Teacher Preparation Notes for Enzymes Help Us Digest Food

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This activity includes three experiments with the enzyme lactase and multiple discussion questions to help students learn the following Teaching Points.

Teaching Points

- An enzyme is a molecule (usually a protein) that speeds up a specific chemical reaction in our body. Without the enzyme, the reaction typically occurs extremely slowly or not at all.
- Digestive enzymes break down (digest) large molecules in our food to smaller molecules that can be absorbed into our blood. For example, lactase breaks down the disaccharide lactose into the monosaccharides glucose and galactose.
- An enzyme molecule returns to its original state after acting on the substrate, so each enzyme molecule can be reused over and over again. For example, a single molecule of lactase can break down many molecules of lactose.
- An enzyme acts only on a specific substrate because only that substrate fits into its active site. For example, lactase digests lactose but not sucrose. Because of enzyme specificity, many different enzymes are needed to digest food (e.g. lactase and sucrase).
- A person who produces very little lactase can only digest very small amounts of lactose, resulting in lactose intolerance. This example illustrates that proteins are not just abstract concepts in biology textbooks, but real parts of our body that have observable effects on our characteristics and health.

Equipment and supplies:

- Lactose solution: 5 g lactose in 200 mL water (20 mL for each group of 3-4 students)*
- Sucrose solution 5 g sucrose in 200 mL water (10 mL per group)*
- Milk (20 mL per group)*
- Lactase solution: 1 g lactase in 50 mL water (3 mL per group) (Store the lactase in the refrigerator until you make the solution on the day of the activity. When you make the solution you will need to smoosh the lumps and stir a lot.)*
- Beakers[+]
- 25 mL graduated cylinders to measure lactose solution, sucrose solution, and milk [+]
- 1 mL transfer pipet for lactase solution[+]
- 15 milliliter test tubes* (2 per group if students will be able to rinse these between uses; otherwise 5 per group) and test tube rack (1 per group)
- Glucose test strips (5 per group)
- Gloves (3 per group)
- Permanent markers and tape or labels for labeling test tubes (1 set per group)

* In order to conserve materials and thus reduce the cost of purchasing lactase, you can use smaller test tubes and correspondingly smaller amounts of each solution.

[+] If you keep the solutions at your desk, you will need four beakers (for each solution and the milk) and a minimum of three graduated cylinders and one transfer pipette for measuring each of these.

Ordering Information

Possible sources:

- Lactase and lactose from Fisher (Sucrose is table sugar and easily available.)
- Glucose test strips ($4.95/100 strips) from

[1] These teacher preparation notes and the related student handout are available at http://serendip.brynmawr.edu/sci_edu/waldron/.

http://app.testyourselfathome.com/cf.inventory.php?action=showinvdetail&invid=874&heading=Glucose%20Early%20Diabetes%20Screening&pagetitle=Glucose%20Early%20Diabetes%20Screening

- Gloves ($4.99/100) from *http://www.cmcgov.com/store/pc/viewPrd.asp?idproduct=604&gclid=CMiR9dSK3KICFcRM5QodJiijxQ*

Teaching Suggestions

To complete this activity in a 50 minute period you probably will want to discuss the introductory section of the student handout in the class period before the activity and you may want to discuss all but the first question on page 6 of the student handout in the class period after the activity.

We recommend organizing students in groups of 3 or 4 with specific assignments to ensure that all students prepare and test at least 1 of the tubes in Experiments 1-3.

Glucose test strips are used by people with diabetes to test for glucose in their urine; when glucose is present in the urine this indicates that blood glucose levels are too high, which can be harmful to their health. Note that the glucose test strip does not react with glucose when the glucose is part of the disaccharide lactose or sucrose. The glucose test strip only reacts with the monosaccharide glucose.

To calculate the number of lactose molecules per lactase molecule for the question near the middle of page 3 of the student handout, we used the amount of lactose and lactase solutions added to the tube, the concentrations of lactose and lactase in the solutions, and the molecular weight of lactose (342) and lactase (approximately 150,000-300,000).

You may want to ask your students to suggest improvements in experimental design. For example, in Experiment 1 it might be useful to test for glucose production after a longer wait period than the designated 3 minutes in order to see whether, given enough time, lactose might break down without the enzyme lactase.

