7.014 Quiz I

2/25/05

Your Name: ______________________________ **TA's Name:**___________________

Write your name on this page and your initials on all the other pages in the space provided.

This exam has 10 pages including this coversheet. Check that you have pages 1-10. The last page has the structures of the amino acids.

This exam has 4 questions. Read all questions before starting to write.

Write your answers as clearly and precisely as possible in the space provided.

This is a closed book exam.

Question	Value	Score
1	36	________
2	36	________
3	14	________
4	14	________
TOTAL:	100	________

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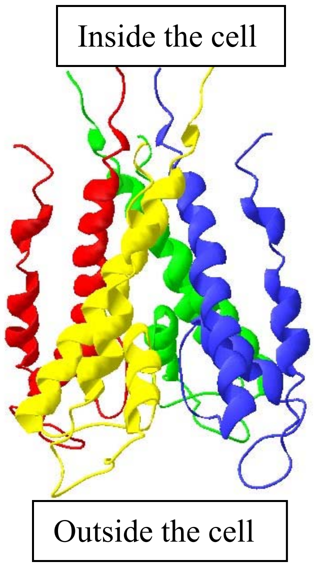
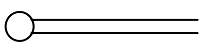
Question 1 (36 points)

Below is a ribbon representation of the K^+ channel, a membrane spanning protein made up of four copies of a single polypeptide. The K^+ channel allows K^+ ions to be shuttled through the membrane.



a) What protein secondary structure is part of the K^+ channel protein as shown above?

b) Does the K^+ channel have quaternary structure? If yes, describe it.

c) Using  as a schematic of a phospholipid, draw a cross-section of the membrane around the K^+ channel shown above.

d) What type(s) of amino acids do you expect to find on the K^+ channel polypeptides

i) next to the tails of the membrane lipids? (Circle all that apply)

Polar Nonpolar Positively charged Negatively charged

Why?

ii) next to the heads of the membrane lipids? (Circle all that apply)

Polar Nonpolar Positively charged Negatively charged

Why?

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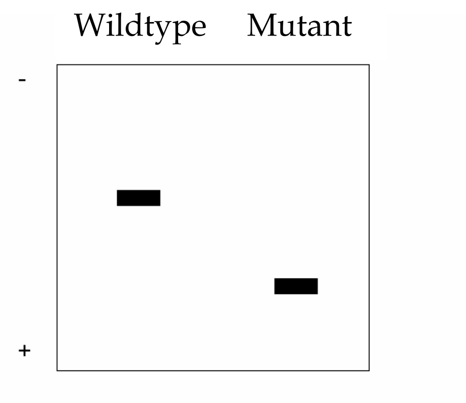
Question 1, continued

e) If you were trying to estimate the volume occupied by this protein, would the picture above provide all the information you need? Why or why not?

The positively charged K^+ ion is a very small soluble molecule.

f) Explain why K^+ cannot come across the membrane without a channel protein.

You isolate a mutant of the K^+ channel that transports less K^+ than normal. You run both the wild-type and mutant proteins on a denaturing gel and get the following result:



g) From the gel data we can conclude that (circle all that apply):

i) Each subunit of the mutant protein is <u>shorter than</u> / <u>the same length as</u> / <u>longer than</u> in the wild-type protein.

Justify your answer(s)

ii) The mutant and wild-type proteins could differ in their <u>primary</u> / <u>secondary</u> / <u>tertiary</u> structure.

Justify your answer(s)

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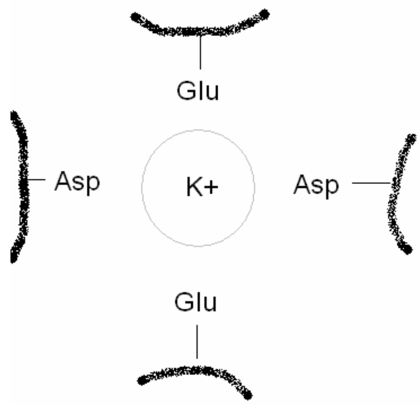
Question 1, continued

The K^+ channel has several binding pockets in which K^+ ions may associate. Below is an image of one of the binding pockets of the K^+ channel shown from above.



h) Circle the strongest type of interaction that exists between the K^+ ion and the Glu residues.

Covalent bond Van der Waals Hydrogen bond Ionic bond

i) You isolate a series of mutant K^+ channel proteins where the two Asp residues have been replaced by amino acid X (see table below). For each X, indicate whether K^+ binding in the resulting pocket will be stronger, weaker, or the same and give a brief explanation of your choice.

