EXPLORING

The World of Biology

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This book is dedicated to Megan Elizabeth Stephens.

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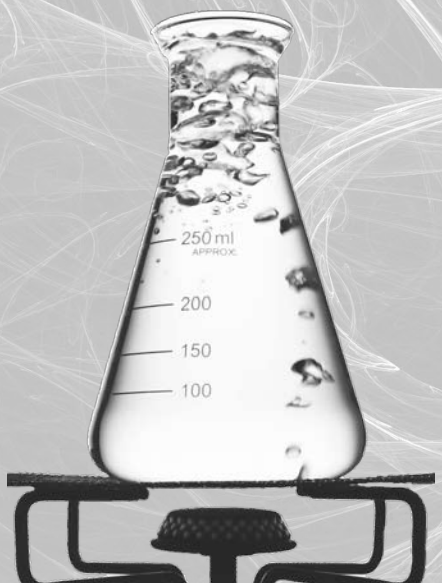
Note to Parents and Teachers:
How to Use *Exploring the World of Biology*

Students of several different ages and skill levels can use *Exploring the World of Biology*. Children in elementary grades can grasp many of the concepts, especially if given parental help. Middle school students can enjoy the book independently and quickly test their understanding and comprehension by the challenge of answering questions at the end of each chapter. Junior high and high school students can revisit the book as a refresher course.

In addition, sections marked "Explore More" can be a springboard for additional study. "Explore More" offers questions, discussion ideas, and research for students to develop a greater understanding of biology.



Biological Classification and Nomenclature

For most of history, biologists used the visible appearance of plants or animals to classify them. They grouped plants or animals with similar-looking features in the same family. Starting in the 1990s, biologists have extracted DNA and RNA from cells as a guide to how plants or animals should be grouped. Like visual structures, DNA (deoxyribonucleic acid) and RNA (ribonucleic acid) reveal the underlying design of creation. Because of the recent switch to DNA and RNA, biological classification is the subject of ongoing debate and proposed changes. Classification is in a state of flux and will remain so for many years. The discussion in this book follows the most settled form of classification, the five-kingdom system, proposed in 1968, which has become a popular standard and is still used by many biologists. The nomenclature uses the English equivalent of Latin terms whenever they are similar.

Chapter 1

The Hidden Kingdom

Classification is the process of grouping objects based on their similarities. For most of history, biologists organized the living world into two kingdoms of plants and animals. Grouping living things into either plant kingdom or the animal kingdom made their work easier. Biologists could easily grasp the broad design of living organisms.

Biologists put into the plant kingdom life that can make food from nonliving material. Chlorophyll (KLOR-uh-fil) is a chemical that gives plants their green color. Plants use chlorophyll and the energy of sunlight to combine water and carbon dioxide to make simple sugars. The process is called photosynthesis (foh-toh-SIN-thuh-siss). Plants use the sugar for growth and to supply energy for building other chemicals, such as cellulose, which makes their cell walls.

Explore

1. **What were the first two categories of living things?**
2. **Why were mushrooms difficult to classify as plants?**
3. **What classification did scientists give to mushrooms?**

Progress

A variety of woodland mushrooms

Biologists put into the animal kingdom forms of life that have sense organs to detect what is around them. Most animals can see and hear. They have a nervous system to interpret what they sense and react to the presence of food or danger. They can move about. Animals cannot make food directly from nonliving minerals. Instead, they must eat plants or other animals.

Biological classification is a system developed by biologists based on their studies and opinions. Once an idea has been accepted for a long time, scientists are reluctant to make changes. From the time of the ancient Greeks — about 400 B.C. — the entire living world was considered made of either plants or animals. But some forms of life, such as mushrooms, did not easily fall into either category.

Although mushrooms looked like plants in some ways, they differ from plants in other ways. The greatest difference was that mushrooms did not have chlorophyll. Mushrooms did not need light. They could live quite well in dark caves, provided they had a source of dead plant or animal matter.

To preserve the two-kingdom classification system, most biologists stubbornly kept mushrooms in the plant kingdom. They insisted upon describing mushrooms as plants without chlorophyll.

