The Immune System: Innate and Adaptive Body Defenses Outline

PART 1: INNATE DEFENSES

21.1 Surface barriers act as the first line of defense to keep invaders out of the body (pp. 772–773; Fig. 21.1; Table 21.1)

A. Skin, a highly keratinized epithelial membrane, and mucous membranes represent a physical barrier to most microorganisms and their enzymes and toxins. (p. 772; Fig. 21.1; Table 21.1)

B. Protective chemicals of the epithelial tissues include acid to inhibit bacterial growth, enzymes (lysozyme) to destroy microorganisms, mucin to create sticky traps, defensins as antimicrobial peptides, and other specialized regional secretions. (pp. 772–773; Fig. 21.1; Table 21.1)

21.2 Innate internal defenses are cells and chemicals that act as the second line of defense (pp. 773–780; Figs. 21.1–21.6; Table 21.2)

A. Phagocytes, such as neutrophils and macrophages, confront microorganisms that breach the external barriers. (pp. 774–775; Figs. 21.1–21.2)

1. Phagocytes must be able to adhere to a pathogen before it can engulf it; to counteract this, pathogens are coated with complement proteins called opsonins.
2. Neutrophils and macrophages destroy pathogens by engulfing them, acidifying the phagolysosome (pathogen-containing vesicles associated with a lysosome within the phagocyte), and digesting the contents with lysosomal enzymes.
3. When phagocytes cannot ingest their targets, they may release chemicals lethal to pathogens.

B. Natural killer cells are able to lyse and kill cancer cells and virally infected cells before the adaptive immune system has been activated, and they secrete chemicals that enhance the inflammatory response. (pp. 774–775; Fig. 21.1)

C. Inflammation occurs any time the body tissues are injured by physical trauma, intense heat, irritating chemicals, or infection by viruses, fungi, or bacteria. (pp. 775–777; Figs. 21.3–21.4; Table 21.2)

1. Inflammation is beneficial because it prevents the spread of damage, disposes of debris and pathogens, alerts the adaptive immune system, and sets up repair.
2. The four cardinal signs of acute inflammation are redness, heat, swelling, and pain.
3. Inflammation results from the release of inflammatory chemicals from damaged cells that cause vasodilation, and increased capillary permeability, which allows fluid containing clotting factors and antibodies to enter the tissues.
4. Soon after inflammation, the damaged site is invaded by neutrophils and macrophages.

a. Injured cells produce leukocytosis-inducing factors that induce neutrophils to enter the blood from the bone marrow, increasing their number.
b. Inflamed endothelial cells produce CAM proteins that mark the cell—a process called margination.
c. Continued signaling causes diapedesis, in which neutrophils squeeze into the tissues between endothelial cells of the capillary walls.
d. Inflammatory chemicals create chemical trails that encourage chemotaxis of neutrophils and other WBCs into the site of damage.

D. Antimicrobial proteins enhance the innate defenses by attacking microorganisms directly or by hindering their ability to reproduce. (pp. 777–778; Figs. 21.5–21.6; Table 21.2)
1. Interferons are small proteins produced by virally infected cells that help protect surrounding healthy cells by causing synthesis of proteins that interfere with viral replication.
2. Complement refers to a group of about 20 plasma proteins that provide a major mechanism for destroying foreign pathogens in the body.
a. Three pathways by which complement can be activated are: the classical pathway, involving antibodies to bind pathogens and complement; the lectin pathway, in which lectin proteins bind to sugars on the surface of the microorganism, and then bind to and activate complement; and the alternative pathway, triggered when complement factors interact on the surface of microorganisms.

E. Fever, an abnormally high body temperature, is a systemic response to microorganisms. (p. 779; Table 21.2)
1. Pyrogens produced by leukocytes and macrophages act on the hypothalamus, causing a rise in body temperature.

