Human Anatomy and Physiology Laboratory Manual: Understanding How Structure Determines Function

HUMAN ANATOMY AND PHYSIOLOGY LABORATORY MANUAL: UNDERSTANDING HOW STRUCTURE DETERMINES FUNCTION

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LAND ACKNOWLEDGEMENT

As part of ROTEL Grant's mission to support the creation, management, and dissemination of culturally-relevant textbooks, we must acknowledge Indigenous Peoples as the traditional stewards of the land, and the enduring relationship that exists between them and their traditional territories. We acknowledge that the boundaries that created Massachusetts were arbitrary and a product of the settlers. We honor the land on which the Higher Education Institutions of the Commonwealth of Massachusetts are sited as the traditional territory of tribal nations. We acknowledge the painful history of genocide and forced removal from their territory, and other atrocities connected with colonization. We honor and respect the many diverse indigenous people connected to this land on which we gather, and our acknowledgement is one action we can take to correct the stories and practices that erase Indigenous People's history and culture.

Identified Tribes and/or Nations of Massachusetts

Historical Nations

- Mahican
- Mashpee
- Massachuset
- Nauset
- Nipmuc
- Pennacook
- Pocomtuc
- Stockbridge
- Wampanoag

Present-Day Nations and Tribes

- Mashpee Wampanoag Tribe
- Wampanoag Tribe of Gay Head Aquinnah
- Herring Pond Wampanoag Tribe
- Assawompsett-Nemasket Band of Wampanoags
- Pocasset Wampanoag of the Pokanoket Nation
- Pacasset Wampanoag Tribe
- Seaconke Wampanoag Tribe
- Chappaquiddick Tribe of the Wampanoag Indian Nation

- Nipmuc Nation (Bands include the Hassanamisco, Natick)
- Nipmuck Tribal Council of Chaubunagungamaug
- Massachusett Tribe at Ponkapoag

At the time of publication, the links above were all active.

Suggested Readings

Massachusetts Center for Native American Awareness

A guide to Indigenous land acknowledgment

'We are all on Native Land: A conversation about Land Acknowledgements' (YouTube video)

Native-Land.ca | Our home on native land (mapping of native lands)

Beyond territorial acknowledgments – âpihtawikosisân

Your Territorial Acknowledgment Is Not Enough

This land acknowledgement was based on the land acknowledgement of the Digital Commonwealth.

THE HUMAN BODY, ANATOMICAL TERMINOLOGY, PLANES AND SECTIONS, BODY ORGANIZATION AND ORGAN SYSTEMS

Objectives

1. Introduce students to the study of the human body.
2. Define and illustrate the anatomical position.
3. Define directional terms and apply directional terms to descriptions of the human body.
4. Define and describe anatomical planes by section.
5. Locate and describe the divisions of major human and the serous membrane covering them.
6. Identify the organ systems of the human body, their functions, components, and interactions.

Levels of Organization

The human body can be studied from a number of perspectives, mainly, gross anatomy and microscopic anatomy. In this section, we will focus on gross anatomy, but we need to consider the levels of organization of the human body, starting with chemical, organelle, cellular, tissue, organ, organ system, and organisms.

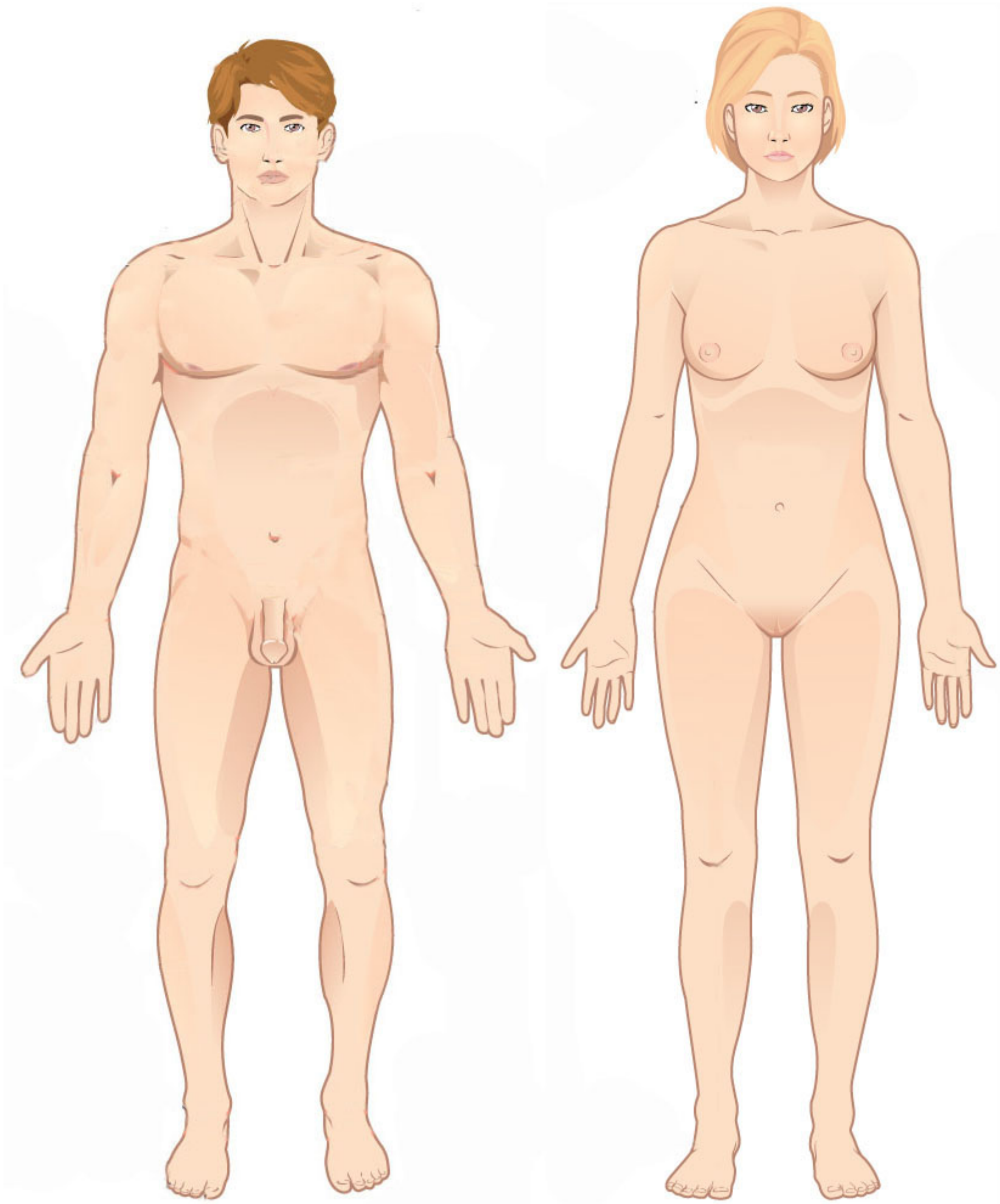

Figure 1: The Anatomical Position

Anatomical Position

The anatomical position allows health care providers to communicate consistently giving the proper orientation when dealing with patients.

The anatomical position refers to upright, facing forward, arms and legs straight, palms facing forward, feet flat on the ground, and eyes open.

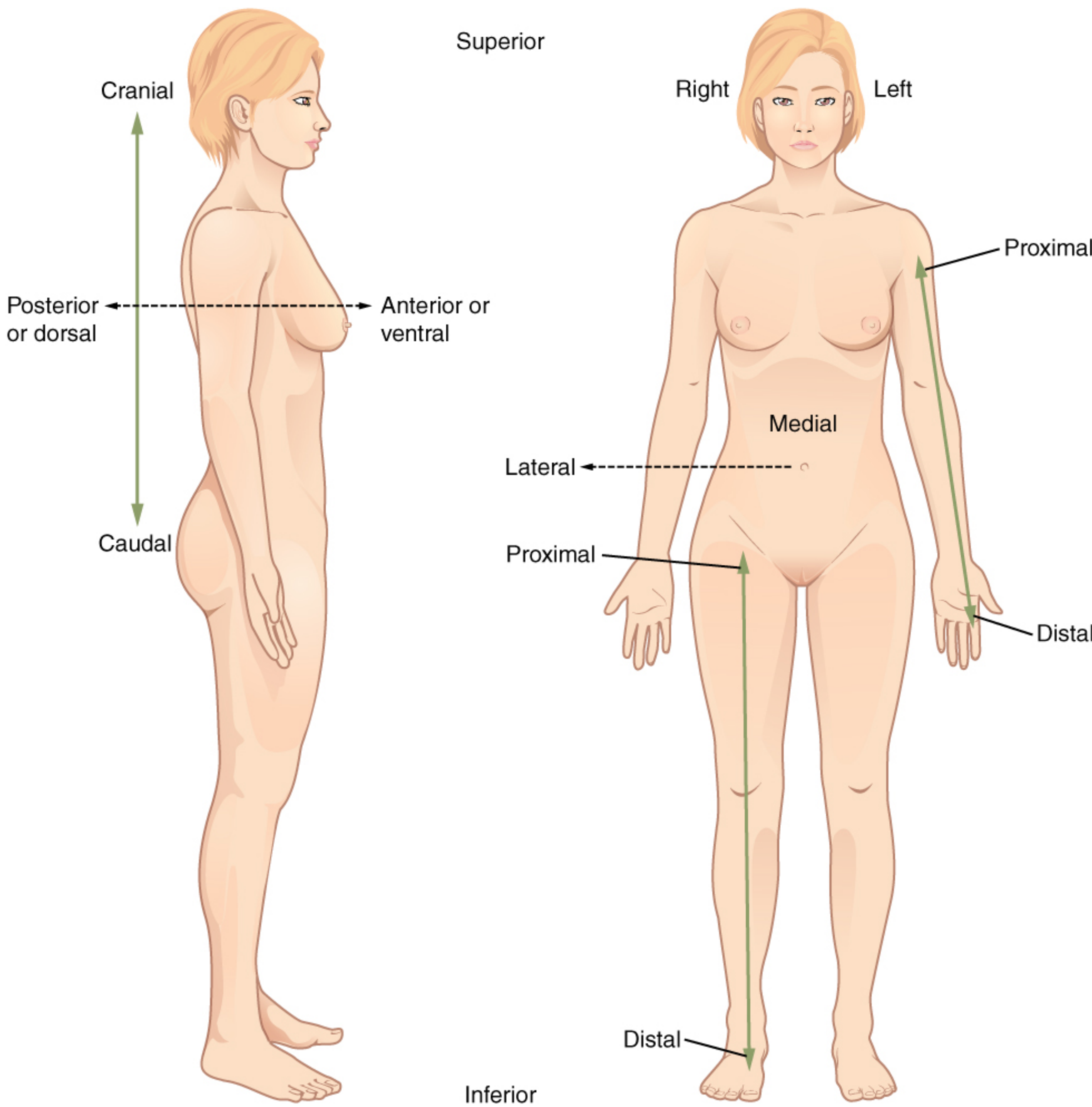

Figure 2: Directional Terms

With the body in anatomical positions, there are specific terms to describe parts of the body with respect to each other.

Table No. 1 – Directional terms

Directional Terms	Location	Examples
Superior	Above	The nose if superior to the chin
Inferior	Below	The stomach is inferior to the pelvis
Medial	Toward the midline	The sternum is medial to the shoulders
Lateral	Toward the side	The ears are lateral to the nose
Superficial	Toward the surface	The skin is superficial to the heart
Deep	Toward the core	The heart is deep to the ribs
Ventral	To the front	The toes are ventral or anterior to the heel
Dorsal	To the back	The spine is dorsal or posterior to the sternum
Proximal	For extremities, near the trunk	The elbow is proximal to the wrist
Distal	For extremities, away from the trunk	The toes are distal to the knee

Planes of sectioning

Planes of sectioning are cuts that divide the body into sections.

Sections

Horizontal or transverse plane: separate the body into superior and inferior parts.

Frontal or coronal: separate the body into anterior-posterior

Sagittal: separate the body into right and left portions

Midsagittal: separate the body into equal right and left portions

Parasagittal: separate the body into unequal right and left portions.

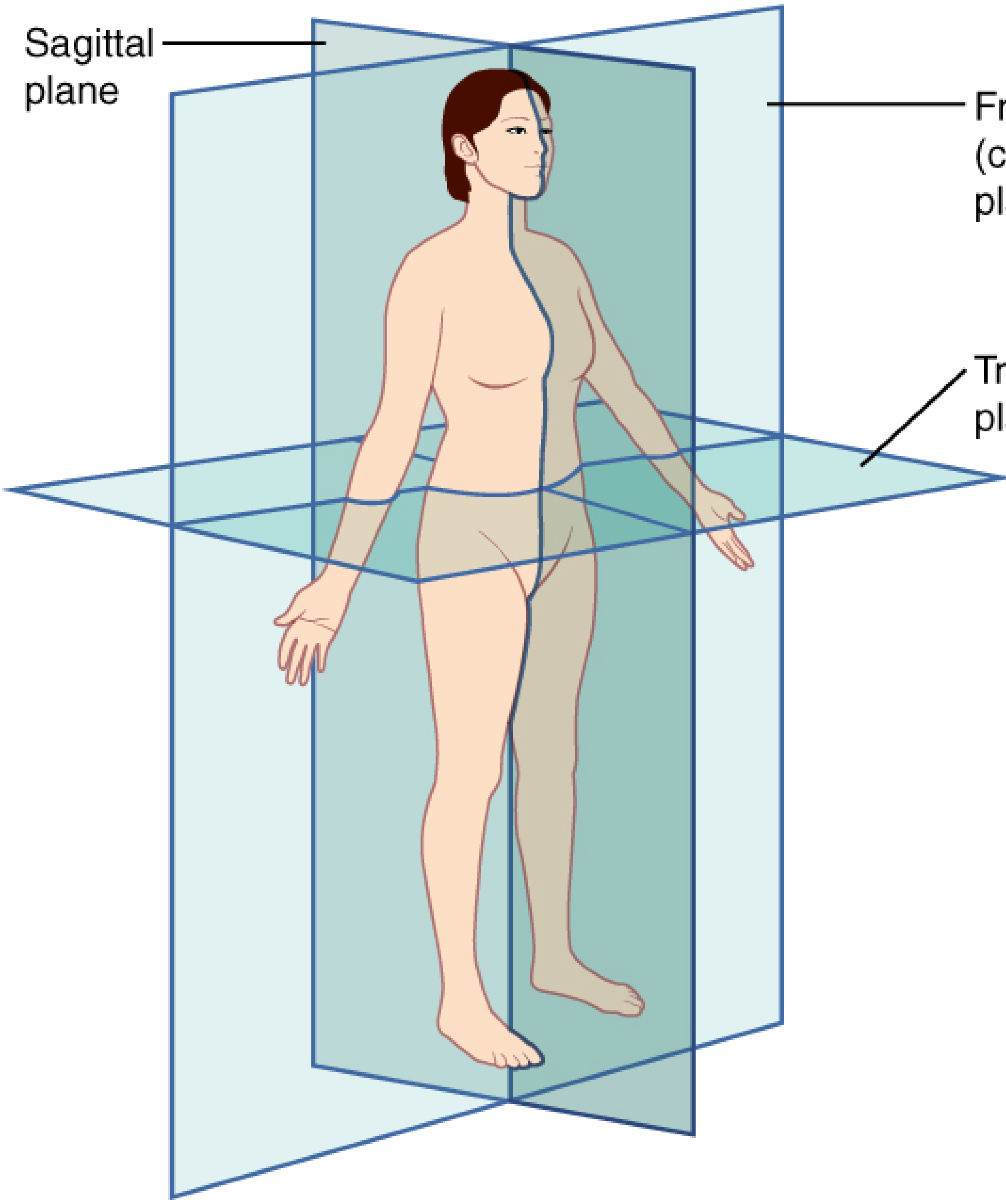

Figure 3: Planes of the Body

Sectional Planes of the Brain

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https://rotel.pressbooks.pub/anatomyphysiology/?p=511#h5p-5

Body Cavities & Serous Membranes

A cavity is an enclosed space inside the body. The human body is divided into two major cavities; ventral (anterior) and dorsal (posterior) and each cavity is subdivided into smaller cavities. They are fluid-filled and contain specific organs. Several of the fluid-filled cavities are formed by thin sheets of tissue, named serous membranes, the cells that form these membranes produce a watery fluid that resembles the serum, that fluid is called serous fluid that lubricates and protects the organs inside those cavities. The serous membranes are composed of two layers, parietal (attached to the body wall) and visceral (attached to specific organs).

The posterior cavity is divided into two smaller cavities; Cranial and Vertebral cavities.

- The Cranial cavity is the area encased by the skull, contains the brain and it is filled with cerebrospinal fluid.
- The vertebral cavity is the area encased by the vertebral column (stacked vertebrae), contains the spinal cord and it is filled with cerebrospinal fluid.

The anterior cavity has two main divisions; the thoracic and abdominopelvic cavities, they are separated by a muscle, the diaphragm. The thoracic cavity is located superior to the diaphragm, it is subdivided into the pleural cavities and the mediastinum.

- The pleural cavities, each pleural cavity surrounds on of the lungs. They are located between two layers of serous membrane, the pleural membrane. These layers are called the parietal pleura (attached to the body wall and the diaphragm) and the visceral pleura (attached to the lungs), between the two there is a thin layer of pleural fluid.

The Abdominopelvic cavity is located inferior to the diaphragm. There are three sub-cavities:

- Abdominal cavity – houses many organs; liver, gallbladder, small intestine, stomach, pancreas, kidneys, adrenal glands, spleen and a portion of the large intestine
- Pelvic cavity – contains sex organs, urinary bladder, rectum and part of the colon.

Peritoneal cavity – formed by serous membranes called the peritoneum. The peritoneum is formed by two layers, the outer layer, the parietal peritoneum that is attached to the body wall and the visceral peritoneum that is attached to many organs of the abdominal and pelvic cavities. Only the organs that are within the peritoneal cavity are called intraperitoneal, the rest are referred as retroperitoneal.

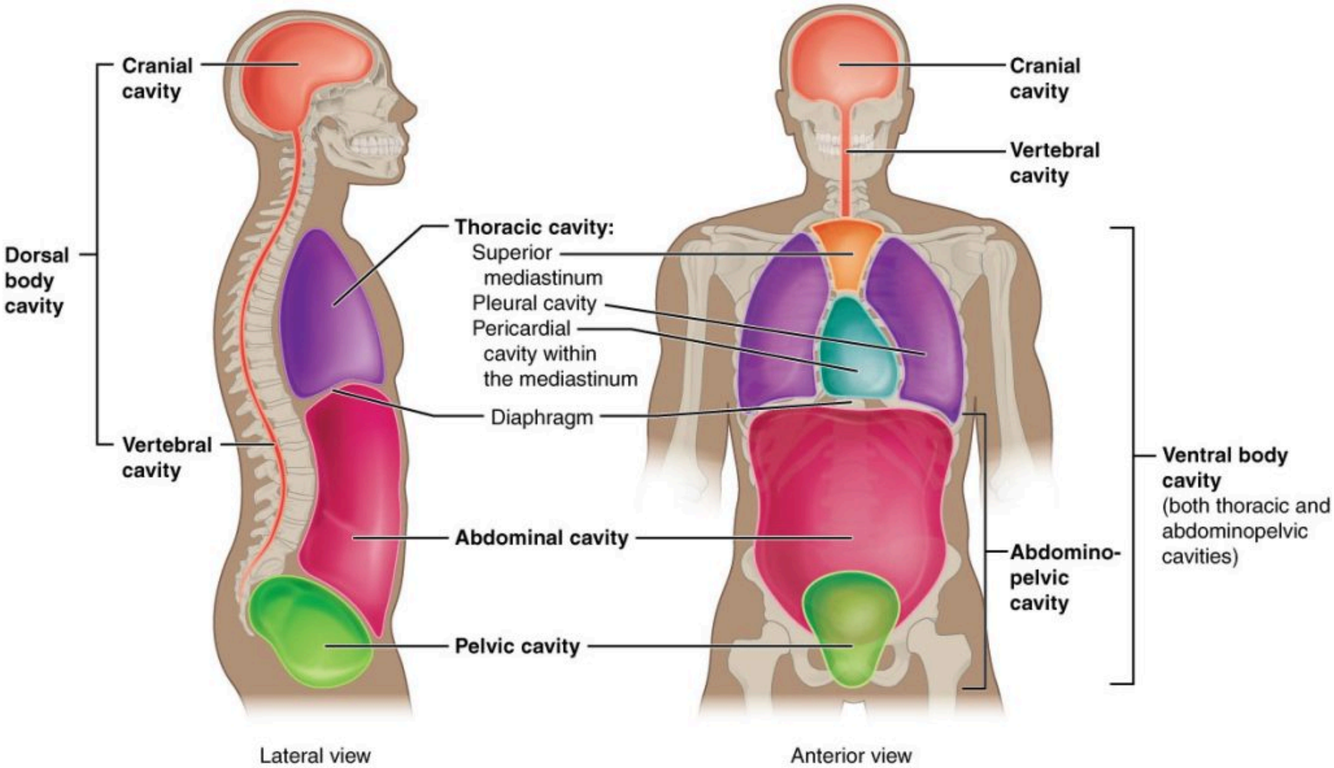

Figure 4: Body Cavities

Body Cavities and Membranes (Dorsal, Ventral)- Anatomy and Physiology

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Body Cavities – Drawn & Defined

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Body Cavities and serous membranes

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Regions of the Body

Anatomical regions refer to terms used for specific parts of the body.

