Chapter 12- The lymphatic system and body defenses

I. The lymphatic system
    A. Consists of two semi-independent parts
        1. Lymphatic vessels
        2. Lymphoid tissues and organs
    B. Lymphatic system functions
        1. Transports escaped fluids back to the blood
        2. Plays essential roles in body defense and resistance to disease

II. Lymphatic characteristics
    A. Lymph- excess tissue fluid carried by lymphatic vessels
    B. Properties of lymphatic vessels
        1. One way system toward the heart
        2. No pump
        3. Lymph moves toward the heart
            a. Milking action of skeletal muscle
            b. Rhythmic contraction of smooth muscle in vessel walls

III. Relationship of lymphatic vessels to blood vessels
    A. Lymphatic vessels
        1. Lymph capillaries
            a. Walls overlap to form flap-like minivalves
            b. Fluid leaks into lymph capillaries
            c. Capillaries are anchored to connective tissue by filaments
            d. Higher pressure on the inside closes minivalves
            e. Fluid is forced along the vessel
        2. Lymphatic collecting vessels
            a. Collect lymph from lymph capillaries
            b. Carry lymph to and away from lymph nodes
            c. Return fluid to circulatory veins near the heart
                1) Right lymphatic duct
                2) Thoracic duct
    B. Lymph
        1. Harmful materials that enter lymph vessels
            a. Bacteria
            b. Viruses
            c. Cancer cells
            d. Cell debris
    C. Lymph nodes
        1. Filter lymph before it is returned to the blood
        2. Defense cells within lymph nodes
            a. Macrophages- engulf and destroy foreign substances
            b. Lymphocytes- provide immune response to antigens

D. Lymph node structure
    1. Most are kidney-shaped and less than 1 inch long
    2. Cortex
        a. Outer part- contains follicles (collections of lymphocytes)
    3. Medulla
        a. Inner part- contains phagocytic macrophages
E. Flow of lymph through nodes
    1. Lymph enters the convex side through afferent lymphatic vessels
    2. Lymph flows through a number of sinuses inside the node
    3. Lymph exits through efferent lymphatic vessels
    4. Fewer efferent than afferent vessels causes flow to be slowed
F. Other lymphoid organs
    1. Several other organs contribute to the lymphatic function
        a. Spleen
            1) Located on the left side of the abdomen
            2) Filters blood
            3) Destroys worn out blood cells
            4) Forms blood cells in the fetus
            5) Acts as a blood reservoir
        b. Thymus
            1) Located low in the throat, overlying the heart
            2) Functions at peak levels only during childhood
            3) Produces hormones (like thymosin) to program lymphocytes
        c. Tonsils
            1) Small masses of lymphoid tissue around the pharynx
            2) Trap and remove bacteria and other foreign materials
            3) Tonsillitis is caused by congestion with bacteria
        d. Peyer's patches
            1) Found in the wall of the small intestine
            2) Resemble tonsils in structure
            3) Capture and destroy bacteria in the intestine
G. Mucosa-associated lymphatic tissue (MALT)
    1. Includes
        a. Peyer's patches
        b. Tonsils
        c. Other small accumulations of lymphoid tissue
    2. Acts as a sentinel to protect respiratory and digestive tracts

IV. Body defenses
A. The body is constantly in contact with bacteria, fungi, and viruses
B. The body has two defense systems for foreign materials
    1. Innate (nonspecific) defense system
    2. Adaptive (specific) defense system

C. Immunity- specific resistance to disease
D. Immune system
E. Body defenses
    1. Innate defense system (nonspecific defense system)
        a. Mechanisms protect against a variety of invaders
        b. Responds immediately to protect body from foreign materials
    2. Adaptive defense system (specific defense system)
        a. Specific defense is required for each type of invader
F. Innate body defenses
    1. Innate body defenses are mechanical barriers to pathogens such as
        a. Body surface coverings
            1) Intact skin
            2) Mucous membranes
        b. Specialized human cells
        c. Chemicals produced by the body
    2. Surface membrane barriers: first line of defense
        a. Skin and mucous membranes
            1) Physical barrier to foreign materials
            2) Also provide protective secretions
                a) pH of the skin is acidic to inhibit bacterial growth
                b) Sebum is toxic to bacteria
                c) Vaginal secretions are very acidic
        b. Stomach mucosa
            1) Secretes hydrochloric acid
            2) Has protein-digesting enzymes
        c. Saliva and lacrimal fluid contain lysozymes, an enzyme that destroy bacteria
        d. Mucus traps microorganisms in digestive and respiratory pathways
    3. Cells and chemicals: second line of defense
        a. Phagocytes
            1) Cells such as neutrophils and macrophages
            2) Engulf foreign material into a vacuole
            3) Enzymes from lysosomes digest the material
        b. Natural killer cells
            1) Can lyse (disintegrate or dissolve) and kill cancer cells
            2) Can destroy virus-infected cells
        c. Inflammatory response
            1) Triggered when body tissues are injured
            2) Four most common indicators of acute inflammation
                a) Redness
                b) Heat
                c) Swelling

