Animal Anatomy and Physiology 1

Webinar
Chapter 9

Blood, Lymph, and Immunity
Blood, Lymph, and Immunity
Chapter 9

Pages 220-246
Textbook Learning Objectives

Chapter 9 – Page 220

• List and describe the functions of blood
• Describe the composition of blood plasma
• Describe the characteristics of mature erythrocytes
• Describe the structure of the hemoglobin molecule and explain the fate of hemoglobin following intravascular and extravascular hemolysis
• Give the origin of thrombocytes and describe their characteristics and functions
• List the types of leukocytes and describe the functions of each
• Describe the formation of lymph fluid and its circulation through the lymphatic system
• List the functions of the lymphatic system
• Describe the structure and functions of the lymph nodes, spleen, thymus, tonsils, and GALT
• List the functions of the immune system
• Differentiate between specific and nonspecific immune reactions
• Differentiate between cell-mediated and humoral immunity
• List the components involved in cell-mediated immunity and explain the role of each
• List and describe the classes of immunoglobulins
• Differentiate between active and passive immunity
List and describe the functions and composition of blood:

**Plasma**
- **Water**: 92% by weight
- **Proteins**: 7% by weight
- **Other solutes**: 1% by weight
  - Albumins: 58%
  - Globulins: 37%
  - Fibrinogen: 4%
  - Regulatory proteins: 1%
- **Electrolytes**
- **Nutrients**
- **Respiratory gases**
- **Waste products**

**Erythrocytes**
- **Erythrocytes**: 4.2–6.2 million per cubic mm

**Buffy Coat**
- **Platelets**: 12–300 thousand per cubic mm
- **Leukocytes**: 5–10 thousand per cubic mm
  - **Lymphocytes**: 20–25%
  - **Neutrophils**: 60–70%
  - **Monocytes**: 3–8%
  - **Eosinophils**: 2–4%
  - **Basophils**: 0.5–1%
Functions of Blood

Blood is a **connective tissue**

- **Transportation**
  - Oxygen, nutrients, waste products, hormones
- **Regulation**
  - Body temperature, tissue fluid content, blood pH
- **Defense System**
  - White blood cell phagocytosis, platelets, clotting factors
Blood – Molecule Transportation System

- Oxygen \((O_2)\), carbon dioxide \((CO_2)\)
- Nutrients
- Waste products
- Hormones
- Antibodies
- WBC’s
- Platelets
Blood – Regulation

• Body temperature
• Body fluid **volume** homeostasis
  ▪ Salt water aquarium homeostasis
  ▪ Hemoconcentration
  ▪ Hemodilution
• Blood **pH** – What is normal? Why?
  ▪ Salt water aquarium homeostasis
Blood – Defense

- Leukocytes (white blood cells)
  - Phagocytosis
    - Neutrophils & macrophages engulf bacteria
  - Antibody production
    - B-lymphocytes (plasma cells) make antibodies against specific viruses
    - Killer T-lymphocytes
- Platelets & clotting factors
  - Clot blood when blood vessel wall is damaged
Internal Medicine
Composition of Blood

Figure 9-1, Page 222

Diagram showing the composition of blood, including percentages by weight and volume. The main components are:

- Plasma: 55% (percentage by volume), composed of:
  - Water: 91%
  - Proteins: 7%
  - Other solutes: 2%

- Formed elements (number per cubic mm):
  - Platelets: 200-500 thous.
  - Leukocytes: 6-17 thous.
  - Erythrocytes: 5.5-8.5 million

- Other fluids and tissues: 93%

- Red blood cells
- White blood cells
- Platelets

Legend:
- Albumins
- Globulins
- Fibrinogen
- Ions
- Nutrients
- Waste products
- Gases
- Regulatory substances
- Neutrophils: 60-77%
- Lymphocytes: 12-30%
- Monocytes: 3-10%
- Eosinophils: 2-10%
- Basophils (rare)
Blood = Plasma + Cells

- Liquid portion: Plasma
- Cellular portion:
  - Red blood cells (erythrocytes)
  - White blood cells (leukocytes)
  - Platelets (thrombocytes)
Blood Plasma

- Over 90% water
- 7% plasma proteins
  - created in liver
  - confined to bloodstream
  - Albumin
  - Globulins (immunoglobulins)
    - form antigen-antibody complexes
  - **Fibrinogen**
    - for clotting
- 2% other substances
  - electrolytes, nutrients, hormones, gases, waste products
Plasma versus Serum

- Both liquids appear identical to the naked eye
- **Serum** – the liquid part of blood AFTER coagulation
- **Fibrinogen** is not found in serum
  - Plasma protein
  - Assists in the blood clotting process
  - Leaves plasma to help clot blood
Difference between blood plasma and blood serum. Plasma is whole blood minus cells; serum is whole blood minus the cells and clotting elements. Plasma is prepared by centrifuging anticoagulated blood; serum is prepared by allowing blood to clot.
Plasma versus Serum

- Blood to which an **anticoagulant** has been added will not clot

- Whole Blood: Plasma, WBCs & platelets, RBCs
- Clotted Blood: Serum, blood clot
Cellular Components
Figure 9-2, Page 224

