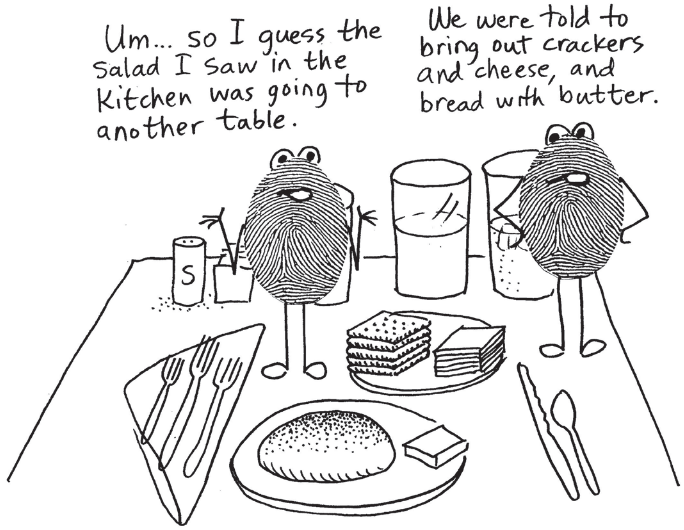
3: Appetizers



That's okay. There is plenty here to dissect! It will take a whole chapter to get through all the chemistry found in butter, cheese, crackers and bread.

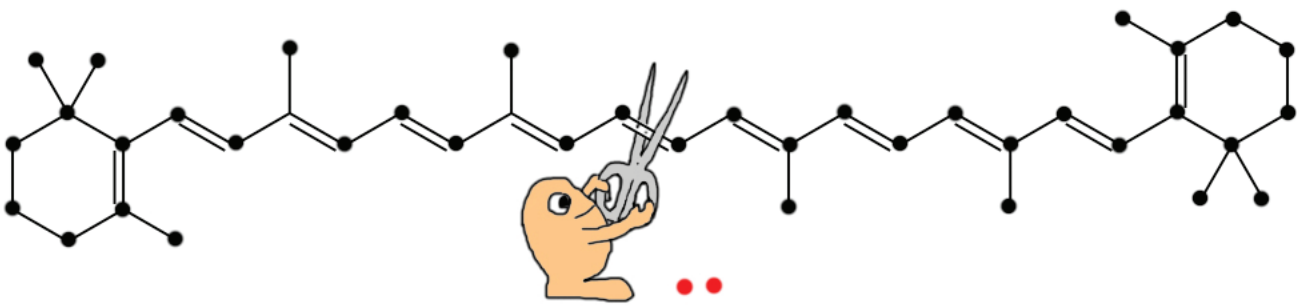
Good idea. Let's start with the butter. Since butter is made from milk we should see lots of familiar things.

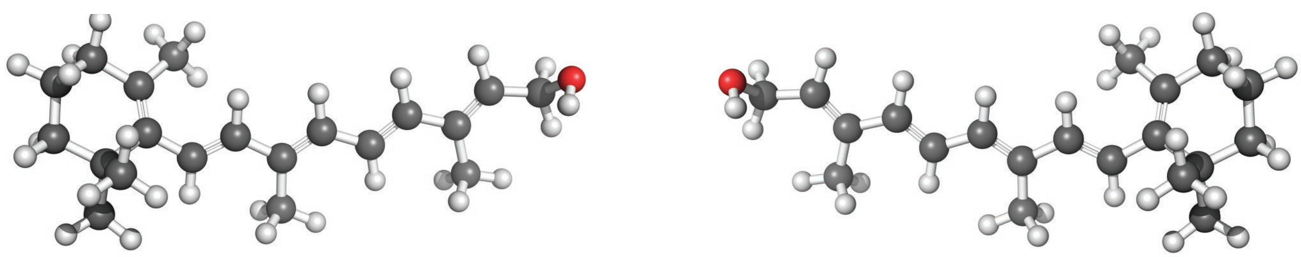
The word "butter" is a very old word. It can be traced back to the Latin word for butter, "butyrum," which came from the ancient Greek word "bouturon" meaning "cow cheese." ("Bous" was "cow," and "turos" was "cheese.") We also saw that the word "casein" came from a Greek word for cheese. There were many kinds cheese back then, just like there are now, so it's not surprising to find more than one word for cheese. Without refrigeration, milk was hard to keep. The natural bacteria found in raw milk made it spoil within a day or two. Ancient peoples found that turning the milk into butter, cheese or yogurt made the milk stay edible for weeks or even months. When butter does finally spoil, we say it goes "rancid." This is due to a smelly acid substance produced by bacteria living in the butter.

The milk that the butter was made from came from cows who ate leaves that had beta-carotene molecules in them. (Green leaves often contain orange or red pigments, but the green "drowns them out.") The leaves were digested in the cow's stomach, releasing the beta-carotene molecues from the plant cells. The beta-carotene molecules then went floating around inside the cow's body, looking for a place to stay. Since the beta-carotene molecule is rich in carbon atoms, it is naturally attracted to other molecules that have a lot of carbon atoms. Triglycerides have three long strings of carbon atoms, so beta-carotene molecules feel right at home in and among them. A lot of animal fat is light yellow in color, due to the presence of these beta-carotenes. The yolks of chicken eggs are rich in beta-carotenes for the same reason.

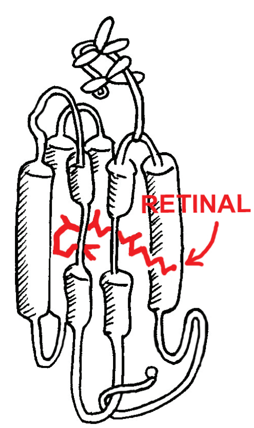
As long as the beta-carotenes stay inside the fat globules in milk, the rays of light can't reach them very well. The outsides of the fat globules scatter all the colors of light equally, so the milk looks white. However, when you make butter, you must smash all those globules open. The triglycerides come spilling out, and so do the beta-carotenes. Once the beta-carotenes are out, they begin to reflect yellowish-orange light, so the butter looks light yellow. People who make their own butter from their own cows notice that the color of their butter changes from season to season, depending on what plants the cows are eating. The butter is more or less yellow at certain times of the year.

The cow's body (and your body) hang on to these molecules of beta-carotene so that they can be used to make ***vitamin A***. Beta-carotene can be cut in half by a scissor enzyme to make two molecules of vitamin A. Those two red dots are oxygen atoms that will be used to patch the ends.





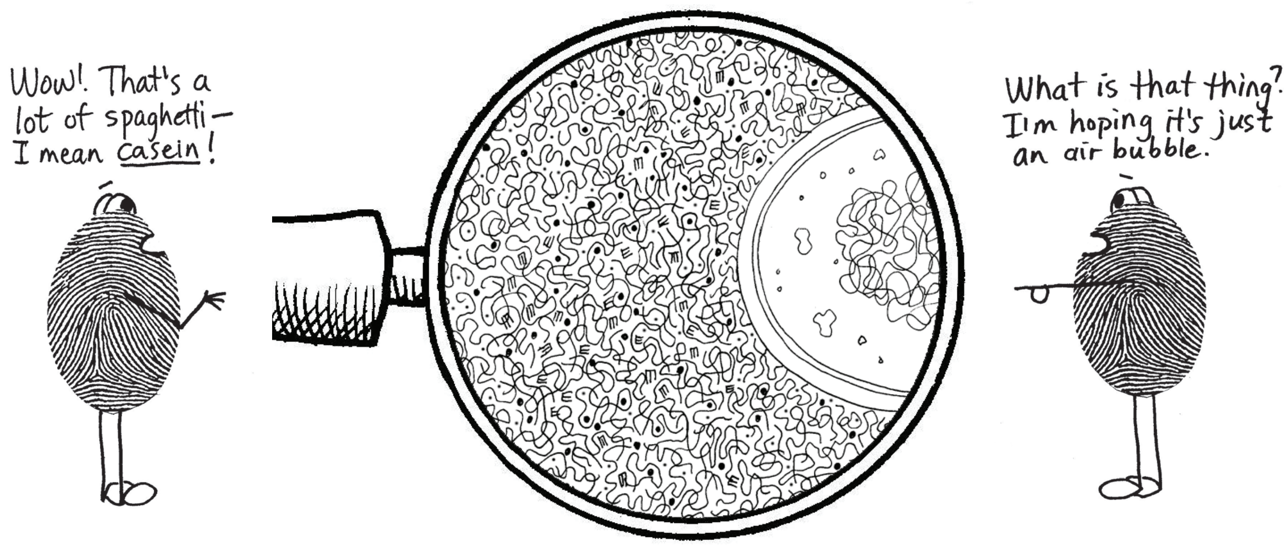
Here are the two halves of beta-carotene, shown as ball and stick models. Now you can see all the hydrogens, and you can see the two oxygens that the enzymes used to patch the cut ends. Each half is now a molecule of ***retinol***, a form of vitamin A. Sometimes other enzymes come over and "tweak" the retinol molecule, making tiny changes that will turn it into different versions of vitamin A.



The most well-known of these variations is called ***retinal***. Retinal is used in the cells of your retina, the area at the back of your eye that senses light. Retinal becomes part of a molecule that absorbs photons of light. (This makes sense, since beta-carotene absorbs light in plant leaves.) Retinal sits inside a special holder made of protein. Without retinal, the holder is useless. There are billions of these holders in the cells of the retina and they must all be filled with retinal. If you don't eat enough beta-carotene or vitamin A, the retina won't work right and your vision will be affected. This is why people say carrots are good for your eyes. However, a little beta-carotene goes a long way, and over-eating carrots isn't going to give you super-power vision.

After beta-carotene is chopped in half, the resulting retinols don't reflect as much yellow and orange light. Animals that store retinol (vitamin A) in their fat, instead of beta-carotene, will produce milk that makes white butter instead of yellow. Butter and cheese made from goat and sheep milk is white. Consumers seem to prefer yellow butter over white, so beta-carotene is often added to sheep butter to make it yellow.

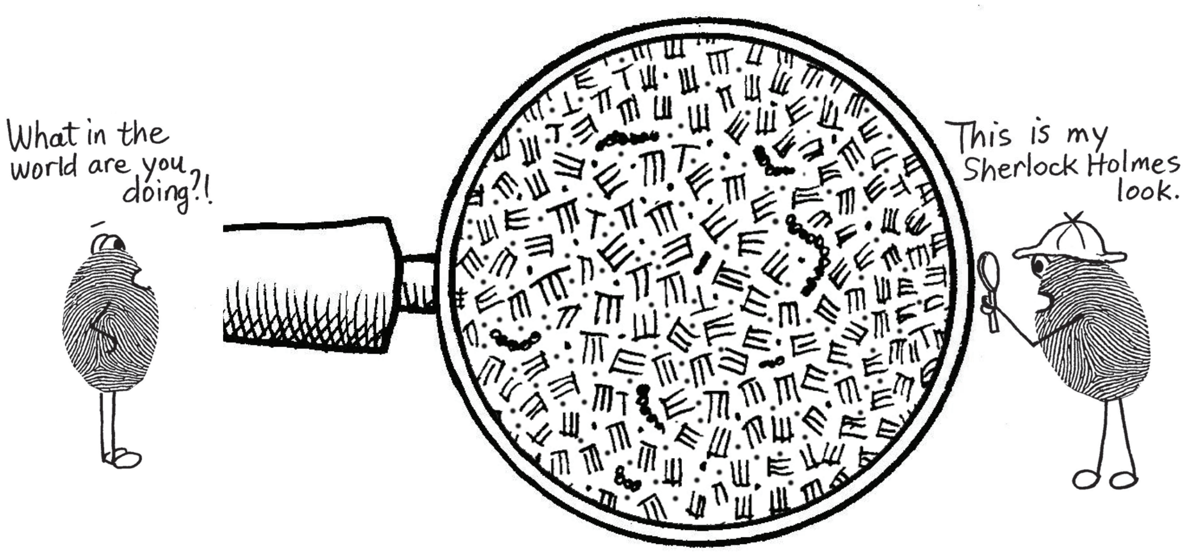
Since cheese is made from milk, will we find the same molecules and structures that we found in milk and butter? Let's take a look.



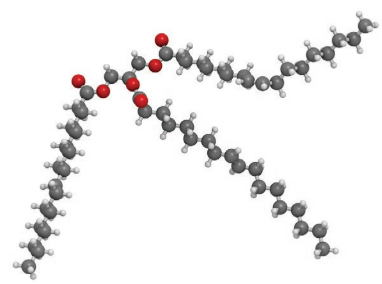
What happened to the casein "spaghetti" balls we saw in the milk on page 24? This is a mess! Casein "noodles" are all over the place! We can see some triglycerides in there, too, so this cheese has some fat in it. Those really tiny dots might be beta-carotene molecules helping to give the cheese its orange color. But what is that HUGE thing sticking into the picture? It looks like part of something that's bigger than our viewing area. We'll have to reduce the magnification a bit in a minute to get a better image of it.

Let's find out what happened to our casein micelles first, then we'll delve into the mystery of that huge whatever-it-is.

Let's get out that Sooper Dooper magnifier and take a look at our butter.



