MICROBES
in Sickness and in Health

NATIONAL INSTITUTE OF ALLERGY AND INFECTIOUS DISEASES
NATIONAL INSTITUTES OF HEALTH

Front cover photo: *Bordetella pertussis* bacteria

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U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
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Contents

What Are Microbes?

Microbes are tiny **organisms**—too tiny to see without a microscope, yet they are abundant on Earth. They live everywhere—in air, soil, rock, and water. Some of them live happily in searing heat, and others in freezing cold. Like humans, some microbes need oxygen to live, but others cannot exist with it. These **microscopic** organisms are in plants, animals, and in the human body.

Some microbes cause **disease** in humans, plants, and animals. Others are essential for a healthy life, and we could not exist without them. Indeed, the relationship between microbes and humans is very delicate and complex. In this booklet, we will learn that some microbes keep us healthy while others can make us sick.

Most microbes belong to one of four major groups: bacteria, viruses, fungi, or protozoa. A familiar, often-used word for microbes that cause disease is "germs." Some people refer to disease-causing microbes as "bugs." "I've got the flu bug," for example, is a phrase you may hear during the wintertime to describe an influenza virus **infection**.

Since the 19th century, we have known microbes cause **infectious diseases**. Near the end of the 20th century, researchers began to learn that microbes also contribute to many chronic diseases and conditions. Mounting scientific evidence strongly links them to some forms of cancer, coronary artery disease, diabetes, multiple sclerosis, autism, and chronic lung diseases.

Note: Words in bold are defined in the glossary at the end of this booklet.

BACTERIA

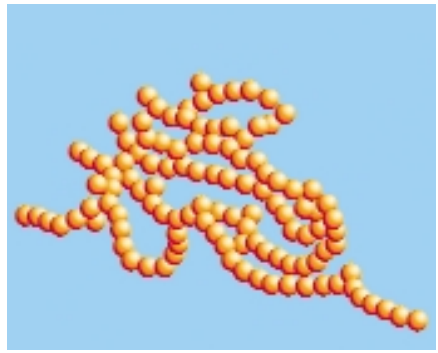
Microbes belonging to the **bacteria** group are made up of only one **cell**. Under a microscope, bacteria look like balls, rods, or spirals. Bacteria are so small that a line of 1,000 could fit across the eraser of a pencil. Life in any form on Earth could not exist without these tiny cells.

Scientists have discovered fossilized remains of bacteria that date back more than 3.5 million years, placing them among the oldest living things on Earth. Bacteria inhabit a variety of environments. Psychrophiles, or cold-loving bacteria, can live in the subfreezing temperature of the Arctic. Thermophiles are heat-loving bacteria that can live in extreme heat, such as in the hot springs in Yellowstone National Park. Extreme thermophiles, or hyperthermophiles, thrive at 235 degrees Fahrenheit near volcanic vents on the ocean floor. Many bacteria prefer the milder temperature of the healthy human body.

Like humans, some bacteria (aerobic bacteria) need oxygen to survive, but others (anaerobic bacteria) do not. Amazingly, some can adapt to new environments by learning to survive with or without oxygen.

Like all living cells, each bacterium requires food for energy and building materials. There are countless numbers of bacteria on Earth—most are harmless and many are even beneficial to humans. In fact, less than 1 percent of them cause diseases in humans. For example, harmless anaerobic bacteria, such as *Lactobacilli acidophilus*, live in human intestines, where they help to digest food, destroy disease-causing microbes, fight cancer cells, and give the body needed vitamins. Healthy food products, such as yogurt, sauerkraut, and cheese, are made using bacteria.

Some bacteria produce poisons called **toxins**, which also can make us sick.



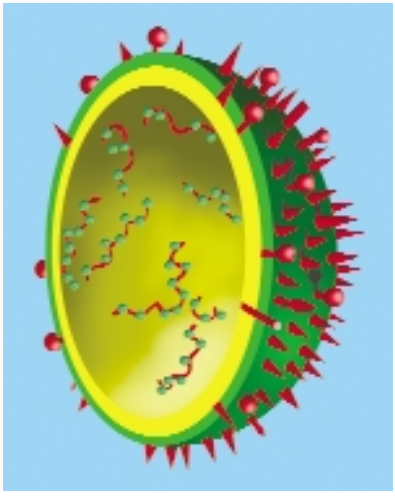
Streptococci Bacteria

ARE TOXINS ALWAYS HARMFUL?

Certain bacteria give off toxins that can seriously affect your health. Botulism, a severe form of food poisoning, affects the nerves and is caused by toxins from *Clostridium botulinum* bacteria. Under certain circumstances, however, bacterial toxins can be helpful. Several **vaccines** that protect us from getting sick are made from bacterial toxins. One type of pertussis vaccine, which protects infants and children from whooping cough, contains toxins from *Bordetella pertussis* bacteria. This vaccine is safe and effective and causes fewer reactions than other types of pertussis vaccine.

VIRUSES

Viruses are among the smallest microbes, much smaller even than bacteria. Viruses are not cells. They consist of one or more **molecules** of **DNA** or **RNA**, which contain the virus's **genes** surrounded by a protein coat. Viruses can be rod-shaped, sphere-shaped, or multisided. Some look like tadpoles.



Influenza Virus

Unlike most bacteria, most viruses do cause disease because they invade living, normal cells, such as those in the human body. They then multiply and produce other viruses like themselves. Each virus is very particular about which cell it attacks. Various human viruses specifically attack particular cells in the body's organs, systems, or **tissues**, such as the liver, respiratory system, or blood cells.

Although types of viruses behave differently, most survive by taking over the machinery that makes a cell work. Briefly, when a single virus particle, a "virion," comes in contact with a cell it likes, it may attach to special landing sites on the surface of that cell. From there, the virus may inject molecules into the cell, or the cell may swallow up the virion. Once inside the cell, viral molecules such as

DNA or RNA direct the cell to make new virus offspring. That's how a virus "infects" a cell.

Viruses can even "infect" bacteria. These viruses, called bacteriophages, may help researchers develop alternatives to **antibiotic** medicines for wiping out bacterial infections.

