STUDY GUIDE - ***Ch. 8.4 - Enzymes Speed up Metabolic Reactions by Lowering Energy Barriers.*** **NAME: ______________________**

- **PHYSICALLY PRINT OUT this PDF and HANDWRITE (with a black or blue pen) your answers directly on this PDF.** *Typed or digitally-written work is **not** accepted. Do **not** answer questions on separate paper.*
- **Importantly, study guides are NOT GROUP PROJECTS!!!** *You, and you alone, are to answer the questions as you **read** your assigned textbook. You are **not** to share answers with other students. You are **not** to copy any answers from any other source, including the internet.*
- **Get in the habit of writing LEGIBLY, neatly, and in a medium-sized font.** *AP essay readers and I will skip grading anything that cannot be easily read so start perfecting your handwriting, and don't write so large you can't add all the relevant details and key elaborations in the space provided.*
- **SCAN physical documents in color and with good resolution. Then, upload your final work as PDFs to Archie.** *Avoid uploading dark, shaded, washed-out, sideways, or upside-down scans of homework. Keep completed physical study guides organized in your biology binder to use as future study and review tools.*
- **READ FOR UNDERSTANDING and not merely to complete an assignment.** ***First**, read a section quickly to get an overview of the topic covered. Then, read it a **second** time slowly, paraphrasing each paragraph **out loud** and analyzing every figure. Finally, read it a **third** time as you answer the study guide questions if assigned and start building your memory. Try to write answers out in your own words, when possible, and try to purposefully and accurately use all new terminology introduced.*

1. **A spontaneous reaction occurs without a NET input of energy** (Though energy is needed initially to destabilize & break the covalent bonds in reactants, more energy will be released into the environment overall when this chemical reaction is complete). Because the **products are more stable than the reactants** (the products have lower free energy than the reactants), this **spontaneous reactions are energetically favorable**!

   Circle the right answer. **True or False:** Spontaneous reactions tend to always occur rapidly.

2. **Certain Proteins known as Enzymes (and some RNA molecules known as Ribozomes) are biological catalysts.** What though is a **catalyst**?

3. What happens during what we call a **chemical reaction**?

4. a. What is a chemical reaction's **Activation Energy (E_A)**? What does it do to reactants?

   b. The Activation Energy needed by reactants in order to react *can* be supplied by thermal energy. Explain **what happens when reactants absorb enough thermal energy to reach their transition state**.

   c. Explain, by comparing a reaction with a low **E_A** versus one with a high **E_A**, why the level of **Activation Energy for the chemical reaction determines the rate of a chemical reaction**?

d. Macromolecules are high in free energy compared to their individual monomers. This means the the break down of macromolecules into monomers is an exergonic, spontaneous, energetically favorable process. Yet, these molecules do **not** decompose on their own. Why is this?

5. a. Though adding thermal energy (increasing the temperature) can supply the activation energy a chemical reaction needs, what are the **TWO reasons why a cell cannot increase its temperature in order to overcome a reaction's activation energy** and make a chemical reaction proceed more rapidly?

   1.

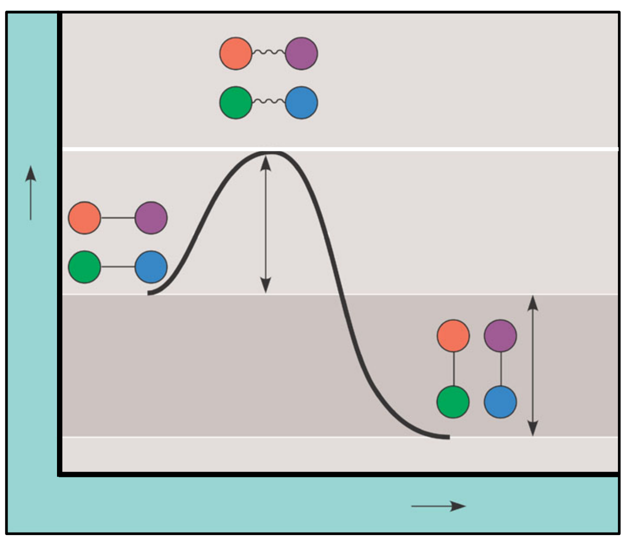
   2.

   b. What **solution does the cell employ to speed up chemical reaction safely**?

   c. What does an **enzyme (a catalyst) do that allows a chemical reaction to proceed faster**?

