STUDY GUIDE - *Ch. 8.1 - An Organism's Metabolism Transforms Matter and Energy.* **NAME: ______________________**
- *Ch. 8.2 - The Free-Energy Change of a Reaction Tells us Whether the Reaction Occurs Spontaneously*

- **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.*

In this chapter you will learn that:

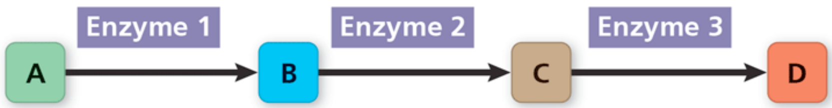
1. **An organisms metabolism** *(the combination of anabolic and catabolic chemical reactions)* **transforms matter and energy.**
2. **The free-energy change of a reaction tells you whether or not the reaction occurs spontaneously or needs a net input of additional energy to occur due to it being non-spontaneous.**
3. **ATP hydrolysis powers cellular work** *(= non-spontaneous processes which require additional energy)* **by coupling exergonic reactions to endergonic reactions and processes.**
4. **Enzymes are proteins that speed up chemical reactions by acting as catalysts and LOWERING energy barriers that prevent chemical reactions from occurring at all or as easily otherwise (Note: They do NOT provide energy, if needed, themselves!).**
5. **Regulating enzyme activity helps control metabolism** *(which specific chemical reactions take place)*.

1. What is meant by the term "**metabolism**"?

2. a. What is a "**metabolic pathway**"?

   b. What role do **enzymes** play in metabolic (a.k.a. biochemical) pathways?

   c. In the depiction of a biochemical pathways below:



1. How many chemical reactions occur? __________
2. **Circle** the second chemical reactions in this metabolic pathway. Then, **label** the reactant and the product of just that second chemical reaction.
3. The **starting molecule of the entire metabolic pathway** not only is the reactant of reaction 1, but is also called the **PRECURSOR** for the entire biochemical pathways. Label the precursor in the illustration above.
4. The **product of the final reaction** is also the called the **PRODUCT** of the ***entire*** biochemical pathways. Label the product of this biochemical pathway in the illustration above.
5. Any product of any of the chemical reactions that make up a metabolic pathway that is ***not*** the final product of the entire pathway is referred to as an **INTERMEDIATE.** Label the 2 intermediates in the illustration above.
6. ***Each*** chemical reaction in a metabolic pathway is catalyzed by its **own unique enzyme**, which is different from the enzymes that catalyze the other chemical reactions in that same pathway.

d. There are two types of reactions in metabolic pathways: **Anabolic** and **Catabolic.**

i. Which reactions **release energy**? ________________________

ii. Which reactions **consume energy**? ________________________

iii. Which reactions **build larger molecules**? ________________________

iv. Which reactions **break down complex molecules into simpler compounds**? ________________________

v. Which reactions are considered **"uphill"** vs **"downhill"**?

vi. What is an example of a **catabolic process**?

vii. What is an example of an **anabolic process**?

3. a. What is **energy**?

b. Define the following types of energy:

i. Kinetic Energy =

How can moving objects perform **work**?

ii. Thermal Energy =

What is **heat**?

iii. Potential Energy (which is not kinetic energy) =

iv. Chemical Energy =

Why do molecules possess **chemical energy**?

4. a. Like water behind a dam, what **type of energy does a concentration gradient of a substance across a biological membrane** possess? Explain. *(Review chapter 7 if needed to find the answer).*

b. What **type of energy does a mole of glucose or other such high-energy organic molecule contain**?

What catabolic process does a cell do with high-energy organic molecules like glucose?

c. **One of the properties of life is that living organisms <u>transform energy</u>.** Let's see if you understand the types of energy by filling in the missing terms in the story below, which describe the energy transformations taking place, as an orange <u>grows</u> on a tree, <u>hangs</u> on the tree, later <u>falls</u> from the tree, the fruit then being <u>digested</u> by someone who eats the orange, and who then goes for a <u>jog</u>. You should be using the following terms: **potential energy, light (radiant) energy, kinetic energy, chemical energy, & thermal energy (heat).**

