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UGA Anatomy and Physiology 2 Lab Manual

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Anatomy and Physiology II Lab Manual

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Blood Composition

Objectives

- Explain how the properties of blood qualify it as a connective tissue
- Describe the various functions of blood
- Distinguish among the three major categories of formed elements
- Describe the shape, structure, and contents of an erythrocyte
- Know what hematocrit test determines, and what are the normal lab values
- Describe the differences between agranulocytes and granulocytes
- Visually differentiate each of the leukocytes on a normal blood smear
- Visually identify platelets, describe their function, and explain what coagulation tests are used to determine

The Cardiovascular System: An Introduction

The term "cardiovascular system" is broadly used to describe a body system that consists of tubular organs, called **vessels,** a fluid tissue, known as **blood,** and a muscular pump (the **heart)** that functions in driving the blood through those vessels. It is often more accurate to describe all of the above components as the **circulatory system,** reserving the term "cardiovascular" for the heart and vessels only.

Blood as Connective Tissue

[Section 18.1: An Overview of Blood]

What are the properties that are common to all connective tissues? (see Section 4.3 in your textbook for review)

Blood is considered to be a "liquid connective tissue." Describe the components of blood that fit the description of a connective tissue.

Functions of Blood

[Section 18.1.1: Functions of Blood]

List the various things that are transported by the blood.

List the many ways in which the blood serves a defensive, immune function for the body.

What homeostatic mechanisms are regulated and maintained by the blood?

Blood Composition

[Section 18.1.2: Composition of Blood]

[Figure 18.2: Composition of Blood]

- Define hematocrit
- 55% = *Plasma*
    - *o* Proteins (for blood pressure, clotting, and immune functions)
    - o Water (92% of plasma)
    - o Electrolytes
    - o Hormones
    - o Nutrients
    - o Blood gases
    - o Waste
- 45% = *Formed Elements*
    - o Red Blood Cells
    - o Platelets
    - o White Blood Cells

Erythrocytes

[Section 18.3.1: Shape and Structure of Erythrocytes]

[Section 18.3.2: Hemoglobin]

Primary function: transport respiratory gases to and from tissues

Lack a nucleus

Most abundant of all blood cells
Biconcave to increase surface area to allow for rapid gas exchange, allows for the cells to squeeze through vessels

Contains millions of Hemoglobin molecules: allow for binding of O2 and CO2

Hematocrit

[Figure 18.2: Composition of Blood]

- Determines the volume of packed elements (mainly RBCs) in a blood sample (reported as a percentage)
- Provides information about the oxygen-carrying capacity of blood. Low percentages mean less RBC's carrying O_2.

- Averages: males:_____%; females:_____%

Platelets

[Section 18.4.5: Platelets]

Produced by the fragmentation of cells in the bone marrow called **megakaryocytes**

Don't survive long

Involved in **coagulation:** the process of clot formation

During coagulation, molecules (fibrin) join to form long threads that form a net to trap platelets and plug the wound

Coagulation

[Section 18.5.3: Coagulation]

Also known as clotting

Happens when blood sits for 3-4 minutes outside of the body

Process of "closing" a wound:

- Person cuts themselves
- Enzymes activate circulating proteins
- Proteins convert fibrinogen to fibrin
- Fibrin joins together to form long threads that form a net that "traps" platelets
- These trapped platelets form a clot

A **coagulation test** determines how fast this occurs in your blood

- A clinical test used to detect bleeding disorders (missing clotting factors, low platelet counts, etc.)
- An unusual coagulation test can result from genetic disorders, or other underlying problems, such as cancer, vitamin deficiency, etc.

Leukocytes

[Section 18.4.2: Classification of Leukocytes]

[Figure 18.11: Granular Leukocytes]

[Figure 18.13: Leukocytes]

Only formed elements with a nucleus

lacks hemoglobin

travel between endothelial cells of capillaries and tissues

most are phagocytes

There are two types of WBC- *granular and agranular*

Granulocytes

All have granules in cytoplasm, these granules are secretory

- **Neutrophils** are the most common granulocytes (70% of total WBC count)
    - 1st to arrive at wound/infection site, release cytotoxins
    - phagocytize bacteria
    - release chemokines (attract other WBCs), and once activated
    - live only a day or two
- **Eosinophils** (3% of total WBC count)
    - phagocytize bacteria and microbes that the immune system has coated with antibodies (Abs)
    - decrease inflammatory response at site of wound
- **Basophil** (<1% of WBCs)
    - release histamines (cause vasodilation) and heparin (prevents clotting)
    - Important in allergies

Agranulocytes

- **Monocytes** (20-30% of total WBC count)
    - Wanderers, patrol body tissue for microbes and worn-out tissue cells, 2nd to arrive at wound site, phagocytize dead cells/debris that has accumulated at site of wound/infection
- **Lymphocytes** (2-8% of WBCs)
    - smallest leukocyte, abundant in bloodstream, occur in lymph nodes and glands
    - specialized lymphocytes:
        - *T-cells:* attach to and destroy infected or cancerous cells by releasing cytotoxic molecules and secreting antiviral/pro-inflammatory molecules
        - *B-cells:* manufacture antibodies that attach to foreign pathogens/cells and help destroy them
        - *Natural Killer cells:* can detect sick, cancerous, and infected cells and release cytotoxic molecules to destroy them

Blood Typing

Objectives

- Describe the antigen-antibody reactions of the ABO and Rh blood groups
- Be able to type a sample of unknown blood to determine the ABO and Rh blood types
- Explain the clinical importance of blood types on pregnancy and transfusions

Blood Typing

[Section 18.6.1: Blood Typing; Antigens, Antibodies, and Transfusion Reactions]

Each blood type is a function of the presence or absence of specific molecules, called antigens, on RBCs

Antigens are molecules that your body can use to differentiate self and non-self (virtually all proteins, carbohydrates, etc. are types of antigens). People with different blood types have RBCs with different antigens on them.

Antibodies are produced in response to some antigens (non-self), and are generally used by the immune system to recognize and remove foreign objects that don't belong.

Antibodies and antigens in an individuals blood do not interact with one another, but what happens when you mix blood/antibodies from different people?

More than 50 blood types in human population

The most clinically significant are the ABO and Rh(+/-) blood groups

The ABO Blood Group

[Section 18.6.2: The ABO Blood Group]

ABO typing does NOT affect a person's Rh designation

Type A blood= "A" antigens on cell, anti B antibodies

Type B blood= "B" antigens on cell, anti A antibodies

Type AB= "A" and "B" antigens on cell, no antibodies

Type O blood= no antigens on cell, anti A and B antibodies

If a different type of blood is put into your bloodstream, the blood will agglutinate (clump) and hemolysis (bursting) occurs within the foreign blood cells

Rh Blood Group

[Section 18.6.3: Rh Blood Groups]

Named after Rhesus monkey where it was first identified

Rh positive (+) contains a D-antigen

Rh negative (-) has no D-antigen, and unlike A/B/O, no anti-D-antibodies are present in Rh negative individuals

Grouped with ABO blood group to identify a blood type (example A+, B-, O-)

The Rh group only has ONE antigen (the D antigen) and ONE antibody (anti D) that could be present.

If RBCs have a D antigen, the blood is positive

If RBCs have no D antigen, the blood is negative

Negative blood DOES NOT have anti D antibodies!

If positive and negative blood is mixed in an Rh(-) individual, anti D antibodies will be produced against the Rh(+) blood after a short while (a couple weeks)

Mixing of Rh positive and negative will result in production of anti D antibodies

You can get away with it once because anti-D antibodies don't exist beforehand, but a second time will cause a reaction

Importance of Rh during Pregnancy

[Section 18.6.3: Rh Blood Groups]

[Figure 18.15: Erythroblastosis Fetalis]

This is VERY important during childbirth. If the mother is Rh-negative, but her child is Rh-positive and any internal bleeding from the Rh(+) child occurs, the mothers blood will begin producing anti-D antibodies which will then hemolyze her babies blood (and any future Rh(+) fetuses). Exposure of the babies blood during childbirth can also be problematic for future Rh(+) fetuses

This is called hemolytic disease of the newborn or erythoblastosis fetalis

RhoGam a dosage of anti-D antibodies is given to the mother at 28 weeks and within 72 hours of giving birth in order to destroy any fetal blood cells in her blood so she will not produce her own anti-D antibodies. RhoGam antibody dosage is small enough not to hurt fetus, but strong enough to keep mom's immune system from attacking baby

Determining Blood Type

[Section 18.6.4: Determining ABO Blood Types]

[Figure 18.16: Cross Matching Blood Types]

To determine blood types, anti-serum is used.

The serum contains either anti-A antibodies or anti-B antibodies which react to the antigens on the RBC surface

If using anti A anti serum and the blood sample clumps:

then the blood could be Type A, or Type AB

You would then test with anti B anti serum

If it does clump, the blood is Type AB, if it doesn't then it is Type A.

