Patterns in the Distribution of Lactase Persistence

hhmi | BioInteractive

Activity
Educator Materials

OVERVIEW

This activity extends concepts covered in the film *Got Lactase? The Co-evolution of Genes and Culture*. Students analyze data from the scientific literature to draw conclusions about the geographic distribution of lactase persistence. The activity begins with students watching the film. They then analyze data on the frequency of lactase persistence and associated alleles. The activity involves using the data to draw pie charts, place the pie charts on a world map, and identify patterns. It provides an interdisciplinary approach to studying lactase persistence by connecting biological concepts and data analysis to world geography and culture.

Additional information related to pedagogy and implementation can be found on this resource's webpage, including suggested audience, estimated time, and curriculum connections.

KEY CONCEPTS

- Humans, like all species, evolve and adapt to their environment through natural selection. Lactase persistence is an example of a human adaptation.
- Both the physical and cultural environment can affect selective pressures. The cultural practice of dairying provided an environment in which lactase persistence was advantageous.
- Combining data from multiple studies can reveal patterns not evident from smaller individual studies.

STUDENT LEARNING TARGETS

- Calculate frequencies and graph data in pie charts.
- Interpret data from different research studies to infer the global distribution of a trait.
- Make claims based on scientific evidence and use scientific reasoning to support the claims.

PRIOR KNOWLEDGE

Students should have a basic understanding of:

- the terms "allele" and "phenotype" and how to apply them to specific examples
- how to calculate frequencies and construct pie charts
- evolution by natural selection

MATERIALS

- the "Student Handout," which includes the "Genetic Data" table (p. 8), the "Phenotype Data" table (p. 9), the "Pie Chart Stencils" (p. 10), and an optional "Quick Guide" (end)
- calculator (one per student)
- a world map, such as the one in the "World Map" supplemental handout
- materials for making pie charts, which depend on how you run the activity (see the "Procedure" section for options); may include:
  - colored pencils
  - prefilled pie charts (end of this document)
  - colored circle stickers
  - scissors
  - glue stick or tape
- computer/references for geography research

Teaching Tips

Running the Activity

- Several options for the activity procedure are provided in the "Procedure" section below.
- Revise the instructions in the "Student Handout" as needed to reflect the procedure you are using.

Clarifications and Caveats

- Make sure students understand what the lactase-persistence frequencies in the data tables represent and why they may not account for everyone who is lactase persistent.
  - In the **"Genetic Data"** table, the lactase-persistence frequencies represent people who have at least one of four specific alleles associated with lactase persistence. There may be other alleles associated with lactase persistence that were not identified or considered in these studies.
  - In the **"Phenotype Data"** table, the lactase-persistence frequencies represent people who tested positive in tests that measure the ability to digest lactose, such as the blood glucose test or the hydrogen breath test. These tests are not always 100% accurate. For example, the blood glucose test measures an increase in glucose after drinking milk, which may occur due to factors other than lactose digestion.
- Students may be surprised to learn that most people in the world are lactase nonpersistent/lactose intolerant. You may want to clarify that people who are lactose intolerant can often still consume milk and milk products. They might be able to drink small amounts of milk without any (or only mild) symptoms or use lactase-containing supplements like Lactaid. They may also have no problem eating milk products, like cheese and yogurt, because these foods have much less lactose than milk does.
- Students may ask why this activity does not include populations from North and South America. Not many studies of lactase persistence have been conducted on the American continent, largely because many people are not indigenous to this continent but instead immigrated there relatively recently. Their lactase-persistence genotypes would depend on their ancestry.
- The data set in this activity, which is from the Global Lactase Persistence Association Database, combines data from multiple studies. You may wish to discuss the benefits and limitations of this approach using the following prompts:
  - Have students look at the "Genetic Data" and "Phenotype Data" tables, paying attention to the references. Students can discuss what they observe and why there are so many different references. Point out that the purpose of the data was to explore the worldwide distribution of lactase persistence.
  - Discuss why scientists might decide to analyze data published in past scientific papers instead of collecting all the data themselves.
  - Have students look at the genetic and phenotype data of one population (for example, Hungary in Row X) and the corresponding references. Discuss the limitations of comparing data for one population from two different studies with different samples.
  - Remind students that when combining studies, it is important to read the "Materials and Methods" sections to determine how each study was conducted. If the studies measured the same trait in different ways, this could affect the results. The "Quick Guide" at the end of the "Student Handout" discusses two different ways to measure lactose digestion, for example.

