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MCB 102 Exam: Metabolism
April 3, 2007

Total points = 100

1. The oxygenic photosynthesis equation has been known for 60 years. **Total 10 pts**

(A) Write this equation. **3 pts**

(0.5) $2H_2O$ + (0.5) CO_2 —(0.5) Light→ (0.5) (CH_2O) + (0.5) O_2 + (0.5) H_2O

(B) In his classical experiment, Van Helmont did not know about gases and concluded that the plant matter he measured came from water only. Which other gas component(s) shown in the reaction in (A) did he miss. **1 pt.**

(0.5) CO_2 and (0.5) O_2

(C) If we fast forward three centuries, we now know that the major reaction for photosynthetic CO_2 fixation is present in all plants. Write the equation for this reaction, including the name of the enzyme (abbreviation OK), cofactor(s) and substrates, and the name and structure of the product. **4 pts**

(0.5) Ribulose-1,5-bisphosphate + (0.5) CO_2 + (0.5) H_2O —(1) Rubisco, (0.5) Mg^{++}→ 2 (0.5) 3-Phosphoglycerate (PGA)

0.25 pts if 2 omitted
0.25 pts for PGA only

(Ribulose-1,5-bisphosphate carboxylase/oxygenase)

(D) Write the name of the new product formed if the reaction is carried out in the presence of oxygen. **1 pt**

(1) Phosphoglycolate

(E) Name the metabolic process by which plants remove the product in (D). **1 pt**

(1) Photorespiration
OK/ glycolate pathway

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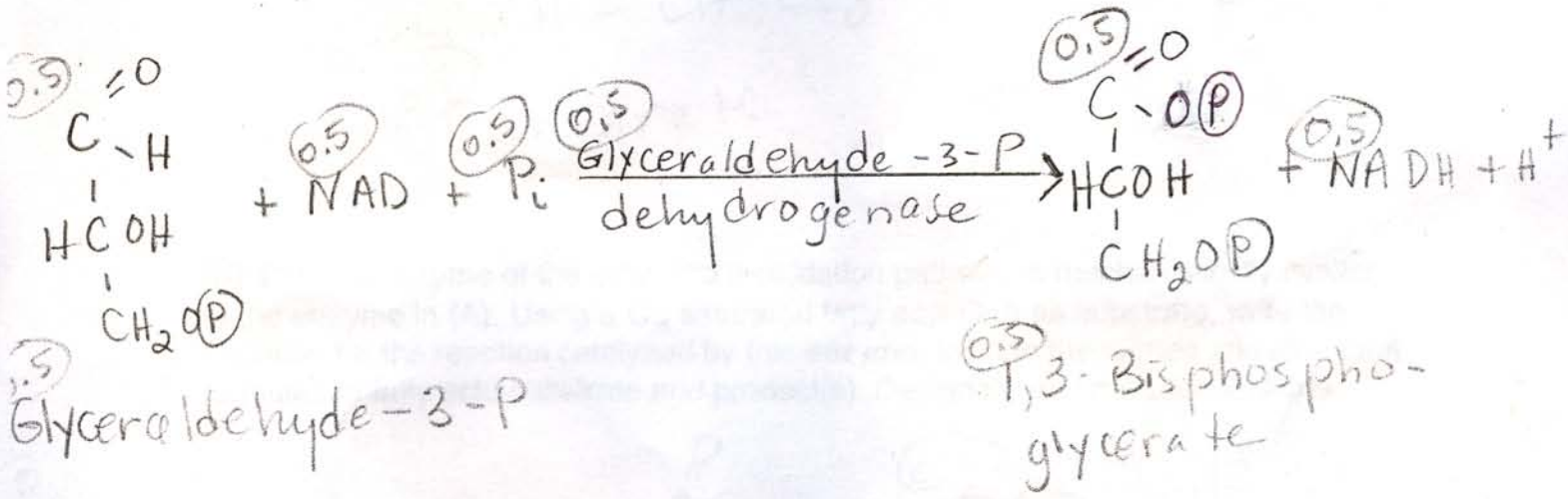
2. Researchers looking for new biofuels are interested in converting cellulose to products such as ethanol. Answer the questions below assuming that there is an effective means to generate glucose from cellulose. **Total 10 pts**

(A) Name the pathway by which glucose is fermented to a precursor of ethanol. **1 pt**

