Enzymes Help Us Digest Food

Partially adapted from "Lactase Investigation" in the School District of Philadelphia Biology Core Curriculum
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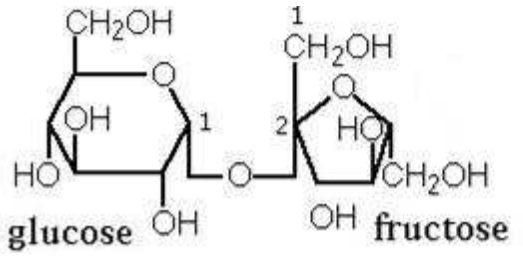
Introduction to Sugars and Enzymes

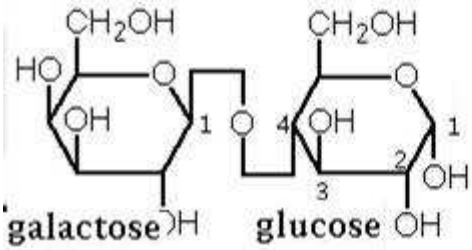
The food we eat contains many different types of molecules, including two types of sugars: **monosaccharides** and **disaccharides**.

★ What is the difference between a monosaccharide and a disaccharide?

Two examples of disaccharides are sucrose and lactose. **Sucrose** is commonly called table sugar and is found in sugar cane, sugar beets, and fruits. The disaccharide sucrose is made up of the monosaccharides, glucose and fructose. The disaccharide **lactose** is made up of the monosaccharides, glucose and galactose.



sucrose

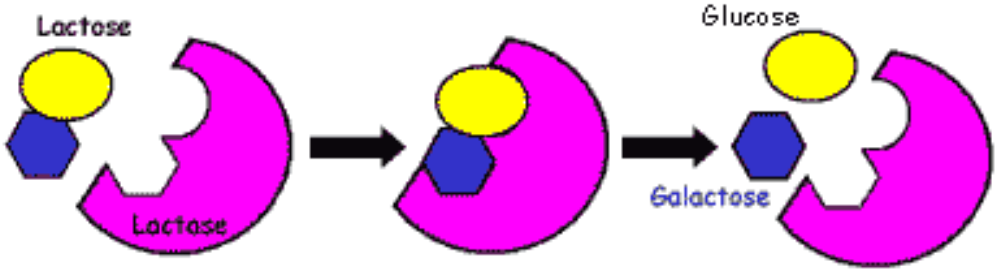


lactose

Monosaccharide molecules like glucose move from inside the small intestine where food is digested to the blood which carries sugar molecules to the cells of your body where they can be used for energy. Each disaccharide molecule must be broken down or **digested** into its monosaccharide components before it can move from the small intestine to the blood. For example, sucrose is digested to glucose and fructose which can be absorbed into your blood and carried to all the cells in your body.

★ When a lactose molecule is digested, which monosaccharides are produced?

The digestion of lactose to glucose and galactose occurs very very slowly unless there is an **enzyme** to speed up the process. The enzyme that speeds up the digestion of lactose is called **lactase**.



Lactase and most other enzymes are proteins. Each enzyme has an **active site** where a **substrate** molecule binds. For example, the substrate lactose binds to the active site of the enzyme lactase. Notice that the name of the enzyme lactase was created by adding the suffix *–ase* to part of the name of the substrate lactose.

[1] Teachers are encouraged to copy this student handout for classroom use. A Word file (which can be used to prepare a modified version if desired), teacher preparation notes, comments, and links to our other hands-on activities are available at http://serendip.brynmawr.edu/sci_edu/waldron/, with additional activities available at http://serendip.brynmawr.edu/exchange/bioactivities.

An enzyme increases the speed of a chemical reaction which converts a substrate or substrates to a **product** or products. The products are released from the enzyme and the enzyme returns to its original shape, so the enzyme is ready to act on another substrate molecule. Thus, an enzyme molecule can be reused over and over. For example, a single molecule of the enzyme lactase can speed up the digestion of many many molecules of lactose.