X	Interaction (choose one)	Explain why
Asn	stronger weaker same	
Leu	stronger weaker same	
Phe	stronger weaker same	

j) Suppose you isolate another mutant that has four Glu residues instead of two Asp and two Glu residues in the pocket above. You find that the mutant has decreased K^+ transport. Explain this result.

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Question 2 (36 points)

a) Fill in the blanks:

A ________________ is an organism that is capable of making its own food store, while a __________________ must rely on getting food from the environment.

b) What types of organisms carry out

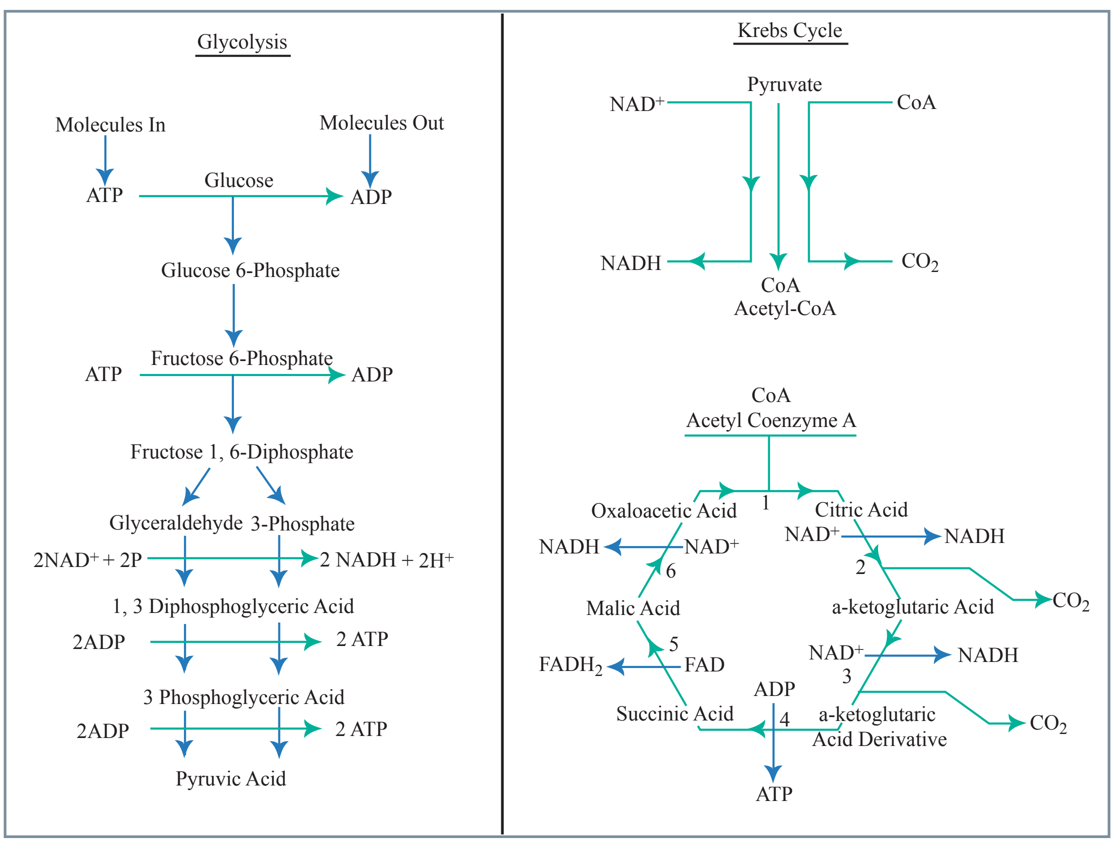
i) glycolysis (circle all that apply)

autotroph heterotroph prokaryotes eukaryotes

ii) photosynthesis (circle all that apply)

autotroph heterotroph prokaryotes eukaryotes

Below are simplified chemical flowcharts of glycolysis and the Krebs (citric acid) cycle.



In the course of glycolysis, NAD^+ is reduced to NADH.

c) In glycolysis, what is the <u>original</u> source of the electrons that are used to reduce NAD^+?

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Question 2, continued

The glycolysis pathway produces energy from glucose.

d) In what molecule is this energy stored?

e) Where in that molecule is the energy that is used to perform work stored? Be specific.

Breakdown of the molecule (in d) is often coupled with other reactions in the cell, making the new, coupled, reaction proceed at an appreciable rate.

f) Describe one mechanism that is commonly used in such coupled reactions.