Supplements and Extensions

- Clines are not typically introduced in high school biology classrooms. If you wish to include that concept, you could ask students the following questions to prompt discussion:

- In biology, a **cline** is the gradual change in a trait, or changes in allele frequencies within the gene pool, over a geographic area within a species. Using your world map with pie charts, look at the lactase-persistence distribution from England to France, Italy, Greece, and finally Turkey. Do you observe a general genetic cline? Support your answer with evidence from the data.
  - Yes, there is a general cline from England to Turkey. As you move from England in the northwest to Turkey in the southeast, the lactase-persistence frequency based on genetic data decreases. For example, northern England (S) 94% → France (V) 67% → Greece (W) 17% → Turkey (BB) 6%.
- At times, clines are defined by environmental changes within the study area. Develop a question that you would like to test regarding links between environment, culture, and lactase persistence in the populations included in the previous question.
  - Answers will vary. An example: "Are the people in England more dependent on milk products than the people in southern Europe due to a shorter growing season in northeastern Europe?"

- The following BioInteractive resources can be used to complement and extend the concepts in this activity:
  - The film activity for the *Got Lactase?* film explores the film's concepts in more depth.
  - The data-driven activity "Blood Glucose Data Analysis" can be used to learn more about the tests used to obtain the phenotype data in this activity.
  - The hands-on lab activity "Milk—How Sweet Is It?" has students measure glucose levels in samples of milk after adding lactase.
  - The Click & Learn *Regulation of the Lactase Gene* explores how expression of the lactase gene is regulated.

PROCEDURE

Begin by having students view the film *Got Lactase? The Co-evolution of Genes and Culture*. If you do this in class, you can pause the film at various parts of the lactase-persistence map (4:15–4:35) and have students consider the frequencies of people who are lactose intolerant (lactase nonpersistent) and lactose tolerant (lactase persistent) in different populations.

In **Part 1**, students calculate 30 genetic and phenotypic frequencies. You may want to divide the calculations up among students, then have individuals/groups report back to the whole class.

In **Part 2**, students map the *genetic* data by creating 30 pie charts and placing them on a world map. General suggestions for Part 2 are as follows:

- You can use any large classroom wall map available to you or print the map provided in the "World Map" supplemental handout.
  - If you decide to print the supplemental handout, set the paper size to 11 × 17 inches or "Tabloid" under "Page Setup." If you don't have 11 × 17 paper, you may be able to print the map on four sheets of 8.5 × 11-inch paper by selecting "Poster" in your printing options.
  - You could also project the world map on a whiteboard, then have students place their pie charts on the whiteboard or draw the pie charts in by hand.
- Instead of having students cut out pie charts, you could use sheets of colored circle stickers to save time. Students can create pie charts by overlaying one color of sticker over another (with the appropriate percentage "slice" cut away). Make sure students are very careful when placing the stickers on the map to ensure that they are correctly placed.

- You could have students also map the *phenotype* data and make statements about general patterns they observe when comparing the genetic and phenotype maps. Students should discover that populations with high phenotypic frequencies of lactase persistence typically also have high frequencies of lactase-persistence alleles.

ANSWER KEY

PART 1: Analyzing Genetic and Phenotype Data

1. To learn more about these concepts, watch the film *Got Lactase? The Co-evolution of Genes and Culture*. Pay particular attention to the worldwide distribution of lactase persistence, shown in the map from 4:15–4:35. Summarize some of your initial observations about this distribution below.
   Student answers may vary. They will explore the worldwide distribution of lactase persistence in more depth throughout the rest of this activity.

2. Using these data, calculate the frequency of lactase persistence in each population sample. Record the frequencies (rounded to two decimal places) in the column labeled **"Lactase-persistence frequency"** in the **"Genetic Data"** table.
   See the completed "Genetic Data" table on p. 9 of this document.