★ The following equation shows the digestion of lactose.

Lactase
Lactose -------- > Glucose + Galactose

Use E to indicate the enzyme, S to indicate the substrate, and P to indicate the products. Circle the molecule that is a protein, and use arrows to indicate the molecules that are sugars.

★ Circle the active site in the enzyme shown on the previous page.

Experiment 1 - Can the sugar lactose be digested without any enzyme?

In this experiment you will test whether the enzyme lactase is needed to digest the sugar lactose. Specifically, you will test whether lactose breaks down to glucose and galactose when there is no enzyme and when the enzyme lactase is present.

★ First, <u>predict</u> what you think will happen. For each column, circle the equation that describes what you think will happen.

Lactose with No Enzyme		**Lactose with Enzyme Lactase**
No Enzyme Lactose -------- > Glucose + Galactose <u>Or</u> No Enzyme Lactose -------- > Lactose (no glucose produced)		Lactase Lactose -------- > Glucose + Galactose <u>Or</u> Lactase Lactose -------- > Lactose (no glucose produced)

To test whether your predictions are correct, you will use **glucose test strips** to test whether glucose has been produced.

Procedure

1. One member of your group should prepare Tube 1 with 10 mL of lactose solution.

2. Another member of your group should prepare Tube 2 with 10 mL of lactose solution and 1 mL of lactase solution. Put on a glove, put your thumb on the top of the tube and invert several times to mix the two solutions.

3. Wait 3 minutes to allow time for lactose to break down to glucose and galactose.

4. While you are waiting, both of the experimenters should get a test strip. Notice that the original color of the test strip is aqua. In the next step, if the test strip turns green, olive or brown, this will indicate that glucose is present.

5. After the 3 minute wait, each experimenter should dip a glucose test strip into the solution in his or her tube until the pad is submerged, and then remove the test strip immediately and run the edge of the strip against the rim of the tube to wipe off excess liquid.

Results

★ Wait 1 minute and then record your results in the table below.

	Tube 1 - 10 mL of lactose solution	**Tube 2 - 10 mL of lactose solution + 1 mL of lactase solution**
Test strip color		
Was there any change in the color of the test strip?		
Conclusion	___ no glucose produced ___ some glucose produced	___ no glucose produced ___ some glucose produced

Interpretation

★ Complete the following equations to describe your results.

No Enzyme

Lactose -------- >

Lactase

Lactose -------- >

★ Is lactase needed to digest the sugar lactose?

★ In Tube 2, there were over 5000 lactose molecules for each lactase molecule. How can a single lactase molecule break down many many lactose molecules? (Hint: See the top of page 1.)

Experiment 2 - Can the same enzyme digest lactose and sucrose?

In Experiment 1 you saw that the enzyme lactase can digest the disaccharide lactose. In this experiment, you will test whether the enzyme lactase can also digest a different disaccharide, sucrose.

★ First, predict what will happen. Circle the equation that describes what you think will happen.

Sucrose with Lactase
Lactase Sucrose -------- > Glucose + Fructose Or Lactase Sucrose -------- > Sucrose (no glucose produced)

Procedure

1. One member of your group should prepare a tube with 10 mL of sucrose solution and 1 mL of lactase solution. Put on a glove, put your thumb on the top of the tube and invert several times to mix the two solutions.

2. Wait 3 minutes to allow time for digestion of sucrose.

3. Dip a glucose test strip into the solution until the pad is submerged, and then remove the test strip immediately and run the edge of the strip against the rim of the tube to wipe off excess liquid.

Results

★ Wait 1 minute and then record your results in the table below.

	Tube with 10 mL of sucrose solution + 1 mL of lactase solution
Test strip color	
Was there any change in the color of the test strip?	
Conclusion	___ no glucose produced ___ some glucose produced

Interpretation

★ Did lactase break down sucrose? How do you know?