Many viral infections do not result in disease. For example, by the time most people in the United States become adults, they have been infected by cytomegalovirus (CMV). Most of these people, however, do not develop CMV disease symptoms. Other viral infections can result in deadly diseases, such as **HIV** infection, which causes acquired immunodeficiency syndrome (AIDS).

FUNGI

A fungus is actually a primitive vegetable. Fungi can be found in air, in soil, on plants, and in water. Thousands, perhaps millions, of different types of fungi exist on Earth. The most familiar ones to us are mushrooms, yeast, mold, and mildew. Some live in the human body, usually without causing illness. In fact, only about half of all types of fungi cause disease in humans. Those conditions are called mycoses.

Mycoses can affect your skin, nails, body hair, internal organs such as the lungs, and body systems such as the nervous system. *Aspergillus fumigatus*, for example, can cause aspergillosis, a fungal infection in the respiratory system.

Penicillin Mold Fungus

Some fungi have made our lives easier. Penicillin and other antibiotics, which kill harmful bacteria in our bodies, are made from fungi. Other fungi, like certain yeasts, also can be beneficial. For example, when a warm liquid like water and a food source are added to certain yeasts, the fungus ferments. The process of fermentation is essential for making healthy foods like some breads and cheeses.

PROTOZOA

Protozoa are a group of microscopic one-celled animals. Protozoa can be **parasites** or predators. In humans, protozoa usually cause disease. Some protozoa, like plankton, live in water environments and serve as food for marine animals, such as some species of whales. Protozoa also can be found on land in decaying matter and in soil, but they must have a moist environment to survive. Termites wouldn't be able to do such a good job of digesting wood without these **microorganisms** in their guts.

Malaria Parasite

Malaria is caused by a protozoan parasite. Another protozoan parasite, *Toxoplasma gondii*, causes toxoplasmosis in humans. This is an especially troublesome infection in pregnant women because of its effects on the fetus and in people with HIV infection or other immune deficiency.

MICROBES IN THE HEALTHY HUMAN BODY*

Ear (outer)	*Aspergillus* (fungus)
Skin	*Candida* (fungus)
Small intestine	*Clostridium*
Intestines	*Escherichia coli*
Vagina	*Gardnerella vaginalis*
Stomach	*Lactobacillus*
Urethra	*Mycobacterium*
Nose	*Staphylococcus aureus*
Eye	*Staphylococcus epidermis*
Mouth	*Streptococcus salivarius*
Large intestine	*Trichomonas hominis* (protozoa)

**A selection of usually harmless microbes, some of which help keep our bodies functioning normally. If their numbers become unbalanced, however, these microbes may make us sick. All are bacteria, unless otherwise noted.*

Microbes Have Bothered Us for Millennia

Microbes have probably always caused diseases in humans. Since ancient times, historians have documented some of those diseases, and present-day archeologists and microbiologists are discovering evidence of infectious disease in prehistoric human skeletons.

In a fascinating find in the late 20th century, researchers uncovered evidence in the mountains of northern Italy that prehistoric humans were troubled by microbial parasites and used natural remedies against them. Along with the frozen mummy of the "Ice Man," who lived between 3300 and 3100 B.C., scientists found a type of tree fungus containing oils that are toxic to intestinal parasites. Later in the laboratory, researchers found the eggs of a microscopic parasitic intestinal roundworm, *Trichuria trichiura* (whipworm), in his intestines.

Smallpox, which is caused by a variola virus, was described in ancient Egyptian and Chinese writings. According to some researchers, over the centuries smallpox was responsible for more deaths than all other infectious diseases combined. It killed millions of people over thousands

HERE ARE SOME OTHER SIGNIFICANT SCIENTIFIC EVENTS AND ADVANCES:

Around 300 B.C.

Aristotle, Greek philosopher and scientist, studied and wrote about living organisms.

1675

Antony van Leeuwenhoek discovered bacteria.

1796

Edward Jenner laid the foundation for developing vaccines.

1848

Ignác Fülöp Semmelweis discovered simple handwashing could prevent passage of infection from one patient to another.

of years before being eradicated late in the 20th century by worldwide vaccination. The last case of smallpox was recorded in 1977.

The protozoan parasite *Plasmodium* causes malaria, a tropical disease that usually is transmitted to humans during the bite of the *Anopheles* mosquito. In ancient times, this disease was mentioned in Egyptian writings called hieroglyphics and was described in detail by the Greek physician Hippocrates. Malaria ravaged invaders from the Roman Empire. Though rare in the United States, malaria remains a serious public health threat worldwide. It kills 3 million people each year, most of whom are children.

Evidence on a 1300 B.C. Egyptian stone engraving shows that poliomyelitis (polio) has been around since ancient times. In the 1990s, public health officials launched a massive international vaccination campaign to eradicate the polio virus, which causes paralysis and can be deadly. Polio has been virtually eliminated in the United States and in much of the rest of the world.

In the 14th century, a bacterium scientists later identified as *Yersinia pestis* caused the bubonic plague, or Black Death. Bubonic plague entered Europe and Africa through infected rodents and fleas that accompanied travelers along trade routes from Mongolia. The plague **epidemic** spread through Europe, Africa, and the Middle East, killing

1857

Louis Pasteur introduced the germ theory of disease.

1867

Joseph Lister showed evidence that microbes caused disease and pioneered the use of antiseptics during surgery to kill germs.

1876

Robert Koch, by studying anthrax, showed the role of bacteria in disease.

1928

Alexander Fleming is credited with discovering penicillin in 1928.

Black Death Plagued Medieval Europe

about 20 million people in Europe alone. Plague is spread to humans through the bites of fleas, which pick up the bacteria while sucking blood from rodents, especially rats. In the United States, health care workers report cases of plague even today, most of which are found in the Southwest.

Viruses caused two major **pandemics** during the 20th century. From 1918 to 1919, the influenza virus ravaged worldwide populations. Estimates of the number of people killed during the so-called "Spanish flu" pandemic range from 20 million to 40 million. HIV, which was identified in 1984, had killed 36.1 million people worldwide by the end of 2000.

