

Name: _____

7.013 Exam One -- 2007

Exam starts at 11:05 am and ends at 11:55 am.

There are 12 pages including this cover page.

Please write your name on each page.

Only writing on the **FRONT** of every page will be graded.
(You may use the backs, but only as scratch paper.)

Topic 1 **22 pts**_____

Topic 2 **30 pts**_____

Topic 3 **28 pts**_____

Topic 4 **20 pts**_____

TOTAL **out of 100**_____

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Topic 1.

A researcher in your lab has developed a way to tag specific proteins in cultured cells to make the proteins fluoresce green. Now when she looks at cells under the microscope, she finds that, depending on which protein is tagged, only certain parts of cell fluoresce green.

When the following proteins are tagged, which organelle or part of the cell is most likely to fluoresce green?

- 1a. (2 points) DNA polymerase: *The nucleus*
- 1b. (2 points) Primase: *The nucleus*
- 1c. (2 points) A protein involved in appending carbohydrates to other proteins:
The endoplasmic reticulum or the Golgi bodies
- 1d. (2 points) Collagen:
The extracellular matrix or the surfaces of the cells
- 1e. (2 points) A protein involved in metabolizing simple sugars to make ATP:
The mitochondria
- 1f. (2 points) A protein involved in digesting food particles that have been taken up by phagocytosis:
Lysosomes
- 1g. (4 points) She then tags a cellular protein whose function is unknown. When she looks under the microscope, she finds that the cells don't fluoresce at all. However, there is a greenish glow to the liquid in which the cells had been growing. Assuming the protein was correctly tagged and expressed, what might have caused this result? Provide your answer in 15 words or less.
"The protein was secreted" or "it is an extracellular protein"

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- 1h. **(2 points)** An error occurs during division of cells that make up the lining of the intestines such that daughter cells inherit an abnormal number of parental chromosomes. Is this more likely to be an error in mitosis or in meiosis? Explain your choice in 15 words or less.

Mitosis, since meiosis only involves the formation of gametes, not cell division within the intestine

- 1i. **(2 points)** A child is born with three copies of chromosome #21 in nearly every cell in its body. This is a disorder commonly called Down Syndrome. Does this disorder most likely reflect an error that occurred during a mitotic cell division or during a meiotic cell division? Explain your choice in 15 words or less.

Meiosis, since this reflects an abnormal gamete that gave rise to all other cells

- 1j. **(2 points)** During which type of cell division would you expect to see chiasmata? Explain your choice in 15 words or less.

Meiosis, during which homologous chromosomes align (and cross over) before the first anaphase event

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Topic 2.

Xylose is a 5-carbon sugar that can be enzymatically converted to xylitol, a low calorie, diabetic-safe sweetener that is used in products such as chewing gum.

- 2a. (2 points) In nature, long polymers made of xylose are major structural components of wood. Would you classify a polymer of xylose as a protein, a lipid, a polypeptide, a nucleic acid, a polysaccharide, a polyethylene, or a polyester?

A polysaccharide

Xylose reductase (XR) is the enzyme that is used to convert xylose into xylitol. Figure 1 illustrates this reaction

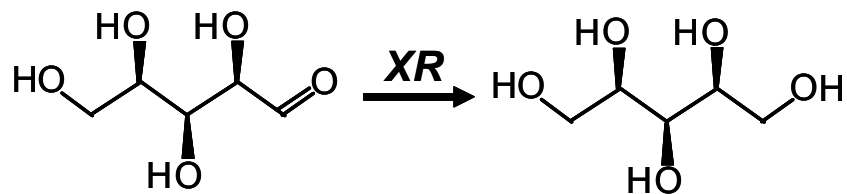


Figure 1. Xylose reductase (XR) converts xylose to xylitol. Other molecules involved in this reaction have been omitted for simplicity.

- 2b. (4 points) As with other enzymes, xylose reductase changes some of the thermodynamic properties of the chemical reaction in which xylose is converted to xylitol. Of the following properties of this reaction, circle all that are changed by the enzyme.

- | | |
|--|--------------------|
| <input checked="" type="checkbox"/> Rate of the reaction | <i>Changed</i> |
| <input type="checkbox"/> ΔG | <i>Not changed</i> |
| <input checked="" type="checkbox"/> Activation energy | <i>Changed</i> |
| <input type="checkbox"/> Equilibrium of the reaction | <i>Not changed</i> |

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Figure 2 is a diagram of the xylose molecule in the active site of xylose reductase. Although the enzyme is composed of many amino acids, only those closest to the xylose molecule are indicated.

