Biology 102 Laboratory Manual: Biology of Plants and Animals

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JEFFREY RAY AND JASON JONES

Contents

Lab Safety Guidelines

Biology 102 — Lab Safety Guidelines

1. Upon entering the laboratory, locate each exit, the fire extinguisher, the chemical shower, the eye wash station, the broken glass container, and the first aid kit.
2. Do not eat, drink, smoke. handle contact lenses, apply cosmetics or lip balm. Restrain long hair and dangling jewelry. It is advisable to wear long pants and close-toed shoes to every lab.
3. Students who have any medical conditions that might necessitate special precautions ***must*** inform the instructor immediately.
4. It is strongly recommended that regular eyeglasses should be worn instead of contact lenses. Contact lenses may absorb volatile chemicals.
5. Decontaminate work spaces at the end of every lab period with the disinfectant provided. This becomes especially important when working with chemicals and preserved tissues/organs.
6. Keep all liquids away from the edge of your work space to avoid spills. In addition, keep all liquids away from computers that may be provided.
7. Mouth pipetting is prohibited.
8. Properly label all test tubes and slides, when indicated.
9. Wear disposable gloves when handling preserved tissues/organs. Cover any open cuts or scrapes with a sterile bandage before donning gloves. Dispose of all gloves in regular trash containers.
10. Place any materials (e.g., swabs) that come into contact with body fluids in containers indicated by your instructor. Red biohazard bags are regularly provided. Labeled bins with a chemical disinfectant (e.g., 10% bleach solution) will be

provided when needed.

11. To prevent contamination by used scalpels, new or decontaminated scalpels will be provided. Use caution when using probes (with sharp ends) and scalpels.
12. Do not leave any heat sources unattended. Turn off and/or unplug these sources when you have completed any experiment. Do not allow the power cord to touch the hot plate.
13. Do not place a beaker without water on the hot plate and Do not allow a beaker to boil dry.
14. Never work alone in the laboratory.
15. Report all accidents (e.g., glass breakage) and spills to your instructor as soon as possible.
16. Wash your hands at the end of every laboratory exercise.

I have read and will abide by these safety guidelines.

Signature _____

Date _____

PART I

MAIN BODY

1. Chapter 1

LAB 1

Animal Organization, Tissues and Integumentary System

Prepared by Dr. Jeff Ray, Dept. of Biology, UNA

OBJECTIVES

After completing these laboratory activities, you should understand/be able to:

- The hierarchical organization of the body and the four major tissue types in humans.
- The name, structure, basic function, and location in the body of the tissues examined in lab.
- Identify slides of the specific tissues prescribed by your lab instructor.
- List the properties of muscle tissues including striated/not, in/voluntary and branching/not.
- Label and identify the layers & components of the skin, the different burn classifications, and the skin cancer model.

Introduction

The basic building blocks of living organisms are **cells**, with an estimated 15-50 *trillion* cells in the human adult body. Groups of specialized cells along with their extracellular matrix that carry out

a specific function are **tissues**. Two or more tissue types which collectively function as a unit are **organs**, and organs function cooperatively as organ systems. The **11 organ systems** in humans contribute to maintaining homeostasis of the individual **organism**. Thus, the hierarchical organization of the body is **cells→ tissues→ organs→ organ systems→ organism**.

Among the more than 200 types of cells in humans, many cells (and thus tissues) are often visually distinguishable by their overall shape, the presence/absence of a nucleus, the amount of fibers in the cell, the amount of extracellular material or spaces between cells, and the presence/absence of cilia or other cell projections. The shapes of cells are invariably linked to their function (i.e. form and function are correlated). Although most cells have a nucleus, exceptions include red blood cells, which lack a nucleus (anuclear), while muscle cells are multi-nucleated. Often, the nucleus takes a similar shape to the overall cell shape. There are dozens of specific tissues in humans, within four major types (classes): **epithelial, connective, muscle, and nervous**. Different combinations of these tissues make up our organs and organ systems.

Histology is the study of microscopic anatomy of cells and tissues of organisms. Traditionally, a light microscope is used to observe cells and tissues at <1000X magnification. In order to be visualized, the specimen must be chemically preserved, embedded (dehydrated & infused with wax) sectioned (into thin slices), and stained onto a slide (fixed-embedded-sectioned-stained). Normally, the nucleus, fibers, cell margins, cilia, villi, intercalated disks and other components are contrasted by the staining process.

* List the levels of organization: _____→ _____→ _____→ _____ organism

* What are the 4 basic types of tissues found in animals? _____ ,_____, _____,_____

Basic Instructions: Microscope Usage

1. Correctly place slide on the microscope stage
2. Using knobs, *center & focus image* (1st coarse, then fine focus)

using LOW power objective lens first
3. Zoom to 10x or 40x to view at ideal magnification (use lab manual images for comparison)
4. Only use fine focus after zooming from low power
5. Do not use the oil immersion setting for the (highest power) objective lens

– For each tissue: the specific name & its location in the body is listed inside the lid of the slide box

– Many other tissues are present in most slides, which must be distinguished from the tissue of interest

– Ask the instructor to verify your tissue identification, compare to book images or look up images

Epithelial Tissue

Epithelial tissue *covers the body, lines its cavities, and forms glands*. It contains one or more layers of closely adhering cells that cover external and internal surfaces like the skin, lungs, and intestines. One surface is exposed (apical: faces the environment), while the other surface is normally anchored to a basement membrane (basal surface). Epithelial tissues mainly **function in either protection, secretion or absorption**. They lack blood vessels (avascular); cells receive oxygen and nutrients from blood vessels that are adjacent to them.

The multi-part name of epithelial tissues generally refers to the number of layers present and the shape of the cells. Layers may be single (**simple)** or ≥ (**stratified**). Three common shapes are **squamous, cuboidal,** and **columnar**. The combinations of these names describe most epithelial tissues: simple columnar, stratified squamous, etc. Pseudostratified tissues appear to be layered, but all cells reach the basement membrane, and are technically one layer thick. Cellular extensions including cilia and microvilli are present some in epithelial tissues.

*Where are epithelial tissues specifically found in the body?

_____

*Epithelial tissues are named based on what two major characteristics? _____, _____

*What do these terms mean in reference to epithelial tissue?

Simple – Stratified –

Pseudostratified –

Squamous – Cuboidal – Columnar –

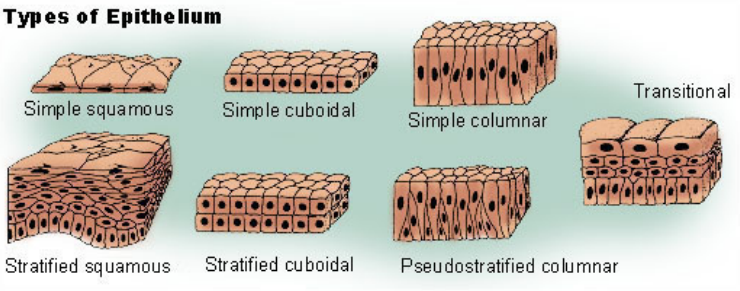
1.)Simple Squamous Epithelium

Function: *Absorption (rapid diffusion)*

Locations: *Linings of lungs and blood vessels*

Tissue to examine: 1.) Human Lung

Simple squamous epithelium lines spaces in the body which primarily function in **absorption (rapid diffusion)**. The single layer of scale-like cells facilitate easy movement across the surface area. Examine a tissue slide from the lining of the human lung. The lining of blood vessels, the heart, and portions of the respiratory, urinary and reproductive tract also contain this tissue.



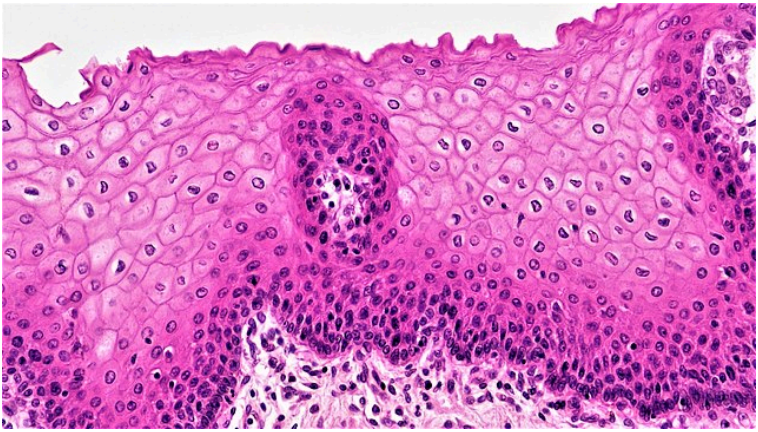
2.)Stratified Squamous Epithelium

Function: *Protection*

Locations: *Epidermis*, *mouth*, *throat*

Tissue to examine: 2.) Human Skin

Stratified squamous epithelium contains multiple cell layers which primarily function in **protection** from abrasion. The layers near the surface (superficial) are flattened and older, while deeper layers have a cuboidal or columnar shape and are more recently formed. You will examine a tissue slide from the human epidermis; try to count the approximately 30 cell layers. The outermost tissues of the skin (epidermis), mouth, esophagus, anal canal, and vagina contain this tissue.



3.)Simple Cuboidal Epithelium

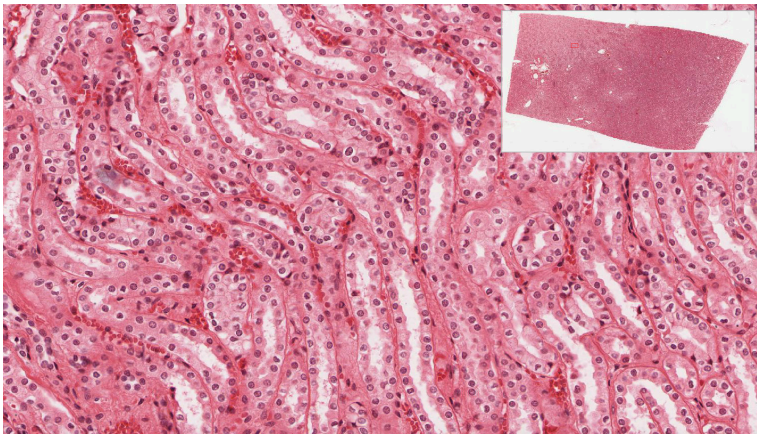
Function: *Absorption of molecules*

Locations: *Kidneys*, *ducts of glands*

Tissue to examine: 3.) Kidneys

Simple cuboidal epithelium contains a single layer of cube-shaped cells anchored to a basement membrane and primarily functions in **absorption**. The outer surface often contains *microvilli* (not visible with light microscope) that increases the surface area for absorption. Examine the tissue slide from the human kidney; notice the centrally-located nucleus that is roughly the same shape as

the cell overall. The tubules of the kidneys, liver, and the ducts of various glands contain this tissue.



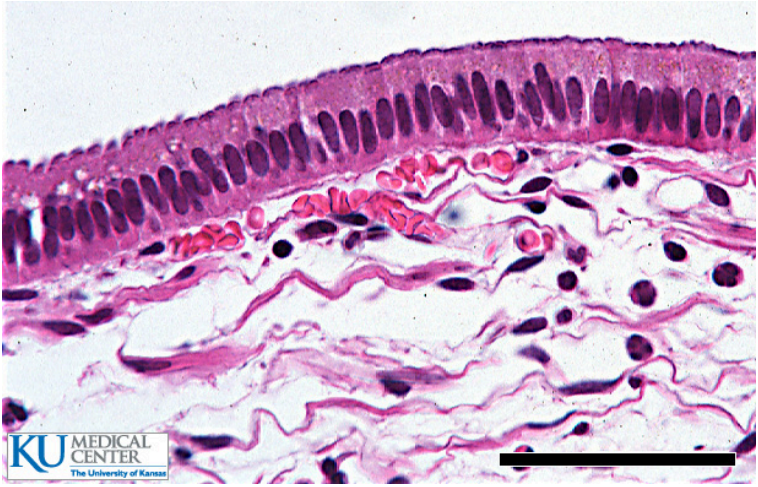
4.)Simple Columnar Epithelium

Function: *Absorption of nutrients*

Locations: *Stomach*, *intestines* (*digestive tract*)

Tissue to examine: 4.) Stomach (pyloric region)

Appears as a row of tall and narrow cells each with a single nucleus near the base; nucleus takes the overall shape of the cell. Primarily functions in nutrient **absorption**. Wavy folds *increase the surface area* for absorption. Examine human stomach tissue; identify goblet cells which secrete mucus (may stain light blue). Mucus lubricates surface and protects from stomach acid & enzymes. The digestive tract is lined by this tissue.



What is the function of the mucus?

_____

5.) Pseudostratified Ciliated Columnar Epithelium
Function: *Sweeps impurities from airway, protects*
Locations: *Trachea (windpipe), bronchi*
Tissue to examine: 5.) Trachea

Pseudostratified ciliated columnar epithelium looks layered due to cell nuclei at different levels, but each cell reaches the basement membrane (pseudo = false). Hair-like projections called **cilia** act as tiny brooms to sweep debris trapped in mucus up and out of the airway. This tissue primarily functions in clearing the airway of dust, bacteria, and other debris that could otherwise enter the lungs. Smoking coats cilia in many fine particles. The wavy folds of the tissues increase the surface area for absorption. Examine the tissue slide from the trachea; identify the goblet cells which secrete mucus (may be stained light blue). Try to identify at least **five other tissues** found in slide 5.

*Where is this type of tissue found in vertebrates?

_____

*What is the function of the cilia?

_____

*How might the cilia be affected by smoking?

_____

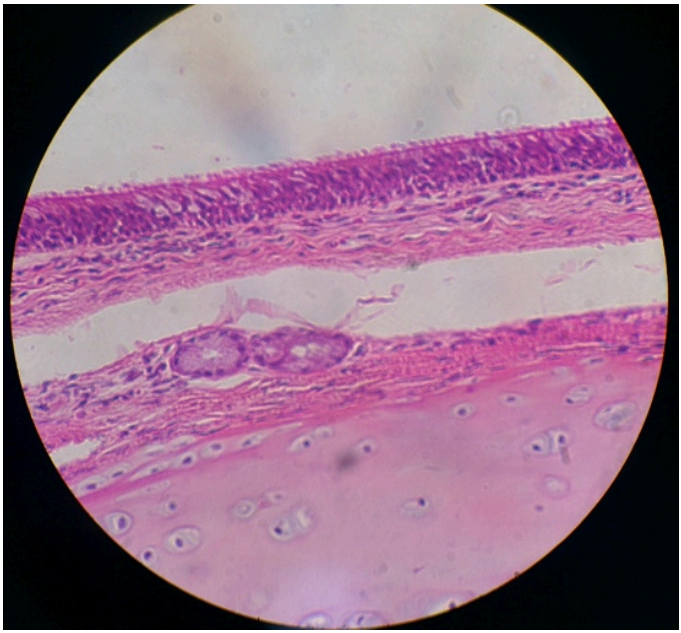


Table 1: EPITHELIAL TISSUE

Type	Structure	Function	Location
Simple Squamous		rapid diffusion	
Stratified Squamous	outer layers flat, inner layers cuboidal		
Simple Cuboidal		secretion & absorption	
Simple Columnar	Taller than wide, nucleus at base		digestive tract, uterus
Pseudostratified ciliated columnar		protection & secretion, sweeps substances	

Complete the missing information in the table above.

Connective Tissue

Connective tissue is the **most variable and widespread tissue** in the body. Specific types vary in their amounts and ratios of cells, fibers, and extracellular matrix. Cells may be numerous or few, fibers vary in amount and type (elastin or collagen), and the extracellular matrix may be limited or extensive and contain gelatinous (cartilage) or rigid materials (as in bone). Connective tissues *function in support*, *binding*, *insulation*, *protection*, *and friction reduction*, among other purposes. Note: fibers in connective tissue are non-cellular fibers made of proteins; fibers in muscle tissue are whole cells- do not confuse connective tissue "fibers" with the fibers of muscle tissue.

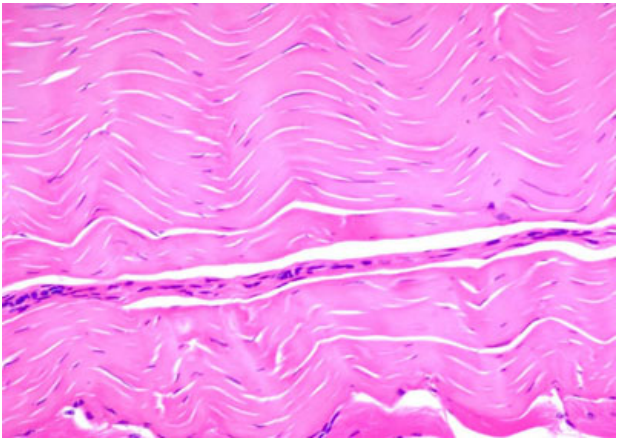
6.)Dense regular connective tissue

Function: *Connect bones and muscles*

Locations: *Tendons*, *ligaments*

Tissue to examine: 6.) Tendon

Dense regular (fibrous) connective tissue is tightly filled with wavy parallel collagen fibers, and the tissue has an appearance somewhat like woven rope. The nuclei are dark-stained and appear pill-shaped, with no extracellular spaces visible within the tissue. Dense fibrous tissue imparts strength to tendons and ligaments, primarily in a single direction; forces applied parallel to the tissue fibers more easily tear the tendon or ligament.



7.)Adipose tissue

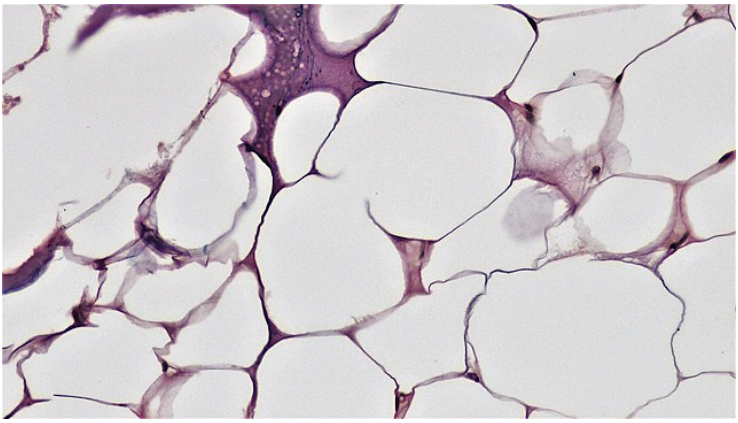
Function: *Insulation*, *protection*, *and energy storage*

Locations: *Beneath skin*, *surrounds organs*, *breasts*, *hips*, *gut*

Tissue to examine: 7.) Adipose tissue

Cells of adipose tissue are filled with fat and triglycerides, which do not stain well, thus the cells appear mostly empty. The nuclei are pushed to the side of the cell and the cell edges have a dark margin. Nuclei are visibly stained along the cell margins and there is no extracellular spaces visible within the tissue. Adipose

tissue functions in storing energy, insulation, and cushioning around organs and other structures.



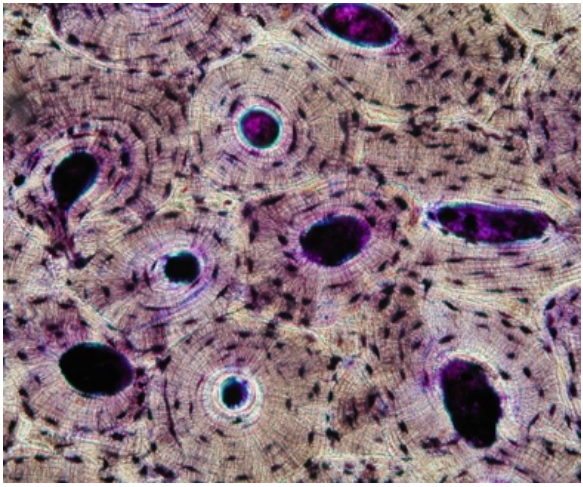
8.)Compact bone

Function: *Support and protection*, *mineral storage*

Locations: *Skeleton*

Tissue to examine: 8.) Compact bone

Bone tissue is one of the most distinct tissues, and is obviously found in the skeleton. **Compact** and **spongy** bone are the two main types; both varieties are found in most bones (e.g. femur); compact bone makes up the majority of the skeleton. A system of interconnecting vascular canals (**haversian systems**) contain the blood supply for living cells (**osteocytes**), which are embedded within a calcified matrix of extracellular materials. The functional unit of compact bone is an osteon, which appear as adjacent tree rings. Examine the slide and the model of bone tissue. Be able to find the **osteon**, **central canal**, and **osteocyte.**



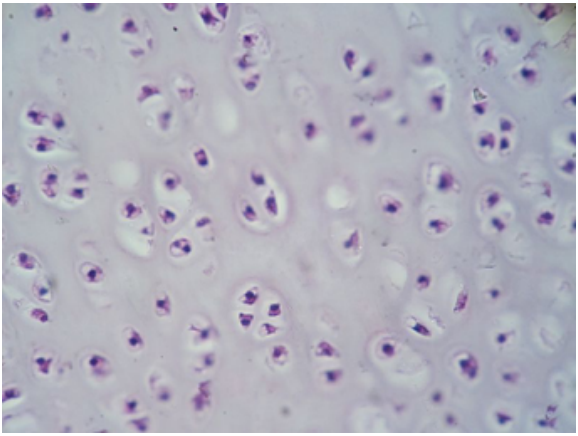
9.)Hyaline Cartilage

Function: *Support and protection, minimizes friction*

Locations: *Nose, trachea and bronchi, ends of bones, ribcage, intervertebral disks*

Tissue to examine: 9.) Hyaline cartilage

Hyaline cartilage is a connective tissue with an extracellular gel-like matrix containing few/no visible fibers, scattered cells called **chondrocytes**, and overall appear *less* organized than bone. This tissue supports, protects, and minimizes friction where bones meet. Hyaline cartilage is found in the nose, trachea, ribcage, intervertebral disks and covers the ends of bones. The two other cartilage types (elastic, fibrous) are not examined in this lab.



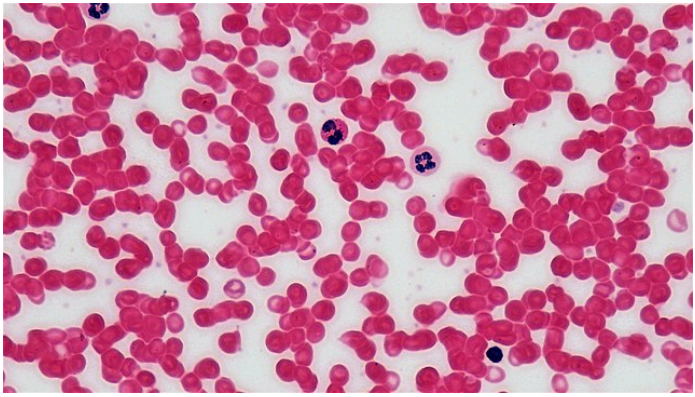
10.)Blood

Function: *Transport of nutrients and wastes*

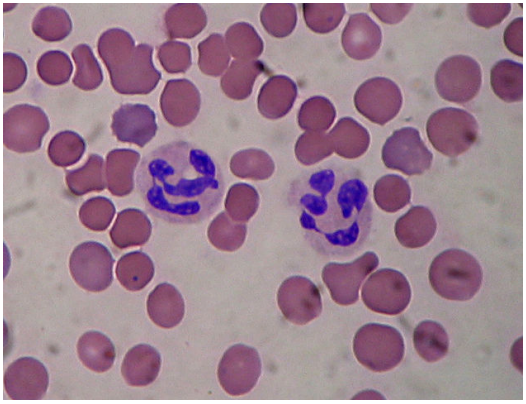
Locations: *In blood vessels and heart*

Tissue to examine: 10.) Blood smear

Blood is a connective tissue which contains a mixture of liquids, cells, and cellular fragments. The liquid remains unstained, while the vast majority of cells are red blood cells, which appear as donut-like disks- no nuclei are present. White blood cells (WBCs) are far fewer in number, but noticeably larger and distinctly stained. The five main types of WBCs are identified based on the shape of their nuclei. WBCs function in fighting infections. Platelets are cell fragments that are essential to blood clotting.



Blood smear dominated by RBCs, zoom to see WBCs & platelets



Blood tissue showing neutrophils (WBCs).

Table 2: CONNECTIVE TISSUE

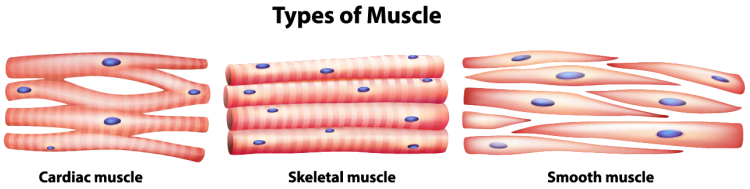
Type	Structure	Function	Location
Dense fibrous		Binds organs, muscles-bones, bones-bones	
Adipose			Beneath skin, surrounds organs, hips, breasts, stomach
Compact bone		Support & Protect	
Hyaline Cartilage	Scattered cells, Gel-like matrix		Nose, trachea & bronchi, bone ends, ribcage
Blood	Plasma, RBCs, WBCs, platelets		

Complete the missing information in the table above.

Muscle Tissue

Muscle cells are long & thin and called **myocytes**, which are filled with fibers that contract by *shortening*. When the tissues contract, they function in moving the body or moving substances like blood or food through the body. Skeletal, cardiac, and smooth muscle tissues vary in shape from one another; the structure gives insight as to

how the muscle functions when contracting. Muscle tissue also varies in being not/striated and in/voluntary; *one or more nuclei* are present.



*All muscle tissues are composed of cells called _____.

*What are the three types of muscle tissues? _____

11.)Skeletal muscle tissue

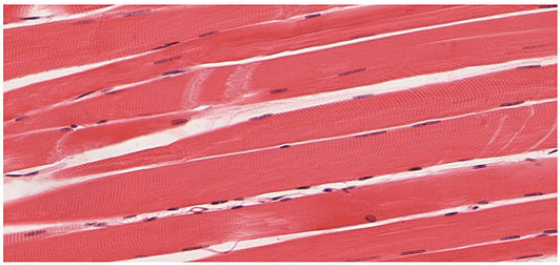
Function: *Movement (voluntary)*

Locations: *Skeletal muscles like biceps, deltoids*

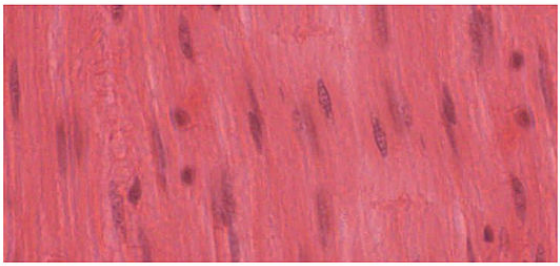
Tissue to examine: 11.) Skeletal muscle

Skeletal muscle tissue contains long, tube-shaped cells filled with parallel fibers containing actin and myosin protein fibers. These fibers alternatively do/not overlap, causing the tissue to have a striated (striped) appearance like a candy cane. The nuclei are numerous (multi-nucleated), darker, and pushed to the margins of the cells. There are no extracellular spaces visible within this tissue. There are more than 600 skeletal muscles that function in moving the body; these are under voluntary (conscious) control of the nervous system. Obtain a slide of skeletal muscle and be able to identify the **fibers, nuclei, and striations**. Adjust the contrast setting to better visualize the striations.

*Is skeletal muscle voluntary or involuntary? _____



(a)



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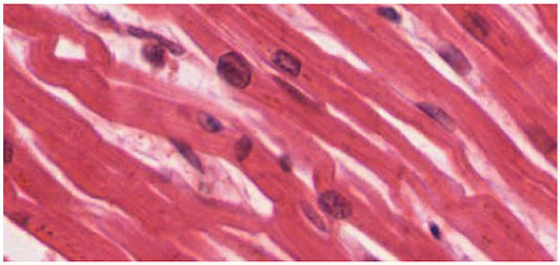


(c)

Top to bottom: skeletal, smooth, cardiac

12.) Cardiac muscle tissue
Function: *Pumps blood*
Locations: *Heart*
Tissue to examine: 12.) Cardiac muscle tissue

Cardiac muscle is restricted to the heart and has an appearance unique among muscle tissue- it is striated and branching with one nucleus per cell. The branching cells are interconnected so the heart may function as a unit. The cell junctions are held together

by zipper-like structures called **intercalated disks**, which allow substances and electrical current to pass seamlessly among cells. There are no extracellular spaces visible within the tissue. Cardiac muscle is involuntary (unconscious).

13.) Smooth muscle tissue

Function: *Move substances through the body organs*

Locations: *Viscera (digestive, endocrine and reproductive organs) in body cavities*

Tissue to examine: 13.) Smooth muscle tissue

Smooth muscle makes up the wall of internal organs like the stomach; it is restricted to the viscera and blood vessels. It has a different appearance from other muscle tissues- it is not striated, is not branched and contains one central nucleus per cell, which normally stains darker than fibers. The cells are filled with fibers, appearing narrow at the ends and wider in the middle giving a spindle-shaped appearance. There are no extracellular spaces visible within the tissue. Smooth muscle is under involuntary (unconscious) control. Smooth muscle is found in the walls of the trachea, esophagus, stomach, intestines, blood vessels, and urinary bladder.

Table 3: MUSCLE TISSUE

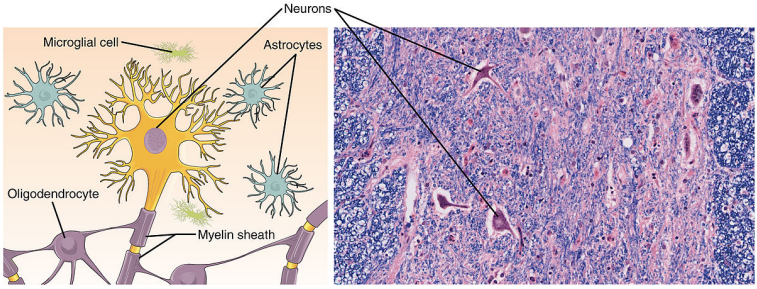
Type	Striated (Yes/No)	In/ Voluntary	Branching (Yes/No)
Skeletal			
Smooth			
Cardiac			

* Complete the missing information in the table above.*

When finished examining the 13 tissue slides, organize them in the slide box in the correct order. If any slides are damaged, please notify your instructor. Turn off and unplug your microscope, put the objective lens on low power setting, and place the plastic cover on the microscope.

Nervous Tissue

No nervous tissue slides will be examined in lab, but several types of nervous tissues are found in the brain, spinal cord, and nerves. Nerve cells that carry electrical impulses are **neurons**, while the numerous supporting cells are **neuroglia**; several sub-ypes of neurons and neuroglia are recognized.



*Where is nervous tissue found in vertebrates? _____
_

*What are the two main types of cells in nervous tissue? _____

Integumentary System

The integumentary system includes the **skin, hair, and nails** which have multiple functions in maintaining homeostasis, including *protection* and *temperature regulation*. The skin is composed of the **epidermis** and the **dermis**. The tissue layer underlying these two layers is the **hypodermis** (=subcutaneous layer) which has a different origin during embryo development and therefore, is not considered a "true" layer of the skin. From superficial (outer) to deep (inner), the layers are e**pidermis—dermis—hypodermis**. The **epidermis** contains *stratified squamous epithelial* tissue that is constantly being replaced. There are variably shaped layers of cells, called **stratum** (layers a-e), the outermost of which are dead and contain a waterproof coating. The **dermis** is thicker and *primarily connective tissue*, but also contains glands, nerves, and blood vessels (epidermis is avascular). The **hypodermis** (layer III) is *adipose tissue* and the layer into which certain medical injections are given (e.g. insulin shots).

Examine the human skin model, including burn pathologies on the back of the model. Note the following:

– 3 skin regions: palm, armpit, scalp – 3 distinct layers (I-III): epidermis, dermis, hypodermis

– Strata (a-e) of the epidermis – Blood vessels, nerves, hair root, etc. in dermis

– Adipose tissue (g) of hypodermis – Depth, damage of 1st, 2nd and 3rd degree burns

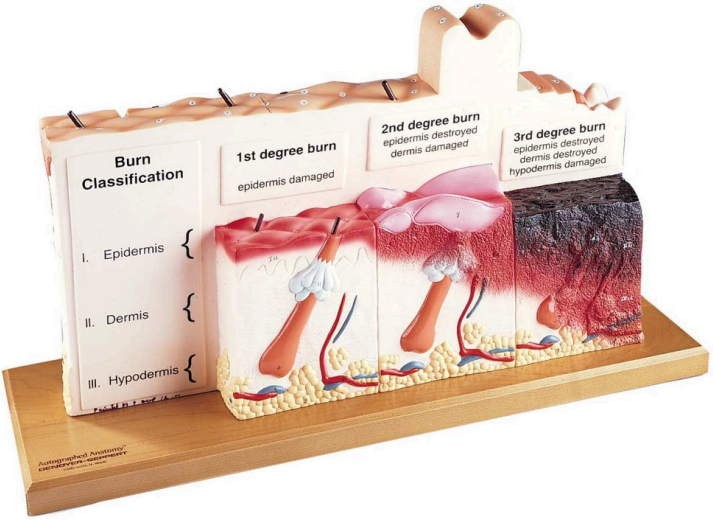
* Which region of skin is the thickest: palm, armpit or scalp? _____

*Name the main tissue types:

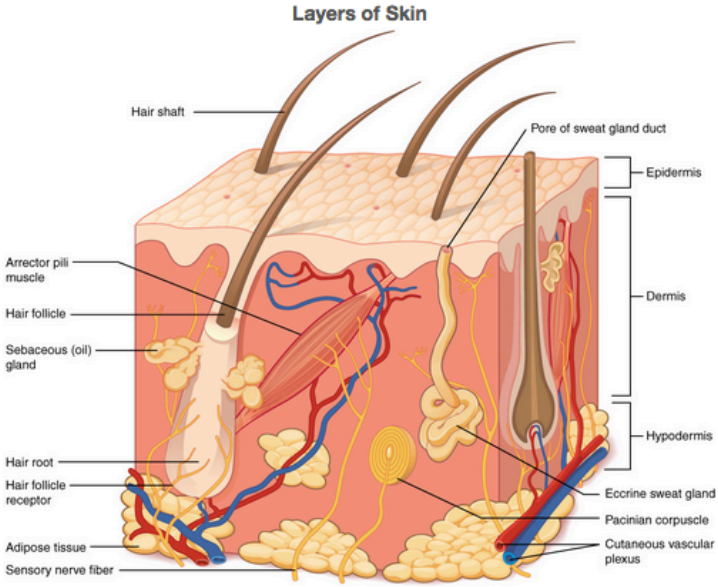
Epidermis: _____ Dermis: _____ Hypodermis: _____

* Which *layer* is thickest: epidermis, dermis or hypodermis? _____

*Which *degree* of burn destroys the epidermis and damages the dermis (often the most painful)? _____



Lab model of the skin. Note I: Epidermis, II: Dermis, III: Hypodermis. Nerve receptors in various locations of the dermis detect light touch, deep pressure, pain, hot, and cold.



Labelled model of the skin.

Skin cancer is the most common type of cancer, due to the (**1**) *constant exposure to the environment*, (**2**) *frequent cell division, and* (**3**) *large size of this organ system*. Of the three main types, **malignant melanoma** is the rarest, but the most deadly (other two: **squamous cell carcinoma, basal cell carcinoma**). The six zones on the model show the progression of untreated melanoma: cells multiply, deepen into the skin, and metastasize (spread elsewhere in the body). The American Cancer Society guide for early detection of melanoma via self-exam uses the "**ABCDE rule**" to assist individuals in monthly self-exams of skin discoloration that might be malignant, to aid in *early* detection by a dermatologist. **A**= *asymmetry* (unequal halves), **B** = *border irregular*, **C** = *color variable* (differing shades), **D** = *diameter* >1/4", **E** = *evolving* (changing).

Examine the skin cancer model, note the following:

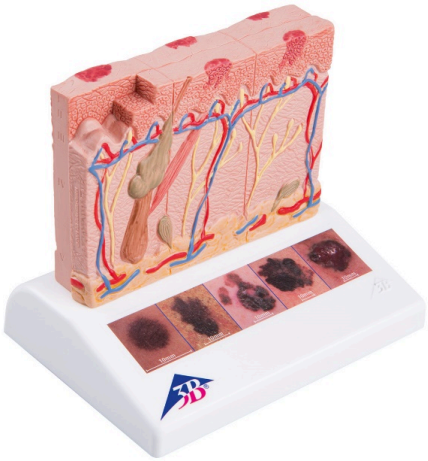
– 6 zones, read left to right, front to back

– Progressive *deepening* of tumor into the skin

– Metastasis into the blood vessels/lymph

– Variable shape of tumors on base of model

***Name the *deadliest* skin cancer** (on model):_____----------



3B Scientific

J15

Skin Cancer Model

Image Credits:

Simple Squamous By https://en.wikipedia.org/wiki/Simple_squamous_epithelium#/media/File:Illu_epithelium.jpg

Stratified squamous By https://commons.wikimedia.org/wiki/File:Epithelial_Tissues_Stratified_Squamous_Epithelium_(40230842160).jpg

Simple cuboidal By https://histology.medicine.umich.edu/sites/default/files/images/slides/1epithelial.jpg

Simple columnar lecannabiculteur.free.fr/SITES/UNIV%20KANSAS/instruction/medicine/anatomy/histoweb/gitract/large/Gi39.jpg

Pseudostratified ciliated columnar By Assassin3577 – Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=26594055

Dense Regular Connective By http://medcell.med.yale.edu/histology/connective_tissue_lab.php

Adipose https://commons.wikimedia.org/wiki/File:Connective_Tissue_Adipose_(41066514324).jpg

Bone By https://commons.wikimedia.org/wiki/File:Compact_bone_-_ground_cross_section.jpg

Cartilage By https://commons.wikimedia.org/wiki/File:Cartilage01.JPG

Blood https://commons.wikimedia.org/wiki/File:Connective_Tissue_Human_Blood_Leukocyte_Survey_(26921278957).jpg

Neutrophils By https://commons.wikimedia.org/wiki/File:Segmented_neutrophils.jpg

Muscle tissues By OpenStax College – Anatomy & Physiology, Connexions Web site. http://cnx.org/content/col11496/1.6/, Jun 19, 2013., CC By 4.0, https://commons.wikimedia.org/w/index.php?curid=30015032

Muscle tissues By http://www.scientistcindy.com/uploads/8/5/1/2/85124478/muscle-tissue1_orig.png

Nervous tissue By By OpenStax College – Anatomy & Physiology, Connexions Web site. http://cnx.org/content/col11496/1.6/, Jun 19, 2013., CC BY 3.0, https://commons.wikimedia.org/w/index.php?curid=30131294

Skin model front and back https://denoyer.com/products/human-skin-series

Skin (labeled) By OpenStax College – Anatomy & Physiology, Connexions Web site https://cnx.org/contents/FPtK1zmh@8.108:RxywCGkA@6/Layers-of-the-Skin

Melanoma model used with Permission of 3B Scientific, images

from https://www.a3bs.com/skin-cancer-model-1000293-j15-3b-scientific,p_54_316.html

BI 102 Lab Worksheet: Tissues Name _____ Section _____

1. What are the 4 major types of tissues found in animals?

2. Name 1 specific location in the body you would find the following epithelial tissues:

a. simple squamous epithelial _____ b. stratified squamous epi._____

3. Find pseudostratified ciliated columnar epithelial tissue (*slide* #5) with your microscope. Put your pointer on this tissue and have your instructor verify it by initialing here _____

4a. Slide #5 **Sketch AND LABEL** this tissue:

4b. List the other tissues present on *slide* #5:

_____, _____
_____,
_____, _____

5. Name 3 specific types of connective tissues (see Table 2**)**

_____,
_____,_____
____

6. **Sketch** the following tissue: Compact Bone (*slide* #8)

7. Find a White Blood Cell (*slide* #10 and **sketch** it (ZOOM in to 40X-include nucleus shape)):

8. What are the 3 basic types of muscle tissue? (*slides #11-13*)

9. Which muscle tissue is striated, branching and not under conscious control (involuntary; Table 3)?

10. **Sketch AND Label** the two "true" layers and the third underlying layer of the skin→

2. Chapter 2

LAB 2

Musculoskeletal System

Prepared by Dr. Jeff Ray, Dept. of Biology, UNA

OBJECTIVES

After completing these laboratory activities, you should understand/be able to:

- The basic structure, function, and total number bones and muscles in the skeletal and muscular systems, including the axial and appendicular divisions.
- The tissues of these systems, including bone, hyaline cartilage, and skeletal muscle.
- Identify the specific bones (including the vertebral regions) and muscles as specified by your instructor.
- The types of joints, muscle movements, and basics of muscle contraction.

Introduction

The **muscular** and **skeletal** systems collectively make up a large percentage of body mass and are studied together due to the interdependence and interaction between these organ systems in supporting and moving the body. **Joints** are at the interface of where bones meet and are moved by muscles. The skeletal system provides a scaffolding for holding up the body and assisting

movements. It functions include support, movement, protection, blood cell production, storage of minerals, and endocrine regulation. The human adult normally has 206 bones.

The muscular system functions in moving bones, provides posture and support, protects internal organs, and generates heat. The more than 600 skeletal muscles are composed of bundles of muscle fibers, are normally attached to bones via tendons to create a lever system, and many function as antagonistic pairs- opposing muscle groups that counterbalance contractions/relaxations.

* Are there more bones or muscles in the human body?

_____

Tissues of the Human Skeletal & Muscular System

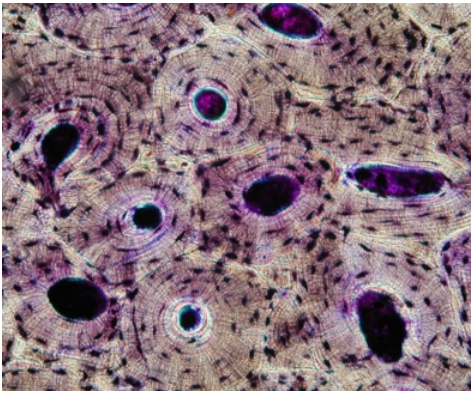
The main tissues of the musculoskeletal system are **bone**, **hyaline cartilage**, and **skeletal muscle**. Be able to recognize each of these tissues, and know their function and location. These tissue slides will be set up at the microscopes on the back counter.

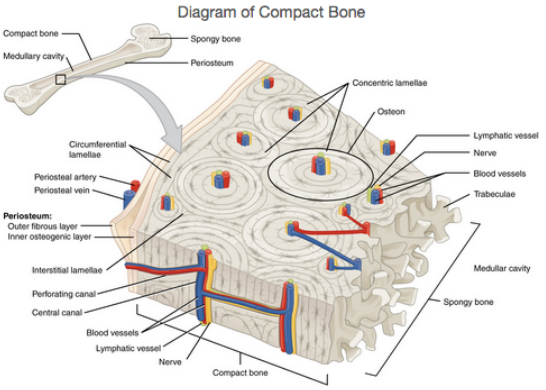
Bone

Function: *Support and protection*, *mineral storage*

Locations: *Skeleton*

Bone tissue is distinctive and primarily extracellular materials. **Compact** and **spongy** bone are found in most bones; compact bone makes up the majority of the skeleton. The functional unit of compact bone is an **osteon**, which appear as adjacent tree rings. The cells (**osteocytes**), are surrounded by a calcified matrix of extracellular materials, but the tissue is living and served by blood vessels, lymph and nerves. Examine the slide and the model of bone tissue.



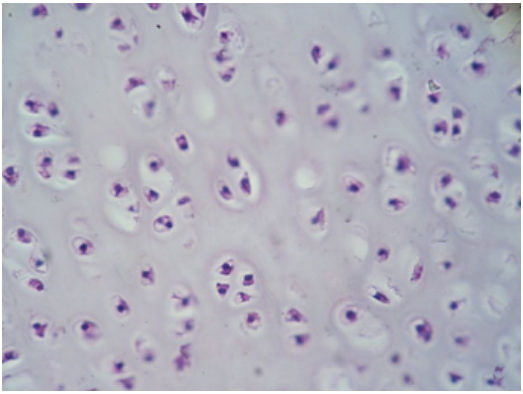


Hyaline Cartilage

Function: *Support and protection*, *reduces friction*

Locations: *Nose*, *trachea and bronchi*, *ends of bones*, *ribcage*, *intervertebral disks*

Hyaline cartilage has an extracellular gel-like matrix containing few/no visible fibers and scattered cells called **chondrocytes**, and overall appears *less* organized than bone. This tissue supports, protects, and minimizes friction where bones meet. Hyaline cartilage is found in the nose, trachea, ribcage, intervertebral disks and covers the ends of bones.

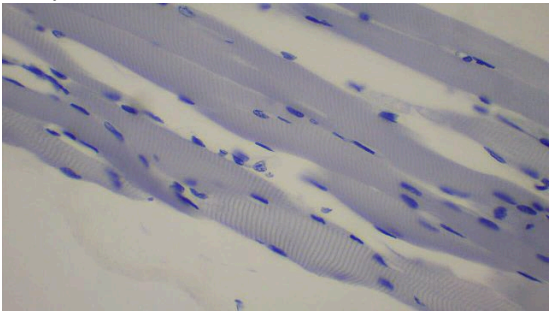


Skeletal muscle tissue

Function: *Movement (voluntary)*

Locations: *Skeletal muscles*

Skeletal muscle tissue contains cells filled with parallel fibers containing actin and myosin protein fibers. These fibers alternatively do/not overlap, causing the tissue to have a striated (striped) appearance like a candy cane. The nuclei are numerous (multi-nucleated), darker, and pushed to the margins of the cells. Identify the **fibers, nuclei, and striations**.

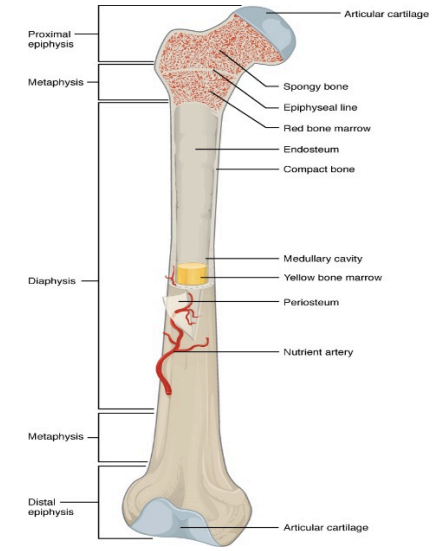


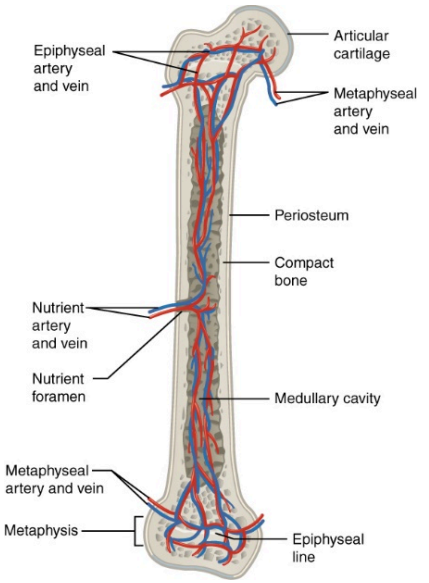
Gross Anatomy of Bones and the Skeletal system

Bones (e.g. humerus) are organs since they contain >2 tissues including blood vessels, lymph vessels, and nerves, in addition to bone tissue. The human skeleton can be logically divided into the **axial** and **appendicular** divisions. The axial skeleton forms the main trunk, while the appendicular skeleton includes the bones of arms

and legs (appendages), and the pectoral and pelvic girdles. In total, the adult skeleton usually contains 206 bones (80 axial and 126 appendicular). Among the 206 bones, there are 22 bones of the skull, 26 vertebrae, 12 pairs of ribs, and 30 bones in each appendage.

Observe a bone from a cadaver that has been cut longitudinally to reveal that it is actually hollow. Since this bone is dried out, it is still strong, but much less flexible than when alive. It contains **compact bone** along the sides and **spongy bone** at the ends. In life, the articular surfaces were covered with glossy **articular cartilage** (imagine the end of a chicken bone), the spongy bone was filled with **red marrow** and the medullary cavity was filled with **yellow marrow** (fat).