Do you recognize those things that look like stretched out letter E's? (We called them weird-looking jellyfish in the last chapter.) Most of them have three "tails." They're triglycerides. The "tri" part means "three" and the "glyceride" part refers to the hanger that the tails are attached to. The tails are called fatty acids and they are made of long strings of carbon atoms with hydrogens attached. They are the smallest type of fat. When we looked at milk, we saw triglycerides inside those big, round globules. Here, the triglycerides are just scattered about everywhere, not inside globules. What happened?

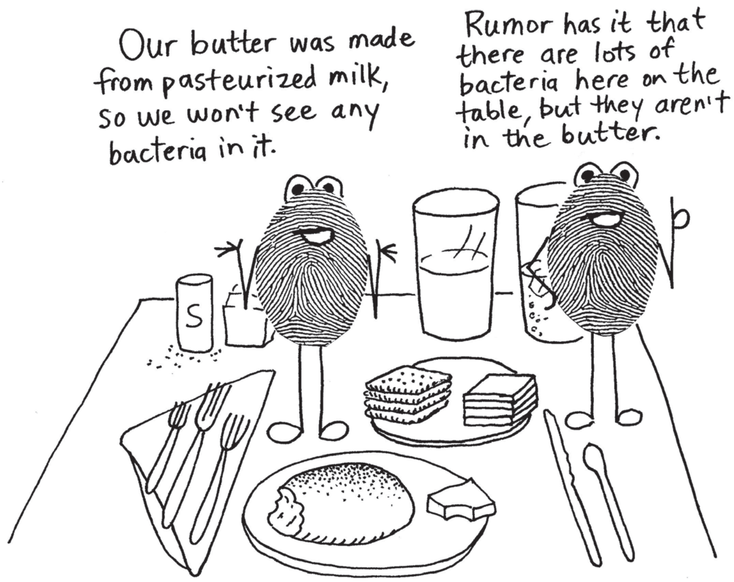

a model of a tryglyceride

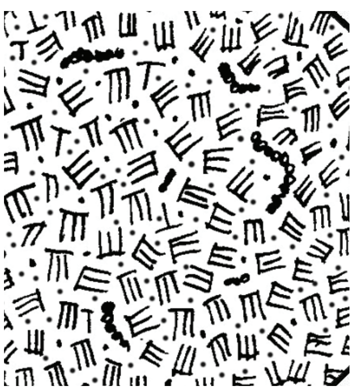
The process of churning butter is all about destroying those fat globules. You bang and smash those globules around as if they were microscopic piñatas filled with fats instead of candy. Once they are all broken open and the triglycerides are no longer contained inside the globules, the fats stick together to form one solid mass. That's butter.

As the fats stick together, most of the water that was between the fat globs gets squeezed out. Part of the butter-making process includes draining off water. This water won't be pure water, however, but will still have a little bit of fat, protein and sugar in it. Dairies usually save this drained off water and either sell it as "buttermilk" or use it as an ingredient in other products such as ice cream.

In the past, buttermilk was used as a source of acid to either curdle milk for cheese, or to react with baking soda in biscuit and bread recipes. But wait... milk as a source of acid? Fresh milk is definitely not sour tasting. How can a milk product be a source of acid? The answer lies in the label on the buttermilk carton. It might say "cultured" buttermilk. In food science, "culture" doesn't refer to great art and literature. A "culture" is a source of microorganisms, often bacteria. So "cultured" buttermilk means it contains bacteria.

These milk bacteria are not harmful like the ones that give you strep throat or pneumonia. Most of the bacteria found in milk are very good for us. We want them to live inside us because they fight against any bad bacteria that might get into our intestines. But even good bacteria need to eat, and these ***Lactobacillus*** *(LACK-toe-ba-SILL-us)* bacteria eat the lactose sugars in the milk. As part of their digestion process, the bacteria produce a chemical called ***lactic acid***. This acid isn't nearly as acidic as lemon juice or vinegar, but it's acidic enough to cause milk to ***curdle*** (form solids). Nowadays, most milk is pasteurized, so dairies must add a bacterial culture to their buttermilk in order to sell it as "cultured" buttermilk. Some cooks prefer to make instant buttermilk in their kitchen by adding lemon juice to fresh milk.

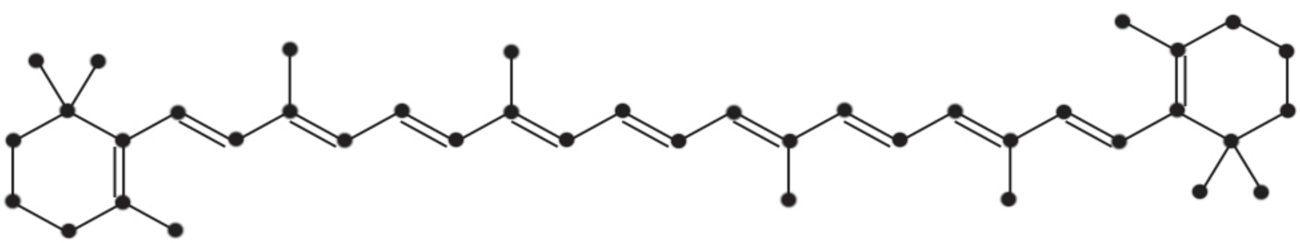




Let's look closer at the magnified butter. What are those other blobs and dots, in and around the triglycerides? A few of them look like tiny bits of protein—chains of amino acids. They could be little pieces of casein that broke off the micelles, or they could be some of those smaller milk proteins, the miscellaneous ones that came from the mother cow. There aren't very many of them, so butter isn't a very good source of protein.

The tiniest dots might represent lactose sugars, but just a few of them. Most of the lactose molecules would have stayed down with the liquid milk and not floated to the top with the cream. When the cream was taken off the top, most of the lactose stayed behind. Butter has a small enough amount of lactose that people who can't digest lactose can often still eat butter.

The rest of the dots represent molecules that give butter its yellow color: ***beta-carotene***.

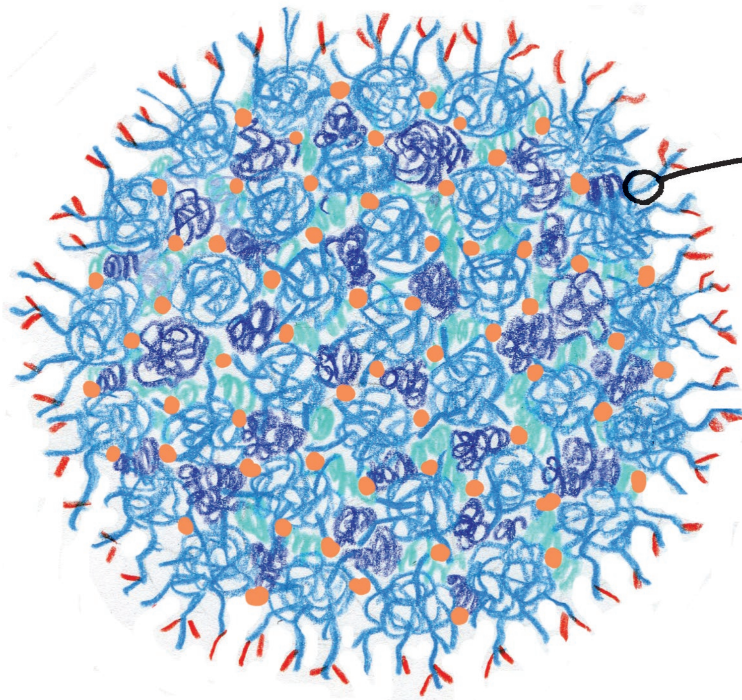


The dots are carbon atoms. There are also many hydrogen atoms attached to the carbons, but all chemists know that the H's are there, and they get lazy and don't bother drawing them. The double lines represent places where carbon atoms are double-sharing their electrons. Notice the pattern of the bonds across the middle of the molecule: double, single, double, single, double, single, etc. This is important. Molecules that have this pattern often reflect light. In this case, beta-carotene ***reflects*** orange and yellow light. Of greater importance is the fact that it ***absorbs*** violet, blue and green light. Beta-carotene is part of the light-collecting system in leaves. The light that is collected is used in the process of photosynthesis, where sunlight, CO_2 and water are turned into glucose sugar.

You might have wondered if the name "carotene" has anything to do with carrots. Yes! Carotenes were named after carrots. As a general rule, orange or yellowish-orange colors in plants are caused by the presence of beta-carotene molecules. Other sources of beta-carotene include cantaloupes, sweet potatoes, mangoes and pumpkins. But how did these plant molecules get into the butter?

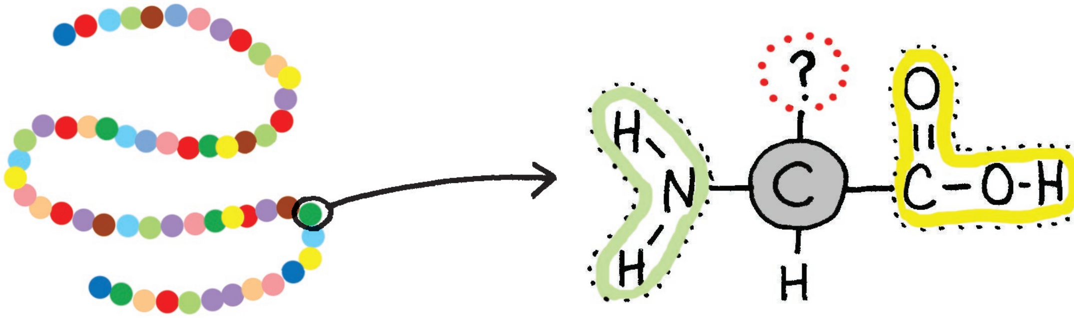
So what did happen to the casein micelles? To understand what happened, we need to learn a little more about the micelles.

Imagine that our micelle is made of yarn instead of protein, and let's use blue as our color scheme. We'd need to use four different shades of blue because there are four different types of casein protein in our micelle. We'd wind many small balls of yarn and then stick them together. (The small balls are called sub-micelles.) A real casein micelle might have as many as 500 hundred of these smaller balls. One of these types of casein has long fringes that hang off, making the ball look furry. We can stick little orange beads between the balls to represent those mineral "meatballs" made of calcium phosphate. These calcium phosphate balls act sort of like magnets to keep the micelles together.



Since the yarn represents protein, and proteins are made of amino acids, we could improve our model by stringing tiny beads onto all the pieces of yarn. The beads could represent the amino acids. We'd need 20 different colors of beads because there are 20 possible amino acids to choose from.

Now, we must remember that amino acids aren't really little balls. Although chemists represent them as circles, you will remember that they are really groups of atoms. There's a carbon atom in the center, with a COOH on one side, and an NH_2 on the other.



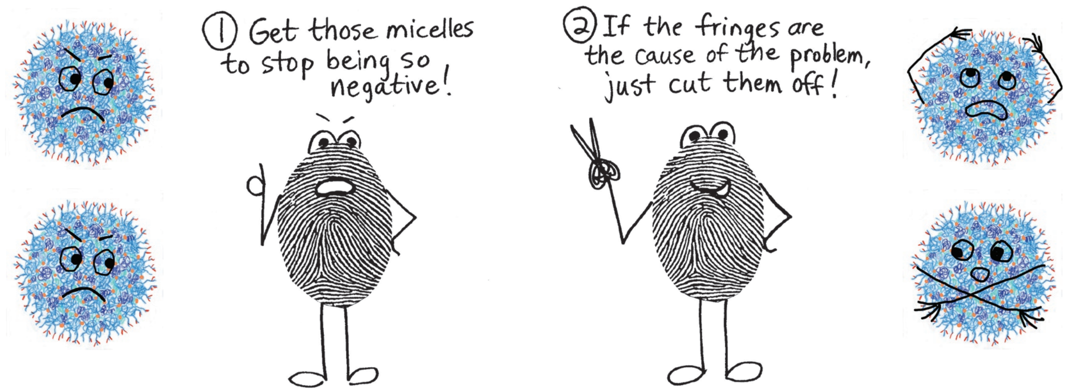
That (?) at the top of the molecule turns out to be very important. That's the part that makes each amino acid different from the others. We saw that glycine, the smallest amino acid, has only an a hydrogen atom, H, in that place. That makes glycine special because it the smallest amino acid. Some amino acids have a chain of carbon atoms hanging off, looking like the fatty acids we saw on the triglycerides. Amino acids that have extra strings of carbon atoms (where the "?" is) hate water and want to hang out with fats. Other amino acids are just the opposite and have extra atoms (where the "?" is) that love to be around water. A few amino acids have an atom of sulfur hanging off, which makes them good at building bridges. We'll meet an amino acid with sulfur when we dissect the bread. Here, in the fringy casein proteins, we find the amino acid ***threonine***, which is particularly good at attaching itself to sugar molecules.

When a string of amino acids grabs and hangs on to some sugar molecules the result is a molecule that is a combination of protein and sugar, and we call it a ***glycoprotein***. ("Glyco" comes from "glucose" but it can mean any kind of sugar molecule.) Those red strings hanging off the blue yarn are glycoproteins. These glycoprotein molecules are largely responsible for the ability of the casein micelles to float around in the milk without clumping together. Which is a good thing while the milk is in the cow.