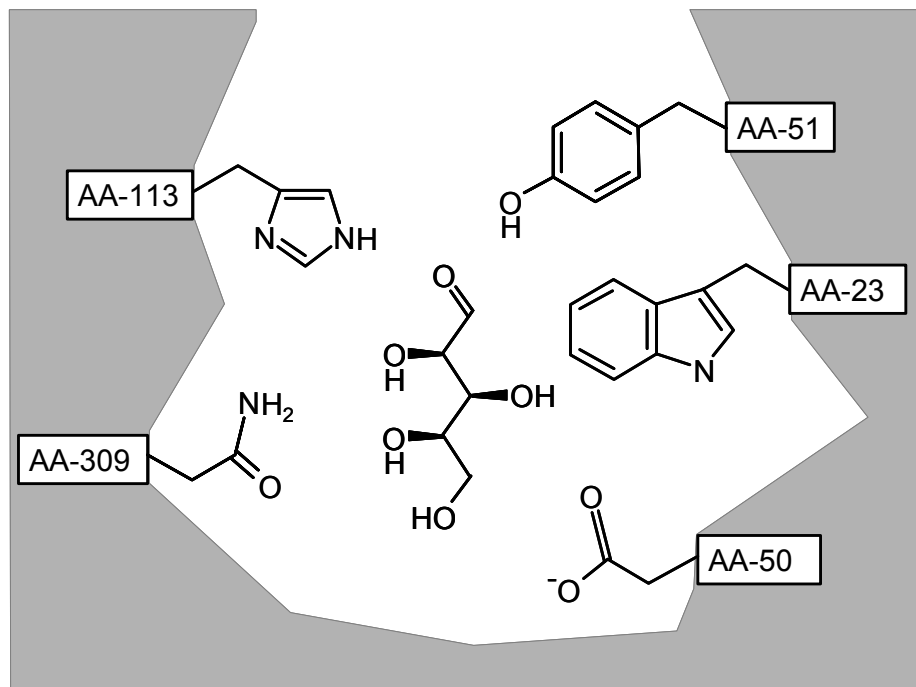


Figure 2. Xylose in the active site of xylose reductase. “AA-#” refers to individual amino acids. Adapted from Kratzer et al., 2006, *Biochem. J.* 393:51-58

- 2c. (8 points)** Based on the description of the chemical reaction provided in Figure 1, which two amino acids are positioned to interact most strongly with the portion of the xylose molecule that will be chemically modified? List the two amino acids by their “AA-#” here. Indicate how each is most likely to interact with the substrate as it is shown in Figure 2 (your choices are: hydrophobic interaction, hydrogen bond, ionic bond, covalent bond).

<i>Amino Acid Numbers</i>	<i>Interaction Type</i>
<u>AA-51</u>	<u>Hydrogen Bond</u>
<u>AA-113</u>	<u>Hydrogen bond</u>

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- 2d. (8 points) Only the side groups have been shown for each of the amino acids in Figure 2 and their common portions have been indicated as boxes. Using the table on the last page of this exam, identify each of the following amino acids, and indicate whether each is hydrophilic or hydrophobic.

<u>Amino Acid Numbers</u>	<u>Amino Acid Names</u>	<u>Hydrophobic or Hydrophilic</u>
AA-23	<u>Tryptophan</u>	<u>Hydrophobic</u>
AA-50	<u>Aspartate</u>	<u>Hydrophilic</u>

- 2e. (2 points) In terms of primary structure, which of the five amino acids shown in the figure of the enzyme's active site is closest to the C terminus of the protein chain?

AA-309

- 2f. (2 points) Assuming xylose reductase is a single subunit enzyme, what is the highest order protein structure one would need to describe the enzyme? Your choices are "primary", "secondary", "tertiary", or "quaternary."

Tertiary (3°)

Triglycerides are common fats produced by a variety of organisms, including bacteria, fungi, plants, and animals. The common structure of triglycerides is as shown in Figure 3.

