Chapter 1, The Blood

Textbook Chapter: _________

* Blood belongs to the connective tissue category.

A. FUNCTIONS

1. Transportation

   a. Primary means of transportation for oxygen, carbon dioxide, nutrients, electrolytes, waste, hormones, and others.

   b. Many of substances necessary for maintenance and protection must travel in blood.

2. Regulation

   a. Homeostasis is the steady state that must be maintained.

   b. Buffers are any substance that resist a change in the pH (normal blood pH is 7.35 to 7.45).

      1.) blood pH is monitored and kept in homeostasis by the lungs and kidneys

      2.) summary (discussed later in semester)

          a.) lungs - use CO₂ elimination to control the blood's carbonic acid.

          b.) kidneys - use bicarbonate retention (via blood pH).

   c. Maintains normal fluid and electrolyte balance.

   d. Regulates body temperature.

   e. Tissue maintenance.

3. Protection

   a. Immune system protects against foreign substances: microorganisms and toxins.

   b. Blood clotting mechanism provides protection against blood loss.
B. Characteristics of Blood

1. Heavier, thicker and more viscous than water.

2. Temperature of blood is about 38°C (100.4°F).

3. The pH is slightly alkaline about (7.35-7.45).


5. **BLOOD VOLUME**
   
a. **MALE**: 5-6 liters (11-12(+)) pints or about 1.5 gallons.
   
b. **FEMALE**: 4-5 liters (9-10(+)) pints or about 1.2 gallons.

C. Organization of Blood

1. Two portions of blood:
   
a. 55% of blood is **plasma**, a watery liquid containing dissolved substances.
   
b. 45% of blood is **formed elements**, which are cells and cell fragments.

2. **Plasma** - 55% of whole blood
   
a. Straw-colored liquid portion.
   
b. 91.5% - 92% of plasma is **WATER**, 7% - 9% are **PROTEINS**, and 1% (+) **SOLUTES** (major solute in concentration is Na+).
      
      1.) **Plasma Proteins**
         
a.) Most are produced by liver.
         
b.) **Albumins** represent 54%-60% of plasma proteins; function in a **colloid manner** - (draws water into the blood to help control the blood volume).
         
c.) **Globulins** represent 36%-38% of proteins.
            
            (1.) **ALPHA GLOBULINS** - transport fat (lipoproteins) and the fat soluble vitamins (A, D, E, & K).
            
            (2.) **BETA GLOBULINS** - transport fat (lipoproteins) and the fat soluble vitamins (A, D, E, and K).
            
            (3.) **Gamma Globulins** - antibodies
d.) **Fibrinogen** represents 4%-7% of proteins. *Important clotting factor*

e.) **Other solutes:** urea, uric acid, creatinine, ammonia, and bilirubin. Also nutrients, vitamins, and regulatory substances: enzymes, hormones, gases and electrolytes.

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**SERUM**

* plasma minus fibrinogen (yellowish in color)
* contain serum antibodies

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3. **WHOLE BLOOD CENTRIFUGED:**

<table>
<thead>
<tr>
<th>PLASMA</th>
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<tbody>
<tr>
<td>1. 55% of whole blood</td>
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<tr>
<td>2. STRAW-COLORED TO CLEAR COLORED</td>
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<tr>
<td>3. CONTAINS: Plasma Antibodies 98% H₂O, 7% PROTEIN, WASTE, etc..</td>
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| BUFFY COAT (WBC and Platelets) |

<table>
<thead>
<tr>
<th>FORMED ELEMENTS</th>
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<tr>
<td>1. 45% of whole blood</td>
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<td>2. Mainly RBCs</td>
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4. **Formed Elements** - 45% of whole blood

a.) **Erythrocytes** (Red Blood Cells)

b.) **Leukocytes** (White Blood Cells)

1.) **Granular leukocytes** (granulocytes)

   a.) Neutrophils
   b.) Eosinophils
   c.) Basophils
2.) **Agranular leukocytes (agranulocytes)**
   a.) **Lymphocytes** (2 types)
      (1.) T cells (T lymphocytes)
      (2.) B cells (B lymphocytes)
   b.) **Monocytes**
   c. **Thrombocytes (platelets)**

**D. Production of Formed Elements**

1. **Hemopoiesis** or **hematopoiesis** is the process by which blood cells are formed.
   a. **Embryonic sites:** yolk sac, liver, spleen, thymus gland, lymph nodes and bone marrow.
   b. **After birth site:** red bone marrow (myeloid tissue).
   c. **Red bone marrow** is found in spongy bone chambers such as the proximal epiphyses of the **humerus** and **femur**; flat bones (such as the **sternum**, **ribs**, and **cranial bones**), the **vertebrae**, and the **pelvis**.

2. **Hemocytoblasts** or **Pluripotent hematopoietic stem cells** come in five types:
   a. **Proerythroblasts** give rise to RBC's.
   b. **Myeloblasts** give rise to neutrophils, eosinophils
   c. **Monoblasts** give rise to monocytes.
   d. **Lymphoblasts** give rise to lymphocytes.
   e. **Megakaryoblasts** give rise to thrombocytes.

3. **Erythropoietin** (or **EPO**) is a hormone produced mainly by the kidneys and in small amounts by the liver, and stimulates proliferation of erythrocytes precursors.

4. **Thrombopoietin** stimulates formation of thrombocytes (platelets).

5. **Cytokines**
   a. They are small glycoproteins produced by red bone marrow cells, leukocytes, macrophages, and fibroblasts.
   b. Regulate hematopoiesis of different blood cell types.
E. Erythrocytes (Red Blood Cells)

* Erythropoiesis - the production of RBCs.

1. 99% of formed elements in blood are erythrocytes.

2. They contain hemoglobin, which is responsible for the red color of whole blood.

3. **RBC Structure**
   a. RBCs appear as biconcave discs averaging about 8 microns in diameter.
   b. Mature red blood cells lack a nucleus and other organelles.
   c. They cannot reproduce or carry on extensive metabolic activities.
   d. **Hemoglobin** is enclosed within the plasma membrane and represents 33% of cell weight.

   e. **Hemoglobin (normal values)**
      1.) infants: 14 - 20 gms./100 ml. blood
      2.) females: 12 - 15/16 gms./100 ml. blood
      3.) males: 13 - 18 gms./100 ml. blood

4. **RBC Function**
   a. **Oxyhemoglobin** is a combination of oxygen and hemoglobin formed in the lungs.
   b. **Deoxyhemoglobin (reduced hemoglobin)** – hemoglobin in which oxygen has been released to the tissues from oxyhemoglobin.
   c. **Globin** is a protein in hemoglobin composed of four polypeptide chains [two called alpha and two called beta], plus four nonprotein pigments called **hemes**.
   d. Each heme contains an iron ion (Fe$^{2+}$) that can combine reversibly with one oxygen molecule.
   e. Oxygen is transported in this state to other tissues; in the tissue, the iron-oxygen reaction reverses and oxygen is released.
   f. Each RBC has 280 million hemoglobin molecules.
   g. Because RBCs have no nucleus, lack mitochondria, and generate ATP anaerobically, they do not consume any of the oxygen that they transport.
h. The biconcaved shape has a greater surface area which:

1.) allows for the diffusion of gas molecules into or out of RBCs.
2.) is very flexible and allows RBCs to squeeze through narrow capillaries.

i. **Buffer** may be defined as anything that will resist

   An example of a buffer reaction associated with the blood (occurs in the Plasma of the blood):

   \[
   \begin{align*}
   \text{H}_2\text{O} & \quad + \quad \text{CO}_2 & \quad \rightarrow & \quad \text{H}_2\text{CO}_3 & \quad + & \quad \text{NaOH} & \quad \rightarrow & \quad \text{H}_2\text{O} & \quad + & \quad \text{NaHCO}_3 \\
   \text{(Water)} & \quad \text{(Carbon Dioxide)} & \quad \text{(Carbonic Acid)} & \quad \text{(Sodium Hydroxide)} & \quad \text{(Water)} & \quad \text{(Sodium Bicarbonate)} & \quad \text{(Lye)}
   \end{align*}
   \]

j. **Sickle-cell anemia (SCA)** is due to a genetic defect that results in substitution of just one amino acids (out of 574 amino acids) in hemoglobin (position #6: valine instead of glutamic acid).

k. Hemoglobin transports **about 23%** of the total carbon dioxide; it may combine with amino acids in the globin to form **carbaminohemoglobin**.

l. **Induced erythrocythemia (Blood Doping)**

1.) Technique used by some athletes.
2.) Red blood cells are removed from the body, stored for a month and then reinjected a few days before an athletic event.
3.) May increase endurance but may also overwork the heart.

5. **RBC Characteristics**

   a. Red blood cells live about 120 days in circulation.

   b. Because of the lack of a nucleus and other organelles, RBCs cannot synthesize new components to replace damaged ones.

   c. As the plasma membrane becomes more fragile with age, it is more likely to burst.

   d. Worn-out red blood cells are removed from circulation and destroyed by fixed phagocytic macrophages in the **spleen** and **liver**.
e. **MALES** have about 5.4 million red blood cells per cubic millimeter (mm³) of blood, and **FEMALES** have about 4.8 million. [There are about 50 mm³ in a drop of blood].

f. 30 trillion RBCs in circulation.

g. The higher value in males is due to testosterone (which stimulates erythropoietin).

h. Hemoglobin is recycled as the globin portion is split from the heme and broken down into amino acids that may be reused for protein synthesis.

i. The **heme portion** is broken down into:
   1.) **iron**, which associates with proteins to form **ferritin** or **hemosiderin**.
   2.) **bilirubin**, a pigment that does not contain iron.

j. **Ferritin** and **hemosiderin** are storage forms of iron found mostly in muscle fibers, liver cells, and macrophages of the spleen and liver.

k. Upon release from a storage site or absorption from gastrointestinal tract, iron attaches to a plasma beta globulin called **transferrin**.

l. Transferrin is used to make new hemoglobin.

m. The **non-iron portion of heme** is converted into **biliverdin**, (a greenish pigment), and then into **bilirubin** (an orange pigment).

n. Bilirubin enters the blood, secreted by the liver cells into the bile; bile passes from the liver into the small intestine and exits with the feces.

o. Bacteria (in large intestine) converts bilirubin into **ubrobilinogen**.

p. Some urobilinogen is absorbed back into the blood, converted to **urobilin** (yellow), and excreted in urine. However, most urobilinogen is eliminated in feces in the form of a brown pigment called **stercobilin**.

q. **Physiologic jaundice** (often seen in premature newborn’s); due to an immature liver.

6. **Production of RBCs**

   a. **Erythropoiesis** is the process of erythrocyte formation.
   b. **Proerythroblast (rubriblast)** gives rise to an early **erythroblast** (prorubricyte).
c. **Erythroblast (prorubricyte)** develop into an intermediate erythroblast (rubricyte) which will synthesize hemoglobin.

d. **Intermediate erythroblast (rubricyte)** develops into a late erythroblast (metarubricyte), in which hemoglobin synthesis is at a maximum.

e. The last erythroblast ejects its nucleus [allows the center of the cell to indent] and becomes a reticulocyte.

f. Reticulocytes pass from bone marrow into the bloodstream and develop into erythrocytes within one to two days.

g. Normally, erythropoiesis and red blood cell destruction proceed at the same pace.

h. If oxygen capacity of the blood falls, a negative feedback system steps up erythrocyte production

7. **Red Blood Cell Deficiency**

   a. **Anemia** (a lower than normal number of RBCs or quantity of hemoglobin) may cause an oxygen deficiency.

      1.) **Anemia**

         a.) **Causes**

         (1.) lack of iron.
         (2.) lack of certain amino acids.
         (3.) lack of vitamin B₁₂.

         b.) **Iron** is needed for the heme part of hemoglobin.

         c.) **Amino acids** are needed for the protein or globin.

         d.) **Vitamin B₁₂** helps the red bone marrow to produce erythrocytes but must be obtained from eating meat and one must have the **intrinsic factor (IF)** (from the stomach's mucosa).

      2.) **Parietal cells** of the stomach's mucosa produce a chemical substance known as **intrinsic factor**. Without this factor, **vit. B₁₂ cannot** be absorbed by the intestinal cells.

b. **Hypoxia** is cellular oxygen deficiency and may occur if not enough oxygen enters the blood (ie. not breathing in enough oxygen).
c. **Erythropoietin** is released by kidneys in response to hypoxia and speeds up the development of proerythroblasts into reticulocytes.

d. **Anisocytosis** - abnormal variation in size of RBC.

e. **Poikilocytosis** - abnormal variation in RBC shape.

8. **Reticulocyte Count ("Retic" Count)** is the measurement of the rate of erythropoiesis.

   a. Reticulocytes take one to two days to mature and account for about .5 to 1.5% of all RBCs

   b. **Hematocrit (or Hct)** - the percentage of red blood cells in blood.
       1.) Test is used to diagnose anemia and polycythemia.
       2.) **Females** average about 38 to 46% and **males** average about 40 to 54%.

F. **LEUKOCYTES (White Blood Cells or WBCs)**

1. **WBC Characteristics**

   a. WBCs, especially lymphocytes, can live for several months or years, but most live only a few days.

   b. During a period of infection, phagocytic WBCs may live only a few hours.

   c. WBCs average from 5,000 to 10,000 cells per cubic millimeter (mm³) of blood.

   d. **Leukocytosis** refers to an increase in the number of WBCs.

   e. **Leukopenia** is an abnormally low number of white blood cells (below 5,000/mm³).

2. **WBC FUNCTIONS**

   a. Once pathogens enter the body, the general function of white blood cells is to combat them by phagocytosis or immune responses.

   b. Neutrophils and macrophages are active in phagocytosis: they can ingest bacteria and dispose of dead matter.
c. **Chemotaxis** - inflamed tissue releases chemicals that may attract phagocytes toward the tissue.

d. **Diapedesis** *(or emigration)* is the ability to squeeze through the minute spaces between the cells that form the walls of capillaries and through connective and epithelial tissues.

3. **WBC Structure**

   a. **Leukocytes** have a nucleus and do not contain hemoglobin.

   b. WBCs are divided into **GRANULAR WBCS** and **NONGRANULAR WBCS**.

   c. **GRANULAR LEUKOCYTES** *(GRANULOCYTES)* have lobed nuclei and conspicuous granules in the cytoplasm.

      1.) **Neutrophils**

         a.) Nuclei has two to six lobes.

         b.) More lobulation occurs with age.

         c.) Older cells may be called **polymorphonuclear leukocytes** *(PMNs), polymorphs* or "polys".

         d.) Younger neutrophils are often called **bands** because of a rod-shaped nucleus.

         e.) Cytoplasm stains a pale lilac color with pink granules.

      f.) **Neutrophil Functions**

         (1.) After engulfing a pathogen during phagocytosis, a neutrophil releases several destructive chemicals.

            (a.) **Lysozyme** destroys certain bacteria.

            (b.) **Strong oxidants** also destroys bacteria.

            (c.) **Defensins** are proteins that exhibit a broad range of antibiotic activity against bacteria, fungi, and viruses. **Defensins** form peptide spears that poke holes in microbe membranes.
(2.) Live in the blood, skin (dermis), and mucosa of the pulmonary and the respiratory systems.

(3.) **A high neutrophil count** might result from bacterial infections, burns, stress, or inflammation. **A low neutrophil count** might be caused by radiation, certain drugs, vitamin B₁₂ deficiency, or systemic lupus erythematosus.

2.) **Eosinophils**

   a.) Nucleus is irregular in shape; and has 2 lobes.

   b.) Large, uniform-sized granules pack the cytoplasm but usually do not cover the nucleus.

   c.) The granules stain red-orange.

   d.) **Eosinophil Functions**

      (1.) Its granules are lysosomes.

      (2.) Eosinophils leave the capillaries and enter tissue fluid. They are believed to release enzymes, such as histaminase, that combat the effects of histamine and other mediators of inflammation in allergic reactions (that is, it inactivates some chemicals associated with allergic reactions).

      (3.) Thus, eosinophils phagocytize antigen-antibody complexes and are effective against parasitic worms.

      (4.) Some of its enzymes help break apart clots.

      (5.) **A high eosinophil count** could indicate allergic reactions, parasitic infections, autoimmune disease, or adrenal insufficiency. **A low eosinophil count** could be caused by certain drugs, stress, or Cushing's syndrome.
3.) **Basophils**

a.) The cytoplasmic granules are round, variable in size, stain blue-black, and commonly obscure the nucleus.

b.) Nucleus has an "S shaped" lobe.

c.) **Basophil Functions**

(1.) **Basophils** are involved in inflammatory reactions, and they enter tissues where they develop into **mast cells**. These can liberate heparin (anticoagulant), histamine (a vasodilator), and serotonin. They intensify the inflammatory response, and are involved in hypersensitivity.

(2.) Their numbers can increase with stress and allergies

(3.) Basophil binding with IgE (a blood antibody):

```
IgE    Histamine
Sensitivity >-----------< &
              Others
```

(4.) **Basophils could be elevated** in some types of allergic responses, some types of leukemia, cancers, and hypothyroidism. **Decreases in basophils** could occur during pregnancy, ovulation, stress, and hyperthyroidism.

d. **AGRANULAR LEUKOCYTES (AGRANULOCYTES)**

1.) No cytoplasmic granules can be seen with a light microscope.

2.) Granules are absent or very small and have poor staining qualities.
3.) **TYPES OF A GRANULAR WBCS:**

a.) **Lymphocyte**

   (1.) The nucleus is darkly stained and round.

   (2.) The cytoplasm stains sky blue and forms a rim around the nucleus.

   (3.) Functions will be explained in the **IMMUNITY** notes.

b.) **Monocyte**

   (1.) The nucleus is usually indented or kidney-shaped, and the cytoplasm has a foamy appearance.

   (2.) **They migrate into tissues, enlarge, and differentiate into MACROPHAGES.**

   (3.) **Fixed macrophages** reside in a particular tissue: alveolar macrophages, spleen macrophages, or stellate reticuloendothelial (Kupffer) cells in the liver. Others are **wandering (free) macrophages,** which roam the tissues and gather at sites of infection or inflammation.

   (4.) **Monocyte Functions**

   (a.) Monocytes take longer to reach a site of infection than do neutrophils, but they arrive in larger numbers and destroy more microbes.

   (b.) Monocytes are the largest (in size) of all WBCs.

   (c.) They differentiate in the tissues into **macrophages.**

   (d.) **A high monocyte count** could result from certain viral or fungal infections, tuberculosis, some leukemias, and chronic diseases. **A below normal monocyte** level rarely occurs.
G. Thrombocytes (Platelets)

1. **Megakaryoblast** transform into **metamegakaryocytes**, (large cells that shed fragments of cytoplasm), and when the fragments are enclosed, they become **thrombocytes or platelets**.

2. Between 250,000 and 400,000 platelets are present in each cubic millimeter (mm³) of blood.

3. Platelets are disc-shaped, 2 to 4 microns in diameter, and exhibit many granules but no nucleus.

4. Platelet granules contain chemicals that (upon release) promote blood clotting.

5. Life span in circulation is from five to nine days.

6. Older platelets are removed by fixed macrophages in the **spleen** and **liver**.

H. **Complete Blood Count** is a valuable test that screens for anemia and various infections and involves the following: a red blood cell count, hemoglobin, hematocrit, white blood cell count, differential white blood cell count, and platelet count.

I. Hemostasis

1. **Hemostasis** refers to the stoppage of bleeding.

   a. **Vascular Spasm** takes place when blood vessels (arteries or arterioles) are damaged and the circularly arranged smooth muscle in its wall contracts immediately.
      
      1.) Blood loss is reduced for several minutes to several hours while the hemostatic mechanisms go into operation.

      2.) The spasm is probably caused by damage to the smooth muscle and from reflexes initiated by pain receptors.

   b. **Platelet Plug Formation**

      1.) First (in what is called the **Platelet Adhesion**) platelets contact and stick to parts of a damaged blood vessel, such as collagen under the damaged endothelial cells.

      2.) In the **Platelet Release Reaction**, many projections enable the platelets to contact one other and begin to liberate the contents of their granules.
3.) Liberated ADP and thromboxane A2 play a major role by acting on nearby platelets to activate them as well.

4.) Serotonin and thromboxane A(2) function as vasoconstrictors, causing contraction of the vascular smooth muscle; this decreases blood flow through the injured vessel.

5.) In Platelet Aggregation, the release of ADP also makes other platelets in the area sticky; the stickiness of the newly recruited and activated platelets causes them to adhere to the originally activated platelets.

6.) Platelet Plug is the accumulation and attachment of large numbers of platelets; this results in the formation of a mass.

7.) This plug is effective in preventing blood loss in small vessels.

c. Coagulation (Clotting)

1.) Normally blood is liquid, but when removed from the body, it thickens and forms a gel (which can separate from the liquid) and is called Serum.

2.) Serum is plasma minus its clotting proteins.

3.) A clot is the gel and consists of a network of insoluble protein fibers (called fibrin) in which the formed elements of blood are trapped.

4.) Coagulation or clotting is the process of gel formation.

5.) Thrombosis is clotting in an unbroken blood vessel.

6.) Clotting involves several enzymes and other chemicals known as coagulation (clotting) factors. THE STAGES ARE:

   a.) Formation of prothrombinase (prothrombin activator).

   b.) Conversion of prothrombin (a plasma protein formed by the liver) into the enzyme thrombin by prothrombinase.

   c.) Conversion of soluble fibrinogen (another plasma protein formed by the liver) into insoluble fibrin by
thrombin. Fibrin forms the threads of the clot. (Cigarette smoke contains at least two substances that interfere with fibrin formation).

7.) **Stage 1: Extrinsic Pathway**

a.) This path has fewer steps and is usually rapid (within seconds).

b.) It is given this name because a tissue protein (tissue factor- TF), also known as thromboplastin or coagulation factor III, leaks into the blood from outside blood vessels and initiates the formation of prothrombinase.

8.) **Stage 1: Intrinsic Pathway**

a.) **Intrinsic pathway** is more complex and it occurs more slowly (requiring several minutes).

b.) Here, the activators are in direct contact with blood, and outside tissue damage is not needed.

c.) If endothelial cells become roughened or damaged, platelets can release phospholipids by the platelets.

d.) Collagen contact activates coagulation factor XII.

e.) Factor XII activates XI, followed by activation of IX. Activated IX joins with factor VIII and platelet phospholipids to activate factor X. Factor X combines with factor V to form the active enzyme prothrombinase.

