2.9 Fighting Disease

pathogen a disease-causing microorganism

DID YOU KNOW?

Cellular Defences

One out of every 100 cells in your body exists to defend the other 99 cells from foreign materials such as dust and pollen, or from microscopic invaders such as fungi, viruses, and bacteria.

Many species of bacteria are parasitic and cause disease in the host organism. Inside the host, the growth of a **pathogen**—a disease-causing microorganism—causes symptoms that result from tissue destruction and from the body's response to the invasion. All pathogenic bacteria act in much the same way. After gaining entrance to the body, the bacteria begin to produce toxins. As seen in the Walkerton example, these toxins are harmful to the human hosts and are able to travel throughout the body via the circulatory system, causing chills, fever, and other related symptoms.

Sometimes these harmful effects may be observed in tissues distant from the site of infection. If you step on a rusty nail contaminated with *Clostridium tetani* endospores, the dormant endospores that enter deep into the tissue of your foot may find favourable conditions for resuming an active bacterial form. As the bacteria multiply, they produce a neurotoxin that causes body spasms and locking, or tetanus, of the muscles, especially those in the jaw. For this reason, tetanus is often called "lockjaw." The spasms can spread to the breathing muscles, causing convulsions or even asphyxiation and death.

The species that causes diphtheria, *Corynebacterium diphtheriae*, produces a very different toxin, one that prevents cell organelles from manufacturing proteins. The host's cells are disabled because most cell functions involve the production of proteins. Diphtheria is initially contracted in the throat, tonsils, nose, and/or skin, but disease effects are felt far beyond these sites.

The Immune-System Response

First Line of Defence: External

The human body has many defences against bacterial infection. The first line of defence is an external, physical barrier (**Figure 1**). Unless broken, human skin forms an almost impenetrable barrier against bacteria. Although some species may enter hair follicles or sweat glands through skin pores, sweat contains salts and amino acids that are poisonous to most bacteria found on skin.

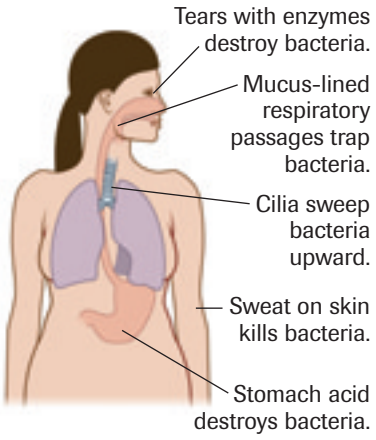

Figure 1
Features of the body fight bacteria before they can enter the internal environment.

Many bacteria enter the body through the nasal passages or the pharynx, both of which are equipped with defensive features. Specialized cells in the lining of these passages secrete mucus, a sticky substance that traps the inhaled bacteria. Mucus also contains digestive enzymes that destroy the cell walls of many bacteria. The lining of the nasal passages and the pharynx also contains specialized cells equipped with cilia. Trapped bacteria and debris are swept upward to the throat by rhythmic beating of the cilia, where they are either swallowed or expelled by coughing.

Bacteria that enter the eyes are attacked by enzymes (e.g., lysozymes, which digest peptidoglycan in bacterial cell walls) contained in tears, which continually bathe eye surfaces, cleaning them of bacteria and dust. Usually, tears drain into the upper nasal passages, where any surviving bacteria are attacked by enzymes in mucus. Bacteria also enter the body through the mouth in food and water, but acids in the stomach kill most of them.

Second Line of Defence: The Lymphatic System

Although the first line of defence keeps many invaders from entering the body, some bacteria penetrate these external barriers. Inside the body, the second line of defence, a complex network of organs (**Figure 2**), works to rid the body of infection. These widely scattered lymphatic organs are connected by a special circulatory system of vessels and nodes (**Figure 3**). The lymphatic vessels circulate lymph, a transparent fluid containing white blood cells, called **lymphocytes**, which are produced in the lymph nodes. Lymph nodes are small round masses of cells throughout the human body that fight infection. As lymph flows through the lymph nodes and the spleen, microorganisms are filtered out, preventing them from entering the bloodstream and causing infection. After travelling throughout the body, lymph is collected and moved from the lymphatic system into blood circulation. Once in the bloodstream, lymphocytes are transported to body tissues where they act as guards against infection.

