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## Introduction

You may have noticed that some things rot quickly, while other things take more time. Fuzzy green mold can show up on old bread in a few days. A leather shoe lost in the woods can take as long as forty years to rot. A granite rock never rots because it's never been alive.

When scientists talk about rotting, they say that a thing *decomposes* or *biodegrades*. A thing is *biodegradable* if it can be decomposed (broken down) by other living things, usually bacteria and fungi.

All organisms are biodegradable, whether they are roses, butterflies, or elephants. Even petroleum products (such as oil and gasoline) can biodegrade because petroleum began long ago as living organisms. On the other hand, steel and glass were never organisms and are not biodegradable.

Think of all of the things that you can buy in a store. Sometimes it's hard to be sure which are biodegradable and which are not. For example, are things made of plastic biodegradable?

The answer to that question is changing. Scientists are inventing amazing new ways to make everyday things—especially plastic things—ready to rot when people are done with them.

**Which of these products do you think are biodegradable?**

## Nature Biodegrades and Recycles

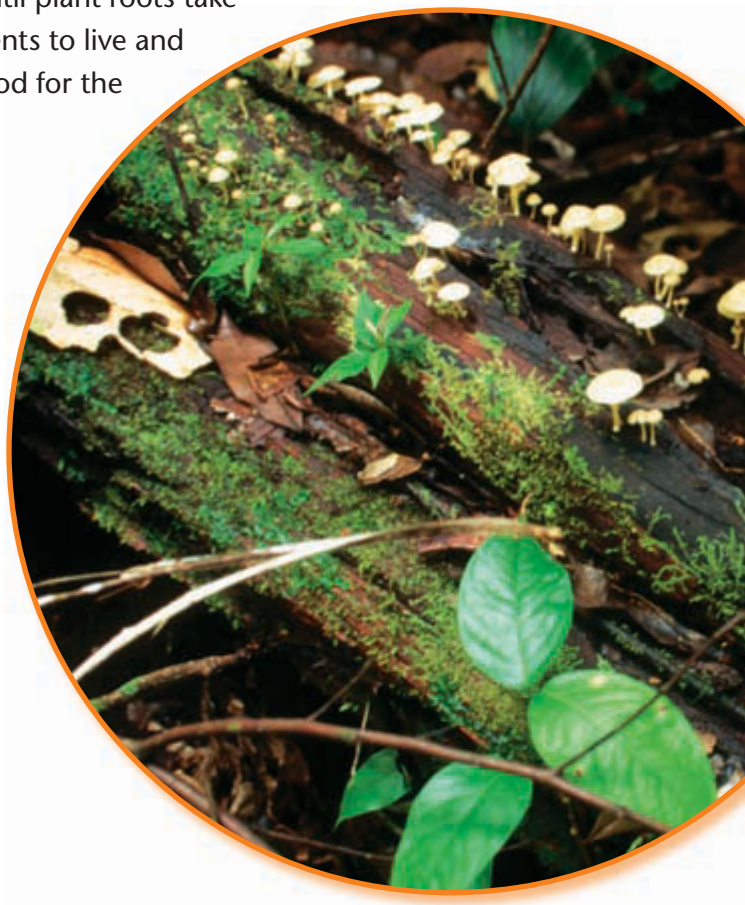
In nature, the main decomposers are fungi and bacteria. The fuzzy green mold on bread is a kind of fungus. More than 50,000 different kinds of fungi, large and small, live by decomposing dead organisms. In a forest, fungi break down the tough part of wood, and then bacteria finish the decomposing.

One gram of soil holds millions of microscopic organisms, and most of them are bacteria. There are many different kinds of bacteria. Some live in frigid Antarctica. Others thrive in Yellowstone Park's hot springs at temperatures higher than 73°C (167°F). Bacteria in a deer's stomach help decompose the tough plants that the deer eats.

