Science

Science

Physical Science

BAKING Chemistry

by Lillian Duggan

Genre	Comprehension Skill	Text Features	Science Content
Nonfiction	Draw Conclusions	• Labels • Captions • Diagrams • Glossary	Changes in Matter

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chemical change	colloid
chemical equation	compound
combustion	conduction
physical change	denaturing
polymer	emulsions
product	gels
reactant	gluten
	nutrients
	solution
	taste buds

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What You Already Know

Matter is always changing, either physically or chemically. If a material goes through a physical change, it is still the same material. During a chemical change, one kind of matter changes into another completely different kind of matter with different properties.

Burning wood is a form of chemical combustion.

During chemical changes, bonds between atoms or molecules break or new bonds form, causing energy to be taken in or given off. Burning wood is undergoing the chemical process of combustion. During combustion, the wood gives off energy in the form of heat and light.

During a chemical reaction, one or more substances change into other substances. A substance used in the reaction is called a reactant. A substance made by the reaction is called a product. A chemical equation is a way of writing what happens during a chemical reaction. When a chemical reaction takes place, matter is never created or destroyed, just changed.

There are several different types of chemical reactions. In a decomposition reaction, compounds split apart to form simpler compounds or elements. In a combination reaction, elements or compounds come together to form new compounds. In a replacement reaction, compounds split apart and the parts switch places, forming new compounds.

Chemical properties can be used to separate mixtures and to help identify materials. Vinegar can dissolve limestone but not fossils. Scientists can separate limestone from fossils by dissolving the limestone with vinegar. Acids and bases react with chemicals in universal indicator paper, changing the paper's color. These reactions can help people identify substances.

Chemists have made important discoveries that have improved many areas of our lives. Alexander Fleming's discovery of the chemical penicillin saved many people from deadly infections. Nylon and plastic are two useful types of polymers developed by chemists. A polymer is a large molecule made of many identical smaller units connected together. Because of advances in chemistry, our vehicles have tires made of safe, durable rubber.

You have probably seen chemical reactions taking place in your own home. People use chemistry every day in the kitchen.