Make sure to NEVER mix anti serums or blood samples!

Transfusions

[Section 18.6.5: ABO Transfusion Protocols]

[Figure 18.17: ABO Blood Group]

The first blood transfusions used animal blood as a source of blood

This often resulted in severe allergic reactions, and often death

In human transfusions, additional complications can arise when the donor's antibodies react with the recipient's RBCs, and vice versa

Thus, only donor RBCs are transferred, *no antibodies*

Type O- is considered the **universal donor**

Type AB+ is considered the **universal recipient**

An incorrect transfusion could cause blood to agglutinate within the recipient's blood vessels

Heart Anatomy

Objectives

- Describe the gross external properties of the heart, including location, size and shape
- List the layers of tissue that comprise the wall of the heart and the pericardium
- Identify the internal structure of the heart and the arrangement of the four chambers
- Identify the four heart valves, describing the function of each
- Identify the great vessels of the heart and describe their relationship to the chambers they serve
- Describe the differences between the pulmonary circuit and the systemic circuit
- Trace the pathway of blood through the pulmonary circuit and systemic circuit
- Identify the vessels of coronary circulation

Introduction

In the previous lab, you learned about the basic organization of the **circulatory system,** focusing on the fluid tissue of that system known as blood. In this lab, we narrow our focus to the muscular pump of the system, the heart. We will also look at the vessels that deliver blood directly into or carry blood immediately out of the heart. When studying only the heart and blood vessels it is common to refer to them as the **cardiovascular system.** While many might use the terms circulatory system and cardiovascular system interchangeably, we want you to be more accurate in differentiating between the two. It would be correct to say that the circulatory system consists of the blood and the cardiovascular system (heart and vessels) that moves and distributes the blood throughout the body.

In the cardiovascular system, there are two major categories of large vessels: arteries and veins. Generally, arteries transport freshly oxygenated blood from the heart to the body's tissues and veins transport deoxygenated blood from those tissues back to the heart. The exceptions to the pattern are the vessels of the pulmonary circuit (the pulmonary arteries and pulmonary veins).

In a later lab you will learn about more types of vessels than these, but for now, know that these are the major types.

Location, Size, and Shape of the Heart

[Section 19.1.1: Location of the Heart]

[Section 19.1.2: Shape and Size of the Heart]

[Figure 19.2: Position of the Heart in the Thorax]

Ventral body cavity, thoracic cavity, mediastinum.

Inferior mediastinum contains pericardial cavity.

Base, apex, cardiac notch.

Be sure you know the dimensions of the heart (in cm) and its mass (in grams); and describe the differences in these values between males and females

Layers of the Heart

[Section 19.1.4.1: Membranes]

[Section 19.1.4.3: Layer]

[Figure 19.5: Pericardial Membranes and Layers of the Heart Wall]

[Figure 19.8: Differences in Ventricular Muscle Thickness]

The pericardium is the serous membrane of the heart

- Two layers (parietal and visceral)
    - Outer parietal
        - attaches heart to mediastinum
        - has fibrous tissue so heart doesn't over-expand
    - Inner visceral layer (epicardium)
        - lines surface of the heart
- Space between= pericardial cavity
    - Filled with serous fluid (reduces friction)
- Both layers have mesothelium which produces serous fluid

The heart wall has 3 layers

- Epicardium
    - same as visceral pericardium
- Myocardium
    - most of heart wall, composed of cardiac muscle tissue (which is made of uninucleated cardiac muscle cells)
- Endocardium
    - thin layer of endothelial tissue that lines the heart chambers

Internal Structure of the Heart

[Section 19.1.5: Internal Structure of the Heart]

[Figure 19.9: Internal Structures of the Heart]

[Figure 19.11: Chordae Tendineae and Papillary Muscles]

[Figure 19.12: Heart Valves]

[Figure 19.13: Blood Flow from the Left Atrium to the Left Ventricle]

[Figure 19.14: Blood Flow from the Left Ventricle into the Great Vessels]

Septa

- Interatrial septum, fossa ovalis, interventricular septum

Right Atrium

- Coronary sinus, pectinate muscles

Right Ventricle

- Papillary muscles, chordae tendineae, trabeculae carneae

Left Atrium

Left Ventricle

Valves

- Right AV (tricuspid), pulmonary semilunar valve, left AV (bicuspid or mitral), aortic semilunar valve

Circulation Through the Heart

[Section 19.1.3: Chambers and Circulation through the Heart]

[Figure 19.4: Dual System of the Human Blood Circulation]

Blood enters the right atrium by way of the superior vena cava & the inferior vena cava

From the right atrium, the blood flows through the tricuspid AV valve into the right ventricle.

After the ventricle contracts, the blood flows through the pulmonary semilunar valve and into the pulmonary arteries.

The pulmonary arteries deliver the blood to the lungs where it is enriched and exits by the pulmonary veins.

The oxygenated blood is delivered to the left atrium, where it then is pushed through the bicuspid (or mitral) AV valve into the left ventricle.

From here the blood is pushed through the systemic semilunar valve, and the aorta and then out into the body.

Coronary Circulation

[Section 19.1.6: Coronary Circulation]

[Figure 19.15: Coronary Circulation]

Arteries supply the myocardium with nutrients and oxygen

- Left coronary artery, circumflex artery, anterior interventricular artery (aka, LAD)
- Right coronary artery, marginal arteries, posterior interventricular artery (aka, PDA)

Veins remove waste and metabolic by-products from the myocardium

- Great cardiac vein, small cardiac vein, middle cardiac vein, posterior cardiac vein
- Coronary sinus (all coronary veins merge into this)
    - Located in posterior region of coronary sulcus
    - Empties deoxygenated blood from myocardium into right atrium

Heart Dissection

Follow your TA to the lab where you will find a dissection guide. Follow the instructions on the guide to dissect a sheep heart. Identify all structures studied above. Notice the dimensions of the sheep heart. What are the differences between this hear and the dimensions of your heart as described in your text?

Cardiovascular Physiology

Objectives

- List the components of the conduction system of the heart
- Explain the different components of a normal ECG
- Define the term "cardiac cycle"
- Describe the events of each of the phases of the cardiac cycle
- Relate the phases of the cardiac cycle with the action of the conduction system that causes the events of the cardiac cycle
- Define auscultation and describe what causes the heart sounds
- Correlate the parts of the ECG, the sounds heard during auscultation, and the phases of the cardiac cycle
- Define the components of blood pressure
- Describe how blood pressure is measured, and how the measurement technique relates to the sounds that are heard during the measurement
- Explain what causes a pulse, and identify the common anatomical locations for measuring a pulse
- Describe how the components of the baroreceptor reflex regulate the heart's pace and rhythm

Cardiac Conduction System

(Section 19.2.2: Conduction System of the Heart)

(Figure 19.18: Conduction System of the Heart)

(Figure 19.19: Cardiac Conduction)

The heart beats originate within the heart itself.
How the CCS works:

- initiates the signal for contraction
- provides a pathway for conducting the signal to all cardiac muscle fibers

1. initiates the signal for contraction
   - **Polarization:** allows for the initiation of an electrical impulse across the cell membrane, polarization is a state in which there is a charge difference across a membrane
   - **polarized** - the outside of the cell has more positive ions than does the inside
   - **depolarized** - a change in the charge across the cell membrane, the inside of the cell is temporarily more positive than the outside

   - SA Node Action Potential
     - Depolarization
       - Na^+ first enters slowly (i_f)
       - Ca^{2+} enters next
     - Repolarization

- K leaves

2. provides a pathway for conducting the signal to all cardiac muscle fibers
- sinoatrial (SA) node
  - aka = the pacemaker
  - located in the wall of the right atrium just below the superior vena cava
  - initiates the electrical impulse in the heart
  - causes the atria to contract
- atrioventricular (AV) node
  - located in the lower interatrial septum
  - receives the electrical impulse from the atria muscle fibers
  - causes a 0.1 second delay
  - allows atria to contract prior to ventricular firing
- AV bundle (bundle of HIS)
  - located in a septum between the atria and ventricles
  - the electrical connection between the atria and ventricles
  - receives signals from the AV node
  - sends signals to the bundle branches
- bundle branches
  - located in the interventricular septum
  - sends signals to the Purkinje fibers
  - right and left bundle branches
- Purkinje fibers
  - located in the apex of the myocardium and the lateral walls of the right and left ventricles
  - sends signals to the ventricular cardiac muscle *starting from the apex and spreading upward*
  - ventricles contract

Electrocardiography

During each cardiac cycle, a sequence of electrical impulses from pacemaker cells and nerves causes the heart muscle to produce electrical currents that result in contraction of heart chambers

These impulses can be detected at the body surface with electrodes

A recording of the impulses is called an *Electrocardiogram* (ECG). It's also called an EKG because it was named in Germany, where cardiogram is spelled with a "K"