These terms include:

Cephalic – head

Cranial

Facial

Frontal – forehead

Orbital – eye

Nasal – nose

Buccal – cheek

Oral – mouth

Mental – chin

Cervical/Nuchal – neck

Trunk

Thoracic – chest

Pectoral

Sternal

Clavicular

Acromial – shoulder

Abdominal – belly

Inguinal – groin

Genital – pubic

Coxal – hip

Vertebral – Vertebral column

Lumbar – lower back

Sacral

Gluteal (buttocks)

Upper extremity

Axillary – armpit

Brachial – arm

Cubital – elbow

Antebrachial – forearm

Carpal – wrist

Manual – hand

Digital – finger

Lower extremity

Femoral – thigh

Popliteal – back of knee

Patellar – kneecap

Crural – leg

Calcaneal – heel

Tarsal – ankle

Pedal – foot

Digital – toe

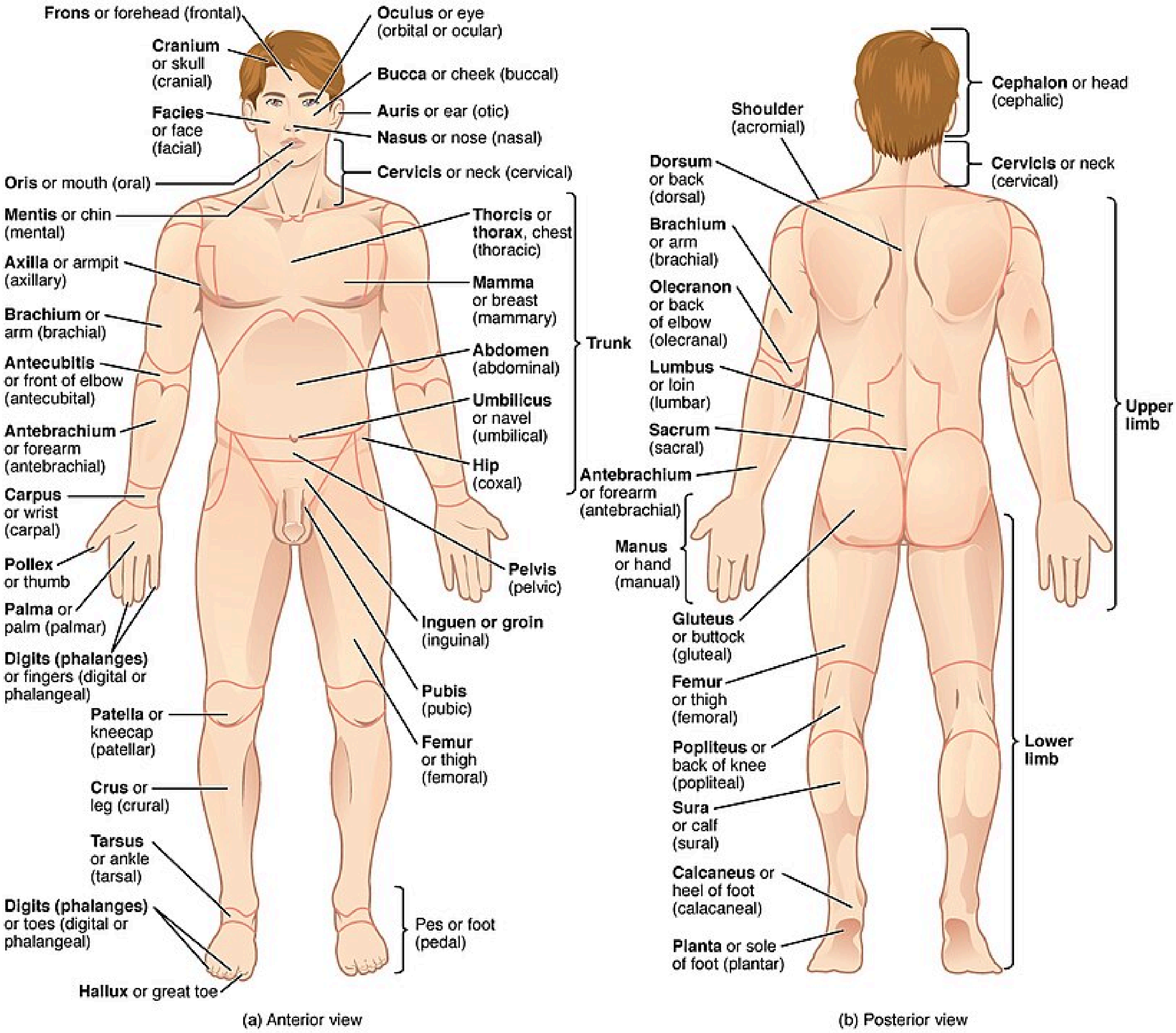

Figure 5: Anatomical Regions of the Human Body

Abdominal Regions

The abdomen can be further divided into four quadrants or nine regions. These are very important in clinical practice.

Four quadrants

Right-upper quadrant
Right-lower quadrant
Left-upper quadrant

Left-lower quadrant

Nine Regions

Right hypochondriac
Right lumbar
Right iliac
Epigastric
Umbilical
Hypogastric
Left hypochondriac
Left lumbar
Left iliac

These regions are shown in the figure below.

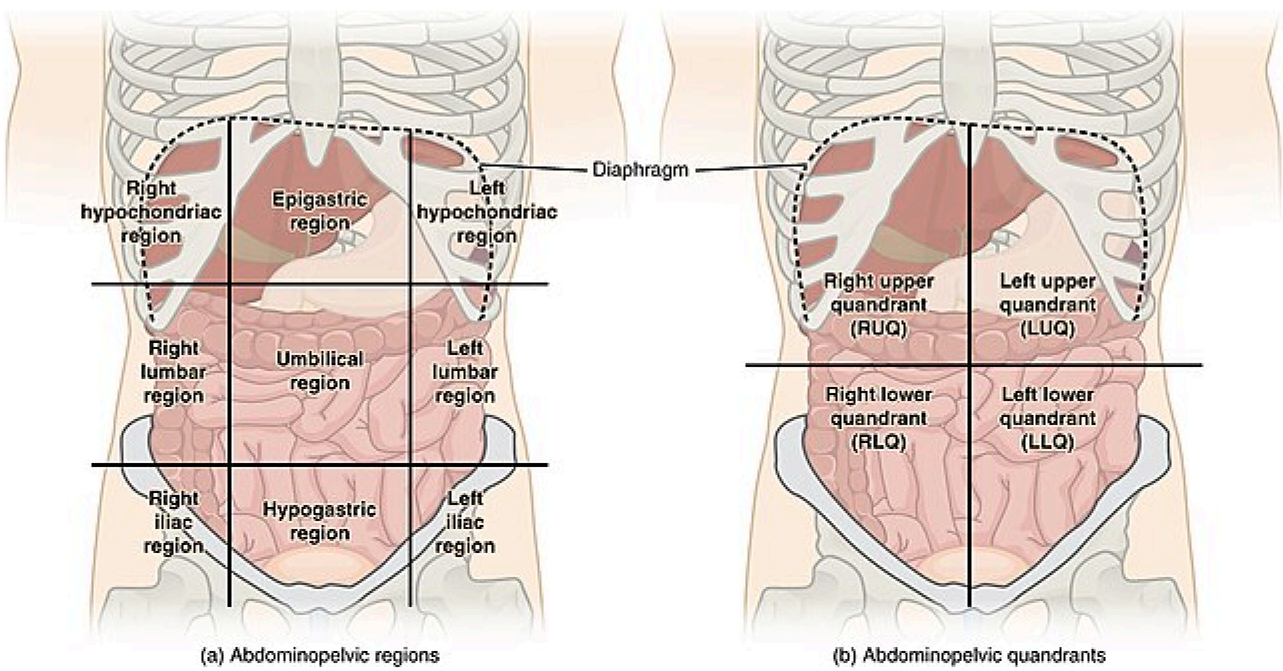

Figure 6: Abdominal Regions and Localized Pain

Organs in the Abdominal Regions

Subdivisions of the Abdomen

Right Hypochondriac Region

Digestive:

Liver

Gall Bladder

Small Intestine

Ascending Colon

Transverse Colon

Endocrine:

Right Kidney

Excretory:

Right Kidney

Lymphatic:

NONE

Reproductive:

NONE

Epigastric Region

Digestive:

Esophagus

Stomach

Liver

Pancreas

Small Intestine

Transverse Colon

Endocrine:

Right & Left Adrenal Glands

Pancreas

Right & Left Kidneys

Excretory:

Right & Left Kidneys

Right & Left Ureters

Lymphatic:

Spleen

Reproductive:

NONE

Left Hypochondriac Region

Digestive:

Stomach

Liver (tip)

Pancreas (tail)

Small Intestine

Transverse Colon

Descending Colon

Endocrine:

Pancreas

Left Kidney

Excretory:

Left Kidney

Lymphatic:

Spleen

Reproductive:

NONE

Right Lumbar Region

Digestive:

Liver (tip)

Gall Bladder

Small Intestine

Ascending Colon

Endocrine:

Right Kidney

Excretory:

Right Kidney

Lymphatic:

NONE

Reproductive:

NONE

Right Iliac Region

Digestive:

Small Intestine

Appendix

Cecum & Ascending Colon

Endocrine:

Right Ovary (Females)

Excretory:

NONE

Lymphatic:

NONE

Reproductive:

Female

Right Ovary

Right Fallopian Tube

Male

NONE

Umbilical Region

Digestive:

Stomach

Pancreas

Small Intestine

Transverse Colon

Endocrine:

Pancreas

Right & Left Kidneys

Excretory:

Right & Left Kidneys

Right & Left Ureters

Lymphatic:

Cisterna chyli

Reproductive:

NONE

Hypogastric Region

Digestive:

Small Intestine

Sigmoid Colon

Rectum

Endocrine:

Right & Left Ovaries (Females)

Excretory:

Right & Left Ureters

Urinary Bladder

Lymphatic:

NONE

Reproductive:

Female

Uterus

Right & Left Ovaries

Right & Left Fallopian Tubes

Male

Vas Deferens

Left Lumbar Region

Digestive:

Small Intestine

Descending Colon

Endocrine:

Left Kidney (tip)

Excretory:

Left Kidney (tip)

Lymphatic:

NONE

Reproductive:

NONE

Left Iliac Region

Digestive:

Small Intestine

Descending Colon

Sigmoid Colon

Endocrine:

Left Ovary (Females)

Excretory:

NONE

Lymphatic:

NONE

Reproductive:

Female

Left Ovary

Left Fallopian Tube

Male

NONE

Organ Systems

The human body consists of several organ systems that work together to maintain homeostasis. The study of organ systems is also referred to as Systemic Anatomy.

Even though we will study the 10 major organ systems of the body separately, there is no real separation; they in fact work all together via close connections, interactions, and chemical signals.

In this lab, we will introduce the organ systems and its components:

- The integumentary system – provides a protective covering to the body
- The muscular system – provide movement to the body
- The skeletal system – provides framework for movement and protection of the organs of the body
- The nervous system – allows us to interact and interpret the environment (inside and outside)
- The endocrine system – produce hormones
- The cardiovascular system (circulatory and lymphatic system)
- Circulatory system – to transport substances in the body
- Lymphatic system – cleanses and returns tissue fluid to the circulatory system
- The respiratory system – exchange of oxygen for carbon dioxide
- The digestive system –to provide nutrition (fuel) to the tissues of the body
- The urinary/excretory system – discard body waste products
- The reproductive system – responsible for maintenance of species

The Integumentary System

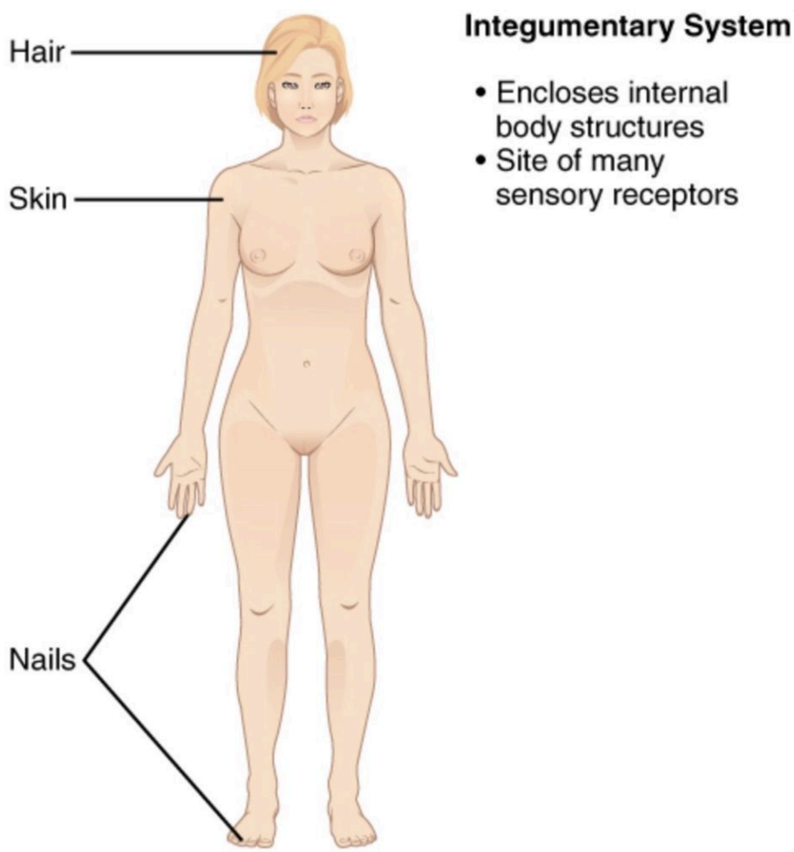

Figure 7: Integumentary System

The **integumentary system** consists of the covering of the body (the skin), including hair and nails as well as other functionally important structures such as the sweat glands and sebaceous glands. The skin is the largest organ we have, it forms a boundary between our delicate inside and the harsh outside environment. It provides containment, structure, and protection for other organs, but it also serves as a major sensory interface with the outside world.

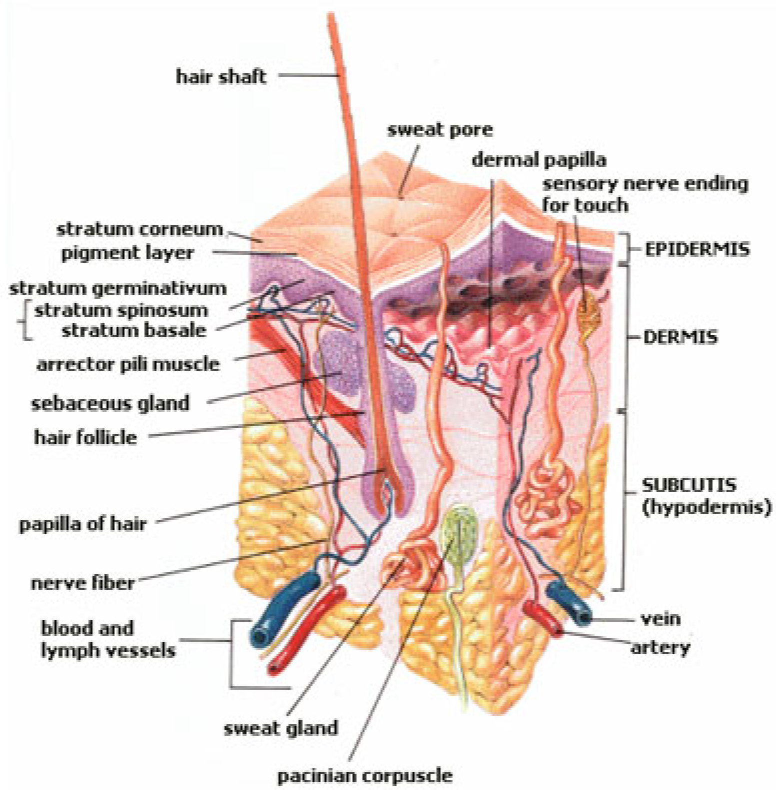

Figure 8: Skin

The Musculoskeletal System

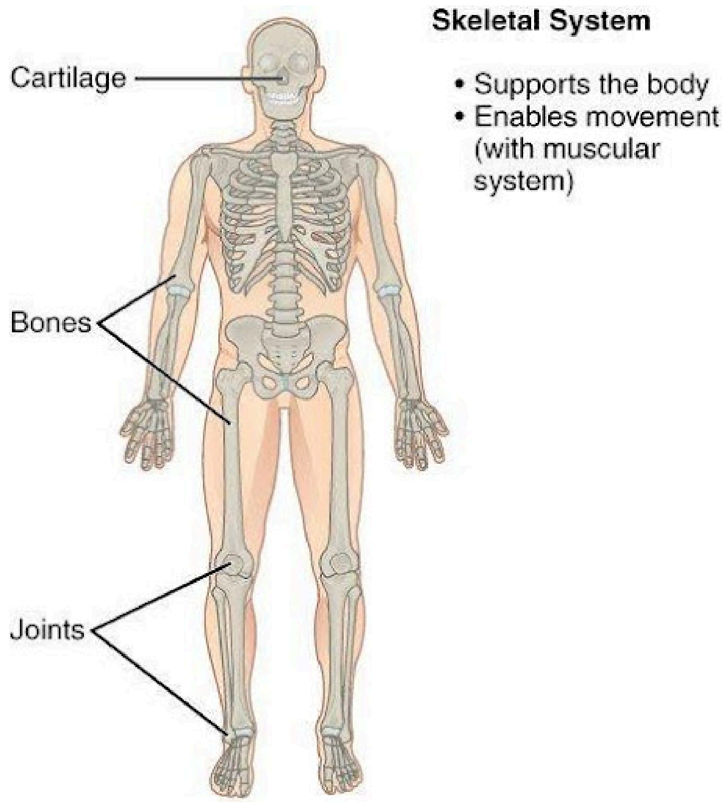

Figure 9: Skeletal System

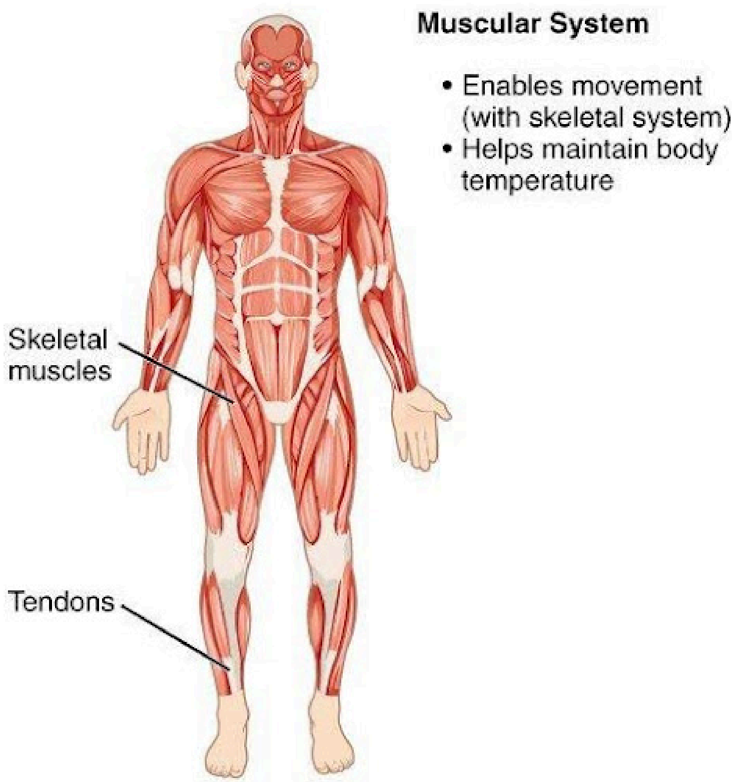

Figure 10: Muscular System

The **musculoskeletal system** consists of the human skeleton (which includes bones, ligaments, tendons, and cartilage) and attached muscles. It gives the body basic structure, protection to important organs, and the ability for movement. In addition to their structural role, the larger bones in the body contain bone marrow, the site of production of blood cells. Also, all bones are major storage sites for calcium and phosphate. This system can be split up into the muscular system, the skeletal system and joints and articulations.

