NAME _____

**FINAL EXAM**
December 19, 1998
Biochemistry I
BI/CH421, BI601, BI/CH621

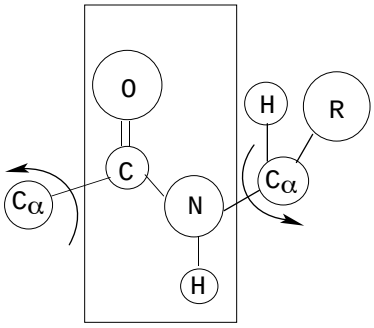
I. _____/245
II. _____/ 50
III. _____/ 32
IV. _____/ 73
TOTAL /400

I. **MULTIPLE CHOICE** (245 points)
Choose the BEST answer to the question by circling the appropriate letter. Questions 1-17 are worth 10 points each (170 pts.) and questions 18-32 are worth 5 points each (75 pts.).

1. An enzyme reaction to be studied at pH 4.0 can best be carried out using a buffer solution made from which of the following acids, and their conjugate bases, with $K_a$ values as shown? (Assume that there is no direct interaction between the buffer molecule and the enzyme to be studied.)

| Acid | $K_a$ |
|---|---|
| A. Phosphoric acid | $7.3 \times 10^{-3}$ |
| B. Lactic acid | $1.4 \times 10^{-4}$ |
| C. Acetic acid | $1.2 \times 10^{-5}$ |
| D. Dihydrogen phosphate ion ($H_2PO_4^-$) | $6.3 \times 10^{-8}$ |
| E. Bicarbonate ion ($HCO_3^-$) | $6.3 \times 10^{-11}$ |

2. In the diagram below, the plane drawn behind the peptide bond indicates the:




A. plane of rotation around the $C_\alpha$-N bond.
B. absence of rotation around the C-N bond because of its partial double bond character.
C. region of steric hindrance determined by the large C=O group.
D. theoretical space between -180° and +180° that can be occupied by the $\varphi$ and $\phi$ angles in the peptide bond.
E. region of the peptide bond that contributes to a Ramachandran plot.

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3. Which of the following amino acids is the most soluble in water at pH 7.0?

   A. Glutamate
   B. Tryptophan
   C. Leucine
   D. Tyrosine
   E. Phenylalanine

4. The folded states of globular proteins in aqueous solutions are stabilized primarily by _____.

   A. hydrophobic interactions
   B. peptide bonds
   C. phosphodiester bonds
   D. ionic bonds
   E. disulfide bonds

5. Which of these statements about enzyme-catalyzed reactions that obey Michaelis-Menten kinetics is false?

   A. At saturating levels of substrate, the rate of an enzyme-catalyzed reaction is proportional to the enzyme concentration.
   B. The Michaelis-Menten constant $K_m$ equals the [S] at which v = 1/2 $v_{max}$.
   C. If enough substrate is added, the normal $v_{max}$ of a reaction can be attained even in the presence of a competitive inhibitor.
   D. The rate of a reaction decreases steadily with time as substrate is depleted.
   E. The activation energy for the catalyzed reaction is the same as for the uncatalyzed reaction, but the equilibrium constant is more favorable in the enzyme-catalyzed reaction.

6. The most efficient substrate of an enzyme is usually considered to be the substrate with the _____.

   A. largest $k_{cat}$
   B. largest $K_m$
   C. largest $k_{cat}/K_m$
   D. smallest $k_{cat}/K_m$
   E. smallest $K_m$

7. Certain restriction enzymes produce cohesive (sticky) ends. This means that they:

   A. cut in regions of high GC content, leaving ends that can form more hydrogen bonds than ends of high AT content.
   B. make a staggered double-strand cut, leaving ends with a few nucleotides of single-stranded DNA protruding.
   C. cut both DNA strands at the same base pair.
   D. stick tightly to the ends of the DNA it has cut.
   E. have none of the above characteristics.

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8. Two oligo-deoxynucleotides, 5'-ACCACGTAACGGA-3' and 5'-GTTAC-3', plus DNA polymerase are added to a reaction mixture containing the appropriate buffer plus radiolabelled dATP, dTTP, dCTP, and dGTP. The radiolabelled bases incorporated into the product of such a reaction would have which of the following base compositions?

A. 3C:2A
B. 1G:1T
C. 3G:2T
D. 3G:3T:2C
E. 5T:4G:3C:1A

9. A = 27% G = 30%
T = 21% C = 22%

If the genome of a newly isolated virus displays the base composition above, the virus most likely consists of _____.

