Name Key

Biochemistry 5700
Fall, 2004
Exam 3

INSTRUCTIONS:
Do not begin until 10:30 AM. The exam contains six questions on six pages. Work any five of six questions (pages) for 20 points each. Draw a huge "X" and write "do not grade" across the one page/problem you choose not to answer. *If you answer all six questions, and do not indicate which question is to be discarded, I will count the lowest five point totals for the six questions to calculate your exam score.*

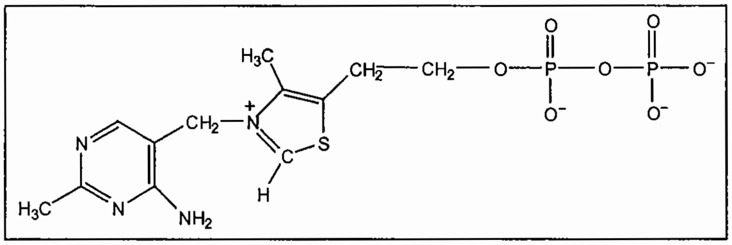
If you do not complete the exam by the end of class time (11:20 AM), you may take additional time to finish the exam at one of the tables in the foyer outside the classroom. The exam must be turned in by 12 noon.

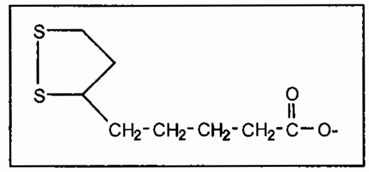
Equations: $\Delta G = \Delta G^{\circ\prime} + RT \ln Q$ $\quad \Delta E' = \Delta E^{\circ\prime} - \frac{RT}{nF} \ln Q$ $\quad \Delta G' = -nFE'$

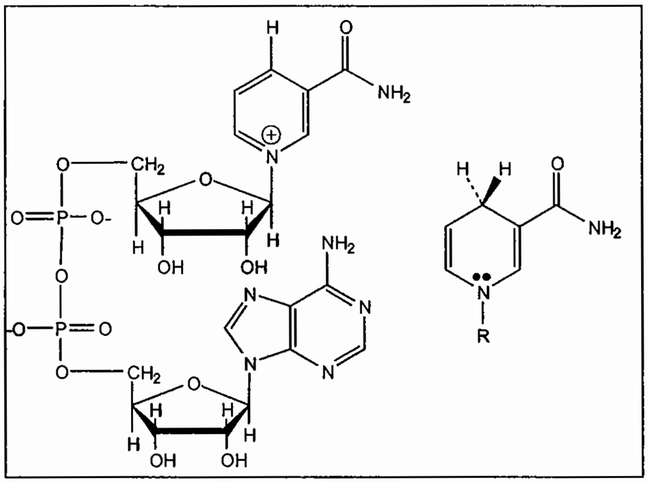
Constants: F = 96.5 kJ/V•mol $\quad$ R = 8.3144 J/mol•K

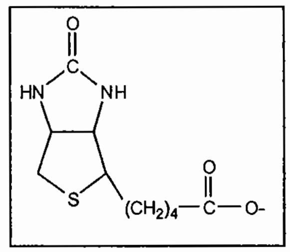
TABLE 13–7 Standard Reduction Potentials of Some Biologically Important Half-Reactions, at pH 7.0 and 25°C (298 K)