The red fringes help to give the casein micelle a negative electrical charge. "Like" charges repel, so the micelles stay away from each other because they are all negative. The same thing would happen if they were all positively charged. But in this case we see negative charges.

The first step in making cheese, yogurt and some milk-based desserts is to get those casein balls to clump together. We call this ***curdling*** the milk. Depending on how it is done, the milk will either turn lumpy, like cottage cheese, or it will get thick, like yogurt and custard. In cottage cheese, the curds are large and very visible. In yogurt or custard, the curds stay so small that the texture remains smooth and creamy.

There are basically two ways to make these casein micelles clump together (curdle).



1) How To Stop Casein Micelles from Being So Negative

Put some positives into their environment! Why don't we toss in some positive hydrogen ions (protons) and have them go over and cancel out some of the negativity? And where do we get a good supply of protons? From acids! That's the definition of an acid—something that gives away protons. Acids that are right there handy in the kitchen are vinegar and lemon juice. Vinegar is the most common substance used for curdling milk to make cottage cheese and Ricotta cheese.

2) How To Cut Off the Negative Fringes

When you need to cut molecules, what do you use? Enzyme scissor guys, of course. You just need the right little enzyme robot, and he'll go over and snip those fringes right off. Where would we find this particular robot? Well, since baby cows' stomachs are good at digesting cow milk, perhaps this would be a good place to look. And, in fact, we will be successful, because people have been extracting this enzyme from baby cow stomachs for thousands of years. Chemists call it ***chymosin***, but food scientists and chefs usually cal it ***rennet***. Rennet is the word you will hear more often. The most famous brand name of rennet is Junket®. (NOTE: There are now plant-based sources of rennet, too.)

Junket tablets and rennet liquid drops

2.5) Another Source of Acid: Bacteria

When milk goes sour on its own, you still see curdled white solids and clear whey. In this case, the bacteria that are making the milk go rotten are producing acids. They are eating the lactose sugars and making lactic acid as a waste product.

Some cheeses require just this first step. Put in some acid and let the milk curdle. After you see the white clumps of casein forming, you can strain them out and use them for your cheese. The watery stuff that is left over is called ***whey***. Whey still has some protein in it, mainly those smaller proteins that aren't casein. Whey proteins can be taken out and dried into a powder. (Some people are really into eating powdered whey protein, and you'll see it sold in health food stores mainly as a supplement for athletes.) In ricotta cheese, the whey is strained off and only the solids are used. In cottage cheese, the whey can be part of the final product. In commercial cottage cheese, the whey often has a thickening agent added, as people don't tend to like watery whey.

Cottage cheese is made of curds and whey.

Hard cheeses—the ones that come in blocks that you can slice—have had a second ingredient added: microorganisms in the form of either ***bacteria*** or ***mold*** (or both). The first cheeses ever made contained the natural bacteria and molds that were in that environment. The microorganisms would have come from places like the skin of people or animals, from plants or dirt, or from barns and houses. Each part of the world had its own unique blend of microorganisms. The spores from these microorganisms would go into the air and float around, and if a pot of milk or curds was left sitting out for a while, it would collect spores that fell out of the air. The bacteria and mold would start to grow in the curds and eventually turn them into a hard cheese.

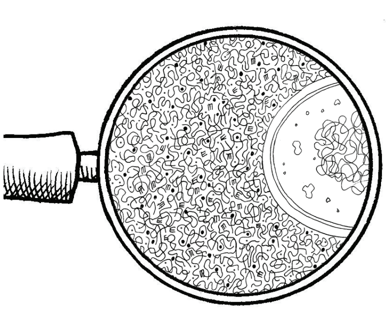
As time went on, cheese makers discovered that they didn't need to wait for spores to fall out of the air. All they needed to do was to save a bit of the last batch of cheese, and add it to the new batch. They didn't understand that they were saving microorganisms, though, because they didn't have microscopes and had no idea that tiny living things were inhabiting their cheese. They also discovered that cheeses made in different places had different flavors. Often, a cheese would be named after the town where it was first made. Cheddar, for example, started out in the English town of Cheddar. This type of cheese became so popular that people outside of Cheddar wanted to make it. They bought cheese in Cheddar, then went elsewhere and added the Cheddar cheese culture to their own curds. Now, Cheddar cheese is made all over the world, but the original culture came from England.

Scientists can now analyze and identify the exact species of microorganisms found in each type of cheese. Cheddar and Colby have *Lactococcus lactis, Lactobacillus casei, Streptococcus cremoris,* and *Streptococcus durans*. (You don't have to try to pronounce those!) Blue cheese has a blue mold called *Penicillium roqueforti*. Swiss cheese has an unusual bacteria that produces carbon dioxide as a waste gas. The carbon dioxide forms bubbles and gives Swiss cheese its holes. Limburger cheese has a species of bacteria that is extremely similar to the bacteria found on human feet. No wonder Limburger cheese smells like stinky socks!

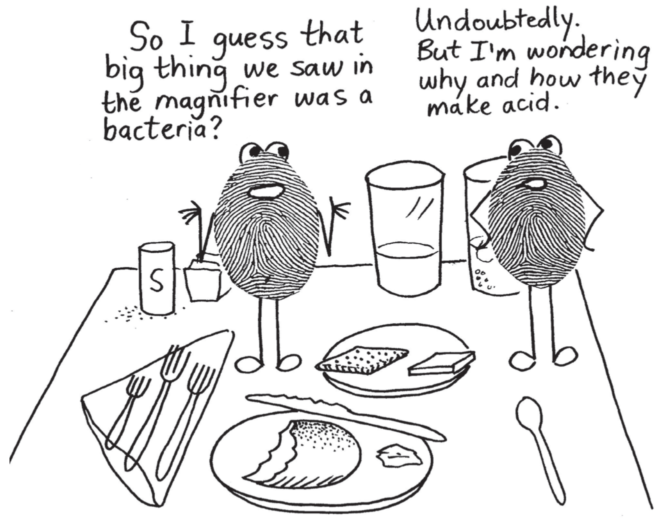
A cheese with blue mold in it.

New cheeses are still being invented. For example, a cheese called Cornish Yarg (that's "Gray" spelled backwards) was first made in Cornwall, England, in 1984. Some Cornish cheese-mongers (that's what you call professional cheese makers) found a very old recipe and decided to try it. They added garlic to their cheese and then wrapped the blocks of cheese in the leaves of the nettle plant. Another new English cheese is called "Stinking Bishop," inspired by the cheese recipes of monks during the Middle Ages who washed their cheeses in pear juice.

Photo credit: Tristan Ferne, UK, from Wikipedia article on Cornish Yarg

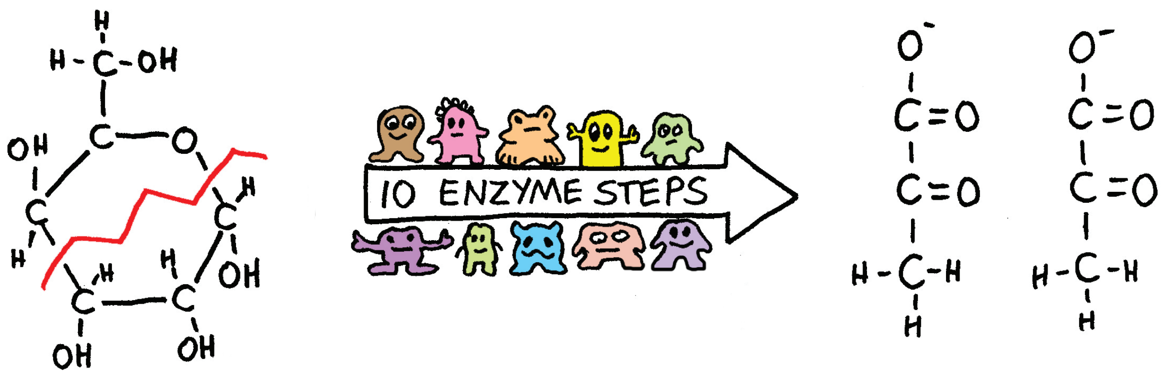


We just saw one end of the bacteria.



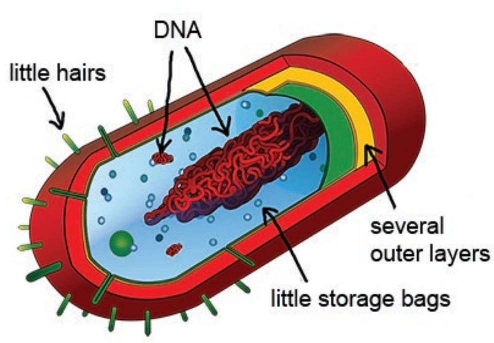
Bacteria make acid as a waste product when they eat. All living things make waste products as a result of eating. Some of the waste products are obvious, like... well, you know... we flush them. Others are not so obvious, like the carbon dioxide that goes out of your lungs when you exhale. Or the lactic acid produced in your muscles when you push them to their limit. Here in our cheese, the bacteria have been doing exactly the same thing that your tired muscles do; they are producing lactic acid as a result of burning glucose molecules for energy.

Glucose is our body's primary source of energy. There is energy locked up in the bonds that hold the carbon atoms together. If you break those bonds, you can release the energy. The first step in using glucose for energy is cutting it in half. As you might guess, you'll need enzyme scissors to help with this process. However, you won't need just one enzyme, but TEN of them! The glucose must be snipped, twisted and patched until two molecules of ***pyruvate*** *(pie-RU-vate)* are formed.

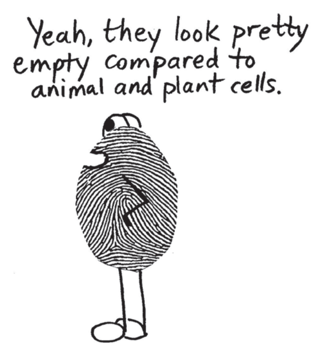


GLUCOSE **2 PYRUVATES**

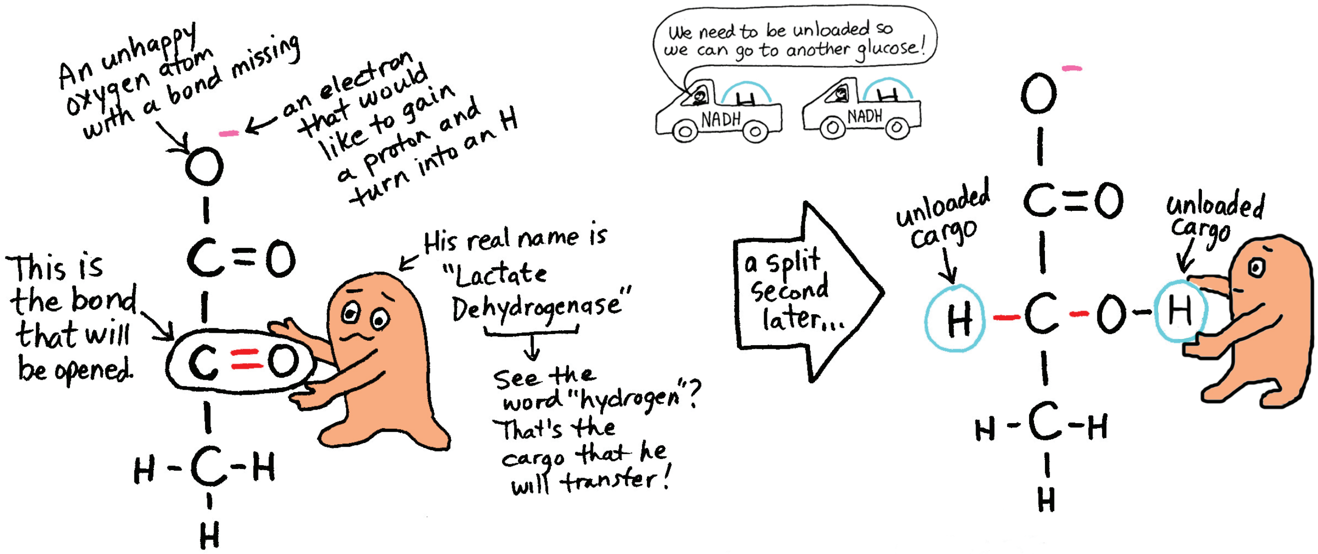
At this point, animal cells (including yours) send these pyruvates to special organelles inside the cell called the ***mitochondria***. Inside the mitochondria, the rest of the bonds between the carbon atoms will be broken to release the remaining energy. Bacteria don't have mitochondria, though, so they can't cut apart those pyruvate molecules. They use them for a different purpose.



A "bacillus" bacteria



The bacteria living in our cheese use the pyruvate molecules to get rid of some atoms are that preventing them from splitting more glucose molecules. We didn't show you all the complicated chemistry going on in those 10 steps. We just drew some cute enzyme guys and let it go at that. But if we showed you every single atom coming and going in this process, you'd see that part of the process involves putting electrons into molecules that act like shuttle buses. The shuttle buses have to be emptied before they can be loaded again. If the shuttle buses are all sitting there full, the process of splitting glucose will stop. So the bacteria have enzyme guys that can unload the shuttles and put their cargo onto the pyruvates. The cargo that is transfered is electrons and protons. The end result that pyruvate gains 2 hydrogen atoms.