A. single-stranded DNA
B. double-stranded DNA
C. single-stranded RNA
D. double-stranded RNA
E. a double-stranded RNA:DNA heteroduplex

10. For protein synthesis, an amino acid needs to be attached by its _____ group to the _____ of the tRNA molecule.

A. amino; phosphoryl group on the 5'-end
B. carboxyl; phosphoryl group on the 3'-end
C. carboxyl; hydroxyl group on the 5'-end
D. carboxyl; hydroxyl group on the 3'-end
E. amino; base on the 5'end

11. The thymidine analog 3'-azidothymidine (AZT) blocks replication of human immunodeficiency virus (HIV). AZT is converted in cells to the 5'-triphosphate nucleotide derivative and then incorporatioed into cDNA copies of the infecting HIV RNA by the HIV's own reverse transcriptase. The cDNA terminates prematurely at the point of the inserted analog. The most likely reason that AZT is not equally inhibitory toward replication of human DNA is that the 5'-triphosphate nucleotide derivative is _____.

A. capable of base-pairing with the riboadenosine in the HIV RNA, but not with the deoxyadenosine in the human DNA
B. replace with the normal deoxynucleotide during DNA replication
C. unable to enter the nucleus, where DNA is replicated
D. hydrolyzed by nuclear enzymes to the thymidine-5'-triphosphate, so the azido-form is not incorporated into replicating DNA
E. bound with much lower affinity (resulting from a higher $K_m$) to human DNA polymerase than to HIV reverse transcriptase.

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12. The basis of precipitation of proteins by ammonium sulfate is best described by which of the following statements?

A. Proteins are rendered insoluble when they bind the ammonium ion.
B. Proteins are rendered insoluble when they bind sulfate ion.
C. Addition of ammonium sulfate adjusts the pH to the isolectric point of the proteins.
D. Ammonium sulfate binds water molecules, making them less available for hydration of proteins.
E. Ammonium sulfate amidates carboxyl groups on the proteins, rendering the proteins insoluble.

13. The pH of a $10^{-8}$ M HCl solution prepared with pure water at pH 7.0 is closest to _____.

A. 6.0
B. 6.9
C. 7.1
D. 7.9
E. 8.0

14. FIGURE DID NOT SCAN IN

Two heme proteins, X and Y, each combine reversibly with oxygen. Based on the $O_2$-binding properties shown in the graph above, which of the following statements about proteins X and Y best explains these results?

A. X is hemoglobin and Y is myoglobin.
B. X combines with $O_2$ more rapidly than does Y.
C. X has a higher affinity for $O_2$ than does Y.
D. X molecules bind more $O_2$ than do Y molecules.
E. X is cooperative, but Y is noncooperative

15. Proteins can be stabilized by bonds that could include the interaction of the side chain of a lysine residue with the side chain of _____.

A. Gly
B. Arg
C. His
D. Asp
E. Asn

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16. Which of the following lists represent bonding interactions in their general order of strength on a "per bond" basis from lowest to highest?

A. hydrogen, ionic, hydrophobic, covalent
B. hydrogen, hydrophobic, ionic, covalent
C. ionic, hydrophobic, hydrogen, covalent
D. hydrophobic, hydrogen, ionic, covalent
E. covalent, hydrophobic, hydrogen, ionic

17. Which of the following molecules or substances contain, or are derived from, fatty acids?

A. glycerolphospholipids
B. beeswax
C. triacylglycerols
D. sphingolipids
E. All of the above are derived from fatty acids.

18. Tay-Sachs disease is the result of a genetic defect in the metabolism of:

A. triacylglycerols.
B. gangliosides.
C. sterols.
D. vitamin D.

19. Which vitamin is derived from cholesterol?

A. A B. $B_{12}$ C. D D. K E. E

20. Which of these statements about the composition of membranes is generally true?

A. The lipid composition of all membranes of eukaryotic cells is essentially the same.
B. All biological membranes contain cholesterol.
C. Free fatty acids are major components of all membranes.
D. The inner and outer membranes of mitochondria have different protein compositions.

21. Peripheral membrane proteins:

A. penetrate deeply into the lipid bilayer.
B. can only be released from membranes by detergent treatment.
C. behave like typical soluble proteins when released from membranes.
D. are generally bound covalently to phospholipid head groups.

