

CHAPTER 7

THE LYMPHATIC AND IMMUNE SYSTEMS

LEARNING OUTCOMES

7.1 Microbes, Pathogens, and You

1. Distinguish between a prokaryotic and eukaryotic cell.
2. Identify the structures of a prokaryotic cell.
3. Describe the structure of a general virus.

7.2 The Lymphatic System

1. Describe the structure of the lymphatic system.
2. Summarize how the lymphatic system contributes to homeostasis.
3. Explain how the lymphatic system interacts with the circulatory system.

7.3 Innate Immune Defenses

1. List examples of the body's innate defenses.
2. Summarize the events in the inflammatory response.
3. Explain the role of the complement system.

7.4 Adaptive Immune Defenses

1. Explain the role of an antigen in the acquired defenses.
2. Summarize the process of antibody-mediated immunity and list the cells involved in the process.
3. Summarize the process of cell-mediated immunity and list the cells involved in the process.

7.5 Acquired Immunity

1. Distinguish between active and passive immunity.
2. Recognize the importance of cytokines in immunity.

7.6 Hypersensitivity Reactions

1. Explain what causes an allergic reaction.
2. Identify the causes of select autoimmune diseases.

EXTENDED LECTURE OUTLINE

7.1 Microbes, Pathogens, and You

Microorganisms are widely distributed in the environment and carry out many beneficial functions. Unfortunately, human infectious diseases are typically caused by bacteria and viruses, collectively called pathogens. The body has three lines of defense against invasion: barriers to entry, first responders, and acquired defenses.

Bacteria

Bacteria are single-celled prokaryotes. Bacteria have a cell wall that contains a unique amino disaccharide, and in some bacteria, a capsule that has a thick, gummy consistency is present outside of the cell wall. Many bacteria have accessory rings of DNA called plasmids that may carry antibiotic resistance. Bacteria reproduce by binary fission.

Bacteria may release toxins that damage the human body.

Viruses

Viruses are acellular and obligate parasites, meaning that they must replicate inside a living cell. A virus always has two parts: an outer capsid composed of protein units and an inner core of nucleic acid, which can be either DNA or RNA. In large measure, viruses rely on the host's enzymes and ribosomes for its own reproduction.

Prions

Prions, or proteinaceous infectious particles, cause a group of degenerative diseases of the nervous system. Prions are proteins of unknown function in the brains of healthy individuals. Disease occurs when certain prion proteins change their shape into a "rogue" form that converts other normal prion proteins into the rogue configuration.

7.2 The Lymphatic System

The lymphatic system consists of lymphatic vessels and the lymphatic organs. It has four main functions: lymphatic capillaries absorb excess tissue fluid and return it to the bloodstream; lacteals absorb fats in the form of lipoproteins from the small intestines and transport them to the bloodstream; the lymphatic system produces, maintains, and distributes lymphocytes, and defends the body against pathogens.

Lymphatic Vessels

Lymphatic vessels form a one-way system of capillaries, vessels, and ducts that take lymph to cardiovascular veins in the shoulders. These take up excess tissue fluid called lymph once inside the lymphatic vessels.

Lymphatic Organs

The lymphatic organs are divided into the primary (red bone marrow and thymus) and secondary (lymph nodes and spleen) organs.

The Primary Lymphatic Organs

Red bone marrow is the site of stem cells that divide and produce blood cells. B cells mature in the bone marrow but T cells mature in the thymus, located in the thoracic cavity. The thymus also produces thymic hormones, and is absolutely critical to immunity.

Secondary Lymphatic Organs

The spleen contains white pulp and red pulp. The white pulp contains a concentration of lymphocytes, while the red pulp is involved in filtering the blood. In the case of infection or a blow, the spleen can burst. Lymph nodes occur along lymphatic vessels. Each node is packed with B lymphocytes. Lymph is filtered through the lymph nodes. Lymphocytes react with pathogens present in

the filtered blood and lymph. They fight infections and attack cancer cells. The tonsils are patches of lymphatic tissue located around the pharynx.

7.3 Innate Immune Defenses

Immunity involves innate and acquired defenses. Innate defenses protect against any pathogen, while acquired defenses are effective against a particular infectious agent.

Physical and Chemical Barriers to Entry

The body has both physical and chemical barriers to infection. Intact skin and mucous membranes are very effective physical barriers that prevent infection. Ciliated cells that line the upper respiratory tract sweep mucus and trapped particles up into the throat where they can be swallowed or coughed out. Chemical barriers include secretions of the sebaceous glands of the skin, the antibacterial enzyme lysozyme in perspiration, saliva and tears, and the acid pH of the stomach and vagina can all inhibit the growth of, or kill, bacteria. A significant chemical barrier is created by the normal flora, microbes that normally reside in certain areas of the body. These normal flora prevent potential pathogens from taking up residence. Chronic antibiotic use can harm the body by killing normal flora.

Inflammatory Response

Redness, heat, swelling, and pain characterize the inflammatory reaction. The release of histamine from damaged tissue cells and mast cells brings about redness and swelling. A rise in temperature increases phagocytosis by neutrophils and macrophages. The swollen area stimulates free nerve endings, causing the sensation of pain. Chemical mediators called **cytokines** attract white blood cells to the area. Among them, monocytes become macrophages which attract lymphocytes, part of the specific arm of the immune system.

Protective Proteins

The complement system, which includes various plasma proteins, assists innate immunity. It amplifies the inflammatory reaction by attracting phagocytes and promoting phagocytosis. Some complement proteins form pores in the surface of bacteria and thereby cause them to burst. Interferons are proteins produced by virus-infected cells that help noninfected cells prepare for possible viral attack. Interferons are used to treat certain viral infections.