In nature, decomposing and recycling are part of all food webs. Decomposers break down dead plants and animals into the most basic nutrients. *Nutrients* are substances that organisms must take in to live and grow.

Nutrients stay in the soil until plant roots take them in. Plants use those nutrients to live and grow. The nutrients become food for the organisms in a food chain.

Nature's recycling does something else—it cleans away dead organisms. If old trees didn't rot away, a forest would become clogged with enormous piles of logs.



### Nature at Work

**What are the fungi doing to this fallen tree?**

We want to have things decompose and recycle, too. We need to save resources for the next generation, and we don't want huge piles of junk building up. One way scientists help to keep this from happening is by finding ways to make more things biodegradable.

## Made to Biodegrade

Everywhere on Earth, people work hard to turn parts of plants and animals into things such as homes, clothes, and tools.

Many times we change foods before eating them. We might cut up vegetables into pieces and mix them together. We cook meat and potatoes. We turn grain into flour, blend it with other food products, and bake the dough into bread. Whatever we do, the food is still biodegradable. If it weren't, we couldn't digest it.

We can turn trees into paper, pencils, and desks. From wool and cotton we make clothing, and from leather we make shoes. Something made from plants or animals may look very different from the original material, but decomposers still recognize it as their food and break it down. This is one important way that things made from plants and animals are different from plastic produced from petroleum.

### Recycling

Extracting petroleum


## Plastic from Petroleum

Plastic is a kind of chemical called a polymer. *Poly-* comes from the Greek word meaning "many." A *polymer* contains many identical molecules, all linked together into a chain. Being a polymer gives plastic some of its special qualities.

Plastic doesn't grow in nature the way trees do. Companies make it from petroleum. At an oil refinery, a high-temperature furnace breaks down the petroleum. Part of the oil is used to make plastic.

Petroleum makes excellent plastics. We use plastic so much because it has wonderful qualities. It weighs less than wood or metal. It is easy to clean. It doesn't cost much. Companies make it in many sizes, shapes, and colors. It can be soft or hard, flexible or stiff.

Unfortunately, petroleum is a nonrenewable resource. It took millions of years for Earth to change dead organisms into petroleum. When the current supply is used up, it will be gone.

After companies take petroleum from the ground, they ship it to a refinery and later to wherever its products will be used. There is always some possibility of an accident and an oil spill. The oil companies very carefully protect their shipments, and there are few oil spills. When there is a spill, however, it is very damaging to the local environment.

## Long-Lasting Plastic

Plastic may crack, but it won't rust or rot. In fact, nature's decomposers don't recognize plastic as food, and they don't biodegrade it. That's a good thing as long as the plastic item is needed. It's a problem when the item becomes garbage.

Because petroleum-based plastic isn't biodegradable, it doesn't turn back into nutrients. Instead, old plastic fills up garbage dumps, piling higher and higher. Making and throwing away plastic uses up resources and takes up a great deal of space.

One good solution to this problem is reusing plastic. Because plastic lasts so long, it can be used over and over again. Another good solution is recycling. Old plastic can be turned into new things.

**What plastic items can you find in your home?**

### Corn: A Good Source of Starch

## Plastic from Plants

Some scientists have also come up with another amazing solution. They now make biodegradable plastics. They call them *bioplastics.* At some fast-food restaurants, the food boxes, cups, and forks are made of bioplastic. Bioplastic is plastic made from organisms rather than from petroleum. One kind of bioplastic, called PLA, is made from plants.

Plants make food energy through photosynthesis. Most plants store that energy in a polymer called *starch.* Starch is especially abundant in corn, potatoes, and wheat.

Some companies use starch from corn and other plants to make plastic. Unfortunately, starch plastic biodegrades too quickly in water. That's why plastic from oil is still better for some uses.

Now scientists have found a way to break apart a starch polymer, change it, and link it back together again. This makes PLA plastic, which for many purposes can be used just as petroleum plastic is used.

