

# OpenStax - Concepts of Biology – Chapter 4 – How Cells Obtain Energy

Take the next ten minutes and preview the chapter. Be sure to review the “How To” guide if you aren’t sure how to approach previewing the chapter.

## PREVIEW

**Introduction** [Take a moment to read the brief introduction. In one short sentence, summarize what is said.]

4.1 \_\_\_\_\_ [what is the title of the first section of the chapter]

**Learning Objectives.** By the end of this session, you will be able to:

1. \_\_\_\_\_
2. \_\_\_\_\_
3. \_\_\_\_\_
4. \_\_\_\_\_
5. \_\_\_\_\_

[Underline or highlight the task words in the learning objectives above.]

**Complete** the Chapter outline below and write the bolded terms in the column to the right. [**REMEMBER:** you aren't reading the chapter or defining terms yet. The key terms list could become flashcards later, and you can put more than one per line.]

- \_\_\_\_\_
- Fig 4.3 \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_
- Fig 4.7 \_\_\_\_\_
- Fig 4.8 \_\_\_\_\_
- Fig 4.9 \_\_\_\_\_
  - \_\_\_\_\_
  - Fig 4.11 \_\_\_\_\_

## Key Terms

4.2 \_\_\_\_\_ [what is the title of the second section of the chapter]

**Learning Objectives.** By the end of this session, you will be able to:

1. \_\_\_\_\_
2. \_\_\_\_\_

4.3 \_\_\_\_\_

**Learning Objectives.** By the end of this session, you will be able to:

1. \_\_\_\_\_
2. \_\_\_\_\_
3. \_\_\_\_\_

[Underline or highlight the task words in the learning objectives above.]

4.2 \_\_\_\_\_

- \_\_\_\_\_
  - \_\_\_\_\_
  - Fig 4.12
- \_\_\_\_\_
  - Fig 4.13

4.3 \_\_\_\_\_

- \_\_\_\_\_
- Fig 4.14
- \_\_\_\_\_
- Fig 4.15
- \_\_\_\_\_

Take a moment to write a few questions you have or your prior knowledge about aerobic respiration. This will help you connect to the material as you read it later.

## Key Terms

4.4 \_\_\_\_\_

**Learning Objectives.** By the end of this session, you will be able to:

1. \_\_\_\_\_
2. \_\_\_\_\_

[Underline or highlight the task words in the learning objectives above.]

4.5 \_\_\_\_\_

**Learning Objectives.** By the end of this session, you will be able to:

1. \_\_\_\_\_
2. \_\_\_\_\_

[Underline or highlight the task words in the learning objectives above.]

4.4 \_\_\_\_\_

- \_\_\_\_\_
- Fig 4.16
- \_\_\_\_\_
- Fig 4.17
- \_\_\_\_\_

4.5 \_\_\_\_\_

- \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_
- Evolution in Action

### Key Terms

|       |
|-------|
| _____ |
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| _____ |

**Questions** [list any questions you have after the preview]

**Make a Plan** [Plan for 3 or more sessions to complete the reading]

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**READING ACTIVITY** Now that you are familiar with what the chapter covered and have a few questions, it's time to dig into reading. Check out the 'How To' guide for more information on using this guide.

**Introduction** [in 1-2 sentences summarize the paragraph the begins with **Virtually**]

**4.1 Energy and Metabolism** Look at the Learning Objectives for Section 4.1.  
What should you be able to do after reading this section?

\_\_\_\_\_ what metabolic pathways are.

Connecting  
metabolism to  
the biological  
macromolecules



**Metabolic Pathways** Read and summarize this section, be sure to describe the types of reactions that occur inside cells (anabolic and catabolic).

### Energy & Thermodynamics

Look at the Learning Objectives for Section 4.1. What should you be able to do after reading this section?

\_\_\_\_\_ the first and second laws of thermodynamics

Define **Thermodynamics**:

Describe what is meant by an open system and a closed system. Are biological systems open or closed?

Describe the first and second laws of thermodynamics. How do these laws apply to biological systems?