22. When a bacterium such as *E. coli* is shifted from a warm growth temperature to a cooler growth temperature, it compensates by:

A. putting longer-chain fatty acids into its membranes.
B. putting more unsaturated fatty acids into its membranes.
C. increasing its metabolic rate to generate more heat.
D. synthesizing thicker membranes to insulate the cell.

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23. An integral membrane protein will commonly be solubilized by extraction with:

A. a buffer of alkaline or acid pH.
B. a solution of high ionic strength.
C. a chelating agent that removes divalent cations.
D. a solution containing detergent.
E. hot water.

24. Which of the following monosaccharides is not an aldose?

A. ribose
B. glucose
C. fructose
D. glyceraldehyde
E. erythrose

25. Which of the following is an epimeric pair?

A. D-glucose and D-mannose
B. D-lactose and D-maltose
C. α-maltose and α-cellobiose
D. L-mannose and L-fructose
E. D-glucose and L-glucose

26. Which of following is an anomeric pair?

A. D-glucose and L-glucose
B. D-glucose and D-fructose
C. α-D-glucose and β-D-glucose
D. α-D-glucose and β-L-glucose
E. D-glucose and L-fructose

27. When the linear form of glucose cyclizes, the product is a(n):

A. glycoside.
B. hemiacetal.
C. anhydride.
D. lactone.
E. oligosaccharide.

28. Starch and glycogen are both polymers of:

A. α-D-glucose.
B. β-D-glucose.
C. glucose-1-phosphate.
D. sucrose.
E. fructose.

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29. In glycoproteins, the carbohydrate moiety is always attached through the amino acid residues:

A. tryptophan, aspartate, or cysteine.
B. asparagine, serine, or threonine.
C. glycine, alanine, or aspartate.
D. aspartate or glutamate.
E. glutamine or arginine.

30. The structure of $NAD^+$ does not include:

A. an adenine nucleotide.
B. riboflavin.
C. a pyrophosphate bond.
D. two ribose residues.
E. the vitamin nicotinic acid.

31. Which of the following molecules binds strongly to avidin?

A. pantothenic acid
B. folic acid
C. niacin
D. lipoic acid
E. biotin

32. FIGURE DID NOTT SCAN IN

The double-reciprocal plot shown above depicts which of the following types of enzyme inhibition by I?

A. uncompetitive
B. competitive
C. noncompetitive
D. suicide
E. covalent

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II. **STRUCTURES: IDENTIFICATION & FUNCTION**. (50 points)

A. Identify the following structures by name (common, or trivial names preferred; systematic names OK, NO abbreviations)

B. **IF** there is a blank for B., list one biologically significant function for that compound. Be as specific as possible.

C. **IF** the compound shown is comprised of an essential vitamin, circle the vitamin part of the molecule.

1. THIS PAGE DID NOT SCAN IN: SEE KEY OUTSIDE DR. TOLAN'S OFFICE

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III. **MATCHING**. (32 points)
Enter the appropriate letter in each blank. All items will be used once.

34. Match these molecules to their biological roles.

| | | | |
|---|---|---|---|
| __ | 1. carbohydrate storage in animal liver | A. | proteoglycan |
| __ | 2. extracellular matrix of animal tissues | B. | starch |
| __ | 3. blood clotting factor | C. | chitin |
| __ | 4. carbohydrate storage in plants | D. | cellulose |
| __ | 5. polyanionic acid-sugar that forms core of proteoglycans | E. | glycogen |
| __ | 6. structural component of plant cell walls | F. | hyaluronic acid |
| __ | 7. disaccharide | G. | sucrose |
| __ | 8. exoskeleton of insects | H. | heparin |

IV. **SHORT ANSWER**. (73 points)
Give a brief answer or diagram to each problem or question.

35. In the last structure shown on page 8, what products would you expect after exhaustive methylation and hydrolysis (just list the names)? What products would you expect following reaction with an $\alpha$-glycosidase? (10 pts)

36. Write the complete reaction for the hydrolysis of ATP to ADP and inorganic phosphate. Briefly name three chemical differeneces between reactants and products that explain the high $\Delta G$ for the reaction in the cell. (10 pts)

37. Describe the differences between a proteoglycan and a glycoprotein. (10 pts)

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38. (43 pts) You have isolated the lysine aminoacyl tRNA synthetase and determined its structure. You are about to look for the most likely active site in your structure. **A)**. Draw the structure of the intermediate that would be bound at the active site prior to transfer of the lysine to an incoming $tRNA^{Lys}$. **B)**. Surround this structure with a wavy line to indicate the surface of the enzyme active site. Show (and name) as many intermolecular interactions between the enzyme and the substrate intermediate you have drawn in (A). In each of the interactions you show suggest an amino acid residue that would provide a chemical group for such an interaction. These amino acids might be those for which you would look in your enzyme structure. **C)**. Denote which residue in your enzyme that you might change by site-directed mutagenesis to investigate the fidelity of this enzyme. Which kinetic constant would you expect to change if you made such a mutant enzyme? **D)**. Denote which residue in your enzyme that you might change by site-directed mutagenesis to investigate the activity of this enzyme. Which kinetic constant would you expect to change if you made such a mutant enzyme?

