NIAID SCIENCE EDUCATION

Understanding MICROBES *in Sickness and in Health*

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
National Institutes of Health

National Institute of Allergy and Infectious Diseases

Front cover photo: *Bordetella pertussis* bacteria

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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 live happily in searing heat, while others thrive in freezing cold. Some microbes need oxygen to live, but others do not. These **microscopic** organisms are found in plants and animals as well as 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 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 common 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**.

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

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 microbes to some forms of cancer, coronary artery disease, diabetes, multiple sclerosis, and chronic lung diseases.

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 billion years, placing them among the oldest living things on Earth. Bacteria can inhabit a variety of environments, including extremely hot and cold areas.

- 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.

Streptococci Bacteria

Many bacteria prefer the milder temperature of the healthy human body.

Like humans, some bacteria (aerobic bacteria) need oxygen to survive. Others (anaerobic bacteria), however, 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 bacteria cause diseases in humans. For example, harmless anaerobic bacteria, such as *Lactobacilli acidophilus*, live in our 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.

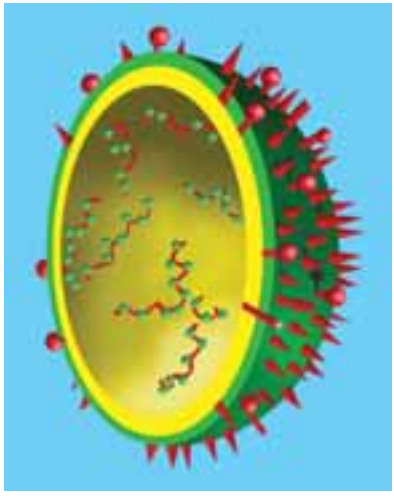
Some bacteria produce poisons called **toxins**, which also can make us sick.

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 viruses look like tadpoles.



Influenza Virus

Unlike most bacteria, most viruses do cause **disease** because they invade living, normal cells, such as those in your 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 your body's organs, systems, or **tissues**, such as the liver, respiratory system, or blood.

Although types of viruses behave differently, most survive by taking over the machinery that makes a cell work. Briefly, when a piece of a virus, called 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 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 preventing and treating 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 AIDS (acquired immunodeficiency syndrome) or Ebola hemorrhagic fever.

FUNGI

A fungus is actually a primitive plant. 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. Fungal diseases are called mycoses.

Penicillin Mold Fungus

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

Some fungi have made our lives easier. Penicillin and other antibiotics, which kill harmful bacteria in our bodies, are made from fungi. Other fungi, such as certain yeasts, also can be helpful. For example, when a warm liquid, such as 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.

MICROBES IN THE HEALTHY HUMAN BODY*

Microbes found in	
Ear (outer)	*Aspergillus* (fungus)
Skin	*Candida* (fungus)
Small intestine	*Clostridium*
Intestines	*Escherichia coli*
Vagina	*Gardnerella vaginalis*
Stomach	*Lactobacillus*
Urethra	*Mycobacterium*
Nose	*Staphylococcus aureus*
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.*

Some protozoa, like plankton, live in water environments and serve as food for marine animals, such as some kinds 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 disorder.

Microbes Have Bothered Us for Millennia

Microbes have probably always caused infections and diseases in humans. Since ancient times, historians have documented some of those diseases. Present-day archeologists and microbiologists (scientists who study microbes) are discovering evidence of infectious disease in prehistoric human skeletons.

In a fascinating find in the late 20th century, researchers uncovered evidence that prehistoric humans were troubled by microbial parasites and used natural remedies against them. Along with the frozen mummy of the "Ice Man," who was found in the mountains of northern Italy and 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.

Black Death Plagued Medieval Europe

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 of years before being eradicated late in the 20th century by worldwide vaccination. The last case of naturally occurring 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.

Evidence on a 1300 B.C. Egyptian stone engraving shows that poliomyelitis (polio) also 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.

SOME OTHER SIGNIFICANT SCIENTIFIC EVENTS AND ADVANCES

Approximately 300 B.C.	**1675**	**1796**	**1848**
Aristotle, Greek philosopher and scientist, studied and wrote about living organisms.	Antony van Leeuwenhoek discovered bacteria.	Edward Jenner laid the foundation for developing vaccines.	Ignác Fülöp Semmelweis discovered that simple handwashing could prevent passage of infection from one patient to another.

