Name____ Biol 211 - Group Number________

Active Learning Exercise 3. Biomolecules, Enzymes, and ATP

Reference: Chapters 4, 5 and 8 (*Biology* by Campbell/Reece, 8th ed.)

Reference: Chapter 4

1. What is the difference between an ***organic*** compound and an ***inorganic*** compound? *Give examples of each.*

2. Why does carbon tend to form 4 covalent bonds? (I.e. why is carbon tetravalent?)

3. Why does being tetravalent make carbon an ideal constituent of biological molecules? Refer to the structures of carbohydrates, lipids, **or** proteins as an example.

Reference: Chapter 5

4. What is a ***polymer***? ***Monomer***? Give an *example of each*.

5. State whether each of the following is an example of dehydration synthesis (***D***) or hydrolysis (***H***). [Note: dehydration synthesis = condensation synthesis]

   _____ The digestion of starch molecules in your mouth to form monosaccharides ☺

   _____ Formation of fat molecules in your adipose tissue so your hips get bigger ☹

   _____ The metabolism of steak protein in your stomach to produce amino acids ☺ / ☹

   _____ Joining together of sugar molecules in skeletal muscle to form glycogen for storage

   _____ Release of fatty acid and glycerol molecules into the blood from adipose tissue as fat molecules breakdown while dieting ☺

   _____ Muscle buildup in a weight lifter (Do you know the kinds of molecules involved?) ☺

6. What are the 4 major groups of biomacromolecules in living things?

   a.) ________________________________ c.) ________________________________

   b.) ________________________________ d.) ________________________________

7. Complete the ***biological molecule table*** on the next two pages. You should be able to *recognize* the structures and know the major functions of the four major classes of large biomolecules.

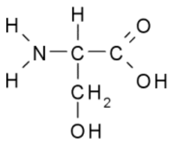
The Four Major Classes of Biomacromolecules

Biological Molecule	Components	Molecular structure		Major Cellular functions
1. Carbohydrates **Monosaccharides**	Mono-saccharide monomer	Draw the structure of α-**Glucose: $C_6H_{12}O_6$**	Draw the structure of **Fructose: $C_6H_{12}O_6$**	
Disaccharides		Draw the structure of **Sucrose: $C_{12}H_{22}O_{11}$**	Draw the structure of **Maltose: $C_{12}H_{22}O_{11}$**	
Polysaccharides		Draw the structure of **Starch** (w/ 4 linked monomers)	**Cellulose** (draw it with 4 linked monomers)	
2. Lipids **Fats (triacylglycerides)**		**Saturated fat** (draw the fatty acids with 12 C's)	**Unsaturated fat** (draw the fatty acids with 12 C's)	
Phospholipids		Draw the structure of a **phospholipid** (label the hydrophilic and hydrophobic parts)		

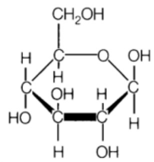
Biological Molecule	Components	Molecular structure	Major Cellular functions
Lipids (cont.) **Steroids**	Four interconnected carbon rings	Draw the structure of **cholesterol**	
3. Proteins	Monomer = ?	Draw the structure of the tripeptide: **glycine – alanine – serine** **<u>Label</u>**: the peptide bonds, the amino and carboxyl ends, the hydrophobic & hydrophilic R-groups	
4. Nucleic Acids **DNA**	Monomer = ?	Draw the structure of **thymidine diphosphate** (dTDP: a thymine diphospho-deoxynucleotide) **<u>Label</u>**: the phosphates, deoxyribose and the thymine nitrogen base	
RNA	Monomer = ?	Draw the structure of **cytidine monophosphate** (CMP: a cytosine monophospho-ribonucleotide) **<u>Label</u>**: the phosphate, ribose and the cytosine nitrogen base	

Use the letters of the structures below to answer the next 4 questions.
(Be able to defend your responses in class.)

(a.)



(b.)



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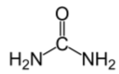
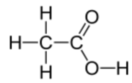
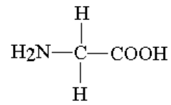


(d.)



(e.)