7.4 Adaptive Immune Defenses

When innate defenses have failed to prevent an infection, the adaptive line of defense comes into play.

How Adaptive Defenses Works

Adaptive defenses respond to antigens, which are molecules the immune system recognizes as foreign to the body. Adaptive defenses primarily depend on the action of either B or T lymphocytes, which differentiate into either B or T lymphocytes

B Cells and Antibody-Mediated Immunity

The receptor on a B cell is called a B-cell receptor. The clonal selection model states that an antigen selects, then binds to the B-cell receptor of only one type of B cell, and then this B cell produces multiple copies (clones) of itself.

B Cells Become Plasma Cells and Memory B Cells

Plasma cells secrete antibodies and eventually undergo apoptosis. Memory B cells remain in the body and produce antibodies if the same antigen enters the body at a later date.

Structure of an Antibody

Antibodies are also called immunoglobulins. They are typically Y-shaped molecules with two arms. Each arm has a heavy and a light polypeptide chain. These chains contain variable and constant regions. The antigen combines with the antibody in the variable regions in a lock-and-key manner.

Classes of Antibodies

There are five different classes of circulating antibodies: IgG, IgM, IgA, IgD, and IgE. They differ from each other as outlined in Table 7.1 on page 142 of the text.

Monoclonal Antibodies

Every plasma cell derived from the same B cell secretes antibodies against a specific antigen. These are monoclonal antibodies. Monoclonal antibodies can be made outside the body, and are being used to diagnose certain conditions, or infections, to deliver drugs, or to treat cancers.

T Cells and Cell-Mediated Immunity

T cells directly attack diseased cells and cancer cells. Other T cells release cytokines that stimulate both innate and adaptive defenses.

How T Cells Recognize an Antigen

Like B cells, each T cell bears a specific receptor. However, for a T cell to recognize an antigen, the antigen must be presented by an antigen-presenting cell (APC), such as a macrophage. A piece of a phagocitized pathogen is displayed in the groove of a major histocompatibility (MHC) protein on the APC's surface. Human MHC proteins are called human leukocyte antigens (HLAs). MHC proteins are self proteins that mark the cell as part of a particular individual. The T cell can compare the antigen and self protein side by side in the plasma membrane of the antigen-presenting cell and destroy cells carrying foreign antigens.

Clonal Expansion

T cells have specific TCRs (T Cell Receptors). An activated T cell undergoes clonal expansion producing many copies of itself. The two classes of MHC proteins are called MHC I and MHC II. The two main types of T cells are cytotoxic and helper T cells. Cytotoxic T cells are responsible for cell-mediated immunity, causing virus-infected cells or tumor cells to undergo apoptosis and die. Helper T cells secrete cytokines which enhance immune cell responses. HIV, the virus that causes AIDS, infects helper T cells, making HIV-infected individuals susceptible to opportunistic infections. Memory T cells remain in the body to initiate an immune reaction to a previous antigen in the case of another exposure.

7.5 Acquired Immunity

Immunity can be brought about artificially by medical intervention.

Active Immunity

Active immunity sometimes develops naturally after a person is infected with a pathogen. Active immunity can also be induced. Vaccines are available to induce long-lived active immunity. After exposure to a vaccine, antibodies are present in the body. Measuring the antibody titer or the amount of antibody present in a sample of plasma, will show that

the secondary response (booster) is higher than the primary response. Active immunity is long-lived because there are memory B cells and memory T cells in the body.

Passive Immunity

Passive immunity occurs when an individual is given antibodies from an outside source. For example, nursing passes antibodies from mother to child. Passive immunity is temporary.

Cytokines and Immunity

Cytokines, including interferon, are signaling molecules produced by T lymphocytes, macrophages and other cells which are used in an attempt to promote the body's ability to recover from cancer. Interferon and interleukins have been used as immunotherapeutic drugs.

Interleukin antagonists are used to prevent transplant rejection.

7.6 Hypersensitivity Reactions

Sometimes the immune system responds in a manner that harms the body.

Allergies

Allergic responses occur when the immune system reacts vigorously to substances not normally recognized as foreign. Immediate allergic responses are due to the activity of antibodies. Symptoms can vary from mild, coldlike symptoms, to anaphylactic shock, which is an immediate allergic response that occurs because an allergen has entered the bloodstream. The immunoglobulin IgE appears to be responsible. Delayed allergic responses, such as contact dermatitis, are due to the activity of T cells. The skin test for TB is a classic example of a delayed allergic response.

Other Immune Problems

Transplant rejection occurs when cytotoxic T cells bring about the destruction of foreign tissue in the body. Immunosuppressive drugs act by inhibiting the response of T cells to cytokines. Xenotransplantation is the use of animal organs instead of human organs in transplant patients. Genetic engineering can make these organs less antigenic to humans. Laboratory grown urinary bladders have been successfully used in human transplantations. In individuals with severe combined immunodeficiency disease (SCID), both antibody- and cell-mediated immunity is lacking or severely reduced. AIDS is an example of an acquired immune deficiency. An autoimmune disease occurs when T cells or antibodies mistakenly attack the body's own cells. In myasthenia gravis, neuromuscular junctions do not work properly. In multiple sclerosis, the myelin sheath of the nerve fibers is broken down. A person with systemic lupus erythematosus has various symptoms eventually leading to death from kidney damage. In rheumatoid arthritis, the joints are affected.