Population Genetics of Lactose Intolerance

Objectives:

- In this activity you will learn more about lactose intolerance
- You will understand the chemical structure of lactose
- Why a person may have difficulty digesting milk,
- How lactose tolerance may have started,
- Why so many Americans can digest it,

Background:

Lactose is found only in milk and milk products. It is disaccharide sugar, composed of two molecules of "simple" sugars chemically bonded together - The enzyme **lactase** breaks down lactose into glucose and galactose which are easily digested by humans. Without lactase the lactose would pass into the colon undigested. **Lactose intolerance** is a condition that results from the malabsorption of lactose. The lactose molecule, which is large, accumulates in the large intestine and affects the osmotic (water) balance there. Since water moves across semi-permeable membranes, such as the intestine, from areas of high concentration to low concentration, the addition of large lactose molecules causes water to enter the intestine. This can result in the very unpleasant experience of watery stool or diarrhea. Since lactose is a sugar, it is also an ideal food for the bacteria which normally inhabit our intestine. However, the lactose will be fermented by these friendly bacteria, and gas will be produced. *Somebody light a match.* According to statistics approximately one-third of all Americans feel ill after consuming milk and other dairy products. Except for certain populations of Western humans, milk consumption stops (or is greatly reduced) with weaning. It also happens that in animals and most humans there is a decline in the level of production of lactase with aging. Since in most persons the body does not continue to secrete large amounts of lactase enzyme after weaning, milk is indigestible by a large majority of the world's population. In the vast majority of adult humans, the gene which specifies production of lactase is turned "off" and these individuals cannot digest lactose. That is what is normal; it's actually unusual for adults to be able to digest milk easily. The term "primary adult lactase deficiency" refers to the condition for most people in whom lactase production has practically ceased. The decline begins in youth and continues to decline, but the onset of symptoms varies with age.

Evolution in pastoral (cattle raising) ancestors that kept dairy animals, in populations of Europeans and some Africans, is thought to have produced the modern people who are lactose absorbers throughout adult life. It was postulated that the presence of lactose in the diet induced the intestinal cells to continue lactase production. There may have been a selective advantage in that group during times when milk and dairy products were relied on almost exclusively for nutrition during shortages of other foods. About 10,000 years have passed since the milking of domestic animals was begun. Nigeria is a case that demonstrates the significance of this lifestyle on human evolution. In the southern region, where conditions are not favorable for cattle, milk is not part of the diet. People there develop lactose intolerance. In contrast, a nomadic tribe that has been raising milk cattle for thousands of years remains lactose tolerant. Most African Americans are descendants of the non-pastoral tribes from Western Africa and do not tolerate lactose well.

Part A. Lactose Intolerance in Families

A. Fill in the pedigree charts for three families.

B. Lactose Intolerance is an autosomal recessive condition

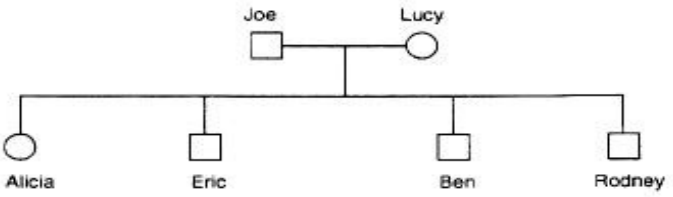
1. What is the topic of this ad?

2. Who would use such a product?

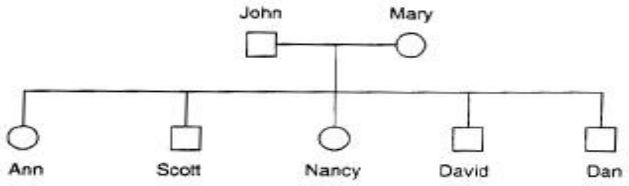
3. Why would they need it?

4. Do you know anyone who would need these products?

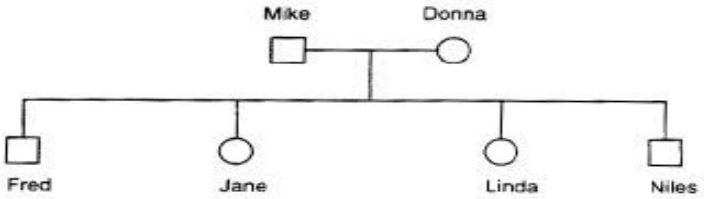
5. Parents Joe and Lucy Anderson are both lactose intolerant.
The four children: Alicia, Eric, Ben, and Rodney are all lactose intolerant.
* Remember that we shade in persons with the phenotype being studied.