ECG Components

(Section 19.2.3: Electrocardiogram)

(Figure 19.23: Electrocardiogram)

(Figure 19.24: ECG Tracing Correlated to the Cardiac Cycle)

- P wave
  - First Event
  - Represents atrial depolarization

    - Arises from SA node just before atrial contraction
- P-R Segment
    - Represents the time for an impulse to travel from the AV node to the ventricles
- P-R Interval (AKA P-Q Interval)
    - Occurs between the start of the P wave and the start of the QRS Complex
    - Equals P-wave + P-R Segment
    - It represents the time required for an impulse to travel from the SA node to the ventricular muscle
- QRS Complex
    - Ventricular depolarization
    - Atrial repolarization occurs at this time, but the electrical event is masked by the QRS complex
- S-T Segment
    - Measures the delay between ventricular depolarization and repolarization
- T wave
    - Represents ventricular repolarization
    - just before the ventricles relax
- Q-T Interval
    - The cycle of ventricular depolarization and repolarization

ECGs can detect abnormalities

- *Tachycardia:* heart rate above 100 beats/min
- *Bradycardia:* heart rate below 60 beats/min
- *Fibrillation:* prolonged tachycardia; rapid uncoordinated contraction; no blood is pumped

The Cardiac Cycle

(Section 19.3: Cardiac Cycle)

(Section 19.3.1: Pressures and Flow)

(Figure 19.27: Overview of the Cardiac Cycle)

One complete heart cycle is called a **cardiac cycle,** lasts about 0.8 sec and is commonly called a heart beat
It is marked by changes in blood pressure and volume in the heart
During the cycle, each atrium and ventricle contract once and relax once
The contraction phase - *Systole*
The relaxation phase - *Diastole*
The human heart averages 75 cardiac cycles/minute

Phases of the Cardiac Cycle

(Section 19.3.2: Phases of the Cardiac Cycle)

(Figure 19.27: Overview of the Cardiac Cycle)

(Figure 19.28: Relationship between the Cardiac Cycle and ECG)

A cycle begins with Atrial Systole - 0.1s
Fills relaxed ventricles (30% of ventricular blood volume enters as a result of atrial systole)
Next, Ventricular Systole - 0.3s
Pump blood out of heart
Last, Atrial/Ventricular Diastole - 0.4s
Most blood (70%) enters the ventricles during this resting period
Decreases time spent in this phase as heart rate increases

Listening to Heart Sounds

(Section 19.3.3: Heart Sounds)

(Figure 19.29: Heart Sounds and the Cardiac Cycle)

(Figure 19.30: Stethoscope Placement for Auscultation)

- Called **auscultation**
- A stethoscope amplifies the sounds to an audible level
- Auscultation of the heart is used to diagnose and evaluate valve function
- Four sounds are produced by the heart during a cardiac cycle

The first two sounds are easily heard and are called S_1 and S_2 (also known as *Lubb* and *Dupp)*

- **S1** (Lubb) - caused by closure of the AV valves as ventricles begin to contract
- **S_2** (Dupp) - occurs as the SL valves close at the beginning of ventricular diastole
- For a demonstration of the sounds, as well as the location for auscultating each of the heart's valves, visit: https://en.wikipedia.org/wiki/Heart_sounds

The third (S_3) and fourth (S_4) sounds are difficult to hear

- **S3** - "SLOSHing in" (S1-S2-S3): Too much fluid volume results in blood oscillating between the walls of the ventricles when blood rushes in from the atria; normal in people younger than 40; Otherwise, due to acute heart failure
- **S4** - "a STIFF wall" (S4-S1-S2): Ventricular hypertrophy; Makes sound during atrial contraction due to higher pressure; can be found in healthy children and athletes; Otherwise, due to long-standing hypertension or heart attack

Abnormal heart sounds are **murmurs** and usually mean there is a problem with the valves. Often, a "swishing" sound is heard because of regurgitation of blood or a high pitched screeching because of constricted valves

- For a sample of all the possible murmurs, and what they sound like, visit: http://www.easyauscultation.com/heart-murmur-sounds

Blood Pressure

(Section 20.2.1.1: Components of Arterial Blood Pressure, Systolic and Diastolic Pressures)

(Section 20.2.3: Measurement of Blood Pressure)

(Figure 20.12: Blood Pressure Measurement)

BP is a measure of the force the blood exerts on the walls of the systemic arteries

- *Systolic Pressure* - LV contracts and pumps blood into the Aorta thereby increasing arterial pressure
- *Diastolic Pressure* - LV relaxes, less blood flows into Aorta, arterial pressure decreases

Average Blood Pressure is 120/80 (male), 110/70 (female)

Arterial blood pressure is affected most importantly by:

1. **Cardiac Output** (CO ml/min): the volume of blood discharged from the left ventricle into the aorta each minute at rest
    a. Know this equation:
    b. CO (Cardiac Output ml/min) = HR (heart beats/min) x (SV) (stroke volume ml)
    c. Stroke volume is the amt of blood pushed from the L ventricle in a single contraction. CO is approx. 5L/min
2. **Blood Volume** (BV): the body's total volume of blood (typically 5-6 L in an adult)
3. **Peripheral Resistance:** the friction caused by blood flow against the vessels walls. Dependent on hormone levels, activity levels, weight, age, and kidney function.

Systolic Pressure: Korotkoff sound first heard, begins to grow louder then softer until…
Diastolic Pressure: absence of Korotkoff sounds
A **sphygmomanometer** is inflated to block blood flow in the brachial artery

- Upon gradually venting the pressure, the blood pressure will exceed the pressure of the cuff
- Blood will spurt through the artery back into the forearm and the turbulent flow produces a *pulsatile sound* - **Korotkoff's sounds.** The pressure at which this pulse-like sound is first heard is recorded as the systolic pressure.
- The pressure at which the Korotkoff's sounds first become inaudible is the diastolic pressure. This is because the artery is no longer compressed and the cuff pressure is equal to the arterial pressure.

Problems with blood pressure

Hypertension

- chronic resting BP > 140/90
- can weaken small arteries and cause aneurysms

Hypotension

- chronic low resting BP
- causes: blood loss, dehydration, anemia

Measuring the Pulse

(Section 20.2.2: Pulse)
(Figure 20.11: Pulse Sites)

Heart rate is determined by measuring the *Pulse* or *pressure wave* in an artery
Ventricular Systole - blood pressure increases and stretches the walls of arteries
Ventricular Diastole - blood pressure decreases and arterial walls rebound
The change in vessel diameter is felt as a throb or pulse at various pressure points on the body
Most common places to feel a person's pulse are the carotid artery and the radial artery. DO NOT push on carotids simultaneously- they supply blood to your brain.

Baroreceptor Reflex

(Section 20.4.1.1: Baroreceptor Reflexes)

(Figure 20.18: Baroreceptor Reflexes for Maintaining Vascular Homeostasis)

Baroreceptors in the carotid sinus and arch of the aorta respond to an increase in blood pressure.
Increased blood pressure stretches carotid arteries and aorta
Baroreceptors increase action potential generation
Action potentials are conducted to medulla oblongata (by way of glossopharyngeal and vagus nerves)
Parasympathetic stimulation to the heart increases, therefore decreasing heart rate.
Decreased sympathetic stimulation to the heart decreases heart rate and stroke volume
Decreased sympathetic stimulation to the blood vessels causes vasodilation
Vasodilation, as well as a decreased heart rate and stroke volume, work together to bring elevated blood pressure back to normal.

Systemic Blood Vessels

For all vessels listed, you should be able to:

- **identify** the vessels on both the diagrams and models
- **distinguish** between right and left for vessels that are bilateral
- state the **major organ** that is supplied or drained by the vessels

Review of Pulmonary Circulation

[Section 20.5.1: Pulmonary Circulation]

[Figure 20.23: Pulmonary Circuit]

[Table 20.4: Pulmonary Arteries and Veins]

The Aorta and Aortic Arch

[Section 20.5.3: The Aorta; Section 20.5.3.2: Aortic Arch Branches]

[Figure 20.24: Systemic Arteries]

[Figure 20.25: Aorta]

[Figure 20.26: Arteries Supplying the Head and Neck]

[Figure 20.27: Arteries Serving the Brain]

[Table 20.5: Components of the Aorta]

aorta (sections):
ascending
aortic arch
descending (here called the "thoracic" aorta)
aorta (branches):
coronary arteries
brachiocephalic trunk
subclavian a.
common carotid a.
external carotid a.
internal carotid a.
vertebral a.
basilar a.
superficial temporal a.
facial a.
maxillary a.

Cerebral Arterial Circle (aka, the Circle of Willis)

internal carotid a.
vertebral a.
basilar a.
anterior cerebral a.
middle cerebral a.

posterior cerebral a.
anterior communicating a.
posterior communicating a.

