HUMAN ANATOMY LABORATORY MANUAL



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Human Anatomy Laboratory Course

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Detailed Licensing

Licensing

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CHAPTER OVERVIEW

1: Overview and the Microscope

WHAT YOU'LL LEARN TO DO: Describe and identify anatomical position and locate major organs.

1.2: Anatomical Position and Planes

1.3: Human Body Cavities and Organ Systems

1.4: Microscopes

1.5: Setting Up a Microscope and Slide Properly

Learning Objectives

- Identify anatomical position and be able to reference it when describing anatomical locations.
- Know where to cut to create each of the following and be able to recognize the views created by a cut in each of the following:
  - mid-sagittal plane
  - para-sagittal plane
  - frontal plane
  - transverse plane
- Be able to look up anatomical nouns and adjectives for external body areas and find what they refer to.
- Apply each pair of terms to locate a structure or direct someone to a structure:
  - superior/inferior
  - anterior/posterior
  - medial/lateral
  - proximal/distal
  - superficial/deep
  - dorsal/ventral
  - cephalad/caudal
  - supine/prone
- Locate each of the following:
  - dorsal body cavity
  - cranial cavity
  - spinal cavity
  - ventral body cavity
  - thoracic body cavity
  - diaphragm
  - abdominopelvic cavity
  - abdominal cavity
  - pelvic cavity
- List the major organs and identify at least two physiological roles for each of the 11 human organ systems:
  - integumentary
  - skeletal
  - muscular
  - nervous
  - endocrine
  - cardiovascular
  - lymphatic/immune
  - respiratory
  - digestive
  - urinary
  - reproductive
- Identify each organ in the anatomical model and know its location within the model body:
  - cranial cavity
  - palate
  - parotid salivary gland
  - sublingual salivary gland
  - submandibular salivary gland
  - larynx
  - trachea
  - esophagus
  - aorta left
  - lung (2 lobes)
  - right lung (3 lobes)
  - diaphragm
  - kidney
  - adrenal (suprarenal) glands
  - liver
  - gall bladder
  - pancreas
  - stomach
  - spleen
  - large intestine
  - small intestine
  - appendix
  - ovaries
  - uterus
  - female urethra
  - testes
  - scrotum

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1.2: Anatomical Position and Planes

Information

When anatomists or health professionals identify the location of a structure in the human body, they do so in reference to a body in anatomical position. That is, they figure out the location based on the assumption that the body is starting out in anatomical position.

Anatomical position for a human is when the human stands up, faces forward, has arms extended, and has palms facing out.

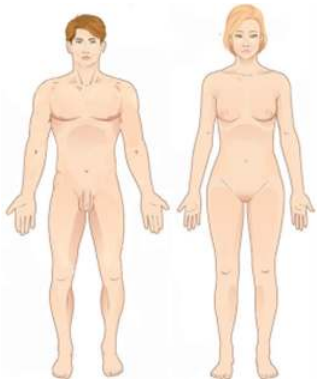


Figure 1.2.1: These two people are both in anatomical position. (CC-BY, Open Stax)

When referencing a structure that is on one side of the body or the other, we use the terms “anatomical right” and “anatomical left.” Anatomical right means that the structure is on the side that a person in anatomical position would consider their right-hand side (not necessarily on the right of the viewer) and anatomical left means that the structure is the side that a person in anatomical position would consider their left-hand side (which likewise is not necessarily the left side of the viewer.)

Anatomical planes

Information

To view the interior of a body, we expose the organs and structures that are visible when that body is cut open along one of four commonly used sectional planes. These planes are the different directions a body is cut to reveal different views of its internal structures.

- **Frontal plane—**A vertical cut that separates the front from the back of the specimen. Also known as a coronal plane.
- **Transverse plane—**A horizontal cut that separates the top from the bottom of the specimen. Also known as a cross-sectional plane.
- **Midsagittal plane—**A vertical cut down the exact center line of the specimen that separates the left half from the right half.
- **Parasagittal plane—**A vertical cut that is off-center that separates the left of the specimen from the right in unequal portions. It does not matter whether it is the left side or the right side that is larger, as long as they are not equal.

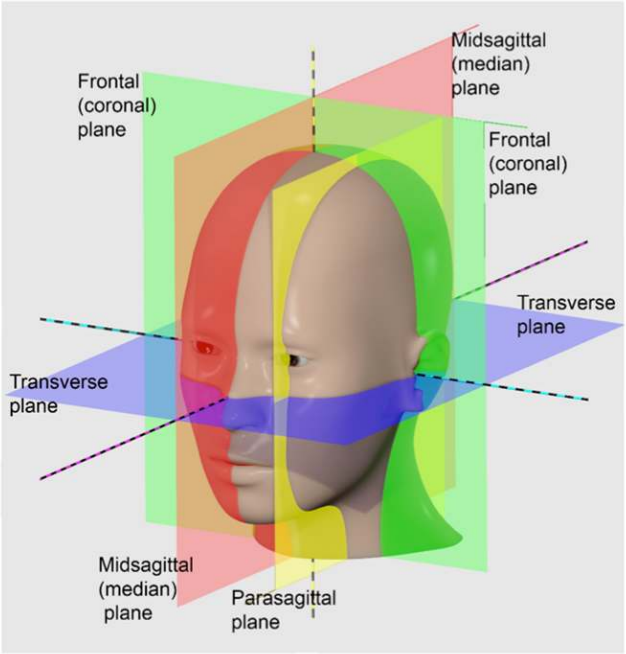


Figure 1.2.2: The different sectional planes used to expose internal structures. (CC-BY-SA, WiliMedia)

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- Figure 1-3. A banana person prior to being cut along transverse, frontal, and midsagittal or parasagittal planes.. **Authored by**: Ross Whitwam. **Provided by**: Mississippi University for Women. **Located at**: http://www.muw.edu/. **License**: ***CC BY-SA: Attribution- ShareAlike***

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Anatomical Vocabulary

Anatomical nouns and adjective for external body parts

Information

Like all areas of science, there is a lot of jargon associated with anatomy and physiology. Often terms are used within the field that differ from what we would name things in everyday conversation. Such jargon usually allows the specialist in the field to be more precise in what exactly they are referring to, but the jargon also can be intimidating and exclusionary. If you don't know it, you are not in the club.

LAB 1 EXERCISE 1-1

Here are a bunch of anatomical adjectives (followed in parentheses by the noun version of the same term). For each, use your smart phone or laptop or whatever is most convenient to you to find what body part the term refers to. (Shortcut hint: the Google search engine will return definitions for words if you type "define: word" in the search box, leaving out the quotation marks.)

Write down the body part or body region next to each term. Use Figure 1.4 to help you make sure you have the correct definition but look up each definition to make sure you are being accurate.

1. Find the body part or region indicated by each of the following terms. Use everyday language to describe the part or region. (Forearm, belly, etc.)

Abdominal (abdomen)		Acromial (acromion)	
Antebrachial (antebrachium)		Antecubital (antecubitis)	
Auricle (auris)		Axillary (axilla)	
Brachial (brachium)		Buccal (bucca)	
Carpal (carpus)		Cephalic (cephalus)	
Cervical (cervicis)		Coxal (coxa)	
Cranial (cranium)		Crural (crus)	
Digital (digit)		Dorsal (dorsa)	
Facial (facies)		Femoral (femur)	
Frontal (frons)		Gluteal (gluteus)	
Inguinal (inguen)		Lumbar (lumbus)	
Mammary (mamma)		Manual (manus)	
Mental (mentis)		Nasal (nasus)	
Olecranal (olecranon)		Oral (oris)	
Ocular (oculus)		Palmar (palma)	
Patellar (patella)		Pelvic (pelvis)	
Plantar (planta)		Popliteal (popliteus)	
Pubic (pubis)		Sacrum (sacral)	
Sural (sura)		Tarsal (tarsus)	
Thoracic (thorax)		Umbilical (umbilicus)	

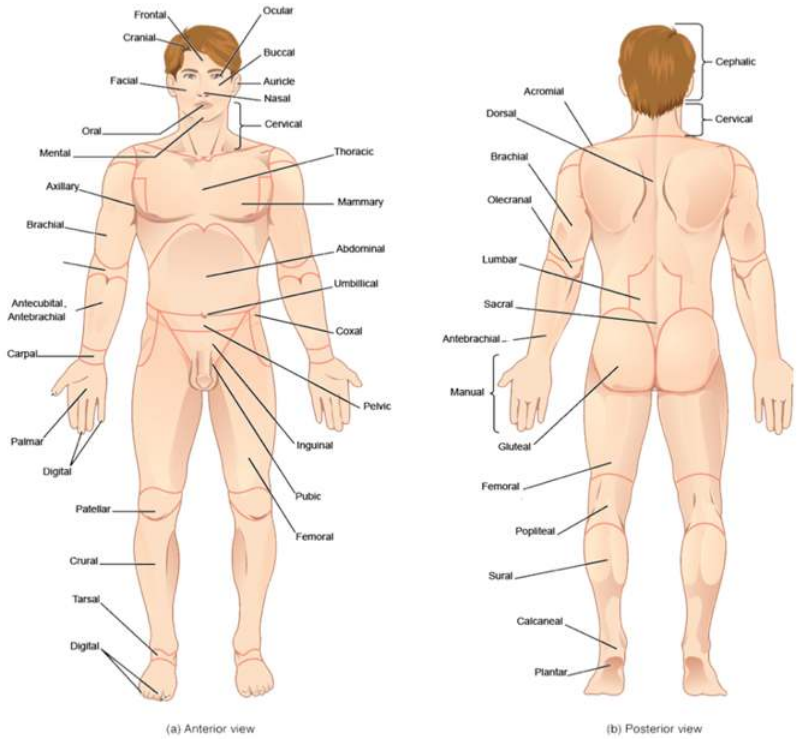


Figure **1.2.3**: Anatomical adjectives for common surface features. (CC-BY, Open Stax)

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Anatomical Orientation and Directions

Information

To be able to direct others to specific anatomical structures, or to find structures based on someone else's directions, it is useful to have specific pairs of terms that allow you to orient your search with respect to the location of another, known structures. The following pairs of terms are used to make comparisons. Each term is used to orient a first structure or feature with respect to the position of a second structure or feature.

- **Superior/Inferior**–Equivalent to above and below when moving along the long axis of a body in anatomical position. The structure that is superior to another is above the second structure when the body is in anatomical position. A feature that is inferior to another is below the second feature when the body is in anatomical position.
- **Proximal/Distal**–Equivalent to near and far. Usually used to orient the positions of structures and features along the limbs with respect to the trunk of the body. A feature that is proximal to something else is closer to the limb's point of attachment to the trunk. A structure that is distal to something else is farther away from the limb's point of attachment. Less precisely but still occasionally used in the trunk of the body itself to indicate whether something is closer to (proximal) or farther away from (distal) something else.
- **Medial/Lateral**–Equivalent to towards the middle or towards the edge. Used with respect to the midline of the trunk of a body in anatomical position. A structure that medial to another is closer to the midline of the body's trunk. A feature that is lateral to another is farther away from the midline of the trunk.

- **Anterior/Posterior**–Equivalent to the front and back of a body in anatomical position. A structure that is anterior to another is closer to the front of the body when the body is in anatomical position. A feature that is posterior to another is closer to the back of the body when the body is in anatomical position.
- **Ventral/Dorsal**–Equivalent to belly-side and back-side of a body in anatomical position. For a human in anatomical position, this pair of terms is equivalent to anterior and posterior. However, for four-legged animals in what is considered their anatomical position, the belly-side is not equivalent to the front of the animal. A structure that is ventral to another is closer to the belly-side of the body. A feature that is dorsal to another is closer to the back of the body.
- **Superficial/Deep**–Equivalent to closer to the surface and farther from the surface.
- **Cephalic/Caudal**–Equivalent to closer to the head and closer to the tail. This is more useful for four-legged animals with tails than for upright humans with only a vestigial tail.

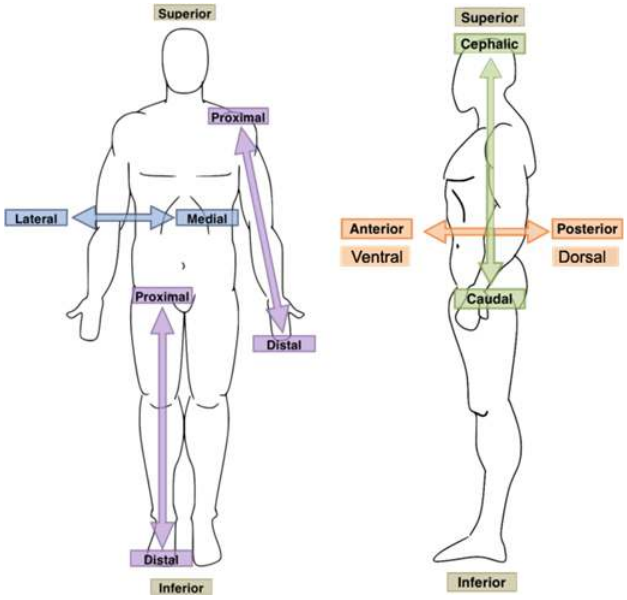


Figure 1.2.4: Pairs of terms providing anatomical direction or orientation. (CC-BY-SA, Osteomyoamare, WikiMedia)

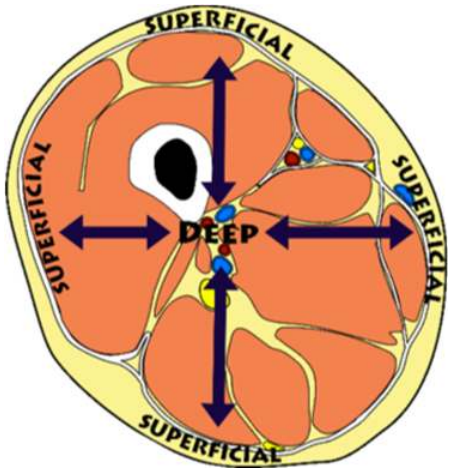


Figure 1.2.5: Cross-section of the thigh. (CC-BY-SA, Marshall Strother, WikiMedia)

LAB 1 EXERCISE 1-2

1. Fill in the blank with the appropriate directional term to complete the following sentences. More than one answer may be correct.

- The heart is_to the lungs.
- The knee is_to the hip.
- The wrist is_to the hand.

- The mouth is_to the nose.
- The thorax is_to the abdomen.
- The thumb is_to the ring finger.
- The sternum is_to the heart.
- The skull is_to the scalp.
- The ears are_to the nose.
- Dorsal refers to the_of the human body, while ventral refers to the of the human body.

2. Find the indicated structures in the diagrams provided, based on the directional terms given. The structure to find will be one of those at the end of an unlabeled line.

A. Label the **extensor digitorum (ED)** muscle in the figure below. It is:

- Distal to the anconeus muscle
- Lateral to the extensor digiti minimi muscle

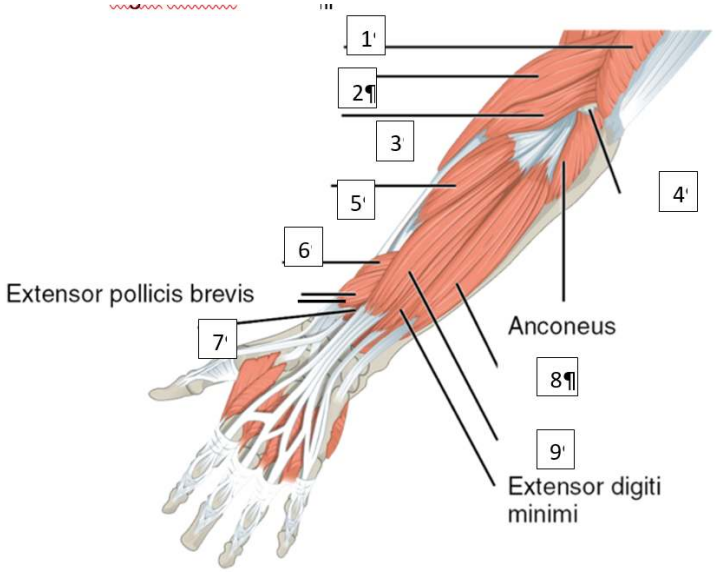


Figure **1.2.6**: Muscles of the forearm

- Superficial to the Extensor pollicis brevis muscle

B. Label the Incus in the figure below. Label only one of the empty boxes. It is:

- Superior to the lateral end of the cochlear nerve
- Medial to the malleus

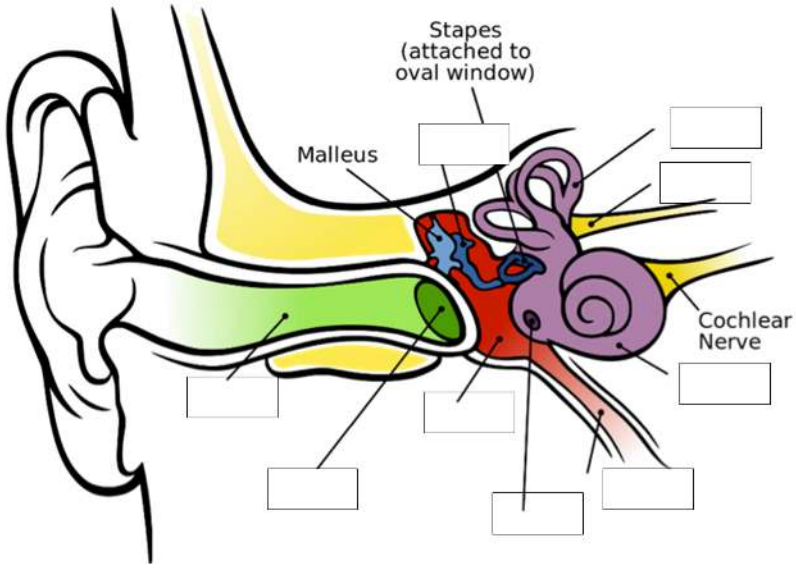


Figure **1.2.7**: Anatomy of the human ear.

- Lateral to the stapes

3. Using your knowledge of the different body planes shown in Figure 1-2 (shown again below), fill in the blanks with the appropriate body plane for each of the following descriptions.

1. The plane that divides the body into anterior and posterior parts is the plane.
2. A transverse plane divides the body into_and regions.
3. A_or_plane divides the body into right and left parts.

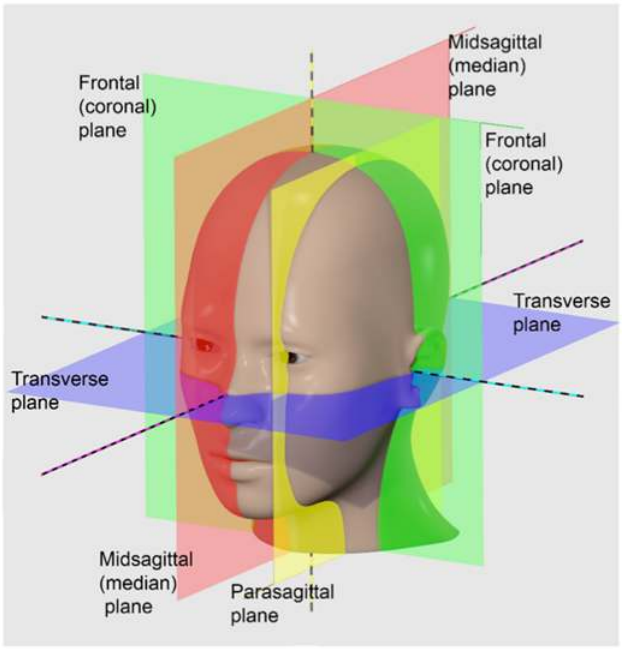


Figure Extra close brace or missing open brace:

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1.3: Human Body Cavities and Organ Systems

Information

The major cavities of the human body are the spaces left over when internal organs are removed. There are additional body cavities which we will only discuss in lecture. These are the cavities created by serous membranes–the pleural cavities, the pericardial cavity, and the peritoneal cavity–and the mediastinum.

- Dorsal body cavity–the cranial cavity and the spinal cavity in combination.
- Cranial cavity–the space occupied by the brain, enclosed by the skull bones.
- Spinal cavity–the space occupied by the spinal cord enclosed by the vertebrae column making up the backbone. The spinal cavity is continuous with the cranial cavity.
- Ventral body cavity–the thoracic cavity, the abdominal cavity, and the pelvic cavity in combination.
- Thoracic cavity–the space occupied by the ventral internal organs superior to the diaphragm.
- Abdominopelvic cavity–the abdominal cavity and the pelvic cavity in combination.
- Abdominal cavity–the space occupied by the ventral internal organs inferior to the diaphragm and superior to the pelvic cavity.

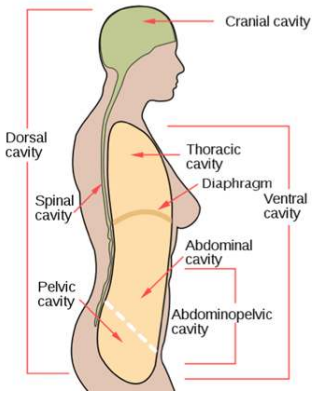


Figure **1.3.1**: The locations of the major body cavities of the human body. (Public Domain, Mysid, Wikimedia)

- Pelvic cavity–the space occupied by the ventral internal organs that are bordered by the bones of the pelvic girdle.

LAB EXERCISE 1-3

Fill in the blank with the appropriate body cavity

1. The two main body cavities are the_____and the _____cavities.

2. The stomach is found in the_____cavity.

3. The heart is found in the_cavity, which is part of the larger_cavity.

4. The brain is found within the_cavity which is part of the larger_cavity

5. The urinary bladder and reproductive organs are found within the _____cavity.

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Figure **1.3.1**. The locations of the major body cavities of the human body.. **Authored by**: Mysid. **Provided by**: Wikipedia. **Located at**: https://commons.wikimedia.org/wiki/F...avities-en.svg. **License**: ***Public Domain: No Known Copyright***

The Human Organ Systems

Information

Organ systems are groups of organs within the body that can be thought of as working together as a unit to carry out specific tasks or functions within the body. The human body is most commonly divided into eleven organ systems, the ones listed below.

It should be kept in mind that these divisions are somewhat arbitrary as to which organs are included and which are excluded. Skeletal muscles attached to bones are part of the muscular system, but the smooth muscles around soft tissues are not. Skeletal muscles are attached to bones, and serve to move the bones, but bones are part of the skeletal system, not the muscular system.

It also bears remembering that no one organ system ever functions independently of the others. The nervous system sends instructions to the muscular system as to when to move particular muscles. The cardiovascular system delivers nutrients and removes wastes from the muscle fibers of the muscular system to allow them to continue to function, etc. Dividing the human body into eleven organ systems is simply a way for the human mind to organize information about what parts do what. In the body itself, the parts that need to interact do interact, regardless of which system they have been grouped into.

The eleven organ systems are shown in Figure **1.3.2**. The figure also lists the organs in each system and some roles for each system.

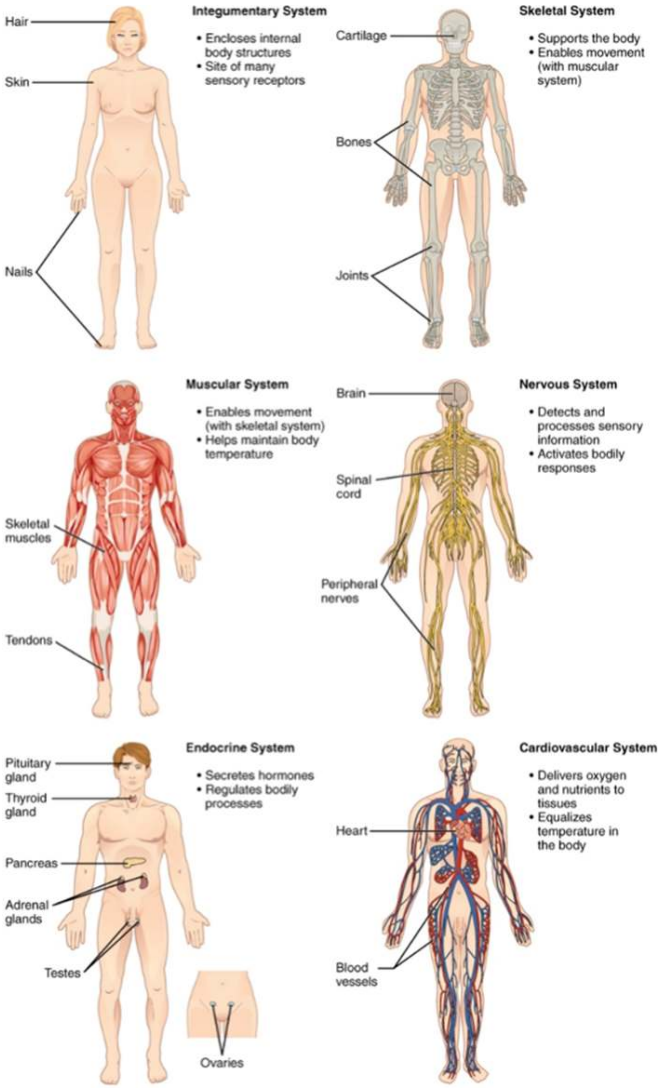


Figure **1.3.2**: Organs that work together are grouped into organ systems. (CC-BY, Open Stax)

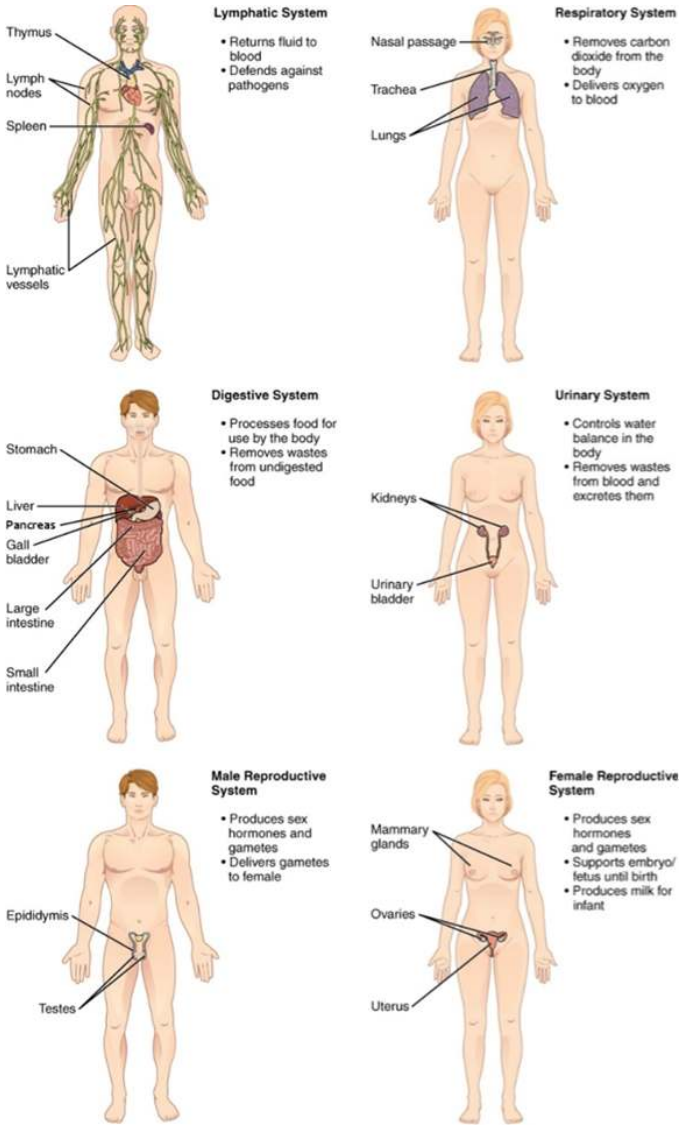


Figure **1.3.3**: Organs that work together are grouped into organ systems. (CC-BY, Open Stax)

Identifying the major internal organs of the body

LAB 1 EXERCISE 1.3.1

For each of the following organs, identify the organ system to which it belongs. There are three organs in this list which each belong to two organ systems; in those cases, list them both.

Brain		Ovaries	
Cartilage		Pancreas	
Skin		Spleen	
Heart		Kidneys	
Lungs		Testes	
Mammary glands		Gall bladder	
Thymus		Pituitary gland	

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Figure **1.3.2**. Organ Systems, part 1.. **Provided by**: OpenStax College. **Located at**: https://cnx.org/resources/9470e72cca...ody(Page1).jpg. **Proje ct**: Anatomy & Physiology . **License**: ***CC BY-SA: Attribution-ShareAlike***

Figure **1.3.2**. Organ Systems, part 2.. **Provided by**: OpenStax College. **Locate at**: https://cnx.org/resources/9490de5610...ody(Page2).jpg. **Licen se**: ***CC BY-SA: Attribution-ShareAlike***

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1.4: Microscopes

Information

Many important anatomical features, especially those that function at the tissue or cellular levels, are too small to be seen by the unaided eye. The compound microscope is a valuable tool for magnifying small sections of biological material so that otherwise inaccessible details can be resolved.

There are many different types of microscopes. We shall only learn about the compound light microscope. It uses visible light to visualize the specimen, but passes that light through two separate lens to magnify the image. The compound microscopes we will use in this course are sturdy instruments but they still have a lot of moving parts. They can be damaged and broken through misuse and mishandling. A large part of learning how to use the microscopes properly involves learning how to avoid damaging it. To do that, you first have to know which parts are which. Figure 1.12 identifies the key parts of the microscope that you need to be familiar with.

In Figure 1.12, there are two compound microscopes shown. The one on the left is monocular and the one on the right is binocular. Many of the parts of the two microscopes are in slightly different locations. Get used to this. Different brands and different models of microscopes position the key parts differently.

When you first sit in front of a microscope, you should always take a second to find the key parts, especially the focus knobs, the condenser adjustment knob (if present), and the stage control knobs. When viewing a specimen, your eyes will be at the eyepieces, and if you grab the wrong knob by accident, you can lose your image at best, and damage the microscope at worst. Don’t assume you remember where the key knobs are. You may have a different microscope than last time.

When storing a microscope you should always follow this list:

1. Remove any slide found on the stage and return it to the slide box.
2. Rotate the smallest lens or no lens into place above the stage. Lower the stage a few turns.
3. Loosely coil the cord in your hand starting near the microscope and working toward the plug.
4. Hang the coiled cord over one ocular lens.
5. Look at the number on the back of the microscope, return that scope to its numbered box.

If there’s already a microscope in that numbered box, check its number and move it. If it is not numbered simply push it to the back of the box and place yours closer to the front. We have a few extra microscopes which we store in this fashion.

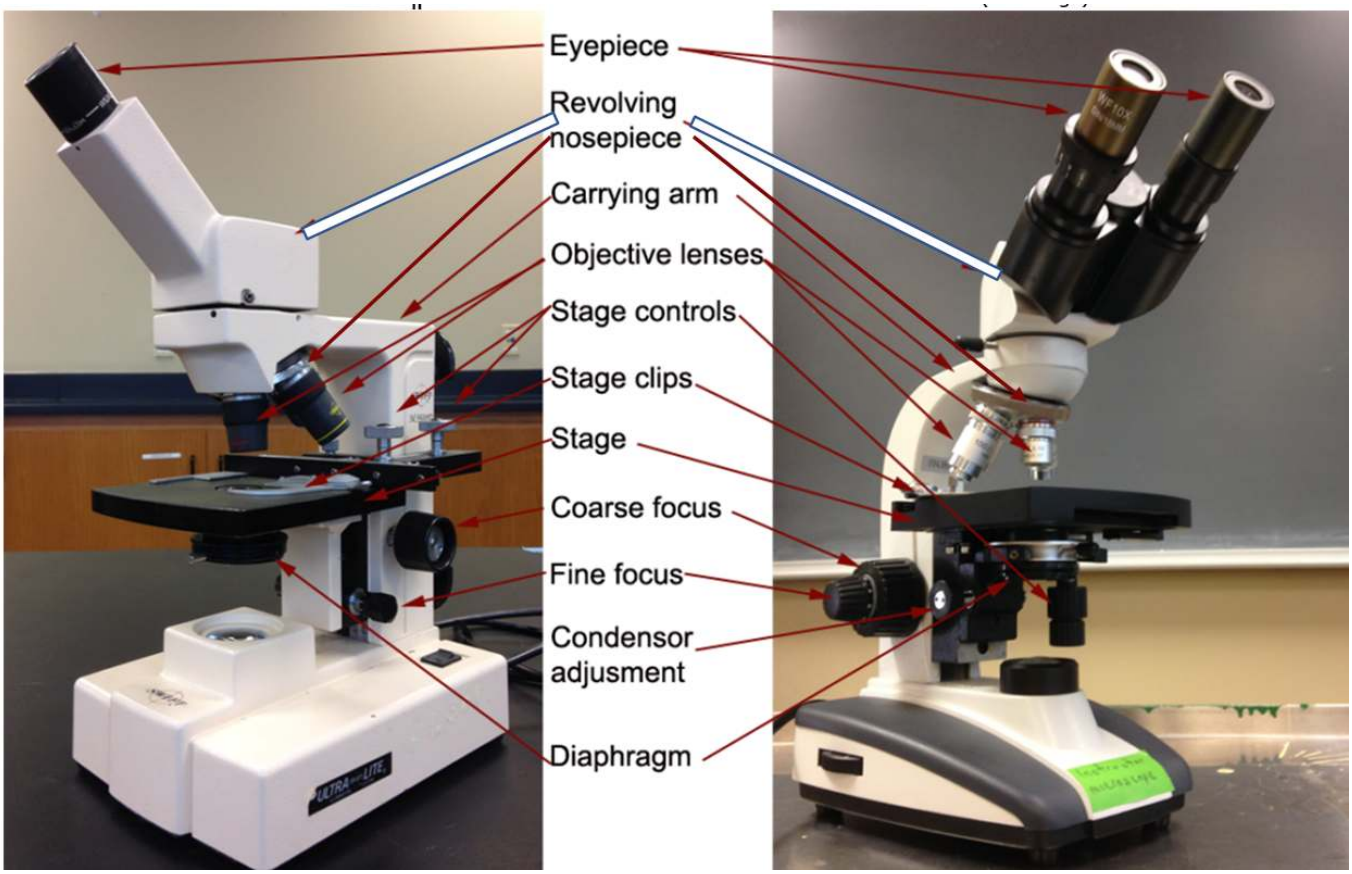


Figure **1.4.1**: Some key parts of a compound light microscope. (CC BY SA; Ross Whitwame http://www.muw.edu/)

The eyepiece

This is where your eyes will be. If the microscope is binocular, use both eyepieces. With binocular microscopes, you almost always can adjust the width of the eyepieces to ensure they fit the spacing of your eyes. The eyepiece contains the eyepiece lens, one of the two lenses doing the actual magnifying in a compound microscope.

The carrying arm

When moving a microscope, even if it is just a few inches, always pick it up by the carrying arm. Do NOT drag the microscope: pick it up. The microscope will have rubber feet that prevent it from sliding, so if you try to drag it, it will shake and vibrate and possible damage parts. Never pick up the microscope by any part other than the carrying arm. The other parts are generally much more fragile and prone to breaking if you try.

The objective lenses

Most compound light microscopes will contain three to four objective lenses that can be rotated over the slide. Sometimes these lenses are just called objectives. When a particular objective has been fully rotated into position, you will hear or feel a click as that objective locks into place. The objective lens is the second of the two lenses doing the actual magnifying in a compound microscope, so if it is not snapped into proper position, you won't see the proper image. Each objective lens can usually be unscrewed from its position in the rotating turret that houses it. Be careful you are rotating the turret, not unscrewing an objective. Do NOT unscrew the objectives from the turret. Each objective lens has a different magnifying power, so the image on your slide will be magnified to lesser or greater extents, depending on which objective lens you have chosen. Each objective's magnification power will be written somewhere on the side of the objective, although sometimes it is hard to see the number. The magnification of an objective lens will always be a whole number. There will be other things written on the side of an objective, but the one that is a whole number greater than 1 will be the magnification. You can ignore everything else written there.

The stage

The stage is the platform that the slide will be clipped on to.

Stage clips

The slide will be held in place on the stage with stage clips. Most of the time, these will clip against the sides of the slide. They do not sit above or below the slide. They are spring-loaded to hold the slide edges and lock the slide in place so that the stage controls can move the position of the slide smoothly. If the slide is not clipped in place, you won't be able to reposition the slide to find microscopic features of interest.

Stage Controls

These allow you to move your slide while you are viewing it, but only if the slide is properly clipped in with the stage clips. Always find where these are on your microscope before you start viewing your slide. They seem to never be in the same place in two different microscopes and if you just blindly grope for them while viewing your slide, you will likely do something unfortunate to your view or to the entire microscope. There are always two dials. One moves the slide left and right. The other moves the slide up and down. Sometimes they are on top of each other, as in the binocular microscope shown on the right in Figure **1.4.1**. Sometimes they are two separate dials, as in the monocular microscope shown on the left in Figure **1.4.1**. Sometimes they are above the stage, as in the monocular microscope . Sometimes they are below the stage, as in the binocular scope . Spend a few seconds to find them every time before you sit down at a microscope.

Coarse focus

This is always the larger of the two focus knobs. You should usually only need to use the coarse focus knob once for each new slide. Use it with the lowest power objective to get the specimen approximately in focus. After that, only use the fine focus knob, even after you change to a higher-power objective. Sometimes the coarse focus knob is with the fine focus knob, as on the binocular microscope in Figure 1.12. Sometimes it is separate from the fine focus knob, as on the monocular microscope in Figure 1.12.

Fine focus

This is always the smaller of the two focus knobs. This is the focus know you will use over and over again in viewing slides. Don't change the coarse focus after using it for the first time, only change the fine focus.

Condenser adjustment

Not all microscopes have a condenser adjustment knob. If there are only two knobs, as on the monocular microscope in Figure **1.4.1**, those two are the coarse focus and the fine focus and you only have to keep those two separate. But if there is a third knob, it is the condenser adjustment knob. As a general rule, do NOT touch or adjust this knob. It controls how far the light condenser is from the slide, which should be properly adjusted before you use the microscope. If you move it, you will have it in the wrong position. If your scope has the knob, find out where it is and avoid it.

Diaphragm

This is directly under the hole in the stage where light passes through to the slide. It is controlled by a lever which opens and closes an iris to let more or less light through the slide. In some specimens there is not much contrast between the colors and shades of the different components being magnified. Changing how bright the view is by adjusting the diaphragm can allow you to better see some of the details you are trying to magnify.

1. Pick up your microscope and physically move it to a new location. Bring it close enough that you can look into it comfortably from where you are sitting. Arrange it so that the stage is facing you and the eyepiece is rotated towards you. What part of the microscope did you grab in order to pick it up and move it?
2. Where are the locations of the two stage adjustment knobs on your microscope?
3. Where is the location of the coarse focus knob?
4. Where is the location of the fine focus knob?
5. Is there a condenser adjustment knob? If so, where is it located?
6. Find the diaphragm lever. Looking in the hole in the center of the stage, what happens when you move the diaphragm leverclockwise?
7. Still looking down at the hole in the center of the stage, what happens when you slide the diaphragm lever counter-clockwise?

Lab 1 Exercise 1.4.1

There are compound microscopes in the large wooden boxes in the front of the room. The boxes and the scopes are numbered. Use any scope you like but please return it to the correctly numbered box. Carry out the activities listed below and fill in the blanks as you do so.

1. Pick up your microscope and physically move it to a new location. Bring it close enough that you can look into it comfortably from where you are sitting. Arrange it so that the stage is facing you and the eyepiece is rotated towards you. What part of the microscope did you grab in order to pick it up and move it?

2. Where are the locations of the two stage adjustment knobs on your microscope?

3. Where is the location of the coarse focus knob?

4. Where is the location of the fine focus knob?

5. Is there a condenser adjustment knob? If so, where is it located?

6. Find the diaphragm lever. Looking in the hole in the center of the stage, what happens when you move the diaphragm lever clockwise?

7. Still looking down at the hole in the center of the stage, what happens when you slide the diaphragm lever counter-clockwise?

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Labelled compound light microscope. Authored by: Ross Whitwam. Provided by: Mississippi University for Women. Located at: http://www.muw.edu/. License: CC BY-SA: Attribution- ShareAlike

Magnification and Resolution

The reason for using a microscope is to magnify features to the point where new details can be resolved.

Magnification is the factor by which an image appears to be enlarged. It will be a whole number greater than 1 and is usually followed by an “x”, as in 10x magnification.

When you look through microscope eyepieces, you are seeing a virtual image because in reality, what you are looking at is not as large as it appears through the eyepieces, and because there can be some distortion of the image.

Resolution is the shortest distance between two points that can still be visually distinguished as separate. The resolution of a typical unaided human eye is about 200 µm. Using a microscope decreases the resolution to distances as short as 0.2 µm. Resolution is a property of the eye.

Resolving power is the ability of a lens to show two adjacent objects as discrete. Resolving power is a property of a lens.

Each lens in a microscope has a numerical aperture, or NA, value. This has to do with the angles of light that enter and exit a lens. Its applications are beyond the scope of this lab, but numerical aperture does influence the resolution possible with a particular lens, and so the NA value for the lens is usually printed on each objective. It will be a number less than 1.0, and you can ignore it for our purposes.

Each lens in a microscope also has a magnifying factor. This is the degree to which that lens magnifies an image. It will be a number larger than 1.0. For instance a 10x objective magnifies the image ten-fold. The magnifying factor for each objective always printed on it, and the magnifying factor for each eyepiece is usually printed on it. (If the eyepiece is missing a printed magnifying factor, you can usually assume it is 10x.)

The total magnification for any image viewed under a compound microscope is calculated by using the formula:

Total Magnification = eyepiece magnifying factor * objective magnifying factor

So, each time you switch objectives, you change the total magnification. Total magnification does not have units, but is usually indicated by an “x”, as in “total magnification = 100x.”

? Lab 1 Exercise 1.4.2

There are compound microscopes in the large wooden boxes in the front of the room. The boxes and the scopes are numbered. Use any scope you like but please return it to the correctly numbered box. Carry out the activities listed below and fill in the blanks as you do so.

1. Write down the magnification factor for the eyepiece lenses on the microscope in front of you.

2. Using the microscope in front of you, write out all the words and numbers written on each objective on your microscope. There are probably three objectives, but some microscopes might have four. Start with the smallest objective and move through them in order of increasing size

Objective one:
Objective two:
Objective three:
Objective four:

3. In the above list, for each objective, circle just the magnification factor for that objective. Remember, the magnifying factor is a whole number, and differs for each different objective.

4. Write down the total magnification (eyepiece magnifying factor * objective magnifying factor) when using each objective on the microscope in front of you.

Objective one:
Objective two:
Objective three:
Objective four:

5. If you observed two features on a slide with your naked eye that were 0.5 mm apart, how far apart would they appear to be if you observed them with the microscope in front of you, using the second objective?

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1.5: Setting Up a Microscope and Slide Properly

All the microscopes in the lab are parfocals. That means that if the slide is in focus under one objective, it will stay largely in focus if the objective is changed. In practical terms, this means you should usually only need to use the coarse focus knob once per slide. You get the slide in focus under the lowest-power objective (where focusing is easiest), then, from that point onward, only make minor adjustments with the fine focus knobs even if you change objectives.

When you first get a new slide, you can usually determine the location of the specimen by looking at the slide while it is still in your hand. The specimen is usually a patch of color somewhere near the center of the coverslip. After you clip your slide securely onto the stage with the stage clips, use the stage control knobs to move the patch of color until it is directly over the hole in the center of the stage where the light comes through. Now when you look through the eyepieces using the lowest objective (always start with the lowest objective) you should be able to find the specimen and get it quickly in focus.

Occasionally the eyepiece or objective lenses will have specks of dirt or dust on them, making it difficult to focus on the specimen. To clean lenses, always use lens paper supplied by the lab instructor or a pure cotton swab. Do not use any other type of cloth or paper as they might scratch the lens. KimWipes are NOT lens paper, NEVER use KimWipes on glass lenses or slides. To remove dirt with lens paper, first roll up the lens paper and try to dry brush away the dirt in a spiraling motion that circles from the center of the lens out. If that doesn't work, moisten the lens paper or pure cotton swab with blue lens cleaning solution (do not apply the water to the lens directly) and clean in a spiraling motion from the center of the lens out.

Below is a checklist for initially setting up a microscope. Every time you get a new slide, you should use this checklist.

? Lab 1 Exercise 1.5.1

☐ 1. Plug in the microscope & turn on light source.

☐ 2. Pick up microscope by carrying arm, position it so it is accessible to your seat, with open side of the stage facing you

☐ 3. Rotate the objectives so that the lowest power objective (smallest in size) clicks into place.

☐ 4. Look at the slide with your naked eye and find the location of the specimen.

☐ 5. Clip the slide into place with the stage clips. The cover slip on the slide must face up. Find the stage controls and make sure that, when they are turned, the slide moves smoothly left and right or up and down, depending on the knob.

☐ 6. Use the stage controls to move the slide so that the light source is shining directly on to the specimen to be magnified.

☐ 7. Find the coarse and fine focus knobs. Watching the stage and objective, use the coarse focus knob to bring the low power objective as close to the slide as it will go.

☐ 8. Put your eye to the eyepiece (or eyepieces, if the microscope is binocular) and rotate the coarse focus knob in the lowering direction until some aspect of the specimen comes into focus.

☐ 9. Move your hand to the fine focus knob and get the specimen into perfect focus for your eyes. **Do NOT touch the coarse focus knob again.**

☐ 10. Use the stage control knobs to move you specimen to close to the exact center of your field of view

☐ 11. Move to the next highest power objective (do not skip the individual objectives) and use only the fine focus to get your image into perfect focus for your eyes.

☐ 12. If you need further magnification, move to the next highest power objective and use only the fine focus to get your image into perfect focus for your eyes.

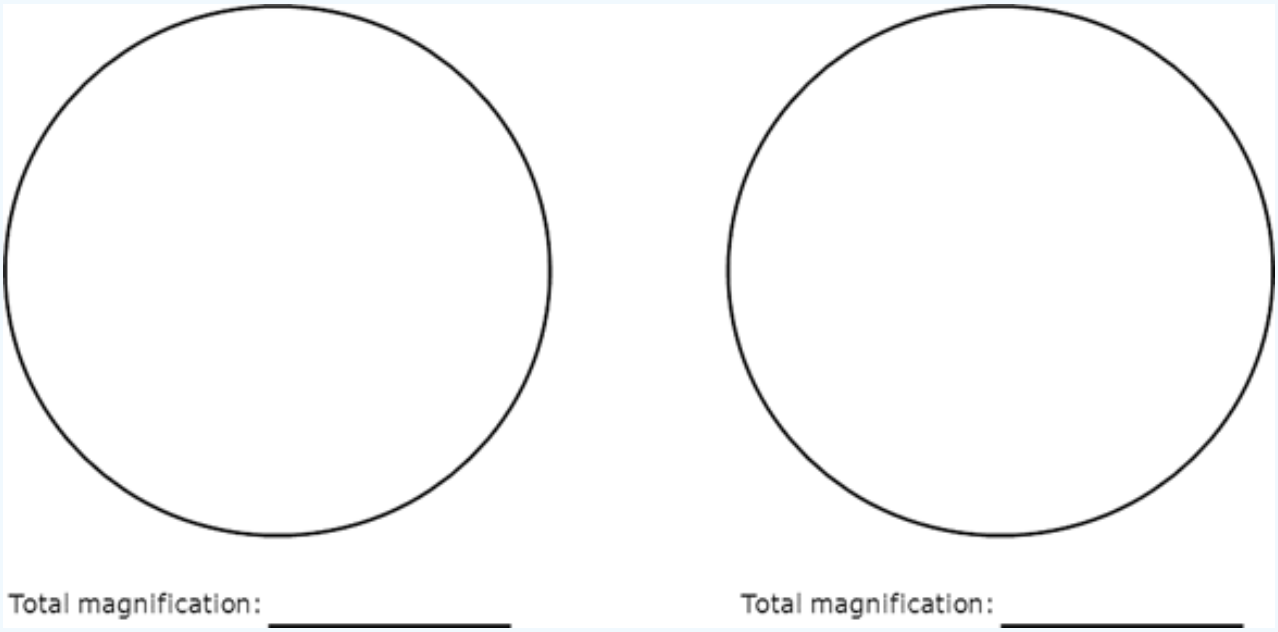
☐ 13. Do not use the 100x objective (if you have one) in this course. It must be used with immersion oil and we won't have students doing that.

How The Virtual Image Differs From The Real Image

The virtual image you see when looking in your microscope is not quite the same as the real image you would see with your eye. For one thing, it is bigger. For another thing, the orientation of the image is different. The two lenses in a compound microscope reflect the original image two times, in two different planes, while magnifying it. So what you think of as the "top" of your image is really the bottom, and what you think of "right" is really left. Usually this is not an issue at the microscopic level, but it is important to understand how the microscope is rearranging your virtual image.

? Lab 1 Exercise 1.5.2

1. Get an "e" slide. If it is already under your microscope, rotate the lowest-power objective into place, use the coarse focus to lower the stage, and remove the slide.
2. Look at the unmagnified "e" on the slide by eye. Rotate the slide around in your hand so that the "e" is right side up. Now clip the slide onto the microscope stage with the stage clips so that the "e" is facing you right side up when you look at it with your unaided eye.
3. In the right-hand circle below, draw what the "e" looks like when you are looking at it right side up. Assume the circle below is the size of the entire coverslip. Draw the "e" you see unaided in the correct proportion to the coverslip. (The unmagnified "e" will take up a tiny portion of the coverslip area.)



4. Clip the slide into your microscope stage so that the "e" is still facing you right side up. Follow the checklist in Lab 1 Exercise 1-7 to ensure you are setting up the microscope properly for use, but stay on the lowest power objective. Get the "e" into your field of view and in focus.
5. In the left-hand circle above, draw what the "e" looks like when viewing it through the microscope under the lowest-power objective. Under the circle, write the total magnification of the image.
6. When viewed under a microscope, how is a specimen rotated?
7. Look at the stage and slide directly (not through the eyepieces.) Move the stage control knob that causes the slide to move away from you on the stage, then move it back to its original position.
8. Now move the stage control knob the exact same way you just did, but view the "e" through the eyepiece. When the stage is moving away from you, what direction does the virtual image appear to be moving?
9. Again, look at the stage and slide directly (not through the eyepiece.) This time, move the stage control knob that causes the slide to move to your right, then move it back to its original position.

10. Now move the stage control knob the exact same way you just did, but view the “e” through the eyepiece. When the stage is moving to your right, what direction does the virtual image appear to be moving?
11. The field of view is the entire area you can see when looking through an eyepiece. Use the stage control knobs to move the virtual image of your “e” to one side of the field of view. Keep most of the “e” in the field of view, but move it to one side or the other.
12. Now switch to the next-power objective. (Do not skip.) To get to the next-power objective, and not the highest-power objective, which way did you have to rotate the objectives, clockwise or counter-clockwise?
13. Using only the fine focus knob (you do NOT use the coarse focus knob on any objective other than the lowest objective), get the “e” in focus.
14. When moving to the next objective, which part of the field of view do you zoom in on?
15. Move away from the eyepieces and look at the distance between the slide and the bottom of the objective. Rotate back to the lowest power objective. Now rotate to the next objective (do not rotate to the highest-power objective by accident). Now rotate to the third-highest objective. What happens to the distance between the slide and the bottom of the objective as you rotate to higher power objectives?
16. With the third-highest power objective still in place, how much space is there between the slide and the bottom of the objective?
17. Notice there is a danger of smashing the objective lens into the slide if you were to use the coarse focus. Why are you instructed to only use the coarse focus with the lowest- power objective?
18. Only draw what you actually see. Even if you expect to see something, if it is not there you should not draw it. Do not base your drawings on what the textbook or some other source tells you should be there. Do not draw things in the shapes that texts or other sources tell you to expect unless you actually see those shapes.

Making Simple But Accurate Line Drawings of Magnified Specimens

You do not have to be a great artist to make a diagram of the cells and structures you see under a microscope. You only have to be careful to draw something that is approximately the same size and shape as what you see. Follow the following guidelines:

1. Only draw what you actually see. Even if you expect to see something, if it is not there you should not draw it. Do not base your drawings on what the textbook or some other source tells you should be there. Do not draw things in the shapes that texts or other sources tell you to expect unless you actually see those shapes.
2. Keep things as simple as possible. Draw strong unbroken lines. Avoid shading or cross- hatching unless there is a very good reason to add them.
3. Feel free to simplify reality by leaving out unnecessary details. Draw what is of interest, but leave out background material, debris, or any other distracting items. Just be careful that, if you are leaving something out, that it isn’t something that is an important part of what you are drawing.

You should always have a basic understanding of what you are looking for before looking in the microscope. Tissues and other microscopic specimens can be confusing and cluttered. If you know in general what you are looking for, and, sometimes more importantly, what you are not looking for, it will make it much easier to find what you want to draw and it will make it much easier to decide how to draw it.

Just remember, what you see under the microscope may look quite different from the perfect specimens that are usually found in the figures put into textbooks and websites. Use the idealized images to track down what you are looking for, but draw the specimen as it actually is, regardless of your expectations.

For instance, in most textbooks, neurons, the most common cell found in nervous tissue, are drawn to look like variations of the drawing in Figure 1.5.1A.

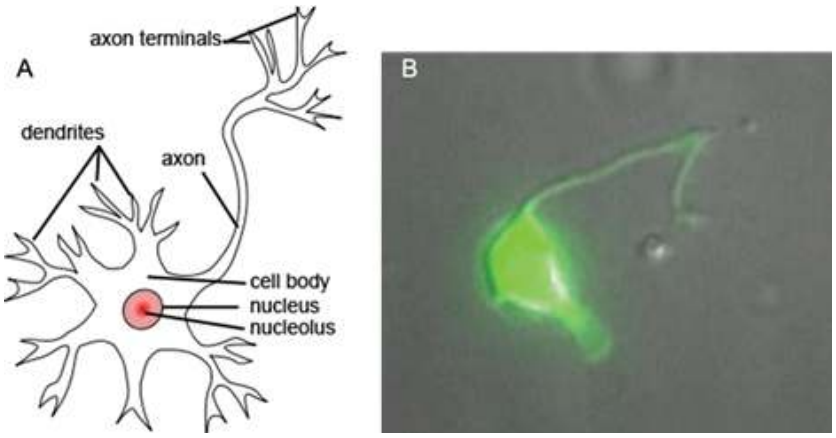


Figure 1.5.1: A. A typical diagram of a neuron. B. An actual neuron. (Left CC-BY-SA, Jonathan Haas, Wikimedia, Right CC-BY, W. Clay Spencer, Rebecca McWhirter, Tyne Miller, Pnina Strasbourger, Owen Thompson, LaDeana W. Hillier, Robert H. Waterston, David M. Miller III)

In the typical diagram of a neuron that appears in texts and on websites, there usually is a clear nucleus, and often a nucleolus visible, too. Sometimes organelles such as mitochondria are visible (there are none in Figure 1.5.1A.) The dendrites are typically short and branched. There almost always is a single, easily-identifiable axon that is longer than all the dendrites and that branches as it ends.

Figure 1.5.1B shows an actual neuron as viewed through a microscope. If you view enough neurons through enough different types of microscopes, you can eventually create a composite diagram that incorporates features from many specimens to present a "typical" neuron, but it is unlikely that if you view a single neuron you will see everything in Figure 1.5.1A. In fact, often actual specimens look very little like their textbook counterparts. Draw what you see, not what you think you are supposed to see. Just make sure you are looking at what you are supposed to be finding (for instance, a neuron and not a piece of dirt or cell debris), and then draw it as it is.

In the case of the actual neuron in Figure 1.5.1B, there is no nucleus visible, there is maybe one large projection and one small projection you could call dendrites – but there aren't many projections – and neither of the projections are branched. There is one long thin projection that is probably an axon, and it is not branched.

If you draw what you see, you end up with a drawing like the one in Figure 1.14B. It does not look like a textbook neuron, but it is a reasonable representation of what is there in this case.

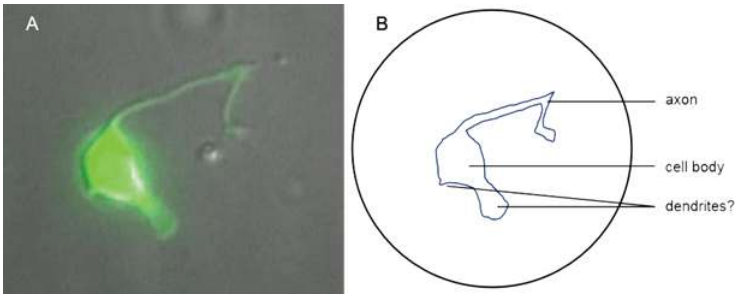


Figure 1.5.2: An actual neuron. (Left CC-BY-SA, Jonathan Haas, Wikimedia, Right CC-BY, W. Clay Spencer, Rebecca McWhirter, Tyne Miller, Pnina Strasbourger, Owen Thompson, LaDeana W. Hillier, Robert H. Waterston, David M. Miller III)

Most students feel they "cannot draw" and are reluctant to sketch what they are seeing under a microscope. You don't let your lack of artistic skills stop you.

1. Draw an outline that approximates the item you want to draw. Don't obsess about making it match perfectly. Approximate is ok.
2. Try to get the proportions approximately right. If something is half as big, or as third as big, as something else, make it that way in the drawing, too.
3. Do not draw everything you see. Improve on reality by only drawing the parts of the specimen you are interested in. You do not have to draw every bit of debris or dirt. Decide what the important parts of your specimen are and draw only those.

4. Do not use shading or cross-hatching unless there is a very good reason to do so. It will actually make it easier to understand your drawing if you stick to drawing just outlines. It will also be easier and quicker to draw.

? Lab 1 Exercise 1.5.3

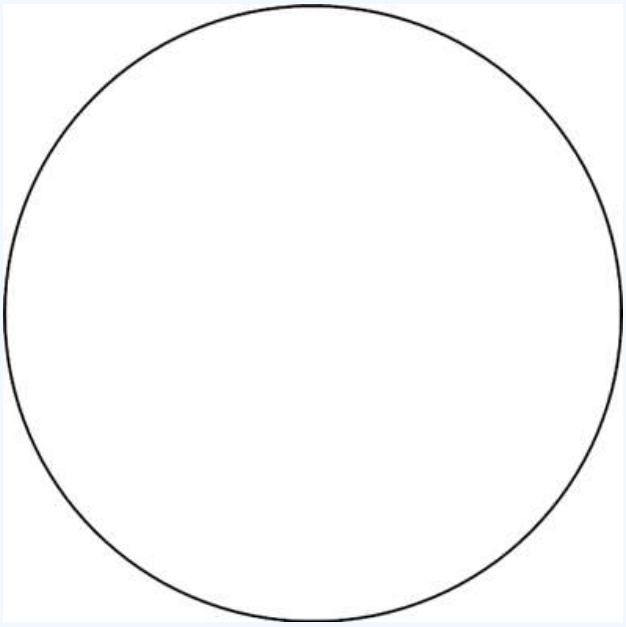
1. Get a human blood smear slide. Rotate your lowest power objective into place on your microscope.

2. Follow the checklist in Lab Exercise 1.5.1 until you are viewing the blood smear under your 40x objective.

3. You will see mostly red blood cells. They will probably be pinkish and they will be the circles without nuclei. Occasionally, some will appear to have blank circles in their centers, but these are not nuclei. If you search around your slide using your stage controls, you will find the rare circular cells with nuclei. These are white blood cells. There will be less than one white blood cell for every 100 red blood cells. These white blood cells will probably be light blue or grey and have purple or dark blue nuclei. Their nuclei will not always be round.

4. Find a section of your slide with two or more white blood cells among all the red blood cells.

5. In the circle below, draw four or five representative red blood cells (do not draw all the red blood cells you see) and draw all the white blood cells in your field of view. Pay careful attention to drawing the white blood cell nuclei as accurately as possible.



6 Do not remove or change the position of your slide until one of your lab partners has verified that your white blood cells are drawn accurately. Introduce yourself to a partner and ask for their help.

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Figure 1.5.1B. A drawing of Figure Figure 1.5.1A's neuron.. Authored by: Ross Whitwam. Provided by: Mississippi University for Women. Located at: http://www.muw.edu. License: CC BY-SA: Attribution-ShareAlike

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Figure Figure 1.5.2. A typical diagram of a neuron.. Authored by: Jonathan Haas. Located at: https://commons.wikimedia.org/w/inde...curid=18271454. License: CC BY-SA: Attribution-ShareAlike

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Figure Figure 1.5.2A. An actual neuron; Figure 1.5.1B. An actual neuron. Authored by: W. Clay Spencer, Rebecca McWhirter, Tyne Miller, Pnina Strasbourger, Owen Thompson, LaDeana W. Hillier, Robert H. Waterston, David M. Miller III. Located at: http://dx.doi.org/10.1371/journal.pone.0112102. License: CC BY: Attribution

When storing a microscope, you should always follow this list:

1. Remove any slide found on the stage and return it to the slide box.
2. Rotate the smallest lens or no lens into place above the stage. Lower the stage a few turns.
3. Loosely coil the cord in your hand starting near the microscope and working toward the plug.
4. Hang the coiled cord over one ocular lens.
5. Look at the number on the back of the microscope, return that scope to its numbered box.
6. If there's already a microscope in that numbered box, check its number and move it. If it is not numbered simply push it to the back of the box and place yours closer to the front. We have a few extra microscopes which we store in this fashion.



Figure 1.5.1: Copy and Paste Caption here. (Copyright; author via source)

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CHAPTER OVERVIEW

2: Cytology

In this lab students will learn to identify main external and internal cell structures. Use your textbook to identify and label the cell structures listed below. Watch the Cytology Lab Video associated with this lab.



2.1: Cell Structure

2.2: Observing Mitosis

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2.1: Cell Structure

Laab 2 Example 2.1.1

1. Plasma membrane	6. Golgi complex
2. Nucleus	7. Golgi vesicles
3. Nuclear envelope	8. Mitochondria
4. Rough endoplasmic reticulum	9. Lysosome
5. Smooth endoplasmic reticulum	10. Centriole

There may be multiple pictures of the same structure

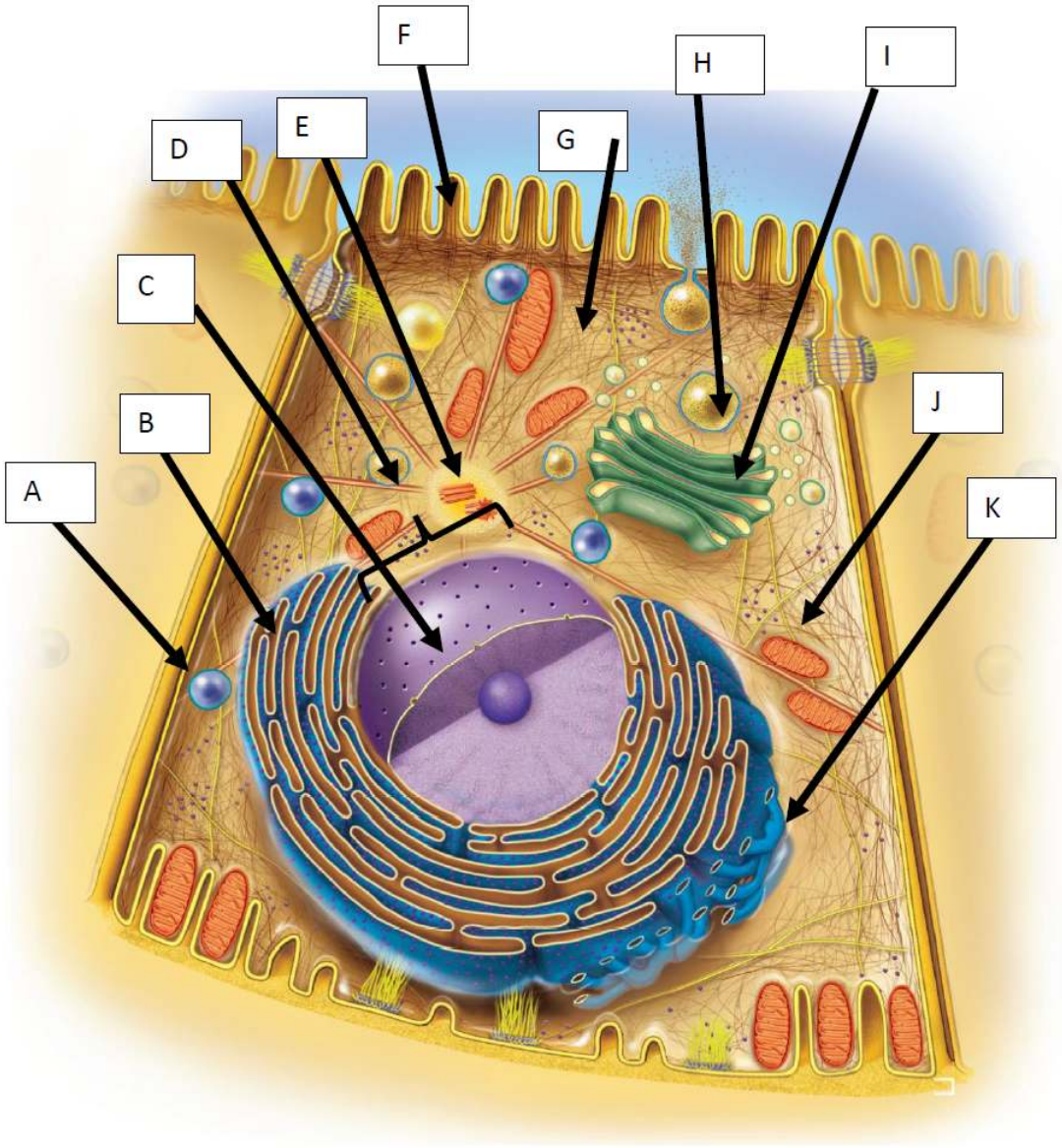


Figure 2.1.1: Downloaded for free from http://www.stkate-las.com/uploads/7/...ology1_lab.pdf

Lab 2 Exercise 2.1.2

requested before 2.1 to help you complete this activity. Place the appropriate letter(s) on the line between the numbers and the name. “NA” = not applicable, do not use.

1. _____ Plasma membrane	6. _____ Golgi complex
2. _____ Nucleus	7. _____ Golgi vesicles
3. _____ Nuclear envelope	8. _____ Mitochondria
4. _____ Rough endoplasmic reticulum	9. _____ Lysosome
5. _____ Smooth endoplasmic reticulum	10. _____ Centriole

There may be multiple pictures of the same structure

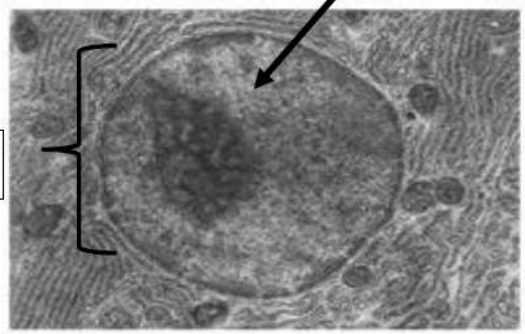
*There may be multiple pictures of the same structure

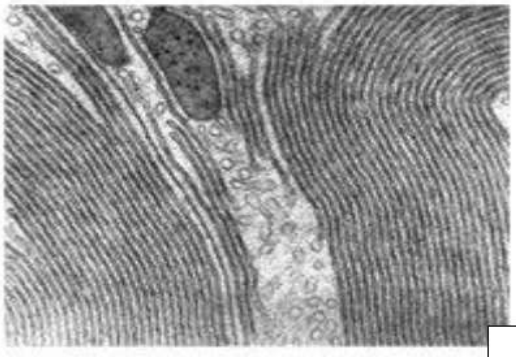
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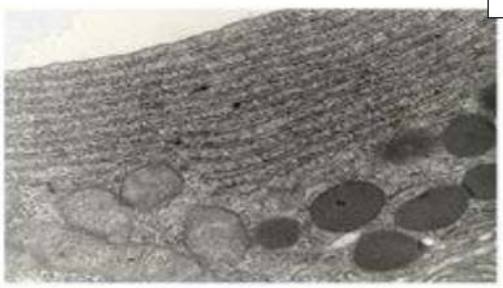
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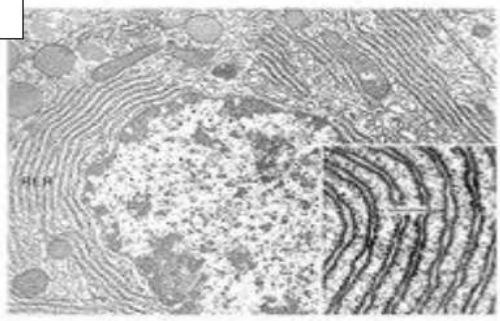


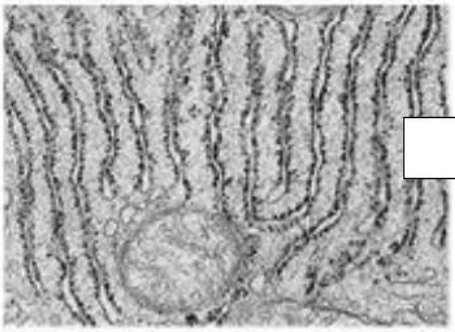




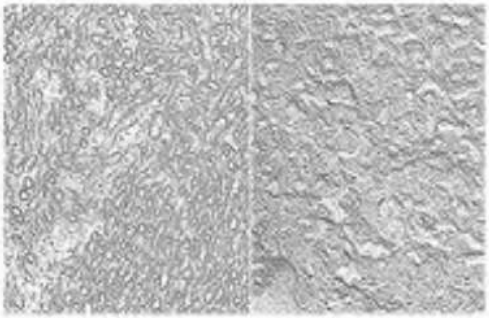
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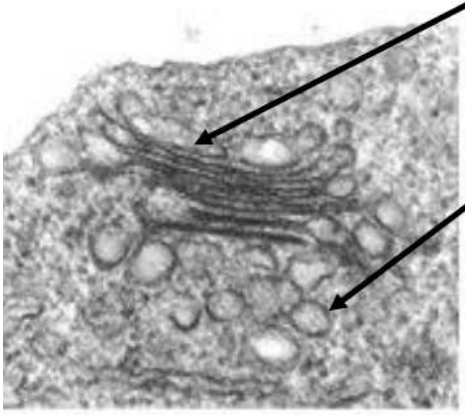




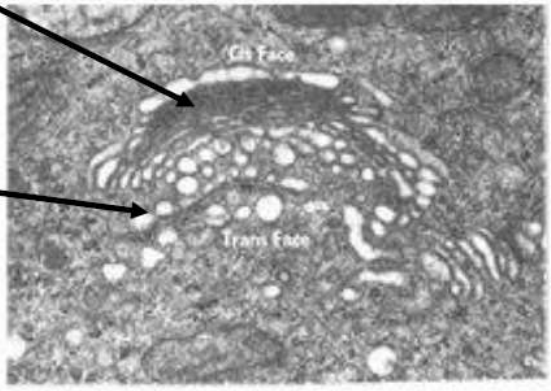
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AB



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AD

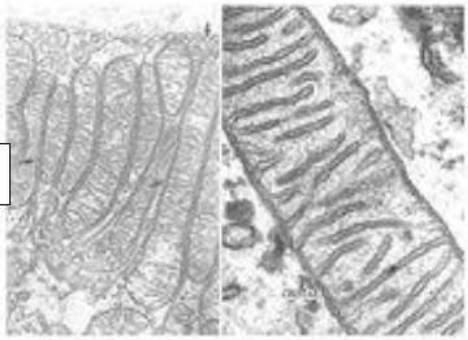


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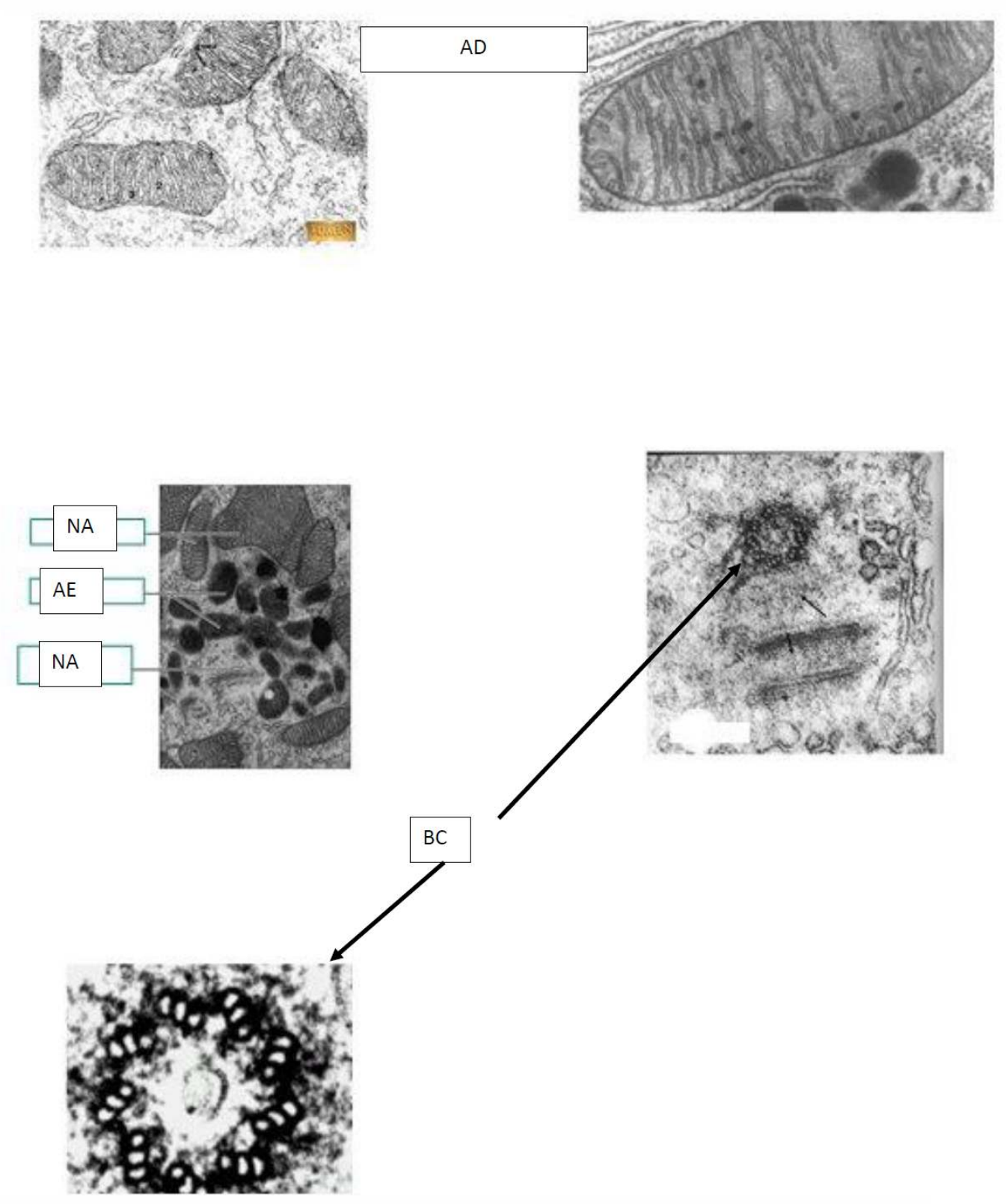


Figure **2.1.1**: http://www.stkate-las.com/uploads/7/...ology1_lab.pdf

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2.2: Observing Mitosis

Mitosis In A Whitefish Embryo

The Cell Cycle and Mitosis:

The cell cycle refers to a series of events that describe the metabolic processes of growth and replication of cells. The bulk of the cell cycle is spent in the “living phase”, known as **interphase**. Interphase is further broken down in to 3 distinct phases: G_1 (Gap 1), S (Synthesis) and G_2 (Gap 2). **G_1** is the phase of growth when the cell is accumulating resources to live and grow. After attaining a certain size and having amassed enough raw materials, a checkpoint is reached where the cell uses biochemical markers to decide if the next phase should be entered. If the cell is in an environment with enough nutrients in the environment, enough space and having reached the appropriate size, the cell will enter the S phase. **S phase** is when metabolism is shifted towards the replication (or synthesis) of the genetic material. During S phase, the amount of DNA in the nucleus is doubled and copied exactly in preparation to divide. The chromosomes at the end of G_1 consist of a single **chromatid**. At the end of S phase, each chromosome consists of two identical **sister chromatids** joined at the **centromere**.

When the DNA synthesis is complete, the cell continues on to the second growth phase called **G_2**. Another checkpoint takes place at the end of G_2 to ensure the fidelity of the replicated DNA and to re- establish the success of the cell’s capacity to divide in the environment. If conditions are favorable, the cell continues on to mitosis.

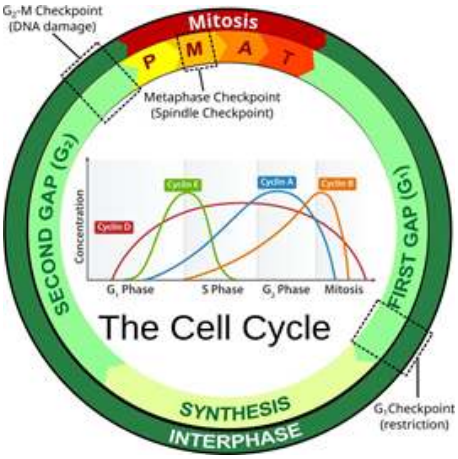
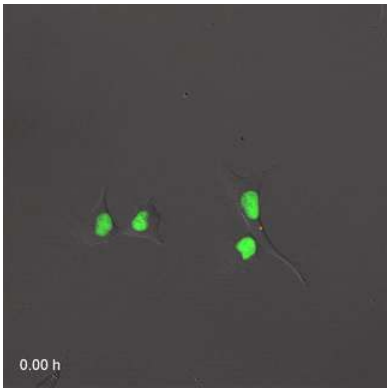


Figure **2.2.1**: Eukaryotic cell cycle is governed by expression of cyclin proteins along with their activity. (CC-BY-NC-SA, Cell division, https://openlab.citytech.cuny.edu/bi...cell-division/





Follow this link above to view a mitosis video.

Mitosis is the process of nuclear division used in conjunction with cytokinesis to produce 2 identical daughter cells. Cytokinesis is the actual separation of these two cells enclosed in their own cellular membranes. Unicellular organisms utilize this process of division in order to reproduce asexually.

Prokaryotic organisms lack a nucleus, therefore they undergo a different process called binary fission. Multicellular eukaryotes undergo mitosis for repairing tissue and for growth. The process of mitosis is only a short period of the lifespan of cells. Mitosis is traditionally divided into four stages: prophase, metaphase, anaphase and telophase.

The actual events of mitosis are not discreet but occur in a continuous sequence—separation of mitosis into four stages is merely convenient for our discussion and organization. During these stages important cellular structures are synthesized and perform the mechanics of mitosis. For example, in animal cells two microtubule organizing centers called centrioles replicate. The pairs of centrioles move apart and form an axis of proteinaceous microtubules between them called spindle fibers.

These spindle fibers act as motors that pull at the centromeres of chromosomes and separate the sister chromatids into newly recognized chromosomes. The spindles also push against each other to stretch the cell in preparation of forming two new nuclei and separate cells. In animal cells, a contractile ring of actin fibers cinch together around the midline of the cell to coordinate cytokinesis. This cinching of the cell membrane creates a structure called the cleavage furrow.

Eventually, the cinching of the membrane completely separates into two daughter cells. Plant cells require the production of new cell wall material between daughter cells. Instead of a cleavage furrow, the two cells are separated by a series of vesicles derived from the Golgi. These vesicles fuse together along the midline and simultaneously secrete cellulose into the space between the two cells. This series of vesicles is called the cell plate.

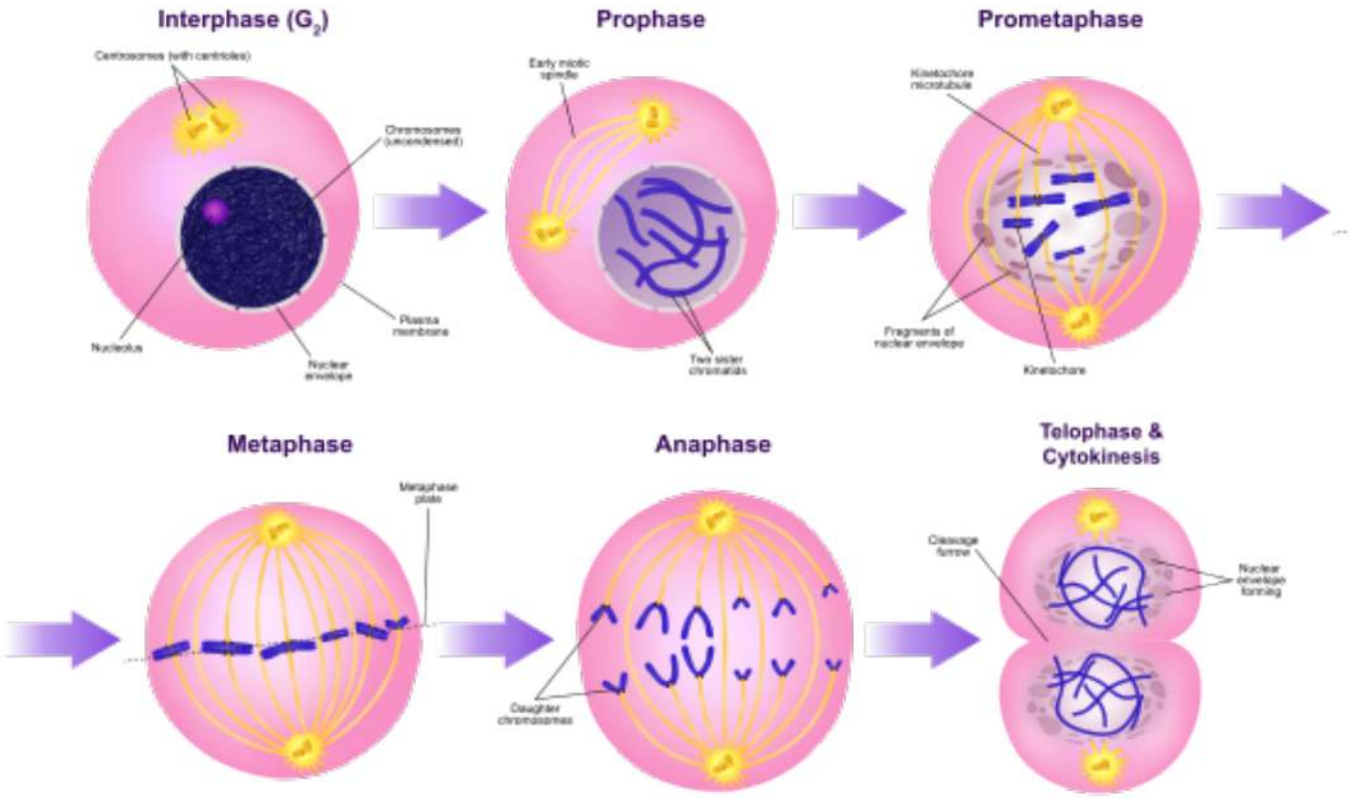
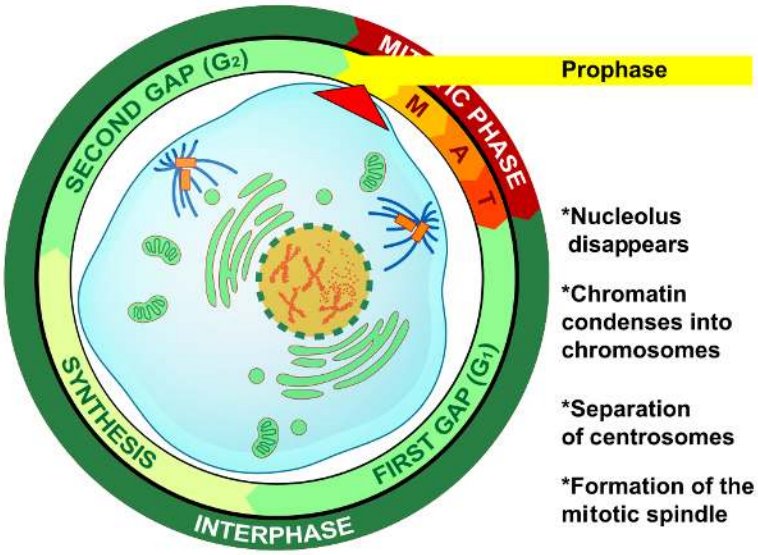
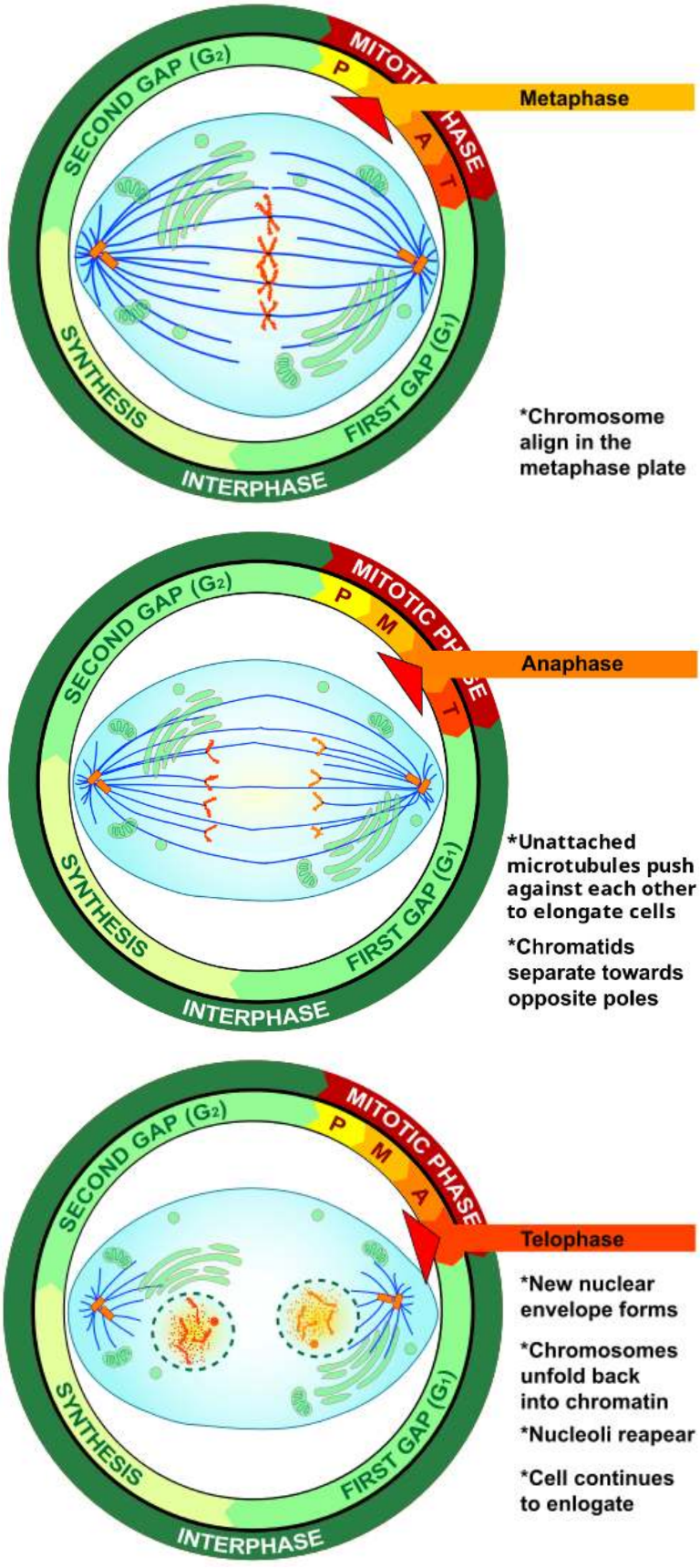


Figure **2.2.2**: Figure **2.2.2**: Mitosis stages (CC-BY-SA, Ali Zifan, Wikimedia)



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SECOND GAP (G2)
P
A
T
SYNTHESIS
FIRST GAP (G1)
INTERPHASE
Metaphase
*Chromosome align in the metaphase plate
SECOND GAP (G2)
P
M
T
SYNTHESIS
FIRST GAP (G1)
INTERPHASE
Anaphase
*Unattached microtubules push against each other to elongate cells
*Chromatids separate towards opposite poles
SECOND GAP (G2)
P
M
A
SYNTHESIS
FIRST GAP (G1)
INTERPHASE
Telophase
*New nuclear envelope forms
*Chromosomes unfold back into chromatin
*Nucleoli reapear
*Cell continues to enlogate

Figur

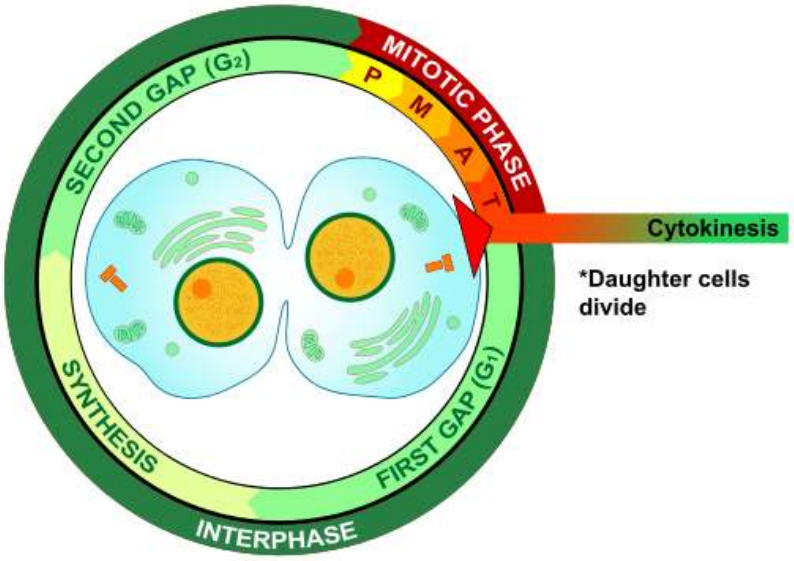


Figure **2.2.3**: (CC-BY-NC-SA, Cell division, https://openlab.citytech.cuny.edu/bi...cell-division/

Review Setting up Your Microscope

☐ 1. Plug in the microscope & turn on light source.

☐ 2. Pick up microscope by carrying arm, position it so it is accessible to your seat, with open side of the stage facing you

☐ 3. Rotate the objectives so that the lowest power objective (smallest in size) clicks into place.

☐ 4. Look at the slide with your naked eye and find the location of the specimen.

☐ 5. Clip the slide into place with the stage clips. The cover slip on the slide must face up. Find the stage controls and make sure that, when they are turned, the slide moves smoothly left and right or up and down, depending on the knob.

☐ 6. Use the stage controls to move the slide so that the light source is shining directly on to the specimen to be magnified.

☐ 7. Find the coarse and fine focus knobs. Watching the stage and objective, use the coarse focus knob to bring the low power objective as close to the slide as it will go.

☐ 8. Put your eye to the eyepiece (or eyepieces, if the microscope is binocular) and rotate the coarse focus knob in the lowering direction until some aspect of the specimen comes into focus.

☐ 9. Move your hand to the fine focus knob and get the specimen into perfect focus for your eyes. **Do NOT touch the coarse focus knob again.**

☐ 10. Use the stage control knobs to move you specimen to close to the exact center of your field of view

☐ 11. Move to the next highest power objective (do not skip the individual objectives) and use only the fine focus to get your image into perfect focus for your eyes.

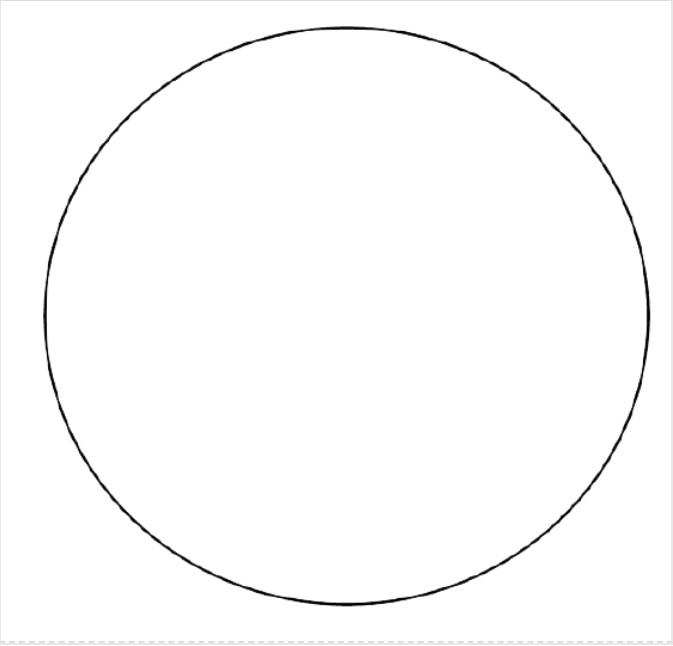
☐ 12. If you need further magnification, move to the next highest power objective and use only the fine focus to get your image into perfect focus for your eyes.

☐ 13. Do not use the 100x objective (if you have one) in this course. It must be used with immersion oil and we won't have students doing that.

Lab 2 Exercise 2.2.1

1. Obtain a slide of a whitefish embryo (blastula) from the slide box at your table.
2. Follow the checklist above to set up your slide for viewing.
3. View the slide on the objective which provides the best view. Find the representative object.
4. In the circles below the name, draw a representative sample of the stage of mitosis, taking care to correctly and clearly draw the true shape in the slide. Draw your structures proportionately to their size in your microscope's field of view.
5. Fill in the blanks next to your drawing.
6. Repeat this for each of the mitosis phases seen below.

A) Prophase

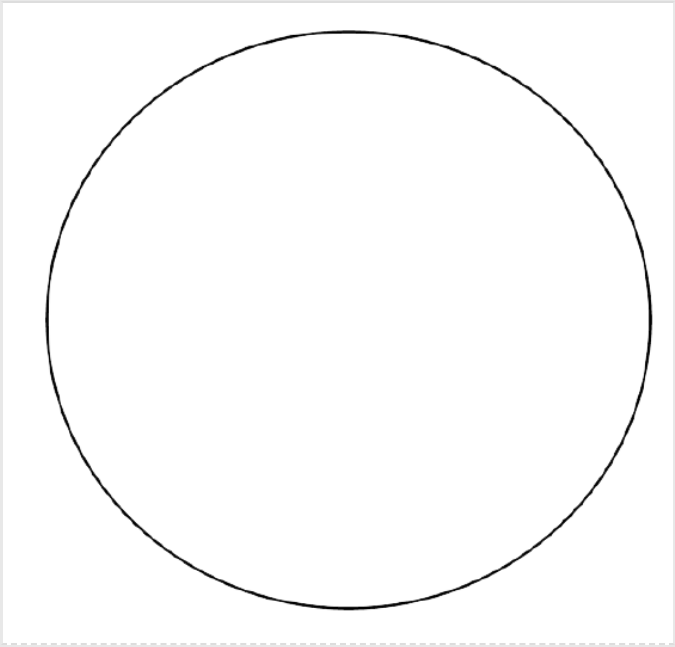


Total Magnification: _____
Type of eptihelium: _____
Source of tissue: _____
Function of this phase: _____
_____

Function of this phase:

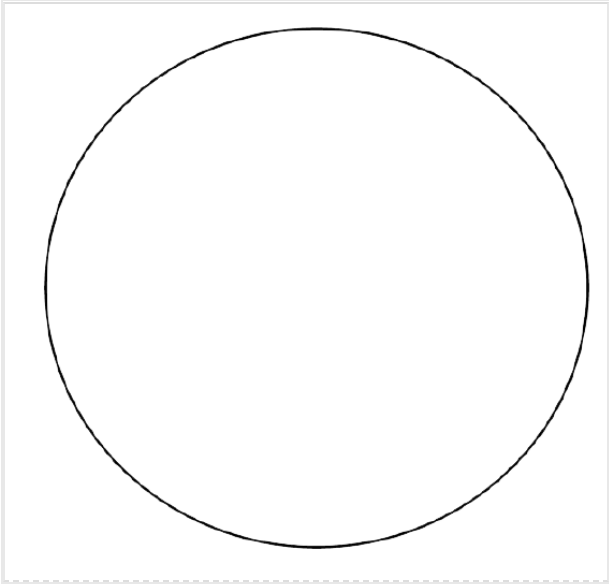
B) Metaphase

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Total Magnification: _____
Type of eptihelium: _____
Source of tissue: _____
Function of this phase: _____
_____

C) Anaphase



Total Magnification: _____
Type of eptihelium: _____
Source of tissue: _____
Function of this phase: _____
_____

D) Telophase/cytokinesis

	Total Magnification: _____ Type of eptihelium: _____ Source of tissue: _____ Function of this phase: _____ _____

Function of this phase:

Storing the microscope

When storing a microscope you should always follow this list:

1. Remove any slide found on the stage and return it to the slide box.
2. Rotate the smallest lens or no lens into place above the stage. Lower the stage a few turns.
3. Loosely coil the cord in your hand starting near the microscope and working toward the plug.
4. Hang the coiled cord over one ocular lens.
5. Look at the number on the back of the microscope, return that scope to its numbered box.
6. If there's already a microscope in that numbered box, check its number and move it. If it is not numbered simply push it to the back of the box and place yours closer to the front. We have a few extra microscopes which we store in this fashion.



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CHAPTER OVERVIEW

3: Histology

3.1: Examining epithelial tissue under the microscope

3.2: Examining Connective Tissue

3.3: Examining Connective Tissue

3.4: Distinguishing Between The Three Types of Muscle Tissue

3.5: Identifying Neurons Within Nervous Tissue

3.6: Practice in Identifying Different Types of Tissues

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3.1: Examining epithelial tissue under the microscope

Information

Epithelial tissue serves two main functions in the body.

1. It provides **linings** for external and internal surfaces that face harsh environments. The outer layer of the skin is epithelial tissue, as are the innermost layers of the digestive tract, the respiratory tract, and blood vessels.
2. It forms **glands** that secrete materials onto epithelial surfaces or into the blood. Sweat glands, salivary glands, mammary glands, adrenal glands, and pituitary glands are examples of glands made of epithelial tissue.

Epithelial tissue is often classified according to numbers of layers of cells present, and by the shape of the cells. See Figure 3.1.

A **simple epithelium** is only one layer of cells thick. A **stratified epithelium** is more than one layer of cells thick. A **pseudostratified epithelium** is really a specialized form of a simple epithelium in which there appears at first glance to be more than one layer of epithelial cells, but a closer inspection reveals that each cell in the layer actually extends to the basolateral surface of the epithelium.

There are three basic shapes used to classify epithelial cells. A **squamous** epithelial cell looks flat under a microscope. A **cuboidal** epithelial cell looks close to a square.

A **columnar** epithelial cell looks like a column or a tall rectangle. A few epithelial layers are constructed from cells that are said to have a transitional shape. **Transitional** epithelial cells are epithelial cells specialized to change shape if they are stretched laterally. They can transition from columnar- and cuboidal-looking shapes in their unstretched state to more squamous-looking shapes in their stretched state.

When classifying a stratified epithelial sheet, the sheet is named for the shape of the cells in its most superficial layers. So, a stratified squamous epithelium only necessarily has squamous-shaped cells in its highest layers and might have a different-shaped cell in its lower layers.

Under a microscope, epithelial cells are readily distinguished by the following features:

- The cells will usually be one of the three basic cell shapes – squamous, cuboidal, or columnar.
- The cells will be closely attached to one another, in either a single layer or in multiple layers, and usually will not have room for extracellular material between the attached cells.

The epithelial layer on one side will face an empty space (or, in some organs, it will face a secreted substance like mucus) and on the other side will usually be attached to connective tissue proper.

Usually, a slide will have a section of tissue cut out of a larger organ. Slides with epithelial tissues usually have some of the underlying tissue found beneath the epithelial tissue with them.

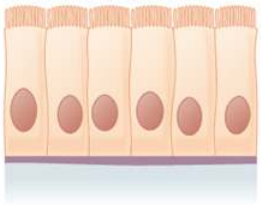
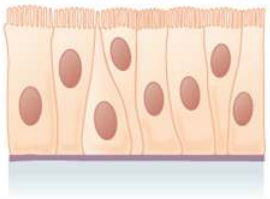
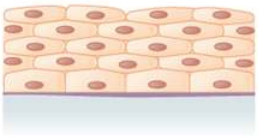
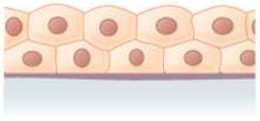
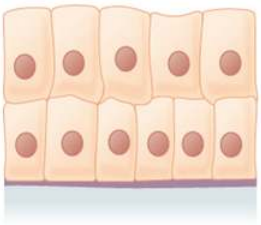
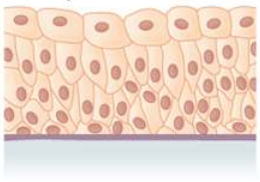
Cells	Location	Function
Simple squamous epithelium 	Air sacs of lungs and the lining of the heart, blood vessels, and lymphatic vessels	Allows materials to pass through by diffusion and filtration, and secretes lubricating substance
Simple cuboidal epithelium 	In ducts and secretory portions of small glands and in kidney tubules	Secretes and absorbs
Simple columnar epithelium 	Ciliated tissues are in bronchi, uterine tubes, and uterus; smooth (nonciliated tissues) are in the digestive tract, bladder	Absorbs; it also secretes mucous and enzymes
Pseudostratified columnar epithelium 	Ciliated tissue lines the trachea and much of the upper respiratory tract	Secretes mucus; ciliated tissue moves mucus
Stratified squamous epithelium 	Lines the esophagus, mouth, and vagina	Protects against abrasion
Stratified cuboidal epithelium 	Sweat glands, salivary glands, and the mammary glands	Protective tissue
Stratified columnar epithelium 	The male urethra and the ducts of some glands	Secretes and protects
Transitional epithelium 	Lines the bladder, uretha, and the ureters	Allows the urinary organs to expand and stretch

Figure **3.1.1**: The different ways sheets of epithelial cells are categorized. (CC-BY, OpenStax, Human Anatomy)

A layer of epithelial cells always serves as an outer layer for some structure, but, when looking at a tissue preparation on a slide, do not assume that just because you have found one end of the tissue sample you are automatically looking at epithelial tissue. Look

for the cell characteristics listed above to be sure you are on the epithelial side of a tissue slice.

In Figure **3.1.2**, only one edge of the tissue slice has epithelial cells. In Figure **3.1.2**A that edge is indicated with an arrow, but when looking at a specimen under a microscope, you have to figure out for yourself where the edge with the epithelial cells is.

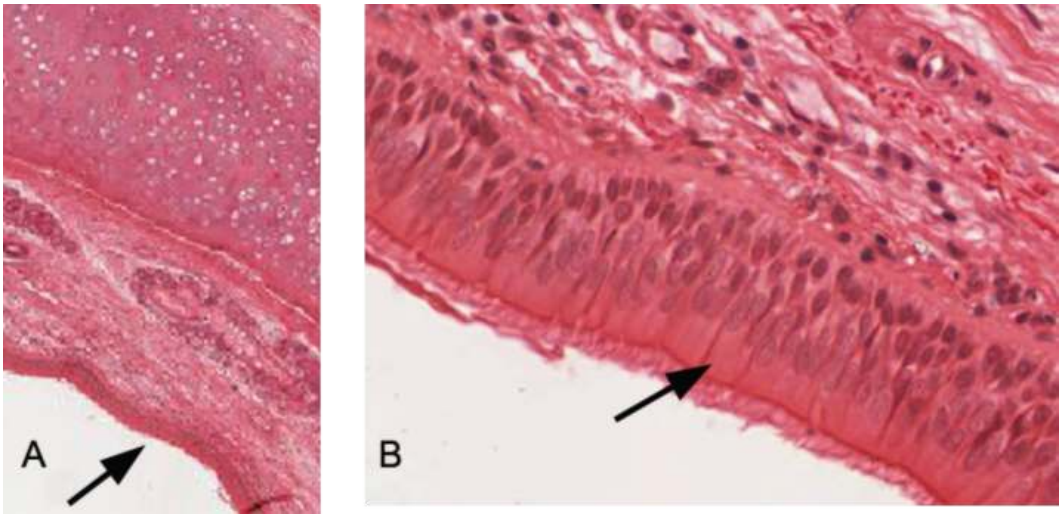


Figure **3.1.2**: A slice of a trachea. A. Magnified 1.8x. The arrow indicates which edge in this slice contains the epithelial cells B. Magnified 20x. The arrow indicates an individual columnar epithelial cell. (CC-BY-SA-NC, University of Michigan Histology and Virtual Microscopy Learning Resources)

In the tissue slice in Figure **3.1.2**, there are three edges that are not epithelial cells. If you just mindlessly started viewing the first edge you find, you have a good chance of looking as something other than the epithelial cells in the preparation. Be sure what you are looking at has the three visual characteristics of epithelial tissue:

- The cells will usually be one of the three basic cell shapes – squamous, cuboidal, or columnar.
- The cells will be closely attached to one another, in either a single layer or in multiple layers, and usually will not have room for extracellular material between the attached cells.
- The epithelial layer on one side will face an empty space (or, in some organs, it will face a secreted substance like mucus) and on the other side will usually be attached to connective tissue proper.