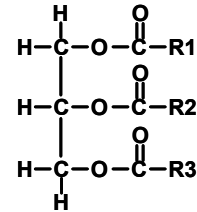


Figure 3. Triglyceride structure

- 2g. (2 points) Many organisms produce triglycerides in which all three R-groups are 15-17 carbons in length. These R-groups are similar in length to those of the lipids found in cell membranes. However, triglycerides are almost never found in cell membranes. What property of such triglycerides makes them unsuitable for incorporation into normal cell membranes? Answer in 15 words or less.

"Triglycerides are too hydrophobic," "they are non-polar," "they lack a phosphate group," "they are not amphipathic" or "they lack a polar group"

- 2h. (2 points) Some bacteria adapt to lower temperatures by increasing the fluidity of their cell membranes. Would you expect increasing the fluidity of a cell membrane to involve *increasing* or *decreasing* the number of double bonds in the fatty acids that make up the membrane lipids? Explain your choice in 15 words or less. **More double bonds: decreases saturation, prevents lipids from packing tightly together, making membranes more fluid.**

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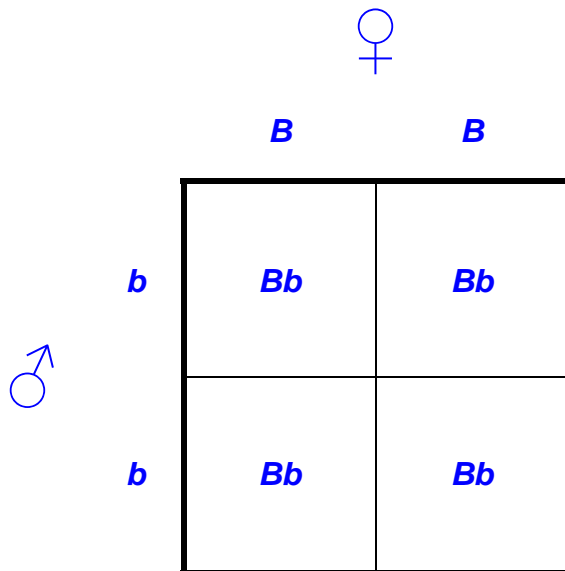
Topic 3.

You've taken over the family business of breeding heffalumps. You cross two true-breeding heffalumps, a female that has uniformly pink fur, and a male that has blue fur with black spots. All of the offspring from this cross have lovely, uniformly pink fur. You then cross two of the resulting siblings, and find that, of the eight offspring, 6 have uniformly pink fur, and 2 have blue fur with black spots.

3a. (4 points) Assuming the simplest interpretation of the above observations, complete the tables below (two boxes are already completed for your convenience):

Alleles	Make up a name for this allele	Character	Genotypes	Phenotypes	Dominance
<i>B</i>	<i>PINK</i>	<i>Fur color</i>	<i>BB</i>	<i>Pink</i>	<i>Pink ></i> <i>(blue + black spots)</i>
<i>b</i>	<i>Pink-1</i>		<i>Bb</i> <i>bb</i>	<i>Pink</i> <i>(Blue+black spots)</i>	

3b. (8 points) Using the allele notation above, use a Punnett square to describe the mating event that gave rise to the F1 generation.



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The market for heffalumps is booming, so you decide to expand your herd to meet the growing demand. You again mate one true breeding female with uniformly pink fur to one true breeding male that has blue fur with black spots. Again, you get offspring that are all uniformly pink. You then take some of the pink offspring and cross them repeatedly to individuals that have blue fur with black spots until you have a herd of 100 of their offspring. Of the one hundred offspring in this new generation, you find that 48 have uniformly pink fur, 48 have blue fur with black spots, 2 have uniformly blue fur, and 2 have pink fur with black spots.

- 3c. (4 points)** What phenomenon most likely caused the appearance of the *new* phenotypes (assuming no spontaneous mutations have arisen)? Answer in 15 words or less.

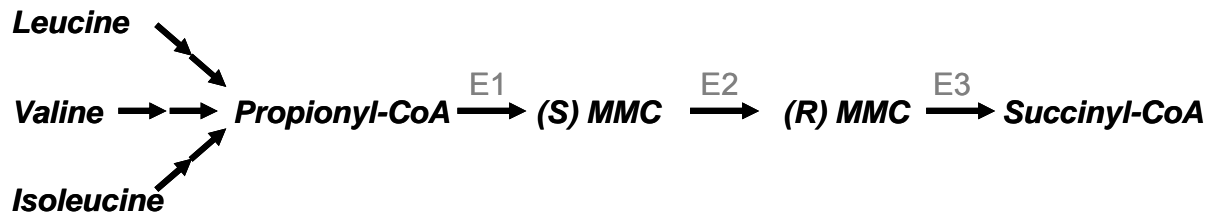
“Fur color” and “spots” are caused by two distinct, tightly linked genes, separated by crossing-over (chiasmata)

- 3d. (4 points)** What is the genetic distance between the genes involved (in centimorgans)?

