**Introduction**

A. The lymphatic system is closely associated with the cardiovascular system and is comprised of a network of vessels that circulate body fluids.

B. Lymphatic vessels transport excess fluid away from interstitial spaces between cells in most tissues and return it to the bloodstream.

C. Lymphatic vessels called lacteals (located in the lining of the small intestine) absorb fats resulting from digestion, and then transport fats to the circulatory system.

D. The organs of the lymphatic system help defend against disease.

**Lymphatic Pathways**

A. Lymphatic pathways start as lymphatic capillaries that merge to form larger vessels that empty into the circulatory system. (This is key to understanding this chapter.)

B. Lymphatic Capillaries

*are microscopic, close-ended tubes that extend into interstitial spaces forming networks that parallel the networks of the blood capillaries

*walls consist of single layer squamous epithelial cells which enables interstitial fluid to enter the lymphatic capillaries

*lymph – the fluid inside a lymph capillary

**Lymphatic System URLs**

- http://www.emc.maricopa.edu/health/farabee/BIOBK/BioBookIMMUN.html
- http://www.cayuga-cc.edu/about/facultypages/greer/
- http://www.unc.pitt.edu/pblb/project/updated-lymphaticsystem.html
- http://www.pblch.com/Healthworks/lymphart.html
**Lymphatic Vessels**

- Walls of lymphatic vessels are thinner than walls of veins.
- Have semilunar valves to prevent backflow of lymph.
- Lymph nodes — specialized lymph organs that are composed of a mass of lymphoid tissue located along the course of a lymphatic vessel.

**Lymphatic Trunks and Collecting Ducts**

- After leaving lymph nodes, the vessels merge to form large lymphatic trunks which drain lymph and are named for the region of the body they serve: lumbar, intestinal, intercostal, bronchomediastinal, subclavian.
- Lymphatic trunks join (are drained by) collecting ducts: the thoracic duct and the right lymphatic duct; these ducts join the subclavian veins.

**Lymphatic Pathway**

- Lymphatic capillary
  - Lymphatic vessel
    - Lymph node
      - Lymphatic vessel
        - Lymphatic trunk
          - Collecting duct
            - Subclavian vein

**Tissue Fluid and Lymph**

**A.** Tissue fluid becomes lymph once it has entered a lymphatic capillary; lymph formation depends on tissue fluid formation.

**B. Tissue Fluid Formation**

- Tissue fluid originates from blood plasma; it is composed of H2O & dissolved substances that leave the blood capillaries by filtration & diffusion; it generally lacks proteins; the protein concentration of tissue fluid rises, the osmotic pressure of the fluid rises.

**C. Lymph Formation**

- Rising osmotic pressure in tissue fluid interferes with return of water to the blood capillaries.
- Increasing pressure within interstitial spaces forces some tissue fluid into lymphatic capillaries, & this fluid becomes lymph.
**Lymph Function**

*D. Lymph Function*

- Lymph returns proteins that leak out of blood capillaries to the bloodstream; it also transports foreign particles, such as bacteria or viruses, to lymph nodes.

**Lymph Movement**

*A. The hydrostatic pressure of tissue fluid drives the entry of lymph into lymphatic capillaries.*

*B. Lymph Flow*

- Tissue fluid enters lymphatic capillaries through flaplike valves between epithelial cells.

**Obstruction of Lymph Flow**

- Conditions that interfere with lymph movement cause tissue fluids to accumulate in the interstitial spaces, producing edema.
- Edema can occur as a result of lymphatic tissue being removed during surgery.

**Lymph Nodes**

*A. Lymph nodes, which contain lymphocytes & macrophages, are located along lymphatic pathways. They fight invading microorganisms.*

- **Structure of a Lymph Node**
  - Hilum: indented region of bean-shaped node, blood vessels & nerves connect at the hilum of the lymph node.
  - Afferent vessels: enter at various points on the convex surface of the node & this is how lymph enters the node.
  - Efferent vessels: exit at the hilum of the node & lymph leaves the node through these vessels.
  - Lymph nodules: structural units of the lymph node & are compartments of the node that contain dense masses of actively dividing lymphocytes & macrophages; nodules are associated with the mucous membranes of the respiratory & digestive tracts & found in tonsils, Peyer’s patches of ileum of the small intestine.