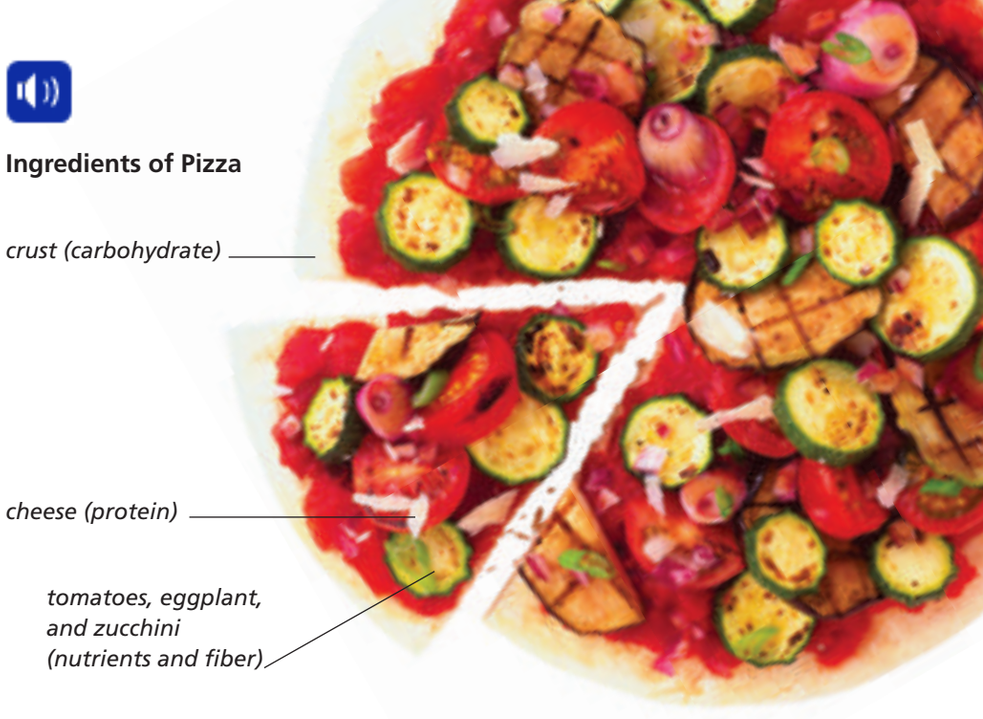
Edible Science

The food we eat contains many different natural chemicals. Many of the chemicals in food are necessary parts of a healthy diet. These chemicals are called nutrients, and they fall into the following groups: proteins, carbohydrates, fats, fiber, vitamins, minerals, and water.

Each type of nutrient performs a different job to keep our bodies healthy. Proteins are necessary for growth and for the repair of damaged tissues. Carbohydrates give our bodies energy. Fats provide energy as well, but in a more concentrated form. Fats also help our bodies use certain vitamins, protect our organs, and help to maintain a normal body temperature. Fiber is a nutrient that aids digestion.

Chemical reactions are necessary to make many of the foods we eat.

Ingredients of Pizza



Vitamins and minerals serve a variety of functions in our bodies. Vitamin B_{12} helps our bodies make blood. It also helps us grow and allows our nerves to work properly. Iron is a mineral that helps build red blood cells and helps blood carry oxygen from the lungs to body cells. Other important minerals are calcium, phosphorus, sodium, and potassium.

Water is probably the most important nutrient. It is used in chemical reactions. It also transports nutrients, regulates body temperature, and gets rid of wastes.

Nutrients are not the only chemicals that make up our food. Some chemicals in food help give it flavor, while others give it color.

When food is prepared or cooked, it may go through physical or chemical changes. Sometimes chemical reactions occur that change the chemical makeup of food. In fact, many of the processes used in cooking—such as heating, mixing, and filtering—are similar to those used in a laboratory.

Baking Basics

Why do we cook our food? For one thing, cooking improves the taste of many foods. Suppose you have some sliced raw apples, cinnamon, brown sugar, and butter in a bowl. You could eat this mixture as it is. But most people would agree that these ingredients taste better when baked together as a pie.

Some foods are safer to eat when they are cooked. The heat from cooking kills harmful microorganisms that may be in food. Foods such as meat and eggs must be cooked in order to ensure that they are free from bacteria. Bacteria called salmonella sometimes grow inside raw eggs and meat. Salmonella bacteria can cause infections in the digestive system. These infections are known as food poisoning. Several types of bacteria, including *E. coli*, may grow in meat. These bacteria may cause dangerous illnesses, such as kidney failure.

Foods may be cooked on a stovetop by a direct flame, or baked in an oven.

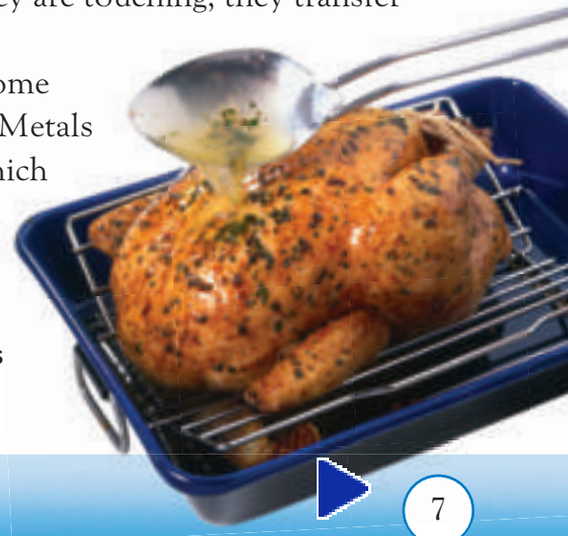
With conduction, heat energy is transferred from the stove to the hot pan to the eggs.