4 cM

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Propionic Acidemia is an inborn error in metabolism that affects 1 in every 100,000 babies born in the United States. Affected individuals cannot properly metabolize several nutrients, including certain common amino acids, and must live on very restricted diets. If not addressed, this disorder causes propionyl-CoA and related toxic compounds to accumulate in the blood. A summary of the pathway for propionyl-CoA metabolism is shown below.



Propionic Acidemia is caused by defects in amino acid catabolism. PROPIONYL-COA CARBOXYLASE (E1) IS A MULTISUBUNIT ENZYME COMPOSED OF TWO VERY DIFFERENT POLYPEPTIDES, WHILE ENZYMES E2 AND E3 ARE EACH COMPOSED OF SINGLE SUBUNITS.

- 3e. (4 points)** In your laboratory you have identified two, independent, true-breeding mouse strains (S1 and S2) that each show an inability to properly metabolize propionyl-CoA. Excited that you may have happened upon an animal model for this unfortunate disorder, you cross the S1 and S2 mouse lines. To your surprise, none of the 10 F1 offspring show any sign of the disorder and are perfectly normal. You then cross siblings from this “normal-looking” generation and find that the disease reappears in the F2 generation at a ratio of 9:7 (normal mice : affected mice). How many different *genes* and *alleles* appear to be involved in this phenomenon?

2 genes with 2 alleles each

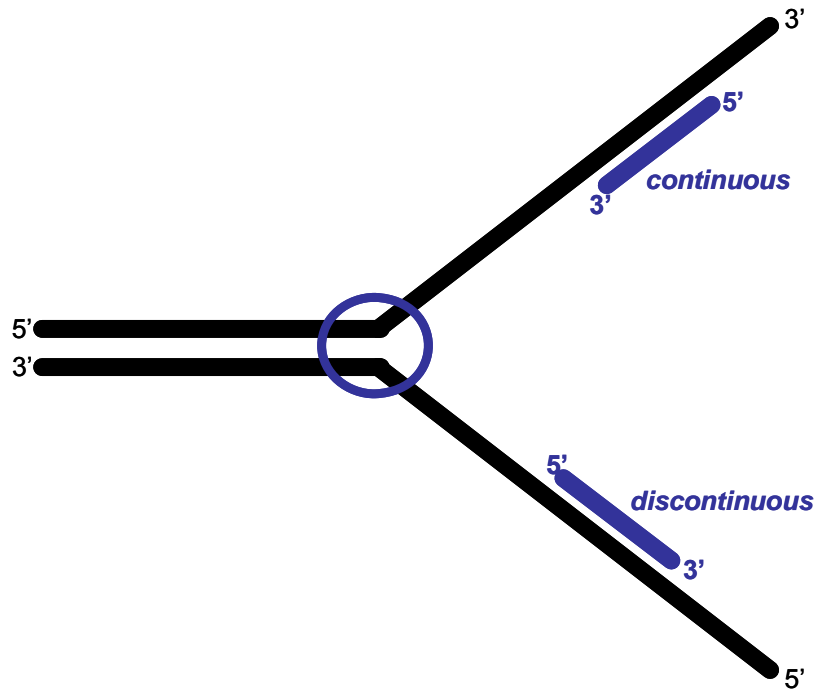
- 3f. (4 points)** Still perplexed, you cross a mouse from the F1 generation (from section 3e) with an S1 mouse. What ratio of normal : affected mice would you expect among its offspring?

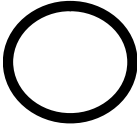
1 : 1 ratio

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Topic 4. Molecular Biology

Below is a diagram of a replication fork.