Through the process called **<u>Photosynthesis</u>**, the plant converts _________________ energy into the _________________ energy stored in the covalent bonds of the high-energy, carbon-based molecules that make up the plant cells, including the sugars found in the fruit cells. As the orange grows on the tree, the entire orange contains _________________ energy just because of its location, gravity pulling on it. When ripe, the orange falls to the ground, some of its _________________ energy being converted, as it moves through the air, into _________________ energy. A hungry passerby eats the ripe orange, digesting the macromolecules and absorbing items like water, ions, and monomers from the fruit into her own body. When the high-energy, carbon-based monomers like glucose and fructose enter this person's cells, the _________________ energy in the bonds of these molecules can be extracted and stored on molecules of ATP through a process known as **<u>Cellular Respiration</u>**. The stored _________________ energy on ATP can later be used to do **<u>work</u>** with in her cell, like contracting muscles in order for her to jog. As energy is released from ATP to do work with and that energy is moved and transformed within the cell, some of this energy is lost to the environment in the form of _________________ energy (heat), which causes increased random motion of particles in the surroundings.

5. What is the study of **<u>transformations of energy</u>** called?

6. a. Explain the difference between an **<u>open system</u>** and a **<u>closed (isolated) system</u>**?

<u>Open Systems</u> =

<u>Closed Systems</u> =

b. What type of system, isolated or open, are organisms such as yeast *(a single-celled fungi)* & bulldogs? Why?

7. a. The words you use when you speak about energy transformations matter. *You **<u>cannot</u>** make a statement that conflicts with the laws of thermodynamics.* **In general, you should never state that energy was "destroyed" or energy was "created" during any biological process as that just isn't the case.** State the **<u>First Law of Thermodynamics</u>**.

b. Organisms transform chemical energy into kinetic energy all the time as they do work, yet, in chapter 1 we mentioned that, while **matter can be recycled on Earth, energy cannot.** Instead, we spoke of how **energy flows through ecosystems**. More energy is always needed, producers obtaining new energy from the sun, for example, storing the energy as chemical energy in the bonds of the high-energy compounds they make, the energy then being passed through the food chains in the ecosystem. **Why can't organisms recycle the energy** they obtain over and over again?

8. a. What exactly is **entropy**?

b. State the **Second Law of Thermodynamics**.

9. a. What is a **spontaneous** (energetically favorable) process?

b. What is a **non-spontaneous processes** in terms of energy and entropy changes?

c. Explain how the human body, with all its complex order and organizational requirements, is able to exist at all given that entropy and the overall randomness in the universe must constantly be increasing?

d. **Does life defy the Second Law of Thermodynamics**? Explain. ***Remember, living organisms are open systems!***

10. How does the **second law of thermodynamics explain diffusion** of substances? *(Check your answer by going to the **Ch.8.1 Concept Check Question #1** answer in Appendix A)*

11. a. Define and provide the symbol for Gibbs **Free Energy**.

b. What is the **formula for calculating free energy changes** for a chemical reaction?

c. What do each of the three **variables** in this formula stand for?

______ =

______ =

______ =

12. a. ***Remember that*** $\boldsymbol{\Delta G = G_{final\ state} - G_{initial\ state}}$. Given this, **which processes are spontaneous in terms of Free Energy changes** *(meaning they do **NOT** need a **NET** input of energy to occur)* **and which processes are not spontaneous** *(meaning they **DO** need a **NET** input of energy to occur)*?

Spontaneous Processes =

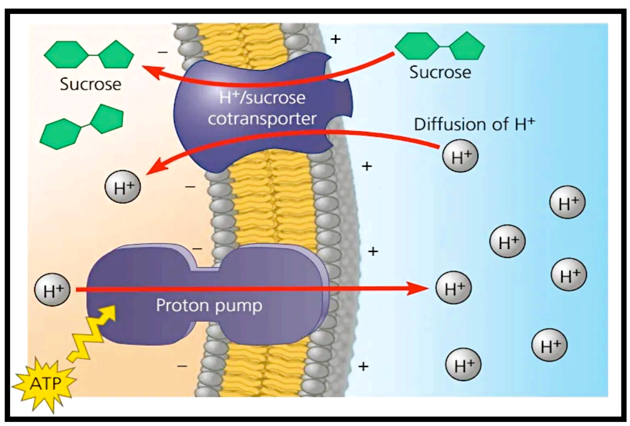
Nonspontaneous Processes =

b. Is energy being lost to the surroundings or gained from its surroundings when a system exhibits a **negative** ΔG value?

c. Is energy being lost to the surroundings or gained from its surroundings when a system exhibits a **positive** ΔG value?