In order to kill bacteria, foods must be cooked until they reach a certain temperature. For example, ground beef is not safe to eat unless it is cooked to 160°F.

Cooking food to certain temperatures may also affect their taste. In 1912 a French chemist named Louis Camille Maillard discovered that all foods go through a browning process at temperatures above 310°F. This browning process is known as the Maillard reaction. The Maillard reaction is a chemical reaction between sugars and proteins that produces a brown color and a taste that most people enjoy.

In cooking, heat is transferred from the hot pan to the food by a process called conduction. During conduction, the heat energy produced by the stove causes the molecules of the pan to vibrate. When these vibrating molecules knock against the molecules of the food they are touching, they transfer heat energy to them.

Heat conducts through some materials better than others. Metals are good heat conductors, which is why they are often used for ovenware.



This turkey has a brown color because of the effects of the Maillard reaction.

Transforming Food

Much of the food we eat has been changed in some way from its original form. The changes that food undergoes may be chemical or physical.

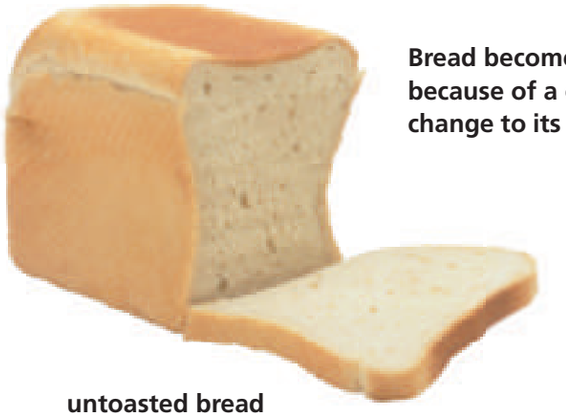
If a change does not affect the food's chemical composition, we call it a physical change. For example, melted cheese has gone through a physical change. It is still the same type of material, but it gets softer when it is heated. The change is easily reversed by cooling the cheese.

Any change that alters the chemicals in the food is a chemical change. Bread contains carbohydrates, which are chemicals made up of carbon, hydrogen, and oxygen. When bread is toasted, the carbohydrates break down into black carbon and water. The carbon gives the bread a dark color and a crunchy texture.
The water escapes into the air.

cheese before melting

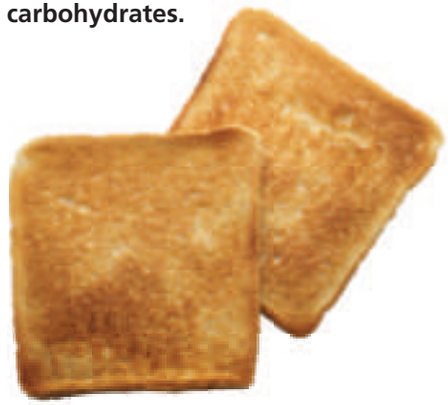
melted cheese

When cheese melts, it becomes soft. It can easily be made firm again if it is cooled.



Bread becomes toast because of a chemical change to its carbohydrates.

untoasted bread



toasted bread

As with most chemical changes, this process cannot be reversed. Once the carbon, hydrogen, and oxygen are separated, they cannot be rejoined.

Cooking meat also causes chemical changes. Meat contains molecules of protein. Natural proteins in raw meat exist in individual units. They are wound up in very tiny coils. The coils are held tightly by bonds within the molecules. When the protein is heated, some of the bonds within the individual molecules are broken. The broken bonds cause the protein to unwind, leaving the bonds exposed and sticking out. This process is called denaturing. The unwound proteins then bump into each other. Their exposed bonds pair up and bond together, forming new bonds.

Denaturing of proteins also happens to eggs, chicken, and fish when they are cooked. The chemical changes that denature proteins cannot be reversed.

Mix it up!

