



unit II

Disease and the First Line of Defense

*T*he first chapter in this unit discusses deviation from the normal, which is the basis for disease. After a general discussion of different types of diseases, the chapter concentrates on infectious diseases and the organisms that cause them, including bacteria, viruses, fungi, protozoa, and worms. Other forms of disease are discussed in chapters on the individual body systems. The skin is the first defense against infectious organisms and other sources of injury. The properties and functions of the skin are discussed in the second chapter of this unit.



SELECTED KEY TERMS

The following terms and other boldface terms in the chapter are defined in the Glossary



acute
antiseptics
asepsis
chronic
diagnosis
disease
disinfection
epidemic
etiology
helminth
microorganism
nosocomial infection
opportunistic infection
pathogen
pathophysiology
prion
prognosis
sign
spore
sterilization
symptom
syndrome
systemic
therapy
toxin
vector

LEARNING OUTCOMES

After careful study of this chapter, you should be able to:

1. Define disease and list seven categories of disease
2. List seven predisposing causes of disease
3. Define terminology used in describing and treating disease
4. Define *complementary and alternative medicine*; cite several alternative or complementary fields of practice
5. Explain methods by which microorganisms can be transmitted from person to person
6. List four types of organisms studied in microbiology and give the characteristics of each
7. List some diseases caused by each type of microorganism
8. Define *normal flora* and explain the value of the normal flora
9. Describe the three types of bacteria according to shape
10. List several diseases in humans caused by worms
11. Give some reasons for the emergence and spread of microorganisms today
12. Describe several public health measures taken to prevent the spread of disease
13. Differentiate *sterilization*, *disinfection*, and *antiseptics*
14. Describe techniques included as part of body substance precautions
15. List some antimicrobial agents and describe how they work
16. Describe several methods used to identify microorganisms in the laboratory
17. Show how word parts are used to build words related to disease (see Word Anatomy at the end of the chapter)

5
chapter

Disease and Disease-Producing Organisms



Disease may be defined as abnormality of the structure or function of a part, organ, or system. The effects of a disease may be felt by a person or observed by others. Diseases may be of known or unknown causes and may show marked variation in severity and effects on an individual.

► Categories of Disease

Diseases fall into a number of different, but often overlapping, categories. These include the following:

- **Infection.** Infectious organisms are believed to play a part in at least half of all human illnesses. Examples of diseases caused by infectious organisms are colds, AIDS, “strep” throat, tuberculosis, and food poisoning. Microorganisms may also contribute to more complex disorders, for example, stomach ulcers and some forms of heart disease. Infectious diseases are discussed in this chapter. Other forms of illness mentioned below are discussed in later chapters.
- **Degenerative diseases.** These are disorders that involve degeneration (breaking down) of tissues in any system of the body. Examples are muscular dystrophy, cirrhosis of the liver, Alzheimer disease, osteoporosis, and arthritis. Some of these disorders are hereditary; that is, they are passed on by parents through their reproductive cells. Others are due to infection, injury, substance abuse, or normal “wear and tear.” For some, such as multiple sclerosis, there is no known cause at present.
- **Nutritional disorders.** Most of us are familiar with diseases caused by a dietary lack of essential vitamins, minerals, proteins, or other substances required for health: scurvy due to a lack of vitamin C; beriberi due to a lack of thiamine; rickets due to a lack of calcium for bone development; kwashiorkor, a disease of children in underdeveloped countries caused by protein deficiency. This category also includes problems caused by excess intake of substances, such as alcohol, vitamins, minerals, or proteins, and the intake of too many calories leading to obesity (see Chapters 19 and 20).
- **Metabolic disorders.** These include any disruption of the reactions involved in cellular metabolism, such as diabetes, gout (a disorder of the joints), digestive disorders, and hereditary dysfunctions. Hormones regulate many metabolic reactions. The glands that produce hormones and the diseases caused by excess or deficiency of hormones are the subject of Chapter 12. Hereditary errors of metabolism result from genetic changes that affect enzymes. The basics of heredity are described in Chapter 25.
- **Immune disorders.** These relate to the system that protects us against infectious diseases (see Chapter 17). Some deficiencies in the immune system are inherited; some, such as AIDS, are the result of infection. This category also includes allergies, in which the immune system is overactive, and autoimmune diseases, which occur when the immune system becomes active against one’s own tissues. Examples of diseases that involve au-

toimmunity are rheumatoid arthritis, multiple sclerosis (MS), and systemic lupus erythematosus (SLE).

- **Neoplasms.** The word *neoplasm* means “new growth” and refers to cancer and other types of tumors. These were described in Chapter 4.
- **Psychiatric disorders.** Psychiatry is the medical field that specializes in the treatment of mental disorders. The brain and the nervous system as a whole are discussed in Chapters 9 and 10. Note, however, that it is often impossible to separate mental from physical factors in any discussion of disease.

Predisposing Causes of Disease

Other factors that enter into the production of a disease are known as **predisposing causes**. Although a predisposing cause may not in itself give rise to a disease, it increases the probability of a person becoming ill. Examples of predisposing causes include the following:

- **Age.** Tissues degenerate with age, becoming less active and less capable of performing normal functions. Decline may be speeded by the normal “wear and tear” of life, by continuous infection, or by repeated minor injuries. Age may also be a factor in the incidence of specific diseases. For example, measles is more common in children than in adults. Other diseases may appear most commonly in young adults or people in middle years.
- **Gender.** Certain diseases are more characteristic of one gender than the other. Men are more susceptible to early heart disease, whereas women are more likely to develop adult onset diabetes and autoimmune diseases.
- **Heredity.** Some individuals inherit a “tendency” to acquire certain diseases—particularly diabetes, many allergies, and certain forms of cancer.
- **Living conditions and habits.** Individuals who habitually fail to get enough sleep or who pay little attention to diet and exercise are highly vulnerable to disease. The abuse of drugs, alcohol, and tobacco also can lower vitality and predispose to disease. Overcrowding and poor sanitation invite epidemics.
- **Emotional disturbance.** Some physical disturbances have their basis in emotional upsets, stress, and anxiety in daily living. Some headaches and so-called “nervous indigestion” are examples.
- **Physical and chemical damage.** Injuries that cause burns, cuts, fractures, or crushing damage to tissues predispose to infection and degeneration. Some chemicals that may be poisonous, carcinogenic, or otherwise injurious if present in excess are lead compounds (in paint), pesticides, solvents, carbon monoxide and other pollutants in air, and a wide variety of other environmental toxins. Exposure to radiation is associated with an increased incidence of cancer.

Many of the so-called “occupational diseases” are caused by exposure to harmful agents on the job. For example, inhalation of coal dust and other types of dusts or fibers has caused lung damage among miners. Metals

or toxins may cause skin reactions, and exposure to pesticides and other agricultural chemicals has been associated with neurologic disorders and cancer.

- ▶ **Preexisting illness.** Any preexisting illness, especially a chronic disease such as high blood pressure or diabetes, increases one's chances of contracting another disease.

Checkpoint 5-1 What is disease?

Checkpoint 5-2 What is the definition of a predisposing cause of disease?

▶ The Study of Disease

The modern approach to the study of disease emphasizes the close relationship of the pathologic and physiologic aspects of any disorder and the need to understand the fundamentals of each in treatment. The term used for this combined study in medical science is **pathophysiology**.

Underlying the basic medical sciences are the still more fundamental disciplines of physics and chemistry. Knowledge of both of these sciences is essential to any real understanding of the life processes.

Disease Terminology

The study of the cause of any disease, or the theory of its origin, is **etiology** (e-te-OL-o-je). Any study of a disease usually includes some indication of **incidence**, which means its range of occurrence and its tendency to affect certain groups of individuals more than other groups. Information about the geographic distribution of a disease and its tendency to appear in one gender, age group, or race more or less frequently than another is usually included in any study on disease incidence. In studying disease incidence within popula-

tions, public health workers use the term **morbidity rate** to describe the proportion of people with a specific disease in a given population per unit of time and **mortality rate** to describe the percentage of the population that dies from a given disease within a period of time. Diseases are often classified on the basis of severity and duration as follows:

- ▶ **Acute.** These diseases are relatively severe but usually last a short time.
- ▶ **Chronic.** These diseases are often less severe but are likely to be continuous or recurring for long periods.
- ▶ **Subacute.** These diseases are intermediate between acute and chronic, not being as severe as acute infections nor as long-lasting as chronic disorders.

A term used in describing a disease without known cause is **idiopathic** (id-e-o-PATH-ik), a word based on the Greek root *idio-* meaning “self-originating.” These diseases are of unknown origin and as yet have no explanation. An **iatrogenic** (i-at-ro-JEN-ik) disease results from the adverse effects of treatment, including drug treatment and surgery. The Greek root *iatro-* relates to a physician or to medicine.

A **communicable** disease is one that can be transmitted from one person to another. If many people in a given region acquire a certain disease at the same time, that disease is said to be **epidemic**. Epidemics of influenza, for example, occur periodically today, and epidemics of smallpox and bubonic plague occurred in earlier ages. If a given disease is found to a lesser extent but continuously in a particular region, the disease is **endemic** to that area. The common cold is endemic in human populations. A disease that is prevalent throughout an entire country or continent, or the whole world, is said to be **pandemic**. AIDS is now considered to be pandemic in certain areas of the globe (see Box 5-1).

Box 5-1 A Closer Look

The CDC: Making People Safer and Healthier

The Centers for Disease Control and Prevention (CDC) in Atlanta, Georgia, are responsible for protecting and improving the health of the American public—at home and abroad. Established in 1946, the CDC has become a world leader in the fight against infectious disease, with an expanded role that now includes control and prevention of chronic diseases such as cancer, heart disease, and stroke. The CDC also works to protect the public from environmental hazards such as waterborne illnesses, weather emergencies, biologic and chemical terrorism, and dangers in the home and workplace. In addition, the CDC provides education to guide informed health and lifestyle decisions.

The CDC's stated goal is “healthy people in a healthy world—through prevention.” During the 1940s, the newly created CDC joined state and local health officials in the fight against malaria. In the 1950s, it participated in the fight against

polio, which has virtually been eliminated in the United States. In the 1960s the CDC joined the World Health Organization in efforts to eradicate smallpox worldwide, and in the 1970s, it identified the pathogen responsible for Legionnaire's disease. In the 1980s the CDC reported the first cases of AIDS and began intensive research on the disease, which continues today. During the 1990s, CDC researchers rapidly identified the strain of hantavirus that caused a serious and often fatal pulmonary disease in people in the Southwestern U.S. and investigated an outbreak of deadly Ebola virus in Zaire. Currently, the CDC is working with laboratories throughout the U.S. to identify and control the organisms that cause West Nile disease and severe acute respiratory syndrome (SARS).

The CDC employs about 8,500 people in state, federal, and foreign locations. They work in more than 170 occupations, including health information, laboratory science, and microbiology.

Checkpoint 5-3 What two medical sciences are involved in any study of disease?

Checkpoint 5-4 What is a communicable disease?

► Treatment and Prevention of Disease

To treat a patient, a physician must first make a **diagnosis** (di-ag-NO-sis), that is, reach a conclusion as to the nature of the illness. To do this, the physician must know the **symptoms**, which are the conditions of disease noted by the patient, and the **signs**, which are the evidence (objective manifestations) the physician or other healthcare professional can observe. Many diseases cause a variety of effects and involve more than one body system. A characteristic group of symptoms and signs that accompanies a disease is called a **syndrome** (SIN-drome). Some complex disorders even have “syndrome” in their names, such as Down syndrome, premenstrual syndrome, acquired immunodeficiency syndrome (AIDS), and many others.

Frequently, the physician uses laboratory tests to help establish the diagnosis. Common methods used for diagnosis include imaging studies, blood tests, and study of tissues removed in biopsy. A **prognosis** (prog-NO-sis) is a prediction of the probable outcome of a disease based on the condition of the patient and the physician’s knowledge about the disease (from the Greek word *gnosis* meaning “knowledge”).

