

Biology 1305

Modern Concepts in Bioscience (ICB Textbook)

Hello and welcome to the weekly resources for BIO-1305 - Biology 1

This week is **Week 12** of class, and typically in this week of the semester, your professors are covering the topics below. If you do not see the topics your particular section of class is learning this week, please take a look at other weekly resources listed on our website for additional topics throughout the semester.

We also invite you to look at the group tutoring chart on our website to see if this course has a group tutoring session offered this semester.

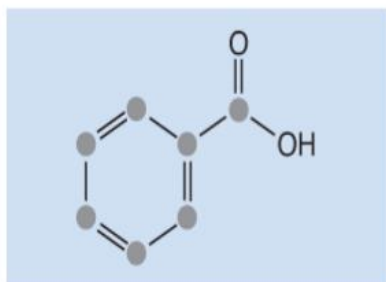
If you have any questions about these study guides, group tutoring sessions, private 30 minute tutoring appointments, the Baylor Tutoring YouTube channel, or any tutoring services we offer, please visit our website www.baylor.edu/tutoring or call our drop in center during open business hours (M-Th 9am-8pm on class days at 254-710-4135).

KEYWORDS: Metabolism, Beta Oxidation, Cellular Respiration, Deamination, Glycolysis

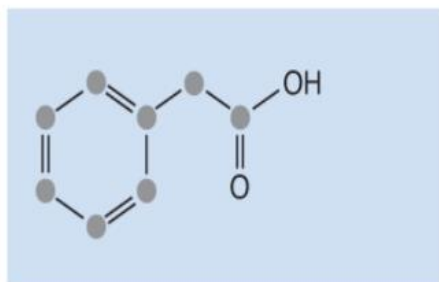
TOPIC OF THE WEEK:

Metabolism

In previous Biology classes, you may have learned about **Cellular Respiration**. We know that this is the process by which living organisms convert chemical energy from macromolecules or nutrients into **adenosine triphosphate (ATP)**, which is commonly known as the “**energy currency**” of the cell. Traditionally, we learn that glycolysis, a pathway that breaks down glucose into pyruvate molecules, is the first step of cellular respiration. While this is true, glycolysis only explains the process in which **sugars (carbohydrates)** are oxidized in the first step of cellular respiration. In order to understand how **lipids** are broken down, we will look at a different process: **Beta Oxidation**.



benzoic acid



phenylacetic acid

An investigator from New York conducted an experiment in which he artificially synthesized a series of six lipids with a benzene ring at the end and fed them to dogs. Because dogs can't digest benzene, he was able to study the synthetic fatty acid waste products and determine how

Heyer and Paradise, unless otherwise specified.

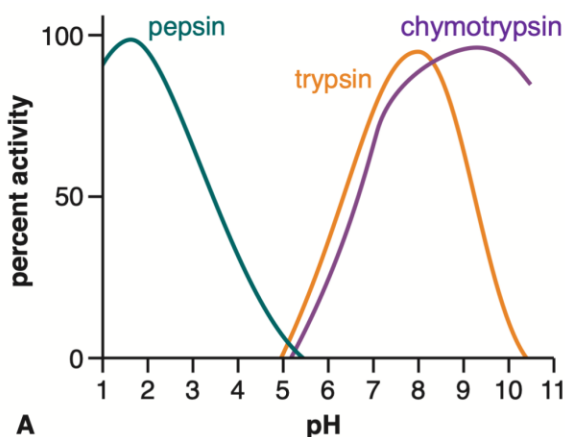
much of the fatty acid was still attached to the benzene ring.

This figure shows two different acids, both with a benzene ring at one end. **Benzoic acid has one carbon attached to the benzene ring, while phenylacetic acid has two carbons.** The benzene group is the hexagonal group which is at the very end of the molecule, and the carboxylic acid (COOH) is at the opposite end of the molecule.

Regardless of the fatty acid's length that the investigator fed to the dogs, all of the waste products were urinated as either benzoic acid or phenylacetic acid. For example, when he covalently attached 16-carbon palmitic acid to a benzene ring, it was secreted as phenylacetic acid. When he fed the dogs either 15- or 17-carbon fatty acids, they were always secreted as benzoic acid.

Because the fatty acids with an odd number of carbons always produced benzoic acid, and those with an even number always produced phenylacetic acid, the investigators were able to verify that **fatty acids are cut into smaller pieces, two carbons at a time, starting at the end containing the acid group of COOH.** As the lipid got smaller, it either terminated in one carbon plus benzene, or two carbons plus benzene. This process of breaking fatty acids into 2-carbon fragments is called **beta oxidation.**

Next, let's look at the first step of **protein metabolism.** Recall that proteins are made up of amino acids which are connected by peptide bonds. A protease is an enzyme that can break these peptide bonds.



