

Understanding Microbes

in Sickness and in Health



NIAID

National Institute of Allergy and Infectious Diseases



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

NIAID SCIENCE EDUCATION

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(cover) Electromicrograph of an amoeba as it entraps a *Legionella pneumophila* bacterium, which causes Legionnaires' disease. **(left)** Macrophage infected by *Francisella tularensis* bacteria, which cause tularemia.



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**.

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

Note: Words in **bold** are in the glossary near the end of this booklet.

(left) *Streptococcus*. There are many kinds of *Streptococcus* bacteria. Some can cause diseases such as strep throat, meningitis, and pneumonia. Others keep us healthy and are found in areas of the human body such as the intestines, skin, mouth, and nose.

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.



(above) Thermophiles are microbes that like the high temperatures found in places like the hot springs of Yellowstone National Park.

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 cold and hot areas.

- Psychrophiles, or cold-loving bacteria, can live in temperatures as cold as those found in the Arctic and Antarctic.
- Thermophiles are heat-loving bacteria that can live in high temperatures, such as in the hot springs of Yellowstone National Park in Wyoming.
- Extreme thermophiles, or hyperthermophiles, can thrive at 235°F near volcanic vents on the ocean floor.

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

Like humans, some bacteria (aerobic bacteria) need oxygen to survive. 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 bacteria cause diseases in humans. For example, harmless anaerobic bacteria, such as *Lactobacilli acidophilus*, live in our intestines, where they help 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, however, produce poisons called **toxins**, which can make us sick. For example, botulism, a severe form of food poisoning, affects the nerves and is caused by toxins from *Clostridium botulinum* bacteria.

ARE TOXINS ALWAYS HARMFUL?

Under certain circumstances, bacterial toxins can be helpful. Several **vaccines** that keep us from getting sick are made from bacterial toxins. For example, one type of pertussis vaccine, which protects infants and children from pertussis (whooping cough), contains toxins from *Bordetella pertussis* bacteria. This vaccine is safe and effective and causes fewer reactions than other types of pertussis vaccines.



(above) A healthcare provider gives a child a vaccine.

Viruses

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



(above) A man with shingles rash on his neck. Shingles, or herpes zoster, is a painful infection caused by varicella-zoster virus, a type of *Herpesvirus*. This virus also causes chickenpox. **(below)** Representation of an influenza virus.

Unlike most bacteria, most viruses do cause disease because they invade living, normal cells, such as those in your body. Once inside the cells, they 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.

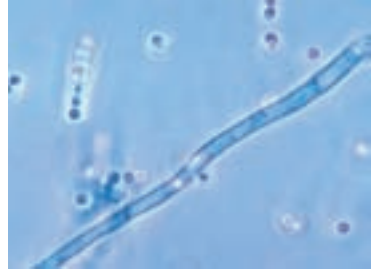
Many viral infections do not result in disease. For example, by the time most people in the United States become adults, they have been infected by cytomegalovirus (CMV). Most people infected with CMV, however, do not develop CMV-disease symptoms



Other viral infections can result in deadly diseases such as AIDS 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.



(above) A photomicrograph of the fungus *Aspergillus fumigatus*.

Fungal diseases are called mycoses. Mycoses can affect your skin, nails, body hair, internal organs such as your lungs, and body systems such as your nervous system. *Aspergillus fumigatus* fungi, for example, can cause aspergillosis, a lung disease.

Some fungi have made our lives easier. Penicillin and other antibiotics, which can 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, such as sugar, 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 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 is caused by a protozoan parasite. Another protozoan parasite, *Toxoplasma gondii*, causes toxoplasmosis, or toxo, in humans. This is an especially troublesome infection in pregnant women because of its effects on the fetus, and in people with HIV/AIDS or other disorders of the immune system.



(above) A pregnant woman looks on while her husband changes the cat's litter. Used litter may contain *Toxoplasma gondii*, a disease-causing parasite that can pass from a mother to her unborn child.