9.) **Common Pathway for Stages 2 and 3**

a.) The steps in clotting after formation of factor X are the same in both pathways **STAGE 2**.

b.) Prothrombinase + prothrombin (from liver) + Ca^{2+} --> Thrombin **STAGE 3**.

c.) Thrombin + fibrinogen (from liver) + Ca^{2+} ---> Loose fibrin threads (insoluble).
d.) Thrombin also activates factor XIII; this strengthens and stabilizes the fibrin threads into a sturdy clot.

e.) Fibrin may absorb and inactivate up to 90% of thrombin, which stops clot formation.

f.) Vitamin K is necessary for the actions of clotting factor II, VII, IV, X.

2. Hemophilia

a. Hemophilia refers to several different hereditary deficiencies of coagulation in which bleeding may occur spontaneously or after only minor trauma.

b. **HEMOPHILIA A**, the most common type, is known for the absence of factor VIII.

c. **HEMOPHILIA B** is the absence of factor IX.

d. **HEMOPHILIA A AND B** occur primarily among males and are sex-linked recessive disorders.

e. **HEMOPHILIA C** is milder, lacks factor XI, and affects both males and females.

f. Hemophilia is characterized by spontaneous or traumatic subcutaneous and intramuscular hemorrhaging, nosebleeds, blood in the urine, and hemorrhages in joints that produce pain and damage.

3. Fibrinolysis

a. **Fibrinolysis** is the dissolution of a clot.

b. **Plasminogen** is the inactive plasma enzyme that is incorporated into the formed clot.

c. **Plasmin (fibrinolysin)** is an active plasma enzyme that can be activated from either body tissues or blood.

   1.) **Plasmin activators are**: thrombin, factor XII, plasminogen activator.

   2.) **Activated plasmin can dissolve clots by**:

      a.) digesting fibrin threads.

      b.) inactivating substances such as: fibrinogen, prothrombin and factor V, VIII, and XII.
4. **Thrombolytic (clot-dissolving) agents** are chemical substances injected into the body that dissolve blood clots to restore circulation.

5. **Intravascular Clotting**

   a. **Thrombosis** is the process of clotting in an unbroken blood vessel (usually a vein).
   b. **Thrombus** is the clot itself.
   c. **Embolus** is a blood clot, bubble of air, fat from broken bones, or a piece of debris transported by the bloodstream (a mobile clot).
   d. **Pulmonary embolism** is an embolus that is lodged in the lungs.

J. **Grouping (Typing) of Blood**

   1. **Agglutinogens** (or **isoantigens**) are genetically determined **antigens** on the surface of erythrocytes.

   2. There are 14 blood group systems and more than 100 antigens that can be detected on the surface of RBCs.

   3. **Major Histocompatibility (MHC) Antigens**

      a. Cell surface proteins that are unique for each individual.

      b. Tissue transplants depend on histocompatibility, which is tissue compatibility between the donor and the recipient.

      c. Tissue typing is done before any organ transplant.

4. Two major blood group classifications: **ABO and Rh**.

5. Others include: Lewis, Kell, Kidd and Duffy system.

6. **ABO blood grouping:**

   a. is based on two glycolipid agglutinogens called A and B.

   b. **People who have:**

      1.) No blood antigen = **O blood**.
      2.) A antigen = **A blood**.
      3.) B antigen = **B blood**.
      4.) A and B antigen = **AB blood**.
c. Every person inherits two genes, one from each parent, that are responsible for the production of these agglutinogens.

1.) **OO produces** type **O blood** (45% of population).
2.) **AO and AA produce** type **A blood** (41% of population).
3.) **BO and BB produce** type **B blood** (10% of population).
4.) **AB produces** type **AB blood** (4% of population).

d. **Isoantibodies** are naturally occurring antibodies found in plasma of blood.

e. **Agglutinins (antibodies)**

1.) a and b agglutinins = **O blood**.
2.) b agglutinin = **A blood**.
3.) a agglutinin = **B blood**.
4.) No agglutinins = **AB blood**.

f. **Hemolysis** is the bursting of RBCs and liberating the hemoglobin.

g. **Type O blood is called the Universal Donor** because it has no antigens to be recognized by the recipient's blood.

1.) O blood can donate at least one pint to all blood groups.
2.) O blood is not limited when donating blood to O blood.
3.) While O blood is not recognized by the recipient's blood, the recipient's blood will recognize O blood, causing agglutination. This is why O is the Universal Donor up to one pint.

h. **Type AB blood is called the Universal Recipient** because it has no antibodies in the plasma to agglutinate the donated blood.

1.) AB blood can receive at least one pint of blood from either of the other blood groups.
2.) AB blood is not limited when receiving blood from an AB donor.
3.) While AB blood is not able to agglutinate donated blood, the donor blood will recognize AB blood, causing agglutination. This is why AB is the Universal Recipient up to one pint.

i. Knowledge of blood types is also used in paternity lawsuits, linking suspects to crimes, and as part of anthropology studies to establish a relationship among races.

7. Typing and Cross-Matching for Transfusion

a. This is done by typing the patient’s blood, and then either cross-matching it to potential donor blood or screening it for presence of antibodies.

b. Missing of incompatible blood causes agglutination.

c. In determining the ABO or Rh factor, a drop of blood is mixed with anti-serum of either ABO or Rh.

8. Rh (85% of the population is Rh positive; 15% of the population is Rh negative).

a. Rh system was so named because it was first worked out in the blood of the Rhesus monkey.

b. Like the ABO grouping, Rh is based on antigens on the surface of erythrocytes.

c. People who have Rh agglutinogens (D antigens) on the surface of their RBCs are designated Rh+ and those who lack Rh agglutinogens are designated Rh-.

d. Normally, plasma does not contain anti-Rh agglutinins. So if an Rh- person receives Rh+ blood, the body starts to make anti-Rh agglutinins that will remain in the blood for the future.

e. Rh- blood may be donated to Rh+ blood, but Rh+ blood may not be donated to Rh- blood.

9. Hemolytic Disease of the Newborn

a. Also called erythroblastosis fetalis; exists when the father is Rh+ and the mother is Rh-.

b. The problem is found with the second Rh+ offspring born to this union.
c. **Normally, there is no direct contact between maternal blood and fetal blood when a woman is pregnant.**

d. **However**, some blood from the fetus may leak through the placenta either during pregnancy or at birth.

e. **As a result**, the mother's body would develop antibodies against Rh\(^+\) (factor D) cells.

f. Second Rh\(^+\) child would experience hemolysis of its RBCs by IgG anti-Factor D antibodies which were developed by the mother.

g. When a baby is born with this condition, blood is slowly removed and replaced (a little at a time) with Rh\(^-\) blood.

h. To prevent this problem, **RhoGAM** may be given to each Rh\(^-\) mother that gives birth to an Rh\(^+\) within a few hours after birth, or possibly in the seventh month of gestation as well.

i. **RhoGAM is a serum (anti-Rh gamma globulin)** which destroys fetal Rh\(^+\) cell before the mother's immune system has an opportunity to respond, preventing the mother's development of a memory cell.

K. **Blood Withdrawal**

1. **Venipuncture** is the withdrawal of blood from a vein. (Veins are more accessible because they are closer to surface and have less pressure).

2. **finger-stick** is a drop or more of capillary blood that is taken from a finger, earlobe, or heel of the foot.

3. **arterial stick** is a sample of blood taken from an artery; the most common sites are the radial artery in the wrist and the femoral artery near the groin.

L. **Disorders**

1. **Anemia** is a condition in which the oxygen-carrying capacity of the blood is reduced and involves a reduced number of RBCs. **Some major types of anemia are:**

   a. **Nutritional Anemia** arises from an inadequate diet, that is, one without enough iron, the necessary amino acids, or vitamin B\(_{12}\).
b. **Pernicious Anemia** is the insufficient hematopoiesis that results from an inability of the stomach to produce intrinsic factor (which is needed for absorption of vitamin B₁₂).

c. **Hemorrhagic Anemia** is an excessive loss of RBCs due to bleeding.

d. **Hemolytic Anemia** is the premature rupturing of RBCs (ie Hemolytic disease of newborn).

e. **Hypochromic Anemia** - abnormally low concentration of hemoglobin.

f. **Thalassemia** represents a group of hereditary hemolytic anemias resulting from a defect in the synthesis of hemoglobin, which produces extremely thin and fragile erythrocytes.

g. **Aplastic Anemia** is the destruction or inhibition of the red bone marrow.

h. **Sickle-Cell Anemia** is a hereditary abnormal hemoglobin and when RBCs give up their oxygen to the interstitial fluid, the abnormal hemoglobin forms long, stiff, rodlike structures that bend the erythrocyte into a sickle shape.

2. **Polycythemia** refers to a disorder characterized by a hematocrit that is elevated significantly above the normal upper limit of about 55.

3. **Infectious Mononucleosis** is a contagious disease primarily affecting lymphoid tissue throughout the body, but also affecting the blood. It is caused by the *Epstein-Barr virus (EBV)* and occurs mainly in children and young adults.

4. **Leukemia**

   a. **Acute leukemia** is a malignant disease of blood-forming tissues characterized by uncontrolled production and accumulation of immature leukocytes.

   b. **Chronic leukemia** is an accumulation of mature leukocytes in the bloodstream because they do not die at the end of their normal life span.

   c. Also classified by site of origins: **myelocytic, lymphocytic, or monocytic** leukemia.

5. **Crenation** - blood cell shrinkage due to the loss of that cell's water to a surrounding **hypertonic** environment.

6. **Hemolysis** - blood cell swelling (and eventually bursting) due to the blood cell gaining water from a surrounding **hypotonic** environment.
Chapter 2, The Lymphatic System

A. Lymphatic System

1. The lymphatic system consists of a fluid called lymph flowing within lymphatic vessels (lymphatics), and in organs that contain lymphatic tissue and bone marrow.

   a. **Lymph** (fluid of the lymphatic system)

      1.) The fluid that flows through lymphatic vessels.

      2.) Similar in composition to interstitial fluid.

      3.) Contains some cells (the majority are lymphocytes; and some macrophages).

   b. **Functions of the lymphatic system**

      1.) **Drains interstitial fluid.**

      2.) **Transports dietary fats.**

      3.) **Protects against invasion** – lymphatic tissue carries out the immune response.

      4.) **Help with the water balance between the tissues and the blood.**

   c. Lymphocytes, aided by macrophages, recognize foreign cells, foreign substances, microbes, cancer cells, and then respond to them in two ways:

      1.) **T-cells** destroy microorganisms directly or indirectly by releasing cytotoxic substances called cytokines.

      2.) **B-cells** differentiate into **plasma cells** that **secrete antibodies** (specific proteins that combine with antigens and cause destruction of specific foreign invaders such as bacteria and virus).

   d. **Nonspecific defense mechanisms** responds to a wide variety of foreign substances such as bacteria, viruses, and toxins.

B. Lymphatic Vessels and Lymph Circulation
1. **Lymphatic capillaries** are the close-ended vessels in spaces between cells that become lymphatic vessels.

2. **Lymphatic vessels** are formed from lymphatic capillaries; they resemble veins structurally but have thinner walls and more valves.

3. At intervals along lymphatic vessels, lymph fluid flows through **lymph nodes**.

4. **Lymphatic capillaries**
   
   a. Lymphatic capillaries are **NOT** found in:
      
     1.) avascular tissues.
     2.) the central nervous system.
     3.) splenic pulp.
     4.) bone marrow.
   
   b. Lymphatic capillaries have a slightly larger diameter than blood capillaries.
   
   c. Lymphatic capillary structure permits interstitial fluid to flow into them but not out; **thus** –
      
     1.) when pressure is greater in the interstitial fluid than in the lymph, fluid enters the lymphatic capillary.
     2.) when pressure is greater inside the lymphatic capillary, lymph cannot flow back into the interstitial fluid (because of the anatomical structure of the lymphatic capillary).

5. **Formation and Flow of Lymph**
   
   a. More fluid seeps out of blood capillaries by filtration than returns to them by absorption.
   
   b. The excess fluid, about 3 liters per day, drains into lymphatic vessels and becomes lymph.
   
   c. **Sequence of lymph flow:**
      
   
   d. Since most plasma proteins are too large to leave the blood vessels, interstitial fluid contains only a small amount of
protein.

e. An important function of lymphatic vessels is to return leaked plasma proteins to the blood.

f. Skeletal muscle contractions compress lymphatic vessels and force lymph toward the subclavian veins.

g. One-way valves within the lymphatic vessels prevent the backflow of lymph.

h. Another factor that helps to maintain lymph flow is respiratory movements.

6. Thoracic (Left Lymphatic) Duct

   a. Begins as a dilation called the cisterna chili.

   b. It is the main collecting duct of the lymphatic system and receives lymph from:

      1.) left side of the head and left neck.
      2.) left chest.
      3.) left upper extremity.
      4.) entire body below the ribs (diaphragm).

7. Right Lymphatic Duct

   a. Drains lymph from the upper right side of the body (above the diaphragm) including the right arm.

   b. Drains lymph from the right jugular trunk, which drains the right side of the head and neck.

C. Lymphatic Tissue

   1. Primary lymphatic organs of the body are the bone marrow (B-cells) and thymus gland (T-cells).

   2. Secondary lymphatic organs are the lymph nodes and spleen.

   3. Most immune responses occur in the secondary lymphatic organs, lymphatic nodules, or diffuse lymphatic tissue.

   4. Lymph Nodes

      a. Are the oval or bean-shaped structure located along the length of lymphatic vessels.
b. Are scattered throughout the body (usually in groups), and are arranged in two sets: superficial and deep.

c. The cortex is the outer portion of the lymph node and contains densely-packed lymphocytes; these are arranged in masses called follicles (lymphatic nodules).

d. The outer rim of each follicle contains T-cells (T lymphocytes) plus macrophages and follicular dendritic cells (which participate in the activation of the T-cells).

e. When an immune response is occurring, the follicles contain lighter-containing central areas called germinal centers, where B-cells (B lymphocytes) are proliferating into antibody-secreting plasma cells.

f. In the medulla, the lymphocytes are arranged in strands called medullary cords, which also contains macrophages and plasma cells.

g. Lymph enters the lymph node through afferent lymphatic vessels.

h. Inside the node, the lymph flows through sinuses in the cortex and then into the medulla; it exists the lymph node via one or more efferent lymphatic vessels.

i. The hilus (or hilum) is the site where blood vessels and lymphatic vessels enter and leave the lymph node.

j. Within the lymph node, macrophages and lymphocytes destroy foreign substances within the body.

5. **Tonsils** are multiple aggregations of large lymphatic nodules embedded in a mucous membrane.

   a. **Pharyngeal tonsils** (or adenoids) are embedded in the posterior wall of the nasopharynx.

   b. **Palatine tonsils** are paired and are found in the space between the pharyngopalatine and glossopalatine arches. These are commonly removed in a tonsillectomy.

   c. The **Lingual tonsil** is located at the base of the tongue.

   d. Tonsils are situated strategically to protect against invasion of foreign substances that are inhaled or ingested.

6. The **Spleen** is the largest mass of lymphatic tissue in the body.
a. The spleen is located in the left hypochondriac region between the fundus of the stomach and the diaphragm.

b. The spleen functions in immunity as the site of B cell proliferation into plasma cells.

c. The main function of the spleen is the phagocytosis of bacteria, wornout or damaged red blood cells, and platelets.

d. The spleen stores and releases blood in times of demand, such as during hemorrhage.

e. A ruptured spleen causes severe intraperitoneal hemorrhage and shock.

f. A splenectomy is the surgical removal of the spleen, and is needed to prevent a patient from bleeding to death.

7. The Thymus Gland is located in the superior mediastinum, posterior to the sternum and between the lungs.

   a. The size depends on the age of the individual.

   b. After puberty, the gland gradually decreases in size.

   c. This gland differentiates lymphocytes (from the bone marrow) into T lymphocytes (T-cells).

8. Metastasis is the process by which cancer cells spread to various parts of the body.

   a. Cancer cells may travel via the lymphatic system and produce clusters of tumor cells in other parts of the body.

   b. Such secondary tumor sites are predictable by the direction of lymph flow and by examining lymph nodes for cancer cells.

IMMUNITY

A. Immunology is a science that studies immunity. Historically, immunity has been understood as a defense against, or resistance to, contagious (infectious) disease. The mechanisms that confer protection against these diseases can also operate when a body mounts a reaction against
some innocuous (harmless) substances. Such a reaction is triggered when certain substances that are not made in the body (“foreign substances”) invade the body from outside.

The mechanisms of immunity can protect against diseases that might be caused by the foreign agents but, these same mechanisms can themselves injure the body and cause disease. Therefore, immunity was redefined as a reaction against foreign substances, including but not limited to, infectious microorganisms. This reaction may or may not be protective and is quite complex, involving many different cells, molecules, and genes and is collectively termed the immune system. The response of the immune system to the introduction of foreign substances is called the immune response.

1. **Innate (natural) immunity** refers to the inborn capacity to resist the invasion of foreign substances. This includes physical barriers like the skin and mucosal surfaces; chemical substances (mostly proteins) that neutralize microorganisms and other foreign particles; and specialized cells that engulf and digest foreign particles (phagocytosis). The mechanisms of innate immunity are non-specific; that is, they Do not discriminate between different kinds of foreign substances.

2. **Acquired immunity** refers to a reaction that is caused by the invasion of a certain foreign substance. The elements of this reaction pre-exist the invasion of the certain foreign agent (which is called an antigen) and changes its magnitude as well as the quality with each successive encounter of the same antigen. The acquired immunity is highly specific; that is, the system discriminates between various antigens, responding with a unique reaction to every particular antigen.

Acquired (or specific) immunity is highly adaptive; that is, the nature or quality of the reaction to an antigen changes after the initial encounter with this antigen, and especially when the individual encounters the same antigen repeatedly. The ability of the immune system to “remember” an encounter with an antigen and to develop a qualitatively better response to it is called the immune memory. This feature is an important property of specific immunity.

Acquired immunity is either active or passive.
   a. **Active immunity** refers to the immune reaction that develops in an individual after the induction of an antigen (due to infectious disease or immunization).

   b. **Passive immunity** refers to an individual that is not immunized but receives blood cells or serum from an actively immunized individual.

3. The purpose of the immune reaction is to rid the individual of foreign
antigens. From birth until death, an individual is surrounded by a host of microorganisms, many of which are dangerous. Using antigen receptors, the immune system continuously monitors many substances in the body, discerning among them and mounting an attack against those that are foreign.

The end result of a successful immune attack is the destruction of foreign substances and particles, including microbial cells such as bacteria and viruses, various toxins (bacterial poisons) and also tumor cells. Once destroyed by the immune system, foreign substances or particles, or their remains are cleared from the body.

4. **Antigen (agglutinogen)** – is a substance that can trigger, or *generate*, immune responses.

   a. It is a substance that the immune system can specifically recognize with the help of antigen receptors on lymphocytes.

   b. Most antigens are proteins, but polysaccharides, certain lipids, and nucleic acids can also trigger immune reactions.

      1.) They include: bacterial enzymes, toxins, and structural proteins or glycoproteins, such as those found on viral surfaces.

   c. In order to be an antigen, a substance must be of enough complexity to bear an imprint of potential “foreignness”.

   d. The immune system reacts against antigens by using molecules called **antibodies**, and cells called **lymphocytes**.

5. **Antibodies (agglutinins)** – are protein molecules synthesized by a class of lymphocytes called **B lymphocytes** (or **B cells**) which then transform into **plasma cells** to produce antibodies.

   a. Antibody molecules recognize antigens through physical contact.

      1.) A specific antibody will generally bind only to a ceratin antigen (**antigen-antibody reaction**).

      2. The process by which antibodies bind to and neutralize the antigen(s) is called an **antigen-antibody response**.

   b. Antibodies can either be expressed on the surface of B cells or secreted by the B cells after transforming into plasma cells.

   c. Antibodies are proteins that belong to the immunoglobulin class.

6. **Lymphocytes**
a. Like many other functions of the body, the immune system performs with the help of specialized cells called **lymphocytes**.

b. Lymphocytes are small cells whose diameter is approximately 8-10 micrometers. In fact, they are the smallest (in size) of all white blood cells (WBCs).

c. Lymphocytes are spherical in shape and have a relatively large nucleus surrounded by a thin rim of cytoplasm.

d. Lymphocytes can be classified as either **B-lymphocytes (B cells)** or **T-lymphocytes (T cells)** depending on the site of differentiation and maturation:

   1.) The entire process of B-lymphocyte maturation in humans takes place in the **bone marrow**. Once developed, these cells play an important role in **Humoral Immunity**, where antibodies are produced against antigens.

   Types of **antibodies (immunoglobulins)** are proteins secreted by **plasma cells (transformed B cells)** that are associated with having antibody activity.

   There are **5 classes** based on differences in physicochemical properties:

   i. **IgG (gamma globulin)**
      1) the most abundant antibody in the human body.
      2) found in blood and lymph fluid.
      3) the only antibody that crosses the placenta.
      4) enhances phagocytosis (opsonization).
      5) activates the complement system (described below).
      6) the primary antibody of the secondary (booster) response.

   ii. **IgM**
      1) the largest antibody (physicochemically).
      2) found in blood and lymph fluid.
      3) **first antibody** to be secreted after exposure to antigen (includes immunization).
      4) has bactericidal activity (kills bacteria).
      5) enhances phagocytosis (opsonization).
      6) **anti-A** and **anti-B** (part of the **ABO blood group system** belong to this category).

   iii. **IgA (Secretory Antibody)**
      1) found in body secretions such as colostrums (mother’s milk), mucous, G-I secretions, saliva and tears.
2) inhibits viral infections on mucosal surfaces.
3) its level can fall when one is under stress (thus, decreased resistance to infection).

iv. IgD
1) found in blood and lymph fluid in very low quantities.
2) act as antigen receptors on the surface of B lymphocytes.
3) reacts with antigen to stimulate B lymphocytes to transform into plasma cells and produce antibodies.

v. IgE (Reaginic Antibody)
1) involved in hypersensitivity (allergy) reactions and in skin sensitivity.
2) found on the surfaces of basophils and mast cells.
3) also produced during parasite infections.

2.) T lymphocytes precursors (from the bone marrow) must undergo their differentiation and maturation in an organ called the thymus gland. Once matured, these cells act directly against antigens on microorganisms and some tumors themselves and destroy them.

3.) T lymphocytes are stimulated by antigens and take part in the immune response called Cell-Mediated Immunity. They are especially effective against viruses, fungi, transplanted cells, cancer cells, and certain bacteria.