The word *mushroom* comes from a French word meaning "moss" or "foam." It is a good choice, because mushrooms are light and airy. Since ancient times, mushrooms have been added to foods to give them a distinctive texture or pleasing taste.

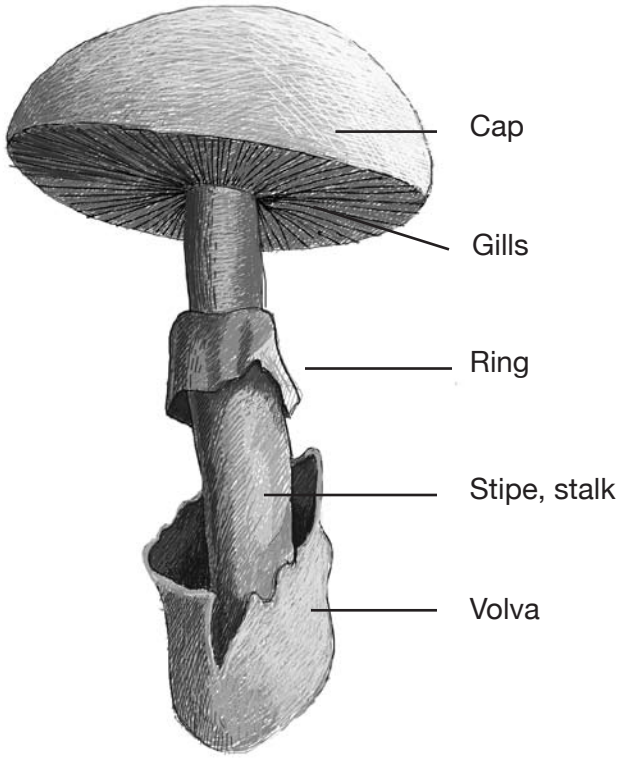
However, scientists did not study mushrooms in detail until the 1700s. They knew that plants had cell walls made of strong cellulose. This gave the cell strength and allowed plants, such as trees, to grow tall despite their immense weight. But study showed mushrooms did not have cellulose.

Biologists discovered that mushroom cell walls were more like those of animals than plants. In addition, mushrooms, like animals, absorbed nutrients from other plants and animals. But biologists could not group mushrooms with animals. Mushrooms had no sense organs, no nervous systems, and no way to move about.

Mushrooms were members of a larger group of similar organisms known as fungi (FUHNG-gye). The singular of fungi is fungus (FUHN-guhss). As biologists learned more about mushrooms, they realized that mushrooms and other fungi did not fit well in either the plant or animal kingdoms.

By the 1960s, biologists agreed that fungi needed a kingdom of their own. They created kingdom Fungi. Into the fungi kingdom they put mushrooms, puffballs, yeasts, molds, mildews, and truffles. The word *fungi* comes from

Basic Structure of a Mushroom



a Greek word meaning "sponge." The best-known types of fungi include the yeast that makes bread rise, molds that grow on the surface of fruit and cause it to spoil, and mushrooms.

The stalk and umbrella-shaped cap of a mushroom that we see above ground is only a small part of the entire mushroom. The main body of a mushroom is underground. It is made of a huge network of fine, rootlike threads called hyphae (HIGH-fee). The word *hyphae* is from a Greek word meaning "web." The web, or mat, of hyphae provides food for the mushroom.

Fungi do not make their own food as plants do. Nor do they ingest food as animals do. Instead, hyphae release enzymes (EN-zimes) around dead plant or animal matter. Enzymes are chemicals that hasten chemical reactions. Fungi enzymes break down complex compounds into simpler ones and change them into a liquid. Once nutrients become liquid, they are absorbed through thin cell walls of fungi. The underground part of the mushroom expands outward in search of more food. The center of the mat of hyphae dies as food is consumed.

As the hyphae grow, they send up mushrooms that are visible above ground. The mushrooms form a circle along the edge of the expanding mat of living hyphae. In the center, where the food is exhausted, no mushrooms grow, and a ring of mushrooms forms. An average-size ring of mushrooms can be a yard or so across. But with the right growing conditions and abundant food, mushroom rings can be traced out in a giant circle nearly a quarter of a mile across. In a large, grassy field, a single underground mushroom mat can cover as much as 30 acres. The mat of hyphae and the mushrooms it sends to the surface can be one of the largest living things on earth.