In the 14th century, a bacterium that modern scientists 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 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 providers 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, killed an estimated 3.1 million people worldwide in 2005 alone.

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 was credited with discovering penicillin.

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. It seeks ways to use that knowledge to prevent and treat the diseases microbes cause. The 20th century saw an extraordinary increase in our knowledge about microbes. Microbiologists and other researchers had many successes in learning how microbes cause certain infectious diseases and how to combat those microbes.

Unfortunately, microbes are much better at adapting to new environments than are people. Having existed 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 destroyed 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 we have 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**.

COMMON DISEASES AND INFECTIONS AND 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				▲

Microbes Can Infect Us

Below are some of the many different ways you can get infected by germs.

SOME MICROBES CAN TRAVEL THROUGH THE AIR

You can transmit microbes to another person through the air by coughing or sneezing. These are common ways to get viruses that cause colds or flu, or the bacteria that cause tuberculosis (TB). Interestingly, international airplane travel can expose you to germs not common in your own country.

CLOSE CONTACT CAN PASS GERMS TO ANOTHER PERSON

Scientists have identified more than 500 types of bacteria that live in our mouths. Some keep the oral environment healthy, while others cause problems like gum disease. One way you can transmit oral bacteria is by kissing.

Microbes such as HIV, herpes simplex virus, 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 through unintentionally passing feces from hand to 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 contaminated surfaces, such as a handrail or telephone.

A HEALTHY PERSON CAN CARRY GERMS AND PASS THEM ONTO 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 those germs. The germs in this case were *Salmonella typhi* bacteria, which cause typhoid fever and are usually spread through food or water.

In the early 20th century, Mary Mallon, an Irish immigrant, 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 *Salmonella* 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, rabies vaccine prevents animals from getting rabies. Vaccines protect people from accidentally getting the virus from an animal. They also prevent people who already 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
- Bovine spongiform encephalopathy (BSE, also called mad cow disease)
- Brucellosis
- Cat scratch disease
- Cryptosporidiosis
- Flu (Influenza)
- Giardiasis
- Hantavirus pulmonary syndrome
- Histoplasmosis
- Hookworm
- Listeriosis
- Rabies
- Ringworm
- Salmonellosis
- SARS (severe acquired respiratory syndrome)
- Toxoplasmosis
- Tularemia

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. Meningitis is the inflammation of the lining of the brain and spinal cord.

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

YOU CAN GET MICROBES FROM TINY CRITTERS

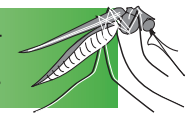
Mosquitoes may be the most common insect carriers, also called vectors, of pathogens. *Anopheles* mosquitoes can pick up *Plasmodium*, which causes malaria, from the blood of an infected person and transmit the protozoan to an uninfected person.

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 the tick picks up from mice.

MOSQUITO

Malaria • Dengue Fever
West Nile Virus • Viral Encephalitis

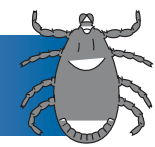


FLEA

Plague

TICK

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



SOME MICROBES IN FOOD OR WATER 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 Centers for Disease Control and Prevention (CDC) estimates there are 76 million cases of such illnesses in the United States each year. In addition, CDC estimates 325,000 hospitalizations and 5,000 deaths are related to foodborne diseases each year. Microbes 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 human and animal feces. These bacteria can get into lake, river, and ocean water from sewage spills, animal waste, and water runoff. Millions can be released from infectious fecal matter. People who drink, swim in, 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

Researchers are investigating the possibility of transplanting animal organs, such as pig hearts, into people. They, however, must guard against the risk that those organs also may transmit microbes that were harmless to the animal into humans, where they may cause disease.

Some People Are Immune to Certain Diseases

We become immune to germs through natural and artificial means. As long ago as the 5th century B.C., Greek doctors 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. You can become immune, or develop **immunity**, to a microbe in several

We become immune to germs through natural and artificial 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.

ways. The first time **T cells** and **B cells** in your **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 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.

Artificial immunity can come from vaccines. **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 system 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 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 anymore, or you will feel sick only once in a while. Most infections caused by microbes fall into three major groups.

- Acute infections
- Chronic infections
- Latent infections

ACUTE INFECTIONS

Acute infections are usually severe and last a short time. 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 or other viruses that may have caused your cold, the cold doesn't come back. If you get another cold, it's probably because you have been infected with other cold-causing viruses.