- Erythrocytes – carry oxygen
- Thrombocytes – help prevent leaks from damaged blood vessels
- Leukocytes
  - Granulocytic or agranulocytic
Hematopoiesis

- Production and maturing of ALL blood cells
- Occurs primarily in red bone marrow
- Fetal hematopoiesis occurs in the liver and spleen
- Neonatal hematopoiesis occurs in red bone marrow
Bone Marrow Produces

- White Blood Cells: Fight Infection
- Red Blood Cells: Carry Oxygen
- Platelets: Control Clotting
Hematopoiesis – Blood Cell Formation

Key:
- Precursor cells or "blasts"
- Formed elements of circulating blood
- Tissue cells

Pluripotent stem cell → Myeloid stem cell → CFU-E → Proerythroblast → Nucleus ejected → Reticulocyte → Red blood cell

Pluripotent stem cell → Myeloid stem cell → CFU-Meg → Megakaryoblast → Megakaryocyte → Platelets → Neutrophil → Plasma cell

Pluripotent stem cell → Myeloid stem cell → CFU-GM → Monoblast → Monocyte → Macrophage

Pluripotent stem cell → Lymphoid stem cell → CFU-GM → Eosinophilic myeloblast → Eosinophil → B lymphocyte

Pluripotent stem cell → Lymphoid stem cell → CFU-GM → Basophilic myeloblast → Basophil → T lymphocyte
Erythropoiesis

- Production of red blood cells
  - **Erythropoietin**: hormone released from cells in kidney in response to hypoxia
    - Triggers stem cell to divide and differentiate
    - Multiple maturation steps
CLINICAL APPLICATION

Blood Volume

Here's the question. How do you know if you can draw 200 ml of blood from an animal without causing serious problems? Our limit will be 25% of the total blood volume, which is more blood than you would routinely draw from an animal, since an animal that loses 25% of its total blood volume has about a 50:50 chance of survival, but let us examine a worst case scenario.

First, you need to know how much blood an animal has. The total blood volume for any animal can be estimated using the animal's lean body weight. *Lean* is the operative word here. A 13.5 kg (30-pound) house cat is not lean. So if you want to figure the total blood volume on this cat, think of it as a 3.5- to 4.5-kg (8- to 12-pound) cat. As a broad rule of thumb, figure 50 to 100 ml (average 75) of blood/kg lean body weight. High-strung animals tend to have more volume because they are always active—pacing, bouncing, running—so they need more oxygen in their muscles.

Using these guidelines, a 454-kg (1000-pound) horse will have a total blood volume of about 34,000 ml or 34 liters (454 kg × 75 ml of blood/kg = 34,050 total blood volume). Taking 200 ml of blood from this horse would result in a blood loss of 0.5% of the total blood volume (200 ml divided by 34,000 ml and multiplied by 100 to get a percentage). Not a problem.

Now let's consider a 16-kg (35-pound) dog with a total blood volume of 1193 ml. Drawing 200 ml from this dog would result in a blood loss of 16%. This is still not a problem, but we're getting closer to trouble.

*A Pint's a Pound the World Around*
Test Yourself – GREAT Reviews for You All Over the Book! 😊

TEST YOURSELF

1. What are the main functions of blood?
2. What is one of the most common causes of hemoconcentration, and how can it affect blood cell counts in peripheral blood?
3. What is the most abundant component of plasma?
4. What are the three main categories of cellular blood components?
5. What is the difference between red bone marrow and yellow bone marrow?
6. What is the difference between plasma and serum?
7. How does one cell population, the pluripotent stem cells, give rise to all the different blood cells?
8. What is the total blood volume of a 675-pound (lean body weight) animal? How about a 3-pound animal?
Mammal Erythrocyte Morphology

- **Most common of blood cells** on a blood smear
- **Biconcave disc**
- **No nuclei in mammal RBC’s**
- Nuclei present normally in bird and reptile blood
- Normal canine RBC’s have a **central pallor** (lightness) to them
How Small Are They? 😊

- They are soooooooooooooo small…………. 
Bird and Reptile RBC’s

Bird RBC’s

Reptile RBC’s
Hemoglobin

- Molecule inside RBC’s that carries oxygen
- **Oxygenated** blood – bright red
- **Deoxygenated** blood – dark red
Red Blood Cell Life Span

- Varies with the species
  - **Dogs ~ 120 days (4 months?)**
  - Cats ~ 68 days
  - Horse and sheep ~ 150 days
  - Cow ~ 160 days
  - Mice ~ 20-30 days
- “Recycled” by **macrophages** from the spleen
Anemia

• Results in decreased $O_2$ carrying capacity of the blood

• Caused by:
  ▪ Low number of circulating mature red blood cells (blood loss, increased RBC destruction, decreased RBC production)
  ▪ Insufficient hemoglobin production (e.g., iron deficiency)
Polycythemia

• Increase in number of RBCs
• Causes:
  ▪ Hemoconcentration due to fluid loss and dehydration (e.g., vomiting, diarrhea)
  ▪ High altitudes
Carbon Dioxide Transport in the Blood