## Bioplastics and the Environment

One advantage of PLA plastic is that plants are a renewable resource. It takes millions of years for Earth to produce petroleum, but it takes only a growing season to produce corn.

Corn and other plants are grown all over the United States. They don't have to be shipped far, and a grain spill is much less of a problem than an oil spill.

Bioplastics are biodegradable. They decompose into natural substances that return nutrients to the Earth. They don't remain in permanent piles of garbage.

## Degradable Disposables

Plastic doesn't have to last forever when it will be used only once. By adjusting the formula, companies can create PLA bioplastic that degrades in a few weeks.

Some doctors close up cuts with bioplastic sutures (stitches) because the sutures don't have to be taken out. They just dissolve. Gardeners can buy

plants in biodegradable pots. They put the entire potted plant in the ground, and after a while the pot degrades, leaving behind carbon dioxide and water.

Some grocery stores put meat, vegetables, or fruit on bioplastic trays and cover the food with degradable wrap. They wrap bread in bioplastic and send the groceries home in degradable grocery bags. You can even collect your grass or fallen leaves in a bioplastic bag.

One company produces food boxes for a popular fast-food restaurant chain. What does it make the boxes from? It uses potato starch left over from making French fries and potato chips. The bioplastic boxes are as good as petroleum-based plastic, and they biodegrade when composted.

Scientists can change the formula when they want to make sturdier bioplastic. A famous electronics company is protecting its portable CD players with a tough bioplastic case. Some hairbrush handles are made of biodegradable plastic. Companies are constantly inventing more ways to make and use long-lasting bioplastics.

**You may have used degradable disposables and not even have known it!**

## Making Plastic from Bacteria

Bacteria are simple, microscopic organisms. They don't store energy in fats, oils, or starches the way plants and animals do. Instead, some bacteria store energy in a molecule called PHA. In fact, their body weight is four-fifths PHA.

PHA is a polymer, and scientists can make plastic from it. In fact, scientists have discovered about 100 different PHA molecules, made by different bacteria. Each kind of PHA turns into a slightly different plastic.

Only a few companies have succeeded in making PHA plastic. They make it in bacterial fermentation plants. In these plants, bacteria are fed sugar so they grow and reproduce. It takes a very large amount of bacteria to make even a little plastic.

PHA plastics are fully biodegradable, so they are perfect for things that will be used only once and then thrown away. For example, they can be used for disposable wipes, tissues, plastic bags, and fast-food boxes and cups.

In addition to being good for the environment, this type of plastic is inexpensive to get rid of. Instead of paying to send it to a landfill, businesses can decompose it cheaply.

PHA plastics are newer than PLA plastics, so they are just beginning to be sold. It is clear, though, that they should have many of the same uses as plastics made from plants.

### Bioplastics

## Growing PHA Plastic in Plants

A fermentation plant is a building in which people grow bacteria for PHA. However, some scientists are working at growing PHA in living plants.

Scientists are still experimenting to find the best way to do this. Through genetic engineering, they put into certain plants the bacterial gene for PHA. Now those plants can make PHA. Growing PHA plants will be less expensive than raising and harvesting bacteria.

The plants will be designed so that the plastic is made only in their roots or leaves. Their seeds will be the same as before. This means that a corn plant's leaves could produce plastic and its corn could be harvested as food.

## What Happens in Landfills

Even biodegradable plastic will not decompose just anywhere. Most of it will not decompose in a landfill.

A landfill is a place where garbage is dumped and then covered with dirt. Most people think that the garbage in a landfill eventually decomposes and returns to nature. Actually, it doesn't work that way.

**A landfill**

The purpose of a landfill is to keep trash separate from the environment. The landfill is lined with clay or petroleum-based plastic.

A huge amount of garbage is put into the landfill over a long period of time. The trash is crunched together very tightly. Then the landfill operators smother the garbage with a blanket of dirt.

