dependent of their individual lifestyles. Thus, although they both use glycolysis, aerobes and anaerobes differ as to final products formed by reactions leading from pyruvate, the product of glycolysis. **Total 10 pts**

A. Write the equation for the reaction by which aerobic cells (animals) metabolize pyruvate. Include structural formulas and names of substrates and products. Name enzymes and cofactors. Use abbreviations as appropriate. **(6 pts)**



B. Write the equation for a reaction by which an anaerobic organism metabolizes pyruvate to yield the same product that accumulates in exercising muscle. Include structural formulas and names of substrates and products. Name enzymes and cofactors. Use abbreviations as appropriate. **(3 pts)**



C. What is the ultimate fate of the metabolic product formed from pyruvate in (A) and in (B)? Limit your answer to 2 sentences. **(1 pt)**

(1) A: Oxidized via citric acid cycle and oxidative phosphorylation (H_2O and CO_2)

B: Lactate accumulates

Name Key
SID:
GSI Name:
Section:

3. The enzymes fructose bisphosphatase 1 (FBPase-1) and phosphofructokinase 1 (PFK-1) of animal tissues are regulated by both allerosteric and covalent modification. Name the following: **Total 6 pts**

A. A sugar phosphate allosteric modifier of these enzymes whose concentration is controlled by covalent modification. State its effects on PFK-1 and FBPase-1. **(1 pt)**

(0.5) Fructose-2,6-P_2 — (.25) PFK-1 ⊕ / (.25) FBPase-1 ⊖

B. An allosteric modifier for each of these enzymes that acts independently of covalent modification. List one allosteric modifier for each enzyme. Indicate whether it functions as an activator or inhibitor. **(2 pts)**

PFK-1: (0.5) ATP ⊖ (0.5)
OR { ADP ⊕ / AMP ⊕ / Citrate ⊖ }

FBPase-1: (0.5) AMP ⊖ (0.5)

C. The enzyme(s) that synthesizes and degrades the metabolite in (A) and the covalent regulatory mechanism that alters its (their) activity. **(1 pt)**

(0.25) PFK-2
(0.25) FBPase-2
} (0.5) Phosphorylation

D. Name a hormone that controls the concentration of the metabolite in (A). **(1 pt)**

(1) Glucagon or epinephrin or insulin

E. If FPBase-1 and PFK-1 both lost the capacity for metabolic regulation, what would be the end metabolic effect? **(1 pt)**

(1) Futile cycle (ATP or hexose-P hydrolysis with no benefit)

4. Under certain conditions, the human body forms large amounts of ketone bodies. **(4 pts)**

A. Name the two conditions we studied that lead to abnormal levels of ketone bodies. **(2 pts)**

(1) Diabetes OR Alcoholism
(1) Starvation Low Carbohydrate diet

B. Which human organ is the major depot of ketone bodies under the conditions in (A)? **(1 pt)**

(1) Brain

C. Identify the principal pathway for the breakdown of ketone bodies. **(1 pt)**

(1) Citric acid cycle

Name Key
SID:
GSI Name:
Section:

5. Urea is synthesized in two cell compartments via a pathway in which the nitrogen atoms are derived from different sources. **Total 10 pts**

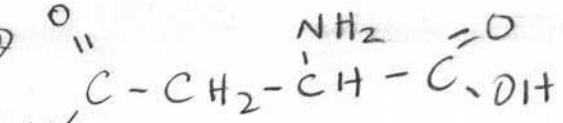
A. Name the two compartments in which urea synthesis takes place. **(1 pt)**

(0.5) Mitochondria
(0.5) Cytosol

B. Write the equation for the reaction in which the first nitrogen (NH_3) is incorporated in the urea cycle. Include the names of the reactants, products and enzyme. Show stoichiometry. **(3 pts)**

(0.5) HCO_3^- (Bicarbonate) (0.5) $+ 2ATP + NH_4^+$ —(0.5) Carbamoyl phosphate synthetase I→ (0.5) Carbamoyl-P + (0.5) $2ADP + P_i$ (0.5)

C. Give the name and draw the structure of the metabolite that contributes the second nitrogen to the urea molecule. **(3 pts)**

(2)

(1) Aspartic acid

D. Name the enzyme that yields the final urea product and the cell compartment in which this reaction takes place. **(1 pt)**