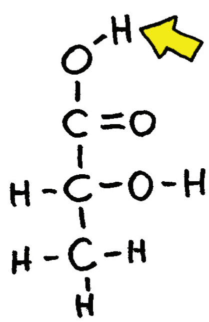


PYRUVATE **LACTATE**

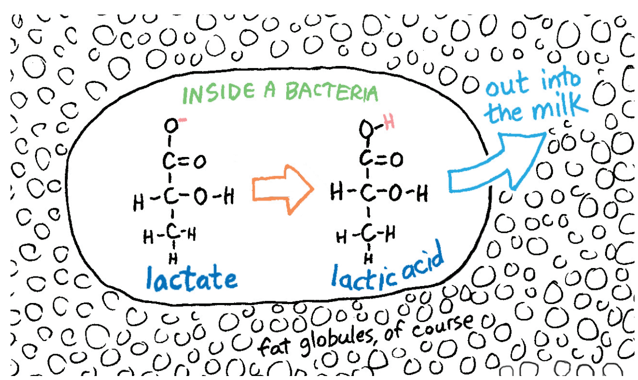
With the H cargo unloaded onto pyruvate, those shuttle bus molecules will now be able to help with the splitting of another glucose molecule. Mission accomplished! (The splitting of glucuse will release come energy.)

Now.. what about the "acid" part of this process? We keep talking about ***lactic acid***, but so far all we have is something called ***lactate***.

That lonely pink electron on the O at the top of the molecule is bound to pick up a passing hydrogen ion (proton). The electron and proton will join together to make a hydrogen atom, and then we'll be able to draw an H connected to that O. (The yellow arrow is pointing to this newly formed H.) The molecule will then officially become lactic acid. It's an acid because that proton that just came in could just as easily decide to go wandering off again. Protons change their minds a lot. By definition, an acid is a molecule that has wandering protons.



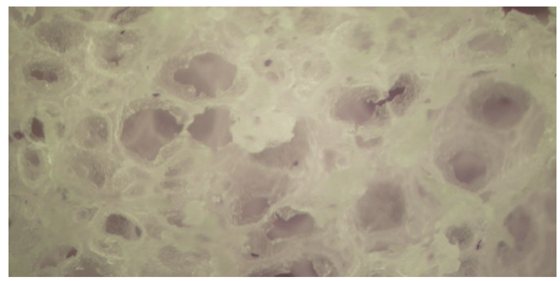
LACTIC ACID



The lactic acid molecules then go out of the bacteria and into the milk around it. Once in the milk, guess what that proton decides to do... yep, it leaves the molecule and goes off to seek its fortune elsewhere. Loose protons wandering about make a substance taste sour.

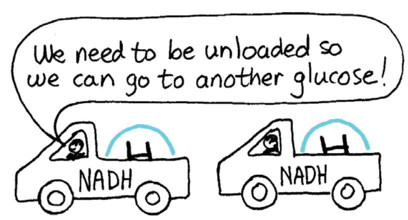
Before we turn our attention to bread and crackers, we need to burden you with two vocabulary words. (Most biology courses require students to memorize the definitions of these words.) The process of splitting glucose in half is called ***glycolysis*** *(glie-KOL-i-sis).* ("Glyco" means "glucose," and "lysis" means "to break apart.") The process of turning pyruvate into lactic acid is called ***fermentation***, or, more correctly, ***lactic acid fermentation***. When we dissect bread, we'll see another type of fermentation where an alcohol molecule is produced instead of lactic acid.

What is bread made of? If we look at bread under a magnifier, we'll see something like this. It looks a bit like a sponge. When the dough was first made, it was smooth and dense. The kneading process forced out any air that was in the dough. But when the bread came out of the oven it was fluffy and spongy. What happened? After we find out the answer to this question, we'll use the Super Duper magnifier to find out what the molecules look like.

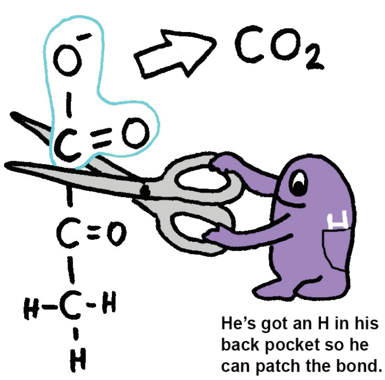


The tiny air holes in the dough were created by another type of fermentation: ***ethanol fermentation***. This fermentation is done by ***yeast*** instead of bacteria. The yeast cells "eat" the sugars in the bread and produce ***carbon dioxide*** and ***ethanol*** as waste products. The carbon dioxide bubbles into the bread dough and produces those holes. The bread hardens as it bakes, so the holes are preserved long after the carbon dioxide is gone.

Ethanol *(ETH-uh-noll)* is a type of alcohol. It is found in alcoholic drinks such as beer and wine, and it can also be used as a fuel. Many gas stations now sell gasoline (petrol) that has ethanol in it. If you see "E10" written on a gas pump that means that the gasoline contains 10% ethanol. In bread, the alcohol evaporates during baking, so the final product doesn't actually contain any alcohol.

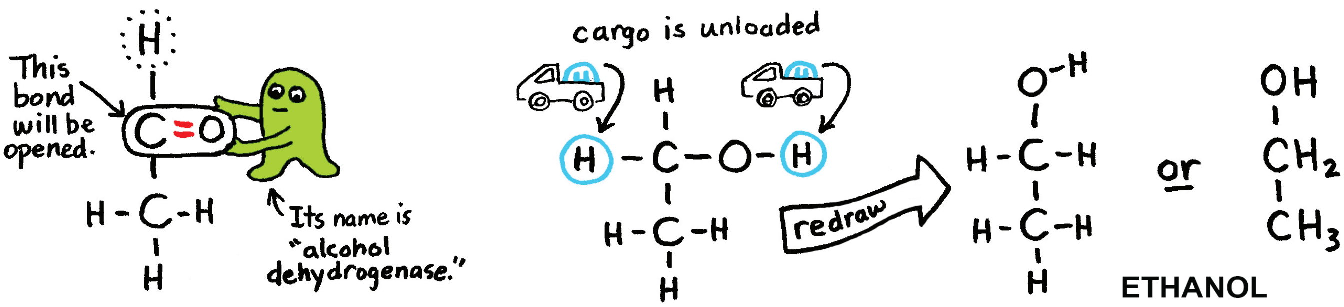


The yeast cells produce ethanol for exactly the same reason that bacteria produce lactic acid. Eating sugar always starts out with glycolysis—splitting a glucose molecule in half. Two of those ten steps of glycolysis involve filling a shuttle bus (shown as a pick-up truck) with an H atom. After completing glycolysis they must find a way to empty their little shuttle trucks so that they can fill them again. The bacteria had an enzyme guy who could open up the double bond on the middle carbon atom and then transfer the two hydrogen atoms from the trucks to the pyruvate molecule, turning it into lactate.

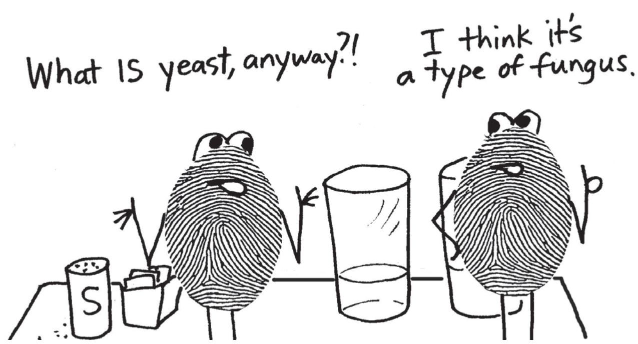


The yeast cells have a similar enzyme guy: ***pyruvate decarboxylase***. This name isn't as hard as it looks! "De" means "from," "carboxyl" is the correct name for COOH, and "-ase" is the label for "enzyme." So the name means "the <u>enzyme</u> that takes <u>COOH</u> <u>from</u> <u>pyruvate</u>." However, you'll notice that the COOH has already been the victim of hydrogen unfaithfulness, and is only COO^-. The hydrogen went wandering off as nothing but a proton, leaving its electron behind. (We'll be nice and still refer to it as "carboxyl," politely ignoring its recent loss.) When the COO^- is clipped off, it goes floating away as CO_2, carbon dioxide. That's how the bubbles in bread are produced.

Now it's time to make ethanol. Another enzyme comes along and opens the double bond on the carbon. If you look back to page 44, you'll see an orange enzyme doing basically the same thing. In this case, though, our enzyme worker is going to transfer the hydrogen cargo in such a way that the molecule will turn into ethanol.



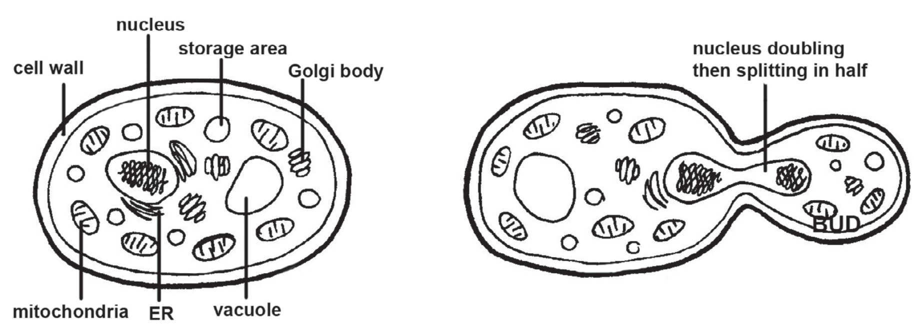
The ethanol in bread is destroyed as it is baked. When bread comes out of the oven the ethanol is gone. However, in other foods the ethanol is an essential ingredient. In beer and wine, the ethanol stays. Alcoholic drinks can be made from just about any type of plant. Yeast isn't too picky about where it gets its sugar. Wine is made from grapes, beer can be made from grains such as wheat or barley (and often with hops flowers added), rum is made from sugarcane, hard cider is made from apples, and mead is made from honey (with water added). Corn, rice, and potatoes can also be fermented into alcohols.



Yes, yeast is a type of fungus, but it is obviously not closely related to mushrooms. Yeast is a unicellular organism (made of single cells), whereas most other types of fungi are multicellular (made of many cells). Yeast cells are more complicated than bacteria cells, and have pretty much all the same cells parts as our human cells. In fact, sometimes research on yeast cells can shed light on things that go on in human cells. If scientists can use yeast cells instead of human cells, the research goes faster because yeast cells are so easy to work with. They can't file a lawsuit if the experiment ends up harming or killing them!

Yeast cells have all the standard cell parts: nucleus with DNA, Golgi bodies, mitochondria (energy makers), endoplastic reticulum, vacuoles (empty "bubbles") and storage areas (similar to vacuoles).

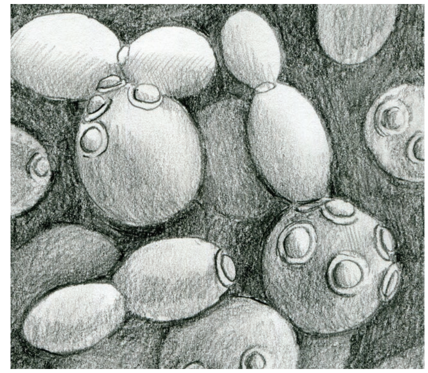
If you have never studied cells, don't worry about this list. All you need to know is that they are different from bacteria.



Yeast cells don't come in male and female—they have no gender. They reproduce by growing a bud. As the bud grows, the yeast cell duplicates all of its cells parts and puts some of them into the bud. The nucleus of the cell (containing the DNA) also is duplicated and an exact copy goes into the bud. When the bud reaches almost the same size as the original cell, it splits off and becomes an independent cell. The bud can actually start to form its own bud even before it reaches its full size. The budding process can be done in just an hour or two.

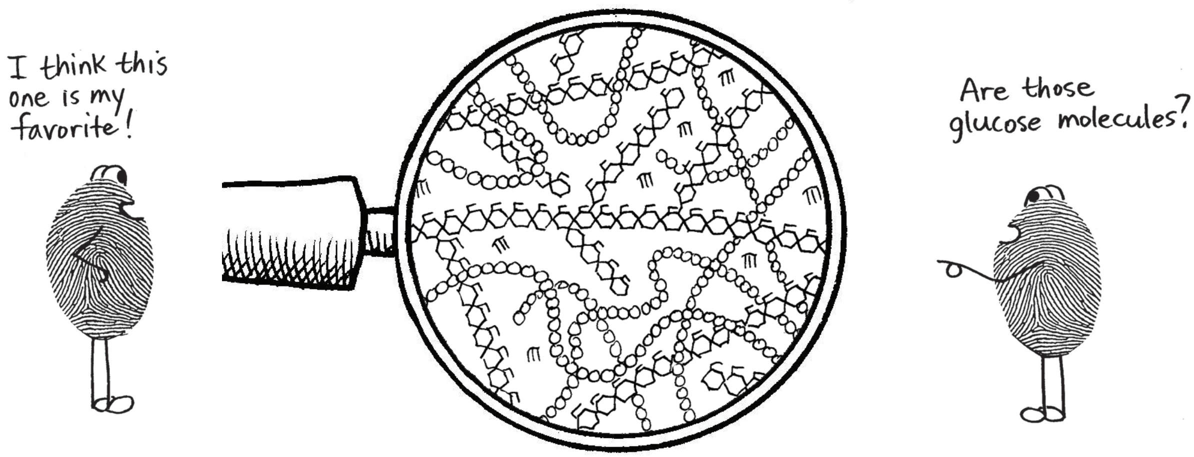
The lifespan of a yeast cell is determined by the number of times it can form a bud. When a bud finally separates from the "parent," it leaves a scar. Yes, even single-celled organisms can have scars. The scar is a place that has been damaged (though healed over) and will not be able to form a new bud. The parent yeast ends up with scars all over its body. When it is completely covered with scars and has no place left to form a new bud, it will stop dividing and die. When single-celled organisms die, they just dissolve and disappear.