PART 2: ADAPTIVE DEFENSES

A. There are three important aspects of the adaptive immune response: (p. 780)
1. The adaptive defenses recognize and destroy the specific antigen that initiated the response.
2. The immune response is a systemic response; it is not limited to the initial infection site.
3. The immune system has memory; after an initial exposure, the immune response is able to recognize the same antigen and mount a faster and stronger defensive attack.

B. Humoral immunity is provided by antibodies produced by lymphocytes present in the body's "humors" or fluids. (p. 780)

C. Cellular immunity is based on direct attack of microorganisms by lymphocytes and has living cells, rather than free proteins, as its protective factor. (p. 780)

21.3 Antigens are substances that trigger the body's adaptive defenses (p. 781; Fig. 21.7)

A. Antigens are substances that can mobilize the adaptive responses, and are the targets of all adaptive immune responses. (p. 781)
1. Complete antigens have immunogenicity, the ability to stimulate the proliferation of specific lymphocytes and antibodies, and reactivity, the ability to react with the activated lymphocytes and antibodies.

2. Haptens are incomplete antigens that are not capable of stimulating the immune response, but if they interact with proteins of the body, they may be recognized as potentially harmful.

B. Antigenic determinants are a specific part of an antigen that are immunogenic and bind to free antibodies or activated lymphocytes. (p. 781; Fig. 21.7)

C. Self-antigens are your body's antigens that are not antigenic to you, only to others, and are identified as "self" by MHC (major histocompatibility complex) proteins on the surface of cells. (p. 781)

21.4 B and T lymphocytes and antigen-presenting cells are cells of the adaptive immune response (pp. 782–785; Figs. 21.8–21.10; Tables 21.3, 21.8)

A. Lymphocytes originate in the bone marrow and, when released, become immunocompetent and self-tolerant in either the thymus (T cells) or the bone marrow (B cells). (pp. 783–784; Figs. 21.8–21.9)

1. Lymphocytes undergo selection in order to gain immunocompetence, the recognition of specific antigens, and self-tolerance, ensuring attack on the body's own cells is prevented, by being subjected to:
   a. Positive selection, which allows only T lymphocytes that recognize MHC proteins to survive.
   b. Negative selection, which selects for T cells that do not recognize self-MHC proteins.
2. Immunocompetent B and T cells are exported from the primary lymphoid organs, the thymus and bone marrow, to colonize the secondary lymphoid organs, such as the spleen and lymph nodes.
3. The first encounter between a lymphocyte and antigens usually occurs in secondary lymphoid organs.
   a. Antigen binding with a particular lymphocyte selects that lymphocyte for further development, a process called clonal selection.
4. Once activated by clonal selection, a lymphocyte divides, producing an entire group of lymphocytes with an identical ability to bind to a given antigen.
   a. Most members of the clone become effector cells that actively fight the infection.
   b. A few members of the clone become memory cells that will respond quickly to future encounters with this antigen.
5. Genes within lymphoid stem cells determine which foreign substances our immune system can attack and destroy by coding for a specific set of pieces that can be combined in different ways to form a variety of antigen receptor sites.

B. Antigen-presenting cells (APCs) are responsible for activating T cells, by engulfing antigens and presenting fragments of these antigens on their surfaces, where they can be recognized by T cells. (pp. 784–785; Fig. 21.10)

1. Dendritic cells are APCs located on body surfaces that have contact with the external environment: They phagocytose antigens and migrate to lymphoid organs to present antigens to T cells.
2. Macrophages are found throughout lymphoid organs and connective tissues and present antigens to T cells in order to be activated by T cells into aggressive phagocytes.

3. B lymphocytes present antigens to helper T cells, in order to become more fully activated B cells.

21.5 In humoral immunity, antibodies are produced that target extracellular antigens (pp. 785–791; Figs. 21.11–21.15; Tables 21.4–21.5)

A. The immunocompetent but naive B lymphocyte is activated when antigens bind to its surface receptors. (pp. 785–786; Fig. 21.11)
   1. The activated B lymphocyte begins clonal selection, the process of the B cell growing and multiplying to form an army of cells that are capable of recognizing the same antigen.
   2. Most cells of the clone develop into plasma cells, the antibody-secreting cells of the humoral response.
   3. The cells of the clone that do not become plasma cells develop into memory cells.