Types of T lymphocytes are:

i. Cytolytic T cells destroy foreign invaders directly by attaching to the antigen on the invader and secreting cytokines, which enhance the function of other cells (notably B lymphocytes and macrophages).

ii. Helper T cells also secrete cytokines, which enhance the function of B lymphocytes and macrophages; secrete interleukin-2 (IL-2), which activates natural killer (NK) cells, other helper T cells and promote B cell proliferation (into plasma cells) and antibody productions. Helper T cells are those that are infected and destroyed by H.I.V.

iii. Suppressor T cells inhibit immune responses mediated by other T and B lymphocytes; they help to regulate the immune system.

iv. Memory T cells recognize the original antigen from a previous exposure and maintains immunological memory for years.

v. Amplifier T cells are stimulator cells. They stimulate plasma
cells to secrete antibodies and suppressor and helper T cells to have more activity.

B. **Other Aspects of Immunity**

1. **Differential White Blood Cell Count** is the process for the determination of the percentage of each type of white blood cell (WBC) in a blood sample. Considering that each type of WBC plays a different role, determining the percentage of each type in the blood can assist in diagnosing a certain condition. The normal percentages of WBCs based on 100 cells is as follows:

   a. **Neutrophils**: 55 – 70%
   b. **Lymphocytes**: 20 – 35%
   c. **Monocytes**: 02 – 09%
   d. **Eosinophils**: 02 – 04%
   e. **Basophils**: 0.5 – 01%

2. **High total WBC counts** could indicate an **infectious disease** taking place in the body.

3. **High neutrophil counts** would normally suggest the presence of a bacterial infection.

4. **High lymphocyte counts** could indicate **viral infections**, immune disorders, and some types of leukemia. **Low lymphocyte counts** might occur as a result of a chronic illness, High steroid levels, and immunosuppression.

5. **Inflammation** is an essential part of nonspecific immunity and usually results in an **increased number** of circulating WBCs.

6. **Interferon** are **antiviral proteins** secreted by viral-infected cells; they inform noninfected cells of the presence of the virus and prevents invasion of those cells by the virus.

7. **The complement system** is a series of 9 different protein components (in the presence of antibody) that facilitate the destruction (**via lysis**) of bacteria and virus in the human body; **this system is what actually destroys the microorganism (bacteria or virus)** following the reaction of the antibody with the antigen (marker) on the bacterial or viral surface.

C. **Hypersensitivity** is an **over-reaction** of the immune system against certain antigens that result in tissue damage **rather** than immunity.

In order for this reaction to occur, a person must first become **sensitized** to a particular antigen. The hypersensitivity reaction then occurs after
subsequent exposure to the same antigen. There are two types: Immediate Hypersensitivity and Delayed-Type Hypersensitivity.

1. **Immediate Hypersensitivity** occurs within minutes upon subsequent exposure to a particular antigen. It is mediated by IgE, which is the principle antibody of this reaction. This hypersensitivity is the immunological correlate of a clinical phenomenon called allergy. IgE mediates this reaction because of its ability to bind to mast cells, basophils and eosinophils. The IgE trapped on the surface of these cells, then binds to a specific antigen to which it was produced against. When this happens, mast cells and basophils release their granules which, in turn, causes such well-known symptoms associated with allergies such as soft swelling, local redness and hyperthermia, bronchoconstriction, and others.

2. **Delayed-Type Hypersensitivity** (DTH) is mediated by T lymphocytes and develops when a person is immunized (“sensitized”) with a microorganism and then exposed again by injecting the same antigen intradermally. In this person, typical signs of local inflammation (swelling, redness, local raising of temperature, and pain) accompanied by the induration (hardening) of the tissue around the injection site, develop in 24-48 hours (hence the term “delayed”) after the “antigenic challenge”. DTH is widely used in clinics as a standard test to establish whether a person has been exposed, infected or previously vaccinated with *Mycobacterium tuberculosis*. DTH is also observed in clinical phenomena such as poison ivy and poison oak exposure (contact dermatitis).

D. **Immunologic Tolerance** is defined as a state of unresponsiveness to an antigen that is induced by prior exposure to that antigen. Tolerance is strictly antigen-specific and develops only after the recognition of the antigen. The tolerance can be subdivided into tolerance to self and tolerance to foreign antigens.

E. **Autoimmunity** is defined as an immune response of a host to its own tissues. Tissue antigens present during fetal and neonatal life are “self” and so are tolerated by the host. No antibodies or hypersensitivity reactions are developed to them. On the other hand, antigens not present during fetal or neonatal life are rejected as “not self” and immune responses to the may develop.

The differentiation of “self” from “not self” must be an important homeostatic function of the body. “Autoimmune disease” may be considered a failure of this homeostatic function, a disorder of immune regulation.
The Heart

Textbook Chapter: ________

A. Heart description

1. The heart is a four-chambered muscular pump.
2. The heart is about the size of your clenched fist.
3. The two top and smaller chambers are atria (atrium - singular) and the two lower and larger chambers are the ventricles.
4. The heart is found in a central cavity called the mediastinum.
5. The top of the heart is the base and the bottom is the apex.

B. Coverings of The Heart

1. PERICARDIAL MEMBRANE is a double sac made up of the parietal pericardium (2 layers) and visceral pericardium (one layer).
   a. Parietal pericardium: part of thoracic wall and has two layers, a fibrous and a serous layer
      1.) Fibrous parietal pericardium: fibrous connective tissue that resembles a bag resting on the diaphragm; anchors the heart to the diaphragm and the sternum, and prevents over-distension of the heart.
      2.) Serous parietal pericardium: the inner layer of the fibrous pericardium; composed of squamous epithelium. At the heart’s base, the serous layer turns down and continues as the visceralpericardium.
   b. Visceral pericardium (or epicardium): the covering of the heart directly adherent to the heart.
2. Pericardial space: negligible space between parietal pericardium and visceral pericardium.
3. Pericardial fluid: fluid found in the pericardial space.
4. Heart Layers (3)
   a. epicardium (just discussed)
   b. myocardium - bulk of heart; composed of cardiac muscle.
c. **endocardium** - lines the heart chambers; composes the heart valves.

**C. Pulmonary Circulation or Circulation through the heart**

1. Blood enters the heart on the right side (**Right Atrium**) by way of the superior vena cava, inferior vena cava, and coronary sinus.

2. This blood has come from all parts of the body.

3. From here, it goes by way of the tricuspid valve to the right ventricle.

4. Blood is pumped from the **Right Ventricle** up the pulmonary trunk (through the pulmonary semilunar valve) ===> pulmonary arteries (R. & L.) ===> pulmonary arterioles ===> pulmonary capillaries of the lung (where gas exchange occurs) ===> (**returned to the heart by**) Pulmonary Venules ===> 4 pulmonary veins ===> **Left Atrium** ===> through the bicuspid valve to the ===> **Left Ventricle** ===> to the Ascending Aorta (through the Aortic semilunar valve). **From the Aorta, blood goes to all parts of the body (SYSTEMIC CIRCULATION).**

**D. Heart Valves and Sounds**

1. The two top chambers, the **atria**, contract together (**atrial systole**), while the ventricles are at rest (**ventricular diastole**).

2. When the atria contract, the cuspid valves are open but the semilunar valves are closed.

3. When the ventricles are in systole, the atria are in diastole.

4. When the ventricles contract (systole), the cuspid valves are closed but the semilunar valves are open.

5. The "**lubb**" sound is made when the cuspid valves close (due to ventricular contraction).

6. The "**dup**" sound is made when the semilunar valves close (as the ventricles relax).

7. The cuspid valves are anchored by **chordae tendineae** which are in turn attached to **papillary muscles** (that are embedded in the walls of the ventricles).

8. Know the **locations** for each valve when listening on the stethoscope.

   a. **TCV** -

   b. **BCV** -
E. Blood Supply to the Heart

1. The coronary arteries supply blood to the heart.

2. The coronary arteries originate at the ascending aorta on each side of the heart.

3. The right coronary artery supplies blood to the right atrium, right ventricle, and part of the left ventricle. Its branches are the right marginal artery and the posterior interventricular artery.

4. The left coronary artery supplies blood to the left atrium, left ventricle, and part of the right ventricle. Its branches are the circumflex artery and the anterior interventricular artery.

5. Blood is returned by coronary veins to the coronary sinus; from the coronary sinus, blood goes to the right atrium.

F. The character of Cardiac Muscle

1. Cardiac muscle cells are branching, striated, and uninucleated.

2. Cardiac cells are connected by intercalated discs.

3. Cardiac muscle rely on aerobic reactions to form ATP, and thus has large amounts of mitochondria.

G. The Conduction System of the Heart

1. Heart beat is initiated at the Sino-Atrial node (or SA node); (it is also known as the pacemaker of the heart).

2. This electrochemical wave passes through both atria (resulting in atria contraction).

3. The Atrioventricular node (AV node) picks up the impulse and relays it to the AV (atrioventricular) bundle (or the Bundle of His) and bundle branches where the impulse is amplified.

4. The impulse continues down the atrioventricular septum, and via the Purkinje fibers, passes into the ventricular myocardium, turns near the apex, then back up into the ventricular walls (then the ventricles contract).
5. The same stimulus that causes the ventricles to contract will also cause the papillary muscles to contract. However, the papillary muscles begin to contract before the ventricles contract; this is necessary to keep the A-V valves closed during ventricular contraction.

H. Electrocardiogram

1. Impulse transmission through the conduction system generates electrical currents that can be detected on the body's surface.

2. A recording of the electrical changes that accompany the cardiac cycle is called an electrocardiogram (ECG or EKG).

3. The instrument used to record the changes is an electrocardiograph.

4. Each portion of the cardiac cycle produces a different electrical impulse.
   a. The P wave is the first wave, and is a small upward wave representing atrial depolarization.
   b. QRS complex (or QRS wave) begins as a downward deflection, continues as a large, upright, triangular wave, and ends as a downward wave at its base. This represents ventricular depolarization.
   c. T wave is dome-shaped, and indicates ventricular repolarization.
   d. Atrial repolarization occurs during the QRS wave, and does not have its own individual wave.

I. Cardiac Cycle Represents the Events Involved in one Heartbeat.

1. At a normal heart rate of 75 beats per minute (normal range 65-80), a cardiac cycle lasts 0.8 seconds.
   a. systole - heart muscle contraction; the 2 divisions are:
      1.) atrial systole
      2.) ventricular systole
   b. diastole - heart muscle relaxation; the 2 divisions are:
      1.) atrial diastole
      2.) ventricular diastole

2. Atrial systole accounts for 0.1 second of the whole 0.8
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Ventricular systole accounts for 0.3 second of the whole 0.8 second.

The remaining 0.4 seconds is the period of total heart relaxation.

The heart rests half of the entire cycle.

If one divides 60 seconds (one minute) by the cardiac cycle (0.8 sec.), one will get the number of heart beats per minute (at rest, this equals 65-80 beats/min).

If one divides 60 seconds (one minute) by the number of heart beats per minute, one will get the cardiac cycle.

The number of heart beats and the cardiac cycle are inversely related, or, as one increases, the other decreases.

The ventricles are approximately 70% filled-up with blood before the atria contract. Thus, the atria "fill-up" only (approximately 30%) of the ventricles when they (the atria) contract.

J. Control of Heart Rate

1. Cardiac Accelerator Center (CAC) in the Medulla speeds up the heart.

2. This fiber is a sympathetic fiber via sympathetic trunk.

3. Cardiac Inhibitory Center (CIC) in the Medulla slows the heart down.

4. This fiber is a parasympathetic fiber and is a cranial nerve (vagus or X).

5. Pressoreceptors (parasympathetic fibers) in the aortic arch and carotid sinus may stimulate the medulla to decrease the heart beat.

6. Increased pressure in the right atrium will cause a reflex increase of heart rate.

7. Chemoreceptors (sympathetic fibers) in the aortic arch and carotid sinus may stimulate the medulla to increase heart beat.

8. Remember that the Sympathetic Division of the Autonomic Nervous System has ascendancy (authority) over the parasympathetic fibers, especially during stress periods. (ie. Running for your life is an example of sympathetic fibers dominating parasympathetic fibers).
9. **Pressoreceptors are parasympathetic fibers** and in this situation ("running for your life"), they would be telling your heart to beat slower.

10. **Chemoreceptors are sympathetic fibers**, and under this stress, they would tell the heart to beat faster.

11. It makes sense that while you are running for your life, the heart would beat faster.

12. This is explained through the dominance of the Sympathetic Division.

**K. Pulse: Alternate Expansion and Recoil of an Artery.**

1. Pulse is caused by the intermittent injections of blood from the heart into the aorta with each left ventricular contraction.

2. Pulse can be felt because of the elasticity of the arterial walls.

3. A **pulse wave** starts at beginning of aorta and proceeds as a wave of expansion throughout arteries.

4. **SOME COMMON PULSE SITES ARE:**
   - a. facial
   - b. temporal
   - c. common carotid
   - d. radial
   - e. brachial
   - f. femoral
   - g. popliteal
   - h. posterior tibial and peroneal
   - i. dorsalis pedis

5. These sites are near the surface and over a firm background, such as bone.

6. **Pressure points** - points where bleeding can be stopped by pressure, are roughly related to places where pulse can be felt.

**L. Starling's Law**

1. The strength of heart contractions is dependent on the length of muscle fibers at rest (diastole).

2. In other words, the strength of the contractions depends upon the degree of **diastolic filling**.

**M. Irregular Heart Rhythms or Arrhythmia Is Any Variation from the**
Normal Rhythm of the Heart Beat.

1. **Tachycardia** - means fast heart rate, usually defined as more than 100 beats per minute.
   a. Tachycardia may be caused by fever.
   b. Stimulation of the heart by its sympathetic nerves.
   c. Certain hormones or drugs or weakening of the heart muscle.
   d. When the myocardium cannot pump blood effectively, homeostatic reflexes are activated that increase the heart rate.

2. **Bradycardia** - describes a heart rate of less than 60 beats per minute. This condition is common in athletes.
   a. Bradycardia may also result from decreased body temperature.
   b. Certain drugs or stimulation of the heart by its parasympathetic nerves.
   c. Bradycardia may occur in patients with atherosclerotic lesions in the carotid sinus region of the carotid artery.

3. **Fibrillation** - the heart also beats very rapidly, but even worse, the contractions are uncoordinated.
   a. **ARTIAL FIBRILLATION** (2X)
   b. **VENTRICULAR FIBRILLATION** (2X)

4. **Ectopic Beat** - sometimes a heart beat results from an impulse that originates at a region other than the SA node.

N. **Cardiac Output**

1. The **cardiac minute output** (CMO) is about 5 liters per minute; it is the amount of blood the ventricle pumps out in one minute.

2. **Stroke volume** is the amount of blood pumped out by a ventricle with each contraction. \( \text{Cardiac Minute Output} = \text{heart rate} \times \text{stroke volume} \).

O. **Physiology of Cardiac Output**

1. Blood circulates because a blood pressure gradient exists within its vessels; the systemic blood pressure gradient (mean arterial pressure minus central venous pressure) equals about 100 mmHg. Average pressure in artery is 100 mmHg. **Some average blood pressures:**
a. **brachial artery** (average range)

\[
\begin{align*}
\text{systole} & = 90-140 \text{ mm.Hg.} & \text{Av.} & = 120 \text{ mm. Hg.} \\
\text{diastole} & = 60-90 \text{ mm.Hg.} & & = 80 \text{ mm. Hg.}
\end{align*}
\]

b. **pulmonary artery** (average range)

\[
\begin{align*}
\text{systole} & = 22 \text{ mm.Hg.} \\
\text{diastole} & = 8 \text{ mm.Hg.}
\end{align*}
\]

c. **capillary pressure** (average range)

1.) 32 - 35 mmHg. (art. end)
2.) 12 - 18 mmHg. (venous end)

2. **Arterial blood pressure** is determined primarily by the volume of blood in the arteries; other factors remaining constant, the greater the arterial blood volume, the greater the arterial blood pressure.

\[\begin{align*}
\uparrow \text{Blood Pressure} \\
\uparrow \text{Blood Volume}
\end{align*}\]

3. Some of the major factors which influence arterial blood pressure are:

a. age
b. weight gain or loss
c. gender factor (probably hormonal and genetic)
d. emotions
e. exercise
f. chemicals

4. **Arterial blood volume** is determined mainly by cardiac minute output and peripheral resistance: directly related to cardiac output and inversely related to resistance.

\[
\text{Blood volume} = \frac{\text{Cardiac minute output}}{\text{Peripheral Resistance}}
\]

5. **Cardiac minute output (C.M.O.)** is determined by the heart's rate of contraction and its systolic discharge and directly related to both factors.

\[\begin{align*}
\uparrow \text{C.M.O} \\
\uparrow \text{Heartrate}
\end{align*}\]
6. The heart's systolic discharge is regulated mainly by the ratio of sympathetic to parasympathetic impulses. 

**Systolic discharge:** Ratio of Sympathetic impulse to Parasympathetic impulse.

7. The heart rate is regulated by presso receptors and by many miscellaneous factors. Increased arterial pressure in the aorta or carotid sinus tends to produce reflex slowing of the heart, whereas increased right atrial pressure tends to produce reflex cardiac acceleration.

8. **Peripheral resistance** is determined mainly by blood viscosity and by arteriole diameter. In general, less blood viscosity means less peripheral resistance, but the smaller the diameter of the arterioles, the greater the peripheral resistance.

9. **Blood viscosity** is determined by the concentration of blood proteins and blood cells and is directly related to both.

10. **Arterial diameter** is determined mainly by pressoreflexes and chemoreflexes. In general, an increase in arterial pressure produces reflex dilation of the arterioles, whereas hypoxia and hypercapnea cause constriction of the arterioles in the blood reservoir organs but dilation of them in local structures (notably in skeletal muscles, the heart and the brain).

11. **The volume of blood circulating per minute** is determined by the blood pressure gradient and peripheral resistance. According to Poiseuille's Law, it is directly related to the pressure gradient and inversely related to the peripheral resistance.

12. Respirations and skeletal muscle contractions tend to increase venous return to the heart.
A. Overview

1. Blood is transported by a syncytial (continuous) system of blood vessels.

2. There are arteries, arterioles, capillaries, venules and veins.

B. Kinds

1. **Arteries**: vessels which carry oxygenated blood away from the heart; **exception**: pulmonary arteries and umbilical arteries carry deoxygenated blood.

2. **Veins**: vessels which carry deoxygenated blood toward the heart; **exception**: pulmonary veins and umbilical veins carry oxygenated blood.

3. **Capillaries**: microscopic vessels which carry blood from small arteries (arterioles) to small veins (venules).

C. Functions:

1. **Arteries and arterioles**: carry blood away from heart to capillaries.

2. **Capillaries**: deliver materials to cells and collect substances from cells (by way of tissue fluid or interstitial fluid); this is a vital function of the entire circulatory system.

3. **Veins and venules**: carry blood from capillaries back to the heart.

D. Structure:

1. **All blood vessels** (except capillaries) have three layers:
   a. **tunica intima** - endothelial tissue; the layer next to the blood
   b. **tunica media** - smooth muscle tissue; the bulk of the vessel
   c. **tunica adventitia (externus)** - connective tissue; the outer layer
2. **Arteries have:**
   a. a very muscular tunica media.
   b. no valves in the tunica intima.
   c. smaller lumens than veins.
   d. thicker tunica adventitia than veins.

3. **Veins have:**
   a. less muscle in the tunica media.
   b. most veins have valves in the tunica intima.
   c. a larger lumen than arteries.
   d. a thinner tunica adventitia.

4. **Capillaries are:**
   a. microscopic vessels with a very thin wall.
   b. sites of active absorption.
   c. focal point of the vascular system.

5. **Sinusoids are:**
   a. similar to capillaries; microscopic
   b. are located in the liver, spleen, and pancreas; however, there are other locations.

6. **Vascular Anastomosis**
   a. is the joining together of arteries serving a common organ; this creates alternate channels for blood to reach the same organ.
   b. may also form between veins, and between arterioles and venules.

7. **Systemic Blood Pressure**
   a. Normal blood pressure in adults is about 120/80 (systole/diastole).
   b. Venous pressure is low because of resistance.
   c. Blood pressure is influenced by cardiac output, peripheral resistance, and blood volume.
   d. Blood pressure is regulated by autonomic reflexes: presso and chemo- reflexes.
e. Blood pressure usually measured by the auscultatory method.

f. **Hypertension** - is high blood pressure (above normal).

g. **Hypotension** - is low blood pressure.

E. Circulatory Pathways

1. **Pulmonary Circulation** transports oxygen-poor, carbon dioxide-laden blood to the lungs for oxygenation and carbon dioxide unloading.

2. **Systemic Circulation** transports oxygenated blood from the left ventricle to all body tissues via the aorta and its branches.

3. **Coronary Circulation** - supplies oxygenated blood to the heart; its pattern is:
   
   * coronary arteries (origin: ascending aorta) ---> coronary capillaries ---> coronary veins ---> coronary sinus ---> right atrium

F. **Hemorrhage** and its effect on blood pressure and heartrate.
   (after you read about this in your textbook, summarize it here).

G. **Shock** - due to hypotension (low blood pressure) and its association to circulating (peripheral) blood flow problems.

1. **Some of the most usual causes for shock include:**

   a. body fluid loss (remember, blood is close to 50% water, and a loss of body fluids effects blood volume, pressure, etc.)

   b. heart problems - (ex.) cardiac output problems, cardiac damage

   c. blood loss itself (ex. - hemorrhaging)

2. **Some (but not all) noticeable symptoms which may be observed** (it depends on the individual and the severity of the shock).

   a. can have skin changes (usually becomes cool, wet, and has a color change)
b. can have disorientation or confusion
c. can have blood pH changes
d. can have urination rate changes
e. can have pulse changes
Chapter 4, The Respiratory System

Textbook Chapter: _____

A. Anatomy of the Respiratory System (six organs associated with external respiration: nose, pharynx, larynx, trachea, bronchi, and lungs).