Though they do not have genders, yeast can still do a very simple form of sexual reproduction where two cells will join together and combine their DNA. There is a survival advantage to mixing up their DNA. Normally, when conditions are good, yeast will just bud. But when conditions around them are not ideal (not enough food, too hot or cold, too dry, etc.) they will switch over to reproducing by trading their DNA. Small differences in DNA could possibly make some yeast cells better at surviving, and by sharing DNA, these advantages can be passed along to new generations.



This is an artist's sketch of a photograph of yeast cells. Those little rings on some of them are bud scars. Look at the cell that has the most scars It has a new bud growing on top, and the new bud is also starting to grow a new bud!

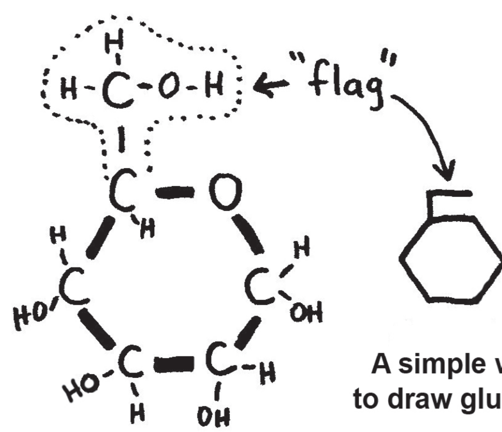
Now let's get out the Super Duper Magnifier and zoom in to the molecular level.



Our magnifier has simplified the molecules for us. We see a few tiny triglycerides here and there, but not a lot. We know there must also be water molecules scattered around, but our viewer has taken them out so they don't clutter the picture. Those strings of beads are actually protein chains made out of amino acids. You'll remember that very often amino acids are drawn as circles or balls. The lines of hexagons are glucose molecules all strung together. Let's start with these hexagons and do the proteins last.

We've already studied glucose. We saw how glucose and fructose can join to form sucrose. We also saw glucose bond to galactose to form lactose. Here we see only glucose molecules, but wow, are there a lot of them!

Glucose molecules are often shown as hexagons, with each vertex (corner) representing one of the atoms that make the ring. Glucose can also form a straight line, but the ring form is what is generally drawn. Sometimes a "flag" is drawn on top of the hexagon to represent that top carbon atom that is not part of the ring. This helps us keep track of "which end is up." Knowing which way the flag is pointing will be very important when we look at lettuce and spinach in the next chapter.



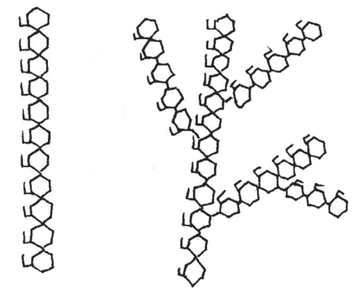
A simple way to draw glucose

Strings of glucose molecules are called ***starch***. There are different types of starch, depending on whether the chains are just straight or whether they have branches coming off. The straight chains with no branches are called ***amylose***. When the chain has branches, it is called ***amylopectin*** *(am-ill-o-peck-tin)*. We can draw these in various ways, depending on how much detail we want to show.

We can keep it very simple and just show them as lines.

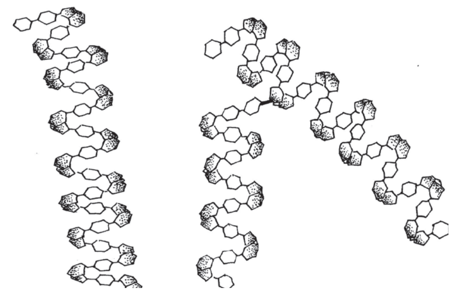
amylose *amylopectin*

We can be more accurate and show all the "flags."



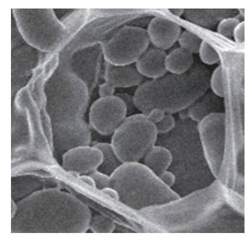
amylose *amylopection*

Or, we can decide to show the way they curl into helix shapes.



amylose *amylopectin*

Starch molecules are made by plant cells as a way to store food. First, the cells use the process of photosynthesis to turn carbon dioxide and water molecules into glucose molecules. Then the glucose molecules are assembled into long strings, and these strings are then put into storage "bags" called ***starch granules***. Starch granules are sort of like a plant cell's pantry or storage cupboard. When the cell needs energy, it can take some starch out of storage and use enzymes to break apart the string, then split the glucose molecules, releasing energy. Plant cells can do glycolysis, but they can also tear apart the pyruvates if oxygen is available. Plant cells don't have to use any type of fermentation. Animal cells are the same way—they can deal with pyruvates if oxygen is available.



starch granules in a plant cell

The strings of starch in our bread came from wheat seeds. The wheat plant stored lots of energy in its seeds. When a seed falls to the ground and starts to grow, the baby plant will use some of the starch energy in the seed. However, a farmer got there first and harvested the wheat seeds. The seeds were ground into a fine powder that we call "flour."

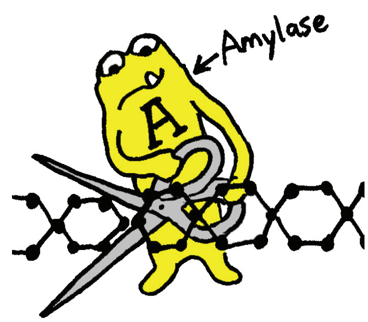
Plants cells usually make more amylopection than amylose. The ratio is typically 4 to 1. That means there are 4 amylopectins for every 1 amylose. The amount of amylose in a starch will cause it to behave in a certain way when it is cooked. Starch granules absorb water when they are boiled. They swell and grow larger and larger. Like an over-stretched balloon, they eventually burst. When they burst, the wet starch molecules come pouring out and start sticking together. This is why rice, pasta and potatoes can feel sticky. The temperature at which they burst will depend on what type of starch is being stored. Amylose is more resistant to boiling, so granules that have a lot of amylose will not burst as easily.

Rice is made of the seeds of the rice plant.

Rice is a good example of how starch ratios affect cooking. Long grain rice contains a lot of amylose, so when it is boiled, fewer granules break open. Less breaking means fewer loose starch molecules escape. Long grain rice tends to be fluffy and not stick together. Short grain rice, however, has very little amylose and a lot of amylopectin. When you cook short grain rice, it becomes so sticky that it will form balls very easily. This can be helpful if you are making sushi and you need the rice to form a solid layer in the sushi roll. Chefs can choose which type of rice they want to use in a recipe. If they want "not-to-fluffy-not-to-sticky," they can use a medium grain rice.

Yes, when you eat starch, your body breaks apart the molecules into individual glucose molecules. How fast this breaking down process happens is called the ***glycemic index***. ("Glyc-" means "sugar.") Foods that are very high on the glycemic index are broken down into glucose very quickly. This would include white crackers, white potatoes, white rice, and white breads. Seeing a pattern there? Starches that are white tend to be easier to digest and therefore put more glucose into our systems in a shorter amount of time. Starches that are brown —the ones we call "whole grains"—take longer to digest. Whole grains include the brown layer that covers the seed, and this brown layer is not really digestible. Besides whole grains, other low glycemic starches include sweet potatoes, oatmeal, barley, and most vegetables. Why does this matter? As a general rule, it's best to keep the amount of glucose in our blood low and steady.

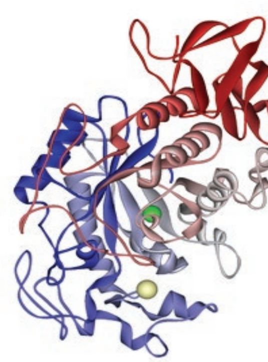
Starches are digested by enzymes. Amylose is taken apart by ***amylase***. Amylase is found in both plants and animals. We can easily forget that from the plant's point of view, those starches are supposed to be used by the baby plant that will grow from the seed. Therefore, the plant must produce not only the starch but also the enzyme that will break it down. Amylase is found in seeds and fruits right there next to amylose, but it doesn't begin working until after the seed has fallen and is ready to begin growing. Part of the ripening process in fruit involves amylose breaking down starches.



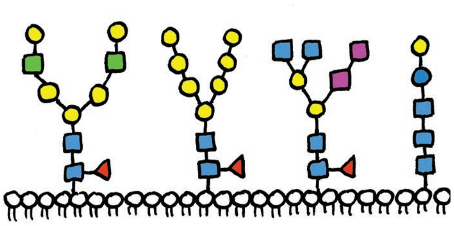
Animal and human bodies make amylase, too. It's the main enzyme found in human saliva. We start digesting those starches even before we swallow them. You can test this by holding a cracker in your mouth without chewing. Not onlyl does it ges soggy and start to fall apart, but it begins to taste sweeter, too.

Amylase has the perfect shape for snapping apart the glucoses. The true shape of amylase is shown here on the right. It is made of amino acids but the artist has simplified the shape and not shown the amino "beads." Those curly places show that proteins, like starches, can form coils.

What would happen if we did not have an enzyme that could disassemble amylose? The long string would pass all the way through our digestive system, unchanged. In the next chapter we will meet a starch molecule we can't digest, though, oddly enough, it is still beneficial to eat lots of it.

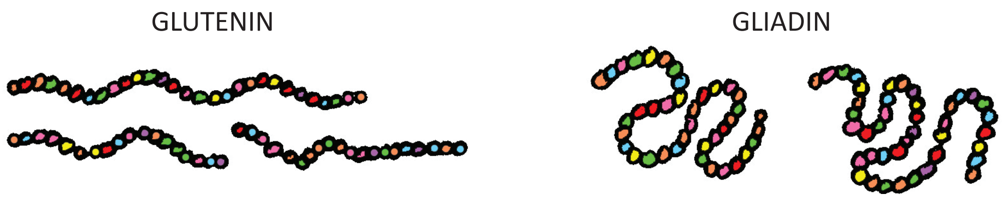


amylase



What will happen to the glucoses after they are snapped apart? Many of them will get used for energy, but not all of them. Glucose molecules are also used to build molecular structures. Strings of glucose molecules show up in a variety of places both inside and outside a cell. For example, they are part of the "post office" system inside a cell, being used in a way similar to address labels. Glycoproteins are used on the surface of a cell as identification markers.

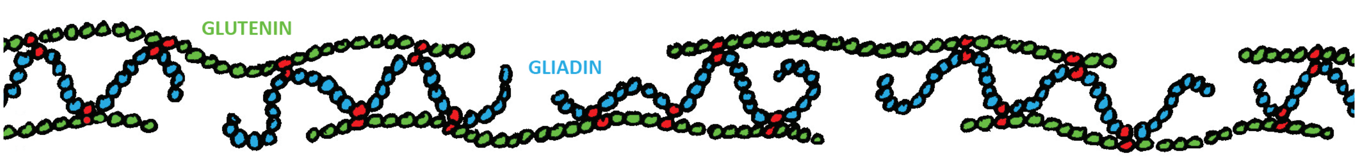
Most people are surprised to find out that bread has a lot of protein in it. We tend to associate the word "protein" with foods like meat, fish, eggs, milk, and perhaps beans and nuts. Grains have quite a bit of protein in them, though. The protein is stored as long strings of amino acids, but we don't have a nice catch-all name for them like we do for glucose strings ("starch"). Storage proteins in plants can be called "storage proteins" but are usually known by their own names. For example, "avenin" is oat protein and "zein" is corn protein. We are going to look at two proteins found in wheat: ***glutenin*** *(GLUE-ten-in)* and ***gliadin*** *(GLIE-ah-din)*. Glutenin is usually shown as a long, straight molecule, and gliadin is usual shown as a curvy shape, or even sometimes as a circle.



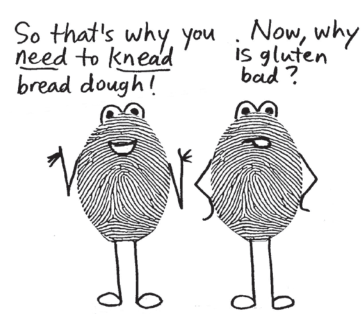
You may be thinking that "glutenin" sounds a lot like a word we hear all the time now: "gluten." With all the hype about products being "gluten-free" you'd think that gluten was some kind of poison. Gluten is just the combination of the proteins glutenin and gliadin. It's actually gliadin, not glutenin, that causes problems for some people, but before we get into why gluten can be a problem, let's look at the positive side and find out what gluten does in bread.