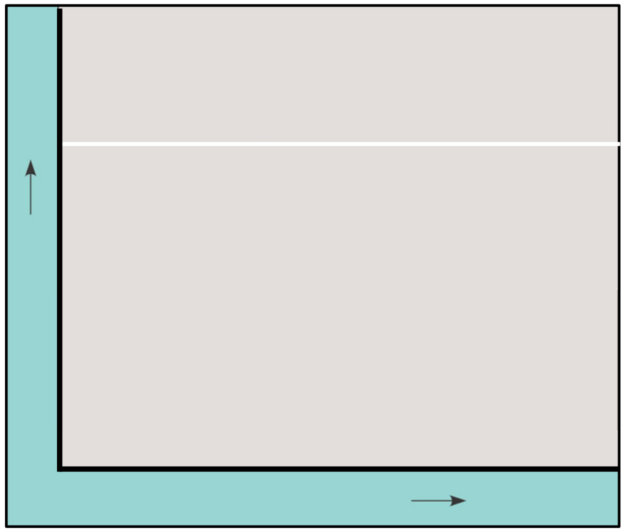
   d. What does an **enzyme (a catalyst) do that allows only the desired chemical reactions to occur** (and not others)?

6. a. Label this diagram, showing the energy profile of a non-catalyzed **exergonic reaction**. *Label the x- and y-axes, Activation Energy, reactants, ΔG, products, and transition state.*

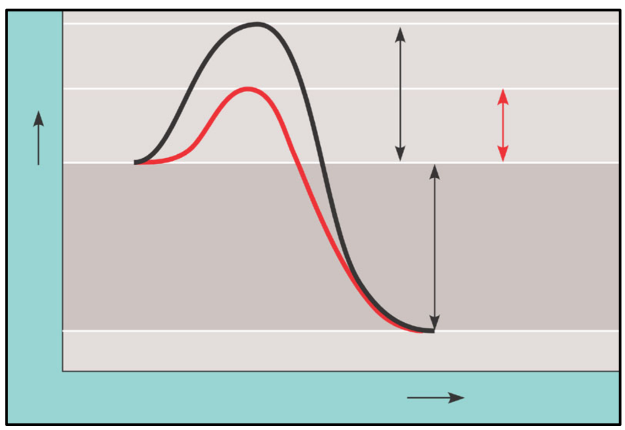


   b. How would the amount of **free energy in the products versus in the reactants of an endergonic chemical reaction differ from the free energy in the products versus in the reactants of an exergonic chemical reaction**? *(Refer back to Figure 8.6 in Chapter 8, Section 2 to make sure you understand this well.)*

c. Now, draw and label a diagram showing the energy profile of a non-catalyzed **endergonic reaction**. *In addition to the graph itself, be sure to label the x- and y-axes, reactants, products, transition state, and add a **labeled arrow** of the right length and orientation to show Activation Energy, and a **labeled arrow** of the right length and orientation to show ΔG.*



7. a. Label the diagram showing the **effects of an enzyme on a reaction's activation energy** (a **catalyzed** reaction). *Label the x- and y-axes, Activation Energy with and without the enzyme, reactants, ΔG, products, and transition state with and without the enzyme.*



b. What **effect does an enzyme have on a reaction's Activation Energy (E_A)**?

c. Is the total **change in free energy, ΔG, for the un-catalyzed reaction** shown in question 7.a positive or negative?

d. Is the total **change in free energy ΔG, for the catalyzed reaction** shown in question 7.a positive or negative?