The core of bones like the pelvis contains bone marrow. This nutrient-filled, spongy tissue produces specialized white blood cells that circulate through the immune system. When a pathogen invades, internal body defences are activated, beginning with white blood cells called **macrophages**. These cells are motile and are able to travel across body membranes to find infection sites. Macrophages engulf foreign bodies such as bacteria and destroy them with digestive enzymes. The white blood cells themselves may also be killed by these enzymes. The mass of dead white blood cells and dead bacteria produced at the site of an infection is called pus. In spite of this second line of defence, some bacteria manage to avoid being digested.

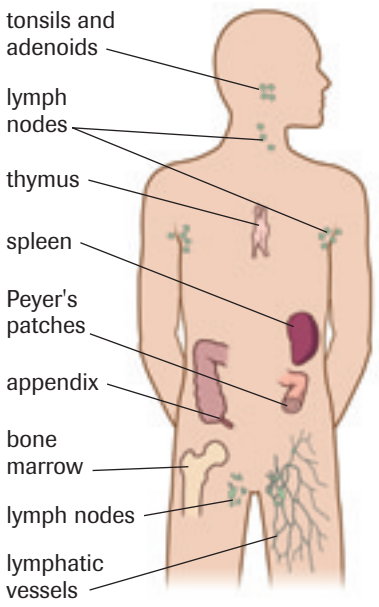

Figure 2
Lymphatic organs and tissues are internal features of the immune system.

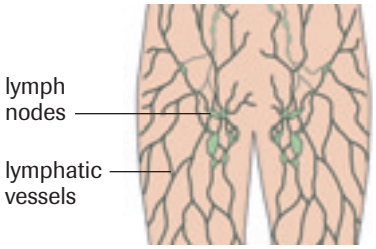

Figure 3
Vessels in the lymphatic system work closely with the circulatory system.

Third Line of Defence: Antibody Formation

Antibodies (**Figure 4**, on the next page) are protein molecules that protect the body from invaders. A foreign material that causes formation of antibodies is called an **antigen**. The surfaces of invaders contain many different antigens, but each antigen stimulates its own specific antibody, meaning that only one specific antibody attaches to an antigen. Antibodies render invaders ineffective, and the antibody-antigen complex provides a signal to macrophages so that these cells can more easily identify and engulf the antigen (e.g., bacterium). It has been estimated that an average human body may contain more than ten million different antibody types, each ready to help repel future antigen invasions.

Active and Passive Immunity to Bacterial Diseases

The production of antibodies to counteract a pathogen is called an immune response. In **active immunity**, the body itself manufactures antibodies to combat a specific disease. This active immunity may be acquired naturally when a person suffers from a bacterial disease and recovers because the body has produced antibodies that identify and help destroy the invader. The same pathogen will trigger an immune-system response in the future, so the immunity is usually lifelong.

lymphocyte a white blood cell (plasma and memory cells) that can make antibodies when stimulated by antigens

macrophage a white blood cell that engulfs and destroys pathogens

antibody a protein that inactivates a foreign substance in the body by binding to its surface

antigen any substance that causes the formation of antibodies

active immunity lasting protection against an invading antigen through the manufacture of antibodies