Most of the substances we come into contact with in our daily lives are mixtures. A mixture is a collection of substances that are not chemically combined. The materials that make up a mixture can usually be separated easily by sorting or sifting.

Mixtures are different from compounds. Compounds are substances in which elements are combined chemically with one another.

There are several different types of mixtures. A mixture of atoms or molecules of one substance dissolved in another substance is called a solution. A sweet soda drink is mainly a solution of sugar dissolved in water. A colloid is a mixture in which tiny particles of one substance are scattered evenly throughout another substance. The scattered particles are too small to see, although they're bigger than individual molecules.

oat flakes

raisins

honey

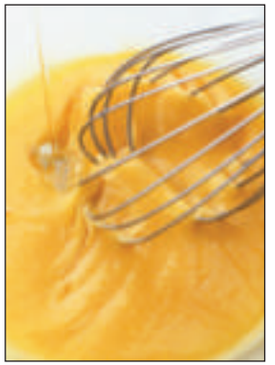
pecans

hazelnuts

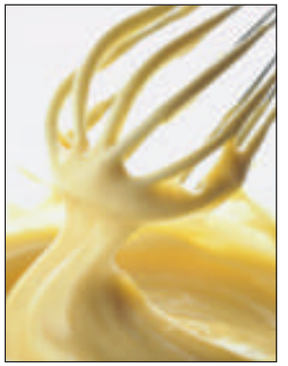
granola

Granola is a mixture. Its ingredients are not chemically combined.

Egg yolks are placed in a bowl.



Oil is added drop by drop.



More oil is added, and the mixture is whisked until creamy.

Two different types of colloids are gels and emulsions. A gel is a colloid in a more solid form. One example of a gel is gelatin desserts, which are made up of water trapped in a network of gelatin molecules. An emulsion is a colloid of two liquids. Mayonnaise is an emulsion that consists of drops of oil mixed into egg yolk.

The substances that make up any mixture keep their individual properties. But the same cannot be said for compounds. When substances come together to form a compound, their properties change. Table salt is a necessary nutrient. It is also a common compound. Its components, sodium and chlorine, are poisonous in their natural state.

Salt is a compound of sodium and chlorine.

Carrot Cake

To get a closer look at the chemistry of baking, let's examine how a carrot cake is made. The main steps to baking any cake are mixing the ingredients and baking them together.

In most cake recipes, the dry ingredients are combined first. The dry ingredients that are used in carrot cake are flour, sugar, salt, baking soda, baking powder, and spices. Flour gives the cake structure. Sugar helps to make it sweet. Salt strengthens the cake batter. Baking powder and baking soda make the cake rise. A chemical reaction causes them to release carbon dioxide gas when they are heated. The carbon dioxide bubbles create the tiny holes in a cake that give it its shape and texture. Spices, such as cinnamon, cloves, nutmeg, and allspice, give carrot cake its unique flavor.

The dry ingredients that make up carrot cake form a mixture.

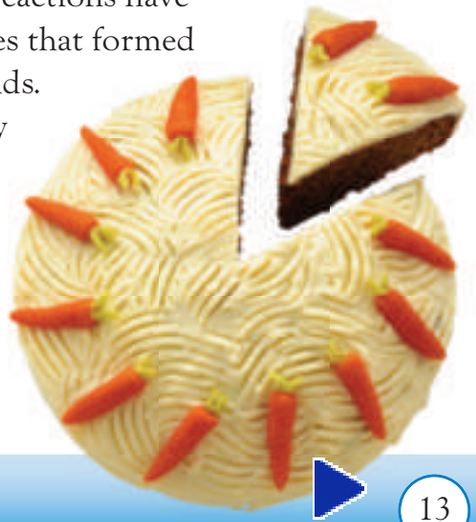
Baking causes some ingredients to react so that they form compounds with one another.

Next, the carrots may be added to the cake. These help give carrot cake its flavor, texture, and color.