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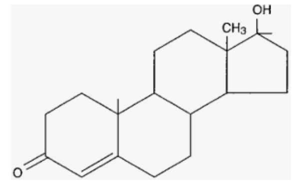


8. Identify the compound(s) that is(are) insoluble in water: ____________________
9. Identify the compound(s) that is(are) amino acids: _________________________
10. Identify the compound(s) that is(are) monosaccharides: _____________________
11. Identify the compound(s) that is(are) steroids: ___________________________
12. True or False (circle your choice): All proteins display primary, secondary, and tertiary levels of protein structure.
13. Identify the interactions that stabilize each level of protein structure by recording the appropriate letter in the spaces provided.

Primary structure _____	a.) Stabilized H-bonds, ionic bonds, covalent and hydrophobic interactions between R groups
Secondary structure _____	b.) Stabilized by Hydrogen bonds between constituents of the polypeptide backbone
Tertiary structure _____	c.) Aggregations and interactions between 2 or more polypeptides
Quaternary structure _____	d.) Stabilized by peptide bonds between a linear chain of amino acids

14. If you want to *selectively label DNA* (i.e. only label DNA) being synthesized by cells, what radioactive compound would you add to the medium? *Circle all choices that apply.*
    a.) ^{35}S-labeled sulfate
    b.) ^{14}C-labeled leucine
    c.) ^{14}C-labeled guanine
    d.) ^{32}P-labeled phosphate
    e.) ^{3}H-labeled thymine

Section 8.1 An organism's metabolism transforms matter and energy, subject to the laws of thermodynamics

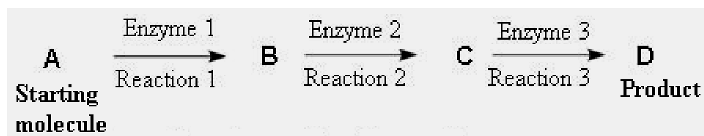
15. Explain why each phenomenon does *not* violate the ***2nd law of thermodynamics***.
    a.) The increasing complexity of an organism during embryonic development

b.) Evolution of complex morphological features (<u>*Note*</u>: Evolution is often <u>*inaccurately*</u> criticized because it violates the 2nd law of thermodynamics.)

16. Select from the following list of terms to complete the narrative below. Terms may be used once, more than once or not at all.

ADP + P	catabolic	endergonic	fat	potential
ATP	cellular	energy	first	second
amino acids	respiration	entropy	heat	sugar
anabolic	change	enzyme(s)	kinetic	water
carbon dioxide	chemical	exergonic	metabolic	work

The enzyme catalyzed stepwise conversion of A to D on the right is an example of a (**a**)________________________ pathway.



A (**b**) ________________________ pathway releases energy by breaking down complex molecules to simpler compounds. A major pathway of catabolism is (**c**) ________________________, in which the sugar glucose is broken down in the presence of oxygen to (**d**) ________________________and (**e**) ________________________. The energy released by a (**f**) ________________________ pathway becomes available to do the work of the cell, such as DNA replication, protein synthesis or membrane transport.

In a(n) (**g**) ________________________ pathway**,** also called biosynthetic pathways, consume (**h**) ________________________ to build complicated molecules from simpler compounds. The synthesis of protein from (**i**) ________________________is an example of anabolism. Energy released from the downhill reactions of a (**j**) ________________________pathway can be stored and then used to drive the uphill reactions of anabolic pathways.

Energy is the capacity to cause (**k**) ________________________or do (**l**) ______________________ i.e. to move matter against an opposing force. (**m**) ______________________ energy is the energy associated with motion. Energy that is not kinetic is called (**n**) ________________________energy, and is energy that matter possesses because of its location or structure.

The (**o**) ________________________ law of thermodynamics states that energy is neither created nor destroyed but converted from one form to another. This property is called the conservation of (**p**) ________________________. When energy is converted from (**q**) ________________________ energy to (**r**) ________________________ energy (e.g. cellular respiration), some of the energy can be used to do (**s**) ________________________, but some energy ends up as (**t**)_________________, a type of (**u**) ________________________ energy. (**v**) ________________________ is the random motion of atoms and molecules.

#17 (cont.)