e. What **effect does an enzyme have on a reaction's change in free energy (ΔG)**?

f. Does the enzyme change the ΔG for a reaction?

g. Can an enzyme make an endergonic reaction exergonic or vice versa?

h. Return to the endergonic reaction's energy curve you drew in 6.c. above. Add a <u>second curve</u> to your drawing, ideally in a different color, to highlight what the graph would look like if this reaction had been assisted by a catalyst. **Label the old curves as non-catalyzed and the new curve you added as catalyzed.**

As you should see, to change from reactants with low total free energy to products with high total free energy, ***even if you lower the activation energy needed to break the initial covalent bonds in the reactants***, a ***<u>NET</u>*** amount of energy still needs to be absorbed to form the products. This is why energetically unfavorable, **endergonic reactions**, **<u>EVEN IF CATALYZED</u>, still required an overall input of energy to occur**. This energy could be supplied by hydrolyzing ATP, for example.

8. Specific terms are used when discussing **<u>enzyme-catalyzed reactions.</u>** Define each of the following terms:

   a. **<u>Substrate</u>** =

   b. **<u>Enzyme-Substrate Complex</u>** =

   c. **<u>Active Site</u>** =

9. Each type of enzyme catalyzes a very specific, different chemical reaction. What determines the **<u>specificity of an enzyme</u>**?

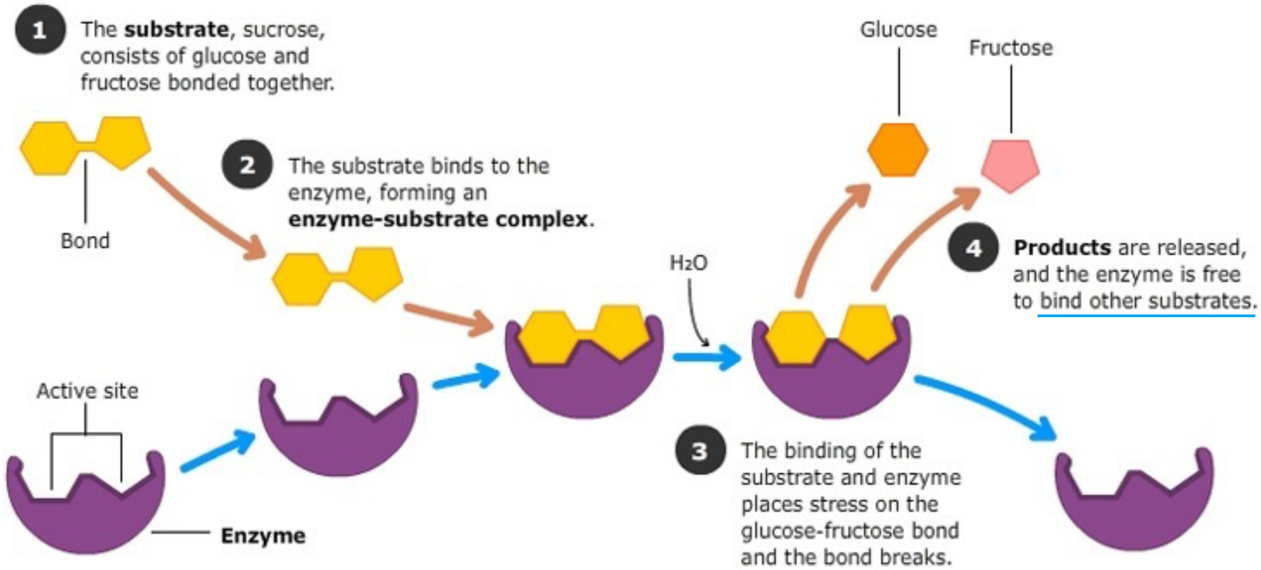
10. a. When substates bind to the active site on an enzyme, the enzyme tightens its binding of these reactants. This is called **<u>Induced Fit.</u>** Describe **<u>why Induced Fit occurs</u>**?

    b. Why **<u>Induced Fit is important for proper enzyme functioning</u>**?