Thoracic and Abdominal Aorta

[Section 20.5.3.3: Thoracic Aorta and Major Branches; Section 20.5.3.4: Abdominal Aorta and Major Branches]

[Figure 20.28: Arteries of the Thoracic and Abdominal Regions]

[Figure 20.29 Major Branches of the Aorta]

[Table 20.7: Arteries of the Thoracic Region]

[Table 20.8: Vessels of the Abdominal Aorta]

thoracic aorta
intercostal aa.
celiac trunk
splenic a.
common hepatic a.
left gastric a.
superior mesenteric a.
renal a.
gonadal a.
inferior mesenteric a.
common iliac a.
internal iliac a.
external iliac a.

Arteries Serving the Upper Limbs

[Section 20.5.5: Arteries Serving the Upper Limbs]

[Figure 20.31: Major Arteries Serving]

[Figure 20.32: Major Arteries of the Upper Limb]

[Table 20.9: Arteries Serving the Upper Limbs]

axillary a.
brachial a.
radial a.
ulnar a.
digital aa.
deep palmar arch
superficial palmar arch

Arteries Serving the Lower Limbs

[Section 20.5.6: Arteries Serving the Lower Limbs],

[Figure 20.33: Major Arteries Serving the Thorax and Upper Limb]

[Figure 20.34: Systemic Arteries of the Lower Limb]

[Table 20.10: Arteries Serving the Lower Limbs]

femoral a.
deep femoral a.
popliteal a.
fibular a.
plantar a.
dorsalis pedis a.
digital aa.

Superior Vena Cava and Veins of Head & Neck

[Section 20.5.7.1: The Superior Vena Cava]

[Section 20.5.7.2: Veins of the Head and Neck]

[Section 20.5.7.3: Venous Drainage of the Brain]

[Figure 20.35: Major Systemic Veins of the body]

[Figure 20.36: Veins of the Thoracic and Abdominal Regions]

[Figure 20.37: Veins of the Head and Neck]

[Figure 20.39: Veins Flowing into the Superior Vena Cava]

internal jugular v.
external jugular v.
brachiocephalic v.
subclavian v.
superior vena cava

Veins Draining the Upper Limbs

[Section 20.5.7.4: Veins Draining the Upper Limbs]

[Figure 20.38: Veins of the Upper Limb]

[Figure 20.39: Veins Flowing into the Superior Vena Cava]

subclavian v.
cephalic v.
axillary v.
brachial v.
basilic v.
median cubital v.
radial v.
ulnar v.
digital vv.

The Inferior Vena Cava

[Section 20.5.7.5: The Inferior Vena Cava]

[Figure 20.40; Venous Flow into Inferior Vena Cava]

inferior vena cava
hepatic v.
renal veins
common iliac v.
internal iliac v.
external iliac v.
azygos v.
hemiazygous v.
renal veins
common iliac v.
internal iliac v.
external iliac v.
gonadal v.

Hepatic Portal System

[Section 20.5.8: Hepatic Portal System]

[Figure 20.43: Hepatic Portal System]

hepatic v.
hepatic portal v.
splenic v.
superior mesenteric v.
inferior mesenteric v.

Veins Draining the Lower Limbs

[Section 20.5.7.6: Veins Draining the Lower Limbs]

[Figure 20.41: Major Veins Serving the Lower Limbs]

[Figure 20.42: Major Veins of the Lower Limb]

femoral v.
great saphenous v.
popliteal v.
plantar venous arch
dorsal venous arch
digital vv.

Anatomy of the Respiratory System

Objectives

- List the structures that make up the respiratory system
- Distinguish between the upper respiratory tract and the lower respiratory tract
- Explain the difference between the conducting zone and the respiratory zone, listing the anatomical structures that are a part of each

Basic Anatomy of the Respiratory System

[Section 22.1: Organs and Structures of the Respiratory System]

[Section 22.1.1: Conducting Zone]

[Figure 22.2: Major Respiratory Structures]

The organs of the respiratory system are divided anatomically into:

The **upper respiratory tract:**

Nose
Nasal cavity (made of a hard and soft palate)
Sinuses
Pharynx

The **lower respiratory tract:**

Larynx
Trachea
Bronchi
Lungs

But, the respiratory system may also be divided functionally into:

The **conducting zone**

organs and structures not involved in gas exchange

The **respiratory zone**

the locations where the exchange of O_2 and CO_2 occur

Structures of the Conducting Zone

Nose

[Section 22.1.1.1: The Nose and its Adjacent Structures]

[Figure 22.3: Nose]

[Figure 22.4: Upper Airway]

External nares (the nostrils)

- hair in the vestibule removes airborne particles
- primary route for entering air

Nasal Septum

- divides nasal cavity
- bony portion = perpendicular plate of the ethmoid bone and vomer bone union
- works with cartilage to form full septum

Nasal conchae (aka, turbinates)

- cause the air to swirl in the nasal cavity and come in contact with mucous membrane covering (which catches debris/dust)
- heat and humidify the air for respiration - allows diffusion of gases in lungs

Pharynx

[Section 22.1.1.2: Pharynx]

[Figure 22.4: Upper Airway]

[Figure 22.6: Divisions of the Pharynx]

Uvula

flips up during swallowing to prevent fluids from entering the nasopharynx (soft palate also raises to prevent food from entering)

The Pharynx is divided into 3 anatomical regions:

1. ***Nasopharynx***
   - Passageway for airflow from nasal cavity
   - Has pseudostratified ciliated columnar epithelieum, pharyngeal tonsils, and eustachian tubes
2. ***Oropharynx***
   - common passageway for food, water, and air
   - stratified squamous epithelium (in common with oral cavity)
   - Contains palatine and lingual tonsils
3. ***Laryngopharynx***
   - Passageway for food
   - stratified squamous epithelium

Larynx

[Section 22.1.1.3: Larynx]

[Figure 22.7: Larynx]

[Figure 22.8: Vocal Cords]

During swallowing, the hyoid bone lifts causing the ***epiglottis*** to lower and protect the ***glottis,*** which consists of the opening in the larynx and the vocal cords.

Glottis

- *false vocal cords* (Vestibular ligaments and folds)
  - During coughing or sneezing, close over the glottis
  - Superior to the true vocal cords
- *true vocal cords* (Vocal ligaments and folds)
  - Responsible for sound production

- Only produces sound when air is exhaled over them
- Sounds change when cords are stretched or relaxed

Larynx (Voice Box)

Made up of 9 cartilages:
1 thyroid cartilage (Adam's apple)
1 cricoid cartilage (connects larynx to trachea)
1 epiglottis
2 arytenoid cartilages
2 corniculate cartilages
2 cuneiform cartilages

Trachea

[Section 22.1.1.4: Trachea]

[Figure 22.9: Trachea]

Lungs

[Section 22.1.1.5: Bronchial Tree]

[Section 22.1.2: Respiratory Zone]

[Figure 22.9: Trachea]

[Figure 22.10: Respiratory Zone]

[Figure 22.11: Structures of the Respiratory Zone]

The right lung of a human has 3 lobes, while the left lung only has 2

Bronchial Tree

- 1° bronchus (R & L)
- 2° bronchus (R & L)
  - R = 3
  - L = 2
  - (corresponds to # of lobes)
- 3° bronchus (R & L)
  - R = 3, 2, 5
  - L = 5, 5 (during development)
  - Fusion events lead to 8 or 9 total after development

Bronchioles

- lack cartilage
- have layer of smooth muscle
- terminal bronchioles
- have cilia, give off 2 or more respiratory bronchioles
- respiratory bronchioles

- divide into 2-10 alveolar ducts

respiratory bronchioles divide into thin walled passages called ***alveolar ducts***
alvoelar ducts end in grapelike clusters of ***alveoli*** called ***alveolar sacs***
the ***alveoli*** provide large surface area (~70sq.m) for gas exchange

Alveoli

[Section 22.1.2: Respiratory Zone]

[Figure 22.10: Respiratory Zone]

[Figure 22.11: Structures of the Respiratory Zone]

Gross Anatomy of the Lungs

[Section 22.2: The Lungs]

[Section 22.2.1: Gross Anatomy of the Lungs]

[Section 22.2.3: Pleura of the Lungs]

[Figure 22.13: Gross Anatomy of the Lungs]

[Figure 22.14: Parietal and Visceral Pleurae of the Lungs]

Physiology of the Respiratory System

Respiration

Respiration has 3 phases:

1. Pulmonary ventilation - movement of air into and out of the lungs
2. External respiration - exchange of gases b/n lungs and blood
3. Internal respiration - exchange of gases b/n blood and tissues

Pulmonary ventilation consists of

1. Inspiration - inhalation, movement of air into lungs
2. Expiration - exhalation, emptying air from lungs into atmosphere

Pulmonary Ventilation

[Section 22.3.2: Pulmonary Ventilation]

[Figure 22.17: Inspiration and Expiration]

For pulmonary ventilation to occur, the pressure in the thoracic cavity must be different from atmospheric pressure