1. NOSE
   a. External nose - the part protruding from the face; contains external nares (nostrils).
   b. Internal nose
      1.) nasal cavity within the skull; above the oral cavity (mouth) and anterior to the nasopharynx, through which it communicates via internal nares.
      2.) openings entering internal nose: paranasal sinus openings (frontal, maxillary, sphenoid, ethmoid) and nasolacrimal ducts
   c. bones and cartilage - maxillary, nasal, frontal, ethmoid (including the perpendicular plate), sphenoid, lacrimal, palatine, vomer, inferior nasal conchae, and hyaline cartilage
   d. nasal septum - hyaline cartilage, vomer, ethmoid (perpendicular plate), maxillae, and palatine
   e. vestibule - just inside the nostrils (anterior part of nasal cavity)
   f. conchae (or turbinate): (3 pairs) - superior and middle conchae (part of ethmoid bone), and the inferior conchae (a separate facial bone).
      * function: to swirl air, which: --------> stimulates olfactory sense, warms, humidifies, and filters air (via mucosal lining).
   g. Meatuses are grooved air passages between conchae.
   h. The nasal cavity is also involved in sound resonation (for speech).
2. **Pharynx (throat)**

   a. Originates **from** the internal nares and goes **to** the divided entrance into larynx/esophagus.

   b. **3 parts:**

      1.) **Nasopharynx** - posterior portion of nasal cavity; separated from oral cavity by the soft palate.

         a.) lined with pseudostratified ciliated epithelium.

         b.) **Pharyngeal tonsil (adenoid)** - lymphoid tissue on posterior wall.

         c.) **openings:**

             (1.) internal nares
             (2.) auditory (Eustachian) tubes from the middle ears

         d.) **function** - respiration

      2.) **Oropharynx** originates **from** the soft palate to the base of the tongue (at level of hyoid bone).

         a.) opening - **fauces** (archway between mouth and oropharynx)

         b.) lined with stratified squamous epithelium.

         c.) **Tonsils:**

             (1.) **Palatine tonsils** (posterior - lateral wall)
             (2.) **Lingual tonsil** (at base of tongue)

         d.) **functions** - respiration and digestive processes

      3.) **Laryngopharynx** is located between the hyoid bone and **entrance** to larynx/esophagus.

         a.) lined with stratified squamous epithelium.

         b.) **functions** - respiration and digestive processes
3. **Larynx (voice box)**
   
a. **from C₄,₅ to C₇**; connects laryngopharynx to trachea.

b. **functions** - prevent fluid/food particles from entering trachea during swallowing, allows air passage for breathing, and to produce sound.

c. **description** - consists of 9 cartilages:

1.) **unpaired cartilages (3)**
   
a.) **thyroid cartilage** (anterior part is called Adam's apple); absent posteriorly

b.) **epiglottis** - at base of posterior tongue
   * covers the **glottis** (laryngeal opening)

c.) **cricoid** - connects thyroid cartilage to trachea; expands posteriorly

2.) **paired cartilages (3 pairs = 6 total)**
   
a.) **arytenoid** - provides attachment for vocal cords; articulates with cricoid and corniculate cartilages.

b.) **corniculate**

c.) **cuneiform**

d. **contains vocal cords**

1.) **2 ventricular (vestibular) folds** - superior folds (also called **false vocal cords**); help prevent foreign objects from entering glottis.

2.) **2 vocal folds** - lower folds called **true vocal cords**; produce sound.

e. **muscles of the larynx** *(NOTE: review their names from lab models).*

1.) **extrinsic muscles (of the larynx):**
   
a.) belong to anterior neck muscles.

b.) stabilize the larynx.

c.) during swallowing, these raise the larynx.
2.) **intrinsic muscles (of the larynx):**
   a.) regulate tension and length of vocal folds.
   b.) open and close the glottis.

f. **Laryngospasm** - a sudden and involuntary closure of the laryngeal muscles.

4. **Trachea (windpipe) is:**
   a. 4 ½ inches long and approximately 1 inch in diameter.
   b. **anterior** to esophagus.
   c. **connects** larynx to primary bronchi.
   d. contains 16-20 rings of cartilage (absent posteriorly).
   e. divides into right and left **primary bronchi** at **carina** (a ridge).

f. **Heimlich maneuver (abdominal thrust)** - used for respiratory obstruction; one needs to be shown and trained on how to correctly do this procedure.

g. **Tracheostomy** - to bypass tracheal blockages via a tube.

h. **Tracheotomy** - surgically opening the trachea.

i. **Intubation** - tube is passed through mouth or nose down through the larynx into the trachea for air passage.

5. **Bronchi** (lined in pseudostratified ciliated columnar epithelium).
   a. Trachea divides in the **mediastinum** (at the carina) to form the **left and right primary bronchi**.
   b. These bronchi have supporting C-shaped hyaline cartilaginous rings.
   c. **right primary bronchus** (versus left):
      1.) larger diameter
      2.) more vertical
3.) odds favor that foreign objects inhaled will go to it (but not always)

d. **Primary bronchi divide into secondary bronchi;** there is one secondary bronchi for each lung lobe (therefore, there are 5 total).

e. **Secondary bronchi branch into tertiary bronchi.**

f. The branching continues into **bronchioles,** which continue to divide until they become **terminal bronchioles;** terminal bronchioles divide (branch) into **respiratory bronchioles,** which give air to **alveolar ducts** (these ducts communicate with **alveoli**).

1.) Eventually, the bronchioles lose the surrounding cartilage (allowing for dilation and constriction of the inner bronchial tree).

2.) Bronchioles are lined with cuboidal epithelium.

6. **Lungs (2)**

a. Divided into **lobes** (3 on the right, 2 on the left).

   * **Remember, a secondary bronchi enters each lobe.**

b. Lobes are divided into **18 bronchopulmonary segments** (10 on right; 8 on left); each of these segments is supplied by a **tertiary bronchus.**

c. They are lined with serous membrane (known as **pleura**).

   1.) **parietal pleura** - attached to the wall of the thoracic cavity

   2.) **visceral pleura** - covers the lungs

     * **Pleural cavity** - space between the pleura; has subatmospheric pressure.

d. Lungs extend from diaphragm to above the first rib.

   1.) **apex** - superior portion
2.) **costal surface** - against ribs

3.) **mediastinal surface** - toward the midline; cardiac notch - concavity on inferior portion of superior lobe of left lung

4.) **lung root** - bronchi, blood vessels, lymphatic vessels, nerves held together by pleura and connective tissue (located on medial lung); between T₅ (R) and T₆ (L)

5.) **hilus** - grooved, medial area of lung

6.) **base** - inferior portion resting on diaphragm

e. **Alveoli**

1.) the location of actual air exchange between the lung and blood.

2.) estimated 150 million alveoli/lung.

3.) **alveolar epithelium** - simple squamous epithelium

4.) special cells:
   a.) **alveolar macrophages** - phagocytize
   b.) **surfactant cells** - produce oily secretion which decreases surface tension (thus, keeping alveoli open).

f. **Respiratory Membrane of the Alveoli** (location of gas exchange)

1.) alveoli's lining: squamous epithelial cells

2.) blood capillary's endothelial cells lining

3.) fusion of #1's and #2's basement membranes

g. **2 arteries supply blood to the lung.**

1.) **Pulmonary arteries** - bring CO₂ to the lungs from the heart.

2.) **Bronchial arteries** (from thoracic aorta) - bring O₂ to bronchial tree and to lung tissue.
B. PHYSIOLOGY OF THE RESPIRATORY SYSTEM

1. Some important laws that pertain to respiratory physiology.

* Remember, gases naturally travel from high pressure to low pressure.

a. Boyle's Law

At a fixed temperature, the volume of confined gas varies inversely with the pressure (that is, when a container's size is decreased, the pressure inside it will increase).

b. Charles' Law

When the pressure remains constant, the volume of a gas is directly proportional to its absolute temperature (that is, if gases warm up, they expand and their pressures increase).

c. Dalton's Law (of Partial Pressure)

Each gas (in a mixture of gases) experts its own pressure as if all the other gases were not present (that is, each gas in the mixture exerts pressure in proportion to its percentage in the mixture); because each gas is only a partial portion of the mixture, each gas has a partial pressure ($P$). Total gas pressure equals the sum of all the partial gas pressures.

d. Henry's Law

The amount of gas that will dissolve in a liquid is proportional to the partial pressure ($P$) of that gas and its solubility coefficient. (Solubility coefficient refers to a gas's chemical and physical attraction for water). When pressure is doubled, twice as much gas passes into solution.

e. Law of diffusion

Gases naturally move from an area of higher pressure to an area of lesser pressure.

f. Bohr effect

Oxygen separates more readily from hemoglobin (hemoglobin loses affinity for oxygen) in an acid environment.
2. The Nervous System's effect on the respiratory system
   
a. **Voluntary breathing**: origin = cerebral cortex of brain sends signals via corticospinal tracts to the respiratory muscles.

   b. **Involuntary breathing**: origin = medulla oblongata of brain communicates via lateral and ventral white matter of spinal cord. The average adult breathing rates are usually listed between 12-21 breaths/minute, with 16 being the average.

   1.) Involuntary breathing is the **rhythmical breathing pattern**.

   2.) It is influenced by CO₂, pH, O₂, and chemicals.

   c. **apneustic center** (in pons) - stimulates inspiratory area of medulla (limits expiration)

   d. **pneumotaxic center** (in pons) - antagonizes apneustic center (limits inspiration)

   e. **central chemoreceptors** - in medulla

   f. **peripheral chemoreceptors** - in nodules associated with aorta and carotid arteries

      1.) **Aortic bodies** - in aortic arch; send sensory information to medulla via vagus (X).

      2.) **Carotid bodies** - in common carotid arteries; send sensory information to medulla via glossopharyngeal nerve (IX).

   g. **Sympathetic nervous system** - dilates bronchioles.

   h. **Parasympathetic nervous system** - constricts bronchioles.

3. **Inspiration is breathing in or inhalation**.

   a. In order to occur, lung air pressure must be lower than atmospheric pressure (760 mm Hg.); achieved via increasing lung volume.

   b. **The process of lowering lung pressure**: (refers to Boyle's Law).
1.) **muscles used during inspiration:**
   *a.) diaphragm (close to 75% of air movement)*
   *b.) external intercostal (elevate ribs)*
   c.) sternocleidomastoid (elevates sternum)
   d.) serratus anterior
   e.) scalenes (3 pairs) - elevate upper ribs.

| * major muscles used during quiet inspiration. |

2.) **Before inspiration,** intrapleural (intrathoracic) pressure is **756 mm. Hg.** (subatmospheric).

3.) The parietal pleura (lining thoracic cavity) is pulled out with inspiration (intrapleural pressure falls to **754 mm. Hg.**); parietal pleura pulls (via subatmospheric pressure) on visceral pleura (which is connected to lungs).

4.) Then the lungs are pulled out (expand).

5.) Intrapulmononic (alveolar) pressure drops from **760 mm. Hg.** to **758 mm. Hg.** (due to the pressure difference).

6.) Then the lungs inflate.

7.) **During forced inspiration,** intrapleural pressure can go to **several mm. Hg. less than 754 mm. Hg.**

8.) **pneumothorax** - atmospheric air (760 mm. Hg.) enters the pleural cavity (756 mm. Hg.); usually leads to the collapsing of the lung.

4. **EXPIRATION** is breathing out or exhaling.
   a. to occur, lung pressure must be **greater** than atmospheric pressure.
   b. **during quiet expiration,** no muscles are needed; it involves.
      1.) recoil of elastic tissue of lungs and stretched muscles becoming relaxed.
      2.) surface tension's inward pull.
c. This decrease in lung volume raises alveolar pressure to 763 mm. Hg. (compared to atmospheric pressure, which is 760 mm. Hg.); air is pushed out.

d. **Forced expiration** involves muscle contraction and can raise intrapulmonary (alveolar) pressure several mm. Hg. above quiet expiration readings. Muscles involved:

1.) internal intercostal
2.) transversus thoracis
3.) abdominal muscles
   a.) rectus abdominus
   b.) external oblique
   c.) internal oblique

5. **Gases (and their percentages) that compose that 760 mm. Hg. (at sea level) are as follows:**

   a. Nitrogen (N₂) = 78% - 79% (78.6% avg.).
   b. Oxygen (O₂) = 21%.
   c. Water (H₂O) Vapor = 0.50%.
   d. Carbon Dioxide (CO₂) = 0.04%.

6. **Therefore, the pressure (out of the 760 mm. Hg.) that each gas would exert would be:**

   a. (N₂) : 78.6% of 760 mm. Hg. = 597 mm. Hg.*
   b. (O₂) : 21% of 760 mm. Hg. = 160 mm. Hg.*
   c. (CO₂): 0.04% of 760 mm. Hg. = 0.3 mm. Hg.*
   d. (H₂O): 0.5% of 760 mm. Hg. = 3.7 mm. Hg.*

   * These are considered partial pressures (P); that is, each pressure given is that gas's contribution to the whole pressure (atmospheric pressure). Refer to **Dalton's Law (of Partial Pressure).**

7. **Atmospheric pressure (at sea level) is considered 760 mm. Hg. As one ascends (in altitude), there is a decrease in the atmospheric pressure of O₂.**

   a. **At 5000 ft. above sea level,** the atmospheric pressure falls to 619-620 mm. Hg. (= 619 mm. Hg. x 21% O₂ = 130 mm. Hg.).
b. **Below sea level**, atmospheric pressure increases by one atmosphere for every 33 ft. (at 33 ft. below sea level, atmospheric pressure = 2 x 760=1520 mm. Hg.).

8. **EXTERNAL AND INTERNAL RESPIRATION**

a. **EXTERNAL RESPIRATION** is the exchange of O₂ and CO₂ between the external environment and the blood.

1.) The partial pressure (P) readings associated with external respiration are:

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>pO₂</th>
<th>pCO₂</th>
<th>pH₂O</th>
<th>pN₂</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>(ALVEOLI)</td>
<td>105</td>
<td>40</td>
<td>47</td>
<td>568</td>
<td>760</td>
</tr>
<tr>
<td>(ARTERIAL BLOOD)</td>
<td>100 (105)</td>
<td>40</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* readings are in mm.Hg.

2.) **Factors** such as gas pressures, lung obstruction and disease, and breathing depths and rates can effect external respiration.

b. **Internal Respiration** is the exchange of O₂ and CO₂ between the blood and the body's cells (tissues).

1.) The partial pressure (p) readings associated with internal respiration are:

<table>
<thead>
<tr>
<th>(LOCATION)</th>
<th>(pO₂)</th>
<th>(p CO₂)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TISSUE</td>
<td>40</td>
<td>45</td>
</tr>
<tr>
<td>VENOUS BLOOD</td>
<td>40</td>
<td>45</td>
</tr>
</tbody>
</table>

* readings are in mm.Hg.

2.) **Oxyhemoglobin (HbO₂)**

a.) Oxygen is primarily carried in the blood bound to hemoglobin (e.g. - oxyhemoglobin or HbO₂; Av.=97%) A very small percent is carried in the plasma. (av. = 3%)

* 1 gm. hemoglobin binds 1.3 ml. of O₂.

Remember:

female: 12-16 gms. Hb/100 ml. blood
male: 13-18 gms. Hb/100 ml. blood*

b.) **Fetal hemoglobin** binds O₂ more efficiently than regular hemoglobin. Therefore, it carries more O₂.

c.) The amount of binding of O₂ to hemoglobin depends on:

1.) **the percent availability of oxygen.**
   - *low blood oxygen (ex. - anemia)*; hemoglobin releases more O₂
   - *more O₂ availability*, more HbO₂ occurs (within limits)

2.) **the pH environment** (see explanation of the Bohr effect).
   - *As pH decreases (more acidic)*, hemoglobin releases more O₂.

3.) **temperature** (within a specific limit or range).
   - *As temperature increases*, the amount of O₂ released from hemoglobin increases.

4.) **BPG (or DPG) levels**
   - *It is substance formed during glycolysis in RBCs. If its level increases*, hemoglobin releases more O₂.

d.) When the human body is resting, most of the oxygen that is available to the tissues is **not** needed and remains in the bloodstream, bound to the RBCs.

   - *This means that when humans need a lot of oxygen (ex. - exercise), it is available for use.

e.) **Hypoxia** - Oxygen deficiency (usually refers to oxygen deficiency at the tissue level).

3.) **CO₂ TRANSPORT**

a.) \[ \text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3 \rightarrow \text{HCO}_3^- + \text{H}^+ \]
   - (carbonic  (bicarbonate)  acid)
b.) The majority (approximately 70%) of CO₂ is converted to bicarbonate ions (HCO₃⁻) in the plasma; this maintains a balance in the ions between the plasma and RBCs.

c.) **Approximately 23%** of CO₂ combines with hemoglobin (carbaminohemoglobin or HbCO₂).

* **Haldane effect** - less CO₂ binds to hemoglobin in the presence of O₂.

d.) **Approximately 7%** of CO₂ is dissolved in plasma.

e.) As the CO₂ (produced by our tissues) is picked up by the bloodstream's capillaries, the RBCs that carry CO₂ convert it (via an enzyme) to carbonic acid. Once the CO₂ reaches the lungs, carbonic acid is converted to CO₂ so that it might be exhaled. CO₂ and carbonic acid are involved in maintaining blood's pH (7.35-7.45).

f.) A blood pH below 7.35 is **acidosis**; a blood pH above 7.45 is **alkalosis**.

1.) **Respiratory Acidosis** (↑ in CO₂ and a ↓ in blood pH).

* It is due to several causes. Two of the causes are: decreased or stopped ventilation, and suppression of breathing (medication, asthma, bronchitis, stroke, etc.).

2.) **Respiratory Alkalosis** (↓ in CO₂ and an ↑ in blood pH).

* It is due to several causes. Two of the causes are: hyperventilation (increased rate) and/or depth of breathing), and reaction to medication.

---

g.) Respiration can also be affected by metabolic disorders.
(1.) **Metabolic Acidosis** (↑ in H⁺, therefore ↓ in pH) causes an increase in ventilation. It could be due to several causes, four of which are: renal disease, acid production increase due to diabetes mellitus, hyperthyroidism, and alcoholism.

(2.) **Metabolic Alkalosis** (↓ in H⁺, therefore an ↑ in pH) causes decreased breathing. There are several causes, two of which are: vomiting and excessive ingestion of alkali (base) substances.

c. **Summary of % O₂ and CO₂:**

<table>
<thead>
<tr>
<th></th>
<th>O₂</th>
<th>CO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inspired Air</strong></td>
<td>21%-23%</td>
<td>0.04%</td>
</tr>
<tr>
<td><strong>Alveolar Air</strong></td>
<td>14%</td>
<td>5.5%</td>
</tr>
<tr>
<td><strong>Expired Air</strong></td>
<td>16%</td>
<td>4.5%</td>
</tr>
</tbody>
</table>

9. **Control of Respiratory Centers**

a. Carbon dioxide is the major regulator of respiration.

1.) Increased blood carbon dioxide content, (up to a certain level) stimulates respiration; above this level, depresses respiration.

2.) Decreased blood carbon dioxide decreases respiration.

b. **Oxygen content of blood influences respiratory center**

1.) Decreased blood O₂, (down to a certain level) stimulates respirations and below this critical level, it depresses them.

2.) O₂ is in control of respiration but is nonoperative under usual conditions.

c. **Miscellaneous factors which influence the respiratory center:** body temperature, pain,
emotions, etc.

10. LUNG VOLUMES CAPACITIES AND ASSOCIATED DEFINITIONS

**NOTE:** The average range of breaths/minutes varies with so many factors; however the range is often given as 12/13 – 20/21 breaths/minute with the average being approximately 16.

<table>
<thead>
<tr>
<th>DEFINITION</th>
<th>MALE</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) <strong>TIDAL VOLUME</strong> - AMOUNT OF AIR MOVED</td>
<td>500 ml.</td>
</tr>
<tr>
<td>(IN &amp; OUT OF LUNGS WITH EACH</td>
<td>* this is usually</td>
</tr>
<tr>
<td>RESPIRATORY CYCLE (EACH NORMAL</td>
<td>the same for</td>
</tr>
<tr>
<td>BREATH)</td>
<td>females and males</td>
</tr>
<tr>
<td>b) <strong>INSPIRATORY RESERVE</strong> - VOLUME OF AIR</td>
<td>3000 ml. – 3100 ml.</td>
</tr>
<tr>
<td>(AFTER TIDAL VOLUME) MAXIMALLY INHALED</td>
<td></td>
</tr>
<tr>
<td>c) <strong>EXPIRATORY RESERVE</strong> - VOLUME OF AIR</td>
<td>1100 ml. – 1200 ml.</td>
</tr>
<tr>
<td>(AFTER TIDAL VOLUME) MAXIMALLY EXHALED</td>
<td></td>
</tr>
<tr>
<td>d) <strong>VITAL CAPACITY</strong> - INSPIRATORY RESERVE,</td>
<td>4600 ml. – 4800 ml.</td>
</tr>
<tr>
<td>TIDAL VOLUME, AND EXPIRATORY RESERVE</td>
<td></td>
</tr>
<tr>
<td>e) <strong>RESIDUAL VOLUME</strong> - AMOUNT LEFT IN LUNG</td>
<td>1200 ml.</td>
</tr>
<tr>
<td>AFTER EXPIRATORY RESERVE</td>
<td></td>
</tr>
<tr>
<td>f) <strong>TOTAL LUNG CAPACITY</strong> - VITAL CAPACITY</td>
<td>5800 ml. – 6000 ml.</td>
</tr>
<tr>
<td>PLUS RESIDUAL VOLUME</td>
<td></td>
</tr>
</tbody>
</table>

* Women generally have 20% - 25% less volumes and capacities than men. However, Tidal Volume is usually the same for both men and women.

* Athletes and larger people can have larger numbers than in the above chart.

11. TERMS ASSOCIATED WITH RESPIRATION

a. NON-RESPIRATORY AIR MOVEMENTS

1.) **coughing** - Deep breath is taken in, the glottis is closed, and air is forced against the closure. Suddenly, the glottis is opened and a blast of air passes upward.

   * **function:** clears lower respiratory passages

2.) **sneezing** - Same as coughing, except air moving upward is directed into the nasal cavity by
closing the opening between the oral cavity and pharynx

* function: clears upper respiratory passages

3.) **yawning** - Deep breath is taken in.

* function: ventilates a large proportion of the alveoli and aids in oxygenation of the blood

4.) **hiccupping** - Diaphragm contracts spasmodically while the glottis is closed.

b. **Some disorders involving gas exchange**

1.) **Pneumonia** is a term that is used to describe conditions in which the alveoli become filled with fluids and blood cells. Pneumonia is usually due to an acute infection of bacterial organisms called pneumococci, or to the presence of certain viruses.

2.) **Tuberculosis** is a bacterial disease that is caused by the *tubercle bacillus*. In this condition, fibrous connective tissue develops around the sites of infection, creating structures called tubercles.

3.) **Atelectasis** refers to the collapse of a lung or some part of it, together with the collapse of the blood vessels that supply the affected region.

4.) **Hyaline Membrane Disease**, which was discussed earlier, is a special form of atelectasis that is characterized by the collapse of alveoli in an infant's lungs due to lack of surfactant.