In the following figures are some more epithelial layers. Note that whether the epithelial layer of the specimen is on the top, bottom, right, or left of the slice varies with how the specimen slice was positioned on the slide. In every case, you have to find which edge has the epithelial layer.

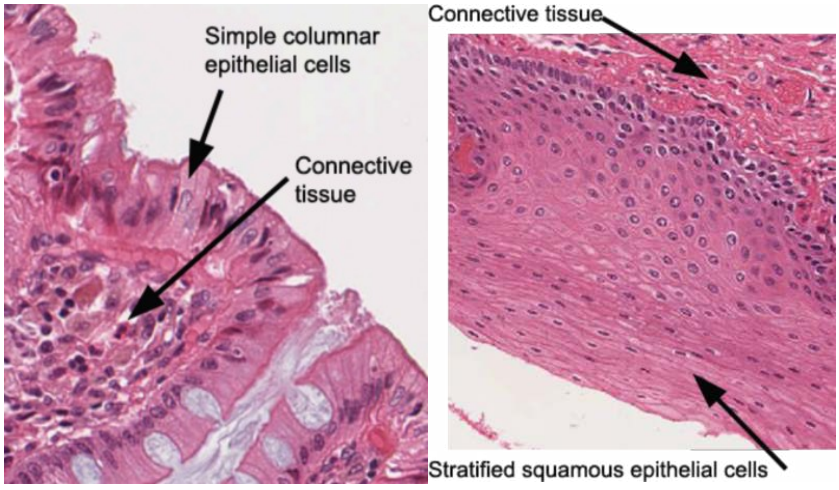


Figure \(\PageIndex{3}\): Left a slice of the colon, 20x. Right Figure 5-4. A slice of the esophagus, 10x. (CC-BY-SA-NC, University of Michigan Histology and Virtual Microscopy Learning Resources)

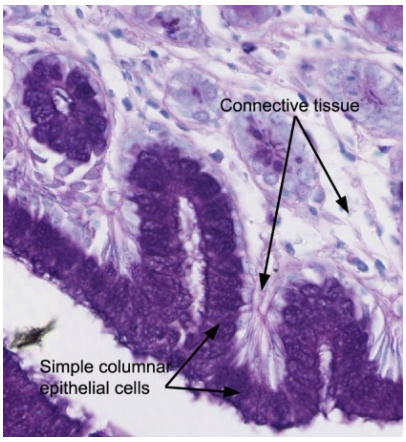


Figure 3.1.4: (CC-BY-SA-NC, University of Michigan Histology and Virtual Microscopy Learning Resources)

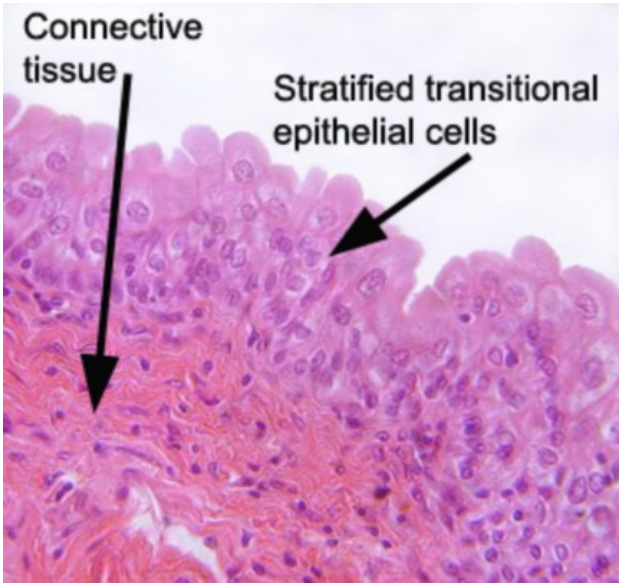


Figure 3.1.5: slice of the urinary bladder, 10x. (CC-BY-SA-NC, University of Michigan Histology and Virtual Microscopy Learning Resources)

Setting up a microscope

? Lab 1 Exercise 1

☐ 1. Plug in the microscope & turn on light source.

☐ 2. Pick up microscope by carrying arm, position it so it is accessible to your seat, with open side of the stage facing you

☐ 3. Rotate the objectives so that the lowest power objective (smallest in size) clicks into place.

☐ 4. Look at the slide with your naked eye and find the location of the specimen.

☐ 5. Clip the slide into place with the stage clips. The cover slip on the slide must face up. Find the stage controls and make sure that, when they are turned, the slide moves smoothly left and right or up and down, depending on the knob.

☐ 6. Use the stage controls to move the slide so that the light source is shining directly on to the specimen to be magnified.

☐ 7. Find the coarse and fine focus knobs. Watching the stage and objective, use the coarse focus knob to bring the low power objective as close to the slide as it will go.

☐ 8. Put your eye to the eyepiece (or eyepieces, if the microscope is binocular) and rotate the coarse focus knob in the lowering direction until some aspect of the specimen comes into focus.

☐ 9. Move your hand to the fine focus knob and get the specimen into perfect focus for your eyes. **Do NOT touch the coarse focus knob again.**

☐ 10. Use the stage control knobs to move you specimen to close to the exact center of your field of view

☐ 11. Move to the next highest power objective (do not skip the individual objectives) and use only the fine focus to get your image into perfect focus for your eyes.

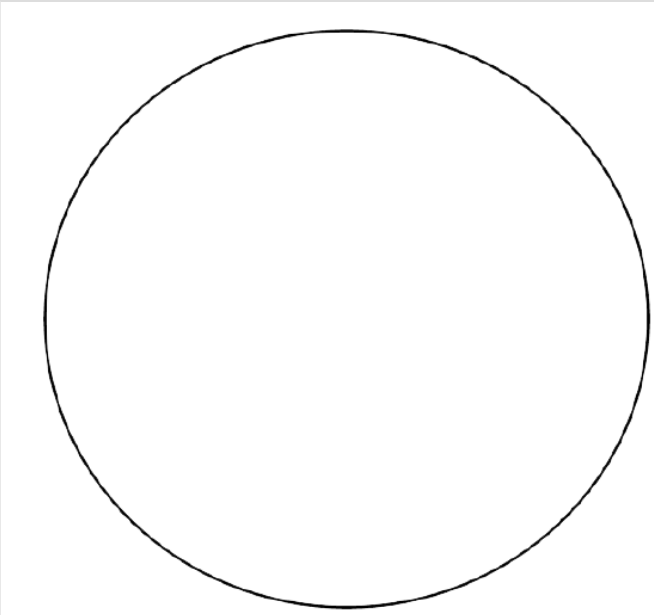
☐ 12. If you need further magnification, move to the next highest power objective and use only the fine focus to get your image into perfect focus for your eyes.

☐ 13. Do not use the 100x objective (if you have one) in this course. It must be used with immersion oil and we won't have students doing that.

? Lab 3 Exercise 3.1.1

Simple columnar

Simple cuboidal

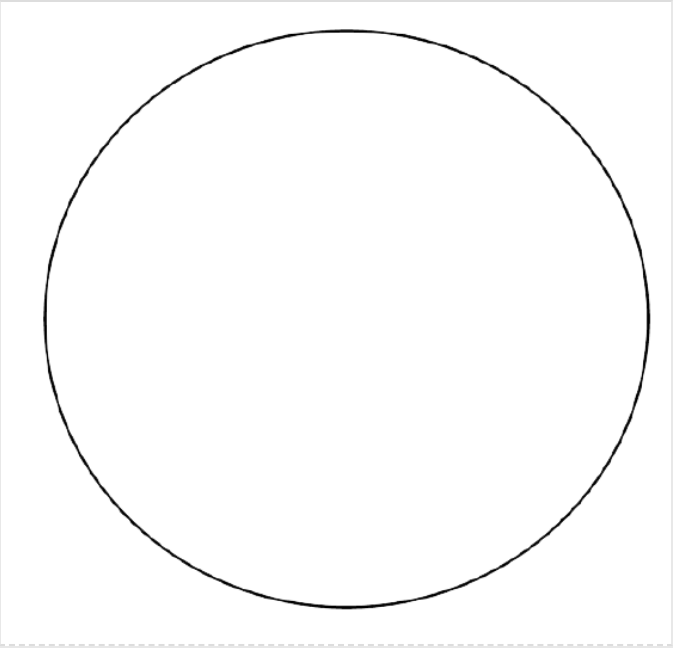


Total Magnification: _____
Type of eptihelium: _____
Source of tissue: _____
Function of this phase: _____
_____

Simple squamous

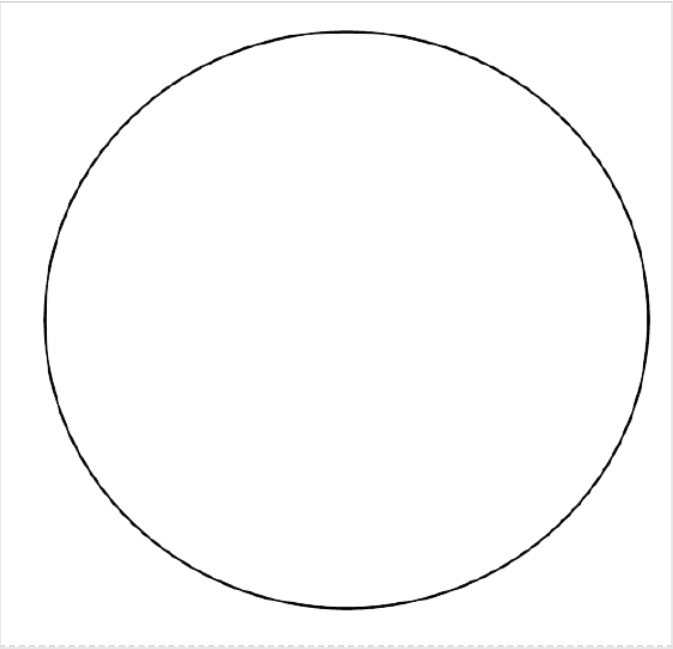
Stratified squamous

Pseudostratified columnar



Total Magnification: _____
Type of eptihelium: _____
Source of tissue: _____
Function of this phase: _____
_____

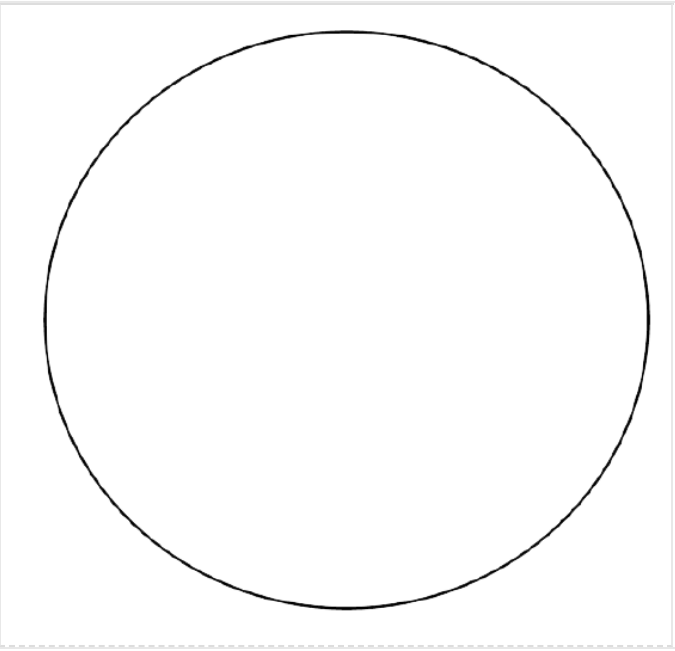
Transitional



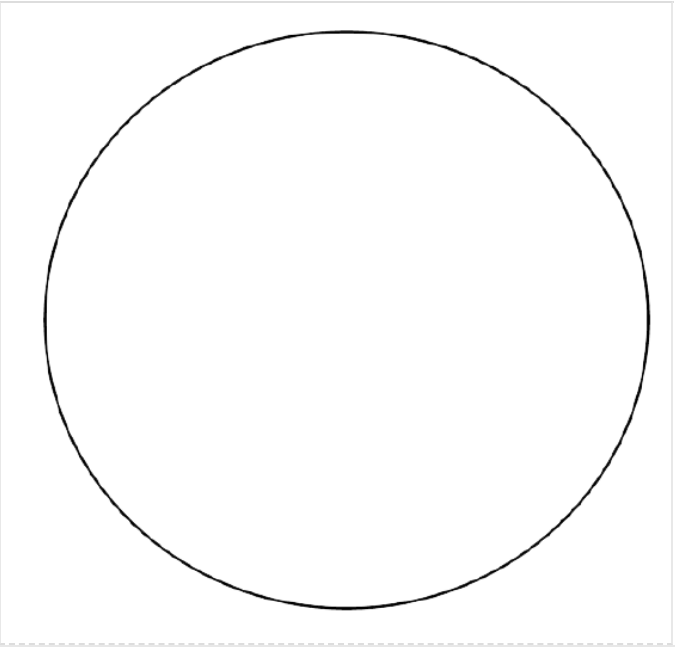
Total Magnification: _____
Type of eptihelium: _____
Source of tissue: _____
Function of this phase: _____
_____

1. Obtain a slide of one of the tissues listed below from the slide box at your table.
2. Follow the checklist above to set up your slide for viewing.
3. View the slide on the objective which provides the best view. Find the representative object.
4. In the circle below the name, draw a representative sample of the tissue, taking care to correctly and clearly draw their true shape in the slide. If it is a stratified epithelium draw all the layers. Draw your structures proportionately to their size in your microscope's field of view.
5. Fill in the blanks next to your drawing.

A) Prophase



Total Magnification: _____
Type of eptihelium: _____
Source of tissue: _____
Function of this phase: _____
_____



Total Magnification: _____
Type of eptihelium: _____
Source of tissue: _____
Function of this phase: _____
_____

Repeat this for each of the tissue types seen below.

References

A&P Labs. **Authored by**: Ross Whitwam. **Provided by**: Mississippi University for Women. **Located at**: http://www.muw.edu/. **License**: ***CC BY-SA: Attribution-ShareAlike***

CC LICENSED CONTENT, SHARED PREVIOUSLY

Figure **3.1.1**. The different ways sheets of epithelial cells are categorized.. **Provided by**: OpenStax College. **Located at**: https://commons.wikimedia.org/wiki/F...sue_CellsN.jpg. **License**: ***CC BY-*** ***SA: Attribution-ShareAlike***

CC LICENSED CONTENT, SPECIFIC ATTRIBUTION

Figure **3.1.2**. A slice of a trachea. A. Magnified 1.8x. The arrow indicates which edge in this slice contains the epithelial cells B. Magnified 20x. The arrow indicates an individual columnar epithelial cell.. **Authored by**: Kent Christensen, Ph.D., J. Matthew Velkey, Ph.D., Lloyd M. Stoolman, M.D., Laura Hessler, and Diedra Mosley-Brower. **Provided by**: University of Michigan Histology and Virtual Microscopy Learning Resources. **Located at**: **http://141.214.65.171/Histology/Basic%20Tissues/Epithelium%20and%20CT/020_HISTO_20X.svs/view.apml**. **License**: ***CC BY-NC-SA: Attribution-NonCommercial-ShareAlike***

Figure **3.1.3*L***. A slice of the colon, 20x.. **Authored by**: Kent Christensen, Ph.D., J. Matthew Velkey, Ph.D., Lloyd M. Stoolman, M.D., Laura Hessler, and Diedra Mosley-Brower. **Provided by**: University of Michigan Histology and Virtual Microscopy Learning Resources. **Located at**: **http://141.214.65.171/Histology/Basic%20Tissues/Epithelium%20and%20CT/176_HISTO_20X.svs/view.apml**. **License**: ***CC BY-NC-SA: Attribution-NonCommercial-ShareAlike***

Figure **3.1.3*R***. A slice of the esophagus, 10x.. **Authored by**: Kent Christensen, Ph.D., J. Matthew Velkey, Ph.D., Lloyd M. Stoolman, M.D., Laura Hessler, and Diedra Mosley-Brower. **Provided by**: University of Michigan Histology and Virtual Microscopy Learning Resources. **Located at**: **http://141.214.65.171/Histology/Basic%20Tissues/Epithelium%20and%20CT/153_HISTO_20X.svs/view.apml**. **License**: ***CC BY-NC-SA: Attribution-NonCommercial-ShareAlike***

Figure **3.1.4** A slice of the stomach, 20x.. **Authored by**: Kent Christensen, Ph.D., J. Matthew Velkey, Ph.D., Lloyd M. Stoolman, M.D., Laura Hessler, and Diedra Mosley-Brower. **Provided by**: University of Michigan Histology and Virtual Microscopy Learning Resources. **Located at**: **http://141.214.65.171/Histology/Basic%20Tissues/Epithelium%20and%20CT/160_HISTO_40X.svs/view.apml**. **License**: ***CC BY-NC-SA: Attribution-NonCommercial-ShareAlike***

Figure **3.1.5**. A slice of the urinary bladder, 10x.. **Authored by**: Kent Christensen, Ph.D., J. Matthew Velkey, Ph.D., Lloyd M. Stoolman, M.D., Laura Hessler, and Diedra Mosley-Brower. **Provided by**: University of Michigan Histology and Virtual Microscopy Learning Resources. **Located at**: **http://141.214.65.171/Histology/Urinary%20System/212_HISTO_40X.svs/view.apml**. **License**: ***CC BY- NC-SA: Attribution-NonCommercial-ShareAlike***

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3.2: Examining Connective Tissue

Information

Connective tissue is found throughout the body, usually in association with other tissues. As its name indicates, it often serves to connect different tissues together, but it also can serve as a wrapper (in locations where a tough epithelial wrapping is not required), a structural support, cushioning, a storage repository, a protective layer, or a transport medium.

Connective tissue has the most types of subcategories and the most varied functions of all the four major tissue types (epithelial, muscular, nervous, and connective tissues.) Bone and cartilage are connective tissues, as are blood and lymph, fat, ligaments, and tendons. Epimysium, the connective tissue wrapping around skeletal muscles, and periosteum, the connective tissue wrapping around bones, are both connective tissues.

The different types of connective tissue are so diverse, there is no one set of characteristics that encompasses all the different types. However, there are three characteristics that we consider diagnostic of most connective tissue types.

1. The cells are dispersed. Connective tissues generally have cells that are not tightly connected to each other, the way the cells in epithelial and muscular tissues usually are. There is usually a fair amount of space between the connective tissue cells. An exception to this is adipose tissue (also known as fat), the rare type of connective tissue in which the cells are packed tightly together.
2. The tissue has more extracellular material than cells. Most connective tissues are solid (blood and lymph are the exceptions) because all the volume between the dispersed cells is filled with an extracellular matrix of viscous ground substance and protein fibers.
3. An extensive network of protein fibers is found in the extracellular matrix. Protein fibers are complexes of millions of individual proteins threaded into long fibrous structures that provide strength and elasticity to the tissue as a whole. The protein fibers are so large, they are longer than the cells they surround and enmesh. Blood and lymph, being liquid connective tissues, do not have these enmeshing protein fibers, but they still have an extensive liquid extracellular matrix.

A common way of classifying the many different types of connective tissue is to subdivide it into three main sub-categories, and further divide those subcategories into specific types of connective tissue. The three main sub-categories of connective tissue are:

1. **Connective tissue proper.** These are the types of connective tissue that typically have all three of the defining characteristics listed above. It is further subdivided into dense connective tissue proper, in which the extracellular protein fibers predominate, and loose connective tissue proper, in which the extracellular protein fibers are not so densely woven.
2. **Supporting connective tissue.** Bones and cartilage are the two types of connective tissue in this sub-category. They both have all three of the defining characteristics listed above, but their extracellular matrix is tougher, denser, and more solid than the various types of connective tissue proper.
3. **Fluid connective tissue.**

Blood and lymph are the two types of connective tissue in this sub-category. Both are fluid, rather than solid, and both lack the network of extracellular protein fibers found in the other types of connective tissue.

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Connective Tissue Proper

Information

Connective tissue proper encompasses the types of connective tissue that usually show all three of the defining cellular characteristics of connective tissue with the fewest deviations from those characteristics.

Dispersed cells

More extracellular material than cells.

Extensive protein fibers in the extracellular matrix.

Nonetheless there is still a great variety among the subcategories of connective tissue proper. Some are classified as **dense connective tissue proper** and have a dense arrangement of extracellular protein fibers that give the tissue strength and toughness. Tendons connecting muscles to bone and ligaments connecting bone to bone are examples of dense connective tissue proper. Other tissues are classified **loose connective tissue proper** and have fewer extracellular protein fibers and more ground substance (the extracellular material surrounding the protein fibers), making the tissues spongier but more fragile. Areolar tissue, found in the hypodermis of the skin and below the epithelial layers of the digestive, respiratory, and urinary tracts, is a loose connective tissue proper, as is adipose tissue, also known as fat.

Table **3.2.1** lists some of the subcategories of connective tissue proper, along with some of their characteristics and properties.

Table
3.2.1
: Summary of the properties of the major types of connective tissue proper.

	Types of connective tissue proper					
	Loose connective tissue proper			Dense connective tissue proper		
Constituents	Areolar connective tissue	Reticular connective tissue	Adipose	Regular dense connective tissue	Irregular dense connective tissue	Elastic dense connective tissue
Cells	Fibroblasts, w/some macrophages, other white blood cells	Fibroblasts, w/many white blood cells	Adipocytes, w/some macrophages, other white blood cells.	Fibroblasts, w/ some macrophages, other white blood cells	Fibroblasts, w/ some macrophages, other white blood cells	Fibroblasts, w/ some macrophages, other white blood cells
Protein fibers	Collagen, elastic	Reticular	Collagen, some reticular	Thick collagen fibers, in parallel	Thick collagen fibers, no consistent arrangement	Elastic mainly, some collagen
Ground substance	Jelly-like, abundant	Jelly-like abundant	Smaller amounts due to abundant cells	Smaller amounts due to abundant fibers	Smaller amounts due to abundant fibers	Smaller amounts due to abundant fibers
Locations	Under epithelia of skin, mucous membranes, capillaries, organs	Spleen, lymph nodes, bone marrow	Under skin, surrounding organs, between muscle fibers, in pericardium.	Tendons, ligaments, aponeuroses	Capsules around joints and organs, dermis of skin	Walls of large arteries, walls of bronchial tubes, vertebral ligaments

In drawing images of connective tissue proper preparations seen under the microscope, it is important to simplify the visuals. Connective tissue preparations are often messy with a number of blotches and shapes irrelevant to the main components of the tissue, which are the cells and the extracellular protein fibers. Especially with connective tissue slides, it is important to make sure you know what you are looking for, find those components, and draw only them in as simple a form as possible, usually with just lines and with minimal shadings or hatchings. Leave out the unnecessary and irrelevant stuff on the slide.

For instance, Figure 3.7 A shows a section of connective tissue taken from just below (deep to) the epithelial layer of the stomach, magnified 40x. Figure 3.7 B illustrates how you should represent that view as a line drawing.

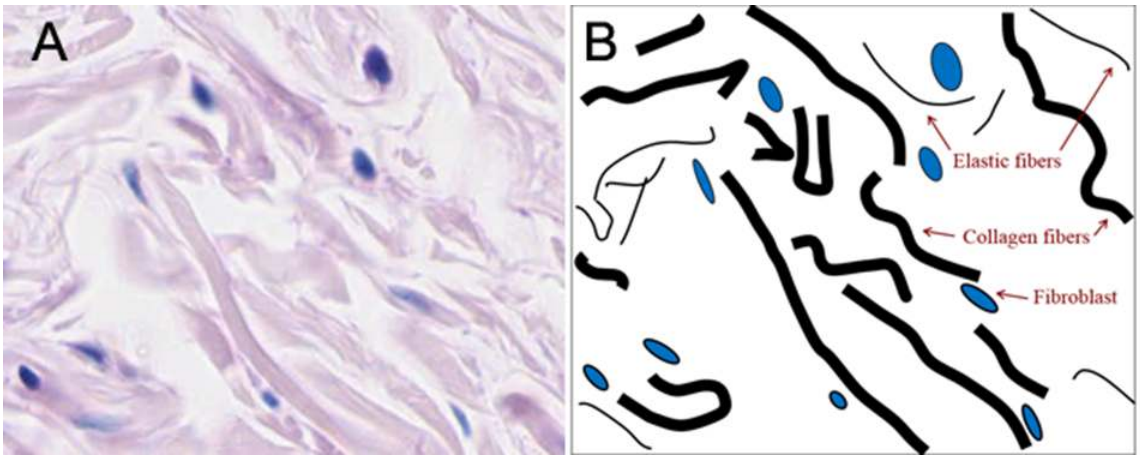


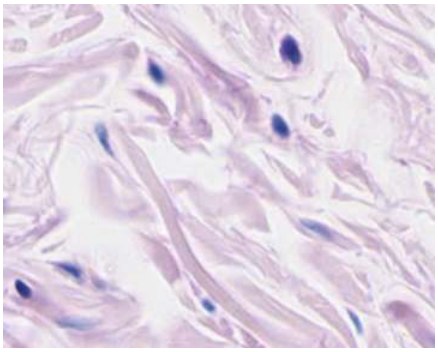
Figure 3.2.2: A photomicrograph, A, and a drawing from the photomicrograph, B, of the connective tissue in the wall of the stomach, just below the epithelial layer. (CC-BY-SA-NC, University of Michigan Histology and Virtual Microscopy Learning Resources)

Notice that in the line drawing not every single thick collagen fiber, nor every single thin elastic fiber, not every single fibroblast was drawn. Also notice that some of the out-of-focus, blurry fibers were not drawn at all, rather than draw fuzzy blotches. The key is to get the important structures (once you know what those are) and leave out distracting, non-essential messiness.

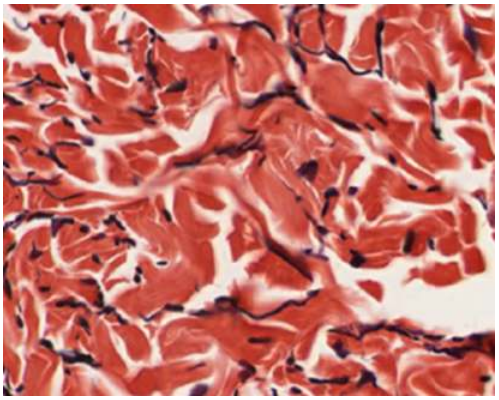
LAB 3 EXERCISE 3.2.2

1. Table 3.1 lists six categories of connective tissue proper. Use the information in that table to identify which category each of the following samples belong to.
2. Under each picture, list the evidence that points to the category you choose.
3. The key identifying features to look for in each picture are: the type(s) of protein fibers present, the type of cells present, and whether there are significant amounts of ground substance present.
4. Collagen protein fibers are thick. Elastic protein fibers are thin. Reticular protein fibers are thin but form a web-like arrangement.
5. If there is abundant space between protein fibers, the tissue is likely one of the loose connective tissues. If there is little space between protein fibers, the tissue is likely one of the dense connective tissues.
6. Adipose is mainly large adipocyte cells containing a large droplet of lipids and nucleus and cytoplasm crammed into one corner of the cell. There are more adipocytes than extracellular material in adipose.

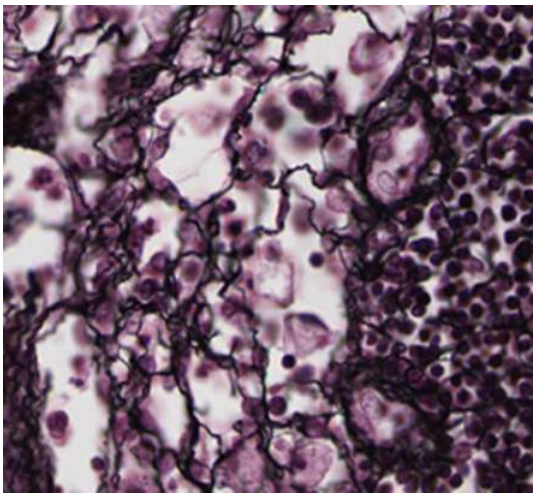
7. The protein fibers in regular dense connective tissue proper will largely parallel each other, but they are often undulate in a wave-like arrangement while being parallel.



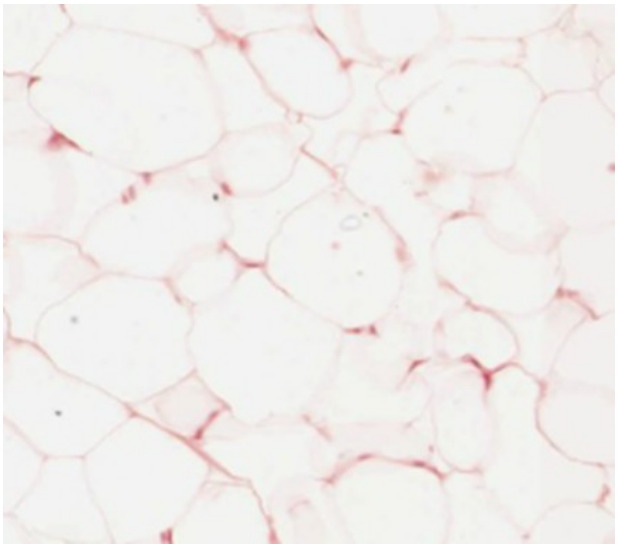
1. Source: Stomach wall
Category:
Evidence:



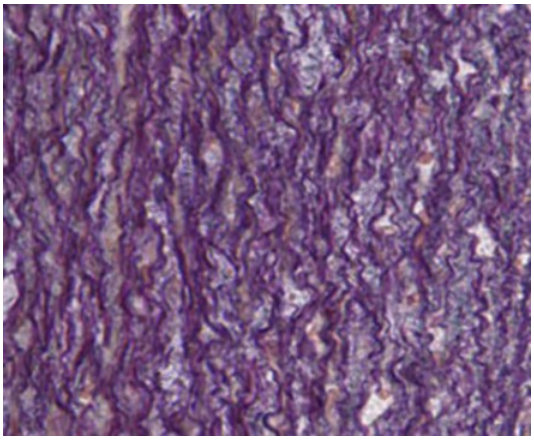
1. Joint Capsule
Category:
Evidence:



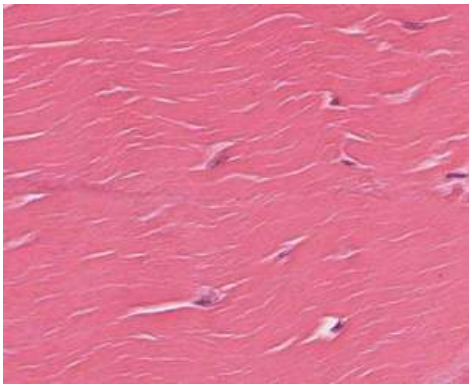
1. Source: Lymph node
Category:
Evidence:



1. Source: Fat
Category:
Evidence:



1. Source: Aorta Wall
Category:
Evidence:

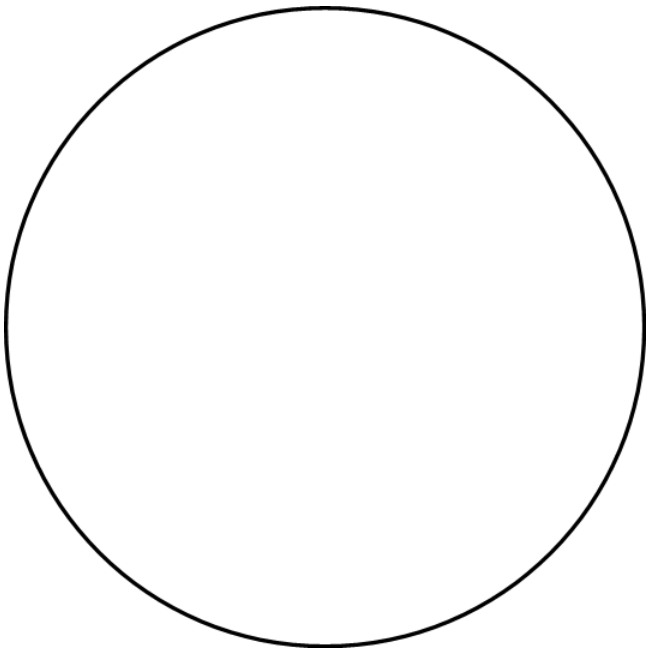


1. Source: Tendon
Category:
Evidence:

LAB 3 EXERCISE 3.2.3

1. Obtain a slide of connective tissue proper/areolar CT from the slide box.
2. View the slide on an appropriate objective.
3. Fill out the blanks next to your drawing.

4. In the circle below, draw a representative sample of key features you identified, taking care to correctly and clearly draw their true shapes and directions. Draw your structures proportionately to their size in your microscope's field of view.

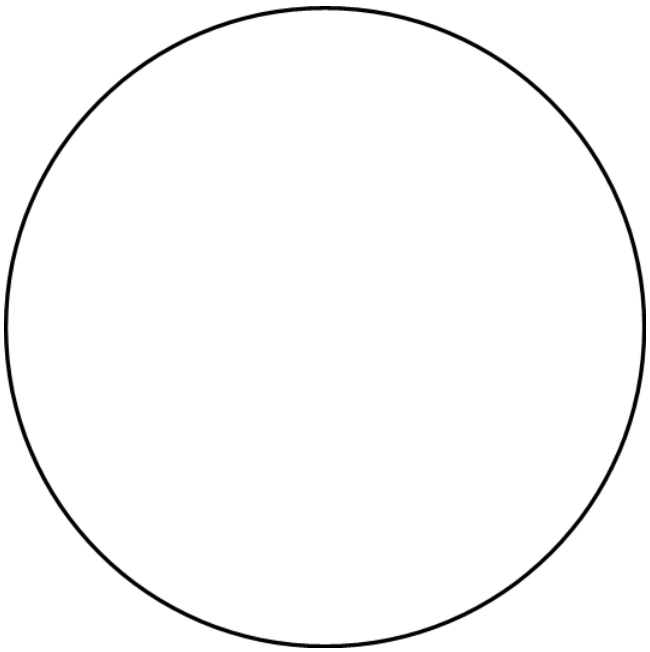


Total Magnification: _____
Type of eptihelium: _____
Source of tissue: _____
Function of this phase: _____
_____

Slide \(\PageIndex{2}\):connective tissue proper/areolar CT

1. Obtain a slide of dense irregular connective tissue from the slide box.
2. View the slide on an appropriate objective.
3. Fill out the blanks next to your drawing.

4. In the circle below, draw a representative sample of key features you identified, taking care to correctly and clearly draw their true shapes and directions. Draw your structures proportionately to their size in your microscope's field of view.

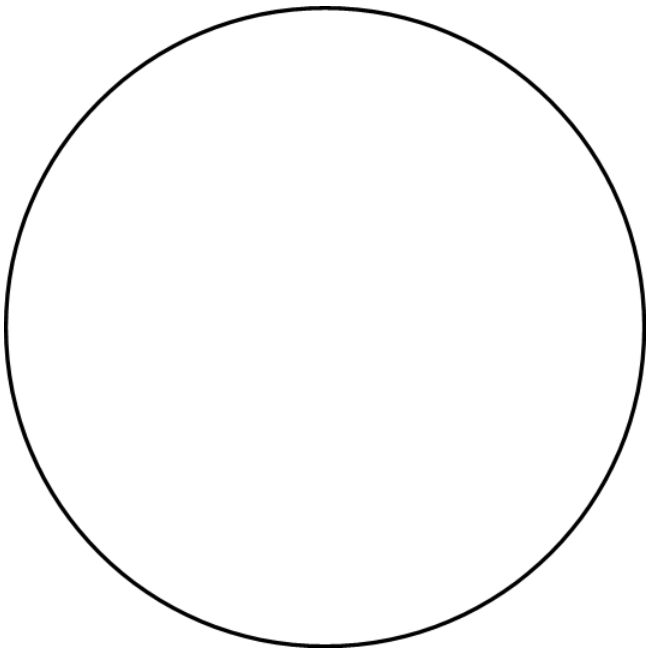


Total Magnification: _____
Type of eptihelium: _____
Source of tissue: _____
Function of this phase: _____
_____

Slide \(\PageIndex{3}\): irregular connective tissue

1. Obtain a slide of a spleen or lymph node with reticular connective tissue from the slide box.
2. View the slide on an appropriate objective.
3. Fill out the blanks next to your drawing.

4. In the circle below, draw a representative sample of key features you identified, taking care to correctly and clearly draw their true shapes and directions. Draw your structures proportionately to their size in your microscope's field of view.

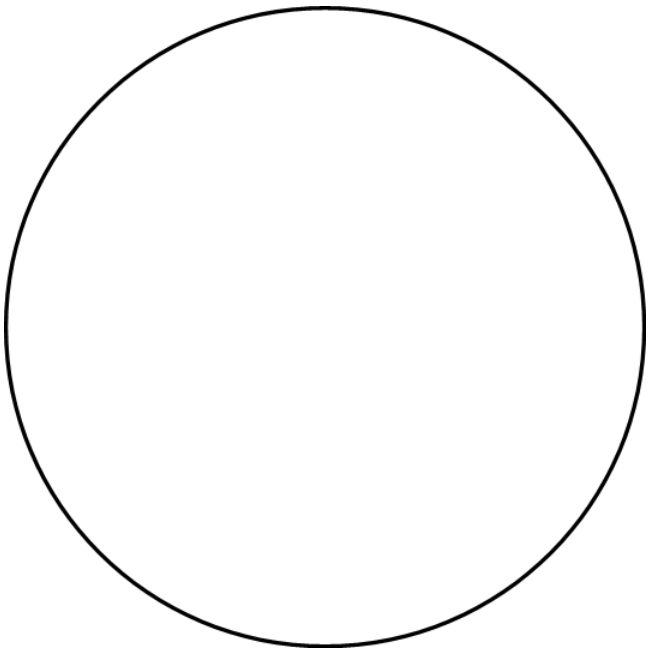


Total Magnification: _____
Type of eptihelium: _____
Source of tissue: _____
Function of this phase: _____
_____

Slide \(\PageIndex{4}\): spleen or lymph node with reticular connective tissue

1. Obtain a slide of adipose connective tissue from the slide box.
2. View the slide on an appropriate objective.
3. Fill out the blanks next to your drawing.

4. In the circle below, draw a representative sample of key features you identified, taking care to correctly and clearly draw their true shapes and directions. Draw your structures proportionately to their size in your microscope's field of view.

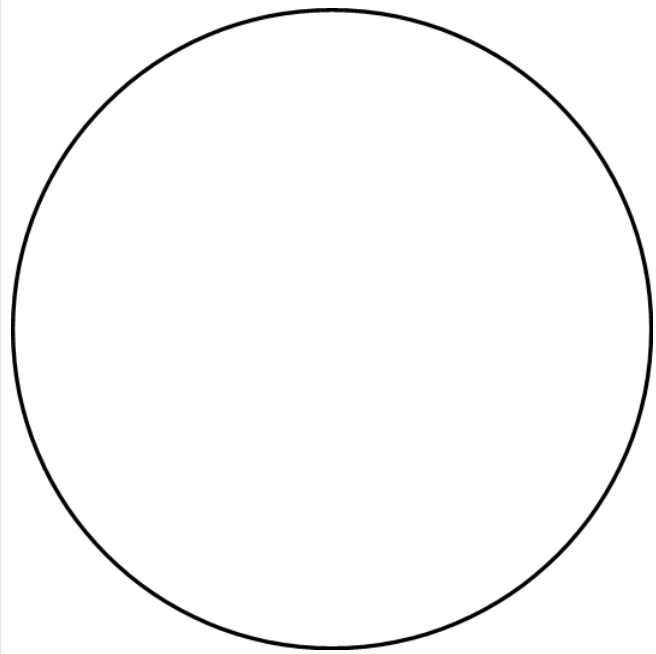


Total Magnification: _____
Type of eptihelium: _____
Source of tissue: _____
Function of this phase: _____
_____

Slide \(\PageIndex{5}\): adipose connective tissue

1. Obtain a slide of a large artery with elastic connective tissue from the slide box.
2. View the slide on an appropriate objective.
3. Fill out the blanks next to your drawing.

4. In the circle below, draw a representative sample of key features you identified, taking care to correctly and clearly draw their true shapes and directions. Draw your structures proportionately to their size in your microscope's field of view.

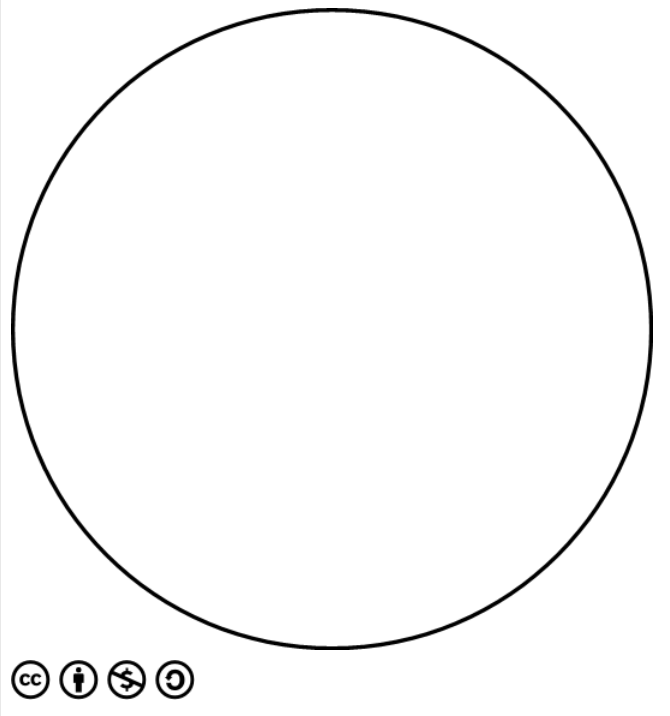


Total Magnification: _____
Type of eptihelium: _____
Source of tissue: _____
Function of this phase: _____
_____

Figure \(\PageIndex{6}\): adipose connective tissue

1. Obtain a slide of a tendon with dense regular connective tissue from the slide box.
2. View the slide on an appropriate objective.
3. Fill out the blanks next to your drawing.

4. In the circle below, draw a representative sample of key features you identified, taking care to correctly and clearly draw their true shapes and directions. Draw your structures proportionately to their size in your microscope's field of view.



Total Magnification: _____
Type of eptihelium: _____
Source of tissue: _____
Function of this phase: _____
_____

Slide \(\PageIndex{7}\): elastic connective tissue

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- Exercise 3.1 A. Source: Stomach wall. **Authored by**: Kent Christensen, Ph.D., J. Matthew Velkey, Ph.D., Lloyd M. Stoolman, M.D., Laura Hessler, and Diedra Mosley-Brower. **Provided by**: University of Michigan Histology and Virtual Microscopy Learning Resources. **Located**
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- Exercise 3.1 B. Joint Capsule. **Authored by**: Kent Christensen, Ph.D., J. Matthew Velkey, Ph.D., Lloyd M. Stoolman, M.D., Laura Hessler, and Diedra Mosley-Brower. **Provided by**: University of Michigan Histology and Virtual Microscopy Learning Resources. **Located**

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- Exercise 3.1 C. Source: Lymph node. **Authored by**: Kent Christensen, Ph.D., J. Matthew Velkey, Ph.D., Lloyd M. Stoolman, M.D., Laura Hessler, and Diedra Mosley-Brower. **Provided by**: University of Michigan Histology and Virtual Microscopy Learning Resources. **Located at**: **141.214.65.171/Histology/Basi...0and%20CT/028- 2_HISTO_40X.svs/view.apml**. **License**: ***CC BY-NC-SA: Attribution-NonCommercial-ShareAlike***
- Exercise 3.1 D. Source: Fat. **Authored by**: Kent Christensen, Ph.D., J. Matthew Velkey, Ph.D., Lloyd M. Stoolman, M.D., Laura Hessler, and Diedra Mosley-Brower. **Provided by**: University of Michigan Histology and Virtual Microscopy Learning

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- Exercise 3.1 F. Source: Tendon. **Authored by**: Kent Christensen, Ph.D., J. Matthew Velkey, Ph.D., Lloyd M. Stoolman, M.D., Laura Hessler, and Diedra Mosley-Brower. **Provided by**: University of Michigan Histology and Virtual Microscopy Learning

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3.3: Examining Connective Tissue

Information

Supporting connective tissue comprises bone and cartilage. We will examine those tissues in greater detail in Lab 5 The Appendicular Skeleton & Lab 6 The Axial Skeleton.

In both bone and cartilage, as in the different types of connective tissue proper, there are extracellular protein fibers embedded in a viscous ground substance. However, in bone and cartilage, the ground substance is so viscous as to be very hard and tough solids. Both bone and cartilage use mainly collagen and elastic protein fibers in their extracellular matrix, but cartilage uses a ground substance rich in the carbohydrate **hyaluronan** and bone uses a ground substance rich in a mineralized calcium phosphate compound known as **hydroxyapatite**.

The carbohydrate hyaluronan (sometimes known as hyaluronic acid or hyaluronate) binds up huge numbers of water molecules in the extracellular matrix of cartilage. This helps solidify the ground substance around the collagen and elastic fibers of cartilage. As a result, it is often difficult to see the protein fibers in cartilage when viewing preparations under the microscope.

They hydroxyapatite that surrounds the mostly collagen protein fibers in the ground substance of bone is not soluble in water and forms a mineral solid in which both the bone cells and the collagen fibers are embedded. As with cartilage, it is usually difficult to see the collagen fibers in the extracellular matrix of bone due to the density of the ground substance that surrounds them.

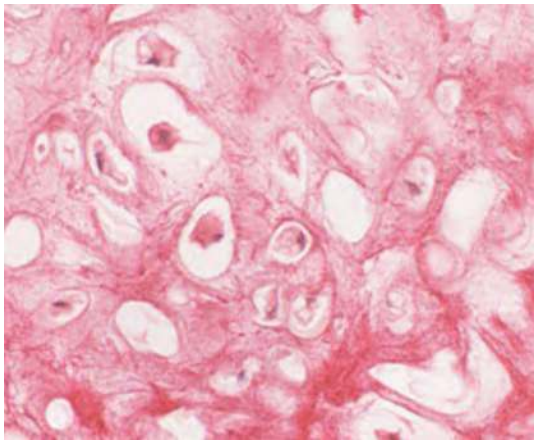
There is only one type of cell in cartilage, **chondrocytes**. They secrete and maintain the extracellular matrix of the tissue. Chondrocytes arise from mesenchymal stem cells, just like the fibroblasts of connective tissue proper do, but chondrocytes are specialized to produce just cartilage. The extracellular matrix produced by the chondrocytes is so tough and durable, the chondrocytes are in danger of being crushed by it. This is why chondrocytes always leave a region around themselves free of the cartilaginous extracellular matrix that makes up the rest of the tissue. These non-cartilaginous pockets around each chondrocyte are called **lacunae** and are clearly visible when examining cartilage under the microscope.

There are four types of bone cells, osteoprogenitor cells, osteoblasts, osteoclasts, and osteocytes, but the **osteocytes** are the most abundant and the only ones found throughout the bone. Osteocytes are found in concentric circles of mineralized extracellular matrix. Each circle is called a **lamella** (plural: lamellae) and the osteocytes are found along the edges of each lamellae. In compact bone, groups of lamellae and osteocytes are arranged into individual **osteons,** the cylindrical arrangement of material that makes up the fundamental building block of the compact bone. Each osteon has a hollow central canal in its center that blood vessels and nerves can travel through. In spongy bone, groups of lamellae are arranged into **trabeculae** (singular: trabecula), which are the individual projections of spongy bone. Trabeculae do not have central canals.

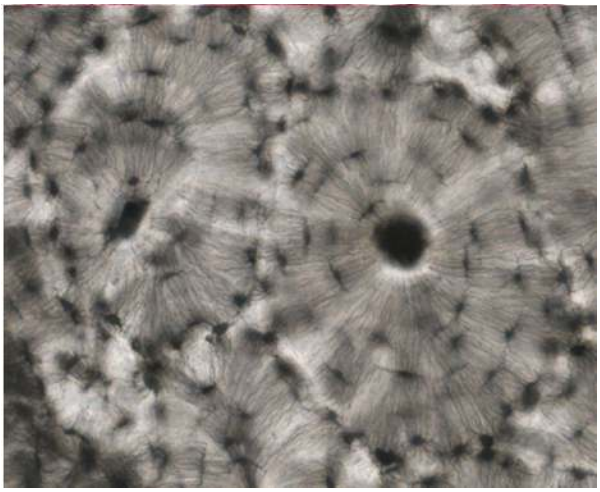
Osteocytes, like chondrocytes, are protected from the extracellular matrix that surrounds them by being housed in **lacunae**, which are spaces free of mineralized extracellular matrix. Osteocytes, unlike chondrocytes, have numerous cytoplasmic extensions that project off of the main cell body. These extension connect up with the extensions from other near-by osteocytes. These projections, like the osteocyte cell body, are in tiny spaces free of the mineralized extracellular matrix. These spaces (but not the cytoplasmic projections themselves) are called canaliculi (singular: canaliculum) because, under the microscope, they look like tiny little canals.

LAB 3 EXERCISE \(\PageIndex{1}\)

1. In the photomicrograph below of **cartilage tissue**, find and label the indicated structures.



Lacuna: _____
Chondrocyle: _____
Elastic protein fibers: _____
Extracellular matix: _____

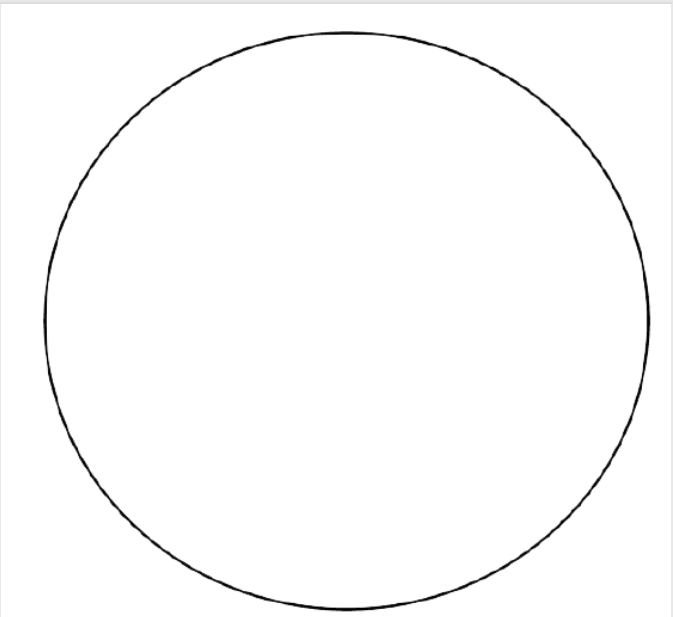


Osteon: _____
Lanella: _____
Lacuna: _____
Osteocyte: _____
Canaliculi: _____
Central canal: _____

2. In the photomicrograph below of **compact bone tissue**, find and label the indicated structures.

1. Obtain a slide of hyaline cartilage connective tissue from the slide box.
2. View the slide on an appropriate objective.
3. Fill out the blanks next to your drawing.

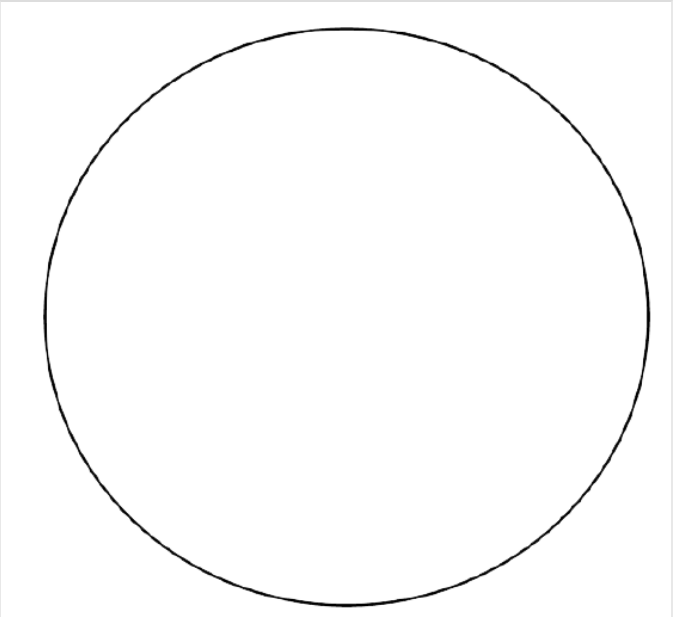
4. In the circle below, draw a representative sample of key features you identified, taking care to correctly and clearly draw their true shapes and directions. Draw your structures proportionately to their size in your microscope's field of view.



Total Magnification: _____
Type of eptihelium: _____
Source of tissue: _____
Function tissue: _____
_____

Slide \(\PageIndex{1}\): hyaline cartilage connective tissue

1. Obtain a slide of ground compact bone connective tissue from the slide box.
2. View the slide on an appropriate objective.
3. Fill out the blanks next to your drawing.
4. In the circle below, draw a representative sample of key features you identified, taking care to correctly and clearly draw their true shapes and directions. Draw your structures proportionately to their size in your microscope's field of view.



Total Magnification: _____
Type of connective tissue: _____
Source of tissue: _____
Function of this tissue: _____
_____
Key features to find and draw:
_____

Slide \(\PageIndex{2}\): ground compact bone connective tissue

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Exercise 3.3. 1. In the photomicrograph below of cartilage tissue, find and label the indicated structures.. **Authored by**: Kent Christensen, Ph.D., J. Matthew Velkey, Ph.D., Lloyd M. Stoolman, M.D., Laura Hessler, and Diedra Mosley-Brower. **Provided by**: University of Michigan Histology and Virtual Microscopy Learning Resources. **Located at: 141.214.65.171/Histology/Basic%20Tissues/Cartilage%20and%20Bone/044H_HISTO_20X.svs/view.apml**. License: *C C BY-NC-SA: Attribution-NonCommercial-ShareAlike*

Exercise 3.3. 2. In the photomicrograph below of compact bone tissue, find and label the indicated structures.. **Authored by**: Kent Christensen, Ph.D., J. Matthew Velkey, Ph.D., Lloyd M. Stoolman, M.D., Laura Hessler, and Diedra Mosley-Brower. **Provided by**: University of Michigan Histology and Virtual Microscopy Learning Resources. **Located at: 141.214.65.171/Histology/Basic%20Tissues/Cartilage%20and%20Bone/051xc_HISTO_40X.svs/view.apml**. License: *C C BY-NC-SA: Attribution-NonCommercial-ShareAlike*

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3.4: Distinguishing Between The Three Types of Muscle Tissue

Information

Muscular tissue is the third of the four major categories of animal tissue. Muscle tissue is subdivided into three broad categories: **skeletal** muscle, **cardiac** muscle, and **smooth** muscle. The three types of muscle can be distinguished by both their locations and their microscopic features.

Skeletal muscle is found attached to bones. It consists of long **multinucleate** fibers. The fibers run the entire length of the muscle they come from and so are usually too long to have their ends visible when viewed under the microscope. The fibers are relatively wide and very long, but **unbranched**. Fibers are not individual cells, but are formed from the fusion of thousands of precursor cells. This is why they are so long and why individual fibers are multinucleate (a single fiber has many nuclei). The nuclei are usually up against the edge of the fiber. There are **striations** in skeletal muscle. These are alternating dark and light bands perpendicular to the edge of the fiber that are present all along the fiber.

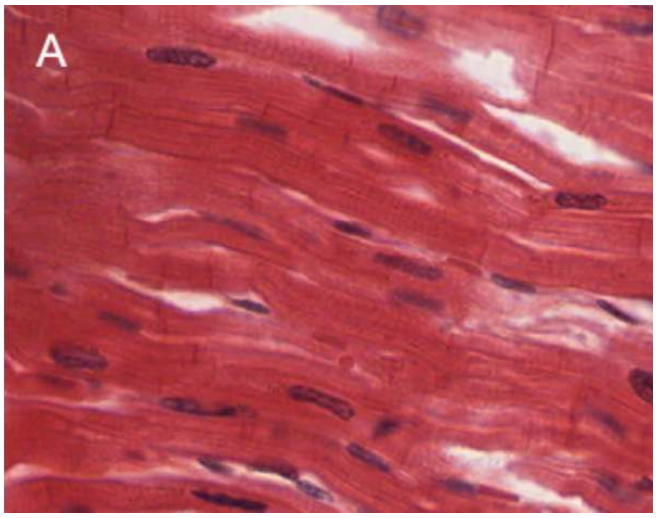
Cardiac muscle is only found in the heart. Its fibers are longer than they are wide, and they are **striated**, like skeletal muscle fibers. But, unlike skeletal muscle fibers, cardiac muscle

fibers have distinct ends to them, called **intercalated discs**. These are dark lines that run from one side of the fiber to the other. The intercalated discs are not much thicker than the striations, but they are usually darker and so distinct for that reason. One cardiac muscle fiber is the material between two intercalated discs. Cardiac muscle fibers are **mononucleate**, with only one nucleus per fiber, and they can sometimes be **branched**.

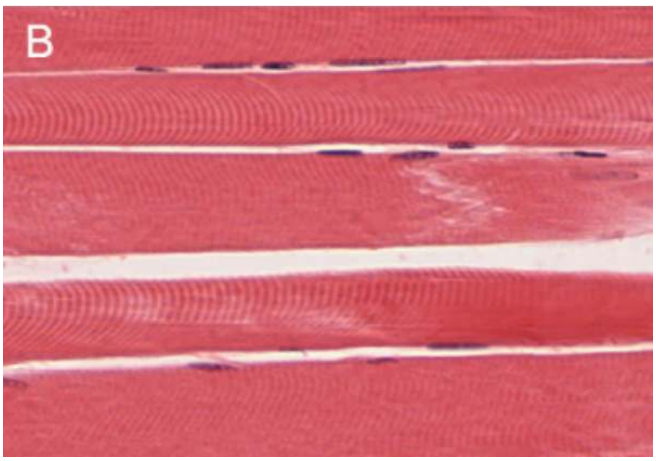
Smooth muscle is found in the walls of internal organs, such as the organs of the digestive tract, blood vessels, and others. It consists of **mononucleate** fibers with **tapered edges**. **No striations** are visible in smooth muscle under the microscope. Because smooth muscle often is wrapping around the organ it is associated with, it can be hard to find an entire smooth muscle fiber in profile in a tissue slice on a microscope slide. Most of the fibers will be sectioned at angles or will be difficult to get into a single plane of focus, but a little bit of searching can usually turn up some with all of the defining characteristics visible.

LAB 3 EXERCISE \(\PageIndex{1}\)

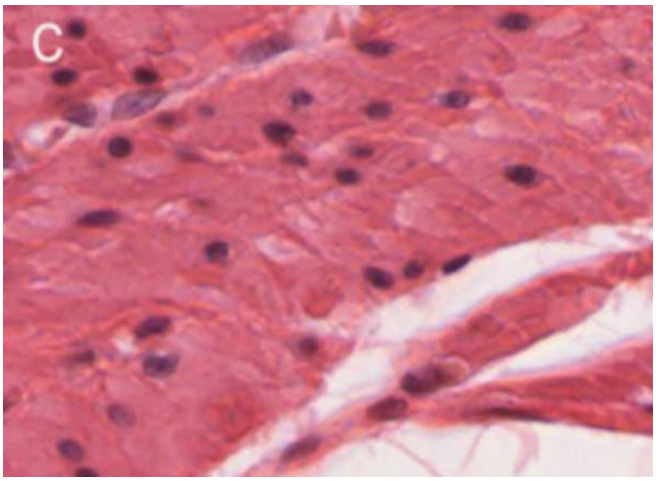
In each of the three photomicrographs below, identify which type of muscle is present. List the defining visual characteristics of that type of muscle, and draw arrows to features on the photograph that illustrate each characteristic.



Muscle type: _____
Visual characteristics
1.
2.
3.
4.



Muscle type: _____
Visual characteristics
1.
2.
3.
4.



Muscle type: _____
Visual characteristics
1.
2.
3.
4.

1. 1. Obtain a slide of cardiac muscle tissue from the slide box.
   2. View the slide on an appropriate objective.
   3. Fill out the blanks next to your drawing.
   4. In the circle below, draw a representative sample of key features you identified, taking care to correctly and clearly draw their true shapes and directions. Draw your structures proportionately to their size in your microscope's field of view.
2. Obtain a slide of skeletal muscle tissue from the slide box.
3. View the slide on an appropriate objective.
4. Fill out the blanks next to your drawing.
5. In the circle below, draw a representative sample of key features you identified, taking care to correctly and clearly draw their true shapes and directions. Draw your structures proportionately to their size in your microscope's field of view.
6. Obtain a slide of smooth muscle tissue from the slide box.
7. View the slide on an appropriate objective.
8. Fill out the blanks next to your drawing.
9. In the circle below, draw a representative sample of key features you identified, taking care to correctly and clearly draw their true shapes and directions. Draw your structures proportionately to their size in your microscope's field of view.

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Exercise \(\PageIndex{1}\)A. **Authored by**: Kent Christensen, Ph.D., J. Matthew Velkey, Ph.D., Lloyd M. Stoolman, M.D., Laura Hessler, and Diedra Mosley-Brower. **Provided by**: University of Michigan Histology and Virtual Microscopy Learning Resources. **Located at: 141.214.65.171/Histology/Cardiovascular%20System/098HE_HISTO_40X.svs/view.apml**. License: *CC BY-NC-SA: Attribution-NonCommercial-ShareAlike*

Exercise \(\PageIndex{1}\)B. **Authored by**: Kent Christensen, Ph.D., J. Matthew Velkey, Ph.D., Lloyd M. Stoolman, M.D., Laura Hessler, and Diedra Mosley-Brower. **Provided by**: University of Michigan Histology and Virtual Microscopy Learning Resources. **Located at: 141.214.65.171/Histology/Basic%20Tissues/Muscle/058L_HISTO_40X.svs/view.apml**. License: *CC BY-NC-SA: Attribution-NonCommercial-ShareAlike*

Exercise \(\PageIndex{1}\)C. **Authored by**: Kent Christensen, Ph.D., J. Matthew Velkey, Ph.D., Lloyd M. Stoolman, M.D., Laura Hessler, and Diedra Mosley-Brower. **Provided by**: University of Michigan Histology and Virtual Microscopy Learning Resources. **Located at: 141.214.65.171/Histology/Basic%20Tissues/Muscle/169_HISTO_40X.svs/view.apml**. License: *CC BY-NC-SA: Attribution-NonCommercial-ShareAlike*

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3.5: Identifying Neurons Within Nervous Tissue

Information

Nervous tissue is the last of the four major categories of animal tissue. Nervous tissue comprises **neuron**s, the cells specialized for the propagation of electrochemical signals, and **neuroglia**, the so-called "supporting cells" of nervous tissue. There are multiple types of neuroglia cells (sometimes called just glial cells), and most of them do assist neurons, but recent research has discovered that some of the neuroglia cells play an active role by themselves in the proper functioning of the central and peripheral nervous systems. It is turning out that neuroglia do more than just support neurons.

We will leave investigation of the neuroglia for later labs. In this lab, we will just focus on the structural features of neurons as they are visible under microscopic examination.

A neuron is typically represented as having the following features. A large cell body (sometimes known as the soma) in which the nucleus and other major organelles are found. Dendrites, which are usually represented as numerous small projections extending from the cell body. A single axon, which is usually represented as a large single projection extending from the cell body, much longer than any of the dendrites. Multiple axon terminals that branch off at the end of the axon. Figure **3.5.1** shows a typical drawn neuron showing all these features.

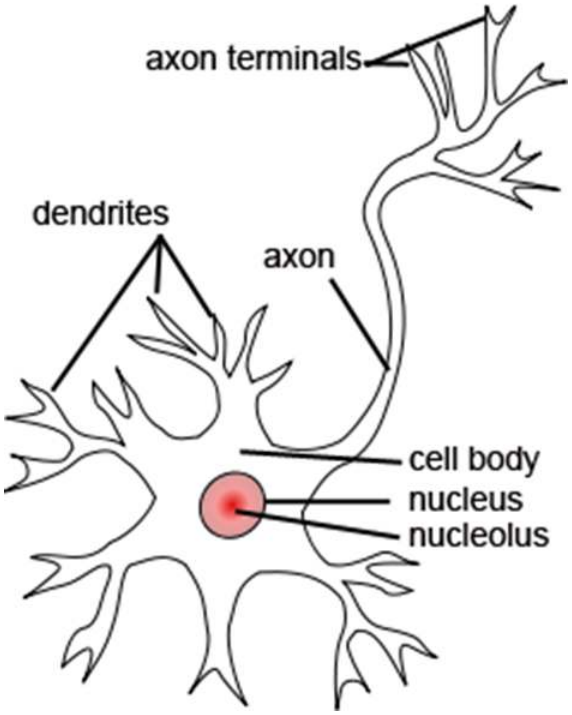


Figure **3.5.1**: A typical diagrammatic representation of neuron. (CC-BY-SA, Jonathan Haas, Wikimedia)

All of these features are important to the functioning of neurons. The cell body is where most of the cellular processes of the neuron take place: protein synthesis, metabolism, etc. The dendrites contact and pick up signals coming in from other cells (other neurons or sensory cells). The axon propagates the neuron's electrical signal to its various targets. And the axon terminals actually contact (synapse with) those targets and send chemical signals to the targets to trigger changes in them. However, most neurons in the body do not look as clear-cut as the neuron in Figure **3.5.1**. Some neurons have short axons. Others have dendrites that are almost as large as the axon. Others have two axons connected to the same cell body. Many have dendrites and axon terminals that are too thin and small too see clearly. Cell bodies tend to come in all sorts of sizes and shapes, and are not always bulbous lumps readily distinguished from the rest of the cell.

What's more, nervous tissue is delicate and fragile. In creating preparations for slides to viewed under a microscope, some of the cells are smushed together, damaged, truncated, or torn. Other times, the nervous tissue cells are simply too densely packed

together to make out individual details. Much of what is visible is not useful to the student looking to find an intact and well-defined neuron. However, a bit of searching will often reveal some intact neurons.

Often these are found at the edges of the preparation where the material is least dense. Keep in mind, you will often see neurons shaped distinctly different from those shown in textbooks and if Figure **3.5.1**.

Figure **3.5.2** shows two different locations in the same slide. Figure **3.5.2** A shows a mass of neurons (stained black) in which it is difficult to distinguish the shape of even one neuron clearly. Figure 3.8 B shows a different area from the same slide, where the neurons are not so crowded, and where one neuron in particular (outlined in red) shows many of the structures we are interested in. So, keep in mind, it is important to know what you want to find in a particular slide, and it is important to search around the slide to find the best example of what you are looking for.

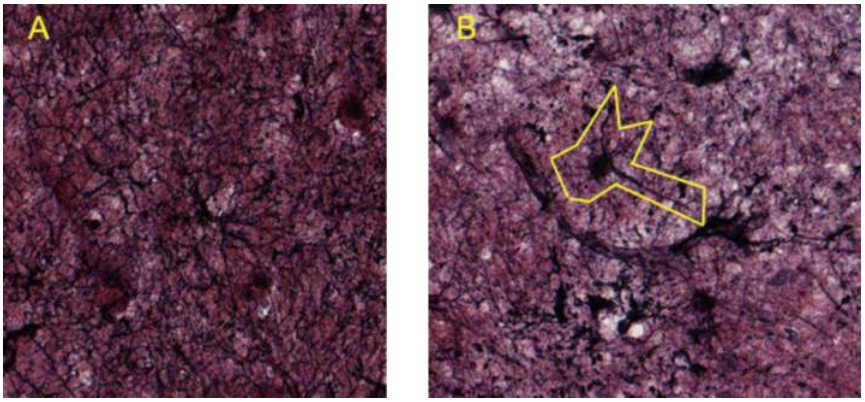


Figure **3.5.2**: Two different areas from the same slide of a nervous tissue preparation. In A, the neurons are too crowded to see any one neuron clearly. In B, the neuron outlined in yellow illustrates a typical dendrite-cell body-axon arrangement. (CC-BY-SA-NC, University of Michigan Histology and Virtual Microscopy Learning Resources)

1. Obtain a slide of nervous tissue from the instructor. Use any nervous tissue except peripheral nerve, there are no nerve cell bodies in a peripheral nerve section.
2. View the slide on the second-highest objective. Search carefully until you find a clear, representative neuron in your field of view.
3. In the circle below, draw the neuron you found. Only draw the single neuron. Do not draw any of the other material. Draw your structures proportionately to their size in your microscope's field of view.
4. Label any neural parts you can clearly recognize.

	Total Magnification: _____ Source of tissue: _____ Parts: _____ _____

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Figure **3.5.1**. A typical diagrammatic representation of neuron.. **Authored by**: Jonathan Haas. **Located at**: **commons.wikimedia.org/w/inde...curid=18271454**. **License**: ***CC BY-SA: Attribution-ShareAlike***

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Figure **3.5.2**. **Authored by**: Kent Christensen, Ph.D., J. Matthew Velkey, Ph.D., Lloyd M. Stoolman, M.D., Laura Hessler, and Diedra Mosley-Brower. **Provided by**: University of Michigan Histology and Virtual Microscopy Learning Resources. **Located at: 141.214.65.171/Histology/Central%20Nervous%20System/13270.svs/view.apml**. License: *CC BY-SA: Attribution- ShareAlike*

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3.6: Practice in Identifying Different Types of Tissues

Name 2 major components of Connective Tissue:

1. _____

2. _____

Name 2 components of Extracellular Matrix:

1. _____

2. _____

Name 3 major connective tissue fibers:

1. _____

2. _____

3. _____

Name the 3 types of muscle tissue:

1. _____

2. _____

3. _____

Name the 2 major cell types in neural tissue:

1. _____

2. _____

Epithelia can be divided into two basic groups based on the number of cell **layers**. These are:

1. _____

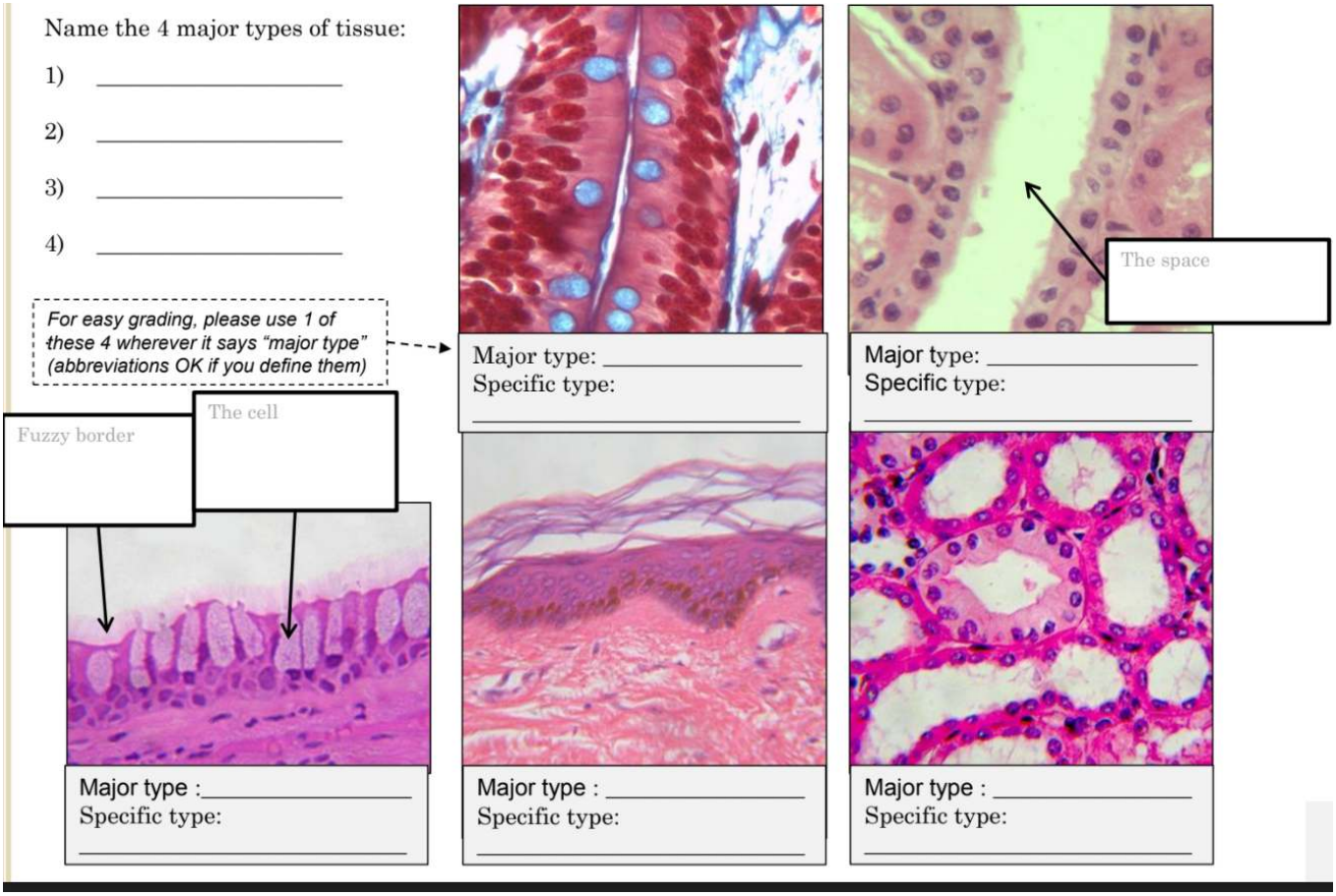
2. _____

Name two epithelia that can be considered an exception:

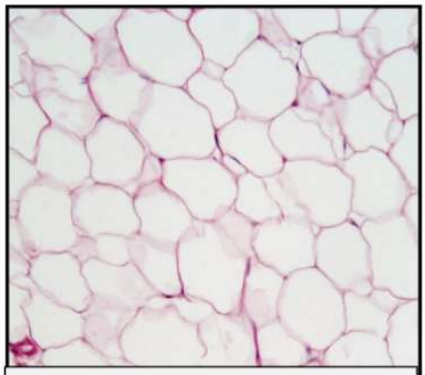
1. _____

2. _____

LAB 3 EXERCISE 3.6.1



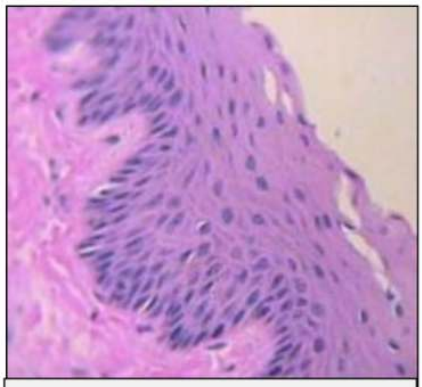
IDENTIFY THE TISSUES SHOWN:



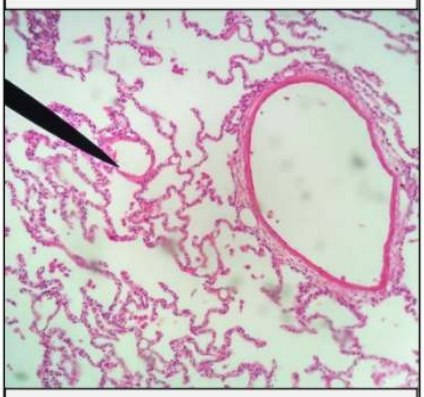
Major type :_____
Specific type:
_____



Major type :_____
Specific type:
_____



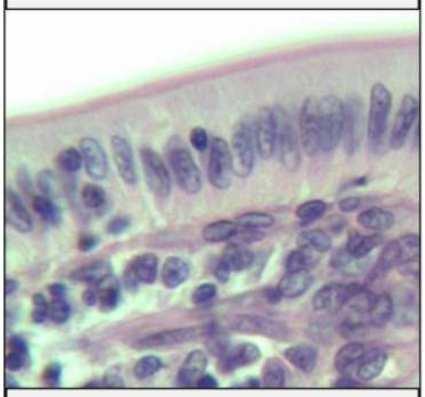
Major type :_____
Specific type:
_____



Major type :_____
Specific type:
_____



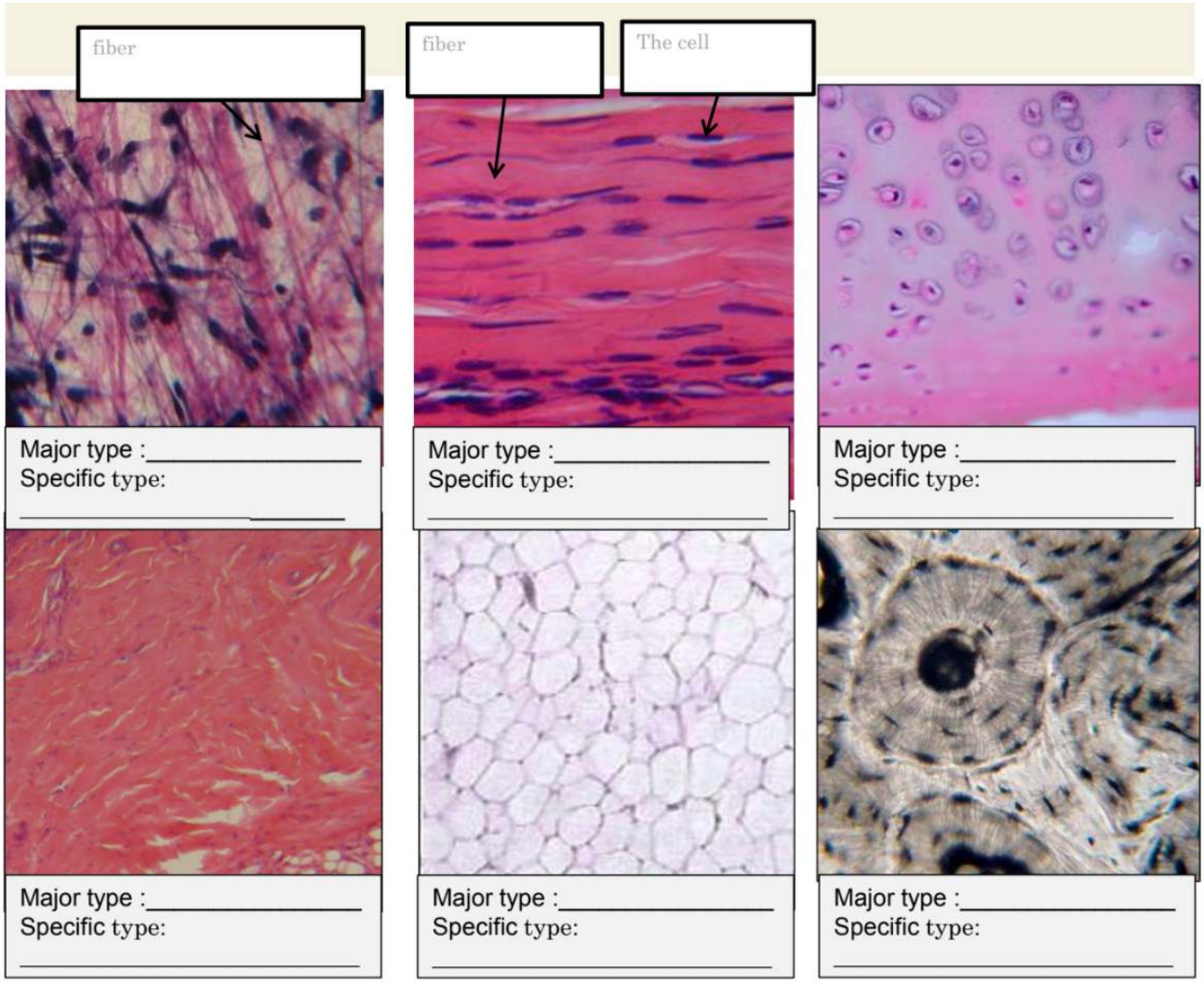
Major type :_____
Specific type:
_____



Major type :_____
Specific type:
_____

IDENTIFY THE TISSUES SHOWN:

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IDENTIFY THE TISSUES SHOWN:

When storing a microscope, you should always follow this list:



1. Remove any slide found on the stage and return it to the slide box.
2. Rotate the smallest lens or no lens into place above the stage. Lower the stage a few turns.
3. Loosely coil the cord in your hand starting near the microscope and working toward the plug.
4. Hang the coiled cord over one ocular lens.
5. Look at the number on the back of the microscope, return that scope to its numbered box.
6. If there's already a microscope in that numbered box, check its number and move it. If it is not numbered simply push it to the back of the box and place yours closer to the front. We have a few extra microscopes which we store in this fashion.

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CHAPTER OVERVIEW

4: The Integumentary System

Learning Objectives

By the end of this section, you will be able to:

- Identify the components of the integumentary system
- Describe the layers of the skin and the functions of each layer
- Identify and describe the hypodermis and deep fascia

4.1: Layers of the Skin
4.2: Exercises
4.3: Skin Models

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4.1: Layers of the Skin

Although you may not typically think of the skin as an organ, it is in fact made of tissues that work together as a single structure to perform unique and critical functions. The skin and its accessory structures make up the **integumentary system**, which provides the body with overall protection. The skin is made of multiple layers of cells and tissues, which are held to underlying structures by connective tissue (**Figure 4.1.1**). The deeper layer of skin is well vascularized (has numerous blood vessels). It also has numerous sensory, and autonomic and sympathetic nerve fibers ensuring communication to and from the brain.

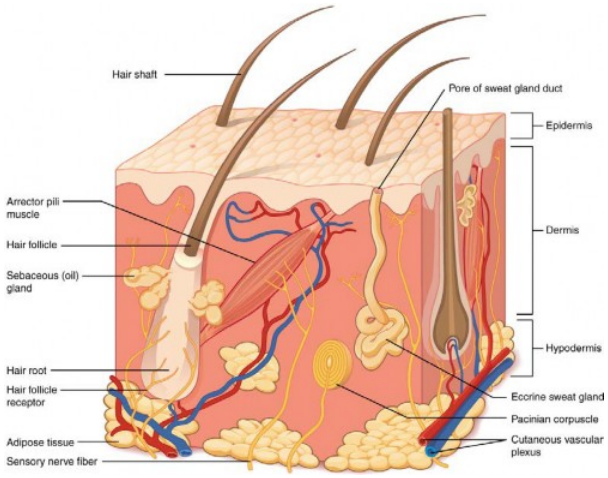


Figure **4.1.1**: Layers of Skin The skin is composed of two main layers: the epidermis, made of closely packed epithelial cells, and the dermis, made of dense, irregular connective tissue that houses blood vessels, hair follicles, sweat glands, and other structures. Beneath the dermis lies the hypodermis, which is composed mainly of loose connective and fatty tissues. (CC-BY-4.0, OpenStax, Human Anatomy)

The Epidermis

The **epidermis** is composed of keratinized, stratified squamous epithelium. It is made of four or five layers of epithelial cells, depending on its location in the body. It does not have any blood vessels within it (i.e., it is avascular). Skin that has four layers of cells is referred to as “thin skin.” From deep to superficial, these layers are the stratum basale, stratum spinosum, stratum granulosum, and stratum corneum. Most of the skin can be classified as thin skin. “Thick skin” is found only on the palms of the hands and the soles of the feet. It has a fifth layer, called the stratum lucidum, located between the stratum corneum and the stratum granulosum.

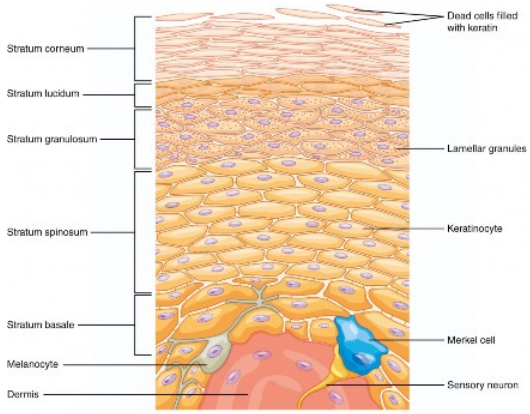


Figure **4.1.2**: *Layers of Epidermis* (CC-BY-4.0, OpenStax, Human Anatomy)

Dermis

The **dermis** might be considered the “core” of the integumentary system (derma- = “skin”), as distinct from the epidermis (epi- = “upon” or “over”) and hypodermis (hypo- = “below”). It contains blood and lymph vessels, nerves, and other structures, such as

hair follicles and sweat glands. The dermis is made of two layers of connective tissue that compose an interconnected mesh of elastin and collagenous fibers, produced by fibroblasts.

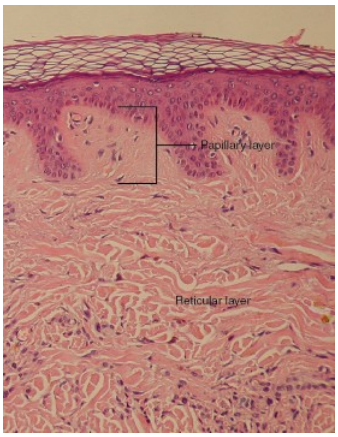


Figure **4.1.3**: Layers of the Dermis This stained slide shows the two components of the dermis—the papillary layer and the reticular layer. Both are made of connective tissue with fibers of collagen extending from one to the other, making the border between the two somewhat indistinct. The dermal papillae extending into the epidermis belong to the papillary layer, whereas the dense collagen fiber bundles below belong to the reticular layer. LM × 10. (credit: modification of work by "kilbad"/Wikimedia Commons)

Hair

Hair is a keratinous filament growing out of the epidermis. It is primarily made of dead, keratinized cells. Strands of hair originate in an epidermal penetration of the dermis called the hair follicle. The hair shaft is the part of the hair not anchored to the follicle, and much of this is exposed at the skin's surface. The rest of the hair, which is anchored in the follicle, lies below the surface of the skin and is referred to as the hair root. The hair root ends deep in the dermis at the hair bulb, and includes a layer of mitotically active basal cells called the hair matrix.

The hair bulb surrounds the **hair papilla**, which is made of connective tissue and contains blood capillaries and nerve endings from the dermis.

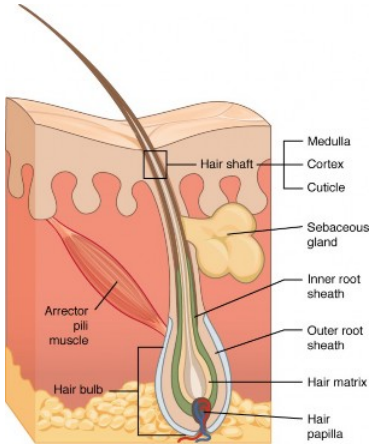


Figure **4.1.4**: Hair Hair follicles originate in the epidermis and have many different parts.

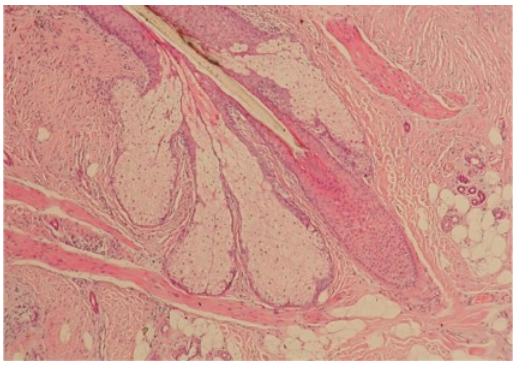


Figure **4.1.5**: Hair Follicle The slide shows a cross-section of a hair follicle. Basal cells of the hair matrix in the center differentiate into cells of the inner root sheath. Basal cells at the base of the hair root form the outer root sheath. LM × 4. (credit: modification of work by “kilbad”/Wikimedia Commons)

\

Nails

The nail bed is a specialized structure of the epidermis that is found at the tips of our fingers and toes. The **nail body** is formed on the **nail bed**, and protects the tips of our fingers and toes as they are the farthest extremities and the parts of the body that experience the maximum mechanical stress. In addition, the nail body forms a back-support for picking up small objects with the fingers. The nail body is composed of densely packed dead keratinocytes. The epidermis in this part of the body has evolved a specialized structure upon which nails can form. The nail body forms at the **nail root**, which has a matrix of proliferating cells from the stratum basale that enables the nail to grow continuously. The lateral **nail fold** overlaps the nail on the sides, helping to anchor the nail body. The nail fold that meets the proximal end of the nail body forms the **nail cuticle**, also called the **eponychium**. The nail bed is rich in blood vessels, making it appear pink, except at the base, where a thick layer of epithelium over the nail matrix forms a crescent-shaped region called the **lunula** (the “little moon”). The area beneath the free edge of the nail, furthest from the cuticle, is called the **hyponychium**. It consists of a thickened layer of stratum corneum.

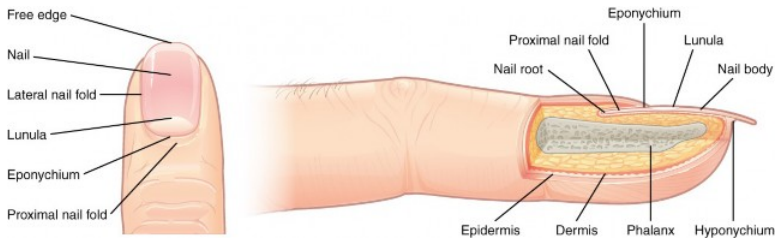


Figure **4.1.6**: Nails The nail is an accessory structure of the integumentary system. (CC-BY-4.0, OpenStax, Human Anatomy)

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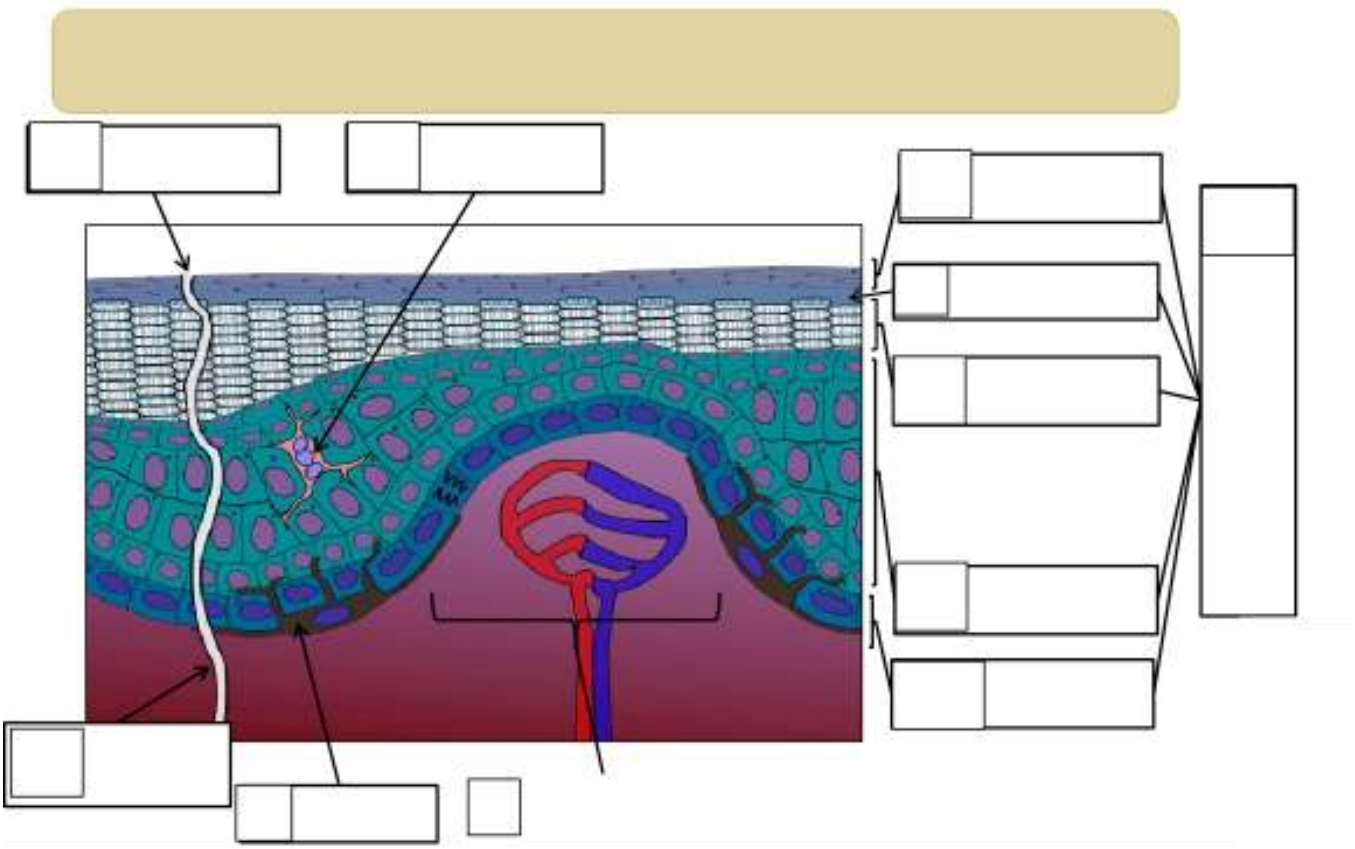
4.2: Exercises

EPIDERMAL LAYERS

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? Lab 4 Exercise 4.2.1

Integument Layers



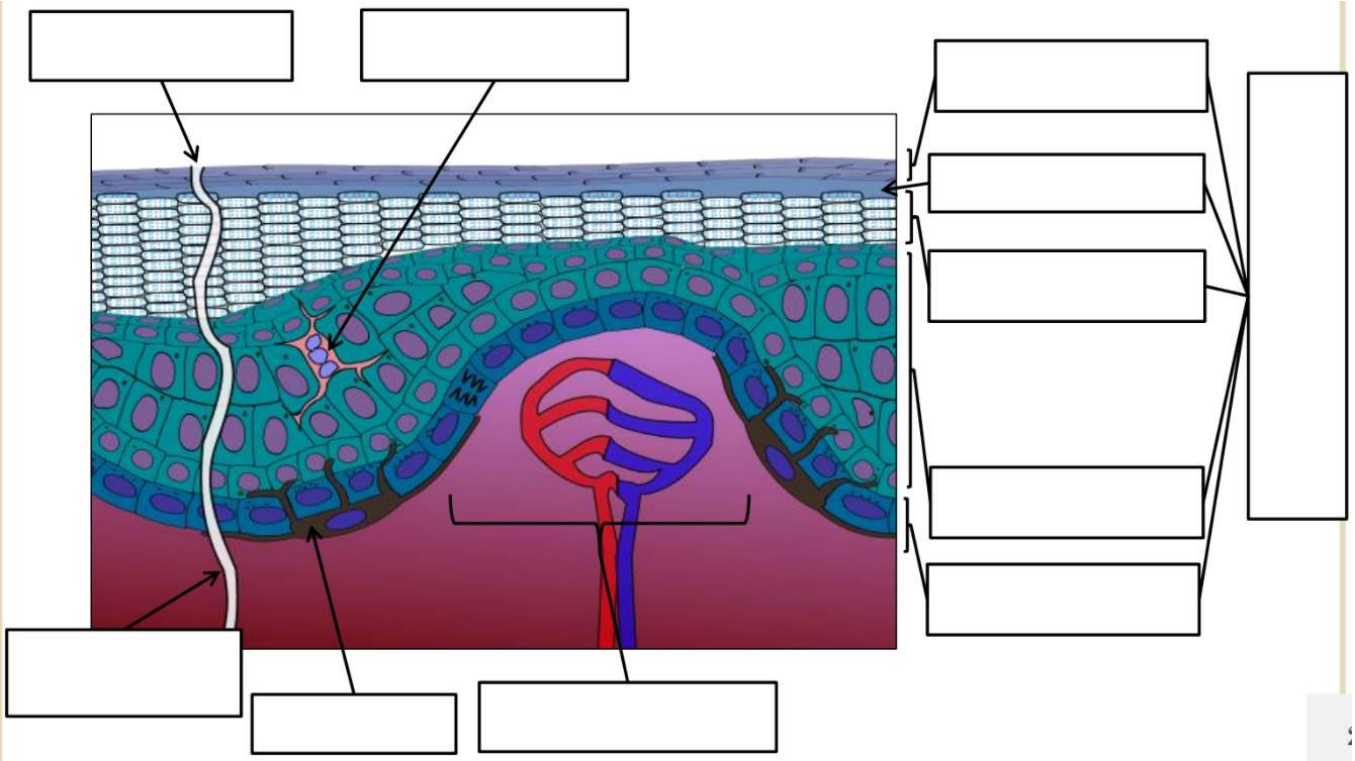
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**Label the following: *Hair follicle * Sebaceous gland * Epidermis * Dermis (papillary layer) ***Dermis (reticular layer) * Hypodermis * Arrector pili muscle * Sweat gland.

1	**Hair follicle**
2	**Sebaceous gland**
3	**Epidermis**
4	**Dermis (papillary layer)**
5	**Dermis (reticular layer)**
6	**Hypodermis**
7	**Arrector pili muscle**
8	**Sweat gland**
9	

? Lab 4 Exercise 4.2.2

Epidermal Layers



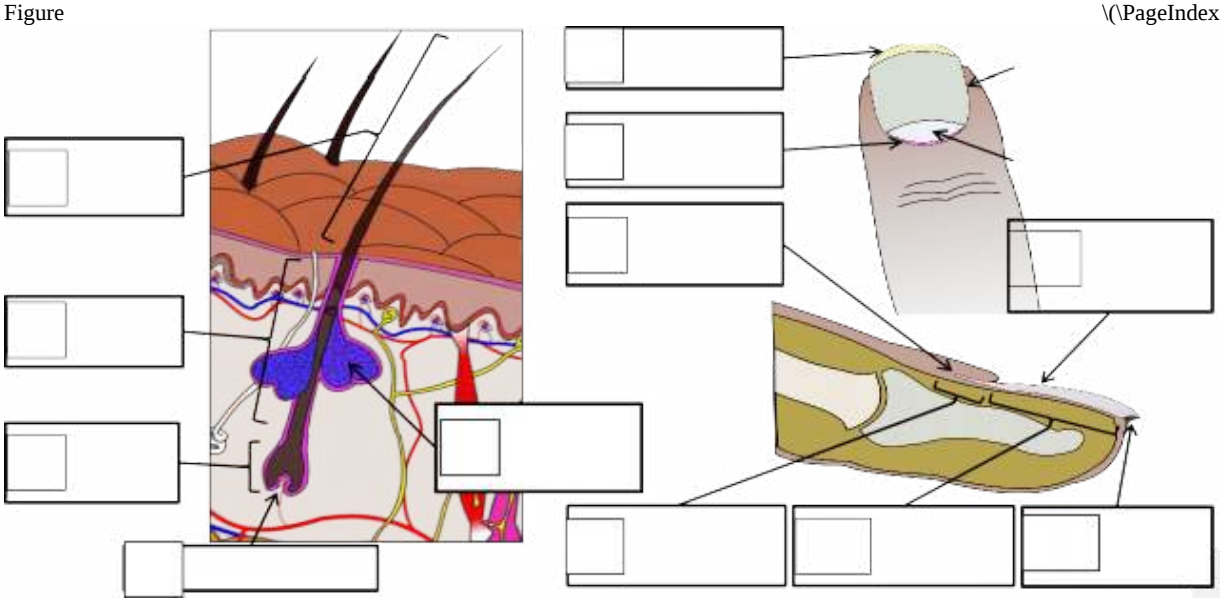
Label the following: Stratum corneum * Stratum lucidum * Stratum granulosum * Stratum spinosum * Stratum basale * Dermal papilla * Sweat duct * Sweat pore * Stratified squamous epithelium * Dendritic cell * Melanocyte

1	**Stratum corneum**
2	**Stratum lucidum**
3	**Stratum granulosum**
4	**Stratum spinosum**
5	**Stratum basale**
6	**Dermal papilla**
7	**Sweat duct**
8	**Sweat pore**
9	**Stratified squamous epithelium**
10	**Dendritic cell**
11	**Melanocyte**

Lab 4 Exercise 4.2.3

Skin Accessories

Figure \(\PageIndex



Label the parts of a hair follicle: Sebaceous gland * Hair shaft * Hair bulb * Hair root * Hair papilla

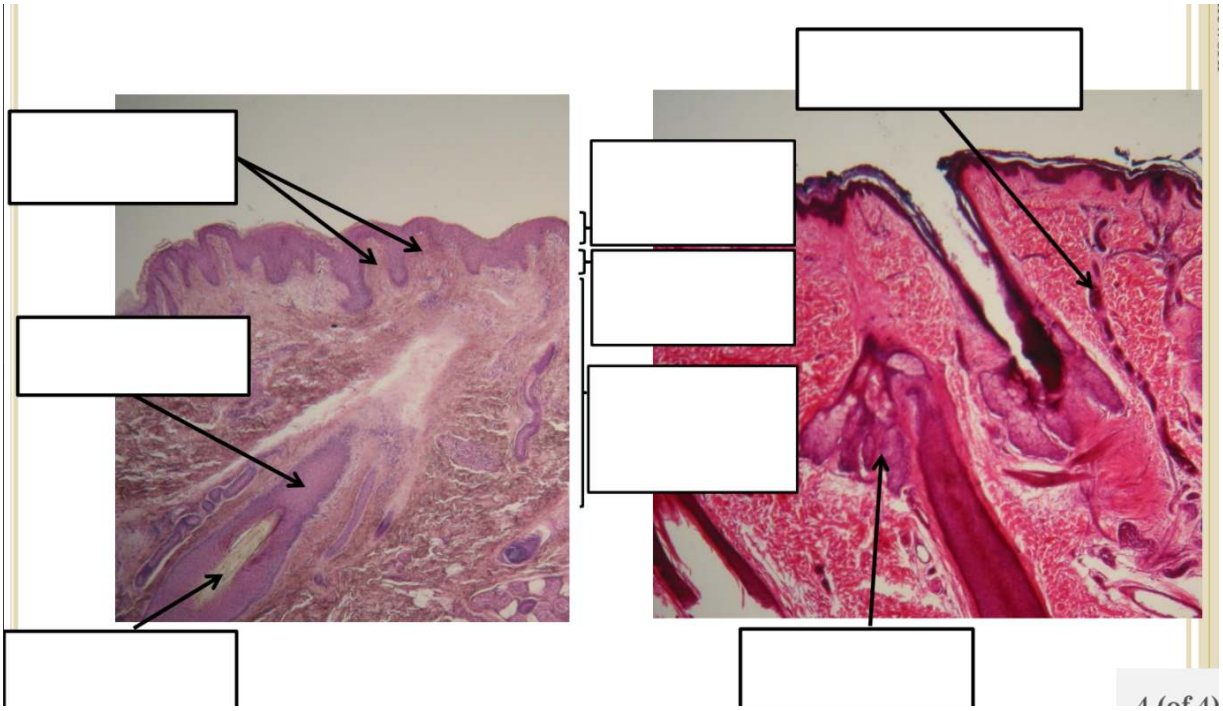
1	**Sebaceous gland**
2	**Hair shaft**
3	**Hair bulb**
4	**Hair root**
5	**Hair papilla**

Label the parts of a nail: Eponychium * Free edge * Hyponychium * Lunula * Nail matrix * Nail root * Lateral nail fold * Nail bed * Nail plate.

1	**Eponychium**
2	**Free edge**
3	**Hyponychium**
4	**Nail matrix**
5	**Nail root**
6	**Lateral nail fold**
7	**Nail bed**
8	**Nail plate.**

Lab 4 Exercise 4.2.4

Integument Layers



Histology: Hair * Hair follicle * Dermal papilla * Sebaceous gland * Eccrine sweat gland * Stratified squamous epithelium * Areolar CT * Dense irregular CT.

1	**Hair follicle**
2	**Dermal papilla**
3	**Sebaceous gland**
4	**Eccrine sweat gland**
5	**Stratified squamous epithelium**
6	**Areolar CT**
7	**Dense irregular CT.**

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4.3: Skin Models

 Thin skin

 Thick skin

 Layers of the skin:

- Epidermis
  - Stratum corneum
  - Stratum lucidum
  - Stratum granulosum
  - Stratum spinosum
  - Stratum basale
- Dermis
  - Papillary layer
  - Reticular layer
  - *Layers beneath the skin (subcutaneous)*
- Hypodermis
  - *Skin structures:*
- Dermal papillae
- Hair follicle
  - Root
  - Shaft
  - Hair follicle
  - Papilla
  - Arrector pilli (or piloerector m.)
  - Bulb
- Blood vessels
- Lamellar corpuscle
  - Tactile corpuscle
- Eccrine (merocrine) sweat gland
  - Pore
  - Duct
  - Apocrine sweat gland
  - Sebaceous glands
- Nail
  - Eponychium
  - Hyponychium

- Free edge
- Lateral nail fold
- Proximal nail fold
- Lunula
- Nail bed
- Nail plate (body)
- Nail matrix
- *Skin cells:*

- Keratinocytes
- Melanocytes
- Fibroblasts

- *Tissues types:*

- Stratified squamous epithelium
- Areolar CT
- Dense irregular CT
- CT – adipose
- Glandular epithelium (simple or stratified cuboidal)

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CHAPTER OVERVIEW

5: The Axial Skeleton

5.1: Bones of the Skull

5.2: The Vertebral Column

5.3: The Thoracic Cage – Ribs and Sternum

5.4: Exercises

5.5: MODELS- Bones

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5.1: Bones of the Skull

Information

The bones of the human body can be divided into two broad groups, the **axial skeleton** and the **appendicular skeleton**. The axial skeleton comprises the bones found along the central axis traveling down the center of the body. The appendicular skeleton comprises the bones appended to the central axis.