Where do our muscles get energy to perform work like lifting a book? Our muscle cells use (**w**) ______________________________ to convert the (**x**) _____________________ energy in food molecules such as sugar and fat molecules to perform work. Chemical energy is a form of (**y**) ____________________ energy. When your body breaks down food molecules, the stored (**z**) ____________________ energy from food can be converted to (**aa**) __________________ energy.

Section 8.2 ΔG, the free-energy change, determines if a chemical reaction occurs spontaneously

17. a.) Label each of the following in the free energy diagram below:

- Activation energy, E_a
- Bonds that have been broken
- Free energy change, ΔG (indicate if > 0 or < 0)
- Products
- Reactants
- Transition state

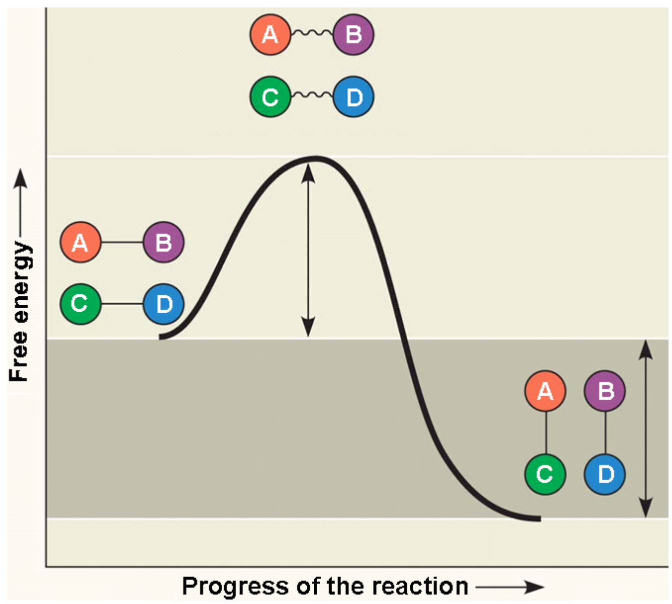
b.) Which is greater, the total…

i.) *bond energy of the products*

or

ii.) *bond energy of the reactants*? (Circle your choice)

Explain what motivated your choice. (Hint: recall that bond breaking is endergonic and bond making is exergonic!)



18. a.) Complete the free energy diagram below for a reaction between reactant molecules AB and CD to produce *products* AD and BC that have *more* potential energy than the reactants.

Label: reactants, products, E_a and ΔG

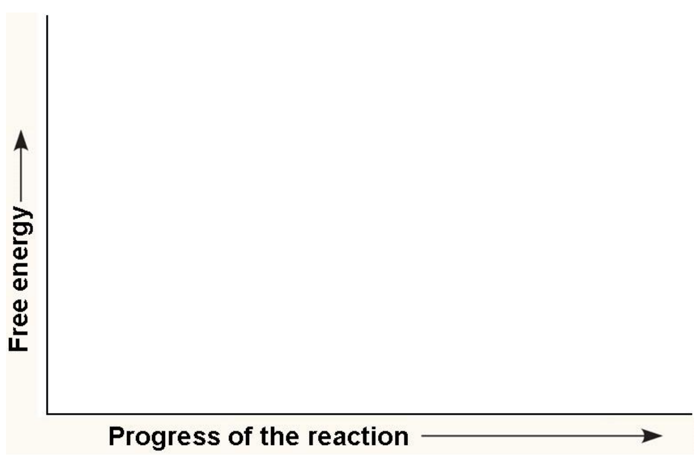
b.) What is the sign of ΔG for the reaction, *positive* or *negative*? (Circle your choice)

c.) Is the reaction *endergonic* or *exergonic*? (Circle your choice)

d.) Does the reaction…

i.) *release energy to the surrounds* or

ii.) *absorb energy from the surroundings*? (Circle your choice)



e.) Without a net addition of energy, will this reaction tend to be *spontaneous* or *nonspontaneous*?
(Circle your choice) *Briefly explain your reasoning* .

19. By definition, ***endergonic reactions*** (i.e. reactions with a *positive ΔG*) do *not* occur spontaneously. But every cell must carry out thousands of endergonic reactions to survive. How do cells make endergonic reactions happen?