If you've ever seen an expert pizza maker tossing a crust, you've seen what gluten can do. t's amazing to see that thin crust swirling around in the air, getting thinner and thinner yet not tearing apart. Gluten is stretchy and tough. Chefs can choose flours that have more or less gluten, and for pizza dough you definitely want a lot of gluten. Gluten is also what catches the carbon dioxide bubbles made by yeast, so it is a key factor in the fluffy texture of breads and rolls. Manufacturers of gluten-free bread must try to find a substitute for gluten. Often, sticky starches from potatoes or tapioca are added to the mix to increase the stretchy qualities of the dough. But if you've ever worked with gluten-free flour, you know that there really isn't a good substitute for gluten when it comes to making bread. Those gluten-free loaves of bread sold in stores are marvels of food engineering!

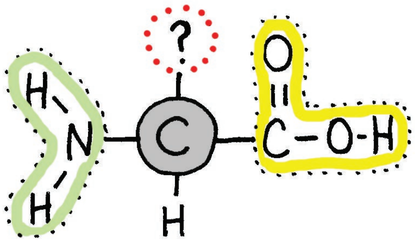
In dry flour, glutenin and gliadin are separate proteins. When water gets mixed into the flour, a major change happens. The water allows bonds to form between these two proteins. The amino acid responsible for this bonding is ***cysteine***. Cysteine has, as part of its R group ("?"), a sulfur atom. Sulfur atoms like to bond with each other and form a ***disulfide bond***. ("Di" means "two.") These disulfide bonds acts like bridges between the strands of protein. When a lot of glutenins bond to a lot of gliadins, we call the resulting substance ***gluten***. The disulfide bonds are very strong so these long strands are stretchy and tough.



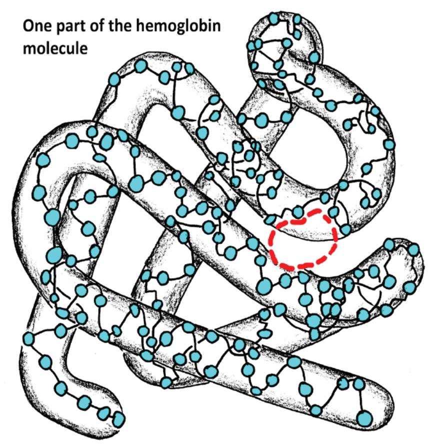
This illustration shows how glutenin and gliadin strands might interact. Glutenin is represented in green, and gliadin in blue. The red dots represent cysteine. This picture makes it easy to see how the cysteines form bonds that are like bridges. When you knead the bread dough, you are moving the protein strands around, and making more and more cysteines come into contact, so you get more bridges. More bridges means more stretchiness. Once the two proteins merge together, we stop naming each separate protein and just call the whole thing "gluten."



To understand why gluten can be harmful, we need to have a good understanding of how proteins work. You will remember that there are only 20 different kinds of amino acids. We briefly met a few of them in the last chapter, and we just met cysteine again on the previous page. Other amino acids you run into a lot include lysine, alanine, proline, valine, serine and glutamine. The amino acids are joined, end to end, to make a long string called a polypeptide. Glutenin and gliadin are polypeptides.



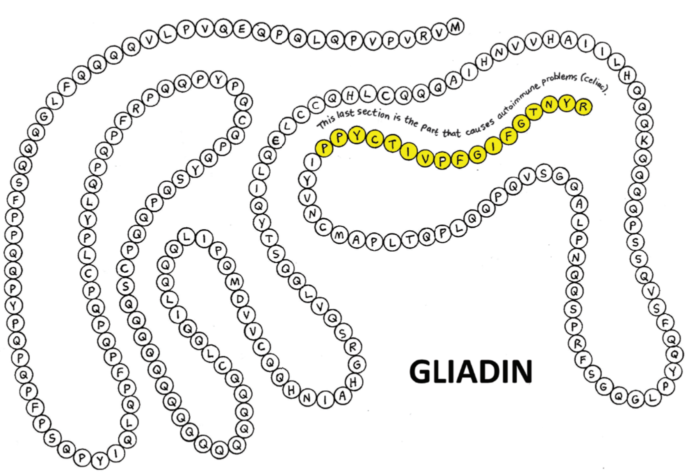
As we learned in the last chapter, each amino acid has parts that are the same: 1) a central carbon atom with an H attached, 2) a COOH (carboxyl) group, and 3) an NH_2 (amine) group. Every amino acid has these parts. What makes them different is the R group, represented here by a question mark. (Think of "R" as standing for the Rest of the molecule.) It is the R group that gives an amino acid its "personality." Some R groups have a small chain carbon atoms and cause the amino acid to love fats and "hate" water, and therefore try to hide in the center of the protein molecule. Other R groups cause the amino acid to love water and be happy on the outside of a molecule. Some R groups are negatively charged and will be attracted to things that are positively charged. Some R groups are acidic or basic. A few amino acids have an extra amine (NH_2) group. Some have a benzene ring as part of their R group.



The interaction of all these various amino acid "personalities" will cause the protein to bend and twist and fold up into a specific shape. The number and order of the amino acids on the string determines the final shape of the protein. That shape will be useful somewhere in the organism that produced the protein, perhaps as an enzyme or a molecular shuttle bus, or as part of a muscle fiber or a strand of hair.

The protein shown here is part of the hemoglobin molecule that carries oxygen in your blood. You can see the chain of amino acids, though all the amino acids are colored blue instead of being different colors. The amino acids are arranging themselves, each one trying to get into a comfortable spot, and the result is this particular shape. The dashed red line shows where a "pocket" has formed. This pocket is where an iron-based molecule will sit. It will hold the oxygen atom.

Storage proteins like glutenin and gliadin are meant to be nothing more than a source of food. They must have an arrangement that **does NOT** fold up to be anything special. They must be random "nonsense" that is only good for being digested and recycled. They should **NOT** resemble any real proteins.

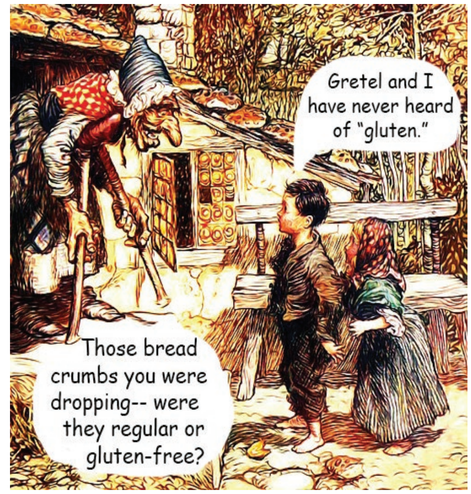


Each letter represents an amino acid. Some letters make sense, such as P for proline, A for alanine, and C for cysteine. Some seem random, such as Q for glutamine. Look at how many Q's there are! Can you find the C's for cysteine? When two C's are close enough, they will try to bond. Where would cysteine bonds *occur in this picture?*

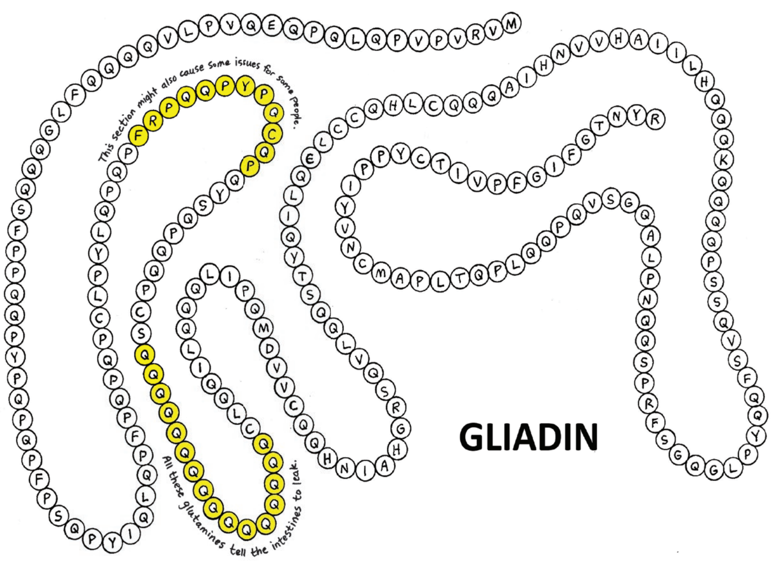
What would happen if a storage protein DID resemble a meaningful protein? This is the problem with gliadin. There is one place, at the end of the string, where the sequence of amino acids is too similar to a meaningful protein sequence.

We have white blood cells all through our body whose job it is to constantly be on the lookout for strange proteins that might be part of something that might hurt us—a toxin (poison), or a bacteria or virus. We call this army of white blood cells our ***immune system***. Unfortunately, the end part of the gliadin molecule is recognized by some people's immune systems. The white blood cells don't have eyes or brains, so they can't see the sequence for what it is—just the end of food protein molecule. To them it feels like an invader. This mistake happens in about 1 in every 100 people. The white blood cells begin a complicated attack process that ends up destroying innocent body tissues. When our immune system attacks normal, healthy body cells this is called an ***autoimmune disease***. The autoimmune reaction to gliadin is called **celiac** *(SEAL-ee-ack)* ***disease***. People with celiac disease can be quite sick with not only intestinal problems, but also fatigue, headaches, muscle and nerve problems, and brain problems. The cure is to never again eat even one crumb of gluten.

Some people who don't have celiac disease also react badly to gluten. There isn't any name for this condition yet, so it is simply called "non-celiac gluten sensitivity." The most mysterious thing about gluten sensitivity is that before the 1980s, it was almost unknown. And now we have 7% of the population who can't eat gluten? What happened? No one knows for sure. Could it be human genetics? Plant genetics? Are plant scientists changing the sequence of the amino acids on the gliadin molecule? Some people blame a chemical named ***glyphosate***, the active ingredient in the popular weed killer *Round-Up*®. Researchers are actively working to try to solve this mystery, and perhaps by the time you read this book, they will have found a good answer.



Interestingly, almost 23 percent of the population thinks they are sensitive to gluten but when they undergo very accurate testing, it turns out that they aren't. They might be reacting to something else in their food and just blaming it on gluten because we hear so much about it.



Gluten sensitivity involves a different place on the gliadin polypeptide, not the end that causes celiac. There are some places in the middle of the gliadin molecule that mimic another body protein, called ***zonulin***. Zonulin is a messenger protein that tells the intestines to leak. Leaky intestines? This sounds like a very bad thing! However, there are times when you want your intestines to leak. As part of our immune defense system, white blood cells can be allowed to leak out of the blood and into the intestines to attack harmful bacteria. The cells of the intestines are very good at repairing the leaks, and most of the time things are quickly patched up. Unfortunately, 6 out of every 100 people have intestinal cells that aren't patching the leaks fast enough. Zonulin continues to be released and their intestines continue to leak, allowing molecules that normally stay in the intestines to get out into the blood. These molecules cause problems in various parts of the body.

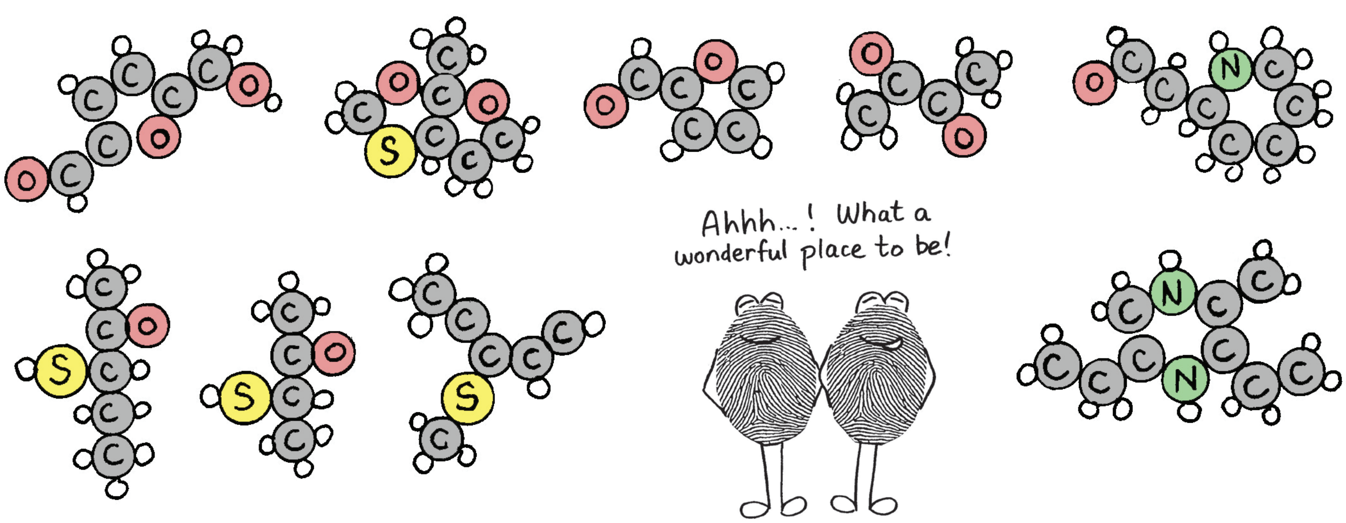
There's one last thing we really must mention. Did you notice how golden brown the top of the roll was? We take "browning" for granted and don't realize that there is some complicated and interesting chemisty going on. This type of browning is known as the ***Maillard reaction***. (Maillard is a French name, and is pronounced (*my-YAR)*. The "d" on the end is silent. This name gets pronounced wrong very often, and it's easy to find bad examples on Internet videos.) The Maillard reaction is also responsible for the browning of meat. If you are a meat fancier, you might enjoy those cripsy browned edges where the meat was "seared" on the pan. The Maillard reaction can be quite delicious.