The other ingredients in carrot cake are oil and eggs. The oil makes the cake tender and moist. Eggs serve a dual purpose—the whites help the cake to rise, while the yolks give it a creamy texture.

All of these ingredients combine to form a mixture. This mixture could be separated into its different components by sorting and sifting, although it would be very difficult.

Once the cake mixture is combined, it's poured into a cake pan and baked in an oven. The finished cake cannot be unbaked, since the heat from the oven has caused chemical changes to take place. These reactions have caused some of the substances that formed the cake to become compounds. The cake is now bound firmly together and the ingredients cannot be separated.



The carrot cake's ingredients cannot be separated after it is baked.

Egg Experiments

Eggs have many uses. You can prepare them as part of a healthy breakfast, lunch, dinner, or even dessert. Some desserts made with eggs include custard and meringue. Meringue is basically a mixture of beaten egg whites and sugar that is baked in the oven.

We're going to look at the process of making a baked meringue, including the physical and chemical changes that occur. The first step is to separate the egg whites from the egg yolks. Next, the egg whites are whisked until they form a stiff foam. The foam is a mixture containing masses of tiny air bubbles trapped in the egg whites. The change in the whites from a thick liquid to a foam is a physical change.

Cracking an egg's shell releases the yolk and white.

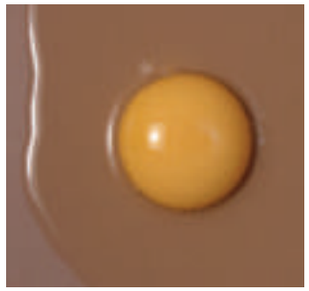
Beating egg whites turns them into a stiff foam.

A chemical change turns egg whites, sugar, and other ingredients into baked meringues.

Next, the egg whites are mixed with other ingredients, including sugar. Then the mixture can be shaped and baked in the oven. Heat produced by the oven causes chemical reactions that change the chemical makeup of the ingredients. The result is a compound called meringue. Sometimes meringue is mixed into other foods or cooked as a pie topping.

Another way to cook eggs is to fry them. Frying an egg is a chemical change, but one that is different from what happens to a baked meringue.

Raw egg white contains coiled protein chains, just as meat does. When the egg is heated in a frying pan, the protein chains begin to unravel and become denatured, as the proteins in cooked meat do. Then the exposed bonds of the egg proteins come together, forming a solid material. This is the reason why an egg turns solid white when it's cooked. When the proteins are still raw, there are spaces between them that let light through.