20. By definition, ***exergonic reactions*** (reactions with a *negative ΔG*) *occur spontaneously*. What keeps the molecules of an exergonic reaction from breaking apart and cell chemistry from racing out of control?

Section 8.3 ATP powers cellular work by coupling exergonic to endergonic reactions

21. a.) What is ***ATP***? What role(s) does it play in a cell.

b.) Make a simple diagram of ATP...Label its three component parts.

22. When ATP is hydrolyzed *in vitro* (i.e. in a test tube) to form ADP and inorganic phosphate, free energy is merely released as heat to the surroundings. In a cell this would be a wasteful use of energy and dangerous rising temperatures would lead to the denaturation of enzymes***. How, then, do cells use the hydrolysis of ATP to perform cellular work?*** A complete response would include the following terms: *energy coupling, endergonic/exergonic, phosphate transfer, and phosphorylated intermediate.* <u>*Hint*</u>: See the example given in figures 8.10 and 8.11 on pages 150 - 151 (*Biology*, 8th ed.).

23. a.) How is ATP regenerated in a cell?

b.) Complete this diagram by showing where "**energy**" both leaves and enters this cycle.

$$\mathbf{ATP} + \mathbf{H_2O} \rightleftharpoons \mathbf{ADP} + \mathbf{P}_i$$

c.) Label the arrow that represents an ***endergonic*** reaction. Where does this energy come from?

d.) Label the arrow that represents an ***exergonic*** reaction. What is the energy liberated used for? <u>*Give several specific examples.*</u>

24. Explain what is meant by the phrase "***ATP is the energy currency of the cell***."

25. A chemical reaction has a ΔG of -5.6 kcal/mol. Which of the following would most likely be true?
   a.) The reaction could be coupled to power an endergonic reaction with a ΔG of +8.8 kcal/mol.
   b.) The reaction would result in a decrease in entropy (*S*) and an increase in the enthalpy content (*H*) of the system.
   c.) The reaction would result in an increase in entropy (*S*) and a decrease in the enthalpy content (*H*) of the system.
   d.) The reaction would result in products with a greater free-energy content than in the initial reactants.

26. When sodium chloride (table salt) crystals dissolve in water, *the temperature of the solution decreases* slightly. This means that, for dissociation of Na^+ and Cl^- ions in solution…
   Hint: $\Delta G = \Delta H - T\Delta S$
   a.) the change in enthalpy (ΔH) is negative.
   b.) the change in enthalpy (ΔH) is positive, but the change in entropy is greater.
   c.) the reaction is endergonic, because it absorbs heat.
   d.) the reaction must be coupled to an exergonic reaction.
   e.) the reaction cannot occur spontaneously.

Section 8.4: Enzymes speed up metabolic reactions by lowering energy barriers

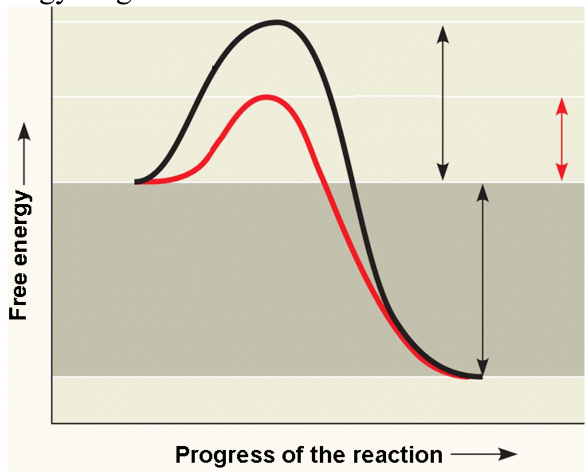
27. a.) What is ***activation energy, E_a,*** and why do *all* chemical reactions require it?

   b.) At room temperature a non-catalyzed chemical reaction with a very large E_a would be very…
   i.) fast. ii.) slow. Circle your response and *briefly explain your reasoning below*.