**Locations of Lymph Nodes**

- Lymph nodes aggregate in groups or chains along the paths of larger lymphatic vessels; are absent in the central nervous system.
- Major locations: cervical, axillary, inguinal, subtrochanteric, & within the pelvic, abdominal, & thoracic cavities.

**Functions of Lymph Nodes**

- 2 primary functions:
  1) Filtering potentially harmful particles from lymph before returning it to the bloodstream & immune surveillance provided by lymphocytes & macrophages.
  2) Lymph nodes are the centers for production of lymphocytes that act against foreign particles.
- Lymph nodes contain macrophages that remove foreign particles from lymph.
Thymus and Spleen

A. The functions of the thymus and spleen are similar to those of lymph nodes.

B. Thymus
- Soft, bi-lobed structure enclosed in a connective tissue capsule located within the mediastinum.
- Thymus shrinks slowly after puberty.
- It is composed of lymphatic tissue subdivided into lobules.
- Lobules contain lymphocytes, most of which are inactive, that develop from precursor cells in bone marrow.
- Some lymphocytes mature into T lymphocytes which leave the thymus and provide immunity.
- The thymus secretes thymosin, which stimulates the maturation of lymphocytes that have migrated to other lymphatic tissues.

C. Spleen
- Largest of lymphatic organs; located just under left portion of diaphragm.
- Resembles a large lymph node that is encapsulated and subdivided into lobules by connective tissues.
- Spaces within lobules are filled with blood instead of lymph.
- Two types of tissues in lobules of spleen:
  1) White pulp - tissue containing many lymphocytes.
  2) Red pulp - contains numerous red blood cells plus many lymphocytes & macrophages.
- The spleen contains many macrophages & lymphocytes, which filter foreign particles & damaged red blood cells from the blood.
- The spleen filters blood much as the lymph nodes filter lymph.

Body Defenses Against Infection

A. Disease-causing agents, called pathogens, can produce infections within the body.
- Pathogens include bacteria, complex single-celled organisms, fungi, & viruses.
- An infection may be present without immediately causing symptoms.

B. The body has two lines of defense against pathogens:
  1) Non-specific defenses that guard against any pathogen (7)
  2) Specific defenses that mount a response against a very specific target.
**Innate (Nonspecific) Defenses**

#1 Species Resistance
*Each species is resistant to certain diseases that may affect other species but is susceptible to diseases other species may resist.*

#2 Mechanical Barriers
*Includes the skin & mucous membranes lining passageways of the respiratory, digestive, urinary, & reproductive systems that prevent entrance of some infectious agents. Prevention can occur as long as these barriers remain intact.*

#3 Chemical Barriers
*enzymes in gastric juice & tears kill some pathogens,*
*low (acidic) pH in the stomach prevents growth of some bacteria,*
*high salt concentration in perspiration kills some bacteria*
*interferons (hormonelike peptides) produced by lymphocytes & fibroblasts stimulate uninfected cells to synthesize antiviral proteins that block proliferation of viruses, stimulate phagocytosis, & enhance activity of cells that help resist infections & stifle tumor growth*
*defensins make holes in bacteria cell walls & membranes*
*collectins provide broad protection against a wide variety of microbes by grabbing onto them*

#4 Fever
*offers powerful protection*
*viral or bacterial infection stimulates certain lymphocytes to secrete endogenous pyrogen, which temporarily raises body temperature*
*higher body temperature & the resulting decrease in blood iron level production by the liver & spleen causes an increase in phagocytic activity that hampers infection*

#5 Natural Killer (NK) Cells
*a group of lymphocytes that secrete cytolytic perforins to destroy cells infected by viruses & cancer; perforins destroy the cell membrane & enhance inflammation*

#6 Inflammation
*inflammation is a tissue response to damage, injury, or infection; it produces localized redness, swelling, heat, & pain*
*chemicals released by damaged tissues attract white blood cells to the site; in bacterial infection, the resulting mass of white blood cells, bacterial cells, & damaged tissue may form a thick fluid called pus*
*clotting may occur in body fluids that accumulate in affected tissues*
*fibrous connective tissue may form a sac around the injured tissue & thus prevent the spread of pathogens*