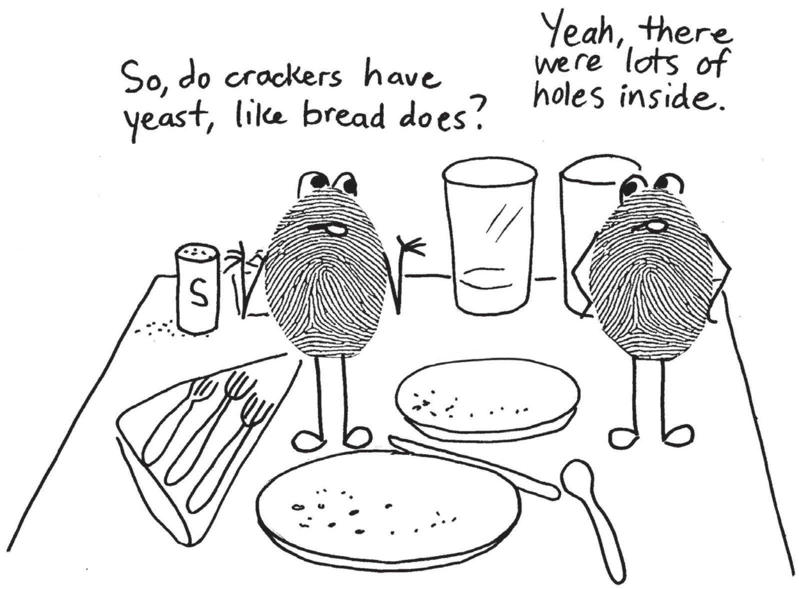
The Maillard reaction happens when sugar molecules get mixed up with amino acids and form bizarre "mutant" molecules. As the temperature rises in the oven, or in the pan, glucose molecules can open up and become a straight line instead of a circle, and amino acids can break apart. Amino acids, or parts of amino acids, start bonding to the sugars, making bizarre, nonsense molecules that are half-amino, half-sugar.

It would be like combining toys with appliances. Chop a bunch of toys in half, chop a bunch of appliances in half, then join them together randomly. What would call these? They have no purpose. You can't call them toys anymore, and you can't call them appliances, either.

Real Maillard molecules don't look funny, like these crazy household combos do, but can still be interesting if you try to identify any remaining recognizable parts of sugars or aminos (such as R groups). Any of the 20 amino acids can be involved in a Maillard reaction, and the molecules can split and recombine in many different ways. The resulting molecules can then split and recombine yet again, so it's like a molecular "free for all" where mutant molecules zip about, combining and recombining to make hundreds of weird, unidentifiable molecules. The final result of this molecular chaos is... delicious smells and tastes!

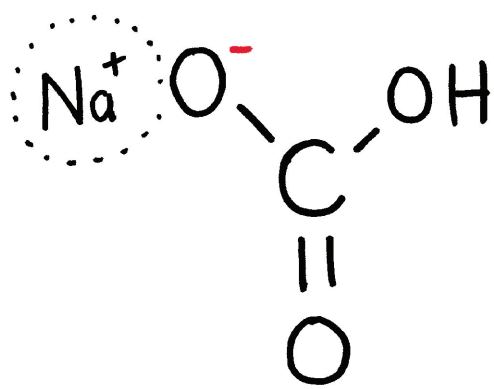
Where might the sulfur atoms have come from in these Maillard molecules? And the nitrogens?





Crackers belong to a large category of baked goods called "quick breads." They are "quick" because in comparison to bread, they can be made very quickly. Yeast takes a long time to make bread rise. All those little single-celled yeast critters have to duplicate their DNA and their organelles and form buds that will become new yeast cells. This process can take several hours—which is pretty fast when you consider the complicated biological processes involved in cell division. But sometimes you need a method of making batter fluffy almost instantly.

Anything that will make a batter or dough fluffy (due to gas bubbles being created) is called a ***leavening*** *(lev-en-ing)* agent. Yeast is one of the slowest leavening agents. The fastest leavening agents are ***baking powder*** and ***baking soda***. They are used in muffins, biscuits, cookies, cakes, pancakes, and some types of crackers.

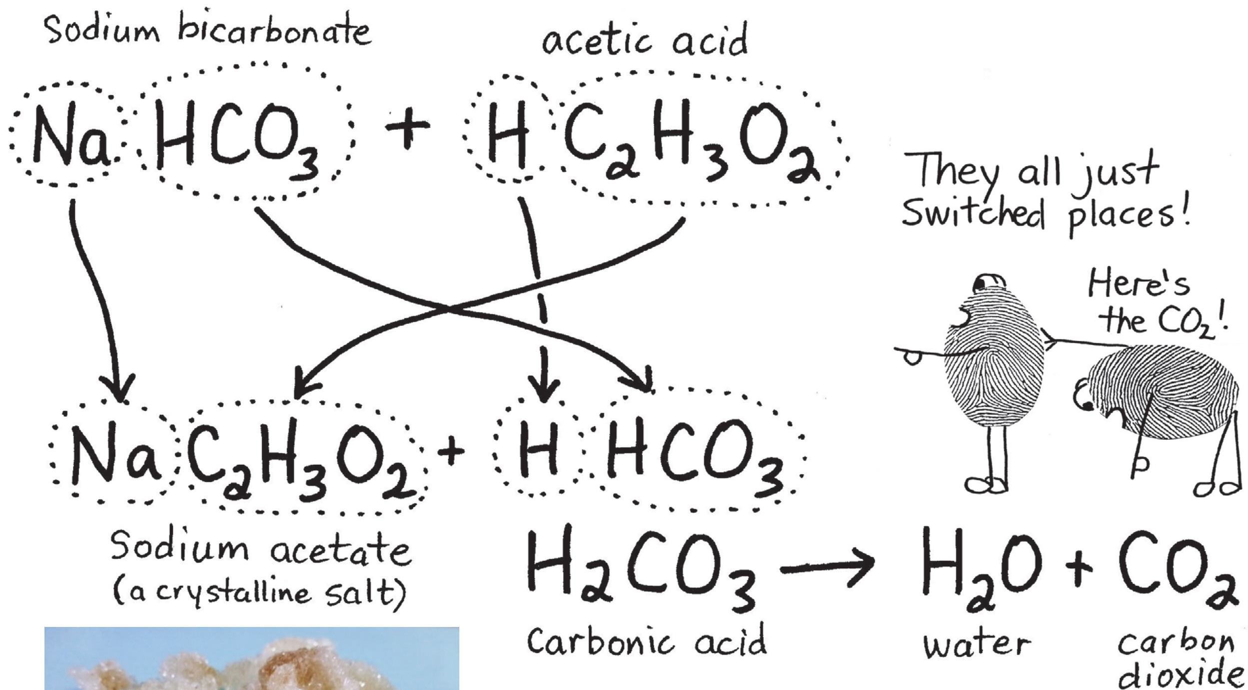


Baking soda (also known as "bicarbonate of soda") is a white powder made of molecules with the chemical formula $NaHCO_3$. From the name, "bi-carbon-ate," we would expect to find two carbon atoms in the molecule, since "bi" means "two." But alas, the name was created using an outdated naming system and was never updated, so we are stuck with a name that does not seem to match the chemical formula. It's one of the rare oddities that chemistry students have to just accept and memorize.

The (HCO_3^-) part of the molecule is called the ***bicarbonate ion***, and it shows up quite frequently in the world of chemistry. As you can probably guess, this used to be a happy molecule with two hydrogens, H_2CO_3, then one of the hydrogens got fed up with never getting to have its electron, so it left the molecule and wandered off as nothing but a proton. The oxygen held on to H's electron, and there it is, in red, giving the oxygen a negative charge. Along comes a positively charged sodium ion (Na^+) and, as they say, "Unlike charges attract." (The sodium atom can't form the same type of bond that carbon does with oxygen. There isn't any sharing of electrons going on, just a strong electrical attraction.)

Where does $NaHCO_3$ come from? Though it might possibly be manufactured in a lab now, it was first discovered underground as a mineral rock, and is still mined today. The baking soda you buy in the store probably came from an underground mine. They send hot water down, dissolve the minerals, then pipe it up. A processing plant takes the water back out, and then puts the dry powder into boxes.

How does baking soda produce bubbles in batter or dough? You probably know the answer. Undoubtedly, you've seen what happens when you mix baking soda and vinegar—lots of bubbles form in just a few seconds. When baking soda is used in a recipe, you must also add an acid for it to react with. This is what happens when baking soda is combined with acetic acid (vinegar):



At the top are the formulas for baking soda and vinegar. (Vinegar is acetic acid in water. The water doesn't participate in the chemical reaction, so we can ignore it in this equation.) The arrows show you how the molecules rearrange themselves when given the chance. An H at the beginning of a molecule (as in $HC_2H_3O_2$) is likely to leave the molecule and wander off to join another molecule. Here, we see the H in acetic acid attaching itself to the bicarbonate ion, HCO_3^-, to form carbonic acid, H_2CO_3. Now we have two H's at the beginning of a molecule—double trouble! The carbonic acid molecule is very unstable and quickly falls apart to become H_2O and CO_2.

When we combine baking soda and vinegar, we get so excited about all the bubbles that we never think to look for anything else. As you can see from the equations above, a substance called ***sodium acetate*** is formed. (We already met this substance briefly on page 22 when we learned that when an acid and a base combine, water and a salt are produced.) Normally, the sodium acetate is dissolved in the water that is formed in the reaction, so we can't see it very well. However, if you boil down the leftover solution, taking all the water out, the sodium acetate will form beautiful crystals, as shown in the photograph. These are salt crystals, but not the kind we put in shakers. Food scientists do use sodium acetate in food products, however. "Salt and vinegar" flavored potato chips owe part of their flavor to sodium acetate. It is widely used (in small amounts) in many food products.

Baking powder is a combination of baking soda (sodium bicarbonate) and a powdered acid, such as ***tartaric acid*** (cream of tartar). When you add water to baking powder, the dry acid powder turns into a wet, highly active acidic solution which will begin to interact with the sodium bicarbonate. If you see the words "double-acting" on your can of baking powder, this means that the food chemists have designed the powder to be temperature sensitive. When you first add the water (or milk), you get a first round of CO_2 bubbles. Then, when you put the food into the oven, the heat will cause a second round of CO_2 bubbles to form while it is baking. Hopefully, the dough will become firm during the time when the reaction is at its peak, producing the maximum amount of bubbles. The trapped bubbles create a fluffy texture.

Comprehension self-check

1) The fats found in butter are mainly triglycerides. A triglyceride has three "tails" that are made of long chains of ____________ atoms (with hydrogens attached).

2) The process of churning cream to make butter does what to the fat globules in it?

3) What comes out of the butter as the fats get packed together? __________ that has a tiny amount of protein floating and sugar floating in it.

4) What creates the acid found in "buttermilk"?

5) What does lactic acid do to milk?

6) What type of sugar is found in milk?

7) Why is butter yellow? It contains this molecule:

8) Name three foods that contain the molecule in #7.

9) Retinol is a form of vitamin ____, and is essential for the proper functioning of the __________ in your eye.

10) What is the most abundant protein found in milk?

11) This protein (in #10) floats around in milk in balls called ________________ and the balls don't stick together because the all have a ______________ electrical charge created by sugar/proteins called ____________________

12) When these protein balls are forced to clump together, this is called _________________ milk. You can do this using a source of positive protons such as _____________ or ________________, or you can use an enzyme called _______________ which comes from the stomach of a baby __________. This process also happens naturally when milk goes sour. What causes milk to go sour? ________________ in the milk

13) When you make cheese, the watery stuff left over is called:

14) When "Little Miss Muffet sat on her tuffet, eating her curds and whey," what was she eating?

15) What microorganisms are used to make hard cheeses? _____________ and/or _______

16) What do you call the process of splitting a glucose molecule, and what two molecules are the result?

17) Bacteria in milk produce __________ acid during the process called f__________________.

18) The gas bubbles that make bread rise are made of ____________________ produced by ___________ cells.

19) The cells in #18 also produce a waste product called ____________, which disappears when bread is baked.

20) The cells in #18 are not bacteria. They are a type of:

21) Amylose and amylopectin are types of ______________ and are made of ____________ molecules.