Nurses and other healthcare professionals play an extremely valuable role in the diagnostic process by observing closely for signs, collecting and organizing information from the patient about his or her symptoms, and then reporting this information to the physician. Once a patient’s disorder is known, the physician prescribes a course of treatment, known as **therapy**. Treatment may include drugs, surgery, radiation, counseling, physical or occupational therapy, and many others, alone or in combinations. Specific measures in a course of treatment include those carried out by the nurse and other healthcare providers under the physician’s orders.

Complementary and Alternative Medicine

The term *complementary and alternative medicine* (CAM) refers to methods of disease prevention or treatment that can be used along with or instead of traditional modern medical practices. Many of these nontraditional approaches have a long history in ancient philosophies and practices. Some examples of complementary and alternative practices are:

- **Naturopathy** (na-chur-OP-a-the), a philosophy of helping people to heal themselves by developing healthy lifestyles
- **Chiropractic** (ki-ro-PRAK-tik), a field that stresses manipulation to correct misalignment for treatment of musculoskeletal disorders
- **Acupuncture** (AK-u-punk-chur), an ancient Chinese method of inserting thin needles into the body at specific points to relieve pain or promote healing

- **Biofeedback** (bi-o-FEED-bak), which teaches people to control involuntary responses, such as heart rate and blood pressure, by means of electronic devices that monitor changes and feed information back to a person

Exercise, massage, yoga, meditation, nutritional counseling, and other health-promoting practices are also included under this heading.

The U.S. National Institutes of Health (NIH) has established the National Center for Complementary and Alternative Medicine (NCCAM) to study the value of these therapies.

Herbal Remedies The use of plant-derived remedies has increased in industrialized countries in recent years. Many plant products are used as conventional drugs, but typically they are measured, purified, and often modified instead of being used in their natural state. Questions of purity, safety, dosage, and effectiveness have arisen in the use of herbal remedies as, to date, they have not been tested as rigorously as conventional drugs. The U.S. government does not test or regulate herbals, and there are no requirements to report their adverse effects. There are, however, restrictions on the health claims that can be made by the manufacturers, and the Federal Drug Administration (FDA) can withdraw products from the market that cause unreasonable risk of harm at the recommended doses. The U.S. Office of Dietary Supplements (ODS) supports and coordinates research on herbal preparations.

Prevention of Disease

In recent years, physicians, nurses, and other healthcare workers have taken on increasing responsibilities in prevention of disease. Throughout most of medical history, the physician’s aim has been to cure patients of existing diseases. The modern concept of prevention, however, seeks to stop disease before it actually happens—to keep people well through the promotion of health. Areas of improvement include cessation of smoking, improved diet, weight control, and adequate exercise. A vast number of organizations exist for the purpose of promoting health, ranging from the World Health Organization (WHO) on an international level to local private and community health programs. In the U.S., the Centers for Disease Control and Prevention (CDC) play an important role in the study of disease (see Box 5-1). A rapidly growing responsibility of all people in health occupations is educating patients on the maintenance of total health, both physical and mental.

Checkpoint 5-5 A physician uses signs and symptoms to identify an illness. What is this identification called?

► Infectious Disease

A predominant cause of disease in humans is the invasion of the body by disease-producing **microorganisms** (mi-kro-OR-gan-izms). The word *organism* means “anything

having life”; *micro* means “very small.” Thus, a microorganism is a tiny living thing, too small to be seen by the naked eye. Other terms for microorganism are *microbe* and, more popularly, *germ*. A microbe, or any other organism, that lives on or within a living **host** and at the host’s expense is called a **parasite**.

Although most microorganisms are harmless to humans, and many are beneficial, a few types cause illness; that is, they are **pathogenic** (path-o-JEN-ic). Any disease-causing organism is a **pathogen** (PATH-o-jen). If the body is invaded by pathogens, with adverse effects, the condition is called an **infection**. If the infection is restricted to a relatively small area of the body, it is **local**; a generalized, or **systemic** (sis-TEM-ik), infection is one in which the whole body is affected. Systemic infections are usually spread by the blood.

An infection that takes hold because the host has been compromised (weakened) by disease is described as an **opportunistic infection**. For example, people with depressed immune systems, such as those with AIDS become infected with organisms that are ordinarily harmless.

Modes of Transmission

Microorganisms may be transmitted from an infected human, insect, or animal host to another susceptible host by direct or indirect contact. For example, infected human hosts may transfer their microorganisms directly to other individuals by touching, shaking hands, kissing, or having sexual intercourse. Microorganisms may be transferred indirectly through touched objects, such as bedding, toys, food, and dishes.

The atmosphere is a carrier of microorganisms. Although microbes cannot fly, the dust of the air is alive with them. In close quarters, germ-laden droplets discharged by

sneezing, coughing, and even normal conversation contaminate the atmosphere. Insects and other pests may deposit infectious material on food, skin, or clothing. Pathogens are spread by such pests as rats, mice, fleas, lice, flies, and mosquitoes. Pets may be an indirect source of some infections.

An insect bite may introduce infectious organisms into the body. An insect or other animal that transmits a disease-causing organism from one host to another is termed a **vector** (VEK-tor). Crowded conditions and poor sanitation increase the spread of disease organisms by all of these mechanisms. (See Box 5-2, The Cold Facts about the Common Cold.)

Portals of Entry and Exit There are several avenues through which microorganisms may enter the body: the skin, respiratory tract, and digestive system as well as the urinary and reproductive systems. These portals of entry may also serve as exit routes, leading to the spread of infection. For example, discharges from the respiratory and intestinal tracts may spread infection through air, by contamination of hands, and by contamination of food and water supplies.

Control of infectious disease involves breaking the “chain of infection” by which microorganisms spread through a population. Microbial control is discussed later in this chapter.

Checkpoint 5-6 What is the relationship between a parasite and a host?

Checkpoint 5-7 What term describes any disease-causing organism?

Checkpoint 5-8 What are some portals of entry and exit for microorganisms?

Box 5-2 • Health Maintenance

The Cold Facts about the Common Cold

Every year, an estimated one billion Americans suffer from the symptoms of the common cold—runny nose, sneezing, coughing, and headache. Although most cases are mild and usually last about a week, colds are the leading cause of doctor visits and missed days at work and school.

Colds are caused by a viral infection of the mucous membranes of the upper respiratory tract. More than 200 different viruses are known to cause cold symptoms. While most colds occur in winter, scientists have found that cold weather does not increase the risk of “catching” a cold; the incidence is probably higher in winter because people spend more time indoors, increasing the chances that the virus will spread from person to person.

Colds spread primarily from contact with a contaminated surface. When an infected person coughs or sneezes, small droplets of water filled with viral particles are propelled through the air. One unshielded sneeze may spread hundreds of thousands of viral particles several feet. Depending upon

temperature and humidity, these particles may live as long as 3 to 6 hours, and others who touch the contaminated surface may pick up the particles on their hands.

To help prevent the transmission of cold viruses:

- ▶ Avoid close contact with someone who is sneezing or coughing.
- ▶ Wash hands frequently to remove any viral particles you may have picked up.
- ▶ Avoid touching or rubbing your eyes, nose, or mouth with contaminated hands.
- ▶ Clean contaminated surfaces with disinfectant.

There are currently no medically proven cures for the common cold, and treatments only ease the symptoms. Because viruses cause the common cold, antibiotics are of no benefit. Getting plenty of rest and drinking lots of fluids are the best ways to speed recovery.

► Microbiology—The Study of Microorganisms

Microorganisms are simple, usually single-cell forms of life. The group includes bacteria, viruses, fungi, protozoa, and algae. The study of these microscopic organisms is **microbiology** (mi-kro-bi-OL-o-je). The organisms included in the study of microbiology along with their scientific specialties are listed here and summarized in **Table 5-1**:


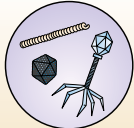
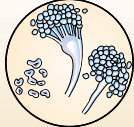
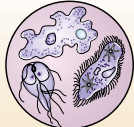

- **Bacteria** (bak-te-re-ah) are primitive, single-cell organisms that grow in a wide variety of environments. The study of bacteria, both beneficial and disease producing, is **bacteriology** (bak-te-re-OL-o-je). The group includes rickettsiae and chlamydiae, which are extremely small bacteria that multiply within living cells.
- **Viruses** (VI-rus-es) are extremely small infectious agents that can multiply only within living cells. **Virology** (vi-ROL-o-je) is the study of viruses.
- **Fungi** (FUN-ji), is a group that included yeasts and molds. **Mycology** (mi-KOL-o-je) is the study of fungi (the root *myco-* refers to a fungus).
- **Protozoa** (pro-to-ZO-ah) are single-cell animals. Their

study is **protozoology** (pro-to-zo-OL-o-je). Although the term *parasitology* (par-ah-si-TOL-o-je) is the study of parasites in general, in practice, it usually refers to the study of protozoa and worms (helminths).

- **Algae** (AL-je) are very simple multicellular or single-cell aquatic plants. Their study is **algology** (al-GOL-o-je). These organisms rarely cause diseases and will not be described any further in this chapter.

Despite the fact that this discussion centers on pathogens, most microorganisms are harmless to humans and are actually essential to the continuation of all life on earth. Algae, single-cell plants, produce a large proportion of the oxygen we breathe, and they serve as food for aquatic animals. Through the actions of microorganisms, dead animals and plants are decomposed and transformed into substances that enrich the soil. Sewage is rendered harmless by microorganisms. Several groups of bacteria transform the nitrogen of the air into a form usable by plants, a process called *nitrogen fixation*. Farmers take advantage of this capacity by allowing a field to lie fallow (untilled) so that the nitrogen of its soil can be replenished. Certain bacteria and fungi produce the antibiotics that make our lives safer. Others produce the fer-

Table 5-1 Organisms Studied in Microbiology

TYPE OF ORGANISM	NAME OF STUDY	CHARACTERISTICS OF ORGANISMS	REPRESENTATIVE EXAMPLES
Bacteria	Bacteriology	Simple, single-cell organisms. Grow in many environments. Lack a true nucleus and most organelles.	 Bacteria
Viruses	Virology	Composed of nucleic acid and protein. Can reproduce only within living cells—obligate intracellular parasites.	 Viruses
Fungi	Mycology	Very simple, non-green, plantlike organisms. Single-cell forms are yeasts; filamentous forms are molds.	 Fungi
Protozoa	Protozoology	Single-cell, animal-like organisms.	 Protozoa
Algae	Algology	Simple aquatic plants. Not parasitic.	 Algae

mented products that make our lives more enjoyable, such as beer, wine, cheeses, and yogurt.

Normal Flora

We have a population of microorganisms that normally grows on and within our bodies. We live in balance with these organisms, which make up the **normal flora**. These populations are beneficial because they crowd out and prevent the growth of other harmful varieties of organisms. Some microorganisms that are normally harmless may become pathogenic if the normal flora are destroyed, as by the administration of antibiotics that act on a wide range of microorganisms.

Checkpoint 5-9 What are the categories of organisms studied in microbiology?

Checkpoint 5-10 What term refers to the microorganisms that normally live in or on the body?

Bacteria

Bacteria are single-cell organisms that are among the most primitive forms of life on earth. They are unique in that their genetic material is not enclosed in a membrane, that is, they do not have a true nucleus. They also lack most of the organelles found in plant and animal cells. They can be seen only with a microscope; from 10 to 1000 bacteria (depending on the species) would, if lined up, span a pinhead. Staining of the cells with dyes helps make their structures more visible and reveals information about their properties.