Some Major and Notable Bones / Bone Groups of the Body

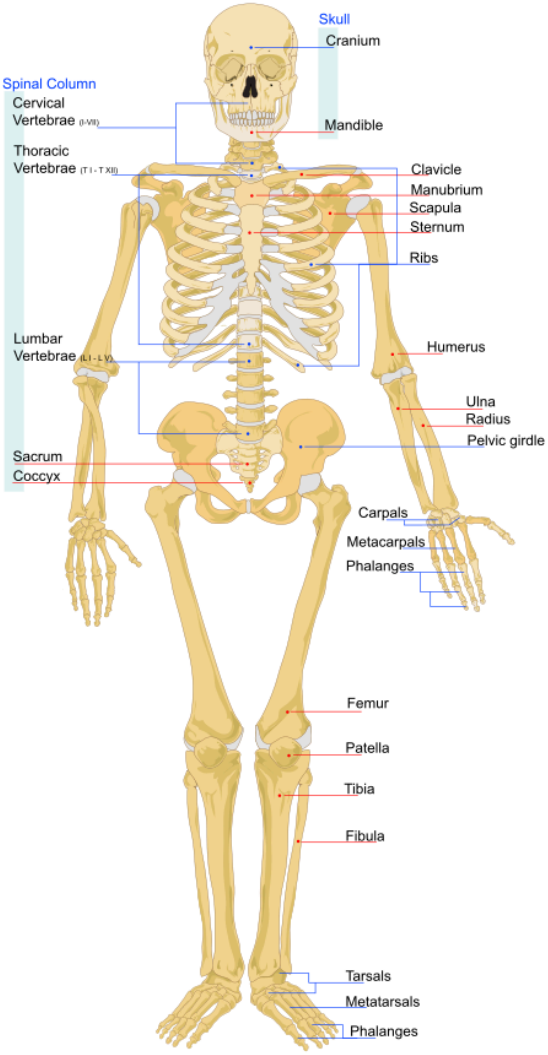
Some basic bone descriptions

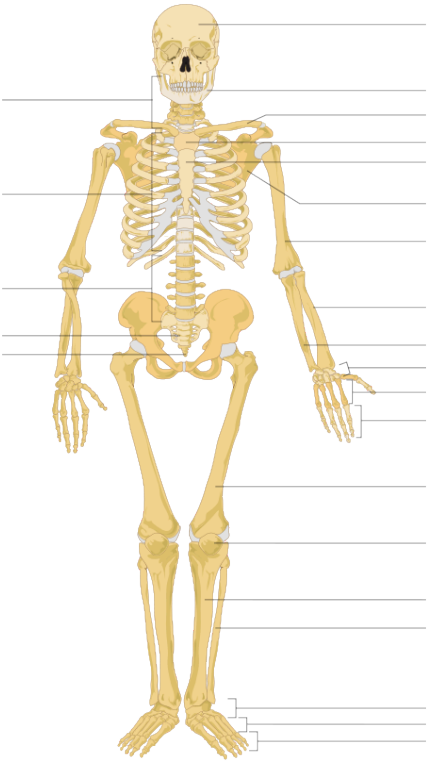
maxilla: upper jaw	mandible: lower jaw	sternum: chest, ribs attach to it	clavicle: collarbone	scapula: shoulder
humerus: upper arm	radius: forearm (thumb side)	ulna: forearm	carpals: wrist	metacarpals: hand
phalanges: fingers	coxal bones: pelvis	sacrum: lower vertebrae (bones are fused)	coccyx: tailbone	femur: thigh
patella: knee	tibia: shin	fibula: lower leg (next to shin)	tarsals: ankle	metatarsals: foot
phalanges: toes				

* Are there more bones in the axial or appendicular division? _____

* Name 2 bones from the axial skeleton _____ _____

* Name 2 bones from the appendicular skeleton _____ _____


Skull
Cranium
Spinal Column
Cervical
Vertebrae (I-VII)
Mandible
Thoracic
Vertebrae (T I - T XII)
Clavicle
Manubrium
Scapula
Sternum
Ribs
Lumbar
Vertebrae (L I - L V)
Humerus
Ulna
Radius
Pelvic girdle
Sacrum
Coccyx
Carpals
Metacarpals
Phalanges
Femur
Patella
Tibia
Fibula
Tarsals
Metatarsals
Phalanges



The following activity will help in learning the location and names of the bones. You will work as a group using the bones mixed up in tubs and *reassemble them into (as complete as possible) a full skeleton.* After assembling the skeleton, do not disassemble it until instructed to do so by you professor.

CSI Activity: a mass grave has been found and a mixture of bones recovered, but it is unclear **how many victims** there were. In order to determine the minimum number of victims, you must determine 1) how many bones of each type (e.g. femur) and 2) which side of the body they are from (Left or Right). Using the fully articulated skeletons at the front of the rooms as a guide, match each bone to the correct part of the body including L/R side. Use any articulation points, grooves, asymmetry, bone angles, and differences between the two ends of the bone to determine L/R. Recall that L/R is

from the patient's (or victim's) perspective. Whichever bone(s) is the most abundant (L/R are counted *separately*, an exception is the vertebrae), represents the minimum number of victims. For example, if the most abundant bone is 4 right femurs, there are at least 4 victims. The first two vertebrae (atlas and axis, C_1 and C_2) are unique and may also be used to count victims.

*** Complete the table. Before putting the bones back into the tubs, have your instructor verify your findings and review the bones you identified.**

Crime Scene Investigation (CSI) Activity

A. Names of Bones

Ex.__*femur*_____

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____
11. _____
12. _____
13. _____
14. _____
15. _____
16. _____
17. _____
18. _____
19. _____
20. _____

B. # Left / # Right if known

Ex._____1 / 2_(at least 2 victims)

1. _____/_____

2. _____/_____
3. _____/_____
4. _____/_____
5. _____/_____
6. _____/_____
7. _____/_____
8. _____/_____
9. _____/_____
10. _____/_____
11. _____/_____
12. _____/_____
13. _____/_____
14. _____/_____
15. _____/_____
16. _____/_____
17. _____/_____
18. _____/_____
19. _____/_____
20. _____/_____

C. Minimum # of Bodies _____

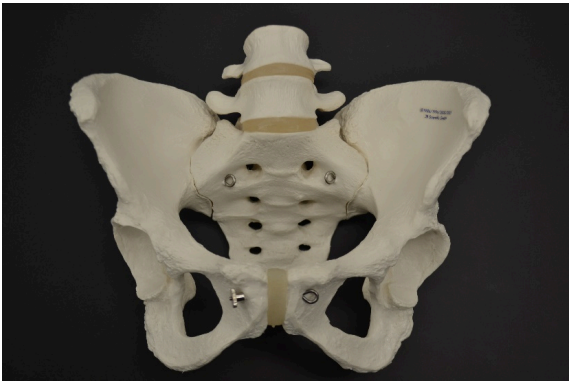
D. Explanation for determining minimum # (most numerous bone(s), which side of body): _____

E. Name the 5 regions of the backbone from top to bottom and list the number of vertebrae in each:

Skull – 1._____ 2._____3._____ ____4._____5._____ – Pelvis

F. Number of vertebrae in each region (total of 26): _____, _____ , _____, _____, _____

Observe the male and female pelvis on the cart or back counter, note any differences.



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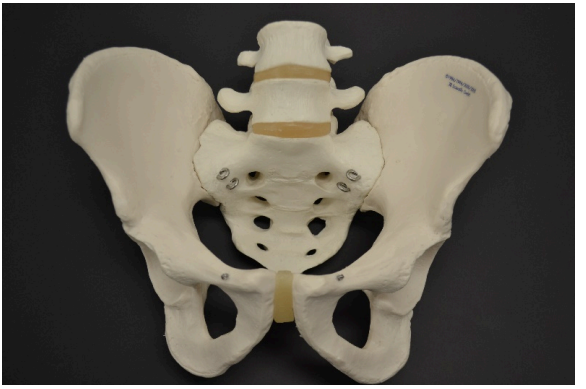


_____

_____

* Label the pelvises above as male or female.

* What are two basic differences between M/F pelvis?

1._____ 2. _____

Muscular System

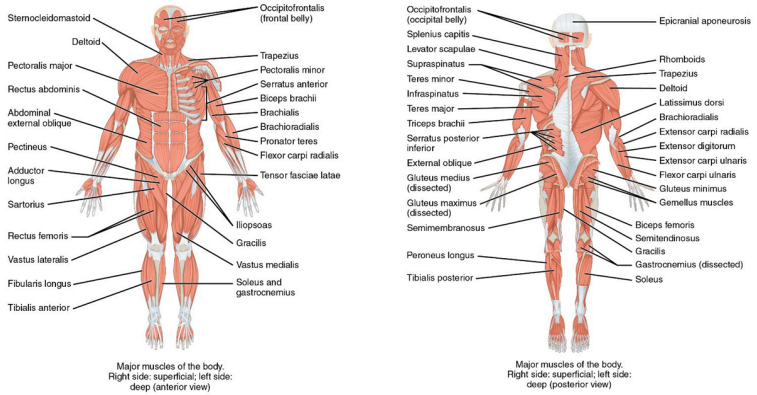
Skeletal muscles are under conscious (voluntary) control and appear striated (striped). Cardiac and smooth muscles are involuntary, and differ visually from skeletal muscle. Tendons are continuous with muscles and attach them to bones. The point of attachment that stays stationary when the muscle contracts is the **origin**, while the attachment that moves is the **insertion**. Since muscles shorten when they contract, they only pull. As a result,

most muscles work in antagonistic pairs (particularly in the appendicular region)- when one contracts the other relaxes.

There are over 600 muscles in humans which are named based on their location, shape, size, movement, number of major parts or various other features. Examine the muscle model and study the images; learn the major "workout" and other muscles that your instructor indicates for the quiz.

Major and Notable Muscles of the Body

Orbicularis oculi	External oblique	Flexor carpi group	Tibialis anterior
Orbicularis oris	Rectus abdominis	Extensor carpi group	Extensor digitorum longus
Masseter	Trapezius	Extensor digitorum	Gluteus maximus
Deltoid	Latissimus dorsi	Quadriceps femoris	Hamstring (Biceps Femoris)
Pectoralis major	Biceps brachii	Sartorius	Gastrocnemius
Serratus anterior	Triceps brachii	Adductor longus	

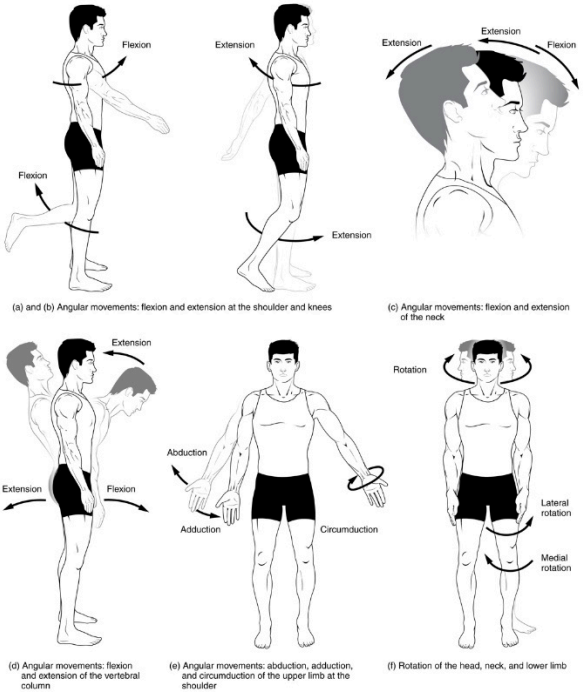


Some basic muscle descriptions

o. oculi: circular muscle around eyes, blinking, winking	biceps brachii: upper arm muscle on front, bends arm at elbow
masseter: chewing muscle	triceps brachii: upper arm muscle on back, straightens arm at elbow
frontalis: forehead muscle raises brows	quadriceps femoris (quads): several muscles on front of leg, straightens leg at knee
deltoid: shoulder muscles, raises and lowers arms to front and side	sartorius: strap-like muscle running diagonally across thigh, moves thigh away from body
pectoralis major: chest muscles, bring arms forward	tibialis anterior: shin muscle, turns foot upward as when walking on heels
external oblique: muscles on your side running diagonally onto stomach	gluteus maximus: butt muscles, extends thigh back
rectus abdominis stomach muscles with fibers running vertically (6-pack abs), bends vertebral column	hamstrings (biceps femoris): several muscles back of leg, bends leg at knee
trapezius: sheet like muscle covering upper back, raises shoulders	gastrocnemius: calf muscles, turns foot downward
latissimus dorsi: (lats) beneath arms onto back, brings arms down and backward behind body	

Muscle movements

Muscle contractions are described based on their movement in relation to the joint or the midline of the body. The main types are flexion, extension, adduction, and abduction. **Flexion**: movement of jointed parts towards one another, **Extension**: movement of jointed parts away from each other, **Adduction**: movement of part toward body's midline, **Abduction**: movement of part away from body's midline.



*** Answer the following**:

The biceps brachii _____ the forearm.

The triceps brachii _____ the forearm.

The quadriceps femoris _____ the leg.

The biceps femoris _____ the leg.

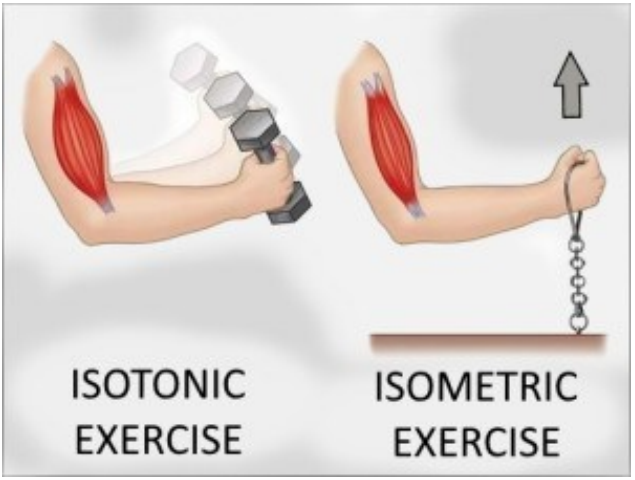
The sartorius _____ the thigh.

The adductor longus _____ the thigh.

Contraction Types

In **isotonic** contractions, the length of the muscle changes. In **isometric** contractions, the length of the muscle does not change.

To demonstrate an isotonic contraction, rest your left forearm on a table. Watch the anterior surface of your left upper arm while you slowly bend your elbow and bring your left forearm toward the upper arm. This is an isotonic contraction of the biceps brachii.



***** What makes this contraction isotonic rather than isometric? _____

To demonstrate an isometric contraction, place the palm of your left hand underneath a tabletop. Push up against the table while you have your right hand cupped over the anterior surface of your left upper arm so that you can feel the muscle there undergo and isometric contraction.

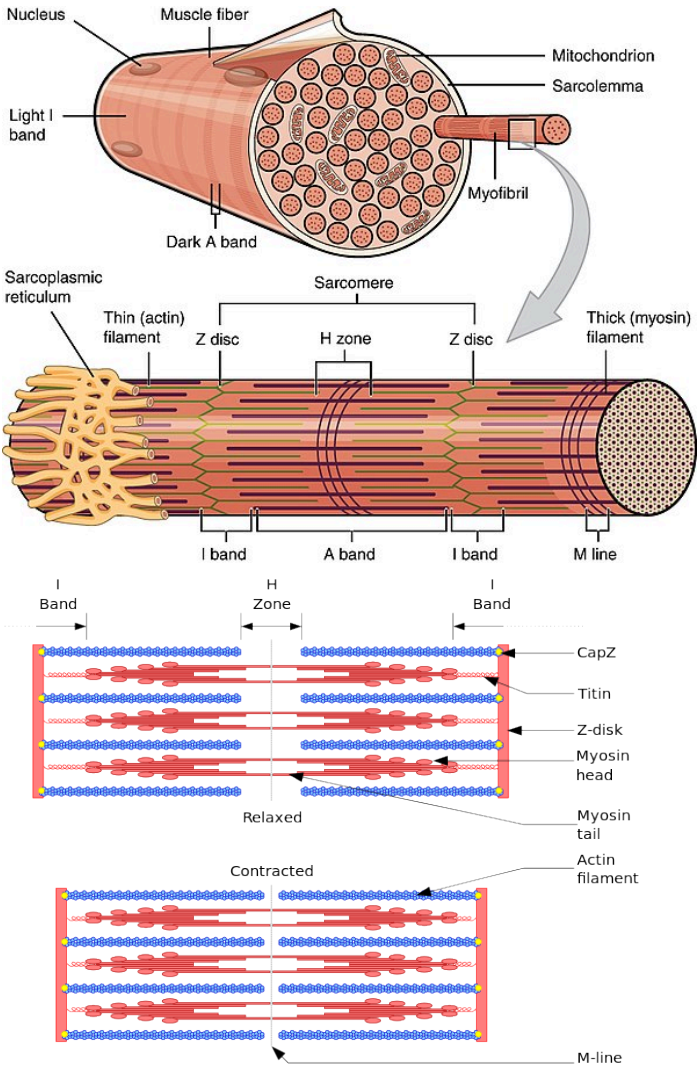
***** What change did you notice in the firmness of the triceps brachii as it is contracted? _____

***** Did your hand or forearm move as you pushed up against the table? _____

***** Did this muscle's fibers shorten as you pushed up against the table? _____

Contraction of muscle fibers

The striations in muscle fibers are due to locations of actin and myosin fibers. During contraction, actin filaments slide past and overlap more with myosin filaments. The result is shortening of the **sarcomere**, the functional unit of muscle. Examine the microscope structure of muscle fibers showing the shortening of the sarcomere.



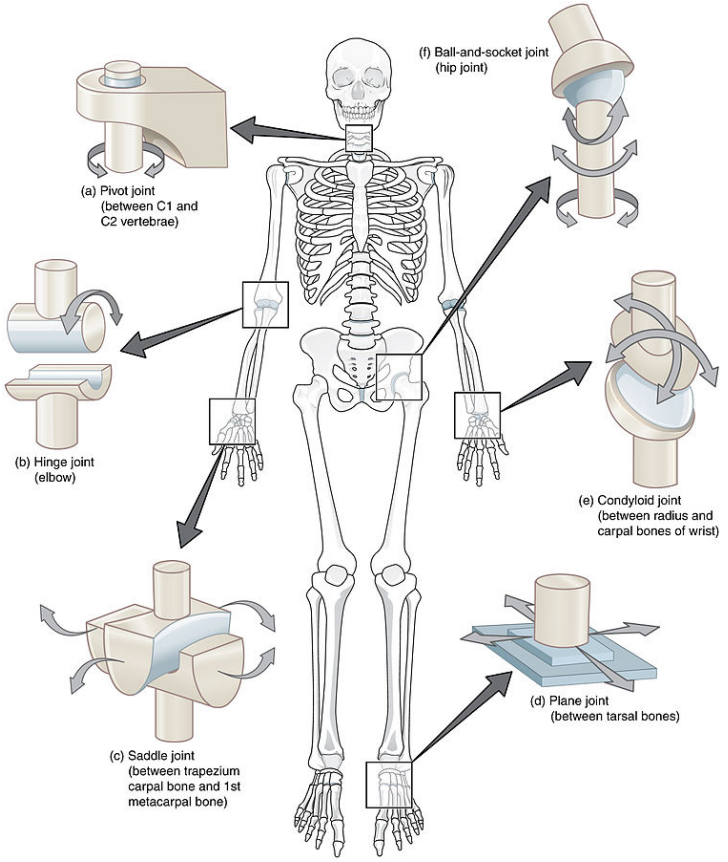
* The functional unit of muscle is called a(n) _____.

* What shortens during a muscle contraction: actin, myosin or the sarcomere? _____

Joints

The study of joints and articulations is **arthrology**, while studying

the body's movements is called **kinesiology**. Where bones meet, joints are generally immovable, slightly movable or freely movable (= **synovial**). There are six main types of synovial joints to know: **1. Ball and socket, 2. Condyloid, 3. Hinge, 4. Pivot, 5. Gliding, 6. Saddle**. These joint types vary in their plane of movement, with ball and socket joints having three planes of movement. Joints are normally named by the articulations of the bones involved. For example, the elbow (a hinge) joint is called the **humeroulnar** joint.



*** Examine the models of the hip, shoulder, and knee joints.** Note the following:

– Deep socket, stability of the hip joint– Shallower socket, greater range of movement of shoulder

– Overall instability of the knee– Ligaments serving the knee front to back & side to side

* Which ball and socket joint is more easily dislocated? _____

Types of Joints in the Body

- ***Immovable*** – ex. sutures between skull bones
- ***Slightly Movable*** – ex. vertebrae and disks & coxal bones (pubic symphysis)
- ***Movable Joints* (Synovial): name all bones involved in the joint**

Complete the following using the word bank:

Terms: *atlas*, *axis*, *carpals*, *coxal* (=*pelvis*), *femur* (2), *humerus* (2), *metacarpals* (2), *phalanges*, *radius* (2), *scapula*, *tibia* (2), *tarsals* (2), *ulna*

1. Ball & Socket*

Shoulder (*name 2 bones involved*) _____.... Hip **(2)** _____

2. Condyloid*

Wrist **(2)** _____.... Foot **(2)** _____

Finger **(2)** _____

3. Hinge*

Elbow (2) _____.... Knee **(2)** _____

4. Pivot*

Lower arm **(2)** _____.... Top two vertebrae **(2)** _____

5. Plane/Gliding Joint

Between wrist bones _____Between ankle bones _____

Image Credits:

Bone By https://commons.wikimedia.org/wiki/File:Compact_bone_-_ground_cross_section.jpg

Diagram of compact bone By OpenStax College – Anatomy & Physiology, Connexions Web site https://cnx.org/contents/FPtK1zmh@8.108:kwbeYj9S@4/Bone-Structure

Cartilage By https://commons.wikimedia.org/wiki/File:Cartilage01.JPG

Muscle tissues By 乌拉跨氪 – Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=46401576

Long Bone By OpenStax College – Anatomy & Physiology, Connexions Web site https://cnx.org/contents/FPtK1zmh@8.108:kwbeYj9S@4/Bone-Structure

Human Skeleton Front By https://commons.wikimedia.org/wiki/File:1105_Anterior_and_Posterior_Views_of_Muscles.jpg

Male and Female Pelvises Photos By Jeffery Ray, author of this lab activity

Human muscles By OpenStax [CC BY 4.0 (https://creativecommons.org/licenses/by/4.0)], via Wikimedia Commons https://commons.wikimedia.org/wiki/File:1105_Anterior_and_Posterior_Views_of_Muscles.jpg

Muscle contractions by

Body Movements https://cnx.org/contents/FPtK1zmh@8.108:qCnsYyus@3/Types-of-Body-Movements

Isotonic/Isometric By http://isowalking.com/

Skeletal muscle fiber https://cnx.org/contents/FPtK1zmh@8.108:bfiqsxdB@3/Skeletal-Muscle

Sliding filament By Richfield, David (2014). "Medical gallery of David Richfield". WikiJournal of Medicine 1 (2). DOI:10.15347/wjm/2014.009. ISSN 2002-4436. – Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=2264027

Joints by By OpenStax College – Anatomy & Physiology, Connexions Web site. http://cnx.org/content/col11496/1.6/, Jun 19, 2013., CC BY 3.0, https://commons.wikimedia.org/w/index.php?curid=30131668

BI 102 Lab Worksheet: Musculoskeletal Name _____ Section _____

1. How many bones in the adult human?_____ How many muscles in the adult human? ____

2. What are the two main divisions of the human skeleton?

1. _____2._____

3-4. Name the bone in the upper arm: General name for bones of the ankle:

Name the bone of the lower jaw: Name for collarbone:

5. Name & sketch the shape of any two types of vertebrate:

1. Type: 2. Type:

6. Name one location you would find a pivot joint:

7. Sketch the basic shape differences of a female vs. a male pelvis (see front cart)→:

8-9. Give the everyday name for the following muscles:

Gastrocnemius: Deltoid:

Masseter:

Gluteus maximus: Quadriceps femoris:

Trapezius:

10. Name & sketch the shape any two tissue types you observed under the microscopes (side/back counter):

1. Tissue: 2. Tissue:

3. Chapter 3

LAB 3

Introduction to the Cardiovascular System

Prepared by Jason R. Jones, University of North Alabama

OBJECTIVES

After completing these laboratory activities, you should understand/be able to:

- Define *cardiovascular system* and be able to describe the main parts and functions of the cardiovascular system.
- Identify the chambers, valves, and major vessels of the heart
- Define the following types of blood vessels: *arteries*, *arterioles*, *capillaries*, *venules*, *veins*
- Identify some of the major vessels carrying blood to (arteries) and carrying blood away from (veins) major body regions
- The difference between *systemic circulation* and *pulmonary circulation*, and be able to trace the path of blood through the heart in each
- How *heart rate* is measured, and how various factors can influence heart rate
- The typical healthy range of human heart rate
- The concept of *blood pressure*, including the difference between *systolic* and *diastolic pressure*
- How systolic and diastolic pressures are measured, and how these values are reported in a blood pressure reading

- The importance of blood pressure as a measure of health, and know the maximum values of a healthy blood pressure reading
- Define the terms *atherosclerosis*, *coronary arteries*, *coronary bypass surgery*, *myocardial infarction*, *plaque*, *stent*

INTRODUCTION

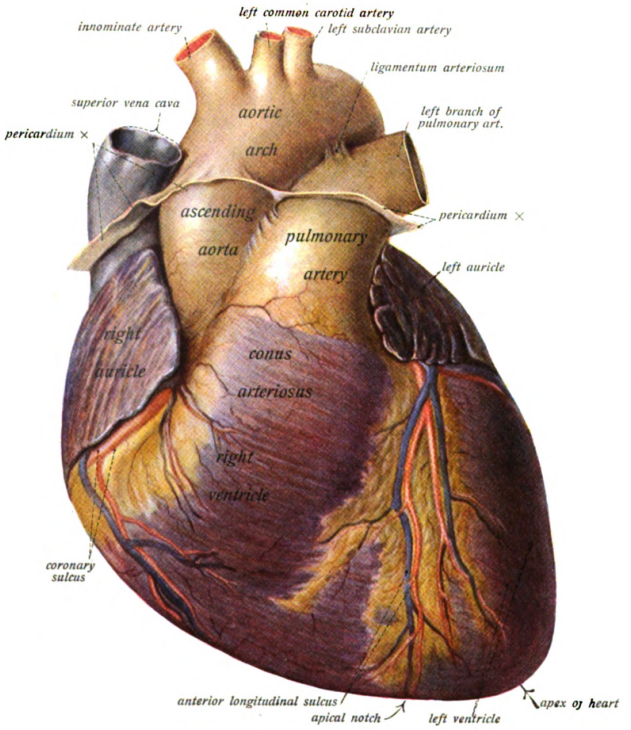
The cardiovascular system **serves as the primary means of transporting molecules throughout the body** to the trillions of cells that require a supply of nutrients/oxygen for the required constant production of ATP and our survival. Additionally, our cells' metabolism produces toxic or unusable wastes that must be removed.

The cardiovascular system (*cardio-* means "heart", and *vascular* means "vessels or tubes") consists of the heart ("pumping station") and the blood vessels (**arteries**, **arterioles**, **veins**, **venules**, and **capillaries**), which can be thought of as highways along which the blood moves.

ACTIVITY I: Anatomy of the Heart

The heart is a located in the thoracic cavity of the body, along with the lungs. It is situated on the midline of the body, behind and slightly to the left of the sternum, which protects it. Look at the provided human heart model and the heart in the human torso model. Externally, several structures of the heart are visible from an anterior (front view). First, you should note the **apex**, or tip of the heart, which points downwards and towards the left side of the body. You should also notice two earlike flaps towards the base (top) of the heart. These flaps are called the **auricles**, and are part of the upper chambers of the heart, which we will discuss below. You will also notice several large blood vessels connected to the heart, namely the large, arching **aorta**, which is the largest artery in the body, the **pulmonary artery** or **pulmonary trunk**, which branches into the left and right pulmonary arteries (only the left pulmonary artery can be seen in the anterior view), the **superior vena cava**, and the **right pulmonary veins**. Use Figures 1 and 2 on the following page to help you identify the structures in bold text on

the provided heart model. There will be a worksheet at the end of this lab exercise, where you will also need to identify these specific structures on the heart model that your instructor may take up after lab, so be sure to fill these in, as well.


left common carotid artery
innominate artery
left subclavian artery
ligamentum arteriosum
superior vena cava
aortic
arch
left branch of pulmonary art.
pericardium
pericardium
ascending
aorta
pulmonary
artery
left auricle
right
auricle
conus
arteriosus
right
ventricle
coronary
sulcus
anterior longitudinal sulcus
apical notch
left ventricle
apex of heart

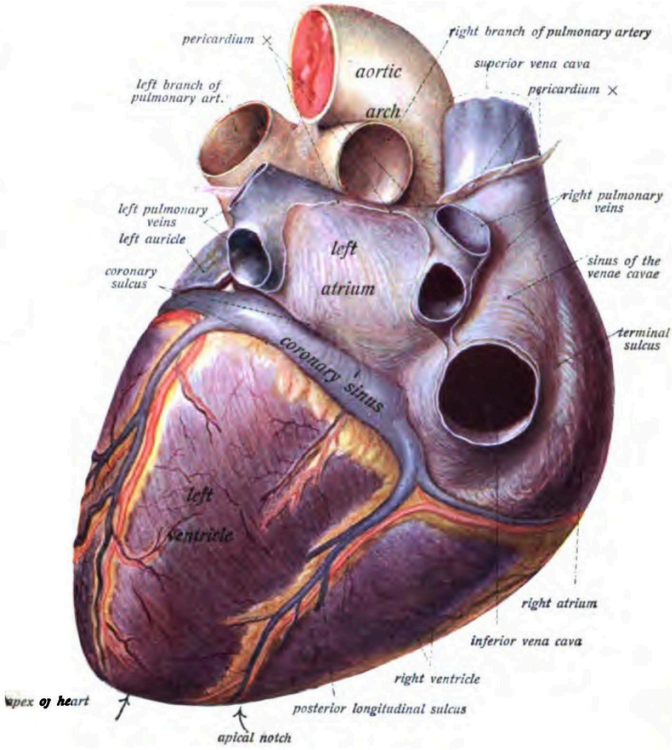


Figure 1. Heart external anatomy, anterior view.**Figure 2.** Heart external anatomy, posterior view.

Now observe the external anatomy of the heart from the posterior view. From the posterior view, the aorta is still visible, as is the superior vena cava. However, on the posterior side of the heart, you can now observe the **right pulmonary artery** (which branches from the pulmonary trunk), the **right pulmonary veins**, and the **inferior vena cava**. We will discuss these major blood vessels in greater detail below. In both views of the heart, you can also see several smaller blood vessels covering the surface of the heart. These are the coronary arteries and cardiac veins, and serve as a blood supply for the tissues of the heart itself.

Now remove the front portion of the human heart model, and notice that internally, the heart is divided into several chambers.

Mammals (including ourselves), have a heart that is divided into four chambers: two upper chambers called the **atria** (**left atrium** and **right atrium**), and two lower chambers called the **ventricles** (**left ventricle** and **right ventricle**). We can describe the functions of these chambers in two different ways. In one way, we can think about the differences between the upper chambers (atria) and the lower chambers (ventricles). You can think about the atria as the receiving chambers of the heart, as the atria receive blood from other parts of the body. One way to remember this is to think about the atrium of a building, which is usually the receiving area of the building. The lower chambers, or ventricles, have the main function of distributing blood elsewhere in the body. Another way to remember that the ventricles are the lower chambers of the heart is to look at the apex, or lower tip of the heart, which has a V-like shape. Examine Figure 3 on the following page, and use it to help you identify the structures in bold text on the provided heart model. There will be a worksheet at the end of this lab exercise, where you will also need to identify these specific structures on the heart model that your instructor may take up after lab, so be sure to fill these in, as well.

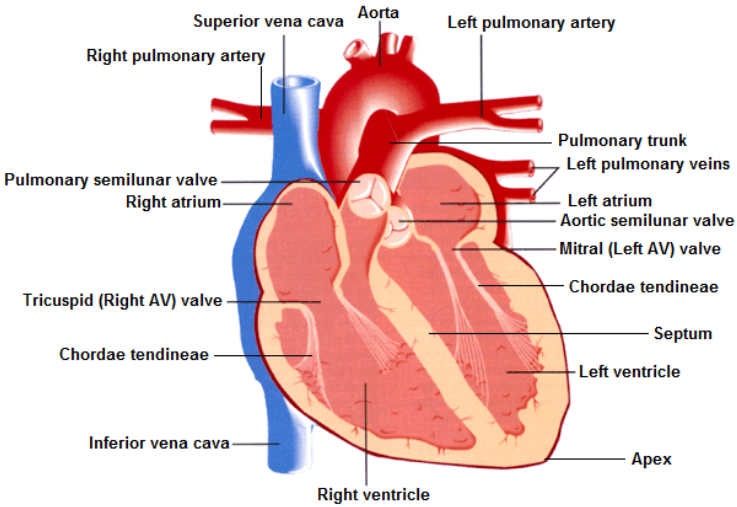


Figure 3. Heart internal anatomy, anterior view.

Notice that the heart is separated into left and right sides by a thick muscular wall called the septum, which separates the circulation of oxygenated and deoxygenated blood. This means that the circulation of blood in our bodies is actually separated into two different pathways, or circuits: the **systemic circuit** and the **pulmonary circuit**. The pulmonary circuit consists of the pathway of deoxygenated blood from the heart to the lungs for re-oxygenation, and then back to the heart. The systemic circuit consists of the pathway of oxygenated blood from the heart to all of the rest of the body (where cells deplete the oxygen supply in the blood), and back to the heart. We'll look at each of these circuits in more detail later, but first, let's continue examining the basic anatomy of the mammalian heart.

Another major feature seen in the mammalian heart is the presence of four special valves, all of which can be seen in Figure 3. These valves are very important, because their main function is to ensure that the flow of blood through the heart is only in a single direction. There are two main kinds of valves that are seen in the heart: atrioventricular valves and semilunar valves.

There are two **atrioventricular valves**, which separate the atrium from the ventricle on each side of the heart. If you look closely at each of the AV valves in the heart model, you will see that each of them are made up of several leaflets, or flaps. The right AV valve consists of three of these leaflets and is referred to as the **tricuspid valve**. The left AV valve consists of two of these leaflets, and referred to as the **bicuspid valve**. More commonly, however, the left AV valve is often called the **mitral valve**. The atrioventricular valves ensure that blood only flows from atrium to ventricle, and not the other way around. When the atria contract, the increased pressure of blood in the atria forces the AV valves open, and blood then flows into the ventricles. However, when the ventricles contract, the AV valves prevent blood from flowing back into the atria. This is achieved due to the unique structure of the AV valves themselves. Notice that at the bottom of each of the AV valves, they are connected to the walls of the ventricles by long, thin, cordlike

tendons called the **chordae tendineae**. When the ventricles contract, the increase in blood pressure in the ventricles *could* potentially force the AV valves to open in the wrong direction. However, tension provided by the chordae tendineae prevents this from happening.

There are also two **semilunar valves** in the heart, which separate the ventricles from the main blood vessels they supply. Between the left ventricle and the aorta is the **aortic semilunar valve**, and between the right ventricle and the pulmonary trunk, there is the **pulmonary semilunar valve**. The semilunar valves ensure that blood flows only in the direction of ventricle to vessel, and not the other way around. When the ventricles contract, the increased pressure of blood in the ventricles forces the semilunar valves open, causing blood to flow into the major vessels supplied by each ventricle. However, due to the force of gravity, blood has a tendency to flow downward, back towards the ventricles. However, the structure of the semilunar valves prevents this. Each semilunar valve is made up of three cuplike structures. When the ventricles contract, imagine the pressure of blood from the ventricles, forcing those cups upward and onto their sides, opening the semilunar valves. However, as the ventricles relax, as blood begins to flow downwards back towards the ventricles, that blood fills those cups up, causing them to tip back upright, closing the valves.

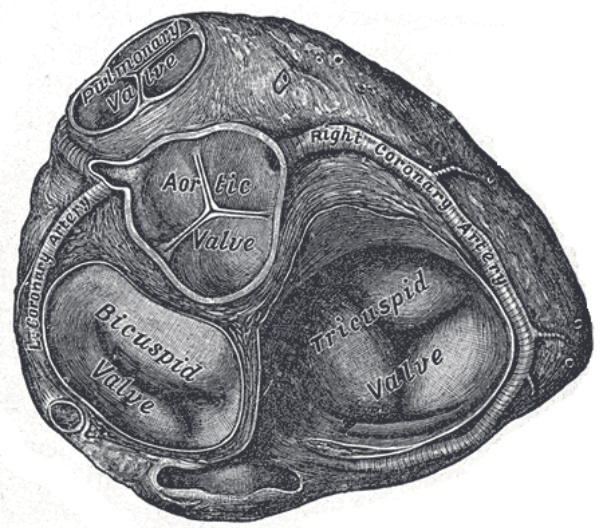


Figure 4. View of valves in the heart (cross section)

What are the two major circuits of the heart, what is the function of each circuit?

a. _____ a.

Function:_____

b._____ b.

Function:_____

ACTIVITY II: Anatomy of Blood Vessels

The heart acts as the pump that provides the force to deliver blood (and materials therein). The blood vessels are the pathways through which blood is delivered to locations throughout the body. The five major types of blood vessels in the cardiovascular system are: **arteries**, **arterioles**, **venules**,**veins**, and **capillaries**. Arteries and arterioles are blood vessels that carry blood in a direction away from the heart; arterioles are smaller branches of larger arteries. Veins and venules are blood vessels that carry blood in a direction back towards the heart; venules are smaller branches of larger veins. Capillaries are the smallest blood vessels where exchange of materials (water, gases, nutrients) occurs between blood and tissues.

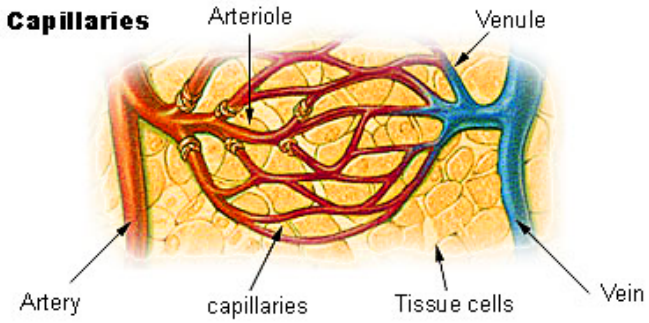


Figure 5. Comparative sizes of blood vessel types.

Aside from the difference in the direction in which they carry blood, arteries and veins have some anatomical differences, as well. Examine Figure 6 . Notice that the walls of arteries are thicker and much more muscular than the walls of veins. If you think about the fact that arteries are carrying blood away from the heart, this should make sense. Blood being carried away from the heart is moved as a result of the strong pumping force of the heart, is under higher pressure, and arteries need much thicker walls to withstand pressure without rupturing.

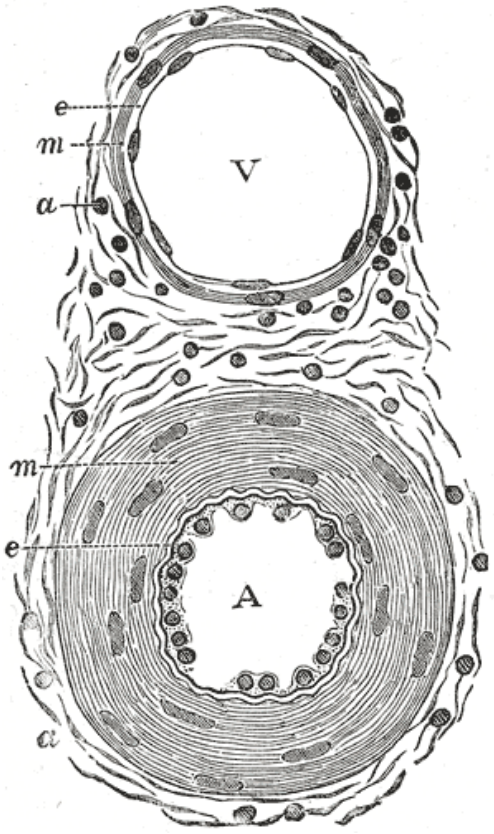


Figure 6. Comparison of veins & arteries. V = **vein**, A = **artery**, e = **endothelium** (simple squamous epithelial tissue), m = **tunica media** (mostly smooth muscle), a = **tunica adventitia** (connective tissue)

The blood flowing through veins is under lower pressure and as a result, veins have thinner walls and larger lumens (openings). This is an advantageous, because it allows for greater blood flow with less resistance from surrounding layers of their walls, facilitating movement of blood back towards the heart. Finally, veins possess valves, while arteries do not. Figure 7, shows valves in veinsthat ensure one-way flow of blood (towards the heart). However, think

for a minute about the blood in your legs, for example. If that blood has to get back to the heart, it has to move upwards, against the force of gravity. How is that accomplished? The valves in veins are part of this answer, but the musculoskeletal system also plays an important part in this role.

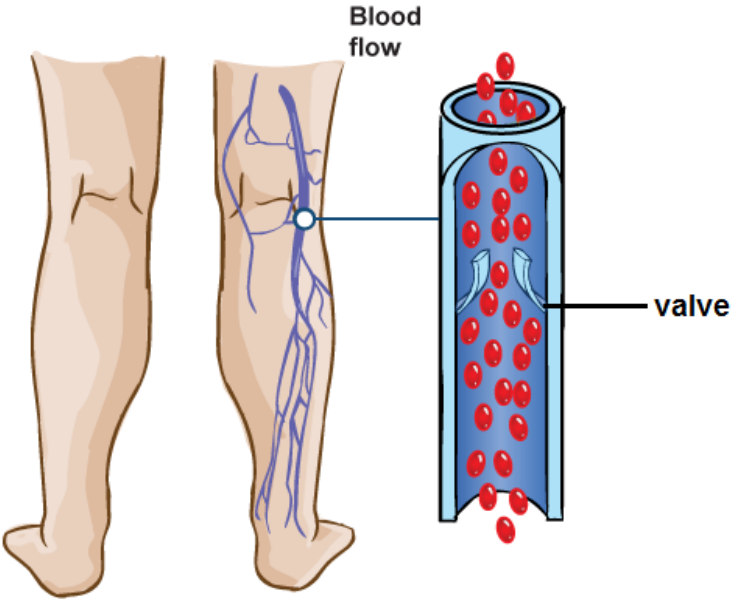


Figure 7. Illustration of how valves in veins prevent backflow of blood due to gravity (image courtesy of the U.S. National Library of Medicine).

When we walk and move around, contractions of our skeletal muscles puts pressure on our veins, like those in our legs, for example. That pressure forces blood to move through our veins. The valves in these veins only allow that movement in one direction. The structure of the valves prevent backflow of blood back down into the legs. Due to gravity, the blood in our legs has a natural tendency to flow downward, but as it does so, that closes the valves in those veins, similar to the way that the semilunar valves work in the heart.

Capillaries are very different than both arteries and veins. Capillaries are the smallest blood vessels, and are so thin, they only allow red blood cells to pass through them in single file. They are

only made up of a single layer, the **endothelium**, which is simple squamous epithelial tissue. This property is what makes capillaries able to fulfill their role of exchange of materials (water, gases, nutrients, hormones, and wastes) between blood and tissues. Since the walls of capillaries are only a single layer thick, that makes it really easy for some molecules (water, oxygen, and carbon dioxide) to diffuse directly across their walls. Additionally, there are also tiny slits or pores between the endothelial cells, which allow molecules or cells that are small enough to fit through them to move into or out of the capillary. This also comes in handy in the case of infection in a particular tissue, because white blood cells, which are part of the immune system's arsenal against invaders, are small enough to move through these slits and into the infected tissue.

Now that we've discussed the basic anatomy of blood vessels, let's examine some of the major blood vessels that supply or drain various regions of the body. Examine Figure 8 on the following page, and use that figure to match various blood vessels in the figure to their appropriate descriptions on the worksheet at the end of this lab exercise.

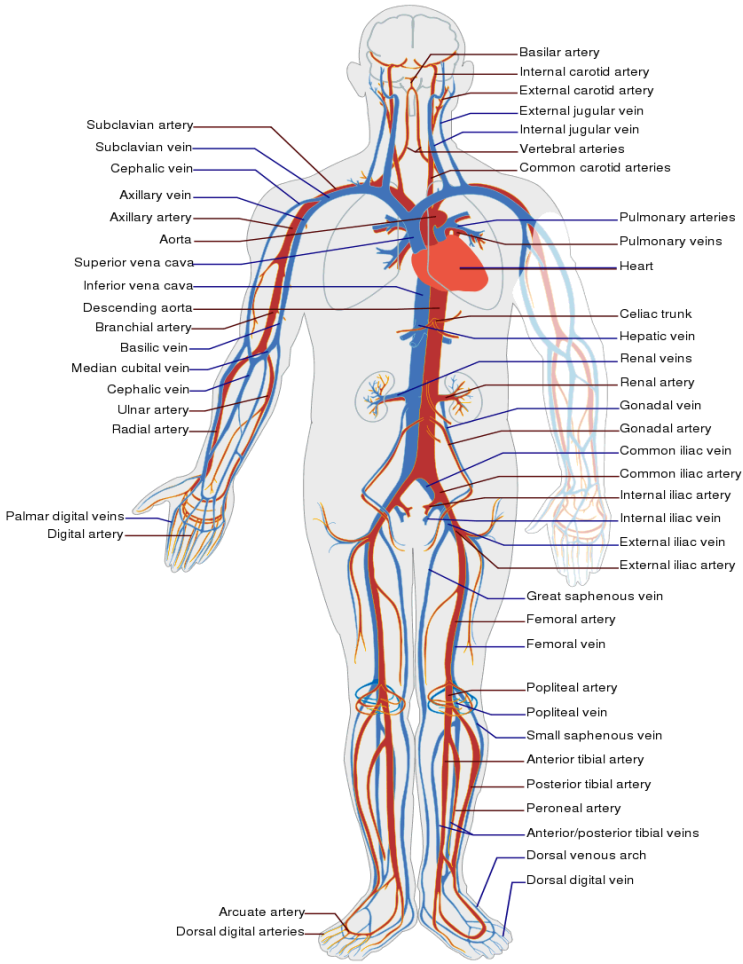


Figure 8. Major arteries and veins of the cardiovascular system.

ACTIVITY III: Pulmonary and Systemic Circulation

Remember, earlier in Activity I, we briefly discussed one main advantage of a four-chambered heart in mammals, birds, and crocodilians. A four-chambered heart allows for complete separation of the circulation of oxygenated and deoxygenated blood. This allows for a greater overall saturation of oxygen in blood supplied to the cells and tissues throughout the body. Essentially, circulation in mammals, birds, and crocodilians is separated into

two separate circuits, or pathways. These pathways are the **pulmonary circuit** and the **systemic circuit**. Each of these circuits begins and ends in the heart. The pulmonary circuit involves the circulation of deoxygenated blood from the heart to the lungs for re-oxygenation, and back to the heart. The systemic circuit involves the circulation of oxygenated blood from the heart to the rest of the body, which uses up the oxygen in that blood, and the return of this deoxygenated blood to the heart.

One easy way to remember the path of blood in both the pulmonary and systemic circuits is that both circuits start in one atrium of the heart, and end in the other atrium of the heart. Each circuit is primarily associated with one side of the heart, however, because each circuit involves both the atrium and ventricle of the same side of the heart. The pulmonary circuit is associated with the right side of the heart, and involves activity of both the right atrium and right ventricle. The systemic circuit is associated with the left side of the heart, and involves activity of the left atrium and left ventricle. As you read about these pathways of blood through the heart, it may be helpful to refer to the provided heart model to visually trace the path of blood through each of these pathways.

The pulmonary circuit is the shortest of the two pathways of blood through the heart. Any time you see the word "pulmonary", that means "relating to the lungs". Again, the pulmonary circuit is the pathway of blood from the heart to the lungs, and back to the heart. The main function of the pulmonary circuit is to receive deoxygenated blood from the rest of the body, and deliver that blood to the lungs for re-oxygenation, before returning that blood back to the heart. On the provided heart model, locate the superior and inferior vena cava. These are two major veins that deliver deoxygenated blood back to the heart, with the superior vena cava returning deoxygenated blood from the head and upper body to the heart, and the inferior vena cava returning deoxygenated blood from the lower body to the heart. Remove the front of the heart model, and notice that both the superior vena cava and inferior vena cava empty into the **right atrium**. When the atria contract, this

deoxygenated blood from the right atrium is pumped into the **right ventricle** through the **tricuspid valve**. Then, when the ventricles contract, the deoxygenated blood in the right ventricle is pumped up through the **pulmonary semilunar valve** into the **pulmonary trunk**, and then to the left and right **pulmonary arteries**, which carry blood to the lungs. In the lungs, numerous capillary beds are where oxygen diffuses from the lungs into the bloodstream (and carbon dioxide in the bloodstream diffuses into the lungs), re-oxygenating the formerly oxygen-depleted blood. See Figure 9 below for an example of these **capillary beds in the lungs**. After this blood is re-oxygenated, it is transported back towards the heart through the **pulmonary veins**, which empty into the left atrium, completing the pulmonary circuit.