MICROBES IN THE HEALTHY HUMAN BODY*

Ear (outer)	<i>Aspergillus</i> (fungus)
Skin	<i>Candida</i> (fungus)
Small intestine	<i>Clostridium</i>
Intestines	<i>E. coli</i>
Vagina	<i>Gardnerella vaginalis</i>
Stomach	<i>Lactobacillus</i>
Urethra	<i>Mycobacterium</i>
Nose	<i>Staphylococcus aureus</i>
Mouth	<i>Streptococcus salivarius</i>
Large intestine	<i>Trichomonas hominis</i> (protozoa)

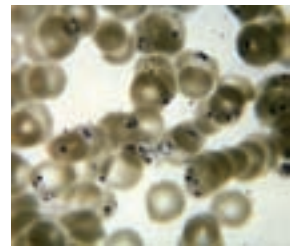
*A selection of usually harmless microbes, some of which help keep our bodies functioning normally. If their numbers become unbalanced, however, these microbes may make us sick. All are bacteria, unless otherwise noted.

Microbes Have Bothered Us for Millennia

Microbes have probably always caused infection and disease 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.

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.



(above) *Plasmodium falciparum*, the protozoa that cause some cases of malaria.

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 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.
1857	1867	1876	1928
Louis Pasteur introduced the germ theory of disease.	Joseph Lister showed evidence that microbes caused disease and pioneered the use of antiseptics during surgery to kill germs.	Robert Koch, by studying anthrax, showed the role of bacteria in disease.	Alexander Fleming was credited with discovering penicillin.

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, healthcare providers report cases of plague even today, most of which are found in the Southwest.

Viruses caused two major **pandemics** in modern times. 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 as the cause of AIDS, killed an estimated 2 million people worldwide in 2008 alone.



(above) The Black Death plagued medieval Europe.

Microbes Can Make Us Sick

According to healthcare 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.

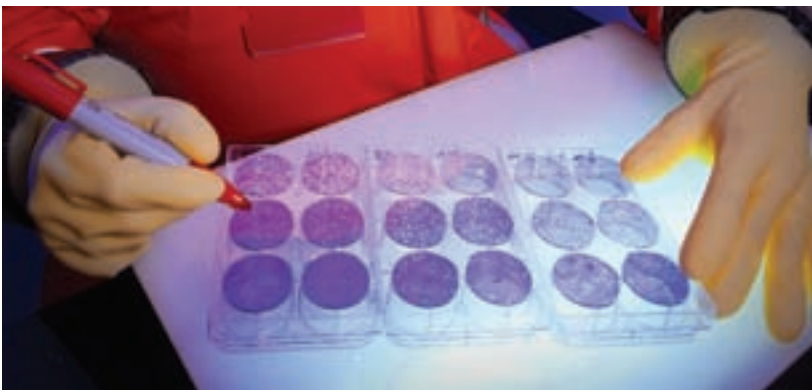
The science of microbiology explores how microbes work and how to control them. It seeks ways to use that knowledge to prevent and treat the diseases microbes cause. The 20th century saw an extraordinary increase in our knowledge about microbes. Microbiologists and other researchers had many successes 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**, such as HIV.

SOME COMMON DISEASES AND INFECTIONS AND THEIR MICROBIAL CAUSES

	Bacteria	Fungus	Protozoa	Virus
Athlete's foot		▲		
Common cold				▲
Diarrheal diseases	▲		▲	▲
Flu				▲
Genital herpes				▲
Meningitis	▲			▲
Pneumonia	▲	▲		▲
Shingles				▲
Sinusitis	▲	▲		
Skin diseases	▲	▲	▲	▲
Strep throat	▲			
Tuberculosis	▲			
Urinary tract infection	▲			
Vaginal infection	▲	▲	▲	



(above) Microbiologist studying highly infectious viruses.

Microbes Can Infect Us

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



(above) *Mycobacterium tuberculosis* is the bacterium that causes most cases of tuberculosis in humans.

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 type 2, which causes genital herpes, and *Neisseria gonorrhoeae* bacteria, which causes gonorrhea, are examples of germs that you can pass to another person through 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. Daycare 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 doorknob or computer keyboard.