(1) Glycolysis

(B) Write the equation(s) for the redox reaction(s) operative in this pathway, giving names of enzyme(s), cofactor(s), and carbon metabolite substrates and products. Also give structural formulas of carbon metabolite substrate(s) and product(s). **4 pts**



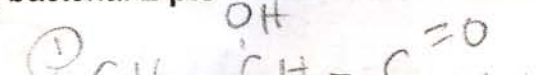
(.5) Glyceraldehyde-3-P

(0.5) 1,3-Bisphospho-glycerate

(C) Describe in no more than 10 words the metabolic basis for the formation of ethanol—that is, why the organism forms ethanol. **3 pts**

(3) Organism must oxidize (use) the NADH to free up NAD

(D) Write the structural formula and name of the alternative product formed by yogurt-making bacteria. **2 pts**

(1) 

(1) Lactic acid

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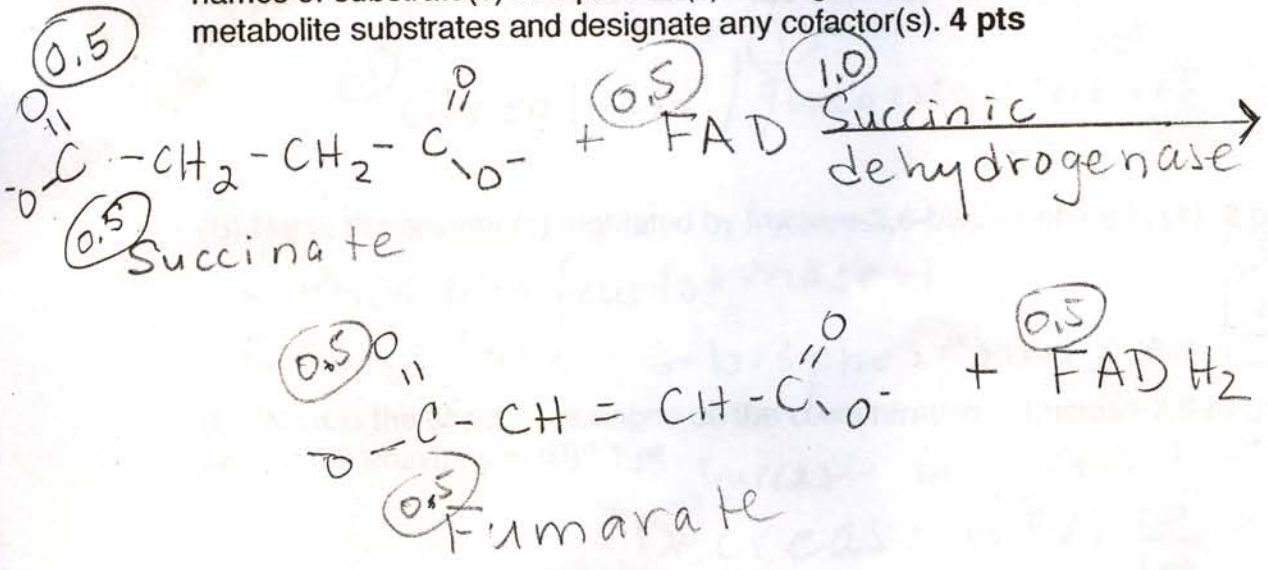
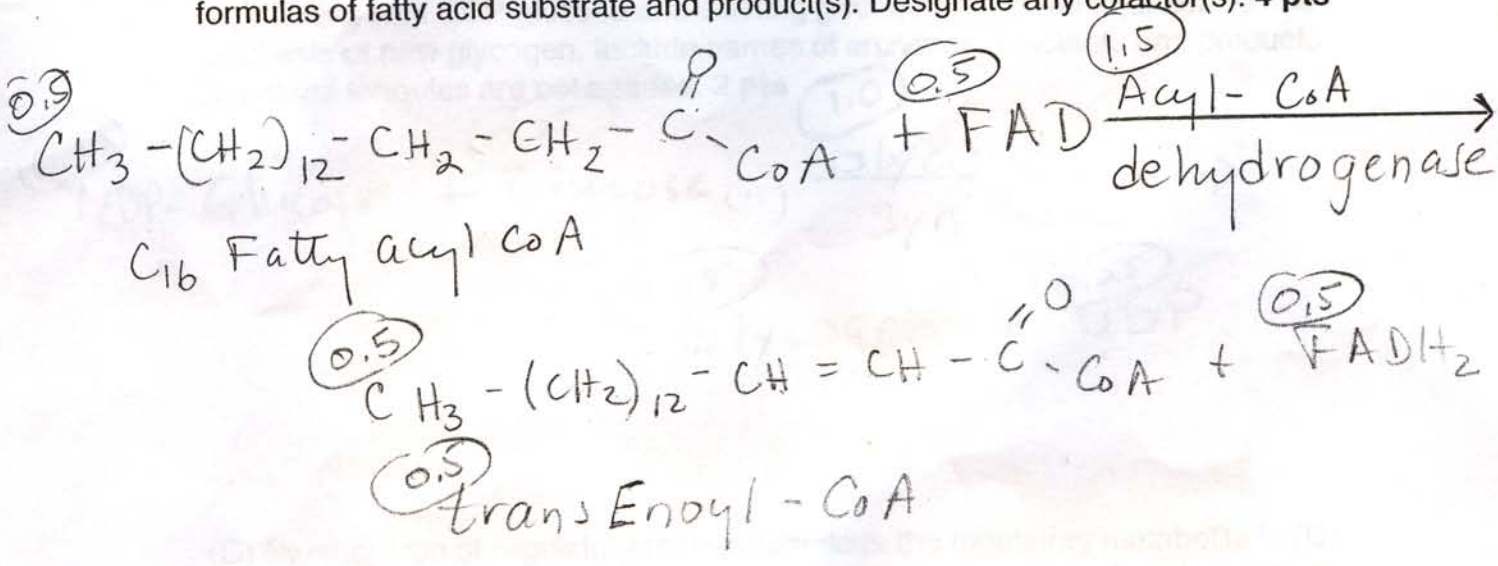
3. One enzyme of the citric acid cycle is membrane-bound. **Total 10 pts**