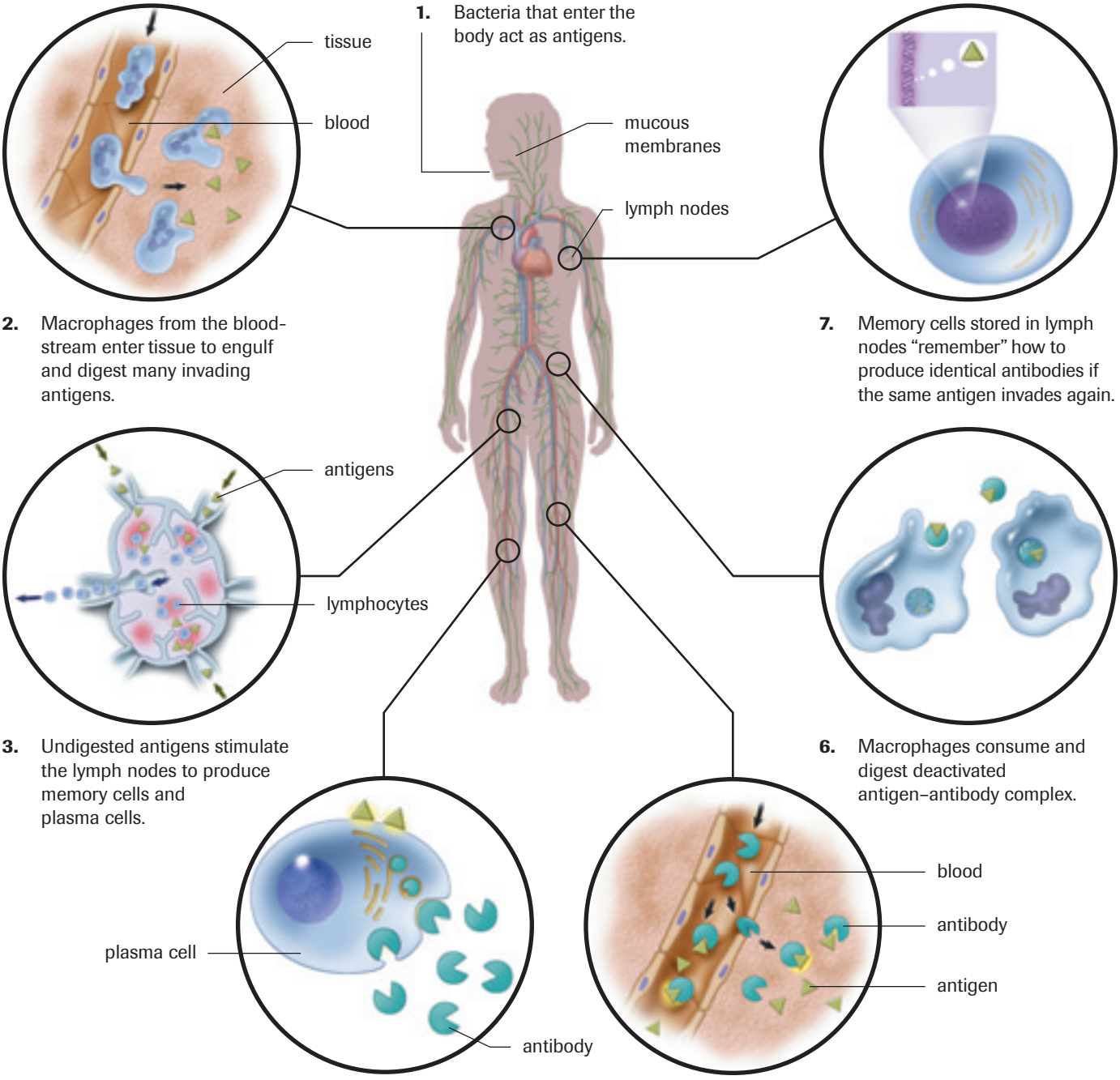

Figure 4
The production and action of antibodies in the circulatory and lymphatic systems

Active immunity may also be induced artificially by the injection of vaccines made of dead or weakened bacterial cells or certain antigens that have been isolated from the bacteria. The body reacts to the vaccine as if it were a real pathogen, and produces antibodies (**Figure 5**). Some vaccines provide lifetime immunity against the disease (e.g., diphtheria), while others must be renewed (e.g., influenza: yearly; smallpox: every three to five years).