3. Using these data, calculate the frequency of lactase persistence in each population sample. Record the frequencies (rounded to two decimal places) in the column labeled "**Lactase-persistence frequency"** in the **"Phenotype Data"** table. (Again, your instructor may ask you to work in groups or as a class.)
   See the completed "Phenotype Data" table on p. 10 of this document.

4. What are the lactase-persistence frequencies in each table based on? In other words, what was measured to collect the genetic data vs. the phenotype data?
   In the "Genetic Data" table, the lactase-persistence frequencies are based on the frequencies of people with at least one of four specific lactase-persistence alleles. In the "Phenotype Data" table, the lactase-persistence frequencies are based on the frequencies of people who were able to digest lactose, as indicated by a test like the blood glucose test or hydrogen breath test.

5. In the **"Genetic Data"** table, look at the sample data for the Somali population in Ethiopia (Row A). Answer the following questions based on this sample.
   a. How many people were sampled?
      74 people
   b. How many people had at least one lactase-persistence allele (out of the four considered in the studies)?
      22 people
   c. How many people did *not* have any of these lactase-persistence alleles?
      74 people total – 22 people with at least one allele = 52 people without the alleles
   d. Calculate the frequency of people in this sample who did *not* have any of these lactase-persistence alleles. Show your work.
      52 people without the alleles/74 people total = 0.70
   e. Assume this sample accurately represents the entire Somali population. In this population, which has around 10 million people, how many people would you expect to have at least one of these lactase-persistence alleles? Show your work.
      Frequency of having at least one allele = 22/74 = 0.30
      0.30 × 10,000,000 people in the population = 3,000,000 people would be expected to have at least one lactase-persistence allele.

6. In the **"Phenotype Data"** table, look at the sample data for the Somali population in Ethiopia (Row A). Answer the following questions based on this sample.

   a. How many people were sampled?
   90 people

   b. How many people tested positive for the ability to digest lactose?
   22 people

   c. How many people were unable to digest lactose?
   90 people total – 22 people who can digest lactose = 68 people who can't digest lactose

   d. Calculate the frequency of people in this sample who tested *negative* for the lactase-persistence phenotype. Show your work.
   68 people who can't digest lactose/90 people total = 0.76

7. Use the two data tables to find the lactase-persistence frequencies and references for the Hungarian population samples (Row X).

Population	Data Type	Lactase-persistence frequency	Reference (Author and Year)
Hungarians	Genetic	***0.86***	***Nagy et al. 2009***
	Phenotype	***0.63***	***Czeizel et al. 1983***

   a. Describe two differences between the genetic and phenotype data.
   There are multiple possible answers, including different lactase-persistence frequencies, different studies, and different authors in different years.

   b. Propose two reasons why the lactase-persistence frequencies based on the genetic and phenotype data might differ.
   Answers will vary. Students may note that the data are from different studies in different years; one study may have sampled more lactase-persistent people by chance, or there may have been changes in the population's demographics over time. Students may also suggest that the methods in the studies had different levels of accuracy, or that some people with lactase-persistence alleles can't digest lactose for other reasons.

8. One genetic study sampled 1876 people in Finland (Row U), which had a total population of 5.3 million at that time. Another genetic study sampled 58 people in France (Row V), which had a total population of 60.4 million at that time.

   a. Which sample, the one from Finland or France, do you think represents its country more accurately?
   Students may suggest the Finnish sample, because it includes a larger percentage of the total population of its country.

   b. Propose two questions you could ask about these samples to help determine how accurately they represent the populations of their countries.
   Answers will vary. Students may ask questions to determine whether each sample is an unbiased reflection of its overall population in terms of representing different regions and demographic categories.

9. Compare the genetic data to the phenotype data for the three populations sampled in Sudan (Rows F, G, H). What patterns do you observe?
   Students may observe that each population has a lower lactase-persistence frequency based on genetic data than based on phenotype data. Also, the genetic-based frequencies are positively correlated with

phenotype-based frequencies; the population with the highest frequency based on the genetic data also has the highest frequency based on the phenotype data.