- CO₂ diffuses into red blood cells and is transformed into carbonic acid
- Ionizes into hydrogen ions and bicarbonate ions
  \[ \text{H}_2\text{O} + \text{CO}_2 = \text{H}_2\text{CO}_3 = \text{H}^+ + \text{HCO}_3^- \]
- Deoxyhemoglobin accepts the hydrogen ion
- Bicarbonate diffuses back into the plasma
Platelets (Thrombocytes)

- **Cellular fragments** of bone marrow megakaryocytes
- **Thrombopoiesis** - production and maturation of platelets in the bone marrow
Blood Clotting

Red blood cell
Platelet
Collagen fibers and damaged endothelium
Platelet Functions

- **Maintain vascular integrity**
  - Release endothelial growth factor into blood vessel endothelial cells

- **Formation of platelet plug**
  - Attracted to exposed connective tissue of damaged blood vessel
  - Adhere to exposed connective tissue and each other

- **Stabilize the hemostatic plug**
  - Fibrin strands form a netlike mesh around and through the platelets.
White Blood Cells (Leukocytes)

Functions

Presence or Absence of Granules

Nuclear Shape
Leukopoiesis

• Production and maturation of all WBC’s
• Occurs in red bone marrow
  ▪ Some lymphocytes develop further outside bone marrow
• Same pluripotent stem cell that produces red blood cells and megakaryocytes
• Each type of WBC has its own stimulus for production
# White Blood Cells

**Table 9-2, Page 231**

<table>
<thead>
<tr>
<th>Name</th>
<th>Cytoplasmic Granules</th>
<th>Nuclear Shape</th>
<th>Function</th>
<th>Site of Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutrophil</td>
<td>Don't stain (usually invisible)</td>
<td>Polymorphonuclear</td>
<td>Phagocytosis</td>
<td>Body tissues</td>
</tr>
<tr>
<td>Eosinophil</td>
<td>Stain red</td>
<td>Polymorphonuclear</td>
<td>Allergic reactions, anaphylaxis, phagocytosis</td>
<td>Body tissues</td>
</tr>
<tr>
<td>Basophil</td>
<td>Stain blue</td>
<td>Polymorphonuclear</td>
<td>Initiation of immune and allergic reactions</td>
<td>Body tissues</td>
</tr>
<tr>
<td>Monocyte (macrophage)</td>
<td>None</td>
<td>Pleomorphic</td>
<td>Phagocytosis and process antigens</td>
<td>Body tissues or blood</td>
</tr>
<tr>
<td>B cell (lymphocyte)</td>
<td>None</td>
<td>Mononuclear</td>
<td>Antibody production and humoral immunity</td>
<td>Lymphoid tissue</td>
</tr>
<tr>
<td>T cell (lymphocyte)</td>
<td>None</td>
<td>Mononuclear</td>
<td>Cytokine production and cell-mediated immunity</td>
<td>Lymphoid tissue and other body tissues</td>
</tr>
</tbody>
</table>
Granulocytes

- **Granulopoiesis** – production and maturation of the granulocytes (neutrophils, eosinophils, and basophils) in the bone marrow
- The “phil” cells! 😊
- Specific cytoplasmic granules produced during maturation
  - Granules contain different substances depending on the cell’s function
Agranulocytes

- **Lymphocytes**
- **Monocytes**
- The “**cyte**” cells! 😊
- No granules in the cytoplasm
Canine Leukocytes

- Neutrophil
- Lymphocyte
- Eosinophil
- Monocyte
- Basophil
Feline Leukocytes
Equine Leukocytes
Avian Leukocytes
Define and list the functions of the lymphatic system
Lymphatic System – What Is It?

- A “water filtration system” for interstitial fluid (ECF)
- Series of vessels
  - Carries excess fluid to blood vessels near heart
- 3 components
  - Lymph
  - Lymph vessels (ducts)
  - Lymph tissue
Lymphatic System

• Series of **vessels/ducts**
• Carry excess interstitial tissue fluid (ECF) to blood vessels near the heart where fluid is put back into the bloodstream
  ▪ Walking Salt Water Aquariums (Secret of Life!)
  ▪ Recycle Resources (Secret of Life!)
• Also **includes lymph tissue** scattered throughout the body (lymph nodes, spleen, thymus, tonsils)
Lymphatic System Functions

- **Removal of excess tissue fluid**
- Waste material transport
  - Interstitial fluid (ECF) contains some of the waste materials from the tissue cells
- **Filtration of lymph**
  - Removal of microorganisms, cellular debris, and other foreign matter
- Protein transport
Describe the formation of lymph fluid and its circulation through the lymphatic system
Lymph – What Is It?