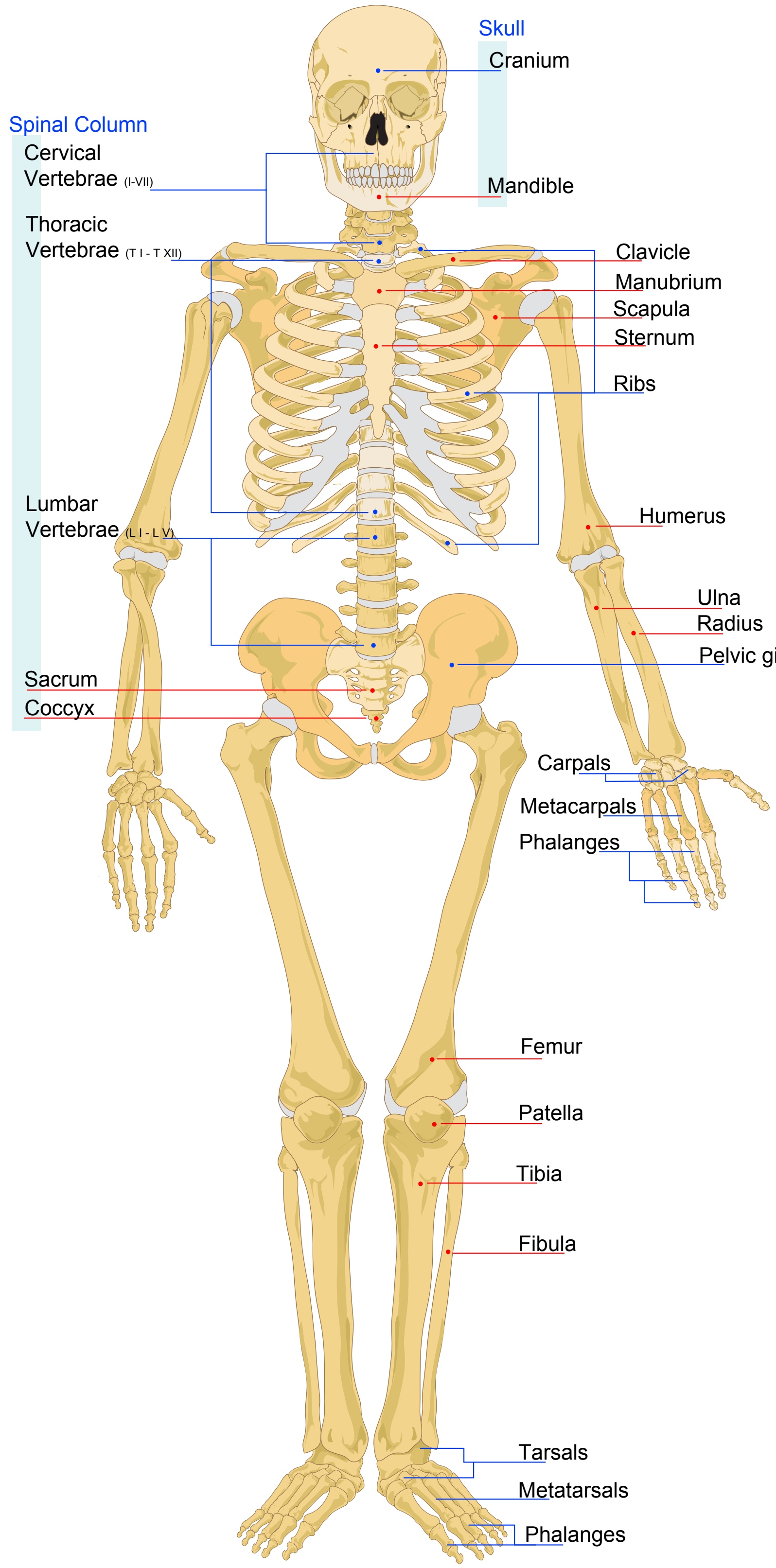

Figure 11: Human Skeleton

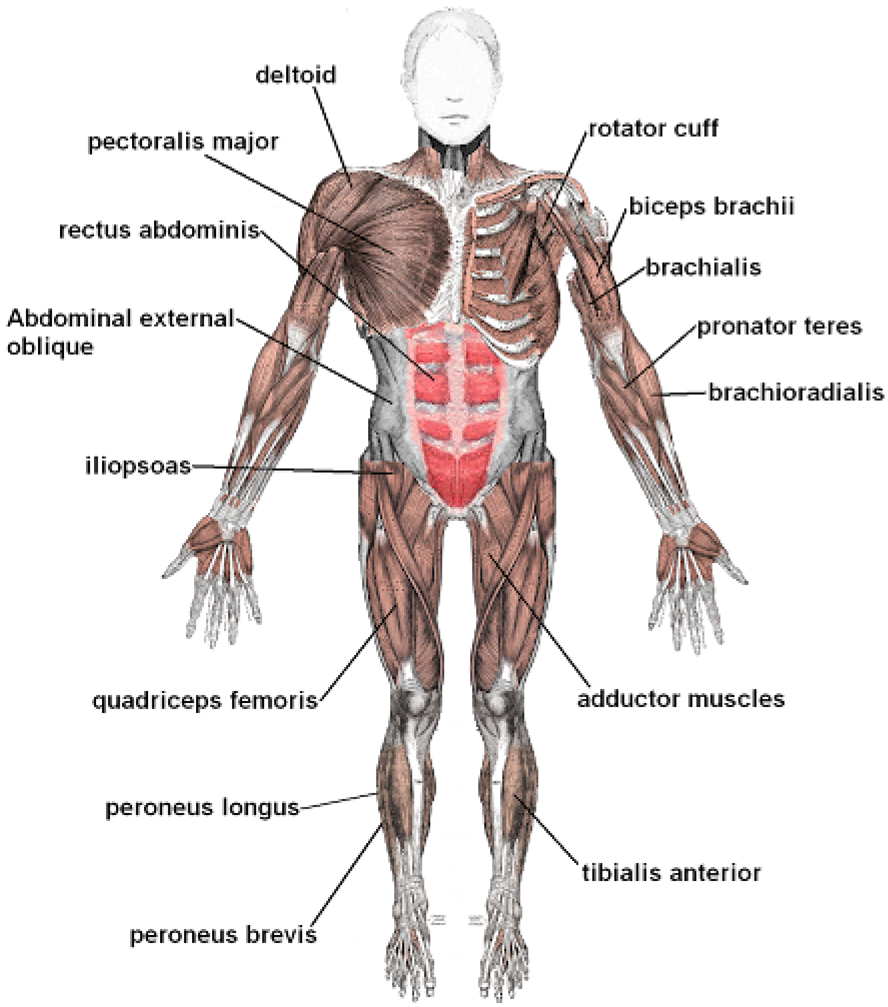

Figure 12: Muscular System

Video – Joints

Ankle joint

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Elbow joint

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Video – Muscles

Gluteal Muscles

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Erector spinae

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The Nervous System

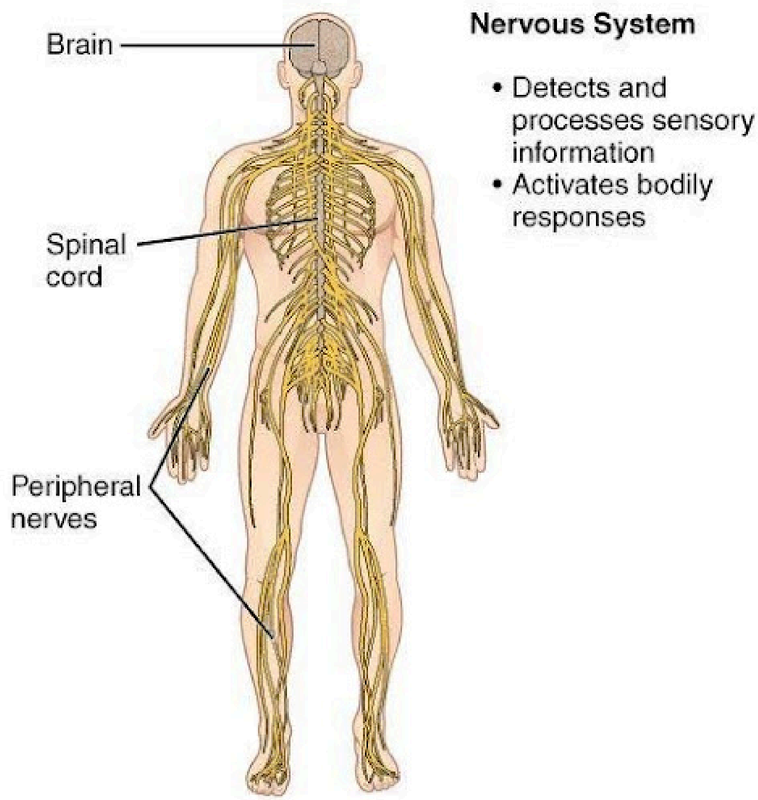


Figure 13: Nervous System

The **nervous system** consists of the central nervous system (CNS; brain and spinal cord) and the peripheral nervous system (PNS; consist of nerves and ganglia outside the CNS. Includes cranial and peripheral nerves, except cranial nerve II). The brain is the control center of the body. It is the organ of thought, emotion, memory, and sensory processing. It allows for communication and controls of various organ systems in the body. The brain is basically divided in three regions; forebrain, midbrain and hindbrain. The nervous system also includes our special senses; vision, hearing, taste, smell and touch. The eyes, ears, tongue, and nose gather information about the body's environment.

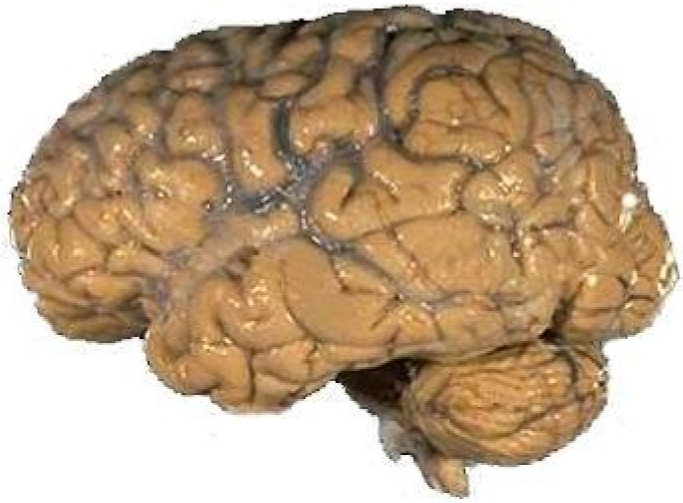
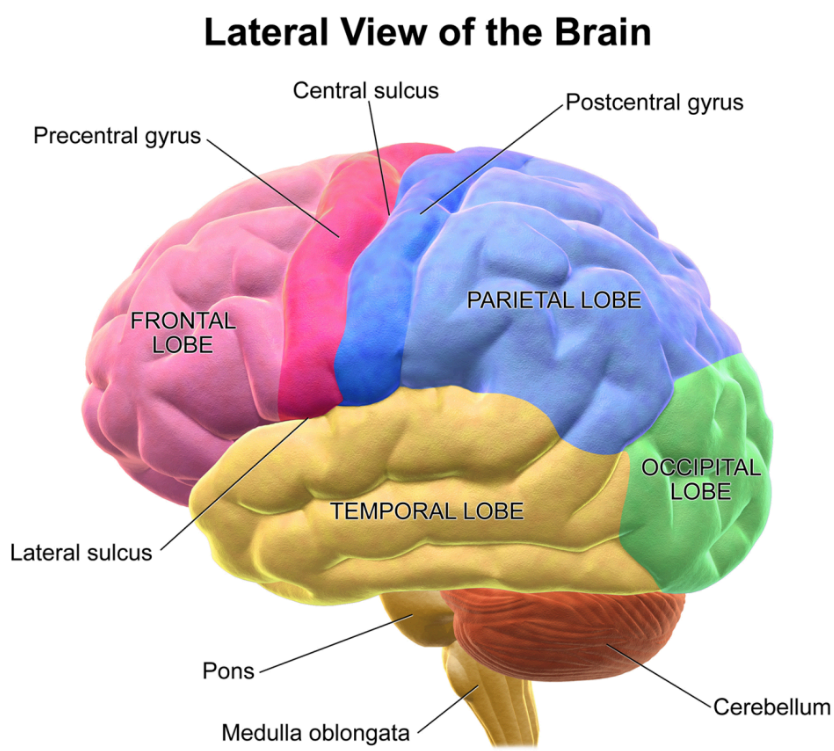


Figure 14: Lateral View of the Brain



Videos

Hypoglossal nerve

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Visual Pathways

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Anatomy of the brain – dissectible model

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The Endocrine System

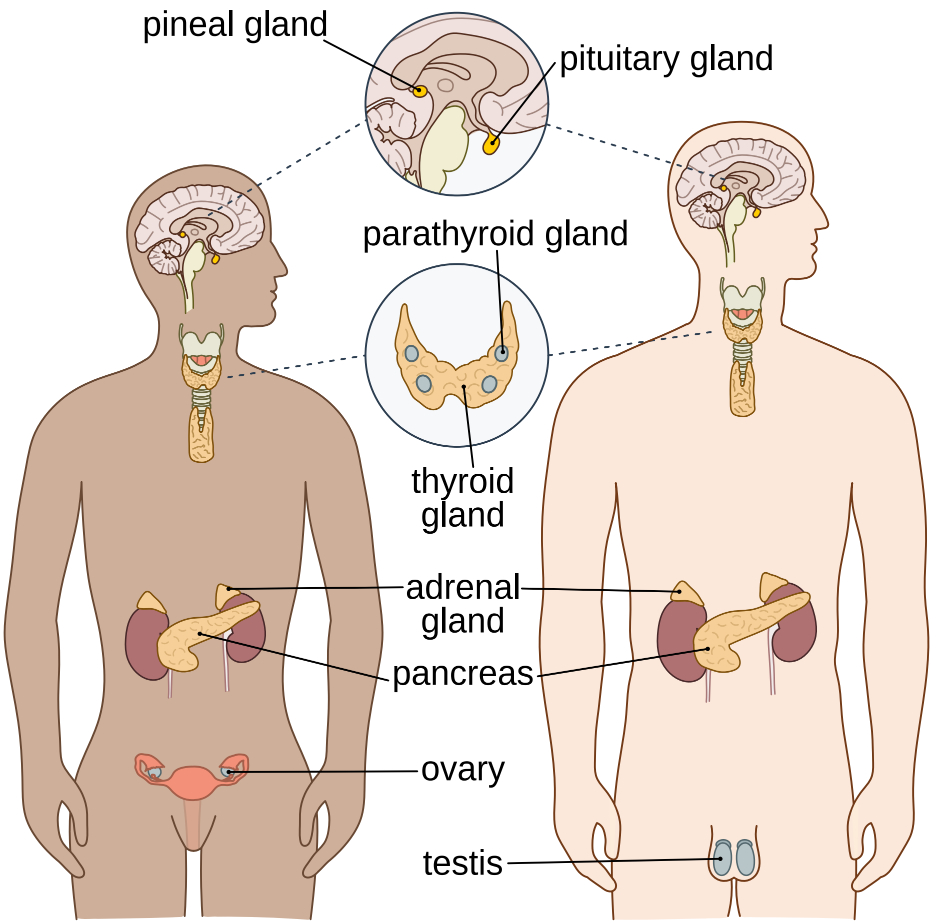

Figure 15: Endocrine System

The **endocrine system** consists of the principal endocrine glands: the pituitary (anterior and posterior), thyroid, parathyroid, pancreas, adrenals, and gonads Ovaries and testes), but nearly all organs and tissues produce specific endocrine hormones as well. The endocrine hormones serve as signals from one body system to another regarding an enormous array of conditions and resulting in variety of changes of function. There is also the exocrine system.

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The Endocrine System

Cardiovascular System

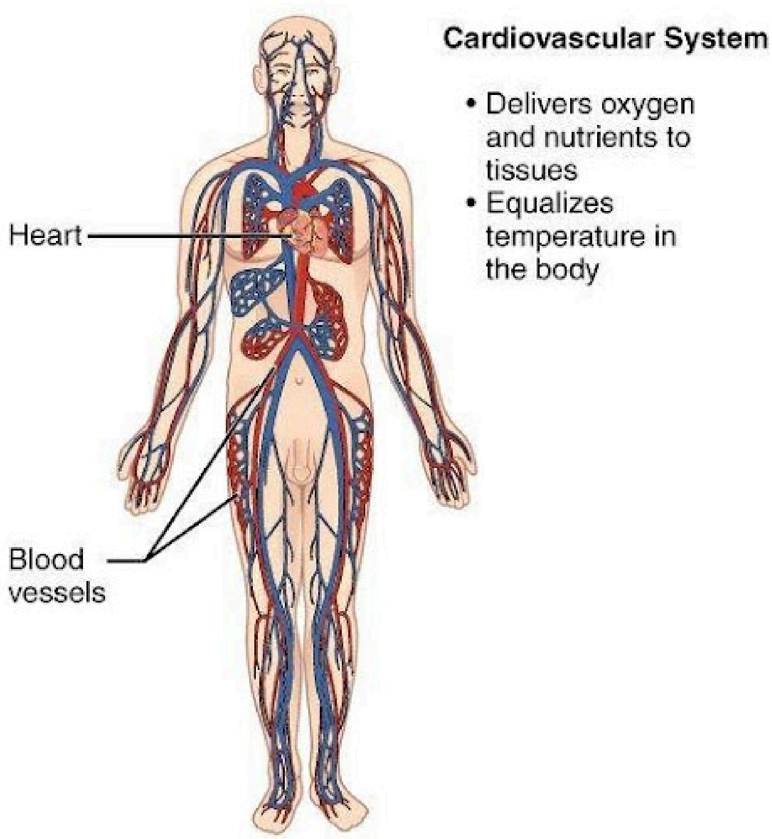

Figure 17: Cardiovascular System

The **cardiovascular system** delivers oxygen and nutrients to tissues and equalizes temperature in the body.

Video link – Cardiovascular anatomy introduction

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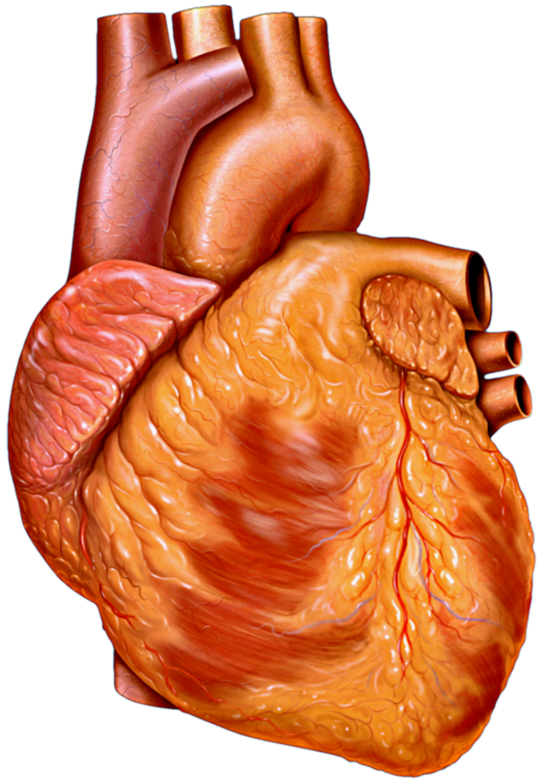

Figure 18: Heart

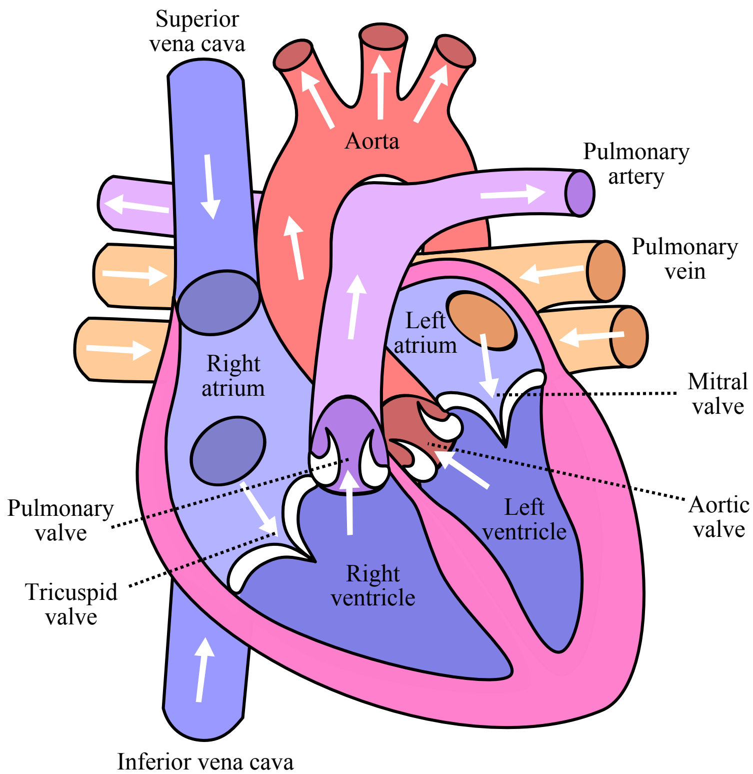

Figure 19: Coronal section of the Heart

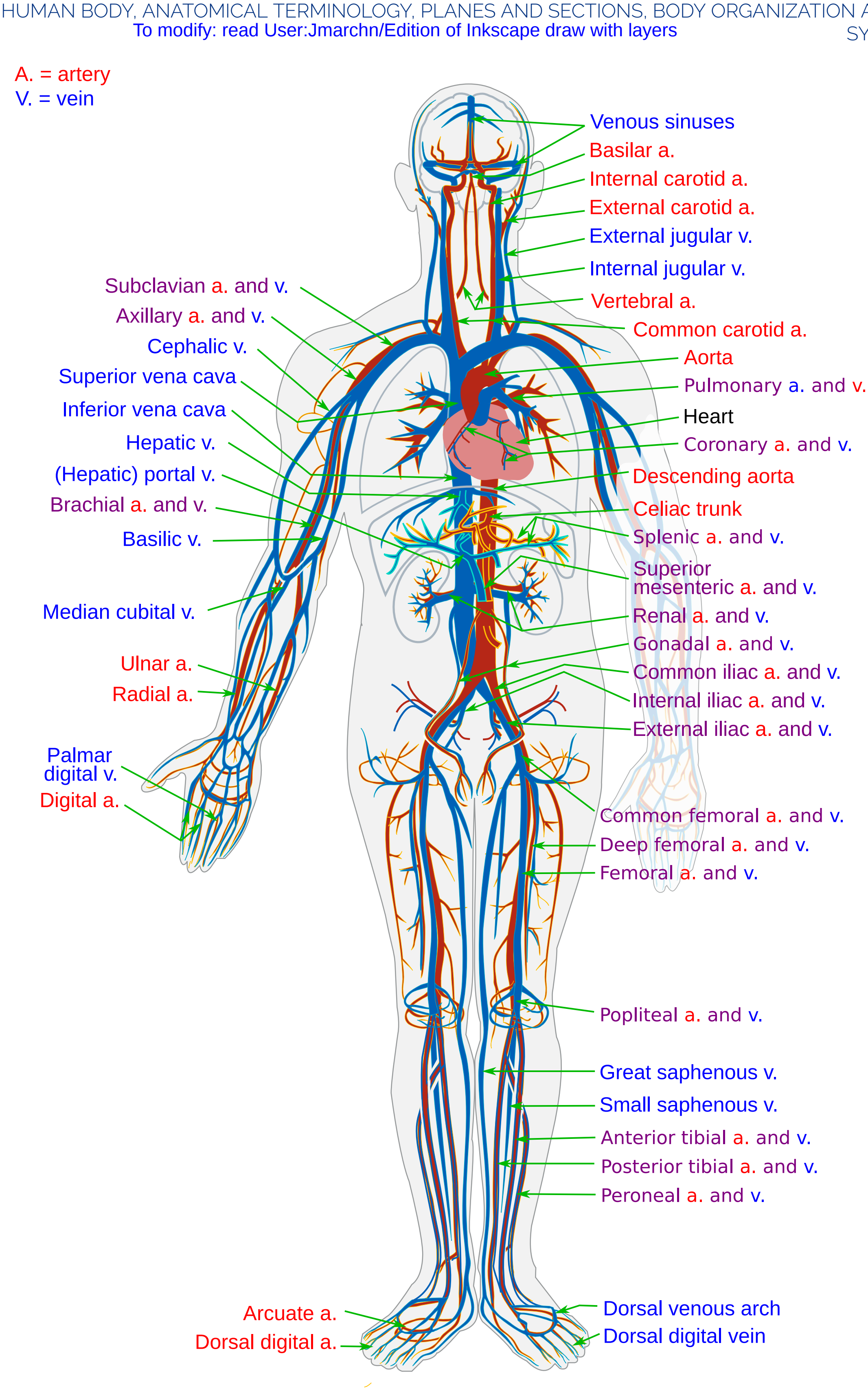

Figure 20: Circulatory System

The human circulatory system (simplified). Red indicates oxygenated blood, blue indicates deoxygenated.