11. How is the **<u>substrate</u>** usually **<u>held in (attracted to) the active site</u>**?

12. Remember, enzymes are proteins and so made of folded polypeptides. Which **<u>parts of the amino acids that make up the enzyme's active site catalyze the chemical reaction</u>**?

13. Below is a model of the enzyme-catalyzed hydrolysis reaction of sucrose by sucrase. Study this and then study Figure 8.16 in your text as well. Let's use these two illustrations to do a quick review of what you learned so far.



a. How again are substrates attracted to an enzyme's active site?

b. What is the name of the shape change in the enzymes that occurs when substates bind to the active site and which helps the enzyme put stress on the substrates' covalent bonds so they break faster?

c. With regards to the energy diagrams, how does the enzyme speed up the rate of the chemical reaction again?

14. Describe the **four mechanisms through which an enzyme and its active site help lower a reaction's activation energy requirement**, therefore, **speeding up the chemical reaction**.

1.

2.

3.

4.

15. a. Why is the **<u>rate of enzyme activity</u>** *(rate of product formation or rate of substrate depletion)* **<u>determined, in part</u>**, **<u>by the concentration of substates</u>** in solution?

b. You can't, though, keep increasing indefinitely the rate of product formation (or substrate depletion) by just increasing the substrate concentration continually over time while keeping enzyme concentration stable. At a high enough substate concentration, your enzymes become saturated and your rate of product formation or substrate depletion stabilizes. What is happening in a solution of substrates and enzymes when the **<u>enzyme is saturated</u>?**

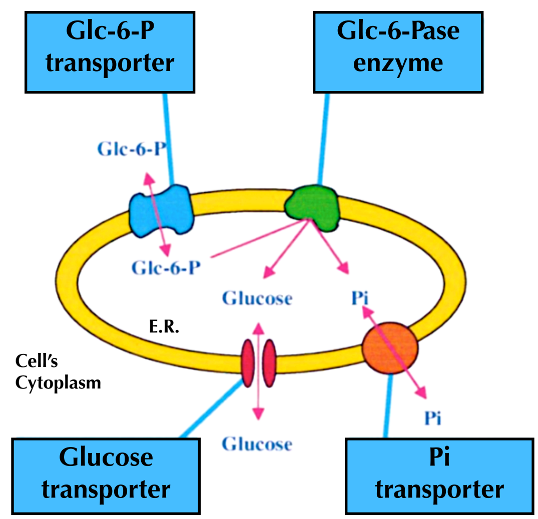
c. **<u>When an enzyme is saturated, what is determining the rate of product formation (enzyme activity)</u>**?

d. How does **<u>increasing substrate concentration even more affect the rate of product formation (enzyme activity) when the enzymes are saturated</u>**?

e. How can a **<u>cell increase its rate of product formation (enzyme activity) if its enzymes are currently saturated</u>**?

16. Scientific Skills Exercise: Making a Line Graph and Calculating a Slope.

1. Graph:



a.

b.

c.

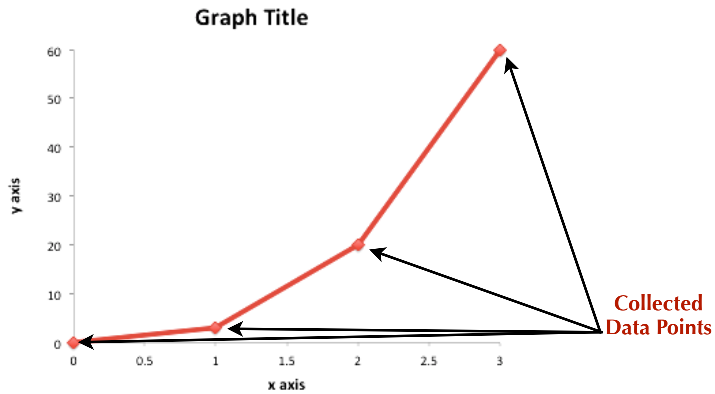
d.