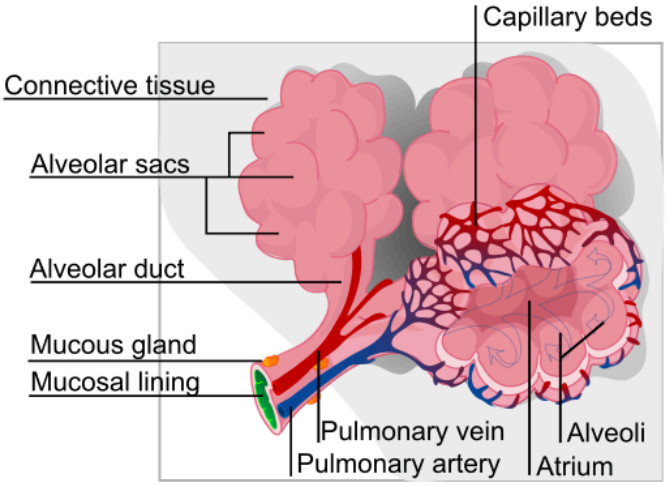


Figure 9. Illustration of alveoli (air sacs) in the lungs, and the associated capillary beds, pulmonary arteries, and pulmonary veins.

The systemic circuit is the longest of the two pathways of blood through the heart. The word "systemic" in anatomic terminology means "relating to the entire body". Again, the systemic circuit is

the pathway of blood from the heart to the entirety of the rest of the body (excluding the lungs), and back to the heart. The main function of the systemic circuit is to receive oxygenated blood from the lungs, and deliver that blood to the rest of the body, where tissues use up the oxygen in the blood, and then the return of that blood back to the heart. Again, examine the provided heart model. Remember, as previously discussed, the pulmonary circuit ends when oxygenated blood from the lungs is returned to the left atrium, marking the beginning of the systemic circuit. The systemic circuit starts with the entry of oxygenated blood into the **left atrium**. When the atria contract, this oxygenated blood from the left atrium is pumped through the **mitral valve** into the **left ventricle**. Then, when the ventricles contract, the oxygenated blood in the left ventricle is pumped through the **aortic semilunar valve** into the **aorta**, which eventually branches into various **systemic arteries** supplying blood to the rest of the body. In **systemic capillaries** in body tissues, oxygen diffuses from the bloodstream into those tissues. Carbon dioxide (and other wastes) from those tissues also diffuse from those tissues into the bloodstream. This blood, now depleted of oxygen is returned to the heart via **systemic veins**, which eventually empty into the **superior vena cava** or **inferior vena cava**, both of which empty into the right atrium of the heart, completing the systemic circuit.

The difference in the distance traveled by blood in the pulmonary and systemic circuits explains some of the anatomical differences between the left and right sides of the heart. Look at the provided heart model, and remove the anterior portion so that you can observe the chambers within. Note that the right ventricle has thinner, less muscular walls, while the left ventricle has thicker, more muscular walls. This should make sense if you consider the fact that the right ventricle, as part of the pulmonary circuit, only has to pump blood to the lungs, which isn't very far, since the lungs are located just to either side of the heart. The left ventricle, however, as part of the systemic circuit, has to distribute blood

everywhere else in the body, and thus has to work harder, thereby necessitating more muscle mass to do so.

Now that you have learned about the two pathways of blood through the heart, complete the exercise on pulmonary and systemic circulation on the worksheet at the end of this lab exercise.

ACTIVITY IV: Measures of Cardiovascular Health

Heart/cardiovascular disease is the leading cause of death in the United States, as well as the entire world. Cardiovascular disease refers to a broad range of conditions affecting the cardiovascular system, such as heart rhythm problems and congenital heart defects, but generally refers to the narrowing or blockage of blood vessels, which can lead to various other conditions, such as a heart attack or stroke. One specific example of a type of cardiovascular disease is a condition known as **atherosclerosis**, which is the buildup of **plaque** (made up of fat, cholesterol, and other substances) in the arteries, causing narrowing and hardening of the arteries, both of which reduce blood flow through those arteries (and thus blood supply to tissues). See Figure 10 below for an example of blood flow in a healthy artery, and one affected by atherosclerosis.

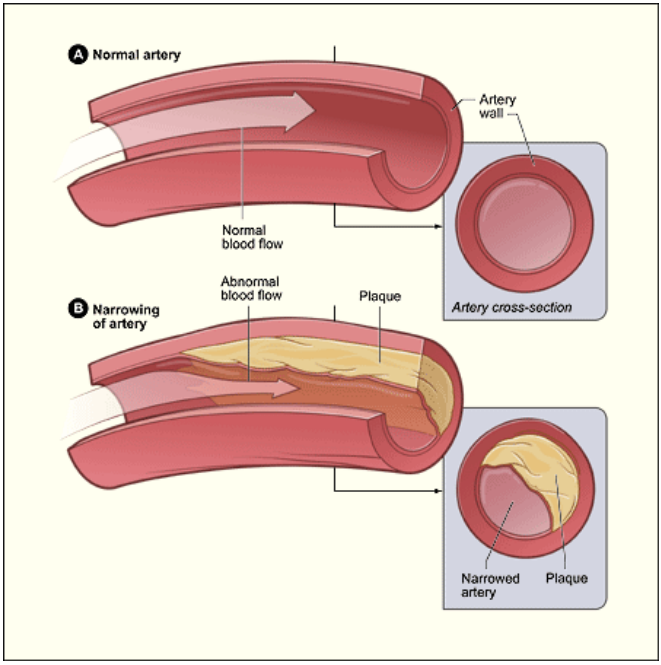


Figure 10. Illustration of blood flow in a healthy artery (A), and in an artery that has been narrowed by atherosclerosis (B). Source: National Heart, Lung, and Blood Institute; National Institutes of Health; U.S. Department of Health and Human Services.

One way in which atherosclerosis is sometimes treated is through the use of a **stent**, or a small mesh tube to widen narrowed arteries, or to reinforce weakened arteries. See Figure 11 on the following page for an example of the procedure used to place a stent in a narrowed artery.

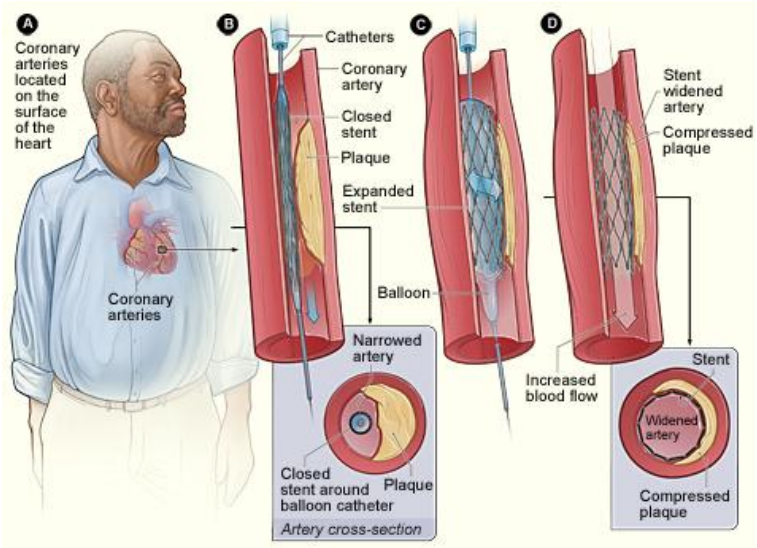


Figure 11. Illustration of the use of a stent in the treatment of an artery narrowed by atherosclerosis.

Source: National Heart, Lung, and Blood Institute; National Institutes of Health; U.S. Department of Health and Human Services.

On the exterior surface of the heart model, there are numerous **coronary arteries** and **coronary veins**. Though these were only briefly mentioned in Activity I, these blood vessels are very important, as they provide circulation to the tissues of the heart itself. Though the heart is pumping blood to the lungs and the rest of the body, the heart needs its own blood supply, as well. Since the heart is constantly pumping, it requires lots and lots of ATP to sustain that activity, and as a result, also requires a large supply of oxygen and nutrients. A blockage in one of the coronary arteries is extremely dangerous, as reduced blood supply to a region of heart tissue can result in damage or death to that tissue, resulting in a heart attack, also known as a **myocardial infarction (MI)**. If a heart attack occurs and is not fatal, overall health is still adversely affected, as the resulting scar tissue decreases heart efficiency.

Sometimes, blockages to coronary arteries can be treated using stents, as shown in Figure 10 above. However, sometimes blockages to coronary arteries are treated using a surgical procedure known as **coronary bypass surgery**. There are two typical approaches through which this type of surgery is performed. In one, a healthy artery in the patient's chest is re-routed to supply blood to the heart tissue past the point of the blockage. In the other, a vein is removed from one of the patient's legs, and grafted to the aorta and a point just past the blockage in the coronary artery. Occasionally, individuals may have blockages in multiple coronary arteries, requiring multiple bypasses. See Figure 12 for examples of each of these techniques. Look at the provided heart model showing coronary bypass surgery, and using the lab model, answer the question on the worksheet at the end of this lab exercise.

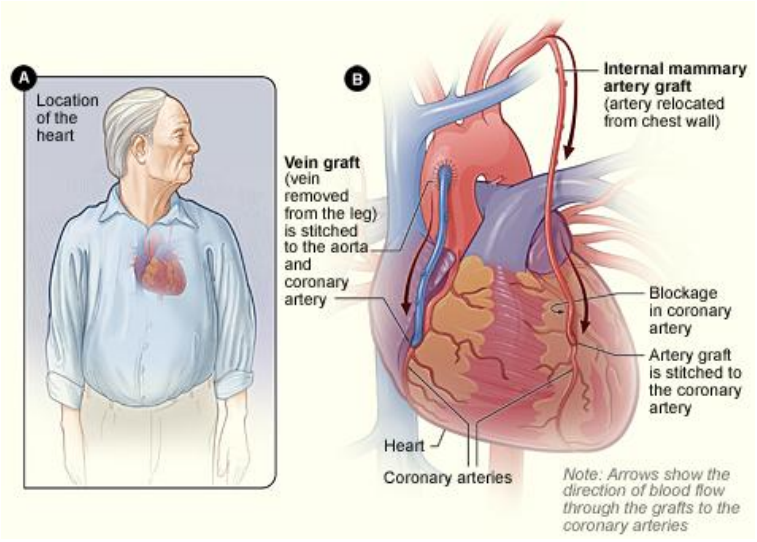


Figure 12. Illustration of the two major methods of coronary bypass surgery. Source: National Heart, Lung, and Blood Institute; National Institutes of Health; U.S. Department of Health and Human Services.

Given the important role of the cardiovascular system, it should come as no surprise that cardiovascular health is extremely

important. As a result, monitoring some aspects of cardiovascular function is part of almost every routine medical examination. During such examinations, an idea of cardiovascular health can be determined by listening to the heart for any abnormal sounds, and determination of **heart rate** and **blood pressure**. In this activity, you will be measuring your own heart rate (pulse rate) and blood pressure. The provided stethoscopes can also be used for you and your partner to listen to one another's hearts, as well.

The resting heart rate of most healthy individuals typically falls within the range of 60 to 100 beats per minute (bpm). However, in extremely active or athletic individuals, resting heart rate may be as low as 40 bpm. Typically, lower resting heart rates reflect greater cardiovascular health. To measure your own heart rate, take the first two fingers of either hand (not the thumb), and lightly press over the radial artery (on the thumb side of the inside of your wrist). Count the number of pulses you feel during a period of 30 seconds, and multiply that number by 2. The resulting number is your heart rate in bpm. Record your heart rate on the worksheet at the end of this exercise.

To maintain good cardiovascular health, aerobic exercise, or exercise that strengthens the heart and lungs. During aerobic exercise, a target heart rate of approximately 50-85% of your estimated maximum heart rate is generally suggested. To estimate your maximum heart rate, subtract your age from 220. Then multiply the resulting number by 0.5. The result would be a good minimum target heart rate during moderate aerobic exercise. Next, multiply your estimated maximum heart rate by 0.85. The result would be a maximum target heart rate during intense aerobic exercise. Record your estimated maximum heart rate and target heart rate range on the worksheet at the end of this exercise. Optionally, your instructor may ask you to exercise (jumping jacks or running in place) for a few minutes, and then have you record your heart rate immediately after exercise. If your instructor asks you to do this, record your heart rate after exercise in the worksheet at the end of this exercise, as well.

Another measure of cardiovascular health is your **blood pressure**. Blood pressure is defined as the pressure, or force, of blood pressing against the walls of blood vessels. Of course, this force is ultimately the result of the pumping action of the heart, so monitoring blood pressure is a good way of monitoring overall cardiovascular health. Blood pressure readings actually consist of two numbers. The first number in a blood pressure reading is always the largest number, and the second number is smaller. The larger number is called the **systolic pressure**, which is the pressure of blood in an artery during the peak of **systole**, or contraction of the ventricles of the heart. The second, smaller number is called the **diastolic pressure**, which is the pressure of blood in an artery during the peak of **diastole**, or relaxation of the ventricles of the heart. It should make sense that the systolic pressure is always greater, since the systolic pressure is the pressure of blood when the heart is actively contracting, creating greater pressure in the arteries. Blood pressure readings are usually reported visually in a format such as "120/80", where the number before the slash is the systolic pressure, and the number after the slash is the diastolic pressure. When reported verbally, the previous blood pressure would be reported as "120 over 80".

Normal blood pressure is considered to be values less than 120/80. Regular monitoring of blood pressure is important, as **hypertension** (high blood pressure) substantially increases an individual's risk of various other health complications, such as heart attack, stroke, kidney damage, damage to the retina of the eyes, erectile dysfunction in men, and even dementia/Alzheimer's disease. High blood pressure often has no noticeable symptoms itself, but is often referred to as the "silent killer", due to the increased risk of death due to heart attack, stroke, or kidney disease associated with hypertension. Table 1 below shows the American Heart Association's newest guidelines on classifying blood pressure values. Patients with hypertension are typically treated with medications to keep blood pressure within lower, safer ranges, but lifestyle changes (such as smokers quitting smoking, reduction of sodium and saturated fats in the diet, weight loss, aerobic exercise,

and reduction of alcohol consumption are usually also recommended to prevent further worsening of hypertension

Table 1. New (2017) blood pressure categories from the American Heart Association

Category	Bl
Normal	Less than 120/80
Elevated	Systolic between 120-129 *and* diastolic less
Stage 1 hypertension	Systolic between 130-139 *or* diastolic betw
Stage 2 hypertension	Systolic at least 140 *or* diastolic at least 90
Hypertensive crisis	Systolic over 180 and/or diastolic over 120

The traditional method of measuring blood pressure is through the use of a stethoscope and a device called a **sphygmomanometer**, which consists of an inflatable cuff attached by rubber tubing to an inflator bulb and a pressure gauge. To obtain a blood pressure reading using a sphygmomanometer, the cuff of the sphygmomanometer is placed around the upper arm, right above the bend of the elbow. At this location, the blood pressure reading obtained is a measurement of the pressure of blood in the **brachial artery** (refer back to Figure 8). The cuff is then inflated to a pressure that is high enough to cut off blood flow beyond the cuff. A stethoscope is then used to listen at a location just below the cuff, and the person taking the reading slowly begins releasing the pressure in the cuff, while simultaneously continuing to listen while also visually monitoring the pressure gauge on the sphygmomanometer. What the person taking the reading is listening for are some special sounds called the **sounds of Korotkoff**, which indicate changes in blood flow in the artery. When the pressure in the cuff is greater than the systolic pressure in

the artery, there is no blood flow past the cuff, and no sounds are heard. As the pressure is decreased, when the pressure in the cuff is equal to the systolic pressure, a slight knocking sound should be heard as blood begins to flow past the cuff, and the pressure on the gauge when the knocking sound is heard is recorded as the systolic pressure. As the pressure is continually decreased, continued knocking or turbulent sounds are heard, because even though blood is flowing past the cuff, the artery is still somewhat compressed. However, eventually, when the pressure in the cuff is equal to the diastolic pressure in the artery, all sounds should stop, as the artery is no longer compressed, and blood is flowing completely freely through the artery. The pressure at which all sounds stop is then recorded as the diastolic pressure. It is fairly difficult to take your own blood pressure using this method, so you and your lab partner should attempt to get a blood pressure reading on one another. Ideally, blood pressure readings should be taken when an individual is seated, with legs uncrossed, and supporting the arm in which the blood pressure is being taken. To get a blood pressure reading from your partner, follow the instructions below.

1. Clean the eartips of your stethoscope using the provided alcohol swabs.
2. Place the eartips of your stethoscope in your ears, making sure that they are pointing forward (away from you), and that they form a tight seal inside your ears. You should be able to hear very little in the room around you if you are using the stethoscope properly.
3. Have your partner present you with the arm of their choice. Blood pressure readings can be taken from either arm. If they are wearing long sleeve shirts that are thicker than an average T-shirt, their sleeve should be pushed up well past their elbow.
4. Place the cuff of the sphygmomanometer around your partner's upper arm, making sure to line up the arrow on the cuff with the location of the artery in their arm.
5. Using the inflator bulb, rapidly inflate the pressure in the cuff

to about 180 mmHg.

6. Place the edge diaphragm or bell of your stethoscope just right under the bottom edge of the cuff, and listen. Initially, you should hear no sound, since blood flow past the cuff is completely obstructed.
7. While continuing to listen, begin slowly releasing the pressure on the cuff by slightly unscrewing the valve at the end of the inflator bulb. Make sure you are also visually monitoring the pressure gauge on the cuff the entire time.
8. Continue to listen as the pressure decreases, and as soon as you hear a clicking or popping noise, note the pressure on the gauge and record this as your partner's systolic pressure.
9. Continue to allow the pressure to decrease as you continue to listen and monitor the pressure gauge. As soon as any sounds you hear stop, note the pressure on the gauge and record this as your partner's diastolic pressure.
10. Remove the cuff from your partner's arm, and the stethoscope from your ears, and again clean the eartips of the stethoscope with alcohol swabs.
11. After attempting to get a blood pressure reading from your partner, swap places and allow them to attempt to get your blood pressure using all the steps above.

It can be tricky to train your ear to listen for the sounds of Korotkoff to obtain a blood pressure reading using the traditional method listed above, but try the traditional method of obtaining a blood pressure reading from your partner at least once. If you have difficulty listening for the sounds of Korotkoff, you can try the traditional method a second time, or you can use one of the provided electronic blood pressure cuffs in lab to get a reading of your own blood pressure. On the worksheet at the end of this lab exercise, record your own blood pressure (not your partner's). Several factors can elevate your blood pressure above your actual baseline blood pressure. Blood pressure readings should be taken when you are quiet, relaxed, and comfortable. Several factors may

falsely elevate blood pressure beyond your normal baseline, such as talking during the reading, recent previous activity, recent caffeine consumption, recent tobacco use, anxiety, a full bladder, feeling chilly, etc.

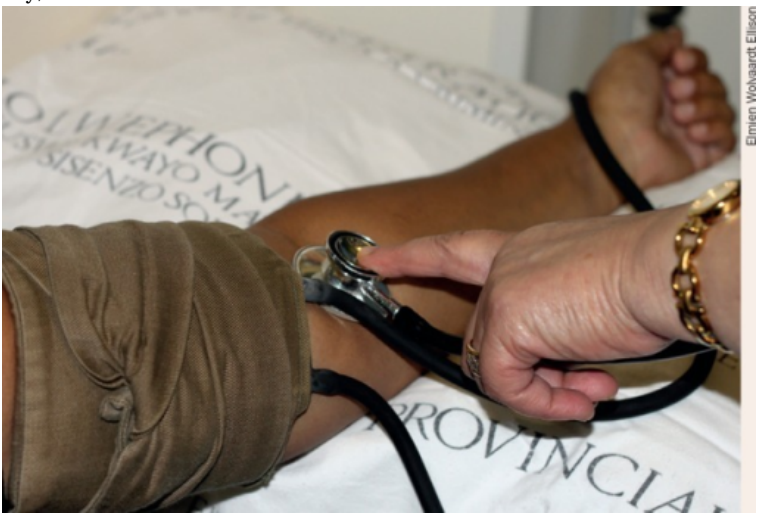


Figure 13. Measuring blood pressure using a stethoscope and sphygmomanometer. Credit: Elmien Woolvardt Ellison. Obtained from http://openi.nlm.nih.gov/, licensed under https://creativecommons.org/licenses/by/2.0/

BI 102 Lab Worksheet: Cardiovascular Name _____ Section _____

ACTIVITY I: Anatomy of the Heart

Using the available human heart models, write the number on the model beside each appropriate structure listed below:

_____ Aorta/aortic arch
_____ Aortic semilunar valve
_____ Inferior vena cava
_____ Left atrium
_____ Left pulmonary artery

_____ Left pulmonary veins
_____ Left ventricle
_____ Biscuspid (mitral/left AV) valve
_____ Pulmonary semilunar valve
_____ Pulmonary trunk
_____ Right atrium
_____ Right pulmonary artery
_____ Right pulmonary veins
_____ Right ventricle
_____ Superior vena cava
_____ Tricuspid (right AV) valve

ACTIVITY II: Anatomy of Blood Vessels

Match the descriptions below to the correct blood vessels.

_____ Blood vessels from heart *to* the neck and head	A. aorta
_____ Blood vessels to heart *from* the neck and head	B. brachial arteries
_____ Blood vessels from heart *to* the lungs for oxygenation	C. carotid arteries
_____ Blood vessels to heart from the lungs	D. inferior vena cava
_____ Blood vessel to heart *from* the head, arms, & upper body	E. pulmonary veins
_____ Blood vessel to heart *from* the lower/ middle body	F. pulmonary arteries
_____ Largest artery in body from heart to many body regions	G. renal arteries

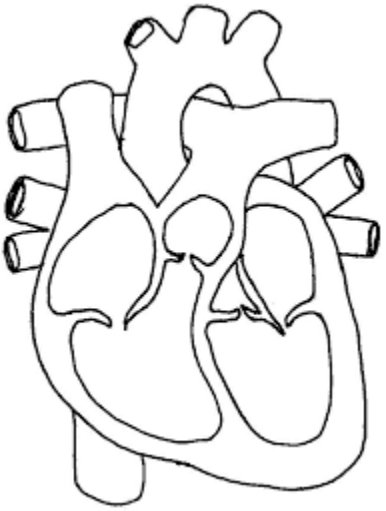
_____ Blood vessels from heart to the upper arm; blood pressure is taken here	H. renal veins
_____ Blood vessels from heart to the kidneys	I. superior vena cava
_____ Blood vessels to heart *from* the kidneys	J. jugular veins

ACTIVITY III: Pulmonary and Systemic Circulation

In the diagram, label the left atrium (LA), right atrium (RA), left ventricle (LV), right ventricle (RV), aorta (A), superior vena cava (SVC), inferior vena cava (IVC), pulmonary trunk (PT), left pulmonary artery (LPA), right pulmonary artery (RPA), left pulmonary veins (LPV), right pulmonary veins (RPV), mitral valve (MV), tricuspid valve (TV), aortic valve (AV), and pulmonary valve (PV).

Using colored pencils (blue to represent deoxygenated blood, and red to represent oxygenated blood), draw colored arrows to show the direction of blood flow through all of the labeled structures. Make sure that you have arrows showing blood flow drawn in all blood vessels shown.

From Venae Cavae	**From lungs**
–> _____ _____ _____	–> _____ _____ _____
–>_____ _____ _____ valve	–> _____ _____ _____
–>_____ _____ _____	–>_____ _____ _____ valve
–>_____ _____ _____ valve	–>_____ _____ _____
–>_____ _____ _____	–>_____ _____ _____ valve
–>_____ _____ _____ **–> To lungs**	**–> To Aorta**



Correctly trace the path of blood flow through the heart from the vena cavae to the aorta. Use each of the terms only once: Aortic semilunar, Bicuspid (AV), Left Atrium, Left Ventricle, Pulmonary

arteries, Pulmonary semilunar, Pulmonary trunk, Pulmonary veins, Right Atrium, Right Ventricle, Tricuspid (AV)

From Venae Cavae	**From lungs**
–> 1. _____ _____ _____	–> 7._____ _____ _____
–> 2._____ _____ _____ valve	–> 8._____ _____ _____
–> 3._____ _____ _____	–> 9._____ _____ _____ valve
–> 4._____ _____ _____ valve	–> 10._____ _____ _____
–> 5. _____ _____ _____	–> 11._____ _____ _____ valve
–> 6. _____ _____ _____	**–> To Aorta**
–> To lungs	

ACTIVITY IV: Measures of Cardiovascular Health

Examine the heart model in lab showing coronary bypass surgery, and fill in the blank below:

The coronary bypass model in lab has _____ (number of) bypasses.

Your resting heart rate: _____ bpm **OPTIONAL:** Your heart rate after exercise: _____ bpm

Your estimated maximum heart rate (220 – your age): _____ bpm

Your target heart range during exercise (50-85% max): between _____ and _____ bpm

Why does heart rate increase during aerobic exercise?

Your blood pressure: _____/_____How would your blood pressure be classified using the AHA's guidelines?

4. Chapter 4

LAB 4

Introduction to the Digestive System

Prepared by Jason R. Jones, University of North Alabama

OBJECTIVES

After completing these laboratory activities, you should understand / be able to:

- Recognize the organs of the digestive system, including those that are part of the *alimentary canal* or *digestive tract*, as well as those that are considered *accessory organs*, and their functions.
- The difference between *mechanical digestion* and *chemical digestion*.
- Define the terms *catalyst*, *enzyme*, and *substrate*.
- That enzyme activity can be affected by multiple factors, and examples of such factors affecting enzyme activity.
- Define the terms *positive control* and *negative control*, and know how/why they are important.
- Define the term *peristalsis*.
- Some of the major digestive enzymes involved in digestion of carbohydrates, proteins, and fats; know where these enzymes are produced, and the site of their actual function.
- Different factors that can affect the activity of digestive (and other) enzymes.

- The role of *bile* in the *emulsification* of fats.

INTRODUCTION

The **digestive system is responsible for processing the food taken into the body and converting** it to usable energy.

The process of digestion can actually be divided into two main types of digestion. The first of these is **mechanical digestion**, which is simply the breaking down of food into smaller pieces, but without any chemical changes to the food. This process is begun in the mouth, through the chewing action of our teeth. By chewing food into smaller pieces, this increases the surface area of the food. This larger surface area thus provides for faster and more efficient **chemical digestion** (which also begins in the mouth), in which various **enzymes** actually further break down the food chemically into smaller molecules that are more easily absorbed and used by our bodies for various functions. An enzyme is an organic molecule (usually a protein) that acts as a **catalyst** (a molecule that speeds up a particular reaction) for the breakdown of large molecules in our food into smaller "building block" molecules. Enzymes are usually very specific, and a given enzyme typically only speeds up a single type of reaction. Enzymes speed up reactions by binding to a **substrate**, which is one of the reactants in a chemical reaction.

In these exercises, you will familiarize yourself with the anatomy of the digestive system, including the organs of the **alimentary canal** (or **digestive tract**) and the various **accessory digestive organs** that also play important roles in digestion. You will also examine the activity of several digestive enzymes, as well as explore factors that may affect the activity of these enzymes.

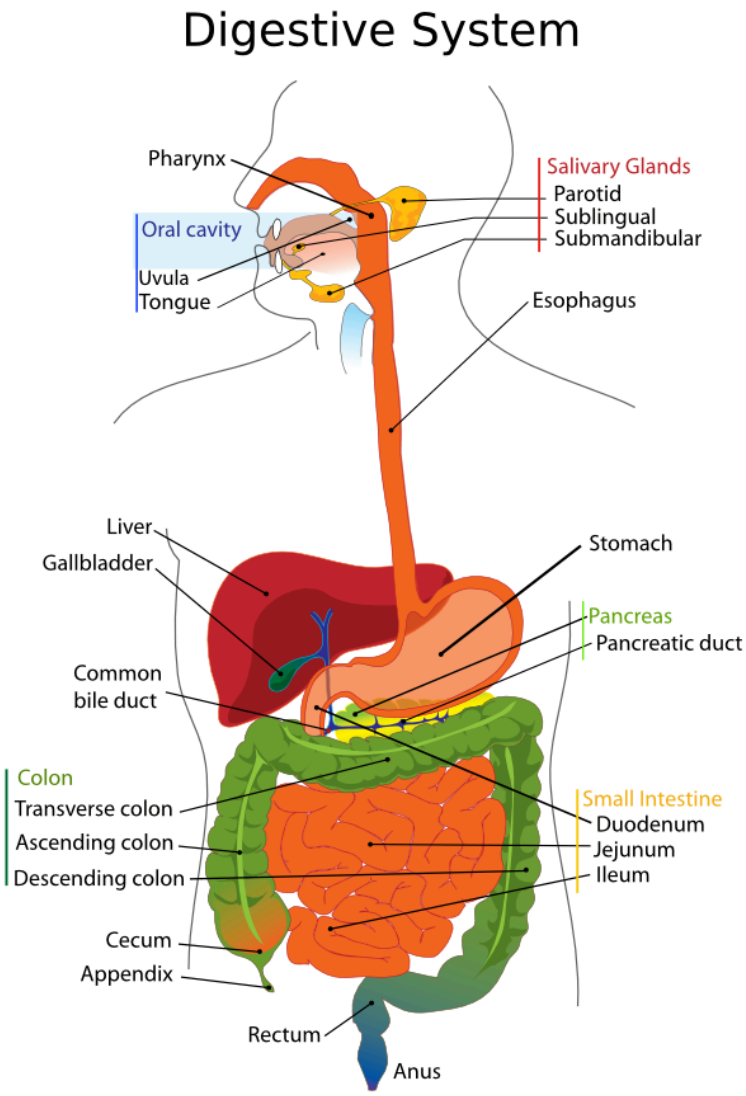


Figure 1. Organs of the digestive system

ACTIVITY I: Organs of the Alimentary Canal

When most people think of the digestive system, they typically think of the **digestive tract**, also known as the **alimentary canal**, though there are other organs that function in digestion (the **accessory digestive organs**, which we'll discuss later). The

alimentary canal consists of all of the organs of the digestive system through which food passes *directly*, and includes the **oral cavity** (mouth), **pharynx** (throat), **esophagus**, **stomach**, **small intestine** (subdivided into several regions), and **large intestine** (also subdivided into several region**s)**. Each of these organs are hollow and can essentially be thought of as subdivisions of a single tube, with an opening at each end (mouth and anus). The overall structure of the organs of the alimentary canal is fairly similar, with each consisting of four basic layers. The inner surface of each of these organs is lined with a mucus membrane, consisting epithelial tissue and a thin layer of smooth muscle. This layer serves several functions, including secretion (mucus, enzymes, hormones, etc.), absorption, and protection from microbial invaders. Surrounding the mucus membrane layer is a layer of dense connective tissue containing blood vessels, lymph vessels, and nerves. The next layer of the alimentary canal (moving outward) is a double layer of smooth muscle tissue. This involuntary muscle tissue is responsible for movement of food along the digestive tract via a wave of contraction (called **peristalsis**) that moves sequentially along the length of the digestive tract. The outermost layer of the digestive tract consists of epithelial tissue and a thin layer of connective tissue. This outermost layer mainly serves to anchor the digestive organs in place, as well as reduce friction as the movable digestive organs slide against one another and along body cavity walls.

Food enters the alimentary canal through the **oral cavity**, or **mouth**. The oral cavity is bounded by the **lips** anteriorly (to the front), by the **cheeks** laterally (to the sides), and the **hard palate** (which has underlying bone) and **soft palate** (with no underlying bone) forming the roof of the mouth, and the **tongue** occupying the floor of the mouth. Inside the oral cavity are the **gums**, **teeth**, **tongue**, and openings to the **salivary glands**, which are **accessory digestive organs**. During chewing, the salivary glands release **saliva**, a watery mixture of mucus, cells, enzymes, and other molecules that moistens (and begins the process of digestion of) the chewed food, facilitating its compression into a mushy ball called a **bolus**. During

swallowing, the tongue moves the bolus towards the back of the mouth towards the pharynx. (Swallowing is actually a fairly complex process, involving over 30 different muscles).

The **pharynx** (throat) is a passageway that contains openings leading into both the digestive tract (via the **esophagus**) and the respiratory tract (via the trachea). To prevent food from entering the respiratory tract, a flap of cartilage called the **epiglottis** folds down to close the glottis (opening of the trachea) during swallowing. To illustrate the activity of the epiglottis in its role of closing the respiratory tract during swallowing, follow the directions below.

1. Place your index and middle fingers on your larynx (voice box). This is easier to see in males than in females, due to the enlarged laryngeal prominence (Adam's apple), which is more pronounced in males. However, if you are a female, you should still be able to easily locate the large area of cartilage that marks the upper portion of the respiratory tract.
2. With slight pressure against the larynx, swallow. You should be able to feel the larynx rise, as well as a slight posterior (backwards) motion, representing the epiglottis folding backwards to cover the opening of the trachea (windpipe).
3. Answer the question on the worksheet at the end of this lab exercise.

After swallowing, the bolus of food then moves into the esophagus, which has no digestive or absorptive function, and simply serves as a passageway into the lower gastrointestinal tract. The esophagus contains smooth muscle, which contracts via wavelike peristaltic motion to move the bolus to the stomach. The opening between the esophagus and stomach is typically closed by a ring of involuntary smooth muscle called the **gastroesophageal sphincter**. Upon swallowing, when the wave of peristaltic contraction reaches this sphincter, it forces it open, allowing the bolus to enter the stomach.

To illustrate the activity of peristaltic contraction and the gastroesophageal sphincter, follow the instructions below.

1. Take the provided stethoscope, and clean the earbuds with an alcohol swab.
2. Have your partner use their fingers to locate their **xiphoid process**, which is the small, inferior-most (lower) bone of their sternum.
3. Have your partner place the membrane of the stethoscope approximately one inch below this point.
4. Use the provided small cup of water. While listening, have your partner take a fairly large mouthful of water, and swallow it.
5. Listen closely, and you should hear two sounds. First, you should hear a splash, as the water strikes the closed esophageal sphincter. As soon as you hear this initial splash, start the provided timer.
6. Continue to listen, and you should hear a second sound. As soon as the peristaltic wave of contraction of the esophagus reaches the sphincter, this should force it open, allowing the water to enter the stomach, which should produce a gurgling sound. When the gurgling sound is heard, stop the provided timer.
7. Answer the questions in the worksheet at the end of this lab exercise.

The **stomach** is a J-shaped, organ that functions in both mechanical and chemical digestion. Look at the provided stomach model. The outer layer of the stomach consists of epithelial tissue, with a thick layer of smooth muscle just underneath. The muscle layer actually consists of three layers of smooth muscle: an outer layer of longitudinal muscle, a middle layer of circular muscle, and an inner layer of oblique smooth muscle (note that the names of each of these layers correspond to the direction in which the muscle fibers are arranged in those layers). The innermost layer of the stomach consists of **simple columnar epithelial** tissue arranged into ridges

and folds, which also contain small pits. These ridges and folds assist with mechanical digestion of food, as contraction of the smooth muscle layers of the stomach churn food in the stomach, as well as pummel food against these ridges, further breaking the food into smaller pieces. These ridges/folds also increase the surface area of the stomach lining, allowing for the presence of a greater number of cells that produce various important molecules, such as mucus (which protects the lining of the stomach), hydrochloric acid (HCl, which is involved in chemical digestion), and digestive enzymes (discussed further later).

After further processing in the stomach, the mixture of partly digested food and gastric juices (acid, digestive enzymes, and mucus) passes through a valve called the pyloric sphincter into the **small intestine**, which is divided into three main regions (in order): **duodenum, jejunum, & ileum**. The first section directly connected to the stomach is the **duodenum**. The majority of the small intestine is the **jejunum**, and the terminal portion that connects to the large intestine is the **ileum**. The human small intestine in a cadaver, stretched out, would be ~20 feet in length. In life, muscle tone of the small intestine reduces its length to ~6 feet. The small intestine is the site of further digestion of food, as well as the site of nearly all absorption of nutrients into the bloodstream. Look at Figure 2 on the following page. Note that the small intestine is lined with numerous fingerlike projections called **villi**, which themselves are covered with even tinier fingerlike projections called **microvilli**. Both villi and microvilli serve to increase the surface area of the small intestine, creating additional surface area for absorption of nutrients.

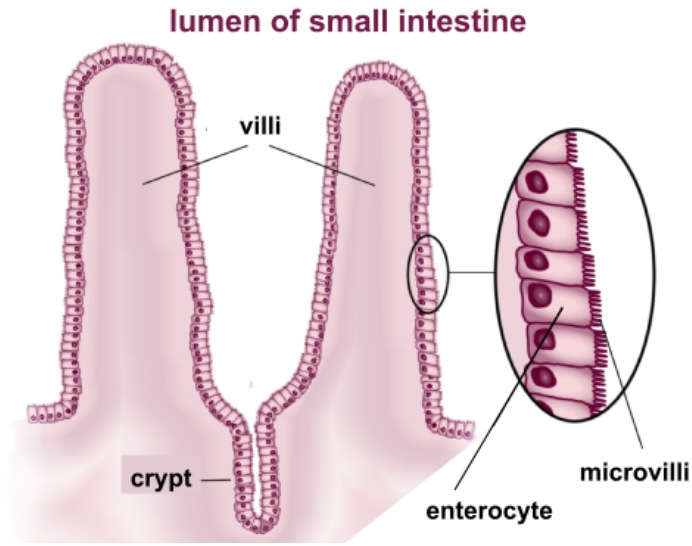


Figure 2. Microscopic view of the lining of the small intestine showing villi and microvilli. This work by BallenaBlanca (modified byMcortNGHH) is licensed under a Creative Commons Attribution 4.0 International (https://creativecommons.org/licenses/by-sa/4.0/deed.en).

The last segment of the small intestine, the **ileum**, empties into the large intestine (or colon). The large intestine plays very little role in the digestion of food, and primarily serves to reabsorb water from the digested food, as well as vitamin K produced by colon bacteria. Like the small intestine, is divided into several distinct regions. The first region of the large intestine, which is directly attached to the ileum of the small intestine, is a pouch shaped region called the **cecum**. At the posterior (lower) end of the cecum is a short, twisted, wormlike pouch called the **appendix**. Though it was previously thought to have little to no function, the appendix primarily serves as a reservoir for beneficial gut bacteria. Superior to (above) the cecum is the segment of the large intestine referred to as the **ascending colon**. The ascending colon then bends in an approximately 90 degree angle, after which the large intestine travels across the body as a region called the **transverse colon**,

which also terminates in a near 90 degree angle, marking the beginning of the **descending colon**. At its lower end, the descending colon leads into an S-shaped curved portion of the large intestine called the **sigmoid colon** ("sigmoid" literally means "S-shaped"). The sigmoid colon leads into the vertical segment of the large intestine called the **rectum**, which serves as an area of storage of formed feces before its eventual elimination from the body through the **anus**, which has two circular **sphincter** muscles: an involuntary internal sphincter of smooth muscle, and a voluntary external sphincter of skeletal muscle. Answer the question about several regions of the large intestine on the worksheet at the end of this lab exercise.

Familiarize yourself with the location of each of the above regions of the digestive tract in Figure 1, as well as on the provided human torso models. On the worksheet at the end of this lab exercise, you will be asked to number the regions of the digestive tract in the order in which food moves through them throughout the digestion and excretion process.

ACTIVITY II: Structure & Function of Accessory Digestive Organs

Activity IIA: Mammalian Tooth Types and Mammal Dental Formulas

The process of mechanical digestion begins with the chewing action of the teeth breaking food into smaller pieces. Mammals (including ourselves) have different types of teeth adapted for different functions. **Incisors**, for example, are narrow-edged teeth towards the front of the mouth that are adapted for cutting. The **canines** are also teeth near the front of the mouth, and are typically pointed. The canines primarily are adapted for tearing food. In carnivores, the canines are generally very pronounced, but in omnivores and herbivores, they may be more similar in shape to the incisors. Moving towards the back of the mouth, the next type of tooth encountered are the **premolars**, also known as **bicuspids** (due to the presence of two cusps, or raised surfaces). Finally, the teeth farthest back in the mouth are known as the **molars**. Molars

are distinguishable from premolars by a greater number of cusps on their surfaces. In omnivores and herbivores, both the premolars and molars are primarily adapted for crushing and grinding food, though in carnivores, they may be more modified for shearing meat.

The skull, and in particular, the teeth of a mammal can actually tell you a great deal about that organism, including the species from which the skull came, as well as some substantial insight into the dietary habits of that organism. Different species of mammals have different numbers and shapes of each type of tooth, and mammals are often described in terms of their **dental formula**. The dental formula of an animal is a way of displaying the number of each type of tooth found in both the upper (maxilla) and lower (mandible) jaw of its skull. To write the dental formula of a mammal, you count the number of teeth of each type (incisor, canine, premolar, and molar) on *only one side* of both the upper and lower jaw. The reason teeth are only counted on one side of each jaw is because mammals are bilaterally symmetrical, and should have the same number of each type of teeth on the other side of the jaw. Dental formulas are written in a format that looks somewhat like a fraction. Below is an example of how a dental formula is typically written:

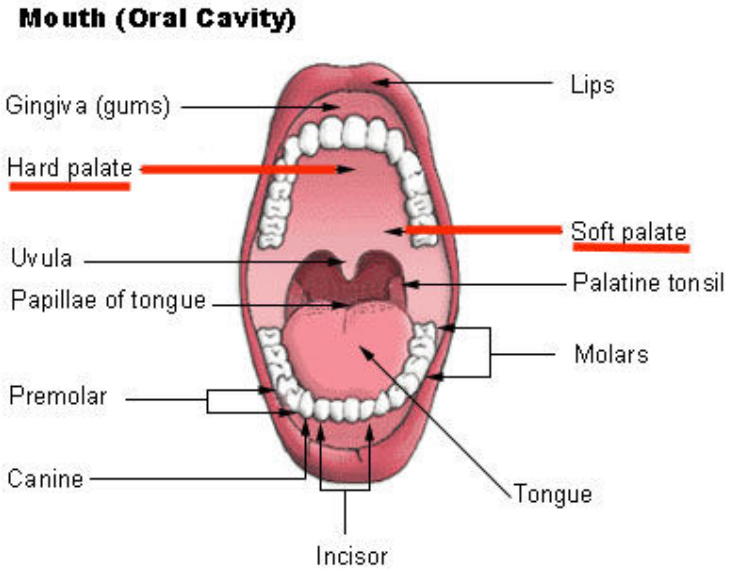
ICPM/ICPM=U/L=T

However, in the dental formula of an actual mammal, the letters above the line would be replaced by the number of each type of tooth on one side of the upper jaw, and the letters below the line would be replaced by the number of each type of tooth on one side of the lower jaw (I = # of incisors, C = # of canines, P = # of premolars, and M = # of molars; U = total # of teeth in the upper jaw, L = total # of teeth in the lower jaw, and T = total # of teeth). To calculate the total number of teeth in the upper and lower jaws, you would add all the numbers above the line (for the upper jaw) or below the line (for the lower jaw), and multiply by two, because remember, dental formulas are written by counting the number of each type of tooth only one one side of the skull. For example, the dental formula of the Virginia opossum (*Didelphis virginiana*) would be written as follows:

5134/4134=26/24=50

This means that a Virginia opossum has a total of 26 teeth in its upper jaw (5 x 2 = 10 incisors; 1 x 2 = 2 canines; 3 x 2 = 6 premolars; 4 x 2 = 8 molars; 10 + 2 + 8 + 6 = 26), and a total of 24 teeth in its lower jaw (4 x 2 = 8 incisors; 1 x 2 = 2 canines; 3 x 2 = 6 premolars; 4 x 2 = 8 molars; 8 + 2 + 8 + 6 = 24), for a total of 50 teeth.

Using the provided model of an adult human skull, and Figure 3 below, see if you can determine the dental formula of an adult human, and write it in the appropriate space on the worksheet at the end of this lab exercise. **Note that the provided model does not illustrate erupted wisdom teeth (3rd molars on each side on both the upper and lower jaws). In your determination of the human dental formula, include the wisdom teeth in your calculation.**



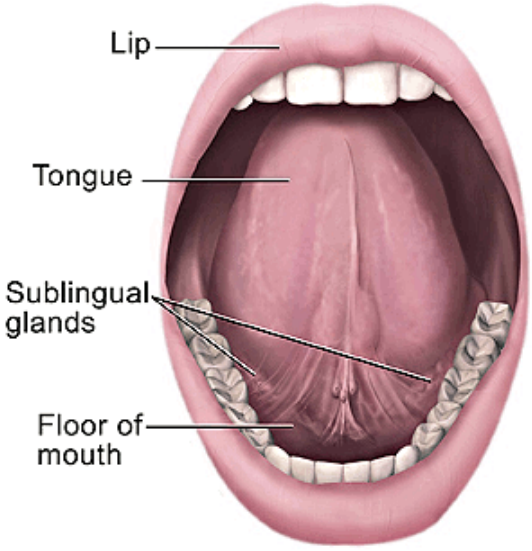


Figure 3. Anatomy of the oral cavity

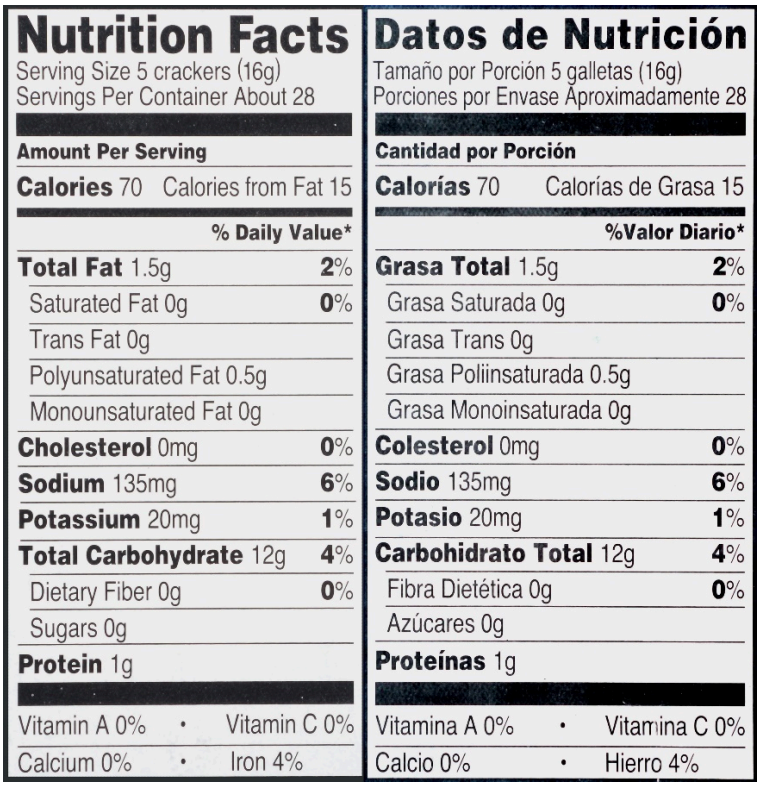
Activity IIB: Location and Function of the Salivary Glands

There are three pairs of salivary glands that empty secretions into the oral cavity. The largest of these glands are the **parotid glands**, which are located in front of the ear, and which empty into the mouth just above the second molar. Another pair, the **submandibular glands**, which are located under the mandible, or lower jaw**,** have ducts that open on either side of the lingual frenulum, which is the membrane that attaches the tongue to the floor of the mouth. Another pair, the **sublingual glands**, is located underneath the tongue, and empty through several ducts towards the lateral (towards the side) aspects of the base of the tongue. Look at Figure 1, and note the location of each of these pairs of glands, and also see if you can locate any of them on the available torso models. Ask your partner to lift their tongue, and see if you can see the openings of the ducts of their submandibular and sublingual glands, and see if they can locate the openings of your ducts of these glands.

Though the amount of saliva that is produced by healthy

individuals is debated, current estimates of saliva production range from about 0.75-1.5 liters of saliva per day, with the majority of saliva (70-75%) being secreted by the submandibular glands. The majority of the volume of **saliva** (about 99.5%) is water, but saliva also contains many other substances, such as mucus (consisting primarily of various proteins), that primarily serves the function of lubrication of the oral cavity and chewed food, as well as various enzymes, including some that function in digestion, as well as some that have antimicrobial activity.

One of the major digestive enzymes produced by the salivary glands is **amylase**, which is an enzyme that breaks complex carbohydrates (like starch) down into simple sugars. Amylase is also produced by the pancreas (and released into the duodenum; but this will be discussed later), but approximately 30% of starch digestion by amylase occurs in the mouth.



Nutrition Facts	
Serving Size 5 crackers (16g)	
Servings Per Container About 28	
Amount Per Serving	
Calories 70	Calories from Fat 15
	% Daily Value*
Total Fat 1.5g	**2%**
Saturated Fat 0g	**0%**
Trans Fat 0g	
Polyunsaturated Fat 0.5g	
Monounsaturated Fat 0g	
Cholesterol 0mg	**0%**
Sodium 135mg	**6%**
Potassium 20mg	**1%**
Total Carbohydrate 12g	**4%**
Dietary Fiber 0g	**0%**
Sugars 0g	
Protein 1g	
Vitamin A 0% •	Vitamin C 0%
Calcium 0% •	Iron 4%

Datos de Nutrición	
Tamaño por Porción 5 galletas (16g)	
Porciones por Envase Aproximadamente 28	
Cantidad por Porción	
Calorías 70	Calorías de Grasa 15
	%Valor Diario*
Grasa Total 1.5g	**2%**
Grasa Saturada 0g	**0%**
Grasa Trans 0g	
Grasa Poliinsaturada 0.5g	
Grasa Monoinsaturada 0g	
Colesterol 0mg	**0%**
Sodio 135mg	**6%**
Potasio 20mg	**1%**
Carbohidrato Total 12g	**4%**
Fibra Dietética 0g	**0%**
Azúcares 0g	
Proteínas 1g	
Vitamina A 0% •	Vitamina C 0%
Calcio 0% •	Hierro 4%

To illustrate the activity of salivary amylase, your instructor will provide you with a saltine cracker. Look at the nutritional label from a typical package of saltine crackers in Figure 3 to the right:

Notice that for a serving of crackers (16g), the majority of its mass is carbohydrates. However, notice the subcategories below the "Total Carbohydrate" information show a sugar content of 0g. This means the majority of saltine crackers consists of large complex carbohydrates, such as starch.