FINAL EXAM Answer Sheet 12/19/98

| Test Question | Correct Answer |
|---|---|
| Multiple Choice | |
| 1 | B |
| 2 | B |
| 3 | A |
| 4 | A |
| 5 | E |
| 6 | C |
| 7 | B |
| 8 | C |
| 9 | A |
| 10 | D |
| 11 | E |
| 12 | D |
| 13 | B |
| 14 | C |
| 15 | D |
| 16 | D |
| 17 | E |
| 18 | B |
| 19 | C |
| 20 | D |
| 21 | C |
| 22 | B |
| 23 | D |
| 24 | C |
| 25 | A |
| 26 | C |
| 27 | B |
| 28 | A |
| 29 | B |
| 30 | B |
| 31 | E |
| 32 | B |

STRUCTURES

1. A. Deoxyguanosine B. part of nucleic acids
2. A. Biocytin B. carbon dioxide carrier
   C. biotin is part
3. A. NADH B. electron (hydride) transfer
   C. niacin is part
4. A. Coenzyme A B. acetate or acyl carrier
   C. pantothenic acid is part
5. A. Steric acid
6. A. Linoleic acid
7. A. Sphigosine
8. A. Phosphatidyl choline (1-palmityl, 2-olyl)
   B. part of membranes
9. A. Cholesterol B. part of membranes in animals, steroid or vitamin D precursor
10 A. Two Gal($\alpha$1,4)GlcNAc attached ($\beta$1,6) and ($\beta$1,2) to Man. C. Mannose is the reducing end.

Matching

| Test Question | Correct Answer | |
|---|---|---|
| MATCHING | 34 | E, A, H, B, F, D, G, C |
| Short Answer | | |
| | 35 | The structure is a sugar unit recognized by phytohemagglutinin: Two Gal($\alpha$1,4)GlcNAc attached ($\beta$1,6) and ($\beta$1,2) to Man. Products of methylation would be: 2,3,4,6 tetramethyl Gal, 3,6 dimethyl 2-N-acetyl Glc, 1,3,4 trimethyl Man. There would be Gal released by an $\alpha$-glycosidase because of the ($\alpha$1,4) links at the non-reducing ends. No glycolytic celavage after that because there are only $\beta$-linked sugars. |
| | 36 | $ATP^{-4} + H_2O <=====> ADP^{-3} + H_2PO_4^{-2} + H^+$<br>1. Increase in resonance forms in the inorganic phosphate product.<br>2. Relief of charge repulsion between $\alpha$ and $\beta$ phosphate groups on reactant, $ATP^{-4}$<br>3. Deprotonation of the immediate product, $ADP^{-2}$, to $ADP^{-3} + H^+$. Thus pulling the equilibrium to the right. |
| | 37 | Both are made up of proteins and polysaccharides. In proteoglycans, the carbohydrate moiety dominates, constituting 95% or more of the mass of the complex. In glycoproteins, the protein constitutes a larger fraction, generally 50% or more of the total mass. |
| | 38 | A. The structure should include AMP-amino acid (Adenine-ribose-phosphate-carboxyl linked lysine) intermediate. B. At a minimum there should be ionic interactions with the Lys, $\alpha$-amino group, phosphate group provided by opposite charges coming from Glu/Asp/His/Arg/Lys; hydrogen bonds to the ribose and /or adenine base and amino acid carbonyl oxygen and the phosphate group (H-bonds whould show proper donor/acceptor orientation); hydrophobic interactions of the adenine and the methylene chain of Lys provided by amino acids such as Ala/Val/Ile/Leu/Met/Phe/Tyr, etc. C. This should denote the interaction with the Lysine $\varepsilon$-amino group that affects $K_m$. The change would be to Asp/Glu or neutral amino acid. D. This should denote changes in those amino acids in contact with the carbonyl oxygen and/or the phosphate group that affects $k_{cat}$ (or $V_{max}$). |