Bacteria are found everywhere: in soil, in hot springs, in polar ice, and on and within plants and animals. Their requirements for water, nutrients, oxygen, temperature, and other factors vary widely according to species. Some are capable of carrying out photosynthesis, as do green plants; others must take in organic nutrients, as do animals. Some, described as **anaerobic** (an-air-O-bik), can grow in the absence of oxygen; others, called **aerobic** (air-O-bik), require oxygen. Other groups of bacteria are de-



Figure 5-1 Endospores. These bacteria have endospores that are visible as clear enlargements at the ends of the cells. (Reprinted with permission from Koneman EW, et al. *Color Atlas and Textbook of Diagnostic Microbiology*. 5th ed. Philadelphia: Lippincott Williams & Wilkins, 1997.)



Figure 5-2 Flagella. Bacteria use these threadlike appendages to swim. (Reprinted with permission from Koneman EW, et al. *Color Atlas and Textbook of Diagnostic Microbiology*. 5th ed. Philadelphia: Lippincott Williams & Wilkins, 1997.)

scribed as **facultative anaerobes**. These cells will use oxygen if it is present but are able to grow without oxygen if it is not available. *Escherichia coli*, an intestinal organism, is an example of a facultative anaerobe.

Some bacteria produce resistant forms, called **endospores**, that can tolerate long periods of dryness or other adverse conditions (Fig. 5-1). Because these endospores become airborne easily and are resistant to ordinary methods of disinfection, pathogenic organisms that form endospores are particularly dangerous. Note that it is common to shorten the name endospore to just “spore,” but these structures are totally different in structure and purpose from the reproductive spores produced by fungi and plants. The organisms that cause tetanus, botulism (a deadly form of food poisoning), and anthrax are examples of spore-forming species.

Many types of bacteria are capable of swimming rapidly by means of threadlike appendages called **flagella** (flah-JEL-ah) (Fig. 5-2). Flagella may be located all around the cell, at one end, or at both ends. Short flagella-like structures called **pili** (PI-li) help bacteria to glide along solid surfaces. Pili also help to anchor bacteria to surfaces, such as to the surface of a liquid to get oxygen, and to attach bacteria to each other for exchange of genetic information in a process called **conjugation**.

Bacteria comprise the largest group of pathogens. Not surprisingly, these pathogenic bacteria are most at home within the “climate” of the human body. When living conditions are suitable, the organisms reproduce by binary fission (simple cell division). Depending on the species and the growth conditions, cells can divide as rapidly as once every 20 minutes or as slowly as just once every 24 hours. When growing rapidly, populations can increase with unbelievable rapidity. Just 10 cells dividing at a rate of once every 20 minutes becomes a population of over 40,000 within 4 hours. Imagine this activity occurring in a wound or in a bowl of food left out at a picnic without refrigeration.

We have a number of natural defenses to protect our bodies against harmful microorganisms. These include physical barriers, such as the skin and mucous membranes, and the immune system, as described in Chapter 17. If bacteria succeed in overcoming these defenses, they can cause damage in two ways: by producing poisons, or **toxins**, and by entering the body tissues and growing within them. Table 1 in Appendix 5 lists some typical pathogenic bacteria and the diseases they cause.

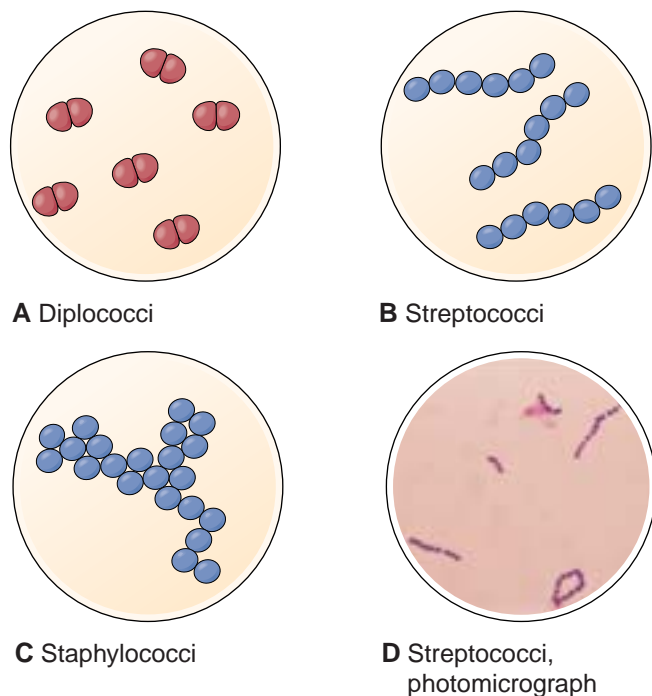


Figure 5-3 Cocci, round bacteria (Gram stained). (A) Diplococci, cocci in pairs. (B) Streptococci, cocci in chains. (C) Staphylococci, cocci in clusters. (D) Streptococci stained and viewed under a microscope. (D, Reprinted with permission from Koneman EW, et al. *Color Atlas and Textbook of Diagnostic Microbiology*. 5th ed. Philadelphia: Lippincott Williams & Wilkins, 1997.) **ZOOMING IN** ♦ *What word describes the shape and arrangement of the cells in D?*

Checkpoint 5-11 What are resistant forms of bacteria called?

Shape and Arrangement of Bacteria There are so many different types of bacteria that their classification is complicated. For our purposes, a convenient and simple grouping is based on the shape and arrangement of these organisms as seen with a microscope:

- ♦ **Cocci** (KOK-si). These cells are round and are seen in characteristic arrangements (Fig. 5-3). Those that are

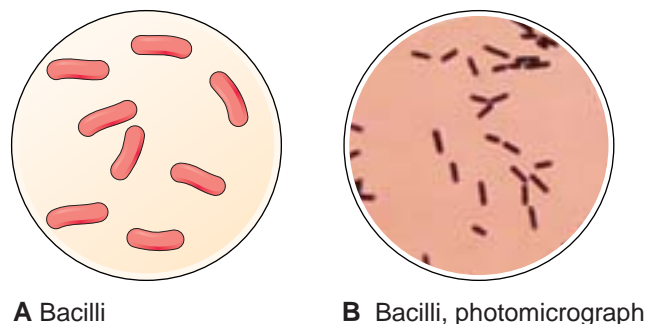


Figure 5-4 Bacilli. (A) Bacilli are rod-shaped bacteria. (B) Bacilli stained and viewed under a microscope. (B, Reprinted with permission from Koneman EW, et al. *Color Atlas and Textbook of Diagnostic Microbiology*. 5th ed. Philadelphia: Lippincott Williams & Wilkins, 1997.)

in pairs are called **diplococci**. Those that are arranged in chains, like a string of beads, are called **streptococci**. A third group, seen in large clusters, is known as **staphylococci** (staf-ih-lo-KOK-si). Among the diseases caused by diplococci are gonorrhea and meningitis; streptococci and staphylococci are responsible for a wide variety of infections, including pneumonia, rheumatic fever, and scarlet fever.

- ♦ **Bacilli** (bah-SIL-i). These cells are straight, slender rods (Fig. 5-4), although some are cigar-shaped, with tapering ends. All endospore-forming bacteria are bacilli. Typical diseases caused by bacilli include tetanus, diphtheria, tuberculosis, typhoid fever, and Legionnaire's disease.

- ♦ **Curved rods**, which includes several categories:

- ♦ **Vibrios** (VIB-re-oze) are short rods with a slight curvature, like a comma (Fig. 5-5 A). Cholera is caused by a vibrio.

- ♦ **Spirilla** (spi-RIL-a) are long and wavelike cells, resembling a corkscrew. The singular is *spirillum*.

- ♦ **Spirochetes** (SPI-ro-ke-tes) are similar to the spirilla, but are capable of waving and twisting motions (see Fig. 5-5 B, C). One infection caused by a spirochete is syphilis. The syphilis spirochetes enter the body at the point of contact, usually through the genital skin or mucous membranes. They then travel into the bloodstream and set up a systemic infection. (See Table 1 in Appendix 5 for a summary of the three stages of syphilis.)

A spirochete is also responsible for Lyme disease, which has increased in the United States since it first appeared in the early 1960s. People who walk in or near woods are advised to wear white protective clothing that covers their ankles. They should examine their bodies for the freckle-sized ticks that carry the disease.

Other Bacteria Members of the genus *Rickettsia* (rih-KET-se-ah) and the genus *Chlamydia* (klah-MID-e-ah) are classified as bacteria, although they are considerably smaller than other bacteria. These microorganisms can exist only inside living cells. Because they exist at the expense of their hosts, they are parasites; they are referred to as *obligate intracellular parasites* because they must grow within living cells.

The rickettsiae are the cause of a number of serious diseases in humans, such as typhus and Rocky Mountain spotted fever. In almost every instance, these organisms are transmitted through the bites of insects, such as lice, ticks, and fleas. A few common diseases caused by rickettsiae are listed in Table 1 in Appendix 5.

The chlamydiae are smaller than the rickettsiae. They are the causative organisms in trachoma (a serious eye infection that ultimately causes blindness), parrot fever or psittacosis, the sexually transmitted infection lymphogranuloma venereum, and some respiratory diseases (see Table 1 in Appendix 5).

Naming Bacteria As is common in naming higher plants and animals, the names of bacteria include a genus

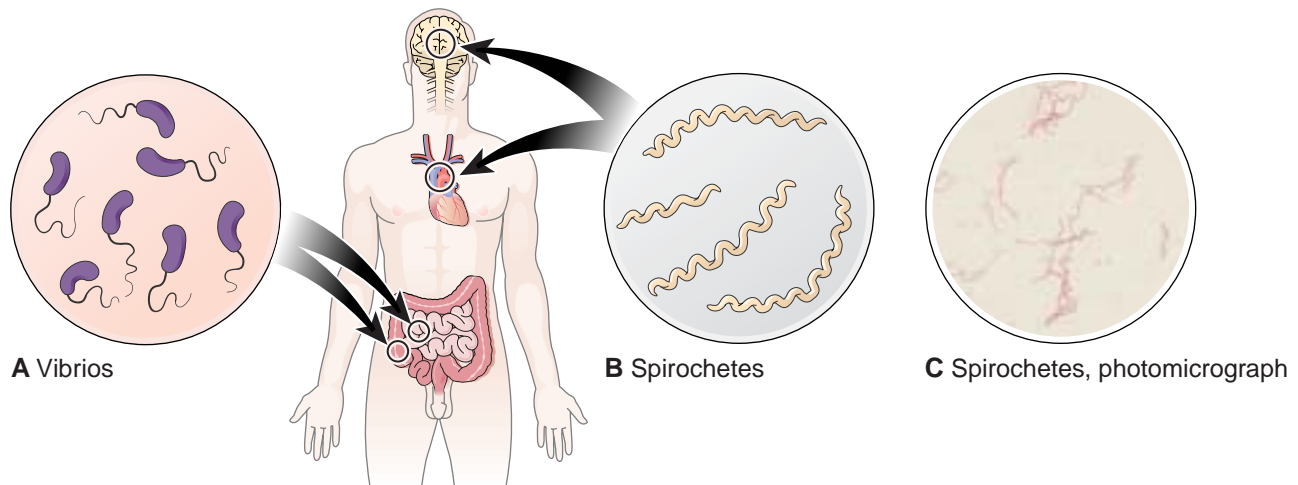


Figure 5-5 Curved rods. (A) Vibrios, comma-shaped organisms. A vibrio causes Asiatic cholera. (B) Spirochetes, spiral-shaped organisms that move with a twisting motion. A spirochete causes syphilis. (C) Spirochetes as seen under a microscope. (C, Reprinted with permission from Koneman EW, et al. *Color Atlas and Textbook of Diagnostic Microbiology*. 5th ed. Philadelphia: Lippincott Williams & Wilkins, 1997.) **ZOOMING IN** ♦ What feature indicates that the cells in A are capable of movement?

name, written with a capital letter, and a species name, written with a small letter, both names italicized. The genus or species names may be taken from the name of an organism's discoverer, as in *Escherichia*, named for Theodor Escherich, or *Rickettsia*, named for Howard T. Ricketts. Some other criteria are shape (e.g., genus *Staphylococcus*, *Bacillus*), the disease caused (e.g., *S. pneumoniae*, which causes pneumonia; *N. meningitidis*, the cause of meningitis), habitat (*S. epidermidis*, which grows on the skin), or growth characteristics. *S. pyogenes* produces pus, and colonies of *S. aureus*, based on the Latin word for gold, have a golden yellow color. More specific information is conveyed by adding names for subgroups such as type, subtype, strain, variety, etc.