CHRONIC INFECTIONS

Chronic infections usually develop from acute infections and can last for days to months to a lifetime. Sometimes people are 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.

THE DIFFERENCE BETWEEN INFECTION AND DISEASE

A *disease* occurs when cells or molecules in your 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 a microbe—such as a virus, bacterium, fungus, or parasite—enters your body and begins to reproduce. The invading microbe can directly damage cells, or the immune system can cause symptoms, such as fever, as it tries to rid your body of the invader. Some infections do not cause disease because the microbe is quickly killed or it remains dormant.

LATENT INFECTIONS

Latent infections are "hidden" or "silent" and may or may not cause symptoms again after the first acute episode. Some infectious microbes, usually viruses, can "wake up"—become active again but not always causing symptoms—off and on for months or years. When these microbes are active in your body, you can transmit them to other people. Herpes simplex viruses, which cause genital herpes and 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.

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.

It is especially important to wash your hands

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

Health care providers should be especially conscientious about washing their hands before and after examining any patient. Workers in child care and elder care settings, too, should be vigilant about handwashing around those in their care.

MEDICINES

There are medicines on the market that help prevent people from getting infected by germs. For example, you can prevent getting the flu (influenza) by taking an antiviral medicine. Vaccines, however, are the best defense against influenza viruses.

Under specific circumstances, health care providers may prescribe antibiotics to protect people 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

In 1796, 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 the form of meningitis caused by *Haemophilus influenzae* type B (Hib) virus.

Vaccines, however, are not only useful for young children. Adolescents and adults should get vaccinated regularly for tetanus and diphtheria. A vaccine to prevent meningococcal

SOME VACCINE-PREVENTABLE INFECTIOUS DISEASES

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

meningitis is now available and recommended for all adolescents. 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. Your health care provider also may recommend immunizations for pneumococcal pneumonia and hepatitis B if you are at risk of getting these diseases.

When You Should Go to the Doctor

YOU SHOULD CALL A HEALTH CARE PROVIDER 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 higher than 100 degrees Fahrenheit
- 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 (blurry vision, for example)
- You have been vomiting

Generally, you should consult your health care provider if you have or think you may have 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 your 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 that their immune systems successfully fight off the viral culprits. In fact, the coughing and sneezing that make you feel miserable are part of your immune system's way of fighting off the culprits.

If, however, you have other conditions in which your immune system doesn't function properly, you should be in contact with your health care provider whenever you suspect you have any infectious disease, even the common cold. Such conditions can include asthma and immune deficiency 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 and the elderly.

Infectious Diseases Are Diagnosed in Many Ways

Sometimes your health care provider can diagnose an infectious disease by listening to your medical history and doing a physical exam. For example, listening to you describe what happened and any symptoms you have noticed plays an important part in helping your 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 medical history and doing a physical exam.

In another type of test, your health care provider 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.

Xrays, 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 your doctor's office or a clinic. Others pose a higher risk to you because they involve procedures that go inside your 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 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, such as lactobacillus in your digestive system, help destroy disease-causing microbes.

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 infectious disease. 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 tool 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 infectious disease include

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

BY YOUR HEALTH CARE PROVIDER

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 for many years, bacteria have become resistant to the killing effects of these drugs. This resistance, called antibiotic 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 is 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 your body's cells where they are protected from medicines in the bloodstream. Researchers developed the first antiviral drug in the late 20th century. The drug, acyclovir, was first approved by the 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 providers treat HIV infection with a group of powerful medicines that can keep the virus in check. Known as highly active antiretroviral therapy, or HAART, this 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 lesions (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.

Although safe and effective treatments and cures for most viral diseases have eluded researchers, 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 medicines 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 people 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, disease control relies heavily on the availability of medicines. Health care providers usually use antiparasitic medicines to treat protozoal infections. Unfortunately, there are very few medicines that fight protozoa, 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 preventing infection if contact can't be avoided.

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

By the mid-20th century, some scientists thought that medicine had conquered infectious diseases. With the arrival of antibiotics and modern vaccines, as well as improved sanitation and hygiene, many diseases that formerly posed an urgent threat to public health were brought under control or largely eliminated.

