Genetic Variation - Lactose Intolerance

Unit: Heredity, patterns of inheritance, and trait distribution across different populations	**Utah SEEd Standard / NGSS Performance Expectation:** **Disciplinary Core Idea:** **NGSS Appendix E** **Standard BIO.3.4** Plan and carry out an investigation and use computational thinking to explain the variation and patterns in distribution of the traits expressed in a population. Emphasize the distribution of traits as it relates to both genetic and environmental influences on the expression of those traits. Examples of variation and patterns in distribution of traits could include sickle-cell anemia and malaria, hemoglobin levels in humans at high elevation, or antibiotic resistance. (LS3.B)	**Time:** Approx. 70 minutes to get through slide 16 and the first two pages of the student sheet. Hardy-Weinberg section may be used as an extension or taught as part of the lesson, likely during the next class period.

Anchor Phenomenon	Lactose Intolerance- Students will watch the video The Genetics Behind Lactose Intolerance, which explains that lactase breaks down lactose, and as people age, they stop producing lactase.
Driving Question(s)	What patterns of lactose intolerance are observed in different worldwide populations?
Performance Task	Students will: • Investigate patterns of allele frequency of lactose intolerance by country. • Explain the evolutionary advantage of lactase persistence. • Use computational thinking to calculate ratios and percentages from Punnett squares. • Use computational thinking with the Hardy-Weinberg equation to determine allele frequency based on trait observance.

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Lesson Summary			
	Time	**Guiding Question / Learning Objective**	**How are students answering the guiding question or meeting the learning objective?**
 **Engage**	5 minutes	Video What is lactose intolerance?	Students will watch the video The Genetics Behind Lactose Intolerance. While watching the video, students will write down at least three new things they learned.
 **Explore**	20 minutes	Stations	Students move around the classroom to each country station, draw alleles from the box, and fill out their worksheets.
 **Explain**	20 minutes	Discussion Worldwide	On the student worksheet, students will compare their results with worldwide results. Students will use patterns seen to infer if lactose intolerance is dominant or recessive.
 **Elaborate**	15 minutes	Reading	Students read an article on lactose intolerance around the world. They will annotate the main ideas and recognize worldwide patterns.
 **Evaluate**	Optional 15 minutes	Hardy Weinberg Equation	Teacher walks students through the United States as an example. Students will then choose a country to investigate and calculate allele frequency in their chosen country's population.

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Three Dimensions Focused on in This Lesson		
Disciplinary Core Idea: **NGSS Appendix E** Standard BIO.3.4 Plan and carry out an investigation and use computational thinking to explain the variation and patterns in distribution of the traits expressed in a population. Emphasize the distribution of traits as it relates to both genetic and environmental influences on the expression of those traits. Examples of variation and patterns in distribution of traits could include sickle-cell anemia and malaria, hemoglobin levels in humans at high elevation, or antibiotic resistance. (LS3.B)	**Science and Engineering Practices:** **NGSS Appendix F** Mathematical and computational thinking in 9- 12 builds on K-8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponentials and logarithms, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions.	**Crosscutting Concept:** **NGSS Appendix G** In grades 9-12, students observe patterns in systems at different scales and cite patterns as empirical evidence for causality in supporting their explanations of phenomena. They recognize classifications or explanations used at one scale may not be useful or need revision using a different scale; thus requiring improved investigations and experiments. They use mathematical representations to identify certain patterns and analyze patterns of performance in order to reengineer and improve a designed system.
Learning Objectives Students will analyze genetic data and use computational thinking to explain how genetic inheritance and environmental selection contribute to the worldwide distribution of lactase persistence and lactose intolerance.		
Related Knowledge and Skills from Prior Grades		
Disciplinary Core Idea: **NGSS Appendix E** The variation and distribution of traits in a population depend on genetic and environmental factors. Genetic variation can result from mutations caused by environmental factors or errors in DNA replication or from chromosomes swapping sections during meiosis.	**Science and Engineering Practices:** **NGSS Appendix F** Mathematical and computational thinking in 6–8 builds on K–5 experiences and progresses to identifying patterns in large data sets and using mathematical	**Crosscutting Concept:** **NGSS Appendix G** In grades 6-8, students recognize that macroscopic patterns are related to the nature of microscopic and atomic-level structure. They identify patterns in rates of change and other numerical relationships that provide information about natural and human designed systems. They