Figure **5.1.1**: The axial skeleton highlighted in blue (Public Domain, LadyofHats Mariana Ruiz Villarreal, Wikimedia)

The axial skeleton consists of the bones of the **skull**, the bones of the **inner ear** (known as ossicles), the **hyoid bone** in the throat, and the bones of the **vertebral column**, including the **sacrum and coccyx** bones in the center of the pelvic girdle.

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The Bones of the Skull

There is only one movable joint in the skull. That is the joint connecting the lower jaw, or mandible, to the rest of the skull. All the other bones in the skull are firmly attached to one another by **sutures**.

Sutures are rigid immovable connections holding bones tightly to one another. Some of the sutures in the skull take a few months-to-years after birth to completely form.

The brain is encased in the **cranium** of the skull. The bones that make up the cranium are called the **cranial bones**. The remainder of the bones in the skull are the **facial bones**.

Figure **5.1.2** and Figure **5.1.3** show all the bones of the skull, as they appear from the outside. In Figure **5.1.5**, some of the bones of the hard palate forming the roof of the mouth are visible because the mandible is not present. Figure **5.1.9** also shows the **foramen magnum**, the large hole at the base of the skull that allows the spinal cord to attach to the brain

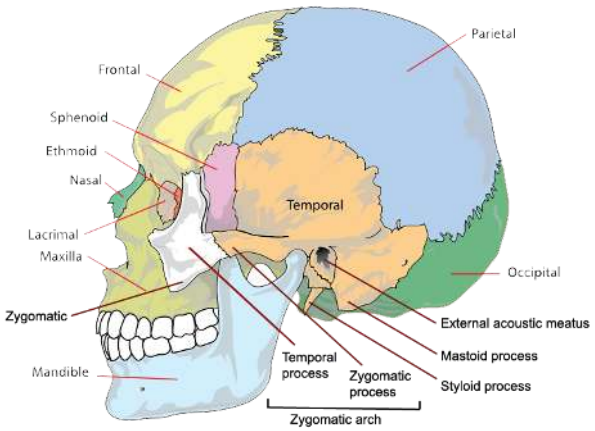


Figure **5.1.2**: The bones of the skull, left lateral view. (Public Domain, LadyofHats Mariana Ruiz Villarreal, Wikimedia)

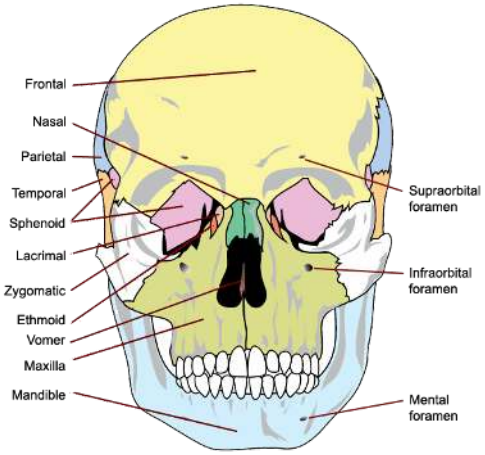


Figure **5.1.3**: The bones of the skull, anterior view. (Public Domain, Wikimedia)

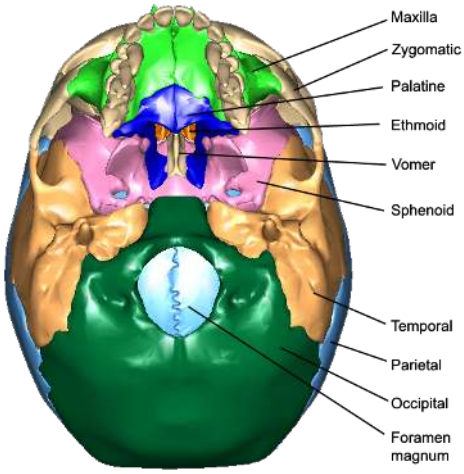


Figure **5.1.4**: The bones of the skull, inferior view, looking up. Mandible removed. (CC-BY-SA, BodyParts3D/Anatomography)

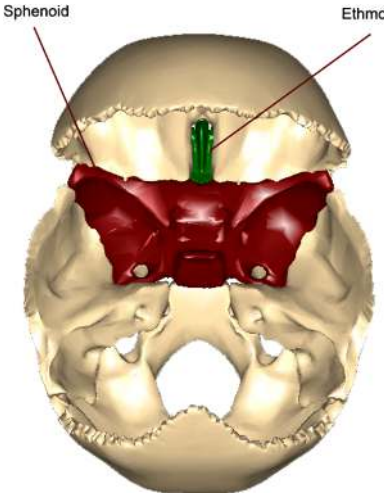


Figure **5.1.5**: The interior of the cranial cavity, viewed from above and behind, with the parietal bones removed. (CC-BY-SA, BodyParts3D/Anatomography)

The **sphenoid** bone, from the outside, appears to contribute to only a small portion of the cranium, but when the parietal bones are removed and the interior of the cranial cavity (where the brain would be housed) is viewed, you can see the butterfly-like shape of the sphenoid bone makes a large contribution to the floor of the cranial cavity. The **ethmoid** bone, which from the outside is only visible in the eye sockets and as the upper conchae (internal bumps) of the nasal cavity, also contributes to the floor of the cranial cavity. The contributions of these two bones to the floor of the cranial cavity are shown in Figure **5.1.5**.

What is commonly referred to as the “cheekbone” is really the processes of two bones connected together: the **zygomatic process** of the temporal bone is sutured to the **temporal process** of the zygomatic bone to produce the **zygomatic arch**.

There are three prominent bone markings on the temporal bones. The **external acoustic meatus** is the opening that leads to the organs of the inner ear. The **styloid process** is a thin, pen-like projection where muscles and ligaments of the neck are attached. The **mastoid process** is a wide and rough projection that serves as another attachment point for neck muscles.

While all the bones of the skull, other than the mandible, are sutured to one another, the flat bones of the cranium are visibly sutured where they articulate to another. There are four different cranial sutures.

The **coronal suture** is the articulation point of the frontal bone with the two parietal bones. The **sagittal suture** is the articulation point between the two parietal bones.

The **squamous sutures** are the articulation points between the each temporal bone and the parietal bone superior to it.

The **lambdoid suture** is the articulation point between the occipital bone and the two parietal bones.

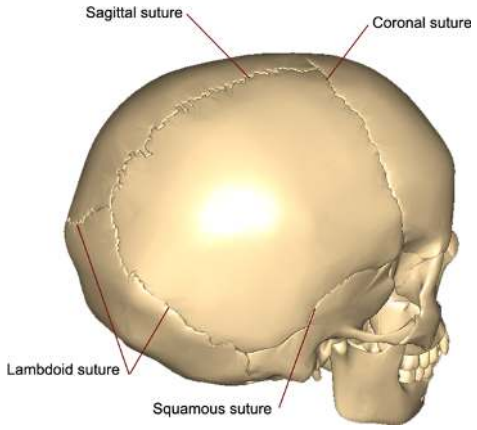
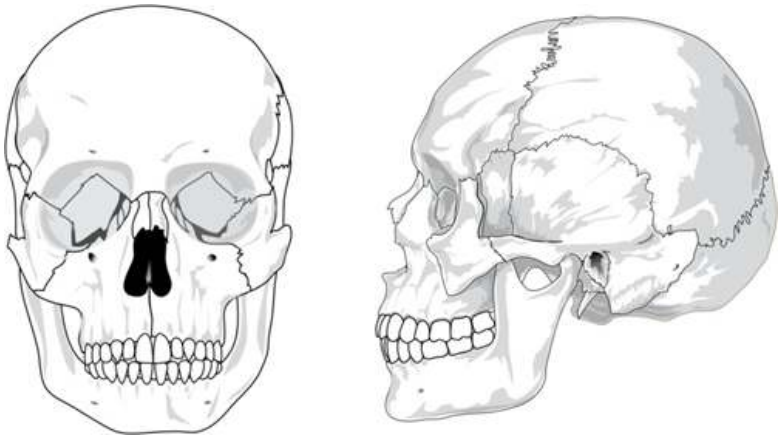


Figure **5.1.6**: The cranial sutures.. (CC-BY-SA, BodyParts3D/Anatomography)

? Lab 5 Exercise **5.1.1**

Models of human skulls may be found in the cabinets. **On the models** identify all of the following and on the diagrams below be able to label and/or color in all the following bones, processes, and foramina:



(Public Domain, Pixabay)

Bones	Sutures	Foramina	Processes
B1 – frontal	S1 – coronal	F1 – supraorbital	P1 – mastoid
B2 – parietal	S2 – squamous	F2 – infraorbital	P2 – styloid
B3 – occipital	S3 – lambdoid	F3 – mental	P3 – zygomatic
B4 – temporal			P4 temporal
B5 – sphenoid			
B6 – ethmoid			
B7 – lacrimal			
B8 – nasal			
B9 – maxilla			
B10 – zygomatic			
B11 – mandible			
B12 – vomer			
B13 – palatine (not visible here)			

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Figure 5.1.5. The interior of the cranial cavity, viewed from above and behind, with the parietal bones removed.. **Authored by**: Made out of, or made from, content published in a BodyParts3D/Anatomography web site. The content of their website is published under the Creative Commons Attribution 2.1 Japan license. The author and licenser of the contents is http://lifesciencedb.jp/bp3d/?lng=en. **Located at**: **http://lifesciencedb.jp/bp3d/?lng=en**. **License**: ***CC BY-SA: Attribution-ShareAlike***

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Figure 5.1.3. The bones of the skull, anterior view.. **Authored by**: LadyofHats Mariana Ruiz Villarreal. **Located at**: **https://commons.wikimedia.org/wiki/F...ront_bones.svg**. **License**: ***Public Domain: No Known Copyright***

Lab exercises 5.1.1. **Located at**: **https://pixabay.com/en/skull-diagram...anatomy-41553/**. **License**: ***Public Domain: No Known Copyright***

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5.2: The Vertebral Column

The Hyoid Bone

The **hyoid** bone in the neck is the only bone in the body that does not articulate directly with at least one other bone. It is U-shaped and is held in place by, and helps anchor, muscles that connect to the floor of the mouth and the tongue. It helps provide greater movement of the tongue and larynx, and so is crucial to human speech.

In about 50% of strangulations, the hyoid bone is fractured.

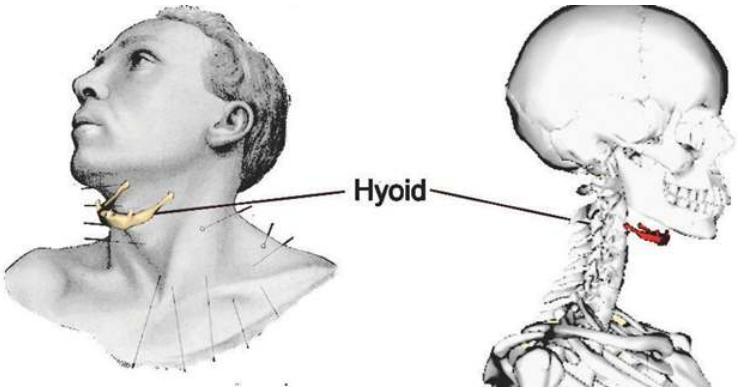


Figure 5.2.1: The hyoid bone. (CC-BY-SA, Was a bee, Wikimedia)

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The Vertebral Column

The vertebral column is more colloquially called the backbone or the spine. It consists of 24 **vertebrae** bones, and two bones from the axial section of the pelvic girdle, the **sacrum** and the **coccyx**.

The vertebrae are divided into three groups. There are **seven cervical vertebrae** (names C1 through C7), **twelve thoracic vertebrae** (named T1 through T12), and **five lumbar vertebrae** (named L1 through L5).

You can use a meal-related mnemonic to remember them – imagine a crunchy breakfast at 7 am (7 cervical vertebrae), a tasty lunch at 12 noon (12 thoracic vertebrae), and a light dinner at 5 pm (5 lumbar vertebrae).

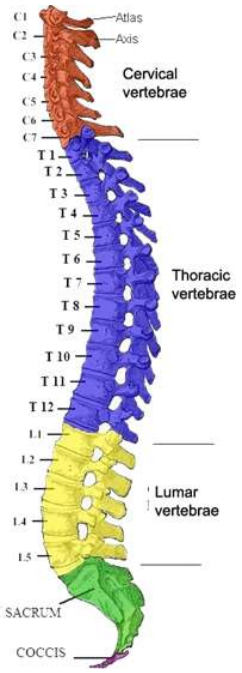


Figure **5.2.2**: The bones of the vertebral column. (CC-BY-SA, Henry Grey, Henry Vandyke Carter, Wikimedia)

The first two cervical vertebrae have alternate names to C1 and C2. C1 is also called the **atlas**. In Greek mythology, Atlas was a titan who held the entire world on his shoulders. As the first vertebra in the column, Atlas in a sense holds up the skull. C2 is also called the **axis**. The axis allows both the skull and the atlas to rotate, so the head can be turned from side to side by neck muscles.

All three types of vertebrae have some structural features in common and some features that should allow you to readily distinguish vertebrae in one category from another.

All vertebrae, except C1 and C2, the atlas and axis, have a solid round portion on their anterior side called the **body** of the vertebra. The body is what allows the vertebrae in the vertebral column to be stacked upon one another, separated by pads of fibrocartilage called the intervertebral discs. The lower you go in the vertebral column, the larger the vertebrae's bodies become.

The axis, or C2 vertebra, also has a bulbous vertical process not found in any of the other vertebrae. This is called the **dens** and it is what allows the axis vertebra above it to rotate.

Posterior to the vertebral body is a large opening in each vertebra called the **vertebral foramen**. This is the hole through which the spinal cord passes.

Posterior to the vertebral foramen there is a central process jutting out of each vertebra. This is the **spinous process**. It points more or less downwards when the vertebrae are correctly stacked into their column.

Surrounding the central spinous processes, there are other processes whose position and number vary depending on whether a vertebra is cervical, thoracic, or lumbar. Some of these processes allow a vertebra to articulate with the vertebrae superior and inferior to it, others, found only on thoracic vertebrae, allow a pair of ribs to articulate with the vertebra.

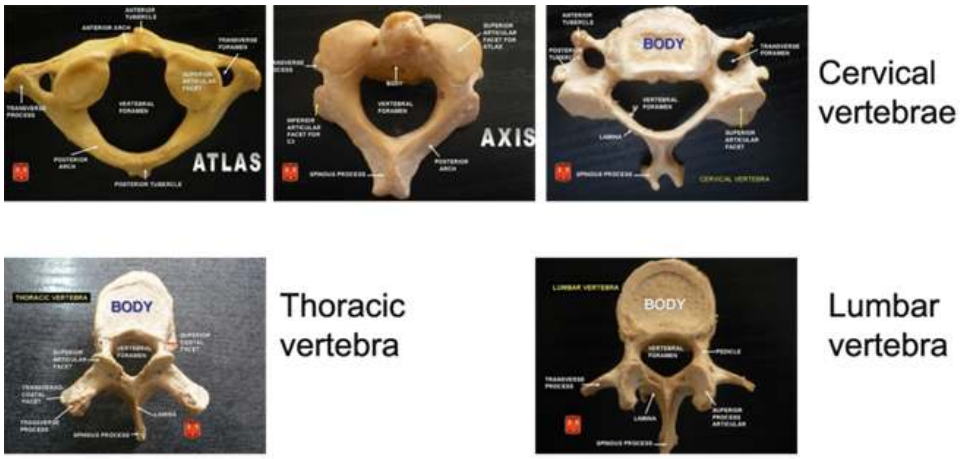


Figure **5.2.3**: The three types of vertebrae. All are being viewed from behind. Note that C1 and C2 vertebrae, the atlas and axis, do not have vertebral bodies. (CC-BY-SA, Anatomist90, Wikimedia)

Figure **5.2.2** The three types of vertebrae. All are being viewed from behind. Note that C1 and C2 vertebrae, the atlas and axis, do not have vertebral bodies.

The **sacrum** is part of both the vertebral column and the pelvic girdle. It articulates with the intervertebral disc under the L5 vertebra above it, and with two coxal bones lateral to it.

The sacrum starts out as five vertebrae that fuse to form the one structure. This fusion is not complete until somewhere between the 18th and 30th year.

The **coccyx** is a vestigial tailbone. It is the evolutionary remnant of an ancestral species to humans that did have tails. It no longer serves as a functional tail, but some muscles, tendons, and ligaments do attach to it, making it useful. It forms from the fusion of usually three vertebrae, but a small proportion of the population have four or even five vertebrae in their coccyx.

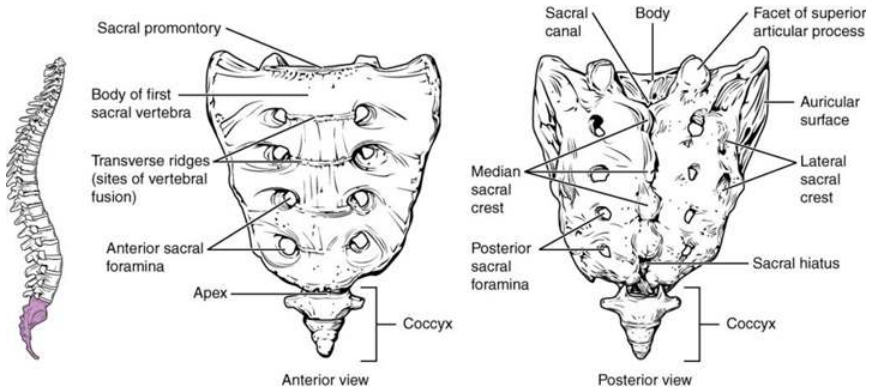


Figure **5.2.4**: The sacrum and coccyx. (CC-BY-SA, OpenStax College, OpenStax)

? Lab 5 Exercise 5.2.1

1. Real or replica vertebrae bones may be found in the cabinets and on the back counters. Identify which in your group are the atlas, axis, cervical vertebrae, thoracic vertebrae, and lumbar vertebrae.

2. Stack your vertebrae in the correct order and in the correct orientation.

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Figure 5.2.3. The three types of vertebrae. All are being viewed from behind. Note that C1 and C2 vertebrae, the atlas and axis, do not have vertebral bodies. . **Authored by**: Anatomist90. **Located at**: https://commons.wikimedia.org/wiki/F..._vertebrae.jpg. **License**: ***CC BY- SA: Attribution-ShareAlike***

Figure 5.2.4. The sacrum and coccyx. **Authored by**: OpenStax College. **Located at**: http://cnx.org/resources/e394fc66a09810ea99d0165de1078c8af2d4dc46/720_Sacrum_and_Coccyx.jpg. **License**: ***CC BY-SA: Attribution-ShareAlike***

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Figure 5.2.2. The bones of the vertebral column. **Authored by**: Henry Grey, Henry Vandyke Carter. **Located at**: https://upload.wikimedia.org/wikiped...red_Ro_mod.JPG. **Project**: Anatomy of the Human Body, 20th Edition (1918). **License**: ***Public Domain: No Known Copyright***

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5.3: The Thoracic Cage – Ribs and Sternum

Information

There is one last component of the axial skeleton we did not cover last lab: the thoracic cage, also called the rib cage. The thoracic cage surrounds and protects the heart and lungs in the thoracic cavity. It consists of the ribs, the sternum, and the thoracic vertebrae, to which the ribs articulate.

We examined the thoracic vertebrae last lab, so here we will only examine the ribs and sternum.

There are twelve pairs of ribs. The number is the same in both males and females. Each pair articulates with a different thoracic vertebra on the posterior side of the body. The most superior rib is designated rib 1 and it articulates with the T1 thoracic vertebrae. The rib below that is rib 2, and it connects to the T2 thoracic vertebra, and so on. Ten of the twelve ribs connect to strips of hyaline cartilage on the anterior side of the body. The cartilage strips are called **costal cartilage** ("costal" is the anatomical adjective that refers to the rib) and connect on their other end to the sternum.

On an individual rib, one end has various processes, facets, and bumps. This is the end that articulates with the vertebra. The other end is blunt and smooth. This is the end that connects to costal cartilage (unless it is a floating rib. See below.)

Ribs 1-7 are called the **true ribs**. Each true rib connects to its own strip of costal cartilage, which in turn connects to the sternum. Ribs 8-12 are called the **false ribs**. Ribs 8, 9, and 10 do connect to the sternum, but the costal cartilage of each of these ribs connects to the costal cartilage of the rib above it, rather than directly to the sternum. Ribs 11 and 12 do not have any costal cartilage connected to them at all, and in addition to being grouped in the false ribs, these two are also called **floating ribs**, to reflect that fact.

The **sternum** has three parts. The **manubrium**, at the superior end of the sternum, and wider than the rest of the bone, provides articulation points for the clavicles and for the costal cartilage extending from rib 1. The central, thin **body** provides articulation points for costal cartilage from ribs 2 through 7. The **xiphoid process** which hangs down at the inferior end of the process ("xiphoid" is from the Greek for sword), starts out as cartilage, and does not typically ossify into bone until an individual is about 40 years old.

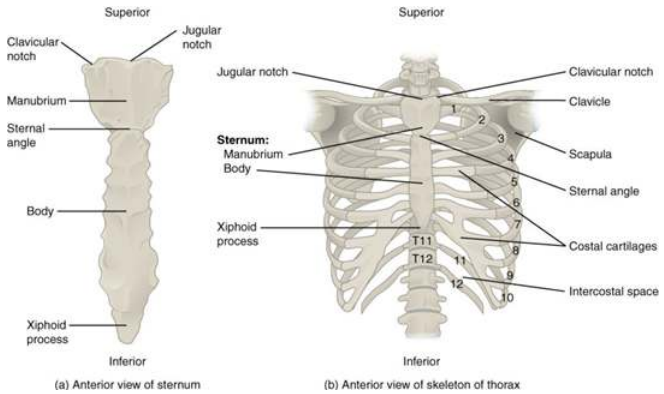


Figure **5.3.1**: Ribs and sternum**.** (CC-BY-SA, OpenStax College, OpenStax)

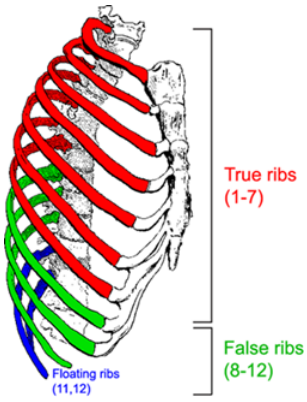


Figure **5.3.1**: True, false, and floating ribs. (CC-BY-SA, Cristobal carrasco., Wikimedia)

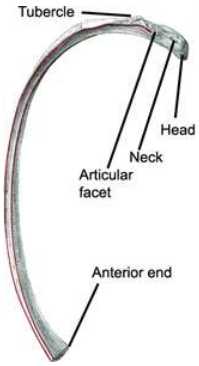


Figure **5.3.1**: The parts of a rib. (CC-BY-SA, Henry Vandyke Carter, Wikimedia)

? Lab 5 Exercise **5.3.1**

1. Ribs may be found in the cabinets. On an individual rib, identify which end is the head and which is the anterior end.
2. On one of the intact skeletons in the lab, identify all the following components of the thoracic cage:

   the true ribs the false ribs the floating ribs
   costal cartilage sternum xiphoid process
   manubrium sternal body

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Figure **5.3.1**. Ribs and sternum.. **Authored by**: OpenStax College. **Provided by**: Anatomy & Physiology, Connexions Web site. https://cnx.org/contents/FPtK1zmh@8....-Thoracic-Cage. **Located at**: **https://cnx.org/resources/e1cbee95a6...1_Rib_Cage.jpg**. **License**: ***CC BY-SA: Attribution- ShareAlike***

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Figure **5.3.2**. True, false, and floating ribs.. **Authored by**: Cristobal Carrasco. **Located at**: **https://commons.wikimedia.org/wiki/File:Costillas.png**. **License**: ***CC BY-SA: Attribution-ShareAlike***

Figure **5.3.3**. The parts of a rib.. **Authored by**: Henry Vandyke Carter. **Located at**: **commons.wikimedia.org/wiki/File:Image122.gif**. **License**: ***CC BY-SA: Attribution-ShareAlike***

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5.4: Exercises

Lab 5 Exercise 5.4.1

1. The instructor will provide you with a single rib from the human body. On that individual rib, identify which end is the head, and which is the anterior end.

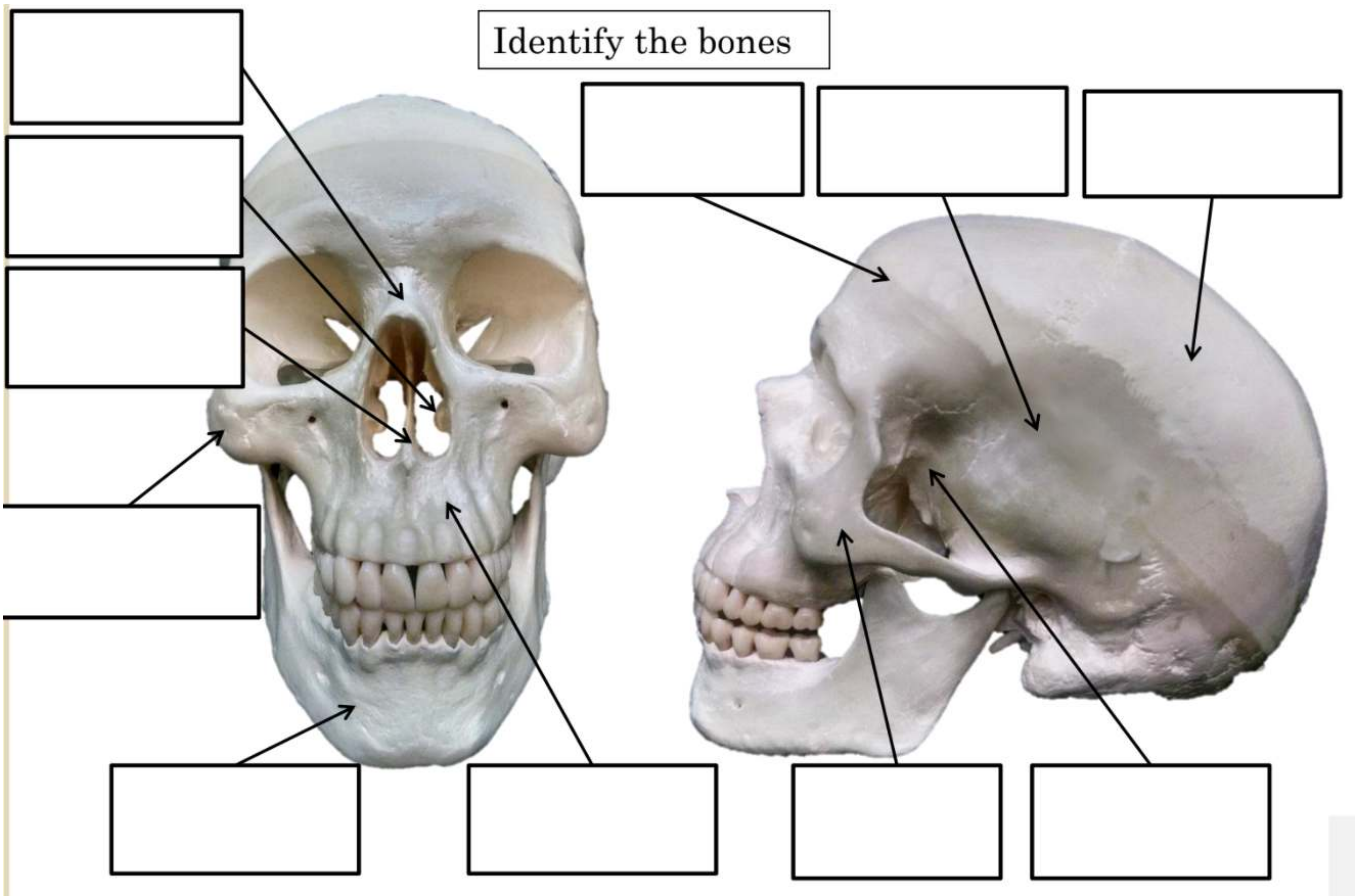
2. On one of the intact skeletons in the lab, identify all the following components of the thoracic cage:

the true ribs	the false ribs	the floating ribs
costal cartilag	sternum	xiphoid process
manubrium	sternal body	

Lab 5 Exercise 5.4.1

1. The instructor will provide you with a single rib from the human body. On that individual rib, identify which end is the head, and which is the anterior end.

2. On one of the intact skeletons in the lab, identify all the following components of the thoracic cage:







1	Zygomatic bones	6	Inferior orbital foramen
2	Lacrimal bones	7	Glabella
3	Coronal suture	8	Superior orbital fissure
4	Sagittal suture	9	Inferior orbital fissure
5	Superior orbital notch/foramen		





1	Occipital bone	7	Mastoid process
2	Temporal bone	8	Glabella
3	Sphenoid bone	9	Styloid process
4	Maxilla	10	Lambdoid suture
5	Mandible	11	Zygomatic process of the temporal bone
6	External acoustic meatus	12	Temporal process of the zygomatic bone
		13	Sutural bones



1	Zygomatic arch8	8	Internal acoustic meatus
2	Foramen ovale	9	Occipital condyle
3	Foramen spinosum	10	Mandibular fossa
4	Foramen lacerum	11	Ethmoid bone
5	Jugular foramen	12	Anterior cranial fossa
6	Carotid canal	13	Middle cranial fossa
7	Foramen magnum	14	Posterior cranial fossa.









1	Cervical vertebrae	8	Lumbar curvature
2	Cervical curvature	9	Atlas
3	Thoracic vertebrae	10	C1
4	Thoracic curvature	11	C2
5	5	12	12
6	Carotid canal	13	Axis
7	7	14	Dens



1	True ribs	3	False ribs
2	Floating ribs	4	Costal cartilages.

Lab 5 Exercise 5.4.3

1. Using one of the full skeletons in the room, fill out the tables below with three or four steps to determine whether each individual upper limb bone comes from the anatomical left or anatomical right.
2. You can describe any features on that bone and which direction it has to face to allow you to determine whether that particular bone came from anatomical left or anatomical right.

3. You don't have to use anatomical jargon if you don't want. Use terms which will make sense to you when you read it again. Use as many steps as you need, not necessarily four.

Humerus – Anatomical left from anatomical right
1.
2.
3.
4.

Ulna – Anatomical left from anatomical right
1.
2.
3.
4.

Radius – Anatomical left from anatomical right
1.
2.
3.
4.

? Lab 5 Exercise 5.4.4

1. Using one of the full skeletons in the room, fill out the tables below with three or four steps to determine whether an individual coxal bone comes from the anatomical left or the anatomical right.
2. You can describe any features on the bone and which direction it has to face to allow you to determine whether that particular bone came from anatomical left or anatomical right.
3. You don't have to use anatomical jargon if you don't want. Use terms which will make sense to you when you read it again. Use as many steps as you need, not necessarily four.

Coxal bone – Anatomical left from anatomical right
1.
2.
3.
4.

Exercise 5.4.5

1. There will be an intact pelvis set up at the instructor's station. Using the criteria in this image determine if the pelvis came from a male or female. Give three lines of evidence to support your conclusion.

Male or female?	
Evidence 1	
Evidence 2	
Evidence 2	

Exercise 5.4.1

1. Using one of the full skeletons in the room, fill out the tables below with three or four steps to determine whether each individual lower limb bone comes from the anatomical left or anatomical right.
2. You can describe any features on that bone and which direction it has to face to allow you to determine whether that particular bone came from anatomical left or anatomical right.
3. You don't have to use anatomical jargon if you don't want. Use terms which will make sense to you when you read it again. Use as many steps as you need, not necessarily four.

Femur – Anatomical left from anatomical right
1.
2.
3.
4.

Tibia – Anatomical left from anatomical right
1.
2.
3.
4.

Fibula – Anatomical left from anatomical right
1.
2.
3.
4.



Figure **5.4.1**: Copy and Paste Caption here. (Copyright; author via source)

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5.5: MODELS- Bones

Lab List Skull

Easy difficulty	Medium difficulty	Hard difficulty
Bones: • *Identify from external views:* • Parietal, Ethmoid, Sphenoid, Temporal, • Occipital, Frontal • Vomer, Inferior nasal concha, Nasal, Maxilla, Mandible, Palatine, Zygomatic, Lacrimal	**Bones**: • *identify bones than can be seen from the internal view* (occipital, temporal, ethmoid, sphenoid, frontal) • *identify disarticulated skull bones* • (sphenoid and ethmoid)	**Bones** :
Landmarks: • Mastoid Process, Mandibular Fossa, • Sphenoid: Greater & lesser wings • Sutures: sagittal, coronal, squamous, lambdoid.	•**Landmarks**: • Cranium: Glabella. Occipital condyles. Styloid process. • Face: Alveolar processes of maxilla & mandible. lacrimal fossa • U*nderstand the difference between* the zygomatic bone, zygomatic arch & zygomatic process (of the temporal bone). • Temporal process of zygomatic bone • Sphenoid: sella turcica, pterygoid plates. • Mandible: ramus, condyle, body, coronoid process.	**Landmarks**: • Sinuses: frontal, sphenoid, maxillary. • Petrous & squamous part of temporal bone • Palatine process of maxilla • orbital margins • Sphenoid: Hypophyseal fossa • Ethmoid: lateral masses, superior & middle nas perpendicular plate, cribiform plates.
Foramen • Foramen magnum • External acoustic meatus	**Foramen**: • mental, optic canal, superior orbital notch/foramen, infraorbital , olfactory foramina, carotid canal, jugular, ovale, lacerum, spinosum.	**Foramen**: • stylomastoid, internal acoustic meatus, rotundu incisive, greater palatine.
Areas: • Cranium (*mnemonic: Pest of 6)* • Face *(mnemonic: Virgil cannot make* • *my pet zebra laugh)*	**Areas**: • Cranial fossa: anterior, middle, posterior.	

Lab List Spine / Axial Skeleton

Bones: • 7 cervical, 12 thoracic, 5 lumbar vertebrae • Atlas & axis • Sacrum & coccyx • Sternum • Hyoid	**Bones**: • *Identify disarticulated vertebrae as* • atlas/axis/cervical/thoracic or lumbar	
Vertebrae landmarks: Body • Transverse process, spinous process • Transverse foramen, Intervertebra • foramenl, Vertebral foramen, • Superior & inferior articular processes	**Vertebrae landmarks:** • Costal facets • Costal demifacets: inferior & superior. Dens of axis	**Vertebrae landmarks:** • Pedicles, Arch, Lamina, Superior & inferior nc
Sternum landmarks • manubrium, body, xiphoid process	**Sternum landmarks** • Jugular notch, sternal angle.	
	Sacrum landmarks • Sacral foramen, Ala, Body, Auricular surface	
Misc: • Identify true/false/floating ribs on articulated spine. • *Know number of* ribs. • *List 1 identifying characteristic of the 3 different types of* vertebrae	**Misc**:	**Misc**: • Spinal curves: cervical, thoracic, lumbar, sacra

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CHAPTER OVERVIEW

6: The Appendicular Skeleton

The appendicular skeleton is made up by the bones attached or appended to the axial skeleton. These are the bones of the limbs, hands, and feet, the bones of the pectoral (shoulder) girdles, and the coxal bones of the pelvic girdle.

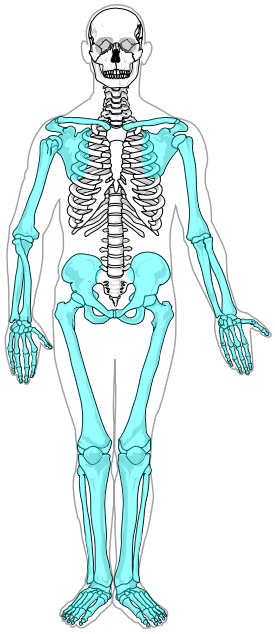


Figure 6.1: The appendicular skeleton highlighted in blue. (Public Domain; LadyofHats Mariana Ruiz Villarreal via Wikipedia)

6.1: The Pectoral girdles
6.2: The Upper Limbs
6.3: The Pelvic Girdle
6.4: The Pelvis
6.5: The Lower Limbs
6.6: Exercises
6.7: MODELS- Upper and Lower Limbs

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6.1: The Pectoral girdles

There is a pectoral girdle above each arm, consisting of the **scapula** (shoulder blade) and **clavicle** (collar bone.)

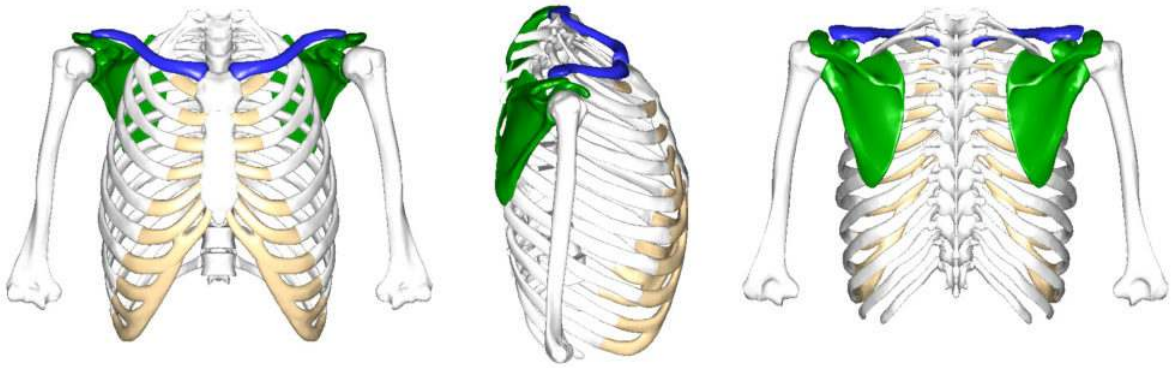


Figure **6.1.1**: **The pectoral girdle. The scapulae are in green and the clavicles are in blue.**. (CC-BY-SA, Wikimedia, BodyParts3D/Anatomography)

The scapula has a triangular body with three main processes coming off the body. On the posterior side is the **spine** of the scapula that ends in the **acromion process**, which articulates with the lateral end of the scapula. On the anterior side, facing into the body, is a right-angled process called the **coracoid process**. While at the superior lateral edge of the scapula the **glenoid cavity**, which serves as the socket for the head of the humerus bone. The glenoid cavity always points laterally, while the spine and acromion are posterior. This will help you determine whether a particular scapula comes from the anatomical left or right.

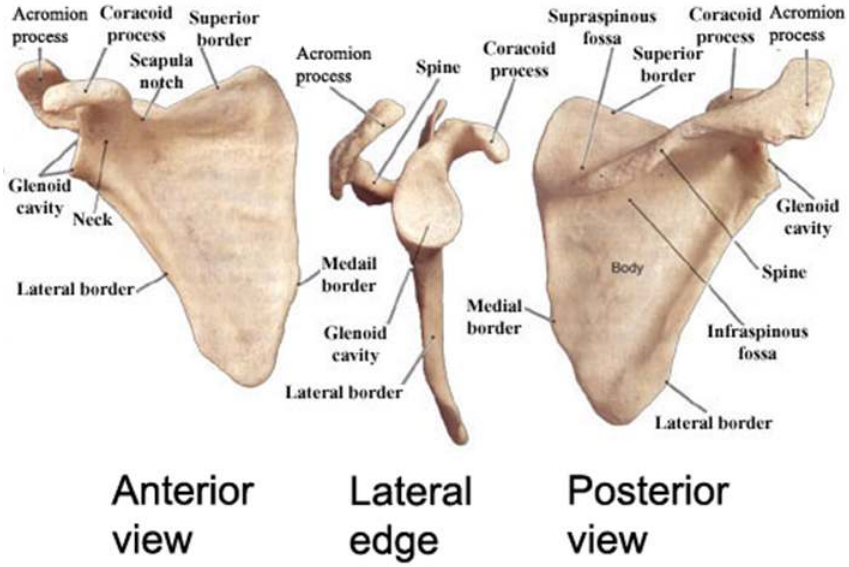


Figure **6.1.2**: **The scapula bone**. (CC-BY-SA, Wikimedia)

The clavicle is a vaguely S-shaped bone which articulates with the scapula in the lateral and articulates with the sternum at the medial end. The flatter broader end is the **acromial extremity (end)**, which articulates with the acromion process of the scapula. The superior surface of the acromial extremity is smoother than its inferior surface, which can help you determine whether a particular clavicle bone comes from the left or right. The more circular end is the **sternal extremity (end)**, which articulates with the manubrium of the sternum.

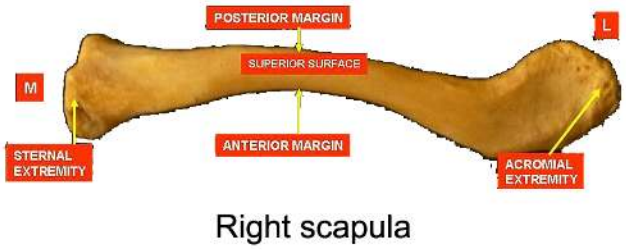


Figure **6.1.3**: The right clavicle bone. (CC-BY-SA, Wikimedia)

LAB 6 EXERCISE 6.1.1

1. Using one of the full skeletons in the room, fill out the table below with three or four steps to determine whether an individual scapula comes from the anatomical left or anatomical right. You must use any features that are already filled in. The clavicle was done as an example.
2. You can describe any features on that bone and which direction it has to face to allow you to determine whether that particular bone came from anatomical left or anatomical right.
3. Sample instructions for the clavicle are provided as an example for all subsequent exercises. Use proper anatomical terminology. Use terms which will make sense to anyone schooled in anatomy if they read it. Use as many steps as you need, not necessarily four.

Clavicle – Anatomical left from anatomical right

1. Put the smooth side of the acromial end facing superiorly.
2. Put the curve in the middle of the bone facing anteriorly.
3. If the acromial end is on the right, the clavicle is from the anatomical right.
4. If the acromial end is on the left, the clavicle is from the anatomical left

Scapula – Fill in four steps to determine anatomical left from anatomical right

1. Glenoid cavity -

2.

3.

4.

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6.2: The Upper Limbs

Information

For anatomists, the upper limb consists of the arm (the upper arm), the forearm (the lower arm), and the hand. The arm consists of a single bone, the humerus. The forearm consists of two bones, the ulna and radius. And the hand consists of 27 bones, which are grouped into the phalanges, metacarpals, and carpals.

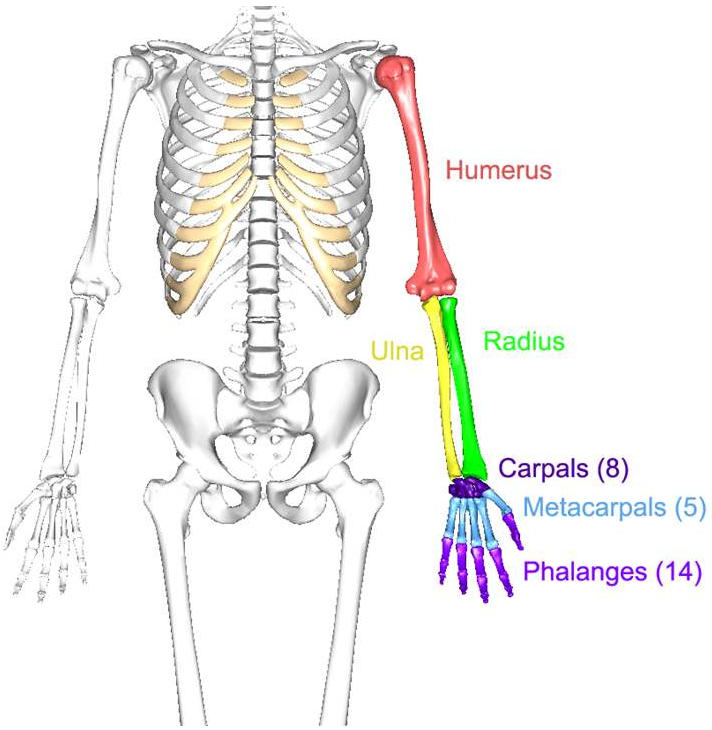


Figure **6.2.1**: **The bones of the left upper limb.** (CC-BY-SA, BodyParts3D/Anatomography)

The major processes and markings of the **humerus, ulna**, and **radius** bones are shown in Figures **6.2.2**, **6.2.3**, and **6.2.4**, respectively.

The bones of the hands are divided into three groups. The **carpals** articulate with the ulna and radius bones of the forearm and are named after the carpus, or wrist. There are 8 carpal bones and each has its own name. In Figure **6.2.5** they are numbered so that 1-trapezium, 2-trapezoid, 3-capitate, 4-hamate, 5-pisiform, 6-triquetrum, 7-lunate, 8- scaphoid.

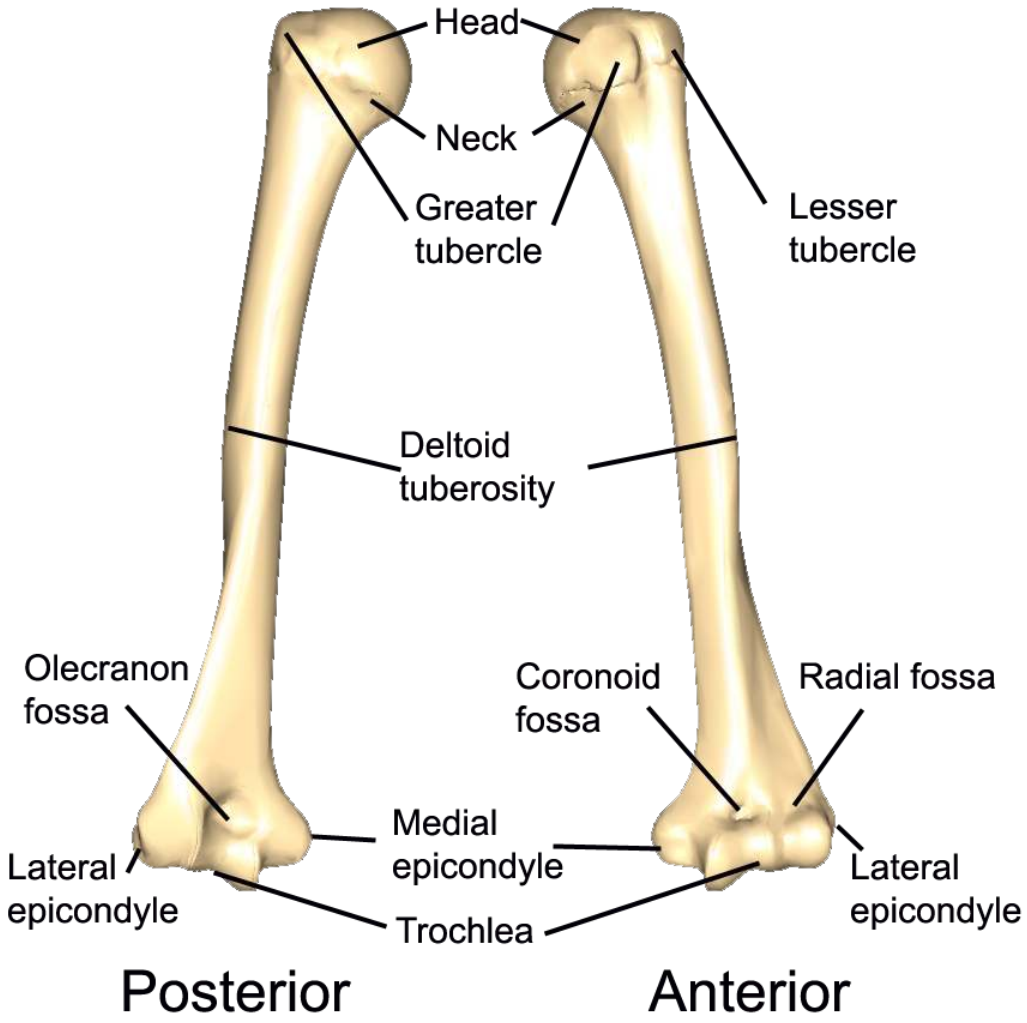


Figure **6.2.2**: The left humerus and its various processes and markings. (CC-BY-SA, Wikimedia, BodyParts3D/Anatomography)

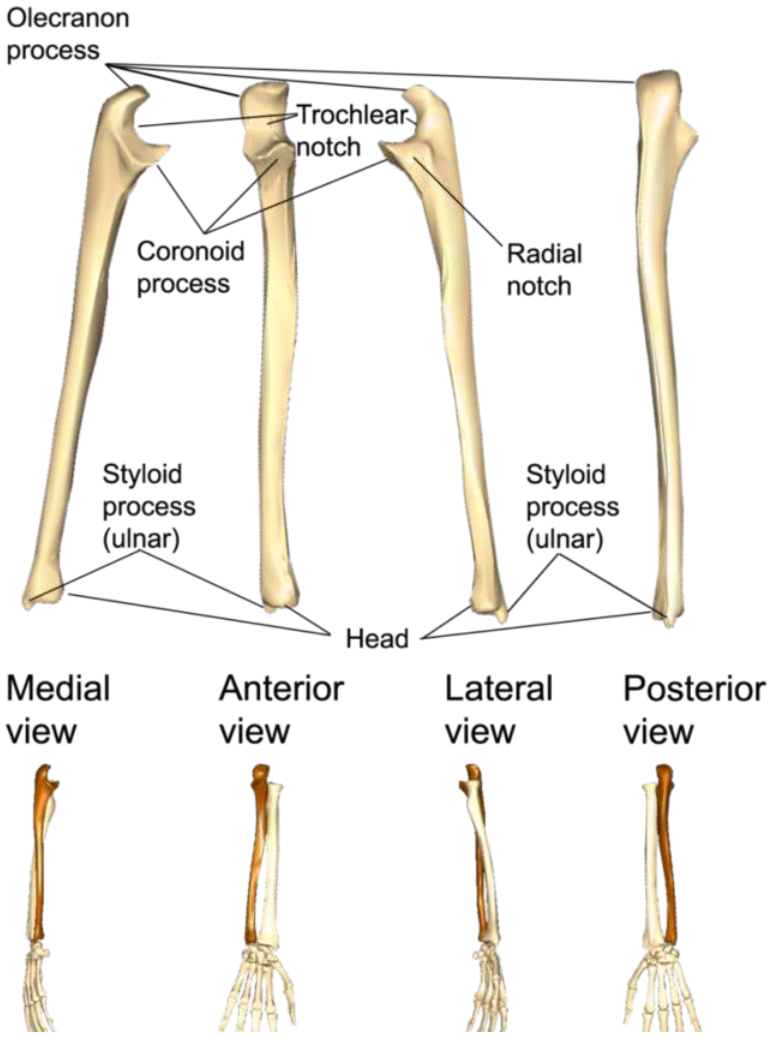


Figure **6.2.3**: The left ulna (in brown) and its major markings and processes. (CC-BY-SA, BodyParts3D/Anatomography)

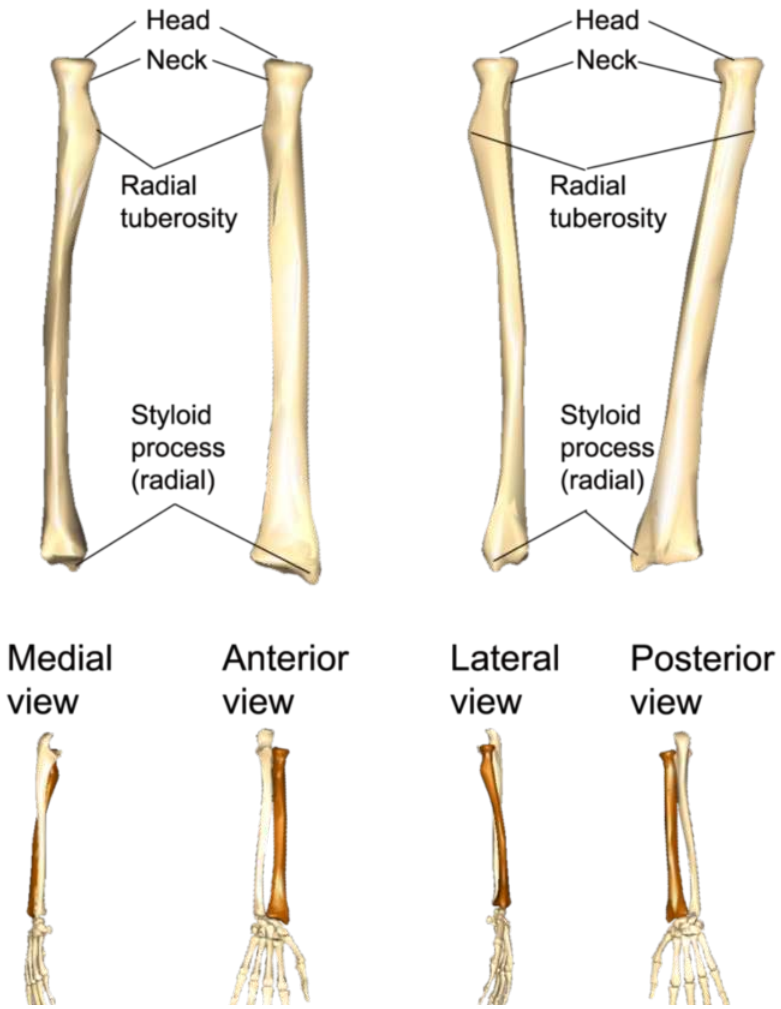


Figure **6.2.4**: he left radius (in brown) and its major markings and processes. (CC-BY-SA, BodyParts3D/Anatomography)

The **metacarpals** are five individual bones that are wrapped in muscle and collective tissue to create a single solid mass that serves as the palm of the hand. They are numbered I – V, starting with the metacarpal under the thumb and moving sequentially to the little finger.

Metacarpals are individually named according to the hand they come from and their number. So the metacarpal under the little finger in Figure 6.9 is named left metacarpal V.

There are 14 bones that make up the fingers. All are called **phalange**s (singular is **phalanx**). Each finger is made up of three phalanges, labelled the proximal, middle and distal phalanges as you move farther out from the metacarpals. Each thumb only has two phalanges, labelled proximal and distal. The phalanges are numbered I through V, like the metacarpals. Each phalanx then is named according to which hand it comes from, which number it is, and whether it is proximal, middle, or distal. So the second phalanx on the pointing finger in Figure is the left medial phalanx II.

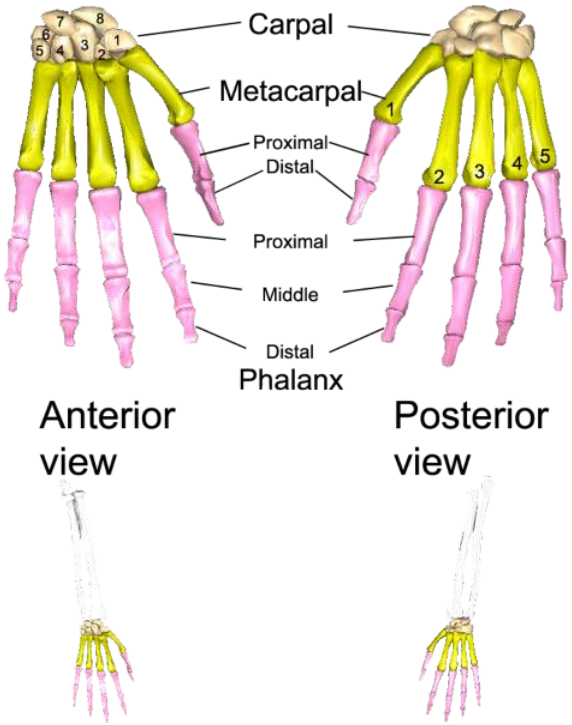


Figure **6.2.5**: The bones of the left hand.. (CC-BY-SA, BodyParts3D/Anatomography)

LAB 6 EXERCISE 6.2.1:

1. Using one of the full skeletons in the room, fill out the table below with three or four steps to determine whether an individual bone comes from the anatomical left or anatomical right. You must use any features that are already filled in.
2. You can describe any features on that bone and which direction it has to face to allow you to determine whether that particular bone came from anatomical left or anatomical right.
3. Sample instructions for the clavicle are provided as an example for all subsequent exercises. Use proper anatomical terminology. Use terms which will make sense to anyone schooled in anatomy if they read it. Use as many steps as you need, not necessarily four.

Humerus – Anatomical left from anatomical right.

1. Olecranon fossa -

2.

3.

4.

Ulna – Anatomical left from anatomical right.

1. Radial notch -

2.

3.

4.

Radius – Anatomical left from anatomical right.

1. Styloid process -

2.

3.

4.

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Fig 6.2.1:. The bones of the left upper limb.. **Authored by**: Images in Figure 7-8 were made out of, or made from, content published in a BodyParts3D/Anatomography web site. The content of their website is published under the Creative Commons Attribution 2.1 Japan license. The author and licenser of the contents is http://lifesciencedb.jp/bp3d/?lng=en. **Located at**: http://lifesciencedb.jp/bp3d/?lng=en. License: *CC BY-SA: Attribution-ShareAlike*

Figure 6.2.2:. The left humerus and its various processes and markings.. **Authored by**: Images in Figure 7-9 were made out of, or made from, content published in a BodyParts3D/Anatomography web site. The content of their website is published under the Creative Commons Attribution 2.1 Japan license. The author and licenser of the contents is http://lifesciencedb.jp/bp3d/?lng=en. **Located at**: http://lifesciencedb.jp/bp3d/?lng=en. License: *CC BY-SA: Attribution-ShareAlike*

Figure 6.2.3:. The left ulna (in brown) and its major markings and processes.. **Authored by**: Images in Figure 7-10 were made out of, or made from, content published in a BodyParts3D/Anatomography web site. The content of their website is published under the Creative Commons Attribution 2.1 Japan license. The author and licenser of the contents is http://lifesciencedb.jp/bp3d/?lng=en. **Located at**: http://lifesciencedb.jp/bp3d/?lng=en. **License**: ***CC BY-SA: Attribution- ShareAlike***

Figure 6.2.4:. The left radius (in brown) and its major markings and processes.. **Authored by**: Images in Figure 7-11 were made out of, or made from, content published in a BodyParts3D/Anatomography web site. The content of their website is published under the Creative Commons Attribution 2.1 Japan license. The author and licenser of the contents is http://lifesciencedb.jp/bp3d/?lng=en. **Located at**: http://lifesciencedb.jp/bp3d/?lng=en. **License**: ***CC BY-SA: Attribution- ShareAlike***

Figure 6.2.5:. The bones of the left hand.. **Authored by**: Images in Figure 7-12 were made out of, or made from, content published in a BodyParts3D/Anatomography web site. The content of their website is published under the Creative Commons Attribution 2.1 Japan license. The author and licenser of the contents is http://lifesciencedb.jp/bp3d/?lng=en. **Located at**: http://lifesciencedb.jp/bp3d/?lng=en. License: *CC BY-SA: Attribution-ShareAlike*

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6.3: The Pelvic Girdle

Information

The pelvic girdle is name given the left and right **coxal bones**. Colloquially, these are known as the “hip bones”. The pelvic girdle is just the two coxal bones, but the pelvis itself is the bowl- like structure created by the two coxal bones joined in the anterior by the sacrum, and coccyx. (“Pelvis “comes from the Latin word for “basin”.)

At birth, each coxal bone starts out as three separate bones – the **ilium**, (ILL-ee-um),

the **ischium**, (ISH-ee-um) and the **pubis** (PYOO-bus) bones – joined by hyaline cartilage. Figure 6.10 shows what these bones look like initially. By the age of 25, these three bones have fully fused into a single coxal bone. We still subdivide the fully-formed coxal bone into three regions based on the positions of the three bones that fused to form it, each region named after the bone that gave rise to that region.

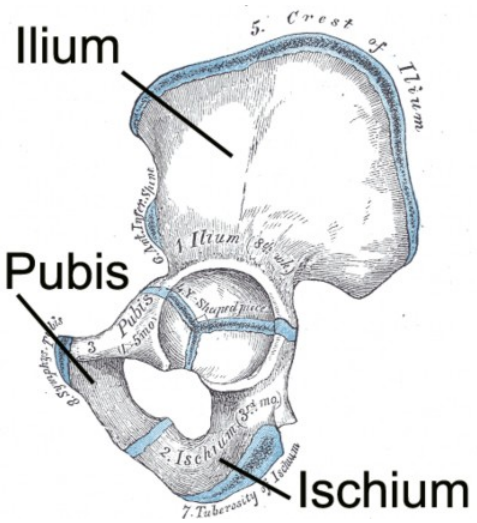


Figure **6.3.1**: The three bones of an unfused coxal bone. (CC-BY-SA, Wikimedia)

In a fully fused coxal bone, the ilium is the most superior portion, forming the “wing” that makes up the most prominent part of the coxal bone. The interior-facing side of this “wing” is called the **iliac fossa**. The ilium is where the sacrum attaches to each coxal bone to complete the pelvic bowl. This attachment point is alternatively called the **sacroiliac joint**, the sacroiliac articulation, or the iliac tuberosity, and is a rough surface. In anatomical position, the rough sacroiliac joint is always facing anterior.

In anatomical position, the ischium is posterior to the pubis. You “sit on the ischium” portion of the coxal bone. It is thicker and stronger than the pubis, allowing it to support your weight.

The large socket of the coxal bone is called the **acetabulum** (“ah-set-TAB-you-lum”). It faces laterally and is where the ball-like head of the femur bone articulates with the pelvis. Its name is derived from the Latin for vinegar cup, because of its cup-like shape. Inferior to the acetabulum is a large opening called the obturator foramen (“OB-tur-aye-tor for-AY-men”).

The major processes and markings of the coxal bone are shown in Figure **6.3.2**.

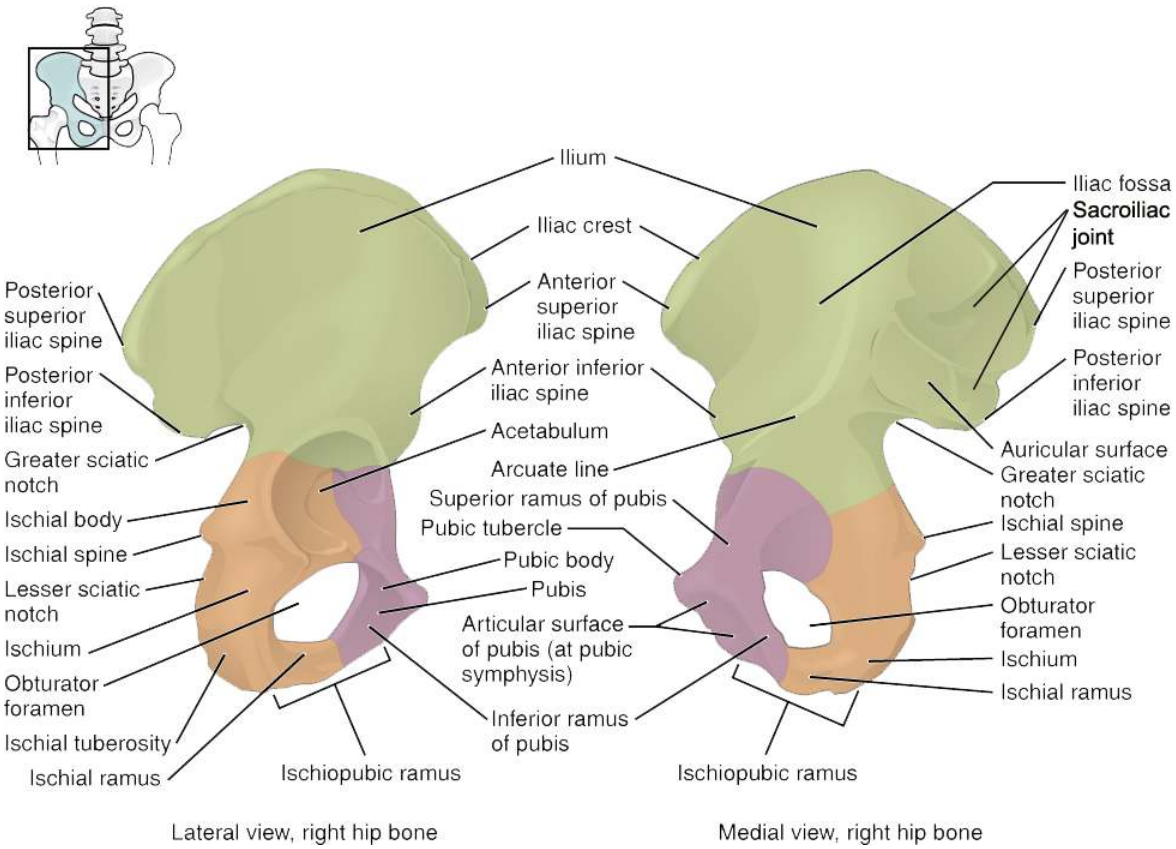


Figure **6.3.2**: The right coxal bone. (CC-BY-SA, OpenStax)

LAB 6 EXERCISE 6.3.1:

Coxal bone – Anatomical left from anatomical right

1. Using one of the full skeletons in the room, fill out the table below with three or four steps to determine whether an individual bone comes from the anatomical left or anatomical right. You must use any features that are already filled in.
2. You can describe any features on that bone and which direction it has to face to allow you to determine whether that particular bone came from anatomical left or anatomical right.
3. Sample instructions for the clavicle are provided as an example for all subsequent exercises. Use proper anatomical terminology. Use terms which will make sense to anyone schooled in anatomy if they read it. Use as many steps as you need, not necessarily four.

1. Pubis -

2.

3.

4.

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Figure **6.3.2**. The right coxal bone.. **Authored by**: OpenStax College. **Located at**: http://cnx.org/contents/FPtK1zmh@8.8...dle-and-Pelvis. **License**: ***CC BY-SA: Attribution-*** ***ShareAlike***

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Figure 6.3.1. The three bones of an unfused coxal bone.. **Authored by**: Henry Vandyke Carter. **Located at**: https://commons.wikimedia.org/wiki/File:Gray237.png. **License**: ***CC BY-SA: Attribution-ShareAlike***

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6.4: The Pelvis

Information

The pelvis is the bowl-shaped structure generated by the two coxal bones articulated with the sacrum and coccyx bones. On the anterior side of the pelvis, the pubis portions of the two coxal bones do not articulate with each other, but instead are joined with a small piece of cartilage called the **pubic symphysis** (“PYOO-bick SIM-fiss-is”)

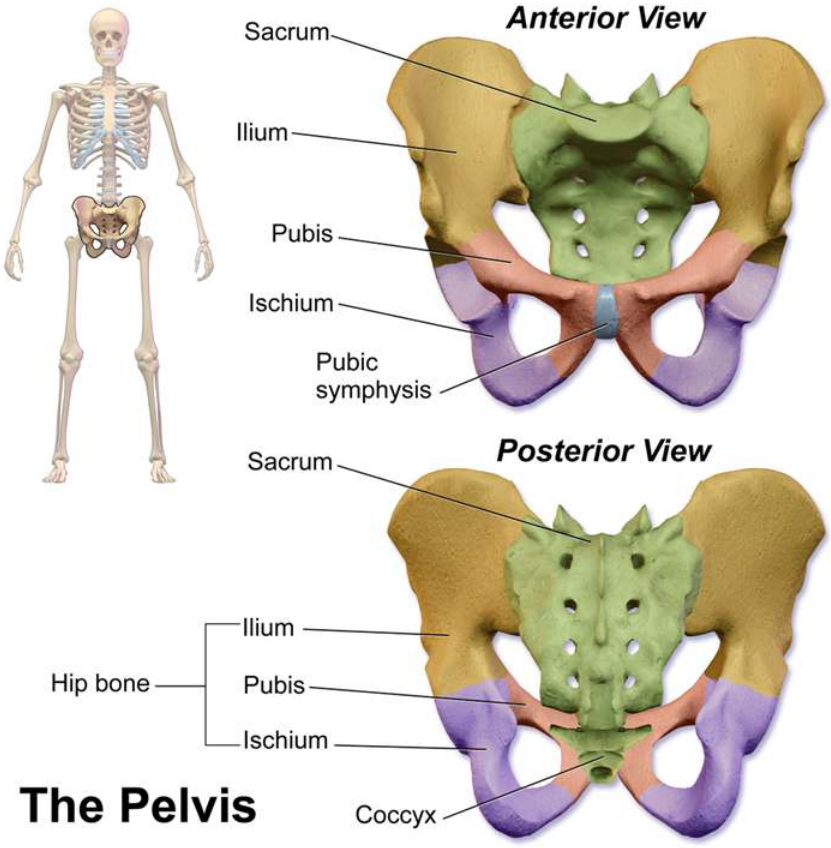


Figure **6.4.1**: The bones of the pelvis. (Public Domain, BruceBlaus, Wikimedia)

Anatomists divide the pelvis into two regions. The **false pelvis** is superior and is surrounded by iliac fossa portions of the coxal bones and the upper portion of the sacrum. The **true pelvis** is inferior and is surrounded by the pubis and ischium portions of the coxal bones, in addition to the lower sections of the ilium and the sacrum. In women, the true pelvis defines the space babies must squeeze through during childbirth.

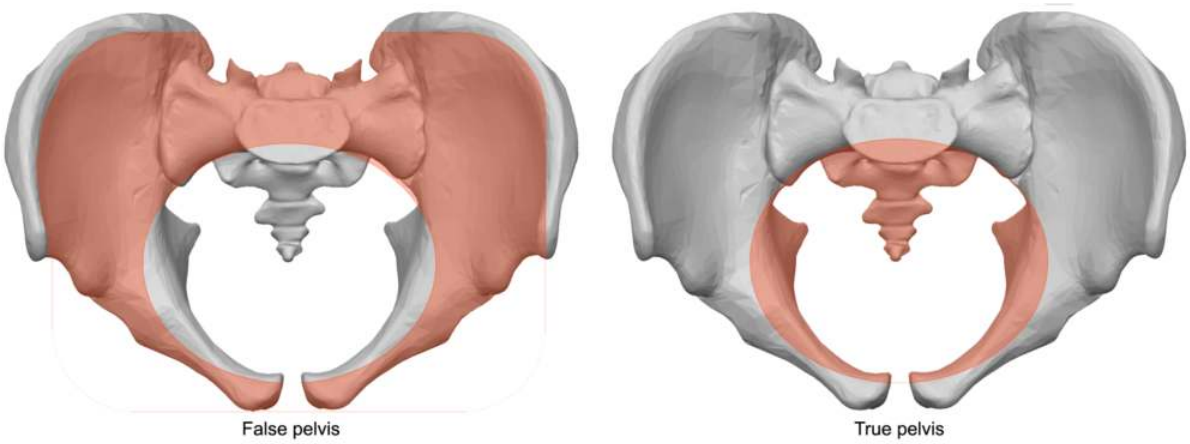


Figure **6.4.2**:The true pelvis vs. the false pelvis. (CC-BY-SA, Wikimedia)

One of the few ways a skeleton stripped of all flesh can be reliably established as either male or female comes from examining the pelvis. The female pelvis can be distinguished from the male pelvis by a number or criterion, three of which are shown in Figure **6.4.3**.

Most of these anatomical differences between the pelvises of males and females reflect the fact that only female pelvises have to serve as part of the birth canal, and these sex differences are not as pronounced in the skeletons of children who have not finished puberty.

In female pelvises, both the pelvic inlet and the pelvic outlet (not shown in Figure **6.4.3**) are wider and more oval-shaped than those in male pelvises. The pelvic inlet in males tends to be more heart-shaped (narrower on the dorsal side) and the pelvic outlet tends to be more narrow. The pubic arch, found immediately inferior to the pubic symphysis, tends to form an angle closer to 90° in females, but forms an angle closer to 60° in males. The sacrum in female pelvises tends to be less curved; in male pelvises, the sacrum is more curved and tends to impinge upon the space of the pubic outlet.

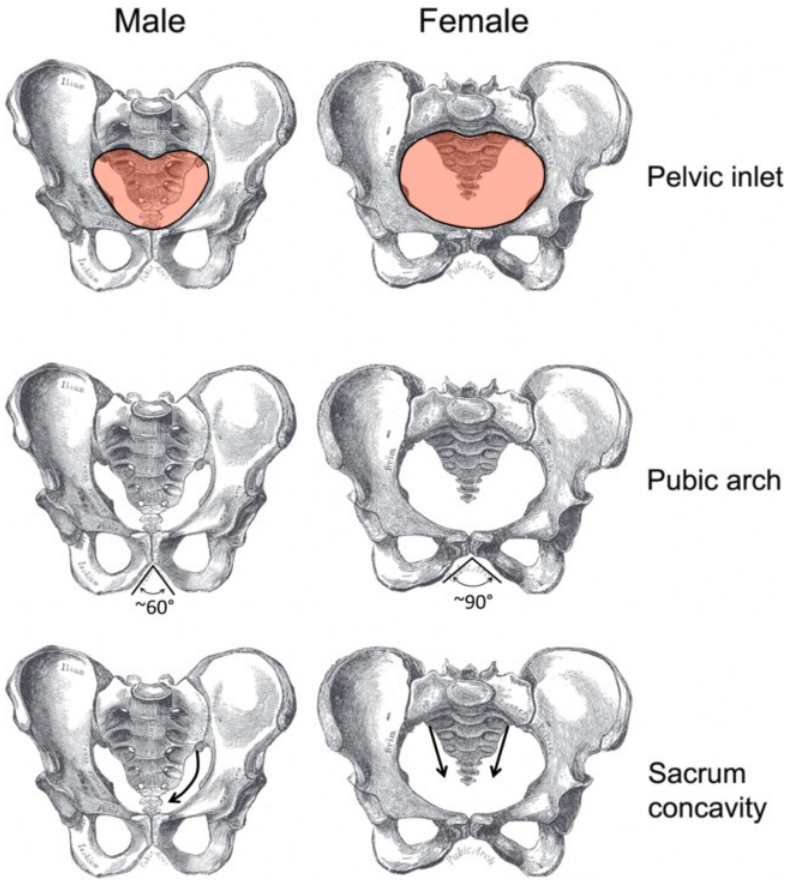


Figure **6.4.3**: Major differences that distinguish the adult male pelvis from the adult female pelvis. (CC-BY-SA, Henry Vandyke Carter, Wikimedia)

LAB 6 EXERCISE 6.4.1

Obtain an intact pelvis from the cabinet. Using the criteria in Figure 6.14 determine if the pelvis came from a male or female. Give three lines of evidence to support your conclusion.

Male or female?
Evidence 1.
Evidence 2.
Evidence 3.

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Figure **6.4.1**. The bones of the pelvis.. **Authored by**: BruceBlaus.. **Located at**: https://commons.wikimedia.org/wiki/F...723_Pelvis.png. **License**: ***Public Domain: No Known Copyright***

Figure **6.4.2**. The true pelvis vs. the false pelvis.. **Located at**: commons.wikimedia.org/wiki/F...is_(male)_03_-_superior_view.png. **License**: ***CC BY-SA: Attribution-ShareAlike***

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Figure **6.4.3**. Major differences that distinguish the adult male pelvis from the adult female pelvis.. **Authored by**: Henry Vandyke Carter. **Located at**: **commons.wikimedia.org/wiki/F...lvis_LT.PNG%20**. **License**: ***CC BY-SA: Attribution-ShareAlike***

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6.5: The Lower Limbs

Information

For anatomists, the lower limb consists of the thigh (the upper leg), the leg (the lower leg), and the foot. The thigh consists of a single bone, the **femur**. The leg consists of two long bones, the **tibia** and **fibula**, and the sesamoid bone, the **patella**, that serves as the knee cap. The foot consists of 26 bones, which are grouped into the **tarsals**, **metatarsals**, and **phalanges**.

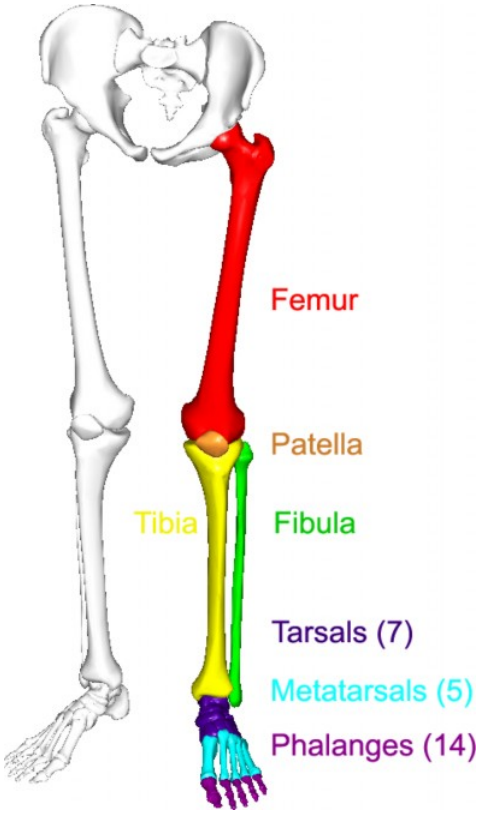


Figure 6.5.1: The bones of the left lower limb. (CC-BY-SA, BodyParts3D/Anatomography)

The major processes and markings of the **femur, patella**, and **tibia & fibula** bones are shown in Figures 6.5.2, 6.5.3, and 6.5.4, respectively. The interosseous membrane connecting the tibia and fibula bones is shown in Figure 6.5.5

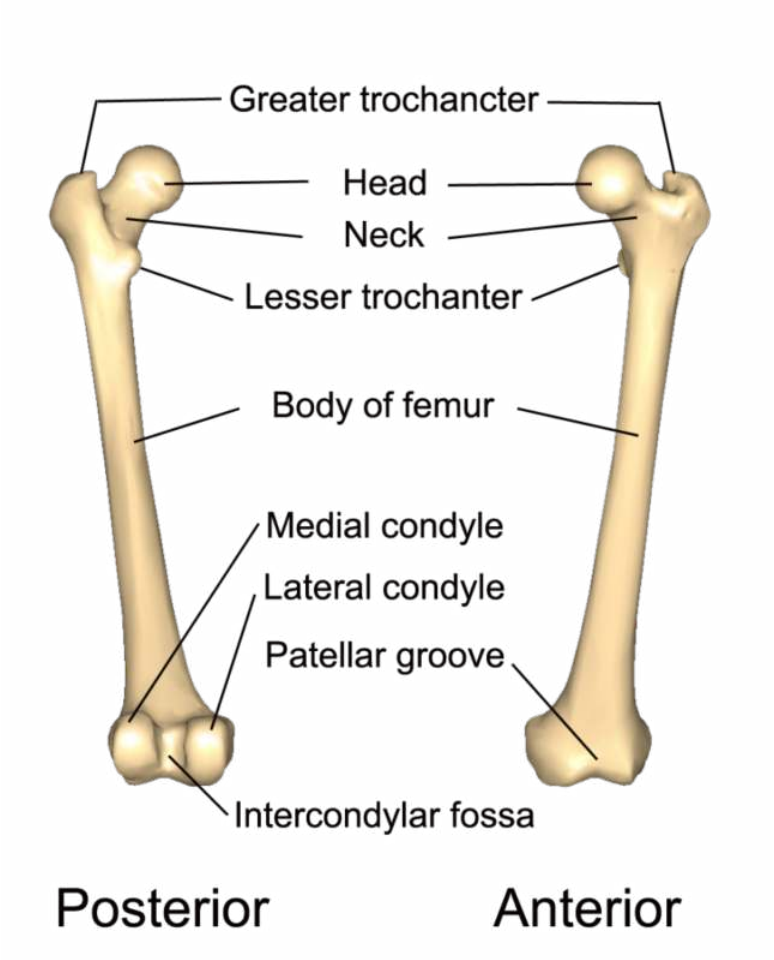


Figure **6.5.2**: The left femur and its various processes and markings.(CC-BY-SA, BodyParts3D/Anatomography)

Lateral condyle

Medial condyle

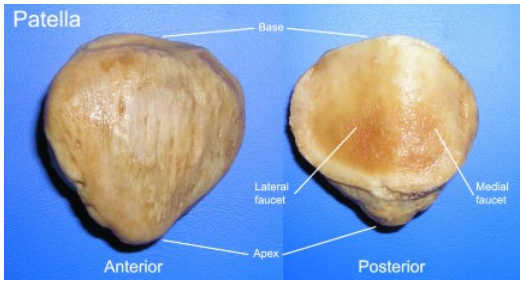


Figure **6.5.3**: The Right patella. (CC-BY-SA, Palica, Wikimedia)

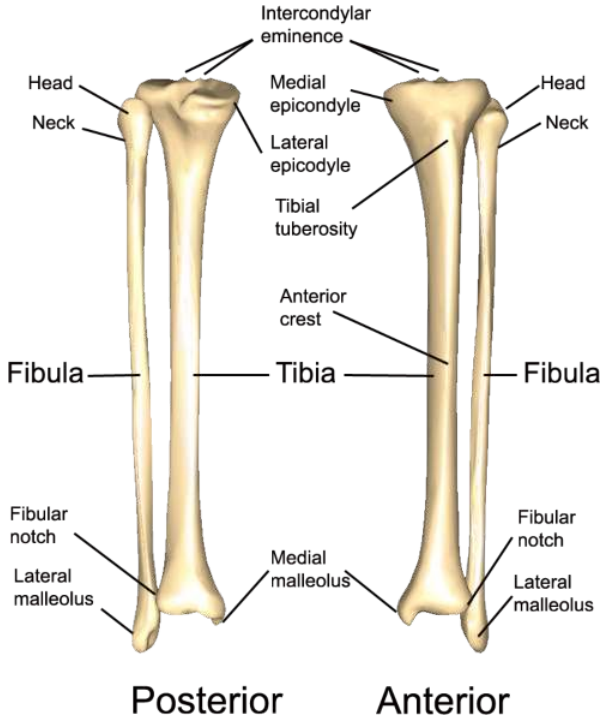


Figure **6.5.4**: The left tibia and femur and their various processes and markings. (CC-BY-SA, BodyParts3D/Anatomography)

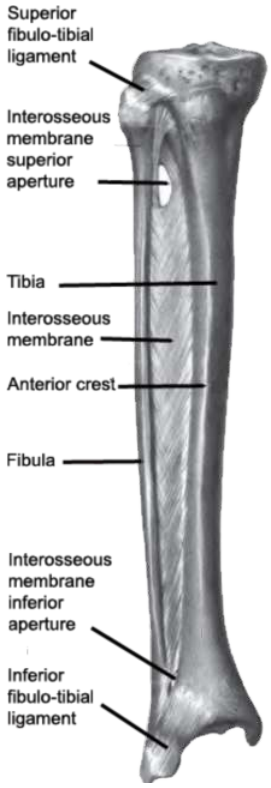


Figure **6.5.5**: The interosseous membrane of the left leg. (CC-BY-SA, Berichard, Wikimedia)

The bones of the foot are shown in Figure 6.20 below. The **calcaneus** is the heel bone, and the **talus** bone forms the ankle joint with the tibia and fibula. The calcaneus and tarsus are two of the seven **tarsal** bones that are posterior to the first long bones of the foot, the **metatarsal** bones. The bones of the toes are **phalanges**, the same name used for finger bones.

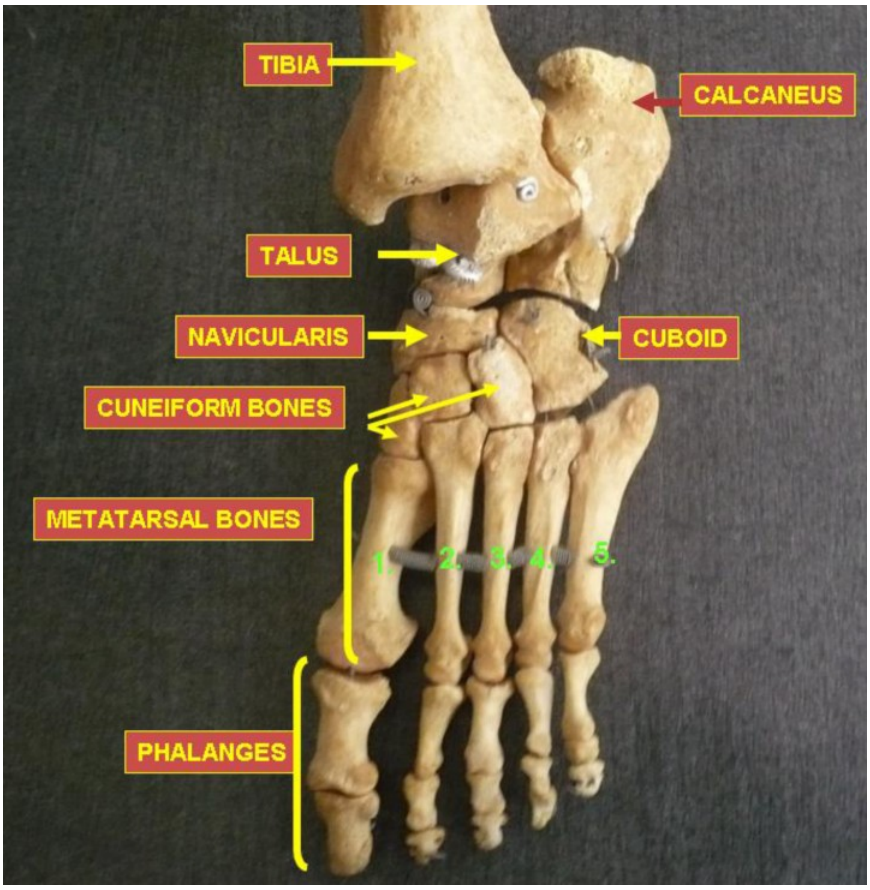


Figure **6.5.6**: The bones of the left foot. (CC-BY-SA, Anatomist90, Wikimedia)

LAB 6 EXERCISE 6.5.1

1. Using one of the full skeletons in the room, fill out the table below with three or four steps to determine whether an individual bone comes from the anatomical left or anatomical right. You must use any features that are already filled in.
2. You can describe any features on that bone and which direction it has to face to allow you to determine whether that particular bone came from anatomical left or anatomical right.

3. Sample instructions for the clavicle are provided as an example for all subsequent exercises. Use proper anatomical terminology. Use terms which will make sense to anyone schooled in anatomy if they read it. Use as many steps as you need, not necessarily four.

	Femur – Anatomical left from anatomical right.
1	Head
2	
3	
4	

	Tibia – Anatomical left from anatomical right.
1	Tibial tuberosity
2	
3	
4	

	Fibula – Anatomical left from anatomical right.
1	Lateral malleolus
2	
3	
4	

1. Using one of the full skeletons again, fill out the tables below with three or four steps to determine how to distinguish the calcaneus bone from the talus bone.
2. Use proper anatomical terminology. Use terms which will make sense to anyone schooled in anatomy if they read it. Use as many steps as you need, not necessarily three.

	Calcaneus bone
1	
2	
3	

	Talus bone
1	
2	
3	

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Figure 6.5.1. The bones of the left lower limb.. **Authored by**: Images in Figure 7-18 were made out of, or made from, content published in a BodyParts3D/Anatomography web site. The content of their website is published under the Creative Commons Attribution 2.1 Japan license. The author and licenser of the contents is http://lifesciencedb.jp/bp3d/?lng=en.. **Located at: . License:** ***CC BY-SA: Attribution-ShareAlike***

Figure 6.5.2. The left femur and its various processes and markings.. **Authored by**: Images in Figure 7-19 were made out of, or made from, content published in a BodyParts3D/Anatomography web site. The content of their website is published under the Creative Commons Attribution 2.1 Japan license. The author and licenser of the contents is http://lifesciencedb.jp/bp3d/?lng=en.. **Located at: . License:** ***CC BY-SA: Attribution-ShareAlike***

Figure 6.5.4. The left tibia and femur and their various processes and markings.. **Authored by**: Images in Figure 7-21 were made out of, or made from, content published in a BodyParts3D/Anatomography web site. The content of their website is published under the Creative Commons Attribution 2.1 Japan license. The author and licenser of the contents is http://lifesciencedb.jp/bp3d/?lng=en.. **Located at**: . **License**: ***CC BY-SA: Attribution-ShareAlike***

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Figure 6.5.5. The interosseous membrane of the left leg.. **Authored by**: Berichard. **Located at**: **https://commons.wikimedia.org/wiki/F...ia_Fibula1.png**. **License**: ***CC BY-SA: Attribution-ShareAlike***

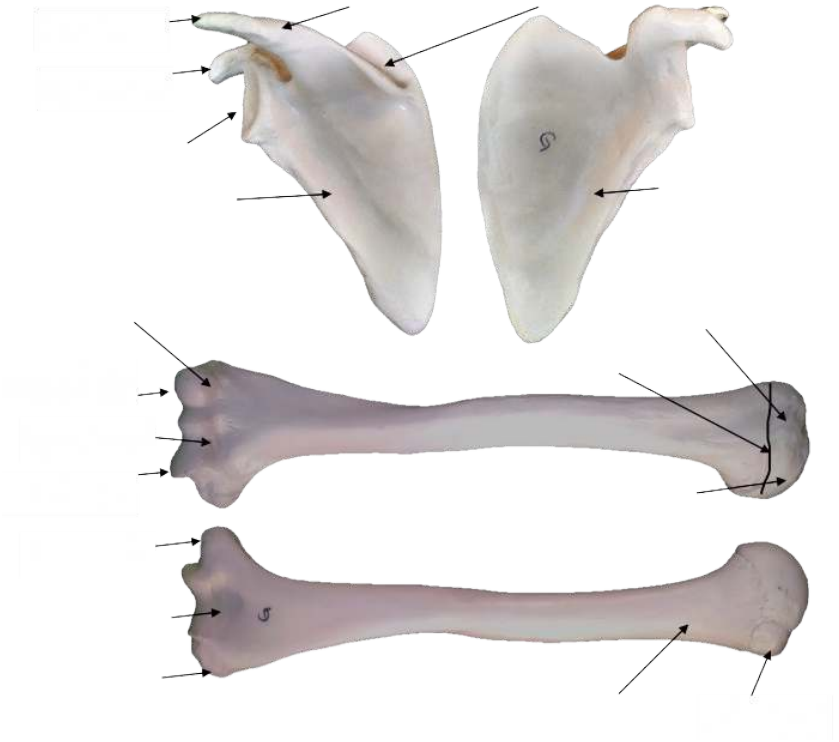
Figure 6.5.6. The bones of the left foot.. **Authored by**: Anatomist90. **Located at**: **upload.wikimedia.org/wikiped...7/Foot_bones_-_tarsus%2C_metatarsus_and_phalanges.jpg**. **License**: ***CC BY-SA: Attribution-ShareAlike***

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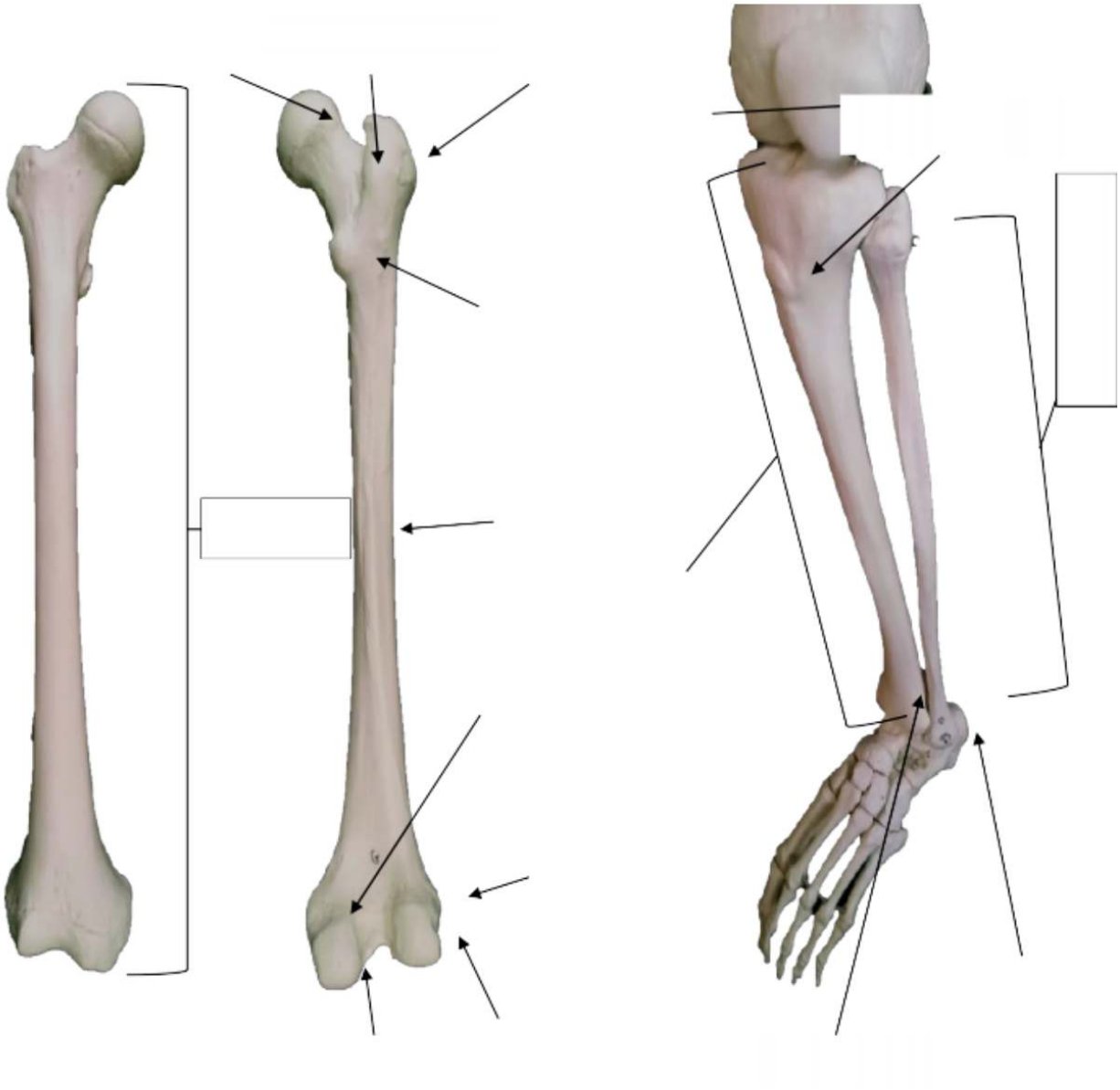
Figure Extra close brace or missing open brace. The Right patella.. **Authored by**: Palica . **Located at: commons.wikimedia.org/wiki/F...e:Patella_post.jpg**. **License**: ***Public Domain: No Known Copyright***

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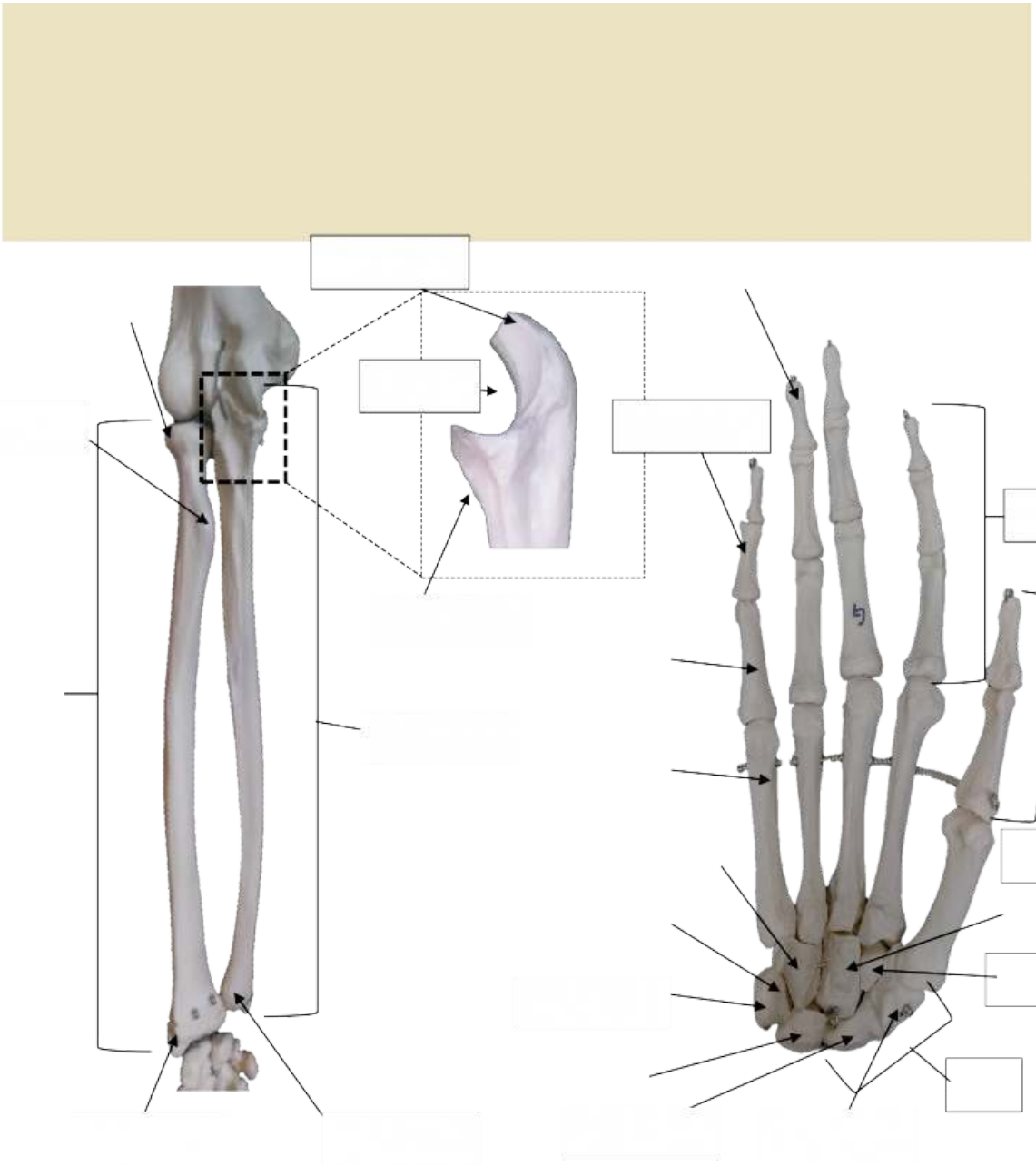
6.6: Exercises



1	Scapula Spine	10	Trochlea
2	Coracoid process	11	Capitulum
3	Acromion	12	Olecranon fossa
4	Supra-spinous fossa	13	Coronoid fossa
5	Infra-spinous fossa	14	Radial fossa
6	Sub-scapular fossa	15	Medial epicondyle
7	Glenoid cavity Humerus Head	16	Lateral epicondyle
8	Neck	17	Greater tubercle
9	(surgical and anatomical)	18	Lesser tubercle

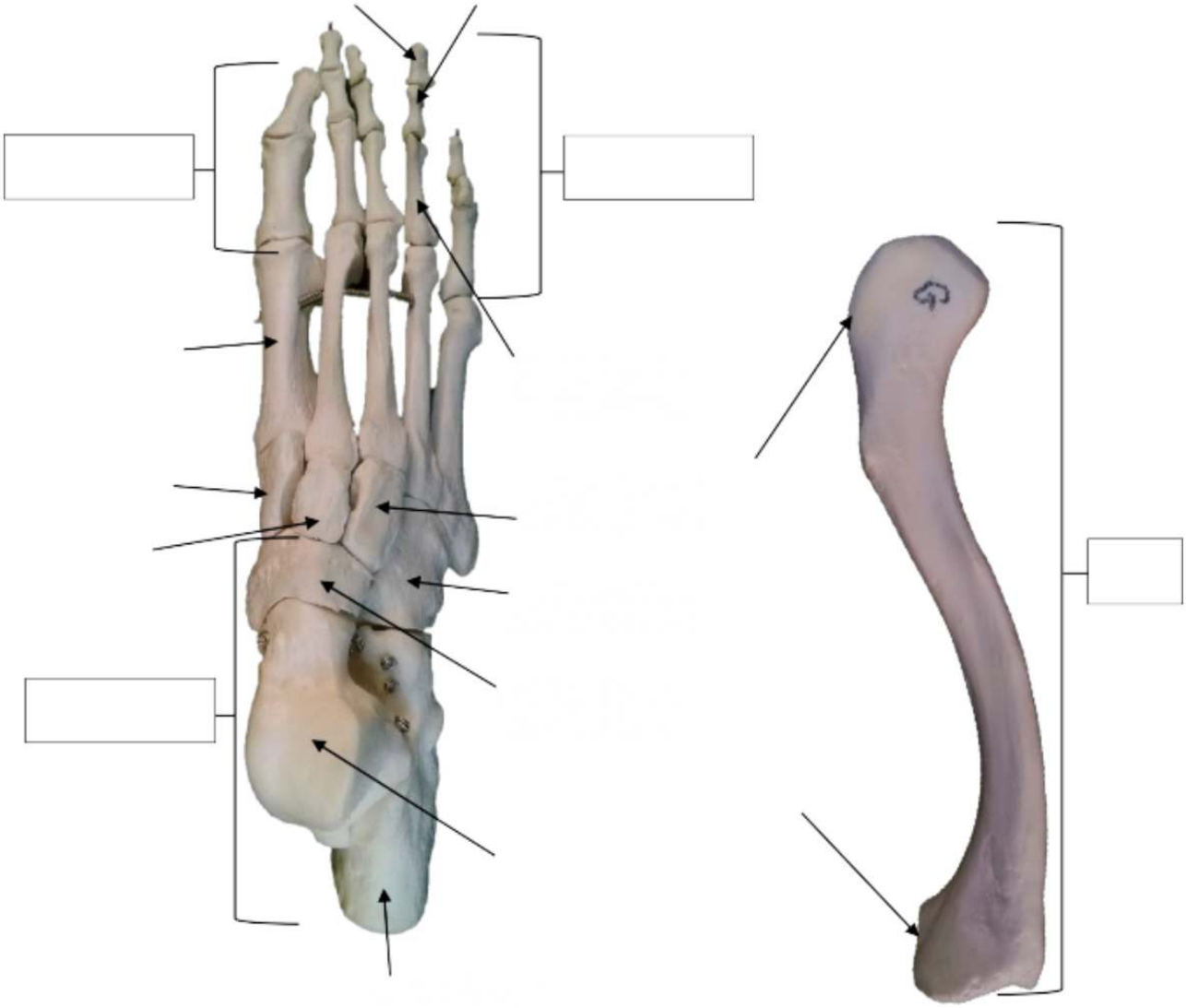


1	Femur	9	Lateral epicondyle
2	Head	10	Linea aspera
3	Neck	11	Olecranon fossa
4	Greater trochanter	12	Tibia
5	Lesser trochanter	13	Medial malleolus
6	Medial condyle	14	Tibial tuberosity
7	Lateral condyle	15	Fibula
8	Medial epicondyl	16	Lateral malleolus
		17	Patella



1	Radius	13	Triquetral
2	Styloid process	14	Pisiform
3	Radial head	15	Trapezium
4	Radial tuberosity	16	Trapezoid
5	Ulna	17	Capitate
6	Olecranon	18	Hamate
7	Trochlear notch	19	Metacarpals

8	Coronoid process	20	Lateral malleolus
9	Styloid process	21	Phalanges proximal
10	Carpals	22	middle
11	Scaphoid	23	distal
12	Lunate	24	Pollex



Tarsals * Talus * Calcaneus * Cuboid * Navicular * Medial,intermediate & lateral cuneiforms * Metatarsals Phalanges * proximal * middle * distal. Hallux Clavicle * sternal end * acromial end

1	Tarsals	10	proximal
2	Talus	11	middle
3	Calcaneus	12	distal
4	Cuboid	13	Hallux
5	Navicular	14	Clavicle
6	Medial cuneiforms	15	sternal end
7	intermediate cuneiforms lateral	16	acromial end
8	lateral cuneiforms		
9	Metatarsals Phalanges		

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6.7: MODELS- Upper and Lower Limbs

Upper Limb

Easy difficulty	Medium difficulty	Hard difficulty
Bones: • Clavicle, Scapula • Humerus, Ulna, Radius, • Metacarpals, Carpals (*group*), • Phalanges (distal, medial, proximal)	**Bones** • Scaphoid, Lunate, Triquetral, Pisiform, • Trapezium, Trapezoid, Capitate, Hamate.	• Pollex
Humerus landmarks: • Head • Medial & Lateral epidondyles.	**Humerus landmarks** : • Anatomical neck, Surgical neck • Greater & lesser tubercles • Deltoid tuberosity • Trochlea, Capitulum.	**Humerus landmarks**: Coronoid fossa, Olecrannon fossa, Radial foss
Ulna landmarks: • Olecranon process.	**Ulna landmarks** : • Coronoid process, Trochlear notch, Styloid process. **Radius landmarks :** • Head • Styloid process.	**Ulna landmarks**: • Radial notch. **Radius landmarks** • Radial tuberosity.
	Clavicle landmarks: • Acromial end, Sternal end.	**Clavicle landmarks**: • Conoid tubercle.
	Scapula landmarks : • Acromion, Coracoid process • Glenoid cavity • Spine.	**Scapula landmarks** • Supraspinous fossa, Infraspinous, • fossa, Subscapular fossa.