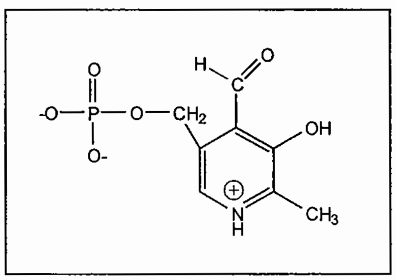
Half-reaction	E'° (V)
$\frac{1}{2}O_2 + 2H^+ + 2e^- \longrightarrow H_2O$	0.816
$Fe^{3+} + e^- \longrightarrow Fe^{2+}$	0.771
$NO_3^- + 2H^+ + 2e^- \longrightarrow NO_2^- + H_2O$	0.421
Cytochrome *f* (Fe^{3+}) + e^- $\longrightarrow$ cytochrome *f* (Fe^{2+})	0.365
$Fe(CN)_6^{3-}$ (ferricyanide) + e^- $\longrightarrow$ $Fe(CN)_6^{4-}$	0.36
Cytochrome a_3 (Fe^{3+}) + e^- $\longrightarrow$ cytochrome a_3 (Fe^{2+})	0.35
$O_2 + 2H^+ + 2e^- \longrightarrow H_2O_2$	0.295
Cytochrome *a* (Fe^{3+}) + e^- $\longrightarrow$ cytochrome *a* (Fe^{2+})	0.29
Cytochrome *c* (Fe^{3+}) + e^- $\longrightarrow$ cytochrome *c* (Fe^{2+})	0.254
Cytochrome c_1 (Fe^{3+}) + e^- $\longrightarrow$ cytochrome c_1 (Fe^{2+})	0.22
Cytochrome *b* (Fe^{3+}) + e^- $\longrightarrow$ cytochrome *b* (Fe^{2+})	0.077
Ubiquinone + $2H^+ + 2e^-$ $\longrightarrow$ ubiquinol + H_2	0.045
Fumarate^{2-} + $2H^+ + 2e^-$ $\longrightarrow$ succinate^{2-}	0.031
$2H^+ + 2e^- \longrightarrow H_2$ (at standard conditions, pH 0)	0.000
Crotonyl-CoA + $2H^+ + 2e^-$ $\longrightarrow$ butyryl-CoA	−0.015
Oxaloacetate^{2-} + $2H^+ + 2e^-$ $\longrightarrow$ malate^{2-}	−0.166
Pyruvate$^-$ + $2H^+ + 2e^-$ $\longrightarrow$ lactate$^-$	−0.185
Acetaldehyde + $2H^+ + 2e^-$ $\longrightarrow$ ethanol	−0.197
FAD + $2H^+ + 2e^-$ $\longrightarrow$ $FADH_2$	−0.219*
Glutathione + $2H^+ + 2e^-$ $\longrightarrow$ 2 reduced glutathione	−0.23
$S + 2H^+ + 2e^- \longrightarrow H_2S$	−0.243
Lipoic acid + $2H^+ + 2e^-$ $\longrightarrow$ dihydrolipoic acid	−0.29
$NAD^+ + H^+ + 2e^-$ $\longrightarrow$ NADH	−0.320
$NADP^+ + H^+ + 2e^-$ $\longrightarrow$ NADPH	−0.324
Acetoacetate + $2H^+ + 2e^-$ $\longrightarrow$ β-hydroxybutyrate	−0.346
α-Ketoglutarate + CO_2 + $2H^+ + 2e^-$ $\longrightarrow$ isocitrate	−0.38
$2H^+ + 2e^- \longrightarrow H_2$ (at pH 7)	−0.414
Ferredoxin (Fe^{3+}) + e^- $\longrightarrow$ ferredoxin (Fe^{2+})	−0.432

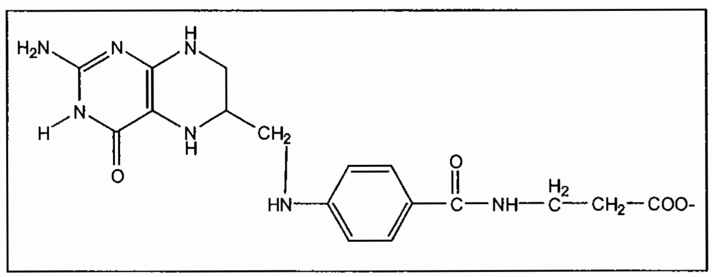


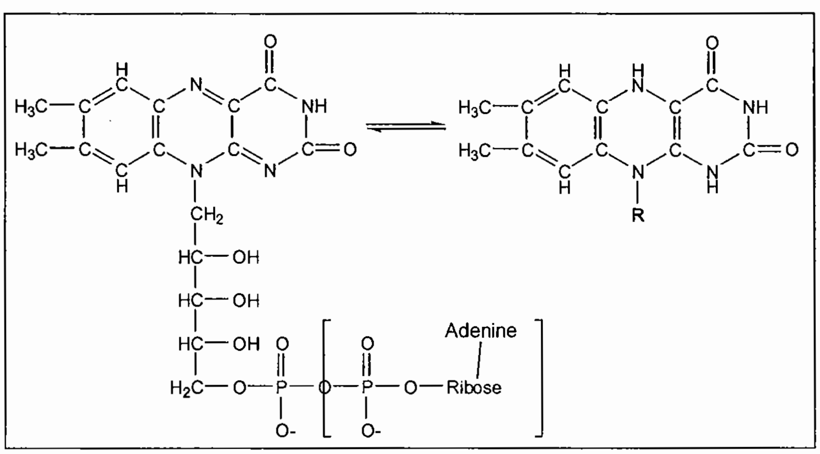


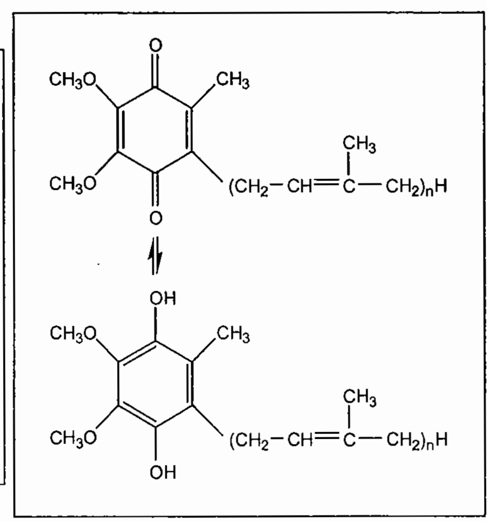









Adenine
Ribose



 Name ______________________________

(1) 20 points. Pot pourri of definitions.

