The Lymphatic System
Transports escaped fluids back to the blood
Plays essential roles in body defense and resistance to disease

- **Lymph**—excess tissue fluid carried by lymphatic vessels

- Properties of lymphatic vessels
  - One way system toward the heart
  - No pump
  - Lymph moves toward the heart
Lymphatic Vessels

- Fibroblast in loose connective tissue
- Flaplike minivalve
- Filaments anchored to connective tissue
- Endothelial cell

(a) Tissue fluid
- Tissue cell
- Lymphatic capillary
- Blood capillaries

(b) Arteriole
Venule
Lymphatic collecting vessels
- Collect lymph from lymph capillaries
- Carry lymph to and away from lymph nodes
- Return fluid to circulatory veins near the heart

- Right lymphatic duct drains ¼ of body
- Thoracic duct drains ¾ of body
• Harmful materials that enter lymph vessels
  – Bacteria
  – Viruses
  – Cancer cells
  – Cell debris

Lymph Nodes
1. Filter lymph before it is returned to the blood
2. Defense cells within lymph nodes
   – Macrophages—engulf and destroy foreign substances
   – Lymphocytes—provide immune response to antigens
3. Most are kidney-shaped and less than 1 inch long
• Lymph enters the convex side through afferent lymphatic vessels
• Lymph flows through a number of sinuses inside the node
• Lymph exits through efferent lymphatic vessels
• Fewer efferent than afferent vessels causes flow to be slowed
Other Lymphoid Organs

Spleen
- Located on the left side of the abdomen
- Filters blood
- Destroys worn out blood cells
- Forms blood cells in the fetus
- Acts as a blood reservoir
Thymus Gland

- Located low in the throat, overlying the heart
- Functions at peak levels only during childhood
- Produces hormones (like thymosin) to program lymphocytes
Tonsils

- Small masses of lymphoid tissue around the pharynx
- Trap and remove bacteria and other foreign materials
- Tonsillitis is caused by congestion with bacteria
Peyer’s Patches

- Found in the wall of the small intestine
- Resemble tonsils in structure
- Capture and destroy bacteria in the intestine
The Immune System

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Second Line of Defense

• Phagocytes
  – Cells such as neutrophils and macrophages
  – Engulf foreign material into a vacuole
  – Enzymes from lysosomes digest the material

• Natural killer (NK) cells
  – Can lyse (disintegrate or dissolve) and kill cancer cells
  – Can destroy virus-infected cells
Phagocytes

– Cells such as neutrophils and macrophages
– Engulf foreign material into a vacuole
– Enzymes from lysosomes digest the material
• Phagocytosis
  – Neutrophils move by diapedesis to clean up damaged tissue and/or pathogens
  – Monocytes become macrophages and complete disposal of cell debris

• Interferon
  – Proteins secreted by virus-infected cells
  – Bind to healthy cell surfaces to interfere with the ability of viruses to multiply
Complement System

- Complement proteins
  - A group of at least 20 plasma proteins
  - Activated when they encounter and attach to cells (complement fixation)
  - Damage foreign cell surfaces

Activated complement proteins attach to pathogen’s membrane in step-by-step sequence, forming a membrane attack complex (a MAC attack).

MAC pores in the membrane cause cell lysis.
Third Line of Defense

• Antibodies are proteins that protect from pathogens

• Three aspects of adaptive defense
  – Antigen specific—recognizes and acts against particular foreign substances
  – Systemic—not restricted to the initial infection site
  – Memory—recognizes and mounts a stronger attack on previously encountered pathogens
• Types of Immunity
  – **Humoral immunity** = antibody-mediated immunity
    • Provided by antibodies present in body fluids
  – **Cellular immunity** = cell-mediated immunity
    • Targets virus-infected cells, cancer cells, and cells of foreign grafts
• **Antigens (nonself)**
  – Any substance capable of exciting the immune system and provoking an immune response
  – Examples of common antigens
    • Foreign proteins (strongest)
    • Nucleic acids
    • Large carbohydrates
    • Some lipids
    • Pollen grains
    • Microorganisms
• Self-antigens
  – Human cells have many surface proteins
  – Our immune cells do not attack our own proteins
  – Our cells in another person’s body can trigger an immune response because they are foreign
    • Restricts donors for transplants
Cells of Immune System

- **Lymphocytes** respond to specific antigens
  - B lymphocytes (B cells)
  - T lymphocytes (T cells)
- **Macrophages** (Big Eater) help lymphocytes
- Lymphocytes
  - Originate from hemocytoblasts in the red bone marrow
  - B lymphocytes become immunocompetent in the bone marrow (remember B for Bone marrow)
  - T lymphocytes become immunocompetent in the thymus (remember T for Thymus
Lymphocytes destined to become T cells migrate from bone marrow to the thymus and develop immunocompetence there. B cells develop immunocompetence in the bone marrow.

After leaving the thymus or bone marrow as naive immunocompetent cells, lymphocytes “seed” the infected connective tissues (especially lymphoid tissue in the lymph nodes), where the antigen challenge occurs and the lymphocytes become fully activated.

Activated (mature) lymphocytes circulate continuously in the bloodstream and lymph, and throughout the lymphoid organs of the body.

**KEY:**
- Site of lymphocyte origin
- Sites of development of immunocompetence as B or T cells; primary lymphoid organs
- Site of antigen challenge and final differentiation to mature B and T cells
- Macrophages
  - Arise from monocytes
  - Become widely distributed in lymphoid organs
  - Secrete cytokines (proteins important in the immune response)
  - Tend to remain fixed in the lymphoid organs
Primary Response
(initial encounter with antigen)

Antigen binding to a receptor on a specific B cell (lymphocyte) (B cells with non-complementary receptors remain inactive)

B lymphoblasts

Proliferation to form a clone

Cloning to form a clone

Plasma cells

Secreted antibody molecules

Secondary Response
(can be years later)

Subsequent challenge by same antigen

Clone of cells identical to ancestral cells

Plasma cells

Secreted antibody molecules

Memory B cells

Memory B cell

Antigen
Types of Acquired Immunity

- Naturally acquired
  - Active: Infection; contact with pathogen
  - Passive: Antibodies pass from mother to fetus via placenta or to infant in her milk

- Artifially acquired
  - Active: Vaccine; dead or attenuated pathogens
  - Passive: Injection of immune serum (gamma globulin)
Antibodies (Immunoglobulins or Igs)

- Soluble proteins secreted by B cells (plasma cells)
- Carried in blood plasma
- Capable of binding specifically to an antigen
Antibody structure

- Four amino acid chains linked by disulfide bonds
- Two identical amino acid chains are linked to form a heavy chain
- The other two identical chains are light chains
- Specific antigen-binding sites are present
• Antibody classes
  – Antibodies of each class have slightly different roles
  – Five major immunoglobulin classes (MADGE)
    • IgM—can fix complement
    • IgA—found mainly in mucus
    • IgD—important in activation of B cell
    • IgG—can cross the placental barrier and fix complement
    • IgE—involved in allergies
  – Antibodies inactivate antigens in a number of ways
    • Complement fixation
    • Neutralization
    • Agglutination
    • Precipitation
Antigen-antibody complex

**Inactivates by**
- Neutralization (masks dangerous parts of bacterial exotoxins; viruses)
- Agglutination (cell-bound antigens)
- Precipitation (soluble antigens)

**Fixes and activates**
- Complement

**Enhances**
- Phagocytosis
- Inflammation (chemotaxis, histamine release)

**Leads to**
- Cell lysis