Microbes Can Make Us Sick

According to health care experts, infectious diseases caused by microbes are responsible for more deaths worldwide than any other single cause. They estimate the annual cost of medical care for treating infectious diseases in the United States alone is about $120 billion.

The science of microbiology explores how microbes work and how to control them, and it seeks ways to use that knowledge to prevent and treat the diseases microbes cause. The 20th century saw an extraordinary increase in knowledge about microbes. Microbiologists (scientists who study microbes) and other researchers scored many successes in learning how microbes cause certain infectious diseases and how to combat those microbes.

COMMON DISEASES AND INFECTIONS WITH THEIR MICROBIAL CAUSES

	Bacteria	Fungus	Protozoa	Virus
Athlete's foot		▲		
Chickenpox				▲
Common cold				▲
Diarrheal disease	▲		▲	▲
Flu				▲
Genital herpes				▲
Malaria			▲	
Meningitis	▲			▲
Pneumonia	▲	▲		▲
Sinusitis	▲	▲		
Skin diseases	▲	▲	▲	▲
Strep throat	▲			
Tuberculosis	▲			
Urinary tract infection	▲			
Vaginal infections	▲	▲		
Viral hepatitis				▲

Unfortunately, microbes are much better at adapting to new environments than people are. On Earth for billions of years, microbes are constantly challenging human newcomers with ingenious new survival tactics.

- Many microbes are developing new properties to resist drug treatments that once effectively combated them. Drug resistance has become a serious problem worldwide.

- Changes in the environment have put certain human populations in contact with newly identified microbes that cause diseases never seen before or that previously occurred only in isolated populations.

- Newly emerging diseases are a growing global health concern. Since 1976, scientists have identified approximately 30 new **pathogens**.

Microbes Can Infect Us

You can get infected by germs in many different ways, including:

SOME MICROBES CAN TRAVEL THROUGH THE AIR

Microbes can be transmitted from person to person through the air, as in coughing or sneezing. These are common ways to get viruses that cause colds or flu or the bacterium that causes tuberculosis (TB). Interestingly, international airplane travel can expose passengers to germs not common in their own countries.

GERMS CAN BE PASSED DIRECTLY FROM PERSON TO PERSON

Scientists have identified more than 500 types of bacteria that live in the human mouth. Some keep the oral environment healthy, while others cause gum disease, for example. One way to transmit oral bacteria from person to person is by kissing.

Microbes such as HIV, herpes simplex virus 1, and gonorrhea bacteria are examples of germs that can be transmitted directly during sexual intercourse.

YOU CAN PICK UP AND SPREAD GERMS BY TOUCHING INFECTIOUS MATERIAL

A common way for some microbes to enter the body, especially when caring for young children, is to unintentionally pass feces on your hand to your mouth or the mouths of young children. Infant diarrhea is often spread in this way. Day care workers, for example, can pass diarrhea-causing **rotavirus** or *Giardia lamblia* (protozoa) from one baby to the next between diaper changes and other childcare practices.

It also is possible to pick up cold viruses from shaking someone's hand or from touching surfaces such as a handrail or telephone.

A HEALTHY PERSON CAN BE A GERM CARRIER AND PASS IT TO OTHERS

The story of "Typhoid Mary" is a famous example from medical history about how a person can pass germs on to others, yet not be affected by them. The germs in this case were *Salmonella typhi* bacteria, which cause typhoid fever and are usually spread through food or water.

Mary Mallon, an Irish immigrant who lived at the turn of the 19th century, worked as a cook for several New York City families. More than half of the first family she worked for came down with typhoid fever. Through a clever deduction, a researcher determined that the disease was caused by the family cook. He concluded that although Mary had no symptoms of the disease, she probably had had a mild typhoid infection sometime in the past. Though not sick, she still carried the bacteria and was able to spread them to others through the food she prepared.

GERMS FROM YOUR HOUSEHOLD PET CAN MAKE YOU SICK

You can catch a variety of germs from animals, especially household pets. The rabies virus, which can infect cats and dogs, is one of the most serious and deadly of these microbes. Fortunately, the rabies vaccine prevents animals from getting rabies. Vaccines also protect people from accidentally getting the virus from an animal and prevent people who have been exposed to the virus, such as through an animal bite, from getting sick.

SELECTED DISEASES WE CAN GET DIRECTLY OR INDIRECTLY FROM ANIMALS

- Anthrax
- Babesiosis
- Brucellosis
- Cat scratch disease
- Cryptosporidiosis
- Fascioliasis
- Giardiasis
- Hantavirus pulmonary syndrome
- Histoplasmosis
- Listeriosis
- Psittacosis
- Q fever
- Rabies
- Salmonellosis
- Toxocariasis
- Toxoplasmosis
- Trichinosis

Dog and cat saliva can contain any of more than 100 different germs that can make you sick. *Pasteurella* bacteria, the most common, can be transmitted through bites that break the skin causing serious, and sometimes fatal, diseases such as blood infections and **meningitis**.

Warm-blooded animals are not the only ones that can cause you harm. Pet reptiles such as turtles, snakes, and iguanas can transmit *Salmonella* bacteria to their unsuspecting owners.

YOU CAN GET MICROBES FROM TINY CRITTERS

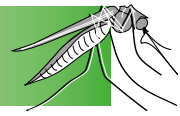
Mosquitoes may be the most common insect **carriers** (vectors) of pathogens. *Anopheles* mosquitoes can pick up *Plasmodium*, which causes malaria, from the blood of an infected person and transmit the protozoan to an uninfected person.

Fleas that pick up *Yersinia pestis* bacteria from rodents can then transmit plague to humans.

Ticks, which are more closely related to crabs than to insects, are another common vector. The tiny deer tick can infect humans with *Borrelia burgdorferi*, the bacterium that causes Lyme disease, which it picks up from deer.