Name the product of the reaction catalyzed by glyceralde-3-phosphate dehydrogenase	
Name the products of the reaction catalyzed by aldolase	glyceraldehyde-3-phosphate & dihydroxyacetone phosphate
The oxidative portion of the pentose phosphate pathway is intended to produce what two molecules ?	ribose & NADPH
What is the general name for the class of enzymes that transfer a phosphoryl group to water?	phosphatase
Name a specific enzyme that catalyzes a nonoxidative decarboxylation reaction ***NOT requiring TPP***	pyruvate decarboxylase
Name the two specific enzymes from glycolysis that catalyze substrate level phosphorylation of ADP	pyruvate kinase, phosphoglycerate kinase
What molecule is the initial electron acceptor of the pyruvate dehydrogenase enzyme complex?	lipoamide
Name a cofactor used to facilitate homolytic bond cleavage	B_{12} (cobalamin)
Name an enzyme that can discriminate between the two prochiral arms of its substrate	aconitase
What compound is exhaled in the breath of diabetic individuals?	acetone
How does biochemical standard state differ from chemical standard state?	pH = 7 & $[H_2O]$ = 55M
What is the final product of beta-oxidation of an odd-chain saturated fatty acid?	propionyl-CoA
Dietary fat is transported through the bloodstream in particles called what?	Chylomicrons, lipoprotein particles
Name a dehydrogenase that uses FAD rather than NAD+ as electron acceptor.	succinate DH or acyl-CoA DH
The reaction catalyzed by citrate synthase is an example of _______________ condensation	Claisen
What cofactor is used by Propionyl-CoA carboxylase?	biotin
Which enzyme has a lower K_m for glucose: hexokinase in the muscle, or glucokinase in the liver?	hexokinase
Name a high energy compound from central metabolism that is an acylphosphate	1,3-diphosphoglycerate
Name a high energy compound that is an enolphosphate	phosphoenolpyruvate
Name a high energy compound that is a thioester	Acetyl-CoA, succ.-CoA, acyl-CoA, etc

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(2) (20 points total)

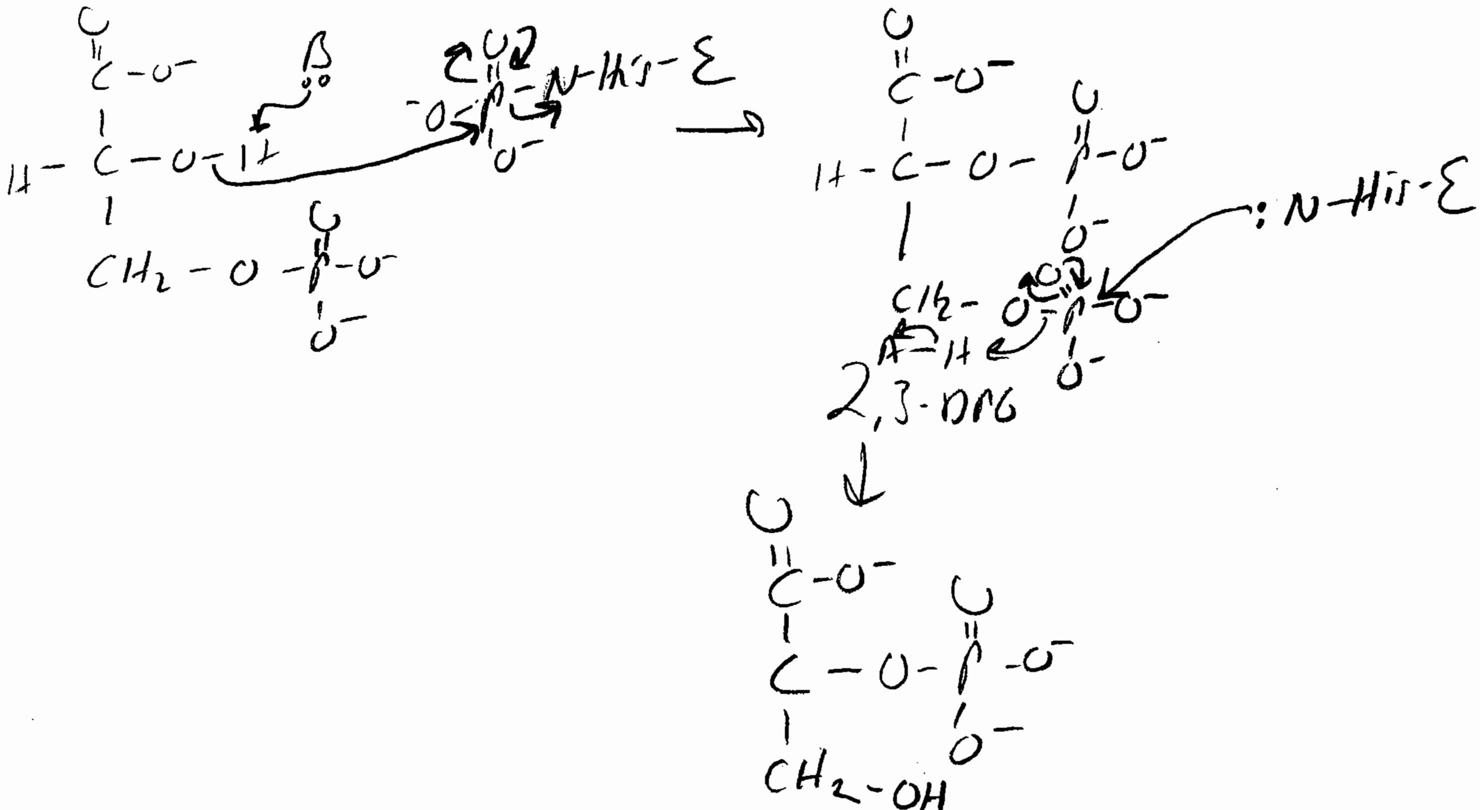
(a) The reactions catalyzed by succinyl-CoA synthetase and phosphoglycerate mutase each involve phosphoenzyme intermediates.