        d) Pain
    3) Results from a chain of events leading to the protection and healing
    4) Functions of the inflammatory response
        a) Prevents spread of damaging agents
        b) Disposes of cell debris and pathogens
            i. Phagocytosis
            ii. Neutrophils move by diapedesis to clean up damaged tissue and/or pathogens
            iii. Monocytes become macrophages and complete disposal of cell debris
        c) Sets the stage for repair
d. Antimicrobial proteins
    1) Attack microorganisms
    2) Hinder reproduction of microorganisms
    3) Most important
        a) Complement proteins
            i. A group of at least 20 plasma proteins
            ii. Activated when they encounter and attach to cells (complement fixation)
            iii. Damage foreign cell surfaces
            iv. Release vasodilators and chemotaxis chemicals, cause opsonization
        b) Interferon
            i. Proteins secreted by virus-infected cells
            ii. Bind to healthy cell surfaces to interfere with the ability of viruses to multiply
e. Fever
    1) Abnormally high body temperature
    2) Hypothalamus heat regulation can be reset by pyrogens (secreted by white blood cells)
    3) High temperatures inhibit the release of iron and zinc from the liver and spleen needed by bacteria
    4) Fever also increases the speed of tissue repair

4. Adaptive defense system: third line of defense
    a. Immune response is the immune system's response to a threat
    b. Immunology is the study of immunity
    c. Antibodies are proteins that protect from pathogens
    d. Three aspects of adaptive defense
        1) Antigen specific- recognizes and acts against particular foreign substances
        2) Systemic- not restricted to the initial infection site

3) Memory- recognizes and mounts a stronger attack on previously encountered pathogens

e. Types of immunity
    1) Humoral immunity = antibody- mediated immunity
        a) Provided by antibodies present in body fluids
    2) Cellular immunity = cell-mediated immunity
        a) Targets virus-infected cells, cancer cells, and cells of foreign grafts

f. Antigens (nonself)
    1) Any substance capable of exciting the immune system and provoking an immune response
    2) Examples of common antigens
        a) Foreign proteins (strongest)
        b) Nucleic acids
        c) Some lipids
        d) Pollen grains
        e) Microorganisms
    3) Self-antigens
        a) Human cells have many surface proteins
        b) Our immune cells do not attack our own proteins
        c) Our cells in another person's body can trigger an immune response because they are foreign
            i. Restricts donors for transplants
    4) Allergies
        a) Many small molecules (called haptens or incomplete antigens) are not antigenic, but link up with our own proteins
        b) The immune system may recognize and respond to a protein-hapten combination
        c) The immune response is harmful rather than protective because it attacks our own cells

g. Cells of the adaptive defense system
    1) Lymphocytes respond to specific antigens
        a) B lymphocytes (B cells)
        b) T lymphocytes (T cells)
    2) Macrophages help lymphocytes
    3) Immunocompetent- cells become capable of responding to a specific antigen by binding to it
    4) Cells of the adaptive defense system
        a) Lymphocytes
            i. Originate from hemocytoblasts in the red bone marrow

ii. B lymphocytes become immunocompetent in the bone marrow (remember B for Bone marrow)
iii. T lymphocytes become immunocompetent in the thymus (remember T for Thymus)

b) Macrophages
i. Arise from monocytes
ii. Become widely distributed lymphoid organs
iii. Secrete cytokines (proteins important in the immune response)
iv. Tend to remain fixed in the lymphoid organs

h. Humoral (Antibody-mediated) immune response
1) B lymphocytes with specific receptors bind to a specific antigen
2) The binding event activates the lymphocyte to undergo clonal selection
3) A large number of clones are produced (primary humoral response)
4) Most B cells become plasma cells
a) Produce antibodies to destroy antigens
b) Activity lasts for 4 or 5 days
5) Secondary humoral responses
a) Memory cells are long-lived
b) A second exposure causes rapid response
c) The secondary response is stronger and longer lasting
6) Some B cells become long-lived memory cells (secondary humoral response)
7) Active immunity
a) Occurs when B cells encounter antigens and produce antibodies
b) Active immunity can be
i. Naturally acquired during bacterial and viral infections
ii. Artificially acquired from vaccines
8) Passive immunity
a) Occurs when antibodies are obtained from someone else
i. Conferred naturally from a mother to her fetus (naturally acquired)
ii. Conferred artificially from immune serum or gamma globulin (artificially acquired)
b) Immunological memory does not occur
c) Protection provided by "borrowed antibodies"

d) Monoclonal antibodies
e) Antibodies prepared for clinical testing over diagnostic services
f) Produced from descendents of a single cell line
g) Examples of uses for monoclonal antibodies
i. Diagnosis of pregnancy
ii. Treatment after exposure to hepatitis and rabies