Now take the provided saltine cracker, and put it into your mouth, and begin chewing, but do not swallow. Continue chewing the cracker for at least 1 full minute, and notice the physical changes in

the texture of the cracker, as well as any changes in flavor you may notice. Record this information in the worksheet at the end of this lab exercise.

Figure 4. Nutritional information for a typical package of saltine crackers.

Activity IIC: Additional Accessory Digestive Organs and their Functions

In addition to the teeth and salivary glands, there are several additional **accessory digestive organs**. Again, accessory digestive organs are organs through which food does not pass directly, but which contribute substantially to digestive function. These organs include the **liver**, **gallbladder**, and **pancreas**.

After the skin, the **liver** is the second largest organ of the body (weighing approximately 3 pounds), and also the body's largest gland. The liver is located in the abdominal cavity, just below the diaphragm (the large sheet of muscle that separates the thoracic cavity, containing the heart and lungs, from the abdominal cavity), anterior to (in front of) the stomach, and towards the right side of the body. The liver performs many important functions, such as filtering blood from the digestive tract before returning it to the body's general circulation, working with the pancreas to regulate blood glucose levels, synthesis of proteins important for blood clotting, and detoxifying chemicals and metabolizing medications. However, the primary digestive function of the liver is the production of **bile**. **Bile** is a mixture of cholesterol, bile salts, and a pigment called bilirubin, which is the result of the breakdown of hemoglobin. Small amounts of bilirubin are excreted in the urine, but the products of the breakdown of bilirubin are also responsible for the brown coloration of feces. The main function of bile is in the digestion of fat, but it is mostly involved in the mechanical breakdown, and not the chemical digestion of fat.

After being produced in the liver, bile is secreted into the **gallbladder**, a small green sac-like structure on the inferior (lower) surface of the liver, where it is stored until the ingestion of fats. When ingested food with substantial fat content enters the

duodenum (the first section of the small intestine connected to the stomach), the gallbladder contracts, emptying bile into the duodenum. Again, bile does not chemically break down fat. Instead, bile helps **emulsify** fat with the gastric juices leaving the stomach and entering the duodenum. By **emulsification**, we refer to a more evenly distributed mixture of fluids that do not normally mix well. For example, imagine making a salad dressing of oil and vinegar. Normally, oil and vinegar do not mix well, since oil consists of nonpolar molecules, and vinegar (consisting of mostly water) consists of a polar solution. Because of the differences in polarity the molecules of water in the vinegar and the molecules of oil show no attraction to one another, causing them to separate into distinct layers, with the oil on top due to a lower density. However, in making such a salad dressing, one could add an emulsifying agent (such as a beaten egg or mustard), which contains molecules that have both polar and nonpolar regions. The polar regions of the emulsifying agent molecules are attracted to water molecules in the vinegar, and the nonpolar regions of the emulsifying agent molecules are attracted to the molecules of oil, and, after a good shake, this allows the oil molecules to be mixed evenly with the water molecules of the vinegar. This is exactly how bile allows emulsification of fats in the gastric juices, which are mostly water. The nonpolar regions of bile salt molecules essentially clump around tiny globules of oil molecules, with their polar regions facing outwards, and being attracted to water molecules in the gastric fluids. See Figure 5 on the following page for an example of this process.

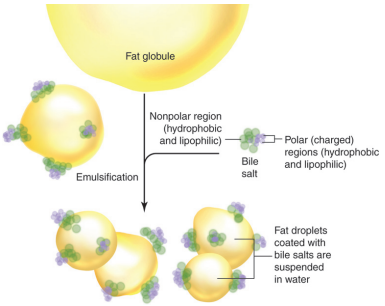


Figure 5. Emulsification of a fat globule by bile salts. This work by Cenveo is licensed under a Creative Commons Attribution 3.0 United States (http://creativecommons.org/licenses/by/3.0/us/).

Follow the directions below to illustrate the role of bile salts in the emulsification of fats.

1. Obtain 2 test tubes.
2. Label one tube "NB" to stand for "no bile", and one tube "B" to stand for "bile".
3. To each tube, add 3 mL of distilled water.
4. Next, add 3 mL of vegetable oil to each tube.
5. To the tube labeled "B" **only**, add a small pinch of bile salts (available on the cart at the front of the lab).
6. Now cover each tube with a small square of Parafilm, and cover the opening and Parafilm of each tube with your thumb.
7. Shake each tube vigorously for at least 30 seconds, and return the test tubes to your test tube rack.
8. After 10 minutes, observe each tube, and answer the questions on the worksheet at the end of this lab exercise.

An additional important accessory digestive organ is the **pancreas**, which is a small, triangular gland that is found between the spleen and the duodenum. The pancreas plays a role as both an endocrine gland (secreting hormones involved in blood sugar regulation directly into the bloodstream), but also as an exocrine digestive gland (secreting several important digestive enzymes, discussed

later, into the duodenum). Additionally, as the highly acidic gastric juices from the stomach are passed into the duodenum, the pancreas also secretes sodium bicarbonate (NAOH), a highly basic fluid into the duodenum to neutralize the acid from the stomach.

Activity III: Digestive Enzymes and Factors Affecting their Function

Several digestive **enzymes** are produced by various organs of the digestive system, and are responsible for the **chemical digestion** of various organic macromolecules (chemically breaking the larger organic molecules into smaller building block molecules). **Enzymes** are organic molecules (typically proteins) that act as **catalysts** (molecules that speed up particular chemical reactions), without being used up in the process (enzyme molecules are not destroyed, and can be used again/recycled). The names of enzymes usually (but not always) end in the suffix "-ase," so any time you see a biological reference to a molecule with that ending to its name, it is a safe bet that that molecule is an enzyme. Enzymes are usually very specific, and speed up only a single type of chemical reaction. Enzymes work by acting on a **substrate** (a molecule that temporarily binds to the enzyme molecule, with the enzyme speeding up a reaction in which that substrate is a reactant). Look at Table 1 below listing several major digestive enzymes, where they are produced, the site of their action, their substrates, and their products. Your instructor may ask you questions about some of these digestive enzymes on the quiz at the beginning of the following week's lab.

Table 1. Several important digestive enzymes, and details about their production and activity.

Enzyme	Site of production	Site of action	Substrate	Products
Amylase	Salivary glands (*salivary lipase*) Pancreas (*pancreatic lipase*)	Mouth Small intestine	Starch & other polysaccharides	Simple sugars
Pepsin	Stomach	Stomach	Proteins	Large polypeptides
Trypsin	Pancreas	Small intestine	Large polypeptides	Smaller polypeptides
Lipase	Salivary glands (*salivary lipase*) Pancreas (*pancreatic lipase*)	Mouth Small intestine	Triglycerides (fats)	Monoglycerides and fatty acids

In the following exercises, you will explore the activity of a few of these enzymes, as well as some factors that affect their function. If you remember the discussion of biochemistry in BI 101, you should be aware that the function of enzymes, as proteins, depends entirely on the shape of the enzyme (protein) molecule. Any factors (such as temperature, pH, etc.) that can change the shape of the enzyme (protein) molecule can change the function of that particular enzyme. Some changes in shape may make an enzyme more effective, some may make them less effective, and in some cases, some changes in shape may make the enzyme nonfunctional. When an enzyme's shape has been changed in such a way that its function has been eliminated, we say that the enzyme has been **denatured**.

When conducting tests of an enzyme's activity, it is important to test each treatment for the presence of the enzyme's substrate, as well as the products of the reaction catalyzed by the enzyme. In addition, in using indicators to test for both substrate and product(s), it is also important to use both **positive controls** and

negative controls. A **positive control** is a solution, which, before testing, we know DOES contain the molecule of interest. A **negative control** is a solution, which, before testing, we know DOES NOT contain the molecule of interest.

Activity IIIA: Effects of Time and Temperature on Starch Hydrolysis (breakdown) by Amylase

Amylase is an *enzyme* (produced by both **salivary glands** and the **pancreas**) that digests starch and other complex carbohydrates into simple sugars. Amylase breaks bonds between sugar molecules via **hydrolysis,** a reaction with water. In this activity, you will explore the roles that both time and temperature play in the activity of amylase with (starch) and its products (simple sugars).

To conduct a test for the presence of starch, you will add 4 drops of Lugol's iodine (IKI) to the tubes as instructed below. A positive test for starch will result in the development of a blue-black color, while a negative test for starch will result in an amber color.

To conduct a test for the presence of simple sugars, you will add a dropper full of Benedict's solution to the tubes as instructed below, and then place the tubes you are testing for sugars in a boiling water bath for 2 minutes. A positive test for sugars will result in a color change indicating the relative amount of sugar in the sample as follows: green (small amount of sugars), orange/yellow (moderate amount of sugars), or red (large amount of sugars). A negative test for sugars will result in the maintenance of the blue coloration of the Benedict's solution after boiling.

1. For this activity, you will need to label a total of 15 test tubes. Label one tube "BA", and the other 14 tubes A1-A14.
2. Prepare a boiling water bath in a 400 mL beaker on your hot plate.
3. To the tube labeled "BA", add 5 mL of the provided amylase solution.
4. Place the tube labeled "BA" in a boiling water bath in a 400 mL beaker for 15 minutes.
5. After boiling the tube labeled "BA", remove it from the boiling

water bath, and return it to your test tube rack to cool.

6. After the "BA" tube has cooled, add the appropriate amounts of the appropriate solutions listed in the table on the following page, and conduct the appropriate tests (for starch or sugars) at the time specified in the table for each tube, and record your results for each test (positive or negative) in Table 2 below.

Table 2. Data from exercise on the effects of time and temperature on amylase activity.

Tube #	Solutions to add	Test to Conduct	Time	Results (+ or -)
A1	2 mL distilled H_2O	Starch	Immediately	
A2	2 mL distilled H_2O	Sugar	Immediately	
A3	2 mL starch solution	Starch	Immediately	
A4	2 mL starch solution	Sugar	Immediately	
A5	2 mL glucose solution	Starch	Immediately	
A6	2 mL glucose solution	Sugar	Immediately	
A7	1 mL starch + 1 mL amylase	Starch	Immediately	
A8	1 mL starch + 1 mL amylase	Sugar	Immediately	
A9	1 mL starch + 1 mL amylase	Starch	After 30 min	
A10	1 mL starch + 1 mL amylase	Sugar	After 30 min	
A11	1 mL starch + 1 mL boiled amylase (BA)	Starch	Immediately	
A12	1 mL starch + 1 mL boiled amylase (BA)	Sugar	Immediately	
A13	1 mL starch + 1 mL boiled amylase (BA)	Starch	After 30 min	
A14	1 mL starch + 1 mL boiled amylase (BA)	Sugar	After 30 min	

Using your results from the experimental activity above, answer the questions on the worksheet at the end of this lab exercise.

BI 102 Lab Worksheet: Digestion Name _____ Section _____

ACTIVITY I: Organs of the Alimentary Canal

1. Why is the closure of the trachea by the epiglottis an important event that occurs during swallowing?

2. The duration between the sounds heard after my partner swallowed a mouthful of water was _____ seconds.

3. Given that the esophagus is approximately 25 cm in length, it can be estimated that the peristaltic wave of muscular contractions of the smooth muscle of the esophagus moves at a velocity of _____ cm/s.

4. Look at Figure 1, as well as the provided human torso model. After tracing the path of food through the digestive tract, describe how the ascending colon, transverse colon, and descending colon got their names.

5. Number the regions of the digestive system listed below in the order in which food moves through them, with "1" being the first region which food passes through:

_____ Anus
_____ Ascending colon
_____ Cecum
_____ Descending colon
_____ Duodenum
_____ Esophagus
_____ Ileum
_____Jejunum

_____ Oral cavity

_____ Pharynx

_____ Rectum

_____ Stomach

_____ Transverse colon

Activity IIA: Mammalian Tooth Types and Mammal Dental Formulas

6. Write the dental formula of an adult human below.

_____ = _____ = _____

7. Describe the changes in texture and flavor you experienced after chewing the saltine cracker, and attribute these changes to specific components found in saliva.

Activity IIC: Additional Accessory Digestive Organs and their Functions

8. Describe the appearance of the contents of the tube with oil and water only ("NB"), and the tube with oil, water, and bile salts ("B"). How do the differences in the appearances of the tubes' contents reflect the activity of bile?

Activity IIIA: Effects of Time and Temperature on Starch Hydrolysis by Amylase

9. What is the significance of tubes #A1 & #A5?

10. What is the significance of tubes #A2 & #A4?

11. What is the significance of tube #A3?

12. What is the significance of tube #A6?

13. Compare your results for your tests of tubes #A7-A10. What does this tell you about the role that time plays on enzyme activity?

14. Compare your results for your tests of tubes #A11-A14. What

does this tell you about the effect of extreme temperature (boiling) on the activity of amylase?

5. Chapter 5

LAB 5

Homeostasis

Prepared by Dr. Jeff Ray, Dept. of Biology, UNA

OBJECTIVES

After completing these laboratory activities, you should understand / be able to:

- Homeostasis as the central theme of physiology and the importance of the liver, kidneys, and lungs in this process.
- The liver's role in maintaining blood glucose homeostasis and why the serum from blood vessels in proximity to the liver will have differing amounts of glucose immediately after eating a meal versus after fasting for 6 hours.
- The kidney's role in maintaining homeostasis, explain the 4 basic steps of kidney function, and name substances that should/should *not* be in the urine.
- The results of the urinalysis and identify the abnormal values in the patient.
- The lungs' role in homeostasis and know what vital capacity represents.

Introduction

Homeostasis is the central theme of physiology and refers to the *dynamic equilibrium of the body's internal environment*. Parameters

like body temperature, blood glucose levels, heart rate, and other values are constantly fluctuating above and below a **set point** (varying within tolerable ranges). To maintain values near the set point (e.g. 98.6° F for body temperature), feedback systems/loops in the body use **receptors** to detect change, a **control center** to process the information, and an **effector** to carry out the change in a feedback loop (pathway of the loop is receptor control center effector). Receptors include chemoreceptors (that detect molecules like CO_2), a control center (normally the brain, especially the hypothalamus); and an effector (usually a muscle or gland). Homeostasis is primarily maintained by **negative feedback**. Negative feedback involves adjustments that *oppose* the initial change (i.e. cause change in the opposite direction). Positive feedback is less common and *often irreversible*; examples include digestion of proteins, blood clotting, and action potentials in neurons. All organs system contribute to homeostasis, but the three particularly important organs within the digestive, respiratory, and urinary systems are the **liver, lungs, and kidneys**, which exchange materials with the blood.

Today's lab, activities will illustrate the central roles played by the **liver** (maintain blood glucose levels), **kidneys** (filter wastes from blood), and **lungs** (exchange O_2/CO_2) in maintaining homeostasis.

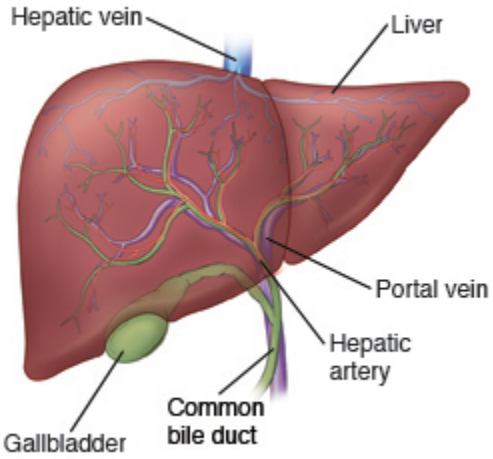
Liver

The liver is the largest organ in the abdominal cavity, averaging three pounds in the adult. It is located in the upper right quadrant, immediately beneath the diaphragm and on top of the stomach. The liver has a variety of roles (500+ known) in the body including: (1) store/release vitamins and minerals, (2) produce bile, (3) produce blood proteins, and (4) detoxify substances like alcohol.

One major role of the liver is to maintain **blood glucose homeostasis** and it is ideally positioned to serve this role, due to its proximity to the digestive tract. There are several major blood vessels associated with this activity. Carrying blood from the aorta to the digestive system is the **mesenteric artery**. In the digestive tract, nutrients are gathered and funneled into the **hepatic portal**

vein which leads to the liver; exiting from the liver is the **hepatic vein**.

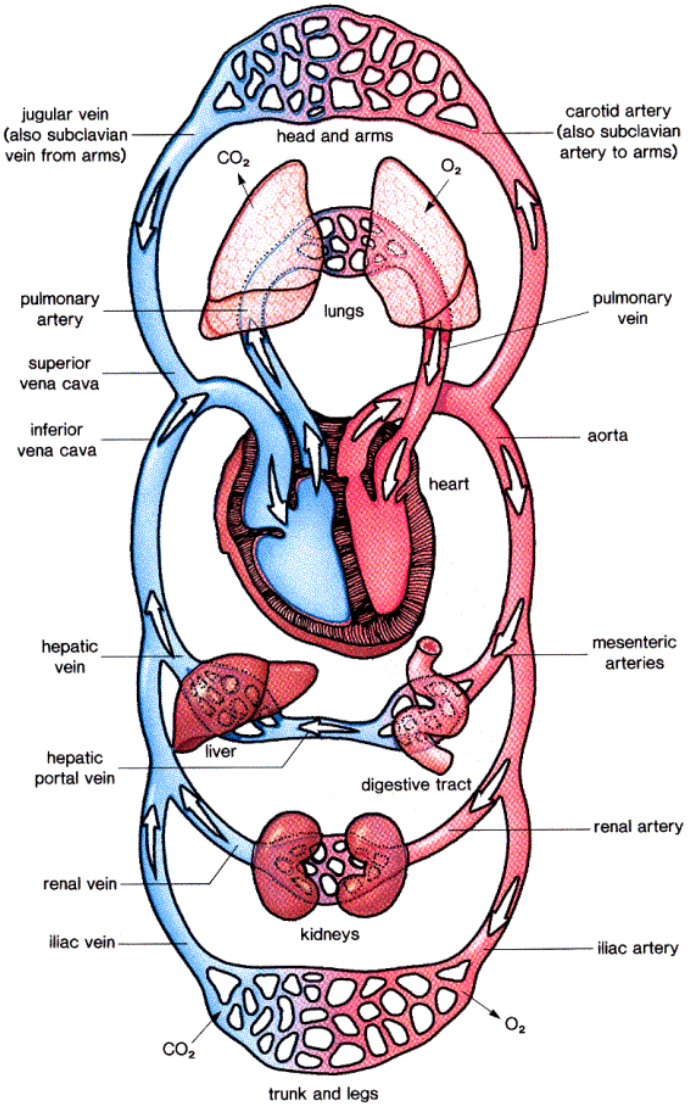
The pathway is (**mesenteric artery**→ digestive tract→ **hepatic portal vein**→ liver→ **hepatic vein**).



Blood glucose homeostasis is a negative feedback mechanism. Whether one has recently eaten or not, *cells require a constant supply of glucose* (sugar), which is the direct fuel to produce ATP. As a result, the liver must keep the glucose level in blood at around 0.1% by storing excess glucose (as **glycogen**) and releasing glucose as needed.

Another organ, the **pancreas**, actually monitors glucose levels and signals the liver with hormones. After eating, blood glucose levels rise. This increase is detected by the pancreas, which in response secretes **insulin**. Insulin travels through the bloodstream and binds to cells in the liver signaling the cells to *absorb glucose* and store it as glycogen. While fasting, blood glucose levels begin to drop, this reduction is detected by the pancreas, which secretes **glucagon**, a hormone that causes the liver to *release glucose*, thereby

maintaining blood glucose levels near 0.1%. (*insulin signal: store glucose; glucagon signal: release glucose*).



Basic Instructions: Blood Glucose Homeostasis

In the following exercise, you will conduct a simulation of blood glucose levels in three blood vessels (see figure).

A = Mesenteric artery (before digestive tract)

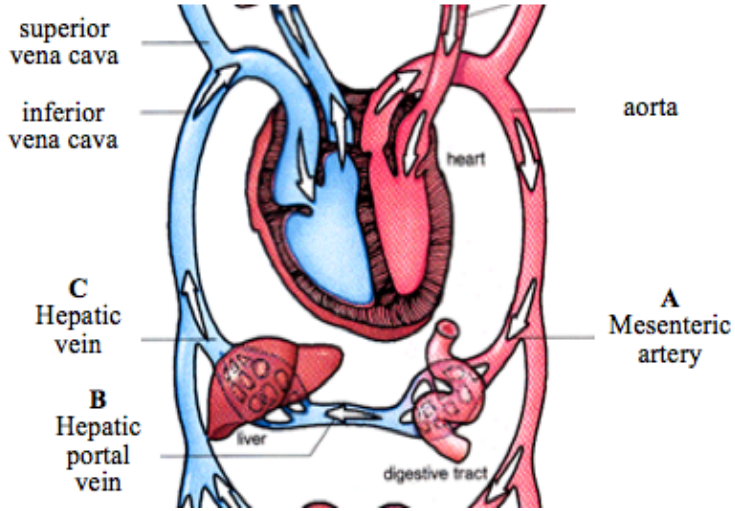
B = Hepatic portal vein (b/w digestive–liver)

C = Hepatic vein (after liver)

You will observe differences in blood glucose levels in each of these vessels under two simulated conditions:

1 = immediately after eating a meal

2 = after fasting for 6 hours



* Solutions labeled A1, B1 & C1 simulate blood glucose levels *immediately after eating.*

* Solutions labeled A2, B2 & C2 simulate blood glucose levels *after fasting for 6 hours.*

Follow the directions carefully. Check each step after completing it:

____ Prepare a boiling water bath: fill a 400 mL beaker about 2/3 full with tap water; place it on your hot plate. Do **NOT** let all of the H_2O evaporate or the beaker may break- add H_2O as needed.

____ Using a Sharpie, label 6 test tubes "A1", "B1", "C1", "A2", "B2", and "C2".

____ To each test tube add 2 pipets of the appropriate solution. Use the labeled pipets ONLY for their

intended solutions to avoid cross-contamination of solutions.

____ Add 3 pipets of Benedict's solution* to each of your test tubes.

(*Benedict's solution tests for the presence of glucose. *After boiling*, Benedict's solution will **change from blue if glucose is present** (blue/cloudy= no/low glucose, yellow/orange= moderate glucose, red= high glucose).

____ After your water bath is boiling, add tubes A1, B1, and C1 to the boiling bath AT THE SAME

TIME,

and WATCH CLOSELY for the *order of change*.

____ Record the order in which the solutions in the tubes changed color in the table below.

A FASTER COLOR CHANGE INDICATES A HIGHER CONCENTRATION OF GLUCOSE.

____ If no color change is observed in the last tube after 2 minutes of boiling, you may stop the procedure.

Blood Glucose Levels After Eating (Time 1)

Test tubes (in order of change) $	**Blood vessel associated with t**
1st	
2nd	
Last	

$

answer will be A1, B1 or C1 # answer will be mesenteric artery, hepatic portal vein or hepatic vein

* Which blood vessel contains the most glucose after eating a meal? _____

*Why did the hepatic vein contain less glucose than the hepatic portal vein after just eating a meal? _____
_____

____ Remove tubes A1, B1, and C1 from the boiling water bath.

____ Add tubes A2, B2, and C2 to the boiling bath AT THE SAME TIME, and WATCH CLOSELY.

____ Record the order in which the solutions in the tubes change color in the table below.

____ If no color change is observed in the last tube after 3 minutes of boiling, you may stop the procedure.

____ *Clean your station: Turn off your hot plate. Dump liquids from tubes down the drain with water running, place used test tubes in tub. Return all materials to their starting location. Wipe off your table.

Blood Glucose Levels After Fasting for 6 hours (Time 2)

Test tubes (in order of change) $	**Blood vessel associated with t**
1st	
2nd	
Last	

$

answer will be A2, B2 or C2 # answer will be mesenteric artery, hepatic portal vein or hepatic vein

*Which blood vessel contains the most glucose after fasting for ~6 hours? _____

*Why did the hepatic vein contain more glucose than the hepatic portal vein after fasting?

_____
_____

So, the role of the liver in maintaining blood glucose homeostasis is to <u>store extra glucose (as glycogen) after eating and release glucose during fasting</u> (glucose fuels our cell's activities 24/7)

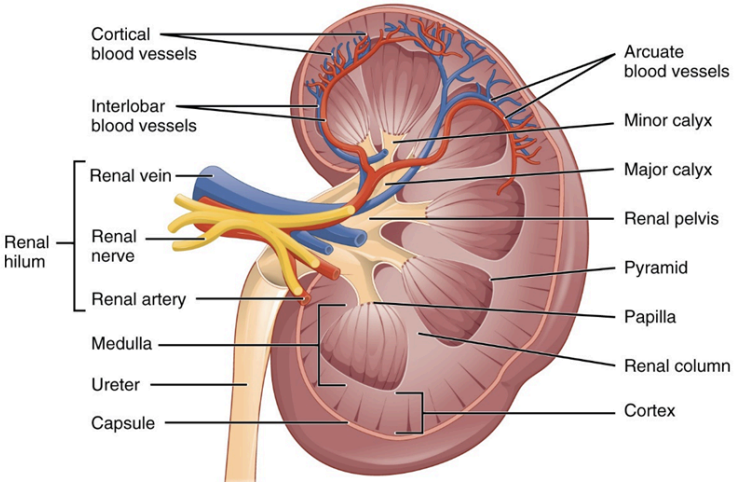
Kidneys

Kidneys are fist-sized organs located along the dorsal abdominal wall, behind the intestines. Their basic function is to *filter metabolic wastes and toxins* from the blood to produce urine. Specifically, kidneys excrete nitrogen by-products and regulate blood volume, blood pressure, and pH. Large substance like red blood cells, white blood cells, and proteins do not normally leave blood vessels and get filtered by the kidneys, these *should not be found in the urine*, but normally stay in the blood. Small molecules move into the kidneys filtering units called **nephrons**, and either must be excreted by the kidneys in the urine or be recovered for use in the body. **Urea** is a small molecule and waste product of protein metabolism that must be excreted. Other substances like *glucose* move into the kidneys, but are mostly recovered for use by the body, although excess (abnormal) amounts will be disposed of in urine. Thus, whatever is/is not in urine gives insight into kidney function. Learning the structure and function of the nephron will help in understanding urinalysis results.

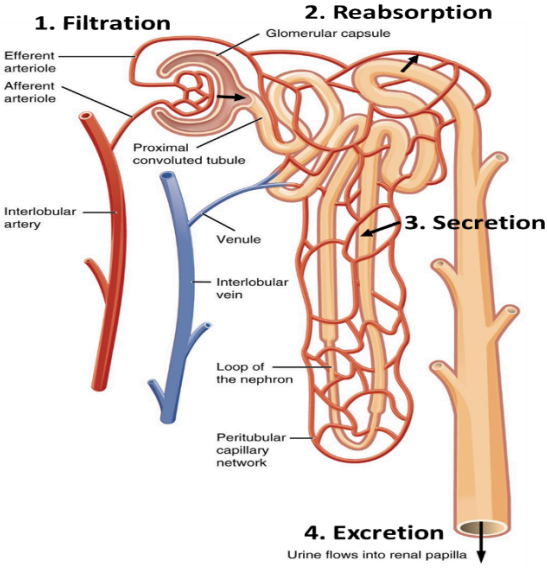
Kidneys collectively filter 180 *liters* of blood plasma daily to produce about 1.5 liters of urine/day.

Although complex, the basic steps of nephron functioning are 1) **filtration**, 2) **reabsorption**, 3) **secretion, and** 4) **excretion**. Filtration is the movement of water and solutes from plasma into the nephron and is primarily driven by blood pressure pushing into the first part of the nephron (*glomerulus*) that is very permeable. Once in the nephron, this liquid becomes the **filtrate**. The filtrate continues through the *tubules* and is reabsorbed. **Reabsorption** is the movement of water and solutes back into the network of capillaries surrounding the tubule. Substances that are waste products or in

excess amounts move back into the tubules via secretion. **Secretion** is essential to regulate blood volume, pH and electrolyte levels. **Excretion** eliminates substances like *urea* in the filtrate, which is now "urine".



Kidney & blood vessels; ureter empties to the bladder.



Nephron, the

functional unit of the kidney showing the 4 steps of cleansing the blood.

* What is the kidneys' job in maintaining homeostasis?

_____

Urinalysis

A urinalysis is a non-invasive procedure that gives insight into the basic health and functioning of kidneys and other organs, including the liver. You will conduct the same urinalysis that is regularly performed in a doctor's office using *artificial* urine. This test is different from those given to job applicants, which screens for illegal drugs in the body. A basic urinalysis uses urine test strips to measure 10-12 values that either: **(1)** should be within a certain range (specific gravity, pH) or **(2)** detects substances that should not be in the urine (e.g. leukocytes- white blood cells), because they normally remain in the blood since they are too large and do not pass into the nephrons of the kidneys. Chemstrip 10's will be used to look at 10 different parameters of the urine. The color and odor of urine also give insight into body conditions (like dehydration) as does the microscopic examination of substances in urine. Abnormal values may be temporary and do not necessarily indicate any long-term problems, but a doctor might request additional tests as a follow-up to confirm any values outside of the normal range.

Patient #1 reports that they are often thirsty, but also urinate frequently. Patient #1 eats a normal diet of approximately 2,000 calories, but has experienced weight loss over the past 6 months. The individual also feels tired and run down. What condition is likely affecting patient #1? A urinalysis may help diagnose their disease. *Follow the directions below and record your results.*

Basic Instructions: Urinalysis

____ Obtain a Chemstrip 10 urinalysis test strip. Lay this strip on top of two paper towels on your lab table.

____ Using the pipet, place 1 drop of patient #1's simulated urine on each colored square on the test strip, do not let urine from separate squares run together. Holding the test strip by the handle,

turn the strip on its edge and gently tap any excess urine onto the paper towel.

____ Within 1 minute, compare the results on the test strips to the scale on the side of the test strip vial (read handle side up). You may also try the automated urinalysis reader in the back of the room (these are used in Dr.'s offices). Record your results below.

____ **Do your own urinalysis – see professor for additional instructions**

____ **Clean up your station**: throw away used paper towels and test strips. If you did your own urinalysis, put the urine cup where your instructor tells you, do not leave it at your station.

URINALYSIS TESTING – circle any *abnormal* values

Patient Values (normal)	**Your Values (normal)**
1. _____ Specific gravity (1.005-1.035)	1. _____ Specific gravity (1.005-1.035)
2. _____ pH (=acidity; varies)	2. _____ pH (=acidity;varies)
3. _____ Leukocytes (=WBC's; negative)	3. _____ Leukocytes (=WBC's; negative)
4. _____ Nitrite (negative)	4. _____ Nitrite (negative)
5. _____ Protein (negative)	5. _____ Protein (negative)
6. _____ Glucose (<50)	6. _____ Glucose (<50)
7. _____ Ketones (negative)	7. _____ Ketones (negative)
8. _____ Urobilinogen (<1)	8. _____ Urobilinogen (<1)
9. _____ Bilirubin (negative)	9. _____ Bilirubin (negative)
10. _____ Blood (negative)	10. _____ Blood (negative)
Diagnosis: _____	Diagnosis: _____

* The 3 values for the patient that were *abnormal* were:

a. _____* Low (=acidic), Moderate (neutral=7.0) or High (basic, >7)

b. _____Low, Moderate or High

c. _____ Low, Moderate or High

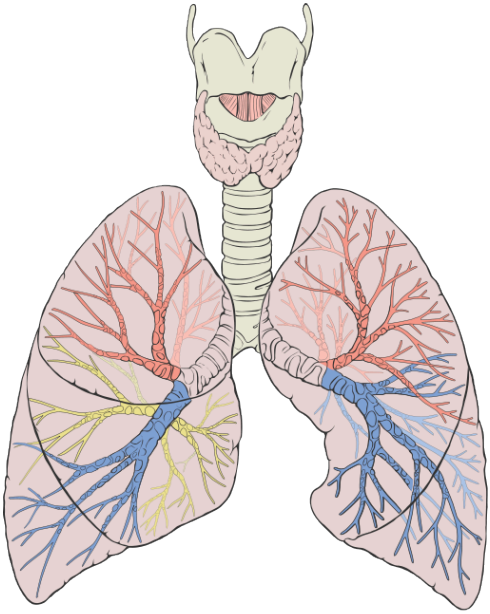
*What is the diagnosis of your patient (what condition)?

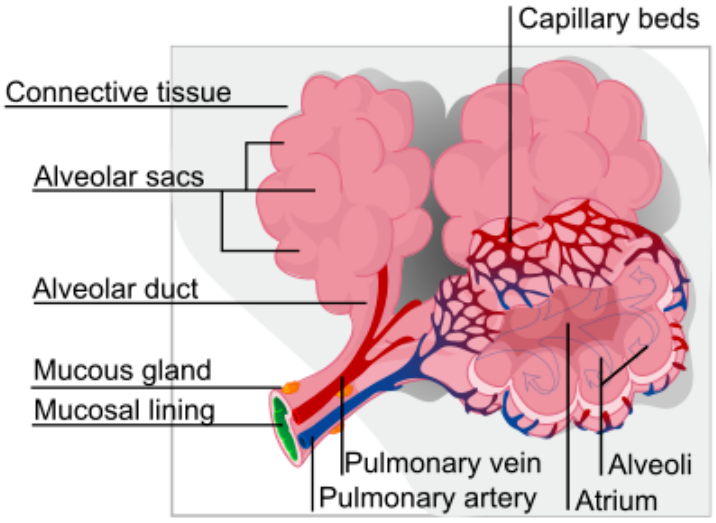
_____

Parameter	Normal Range	Abnormal	Possible Conditions
Specific gravity	1.002 – 1.035	> 1.035	Dehydration, diabetes, kidney damage
pH	4.5 – 8		Low pH may indicate high protein diet; high pH may indicate diet rich in fruits and vegetables
Leukocytes	Negative	Positive	Urinary tract infection
Nitrites	Negative	Positive	Urinary tract infection
Protein	< 10 mg/dL	> 10 mg/dL	Kidney disease
Glucose	Negative	Positive	Trace amounts (< 50 mg/dL) possible after a meal high in carbs; otherwise may indicate diabetes
Ketones	Negative	Positive	Low carb diet, starvation, alcoholism, diabetes
Urobilinogen	Negative	Positive	Trace amounts (< 1 mg/dL) are normal; otherwise may indicate liver disease
Bilirubin	Negative	Positive	Liver disease or bile duct blockage
Blood/Hemoglobin	Negative	Positive	Kidney disease, damage to urinary tract, hemolytic disease

Lungs

Lungs are located in the pleural cavities (overall within the thoracic cavity) and are lateral to the heart. The right lung has three lobes and is larger than the left, which has two lobes; the lungs collectively weigh about 3 pounds. Lungs exchange gases with the blood (O_2 in / CO_2 out) via simple diffusion- no cellular energy is required. The lungs contain approximately 1,500 miles of airways and 300 to 500 million **alveoli**, which appear as grape clusters. Gas exchange occurs at **alveoli**, which contain single-layered flat cells (simple squamous epithelium) that maximize surface area exchange.





Respiration

The physical process of breathing, respiration, includes

inhalation and exhalation. The active part of breathing is inhalation and involves a dome-shaped breathing muscle, the diaphragm.

Different measures of lung function are made based upon volumes of air (see chart below), but the most commonly reported measure is **vital capacity** (see figure next page)**,** which is the *maximum amount of air a person can expel from the lungs after a maximum inhalation.* Vital capacity is measured with a **spirometer** (in liters or milliliters) and may aid in a diagnosis of underlying lung disease if vital capacity is reduced.

Basic Instructions: Lung Volume

Clean the spirometer with an alcohol swab before & after use. Put a clean, disposable mouthpiece on the spirometer. Set spirometer dial to zero by turning the silver ring on top. While standing, take a full breath OUT. Breathe in fully, then place your mouth on the disposable mouthpiece & blow all air from your lungs into spirometer. Do **NOT** breathe IN with spirometer to your lips. You may also try the lung volume bags on the front table.

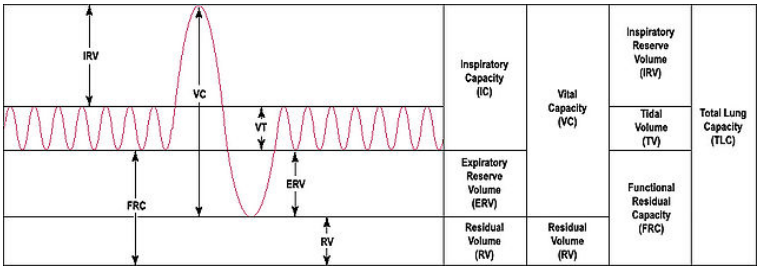
Record your **vital capacity** in Liters three separate times, then calculate the average of the three values.

1. _____ Liters 2. _____ Liters
3. _____ Liters

Average vital capacity _____ Liters

*Average volumes in adults are 2-4 liters: females & 3-5 liters: males.

_____
_____
_____



Lung Measures including Vital Capacity

Basic Instructions: Body Composition Monitor

Enter your information into the handheld monitor following the onscreen prompts. Record your information in the blanks below. Determine your BMI based on the chart that is with the body composition monitor with the understanding that BMI does **NOT** fully account for differences in body types in determining obesity.

1. _____ Height (inches) 2. _____ Weight (pounds) 3. _____ Age (years)

4. _____ Male or Female 5. _____ Normal or Athletic

A. _____ **Body Mass Index (BMI)** B. _____ **Body Fat Percentage (%)**

Concept Questions – *consult your textbook if needed*

How do the kidneys respond when the blood pressure and volume are too high? Too low?

_____
_____
_____

_____
_____
_____

List the steps in urine formation and define each step

1._____ 2. _____
_____

3. _____ 4. _____

With regard to urine formation, name a substance found in both the filtrate and the urine.

_____
_____
_____

With regard to urine formation, name a substance found in the filtrate and not in the urine.

_____

_____
_____

Image Credits:

Liver by http://www.stanfordchildrens.org/en/topic/default?id=how-the-liver-works-90-P02006

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Kidneys and Nephron

https://cnx.org/contents/FPtK1zmh@12.8:7l9EIHui@7/Gross-Anatomy-of-the-Kidney

Alveoli By LadyofHats – self-made (extracted from Image: Respiratory system complete.svg) (duplicate of Image:Respiratory system complete en.svg), Public Domain, https://commons.wikimedia.org/w/index.php?curid=3222341

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BI 102 Lab Worksheet: Homeostasis Name _____ Section _____

1. What is the liver's job in maintaining blood glucose homeostasis?

2. Sketch the locations of the mesenteric artery, hepatic portal vein and hepatic vein in relation to the digestive system and liver.

3. What is the kidneys' job in maintaining homeostasis?

4-6. The 3 values for Patient #1 that were *abnormal* were:

a. _____* Low (=acidic), Moderate (neutral=7.0) or High (basic, >7)

b. _____Low, Moderate or High

c. _____ Low, Moderate or High

*by itself, not a cause for concern, may be abnormal due to mild dehydration or overhydration

7. What is the diagnosis of your Patient #1 (what condition)?

8. Which value was High due to the breakdown (metabolism) of fats?

a. glucose b. ketones c. bilirubin

9. Name 2 of the substances tested for which you would NOT expect to find in a normal urinalysis.

10.What is the lungs' job in maintaining homeostasis?

11. Avg. volumes in adults are ___-___ liters: females & ___-___ liters: males. How did your values compare?

6. Chapter 6

LAB 6

Introduction to the Nervous System

Prepared by Jason R. Jones, University of North Alabama

OBJECTIVES

After completing these laboratory activities, you should understand / be able to:

- Define the terms *central nervous system*, *peripheral nervous system*, *neuron*, *neuroglia*, *synapse*, *neurotransmitter*, *nerve*, *effector*, *gray matter*, *white matter*, *spinal reflex*.
- Identify and label the following parts of a neuron, as well as know their functions: *cell body*, *dendrite*, *axon*, *axon terminal*, *Schwann cell*, *myelin sheath*.
- Explain the different functions of the following: *sensory neuron*, *interneuron*, *motor neuron*.
- List the parts found in each of these three major regions of the brain, and their functions: *forebrain*, *midbrain*, *hindbrain*
- Locate and identify the following structures in the brain, as well as know their functions:
- *cerebrum*, *ventricles*, *thalamus*, *hypothalamus*, *pituitary gland*, *cerebellum*, *pons*, *medulla oblongata*
- The following lobes of the *cerebrum*, and be able to list their major functional roles: *frontal lobe*, *parietal lobe*, *occipital lobe*, *temporal lobe*,

- The basics of how *spinal reflexes* work, and be able to give an example of a spinal reflex observed in lab.

INTRODUCTION

The vertebrate nervous system is comprised of the brain, spinal cord, and the body's network of nerves. However, the parts of the nervous system are often grouped into two main divisions. The **central nervous system** (CNS) consists of the **brain** and **spinal cord**, while the cranial nerves, spinal nerves make up the other division, the **peripheral nervous system** (PNS). Although most organs are made up of almost all four major tissue types (epithelial, connective, muscle, and nervous), the functional parts of the organs of the nervous system consist of nervous tissue (though there are some associated connective tissues). The primary function of the nervous system is the rapid transmission of signals throughout the body, allowing quick detection of and responses to changes in an organism's internal and/or external environment.

In these exercises, you will familiarize yourself with the anatomy of the nervous system, starting at the cellular and tissue level. You will continue this exploration into higher levels of organization, and examine the anatomy of nerves, the brain, and spinal cord. You will also investigate the phenomenon of spinal reflexes, and learn how spinal reflexes result in physical responses without initial involvement of or processing by the brain. Finally, you will measure your average reaction time, and may be asked to compare it to others in your lab section. Your instructor may wish to compare averages of male & female reaction times, and/or turn the reaction time activity into a contest of sorts.

ACTIVITY I: Cells of Nervous Tissue

Nervous tissue consists of two main types of cells: **neurons** and **neuroglia** (aka **glia** or **glial cells**). With regards to the function of transmission of signals throughout the body, that role is performed by the neurons, which are specialized cells that transmit electrical and chemical signals. There are three main regions of a typical neuron. The part of the neuron that contains the nucleus is called

the **cell body**. Extending from the cell body may be one or several projections. Neurons can be classified based on the number of projections extending from the cell body. Unipolar neurons have a single projection (which divides into two branches) extending from the cell body. Bipolar neurons have two projections: a branch-like **dendron**, which carries signals to the cell body, and a long **axon**, which carries signals away from the cell body. Most neurons, however, are multipolar neurons, with multiple branch-like **dendrites** that carry messages to the cell body, and a single **axon** that carries signals away from the cell body. See Figure 1 for examples of unipolar, bipolar, and multipolar neurons. Also see Figure 2 for a more detailed look at the anatomy of a multipolar neuron.

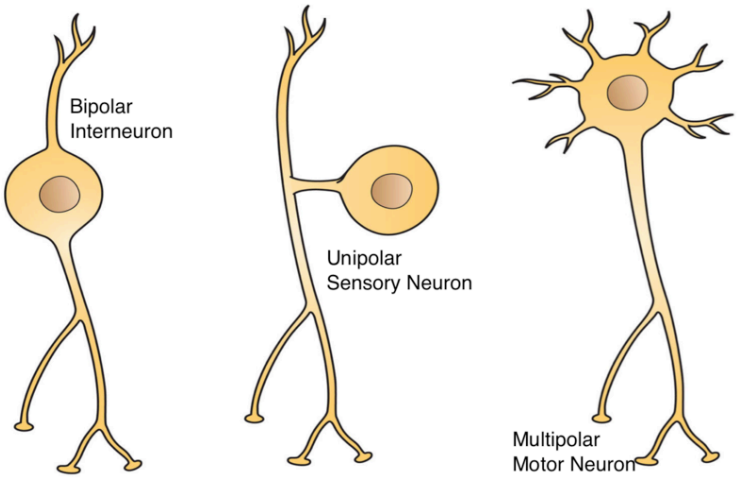


Figure 1. Examples of bipolar, unipolar, and multipolar neurons. Source: http://open.umich.edu/education/med/resources/second-look-series/materials

Notice in Figure 1, the axons of each type of neuron have button-like expanded regions at their tips. These regions are referred to as the **axon terminals** or **terminal buttons**. These terminals form

junctions, called **synapses**, with other cells. Neurons can be classified based on the basis of the direction in which they are transmitting signals. **Sensory neurons** are neurons that detect stimuli (such as pain, heat, light, chemicals, etc.), and convert this information into electrical signals that are carried towards the central nervous system for processing. **Motor neurons** are neurons that carry processed signals in a direction from the central nervous system to an **effector** (such as a muscle or gland, which acts in response to this processed signal). However, there are other types of neurons, called **interneurons** or **relay neurons**, which carry information between sensory and motor neurons. See Figure 3 for examples of a sensory neuron, an interneuron, and a motor neuron. When an electrical signal (called an **action potential**) reaches the end of an axon, this causes the release of **neurotransmitters**, which are molecules that affect the activity of the other cells that meet with the neuron at the synapse. See the expanded view of a synapse in Figure 2, illustrating the release of neurotransmitter molecules from an axon terminal, and binding of the neurotransmitter to receptor proteins on the surface of a cell after the synapse. Most neurons form synapses with other neurons, and the neurotransmitters released from the **pre-synaptic neuron** (the neuron before the synapse) at those synapses can either make the **post-synaptic neuron** more likely to fire an action potential (excitatory) or less likely to fire an action potential (inhibitory). However, synapses also occur between neurons and muscle fibers, neurons and glands, and neurons and blood vessels. Neurotransmitters released from synapses between a neuron and a muscle fiber result in contraction of the muscle fiber involved. Neurotransmitters released from synapses between a neuron and a gland result in secretion of substances from the involved gland. Some neurotransmitters, however, are secreted directly from axon terminals into the bloodstream. See Figure 4 for some examples of several types of synapses between neurons and other cells.

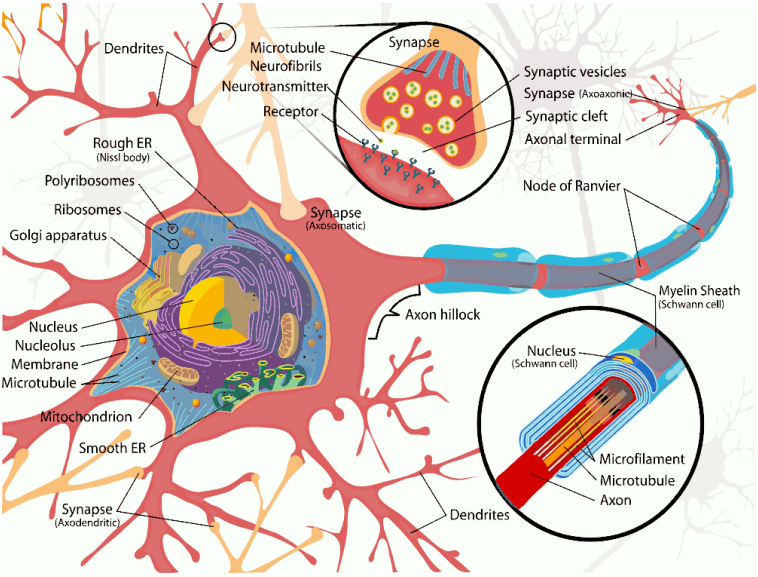


Figure 2. Anatomy of a typical multipolar neuron.