Checkpoint 5-12 What are the three basic shapes of bacteria?

Viruses

Although bacteria seem small, they are enormous in comparison with viruses (Fig. 5-6). Viruses are comparable in size to large molecules, but unlike other molecules, they contain genetic material and are able to reproduce. Viruses are so tiny that they are invisible with a light microscope; they can be seen only with an electron microscope. Because of their small size and the difficulties associated with growing them in the laboratory, viruses were not studied with much success until the middle of the 20th century.

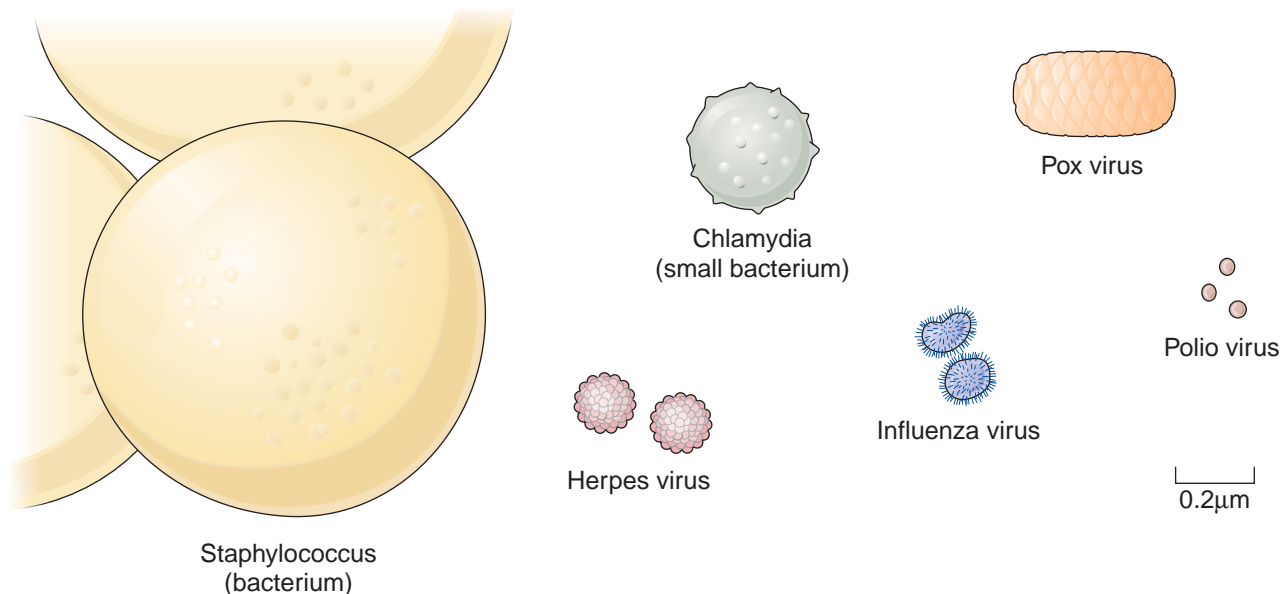


Figure 5-6 Virus size comparison. A chlamydia and a staphylococcus are shown for reference.

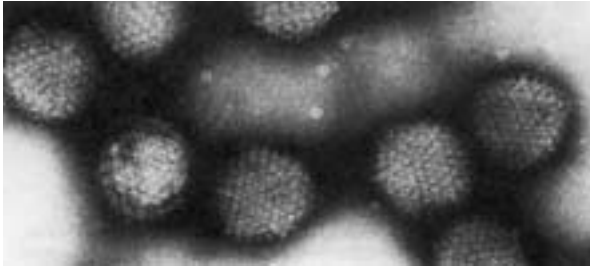


Figure 5-7 Virus structure. Note the regular arrangement of units in the protein coat. Magnified $\times 234,000$. (Reprinted with permission from Koneman EW, et al. *Color Atlas and Textbook of Diagnostic Microbiology*. 5th ed. Philadelphia: Lippincott Williams & Wilkins, 1997.)

Viruses have some of the fundamental properties of living matter, but they are not cellular, and they have no enzyme system. They are composed of a core of nucleic acid, either DNA or RNA, surrounded by a coat of protein (Fig. 5-7). Like the rickettsiae and the chlamydiae, they can grow only within living cells—they are obligate intracellular parasites. Unlike these other organisms, however, viruses are not susceptible to antibacterial agents (antibiotics) and must be treated with antiviral drugs.

Viruses are classified according to the type of nucleic acid they contain—DNA or RNA—and whether that nucleic acid is single stranded (ss) or double stranded (ds). They are further grouped according to the diseases they cause, of which there are a considerable number—measles, poliomyelitis, hepatitis, chickenpox, and the common cold, to name just a few. AIDS is a very serious viral disease discussed in Chapter 17. The virus that causes AIDS and other representative viruses are listed in Table 2 in Appendix 5.

Viruses are named according to where they were isolated (Hanta, Ebola, West Nile), the symptoms they cause (yellow fever virus, which causes jaundice; hepatitis virus, which causes inflammation of the liver), the host (chickenpox, human immunodeficiency virus, swine influenza), or the vector that carries them (Colorado tick fever).

Infectious Agents Smaller than Viruses Viruses were considered the smallest known infectious agents until the discovery of two even smaller and simpler agents of disease. **Prions** (PRI-ons) are infectious particles composed solely of protein (the name comes from **pro**teinaceous **in**fectious agent). Prions have been linked to several fatal diseases in humans and animals. They are very slow-growing and hard to destroy, producing spongy degeneration of brain tissue, described as *spongiform encephalopathy* (en-sef-ah-LOP-a-the). Some examples of diseases caused by prions are Creutzfeldt-Jacob disease (CJD) in humans; bovine spongiform encephalopathy (BSE), the so-called “mad cow disease,” in cows, a variant of which affects humans; and scrapie in sheep. Some diseases caused by prions are described in Table 3 of Appendix 5.

Viroids (VI-roysd), in contrast, are composed of RNA alone with no protein coat. They are also intracellular parasites, but so far, they have been linked only to diseases in plants.

Checkpoint 5-13 How do viruses differ from bacteria?

Fungi

The true **fungi** (FUN-ji) are a large group of simple plant-like organisms. Only a few types are pathogenic. Although fungi are much larger and more complicated than bacteria, they are a simple form of life. They differ from the higher plants in that they lack the green pigment chlorophyll, which enables most plants to use the energy of sunlight to manufacture food. Like bacteria, fungi grow best in dark, damp places. Single-cell forms of fungi are generally referred to as **yeasts**; the fuzzy, filamentous forms are called **molds** (Fig. 5-8). Molds reproduce in several ways, including by simple cell division and by production of large numbers of reproductive spores. Yeasts reproduce by simple cell division and can also form buds that pinch off as new cells. Familiar examples of fungi are mushrooms, puffballs, bread molds, and the yeasts used in baking and brewing.

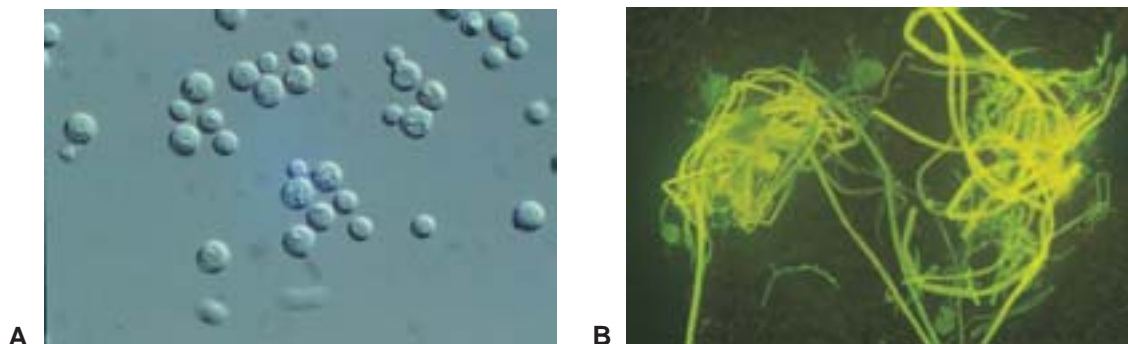


Figure 5-8 Fungi. (A) Yeasts. Some of these single-cell fungi are budding to form new cells (B) Molds, filamentous forms of fungi. (A, Reprinted with permission from LWW’s Organism Central [CD-ROM for Windows]. Philadelphia: Lippincott Williams & Wilkins, 2001. B, Reprinted with permission from Koneman EW, et al. *Color Atlas and Textbook of Diagnostic Microbiology*. 5th ed. Philadelphia: Lippincott Williams & Wilkins, 1997.)

Fungal Diseases Diseases caused by fungi are called **mycotic** (mi-KOT-ik) infections (*myco-* means “fungus”). Examples of these are athlete’s foot and ringworm. *Tinea capitis* (TIN-e-ah KAP-ih-tis), which involves the scalp, and *Tinea corporis* (kor-PO-ris), which may be found almost anywhere on the nonhairy parts of the body, are common types of ringworm.

One yeast like fungus that may infect a weakened host is *Candida*. This is a normal inhabitant of the mouth and digestive tract that may produce skin lesions, an oral infection called *thrush*, digestive upset, or inflammation of the vaginal tract (vaginitis) as an opportunistic infection in a weakened host.

Although fungi cause few systemic diseases, some diseases they cause are very dangerous and may be difficult to cure. Pneumonia can be caused by the inhalation of fungal spores contained in dust particles. An atypical fungus, *Pneumocystis jiroveci* (formerly called *P. carinii*) causes a previously rare pneumonia known as PCP (*Pneumocystis* pneumonia) in people with AIDS and others with weakened immune systems. Table 4 in Appendix 5 is a list of typical fungal diseases.

Protozoa

With the **protozoa** (pro-to-ZO-ah), we come to the only group of microbes that can be described as animal-like. Although protozoa are also single-cell organisms, they are much larger than bacteria (Fig. 5-9).

Protozoa are found all over the world in the soil and in almost any body of water from moist grass to mud puddles to the sea. There are four main divisions of protozoa:

- ♦ **Amebas** (ah-ME-bas). An ameba (also spelled *amoeba*) is an irregular mass of cytoplasm that propels itself by extending part of its cell (a pseudopod, or “false foot”) and then flowing into the extension. Amebic dysentery is caused by a pathogen of this group (see Fig. 5-9 A, B).
- ♦ **Ciliates** (SIL-e-ates). This type of protozoon is covered with tiny hairs called *cilia* that produce a wave action to propel the organism.
- ♦ **Flagellates** (FLAJ-eh-lates). Long, whiplike filaments called flagella propel these organisms. One of this group, a **trypanosome** (tri-PAN-o-some), causes African sleeping sickness, which is spread by the tsetse fly (see Fig. 5-9 C, D). *Giardia* is a flagellated protozoon that contaminates water supplies throughout the world. It infects the intestinal tract, causing diarrhea. The disease, giardiasis, is the most common waterborne disease in the United States.
- ♦ **Sporozoa** (spor-o-ZO-ah), also known as **apicomplexans** (ap-i-kom-PLEK-sans). Unlike other protozoa, sporozoa cannot propel themselves. They are obligate parasites, unable to grow outside a host. Members of the genus *Plasmodium* (plaz-MO-de-um) cause malaria (see Fig. 5-9 E, F). These protozoa, carried by a type of mosquito as a vector, cause much serious illness in the tropics, resulting in over 1 million deaths each year. The sporozoon *Cryptosporidium* is an opportunistic pathogen that causes severe

and prolonged diarrhea in people suffering from AIDS and in those whose immune system is working poorly.