(A) Give the name of this enzyme and write the equation for its reaction. Include the names of substrate(s) and product(s). Also give the structural formulas of carbon metabolite substrates and designate any cofactor(s). **4 pts**



(B) The first enzyme of the fatty acid β-oxidation pathway is mechanistically similar to the enzyme in (A). Using a C_{16} saturated fatty acyl-CoA as substrate, write the equation for the reaction catalyzed by this enzyme. Include the names and structural formulas of fatty acid substrate and product(s). Designate any cofactor(s). **4 pts**



(C) Name the organelle in which (A) and (B) are located. **2 pts**

(2) Mitochondrion

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4. Fructose-2,6-bisphosphate is a key regulator of carbohydrate metabolism in liver. **Total 10 pts**

(A) Name the pathway(s) that fructose-2,6-bisphosphate regulate(s) in the liver. **2 pts**

(1) Glycolysis / (1) gluconeogenesis

(B) Name the enzyme(s) regulated by fructose-2,6-bisphosphate in (A). **2 pts**

(1) Phosphofructokinase-1
(1) Fructose 1,6-bisphosphatase – 0.5 PFK-1, 0.5 FB Pase-1

(C) What is the effect of glucagon on the concentration of fructose-2,6-bisphosphate and on the enzymes in (B)? **1 pt**

Increase in FBPase-1 activity (½ pt.)
Decrease in [F-2,6-BP] and PFK-1 activity (1 pt) (½ pt.)

(D) Give the name or abbreviation of the regulatory metabolite by which glucagon regulates the concentration of fructose-2,6-bisphosphate. **1 pt**

Cyclic-AMP (c-AMP)

(E) Starting with UDP-glucose and existing glycogen, write the equation for the synthesis of new glycogen. Include names of enzymes, reactants and products. Structural formulas are not needed. **2 pts**

(0.25) UDP-Glucose + (0.25) Glucose(n) —(1.0) Glycogen synthase→ (0.25) Glycogen + (0.25) UDP

(G) By what type of regulatory mechanism does the regulatory metabolite in (D) bring about the change in the concentration of fructose-2,6-bisphosphate? **2 pts**

(2) Protein phosphorylation

OR 1 pt. for covalent modification OK phosphorylation / dephosphorylation

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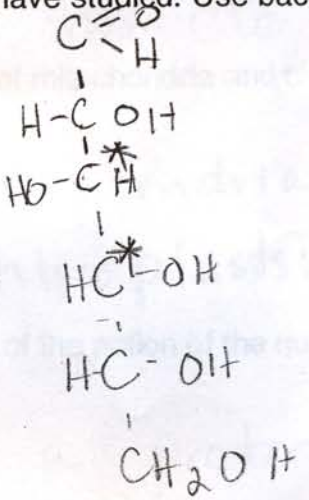
5. Glutamine is one of the amino acids that can provide carbon for the synthesis of glucose under certain circumstances. **Total 10 pts**