The purpose of a landfill is to keep garbage from polluting the ground around it. Air is kept out so that the wind won't carry off smells and pollution. Water is kept out so that the garbage doesn't pollute the groundwater. That's important because trash can include poisons as well as food scraps.

However, decomposers need oxygen and water to live, so they don't do well at landfills. This means that the trash doesn't break down very quickly, no matter how biodegradable it is.

In one study, scientists found that they could still read newspapers that had been buried for thirty years. Even some hot dogs still looked like hot dogs.

Some landfills allow faster decomposing than others. In any landfill, however, most biodegradable plastics won't decompose any better than will newspapers or hot dogs. This means their nutrients won't return to the soil and the landfills will continue to become full.

**Mount Trashmore**

**Mount Trashmore, in Virginia, was once a landfill, but it has been turned into a park. Why do you think the area was named Mount Trashmore?**

## What Happens in Compost Heaps

A compost heap is very different from a landfill. The goal of composting is to decompose trash.

*Composting* is setting up a place with the right conditions so that degradable materials will decompose. We use the word *compost* for what is left after these materials decay.

Compost looks much like soil. It is dark and rich with nutrients. Compost is excellent for making a lawn or garden grow better.

When people compost in their yards, they often pile the materials in heaps or in wooden bins. Some materials that compost well are fruits, vegetables, leaves, grass, newspapers, and, of course, bioplastic. In a compost heap, materials degrade more quickly when they have the right mix of air, moisture, and temperature.

## Composting Plastic

Composting is easy for people who use bioplastic. The plastic wrapping, the messy food scraps, and the bag that holds them are all biodegradable. The person dumps all of it, including the bag, directly onto the compost heap.

A backyard composting pile

Composting isn't just for backyards. Some companies specialize in composting large amounts of biodegradables. This means that businesses using bioplastics don't need to do their own composting. A fast-food restaurant can put used degradable cups and food boxes into bioplastic bags and send them off to a composting company. The cost is less than hauling waste to a landfill.