22) The enzyme that can break apart amylose is called _____________. Do plants make this enzyme?

23) Gluten is made of two proteins, called _______________ and _________________.

24) The sulfur-containing amino acid responsible for the creation of stretchy gluten is called:

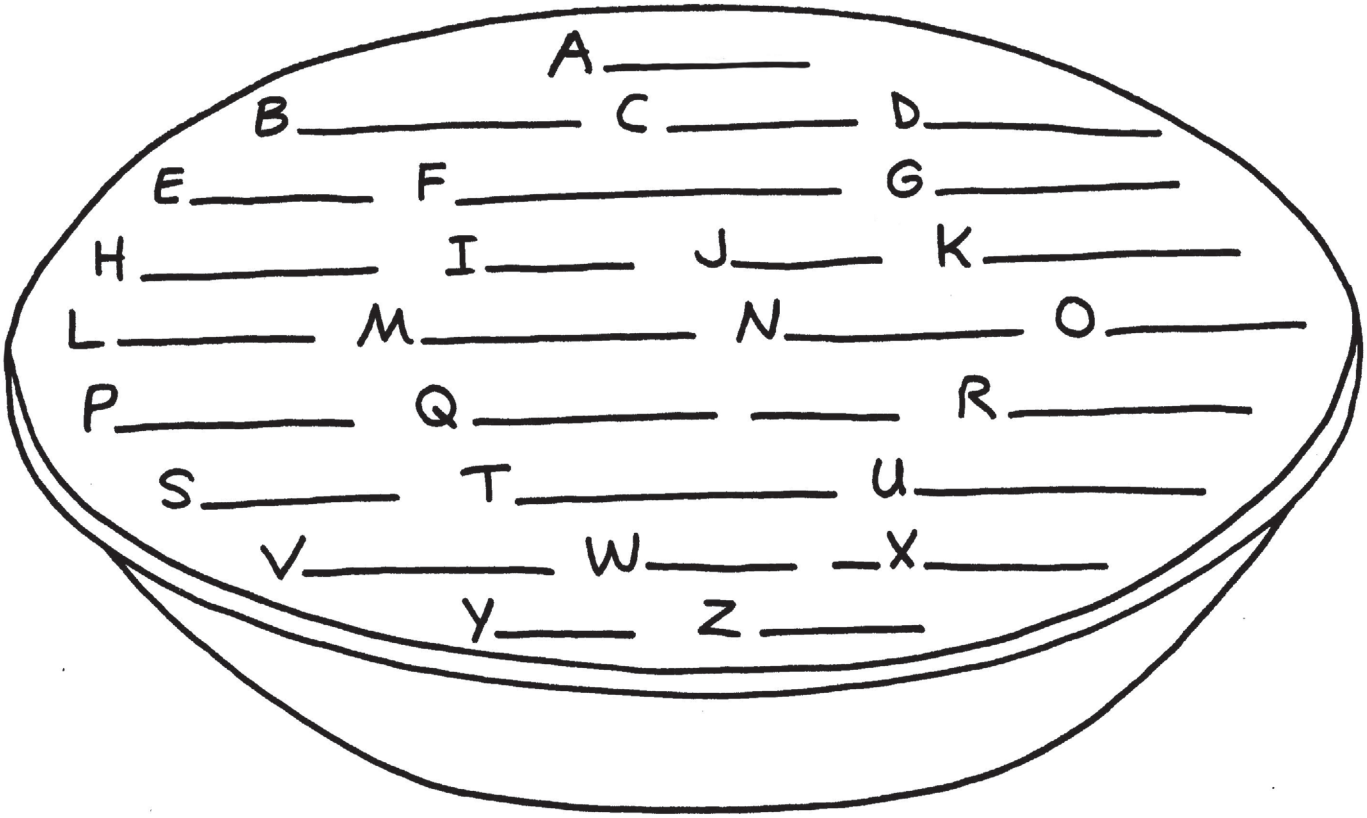
25) People who are sensitive to gluten have immune systems that release too much ______________, a messenger molecule that tells the intestines to become temporarily leaky.

26) This reaction is caused by broken pieces of sugars and amino acids bonding together: ________________

27) If you use baking soda ($NaHCO_3$) in a recipe, what must you also add in order to get bubbles?

ACTIVITY 3.1 ALPHABET SOUP

Fill in a word for each letter of the alphabet. The clues below are in random order. Cross them out (or put a mark next to them) as you use them.



The tiny mineral clumps found in casein micelles are mostly made of calcium ________.
Beta-carotene makes food yellow or _______.
This amino acid is found in the strings hanging off casein micelles and it is very good an hanging on to sugars.
This molecule is created when enzymes add hydrogens to pyruvate.
Milk can be curdled instantly by using vinegar or lemon _______.
If you give an electron to a proton, you have made a ______.
Long strings of glucose molecule that can be broken apart by amylase
Oat protein
Corn protein
The watery liquid that is created during the cheese making process
The amino acid cysteine contains the element sulfur which allows proteins to form _______ bonds.
This is the room in your house where you do food chemistry experiments.
This organelle is found inside of animal and plant cells and harvests energy from pyruvate molecules.
An enzyme called Lactate Dehydrogenase puts H's onto pyruvate in order to __________ "shuttle bus" molecules.
Cornish ______ is a type of cheese.
Watery substance left over when butter is made.
This atom is used to patch the ends of the beta-carotene molecule when it is chopped in half.
The correct name for COOH
The part of gluten that causes problems
The casein micelles are surrounded by a _______ electrical charge.
Each of the 20 amino acids has a unique group of atoms located at the place where we put a ___________ _______.
An empty bubble inside a yeast cell
The rate at which a starch can be broken down and absorbed by the body is called the glycemic ______.
A protein with a special shape that allows it to do a particular job
The molecule that fits into a protein holder in the cells in the retina of your eye
The process of turning pyruvate into lactic acid

ACTIVITY 3.2 STINKY CHEESE PUZZLE

Bacteria can be blamed for a lot of smells in the natural world—stinky feet, smelly arm pits, intestinal gas, bad breath, rotting meat, fermenting sauerkraut, and more. However, not all bacteria smell bad; a few actually smell flowery or fruity. But that's no fun. Smelly bacteria are more interesting. It's not just bacteria and molds that are used to make cheese—insects and arachnids are used, too. Yuck!

Learn the names of the stinkiest cheeses by using the key words at the bottom.





1) ___ ___ ___ ___ ___ ___ ___ ___ ___
16 10 5 4 8 2 20 14 17

Made using *Brevibacterium linens*, a bacteria found on our feet, so it smells like stinky socks and armpits. Has been made for centuries in Belgium and Germany, and is probably the most famous stinky cheese.

2) ___ ___ ___ ___ ___ ___ ___ ___ ___
18 21 5 14 5 4 14 17 13

This cheese is said to smell like a barnyard or like stinking laundry with hints of garlic. It uses raw, unpasteurized milk and is very runny because of the fluids produced by the fermentation process.

3) ___ ___ ___ ___ ___ ___ ___ ___
14 1 2 10 22 22 12 22

Made with raw milk and rinsed in brandy. Internet rumors say it is so smelly that it was banned from public transport in France. So runny it has to be sold in boxes. Napoleon loved it.

4) ___ ___ ___ ___ ___ ___ ___ ___
13 21 16 14 20 20 10 2

Made in Italy, smells like a combination of wet socks and wet grass. Is one of the oldest soft cheeses, dating back to the 10th century. Washed in seawater once a week. The taste is not so bad, a bit salty and fruity.

5) ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___
22 13 10 11 6 10 11 20 4 10 22 15 2 1

Smells like wet hay, or the changing room of a football team. Based on a recipe that dates back to 1615. Uses milk from a rare breed of cow. The curing cheeses are washed in fermented juice made from "Stinking bishop" pears.

6) ___ ___ ___ ___ ___ ___ ___ ___ ___
17 2 7 8 14 12 2 17 13

Made using a blue *penicillium* mold that was orignally found in caves in southern France. Some people think it smells like rotten butter. Uses unpasteurized sheep milk so there is a small risk of *Listeria* food poisoning.

7) ___ ___ ___ ___ ___ ___ ___ ___
17 21 18 16 14 13 13 14

This is one of the runniest cheeses in the world. It is served warm, which makes is even runnier. It comes from the Alps of Switzerland where it is most often eaten at social gatherings. Some people think it smells like dirity feet.

8) ___ ___ ___ ___ ___ ___ ___ ___ ___
5 10 5 2 16 14 13 13 14

Made in France. It is formed into balls that look like cantaloupes. One of the key ingredients in its fermentation is the presence of mites, a tiny member of the spider family. The mites secret chemicals that give it flavor.

9) ___ ___ ___ ___ ___ ___ ___ ___ ___
18 21 22 8 5 21 17 9 8

Made on the island of Sardinia, this cheese contains live maggots (larvae) from the cheese fly. The maggots can jump as far as 15 cm, so you have to hold your hand over the cheese as you eat. Or, you can put the cheese in a plastic bag an hour before you want to eat the cheese and the maggots will die.

10) ___ ___ ___ ___ ___ ___ ___ ___
1 21 17 5 14 22 10 11

This Italian cheese is very smelly, but you have probably eaten some of it and enjoyed it. It is a very hard cheese, so hard that it must be shredded with a grater before eaten. It is often sprinkled over spaghetti.

<u>KEY WORDS</u>:

Amino acids are bonded together to make a ___ ___ ___ ___ ___ ___ ___ (1, 2, 3)

The watery stuff leftover during the process of making butter: ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ (4, 5, 6)

Whey is the ___ ___ ___ ___ ___ ___ leftover when producing curds. (7, 8)

This messenger molecule tells the intestines to leak, to allow immune cells to enter. ___ ___ ___ ___ ___ ___ ___ (9, 10, 11)

Beta-carotene ___ ___ ___ ___ ___ ___ ___ ___ orange and yellow light but absorbs green and blue light. (12, 13)

This alcohol is produced by yeast as they harvest energy from pyruvate molecules. ___ ___ ___ ___ ___ ___ ___ (14, 15, 16)

When butter goes bad we say that is has gone ___ ___ ___ ___ ___ ___ (17, 18, 19)

White butter can be made from the milk of sheep and ___ ___ ___ ___ ___ (20, 21, 22)

ACTIVITY 3.3 Third installment of "Chew It Over," a group game to be played during a meal

Here is another round of questions for you to use at a mealtime that you share with family or friends. These questions relate to the topics we learned about in this chapter. Again, you can use these questions in a varity of ways. You can be the quiz master and determine who gets which questions, or you can cut the questions out of the book and put them into a bag or bowl and let people choose a question randomly. The answers on are the back of this page.

CHAPTER 3: BUTTER, CHEESE, and BREAD 1) What makes the holes in Swiss cheese?	CHAPTER 3: BUTTER, CHEESE and BREAD 2) Which state in the U.S. is famous for its cheese making?
CHAPTER 3: BUTTER, CHEESE and BREAD 3) Queen Victoria received a giant wheel of Cheddar cheese as a wedding gift. About how much did it weigh? a) 50 lbs (23 kg) b) 500 lbs (225 kg) c) 1,000 lbs (450 kg) d) 10,000 lbs (4,535 kg)	CHAPTER 3: BUTTER, CHEESE and BREAD 4) How many varieties of cheese are there in the world? a) 100 b) 2,000 c) 10,000 d) a million
CHAPTER 3: BUTTER, CHEESE and BREAD 5) What is the most popular (and most used) type of cheese in the world?	CHAPTER 3: BUTTER, CHEESE and BREAD 6) "Pule," the most expensive cheese in the world (300 US dollars per pound) comes from Serbia and is made from the milk of: a) sheep b) donkeys c) elephants
CHAPTER 3: BUTTER, CHEESE and BREAD 7) What did ancient Egyptians use moldy bread for? a) making soup b) feeding cats c) treating wounds d) temple offerings	CHAPTER 3: BUTTER, CHEESE and BREAD 8) Where was a 2,000 year old loaf of bread found? a) volcanic ruins in Italy b) pyramid in Egypt c) under a glacier in Norway
CHAPTER 3: BUTTER, CHEESE and BREAD 9) Many words are used to describe the smells of stinky cheeses. If you had to eat a stinky cheese, which of these would you choose? funky, musty, goaty, tangy	CHAPTER 3: BUTTER, CHEESE and BREAD STRANGE FACT: During World War II, when food was rationed, it was illegal to sell fresh bread in the UK. They thought the delicious smell of the fresh bread would cause people to too much all at once. The bread had to sit for 24 hours before it could be sold.
CHAPTER 3: BUTTER, CHEESE and BREAD 11) How many people do you know who don't eat gluten?	cCHAPTER 3: BUTTER, CHEESE and BREAD 12) Go around the table and try to guess each person's favorite starchy food. (anything made from rice, corn, wheat, or various types of flour)

1) Carbon dioxide bubbles from the bacteria that ferment the cheese as it hardens.
2) Wisconsin
3) 1,000 lbs (450 kg)
4) 2,000
5) Mozzarella
6) donkeys
7) treating wounds
8) volcanic ruins in Italy