Table 5 in Appendix 5 presents a list of typical pathogenic protozoa with the diseases they cause.

Checkpoint 5-14 What group of microorganisms is most animal-like?

Parasitic Worms

Many species of worms, also referred to as **helminths**, are parasites with human hosts. The study of worms, particularly parasitic worms, is called **helminthology** (hel-min-THOL-o-je). Whereas invasion by any form of organism is usually called an *infection*, the presence of parasitic worms in the body also can be termed an *infestation* (Fig. 5-10). Although worms themselves can be seen with the naked eye, a microscope is required to see their eggs or larval forms.

Roundworms

Many human parasitic worms are classified as roundworms, one of the most common of which is the large worm *ascaris* (AS-kah-ris) (see Fig. 5-10 A). This worm is prevalent in many parts of Asia, where it is found mostly in larval form. In the United States, it is found most frequently among children (ages 4 to 12 years) in rural areas with warm climates.

Ascaris is a long, white-yellow worm pointed at both ends. It may infest the lungs or the intestines, producing intestinal obstruction if present in large numbers. The eggs produced by the adult worms are deposited with feces (excreta) in the soil. These eggs are very resistant; they can live in soil during either freezing or hot, dry weather and cannot be destroyed even by strong antiseptics. New worms develop within the eggs and later reach the digestive system of a host by means of contaminated food. *Ascaris* infestation may be diagnosed by a routine stool examination.

Another fairly common infestation, particularly in children, is the seat worm, or **pinworm** (*Enterobius vermicularis*), which is also hard to control and eliminate. The worms average 12 mm (somewhat less than 1/2 inch) in length and live in the large intestine. The adult female moves outside the vicinity of the anus to lay its thousands of eggs. A child’s fingers often transfer these eggs from the itching anal area to the mouth. In the digestive system of the host, the eggs develop to form new adult worms, and thus a new infestation is begun. A child also may infect others by this means. In addition, pinworm eggs that are expelled from the body constitute a hazard because they may live in the external environment for several months. Patience and every precaution, with careful attention to medical instructions, are necessary to rid a patient of the worms. It is essential to wash the hands, keep the fingernails clean, and avoid finger sucking.

Hookworms are parasites that live in the small intestine. They are dangerous because they suck blood from

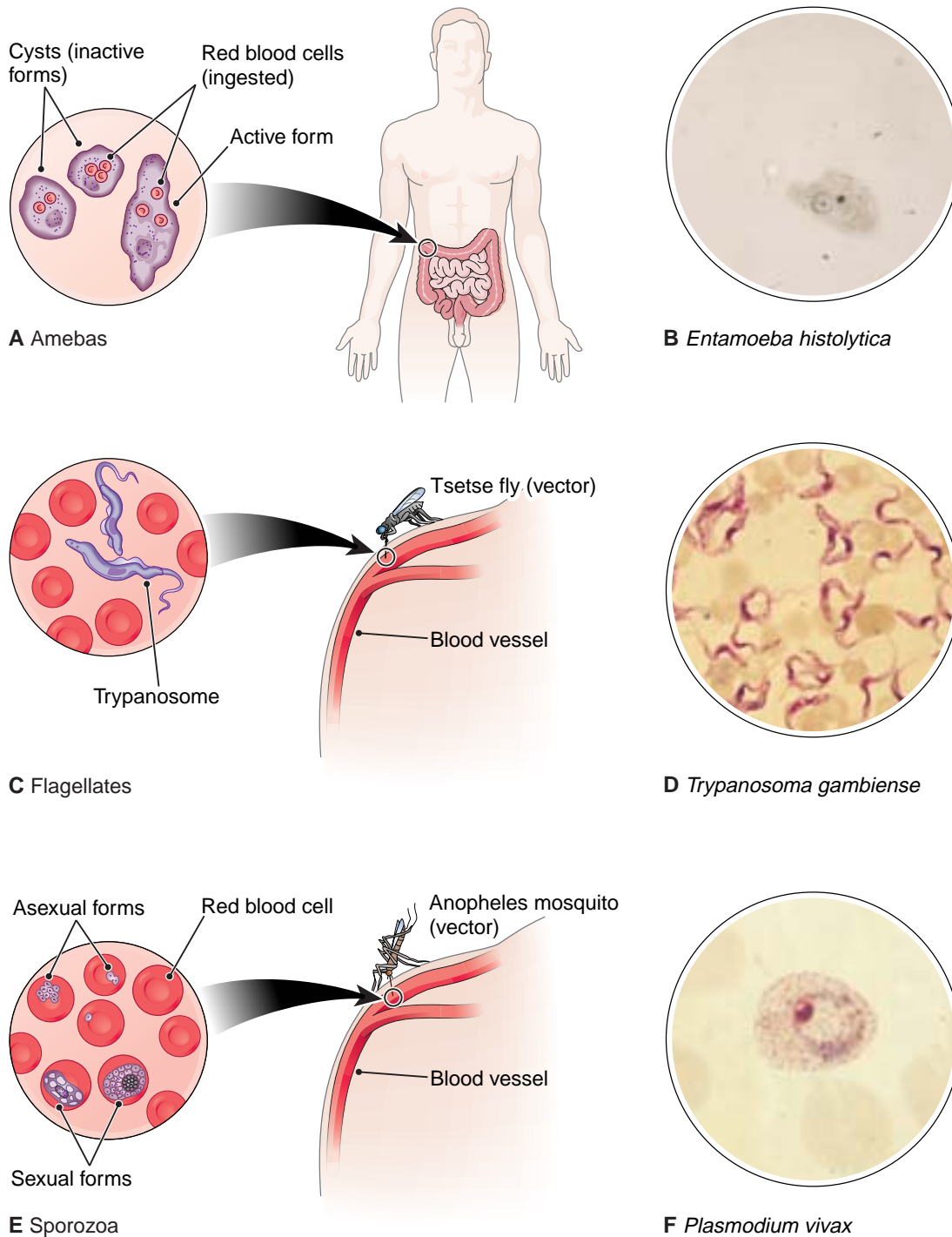


Figure 5-9 Some parasitic protozoa. (A) Amebas. (B) *Entamoeba histolytica*, cause of amebic dysentery, seen under the microscope. (C) Flagellates. Trypanosomes cause African sleeping sickness. (D) Trypanosomes in a blood sample seen under the microscope. (E) Sporozoa. *Plasmodium vivax* causes malaria. (F) An enlarged red blood cell with a single parasite seen under the microscope. (B, D, F, Reprinted with permission from Koneman EW, et al. Color Atlas and Textbook of Diagnostic Microbiology. 5th ed. Philadelphia: Lippincott Williams & Wilkins, 1997.) **ZOOMING IN ♦ Why are the parasites in E described as intracellular? What is the role of the vectors shown in C and E?**

the host, causing such a severe anemia (blood deficiency) that the victim becomes sluggish, both physically and mentally. Most victims become susceptible to various chronic infections because of extremely reduced resistance following great and continuous blood loss.

Hookworms lay thousands of eggs, which are distributed in the soil by contaminated feces. The eggs develop into small larvae, which are able to penetrate the intact skin of bare feet. They enter the blood and are carried to the lungs and the upper respiratory tract, finally reaching

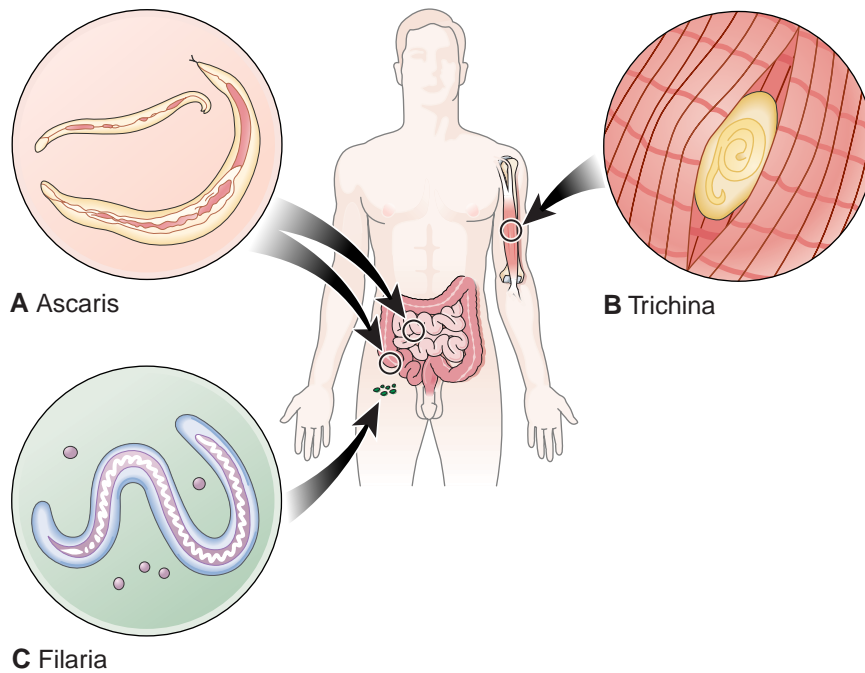


Figure 5-10 Common parasitic roundworms. (A) *Ascaris* infests the digestive tract. (B) *Trichina* is transmitted in meat and encysts in muscles. (C) *Filaria* may cause elephantiasis. **ZOOMING IN** ◆ What kind of muscle tissue is shown in B?

the digestive system. Proper disposal of body wastes, attention to sanitation, and wearing shoes in areas where the soil is contaminated best prevent this infestation.

The small roundworm *trichina* (trik-I-nah) is not transmitted by feces, but in pork and the meat of wild game, such as bear and wild pig. The tiny worms become enclosed in cysts, or sacs, inside the muscles of these animals (Fig. 5-10 B). If the undercooked meat is eaten, the host's digestive juices dissolve the cysts, and the worms are released into the intestine. In a day or two, they lay eggs. When the larvae emerge, they travel to the host's muscles, where they again become encysted the females mate. This disease is known as **trichinosis** (trik-ih-NO-sis).

Biting insects, such as flies and mosquitoes, transmit the tiny, threadlike *filaria* worm that causes **filariasis** (fil-ah-RI-ah-sis) (see Fig. 5-10 C). The worms grow in large numbers, causing various disturbances. If they clog the lymphatic vessels, a condition called **elephantiasis** (el-eh-fan-TI-ah-sis) results, in which the lower extremities, the scrotum, the breasts and other areas may become tremendously enlarged (Fig. 5-11). Filariasis is most common in tropical and subtropical lands, such as southern Asia and many of the South Pacific islands.

Flatworms

Some flatworms resemble long ribbons, whereas others have the shape of a leaf. Tapeworms may grow in the intestinal tract to a length of 1.5 to 15 meters (5 to 50 feet) (Fig. 5-12 A, B). They are spread by infected, improperly

cooked meats, including beef, pork, and fish. Like that of most intestinal worm parasites, the flatworm's reproductive system is highly developed, so that each worm produces an enormous number of eggs, which may then contaminate food, water, and soil. Leaf-shaped flatworms, known as *flukes*, may invade various parts of the body, including the blood, lungs, liver, and intestine (see Fig. 5-12 C).

Checkpoint 5-15 What is the study of worms called?

Microbial Control

As a result of immunization programs and the development of antibiotics, it was commonly believed by the mid-20th century that infectious diseases soon would be conquered. Indeed, smallpox was eradicated from the world by 1980. It is now clear that we are far from reaching this goal, and that infectious diseases are increasing

due to factors that include:

- ◆ Increase in the world population, with more crowding of people into cities and poor sanitation. These conditions increase the spread of microorganisms by direct contact, through the air, and by pests.
- ◆ Disruption of animal habitats, with more contact between humans and animals, allowing animal pathogens to spread to human hosts. Some organisms that have made this shift include HIV, the cause of AIDS, which originated in chimpanzees; West Nile virus from birds;



Figure 5-11 Filariasis. The photo shows massive enlargement (elephantiasis) of the scrotum and left leg. (Reprinted with permission from Rubin E, Farber JL. Pathology 3rd ed. Philadelphia: Lippincott Williams & Wilkins, 1999.)