- ***Inspiration*** is an ***active process,*** it requires the contraction of several muscles to change volumes and pressures
- ***Expiration*** is ***passive,*** muscles relax, thoracic wall and lungs recoil, air moves out

Lung Volumes and Capacities

[Section 22.3.3: Respiratory Volumes and Capacities]

[Figure 22.18: Respiratory Volumes and Capacities]

A ***Spirometer*** measures respiratory volumes

- ***Tidal Volume**** is the amount of air inhaled or exhaled during normal resting breathing
- ***Inspiratory Reserve Volume (IRV)*** is the amount of air forcibly inspired above normal inhalation
- ***Expiratory Reserve Volume (ERV)**** is the amount of air forcibly expired after a normal exhalation
- ***Vital Capacity**** is the maximum amount of air exhaled from lungs after maximum inhalation

**** can be measured directly with spirometer***

IRV can be calculated from the VC, TV, and ERV:

$$VC = IRV + ERV + TV \rightarrow IRV = VC - ERV - TV$$

The respiratory system always contains some air

- The ***Residual Volume*** is the amount of air that cannot be forcefully exhaled from the lungs

- ***Total Lung Capacity*** is ~ 6,000 ml; ***TLC = VC + RV***
- ***Minimal Volume*** is the amount of residual air that stays in the lungs even after collapse
- ***Respiratory Rate*** is the number of breaths taken per minute
- ***Minute Volume*** amount of air exchanged b/n lungs and environment in 1 minute: ***MV = TV x RR***

Renal Anatomy

Major Organs:

[Section 25.2: Gross Anatomy of Urine Transport]

- kidneys
- ureters
- urinary bladder
- urethra

Functions:

[Section: Introduction (chapter 25)]

- filters dissolved material from the blood
- regulates electrolytes
- regulates fluid volume
- concentrates and stores waste products
- reabsorbs metabolically important substances back into the circulatory system

Urethra

[Section 25.2.1: Urethra]

[Figure 25.3: Female and Male Urethras]

- carries urine from the internal urethral orifice to the external urethral orifice and exits the body
- Note the basic differences in length between male and female ureters. What additional risk does this cause for females?
- Notice that the male urethra is a common exit for both the urinary and reproductive systems.

Urinary Bladder

[Section 25.2.2: Bladder]

[Figure 25.4: Bladder]

- trigone - triangular region on the posterior wall of the urinary bladder - contains the ureteral openings, the entrance of the ureters to the urinary bladder - inferiorly the urethra exits
- inner surface lined with transitional epithelium (allows for expansion)
- detrusor muscles - in the wall of the bladder (expels urine from bladder)
- rugae - folds formed from epithelial lining

Ureters

[Section 25.2.3: Ureters]

[Figure 25.6: Ureter]

- narrow, long, muscular tubes
- urine is moved by peristalsis from the kidney to the urinary bladder

Kidneys:

[Section 25.3: Gross Anatomy of the Kidney (all subsections)]

[Figure 25.7: Kidneys]

[Figure 25.8: Left Kidney]

- located posterior to the parietal peritoneum
- basic anatomy:
    - *o* renal capsule
    - **o** renal cortex
    - **o** renal medulla
        - renal pyramid
        - renal column
        - renal papilla
    - **o** calyces (major and minor)
    - **o** renal pelvis
    - **o** renal hilum

Blood Flow through the Kidney

[Throughout Section 25.3]

[Figure 25.9: Blood Flow in the Kidney]

Since the primary function of the kidneys is to filter waste materials from the blood, it is important for you to understand the complexities of the flow of blood into and out of the kidneys.

- Blood is delivered via the *renal artery,* which branches from the abdominal aorta
- Then it branches into *segmental arteries* then into *interlobar arteries,* which pass through renal columns
- Interlobar a. then divide into *arcuate arteries,* which cross the base of pyramids and enter the renal cortex as *interlobular arteries*
- These branch into *afferent arterioles* which are what forms the glomerulus
- At the end of the glomerulus, opposite the afferent arteriole, an *efferent arteriole* exits the glomerulus
- The efferent arteriole forms a bed of *peritubular capillaries* around the entire tubular portion of cortical nephrons
- But only around the proximal and distal convoluted tubules in juxtamedullary nephrons
- In juxtamedullary, the loop of henle is surrounded by *vasa recta capillaries*
- Both networks drain into *interlobular veins,* which drain into *arcuate veins,* to *interlobar veins* and finally the *renal vein*

Specific Kidney Functions

1. Remove waste: The kidneys filter waste products and excess fluid out of the blood and remove them from the body in the form of urine. (nitrogenous wastes such as urea and ammonium)
2. Maintain the right balance of chemicals in the body: The kidneys keep the right balance of chemicals, such as sodium, potassium, calcium, magnesium, and other substances your body needs to function properly. They filter excess amounts of these chemicals from the blood and get rid of them in the urine.
3. Synthesize several regulatory chemicals: The kidneys produce and secrete three important chemicals: renin, erythropoietin, and the active form of vitamin D (Calcitriol).

Production of Urine: An Overview

- The kidneys maintain the chemical balance of body fluids by removing metabolic wastes, excess water and electrolytes
- Three physiological process occur in nephrons to produce urine:
  1. Filtration
     - Blood is initially filtered in the glomerulus
  2. Reabsorption
     - as the filtrate moves through the PCT, 60-70% of water and 100% of the organic nutrients (glucose, amino acids) are reabsorbed into the blood
     - The loop of Henle conserves water and salt while concentrating the filtrate for modification by the DCT
     - Reabsorption in the DCT is controlled by two hormones, aldosterone and anitdiuretic hormone (ADH)
  3. Secretion
     - Most secretion takes place in the DCT

The Nephron

[Section 25.4: Microscopic Anatomy of the Kidney]

[Figure 25.10: Blood Flow in the Nephron]

- The basic functional unit of the kidney is the nephron
- Here, water, ions and other waste material are removed from the blood to produce filtrate
- The filtrate then circulates through tubules and anything still needed is absorbed back into the blood
- The remaining filtrate is excreted as urine
- *2 types of nephrons:*
  - Cortical make up about 85% of all nephrons in a kidney
  - Juxtamedullary make up the other 15%

Nephron Anatomy

Each nephron consists of 2 distinct regions:

1. renal corpuscle - filters blood
2. renal tubule - modifies the filtrate through reabsorption and secretion to form urine

Nephron Part 1: The Renal Corpuscle

[Section 25.4.1.1: Renal Corpuscle]

[Figure 25.11: Podocytes]

[Figure 25.12: Fenestrated Capillary]

- initial filtration of blood
- Consists of two components: the glomerulus and Bowman's capsule
- Filterable blood components such as water, nitrogenous waste, and nutrients form the glomerular filtrate.
- Non-filterable blood components such as blood cells and platelets remain in the blood and exit the glomerulus via the efferent arteriole.

Nephron Part 2: The Renal Tubule

- modifies the filtrate through reabsorption and secretion to form urine
- consists of multiple sections:
    - the proximal convoluted tubule
    - the nephron loop or loop of Henle; consists of two distinct parts:
        - descending limb
        - ascending limb
    - the distal convoluted tubule
- all tubules empty into collecting ducts which channel urine towards the center of each kidney

Proximal Convoluted Tubule

[Section 25.4.1.2: Proximal Convoluted Tubule]

- the major site for reabsorption of water and solutes from the filtrate into the interstitial fluid and then into blood capillaries
- reabsorb 100% of most organic solutes (amino acid, glucose, etc.); 65% of water, sodium ions, and potassium ions; and 50% of chloride ions

Descending Limb (of nephron loop)

[Section 25.4.1.3: Loop of Henle]

- the nephron loop is also called the loop of Henle
- 15% of the water in the filtrate is reabsorbed by osmosis into the interstitial fluid
- the descending limb is impermeable to solutes

Ascending Limb (of nephron loop)

[Section 25.4.1.3: Loop of Henle]

- reabsorbs solutes

- impermeable to water

Distal Convoluted Tubule

[Section 25.4.1.4: Distal Convoluted Tubule]

- reabsorbs a small amount of water and solutes
- mainly, secretes solutes from the blood into the filtrate
- drains into a collecting duct

Collecting Ducts

[Section 25.4.1.5: Collecting Ducts]

- reabsorbs a small amount of water and solutes
- mainly, secretes solutes from the blood into the filtrate
- merge to form larger papillary ducts

Assessing Urinary Function: The Urinalysis

[Entire Lab based on Section 25.1: Physical Characteristics of Urine]

[Table 25.1: Normal Urine Characteristics]

[Table 25.2: Urine Volumes]

Urine Composition

- Water accounts for about 95% of the volume of urine
- The other 5% is excess vitamins, drugs, electrolytes, and nitrogenous wastes
- Abnormal substances in the urine can be detected by ***urinalysis***