MOSQUITO

Malaria • Dengue Fever
West Nile Fever • Viral Encephalitis

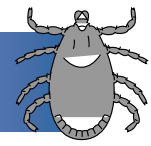


FLEA

Plague

TICK

Babesiosis • Ehrlichiosis • Lyme Disease • Relapsing Fever
Colorado Tick Fever • Rocky Mountain Spotted Fever



MICROBES IN THE FOOD YOU EAT OR WATER YOU DRINK COULD MAKE YOU SICK

Every year, millions of people worldwide become ill from eating contaminated foods. Although many cases of foodborne illness or "food poisoning" are not reported, the U.S. Centers for Disease Control and Prevention (CDC) estimates there are 76 million illnesses, 325,000 hospitalizations, and 5,200 deaths in the United States each year that are caused by foodborne bacteria. Bacteria, viruses, and protozoa can cause these illnesses, some of which can be fatal if not treated properly.

Poor manufacturing processes or poor food preparation can allow microbes to grow in food and subsequently infect you. *Escherichia coli (E. coli)* bacteria sometimes persist in food products such as undercooked hamburger meat and unpasteurized fruit juice. These bacteria can have deadly consequences in vulnerable people, especially children and the elderly.

Cryptosporidia are bacteria found in fecal matter and can get into lake, river, and ocean water from sewage spills, animal waste, and water runoff. They can be released in the millions from infectious fecal matter. People who drink, swim, or play in infected water can get sick.

People, including babies, with diarrhea caused by *Cryptosporidia* or other diarrhea-causing microbes, such as *Giardia* and *Salmonella*, can infect others while using swimming pools, waterparks, hot tubs, and spas.

TRANSPLANTED ANIMAL ORGANS MAY HARBOR GERMS

As researchers investigate the possibility of transplanting animal organs, such as pig hearts, into people, they must guard against the risk that organs also may transmit microbes that were harmless to the animal into humans, where they indeed may cause disease.

Some People Are Immune to Certain Diseases

As long ago as the 5th century B.C., Greek physicians noticed that people who had recovered from the plague would never get it again—they seemed to have become immune or resistant to the germ. People can become immune, or develop immunity, to a microbe in several ways. The first time **T cells** and **B cells** in a person's **immune system** meet up with an **antigen**, such as a virus or bacterium, they prepare the immune system to destroy the antigen. Because the immune

We become immune to germs through natural and artifical means. Before birth, we received natural immunity from our mothers. Once we are exposed to a germ, we get natural immunity from special cells in our immune systems programmed to fight off that pathogen if it invades our bodies again. Artificial immunity can come from vaccines.

system often can remember its enemies, those cells become active if they meet that particular antigen again. This is called naturally acquired immunity.

Another example of naturally acquired immunity occurs when a pregnant woman passes antibodies to her unborn baby. Babies are born with weak immune responses, but they are protected from some diseases for their first few months of life by **antibodies** received from their mothers before birth. Babies who are nursed also receive antibodies from breast milk that help protect their digestive tracts.

Immunization with vaccines is a safe way to get protection from germs. Some vaccines contain microorganisms or parts of microorganisms that have been weakened or killed. If you get this type of vaccine, those microorganisms (or their parts) will start your body's immune response, which will demolish the foreign invader but not make you sick. This is a type of artificially acquired immunity.

Immunity can be strong or weak and short- or long-lived, depending on the type of antigen, the amount of antigen, and the route by which it enters your body. When faced with the same antigen, some people's immune systems will respond forcefully, others feebly, and some not at all.

The genes you inherit also can influence your likelihood of getting a disease. In simple terms, the genes you get from your parents can influence how your body reacts to certain microbes.

Microbes Cause Different Kinds of Infections

Some disease-causing microbes can make you very sick very quickly and then not bother you again. Some can last for a long time and continue to damage tissues. Others can last forever, but you won't feel sick any more, or you will only feel sick once in a while. Most infections caused by microbes fall into three major groups:

- Acute infections
- Chronic infections
- **Latent** infections

ACUTE INFECTIONS

Acute infections usually last a short time, but they can make you feel very uncomfortable, with signs and symptoms such as tiredness, achiness, coughing, and sneezing. The common cold is such an infection. The signs and symptoms of a cold can last for 2 to 24 days (but usually a week), though it may seem like a lot longer. Once your body's immune system has successfully fought off one of the many different types of rhinoviruses that caused your cold, the cold doesn't come back. If you get another cold, it's probably because you have been infected with someone else's rhinoviruses.

CHRONIC INFECTIONS

Chronic infections usually develop from acute infections and can last for days to months to a lifetime. Sometimes, people are totally unaware they are infected but still may be able to transmit the germ to others. For example, hepatitis C, which affects the liver, is a chronic viral infection. In fact, most people who have been infected with the hepatitis C virus don't know it until they have a blood test that shows antibodies to the virus. Recovery from this infection is rare—about 85 percent of infected persons become chronic carriers of the virus. In addition, serious signs of liver damage, like cirrhosis or cancer, may not appear until as long as 20 years after the infection began.

LATENT INFECTIONS

Latent infections are "hidden" or "silent" and may or may not cause symptoms again after the initial acute episode. Some infectious microbes, usually viruses, can "wake up" and become active again, sometimes off and on for months or years, and cause symptoms. When active, these microbes can be transmitted to other people. Herpes simplex viruses, which cause genital herpes and common cold sores, can remain latent in nerve cells for short or long periods of time, or forever.

Chickenpox is another example of a latent infection. Before the chickenpox vaccine became available in the 1990s, most children in the United States got chickenpox. After the first acute episode, usually when children are very young, the *Varicella zoster* virus goes into hiding in the body. In many people, it emerges many years later when they are older adults and causes a painful disease of the nerves called herpes zoster, or shingles.

Researchers are studying what turns these microbial antics off and on and are looking for ways to finally stop the process.

DIFFERENCE BETWEEN INFECTION AND DISEASE

A *disease* occurs when cells or molecules in a person's body stop working properly, causing symptoms of illness. Many things can cause a disease, including altered genes, chemicals, aging, and infections. An *infection* occurs when another organism—such as a virus, bacterium, or parasite—enters a person's body and begins to reproduce. The invading microbe can directly damage cells, or the immune system can cause disease symptoms, such as fever, as it tries to rid the body of the invader. Some infections do not cause disease because the microbe is quickly killed or it hides out where it cannot be detected.