10. Compare the samples for these three populations: Wolof (Row D), Dinka (Row G), and Japanese (Row N).
    a. In the "Genetic Data" table, what do the lactase-persistence frequencies of these population samples have in common?
    These frequencies are all zero.

    b. In the "Phenotype Data" table, the lactase-persistence frequencies of these populations' samples range from 0.25 to 0.51. What might explain the difference between these frequencies and the ones in Part A?
    Answers will vary. One possibility is that there are other alleles or genes not considered in these genetic studies that also give people the ability to digest lactose.

11. Compare the three populations sampled in Uganda (Row I), China (Row P), and Papua New Guinea (Row R). Using both the genetic and phenotype data, develop a hypothesis about the cultural practices in these populations regarding using animals for milk.
    In the samples for these populations, the lactase-persistence frequencies based on both the genetic and phenotype data are all low (< 0.10). One hypothesis is that the ancestors of people in these populations did not commonly use animals for milk or consume milk products. If milk was not a major food source in these populations, the lactase-persistence trait wouldn't have been as advantageous, so it wouldn't have become more common due to natural selection.

12. The Dinka population in Sudan (Row G) traditionally has an **agropastoralist** culture, meaning that they depended on agriculture during some seasons and raising animals for food (including milk) during others. According to the study referenced in the "Genetic Data" table, the Dinka people sampled had a lactase-persistence frequency of 0, which may seem inconsistent with an agropastoralist culture. Why do you think this is? (*Hint*: What might have been a limitation of the study?)
    Answers will vary. One possibility is that the number of people sampled (18) is too low to accurately represent the entire population.

PART 2: Mapping Lactase-Persistence Frequencies

Questions 13–19 walk students through the map activity. A completed version of the map is shown on p. 11 of this document.

19. Based on your finished map, make three general claims about the worldwide distribution of lactase persistence. Provide examples that support each claim, as well as potential counterexamples (examples that do not support the claim), if any.
    Answers will vary. Below are a few examples.

Claim	**Supporting examples** and **counterexamples**
In general, the lactase-persistence frequencies in Europe are higher than in other areas represented on the map.	***Supporting examples: S, T, U, V, X, Y*** ***Counterexamples: W, Z***
Most of the populations in Asia have low lactase-persistence frequencies.	***Supporting examples: L, M, N, P, Q*** ***Counterexamples: O***
Most of the populations in Africa have high lactase-persistence frequencies.	***Supporting examples: A, C, D, E, F, G, H, I*** ***Counterexamples: B, J, K***

20. Compare the sample lactase-persistence frequencies of the two populations from Kenya: the Maasai (B) and the Sengwer (C).

a. How do these frequencies differ?
The lactase-persistence frequency is high in the Maasai sample and very low in the Sengwer sample.

b. Based on the information in the *Got Lactase?* film, what could have caused this difference? Explain your answer.
As shown in the film, the Maasai people have been raising animals for milk and consuming milk for thousands of years, so the lactase persistence trait provided a selective advantage in their population. Consuming milk may have been less common for the Sengwer people, which could explain why lactase persistence is less common in their population.

21. Compare the sample lactase-persistence frequencies of the two populations from England (S and T) and the two populations from Italy (Y and Z). What do you notice when you compare the populations within each country? What question(s) does this comparison raise for you?
The two populations from England (S, T) have similar sample lactase-persistence frequencies (0.94 and 0.91), but the two populations from Italy (Y, Z) have very different sample lactase-persistence frequencies (0.14 and 0.61). Students could ask why the two populations from Italy differ so much from each other, why the populations from Italy differ from those in England, etc.

22. Compare the sample lactase-persistence frequencies for Northern Europe and Asia/Australasia. In general, what differences do you observe? What reason(s) could there be for these differences?
In general, the populations from Northern Europe have higher sample lactase-persistence frequencies compared to the populations from Asia/Australasia. The differences between these two regions could be due to cultural practices regarding diet. The populations from Northern Europe may have been more dependent on milk than the populations from Asia/Australasia were.