This puffball is releasing spores, which are so tiny and numerous they appear to form a cloud.

The above-ground stalk and umbrella — what we usually think of as a mushroom — is a spore case. Spores are one of the ways that mushrooms reproduce. A spore is a tough bit of living matter that can go a long time without water or warmth. Spores grow in the caplike top of mushrooms.

Most mushroom caps have small slits, called gills, on the bottom that release the spores. However, puffball mushrooms have no gills but grow spores inside the ball. The puffball is the champion at releasing spores. Scientists estimate that a single puffball may contain a thousand million of the nearly invisible spores. Millions are released if a person or animal steps on the puffball. Even the pressure of a single raindrop falling on a ripe puffball sends out a cloud of spores.

Spores are lightweight and drift along on air currents. Of the millions released, only a few find the right growing conditions. However, a single spore can grow into a new individual.

Although some mushrooms are good to eat, the actual nutritional value of mushrooms is slight. A bowl of mushrooms has only about 40 calories of food energy. Instead, mushrooms are used to give flavor and texture to other foods.

But most mushrooms do not make good food. They have a bad odor, a tough texture, or disagreeable taste. Others may be all right to eat when fresh, but like other foods, they cause an upset stomach if eaten after they spoil.

A few mushrooms are definitely poisonous. The death cap is the most dangerous. It contains a toxin that causes the stomach lining to dissolve. It destroys the liver and kidneys. About half the people who eat death cap die within 24 hours.

Some people use the name toadstools for poisonous mushrooms. However, this has no scientific basis. Mushrooms and toadstools have no physical differences. Toadstools have no visible feature that warns a person they are poisonous. Unless a person can identify a mushroom exactly, the only mushrooms safe to eat are those grown commercially.

Mushrooms for sale in grocery stores are grown in caves, dark cellars, or special barns. The mushrooms grow in beds of rotted manure and straw covered by a layer of soil. Eatable mushrooms are harvested and taken to market while still fresh.

Some types of mushrooms and edible fungi are difficult to grow commercially. Truffles, for instance, are the most highly prized of the edible fungi. But they are so difficult to grow that most are harvested in the wild. They grow underground. They have a distinctive odor. Some people can smell where they are growing beneath the soil. But most truffle hunters use dogs or pigs that have been trained to sniff them out. Pigs not only find the truffles but can also dig them with their strong snouts.

Even if mushrooms are not used for food, they have been given an important role in nature. They help break down dead trees and other plant life and return nutrients to the soil.

Yeasts are fungi too, but they are made of a single cell. Unlike mushrooms, they are invisible to the unaided eye and can only be seen with a microscope. For almost 200 years after the invention of the microscope, most scientists ignored single-celled life. They thought microscopic life could not affect larger forms of life. Louis Pasteur proved otherwise.

Louis Pasteur, the French scientist, was the first person to understand the true nature of yeast. Louis Pasteur is well known today for his many important scientific discoveries. But in 1854 he was a struggling young science teacher.

A businessman came to Louis with a problem. "I produce alcohol from beet root sugar," the man said. "Something is going wrong. The alcohol

turns sour and useless. Will you investigate the matter?"

Louis agreed to help the businessman. He learned all he could about fermentation (fur-ment-tay-shun), the process that changes beet sugar to alcohol. He knew that fermentation was an important process. People have used the natural process of fermentation since ancient times. One type of fermentation changed milk to cheese. Another type changed flour into light and tasty bread. Fermentation could also be a nuisance by changing fresh milk into sour milk and sweet grape juice into sour vinegar.