2. Parent Mary Wallace is lactose intolerant and her husband, John is lactose tolerant. They had five children. Ann, David, and Dan are lactose intolerant.
Nancy and Scott are lactose tolerant.



3. Parents Mike and Donna Miller are both lactose tolerant.
Their children Fred, Niles, and Linda are lactose tolerant.
Their other child, Jane is lactose intolerant.



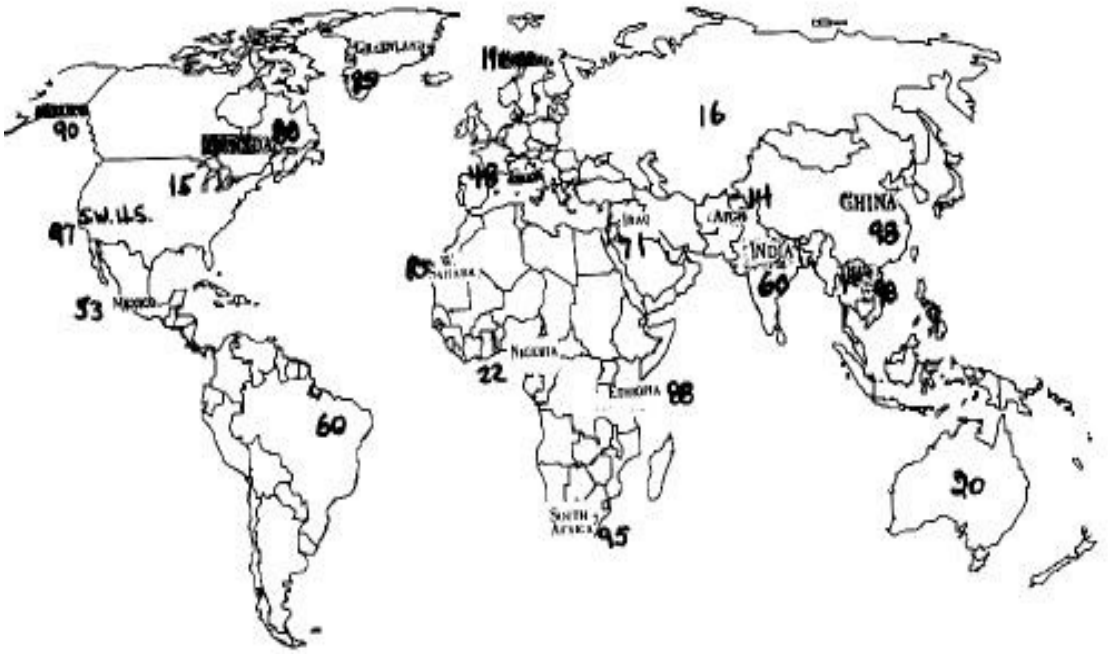
4. Can two parents who both tolerate lactose (digest it) produce children who do not?

a) Show your reasoning with a Punnet square

b) Give phenotype ratio

Part B. Map of the world

The numbers indicate the percentage of the population in each area that is lactose intolerant (data is also in the table below).



Country /Area	Alaska	SW US	Mexico	Brazil	Australia	Thailand	China	India	Iraq
Lactose Intolerance (%)	**90**	**97**	**53**	**60**	**20**	**98**	**98**	**60**	**71**
Country /Area	Quebec	Minnesota	Pakistan	Russia	Sweden	Greenland	Ethiopia	South Africa	Nigeria
Lactose Intolerance (%)	**80**	**15**	**14**	**16**	**48**	**85**	**88**	**95**	**22**

USE THE MAP DATA TO MAKE A GRAPH

- You will create one graph per person
- Group Counties by Continent of Origin
- Make a Bar Graph of the data (there will be a separate bar for each country)
- Plot Country of origin (X) vs. Percentage of Lactose Intolerance (Y)

Analysis Questions:

1. Can you identify common trait in the groups that have a higher level of lactose intolerance?
2. Which type of sugar is lactose?
3. What reaction is catalyzed by the enzyme lactase?
4. What are the products of lactose digestion?
5. When the body does not secrete lactase enzyme in the intestine, the lactose sugar is not digested. How does this contribute to the symptoms of lactose intolerance?
6. What would the effect be if you added lactase enzyme to milk?
7. How do you think they make Lactose Free Milk?
8. Based on the graph you created, where did lactose tolerance probably first originate?
9. Which parts of the world were the original homes of the early American settlers?
10. How can migration and gene flow affect a population?
11. Use your knowledge of evolution and natural selection to explain how some populations may have become lactose tolerant.
12. What would explain the statistics that approximately 30% of all Americans are lactose intolerant compared to other parts of the world where that number is more than 80%?