LACTOSE INTOLERANCE: FACT OR FICTION?

OVERVIEW

This activity was developed to supplement the viewing of the film *Got Lactase*? *The Co-evolution of Genes and Culture*. Students evaluate and discuss several statements about lactose intolerance and evolution before and after watching the film. This activity can be used as an anticipation guide to focus students on several of the key concepts presented in the film. It can also serve as a pre- and post-assessment.

KEY CONCEPTS AND LEARNING OBJECTIVES

- Humans, like all species, evolve and adapt to their environment through natural selection. Lactase persistence is an example of a human adaptation that arose within the last 10,000 years in response to a cultural change.
- Both the physical and cultural environment can affect selective pressures. The practice of dairying provided an environment in which lactase persistence was advantageous.
- Many molecules in food have to be converted into simpler molecules that can be absorbed and used by cells in the body.
- Different enzymes help digest different types of compounds in food. For example, someone who cannot digest lactose because they lack the enzyme lactase will still be able to digest the proteins in milk.

Students will be able to

- evaluate claims based on information and evidence presented in a film; and
- participate in a collaborative discussion of their interpretation of the evidence with their peers.

CURRICULUM CONNECTIONS

Curriculum	Curriculum Topics
AP (2012-13 Standards)	1.A.1, 1.A.2, 1.C.3, 2.A.2, 2.D.2, 2.E.1, 3.B.1, 3.C.1, 3.C.2
IB (2009 Standards)	3.2, 3.6, 4.1, 5.4, 6.1, A.3.1, D.3.10
NGSS	MS-PS1.B, MS-LS3.B, MS-LS4.B, MS-LS4.C HS-LS1.A, HS-LS2.A, HS-LS3.A, HS-LS3.B, HS-LS4.B, HS-LS4.C
Common Core	CCSS.ELA-Literacy.RST.6-8.4, CCSS.ELA-Literacy.SL.8.1, CCSS.ELA-Literacy.L.8.1, CCSS.ELA-Literacy.L.8.2, CCSS.ELA-Literacy.L.8.6, CCSS.ELA-Literacy.RST.9-10.4, CCSS.ELA-Literacy.SL.9-10.1, CCSS.ELA-Literacy.L.9-10.1, CCSS.ELA-Literacy.L.9-10.6, CCSS.ELA-Literacy.L.9-10.2, CCSS.ELA-Literacy.RST.11-12.4, CCSS.ELA-Literacy.SL.11-12.1, CCSS.ELA-Literacy.L.11-12.1, CCSS.ELA-Literacy.L.11-12.4, CCSS.ELA-Literacy.L.11-12.6

KEY TERMS

blood glucose, coding DNA, co-evolution, culture, enzyme, gene, lactase, lactase persistence, lactose, lactose intolerance, noncoding DNA

TIME REQUIREMENT

This activity was designed to be completed during one 50-minute class period, including watching the film. Depending on the amount of class discussion, the activity may take longer.

SUGGESTED AUDIENCE

This activity is appropriate for middle school life science and all levels of high school biology.

PRIOR KNOWLEDGE

It may be helpful for students to have a basic understanding of heredity and natural selection. They should be aware that mutations are a source of genetic variation. Students should know that enzymes are important in digestion and that in the absence of the appropriate enzyme, a particular molecule in food cannot be digested.

MATERIALS

Students will need the student worksheet for this activity as well access as the HHMI short film *Got Lactase*? *The Co-evolution of Genes and Culture*.

PROCEDURE

Before Viewing the Film

1. Have students work in pairs to complete the *Before* column of the table. Let your students know that they are not supposed to know all the answers, but they should just record their ideas at this point. Also mention to students that for some of the statements, there may not be a "right" answer.
2. Have a classroom discussion about each of the statements in the worksheet and ask students why they answered the way they did.
3. Have students watch the film with the objective being to find evidence that supports or refutes their responses on the worksheet.

After Viewing the Film

4. Have students work in pairs to discuss the accuracy of the statements based on information presented in the film and complete the *After* column in the table. Students should explain in one or two sentences why they think each statement is true or false.
5. Have a classroom discussion about each of the statements in the worksheet and ask students which ones are true or false. Students should realize that for some of the statements there is no right answer. The key is that students support their claims with information and evidence from the film.

TEACHING TIPS

- There is no wrong or right answer to some of the statements. For example, "lactase is an enzyme" is a true statement. But other statements in the worksheet are open to interpretation.
- Discuss with students that scientists interpret observations and facts to then develop hypotheses that they can test. For a few statements in the worksheet, you could ask students what additional evidence they would need to collect before they can evaluate a particular statement.
- Once students have completed their worksheets, you may have them discuss some additional thought-provoking questions, such as "Why are so few people allergic to milk while so many are lactose intolerant?" "Why

would it be beneficial for humans and other mammals to lose the ability to digest milk as adults?," and "How is lactase persistence in humans an example of co-evolution and can you think of other examples?"