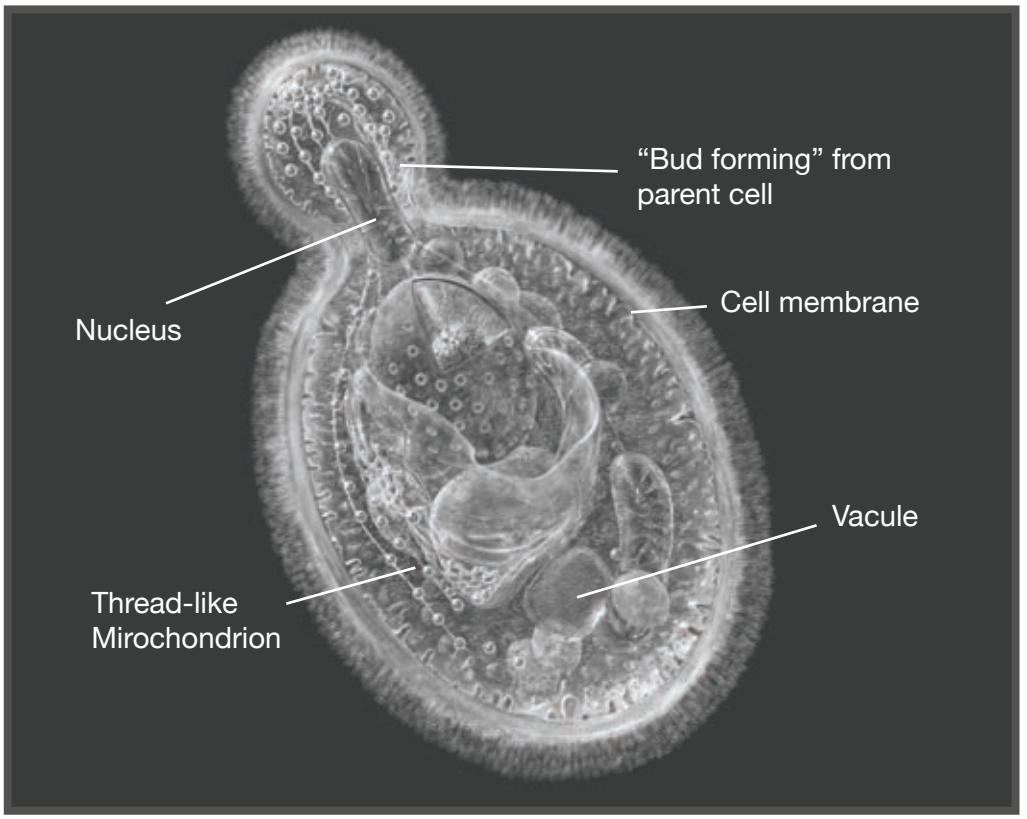
People used brewer's yeast to make alcohol and baker's yeast to change flour to bread. Yet no one understood how yeast worked. Chemists believed yeast to be nothing more than a complex chemical substance. Most said, "Fermentation is purely a chemical process." Chemists wrote this in textbooks and taught it in classrooms.

Truffles are edible fungi that grow underground.