The emergence of new microbes and the re-emergence of old microbes has continued, however, as it has throughout history. Several pressures are contributing to the emergence of new diseases such as

- Rapidly changing human demographics
- Rapid global travel
- Changes in land use patterns
- Ecological, environmental, and technological changes

Even public health practices such as widespread antibiotic use are contributing to this emergence. These pressures are both shaping the evolution of microbes and bringing people into closer and more frequent contact with microbes.

Unsanitary conditions in animal agriculture and increasing commerce in exotic animals (for food and as pets) have also contributed to the rise in opportunity for animal microbes to jump from animals to humans. From time to time, with the right combination of selective

pressures, a formerly harmless human or animal microbe can evolve into a pathogen that can cause a major outbreak of human disease. At times, changes in societal and environmental factors can also lead to re-emergence of diseases that were previously under control.

EMERGING MICROBES

Scientists usually define newly emerging microbes as those that have only recently appeared in a population or have existed but are rapidly increasing in incidence or geographic range. Recent examples of the infectious diseases they cause include West Nile virus (WNV) infection, SARS (severe acute respiratory syndrome), and avian influenza (bird flu).

West Nile virus infection

In the early summer of 1999, a mysterious cluster of encephalitis (inflammation of the brain) cases and related deaths appeared in New York City, raising the concern of public health officials. Within a short time, researchers identified the cause of the outbreak as WNV, which is common in Africa, West Asia, and the Middle East, but never before seen in North America.

Symptoms of WNV infection are usually mild and include fever, headache, body aches, skin rash, and swollen lymph glands. If WNV enters the brain, however, it can cause life-threatening encephalitis or meningitis. These more severe complications of the disease most often affect the elderly or people with weakened immune systems.

WNV is transmitted to humans by mosquitoes, which pick up the virus from infected birds. Although health experts don't know the route by which WNV entered the United States, they think the virus may been introduced by one of three possible ways

- An infected bird imported into the country
- An infected mosquito that stowed away on a shipment or transport vehicle entering the country
- An infected person returning from a country where the virus is common

Since WNV first appeared in the United States, there have been annual outbreaks of the disease and it has spread across the country. Experts believe WNV has now become established as a seasonal epidemic in North America that flares up in the summer and continues into the fall.

SARS

In 2002, a deadly new human pneumonia emerged in southeastern China and caused an epidemic that spread across many Asian countries and even across the ocean to Canada and the United States in 2003. The new disease was named severe acute respiratory syndrome, or SARS. A global research effort resulted in rapidly identifying the virus that caused SARS—part of the human coronavirus family. Prior to the emergence of SARS, coronaviruses were best known for their role in causing up to 30 percent of common colds in humans and for causing a host of other diseases that affect birds and mammals. The SARS virus is thought to be a rare recombination between avian and mammalian coronaviruses that may have made the jump to humans through animals sold in Asian food markets.

Avian Influenza

Since 2003, yet another new microbe has emerged as a threat to human health: the H5N1 avian influenza virus. Although avian influenza usually infects only birds, there have been numerous instances of transmission of these viruses to humans, resulting in severe disease or death in those affected.

At the moment, this avian influenza virus is not easily transmitted from human to human. If the virus was to acquire the ability to spread from one human to another, however, it could result in a flu pandemic that would cause widespread illness, death, and social disruption. For this reason, the public health community continues surveillance of avian influenza and has made flu preparedness and prevention an urgent public health priority.

RE-EMERGING MICROBES

The reappearance of microbes that had been successfully conquered or controlled by medicines and vaccines is distressing to the scientific and medical communities, as well as to the public. One major cause of disease re-emergence is that microbes responsible for causing these diseases are becoming resistant to the drugs used to treat them. Also, the decrease in vaccine use for vaccine-preventable diseases is contributing to re-emergence of previously controlled diseases. Some examples of re-emerging infectious diseases that are of significant public health concern are TB, malaria, and polio.