In **passive immunity**, the antibodies themselves are introduced directly into the bloodstream of an individual. Passive immunity can be acquired naturally when antibodies pass from a woman to her unborn child during the last month of pregnancy and the initial stages of breast-feeding. The child will then be immune to the same bacteria as its mother for a short period of time. This protection lasts for only a few months, so babies begin receiving immunization shots (vaccinations) in the first year. Passive immunity can also be acquired, on a short-term basis, by the injection of plasma (blood from which the red blood cells have been removed) from an animal that has been exposed to a disease into the blood of another animal. A tetanus shot contains antibodies from a horse against the tetanus toxin. The vaccination protects humans from *C. tetani* for ten years. Booster or refresher shots are needed at this interval to provide continuing immunity.

passive immunity temporary protection against a particular disease by the direct introduction of antibodies

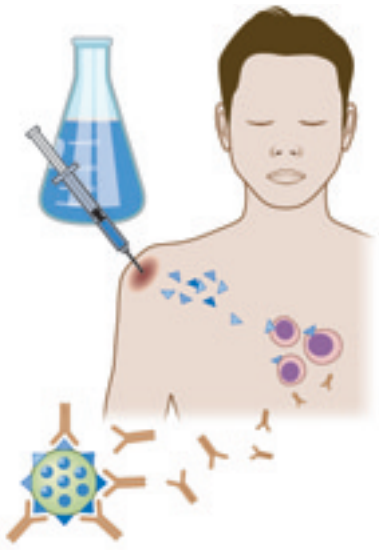

Figure 5
Vaccines stimulate antibody production

Resisting Bacterial Infection

Infectious diseases spread from one individual to another in a variety of ways: moisture droplets in the air, dust, direct contact, fecal contamination, animal bites, and wounds (cuts and scratches). Fortunately for most people, protection from disease is provided by the body's own defence mechanisms. Other methods that provide protection include

- sterilization of instruments (operating rooms and tattoo parlours);
- use of **disinfectants**—chemicals that can kill microorganisms on surfaces (hospitals, restaurant kitchens);
- use of **antiseptics**—chemicals that can be used on the skin (mouthwash, antibacterial soap) to slow the growth of microorganisms;
- extermination of animals that carry disease (foot-and-mouth disease);
- use of antibacterial medication (topical creams for burns and cuts).

disinfectant a strong chemical used to destroy or impede the growth of disease-causing organisms

antiseptic a chemical that destroys or impedes the growth of disease-causing organisms without harming body cells

Section 2.9 Questions

Understanding Concepts

1. Make a list of all body defences that fight bacteria.
2. How are the lymphatic and circulatory systems connected?
3. Describe the location and function of the following immune-system cells:
   (a) macrophage (c) lymphocyte
   (b) lymph (d) antibody
4. List the main modes of disease transmission.
5. You have fallen off your skateboard and cut your knee. The wound has been cleaned, and, underneath the bandage and inside your cells, healing has begun. Draw a diagram with captions showing how your body is fighting the bacteria that entered your cut.
6. Design a spider diagram to illustrate the types of active and passive immunity.
7. What is the difference between antiseptics and disinfectants?
8. The two photographs in **Figure 6** show a white blood cell and *E. coli* bacteria. Describe what is happening. How does this relate to the immune system?

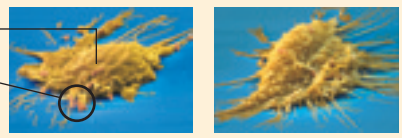

Figure 6

Making Connections

9. Autoimmune diseases occur when the immune system mistakenly attacks the body. Multiple sclerosis and rheumatoid arthritis are examples of autoimmune diseases. Research either example.

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