9) Antibodies (immunoglobulins or lgs)
a) Soluble proteins secreted by B cells (plasma cells)
b) Carried in blood plasma
c) Capable of binding specifically to an antigen
d) Antibody structure
i. Four amino acid chains linked by disulfide bonds
ii. Two identical amino acid chains are linked to form a heavy chain
iii. The other two identical chains are light chains
iv. Specific antigen-binding sites are present
e) Antibody classes- antibodies of each class have slightly different roles, Five major immunoglobulin classes (MADGE)
i. IgM- can fix complement
ii. IgA- found mainly in mucus
iii. IgD - important in activation of B cell
iv. IgG- can cross the placental barrier and fix complement
v. IgE- involved in allergies
f) Antibody function
i. Antibodies inactivate antigens in a number of ways:
ii. Complement fixation
iii. Neutralization
iv. Agglutination
v. Precipitation

i. Cellular (cell-mediated) immune response
1) Antigens must be presented by macrophages to an immunocompetent T cell (antigen presentation)
2) T cells must recognize nonself and self (double recognition)
3) After antigen binding, clones form as with B cells, but different classes of cells are produced
4) T cell clones
a) Cytotoxic (killer) T cells

i. Specialize in killing infected cells
ii. Insert a toxic chemical (perforin)

b) Helper T cells
i. Recruit other cells to fight the invaders
ii. Interact directly with B cells

c) Regulatory T cells
i. Release chemicals to suppress the activity of T and B cells
ii. Stop the immune response to prevent uncontrolled activity

d) A few members of each clone are memory cells

V. Organ transplants and rejection
A. Major types of grafts
1. Autografts- tissue transplanted from one site to another site on same person
2. Isografts- tissue grafts from identical person (identical twin)
3. Allografts- tissue taken from an unrelated donor
4. Xenografts- tissue taken from a different animal species
B. Autografts and isografts are ideal donors
C. Xenografts are never successful
D. Allografts are more successful with a closer tissue match

VI. Disorders of immunity: allergies (hypersensitivity)
A. Abnormal, vigorous immune responses
B. Types of allergies
C. Immediate hypersensitivity
1. Triggered by release of histamine from IgE binding to mast cells
2. Reactions begin within seconds of contact with allergen
3. Anaphylactic shock- dangerous, systemic response
D. Types of allergies (continued)
1. Delayed hypersensitivity
a. Triggered by the release of lymphokines from activated helper T cells
b. Symptoms usually appear 1-3 days after contact with the antigen

VII. Disorders of immunity: immunodeficiency's
A. Production or function of immune cells or complement is abnormal
B. May be congenital or acquired
C. Includes AIDS (acquired immune deficiency syndrome)
D. The immune system does not distinguish between self and non-self
E. The body produces antibodies and sensitized T lymphocytes that attack its own tissues
F. Examples of autoimmune diseases
1. Multiple sclerosis- white matter of brain and spinal cord are destroyed
2. Myasthenia gravis- impairs communication between nerves and skeletal muscles
3. Type 1 diabetes mellitus- destroys pancreatic beta cells that produce insulin

4. Rheumatoid arthritis- destroys joints
5. Systemic lupus erythematosus (SLE)
    a. Affects kidney, heart , lung and skin
6. Glomerulonephritis- impairment of renal function

G. Self tolerance breakdown
    1. Inefficient lymphocyte programming
    2. Appearance of self-proteins in the circulation that have not been exposed to the immune system
        a. Eggs
        b. Sperm
        c. Eye lens
        d. Proteins in the thyroid gland

H. Cross-reaction of antibodies produced against foreign antigens with self-antigens
    1. Rheumatic fever

VIII. Developmental aspects of the lymphatic system and body defenses

A. Except of thymus and spleen, the lymphoid organs are poorly developed before birth

B. A newborn has no functioning lymphocytes at birth, only passive immunity from the mother

C. If lymphatics are removed or lost, severe edema results, but blood vessels grow back in time