28. The oxidation of glucose to CO_2 and H_2O is highly exergonic: $\Delta G = -636$ kcal/mole. Why doesn't glucose spontaneously combust?
   a.) At room temperature very few glucose molecules have the activation energy—i.e. $\overline{E}_k < E_a$
   b.) There is too much CO_2 in the air.
   c.) CO_2 has higher energy than glucose.
   d.) The formation of six CO_2 molecules from one glucose molecule decreases entropy.
   e.) The water molecules quench the reaction

29. a.) Label each of the following in the free energy diagram below:

- E_a with enzyme
- E_a without enzyme
- Free energy change, ΔG (indicate if > 0 or < 0)
- Products
- Reactants
- Reaction path with enzyme
- Reaction path without enzyme
- Transition state with enzyme
- Transition state without enzyme



b.) What effect does an enzyme have on the following?

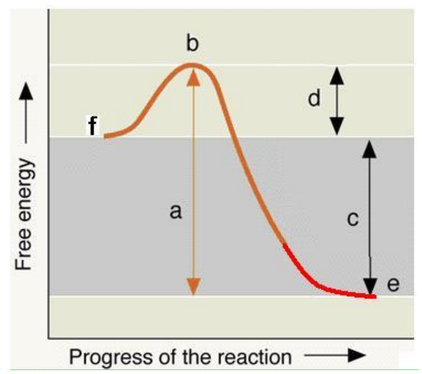
i.) ΔG of a reaction: *increase* or *decrease* or *no effect* (circle your choice)

ii.) Position of equilibrium: *increase* or *decrease* or *no effect* (circle your choice)

iii.) Rate of reaction: *increase* or *decrease* or *no effect* (circle your choice)

30. In the free energy diagram to the right, which of the would be the *same* in both the enzyme-catalyzed and uncatalyzed reactions? (*Circle all that apply!)*

a.) a b.) b c.) c d.) d e.) e f.) f



31. The following two reactions are responsible for the generation of light in fireflies and many other bioluminescent organisms. Luciferase catalyzes the 1st reaction:

Reaction 1. **luciferin + ATP ↔ adenyl-luciferin + pyrophosphate**

While the second reaction occurs quickly and spontaneously with out a catalyst:

Reaction 2. **adenyl-luciferin + O_2 → oxyluciferin + H_2O + CO_2 + AMP + light**

What is the role of luciferase? (*circle your choice*)

a.) Luciferase makes the ΔG of the reaction more negative.
b.) Luciferase lowers the transition energy of the reaction.
c.) Luciferase alters the equilibrium point of the reaction.
d.) Luciferase makes the reaction irreversible.
e.) all of the above

32. Enzyme molecules are organic biomolecules. To which of the 4 major groups of biomolecules do they belong?

33. Explain why all enzymes are catalysts, but not all catalysts are enzymes. What is the difference between a catalyst and an enzyme?

34. Describe the ***induced fit*** model of enzyme action and explain why the ***lock-and-key analogy*** is flawed

35. Make a <u>*labeled drawing*</u> that illustrates the catalytic cycle of an enzyme that promotes ***an anabolic reaction***. Include and <u>*label*</u> the following: enzyme, substrate(s), enzyme-substrate complex, product(s), active and allosteric sites. ***Be original!*** Do not simply copy from your text!

36. Would you expect the enzyme ***lactase*** (found in the small intestine of all mammals early in their lives) to have the ability to digest both of the following disaccharides: the milk sugar ***lactose*** (galactose—glucose) and the fruit sugar ***sucrose*** (fructose—glucose)? <u>*Yes*</u> or <u>*No*</u> (Circle your choice.) <u>*Briefly explain*</u>.

37. Would you expect the *concentrations* of the various hydrolytic digestive enzymes in the gut of an elephant to be *high* or *low*? *Circle your choice and briefly explain*.