raw egg

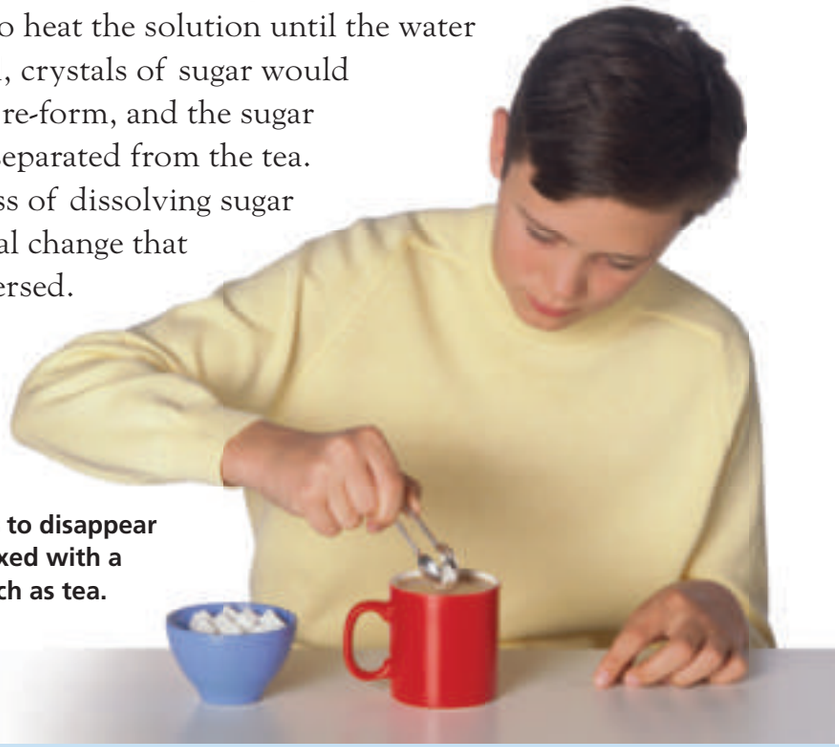
fried egg

Sugar Changes

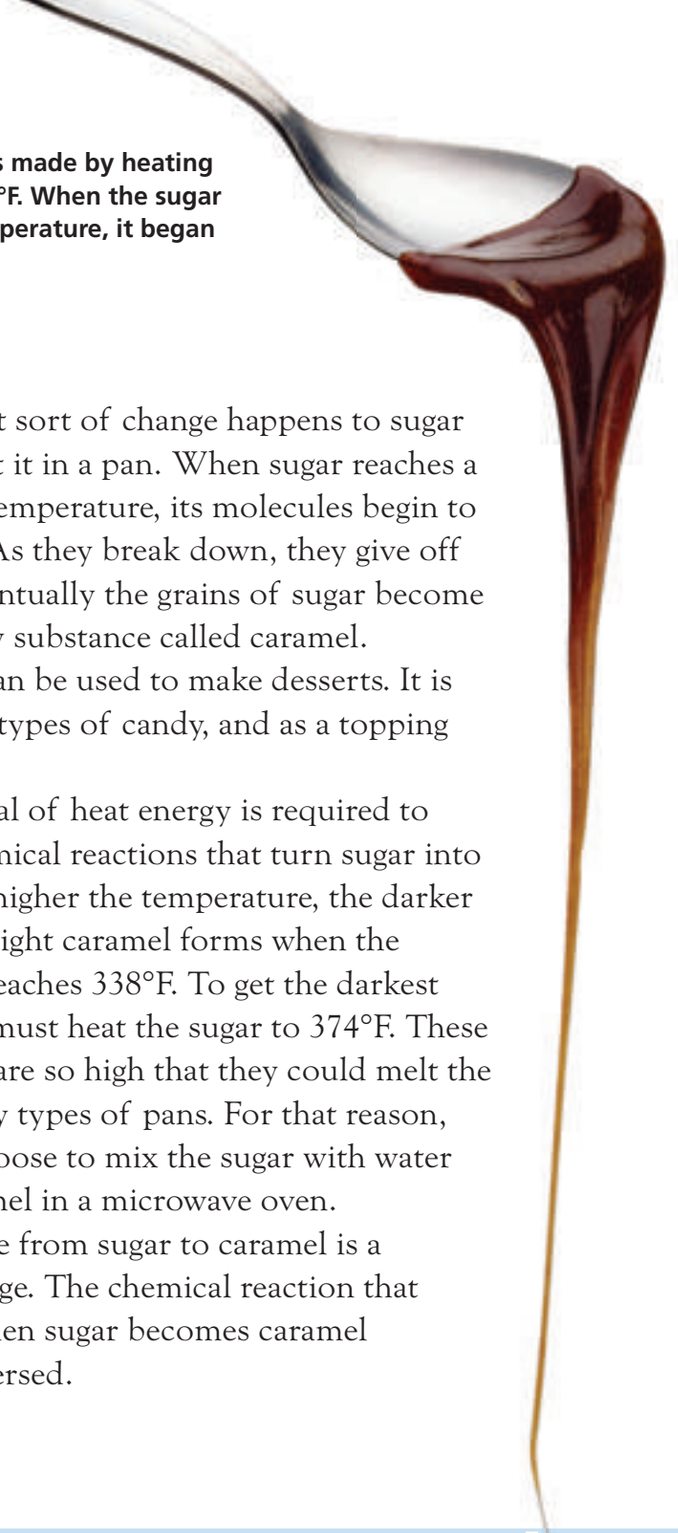
sugar cubes

Sugar is used in more foods than you could probably count. It's an important part of desserts, and it's also an ingredient in many sauces and soups. We use sugar to sweeten a lot of the beverages we drink, such as iced tea and lemonade. When sugar is used in preparing something to eat or drink, it goes through either a physical change or a chemical change, depending on whether or not the sugar is cooked.