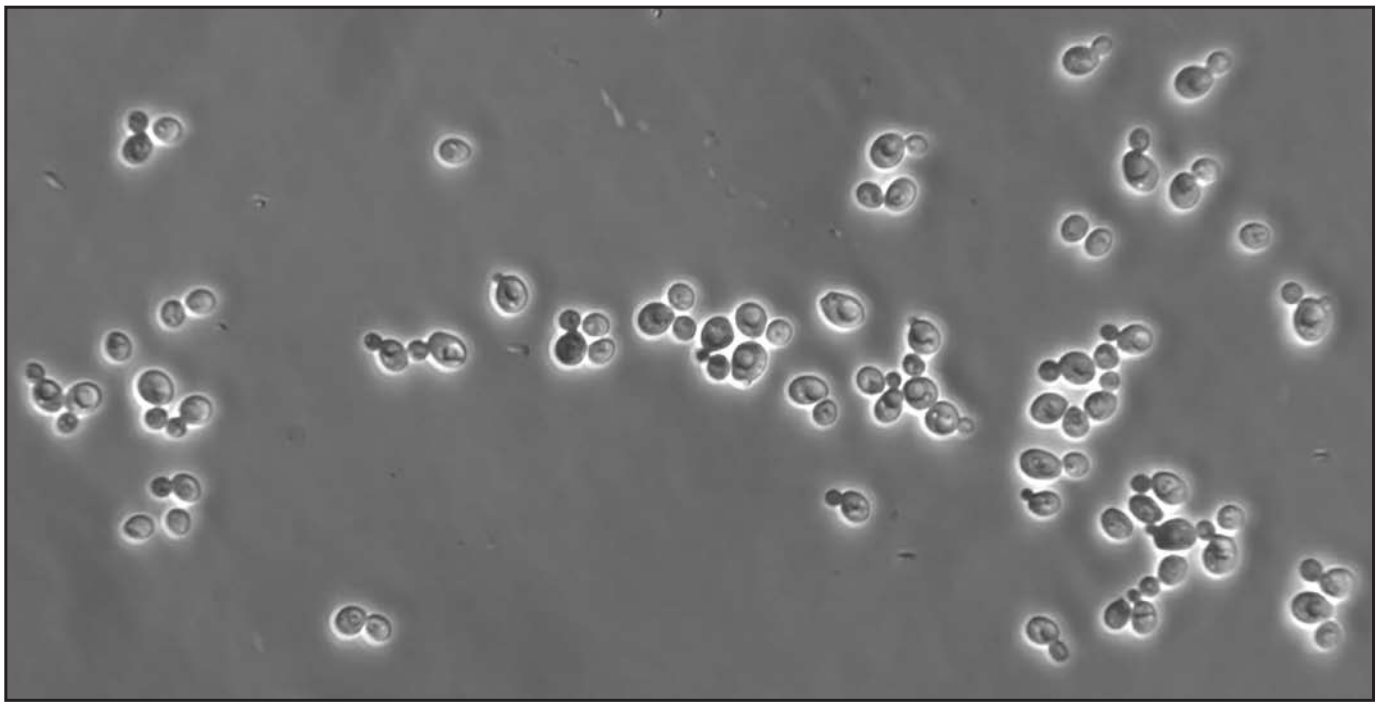
Louis Pasteur collected samples of beet juice at various stages of its manufacture: at its start, when well underway, and at its completion. He took samples of the good juice and of the bad. He peered for hours at samples of beet juice through a simple student's microscope.

Almost at once he saw ball-like yeast cells in the liquid from the good samples. He noticed that a drop of beet juice swarmed with yeast cells. As he watched, a yeast cell sprouted a bud that grew larger. Then it broke away from the parent cell. Pasteur saw that yeast grew and reproduced by budding. A small bud formed on the surface of a parent cell. The daughter cell enlarged, matured, and detached from the parent.

Reproduction from a single parent is asexual reproduction. In asexual reproduction, genetic material comes from only



Yeast grow and reproduce by budding.



Photomicrograph of the yeast form *Candida albicans*, a disease-causing fungus.

one parent. The daughter cell of yeast is identical to the parent cell.

"The yeast cells are alive," Louis whispered. "They grow. They multiply."

Pasteur proved that yeast cells were living things. Until Louis investigated, scientists did not know that yeast was alive, nor did they know that tiny living cells could change sugar into alcohol. Louis showed that yeast cells consume sugar as food and change it into carbon dioxide and alcohol.

Fermentation of beet juice produced carbon dioxide gas and alcohol. Louis could tell how well fermentation was going by how much carbon dioxide gas bubbled to the surface. Fermentation took place most rapidly while the beet juice teemed with ball-like yeast cells. Fermentation stopped when yeast died.

He compared the good juice with the bad. In juice from the spoiled vats, he found only a few ball-like yeast cells. Instead, a vast number of rod-shaped cells grew all through the sour beet juice. Now he knew the reason for spoiled juice. Two types of microscopic life lived in the juice and competed with one another. If the yeast won, then the juice remained good. If rodlike microorganisms prevailed, they changed sugar and even alcohol into lactic acid, which is sour.

He explained his discovery to the businessman. "It's like a war between two types of microscopic organisms that grow in the beet juice. Round cells change sugar into alcohol. When rodlike microorganisms take control, they produce lactic acid instead of alcohol."