First law:

Second law:

**Potential and Kinetic Energy** Look back at the Learning Objectives for section 4.1, What should you be able to do after reading this section?

\_\_\_\_\_ the difference between kinetic and potential energy.

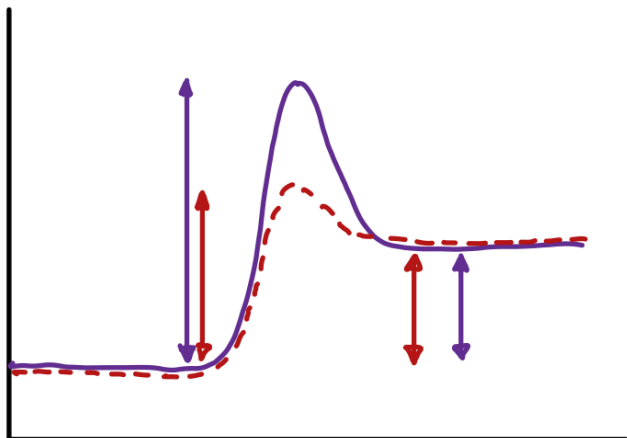
Define the following terms and provide two examples of each:

|   |
|---|
| Kinetic Energy:<br><br><br>Example 1:<br><br>Example 2:   |
| Potential Energy:<br><br><br>Example 1:<br><br>Example 2: |
| Can potential energy be stored in a chemical bond?        |

**Free and Activation Energy** Look back at the Learning Objectives for section 4.1, What should you be able to do after reading this section?

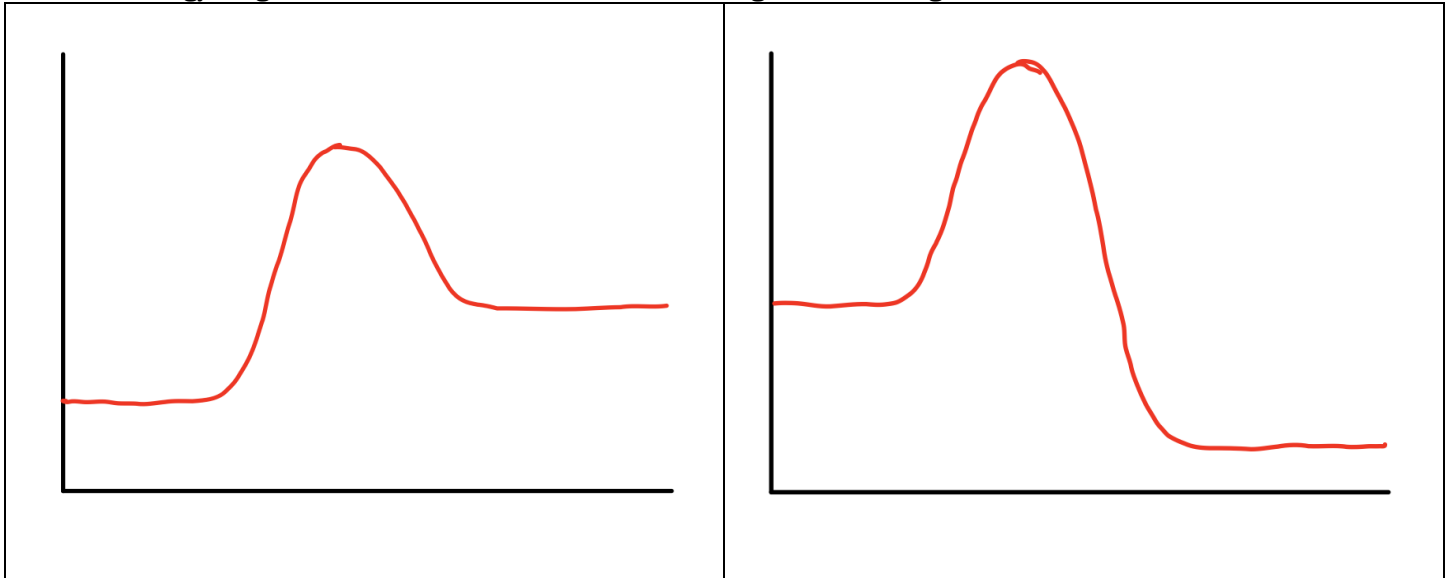
\_\_\_\_\_ endergonic and exergonic reactions.