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Use computational thinking and patterns to make predictions about the expression of specific traits that are passed in genes on chromosomes from parents to offspring. Emphasize that various inheritance patterns can be predicted by observing the way genes are expressed. Examples of tools to make predictions could include Punnett squares, pedigrees, or karyotypes. Examples of allele crosses could include dominant/recessive, incomplete dominant, codominant, or sex-linked alleles.	concepts to support explanations and arguments.	use patterns to identify cause and effect relationships, and use graphs and charts to identify patterns in data

Connections to Mathematics and ELA/Literacy Standards	
ELA/Literacy Standards: **RST.11-12.1:** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. *(HS-LS3-2)* **WHST.9-12.1:** Write arguments focused on *discipline-specific content.* (HS-LS3-2)	**Mathematics Standards:** **MP.2:** Reason abstractly and quantitatively. (HS-LS3-2)

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Materials

Link to all materials on the 3DRST website (3drst.byu.edu): https://3drst.byu.edu/lactose-intolerance
Link to all materials on Canvas Commons: https://tinyurl.com/3DRSTbiology

Handouts	Videos and other links	Other Resources
- Student worksheet: Does milk make you sick? - Country Punnett Square Class Datasheet - Student Reading: The evolution of lactase persistence **Lab supplies** - Boxes for country stations - Cut out alleles for each country - Flags and pictures for each box - Sticky notes	Video: The Genetics Behind Lactose Intolerance Lactose Intolerance by Country web resource: https://worldpopulationreview.com/country-rankings/lactose-intolerance-by-country	Teacher PowerPoint Student worksheet scoring key Additional data: Cornell study finds lactose intolerance seems linked to ancestral struggles with harsh climate and cattle diseases.

ENGAGE

Teacher:
• **Slide 1** – Open the Lactase Persistence PowerPoint to show the lesson's title.
• **Slide 2** – Ask students to discuss with a neighbor anything they know about lactose intolerance
  ○ Choose a few students to share out anything interesting that came up in their discussion
• **Slide 3** – Ask students, "Do you know anyone who is lactose intolerant? How does it affect their life?"
  ○ Ask students to show thumbs up or thumbs down if they are lactose intolerant.
  ○ Ask students to show thumbs up or thumbs down if they know someone else who is lactose intolerant.
  ○ Ask students if they have ever gotten an upset stomach from eating or drinking dairy products like milk, cheese, or ice cream.
  ○ Ask students who are lactose intolerant if their family members are also lactose intolerant.
• Before the video, ask students to use the sticky note to write down at least three things they learn from the video.
	Teacher tips
	
	Give each student a sticky note before the video.
	
	A brief discussion could be held with the students about their answers to these questions.

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• **Slide 4** – Show the video The Genetics Behind Lactose Intolerance. • After the video, in small groups or pairs, students share what they wrote on the sticky notes. Ask students to share something they wrote from the video. • **Slide 5** –Class discussion about what lactose intolerance is and is not. Be sure students are clear on what lactose intolerance is and clear up any misconceptions, such as milk allergies being lactose intolerance.	

EXPLORE

Student Handout: Does milk make you sick?
Teacher:

- **Slide 6** – Explanation of the Country Punnett Square stations
  - Students will visit each country with their partners.
    - One student draws two times with replacement to find parent 1, and the other student draws two times with replacement for parent 2.
    - Students will fill in Punnett squares and identify possible genotypes of offspring.
    - Students will add their data (genotype ratios) to the Country Punnett Square Class Datasheet.

Student:

- Visit each country.
- Draw each parent with replacement (two slips of paper for each parent).
- Complete Punnett squares.
- Calculate genotype ratios and percentages.
  - Ratios are the raw numbers of each genotype.
  - Since the Punnett square has four boxes, each box is worth 25%. It may help to think of the 4 boxes as quarters, representing 25, 50, 75, and 100.
- Add your data to the Country Punnett Square Class Data.
  - Ratios are what you'll add to the class data sheet.
  - If you are in groups, you will add your ratio numbers together before adding them to the class sheet.