Lower Limb

Easy difficulty	Medium difficulty	Hard difficulty
Bones: • Ilium, Ischium, Pubis, • Femur, Patella, Tibia, Fibula, • Tarsals (*group*), Metatarsals.	**Bones** • Talus • Calcaneus	**Bones** • Cuboid • Navicular • Cuneiforms: medial, intermediate, latera • Hallux
Hip landmarks: • Pubis symphysis	**Hip landmarks** • Acetabulum • Obturator foramen • Iliac crest	**Hip landmarks**: • Anterior Superior Iliac spine • Anterior Inferior Iliac spine • Posterior Superior Iliac spine • Posterior Inferior Iliac spine • Greater sciatic notch • Iliac fossa • Ischial tuberosity • Ischial spine
Femur landmarks: • Head • Neck • Greater trochanter , Lesser • trochanter.	**Femur landmarks :** • Lateral & medial condyles • Lateral & medial epicondyles	**Femur landmarks**: • Fovea capitis • Gluteal tuberosity • Linea aspera
	Tibia landmarks : • Medial malleolus. **Fibula landmarks**: • Lateral malleolus.	**Tibia landmarks:** • Tibial tuberosity

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CHAPTER OVERVIEW

7: Joints

7.1: Introduction

7.2: Knee Joint

7.3: Elbow Joint

7.4: Shoulder Joint

7.5: Exercises

7.6: Models- Knee, Shoulder, Hip and Spine

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7.1: Introduction

The adult human body has 206 bones, and with the exception of the hyoid bone in the neck, each bone is connected to at least one other bone. Joints are the location where bones come together. Many joints allow for movement between the bones. At these joints, the articulating surfaces of the adjacent bones can move smoothly against each other. However, the bones of other joints may be joined to each other by connective tissue or cartilage. These joints are designed for stability and provide for little or no movement. Importantly, joint stability and movement are related to each other. This means that stable joints allow for little or no mobility between the adjacent bones. Conversely, joints that provide the most movement between bones are the least stable. Understanding the relationship between joint structure and function will help to explain why particular types of joints are found in certain areas of the body.

The articulating surfaces of bones at stable types of joints, with little or no mobility, are strongly united to each other. For example, most of the joints of the skull are held together by fibrous connective tissue and do not allow for movement between the adjacent bones. This lack of mobility is important, because the skull bones serve to protect the brain. Similarly, other joints united by fibrous connective tissue allow for very little movement, which provides stability and weight-bearing support for the body. For example, the tibia and fibula of the leg are tightly united to give stability to the body when standing. At other joints, the bones are held together by cartilage, which permits limited movements between the bones. Thus, the joints of the vertebral column only allow for small movements between adjacent vertebrae, but when added together, these movements provide the flexibility that allows your body to twist, or bend to the front, back, or side. In contrast, at joints that allow for wide ranges of motion, the articulating surfaces of the bones are not directly united to each other. Instead, these surfaces are enclosed within a space filled with lubricating fluid, which allows the bones to move smoothly against each other. These joints provide greater mobility, but since the bones are free to move in relation to each other, the joint is less stable. Most of the joints between the bones of the appendicular skeleton are this freely moveable type of joint. These joints allow the muscles of the body to pull on a bone and thereby produce movement of that body region. Your ability to kick a soccer ball, pick up a fork, and dance the tango depend on mobility at these types of joints.

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7.2: Knee Joint

The knee joint is the largest joint of the body (**Figure 7.2.1**). It actually consists of three articulations. The **femoropatellar joint** is found between the patella and the distal femur. The **medial tibiofemoral joint** and **lateral tibiofemoral joint** are located between the medial and lateral condyles of the femur and the medial and lateral condyles of the tibia. All of these articulations are enclosed within a single articular capsule. The knee functions as a hinge joint, allowing flexion and extension of the leg. This action is generated by both rolling and gliding motions of the femur on the tibia. In addition, some rotation of the leg is available when the knee is flexed, but not when extended. The knee is well constructed for weight bearing in its extended position, but is vulnerable to injuries associated with hyperextension, twisting, or blows to the medial or lateral side of the joint, particularly while weight bearing.

At the femoropatellar joint, the patella slides vertically within a groove on the distal femur. The patella is a sesamoid bone incorporated into the tendon of the quadriceps femoris muscle, the large muscle of the anterior thigh. The patella serves to protect the quadriceps tendon from friction against the distal femur. Continuing from the patella to the anterior tibia just below the knee is the **patellar ligament**. Acting via the patella and patellar ligament, the quadriceps femoris is a powerful muscle that acts to extend the leg at the knee. It also serves as a "dynamic ligament" to provide very important support and stabilization for the knee joint.

The medial and lateral tibiofemoral joints are the articulations between the rounded condyles of the femur and the relatively flat condyles of the tibia. During flexion and extension motions, the condyles of the femur both roll and glide over the surfaces of the tibia. The rolling action produces flexion or extension, while the gliding action serves to maintain the femoral condyles centered over the tibial condyles, thus ensuring maximal bony, weight-bearing support for the femur in all knee positions. As the knee comes into full extension, the femur undergoes a slight medial rotation in relation to tibia. The rotation results because the lateral condyle of the femur is slightly smaller

than the medial condyle. Thus, the lateral condyle finishes its rolling motion first, followed by the medial condyle. The resulting small medial rotation of the femur serves to "lock" the knee into its fully extended and most stable position. Flexion of the knee is initiated by a slight lateral rotation of the femur on the tibia, which "unlocks" the knee. This lateral rotation motion is produced by the popliteus muscle of the posterior leg.

Located between the articulating surfaces of the femur and tibia are two articular discs, the **medial meniscus** and **lateral meniscus** (see **Figure 7.2.1b**). Each is a C-shaped fibrocartilage structure that is thin along its inside margin and thick along the outer margin. They are attached to their tibial condyles, but do not attach to the femur. While both menisci are free to move during knee motions, the medial meniscus shows less movement because it is anchored at its outer margin to the articular capsule and tibial collateral ligament. The menisci provide padding between the bones and help to fill the gap between the round femoral condyles and flattened tibial condyles.

Some areas of each meniscus lack an arterial blood supply and thus these areas heal poorly if damaged.

The knee joint has multiple ligaments that provide support, particularly in the extended position (see **Figure 7.2.1c**). Outside of the articular capsule, located at the sides of the knee, are two extrinsic ligaments. The **fibular collateral ligament** (lateral collateral ligament) is on the lateral side and spans from the lateral epicondyle of the femur to the head of the fibula. The **tibial collateral ligament** (medial collateral ligament) of the medial knee runs from the medial epicondyle of the femur to the medial tibia. As it crosses the knee, the tibial collateral ligament is firmly attached on its deep side to the articular capsule and to the medial meniscus, an important factor when considering knee injuries. In the fully extended knee position, both collateral ligaments are taut (tight), thus serving to stabilize and support the extended knee and preventing side-to-side or rotational motions between the femur and tibia.

The articular capsule of the posterior knee is thickened by intrinsic ligaments that help to resist knee hyperextension. Inside the knee are two intracapsular ligaments, the **anterior cruciate ligament** and **posterior cruciate ligament**. These ligaments are anchored inferiorly to the tibia at the intercondylar eminence, the roughened area between the tibial condyles. The cruciate ligaments are named for whether they are attached anteriorly or posteriorly to this tibial region. Each ligament runs diagonally upward to attach to the inner aspect of a femoral condyle. The cruciate ligaments are named for the X-shape formed as they pass each other (cruciate means "cross"). The posterior cruciate ligament is the stronger ligament. It serves to support the knee when it is flexed and weight bearing, as when walking downhill. In this position, the posterior cruciate ligament prevents the femur from

sliding anteriorly off the top of the tibia. The anterior cruciate ligament becomes tight when the knee is extended, and thus resists hyperextension.

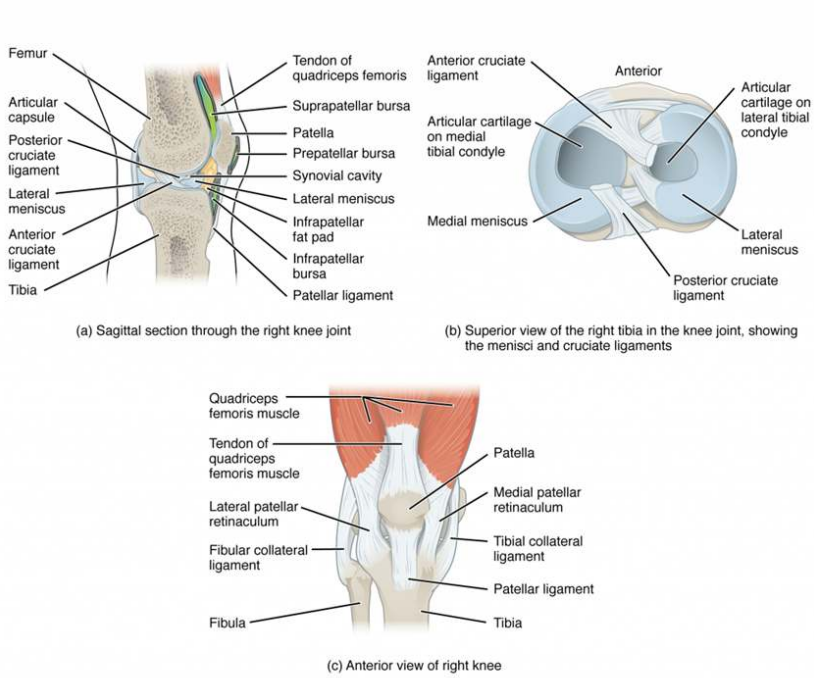


Figure **7.2.1**: (a) The knee joint is the largest joint of the body. (b)–(c) It is supported by the tibial and fibular collateral ligaments located on the sides of the knee outside of the articular capsule, and the anterior and posterior cruciate ligaments found inside the capsule. The medial and lateral menisci provide padding and support between the femoral condyles and tibial condyles. (CC-BY-SA, Open Oregon)

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7.3: Elbow Joint

The **elbow joint** is a uniaxial hinge joint formed by the **humeroulnar joint**, the articulation between the trochlea of the humerus and the trochlear notch of the ulna. Also associated with the elbow are the humeroradial joint and the proximal radioulnar joint. All three of these joints are enclosed within a single articular capsule (Figure **7.3.1**).

The articular capsule of the elbow is thin on its anterior and posterior aspects, but is thickened along its outside margins by strong intrinsic ligaments. These ligaments prevent side-to-side movements and hyperextension. On the medial side is the triangular ulnar collateral ligament. This arises from the medial epicondyle of the humerus and attaches to the medial side of the proximal ulna. The strongest part of this ligament is the anterior portion, which resists hyperextension of the elbow. The ulnar collateral ligament may be injured by frequent, forceful extensions of the forearm, as is seen in baseball pitchers. Reconstructive surgical repair of this ligament is referred to as Tommy John surgery, named for the former major league pitcher who was the first person to have this treatment.

The lateral side of the elbow is supported by the radial collateral ligament. This arises from the lateral epicondyle of the humerus and then blends into the lateral side of the annular ligament. The annular ligament encircles the head of the radius. This ligament supports the head of the radius as it articulates with the radial notch of the ulna at the proximal radioulnar joint. This is a pivot joint that allows for rotation of the radius during supination and pronation of the forearm.

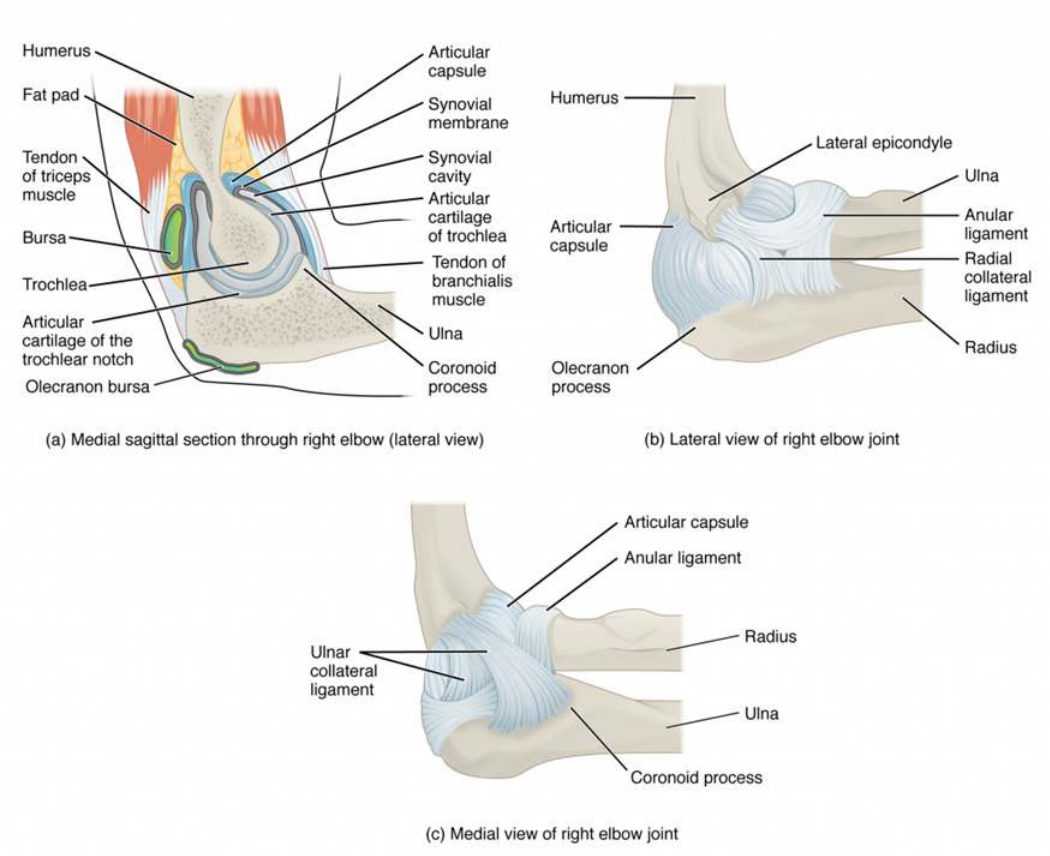


Figure **7.3.1**:Elbow Joint (a) The elbow is a hinge joint that allows only for flexion and extension of the forearm. (b) It is supported by the ulnar and radial collateral ligaments. (c) The annular ligament supports the head of the radius at the proximal radioulnar joint, the pivot joint that allows for rotation of the radius. (CC-BY-SA, Open Oregon)

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7.4: Shoulder Joint

The shoulder joint is called the glenohumeral joint. This is a ball-and-socket joint formed by the articulation between the head of the humerus and the glenoid cavity of the scapula (Figure 7.3). This joint has the largest range of motion of any joint in the body. However, this freedom of movement is due to the lack of structural support and thus the enhanced mobility is offset by a loss of stability.

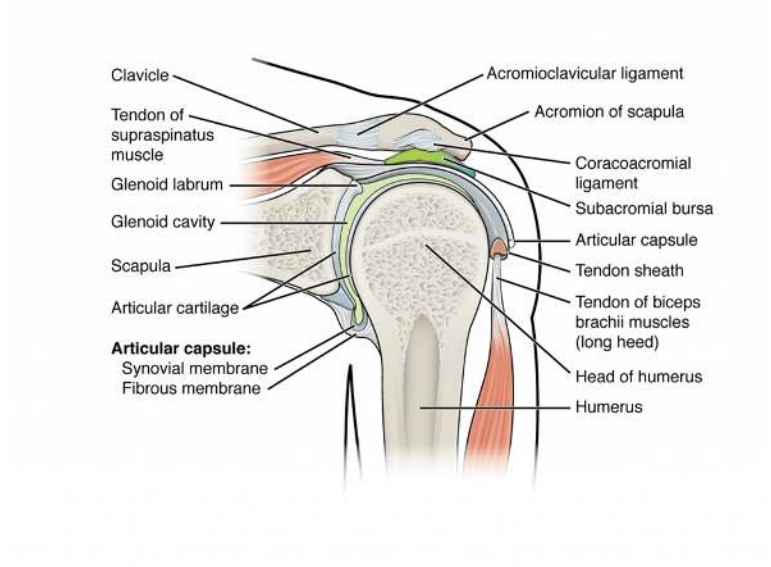


Figure **7.4.1**: Glenohumeral Joint The glenohumeral (shoulder) joint is a ball-and-socket joint that provides the widest range of motions. It has a loose articular capsule and is supported by ligaments and the rotator cuff muscles. (CC-BY-SA, Open Oregon)

The large range of motions at the shoulder joint is provided by the articulation of the large, rounded humeral head with the small and shallow glenoid cavity, which is only about one third of the size of the humeral head. The socket formed by the glenoid cavity is deepened slightly by a small lip of fibrocartilage called the glenoid labrum, which extends around the outer margin of the cavity. The articular capsule that surrounds the glenohumeral joint is relatively thin and loose to allow for large motions of the upper limb. Some structural support for the joint is provided by thickenings of the articular capsule wall that form weak intrinsic ligaments. These include the coracohumeral ligament, running from the coracoid process of the scapula to the anterior humerus, and three ligaments, each called a glenohumeral ligament, located on the anterior side of the articular capsule. These ligaments help to strengthen the superior and anterior capsule walls.

However, the primary support for the shoulder joint is provided by muscles crossing the joint, particularly the four rotator cuff muscles. These muscles (supraspinatus, infraspinatus, teres minor, and subscapularis) arise from the scapula and attach to the greater or lesser tubercles of the humerus. As these muscles cross the shoulder joint, their tendons encircle the head of the humerus and become fused to the anterior, superior, and posterior walls of the articular capsule. The thickening of the capsule formed by the fusion of these four muscle tendons is called the rotator cuff. Two bursae, the subacromial bursa and the subscapular bursa, help to prevent friction between the rotator cuff muscle tendons and the scapula as these tendons cross the glenohumeral joint. In addition to their individual actions of moving the upper limb, the rotator cuff muscles also serve to hold the head of the humerus in position within the glenoid cavity. By constantly adjusting their strength of contraction to resist forces acting on the shoulder, these muscles serve as “dynamic ligaments” and thus provide the primary structural support for the glenohumeral joint.

Injuries to the shoulder joint are common. Repetitive use of the upper limb, particularly in abduction such as during throwing, swimming, or racquet sports, may lead to acute or chronic inflammation of the bursa or muscle tendons, a tear of the glenoid labrum, or degeneration or tears of the rotator cuff. Because the humeral head is strongly supported by muscles and ligaments around its anterior, superior, and posterior aspects, most dislocations of the humerus occur in an inferior direction. This can occur when force is applied to the humerus when the upper limb is fully abducted, as when diving to catch a baseball and landing on your hand or elbow.

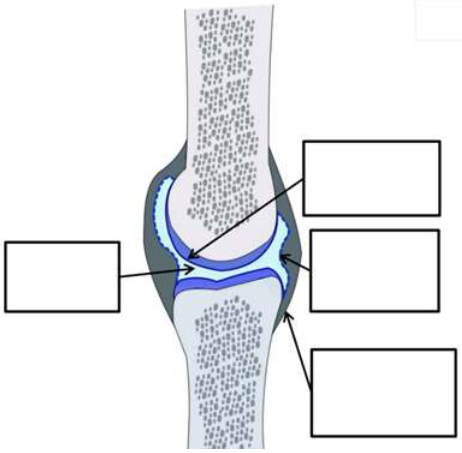
Inflammatory responses to any shoulder injury can lead to the formation of scar tissue between the articular capsule and surrounding structures, thus reducing shoulder mobility, a condition called adhesive capsulitis (“frozen shoulder”)

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7.5: Exercises

LAB 7 EXERCISES 7.5.1

Match the following



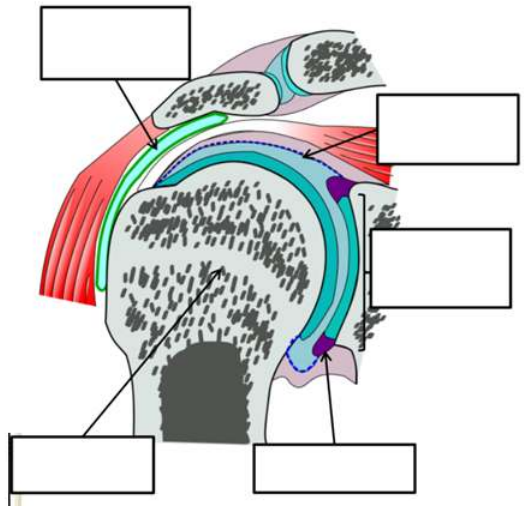
1	Joint cavity
2	Articular cartilages
3	Fibrous capsule
4	Synovial membrane

Organize the following types of joints into a diagram or table

1	Ball & socket	7	Plane
2	Cartilaginous	8	Saddle
3	Condylar	9	Suture
4	Fibrous	10	Synovial
5	Hinge	11	Synchondrosis
6	Pivot	12	Symphysis

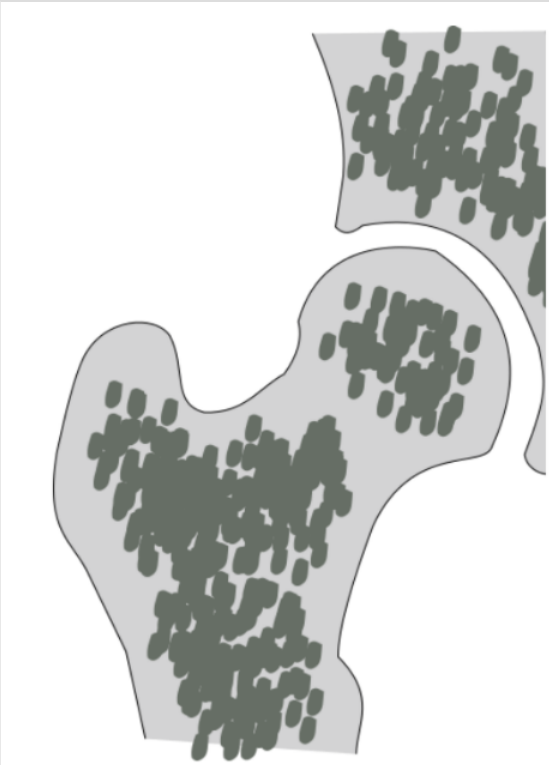
LAB 7 EXERCISES 7.5.2

Identify the components of the shoulder and hip joints



1	Bursa
2	Glenoid labrum
3	Synovial membrane
4	Head (of humerus)
5	Glenoid cavity of scapula

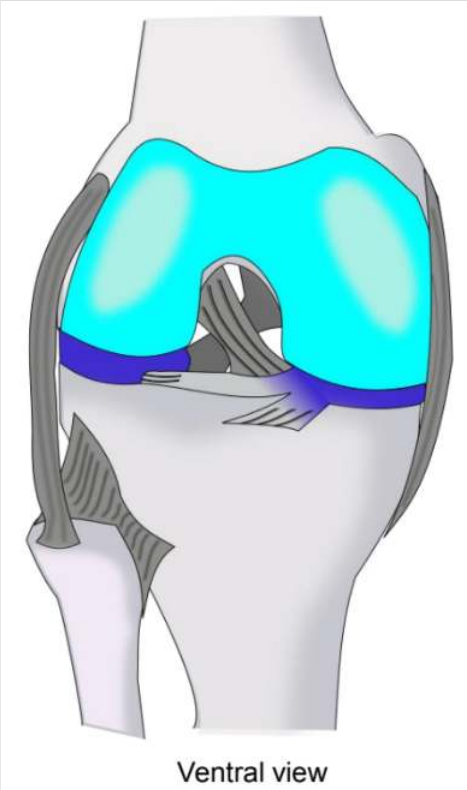
Draw and Label the following on this hip socket cross-section



1	Articular cartilage
2	Acetabular labrum
3	Ligamentum teres
4	Synovial membrane
5	Synovial cavity
6	Joint capsule

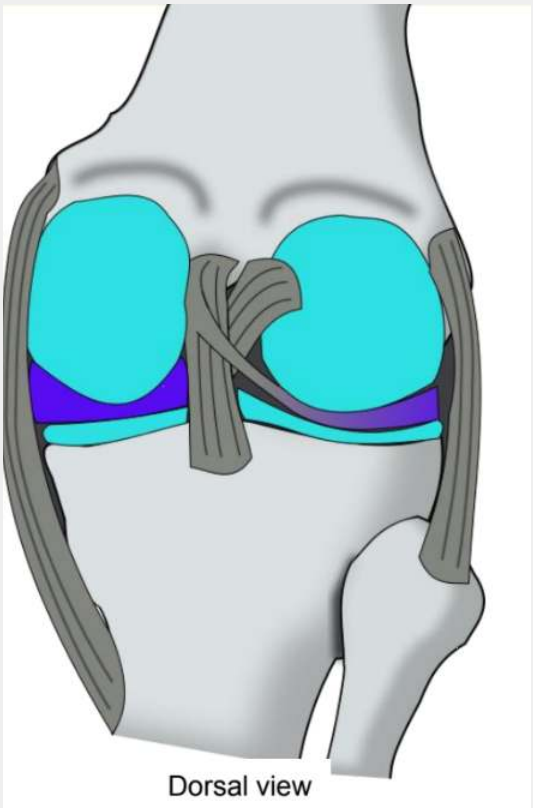
LAB 7 EXERCISES 7.5.3

Identify the components of the knee joint



Ventral view

1	Medial condyle
2	Lateral condyle
3	Medial collateral ligament
4	Medial meniscus
5	Lateral meniscus
6	Anterior cruciate ligament
7	Posterior cruciate ligamen

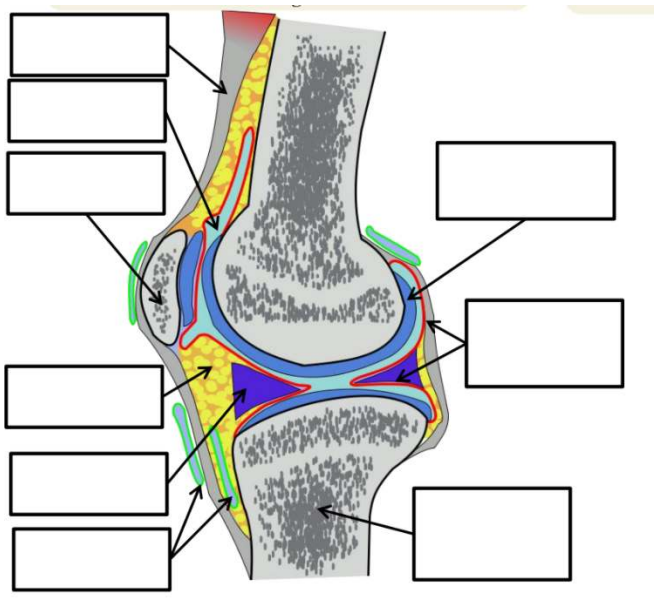


Dorsal view

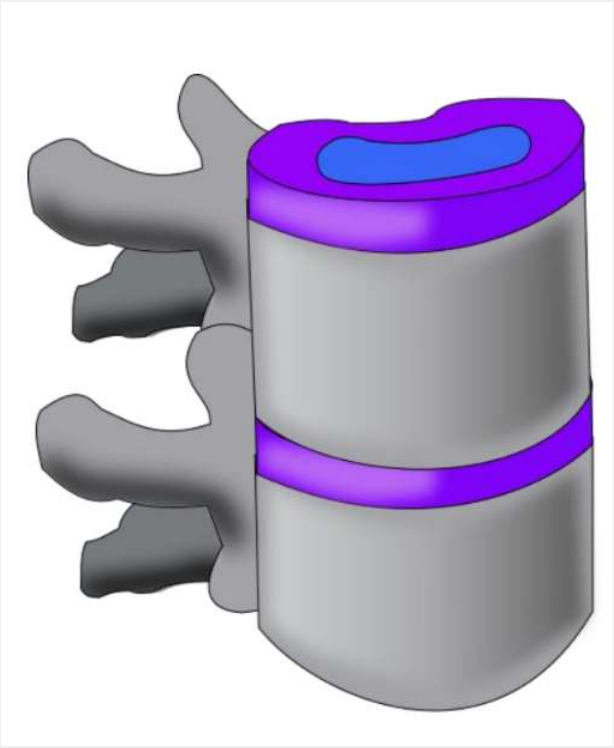
1	Anterior cruciate ligament
2	Posterior cruciate ligament
3	Medial collateral ligament
4	Lateral collateral ligament
5	Medial meniscus
6	Lateral meniscus
7	Medial condyle
8	Lateral condyle

LAB 7 EXERCISES 7.5.4

Identify the components of the knee joint



1	Quadriceps femoris tendon
2	Patella
3	Bursae
4	Fat pad
5	Joint cavity
6	Synovial membrane
7	Meniscus
8	Tibia
9	Articular cartilage



1	Nucleus pulposis
2	Annulus fibrosus
3	Superior articular process
4	Inferior articular process.

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7.6: Models- Knee, Shoulder, Hip and Spine

Knee joint:

- Anterior cruciate ligament
- Posterior cruciate ligament
- Fibular (Lateral) collateral ligament
- Tibial (Medial) collateral ligament
- Lateral meniscus
- Medial meniscus
- Quadriceps tendon

Elbow joint:

- Fibrous capsule
- Ulnar collateral ligament
- Annular ligament of radius
- Radial collateral ligament

Shoulder joint

- Fibrous capsule
- Coraco-humeral ligament
- Coraco-acromial ligament
- Gleno-humeral ligaments
- Transverse humeral ligament

Vertebral column

- Vertebral disc

Skeletal structures to review:

- Acromion
- Acetabulum
- Capitulum
- Clavicle
- Coracoid process
- Femur
- Fibula
- Glenoid cavity
- Head of humerus
- Head of femur
- Humerus
- Lateral condyle of femur
- Medial condyle of femur
- Olecranon
- Olecranon fossa
- Patella
- Popliteal surface
- Radius
- Radial fossa
- Scapula
- Trochlea

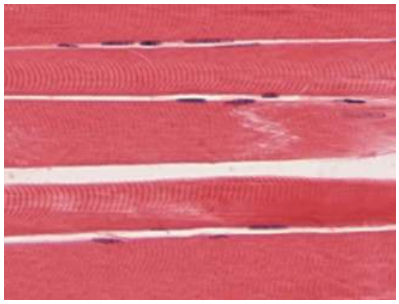
- Ulna

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CHAPTER OVERVIEW

8: The Axial Muscles

Skeletal muscle is found attached to bones. It consists of long **multinucleate** fibers. The fibers run the entire length of the muscle they come from and so are usually too long to have their ends visible when viewed under the microscope. The fibers are relatively wide and very long, but **unbranched**. Fibers are not individual cells, but are formed from the fusion of thousands of precursor cells. This is why they are so long and why individual fibers are multinucleate (a single fiber has many nuclei). The nuclei are usually up against the edge of the fiber. There are **striations** in skeletal muscle. These are alternating dark and light bands perpendicular to the edge of the fiber that are present all along the fiber.



8.1: The Muscles of the Head and Neck

8.2: The Muscles of the Trunk

8.3: Exercises

8.4: MODELS- Head and Neck and Torso

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8.1: The Muscles of the Head and Neck

Figure **8.1.1** lists the muscles of the head and neck that you will need to know. A single **platysma** muscle is only shown in the lateral view of the head muscles in Figure 8.1. There are two platysma muscles, one on each side of the neck. Each is a broad sheet of a muscle that covers most of the anterior neck on that side of the body. The other anterior neck muscles are below them, and most models have the platysma muscles cut away to show the deeper muscles. The platysma muscles help pull down the lower jaw (mandible.)

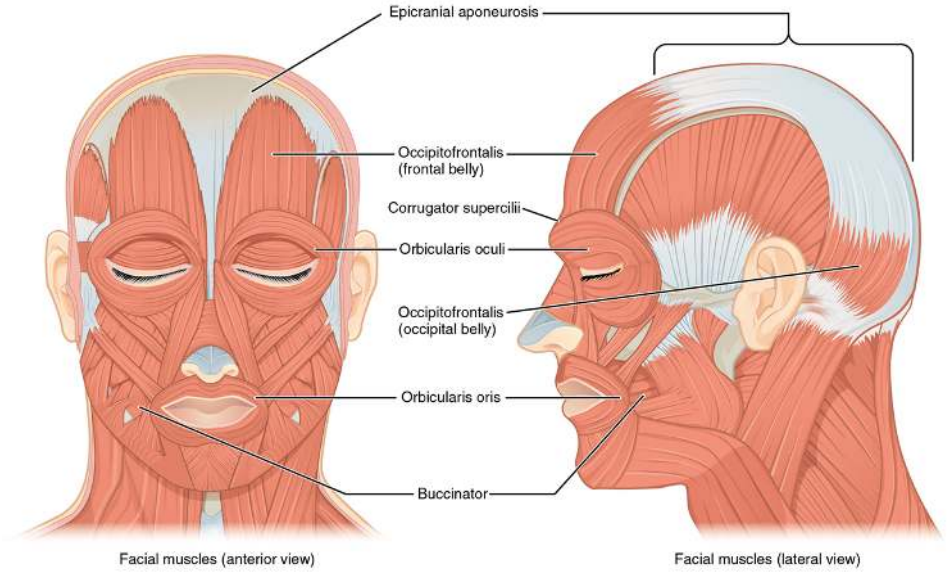


Figure **8.1.1**: The muscles of the head. (CC-BY-4.0, OpenStax, Human Anatomy)

Under the platysma are two **sternocleidomastoid** muscles. One on each side of the neck. These muscles have two origins, one on the sternum and the other on the clavicle. They insert on the mastoid process of the temporal bone. They can flex or extend the head, or can rotate the towards the shoulders.

The **epicranius** muscle is also very broad and covers most of the top of the head. The epicranius muscle includes a middle section which is all aponeurosis. The actual muscle tissue is only found over the forehead (the portion of the muscle called the **epicranius frontalis**; sometimes called the frontal belly of the epicranius) and the back of the head (the portion of the muscle called the **epicranius occipitalis**; sometimes called the occipital belly of the epicranius).

The **buccinator** muscles, one on each side of the face, compress the cheeks when contracted. The name is from the Latin for trumpet, which requires blowing air out of the cheeks to play, and also reflects the anatomical adjective for the cheek, buccal.

The two **masseter** muscles are also on each side of the face. They close the jaw when contracted. Its name is derived from the same Greek root as mastication, which means to chew.

The **zygomaticus major** muscles and the **zygomaticus minor** muscles are found on each side of the face both have their origins on the zygomatic bone. They both can change the shape of the mouth by elevating it.

LAB 8 EXERCISE 8-1

1. The following are muscles of **facial expression**. For each, give its location and describe its action when it contracts. Complete figure **8.1.1**: above by adding in any muscles found in the table below.

Muscle	Location	Action when contracted
Epicranius frontalis		
Epicranius occipitalis		
Orbicularis oculi		
Zygomaticus major		
Zygomaticus minor		
Buccinator		
Orbicularis oris		
Platysma		
Levator labii sup.		
Depressor labii inf.		
Levator anguli oris		
Depressor anguli oris		

2. The following are muscles of **mastication**. For each, give its location and describe its action when it contracts.

Muscle	Location	Action when contracted
Masseter		
Temporalis		
Medial pterygoid		
Lateral pterygoid		

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Figure **8.1.1**. The muscles of the head.. **Authored by**: OpenStax College. **Located at:** https://cnx.org/resources/9b369a7466... the Muscles of Facial Expressions.jpg. **License:** ***CC BY-SA: Attribution-ShareAlike***

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8.2: The Muscles of the Trunk

Information

Figures **8.2.1** and **8.2.2** shows many of the muscles of the body's trunk that you need to know, as well as some of the muscles of the arms and legs you will learn about in the next lab.

The **deltoid** muscles are the triangular muscles over each shoulder.

Some of the trunk muscles have been given nicknames by gym rats. For instance, the pecs are the **pectoralis major** muscles at each breast.

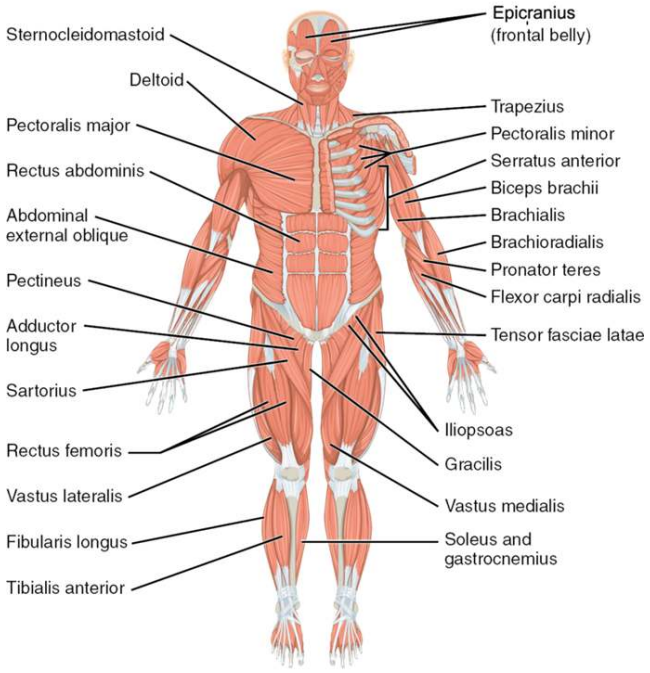
Lats are the **latissimus dorsi** muscle that covers most of the lower back with its lateral fibers.

The upper back is covered by the large **trapezius** muscle that is almost diamond-shaped as it extends from the neck, out to the shoulders, then tapers in midway down the back.

Obliques are the **external oblique** muscle whose fibers angle down as it covers both sides of the abdominal region. The external oblique muscle has two sets of fibers, which cover the left and right abdomen, that are connected by a wide aponeurosis sheet in the center of the abdomen. In most muscle models that aponeurosis sheet is cut away to reveal the rectus abdominis muscles below it.

What gym rats call the core muscles are three layers of muscle that sit over the abdomen. These layers are shown in Figure **8.2.3**. The outer layer is the **external oblique** muscle, with its aponeurosis covering the medial abdomen. Under the external oblique are the **internal obliques** on the sides of the abdomen and the **rectus abdominis** muscle in-between the internal obliques. The fibers of the internal obliques run up at an angle, opposite in direction to the fiber angle of the external obliques. The rectus abdominis muscle is also known as the abs. The deepest layer has the **transverse abdominis** muscle, whose fibers run laterally. Its fibers are concentrated at the sides of the abdomen and, like the external oblique, has an aponeurosis covering the medial abdomen under the rectus abdominis.

Extending from the back and wrapping around the sides of the rib cage is the **serratus anterior** muscle. This muscle's anterior edges are serrated like the teeth of a saw because this muscle's origins are on ribs 1 through 8 and each serration is the attachment point to another rib. This muscle is shown in Figure **8.2.4**.



Major muscles of the body.
Right side: superficial; left side:
deep (anterior view)

Figure **8.2.1**: The major muscles of the body, anterior view. Anatomical right shows superficial muscles. Anatomical left shows deep muscles. (CC-BY-4.0, OpenStax, Human Anatomy)

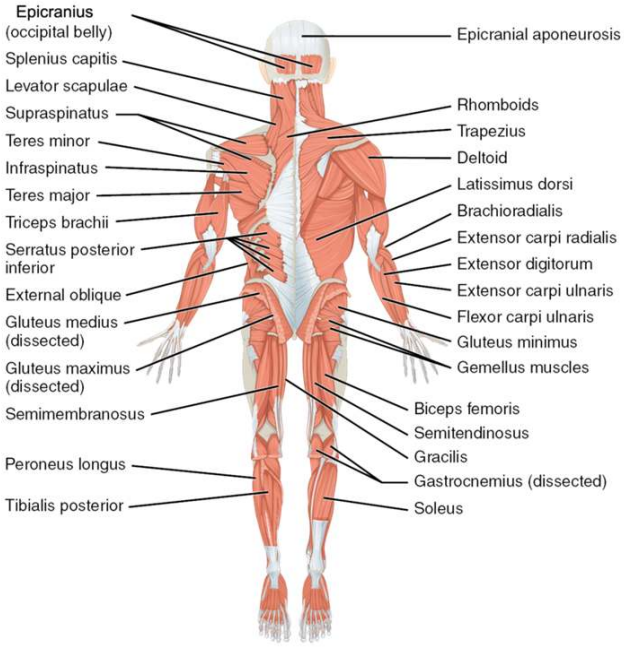


Figure **8.2.2**: The major muscles of the body, posterior view. Anatomical right shows superficial muscles. Anatomical left shows deep muscles. (CC-BY-4.0, OpenStax, Human Anatomy)

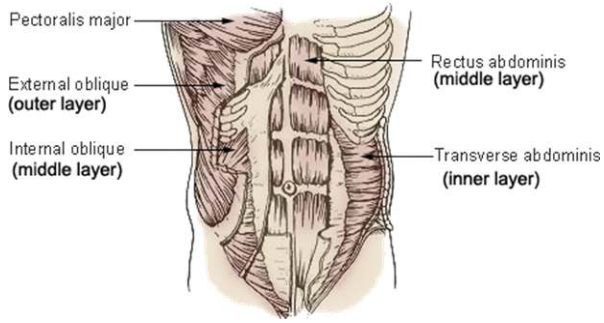


Figure **8.2.3**: The three layers of muscles in the abdomen. (CC-BY-SA, Wikimedia)

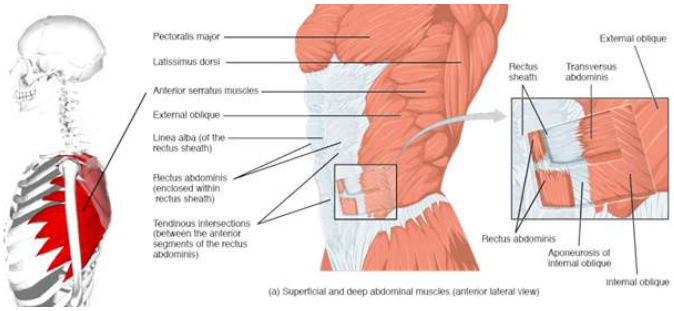


Figure **8.2.4**: The external muscles of the body, lateral view. (CC-BY-4.0, OpenStax, Human Anatomy)

LAB 8 EXERCISE 8.2.1

1. The following are muscles that **move the pectoral girdle**. For each, give its location and describe its action when it contracts.

Muscle	Location	Action when contracted
Trapezius		
Pectoralis minor		
Serratus anterior		

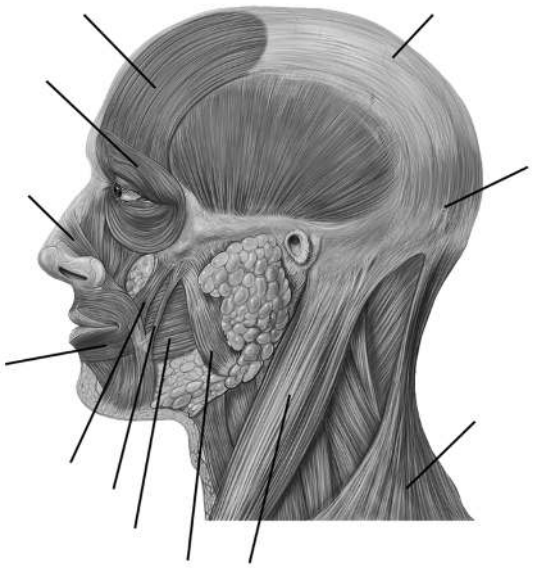
2. The following are muscles that **move the arm**. For each, give its location and describe its action when it contracts.

Muscle	Location	Action when contracted
Pectoralis major		
Latissimus dorsi		
Deltoid		

3. The following are muscles of the **abdominal wall**. For each, give its location and describe its action when it contracts.

Muscle	Location	Action when contracted
Rectus abdominis		
External oblique		
Internal oblique		
Transversus abdominis		

4. Label the indicated facial muscles in Figure 8.2.5. (CC-BY-SA, Wikimedia)



1	
2	
3	
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Figure 8.2.4. The external muscles of the body, lateral view.. **Authored by**: This image was made out of, or made from, content published in a BodyParts3D/Anatomography web site. . **Provided by**: BodyParts3D, u00a9 The Database Center for Life Science licensed under CC Attribution-Share Alike 2.1 Japan.. **Located at**: https://commons.wikimedia.org/wiki/F...es_lateral.png. **License**: ***CC BY-SA: Attribution- ShareAlike***

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Figure 8.2.1 The major muscles of the body, anterior view. Anatomical right shows superficial muscles. Anatomical left shows deep muscles.. **Authored by**: OpenStax College. **Located at**: https://cnx.org/resources/8a3b1231f3...s_of_Muscles.j **pg**. **License**: ***CC BY-SA: Attribution-ShareAlike***

Figure 8.2.2. The major muscles of the body, posterior view. Anatomical right shows superficial muscles. Anatomical left shows deep muscles.. **Authored by**: OpenStax College. **Located at**: https://cnx.org/resources/8a3b1231f3...s_of_Muscles.j **pg**. **License**: ***CC BY-SA: Attribution-ShareAlike***

Figure 8.2.4. The external muscles of the body, lateral view.. **Authored by**: OpenStax College. **Located at**: https://cnx.org/resources/33fa36d780...he_Abdomen.jpg. **License**: ***CC BY-SA: Attribution-ShareAlike***

Figure 8.2.5. Facial muscles.. **Authored by**: Patrick J. Lynch. **Located at**: https://commons.wikimedia.org/wiki/F...ad_anatomy.jpg. **License**: ***CC BY-SA: Attribution-ShareAlike***

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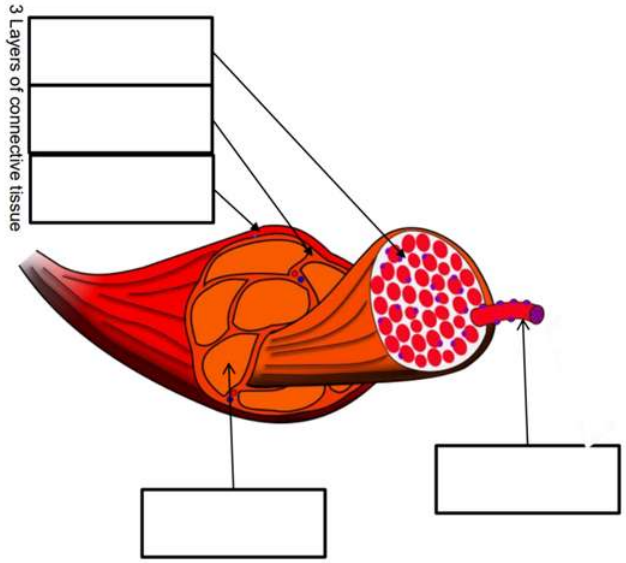
Figure 8.2.3 The three layers of muscles in the abdomen.. **Authored by**: Arcadian. **Located at**: https://commons.wikimedia.org/wiki/F...nk_muscles.jpg. **License**: ***Public Domain: No Known Copyright***

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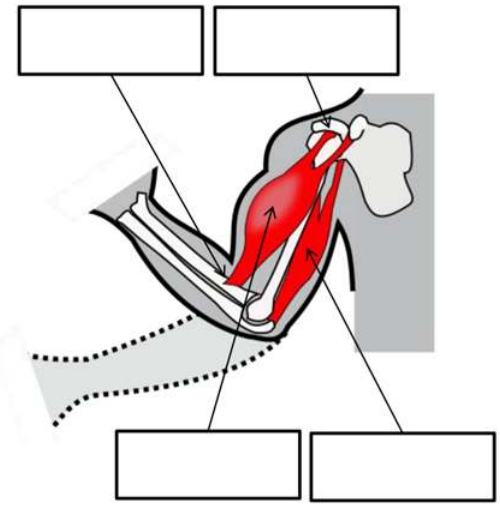
8.3: Exercises

LAB 8 EXERCISE 8.3.1

Identify the following

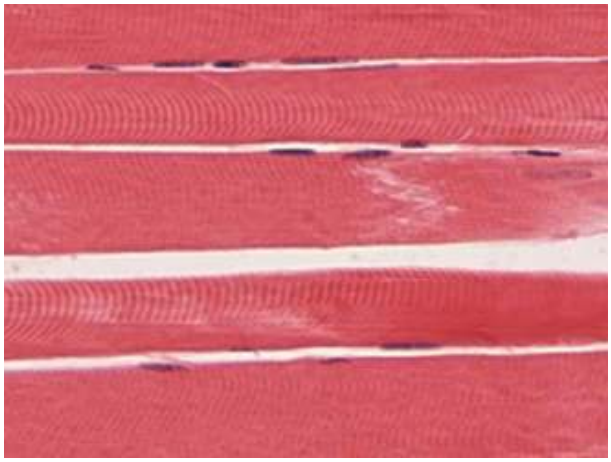


1	epimysium
2	perimysium
3	endomysium
4	muscle fascicle
5	muscle fiber



1	origin
2	insertion
3	extensor
4	flexor

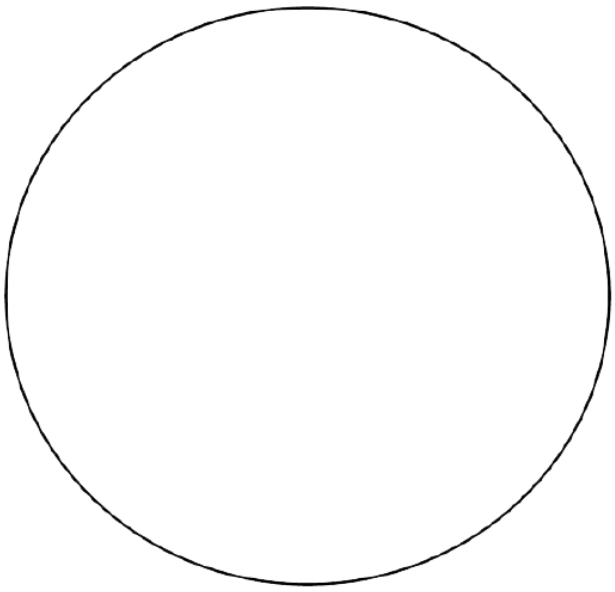
List the defining visual characteristics of this muscle and draw arrows to features on the photograph that illustrate each characteristic.



Muscle Type
Visual characteristics
1. _____
2. _____
3. _____
4. _____

1. Obtain a slide of skeletal muscle tissue from the slide box.
2. View the slide on an appropriate objective.
3. Fill out the blanks next to your drawing.

In the circle below, draw a representative sample of key features you identified, taking care to correctly and clearly draw their true shapes and directions. Draw your structures proportionately to their size in your microscope's field of view.

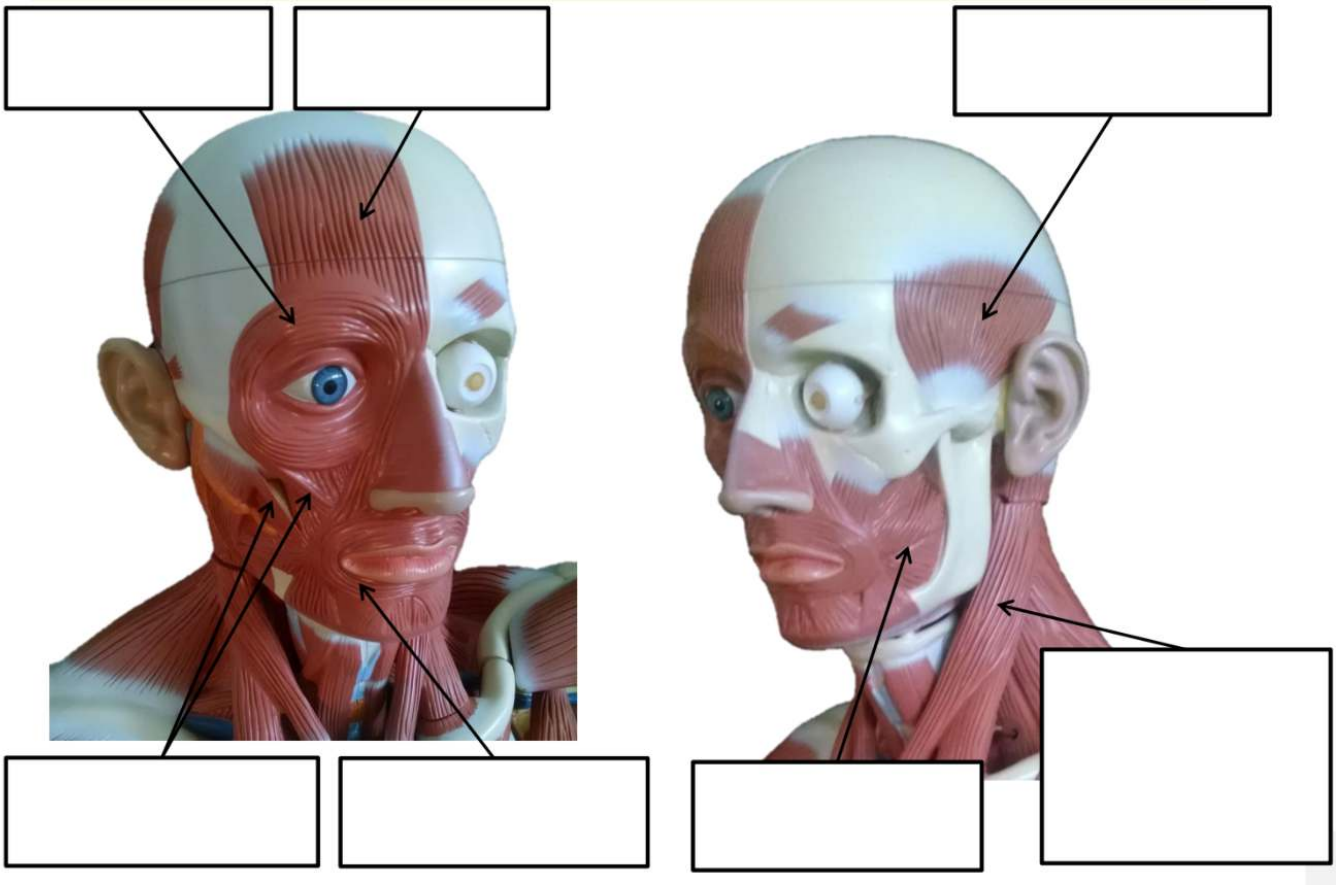


Total Magnification: _____
Type of eptihelium: _____
Source of tissue: _____
Function of this phase: _____
_____

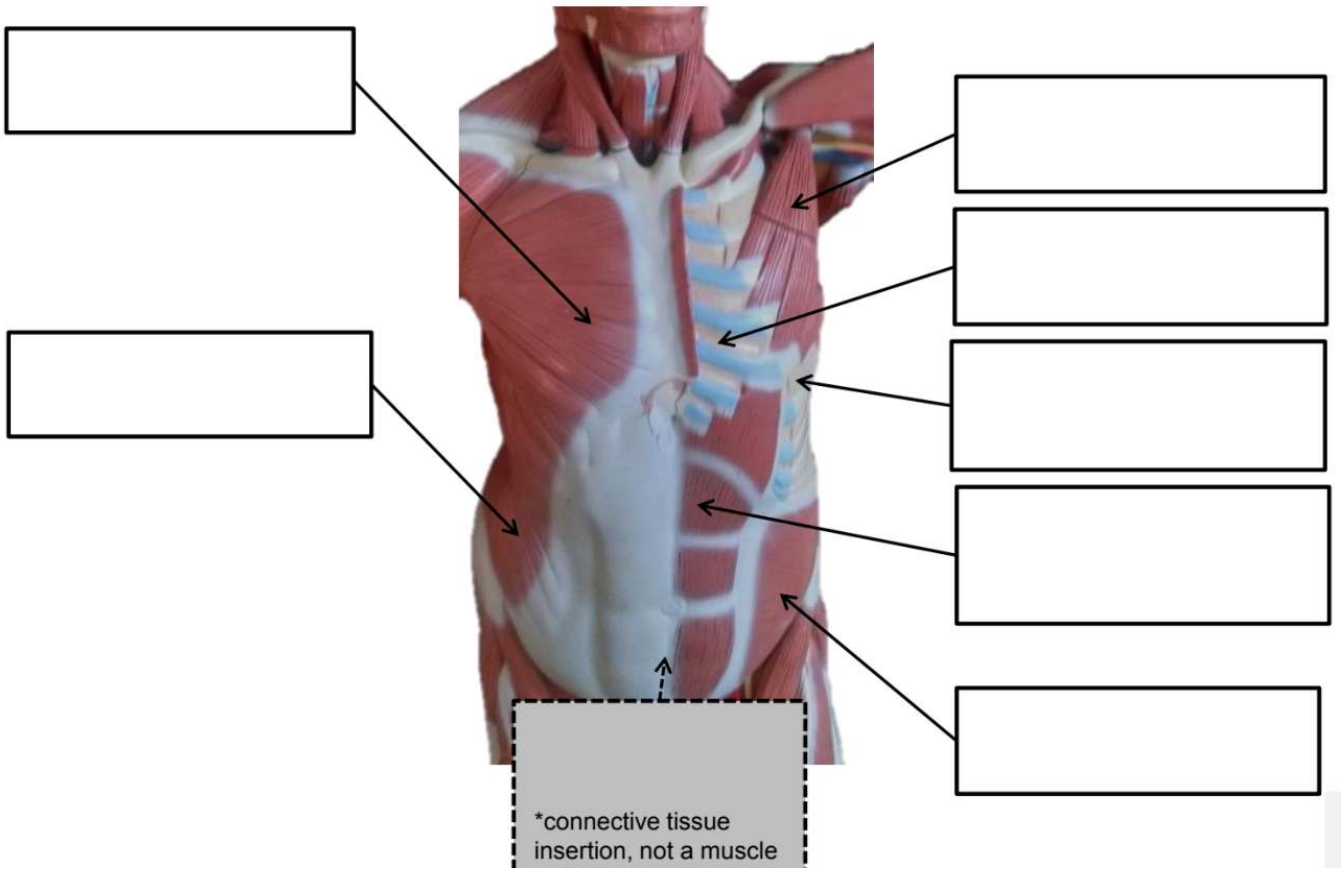
Type of muscle tissue:

image

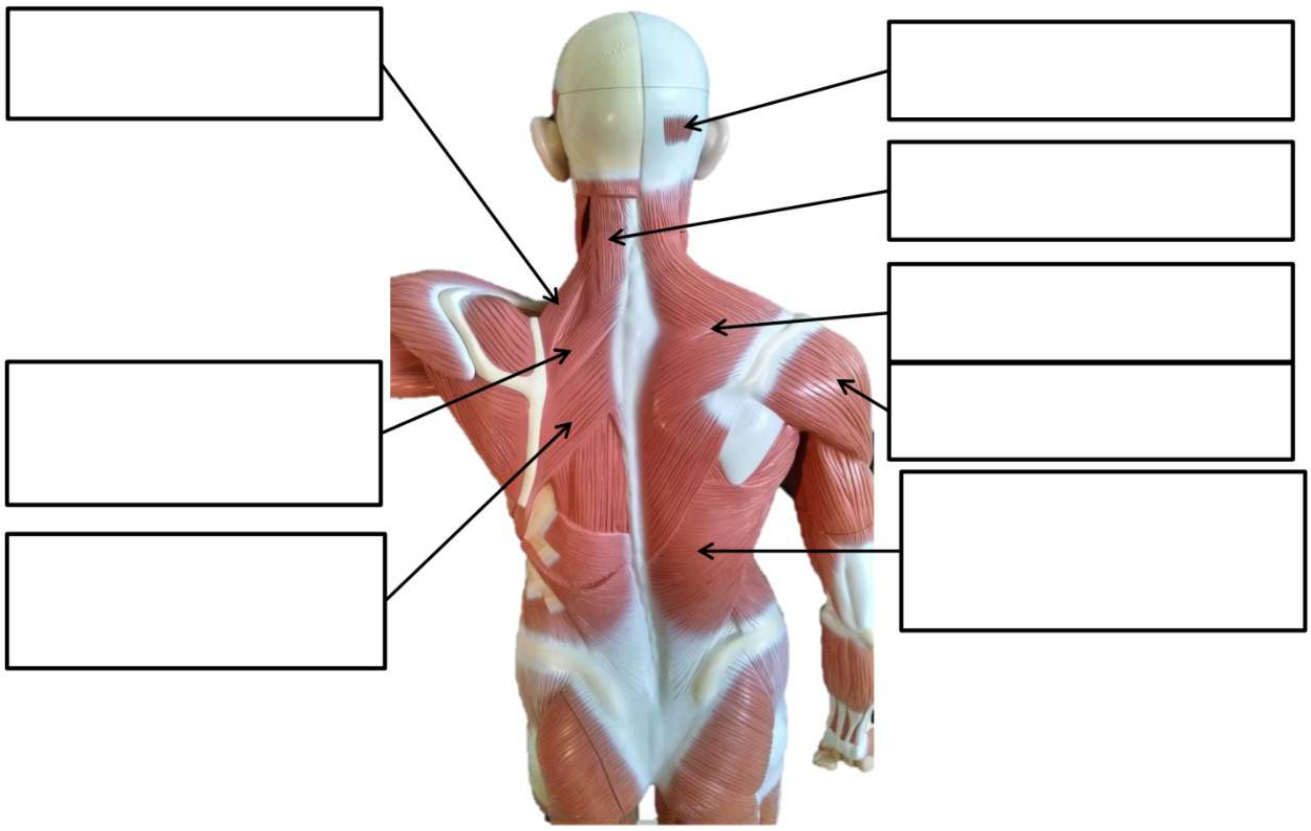
LAB 8 EXERCISE 8.3.2



https://med.libretexts.org/@go/page/52760


*connective tissue
insertion, not a muscle

LAB 8 EXERCISE 8.3.4



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8.4: MODELS- Head and Neck and Torso

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Name	Action	Origin	Insertion
Muscles of facial expression			
Frontalis (epicranius)	Raises eyebrows , wrinkles forehead	Frontal Bone	Skin of the brow
Occipitalis (epicranius)	Pull scalp posteriorly	Occipital bone	Aponeurosis connecting to frontalis
Orbicularis oris	Closes mouth	Maxillae and Mandible	Lips
Zygomaticus (major/minor)	smile	Zygomatic Bone	mouth
Orbicularis oculi	Closes eye	Margin of Orbit	Eyelid
Masseter	Elevates mandible	Zygomatic Arch	Mandible
Temporalis	Elevates mandible	Temporal Bone	Mandible
Buccinator	Presses cheek inward	Maxillae and Mandible	orbicularis oris
Muscles of the head, vertebral column and abdominal wall			
Splenius capitis	extend + laterally flex head	upper spine	Temporal & occipital
Sternocleidomastoid	Flexes + rotates neck (also elevates ribs)	Sternum & Clavicle	Mastoid Process
Scalenes	Flexes neck (also elevates ribs)	Cervical Vertebrae	1st Two Ribs
Rectus abdominus	Flexes vertebral column , compresses abdomen	Pubis	Lower Ribs and Xiphoid
External oblique	Flexes + rotates vertebral column, compresses abdomen	Lower Ribs	Linea alba and Ilium
Internal oblique	Flexes + rotates vertebral column, compresses abdomen	Lumbar Vertebrae & Ilium	Lower Ribs, Linea alba, Sternum
Transverse abdominus	Compresses abdomen	Lower Ribs, Ilium, Lumbar Vertebrae	Linea Alba & Pubis
Erector spinae *group*	Extends vertebral column	Ilium, Sacrum, Ribs, Vertebrae	Ribs, Vertebrae, Base of Skull
Levator scapulae	Extends neck (also elevates scapula)	Cervical Vertebrae	Scapula

Name	Action	Origin	Insertion
Thoracic & shoulder muscles			
Pectoralis major	Flexes, adducts + medially rotates arm at shoulder	Sternum & Clavicle	Humerus

Pectoralis minor	Elevates ribs (also moves scapula anterior and inferior)	Ribs	Scapula
External intercostals	Elevates ribs	Inferior Rib	Superior rib
Internal intercostals	Depresses ribs	Superior rib	Inferior Rib
Diaphragm	Increases thoracic volume	Xiphoid Process, Ribs, Lumbar Vertebrae	Central Tendinous Sheet
Arm movers			
Serratus anterior	Moves and fixes scapula anteriorly	Ribs	Scapula
Trapezius	Elevates, retracts, depresses+ rotates scapula upward (also extends neck)	Occipital Bone & Thoracic Vertebrae	Scapula
Rhomboids (major & minor)	Elevates + adducts scapula	Cervical & Thoracic Vertebrae	Scapula
Latissimus dorsi	Extends, adducts + medially rotates arm at shoulder	Thoracic, Lumbar Vertebrae, Ribs	Humerus
Deltoid	Abducts arm at shoulder (also anterior fibers flex + posterior fibers extend arm at shoulder)	Clavicle & Scapula	Humerus
Teres major	Medially rotate arm	Scapula	Humerus
Rotator cuff (SITS)			
Infraspinatus	Laterally rotates shoulder	Scapula	Humerus
Supraspinatus	Abducts shoulder	Scapula	Humerus
Subscapularis	Medially rotates shoulder	Scapula	Humerus
Teres minor	Laterally rotates shoulder	Scapula	Humerus

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CHAPTER OVERVIEW

9: The Appendicular Muscles

9.1: Muscles of the Rotator Cuff
9.2: Muscles of the Upper Arm
9.3: Muscles of the Lower Arm and Hand
9.4: Muscles of the Hips and Thighs
9.5: Muscles of the Lower Leg and Foot
9.6: Exercises
9.7: MODELS- Arm and Leg

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9.1: Muscles of the Rotator Cuff

Information

The rotator cuff is the name given to the group of four muscles that are largely responsible for the ability to rotate the arm. Three of the four rotator cuff muscles are deep to the deltoid and trapezius muscles and cannot be seen unless those muscles are first removed and one is on the anterior side of the scapula bone and cannot be seen from the surface.

On the anterior side of scapula bone is a single muscle, the **subscapularis**. It is triangular in shape and covers the entire bone. Its origin is along the fossa that makes up most of the "wing" of the scapula and it inserts on the lesser tubercle of the humerus bone. The subscapularis muscle is shown in Figure **9.1.1**.

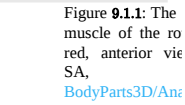


Figure **9.1.1**: The muscle of the ro red, anterior vie SA, BodyParts3D/Ana

On the posterior side of the scapula bone are the other three muscles of the rotator cuff. All three insert on the greater tubercle of the humerus, allowing them, in combination with the subscapularis, to control rotation of the arm. The **supraspinatus** muscle is above the spine of the scapula. The **infraspinatus** muscle is below the spine of the scapula. The relatively thin **teres minor** muscle is the most inferior of the rotator cuff muscles. The three posteriorly- positioned muscles of the rotator cuff are shown in Figure **9.1.2**.

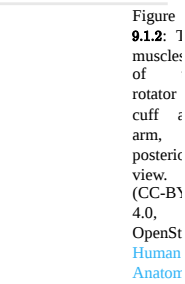


Figure **9.1.2**: T muscles of rotator cuff a arm, posteric view. (CC-BY 4.0, OpenSt Human Anatom

The **teres major muscle** has its origin on the scapula, like the rotator cuff muscles, but is not involved in rotating the arm. It inserts lower on the humerus than the rotator cuff muscles and is involved in adducting the arm (bringing it closer to the midline of the body.)

LAB 9 EXERCISES 9.1.1

1. Using the full-scale arm model, locate and identify all four muscles of the rotator cuff, as well as the deltoid muscle and the teres major muscle.

2. The following are muscles of **arm rotation and adduction**. For each, give its origin(s) and insertion(s) and whether or not it is part of the rotator cuff.

Muscle	Origin(s)	Insertion(s)	Part of rotator cuff?
Subscapularis			
Supraspinatus			
Infraspinatus			
Teres major			
Teres minor			
Deltoid			

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Figure **9.1.1**. The subscapularis muscle of the rotator cuff, in red, anterior view.. **Authored by**: Was a bee. **Provided by**: Images in Figure 9.1 were made out of, or made from, content published in a BodyParts3D/Anatomography web site. The content of their website is published under the Creative Commons Attribution 2.1 Japan license. The author and licenser of the contents is http://lifesciencedb.jp/bp3d/?lng=en.. **Located at**: https://commons.wikimedia.org/wiki/F...le_frontal.png. **License**: ***CC BY-SA: Attribution-ShareAlike***

Figure **9.1.2**. The muscles of the rotator cuff and arm, posterior view.. **Authored by**: OpenStax College. **Located at**: http://cnx.org/resources/e5ba9b5bb7343a347f55336ebd7a61f3b35b0cdc/1119_Muscles_that_Move_the_Humerus.jpg. **Lice nse**: ***CC BY-SA: Attribution-ShareAlike***

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9.2: Muscles of the Upper Arm

Anatomists refer to the upper arm as just the arm or the brachium. (The lower arm is the forearm or antebrachium.) There are three muscles on the upper arm that are parallel to the long axis of the humerus, the biceps brachii, the brachialis, and the triceps brachii.

The **biceps brachii** is on the anterior side of the humerus and is the prime mover (agonist) responsible for flexing the forearm. It has two origins (hence the "biceps" part of its name), both of which attach to the scapula bone. It inserts on the radius bone. The biceps brachii has two synergist muscles that assist it in flexing the forearm. Both are found on the anterior side of the arm and forearm. One of these is the **brachioradialis** muscle which is largely on the forearm (see the next section) and the other is the **brachialis**, which is largely on the upper arm. The brachialis muscle is deep to the biceps brachii and both its origin and its insertion are more distal to the shoulder than its equivalents on the biceps brachii. Like the biceps brachii the origin of the brachialis is on the humerus. Parts on the brachialis can be seen peeking out from under the biceps brachii, especially lower on the arm. The locations of these three muscles are shown in Figure 9.3.

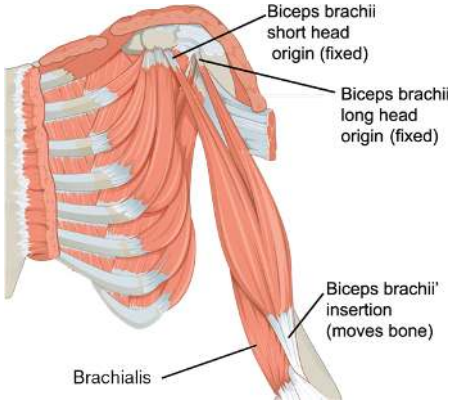


Figure **9.2.1**: The muscles of the arm. (CC-BY-4.0, OpenStax, Human Anatomy)

On the posterior side of the arm is the **triceps brachii** muscle. It the antagonist to the biceps brachii. When the triceps brachii contracts it extends the forearm, undoing any flexing brought about by contractions of the biceps brachii. As a result, when the triceps brachii is contracted, the biceps brachii and its synergists must be relaxed, and vice versa. The triceps brachii has three origins, called the long head, the lateral head, and the medial head. Figure 9.4 shows the three origins of the triceps brachii in different colors. It is easiest to view the triceps brachii from the posterior, but the medial head and its origin are deep to the lateral head and the long head, and so is the medial head of the triceps brachii is partially obscured from the posterior.

Figure **9.2.2**:. The
of the triceps b
coded to distin
Keep in mind,
different colors
parts of the same
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BodyParts3D/Ana

LAB 9 EXERCISES 9-2

1. Using the full-scale arm model, locate and identify the biceps brachii, brachialis, and triceps brachii muscles.

2. The following are muscles of **arm rotation and adduction**. For each, give its origin(s) and insertion(s).

Muscle	Origin(s)	Insertion(s)
Biceps brachii		
Brachialis		
Triceps brachii		

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Figure **9.2.1**:. The muscles of the arm.. **Authored by**: OpenStax College. **Located at**: http://cnx.org/resources/6669b272a691b9377071de429a1336fec0469a5c/1120_Muscles_that_Move_the_Forearm.jpg. **Lice nse**: ***CC BY-SA: Attribution-ShareAlike***

Figure **9.2.2**:. The three heads of the triceps brachii color-coded to distinguish them. Keep in mind, despite the different colors all three are parts of the same one muscle.. **Authored by**: Was a bee. **Provided by**: Images in Figure **9.2.2** were made out of, or made from, content published in a BodyParts3D/Anatomography web site. The content of their website is published under the Creative Commons Attribution 2.1 Japan license. The author and licenser of the contents is http://lifesciencedb.jp/bp3d/?lng=en. **Located at**: https://commons.wikimedia.org/wiki/F...nimation02.gif. **License**: ***CC BY-SA: Attribution- ShareAlike***

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9.3: Muscles of the Lower Arm and Hand

Information

Anatomists refer to the lower arm as the forearm or antebrachium. The musculature of the forearm is complicated. Figure **9.3.1** shows the muscles of the forearm.



Figure **9.3.1**: Muscle of forearm (CC-BY 4.0, OpenSt Human Anatom

Figure **9.3.2** shows the muscles of the hands.



Figure **9.3.2**: T muscles of hands. (CC-BY 4.0, OpenSt Human Anatom

LAB 9 EXERCISES 9.3.1

1. Using the full-scale arm model, locate and identify the muscles of the forearm selected by your instructor.

2. Write down the muscles of the forearm selected by your instructor and, for each, give the location of that muscle and what effect contracting that muscle has.

Muscle	Location & description	Action(s)

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Figure **9.3.1**. Muscles of the forearm.. **Authored by**: OpenStax College. **Located at**: https://cnx.org/resources/6669b272a6...he_Forearm.jpg. **Lic ense**: ***CC BY-SA: Attribution-ShareAlike***

Figure **9.3.2**. The muscles of the hands.. **Authored by**: OpenStax College. **Located at**: https://cnx.org/resources/49b609261e...f_the_Hand.jpg. **Licen se**: ***Public Domain: No Known Copyright***

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9.4: Muscles of the Hips and Thighs

Information

There are three layers of gluteal muscles on the posterior hips, just like there are three layers of muscles in the abdominal trunk. The largest of them is the most superficial muscle, the **gluteus maximus.** Its origin is on the ilium of the coxal bone, and it inserts part-way down the shaft of the femur. It helps maintain erect posture, abducts the thigh, and rotates the thigh outward.

Below the gluteus maximus is the smaller **gluteus medius**. The gluteus medius muscle helps abducts the thigh along with the gluteus maximus, but can rotate the thigh inward where the gluteus maximus rotates the thigh outward.

Below the gluteus medius are several muscles, one of which is the **gluteus minimus**, the smallest of the gluteal muscles. It is a synergist for the gluteus medius.

Figure **9.4.1**: three lay of glu muscles gluteus maximu gluteus medius, gluteus minimus (CC-BY SA, Wikime

Like the forearm, the upper leg, or thigh, has a dense arrangement of many muscles. On the anterior side, the most prominent of the muscles are the sartorius muscle and the four muscles that make up quadriceps muscle group (the “quads”.)

The quadriceps sounds like it should be just one muscle, akin to the triceps brachii, but it is a group of four muscles, three visible on the surface, and the fourth obscured. The three surface muscles of the quadriceps are the **rectus femoris** in the center, the **vastus medialis** on the medial side, and the **vastus lateralis** on the lateral side. These three muscles are visible in Figure **9.4.2**. Below the rectus femoris and largely hidden by it is the **vastus intermedius**. This muscle’s position can be seen in Figure 9.9. The four muscle of the quadriceps all extend the lower leg, and the rectus femoris additionally can flex the thigh at the hip.

Figure **9.4.2**: superfic muscles the th (CC-BY SA, Wikime

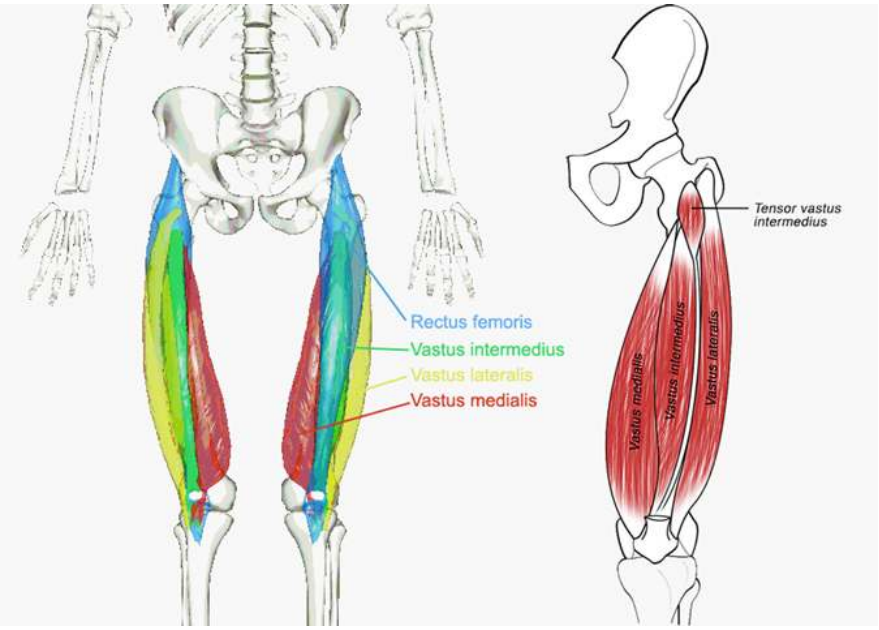


Figure **9.4.3**: The quadriceps group of four muscles. The view on the left has the rectus femoris cut away to show the vastus intermedius which is below it. (CC-BY-SA, Wikimedia)

The **sartorius** muscle is a distinctively long and thin muscle that crosses the thigh diagonally. It is visible in Figure 9.9. Sartorius comes from the Latin for tailor, and this is sometimes called the tailor's muscle, although the reasons for the nickname are obscure. It may be because the shape of the muscle is thin and long, like a tailor's measuring tape; it may be because it is close to the inseam a tailor measures when tailoring pants, or it may be because it helps bring about the cross-legged position that tailors often adopt when working.

In the posterior thigh the bulk of the musculature is made up of three long muscles that are collectively called the hamstrings. The origin of this nickname is obscure, but it may have to do with the practice of butchers of hanging the thighs of butchered animals such as pig (the "hams") by the tendons of these three muscles. Move from the medial edge to the lateral edge of the posterior thigh, the hamstring muscles are the **semimembranous** muscle, the **semitendinosus** muscle, and the **biceps femoris**muscle. Notice the upper leg has a "biceps" muscle just like the upper arm does. This is why you have to indicate which biceps you are taking about when discussing one or other of these muscles. On the medial edge of the posterior thigh is the **gracilis** muscle. It is also visible on the medial edge of the thigh from the anterior.

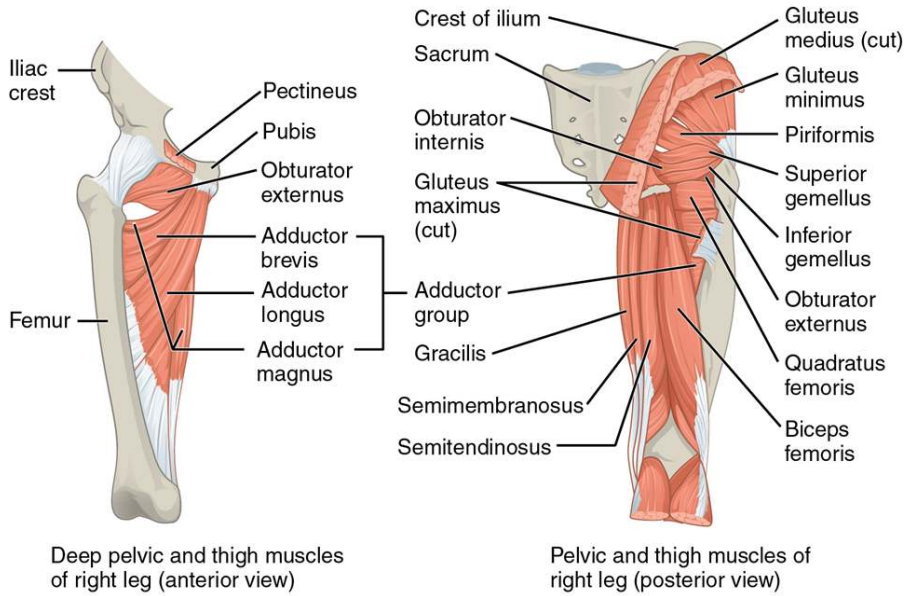


Figure **9.4.4**: The muscles of the posterior thigh. (CC-BY-4.0, OpenStax, Human Anatomy)

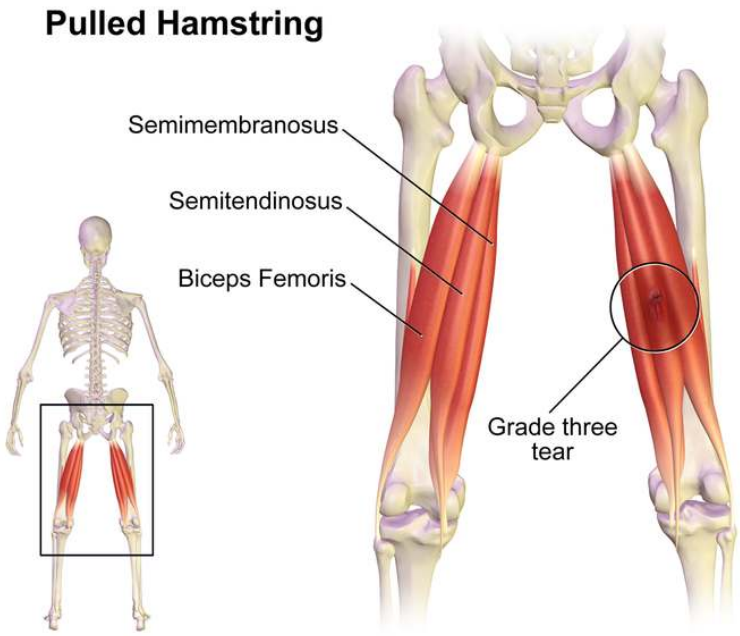


Figure 9.4.5: The hamstring group of muscles of the posterior thigh. (CC-BY-SA, Wikimedia)

LAB 9 EXERCISES 9.4.1

1. Using the full-scale leg model, locate and identify the muscles of the thigh listed in the table below.

2. Write down the muscles of the thigh in the table below and, for each, give the location of that muscle and what effect contracting that muscle has.

Muscle	Location & description	Action(s)
Rectus femoris		
Vastus intermedius		
Vastus medialis		
Vastus lateralis		
Sartorius		
Gracilis		
Semimembranosus		
Semitendinosus		
Biceps femoris		

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Figure 9.4.1. The three layers of gluteal muscles, gluteus maximus, gluteus medius, gluteus minimus.. **Authored by**: Beth ohara~commonswiki. **Located at**: https://commons.wikimedia.org/wiki/F..._Muscles_3.PNG. **License**: ***CC BY-SA: Attribution-ShareAlike***

Figure 9.4.2. The superficial muscles of the thigh.. **Authored by**: OpenStax College. **Located at**: https://cnx.org/resources/49a26b0c63...e_the_Femur.jpg. **License**: ***CC BY-SA: Attribution-ShareAlike***

Figure 9.4.3. The quadriceps group of four muscles. The view on the left has the rectus femoris cut away to show the vastus intermedius which is below it.. **Authored by**: Athikhun.suw. **Located at**: https://commons.wikimedia.org/wiki/F...ius_muscle.jpg. **License**: ***CC BY-SA: Attribution-ShareAlike***

Figure 9.4.4 The muscles of the posterior thigh.. **Authored by**: OpenStax College. **Located at**: http://cnx.org/resources/49a26b0c6351a2052a16c4fcd339bc092505e492/1122_Gluteal_Muscles_that_Move_the_Femur.jpg. **License**: ***CC BY-SA: Attribution-ShareAlike***

Figure 9.4.5. The hamstring group of muscles of the posterior thigh.. **Authored by**: BruceBlaus. **Located at**: https://commons.wikimedia.org/wiki/F..._Hamstring.png. **License**: ***CC BY-SA: Attribution-ShareAlike***

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Figure 9.4.1. The three layers of gluteal muscles, gluteus maximus, gluteus medius, gluteus minimus.. **Authored by**: Dr. Johannes Sobotta. **Provided by**: Sobotta's Human Anatomy 1909. **Located at**: https://commons.wikimedia.org/wiki/F...Sobo_1909_575-576.png. **License**: ***Public Domain: No Known Copyright***

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9.5: Muscles of the Lower Leg and Foot

Information

The muscles of the lower leg, called simply the leg by anatomists, largely move the foot and toes. The major muscles of the lower leg, other than the gastrocnemius which is cut away, are shown in Figure 9.12. The **gastrocnemius** muscle has two large bellies, called the medial head and the lateral head, and inserts into the calcaneus bone of the foot via its calcaneal tendon (also known as the Achilles tendon.) The **soleus** muscle is deep to the gastrocnemius, and the two muscles serve together as the calf of the leg. The gastrocnemius muscle is shown in Figure 9.13.

Figure **9.5.1**: T
muscles
of
lower l
(CC-BY
4.0,
OpenSt
Human
Anatom

Figure
**The
gastrocne
muscle**
BY-SA,
Wikimedi
Nikai)

Figure **9.5.2** shows the muscles of the feet.

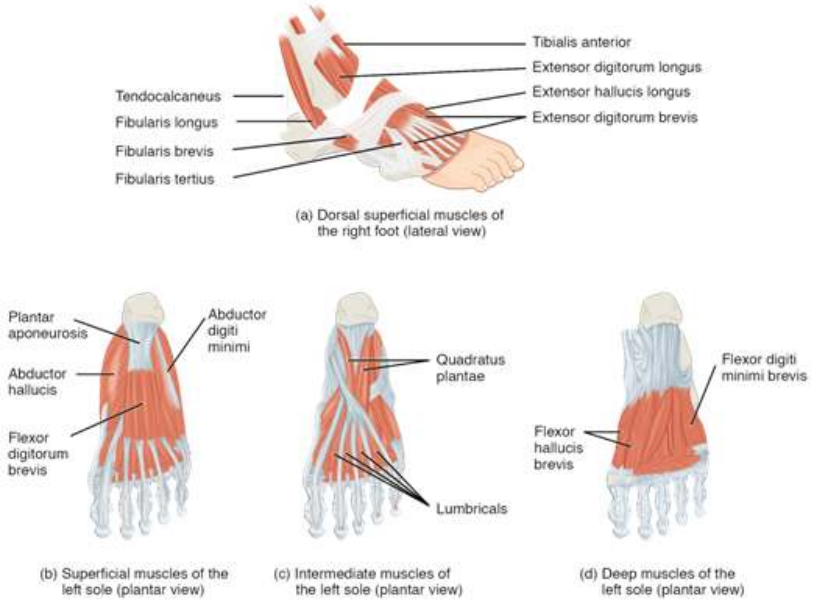


Figure **9.5.2**: Muscles of the feet. (CC-BY-4.0, OpenStax, Human Anatomy)

LAB 9 EXERCISES 9-5

1. Using the full-scale leg model, locate and identify the muscles of the lower leg listed in the table below.

2. For each of the muscles of the leg, give the location of that muscle and what effect contracting that muscle has.

Muscle	Location & description	Action
Gastrocnemius		
Soleus		
Tibialis anterior		
Fibularis longus		

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Figure 9.5.1. The muscles of the lower leg. **Authored by**: OpenStax College. **Located at**: **http://cnx.org/resources/adeb0a7399faaf57fe6dd39c017a6d25a03e6916/1123_Muscles_of_the_Leg_that_Move_the_Foot_and_Toes.jpg**. **License**: ***CC BY-SA: Attribution-ShareAlike***

Figure 9.5.2. The gastrocnemius muscle. **Authored by**: Nikai . **Located at**: **https://commons.wikimedia.org/wiki/F...trocnemius.png**. **License**: ***CC BY-SA: Attribution-ShareAlike***

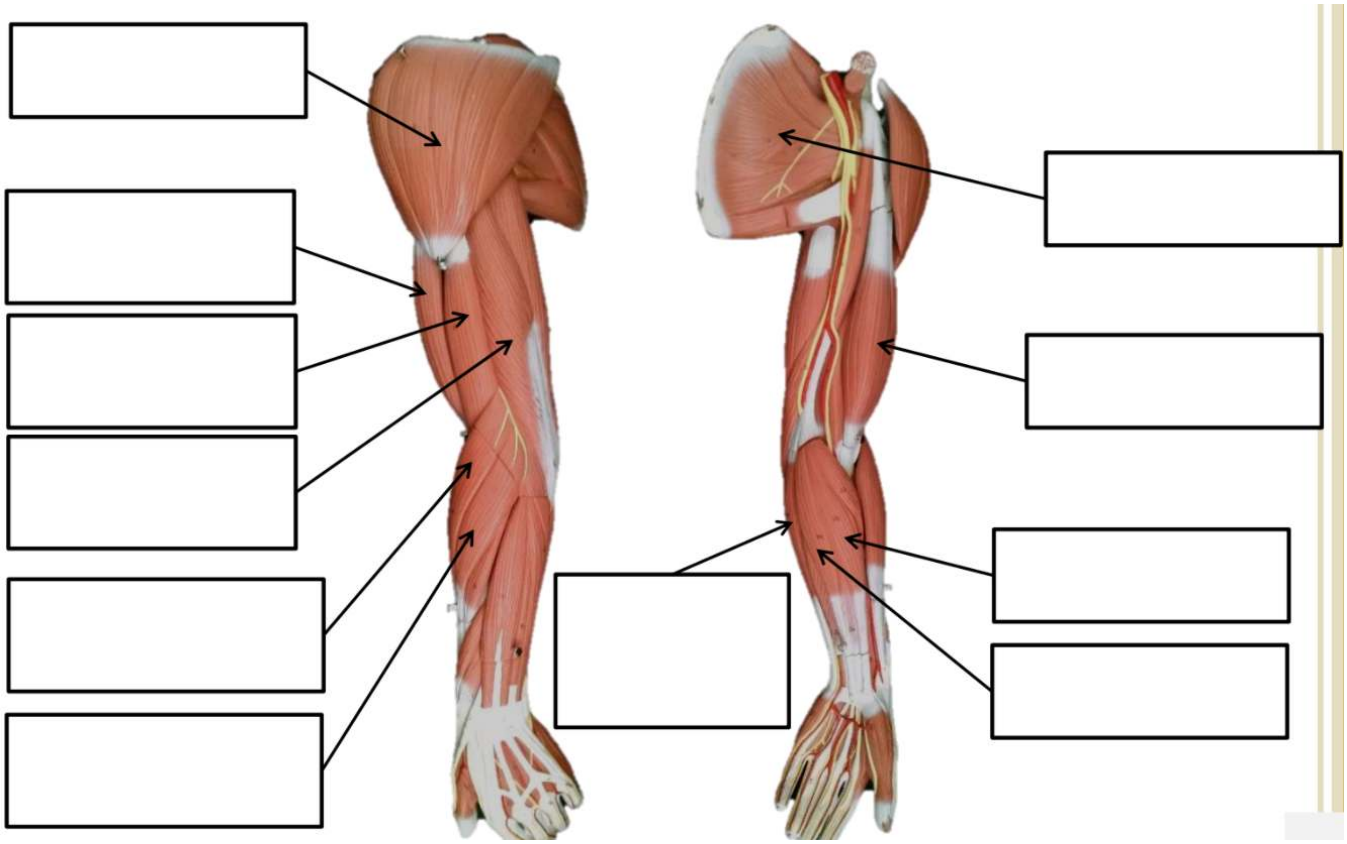
Figure 9.5.3. The muscles of the feet.. **Authored by**: OpenStax College. **Located at**: **https://cnx.org/resources/747c45c729...f_the_Foot.jpg**. **Licens e**: ***CC BY-SA: Attribution-ShareAlike***

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9.6: Exercises

LAB 9 EXERCISES Figure 9.6.1

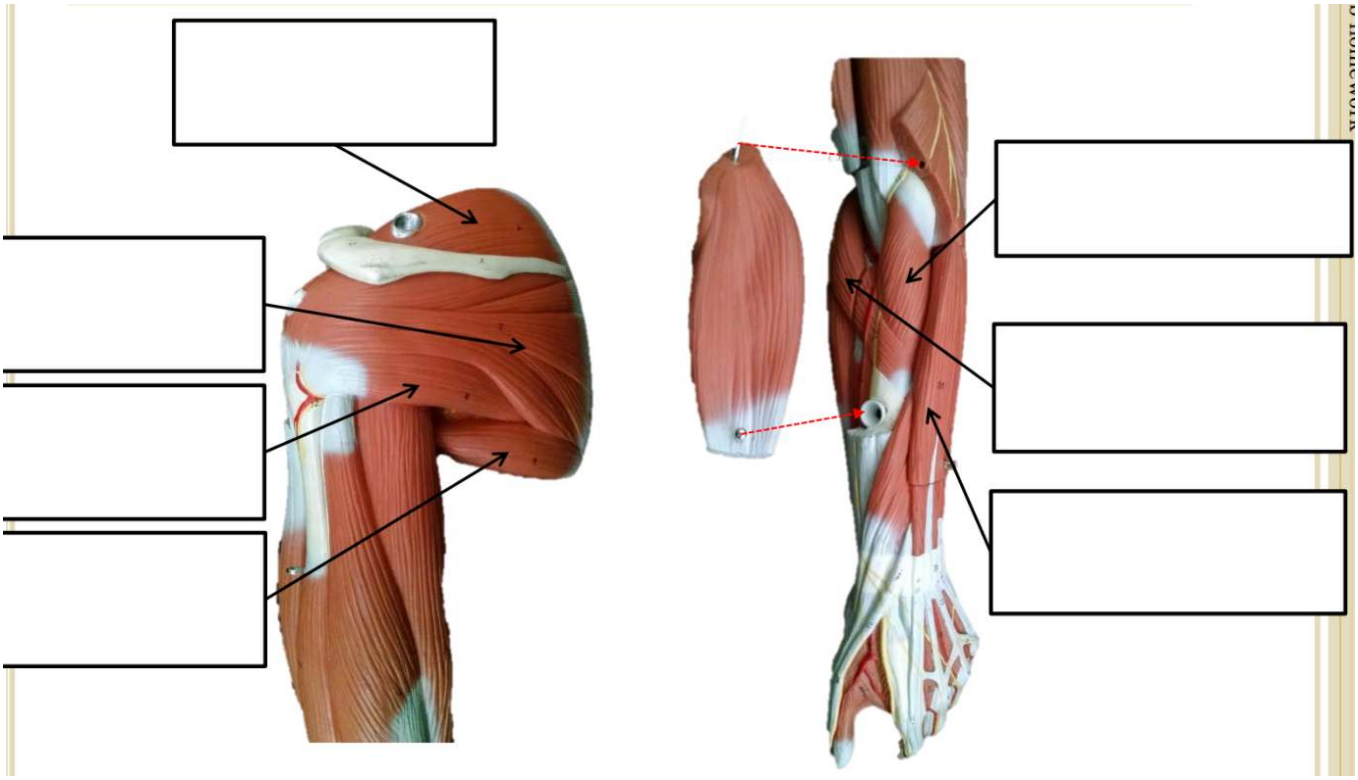
IDENTIFY THE MUSCLES OF THE ARM



LAB 9 EXERCISES Figure 9.6.2

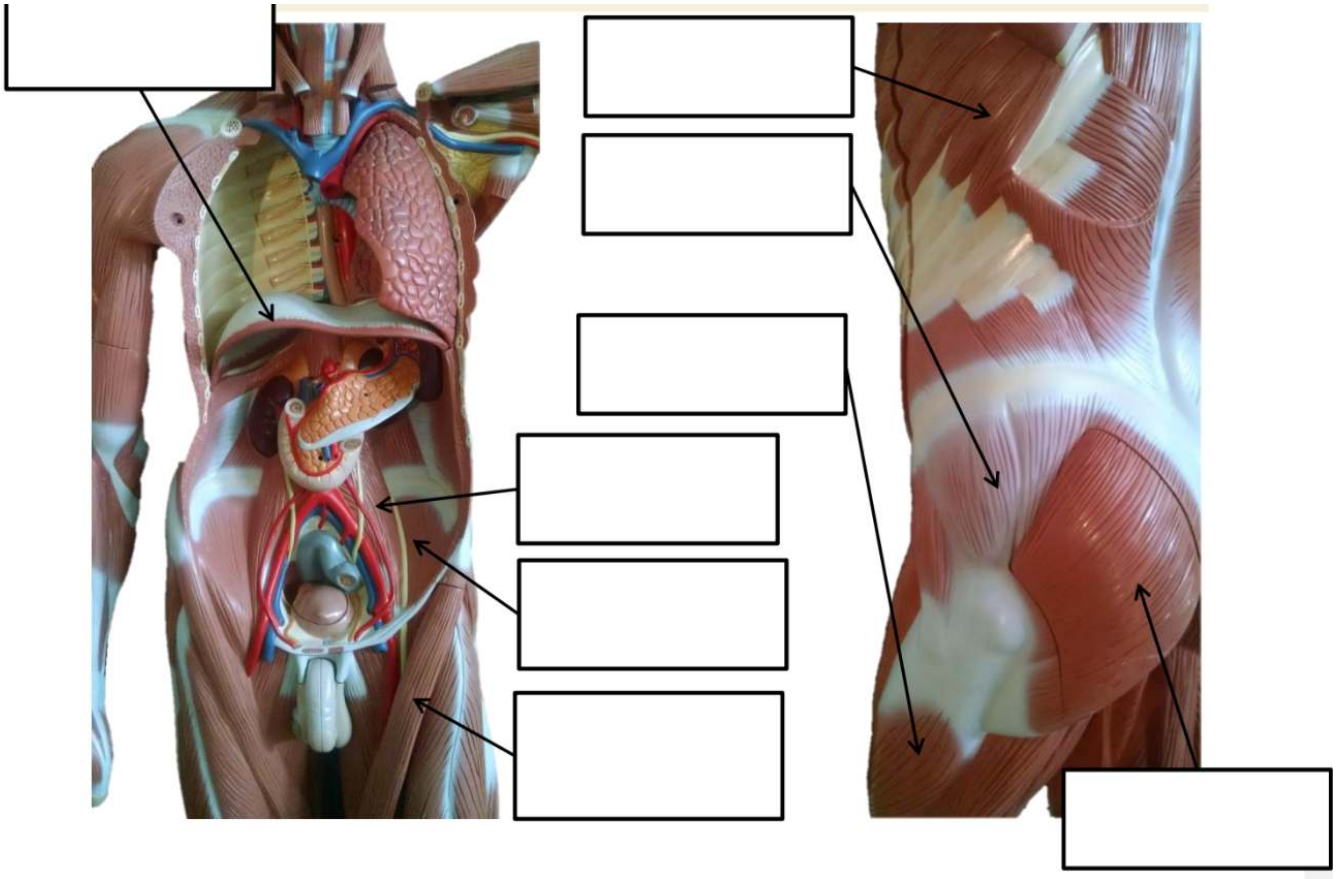
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IDENTIFY THE DEEP MUSCLES OF THE ARM & SHOULDER



LAB 9 EXERCISES Figure 9.6.3

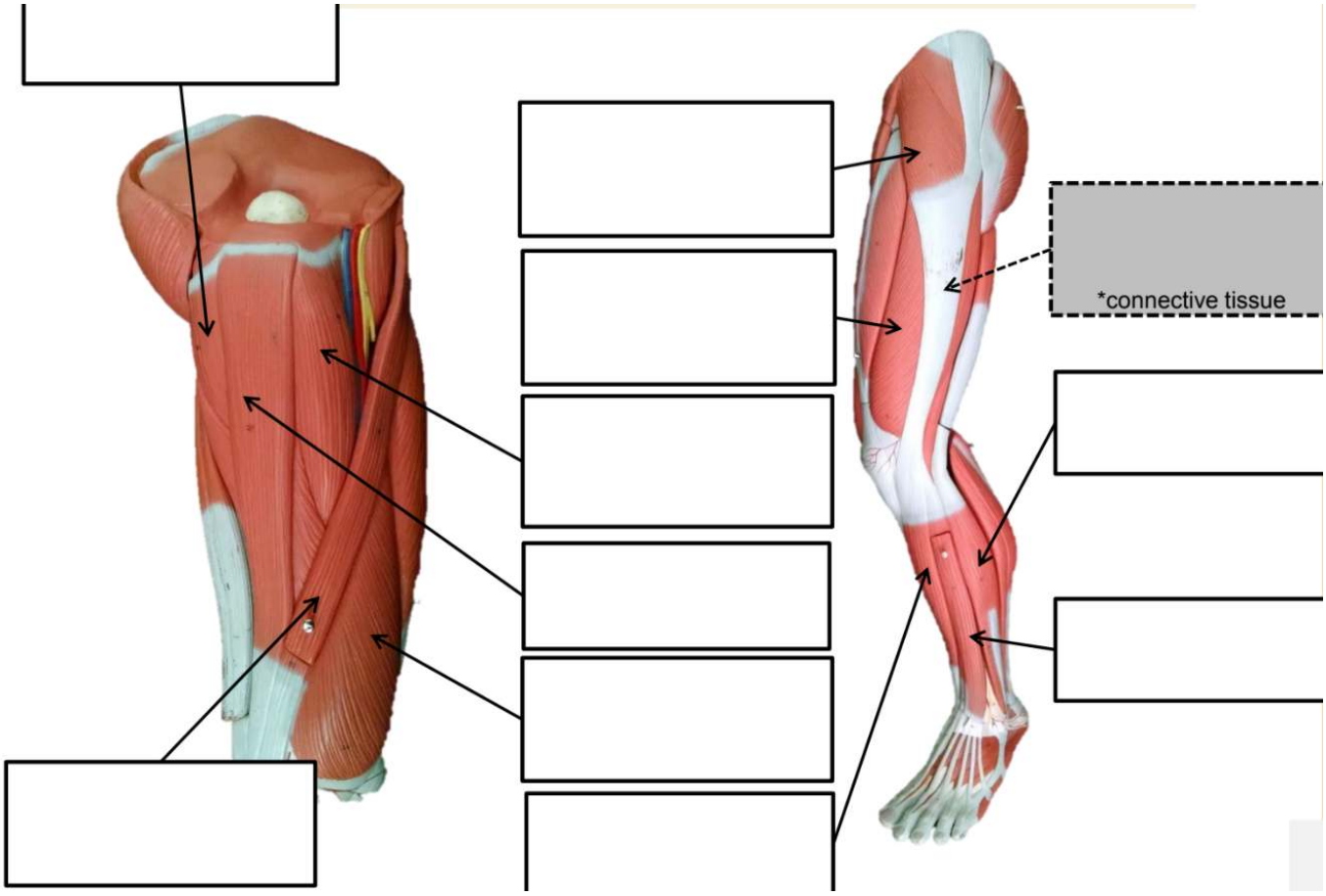
IDENTIFY MUSCLES OF THE ABDOMEN & LEG



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LAB 9 EXERCISES Figure 9.6.4

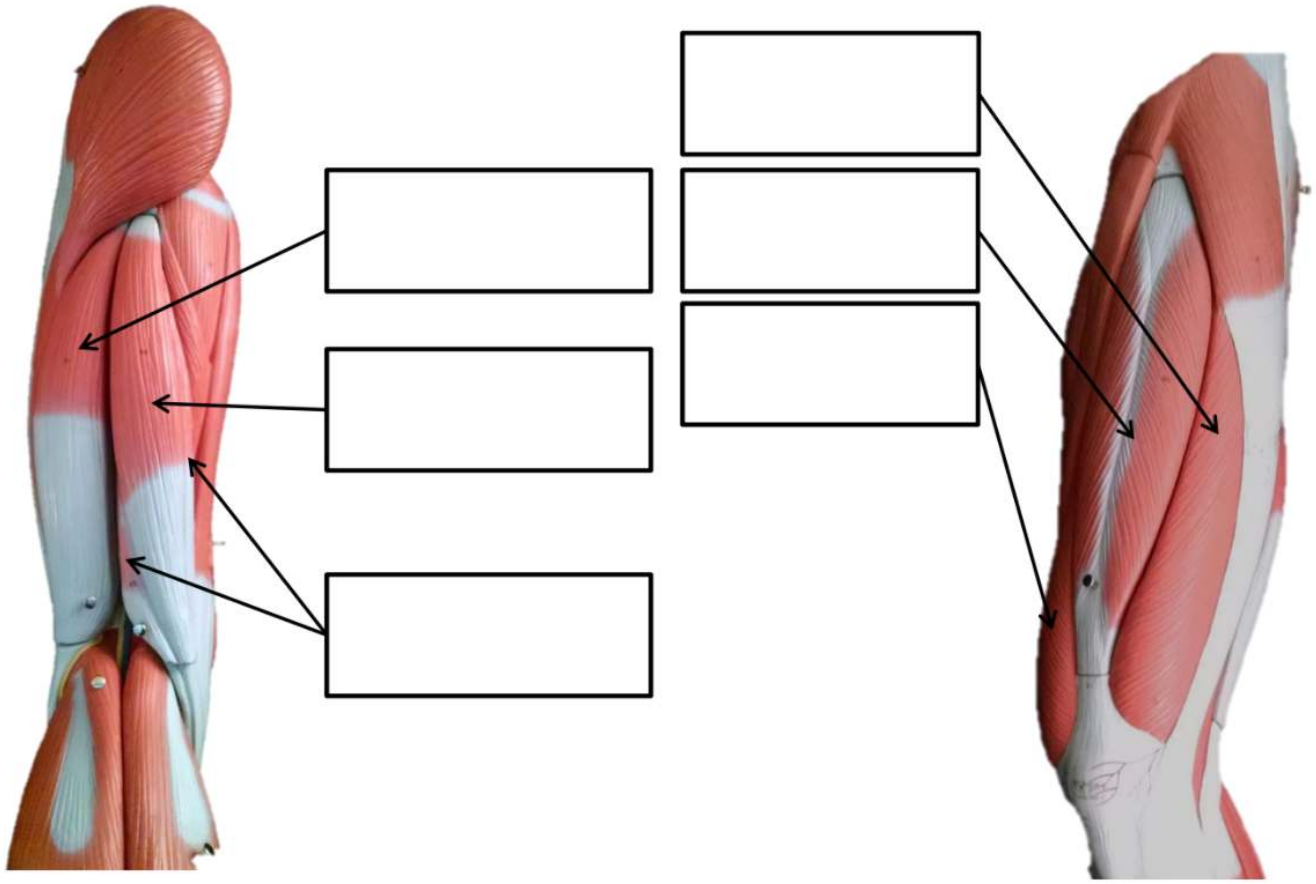
IDENTIFY THE MUSCLES OF THE THIGH & LEG



LAB 9 EXERCISES Figure 9.6.5

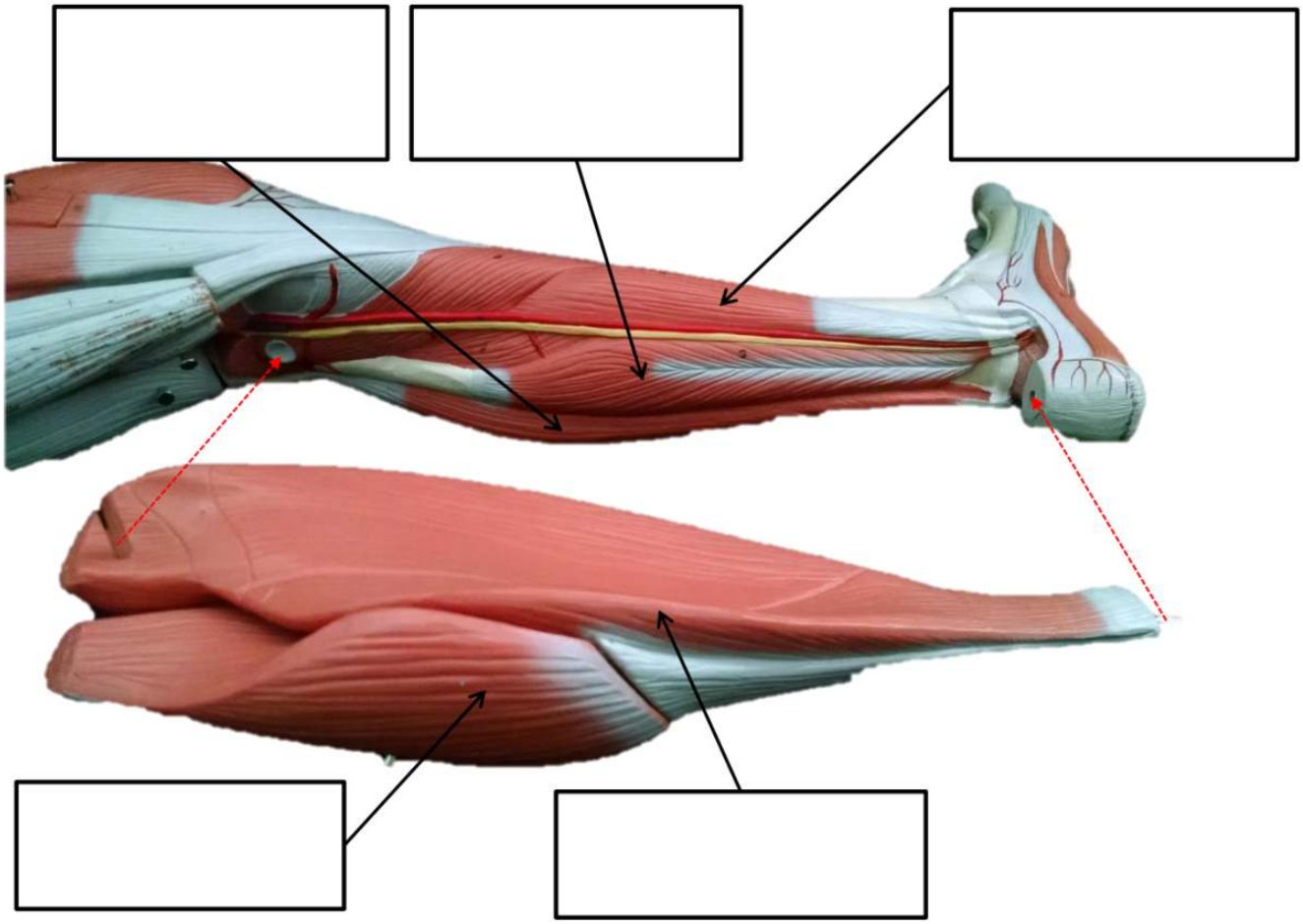
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IDENTIFY THE MUSCLES OF THE THIGH



LAB 9 EXERCISES Figure 9.6.6

IDENTIFY THE MUSCLES OF THE LEG



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Name	Action	Origin	Insertion
Forearm movers			
Biceps brachii	Flexes arm at elbow	Scapula	Radius
Brachialis	Flexes arm at elbow	Humerus	Ulna
Triceps brachii	Extends arm at elbow	Humerus & Scapula	Ulna
Pronator teres	Pronates forearm	Humerus & Ulna	Radius
Supinator	Supinates forearm	Humerus & Ulna	Radius
Brachioradialis	Flexes arm at elbow (*beer raising)*	Humerus	Radius
Hand & finger movers			
Name	**Action**	**Origin**	**Insertion**
Flexor carpi radialis	Flexes & abducts hand at wrist	Humerus	Carpal Bones
Palmaris longus	Flexes hand at wrist	Humerus	Carpal Bones
Flexor carpi ulnaris	Flexes & adducts hand at wrist	Humerus	Carpal Bones
Extensor carpi radialis	Extends & abducts hand at wrist	Humerus	Carpal Bones
Extensor digitorum	Extends fingers	Humerus	Digits
Extensor carpi ulnaris	Extends & adducts hand at wrist	Humerus	Carpal Bones
Muscles of the thigh & leg			
Name	**Action**	**Origin**	**Insertion**
Flexor digitorum longus	Flexes toes	Tibia	Digits
Flexor hallucis longus	Flexes hallux	Fibula	big toe
Tibialis anterior	Dorsiflex foot at ankle, inverts foot	Tibia	1st metatarsal
Extensor digitorum longus	Extends toes	Tibia & fibula	digits
Fibularis (peroneus) longus	plantarflexes	Tibia & fibula	1st metatarsal
Gastrocnemius	plantarflexes	Femur	calcaneous
Soleus	Plantarflexes	Femur & tibia	calcaneous

Name	Action	Origin	Insertion
Muscles of the leg & thigh			
Psoas major	Flexes thigh at hip (also flexes vertebral column)	Thoracic and Lumbar Vertebrae	Femur
Iliacus	Flexes thigh at hip	Ilium	Femur
Adductor longus	Adducts thigh at hip	Pubis	Femur
Adductor magnus	Adducts thigh at hip	Pubis and Ischium	Femur
Gracilis	Adducts thigh at hip	Pubis	Tibia
Gluteus maximus	Extends thigh at hip, rotates thigh laterally	Ilium, Sacrum and Coccyx	Femur, ITB
Gluteus medius	Abducts thigh at hip, rotates thigh medially	Ilium	Femur
Sartorius	Flexes leg at knee (also flexes + rotates thigh at hip)	Ilium	Tibia
Tensor fascia latae	tenses the ITB, supports knee	Ilium	ITB
Iliotibial band (IT band/tract)	*Not a muscle*	n/a	n/a

Quadriceps femoris			
Name	**Action**	**Origin**	**Insertion**
Rectus femoris	Extends leg at knee (also flexes thigh at hip)	Ilium	Tibia
Vastus lateralis	Extends leg at knee	Femur	Tibia
Vastus medialis	Extends leg at knee	Femur	Tibia
Vastus intermedius	Extends leg at knee	Femur	Tibia

Hamstrings			
Name	**Action**	**Origin**	**Insertion**

Biceps femoris	Flexes leg at knee (also extends thigh at hip)	Ischium & Femur	Tibia & Fibula
Semitendinosus	Flexes leg at knee (also extends thigh at hip)	Ischium	Tibia
Semimembranosus	Flexes leg at knee (also extends thigh at hip)	Ischium	Tibia

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CHAPTER OVERVIEW

10: Nervous Tissue

10.1: Neurons and Glial Cells

10.2: Exercises

10.3: MODELS- Nerve Tissue

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10.1: Neurons and Glial Cells

Nervous tissue is composed of two types of cells, neurons and glial cells. Neurons are the primary type of cell that most anyone associates with the nervous system. They are responsible for the computation and communication that the nervous system provides. They are electrically active and release chemical signals to target cells. Glial cells, or glia, are known to play a supporting role for nervous tissue. Ongoing research pursues an expanded role that glial cells might play in signaling, but neurons are still considered the basis of this function. Neurons are important, but without glial support they would not be able to perform their function.