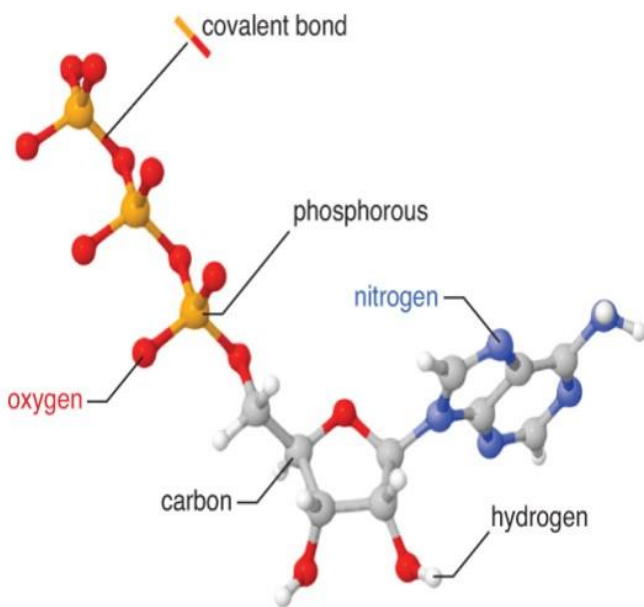
This graph shows the results of an experiment in which each of three different proteases was mixed with a suitable substrate and a buffer of known pH. After a fixed amount of time, the relative amount of enzyme activity was quantified and graphed for each pH. Because the pH of the stomach is typically 1 or 2, we can see in this comparison that **pepsin is the primary protease** that functions in your stomach.

Therefore, the first step of protein metabolism takes place in your stomach. During this step, a polypeptide can be broken down into individual amino acids.

HIGHLIGHT #1: Energy

In order to better understand metabolism, it is important for us to understand how energy is converted and stored in chemical reactions. **Thermodynamics** is the field of study that focuses on the conversion of heat to mechanical work. The **first law of thermodynamics** states that energy can be transformed, or changed from one form to another, but cannot be created or destroyed. The **second law of thermodynamics** states that as energy is transferred or transformed, the **entropy**, or disorder, of a system increases over time unless energy is expended to reduce entropy.

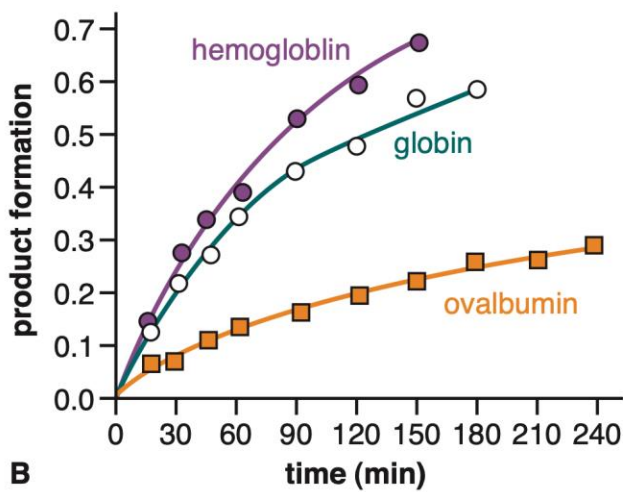
In chemical reactions, it is important to remember that energy is stored in the chemical bonds of molecules. This process explains why it takes energy to form bonds and why energy is released when bonds are broken.



This figure shows a molecule of ATP. The connections between the spheres (atoms) are covalent bonds. The gray spheres represent carbon atoms, red represents oxygen, white represents hydrogen, blue represents nitrogen, and orange represents phosphorus. In this molecule of ATP, we can see that there are three phosphorus atoms in a row, each of which is surrounded by multiple oxygen atoms. Each of these phosphorus and oxygen groups is called a **phosphate group**. **When ATP is converted to ADP, the last phosphate group at the end of the molecule is broken, releasing the energy that is stored in that bond and converting the ATP molecule to ADP.**