Teacher Tips

Preparation: Teacher needs to print copies of the country alleles, cut and fold them, and place them in separate containers. There are also maps and pictures that can be printed for each country station.

Help students follow the conventions of Punnett squares by placing the dominants and recessives in the correct places, as learned in prior grades. Dominant alleles go first, and recessives go second. Remind students how to find ratios and percentages from the Punnett squares.

The teacher can convert the Excel spreadsheet to a Google Sheet and share it with the students so they can update the data in real time, or the teacher can gather the data in class and add it to the Excel file. We recommend that the data be displayed on a display board, if possible.

The teacher can decide whether students work together in pairs, in groups, or individually when drawing alleles.
Additionally, the teacher could double the number of stations to reduce the number of students at each station.
The teacher may also find it helpful to use a timer to tell students when to move to the next station.

The teacher assigns students or groups the number they use to enter the data on the data sheet.

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EXPLAIN

Teacher:

- **Slide 7** – Refer students to the student worksheet
  - Students fill in genotype class data totals on their worksheets.
  - Students individually answer questions 1 & 2
- **Slides 8 & 9** – Hold a class discussion about questions 1 & 2, and point out any patterns noticed.
- Before finishing the discussion, make sure that students:
  - Know that lactose intolerance is a recessive trait
  - Understand that lactase persistence is the dominant trait
  - Recognize that genetic variability is different across worldwide populations.
- Use slide 9 to help students understand the relationship between genotypes and phenotypes for lactose intolerance.
- **Slide 10** – Questions 3 & 4 require students to see worldwide data by comparing lactose intolerance in worldwide populations.
  - Differences may be due to sample size, time of collection, method of collection, bias, etc.
- Complete the table with the Lactose Intolerance % and Lactase Persistence %—the two possible phenotypes for this trait.

Teacher Tips

The students will enter their ratios into the group spreadsheet. Once the entire class has entered their ratios, they can record the class's total percentages on their worksheets.

Once the class understands lactose intolerance is recessive, they can complete the phenotypes in the table at the top of page two.

ELABORATE

Teacher:

- **Slide 11** – Give each student a copy of the article "Evolution of Lactase Persistence."

Students:

- Read the article and annotate ideas that are new to you.
- Answer questions 5 & 6 on the student worksheet.

Teacher:

- **Slides 12-16** – Class discussion
  - Is there data for all countries?
  - What differences are there between the maps?
  - Note the map of Africa on slide 14—even different populations within the same continent may have drastically different genetic variability for a particular trait.
  - Some maps show TOLERANCE, while others show INTOLERANCE

Teacher Tips

Teachers should determine whether reading individually or as a class would be more beneficial.

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EVALUATE

Student: • Students revisit questions 5 and 6. • Students answer question 7 on their student worksheet.	

POSSIBLE EXTENSION / ALTERNATIVE ADAPTATIONS

Hardy-Weinberg Activity Teacher: • Point out that in a place where 100% of the population is lactose intolerant, it is easy to figure out the allele frequencies of the entire population. • However, most countries are more complicated. Explain that the printed alleles in the boxes were determined using the population of lactose intolerance (homozygous recessive). Using that information, they can determine the remaining alleles. • **Slide 17** – Use the Hardy-Weinberg Principle to determine the prevalence of each allele based on the occurrence of the trait (lactose intolerance). • Complete the United States (52% lactose intolerant) together as an example. See teacher answer key. Student: • Work through the United States with the class as an example • Choose a country from the website showing Lactose Intolerance by Country and complete the table finding your allele frequencies.	**Teacher tips** Teacher tip: specify to students that they may NOT choose a country with 100% lactose intolerance to calculate allele frequency. https://worldpopulationreview.com/country-rankings/lactose-intolerance-by-country

This lesson was developed by Doug Morris, Julie Castellon, Austin Moore, & Jami Slack

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