Neurons

Neurons are the cells considered to be the basis of nervous tissue. They are responsible for the electrical signals that communicate information about sensations, and that produce movements in response to those stimuli, along with inducing thought processes within the brain. An important part of the function of neurons is in their structure, or shape. The three- dimensional shape of these cells makes the immense numbers of connections within the nervous system possible.

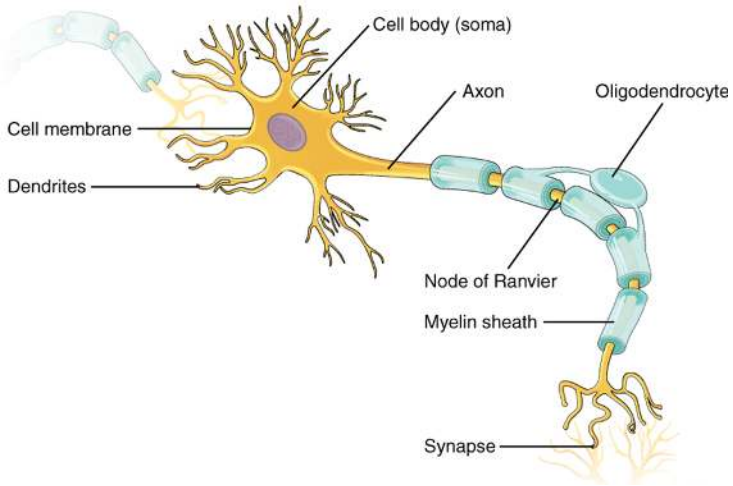


Figure **10.1.1**: The major parts of the neuron are labeled on a multipolar neuron from the CNS. Where the axon emerges from the cell body, there is a special region referred to as the **axon hillock**. (CC-BY-4.0, OpenStax, Human Anatomy)

Glial Cells

Glial cells, or neuroglia or simply glia, are the other type of cell found in nervous tissue. They are considered to be supporting cells, and many functions are directed at helping neurons complete their function for communication. The name glia comes from the Greek word that means “glue,” and was coined by the German pathologist Rudolph Virchow, who wrote in 1856: “This connective substance, which is in the brain, the spinal cord, and the special sense nerves, is a kind of glue (neuroglia) in which the nervous elements are planted.” Today, research into nervous tissue has shown that there are many deeper roles that these cells play. And research may find much more about them in the future.

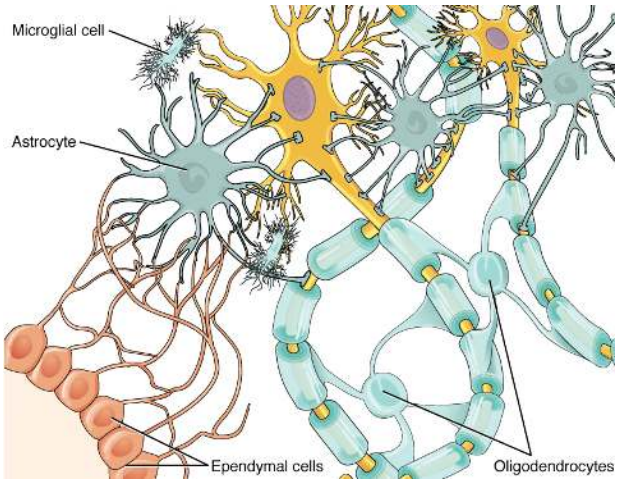


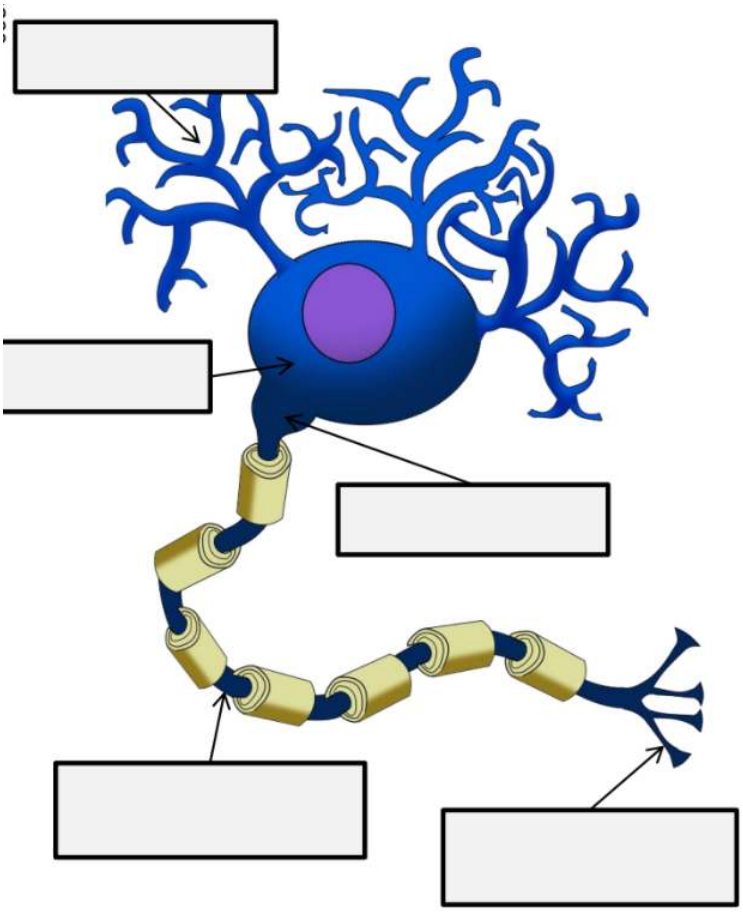
Figure **10.1.2**: Glial Cells (CC-BY-4.0, OpenStax, Human Anatomy)

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10.2: Exercises

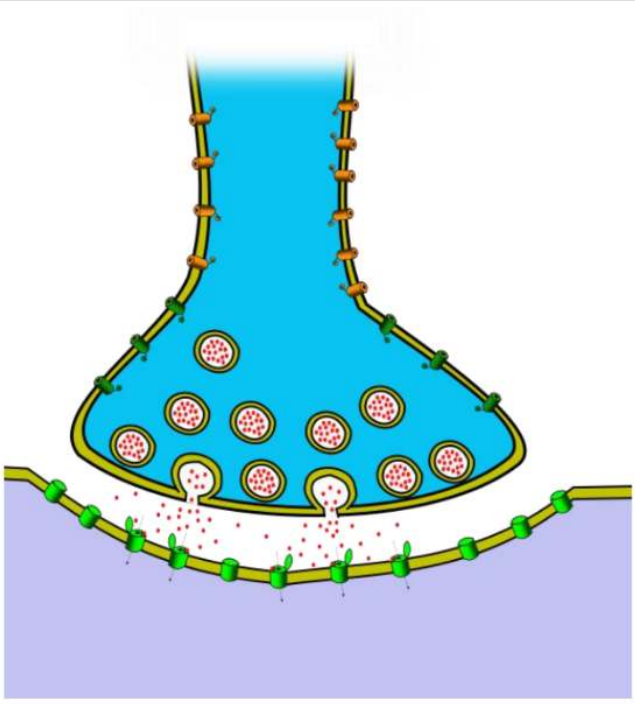
Lab 10 Exercise 10.2.1

Identify the pats of a "neuron"



Lab 10 Exercise 10.2.2

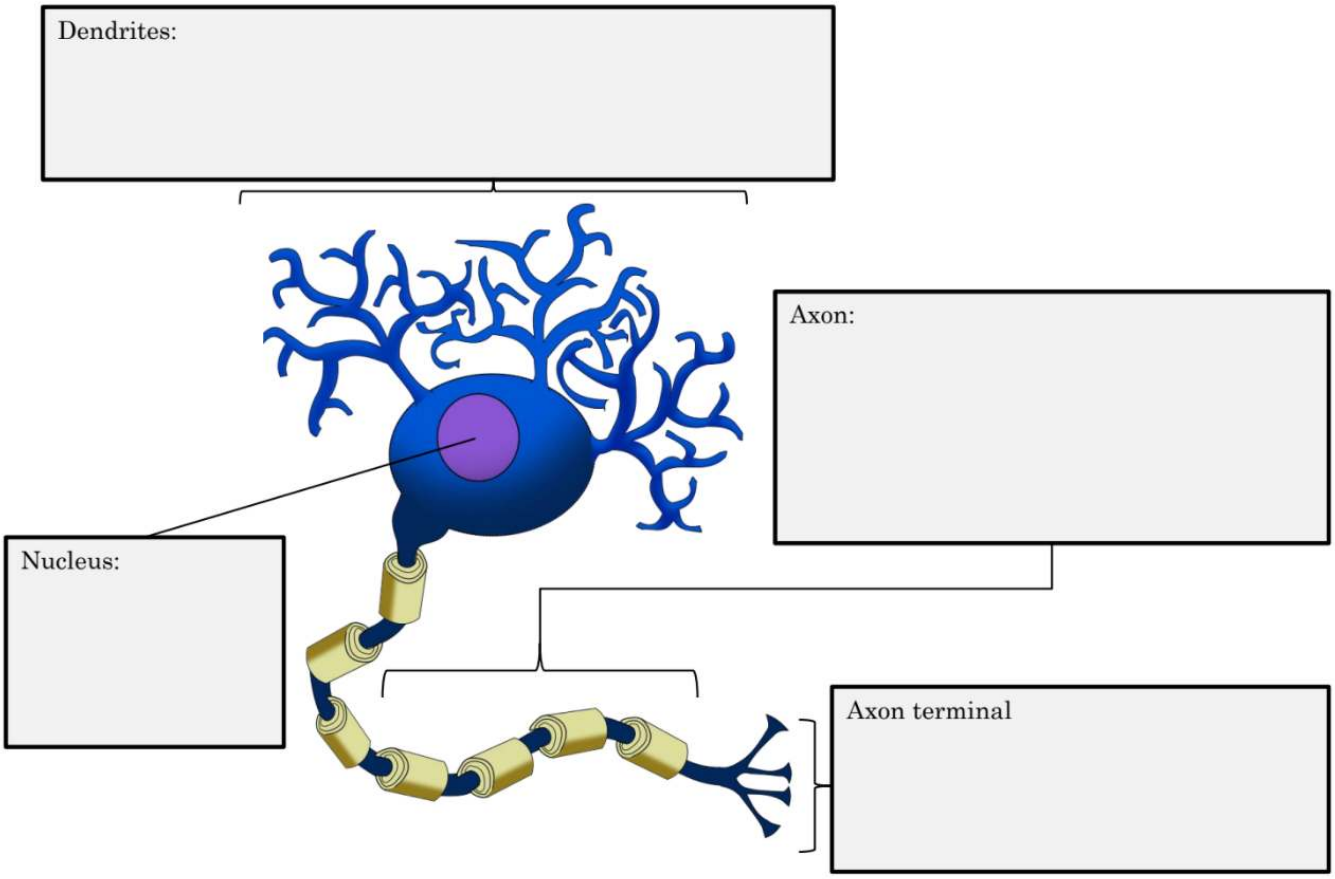
Label the following:



1	Axon
2	Synaptic cleft
3	Receptor,
4	Neurotransmitter
5	Synaptic terminal
6	Vesicles
7	Voltage-gated ion channels.

Lab 10 Exercise 10.2.3

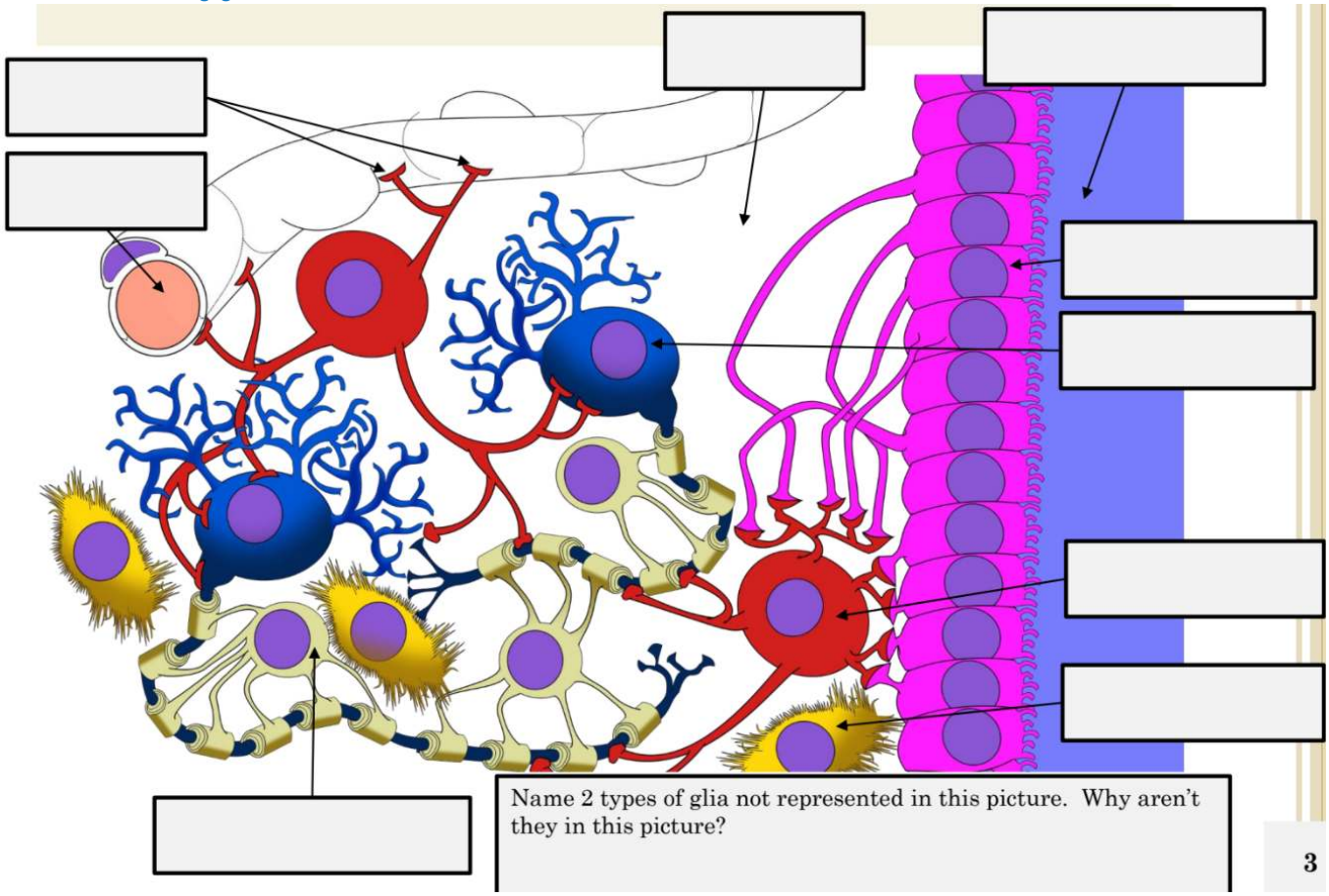
Match these items or actions to their locations on a neuron: graded potentials, action



1	graded potentials	7	EPSPs
2	action action	8	IPSPs
3	neurotransmitter-filled vesicles	9	pre-synaptic membrane
4	neurotransmitter receptors	10	post-synaptic membrane
5	voltage-gated sodium channels	11	Genes (that encode receptor proteins)
6	ligand-gated ion channels		

Lab 10 Exercise 10.2.4

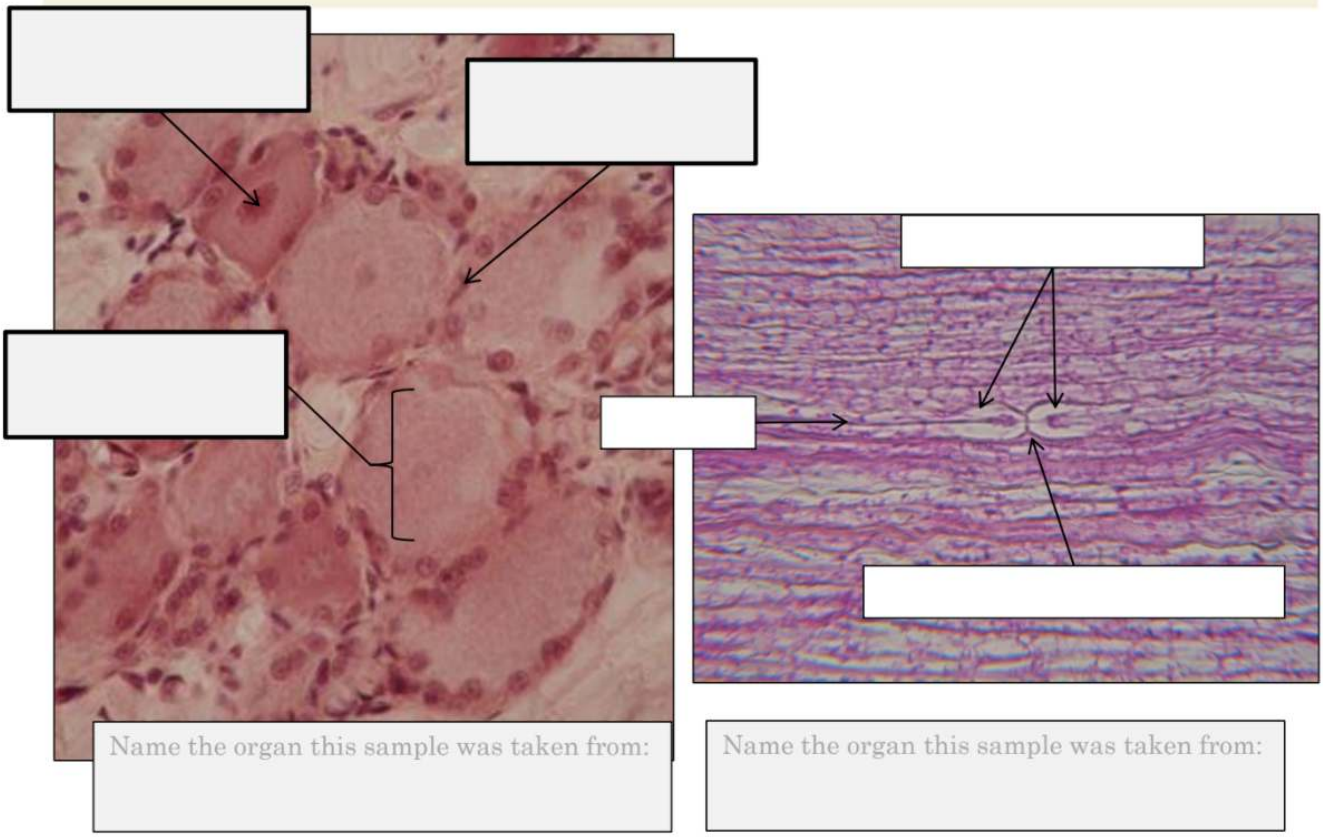
Label the following glia & related items:



1	Astrocyte	6	Cerebrospinal fluid (CSF)
2	Perivascular feet	7	Extracellular fluid (ECF)
3	Oligodendrocyte	8	Neuron
4	Microglia	9	Capillary
5	Ependymal cell		

Lab 10 Exercise 10.2.5

Label the histological sections



Lab 10 Exercise 10.2.6

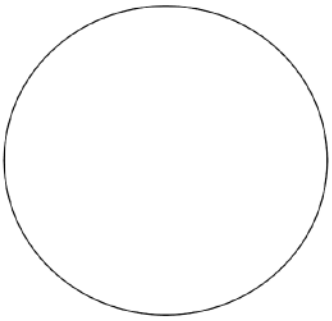
Obtain slides of each of the following tissues, observe them, draw and label the significant features. SLIDES: Spinal cord, cerebral cortex, cerebellum, dorsal root ganglion, peripheral nerve, neuromuscular junction:

1. Obtain a slide of nervous tissue from the slide box. Use any nervous tissue except peripheral nerve, there are no nerve cell bodies in a peripheral nerve section.

2. View the slide on the second-highest objective. Search carefully until you find a clear, representative neuron in your field of view.

3. In the circle below, draw the neuron you found. Only draw the single neuron. Do not draw any of the other material. Draw your structures proportionately to their size in your microscope's field of view.

4. Label any neural parts you can clearly recognize.



Total Magnification: _____

Source of tissue: _____

1	
2	
3	
4	
5	
6	
7	
8	

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10.3: MODELS- Nerve Tissue

Anatomical divisions:

Central nervous system

- Brain
- Spine

Peripheral nervous system

- Nerves
- Functional divisions:

Somatic nervous system

Autonomic nervous system

- Sympathetic nervous system
- Parasympathetic nervous system

Histology:

Neurons

- Cell body
- Nuclei
- Axon
- Axon hillock
- Myelin sheath
- Nodes of Ranvier
- Telodendria
- Axon terminal
- Dendrite
- Synaptic cleft

Neuroglia

- Schwann cells
- Oligodendrocytes
- Satellite cells
- Astrocytes
- Microglial cells
- Ependymal cells

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CHAPTER OVERVIEW

11: The Central Nervous System (Brain)

The brain and the spinal cord are the central nervous system, and they represent the main organs of the nervous system. The spinal cord is a single structure, whereas the adult brain is described in terms of four major regions: the cerebrum, the diencephalon, the brain stem, and the cerebellum. A person's conscious experiences are based on neural activity in the brain. The regulation of homeostasis is governed by a specialized region in the brain. The coordination of reflexes depends on the integration of sensory and motor pathways in the spinal cord.

11.1: The Cerebrum
11.2: The Diencephalon
11.3: The Brain Stem
11.4: The Cerebellum
11.5: Exercises
11.6: MODELS- 3D Brains, Ventricles, Sagittal and Coronal Brain Slices, Torsos, Sagittal Head
11.7: Sheep Brain Dissection

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11.1: The Cerebrum

The iconic gray mantle of the human brain, which appears to make up most of the mass of the brain, is the **cerebrum** (**Figure 11.1**). The wrinkled portion is the **cerebral cortex**, and the rest of the structure is beneath that outer covering. There is a large separation between the two sides of the cerebrum called the **longitudinal fissure**. It separates the cerebrum into two distinct halves, a right and left **cerebral hemisphere**. Deep within the cerebrum, the white matter of the **corpus callosum** provides the major pathway for communication between the two hemispheres of the cerebral cortex.

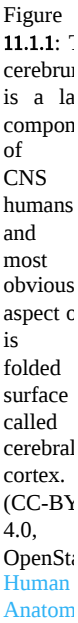


Figure **11.1.1**: T cerebru is a la compon of CNS humans and most obvious aspect c is folded surface called cerebral cortex. (CC-BY 4.0, OpenSt Human Anatom

Cerebral Cortex

The cerebrum is covered by a continuous layer of gray matter that wraps around either side of the forebrain—the cerebral cortex. This thin, extensive region of wrinkled gray matter is responsible for the higher functions of the nervous system. A **gyrus** (plural = gyri) is the ridge of one of those wrinkles, and a **sulcus** (plural = sulci) is the groove between two gyri. The pattern of these folds of tissue indicates specific regions of the cerebral cortex.

The head is limited by the size of the birth canal, and the brain must fit inside the cranial cavity of the skull. Extensive folding in the cerebral cortex enables more gray matter to fit into this limited space. If the gray matter of the cortex were peeled off of the cerebrum and laid out flat, its surface area would be roughly equal to one square meter.

The folding of the cortex maximizes the amount of gray matter in the cranial cavity. During embryonic development, as the telencephalon expands within the skull, the brain goes through a regular course of growth that results in everyone's brain having a similar pattern of folds. The surface of the brain can be mapped on the basis of the locations of large gyri and sulci. Using these landmarks, the cortex can be separated into four major regions, or lobes (**Figure 11.2**). The **lateral sulcus** that separates the **temporal lobe** from the other regions is one such landmark. Superior to the lateral sulcus are the **parietal lobe** and **frontal lobe**, which are separated from each other by the **central sulcus**. The posterior region of the cortex is the **occipital lobe**, which has no obvious anatomical border between it and the parietal or temporal lobes on the lateral surface of the brain. From the medial surface, an obvious landmark separating the parietal and occipital lobes is called the **parieto- occipital sulcus**.

The fact that there is no obvious anatomical border between these lobes is consistent with the functions of these regions being interrelated.

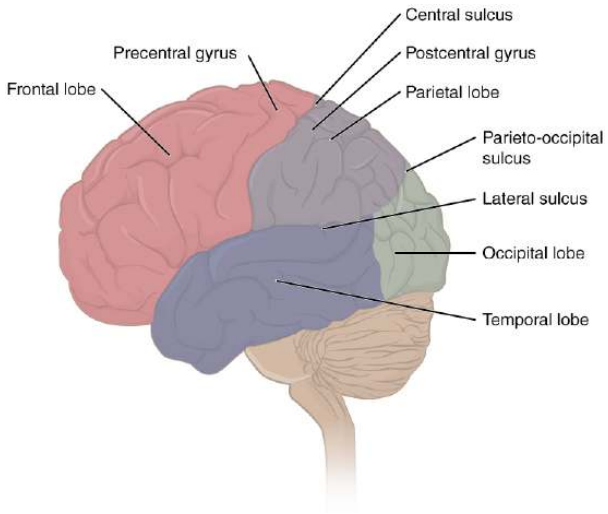


Figure 11.1.2: Lobes of the Cerebral Cortex The cerebral cortex is divided into four lobes. Extensive folding increases the surface area available for cerebral functions. (CC-BY-4.0, OpenStax, Human Anatomy)

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11.2: The Diencephalon

The diencephalon is the one region of the adult brain that retains its name from embryologic development. The etymology of the word diencephalon translates to “through brain.” It is the connection between the cerebrum and the rest of the nervous system, with one exception. The rest of the brain, the spinal cord, and the PNS all send information to the cerebrum through the diencephalon. Output from the cerebrum passes through the diencephalon. The single exception is the system associated with olfaction, or the sense of smell, which connects directly with the cerebrum. In the earliest vertebrate species, the cerebrum was not much more than olfactory bulbs that received peripheral information about the chemical environment (to call it smell in these organisms is imprecise because they lived in the ocean).

The diencephalon is deep beneath the cerebrum and constitutes the walls of the third ventricle. The diencephalon can be described as any region of the brain with “thalamus” in its name. The two major regions of the diencephalon are the thalamus itself and the hypothalamus (Figure 11.3). There are other structures, such as the epithalamus, which contains the pineal gland, or the subthalamus, which includes the subthalamic nucleus that is part of the basal nuclei.

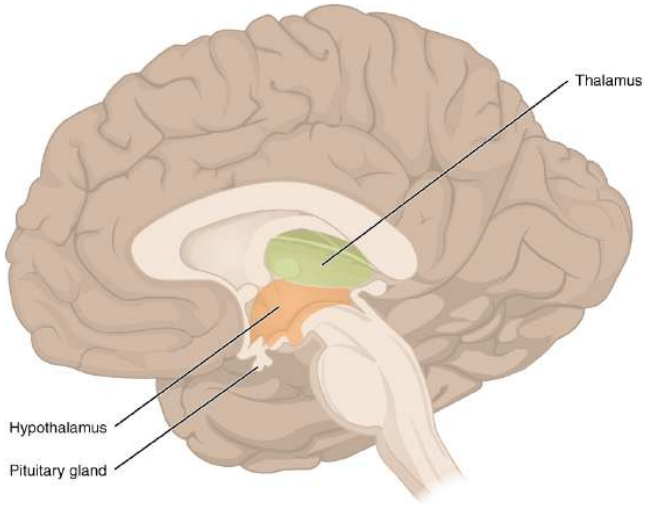


Figure **11.2.1**: The Diencephalon (CC-BY-4.0, OpenStax, Human Anatomy)

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11.3: The Brain Stem

The midbrain and hindbrain (composed of the pons and the medulla) are collectively referred to as the brain stem (**Figure 11.3.1**). The structure emerges from the ventral surface of the forebrain as a tapering cone that connects the brain to the spinal cord. Attached to the brain stem, but considered a separate region of the adult brain, is the cerebellum. The midbrain coordinates sensory representations of the visual, auditory, and somatosensory perceptual spaces. The pons is the main connection with the cerebellum. The pons and the medulla regulate several crucial functions, including the cardiovascular and respiratory systems and rates.

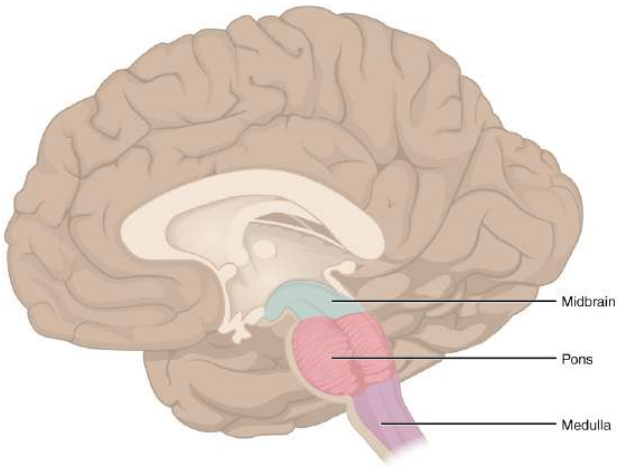


Figure **11.3.1**: Brian Stem (CC-BY-4.0, OpenStax, Human Anatomy)

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11.4: The Cerebellum

The **cerebellum**, as the name suggests, is the "little brain." It is covered in gyri and sulci like the cerebrum, and looks like a miniature version of that part of the brain (**Figure 11.4.1**). The cerebellum is largely responsible for comparing information from the cerebrum with sensory feedback from the periphery through the spinal cord. It accounts for approximately 10 percent of the mass of the brain.

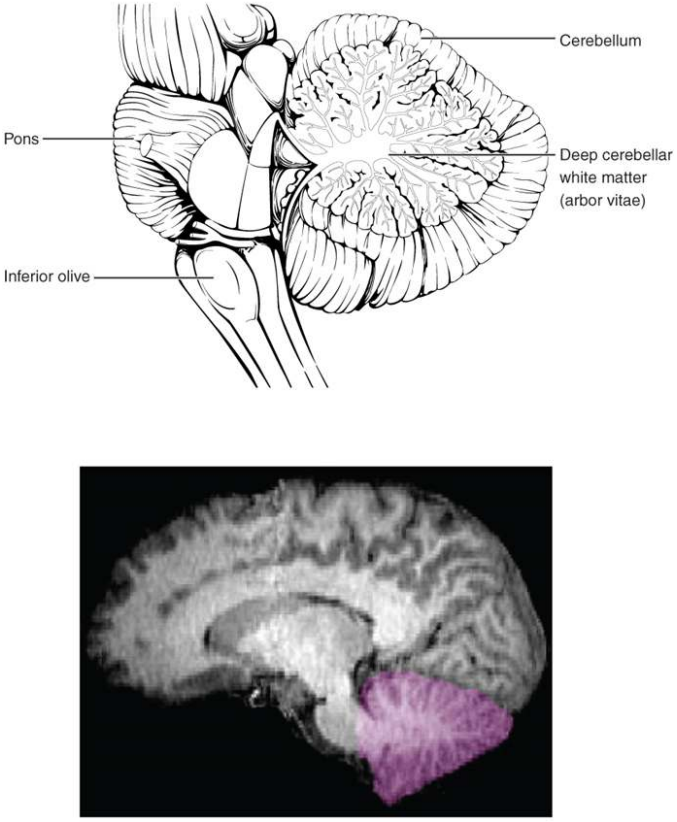
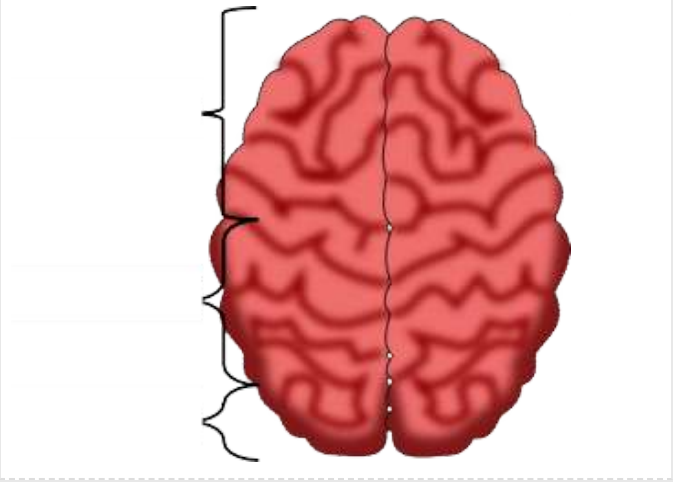


Figure **11.4.1**: **The Cerebellum** The cerebellum is situated on the posterior surface of the brain stem. Descending input from the cerebellum enters through the large white matter structure of the pons. Ascending input from the periphery and spinal cord enters through the fibers of the inferior olive. Output goes to the midbrain, which sends a descending signal to the spinal cord. (CC-BY-4.0, OpenStax, Human Anatomy)

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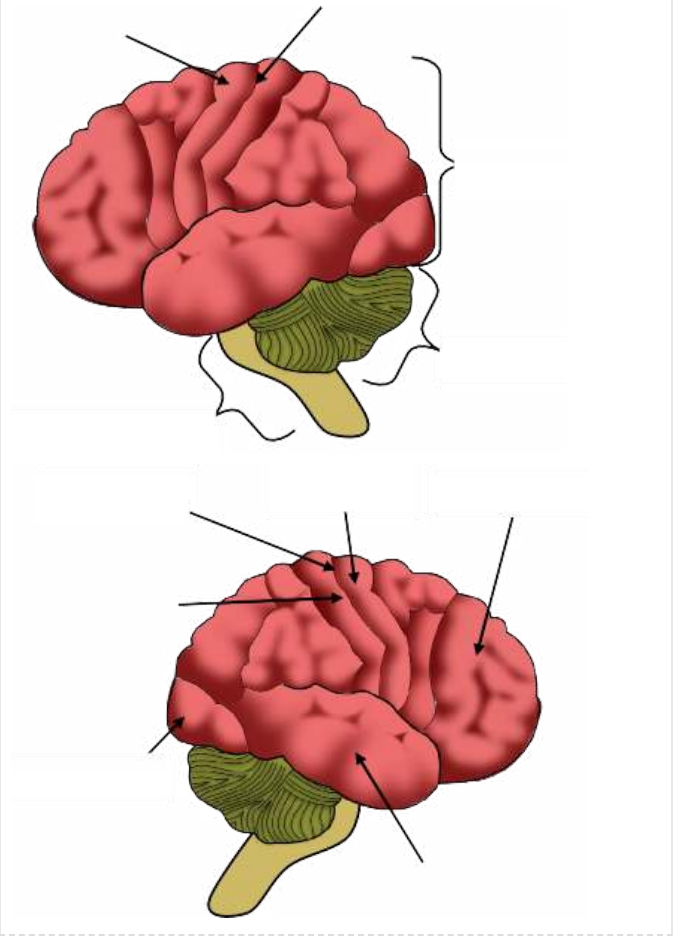
11.5: Exercises

LAB 11 EXERCISES 11.5.1



Label the (visible) lobes of the cerebrum

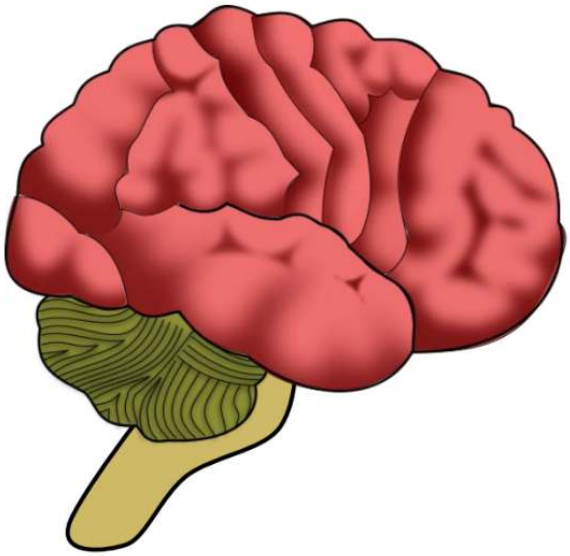
1	
2	
3	



Label the following

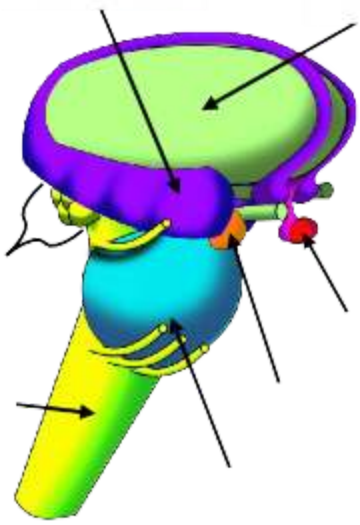
1	a Gyrus
2	a Sulcus
3	Cerebrum
4	Cerebellum
5	Brainstem

LAB 11 EXERCISES 11.5.2



Label the following

1	Pre-central gyrus
2	Post-central gyrus
3	Central sulcus
4	Pre-frontal cortex
5	Temporal lobe
6	Occipital lobe



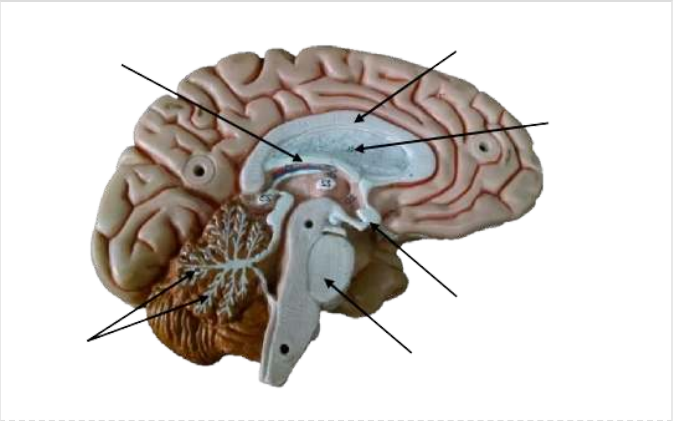
Label the following

1	Amygdala
2	Hippocampus
3	Pituitary gland
4	Medulla Oblongata
5	Pons
6	Thalamus
7	Superior & Inferior colliculi

LAB 11 EXERCISES 11.5.3

Diencephalon and Brain Stem

Midbrain, Lateral ventricle, 3rd ventricle, Cerebral Aqueduct, 4th ventricle, Central canal

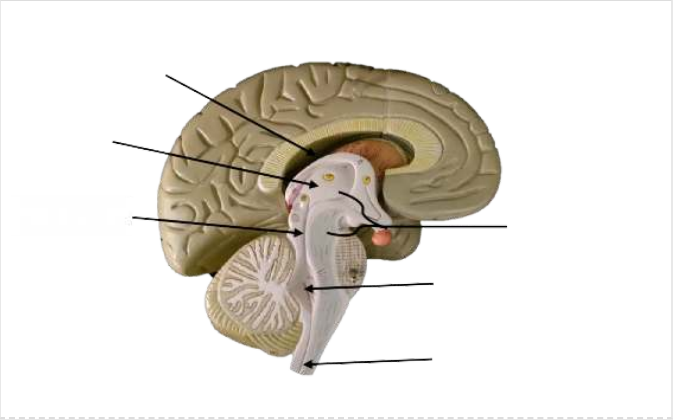


Label the following

1	Arbor vitae
2	Corpus callosu
3	Septum pellucidum
4	Fornix
5	Optic chiasm
6	Pons

LAB 11 EXERCISES 11.5.4

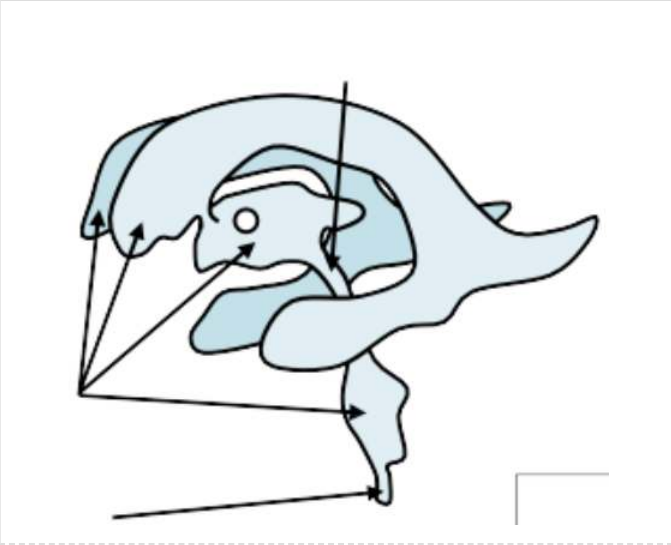
Ventricular System



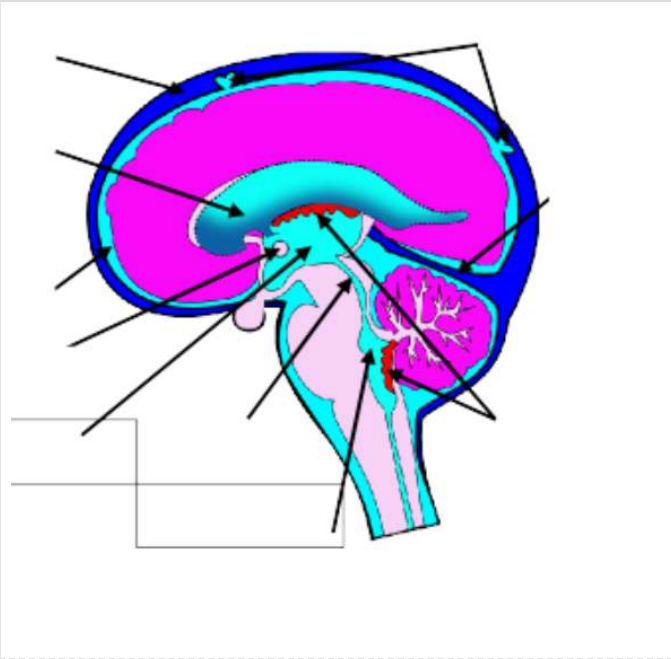
Label the following

1	Midbrain
2	Lateral ventricle
3	3rd ventricle
4	Cerebral Aqueduct
5	4th ventricle
6	Central canal

LAB 11 EXERCISES 11.5.6



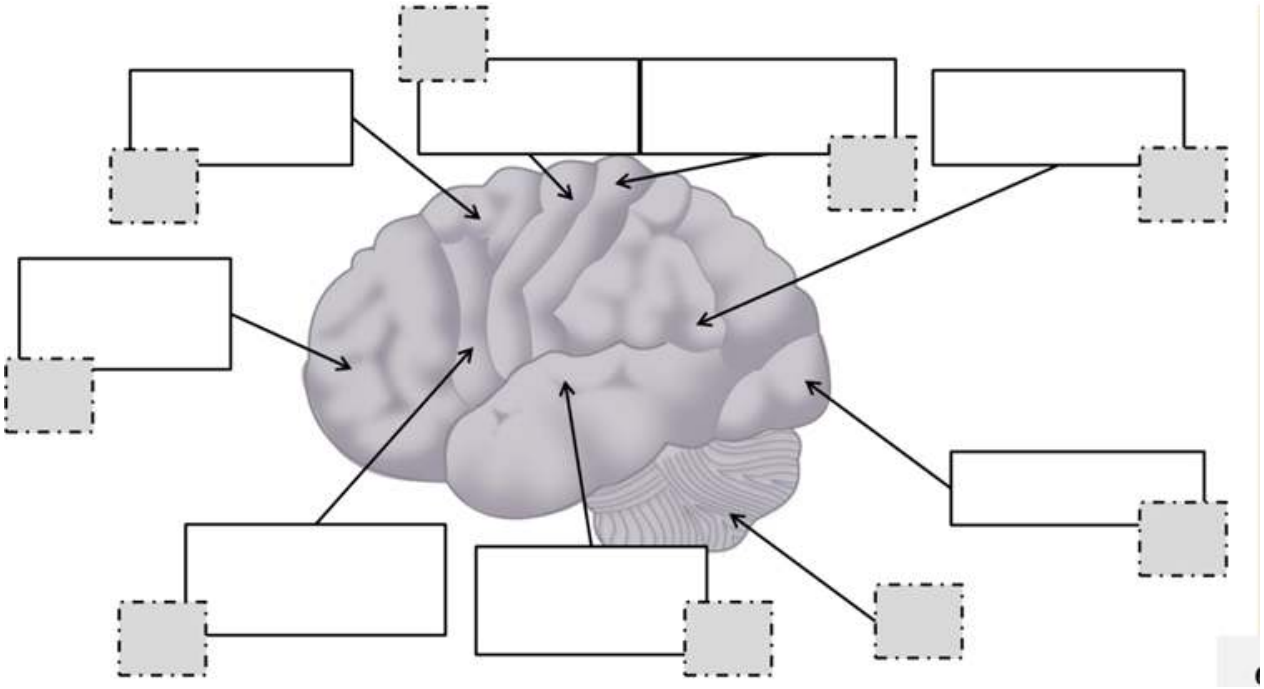
1) **Label** the ventricles, aqueduct and canal.
2) **Draw** two choroid plexuses (in red, if you have a red pen handy).



Label CSF-related areas:

1	Lateral ventricle,
2	Lateral ventricle
3	3rd ventricle
4	4th ventricle
5	Superior sagittal sinus
6	Straight sinus,
7	Subarachnoid space,
8	Cerebral aqueduct,
9	Arachnoid granulation,
10	Choroid plexus,
11	Interthalamic adhesion

LAB 11 EXERCISES 11.5.7



Label the following regions of the cortex

1	Primary motor cortex
2	Primary sensory cortex
3	Primary auditory cortex
4	Primary visual cortex
5	Motor association area
6	Pre-frontal cortex
7	Broca's area
8	Wernicke's area

Match the following symptoms to the brain region they are associated with:

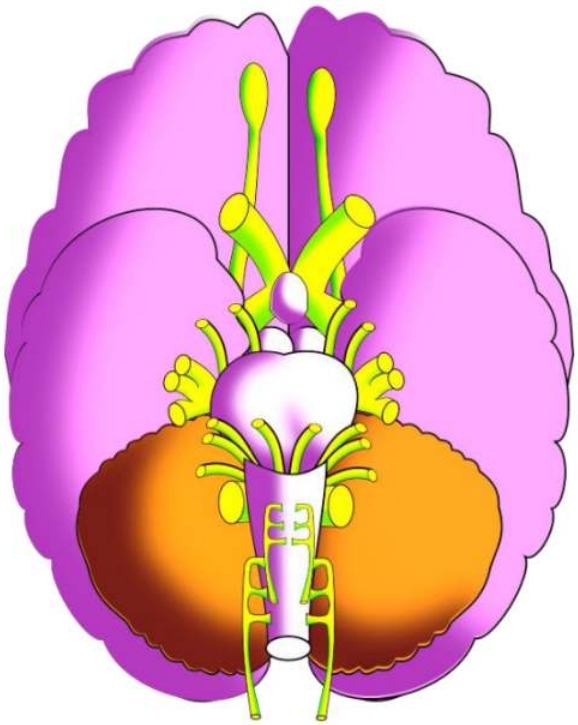
A	Ataxia
B	Inability to form words
C	Nonsensical speech
D	Hearing loss
E	Vision loss
F	Poor decision making
G	Drooping facial muscles
H	Paralysis of fingers
I	Phantom limb

LAB 11 EXERCISES 11.5.8



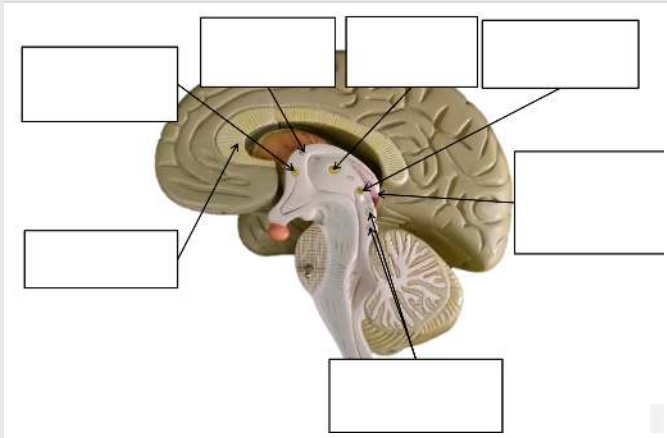
Label the following

1	Falx cerebri
2	Tentorum cerebellum
3	Superior sagittal sinus
4	Straight sinus



Label the following

1	Pituitary gland
2	Mamillary bodies
3	Pons
4	Medulla oblongata
5	Temporal lobe
6	Frontal lobe
7	Cerebellum

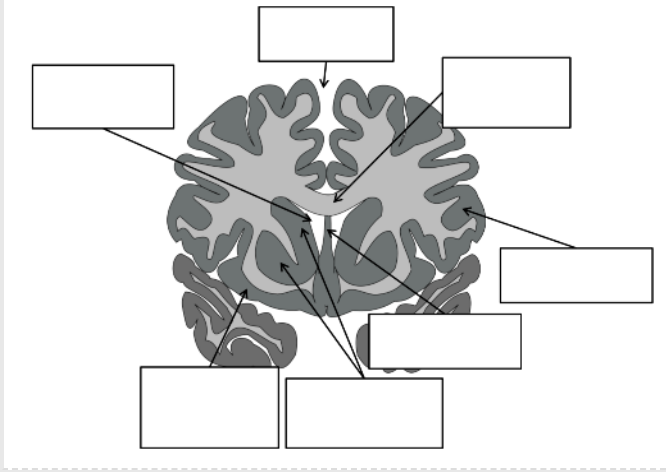


Identify the following regions:

1	Corpus callosum
2	Anterior commissure
3	Posterior commissure
4	Fornix
5	Interthalamic adhesion
6	Choroid plexus
7	Corpora quadrigemina

LAB 11 EXERCISES 11.5.9

Coronal View and Miscellaneous



Identify the following regions:

1	Septum pellucidum
2	Grey matter
3	Insula
4	Basal ganglia
5	Corpus callosum
6	Lateral ventricle
7	Longitudinal fissure

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11.6: MODELS- 3D Brains, Ventricles, Sagittal and Coronal Brain Slices, Torsos, Sagittal Head

3D Brains, Ventricles, Sagittal & Coronal Brain Slices, Torsos, Sagittal Head

Cerebrum

- Gyrus (plural = gyri)
  - Pre-central gyrus
  - Post-central gyrus
- Sulcus (plural = sulci or sulcusses)
  - Central sulcus
  - Lateral sulcus
- Fissures
  - Longitudinal fissure
- Lobes of cerebrum
  - Frontal lobe
  - Parietal lobe
  - Temporal lobe
  - Occipital lobe
  - Insula
- Cerebral cortex (gray matter)
- Basal nuclei
- White matter (tracts)
- Corpus callosum
- Septum pellucidum
- Fornix
- Choroid Plexuses
- Olfactory bulb
- Olfactory tract
- Optic chiasm
- Optic tract

Brain stem

- Midbrain
- Pons
- Medulla oblongata

Cerebellum

- Vermis
- Cerebellar cortex
- Arbor vitae

Ventricular system

- Lateral ventricles
- Interventricular foramen
- 3rd ventricle
- Cerebral aqueduct
- 4th ventricle
- Central canal

Meningeal layers

- Dura mater
- Falx cerebri
- Falx cerebelli
- Tentorium cerebella
- Dural venous sinuses
- Straight sinus
- Superior sagittal sinus
- Arachnoid mater
- Arachnoid granulations
- Pia mater

Diencephalon

- Thalamus
  - Interthalamic adhesion
- Anterior commissure
- Posterior commissure
- Hypothalamus
- Pituitary gland
  - Infundibulum
- Mamillary bodies
- Pineal gland
- Copora Quadrigemina (superior & inferior colliculi)

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11.7: Sheep Brain Dissection

Background Information:

The sheep brain is remarkably similar to the human brain. One major difference, however, is in proportion. For example, the sheep brain has a proportionately smaller cerebrum. Another difference is in orientation of the spinal cord. The sheep spinal cord is orientated anterior to posterior, as in any four-legged animal. The human spinal cord is orientated superior to inferior. This orientation difference has a major affect on the location of the brain stem. The sheep brain stem is located more towards the rear (posteriorly). The sheep skull, in order to compensate for this, has the foramen magnum located more towards the rear of the skull. In humans, since we walk upright (bipedalism), the spinal cord is in a more vertical plane, thus the foramen magnum is located centrally on the bottom of the skull (inferiorly). By observing the movement of this major skull feature from the rear (as in very early human ancestors) to the current location (modern humans), scientists have been able to determine when the human species began to walk upright on two legs.

Dissection Instructions:

1. Obtain a preserved sheep brain from the bucket in the front of the classroom. Place this on your dissection tray.
2. You will need the following dissection tools to properly perform this lab:

- scalpel
- scissors
- probes

3. The sheep brain is enclosed in a tough outer covering called the dura mater. You can still see some structures on the brain before you remove the dura mater. Take special note of the pituitary gland and the optic chiasma. These two structures will likely be pulled off when you remove the dura mater.



Figure **11.7.1**: Brain with Dura Mater Intact



Figure 11.7.2: Removal of the Dura Mater

4. This image shows the ventral surface of the sheep's brain with most of the dura mater removed. The pituitary gland and the optic chiasma are still intact. (A = pituitary gland, B = optic chiasma, C = olfactory bulb)



Figure 11.7.3: A = pituitary gland, B = optic chiasma, C = olfactory bulb

5. On this image, the dura mater has been completely removed, you can still see the optic chiasma but the pituitary gland is missing. The infundibulum (pituitary stalk) is now visible in the center. Careful dissection also reveals two other large nerves: the oculomotor

nerves (C.2). Often these two nerves are removed with the dura mater, but in this image they are still intact.

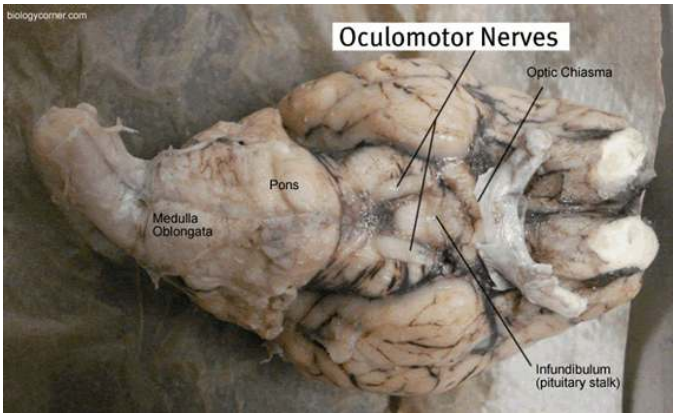


Figure **11.7.4**: Ventral view of the brain with dura mater removed

These two figures show the fissures located on the surface of the brain. Longitudinal fissure Transverse fissure



Figure **11.7.5**: These two figures show the fissures located on the surface of the brain with the longitudinal fissure on the left and the transverse fissure on the right

6. If you flip the brain over to the other side, you can see the **cerebellum**, it will be loosely attached to the **cerebrum** in most cases. If you did not carefully remove the dura mater you may have accidentally pulled the entire cerebellum away from the brain. The lobes of the brain are visible, as well as the **transverse fissure**, which separates the cerebrum from the cerebellum. The convolutions of the brain are also visible as bumps (**gyri**) and grooves (**sulci**).

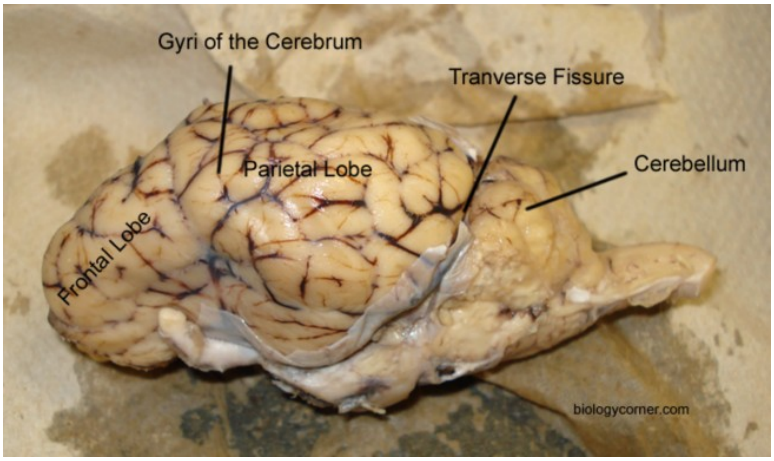


Figure **11.7.6**:Dorsal View of the Sheep Brain

7. The gap between the cerebrum and the cerebellum at the transverse fissure can reveal some internal parts of the brain. In this image, a student is bending the cerebellum down to show the **superior and inferior colliculi**. Just behind the colliculi, the pineal gland is just barely visible.



Figure **11.7.7**: the superior and inferior colliculi

8. Using a scalpel and the **longitudinal fissure** as a guide, the brain is separated into the left and the right hemispheres. Sharp scalpels work best for this procedure. Always leave the specimen in the dissecting tray when cutting it, do NOT hold it in your hand!

If you are very careful, you will cleanly cut the brain into two halves and can see the internal structures, the most visible of them being the **corpus callosum**, which divides the left and right hemispheres. The cerebrum will still be visible as a wrinkled structrure, and you can even locate the "bumps" of the **superior and inferior colliculi**. Remember, you located those structures by pulling down the cerebellum.

The cerebellum, when cut will have a very distinct tree-like white area within it. This is called the **arbor vitae**, or the tree of life.

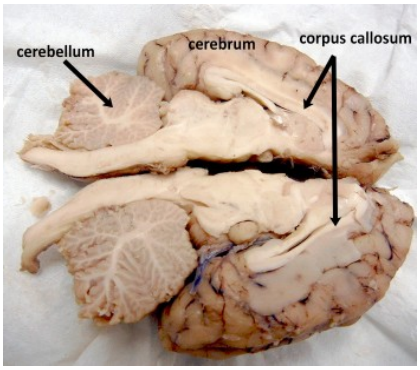


Figure **11.7.8**: The cut cerebellum exposing the arbor vitae

9. In the image below, a probe indicates the location of the **lateral ventricle**.

Figure **11.7.9**: The probe indicate the location of t **lateral ventric**

10. Once the brain is cut this way, the colliculi can also be seen from the inside and the pineal gland is revealed only if you made a very careful incision.

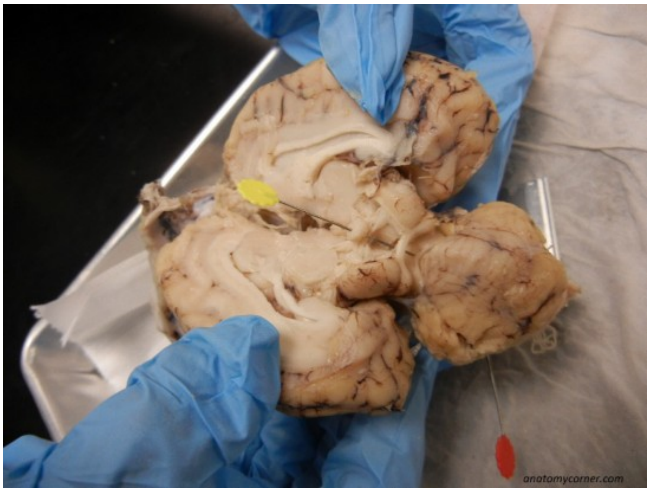


Figure **11.7.10**: *On this image, the pineal is pinned in yellow and the pin continues on to where the colliculi have been bisected.*

11. Other major structures are visible, here the probe indicates the **arbor vitae** (tree of life) found within the cerebellum. The fissure between the cerebrum and the cerebellum is called the **transverse fissure**. The cerebellum only loosely connects to the rest of the brain when the dura is removed.

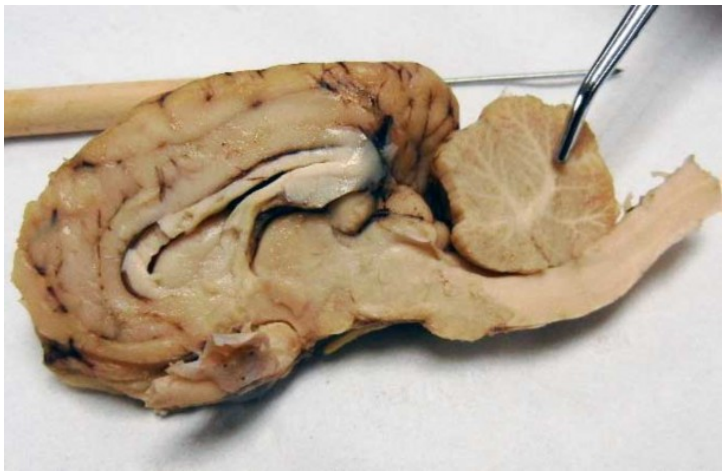


Figure **11.7.11**: The probe indicates the **arbor vitae**

12. This brain is pinned to show the **pineal gland** (blue pin), **thalamus** (red pin) and **lateral ventricle** (green pin).

Figure **11.7.12**: The **pineal gland** (blue pin), **thalam** (red p and **lateral ventric** (green pin)

13. The image below shows a cleanly separated brain with the major internal structures visible and labeled.

Figure **11.7.13**: The major interna structu visible and labeled

14. Finally, a section of the brain is cut to examine the difference between white matter and gray matter.



Figure **11.7.14**: Cut to show the difference between white and grey matter

15. Once you have made the cut like in the above diagram, you should be able to see the difference between the white and gray matter, just like the diagram below.

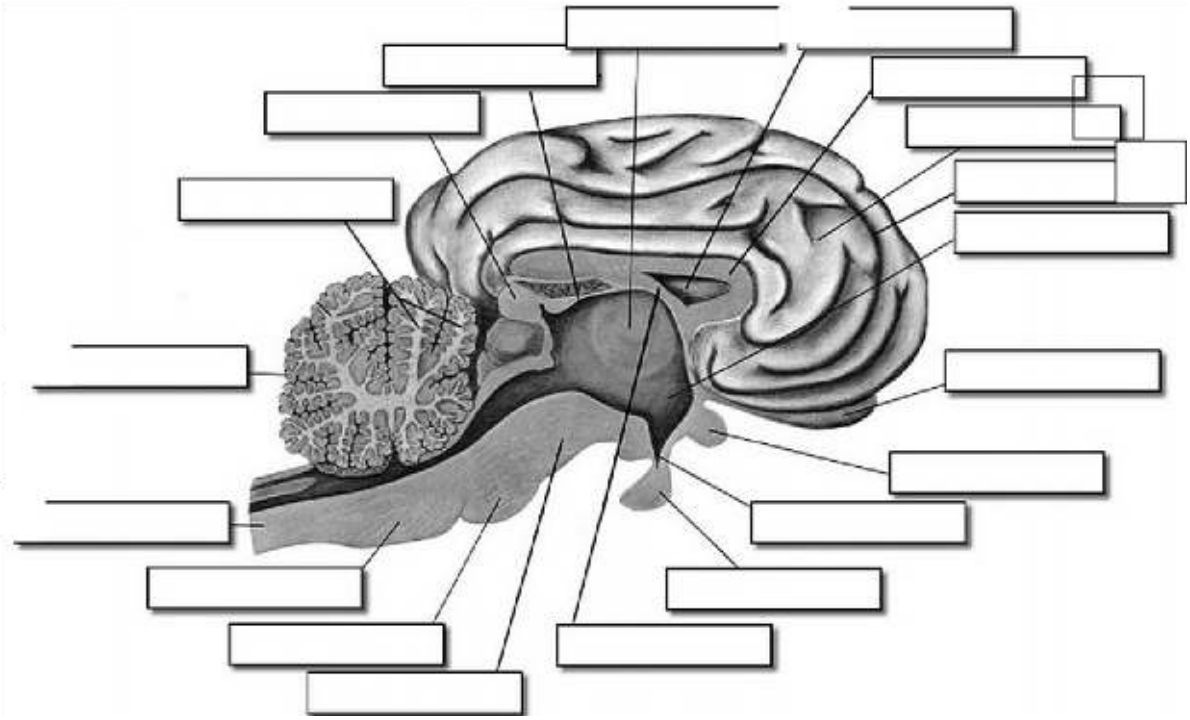
Figure **11.7.15**: Showin the differer betwee the wh and g matter

16. The diagram below will help you understand the difference between the gyri and the sulcus.

Figure **11.7.16**: Showin the differer betwee the g and sulcus

Sheep brain dissection maybe downloaded at the following site:https://www.biologycorner.com/anatomy/chap9.html

LAB 11 EXERCISES 11.7.1:



Sheep Brain Dissection Analysis:

Match the structure to the description

a	looks like a butt		Arbor Vitae
b	leathery covering over the entire brain		Lateral Ventricle
c	cauliflower, the area toward the back of the brain		Optic Chiasma
d	behind the colliculi, looks like a little nub		Superior Colliculi
e	looks like a "tree"		Dura Mater
f	the rounded part of the brain stem		Cerebellum
g	shaped like an X		Pineal Gland
h	large area under the corpus callosum		Thalamus
i	space for fluid between the corpus callosum and the fornix		Pons
j	contains nerves, connects to the far front of the brain		Olfactory Bulb

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CHAPTER OVERVIEW

12: Cranial and Spinal Nerves

12.1: The Spinal Cord

12.2: Exercises

12.3: MODELS" Spinal Cord, Spinal Columns (Flat), Spinal Cord in Vertebral Column, Blank Brain Picture

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12.1: The Spinal Cord

The description of the CNS is concentrated on the structures of the brain, but the spinal cord is another major organ of the system. Whereas the brain develops out of expansions of the neural tube into primary and then secondary vesicles, the spinal cord maintains the tube structure and is only specialized into certain regions. As the spinal cord continues to develop in the newborn, anatomical features mark its surface. The anterior midline is marked by the **anterior median fissure**, and the posterior midline is marked by the **posterior median sulcus**. Axons enter the posterior side through the **dorsal (posterior) nerve root**, which marks the **posterolateral sulcus** on either side. The axons emerging from the anterior side do so through the **ventral (anterior) nerve root**. Note that it is common to see the terms dorsal (dorsal = "back") and ventral (ventral = "belly") used interchangeably with posterior and anterior, particularly in reference to nerves and the structures of the spinal cord. You should learn to be comfortable with both.

Gray Horns

In cross-section, the gray matter of the spinal cord has the appearance of an ink-blot test, with the spread of the gray matter on one side replicated on the other—a shape reminiscent of a bulbous capital "H." As shown in **Figure 12.1.1**, the gray matter is subdivided into regions that are referred to as horns.

The **posterior horn** is responsible for sensory processing. The **anterior horn** sends out motor signals to the skeletal muscles. The **lateral horn**, which is only found in the thoracic, upper lumbar, and sacral regions, is the central component of the sympathetic division of the autonomic nervous system.

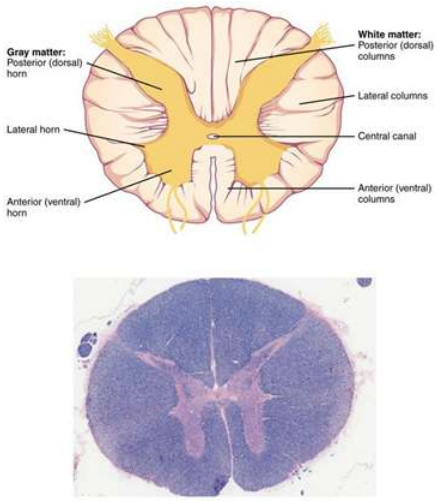


Figure **12.1.1**: **Cross-section of Spinal Cord** The cross-section of a thoracic spinal cord segment shows the posterior, anterior, and lateral horns of gray matter, as well as the posterior, anterior, and lateral columns of white matter. LM × 40. (Micrograph provided by the Regents of University of Michigan Medical School © 2012) (CC-BY-4.0 Open Oregon, Anatomy and Physiology)

Cranial Nerves

The nerves attached to the brain are the cranial nerves, which are primarily responsible for the sensory and motor functions of the head and neck (one of these nerves targets organs in the thoracic and abdominal cavities as part of the parasympathetic nervous system). There are twelve cranial nerves, which are designated CNI through CNXII for "Cranial Nerve," using Roman numerals for 1 through 12. They can be classified as sensory nerves, motor nerves, or a combination of both, meaning that the axons in these nerves originate out of sensory ganglia external to the cranium or motor nuclei within the brain stem. Sensory axons enter the brain to synapse in a nucleus. Motor axons connect to skeletal muscles of the head or neck. Three of the nerves are solely composed of sensory fibers; five are strictly motor; and the remaining four are mixed nerves.

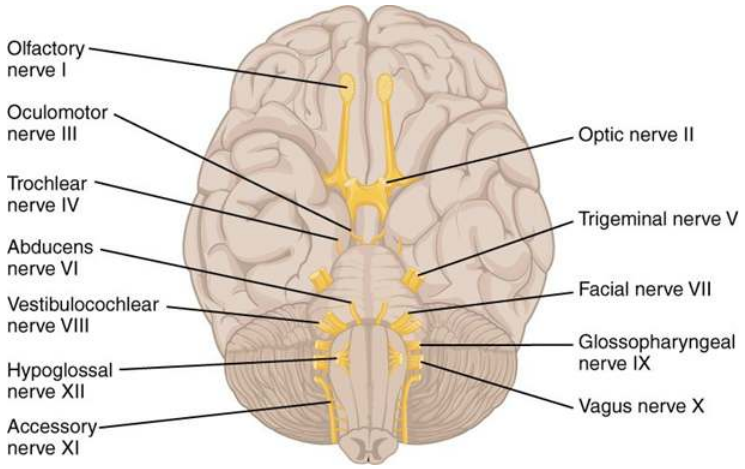
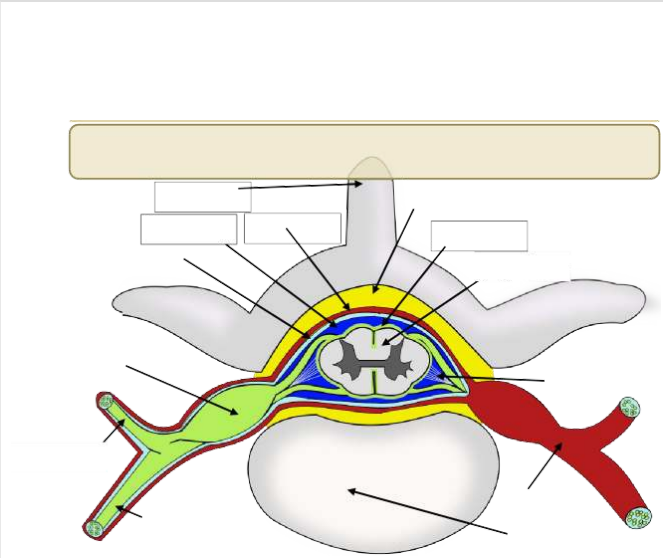


Figure **12.1.2**: **The Cranial Nerves** The anatomical arrangement of the roots of the cranial nerves observed from an inferior view of the brain. (CC-BY-4.0, OpenStax, Human Anatomy)

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12.2: Exercises

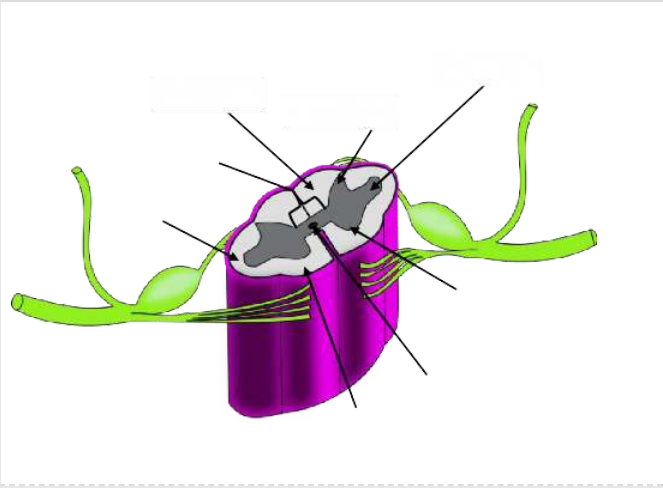
LAB 12 EXERCISES 12.2.1



Label the following

1	Dura mater
2	Arachnoid mater
3	Pia mater
4	Epidural space
5	Subarachnoid space
6	Spinal cord
7	Denticulate ligament
8	Dorsal Root Ganglion
9	Body (of vertebrae)
10	Spinous process (of vertebrae)
11	Dorsal Ramus
12	Ventral ramus

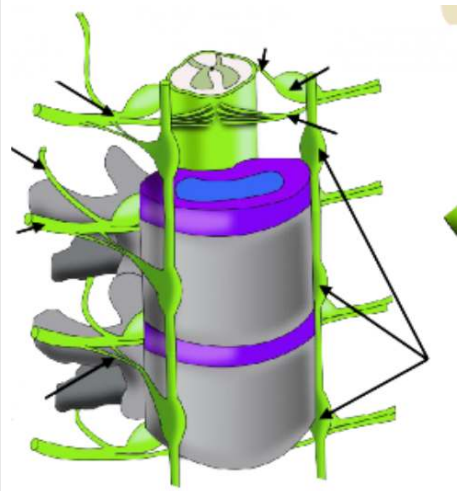
LAB 12 EXERCISES 12.2.2



Label the following

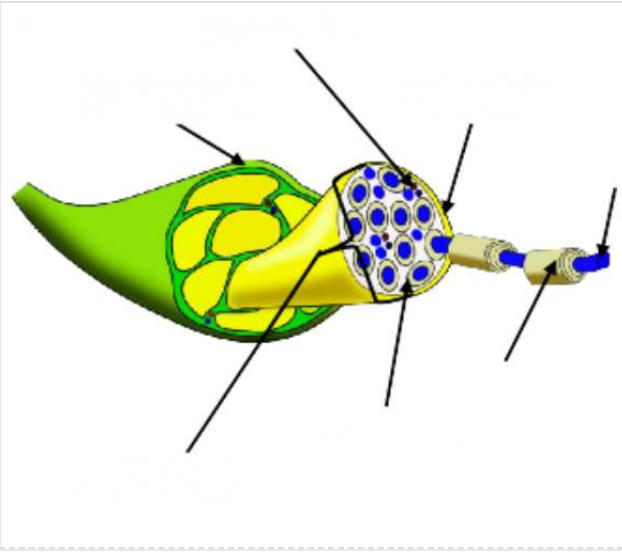
1	Dorsal horn
2	Lateral horn
3	Ventral horn
4	Dorsal column
5	Lateral column
6	Ventral column
7	Central column
8	Grey commisure

LAB 12 EXERCISES 12.2.3



Label the following

1	Dorsal root
2	Ventral root
3	Dorsal root ganglion
4	Sympathetic chain ganglion
5	Spinal nerve
6	Rami communicantes
7	Dorsal ramus
8	Ventral ramus

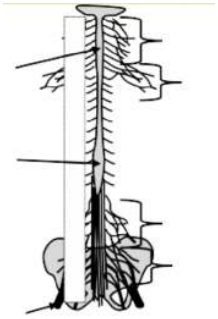


Label the parts of a nerve

1	Blood vessels
2	Schwann cell
3	Fascicle
4	Epineurium
5	Perineurium
6	Endoneurium
7	Axon

LAB 12 EXERCISES 12.2.4

Vertebral Column



A



B

Identify the following

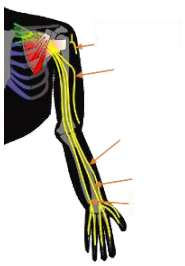
1	Cervical plexus
2	Brachial plexus
3	Lumbar plexus
4	Sacral plexus
5	Sciatic nerve
6	Cervical enlargement
7	Lumbar enlargement

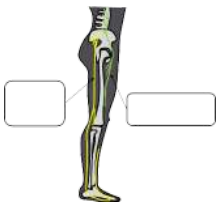
Match these items to their relative position: Cervical enlargement, Lumbar enlargement*, Conus medullaris, Cauda equina, Filum terminale (** trickier than you might expect)*

Cervical region:	
Thoracic region:	
Lumbo-sacral region:	

LAB 12 EXERCISES 12.2.5

Peripheral nerves and plexuses



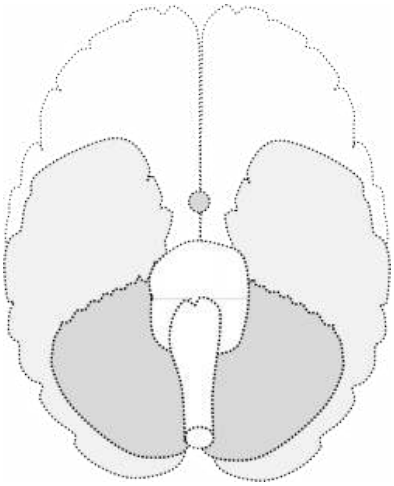


Label the nerves

1	Axillary nerve
2	Median nerve
3	Radial nerve
4	Ulnar nerve
5	Musculocutaneous nerve

LAB 12 EXERCISES 12.2.6

Draw your own cranial nerve study sheet



	Mnemonic	Cranial nerve name
I		
II		
III		
IV		
V		
VI		
VII		
VIII		
IX		
X		
XI		
XII		

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12.3: MODELS" Spinal Cord, Spinal Columns (Flat), Spinal Cord in Vertebral Column, Blank Brain Picture

Spinal cord anatomy

Meningeal layers	Dura mater	Epidural space
	Arachnoid mater	Subarachnoid space
	Pia mater	Denticulate ligaments
Conus medullaris		
Cauda equina	Filum terminale	
Cervical enlargement		
Lumbar enlargement		
Spinal nerve	Ventral root	
	Dorsal root	
	Dorsal root ganglion	
	Ventral Ramus	
	Dorsal Ramus	
Spinal cord cross sectional anatomy:	Dorsal horn	
	Lateral horn	
	Ventral horn	
	Dorsal column	
	Lateral column	
	Ventral column	
	Gray commissure	
	Central canal	
	Dorsal median sulcus	
	Ventral median fissure	

Cranial nerves

I Olfactory
II Optic
III Occulomotor
IV Trochlear
V Trigeminal
VI Abducens
VII Facial
VIII Acoustic / Vestibulocochlear
IX Glossopharyngeal

X Vagus
XI (spinal) Accessory
XII Hypoglossal

Peripheral Nerves

Nerve anatomy:	Epineurium	
	Perineurium	
	Endoneurium	
	Fascicle	
Cervical Plexus	Phrenic n.	
Brachial Plexus	Axillary n.	
	Radial n.	
	Ulnar n.	
	Median n.	
	Musculocutaneous n.	
Intercostal nerves		
Lumbar plexus	Femoral n.	
Sacral plexus	Sciatic n.	
	Pudendal n.	
Autonomic NS	Sympathetic chain ganglion	
	Sympathetic chain	
	Rami communicantes	
	Lateral horn	

Note: remember that dorsal/posterior, and ventral/anterior are interchangeable.

Histology

Spinal cord & dorsal root ganglia	See cross sectional anatomy	
See cross sectional anatomy		

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CHAPTER OVERVIEW

13: The Somatic Nervous System (Special Senses)

13.1: Gustation (Taste)

13.2: Olfaction (Smell)

13.3: Audition (Hearing)

13.4: Vision

13.5: Exercises

13.6: MODELS- Eye, Ear, Torso, Mid-Sagittal Head and Cochlea

13.7: Cow Eye Dissection

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13.1: Gustation (Taste)

Gustation is the special sense associated with the tongue. The surface of the tongue, along with the rest of the oral cavity, is lined by a stratified squamous epithelium. Raised bumps called **papillae** (singular = papilla) contain the structures for gustatory transduction. There are four types of papillae, based on their appearance (Figure **13.1.1**): circumvallate, foliate, filiform, and fungiform. Within the structure of the papillae are **taste buds** that contain specialized **gustatory receptor cells** for the transduction of taste stimuli. These receptor cells are sensitive to the chemicals contained within foods that are ingested, and they release neurotransmitters based on the amount of the chemical in the food.

Figure
The Tongu
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13.2: Olfaction (Smell)

Like taste, the sense of smell, or **olfaction**, is also responsive to chemical stimuli. The olfactory receptor neurons are located in a small region within the superior nasal cavity (Figure **13.2.1**). This region is referred to as the **olfactory epithelium** and contains bipolar sensory neurons. Each **olfactory sensory neuron** has dendrites that extend from the apical surface of the epithelium into the mucus lining the cavity. As airborne molecules are inhaled through the nose, they pass over the olfactory epithelial region and dissolve into the mucus. These **odorant molecules** bind to proteins that keep them dissolved in the mucus and help transport them to the olfactory dendrites. The odorant–protein complex binds to a receptor protein within the cell membrane of an olfactory dendrite. These receptors are G protein–coupled, and will produce a graded membrane potential in the olfactory neurons.

The axon of an olfactory neuron extends from the basal surface of the epithelium, through an olfactory foramen in the cribriform plate of the ethmoid bone, and into the brain. The group of axons called the olfactory tract connect to the **olfactory bulb** on the ventral surface of the frontal lobe. From there, the axons split to travel to several brain regions. Some travel to the cerebrum, specifically to the primary olfactory cortex that is located in the inferior and medial areas of the temporal lobe. Others project to structures within the limbic system and hypothalamus, where smells become associated with long-term memory and emotional responses. This is how certain smells trigger emotional memories, such as the smell of food associated with one’s birthplace. Smell is the one sensory modality that does not synapse in the thalamus before connecting to the cerebral cortex. This intimate connection between the olfactory system and the cerebral cortex is one reason why smell can be a potent trigger of memories and emotion.

The nasal epithelium, including the olfactory cells, can be harmed by airborne toxic chemicals. Therefore, the olfactory neurons are regularly replaced within the nasal epithelium, after which the axons of the new neurons must find their appropriate connections in the olfactory bulb. These new axons grow along the axons that are already in place in the cranial nerve.

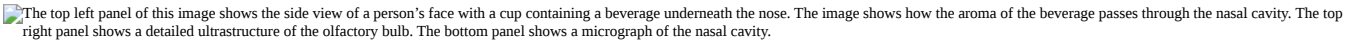

The top left panel of this image shows the side view of a person's face with a cup containing a beverage underneath the nose. The image shows how the aroma of the beverage passes through the nasal cavity. The top right panel shows a detailed ultrastructure of the olfactory bulb. The bottom panel shows a micrograph of the nasal cavity.

Figure **13.2.1**: **The Olfactory System** (a) The olfactory system begins in the peripheral structures of the nasal cavity. (b) The olfactory receptor neurons are within the olfactory epithelium. (c) Axons of the olfactory receptor neurons project through the cribriform plate of the ethmoid bone and synapse with the neurons of the olfactory bulb (tissue source: simian). LM × 812. (Micrograph provided by the Regents of University of Michigan Medical School © 2012) (CC-BY-4.0, OpenStax, Human Anatomy)

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13.3: Audition (Hearing)

Hearing, or **audition**, is the transduction of sound waves into a neural signal that is made possible by the structures of the ear (Figure 13.3.1). The large, fleshy structure on the lateral aspect of the head is known as the **auricle**. Some sources will also refer to this structure as the pinna, though that term is more appropriate for a structure that can be moved, such as the external ear of a cat. The C-shaped curves of the auricle direct sound waves toward the auditory canal. The canal enters the skull through the external auditory meatus of the temporal bone. At the end of the auditory canal is the **tympanic membrane**, or ear drum, which vibrates after it is struck by sound waves. The auricle, ear canal, and tympanic membrane are often referred to as the **external ear**. The **middle ear** consists of a space spanned by three small bones called the **ossicles**. The three ossicles are the **malleus**, **incus**, and **stapes**, which are Latin names that roughly translate to hammer, anvil, and stirrup. The malleus is attached to the tympanic membrane and articulates with the incus. The incus, in turn, articulates with the stapes. The stapes is then attached to the **inner ear**, where the sound waves will be transduced into a neural signal. The middle ear is connected to the pharynx through the Eustachian tube, which helps equilibrate air pressure across the tympanic membrane. The tube is normally closed but will pop open when the muscles of the pharynx contract during swallowing or yawning. (CC-BY-4.0, OpenStax, Human Anatomy)

Figure 13.3.1: **Structu of the** The external contains auricle, canal, tympani membra The mi ear cont the ossi and connecte to pharynx the Eustachi tube. inner contains cochlea vestibule which responsi for audi and equilibri respecti (CC-BY- 4.0, OpenSta Human Anatom

A cross-sectional view of the cochlea shows that the scala vestibuli and scala tympani run along both sides of the cochlear duct (Figure 13.3.2). The cochlear duct contains several **organs of Corti**, which tranduce the wave motion of the two scala into neural signals. The organs of Corti lie on top of the **basilar membrane**, which is the side of the cochlear duct located between the organs of Corti and the scala tympani. As the fluid waves move through the scala vestibuli and scala tympani, the basilar membrane moves at a specific spot, depending on the frequency of the waves. Higher frequency waves move the region of the basilar membrane that is close to the base of the cochlea. Lower frequency waves move the region of the basilar membrane that is near the tip of the cochlea.

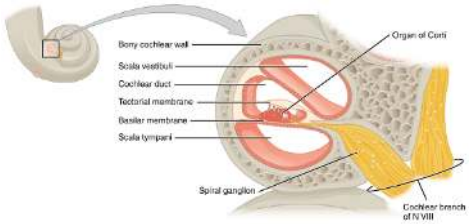


Figure **13.3.2**: Cross-sectional view of the cochlea. (CC-BY-4.0, OpenStax, Human Anatomy)

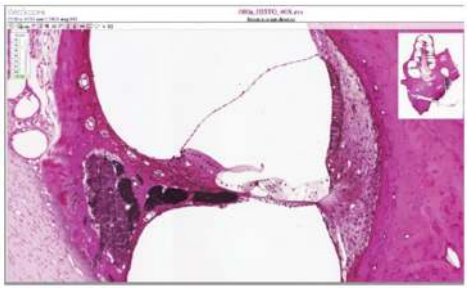


Figure **13.3.3**: **Cochlea and Organ of Corti** LM × 412. (Micrograph provided by the Regents of University of Michigan Medical School © 2012) (CC-BY-4.0, OpenStax, Human Anatomy)

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13.4: Vision

Vision is the special sense of sight that is based on the transduction of light stimuli received through the eyes. The eyes are located within either orbit in the skull. The bony orbits surround the eyeballs, protecting them and anchoring the soft tissues of the eye (Figure **13.4.1**). The eyelids, with lashes at their leading edges, help to protect the eye from abrasions by blocking particles that may land on the surface of the eye. The inner surface of each lid is a thin membrane known as the **palpebral conjunctiva**. The conjunctiva extends over the white areas of the eye (the sclera), connecting the eyelids to the eyeball. Tears are produced by the **lacrimal gland**, located beneath the lateral edges of the nose. Tears produced by this gland flow through the **lacrimal duct** to the medial corner of the eye, where the tears flow over the conjunctiva, washing away foreign particles.

Figure **13.4.1**: T **Eye in Orbit** T eye located within orbit surroun by tissues t protect support functior The o is surroun by cra bones the sk (CC-BY 4.0, OpenSt Human Anatom

Movement of the eye within the orbit is accomplished by the contraction of six **extraocular muscles** that originate from the bones of the orbit and insert into the surface of the eyeball (Figure **13.4.2**). Four of the muscles are arranged at the cardinal points around the eye and are named for those locations. They are the **superior rectus**, **medial rectus**, **inferior rectus**, and **lateral rectus**. When each of these muscles contract, the eye to moves toward the contracting muscle. For example, when the superior rectus contracts, the eye rotates to look up. The **superior oblique** originates at the posterior orbit, near the origin of the four rectus muscles. However, the tendon of the oblique muscles threads through a pulley-like piece of cartilage known as the **trochlea**. The tendon inserts obliquely into the superior surface of the eye. The angle of the tendon through the trochlea means that contraction of the superior oblique rotates the eye medially. The **inferior oblique** muscle originates from the floor of the orbit and inserts into the inferolateral surface of the eye. When it contracts, it laterally rotates the eye, in opposition to the superior oblique. Rotation of the eye by the two oblique muscles is necessary because the eye is not perfectly aligned on the sagittal plane. When the eye looks up or down, the eye must also rotate slightly to compensate for the superior rectus pulling at approximately a 20-degree angle, rather than straight up. The same is true for the inferior rectus, which is compensated by contraction of the inferior oblique. A seventh muscle in the orbit is the **levator palpebrae superioris**, which is responsible for elevating and retracting the upper eyelid, a movement that usually occurs in concert with elevation of the eye by the superior rectus (see Figure **13.4.3**).

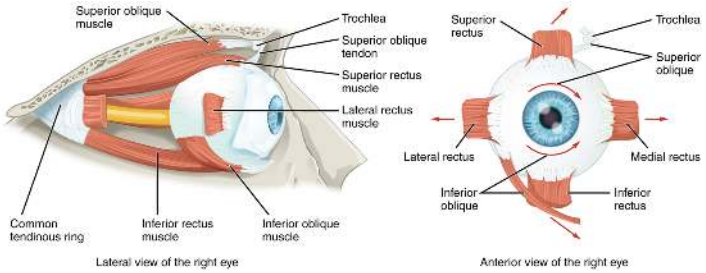


Figure **13.4.2**: **Extraocular Muscles** The extraocular muscles move the eye within the orbit. (CC-BY-4.0, OpenStax, Human Anatomy)

Figure **13.4.3**: **Structu of the I** The sph of the can divided into anterior and posterio chambe The v of the is compos of th layers: fibrous tunic, vascular tunic, neural tunic. Within neural tunic is retina, with th layers cells two synaptic layers betweer The cer of retina a sn indentat known the fov (CC-BY 4.0, OpenSta Human Anatom

Light falling on the retina causes chemical changes to pigment molecules in the photoreceptors, ultimately leading to a change in the activity of the RGCs. Photoreceptor cells have two parts, the **inner segment** and the **outer segment** (Figure **13.4.4**). The inner segment contains the nucleus and other common organelles of a cell, whereas the outer segment is a specialized region in which photoreception takes place. There are two types of photoreceptors—rods and cones—which differ in the shape of their outer segment. The rod-shaped

outer segments of the **rod photoreceptor** contain a stack of membrane-bound discs that contain the photosensitive pigment **rhodopsin**. The cone-shaped outer segments of the **cone photoreceptor** contain their photosensitive pigments in infoldings of the cell membrane. There are three cone photopigments, called **opsins**, which are each sensitive to a particular wavelength of light. The wavelength of visible light determines its color. The pigments in human eyes are specialized in perceiving three different primary colors: red, green, and blue.