23. The Han population (P) in China makes up 92% of mainland China's population and roughly one-fifth of the world's population. Of the 200 people sampled, what percentage would you expect to be lactose intolerant?
The lactase-persistence frequency in this sample (based on genetic data) is 0, meaning that no one in the sample had one of the four lactase-persistence alleles considered in the studies. Assuming that no one in the sample had other alleles associated with lactase persistence, we would expect 100% of the people sampled to be lactose intolerant.

24. Based on Figure 1, predict how the lactase-persistence frequency in the Han population (P) might change after 1,000 years. Explain your prediction, noting what (if any) selective pressures might be present.
Answers may vary. Assuming that milk consumption remains high, that those who drink milk have a survival/reproductive advantage over those who don't, and that a genetic variation for lactase persistence exists in the population, we may expect the frequency of lactase persistence in the population to increase over the next 1,000 years.

However, people today have many different foods available to them, so there probably wouldn't be as much selective pressure for milk drinking as there was thousands of years ago. Also, modern products, like Lactaid, allow lactase-nonpersistent people to digest lactose, which may make selective pressure for lactase persistence negligible. If so, we would not expect changes in lactase-persistence frequencies due to natural selection.

25. The traditional diet of the Bantu population (I) in Uganda has many main food sources other than milk, including meat, nuts, fruits, and vegetables. Given this information, are the sample lactase-persistence frequencies for this population what you'd expect? Explain why or why not.
The lactase-persistence frequency for the Bantu population sample is extremely low (0 based on the genetic data). This result is consistent with the description of their traditional diet, which depends on food

sources other than milk. If the population did not depend on milk, lactase persistence would not offer a selective advantage.

26. The *Got Lactase?* film claims that lactase persistence is an example of "gene-culture co-evolution." In a few sentences, explain and provide evidence for this claim. Your evidence should include one or more examples from the data you examined in this activity.

    Answers will vary. An example answer could be as follows:
    This claim means that lactase persistence is an example of a human adaptation that arose in response to a cultural change. The cultural practice of dairying and drinking milk as adults provided an environment in which lactase persistence became advantageous. This practice created a strong selective advantage for lactase persistence, because only the people with the ability to digest milk could benefit from it nutritionally.

    For example, consider the Maasai population in Kenya (B) and the Bantu population in Uganda (I), which vary in their cultural practices. The Maasai raised animals for milk (as discussed in the film) and had a high lactase-persistence frequency in their sample. The Bantu population did not depend on milk (as discussed in the previous question) and had a very low lactase-persistence frequency in their sample.

CREDITS

Written by Ann Brokaw, Rocky River High School, OH
Edited by Esther Shyu, Laura Bonetta, Melissa Csikari, HHMI; Susan Dodge, consultant
Scientific review by Paul Beardsley, Cal Poly Ponoma, CA

Genetic Data

Data indicate the number of people in each sample who had at least one copy of a lactase-persistence allele (out of the four considered in these studies).