B. Immunological Memory (pp. 786–787; Fig. 21.12)
   1. The primary immune response occurs on first exposure to a particular antigen, with a lag time of about 3–6 days.
      a. After mobilization, the antibody titer in the blood rises, peaking in about 10 days, and then declines to a low level.
   2. The secondary immune response occurs when someone is exposed to the same antigen for a second time, and is a faster, more prolonged, more effective response.
      a. Mobilization of B cells takes only a few hours and rises to a much higher peak concentration after only 2–3 days, producing antibodies with a much higher binding affinity for the antigen that may persist for weeks or months.

C. Active and Passive Humoral Immunity (pp. 787–788; Fig. 21.13)
   1. Active immunity occurs when the body mounts an immune response to an antigen.
      a. Naturally acquired active immunity occurs when a person suffers through the symptoms of an infection.
      b. Artificially acquired active immunity occurs when a person is given a vaccine.
   2. Passive immunity occurs when a person is given preformed antibodies.
      a. Naturally acquired passive immunity occurs when a mother's antibodies enter fetal circulation.
      b. Artificially acquired passive immunity occurs when a person is given preformed antibodies that have been harvested from another person.

D. Antibodies, or immunoglobulins, are proteins secreted by plasma cells in response to an antigen that are capable of binding to that antigen. (pp. 788–791; Figs. 21.14–21.15; Table 21.5)
   1. The basic antibody structure consists of four looping polypeptide chains: two identical heavy (H) chains, and two identical, shorter, light (L) chains.
      a. Each chain has a variable region at one end, which varies depending on the antigen it binds, and a constant region at the other end, which is nearly identical among all members of a given class of antibodies.
   2. Antibodies are divided into five classes based on their structure: IgM, IgG, IgA, IgD, and IgE.
   3. Antibody Targets and Functions

a. Neutralization occurs when antibodies block specific sites on viruses or bacterial exotoxins, causing them to lose their toxic effects.
b. Agglutination occurs when antibodies cross-link to antigens on cells, causing clumping.
c. Precipitation occurs when soluble molecules are cross-linked into large complexes that settle out of solution.
d. Complement fixation and activation occur when complement binds to antibodies attached to antigens and lead to lysis of the cell.

21.6 Cellular immunity consists of T lymphocytes that direct adaptive immunity or attack cellular targets (pp. 791–799; Figs. 21.16–21.20; Tables 21.4, 21.6–21.8)

A. There are two major populations of T cells, based on which of the cell differentiation glycoproteins the mature cell displays: CD4 cells and CD8 cells. (pp. 791–792; Fig. 21.16)
1. Activated CD4 cells usually become helper T cells that activate B cells, T cells, and macrophages; some become regulatory T cells that moderate the immune response.
2. Activated CD8 cells become cytotoxic T cells that destroy cells or other foreign substances.

B. Antigen presentation through the use of MHC (major histocompatibility complex) proteins is necessary for both activation and normal functioning of T cells. (pp. 792–794; Table 21.6)
1. Class I MHCs are found on all body cells except RBCs and display antigens synthesized from within the cell or, if infected, the MHCs may also include fragments of foreign antigens.
2. Class II MHCs are antigens arising from outside the cell that are engulfed by the displaying cell.
3. CD4 cells bind antigens only on class II MHC proteins; CD8 cells are activated by antigen fragments on class I MHCs, and may bind this antigen on any cell in the body.

C. Activation and Differentiation of T Cells. (pp. 794–795; Fig. 21.17; Table 21.7)
1. When T cell antigen receptors bind an antigen, the cell must accomplish a double recognition process: It must recognize both the MHC protein and the antigen it displays.
2. Following antigen binding, a T cell must bind one or more co-stimulatory signals present on the antigen-presenting cell.
3. Once activated, a T cell enlarges and proliferates to form a clone of cells that differentiate and perform functions according to their T cell class.
4. Cytokines are chemical signals, such as interferons, secreted to amplify the immune response.