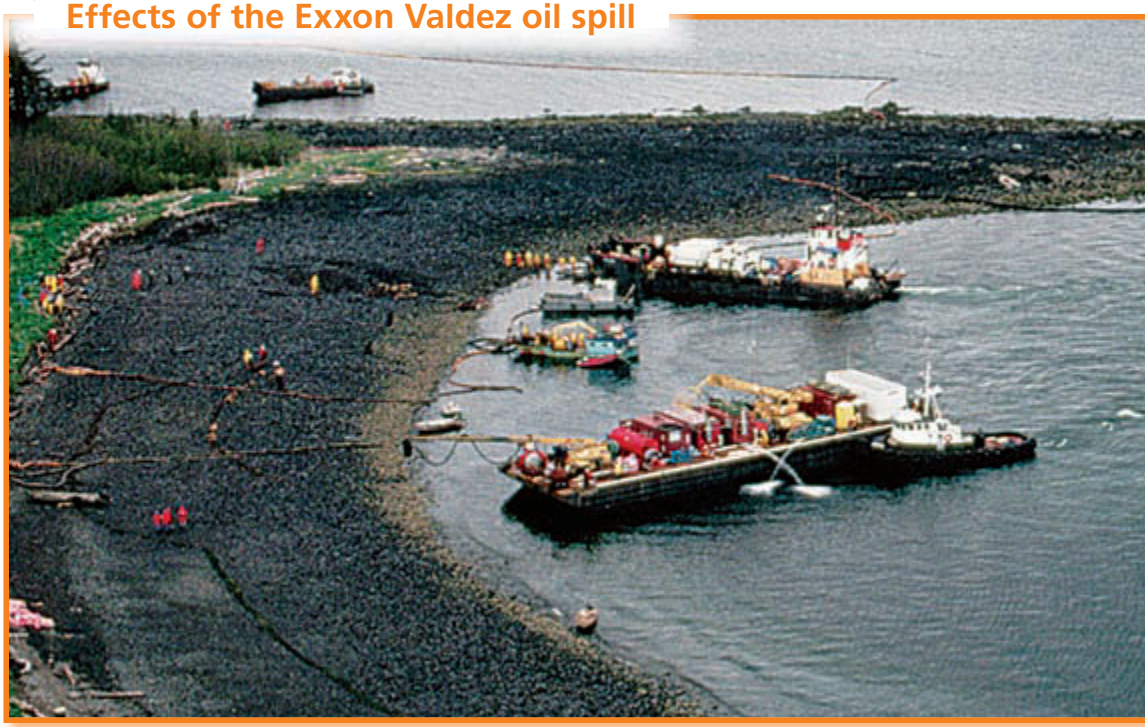
## Cleaning Up Oil Spills

Sometimes, an enormous amount of oil accidentally spills on land or in the water. Petroleum does biodegrade, and there are always bacteria present that can decompose it. Unfortunately, there are usually not enough bacteria in an area to clean up a huge oil spill very quickly.

Biodegrading oil quickly is important because a large amount of oil can harm plants and animals. The answer is to make biodegradation happen faster.

When an oil spill is on water, sometimes cleanup begins by putting a dispersant on the surface. A *dispersant* breaks up the oil and spreads it apart