Row	Continent/ Region	Country	Population	# people sampled	# people with lactase-persistence allele	Lactase-persistence frequency	Reference
A	Africa	Ethiopia	Somali	74	22	***0.30***	Ingram et al. (2009) *Hum. Gen.* **124**, 579.
B	Africa	Kenya	Maasai	64	54	***0.84***	Tishkoff et al. (2007) *Nat. Genet.* **39**, 31.
C	Africa	Kenya	Sengwer	32	4	***0.13***	Tishkoff et al. (2007) *Nat. Genet.* **39**, 31.
D	Africa	Senegal	Wolof	118	0	***0.00***	Ingram et al. (2009) *Hum. Gen.* **124**, 579.
E	Africa	South Africa	Xhosa	109	27	***0.25***	Torniainen et al. (2009) *BMC Genet.* **10**, 31.
F	Africa	Sudan	Beni Amer	162	73	***0.45***	Ingram et al. (2009) *Hum. Gen.* **124**, 579.
G	Africa	Sudan	Dinka	18	0	***0.00***	Tishkoff et al. (2007) *Nat. Genet.* **39**, 31.
H	Africa	Sudan	Jaali	172	46	***0.27***	Ingram et al. (2009) *Hum. Gen.* **124**, 579.
I	Africa	Uganda	Bantu	44	0	***0.00***	Mulcare et al. (2004) *Am. J. Hum. Genet.* **74**, 1102.
J	Africa	Tanzania	Burunge	36	22	***0.61***	Tishkoff et al. (2007) *Nat. Genet.* **39**, 31.
K	Africa	Tanzania	Maasai	38	26	***0.68***	Tishkoff et al. (2007) *Nat. Genet.* **39**, 31.
L	Asia	Afghanistan	Tadjik	98	19	***0.19***	Mulcare (2006) London: University of London PhD.
M	Asia	India	Indian	68	17	***0.25***	Mulcare (2006) London: University of London PhD.
N	Asia	Japan	Japanese	62	0	***0.00***	Bersaglieri et al. (2004) *Am. J. Hum. Genet.* **74**, 1111.
O	Asia	Russia	Udmurt	60	33	***0.55***	Enattah et al. (2008) *Am. J. Hum. Genet.* **82**, 57.
P	Asia	China	Han	200	0	***0.00***	Enattah et al. (2008) *Am. J. Hum. Genet.* **82**, 57.
Q	Asia	China	Mongol	82	8	***0.10***	Sun et al. (2007) *Asia Pac. J. Clin. Nutr.* **16**, 4.
R	Australasia	Papua New Guinea	Papuan	34	0	***0.00***	Bersaglieri et al. (2004) *Am. J. Hum. Genet.* **74**, 1111.
S	Europe	England	British, northern	1168	1098	***0.94***	Davey Smith et al. (2009) *Eur. J. Human Gen.*, **17**, 357-367.
T	Europe	England	British, southeastern	947	862	***0.91***	Davey Smith et al. (2009) *Eur. J. Human Gen.*, **17**, 357-367.
U	Europe	Finland	Finn	1876	1538	***0.82***	Enattah et al. (2008) *Am. J. Hum. Genet.* **82**, 57.
V	Europe	France	French	58	39	***0.67***	Bersaglieri et al. (2004) *Am. J. Hum. Genet.* **74**, 1111.
W	Europe	Greece	Greek	100	17	***0.17***	Anagnostou et al. (2009) *Am. J. Hum. Biol.* **21**, 217.
X	Europe	Hungary	Hungarian	110	95	***0.86***	Nagy et al. (2009) *Eur. J. Clin. Nutr.* **63**, 909.
Y	Europe	Italy	Northern Italian	28	17	***0.61***	Bersaglieri et al. (2004) *Am. J. Hum. Genet.* **74**, 1111.
Z	Europe	Italy	Sardinian	153	21	***0.14***	Anagnostou et al. (2009) *Am. J. Hum. Biol.* **21**, 217.
AA	Near/Middle East	Jordan	Jordanian	112	22	***0.20***	Enattah et al. (2008) *Am. J. Hum. Genet.* **82**, 57.
BB	Near/Middle East	Turkey	Anatolian Turk	98	6	***0.06***	Mulcare (2006) London: University of London PhD.
CC	Near/Middle East	Saudi Arabia	Bedouin	94	69	***0.73***	Ingram et al. (2009) *Hum. Gen.* **124**, 579.
DD	Near/Middle East	Saudi Arabia	Arab	248	206	***0.83***	Enattah et al. (2008) *Am. J. Hum. Genet.* **82**, 57.