- This liquid consists of:
  - Blood cells – mostly lymphocytes
  - Nutrients (proteins, fats, etc.)
  - Hormones
- Some T cells circulate from blood to interstitial fluid to lymph and back to blood
- B cells are found primarily in lymph tissues and rarely recirculate
Lymph Characteristics

- **Transparent or translucent liquid** containing varying numbers of cells, primarily *lymphocytes*
- More water, sugar, and electrolytes than plasma
- Fewer of the larger proteins found in plasma
- **Chyle** – Lymph from the digestive system
  - *Chylomicrons* cause lymph to appear white or pale yellow and cloudy
Figure 9-8  **Formation of lymph.** 1, Blood pressure forces plasma out into tissues. 2, Osmotic pressure draws some of tissue fluid back into capillary, but not all of it. 3, Blind-ended lymph capillary picks up excess tissue fluid and carries it off into progressively larger lymph vessels that eventually return it to bloodstream.
Lymph

• Excess tissue fluid picked up by blind-ended **lymph capillaries**
• **Fluid is actually plasma** from blood capillaries
  - Nutrients
  - **O$_2$, CO$_2$**
  - Waste molecules
Lymph Circulation

- **Lymph capillaries** join together to form larger and **larger lymph vessels**
- Many contain **one-way valves** that prevent lymph from flowing backwards
- Body movements propel lymph **toward the heart**
Lymph Circulation

• Lymph vessels eventually join to form the **thoracic duct** that **empties lymph into the vena cava** just before it enters the heart
  ▪ Lymph now called “**chyle**”
• Lymph vessels pass through at least one **lymph node** and pick up lymphocytes
• Any **microorganisms in the lymph are removed by macrophages** found in the lymph nodes
So What Does This Look Like?
Trace a Drop of Lymph.......
 Describe the structure and functions of the lymph nodes, spleen, thymus, tonsils.
Lymph Nodes
Figure 9-9, Page 240

- Small kidney-shaped structures at various points along lymph vessels
- Lymph **filtration**
  - Cellular debris (cancer cells?)
  - Microorganisms
- Antibody production (**lymphocytes**)
Lymph Nodes in the Dog

- Parotid lymph node
- Retropharyngeal lymph nodes
- Submandibular lymph node
- Prescapular lymph node
- Axillary lymph node
- Tracheal duct
- Thoracic duct
- Cisterna chyli
- Mesenteric lymph nodes
- Popliteal lymph node
- Bronchial lymph nodes
- Superficial inguinal lymph nodes
Spleen

- Largest lymphoid organ
- **Storage of blood**
- **Lymphocyte cloning**
- Removal of old RBC’s (Secret of Life!)
Thymus, Tonsils

• Thymus
  - Lymphoid organ in young animals
  - Ventral thorax near trachea
  - **T-cells** mature here
  - Atrophies with age

• Tonsils
  - Nodules of lymphoid tissue
  - Found close to mucosa, at beginning of lymph drainage
  - **Palatine tonsils**
Define and list functions of the immune system

**Immunity**
- **Innate** (inborn)
  - Genetic factors
- **Acquired**
  - **Active**
    - Own antibodies
      - Natural
        - Exposure to infectious agents
      - Artificial
        - Immunization
  - **Passive**
    - Ready-made antibodies
      - Natural
        - Maternal antibodies
      - Artificial
        - Antibodies from other sources
Immune System Definitions

- Immunology
- Immune system – protects animal body from infection by pathogens or antigens
- Immunity – immune reaction that helps fight pathogens & antigens
- Immunization – animal develops specific immunity to a particular pathogen or antigen
  - Natural or artificial
“Invader” Definitions

- **Pathogens** – disease-causing organisms
  - Viruses
  - Bacteria
  - Parasites, Fungi?

- **Antigens** – foreign proteins
  - From pathogens
  - From anything protein
  - From “self” (Autoimmune diseases)
Immune System Functions

- Protect animal from **pathogens**
- Recognize **antigens** that threaten health of animal
- Deals with
  - Infectious disease control and prevention
  - Cancer
  - Allergies
Types of Immunity

Innate Immunity

Non-innate (Acquired) Immunity
Body Lines of Defense

First Line of Defense (Innate – Barriers)
Second Line of Defense (Innate – Phagocytes)
Third Line of Defense (Acquired – Specific Immune Response)
Lines of Defense in Animal’s Body

- **1st line of defense** – skin & mucosa, etc.
- **2nd line of defense** – neutrophils & macrophages (inflammatory response)
- **3rd line of defense** – lymphocytes (immune response)
3 Lines of Defense

- Physical barriers
- Innate immunity
- Acquired immunity

Time: Minutes, Hours, Days, Time

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Topic 21

Compare specific and nonspecific immune reactions
Nonspecific Immunity – Innate

- **First Line of Defense**
  - Mechanical **barriers** – skin and mucous membranes
  - Chemical barriers (e.g., hydrochloric acid in the gastric mucosa)

- **Second Line of Defense**
  - **Inflammatory** response – tissue damage provokes release of chemical mediators (e.g., histamine) Phagocytosis by neutrophils, monocytes and tissue macrophages
Specific Immunity – Acquired

• **Third Line of Defense**
  - B lymphocytes that produce antibodies or direct other cells to attack the antigen
  - T lymphocytes that attack more directly
Lines of Defense in Animal’s Body