#7 Phagocytes
*neutrophils & monocytes are the most active phagocytes in blood*
*monocytes give rise to macrophages, which remain in fixed tissues*
*phagocytic cells associated with the linings of blood vessels in the bone marrow, liver, spleen, & lymph nodes constitute the mononuclear phagocytic system*
*phagocytes remove foreign particles from tissues & body fluids*

***Read more about this in your textbook.***

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**Adaptive (Specific) Defenses or Immunity**

Immunity refers to the response mounted by the body against specific, recognized foreign antigens (non-self molecules). Lymphocytes & macrophages that recognize specific foreign molecules (nonself antigens) carry out immune responses.

*antigen – a chemical that stimulates cells to produce antibodies*
*antibody – a protein that B cells of the immune system produce in response to the presence of a nonself antigen; it reacts with the antigen*
Antigens: “Before birth, body cells inventory the proteins & other large molecules in the body & learn to identify them as “self” molecules.

* The lymphatic system responds to nonself, or foreign antigens. It doesn’t respond to self antigens.

* After inventory, lymphocytes develop receptors that allow them to differentiate between nonself (foreign) & self antigens.

* Nonself antigens combine with the T cell & B cell surface receptors & stimulate these cells to cause an immune reaction.

* Antigens may be proteins, polysaccharides, glycoproteins, or glycolipids.

* Sometimes small molecules (haptens) cannot stimulate an immune response so they combine with a larger one.

* Haptens are small molecules that can combine with larger ones, becoming antigenic. Haptens are found in penicillin, certain household chemicals, dust, & animal dander.

Lymphocyte Origins

* Lymphocytes originate in red bone marrow of fetus; the bone marrow releases them into the blood before they differentiate.

* Half of these cells reach the thymus (thymocytes) & they remain for a time & mature into T cells; later the blood transports T cells, where they make up 70-80% of circulating lymphocytes. T cells are found in lymphatic organs, nodes, thoracic duct, & white pulp of the spleen.

* Other lymphocytes remain in the red bone marrow & differentiate into B cells (B lymphocytes); blood distributes B cells; are found in lymphatic organs, lymph nodes, spleen, bone marrow & intestinal lining.

B-Cell and T-Cell Origin

(1) Stem cells in red bone marrow give rise to undifferentiated lymphocytes.

(2) Undifferentiated lymphocytes enter blood.

(3) Some lymphocytes are processed in thymus gland to become T cells.

(4) Other lymphocytes are processed in bone marrow to become B cells.

(5) T cells and B cells are transported to lymphatic organs by blood.

B Cells and Antibody-Mediated Immunity

* B cells attack foreign antigens in a different way than T cells. They differentiate into plasma cells which produce & secrete large globular proteins called antibodies, also called immunoglobulins. Plasma cells can produce many antibodies (2,000 antibody molecules/second).

* Antigen-meditated immunity – antibodies carried by body fluids that react to destroy specific antigens.

* Antibodies are proteins called immunoglobulins; are soluble, globular proteins, gamma globular fraction of plasma proteins; each is composed of 4 chains of amino acids that are linked by pairs of sulfur atoms; light & heavy chains; variable regions at the ends of these chains are specialized into antigen binding sites to react with antigens.

T Cells and Cell-Mediated Immunity

* T cells respond to antigens by cell-to-cell contact.

* T cells secrete & synthesize polypeptides called cytokines to enhance other cell responses to antigens.

* Cytokines – a type of protein that is secreted by T lymphocytes; attacks viruses, virally infected cells, & cancer cells.

* Interleukins are cytokines.

* T cell types & activation:

  * T cells are activated when an antigen-presenting cell (accessory cell) displays a foreign antigen.

  * Helper T cells – become activated when they encounter displayed antigens for which they are specialized to react (HIV cripples these cells).

  * Memory T cells provide for a no-delay response to any future exposure to the same antigen.