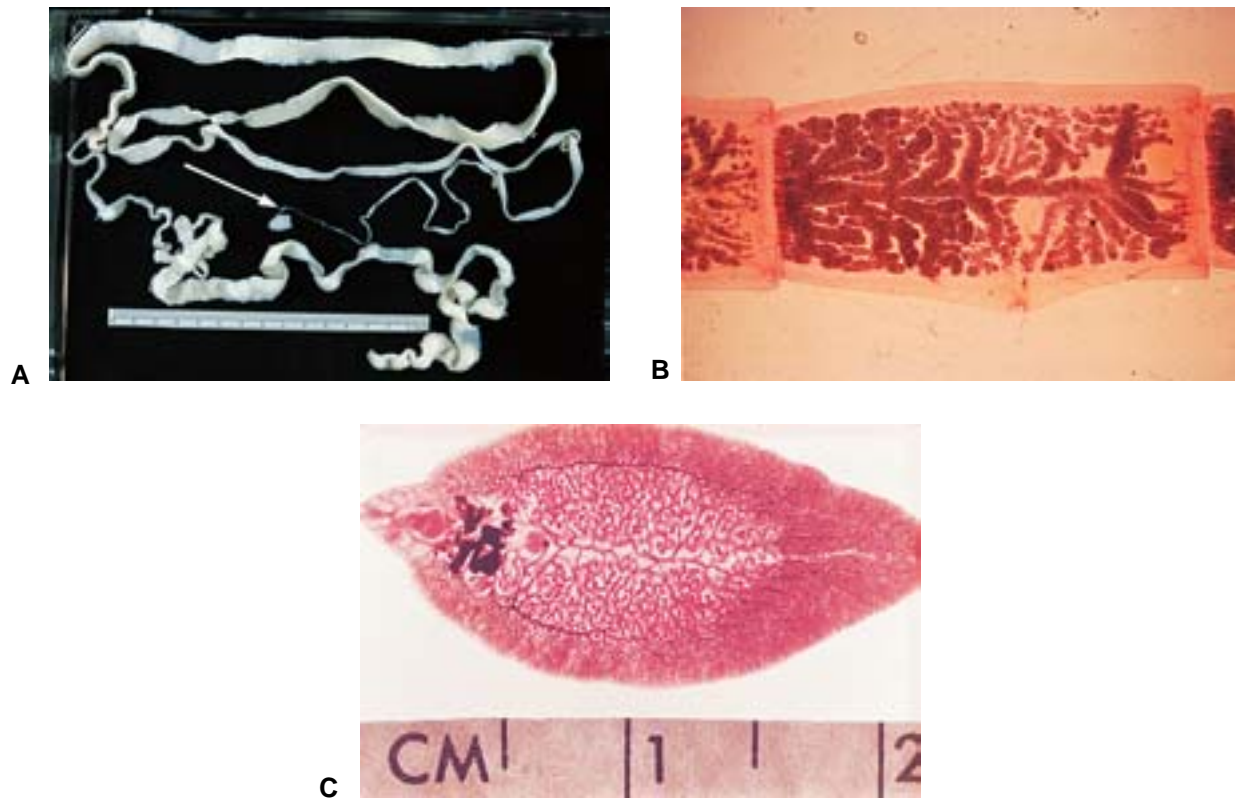


Figure 5-12 Flatworms. (A) Tapeworms can measure more than 30 feet in length. The arrow shows the headlike attachment point. (B) Segments of a tapeworm. (C) A fluke. (Reprinted with permission from Koneman EW, et al. *Color Atlas and Textbook of Diagnostic Microbiology*. 5th ed. Philadelphia: Lippincott Williams & Wilkins, 1997.)

severe acute respiratory syndrome (SARS), believed to have come from some small wild mammal used for food; and various strains of influenza.

- ▶ Increased travel, especially air travel, which can spread an infectious organism throughout the globe in a day. SARS spread rapidly from China to other countries in the spring of 2003.
- ▶ Medical advances that keep people alive longer, but in a debilitated state, subject to opportunistic infections.
- ▶ Changes in food handling that allow foods to be stored, processed, and shipped long distances on a large scale, sometimes with inadequate oversight.

Because of their huge variety and adaptability, there is scarcely a place on earth that is naturally free of microorganisms. One exception is the interior of normal body tissue. However, body surfaces and passageways leading to the outside of the body, such as the mouth, throat, nasal cavities, and large intestine, harbor an abundance of both harmless and potentially pathogenic microbes. If a person's natural defenses are sound, he or she may harbor many microbes safely. If that person's resistance becomes lowered, however, an infection can result. Although many vaccines are available to protect against disease, inhabitants in poor areas may not have access to them. Lack

of immunization in combination with lowered resistance due to poor nutrition and disease create a susceptible host.

Microbes and Public Health

All societies establish and enforce measures designed to protect the health of their populations. Most of these practices are concerned with preventing the spread of infectious organisms. A few examples of fundamental public health considerations are listed below:

- ▶ **Sewage and garbage disposal.** In times past, when people disposed of the household “slops” by the simple expedient of throwing them out the window, great epidemics were inevitable. Modern practice is to divert sewage into a processing plant in which harmless microbes are put to work destroying the pathogens. The resulting noninfectious “sludge” makes excellent fertilizer.
- ▶ **Purification of the water supplies.** Drinking water that has become polluted with untreated sewage may be contaminated with such dangerous pathogens as typhoid bacilli, the viruses of polio and hepatitis, and dysentery amebas. A filtering process usually purifies the municipal water supply, and a close and constant

watch is kept on its microbial population. Industrial and chemical wastes, such as asbestos fibers, acids and detergents from homes and from industry, and pesticides used in agriculture, complicate the problem of obtaining pure drinking water.

- Prevention of food contamination.** Various national, state, and local laws seek to prevent outbreaks of disease through contaminated food. Certain animal diseases (e.g., tuberculosis and tularemia) can be passed on to humans through food, and food is also a natural breeding place for many dangerous pathogens. Some of the organisms that cause food poisoning are the botulism bacillus (*Clostridium botulinum*) that grows in improperly canned foods, so-called *staph* (*Staphylococcus aureus*), and species of *Salmonella* transmitted in eggs, poultry, and dairy products. In recent years, a variety of the normally harmless intestinal bacillus *Escherichia coli* (*E. coli* 0157:H7) has caused outbreaks of food poisoning from undercooked meat and from produce. For further information, see Table 1 in Appendix 5. Most cities have sanitary regulations requiring, among other things, compulsory periodic inspection of food-handling establishments.
- Milk pasteurization.** Milk is rendered free of pathogens by pasteurization, a process in which the milk is heated to 63°C (145°F) for 30 minutes and then cooled rapidly before being packaged. Sometimes, slightly higher temperatures are used for a much shorter time with satisfactory results. The entire pasteurization process, including the cooling and packing, is accomplished in a closed system, without any exposure to air. Pasteurized milk still contains microbes, but no harmful ones. Pasteurization is also used to preserve other beverages and dairy products.

Aseptic Methods

In the practice of medicine, surgery, nursing, and other health fields, specialized procedures are followed to reduce

or eliminate the growth of pathogenic organisms. The word *sepsis* means “poisoning due to pathogens”; *asepsis* (a-SEP-sis) is its opposite—a condition in which no pathogens are present. Procedures that are designed to kill, remove, or prevent the growth of microbes are called *aseptic methods*.

There are a number of terms designating aseptic practices. These are often confused with one another. Some of the more commonly used terms and their definitions are as follows (Fig. 5-13):

- Sterilization.** To sterilize an object means to kill every living microorganism on it. In operating rooms and delivery rooms especially, as much of the environment as possible is kept sterile, including the gowns worn by operating room personnel and the instruments used.

The most common method of sterilization is by means of steam under pressure in an **autoclave**. Dry heat is also used. Ethylene oxide, a gas, is used to sterilize supplies and equipment that are not able to withstand high temperatures. Most pathogens can be killed by exposure to boiling water for 4 minutes. However, the time and temperature required to ensure the destruction of all spore-forming organisms in sterilization are much greater than those required to kill most pathogens.
- Disinfection.** Disinfection refers to any measure that kills all pathogens (except spores) but does not necessarily kill all harmless microbes. Most **disinfectants** (disinfecting agents) are chemicals that can be applied directly to nonliving surfaces. Examples are chlorine compounds, such as household bleach, phenol compounds, and mercury compounds. Commercial products for disinfection contain more than one chemical agent in order to kill a variety of organisms. Two other terms for bacteria-killing agents, synonymous with disinfectant, are **bactericide** and **germicide**, agents that kill bacteria and germs.
- Antisepsis.** This term refers to any process in which pathogens are not necessarily killed but are prevented

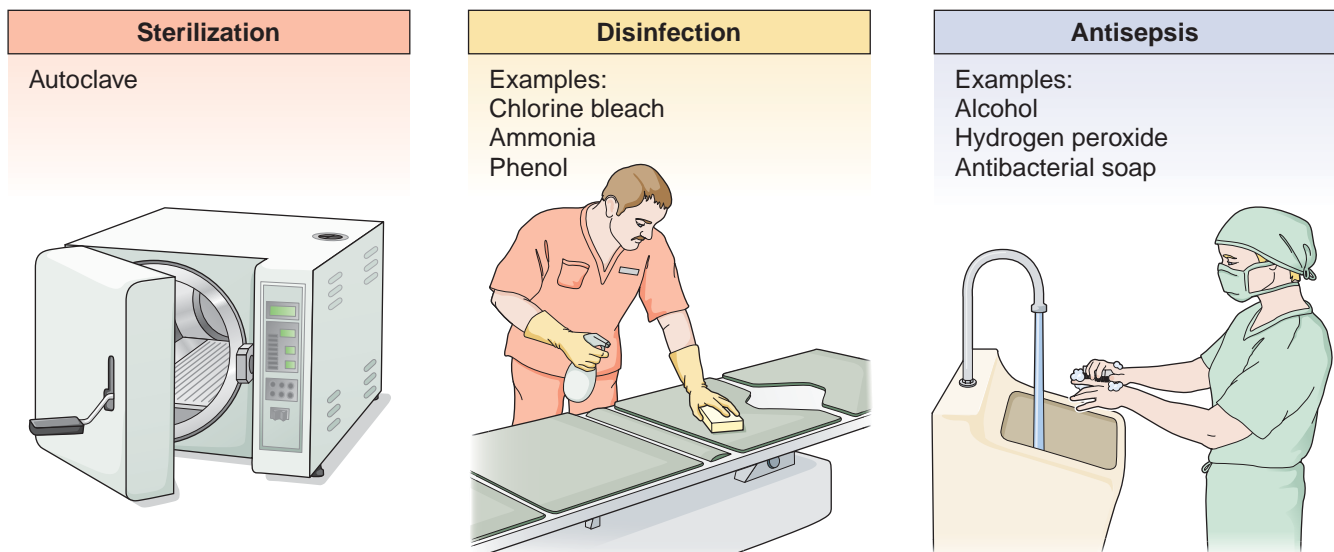


Figure 5-13 Aseptic methods.

from multiplying, a state called **bacteriostasis** (bak-ter-i-o-STA-sis) (*stasis* means “steady state.”) **Antiseptics** are less powerful than disinfectants and are safe to use on living tissues. Examples are alcohol, organic iodine solutions, and hydrogen peroxide.