Video – Carotid body and carotid sinus anatomy

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Lymphatic System

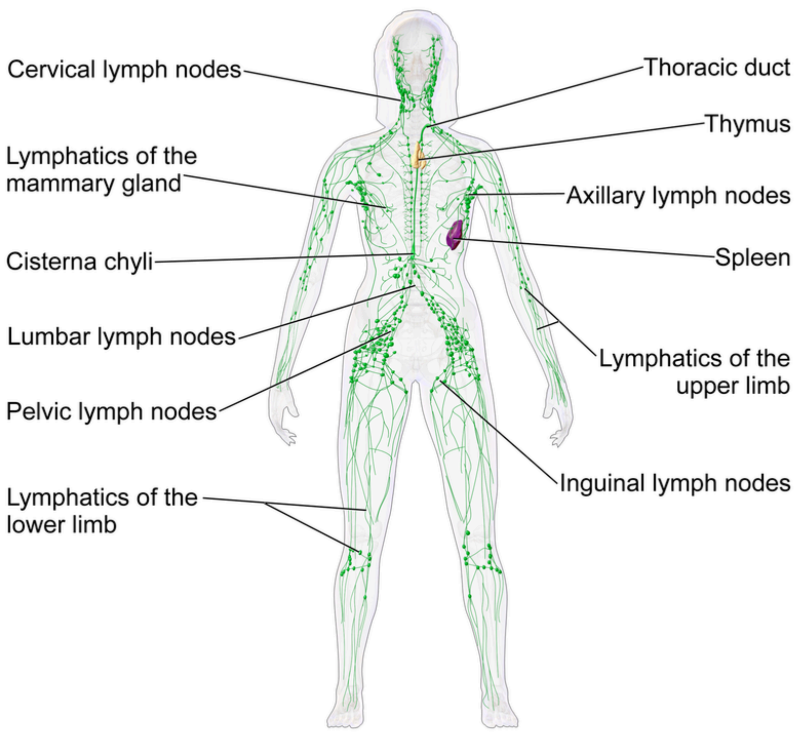

Figure 21: Lymphatic System

The lymphatic system is part of the circulatory system. It consists of lymphatic organs, lymphatic tissue, lymphatic vessels and lymph. The main function of the lymphatic system is to assist the circulatory system in transporting lymph (the fluid found in between cells Interstitial fluid). The lymphatic organs include the thymus, spleen, lymph nodes, and tonsils. Lymphatic tissue includes Peyer's patches (small intestine). The lymphatic vessels include right duct, thoracic duct, cisternae chili and lymph vessels. Lymph is very similar to blood plasma, contains white blood cells, waste products, debris of cells, bacteria and proteins.

The Immune System

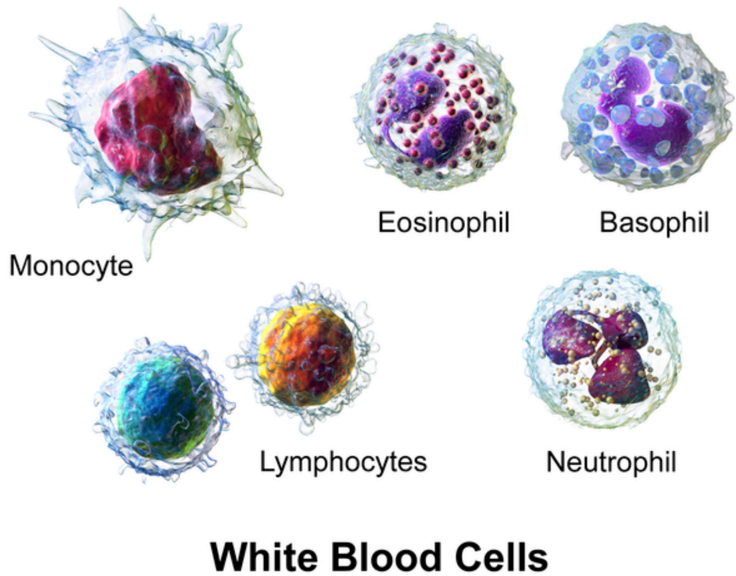

Figure 22: White Blood Cells

The immune system consists of the white blood cells, the thymus, lymph nodes and lymph channels, which are also part of the lymphatic system. The immune system provides a mechanism for the body to distinguish its own cells and tissues from alien cells and substances and to neutralize or destroy the latter by using specialized proteins such as antibodies, cytokines, and toll-like receptors, among many others.

The Respiratory System

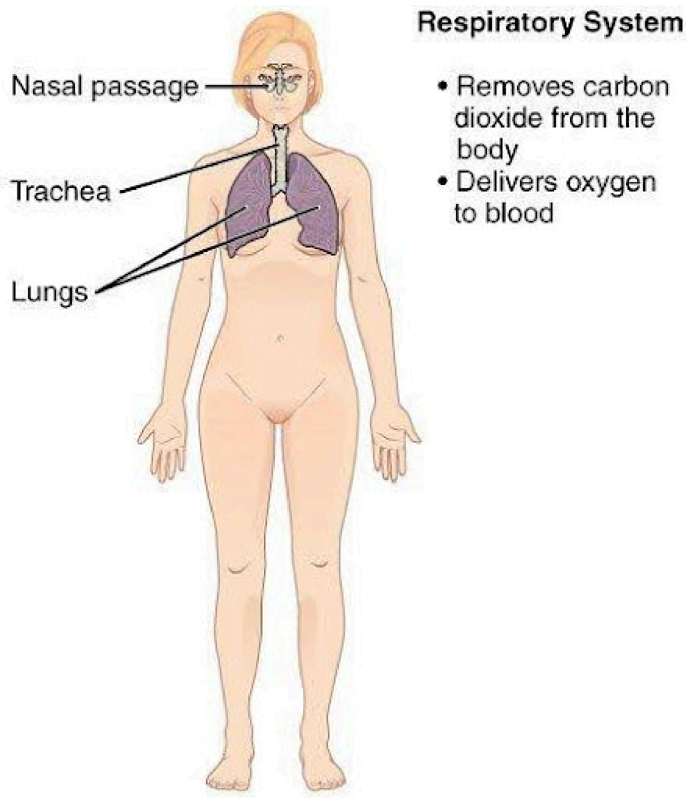

Figure 23: Respiratory System

Respiratory System

- Removes carbon dioxide from the body
- Delivers oxygen to blood

The respiratory system consists of the nostrils, nose, nasal cavity, nasopharynx, trachea, bronchi, bronchioles and lungs. The lungs serve as a site for exchange of gasses, carbon dioxide from metabolic waste from cells with oxygen from the air. The respiratory system also has a minor function as an excretory organ.

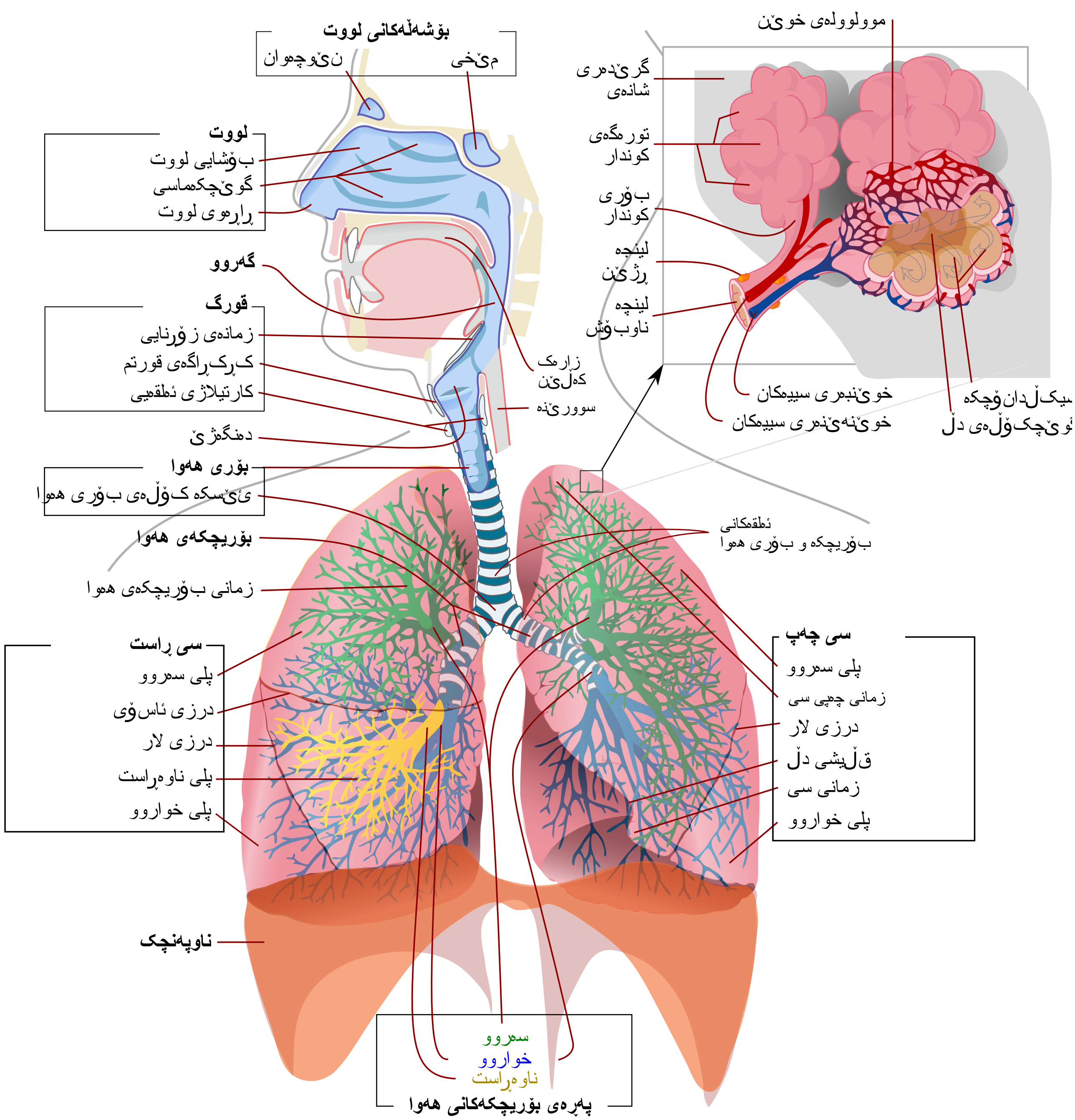

Figure 24: Respiratory System: Schematic View

The Digestive System

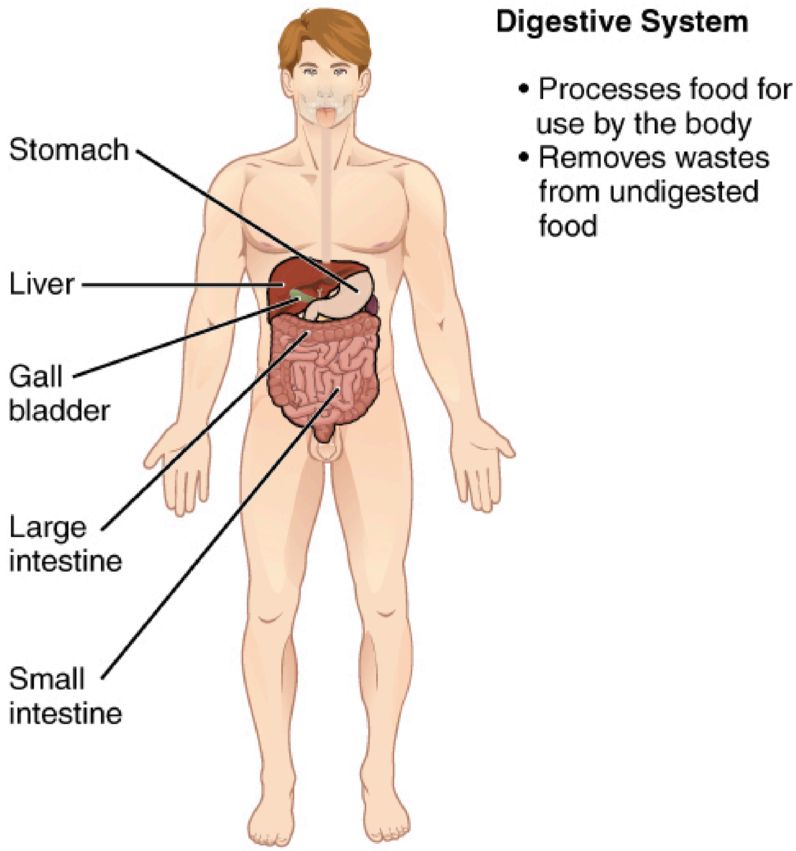

Figure 25: Digestive System

The digestive system processes food for use by the body and removes waste from undigested food.

The digestive system consists of the mouth including the tongue and teeth, esophagus, stomach, gut (gastrointestinal tract (GI), small and large intestines, and rectum). It also has accessory organs such as the liver, gallbladder, pancreas, and salivary glands. It converts the food we ingest into smaller units of nutritional content, to be absorbed by the intestines into circulation for further distribution of fuels for all cells of the body. The circulatory system absorbs what is needed, and excretes the unused residue as feces.

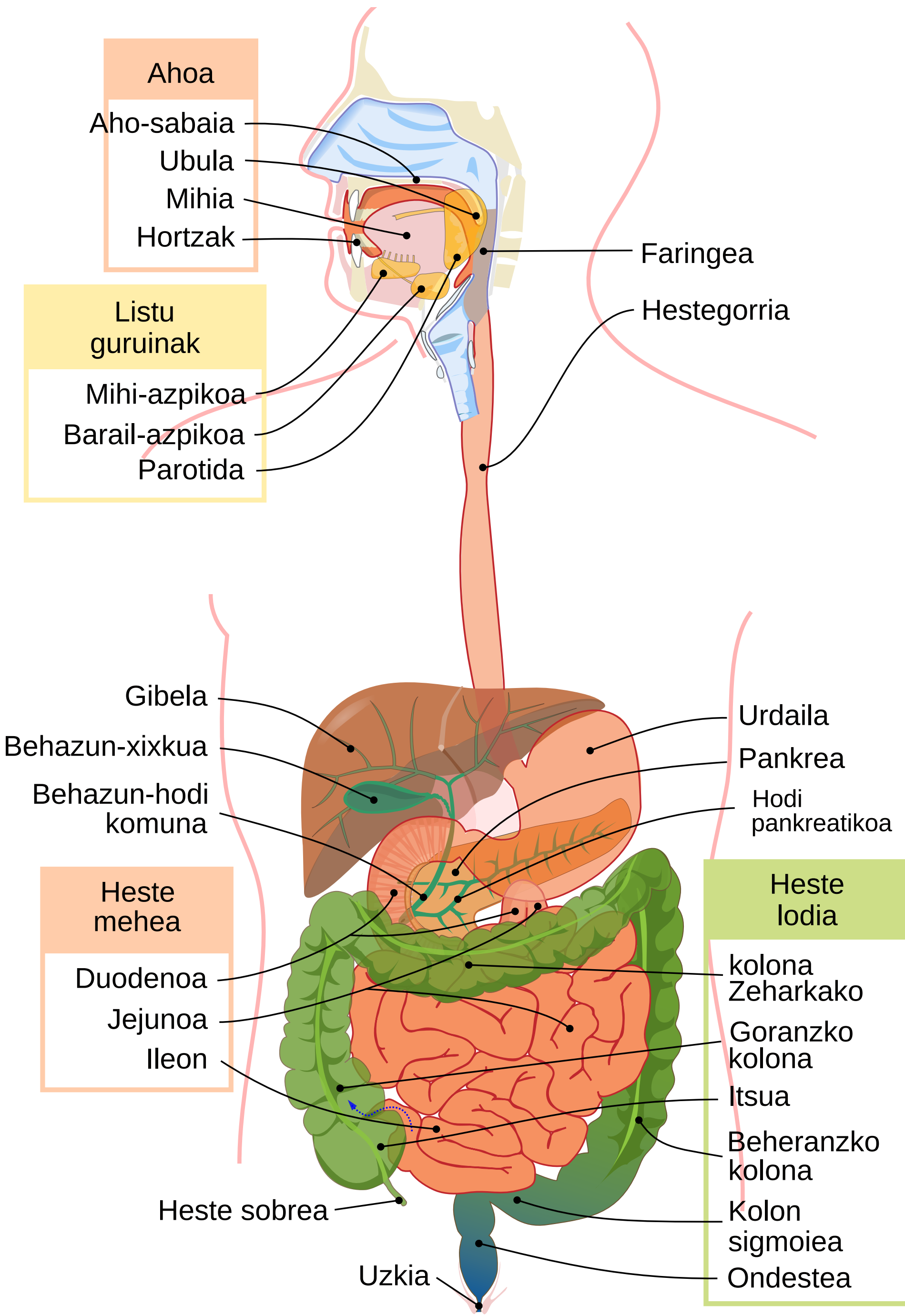

Figure 26: Human Digestive System

Video – stomach

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The Urinary System

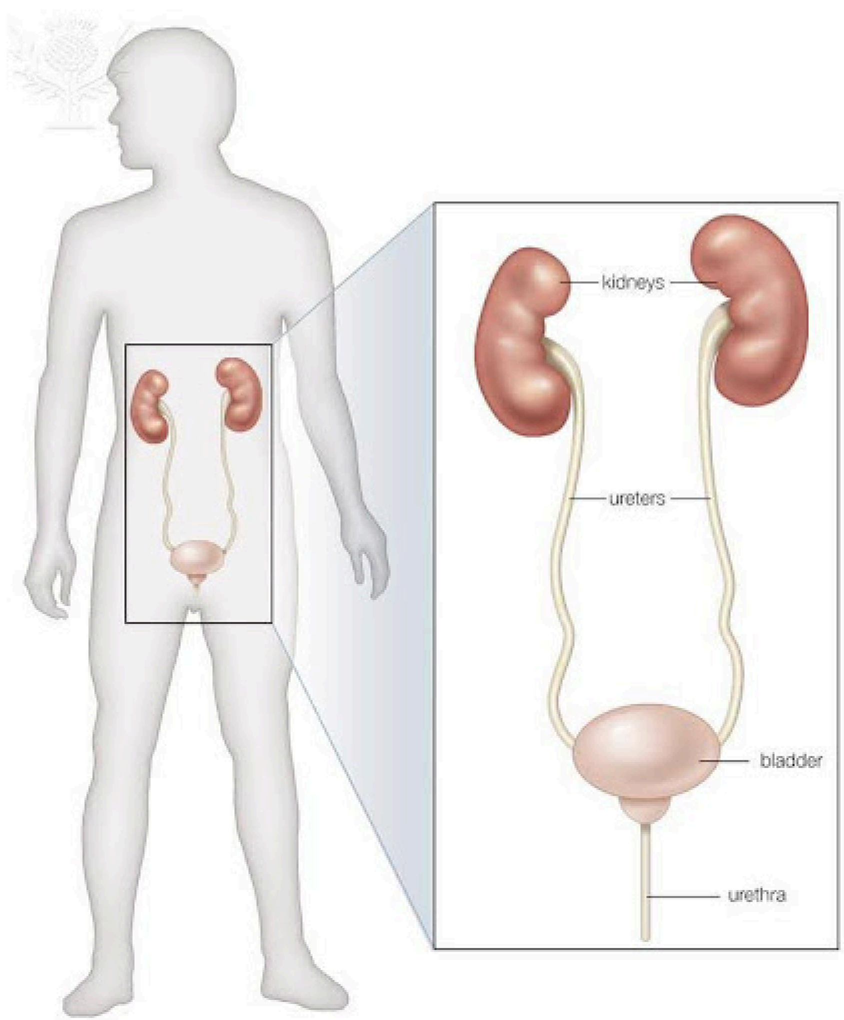


Figure 27: Urinary System

The urinary system consists of the kidneys, ureters, urinary bladder, and urethra. It removes metabolic wastes from the blood to produce urine, which carries a variety of waste molecules and excess ions and water out of the body. The kidneys are the major organs of filtration; they consist of millions of functional units called nephrons. The nephrons are composed of the renal corpuscle (glomerulus and Bowman's capsule) and the tubules (proximal convoluted tubule, loop of Henle, distal convoluted tubule). The collecting ducts collect urine from several nephrons and drain into the minor calices.