(a.i.) (4 points) Write the net reactions catalyzed by these two enzymes.

succinyl-CoA + GDP + P_i $\rightleftharpoons$ GTP + succinate + CoA

3-phosphoglycerate $\rightleftharpoons$ 2-phosphoglycerate

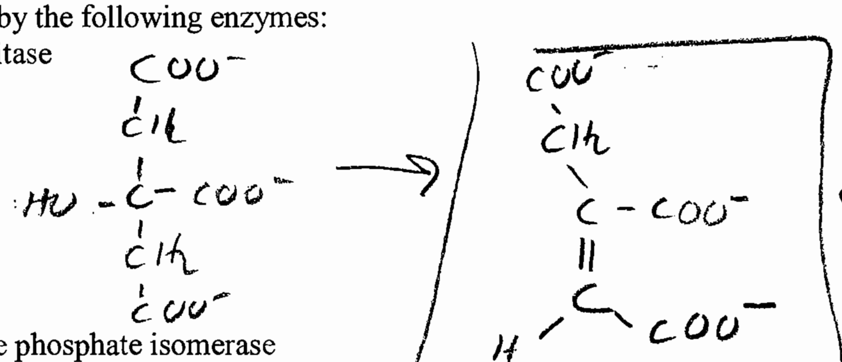
(a.ii.) (10 points) For one of the two enzymes above (you choose which one) write a complete reaction mechanism, showing all necessary general acids, bases, intermediates, and correct electron pushing.



See next page for Succ CoA synthetase

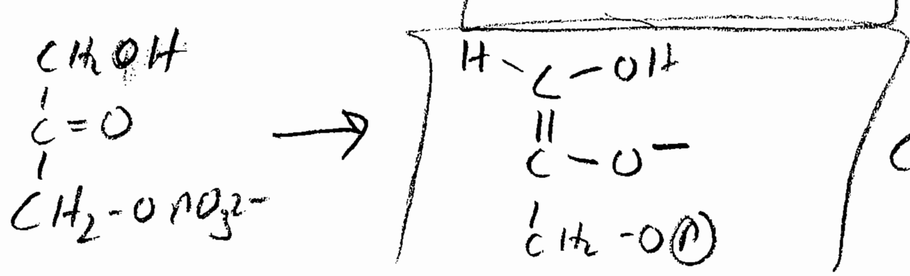
(b) (6 points) Draw the structures of the key intermediates formed during conversion of substrate to product by the following enzymes:

bi (a) aconitase



cis-aconitate

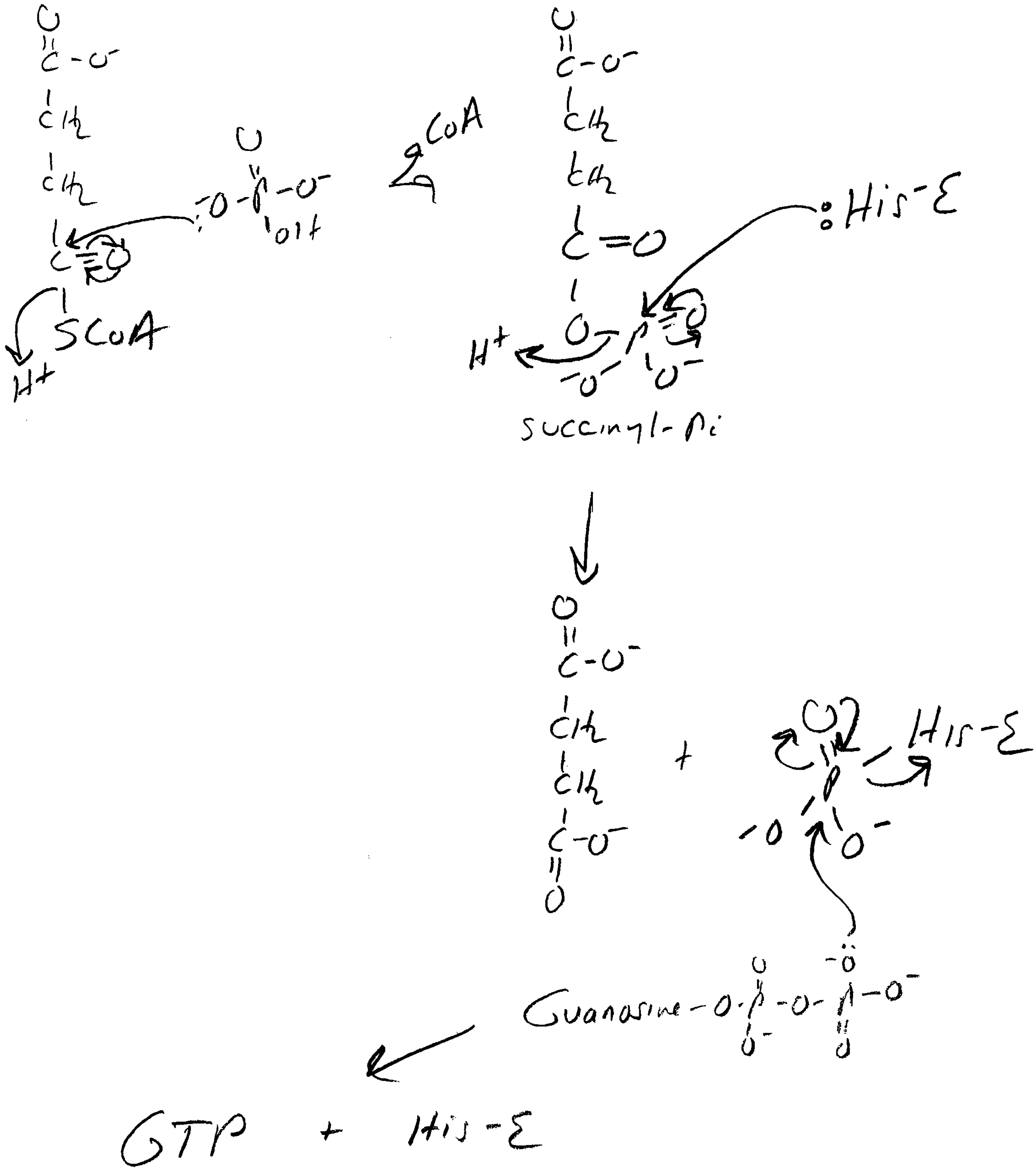
bii (b) triose phosphate isomerase



cis-enediolate

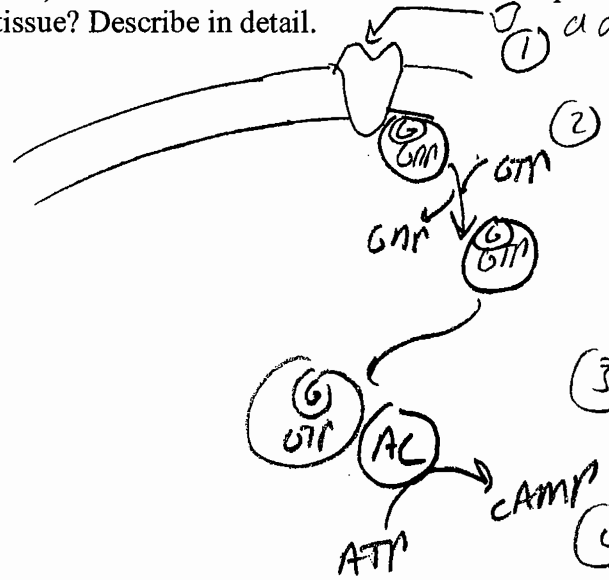
#2 cont.:

Succinyl-CoA synthetase:



(3) (20 points total)

(a) (6 points) What events and reactions result in the production of cAMP in the liver, muscle, or adipose tissue? Describe in detail.



