

Enzymes and Lactose Intolerance

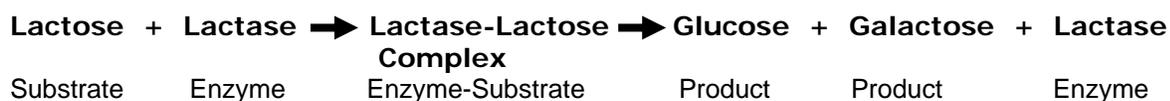
Introduction:

When some people eat dairy products (milk, ice cream, and cheese), they experience digestive discomforts such as flatulence (gas), bloating, cramping, and even diarrhea. These individuals do not produce enough of an enzyme called lactase, the enzyme that digests lactose, a carbohydrate found in milk.

When undigested lactose accumulates in the intestine of a person with lactose intolerance, bacteria in the intestine feed on the lactose and produce waste gases that cause flatulence and bloating. Large amounts of undigested lactose may also cause water to diffuse from the blood into the intestine resulting in diarrhea.

Part I: Modeling Lactase Activity

Lactase is a protein enzyme that digests (breaks down) lactose (milk sugar) into glucose and galactose (smaller sugars). The chemical equation below illustrates what happens when the enzyme lactase digests lactose (milk sugar).



1. Your lab kit contains a sheet of labeled colored drawings of “Molecules Involved in the Digestion of Lactose.” Cut these drawings out.
2. Your kit also contains a sheet with the “Chemical Equation for the Digestion of Lactose.” Tape or glue the cut out drawings of the molecules in the appropriate boxes on this sheet.
3. What is the name of the molecule that is the enzyme? _____
4. What is the name of the molecule that is the substrate? _____
5. What word ending is associated with enzymes—“ose” or “ase”? _____

6. What two products are formed when the enzyme lactase digests lactose?

_____ and _____

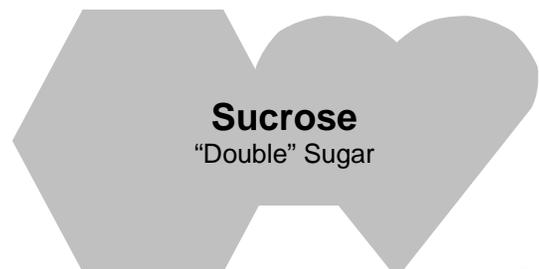
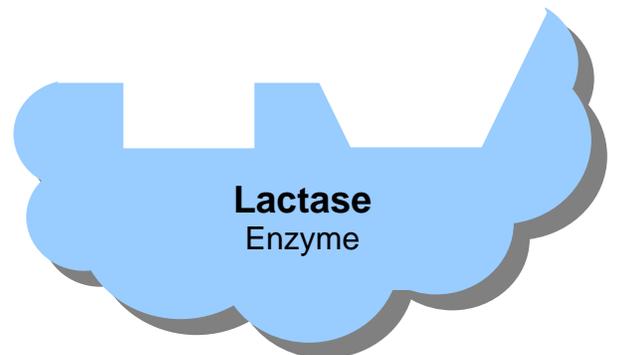
7. Enzymes are types of proteins that function as catalysts. Catalysts are substances that speed up the rate of reaction between substances. What might happen to the reaction if lactase was not working properly?

8. Unlike other substances involved in a chemical reaction, the enzyme is not consumed in the reaction. Was the lactase molecule used up (consumed) in the reaction? How can you tell?

9. Notice that the lactase enzyme has a “cut out” region on its surface called the **active site** that fits with the substrate. During a reaction using an enzyme, the substrate enters the active site and forms an enzyme–substrate complex.

- Label the active site on the lactase diagram on the right.
- High temperatures can change the shape of enzymes. Explain why changing the shape of the active site on the lactase enzyme would decrease the rate of lactose digestion.

- Enzymes are specific. They will only work on certain substrates. Explain why lactase can digest lactose but cannot digest other double sugars such as sucrose or maltose.



Part 2: Does LACTAID Really Digest Lactose?

There is a dietary supplement called LACTAID that contains the enzyme lactase. The makers of LACTAID promise that the lactase in this product will allow people with lactose intolerance to enjoy eating dairy products. Read the product information below from the box of LACTAID pills.

LACTAID® Fast Act

LACTAID® Dietary Supplements work naturally to break down lactose (milk sugar), so you can enjoy the dairy foods you love.

LACTAID® Fast Act contains the enzyme lactase that breaks lactose down into easily absorbed sugars.

Simply take one (1) easy-to-swallow LACTAID® Fast Act caplet with your first bite of dairy food and enjoy!



Supplement Facts
Serving Size 1 Caplet

Amount Per Caplet	% Daily Value
Sodium 5 mg	<1%*
Lactase Enzyme 9000 FCC Units	**

* Percent Daily Values are based on a 2,000 calorie diet
** Daily Value not established

www.lactaid.com/lactose/index.jhtml?id=lactaid/lactose/facts.inc

1. What is the active ingredient in a LACTAID caplet that makes it possible for people who are lactose intolerant to enjoy dairy foods? _____
2. What two substances will be produced if LACTAID is working properly?
_____ and _____

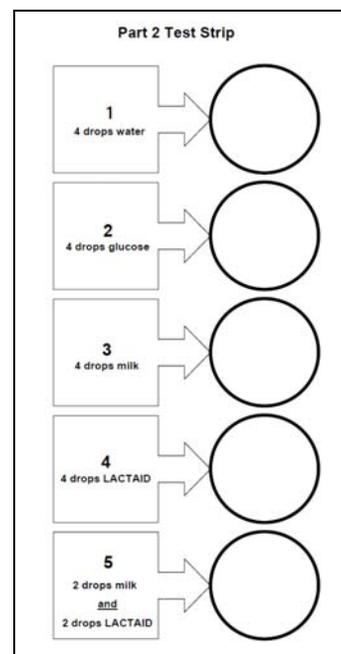
Your Task:

Conduct an experiment to determine if LACTAID really works to digest milk sugar (lactose).