38. An enzyme greatly enhances the rate of a chemical reaction by decreasing the ***activation energy*** of the reaction. Cite *four different ways* an enzyme might act to lower the activation energy of a chemical reaction.

    i.) ____

    ii.) ____

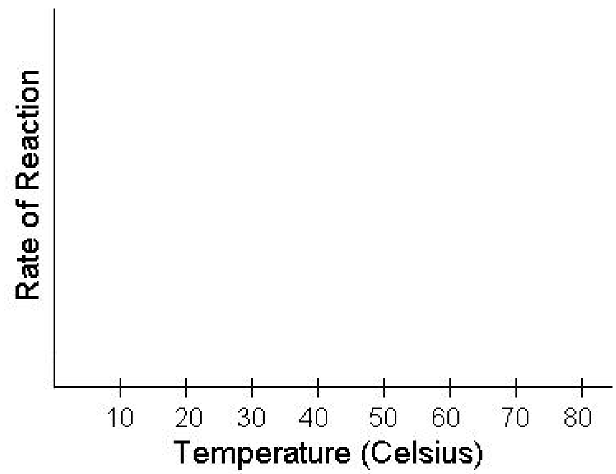
    iii.) ____

    iv.) ____

39. How does the changing of *pH* affect the rate of an enzyme-controlled chemical reaction? *Explain* in terms of the role of the tertiary structure in enzyme function, the *relevant bonds* within the tertiary structure affected by *pH*, *E-S* complex formation, E_a lowering, etc.

40. a.) Make a rough sketch on the graph below that illustrates the effect of increasing the temperature in <u>*5-degree increments*</u> from 0 to 75 ^{o}C on the rate of a chemical reaction that does <u>not</u> involve an enzyme. Label the curve "***without enzyme***." Now use the ***kinetic molecular theory*** to <u>*explain why*</u> increasing the temperature affects the rate of reaction

b.) Make a rough sketch on the graph to the right that illustrates how the changing of temperature in <u>*5-degree increments*</u> from 0 to 75 ^{o}C affects the rate of an <u>*enzyme-catalyzed*</u> chemical reaction within the cells of your liver. <u>*Label the curve "**with enzyme**" and clearly indicate on the graph the*</u> ***optimum rate*** *and* ***optimum temperature***.



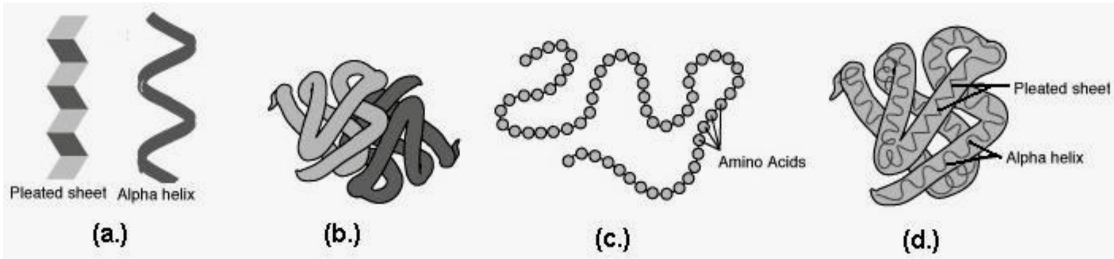
c.) <u>*Explain*</u> why the rate of the enzyme-catalyzed reaction decreases at temperatures <u>*above*</u> the optimum temperature. Explain in terms of the role of the tertiary structure in enzyme function, the <u>*relevant bonds*</u> within the tertiary structure that are affected, *E-S* complex formation, E_a lowering, etc.

41. An important feature of living cells is that they can make their own enzymes. An enzyme is a polymer of amino acids linked together in a specific order.

a.) What very large biomolecule provides the cell with the "information" for putting these amino acids together to make the proper enzymes and other proteins needed by a cell?

b.) Where is this "**informational molecule**" located in the cell?

42. Below are diagrams of the ***four levels of protein structure***. Identify each level of protein structure by recording the appropriate letter in the spaces provided below and then *briefly describe each level of protein structure*. (See **section 5.4** for this question.)