Infection Control Techniques

In the 1980s, concern about the spread of blood-borne infections, such as hepatitis B and HIV, led to the development of isolation and barrier techniques for the handling of blood and other body fluids that might contain blood. These *universal precautions* have now been extended to include all potentially infective body substances and are entitled *body substance precautions* or *body substance isolation*. According to guidelines established by the CDC (Centers for Disease Control and Prevention), healthcare personnel must use barriers for any contact with moist body substances, mucous membranes, or nonintact skin, whether or not blood is visible and regardless of the patient’s diagnosis. Gloves must be worn for each patient contact and changed if necessary during care. Protective coverings such as a mask, eye protection, face shield, or fluid-repellent gown should be worn during procedures that may generate sprays of blood or body fluids. Soiled linen, trash, and other waste must be treated as if contaminated and disposed of properly. Needles and other sharp instruments must be handled safely and disposed of in puncture-proof containers. To avoid the risk of needlestick injuries, **needles are not recapped**. In circumstances when it is necessary to recap, the needle should be slipped into the cap with one hand or by using a recapping device.

Additional isolation precautions are instituted for infections that are spread by airborne routes, such as tuberculosis, measles (rubeola), and SARS; for those spread by droplets or direct contact; and for infections involving antibiotic-resistant organisms. These measures may include keeping a patient in a private room and limiting visitor contact, filtering circulating air, and having health personnel wear protective clothing.

Handwashing Handwashing is the single most important measure for preventing the spread of infection in all settings. Thorough washing promptly after patient contact and after contact with any body secretions is of utmost importance in infection control. Standard precautions include handwashing after removal of gloves due to the rapid multiplication of normal flora inside the gloves. Gloves are not considered a substitute for handwashing because they may have small defects, they may be torn, or hands may become contaminated when the gloves are removed.

OSHA The Occupational Safety and Health Administration (OSHA) is a U.S. government agency that establishes minimum health and safety standards for workers. The agency has issued regulations for protection against in-

fectious materials based on the CDC guidelines and has enforced these regulations. Employers at healthcare facilities must provide workers with the equipment and supplies needed to prevent their exposure to infectious materials.

Checkpoint 5-16 Aseptic practices are intended to eliminate pathogens. What are the three levels of asepsis?

Checkpoint 5-17 What is the single most important measure for preventing the spread of infection?

Antimicrobial Agents

Antimicrobial (antiinfective) agents are drugs that act to kill or inhibit infectious microorganisms. These include antibacterial, antiviral, antifungal, and antiparasitic substances, which work by interfering with vital metabolic processes that the infecting agents need to survive and reproduce. A drug that acts on intestinal worms is an anthelmintic (ant-hel-MIN-tik) agent or vermifuge (VER-mih-fuj). The term *antibiotic*, in its most general sense, refers to any substance that acts against a living organism, but the term has come to be used only for drugs that act against bacteria.

Antibiotics (Antibacterial Agents) An antibiotic is a substance produced by living cells that has the power to kill or arrest the growth of bacteria. Most antibiotics are derived from fungi (molds) and soil bacteria. Penicillin, the first widely used antibiotic, is made from a common blue mold, *Penicillium*. Often, the drugs derived from penicillin can be recognized by the ending *-cillin* in the name. Other fungi that produce a large number of antibiotics are members of the group *Cephalosporium*. The soil bacteria *Streptomyces* produce a number of frequently used antibiotics. These drug names often end in *-mycetin*.

The development of antibiotics has been of incalculable benefit to humanity. Since the time that penicillin saved many lives on the battlefields of World War II in the 1940s, antibiotics have been considered miracle drugs. Enthusiasm for their use, however, has given rise to some undesirable effects.

One danger of antibiotic use is the development of opportunistic infections. As noted, there is a normal flora of microorganisms in the body that competes with pathogens. Antibiotics, especially those that kill a wide variety of bacteria (broad-spectrum antibiotics), eliminate these competitors and allow pathogens to thrive. For example, antibiotics often destroy the normal flora of the vaginal tract and allow a troublesome yeast infection to develop.

The widespread use of antibiotics has resulted in the natural selection of pathogens that are resistant to these medications. Under some circumstances, bacteria can even transfer genes for resistance directly from one cell

to another. Some strains of common organisms, such as streptococci, staphylococci, pneumococci, *E. coli*, and tuberculosis are now resistant to most antibiotics (see Appendix 5 for diseases caused by these microorganisms).

The prevalence of antibiotic-resistant pathogens is a serious problem in hospitals today. These organisms cause infections that do not respond to drugs. In the United States, about 5% of acute care hospital patients contract one or more such infections. Patients who are elderly or severely debilitated are most susceptible to these **nosocomial** (nos-o-KO-me-al) (hospital-acquired) infections (the word *nosocomial* comes from a Greek word for hospital). Some strains currently causing nosocomial infections are methicillin-resistant *Staphylococcus aureus* (MRSA) and vancomycin-resistant enterococci (VRE).

When taking antibiotics, it is important to complete the entire course of treatment to guarantee the destruction of all pathogens. If not, the more resistant cells will be able to survive treatment and grow out in great numbers, leading to the development of strains that do not respond to that antibiotic. Also, patients should not press physicians to prescribe antibiotics when they will do no good, as for the treatment of viral infections, such as colds and flu.

Pharmaceutical companies may be able to find new antibiotics. Also, using these drugs in combinations may help to eliminate all the bacteria causing an infection. We may be able to reverse the trend toward resistance by using these drugs with more care. Large quantities of antibiotics are now used in agriculture to control disease among farm animals and increase productivity. Some people now shop for meats that are free of antibiotics. There is some evidence that susceptibility to a given drug will reappear when a bacterial population is no longer exposed to it.

Checkpoint 5-18 What is an antibiotic?

Antiviral agents There are not many effective antiviral drugs, and each one has a limited range of action. These agents function to:

- ♦ block removal of the protein coat of the virus after it enters a cell, as in treatment of influenza A virus.
- ♦ block production of viral nucleic acid, as does the drug AZT (zidovudine). The reverse transcriptase inhibitors used to treat HIV infections block the enzyme needed for viral RNA to function in the host cell.
- ♦ block enzymes that are needed to assemble and release new virus particles, as does the drug indinavir, a so-called *protease inhibitor*, used to treat HIV infection.

Note that viruses mutate rapidly to become resistant to these drugs, and none can eliminate latent (temporarily inactive) infections. In treating AIDS, the drugs are commonly used in combinations.

Laboratory Identification of Pathogens

The nurse, physician, or laboratory worker often obtains specimens from patients to identify bacteria and other organisms. Specimens most frequently studied are blood, spinal fluid, feces, urine, and sputum along with swabbing from other areas. Swabs are used to collect specimens from the nose, throat, eyes, and cervix as well as from ulcers or other infected areas. The healthcare worker must label each specimen completely and accurately with the patient's name, appropriate identification, source of the specimen, physician's name, the date, and time. He or she must then deliver it to the laboratory promptly.

Bacterial Isolations and Tests

In the lab, bacterial cells are grown out in cultures using substances called **media**, such as nutrient broth or agar, that the bacteria can use as food. Individual organisms are then isolated, that is, separated from other cells in the specimen, usually by streaking the cultures over the surface of a solid medium. The isolated cells then multiply to form separate colonies (clones) on the surface of the medium (Fig. 5-14). The laboratory technicians then perform a variety of tests to identify the organism or organisms obtained from the specimen. At this time, the organism is usually tested for sensitivity to various antibiotics that might be used to treat the infection. This whole procedure is described as a culture and sensitivity (C & S).

Staining Techniques

One of the most frequently used methods for beginning the process of identification involves examining the cells under the microscope. To make the cells visible under the microscope, they must first be stained with colored dyes (stains), which are applied to a thin smear of the culture on a glass slide. The most commonly used staining pro-



Figure 5-14 Isolated colonies of bacteria growing on a solid medium. Each colony contains all the offspring of a single cell. (Reprinted with permission from Koneman EW, et al. Color Atlas and Textbook of Diagnostic Microbiology. 5th ed. Philadelphia: Lippincott Williams & Wilkins, 1997.)

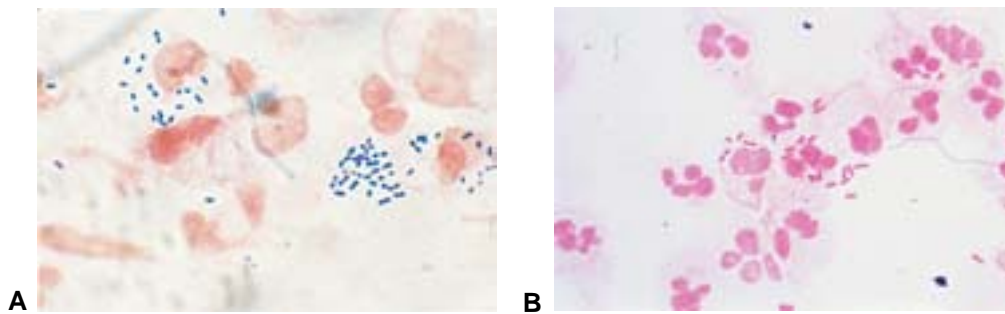


Figure 5-15 Gram stained bacteria. (A) Gram positive diplococci. (B) Gram negative bacilli among white blood cells in a urine sediment. (Reprinted with permission from Koneman EW, et al. *Color Atlas and Textbook of Diagnostic Microbiology*. 5th ed. Philadelphia: Lippincott Williams & Wilkins, 1997.)

cedure is known as the **Gram stain** (Fig. 5-15). A bluish purple dye (such as crystal violet) is applied, and then a weak solution of iodine is added. This causes a colorfast combination within certain organisms, so that washing with alcohol does not remove the dye. These bacteria are said to be *Gram positive* and appear bluish purple under the microscope (Fig. 5-15 A). Examples are the pathogenic staphylococci and streptococci; the cocci that cause certain types of pneumonia; and the bacilli that produce diphtheria, tetanus, and anthrax. Other organisms are said to be *Gram negative* because the coloring can be removed from them by the use of a solvent. These are then stained for visibility, usually with a red dye (see Fig. 5-15 B). Examples of gram-negative organisms are the diplococci that cause gonorrhea and epidemic meningitis and the bacilli that produce typhoid fever, pneumonia, and one type of dysentery. The colon bacillus (*E. coli*) normally found in the intestine is also gram negative, as is the cholera vibrio. Can you tell which of the organisms in Figure 5-4 are Gram positive and which are Gram negative?

Another stain used to identify organisms is the **acid-fast stain**. After being stained with a reddish dye (carbol-fuchsin), the smear is treated with acid. Most bacteria quickly lose their stain upon application of the acid, but the organisms that cause tuberculosis and other acid-fast cells retain the red stain. The negative cells are then stained with a different dye, usually a blue one.

A few organisms, such as the spirochetes of syphilis and the rickettsiae, do not stain with any of the commonly used dyes. Special techniques must be used to identify these organisms.

Other Methods of Identification

In addition to the various staining procedures, laboratory techniques for identifying bacteria include:

- ♦ Observing the growth characteristics of the cultures in liquid and solid medium
- ♦ Studying the oxygen requirements of the cells
- ♦ Observing the ability of the bacteria to utilize (ferment) various carbohydrates (sugars)

Box 5-3 Hot Topics

PCR: The Molecular Detective

Before an infectious disease can be treated appropriately, a laboratory technician must accurately identify the pathogen that causes it. Using traditional methods, this can be a laborious process that requires time to grow the pathogen in culture and perform a variety of tests on it. Any pathogen that cannot be grown in the laboratory cannot be identified in this way. While culturing continues to play an important role in studying microorganisms, new techniques like the polymerase chain reaction (PCR) have decreased the time needed to identify pathogens and increased the number that can be identified. PCR gives results in a few days or less and costs less than standard culturing and testing.