Louis Pasteur showed that as yeast received their nutrition, they changed complex chemicals into simpler substances. For instance, yeast changed the carbohydrates of flour into alcohol and carbon dioxide. Yeast caused bread to rise by releasing carbon dioxide gas. The gas produced

Pasteurization

One morning as Louis Pasteur's wife fixed breakfast, she drew back in distaste as she sniffed the milk. "The milk has spoiled."

"Why does milk sour?" Louis wondered. He had found that microscopic life forms could cause beet sugar to become sour. "Could tiny microorganisms be the cause in milk, too?"

Louis studied how the milk soured. As he suspected, he found tiny microorganisms that flourished when the milk turned bad. He could see them budding and multiplying.

Louis told his wife, "I have found the cause, but now I must learn how to prevent the milk from spoiling."

Louis knew that microorganisms grew when the conditions were right for them. After a series of experiments, he learned that gentle heating of the milk destroyed the tiny life. Yet the milk still stayed fresh and tasted the same.

The process became know as pasteurization. It could be used to preserve countless perishable beverages and foods, including milk, cider, and cheese. Pasteurization became a household word. Louis Pasteur became famous around the world.

"Pasteurization will make you a wealthy man," his friends assured him. As a schoolteacher and part-time scientist, he had a meager income. Would this discovery be the end of his financial worries?

"No," Louis decided. "I became a scientist to bring science to the benefit of mankind. I will give the discovery to the public."

Louis based his decision upon the teachings of Jesus. He believed he had a duty to help those in need. Pasteurization turned out to be an important advance in the history of science. Yet Louis Pasteur made not a cent from the discovery.

Some scientists resented his success and called it mere luck. Louis Pasteur replied promptly, "Luck favors the prepared mind."

One way he prepared his mind was with Bible study and prayer. Louis often spoke to his family about the importance of Christian faith. In letters to his sisters, he told how he read the New Testament to let its simple truths guide his life. He encouraged them to pray for one another.

Despite his long hours of research, Louis continued to teach and train young people. He told his students, "I say to each of you, do not let yourself be tainted by that spirit of disbelief which likes to belittle everything.

"Say to yourself first of all: 'What have I done to educate myself?' Then, as you advance further, ask yourself, 'What have I done for my country?'

"But whatever happens, whether your work succeeds or fails in the test of life, the most important thing of all, as one approaches the end, is to be able to say, 'I have done what I could.' "

Louis' study of science helped him admire and worship God. Louis said, "The more I study nature, the more I stand amazed at the work of the Creator. Into His tiniest creatures, God has placed extraordinary properties."

tiny pockets in the dough. The alcohol in bread was driven off as it was baked. The alcohol gave baking bread a pleasant aroma.

Louis Pasteur was the first scientist to call attention to the power of microscopic creatures. He proved that germs could cause infection and disease in animals and even in humans. He said, "The role of the infinitely small in nature is infinitely great."

Molds, like mushrooms and yeast, are also members of the fungi kingdom. Although small, molds are just visible to the unaided eye. They grow on bread that is moist and warm. Bread molds viewed through a magnifying glass appear similar to miniature mushrooms. Molds appear as small balls on tiny stalks. They have threadlike structures that cover the surface of the food and extend below the surface.