**Effects of the Exxon Valdez oil spill**

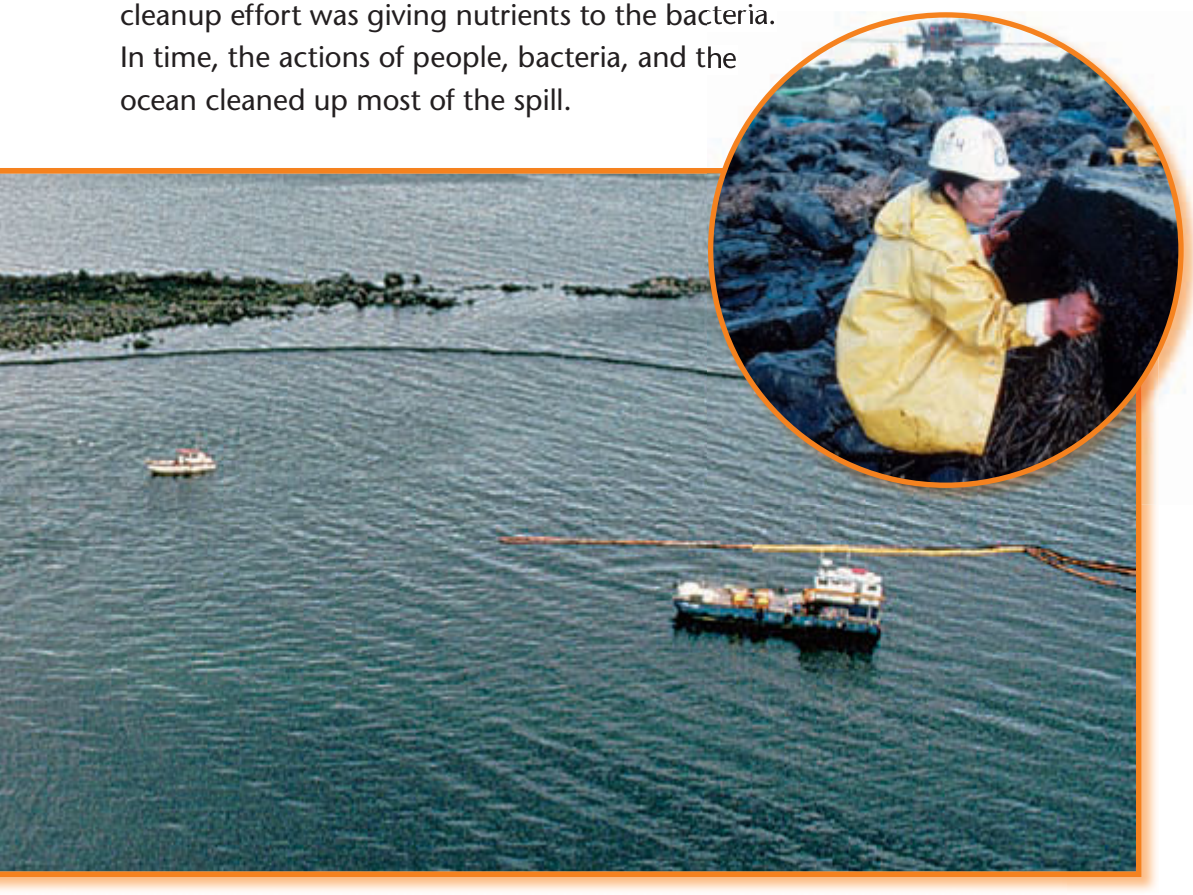


in the water. This helps the oil biodegrade faster and may be all that needs to be done.

Sometimes, after the dispersant has worked, the cleanup crew adds nutrients to encourage decomposing bacteria to grow. Another way to increase the number of bacteria is called *seeding.* Seeding is adding more oil-decomposing bacteria to the spill. Scientists disagree about whether seeding makes any difference, because bacteria reproduce so well with plentiful nutrients.

Nutrients were used to clean up the worst oil spill in U.S. history. On March 24, 1989, an oil tanker named the *Exxon Valdez* ran aground off the coast of Alaska. Approximately 11 million gallons of oil flooded out. A storm on March 26 spread the oil over a large area of coastline.

Oil covered sea and shore. Thousands of fish, birds, and sea mammals died. Volunteers worked nonstop to clean up the mess. One part of the great cleanup effort was giving nutrients to the bacteria. In time, the actions of people, bacteria, and the ocean cleaned up most of the spill.



## Plants Can Clean Up Soil

Some scientists have found a different way to decompose pollutants. *Pollutants* are harmful chemicals that get into the environment. It turns out that plants, as well as the bacteria that live near their roots, can break down pollutants in the soil.

Microscopic organisms biodegrade many pollutants along with the other things they decompose. These organisms live in high numbers near a plant's roots. They live well there because the roots give off nutrients and oxygen.

When a plant is put into polluted soil, the organisms near its roots begin decomposing pollutants. Because so many organisms are near the roots, pollutants break down more quickly than if the plant weren't there.

This process happens only near the plant's roots. Scientists like to use trees for cleanup because tree roots spread deeper and wider than the roots of most other plants.

Although bacteria do most of the decomposing, some plants can do it too. Sometimes when a pollutant is pulled into a plant, the plant's own cells change the pollutant and make it harmless.

Plants can help clean up water, too. In one cleanup effort, the EPA planted poplar trees in polluted soil. The poplar roots sucked up nutrients and poisons from both groundwater and stream water.

**Houseplants, through their leaves and roots, can actually extract some pollutants from the air.**

## Think and Write

1. Explain an important thing that a bioplastic drinking cup has in common with the orange juice inside it.
2. Many microscopic organisms live in garden dirt. If you sealed up garden dirt and a bioplastic bag in an airtight can, what do you think would happen?
3. Make a chart comparing petroleum-made plastic with plant-made plastic. Include ways that the two kinds of plastic are the same and ways that they are different.
4. **Narrative Writing** Write a story about someone inventing a way to make something more biodegradable. Be sure to describe what thing becomes more biodegradable and how that makes a difference.

## Hands-On Activity

Make a collage of pictures of plastic objects. Include pictures of at least ten plastic items that are as different as possible from one another. They can be different in size, shape, stiffness, and other ways.

## School-Home Connection

Talk with a family member about plastic things in your home. Ask which things are used once and thrown away and which things are used over and over.

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