- 4a. (2 points) Using a circle about this big:  show on the diagram above where you would expect to find the enzyme Helicase.
- 4b. (4 points) On which strand would you expect to find a primer that initiates continuous replication? Answer this by drawing a primer as a short line in its appropriate position on the diagram above. Indicate which is the 5' end and which is the 3' end on your drawing, and label the primer "**continuous**".
- 4c. (4 points) On which strand would you expect to find the primer that is required for discontinuous replication? Answer this by drawing the primer as a short line in its appropriate position on the diagram above. Indicate which is the 5' end and which is the 3' end on your drawing, and label the primer "**discontinuous**".
- 4d. (4 points) What is an origin of replication? Answer in 15 words or less.

The origin is the point on a DNA molecule where replication begins

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Under the right conditions, DNA polymerase will carry out its job even in a test tube. In other words, if provided with a single stranded-DNA template, a primer, and ample deoxyribonucleotide triphosphates (dATP, dCTP, dGTP, and dTTP), (as well as a few other ingredients that are not important for this question) the enzyme will catalyze the polymerization of DNA.

Primer sequence: 5'-GGAUCCUU-3'

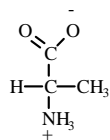
Template DNA sequence: 3'-ACGCTCTTGGATCCTTATCCTAGGAAAGGCAATCTTGCA-5'

- 4e. (2 points)** Given the primer and DNA sequences indicated above, where will the primer align along the DNA molecule? Draw a box around only the bases of the template to which the primer will anneal.
- 4f. (4 points)** What are the first 10 nucleotides that will be incorporated as the polymerase extends from the primer (do not include the primer's sequence itself)? Use A, C, G, and T as abbreviations for the individual nucleotides. Label the 5' and 3' ends of your sequence.

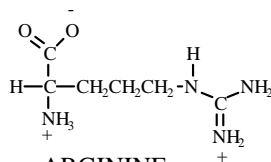
5' CCCGTTAGAA 3'

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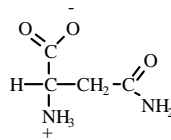
Structures
at pH 7.0



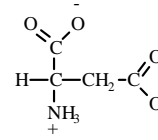
ALANINE
(ala)



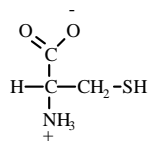
ARGININE
(arg)



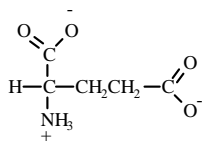
ASPARAGINE
(asN)



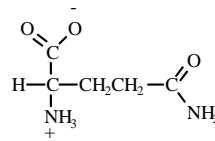
ASPARTIC ACID
(asp)



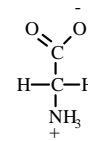
CYSTEINE
(cys)



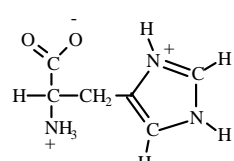
GLUTAMIC ACID
(glu)



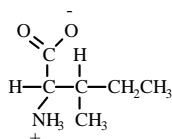
GLUTAMINE
(glN)



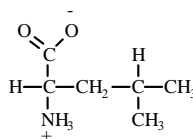
GLYCINE
(gly)



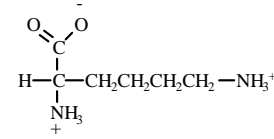
HISTIDINE
(his)



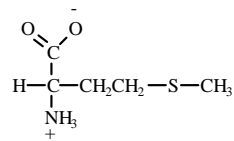
ISOLEUCINE
(ile)



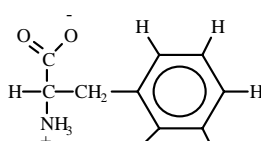
LEUCINE
(leu)



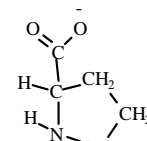
LYSINE
(lys)



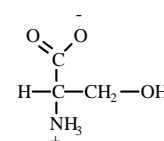
METHIONINE
(met)



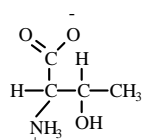
PHENYLALANINE
(phe)



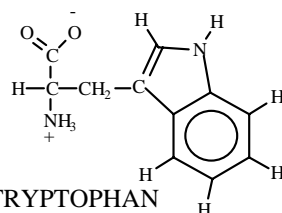
PROLINE
(pro)



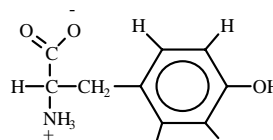
SERINE
(ser)



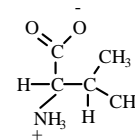
THREONINE
(thr)



TRYPTOPHAN
(trp)



TYROSINE
(tyr)



VALINE
(val)