Procedure:

3. Open the packet containing the LACTAID tablet. Place the tablet into the large tube labeled "LACTAID."
4. Add enough tap water to fill the 3 large tubes (labeled "LACTAID", "Glucose", "Powdered Milk") approximately one-half full. Cap and shake each of the tubes vigorously for three minutes to dissolve the materials in the tubes.

5. Fill the small tube labeled “Water” with tap water.
6. Take out the *Part 2 Test Strip* from your kit. Set the *Part 3 Test Strip* aside for use during Part 3.
7. Use the information in the boxes on the left of the *Part 2 Test Strip* to mix materials from the tubes in the appropriate circles on the right of the test strip. Be sure to use the appropriately labeled droppers!
8. Stir the contents in each of the test strip circles using a clean toothpick. Make sure you use a different toothpick for each circle and discard the used toothpicks.
9. Wait for 5 minutes before going to the next step.
10. Remember that when lactose is digested, glucose is produced. Follow the directions below to test the contents of each of the circles for the presence of glucose. Then, record the results in Columns 2 and 3 of Data Table 1.
 - Use a clean and dry piece of glucose indicator paper for each test.
 - Drop one piece of glucose indicator paper into the liquid in each circle.
 - Wait for 60 seconds for the color to develop.
 - If a light or dark green color develops, glucose is present.
 - If the paper stays yellow, glucose is not present.



Data Table 1

Test Strip Circle	Column 1	Column 2	Column 3
	Put in labeled circles of Test Strip	Results: Color of Paper	Glucose Present (+) Glucose NOT Present (-)
1	4 drops water		
2	4 drops glucose		
3	4 drops milk		
4	4 drops LACTAID		
5	2 drops milk <u>and</u> 2 drops LACTAID		

11. Which test strip circles (1–5) contained lactose at the beginning of the experiment? _____
12. Which test strip circles (1–5) contain lactase? _____
13. In which test strip circle (1–5) is lactase digesting the lactose into smaller glucose molecules? _____
14. Which test strip circle (1–5) was a control to show that LACTAID does not contain glucose? _____
15. Which test strip circle (1–5) is a control to show that the glucose indicator paper is working properly? _____
16. Which test strip circle (1–5) is a control to show that milk does not contain glucose? _____
17. Based on the results of your experiment, can you conclude that LACTAID really works to break down milk sugar (lactose)? _____

Explain how the results of your experiment support your conclusion.

18. Save the tubes and labeled droppers (LACTAID, milk, glucose, and water) for use in Part 3.
19. Discard the used *Part 2 Test Strip*, used test papers and used toothpicks.

Part 3: Could LACTAID work in a person's stomach?

One skeptical biology student suggests that LACTAID may work in lab tests but he is not sure it works if people eat it with their food. He points out that when you take a LACTAID pill, it gets mixed with the acid in your stomach. He learned in biology class that acids denature (change the shape of) enzymes so that they don't work properly.

1. What is your hypothesis? Do you think that LACTAID mixed with acid will still work to digest lactose into glucose? Explain why or why not.

2. Your lab kit contains a tube of "Acid" (vinegar) that has the same pH as the contents of the stomach. The kit also contains a dropper for the "Acid" and a *Part 3 Test Strip*.
3. Design an experiment to determine if LACTAID works when it is mixed with acid.
 - In Column 1 of Data Table 2, write what substances you will mix together in the circles on your test strip. You may not need to use all of the boxes in Column 1.
 - Be certain to include controls in your experiment to show that the lactase enzyme and glucose test papers work properly.

Data Table 2

	Column 1	Column 2	Column 3
Test Strip Circle	What will you put in the labeled circles on the Test Strip?	Results: Color of glucose indicator paper	Glucose Present (+) Glucose NOT Present (-)
1			
2			
3			
4			
5			

4. Conduct your experiment by mixing the appropriate substances in the circles on the *Part 3 Test Strip*. You may not need to use all of the test strip circles. Remember to stir using a clean toothpick.

5. Add 1 piece of glucose indicator paper to each of the circles. Record the results of your experiment in Column 2 and 3 of Data Table 2.

6. Which *Part 3 Test Strip* circle (1–5) represents the control for your experiment?

7. Does LACTAID work when it is mixed with acid? Explain how you could tell from the results of your experiment.

8. Hot chocolate is made by mixing hot milk with chocolate. High temperatures denature (change the shape of) enzymes. Do you think that that LACTAID would work if you added it to a cup of hot chocolate? Explain why or why not. Use the term “active site” in your answer.

9. Some people experience gas and discomfort after eating vegetables, grains, beans, and other high-fiber foods. There is an enzyme product called “BEANO” that breaks down the complex carbohydrates (long chains of sugars) into simple sugars. Do you think that the enzyme in BEANO will work to digest the lactose in milk? Explain why or why not.