Your results illustrate a general principle called **enzyme specificity**. Enzymes act only on specific substrates. In many cases an enzyme can only react with a single kind of substrate. For example, lactase can digest lactose, but not other types of sugars.

★ Which part of an enzyme is responsible for this enzyme specificity? (Hint: See the bottom of page 1.)

Because of enzyme specificity, our bodies need lots of different enzymes to digest different types of food molecules. For example, our small intestine has the enzyme lactase to digest lactose and a different enzyme to digest sucrose.

★ What do you think is the name of the enzyme that digests sucrose? (Hint: See the bottom of page 1.)

★ Complete the following equation to show the digestion of sucrose. Include the enzyme and the products.

Sucrose ---------- >

Experiment 3 - Do we need the enzyme lactase to digest milk?

Some people have trouble digesting milk because their bodies do not make the enzyme needed to digest the sugar in milk. To determine whether lactase is the enzyme needed to digest the sugar in milk, you will test whether glucose is present in milk with lactase added and in milk with no enzyme added.

★ Explain how testing for glucose both in milk with lactase added and in milk without lactase added allows you to determine whether lactase digests the sugar in milk. The information in the table can help you think about why both tests are needed.

	Milk with no enzyme	**Milk with lactase added**
If milk has glucose	no enzyme glucose -- > glucose	* glucose -- > glucose
If milk has lactose	no enzyme lactose -- > lactose	lactase lactose -- > glucose + galactose
If milk has sucrose	no enzyme sucrose -- > sucrose	* sucrose -- > sucrose

*Lactase is present but does not have an effect on glucose or sucrose

Procedure

1. One member of your group should prepare Tube 1 with 10 mL of milk.

2. Another member of your group should prepare Tube 2 with 10 mL of milk and 1 mL of lactase solution. Put on a glove, put your thumb on the top of the tube and invert several times to mix the milk and lactase solution.

3. Wait 3 minutes to allow time for digestion of the sugar in milk.

4. After the 3 minute wait, each experimenter should dip a glucose test strip into the solution in his or her tube until the pad is submerged, and then remove the test strip immediately and run the edge of the strip against the rim of the tube to wipe off excess liquid.

Results

★ Wait 1 minute and then record your results in the table below.

	Tube 1 -- 10 mL of milk	**Tube 2 -- 10 mL of milk +1 mL of lactase solution**
Test strip color		
Was there any change in the color of the test strip?		
Conclusion	___ no glucose ___ some glucose	___ no glucose produced ___ some glucose produced

Interpretation

★ Is lactase needed to digest milk? How do you know?

★ Which sugar does milk contain: glucose, lactose or sucrose? How do you know?

★ Suppose that your body did not make any lactase. What do you think would happen to the lactose molecules in milk you drink?

Human babies and the babies of all other mammals depend on milk for their nutrition. All babies produce the enzyme lactase to digest lactose, which is the main sugar in milk.

In contrast, many adults produce very little lactase, so they can only digest very small amounts of lactose. When a person who produces very little lactase consumes large amounts of lactose in a short time period, most of the lactose is not digested in the small intestine and lactose reaches the large intestine where it is digested by bacteria. This can result in symptoms such as diarrhea, flatulence, and abdominal pain. This condition is called **lactose intolerance**.

★ Name some foods that might result in discomfort for a person who is lactose intolerant.

People who are lactose intolerant can buy lactose-free milk to gain the benefits of the protein, calcium and vitamin D that milk provides.

★ How do you think lactose-free milk is made?

★ Do you think lactose-free milk contains glucose? Where did it come from?

★ Milk contains many other types of molecules in addition to lactose. The table below shows some of the major types of molecules and an ion contained in milk. Enzymes are needed to digest large molecules into smaller molecules that can be absorbed into the blood. Small molecules and ions can move into the blood without being digested by enzymes. Complete the table.

Molecule or ion	**Are enzymes needed to digest this type of molecule or ion?**
Calcium (Ca++)	
Proteins	
Triglycerides (fat)	
Water (H_2O)	