When sugar is used as a sweetener, perhaps in tea, it seems to disappear when it's mixed in the liquid. Dissolving the sugar causes its molecules to spread out among the water molecules in the tea, forming a solution. But if you were to heat the solution until the water evaporated, crystals of sugar would eventually re-form, and the sugar would be separated from the tea. The process of dissolving sugar is a physical change that can be reversed.



Sugar seems to disappear when it's mixed with a beverage such as tea.



This caramel was made by heating sugar above 338°F. When the sugar reached this temperature, it began to break down.

A different sort of change happens to sugar when you heat it in a pan. When sugar reaches a high enough temperature, its molecules begin to break down. As they break down, they give off water, and eventually the grains of sugar become a brown sticky substance called caramel.

Caramel can be used to make desserts. It is used in many types of candy, and as a topping for ice cream.

A great deal of heat energy is required to cause the chemical reactions that turn sugar into caramel. The higher the temperature, the darker the caramel. Light caramel forms when the temperature reaches 338°F. To get the darkest caramel, you must heat the sugar to 374°F. These temperatures are so high that they could melt the lining of many types of pans. For that reason, cooks may choose to mix the sugar with water or make caramel in a microwave oven.

The change from sugar to caramel is a chemical change. The chemical reaction that takes place when sugar becomes caramel cannot be reversed.

Fungus at Work

Not everybody likes to eat fungi, such as mushrooms, but fungus is used to make a food you may eat every day—bread. Yeast is a microscopic fungus that is often used in making bread.

Basic bread dough is a mixture of flour, salt, water, yeast, and sugar. After these ingredients are combined, the dough is kneaded. Kneading involves stretching and pressing the dough by hand to develop a protein called gluten. Gluten is formed when the proteins in flour combine with a liquid, such as water. Gluten makes the dough smooth and stretchy.

yeast

Kneading dough can be hard work, but it gives bread its unique texture.

This pita bread is flat because it was made without yeast. Flat breads are also called unleavened breads.

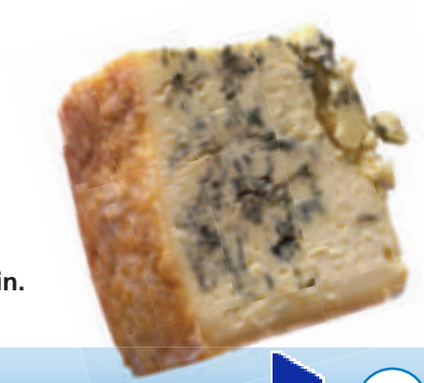
The holes in this bread were formed by bubbles of carbon dioxide, which were made by yeast in the bread dough.

After the dough is kneaded, it is put in a warm place. While the dough sits, the yeast produces chemicals that react with starch in the flour. These reactions produce sugar and carbon dioxide gas. The carbon dioxide creates bubbles in the dough, causing it to rise.

While the dough bakes in the oven, the high temperatures kill the yeast. The carbon dioxide gases expand to give the bread a spongy texture.

If dough is cooked without yeast, it will not rise. The flat bread that results is called unleavened bread. Some common flat breads are pita bread and flour tortillas, which are used for tacos and burritos.

Blue cheese gets its color and taste from another fungus, called penicillin. Cheese makers combine penicillin with the cheese. While it ripens, or ages, the cheese develops its characteristic blue-green streaks and sharp taste.