An organism's genetic material contains unique sequences of DNA (RNA in certain types of viruses)—an identifying mo-

lecular “fingerprint.” PCR looks for a particular nucleic acid sequence in a sample and duplicates it repeatedly—like a molecular photocopying machine. The many copies then can easily be detected using additional molecular techniques. In a clinical laboratory, PCR can be used to identify a pathogen directly in a sample taken from a patient by finding its specific sequences of DNA or RNA.

Although still relatively new, PCR has quickly become an important technique for diagnosing infectious diseases such as AIDS, hepatitis, and Lyme disease and for identifying the pathogens responsible for emerging diseases such as West Nile disease and severe acute respiratory syndrome (SARS). Epidemiologists are using PCR to monitor the spread of disease within a population, because it can identify individuals infected by the same strain of organism.

- ▶ Analyzing reactions to various test chemicals
- ▶ Studying the bacteria by serologic (immunologic) tests based on the antigen–antibody reaction (see Chapter 17).

Scientists now use modern methods of genetic analysis to identify organisms by determining the composition of their nucleic acids. These newer, refined techniques reveal minute differences in bacteria, and this information

can be used to identify the source and trace the spread of infections in a population. (See Box 5-3, PCR: The Molecular Detective.)

Checkpoint 5-19 One way of identifying microorganisms is to examine them under a microscope. Before examination, the cells are colored so they can be seen. What are the dyes used to color the cells called?

Word Anatomy

Medical terms are built from standardized word parts (prefixes, roots, and suffixes). Learning the meanings of these parts can help you remember words and interpret unfamiliar terms.

WORD PART	MEANING	EXAMPLE
Categories of Disease		
psych/o	mind	The medical field of <i>psychiatry</i> specializes in treatment of mental disorders.
pre-	before	A <i>predisposing</i> cause enters into production of disease.
The Study of Disease		
idio-	self, separate, distinct	An <i>idiopathic</i> disease has no known cause; it is “self-originating.”
iatro	physician, medicine	An <i>iatrogenic</i> disease results from the adverse effects of treatment.
pan-	all	A <i>pandemic</i> disease is prevalent throughout an entire country, continent, or the world.
syn-	together	A <i>syndrome</i> is a group of symptoms and signs that together characterize a disease.
chir/o	hand	<i>Chiropractic</i> treatment involves use of the hands for manipulation to correct misalignment of the body.
Infectious Disease		
myc/o	fungus	<i>Mycology</i> is the study of fungi.
aer/o	air, gas	An <i>aerobic</i> organism requires air (oxygen) to grow.
an-	absent, deficient, lack of	An <i>anaerobic</i> organism does not require air (oxygen) to grow.
tox/o	poison	Bacteria can harm the body by producing <i>toxins</i> .
diplo-	double	<i>Diplococci</i> are round bacteria arranged in pairs.
strepto-	chain	<i>Streptococci</i> are round bacteria arranged in chains.
staphylo-	grapelike cluster	<i>Staphylococci</i> are bacteria in clusters.
py/o	pus	The species name <i>pyogenes</i> indicates that an organism produces pus.
Microbial control		
septic	poison, rot, decay	<i>Aseptic</i> methods are used to kill or prevent the growth of microorganisms.
–cide	kill or destroy	A <i>bactericide</i> is an agent that kills bacteria.

Summary

- I. Categories of disease**—infection, degenerative disease, nutritional disorders, metabolic disorders, immune disorders, neoplasms, psychiatric disorders
- A.** Predisposing causes of disease—age, gender, heredity, living conditions and habits, emotional disturbance, physical and chemical damage, preexisting illness

II. The study of disease—pathophysiology

- A.** Disease terminology
 - 1.** Etiology—study of origin or causation
 - 2.** Incidence—range of occurrence
 - a. Morbidity rate—proportion of people with a specific disease in a population per unit of time
 - b. Mortality rate—percentage of population that dies of a specific disease within a given period of time

3. Terms related to severity and duration
 - a. Acute—severe, of short duration
 - b. Chronic—less severe, of long duration
 - c. Subacute—intermediate between acute and chronic
4. Idiopathic—of unknown cause
5. Iatrogenic—results from adverse effects of treatment
6. Communicable—can be transmitted from person to person
 - a. Epidemic—widespread in a given region
 - b. Endemic—found at lesser level but continuously in a population
 - c. Pandemic—prevalent throughout an entire country or the world

III. Treatment and prevention of disease

1. Diagnosis—determination of the nature of the illness
 - a. Symptom—change in body function felt by the patient
 - b. Sign—change in body function observable by others
 - c. Syndrome—group of signs and symptoms that characterize a disease
2. Prognosis—prediction of probable outcome of disease
3. Therapy—course of treatment
- A. Complementary and alternative medicine (CAM)—methods of disease prevention or treatment used along with or instead of traditional modern medical practices—e.g. naturopathy, chiropractic, acupuncture, biofeedback
 - a. Herbal remedies—plant products
- B. Prevention of disease—removal of potential causes of disease

IV. Infectious disease

1. Parasite—organism that lives on or within a host at host's expense
2. Pathogen—disease-causing organism
3. Infection—invasion by pathogens with adverse effects
 - a. Local—small area
 - b. Systemic—generalized; usually spread by blood
4. Opportunistic infection—takes hold in a weakened host
- A. Modes of transmission
 1. Direct contact
 2. Indirect—touched objects, air, pests
 - a. Vector—animal that transfers organisms from host to host
 3. Portals of entry and exit—skin, respiratory, digestive, urinary, and reproductive systems

V. Microbiology—study of microorganisms

- A. Normal flora—population of microorganisms normally growing on and within the body
- B. Bacteria
 1. Some features
 - a. Oxygen requirements—aerobic, anaerobic, facultative anaerobes
 - b. Endospores—resistant forms
 - c. Flagella—used for swimming
 - d. Pili—short, threadlike; used for attachment
 2. Shape and arrangement
 - a. Cocci—round
 - (1) Diplococci—pairs
 - (2) Streptococci—chains
 - (3) Staphylococci—clusters

- b. Bacilli—straight rods; some produce endospores
- c. Curved rods
 - (1) Vibrios—comma shaped
 - (2) Spirilla—corkscrew or wavy
 - (3) Spirochetes—flexible spirals

3. Other bacteria—obligate intracellular parasites
 - a. Rickettsiae
 - b. Chlamydiae

C. Viruses

1. Contain only nucleic acid and protein
2. Obligate intracellular parasites
3. Infectious agents smaller than viruses
 - a. Prions—contain only protein; cause slow-growing brain diseases
 - b. Viroids—contain only RNA

D. Fungi—simple, plantlike organisms

1. Yeasts—single cell
2. Molds—filamentous

E. Protozoa—single-cell, animal-like organisms

1. Amebas—dysentery
2. Ciliates
3. Flagellates—African sleeping sickness, giardiasis
4. Sporozoa (apicomplexans)—malaria, *Cryptosporidium* infection

VI. Parasitic worms (helminths)

A. Roundworms

1. Ascaris
2. Pinworms
3. Hookworms
4. Trichina—transmitted in undercooked meat
5. Filaria—causes filariasis (elephantiasis)

B. Flatworms

- a. Tapeworms
- b. Flukes

VII. Microbial control

1. Emergence and spread of microorganisms—factors related to population growth, technology

A. Microbes and public health

1. Sewage and garbage disposal
2. Water purification
3. Prevention of food contamination
4. Milk pasteurization

B. Aseptic methods

1. Sterilization—killing of all organisms
2. Disinfection—destruction of all pathogens (except endospores); bactericidal
3. Antisepsis—pathogens killed or prevented from multiplying (bacteriostasis); safe for living tissue

C. Infection control techniques

1. Body substance precautions (body substance isolation)
 - a. Assume all body fluids potentially infective
 - b. Barriers—gloves, masks, eye protection, gowns
 - c. Handwashing stressed
 - d. OSHA—Occupational Safety and Health Administration

D. Antimicrobial agents—interfere with essential metabolism

1. Antibiotics—antibacterial agents
 - a. Disadvantages—opportunistic infections, bacterial resistance, nosocomial (hospital-acquired) infections

2. Antivirals—block removal of protein coat, production of nucleic acid, assembly and release of new virus

VIII. Lab identification of pathogens

1. Collection of specimens; accurate labeling and prompt delivery to lab
- A. Bacterial isolations and tests
B. Staining techniques (e.g., Gram, acid-fast)

- C. Other methods of identification
 1. Growth characteristics
 2. Oxygen requirements
 3. Fermentation
 4. Reactions to test chemicals
 5. Serologic (immunologic) tests
 6. Genetic analysis

Questions for Study and Review

Building Understanding

Fill in the blanks

1. An inadequate diet may result in _____ disorders such as scurvy or rickets.
2. The study of the cause of any disease or the theory of its origin is _____.
3. A(n) _____ infection attacks an individual already weakened by disease.
4. Mycotic infections are caused by _____.
5. Certain molds and soil bacteria produce bacteria-killing substances called _____.

Matching

Match each numbered item with the most closely related lettered item.

- | | |
|---|--------------|
| ___ 6. Organisms that cause pneumonia, diphtheria, and syphilis | a. protozoa |
| ___ 7. Organisms that cause AIDS, hepatitis, and the common cold | b. helminths |
| ___ 8. Organisms that cause athlete's foot, ringworm, and thrush | c. viruses |
| ___ 9. Organisms that cause amebic dysentery, giardiasis, and malaria | d. fungi |
| ___ 10. Organisms that cause pinworm, trichinosis, and filariasis | e. bacteria |

Multiple choice

- ___ 11. The incidence of early heart disease is higher in men than women. A predisposing cause of this disease appears to be
 - a. age
 - b. gender
 - c. heredity
 - d. living conditions and habits
- ___ 12. A syndrome is defined as a
 - a. disease accompanied by a characteristic group of signs and symptoms
 - b. widespread disease
 - c. disease that is neither acute nor chronic
 - d. communicable disease
- ___ 13. Structures that allow some bacteria to move along solid surfaces are called
 - a. endospores
 - b. flagella
 - c. pili
 - d. vibrios
- ___ 14. Which of the following protozoa are obligate parasites?
 - a. amebas
 - b. flagellates
 - c. sporozoa
 - d. ciliates
- ___ 15. An antibiotic should be prescribed only for a
 - a. fungal infection
 - b. viral infection
 - c. parasitic infection
 - d. bacterial infection

Understanding Concepts

16. Explain the difference between the terms in each of the following pairs:
 - a. acute and chronic
 - b. epidemic and endemic
 - c. symptom and sign
 - d. host and parasite
 - e. pathogen and vector
17. List five portals that pathogens may use to enter or exit the body.
18. Classify bacteria into three groups based on oxygen requirements and three groups based on shape.
19. How do rickettsiae and chlamydiae differ from other bacteria in size and living habits? Name some diseases caused by rickettsiae and chlamydiae.
20. What is the difference between a virus and a prion?
21. Explain how an infectious disease can emerge and spread across the country and the world. Name some public health measures that can prevent disease outbreaks.
22. Why are standard precautions followed? What measures are included in the use of standard precautions?

Conceptual Thinking

23. While you are on a work-exchange program in the tropics, a cholera epidemic sweeps through the area where you are staying. Of the 1000 people living in the area, 100 people contract cholera and 10 die of it. What is the mortality rate and morbidity rate of cholera in the area? What precautions could you take to lessen your risk of contracting this bacterial disease?

24. Mr. Baker is in the hospital with severe burns to more than half of his body. His chart calls for close adherence to aseptic methods. Describe three procedures used in

healthcare facilities to ensure asepsis. What kind of infection is Mr. Baker at increased risk of contracting during his long recovery in the hospital?

25. While working in the lab, you are given the job of identifying bacteria cultured from a patient's sputum sample. You smear a sample of the bacteria onto a glass slide and Gram stain it. Microscopic examination reveals bluish purple cells arranged in chains. What do you think the bacteria could be? What disease could the patient have? What kind of drug therapy may be prescribed?