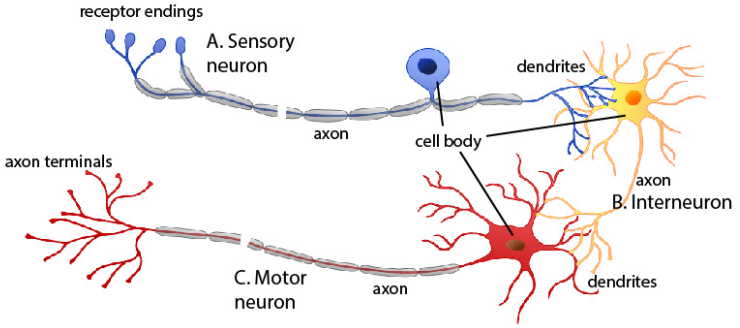


Figure 3. Illustration of a sensory neuron (A), an interneuron (B), and a motor neuron (C). Source: OpenStax at https://cnx.org/contents/pMqJxKsZ@6/Nervous-System

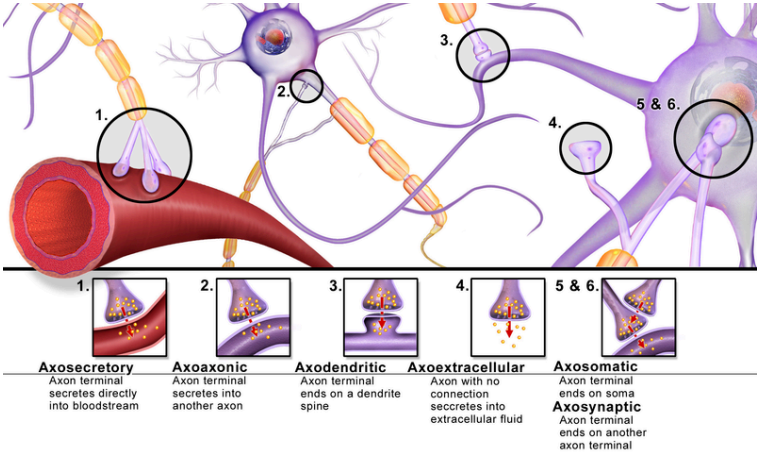


***Figure* 4.** *Examples of several types of synapses. Source: Blausen.com staff (2014). "Medical gallery of Blausen Medical 2014". WikiJournal of Medicine* **1** *(2). DOI:10.15347/wjm/2014.010. ISSN 2002-4436*

Though neurons are the cells that play the important role of signal transmission, several other important functions are performed by **neuroglia**, also known as **glia** or **glial cells**. Though they are not involved in signal transmission like neurons, glia have several functions that provide support to neurons in various ways. One function of glia is to act as the "glue" of nervous tissue, surrounding neurons and holding them into place. Glia also provide oxygen and nutrients to neurons, helping to keep them alive. Some glial cells also insulate neurons from other neurons by coating them with their cell membranes. Finally, some glial cells are capable of phagocytosis ("cell eating"), and can remove pathogens and dead neurons from nervous tissue. See Figure 5 for examples of several types of glial cells found in both the central and peripheral nervous system.

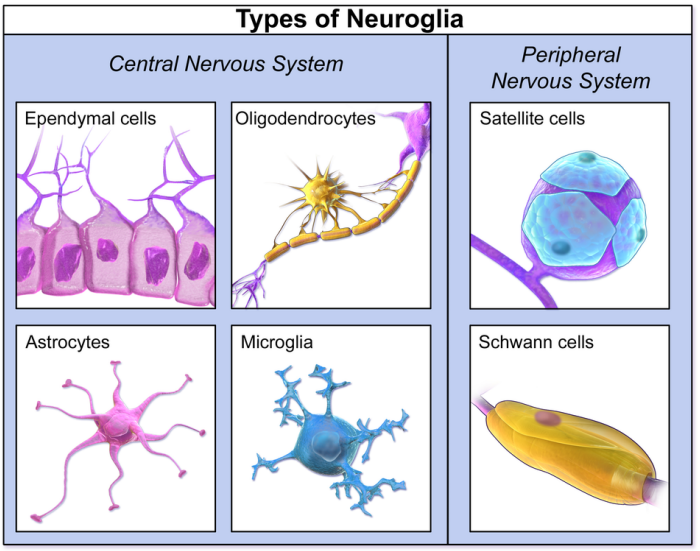


Figure 5. Types of neuroglia. Source: Blausen.com staff (2014). "Medical gallery of Blausen Medical 2014". WikiJournal of Medicine **1** (2). DOI:10.15347/wjm/2014.010. ISSN 2002-443

6.

You will not have to learn all of the different types of glial cells, but there is one type found in the peripheral nervous system (nerves outside of the brain and spinal cord that carry signals from the central nervous system to muscles, glands, and organs) that you should know. These types of cells are called **Schwann cells**, which can be seen in the bottom right of Figure 5, but also wrapped around the axon of the multipolar neuron shown in Figure 2. Schwann cells cover the surface of neurons in the PNS with a fatty substance known as **myelin**, providing a coating to the axon known as the **myelin sheath**. The function of the myelin sheath is to provide insulation to the axon of PNS neurons. Think about the myelin sheath as being analogous to a rubber coating on electrical wires.

However, the myelin sheath does not cover the entire axon. There are gaps between the Schwann cells surrounding the axon where there is no myelin. These gaps are known as the **nodes of Ranvier**. These gaps in the insulating myelin facilitate more efficient transmission of electrical signals (action potentials) along the axon. Since these regions are not insulated, that allows the electrical signals passed along the axon to jump from node (non-insulated region) to node, instead of having to travel along the length of the axon continuously. This allows signals to be carried along PNS neurons much more quickly.

Examine the neuron model, and answer the questions on the worksheet at the end of this lab exercise.

Next, ***Place the microscope slide of nervous tissue on the stage of a compound light microscope***

Starting with the scanning power (4x) objective, get the tissue on the slide into as sharp focus as possible using the coarse focus knob. After getting the tissue in focus on the scanning power objective, move up to the low power (10x) objective, and adjust the focus (if necessary) using the fine focus knob. Finally, move up to the high-power (40x) objective (providing a total magnification factor of 400x), and re-adjust fine focus as needed. You will likely see plenty of glia on the slide, but try to locate a neuron in this tissue. This may require scanning around the slide using the stage adjustment knobs. You may also need to make adjustments to the light intensity using the rheostat on the microscope, as well as to the condenser to best visualize the cells in this tissue. Once you have located a clearly visible neuron, go to the worksheet at the end of this lab exercise, and answer the appropriate questions regarding the micrographic view of this nervous tissue.

ACTIVITY II: Anatomy of the Brain

The brain is an organ seen in all vertebrates, and many invertebrates. Vertebrate brains vary among different vertebrate groups, but overall share the same basic structures. The brain is the enlarged anterior portion of the spinal cord, and with the spinal

cord, as the central nervous system, acts as the main control center for the rest of the body.

The brain can be divided into three main regions: the **forebrain**, **midbrain**, and **hindbrain**, each of which consist of several other subregions/divisions. Using Figures 6-12 on pages 6-9 and Table 1 on the following page, you should familiarize yourself with several regions of the brain and their functions, and be able to identify them on the provided brain models.

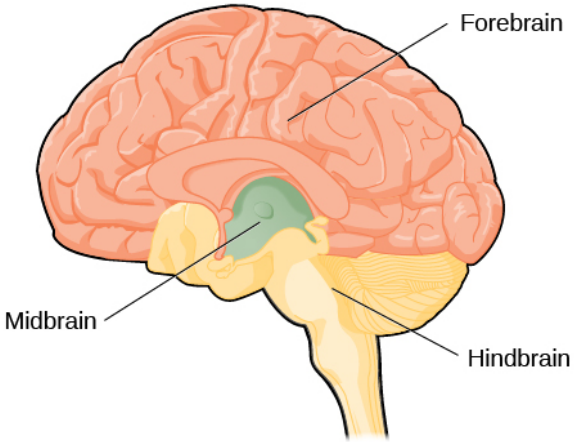


Figure 6. Major divisions of the brain. Source: OpenStax at https://archive.cnx.org/contents/fc8a38cc-fd1c-44cc-b91d-726fcfa62165@7/the-brain-and-spinal-cord

Table 1. Parts of the brain and their functions.

Brain Part	Major Functions
Forebrain **Cerebrum** **Frontal lobe** **Central sulcus** **Parietal lobe** **Temporal lobe** **Olfactory bulb** **Occipital lobe** **Corpus callosum** **Thalamus** **Hypothalamus**	Higher order thinking and sensory processing Thought, problem solving, voluntary muscle control speech production Separates frontal lobe from parietal lobe Processing sensory input, sensory discrimination, body orientation Sound reception, expressed behavior, speech comprehension, memory Perception of smell Visual reception and interpretation Connects L/R hemispheres; allows communication between L/R brain Relays sensory info to cerebrum; regulation of sleep/consciousness Homeostasis (blood pressure, body temp, etc); pain/pleasure centers
Midbrain	Responses to visual stimuli; motor coordination; eye movement
Hindbrain **Cerebellum** **Pons** **Medulla oblongata**	Essential body functions Equilibrium/balance & motor coordination Relays messages between cerebrum & cerebellum Control of heart, blood pressure, breathing; coughing, vomiting, sneezing, and swallowing reflexes

Other Brain Parts to Know **Ventricles** **Pituitary gland**	Filled with cerebrospinal fluid (acts as a shock absorber for CNS; provides nutrients to brain & spinal cord, and removes wastes from CNS) "Master gland" that produces hormones that control other glands of the endocrine system (thyroid, adrenal glands, gonads, etc.)

Note that the **brain stem** is not mentioned in the table above. However, the brain stem, which controls the most basic body functions, consists of three main regions mentioned in Table 1: the **midbrain**, **pons**, and **medulla oblongata**.

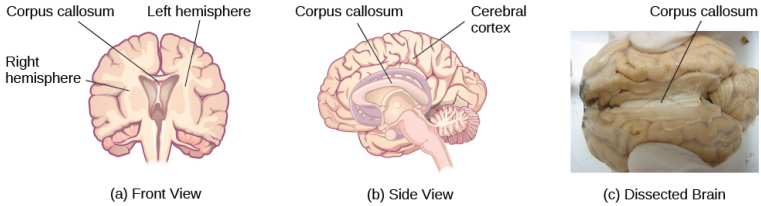


Figure 7. Illustration of the left and right cerebral hemispheres, and the corpus callosum, which connects them. Source: OpenStax at https://archive.cnx.org/contents/fc8a38cc-fd1c-44cc-b91d-726fcfa62165@7/the-brain-and-spinal-cord

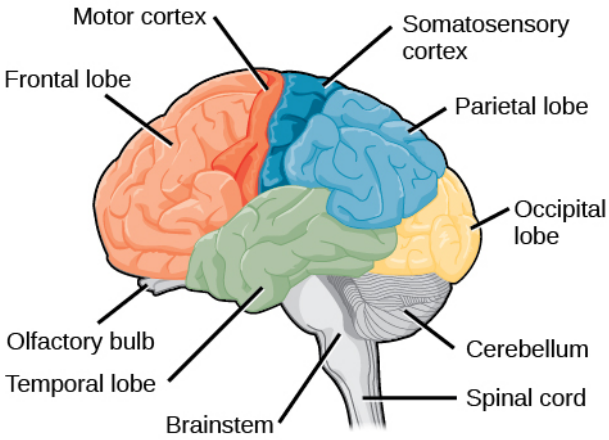


Figure 8. Lobes and cortices of the cerebrum. Source: OpenStax at https://archive.cnx.org/contents/2337db2c-8336-4955-bfd8-f57d3b9deaa4@2/human-biology-chapter-17-4-the-central-and-peripheral-nervous-systems

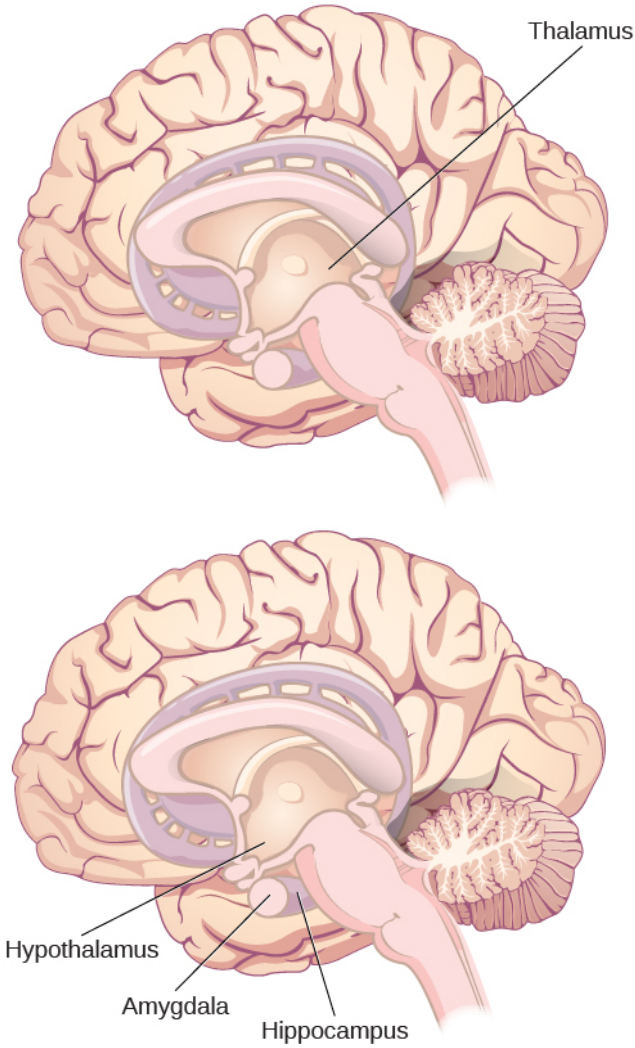


Figure 9. Other regions of the forebrain. Source: OpenStax at https://archive.cnx.org/contents/fc8a38cc-fd1c-44cc-b91d-726fcfa62165@7/the-brain-and-spinal-cord

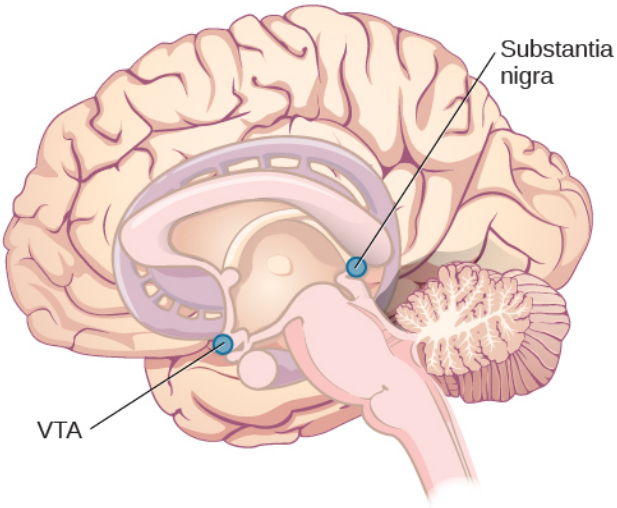


Figure 10. Structures of the midbrain. Source: OpenStax at https://archive.cnx.org/contents/fc8a38cc-fd1c-44cc-b91d-726fcfa62165@7/the-brain-and-spinal-cord

You will not need to know the structures illustrated in Figure 10. However, you should be aware of the basic location and structure of the midbrain. The midbrain is located deep within the brain, between the forebrain and hindbrain. The midbrain is primarily involved in movement, including eye movement, the processing of visual and auditory information, sleeping/waking cycles, and alertness/arousal. Additionally, the two regions illustrated in Figure 10, the ventral tegmental area (VTA) and the substantia nigra, contain cells that produce the neurotransmitter **dopamine**, which is involved in regulation of mood, including the perception of "rewarding" stimuli. Dopamine is also implicated in addiction, as release of dopamine occurs upon engaging in behavior in search of stimuli perceived as rewarding. Additionally, degeneration of these regions of the brain is also associated with progression of Parkinson's disease.

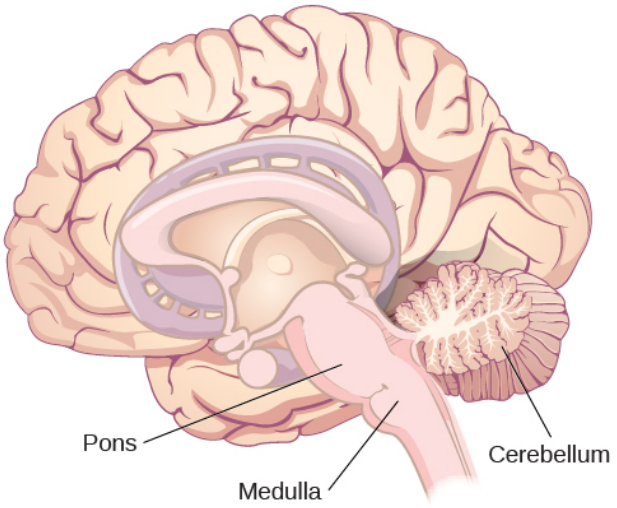


Figure 11. Structures of the hindbrain. Source: OpenStax at https://archive.cnx.org/contents/fc8a38cc-fd1c-44cc-b91d-726fcfa62165@7/the-brain-and-spinal-cord

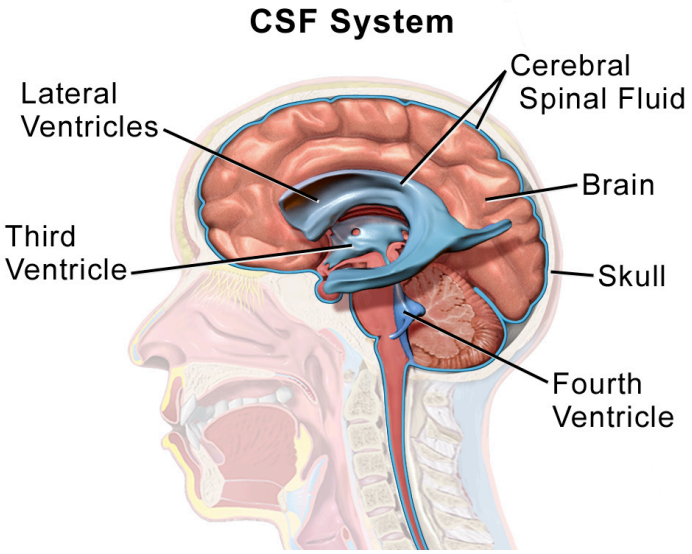


Figure 12. Illustration of the ventricles of the brain (hollow chambers containing cerebrospinal fluid, which acts as a shock absorber for the CNS, and provides nutrients to and removes wastes from the brain and spinal cord). Source: Blausen.com staff (2014). "Medical gallery of Blausen Medical 2014". WikiJournal of Medicine **1** (2). DOI:10.15347/wjm/2014.010. ISSN 2002-4436.

Using the provided brain model, Figures 6-12, and Table 1, answer the questions on the worksheet at the end of this lab exercise.

ACTIVITY III: Anatomy of the Spinal Cord

In addition to the brain, the spinal cord is also part of the central nervous system. It is continuous with the medulla oblongata of the brain stem, and exits the base of the skull through a large hole called the **foramen magnum**. The spinal cord then passes through central holes in the vertebrae called the vertebral foramina, and extends down to the level of the first or second lumbar vertebra. Though not shown in Figure 13 below, the spinal cord is hollow, with a central canal filled with cerebrospinal fluid (CSF).

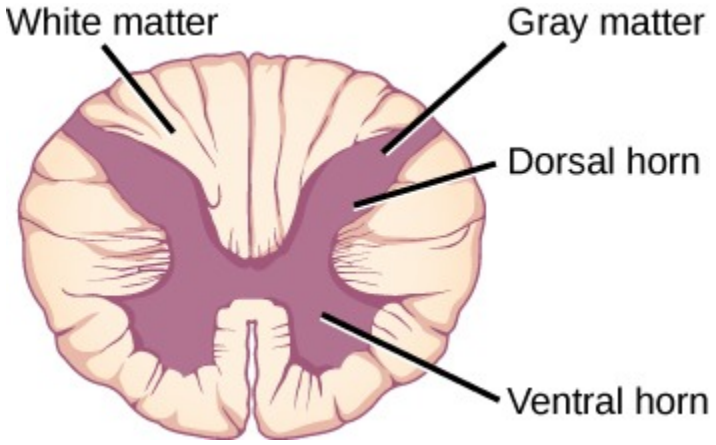


Figure 13. Cross section through the spinal cord showing gray matter (containing cell bodies and interneurons) and white matter

(containing axons). Source: OpenStax at http://tea.cnx.org/contents/Rf2UxDVq@4/The-Central-Nervous-System

Using Figure 13 and the information in this exercise, answer the questions on the worksheet.

ACTIVITY IV: Anatomy of Nerves

The peripheral nervous system (PNS) consists of the cranial nerves (of which there are twelve pairs; illustrated on the provided brain models with Roman numerals), and the spinal nerves, which are also paired. Look at the provided model of the vertebral column, and count the number of roots of the spinal nerves (on the model, yellow structures sticking out laterally between vertebrae). Note that these models do not show the last sacral nerve (S5) or the coccygeal nerve (C0). Answer the question on spinal nerves on the worksheet. Remember to add the two pairs of nerves not shown on the model!

Nerves consist of bundles of axons of neurons grouped together in bundles called **fascicles**, each of which is surrounded by a layer of tissue called the perineurium. The fascicles are also held together in larger clusters of bundles by a layer of dense connective tissue (the epineurium) to make up the entire nerve. Look at Figure 14. Note that nerves are also vascularized (supplied by blood vessels), which serves to deliver oxygen and nutrients to neurons in the nerve, and to remove carbon dioxide and other wastes from those cells. After examining Figure 14 closely, look at the (somewhat crude, but rather effective/illustrative model of nerve anatomy on the cart at the front of the room. Then answer the questions on the worksheet at the end of this lab exercise.

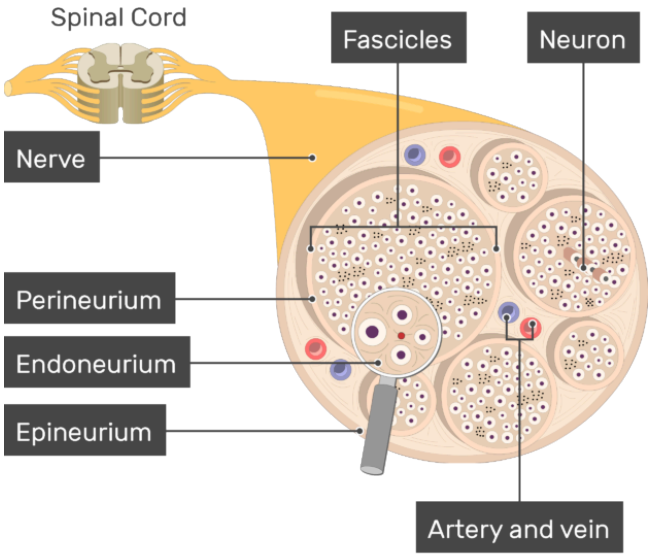


Figure 14. Illustration of the basic anatomy of a nerve. Source: https://www.getbodysmart.com/nerves/nerve-structure

ACTIVITY V: Spinal Reflexes

Reflexes are predictable, involuntary, and rapid responses to various environmental stimuli without said stimuli being first processed by the brain. Reflexes involve transmission of signals between two to three types of neurons, which were already discussed in Activity I: **sensory neurons**, **interneurons** (in some cases), and **motor neurons**. When an external stimulus (like stepping on a sharp nail) stimulates a sensory neuron, this information is relayed to the central nervous system (in some cases, to the brain stem, but in many cases, to the spinal cord). The signal from the sensory neuron is then relayed to an interneuron, and then to a motor neuron, or in some cases, directly from the sensory neuron to a motor neuron with no interneuron in between. This motor neuron then transmits the signal to an **effector** (such as a muscle), triggering the response. During this process, the response occurs before the stimulus is actually detected and processed by the brain, as the signal reaches the effector before the information is

sent from the spinal cord to the brain. Figure 15 below illustrates the basic pathway of signal transmission in a spinal reflex arc.

In this exercise, you will explore a reflex with which you may already be familiar. If your doctor has ever tapped your knee with a rubber hammer, he or she did so to check transmission of signals between sensory neurons, the spinal cord, and motor neurons. This particular reflex is called the **patellar reflex**, or the **knee jerk reflex**. When your knee is struck with a reflex hammer, this causes a tendon, which is attached to both your patella (kneecap) and the quadriceps femoris muscle, to be stretched. This stretching stimulates receptors to generate electrical impulses that are passed from sensory neurons to the spinal cord, and then to motor neurons that stimulate the quadriceps femoris muscle itself. Figure 16 on the following page illustrates the pathway of signal transmission in the patellar spinal reflex arc.

To illustrate the patellar reflex, sit on the edge of your lab bench, so that your legs hang freely. Your partner will then take a rubber reflex hammer, and strike the lower edge of your kneecap with the pointed side of the hammer. If you do not initially exhibit a response to the strike of the hammer, your partner should try striking around the patella in slightly different locations until a response is observed. After observation of your response, switch places with your partner, and see if you can elicit a reflex response from them, as well.

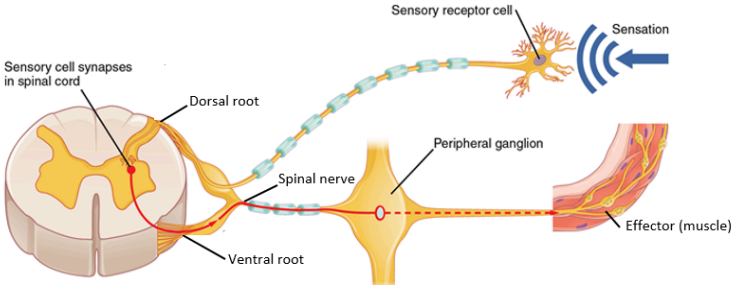


Figure 15. Illustration of signal transmission in a spinal reflex arc. Note that the sensory information is carried to the spinal cord through the dorsal root (on the back/upper side of the body), and

relayed through interneurons (in some, but not all occasions) in the gray matter (not shown, but represented by the red dot in this figure), and back to the effector (a muscle) via the ventral root (on the front/lower side of the body) through a spinal nerve. Modified from OpenStax at https://archive.cnx.org/contents/a4ca89c4-ab19-492f-a910-8f0f7867999f@6/nervous-system

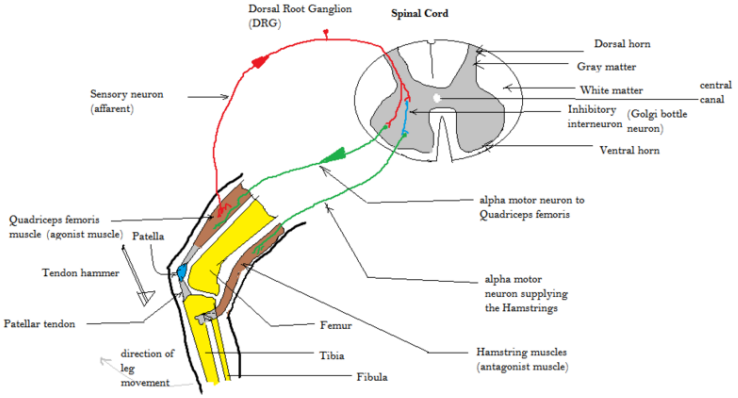


Figure 16. Illustration of the reflex arc of the patellar (knee jerk reflex). Source: Amiya Sarkar, from https://commons.wikimedia.org/wiki/File:Patellar_tendon_reflex_arc.png, licensed under Creative Commons Attribution-Share Alike 4.0 International license.

ACTIVITY VI: Measurement of Reaction Time

Follow the directions below for determination of you and your partner's average reaction times:

1. Your partner will stand in front of you while you are seated, and will hold the provided reaction time stick in the "Release" area between their thumb and forefinger.
2. You should hold your thumb and forefinger of your dominant hand open about an inch apart and on each side of the "thumb line" on the reaction time stick, with your thumb closest to

you, and your forefinger on the side of the reaction time stick farther away from you.

3. Let your partner know when you are ready. Then, at some unspecified point, your partner will release the reaction time stick.
4. You should attempt to catch the reaction time stick between your thumb and forefinger as quickly as possible.
5. You can read your reaction time in milliseconds using the numbered markings on the reaction time stick.
6. Record this reaction time in the space marked "RT1" on the worksheet at the end of this lab exercise.
7. You should repeat this procedure for a total of 10 reaction time measurements, recording each reaction time on the worksheet.
8. After your 10 trials, you and your partner will switch places, with you holding the reaction time stick, and your partner attempting to catch it as quickly as possible.
9. Repeat for a total of 10 reaction time measurements for your partner, as well.

BI 102 Lab Worksheet: Nervous I Name _____ Section _____

ACTIVITY I: Cells of Nervous Tissue

1. _____also known as nerve cells, are the functional units of the nervous system.
2. Using the model of a multipolar neuron, write the number from the model corresponding to the appropriate structures in the space below:

_____ Axon

_____ Dendrites

_____ Linked Schwann cells at node of Ranvier

_____ Nucleus

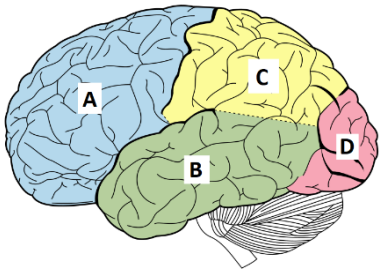
_____ Schwann cell (with nucleus)

_____ Synaptic terminal (axon terminal)

ACTIVITY II: Anatomy of the Brain

3. The most basic functions of the body like heartbeat and breathing are controlled by which part of the brain that includes the medulla and the pons? (damage/swelling in this part of the brain is often fatal)

4. Using the figure, match the letters to the correct cerebral lobes below, as well as their functions:



_____ Frontal lobe

_____ Occipital lobe

_____ Parietal lobe

_____ Temporal lobe

_____ Movement, thought, language production

_____ Auditory reception, behavior, expressed speech, behavior

_____ Processing/discrimination of sensory input, body orientation

_____ Visual center

5. Using the brain model on the table, write the number on the model corresponding to the appropriate structures on the model next to the appropriate structures below:

_____ Central sulcus

_____ Cerebellum

_____ Frontal lobe

_____ Hypothalamus

_____ Medulla oblongata
_____ Occipital lobe
_____ Olfactory bulb
_____ Parietal lobe
_____ Pituitary gland
_____ Pons
_____ Temporal lobe
_____ Thalamus

ACTIVITY III: Anatomy of the Spinal Cord

6. What structures are found in the gray matter of the spinal cord?

7. What structures are found in the white matter of the spinal cord?

ACTIVITY IV: Anatomy of Nerves

8. On the provided handmade model of nerve anatomy, what is represented by all of the different colored wires exiting the black tubing?

9. How many total pairs of spinal nerves are found in the human body? _____

ACTIVITY V: Spinal Reflexes

10. Order the events below from 1 (first) to 5 (last) in the events that occur in the patellar spinal reflex:

_____ Motor neuron from spinal cord triggers contraction of quadriceps femoris
_____ Perception of strike to knee received and processed by brain
_____ Sensation of stretching travels to spinal cord
_____ Stretching of quadriceps triggers sensory neuron in knee
_____ Striking patella stretches the tendon attached to the patella and quadriceps femoris muscle

When the patella is struck with a reflex hammer, does this cause the leg to flex or extend?

ACTIVITY VI: Measurement of Reaction Time

11. Record each of your reaction times for a total of 10 trials below, then calculate your average reaction time:

RT1: _____ ms

RT2: _____ ms
RT3: _____ ms
RT4: _____ ms
RT5: _____ ms
RT6: _____ ms
RT7: _____ ms
RT8: _____ ms
RT9: _____ ms
RT10: _____ ms
Avg. RT = _____ ms

12. Do you think that practice and/or learning had an effect on your reaction time? If so, provide evidence of this based on your data from your 10 trials.

13. If your instructor compared averages between reaction times in males and females (or made any other comparisons), which had faster reaction times? Do you think this is accurate? Why or why not?

If your instructor provides you with the class data, or a range from fastest to slowest reaction time in the class, answer the following questions. What was the fastest reaction time in your lab section? What was the slowest? Where did you fall in this range? Name some factors that you think might have an influence on average reaction time.

7. Chapter 7

LAB 7

The Senses

Prepared by Jason R. Jones & Dr. Jeff Ray, University of North Alabama

Introduction

To detect our environment, the body uses **receptors** to detect various stimuli in the internal and external environment to help maintain **homeostasis**. These stimuli are transmitted as electrical impulses through nerves to the **brain** for processing/ interpretation. Receptors include **photoreceptors** (visible light), **chemoreceptors** (detect various molecules like CO_2), **thermoreceptors** (hot or cold), **mechanoreceptors** (including pressure & in the ear for hearing and balance), and **pain receptors**.

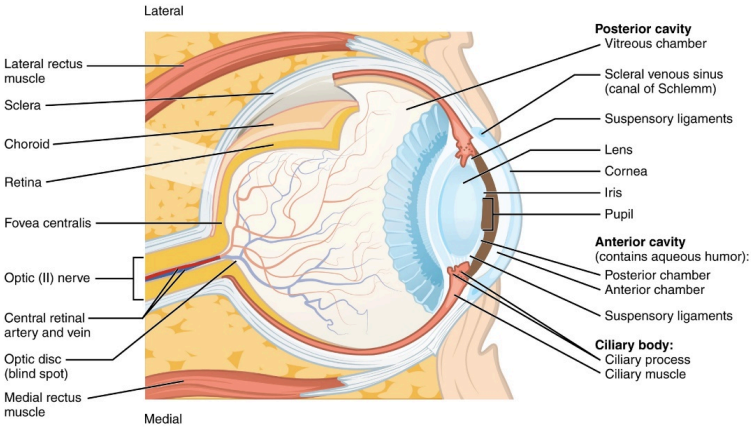
In today's lab, you will do activities that measure the five traditional senses for vision, smell, taste, sound, touch, and also temperature.

* What type of receptors detect light? _____smell & taste? _____
sound? _____temperature? _____

Eyes and Vision

Eyes are special sense organs for detecting wavelengths of

visible light using photoreceptors. Humans have a camera-type eye that focuses light rays on the retina to form an image detected by the brain. The **cornea** is the outer surface known as the 'window of the eye'. The pressure in the front portion of the eye is maintained by the water-like **aqueous humor**. The **iris** is the colored portion of the eye, while the **pupil** can constrict or dilate to control the amount of light passing through it into the eye. A single **lens** focuses the image onto the **retina**. Before reaching the retina, light passes through the jelly-like **vitreous humor**. Light rays strike the **retina**, which contains two main types of photoreceptors, **rods** and **cones**. **Rods** are more numerous and detect the presence/intensity of light. The **cones** are fewer in number and each of three types detect different wavelengths (colors) of light; the combinations of these types forms the various colors we perceive.



*What is the path of light from outside the eye to where it is detected by photoreceptors?

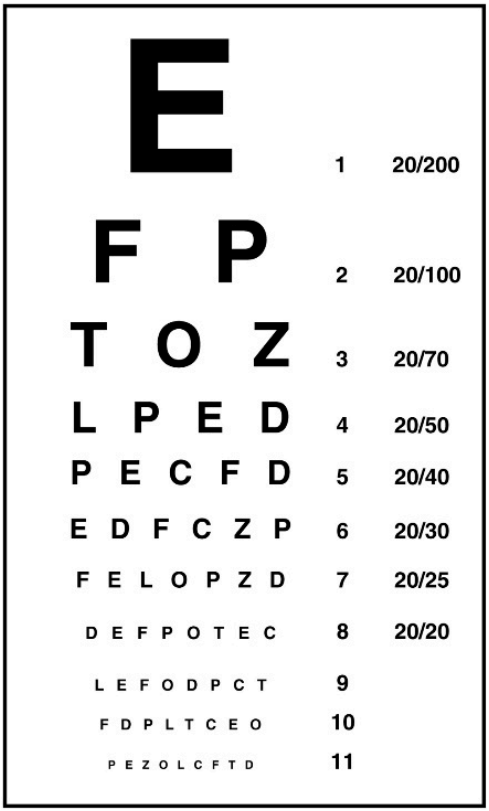
(word bank: aqueous humor, cornea, lens, pupil, retina, vitreous humor)

_____→ _____→ _____→ _____→ _____→ _____

Check the boxes when you complete each exercise. Do the visual acuity and astigmatism together using the wall charts.

Visual Acuity

The **Snellen chart** for visual acuity presents a limited number of letters in lines of decreasing size. The line with letters that are marked 20/20 represent the smallest letters that a person with normal acuity should be able to read with 100% accuracy from 20 feet. The different sizes of letters in the other lines represent rough approximations of what a person of normal acuity can read at different distances. For example, the line that represents 20/200 vision would have larger letters so that they are legible to the person with normal acuity at 200 feet. The 20/200 value (or worse) is considered "legally blind" if not corrected with lenses.



_____ To Test For Visual Acuity: Use the Snellen

eye charts^ on the wall, stand 20' away. Do not squint. If you wear glasses, test both with and without your glasses. Do not remove contacts to test.

1. Test 1 eye at a time, do the left eye first. Have your partner stand at the eye chart and point to each line.

2. Close or cover your right eye. Read each line from the top to the bottom of the chart.

3. The bottom-most line you read with 100% accuracy gives an *approximation* of your visual acuity versus what is considered normal vision (20/20).

4. Repeat for your right eye, close or cover your left eye.

5. Record your results below, use the second set of blanks after removing your glasses, if you wear any.

a. Left eye 20/_____b. Right eye 20/_____c. Left eye 20/____d. Right eye 20/____

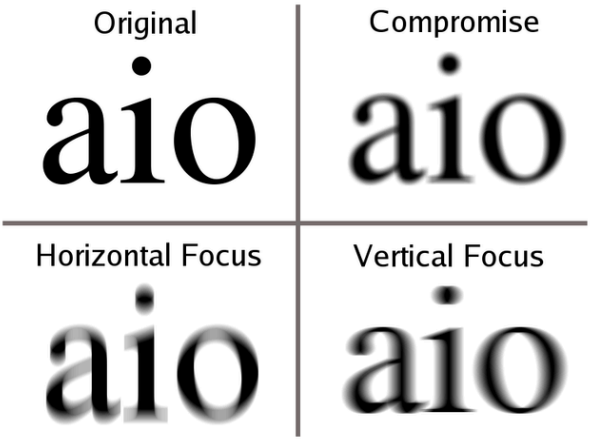
^ This test is very primitive as compared to the advanced instruments an optician can use to determine your visual acuity and correct deficiencies in vision.

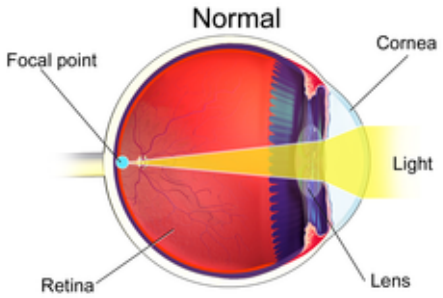
Explanation: If your vision is 20/40, you can see at 20' what can be seen from 40' in a person with normal vison; you have *worse* than average vision. If your vision is 20/15, you can see at 20' what a person with normal vision can only see clearly from 15' (closer up), you have *better* than average vision.

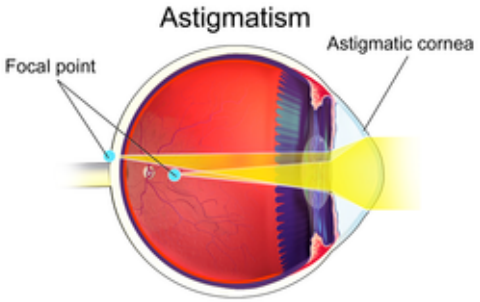
Astigmatism

Astigmatism is a refractive error in the eye caused by an *unevenness in the cornea or lens* that can blur or distort vision at all distances. These surface abnormalities tend to bend light irregularly based upon the convex and/or concave shape of the eye surface. The result is the scattering of light and a lack of clarity in a portion of the field of vision. Astigmatism is normally corrected by glasses, contacts or surgery. If left uncorrected, astigmatism can lead to

headaches, fatigue, squinting and pain in the muscles around your eye.







Astigmatic cornea distorts the focal point of light in front of and/or behind the retina

____ To Test for Astigmatism: Use the astigmatism wheel charts^ on the wall, stand 20' away. Do not squint.

1. Test 1 eye at a time, do the left eye first.

2. Close or cover your right eye. Focus your vision on the center circle, while examining each line that radiates off of it. If you do not have astigmatism, the lines will appear sharply focused and equally dark. You *may* have astigmatism if some lines appear sharp and dark, while others are blurred and lighter.

3. Test the right eye following the same steps. Record your observations below.

Astigmatism a. Left eye: Yes / No b. Right eye: Yes / No

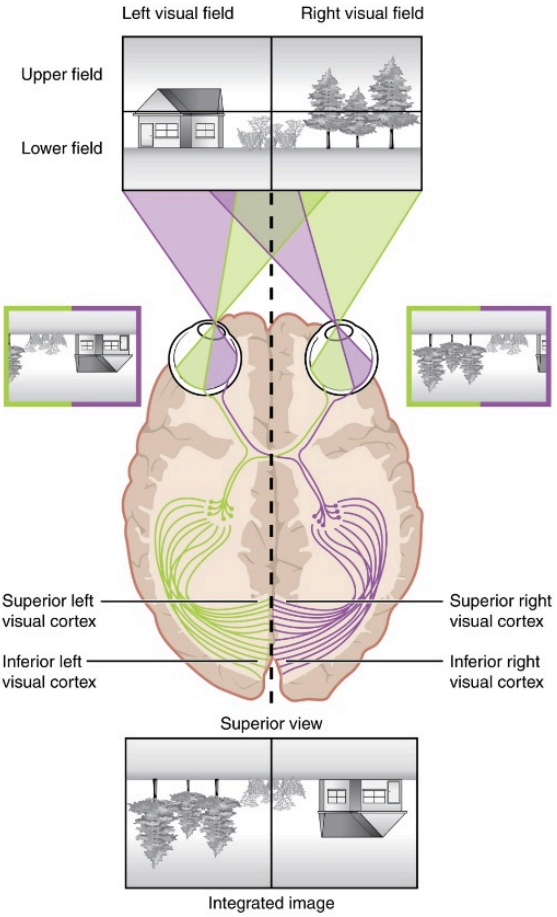
^ This test is very primitive as compared to the advanced instruments an optician can use to diagnose astigmatism.

*Which part(s) of the eye are abnormal in an astigmatism?

_____
_____

Superimposition

Superimposition refers to the process by which the *separate* images detected by each eye are combined into a single three-dimensional image by the brain. Since each eye has a separate field of view, the two images differ slightly, but your brain combines them into one cohesive image. For this activity, you are going to trick your brain by having your eyes send conflicting information about what you are seeing.



_____ To Demonstrate Superimposition: Use the hollow paper tube at your table.

1. Find an object on the wall, such as an exit sign, as your object to view.

2. Close your left eye and keep your right eye open. Raise the tube and hold it up against your right eye and view the wall object through the tube. Your field of view should be the sign through the tube.

3. Raise your left hand 12" in front of your left eye alongside the tube with your palm facing away, while holding the tube steady.

4. Close your right eye and open your left eye. You field of view should be the back of your hand.

5. While leaving the tube and your hand in place, open both eyes and note what you see. Slide your hand up and down the tube with your palm facing away to highlight this optical illusion.

6. Switch sides with the tube if the effect is minimal- one eye is often dominant and the brain prefers info from that side.

*****Describe what you see when looking through the tube with both eyes open:

_____
_____

Explanation: one is generally unaware of superimposition under *normal* conditions- the brain combines the separate images into a single visual perception which generally does not conflict. This exercise created a situation called a binocular rivalry in which one is directly aware of the two separate fields of view.

Afterimages

We see because the rods and cones are generating nerve impulses that are transmitted to the brain. Occasionally, the brain retains an image even after the impulses have stopped (**afterimages**). Positive afterimages are when the bright parts of the object remain bright & the dark parts remain dark. Negative afterimages are when the bright parts of the object appear dark & the dark parts appear bright.

____To Demonstrate Afterimages: Use fluorescent strips, black paper, white paper.

1. Center the fluorescent green strip of paper on the black construction paper and stare intently at the green strip for 30 seconds without shifting the eyes. Then have your partner quickly slide a white sheet of paper over the green strip. Record what afterimage you see, if any (possibly a flash of different color).

*** Green afterimage- describe what you see:**_____
_____

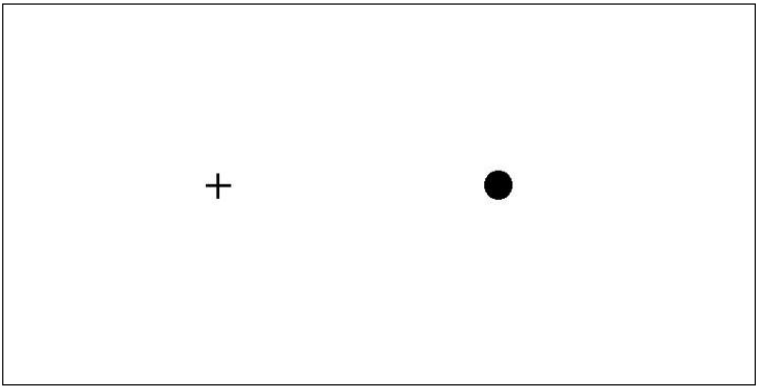
Repeat the procedure using the fluorescent orange strip of paper.

*** Orange afterimage- describe what you see:**_____
_____

The Blind Spot of the Eye

The blind spot occurs where the optic nerve exits the **retina**. Since the surface of the **optic nerve** lacks any photoreceptors, when light rays strike this portion of the retina, *no image is detected* due to the absence of both **rods** and **cones**.

____ To Demonstrate the Blind Spot: Use the strip of paper which has a small circle and a cross.



1. Test 1 eye at a time, do the left eye first.
2. Hold the paper strip at arm's length with the cross *directly* in front of your left eye and the circle to the left. Close your right eye.
3. Stare only at the cross, do not let your left eye wander from it (the circle will be in the periphery).
4. Slowly move the paper toward your eye until the circle disappears.
5. Repeat as needed to find the blind spot (adjust it closer/further to find the exact distance it disappears).
6. With your partner's help, measure the distance from your eye to the paper using a meter stick, record in **cm**.
7. Repeat procedure with your other eye, record distance.

***Blind spot distance: Left: _____ cm Right: _____ cm**

*Which part of the eye which lacks rods & cones and causes the blind spot? _____

Explanation: one is generally unaware of the blind spot under *normal* conditions- the brain interprets what we perceive in part on past experience and essentially, fills in missing gaps. This exercise created an artificial situation in which one is directly aware of how perception if constrained by eye anatomy.

Accommodation of the Eye

When the eye ***accommodates*** to see objects at different distances, the shape of the **lens** changes. When you are looking at a distant object, the lens is *flatter*. When you are looking at a closer object, the lens becomes more *curved (rounded*). The lens shape is controlled by the **ciliary muscles** attached to it. The rounded lens bends light more to accommodate the closer image to fit into the eye. The ciliary muscles and the elasticity of the lens determines how well the eye can accommodate, and lens elasticity decreases with age, a condition called **presbyopia**. Presbyopia is the reason many older people need reading glasses to see near objects. The **near point** is the closest distance at which your eye can change shape to bring an object into focus (**accommodation**).

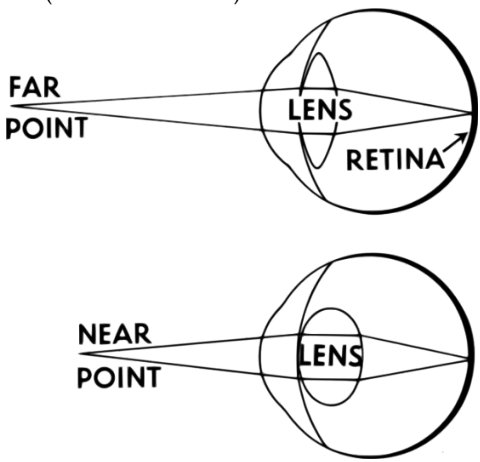


Figure: Light from a distant object and light from a near object brought to a focus on the retina. Notice how the **lens** is *flatter* for

distant objects and is *rounder* for close objects. The lens rounds to **accommodate** near objects.

____ To Demonstrate Accommodation/ Determine Near Point:Use a pencil and meter stick.

1. Test 1 eye at a time, do the left eye first.
2. Hold the pencil at full arm's length with the pencil tip pointing towards the ceiling. Close your right eye.
3. Focus on the pencil tip, and slowly move it toward your left eye until the end is out of focus.
4. Repeat as needed to find the distance (adjust closer/further to find the exact distance it goes out of focus).
5. With your partner's help, measure the distance from your eye to the pencil using a meter stick, record in **cm**.
6. Repeat procedure with your other eye, record distance.
7. Compare your near point accommodation with values from the chart below. Determine the "age" of your eye.

***Near point accommodation: Left: _____ cm Right: _____ cm**

Age (years)	8	15	20	25	30	35	40	42
Near Point (cm)	6	9	10	11	12	15	18	21

*What is the "age" of each eye? Left: _____ Right: _____

*Which part of the eye changes shape to accommodate? _____

Color Blindness

Color blindness is the decreased ability to see color or color differences and is due to a lack of functional **cones** (photoreceptor proteins) on the retina. Although a given color wavelength of visible light strikes the retina, it is not detected since there are no functional cones to detect it, no stimulus is sent to the brain and the person is 'color blind.' The genetic condition is more common in males versus females since the genes responsible for most forms of color blindness are on the X chromosome (females have two

copies, so if one is defective, and the second copy functions, the individual would not be color blind). Diagnosis is typically with the **Ishihara color test**; but a number of other testing methods have been developed.

__To Test for Color Blindness: Use the Ishihara's Tests for Colour Deficiency book at the table.

1. Observe plates 1-14 with both eyes. Plates will contain numbers, lines or patterns distinct from the surrounding dots. Count the number of plates you can clearly read.