2. a.

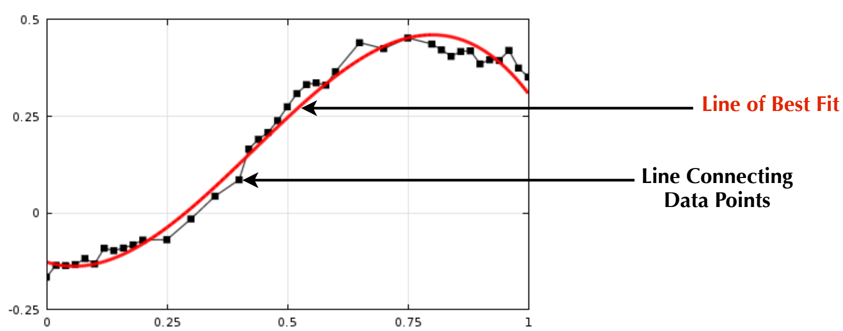
   b.

3. Plot your data points and draw your connecting line. *Here is some useful **MUST KNOW** information on graphing.*

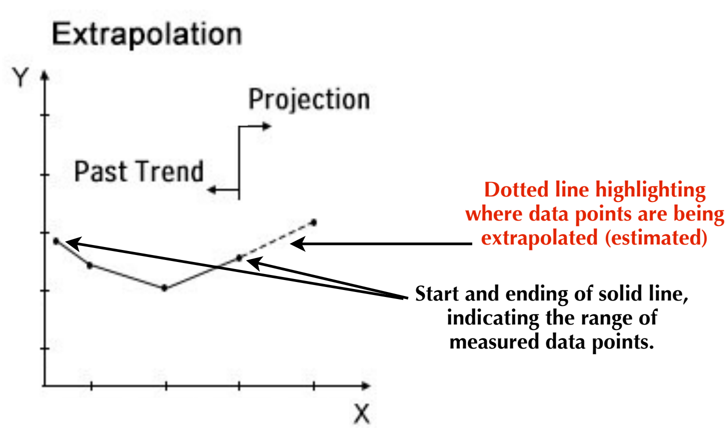
FYI: When drawing a line that connects known data points, the line ought to be solid and ought to **STOP** where the last collected data point stops. Here is an example:



When you have multiple data points, you can estimate the "**Line of best fit**," which refers to a line through a scatter plot of data points that best expresses the relationship between those points. Scientists or statisticians collect a set of data points, each including a complete set of dependent and independent variables. On a chart, these data points would appear as scatter plot, a set of points that may or may not appear to be organized along any line. If a linear pattern is apparent, it may be possible to sketch a line of best fit that minimizes the distance of those points from that line. Here is an example:



FYI: If one is to lengthen the line **past** the range of data points, the line must be drawn as a **dotted line** outside the range of data point to imply that that portion of the line is an **extrapolation**. *Extrapolation means projecting off of known data to **estimate** unknown values.*



4. a. (**Hint**: Whenever you have to discuss the changes in the shape of a graph, ***"walk along the x-axis,"*** describing meticulously the changes noted in the y-axis as you move along every step of the x-axis)

b. (**Hint:** Answer **ALL** parts of questions & **ALWAYS** show your calculations while you later **explain** your calculation in words)

c.

5. (**Hint:** Answer **ALL** three parts of questions)

17. **Enzymes are globular proteins.** What can be said about the shape of an enzyme under **optimal conditions**?

18. Enzymes function at an optimal temperature.
    a. Why is the **rate of enzyme activity smaller at temperatures colder than the enzyme's optimal temperature**?

    b. Why is the **rate of enzyme activity smaller at temperatures warmer than the enzyme's optimal temperature**?

    c. Why is the **rate of enzyme activity the largest at the enzyme's optimal temperature**?