HIGHLIGHT #2: Pepsin Activity

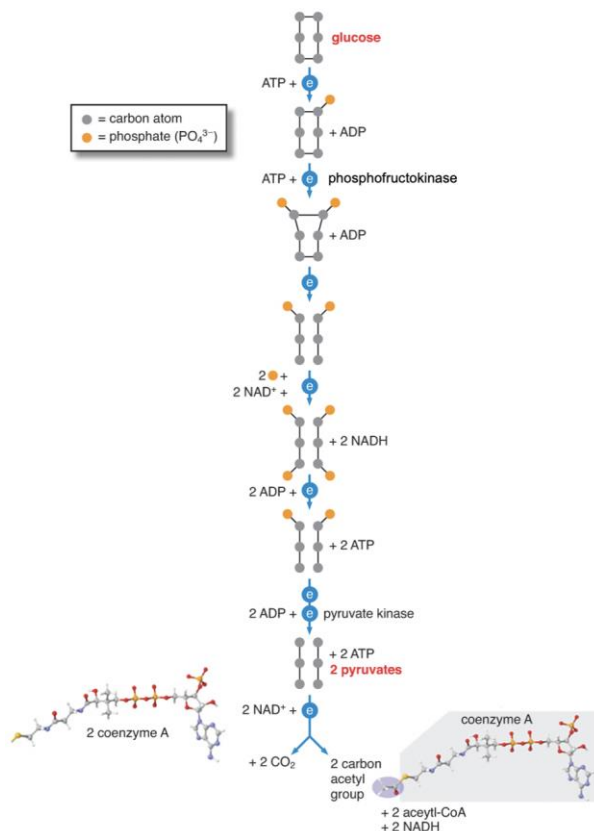
As we saw above, pepsin is a protease which acts in the stomach to break peptide bonds between the amino acids in polypeptides. This process is the first step of protein metabolism. In addition to having an optimal pH range where catalytic activity is the highest, **each protease also cleaves some protein substrates better than others.** This is illustrated in the figure below.



This graph shows the results of an experiment in which pepsin was incubated with three different protein substrates, and their degradation was monitored over four hours. We can see that **hemoglobin is digested by pepsin at a high rate, but ovalbumin, a different protein, is not easily digested by pepsin.** Ovalbumin would require additional digestion by other enzymes such as trypsin and chymotrypsin, which are found in your small intestine.

HIGHLIGHT #3: Carbohydrate Metabolism

So far, we have discussed the beginning stages of lipid and protein metabolism. Now, we will look at a brief overview of glycolysis, which is the first step of carbohydrate metabolism.



This figure shows us that in glycolysis, a **6 carbon glucose molecule is oxidized into two 3 carbon molecules called pyruvates.** It isn't necessary to memorize every step, but notice that ATP is consumed during the first half of this process and is then produced in the second half. In addition to the pyruvate molecules, the net products of glycolysis are **NADH and ATP.** Additionally, after glycolysis, the resulting pyruvate molecules are further oxidized into CO_2 plus an acetyl group, which is covalently attached to CoA. Therefore, **Acetyl-CoA** is the common intermediate product which is formed in carbohydrate metabolism, lipid metabolism, and protein metabolism.

CHECK YOUR LEARNING

(Answers below)

1. Define beta oxidation. Which class of molecules is this process used to oxidize?
 2. In an environment with a pH of 8, would trypsin, chymotrypsin, or pepsin have the highest percentage rate of activity?
 3. What do ATP and ADP stand for? How does this help us understand how energy is released from these molecules when ATP is converted to ADP?
 4. How many molecules of Acetyl-CoA can be produced if one molecule of glucose undergoes glycolysis?
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THINGS YOU MAY STRUGGLE WITH

- The **limiting factor** in lipid metabolism is availability of CoA. When your cells have plenty of acetyl-CoA, any new lipid is stored as fat. When your cells have abundant CoA not bound to the 2-carbon acetyl groups, then fatty acids are covalently linked to CoA and immediately imported into the mitochondria and fully oxidized to produce acetyl-CoA. Therefore, Beta oxidation is regulated by the availability of CoA as a limiting factor to regulate fatty acid digestion versus storage. Throughout this chapter, be on the lookout for limiting and inhibiting factors for every pathway!
- Remember that every covalent bond contains a pair of shared electrons, and these electrons are a source of energy. When bonds are broken, energy is released, and when bonds are formed, energy is used (stored in the bonds).

ANSWERS

- 1) Beta oxidation is the process of breaking fatty acids into 2-carbon fragments
- 2) Trypsin
- 3) **ATP**: Adenosine triphosphate, **ADP**: Adenosine diphosphate; Energy is released when a phosphate group is removed, so that ADP only has 2 phosphate groups while ATP has 3.
- 4) 2 molecules (one from each of the two pyruvate molecules)

Thanks for checking out these weekly resources! Don't forget to check out our website for group tutoring times, video tutorials and lots of other resources: www.baylor.edu/tutoring! Answers to Check your Learning questions are below!