D. Roles of Specific Effector T Cells (pp. 795–799; Figs. 21.18–21.20; Tables 21.4, 21.8)
1. Helper T cells stimulate proliferation of other T cells and B cells that have already become bound to antigen.
2. Cytotoxic T cells are the only T cells that can directly attack and kill other cells displaying antigen to which they have been sensitized, through the use of perforins and granzymes, or by triggering apoptosis of the target cell.

3. Regulatory T cells either by direct inhibition, or by causing the release of cytokines, suppress the activity of both B cells and other types of T cells.

E. Organ Transplants and Prevention of Rejection (p. 799)
1. The goal of organ transplantation is to provide patients with a functional organ from a living or deceased donor.
2. Transplant success depends on the similarity of the tissues because cytotoxic T cells, NK cells, and antibodies work to destroy foreign tissues.
3. Allografts, the most common type of transplant, are grafts transplanted from individuals of the same species.
4. Immunosuppressive therapy following the transplant uses drugs to suppress rejection, but results in a weakened immune system.

21.7 Insufficient or overactive immune responses create problems (pp. 799–802; Fig. 21.21)

A. Immunodeficiencies are any congenital or acquired conditions that cause immune cells, phagocytes, or complement to behave abnormally. (p. 800)
1. Severe combined immunodeficiency (SCID) is a congenital condition that produces a deficit of B and T cells.
2. Acquired immune deficiency syndrome (AIDS) cripples the immune system by destroying helper T cells, and ultimately impairing T and B lymphocyte functioning.

B. Autoimmune diseases occur when the immune system loses its ability to differentiate between self and non-self and ultimately destroys itself. (pp. 800–801)
1. Autoimmune disorders are treated by suppressing the entire immune system, either by blocking cytokines, or co-stimulatory factors.
2. Failure of self-tolerance occurs when weakly self-reactive lymphocytes are activated when foreign antigens resemble self-antigens, or new self-antigens appear.

C. Hypersensitivities result when the immune system causes tissue damage as it fights off a perceived threat that would otherwise be harmless. (pp. 801–802; Fig. 21.21)
1. Immediate hypersensitivities (acute, or type I hypersensitivities), or allergies, begin within seconds after contact and last about half an hour.
a. The initial contact produces no symptoms, but sensitizes the individual to the allergen.
b. Subsequent contact with the same allergen results in immediate binding of the allergen to IgE antibodies on mast cells and basophils, causing a release of histamine, and promotion of inflammation.
2. Subacute hypersensitivities are caused by antibodies, take 1–3 hours to occur, and last 10–15 hours.
a. Cytotoxic (type II) reactions occur when antigens bind to antigens on specific body cells and cause phagocytosis and complement-mediated lysis of cellular antigens.
b. Immune complex (type III) hypersensitivities result when antigens are widely distributed in the body, and form large numbers of insoluble antigen-antibody complexes that cannot be cleared from an area.
3. Delayed hypersensitivity reactions are caused by T lymphocytes, activated when chemicals diffuse through the skin and bind to haptens, and can take 1–3 days to occur.

Developmental Aspects of the Immune System (pp. 802–803)

A. Stem cells of the immune system originate in the liver and spleen during weeks 1–9 of embryonic development; later, the bone marrow takes over this role. (p. 802)
B. In late fetal life and shortly after birth, lymphocytes develop immunocompetence in the thymus and bone marrow, and then populate other lymphoid tissues. (p. 802)
C. The newborn immune system relies mostly on antibodies, but gets stronger and learns from encounters with microbes in the environment. (p. 802)
D. Later in life, the ability and efficiency of our immune system decline, possibly because progenitor cells reach the limits of their ability to divide. (pp. 802–803)