(0.5) Arginase – (0.5) Cytosol

E. Identify the pathway that contributes to the carbon skeleton of the metabolite in (C). **(1 pt)**

(1) Citric acid cycle

F. How many ATP's are required for the synthesis of one molecule of urea? **(1 pt)**

(1) 3

Name Key
SID:
GSI Name:
Section:

6. We have seen that the synthesis of ATP from ADP and Pi takes place via the transport of electrons from NADH to O_2 in mitochondria. Four enzyme complexes contribute to this synthesis. **Total 10 pts**

A. Identify (by name) the complexes and the electron donors linking the oxidation of metabolites to each complex. Show the flow of electrons. **(3 pts)**

(0.5) Complex I (0.25) → Q (0.5) → Complex III (0.25) → Cytochrome c (0.5) → Complex IV

(0.25) NADH

(0.5) Complex II OR (Succinic Dehyd)

(0.25) $FADH_2$

B. Indicate which of these complexes are involved in the transport of protons and give the number of protons transported per 2 electrons for each. **(1.5 pts)**

(0.25) Comple I: (0.25) 4 protons

(0.25) " III: (0.25) 4 "

(0.25) " IV: (0.25) 2 "

C. What is the maximal number of ATP's formed from NADH in the transport of two electrons to oxygen via the electron transport pathway. **(0.5 pts)**

(0.5) 2.5 (3,3)

D. Give the name of the mitochondrial enzyme that catalyzes the synthesis of ATP from ADP and Pi and describe its mechanism of action. Limit your answer to 2 sentences. **(2 pts)**

(1) ATP synthase

(1) Binding change mechanism (Describe correctly)

E. Name the 2 principal metabolites that carry reducing equivalents (hydrogens) from the cytosol to the mitochondrion matrix. **(2 pts)**

(1) Malate

(1) Glycerol (Glycerol-3-P) ($FADH_2$)

F. Give the number of ATP's formed in the mitochondrion per 2 electrons derived from each of the metabolites in (E). **(1 pt)**