A healthy person can carry germs and pass them to others

The story of “Typhoid Mary” is a famous example from medical history about how a person can pass germs 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.

HOW IS TYPHOID FEVER SPREAD?

Salmonella typhi bacteria live only in humans—in their bloodstreams and intestinal tracts. In addition, a small number of people, called carriers, get better after having typhoid fever, but continue to be infected (carry the bacteria). People who are infected or who have the disease can shed *S. typhi* in their feces.

You can get typhoid fever if you eat food or drink liquids that have been prepared by someone who has typhoid fever or who is infected with *S. typhi*. Untreated sewage also can contain the bacteria, which can then get into the water you drink or use to wash food.



(above) Preparing food properly helps get rid of microbes that may cause a foodborne illness.

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 also protect people from accidentally getting the virus from an animal. In addition, vaccines 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

BSE (bovine spongiform encephalopathy, also called mad cow disease)

Brucellosis

Cat scratch disease

Cryptosporidiosis

Flu

Giardiasis

Hantavirus pulmonary syndrome

Histoplasmosis

Hookworm

Listeriosis

Rabies

Ringworm

Salmonellosis

SARS (severe acute 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 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 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	FLEA	TICK
<ul style="list-style-type: none">• Dengue fever• West Nile virus infection• Viral encephalitis	<ul style="list-style-type: none">• Plague• Typhus	<ul style="list-style-type: none">• Babesiosis• Lyme disease• Rocky Mountain spotted fever• Tularemia

(above) Mosquito, flea, and tick and some of the diseases they can transmit. (upper right) A turtle.

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.



(above) Scientist sampling pollution levels in a creek.

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.

Anyone, 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.

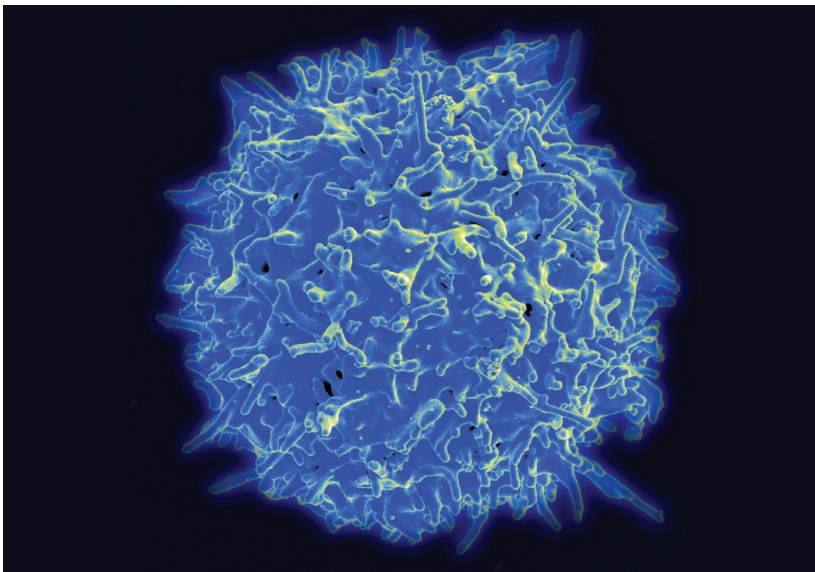
Transplanted animal organs may harbor germs

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 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.



(above) T cell.



(above) A baby can acquire immunity through breastfeeding. (below and right) Representation of an influenza virus.

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 paren



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.