Define the following terms:

|                      |  |
|----------------------|--|
| $\Delta G$ (delta G) | Activation Energy (Label the figure, see fig 4.7 <sup>1</sup> ):<br><br> |
| exergonic reactions  |  |
| endergonic reactions |  |

<sup>1</sup> OpenStax Concepts of Biology, modified by Kathryn M. Dye

Label the energy diagrams and determine if it shows an exergonic or endergonic reaction.



**Enzymes** Look back at the Learning Objectives for Section 4.1, What should you be able to do after reading this section?

\_\_\_\_\_ how enzymes \_\_\_\_\_ as molecular catalysts.

Watch  
me →



To help you become more familiar with enzymes and what they do, start by labeling the figure<sup>2</sup> below and describing what is happening at each step.

What is this model called?

Step 1      Step 2      Step 3      Step 4

|  |  |  |  |
|--|--|--|--|
|  |  |  |  |
|--|--|--|--|

<sup>2</sup> OpenStax Concepts of Biology, modified by Kathryn M. Dye

Describe the ways that enzymes are regulated by the environment they are in:

Describe the ways that enzymes are regulated by other molecules:

Competitive inhibition:

Noncompetitive inhibition:

Allosteric inhibition:

Allosteric activation:

Describe the role of coenzymes and cofactors in enzyme function, be sure to include how they interact with the enzyme, and an example:

**Feedback Inhibition in Metabolic Pathways.** Where do the molecules involved in inhibition and activation come from? Read this section and complete the table below:

Define feedback inhibition:

Draw out a feedback inhibition mechanism (see fig 4.11):

This is a good spot to stop and take a break – go for a walk and have a glass of water for your neurons!

Kathryn M. Dye, 2019

## 4.2 Glycolysis

Look at the Learning Objectives for Section 4.2.  
What should you be able to do after reading this section?

ATP Video →

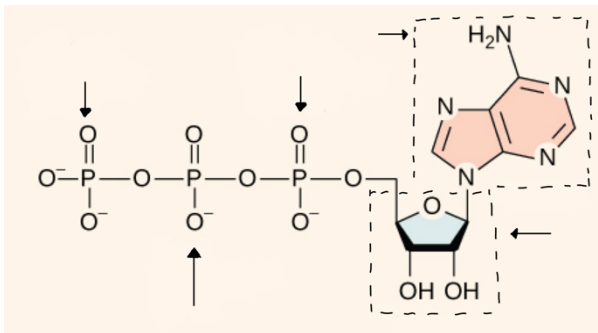


\_\_\_\_\_ how ATP is used by the cell as an energy source.

### ATP in Living Systems, Structure, and Function

Watch the video linked to the right and read this section then summarize the role of ATP in living systems.

Label the parts of ATP:



**Across chapters connection!** Back in Chapter 3, you learned about concentration gradients and how molecules are transported across membranes. What role does ATP play in this process?

## Glycolysis.

Look at the Learning Objectives for Section 4.2.  
What should you be able to do after reading this section?

Glycolysis song →  
Cheesy but helpful



\_\_\_\_\_ the overall result in terms of molecules produced by the breakdown of glucose by glycolysis.

Draw and describe glycolysis. Be sure to include all of the molecules and enzymes! (see fig. 13)

Where does glycolysis occur?

Complete the table of products of glycolysis:

| # of glucose broken down | # of ATP spent/used | # of ATP generated | # of NADH generated | # of pyruvates produced |
|--------------------------|---------------------|--------------------|---------------------|-------------------------|
|                          |                     |                    |                     |                         |



**4.3 Citric Acid Cycle and Oxidative Phosphorylation** Look at the Learning Objectives for Section 4.3.  
What should you be able to do after reading this section?

\_\_\_\_\_ the location of the citric acid cycle and oxidative phosphorylation.

\_\_\_\_\_ the overall outcome of the citric acid cycle and oxidative phosphorylation in terms of the products of each.