(A) Using words, write the equation for the reaction that glutamine must undergo as the first step in this conversion. Include the name of the enzyme and any cofactor(s). **2 pts**

(0.25) Glutamine + (0.25) H_2O $\xrightarrow{\text{(1.0) Glutaminase}}$ (0.25) NH_3 (NH_4^+) + (0.25) Glutamate

(B) Starting with ^{14}C-glutamine labeled in the amino (no. 2) carbon, show which carbon(s) in the derived glucose would be labeled when glutamine is processed by the pathway(s) we have studied. Use back of this page to trace the carbons. **5 pts**



Carbons 3 + 4 are equally labeled

*1 pt. deducted for each carbon labeled above the 2 correct carbons

(C) Using words, write the equation(s) for the reaction(s) by which the glucose in (B) would enter the oxidative pentose phosphate pathway to generate the initial NADPH. Include name(s) of enzyme(s) and cofactor(s). **3 pts**

(0.25) Glucose + (0.25) ATP $\xrightarrow[\text{(0.25) } Mg^{++}]{\text{(0.25) Hexokinase}}$ (0.25) Glucose-6-P + (0.25) ADP

(0.25) Glucose-6-P + (0.25) NADP $\xrightarrow[\text{dehydrogenase}]{\text{(0.25) Glucose-6-P}}$ (0.25) 6-Phosphoglucono-lactone + NADPH + H^+

(K) 6-Phosphogluconate + NADP $\xrightarrow[\text{dehydrogenase}]{\text{6-Phosphogluconate}}$ Ribulose-5-P + NADPH + H^+

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6. Oxidative phosphorylation and photophosphorylation have certain features in common, including the central position of a quinone in the electron transport chain. **Total 10 pts**

(A) Give the name(s) of the quinone(s) functional in each of these transport pathways. **2 pts**

(1) Coenzyme Q
(1) Plastoquinone

ok ubiquinone

(B) What is the role the quinone plays in each of these pathways? **2 pts**

Functions as an (1) electron and a (1) proton carrier
(one- or two- electron carrier)

(C) Name the complexes of mitochondria and chloroplasts that interact with quinone. **2 pts**

ok complex III

* if anything beyond the cytochromes was listed, only 1 pt. given

Mitochondria: (1) Cytochrome b/c1
Chloroplasts: (1) Cytochrome b6/f

ok b6-b6/f

(D) What is the end result of the action of the quinone that results in the formation of ATP? **1 pt**

(1) Forms a proton gradient

(E) Name the enzyme and the mechanism by which the quinone generates ATP in each electron transport chain. **2 pts**

(1) ATP synthase / (1) Binding change mechanism

(G) In which phase of the catalytic mechanism in (E) is the energy generated by electron transport used? **1 pt**

(1) Release of ATP

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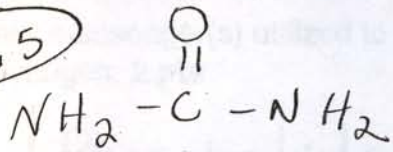
7. Urea stands out in the history of science since it was the first organic compound synthesized, as well as the first biochemical metabolite synthesized by a metabolic cycle. **10 pts**

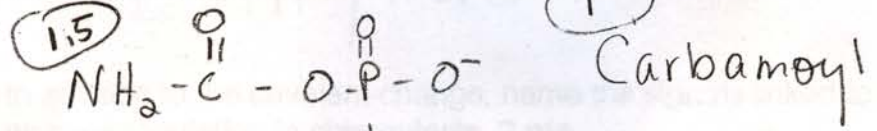
(A) Write the structural formula for urea. **1.5 pts**

(1.5)



(B) Write the names and structural formulas of the metabolites that serve as the precursors of the nitrogen and carbon groups of urea, indicating which urea atom the precursor gives rise to. **7.5 pts**

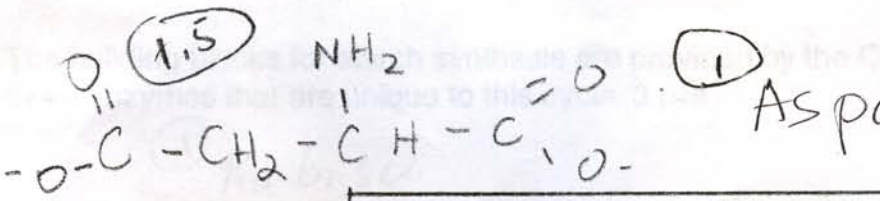
1st NH_2: (1.5) (1)