• Plate No. 1 is a control and should be readable as '12' by all persons with basic visual abilities.

• Plates 1-11 determine normal/defective color vision. Plates 12-14 determine the type and degree of color vision deficiencies.

• Analyze your results and look up explanations in the small booklet provided with the Ishihara book.

*** Your Color vision score (#plates read): _____**

10 or more plates: normal color vision7 or fewer: color vision deficient.See booklet for explanations

*** Is color-blindness caused by a lack of functional *rods or cones* in the retina? _____**

Sense of Touch and Sense of Hot & Cold

The sensory receptors in skin respond to touch, pain, temperature, and pressure. Each of these stimuli have *different* receptors that detect them (hot & cold receptors are also separate), as well as free nerve endings, which respond to pressure, pain, and temperature. These messages are sent as electrical stimuli to the brain and processed.

____ To Measure Sense of Touch:

Use the grey calipers to pressure the skin and measure the distance between points. You will be testing the subject's ability to discriminate between the two points of the calipers at the four different locations listed below.

*A laboratory partner is required for this procedure. Enter your data, not your partner's data.

1. The subject must be seated with eyes closed. Hold the points of the calipers 20 mm apart on the given skin area, with both points *gently* touching the subject. Ask the subject whether the experience involves 'one or two?' touch sensations.

2. Move the calipers a few mm closer each time until the subject can only discriminate a single point. Record the shortest distance between the caliper points the subject can make a two-point discrimination.

3. Record the data in the blanks below. Remember, the subject cannot look at the calipers when being tested.

a. Forearm: _____ mm

b. Back of the neck: _____ mm

c. Index finger: _____ mm

d. Back of the hand: _____ mm

*Which area had the *smallest* two-point discrimination? _____

This area would have the most nerve endings allowing for the greatest sense of touch.

____ To Measure Sense of Hot & Cold:

Use the three large beakers containing hot, cold & room temperature tap water (on cart).

1. Immerse your left hand in the ice water beaker and your right hand in the hot water beaker for 30 seconds.

2. Simultaneously move both hands very quickly to the room temperature water in the middle beaker.

3. Record the *immediate* sensation you feel in both your L and R hands. Switch the beakers if you have time.

Temperature perceived in: a. Left hand: _____

b. Right: _____

* Explain your results: _____
_____

_____
_____

Explanation: Your skin has *separate* receptors for pressure, hot,

and cold. Pressure receptors are *more accurate* than temperature receptors. In all three beakers, the pressure receptors are active (so nothing 'changes' when you place your hands immediately in the middle beaker). Thus, after saturating your pressure and your hot *or* cold receptors in separate beakers, your brain initially gets a mixed message (pressure and hot + cold) in the middle beaker. Since your brain never expects to get a message of *hot + cold* from the same place simultaneously, whichever temperature is the most intense (hottest or coldest) is probably the one you perceive in the middle beaker, not both (varies).

Ears, Hearing, and Equilibrium

Anatomy of the Ear

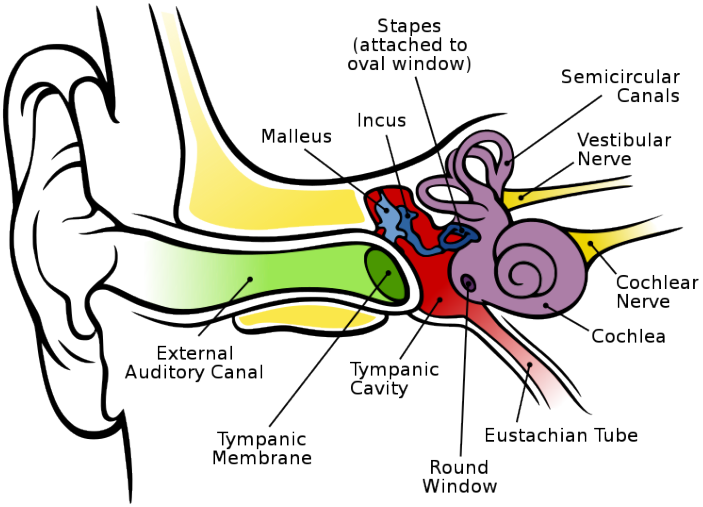
The ear of mammals can be divided into three main regions: the **outer ear**, **middle ear**, and **inner ear**. The outer ear consists of the **pinna**, which is the external portion of the ear visible outside the head, and the **auditory canal** (**ear canal**). The structure of the auricle serves as a sort of funnel which collects sound and directs it into the auditory canal.

The middle ear consists of the **tympanic membrane** (**eardrum**), the **ossicles**, the **tympanic cavity**, and the **Eustachian tube** (=auditory tube). When sound waves enter the auditory canal, they strike the tympanic membrane, causing it to vibrate. These vibrations are then transmitted to the ossicles (three small bones in situated in the tympanic cavity): the **malleus** ("hammer"), then to the **incus** ("anvil"), and finally the **stapes** ("stirrup"). The Eustachian tube, which connects the middle ear to the nasopharynx is not directly involved in hearing, and is normally collapsed, but opens during swallowing and with positive pressure. Its main functions include the drainage of mucus from the middle ear into the throat, as well as equalization of pressure between the middle ear and the atmosphere. When pressure in the middle ear is different from atmospheric air pressure (such as when at high altitudes, flying, or scuba diving), the pressure can be equalized by yawning, swallowing, or chewing gum, all of which open the Eustachian tubes,

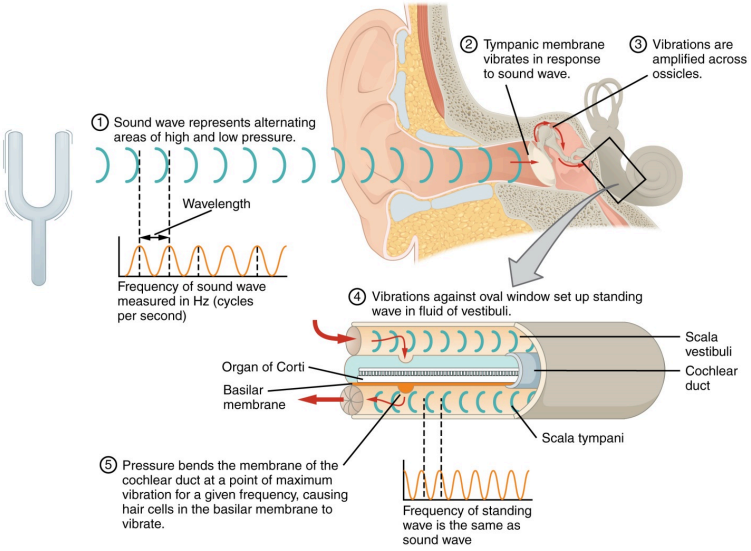
resulting in a small popping sound as the pressure in the middle air is equalized.

The inner ear contains a fluid-filled, spiral, snail shell-shaped organ called the **cochlea**, which is where auditory stimuli are converted to electrochemical signals that are sent to the brain for processing via the **cochlear nerve**.

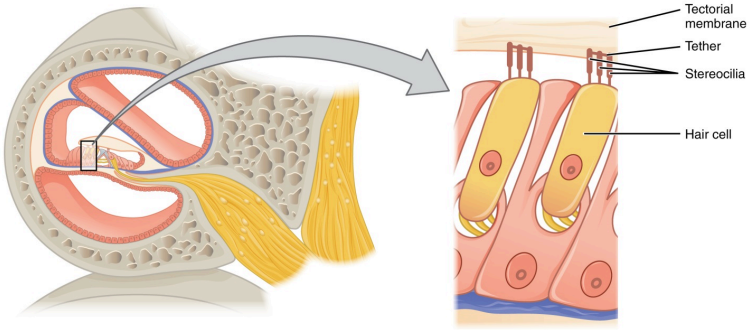
When sound waves enter the ear, they cause the tympanic membrane to vibrate. These vibrations are then passed through the malleus, incus, and stapes (the ossicles), and the vibration of the stapes is transmitted to the **oval window** on the outside of the cochlea. The vibration of the oval window causes vibration of fluid inside the cochlea, which causes movement of **hair cells** in the **organ of Corti** inside the cochlea. Hair cells are sensory receptors that transform the sound vibrations into electrical signals that are relayed to the brain through the **cochlear nerve**. Other parts of the inner ear include the **vestibule** and **semicircular canals**, which are involved in equilibrium, balance, and perception of positional information. Using the figures on the following pages, try to locate all of the structures of the outer, middle, and inner ear on the provided model. Additionally, answer the question on transmission of sound waves/signals on the worksheet at the end of this lab exercise.



Anatomy of the ear.



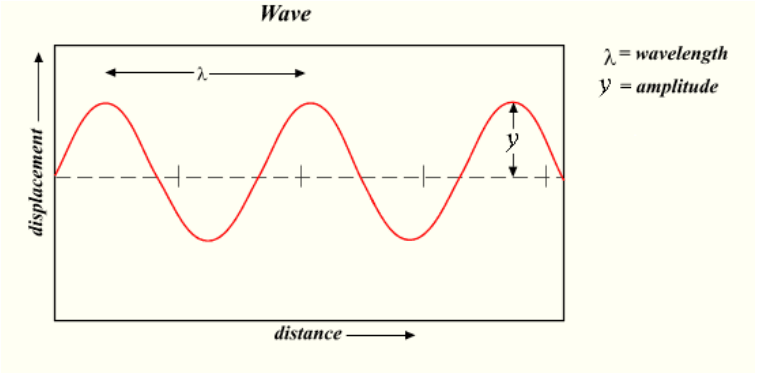
Events involved in audition (hearing).



Organ of Corti inside cochlea, and magnified view of hair cells.

Perception of Sound

Sound, as defined in physics, is a vibration that propagates as a wave of pressure through a gas, liquid, or solid. Sounds are perceived differently based on characteristics of these waves. One feature of sound waves that affects their perception is their **amplitude**. The higher the amplitude of a sound wave, the louder that sound will be perceived. There is also a relationship between a sound wave's **frequency** and its perceived pitch. The frequency of a sound wave has an inverse relationship with the wavelength of that wave (in other words, the longer the wavelength, the lower the frequency; conversely, the shorter the wavelength, the higher the frequency of that wave). The frequency of sound waves is usually measured units called **Hertz**, which are defined as cycles per second. You have been provided with several tuning forks, each of which is stamped with its vibrational frequency in Hertz. Take one of the provided tuning forks, and note its frequency. Strike the tuning fork on the provided rubber wedge, and note the sound produced. Repeat this for the other tuning forks. Did you notice the relationship between the frequency and pitch of each tuning fork? Answer the question regarding this on the worksheet at the end of this lab exercise.



Characteristics of waves.

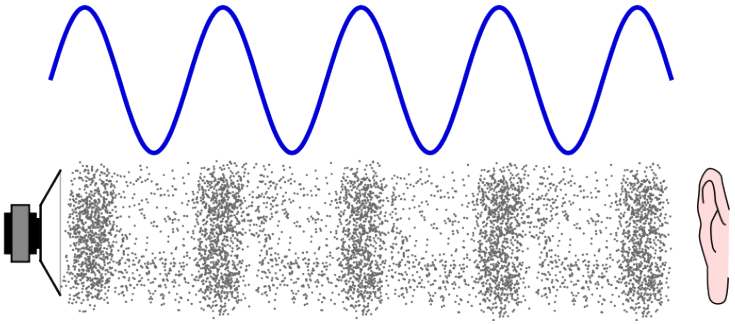


Diagram showing physical manifestation of a sound wave through air from a speaker to a human ear

Locating Sound

1. Sounds are located using the combined perception of those sounds by both ears. Differences in hearing between the ears can result in an incorrect determination for the location between sounds. In this exercise, you and your partner will explore your abilities to determine the location of sounds. Follow the directions below to conduct this activity:
2. Have your partner be seated, with eyes closed.
3. Strike the provided tuning fork with the lowest frequency at

one of the following locations relative to your partner's head (use a random order for these):

a. Directly below and behind the head: _____

b. Directly behind the head: _____

c. Directly above the head: _____

d. Directly in front of the face: _____

e. To the right side of the head: _____

f. To the left side of the head: _____

4. Ask your partner to give the exact location of each sound, and record their responses in the blanks above.

5. Repeat the process using the provided tuning fork with the highest frequency, and record your partner's responses below:

a.Directly below and behind the head: _____

b. Directly behind the head: _____

c. Directly above the head: _____

d. Directly in front of the face: _____

e. To the right side of the head: _____

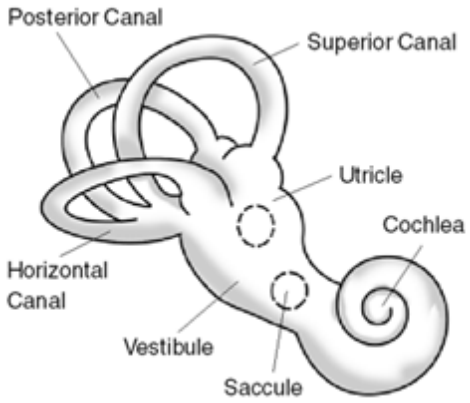
f. To the left side of the head: _____

6. Switch roles with your partner, with yourself trying to determine the location of sound as above.

7. Answer the questions regarding this activity on the worksheet at the end of this lab exercise.

The inner ear also contains several organs collectively referred to as the **vestibular system**, shown in the figure on the following page. The organs of the vestibular system include the **vestibule**, the **utricle**, the **saccule**, and three **semicircular canals**. Each of these organs contains hair cells, similar to the cochlea, but are not involved with hearing. Instead, these organs are involved with equilibrium, balance, and detection of positional information and directional acceleration. The saccule and utricle sit below a gelatinous layer of the vestibule, with the cilia of their hair cells projected into the gelatin. Inside the gelatin layer are crystals of calcium carbonate called **otoliths** (which literally means "ear stones"). Changes in the angular position of the head causes these crystals to shift, bending the cilia of the hair cells in the utricle and saccule. The bending of the hair cells stimulates neurons, which carry this signal information to the brain via the **vestibular nerve**.

The semicircular canals are fluid-filled tube-like structures that also contain hair cells. These canals are involved in the detection of angular acceleration and deceleration from rotation. When turning your head, this shifts fluid in these canals, which also bends the cilia of hair cells inside the canals, and signals from the canals are sent to the brain for processing. When movement in a particular direction is accelerated or decelerated, this also causes movement of fluid in these canals. One way to think about this is if you are standing still and holding a glass of water, and suddenly begin walking quickly forward, some of the water may splash backwards onto your hand. Then, if you suddenly stop walking, the water may splash forward. In this way, the semicircular canals are responsive to changes in velocity. This information is also relayed through the vestibular nerve to the brain for processing.



Organs of the vestibular system of the inner ear.

Illustration of Post-rotatory Nystagmus

In this activity, you will examine **nystagmus**, which is the movement of the eyes in response to stimulation of hair cells in the semicircular canals. Nystagmus displays two component motions, called the **slow phase** and the **fast phase**. When the head is rotated, the eyes move slowly in the opposite direction, then quickly back to the other side, and then begins the slow movement again. Using the steps below, you will induce **post-rotatory nystagmus**, which is the result of repeated rotational movement, followed by cessation (stopping) of that movement. To illustrate post-rotatory nystagmus, follow the steps below:

1. Get your partner to sit in his or her chair, and raise his/her feet off the floor.
2. Your partner should then bend their head forward at an angle of about 30 degrees.
3. Rotate your partner in their chair to the right (clockwise) for about 20 seconds at a rate of one turn every two seconds. (Be careful not to fling your partner out of their chair!)
4. Suddenly stop the rotation, and **quickly** observe the movement of your partner's eyes as soon as the rotation stops, noting the direction of movement of the slow and fast phases of nystagmus.

5. Repeat Steps 1-4, only this time rotating your partner to the left (counter-clockwise).
6. Answer the question on the worksheet at the end of this lab exercise.
7. Repeat, switching roles with your partner so that they may observe nystagmus of your eyes.

The Chemical Senses: Smell and Taste

Both smell and taste are chemical senses, in which chemical stimuli are received by chemoreceptors (in the nose in the case of smell, and on the tongue in the case of taste). In the following activities, you will explore your own senses of smell and taste, as well as familiarize yourself with the anatomy of organs involved in each of these senses, as well as the physiology of how chemical stimuli are detected and processed.

Sense of Smell

Olfaction is the technical term used to describe the sense of smell. In the superior (upper portion) nasal cavity, there are multiple olfactory receptor cells, which are hair cells with cilia, similar to those seen in the cochlea and the vestibular apparatus. As molecules in the air are inhaled, they pass over the **olfactory epithelial tissue** and become dissolved in the mucus coating the surface of that tissue. These molecules then bind to proteins, which help transport them to the **olfactory dendrites**. Once these odorant molecules (and proteins to which they are bound) reach the olfactory dendrites, they bind to receptor proteins in the dendrites' cell membranes. The binding of these molecules to the olfactory dendrites is then converted to an electrical signal, which is carried to the olfactory bulb on the inferior (lower) surface of the brain. This information is then carried via the olfactory tract for processing by various parts of the brain, including the olfactory cortex, hippocampus, amygdala, and hypothalamus. Many of these parts of the brain are also part of the **limbic system**, which is associated with emotions and memory. This is one reason that certain smells

often evoke certain memories associated with those particular scents.

Humans have a total of about 40 million olfactory receptors, each of about 350 different subtypes. Stimulation of different olfactory receptors in various combinations allow us to distinguish about 10,000 different odors. Many other mammals have an even greater sense of smell. For example, mice have about 1,300 different types of olfactory receptors, almost 4 times as many as humans, and so are probably able to distinguish many more odors than humans. Dogs also have LOTS more olfactory receptors than humans. Though the number of olfactory receptors in dogs varies among individuals and different breeds, just as an example, German shepherds have about 2 BILLION olfactory receptors (individual receptor cells, not subtypes), which is four times the number of total olfactory receptors in humans!

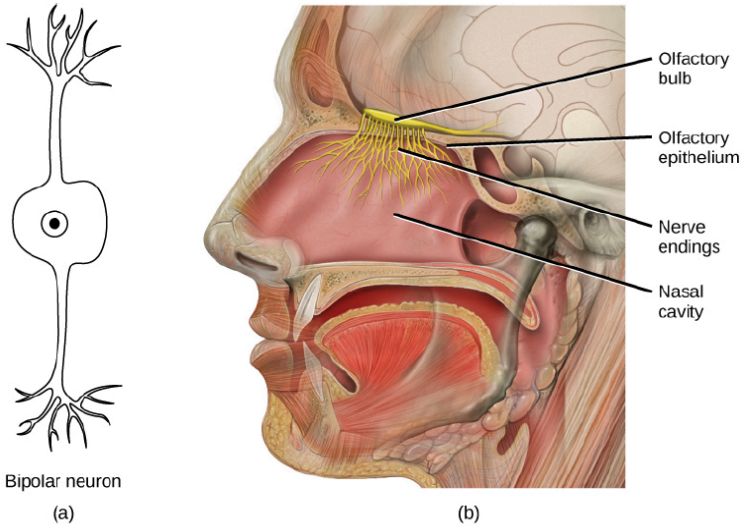
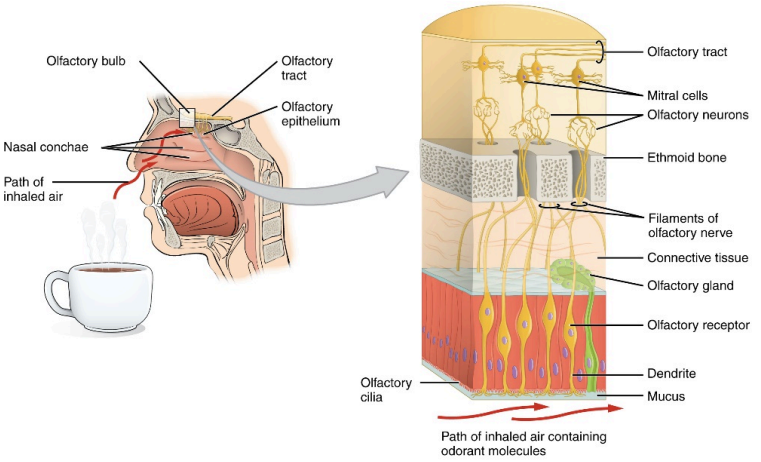
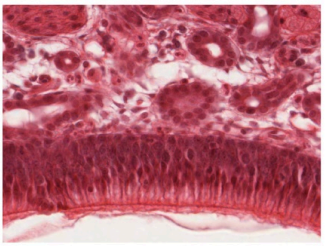


Illustration of (a) bipolar neurons found in the nasal cavity, and (b) olfactory epithelial tissue and the olfactory bulb.





(c) Olfactory epithelium

The olfactory system

To test your olfactory abilities, you will use several vials containing artificial and natural scents. Each table has been supplied with 10 of these vials, numbered 1-10. One pair of students at each table has a basket with vials 1-5, and the other pair of students should have vials 6-10. For this exercise, you will need to smell all 10 vials, so share with your tablemates as necessary. For each vial, you should unscrew the lid and smell the contents. Though not necessary, you may wish to close your eyes to reduce visual stimuli and focus more on your sense of smell. After smelling each vial, record what you think the scent in that vial is supposed to be in the table on the worksheet at the end of this lab exercise. After smelling

each vial and recording what scent you *think* is in each vial, your instructor will provide you with the actual scents to compare to your guesses, and to also record in the table.

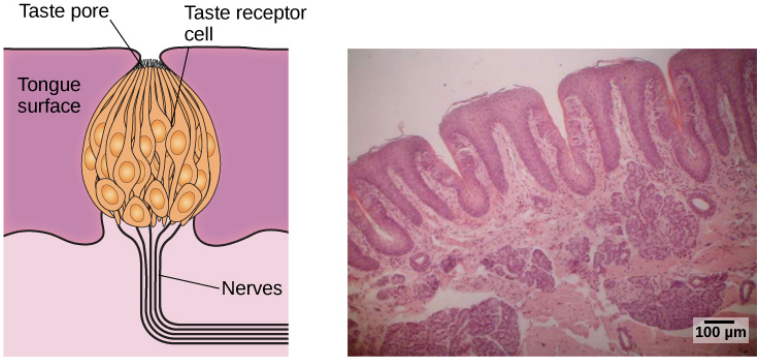
Sense of Taste

Like olfaction (the sense of smell), **gustation** (the sense of taste) is also a chemical sense, involving chemoreceptor cells that respond to chemical stimuli, convert that information to electrical signals that is relayed to the brain for interpretation. Though smell and taste are often perceived as completely separate senses, the two senses do work together to form impressions of perceived flavors. You may have noticed, for example, that your sensation of flavor is dulled somewhat if you have a stuffy nose.

The primary organ of taste is the **taste bud**, which is a cluster of taste cells. Taste buds are found on bumps, called **papillae**, on the tongue. Look at the figure on the following page, and notice that there are several different types of papillae on the tongue, and each type differs in the numbers of taste buds they possess. For example, the **filiform papillae**, found all over the tongue, do not have any taste cells. The **fungiform papillae**, which are mainly located on the anterior (front) two thirds of the tongue, contain 1-8 taste buds each, as well as pressure and temperature receptors. The **circumvallate papillae**, which are quite large, and form an upside-down "V" near the rear of the tongue contain 100-250 taste buds. Finally, the **foliate papillae**, which are found in parallel folds along the edges and back of the tongue, contain approximately 1,300 taste buds each. Taste bud cells are replaced about every 10 to 14 days.

When eating, molecules in food are dissolved in saliva, and bind with and stimulate taste hairs on the tips of taste bud cells. Most of the taste receptors on the tongue are found on the outer edge and front of the tongue. There are different types of taste receptors for different flavors. Humans perceive five main primary tastes, and each of these different types of tastes has one corresponding type of receptor. The five primary tastes humans can detect include **salty**, **sour**, **sweet**, **bitter**, and **umami**. Salty foods contain sodium chloride, and ingesting them dissolves the sodium chloride into

sodium and chloride ions. The sodium ions directly enter into taste neurons, exciting them. Sour tasting foods contain acids. When acids bind to receptors, that triggers hydrogen ion channels to open, allowing hydrogen ions into the receptors, triggering them. Sweet, bitter, and umami tastes require a special kind of receptor (called a G-protein coupled receptor, or GPCR), which uses a protein (a G protein) that acts as a molecular switch inside cells. The sense of taste has a tendency to decline with age, often dramatically beginning around age 50.



(a): Schematic drawing of a taste bud.
(b): micrograph of human tongue tissue.

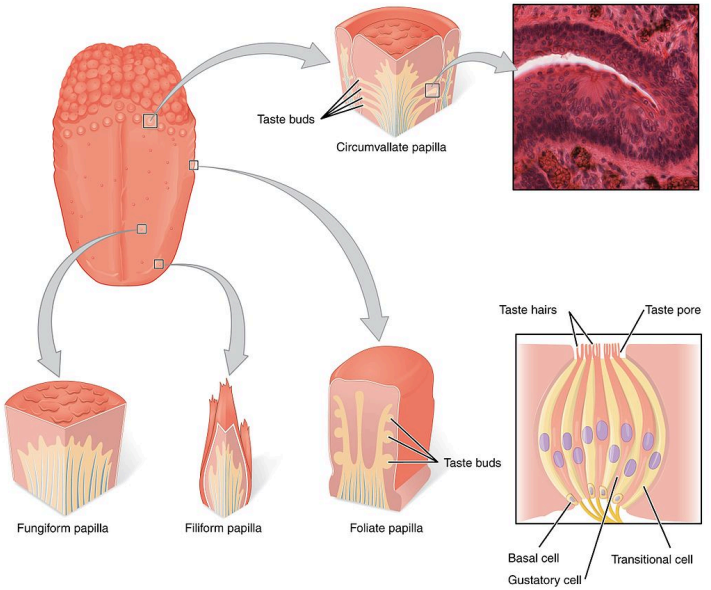


Illustration of the various types of papillae on the tongue, as well as a magnified view of a taste bud.

In the following exercise, you will examine your own sense of taste, as well as learn something about the microscopic anatomy of your own tongue. For this exercise, you have been provided with 4 vials of paper strips. One vial of these strips contains "Control" paper, which is just plain paper. The other vials contain strips of paper which are impregnated with various chemicals, including **Phenylthiocarbamide** (**PTC**), **thiourea**, and **sodium benzoate**. The interesting thing about each of these chemicals is that some people vary in terms of whether they are able to taste those compounds. Interestingly, the ability to taste each of these compounds is genetic, as the genes involved in whether individuals do/do not taste these compounds are genes that affect the expression of specific receptor proteins in taste buds.

For example, the ability to taste PTC (detecting it as a bitter flavor) is due to a dominant allele. Non-tasters thus have two recessive alleles coding for the receptor protein in question. Individuals that are homozygous dominant (have two dominant

alleles) may perceive the taste of PTC to be more bitter than heterozygotes (individuals with one dominant and one recessive allele), though heterozygotes are able to taste PTC as bitter. In a group of studies, individuals that were tasters of PTC tended to avoid broccoli and grapefruit juice, and tend to find green vegetables quite bitter.

Thiourea is another compound somewhat similar to PTC, but the ability to taste it is inherited independently. Thus, the ability to taste PTC does not mean that PTC tasters will also be able to taste thiourea, and vice versa. To tasters, thiourea also tends to have a very bitter taste.

Sodium benzoate is commonly used as a preservative in many foods, but in very low concentrations. However, some people are very sensitive to its taste. Perceptions of the taste of sodium benzoate (in tasters) varies, with some perceiving it as sweet, some as salty, some as bitter, and some as sour. The ability to taste sodium benzoate is also inherited independently of the ability to taste PTC, but the interactions to sensitivity to each of these molecules has been shown to influence people's reactions to different foods. For example, PTC tasters that taste sodium benzoate as salty tend to like sauerkraut, buttermilk, turnips, and spinach more than the average person, and PTC tasters that taste sodium benzoate as bitter tend to like those foods less than the average person.

1. Using the provided vials of control, PTC, thiourea, and sodium benzoate paper, follow the directions below:
2. Obtain a piece of "Control Paper". This strip of paper is nothing more than paper, and will be used for a basis for comparison to the other strips.
3. Place the piece of control paper in your mouth. You should notice no strong flavor, other than just the bland flavor of the paper itself. Try to remember the general baseline flavor of this paper.
4. Remove the control paper from your mouth and throw it away.

5. Next, take a piece of PTC paper, and put it on your tongue. If you do not immediately detect a noticeable flavor, briefly chew the strip of PTC paper. If you do not notice any flavor at all, you are a non-taster for PTC.
6. Remove the PTC paper from your mouth (do not swallow it), and throw it away.
7. Repeat steps 5 & 6 for both the thiourea paper and the sodium benzoate paper.
8. **Record your observations** of your perceived taste/lack of taste of each compound in the table on the worksheet at the end of this lab exercise.

- _____

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Near Point Chart By http://www.ssc.education.ed.ac.uk/courses/outreach/dublini.html

Astigmatism By The original uploader was Tallfred at English Wikipedia – Originally from en.wikipedia; description page is/was here., BSD, https://commons.wikimedia.org/w/index.php?curid=3098293

Astigmatism By BruceBlaus (Own work) [CC BY-SA 4.0 (https://creativecommons.org/licenses/by-sa/4.0)], via Wikimedia Commons

Anatomy of the ear: Chittka L. Brockmann – Perception Space—The Final Frontier, A PLoS Biology Vol. 3, No. 4, e137 doi:10.1371/journal.pbio.0030137 (Fig. 1A/Large version), vectorised by Inductiveload; Licensed under Creative Commons Attribution 2.5 Generic.

Audition: https://archive.cnx.org/contents/238b840d-2428-4d16-bcd3-ab481a44522a@1/derived-copy-of-sensory-perception

Organ of Corti: https://archive.cnx.org/contents/238b840d-2428-4d16-bcd3-ab481a44522a@1/derived-copy-of-sensory-perception

Sound wave diagram: Wikimedia Commons; author Pluke; licensed under Creative Commons – CC0 1.0 Universal

Vestibular system: http://www.nidcd.nih.gov/health/balance/balance_disorders.asp

Olfactory neurons, epithelial tissue, and olfactory bulbs: modification of work by Patrick J. Lynch, medical illustrator; C. Carl Jaffe, MD, cardiologist

Olfactory system: https://archive.cnx.org/contents/13be3d63-b803-4d7b-9265-14da1c5585ae@1/sensory-perception

Closeup of taste bud: Jonas Töle; released to public domain; Micrograph of tongue tissue: https://archive.cnx.org/contents/370f4538-a2ec-4bf7-a3f4-c00b15548c04@5/the-other-senses

Tongue & papillae: https://legacy-staging1.cnx.org/content/m10555/latest/?collection=col10044/latest (modification of work by Vincent Rizzo).

BI 102 Lab Worksheet: Senses Name _____ Section _____

Visual acuity:

Left eye:20/___ Right eye:20/__

Astigmatism:

Left eye: _____ (yes/no) Right eye: _____ (yes/no)

Accommodation:table 30.2

Left eye: _____ cm "Age" of your L eye: _____

Right eye: _____ cm "Age" of your R eye: _____

Blind spot:

Left eye: _____ cm Right eye: _____ cm

Color Blindness Score: _____ (count # of plates you cannot read)

Superimposition

Describe what you saw during the superimposition exercise.

Afterimages:

Describe what you saw during the afterimages exercise using the strip of green paper.

Describe what you saw during the afterimages exercise using the strip of orange paper.

2-point discrimination (touch):

Forearm: ___ mm Back of neck: ___ mm Index finger: ___ mm Back of hand: ____ mm

Which area contains the greatest density of touch receptors? Why do you think this is the case?

Sense of Heat and Cold:

Describe the sensations experienced in your left and right hands during this exercise.

The Ear, Hearing, and Equilibrium:

Number the following structures below in the order in which sound waves/vibrational pass through them.

_____ Auditory canal
_____ Cochlea
_____ Cochlear nerve
_____ Incus
_____ Malleus
_____ Oval window
_____ Pinna
_____ Stapes
_____ Tympanic membrane

Perception of Sound:

What is the relationship between the frequency of a sound and its perceived pitch?

Locating Sound:

Was it more difficult for you to accurately locate sounds with lower or higher pitches?

Illustration of Post-rotatory Nystagmus:

Describe the direction of eye movements during the slow and fast phases of nystagmus below:

After rotating clockwise: Direction of slow phase: _____ Direction of fast phase: _____

After rotating counter-clockwise: Direction of slow phase: _____ Direction of fast phase: _____

Sense of Smell:

Vial #	What you *think* is the scent	The actual scent

Sense of Taste:

Type of Paper	Describe taste (no taste, sweet, sour, salty, or bitter)
Control	No taste
Phenylthiocarbamide (PTC)	
Thiourea	
Sodium benzoate	

8. Chapter 8

LAB 8

Basic Mammalian Anatomy

Prepared by Dr. Jeff Ray, Dept. of Biology, UNA

OBJECTIVES

After completing these laboratory activities, you should understand/be able to:

- Have a basic understanding of the steps of a dissection of a mammal, and how the dissection of the fetal pig is a surrogate for the human.
- Identify the structures of the fetal pig as specified by your instructor and know the basic function of each.
- Identify the structures of the human models as specified by your instructor and know the basic function of each.

Introduction

In today's lab, you will dissect and study the anatomy of the fetal pig^ as a surrogate for the human. The fetal pig is exceedingly similar to the internal human anatomy in multiple aspects. While performing the dissection, keep in mind these structures are present in the same location and serve the same basic function in humans. Be sure to compare the anatomical structures in the pig with the human torso model.

^These pigs were not killed for the purposes of being dissected,

but are the by-product of the food processing (pork) industry and would be otherwise be used as fertilizer or thrown away if not used for dissection purposes.

Instructions

Check off each structure on the worksheet as you find it.*

Work in groups of 2-3. Wear gloves and a disposable apron if you are dissecting or assisting the "surgeon." If you are not participating, it is your job to read and instruct the surgeon on the proper steps and to make sure *all* activities are completed. The pigs will be washed, but after opening the body cavity, it will be useful to rinse fluids out of the cavity to better observe internal anatomy. Have paper towels ready and also use Febreze™ to spray the inside of the pig to remove any smell-use liberally. Ask your instructor for assistance.

External Anatomy

All Mammals possess **mammary glands** and **hair**. Both pigs and humans are placental mammals, and development occurs within the uterus (*in utero*). An **umbilical cord** is the pipeline between the fetus and the placenta. At this interface, oxygen and nutrients are exchanged for carbon dioxide and wastes. Within the umbilical cord, one **umbilical vein** carries nutrients to the fetus while two **umbilical arteries** carry wastes away. Pigs and humans are also both tetrapods–four-limbed vertebrates. Pigs actually walk on their toes (their toenails are hooves). Notice the bones of the ankle are halfway up the hind leg.

*What key features define pigs and humans as mammals? _____

Securing the Pig to the Dissection Pan

1. Place the pig on its back in the pan. Tie a string around one front leg, then bring the string *underneath* the pan, and tie the string to the other front leg. Do not tighten the knot until you have removed any slack from the string or the pig will not stay in place.

2. Repeat this process for the back legs- tie a string around one back leg, bring the string *underneath* the pan, and then tie the string

to the other hind leg. This will hold the pig with all four limbs extended.

***Check the boxes as you complete each exercise**

____

Umbilical Cord

1. Locate the **umbilical cord** arising from what will become the "belly button."

2. **Cut the umbilical cord** near the end and observe the three tubes within it – **2 umbilical arteries** and **1 umbilical vein** (use the blunt probe to find these).

* What is the function of the umbilical arteries? _____

* What is the function of the umbilical vein? _____

____ Nipples and Hair:

1. Locate and count the number of small **nipples**, the external openings of the **mammary glands**. Nipples are not an indication of gender, since both males and females possess them^. In Mammals, there are generally two mammary glands for each offspring (on average).

2. All mammals have hair. *Where is the hair on your pig located?_____

* How many nipples does your pig have? _____

^*Explanation*: During early embryo development, the nipples start to form before gender is expressed; this explains why both female *and male* mammals have nipples and is known as a developmental constraint.

___ Anus and External Genitalia:

1. Locate the **anus**, the opening of the digestive system, under the tail.

2. Just *below* the anus, locate the **urogenital opening**, and the **urogenital papilla** projecting from it. If present, your pig is **female**.

3. If absent, look below the umbilical cord and locate the **urogenital opening**. If present, your pig is **male**. Below this urogenital opening and hidden under the skin is the **penis**, which is held inside the body. Depending on the size of your pig, a scrotal sac may be developing near the anus. Within this sac, are the **testes**.

4. Find another group nearby who has a pig of the other gender and examine it – you are responsible for identifying pigs of either gender.

* Is your pig male or female? _____

Oral Cavity and Pharynx

Within the oral cavity (mouth), notice the teeth (watch out for sharp canines!) and muscular tongue. To the back of the oral cavity is the **pharynx**, which contains three openings: **glottis**, **esophagus**, and **nasopharynx**. The glottis is the opening that leads to the **trachea** ("windpipe"). The esophagus is dorsal (towards the back) to the trachea and leads to the stomach. The **nasopharynx** leads up to the nasal passages.

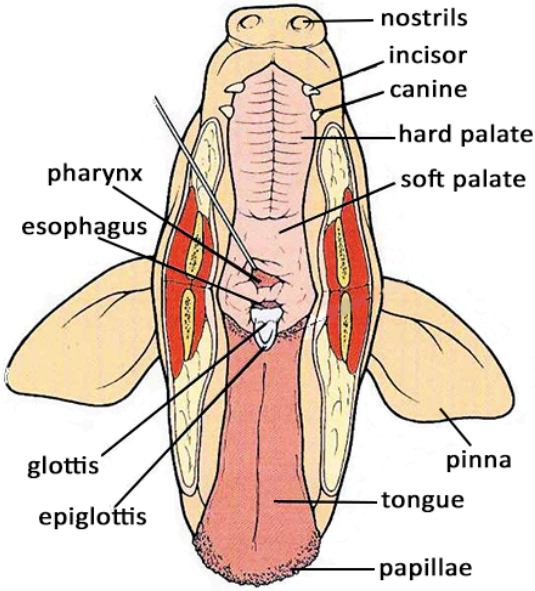
____ Oral Cavity & Pharynx

1. To expose the pharynx, use the scalpel to carefully cut back from the corner of the mouth 1" or more through the thick muscle and ligaments on each side to separate the upper and lower jaws.

2. Apply pressure with your hands to separate (tear) the tissues so the mouth stays open.

3. Locate the **hard palate** (ridged roof) and **soft palate** (smooth), which is posterior (to the back of) it. Notice the lack of a **uvula** (downward extension of soft palate) in the pig (humans have a uvula).

4. Continue to dislocate the jaws using your hands to expose the **epiglottis**, a flap of elastic tissue that covers the **glottis** (opening to trachea) when swallowing to prevent choking.



5. Insert a blunt probe into the **glottis** to show it leads to the **trachea**. Insert the probe into the back of the pharynx into the nearby opening- this is the **esophagus**.

*What is the function of the epiglottis? _____

_____

*Why is it correct to say that food and air passages cross in the pharynx? _____

_____

_____

Thoracic and Abdominal Cavities

1. Make a series of *careful* incisions with the scalpel to expose the internal organs. Do not make deep, plunging cuts, instead make shallow, but firm cuts to penetrate the skin and muscle, but NOT the organs. Try not to cut the **diaphragm**. Better to make several shallow cuts into skin and muscle than one deep cut.

2. Follow the incision diagram below.

3. Starting at the hair of the chin, cut down to near the

diaphragm. The thick sternum must be cut through in the chest. Next, make two lateral cuts, one above the forelimbs, one below.

4. Cut posteriorly from the diaphragm to near the umbilical cord.

5. Cut around the umbilical cord to avoid damaging the **umbilical arteries** and **urinary bladder**.

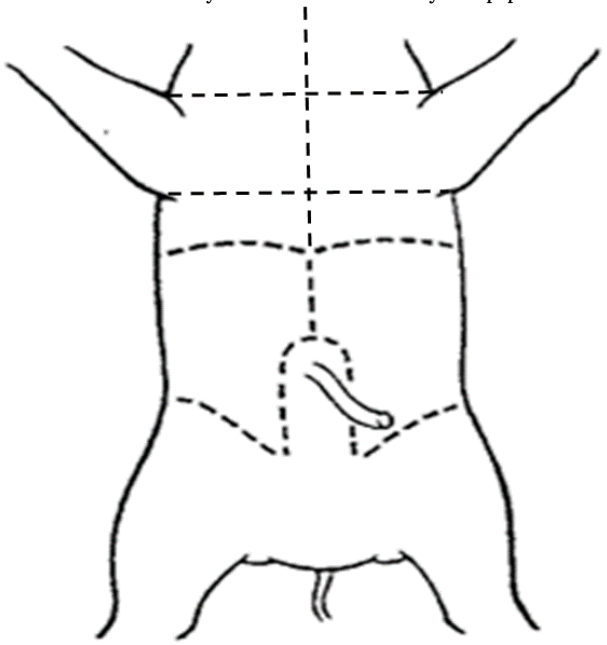
6. Make a lateral cut posterior to (below) the **diaphragm**.

7. Make two cuts, one on each side of the umbilical cord flap, just anterior to (in front of) the hindlegs.

8. Lifting the umbilical cord flap first requires the umbilical vein to be tied then cut. Tie short strings above and below the **umbilical vein** between where you will cut it.

9. Leaving your pig on the tray, take it to the sink and rinse out the body cavity after it is cut open. Spray the organs generously with Febreze™ to minimize odor.

10. If needed, use dissecting pins to hold structures open or in place. Suction out any excess fluids with your pipette.



_ _ _ _ Cervical region (Neck)

1. Use the scalpel and blunt probe to separate the many muscles and ligaments of the neck from other tissues. Be careful not to destroy the **thyroid**, which sits atop the **trachea**. In the fetal stage, the **thymus**, which looks like fat globs, is extensive in the cervical region and into the thoracic (chest) region.

2. Separate tissues to expose the **trachea** (windpipe), which looks like an earthworm, due to its cartilage rings. The **thyroid** is a small, butterfly-shaped organ sitting atop the trachea (often damaged). It is easier to find in the torso model.

3. Use the blunt probe to find & hook the **esophagus**, which is immediately dorsal to (behind) the trachea. The **esophagus** looks like a flat tube, which stretches to accommodate food and water as they pass to the **stomach**.

4. At the superior end of the **trachea**, find the whitish, enlarged **larynx** ("voicebox") composed of hyaline cartilage.

5. Trace the trachea to the **bronchi** and then the **lungs** of the thoracic cavity.

* Describe the location of the trachea relative to the esophagus:

_____

____ Thoracic (Chest) Cavity

The major organs of the thoracic cavity include the **heart** and **lungs**. Notice how the heart is slightly offset to the left resulting in *asymmetry* of the two lungs in terms of size and number of lobes (4 R, 3L). Many blood vessels, including the **aorta** and **vena cava**, serve the heart.

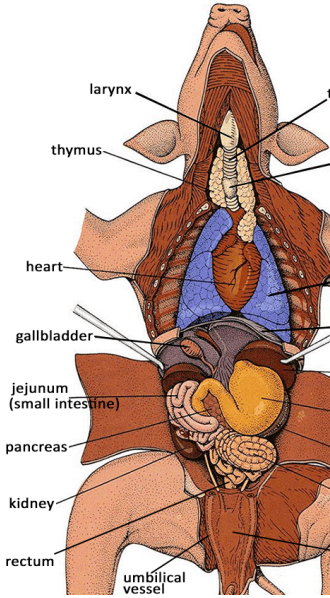
1. Notice the compartments of each lung and the heart and the membranes covering them, these minimize friction and isolate/ protect these organs.

2. Find the **atria** of the heart which are small, lighter-colored flaps atop the heart. Find the **aorta.**

3. Find the 4 right and 3 left **lobes** of the lungs. Find the left and right **bronchi** branching from the trachea.

4. Notice the **diaphragm** inferior to the thoracic cavity.

* Which lung is larger?



Abdominal Cavity

Be sure the abdominal cavity is well-rinsed in order to view all organs

The major organs of the abdominal cavity serve the digestive, lymphatic, endocrine, urinary, and reproductive systems. The largest organ of the abdominal cavity is the liver, although the small intestine is extensive. Notice the clear membrane (**peritoneum**) covering the abdominal wall and organs. Sheets of peritoneum (**mesentery**) extend from the body wall and support the organs.

1. Find the **liver**, which fills the upper right quadrant. The liver has various functions including storing vitamins & minerals, recycling red blood cells, producing blood proteins, and storing/releasing glucose to maintain blood glucose levels. Find the greenish **gallbladder** on the underside of the liver. The gallbladder stores the bile produced by the liver.

2. Locate the **stomach** and **spleen** in the upper left quadrant. The stomach is a J-shaped organ that looks like a deflated ball in the pig. The spleen looks like a long skinny tongue that is held to the stomach by **mesentery**. The spleen is bean-shaped in humans; it functions in immunity and red blood cell storage.

3. Beneath the stomach, find the **pancreas**, which is poorly defined, and looks like a small collection of tapioca or corn meal. The pancreas produces digestive enzymes and hormones (insulin/glucagon) for blood glucose homeostasis.

4. Find the small intestine, a mass of bends and coils held by mesentery. Find where the stomach attaches to the 1st part of the **small intestine** (=**duodenum**). The small intestine chemically digests & absorbs nutrients.

5. Find the **large intestine** or spiral colon in the pig. The last portion of the large intestine is the **rectum**, which leads to the **anus**. In the fetal pig, the colon will contain waste, which will become the first bowel movement (poop). Be careful not to puncture the colon. The large intestine looks like a question mark in the human.

6. Folding back the flap of the umbilical cord, find the **umbilical arteries**, which are two tubes where the umbilical cord enters the body. Between these arteries is the **urinary bladder**, which stores urine.

7. Push the intestines to the side, and locate both **kidneys** in the dorsal (back) side of the abdominal cavity. The kidneys filter wastes from the blood, which are carried to the bladder via the **ureters**, two dull colored tubes which drain to the urinary bladder. Sitting atop each kidney are the **adrenal glands**, which are easily viewed in the torso model.

*What structure separates the thoracic and abdominal cavities?_____

When finished with the dissection

Remove all dissecting pins, place these with your tools for

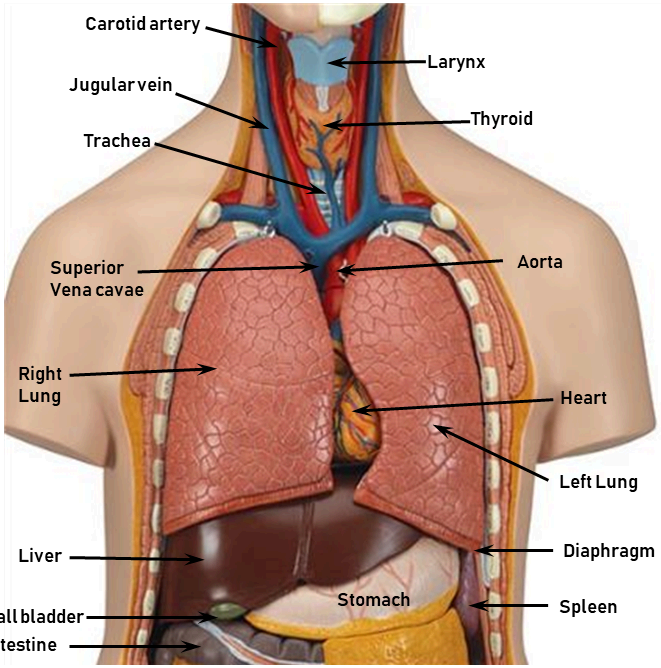
cleaning. Take the pig and tray to the sink. Leaving the strings on the pig, place it in the tub marked for used pigs. Clean your tray, tools, and beaker, then place them on the cart to dry. Spray and wipe down your work area and replenish all materials for the next lab. Thoroughly wash your hands with soap before handling any other materials.