5.) **SOME BREATHING DISORDERS:**

Although respiratory disorders are caused by a variety of factors, some result from inadequate ventilation. This group includes paralysis of carious breathing muscle, bronchial asthma, emphysema and lung cancer.
a.) **asthma**: involuntary contraction of the bronchiolar smooth muscle (usually due to allergic reaction to foreign substance or hypersensitivity to irritants in the air); causes difficulty in expiration.

b.) **emphysema**: is a progressive, degenerative disease characterized by the destruction of many alveolar walls; difficulty in expiration causing the alveoli to be overstretched with unexpired air.

c.) **lung cancer**: like other cancers, it involves an uncontrolled growth of abnormal cells.

c. **BREATHING TERMS:**

1.) **Eupnea** is normal breathing.

2.) **Apnea** is not breathing.

3.) **Dyspnea** is difficult or painful breathing/irregular breathing

4.) **Cheyene Stokes** – is the most common abnormal breathing pattern prior to death. It is characterized by alternate periods of apnea and dyspnea. Sometimes known as the "death rattle" pattern of breathing.
A. Digestion: - the mechanical and chemical processes that prepare food for utilization by the body.

B. Organization:

NOTE: from mouth to anus is called **ALIMENTARY CANAL**; it averages 29-30 feet long in adults

1. **MAIN ORGANS OF DIGESTION:**
   a. Mouth
   b. Pharynx (oropharynx and laryngopharynx)
   c. Esophagus
   d. Stomach
   e. Small intestine
   f. Large intestine

2. **ACCESSORY ORGANS OF DIGESTION:**
   a. Teeth
   b. Salivary glands
   c. Tongue
   d. Gallbladder
   e. Pancreas
   f. Liver
   h. Vermiform Appendix

3. **COATS OF DIGESTIVE TRACT:**
   a. **Fibroserous** (serosa)
      1.) Purpose is protection.
      2.) Outer coat
      3.) Serous membrane
   b. **Muscular**
      1.) Purpose is movement.
      2.) Composed of smooth muscle
      3.) Longitudinal & circular muscle

   **Exception:** The stomach has (3 layers):
a.) Longitudinal
b.) Circular (transverse)
c.) Oblique

c. **Submucous**
   1.) Purpose is vascular layer (blood vessels).
   2.) Absorption takes place here.
   3.) Contains a lot of the glands needed for digestion.

d. **Mucous**
   1.) layer next to the food
   2.) Purpose is secretion of mucus.
   3.) Some areas have villi and microvilli.

<table>
<thead>
<tr>
<th>Organs</th>
<th>Mechanical Process</th>
<th>Nature of Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mouth (and teeth)</td>
<td>Mastication</td>
<td>Chewing movements tongue reduce size of food particles &amp; mix them with saliva.</td>
</tr>
<tr>
<td>Pharynx</td>
<td>Deglutition</td>
<td>Swallowing movement of food from mouth to stomach</td>
</tr>
<tr>
<td>Esophagus</td>
<td>Mild Peristalsis</td>
<td>Wormlike movements that squeeze food downward in tract; constricted ring forms first in one section &amp; then next, etc., causing waves of contraction to spread throughout canal</td>
</tr>
<tr>
<td>Stomach</td>
<td>Churning</td>
<td>Forward and backward movement of gastric contents; peristalsis propels it forward; closed pyloric sphincter deflects it backward</td>
</tr>
<tr>
<td>Small Intestine</td>
<td>Peristalsis</td>
<td>Moves material through stomach and at intervals into duodenum. Peristalsis: a propulsive movement. It has been described as a wave of constriction, preceded by wave of relaxation, that passes down the gut, pushing small amount of material before it, but in practice the relaxation phase is often not very apparent.</td>
</tr>
<tr>
<td>Large Intestine</td>
<td>Haustral Churning</td>
<td>Churning movements within haustral sacs</td>
</tr>
<tr>
<td>Descending Colon</td>
<td>Massive Peristalsis</td>
<td>Entire contents moved into sigmoid colon &amp; rectum; usually occurs after a meal.</td>
</tr>
<tr>
<td>Rectum</td>
<td>Defecation</td>
<td>Emptying of rectum, so-called bowel movement.</td>
</tr>
</tbody>
</table>

**C. ANATOMY OF THE MOUTH**

1. **Cheeks** represent the sidewalls of the mouth.
   
a. cheeks and lips (labia) have a core of skeletal muscle covered externally by skin.
   b. The orbicularis oris muscle forms the bulk of the fleshy lips.
2. **Tongue** composes most of the floor of the mouth and is made of skeletal muscle covered with mucous membrane.
   
a. **Papillae** are the rough elevations on the tongue's surface.
   
   1.) *filiform papillae*
   
   2.) *fungiform papillae*
   
   3.) *circumvallate papillae*

   b. **Taste buds** are dendrites on the papillae.

   c. **Frenulum** is a fold of mucous membrane in the midline of the undersurface of the tongue that helps to anchor the tongue to the floor of the mouth.

3. **Hard & Soft Palates** form the roof of the mouth.

4. **Fauces** is the opening (the arch) which leads from the mouth into the oropharynx.

5. **Uvula** is the small cone-shaped process at the posterior soft palate that closes off the internal nares during deglutition.

6. **Salivary Glands:** (pairs)
   
a. **Parotids** - anterior and inferior to the ear

   b. **submandibular (submaxillary)** - inferior part of floor of mouth

   c. **Sublingual** - inferior part of floor of mouth (under tongue)

7. **Teeth:**
   
a. **Deciduous teeth** are also called *baby teeth, primary teeth, or milk teeth.*

   1.) There are 20 deciduous teeth.

   2.) **Classification:**

   a.) 4 central incisors
   
   b.) 4 lateral incisors
   
   c.) 4 cuspids or canines
   
   d.) 8 molars

   b. **Permanent teeth** - those that replace baby teeth.

   1.) There are 32 permanent teeth *(if one has all*
his/her wisdom teeth).

2.) **Classification:**

   a.) 4 central incisors - cutting
   b.) 4 lateral incisors - cutting
   c.) 4 cuspids or canines - cutting, tearing, shreading
   d.) 8 premolars (bicuspids) - crushing
   e.) 8 to 12 molars (4 are wisdom teeth) - crushing and grinding

3.) **Anatomy of the tooth.**

   a.) **Crown** is the portion above the gum.
   b.) **Root** is the portion below the gum.
   c.) **Neck** - between the crown and root.
   d.) **Gingiva** is the same as gum.
   e.) **Enamel** is the outer white surface (the hardest portion of the tooth).
   f.) **Dentin** is a bonelike material that forms most of the tooth.
   g.) **Pulp (Pulp cavity)** is a combination of several soft tissues such as connective tissue, blood vessels and nerve fibers.
   h.) **Cementum** - outer layer of root

D. **Chemical Activity of Mouth - SECRETION OF SALIVA.**

1. **Saliva** is a moistening, cleaning, and lubricating solution that is constantly secreted in the mouth; it binds food particles together; it begins the digestion of starch; it has enzyme (lipase) to attach emulsified fat.

2. **Saliva** is 99% water and the rest are electrolytes like sodium, potassium, chloride, bicarbonate and others.

3. The mucus in saliva creates an atmosphere for food digestion.

4. Secretion of saliva is controlled by parasympathetic nerves and may stop during dehydration to conserve water. When water is restored, the salivation continues.

5. Begins the digestion of starch (polysaccharide) with **amylase**, and begins the digestion of emulsified fat with **lipase**.

6. Saliva may not always contain the enzyme **ptyalin** (amylase of the mouth). **Ptyalin** is in the saliva when you:

   a. eat food
   b. imagine food
   c. smell food
   d. have other food recognition activities
7. When Ptyalin is swallowed and reaches the stomach, it stimulates the parietal cells to release hydrochloric acid (HCL).

8. **SALIVARY GLANDS:**
   a. **PAROTID GLANDS**
      1.) are located anterior and inferior to the ear.
      2.) secrete watery mucous and a large amount of ptyalin.
      3.) The parotid duct is also known as Stenson's duct
   b. **SUBMANDIBULAR (SUBMAXILLARY) GLANDS.**
      1.) are in the inferior floor of mouth.
      2.) secrete semi-thick mucous with a reasonable amount of ptyalin.
      3.) The duct is known as Wharton's duct
   c. **SUBLINGUAL GLANDS**
      1.) are in the inferior part of floor of mouth (under tongue).
      2.) secrete thicker mucous and a small amount of ptyalin.

E. **Esophagus**
1. The esophagus is a collapsible tube about 10 inches long.
2. It extends from the pharynx to the stomach, piercing the diaphragm in its descent from the thoracic cavity to the abdominal cavity.
3. It lies posterior to the trachea and heart.
4. It passes a **bolus** into the stomach by peristalsis.
5. Slants left.
6. **pH:** alkaline (base)

F. **STOMACH**
1. Size varies according to many factors.
2. It lies in the upper part of the abdominal cavity, below the diaphragm.
3. **Divisions:**
   a. **Fundus** - the enlarged portion to the left and
above the opening of the esophagus.

b. **Cardiac** - the portion just after the cardiac sphincter.

c. **Body** - central part of the stomach.

d. **Pylorus** - lower portion.

4. **Curves:**

a. The superior right border of the stomach presents what is known as the lesser curvature.

b. The inferior border presents the greater curvature.

5. **Sphincter Muscles:**

a. **Cardiac Sphincter** - guards the opening of the esophagus into the stomach.

b. **Pyloric Sphincter** - guards the opening from the pyloric portion of the stomach into the first part of the small intestine (the duodenum).

6. **Glands:**

a. **Epithelial cells** produce mucus to protect the stomach during digestion.

b. **Parietal cells** produce hydrochloric acid (HCL).

1.) This will lower the pH of the stomach which allows the enzyme to be released. **Zymogen** or **chief cells** produce pepsinogen, a proenzyme. When pH is lowered, pepsinogen is converted to **pepsin**, an active enzyme that will digest proteins.

2.) Pepsinogen (proenzyme) + HCL (catalyst & low pH) ---> Pepsin (an enzyme) ---> digestion of proteins.

c. **Chief (zymogen) cells** secrete enzymes.

7. **Functions:**

a. It serves as a reservoir, storing food until it can be partially digested and moved farther along the gastrointestinal tract.

b. It secretes **gastric juice**, one of the juices whose
enzymes digest food.

c. Through contractions of its muscular coat, it churns the food, breaking it into small particles and mixing them well with the gastric juices. In due time, it moves the gastric contents into the duodenum.

d. It secretes the intrinsic factor.

e. It carries on a limited amount of absorption of water, alcohol, and certain drugs.

f. After the bolus has been processed by the stomach, it is called chyme.

8. Digestion:

a. Consist of the conversion of proteins into peptides by pepsin; some digestion of emulsified fat by lipase.

b. Gastric secretion is regulated by nervous and hormonal mechanisms.

c. Gastric emptying is stimulated in response to distension, and stomach gastrin released in response to the presence of certain types of food.

9. Ligaments

a. greater omentum - connects stomach to transverse colon.

b. lesser omentum - connects liver to stomach and duodenum.

G. PANCREAS

1. Size, shape and location

a. Larger in men than in women.

b. Shaped something like a fish.

c. Its head lies in the C-shaped curve of the duodenum; its tail goes toward the spleen.

2. Structure - similar to salivary glands.

a. Divided into lobes and lobules.

b. Pancreatic cells pour their secretions into a pancreatic duct that runs the length of the gland and empties into the duodenum at the greater duodenal papilla (the opening is called the ampulla of Vater).

c. Clusters of cells (not connected with any ducts) lie between pancreatic cells; these clusters are called islets or islands of Langerhans.
3. Functions:
   a. **Secretes pancreatic juice (pancreatin)**
      1.) **Trypsin**, **chymotrypsin**, and **carboxypeptidase** digest protein.
      2.) Pancreatic **lipase** (steapsin) hydrolyses neutral fats (emulsified fat).
      3.) Pancreatic **amylase** (amylopsin) breaks down all carbohydrates (except cellulose) to disaccharides.
      4.) **Esterase** - breaks down cholesterol esters.
      5.) **Ribonuclease** and **deoxyribonuclease** - split the nucleic acids of RNA and DNA into free nucleotides.
      6.) **Enterokinase** - all proteolytic enzymes are secreted in an inactive form. Enterokinase in the duodenum activates the proteolytic enzymes.
   
   b. **Secretes hormones**
      1.) **Beta cells** of islands of Langerhans secrete **insulin** (which **lower** blood sugar level).
      2.) **Alpha cells** of islands of Langerhans secrete **glucagon** (which **raises** blood sugar level).

H. Liver

1. **Location and size**
   a. Occupies most of right hypochondrium and part of epigastrium.
   b. Largest gland in the body.
   c. **Falciform ligament** anchors the liver to the diaphragm.

2. **Lobes**
   a. **Right lobe**, subdivided into three smaller lobes: right lobe proper, caudate, and quadrate.
   b. Left lobe.
   c. Lobes divided into lobules by blood vessels and fibrous partitions.

3. **Ducts**
   a. **Two hepatic ducts** from liver form the **common hepatic duct**.
   b. Gallbladder's duct is the **cystic duct**.
   c. **Common bile duct** formed from the union of the common hepatic duct and the cystic duct; opens into duodenum at **ampulla of Vater** (duodenal papilla).

4. **Functions:**
a. **Produces bile**

1.) Consists of 97% water, bile salts, bile pigments (bilirubin), cholesterol, electrolytes and lecithin.

2.) Only the bile salts and the phospholipids aid in digestion.

3.) **Bile** is a yellowish-green, watery solution which breaks down unemulsified fat into emulsified fat.

   * **NOTE:** Bile has no enzymes in it.

b. It plays an essential role in the metabolism of carbohydrates, proteins, and fats.

1.) **Glycogenesis** - glucose converted to human starch (glycogen).

2.) **Glycogenolysis** - glycogen converted to glucose.

3.) **Gluconeogenesis** - fats and proteins converted to glucose.

4.) **Ketogenesis** - making ketone bodies from fats.
   a) Fatty acids of fats make ketones.
   b) Fatty acids of proteins make glucose.
   c) Here is the explanation why dieting often does not work for losing weight.

5.) **Lipogenesis** - making fats from foods.

c. Synthesizes various blood proteins.

d. Assimilates foodstuff in the body.

e. Filters blood of its wastes.

f. Stores iron and certain vitamins.

g. Converts excess amino acids to fatty acids and urea.

h. Detoxifies.

---

I. **Gallbladder**

1. **Size, shape, and location**

a. Approximately the size and shape of a small pear.

b. It lies on the undersurface of the liver.

2. **Structure** - It is a sac of smooth muscle with a mucous lining arranged in rugae.
3. **Functions:**
   a. Concentrates and stores bile.
   b. During digestion, ejects bile into duodenum under the influence of **cholecystokinin (CCK) (a hormone).**

4. **Cholelithiasis** - gallstones

J. **Small Intestine**

1. **Characteristics**
   a. Approximately 1 inch in diameter & 21 feet in length.
   b. Its coiled loops fill most of the abdominal cavity.
   c. It contains **plicae circularis.**
   d. **Lieberkuhn cells** secrete enzymes.
   e. Because the enzymes kill bacteria, the small intestine is generally considered sterile.

2. **Divisions**
   a. **Duodenum** - about 1" in diameter.
      1.) First 12-14 inches of small intestine.
      2.) Common bile duct & pancreatic duct unite in duodenum at the ampulla of Vater.
      3.) Produces **proteases, lipases, amylase,** and double sugar(disaccharide) enzymes (**Maltase, Sucrase, Lactase**).
      4.) Proteins are digested to amino acids.
      5.) Triglycerides are digested to fatty acids and glycerol.
      6.) Carbohydrates are digested to monosaccharides (ex. glucose, fructose, galactose).
      7.) DUODENUM ENDS AT THE LIGAMENT OF TRIETZ
   b. **Jejunum**
      1.) Constitutes about 2.2 m (7.5 ft) of small intestine.
      2.) Longer than the duodenum but shorter than the ileum.
      3.) Involved in absorption; most of foodproducts enter the bloodstream through the wall of the jejunum.
   c. **Ileum**
      1.) Approximately 12 ft. in length.
2.) No definite division between jejunum and ileum.
3.) Longest portion of small intestine.
4.) Ileum ends in the ileocecal valve.
5.) Remainder of food products enter bloodstream through the wall of the ileum

K. Large Intestine

1. Size
   a. Approximately 2.5 inches in diameter.
   b. 5 to 6 feet in length.

2. Divisions
   a. Cecum - beginning of large intestine and is located in the lower right quadrant. Vermiform appendix is attached to the cecum.
   b. Colon (4 divisions)
      1.) Ascending Colon - on the right side; from the cecum to the hepatic flexure.
      2.) Transverse Colon - connected by the greater omentum to the stomach; from the hepatic flexure to the splenic flexure.
      3.) Descending Colon - on the left side; from the splenic flexure to the sigmoid colon
      4.) Sigmoid Colon - lower left quadrant; when it crosses the pelvic brim (around S3) it becomes the rectum.
   c. Rectum
   d. Anus

3. Special Structures
   a. haustra
   b. taenia coli (smooth muscle)

4. Functions:
   a. Reabsorption of water, mineral salts, and vitamins.
   b. Elimination of digestive wastes.
   c. No enzymatic digestion and no villi.
   d. The last stages of chemical digestion occur in the large intestine through bacterial (rather than enzymatic) action. Substances are further broken down and some vitamins are synthesized by normal flora.
   e. Defecation
      1.) It is the elimination of feces from the large
intestine.

2.) Defecation is a reflex action aided by voluntary contractions of the diaphragm and abdominal muscles.

L. Vermiform Appendix

1. Size, shape, and location.
   a. It is about the size and shape of a large worm.
   b. It is a blind-end tube at the distal end of the cecum (in right, lower quadrant)

2. Structure - similar to the rest of the intestine; it has a lymphatic component.
<table>
<thead>
<tr>
<th>LOCATION</th>
<th>CARBOHYDRATES</th>
<th>FATS</th>
<th>PROTEIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOUTH (SALIVA)</td>
<td>POLYSACCHARIDE (STARCH)</td>
<td>EMUL. FAT</td>
<td></td>
</tr>
<tr>
<td></td>
<td>AMYLASE (PTYALIN)</td>
<td>LIPASE</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DISSACHARIDE</td>
<td>FATTY ACIDS &amp; GLYCEROL</td>
<td></td>
</tr>
<tr>
<td>STOMACH</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CHIEF/ZYMOGEN CELLS</td>
<td>very small amount of amylase; does not do well in an acid environment</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>EMULSIFIED FAT</td>
<td>PROTEIN</td>
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<td></td>
<td>LIPASE</td>
<td>PEPisin</td>
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<td></td>
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<td>FATTY ACIDS &amp; GLYCEROL</td>
<td>SMALLER PROTEINS</td>
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<td>MILK PROTEIN</td>
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<td>CURDLE</td>
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<tr>
<td>PANCREAS (ACINI CELLS)</td>
<td>AMYLASE POLY -------&gt; DISSAC.</td>
<td>EMULSIFIED FAT</td>
<td>PROTEIN</td>
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<td>LIPASE</td>
<td>PROTEASES</td>
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<td>F.A.+ GLYCEROL</td>
<td>SMALLER PROTEINS</td>
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<td></td>
<td></td>
<td></td>
<td>+ AMINO ACIDS</td>
</tr>
<tr>
<td>SMALL INTESTINE</td>
<td>AMYLASE POLY. -------&gt; DISSAC.</td>
<td>EMULSIFIED FAT</td>
<td>PROTEIN</td>
</tr>
<tr>
<td>LIEBERKUHN CELLS</td>
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<td>LIPASE</td>
<td>PROTEASES</td>
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<td></td>
<td>SUCRASE SUCROSE -------&gt; M</td>
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<td></td>
<td>LACTASE N LACTOSE -------&gt; O</td>
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<td>S. MALTOSE MALTOSE -------&gt;</td>
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</tbody>
</table>
Textbook Chapter: Metabolism

1. Definitions:

   1. **Basal metabolic rate**: The rate of metabolism measured under standard conditions; rate at which a quiet, resting, fasting body breaks down nutrients to liberate energy.

   2. **Metabolism**: the sum of all the chemical reactions in the body.

2. Metabolism:

   1. Two categories:

      1. **Anabolism**: metabolic reactions that consume energy and construct more complex molecules from simpler ones. These reactions are performed for growth, repair, maintenance and production of secretions.

      2. **Catabolism**: metabolic reactions that produces energy and break down complex molecules into simpler ones. These reactions are performed to provide energy for body function.

3. Nutrients

   1. **Nutrient**: an ingested substance needed by the body for growth, maintenance or repair.

   2. Six categories:

      1. Carbohydrates
      2. Proteins
      3. Lipids
      4. Vitamins
      5. Minerals
      6. Water
4. **Carbohydrates (a review):**

1. **Monosaccharides** (simple sugars) - the carbohydrate unit used to form disaccharides and monosaccharides; composed of 3-7 carbon atoms; the most common formula is $C_6H_{12}O_6$, and examples are glucose, fructose, and galactose.

![Structural formula of glucose, galactose, and fructose](image)

2. **Disaccharides** (double sugars) - a group of carbohydrates with the common formula of $C_{12}H_{22}O_{11}$; each disaccharide is composed of two monosaccharides.

   1. **Sucrose** or table sugar or cane sugar (glucose and fructose),
   2. **Maltose** or grain sugar (glucose and glucose)
   3. **Lactose** or milk sugar (glucose and galactose)

3. **Polysaccharides** - a group of carbohydrates composed of more than three molecules of monosaccharides

   1. Starch
   2. Glycogen: ‘animal starch’ found in liver and muscle cells
5. **Carbohydrate Catabolism:**

1. **Glucose catabolism**

   1. **Cellular respiration overview:**

      1. Catabolism of carbohydrates yields 4 kcals of energy per gram
      2. Three main steps:

         1. Glycolysis
         2. Kreb’s Cycle, also called the citric acid cycle and the mitochondrial matrix reactions
         3. Electron transport chain also known as the mitochondrial membrane reactions

   2. **Glycolysis:**

      1. Series of reactions that breakdown a glucose molecule (containing 6 carbon atoms) to 2 molecules of pyruvate (each containing 3 carbon atoms)

      (NOTE: pyruvate is the negative ion of pyruvic acid)

      2. There is a net gain of 2 ATP molecules for each glucose converted to pyruvate.

      3. **Steps in glycolysis:**

         1. Phosphorylation of glucose requires an ATP molecule

            phosphorylated glucose cannot diffuse out of the cell

            maintains a low concentration of glucose in the cell so that more glucose will diffuse into the cell

         2. Re-arrangement of glucose 6-phosphate to fructose 6-phosphate
3. Phosphorylation to form fructose 1,6-biphosphate
   1. requires an ATP molecule
   2. prevents the 2 phosphorylated halves to diffuse out of the cell
4. Cleavage into 2 molecules of glyceraldehyde 3-phosphate (G3P), also called phosphoglyceraldehyde (PGAL)
5. Oxidation (loss of electrons) and addition of phosphate group
   1. 2 hydrogen atoms and one proton are lost from the PGAL and picked up by NAD$^+$ to form NADH + H$^+$
6. Dephosphorylation
   1. Phosphate is removed from one end of the molecule, then the other and added to ADP to form 2 ATP molecules
   2. 2 molecules of pyruvic acid (pyruvate) are formed
7. Glycolysis overall reaction:
   Glucose ($C_6H_{12}O_6$) + 2 ATP + 2 NAD$^+$ + 2 $P_i$ --> 2 pyruvate ($C_3H_4O_3$) + 2 NADH + 2 H$^+$ + 4 ATP
3. Fermentation:
   1. Anaerobic conditions: If oxygen is NOT present upon the completion of glycolysis, pyruvic acid will be converted to lactic acid.
   2. This process occurs in the cytoplasm, mostly of muscles cells.
      Lactic acid causes soreness and burning in the muscles if
allowed to remain in the cells.