Source: Global Lactase Persistence Association Database

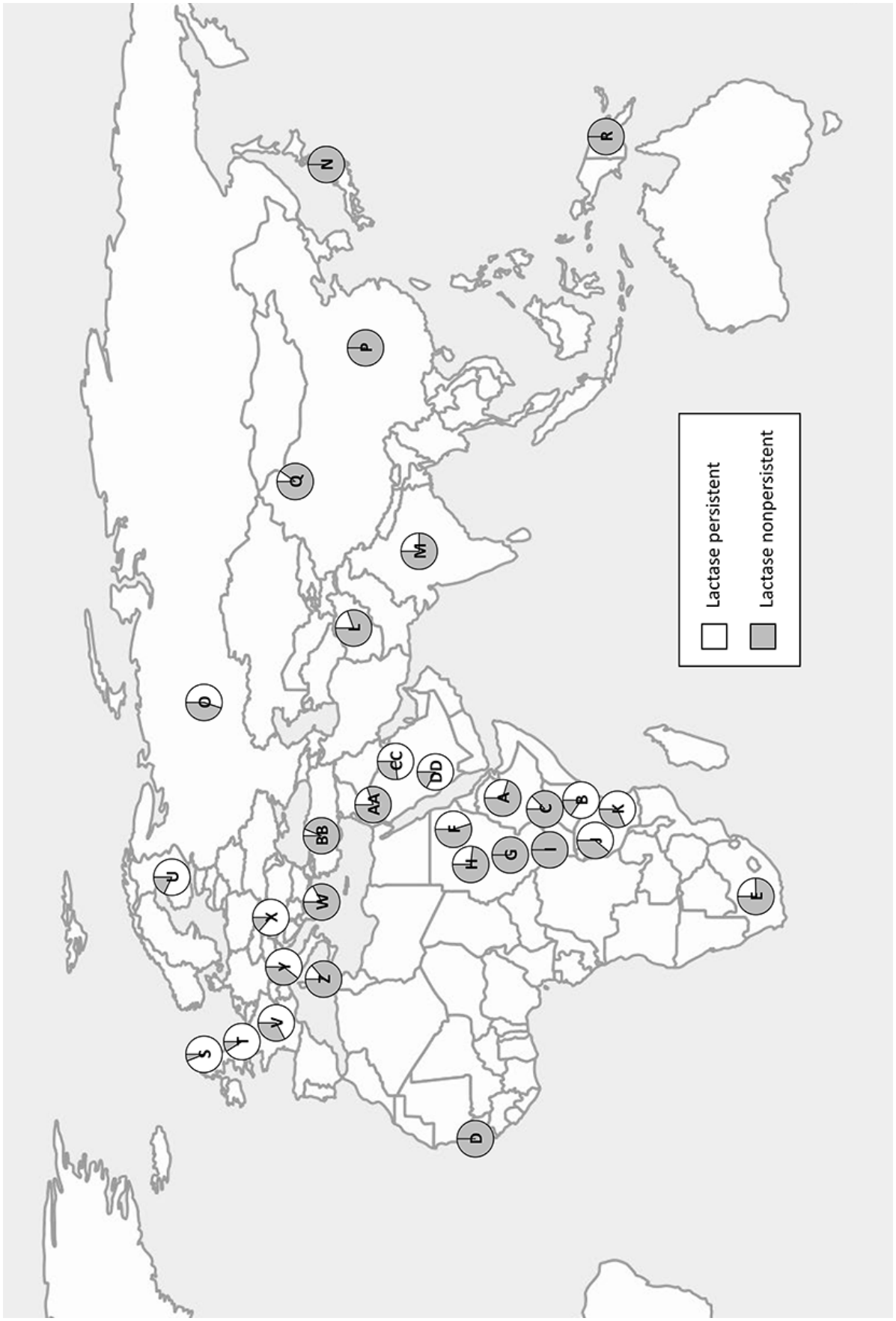
Phenotype Data

Data indicate the number of people in each sample who tested positive for the ability to digest lactose (e.g., using a blood glucose test or hydrogen breath test).