TB

According to the World Health Organization (WHO), nearly 2 billion people, one-third of the world's population, are infected with *Mycobacterium tuberculosis*, the bacterium that causes 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. Failure to stop the spread of TB can be attributed to several factors, including

- The co-epidemic with HIV/AIDS which has led to more and more TB cases developing in people with weakened immune systems
- The failure of infected people to complete the entire drug treatment needed to eliminate the disease (this treatment may take up to 9 months to complete)
- The emergence of multidrug-resistant TB (MDR-TB), which does not respond to available treatments

SOME NEWLY EMERGING/ EMERGED PATHOGENS

Ebola virus
H5N1 avian influenza virus
Nipah virus
Marburg virus
SARS virus
West Nile virus

In 2003 alone, more than 300,000 new cases of MDR-TB were registered by WHO. In a recent study, researchers detected strains of *M. tuberculosis* that were resistant to multiple drugs in 74 of 77 geographic regions surveyed worldwide. As a result of these many

factors, a disease that was once considered "old" and curable is making a strong comeback in resource-poor countries and is also re-emerging in the United States.

Malaria

Malaria, the most deadly of all tropical parasitic diseases, has been resurging dramatically in recent years. Increasing resistance of *Plasmodium* protozoa (one of the microbes that causes malaria) 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, causing more than 1 million deaths annually. In the United States, approximately 1,300 cases are reported annually. Most of the U.S. cases occur in people who had been infected while traveling abroad. Other cases occur in people bitten by infected mosquitoes in the United States.

Polio

Polio is another disease that had come close to eradication (elimination), due to the widespread use of polio vaccines. Recently, however, polio has been re-emerging. According to the Global Polio Eradication Initiative, global polio eradication efforts have resulted in a reduction from 350,000 cases in 1988 to 1,111 cases worldwide by August 2005. Six countries, however, continue to see new polio cases (Nigeria, India, Pakistan, Afghanistan, Niger, and Egypt). In addition, poliovirus has been spreading to previously polio-free countries. Since mid-2003, eighteen previously polio-free countries have been re-infected. There are ongoing efforts to increase vaccine coverage in these areas.

Research

The National Institute of Allergy and Infectious Diseases (NIAID), part 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 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 drugs and vaccines.

- 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 laboratories. NIAID and other parts of NIH 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 influenza.

- Clinical trials involving several experimental HIV vaccines. NIAID scientists and grantees have conducted trials on more than 52 vaccine candidates since 1987. In 1999, NIAID began the first HIV vaccine trial in Africa, an important step for developing global vaccines. Trials are underway in countries on five continents, reflecting the global nature of this disease. The HIV Vaccine Trials Network, supported by NIAID, is a network of domestic and international clinical research institutions that conducts all phases of vaccine clinical trials.

- Three research 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.

- Research on the pathogenesis of bacterial and viral sexually transmitted infections and prevention strategies to control these infections.

Institute researchers work closely with other agencies, institutions, and scientists 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 www.niaid.nih.gov.

Glossary

antibiotics—medicines that damage or kill bacteria and are 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 come from foreign materials 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.

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 that 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.

genomes—all of an organism's genetic material. A genome is organized into specific functional units called genes.

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

immune response—reaction of the immune system to foreign invaders such as microbes.

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

immunity—protection from germs.

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.

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 chemical substance that still keep the chemical properties of that 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.

protein—a chain of small chemical compounds called amino acids.

RNA (ribonucleic acid)—a complex molecule 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 the following.

National Institute of Allergy and Infectious Diseases
National Institutes of Health
6610 Rockledge Drive, MSC 6612
Bethesda, MD 20892–6612
301–496–5717
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
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.

MedlinePlus
National Library of Medicine
8600 Rockville Pike
Bethesda, MD 20894
1–888–FIND–NLM (1–888–346–3656) or 301–594–5983
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.

Centers for Disease Control and Prevention
1600 Clifton Road
Atlanta, GA 30333
1–800–311–3435 or 404–639–3534
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.

National Immunization Program
Centers for Disease Control and Prevention
1600 Clifton Road
Atlanta, GA 30333
1–800–232–2522
www.cdc.gov/nip

CDC is the main U.S. Government agency that develops policy and recommendations for immunizations. NIP 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)
www.fda.gov

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

U.S. Department of Agriculture
Agricultural Research Service
5601 Sunnyside Avenue
Beltsville, MD 20705–5134
www.ars.usda.gov

ARS is the principal research agency of USDA. 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 offers technical information for scientists, it also has materials specifically for the general public.

World Health Organization
Avenue Appia 20
1211 Geneva 27
Switzerland
(00 41 22) 791 21 11
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, Spanish, Russian, Chinese, and Arabic.

NOTES

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
National Institutes of Health

National Institute of Allergy and Infectious Diseases

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