You Can Prevent Catching or Passing on Germs

HANDWASHING

Handwashing is one of the simplest, easiest, and most effective ways to prevent getting or passing on many germs. Amazingly, it is also one of the most overlooked. Health care experts recommend scrubbing your hands vigorously for at least 15 seconds with soap and water, about as long as it takes to recite the English alphabet. This will wash away cold viruses and staph and strep bacteria as well as many other disease-causing microbes. This also will help prevent accidentally passing those germs on to others.

It is especially important to wash your hands:

- Before preparing or eating food
- After coughing or sneezing
- After changing a diaper
- After using the bathroom

Health care providers should be especially conscientious about washing their hands before and after examining any patient. Day care workers, too, should be vigilant about handwashing around their young children.

MEDICINES

There are medicines on the market that help prevent people from getting infected by germs. For example, you can prevent getting the flu by taking a medicine such as Tamiflu, Flumadine, or Symmetrel. Vaccines, however, are the best defense against influenza viruses. Under specific circumstances, doctors may prescribe antibiotics to protect patients from getting certain bacteria such as *Mycobacterium tuberculosis*,which causes TB. Health care experts usually advise people traveling to areas where malaria is present to take antiparasitic medicines to prevent possible infection.

VACCINES

Edward Jenner laid the foundation for modern vaccines by discovering one of the basic principles of immunization. He had used a relatively harmless microbe, cowpox virus, to bring about an immune response that would help protect people from getting infected by the related but deadly smallpox virus.

Dr. Jenner's discovery helped researchers find ways to ease human disease suffering worldwide. By the beginning of the 20th century, doctors were immunizing patients with vaccines for diphtheria, typhoid fever, and smallpox.

Today, safe and effective vaccines prevent childhood diseases, including measles, whooping cough, chickenpox, and meningitis caused by *Haemophilus influenzae* type B (Hib).

Vaccines are not only for young children. Adolescents and adults should get vaccinated regularly for tetanus and diphtheria. In addition, adults who never had diseases such as measles or chickenpox during childhood or who never received vaccines to prevent them should consider being immunized. Childhood diseases can be far more serious in adults.

More people travel all over the world today. So, finding out which immunizations are recommended for travel to your destination(s) is even more important than ever. Vaccines also can prevent yellow fever, polio, typhoid fever, hepatitis A, cholera, rabies, and other bacterial and viral diseases that are more prevalent abroad than in the United States.

In the fall of the year, many adults and children may benefit from getting the flu vaccine. A doctor also may recommend immunizations for pneumococcal pneumonia and hepatitis B for people at risk of getting these diseases.

SOME VACCINE-PREVENTABLE INFECTIOUS DISEASES

- Anthrax
- Bacterial meningitis
- Chickenpox
- Cholera
- Diphtheria
- *Haemophilus influenzae* type B
- Hepatitis A
- Hepatitis B
- Influenza (Flu)
- Measles
- Mumps
- Pertussis
- Pneumococcal pneumonia
- Polio
- Rabies
- Rubella
- Tetanus
- Yellow fever

When You Should Go to the Doctor

YOU SHOULD CALL A DOCTOR IMMEDIATELY IF....

- You have been bitten by an animal
- You are having difficulty breathing
- You have a cough that has lasted for more than a week
- You have a fever of 100 degrees Fahrenheit or higher
- You have episodes of rapid heartbeat
- You have a rash (especially if you have a fever at the same time)
- You have swelling
- You suddenly start having difficulty with seeing (for example, your vision is blurry)
- You have been vomiting

Generally, you should consult a doctor or other health care professional if you have or think you may have contracted an infectious disease. These trained professionals can determine whether you have been infected, determine the seriousness of your infection, and give you the best advice for treating or preventing disease. Sometimes, however, a visit to the doctor may not be necessary.

Some infectious diseases, such as the common cold, usually do not require a visit to the doctor. They often last a short time and are not life-threatening, or there is no specific treatment. We've all heard the advice to rest and drink plenty of liquids to treat colds. Unless there are complications, most victims of colds find their immune systems successfully ward off the viral culprits. In fact, the coughing, sneezing, and fever that make you feel miserable are part of your immune system's way of fighting them off.

If, however, you have other conditions in which your immune system doesn't function properly, you should be in contact with your doctor whenever you suspect you have any infectious disease, even the common cold. Such conditions can include asthma and immunodeficiency diseases like HIV infection and AIDS.

In addition, some common, usually mild infectious diseases, such as chickenpox or flu, can cause serious harm in very young children or the elderly.

Infectious Diseases Are Diagnosed in Many Ways

Sometimes a doctor or other health care professional can diagnose an infectious disease by listening to your medical history and doing a physical exam. For example, listening to a patient describe what happened and any symptoms they have noticed plays an important part in helping a doctor find out what's wrong.

Blood and urine tests are other ways to diagnose an infection. A laboratory expert can sometimes see the offending microbe in a sample of blood or urine viewed under a microscope. One or both of these tests may be the only way to determine what caused the infection, or they may be used to confirm a diagnosis that was made based on taking a history and doing a physical exam.

In another type of test, a doctor will take a sample of blood or other body fluid, such as vaginal secretion, and then put it into a special container called a Petri dish to see if any microbe "grows." This test is called a culture. Certain bacteria, such as chlamydia and strep, and viruses, such as herpes simplex, usually can be identified using this method.

X-rays, scans, and biopsies (taking a tiny sample of tissue from the infected area and inspecting it under a microscope) are among other tools the doctor can use to make an accurate diagnosis.

All of the above procedures are relatively safe, and some can be done in a doctor's office or a clinic. Others pose a higher risk to patients because they involve procedures that go inside the body. One such invasive procedure is taking a biopsy from an internal organ. For example, one way a doctor can diagnose *Pneumocystis carinii* pneumonia, a lung disease caused by a fungus, is by doing a biopsy on lung tissue and then examining the sample under a microscope.

Infectious Diseases Are Treated in Many Ways

How an infectious disease is treated depends on the microbe that caused it and sometimes on the age and medical condition of the person affected. Certain diseases are not treated at all, but are allowed to run their course, with the immune system doing its job alone. Some diseases, such as the common cold, are treated only to relieve the symptoms. Others, such as strep throat, are treated to destroy the offending microbe as well as to relieve symptoms.