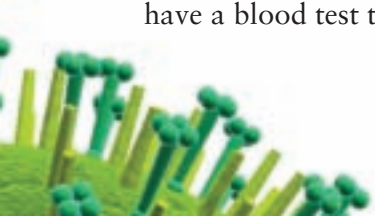
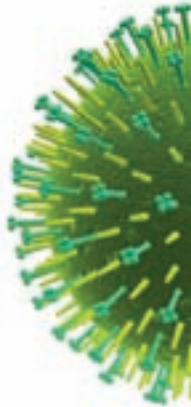
- Acute infections
- Chronic infections
- Latent infections

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

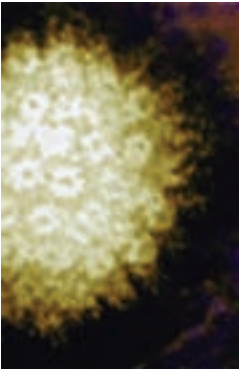
Chronic infections usually develop from acute infections and can last for days to months to a lifetime. Sometimes people are unaware they are infected but still may be able to transmit the germ to others. For example, hepatitis C, which affects the liver, is a chronic viral infection. In fact, most people 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.

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.



(above) An electromicrograph of a varicella-zoster virus, which causes chickenpox and shingles.

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.

THE DIFFERENCE BETWEEN DISEASE AND INFECTION

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 infection. An *infection* occurs when a microbe 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 don't cause disease because the microbe is killed quickly or it remains dormant (asleep).

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. Healthcare 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 and flu viruses and staph and strep bacteria as well as many other disease-causing microbes.

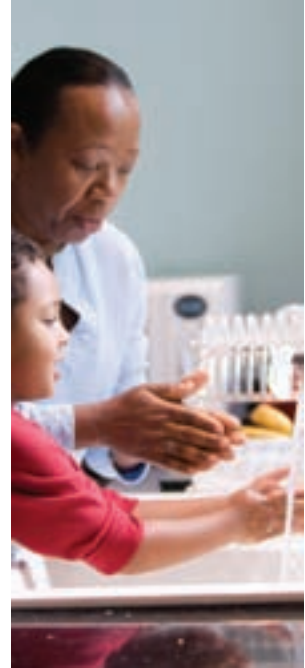
It is especially important to wash your hands

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

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

Medicines

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



(above) Washing your hands well is an excellent way to help prevent passing disease-causing microbes to yourself and others.

Under specific circumstances, your healthcare provider may prescribe antibiotics to protect you from getting certain bacteria such as *Mycobacterium tuberculosis*, which causes TB. Healthcare 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



(above) Edward Jenner vaccinates his son.

tetanus and diphtheria. A vaccine to prevent meningococcal meningitis is 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.

If you travel or plan to travel outside the United States, getting the immunizations that are recommended for your destination(s) is very important. Vaccines can prevent yellow fever, polio, typhoid fever, hepatitis A, cholera, rabies, and other diseases that are more prevalent abroad than in this country.

SOME VACCINE-PREVENTABLE INFECTIOUS DISEASES

Bacterial meningitis

Chickenpox

Cholera

Diphtheria

Haemophilus influenzae type B (Hib)

Hepatitis A

Hepatitis B

Influenza (flu)

Measles

Mumps

Pertussis (whooping cough)

Pneumococcal pneumonia

Polio

Rabies

Shingles

Tetanus (lockjaw)

Yellow fever



(above) Vaccine vials.

When You Should Go to the Doctor

Generally, you should consult your healthcare 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.

YOU SHOULD CALL A HEALTHCARE 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°F
- 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

Some infectious diseases, such as the common cold, usually do not require a visit to a healthcare provider. They often last a short time and are not life-threatening, or there is no specific treatment. We've heard the advice to rest and drink plenty of liquids to treat colds. Unless there are complications, most people with 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 those culprits.

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

In addition, some common, usually mild infectious diseases, such as chickenpox or sear, very young children and t



Infectious Diseases Are Diagnosed in Many Ways

Sometimes your healthcare 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.

In another type of test, your healthcare 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 whether any microbe “grows.” This test is called a culture. Lab workers usually can identify certain bacteria, such as chlamydia, and viruses, such as herpes simplex, 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 your healthcare provider can use to make an accurate diagnosis.

All of the above procedures are relatively safe, and some can be done in your healthcare provider'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.

(left) A stethoscope is one of many tools a healthcare provider can use to help diagnose the cause of an illness.