S. oxyphiliae is an organism that can undergo fermentation or respiration.

g) You take equal aliquots of the same *oxyphiliae* culture and supply both with equal amount of food. You place aliquot A into an airtight bottle and aliquot B into an open shallow container.

   i) Are the cells in cultures A and B deriving <u>all</u> of their energy in the same way? Explain.

   ii) Will one culture run out of food faster? If yes, state which culture, and explain why. If no, explain why not.

   iii) At the time when both cultures run out of food, will there be approximately the same number of cells in each? Why or why not?

h) In the Krebs cycle itself, only one ATP molecule is generated per molecule of pyruvate. Yet we know that respiration overall yields more additional ATP molecules. Beginning with the products of the Krebs cycle, briefly outline how that additional ATP is generated.

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Question 2, continued

i) What is the main overall product of the dark reactions of photosynthesis?

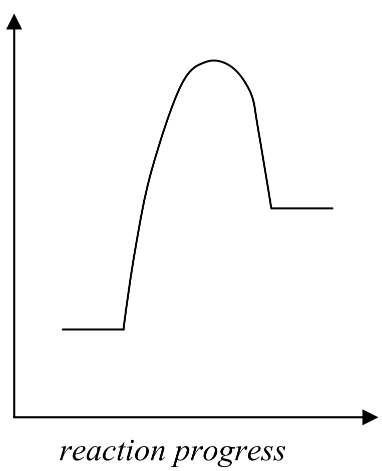
All enzymatic reactions, including those in glycolysis and the Krebs cycle, are reversible. You decide to study where in the cell glycolytic enzymes are found. You are surprised to find that these enzymes are not only found in the cytoplasm, but also in chloroplasts.

j) Explain why these enzymes are found in chloroplasts.

k) Explain, in evolutionary terms, why two species that diverged billions of years ago still use many of the same enzymes and reactions.

Question 3 (14 points)

Below is the energy diagram for the reaction C+D →A+B.



a) On the energy diagram above, label the following:

•E_a ($\Delta G^{\ddagger}$) •ΔG •A+B •C+D

b) Based on the diagram above,

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ΔG<0 ΔG=0 ΔG>0

Question 3, continued

c) How would the enzyme change

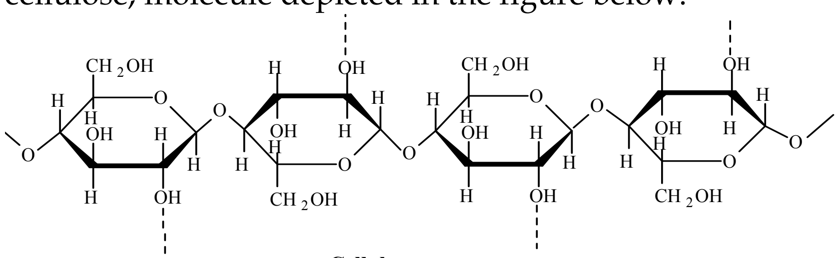
i) ΔG?
Explain

ii) E_a ($\Delta G^{\ddagger}$)?
Explain

iii) speed of reaction?
Explain

Question 4 (14 points)

A popular line of research in developing environmentally cleaner and cheaper energy sources focuses on biomass fuel, or using ethanol produced from organic sources as fuel. In order for this approach to be economical, sources such as corn stover, wheat straw, wood chips and waste paper would need to be converted to ethanol. All these potential sources are rich in cellulose, molecule depicted in the figure below.



Cellulose
(Unbranched polymer of Glucose in (β1⟶4) linkage)

A class of enzymes called cellulases that break down cellulose would be required to start the process of converting these materials into ethanol.

a) Starting with cellulose, briefly outline the pathway needed to produce ethanol.

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Question 4, continued

In the 1990's a group of researchers, called bioprospectors, set out to find bacteria that could help in the production of biomass fuel. For biomass fuel production, cellulases would have to remain functional in the harsh conditions used by industry (high temperature and acidity).

To isolate thermo- and pH-stable cellulases, bacteria from several sources were examined.

b) Among the possible sources of bacteria listed below, choose the one you believe to be the most likely to produce cellulases stable at high temperature and low pH. For your choice, list the strong and weak points.

- Cow rumen (stomach)
- Human stomach
- Tree bark
- Acidic springs near active volcanoes

The bioprospectors eventually isolated the bacteria *Acidothermus cellulolyticus* in Yellowstone National Park. These bacteria secrete cellulases that function optimally at 80°C and pH 5, conditions that denature most proteins.

c) What type of bond might help stabilize the protein tertiary structure under such conditions?

Bacteria do not produce enough cellulases for industrial applications. Scientists are now attempting to make high levels of the cellulases in plants for more efficient production.