① adrenaline hormone binds receptor protein on outside of cell

② hormone-bound receptor undergoes conformational change, inducing conf. change in G protein. G protein exchanges bound GDP for GTP

③ GTP-bound G protein binds adenylyl cyclase, activates the enzyme

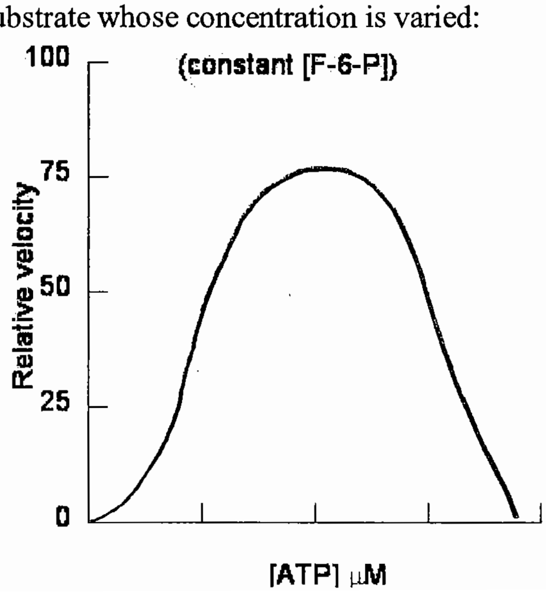
④ adenylate cyclase hydrolyzes & cyclizes ATP to cAMP

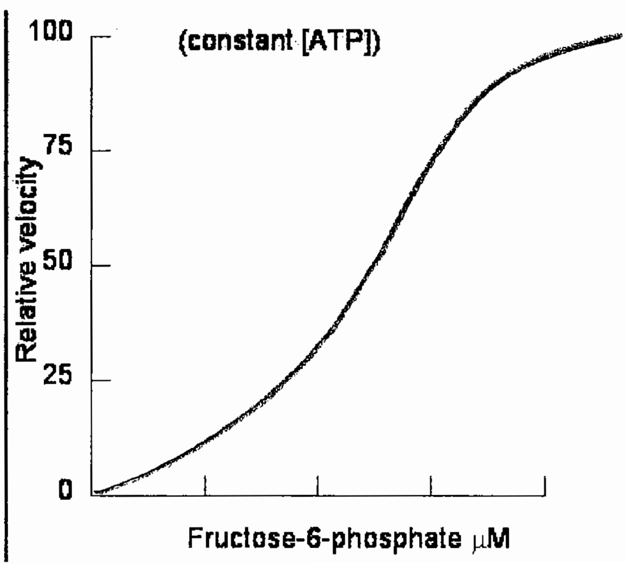
(b) (4 points) How does cAMP activate protein kinase?

cAMP binds to a regulatory site on regulatory subunits of PK. Binding of cAMP induces conf. change in regulatory subunits causing them to open the substrate binding sites of the catalytic subunits

(c) (4 points) Glycogen phosphorylase in the liver is a glucose/AMP (circle one) sensor, and binds this metabolite in the phosphorylated/unphosphorylated (circle one) form. In contrast, glycogen phosphorylase in the muscle is a glucose/AMP (circle one) sensor and binds this metabolite in the phosphorylated/unphosphorylated (circle one) form.

(d) (6 points) Recall that ATP is both a substrate and allosteric effector of phosphofructokinase. Draw the v vs. S plots for phosphofructokinase, focusing on either ATP or fructose-6-phosphate as the substrate whose concentration is varied:





(4) (a) (10 points) Use information from the first page of the exam to calculate $\Delta G^{\circ\prime}$ and K_{eq} for the following reaction:

$$\text{lactate} + NAD^{+} \rightleftharpoons \text{pyruvate} + NADH + H^{+}$$

(b) (10 points) Diagram the reaction mechanism by which lactate dehydrogenase catalyzes this reaction in the direction written, showing all necessary cofactors, general acids, bases, intermediates, and correct electron pushing. You may abbreviate the ADP-ribose portion of NAD^{+} and NADH as "R", as shown for NADH on the cofactors sheet (page 2).

a)

$$\text{lactate} \rightarrow \text{pyruvate} + \cancel{2e^-} + \cancel{2H^+} \qquad \mathcal{E}^{\circ\prime} = +0.185V$$

$$NAD^+ + \cancel{2e^-} + \cancel{H^+} \rightarrow NADH \qquad \mathcal{E}^{\circ\prime} = -0.320V$$

$$\text{lactate} + NAD^+ \rightarrow \text{pyruvate} + NADH + H^+ \qquad \mathcal{E}^{\circ\prime} = -0.135V$$

$$\Delta G^{\circ\prime} = -nF\mathcal{E}^{\circ\prime} = -(2)\left(96.5\frac{kJ}{V\cdot mol}\right)(-0.135V)$$