**Citric Acid Cycle.** Complete the table below.

|   |
|---|
| Where does the citric acid cycle occur? (describe the process by which it goes from one place to the next)    |
| Draw and describe the Citric Acid Cycle: be sure to include all of the molecules and enzymes! (see fig. 4.14) |

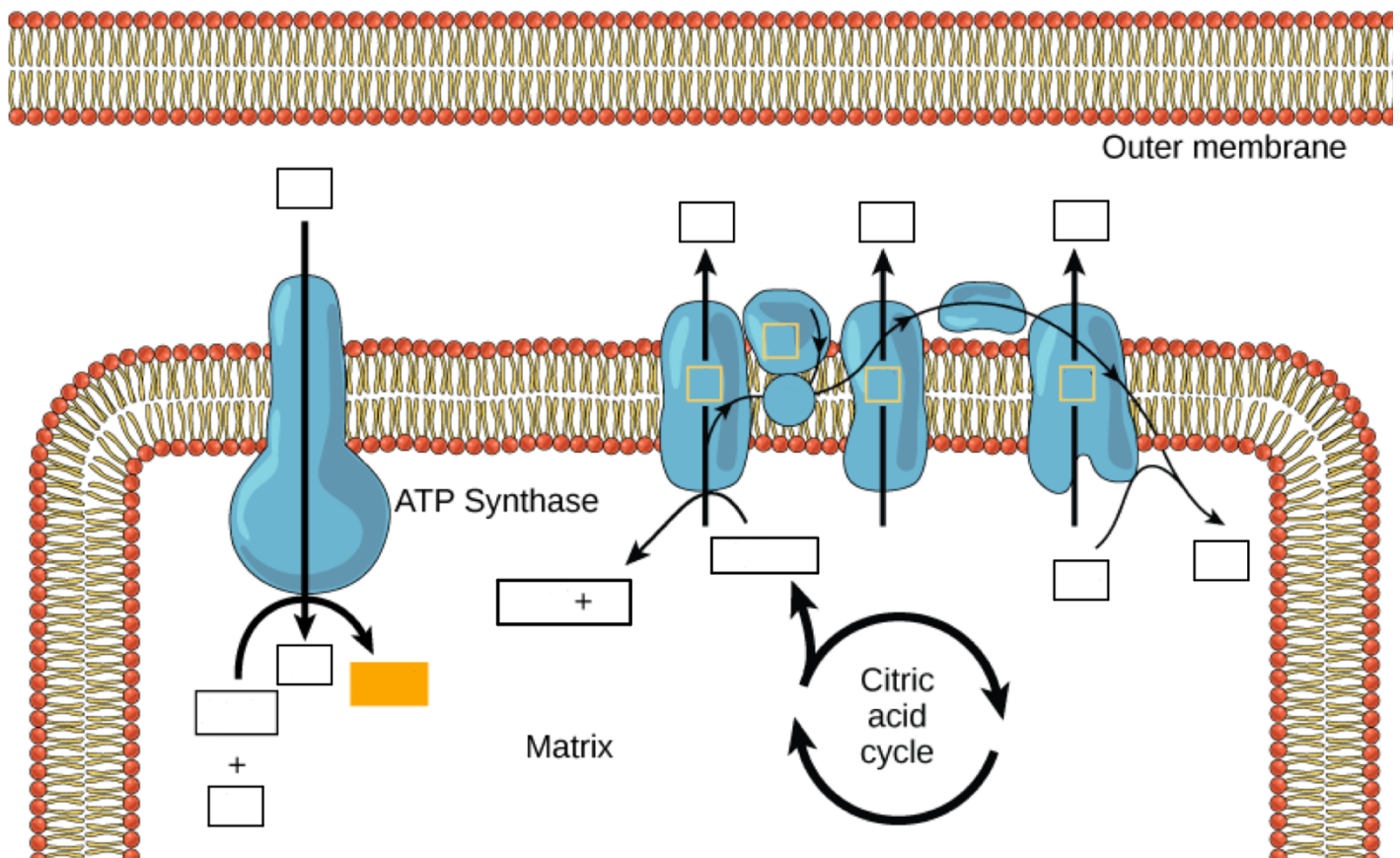
Complete the table of products of the citric acid cycle:

| # Pyruvic Acid broken down | # NADH generated | # FADH <sub>2</sub> generated | # ATP generated | # CO <sub>2</sub> produced |
|----------------------------|------------------|-------------------------------|-----------------|----------------------------|
|                            |                  |                               |                 |                            |

**Oxidative Phosphorylation.** Complete the table below.

Where does oxidative phosphorylation occur?