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 who is sick. 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

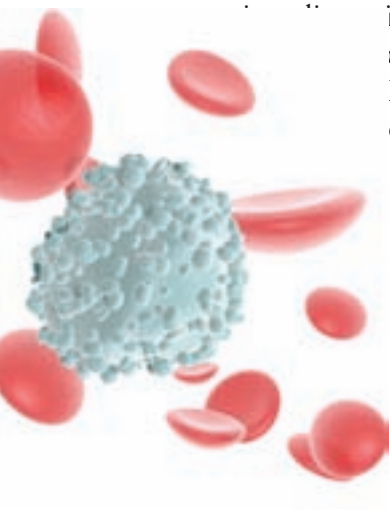
Your immune system has an arsenal of ways to fight off microbes. Most begin with B and T cells and dendritic cells, whose sole purpose is to keep your body healthy. Some of these cells sacrifice their lives to rid you of disease and restore your body to a healthy state. Some microbes normally present in your body also help destroy microbial invaders. For example, normal, good bacteria, such as *lactobacillus* in your digestive system, help destroy germs that find their way there.

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

Fever

(above) Red blood cells and a white blood cell (leukocyte). B and T cells are lymphocytes, one kind of leukocyte.

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°F. Your body uses fever to destroy influenza viruses, for example.



Coughing and sneezing

Another tool in your immune system's reaction to invading disease-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



(above) A sneeze captured in progress. Droplets from sneezing can contain germs that can infect another person several feet away.

By your healthcare 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. Healthcare providers, however, sometimes prescribe antibiotics unnecessarily for a variety of reasons, including pressure from patients with viral diseases such as the flu.

Because antibiotics have been prescribed too often or prescribed for the wrong diseases for many years, some bacteria have become resistant to the killing effects of these drugs. This resistance, commonly 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.

Healthcare 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 and lengthened the lives of many suffering from this deadly infection.



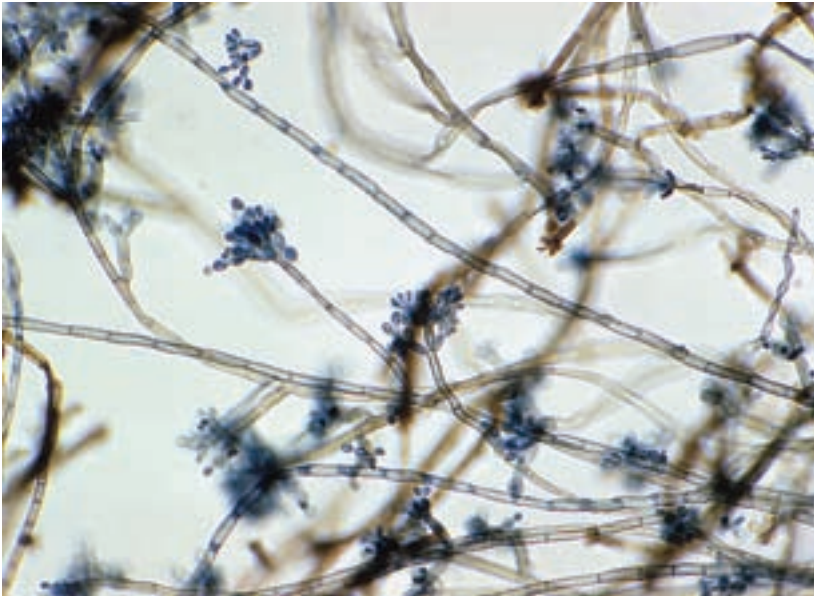
(above) Drinking water and other fluids can help reduce the loss of body fluids due to a fever, even a mild one.

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 itchy skin lesions (sores) caused by the virus. Bacteria such as *Staphylococcus* can enter those lesions and cause a bacterial infection. The healthcare provider may then prescribe an antibiotic to destroy the bacteria. The antibiotic, however, will not destroy the chickenpox virus, only the staph bacteria.