Physical and Chemical Analysis of Urine

- The average pH of urine is 6.0, it can range b/n 4.5 and 8.0.
- Vegetarians have a pH above 7.0
- High-protein diets yield an acidic pH, below 7.0
- Concentration of urine has traditionally been measured as specific gravity. Specific gravity is a way of comparing the weight of one fluid (like urine in this case) to the weight of a reference fluid (pure, distilled water). The specific gravity of urine is between 1.003 and 1.030.
- It is more common now for labs to measure concentration in osmolarity. The reference range for urine is around 100 - 1200 mOsmol/L.
- Drinking lots of fluids, lowers the specific gravity (makes it more dilute). Taking in less fluids increases specific gravity (makes it more concentrated).
- Excessively concentrated urine results in crystallization of solutes, usually salts, into insoluble kidney stones

Physical and Chemical Analysis of Urine

Certain materials in urine suggest renal disease, injury, or other pathological conditions:

- ***Ketonuria*** (ketones in urine) - observed in the urine in the event of starvation, diabetes or a low carb diet. Fat catabolism produces fatty acids. The liver cells convert excess fatty acids to ketones
- ***Glycosuria*** (glucose in urine) - indicates diabetes or stress
- ***Albuminuria*** (albumin in urine) - suggest an increase in permeability of glomerular membrane. May be due to injury, high blood pressure, disease, bacterial toxins
- ***Hematuria*** (RBCs or whole blood in urine) - indicates bleeding caused by inflammation or infection of urinary tract. Kidney stones, trauma, menstruation or tumor formation
- ***Pyuria*** (WBCs in urine) - urinary tract infection

Bilirubinuria (bilirubin in urine) - result of the breakdown of hemoglobin from old RBCs being removed from the circulatory system by phagocytic cells in the liver.

Urobilinogenuria (urobilinogen is produced by the breakdown of bilirubin) - may indicate hepatitis, cirrhosis, congestive heart failure, or other diseases

Digestive System Anatomy

Overview of Digestive Anatomy

[Section 23.1: Overview of the Digestive System]

[Section 23.1.1: Digestive System Organs]

[Figure 23.2: Components of the Digestive System]

The organs of the digestive system are divided into 2 main groups:

1. the alimentary canal (GI tract)
    - Tube that runs from the mouth to the anus
    - organs include: pharynx, esophagus, stomach, intestines, rectum, anus
    - the lumen of the alimentary canal opens to the external environment at both ends and therefore anything inside the lumen is considered external to the body
2. accessory organs
    - these organs are not part of the tube, i.e. they are not hollow organs that food passes through
    - secrete substances into the tube
    - many of these substances are required for digestion or enhance digestion
    - include: teeth, tongue, salivary glands, liver, gallbladder, and pancreas
        - the liver/gallbladder and pancreas will be considered separately at the end of this lab

Histology of the Alimentary Canal

[Section 23.1.2: Histology of the Alimentary Canal]

[Figure 23.3: Layers of the Alimentary Canal]

MSMS = mucosa, submucosa, muscularis, serosa

1. Mucosa
    a. epithelium
        i. in mouth, pharynx, and esophagus the epithelium is stratified squamous
        ii. in stomach, small intestine and large intestine, the epithelium is simple columnar
        iii. in anal canal the epithelium becomes stratified squamous again
        iv. the epithelium has a high rate of turnover (rate of mitosis); some cells live only a few days, others up to a week
    b. lamina propria
        i. loose connective tissue containing blood vessels and lymphatic tissues
2. Submucosa
    a. dense connective tissue

   b. blood vessels and lymphatic vessels for transporting absorbed nutrients from food to rest of body
3. Muscularis (aka, muscularis externa)
   a. in the mouth, pharynx, esophagus, and anal canal this muscular layer is skeletal muscle, providing some voluntary control
   b. the small intestine has a basic 2-layer organization of smooth muscle (named for direction of fibers):
      i. inner layer called the **circular** layer
      ii. outer layer called **longitudinal**
   c. the 2-layer organization is modified in the stomach with an additional layer
      i. the **oblique** layer is superficial to the longitudinal layer in the stomach wall
   d. the large intestine technically has 2 layers, but the outer longitudinal layer is separated into three, narrow bands called **tenia coli**
4. Serosa
   a. present only on organs within the abdominal cavity
   b. covers the tubular organs in this cavity
   c. doubles back on itself to form the **mesenteries** that hold the alimentary canal in place within the abdominal cavity

Six Major Processes of Digestion

[Section 23.2: Digestive System Processes; Section 23.2.1: Digestive Processes]

[Figure 23.5: Peristalsis; Figure 23.6: Digestive Processes]

1. Ingestion of food into the mouth
2. Movement of food through the digestive tract
   - swallowing and peristalsis
3. Mechanical digestion of food
   - process of physically grinding bites of food and separating them in to smaller pieces
   - this increases the surface area of the food particles to increase contact with digestive juices
4. Chemical digestion of food
   - unlike mechanical digestion, chemical digestion requires enzymes
   - enzymatic breakdown of large food polymers into their monomers (proteins into amino acids, for example)
5. Absorption of nutrients in the blood
6. Formation and elimination of indigestible materials and waste.

GI Tract: Mouth and Oral Cavity

[Section 23.3.1: The Mouth]

[Figure 23.7: Mouth]

- Mainly mechanical digestion
- Limited amount of chemical digestion with **salivary amylase** and **lingual lipase**

- hard & soft palates - form the roof of the mouth
- tongue - forms the floor of the mouth
- gingiva - gums
- superior and inferior labial frenulum - attaches the lips to the gums
- vestibule - region between teeth and cheek.
- lingual frenulum - attaches the tongue to the gums
    - read more about ankyloglossia in the "Tongue" section of your text
    - it can impair speech, but it can also severely impair a newborn's ability to latch and breastfeed
- uvula - oval process that hangs down the posterior portion of the oval cavity - prevents food or liquid from moving into the nasal cavity

Tongue

[Section 23.3.2: The Tongue]

[Figure 23.8: Tongue]

muscles of the tongue perform 3 important functions:

1. position food while chewing
2. form and shape food into a bolus
3. position food for swallowing

surface covered with papillae

- most of the surface of the tongue is covered by two types of papillae
    1. **fungiform** that contain the microscopic structures known as taste buds
    2. **filiform** papillae that have touch receptors and create an abrasive surface for moving food around in the mouth

Salivary glands

[Section 23.3.3: Salivary Glands]

[Figure 23.9: Salivary Glands]

1. Parotid *(serous* gland)
2. Submandibular *(mucous + serous* gland)
3. Sublingual *(mucous + serous* gland)

Teeth

[Section 23.3.4: The Teeth]

[Figure 23.10: Permanent and Deciduous Teeth; Figure 23.11: Anatomy of a Tooth]

- Tooth is anchored to the jaw bone by periodontal ligament that lines the embedded part of the tooth, the root.
- Crown is the portion of the tooth above gingiva or gum
- Only inner pulp cavity is filled with living tissue, the pulp.
- Surrounding pulp cavity is dentin, which makes up most of the structural mass of the tooth.

- The exposed crown is covered with enamel, the hardest substance produced by living organisms.

GI Tract: Esophagus

[Section 23.3.6: The Esophagus]

[Section 23.3.6.1: Passage of Food through the Esophagus]

[Figure 23.13: Esophagus]

- food moves from the mouth into the oropharynx, laryngopharynx, and then into the esophagus
- it is a closed tube
- a food lump, bolus, is moved through the esophagus by skeletal muscles - peristalsis
- upper and lower esophageal sphincters

GI Tract: Stomach

[Section 23.4: The Stomach]

[Section 23.4.1: Stomach Structure]

[Figure 23.15: Stomach]

- Four areas of stomach:
  1. cardia
  2. fundus
  3. body
  4. pylorus
- Esophageal or cardiac sphincter - prevents stomach contents from moving into the esophagus
  - remember, the mucosa of the esophagus has a much thinner lamina propria, so acids from stomach can severely erode the esophagus
  - GERD = gastroesophageal reflux disorder (or disease) can be painful and severe, but is also associated with an increased risk of esophageal cancers
- Cardia - where food enters from esophagus
- Z-line - epithelial cells change from squamous to columnar
- Fundus - serves as a temporary holding area for food
- Rugae - large ridges that allow the stomach to be stretched
- Body- the main, central region of stomach
- Pylorus - the lower region of stomach
- Pyloric sphincter - smooth muscle that allows release of stomach contents into the first part of the small intestine

GI Tract: Small Intestine

[Section 23.5: The Small and Large Intestines]

[Section 23.5.1: The Small Intestine]

[Figure 23.18: Small Intestine]

[Figure 23.19: Histology of the Small Intesine]