- 1\textsuperscript{st} line of defense – skin & mucosa, etc.
- 2\textsuperscript{nd} line of defense – neutrophils & macrophages (	extit{inflammatory response})
- 3\textsuperscript{rd} line of defense – lymphocytes (	extit{immune response})
3 Lines of Defense
1\textsuperscript{st} Line of Defense – Physical Barriers

- **Skin** is most visible barrier
- Covers majority of surfaces in obvious contact with environment
- **Mucous membranes** barrier that lines digestive tract, respiratory tract and genitourinary tract
  - Mucous protest these surfaces from infections
Antimicrobial factors in saliva (lysozyme, peroxidase, lactoferrin)

Lysozyme in tears and other secretions and in phagocytes

Removal of inhaled particles

Normal flora

Mucus, cilia

Skin—physical barrier, fatty acids, sweat, normal flora

Acid in stomach (low pH)

Normal flora

Rapid pH change from stomach to upper intestine

pH and normal flora of vagina

Flushing of urinary tract
2nd Line of Defense—Phagocytes (Inflammatory Response)

- Neutrophils
- Macrophages
(a) Normal blood flow in the tissues as injury occurs
• Microbial products
• Microbes
• Tissue damage

(b) Substances released cause dilation of small blood vessels and increased blood flow in the immediate area.
Neutrophil Characteristics

- In peripheral circulation for about 10 hours
- Part of 2nd Line of Defense in animal body
- **Diapedesis** – process used by neutrophils to go from circulation into tissue spaces
- **Chemotaxis** – process that attracts neutrophils to inflammatory chemicals at a site of infection
Neutrophil Diapedesis
Figure 9-5, Page 234

Figure 9-5 Diapedesis. 1, Neutrophil lying against vessel wall begins to squeeze through the space between endothelial cells by flowing into pseudopod (false foot). 2, Pseudopod continues to push its way between cells. Rest of the cell cytoplasm flows along with it. 3, Pseudopod and the rest of the cell emerge on tissue side of blood vessel. 4, Neutrophil is off in search of foreign invaders to phagocytize.
(d) The attraction of phagocytes causes them to move to the site of damage and inflammation. Collections of dead phagocytes and tissue debris make up the pus often found at sites of an active inflammatory response.
Figure 9-6  **Phagocytosis and destruction of microorganisms.**  
1. Neutrophil membrane engulfs microorganisms.  
2. Phagocytic vacuole is formed.  
3. Cytoplasmic granules (lysosomes) line up around phagocytic vacuole and empty their digestive enzymes into vacuole.  
4. Microorganisms are destroyed.
Macrophage Attacking *E. coli*
3rd Line of Defense – Lymphocytes

Acquired Immunity

B-Lymphocytes

T-Lymphocytes
Topic 22

Compare cell-mediated and humoral (antibody) immunity
3rd Line of Defense – Lymphocytes
Acquired Immunity

B-Lymphocytes
T-Lymphocytes
Immune System You Tubes!

http://www.youtube.com/watch?v=4kNsYa2oEJU&NR=1
The Immune Response (AWESOME!)

http://www.youtube.com/watch?v=cL9KY_ECzfo&feature=related
Pathogen Recognition

http://www.youtube.com/watch?v=lrYlZJiuf18&NR=1
Antibody Immune Response

http://www.youtube.com/watch?v=1tBOmGoQMbA&feature=related
Cell Mediated Immune (CMI) Response
Lymphocyte Characteristics

• 2 types
  ▪ B-lymphocytes – antibody formation
  ▪ T-lymphocytes – “killer” cells
• Part of 3rd Line of Defense in animal body
• Memory cells
Types of Acquired Immunity

Cell Mediated Immunity (CMI)
Humoral Immunity (Antibodies)
Cell Mediated Immunity (CMI)

**T-lymphocytes**
- Circulate in blood and lymph
- Attach to antigen or foreign cells
- Attack and destroy foreign cells and diseased host cells

**Memory cells**
- Delayed hypersensitivity
Examples of Cell Mediated Immunity

- TB testing
- Allergy testing
Humoral Immunity (Antibodies)

- **B-lymphocytes** transform into **plasma cells**
  - Produce antibodies (**immunoglobulins**) to specific antigens
  - Stay in lymphocytes, send antibodies into bloodstream
- **Memory cells**
- Immediate hypersensitivity
Antigens and Antibodies

Figure 9-7, Page 238

Figure 9-7 *Antigens and antibodies.* Every antigen has a uniquely shaped epitope on its cell membrane that will fit into a combining shape on an antibody.
Types of Antibodies
Immunoglobulins (Ig)

- IgM - first Ig made during first exposure to an antigen
- IgG - made when animal exposed to an antigen for a long time or when exposed to the antigen for the second time; can cross the placenta
- IgA - can leave blood and enter tissue fluids; plays a role in protecting mucosal surfaces (e.g., intestinal tract and lungs)
- IgE - associated with an allergic response
- IgD - function is unknown
Examples of Humoral Immunity