Video – Kidney Anatomy

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://rotel.pressbooks.pub/anatomyphysiology/?p=511#oembed-14

The Reproductive System

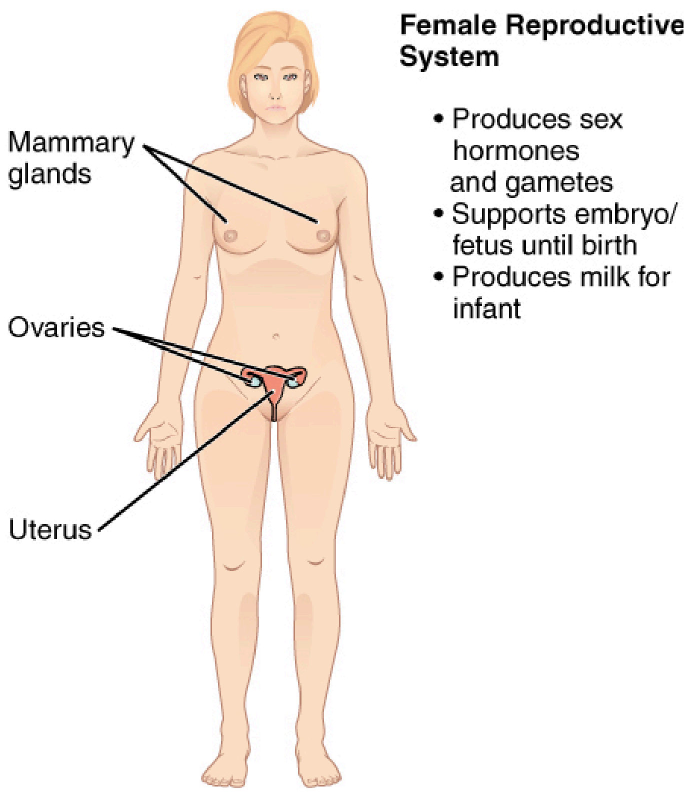


Figure 28: Female Reproductive System

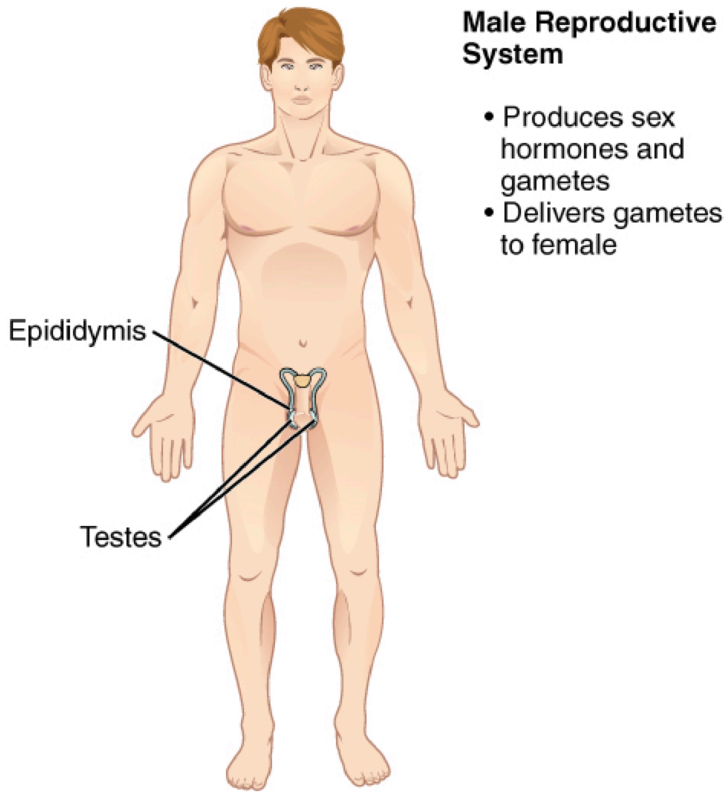


Figure 29: Male Reproductive System

The reproductive system consists of the gonads and the internal and external sex organs. The reproductive system produces gametes in each sex (sperm and oocytes), a site for their combination (fertilization) and formation of the zygote, implantation of the zygote and a nurturing environment for the first 9 months of development of the fetus into an infant.

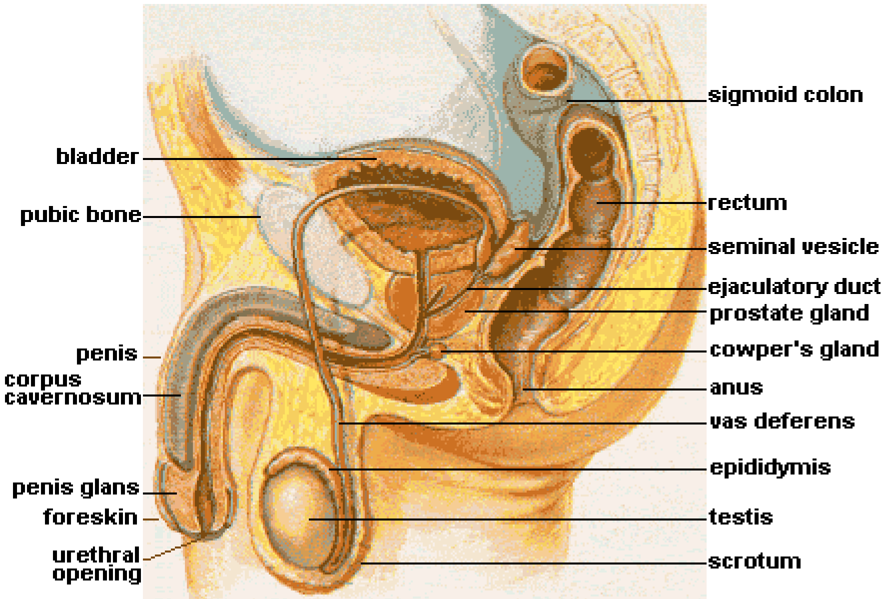


Figure 30: Male Reproductive System

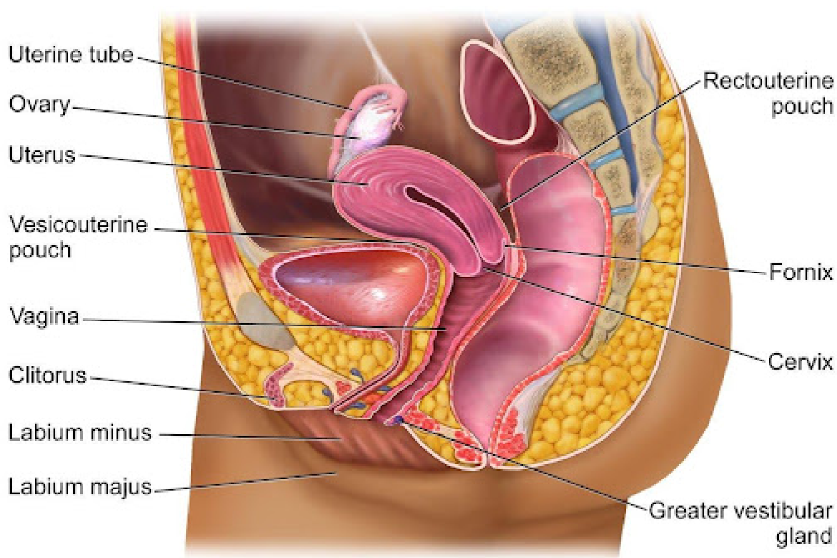


Figure 31: Female Reproductive System

Video – Inguinal Canal

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://rotel.pressbooks.pub/anatomyphysiology/?p=511#oembed-15

Laboratory Activity

Activity A – Regional Terms

1. Use the images of the Mini Muscle Man/Woman (anterior and posterior view) to label the regions shown.

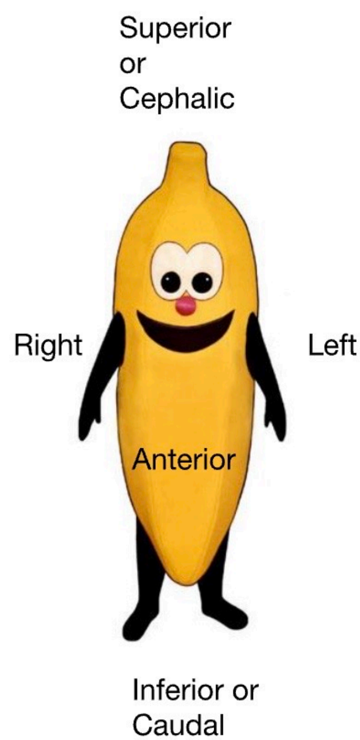
2. Find the following locations of the body using the muscle man image (above), then provide the appropriate regional terms on the table shown below

Common term	Regional Term
Elbow	
Neck	
Kneecap	
Armpit	
Leg	
Hip	
Inguinal	
Shoulder	
Arm	
Neck	

Activity B – Relative Positions, Planes and Sections

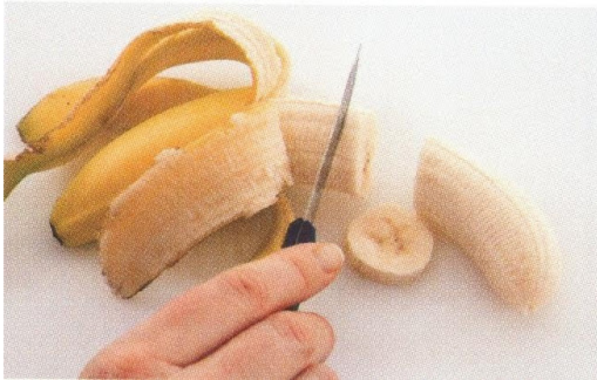
You will use a green or hard yellow banana, a green onion, a plastic knife and **black sharpie**.

Procedure



1. Review the following terms:
   1. Longitudinal
   2. Coronal
   3. Sagittal
   4. Parasagittal
   5. Horizontal
   6. Transverse
2. **Do not peel your banana.**
3. Using the caricature shown here as an example, mark the following regions on your banana peel
   1. Anterior
   2. Posterior
   3. Cephalic (superior)
   4. Caudal (inferior)
   5. Right and Left
4. Take a picture of your banana to upload on your Learning Management System (LMS).

5. Perform the following cuts:



What type of section is this?

What type of section is this?

What type of section is this?

6. Also perform the following cuts:
   1. Sagittal
   2. Coronal
   3. Transverse
   4. Parasagittal

7. Mention two types of longitudinal cuts:

8. Is a transverse cut the same as a horizontal cut? And a cross section (c.s.)?

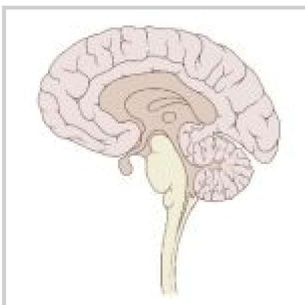
9. Using a green onion, perform a transverse cut, oblique cut and a longitudinal cut.

What do you see, how does this related to a cut through a section of small intestine?

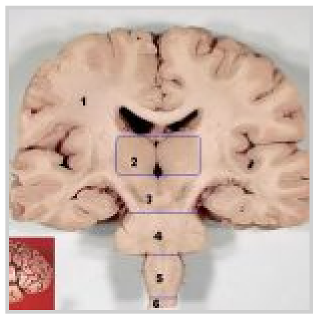
What type of sections is shown here?

Activity C – Identify Planes and Sections

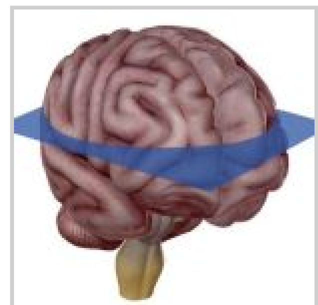
1. These are images of the brain. Name the type of section performed in each of the images shown below:



Brain image #1



Brain image #2



Brain image #3

For 100% online courses, skip using the brain images and use the drag and drop activity provided below to complete the labeling activities.

An interactive H5P element has been excluded from this version of the text. You can view it online here:
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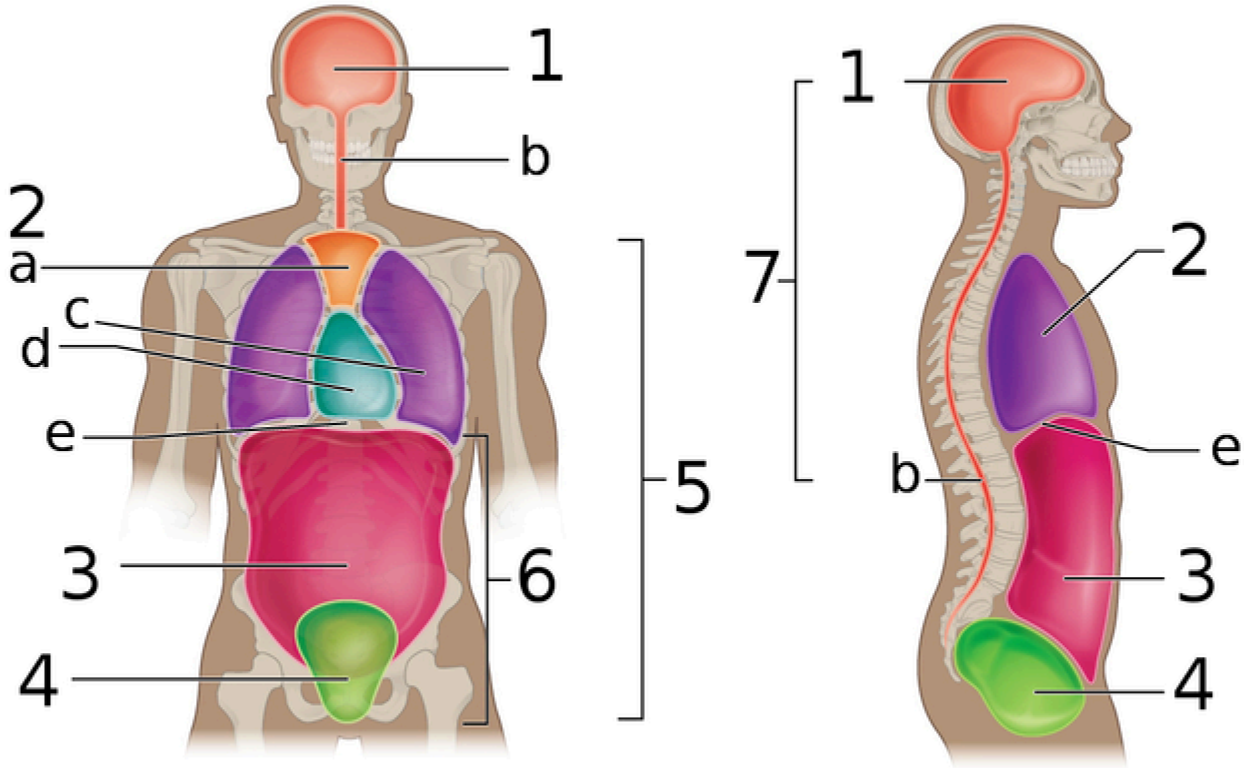
Activity D – Body Cavities

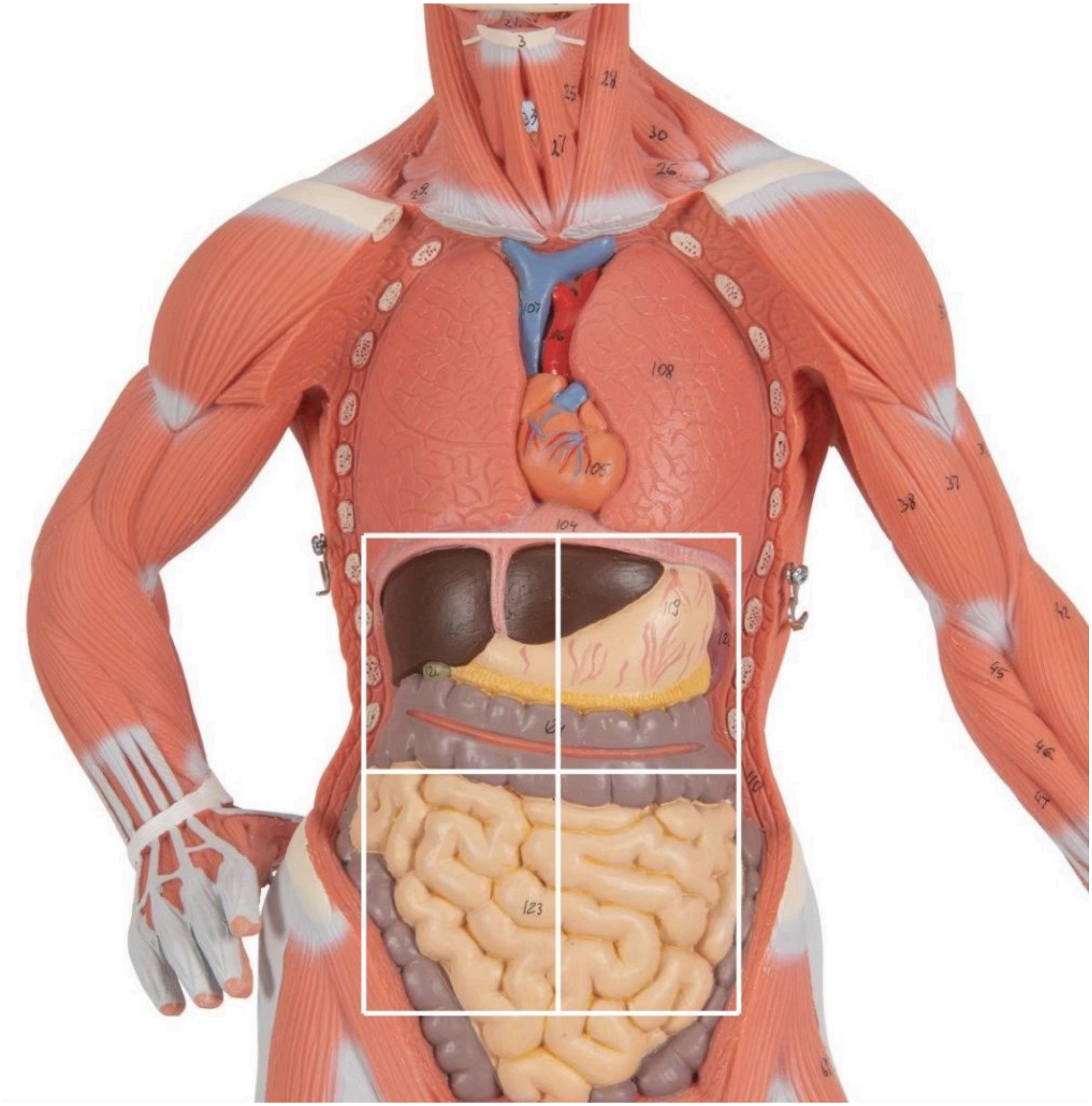
1. Name the body cavities shown on these images – use the table provided below.



Number	Name of Body Cavity
1	
2a	
2b	
2c	
2d	
3	
4	
5	
6	
7	

Activity E – Label the regions of the abdomen

1. Label the 4 quadrants of the abdominal area



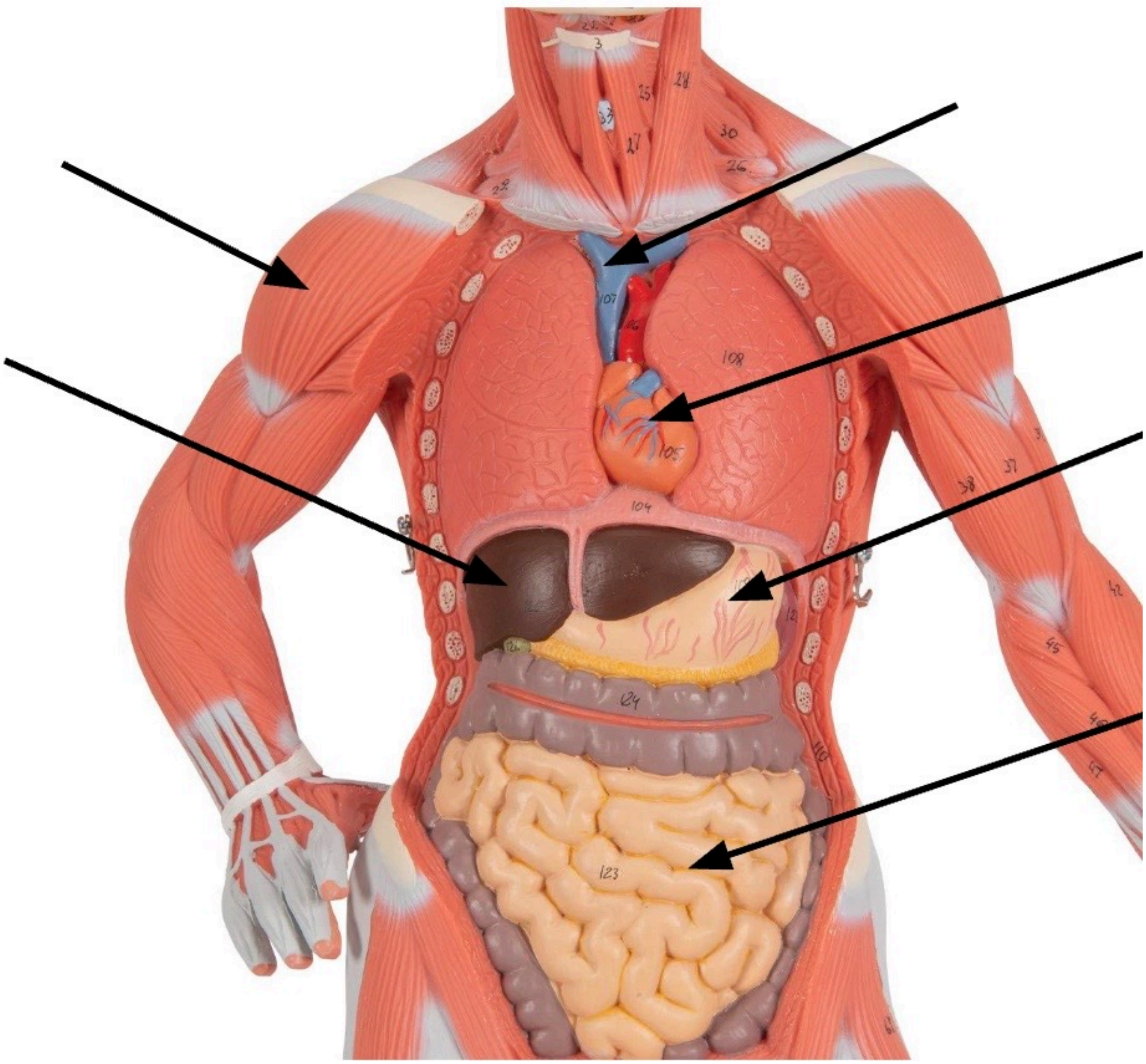
2. Name the organs located in the epigastric region

3. Name the organs located in the right iliac region

4. Name the organs located in the left lumbar region

Activity 4 – Organ systems

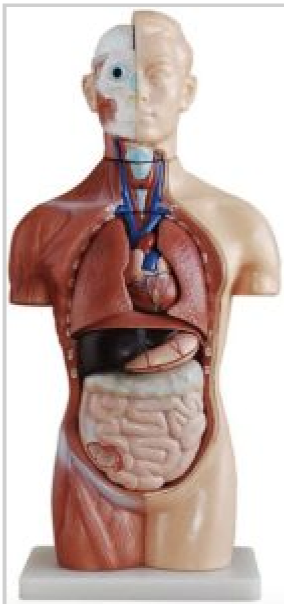
1. Label the name of the organ and by the side of the name in parenthesis write the name of the organ system to which that organs belongs to.