Row	Continent/ Region	Country	Population	# people sampled	# people tested positive for lactase persistence	Lactase-persistence frequency	Reference
A	Africa	Ethiopia	Somali	90	22	***0.24***	Ingram et al. (2009) *Hum. Gen.* ***124,*** 579.
B	Africa	Kenya	Maasai	26	23	***0.88***	Tishkoff et al. (2007) *Nat. Genet.* **39**, 31.
C	Africa	Kenya	Sengwer	12	2	***0.17***	Tishkoff et al. (2007) *Nat. Genet.* **39**, 31.
D	Africa	Senegal	Wolof	53	27	***0.51***	Arnold et al. (1980) *C. R. Seances Soc. Biol. Fil.* **174**, 983.
E	Africa	South Africa	Xhosa	17	3	***0.18***	Segal et al. (1983) *Am. J. Clin. Nutr.* **38**, 901.
F	Africa	Sudan	Beni Amer	40	35	***0.88***	Bayoumi et al. (1982) *Am. J. Phys. Anthropol.* **58**, 173.
G	Africa	Sudan	Dinka	208	52	***0.25***	Bayoumi et al. (1982) *Am. J. Phys. Anthropol.* **58**, 173.
H	Africa	Sudan	Jaali	113	60	***0.53***	Bayoumi et al. (1981) *Hum. Genet.* **57**, 279.
I	Africa	Uganda	Bantu	17	1	***0.06***	Cook et al. (1966) *Lancet* **1**, 725.
J	Africa	Tanzania	Burunge	16	6	***0.38***	Tishkoff et al. (2007) *Nat. Genet.* **39**, 31.
K	Africa	Tanzania	Maasai	15	10	***0.67***	Tishkoff et al. (2007) *Nat. Genet.* **39**, 31.
L	Asia	Afghanistan	Tadjik	79	14	***0.18***	Rahimi et al. (1976) *Hum. Genet.* **34**, 57.
M	Asia	India	Indian	100	36	***0.36***	Desai et al. (1970) *Indian J. Med. Sci.* **24**, 729.
N	Asia	Japan	Japanese	40	11	***0.28***	Yoshida et al. (1975) *Gastroenterol. Jpn.* **10**, 29.
O	Asia	Russia	Udmurt	30	18	***0.60***	Kozlov (1998) *Int. J. Circumpolar Health* **57**, 18.
P	Asia	China	Han	248	20	***0.08***	Yongfa et al. (1984) *Hum. Genet.* **67**, 103.
Q	Asia	China	Mongol	198	24	***0.12***	Yongfa et al. (1984) *Hum. Genet.* **67**, 103.
R	Australasia	Papua New Guinea	Papuan	30	3	***0.10***	Jenkins et al. (1981) *Ann. Hum. Biol.* **8**, 447.
*****	Europe	England	British	150	143	***0.95***	Ferguson et al. (1984) *Gut* **25**, 163.
U	Europe	Finland	Finn	638	530	***0.83***	Jussila (1969) *Ann. Clin. Res.* **1**, 199.
V	Europe	France	French	102	78	***0.76***	Cloarec et al. (1991) *Gastroenterol. Clin. Biol.* **15**, 588.
W	Europe	Greece	Greek	600	330	***0.55***	Kanaghinis et al. (1974) *Am. J. Dig. Dis.* **19**, 1021.
X	Europe	Hungary	Hungarian	535	337	***0.63***	Czeizel et al. (1983) *Hum. Genet.* **64**, 398.
Y	Europe	Italy	Northern Italian	208	102	***0.49***	Burgio et al. (1984) *Am. J. Clin. Nutr.* **39**, 100.
Z	Europe	Italy	Sardinian	53	6	***0.11***	Meloni et al. (1998) *Ital. J. Gastroenterol. Hepatol.* **30**, 490.
AA	Near/Middle East	Jordan	Jordanian	148	37	***0.25***	Hijazi et al. (1983) *Trop. Geogr. Med.* **35**, 157.
BB	Near/Middle East	Turkey	Anatolian Turk	122	32	***0.26***	Flatz et al. (1986) *Am. J. Hum. Genet.* **38**, 515.
CC	Near/Middle East	Saudi Arabia	Bedouin	21	17	***0.81***	Dissanayake et al. (1990) *Ann. Saudi Med.* **10**, 598.
DD	Near/Middle East	Saudi Arabia	Arab	109	47	***0.43***	Dissanayake et al. (1990) *Ann. Saudi Med.* **10**, 598.

Source: Global Lactase Persistence Association Database

Worldwide distribution of lactase-persistence and lactase-nonpersistence frequencies (based on genetic data)



Prefilled Pie Charts