- The following videos and animations provide additional information about lactose tolerance/intolerance:
  Genetics of Human Origins and Adaptation, Sarah Tishkoff http://media.hhmi.org/hl/11Lect2.html
  Recent Adaptations in Humans http://www.hhmi.org/biointeractive/recent-adaptations-humans
  Lactose Digestion in Infants http://www.hhmi.org/biointeractive/lactose-digestion-infants
  Natural Selection of Lactose Tolerance http://www.hhmi.org/biointeractive/natural-selection-lactose-tolerance

ANSWER KEY

Each of the statements below is followed by information that may help guide the in-class discussion.

1. **Baby mammals depend on milk to survive**.

Depending on how a student interprets this statement, it could be thought to be either true or false. According to the film, one characteristic unique to mammals is that the mother feeds her offspring milk, which she produces. Milk provides a balanced diet for the young mammal; it has the right amount of proteins, fats, sugars, minerals, and vitamins to support the infant's proper growth and development. Some students may, however, note that human babies (and babies of mammals that are domesticated or kept in zoos) can survive on formula, so they don't actually depend on their mother's milk to survive. The formula serves as a milk substitute.

Additional background information:

Most human infant formula is made with cow's milk that was altered to resemble human breast milk, giving it the right balance of nutrients and making it easier to digest by infants. Most babies do well on cow's milk formula. Some babies, however—such as those allergic to the proteins in cow's milk—need other types of infant formula, such as soy-based formulas.

Students may wonder why babies cannot just drink cow's milk. All mammalian species produce milk, but the composition of milk for each species varies widely. Milk from other mammals is different from human breast milk. For example, whole cow's milk contains too little vitamin E, iron, and essential fatty acids for the growth and development of human babies. It also contains too much protein, sodium, and potassium, making it difficult for babies' digestive systems to process.

2. **Milk is a healthy food for an adult cat**.

The film says it's risky to give milk to an adult cat. Many veterinarians recommend against giving cow's milk to adult cats. In the wild, the only time mammals are exposed to lactose is when they're infants and with their mother's milk. When infant mammals are weaned from their mother's milk, most of them will stop producing lactase, as it is no longer needed. If a lactose-intolerant cat drinks milk, the undigested lactose passes through the intestinal tract, leading to diarrhea and gas, just as it does in lactose-intolerant humans.

However, some students may point out that they know of cats that appear to drink milk without any problems. These cats could be lactose tolerant. There is some evidence that lactose tolerance has evolved in cats just as it has in humans and that the geographic distribution of lactose tolerance in cats mirrors that in humans. Cats were domesticated between 8,000 and 5,000 years ago and may have started drinking milk from domesticated cows and goats just like their human companions.

3. Throughout human history, people have always consumed the milk of other animals.

According to the film, lactose tolerance and the practice of dairying (or using milk from domesticated animals) arose at about the same time—about 9,000 to 3,000 years ago in different parts of the world. Before this time, humans did not drink the milk of other animals. To put this date into perspective, remind students that archaeological and genetic evidence suggests that modern humans evolved about 200,000 years ago and that the lineage that led to humans split from the lineage that led to chimpanzees and bonobos about 6 million years ago. Thus, dairying is a recent cultural practice in human history.

Additional background information:

We know from archaeological evidence that before the domestication of animals, humans did not drink the milk of other animals. The beginning of the Neolithic period defines the transition from a lifestyle based on hunting and gathering, to a culture in which agriculture and animal domestication became the dominant way to survive. The beginning of the Neolithic transition dates back to about 12,000 years ago. Animal domestication started in the Near East around 11,000 years ago with goats and sheep, followed by cattle. The practice of domestication later spread across Europe. Initially, domesticated animals were used for their meat, but then humans started using them for their milk, wool, and labor.

The film describes how Richard Evershed of the University of Bristol, UK, analyzed ancient potsherds by mass spectrometry to find evidence that those pots once held milk. They identified the earliest evidence for dairying in nearly 9,000-year-old potsherds from Anatolia (Evershed, R. P. *et al*. 2008. *Nature* 455, 528–531).

4. Lactose is a sugar in milk.

The film clearly states that lactose is the main sugar in milk.

Additional background information:

Lactose is the main carbohydrate found in milk. It is a disaccharide, a carbohydrate composed of two basic units, or monosaccharides. Lactose is composed of the monosaccharides glucose and galactose. Lactose, glucose, and galactose are all sugars, which are carbohydrates that dissolve in water.

5. Most human adults around the world can digest the lactose in milk; a minority of people cannot digest lactose.

According to the film, only about a third of human adults worldwide can digest milk. People who can digest milk into adulthood without any problems are lactase persistent. The geographic distribution of lactase persistence is not uniform but shows a correlation with a history of pastoralism and dairying.