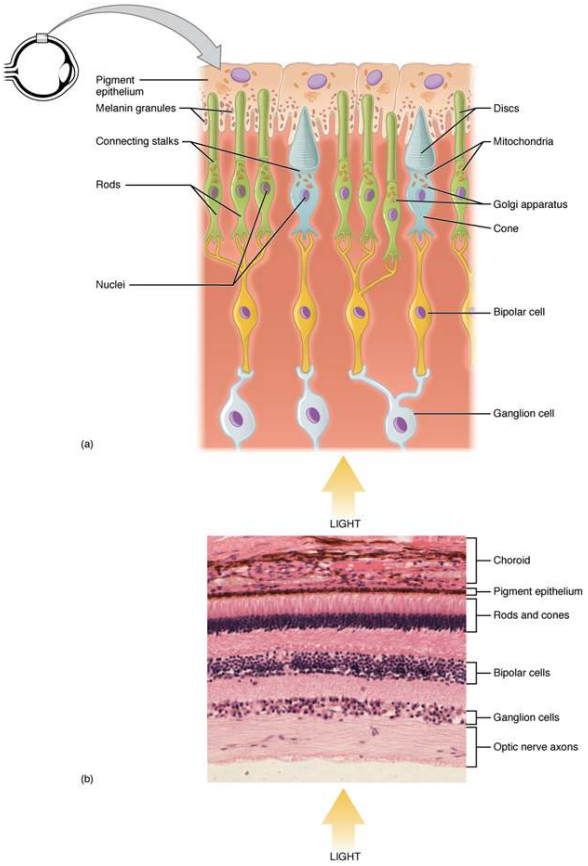
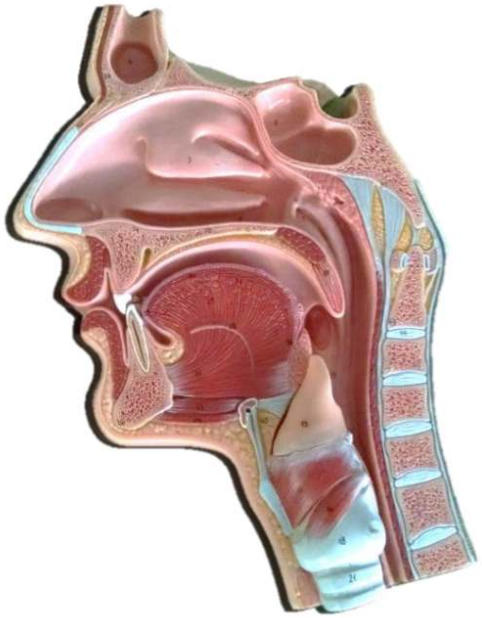


Figure **13.4.4**: **Photoreceptor** (a) All photoreceptors have inner segments containing the nucleus and other important organelles and outer segments with membrane arrays containing the photosensitive opsin molecules. Rod outer segments are long columnar shapes with stacks of membrane-bound discs that contain the rhodopsin pigment. Cone outer segments are short, tapered shapes with folds of membrane in place of the discs in the rods. (b) Tissue of the retina shows a dense layer of nuclei of the rods and cones. LM × 800. (Micrograph provided by the Regents of University of Michigan Medical School © 2012) (CC-BY-4.0, OpenStax, Human Anatomy)

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13.5: Exercises

Lab 13 Exercise 13.5.1

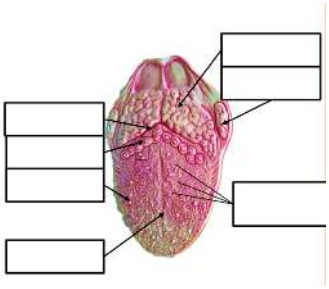


Draw the following:

1	Olfactory bulb
2	Olfactory receptor

Label the following

1	Cribiform plate
2	Olfactory mucosa



Label the following:

1	Circumvallate papillae
2	Fungiform papillae
3	Filiform papillae
4	Sulcus terminalis
5	Median lingual sulcus
6	Lingual tonsil
7	Palatine tonsil

Lab 13 Exercise 13.5.2

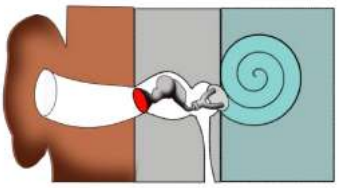
Basic Ear Anatomy

Outer Ear	
Middle Ear	
Inner Ear	

Match the following items to their proper location

1	Auricle
2	Auditory canal
3	Auditory tube
4	Auditory ossicles
5	Cochlea
6	Semicircular Canals
7	Tensor Tympani muscle
8	Cochlea
9	Outer ear
10	Middle ear
11	Inner ear

Label the following on this stylized diagram: Auricle, Auditory canal, Pharyngotympanic tube, Stapes, Incus, Malleus, Tympanic membrane, Cochlea, Outer ear, Middle ear, Inner ear



1	Auricle
2	Auditory canal
3	Pharyngotympanic tube
4	Stapes
5	Incus
6	Malleus
7	Tympanic membrane
8	Cochlea
9	Outer ear
10	Middle ear
11	Inner ear

Lab 13 Exercise 13.5.3

Inner Ear Anatomy



Figure 13.5.2: Copy and Paste Caption here. (Copyright; author via source)

Label the following: Auricle, External Acoustic meatus, Pharyngotympanic tube, Cochlea, Vestibule, Semicircular canals, Tympanic membrane, Middle ear

Label the following:

1	Auricle	5	Vestibule
2	External Acoustic meatus	6	Semicircular canals
3	Pharyngotympanic tube	7	Tympanic membrane
4	Cochlea	8	Middle ear

Lab 13 Exercise 13.5.4

Inner Ear Anatomy



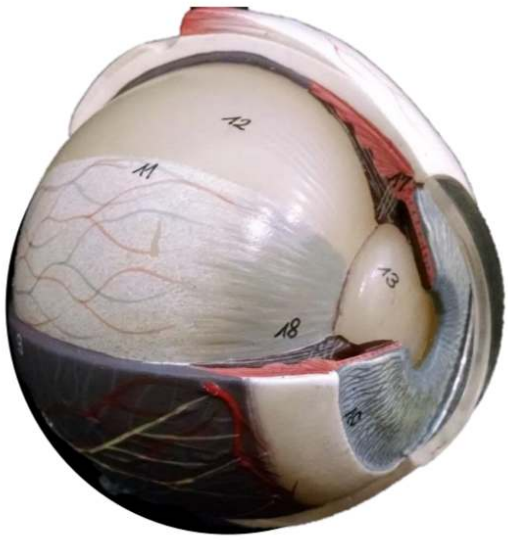
Label the following:

1	Utricle
2	Saccule
3	Semicircular canals
4	Ampulla
5	Cochlea
6	Cranial nerve VIII
7	Malleus
8	Incus
9	Stapes

Lab 13 Exercise 13.5.5

Label the following: Lens, Suspensory ligaments, Ciliary body, Cornea, Iris, Choroid, Vitreous humor

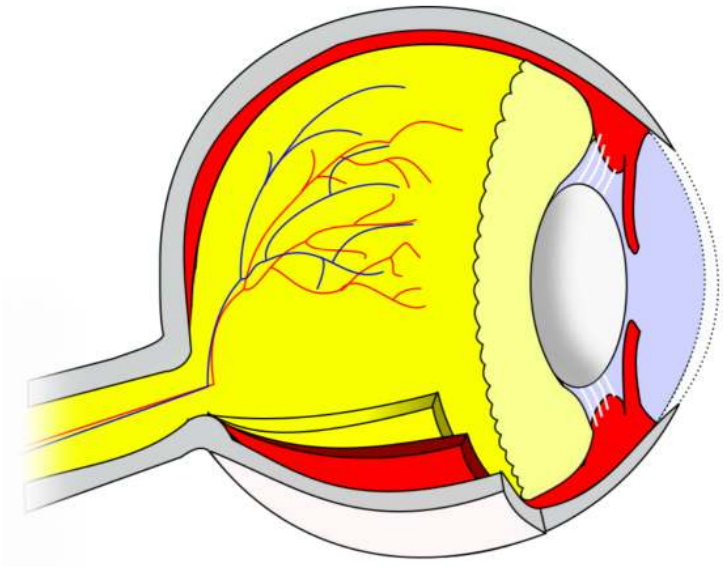
https://med.libretexts.org/@go/page/52791



Label the following:

1	Lens
2	Suspensory ligaments
3	Ciliary body
4	Cornea
5	Iris
6	Choroid
7	Cochlear nerve (*part of the vestibulocochlear nerve)*
8	Vitreous humor

Lab 13 Exercise 13.5.6

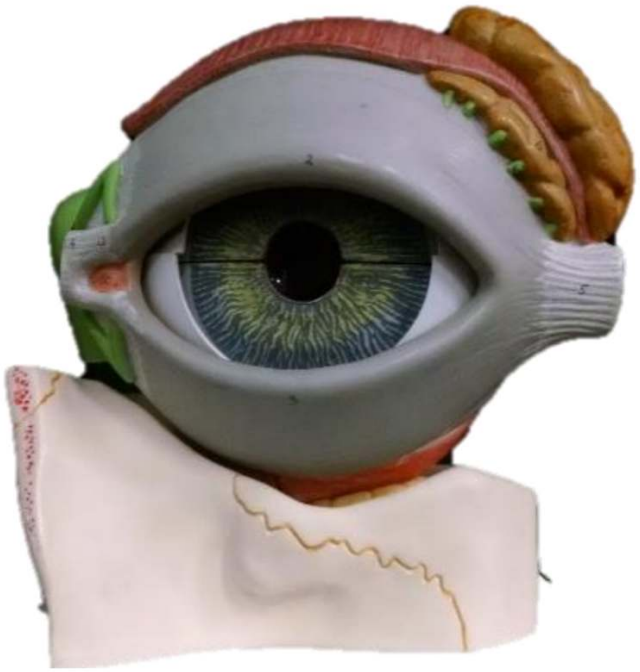


Identify Internal regions and layers of the eye:

1	Fibrous tunic
2	Vascular tunic
3	Neural tunic
4	Iris
5	Lens
6	Corea
7	Sclera
8	Optic nerve
9	Aqueous humor
10	Vitreous humoer
11	Cilary body
12	Suspensory ligaments

Lab 13 Exercise 13.5.7

Eye Anatomy

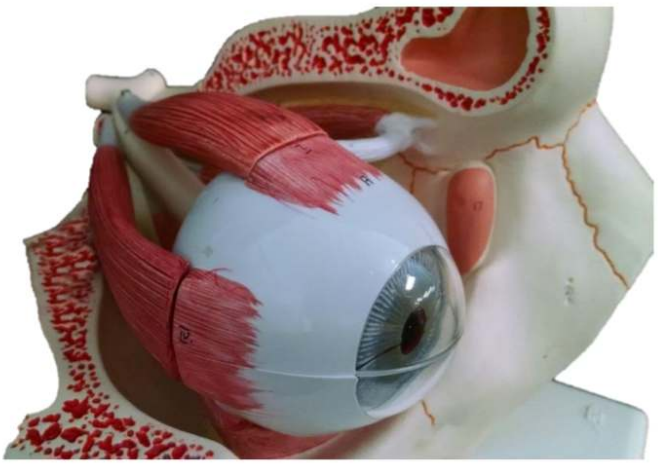


Label the following:

1	Levator palpebrae m.
2	Tarsal plate
3	Lacrimal gland
4	Lacrimal ducts
5	Lacrimal Sac
6	Lacrimal caruncle
7	Medial canthus
8	Lateral canthus

Lab 13 Exercise 13.5.8

Extrinsic Eye Muscles





Identify the extrinsic eye muscles ***(4 are clearly visible)***

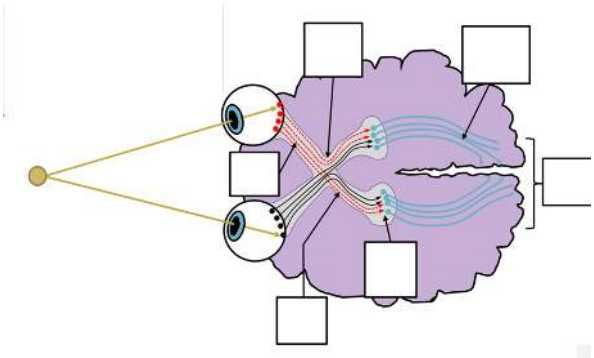
1	
2	
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Lab 13 Exercise 13.5.9

Optical Chiasm

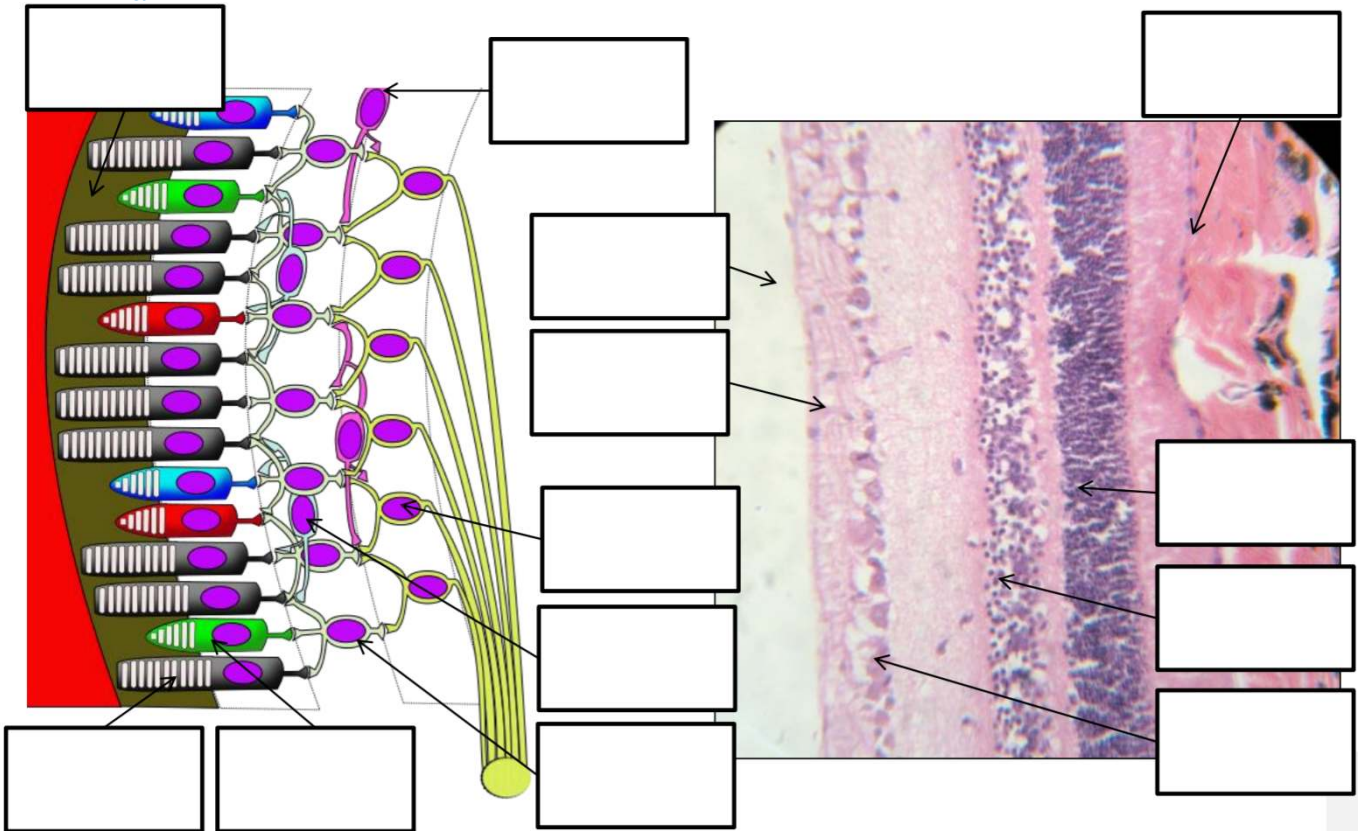
Label the following:

1. Conscious visual sensation;
2. Beginning of axons of retinal ganglion cells;
3. 3rd order neuron;
4. synapse between 2nd & 3rd order neuron;
5. Half of nerve fibers decussate here;
6. First region with axons from only the left side of both eyes



Lab 13 Exercise 13.5.10

Retina Histology



A B

Label the following

1	Rod	6	Rods and cones
2	Cone	7	Bipolar cells
3	Horizontal Cell	8	Ganglion cells
4	Bipolar Cell	9	Optic nerve axons
5	Ganglion cell	10	Pigmented epithelium
		11	Vitreous humor

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13.6: MODELS- Eye, Ear, Torso, Mid-Sagittal Head and Cochlea

Olfaction (sagittal head model)

- Nare
- Vestibule
- Nasal conchae (superior, middle, inferior)
- Nasal meatuses
- Nasal cavity

Eye (various models)

External Structures

- Palpebrae
- Tarsal plates
- Levator Palpebrae m.
- Orbicularis Oculi m.
- Medial and lateral canthus
- Lacrimal caruncle
- Lacrimal gland
- Lacrimal ducts
- Lacrimal sac

Extra-ocular muscles:

- Lateral rectus m.
- Medial rectus m.
- Superior rectus m.
- Inferior rectus m.
- Superior oblique m.
- Inferior oblique m.

Internal structures

- Fibrous tunic:
  - Sclera
  - Cornea
- Vascular tunic:
  - Choroid
  - Ciliary body / muscle
  - Suspensory ligaments
  - Iris
- Sensory (neural) tunic:
  - Retina
  - Macula Lutea
    - Fovea centralis
  - Optic Nerve
    - Optic disc
- Lens
  - Posterior cavity/Vitreous Humor
  - Anterior cavity/ Aqueous Humor

Structures of the ear (various models)

- Outer ear
  - Auricle
  - External auditory canal
- Middle ear
  - Tympanic membrane
  - Auditory ossicles:
    - Malleus
    - Incus
    - Stapes
  - Pharyngotympanic tube (Eustachian, auditory)
- Inner ear
  - Bony labyrinth
  - Membranous labyrinth
  - Vestibule
    - Utricle
    - Saccule
  - Semicircular canals
    - Semicircular ducts
    - Ampulla
  - Cochlea
  - Oval window
  - Round window
  - Vestibulocochlear nerve

Cochlea (cross-sectional model)

- Vestibular duct (scala vestibuli)
- Vestibular duct (scala vestibuli)
- Cochlear duct (scala media)
- Tympanic duct (scala tympani)
- Vestibular membrane
- Basilar membrane
- Organ of Corti (& hair cells)
- Tectorial membrane
- Spiral ganglion
- **Tongue (tongue model)**
  - Papillae:
    - Filiform
    - Fungiform
    - Foliate
    - Circumvallate.
    - Sulcus terminalis
    - Median sulcus
    - Taste buds
      - Taste pore
      - Support & taste cells
- ***Histology:***

- Eye – retina:
  - Rods & Cones
  - Bipolar cell layer
  - Ganglion cell layer
  - Axons of ganglion cells
  - Retinal pigment epithelium
  - Choroid layer
  - Sclera
- Ear
  - Basilar membrane
  - Scala media (cochlear duct)
  - Scala tympani (tympanic duct)
  - Scala vestibuli (vestibular duct)
  - Spiral ganglion
  - Spiral organ (Organ of Corti)
  - Tectorial membrane
  - Vestibular membrane
- Tongue
  - Taste bud
  - Taste pore
  - Support and Taste cells

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13.7: Cow Eye Dissection



1. Examine the outside of the eye. You should be able to find the **sclera,** or the whites of the eye. This tough, outer covering of the eyeball has fat and muscle attached to it

2. Locate the covering over the front of the eye, the **cornea**. When the cow was alive, the cornea was clear. In your cow's eye, the cornea may be cloudy or blue in color.

2. Cut away the fat and muscle, this may only be necessary if fat is covering the cornea of the eye and is in your way. Fat around the backside of the eye can be left alone. Flip the eye over to find the **optic nerve** where it exits out the back of the eye. It will be stronger and more rope-like than the surrounding fat tissue.

4. Use a scalpel or scissors to make an incision in the cornea. The cornea is tougher than it appears and may require some force to puncture, be careful when using the scalpel. Once the cornea is broken, clear liquid will leak (or squirt) out – this liquid is the **aqueous humor**.

5. Quick Check: Outer Tunic

A. The white of the eye is the _____

B. The front surface of the eye,continuous with (A) is the _____

C. The liquid found in the front of the eye is the _____

D. What is the name of the nerve found on the back of the eye? _____



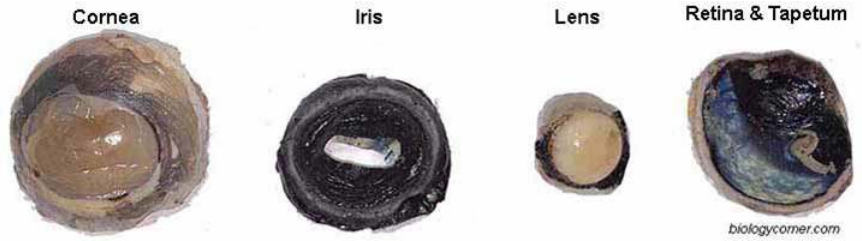
6. Use a scalpel or scissors to make an incision in the sclera so that you can cut around the outside of the eye. Your goal is to separate the eye into a front and a back half.

7. Separate the inner parts of the eye.

The gelatinous liquid in the middle of the eye is the **vitreous humor** , which will also contain a hard, sphere-shaped **lens**.

Find the cornea (which you punctured in step 1) and then the disk-shaped **iris** behind it. The iris will be dark in color and contain a center opening, the **pupil**.

8. The image below shows how each part of the eye appears when it has been separated. Take a photo of your own eye and share it on social media. #coweye (optional)

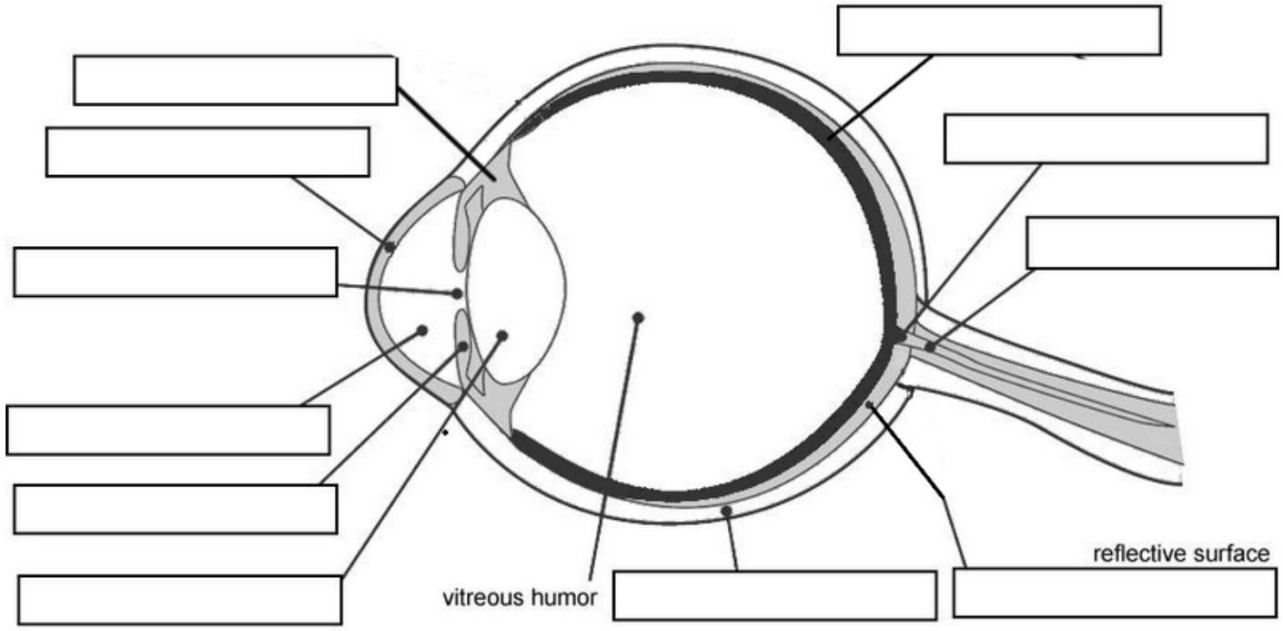


9. The back of the eye has two layers, a very thin layer of cells that is easy to scrape off (and may fall off on its own), which is the **retina** . Behind, the retina is a blue, reflective layer known as the **tapetum**.

10. The retina will converge at a point on the eye where it connects with the optic nerve. This is the **optic disk**. It may be easiest to find by scraping off the retina and locating the spot where it remains closely attached. Flipping the eye over will also show how that spot is directly in front of the optic nerve.

LAB 13 EXERCISE 13.7.1

Label the Cow Eye (use your book or other resources)



Contributed by

Biology Corner: https://www.biologycorner.com/worksheets/cow_eye_dissection.html

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CHAPTER OVERVIEW

14: The Endocrine System

14.1: Structures of the Endocrine System

14.2: Exercises

14.3: MODELS- Endocrine Torso and Mid Sagittal Head

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14.1: Structures of the Endocrine System

The endocrine system consists of cells, tissues, and organs that secrete hormones as a primary or secondary function. The **endocrine gland** is the major player in this system. The primary function of these ductless glands is to secrete their hormones directly into the surrounding fluid. The interstitial fluid and the blood vessels then transport the hormones throughout the body. The endocrine system includes the pituitary, thyroid, parathyroid, adrenal, and pineal glands (Figure **14.1.1**). Some of these glands have both endocrine and non-endocrine functions. For example, the pancreas contains cells that function in digestion as well as cells that secrete the hormones insulin and glucagon, which regulate blood glucose levels. The hypothalamus, thymus, heart, kidneys, stomach, small intestine, liver, skin, female ovaries, and male testes are other organs that contain cells with endocrine function. Moreover, adipose tissue has long been known to produce hormones, and recent research has revealed that even bone tissue has endocrine functions.

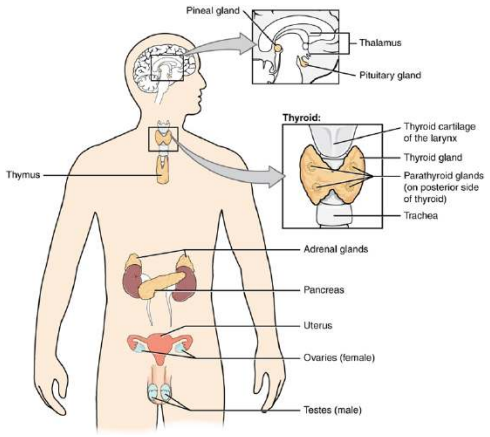


Figure **14.1.1**: **Endocrine System** Endocrine glands and cells are located throughout the body and play an important role in homeostasis. (CC-BY-4.0, OpenStax, Human Anatomy)

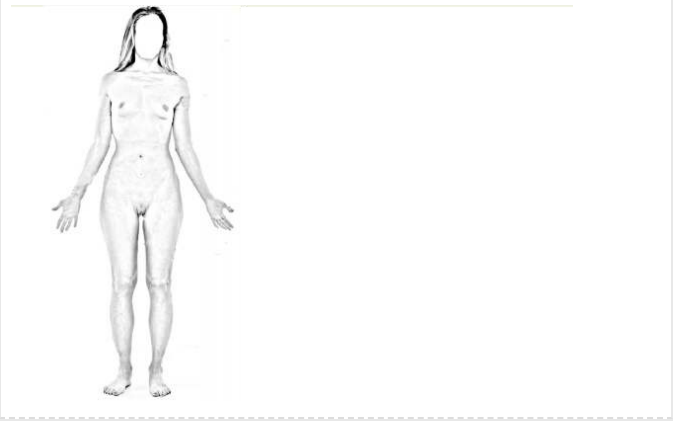
The ductless endocrine glands are not to be confused with the body's **exocrine system**, whose glands release their secretions through ducts. Examples of exocrine glands include the sebaceous and sweat glands of the skin. As just noted, the pancreas also has an exocrine function: most of its cells secrete pancreatic juice through the pancreatic and accessory ducts to the lumen of the small intestine

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14.2: Exercises

Lab 14 Exercise 14.2.1

Label the following:



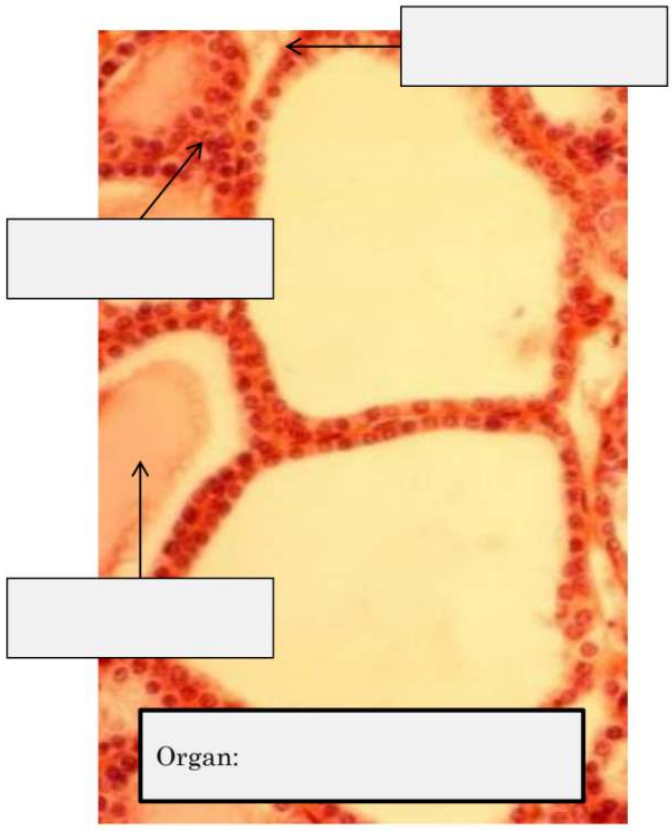
On the person**, draw and label** the following endocrine organs:

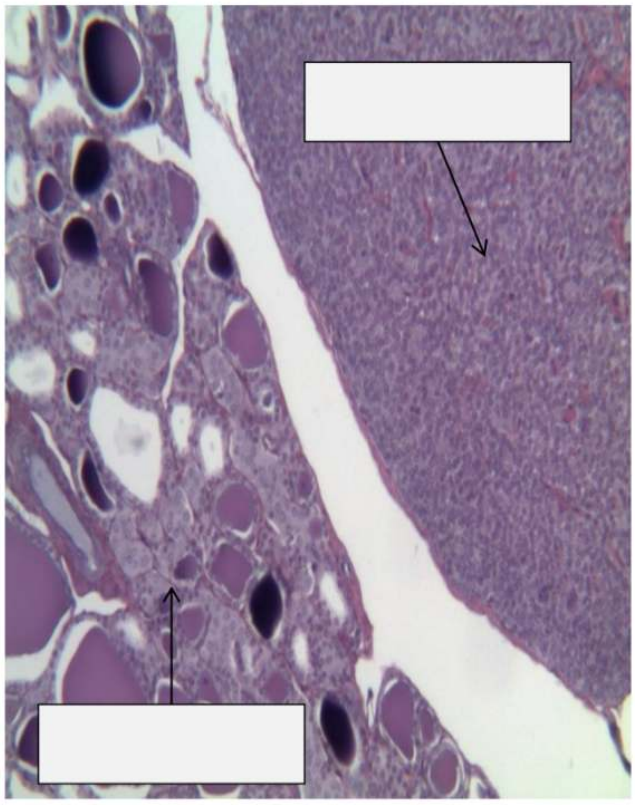
1	Thyroid
2	Adrenals
3	Pancreas
4	Ovaries
5	Hypothalmus
6	Pituitary

Lab 14 Exercise 14.2.2

Endocrine system - CNS and histology

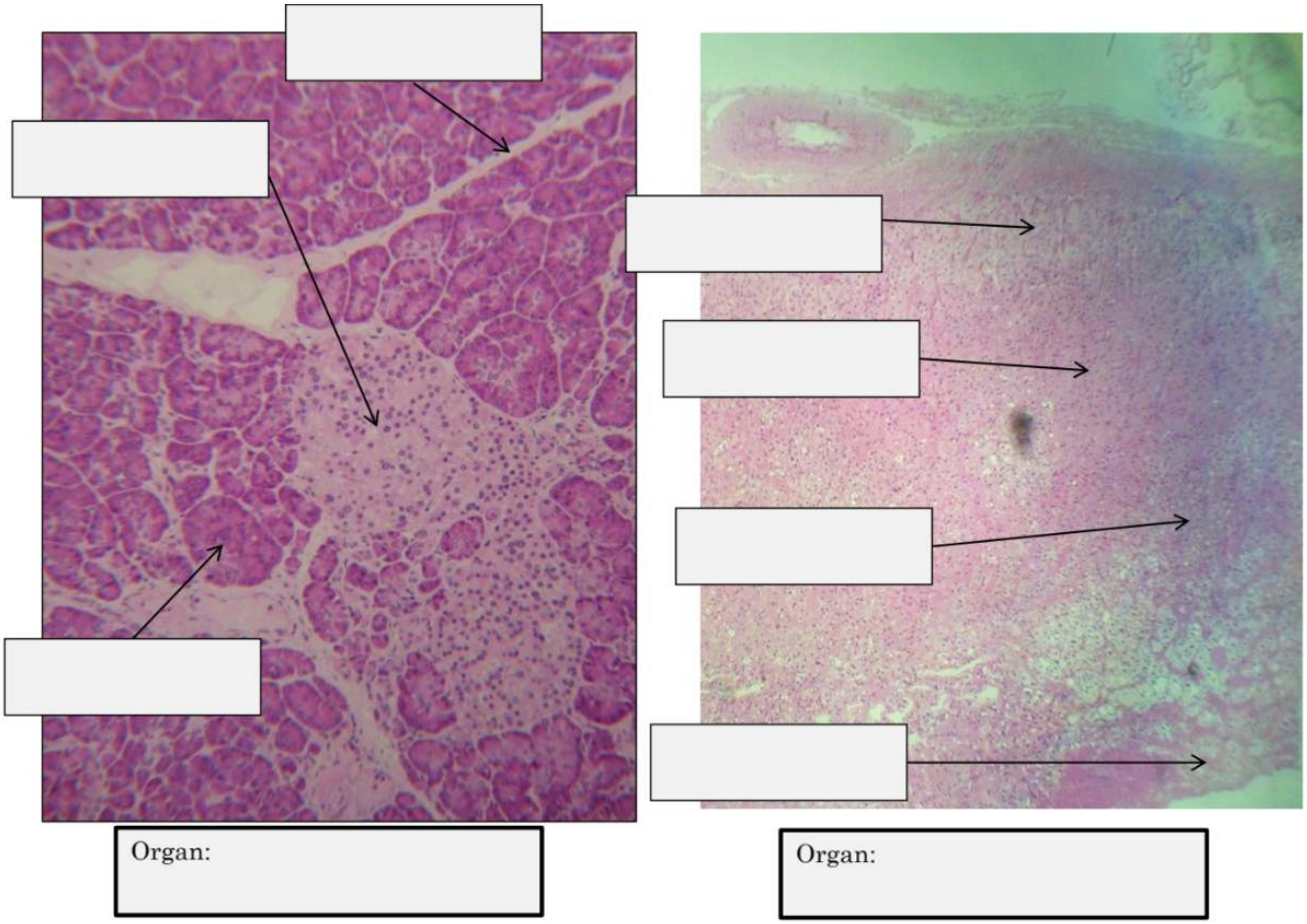
Identify the organ on the right and it's related structures. For the figure on the left label the Thyroid and parathyroid





Lab 14 Exercise 14.2.3

Identify the organs and their related structures



Lab 14 Exercise 14.2.4

1. Obtain a slide of each of the tissues listed below from the slide box at your table.

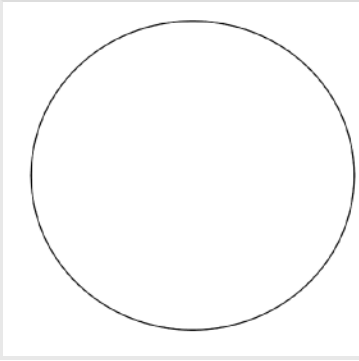
2. Follow the checklist above to set up your slide for viewing.

3. View the slide on the objective which provides the best view. Find the representative object.

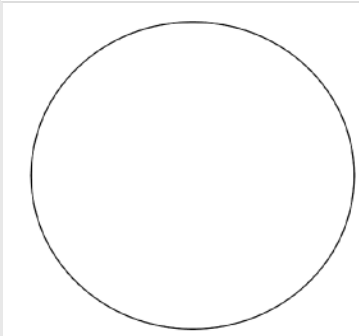
4. In the circle below the name, draw a representative sample of the tissue, taking care to correctly and clearly draw their true shape in the slide. If it is a stratified epithelium draw all the layers. Draw your structures proportionately to their size in your microscope's field of view.

5. Fill in the blanks next to your drawing and identify the structures listed on the last page under, "Histology"

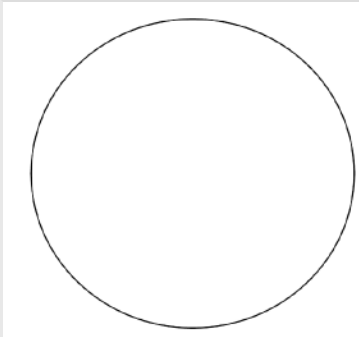
Repeat this for each of the tissue types seen below



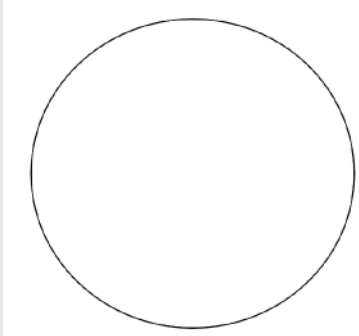
Pituitary
Total magnification _____
Type of epithelium _____
Source of tissue _____
Function of tissue _____
_____



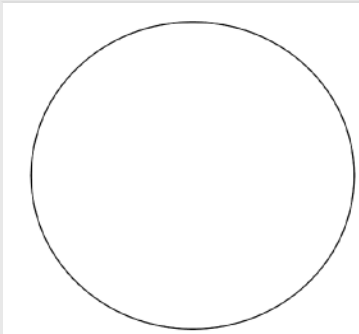
Pancreas
Total magnification _____
Type of epithelium _____
Source of tissue _____
Function of tissue _____
_____



Thyroid
Total magnification _____
Type of epithelium _____
Source of tissue _____
Function of tissue _____
_____



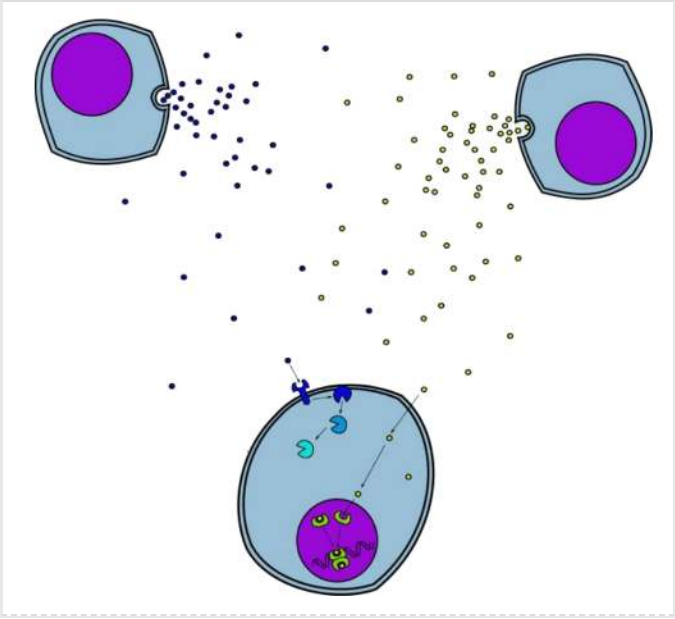
Parathyroid
Total magnification _____
Type of epithelium _____
Source of tissue _____
Function of tissue _____
_____



Adrenal/suprarenal
Total magnification _____
Type of epithelium _____
Source of tissue _____
Function of tissue _____
_____

Lab 14 Exercise 14.2.4

Hormone action



Label the following

1	Target cell
2	Endocrine cells x2
3	Water soluble hormone
4	Steroid hormone
5	Steroid hormone receptor
6	Cell surface hormone receptor
7	Second messenger system

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14.3: MODELS- Endocrine Torso and Mid Sagittal Head

Found on models:

- Hypothalamus
- Pituitary gland
- Infundibulum
- Pancreas
- Pineal gland
- Adrenal glands
- Testis
- Ovary
- Thyroid gland
- Ithsmus

Histology:

- Pituitary
  - Anterior pituitary
  - Posterior pituitary
  - Infundibulum
- Pancreas
  - Endocrine pancreas
    - Pancreatic islet of Langerhans
    - Capillary in pancreatic islet
  - Exocrine pancreas
    - acini
    - duct
- Thyroid gland
  - Follicular cell
  - Parafollicular cell
  - Colloid
  - Thyroid follicle
- Parathyroid gland
- Adrenal glands
  - Capsule of suprarenal gland
  - Suprarenal cortex
    - Zona fasciculata
    - Zona glomerulosa
    - Zona reticularis
  - Suprarenal medulla

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CHAPTER OVERVIEW

15: Blood

An Overview of Blood

Learning Objectives

- Name the fluid component of blood and the three major types of formed elements, and identify their relative proportions in a blood sample

15.1: Composition of Blood
15.2: Exercises
15.3: MODELS- Blood, Histology

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15.1: Composition of Blood

You have probably had blood drawn from a superficial vein in your arm, which was then sent to a lab for analysis. Some of the most common blood tests—for instance, those measuring lipid or glucose levels in plasma—determine which substances are present within blood and in what quantities. Other blood tests check for the composition of the blood itself, including the quantities and types of formed elements.

One such test, called a **hematocrit**, measures the percentage of RBCs, clinically known as erythrocytes, in a blood sample. It is performed by spinning the blood sample in a specialized centrifuge, a process that causes the heavier elements suspended within the blood sample to separate from the lightweight, liquid plasma (Figure **15.1.1**). Because the heaviest elements in blood are the erythrocytes, these settle at the very bottom of the hematocrit tube. Located above the erythrocytes is a pale, thin layer composed of the remaining formed elements of blood. These are the WBCs, clinically known as leukocytes, and the platelets, cell fragments also called thrombocytes. This layer is referred to as the **buffy coat** because of its color; it normally constitutes less than 1 percent of a blood sample. Above the buffy coat is the blood plasma, normally a pale, straw- colored fluid, which constitutes the remainder of the sample.

The volume of erythrocytes after centrifugation is also commonly referred to as **packed cell volume (PCV)**. In normal blood, about 45 percent of a sample is erythrocytes. The hematocrit of any one sample can vary significantly, however, about 36–50 percent, according to gender and other factors. Normal hematocrit values for females range from 37 to 47, with a mean value of 41; for males, hematocrit ranges from 42 to 52, with a mean of 47. The percentage of other formed elements, the WBCs and platelets, is extremely small so it is not normally considered with the hematocrit. So the mean plasma percentage is the percent of blood that is not erythrocytes: for females, it is approximately 59 (or 100 minus 41), and for males, it is approximately 53 (or 100 minus 47).

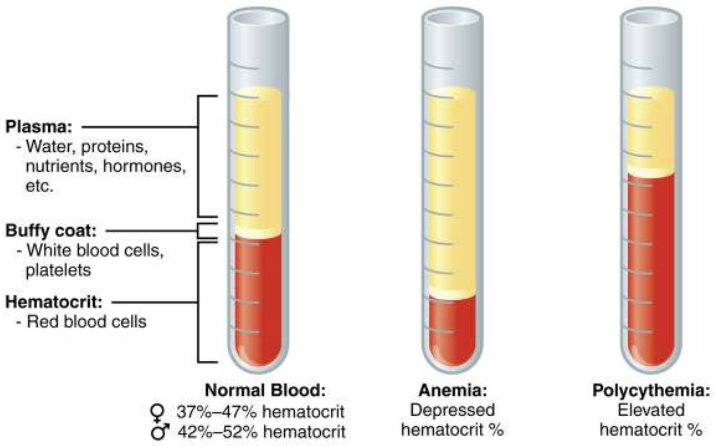


Figure **15.1.1**: **omposition of Blood** The cellular elements of blood include a vast number of erythrocytes and comparatively fewer leukocytes and platelets. Plasma is the fluid in which the formed elements are suspended. A sample of blood spun in a centrifuge reveals that plasma is the lightest component. It floats at the top of the tube separated from the heaviest elements, the erythrocytes, by a buffy coat of leukocytes and platelets. Hematocrit is the percentage of the total sample that is comprised of erythrocytes. Depressed and elevated hematocrit levels are shown for comparison. (CC-BY-4.0, OpenStax, Human Anatomy)

Formed element	Major subtypes	Numbers present per microliter (μL) and mean (range)	Appearance in a standard blood smear	Summary of functions	Comments
Erythrocytes (red blood cells)		5.2 million (4.4–6.0 million)	Flattened biconcave disk; no nucleus; pale red color	Transport oxygen and some carbon dioxide between tissues and lungs	Lifespan of approximately 120 days
Leukocytes (white blood cells)		7000 (5000–10,000)	Obvious dark-staining nucleus	All function in body defenses	Exit capillaries and move into tissues; lifespan of usually a few hours or days
	Granulocytes including neutrophils, eosinophils, and basophils	4360 (1800–9950)	Abundant granules in cytoplasm; nucleus normally lobed	Nonspecific (innate) resistance to disease	Classified according to membrane-bound granules in cytoplasm
	Neutrophils	4150 (1800–7300)	Nuclear lobes increase with age; pale lilac granules	Phagocytic; particularly effective against bacteria. Release cytotoxic chemicals from granules	Most common leukocyte; lifespan of minutes to days
	Eosinophils	165 (0–700)	Nucleus generally two-lobed; bright red-orange granules	Phagocytic cells; particularly effective with antigen- antibody complexes. Release antihistamines. Increase in allergies and parasitic infections	Lifespan of minutes to days
	Basophils	44 (0–150)	Nucleus generally two-lobed but difficult to see due to presence of heavy, dense, dark purple granules	Promotes inflammation	Least common leukocyte; lifespan unknown
	Agranulocytes including lymphocytes and monocytes	2640 (1700–4950)	Lack abundant granules in cytoplasm; have a simple-shaped nucleus that may be indented	Body defenses	Group consists of two major cell types from different lineages
	Lymphocytes	2185 (1500–4000)	Spherical cells with a single often large nucleus occupying much of the cell's volume; stains purple; seen in large (natural killer cells) and small (B and T cells) variants	Primarily specific (adaptive) immunity: T cells directly attack other cells (cellular immunity); B cells release antibodies (humoral immunity); natural killer cells are similar to T cells but nonspecific	Initial cells originate in bone marrow, but secondary production occurs in lymphatic tissue; several distinct subtypes; memory cells form after exposure to a pathogen and rapidly increase responses to subsequent exposure; lifespan of many years
	Monocytes	455 (200–950)	Largest leukocyte with an indented or horseshoe-shaped nucleus	Very effective phagocytic cells engulfing pathogens or worn out cells; also serve as antigen-presenting cells (APCs) for other components of the immune system	Produced in red bone marrow; referred to as macrophages after leaving circulation
Platelets		350,000 (150,000–500,000)	Cellular fragments surrounded by a plasma membrane and containing granules; purple stain	Hemostasis plus release growth factors for repair and healing of tissue	Formed from megakaryocytes that remain in the red bone marrow and shed platelets into circulation

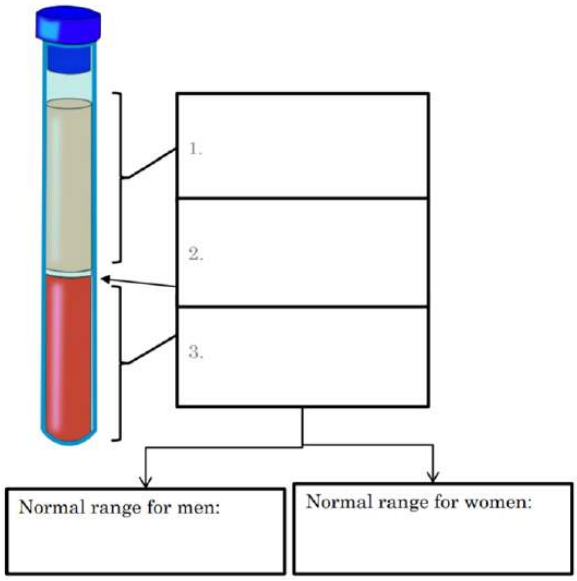
Figure **15.1.2**: Summary of Formed Elements in Blood (CC-BY-4.0, OpenStax, Human Anatomy)

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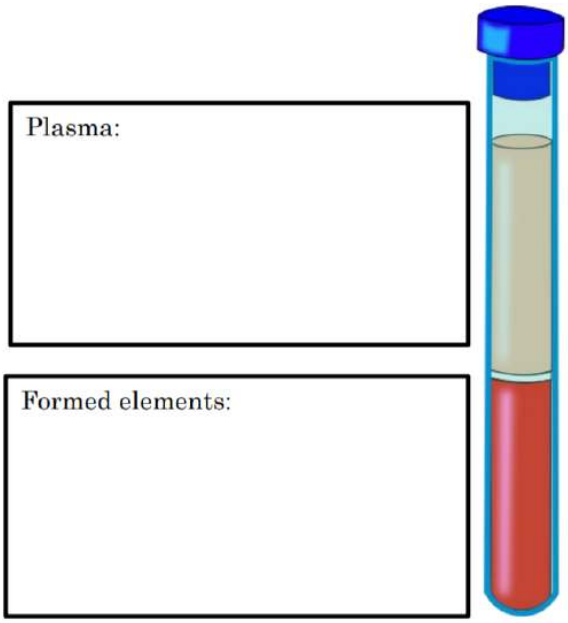
15.2: Exercises

LAB 15 EXERCISES 15.2.1

Identify the 3 major components of a hematocrit:



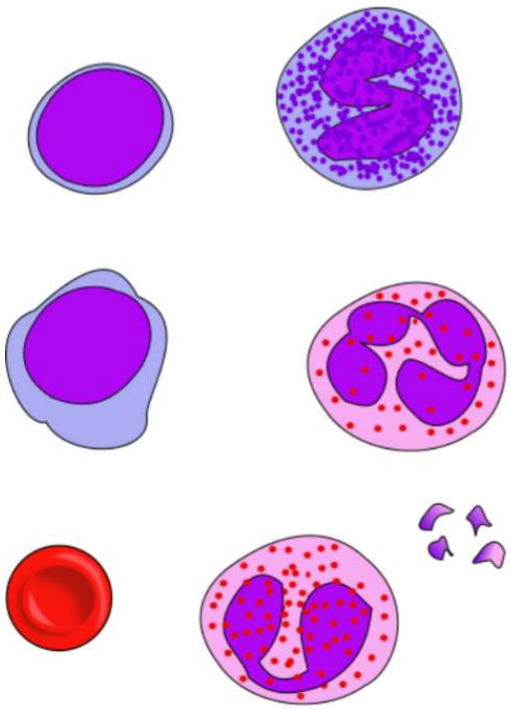
Match the following items to their location: Albumin, Erythrocytes, Glucose, Chloride, Antibodies, Platelets, Monocytes, Neutrophils, Fibrinogen



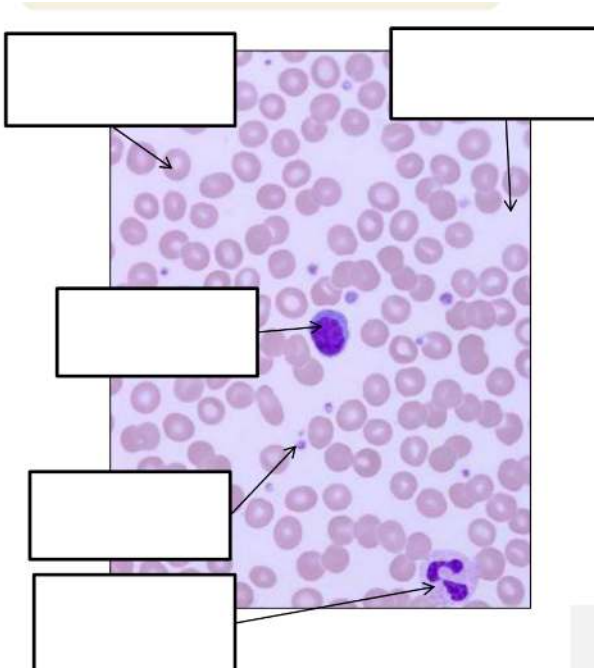
LAB 15 EXERCISES 15.2.2

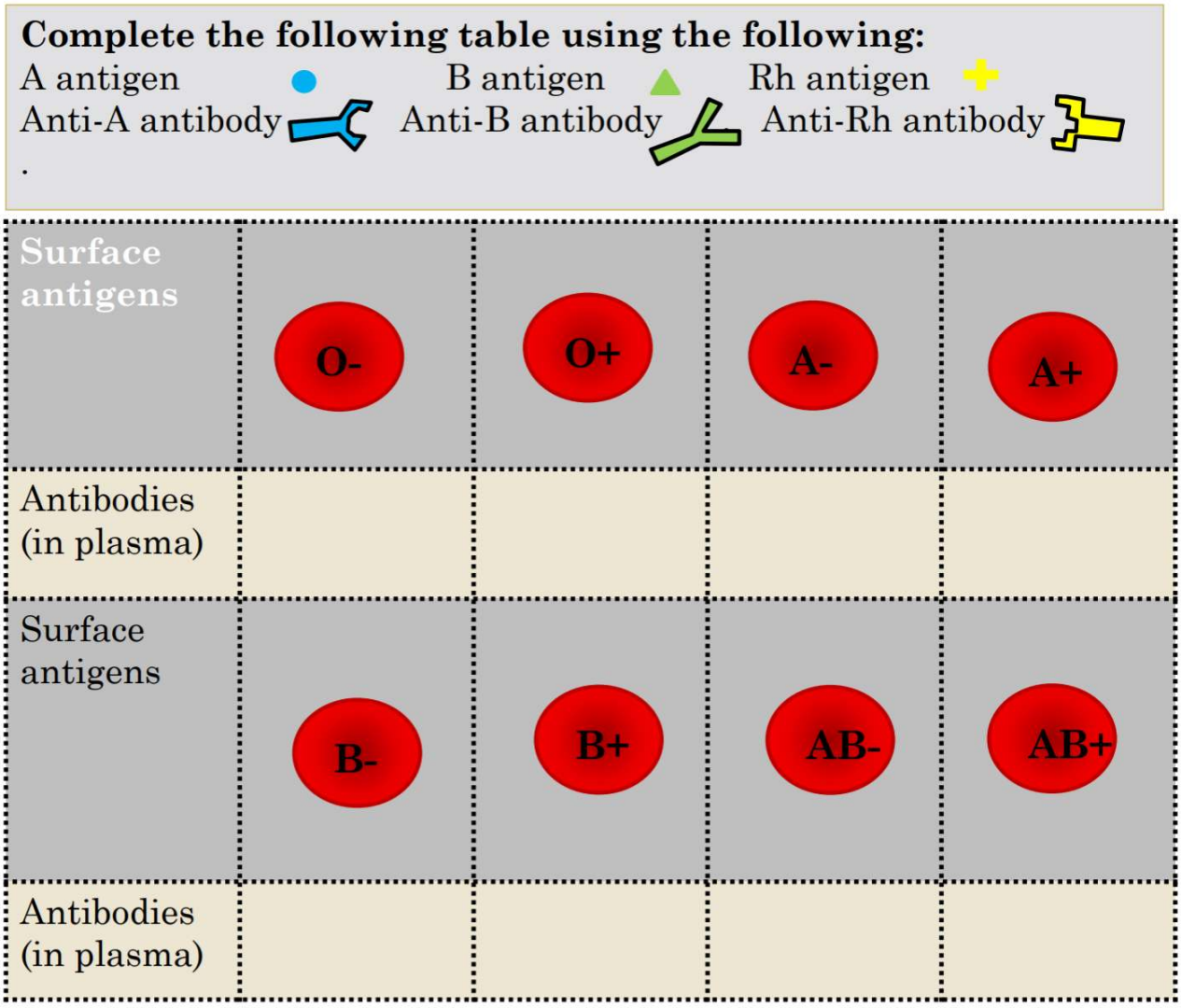
Blood Cell Identification

Identify the formed elements by their picture below:



Label the image below





Fill in the Following Table

Blood Type	Can Safely Receive	Can Safely Donate T0
O+		
A-		
B+		
AB-		
AB+		

LAB 15 EXERCISES 15.2.3

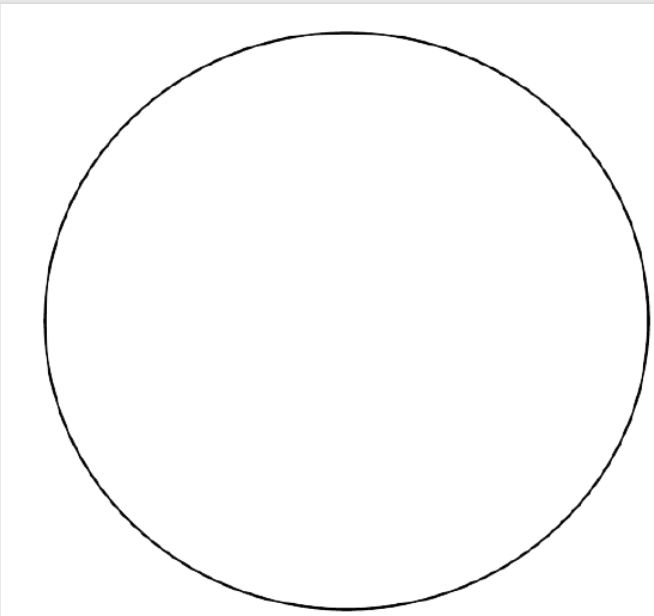
1. Obtain a slide of blood from the slide box at your table.

2. Follow the checklist above to set up your slide for viewing.

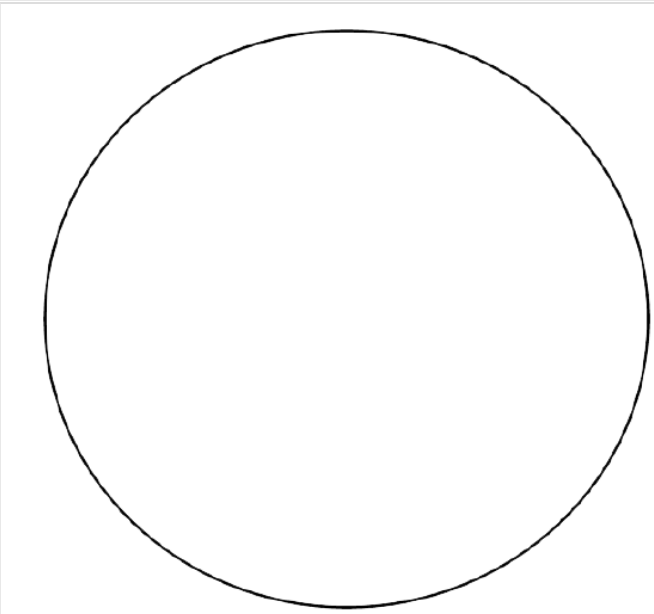
3. View the slide on the objective which provides the best view (400X). Find the representative object.

4. In the circle below the name, draw a representative sample of the blood cell, taking care to correctly and clearly draw their true shape in the slide. Draw your structures proportionately to their size in your microscope's field of view.

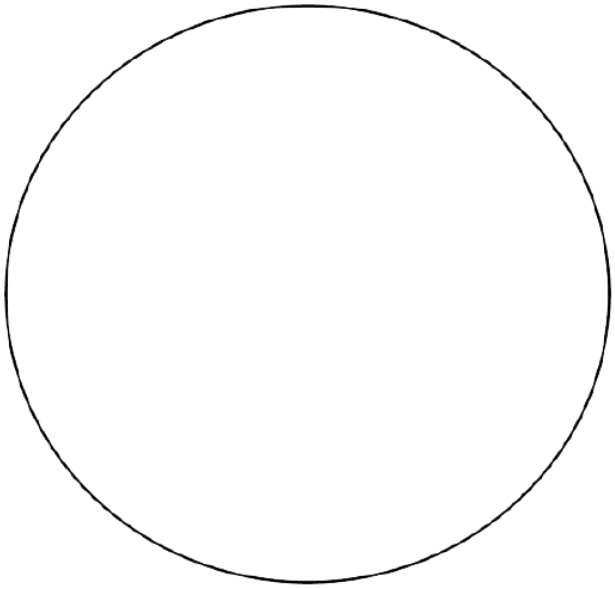
Repeat this for each of the blood cell types seen below



Erythrocytes
Total Magnification: _____
Type of eptiheleum:_____
Source of tissue: _____
Function : _____
_____



Thrombocytes
Total Magnification: _____
Type of eptiheleum:_____
Source of tissue: _____
Function : _____
_____



Leukocytes
Total Magnification: _____
Type of eptiheleum:_____
Source of tissue: _____
Function : _____
_____

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15.3: MODELS- Blood, Histology

Hematocrit:

- Plasma
- Buffy coat
- RBCs
  - (including average ranges for men and women)

Blood histology

- Erythrocytes
- Leukocytes:
  - Granulocytes:
    - Neutrophil
    - Basophil
    - Eosinophil
  - Agranulocytes:
    - Lymphocyte
    - Monocyte
- Platelets
- Plasma

Blood types – *students should understand the following terms and how they fit into the two blood typing mechanisms listed.*

Know the antigens and antibodies present for a given blood type.

Students must know which blood types can be safely donated to or received from another given blood type.

Antigens

Antibodies

ABO system

- Type A
- Type B
- Type AB
- Type O

Rh system

- Rh+
- Rh-

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CHAPTER OVERVIEW

16: The Heart

Learning Objectives

- Describe the location and position of the heart within the body cavity
- Describe the internal and external anatomy of the heart
- Identify the tissue layers of the heart
- Identify the veins and arteries of the coronary circulation system
- Trace the pathway of oxygenated and deoxygenated blood thorough the chambers of the heart

16.1: Location of the Heart
16.2: Chambers and Circulation through the Heart
16.3: Membranes, Surface Features, and Layers
16.4: Internal Structure of the Heart
16.5: Exercises
16.6: MODELS- Heart and Torsos
16.7: Heart Dissection

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16.1: Location of the Heart

The human heart is located within the thoracic cavity, medially between the lungs in the space known as the mediastinum. Figure **16.1.1** shows the position of the heart within the thoracic cavity. Within the mediastinum, the heart is separated from the other mediastinal structures by a tough membrane known as the pericardium, or pericardial sac, and sits in its own space called the **pericardial cavity**. The dorsal surface of the heart lies near the bodies of the vertebrae, and its anterior surface sits deep to the sternum and costal cartilages. The great veins, the superior and inferior venae cavae, and the great arteries, the aorta and pulmonary trunk, are attached to the superior surface of the heart, called the base. The base of the heart is located at the level of the third costal cartilage, as seen in Figure **16.1.1**. The inferior tip of the heart, the apex, lies just to the left of the sternum between the junction of the fourth and fifth ribs near their articulation with the costal cartilages. The right side of the heart is deflected anteriorly, and the left side is deflected posteriorly. It is important to remember the position and orientation of the heart when placing a stethoscope on the chest of a patient and listening for heart sounds, and also when looking at images taken from a midsagittal perspective. The slight deviation of the apex to the left is reflected in a depression in the medial surface of the inferior lobe of the left lung, called the **cardiac notch**.

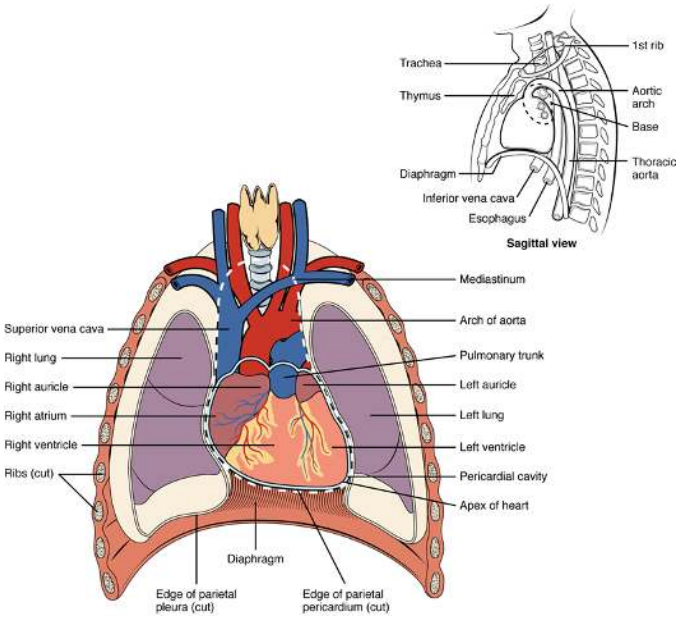


Figure **16.1.1**: Position of the Heart in the Thorax The heart is located within the thoracic cavity, medially between the lungs in the mediastinum. It is about the size of a fist, is broad at the top, and tapers toward the base. (CC-BY-4.0, OpenStax, Human Anatomy)

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16.2: Chambers and Circulation through the Heart

The human heart consists of four chambers: The left side and the right side each have one **atrium** and one **ventricle**. Each of the upper chambers, the right atrium (plural = atria) and the left atrium, acts as a receiving chamber and contracts to push blood into the lower chambers, the right ventricle and the left ventricle. The ventricles serve as the primary pumping chambers of the heart, propelling blood to the lungs or to the rest of the body.

There are two distinct but linked circuits in the human circulation called the pulmonary and systemic circuits. Although both circuits transport blood and everything it carries, we can initially view the circuits from the point of view of gases. The **pulmonary circuit** transports blood to and from the lungs, where it picks up oxygen and delivers carbon dioxide for exhalation. The **systemic circuit** transports oxygenated blood to virtually all of the tissues of the body and returns relatively deoxygenated blood and carbon dioxide to the heart to be sent back to the pulmonary circulation.

The right ventricle pumps deoxygenated blood into the **pulmonary trunk**, which leads toward the lungs and bifurcates into the left and right **pulmonary arteries**. These vessels in turn branch many times before reaching the **pulmonary capillaries**, where gas exchange occurs: Carbon dioxide exits the blood and oxygen enters. The pulmonary trunk arteries and their branches are the only arteries in the post-natal body that carry relatively deoxygenated blood. Highly oxygenated blood returning from the pulmonary capillaries in the lungs passes through a series of vessels that join together to form the **pulmonary veins**—the only post-natal veins in the body that carry highly oxygenated blood. The pulmonary veins conduct blood into the left atrium, which pumps the blood into the left ventricle, which in turn pumps oxygenated blood into the aorta and on to the many branches of the systemic circuit. Eventually, these vessels will lead to the systemic capillaries, where exchange with the tissue fluid and cells of the body occurs. In this case, oxygen and nutrients exit the systemic capillaries to be used by the cells in their metabolic processes, and carbon dioxide and waste products will enter the blood.

The blood exiting the systemic capillaries is lower in oxygen concentration than when it entered. The capillaries will ultimately unite to form venules, joining to form ever-larger veins, eventually flowing into the two major systemic veins, the **superior vena cava** and the **inferior vena cava**, which return blood to the right atrium. The blood in the superior and inferior venae cavae flows into the right atrium, which pumps blood into the right ventricle. This process of blood circulation continues as long as the individual remains alive. Understanding the flow of blood through the pulmonary and systemic circuits is critical to all health professions (**Figure 16.2**).

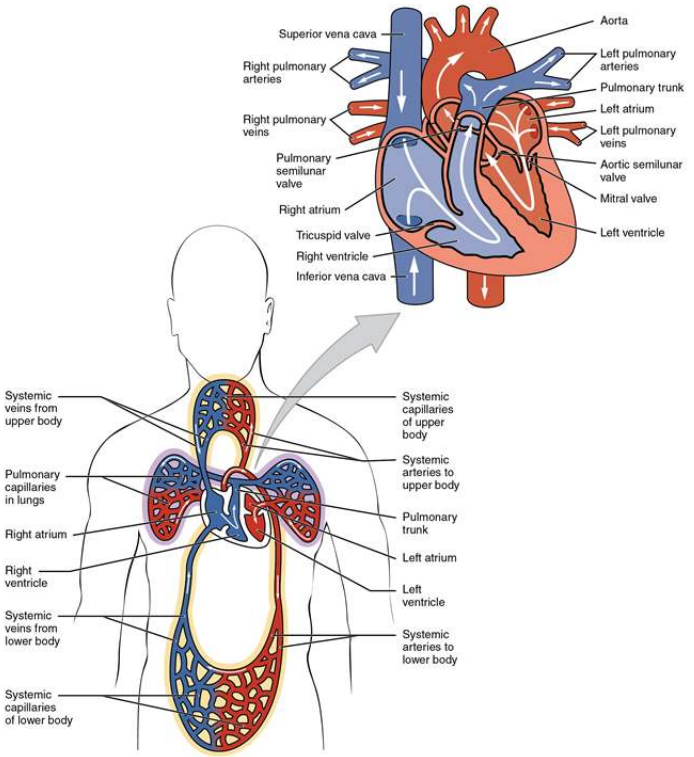


Figure **16.2.1**: Dual System of the Human Blood Circulation Blood flows from the right atrium to the right ventricle, where it is pumped into the pulmonary circuit. The blood in the pulmonary artery branches is low in oxygen but relatively high in carbon dioxide. Gas exchange occurs in the pulmonary capillaries (oxygen into the blood, carbon dioxide out), and blood high in oxygen and low in carbon dioxide is returned to the left atrium. From here, blood enters the left ventricle, which pumps it into the systemic circuit. Following exchange in the systemic capillaries (oxygen and nutrients out of the capillaries and carbon dioxide and wastes in), blood returns to the right atrium and the cycle is repeated. (CC-BY-4.0, OpenStax, Human Anatomy)

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16.3: Membranes, Surface Features, and Layers

Our exploration of more in-depth heart structures begins by examining the membrane that surrounds the heart, the prominent surface features of the heart, and the layers that form the wall of the heart. Each of these components plays its own unique role in terms of function.

Membranes

The membrane that directly surrounds the heart and defines the pericardial cavity is called the **pericardium** or **pericardial sac**. It also surrounds the "roots" of the major vessels, or the areas of closest proximity to the heart. The pericardium, which literally translates as "around the heart," consists of two distinct sublayers: the sturdy outer fibrous pericardium and the inner serous pericardium. The fibrous pericardium is made of tough, dense connective tissue that protects the heart and maintains its position in the thorax. The more delicate serous pericardium consists of two layers: the parietal pericardium, which is fused to the fibrous pericardium, and an inner visceral pericardium, or **epicardium**, which is fused to the heart and is part of the heart wall. The pericardial cavity, filled with lubricating serous fluid, lies between the epicardium and the pericardium

In most organs within the body, visceral serous membranes such as the epicardium are microscopic. However, in the case of the heart, it is not a microscopic layer but rather a macroscopic layer, consisting of a simple squamous epithelium called a **mesothelium**, reinforced with loose, irregular, or areolar connective tissue that attaches to the pericardium. This mesothelium secretes the lubricating serous fluid that fills the pericardial cavity and reduces friction as the heart contracts. Figure **16.3.1** illustrates the pericardial membrane and the layers of the heart.

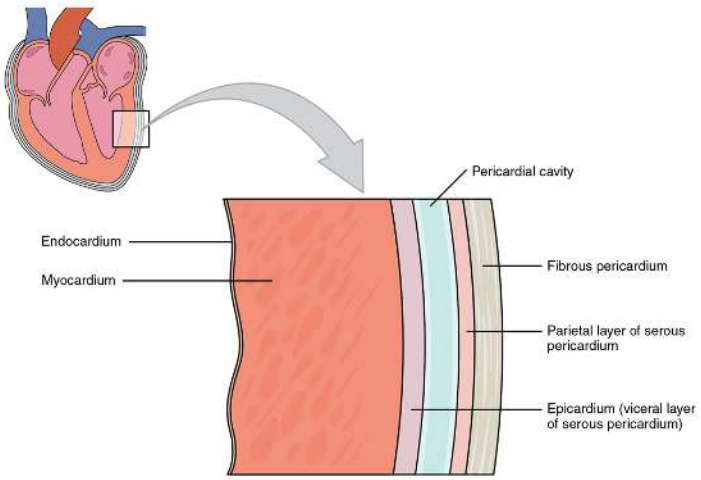


Figure **16.3.1**: **Pericardial Membranes and Layers of the Heart Wall** The pericardial membrane that surrounds the heart consists of three layers and the pericardial cavity. The heart wall also consists of three layers. The pericardial membrane and the heart wall share the epicardium. (CC-BY-4.0, OpenStax, Human Anatomy)

Surface Features of the Heart

Inside the pericardium, the surface features of the heart are visible, including the four chambers. There is a superficial leaf-like extension of the atria near the superior surface of the heart, one on each side, called an **auricle**—a name that means "ear like"—because its shape resembles the external ear of a human (Figure **16.3.2**). Auricles are relatively thin-walled structures that can fill with blood and empty into the atria or upper chambers of the heart. You may also hear them referred to as atrial appendages. Also prominent is a series of fat-filled grooves, each of which is known as a **sulcus** (plural = sulci), along the superior surfaces of the heart. Major coronary blood vessels are located in these sulci. The deep **coronary sulcus** is located between the atria and ventricles. Located between the left and right ventricles are two additional sulci that are not as deep as the coronary sulcus. The **anterior interventricular sulcus** is visible on the anterior surface of the heart, whereas the **posterior interventricular sulcus** is visible on the posterior surface of the heart. Figure **16.3.2**illustrates anterior and posterior views of the surface of the heart.

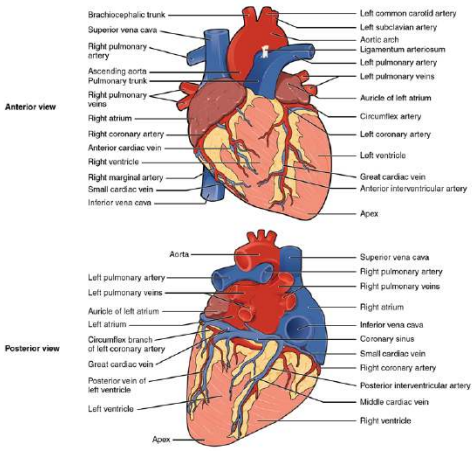


Figure **16.3.2**: **External Anatomy of the Heart** Inside the pericardium, the surface features of the heart are visible (CC-BY-4.0, OpenStax, Human Anatomy)

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16.4: Internal Structure of the Heart

Recall that the heart's contraction cycle follows a dual pattern of circulation—the pulmonary and systemic circuits—because of the pairs of chambers that pump blood into the circulation. In order to develop a more precise understanding of cardiac function, it is first necessary to explore the internal anatomical structures in more detail.

Septa of the Heart

The word septum is derived from the Latin for "something that encloses;" in this case, a **septum** (plural = septa) refers to a wall or partition that divides the heart into chambers. The septa are physical extensions of the myocardium lined with endocardium. Located between the two atria is the **interatrial septum**. Normally in an adult heart, the interatrial septum bears an oval-shaped depression known as the **fossa ovalis**, a remnant of an opening in the fetal heart known as the **foramen ovale**. The foramen ovale allowed blood in the fetal heart to pass directly from the right atrium to the left atrium, allowing some blood to bypass the pulmonary circuit. Within seconds after birth, a flap of tissue known as the **septum primum** that previously acted as a valve closes the foramen ovale and establishes the typical cardiac circulation pattern.

Between the two ventricles is a second septum known as the **interventricular septum**. Unlike the interatrial septum, the interventricular septum is normally intact after its formation during fetal development. It is substantially thicker than the interatrial septum, since the ventricles generate far greater pressure when they contract.

The septum between the atria and ventricles is known as the **atrioventricular septum**. It is marked by the presence of four openings that allow blood to move from the atria into the ventricles and from the ventricles into the pulmonary trunk and aorta. Located in each of these openings between the atria and ventricles is a **valve**, a specialized structure that ensures one-way flow of blood. The valves between the atria and ventricles are known generically as **atrioventricular valves**. The valves at the openings that lead to the pulmonary trunk and aorta are known generically as **semilunar valves**. The interventricular septum is visible in Figure 16.4.1. In this figure, the atrioventricular septum has been removed to better show the bicupid and tricuspid valves; the interatrial septum is not visible, since its location is covered by the aorta and pulmonary trunk. Since these openings and valves structurally weaken the atrioventricular septum, the remaining tissue is heavily reinforced with dense connective tissue called the **cardiac skeleton**, or skeleton of the heart. It includes four rings that surround the openings between the atria and ventricles, and the openings to the pulmonary trunk and aorta, and serve as the point of attachment for the heart valves. The cardiac skeleton also provides an important boundary in the heart electrical conduction system.

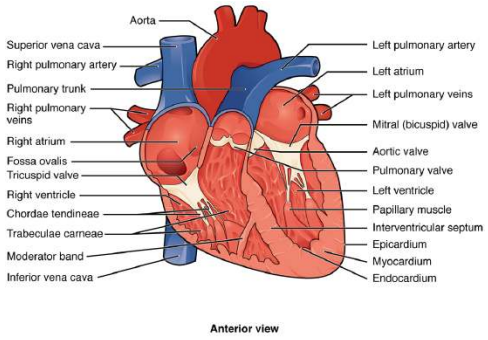


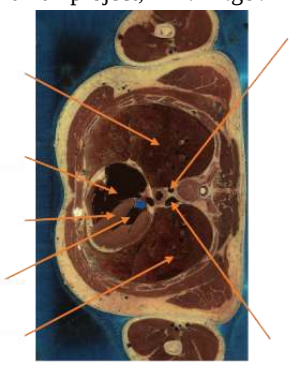
Figure 16.4.1: **Internal Structures of the Heart** This anterior view of the heart shows the four chambers, the major vessels and their early branches, as well as the valves. The presence of the pulmonary trunk and aorta covers the interatrial septum, and the atrioventricular septum is cut away to show the atrioventricular valves. (CC-BY-4.0, OpenStax, Human Anatomy)

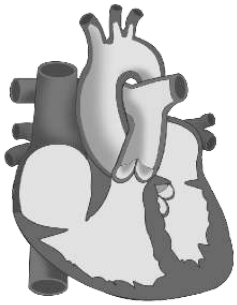
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16.5: Exercises

LAB 16 EXERCISES 16.5.1

Visible human project, nlm.nih.gov





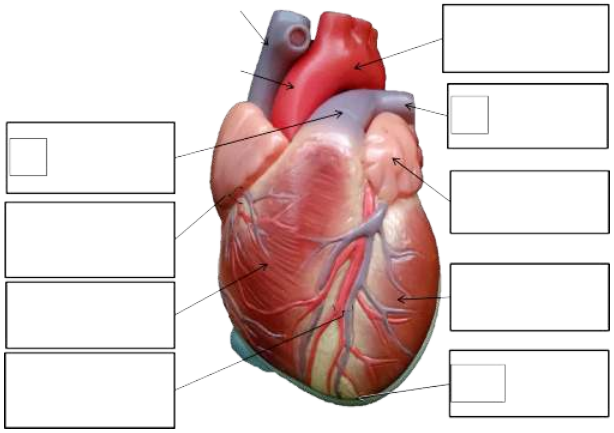
Draw the pathway of blood through the heart

Label the following

1	Aorta
2	Inferior vena cava
3	L. ventricle
4	R. ventricle
5	Lungs
6	Interventricular septum

Draw the pathway of blood through the heart

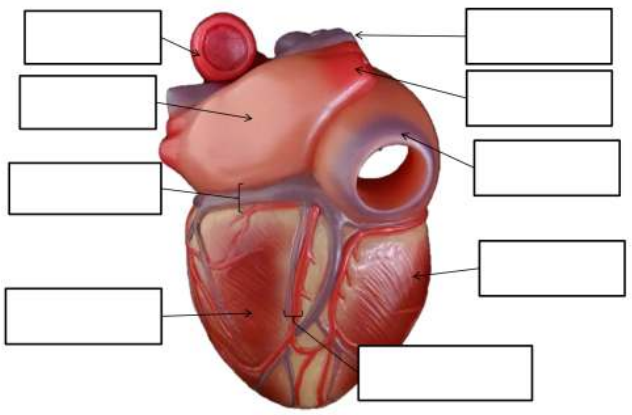
LAB 16 EXERCISES 16.5.2



Label the following

1	Apex
2	Ascending aorta
3	Aortic arch
4	Anterior interventricular sulcus
5	L. Pulmonary artery
6	L. auricle
7	L. ventricle
8	Pulmonary trunk
9	Superior vena cava
10	R. ventricle
11	Coronary Sulcus

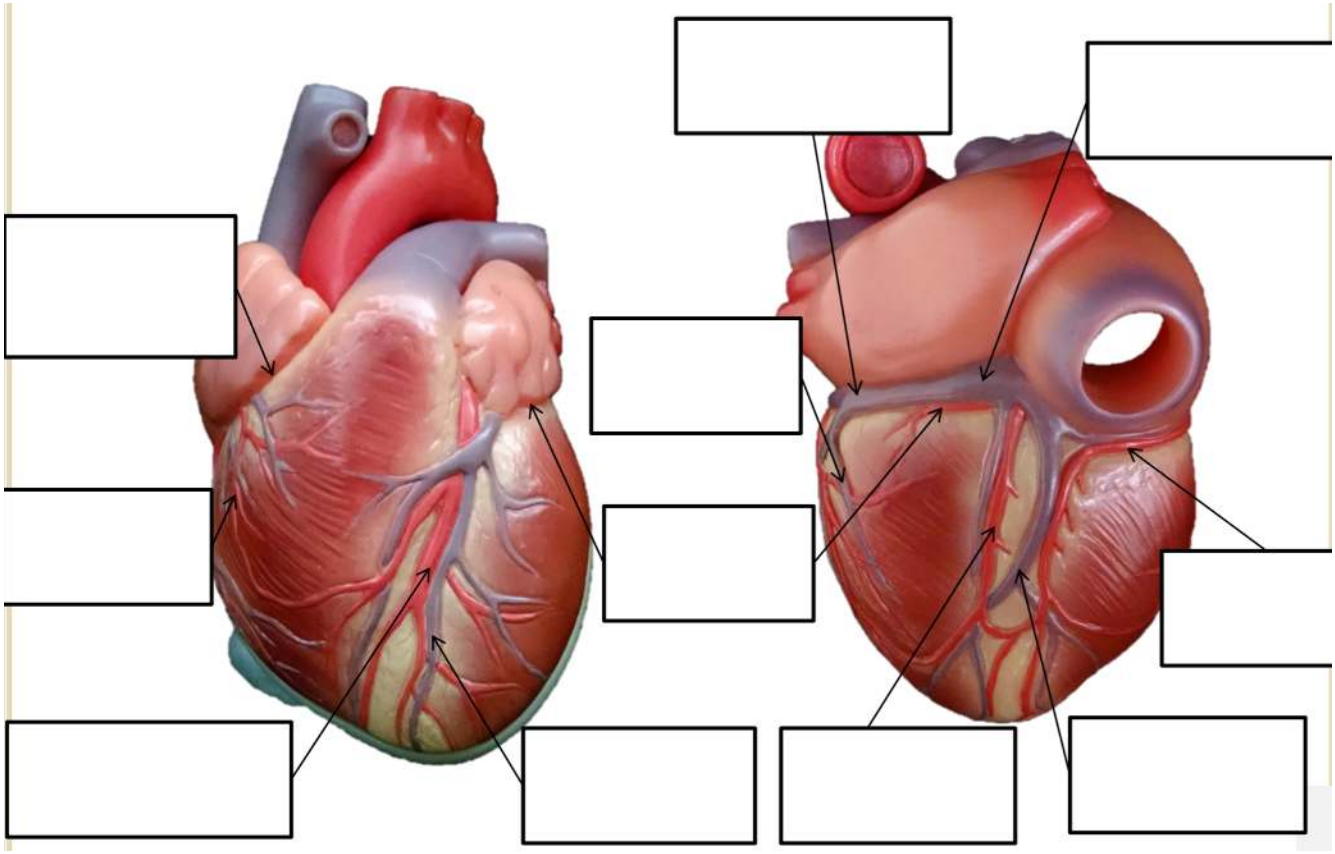
LAB 16 EXERCISES 16.5.3



Label the following

1	Aorta
2	Coronary sulcus
3	L. atrium
4	L. ventricle
5	Inferior Vena Cava
6	R. Pumonary a
7	R. Pulmonary v.
8	Posterior interventricular sulcus
9	R. ventricle

LAB 16 EXERCISES 16.5.4



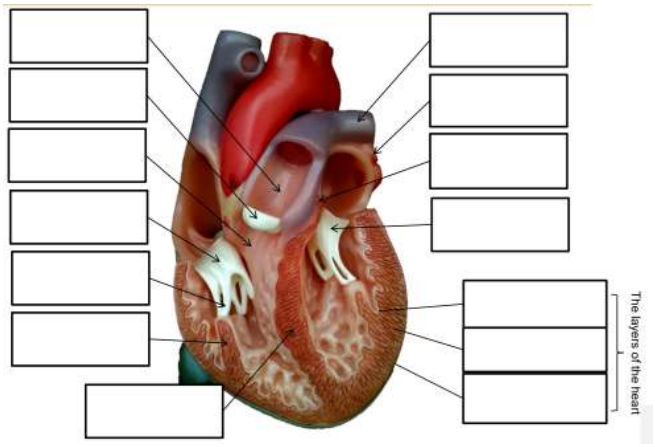
Label the following

1	R. Coronary a. (RCA)
2	R. Marginal branch of RCA
3	Anterior interventricular a
4	Great cardiac vein
5	Circumflex A

Label the following

1	Great cardiac vein
2	Posterior interventricular a
3	Middle cardiac vein
4	Right coronary a.
5	Coronary sinus
6	Circumflex a.
7	L. marginal vein

LAB 16 EXERCISES 16.5.5

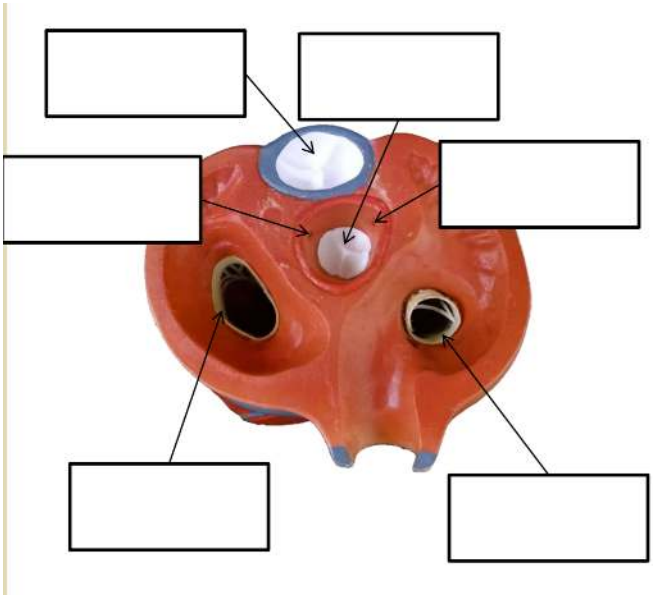


Label the following

1	L. Pulmonary a.
2	L. Pulmonary v.
3	Interventricular septum
4	Mitral valve
5	Tricuspid valve
6	Pulmonary semilunar valve
7	Chordae tendinae
8	Papillary muscle
9	Endocardium
10	Myocardium
11	Epicardium
12	L. coronary a.
13	Pulmonary trunk
14	Conus arteriosis

LAB 16 EXERCISES 16.5.6

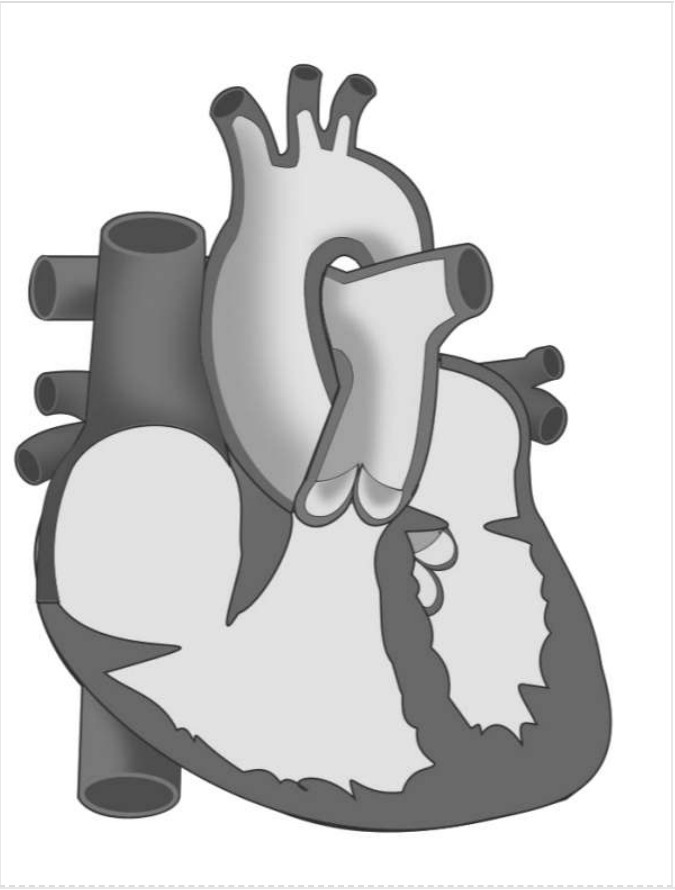
Valves and Conduction System



Label the following

1	R. coronary a.
2	L. coronary a.
3	Mitral valve
4	Tricuspid valve
5	Pulmonary SL valve
6	Aortic SL valve

LAB 16 EXERCISES 16.5.7



On this picture, draw and label the following:

1	SA Node
2	AV node
3	Bundle of His
4	Bundle branches
5	Purkinje fibers

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16.6: MODELS- Heart and Torsos

Inferior vena cava

Superior vena cava

Right atrium

- Pectinate muscles
- Fossa ovalis

Right atrioventricular valve (tricuspid)

- Chordae tendineae
- Papillary muscles

Right ventricle

- Trabeculae carneae

Conus arteriosus

Pulmonary SL valve

Pulmonary trunk

Pulmonary arteries

Pulmonary veins

Left atrium

Left atrioventricular valve (mitral, bicuspid)

Left ventricle Aortic SL valve

Aorta

- Ascending, arch, descending, abdominal
- R. Brachiocephalic, L. Common Carotid a, L subclavian a.
- Apex

Auricles

Anterior interventricular sulcus

Posterior interventricular sulcus

Coronary sulcus

Inter-atrial septum

Interventricular septum

Electrical conduits: (clear heart model)

- Sinoatrial (SA) node
- Atrioventricular (AV) node
- Atrioventricular (AV) bundle (Bundle of His)
- Right and left bundle branches
- Purkinje fibers
- Moderator band

Tissue layers:

- Parietal pericardium
- Visceral pericardium (epicardium)

- Myocardium
- Endocardium

Coronary circulation:

- R. coronary a.
- Anterior interventricular a.
- Posterior interventricular a.
- Circumflex a.
- L. coronary a.
- Middle cardiac v.
- Great cardiac v.
- Coronary sinus
- Marginal arteries

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16.7: Heart Dissection

The heart dissection is probably one of the most difficult dissections you will do. Part of the reason it is so difficult to learn is that the heart is not perfectly symmetrical, but it is so close that it becomes difficult to discern which side you are looking at (dorsel, ventral, left or right). Finding the vessels is directly related to being able to orient the heart correctly and figuring out which side you are looking at.



Figure **16.7.1**: In the beginning

The heart is also difficult because the fatty tissue that surrounds the heart can obscure the openings to the vessels. This means that you really must experience the heart with your hands and feel your way to find the openings. Many people will be squeamish about this, and because the heart is slippery, it is easy to drop. Don't be shy with the heart, use your fingers to feel your way through the dissection.

1. When you first remove your heart from the bag, you will see a lot of fatty tissue surrounding it. It is usually a waste of time to try to remove this tissue. Grab some colored pencils to help you identify and mark the vessels you find.

   There are a few clues to help you figure out the left and the right side, but often the packaging and preserving process can cause the heart to be misshapen. If you are lucky, the heart will be nicely preserved and you will see that the front (ventral) side of the heart has a couple of key features: 1) a large pulmonary trunk that extends off the top of it 2) the flaps of the auricles covering the top of the atria. 3) the curve of the entire front side, whereas the backside is much flatter.

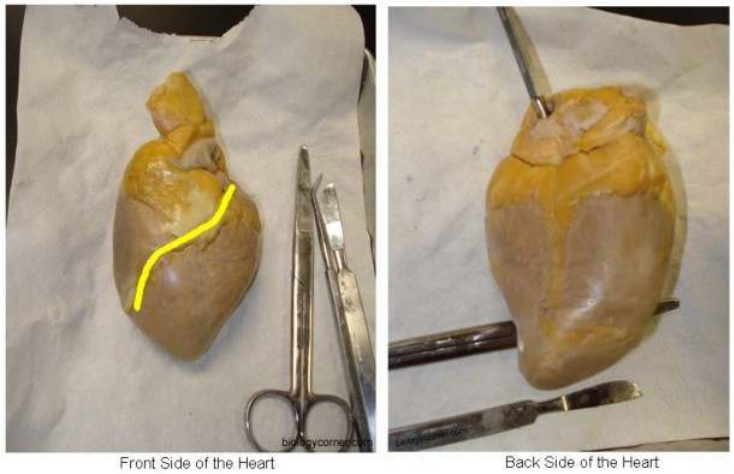


Figure **16.7.2**: Front and back side

   The first image shows the front side of the heart, often identified by the anterior interventricular artery that runs cross it at an angle (yellow).

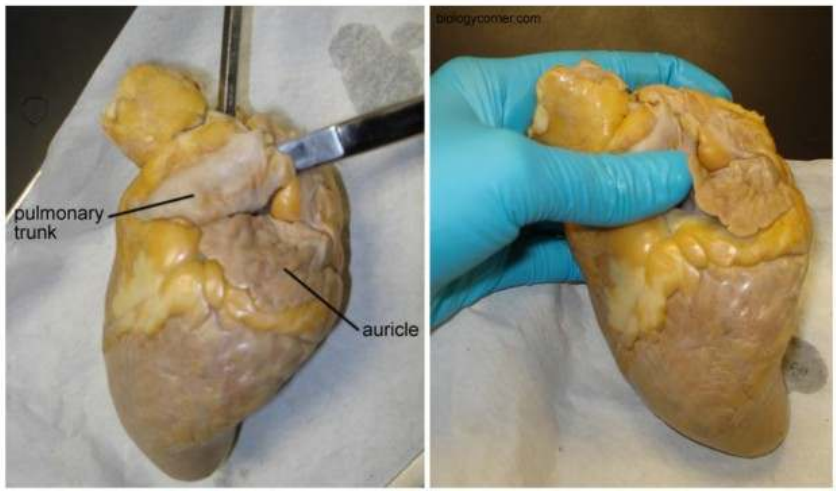


Figure **16.7.3**: The auricle

The auricle is the flap that covers the atrium, it looks like an ear. The pulmonary trunk is the located at the front of the heart and enters at an angle.

Step 2: Locate the Aorta

Use your fingers to probe around the top of the heart. Four major vessels can be found entering the heart: the pulmonary trunk, aorta, superior vena cava, and the pulmonary vein. Remember that if you are looking at the back of the heart, then the right and left sides are the same as your right and left hand. This picture was on the board the day of the dissection so that you could glance up and recall which vessel entered which part of the heart.

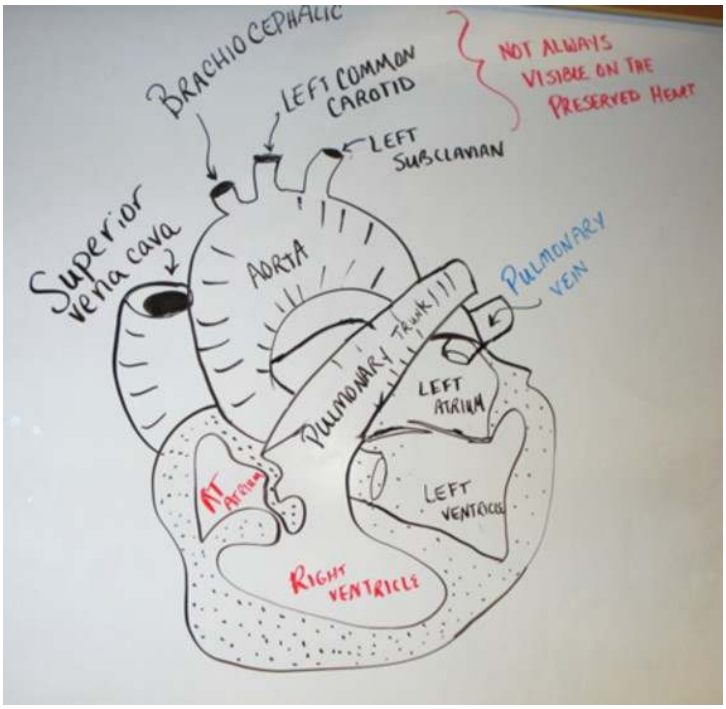


Figure **16.7.4**: Schematic of the heart showing the aorta and veins

If you find the pulmonary vein, the aorta should be situated a little bit behind it. It may be covered by fat, so use your fingers to poke around until you find the opening. Push your finger all the way in and you will feel inside of the left ventricle. The left ventricle has a very thick wall, unlike the right ventricle. Insert your finger through the pulmonary vessel to feel the left ventricle and you will notice and feel that it is much thinner than the left side of the heart.

With your fingers or probes in the aorta and the pulmonary trunk you should notice that they criss-cross each other, with the pulmonary trunk in the front. At this point, you may want to use your colored pencils to mark these vessels so that you don't get them confused when you are searching for the other two openings that top of the heart.



Figure
16.7.5
: The pulmonary vein

Step 3: Locate the Veins

The two major veins that enter the heart can be found on the backside, as both enter the atria. On the left side, you should be able to find the opening of the pulmonary vein as it enters the left atrium. The superior vena cava enters the right atrium. In many preserved hearts, the heart was cut at these points, so you won't see the vessels themselves, you will just find the openings. Again, use your fingers to feel around the heart to find the openings. If you've marked the aorta and pulmonary then you won't mistake them for the veins you are looking for. This picture shows all of the vessels labeled.

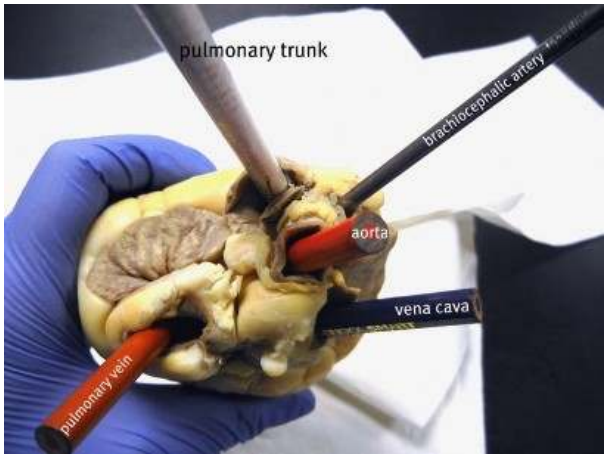


Figure **16.7.6**: Using pencils to mark the openings

Sometimes, the aorta still has its branches attached to it. There are three vessels that branch from the aorta: the brachiocephalic, left common carotid and the left subclavian. The majority of the time, these vessels are not visible because the aorta was cut too close to the main part of the heart when the heart was removed from the animal. Occassionally, you can find the brachiocephalic artery attached, as it is in this photo.

Step 4: Make the Incisions



Figure 16.7.7: Opening the heart

Now that you have all of the vessels located and marked, you can now open the heart to view the inner chambers. Use the superior vena cava and pulmonary vein as guides for where to cut. You are basically going to be cutting each side of the heart so that you can look inside. (Some dissections will ask you to make a coronal cut where a single cut opens the entire back side of the heart). The heart below is marked to show you where the two incisions should be made.

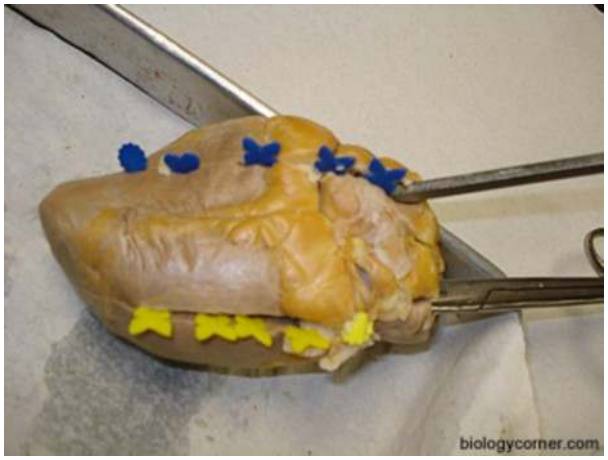


Figure 16.7.8: Where to make incisions

Cut the heart in half to expose the chambers. My students affectionally call these two variations the "hot dog cut" as pictured above because it looks like a hot dog bun, or the "hamburger cut, where the heart is cut into the front and the back half, as shown below.Figure 16.7.2: Copy and Paste Caption here. (Copyright; author via source)

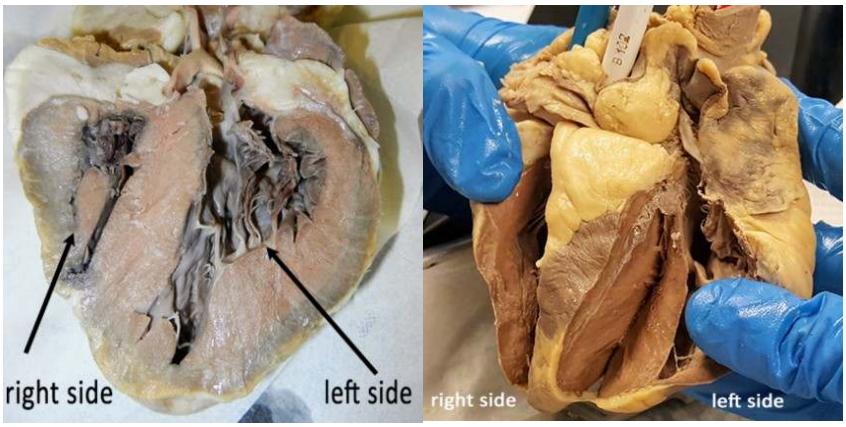


Figure 16.7.9: The opened heart

Step 5: Viewing the Chambers

At this point it is helpful to have two hands, one to hold the heart apart so you can take a peak inside of it and another to use a probe to locate the specific parts. Your colored pencils you used to mark the heart in step 2 can also now be used to see where those vessels connect within the heart. For instance, the aorta pencil can now be seen ending in the left ventricle.

You can also now see how much thicker the walls of the left ventricle are compared to the right ventricle.

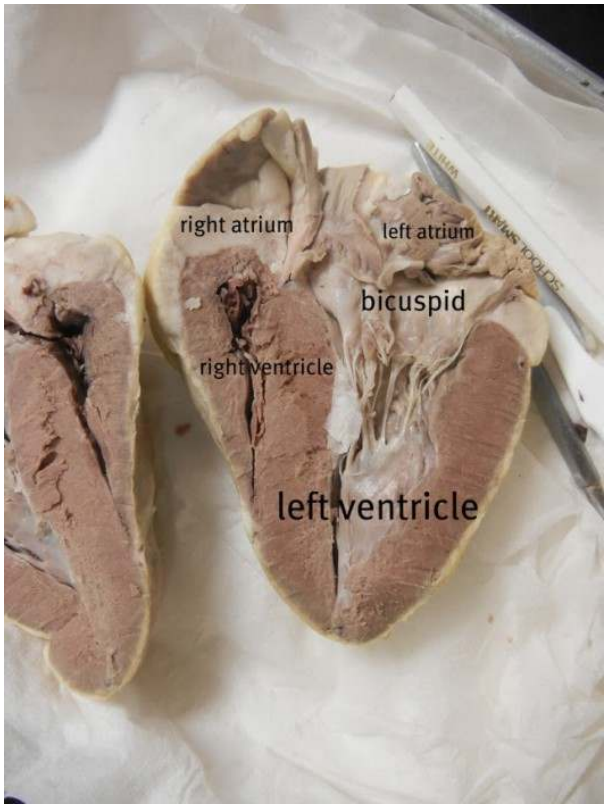


Figure **16.7.10**: The opened heart

The other obvious structures seen within the heart are the chordae tendinae which are attached to papillary muscles. These tendons hold the heart valves in place, sometimes they are called the "heartstrings". The valves were probably cut when the heart was opened, but if you follow the "cords" they should lead you to a thin flap that is the atrioventricular (bicuspid) valve. You can find a similar valve on the right side of the heart (tricuspid).

Image shows the left atrioventricular valve (bicuspid) and the chordae tendinae.



Figure 16.7.11: Displaying the chordae tendinae

Heart Dissection: Biology Corner https://www.biologycorner.com/anatomy/circulatory/heart/heart_dissection.html

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CHAPTER OVERVIEW

17: Blood Vessels and Circulation

Learning Objectives

- Compare and contrast the three tunics that make up the walls of most blood vessels
- Distinguish between elastic arteries, muscular arteries, and arterioles on the basis of structure and location
- Describe the basic structure of a capillary bed, from the supplying metarteriole to the venule into which it drains
- Explain the structure of venous valves in the large veins of the extremities

17.1: Shared Structures
17.2: Exercises
17.3: MODELS- Flat Body, Skull with Arteries and Nerves, Torso, Leg, Arm, and Sagittal Head

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17.1: Shared Structures

Different types of blood vessels vary slightly in their structures, but they share the same general features. Arteries and arterioles have thicker walls than veins and venules because they are closer to the heart and receive blood that is surging at a far greater pressure (**Figure 17.1**). Each type of vessel has a **lumen**—a hollow passageway through which blood flows. Arteries have smaller lumens than veins, a characteristic that helps to maintain the pressure of blood moving through the system. Together, their thicker walls and smaller diameters give arterial lumens a more rounded appearance in cross section than the lumens of veins.