However, active cellulases can not be produced in plants without destroying the plant. Cellulases have multiple subunits, and when each subunit is manufactured in a separate plant, the plants are not destroyed.

d) Explain why manufacturing the entire enzyme in plants destroys the plants, whereas manufacturing separate subunits does not.

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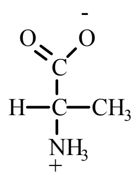
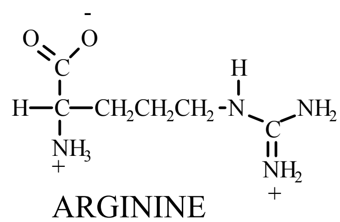
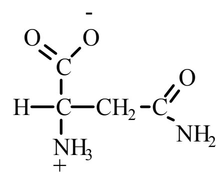
STRUCTURES OF AMINO ACIDS
at pH 7.0



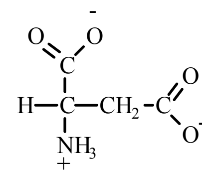
ALANINE
(ala)



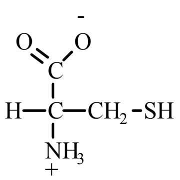
ARGININE
(arg)



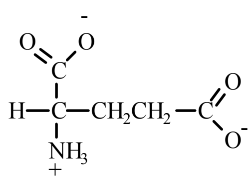
ASPARAGINE
(asN)



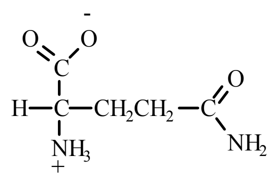
ASPARTIC ACID
(asp)



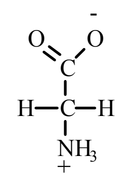
CYSTEINE
(cys)



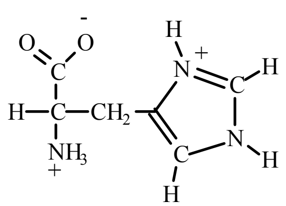
GLUTAMIC ACID
(glu)



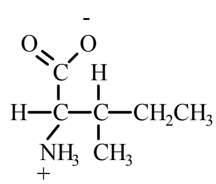
GLUTAMINE
(glN)



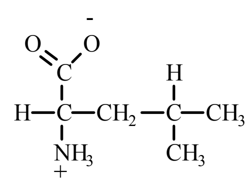
GLYCINE
(gly)



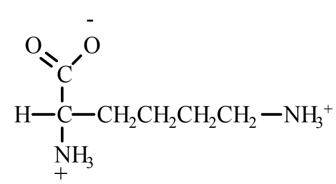
HISTIDINE
(his)



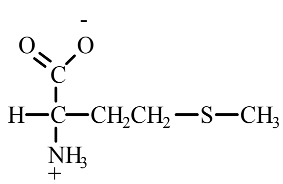
ISOLEUCINE
(ile)



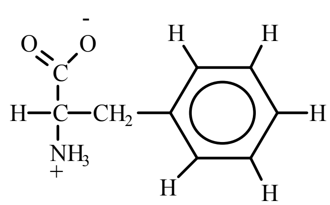
LEUCINE
(leu)



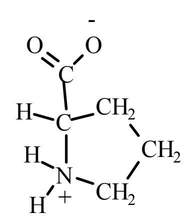
LYSINE
(lys)



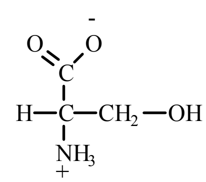
METHIONINE
(met)



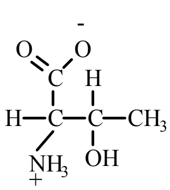
PHENYLALANINE
(phe)



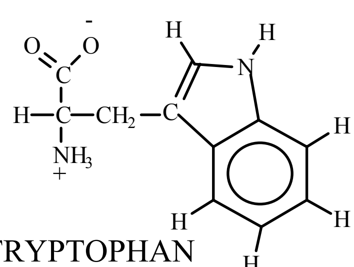
PROLINE
(pro)



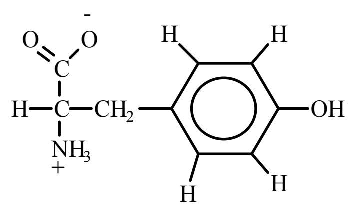
SERINE
(ser)



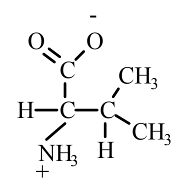
THREONINE
(thr)



TRYPTOPHAN
(trp)



TYROSINE
(tyr)



VALINE
(val)