Students may be surprised to find out that most people are lactose intolerant. If your students are primarily of European descent and most of their friends and relatives are also of European descent, they might only know people who are lactose tolerant. In addition, people who don't produce lactase and cannot digest lactose don't always know that they are lactose intolerant. Drinking small quantities of milk, or eating cheese or yogurt (which generally contain small amounts of lactose), may not produce any symptoms in someone who does not have the lactase enzyme.

Additional background information:

According to the National Institutes of Health, lactose intolerance, or the inability to digest lactose as an adult, is most prevalent in people of East Asian descent, affecting more than 90 percent of adults in some of these

communities. Lactose intolerance is also very common in people of West African, Arab, Jewish, Greek, and Italian descent (http://ghr.nlm.nih.gov/condition/lactose-intolerance).

6. Digesting lactose causes a person's blood glucose levels to increase.

One of the animations in the film shows that digesting lactose produces glucose and galactose and that both of these sugars readily diffuse from the small intestine into the circulatory system. Thus if a person drinks milk and digests lactose, blood glucose levels should increase. The film also shows that one way to determine whether a person is lactase persistent is to monitor blood glucose levels for a period of time after drinking milk.

You may ask your students what would happen if a person who is lactose intolerant were to drink a liter of milk like the narrator did in the film. If a person is lactose intolerant and cannot digest lactose, blood glucose levels will not increase. That person will likely feel some discomfort, caused by nausea and bloating. In some cases, if a lactose-intolerant individual drinks a lot of milk, he or she will get diarrhea.

Additional background information:

Many foods cause blood glucose levels to increase. When we eat, molecules in food are broken down into smaller components, which will affect blood glucose levels differently depending on what those molecules are (e.g., carbohydrates, lipids, or proteins). Also important is the amount consumed, how the molecules are absorbed, and how cells use them. Almost all the carbohydrates we eat are eventually converted into glucose, which ends up in the bloodstream and is delivered to cells. (The only carbohydrates that are not converted to glucose are those that cannot be digested, like fiber.) Cells convert glucose to energy, needed for all the body's functions, like breathing, digesting, and making cells.

Students may have heard about glucose in relation to diabetes. Diabetes mellitus refers to a group of diseases that affect how your body uses blood glucose. Normally, glucose in the blood enters cells, where it is used as energy. For glucose to enter cells, the body has to produce the hormone insulin. People with diabetes either don't have enough insulin or their cells do not respond to the insulin that is made. Either way, the result is that glucose is not properly absorbed by cells and there is too much glucose in blood. Too much blood glucose can lead to serious health problems.

Everyone, including people with diabetes, needs glucose for energy. However, people with diabetes need to balance the amount of food that they eat (especially food that contains carbohydrates) with their medication and activity level to make sure that their blood glucose levels do not get too high or too low.

7. Lactose intolerance is an allergy to milk and milk products.

Although the film does not discuss milk allergies, students might know that allergies involve the immune system, whereas lactose intolerance does not. The film explains that lactose intolerance is the inability to digest the disaccharide lactose due to a lack of the enzyme lactase. A milk allergy is an abnormal response by the body's immune system to milk and products containing milk.

Additional background information:

Globally, 2 percent to 6 percent of infants and 0.1 percent to 0.5 percent of adults suffer from cow's milk allergy (Crittenden, R. G. and L. E. Bennett. 2005. Cow's milk allergy: a complex disorder. *Journal of the American College of Nutrition* 24(6 Suppl):582S–591S). This means that unlike lactose intolerance, a milk allergy

is a rare condition, and it primarily affects infants. Infants with a milk allergy are sometimes put on a soy-based formula.

Allergies involve the body's immune system. When someone is allergic to a particular food, the immune system overreacts to one or more proteins in that food. When an allergic individual consumes milk proteins, the immune system interprets them as pathogens and inappropriately responds to fend off the invader. This response is what causes an allergic reaction. The main culprit in milk allergies is a protein in cow's milk called casein.

8. **Lactose intolerance is a genetic trait**.

The film explains that whether a person is lactose tolerant or intolerant depends on a change in the genetic material, or DNA. Thus, students should conclude that lactose intolerance is a genetic trait.

Additional background information:

More accurately, lactase nonpersistence is the genetic trait. The DNA sequence in the genetic switch of the lactase gene determines whether the enzyme lactase is produced in adults. An individual who does not produce lactase (i.e., who is lactase nonpersistent) will *likely* have symptoms of lactose intolerance (e.g., bloating and diarrhea) but not necessarily. That depends on a variety of factors, such as how much milk a person drinks, whether that person consumes milk or yogurt, as well as a person's composition of gut bacteria. The terms lactase nonpersistence and lactose intolerance are, however, often used interchangeably.

REFERENCES

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