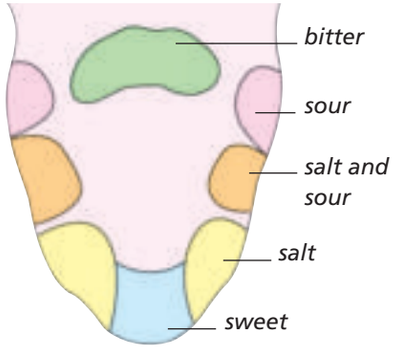


Blue cheese gets its unique color and taste from penicillin.

Food Sensors

Food is not just good for our bodies. For most people, the taste of food is very enjoyable. Thanks to our taste buds, we can detect the flavor of foods, and distinguish between the ones we like and the ones we dislike. Taste buds are microscopic organs on our tongues. Each of us has about ten thousand taste buds.

But our taste buds do more than just help us enjoy food. They also act as a safety mechanism, since an unpleasant taste may be a warning that a substance is harmful to the body.



Different sections of your tongue detect different flavors.

Without a sense of smell we would not be able to detect many different flavors.

Your eyes water when you're near a cut onion. This protects them from irritating sulfur compounds.

Even though we have thousands of taste buds, our tongues detect only four tastes: bitter, sour, salt, and sweet. Each of these tastes is detected by different parts of our tongue.

If your tongue can pick up only four tastes, how are you able to enjoy such a wide variety of food flavors? Flavor is a combination of taste and smell. Your sense of smell picks up most of the information about a food's unique taste.

You can smell for yourself how helpful your nose is when it comes to enjoying a meal. Try tasting different fruit juices while wearing a blindfold and holding your nose. Can you recognize any of the juices?

Have you ever gotten teary-eyed when you were near a chopped onion? Your eyes don't water because you're sad about the dinner menu, but because they're reacting to substances in the onion. Onion cells contain sulfur compounds, which can irritate your eyes. You produce tears to wash away the chemicals before they affect your eyes.

Kitchen Laboratory

Now you know some of the science that happens when you prepare food. Food itself is a combination of chemicals, including important nutrients.

Physical and chemical changes turn simple ingredients into pleasing meals, desserts, and drinks. Physical changes do not affect a food's chemical composition, but chemical changes do. The denaturing of proteins during cooking is a chemical change that affects meat and eggs.

Combinations of food ingredients can be described as mixtures or compounds. Unlike the substances in a compound, those that make up a mixture are not chemically combined.

Sugar can also undergo both physical and chemical changes. Dissolving it in a liquid causes a physical change. However, heating sugar to make caramel brings about a chemical change.

Yeast is a fungus that brings about a chemical reaction. It makes bread rise. Carbon dioxide gas released by yeast gives bread its spongy texture.

Without taste buds and our sense of smell, we wouldn't be able to enjoy the flavors of all these physical and chemical changes.

Remember that while cooking is fun, it can also be dangerous. Make sure an adult is nearby when you're working in your own kitchen laboratory.

Glossary

colloid	a mixture in which tiny particles of one substance are scattered evenly throughout another substance
compound	a substance in which elements are combined chemically with one another
conduction	the process by which heat energy is transferred from the oven or stove to food
denaturing	the process of changing the arrangement of protein molecules
emulsions	colloids made of two liquids
gels	colloids in a more solid form
gluten	a protein in flour that makes dough smooth and stretchy
nutrients	substances that we need to eat for energy, growth, and the repair of our bodies
solution	a mixture in which atoms or molecules of one substance are dissolved in another
taste buds	tiny organs on the tongue that detect the flavor of foods

What did you learn?

1. Name two nutrients and describe their role in the body.

2. What is the Maillard reaction?

3. What is the difference between a mixture and a compound?

4. **Writing** in Science The detection of food flavors involves more than one of our senses. Write to explain how we determine the taste of food. Include details from the book to support your answer.

5. **Draw Conclusions** Does the process of rising bread involve a physical change or a chemical change? How do you know?