19. In your own words (based on your studies of the causes for proteins' secondary, tertiary, and quaternary levels of folding studied in Chapter 5), why might **pH affect enzyme activity**? *(HINT: What changes in the solution when pH changes and how might that affect protein folding?*

20. a. Name a human enzyme that functions well in pH 2 and state where it is found in the body?

b. Name a human enzyme that functions well in slightly basic conditions and where it is found in the body?

21. **A lysosome has an internal pH of around 4.5**. Using figure 8.17 as your guide, draw a graph showing what you would predict for the rate of reaction for a lysosomal enzyme as you vary pH from 0 to 10. On your graph, label the *x-axis, y-axis, and lysosomal enzyme's optimal pH*, assuming its optimal pH has evolved to match the environment it is to function in. **Remember, the independent variable is always plotted on the x-axes and the dependent variable on the y-axes.** *(Check your answer by going to the* ***Ch.8.4 Concept Check Question #4*** *answer in Appendix A)*

22. a. Some enzymes necessitate the presence of a nonprotein cofactor or coenzyme in the active site for catalysis to occur. What **kinds of chemical processes do these cofactors and coenzymes often help with**?

b. Distinguish between **cofactors** and **coenzymes**.

Cofactor =

Coenzyme =

c. Provide an **example** of each.

Cofactor =

Coenzyme =

23. Sometimes it may be desirable and possible to inhibit the activity of an enzyme. What is the difference between a **reversible versus irreversible inhibitor**?

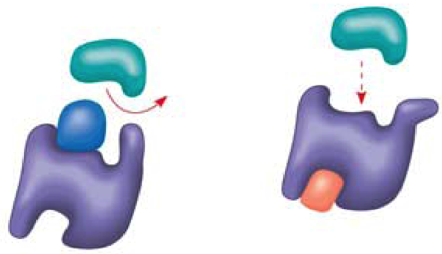
Irreversible Inhibitors (*FYI: These inhibitors are often toxins and poisons meant to harm other organisms) =*

Reversible Inhibitors *(FYI: Most inhibitors used in your own body on your own enzymes are* ***reversible****: They dock on to the enzyme, but later fall off due to the effects of the thermal energy in the system)* =

24. a. Describe **how a competitive inhibitor works to inhibit the enzyme's ability to catalyze a chemical reaction**?

b. Describe **<u>how a noncompetitive inhibitor works to inhibit the enzyme's ability to catalyze a reaction</u>**?

c. Label each **<u>type of inhibitor</u>** in this figure, as well as *the enzymes, substrates, active sites, and allosteric site*.



c. Can **<u>increasing the substrate concentration overcome competitive inhibition</u>**? Why or why not? *(Your answer should discuss how altering substrate concentration may or may not alter the mathematical **<u>PROBABILITY</u>** that substrates binds to the active site)*

d. Can **<u>increasing the substrate concentration overcome noncompetitive inhibition</u>**? Why or why not? Explain.

25. Describe **<u>how new enzymes evolve due to DNA mutations</u>**?

26. Let's practice applying the knowledge you have amassed. *Think:* Malonate is an inhibitor of the enzyme succinate dehydrogenase. How would you determine whether malonate is a competitive or noncompetitive inhibitor? Explain your logic fully. *(Only after you really gave this answer a serious try, check your answer by going to the* ***Ch.8.4 Concept Check Question #3*** *answer in Appendix A)*

27. **Note:** Many enzymes can be regulated by **allosteric regulators**, molecules that attach to an enzyme outside of the activate site and, by altering the conformational shape of the enzyme and thus altering the shape of the active site, **either turn off an enzyme that was on or turn on an enzyme that was off. While allosteric inhibitors block or slow down enzyme catalysis, allosteric activators activate or enhance enzyme catalysis.**

Review the figure below, which highlights **allosteric inhibition versus allosteric activation.**