• Vaccines
• Tetanus Toxoid injections
# Humoral versus CMI

**Table 9-3, Page 243**

<table>
<thead>
<tr>
<th></th>
<th>Humoral Immune Response</th>
<th>Cell-Mediated Immune Response</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cell type involved</strong></td>
<td>B cell that transforms into a plasma cell after antigenic stimulation</td>
<td>T lymphocyte that transforms into cytotoxic T cell, helper T cell or suppressor T cell after antigenic stimulation</td>
</tr>
<tr>
<td><strong>Substance produced</strong></td>
<td>Immunoglobulins (antibodies)</td>
<td>Lymphokines</td>
</tr>
<tr>
<td><strong>Cellular mobility</strong></td>
<td>B cells and plasma cells stay in the lymphoid tissue. Antibodies are released into plasma.</td>
<td>T cells can enter circulation and travel to the site where an antigen entered the body</td>
</tr>
<tr>
<td><strong>Memory cells produced?</strong></td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Humoral versus CMI Immunity
Figure 9-12, Page 244
Differentiate between acquired active and passive immunity
Types of Antibodies
Immunoglobulins (Ig)

- IgM – first Ig made during *first exposure* to an antigen
- IgG – made when animal exposed to an antigen for a long time or when *exposed to the antigen for the second time*; can cross the placenta
- IgA – can leave blood and enter tissue fluids; plays a role in protecting *mucosal surfaces* (e.g., intestinal tract and lungs)
- IgE – associated with an *allergic response*
- IgD – function is unknown
Passive Immunity – Temporary Immunity

• **Animal receives preformed antibodies**
  - Antibodies produced by a mother that are passed to a fetus transplacentally
  - Ingestion of **colostrum** (antibody-rich first milk produced)
  - Antibodies produced by another animal and given to a sick animal (e.g., administration of tetanus antitoxin)

• **No memory cells produced**
Active Immunity – Permanent Immunity

- **Exposure to antigen that triggers animal’s own immune response**
- **Memory T or B cells are produced**
- **Immunization** – activate animal’s own immune systems
  - Vaccines contain epitope of the antigens
  - Killed or live-but-weakened (attenuated) antigens
The Big Picture of This! 😊

- **Acquired immunity**
  - Naturally acquired
    - **Active**
      - Antigens enter the body naturally; body produces antibodies and specialized lymphocytes
    - **Passive**
      - Antibodies pass from mother to fetus via placenta or to infant in the mother’s milk
  - Artificially acquired
    - **Active**
      - Antigens are introduced in vaccines; body produces antibodies and specialized lymphocytes
    - **Passive**
      - Preformed antibodies in immune serum introduced into body by injection

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Types of Immunity

Active (Developed)
Passive ("Borrowed")
**Principles of Immunity**

<table>
<thead>
<tr>
<th>Natural</th>
<th>Active</th>
<th>Passive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural immunity is acquisition of adaptive immunity through natural events</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deliberate exposure to antigen induces an immune response; immunization of children.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transfer of antibodies or cells produced by others; temporary immunity from antibodies of the mother transferred to infant across the placenta or in milk.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Artificial</th>
<th>Active</th>
<th>Passive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antibodies in immune serum are introduced into body; injection of rabies immune globulin after a dog bite.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Naturally acquired immunity is acquisition of adaptive immunity through natural events.
- Immunization mimics these events by inducing artificially acquired immunity.
- Natural or artificial immunity can be divided into:
  - Active immunity
  - Passive immunity
<table>
<thead>
<tr>
<th>Natural Exposure</th>
<th>Passive Exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active</td>
<td>Passive</td>
</tr>
<tr>
<td>Natural</td>
<td>Artificial</td>
</tr>
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<td>Natural exposure to antigen induces an immune response; immunity following an attack of measles.</td>
<td>Transfer of antibodies or cells produced by others; temporary immunity from antibodies of the mother transferred to infant across the placenta or in milk.</td>
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<td>Deliberate exposure to antigen induces an immune response; immunization of children.</td>
<td>Antibodies in immune serum are introduced into body; injection of rabies immune globulin after a dog bite.</td>
</tr>
</tbody>
</table>
Active Immunity

- Antibodies made by animal
  *(Secret of Life!!– Get Tough or Die!!)*
- Long-acting
- Memory cells
- Examples
  - Disease itself
  - Vaccines
  - Tetanus toxoid
### Active Immunity

- Result from immune response upon exposure to an antigen
- Active immunity can develop **naturally**
  - Following **illness**
- Or **artificially**
  - After **immunization**

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</tbody>
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Passive Immunity

- Antibodies “borrowed” from another source (preformed in another animal)
- **Young** animals
- Short-acting, used up quickly
- No “memory cells”
- Examples
  - Maternal antibodies *(colostrum)*
  - Tetanus antitoxin (TAT)
Passive Immunity

- Occurs naturally during pregnancy
- Occurs naturally as result of breast feeding (colostrum)
- Artificial passive immunity involves transfer of antibodies produced by another person or animal
  - TAT
  - Pasteur Rabies Treatment

Transfer of antibodies or cells produced by others; temporary immunity from antibodies of the mother transferred to infant across the placenta or in milk.