Fill in the details of the electron transport chain (see fig. 14.15c which shows the reaction chain as it would be found in the cell):



What molecules feed into the electron transport chain?

What molecules are produced by the electron transport chain directly and indirectly?

What factors impact the amount of ATP produced?

Summarize the steps of the electron transport chain:

What are mitochondrial diseases? What happens to people with these diseases?

**Bringing it all together.** Look at the Learning Objectives for Section 4.3.  
What should you be able to do after reading this section?

Summary of →  
Aerobic Respiration



\_\_\_\_\_ the relationships of glycolysis, the citric acid cycle, and oxidative phosphorylation in terms of their inputs and outputs.

Create a diagram of one molecule of glucose going through glycolysis, the citric acid cycle, and the electron transport chain (collectively known as aerobic respiration).

[**Creating** your own diagram will help you better understand and remember these mechanisms.]

This is a good spot to stop and take a break – go for a walk and have a glass of water for your neurons!

Kathryn M. Dye, 2019

#### 4.4 Fermentation

Look at the Learning Objectives for Section 4.4.  
What should you be able to do after reading this section?

Fermentation  
Video →



\_\_\_\_\_ the fundamental difference between anaerobic cellular respiration and fermentation.

To complete the Learning Objective summarize the first paragraph the begins with 'In aerobic respiration.'

|  |
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**Lactic Acid Fermentation** Look at the Learning Objectives for Section 4.4.  
What should you be able to do after reading this section?

Does Lactic Acid make  
your muscles sore?



\_\_\_\_\_ the type of fermentation that readily occurs in animal cells and the conditions that initiate that fermentation.

Complete the table below to explore Lactic Acid Fermentation.

|  |
|--|
| Write the chemical reaction for fermentation.                        |
| Compare and contrast Lactic Acid Fermentation with Glycolysis:       |
| What conditions are necessary for Lactic Acid Fermentation to occur? |
| Watch the video above. Summarize the findings shared in the video.   |



**Alcohol Fermentation** Watch the videos to learn more about alcohol fermentation and its role in food production. The video to the left includes a fun experiment that you can do in your own home. The video to the right gives a history of alcohol production and more detail about how alcohol fermentation works.



Describe Alcohol Fermentation and how it differs from Lactic Acid Fermentation.

**Anaerobic Respiration** Read this section and summarize the other types of anaerobic respiration.

**4.5 Connections to Other Metabolic Pathways** Look at the Learning Objectives for Section 4.5. What should you be able to do after reading this section?

\_\_\_\_\_ why metabolic pathways are not considered closed systems.

To complete the Learning Objective summarize the first paragraph the begins with '**You have learned.**'

Look at the Learning Objectives for Section 4.5. What should you be able to do after reading this section?

\_\_\_\_\_ the way in which carbohydrate metabolic pathways, glycolysis, and the citric acid cycle interrelate with protein and lipid metabolic pathways.

**Connections of Other Sugars to Glucose Metabolism** Read this section and summarize.

**Connections of Proteins to Glucose Metabolism** Read this section and summarize it.

**Connections of Lipids of Glucose Metabolism** Read this section and summarize.

Use Figure 4.20 to help explain how protein and lipid metabolic pathways relate to the carbohydrate metabolic pathways. Draw a diagram as part of your explanation.

**Congratulations!** You've finished chapter 4. Now take a moment and reflect on what you've learned. Look back over the activity and see if you have any questions or if there is anything you want to ask about during the next class, in office hours, or on a class discussion board. Put them in the box below.