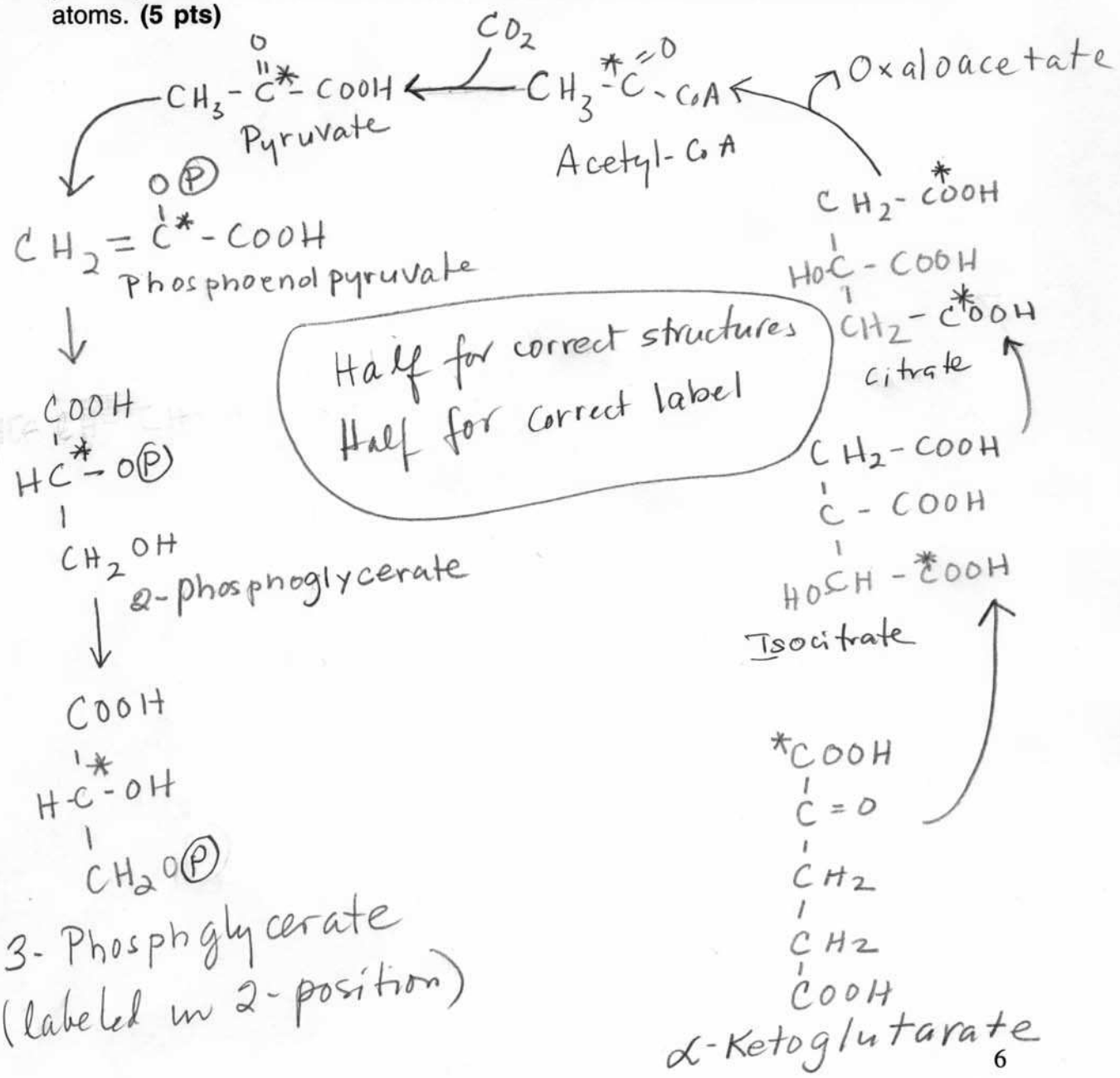
(0.5) Malate 2.5

(0.5) Glycerol 1.5 (Glycerol-3-P) ($FADH_2$)

Name Key
SID:
GSI Name:
Section:

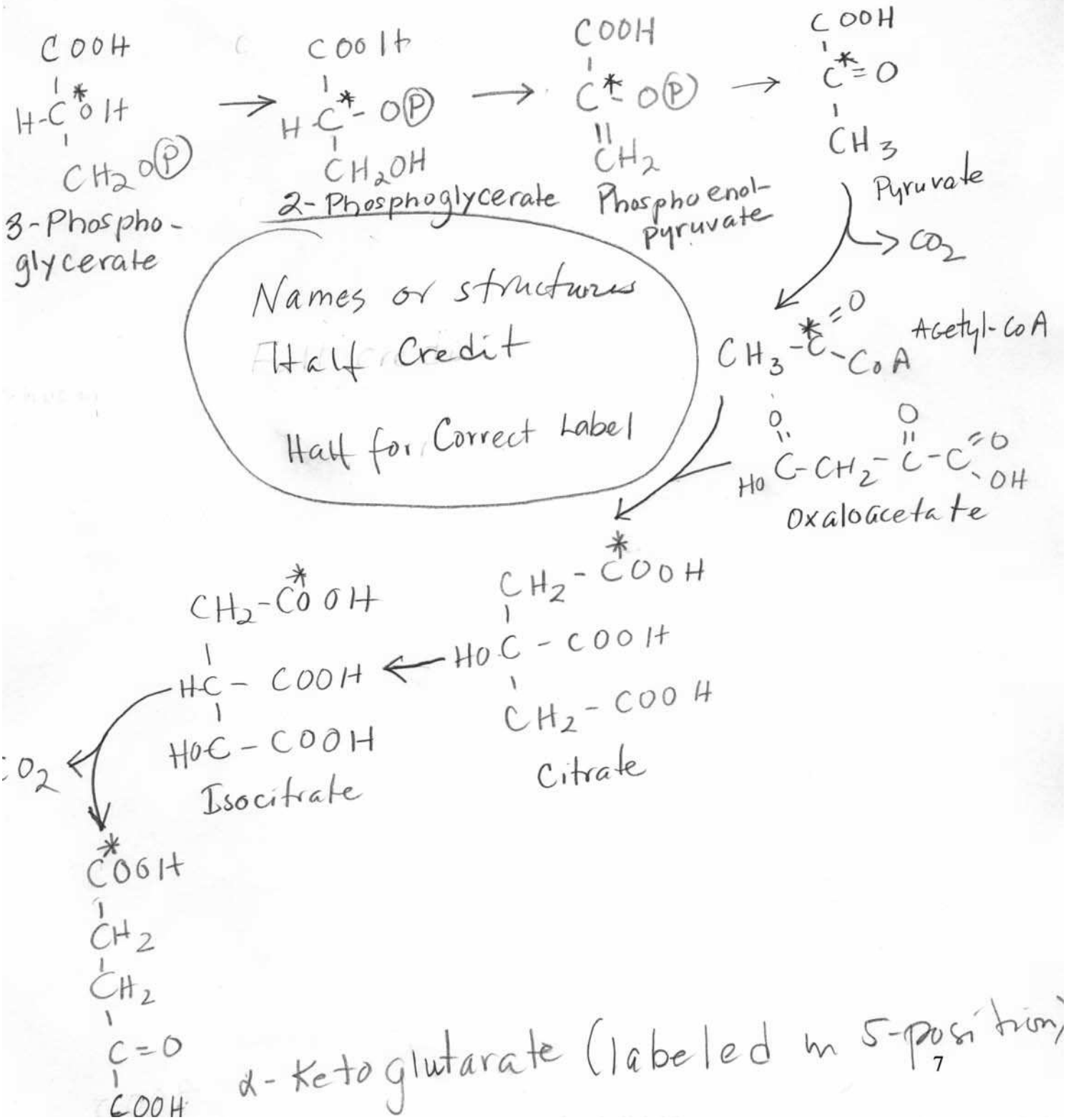
7. We have seen that the citric acid cycle can be reversed in certain photosynthetic bacteria that assimilate CO_2 by this pathway. These organisms also use the gluconeogenesis pathway in the formation of glucose. In the question below, start with α-ketoglutarate labeled with ^{14}C in the no. 1 carboxyl carbon (next to the carbonyl). **Total 10 pts**