Carbamoyl phosphate

C: (1.5) (1)

2nd NH_2: (1.5) (1)



Aspartate

Half credit if NH_2 sequence wrong

(C) Name the cell compartment(s) in which the urea cycle takes place. **1 pt**

(.5) Mitochondria (.5) Cytosol

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8. The synthesis of glycogen (from glucose in liver) and starch (from CO_2 in chloroplasts) is under several levels of control. **Total 10 pts**

(A) Give the name of the main type of covalent enzyme regulation functional in each process. **2 pts**

phosphorylation / redox

(B) Name the secondary messenger(s) utilized to link hormones to the breakdown and synthesis of glycogen. **2 pts**

Cyclic AMP / Phosphatidyl inositol triphosphate

c-AMP / PIP3

(C) In addition to the covalent change, name the signals linked to light that function in enzyme regulation in chloroplasts. **2 pts**

(1) ΔpH

(1) Mg^{++}

(D) The building blocks for starch synthesis are provided by the Calvin cycle. Name three enzymes that are unique to this cycle. **3 pts**

(1) Rubisco

(1) Phosphoribulokinase (ribulose-5P kinase)

(1) Sedoheptulose-1,7-bisphosphatase

(E) Give the name of the enzyme in (D) that is <u>not</u> under covalent regulation. **1 pt**

(1) Rubisco

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9. Indicate whether each of the following statements is True of False by writing "T" or "F." **Total 5 pts 1 pt. each.**

(A) F The citric acid cycle is irreversible in all cells.

(B) F Carnitine functions in the transport of fatty acids into chloroplasts.

(C) T Fructose-2,6-bisphosphate regulates sucrose synthesis in leaves.

(D) F Energy is transferred from chlorophyll a to carotenoids.

(E) F Pyridoxal phosphate functions only in amino transfer reactions.

10. Fill in the blanks. **Total 5 pts 1 pt each.**

(A) Glucagon/epinephrin is the hormone that promotes the breakdown of triacylglyerols.

(B) The cytochrome b6/f complex of chloroplasts links plastocyanin to photosystem II.

(C) Plants known as C_4 plants have a superior type of photosynthesis.

(D) Pepsin is the protease that degrades protein in the stomach.

(E) Sedoheptulose-1,7-bisphosphate is a sugar that is a member of the Calvin cycle.

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11. Lactate dehydrogenase catalyzes the reversible reaction given below. **Total 5 pts**

Given the standard reduction potentials described below calculate the $\Delta G'^{\circ}$ for the reaction assuming that reactants and products are present at 1 M concentrations and that Faraday's constant is100 kJ/V·mol. Note that the standard electrode potentials have been rounded off to simplify calculations. If needed, use the back of this page for calculations. ~~Total 10 pts~~

Standard Reduction Potentials at 25 °C and pH 7

Half-reaction	E'° (V)
$NAD^+ + H^+ + 2\,e^- \longrightarrow NADH$	-0.30
$Pyruvate + 2\,H^+ + 2\,e^- \longrightarrow Lactate$	-0.20

$\Delta E'^{0} = E'^{0}(oxidant) - E'^{0}(reductant)$ (1pt)

$E'^{0} = -0.20 - (-0.30) = +0.10\,V$ (1pt) - for correct math

$\Delta G'^{0} = n\,\mathcal{F}\,\Delta E'^{0}$ (1pt.)

$= -(2)(100\ kJ/V \cdot mol)(0.10\,V)$ (1pt. for correct math)

$= -20\ kJ/mol$ (1pt) for correct units

12. Suppose a rat were put on a diet of mainly fat meat. **Total 5 pts**

(A) What class of compounds functional in energy transformations would the animal have difficulty synthesizing? **1 pt**

Carbohydrates OR SUGARS

(B) What type of compounds would be enriched in the animal's blood? **1 pt**

Ketone bodies

(C) Name the type of enzymes that prevent the problem in (A) in well fed rats. **1 pt**

Anapleurotic

(D) Name the hormone that might help correct the problem in deficient rats. **1 pt**

Insulin

(E) Name the metabolite needed for the synthesis of urea that would be decreased in these animals. **1 pt**

Aspartate