3. Fermentation occurs to facilitate the production of the 2 ATP molecules produced during glycolysis.

4. Conversion of pyruvic acid to lactic acid regenerates NAD\(^+\), which is necessary for glycolysis to occur.

5. When oxygen becomes available, lactic acid can be converted back to pyruvic acid and aerobic respiration can continue.

6. Performing a proper ‘cool down’ after running or working out will allow the muscle cells to fill with oxygen, and convert the lactic acid to pyruvic acid, thus preventing muscle soreness.

7. Fermentation is the only mechanism available to bacteria and other simple organisms.

4. Conversion of pyruvate to Acetyl-CoA

1. Three processes occur to prepare each pyruvic acid molecule to enter the citric acid cycle:

2. CO\(_2\) is removed (decarboxylation) forming a molecule with 2 carbon atoms.

3. NAD\(^+\) removes a hydrogen atom forming another NADH\(^+\) H\(^+\) and an acetyl group (acetic acid).

4. Coenzyme A binds to the acetyl group forming acetyl-CoA

5. The citric acid cycle

1. Also known as the tricarboxylic acid cycle (TCA), the Krebs cycle, and the mitochondrial matrix reactions because it occurs in the mitochondrial matrix (the fluid inside the mitochondria)
2. Series of reactions that begin with acetyl-CoA, a molecule with 2 carbon atoms.

3. Hydrogen atoms are removed and added to the coenzymes NAD$^+$ and FAD.

4. Decarboxylation occurs, removing the remaining carbon atoms.

5. This is a ‘cycle’ because the initial molecule (oxaloacetate) that reacts with acetyl-CoA is regenerated in the process. In this way, the cycle can occur over and over again.

6. Summary of steps in the citric acid cycle:
   1. Acetyl-CoA (2 carbons) reacts with oxaloacetate (4 carbons), forming citric acid (6 carbons) and releasing the CoA.
   2. Water is removed and the molecule is rearranged, but still has 6 carbons.
   3. NAD$^+$ accepts hydrogen atoms forming NADH + H$^+$
   4. CO$_2$ is removed (decarboxylation) forming a molecule with 5 carbon atoms.
   5. NAD$^+$ accepts hydrogen atoms forming NADH + H$^+$
   6. CO$_2$ is removed (decarboxylation) forming a molecule with 4 carbon atoms.
   7. Some of the energy in the 4 carbon molecule is released to form GTP which can then be converted to ATP.
   8. Two hydrogen atoms are removed by FAD to form FADH$_2$.
   9. Water is added.
   10. NAD$^+$ accepts hydrogen atoms forming NADH + H$^+$,
regenerating oxaloacetate (4 carbons).

7. The citric acid cycle occurs twice for each glucose molecule catabolized.

8. All the carbons remaining from the original glucose have been released as CO₂.

9. The energy from the glucose is now in the form of ATP or is contained in the coenzymes NADH + H⁺ and FADH₂.

10. Citric acid cycle overall reaction, including conversion to acetyl-CoA:

   2 pyruvate + 2 ADP + 2 Pᵢ + 8 NAD⁺ + 2 FAD + 6H₂O → 6 CO₂ + 2 ATP + 8 NADH + 8 H⁺ + 2 FADH₂

6. The electron transport chain

1. This series of oxidation-reduction reactions occurs utilizing molecules bound to the inner membranes of the mitochondria.

   Members of the chain are:

   1. Flavin mononucleotide (FMN)
   2. Iron-sulfur protein (Fe-S) (2 locations in the chain)
   3. Coenzyme Q (CoQ)
   4. Copper (Cu)
   5. 5 Cytochromes
      cytochrome b (cyt b)
      cytochrome c₁ (cyt c₁)
      cytochrome c (cyt c)
      cytochrome a (cyt a)
      cytochrome a₃ (cyt a₃)
1. **Series of reactions:**

   1. NADH + H^+ is oxidized (donates H atoms) to FMN, reducing FMN (electron acceptor)
   2. FMN is oxidized, Fe-S is reduced
   3. Fe-S is oxidized, CoQ is reduced
   4. CoQ is oxidized, cyt b is reduced
   5. Cyt b is oxidized, Fe-S is reduced
   6. Fe-S is oxidized, cyt c₁ is reduced
   7. cyt c₁ is oxidized, Cu is reduced
   8. Cu is oxidized, cyt a is reduced
   9. Cyt a is oxidized, cyt a₃ is reduced
   10. Cyt a₃ is oxidized, oxygen is reduced to form H₂O

2. **Energy is produced by using the energy released during the oxidation-reduction reactions to pump hydrogen ions (protons) across the inner membrane of the mitochondria.**

3. **There are 3 proton pumps included in the electron transport chain molecule complexes.**

4. **NADH + H^+ is able to use all three proton pumps, thus pumping a total of 6 protons to the inner membrane space for each NADH + H^+.**

5. **FADH₂ is only able to use 2 of the proton pumps. FADH₂ is not able to donate electrons to FMN, so it cannot use that proton pump. A total of 4 protons are pumped into the inner membrane space for each FADH₂.**
6. Hydrogen ions accumulate in the inner membrane space, but cannot diffuse across the membrane. The only way to cross the membrane is through a protein channel called ATP synthase.

7. Each time 2 hydrogen ions go through ATP synthase, enough energy is released to form a bond between an ADP molecule and an inorganic phosphate (P$_i$): \[ \text{ADP} + \text{P}_i \rightarrow \text{ATP} \]

8. Coupling the formation of ATP to the reduction of oxygen is called ‘oxidative phosphorylation’.

9. Summary of ATP formation during the electron transport chain:

- NADH + H$^+$: pump 6 protons to the inner membrane space
- FADH$_2$: pumps 4 protons to the inner membrane space

Each 2 protons crossing through ATP synthase generates 1 ATP. Therefore:

- NADH + H$^+$: 6 protons \rightarrow 3 ATPs
- FADH$_2$: 4 protons \rightarrow 2 ATPs

10. Where do the NaDH + H$^+$ and FADH$_2$ come from: (these numbers are per glucose molecule)

1. Glycolysis: 2 NADH + H$^+$
2. Formation of Acetyl-CoA: 2 NADH + H$^+$
3. Citric Acid Cycle 6 NADH + H$^+$ & 2 FADH$_2$

2. Summary of ATP production in Cellular Respiration per glucose molecule catabolized):

1. Glycolysis:
   1. 2 ATP
   2. 2 NADH + H$^+$\rightarrow\text{Electron transport chain}

3. These NADH + H$^+$ formed in glycolysis may require the use of
ATP to enter the mitochondria to be transported to the Electron transport chain. If so, they do not generate as much net ATP and the NADH + H⁺ produced in the mitochondria.

2. Formation of Acetyl-Co A
   1. 2 NADH + H⁺ ---> Electron transport chain

3. Citric Acid Cycle
   1. 6 NADH + H⁺ ---> Electron transport chain
   2. 2 FADH₂ ---> Electron transport chain
   3. 2 ATPs

4. Electron Transport chain:
   1. 8 - 10 NADH + H⁺ ---> 28 - 30 ATPs
   2. 2 FADH₂ ---> 4 ATPs

5. TOTAL: 36 - 38 ATPs

6. Other carbohydrate metabolic processes:
   1. Glycogenesis: formation of glycogen (animal starch)
      1. Glycogen is a storage form of glucose found in muscle cells. In skeletal and cardiac muscle cells, glycogen is a reserve form of glucose to be utilized when the muscles are contracting. Glycogen is also stored in liver cells as a source of glucose when blood glucose levels fall below normal values.
      2. Glycogenesis is stimulated by the hormone insulin.
      3. Reaction:
         ATP --> ADP
         glycogen synthase
         Blood glucose --------> glucose 6-phosphate---->glucose 1-phosphate ---------> glycogen

   2. Glycogenolysis: breakdown of glycogen stored in the liver into glucose. This
process occurs between meals when blood glucose levels fall below normal values.

1. Stimulated by the hormones glucagon and epinephrine.

2. Reaction:

\[
\begin{align*}
glycogen \text{ phosphohorylase} & \quad \text{glucose} \\
glycogen + P_i \xrightarrow{6\text{-phosphatase}} \text{glucose 1-phosphate} \xrightarrow{\text{glucose}} \\
\end{align*}
\]

3. Gluconeogenesis: production of glucose from a non-carbohydrate source. When glycogen levels are low, glucose necessary to maintain normal blood glucose levels can be produced from amino acids or lipids.

7. **Proteins (a review):**

1. Proteins are made by binding amino acids together with peptide bonds. There are 20 different amino acids that compose most proteins. Nine of these are essential amino acids that must be consumed in the diet. The other eleven are non-essential amino acids and can be synthesized in the body.

2. Amino acid structure:

   \[
   \begin{align*}
   &\text{NH}_2 \quad \text{Amino group} \\
   &\text{H} \quad \text{C} \quad \text{COOH} \quad \text{Carboxyl group} \\
   &\text{R} \quad \text{variable side chain}
   \end{align*}
   \]

3. An average protein has about 400 amino acids in its chain.

4. Protein uses in the body:

   1. Structural components
   2. Hormones
   3. Enzymes
   4. Contractile proteins (examples myosin and actin)
   5. Transport vessels
6. Antibodies
7. Plasma proteins
8. Protein Catabolism:

1. **Deamination:** In order to utilized as fuel for the body, the amine group (-NH₂) must be removed from amino acids. This leaves a carbon skeleton that can then be used in the cellular respiration reactions to produce ATP.
   1. Deamination occurs in the liver when the blood glucose levels are below normal values and the lipid reserves are not adequate.
   2. The enzyme deaminase removes amine groups from amino acids, producing a keto acid and ammonia (NH₃).
   3. The liver converts the ammonia to urea which is excreted in the urine, the saliva or sweat.
   4. The keto acids are:
      1. Converted to glucose (gluconeogenesis)
      2. Oxidized in the cellular respiration reactions to produce ATP.

2. **Transamination:** This is the process of transferring an amino group from one amino acid to a keto acid, producing a different amino acid.
   1. Transamination is the mechanism by which the body produces the non-essential amino acids
2. Example:

\[
\text{Pyruvic acid} \rightarrow \text{Alanine}
\]

\[
\text{Glutamic acid} \rightarrow \text{Alpha-ketoglutaric acid}
\]

In this example, the keto acid pyruvic acid gains an amino group from the amino acid glutamic acid to form alanine and a new keto acid, alpha-ketoglutarate.

3. Amino acids catabolized for energy:
   1. 6 amino acids, after deamination can be converted to pyruvic acid
   2. 8 amino acids, after deamination can be converted to acetyl-Co A
   3. Other amino acids after deamination enter the citric acid cycle as one of the intermediates.

4. Proteins yield 4 kilocalories of energy per gram.

9. **Protein Anabolism (Protein synthesis):** Review protein synthesis that was discussed in BIOL 2401, or review that chapter in your textbook.
10. **Lipids (a review):**

1. Major categories of lipids:
   
   1. **Triglycerides**
      
      1. Composed of:
         
         1. Glycerol
         
         2. 3 fatty acids, either saturated or unsaturated
         
         2. Used as a source of energy
         
         3. Triglycerides are the lipids we consume as ‘fats’ and ‘oils’ in the diet.
         
         4. Triglycerides are the lipids we store as ‘fat’ in the adipose tissue.

   2. **Phospholipids**
      
      1. A major component of cell membranes
      
      2. Composed of:
         
         1. glycerol
         
         2. 2 fatty acids
         
         3. a phosphate group

   3. **Sterols**

11. **Lipid catabolism (Lipolysis):**

1. Triglycerides either from the diet or from stores in the adipose tissue are broken down into glycerol and 3 fatty acids.

   1. Glycerol is a 3 carbon molecule which can be converted to pyruvic acid which is then catabolized to produce ATP.

   2. Fatty acids are very long chains of carbon molecules with lots of hydrogens:

   
   \[ \text{CH}_3--\text{CH}_2--\text{CH}_2--\text{CH}_2--\text{CH}_2--\text{CH}_2--\text{CH}_2--\text{CH}_2--\text{CH}_2--\text{CH}_2--\text{CH}_2--\text{CH}_2--\text{C}--\text{OH} \]
3. Fatty acids are broken down into 2 carbon subunits which are converted to acetyl-CoA. Acetyl-Co A can enter the citric acid cycle to produce ATP.

2. **Ketogenesis**: production of ketone bodies

1. When more acetyl-CoA is produced than can be used in the citric acid cycle, the liver processes the acetyl-Co A and forms ketone bodies. These 4 carbon compounds are then released into the bloodstream.
   1. **Acetone**: a ketone body that is released through the lungs, giving the breath a ‘fruity’ odor.
   2. Many ketone bodies are used in other cells in the citric acid cycle.

2. **Ketosis**: Excess ketone bodies in the blood from starvation, and diets that do not contain enough carbohydrates.
   1. The excess ketone bodies, which are acidic, cause metabolic acidosis.
   3. Breath smells fruity are individual breath rapidly to get rid of the excess carbonic acid and return blood to a normal pH.
   4. Severe cases can cause coma and death.
   5. High proteins diets, such as the Atkin’s diet, induce the body to utilized the stored fats for energy by reducing the normal energy source, carbohydrates, in the diet. Weight loss is achieved by converting the body to fat-burning rather than carbohydrate burning. Prolonged dietary ketosis can lead to kidney damage and other medical problems.
3. **Diabetic Ketoacidosis**: a condition that may occur in diabetics with severe insulin deficiency. Metabolic acidosis develops from the accumulation of ketones. This is not the same condition as ketosis.

4. **Ketonuria**: excess ketones in the urine

5. **Ketonemia**: excess ketones in the blood

12. **Lipid Anabolism (Lipogenesis):**

   1. When excess calories are consumed in the diet, any organic molecule (carbohydrates, proteins and lipids) can be converted to acetyl-Co A. Acetyl-Co A molecules bind together to form fatty acids. Fatty acids then bind to glycerol molecules to form triglycerides, which are then stored in the adipose tissue.

13. **Endocrine regulation of Lipid metabolism:**

   1. **Lipogenesis**
      
      1. Stimulated by:
         
         1. Insulin
      
      2. Inhibited by:
         
         1. Human growth hormone
         2. Glucagon

   2. **Lipolysis**:
      
      1. Stimulated by:
         
         1. Human growth hormone
         2. Glucocorticoids
         3. Thyroxine
         4. Epinephrine (adrenalin)
      
      2. Inhibited by:
1. Insulin

3. Ketogenesis

1. Stimulated by:
   1. Glucagon
   2. Human growth hormone
   3. Glucocorticoids
   4. Epinephrine

2. Inhibited by:
   1. Insulin

14. Lipoproteins:

Lipids are hydrophobic and therefore cannot be transported in the aqueous blood plasma. Lipoproteins are complexes of phospholipids, proteins, triglycerides and cholesterol that transport lipids throughout the body.

There are 4 major classes of lipoproteins.

1. Chylomicrons:
   1. 2% protein, 90% triglycerides, 5% cholesterol, 3% phospholipids
   2. Transport absorbed triglycerides from the small intestines through the lymphatic system to the bloodstream.

2. VLDL: Very Low Density Lipoprotein
   1. 8% protein, 55% triglycerides, 20% cholesterol, 17% phospholipids
   2. Synthesized by the liver
   3. Deliver triglycerides to the adipose tissue for storage.

3. LDL: Low Density Lipoprotein
   1. 20% protein, 6% triglycerides, 53% cholesterol, 21%
2. Called the ‘Bad’ cholesterol
3. Delivers cholesterol to the cells

Cholesterol is used to make hormones put into cell membrane.

Excess cholesterol returns to the bloodstream.

HDL: High Density Lipoprotein

50% protein, 5% triglycerides, 20% cholesterol, 25% phospholipids

Called ‘Good’ cholesterol

Scavenges up excess cholesterol from the tissues and blood stream

and returns it to the liver.

Cholesterol returned to the liver is excreted in the bile or put into an LDL.

**Overview of Metabolism:**

<table>
<thead>
<tr>
<th>Lipids</th>
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<tbody>
<tr>
<td>Triglycerides</td>
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</table>

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<table>
<thead>
<tr>
<th>Fatty Acids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glycerol</td>
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</tbody>
</table>
Chapter 7, Urinary System

Textbook Chapter: _________

A. Functions:

1. Removes soluble waste products from the blood.
3. Controls blood pressure.
4. Regulates water retention or loss from the body.

B. Components

1. kidneys - produce urine by filtering the blood.
2. ureters - carry urine to the bladder.
3. urinary bladder - a storage site for urine.
4. urethra - the passage way for urine to reach the external environment.

C. Kidneys

1. Anatomy
   a. Paired organs located on the posterior wall of the abdomen just above the waistline. They are positioned behind the peritoneal lining (i.e. retroperitoneal) and lateral to the vertebral column.
   b. The kidney is dark red and shaped like a bean.
   c. The medial border is concave and contains an indented opening called a hilus. The hilus is where the renal blood vessels, nerves and ureter enter the kidney.
   d. Lateral border is convex.
   e. Three layers of tissue surround the kidney:
      1.) renal capsule - the innermost layer of tissue that covers the kidney.
      2.) adipose capsule - the middle layer of fatty tissue that surrounds the renal capsule.
      3.) renal fascia - the outer layer of tissue which anchors the kidney to the body wall.
   f. The internal anatomy of the kidney reveals three
distinct regions:

1.) **Renal cortex** - outer reddish area; between the pyramids are parts of the cortex called **renal columns**.

2.) **Renal medulla** - middle area which contains 8-18 cone shaped structures called **renal pyramids**. The base of the renal pyramids faces the cortex.

3.) **Renal pelvis** - at the center of the kidney a large cavity with cup like extensions called **major and minor calyces**:
   a. Composed of 3-4 major calyces.
   b. Several minor calyces compose a **major calyx**.

g. **Renal blood flow:**

1.) Blood enters the kidney through the **renal artery** which branches into segmental arteries as follows: Segmental arteries --> Interlobar arteries --> Arcuate arteries --> Interlobular arteries --> Afferent arterioles (which carry blood to the filtration site).

2.) Each **afferent arteriole** branches to form a ball of capillary loops called a **glomerulus**.

3.) Some blood leaves the glomerulus by the **efferent arteriole**.

4.) The efferent arteriole branches to form the **peritubular capillaries** which unite to form the --> stellate vein --> interlobular veins --> arcuate veins --> interlobar veins --> segmental veins --> renal vein --> inferior vena cava.

5.) **Vasa recta** are extensions of the efferent arteriole that provide the kidney with an emergency system to maintain blood pressure and urine concentration.

h. **Renal nerve supply**

1.) **nerves originate from the renal plexus** (sympathetic division of the autonomic nervous system).

2.) Regulate blood flow by regulating diameter of the arterioles.

D. **Nephron:**
1. The **functional unit of the kidney**. Each nephron is a urine-making unit.

2. Each kidney contains over 1 million nephrons.

3. **Components of the nephron**:
   
a. **Renal corpuscle** - fluid is filtered here
   
   1.) **glomerulus** - a group of capillary loops.
   
   2.) **glomerular (Bowman's) capsule** - a double walled epithelial cup.
   
   b. **Renal tubule** - 3 segments:
   
   1.) **proximal convoluted tubule**.
   
   2.) **loop of the nephron (loop or limb of Henle)**.
   
   3.) **distal convoluted tubule**.

4. **Collecting duct** - receives the secretions from the nephrons.

5. **Nephron's function**:
   
a. **Filtration** - take place in the glomerulus; allows water and soluble components to exit the blood.
   
   b. **Secretion** - waste products are secreted into the collecting system.
   
   c. **Reabsorption** - select nutrients, ions and water are reabsorbed from the collecting system.

6. **Types of Nephrons**:
   
a. **Cortical Nephron** - glomerulus located in the outer cortex of the kidney; short loop of Henle.
   
   b. **Juxtamedullary nephron** - glomerulus located deep in the cortex of the kidney; long loop of Henle.

7. **Glomerular Filtration**:
   
a. A process that forces fluid and dissolved substances from the glomerular capillaries into the glomerular capsule.
   
   b. First step in the production of urine.
   
   c. About 180 liters of "filtrate" enter the glomerular capsular space each day.
   
   d. **Glomerular filtration rate (GFR)**:
1.) the amount of filtrate produced per hour. (125ml/min-adult).

2.) Glomerular filtration rate is directly related to Effective Filtration Pressure; this pressure depends on:
   a.) glomerular blood pressure (promotes filtration).
   b.) capsular hydrostatic pressure (opposes filtration).
   c.) blood colloid osmotic pressure (opposes filtration).

3.) Regulation of GFR
   a.) effective filtration pressure.
   b.) capillary permeability.
   c.) Intrinsic renal autoregulation.
      (1.) The kidney can maintain a constant GFR despite changes in arterial pressure.
      (2.) Negative feedback that involves the juxtaglomerular apparatus.
   d.) Hormonal regulation: renin - angiotensin system.
   e.) Neural regulation.

E. Juxtaglomerular Apparatus

1. Components:
   a. Macula densa - specialized epithelial cells of the terminal portion of the distal convoluted tubule. Tall, narrow cells that monitor salt concentration in the tubular fluid.

   b. Juxtaglomerular cells - Modified smooth muscle cells of the efferent or afferent arterioles. In contact with the macula densa. Cytoplasm contains renin granules.