BY YOUR IMMUNE SYSTEM

Your immune system has an arsenal of ways to fight off invading microbes. Most begin with B and T cells and antibodies whose sole purpose it is to keep your body healthy. Some of these cells sacrifice their lives to rid you of disease and restore your body to a healthy state. Some microbes normally present in your body also help destroy microbial invaders. For example, normal bacteria in your digestive system help destroy disease-causing microbes, such as listeria in that hot dog you had at lunch.

Other important ways your body reacts to an infection include fever and coughing and sneezing.

Fever
Fever is one of your body's special ways of fighting an infection. Many microbes are very sensitive to temperature changes and cannot survive in temperatures higher than normal body heat, which is usually around 98.6 degrees Fahrenheit. Your body uses fever to destroy flu viruses, for example.

Coughing and sneezing
Another piece in your immune system's reaction to invading infection-causing microbes is mucus production. Coughing and sneezing help mucus move those germs out of your body efficiently and quickly.

Other methods your body may use to fight off an infection include:

- **Inflammation**
- Vomiting
- Diarrhea
- Fatigue
- Cramping

BY YOUR DOCTOR

For bacteria

The last century saw an explosion in our knowledge about how microbes work and in our methods of treating infectious diseases. For example, the discovery of antibiotics to treat and cure many bacterial diseases was a major breakthrough in medical history.

Doctors, however, sometimes prescribe antibiotics unnecessarily for a variety of reasons, including pressure from patients with viral infections. Patients may insist on being prescribed an antibiotic without knowing that it won't work on viruses. Colds and flu are two notable viral infections for which some doctors send their patients to the drugstore with a prescription for an antibiotic.

Because antibiotics have been overprescribed or inappropriately prescribed over the years, bacteria have become resistant to the killing effects of these drugs. This resistance, called antimicrobial or drug resistance, has become a very serious problem, especially in hospital settings.

Bacteria that are not killed by the antibiotic become strong enough to resist the same medicine the next time it's given. Because bacteria multiply so rapidly, changed or mutated bacteria that resist antibiotics will quickly outnumber those that can be destroyed by those same drugs.

For viruses

Viral diseases can be very difficult to treat because viruses live inside the body's cells where they are protected from medicines in the blood stream. Researchers developed the first antiviral drug in the late 20th century. The drug, acyclovir, was first approved by the U.S. Food and Drug Administration to treat herpes simplex virus infections. Only a few other antiviral medicines are available to prevent and treat viral infections and diseases.

Health care professionals treat HIV infection with a group of powerful medicines which can keep the virus in check. Known as highly active antiretroviral therapy, or HAART, the new treatment has improved the lives of many suffering from this deadly infection.

Viral diseases should *never* be treated with antibiotics. Sometimes a person with a viral disease will develop a bacterial disease as a complication of the initial viral disease. For example, children with chickenpox often scratch the skin sores caused by the viral infection. Bacteria such as staph can enter those lesions and cause a bacterial infection. The doctor may then prescribe an antibiotic to destroy the bacteria. The antibiotic, however, will not work on the chickenpox virus. It will work only against staph.

Unfortunately, safe and effective treatments and cures for most viral diseases have eluded researchers, but there are safe vaccines to protect you from viral infections and diseases.

For fungi
Medicines applied directly to the infected area are available by prescription and over the counter for treating skin and nail fungal infections. Unfortunately, many people have had limited success with them. During the 1990s, oral prescription medicines became available for treating fungal infections of the skin and nails.

For many years, very powerful oral antifungal medicines were used only to treat systemic (within the body) fungal infections, such as histoplasmosis. Doctors usually prescribe oral antifungal medications cautiously because all of them, even the milder ones for skin and nail fungi, can have very serious side effects.

For protozoa
Diseases caused by protozoan parasites are among the leading causes of death and disease in tropical and subtropical regions of the world. Developing countries within these areas contain three-quarters of the world's population, and their populations suffer the most from these diseases. Controlling parasitic diseases is a problem because there are no vaccines for any of them.

In many cases, controlling the insects that transmit these diseases is difficult because of pesticide resistance, concerns regarding environmental damage, and lack of adequate public health systems to apply existing insect-control methods. Thus, control of these diseases relies heavily on the availability of medicines.

Doctors usually use antiparasitic medicines to treat protozoal infections. Unfortunately, there are very few medicines that fight protozoal infections, and some of those are either harmful to humans or are becoming ineffective.

The fight against the protozoan *Plasmodium falciparum*, the cause of the most deadly form of malaria, is a good example. This protozoan has become resistant to most of the medicines currently available to destroy it. A major focus of malaria research is on developing a vaccine to prevent people from getting the disease. In the meantime, many worldwide programs hope to eventually control malaria by keeping people from contact with infected mosquitoes or from getting infected if contact can't be avoided.

"New" and "Old" Microbes Emerge on the Scene

Although at odds with the belief that medicine had mastered infectious diseases, the emergence of new microbes and the re-emergence of old ones are nothing new. The factors involved in this process go back centuries. For example, microbes have always traveled, like the bacteria that emerged in the 14th century to spread bubonic plague through Mongolia, Europe, and finally North Africa.

EMERGING MICROBES

From time to time, strange new disease-causing microbes seem to come out of nowhere. Scientists usually define newly emerging infectious diseases as those that have only recently appeared in a population or have existed but are rapidly increasing in incidence or geographic range. Recent examples include West Nile fever, *E. coli* infection, chronic hepatitis C, flu, hantavirus infection, and Lyme disease. Re-emerging infectious diseases, like TB, are those that were once under control.

In addition, pathogens previously not seen in the United States, like West Nile virus, may become more common here because of the increased speed of international travel and because more people are traveling.

In the early summer of 1999, cases of encephalitis (inflammation of the brain) and death began to appear in New York City. Researchers later identified West Nile virus as the cause. Prior to that time, health care experts had never seen cases of illness caused by this virus in the United States. The virus is common in Africa, West Asia, and the Middle East. Mosquitoes become infected when they feed on infected birds, which may circulate the virus in their blood for a few days. Infected mosquitoes can then transmit West Nile virus to humans and animals while biting to take blood. Every summer since it first appeared, West Nile virus has been found in a continuously increasing number of states.