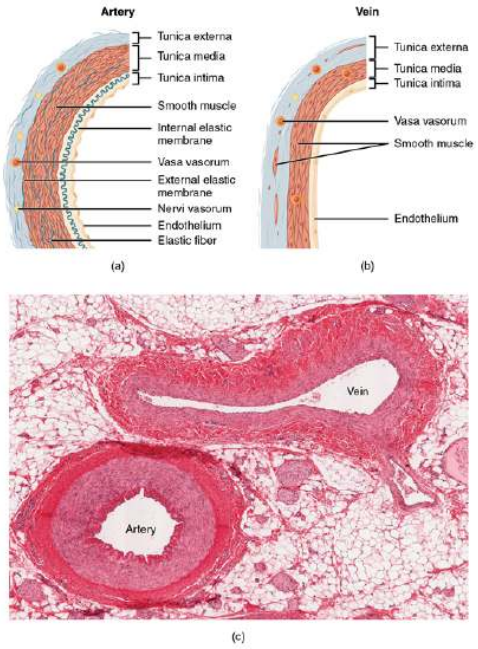


Figure **17.1.1**: Structure of Blood Vessels (a) Arteries and (b) veins share the same general features, but the walls of arteries are much thicker because of the higher pressure of the blood that flows through them. (c) A micrograph shows the relative differences in thickness. LM × 160. (Micrograph provided by the Regents of the University of Michigan Medical School © 2012) (CC-BY-4.0, OpenStax, Human Anatomy)

Comparison of Tunics in Arteries and Veins

	Arteries	Veins
General Appearance	Thick Walls with small lumens Generally appear round	Thin walls with large lumens Generally appear flattened
Tunica Intima	Endothelium usually appears wavy due to constriction of smooth muscle Internal elastic membrane presents in larger vessels	Endolithelium appears smooth Internal elastic membrane absent
Tunica media	Normally the thickest layer in arteries Smooth muscle cells and elastic fibers predominate (the proportions of these vary with distance from the heart" External elastic membrane present in larger vessels	Normally thinner than the tunica externa Smooth muscle cells and collagenous fibers predeominate Esternal elastic membrane absent
Tunica externa	Normally thinner than the tunica media in all but the largest arteries Collagenous and elastic fibers Nervi vasorum and vasa vasorum present	Normally the thickest layer in veins Collagenous and smooth fibers predominate Some smooth muscle fibers Nervi vasoum and vasa vasorum present

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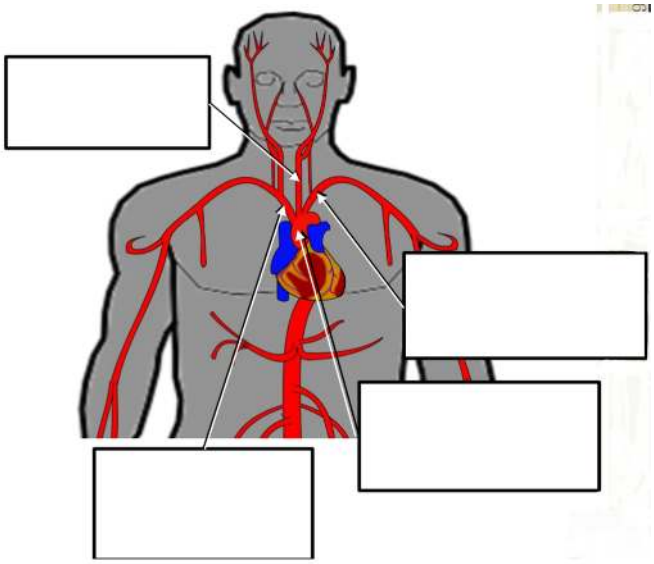
17.2: Exercises

LAB 17 EXERCISES 17.2.1



Label the following

1	Tunica interna
2	Tunica media
3	Tunica externa
4	Valve
5	Vasa vasorum
6	Artery
7	Vein.

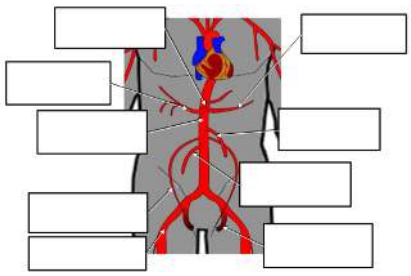


Label the following (include Left/right on all pages)

1	Aorta
2	L common carotid a
3	Brachiocephalic trunk
4	L subclavian a.

LAB 17 EXERCISES 17.2.2

Arteries of the Abdomen

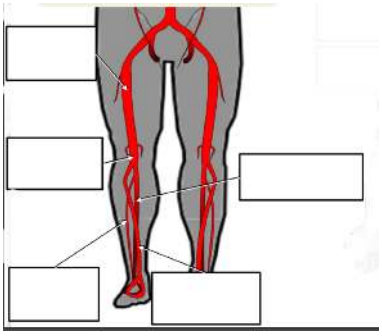


Label the following (include Left/right where appropriate)

1	Celiac trunk
2	Common hepatic a.
3	Common hepatic a.
4	Superior mesenteric a. s
5	Inferior mesenteric a.
6	Internal iliac a.
7	External iliac a.
8	Common Hepatic a.
9	Splenic a.
10	Abdominal aorta

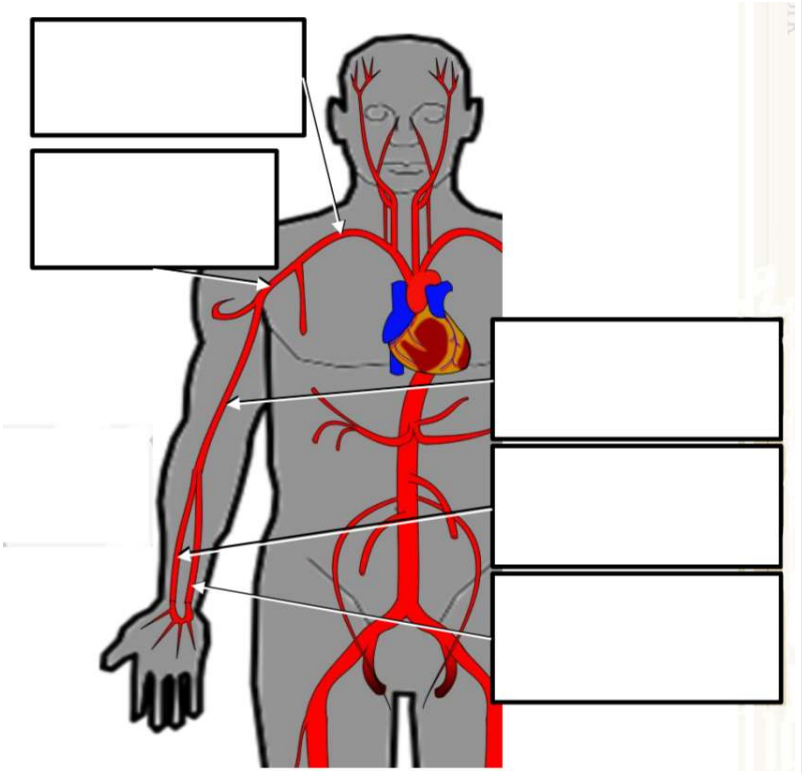
LAB 17 EXERCISES 17.2.3

Arteries of the limbs



Label the following (include Left/right where appropriate)

1	Popliteal a.
2	Posterior tibial a
3	Anterior tibial a
4	Fibular a.
5	Femoral a.



Label the following (include Left/right where appropriate)

1	Ulnar a
2	Radial a
3	Brachial a
4	Subclavian a.
5	Axillary a

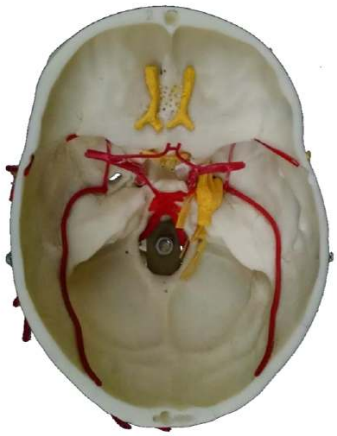
LAB 17 EXERCISES 17.2.4

Arteries of the head



Identify the following:

1	Superficial temporal a.
2	Facial a
3	Common carotid a
4	Vertebral a.
5	Internal carotid a.
6	External carotid a
7	Occipital a

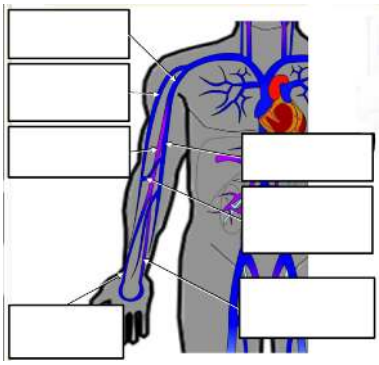


Identify the following:

1	Circle of Willis
2	Basilar a.
3	Vertebral a.
4	Internal carotid a.

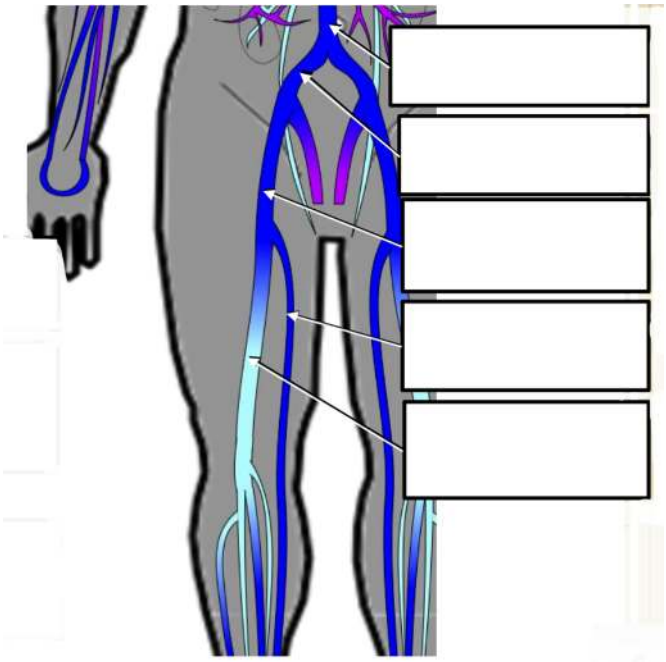
LAB 17 EXERCISES 17.2.5

Veins



Identify the veins (Include Left/Right where appropriate)

1	Basilic v
2	Cephalic v.
3	Brachial v
4	Axillary v.
5	Median cubital v
6	Radial v
7	Ulnar v

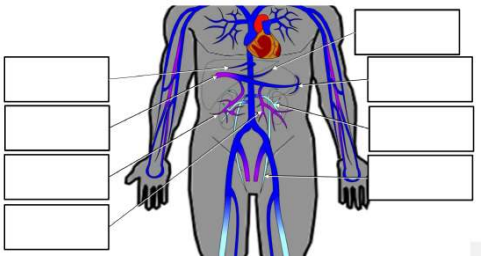


Label the veins (Include Left/Right where appropriate):

1	Femoral v
2	Common iliac v.
3	External iliac v.
4	Great saphenous v.
5	Inferior vena cava.

LAB 17 EXERCISES 17.2.6

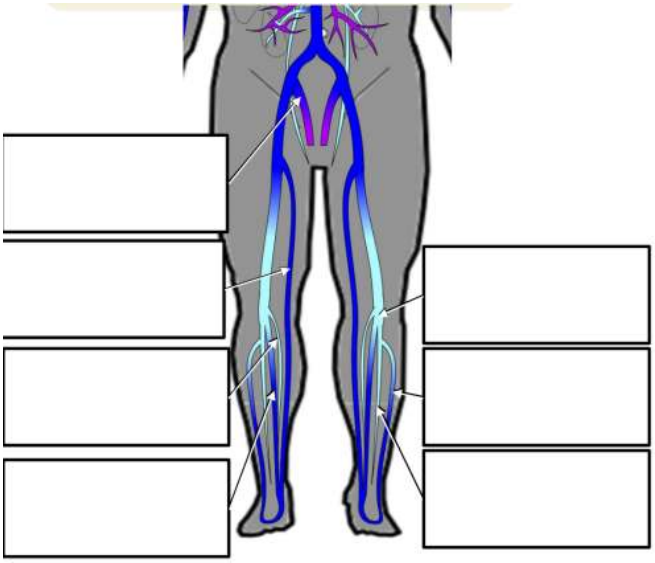
Veins



Label the veins:

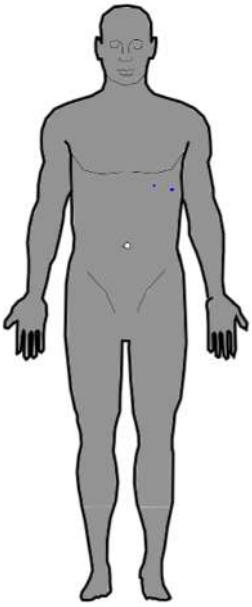
1	R. Hepatic v
2	Hepatic Portal v
3	Hepatic Portal v
4	Splenic v.
5	Inferior mesenteric v.
6	Superior mesenteric v.
7	L Gonadal v.
8	* L Renal v.

LAB 17 EXERCISES 17.2.7



Label the following (Include Left/Right where appropriate):

1	Internal iliac v.
2	Great saphenous v
3	Small saphenous v.
4	Popliteal v
5	Anterior tibial v
6	Posterior tibial v
7	Fibular v



Label 4 common pulse pressure points with names and arrows (places where you could find a pulse on a patient)

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17.3: MODELS- Flat Body, Skull with Arteries and Nerves, Torso, Leg, Arm, and Sagittal Head

Blood vessel histology:

- Tunica externa
- Tunica media
- Tunica interna
- Vasa vasorum
- Valves
- Varicose vein

Arteries (All arteries should have the word arteries at the end)

- Aorta
  - Ascending * arch * descending * thoracic * abdominal
- Brachiocephalic trunk
- Common carotid (skull)
  - External carotid (skull)
    - Superior thyroid (torso)
    - Facial (skull)
    - Superficial temporal (skull)
    - Occipital (skull)
  - Internal carotid
  - Circle of Willis (skull)
- Subclavian
  - Vertebral artery
    - Basilar artery (skull)
  - Axillary artery
  - Brachial artery
    - Radial artery
    - Ulnar artery
- Celiac trunk
- Left & right gastric artery
- Splenic
- Common hepatic a.
  - Hepatic
  - Superior mesenteric
- Suprarenal
- Renal
- Gonadal
- Inferior mesenteric
- Common iliac
- Internal iliac
- External iliac
- Femoral
- Popliteal
- Anterior tibial
- Posterior tibial

Veins (All veins except the Vena Cava should have the word vein at the end)

- Superior vena cava
- Brachiocephalic
- Internal jugular
  - Superior sagittal sinus
  - Straight sinus
- External jugular
- Subclavian
  - Axillary
  - Cephalic
  - Brachial
    - Radial
    - Ulnar
  - Basilic
    - Median cubital
- Inferior vena cava
  - Hepatic
  - Suprarenal
  - Renal
  - Gonadal
  - Common iliac
    - Internal iliac
    - External iliac
- Great saphenous
- Femoral
  - Popliteal
  - Anterior tibial
  - Posterior tibial
- Fibular
- Small saphenous
- Inferior mesenteric
- Splenic
- Superior mesenteric
- Hepatic portal vein

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CHAPTER OVERVIEW

18: The Lymphatic System

Learning Objectives

- Describe the structure of the lymphatic tissue (lymph fluid, vessels, ducts, and organs)
- Describe the structure of the primary and secondary lymphatic organs

The **lymphatic system** is the system of vessels, cells, and organs that carries excess fluids to the bloodstream and filters pathogens from the blood. The swelling of lymph nodes during an infection and the transport of lymphocytes via the lymphatic vessels are but two examples of the many connections between these critical organ systems.

18.1: Structure of the Lymphatic System
18.2: Lymphoid Organs
18.3: Spleen
18.4: Lymphoid Nodules
18.5: Exercises
18.6: MODELS- Torsos and Mid-Sagittal Head

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18.1: Structure of the Lymphatic System

The lymphatic vessels begin as open-ended capillaries, which feed into larger and larger lymphatic vessels, and eventually empty into the bloodstream by a series of ducts. Along the way, the lymph travels through the lymph nodes, which are commonly found near the groin, armpits, neck, chest, and abdomen. Humans have about 500– 600 lymph nodes throughout the body (Figure **18.1.1**).

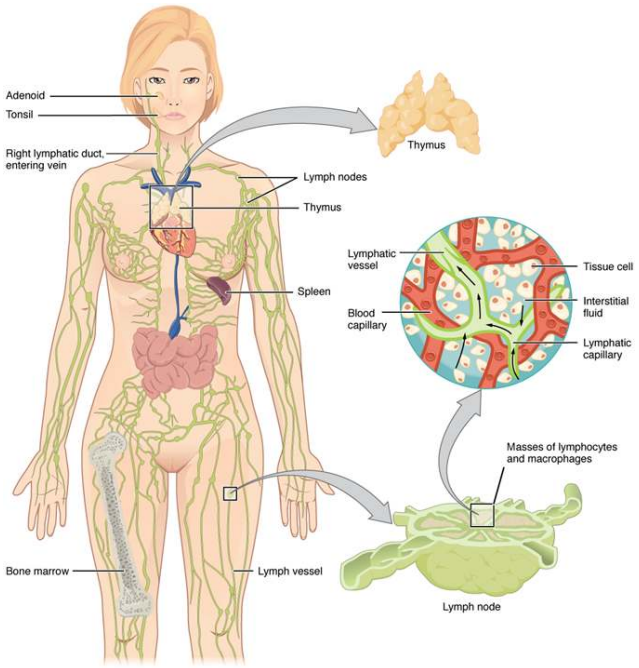


Figure **18.1.1**: Anatomy of the Lymphatic System Lymphatic vessels in the arms and legs convey lymph to the larger lymphatic vessels in the torso. (CC-BY-4.0, OpenStax, Human Anatomy)

Lymphatic Capillaries

Lymphatic capillaries, also called the terminal lymphatics, are vessels where interstitial fluid enters the lymphatic system to become lymph fluid. Located in almost every tissue in the body, these vessels are interlaced among the arterioles and venules of the circulatory system in the soft connective tissues of the body (Figure **18.1.2**).

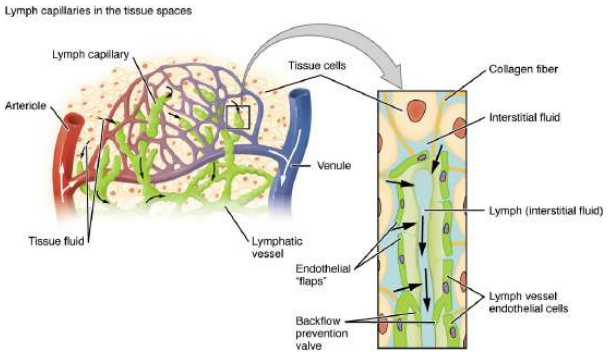


Figure **18.1.2**: Lymphatic Capillaries Lymphatic capillaries are interlaced with the arterioles and venules of the cardiovascular system. Collagen fibers anchor a lymphatic capillary in the tissue (inset). Interstitial fluid slips through spaces between the overlapping endothelial cells that compose the lymphatic capillary. (CC-BY-4.0, OpenStax, Human Anatomy)

Larger Lymphatic Vessels, Trunks, and Ducts

The lymphatic capillaries empty into larger lymphatic vessels, which are similar to veins in terms of their three- tunic structure and the presence of valves. These one-way valves are located fairly close to one another, and each one causes a bulge in the lymphatic vessel, giving the vessels a beaded appearance (see Figure **18.1.2**).

The superficial and deep lymphatics eventually merge to form larger lymphatic vessels known as **lymphatic trunks**. On the right side of the body, the right sides of the head, thorax, and right upper limb drain lymph fluid into the right subclavian vein via the right lymphatic duct (Figure **18.1.3**). On the left side of the body, the remaining portions of the body drain into the larger thoracic duct, which drains into the left subclavian vein. The thoracic duct itself begins just beneath the diaphragm in the **cisterna chyli**, a sac-like chamber that receives lymph from the lower abdomen, pelvis, and lower limbs by way of the left and right lumbar trunks and the intestinal trunk.

The overall drainage system of the body is asymmetrical (see Figure **18.1.3**). The **right lymphatic duct** receives lymph from only the upper right side of the body. The lymph from the rest of the body enters the bloodstream through the **thoracic duct** via all the remaining lymphatic trunks. In general, lymphatic vessels of the subcutaneous tissues of the skin, that is, the superficial lymphatics, follow the same routes as veins, whereas the deep lymphatic vessels of the viscera generally follow the paths of arteries.

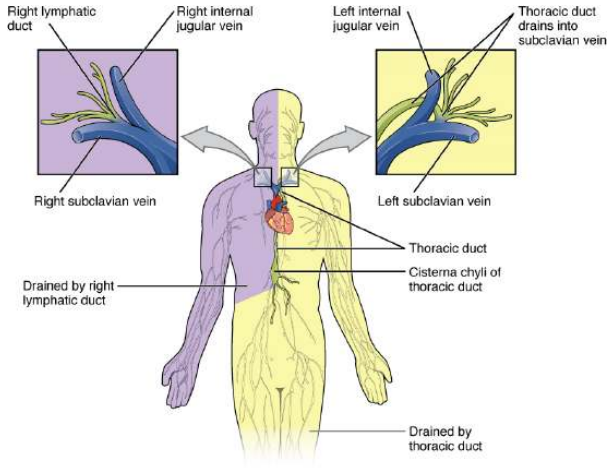


Figure **18.1.3**: CoMajor Trunks and Ducts of the Lymphatic System The thoracic duct drains a much larger portion of the body than does the right lymphatic duct. (CC-BY-4.0, OpenStax, Human Anatomy)

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18.2: Lymphoid Organs

The **thymus** gland is a bilobed organ found in the space between the sternum and the aorta of the heart (Figure 18.2.1). Connective tissue holds the lobes closely together but also separates them and forms a capsule. The connective tissue capsule further divides the thymus into lobules via extensions called trabeculae. The outer region of the organ is known as the cortex and contains large numbers of thymocytes with some epithelial cells, macrophages, and dendritic cells (two types of phagocytic cells that are derived from monocytes). The cortex is densely packed so it stains more intensely than the rest of the thymus (see Figure 18.2.1). The medulla, where thymocytes migrate before leaving the thymus, contains a less dense collection of thymocytes, epithelial cells, and dendritic cells.

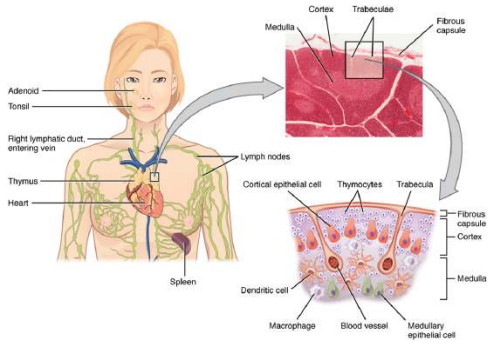


Figure 18.2.1: Location, Structure, and Histology of the Thymus The thymus lies above the heart. The trabeculae and lobules, including the darkly staining cortex and the lighter staining medulla of each lobule, are clearly visible in the light micrograph of the thymus of a newborn. LM × 100. (Micrograph provided by the Regents of the University of Michigan Medical School © 2012) (CC-BY-4.0, OpenStax, Human Anatomy)

Lymph Nodes

Lymph nodes function to remove debris and pathogens from the lymph, and are thus sometimes referred to as the “filters of the lymph” (Figure 18.2.2). Any bacteria that infect the interstitial fluid are taken up by the lymphatic capillaries and transported to a regional lymph node. Dendritic cells and macrophages within this organ internalize and kill many of the pathogens that pass through, thereby removing them from the body. The lymph node is also the site of adaptive immune responses mediated by T cells, B cells, and accessory cells of the adaptive immune system. Like the thymus, the bean- shaped lymph nodes are surrounded by a tough capsule of connective tissue and are separated into compartments by trabeculae, the extensions of the capsule. In addition to the structure provided by the capsule and trabeculae, the structural support of the lymph node is provided by a series of reticular fibers laid down by fibroblasts.

The major routes into the lymph node are via **afferent lymphatic vessels** (see Figure 18.2.2). Cells and lymph fluid that leave the lymph node may do so by another set of vessels known as the **efferent lymphatic vessels**. Lymph enters the lymph node via the subcapsular sinus, which is occupied by dendritic cells, macrophages, and reticular fibers. Within the cortex of the lymph node are lymphoid follicles, which consist of germinal centers of rapidly dividing B cells surrounded by a layer of T cells and other accessory cells. As the lymph continues to flow through the node, it enters the medulla, which consists of medullary cords of B cells and plasma cells, and the medullary sinuses where the lymph collects before leaving the node via the efferent lymphatic vessels.

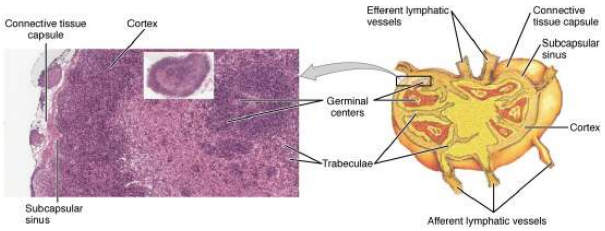


Figure 18.2.2: Structure and Histology of a Lymph Node Lymph nodes are masses of lymphatic tissue located along the larger lymph vessels. The micrograph of the lymph nodes shows a germinal center, which consists of rapidly dividing B cells surrounded by a layer of T cells and other accessory cells. LM × 128. (Micrograph provided by the Regents of the University of Michigan Medical School © 2012) (CC-BY-4.0, OpenStax, Human Anatomy)

Spleen

In addition to the lymph nodes, the **spleen** is a major secondary lymphoid organ (Figure 18.2.3). It is about 12 cm (5 in) long and is attached to the lateral border of the stomach via the gastrosplenic ligament. The spleen is a fragile organ without a strong capsule, and is dark red due to its extensive vascularization.

The spleen is sometimes called the “filter of the blood” because of its extensive vascularization and the presence of macrophages and dendritic cells that remove microbes and other materials from the blood, including dying red blood cells. The spleen also functions as the location of immune responses to blood- borne pathogens.

The spleen is also divided by trabeculae of connective tissue, and within each splenic nodule is an area of red pulp, consisting of mostly red blood cells, and white pulp, which resembles the lymphoid follicles of the lymph nodes. Upon entering the spleen, the splenic artery splits into several arterioles (surrounded by white pulp) and eventually into sinusoids. Blood from the capillaries subsequently collects in the venous sinuses and leaves via the splenic vein. The red pulp consists of reticular fibers with fixed macrophages attached, free macrophages, and all of the other cells typical of the blood, including some lymphocytes.

The white pulp surrounds a central arteriole and consists of germinal centers of dividing B cells surrounded by T cells and accessory cells, including macrophages and dendritic cells. Thus, the red pulp primarily functions as a filtration system of the blood, using cells of the relatively nonspecific immune response, and white pulp is where adaptive T and B cell responses are mounted.

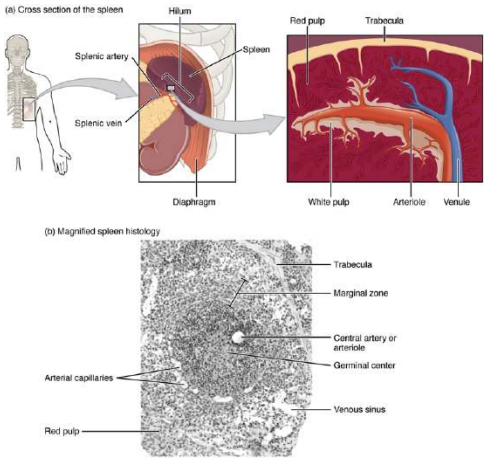


Figure 18.2.3: Spleen (a) The spleen is attached to the stomach. (b) A micrograph of spleen tissue shows the germinal center. The marginal zone is the region between the red pulp and white pulp, which sequesters particulate antigens from the circulation and presents these antigens to lymphocytes in the white pulp. EM × 660. (Micrograph provided by the Regents of the University of Michigan Medical School © 2012) (CC-BY-4.0, OpenStax, Human Anatomy)

Lymphoid Nodules

Tonsils are lymphoid nodules located along the inner surface of the pharynx and are important in developing immunity to oral pathogens (Figure 18.2.4). The tonsil located at the back of the throat, the pharyngeal tonsil, is sometimes referred to as the adenoid when swollen. Such swelling is an indication of an active immune response to infection. Histologically, tonsils do not contain a

complete capsule, and the epithelial layer invaginates deeply into the interior of the tonsil to form tonsillar crypts. These structures, which accumulate all sorts of materials taken into the body through eating and breathing, actually “encourage” pathogens to penetrate deep into the tonsillar tissues where they are acted upon by numerous lymphoid follicles and eliminated. This seems to be the major function of tonsils—to help children’s bodies recognize, destroy, and develop immunity to common environmental pathogens so that they will be protected in their later lives. Tonsils are often removed in those children who have recurring throat infections, especially those involving the palatine tonsils on either side of the throat, whose swelling may interfere with their breathing and/or swallowing.

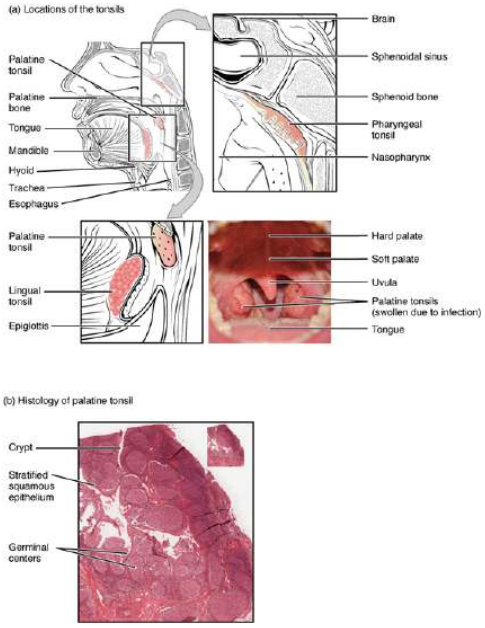


Figure **18.2.4**: Locations and Histology of the Tonsils (a) The pharyngeal tonsil is located on the roof of the posterior superior wall of the nasopharynx. The palatine tonsils lay on each side of the pharynx. (b) A micrograph shows the palatine tonsil tissue. LM × 40. (Micrograph provided by the Regents of the University of Michigan Medical School © 2012) (CC-BY-4.0, OpenStax, Human Anatomy)

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18.3: Spleen

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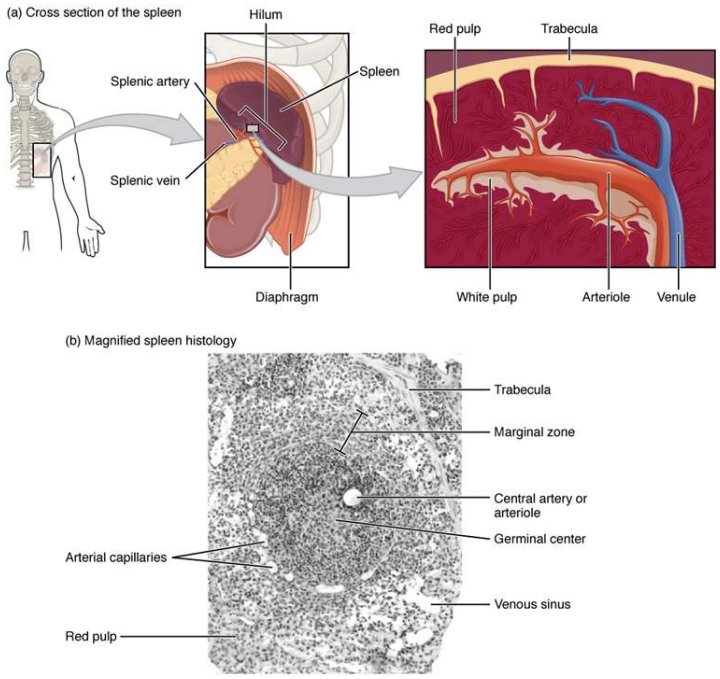


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18.4: Lymphoid Nodules

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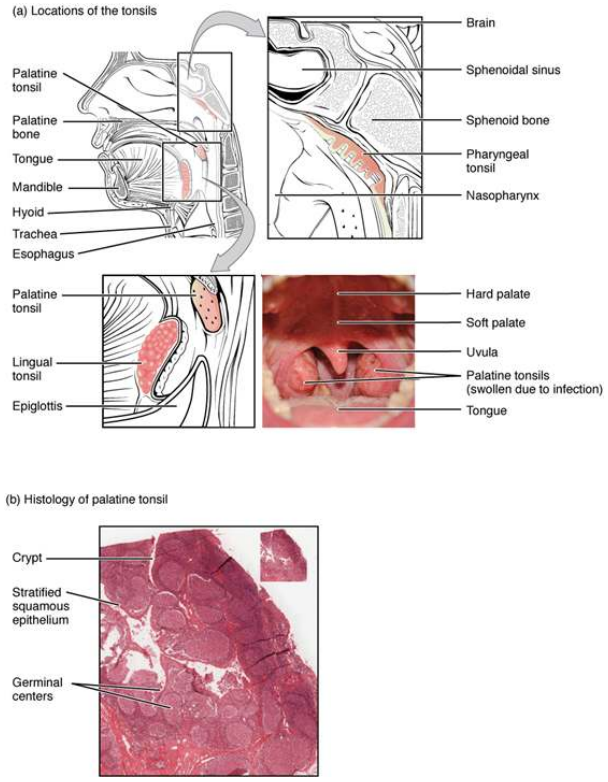
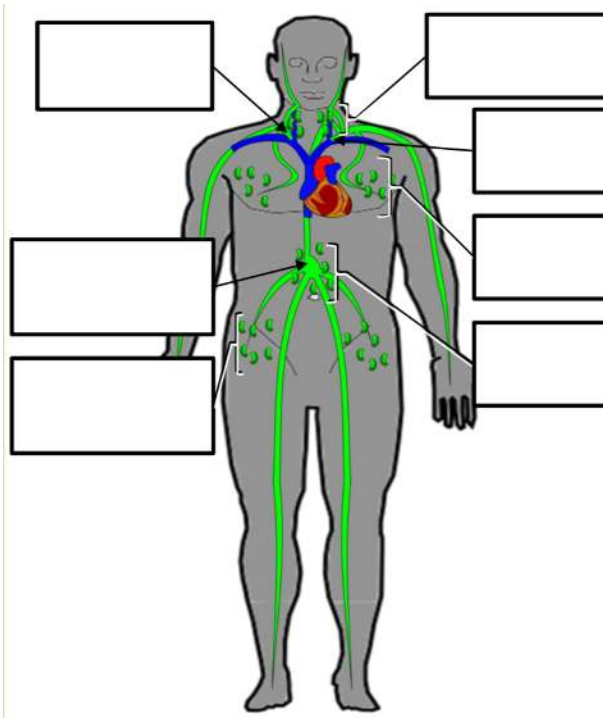


Figure **18.4.1**: Locations and Histology of the Tonsils (a) The pharyngeal tonsil is located on the roof of the posterior superior wall of the nasopharynx. The palatine tonsils lay on each side of the pharynx. (b) A micrograph shows the palatine tonsil tissue. LM × 40. (Micrograph provided by the Regents of the University of Michigan Medical School © 2012) (CC-BY-4.0, OpenStax, Human Anatomy)

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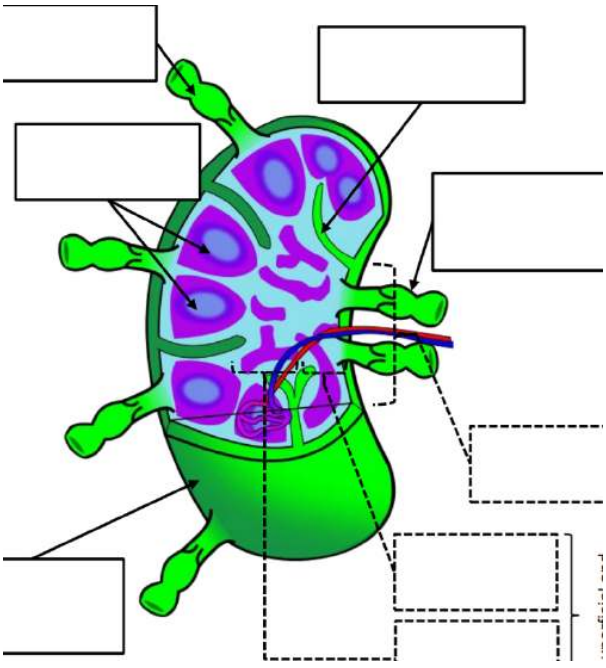
18.5: Exercises

LAB 17 EXERCISES 18.5.1



Match the following

1	Cisterna Chyli, R.
2	Lymphatic duct
3	Thoracic duct
4	Axillary lymph nodes
5	Abdominal lymph nodes
6	Cervical lymph nodes
7	Inguinal lymph nodes

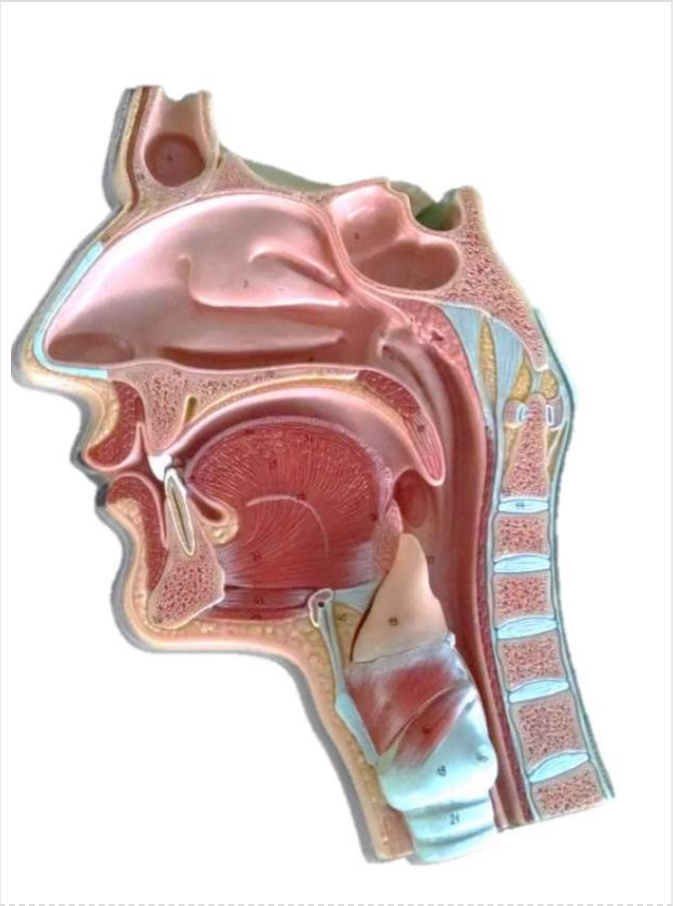


Match the following

1	Capsule
2	Afferent vessel
3	Efferent vessel
4	Hilus
5	Cortex
6	Medulla
7	Nodules
8	Trabeculae

LAB 17 EXERCISES 18.5.3

Tonsils



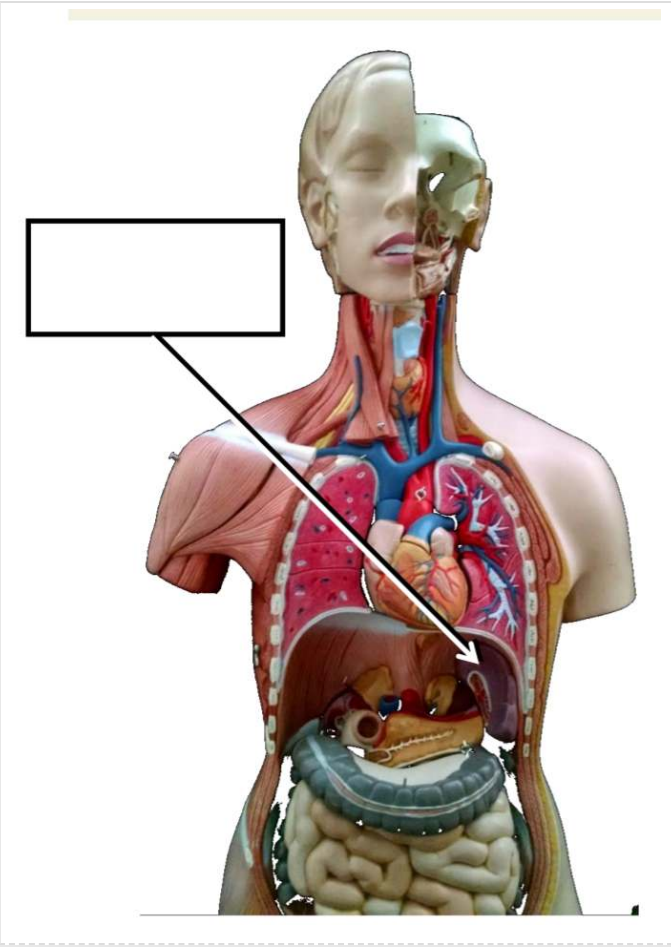
Label tonsils

https://med.libretexts.org/@go/page/52819



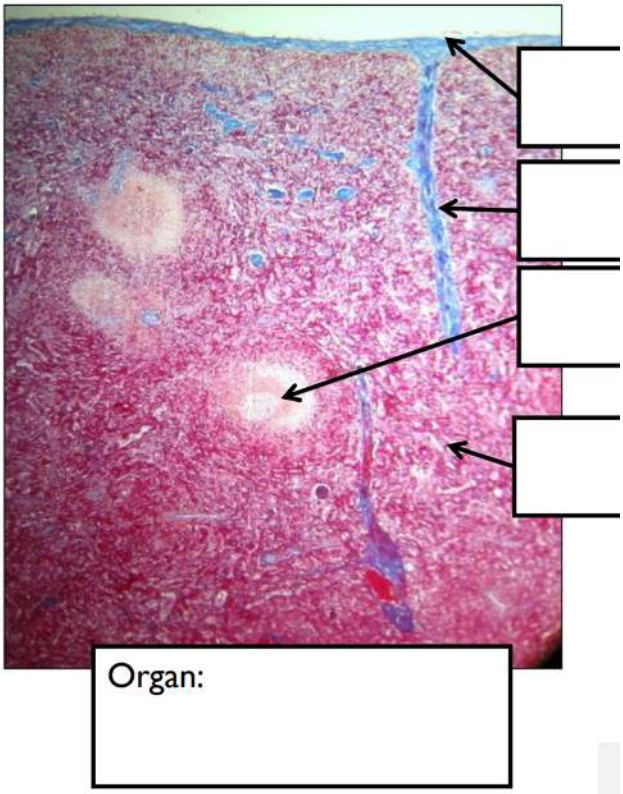
Identify the lymphatic structure found in the ileum and colon

LAB 17 EXERCISES 18.5.1



Label the following

1	Tunica interna
2	Tunica media
3	Tunica externa
4	Valve
5	Vasa vasorum
6	Artery
7	Vein.



Fill in and identify all the boxes

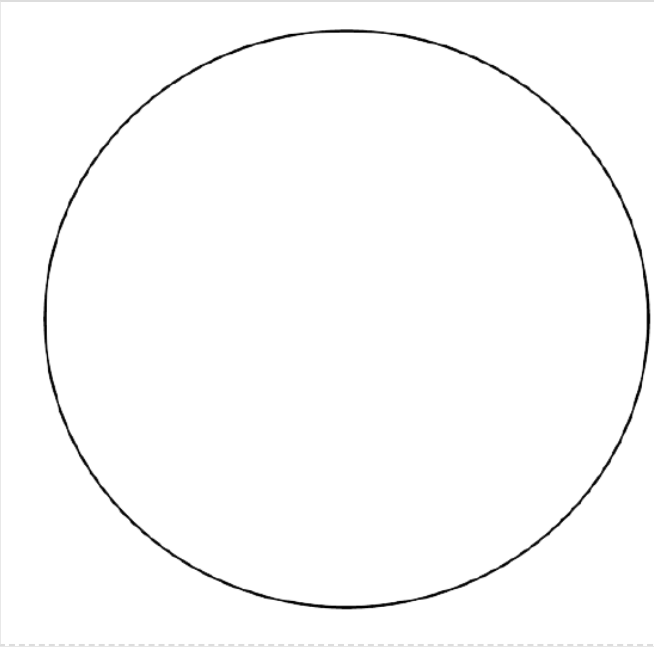
1	
2	
3	
4	
5	
6	
Organ	

LAB 17 EXERCISES 18.5.4

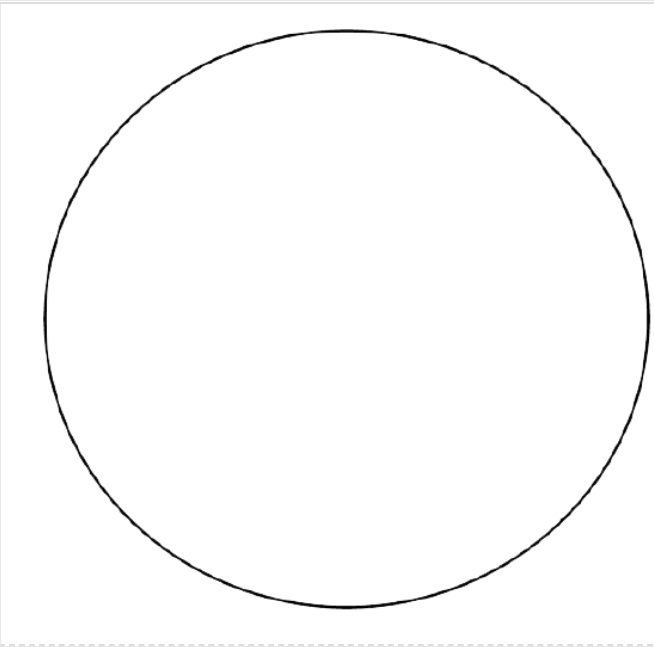
Peyer's patches (Mucosal associated lymphatic tissue, MALT) and Tonsil

1. Obtain a slide of each of the gland listed below from the slide box at your table.
2. Follow the checklist above to set up your slide for viewing.
3. View the slide on the objective which provides the best view. Find the representative object.
4. In the circle below the name, draw a representative sample of the tissue, taking care to correctly and clearly draw their true shape in the slide. Draw your structures proportionately to their size in your microscope's field of view.
5. Fill in the blanks next to your drawing and identify the structures listed on the last page under, "Histology"

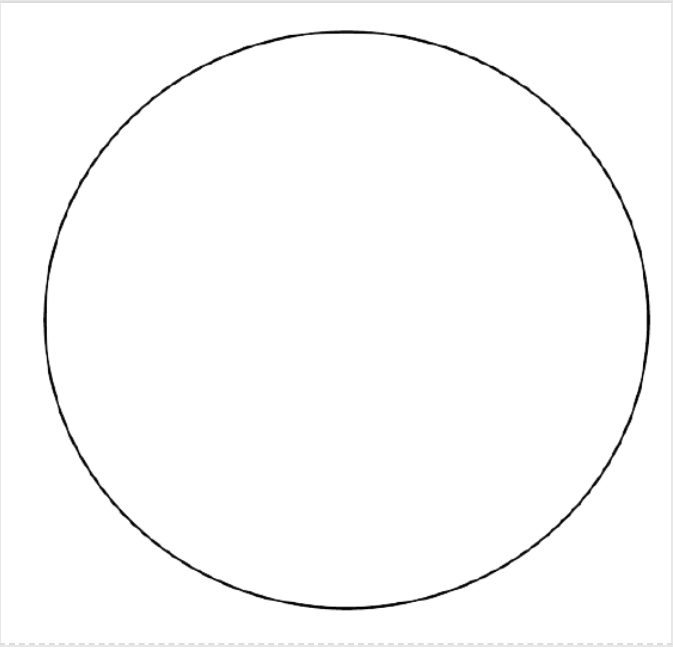
Repeat this for each of the tissue types seen below.



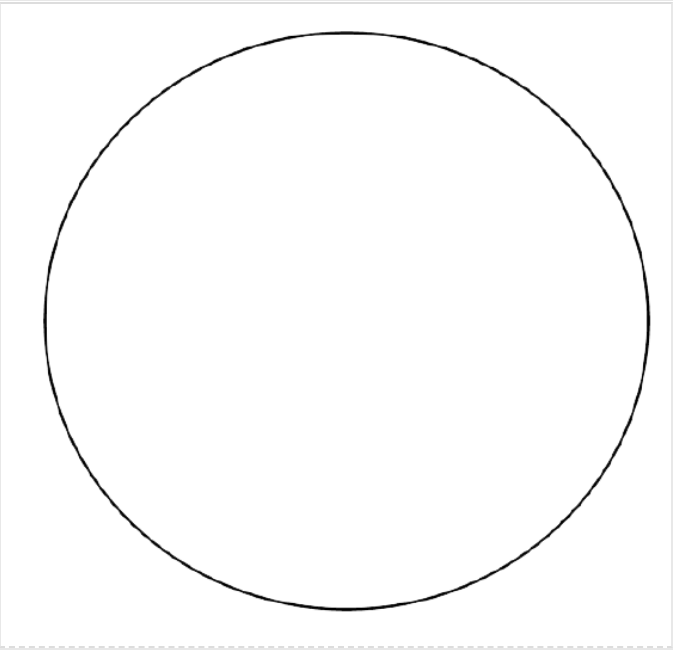
Lymph Node
Total Magnification: _____
Type of eptihelium: _____
Source of tissue: _____
Function of this tissue: _____
_____



Spleen
Total Magnification: _____
Type of eptihelium: _____
Source of tissue: _____
Function of this tissue: _____
_____



Peyer's Patches
Total Magnification: _____
Type of eptihelium: _____
Source of tissue: _____
Function of this tissue: _____
_____



Tonsil
Total Magnification: _____
Type of eptihelium: _____
Source of tissue: _____
Function of this tissue: _____
_____

F

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18.6: MODELS- Torsos and Mid-Sagittal Head

- Appendix (vermiform)
- Lymph node clusters:
  - Cervical
  - Inguinal
  - Thoracic
  - Axillary
- Thoracic duct
- Right lymphatic duct
- Cisterna Chyli
- Spleen
- Tonsils:
  - Pharyngeal tonsils
  - Palatine tonsils
  - Lingual tonsil
  - Tubal tonsils
- **Histology**:
- Lymph node
  - Medulla
  - Cortex
  - Hilus
  - Afferent & efferent vessels
- Spleen
  - White pulp
  - Red pulp
- Peyer's patches (Mucosal associated lymphatic tissue, MALT)
- Tonsil

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CHAPTER OVERVIEW

19: The Respiratory System

Learning Objectives

- List the structures that make up the respiratory system

19.1: The Nose and its Adjacent Structures
19.2: Pharynx
19.3: Larynx
19.4: Trachea
19.5: Bronchial Tree
19.6: Respiratory Zone
19.7: Exercises
19.8: MODELS- Bronchial Tree, Lungs and Heart, Trachea, Torsos and Mid-Sagittal Head

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19.1: The Nose and its Adjacent Structures

The major entrance and exit for the respiratory system is through the nose. When discussing the nose, it is helpful to divide it into two major sections: the external nose, and the nasal cavity or internal nose.

The **external nose** consists of the surface and skeletal structures that result in the outward appearance of the nose and contribute to its numerous functions (Figure 19.1.1). The **root** is the region of the nose located between the eyebrows. The **bridge** is the part of the nose that connects the root to the rest of the nose. The **dorsum nasi** is the length of the nose. The **apex** is the tip of the nose. On either side of the apex, the nostrils are formed by the alae (singular = ala). An **ala** is a cartilaginous structure that forms the lateral side of each **naris** (plural = nares), or nostril opening. The **philtrum** is the concave surface that connects the apex of the nose to the upper lip.

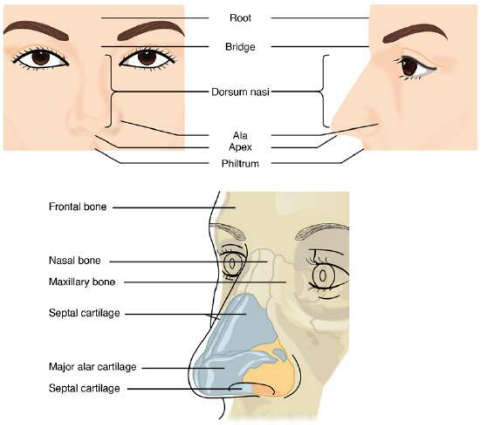


Figure 19.1.1: Nose This illustration shows features of the external nose (top) and skeletal features of the nose (bottom). (CC-BY-4.0, OpenStax, Human Anatomy)

The nares open into the nasal cavity, which is separated into left and right sections by the nasal septum (Figure 19.1.2). The **nasal septum** is formed anteriorly by a portion of the septal cartilage (the flexible portion you can touch with your fingers) and posteriorly by the perpendicular plate of the ethmoid bone (a cranial bone located just posterior to the nasal bones) and the thin vomer bones (whose name refers to its plough shape). Each lateral wall of the nasal cavity has three bony projections, called the superior, middle, and inferior nasal conchae. The inferior conchae are separate bones, whereas the superior and middle conchae are portions of the ethmoid bone.

Conchae serve to increase the surface area of the nasal cavity and to disrupt the flow of air as it enters the nose, causing air to bounce along the epithelium, where it is cleaned and warmed. The conchae and **meatuses** also conserve water and prevent dehydration of the nasal epithelium by trapping water during exhalation. The floor of the nasal cavity is composed of the palate. The hard palate at the anterior region of the nasal cavity is composed of bone. The soft palate at the posterior portion of the nasal cavity consists of muscle tissue. Air exits the nasal cavities via the internal nares and moves into the pharynx.

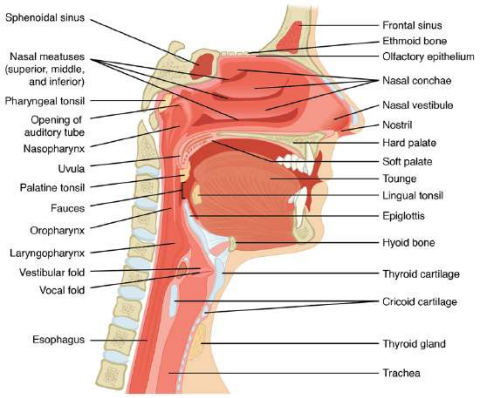


Figure 19.1.2: **Upper Airway** (CC-BY-4.0, OpenStax, Human Anatomy)

The conchae, meatuses, and paranasal sinuses are lined by **respiratory epithelium** composed of pseudostratified ciliated columnar epithelium (Figure 19.1.3). The epithelium contains goblet cells, one of the specialized, columnar epithelial cells that produce mucus to trap debris. The cilia of the respiratory epithelium help remove the mucus and debris from the nasal cavity with a constant beating motion, sweeping materials towards the throat to be swallowed. Interestingly, cold air slows the movement of the cilia, resulting in accumulation of mucus that may in turn lead to a runny nose during cold weather. This moist epithelium functions to warm and humidify incoming air. Capillaries located just beneath the nasal epithelium warm the air by convection. Serous and mucus-producing cells also secrete the lysozyme enzyme and proteins called defensins, which have antibacterial properties. Immune cells that patrol the connective tissue deep to the respiratory epithelium provide additional protection.

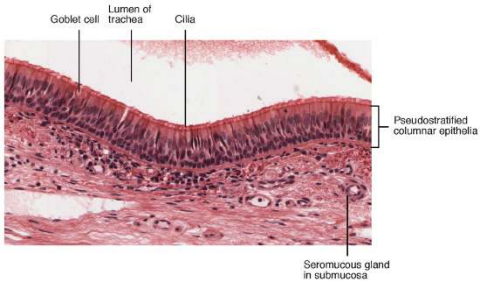


Figure 19.1.3: Pseudostratified Ciliated Columnar Epithelium Respiratory epithelium is pseudostratified ciliated columnar epithelium. Seromucous glands provide lubricating mucus. LM × 680. (Micrograph provided by the Regents of University of Michigan Medical School © 2012) (CC-BY-4.0, OpenStax, Human Anatomy)

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19.2: Pharynx

The **pharynx** is a tube formed by skeletal muscle and lined by mucous membrane that is continuous with that of the nasal cavities (see **Figure 19.2**). The pharynx is divided into three major regions: the nasopharynx, the oropharynx, and the laryngopharynx (Figure **19.2.1**).

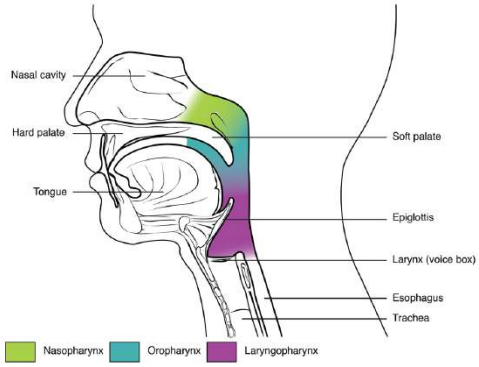


Figure **19.2.1**: Divisions of the Pharynx The pharynx is divided into three regions: the nasopharynx, the oropharynx, and the laryngopharynx. (CC-BY-4.0, OpenStax, Human Anatomy)

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19.3: Larynx

The **larynx** is a cartilaginous structure inferior to the laryngopharynx that connects the pharynx to the trachea and helps regulate the volume of air that enters and leaves the lungs (Figure **19.3.1**). The structure of the larynx is formed by several pieces of cartilage. Three large cartilage pieces—the thyroid cartilage (anterior), epiglottis (superior), and cricoid cartilage (inferior)—form the major structure of the larynx. The **thyroid cartilage** is the largest piece of cartilage that makes up the larynx. The thyroid cartilage consists of the **laryngeal prominence**, or "Adam's apple," which tends to be more prominent in males. The thick **cricoid cartilage** forms a ring, with a wide posterior region and a thinner anterior region. Three smaller, paired cartilages—the arytenoids, corniculates, and cuneiforms—attach to the epiglottis and the vocal cords and muscle that help move the vocal cords to produce speech.

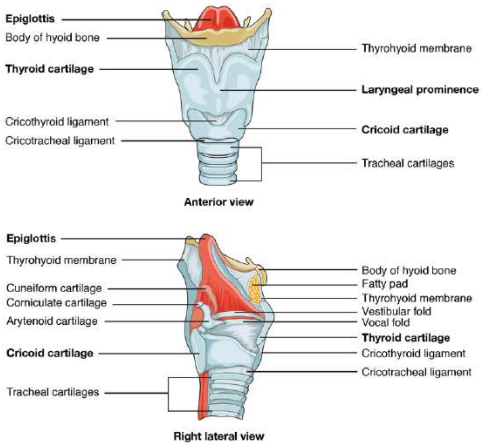


Figure **19.3.1**: The larynx extends from the laryngopharynx and the hyoid bone to the trachea. (CC-BY-4.0, OpenStax, Human Anatomy)

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19.4: Trachea

The trachea (windpipe) extends from the larynx toward the lungs (**19.4.1**). The **trachea** is formed by 16 to 20 stacked, C-shaped pieces of hyaline cartilage that are connected by dense connective tissue. The **trachealis muscle** and elastic connective tissue together form the **fibroelastic membrane**, a flexible membrane that closes the posterior surface of the trachea, connecting the C-shaped cartilages. The fibroelastic membrane allows the trachea to stretch and expand slightly during inhalation and exhalation, whereas the rings of cartilage provide structural support and prevent the trachea from collapsing. In addition, the trachealis muscle can be contracted to force air through the trachea during exhalation. The trachea is lined with pseudostratified ciliated columnar epithelium, which is continuous with the larynx. The esophagus borders the trachea posteriorly.

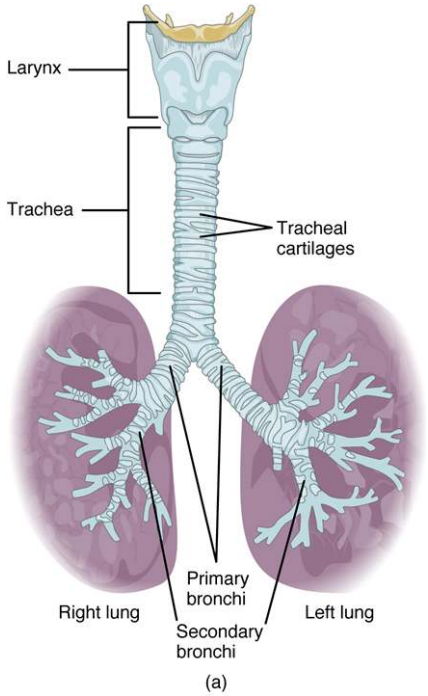


Figure **19.4.1**: The tracheal tube is formed by stacked, C-shaped pieces of hyaline cartilage. (CC-BY-4.0, OpenStax, Human Anatomy)

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19.5: Bronchial Tree

The trachea branches into the right and left primary **bronchi** at the carina. These bronchi are also lined by pseudostratified ciliated columnar epithelium containing mucus-producing goblet cells (**19.5.1**b). The carina is a raised structure that contains specialized nervous tissue that induces violent coughing if a foreign body, such as food, is present. Rings of cartilage, similar to those of the trachea, support the structure of the bronchi and prevent their collapse. The primary bronchi enter the lungs at the hilum, a concave region where blood vessels, lymphatic vessels, and nerves also enter the lungs. The bronchi continue to branch into bronchial a tree. A **bronchial tree** (or respiratory tree) is the collective term used for these multiple-branched bronchi. The main function of the bronchi, like other conducting zone structures, is to provide a passageway for air to move into and out of each lung. In addition, the mucous membrane traps debris and pathogens.

A **bronchiole** branches from the tertiary bronchi. Bronchioles, which are about 1 mm in diameter, further branch until they become the tiny terminal bronchioles, which lead to the structures of gas exchange. There are more than 1000 terminal bronchioles in each lung. The muscular walls of the bronchioles do not contain cartilage like those of the bronchi. This muscular wall can change the size of the tubing to increase or decrease airflow through the tube.

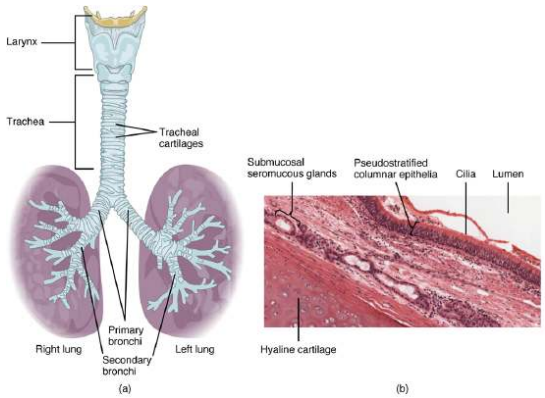


Figure **19.5.1**: Trachea (a) The tracheal tube is formed by stacked, C-shaped pieces of hyaline cartilage. (b) The layer visible in this cross-section of tracheal wall tissue between the hyaline cartilage and the lumen of the trachea is the mucosa, which is composed of pseudostratified ciliated columnar epithelium that contains goblet cells. LM × 1220. (Micrograph provided by the Regents of University of Michigan Medical School © 2012) (CC-BY-4.0, OpenStax, Human Anatomy)

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19.6: Respiratory Zone

In contrast to the conducting zone, the respiratory zone includes structures that are directly involved in gas exchange. The respiratory zone begins where the terminal bronchioles join a **respiratory bronchiole**, the smallest type of bronchiole (Figure **19.6.1**), which then leads to an alveolar duct, opening into a cluster of alveoli.

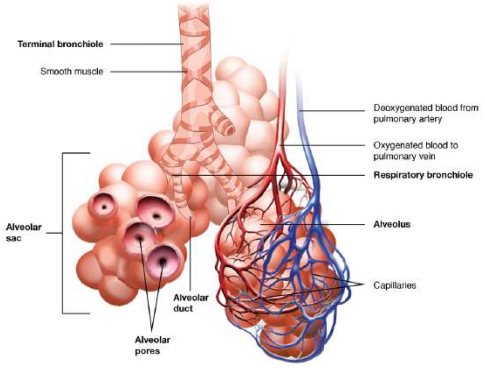


Figure **19.6.1**: Respiratory Zone Bronchioles lead to alveolar sacs in the respiratory zone, where gas exchange occurs. (CC-BY-4.0, OpenStax, Human Anatomy)

Figure 19.7 Respiratory Zone Bronchioles lead to alveolar sacs in the respiratory zone, where gas exchange occurs.

Alveoli

An **alveolar duct** is a tube composed of smooth muscle and connective tissue, which opens into a cluster of alveoli. An **alveolus** is one of the many small, grape-like sacs that are attached to the alveolar ducts.

An **alveolar sac** is a cluster of many individual alveoli that are responsible for gas exchange. An alveolus is approximately 200 µm in diameter with elastic walls that allow the alveolus to stretch during air intake, which greatly increases the surface area available for gas exchange. Alveoli are connected to their neighbors by **alveolar pores**, which help maintain equal air pressure throughout the alveoli and lung (Figure **19.6.2**).

The alveolar wall consists of three major cell types: type I alveolar cells, type II alveolar cells, and alveolar macrophages. A **type I alveolar cell** is a squamous epithelial cell of the alveoli, which constitute up to 97 percent of the alveolar surface area. These cells are about 25 nm thick and are highly permeable to gases. A **type II alveolar cell** is interspersed among the type I cells and secretes **pulmonary surfactant**, a substance composed of phospholipids and proteins that reduces the surface tension of the alveoli. Roaming around the alveolar wall is the **alveolar macrophage**, a phagocytic cell of the immune system that removes debris and pathogens that have reached the alveoli.

The simple squamous epithelium formed by type I alveolar cells is attached to a thin, elastic basement membrane. This epithelium is extremely thin and borders the endothelial membrane of capillaries. Taken together, the alveoli and capillary membranes form a **respiratory membrane** that is approximately 0.5 mm thick. The respiratory membrane allows gases to cross by simple diffusion, allowing oxygen to be picked up by the blood for transport and CO2 to be released into the air of the alveoli.

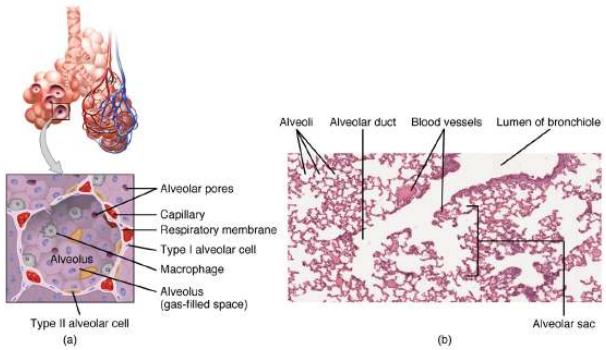
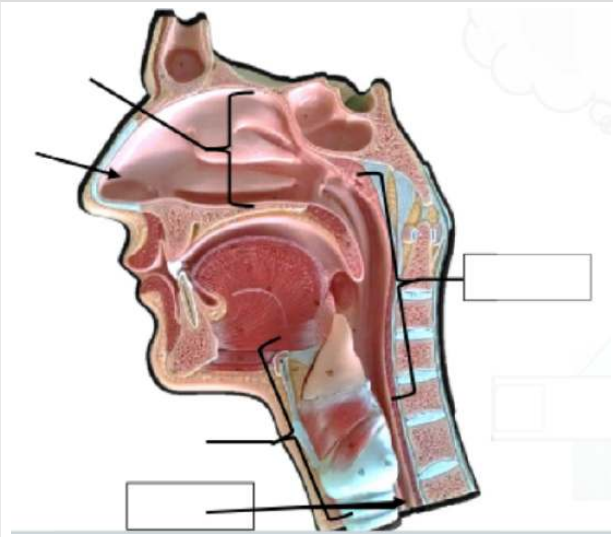


Figure **19.6.2**: Structures of the Respiratory Zone (a) The alveolus is responsible for gas exchange. (b) A micrograph shows the alveolar structures within lung tissue. LM × 178. (Micrograph provided by the Regents of University of Michigan Medical School © 2012) (CC-BY-4.0, OpenStax, Human Anatomy)

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19.7: Exercises

LAB 19 EXERCISES 19.7.1



Identify the following

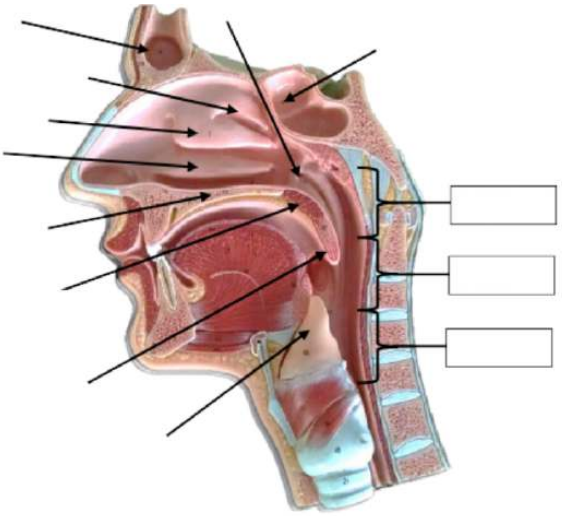
1	Nasal vestibule
2	**Nasal cavity**
3	Esophagus
4	Pharynx
5	Larynx.



Match the following

1	Naris
2	Ala (of nose)
3	Bridge (of nose)
4	Philtrum.

LAB 19 EXERCISES 19.7.2

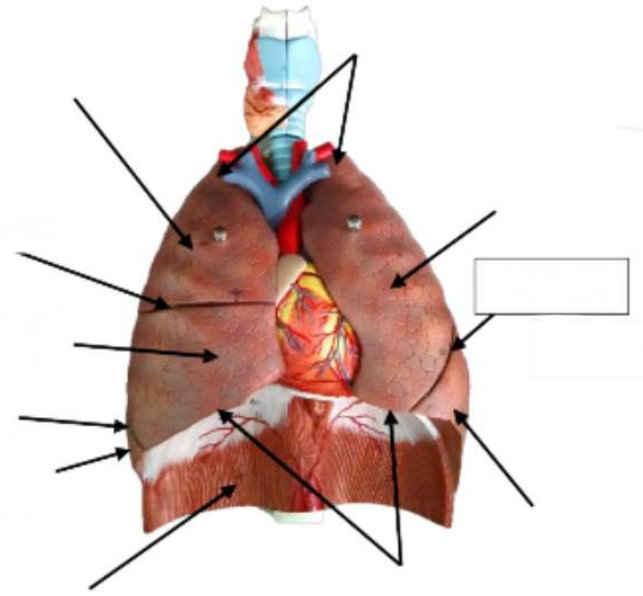


Identify the following components of the upper repiratory tract

1	Superior nasal conchae	8	Oropharynx
2	Middle nasal conchae	9	Laryngopharynx
3	Inferior nasal conchae	10	Epiglottis
4	Hard palate	11	Uvula
5	Soft palate	12	Sphenoid sinus
6	Eustachian tube	13	Frontal sinus
7	Nasopharynx		

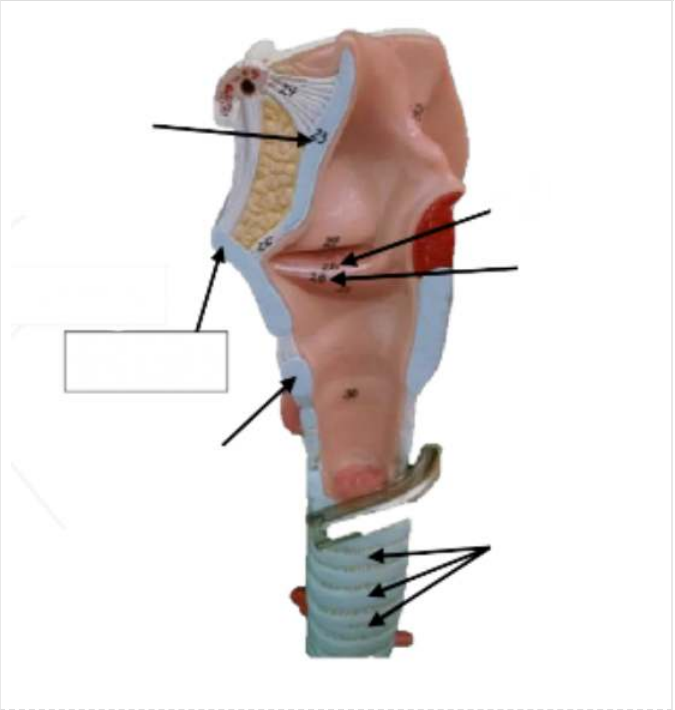
LAB 19 EXERCISES 19.7.2

Upper Respiratory Tract



Label the following

1	All of the lobes of the lungs
2	All the fissures of the lungs
3	Apex
4	Base
5	Diaphragm.
7	Vein.

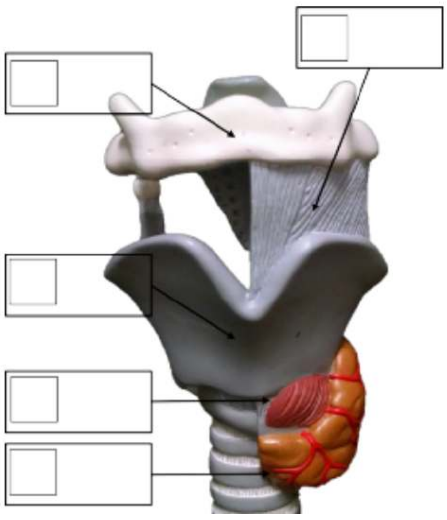


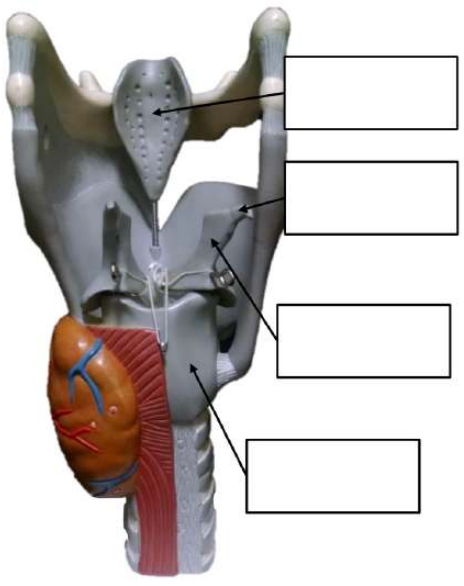
Label these components of the larynx

1	Epiglottis
2	Tunica media
3	Tunica externa
4	Valve
5	Vasa vasorum
6	Artery
7	Vein.

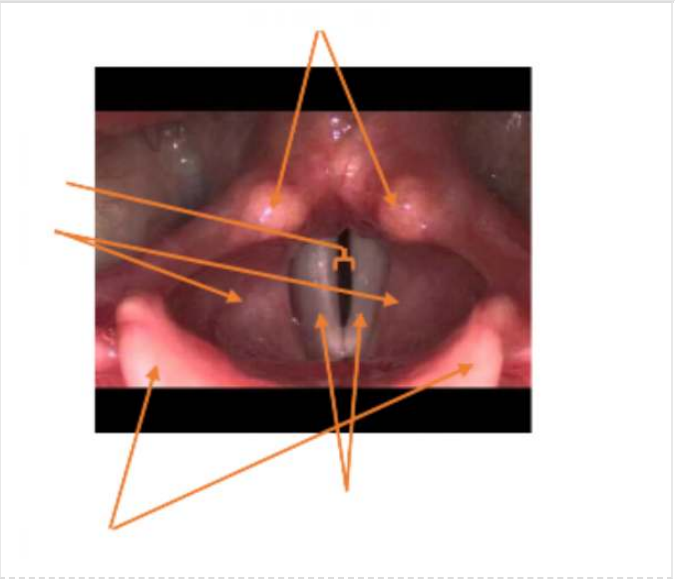
LAB 19 EXERCISES 19.7.3

Label the Cartilages and Ligaments



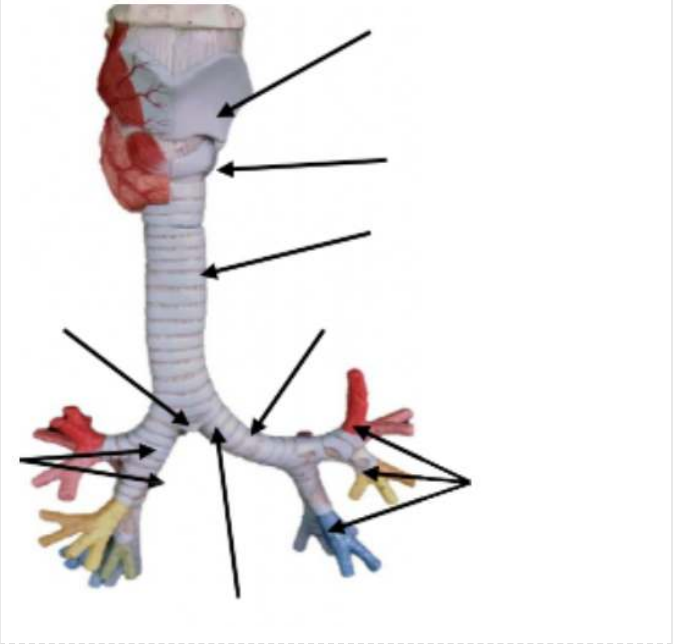


LAB 19 EXERCISES 19.7.4



Label the following

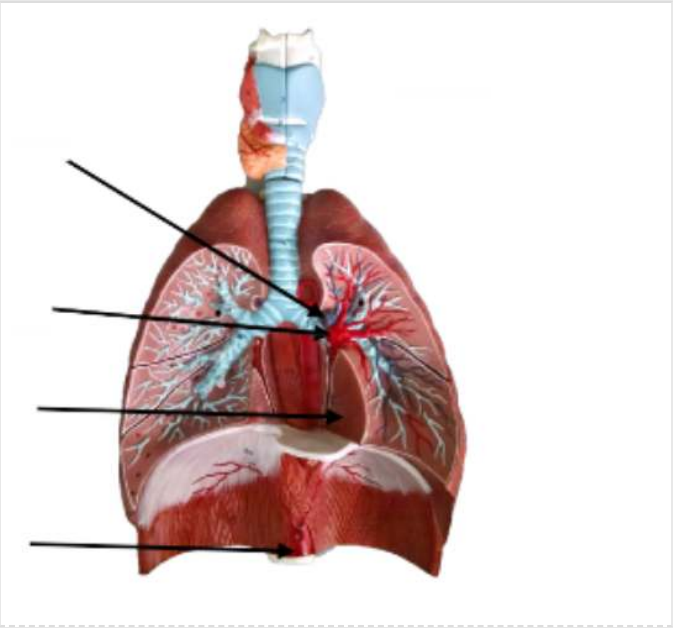
1	Vestibular folds
2	Epiglottis
3	Glottis
4	Arytenoid cartilage.



Label the following

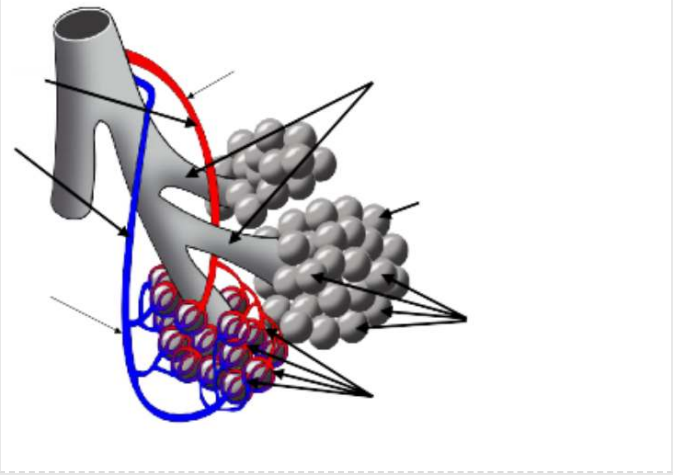
1	Thyroid cartilage
2	Cricoid cartilage
3	Cricoid cartilage
4	Carina
5	R. primary bronchus
6	L. primary bronchus
7	Secondary bronchi
8	Tertiary bronchi

LAB 19 EXERCISES 19.7.5



Label the following

1	Cardiac notch
2	Pulmonary artery
3	Pulmonary vein
4	Abdominal aorta

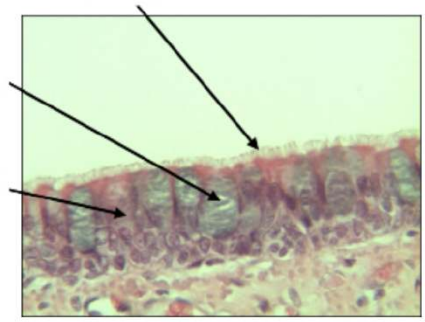


Label the following

1	Bronchiole
2	Alveoli
3	Alveolar sac
4	Pulmonary venule
5	Pulmonary arteriole
6	Capillary network

LAB 19 EXERCISES 19.7.6

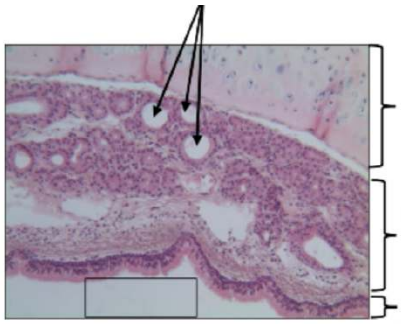
Histology



Label the tracheal histology

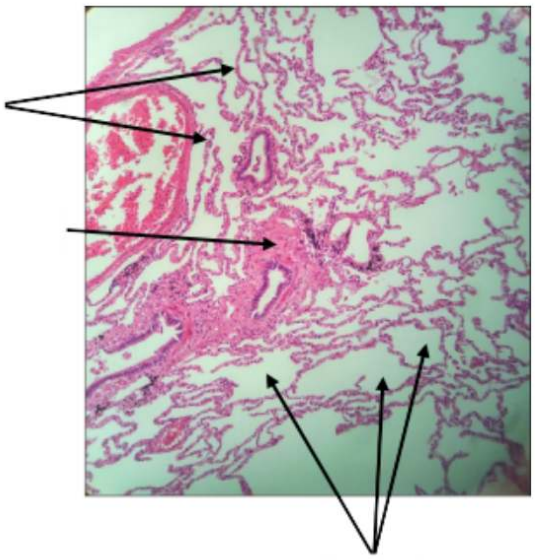
1	Pseudostratified ciliated columnar epithelium
2	Goblet cell
3	Cilia

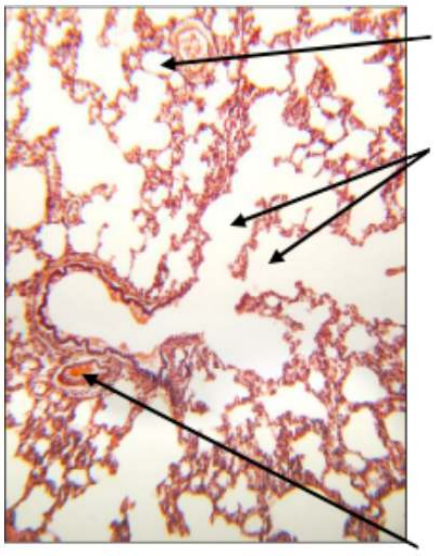
Lower Respiratory Tract



Label the tracheal cartilage histology

1	Hyaline cartilage
2	Mucosa
3	Submucosa
4	Lumen
5	Mucous gland.





Label the following lung histology components

1	Simple squamous epithelium
2	Smooth muscle
3	Alveloi
4	Aveolar sac
5	Bronchiole
6	Arteriole

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19.8: MODELS- Bronchial Tree, Lungs and Heart, Trachea, Torsos and Mid-Sagittal Head

- Pleura
  - parietal & visceral
- Pleural cavity
- Right lung
  - Lobes: upper * middle * lower
  - Horizontal fissure
  - Oblique fissure
  - Hilus
- Left Lung:
  - lobes: upper * lower
  - Oblique fissure
  - Cardiac notch
  - Hilus
- Philtrum
- Nose
  - Bridge
  - Ala
  - Nares
- Nasal cavity
  - Vestibule
  - Nasal conchae:
    - superior * middle * & inferior
  - Nasal meatuses:
    - superior * middle * & inferior
  - Nasal septum
  - Pharyngotympanic tube (Eustachian)
- Sinuses (Sphenoid * frontal)
- Hard palate
- Soft palate
  - Uvula
  - Hyoid bone
- Pharynx:
  - Nasopharynx
  - Oropharynx
  - Laryngopharynx
- Larynx:
  - Epiglottis
  - Thyroid cartilage
  - Cricoid cartilage
  - Crico-thyroid ligament
  - Crico-tracheal ligament
  - Hyo-thyroid ligament
  - Vestibular folds (false vocal cords)

- True vocal cords
  - Arytenoid cartilage
  - Corniculate cartilage
- Trachea:
  - Tracheal cartilages
  - Carina
- Bronchial tree:
  - L * R primary (main) bronchi
  - Secondary (lobar) bronchi
  - Tertiary (segmental) bronchi
- Lung tissue:
  - Bronchioles
  - Alveolar sac
  - Alveoli
- Muscles:
  - Diaphragm
  - External intercostals
  - Internal intercostals
- Vasculature
  - Pulmonary arteries
  - Pulmonary veins
  -

Lung Histology: (2 slides)

- Trachea
  - Adventitia
  - Tracheal cartilage (hyaline)
  - Trachealis muscle
  - Mucosa (pseudostratified ciliated columnar epithelium)
- Lungs
  - Alveoli (Simple squamous epithelia)
  - Bronchioles
  - Pulmonary arterioles * venules * & capillaries

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CHAPTER OVERVIEW

20: The Digestive System

Learning Objectives

- Identify the organs of the alimentary canal from proximal to distal
- Identify the accessory digestive organs

20.1: Overview
20.2: Alimentary Canal Organs
20.3: Stomach
20.4: Small Intestine
20.5: Large Intestine
20.6: Exercises
20.7: MODELS- Hollow Organs, Teeth, Live/Gall Bladder, Upright Torsos, Mid-Sagittal Head

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20.1: Overview

The function of the digestive system is to break down the foods you eat, release their nutrients, and absorb those nutrients into the body. Although the small intestine is the workhorse of the system, where the majority of digestion occurs, and where most of the released nutrients are absorbed into the blood or lymph, each of the digestive system organs makes a vital contribution to this process (Figure **20.1.1**).

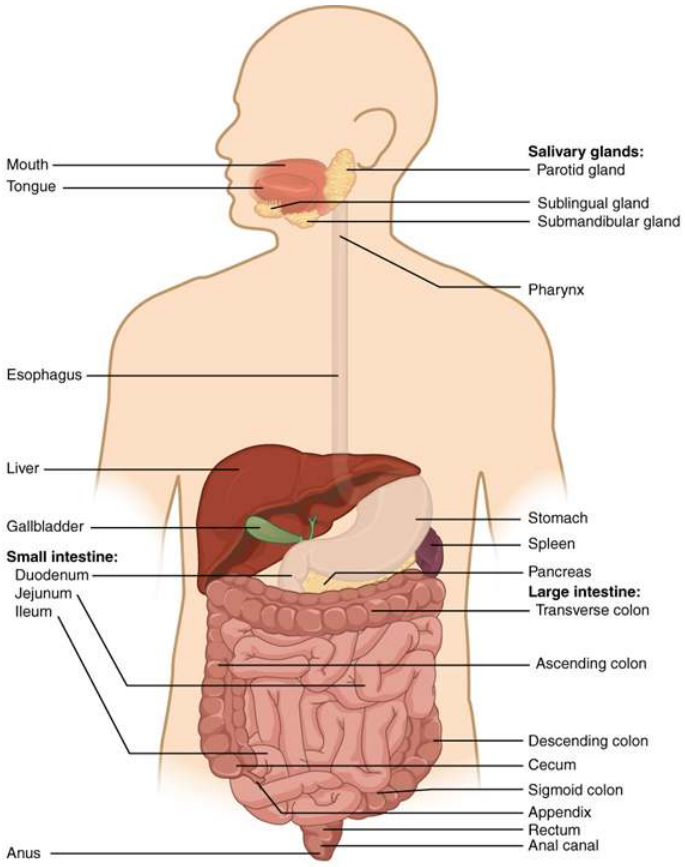


Figure **20.1.1**: Components of the Digestive System All digestive organs play integral roles in the life-sustaining process of digestion. (CC-BY-4.0, OpenStax, Human Anatomy)

Digestive System Organs

The easiest way to understand the digestive system is to divide its organs into two main categories. The first group is the organs that make up the alimentary canal. Accessory digestive organs comprise the second group and are critical for orchestrating the breakdown of food and the assimilation of its nutrients into the body.

Accessory digestive organs, despite their name, are critical to the function of the digestive system.

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20.2: Alimentary Canal Organs

Also called the gastrointestinal (GI) tract or gut, the **alimentary canal** (aliment- = "to nourish") is a one-way tube about 7.62 meters (25 feet) in length during life and closer to 10.67 meters (35 feet) in length when measured after death, once smooth muscle tone is lost. The main function of the organs of the alimentary canal is to nourish the body. This tube begins at the mouth and terminates at the anus. Between those two points, the canal is modified as the pharynx, esophagus, stomach, and small and large intestines to fit the functional needs of the body. Both the mouth and anus are open to the external environment; thus, food and wastes within the alimentary canal are technically considered to be outside the body. Only through the process of absorption do the nutrients in food enter into and nourish the body's "inner space."

Accessory Structures

Each **accessory digestive organ** aids in the breakdown of food (Figure 20.2.1). Within the mouth, the teeth and tongue begin mechanical digestion, whereas the salivary glands begin chemical digestion. Once food products enter the small intestine, the gallbladder, liver, and pancreas release secretions—such as bile and enzymes— essential for digestion to continue. Together, these are called accessory organs because they sprout from the lining cells of the developing gut (mucosa) and augment its function; indeed, you could not live without their vital contributions, and many significant diseases result from their malfunction. Even after development is complete, they maintain a connection to the gut by way of ducts.

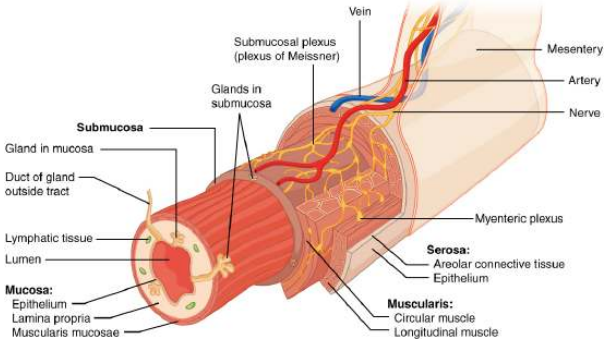


Figure 20.2.1: **Layers of the Alimentary Canal** The wall of the alimentary canal has four basic tissue layers: the mucosa, submucosa, muscularis, and serosa. (CC-BY-4.0, OpenStax, Human Anatomy)

The Mouth

The cheeks, tongue, and palate frame the mouth, which is also called the **oral cavity** (or buccal cavity). The structures of the mouth are illustrated in Figure 20.2.2.

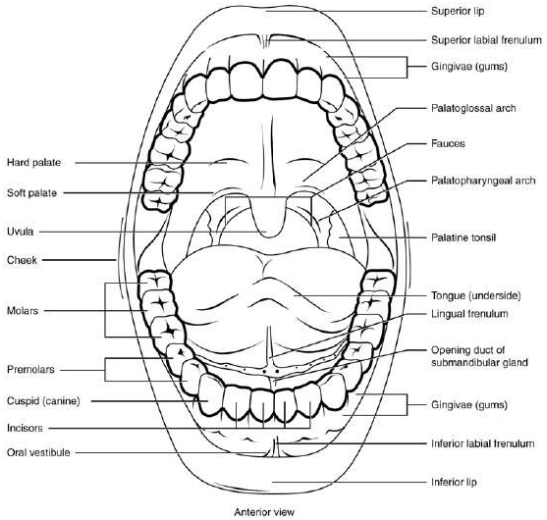


Figure 20.2.2: **Mouth** The mouth includes the lips, tongue, palate, gums, and teeth. (CC-BY-4.0, OpenStax, Human Anatomy)

The Pharynx

The **pharynx** (throat) is involved in both digestion and respiration. It receives food and air from the mouth, and air from the nasal cavities. When food enters the pharynx, involuntary muscle contractions close off the air passageways.

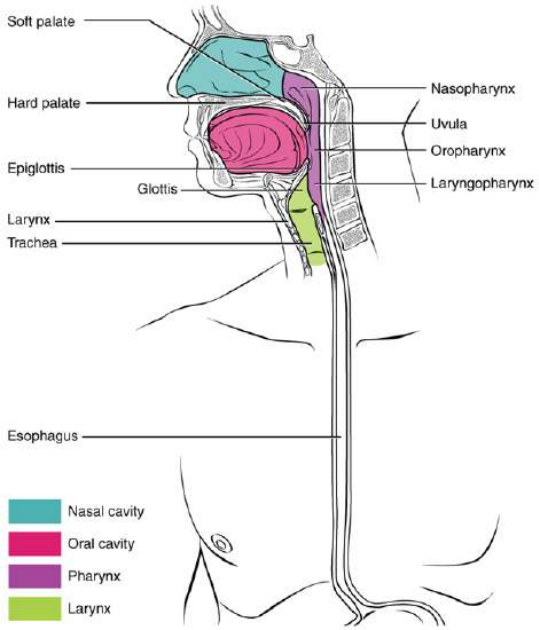


Figure **20.2.3**: **Pharynx** The pharynx runs from the nostrils to the esophagus and the larynx. (CC-BY-4.0, OpenStax, Human Anatomy)

The Esophagus

The **esophagus** is a muscular tube that connects the pharynx to the stomach. It is approximately 25.4 cm (10 in) in length, located posterior to the trachea, and remains in a collapsed form when not engaged in swallowing. As you can see in Figure **20.2.4**, the esophagus runs a mainly straight route through the mediastinum of the thorax. To enter the abdomen, the esophagus penetrates the diaphragm through an opening called the esophageal hiatus.

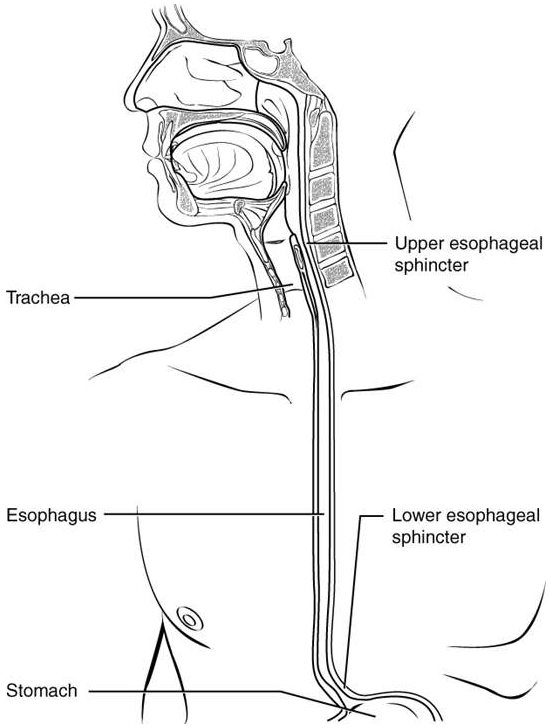


Figure **20.2.4**: **Esophagus** The upper esophageal sphincter controls the movement of food from the pharynx to the esophagus. The lower esophageal sphincter controls the movement of food from the esophagus to the stomach. (CC-BY-4.0, OpenStax, Human Anatomy)

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20.3: Stomach

There are four main regions in the **stomach**: the cardia, fundus, body, and pylorus (Figure **20.3.1**). The **cardia** (or cardiac region) is the point where the esophagus connects to the stomach and through which food passes into the stomach. Located inferior to the diaphragm, above and to the left of the cardia, is the dome-shaped **fundus**.

Below the fundus is the **body**, the main part of the stomach. The funnel-shaped **pylorus** connects the stomach to the duodenum. The wider end of the funnel, the **pyloric antrum**, connects to the body of the stomach. The narrower end is called the **pyloric canal**, which connects to the duodenum. The smooth muscle **pyloric sphincter** is located at this latter point of connection and controls stomach emptying. In the absence of food, the stomach deflates inward, and its mucosa and submucosa fall into a large fold called a **ruga**.

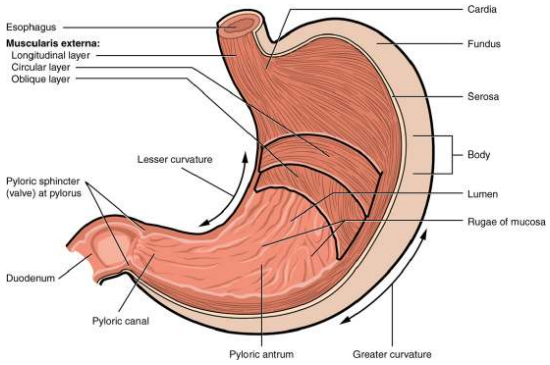


Figure **20.3.1**: Stomach The stomach has four major regions: the cardia, fundus, body, and pylorus. The addition of an inner oblique smooth muscle layer gives the muscularis the ability to vigorously churn and mix food. (CC-BY-4.0, OpenStax, Human Anatomy)

Histology

The wall of the stomach is made of the same four layers as most of the rest of the alimentary canal, but with adaptations to the mucosa and muscularis for the unique functions of this organ. In addition to the typical circular and longitudinal smooth muscle layers, the muscularis has an inner oblique smooth muscle layer (**Figure 20.7**). As a result, in addition to moving food through the canal, the stomach can vigorously churn food, mechanically breaking it down into smaller particles.

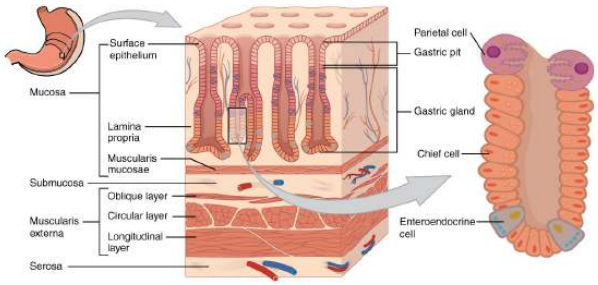


Figure **20.3.2**: Histology of the Stomach The stomach wall is adapted for the functions of the stomach. In the epithelium, gastric pits lead to gastric glands that secrete gastric juice. The gastric glands (one gland is shown enlarged on the right) contain different types of cells that secrete a variety of enzymes, including hydrochloride acid, which activates the protein- digesting enzyme pepsin. (CC-BY-4.0, OpenStax, Human Anatomy)

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20.4: Small Intestine

The coiled tube of the small intestine is subdivided into three regions. From proximal (at the stomach) to distal, these are the duodenum, jejunum, and ileum (Figure **20.4.1**).

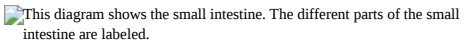


Figure **20.4.1**: Small Intestine The three regions of the small intestine are the duodenum, jejunum, and ileum. (CC-BY-4.0, OpenStax, Human Anatomy)

Histology

The wall of the small intestine is composed of the same four layers typically present in the alimentary system. However, three features of the mucosa and submucosa are unique. These features, which increase the absorptive surface area of the small intestine more than 600-fold, include circular folds, villi, and microvilli (**Figure 20.9**). These adaptations are most abundant in the proximal two-thirds of the small intestine, where the majority of absorption occurs.

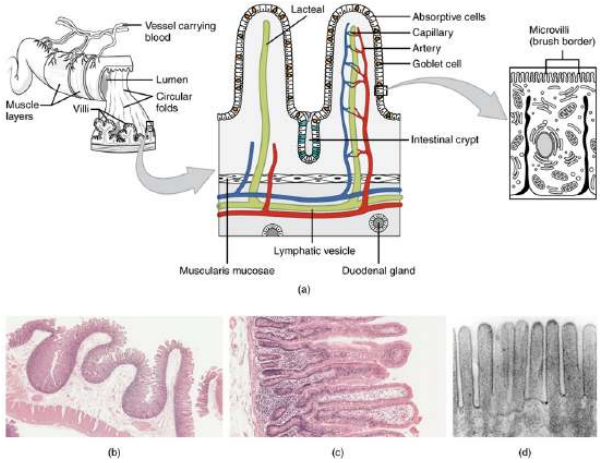


Figure **20.4.2**: Histology of the Small Intestine (a) The absorptive surface of the small intestine is vastly enlarged by the presence of circular folds, villi, and microvilli. (b) Micrograph of the circular folds. (c) Micrograph of the villi. (d) Electron micrograph of the microvilli. From left to right, LM x 56, LM x 508, EM x 196,000. (credit b-d: Micrograph provided by the Regents of University of Michigan Medical School © 2012) (CC-BY-4.0, OpenStax, Human Anatomy)

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20.5: Large Intestine

The large intestine runs from the appendix to the anus. It frames the small intestine on three sides. Despite its being about one-half as long as the small intestine, it is called large because it is more than twice the diameter of the small intestine, about 3 inches.

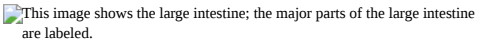


Figure 20.5.1: Large Intestine The large intestine includes the cecum, colon, and rectum. (CC-BY-4.0, OpenStax, Human Anatomy)

Three features are unique to the large intestine: teniae coli, haustra, and epiploic appendages (Figure 20.5.2).

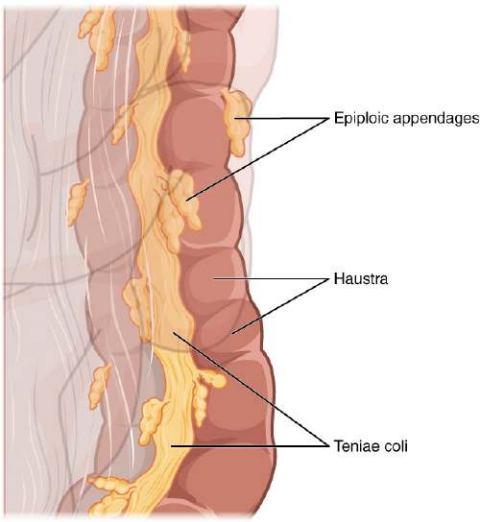


Figure 20.5.2: Teniae Coli, Haustra, and Epiploic Appendages. (CC-BY-4.0, OpenStax, Human Anatomy)

Histology

There are several notable differences between the walls of the large and small intestines (Figure 20.5.3). For example, few enzyme-secreting cells are found in the wall of the large intestine, and there are no circular folds or villi. Other than in the anal canal, the mucosa of the colon is simple columnar epithelium made mostly of enterocytes (absorptive cells) and goblet cells. In addition, the wall of the large intestine has far more intestinal glands, which contain a vast population of enterocytes and goblet cells. These goblet cells secrete mucus that eases the movement of feces and protects the intestine from the effects of the acids and gases produced by enteric bacteria. The enterocytes absorb water and salts as well as vitamins produced by your intestinal bacteria.

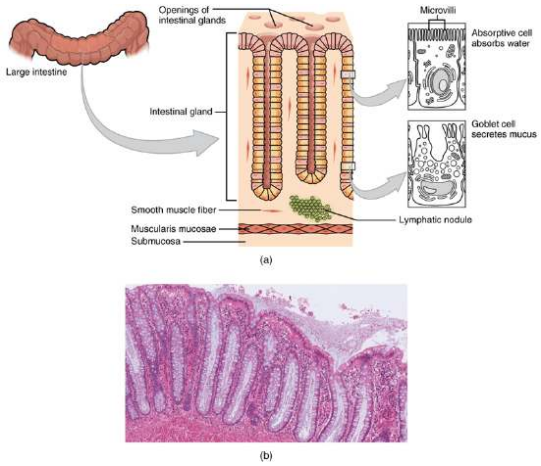


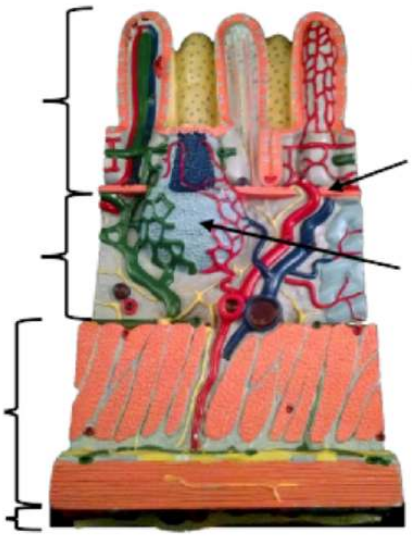
Figure 20.5.3: Histology of the large Intestine (a) The histologies of the large intestine and small intestine (not shown) are adapted for the digestive functions of each organ. (b) This micrograph shows the colon's simple columnar epithelium and goblet cells. LM x 464. (credit b: Micrograph provided by the Regents of University of Michigan Medical School © 2012) (CC-BY-4.0, OpenStax, Human Anatomy)

* Enteric neuron.