Background information on lactose intolerance is provided on the next page. You might want to bring in the ingredient list from a carton of Lactaid, so the students can see that lactase is listed as an ingredient.

An inquiry activity that can be used as a substitute or extension of this activity is shown at the end of this document, with the student handout on page 4 and the teacher notes on page 5.

Additional activities to help students understand the functions of proteins are presented in "Understanding the Functions of Proteins and DNA", available at http://serendip.brynmawr.edu/sci_edu/exchange/bioactivities.

Background Information on Lactose Intolerance

For virtually all infants and for adults with lactase persistence:
-- in small intestine:

lactase
lactose -------- > glucose + galactose

For about two-thirds of adults worldwide:
-- in small intestine:
very low levels of lactase (lactase nonpersistence) -- > lactose maldigestion
-- so, in colon:

fermentation by
anaerobic bacteria
lactose ---------- > short-chain fatty acids + gases
\/ \/ \/
osmotic influx of water -- > diarrhea flatulence
\/ \/
lactose intolerance*

* can be reduced by
- adaptation of bacteria in colon to regular lactose consumption
- bacteria in yogurt or lactase supplements
- dairy products (e.g. cheese) with lactose reduced by fermentation during production
- small amounts of milk at multiple times during the day

-- enzyme lactase is located in the plasma membrane of cells that line the small intestine

-- The gene for lactase has alleles which differ in the nucleotide sequence in the regulatory DNA:
-- lactase nonpersistence allele results in production of lactase by infants, but very low levels of lactase in adults, resulting in lactose intolerance
-- lactase persistence alleles result in production of lactase throughout life

-- e.g. of natural selection in humans:
-- lactase nonpersistence alleles nearly universal in mammals and early humans
-- when some groups of humans began raising dairy animals,
natural selection -- > lactase persistence alleles became more common
-- different lactase persistence alleles in European and African herding groups illustrate similar characteristics evolving independently in different populations
= convergent evolution

Useful general sources on lactose intolerance:
-- Lactose intolerance
(http://digestive.niddk.nih.gov/ddiseases/pubs/lactoseintolerance/index.htm)
-- Why do people become lactose-intolerant? Wall Street Journal, February 16, 2010

Enzyme Lab

by Deane Gordon, Philadelphia Military Academy @ Leeds

Your task is to identify and name the unknown enzyme that is in the numbered bottle.

Use your previous knowledge to answer your question and complete a standard lab report with your findings.

You have previously observed that glucose test strips change color when glucose (as a monosaccharide) is present. Any color change (greenish) indicates at least trace amounts of glucose. As the strip's color moves toward a brown color more glucose is being detected.

Here are the possible enzymes.

Sucrose→ Glucose+ Fructose Enzyme Sucrase

Lactose→ Glucose+ Galactose Enzyme Lactase

There are also bottles with no enzymes, so you have three possibilities.

Here is a **partial** list of materials to help you get started:

One Numbered Bottle containing sucrase or lactase or no enzyme.
Test Tubes
Test Tube Rack
Glucose test strips
YOU COMPLETE THE LIST

Your lab report will be in the standard format. Make sure your conclusion contains a statement about your hypothesis. Please make sure to identify the unknown and explain why you came to that conclusion. Also, include possible sources of error.

Have fun.

Enzyme Lab -- Teacher Notes

by Deane Gordon, Philadelphia Military Academy @ Leeds

This lab is intended as an extension activity for the Enzymes Help Us Digest Food activity. It may be used independently, depending on student readiness and their understanding of enzyme specificity.

Refer to the Teacher Preparation Notes for Enzymes Help Us Digest Food for solution concentrations and amounts.

Prepare appropriate number of bottles depending on the number of student groups.

One set of bottles with lactase enzyme (Bottle #1)
*One set of bottles with fake sucrase enzyme (Bottle #2)
*One set of bottles with water (Bottle #3)

*Add some baking soda or some other solute to make it look like Bottle #1.

The students should select the sucrose solution and either the lactose solution or milk to test their enzyme. They may also use the glucose solution and/ or water as controls.

Obviously, the only two real choices are the lactase enzyme and no enzyme. The fake sucrase is there just to give them something more to think about (and some groups will select sucrase).