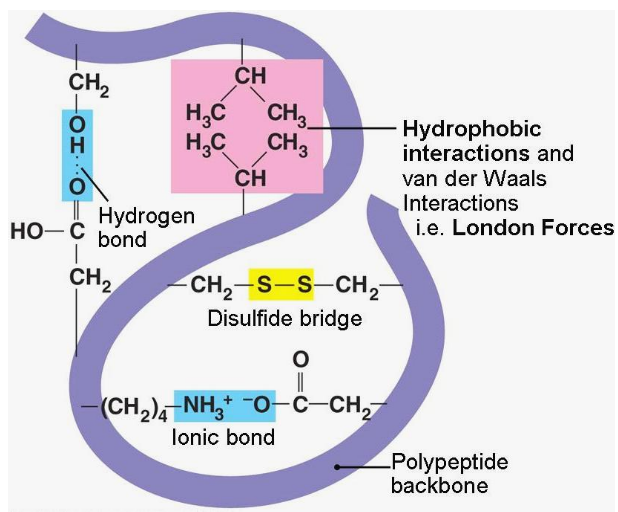
i.) ***Primary structure:*** _____

ii.) ***Secondary structure***: _____

iii.) ***Tertiary structure***: _____

iv.) ***Quaternary structure***: _____

43. Use the figure to the right (from **fig. 5.21** of your text) as a guide and your knowledge of chemical bonding to identify the kind of bond(s) within a protein's tertiary structure that would most likely be broken by each of the following.



a.) An increase in temperature from 37 to 50 °C

b.) A change in pH

c.) The binding of a competitive inhibitor

d.) The binding of an allosteric activator

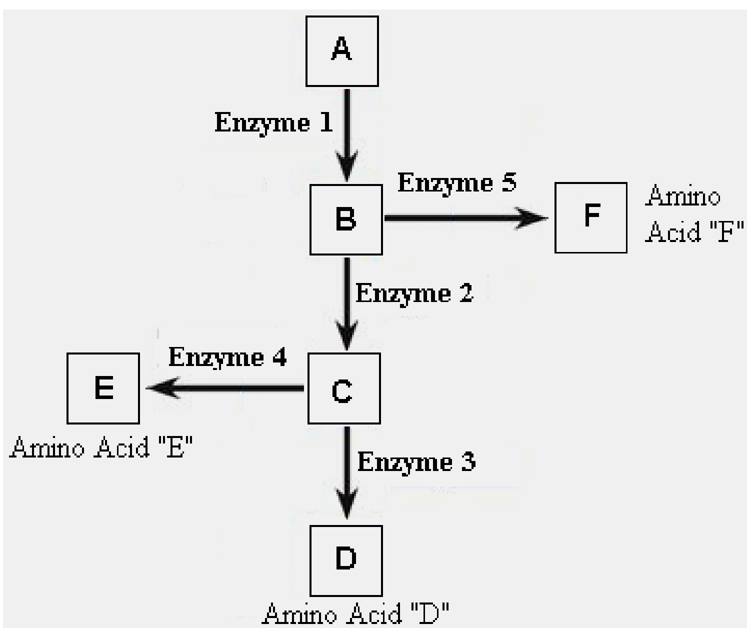
44. There are several species of very colorful and beautiful cyanobacteria that live in the near boiling water of hot springs, e.g. Yellowstone NP. What is different about their enzymes? Why don't they denature at these high temperatures?

Section 8.5: Regulation of Enzyme Activity

45. Vioxx and other prescription non-steroidal anti-inflammatory drugs (NSAIDs) are potent inhibitors of the cycloxygenase-2 (COX-2) enzyme. ***High substrate concentrations*** reduce the efficacy of inhibition by these drugs. These drugs are…
    - a.) competitive inhibitors.
    - b.) noncompetitive inhibitors.
    - c.) allosteric regulators.
    - d.) prosthetic groups.
    - e.) feedback inhibitors.

46. ***Adenosine monophosphate*** (AMP) activates the enzyme ***phosphofructokinase*** (***PFK***) by binding at a site distinct from the substrate binding site. This is an example of…
    - a.) cooperative activation.
    - b.) allosteric activation.
    - c.) activation by an enzyme cofactor.
    - d.) coupling exergonic and endergonic reactions.
    - e.) competitive inhibition

47. Illustrate using arrows and by circling the key regulatory enzymes in the hypothetical biosynthetic pathway below to show how ***negative feedback*** would work *most efficiently* to allosterically regulate the production of the amino acids D, E and F from precursor molecule A.



If you're not part of the solution, you're part of the precipitate. (Henry J. Tillman)