Antibodies in immune serum are introduced into body; injection of rabies immune globulin after a dog bite.
Active vs. Passive Immunity

Tetanus toxoid

Immune horse serum (tetanus immune globulin)

Immunized horse

Unprotected horse

Protected horse
Examples of Artificial Active Immunity

- Vaccines
- Bacterins

"Have you heard about our new polyvalent vaccine that immunizes against everything?"
Creating Immunity in Animal

- **Biological** – product of a living organism that produces immunity in an animal
  - Vaccines – viruses
  - Bacterins – bacteria
    - Immunity not as strong
    - Tissue reactions? (“Vaccine reactions”?)
- **Immunization** – giving of a biological to produce immunity
Fundamentals of Immunization

- Vaccine **series** for young animals
- Core “Booster vaccines” & annual health exam
- Give entire vaccine, regardless of animal size
- Expiration dates, refrigeration
- New sterile needle and syringe
- Do not use products in wrong species
2 Types of Antibodies
Immunoglobulins (Ig)

- **IgM** – made during first exposure to antigen
  - Primary response
  - Slow production
- **IgG** – made during second exposure to antigen
  - Most common immunoglobulin
  - Secondary (“booster”) response
  - Production more rapid than IgM
  - Can cross the **placenta**
Primary & Secondary Response

The graph illustrates the antibody titer over days following two exposures. The primary response shows a lower peak in antibody titer compared to the secondary response, which peaks higher after a second exposure. The antibodies IgM and IgG are indicated, with IgG having a higher titer peak than IgM in the secondary response.
"A BOOSTER SHOT"...what does that mean? When an animal or human is vaccinated they generally will develop a response to the vaccine by increasing their level of protective defense immunity. This level may be high, low, or none. Usually there is a measurable response indicating some protection. If a second vaccine for the same disease is given at a later time...this second vaccine will BOOST the protective levels of immunity that were induced by the first vaccine. So, whether the vaccine is for Rabies or Parvovirus or Feline Leukemia, it might be called a "BOOSTER SHOT" if it is given sometime after an original vaccination.
Superheroes in a Syringe: How Vaccines Work


A behind-the-scenes look at how your horse’s immune system is best primed for battle.

If you weren’t felled by polio, your children missed the measles, your barn dodged a flu outbreak, and you’ve never seen a horse tormented by tetanus, you probably can thank

Work with your veterinarian to decide what vaccinations your horse needs, as well as when and how often to vaccinate.

Related Content

Equine Influenza
Most animals produce an adequate immune response

- These few animals produce a poor immune response and so will be poorly protected
- These few animals produce a superior immune response and so will be well protected
Canine Core Vaccines – AAHA

- Canine distemper
- Canine hepatitis (adeno-virus 2)
  - Cross immunization
- Parvo virus
- Rabies (zoonosis)
2011 AAHA Canine Vaccination Guidelines
Published in 2011 (Sep/Oct)

Since the last time the American Animal Hospital Association’s (AAHA) Canine Vaccination Guidelines were revised in 2006, new vaccines have been licensed, others have been withdrawn, and new information has led to the revision of previous recommendations. The 2011 AAHA Canine Vaccination Guidelines offer a comprehensive review of canine vaccines currently available in North America, updated recommendations for core versus non-core vaccines, and revised recommendations for shelter-housed dogs.

Developed in a manner consistent with best vaccination practices, the 2011 Guidelines include expert opinions supported by scientific study, published and unpublished documents, and encompass all canine vaccines currently licensed in the U.S. and Canada. The task force that developed the guidelines included experts in immunology, infectious diseases, internal medicine, law, and clinical practice.

To help address common questions heard by members of the task force about canine vaccination issues asked by practicing veterinarians, a Frequently Asked Questions (FAQs) section was added to the Guidelines. Since scientific studies and referred journal publications are not available to support all of the vaccination recommendations included within the FAQ section, some answers are based on unpublished studies, current knowledge of immunology, and the experiences of experts in the field.

Also new to this edition:

- Updated recommendations on serologic testing
- Expanded discussion on vaccine adverse events
- Review of the legal implications associated with administering vaccines in clinical practice
- Full consideration of both U.S. and Canadian canine vaccination regulations

To view the 2011 AAHA Canine Vaccine Guidelines, please click here.
Core Vaccines – Cats (FVRCP)

- Feline Distemper (Panleukopenia)
- Feline Viral Rhinotracheitis (FVR)
- Feline Calici Virus
- Rabies
## American Association of Feline Practitioners 2006 Feline Vaccination Guidelines. Summary: Vaccination in General Practice