- primary functions = chemical digestion and nutrient absorption
- Has circular folds, villi, and microvilli to increase surface area
- ileocecal sphincter separates the small and large intestines
- Three distinct regions:
  1. Duodenum
     - first 25 cm of small intestine
     - C-shaped structure that begins at the pyloric sphincter of the stomach
  2. Jejunum
     - approximately 2 meters
     - has a thick layer smooth muscle
     - Site of most nutrient absorption
  3. Ileum
     - approximately 3 meters
     - contains dense numbers of Peyer's patches (clusters of immune cells) to aid in immune defense
       - read more about MALT in chapter 21, the paragraph just above figure 21.11
     - Empties into cecum of large intestine through ileocecal sphincter

GI Tract: Large Intestine

[Section 23.5.2: The Large Intestine]

[Figure 23.21: Large Intestine]

[Figure 23.23: Teniae Coli, Haustra, and Epiploic Appendages]

- approximately 1.4 m long
- major function is absorption of water, vitamins, and solutes & the formation of feces
- Composed of 3 main regions:
  1. cecum
     a. appendix: may play an immunological role or may serve as bacterial reservoir to replenish colon bacterial after severe diarrhea
  2. colon (4 subdivisions):
     a. ascending colon
     b. transverse colon
     c. descending colon
     d. sigmoid colon
  3. rectum
     a. anal canal
     b. internal anal sphincter is smooth muscle and is involuntary
     c. external anal sphincter is skeletal muscle and is voluntary

Accessory Organ: Liver

[Section 23.6: Accessory Organs in Digestion: The Liver, Pancreas, and Gallbladder]

[Section 23.6.1: The Liver]

[Figure 23.24: Accessory Organs; Figure 23.25: Microscopic Anatomy of the Liver; Figure 23.27: Gallbladder]

- Liver has 4 lobes
  - **left** and **right lobes** can both be seen from the anterior view
  - on the posterior/inferior view the **caudate** and **quadrate lobes** can also be seen
- Each lobe is organized into microscopic columns called **lobules.**
  - Primarily made of cells called hepatocytes
  - hepatocytes arranged in hexagonal columns around central vein
- Bile is produced by hepatocytes
  - Bile flows through a series of small ducts called canaliculi
  - Canaliculi ducts drain into the right and left hepatic ducts (better seen in figure 23.27)
  - These join to form the common hepatic duct
  - The cystic duct of the gallbladder and common hepatic duct join to form the common bile duct
  - This joins with the pancreatic duct in the pancreas before draining into the duodenum of small intestine

Accessory Organ: Gall Bladder

[Section 23.6.3: The Gallbladder]

[Figure 23.24: Accessory Organs; Figure 23.27: Gallbladder]

- Small organ (~3"x1.5")
- Excess bile is pushed up the cystic duct by peristalsis
- Bile is stored and concentrated until needed
- Microvilli on innermost epithelial layer absorb water
- Muscle layer pushes bile back into cystic duct

Accessory Organ: Pancreas

[Section 23.6.2: The Pancreas]

[Figure 23.24: Accessory Organs; Figure 23.26: Exocrine and Endocrine Pancreas]

- ~6"long
- Connects to duodenum
- Endocrine gland (produces hormones)
  - Insulin
  - Glucogon
- Exocrine function
  - Produces digestive enzymes

- See, but don't memorize, Table 23.8 for an overview of the major digestive enzymes. Notice how many of the total are produced and secreted by the pancreas

Digestive Physiology

[Section 23.7: Chemical Digestion and Absorption: A Closer Look]

[Figures 23.28, 23.29, 23.30, 23.31, 23.32, 23.33]

Note: You will notice while studying this lab that much of the material repeats from the previous lab, especially many of the anatomical descriptions of some organs. We do want you to study the material again as you learn more about the physiology of mechanical and chemical digestion. We feel that the repeated material is necessary for you to understand the context of where the physiological events take place in the alimentary canal. We do want you to study these structures again for the next practical. We also want you to study the material included in the handout that details the activities you will perform in lab.

Physiology of the Alimentary Canal

Salivary Glands

- secrete saliva into the oral cavity
  - saliva = mucous + salivary amylase
  - salivary amylase starts starch / carbohydrate digestion
- Three main glands:
  - Parotid *(serous* gland)
  - Submandibular *(mucous* + *serous* gland)
  - Sublingual *(mucous* + *serous* gland)
- Secrete in response to *parasympathetic* activity (sympathetic activity inhibits salivation)

Stomach

- chyme - mixture of food, enzymes, and hydrochloric acid in the stomach
- acids in the stomach denature proteins into shorter fragments and can create a pH of 1 or 2
- Enzymes, such as trypsin and pepsin, start protein digestion

Duodenum

- Receives digestive secretions (bile, enzymes, and buffers) from the liver, gall bladder, and pancreas to aid in digestion and to raise the pH to ~7
- Lipid / Fat digestion begins here using lipases from the pancreas
  - lipid digestion is optimized by bile from liver/gallbladder
- Nucleic acid digestion begins with nucleases from the pancreas

Jejunum

- Site of most nutrient absorption

Ileum

- contains Peyer's patches to aid in immune defense

Large Intestine

- major function is absorption of water, vitamins, and solutes & the formation of feces
- Appendix is accessory organ with no known function, but may have some immune function

Accessory Organs

Liver

- processes digestive material from the vessels returning blood from the intestines
- has a role in either moving nutrients into the bloodstream or storing them in the liver tissue
- Have *Kupffer cells (stellate macrophages)* that destroy foreign bodies entering
- In the lobules, cells called hepatocytes secrete bile, which emulsifies fat in the ingested food.
- Blood from the hepatic artery and from the hepatic portal vein drain into spaces in the lobules called *sinusoids,* surrounded by hepatocytes and Kupffer cells to filter blood, and the sinusoids then empty into a central vein, which carries filtered blood to the hepatic veins into systemic circulation via the Inferior Vena Cava.
- Hepatocytes lining the sinusoids phagocytize worn blood cells.
- Sinusoids: location for O_2 rich blood from hepatic artery & nutrient-rich blood from hepatic portal vein

Gall Bladder

- releases bile into the duodenum
- used for bile storage
- the bile breaks lipids into smaller droplets

Pancreas

- secretes many digestive enzymes and buffers, which neutralize the stomach acids
- has islets of Langerhans
- endocrine function
- insulin & glucagon

Digestion and Absorption of Food Components

Carbohydrates

- Digestion starts in oral cavity with salivary amylase
- Water soluble
- Absorption in small intestines through blood capillaries → superior / inferior mesenteric vein → hepatic portal vein → liver → hepatic vein → IVC → heart → systemic circulation

Proteins

- Digestion starts in stomach with breakdown by acid and enzymes
- Also water soluble, so follows the same pathway as carbs

Lipids

- Digestion starts in duodenum with bile and lipases
- Fat soluble, so insoluble in GI tract
- Bile and lipases breakdown fats into smaller fat globules and keep them from combining into larger droplets
- Still too big for absorption into blood capillaries
- Absorbed by lacteal (larger than blood capillaries with open valves for absorption) — lymphatic vessel — lymphatic system (filters the fats carried in lymph) — thoracic duct — left subclavian vein — left brachiocephalic vein — SVC — heart — systemic circulation

Male Reproductive System

Objectives

- Identify and give functions of all components of male systems
- Describe the composition of semen and its functions
- Identify the three regions of the male urethra
- Identify the structures and tissues of the penis
- Describe the process/pathway of sperm and development of semen

Male Reproductive Anatomy

The male reproductive system consists of a pair of ***testes, conducting ducts, accessory glands*** and the ***penis***

Testes

[Section 27.1: Anatomy and Physiology of the Male Reproductive System]

[Section 27.1.1: Scrotum]

[Section 27.1.2: Testes]

[Figure 27.2: Male Reproductive System; Figure 27.3: The Scrotum and Testes]

- paired, separated by the Dartos muscle
- Produces spermatozoa and testosterone (interstitial cells)
- Lies in the scrotum outside the abdominopelvic cavity where the temperature is slightly lower than inside the body. The lower temperature optimizes the rate of sperm production
- Each is covered by a dense connective tissue capsule called the **tunica albuginea** ("white tunic")
    - Inward extensions of the tunica albuginea divide the testes into lobes containing **seminiferous tubules**
        - These tubules produce millions of spermozoa a day

Conducting System

[Section 27.1.4: Sperm Transport]

[Figure 27.2: Male Reproductive System; Figure 27.4: Anatomy of the Testes]

Epididymis, vas deferens, ejaculatory duct and urethra form a system of tubules for the transport of spermatozoa from testes to the pelvic cavity. There they will be combined with the secretions of the accessory glands to form semen.

Epididymis

[Section 27.1.4.1: Role of the Epididymis]

[Figure 27.2: Male Reproductive System; Figure 27.4: Anatomy of the Testes]

- An elongated structure on posterolateral surface of testis that caps on the superior side.