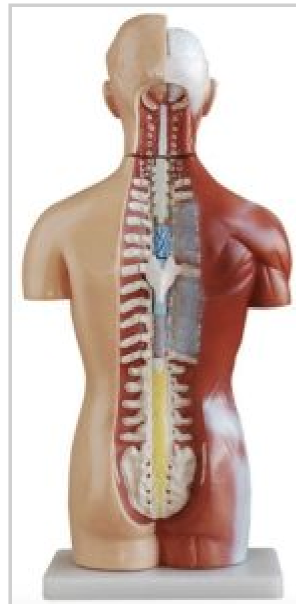
2. Locate and label the following organs on the torso model's images shown here in the tables

Organ	**Organ System**	
Brain		
Spinal Cord		
Thyroid gland		
Adrenal glands		
Pancreas		
Ovaries		
Testis		
Heart		
Larynx		
Lungs		
Trachea		
Esophagus		
Stomach		
Small intestine		
Large intestine		
Vermiform Appendix		
Rectum		
Liver		
Gallbladder		
Spleen		
Axillary Lymph nodes		
Urinary bladder		
Ureters		
kidneys		
Prostate gland		
Urethra		
Mammary glands		

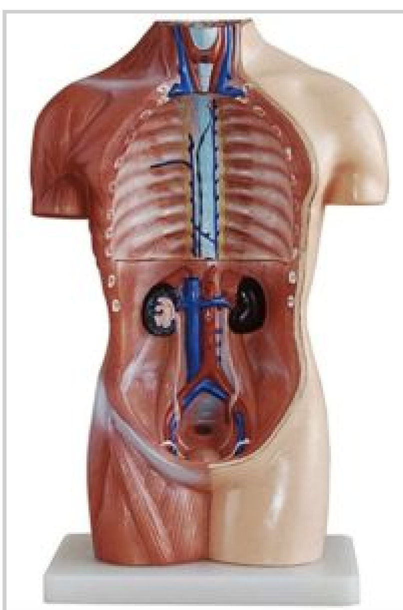
Organ	Organ System	
Abdominal Aorta		
Superior Vena Cava		
Inferior Vena Cava		



Anatomical Model, Torso – Anterior View

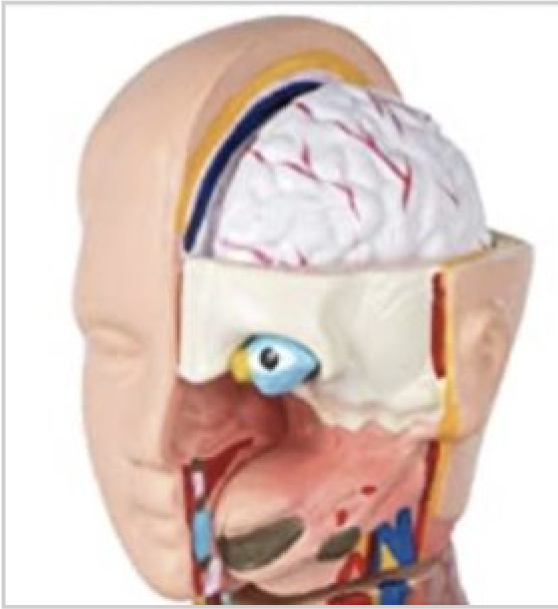


Anatomical Model, Torso – Posterior View



Anatomical Model, Torso – Interior View

Anatomical Model, Torso – Internal organs, detached



Anatomical Model, Torso – head section, Internal organs

Anatomical Model, Torso – neck section, Internal organs

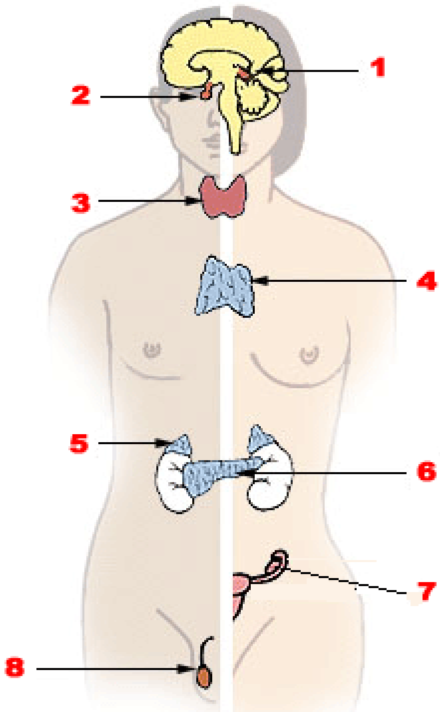
Anatomical Model, Torso – chest section, Internal organs

Anatomical Model, Torso – Lower abdomen section, Internal organs

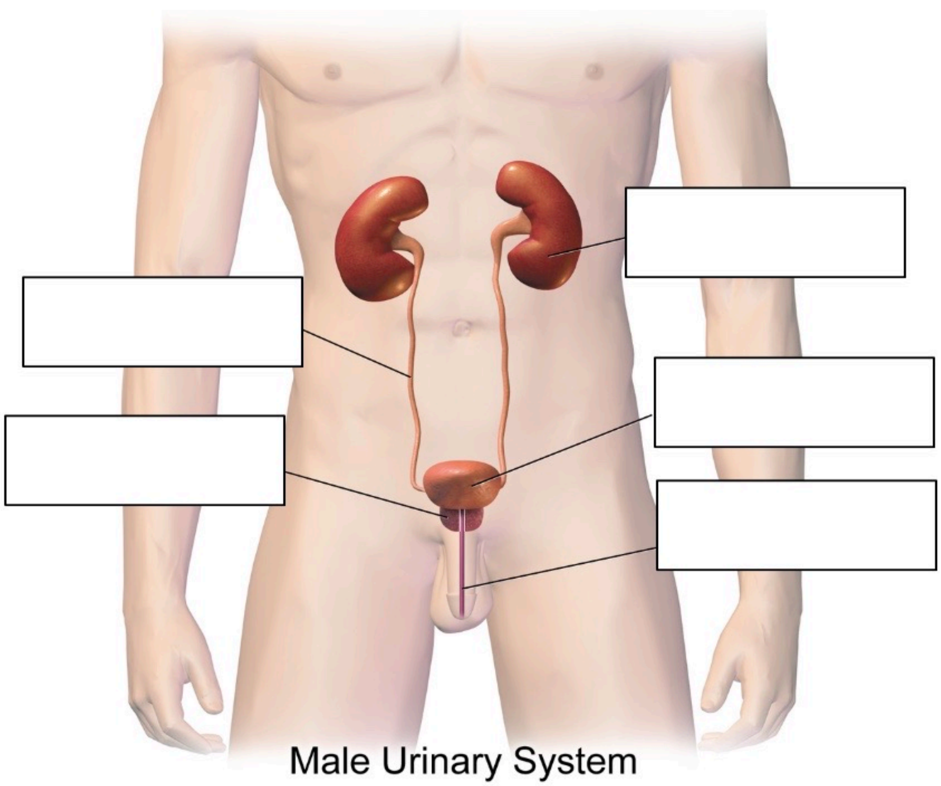
Anatomical Model, Female Reproductive System

Anatomical Model, Male Urogenital System

3. Name the components of the Endocrine system



4. Name the components of the male urinary system



Activity 5 – Critical thinking/Apply what you learned today

1. Describe using anatomical and directional terms the location of the tattoo shown here

Plastic Anatomy – By Sam Webster

Feel free to review the following short videos and animations to complement your lab:

Thorax organs – plastic anatomy

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://rotel.pressbooks.pub/anatomyphysiology/?p=511#oembed-16

Blood supply to small intestine

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://rotel.pressbooks.pub/anatomyphysiology/?p=511#oembed-17

Abdominal organs

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://rotel.pressbooks.pub/anatomyphysiology/?p=511#oembed-18

Arcuate line

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Ureters

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://rotel.pressbooks.pub/anatomyphysiology/?p=511#oembed-20

Blood supply to the stomach

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Hepatic Portal vein

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Aorta

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Stomach

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Gall bladder and biliary tree

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Spleen anatomy

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Pancreas anatomy

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Liver anatomy

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Large intestine anatomy

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Small intestine anatomy

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Inguinal canal

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Posterior Abdominal wall

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Adrenal glands

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://rotel.pressbooks.pub/anatomyphysiology/?p=511#oembed-33

Kidney anatomy

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Peritoneum in cling film

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Vena Cava

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The greater omentum

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The lesser omentum

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://rotel.pressbooks.pub/anatomyphysiology/?p=511#oembed-38

Round ligament of liver or ligamentum teres

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Vagus nerve anatomy

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Cardiovascular anatomy

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Duodenum

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Abdomen transverse CT imaging anatomy

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Heart Anatomy

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Female pelvic organs introduction

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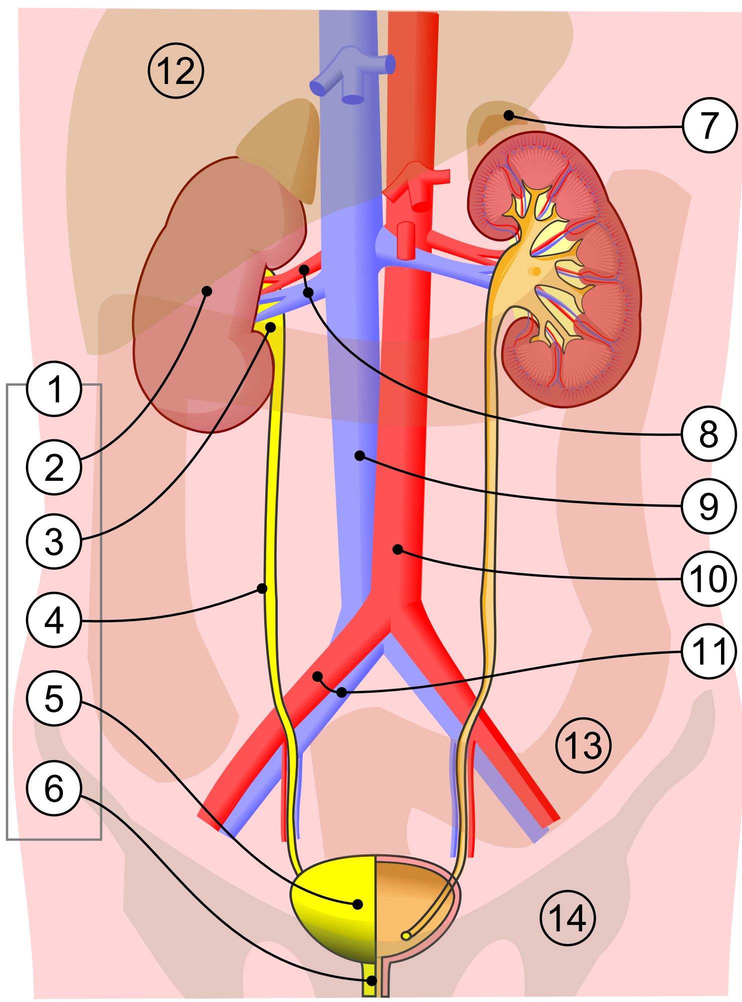
Organ Systems Worksheets

The Urinary System

- Label the main structures of the Urinary System. After completing this activity, self-assess your answers by comparing with the key provided in the next page.



Number	**Structure**	**Number**	**Structure**
1		8	
2		9	
3		10	
4		11	
5		12	
6		13	
7		14	

For 100% online courses, skip using the brain images and use the drag and drop activity provided below to complete the labeling activities.

An interactive H5P element has been excluded from this version of the text. You can view it online here:
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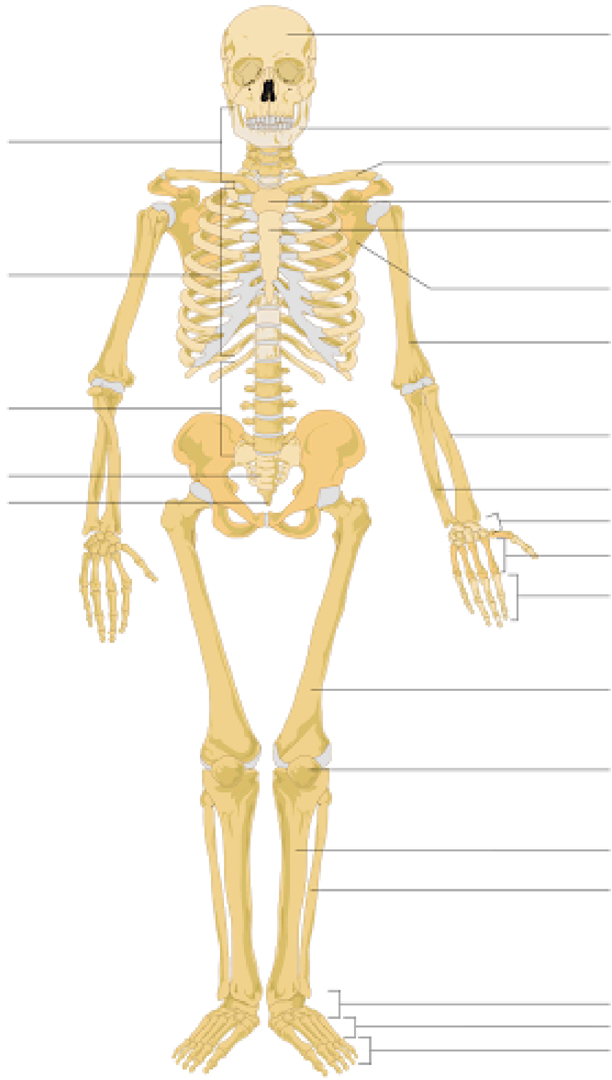
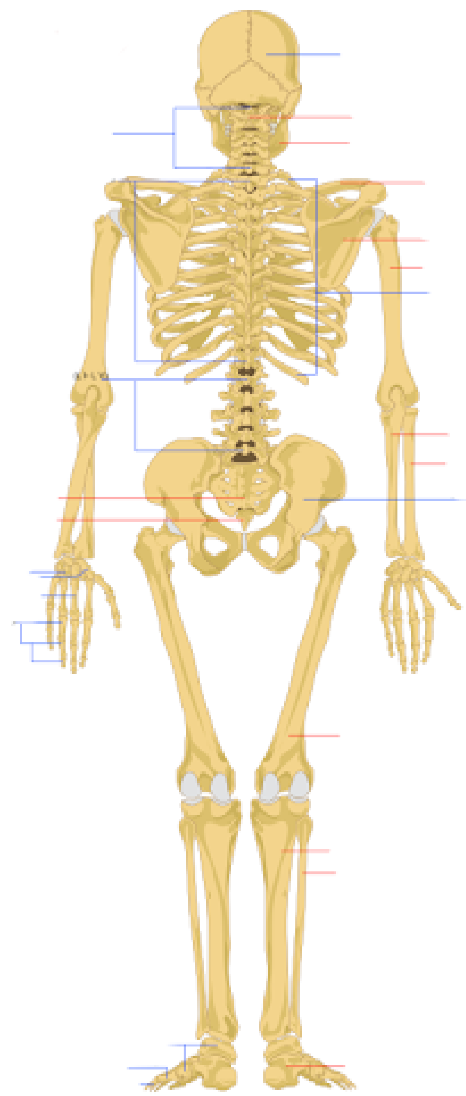
The Skeletal System – Diagrams

Label the main bones of the human body.



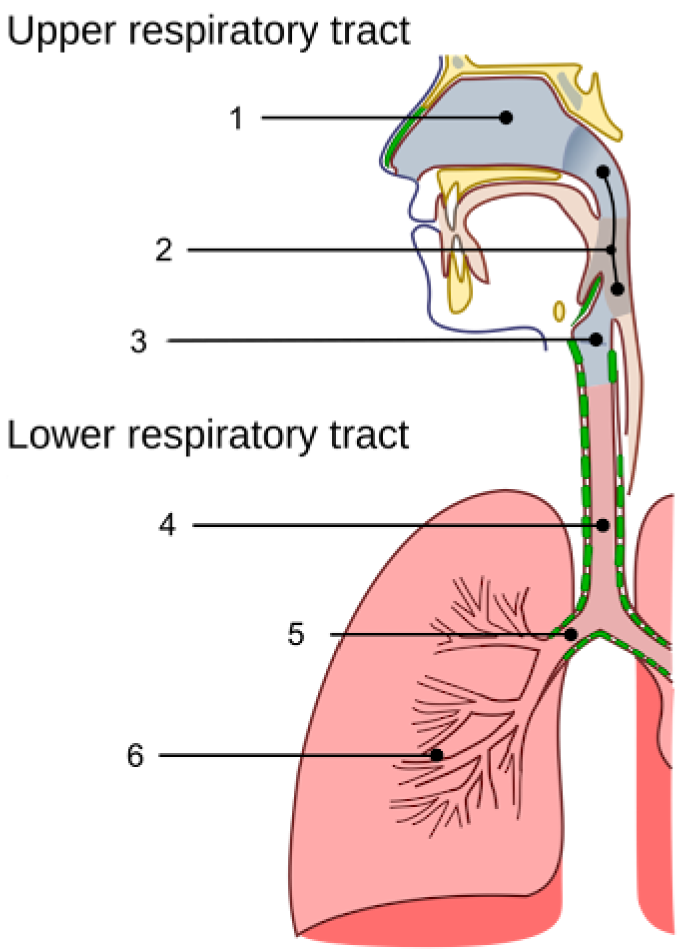


The Respiratory System

The human respiratory system is divided into the upper and lower tracts. The upper respiratory tract includes the nose and nasal passages, paranasal sinuses, the pharynx, and the portion of the larynx above the vocal folds (cords). The lower respiratory tract includes the portion of the larynx below the vocal folds, trachea, bronchi, and bronchioles. The lungs are included in the lower respiratory tract.

Activity

- Label the main structures of the Respiratory System. After completing this activity, self-assess your answers by comparing with the key provided in the next page.



Number	Main structures of the Respiratory system
1	
2	
3	
4	
5	
6	

For 100% online courses, skip using the brain images and use the drag and drop activity provided below to complete the labeling activities.