Identified in 1989, the hepatitis C virus causes approximately 20 percent of all cases of acute viral liver disease each year in the United States. CDC estimates that nearly 4 million Americans are infected with hepatitis C, many of whom are not aware of their infection. Chronic liver disease due to hepatitis C causes between 8,000 and

10,000 deaths and leads to about 1,000 liver transplants each year in the United States. Over the next two decades, the number of annual deaths from hepatitis C is expected to triple if there continues to be no effective treatment.

SOME NEWLY RECOGNIZED PATHOGENS

Babesia protozoa
Bartonella henselae bacteria
Borrelia burgdorferi bacteria
Ebola virus
Ehrlichiosis bacteria
Hantaviruses
Helicobacter pylori bacteria
Hepatitis C virus
Hepatitis E virus
Human herpesvirus 6
Human herpesvirus 8
Human immunodeficiency virus
Nipah virus
Parvovirus B19

Within the past few years, many outbreaks of intestinal disease with bloody diarrhea have been reported in the United States and abroad. These outbreaks are often due to the newly pathogenic O157:H7 strain of *E. coli*, which was first recognized in 1982. Other strains of *E. coli* are common in other countries but less frequent in the United States. Approximately 10 to 15 percent of people infected with these organisms develop hemolytic uremic syndrome (HUS), a serious complication that can lead to kidney failure and death. Children and the elderly are particularly at risk for developing HUS.

Environmental changes can cause a microbe to become a health threat to humans. Lyme disease and hantavirus pulmonary syndrome are two examples.

Lyme disease emerged in 1975 in the northeastern United States as people expanded their communities into wooded areas occupied by infected deer ticks. It is the most common tickborne infection in this country, affecting people in almost every state. Although not deadly, Lyme disease can cause serious illness. In 1981, scientists identified *B. burgdorferi* bacteria as the cause of Lyme disease. From then until 1999, health care workers reported more than 128,000 cases of the disease to CDC.

In 1993, an outbreak of a mysterious, often fatal lung disease occurred in the southwestern United States. That outbreak occurred in part from weather changes like those brought about by El Niño, which fosters increases in the rodent populations that carry diseases. Scientists quickly determined the illness was caused by a previously unknown strain of hantavirus, a family of disease-causing viruses that occurs naturally in mice and other rodents. By April 2001, health care workers had reported that 283 people had developed the condition known as hantavirus pulmonary syndrome. More than a third have died from the disease.

RE-EMERGING MICROBES

The reappearance of microbes that had been successfully conquered or controlled by medicines is distressing to the scientific and medical communities as well as to the public. A major cause of this re-emergence is that microbes, which cause these diseases, are becoming resistant to the drugs used to treat them.

According to the World Health Organization (WHO), nearly 2 billion people, one-third of the world's population, have TB. This includes between 10 and 15 million people in the United States. TB is the world's leading cause of death from a single infectious organism, killing 2 million people each year. The TB crisis has intensified because multidrug-resistant (MDR) microbes have emerged. An incurable form of the disease may develop from infections caused by these organisms. WHO estimates more than 50 million people worldwide may be infected with MDR strains of TB.

Malaria, the most deadly of all tropical parasitic diseases, has been resurging dramatically. Increasing resistance of *Plasmodium* protozoa to inexpensive and effective medicines presents problems for treating active infections. WHO estimates between 300 million and 500 million new cases of malaria occur worldwide each year. At least 2.7 million people die annually. In the United States, approximately 1,000 cases are reported annually, which researchers estimate represent only 25 to 50 percent of actual cases. Although most of these cases occurred in

people who had been infected while traveling abroad, others occurred in people bitten by infected mosquitoes in states such as New York.

In the United States, approximately 25 percent of the population has flu-associated illness annually, leading to an average of 20,000 to 40,000 deaths per year. Influenza viruses change from year to year and powerful strains have re-emerged throughout history to cause worldwide, catastrophic pandemics. Many scientists believe the next pandemic is long overdue. In addition, in the 1990s, people in Hong Kong became infected with avian influenza—the first known case of an influenza virus jumping directly from birds to people.

RE-EMERGING PATHOGENS

Cholera bacteria
Coccidioides immitis fungus
E. coli bacteria
Enterovirus
Dengue virus
Group A streptococcus bacteria
Influenza virus
West Nile virus

Source: NIAID Division of Microbiology and Infectious Diseases, February 2001.

Research

The National Institute of Allergy and Infectious Diseases (NIAID), a component of the National Institutes of Health (NIH), is the Federal Government's lead agency for conducting and funding research on many infectious diseases, including their causes, diagnoses, treatments, and prevention methods. Biomedical research supported by NIAID provides the tools necessary to develop diagnostic tests, new and improved treatments, vaccines, and other means to combat the microbial threats of today and tomorrow.

NIAID's research activities include:

- Projects to sequence the whole or partial genomes of a variety of pathogenic microbes. These projects should help scientists understand how the organisms cause disease and identify new drug and vaccine targets.

- A broad malaria research program. This program is conducted by scientists at institutions throughout the United States and in several countries where malaria is endemic, and by scientists working in NIAID's laboratories in Bethesda, Maryland, and Hamilton, Montana. NIAID and other NIH components also participate in the Multilateral Initiative on Malaria, a global group that boosts international collaboration among malaria scientists and identifies resources to enhance malaria research.

- Research on the basic biology of influenza viruses and on efforts to find more effective vaccines and treatments for flu.

- Clinical trials involving several experimental HIV vaccines. NIAID scientists and grantees have been conducting these trials since 1987. In 1999, NIAID began the first HIV vaccine trial in Africa, an important step for developing global vaccines.

- The HIV Vaccine Trials Network (HVTN). HVTN is a network of domestic and international clinical research institutions. Established in 2000, HVTN conducts all phases of vaccine clinical trials.

- Emerging Virus Research Groups. NIAID supports three groups to learn more about emerging viruses. By learning how these viruses work, researchers hope to develop better ways to diagnose and treat the diseases they cause.