13. Study Figure 8.5. Understand that **unstable systems are higher in free energy, G, than more stable systems.** Systems with higher amount of free energy have a tendency (it is energetically favorable for them) to change, spontaneously, into more stable states. This change will release free energy, resulting in a **$-\Delta G$**. Such a change can be **harnessed to perform work**!

a. Let's consider the movement of protons across a membrane as occurs during **diffusion** of protons through a transport protein which causes a concentration gradient to **disappear** compared to the transport of protons by a proton **pump** across a membrane which **creates** a concentration gradient. Which process results in the system having higher free energy?



b. Which the process can used to perform work? And....what is the work that is performed in this case? *(Remember, to perform work, a non-spontaneous process, you need energy so the system you pick has to be the one that will release energy that can then be used to do work with. Only spontaneous process can, therefore, drive work)*

14. a. At which point is a **chemical reaction most stable AND what is happening at this stage**?

b. **When is a -ΔG chemical reaction spontaneous in reference to its equilibrium point**? *Remember this! It will come up in Ch.9 again…*

c. When a **chemical reaction is at equilibrium** (which hopefully you put and explained as your answer to 14.a) what **level is G at**?

d. Can a process that is at equilibrium perform work?

e. When can a chemical reaction be used to perform work?

15. Contrast **exergonic and endergonic reactions** in terms of the following aspects.

Exergonic Reactions

Will the reaction take place without a **net, overall, input of energy or not**?

Is **Free Energy (G) released or absorbed**?

Comment on the relative **stability of its reactants vs its products.**

Comment on whether the reaction is **spontaneous (energetically favorable) or non-spontaneous**.

Can the reaction be used to perform work or not?

Endergonic Reactions

Will the reaction take place without a **net, overall, input of energy or not**?

Is **Free Energy (G) released or absorbed**?

Comment on the relative **stability of its reactants vs its products.**

Comment on whether the reaction is **spontaneous (energetically favorable) or non-spontaneous**.

Can the reaction perform work or not?

16. **Chemical processes either release energy or absorb energy as the chemistry occurs and products form.** ***Study Fig. 8.6!*** Though you cannot have a negative amount of energy, mathematically you will calculate a negative or a positive value for ΔG when you subtract the G in the resulting products from the G in the initial reactants.

   a. For an **exergonic reaction, is the calculated ΔG negative or positive**?

   b. For an **endergonic reaction, is the calculated ΔG negative or positive**?

17. a. At nighttime celebrations, revelers can sometimes be seen wearing glow-in-the-dark necklaces. The necklaces start glowing once they are "activated," which usually involves the snapping the necklace in a way that allows two chemicals to react and emit light in the form of "chemiluminescence." Is the chemical reaction exergonic or endergonic? Explain. *(Check your answer by going to the* ***Ch.8.2 Concept Check Question #3*** *answer in Appendix A)*

   b. Cellular respiration starts with glucose, which has high levels of free energy, and oxygen, the process releasing carbon dioxide and water, which have low levels of free energy. Is **cellular respiration a spontaneous process or not**?

   c. Is **cellular respiration as an overall biochemical process endergonic or exergonic**? Why?

   d. What is the **ΔG for the cellular respiration reaction**? **ALWAYS INCLUDE UNITS WITH ANY QUANTITATIVE MEASUREMENT REPORTED!!!**

   e. Photosynthesis takes carbon dioxide and water, which both have low levels of free energy, and eventually produces glucose, which has high levels of free energy, and oxygen. Is **photosynthesis an endergonic or exergonic process**? Why?

   f. FILL IN THE BLANK: **If a chemical process is ________________ (downhill) in one direction, releasing energy, then the reverse process must be ________________ (uphill), requiring/using energy.**

   g. What is the **ΔG for the photosynthesis reaction**? **ALWAYS INCLUDE UNITS WITH ANY QUANTITATIVE MEASUREMENT REPORTED!!!**

h. What is the **energy source that drives photosynthesis**?

18. a. Remember, when a chemical reaction reaches **equilibrium**, the concentration of reactants and products do not have to be the same, *BUT* **the rate of the forward reaction equals the rate of the reverse reaction.** What is the **ΔG of a chemical reaction that has reached dynamic equilibrium**? (This should make sense since if the forward reaction releases a net amount of energy -ΔG, the reverse reaction will absorb that same net amount of energy +ΔG. Alternatively, if the forward reaction absorbs a net amount of energy +ΔG, the reverse reaction will release that same net amount of energy -ΔG.)

b. Can a **closed system at equilibrium do work**? Why or why not?

c. Explain how a living cells (open systems), which **would not be able to perform work if all its processes reached chemical (metabolic) equilibrium**, continues to do work throughout its life.