A. Show which carbon is labeled in the 3-phosphoglycerate synthesized via the reverse citric acid cycle and the associated gluconeogenesis pathway. Assume that acetyl-CoA is the only labeled intermediate entering the gluconeogenic pathway. Draw structures of the intermediates and indicate the labeled carbon atoms. **(5 pts)**



Name Key
SID:
GSI Name:
Section:

7 (B). Starting with the ^{14}C-labled 3-phosphoglycerate in (A), which carbon(s) would be labeled in the α-ketoglutarate formed via glycolysis and the forward citric acid cycle. **(5 pts)**



Name Key
SID:
GSI Name:
Section:

8. We have seen that the enzymatic breakdown of glycogen is regulated by a series of ordered reactions that constitute a regulatory cascade. The end result is to break down glycogen. **Total 10 pts (1 pt for each question A – J)**

A. Name the main enzyme that breaks down glycogen. This is a regulatory enzyme.

(1) Glycogen Phosphorylase

B. Name the product(s) formed by the enzyme in (A).

(1) Glucose-1-phosphate + Glycogen

C. Identify the linkage in glycogen that the enzyme in (A) cleaves.

(1) α-1, 4

D. Name the type of glycogen linkage(s) resistant to the action of the enzyme in (A), if any?

(1) α-1, 6

E. Name the enzyme that breaks the bond(s) in (D), if any.

(1) Debranching Enzyme

F. Identify ~~the~~ & cellular hormone that triggers the breakdown of glycogen.

(1) Glucagon or epinephrin

G. Name the metabolite that transmits the hormonal signal to the regulation of glycogen synthesis or breakdown.

(1) C-AMP

H. Identify the change in the enzyme in (A) that results from the action of the hormone in (F).

(1) Phosphorylation

I. Name the hormone that upregulates the synthesis of glycogen.

(1) Insulin

J. What is the advantage of a regulatory cascade? Limit your answer to one sentence.

(1) Amplifies hormone signal.

Name key
SID:
GSI Name:
Section:

9. Certain enzymes of the Calvin cycle function in other pathways. Other enzymes are unique to the Calvin cycle. **Total 10 pts**

[A] As appropriate, identify the pathway in which the following enzymes function in addition to the Calvin cycle. Some of the enzymes may be unique to the Calvin cycle. Write "None" if enzyme is unique to the Calvin cycle. **(3 pts.)**

(0.5) None	Sedoheptulose-1,7-bisphosphatase
(0.5) None	Phosphoribulokinase (Ribulose-5-P Kinase)
(0.5) Glycolysis (Gluconeogenesis)	Phosphoglycerate kinase (3-Phosphoglycerate Kinase)
(0.5) Pentose phosphate pathway	Transketolase (or Nonoxidative pentose Pathway)
(0.5) Gluconeogenesis (Sucrose synthesis)	Fructose-1,6-bisphosphatase
(0.5) None	Rubisco

[B] Which enzyme(s) in (A) is (are) regulatory member(s) of the Calvin cycle? **(2 pts.)**

