Name: Period:

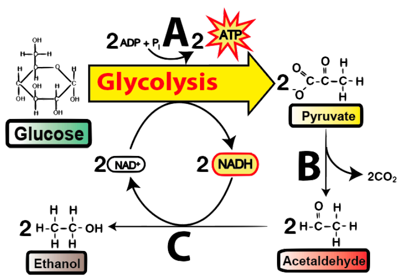
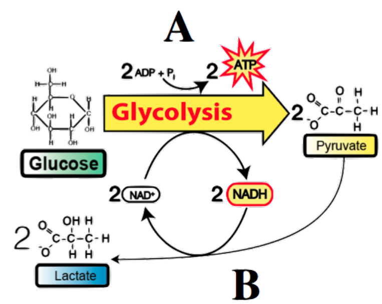
Fermentation / Anaerobic Respiration

Background:

We've learned that aerobic respiration produces between 30 and 32 ATP/molecule of glucose. As its name indicates, aerobic respiration requires oxygen. What do cells do if 1) they aren't being supplied with enough oxygen, or 2) they belong to organisms that evolved to live in low oxygen environments, and lack the enzymes for aerobic respiration?

The answer is **fermentation**. Fermentation is about maintaining conditions for glycolysis to continue. Why? Because even though glycolysis generates only two ATPs/glucose (~1/16 of the ATP that aerobic respiration can create), those two ATPs are much better than none. They can keep cells going for either a short period of time (for example, when a fleeing animal is sprinting away from a predator), or indefinitely (if this is in an anaerobic organism).

There are many types of fermentation reactions, but we're going to focus on two:

type	**Alcohol Fermentation**	**Lactic Acid Fermentation**
Performed by	yeast	Muscle cells, lactic acid fermenting bacteria
diagram		
Explanation of steps		

Alcohol Fermentation Demonstration:

	Flask 1	Flask 2	Flask 3
Contents			
Prediction			
Outcome			
Explanation			

Making Yogurt: How

Start with milk that has a very low bacterial load. This could be milk right from the cow (or goat, sheep, or other mammal of your choice). Or you can heat the milk in a way that destroys almost all the bacteria. The dairy industry does this through pasteurization: a process of repeated heating and cooling (discovered by Louis Pasteur in the 1800s).

Then, you culture the milk by adding yogurt making bacteria such as *Lactobacillus* and *Acidophilus*. Once you've added our culture, place your cultured milk in a warm place overnight.

Over the next few hours (or days) *Lactobacillus and Acidophilus* will take lactose (milk sugar, more about it below), convert it into monosaccharides like glucose, and use that as a fuel to create ATP. Lactic acid is the waste product. As it accumulates, the pH of the milk drops to where it causes milk proteins to denature, changing them from a liquid form to a gel. The result is yogurt.

If you want to make your yogurt thicker, add some powdered milk before culturing.

Nutrition Facts

Serving Size 1 cup (240mL)
Servings [See Chart]

Amount Per Serving	
Calories 110	Calories from Fat 20
	% Daily Value*
Total Fat 2.5g	**4%**
Saturated Fat 1.5g	**8%**
Trans Fat 0g	
Cholesterol 15mg	**5%**
Sodium 130mg	**5%**
Potassium 410mg	**12%**
Total Carbohydrate 13g	**4%**
Dietary Fiber 0g	**0%**
Sugars 12g	
Protein 9g	

Figure 1: Milk Nutrition Facts

Understanding Lactose Intolerance

Study the low fat (1%) milk nutrition facts label at left. Notice the 12 grams of sugar. That sugar is lactose. Lactose is a disaccharide, composed of two linked monosaccharides: galactose and glucose.

The first food that mammals eat after being born is milk. To digest milk, infant mammals (everything from baby bats to baby whales) produce an enzyme called *lactase* that breaks bond between the glucose and galactose, making both of the resulting monosaccharides available to the cells of the body.

When mammals are weaned, they stop drinking milk, and switch to eating whatever food their species eats. Since it would be wasteful for the body to produce lactose-digesting enzymes when milk is no longer part of an individual's diet, there's natural selection for most mammals to turn off the genes for lactase production after weaning. As a result, most adult mammals are *lactose intolerant*. Lacking the enzymes to digest lactose, any ingested lactose, instead of being broken down to monosaccharides and absorbed into the body, stays in the gut where it has two unpleasant effects: 1) it draws water into the gut by osmosis, potentially causing diarrhea, and 2) it acts as food for bacteria in the gut, which produce gases (methane gas and hydrogen gas) that cause bloating, cramps, and flatulence (farting).

For almost all adult mammals (horses, lions, giraffes, rats, etc.), lactose intolerance is not a problem. After weaning, these mammals never drink milk. Humans are the exception: milk from cows, goats and camels is a part of the diet of many cultures. That leads to questions like

- How did lactose tolerance in humans evolve?
- Why is lactose tolerance limited to only some cultures, and to some individuals within those cultures?
- What's going on with lactose *intolerance* in humans?
- Why do we have products like Lactaid milk or Lactaid pills that enable those of us who are lactose intolerant to enjoy milk and milk products?

For answers, we need some evolutionary context. For 90% of our history as a species, we humans were hunter-gatherers. About 10,000 years ago, humans started to develop agriculture, which included, in various parts of the world, domestication of animals such as cattle, goats, and camels. In a few of these human populations, a mutation arose that delayed the inactivation of the gene for lactase production. This allowed individuals with this mutation to continue to be able to digest lactose throughout their lifespan. The result was, in certain human populations, evolution of lactose *tolerance*, as milk from domesticated animals became an important part of the diets of these agricultural peoples (and their descendants).

But this process was far from universal. Today, more than half of the human population is lactose intolerant (which, you should remember, is what you would expect from adult mammals). Cultures that are lactose-tolerant are the exception, not the rule, and these cultures are limited to those that originated in Northern Europe, the Middle East, and Eastern Africa. In these ethnic groups, lactase genes stay turned on throughout the lifespan.

But even within these groups there are many adults who are unable to tolerate lactose. That included 30 to 50 million U.S. citizens. To enable these folks to enjoy products like milk and ice cream, companies sell milk that has been treated with lactase, breaking down the lactose. Alternatively, people can take lactase pills when they eat milk products.

Questions about the lab.
1. Why did we have to heat the milk (or pasteurize it) before adding the yogurt?
2. If the milk is heated, why do we have to allow it to cool before adding the yogurt?
3. What's the pH of yogurt? How does this compare to milk? What caused this change?
4. Milk is liquid. Yogurt is much more solid. How does this happen?
5. One of the bacterial species used to make yogurt is called *Lactobacillus acidophilus.* Why is this such a great name?
6. In the days before refrigeration, one of yogurt's great assets was that it would last much longer than milk without spoiling. Why would this be so?
7. People who are lactose intolerant lack enzymes for breaking down lactose. Drinking milk causes intestinal distress. But eating yogurt is fine. Why?