<table>
<thead>
<tr>
<th>Vaccine</th>
<th>Primary Series-Kittens (≤ 16 weeks)</th>
<th>Primary Series-Adolescent/Adult (≥ 16 weeks)</th>
<th>Booster</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panleukopenia Virus (FPV) /Feline Herpesvirus-1 and Feline Calicivirus (FHV-1/FCV) Injectable:</td>
<td>Begin as early as 6 weeks of age, then every 3-4 weeks until 16 weeks of age.</td>
<td>2 doses, 3 to 4 weeks apart</td>
<td>A single dose is given 1 year following the last dose of the initial series, then no more frequently than every 3 years.</td>
<td>Core:</td>
</tr>
<tr>
<td>- MLV, non-adjuvanted</td>
<td></td>
<td></td>
<td></td>
<td>- Killed vaccines are preferred for use in pregnant cats (and only if absolutely necessary) and in FeLV and/or FIV infected cats, especially those showing evidence of immunosuppression.</td>
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<tr>
<td>- Killed, adjuvanted</td>
<td></td>
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<td>- Killed panleukopenia vaccines should be used in kittens less than 4 weeks of age.</td>
</tr>
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<td>- Killed, non-adjuvanted</td>
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<td></td>
<td>- All kittens and cats should receive at least one injectable panleukopenia injection.</td>
</tr>
<tr>
<td>Intranasal</td>
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<td></td>
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<td></td>
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<td>- MLV, non-adjuvanted</td>
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<td></td>
</tr>
<tr>
<td>Rabies&lt;sup&gt;6&lt;/sup&gt; Injectable:</td>
<td></td>
<td></td>
<td></td>
<td>Core:</td>
</tr>
<tr>
<td>- Canarypox virus-vectored recombinant (rRabies), non-adjuvanted</td>
<td>Administer a single dose as early as 8 or 12 weeks of age depending on the product label. Revaccinate 1 year later.</td>
<td>Administer 2 doses, 12 months apart.</td>
<td>Annual booster is required. Vs. Every 3 years or as required by State or local ordinance for 3-year</td>
<td>- In States and municipalities where feline rabies vaccination is required, veterinarians must follow applicable statutes.</td>
</tr>
<tr>
<td>- 1-year killed, adjuvanted</td>
<td></td>
<td></td>
<td></td>
<td>- Booster vaccination with a 1-year rabies vaccine is only appropriate in States and municipalities where permitted by law.</td>
</tr>
<tr>
<td>- 3-Year killed, adjuvanted</td>
<td></td>
<td></td>
<td></td>
<td>- Any rabies vaccine can be used for revaccination, even if the product is not the same brand or type of product previously administered.</td>
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<sup>1</sup> Killed vaccines are preferred for use in pregnant cats (and only if absolutely necessary) and in FeLV and/or FIV infected cats, especially those showing evidence of immunosuppression.

<sup>2</sup> Killed panleukopenia vaccines should be used in kittens less than 4 weeks of age.

<sup>3</sup> All kittens and cats should receive at least one injectable panleukopenia injection.

<sup>4</sup> In States and municipalities where feline rabies vaccination is required, veterinarians must follow applicable statutes.

<sup>5</sup> Booster vaccination with a 1-year rabies vaccine is only appropriate in States and municipalities where permitted by law.

<sup>6</sup> Any rabies vaccine can be used for revaccination, even if the product is not the same brand or type of product previously administered.

<sup>7</sup> No laboratory or epidemiologic data exist to support the annual or biennial administration of 3-year vaccines following the initial series.
What About Rabies?

• **Zoonosis!!!**
• Fatal disease
• Wildlife
  - Bats
  - Skunks
  - Raccoons
• Percentage of dogs & cats vaccinated
Rabies in the U.S.

Public Health Importance of Rabies

Over the last 100 years, rabies in the United States has changed dramatically. More than 90% of all animal cases reported annually to CDC now occur in wildlife; before 1960 the majority were in domestic animals. The principal rabies hosts today are wild carnivores and bats.

The number of rabies-related human deaths in the United States has declined from more than 100 annually at the turn of the century to one or two per year in the 1990's. Modern day prophylaxis has proven nearly 100% successful.

In the United States, human fatalities associated with rabies occur in people who fail to seek medical assistance, usually because they were unaware of their exposure.
Wild animals accounted for 92% of reported cases of rabies in 2010. Raccoons continued to be the most frequently reported rabid wildlife species (36.5% of all animal cases during 2010), followed by skunks (23.5%), bats (23.2%), foxes (7.0%), and other wild animals, including rodents and lagomorphs (1.8%). Reported cases decreased among all wild animals during 2010.

Outbreaks of rabies infections in terrestrial mammals like raccoons, skunks, foxes, and coyotes are found in broad geographic regions across the United States. Geographic boundaries of currently recognized reservoirs for rabies in terrestrial mammals are shown on the map below:
Rabid Cats and Dogs Reported in the United States during 2010

Map of rabid dogs and cats reported in the United States during 2010.
Wellness Plan for Pets

• Nutrition
• Vaccinations
• Parasite control
• Surgical neutering
• Behavior counseling
Test Yourself
KNOW THESE IN EVERY CHAPTER!

Pages 225, 229, 230, 231, 239, 242, 246
Clinical Applications

GREAT Clinical Applications to Review

- Postprandial Lipemia (Page 222)
- Blood Volume (Page 225)
- Blood Glucose & RBC Metabolism (Page 227)
- Jaundice/Icterus (Page 228)
- Venipuncture & Platelets (Page 250)
- Total WBC Count & Differential Count (Page 252)
- Leukemia (Page 252)
- Swollen Lymph Nodes (Page 241)
- Autoimmune Diseases (Page 242)