Human Anatomy: Torso Model

Examine a Torso Model, Locate the Organs, Compare to the Fetal Pig:

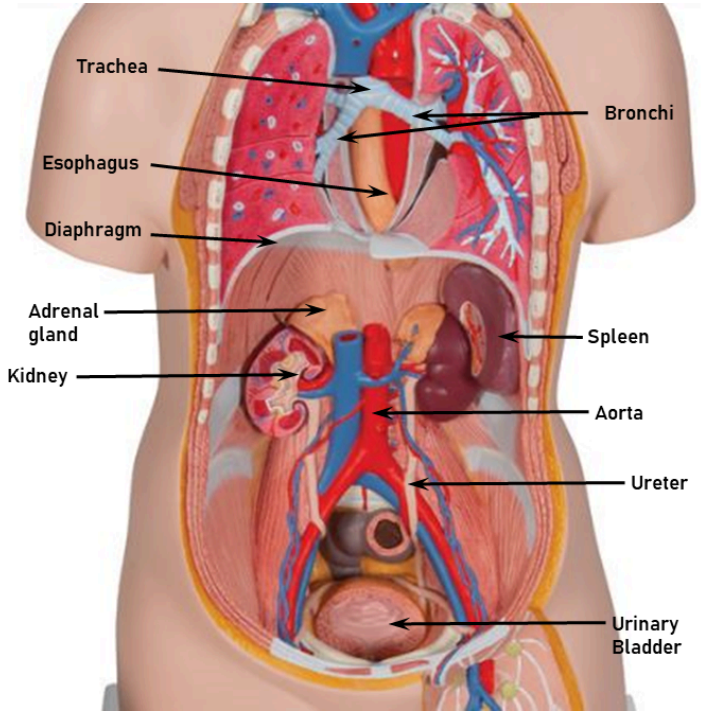
Following the checklist on your lab worksheet, find all structures listed for the torso model. You are responsible for knowing all listed terms for the lab practical- many of these are structures already studied in previous labs. Notice many structures, including the **carotid arteries, thyroid, aorta, adrenals, and ureters** that may not have been found on the fetal pig. Blood vessels are easier to find and identify. The structures and organs on your list won't necessarily be uniquely numbered or lettered- one to the next, many are the same.

*Attempt to take the torso model *completely* apart and put it back together correctly- looks easy, but it can be difficult, as it will only fit together one way.*



3B Scientific

b09 Classic Unisex Torso, 12-part



3B Scientific

b09 Classic Unisex Torso, 12-part

Review Questions- *complete using the lab manual, your textbook or other resources.*

What two features identify/define a mammal?

_____
_____
_____

What difficulty may occur if the epiglottis was surgically removed due to cancer?

_____

_____
_____

What structure separates the thoracic and the abdominal cavities? _____

Name two organs in the thoracic cavity and give a function for each._____

_____
_____
_____

Name the largest organ in the abdominal cavity and list two functions. _____

_____
_____
_____

Why is it proper to associate the gallbladder with the liver?

_____
_____
_____

Where is the pancreas located (near what other organ/structure)?_____

Name two or more **internal** differences between the fetal pig and the human organs.

_____
_____
_____

_____
_____
_____

Credits

Fetal pig images https://www.biologycorner.com/pig/review.html This work is licensed under a Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License.

Human torso model used with Permission of 3B Scientific, images from https://www.a3bs.com/classic-unisex-torso-12-part-1000186-b09-3b-scientific,p_58_186.html

BI 102 Lab Worksheet: Anatomy Name _____ Section _____

Other group members: _____

*Is your pig a female or male? _____ Observe a pig of the other gender for comparison.

List the number / letter of the parts on the torso model. If they are not labeled, find them and put a check mark in the blank. Find the corresponding parts on the pig. Ask the instructor for help.

Check if found on pig (in order of dissection)

_____ Umbilical cord
_____ Umbilical artery
_____ Umbilical vein
_____ Urogenital papillae (female pig only)
_____ Pharynx (a space)
_____ Epiglottis
_____ Larynx
_____ Thymus (pig only)
_____ Thyroid gland (on neck)*
_____ Trachea
_____ Esophagus
_____ Carotid artery
_____ Thoracic cavity (a space)
_____ Heart
_____ Atrium, left and right
_____ Ventricles, left and right
_____ Aorta
_____ Vena Cavae (superior & inferior)
_____ Lungs, left and right
_____ Diaphragm
_____ Abdominal cavity

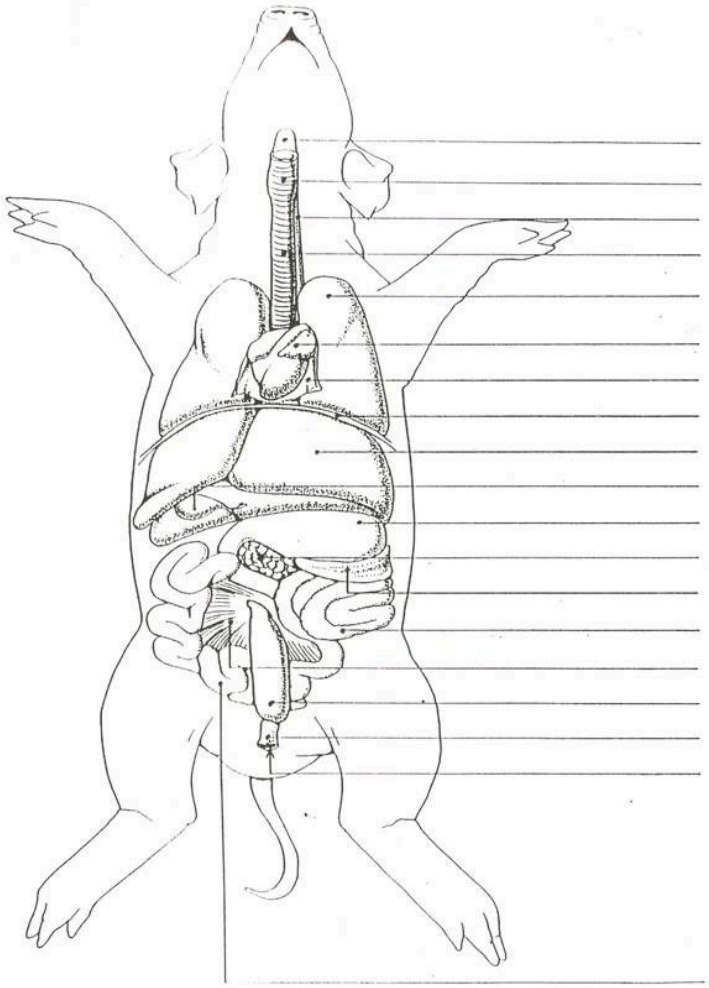
_____ Liver
_____ Gall Bladder
_____ Stomach
_____ Pancreas
_____ Spleen
_____ Small Intestine
_____ Duodenum
_____ Large Intestine
_____ Urinary Bladder
_____ Umbilical arteries
_____ Kidney
_____ Adrenal gland (atop kidneys)*

/ letter on torso model (top to bottom)

_____ Pharynx (not labeled, a space)
_____ Larynx
_____ Thyroid gland
_____ Trachea
_____ Esophagus
_____ Carotid artery
_____ Jugular vein
_____ Thoracic cavity (not labeled, a space)
_____ Heart
_____ Atrium, left and right
_____ Ventricles, left and right
_____ Aorta
_____ Vena Cavae (superior & inferior)
_____ Pulmonary trunk
_____ Lungs, left and right
_____ Diaphragm
_____ Abdominal cavity (not labeled, a space)
_____ Liver
_____ Gall Bladder
_____ Stomach
_____ Small Intestine
_____ Duodenum (part of the small intestine)

_____ Pancreas
_____ Spleen
_____ Large Intestine
_____ Cecum
Remove organs to find
_____ Aorta (abdominal)
_____ Vena Cavae (inferior)
_____ Kidney
_____ Renal artery (not labeled, red blood vessel)
_____ Renal vein (not labeled, blue blood vessel)
_____ Adrenal gland
_____ Ureter
_____ Urinary Bladder
*Note: Difficult to find on pig, but often color-coded and easier to locate on torso
OVER
What is the function of the following organs/structures?
a. Diaphragm:
b. Kidneys:
c. Pancreas:
d. Spleen:
e. Thymus:
f. Thyroid gland:
g. Umbilical artery/vein:
h. Liver:
i. Gall Bladder:

Label this figure:



9. Chapter 9

LAB 9

Reproduction and Development

Prepared by Dr. Jeff Ray, Dept. of Biology, UNA

OBJECTIVES

After completing these laboratory activities, you should understand / be able to:

- The basic structure and function of the male and female anatomy.
- The path of sperm in the male and female and the path of egg in the female.
- The process and locations of fertilization and implantation.
- Embryonic and fetal development in humans and the organs involved, using chick embryos for comparison.
- The composition & function of the placenta as a shared organ between mother and baby.
- The unique pathway for fetal circulation and the composition and function of the umbilical cord.

Human Reproductive Anatomy

Reproduction is a shared characteristic of all living things from bacteria to blue whales. Most animals reproduce sexually, and have

separate male and female genders. The production of egg and sperm cells via **meiosis**– those containing half the usual number of chromosomes (***n***, **haploid**) is a necessary precursor to sexual reproduction. The fusion of these haploid cells results in a genetically unique **diploid** (**2*n***) organism called a **zygote**, which then divides by **mitosis** to grow and differentiate into a fully formed offspring.

We will cover the male anatomy first since the remainder of the lab activity will focus on female anatomy, fertilization & implantation, offspring development, and pregnancy.

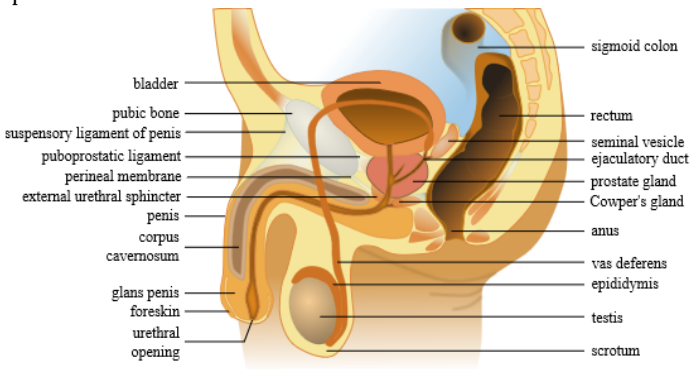
*Instructions**

Check the boxes as you complete each exercise

Male Anatomy

____ Observe the male pelvis model, find the numbers/letters indicated on the worksheet at the end of this lab activity.

The primary male sexual organs are the **testes** and **penis** which produce and deliver **sperm** to the female reproductive tract, respectively. The testes are also responsible for the production of male hormones called **androgens**. After production in the testes, sperm passes through a series of structures which help it to become fully functional. Accessory glands add important substances which facilitate the sperm to ultimately reaching the **egg**; collectively the sperm plus these substances is known as **semen**.



After initial formation in the testes, sperm pass through the following structures, in order:

The **epididymis** is a whitish mass of tightly coiled tubes against the testicles, acts as a maturation and storage for sperm before they pass into the vas deferens. The **vas deferens** is a thin tube approximately 12" long that carries the sperm from the epididymis to **ejaculatory duct**. From the ejaculatory duct, the sperm move through the **urethra** until their exit from the body. Sperm that do not leave via ejaculation are reabsorbed by the body.

Three accessory glands provide fluids that lubricate the duct system and nourish the sperm cells: **seminal vesicles**, **prostate gland**, and **bulbourethral glands** (Cowper's gland).

*What is the path of sperm in the male from where it forms to where it leaves the body?

(word bank: ejaculatory duct, epididymis, testes, urethra, vas deferens)

_____→ _____→

_____→ _____→

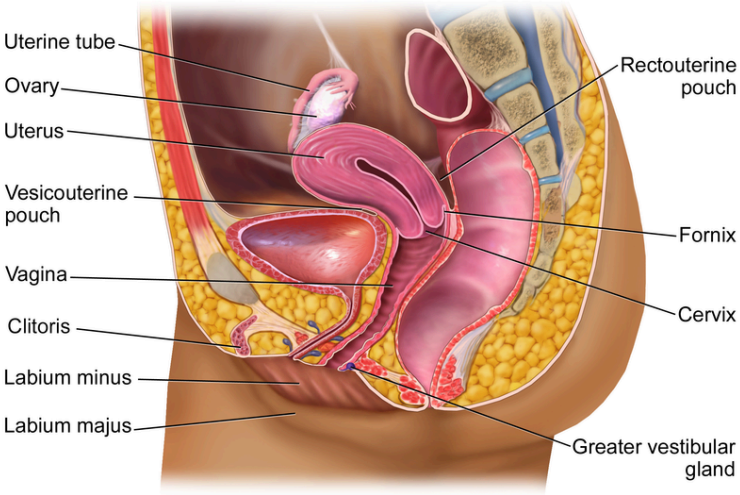
_____

Female

Anatomy

____ Observe the female pelvis model, find all numbers/letters indicated on the worksheet at the end of this lab activity.

Major reproductive organs of the female are the **ovaries**, **uterus**, and **vagina**. The female reproductive system involves hormonal communication between key organs, particularly the **ovaries** and **uterus**, whose basic functions are to produce the egg, and house the developing embryo, respectively.



The Female Reproductive System

The **ovaries** are paired and produce both eggs and sex hormones (e.g. estrogen); they are the functional equivalent of the male testes. Ovaries are about the size of a walnut, and at birth contain approximately two million ova (eggs) each. During nearly every menstrual cycle, one (or more) eggs mature and are released during **ovulation** from the **follicle** within the ovary, which also releases **estrogen**. Upon release, the egg passes into a narrow tube known as the **oviduct** (uterine tube) which is lined with cilia that sweep the egg towards the uterus.

The **uterus** is fist-sized and thick smooth muscle that contracts during labor & childbirth. The interior lining of the uterus is the **endometrium**, which thickens during the menstrual cycle in anticipation of housing the developing offspring. The lowermost portion of the uterus narrows into an opening known as the **cervix**.

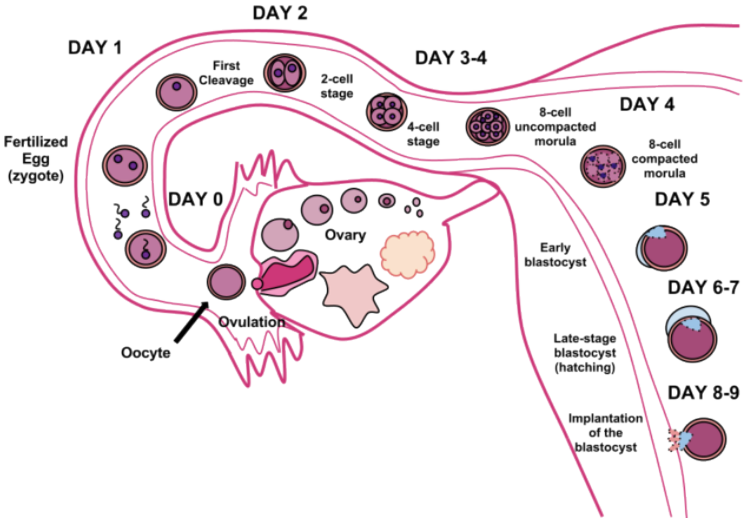
The **vagina** is a muscular organ that serves as a passageway into and out of the uterus. Externally, the female reproductive anatomy (known as the **vulva**) includes the **labia major**, **labia minor**, and **clitoris**.

Fertilization and Implantation

_____ Observe the fertilization model, find the locations of fertilization & implantation, and trace the path of egg and sperm in the female.

Fertilization & **Implantation** occur in separate locations and at different times; implantation normally occurs about 8 days post-fertilization. **Fertilization** (conception) is the process by which the nuclei of a single-celled egg and sperm fuse to form a **zygote**. Fertilization normally occurs in the **oviduct** (uterine tube), where the egg travels from the **ovary**. To reach the egg, sperm cells must travel a distance approximately 100,000 times their body length, which is equivalent to a person running a 110 mile race! Predictably, not all sperm reach the egg, and the first ones that do, generally do not fertilize the egg, since they must penetrate the outer covering of the egg; a single sperm that follows ultimately fuses with the nuclei of the egg to form the **zygote**.

The **zygote** is swept by cilia that line the oviduct toward the **uterus**. As it slowly moves, it undergoes successive rounds of **mitosis** that build the single cell into a hollow ball of ~100 cells called a **blastocyst**. After approximately one week, it will reach the uterus where implantation occurs in the blood vessel-rich tissue of the uterus, the **endometrium**. On occasion, the blastocyst will not reach the uterus and may start to implant on the oviduct. If so, the pregnancy is *inviable* as this location is not large enough to allow for embryo growth – this is known as an **ectopic or tubal pregnancy**. An egg, even if fertilized, may also fail to implant in the uterus and then leaves the body during **menstruation**.



Locations of fertilization and implantation

*Where does fertilization normally occur?

_____

*Where does implantation normally occur?

_____

*What is the path of the egg from where it forms to where it leaves the body if not fertilized?

(word bank: cervix, ovary, oviduct, uterus, vagina)

_____→ _____→ _____→ _____→ _____

*What is the path of the sperm from where it enters the female to where it fertilizes the egg?

(word bank: cervix, oviduct, uterus, vagina)

_____→ _____→ _____→ _____

Early Stages of Development (Chick Embryo)

If the **blastocyst** successfully implants into the endometrium and continues with mitosis and development, a predictable series of structures form. Three embryonic tissue (or germ) layers

(**endoderm, mesoderm, ectoderm**) are established, and the organ level of development continues until all organs have formed. The first organs to develop are the 1) **heart**, 2) **brain & neural tube**, and 3) **digestive tract**.

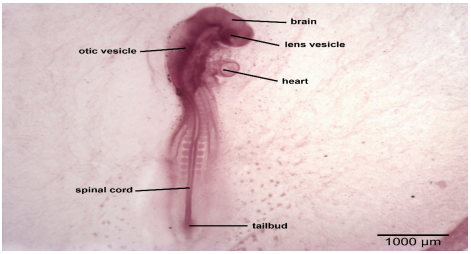
_____ Examine the early stages of development in the chick embryos under the microscopes. On your worksheet, sketch the stage(s) of the chick embryo and identify/label at least 2 structures.

24 Hour Chick Embryo

Early structures that are visibly forming include **somites** (blocks of developing muscle tissue), **head fold**, **notochord** (below surface), **neural groove and fold**, and surface ectoderm. See the figure next to the microscope for complete details.

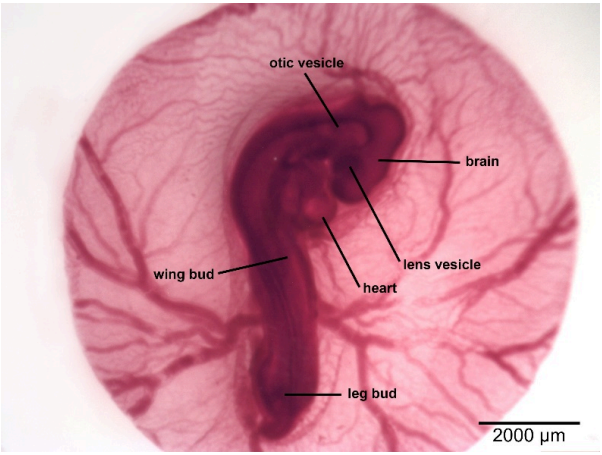
38-43 Hour Chick Embryo

Many organs are now more clearly visible: the **heart** is now contracting and circulating blood; the **brain** has several distinct regions (forebrain, midbrain, hindbrain); the **eye** has a developing lens; the **somites** enlarge; the **neural tube** is clearly visible.



72-Hour Chick Embryo

In addition to the clearly visible heart, eye, brain, and other major organs, a wingbud and hindlimb bud have noticeably formed. The brain has continued to differentiate, while the neural tube has closed along the length of the body—it is now called the **spinal cord**.



96-Hour Chick Embryo

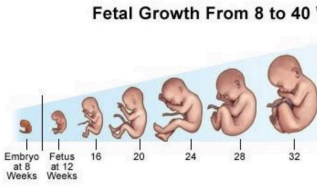
Tissue differentiation has continued to produce visibly distinct organs. The amnion noticeably surrounds the embryo and the number of somites has increased.

Human Embryonic & Fetal Development

_____ Observe & measure the embryo/fetal models on the back table (from 4 wks to 6 mo. gestation).

Normal human development requires a full nine months (40 weeks) of gestation to support a fully functioning offspring. **Embryo development** includes the first eight weeks (two months). By the end of development, all organs have initially formed, but are not functional enough to support independent life. During **fetal development** (seven months), organs mature and become functional; dramatic weight gain also occurs. The offspring increases greatly from <1" at 4 weeks to about 20" at 38 weeks. It will double in weight from about 4 to 8 pounds between months 7 and 9.

*At _____weeks the baby is 1.5 inches long (use ruler). Size at 5 months (20 weeks)? _____ inches



The Placenta & Pregnancy

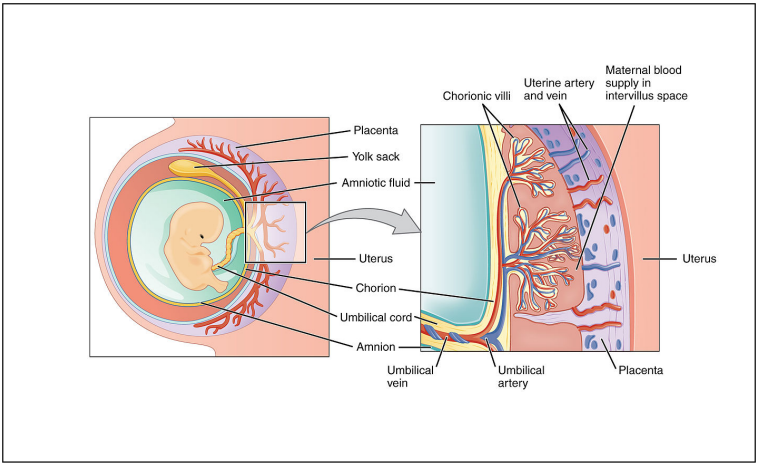
Placenta

The **placenta** is a large, blood vessel-rich organ containing tissues from both mom and offspring. It serves as an interface that allows for exchange of nutrients and wastes, while keeping mom and offspring isolated from each other. Blood is not exchanged between mom—offspring, as their bodies may contain incompatible differences (including blood type) between their immune systems.

The fetus is housed in the uterus (womb) and connected to the mother via the umbilical cord which leads to the placenta. The maternal portion of the placenta is the **endometrium**. The fetal portion of the placenta is the **chorion**. In addition, the **amnion** is the layer in which the fetus is housed and surrounded by protective **amniotic fluid**.

*What materials are exchanged between mother and fetus at the placenta? _____

* At the placenta, blood **IS / IS NOT** exchanged between mother and fetus?

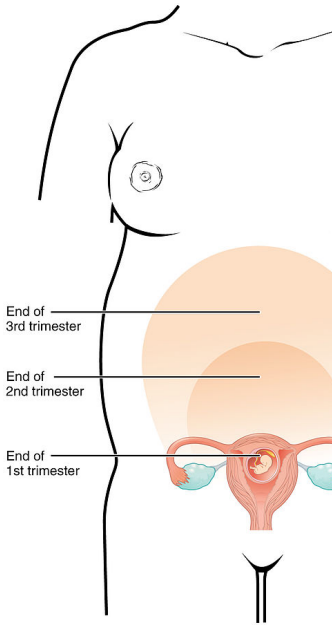


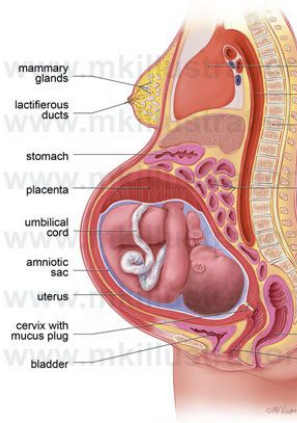
Pregnancy

_____ Examine the pregnancy model, be sure to find and name the following structures: 31, 37, 38:

Pregnancy, also known as **gestation**, lasts approximately 267 days from conception to birth (280 days if calculated from the last menstrual period to childbirth). Pregnancy can be divided into trimesters, each is approximately three months long. The first trimester has the highest possibility of miscarriage (natural death of embryo or fetus). During the second trimester, fetal movements may be felt. At 28 weeks, more than 90% of babies can survive outside of the uterus if provided with high-quality medical care. The third trimester is marked by rapid weight gain.

Major anatomical, metabolic, and physiological changes occur in the mother, including considerable weight gain occurs during a normal pregnancy. As pregnancy progresses, the uterus pushed into the abdominal cavity, exerting pressure on many organs, collecting pushing up against the diaphragm. Physiological changes may include morning sickness, which is thought to be related to elevated hormone levels.



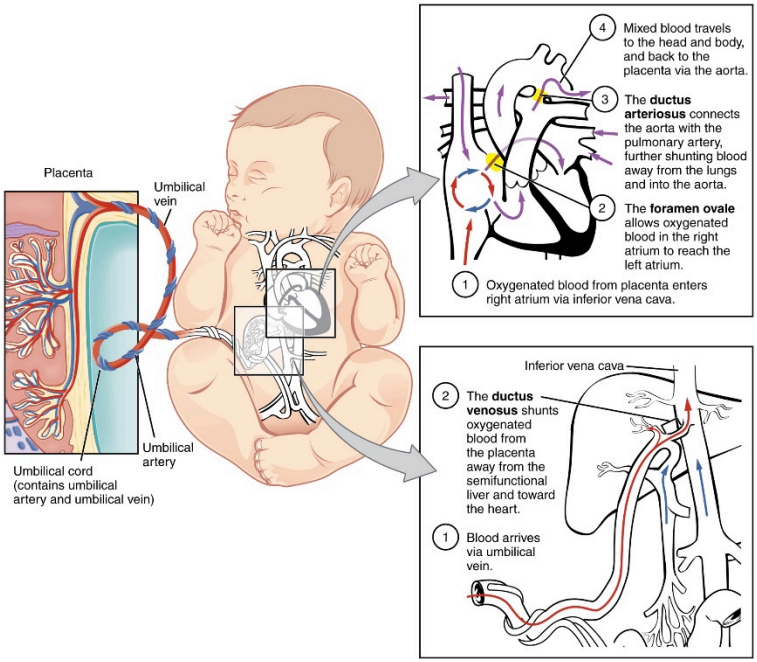


- * Using the pregnancy model, which maternal organs are *most* compacted by the fetus? _____
- * Name the two structures (#36-37) the fetus must pass through during birthing: _____, _____

Fetal Circulation Model

___ Observe the fetal circulatory system model and find the **oval opening** and the **arterial duct.**

Two structures in the fetal heart are present that allow blood to bypass a non-utilized organ in the baby—the **lungs**. In the heart, the **oval opening** (foramen ovale) between the *right atrium* and *left atrium* shunts blood away from the lungs. Also, the **arterial duct** (ductus arteriosus) connects two blood vessels, the *pulmonary trunk* and the *aorta*, to again shunt blood away from the lungs. These structures close after birth in normal development: the oval opening becomes the **fossa ovalis**, while the arterial duct becomes the **ligmentum arteriosum**.



* Which two chambers of the heart are connected by the **oval opening**? _____, _____

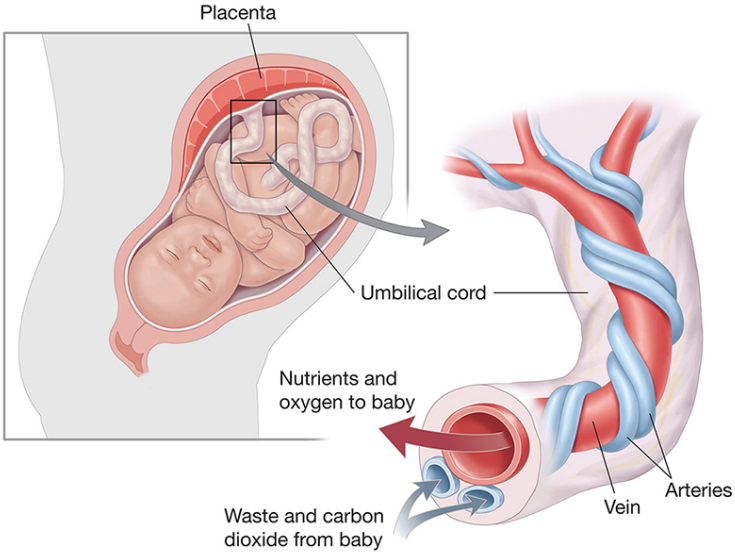
* The **arterial duct** connects which two blood vessels? _____, _____

* Which structure is *non-functional* and being bypassed by the blood? _____

Umbilical Cord

____ Find the **umbilical arteries and vein** in the model.

The **umbilical cord** contains a total of 3 blood vessels within it, these facilitate movement of nutrients and wastes between the fetus and the placenta. There are **two umbilical arteries** going from the fetus to the placenta and **one umbilical vein** going from the placenta to the fetus (specifically to the liver of the fetus). The umbilical arteries carry wastes *away from the fetus* including CO_2 (they are O_2-poor); the umbilical vein brings O_2 and nutrients to the fetus. Following birth, the umbilical arteries and vein become non-functional: the umbilical vein becomes the **round ligament** of the liver, the umbilical arteries regress and become the medial umbilical ligament, and a branch of the anterior division of the internal iliac artery. After it is cut, the remnants of the umbilical cord become the navel or "belly button."



* Do the umbilical arteries carry O_2 rich or O_2 poor blood? _____

* What does the umbilical vein become once the fetus is born?

_____

_____

_____

Male anatomy By Male_anatomy.png: alt.sex FAQderivative work: Tsaitgaist (talk) – Male_anatomy.png, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=6569849By Ttrue12 – Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=19679961

Female anatomy By BruceBlaus. When using this image in external sources it can be cited as:Blausen.com staff (2014). "Medical gallery of Blausen Medical 2014". WikiJournal of Medicine 1 (2). DOI:10.15347/wjm/2014.010. ISSN 2002-4436. – Own work, CC BY 3.0, https://commons.wikimedia.org/w/index.php?curid=29600451

48 hour chick embryo https://sites.newpaltz.edu/histology/developmental-biology/chick/chick-48hr-1x/

72 hour chick embryo https://sites.newpaltz.edu/histology/developmental-biology/chick/chick-72hr-0-6x/

Blastocyst By Seans Potato Business (derivative of the source cited above) – Blastocyst.png, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=3306843

Fetal Growth by https://medium.com/@sonal9896225664/stages-of-pregnancy-649b2588423b

Embryo attached to placenta in amniotic cavity By OpenStax College – Anatomy & Physiology, Connexions Web site. http://cnx.org/content/col11496/1.6/, Jun 19, 2013., CC BY 3.0, https://commons.wikimedia.org/w/index.php?curid=30148598

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Pregnancy anatomy by http://baldaivirtuves.info/wp-content/uploads/2017/12/human-anatomy-pregnancy-human-anatomy-pregnancy-anatomy-detail-birth-example-human-free-ideas.jpg

Umbilical cord By http://www.jdimesmedivisual.com/wp-content/gallery/anatomy/BC_Umbilical-Cord_FINAL.jpg

BI 102 Lab Worksheet: Reproductive Name _____ Section _____

1-2. Number the following structures of the reproductive system on the male & female models on your lab table

Male

_____ Epididymis
_____ Vas deferens
_____ Testis
_____ Prostate gland
_____ Scrotum
_____ Urethra
_____ Ureter (look at urinary system)
_____ Urinary bladder
_____ Penis

Female

_____ Vagina
_____ Oviduct
_____ Ovary
_____ Urethra
_____ Cervix
_____ Uterus
_____ Urinary bladder
_____ Clitoris
_____ Rectum

3. In the human female, where does **fertilization** occur? (where sperm & egg fuse; see model) _____

4. In humans, the embryo/fetus develops in which part of the

mother's body (hint: also called the womb)? _____

5. Using the pregnancy model at your table, which maternal organs are most compacted by the fetus?

6. *Go to the Microscopes*: sketch, label & list **2** structures visible in the chick embryo. List embryo stage.

Sketch Structure Name

Stage (days or hours)

A.

B.

Go to the back counter:

7. At _____weeks the baby is 1.5 inches long (use ruler). Size at 5 months (20 weeks)? _____ inches

8. In humans, **embryonic** development occurs during the first _____ months, **fetal** development occurs during the last _____months.

Go to the front cart:

9. The placenta has a fetal (baby) & maternal (mom) portion. Which forms the fetal portion of the placenta? _____.

Which forms the maternal portion? _____

10. **Oval opening** (*foramen ovale*): an opening between which two chambers of the heart? (see model)

_____
_____

11. **Arterial duct** (*ductus arteriosis*) a blood vessel connecting which two blood vessels?

_____
_____

12. What organ is bypassed by much of the blood in fetal circulation using structures in Q# 10-11 (not used, mom does this task)? _____

10. Chapter 10

LAB 10

Plant Diversity & Flowering Plant Organization

Prepared by Jason R. Jones, University of North Alabama

OBJECTIVES

After completing these laboratory activities, you should understand/be able to:

- Define the terms *angiosperm*, *autotroph*, *bryophyte*, *consumer*, *eudicot*, *gametophyte*, *gymnosperm*, *heterotroph*, *meristem*, *monocot*, *producer*, *pteridophyte*, *secondary growth*, *sporophyte*, *vegetative propagation*
- The basic anatomy of plant roots, stems, and leaves.
- The three basic types of tissues in vascular plants: *dermal tissue*, *ground tissue*, and *vascular tissue*
- The two types of vascular tissue in plants, and what they transport: *xylem* (water & ions), and *phloem* (transports sugars)
- Identify each of the following structures on a plant: *leaf*, *blade*, *petiole*, *node*, *internode*, *axillary bud*, *apical bud*, *taproot*, *lateral roots*.
- The major anatomical differences between monocots and eudicots.
- The botanical distinction between vegetables and fruits.
- Give examples of vegetables and recognize whether the eaten portions are roots, stems, or leaves.

- Examine secondary (woody) growth in angiosperms, and learn how to determine the age of trees.

INTRODUCTION

Plants are a crucial part of every ecosystem on Earth. Through the process of **photosynthesis**, plants combine carbon dioxide, water, and light energy harvested from the sun, and store that energy in the form of the chemical bonds in glucose and other carbohydrates. Since plants make their own food, they are referred to as **producers** (or **autotrophs**, literally "self feeders"). This energy is then available to other organisms (**consumers**, aka **heterotrophs**) that utilize this stored energy.

Plants are an extremely diverse group of organisms, with an estimated **300,000 species** globally. Of this diversity, plants can be further broken down into several sub-groups:

- **Bryophytes** (non-vascular plants, including mosses, liverworts, and hornworts – approximately 22,750 species
- **Pteridophytes** (vascular seedless plants, including ferns, horsetails, and their relatives) – approximately 15,000 species
- **Gymnosperms** (vascular non-flowering seed plants including conifers and their relatives) – approximately 1,050 species
- **Angiosperms** (vascular flowering seed plants): plants with specialized tissues for transport of water and nutrients; produce seeds housed inside fruits which are derived from flowers – about 250,000 species

In this lab, you will examine the diversity and anatomy of **angiosperms**, or flowering plants., particularly the three main organs in flowering plants: **roots**, **stems**, and **leaves**. The lab is set up with several different stations at each lab table, you must visit each lab table, and observe the various materials at each. The stations can be completed in any order you like.

Answer all questions in the worksheet at the end of this lab exercise.

STATION I: Plant Diversity

At this station, there are several examples of **angiosperms** (flowering plants). a**ngiosperms**, are vascular plants that produce flowers, fruits, and seeds. Angiosperms are divided into two major groups, the **monocots** and the **eudicots**, based on several different characteristics, some of which are shown in Figure 4 below.

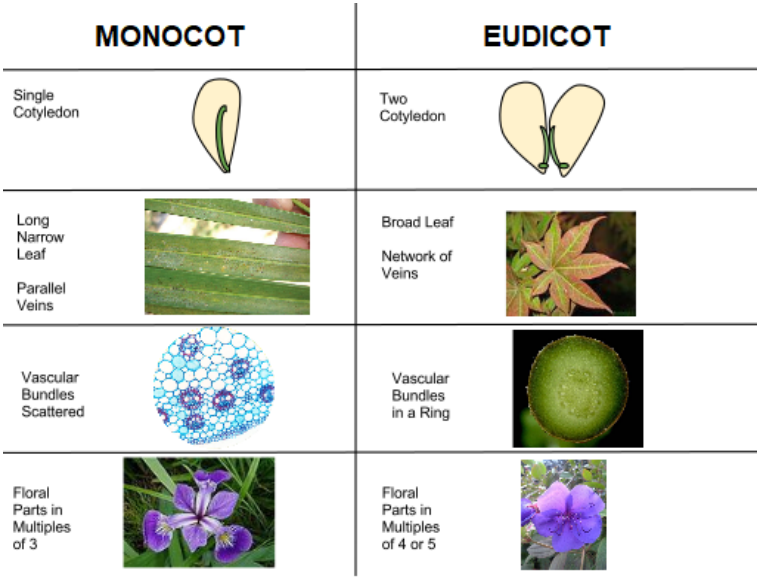

Figure 4. Several differences between monocots and eudicots. Credit: Flowerpower207 on Wikipedia (modified). (*https://en.wikipedia.org/wiki/Monocotyledon#/media/File:Monocot_vs_Dicot.svg*)

Using the characteristics of leaves and flowers as shown in Figure 4, determine whether each Angiosperm at this station is either a Monocot or a Eudicot, and fill in the table on the worksheet at the end of this lab exercise.

Basic Angiosperm Anatomy

All angiosperms consist of two major organ systems: the subterranean (below ground) **root system**, and the above ground **shoot system**. The shoot system also includes other important plant organs: **leaves**, and in angiosperms only, **flowers**. Overall, however,

the major non-reproductive organs of angiosperms are **roots**, **stems**, and **leaves**.

The root system of monocots and eudicots are different. Monocots have a root system that is referred to as a **fibrous root system**, composed of many roots all about the same size. Eudicots, on the other hand, typically have one large central root, called the **taproot**, which may have many smaller lateral roots extending from it. The root systems of plants serve several functions: (1) anchor a plant into place, (2) absorb water and minerals from the soil in which they grow. Examine the modified roots that serve *other* purposes in some plants.

The shoot system of angiosperms includes both the **stem** and **leaves**. The primary function of most stems is to provide support to the leaves, which are the primary site of glucose (food) production during photosynthesis. The stems of angiosperms can be divided into several regions. The points at which leaves emerge from the stem are referred to as **nodes**, and the lengths of stem in between the nodes are called **internodes**. The leaves themselves can be divided into two main regions. The **blade** of the leaf is the large, expanded portion of the leaf where the majority of chloroplasts (the site of photosynthesis) can be found, and the **petiole** is the stem-like portion of the leaf that attaches it to the stem. Occasionally buds, which can produce either new leaves or flowers can be found on the stem. Buds that are found at the tips of stems are referred to as **apical buds**, while buds found along the axis of the stem are called **axillary buds**. Familiarize yourself with the previously described angiosperm anatomy, using Figure 5 to assist you.

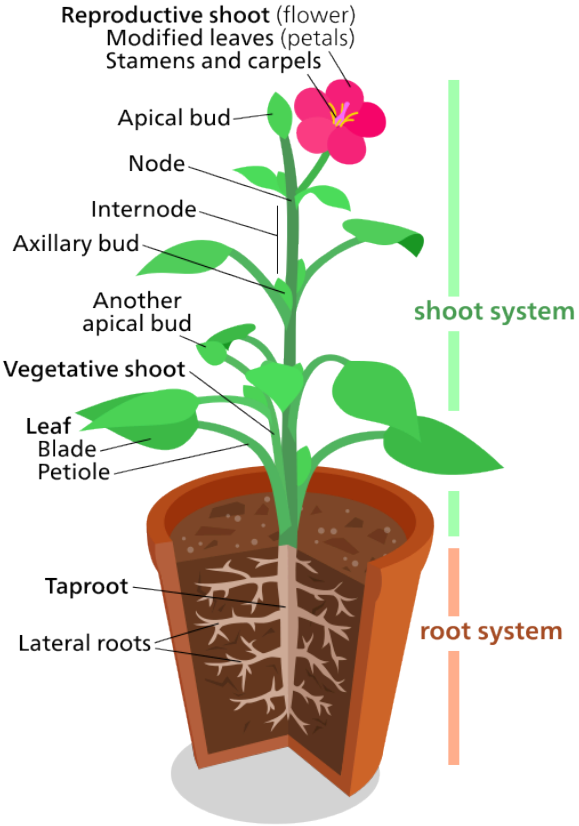

Figure 5. Basic eudicot anatomy. Credit: Kelvinsong on Wikipedia (*https://en.wikipedia.org/wiki/Botany#/media/File:Plant.svg*)

STATION II: Root Anatomy & Diversity

Examine the basic anatomy of roots, compare the root systems of monocots and eudicots, examine a few adaptations of roots for different purposes, examine relationships between plant roots and other organisms, and also observe several roots used as food.

First, examine the model of a monocot root. Make sure you are able to locate and identify the following structures, and their functions. Notice the three main types of tissues found in vascular plants: **dermal tissue**, which forms the "skin" of plants, and protects,

ground tissue which mostly serves as support tissue, and a site for storage/secretion of materials, and **vascular tissue**, which transports water and nutrients throughout plants.

Locate the root **epidermis**. The epidermis is the outer layer of cells covering the root's surface, and mostly provides protection to the root. Next, look at the cross sectional view from the top of the model, and locate the **cortex**, which is composed of parenchyma cells (ground tissue), and forms the majority of the interior of the root. Next, locate the two types of vascular tissue in the root. **Xylem**, which transports water throughout vascular plants, is composed of two different types of cells (tracheids and vessel members), both of which are actually dead at functional maturity. **Phloem**, which transports sugars in vascular plants, consists of several types of cells, including sieve elements, companion cells, fibers, and parenchyma cells, which are alive at functional maturity.

Also locate the **root apical meristem** on the root model. In plants, **meristems** are areas of plant tissue where active cell division takes place. The word "apical" means "near the tip", so this is the region of active cell division near the root's tip where root elongation occurs. Incidentally, the tips of plant shoots also have apical meristems, which lengthen the shoots. Some plants also have **lateral meristems** that increase root/shoot girth instead of length.

Also notice that the tips of roots are protected by a **root cap**. The root cap is produced by cells formed during cell division at the apical meristem. Initially, these cells differentiate into a type of cell called columella cells, which contain structures that allow for gravity detection, and thus directs the root to grow downward. If the root cap is removed from a root, the root would grow in random directions instead of downward. The root cap also serves to protect the delicate, newly-produced cells generated during cell division at the apical meristem, as well as to lubricate the root, allowing it to more easily penetrate the soil. Additionally, notice that the exterior of the root has multiple projecting **root hairs**. Using the model, answer the questions on the worksheet at the end of this lab exercise.

Comparing monocot and eudicot roots

The root systems of monocots and eudicots are different. Firstly, the root systems of monocots consist of numerous small roots that are all about the same size in diameter. This is what is referred to as a **fibrous root system**. Eudicots, on the other hand, typically have one large central root called a **taproot**, which may have numerous smaller **lateral roots** that extend from it. Grass would be a good example of a monocot showing a fibrous root system, and a carrot (a eudicot) would be a good example of a taproot. The roots of monocots and eudicots also differ in terms of the arrangement of their vascular tissue, which you will examine later at another station.

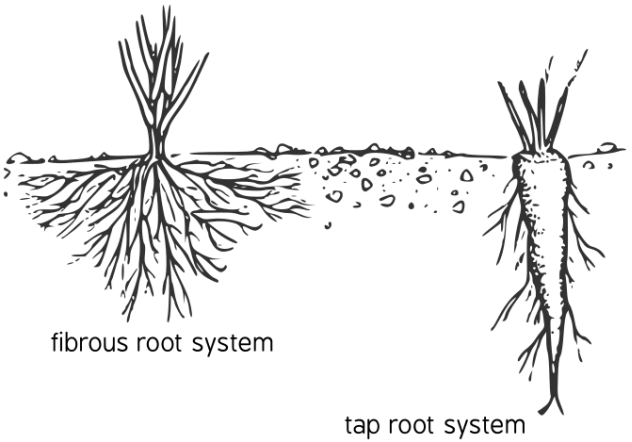

Figure 6. Fibrous and tap root systems.

Look at the provided sedge (grass) and dandelion plants. Compare their roots and answer the questions on the worksheet at the end of this lab exercise.

Normally, roots typically develop from other root tissues. However, occasionally, plants will develop new roots from other plant organs, such as stems or leaves. These types of roots are known as **adventitious roots**, and they may play additional or different roles beyond those performed by "normal" roots. Two examples of plants displaying adventitious roots are provided: **English ivy** and **corn**, both of which develop adventitious roots

that arise from stem tissue. Examine these adventitious roots, and answer the questions about them on the worksheet at the end of this lab exercise.

Finally, observe the examples of root vegetables provided at this station. If you are curious about the technical botanical difference between vegetables and fruits, that distinction is made based on which plant part is being eaten. Vegetables, botanically speaking, are edible plant parts that are derived from either the roots, stems, or leaves of plants, while fruits are edible plant parts that are derived from the ovary/ovaries of flowers, and contain seeds. At this station, you may notice that there are some vegetables you'd expect to see here, as you might think of them as roots, but you may be surprised to actually correctly find them placed at another station.

Answer the questions on the worksheet related to the root model.

STATION III: Stem Anatomy & Diversity

The main functions of plant stems are to support the organs of photosynthesis, the leaves, but also to carry water and minerals to the leaves (through xylem), and to carry sugars made during photosynthesis to other parts of the plant (through phloem). At this station, you will be observing the major differences between the stems of monocots and eudicots, observing several examples of modified stems, learning a few vegetables that are composed of stem tissue, and examining **secondary growth** (also known as **woody growth**) in eudicots, and learning how to determine the age of trees by examining this secondary growth.

The stems of both monocots and eudicots contain all three major types of plant tissue: dermal tissue, ground tissue, and vascular tissue. Observe the models of both monocot and eudicot stems, and locate the following structures on each: **epidermis** (composed of dermal tissue), **cortex** (composed of ground tissue), and the **xylem** and **phloem** (vascular tissue). Also notice that in stems, the vascular tissue is arranged in **vascular bundles**, which are surrounded by **vascular bundle girdles**. Notice that the way that these vascular bundles are arranged differs in monocots and eudicots. Use these

models to answer the questions about stem anatomy on the worksheet at the end of this lab exercise.

Now you will examine some examples of modified stems that do not look like "typical" stems. These include specialized stems called **stolons**, **rhizomes**, **bulbs**, and **tubers**.

First, look at the herbarium sheet showing a grass plant exhibiting a **stolon**, which is a horizontal plant stem that takes roots at points along its length to form new plants, or, in other words, is a means for plants that have them to engage in **vegetative propagation**, which is a form of asexual reproduction that produces new plants that are clones of the original parent plant. For another example of vegetative propagation, you can also examine the mother of thousands plant at Station 1. Another example of a stolon can be seen in Figure 7.

Figure 7. Vegetative propagation in a grass through the use of stolons.

Another type of modified stem is a **rhizome**, which is similar to a stolon. A rhizome is a a horizontal underground stem that puts out lateral shoots and adventitious roots. This type of modified stem can be seen in plants such as irises, and also ginger. Examine the provided iris and ginger rhizomes, and note the lateral shoots and

adventitious roots on the iris rhizome. An example of a rhizome can also be seen in Figure 8.

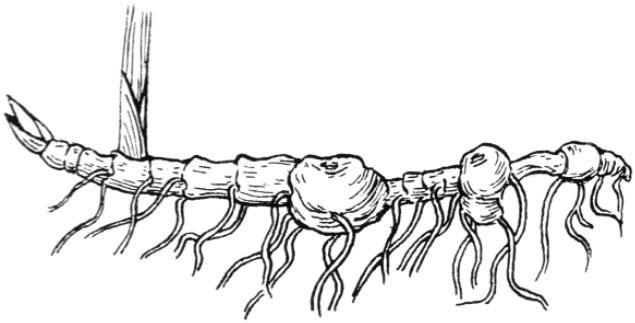

Figure 8. A rhizome.

Another type of modified stem is a **bulb**. A **bulb** is an underground stem that consists of one or more buds enclosed in overlapping fleshy or membranous leaves. Bulbs primarily serve as food storage organs as a source of stored carbohydrates that are used during periods when the rest of the plant is dormant. Some examples of bulbs that are used as food include **onions, garlic, and shallots**. Even though you might think of these as "root vegetables", they truly are not, as the part that is eaten is actually stem tissue. Examine the provided onions and garlic, and observe the small roots at the base of the bulb.

A final type of modified stem that you will examine this week is the **tuber**. A **tuber** is a much thickened underground part of a stem, serving as a food reserve, and producing buds from which new plants arise. A classic example of a tuber used as food is the white potato. Potatoes are very rich in starch, which is a polymer of glucose molecules. In this way, tubers are similar to bulbs, in that both serve as underground food storage organs for the plants that produce them. Incidentally, the "eyes" of potatoes are buds that can produce new potato plants.

Finally, at this station, you will observe **secondary growth**, also known as **woody growth**, which produces (unsurprisingly) wood. True woody growth is only seen in eudicots, and not monocots. In secondary growth, woody eudicots produce additional vascular

tissue (xylem and phloem) as they grow, as well as bark, consisting of new ground and dermal tissue. These additional tissues are actually produced by two lateral meristematic regions (remember, meristems are areas of active cell division in plants). Also, since these meristematic regions are lateral tissues, cell division in each of these meristems results in an increased girth in woody plants as they grow.

In eudicots that exhibit secondary (woody) growth, the meristematic region that produces new vascular tissue is a layer called the **vascular cambium**, which is a layer found between the primary xylem and primary phloem. As woody eudicots grow, new layers of secondary xylem and secondary phloem are formed, increasing the diameter of the eudicot, forming the characteristic growth rings that can be observed in woody eudicots. The actual tissue that is referred to as **wood** is actually the **secondary xylem** tissue. The darker wood towards the center of woody eudicots is often referred to as **heartwood**, and consists of dry dead cells that no longer transport water, and primarily serves to support the woody eudicot. The lighter wood surrounding the heartwood is known as the **sapwood**, which contains xylem that is actually transporting water and nutrients through the plant.