2. Tubular Reabsorption:
   a. About 99% of the filtrate that passes through the renal tubules is reabsorbed into the blood.
   b. Movement of water, some salts, amino acids and glucose back into the peritubular capillary is called tubular reabsorption.
   c. The majority of reabsorption takes place in the proximal convoluted tubules.
   d. Both active and passive transport occurs.

3. Tubular Secretion:
a. Removes products from the blood and returns them to the filtrate (tubules).
   1. waste disposal system, (urea and ammonia).
   2. method of controlling blood pH.

F. Counter Current Multiplier System

1. The solute concentration of the interstitial fluid in the kidney increases greatly from 300 m Osm/liter in the cortex to 1200 m Osm/liter in the medulla.
2. The high medullary concentration of solutes is maintained by the counter current multiplier system.
3. The anatomical arrangement of the vasa recta and loop of the nephron assures that urine is more concentrated at the end of the nephron tubule than it was at the beginning.
4. Fluid flow in the descending limb of the loop of Henle runs parallel and opposite to fluid flowing in the ascending limb. This is counter current flow.
5. The effect of counter current flow in the kidney is that the filtrate is progressively more concentrated as it moves down the loop and progressively more dilute as it moves up the loop.

G. Role of different segments (tubules) of the nephron:

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<tr>
<th>NEPHRON SEGMENT</th>
<th>TUBULAR REABSORPTION</th>
<th>TUBULAR SECRETION</th>
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<tbody>
<tr>
<td>PROXIMAL CONVOLUTED TUBE</td>
<td>ACTIVE TRANSPORT OF GLUCOSE, AMINO ACIDS, Na⁺ (98%) K⁺, Mg, Ca²⁺. PASSIVE TRANSPORT, OF H₂O, Cl⁻, UREA</td>
<td>K⁺, H⁺, METABOLIC PRODUCTS, DRUGS (ASPIRIN, ANTIBODIES)</td>
</tr>
<tr>
<td>THIN DESCENDING LIMB OF HENLE</td>
<td>MOSTLY H₂O</td>
<td></td>
</tr>
<tr>
<td>THICK ASCENDING LIMB OF HENLE</td>
<td>ACTIVE TRANSPORT OF Na⁺ PASSIVE TRANSPORT OF Cl⁻, UREA</td>
<td></td>
</tr>
<tr>
<td>DISTAL CONVOLUTED TUBE</td>
<td>Na⁺ (2%) UNDER THE INFLUENCE OF ALDOSTERONE. PASSIVE TRANSPORT OF H₂O, Cl⁻</td>
<td>CREATININE, DRUGS, K⁺, H⁺</td>
</tr>
<tr>
<td>COLLECTING DUCT</td>
<td>H₂O, UREA</td>
<td>K⁺, H⁺</td>
</tr>
</tbody>
</table>

H. Ureters

1. There are two ureters, one for each kidney.
2. Function: to transport urine from the renal pelvis to the bladder.
3. Tubular structure with an outer serosa, middle layer of longitudinal and circular smooth muscle, and inner covering of mucosa (on epithelium).
4. Peristaltic contractions carry the urine in the direction of the urinary bladder.

I. Urinary Bladder

1. A hollow retroperitoneal organ located in the pelvic cavity.

2. Storage site for urine.

3. Three layers make up the bladder wall:
   a. outer: serosa
   b. middle: smooth muscle = detrusor muscle.
c. **inner**: transitional epithelium. (epithelium that is able to stretch with inflation of the bladder).

4. Ureters open into the posterior aspect of the bladder.

5. **Trigone**: triangular shaped area on the floor of the bladder; contains no rugae.

6. A voluntary **external urethral sphincter** keeps urine from leaving the bladder until it is time to urinate. This sphincter is composed of skeletal muscle.

**J. Urethra:**

1. A tube that transports urine from the bladder to the outside during urination.

2. Much longer in the male than in the female.

3. Male urethra has 3 parts:
   a. prostatic
   b. membranous
   c. penile

**K. URINE:**

1. **Urine is composed of**: H₂O (water is approximately 96% of urine), urea, chloride, potassium, creatinine, phosphate, sulfates, and uric acid.

2. Abnormal urine constituents include: protein, glucose, ketone bodies, calculi.

3. Physical qualities of urine:
   a. Urine is slightly acidic (average is 6), with pH ranging from **4.8 to 8.0**.
   b. It is normally clear and yellowish, but its color can vary greatly in a healthy person.
   c. Its specific gravity ranges from **1.002 to 1.035**.
L. **Urination = micturition:** is the emptying of the urinary bladder. Urination **in infants** is a spinal reflex action initiated by the distention of the bladder. **In an adult,** the impulses generated by stretch receptors in the bladder are sent to the brainstem and cerebral cortex.

1. Conscious control of micturition must be learned.

2. A healthy person excretes between 1.0 and 1.8 liters of urine daily (av. = 1200-1800 ml./day in a temperature, controlled environment).

3. In order to maintain homeostasis, an adult must excrete at least 0.45 liters of urine daily.

4. Volume and concentration of urine are influenced by:
   a. **Diet:** Increased urine output with increased H₂O intake in a short period of time.
   b. **Diuretics:** Increase urine output. Substances like:
      1.) **Digitalis:** improves blood flow through the kidney.
      2.) **Caffeine:** dilates renal blood vessels.
      3.) **Alcohol:** inhibits A.D.H. release.
   c. **Other factors:** age, health, etc.
   d. **THE VOLUME/CONCENTRATION OF URINE IS REGULATED BY:**
      1.) **A.D.H. (antidiuretic hormone)** produced by hypothalamus: and is stored in the posterior pituitary.
         a.) It is also called **vasopressin.**
         b.) A deficiency of A.D.H. results in a disease called **diabetes insipidus.** Without A.D.H., a large volume of urine is excreted --> 5 liters per day, this leads to dehydration and **constant thirst.**
         c.) The main target of A.D.H. is the kidneys. It works by: increasing the permeability of the kidney tubule, allowing H₂O to be reabsorbed into the body rather than excreted in urine.
      2.) **Aldosterone:** mineralocorticoid produced by adrenal cortex that brings about sodium and water reabsorption and potassium secretion.
      3.) **Renin:**
a.) enzyme produced by smooth muscles of arterioles of juxtaglomerular apparatus (which set up renin-angiotensin system).
b.) Constriction of the efferent arterioles causes the glomerular pressure to rise, thereby increasing the glomerular filtration rate.

M. **Effects of aging on the urinary system:**

1. Kidney function usually decreases with age, as arteries to the kidneys become narrowed.
2. Elderly men may urinate more frequently as the prostate enlarges, and incontinence may occur when the muscles that control urination are weakened.
N. RENIN-ANGIOTENSIN SYSTEM:

DEHYDRATION, Na⁺ DEFICIENCY, HEMORRHAGE

DECREASE IN BLOOD VOLUME

DECREASE IN BLOOD PRESSURE

INCREASE PRODUCTION AND RELEASE OF RENIN (ENZYME) BY THE KIDNEY

CLEAVES

<table>
<thead>
<tr>
<th>ANGIOTENSIONOGEN</th>
<th>ANGIOTENSIN I</th>
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<td>produced by the liver</td>
<td>(inactive form)</td>
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<tr>
<th>ANGIOTENSIN</th>
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<tr>
<th>ANGIOTENSIN II</th>
<th>ADRENAL CORTEX</th>
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<th>Na⁺ &amp; WATER REABSORPTION. K⁺ SECRETION INTO RENAL TUBULES.</th>
<th>ALDOSTERONE FROM ADRENAL CORTEX</th>
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<tr>
<td>POTENT</td>
<td>VASOCONSTRICTION</td>
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O. **Clinical problems:**

1. **Acute renal failure:** Total or partial termination of kidney function. Little or no urine is produced and body waste products are retained. Caused by:
   
   a. Greatly reduced blood supply to the kidneys due to hemorrhage, heart attack, shock, etc.
   
   b. Obstruction of urine outflow by kidney stones, tumor, trauma, etc.
   
   c. Toxins

2. **Chronic renal failure:** develops slowly over many years. Causes:
   
   a. Inflammation of renal pelvis from bacteria = pyelonephritis.
   
   b. Glomerulonephritis-inflammation of the glomeruli.
   
   c. High blood pressure.
   
   d. **Symptoms:** poor appetite, dilute urine, high blood pressure, vomiting, weight loss.
   
   e. **Therapy:** low protein diet; dialysis.

3. **Pyelonephritis:**
   
   a. caused by bacterial infection, usually from the intestinal bacteria spread from bladder --> ureters --> kidneys.
   
   b. Occurs more in females because their urethras are short and closer to the rectal and vaginal openings.
   
   c. **Symptoms:** fever (101°F), back pain, increased leukocytes in the blood, painful urination (dysuria), cloudy urine with ammonia smell and presence of bacteria in the urine.

   * Complications for diabetics because they have glycosuria (source of sugar for bacteria).
4. **Renal calculi = kidney stones.** May appear anywhere in the urinary tract, but are most common in renal pelvis or calyx. Kidney stones from calcium oxalate, trapped in the ureter, are usually the ones that cause intensive pain.

5. **Cystitis:** inflammation of the urinary bladder.

6. **Urethritis:** inflammation of the urethra.
   a. **Cause:** bacterial infection.
   b. **Symptoms:** frequent urges to urinate, blood in urine.

7. **Urinary incontinence:** inability to retain urine in the urinary bladder and control urination.
Chapter 8, Fluid, Electrolyte, and Acid-Base Balance

Textbook Chapter: _____

A. **Body Fluid** (or Body Water plus dissolved substances) averages close to 60% of body composition for **males** and a little over 50% of body composition for **females**.

1. Average infant is 70-75% water, and as we age, the percentage drops.
2. Lean people have a greater percentage of water to body ratio due to fat being mostly water free.
3. Body fluid is divided into 2 locations: **extracellular fluid** (ECF) and **intracellular fluid** (ICF).

B. **Extracellular Fluid (ECF)**:

1. accounts for approximately 1/3 of the body fluids.
2. **locations** - (outside of the body's cells):
   a. interstitial fluids (majority).
   b. blood plasma
   c. some others: CSF (cerebrospinal fluid), lymph, serous liquids, synovial fluid, G-I fluids, fluids inside the eyeball, etc...
3. **major ions involved**: chloride (CL\(^-\)), sodium (Na\(^+\)), bicarbonate (HCO\(_3\)^-).

C. **Intracellular Fluid (ICF)**:

1. accounts for approximately 2/3 of the body fluids.
2. **location**: inside the body's cells.
3. **major ions involved**: phosphate (PO\(_4\)^3-), magnesium (Mg\(^2+\)), potassium (K\(^+\)), proteins (negatively charged ones).

D. The cell membrane works with such mechanisms as **selective permeability**, **osmosis**, and **active transport** to control the movement of ions between ICF and ECF. Remember, changes in solutes effects water movement's distribution between the body's compartments, and water movement occurs passively due to the concentration of solutes (osmotic gradients).

E. **Water**

1. Water is the largest component of the human body.
2. At birth, a newborn is usually over 70% water.
3. If one has a great gain in fat (obesity), the percentage of water decreases.

4. **Daily water intake**:
   a. **two-thirds** from liquid ingestion; **one-third** from ingested food (including the chemical breakdown of food products).
   b. **average daily intake**: 2,500 ml. daily.
c. the amount varies with metabolism, environment, and the health of the individual.

5. **Daily water loss** (an average of approximately 2500 ml. daily; average lost should equal the average taken in):
   a. from urine: 1,200 - 1,800 ml. daily.
   b. from skin (includes sweating ((sweat glands)) and insensible perspiration): 450 - 500 ml. daily.
   c. from respiration: 300 - 400 ml. daily.
   d. from feces: 100- 150 ml. daily.
   e. from mucus and tears: small amount.
   f. the amount varies with metabolism, environment, and the health of the individual.

6. **Insensible water loss:** (750 - 900 ml.)
   a. water loss via evaporation from respiratory tract.
   b. water loss via diffusion through the skin.

7. **Some internal secretions** (most of which will be reabsorbed):
   a. saliva: approximately 1,500 ml./day.
   b. gastric: 1,500 - 2,500 ml./day.
   c. bile: 500 - 1,000 ml./day.
   d. pancreas: 700 - 1,000 ml./day.
   e. intestines: 2,000 - 3,000 ml./day.

F. **Nonelectrolytes vs. electrolytes:**

1. **Nonelectrolytes** - compounds with covalent bonds (i.e. - the atoms of the molecules that compose these compounds do not form ions when dissolved); include most of the organic compounds such as glucose.
2. **Electrolytes** - also called **ions**; compounds that have at least one **ionic bond**; they dissociate in specific liquids into **cations** (ions with positive charges, i.e. sodium) and **anions** (ions with negative charges, i.e. chloride); **examples of electrolytes are acids, bases, and salts**.

   a. electrolytes are generally inorganic compounds; however, some are organic (i.e. citric acid and lactic acid).
   b. electrolytes carry an electrical current.
   c. electrolytes control water movement (osmosis) from one area of the body to another.
   d. electrolytes help to keep the acid-base (pH) balance of cells.
   e. electrolytes help to keep the body electrically and chemically balanced.

G. **Edema** - excess fluid in the body's tissue.

1. **extracellular edema**
   a. characterized by an excess extracellular fluid accumulation within the interstitial spaces.
   b. **usually due to the following** (although other factors can also contribute):
      1.) capillary pressure increasing or capillaries becoming more permeable.
      2.) decrease of lymph return to bloodstream.
      3.) plasma protein level decreases.
      4.) kidney problems that result in retention of water or salt.
      5.) cardiovascular problem (especially heart problems).

2. **intracellular edema**:
   a. characterized by an excess fluid accumulation within the cell.
   b. **examples**:
      1.) cells failure to remove specific ions (ex. → Na⁺ resulting in fluid (water) accumulation.
      2.) **metabolic problems** of the body resulting in imbalance between electrolytes and fluids within the cell.
      3.) **circulatory (cardiovascular) problems** resulting in imbalance between electrolytes and fluids within the cell.
H. **Major ions involved in extracellular fluid (ECF):**

1. **chloride (Cl⁻)**
   a. **the major extracellular anion.**
   b. balances osmotic pressure between body compartments.
   c. part of stomach acid (HCL).
   d. passively follows sodium.
   e. exits the body primarily via urine and sweat.
   f. hormone regulation: aldosterone is indirectly involved.

2. **sodium (Na⁺)**
   a. **the major extracellular cation.**
   b. necessary for action potential conduction (in muscle and nerve tissues).
   c. major role in fluid and electrolyte balance (and osmosis).
   d. exits the body via urine, sweat, and feces.
   e. hormone regulation: several, some of which are ADH and aldosterone.

I. **Major ions involved in intracellular fluid (ICF):**

1. **phosphate**
   a. **most common forms in the body:** \( \text{H}_2\text{PO}_4^-; \text{HPO}_4^{2-}; \text{PO}_4^{3-} \).
   b. anion; most is present in the adult as calcium phosphate salts in bone; another form is ATP.
   c. involved in bone and teeth structure, and in buffering.
   d. note: a lot of carbonate drinks contain phosphate; consumption of large amounts of these drinks can cause excess phosphate in the blood.
   e. hormone regulation: parathormone and calcitonin.

2. **magnesium (Mg²⁺)**
   a. cation; mainly in bone and intracellular fluid.
   b. some major functions: cofactor for enzymes used in protein and carbohydrate metabolism; also nervous system transmission, heart functioning, and involved in the sodium pump.
   c. exits the body primarily through urine.
   d. hormone regulation: aldosterone.
3. **potassium (K⁺)**
   a. most abundant intracellular cation.
   b. some major functions: neuromuscular and cardiac functions, fluid volume, help regulate pH by exchanging with H⁺.
   c. exits the body primarily through urine.
   d. hormone regulation: mineralocorticoids.

J. **Acidosis and Alkalosis**

1. blood pH is 7.35 - 7.45:
   a. **acidosis**: blood pH lower than 7.35.
   b. **alkalosis**: blood pH greater than 7.45.

2. **clinically**, the major effect of acidosis is the depression of the central nervous system (causes disorientation and can cause coma). Two types of acidosis:
   a. **metabolic acidosis** (H⁺ is increased, thus pH is decreased):
      1.) can be due to acid accumulation or loss of bases.
      2.) **some symptoms**: increased ventilation and fatigue.
   b. **respiratory acidosis** (CO₂ increases, thus pH decreases):
      1.) due to factors that cause an increase in CO₂, accompanied by an increase in the respiratory acid (carbonic acid).
      2.) **some symptoms**: ventilation is decreased or nonexistent, weakness.

3. **clinically**, the major effect of alkalosis is that the nervous system becomes overexcitable. Two types of alkalosis:
   a. **metabolic alkalosis** (H⁺ is decreased, thus pH is increased):
      1.) due to excessive H⁺ loss or gain in base or bases.
      2.) **some symptoms**: breathing is depressed, confusion, and muscles can go into a state of tetany (tonic spasm).
b. **respiratory alkalosis** (decreased CO₂, thus pH is increased):

1.) due to excessive loss of CO₂, thus loss of carbonic acid.
2.) **some symptoms**: increased depth and rate of breathing, lightheadedness, and numbness.

K. **The major buffer systems for the body's fluids:**
**bicarbonate, phosphate, and protein buffer systems.**

1. **bicarbonate buffer system:**
   a. based on carbonic acid (H₂CO₃) and sodium bicarbonate (NaHCO₃).
   examples:
   1.) HCL + NaHCO₃ → H₂CO₃ + NaCL  
      (strong acid)  (weak acid)
   2.) H₂CO₃ → H₂O + CO₂
   3.) NaOH + H₂CO₃ → NaHCO₃ + H₂O  
      (strong base)  (weak base)
   b. a regulator of blood pH via respiratory and urinary system.
   c. kidneys reabsorb HCO₃⁻, excrete H⁺ to help maintain pH.

2. **phosphate buffer system** (primarily intracellular):
   a. based on H₂PO₄⁻ (NaH₂PO₄) and HPO₄²⁻ (Na₂HPO₄)
   examples:
   1.) HCL + NaH₂PO₄ → NaH₂PO₄ + NaCL
   2.) NaOH + NaH₂PO₄ → Na₂HPO₄ + H₂O
   b. a regulator of pH in RBCs and the kidney's fluids.
3. **protein buffer system** (in pH of blood plasma and in cells):
   * based on amino acid chemistry
   a. **acid component**: COOH.
   b. **base component** is the amino group: NH₂.
   c. **examples**:
      1.) -COOH ... --> COO⁻ + H⁺
      * here it acts as an **acid** by releasing H⁺
      (condition for this to happen: when pH rises and needs to be buffered).
      2.) -NH₂ + H⁺ ... --> NH₃⁺
      * here it acts as a **base** by combining with H⁺
      (condition for this to happen: when the pH falls and needs to be buffered).

4. two important amino acid buffers are: **histidine** and **cysteine**.

L. **Hormone regulation of fluid and electrolyte balance**:

1. **Antidiuretic Hormone** (ADH).
   a. **origin**: hypothalamus.
   b. secreted in reference to ECF osmolarity.
   c. **Results**:
      1.) water conservation in the kidney.
      2.) stimulate's brain "thirst center" to stimulate drinking of fluids.

2. **Aldosterone**
   a. **origin**: adrenal cortex.
   b. stimulated (via renin - angiotensin system in kidney) by such causes as a decrease in blood pressure or a decrease in plasma volume (there are other causes).
   c. helps to determine sodium absorption by the kidney (its secretion causes more sodium to be absorbed by the kidney); water follows this sodium and results in water retention.
3. **Atrial Natriuretic Peptide (ANP)**

   a. **origin**: cardiac muscle fibers.

   b. stimulated by atrial wall stretching due to blood volume increase or an increase in blood pressure.

   c. **Results**:
      1.) both ADH and aldosterone to be blocked.
      2.) decreases the desire to drink fluids. (decreases thirst)
THE REPRODUCTIVE SYSTEM

INTRODUCTION

Reproduction is a process in which offspring are produced, and hereditary traits are transmitted from parents to offspring. There are two types of reproductive systems, the male reproductive system and the female reproductive system.

A. The male reproductive system is made up of four different structures:
   1. Gonads or Testes or Testicles.
   2. Spermatic ducts.
   3. Accessory Glands.
   4. Penis and Prepuce.

1. TESTES:

   a. ANATOMY

   1.) Paired glands located in the scrotum.
   2.) The testes are formed in the abdomen and descend into the scrotum just before or after birth. *Note: the scrotum is a double pouch-like structure which is derived from the skin and fascia of the abdominal wall and is located in the perineal region.
   3.) Cryptorchidism: a condition in which one or both testes remain in the abdominal or pelvic cavity.
   4.) The scrotum is lined by a layer of smooth muscle called the dartos muscle.
   5.) Testes temperature is 3°F cooler than body temperature to optimize spermatogenesis. In case of cold temperature, the cremaster muscle (which is an extension of the internal oblique muscle) pulls the testes towards the pelvic area.
   6.) Two coverings surround the testes:
      a.) Tunica vaginalis: the outer layer which is an extension of the peritoneum.
      b.) Tunica albuginea: divides each testes into lobules.
   7.) Each lobule contains seminiferous tubules. The seminiferous tubules are composed of germ cells and nurse cells (the nurse cells are also called sustentacular cells or sertoli cells). Sertoli cells are involved in:
      a.) supporting spermatogenic epithelium.
      b.) spermatogenesis
      c.) spermiation - the release of the germ cells into the lumen of the seminiferous tubule.
   8.) Leydig cells (also called interstitial cells) are located between seminiferous tubules and are involved in androgen production.

   b. PHYSIOLOGY
Testes are mixed glands because they have both **exocrine** and **endocrine** functions.

1.) **Exocrine function:** sperm production by spermatogenic cells; the sequence of cell development is as follows:

- spermatogonia -> primary spermatocyte -> secondary spermatocyte -> Round spermatid -> elongated spermatid -> spermatozoa (takes place in the seminiferous tubules).

   a.) **Spermatogenesis:** phenomenon during which spermatogonia undergoes both **meiosis** and **mitosis** divisions to give rise to spermatozoa. **Three steps are involved:**

   (1.) **Reduction division (Meiosis I):** primary spermatocytes (2n) are transformed into secondary spermatocytes (1n).

   (2.) **Equatorial Division (Meiosis II):** secondary spermatocytes (1n) are transformed into round spermatids (1n).

   (3.) **Spermiogenesis:** spermatids (1n) are transformed into spermatozoa by a series of progressive morphological changes.

b.) **Spermatozoon** (plural is spermatozoa)

   The spermatozoon (or sperm cell) consists of three main components:

   (1.) The **head** is composed of the:

      (a.) **Nucleus** - chromatin which contains genetic material.