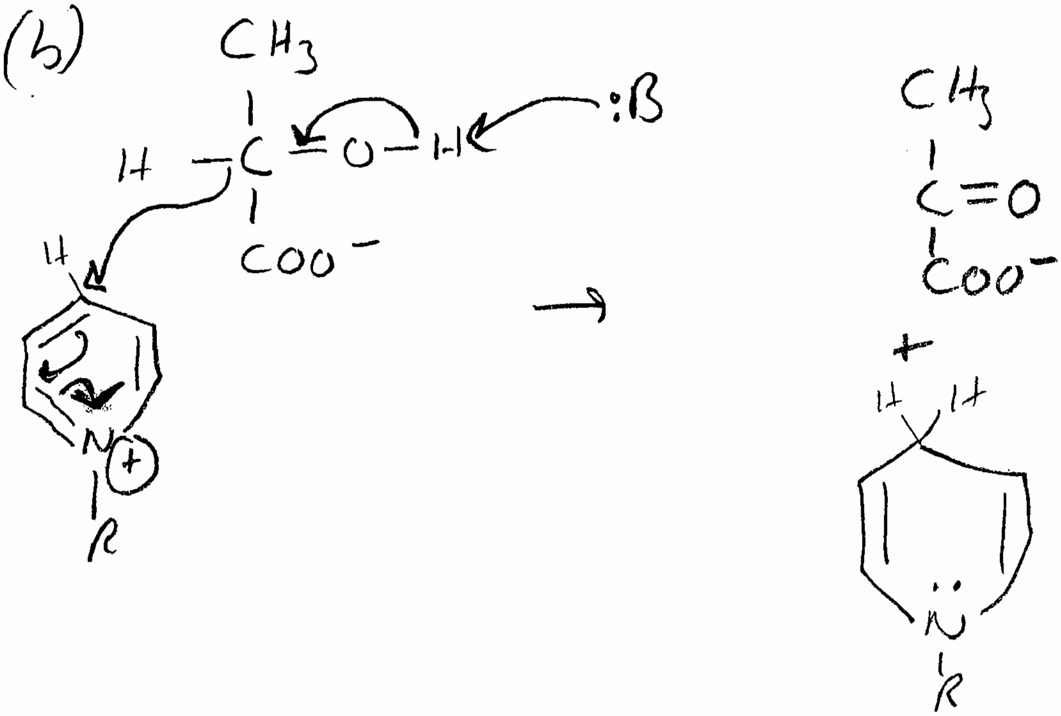
$$\boxed{\Delta G^{\circ\prime} = +26.05\frac{kJ}{mol}}$$

$$K_{eq} = e^{-\Delta G^{\circ\prime}/RT}$$

$$= \exp\left(-26.05\frac{kJ}{mol}\right)\left(\frac{1}{8.314\frac{J}{mol\,K}}\right)\left(\frac{1}{298K}\right)\left(\frac{1000J}{kJ}\right)$$

$$\boxed{K_{eq} = 2.71 \times 10^{-5}}$$

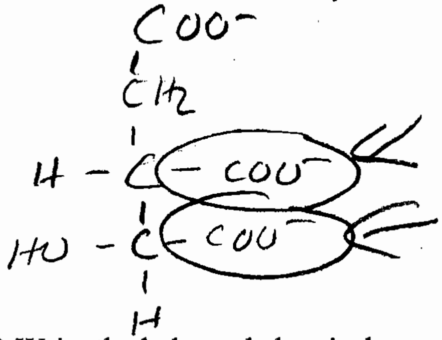
(b)



 Name Key

(5) (20 points total)

(a) (5 points) Draw the structure of isocitrate. Circle the carbon atoms on isocitrate that are released as CO_2 during one turn of the citric acid cycle.



(b) (3 points) Write the balanced chemical equations for conversion of one molecule glucose to ~~pyruvate by~~ glycolysis.

1 glc + 2NAD$^+$ + 2ADP + 2P$_i$ → 2 pyruvate + 2NADH + 2H$^+$ + 2ATP + 2H$_2$O

important things circled

(c) (3 points) Write the balanced chemical equation for one turn of the citric acid ~~cycle~~ (starting with acetyl-CoA).

Ac-CoA + 3NAD$^+$ + FAD + GDP + P$_i$ → 2CO$_2$ + 3NADH + FADH$_2$ + GTP + CoA

(d) (3 points) Write the balanced chemical equation for the oxidation of one molecule of stearic [redacted] acid (saturated C18 fatty acid) to CO_2 by beta oxidation and the Citric Acid Cycle (your answer to part (c) above should help you here). C18 → 9AcCoA via $\underline{\underline{8}}$ rounds of β-oxid^n

each round: 1FAD + H$_2$O + NAD$^+$ · CoA → FADH$_2$ + NADH + H$^+$ (final round gives 2 C2)

so 8 rounds: 8FAD + 8H$_2$O + 8NAD$^+$ + 9CoA → 8FADH$_2$ + 8NADH + 8H$^+$

+ part(c) × 9

Oleic acid + 35NAD$^+$ + 17FAD + 9GDP + 9P$_i$ + 8H$_2$O → 18CO$_2$ + 35NADH + 17FADH$_2$ + 9GTP + 9P$_i$

(e) (6 points) For each of the general terms below, write a reaction from central metabolism that illustrates that process, and name the enzyme involved:

(e.i) Phosphorolysis

(glycogen)$_n$ + P$_i$ → (glycogen)$_{n-1}$ + glc 1-P glycogen phosphorylase

(e.ii) Hydrolysis

Triacylglycerol + 3H$_2$O → 3FA + glycerol lipase

(Starch)$_n$ + H$_2$O → (Starch)$_{n-1}$ + glucose α-amylase

MANY MANY MORE!