**Reflection.** Good job, you finished the first reading guide for Concepts of Biology. This type of learning is often new to students and can take time to become accustomed to the amount of effort needed to learn the material.

Take a few minutes to think and write about your experience with this first chapter.

**Planning.** Students new to taking science courses often underestimate the amount of time that will be needed to prepare for class and complete the assignments. Take a few minutes and plan for the next week or so, when can you make time to do practice problems for Chapter 1? When will you be able to start working on Chapter 2? By keeping a plan, you'll find it easier to see if you're getting your work done. [See the 'How To' guide for an example.]

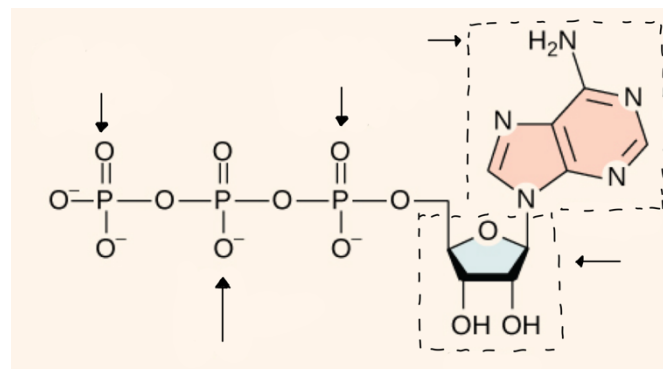
Complete the three retrieval activities in separate sessions as they will be most effective if spaced out. They also increase in difficulty as you go, so be sure to complete them in order and without referring to your notes. Treat this as a quiz, anything you aren't able to answer, you can look up after you finish.

## RETRIEVAL ACTIVITY #1

1. Define **Kinetic** and **Potential Energy** and include an example of each:

2. What is the function of an **Enzyme**?

3. Label the structure of **ATP** and describe its function:



4. Complete the table on **aerobic cellular respiration**:

| Stage                    | Location it occurs | Describe this stage of aerobic cellular respiration |
|--------------------------|--------------------|---|
| Glycolysis               |                    |   |
| Citric Acid Cycle        |                    |   |
| Electron Transport Chain |                    |   |

5. Complete the table about **fermentation**:

| Type of fermentation | Type of organism it occurs in: | Food products through this process: |
|----------------------|--------------------------------|-------------------------------------|
| 1.                   |                                |                                     |
| 2.                   |                                |                                     |

**Reflect and Review** Correct your work and list any of the topics you were not able to recall in the box below. This exercise focused on **direct recall of knowledge**, consider making flashcards with definitions, reprint & practice filling in the empty tables.

|  |  |
|--|--|
|  | Plan when you'll do the next exercise: |
|--|--|



**RETRIEVAL ACTIVITY #2** Before beginning this activity, make sure you have reviewed any of the content you had trouble with on the previous activity. This activity focuses on the next level of content knowledge: **Understanding**, which means you need to have more than just a grasp of the definitions.

1. Describe the **induced-fit model** of enzyme-substrate interaction, and outline the steps, use drawings to support your description.

2. What is the formula/equation for Aerobic Cellular Respiration?

3. Describe the role of NADH in aerobic cellular respiration.

| 4. Complete the table of products of glycolysis: |                     |                    |                     |                         |
|--|---------------------|--------------------|---------------------|-------------------------|
| # of glucose broken down                         | # of ATP spent/used | # of ATP generated | # of NADH generated | # of pyruvates produced |
|  |                     |                    |                     |                         |

| 5. Complete the table of products of the citric acid cycle: |                  |                               |                 |                            |
|---|------------------|-------------------------------|-----------------|----------------------------|
| # Pyruvic Acid broken down                                  | # NADH generated | # FADH <sub>2</sub> generated | # ATP generated | # CO <sub>2</sub> produced |
|   |                  |                               |                 |                            |