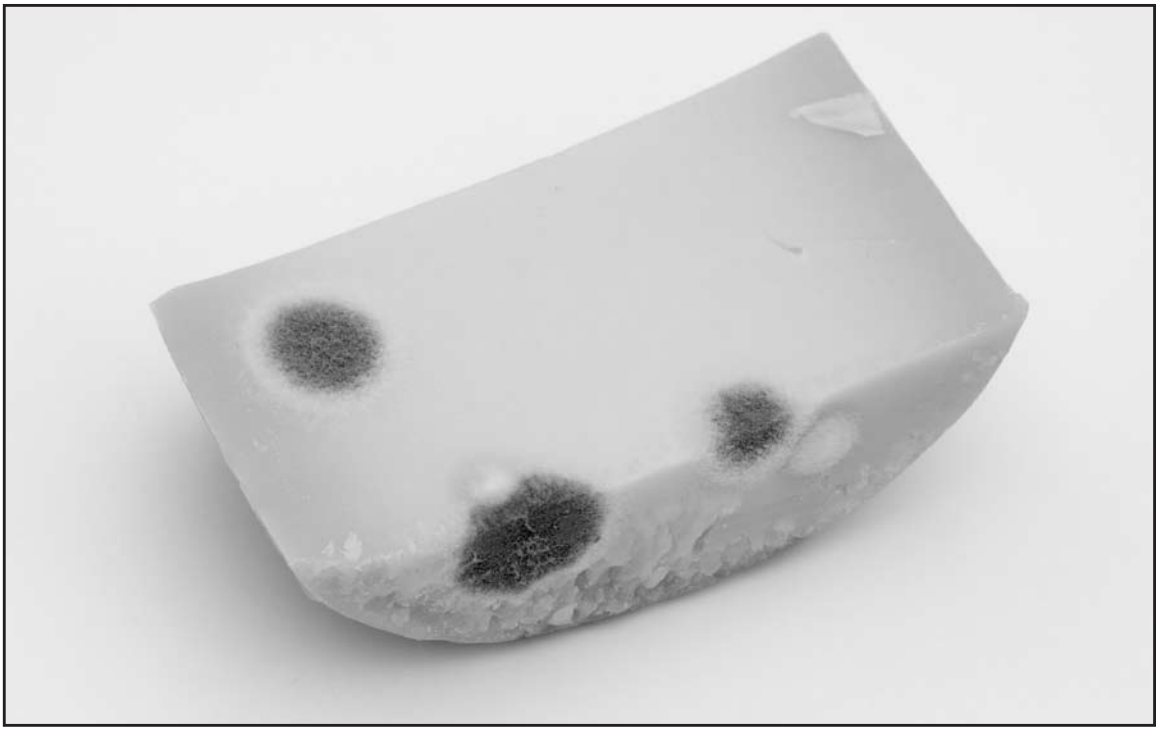
In humid climates, molds grow on any surface that is made of something that was once alive; that is, an organic (or-GAN-ik) substance. An organic substance is one that comes from a living source. Molds grow on clothes made of cotton and on shoes and purses made of leather. They also grow on food, especially fruits that have high sugar content. As molds digest sugar, fruit becomes soft and mushy.

Molds, like mushrooms, reproduce by spores. Molds have a knoblike spore case at the top of a stalk. After the knob becomes ripe, it breaks open and releases spores. Airborne spores fall upon organic material and begin growing. If spores fall on cotton, leather, or anything else from a plant or animal, they can begin growing, especially in a warm and humid climate.

Molds cause bread to spoil. Mold needs moisture to thrive. In the past, bread was toasted to make it crusty all the way through. Even today, the hard, dry crust of bread slows mold from taking hold.

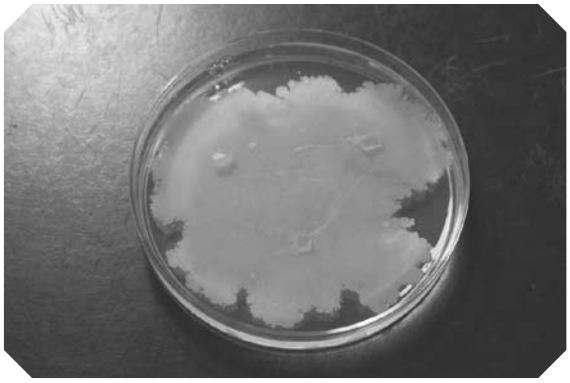
Although not always poisonous, some mold makes food taste bad. On the other hand, humans eat some types of mold as food. Roquefort cheese contains a blue-green mold that gives it a sharp flavor.

Penicillium (pen-uh-SIL-e-uhm) mold is another example of a useful mold. It produces penicil-



Mold on cheese

Alexander Fleming



Petri dish with bacteria colony growing in it.

Alexander Fleming, a British medical researcher, discovered penicillin. He worked at St. Mary's Hospital in London, England. During the warm days of September 1928, Fleming raised the laboratory windows.