Institute researchers work closely with other agencies, institutions, and individuals from across the United States and around the world to achieve the common goal of controlling and eliminating infectious diseases. Information on current NIAID research activities is available at the institute Web site http://www.niaid.nih.gov.

Glossary

antibiotic—a drug used to treat some bacterial diseases.

antibodies—molecules (also called immunoglobulins) produced by a B cell in response to an antigen. When an antibody attaches to an antigen, it destroys the antigen.

antigen—a substance or molecule that is recognized by the immune system. The molecule can be from a foreign material such as bacteria or viruses.

B cells—small white blood cells crucial to the immune defenses. Also known as B lymphocytes, they come from bone marrow and develop into blood cells called plasma cells, which are the source of antibodies.

bacteria—microscopic organisms composed of a single cell and lacking a defined nucleus and membrane-enclosed internal compartment.

carriers—apparently healthy people who harbor disease-causing microbes in the body and who can infect others by passing the microbes on to them.

cell—the smallest unit of life; the basic living unit that makes up tissues.

disease—a state in which a function or part of the body is no longer in a healthy condition.

DNA (deoxyribonucleic acid)—a complex molecule found in the cell nucleus which contains an organism's genetic information.

epidemic—a disease outbreak that affects many people in a region at the same time.

genes—units of genetic material (DNA) that carry the directions a cell uses to perform a specific function.

human immunodeficiency virus (HIV)—the virus that causes AIDS.

immune system—a complex network of specialized cells, tissues, and organs that defends the body against attacks by disease-causing microbes.

immunization—vaccination or other process that induces protection (immunity) against infection or disease caused by a microbe.

infection—a state in which disease-causing microbes have invaded or multiplied in body tissues.

infectious diseases—diseases caused by microbes that can be passed to or among humans by several methods.

inflammation—an immune system process that stops the progression of disease-causing microbes, often seen at the site of an injury like a cut. Signs include redness, swelling, pain, and heat.

latent—present but not seen. A latent viral infection is one in which no virus can be found in the blood cells but in which those virus-infected cells can produce virus under certain circumstances.

meningitis–inflammation of the meninges, the membranes that surround the brain and spinal cord.

microorganisms—microscopic organisms, including bacteria, viruses, fungi, plants, and animals.

microscopic—too small to be seen with the naked eye.

molecules—the smallest physical units of a substance that still retain the chemical properties of that chemical substance; molecules are the building blocks of a cell. Some examples are proteins, fats, carbohydrates, and nucleic acids.

organisms—individual living things.

pandemics—diseases that affect many people in different regions around the world.

parasites—plants or animals that live, grow, and feed on or within another living organism.

pathogens—disease-causing organisms.

RNA (ribonucleic acid)—a complex molecule that is found in the cell cytoplasm and nucleus. One function of RNA is to direct the building of proteins.

rotavirus—a group of viruses that can cause digestive problems and diarrhea in young children.

T cells—small white blood cells (also known as T lymphocytes) that direct or directly participate in immune defenses.

tissues—groups of similar cells joined to perform the same function.

toxins—agents produced by plants and bacteria, normally very damaging to human cells.

vaccines—substances that contain parts of antigens from an infectious organism. By stimulating an immune response (but not disease), they protect the body against subsequent infection by that organism.

More Information

You can get more in-depth information on microbes and infectious diseases from a local library or a health care provider. Other sources of information include:

National Institute of Allergy and Infectious Diseases
National Institutes of Health
Building 31, Room 7A50
31 Center Drive, MSC 2520
Bethesda, MD 20892-2520
http://www.niaid.nih.gov

NIAID conducts and supports research on infectious, immunologic, and allergic diseases. The Web site has information on many of these diseases as well as links to other sources of information.

National Institutes of Health
Bethesda, MD 20892
http://www.nih.gov

NIH is the U.S. Government agency that, through its institutes and centers, conducts and supports a broad range of biomedical research. The Web site contains information on the causes, symptoms, prevention, and treatment of many diseases and conditions that affect the human body.

National Library of Medicine
8600 Rockville Pike
Bethesda, MD 20894
301-496-6308
http://www.medlineplus.gov

NLM is the largest medical library in the world. The MEDLINEplus Web site has information about hundreds of diseases, conditions, and wellness issues. It also has information about clinical research studies that are being conducted on certain diseases and conditions.

Agricultural Research Service
Department of Agriculture
5601 Sunnyside Avenue
Beltsville, MD 20705-5134
http://www.ars.usda.gov

ARS is the principal research agency of the U.S. Department of Agriculture. ARS works to expand the nation's scientific knowledge across a broad range of areas, such as food safety, that affect people every day. Although the Web site primarily has technical information for scientists, it also has materials specifically for the general public.

Centers for Disease Control and Prevention
1600 Clifton Road
Atlanta, GA 30333
1-888-232-3228
http://www.cdc.gov

Among its other duties, CDC is the U.S. Government agency charged with tracking outbreaks of infectious disease in the United States and sometimes other countries. The agency also searches for disease causes and issues guidelines for preventing and treating many of them. CDC has material on many infectious diseases as well as travel-related information such as the shots required for visiting foreign countries.

CDC National Immunization Information Program
1-800-232-2522
http://www.cdc.gov/nip/

CDC is the main U.S. Government agency that develops policy and recommendations for immunizations. This program has the most recent information on immunizations including the diseases that can be prevented by vaccines, the benefits of immunization, and the risks of immunization versus the risk of getting a disease.

Food and Drug Administration
5600 Fishers Lane
Rockville, MD 20857-0001
1-888-INFO-FDA (1-888-463-6332)
http://www.fda.gov

FDA is the U.S. Government consumer protection and regulatory agency for food and drugs. Contact this agency for information about the safety of food, medical products, medicines, and cosmetics.

World Health Organization
Avenue Appia 20
1211 Geneva 27
Switzerland
41-22-791-21-11
http://www.who.int

WHO, part of the United Nations, is devoted to improving the health of people around the world. This international organization has health and disease surveillance information in English, French, and Spanish.

NOTES

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U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
NATIONAL INSTITUTES OF HEALTH

NATIONAL INSTITUTE OF ALLERGY AND INFECTIOUS DISEASES

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