Additionally, as woody eudicots grow, another layer of lateral meristematic tissue called the **cork cambium**, produces **cork**, a protective substance consisting of dead cells, and new epidermal tissue, as well as new living parenchyma tissue, all of which constitute the **bark**. See Fig. 9 on the following page for an illustration of secondary growth.

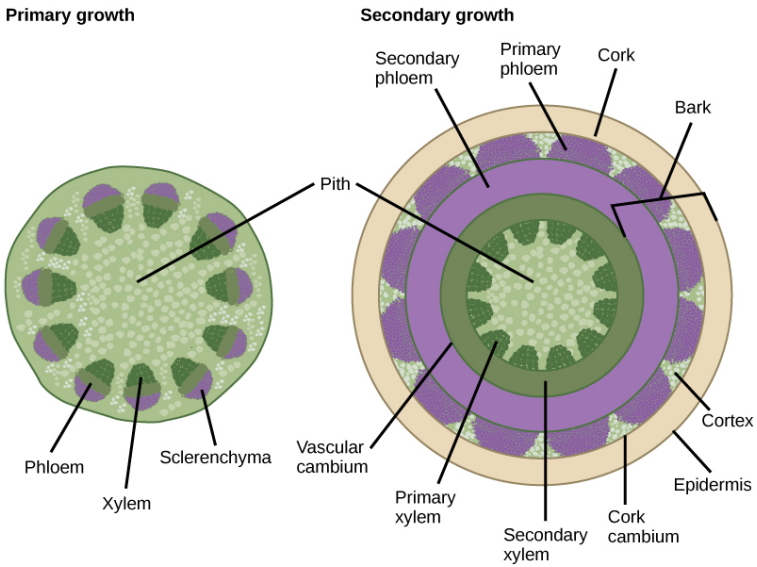

Figure 9. Differences between primary and secondary growth in eudicots.

Examine the model of secondary growth in woody eudicots, which is essentially a model illustrating a cross section through a tree. Using Figure 9 on the previous page, try to identify the primary xylem, primary phloem, vascular cambium, secondary xylem, secondary phloem, cork cambium, cork, and epidermis. Also, notice the ring-like pattern of growth in the wood, which displays wider, lighter colored rings called **early wood**, and thinner, darker rings called **late wood**. The early wood, per its name, is produced during periods of rapid growth in the spring and early summer, and late wood is produced in late summer and fall. The rings of late wood are thinner because growth is slower during that time of year. Together, a single ring of early wood and the following single ring of late wood represent a single year's worth of growth, and are referred to as **annual rings**. See Figure 10 below for an example of these.

Examine the provided "tree cookies" (yes, they're actually called that!) of various woody eudicot species, and see if you can determine how old they were when they were cut. Pick at least 2 of

the available species, and record your estimates of their age when cut on the worksheet at the end of this lab exercise.

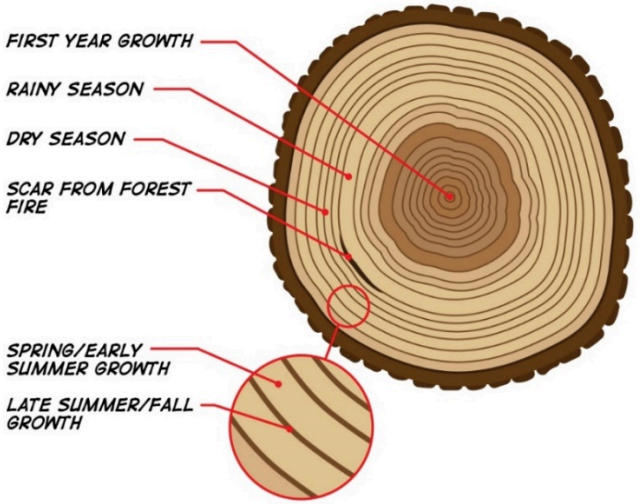

Figure 10. Annual growth rings in trees.

STATION IV: Leaf Anatomy & Diversity

Leaves are the primary photosynthetic organs in plants. At this station, familiarize yourself with basic leaf anatomy, examine the major difference between the leaves of monocots and eudicots, learn about various characteristics of leaves, examine the differences between simple and compound leaves, as well as observe several examples of leaves used in food, and for other culinary purposes.

The basic structure of angiosperm includes all three types of plant tissues (dermal, ground, and vascular tissues). The upper and lower surfaces of leaves consist of single layers of dermal cells arranged to form the **epidermis** of the leaf. In many species, these epidermal cells produce a waxy secretion deposited on top of the epidermal cells, and formsia protective called the **cuticle**, which primarily serves to reduce water loss. On the lower epidermis, pore-like openings called **stomata** (singular = **stoma**)primarily function

in gas exchange. During photosyntheis, plants use carbon dioxide as a carbon source for producing glucose, and CO_2, enters the leaf through the stomata. Plant cells also produce oxygen as a waste product during photosynthesis; O_2, is also released from leaf tissue through the stomata. The drawback of having stomata openfor gas exchange, is that water is lost from the leaf. Fortunately, plants regulate when stomata are open, in the form of two bean-shaped **guard cells** on either side of each stoma. When conditions are hot and dry, the guard cells change shape to close the stomata to reduce water loss in this way.

Just beneath the upper epidermis is a layer of ground tissue called the **palisade mesophyll**, whose cells contain numerous chloroplasts, the site of photosynthesis. The cells of the palisade mesophyll are arranged in a very regular fashion, making this layer easy to distinguish. Below the palisade mesophyll, is another layer of mesophyll tissue (also containing numerous chloroplasts) called the **spongy mesophyll**. Spongy mesophyll cells are arranged much more haphazardly than the palisade mesophyll, and have lots of air spaces between them, which allow for more efficient air circulation and gas exchange.

Additionally, leaves of vascular plants such as angiosperms also possess vascular tissue in the form of **xylem** and **phloem**, which, in the leaves, take the form of **vascular bundles** that form **veins**. The xylem in leaf veins brings water from the roots (through the stem) to the leaf tissue, and the phloem in leaf veins carries sugars manufactured in the leaves during photosynthesis to other parts of the plant. Examine Figure 11 on the following page and the provided leaf tissue model, and try to identify each of the structures shown below on the leaf model. Answer the questions on the worksheet at the end of this lab exercise.

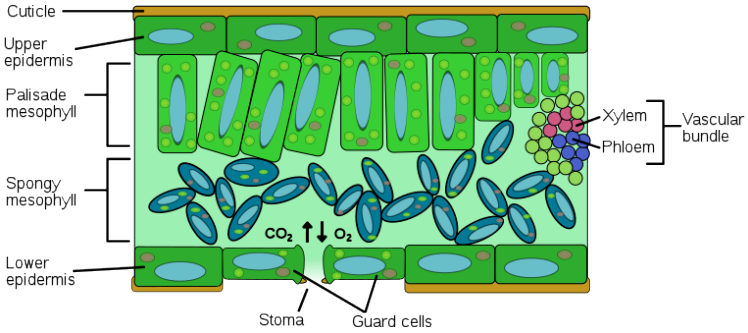

Figure 11. Basic leaf anatomy. Credit: H McKenna on Wikimedia Commons (*http://commons.wikimedia.org/wiki/File:Leaf_anatomy.svg*)

One of the major differences between the leaves of monocots and eudicots is the pattern in which their leaf veins are arranged. You may have noted this difference back at Station 1 when you were identifying each of the provided angiosperms as either a monocot or eudicot. To refresh your memory, examine the laminated figure showing the difference in the venation (vein arrangement pattern) in monocot and eudicot leaves, and answer the questions on the worksheet at the end of this lab exercise.

Leaves can be described based on a number of their characteristics, including such things as the shape of the leaf, the shape of the leaf's margin, the pattern of veining in the leaf, and whether it is a **simple leaf** or a **compound leaf**. Remember, a leaf's petiole joins the stem of a plant at a node. A **simple leaf** is a leaf whose petiole has a single blade. However, a **compound leaf** is a leaf whose blade tissue is subdivided to form several **leaflets**, all of which are connected to a single petiole. Compound leaves can be **pinnately compound**, where several leaflets emerge along the sides (and tip) of the petiole, much in the way that the barbs of a feather are all joined to the feather's central shaft. Alternatively, compound leaves can be **palmately compound**, in which all leaflets emerge from a single point on the tip of the petiole, similar to how all of your fingers emerge from your hand. Look at Figure 12, the laminated sheet of leaf characteristics, and the provided leaf

examples to familiarize yourself with the differences between leaf types. Answer the question on the worksheet at the end of this lab.

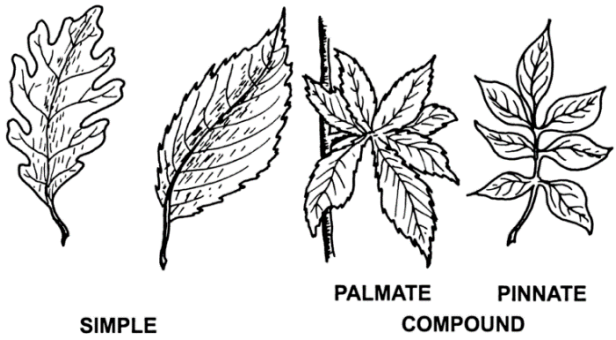

Figure 12. Simple and compound leaves.

Similar to modifications seen in roots and stems, many plants have modified leaves that serve different and/or additional functions besides photosynthesis. For example, the leaves of the Venus flytrap are photosynthetic, but they are also modified to capture insect prey. Venus flytraps grow in areas where the soil is very poor in nitrogen, an important element for plant growth. Insects, are a very rich source of nitrogen, and their modified "trap jaw" leaves are adaptations that allow Venus flytraps to obtain sufficient nitrogen.

Figure 13. Venus flytraps showing leaves modified for prey capture. Credit: Юкатан on Wikimedia Commons (*http://commons.wikimedia.org/wiki/File:Venus_flytrap_in_Utopia_park_Israel_-_01.jpg*)

Another great example of a group of plants with leaves modified for another purpose are the cacti. Look at the provided cactus, and identify the spines all over its surface. The spines of cacti are actually modified leaves that protect cacti from herbivores. Using this information, answer the question on the worksheet at the end of this lab exercise.

Examine some examples of leaves used as food, as well as for other culinary purposes. First, examine the stalk of celery in the beaker of colored water. You might be tempted to think that a celery stalk is actually stem tissue, but celery is technically a leaf vegetable, because the celery stalk is actually a modified **petiole**, or the leaf stalk from which the blades of the celery leaves emerge. Notice that in the celery, certain tissue is stained the same color as the water in which the stalk is sitting. Using what you have learned about plant tissues so far, answer the question on the worksheet at the end of this lab exercise.

Finally, examine the other examples of leaves used as food and other culinary purposes. This includes several different leaf vegetables, tea, which is brewed from leaves of the tea plant, and several different **herbs**. Incidentally, the difference between **herbs** and **spices**, botanically speaking, is that herbs are food seasonings derived from the leaves of plants, and spices are food seasonings that are derived from other plant parts (bark, seeds, roots, etc.). Answer the question on the worksheet at the end of this lab exercise.

STATIONS V-VI: Microscopic Examination of Plant Tissues

These last two stations are located on the back two tables in the lab, and consist of several microscopes set up for you to make microscopic examinations of various plant tissues, including root tissue, stem tissue, and leaf tissue. Essentially, all you will do for these stations is to make sure you visit each microscope and view

the slide set up on each one, and use those to answer question on the worksheet at the end of this lab exercise.

BI 102 Lab Worksheet: Plants I Name _____ Section _____

STATION I: Plant Diversity

- List each of the angiosperms at Station 1 in the table below, and identify each of those plants as either a monocot or a eudicot. Also list the characteristic(s) you used to determine whether each is a monocot or a eudicot.

Plant Name	Monocot or Eudicot?	Characteristic(s) used to determine monocot or eudicot

STATION II: Root Anatomy & Diversity

2. Write the number(s) on the structures on the root model next to the correct names of the structures below:

_____ Apical meristem
_____ Cortex
_____ Epidermis
_____ Phloem
_____ Root cap
_____ Xylem

3. Based on its roots, is the grass a monocot or a eudicot? What about the dandelion?

4. What is the function of adventitious roots in ivy or Virginia creeper?

5. What are the functions of prop roots in corn?

STATION III: Stem Anatomy & Diversity

6. Write the number(s) on the structures on the **monocot stem** model next to the correct names of the structures below:

_____ Cortex
_____ Epidermis
_____ Phloem
_____ Vascular bundle girdle
_____ Xylem

7. Write the number(s) on the structures on the **eudicot stem** model next to the correct names of the structures below:

_____ Cortex
_____ Epidermis
_____ Phloem
_____ Vascular bundle girdle
_____ Xylem

8. What is the major difference between the arrangement of vascular bundles in monocot and eudicot stems?

9. Onions and potatoes grow underground. However, they are not considered root vegetables. Why not?

10. Pick at least two of the provided "tree cookies", and list the species you chose, and your estimates of their ages below:

Tree species	Estimated age (years)

STATION IV: Leaf Anatomy & Diversity

11. Write the number(s) from the **leaf model** next to the correct names of the structures below:

_____ Chloroplast
_____ Cuticle
_____ Lower epidermis
_____ Palisade mesophyll
_____ Phloem
_____ Spongy mesophyll
_____ Stoma
_____ Upper epidermis
_____ Vascular bundle sheath
_____ Xylem

12. In the space below, sketch a monocot leaf and a eudicot leaf, making sure to illustrate the differences in the arrangement of their veins. Label each picture as either a monocot or a eudicot, and also give a description of the arrangement of their leaf veins.

13. Knowing that the spines on the provided cactus are actually modified leaves, what is the green portion of the cactus at this station, and where (in what structure) would photosynthesis occur in this cactus?

14. What specific tissue in the celery stalk is stained the same color as the colored water? How did you come to this conclusion?

15. What is the botanical difference between herbs and spices?

STATIONS V-VI: Microscopic Examination of Plant Tissues

16. Look at the slide showing a longitudinal section of a root with root hairs on its surface. What do you think might be the function of root hairs?

11. Chapter 11

LAB 11

Reproduction in Flowering Plants

Prepared by Jason R. Jones, Modified by J. Ray
University of North Alabama

OBJECTIVES

After completing these laboratory activities, you should understand/be able to:

- Define *angiosperm*, *flower*, *pollen*, *fruit*, *ovule*, *seed*, *perfect flower*, *imperfect flower*.
- The following flower parts and their functions: *anther*, *carpel*, *filament*, *ovary*, *ovule*, *petals*, *receptacle*, *sepals*, *stamen*, *stigma*, *style*.
- The botanical distinction between fruits and vegetables.
- The difference between *simple fruits*, *aggregate fruits*, and *multiple fruits*, and be able to give examples of each.
- The main mechanisms of how seeds are dispersed (wind, animals, and water), and some examples of each.
- The importance of seed dispersal.
- Why pollination is advantageous for angiosperms.

INTRODUCTION

The **angiosperms** (flowering plants) are the most diverse plant group, with 300,000+ species comprising 95% of all vascular plants,

and 90% of all plants as a whole. The success of angiosperms can be directly attributed to their unique reproductive strategy that utilizes structures not seen in any other plants: **flowers**, **pollen**, and **fruits**. In these lab activities, you will learn about reproduction in angiosperms, and familiarize yourself with the anatomy of flowers, different types of fruits, examine the differences in anatomy and development of monocot and eudicot embryos, methods of seed dispersal, and the process of pollination, as well as the anatomy of a pollen grain.

STATION I: Flower Anatomy and Dissection

Examine the basic anatomy of a flower using a model of a "typical" flower, but also through dissection of a flower. **Flowers** represent the reproductive parts of flowering plants, and are essentially modified leaves. Depending on the species of angiosperm in question, (1) **perfect flowers** contain *both* male and female reproductive organs, (2) **imperfect (unisexual) flowers** have male and female reproductive organs *on separate flowers* or (3) **monoecious species** are either male or female (on separate individual plants). The flowers you observe and dissect today, are perfect flowers. Compare Figure 1 below to the flower model in lab. Identify all named structures on the plant model as you can. Know the functions of the flower parts on the following pages, as this material will likely be on your quiz next week.

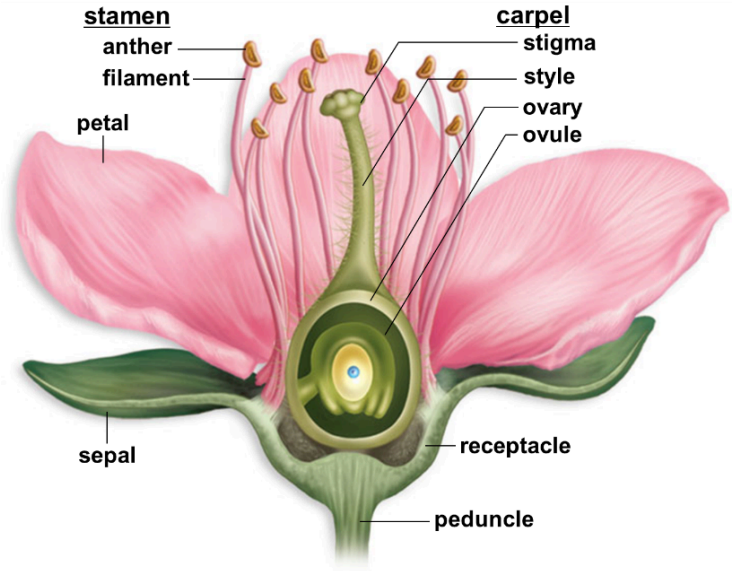

Figure 1. Anatomy of a generalized flower.

Flowers are highly modified leaves. Non-reproductive regions called the **sepals** and **petals** emerge from the **receptacle**. One whorl of leaves is modified into **sepals,** which protect and support the flower. Sepals are often green, but may be other colors and look very similar to the petals. Another whorl of leaves form the **petals**. In animal-pollinated plants, petals are brightly-colored to attract pollinators. Some flowers may also have markings that reflect light waves in the ultraviolet (UV) spectrum, which we cannot see but are visible to some pollinators, even at night. Animal-pollinated flowers often have a **nectary**, a region containing a sugar-rich liquid, which serves as a reward for pollinators.

The reproductive structures of flowers includes the male portion called the **stamen**, which consist of several distinct parts: a stalk-like **filament**, which is topped by an expanded region called the **anther**. The anther contains several **pollen sacs**, which themselves contain cells that divide by meiosis and eventually develop into the **pollen grains**.

The female reproductive portion is the **carpel**, which includes

several distinct structures. The **ovary** is the expanded base of the carpel, and contains **ovules**, which, after fertilization, become seeds. From the top of the ovary extends a stalk-like structure called the **style**, which supports at its top the **stigma**, which receives pollen grains during pollination.

When pollen (~sperm) is carried by animals from one plant to another, pollination occurs. If the pollen reaches the ovule, **double fertilization** occurs, in which one sperm cells fuses with the egg cell to form an **embryo**, and the other sperm cell fuses with embryo sac to form the **endosperm**, which serves as a source of nutrients for the embryo. The embryo and endosperm (the **seed**) are contained within the ovary.

Flower Dissection

Dissect one of the provided flowers; identify as many structures as you can. Make a cross section through an anther, and observe it under the dissecting microscope. See if you can identify the pollen sacs and possibly pollen grains inside the anther. Make a longitudinal section through the **carpel** of your flower, and examine it under your dissecting microscope. See if you can see any ovules inside the ovary.

Answer the questions on the worksheet at the end of this lab exercise relating to the above material

STATION II: Simple Fleshy Fruits

After fertilization, the ovary, now containing one or more seeds, develops into a **fruit**. A **fruit**, defined botanically, is the seed-bearing structure formed from the **ovary**. *Fruits function to ensure seed dispersal* from the parent plant.

Fruits can be classified as **simple fruits**, (formed from a single ovary of a single flower), **aggregate fruits**, (from multiple ovaries of a single flower), or **multiple fruits** (from the fusion of multiple ovaries on multiple flowers). In the case where other structures fuse with the ovary and become part of it, they are called **accessory fruits**.

Simple fruits can be further subdivided into two main classes: **fleshy simple fruits** and **dry simple fruits**. Fleshy simple fruits are fruits in which the ripened wall of a flower's ovary, and any

accessory parts, when applicable) develop into soft, succulent tissue. At this station, you will learn about different types of fleshy simple fruits, and observe examples of them.

To help you learn and understand more about how fleshy simple fruits are classified, it is important to learn about the different layers that make up the pericarp (outer portion) in a fruit.

Outer: **exocarp**, which forms the outer skin of the mature fruit.

Middle: **mesocarp,** typically the thickest layer of the pericarp in fleshy fruits, and usually the part that is eaten. Inner: **endocarp**, which directly surrounds the seeds.

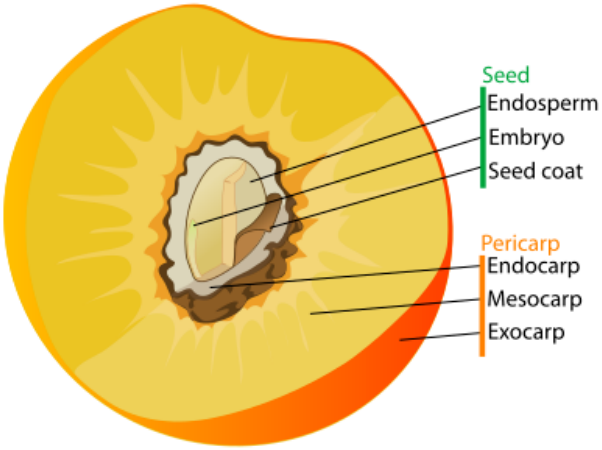

Figure 4. A fleshy fruit illustrating the layers of the pericarp (derived from the ovary), and parts of a seed (derived from an ovule).

Fleshy simple fruits are classified based on the characteristics of the layers of the pericarp (exocarp, mesocarp, and endocarp), as well as the number and types of seeds found within them.

Types of fleshy fruits:

Pome, an *accessory* fruit with an ovary whose pericarp (at least partially) forms a tough core (usually discarded) which contains the seeds, and fleshy tissue derived from the receptacle of the flower.

Example: Apple.

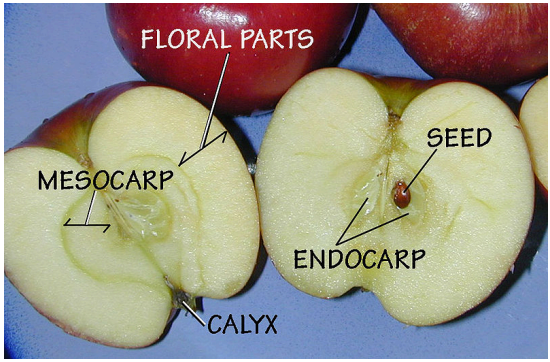

Figure 5. Note the core of the apple is derived from the pericarp (ripened ovary wall). Though not labeled, the darker line forming the outer boundary of the core is the exocarp. The fleshy portion of the apple that is eaten, including the skin (labeled "Floral Parts" in this figure) is derived from receptacle tissue.

Drupe, a fleshy simple fruit with a succulent exocarp (skin) and mesocarp (flesh), with a single seed surrounded by an extremely hardened endocarp. Olives and the peach shown in Figure 6 are drupes.

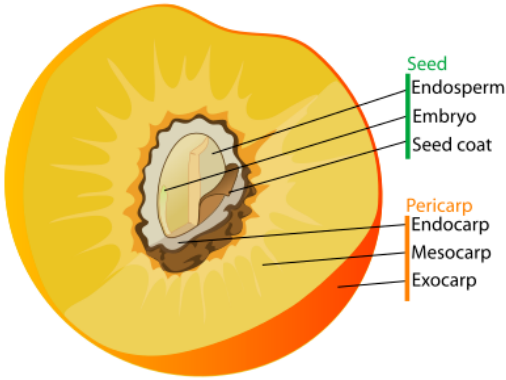

Figure 6. A peach (a drupe) showing the fleshy exocarp and mesocarp, with the seed being surrounded by the stony endocarp. Collectively, the endocarp and enclosed seed of a drupe are referred to as the "stone" or "pit" of a drupe.

Other drupes include almonds and coconuts. An almond is actually only the seed of the fruit, surrounded by parts which are not are eaten. In the unripe almond fruit in Figure 7, note the pale seed (which is eaten) in the middle of the split almond, and the layers surrounding the seed, which are not eaten.

Figure 7. An almond fruit (a drupe) showing the edible seed, and endocarp, mesocarp, and exocarp, which are not eaten.

Coconut. In coconuts, the exocarp and mesocarp of are fibrous, and forms the "husk". The edible white "flesh" of the coconut is actually the endosperm from inside the seed, which is surrounded by the hardened "shell", consisting of the seed coat of the seed itself, bounded to the outside by the stony endocarp. See Figure 8 below, and see if you can identify the exocarp, mesocarp, endocarp, seed coat, and endosperm of the coconut.

Figure 8. A coconut palm and its fruit (a drupe).

Berry. A fleshy fruit that develops from a single flower with a single ovary, containing one or more seeds, in which the entire pericarp develops into potentially edible tissue. Many fruits that have "berry" in their names (such as strawberries, raspberries, and blackberries) are not actually berries. Grapes are a classic example of berries (figure 9). These grapes differ from the grape in the diagram in that they are seedless. Seedless fruits cannot, by definition, reproduce sexually, and thus seedless varieties of fruits are produced by vegetative propagation or through genetic engineering.

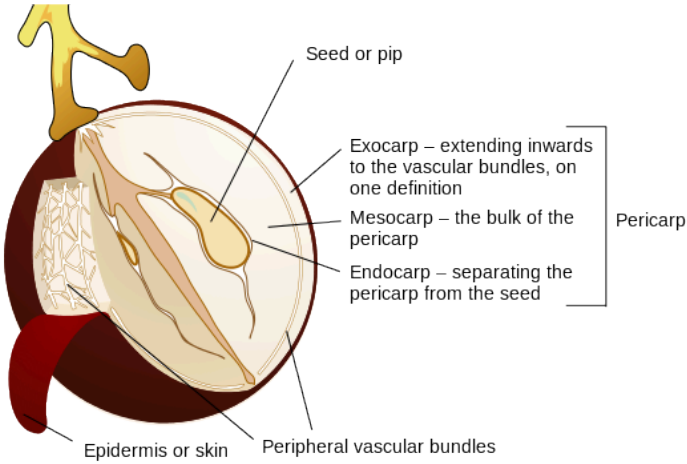

Figure 9. Anatomy of a grape (a berry).

Pepo. A modified berry which develops from a single ovary on a single carpel (not formed from fused carpels) with multiple ovules, in which the exocarp forms a relatively hard outer rind. Examine the provided examples of pepos.

Hesperidium. A modified berry which develops from multiple carpels that fuse. The endocarp is thick and fleshy, and is divided into segments, indicating the boundaries between fused carpels. The mesocarp typically develops into a white pith, with the exocarp developing into a leathery rind.

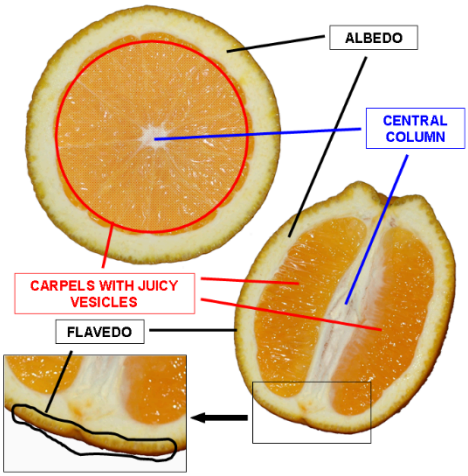

Figure 10. An orange (a hesperidium), showing the thick outer leathery rind (exocarp), white pithy mesocarp, and a fleshy endocarp divided into segments separated by septa between fused ovaries. Credit: Ekko on Wikimedia Commons (*http://en.wikipedia.org/wiki/Fruit_anatomy#/media/File:Orange_cross_section_description.png*)

STATION III: Dry Simple Fruits

A dry simple fruit is formed from 1 pistil (which may consist of multiple fused carpels), and whose coat is dry at maturity. Dry simple fruits can be split into two main groups based on whether they naturally split open at maturity to release the seeds (**dehiscent** dry simple fruits), or do not naturally split open at maturity to release the seeds (**indehiscent** dry simple fruits).

First, we'll start with **dehiscent** dry simple fruits. Again, these are dry simple fruits that naturally split open at maturity to release these seeds. Some examples of dehiscent dry simple fruits include **legumes**, **capsules**, and **follicles**, which, with some other types of dehiscent dry simple fruits can be seen below in Figure 11.

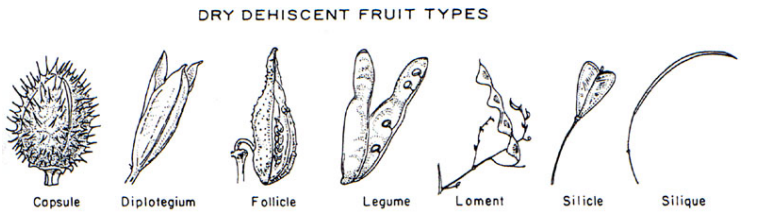

Figure 11. Examples of several types of dehiscent dry simple fruits (dry fruits that split open at maturity to release seeds).

Legume. A dry simple fruit that develops from a single carpel, and which splits along two seams at maturity. Peas and beans are classic examples of legumes. Peas are the actual seeds, containing the embryos of developing pea plants.

Capsule. A dry simple fruit that develops from a single made up of several carpels, which may split along multiple seams representing the boundaries between fused ovaries in the pistil.

Follicles. Dry simple fruits that develop from one carpel, and which split along a single seam at maturity to release the seeds. We do not have a physical example of a follicle, but the fruits of the milkweed plant are good examples of follicles. Examine the laminated picture of a milkweed fruit, and see if you can identify the single seam along which the fruit splits.

Indehiscent fruits are simple dry fruits that do not naturally split open to release the seeds at maturity. Examples include **achenes**, **nuts**, **samaras**, **caryopsis,** and others shown in Figure 11.

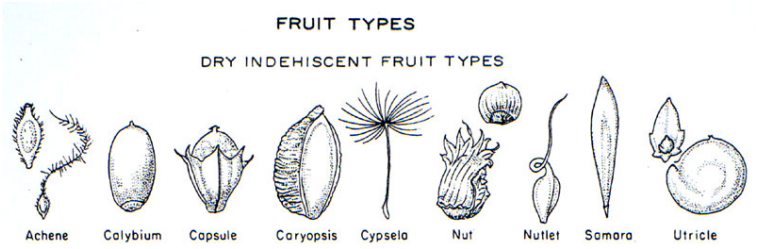

Figure 11. Examples of indehiscent dry simple fruits (dry simple fruits that do not split open to release seeds at maturity).

Achene is a dry fruit with a single seed which is attached to the fruit wall at a single point. Examine the provided example of an achene.

Nuts have a single seed, but with a fruit wall that is much thicker and harder than that seen in the achene. Some fruits with "nut" in the name, however, are not true nuts, but are technically drupes or other fruit types.

Samara is an indehiscent dry simple fruit that contains one or two seeds, with part of the pericarp (fruit wall) expanded into a wing-like structure. These seeds of these types of fruits are typically dispersed by wind, with wind currents catching the wing-like portion of the fruit, often carrying it considerable distances. Several trees, including elms, ashes, and maples produce this type of fruit. Examine the provided maple samaras. Take one and, holding it at shoulder height, drop it, noting its movement as it falls. Answer the question on the worksheet at the end of this lab exercise. (**HINT:** The questions on achenes, nuts, and samaras may be easier to answer after you have visited Station VI!)

Caryopsis. A one-seeded fruit in which the wall of the fruit and the seed coat of the seed inside are completely fused. This type is common in many monocots, such as grasses, corn, wheat, etc. Examine the provide examples of grains.

STATION IV: Aggregate Fruits, Multiple Fruits, and Fruit Identification

At this station, you will examine some examples of **aggregate fruits** and **multiple fruits**, as well as use what you have learned about simple fleshy fruits, simple dry fruits, and aggregate and multiple fruits to identify several fruits as to their types.

Raspberries. An **aggregate fruit**, which is a fruit made up of multiple separate ovaries on multiple separate pistils within a *single flower*. Figure 12 shows that each individual ball-like unit of a raspberry is actually a small single drupe, with a single raspberry

itself consisting of numerous such small drupes, formed from multiple individual ovaries on the same original flower.

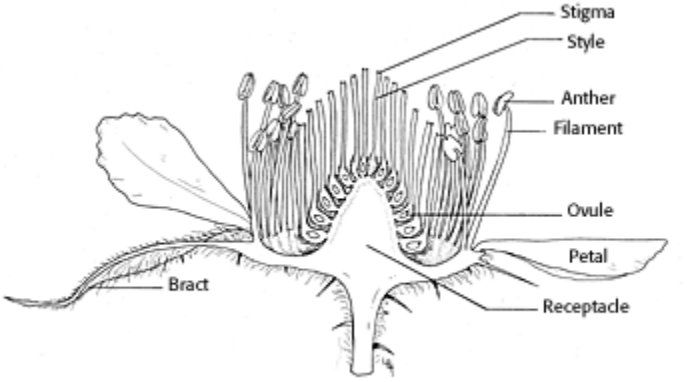

Figure 167. - Longitudinal section of 'Willamett' raspberry flower, x10.

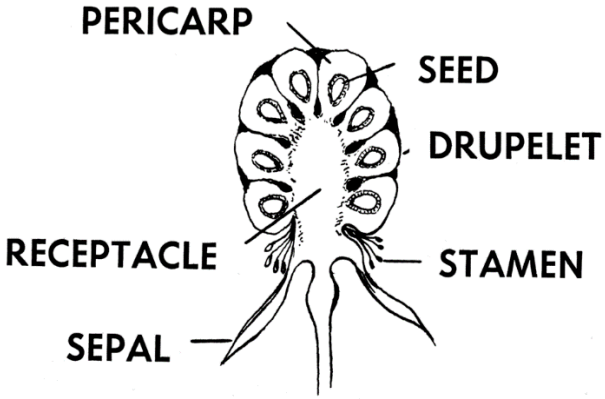

Figure 12. A raspberry flower (left), showing multiple carpels (each containing a single ovary), and a raspberry fruit (aggregate fruit) formed from the fusion of multiple individual drupes, each formed from a single ovary. Technically, a single raspberry

consists of numerous tiny fruits held together by the receptacle of the original flower.

Pineapple. A **multiple fruit**, which is a fruit formed from carpels on multiple individual flowers, often fused together with other accessory structures on each flower. See Figure 13.

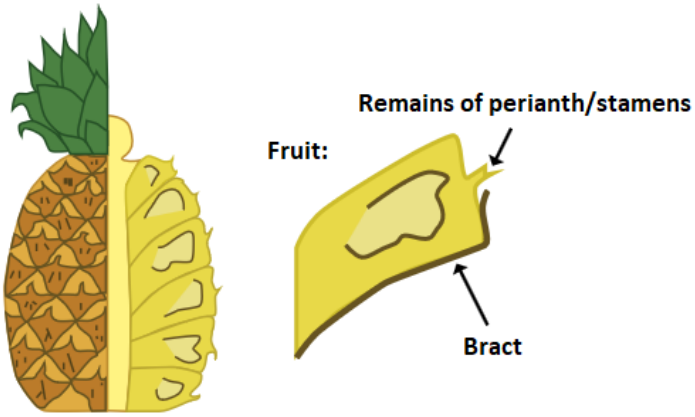

Figure 13. Pineapple (a multiple fruit). Each scale-like/plate-like structure on the surface represents a single fruit formed from a single carpel of a single flower. Thus, an entire pineapple is formed from multiple fruits formed from multiple flowers. The "core" of a pineapple is formed from the peduncle, or the stalk to which all of the flowers were attached. On the right is a single fruit from a single pineapple flower. Note the bract, which is a specialized leaf, often associated with a reproductive structure. The flesh of each pineapple fruit is composed of ovary tissue. The individual fruits of a pineapple are technically berries.

Identifying "Mystery" Fruits

After the raspberries and pineapple at this station, there are several other fruits in trays at this station. In the worksheet at the end of this lab exercise, make a list of all of these "mystery" fruits in the provided table, and using what you've learned about fleshy

simple fruits, dry simple fruits, aggregate fruits, and multiple fruits, and try to see if you can identify the specific type of each of the provided fruits.

STATION V: Embryonic Development in Monocot & Eudicot Seeds

Angiosperms differ in the anatomy of their embryos, as well as in the development of those embryos. Monocots and eudicots differ in terms of the number of their embryonic "seed leaves", which are called the **cotyledons**. Monocots have a single cotyledon ('mono-', one). Eudicots have two cotyledons. Cotyledons are not true leaves, because in most angiosperms, the cotyledons are not capable of photosynthesis. Instead, the cotyledons serve to access the stored nutrients (**endosperm**) inside of the seed, providing those nutrients to the embryo until its first true leaves (two in eudicots, and one in monocots) emerge from the ground and begin photosynthesizing.

The seed is surrounded by a **seed coat**, and the **embryo** is housed inside the seeds of each. The embryos of each group also have several features in common.

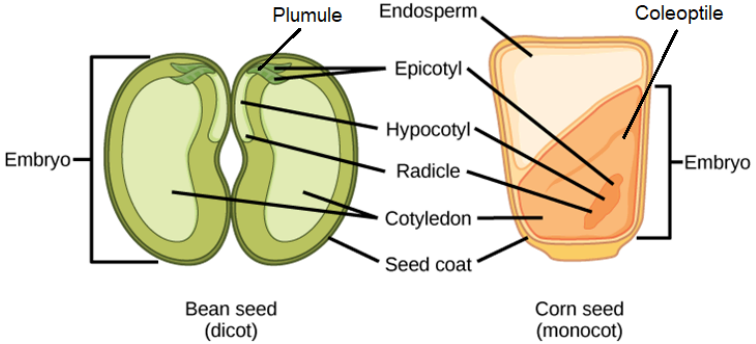

Figure 14. Embryonic development in eudicot (bean) and monocot (corn) seeds.

At this station, you will dissect both a germinating monocot (corn) and eudicot (bean) seed, each containing an embryo. The best way to do this is to simply use a scalpel or razor blade to slice through the corn seed in a longitudinal section right through the middle

of the seed. For the bean seed, you can probably actually slide the seed coat off of the seed with your hands, and then split the bean manually along its midline, separating the two cotyledons.

After dissecting each of these seeds, compare them to Figure 14, as well as the provided models, and see if you can locate and identify all of the structures mentioned in bold above, as well as shown in Figure 14. You will also note that at both the monocot and eudicot dissection stations, you have been provided with a dropper bottle of Lugol's iodine solution, which can be used to test for the presence of starch. Normally, this solution is amber/dark orange in color. However, in the presence of starch, this indicator turns darker, often becoming bluish-black in color. After you have dissected each seed, use the provided Lugol's iodine, and place a single drop of it on the interior surface of each seed, and note your observations on the worksheet at the end of this lab exercise. (**NOTE:** Careful with the Lugol's iodine– it will stain your skin and clothes!)

STATION VI: Seed Dispersal

One major advantage provided by the unique reproductive method of angiosperms (production of flowers and eventually fruits) is that fruits (containing seeds) provide an opportunity for **seed dispersal**, or movement of fruits (with the seeds and embryos within) away from the parent plants that produced them. You might be wondering why this might be such an advantage, but a little bit of thought about basic plant biology can provide us with several lines of insight. First, consider the fact that (for the most part), plants are pretty much confined to the environment in which they sprouted. If a parent plant's seeds fell very close to the original parent plants (which would be larger than the developing seedlings), the developing offspring would be in direct competition with their parents for water, nutrients, and light. In such a case, the larger parents would be at an advantage with their larger size, and would likely outcompete their own offspring for all of the above resources. As a result, the fitness of the parental plants (likelihood of survival of their offspring to eventually produce their own offspring,

perpetuating their parents' genes into future generations) would be reduced.

Additionally, what if the parental plants originally germinated and grew in an environment that was less than ideal, but more suitable habitats could be found some distance away? In both scenarios, the ability to disperse their offspring to other locations is beneficial to both the parents (due to reduced competition) and the offspring (additional reduced competition, as well as the possibility of landing in habitats superior to those of their parents).

In examining the fruits (and enclosed seeds and embryos) of angiosperms, we see a wide variety of adaptations that allow the embryos within the seeds (within the fruits) to be dispersed to areas of varying distances from their parents. Given the diversity of angiosperms, the diverse range of modifications to fruits that allow for various methods of seed dispersal should come as no surprise. However, there are several main mechanisms of seed dispersal that can be observed using different morphological features of fruits themselves: dispersal by **wind**, dispersal by **animals**, and dispersal by **water**. Some less common (but still observed) methods of seed dispersal include dispersal by explosion, as well as dispersal by gravity. Figures 15–17 below and on the following pages provide some examples of seed dispersal mechanisms, as well as examples of plants that utilize those methods of dispersal.

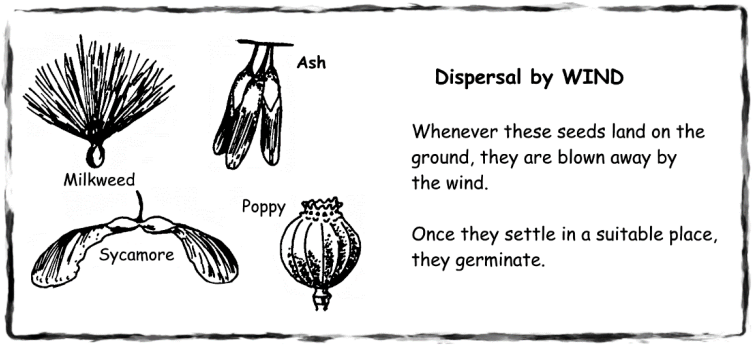

Figure 15. Examples of seed dispersal by wind.

At this station, you should observe all of the provided fruits (again, containing seeds, which contain plant embryos), as well as read

about the methods by which they are dispersed. After observing each of the example fruits, answer the questions at the end of this lab exercise.

Dispersed by ANIMALS:

Forgotten acorns buried by squirrels often become oak trees.

The hooks of the seed of the grapple plant catch hold of animal's fur and are dispersed in this way.

Fruits and berries are eaten by birds. The seeds inside the fruit are excreted unharmed in the birds' droppings.

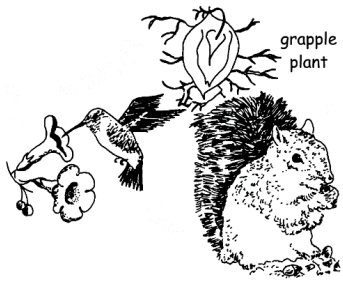

Figure 16. Examples of seed dispersal by animals.

Dispersed with an EXPLOSION:

Some seed-pods like the pea explode to release their seeds.

Seeds squirt out in a fluid at one end of the squirting cucumber when pressed.

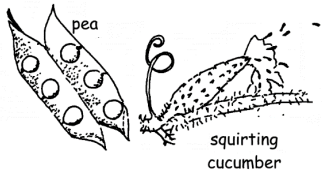

Figure 17. Examples of seed dispersal by explosion.

STATION VII: Pollination and Pollen Tube Growth

Pollination is another advantage to angiosperms in their reproduction. **Pollination** refers to the process of transfer of pollen from the anther of a flower to the stigma of a flower. Some plants have the ability to **self-pollinate**, when pollen from a flower on one plant is deposited on the stigma on a flower on the same plant. However, some plants exhibit what is called **self-incompatibility**, meaning that they are unable to pollinate themselves. At its heart, however, pollination can be advantageous when pollen from one plant is deposited onto the stigma of another plant of the same species, or **cross-pollination**. Cross pollination is advantageous, as it is a form of sexual reproduction, which, as we have learned,

introduces genetic variation into populations. Remember, in sexual reproduction, essentially genetic information from each parent is being randomly shuffled together into each offspring produced, providing for the opportunity of numerous new combinations of genes, any of which may provide advantages in a given stable (or often changing) environment.

The pollination method(s) employed by angiosperms can often be deduced from the structure of their flowers. Wind-pollinated flowers tend not to be very showy, as they don't need colors, flashy structures, or nectars to attract animal pollinators. However, wind pollination tends to be very hit-or-miss, so wind-pollinated plants tend to produce LOTS of pollen.

Plants that are animal-pollinated vary in terms of their flower characteristics, based on the identity and biology of their primary pollinators. For example, plants pollinated by diurnal (active during the day) insects tend to have brightly colored flowers, often with markings that reflect UV light (invisible to humans, but visible to many insect groups). Insect-pollinated plants also tend to have highly fragrant flowers, which attract insects, who have finely-tuned chemical senses. These fragrances are not always very pleasant, however. For example, fly-pollinated flowers often have fragrances similar to rotting meat, which attracts flies that typically feed on dead and decaying organisms. Insect-pollinated flowers also often have nectar, which provides pollinator insects with a sugary "reward" for transferring their pollen, and the structure of insect-pollinated flowers is often such that to obtain a nectar reward, the insect has to crawl into the flower, and thus get coated in lots of pollen which can be transferred to other plants of the same species when those pollinators visit those individuals' flowers.

Bird-pollinated flowers are also typically showy and bright in coloration, to attract their highly visual avian pollinators. Bird-pollinated flowers also often have lots of nectar rewards, but may not necessarily be very fragrant, as the sense of smell of birds is often comparatively poor.

Flowers that are pollinated by nocturnal animals such as moths

and bats tend to be white and ghostly in color, to provide contrast during the dark environment at night, and also tend to be heavily scented, as well as contain abundant nectar, as both moths and bats have strong chemical senses. Bat-pollinated flowers also tend to have very distinct shapes, which form relatively unmistakable "audible pictures" of their anatomy when "viewed" by bat echolocation. Examine Figure 18 for just a small sample of pollination by animals.

(a) Honeybee drinking nectar from a foxglove flower

(b) Ruby-throated hummingbird drinking nectar from a trumpet creeper flower

Figure 18. Two examples of animal pollination in angiosperms.

At this station, you will make microscopic observations of pollen grains by making wet mount slides of pollen that has been incubated in a solution of sucrose and boric acid, both of which stimulate the growth of pollen tubes. Note, pollen tube growth in this lab has been pretty hit or miss over the years, depending on the species used, as well as varied experimental concentrations of both sucrose and boric acid. You may not be able to observe pollen tube growth, but you should definitely be able to make microscopic observations of pollen grains themselves.

After making and observing a wet mount of the provide pollen grains in solution, answer the questions on the worksheet at the end of this lab exercise. For a bit of help/context, you may wish to refer back to the information regarding angiosperm life cycles covered under Station I.

BI 102 Lab Worksheet: Plants II Name _____ Section _____

STATION I: Flower Anatomy and Dissection

1. Carefully dissect a flower and identify the parts. Sketch the basic parts of a flower below. Have your instructor approve your dissection by initialing here _____.

2. What is the main function of flowers in angiosperms?

3. Which part of the flower produces the pollen: Male or Female?

4. The 2 main parts of the male portion of the flower: _____, _____

5. The 4 main parts of the female portion of the flower: _____, _____, _____, _____

STATION II: Simple Fleshy Fruits

6. What part does the fruit develop from? _____

7. What part does the seed develop from? _____

8. Which fruit is normally thought of as a "bean", but is actually the fruit of a berry?

9. Look at one of the cross sections of one of the provided hesperidia. Below, name the hesperidium you chose, and give the

number of visible segments (representing the number of fused carpels) in that fruit.

STATION III: Dry Simple Fruits

10. Based on what you know about the provided achene and nuts, how would you guess that the seeds of these fruits are dispersed?

11. What is advantageous about the wing-like shape of the samara fruits of maples, ashes, and elms?

STATION IV: Aggregate Fruits, Multiple Fruits, and Fruit Identification

12. Fill in the table below with information about all of the provided "mystery" fruits.

Fruit Name	Simple Fruit (Y/N)	If Simple, Fleshy or Dry?	If Simple, Specific Type?	Aggregate or Multiple?	If Aggregate or Multiple, Individual Fruit Type?

STATION V: Embryonic development / Seed Germination

13. Is corn a Eudicot or Monocot? Is a bean and peanut a Eudicot or Monocot?

14. On the peanut, find and define the following:

seed coat:

cotyledons (2):

embryo:

endosperm:

STATION VI: Seed Dispersal

15. How is the fruit of a chestnut dispersed? _____Sycamore dispersed? _____

Coconut dispersed? _____

16. Name at least one other species of plant that exhibits seed dispersal via the following methods:

By wind – By animals –

By water –

STATION VII: Pollination and Pollen Tube Growth

17. Which angiosperm flowers tend to produce more pollen: Wind-pollinated or Animal-pollinated?

18. What was the most interesting thing you learned about angiosperms in lab?