      (b.) **Proteins** - histones.

      (c.) **Acrosome:** contains enzymes which play a fundamental role in fertilization.

   (2.) The **neck** links the head to the tail.

   (3.) The **tail** is subdivided into:

      (a.) **Middle piece** - which contains a flagellar core, fibers, and mitochondria for (ATP); located closest to the neck.

      (b.) **Principal piece** - contains flagellar core, fibers, and fibrous sheath; located between middle piece and end piece.

      (c.) **End tail** consists only of a flagellar core; it is the terminal end of the tail.

* The ATP supplies the energy for movement. The **flagellar core** is involved in the movement of the tail & propulsion of sperm.
* Sperm defects can affect the head, the neck, or the tail.

2.) Endocrine function:

The endocrine function of the testes is governed by the gonadotropic hormones, (LH and FSH) of the pituitary gland.

a.) Secretion of androgens (e.g. testosterone) by the Leydig cells is stimulated by LH (Luteinizing Hormone).

Testosterone exerts many effects, such as:

1.) enhances protein metabolism.
2.) increases muscle and bone growth.
3.) increases growth of accessory organs (prostate, seminal vesicle).
4.) supports the action of FSH on spermatogenesis.
5.) affects male secondary characteristics:
   a.) thickening of the true vocal cords (thereby lowering the voice).
   b.) stimulating apocrine glands.
   c.) stimulates the appearance of pubic, facial, and axillary hair.
6.) supports male reproductive functions.
7.) enhances male sexual drive known as libido.

b.) Hormones secreted by sertoli cells

1.) Androgen binding protein (ABP) is produced by the sertoli cells under the stimulation of FSH. ABP plays an important role in spermatogenesis by maintaining a high concentration of androgens (i.e. testosterone & dihydrotestosterone) within the seminiferous tubules. This stimulates germ cells development.

2.) Inhibin - protein hormones produced by the sertoli cells to regulate the production of FSH by acting through negative feedback on the hypothalamus.

2. SPERMATIC DUCTS:

The sperm from each testicle travels through a system of ducts. The pathway followed by sperm from their site of production to their site of release is as follows: Seminiferous tubules --> straight tubules --> Rete testis --> efferent ductus--> epididymis -->
ductus deferens --> ejaculatory duct --> the urethras.

a. **Seminiferous tubules**: see Testis.
b. **straight tubules (Tubuli recti)**: sperm passageway lined by tall sertoli cells; convey sperm to the rete testis.
c. **Rete testis**: network of tiny tubules lined by simple cuboidal epithelium; drain sperm into the efferent ducts.
d. **Efferent ducts**: A series of ducts lined by simple columnar epithelium and ciliated simple columnar epithelium. They remove excess fluid from sperm and facilitate the transport of spermatozoa towards the epididymis.
e. **Epididymis** - a coiled tube lined by pseudostratified columnar epithelium with stereocilia (microvilli). It is:

1.) **divided into three portions**:
   a.) caput = head.
   b.) corpus = body.
   c.) cauda = tail.
2.) **role of the epididymis**:
   a.) site where sperm mature, acquire their motility and the potential to fertilize the ova.
   b.) place where sperm are stored.
   c.) propels sperm, during ejaculation, through its smooth muscle contraction.
f. **Ductus deferens (vas deferens):**

1.) located between the epididymis and the ejaculatory duct.
2.) Its proximal portion is a component of the spermatic cord. *It is composed of the following:* ductus deferens, spermatic vessels, nerves, lymphatic vessels, cremaster muscle, and connective tissue.

* The veins on the spermatic cord are particularly prominent and form the **pampiniform plexus,** which is a common site for varicose veins.
3.) The dilated portion of the ductus deferens (before it joins the seminal vesicle) is called the **ampulla.**
4.) The ductus deferens lumen is lined by pseudostratified columnar epithelium with stereocilia; it has a thick coat of smooth muscle beneath the epithelium.
5.) **function:** conduit for sperm transfer.
6.) **clinical significance:** site for **vasectomy.**

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g. **Ejaculatory duct:**

1.) Results from the union of the ampulla of the vas deferens and the seminal vesicle duct.
2.) Mixes secretions coming from the seminal vesicle and prostate with sperm; ejects them into the urethra.

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h. **Urethra:**

1.) extends from the base of the urinary bladder; spans the entire length of the penis.
2.) Lumen lined by **transitional epithelium** (on its proximal portion) and by the **stratified squamous epithelium** (on its distal portion).
3.) **Divided into three parts:**
   a.) **Prostatic urethra** = proximal portion that transverses the prostate gland.
   b.) **Membranous urethra** = short portion surrounded by the urogenital diaphragm muscle.
   c.) **Penile urethra** = longest portion which extends from the end of urogenital diaphragm muscle to the external **urethral orifice.**
4.) **urethral functions:**
   a.) micturition (urination)
   b.) ejaculation
3. **(3) ACCESSORY GLANDS**: seminal vesicles, prostate, and bulbourethral glands.

   a. **Seminal vesicles**:
      1.) Paired glands located lateral to each ampulla.
      2.) Produce alkaline secretion composed of water, fructose, ascorbic acid, prostaglandin and fibrinogen.
      3.) Stimulated by sympathetic nerves during ejaculation.
      4.) The seminal vesicle produces the major portion of the seminal fluid.
      5.) **role of the seminal fluid**:
         a.) provides energy to spermatozoa.
         b.) neutralize vaginal acidic secretions.

   b. **Prostate**:
      1.) A single gland located inferior to the urinary bladder.
      2.) Produces slightly acidic secretions made of citric acid, phosphatase, and fibrinolysis.
      3.) Plays an important role in sperm motility and neutralization of the vaginal acidic environment.

   c. **Bulbourethral glands or Cowper's glands**:
      1.) Paired glands located inferior to the prostate in each side of the urogenital diaphragm muscle.
      2.) Produces clear alkaline secretions which lubricate the urethra and neutralize any remaining urine in the urethra.

4. **PENIS**:

   a. **Structure**
      1.) The penis contains **three strands of erectile tissue**: two corpora cavernosa located dorsolateral and one corpora spongiosum surrounding the urethra.
      2.) There are venous sinusoids in the corpora cavernosa.
      3.) **The penis is divided into three segments**:
         a.) **Root** - composed of crura penis (which is the tapered portion of the corpora cavernosa) and the bulb penis (which is the expanded portion of the corpora cavernosa).
         b.) **Body** consists of two corpora cavernosa and the corpus spongiosum.
         c.) **Tip** of the penis (also called glans penis) is crowned by the corona at its base and covered by the prepuce (foreskin) in uncircumcised men.

   b. **Two functions**:
      1.) convey urine to the external urethral orifice...
during micturition.
2.) transform sperm during ejaculation.

c. **Erection**: stiffening of the penis is under the parasympathetic reflex; causes vasodilation of the arterioles with blood which flows to the sinusoids.

d. **Emission and ejaculation** is under the control of the sympathetic reflex.

e. **Semen = ejaculate**: a mixture of accessory sex glands secretions plus sperm. It can be assessed
1.) quantitatively:
   a.) **aspermia** - lack of semen.
   b.) **oligospermia** - small amount of semen.
   c.) **polyspermy** - large amount of semen.
   d.) **oligozoospermia** - reduced amount of sperm cells in the semen.

   * the amount of semen ejaculated varies from 0.5cc to 5 cc but it is possible to come across a sample which can reach 10 cc.

2.) qualitatively - color, smell, and consistently.

3.) chemically - pH, presence of sugar, protein.

4.) microscopically - morphology, motility, viability.

NOTE: minimum sperm requirement by WHO (World Health Organization) for fertility is $20 \times 10^6$ sperm /cc.

5. **CLINICAL PROBLEMS OF THE MALE REPRODUCTIVE SYSTEM**:

   a. **Orchitis**: inflammation of the testicles; may be caused by bacteria or mumps.

   b. **Cryptorchidism**: fail of the testes to descend into the scrotum.

   c. **Prostatitis**: inflammation of the prostate; it can be acute or chronic.

   d. **Benign Prostatic Hyperplasia (BPH)**: enlargement of the prostate; it causes dysuria and affects mostly older men.

   e. **Prostate Cancer**: malignancy of the prostate and affects mostly, middle age and older men.

   f. **S.T.D. (Sexually Transmitted Diseases)** such as gonorrhea, syphilis, venereal warts, genital herpes, AIDS, etc...

B. 

**NOTE**: Unlike its male counterpart, the female reproductive system is very complex; it not only produces the egg, but also it:

1. is subject to a monthly cycle.
2. is the site of fertilization.
3. allows embryo development.
4. provides nutrients to the newborn and infant.

**NOTE**: The female reproductive system is made of six components:
1. Two gonads or ovaries.
2. Two uterine tubes; also known as fallopian tubes, salpinx, and oviducts.
3. uterus or womb.
4. vagina or vaginal canal.
5. external genitalia or vulva.
6. Two mammary glands or (breasts).

1. **Ovaries:**
   
a. Paired glands located in the upper pelvic cavity on the lateral side of the uterus.
   
b. Each ovary is supported by three ligaments:
   1.) **mesovarium**
   2.) **ovarian ligament** - stabilizes ovary to uterus
   3.) **suspensory ligament** - contains blood vessels and nerves to the ovary
   
c. **ANATOMY** - the ovaries have four layers:
   1.) **Germinal epithelium**: misnomer; don't give rise to germ cells; it is the outermost layer.
   2.) **Tunica albuginea**: consists of connective tissue.
   3.) **Cortex** contains **follicles** at different stages of development. (Beneath tunica albuginea).
      
a.) **primordial follicle**: also called quiescent follicle; composed of squamous epithelium surrounding a primary oocyte.
   b.) **primary follicle**: consists of one layer of cuboidal epithelium surrounding primary oocytes; remain dormant until puberty.
c.) **secondary follicle:**
   (1.) Is present following puberty.

   (2.) **Under the stimulation of FSH, the primary follicle grows into the secondary follicle** and is identified by the following criteria:

   (a.) Appearance of **zona granulosa**; results from an increase in the number of layers of follicular cells surrounding the egg.

   (b.) Beginning of the formation of a cavity within the zona granulosa called the **follicular antrum**.

   (c.) Presence of a well defined epithelium around the zona granulosa called **theca interna**; it secretes estrogen and is surrounded by a connective tissue called **theca externa**.

   (d.) The primary oocyte is covered by **zona pellucida** (an amorphous material).

d.) **Tertiary follicle** (also known as a **Graafian follicle or Mature follicle**) - within it the primary oocyte (2n) undergoes reduction division to becomes a **secondary oocyte** (1n).

   (1.) Size of the follicular antrum is tremendously increased due to an increased amount of the **liquor folliculi**.

   (2.) **Occurrence of ovulation**: release of secondary oocyte to the fallopian tube.

e.) **Atretic follicle**: degenerated follicles; can happen at any stage of ova development.

f.) **Corpus luteum**:

   (1.) yellow body occurring **after ovulation**.

   (2.) has an endocrine function.

   (3.) if fertilization does not occur, it degenerate and get transformed into a white scar tissue called **corpus albicans**.

4.) **Medulla** - innermost layer; contains connective tissue and blood vessels.

d. **PHYSIOLOGY**

Ovaries have a double function: exocrine and endocrine.
1.) **Exocrine Function**

   a.) Production of ova (called **Oogenesis**) starts during early fetal development.

   b.) germs cells which migrate from the yolk sac to the ovaries cortex differentiate into **oogonia** (2n).

   c.) By fourth to fifth month of pregnancy, oogonia (2n) undergo mitosis and growth, and become primary oocytes (2n).

   d.) By seventh month of pregnancy, Meiosis I reduction division starts but undergoes arrest during prophase (until puberty).

   e.) At puberty, under the stimulation of gonadotropin hormones, meiosis is completed. Primary oocyte (2n) gives rise to secondary oocyte (n) and the first polar body (n).

   f.) Secondary oocytes undergo Meiosis II (equatorial division) but stop at metaphase.

   g.) Completion of Meiosis II occur after ovulation; fertilization of the secondary oocyte (n) gives rise to ovum and the second polar body.

   h.) all the polar bodies undergo degeneration. **Note** that by the time the baby girl is born, each ovary contains more than 200,000 oocytes. The number of eggs decreases with age because during each menstrual cycle, many follicles develop, but only one matures (the others undergo atresia).

2.) **Endocrine function:**

   a.) Ovaries secrete **three major hormones**, (i.e., estrogens, progesterone, and relaxin).

   (1). **Estrogens (B - estradiol, estrone, - estriol):**

      (a.) stimulate the development and maintenance of sex organs and secondary characteristics.

      (b.) Stimulate the monthly hyperplasia of the endometrium.

      (c.) Controls fluid balance and protein synthesis.

      (d.) Controls FSH production by negative feedback.

   (2.) **Progesterone:**

      (a.) produced by the corpus luteum.

      (b.) Progesterone with estrogen stimulate breast development.

      (c.) Stimulate secretory function of the endometrium during luteal phase of the menstrual cycle.
(d.) maintains pregnancy.

(3.) **Relaxin:**

(a.) secreted near the end of pregnancy by corpus luteum.
(b.) It relaxes the symphysis pubis and the sacroiliac joints, and softens the cervix to facilitate vaginal childbirth.

b.) **Ovaries are regulated by two Gonadotropin hormones:** FSH and LH.

(1.) **FSH:** (Follicle Stimulating Hormone). Stimulates follicle growth --> estrogen level rises and --> inhibition of FSH production occurs via negative feedback.

(2.) **LH:** Luteinizing hormone stimulates ovulation. Stimulate growth of Corpus luteum. Stimulates progesterone production.

e. **Menstrual Cycle** - Hypothalamus controls the menstrual cycle by secreting GnRH (gonadotropin-releasing hormone.) Two phases: Follicular Phase and Luteal Phase.

1.) **Follicular Phase:** Day 1 ---> Day 14. Note that Day 1 is the first day of menses.

   a.) **Day 1 -> Day 5:** - Low progesterone and estrogen level promotes sloughing of the functional layer of the endometrium.
   b.) **Day 6:** - one dominant follicle is selected.
   c.) **Day 7 -> Day 12:** - Rise in the level of estrogen causes thickening of the endometrium.
   d.) **Day 13:** - LH level rises tremendously = LH surge.
   e.) **Day 14:** - release of the secondary oocyte = ovulation.

2.) **Luteal Phase:** Day 15 - Day 28.

   a.) **Day 15 - Day 25:**
   (1.) rise in the level of estrogen and progesterone under the influence of LH.
   (2.) Endometrium enters the secretory phase.

   b.) **Day 25 - Day 28:**
   (1.) Drop in the level of progesterone and estrogen.
   (2.) Degeneration of corpus luteum.
   (3.) Start of the sloughing of endometrium.

2. **Fallopian Tubes** (also known as Uterine Tubes, Salpinx, and Oviducts):

   a. **Anatomy**
1.) There are two of them, one on each side of the uterus.
2.) Each fallopian tube has three main parts: (Infundibulum, Ampulla, Isthmus).
   a.) **Infundibulum:** funnel-shaped end of the fallopian tube, close to the ovary. It contains finger-like projections called *fimbriae.* It plays a fundamental role in capturing the secondary oocyte after ovulation.
   b.) **Ampulla:** the longest portion of the fallopian tube, sandwiched between the infundibulum and the isthmus; it is the site where fertilization occurs.
   c.) **Isthmus:** short narrow portion of the fallopian tube close to the uterus.
3.) Fallopian tube had three layers:
   a.) **Mucosa:** mixture of simple columnar epithelium plus ciliated columnar epithelium.
   b.) **Muscularis:** two smooth muscle layers: circular (inner) and a longitudinal (outer).
   c.) **Adventitia:** outer most layer.
4.) The tonus and contraction of the fallopian tube is under hormonal control.
   b. **Physiology**
   1.) Moves the egg towards the uterus by peristaltic-like contractions. Movement of the egg is facilitated by the beating of the cilia.
   2.) Site of fertilization and early stages of development.
3. **UTERUS or Womb:**
   a. **Anatomy**
   1.) Uterus is located between the urinary bladder (anteriorly) and the sigmoid colon and rectum (posteriorly).
   2.) It is supported by eight ligaments:
      a.) paired round ligaments.
      b.) paired broad ligaments.
      c.) paired uterosacral ligament.
      d.) one posterior ligament.
      e.) one anterior ligament.
   3.) It has three parts: Fundus, Body, Cervix.
      a.) **Fundus:** broad upper part, below it the fallopian tubes join the uterus.
      b.) **Body:** largest part, sandwiched between the fundus and the cervix.
c.) **Cervix**: lowest portion of the uterus.

1. Acts as a valve to close off the lumen of the uterus from the vagina.
2. Has **two openings**:
   - (a.) **Internal ostium**: towards the body of the uterus.
   - (b.) **External ostium**: towards the vagina.
3. Produces cervical mucus:
   - (a.) thin during estrogeic phase.
   - (b.) viscous and thick (forming a plug) during progesteronic phase.
4.) Uterus is composed of three layers: Endometrium, Myometrium, and the Perimetrium.

   a.) **Endometrium** (mucosa): inner layer of the uterus has two sublayers

      (1.) **Stratum functionalis**: thick superficial layer composed of simple columnar epithelium; it is shed during menstruation.

      (2.) **Stratum basalis**
          (a.) Thin deep layer, richly vascularized; it doesn't change during menstrual cycle.
          (b.) Stratum basalis regenerates the lost stratum functionalis.

      * **Note:** endometrium is subject to change depending upon the phase of the menstrual cycle: during the estrogenic (follicular) phase, it undergoes proliferation; however, during progesteronic (luteal) phase, it undergoes secretion.

   b.) **Myometrium** (muscularis) - sandwiched between endometrium and perimetrium; it has three sublayers:

      (1.) inner = longitudinal.
      (2.) middle = circular.
      (3.) outer = longitudinal.

      * **Note:** During pregnancy (due to high level of estrogen), the myometrium becomes ten times longer and larger. This process causes a physiologic hyperplasia (augmentation of number of cells) and hypertrophy (augmentation of the volume of the cells).

   c.) **Perimetrium** (serosa):

      the outer layer which extends to form two broad ligaments that stretch from the uterus to the lateral wall of the pelvis.

b. **Physiology**

   1.) Site of implantation.
   2.) Site of fetal development.
   3.) Under oxytocin stimulation, the myometrium undergoes contraction for childbirth.

4. **Vagina (Birth Canal):**

   a. **Anatomy**

      1.) The vagina is a musculocutaneous tube located between the urinary bladder and urethra.
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(anteriorly) and the rectum and anus the (posteriorly).

2.) In the case of a virgin, the vaginal orifice is partially occluded by a mucosal membrane called the hymen which can be broken either by sexual intercourse or by physical activities.

3.) The projection of the cervix into the proximal portion of the vagina delimits spaces called the anterior fornix and the posterior fornix.

4.) The vagina conforms to the general structure of the reproductive system, thereby it consists of three layers: Mucosa, Muscularis, and Adventitia.

   a.) Mucosa - lined by stratified squamous epithelium; it undergoes changes during different phases of the menstrual cycle.
   b.) Muscularis - is very well developed; it expands extensively during child birth.
   c.) Adventitia - elastic fiber is present.

b. Physiology

   1.) Site of sexual intercourse and deposition of semen.
   2.) Site of excretion of menstrual flow.
   3.) Site of natural childbirth.
   4.) Acidic mucus secretion to protect against germs.

5. External Genitalia (also known as the Vulva or Pudendum).

External genitalia consists of: mons pubis, labia majora, labia minora, vestibular glands, clitoris and vestibule.

   a. Mons Pubis: composed of fatty material that covers the pubis anteriorly. During puberty, it becomes covered with pubic hair.
   b. Labia Majora: the outer boundary of the vulva; it is composed of two vertical folds of skin that extend from the mons pubis to the perineum.
   c. Labia Minora: two small folds of skin medial to the labia majora; contains nerves endings.
   d. Vestibular Glands:
      1.) Bartholin's Glands (greater vestibular glands).
      2.) Skene's Glands (lesser vestibular glands).
      3.) Secretes alkaline mucus that offsets the natural acidity of the vagina.
   e. Clitoris: an erectile organ below the mons pubis. It is homologous to the penis, and is the site of sexual arousal.
   f. Vestibule = space between the two labia minora.

* Note the perineum is a diamond-shaped area
located between the symphysis (anteriorly) and coccyx (posteriorly).

6. **Mammary Glands (Breasts):**

   a. **Anatomy**

      1.) Paired, modified sebaceous glands located in the pectoral region on each side of the sternum.

      2.) They have a convex shape and are supported by suspensory ligaments.

      3.) Their size is related to the amount of adipose tissue.

      4.) Each mammary gland has a tip called the **nipple** which is located centrally on its inferior side. The nipple contains nerve endings, blood vessels, smooth muscle and connective tissue.

      5.) Each mammary gland is composed of:

         a.) fifteen to twenty lobes.

         b.) lobules

         c.) alveoli

         d.) lactiferous ducts.

         e.) lactiferous sinus.

   b. **Physiology**

      The mammary glands change during the menstrual cycle and pregnancy. These changes are controlled by hormones:

      1.) **Estrogen** and **progesterone** control the development of the mammary glands.

      2.) **Prolactin** is produced by the pituitary gland and stimulates milk production.

      3.) **Oxytocin** is produced by the hypothalamus and stored in the posterior lobe of the pituitary gland. It controls milk ejection by causing the contraction of myoepithelial cells.

7. **CLINICAL PROBLEMS OF THE FEMALE REPRODUCTIVE SYSTEM.**

   a. **Oophoritis:** inflammation of the ovary(ies).

   b. **Ovarian cyst:** pocket full of fluid; it affects either follicles or the corpus luteum.

   c. **PID (Pelvic Inflammatory Disease):** inflammation of the fallopian tubes, uterus, and peritoneum resulting from some venereal diseases such as gonorrhea.

   d. **Endometritis:** inflammation of the endometrium.

   e. **Endometriosis:** abnormal invasion of the endometrial tissue into the ovary, myometrium, urinary bladder, etc..

   f. **Cervical Cancer:** cancer of the cervix.

   g. **Breast Cancer:** cancer of the mammary gland.

   h. **S.T.D. (Sexually Transmitted Diseases):** such as gonorrhea, syphilis, venereal warts, genital herpes, AIDS, etc...
### Matching Questions

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<td>1. ____</td>
<td>A. transection of the ductus deferens</td>
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<td>2. epididymis</td>
<td>2. ____</td>
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<td>3. seminal vesicles</td>
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