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20.6: Exercises

LAB 20 EXERCISES 20.6.1



Label the parts of a hollow organ:

1	Mucosa
2	Submucosa
3	Muscularis externa (circular and longitudinal layers) Musculari
4	Serosa
5	Muscularis mucosa
6	Peyer’s patch

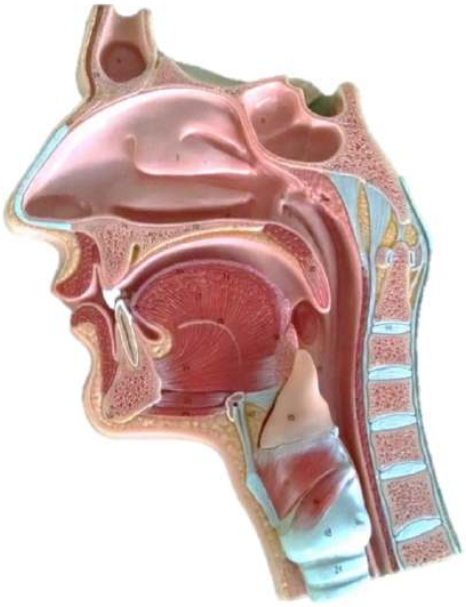


Label the parts of a hollow organ:

1	Villus
2	Lacteal
3	Goblet cell
4	Intestinal crypt
5	Intestinal gland
6	Enteric neuron

LAB 20 EXERCISES 20.6.2

Oral Cavity



Label the components of the oral cavity

1	Uvula
2	Gingiva
3	Oral vestibule
4	Hard palate
5	* Soft palate

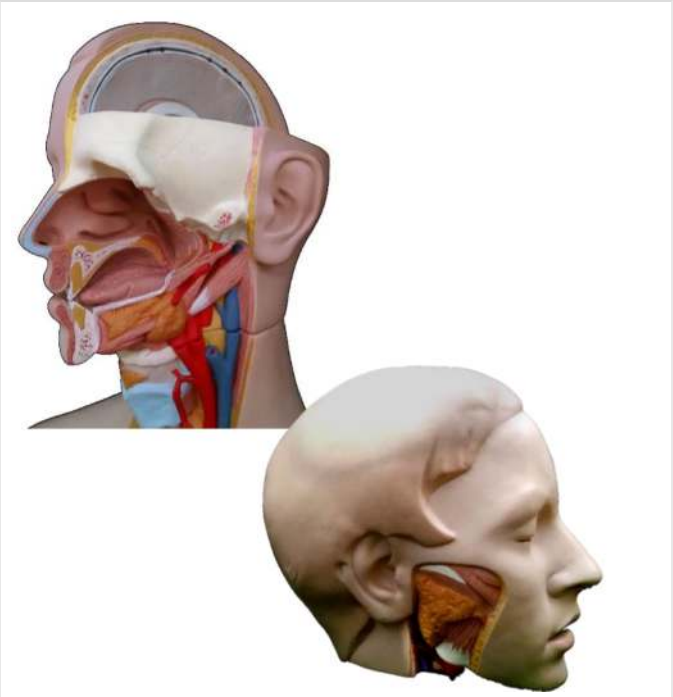


Label the parts of a tooth

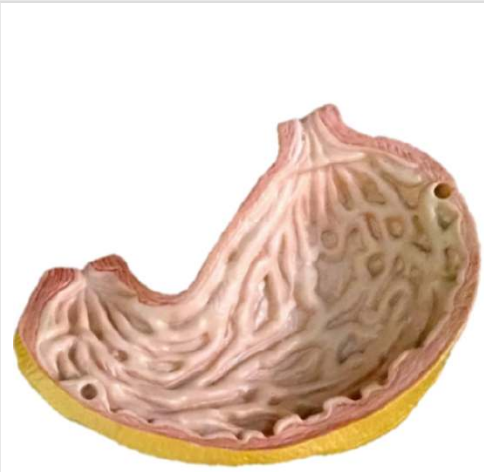
1	Enamel
2	Dentin
3	Cementum
4	Pulp cavity
5	Apical foramen
6	Root canal
7	Crown
8	Root

LAB 20 EXERCISES 20.6.3

Oral Cavity and Stomach



Label the 3 major salivary glands



Label the parts of the stomach

1	Fundus	6	Pyloric sphincter
2	Body	7	Cardiac sphincter
3	Cardiac region	8	Lesser curvature
4	Pyloric canal	9	Greater curvature
5	Pyloric antrum		

LAB 20 EXERCISES 20.6.4



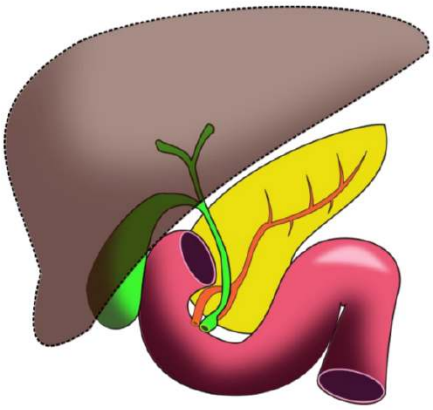
Label the 4 types of teeth: in one quadrant



Label the anatomy of the liver

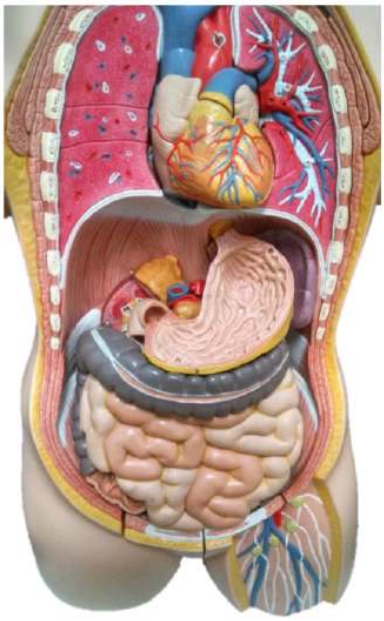
1	Right lobe
2	Left lobe
3	Gall bladder
4	Hepatic portal vein
5	Hepatic artery
6	Inferior vena cava
7	Falciform ligament

LAB 20 EXERCISES 20.6.5



Label the path of bile and pancreatic secretions

1	L. Hepatic duct	7	* Accessory pancreatic duct
2	R. Hepatic duct	8	Hepato-pancreatic ampulla
3	Cystic duct	9	Pancreas
4	* Common Bile duct	10	Duodenum
5	Common Hepatic duct	11	Gall bladder
6	Pancreatic duct		

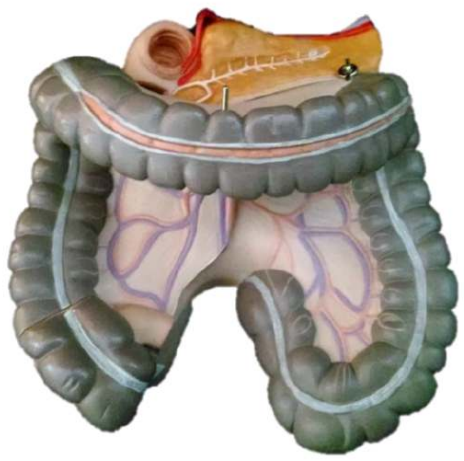


Label the following

1	Stomach
2	Duodenum
3	Jejunum
4	* Ileum
5	Colon

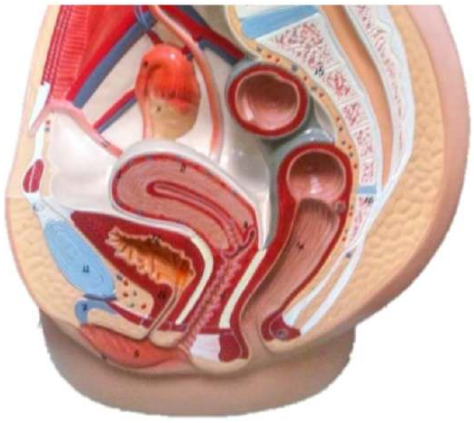
LAB 20 EXERCISES 20.6.6

Colon and Rectium



Label the parts of the colon

1	Cecum	7	Mesocolon
2	Ascending colon	8	Hepatic flexure
3	Transverse colon	9	Splenic flexure
4	Descending colon	10	Haustra
5	Sigmoid colon	11	Teniae Coli
6	Appendix		



Label the following

1	Rectum
2	Anus
3	Rectal valve
4	External Anal sphincter
5	Anal columns

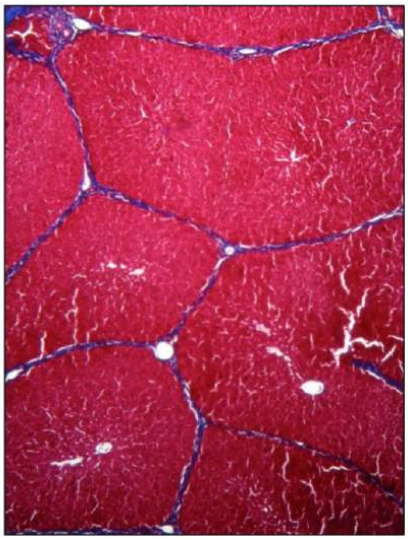
LAB 20 EXERCISES 20.6.7

Histology



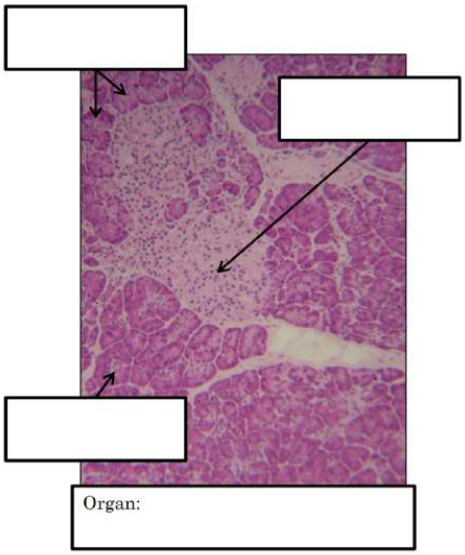
Histology of the liver

1	Hepatic triad
2	Central vein
3	Hepatic artery branch
4	Hepatic Portal vein branch
5	Bile ductule
6	Hepatocyte
7	* Sinusoid



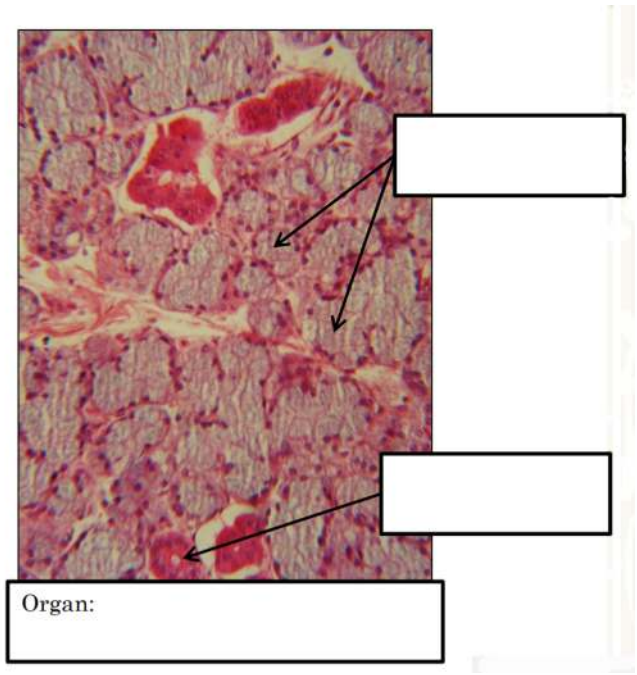
Histology of the liver

1	Hepatic triad
2	Central vein
3	Hepatocyte
4	Sinusoid



Identify this tissue and its relevant components: (see lab list)

1	Tunica interna
2	Tunica media
3	Tunica externa
4	Valve
5	Vasa vasorum
6	Artery
7	Vein.



Label the parts of this gland: (see lab list)

1	Tunica interna
2	Tunica media
3	Tunica externa
4	Valve
5	Vasa vasorum
6	Artery
7	Vein.

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20.7: MODELS- Hollow Organs, Teeth, Live/Gall Bladder, Upright Torsos, Mid-Sagittal Head

- Oral vestibule
- Philtrum
- Labia
- Oral cavity
  - Hard & Soft palate
  - Uvula
  - Pharynx (oro- and laryngo-)
  - Esophagus
- Stomach
  - Cardiac sphincter
  - Cardiac region
  - Fundus
  - Body
  - Pyloric antrum
  - Pyloric canal
  - Pyloric sphincter
  - Rugae
  - Lesser & greater curvature
- Small intestine
  - Duodenum
  - Jejunum
  - Ileum
  - Ileocecal valve
- Large intestine
  - Haustra
  - Taeniae coli
  - Epiploic appendages
  - Cecum
  - Vermiform appendix
  - Ascending colon
  - Hepatic flexure (R)
  - Transverse colon
  - Splenic flexure (L)
  - Descending colon
  - Sigmoid colon
- Rectum
  - Rectal valves
- Anal canal
  - Anal columns
- Pancreas
- Pancreatic duct
  - Hepato-pancreatic ampulla (or papilla)
  - Accessory pancreatic duct
- Teeth

- Crown
- Root
  - Enamel
  - Cementum
  - Dentin
  - Pulp
  - Apical foramen
- Dental Formula: 2 *1 *2 *3
  - Incisors * canines * pre-molar (bicuspids) * molars (tricuspids)
- Tongue
  - Filiform * Fungiform * Circumvallate * Foliate papillae
  - Sulcus terminalis
  - Median lingual sulcus
  - Foramen cecum
  - Taste buds
  - Minor salivary glands
  - Body
  - Base
- Salivary glands (torso)
  - Parotid (gland & duct)
  - Submandibular
  - Sublingual
- Liver/ Gall bladder
  - Lobes: left * right * caudate * quadrate
  - Left/ * Right and Common hepatic ducts
  - Hepatic portal vein
  - Hepatic vein
  - Hepatic arteries
  - Cystic duct
  - Common bile duct
  - Inferior vena cava
- Hollow Organ models:
  - Mucosa
    - Muscularis mucosa
    - Lacteal
    - goblet cell
    - crypt
    - Intestinal gland
  - Submucosa
    - Lymphatic nodule (Peyer’s patch)
    - Lymphatic vessels
    - Enteric neurons
  - Muscularis Externa:
    - Circular *
    - Longitudinal
  - Adventitia or serosa
- Peritoneal cavity
- Visceral & parietal peritoneum

- Mesentaries
- Greater omentum
- Mesocolon

Histology:

- Liver (also see liver histology model)
  - Lobules
  - Triad
  - Central vein
  - Hepatocytes
  - Sinusoids
  - Kupffer cells (macrophages)
- Esophagus
  - Stratified squamous epithelium
- Tongue
  - Skeletal muscle
  - Taste buds
    - Taste pore
    - Receptor & support cells
- Intestines
  - Brush border (microvilli)
  - Simple columnar epithelium
  - Goblet cells
  - Villi
  - Intestinal crypt
  - Intestinal glands
  - MALT
- Salivary glands
  - Acini
  - Ducts
- Pancreas
  - Acini
  - Ducts
  - Pancreatic islets (islet of Langerhans)

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CHAPTER OVERVIEW

21: The Urinary System

Learning Objectives

Gross Anatomy of Urine Transport

- Identify the ureters, urinary bladder, and urethra, as well as their location, structure, and histology
- Compare and contrast male and female urethras

21.1: Urethra

21.2: Bladder

21.3: Ureters

21.4: Gross Anatomy of the Kidney

21.5: Microscopic Anatomy of the Kidney

21.6: Exercises

21.7: MODELS- Kidney, Nephron, Torso and Hemi-Pelvis

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21.1: Urethra

The **urethra** transports urine from the bladder to the outside of the body for disposal. The urethra is the only urologic organ that shows any significant anatomic difference between males and females; all other urine transport structures are identical (Figure **21.1.1**). The urethra in both males and females begins inferior and central to the two ureteral openings forming the three points of a triangular-shaped area at the base of the bladder called the **trigone** (Greek tri- = "triangle" and the root of the word "trigonometry"). The urethra tracks posterior and inferior to the pubic symphysis (see Figure **21.1.1**). In both males and females, the proximal urethra is lined by transitional epithelium, whereas the terminal portion is a nonkeratinized, stratified squamous epithelium. In the male, pseudostratified columnar epithelium lines the urethra between these two cell types. Voiding is regulated by an involuntary autonomic nervous system-controlled **internal urinary sphincter**, consisting of smooth muscle and voluntary skeletal muscle that forms the **external urinary sphincter** below it

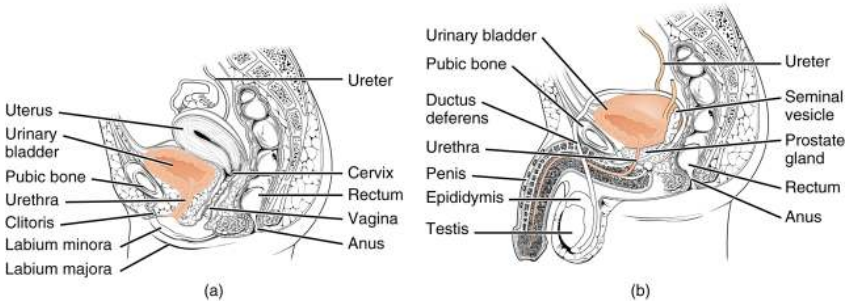


Figure **21.1.1**: Female and Male Urethras The urethra transports urine from the bladder to the outside of the body. This image shows (a) a female urethra and (b) a male urethra. (CC-BY-4.0, OpenStax, Human Anatomy)

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21.2: Bladder

The urinary bladder collects urine from both ureters (Figure **21.2.1**). The bladder lies anterior to the uterus in females, posterior to the pubic bone and anterior to the rectum. During late pregnancy, its capacity is reduced due to compression by the enlarging uterus, resulting in increased frequency of urination. In males, the anatomy is similar, minus the uterus, and with the addition of the prostate inferior to the bladder. The bladder is partially **retroperitoneal** (outside the peritoneal cavity) with its peritoneal-covered "dome" projecting into the abdomen when the bladder is distended with urine.

The bladder is a highly distensible organ comprised of irregular crisscrossing bands of smooth muscle collectively called the **detrusor muscle**. The interior surface is made of transitional cellular epithelium that is structurally suited for the large volume fluctuations of the bladder. When empty, it resembles columnar epithelia, but when stretched, it "transitions" (hence the name) to a squamous appearance (see Figure **21.2.1**). Volumes in adults can range from nearly zero to 500–600 mL.

The detrusor muscle contracts with significant force in the young. The bladder's strength diminishes with age, but voluntary contractions of abdominal skeletal muscles can increase intra-abdominal pressure to promote more forceful bladder emptying. Such voluntary contraction is also used in forceful defecation and childbirth.

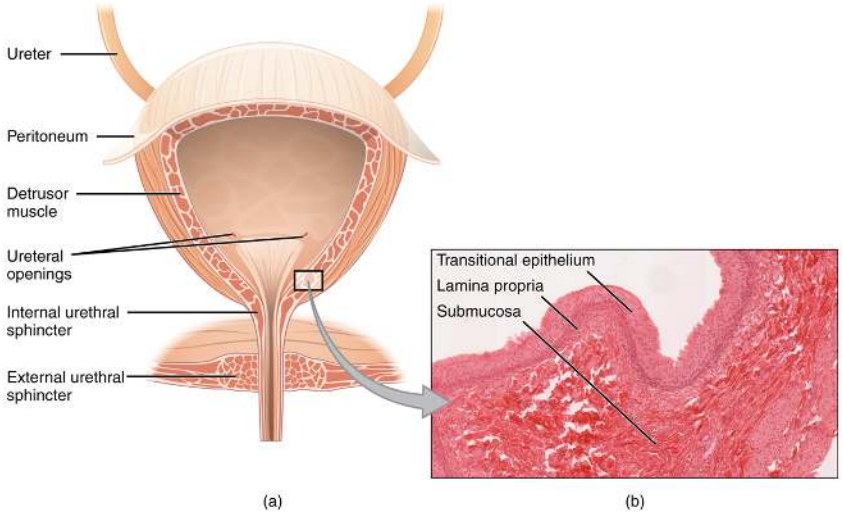


Figure **21.2.1**: (a) Anterior cross section of the bladder. (b) The detrusor muscle of the bladder (source: monkey tissue) LM × 448. (Micrograph provided by the Regents of the University of Michigan Medical School © 2012) (CC-BY-4.0, OpenStax, Human Anatomy)

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21.3: Ureters

The kidneys and ureters are completely retroperitoneal, and the bladder has a peritoneal covering only over the dome. As urine is formed, it drains into the calyces of the kidney, which merge to form the funnel-shaped renal pelvis in the hilum of each kidney. The renal pelvis narrows to become the ureter of each kidney. As urine passes through the ureter, it does not passively drain into the bladder but rather is propelled by waves of peristalsis. As the ureters enter the pelvis, they sweep laterally, hugging the pelvic walls. As they approach the bladder, they turn medially and pierce the bladder wall obliquely. This is important because it creates an one-way valve (a **physiological sphincter** rather than an **anatomical sphincter**) that allows urine into the bladder but prevents reflux of urine from the bladder back into the ureter. Children born lacking this oblique course of the ureter through the bladder wall are susceptible to "vesicoureteral reflux," which dramatically increases their risk of serious UTI. Pregnancy also increases the likelihood of reflux and UTI.

The ureters are approximately 30 cm long. The inner mucosa is lined with transitional epithelium (Figure **21.3.1**) and scattered goblet cells that secrete protective mucus. The muscular layer of the ureter consists of longitudinal and circular smooth muscles that create the peristaltic contractions to move the urine into the bladder without the aid of gravity. Finally, a loose adventitial layer composed of collagen and fat anchors the ureters between the parietal peritoneum and the posterior abdominal wall.

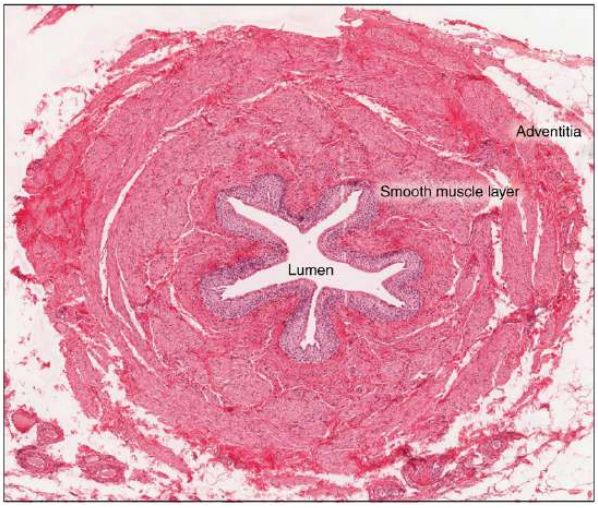


Figure **21.3.1**: **Ureter** Peristaltic contractions help to move urine through the lumen with contributions from fluid pressure and gravity. LM × 128. (Micrograph provided by the Regents of the University of Michigan Medical School © 2012) (CC-BY-4.0, OpenStax, Human Anatomy)

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21.4: Gross Anatomy of the Kidney

External Anatomy

The left kidney is located at about the T12 to L3 vertebrae, whereas the right is lower due to slight displacement by the liver. Upper portions of the kidneys are somewhat protected by the eleventh and twelfth ribs (Figure **21.4.1**). Each kidney weighs about 125–175 g in males and 115–155 g in females. They are about 11–14 cm in length, 6 cm wide, and 4 cm thick, and are directly covered by a fibrous capsule composed of dense, irregular connective tissue that helps to hold their shape and protect them. This capsule is covered by a shock-absorbing layer of adipose tissue called the **renal fat pad**, which in turn is encompassed by a tough renal fascia. The fascia and, to a lesser extent, the overlying peritoneum serve to firmly anchor the kidneys to the posterior abdominal wall in a retroperitoneal position.

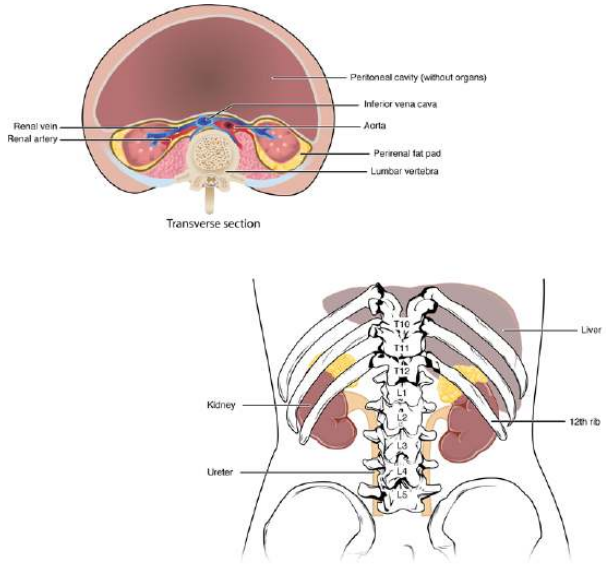


Figure **21.4.1**: **Kidneys** The kidneys are slightly protected by the ribs and are surrounded by fat for protection (not shown). (CC-BY-4.0, OpenStax, Human Anatomy)

Internal Anatomy

A frontal section through the kidney reveals an outer region called the **renal cortex** and an inner region called the **medulla** (Figure **21.4.2**). The **renal columns** are connective tissue extensions that radiate downward from the cortex through the medulla to separate the most characteristic features of the medulla, the **renal pyramids** and **renal papillae**. The papillae are bundles of collecting ducts that transport urine made by nephrons to the **calyces** of the kidney for excretion. The renal columns also serve to divide the kidney into 6–8 lobes and provide a supportive framework for vessels that enter and exit the cortex. The pyramids and renal columns taken together constitute the kidney lobes.

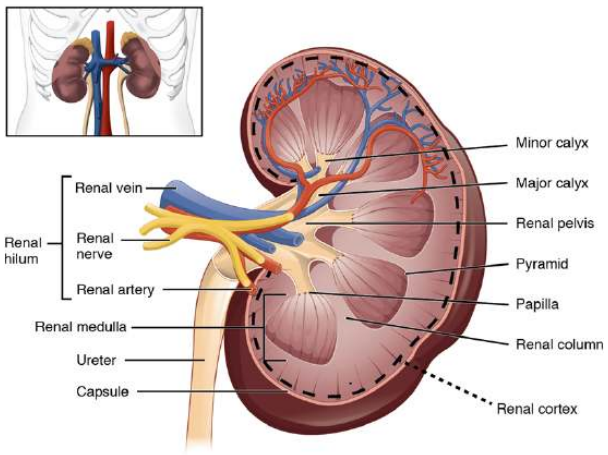


Figure 21.4.2: Kidneys The kidneys are slightly protected by the ribs and are surrounded by fat for protection (not shown). (CC-BY-4.0, OpenStax, Human Anatomy)

Nephrons and Vessels

The renal artery first divides into segmental arteries, followed by further branching to form interlobar arteries that pass through the renal columns to reach the cortex (Figure 21.4.3). The interlobar arteries, in turn, branch into arcuate arteries, cortical radiate arteries, and then into afferent arterioles. The afferent arterioles service about 1.3 million nephrons in each kidney.

Nephrons are the “functional units” of the kidney; they cleanse the blood and balance the constituents of the circulation. The afferent arterioles form a tuft of high-pressure capillaries about 200 μm in diameter, the glomerulus. The rest of the nephron consists of a continuous sophisticated tubule whose proximal end surrounds the glomerulus in an intimate embrace—this is Bowman’s capsule. The glomerulus and Bowman’s capsule together form the renal corpuscle. As mentioned earlier, these glomerular capillaries filter the blood based on particle size. After passing through the renal corpuscle, the capillaries form a second arteriole, the efferent arteriole (Figure 21.4.4). These will next form a capillary network around the more distal portions of the nephron tubule, the peritubular capillaries and vasa recta, before returning to the venous system. As the glomerular filtrate progresses through the nephron, these capillary networks recover most of the solutes and water, and return them to the circulation. Since a capillary bed (the glomerulus) drains into a vessel that in turn forms a second capillary bed, the definition of a portal system is met. This is the only portal system in which an arteriole is found between the first and second capillary beds. (Portal systems also link the hypothalamus to the anterior pituitary, and the blood vessels of the digestive viscera to the liver.)

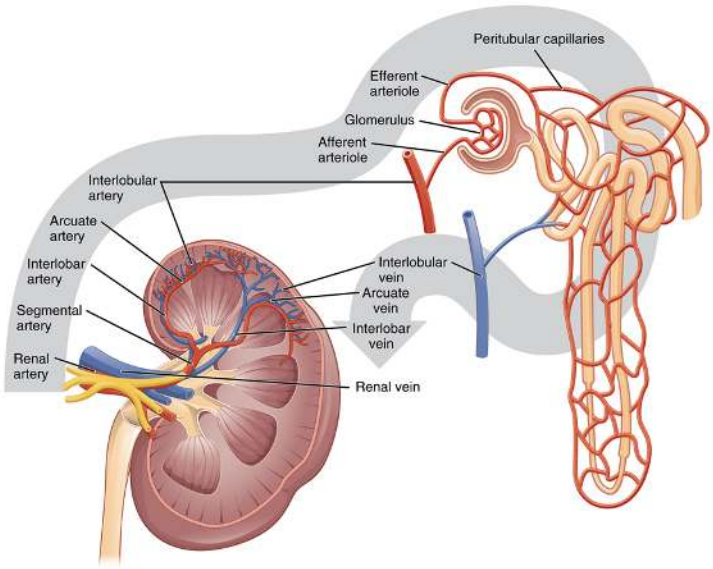


Figure **21.4.3**: Blood Flow in the Kidney (CC-BY-4.0, OpenStax, Human Anatomy)

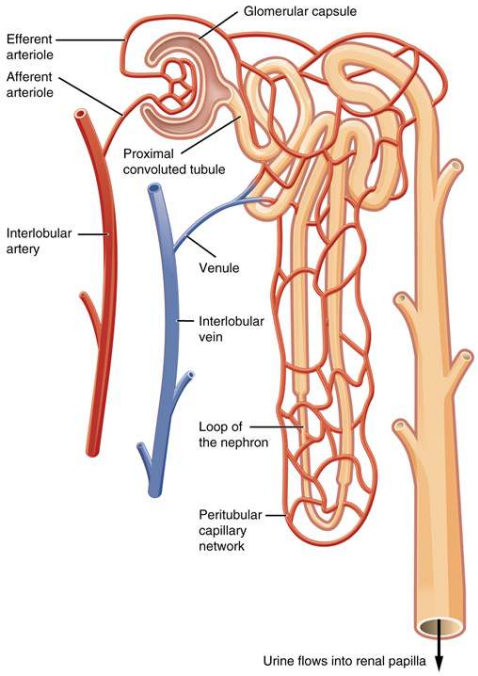


Figure **21.4.4**: Blood Flow in the Nephron The two capillary beds are clearly shown in this figure. The efferent arteriole is the connecting vessel between the glomerulus and the peritubular capillaries and vasa recta. (CC-BY-4.0, OpenStax, Human Anatomy)

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21.5: Microscopic Anatomy of the Kidney

Nephrons: The Functional Unit

Nephrons take a simple filtrate of the blood and modify it into urine. Many changes take place in the different parts of the nephron before urine is created for disposal. The term **forming urine** will be used hereafter to describe the filtrate as it is modified into true urine. The principle task of the nephron population is to balance the plasma to homeostatic set points and excrete potential toxins in the urine. They do this by accomplishing three principle functions—filtration, reabsorption, and secretion. They also have additional secondary functions that exert control in three areas: blood pressure (via production of **renin**), red blood cell production (via the hormone EPO), and calcium absorption (via conversion of calcidiol into calcitriol, the active form of vitamin D).

Renal Corpuscle

As discussed earlier, the renal corpuscle consists of a tuft of capillaries called the glomerulus that is largely surrounded by Bowman's (glomerular) capsule. The glomerulus is a high-pressure capillary bed between afferent and efferent arterioles. Bowman's capsule surrounds the glomerulus to form a lumen, and captures and directs this filtrate to the PCT. The outermost part of Bowman's capsule, the parietal layer, is a simple squamous epithelium. It transitions onto the glomerular capillaries in an intimate embrace to form the visceral layer of the capsule. Here, the cells are not squamous, but uniquely shaped cells (**podocytes**) extending finger-like arms (**pedicels**) to cover the glomerular capillaries (Figure **21.5.1**). These projections interdigitate to form **filtration slits**, leaving small gaps between the digits to form a sieve. As blood passes through the glomerulus, 10 to 20 percent of the plasma filters between these sieve-like fingers to be captured by Bowman's capsule and funneled to the PCT. Where the fenestrae (windows) in the glomerular capillaries match the spaces between the podocyte "fingers," the only thing separating the capillary lumen and the lumen of Bowman's capsule is their shared basement membrane (Figure **21.5.2**). These three features comprise what is known as the filtration membrane. This membrane permits very rapid movement of filtrate from capillary to capsule though pores that are only 70 nm in diameter.

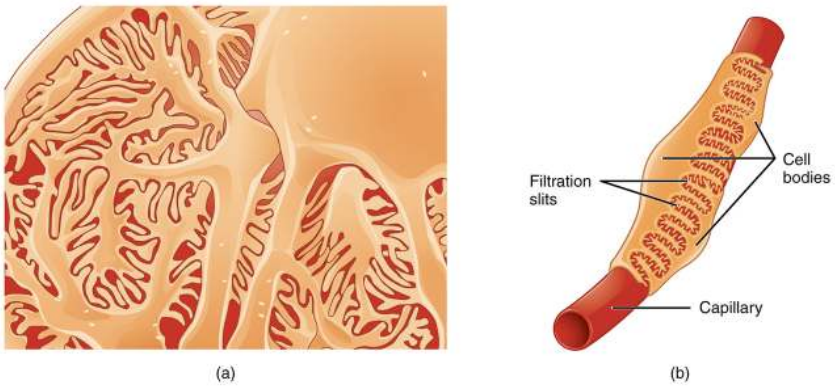


Figure **21.5.1**: Podocytes Podocytes interdigitate with structures called pedicels and filter substances in a way similar to fenestrations. In (a), the large cell body can be seen at the top right corner, with branches extending from the cell body. The smallest finger-like extensions are the pedicels. Pedicels on one podocyte always interdigitate with the pedicels of another podocyte. (b) This capillary has three podocytes wrapped around it. (CC-BY-4.0, OpenStax, Human Anatomy)

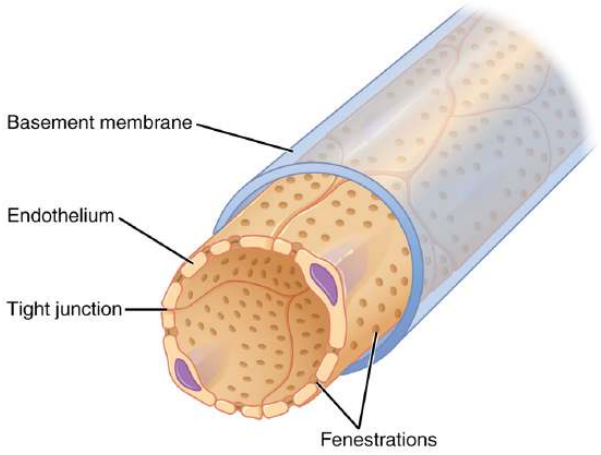


Figure **21.5.2**: Fenestrated Capillary Fenestrations allow many substances to diffuse from the blood based primarily on size. (CC-BY-4.0, OpenStax, Human Anatomy)

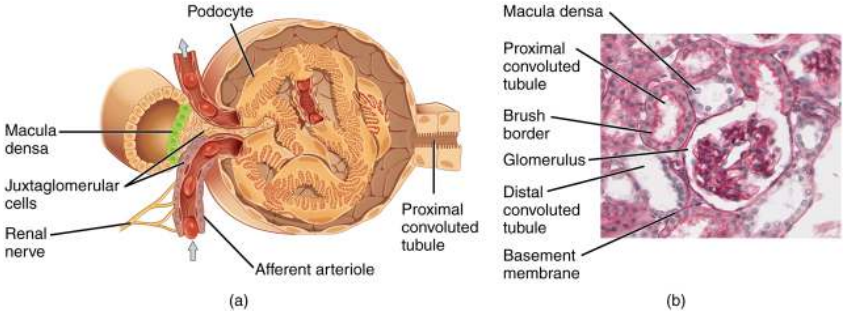
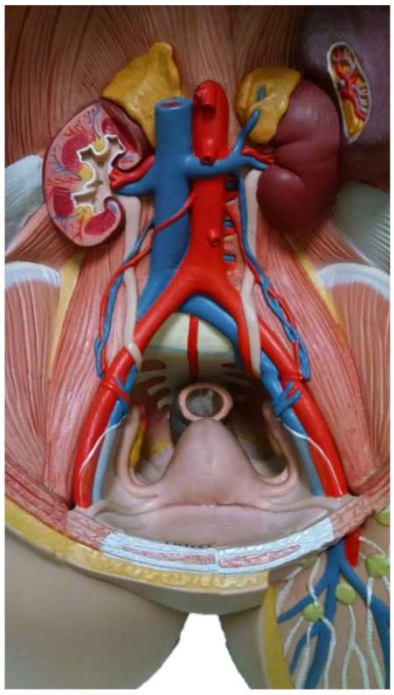


Figure **21.5.2**: **Juxtaglomerular Apparatus and Glomerulus** (a) The JGA allows specialized cells to monitor the composition of the fluid in the DCT and adjust the glomerular filtration rate. (b) This micrograph shows the glomerulus and surrounding structures. LM × 1540. (Micrograph provided by the Regents of University of Michigan Medical School © 2012) (CC-BY-4.0, OpenStax, Human Anatomy)

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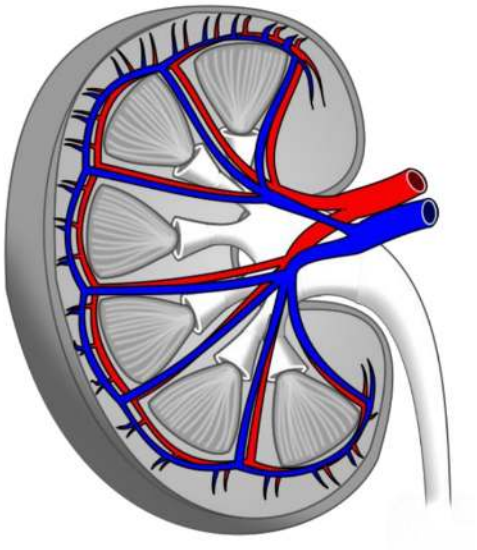
21.6: Exercises

LAB 21 EXERCISES 21.6.1



Identify the following: L. and R. Kidneys

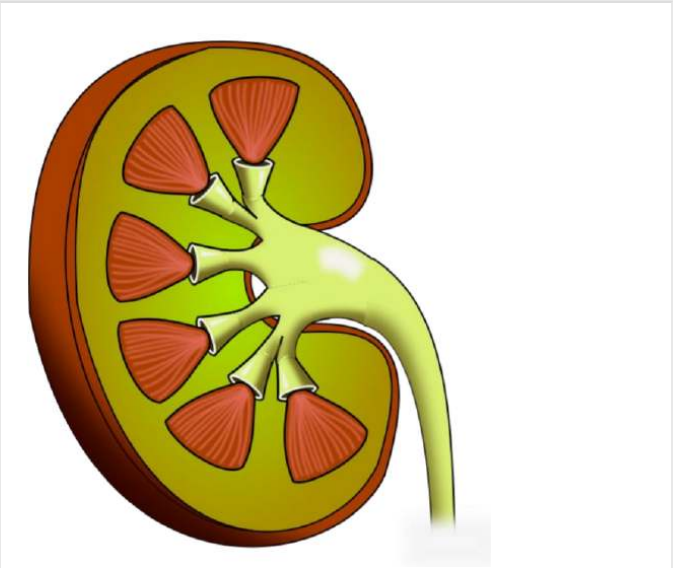
1	L. and R. Kidneys
2	Adrenal glands
3	Ureters
4	Bladder



Identify all of the blood vessels shown.

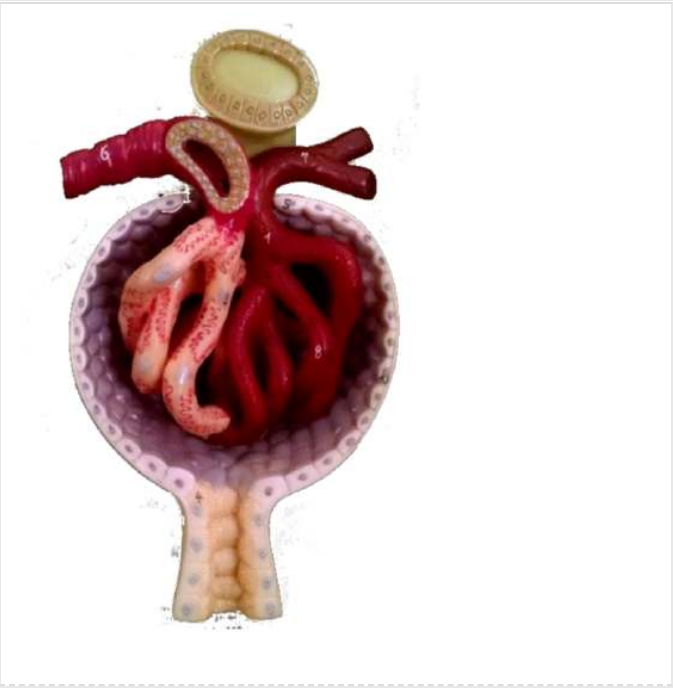
1	
2	
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4	
5	
6	

LAB 21 EXERCISES 21.6.2



Identify the following:

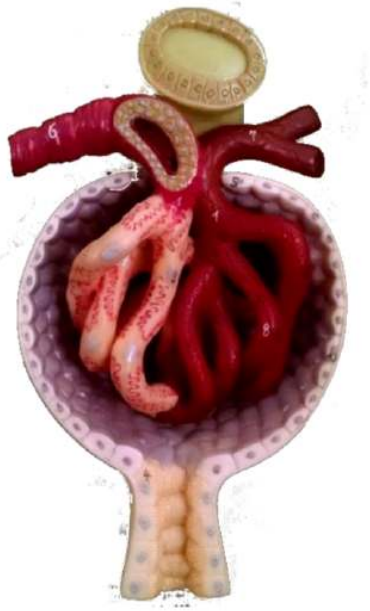
1	Cortex	7	Minor Calyx
2	Medulla	8	Major Calyx
3	Capsule	9	Renal Pelvis
4	Renal Pyramid	10	Ureter
5	* Renal Column	11	Papilla
6	Renal sinus	12	Hilus



Label the following:

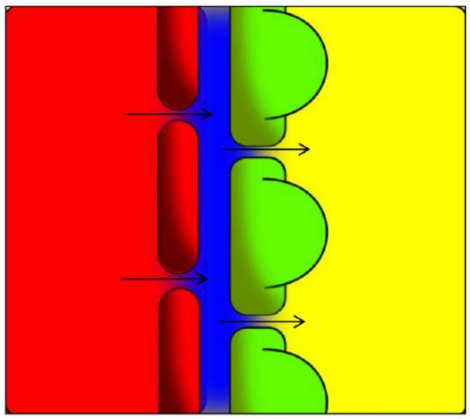
1	Juxtaglomerular apparatus
2	JG cells
3	Macula densa
4	Distal convoluted tubule
5	Proximal convoluted tubule

LAB 21 EXERCISES 21.6.3



Label the following:

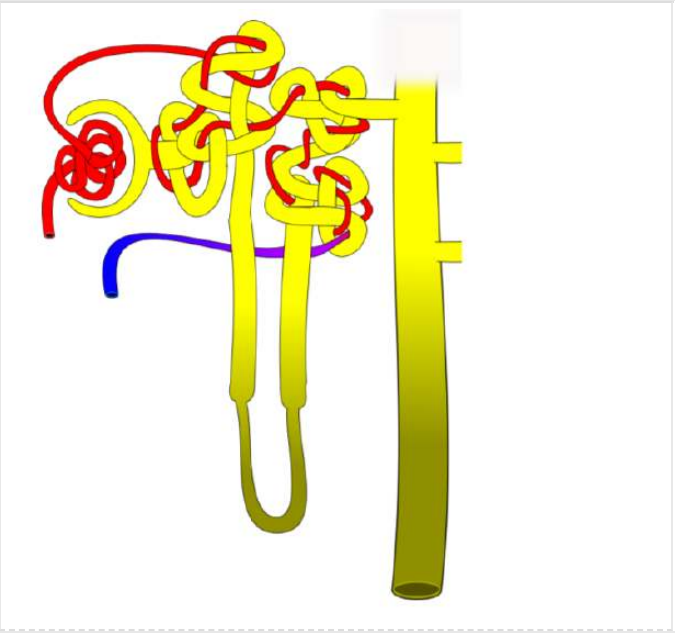
1	Afferent arteriole
2	Efferent arteriole
3	Bowman’s capsule
4	Podocyte
5	Fenestrated endothelium



Label the following:

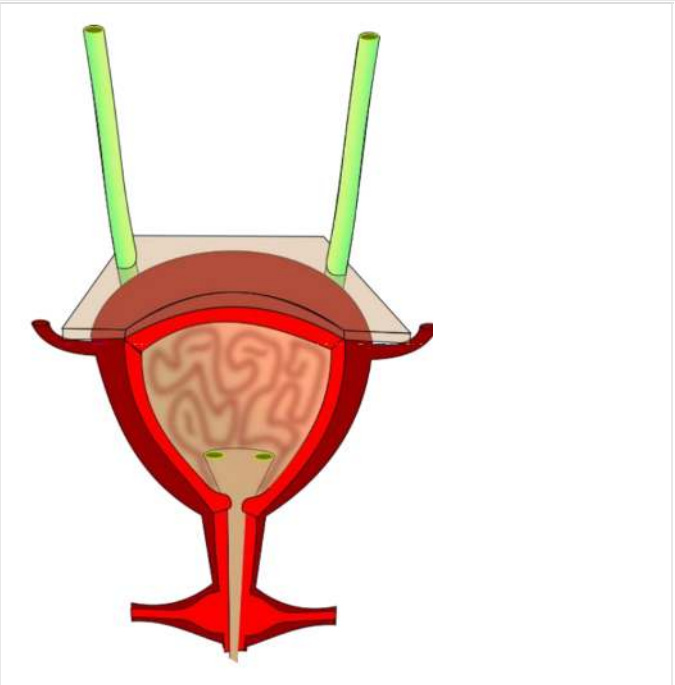
1	Filtration membrane
2	Fenestrated endothelia
3	Podocyte foot process
4	Filtration slit
5	Basement membrane
6	Plasma
7	* Filtrate

LAB 21 EXERCISES 21.6.4



Label the parts of a nephron:

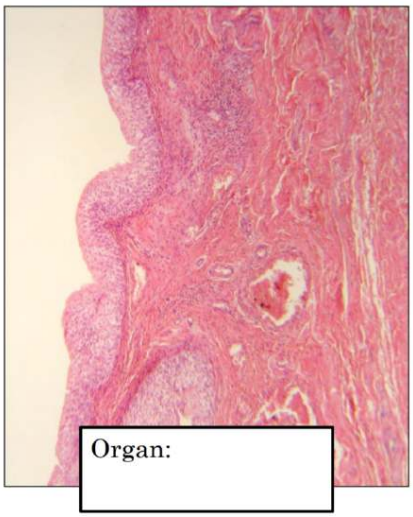
1	Bowman's capsule	6	Afferent arteriole
2	Proximal convoluted tubule	7	Efferent arteriol
3	Distal convoluted tubule	8	Peritubular capillaries
4	Loop of Henle	9	Glomerulus
5	Collecting duct		



Label the following:

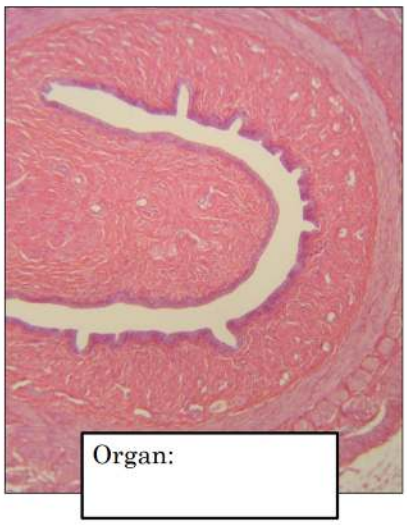
1	Detrusor muscle
2	Ureters
3	Ureteral slits
4	Urethra
5	Internal urethral sphincter
6	External urethral sphincter
7	Trigone
8	Rugae.

LAB 21 EXERCISES 21.6.5



Name this organ
Identify 3 tissue types

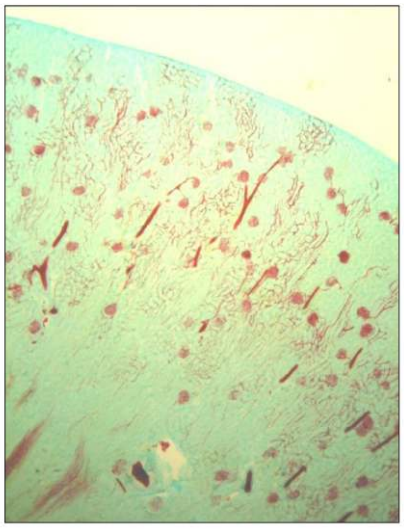
1	
2	
3	



Name this organ
Identify 3 tissue types

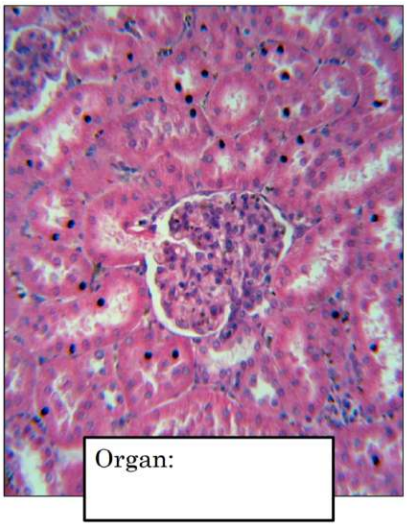
1	
2	
3	

LAB 21 EXERCISES 21.6.6



Label the following:

1	Afferent arteriole
2	Glomerulus
3	Peritubular capillaries



Name this organ
Label the following:

1	Glomerulus
2	Bowman’s capsule
3	Convoluted tubule.

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21.7: MODELS- Kidney, Nephron, Torso and Hemi-Pelvis

- Blood Supply:
  - Renal artery
  - Segmental
  - Interlobar
  - Arcuate
  - Cortical radiate
  - Afferent arteriole
  - Glomerular capillaries
  - Efferent arteriole
  - Peritubular capillaries
  - Cortical radiate venules (interlobular)
  - Arcuate veins
  - Interlobar veins (segmental veins)
  - Renal vein
- Nephron: (model)
  - Renal corpuscle
  - Glomerulus
  - Afferent + efferent arteriole
  - Peritubular capillaries
  - Vasa recta
  - Glomerular (Bowman's) capsule
  - Podocytes
  - Renal tubules:
  - Proximal Convoluted Tubule (PCT)
  - Loop of Henle
    - Descending & ascending limbs
    - Thick & thin segments
  - Distal Convoluted Tubule (DCT)
  - Collecting Duct
  - Papillary duct
  - Juxtaglomerular Apparatus (JGA)
  - JG cells
  - Macula Densa
- Ureters (torso)
  - Urinary Bladder
  - Trigone (2 ureters * 1 urethra)
  - Rugae
  - Detrusor muscle
  - Urethra
- Kidney anatomy (model)
  - Renal capsule
  - Hilum
  - Nephrons
    - Juxtamedullary nephron
    - Cortical nephron
  - Renal cortex

- Renal medulla:
  - Columns
  - Renal sinus
  - Renal Pyramids
  - Papilla
- Minor Calyx (calyces)
- Major Calyx (calyces)
- Pelvis

Histology:

- Kidney:
  - Bowman's capsule
  - Glomerulus
  - Afferent & efferent arterioles
  - simple cuboidal epithelium
  - convoluted tubules
  - Adipose capsule
- Bladder/Ureters
  - Mucosa:
    - Transitional epithelium
  - Submucosa
    - Areolar CT (& other CT)
  - Muscularis externa (detrusor muscle)
    - Smooth muscle

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CHAPTER OVERVIEW

22: The Reproductive System (Male)

Learning Objectives

Anatomy and Physiology of the Male Reproductive System

- Describe the structure of the organs of the male reproductive system
- Describe the structure of the sperm cell

22.1: Scrotum

22.2: Testes

22.3: Structure of Formed Sperm

22.4: Penis

22.5: Exercises

22.6: MODELS- Male Hemi-Pelvis and Torso

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22.1: Scrotum

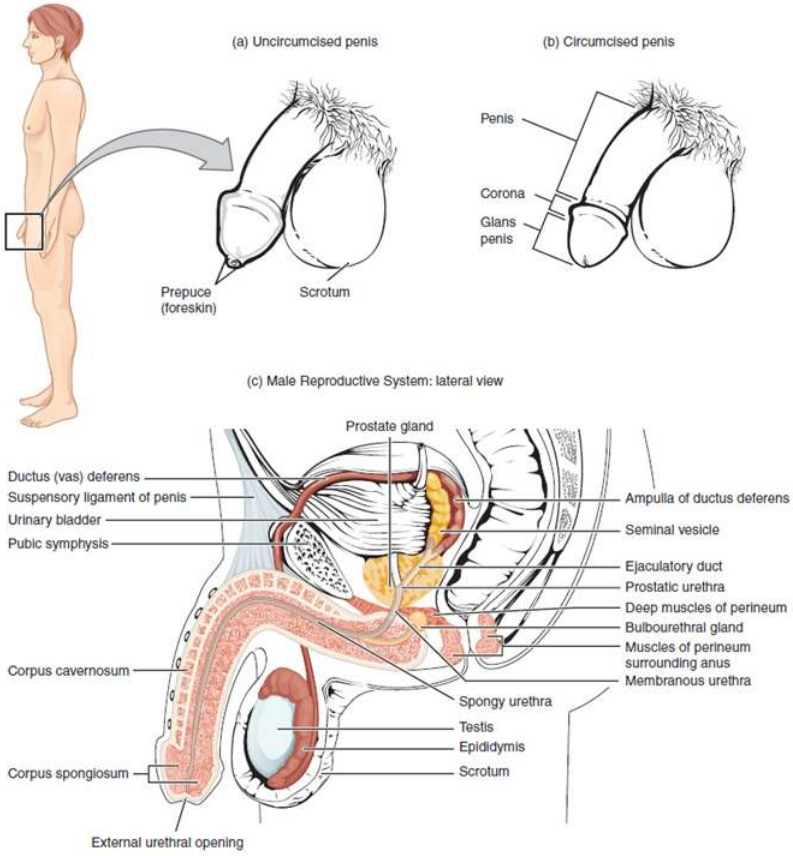


Figure **22.1.1**: Male Reproductive System The structures of the male reproductive system include the testes, the epididymis, the penis, and the ducts and glands that produce and carry semen. Sperm exit the scrotum through the ductus deferens, which is bundled in the spermatic cord. The seminal vesicles and prostate gland add fluids to the sperm to create semen. (CC-BY-4.0, OpenStax, Human Anatomy)

Scrotum

The testes are located in a skin-covered, highly pigmented, muscular sack called the **scrotum** that extends from the body behind the penis (see Figure **22.1.1**). This location is important in sperm production, which occurs within the testes, and proceeds more efficiently when the testes are kept 2 to 4°C below core body temperature. The dartos muscle makes up the subcutaneous muscle layer of the scrotum (Figure **22.1.2**).

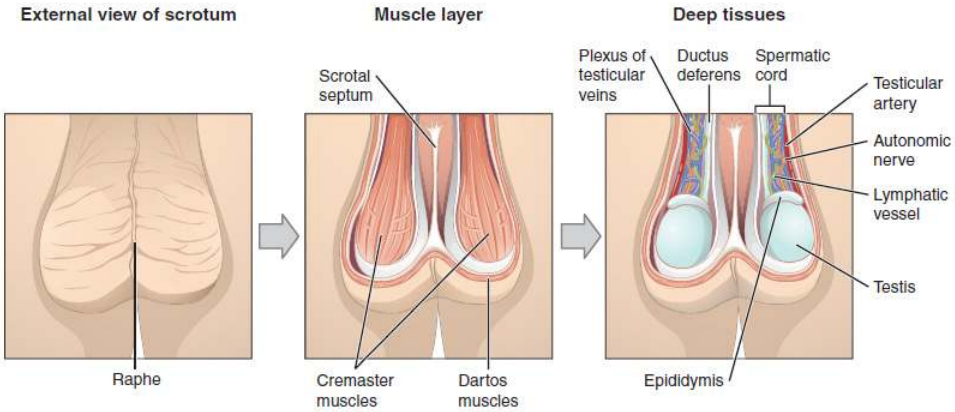


Figure **22.1.2**: The Scrotum and Testes This anterior view shows the structures of the scrotum and testes. (CC-BY-4.0, OpenStax, Human Anatomy)

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22.2: Testes

The **testes** (singular = testis) are the male **gonads**—that is, the male reproductive organs. They produce both sperm and androgens, such as testosterone, and are active throughout the reproductive lifespan of the male.

Paired ovals, the testes are each approximately 4 to 5 cm in length and are housed within the scrotum (see this figure). They are surrounded by two distinct layers of protective connective tissue (Figure **22.2.1**: **Anatomy of the Testis**). The outer tunica vaginalis is a serous membrane that has both a parietal and a thin visceral layer. Beneath the tunica vaginalis is the tunica albuginea, a tough, white, dense connective tissue layer covering the testis itself. The tightly coiled **seminiferous tubules** form the bulk of each testis.

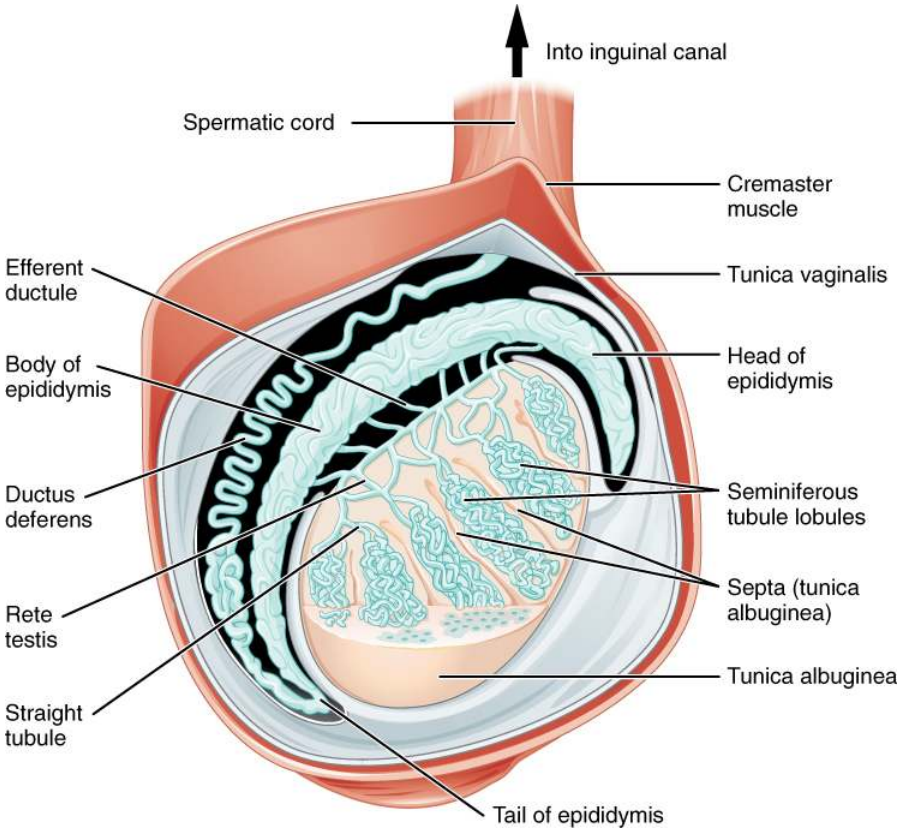


Figure **22.2.1**: **Anatomy of the Testis** This sagittal view shows the seminiferous tubules, the site of sperm production. Formed sperm are transferred to the epididymis, where they mature. They leave the epididymis during an ejaculation via the ductus deferens. (CC-BY-4.0, OpenStax, Human Anatomy)

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22.3: Structure of Formed Sperm

Sperm are smaller than most cells in the body; in fact, the volume of a sperm cell is 85,000 times less than that of the female gamete. Approximately 100 to 300 million sperm are produced each day, whereas women typically ovulate only one oocyte per month. As is true for most cells in the body, the structure of sperm cells speaks to their function. Sperm have a distinctive head, mid-piece, and tail region (Figure **22.3.1**). The head of the sperm contains the extremely compact haploid nucleus with very little cytoplasm. These qualities contribute to the overall small size of the sperm (the head is only 5 μm long). A structure called the acrosome covers most of the head of the sperm cell as a "cap" that is filled with lysosomal enzymes important for preparing sperm to participate in fertilization. Tightly packed mitochondria fill the mid- piece of the sperm. ATP produced by these mitochondria will power the flagellum, which extends from the neck and the mid-piece through the tail of the sperm, enabling it to move the entire sperm cell. The central strand of the flagellum, the axial filament, is formed from one centriole inside the maturing sperm cell during the final stages of spermatogenesis.

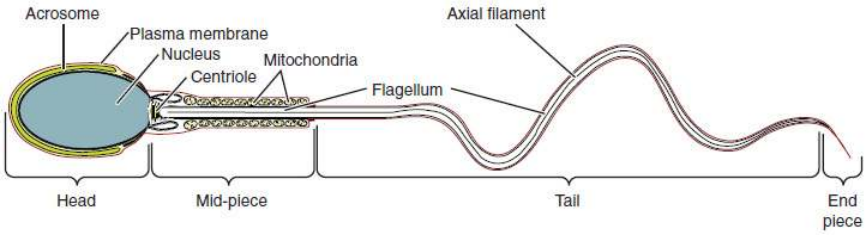


Figure **22.3.1**: Structure of Sperm Sperm cells are divided into a head, containing DNA; a mid-piece, containing mitochondria; and a tail, providing motility. The acrosome is oval and somewhat flattened. (CC-BY-4.0, OpenStax, Human Anatomy)

Sperm Transport

To fertilize an egg, sperm must be moved from the seminiferous tubules in the testes, through the epididymis, and—later during ejaculation—along the length of the penis and out into the female reproductive tract.

Role of the Epididymis

From the lumen of the seminiferous tubules, the immotile sperm are surrounded by testicular fluid and moved to the **epididymis** (plural = epididymides), a coiled tube attached to the testis where newly formed sperm continue to mature (see Figure **22.3.1**).

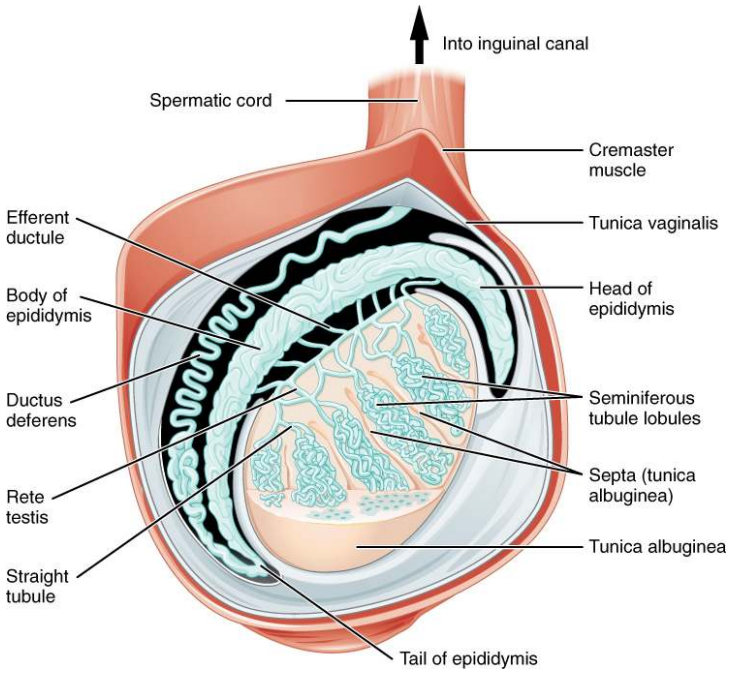


Figure 22.3.1: **Anatomy of the Testis** This sagittal view shows the seminiferous tubules, the site of sperm production. Formed sperm are transferred to the epididymis, where they mature. They leave the epididymis during an ejaculation via the ductus deferens. (CC-BY-4.0, OpenStax, Human Anatomy)

Duct System

During ejaculation, sperm exit the tail of the epididymis and are pushed by smooth muscle contraction to the **ductus deferens** (also called the vas deferens). The ductus deferens is a thick, muscular tube that is bundled together inside the scrotum with connective tissue, blood vessels, and nerves into a structure called the **spermatic cord** (see Figure 22.3.1 and Figure 22.3.2).

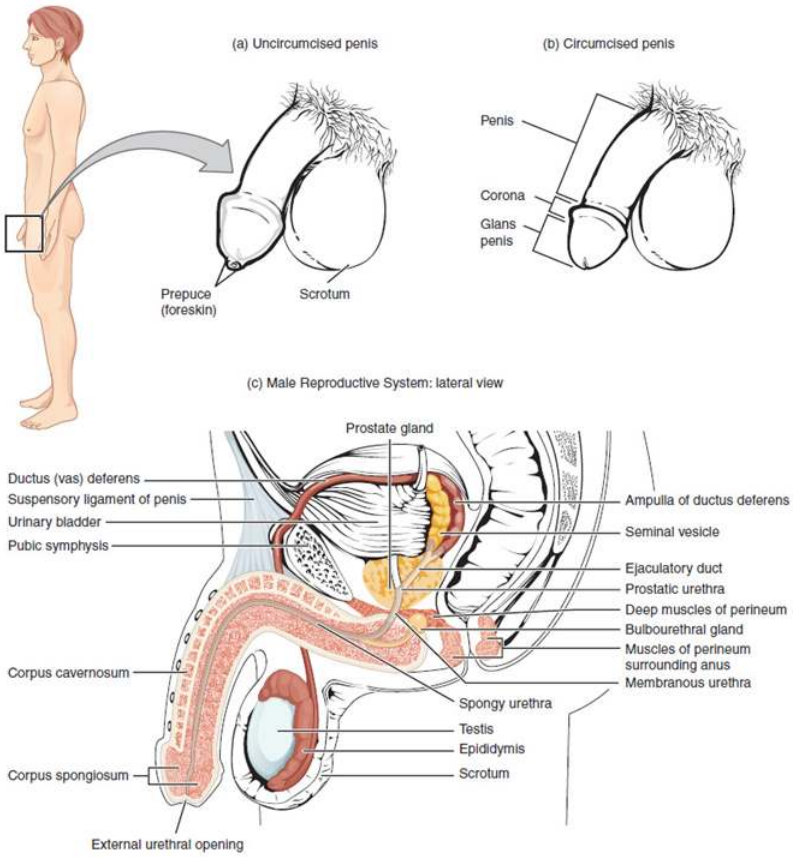


Figure 22.3.2: Male Reproductive System The structures of the male reproductive system include the testes, the epididymis, the penis, and the ducts and glands that produce and carry semen. Sperm exit the scrotum through the ductus deferens, which is bundled in the spermatic cord. The seminal vesicles and prostate gland add fluids to the sperm to create semen. (CC-BY-4.0, OpenStax, Human Anatomy)

Seminal Vesicles

As sperm pass through the ampulla of the ductus deferens at ejaculation, they mix with fluid from the associated **seminal vesicle (**Figure 22.3.2**).**

Prostate Gland

As shown in Figure 22.3.2, the centrally located **prostate gland** sits anterior to the rectum at the base of the bladder surrounding the prostatic urethra (the portion of the urethra that runs within the prostate). About the size of a walnut, the prostate is formed of both muscular and glandular tissues.

Bulbourethral Glands

The final addition to semen is made by two **bulbourethral glands** (or Cowper's glands) that release a thick, salty fluid that lubricates the end of the urethra and the vagina, and helps to clean urine residues from the penile urethra. The fluid from these accessory glands is released after the male becomes sexually aroused, and shortly before the release of the semen. It is therefore sometimes called pre-ejaculate.

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22.4: Penis

The **penis** is the male organ of copulation (sexual intercourse). It is flaccid for non-sexual actions, such as urination, and turgid and rod-like with sexual arousal. When erect, the stiffness of the organ allows it to penetrate into the vagina and deposit semen into the female reproductive tract.

The shaft of the penis surrounds the urethra (Figure **22.4.1**). The shaft is composed of three column-like chambers of erectile tissue that span the length of the shaft. Each of the two larger lateral chambers is called a **corpus cavernosum** (plural = corpora cavernosa). Together, these make up the bulk of the penis. The **corpus spongiosum**, which can be felt as a raised ridge on the erect penis, is a smaller chamber that surrounds the spongy, or penile, urethra. The end of the penis, called the **glans penis**, has a high concentration of nerve endings, resulting in very sensitive skin that influences the likelihood of ejaculation (see). The skin from the shaft extends down over the glans and forms a collar called the **prepuce** (or foreskin). The foreskin also contains a dense concentration of nerve endings, and both lubricate and protect the sensitive skin of the glans penis. A surgical procedure called circumcision, often performed for religious or social reasons, removes the prepuce, typically within days of birth.

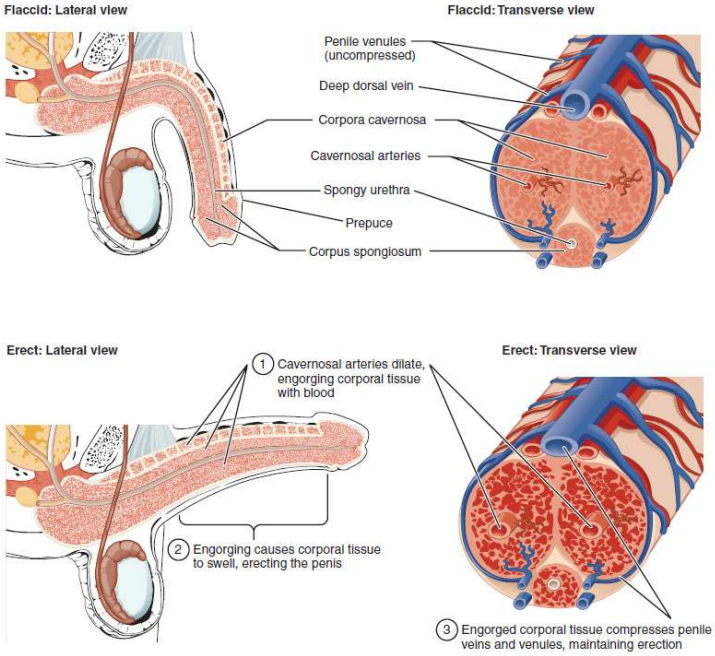
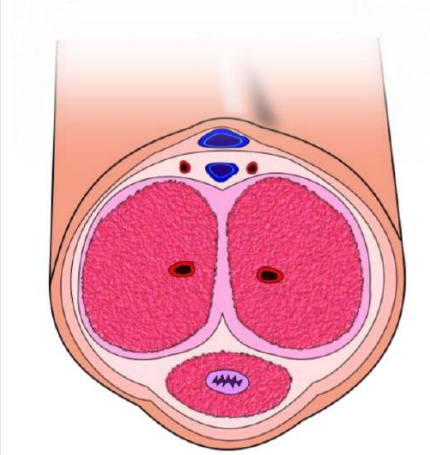


Figure **22.4.1**: Cross-Sectional Anatomy of the Penis Three columns of erectile tissue make up most of the volume of the penis. (CC-BY-4.0, OpenStax, Human Anatomy)

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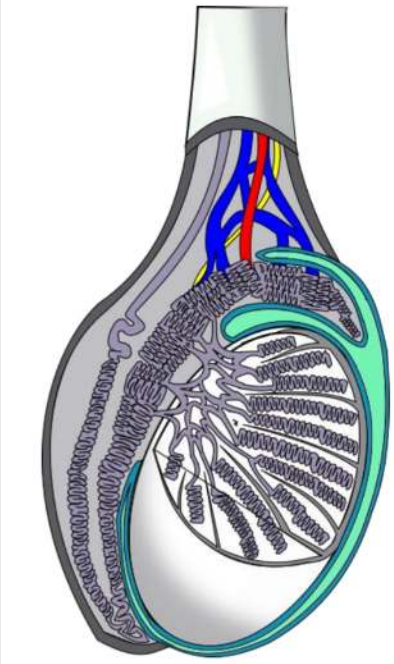
22.5: Exercises

LAB 23 EXERCISES 22.5.1



Label the following:

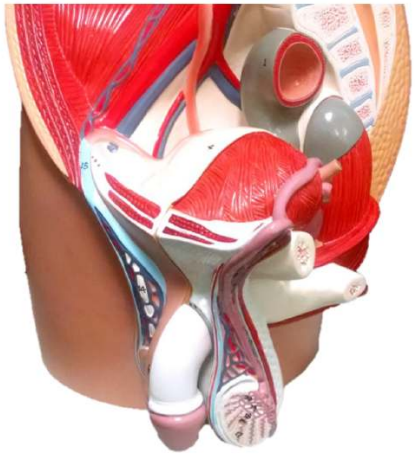
1	Deep artery
2	Dorsal vein
3	Urethra
4	Corpora cavernosa
5	Copora spongiosa
6	Median septum of the penis
7	Skin



Label the following:

1	Spermatic cord
2	Epididymis
3	Seminiferous tubule
4	Tunica albuginea
5	Tunica vaginalis
6	Rete testis
7	Vas deferens

LAB 23 EXERCISES 22.5.2



Label the following:

1	Fascia of spermatic cord
2	Glans
3	Cremaster muscle
4	Pampiniform plexus
5	Tunica vaginalis
6	Ureter

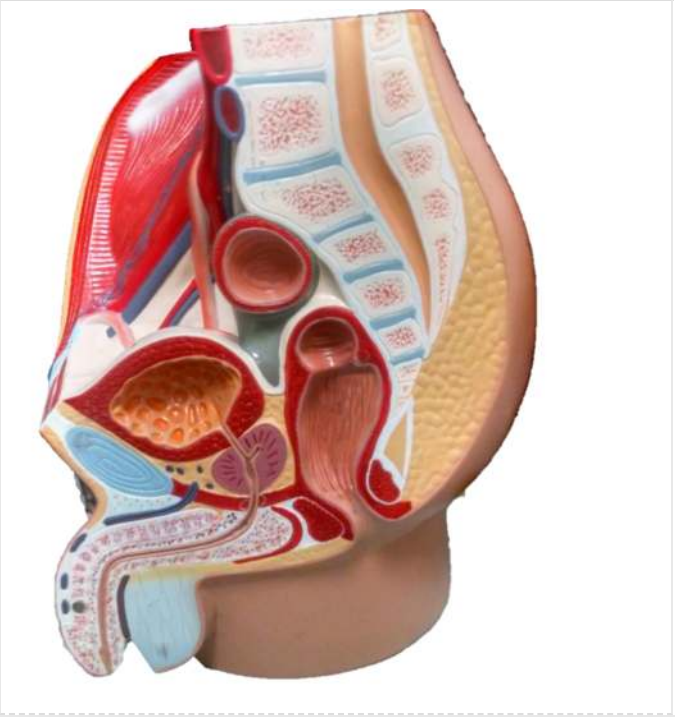
LAB 22 EXERCISES 22.5.3



Label the following:

1	Testis
2	Epididymis
3	R. vas deferensi
4	L. vas deferens
5	Ampulla (of vas deferens)
6	Seminal vesicle
7	Prostate
8	Urinary bladder

LAB 22 EXERCISES 22.5.4



Label the following:

1	Rectum	6	Spongy urethra
2	Prostate	7	Shaft of penis
3	Ejaculatory duct	8	Root of penis
4	Prostatic urethra	9	Urinary bladder
5	Membranous urethra	10	Urogenital diaphragm

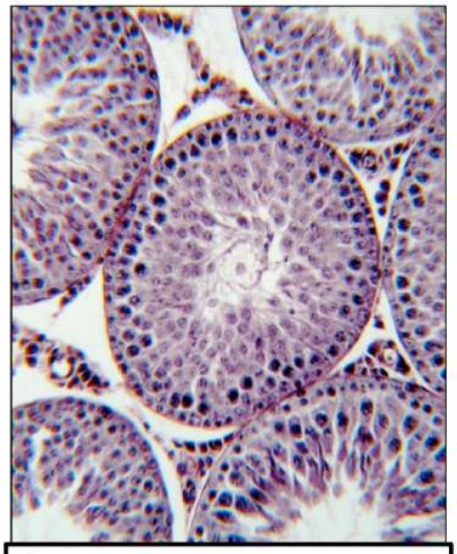
LAB 22 EXERCISES 22.5.5

Histology



Label the following:

1	Head
2	Acrosome
3	Midpiece
4	Tail



Organ:

1) Name this organ sample
2) Label the following:

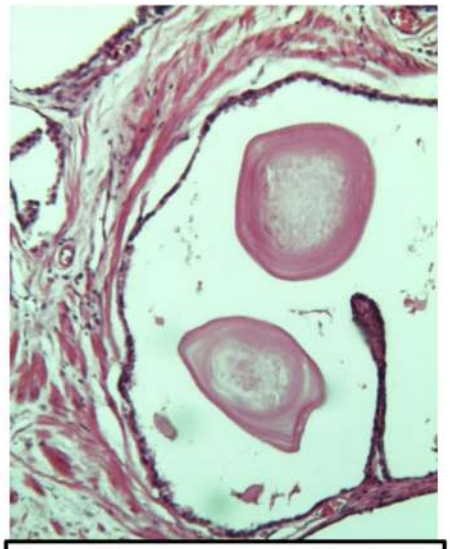
1	Spermatogonia
2	Spermatozoa
3	Interstitial cells
4	Nurse cells
5	Lumen



Organ:

1) Name this organ sample
2) Label the following:

1	Lumen
2	Mucosa
3	Submucosa
4	Muscularis externa



Organ (gland):

Label the following:

1	Mucosa
2	Submucosa
3	Muscularis externa (circular and longitudinal layers) Musculari
4	Serosa
5	Muscularis mucosa
6	Peyer’s patch

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22.6: MODELS- Male Hemi-Pelvis and Torso

- Scrotum
  - Dartos muscle
  - Raphe
- Testes:
  - Tunica albuginea
  - Tunica vaginalis
  - Seminiferous tubules
  - Rete testis
  - Epididymis
- Inguinal Canal
  - Spermatic cord
  - Testicular arteries
  - Pampiniform plexus (blood vessels)
  - Vas deferens (ductus deferens)
  - Cremasteric muscle
- Ejaculatory duct
- Urethra:
  - Prostatic * membranous * spongy
  - External urethral orifice
- Penis
  - Shaft
  - Root
  - Crus (Crura)
  - Corpora cavernosa (x2)
  - Corpora spongiosa
  - Glans penis
  - Dorsal artery/vein Deep artery
- Accessory glands:
  - Seminal Vesicles
  - Prostate
  - Bulbourethral (Cowpers) Glands
- Rectum
- Bladder
- Urogenital diaphragm
- Pubis Symphisis

Histology:

- Penis:
  - corpora cavernosa
  - corpora spongiosa
  - Erectile tissue
  - Urethra
  - Central artery
  - Deep dorsal vein
- Testis
  - tunica albuginea

- tunica vaginalis
- seminiferous tubules
- lumen *
- interstitial cells
- spermatids
- spermatogonia

- Sperm
  - Acrosome
  - head
  - midpiece
  - tail/flagellum
- Vas deferens & urethra
  - Mucosa
  - Submucosa
- Muscularis externa
- Prostate gland
  - Glandular epithelium
  - concretion

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CHAPTER OVERVIEW

23: The Reproductive System (Female)

Learning Objectives

By the end of this section, you will be able to:

- Describe the structure of the organs of the female reproductive system
- Trace the path of an oocyte from ovary to fertilization

23.1: External Female Genitals

23.2: Ovaries

23.3: Uterine Tubes

23.4: Uterus and Cervix

23.5: Breasts

23.6: Exercises

23.7: MODELS- Female Hemi-Pelvises, Torso, Breast and Ovary

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23.1: External Female Genitals

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The female reproductive system functions to produce gametes and reproductive hormones, just like the male reproductive system; however, it also has the additional task of supporting the developing fetus and delivering it to the outside world. Unlike its male counterpart, the female reproductive system is located primarily inside the pelvic cavity (Figure 23.1.1). Recall that the ovaries are the female gonads. The gamete they produce is called an **oocyte**.

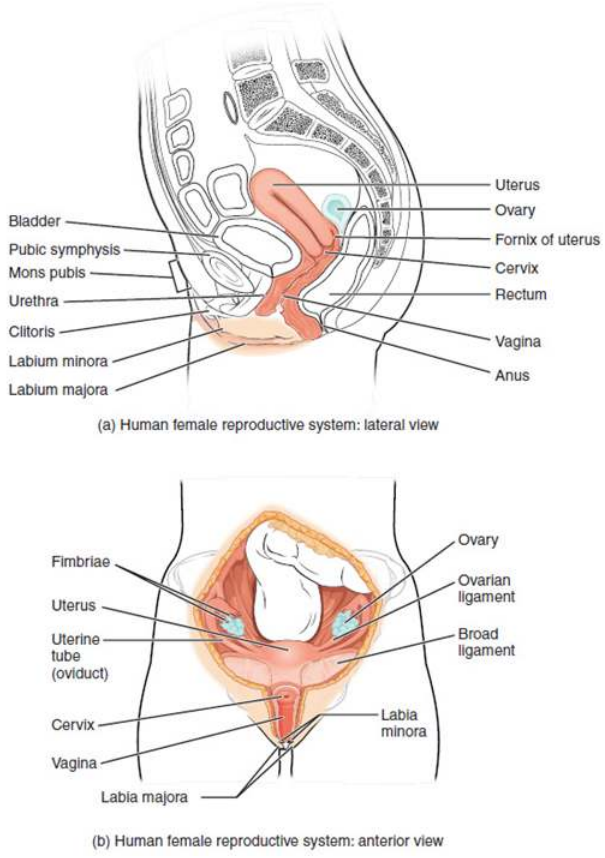


Figure 23.1.1: **Female Reproductive System** The major organs of the female reproductive system are located inside the pelvic cavity. (CC-BY-4.0, OpenStax, Human Anatomy)

External Female Genitals

The external female reproductive structures are referred to collectively as the **vulva** (Figure 23.1.2). The **mons pubis** is a pad of fat that is located at the anterior, over the pubic bone. After puberty, it becomes covered in pubic hair. The **labia majora** (labia = "lips"; majora = "larger") are folds of hair-covered skin that begin just

posterior to the mons pubis. The thinner and more pigmented **labia minora** (labia = "lips"; minora = "smaller") extend medial to the labia majora. Although they naturally vary in shape and size from woman to woman, the labia minora serve to protect the female urethra and the entrance to the female reproductive tract.

The superior, anterior portions of the labia minora come together to encircle the **clitoris** (or glans clitoris), an organ that originates from the same cells as the glans penis and has abundant nerves that make it important in sexual sensation and orgasm. The **hymen** is a thin membrane that sometimes partially covers the entrance to the vagina. An intact hymen cannot be used as an indication of "virginity"; even at birth, this is only a partial membrane, as menstrual fluid and other secretions must be able to exit the body, regardless of penile–vaginal intercourse. The vaginal opening is located between the opening of the urethra and the anus. It is flanked by outlets to the **Bartholin's glands** (or greater vestibular glands).

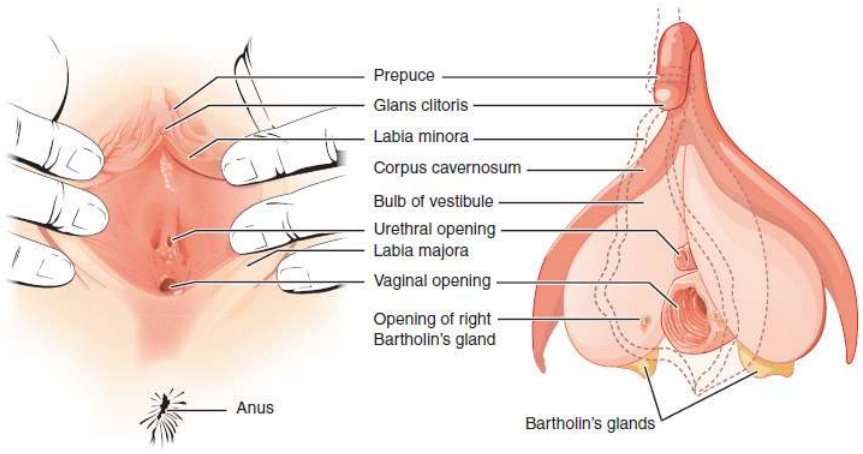


Figure **23.1.2**: **The Vulva** The external female genitalia are referred to collectively as the vulva. (CC-BY-4.0, OpenStax, Human Anatomy)

Vagina

The **vagina**, shown at the bottom of **23.1.1** and **23.1.2**, is a muscular canal (approximately 10 cm long) that serves as the entrance to the reproductive tract. It also serves as the exit from the uterus during menses and childbirth. The outer walls of the anterior and posterior vagina are formed into longitudinal columns, or ridges, and the superior portion of the vagina—called the fornix—meets the protruding uterine cervix. The walls of the vagina are lined with an outer, fibrous adventitia; a middle layer of smooth muscle; and an inner mucous membrane with transverse folds called **rugae**. Together, the middle and inner layers allow the expansion of the vagina to accommodate intercourse and childbirth. The thin, perforated hymen can partially surround the opening to the vaginal orifice. The hymen can be ruptured with strenuous physical exercise, penile–vaginal intercourse, and childbirth. The Bartholin's glands and the lesser vestibular glands (located near the clitoris) secrete mucus, which keeps the vestibular area moist.

The vagina is home to a normal population of microorganisms that help to protect against infection by pathogenic bacteria, yeast, or other organisms that can enter the vagina. In a healthy woman, the most predominant type of vaginal bacteria is from the genus *Lactobacillus*. This family of beneficial bacterial flora secretes lactic acid, and thus protects the vagina by maintaining an acidic pH (below 4.5). Potential pathogens are less likely to survive in these acidic conditions. Lactic acid, in combination with other vaginal secretions, makes the vagina a self- cleansing organ. However, douching—or washing out the vagina with fluid—can disrupt the normal balance of healthy microorganisms, and actually increase a woman's risk for infections and irritation. Indeed, the American College of Obstetricians and Gynecologists recommend that women do not douche, and that they allow the vagina to maintain its normal healthy population of protective microbial flora.

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23.2: Ovaries

The **ovaries** are the female gonads (see Figure **23.2.1**). Paired ovals, they are each about 2 to 3 cm in length, about the size of an almond. The ovaries are located within the pelvic cavity, and are supported by the mesovarium, an extension of the peritoneum that connects the ovaries to the **broad ligament**. Extending from the mesovarium itself is the suspensory ligament that contains the ovarian blood and lymph vessels. Finally, the ovary itself is attached to the uterus via the ovarian ligament.

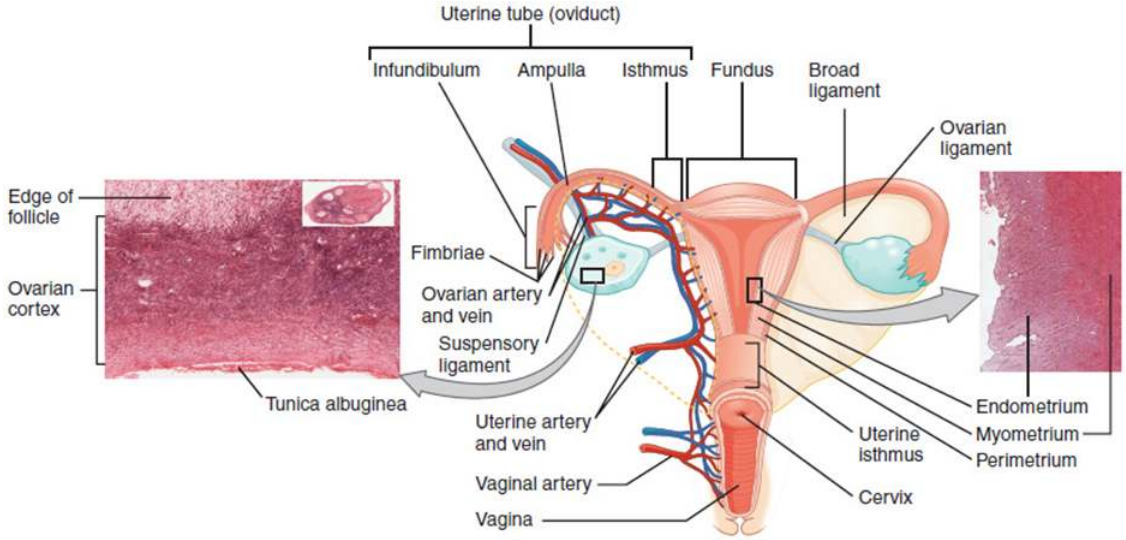


Figure **23.2.1**: **Female Reproductive System** The major organs of the female reproductive system are located inside the pelvic cavity. (CC-BY-4.0, OpenStax, Human Anatomy)

The ovary comprises an outer covering of cuboidal epithelium called the ovarian surface epithelium that is superficial to a dense connective tissue covering called the tunica albuginea. Beneath the tunica albuginea is the cortex, or outer portion, of the organ. The cortex is composed of a tissue framework called the ovarian stroma that forms the bulk of the adult ovary. Oocytes develop within the outer layer of this stroma, each surrounded by supporting cells. This grouping of an oocyte and its supporting cells is called a **follicle**. The growth and development of ovarian follicles will be described shortly. Beneath the cortex lies the inner ovarian medulla, the site of blood vessels, lymph vessels, and the nerves of the ovary. You will learn more about the overall anatomy of the female reproductive system at the end of this section.

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23.3: Uterine Tubes

The **uterine tubes** (also called fallopian tubes or oviducts) serve as the conduit of the oocyte from the ovary to the uterus (Figure **23.3.1**). Each of the two uterine tubes is close to, but not directly connected to, the ovary and divided into sections. The **isthmus** is the narrow medial end of each uterine tube that is connected to the uterus. The wide distal **infundibulum** flares out with slender, finger-like projections called **fimbriae**. The middle region of the tube, called the **ampulla**, is where fertilization often occurs. The uterine tubes also have three layers: an outer serosa, a middle smooth muscle layer, and an inner mucosal layer. In addition to its mucus-secreting cells, the inner mucosa contains ciliated cells that beat in the direction of the uterus, producing a current that will be critical to move the oocyte.

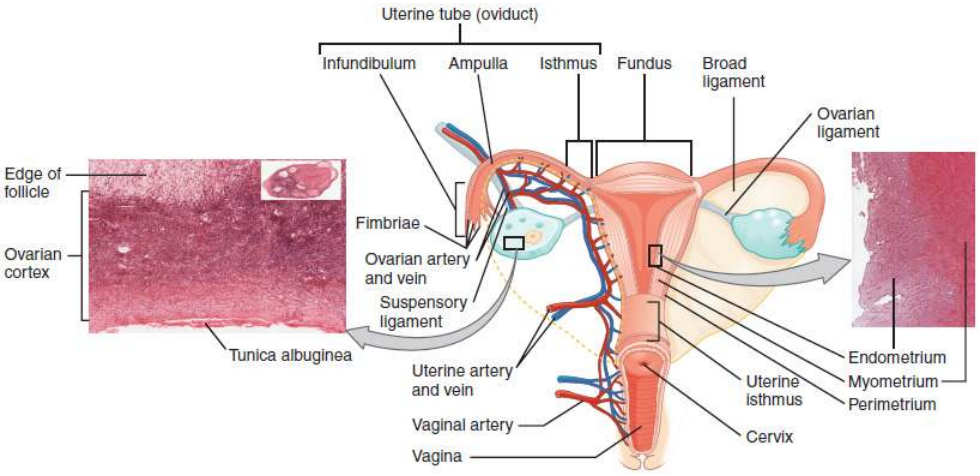


Figure **23.3.1**: **Ovaries, Uterine Tubes, and Uterus** This anterior view shows the relationship of the ovaries, uterine tubes (oviducts), and uterus. Sperm enter through the vagina, and fertilization of an ovulated oocyte usually occurs in the distal uterine tube. From left to right, LM × 400, LM × 20. (Micrographs provided by the Regents of University of Michigan Medical School © 2012) (CC-BY-4.0, OpenStax, Human Anatomy)

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23.4: Uterus and Cervix

The **uterus** is the muscular organ that nourishes and supports the growing embryo (see Figure **23.4.1**). Its average size is approximately 5 cm wide by 7 cm long (approximately 2 in by 3 in) when a female is not pregnant. It has three sections. The portion of the uterus superior to the opening of the uterine tubes is called the **fundus**. The middle section of the uterus is called the **body of uterus** (or corpus). The **cervix** is the narrow inferior portion of the uterus that projects into the vagina. The cervix produces mucus secretions that become thin and stringy under the influence of high systemic plasma estrogen concentrations, and these secretions can facilitate sperm movement through the reproductive tract.

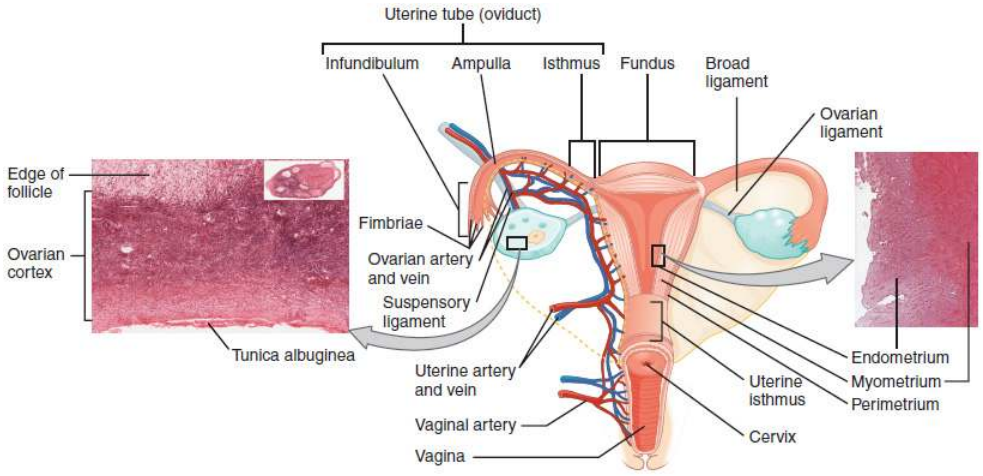


Figure **23.4.1**: **Ovaries, Uterine Tubes, and Uterus** This anterior view shows the relationship of the ovaries, uterine tubes (oviducts), and uterus. Sperm enter through the vagina, and fertilization of an ovulated oocyte usually occurs in the distal uterine tube. From left to right, LM × 400, LM × 20. (Micrographs provided by the Regents of University of Michigan Medical School © 2012) (CC-BY-4.0, OpenStax, Human Anatomy)

The Breasts

Whereas the breasts are located far from the other female reproductive organs, they are considered accessory organs of the female reproductive system. The function of the breasts is to supply milk to an infant in a process called lactation. The external features of the breast include a nipple surrounded by a pigmented **areola** (**Figure 23.4**), whose coloration may deepen during pregnancy. The areola is typically circular and can vary in size from 25 to 100 mm in diameter. The areolar region is characterized by small, raised areolar glands that secrete lubricating fluid during lactation to protect the nipple from chafing. When a baby nurses, or draws milk from the breast, the entire areolar region is taken into the mouth.

Breast milk is produced by the **mammary glands**, which are modified sweat glands. The milk itself exits the breast through the nipple via 15 to 20 **lactiferous ducts** that open on the surface of the nipple. These lactiferous ducts each extend to a **lactiferous sinus** that connects to a glandular lobe within the breast itself that contains groups of milk-secreting cells in clusters called **alveoli** (see **Figure 23.4**). The clusters can change in size depending on the amount of milk in the alveolar lumen. Once milk is made in the alveoli, stimulated myoepithelial cells that surround the alveoli contract to push the milk to the lactiferous sinuses. From here, the baby can draw milk through the lactiferous ducts by suckling. The lobes themselves are surrounded by fat tissue, which determines the size of the breast; breast size differs between individuals and does not affect the amount of milk produced. Supporting the breasts are multiple bands of connective tissue called **suspensory ligaments** that connect the breast tissue to the dermis of the overlying skin.

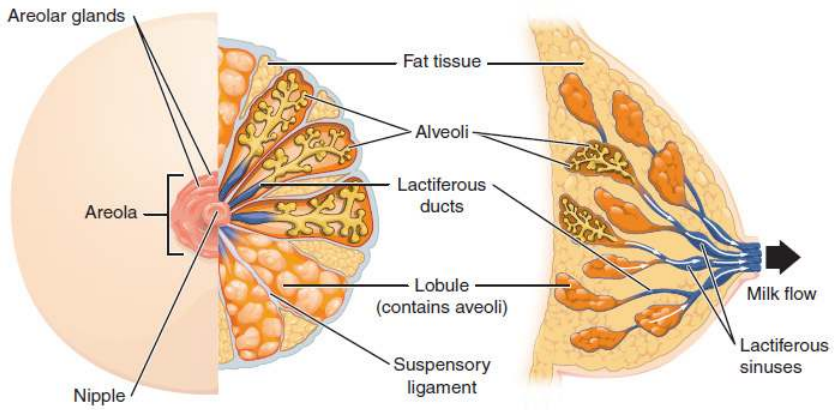


Figure **23.4.2**: **Anatomy of the Breast** During lactation, milk moves from the alveoli through the lactiferous ducts to the nipple. (CC-BY-4.0, OpenStax, Human Anatomy)

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23.5: Breasts

Whereas the breasts are located far from the other female reproductive organs, they are considered accessory organs of the female reproductive system. The function of the breasts is to supply milk to an infant in a process called lactation. The external features of the breast include a nipple surrounded by a pigmented **areola** (Figure **23.5.1**), whose coloration may deepen during pregnancy. The areola is typically circular and can vary in size from 25 to 100 mm in diameter. The areolar region is characterized by small, raised areolar glands that secrete lubricating fluid during lactation to protect the nipple from chafing. When a baby nurses, or draws milk from the breast, the entire areolar region is taken into the mouth.

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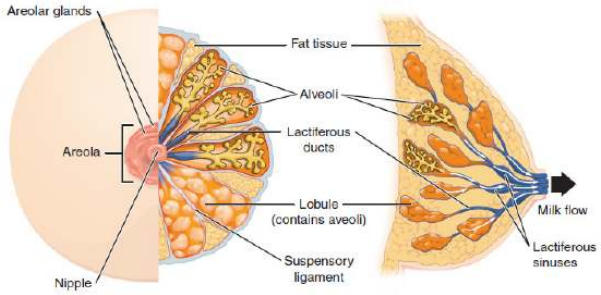
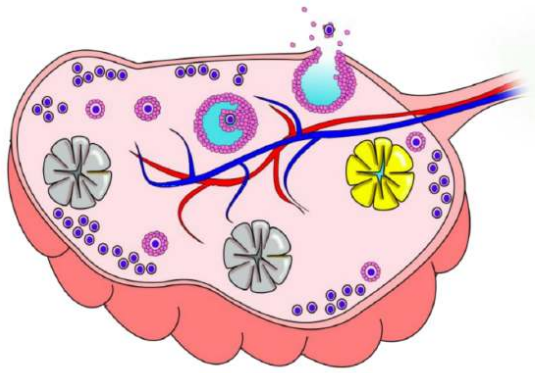


Figure **23.5.1**: Anatomy of the Breast During lactation, milk moves from the alveoli through the lactiferous ducts to the nipple. (CC-BY-4.0, OpenStax, Human Anatomy)

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23.6: Exercises

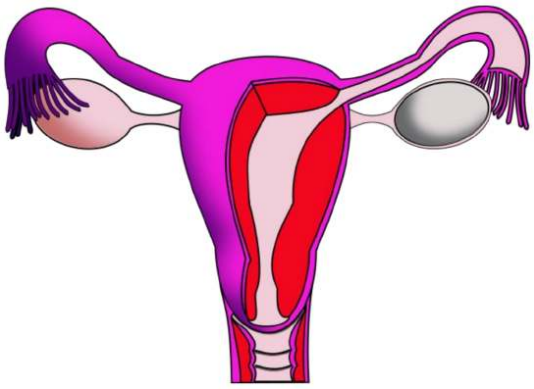
LAB 23 EXERCISES 23.6.1



Label the following:

1	Tunica albuginea	7	Secondary follicle
2	Cortex	8	Vesicular follicle
3	Medulla	9	Ovulated oocyte
4	Ovarian ligament	10	Corpus luteum
5	Primordial follicles	11	Corpus albicans
6	Primary follicle		

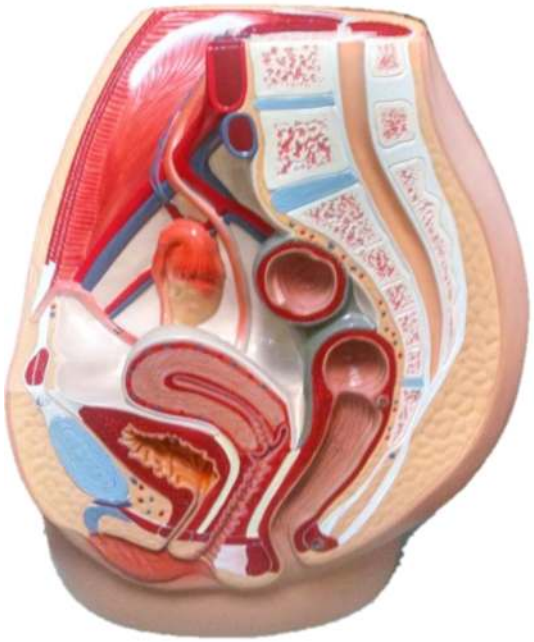
LAB 23 EXERCISES 23.6.2



Label the following:

1	Body	8	Ovary
2	Fundus	9	Ovarian ligament
3	Cervix	10	Endometrium
4	Fornix	11	Myometrium
5	Fallopian tube	12	Perimetrium
6	Ampulla	13	Internal os
7	Fimbriae	14	External os

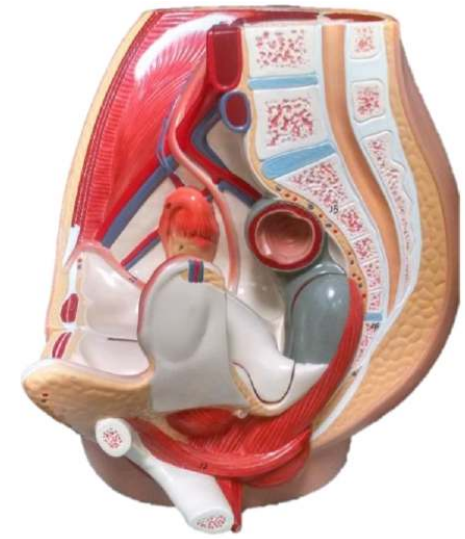
LAB 23 EXERCISES 23.6.3



Label the following:

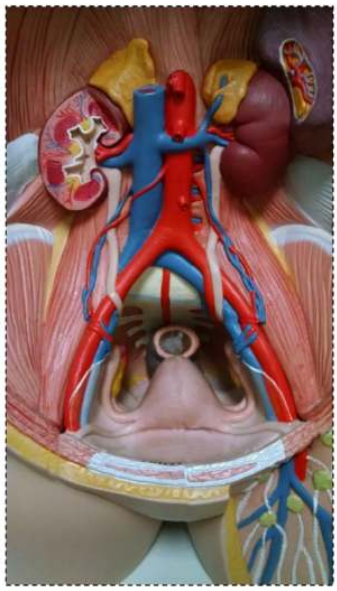
1	Fallopian tube	7	Clitoris
2	Ovary	8	Labia minora
3	Recto-uterine pouchi	9	Labia Majora
4	Rectum	10	Uterus
5	Urinary bladder	11	Vagina
6	Urethra	12	Pubis Symphysis

LAB 23 EXERCISES 23.6.4



Label the following:

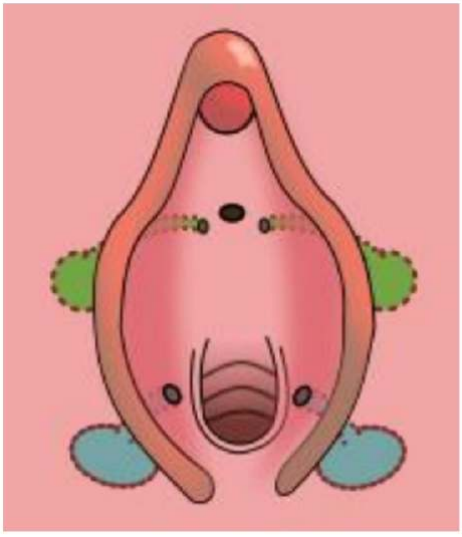
1	Urogenital diaphragm
2	Round ligament
3	Infundibulum (of the fallopian tube)



Label the following:

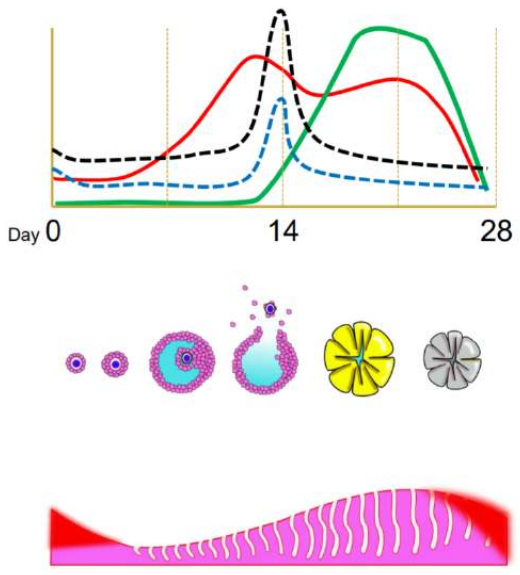
1	Uterus
2	Fallopian tube
3	Round ligamenti
4	Ureter

LAB 23 EXERCISES 23.6.5



Label the structures:

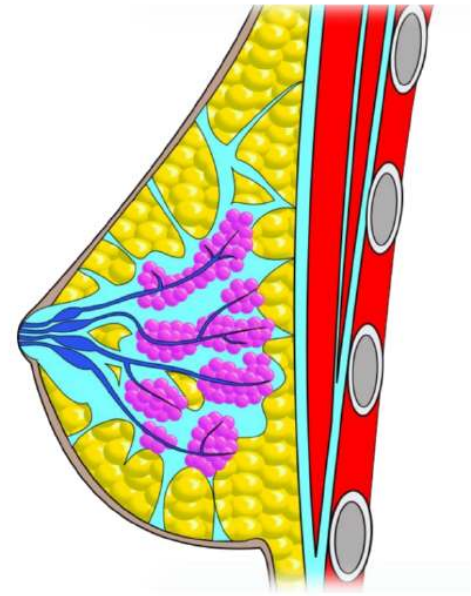
1	Glans Clitoris
2	Greater vestibular gland
3	Skene's (para-urethral) glands
4	Urethral orifice



Label the following:

1	FSH	6	Luteal phase
2	LH	7	Menstrual phase
3	Estrogen (E2)	8	Proliferative phase
4	Progesterone (P)	9	Secretory phase
5	Follicular phase	10	Ovulation

LAB 23 EXERCISES 23.6.6



Label the following:

1	Lactiferous ducts
2	Suspensory ligaments
3	Lactiferous sinus
4	Pectoralis minor
5	Pectoralis major
6	Intercostal muscles
7	Fascia
8	Fascia

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23.7: MODELS- Female Hemi-Pelvises, Torso, Breast and Ovary

- Fallopian Tubes (uterine tubes)
  - Ampulla
  - Fimbriae
  - Infundibulum
  - Isthmus
- Uterus
  - Fundus
  - Body
  - Cervix
  - Cervical os (internal & external)
  - Endometrium
  - Myometrium
  - Perimetrium
  - Round ligament
- Vagina
  - Rugae
  - Fornix
- Vulva
  - Mons pubis
  - Vestibule
  - Urethral orifice
  - Labia minora
  - Labia majora
- Clitoris
  - Glans clitoris
  - Clitoral hood
- Ovary (model)
  - Primordial * Primary * Secondary * Vesicular/Graafian follicles
  - Corpus luteum
  - Corpus albicans
  - Ovarian ligament
  - Suspensory ligament (of the ovary)
- Recto-vaginal (recto-uterine) pouch
- Breast (Mammary Glands)
  - Areola
  - Nipple
  - Lobe
  - Lactiferous duct
  - Lactiferous sinus
  - Adipose tissue
  - Pectoralis major muscle
  - Suspensory (Cooper's) ligaments

Histology:

- Ovary
  - Follicles: graafian (secretory) * secondary * primary.

- corpus luteum
- corpus albicans
- oocyte
- follicular cells
- antrum

- Uterus
  - Endometrium & myometrium
- Fallopian tubes
  - Mucosa * Muscularis * Lumen

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