  * Cytotoxic T cells recognize foreign antigens on cancerous cells & tumors by releasing the protein perforin.

B-Cell Proliferation

* Antigens stimulate B cells to produce antibodies.

* Activation of B cells results in proliferation, differentiation of the B cell, and production of antibodies.

* Cytokines are secreted by activated helper T cells to stimulate B cell proliferation.

* Clone of B cells is produced, each producing antibodies specific to the antigen.
Types of Immunoglobulins – Antibodies

- **5 major types:**
  - IgG, IgA, IgM, IgD, & IgE = MADGE
  - IgG, IgA, & IgM make up most of the circulating antibodies; IgG is most abundant type
  - IgD – activates B cells
  - IgM – potent agglutinating agent
  - IgG – crosses the placenta & confers passive immunity from the mother to the fetus
  - IgA – found in body secretions, saliva, sweat, intestinal juice, & milk; helps prevent attachment of pathogens to epithelial cell surfaces
  - IgE – causes cells to release histamine & other chemicals that mediate inflammation & an allergic reaction

- **Antibody Actions:***
  - react to antigens in 3 ways:
    1. direct attack - cause them to clump together or agglutinate, or precipitate, or neutralize
      - this allows phagocytic cells to lyse the antigens
    2. activate enzymes to attack
    3. stimulate changes in local areas that help prevent the spread of the antigens

- **PLAN =** precipitate, lyse, agglutinate, and neutralize

- **OTHER attack mechanisms:**
  - complement – a group of proteins in plasma/body fluids that along with IgG or IgM which combine with the antigens & trigger a series of reactions that activate the complement to coat the antigen-antibody complex & make them susceptible to phagocytosis (opsonization); also attract macrophages & neutrophils into the region (chemotaxis)

Specific Defenses (Immunity)

- **Imune Responses:**
  - **Primary immune response** – when B cells or T cells become activated as a result of encountering the antigens for which they are specialized to react; as a result antibodies are produced for several weeks
  - *after a primary immune response some B cells serve as memory cells & react to the identical antigen if it appears in the future = immunity
  - **Secondary immune response** – occurs as a result of memory cell response if the same antigen is encountered later
Types of Immunity

*naturally acquired active immunity* – occurs after a person develops a primary immune response

*artificially acquired active immunity* - vaccines contain a dead or weakened pathogen, or part of it, & develops this type of immunity

*naturally acquired passive immunity* - fetus develops this when antibodies pass through a placental membrane from a pregnant woman (mother)

*artificially acquired passive immunity* – developed when a person receives an injection of antibodies

*active immunity* lasts much longer than *passive immunity*

Allergic Reactions

*an immune attack against a nonharmful substance, & can damage tissues; also called a hypersensitive reaction

*allergens* – antigens that trigger allergic responses

*autoimmunity* – an immune response against a person’s own tissues; autoallergy

*anaphylactic shock* – a severe form of immediate reaction in which mast cells release allergy mediators throughout the body; can feel apprehension, itching from a breakout of hives, vomiting, & diarrhea. The face, tongue, & larynx may swell restricting breathing. An immediate shot of epinephrine or a tracheotomy. This kind of shock is caused most often by insect stings or penicillin. Peanut allergies can cause similar symptoms.

Transplantation and Tissue Rejection

*a transplant recipient’s immune system may react against the donated tissue in a tissue rejection reaction

*matching donor & recipient tissues & using immunosuppressive drugs can minimize tissue rejection; these drugs can increase susceptibility to infection, however

*transplants can be successful between identical twins, from one body part to another, between unrelated individuals of the same species, or even between individuals of different species*
4 major varieties of grafts (transplant tissue)

1. Isograft – tissue from genetically identical twin
2. Autograft – tissue taken from same individual
3. Allograft – tissue taken from same species
4. Xenograft – tissue taken from different species

Autoimmunity
* immune system can fail to recognize self from nonself
* bring on an immune response against a person’s own tissues called autoimmunity
* in autoimmune disorders, the immune system manufactures autoantibodies that attack one’s own body tissues
* autoimmune disorders may result from a previous viral infection, faulty T cell development, or reaction to a nonself antigen that resembles a self antigen