(0.5) Sedoheptulose-1,7-bisphosphatase
(0.5) Phosphoribulokinase (Ribulose-5-P Kinase)
(0.5) Fructose-1,6-bisphosphatase
(0.5) Rubisco

[C] Which enzyme(s) in (A) require(s) ATP? **(2 pts)**

(1) Phosphoribulokinase (Ribulose 5-P Kinase)
(1) Phosphoglycerate Kinase

[D] Identify the type of covalent modification that is involved in regulating enzymes of the Calvin cycle. Indicate which form of the enzyme is active in the light and in the dark. **(3 pts)**

Disulfide Bond

(1) (S-S) ⟶ (1) (-SH HS-)

(0.5) Disulfide Dark

(0.5) Sulfhydryl Light

Sulfhydryl Bond

Name Key
SID:
GSI Name:
Section:

10. We have seen that ATP drives thermodynamically unfavorable reactions. In some cases, this applies to electron transport reactions when ATP is used to drive electrons "uphill" against an electrochemical gradient. Assuming an energy of hydrolysis of –30 kJ/mol, calculate how many electron volts one would generate from the conversion of 10 ATP to 10 ADP + 10 Pi using a 2 electron couple. The Faraday constant is 100kJ/V·mol. **Total 5 pts**

$$\Delta G'^{\circ} = -n\,\mathcal{F}\,\Delta E'^{\circ}$$

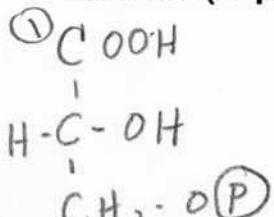
$$(10)(-30\ kJ/mol) = -(2)(100\ kJ/V\cdot mol)(E'^{\circ})$$

$$\frac{-300\ kJ/mol}{-200\ kJ/V\cdot mol} = E'^{\circ}$$

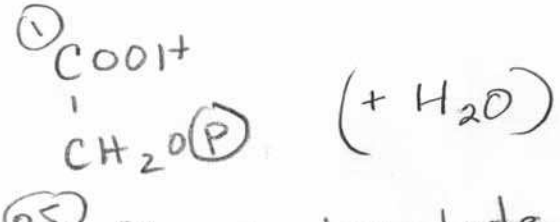
$$E'^{\circ} = 1.5\ volts$$

11. In photosynthesis O_2 competes with CO_2 at the active site of ribulose 1,5-bisphosphate carboxylase/oxygenase (Rubisco). **Total 5 pts**

A. Draw the structures and give the names of the product(s) of the oxygenase reaction. **(3 pts)**

(1) 

(0.5) 3-Phosphoglycerate

(1) 

(0.5) 2-Phosphoglycolate (Phosphoglycolate)

B. Name the cycle or pathway that each product in (A) may enter. **(2 pts)**

3-Phosphoglycerate → (1) Calvin cycle or {Starch biosyn., Export (sucrose)

2-Phosphoglycolate (Phosphoglycolate) → (1) Photorespiration (Glycolate pathway)

Name Key
SID:
GSI Name:
Section:

12. In noncyclic photophosphorylation in chloroplasts, electrons flow from water to reductants that function in CO_2 assimilation and related reactions. Assuming that an electron originates in water, identify the following:
Total 10 pts (1 pt for each question A – J)

A. The atom in water in which the electron originates.

(1) H

B. The first photosystem in which the electron interacts.

(1) PS II (½ P_{680})

C. The carrier of the electron transport pathway with which the electron joins a proton.

(1) Plastoquinone (½ b_6/f complex) (PQ) (1)

D. Its interacting carrier that contains copper as a prosthetic group.

(1) Plastocyanin (PC)

E. The second photosystem with which the electron interacts.

(1) PS I (½ P_{700})

F. The iron-sulfur protein that carries the electron to the soluble phase of the chloroplast (stroma).

(1) Ferredoxin (Fd)

G. The carrier that receives the electron from (F) and donates it to an intermediate of the Calvin cycle.

(1) $NADP^+$

H. The name of the enzyme that transfers the electron from (F) to (G).

(1) Ferredoxin-$NADP^+$ Oxidoreductase (Ferredoxin-NADP Reductase)

I. The metabolite intermediate that receives the electron in (G).

(1) 1,3-Bisphosphoglycerate

J. The name of the enzyme that transfers the electron from (G) to (I).

(1) (NADP)-Glyceraldehyde 3-phosphate Dehydrogenase