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

For fungi

Medicines applied directly to the infected area are available by prescription and over the counter to treat skin and nail fungal infections. Unfortunately, many people have had limited success with them. Very powerful oral antifungal medicines are available only to treat systemic (within the body) fungal infections, such as histoplasmosis. Healthcare providers usually prescribe oral antifungal medicines with caution because all of them, even the milder ones for skin and nail fungi, can have very serious side effects.



(above) Onychomycosis (fungal infection of the nail) caused by *Trichophyton rubrum*. *T. rubrum* also can cause athlete's foot, jock itch, and ringworm.

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. Currently, there are no vaccines that can control parasitic diseases.

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. Healthcare 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 first place. 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.



(above) The *Anopheles* mosquito can transmit *Plasmodium*, protozoa that cause malaria.

New and Old Microbes Emerge on the Scene

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. As a result, by the mid-20th century some scientists thought that medical science had conquered infectious diseases.

Despite these public health advances, new microbes emerge and old microbes re-emerge just as they have throughout history. Several pressures contribute to the emergence of diseases, such as

- Redistribution of human populations
- Rapid global travel
- Changes in the way we use land
- Ecological, environmental, and technological changes



(above) Rapid global travel contributes to the emergence of new diseases.

Practices such as the misuse of antibiotic medicines also contribute to disease emergence.

In addition, unsanitary conditions in animal agriculture and increasing commerce in exotic animals have 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 microbe found in humans or animals can evolve into a pathogen that can cause a major outbreak of human disease. These pressures are shaping the evolution of microbes and bringing people into closer and more frequent contact with pathogens.

Emerging microbes

Scientists usually define emerging microbes as those that have appeared only recently in a population or have existed but are rapidly increasing in incidence or geographic range. Recent examples of such disease-causing microbes are methicillin-resistant *Staphylococcus aureus* (MRSA) bacteria, West Nile virus, and 2009 H1N1 influenza virus.

SOME NEWLY EMERGING/EMERGED MICROBES

2009 H1N1 influenza virus

Ebola virus

H5N1 avian influenza virus

Marburg virus

MRSA bacteria

Multidrug-resistant and extensively drug-resistant TB bacteria

Nipah virus

SARS virus

West Nile virus



(above) A fruit bat (flying fox). Fruit bats in India and Malaysia have been found to carry Nipah virus.

Re-emerging microbes

The reappearance of microbes that had been conquered successfully 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 many microbes responsible for causing these diseases are becoming resistant to the drugs used to treat them. Some examples of re-emerging infectious diseases that are of significant public health concern are dengue, malaria, TB, and polio.

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.



(above) Lab work.

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. Since 1987, NIAID scientists and grantees have conducted

trials on more than 67 vaccine candidates and 18 types of adjuvants—substances added to vaccines to improve the immune system response so that less vaccine is needed to provide protection. In 2009, a major NIAID-supported HIV vaccine study in Thailand revealed a candidate vaccine to be 31 percent effective at preventing HIV infection—the first time an HIV vaccine has shown any ability to prevent infection in people. NIAID continues to build upon scientific findings by both conducting basic research to better understand the virus and developing and testing promising HIV vaccine candidates.

- 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 disease-causing microbes and infectious diseases.

You can get information on current NIAID research activities on the Institute Web site at www.niaid.nih.gov.



(above) Lab work.

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 healthcare 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

866–284–4107 or 301–496–5717

www.niaid.nih.gov

National Institutes of Health

Bethesda, MD 20892

www.nih.gov

MedlinePlus

National Library of Medicine

8600 Rockville Pike

Bethesda, MD 20894

888–FIND–NLM (888–346–3656) or 301–594–5983

www.medlineplus.gov

Centers for Disease Control and Prevention

1600 Clifton Road

Atlanta, GA 30333

800–CDC–INFO (800–232–4636)

www.cdc.gov

National Center for Immunization and Respiratory Diseases

Centers for Disease Control and Prevention

1600 Clifton Road

Atlanta, GA 30333

800–CDC–INFO (800–232–4636)

www.cdc.gov/vaccines

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

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

World Health Organization
Avenue Appia 20
1211 Geneva 27
Switzerland
(00-41-22) 791-21-11
www.who.int

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