An interactive H5P element has been excluded from this version of the text. You can view it online here:
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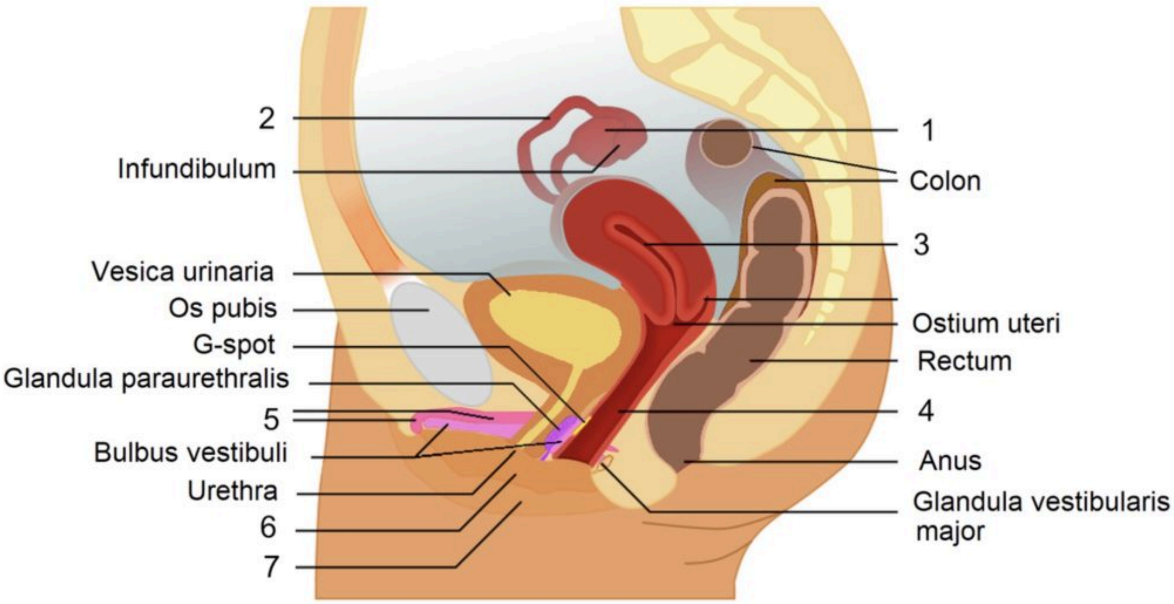
The Reproductive System

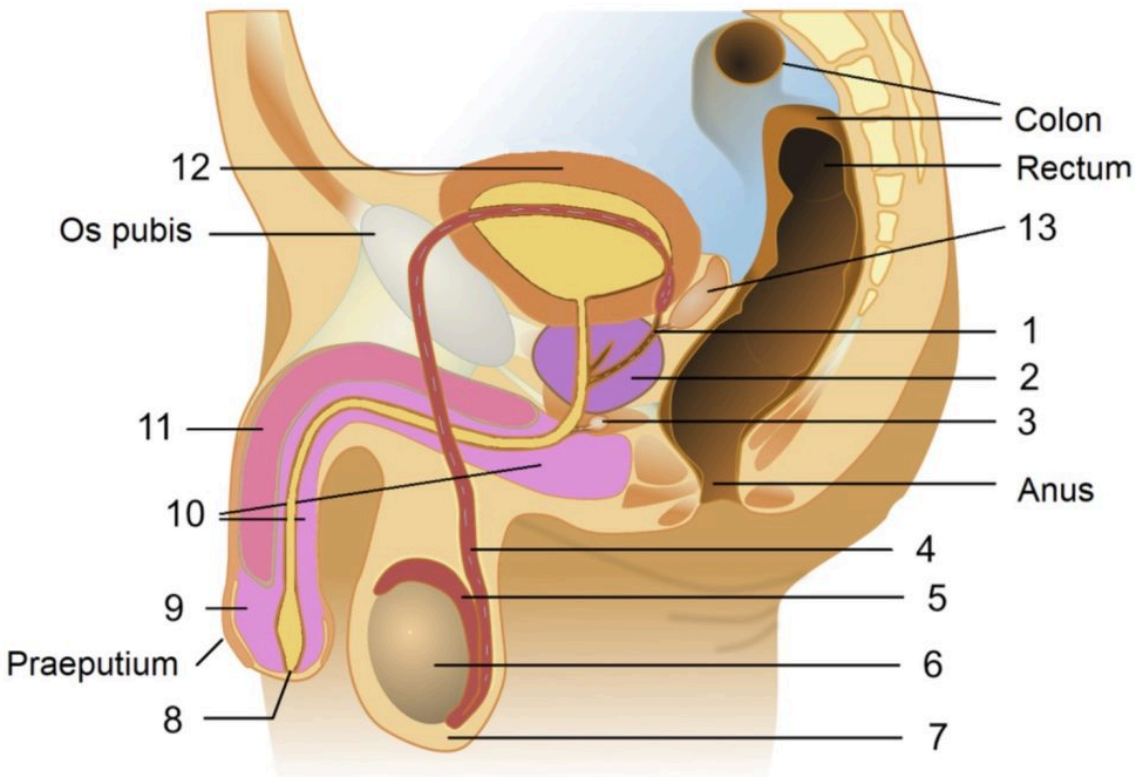
Label the diagrams

- Female – sagittal section of pelvis



#	**Structure**
1	
2	
3	
4	
5	

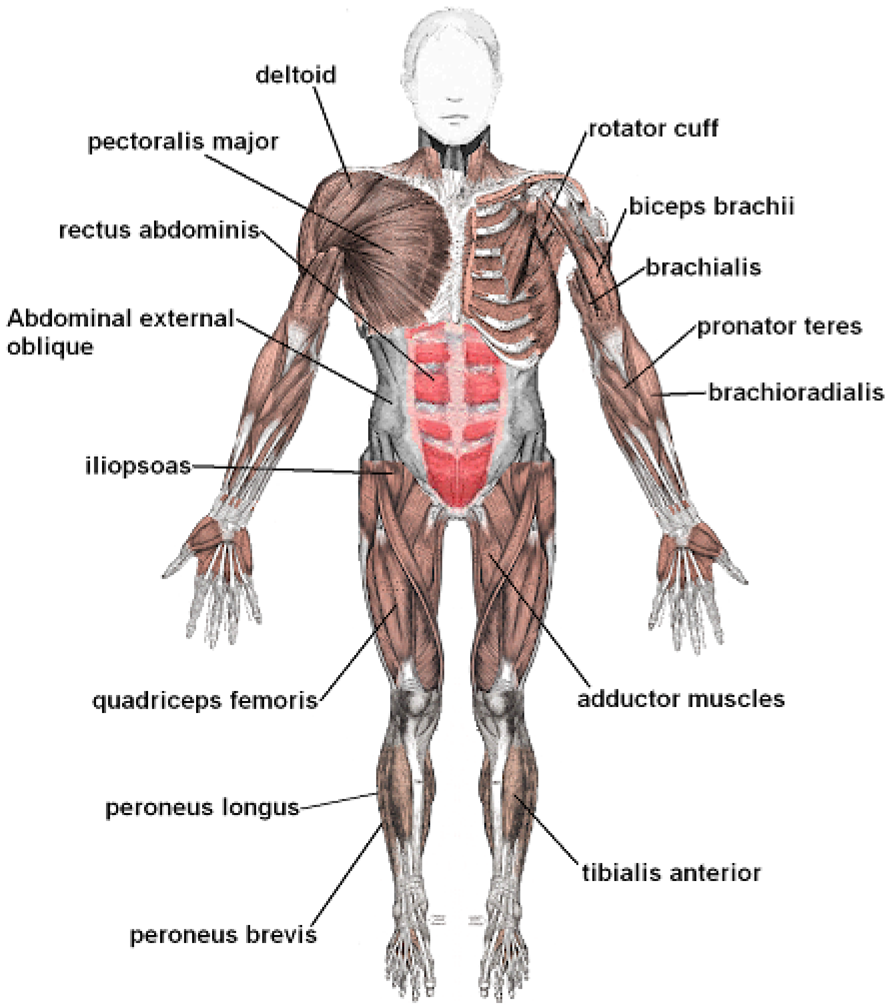
- Male – sagittal section of pelvis



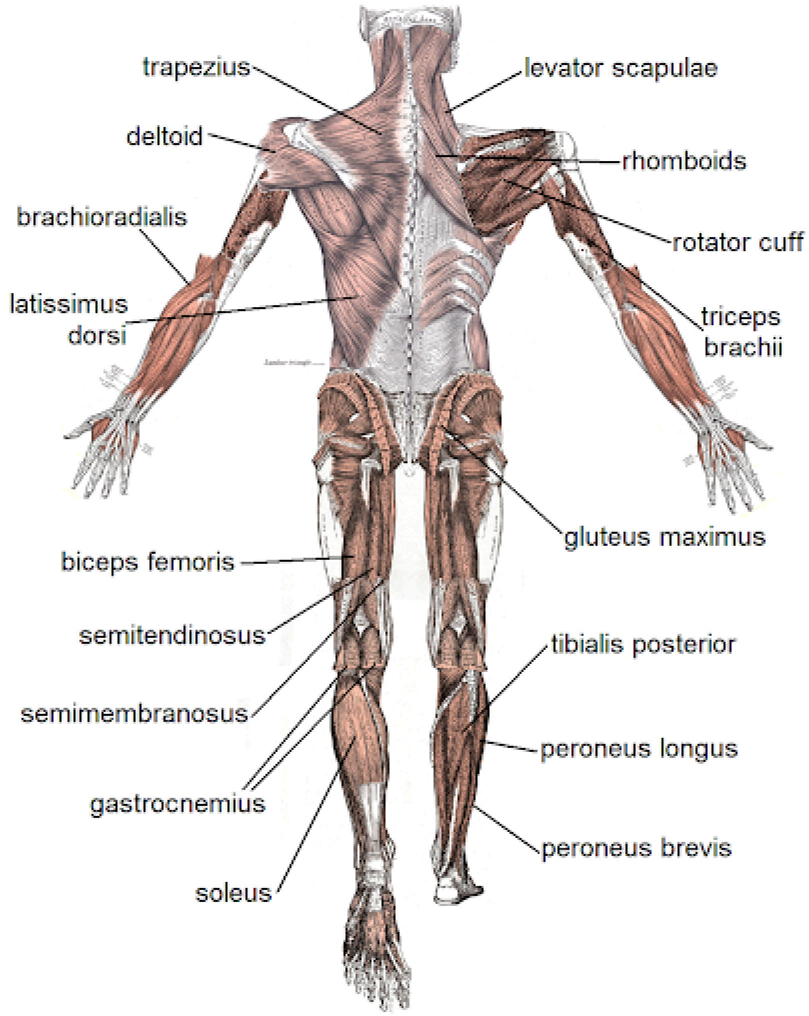
#	Structure
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	

The Muscular System

Review the main muscles of the human body



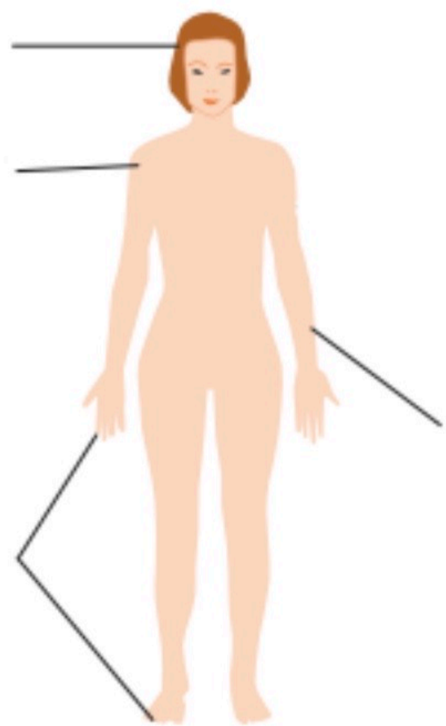
File: Muscles anterior labeled.png https://commons.wikimedia.org/wiki/File:Muscles_anterior_labeled.png This work is in the public domain in its country of origin and other countries and areas where the copyright term is the author's life plus 100 years or fewer.



File: Muscle posterior labeled.png https://commons.wikimedia.org/wiki/File:Muscle_posterior_labeled.png This work is in the public domain in its country of origin and other countries and areas where the copyright term is the author's life plus 100 years or fewer.

The Integumentary System

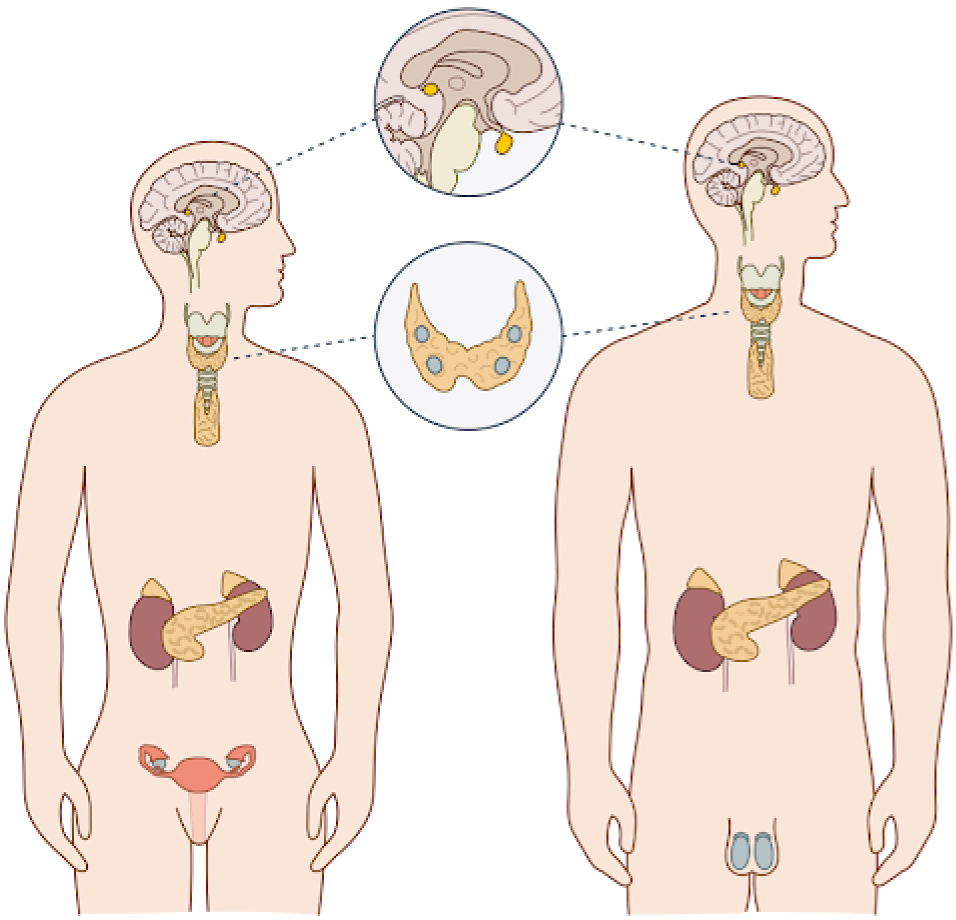
Label the diagram – components of the integumentary system



Hair
Nail
Skin
Glands in skin

The Endocrine System

- Label the main structures of the Endocrine System. After completing this activity, self-assess your answers by comparing with the key provided in the next page.



Main structures
1.
2.
3.
4.
5.
6.
7.
8.
9.

For 100% online courses, skip using the brain images and use the drag and drop activity provided below to complete the labeling activities.

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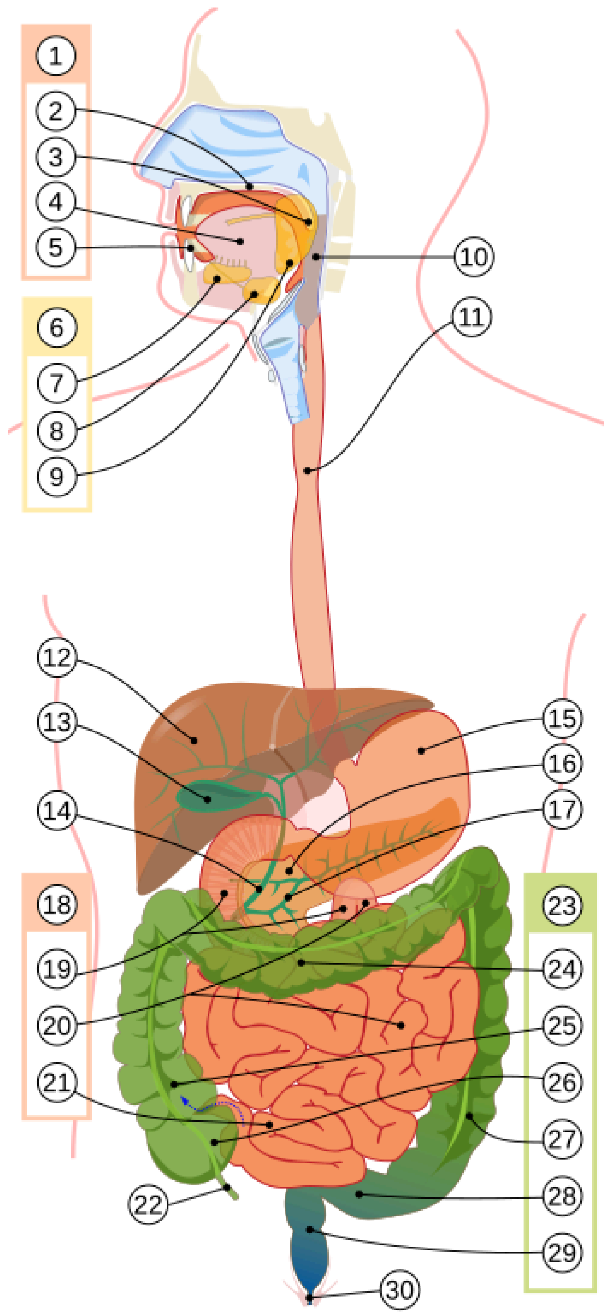
https://rotel.pressbooks.pub/anatomyphysiology/?p=511#h5p-1

The Digestive System

The gastrointestinal tract, also called the digestive tract, alimentary canal, or gut, is the system of organs within multicellular animals that takes in food, digests it to extract energy and nutrients, and expels the remaining waste.

Label the main structures of the Digestive System. After completing this activity, self-assess your answers by comparing with the key provided in the last page.


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30

Number	Main structures of the Urinary system
1	
2	
3	
4	
5	
6	
7	
8	
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11	
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14	
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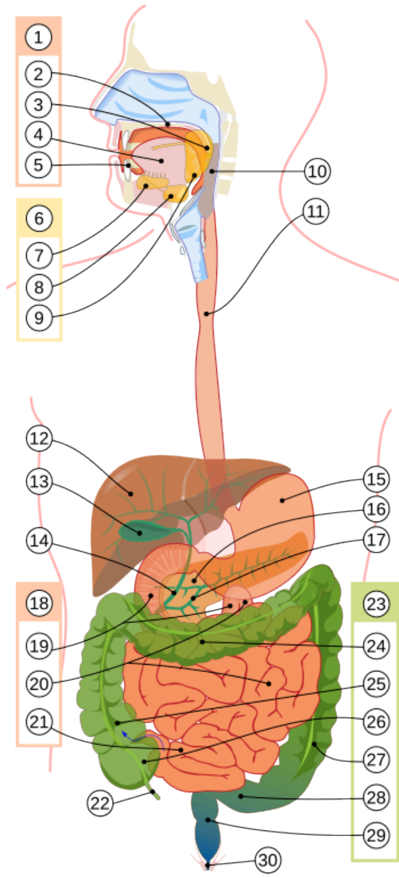
For 100% online courses, skip using the brai

Number	Main structures of the Urinary system
28	
29	
30	

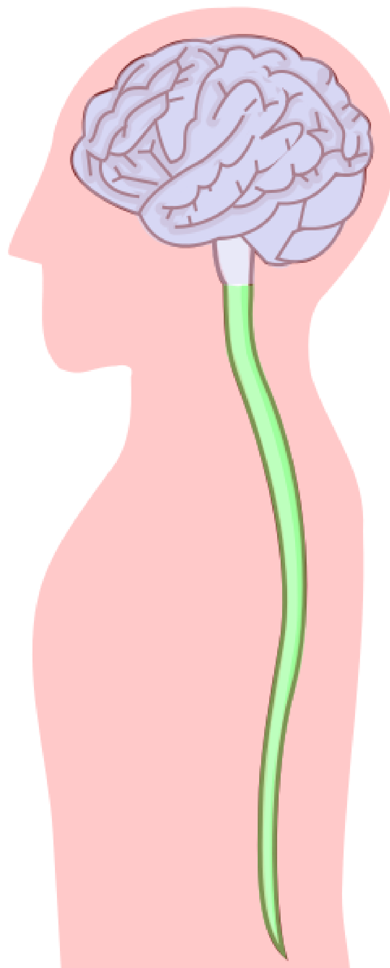
n images and use the drag and drop activity provided below to complete the labeling activities.



An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://rotel.pressbooks.pub/anatomyphysiology/?p=511#h5p-13

The Nervous System

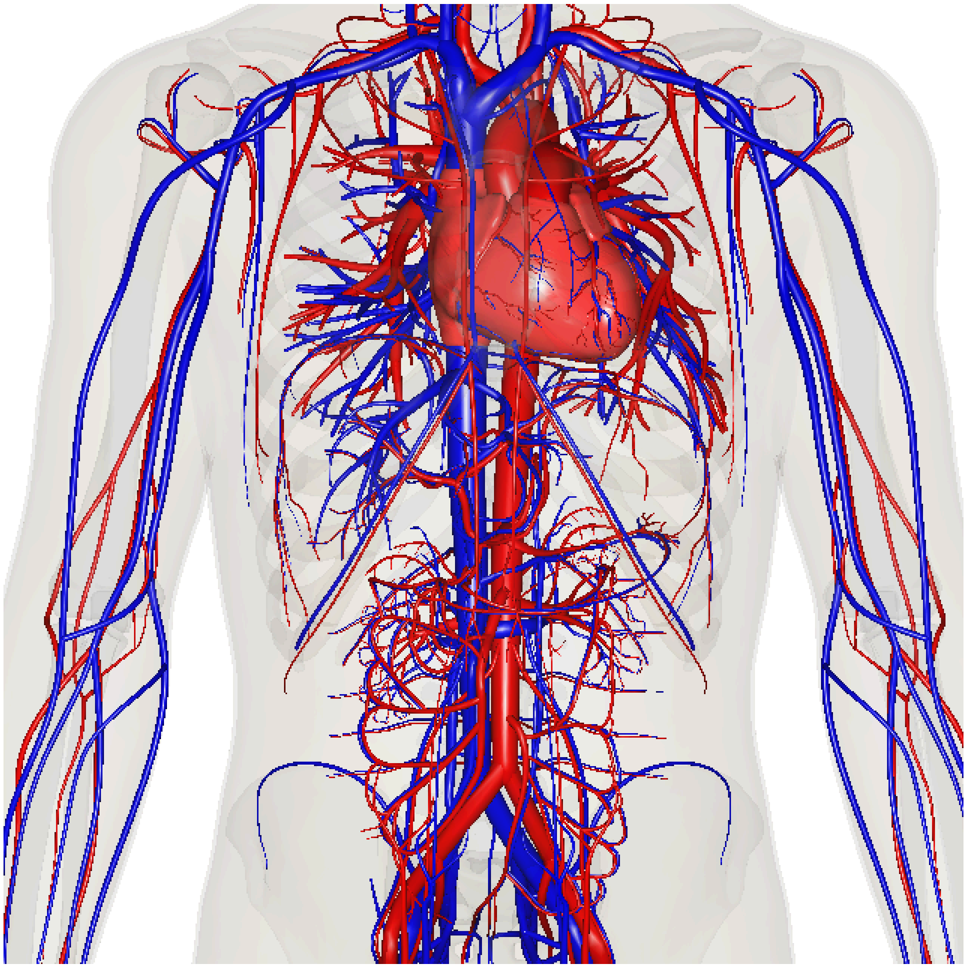
Label the components of the CNS: Brain and Spinal cord.