(e.iii) Thiolysis

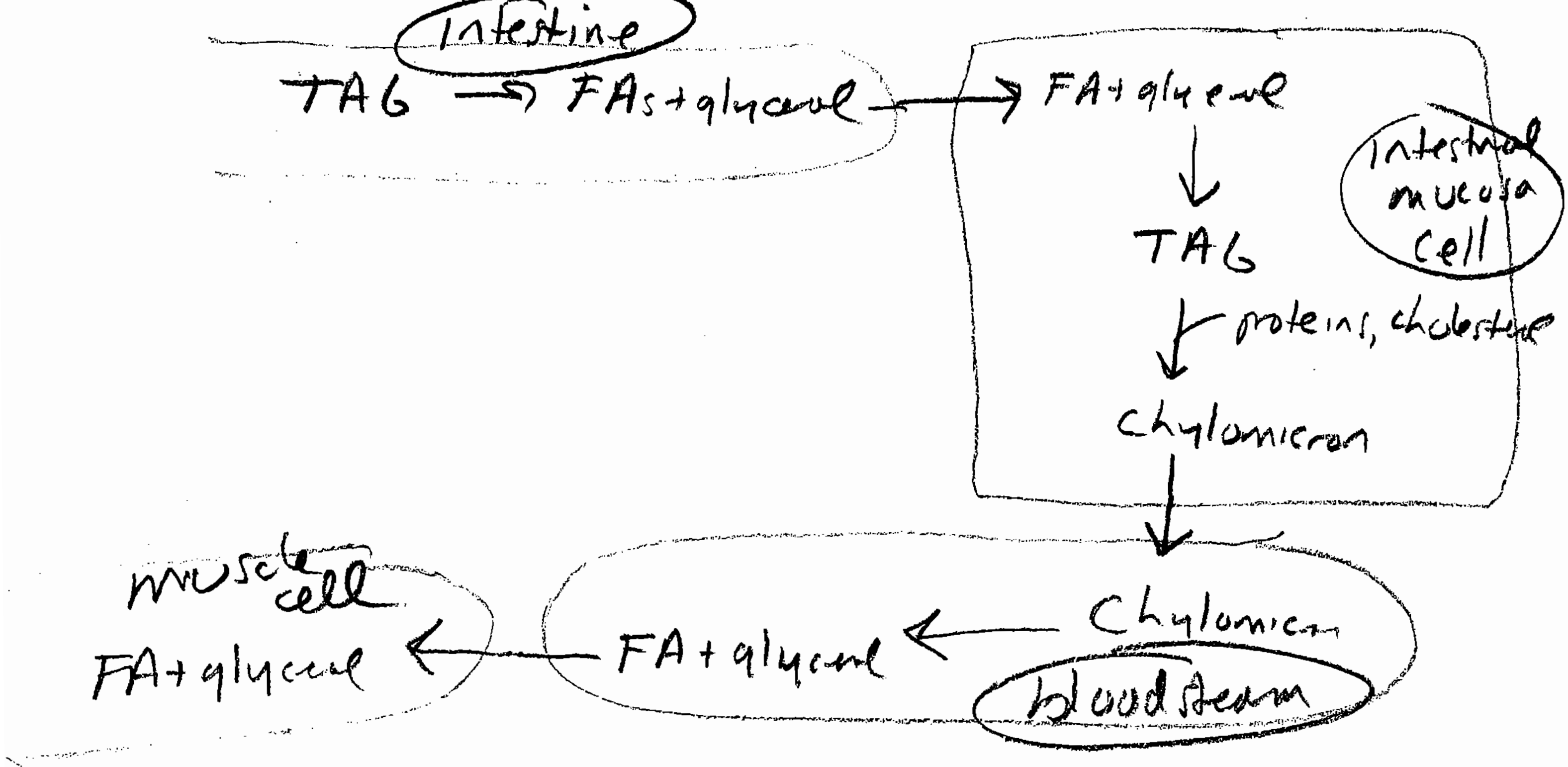
Acetoacetyl-CoA + CoA → 2Acetyl-CoA thiolase

these are examples; there are many more you

 Name Key

(6) (20 points)

(a) 10 points) You have just eaten a big juicy, fatty hamburger. Explain (feel free to diagram) how the portion of the hamburger that is fat eventually arrives in your muscle cell (i.e., what is the biochemical/molecular path ~~from intestine~~ to muscle?



(b) 10 points) Diagram the pathway by which fatty acids are transported from the cytosol to the mitochondrial matrix.