Alexander Fleming experimented with Staphylococcus (staff-i-low-COCK-us) bacteria that cause boils and other infections in humans. Staph infections could be deadly. He grew the bacteria in circular, flat dishes designed to hold a jellylike food for growing bacteria.

One day he noticed a bluish mold growing in one of the dishes. A mold spore had probably floated in through the open window from outside and begun growing as opportunity provided.

Fleming examined the border of the mold. *That's funny*, he thought. *Yellow colonies of bacteria should be growing all around the mold*. Instead, the staph bacteria had been dissolved by the mold or something the mold released.

He transferred a bit of the mold to nutritive soup. Within days, the mold covered the surface of the Petri dish. Fleming drew off a bright yellow liquid released by the mold. He found that the golden liquid alone would kill staph bacteria. Fleming diluted it a thousand times in water. Even in the dilute form, it proved to be a powerful germ killer. It killed not only Staphylococcus, but also several other types of bacteria.

Apparently in its competition with bacteria for the same food, molds release chemicals that kill bacteria and eliminate the competition.

Fleming gave the name penicillin (PEN-ah-sil-in) to the active agent released by the mold. Tests showed that the penicillin produced by the mold would kill germs but not damage human cells. Penicillin came into widespread use during World War II. Since then, several other molds have been found with the ability to destroy bacteria that cause diseases.

Fleming's keen observation overcame primitive conditions in a poorly equipped laboratory to make the most important disease-fighting discovery of the last 100 years.

lin, a powerful treatment to fight bacteria that cause infections. Because penicillin kills bacteria, it is called an antibiotic drug. The word *antibiotic* comes from *anti*, meaning "against," and *bio*, meaning "life." In this case, the life that penicillin acts against is small bacteria.

Bacteria are tiny, one-celled creatures even smaller than fungi. Bacteria are not members of the fungi kingdom, but many of them do compete with fungi for the same food.

Discovery

1. **Early scientists classified all livings things as plants or animals.**
2. **Mushrooms do not make food by photosynthesis.**
3. **Mushrooms are members of the Fungi kingdom.**

Questions

T F 1. For most of history, living things were classified as either plants or animals.

A B 2. Mushrooms were studied in detail by (A. the Greeks in 400 B.C. B. scientists in the 1700s).

A B C D 3. To keep mushrooms in the plant kingdom, scientists described mushrooms as plants without (A. cell walls B. chlorophyll C. seeds D. sunlight).

A B C D 4. Today, biologists classify mushrooms as members of the (A. animal kingdom B. bacteria kingdom C. fungi kingdom D. plant kingdom).

T F 5. The only way mushrooms can reproduce is by sending out hyphae.

T F 6. The mat of hyphae and the mushrooms it sends to the surface can be one of the largest living things on earth.

A B C D 7. The above-ground stalk and umbrella of a mushroom is used to (A. absorb carbon dioxide B. catch sunlight C. release spores D. sense the presence of enemies).

A B 8. Pigs are used to hunt for (A. truffles B. death cap mushrooms).

A B 9. Louis Pasteur realized yeast cells were alive when he saw them (A. cause milk to sour B. grow and reproduce).

A B C D 10. What do yeast cells consume as food? (A. alcohol B. carbon dioxide C. sugar D. vinegar).

A B C D 11. Fungi that are growing on bread and are just visible to the unaided eye and look like miniature mushrooms are most likely: (A. lichen B. mold C. truffle D. yeast)

A B 12. The mold that grew in Alexander Fleming's dish was there because (A. he was experimenting with bread mold B. it probably drifted in through an open window.)

Explore More:

Explore More is an opportunity to explore the subject in your own way. Take a photograph, draw a picture, collect a sample, make a poster, write a poem about the subject, list the pros or cons as to whether the subject is helpful or harmful, or interview a person who has experience with the subject. For example, interview a person who has had pneumonia. How did the doctors treat the disease? Have you ever eaten Roquefort cheese? How would you describe its taste?

Subjects for more exploration:

lichen, rust (plant disease), mildew, Dutch elm disease, Roquefort cheese, pneumonia, penicillin-resistant diseases