- First portion of duct system
- Provides site for maturation of sperm

Ductus Deferens (Vas Deferens)

[Section 27.1.4.2: Duct System]

[Figure 27.2: Male Reproductive System; Figure 27.4: Anatomy of the Testes]

- upon ejaculation, sperm is received here from the epididymis by peristalis
- passes through the inguinal canal into the pelvic cavity and superiorly over the bladder
- enclosed with **spermatic cord** (a connective tissue sheath consisting of blood vessels, nerves and the **cremaster muscle.** This muscle encases the testes & elevates or lowers them to maintain the temperature needed to create sperm.
- end is enlarged (called **ampulla)**
- empties into the ejaculatory duct

Ejaculatory Duct

- During ejaculation, its contraction pushes sperm through the prostrate and to the **prostatic urethra** where it joins the **seminal vesicle**

Urethra

- from the **prostatic urethra,** sperm travels through the **membranous urethra** and then into the **spongy urethra** that runs the length of the penis.

Accessory Glands

Three accessory glands produce seminal fluids that nourish, protect and support the spermatozoa
Combined with spermatozoa from the testes, these fluids form the ejaculate or **semen**
Each gland contributes a certain percentage to the total volume of semen

Seminal Vesicles

[Section 27.1.4.3: Seminal Vesicles]

[Figure 27.2: Male Reproductive System]

- produces 60% of seminal fluid
- lie close to end of ductus deferens
- produce an alkaline secretion made of fructose and other fluids that provide ATP for the motion of the sperm tail and promotes fertility.
- duct merges with duct of ductus deferens to form ejaculatory duct (this allows sperm and seminal fluid to enter urethra together)

Prostate

[Section 27.1.4.4: Prostate Gland]

[Figure 27.2: Male Reproductive System]

- 20-30% of fluid

- circles around urethra and secretes a milky fluid that coagulates semen.
- This works to help activate the sperm
- Because it encircles the urethra, if the prostate becomes enlarged due to cancer or other facts, men will have a difficult time urinating

Bulbourethral Glands

[Section 27.1.4.5: Bulbourethral Glands]

[Figure 27.2: Male Reproductive System]

- produces approx. 5% of fluid
- pea shaped and very small
- produce thick, clear alkaline secretion mucus that drains into the membranous urethra
- this secretion is to intended to wash any urine out of the urethra when ejaculation of semen occurs as well as act as a buffer to the female reproductive tract (which is an acidic environment.)
- alkalinity neutralizes acidity of the male urethra and female vagina

Penis

[Section 27.1.5: The Penis]

[Figure 27.2: Male Reproductive System; Figure 27.7: Cross-Sectional Anatomy of the Penis]

- The penis is the male copulatory organ.
- External (along with scrotum)
- Designed to deliver sperm to the female reproductive tract. (The **spongy urethra** transports both urine and semen through the penis)
- Consists of three main parts:
    - **shaft/body**
    - **glans** (large tip of the shaft)
    - **prepuce/foreskin** (loose skin of the penis which covers the glans and is often removed by a process called circumcision)
- The **body** of the penis consists of 3 cylinders of erectile tissue
    - A pair of **corpora cavernosa** on the dorsal side
    - A single **corpus spongiosum** on the ventral side
- During sexual arousal, the three cylinders become engorged with blood, causing an erection

Female Reproductive System

Objectives

- Identify the internal and external organs of the female reproduction system and their features
- Describe lactation and identify the structures of the mammary glands
- Describe the phases of the menstrual cycle
- Describe the movement of an egg from the ovary to the external environment

Female Reproductive Anatomy

[Section 27.2: Anatomy and Physiology of the Female Reproductive System]

The female reproductive system includes both ***internal and external organs***
Collectively, they function to:

- Produce the female gamete
- Receive male gametes
- Transports oocytes
- Protect and nourish developing embryo
- Deliver child

External Organs

Vulva

[Section 27.2.1: External Female Genitals]

[Figure 27.9: Female Reproductive System; Figure 27.10: The Vulva]

"Vulva" is the collective term for the external female genitalia.
They consist of:

- ***Mons pubis:*** fatty pad that cushions and protects pubic symphysis during sexual intercourse
- ***Labia majora:*** two fatty folds that extend posteriorly from the mons pubis; homologous to the male scrotum; contain pubic hair, sudoriferous and sebaceous glands
- ***Labia minora-*** two smaller parallel folds, contain sebaceous glands but no hair, covers clitoris
- ***Clitoris-*** made of highly sensitive erectile tissue (same embryonic tissue that forms male penis), exposed region is called the glans
- ***Vestibule-*** between labia minora, contains vaginal orifice, hymen, the external urethra orifice (which has no reproductive function) and greater vestibular glands (secrete lubricant)

Internal Organs

Vagina

[Section 27.2.2: Vagina]

[Figure 27.9: Female Reproductive System; Figure 27.10: The Vulva]

- Female copulatory organ
- Birth canal
- Lined with stratified squamous epithelium in order to handle "abrasion" during childbirth or intercourse
- Passageway for menstruation
- Approximately 10 cm (4 in) long

- The **vaginal orifice** is the external opening of the vagina (occluded by the hymen)

Ovaries

[Section 27.2.3: Ovaries]

- The primary reproductive organ of females
- Produce endocrine (estrogen and progesterone) and exocrine (eggs, or ova) products
- Supported by the *ovarian ligament,* the *suspensory ligaments* and the *mesovarium.*
- Houses the female gametes (eggs) in *follicles*
- *Ovulation* is the ejection of the gametes from the ovary
- NOT directed connected to uterus; instead *fimbriae* create fluid currents that "wave" the egg down the *fallopian tubes (uterine tubes)* and into the uterus

Fallopian (Uterine) Tubes

[Section 27.2.5: The Uterine Tubes]

[Figure 27.14: Ovaries, Uterine Tubes, and Uterus]

- Not directly connected to the ovaries.
- This space between the gonads (ovaries) and the tubes is the reason that STDs like gonorrhea in females can spread outside of the reproductive system and cause inflammation of the pelvic region *(pelvic inflammatory disease)*
- Has 4 parts:
  1. Fimbriae- fingerlike projections that move egg into tube
  2. Infundibulum- expansion at beginning of tube, ciliated epithelium moves egg down tube, where most fertilization occurs
  3. Ampulla- widened area of tube (majority of fertilizations occur here)
  4. Isthmus- last point of tube, narrow, connects to uterus
- Most fertilization occurs in the upper 1⁄3 of the tube and then implants in the uterus. If the egg implants in the tubes, it is called an **ectopic pregnancy.** Because the tubes cannot support the growing fetus, this is very dangerous as rupturing can occur which endangers the mother's life

Uterus

[Section 27.2.6: The Uterus and Cervix]

[Figure 27.14: Ovaries, Uterine Tubes, and Uterus]

- Between bladder and rectum

- Site of implanted fertilized ovum as well as fetal development
- 3 parts
    1. Fundus- dome shaped
    2. Cervix- inferior, narrow portion
    3. Body - everything between the fundus and cervix

Uterine Wall

[Section 27.2.6: The Uterus and Cervix]

[Figure 27.14: Ovaries, Uterine Tubes, and Uterus]

Consists of 3 layers:

1. **Perimetrium-** outer layer, continuous with the visceral peritoneum, also called the serosa
2. **Myometrium-** muscular middle layer (3 layers of smooth muscle), responsible for labor contractions
3. **Endometrium-** two layers
    - ***stratum basalis*** - covers myometrium and produces new functional zone each month
    - ***stratum functionalis*** - very glandular and vascularized, supports embryo, sheds monthly during menstruation do to changes in ovarian hormone levels

Menstrual Cycle

[Section 27.2.7: The Menstrual Cycle]

[Figure 27.15: Hormone Levels in Ovarian and Menstrual Cycles]

hormonally regulated by FSH and LH from the anterior pituitary and by estrogen and progesterone from the ovaries
3 phases:

1. Menstrual phase (menses): approx. day 1-5, "sloughing off of lining, accompanied with bleeding
2. Proliferative phase: approx. day 6-14, due to estrogen: endometrium is repaired, glands and vessels proliferate, and endometrium thickens. Ovulation occurs during this phase (ovulation is caused by LH from the pituitary)
3. Secretory phase: approx. day 15-28, due to progesterone: vascular supply further increases, size of glands increases and secrete nutrients for sustaining an embryo if present. If there is not an embryo present- the corpus luteum deteriorates, endometrium becomes spastic and menses will occur.

Lactation

[Section 27.2.8: The Breasts]

[Figure 27.17: Anatomy of the Breast]

The *mammary glands* are modified sweat glands that produce milk in a process called *Lactation*
Each breast consists of:

- ***Lobes*** (15-20) Separated by fat and CT
- ***Lobules*** -contain alveoli

- ***Alveoli*** - milk secreting cells
- ***Lactiferous Duct-*** drain milk from lobules
- ***Lactiferous* Sinus** -empty milk into nipples
- ***Nipple*** -surrounded by pigmented *areola*