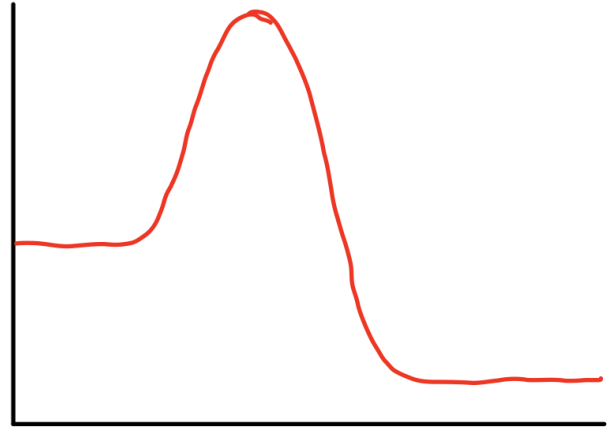
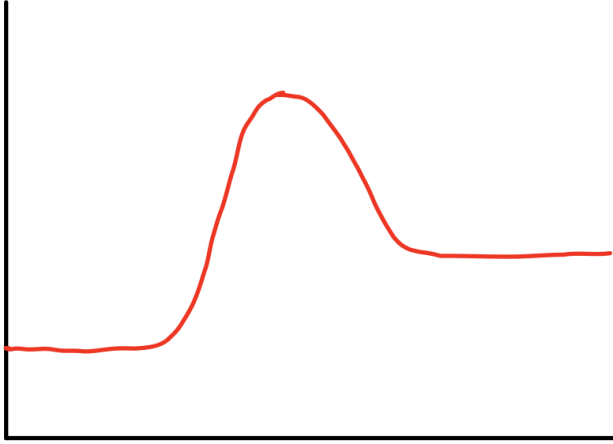
6. What molecules feed into the electron transport chain? And what molecules are produced by the electron transport chain?

**Reflect and Review** Correct your work. If you had any difficulty with the questions above, indicate the topics you want to review in the box below. This exercise focused on your **understanding** of the chapter content. Activities you can do to improve this level of knowledge include: making concept maps, writing about the different topics in your own words without referring to your notes, creating a study guide, and finding a friend to talk with about the chapter.

|  |  |
|--|--|
|  | Plan when you'll do the next exercise: |
|--|--|

**RETRIEVAL ACTIVITY #3** Before beginning this activity, make sure you have filled any gaps in your knowledge that were revealed by the previous two retrieval activities. This activity focuses on your ability to **apply** what you have learned. An excellent way to prepare for this third activity is to pretend you are going to be teaching this chapter to a class or your study group partners. Review examples provided and try to come up with some of your own.

1. Label each of the two diagrams as either endergonic or exergonic. Explain how you know and whether the  $\Delta G$  (delta G) would be negative or positive.



2. Feedback inhibition helps to prevent enzymes from breaking down or making too many molecules. ATP is a byproduct of cellular respiration. When ATP is abundant, it **allosterically inhibits** pyruvate kinase (the enzyme responsible for phosphorylating  $\text{ADP} \rightarrow \text{ATP}$  in the last step of glycolysis). Use what you know about feedback inhibition to explain what this means. Draw a picture of how ATP could inhibit pyruvate kinase (i.e., prove you understand allosteric inhibition).

3. You are getting ready to go for a run; you eat a candy bar and start to warm up. You take a few deep breaths and start out on your run. Describe the process of how the oxygen you inhale becomes the carbon dioxide you exhale [hint: that candy bar has a lot of glucose in it].

**Reflect and Review** Congratulations! You have finished the last and most difficult of the retrieval exercises. Now your task is to correct your work. You may not be able to find all of the exact answers in the book or your notes. An excellent way to work through this last activity is to get together with a group from your class and discuss your answers. Explain to each other why you think your answer is correct. At the end, if you have any that you are uncertain about or have more questions, write them in the box below and bring them to class, office hours, or your campus tutoring center.

Questions you still have:

**Reflection** Think about your experience with chapter 4, are you happy with your level of understanding of the material? Have you found anything that is of particular interest to you or that you'd like to know more about?

**Make a Plan** In the box plan, when you are going to work in time to start chapter 5 and continue to review previous chapters. One of the keys to success on exams is to practice regularly and to keep looking over past material. That will make studying for your exams much easier since you won't be relearning the material.