The Cardiovascular System

The cardiovascular system includes the heart, blood vessels, and blood which is located inside the blood vessels and circulates throughout the entire body bringing nutrients to all cells and removing their metabolic waste.

Label the main structures of the Cardiovascular System.



Number	Main structures of the Cardiovascular system
1	
2	
3	

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THE MICROSCOPE

Laboratory – Effective Use and Care of the Microscope

Objectives:

1. Describe and demonstrate how to carry, clean, use, and store a compound light microscope.
2. Identify all parts of the microscope and describe their function.
3. Learn to calculate total magnification for each objective lens.
4. Learn the relationship between working distance, field of view and illumination.
5. Measure the diameter of a cell.

A compound light microscope is used to observe structures that can't be seen with the naked eye, structures that are below the normal resolution of our eyes. These can be cells, tissues, organs, etc.

The compound microscope used two types of lenses, the ocular lens and the objective lens, as they are used simultaneously, they magnify the image.

The compound light microscopes we have in the lab can magnify an object up to 1000X.

Learning microscopy is very important for us, we can examine different types of cells and tissues and make correlations between their structure and function. We can also compare normal and disease state cells, as changes in the normal structure are part of a particular disease process.

Care and Transport of a Microscope

We must learn how to use, care for, and transport the microscope because it is an expensive and an essential tool required in our laboratory.

Transport

- To take the microscope out of the cabinet, use the following instructions:
  - Use your dominant hand to hold the arm of the microscope, and your non-dominant hand to hold the base of the microscope.
- Carry the microscope upright. That way the ocular lenses located in the eyepiece do not fall out.

- Make sure the electrical cord is wrapped or removed from the microscope, avoid tripping on the cord.
- Place the microscope on a table in front of you.

Care

- Turn off the microscope.
- Turn the intensity of the light to the lowest level.
- Turn the revolving piece to have lowest magnification, usually 4X.
- Disconnect from power source.
- Wrap cord around the microscope.
- After you have used the microscope, make sure to clean the lenses, particularly the 100X with lens paper to remove any remnant of immersion oil.
- Place the microscope back in the cabinet using the transport instructions.

Clean the Lens

- Moisten the end of a Q-tip with lens cleaner.
- Clean the topical surface with the wet end and dry it with the other end, using circular motion.
- Start with the scanning objective and move your way up to the immerse oil objective, changing the cotton swab for each objective.
- Use alcohol for difficult cleaning and only as last resort use xylene, Regular use if xylene will destroy the lens coating.

Parts of the Microscope

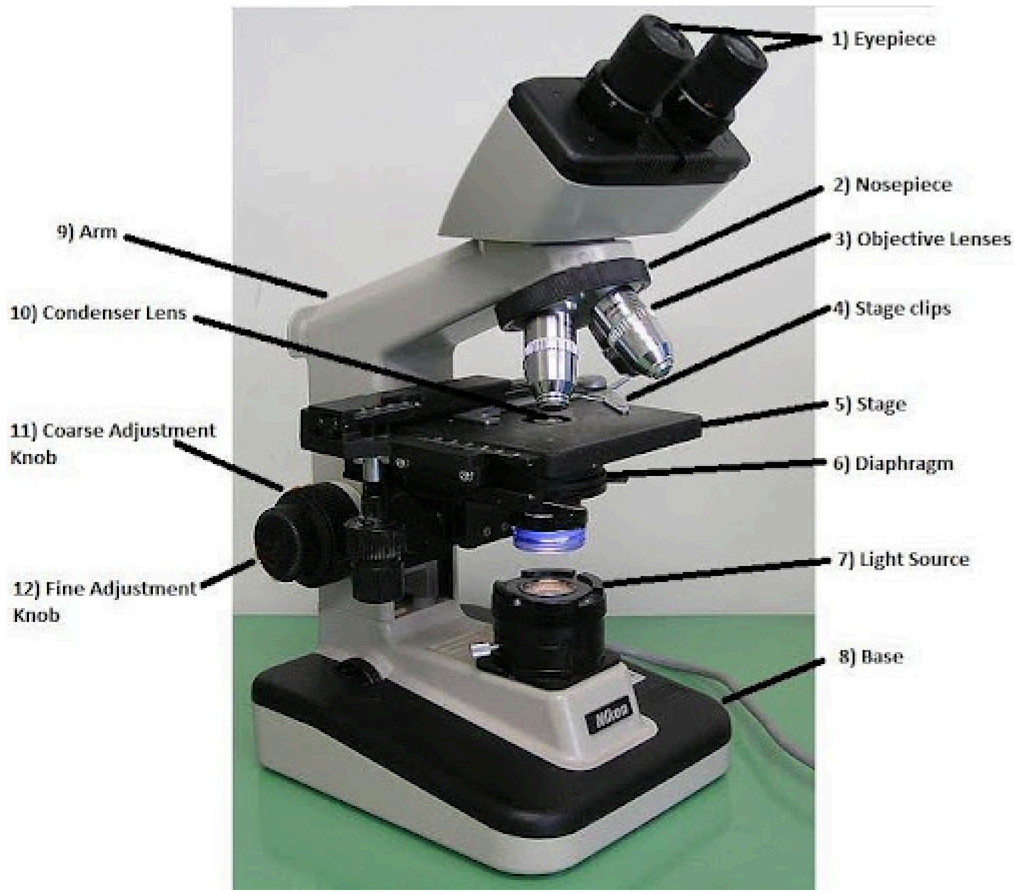


Figure 1. Parts of the compound light microscope

Description and Function of the Parts of the Microscope

- Eyepiece – removable, holds ocular lenses. Typically, these lenses magnify the image 10X.
- Revolving nosepiece – contains the objective lenses.
- Objective lenses – Mounted in the revolving nosepiece, typically a microscope has 4, the 4X, 10X, 40X and 100X.
- Head – Upper part, contains the ocular lenses and the rotating nosepiece with the objective lenses.
- Stage clips – located in the Stage, their function is to hold the slide in place.
- Stage – Platform located below the objectives where the slide is placed.
- Mechanical stage – holds the slide in place (with clamp), can be moved using the adjusting knobs.
- Iris-diaphragm – located beneath the condenser, regulates the amount of light by opening or closing its aperture.
- Light – light source, usually a bulb built in the base of the microscope, it has a dial to regulate the intensity of light.

- Condenser – located below the stage, contains a lens that condenses light through the specimen.
- Arm – The area of the microscope that connects the base to the head, it can be straight or curved depending on the microscope.
- Base – The wide bottom of the apparatus, it supports the microscope.
- Coarse focus – large knob located on each side of the microscope toward the base, it moves the stage up or down quickly, used for coarse focusing.
- Fine focus – small knob located on each side of the microscope, usually inside the coarse knob, used for precision focusing.

Calculating magnification

The total magnification is determined by multiplying the ocular lens power by the objective lens power.

Relationship between magnification, working distance and field of view

There is an inverse relationship between the objective lens magnification and the working distance, field of view and intensity of the light (shown in the figure 2)

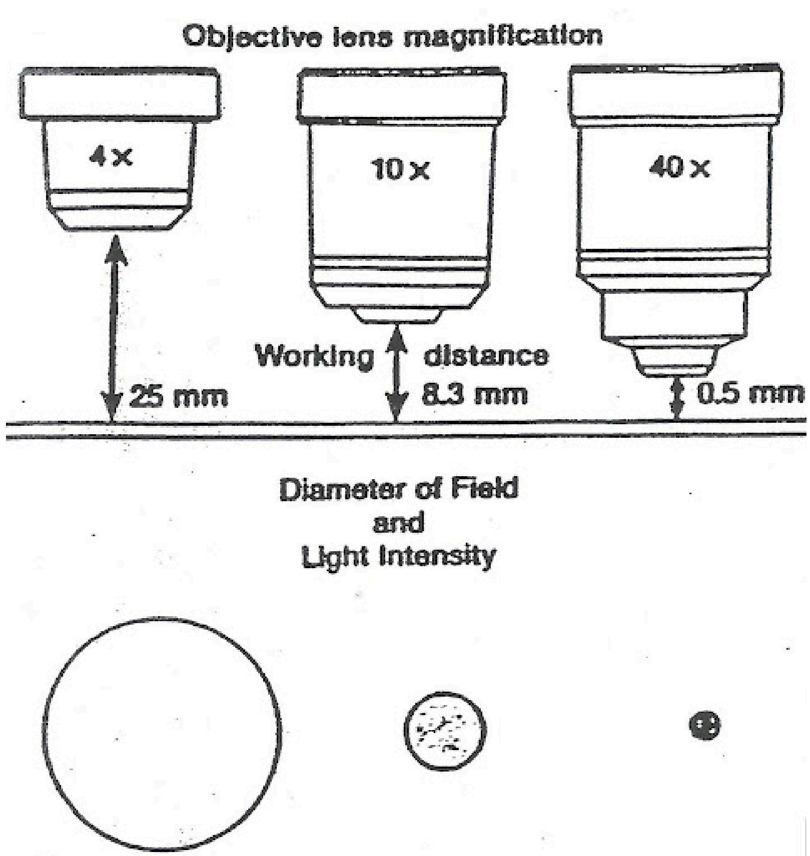


Figure 2. The relationship between the objective power, working distance, diameter field and light intensity.

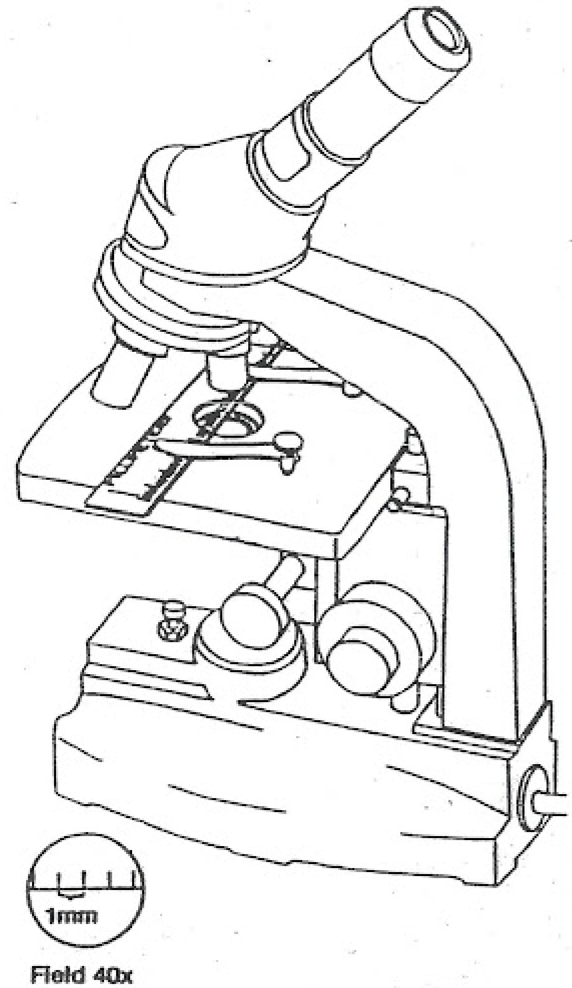


Figure 3. Estimating the diameter of field

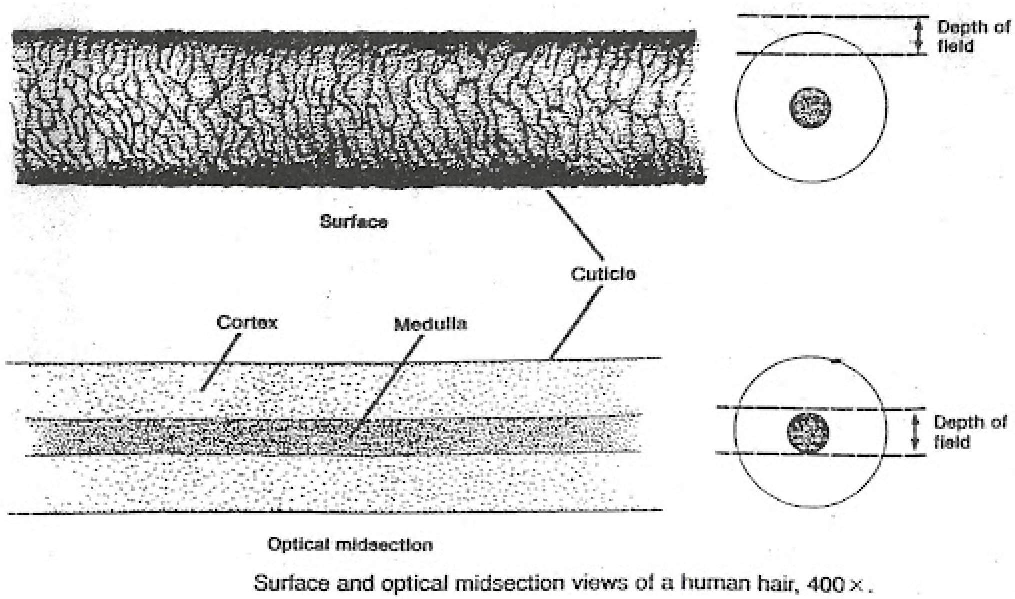
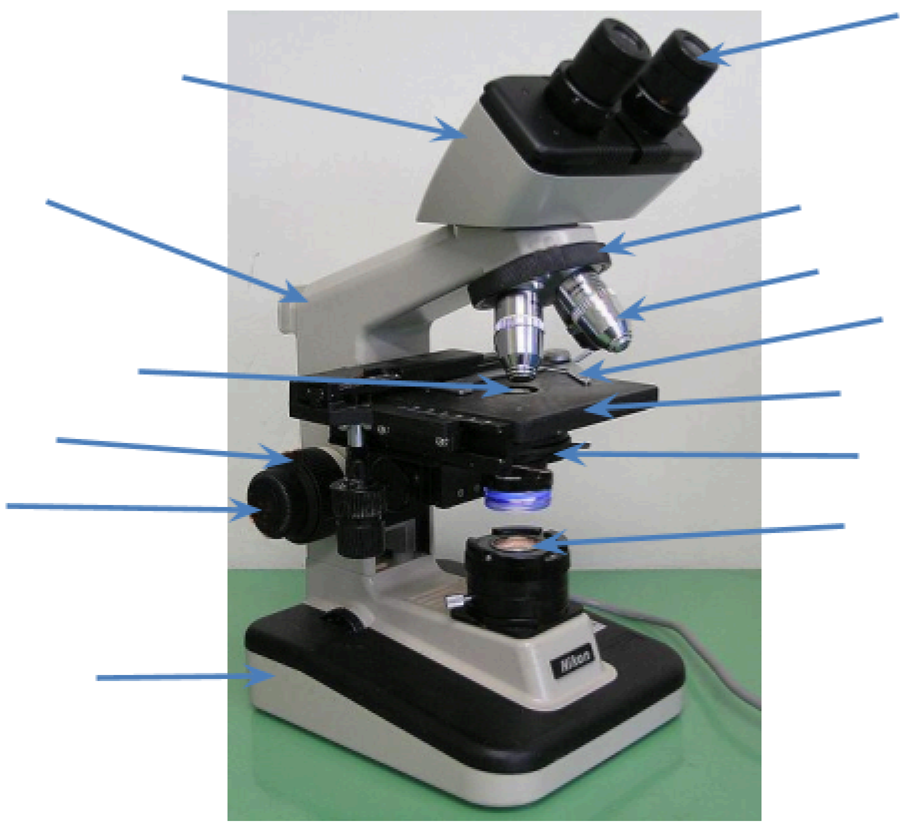


Figure 4. Surface and optical midsection of a human hair, 400X

Lab Activity

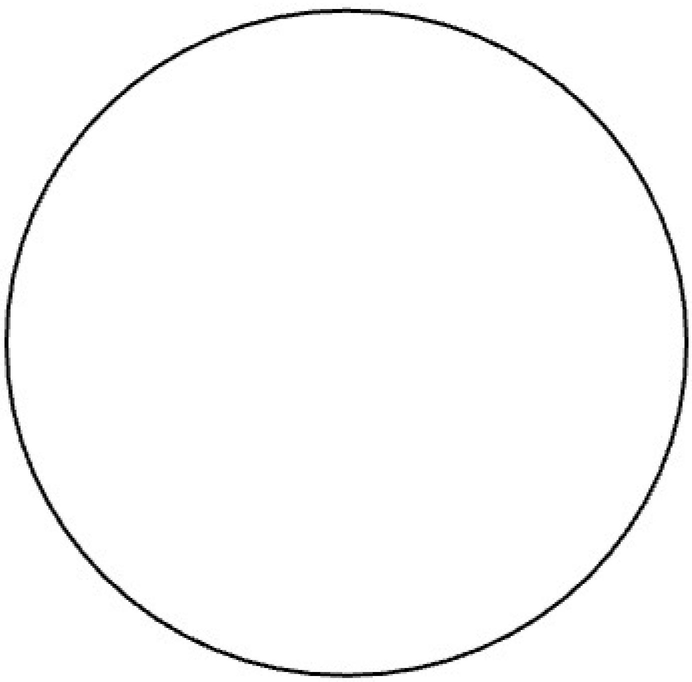
1. Identify the part of the microscope, use figure provided above.



2. Calculate total magnification using the microscope objectives available:

Ocular lens	Objective name	Objective Magnification	Total Magnification
10X	Scanning power	4X	
10X	Low power	10X	
10X	High power	40X	
10X	Immersion oil	100X	

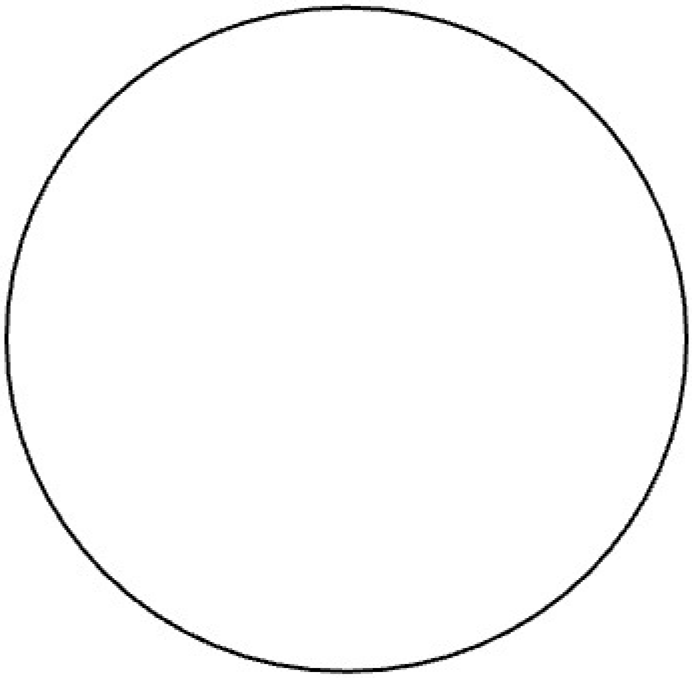
3. Look at the letter e and draw what you see



For 100% online courses – watch the following video;

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://rotel.pressbooks.pub/anatomyphysiology/?p=515#oembed-1

4. Using a microscope slide of simple squamous, cuboidal or columnar epithelium, draw and measure the dimensions of a one cell.



For 100% online courses – use the UM virtual microscope, choose any of the three slides listed here. Please note you will not be able to measure the dimension of the cell. This microscope does not have a scale included.

Simple squamous – UM slide #030: Mesentery, H&E, 40X (simple squamous epithelium in blood vessels and at surface).
Simple cuboidal – UM slide # 210: Kidney, H&E, 40X (simple cuboidal epithelium).
Simple columnar – UM slide # 029-1: Small intestine, H&E, 40X (simple columnar epithelium, simple squamous epithelium).

Assessment

1. What is the total magnification achieved when using the scanning objective?

2. What is the total magnification achieved when using the immersion oil objective?

3. How does the diameter of the scanning power field of view compare with that of the low power field?

4. What change occurred in the light intensity of the field of view when you change from the low power objective to high power objective?

5. After looking at the letter e, what has the lens system of the microscope done to the image?

6. When you move the image to the right, what direction did the image move in the field of view?

7. Match the names of the microscope parts with the descriptions

1	Coarse adjustment knob	______	Increases the light intensity
2	Arm	______	Platform that supports the microscope slide
3	Condenser	______	Concentrates light onto the specimen
4	Eyepiece (ocular)	______	Causes the stage to move upward or downward
5	Field of view	______	After the light passes through the specimen, it next enters this lens system
6	Iris/diaphragm	______	Holds a microscope slide in position
7	Nosepiece	______	Contain a lens at the top of it
8	Objective lens	______	Serves as a handle to carry the microscope
9	Stage	______	Part of which the objective lenses are attached
10	Stage clip	______	Circular area seen through the eyepiece

An interactive H5P element has been excluded from this version of the text. You can view it online here:
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Media Attributions

- The Microscope Question 9

THE CELL

Pre-laboratory Activity – The Animal cell

Before you come to the lab, you should prepare yourself for the weekly lab activity, read the corresponding chapter in your textbook and complete the pre-lab activity.

Part 1 – Definitions

1. Define the term cell
2. Define the term cytology
3. Define plasma membrane, cytoplasm, cytosol, nucleus and nucleolus

Part 2 – Drawing Activity

1. Draw an animal cell.
2. List the components of the cell using different colors.
3. Color the structures of an animal cell using the color scheme you developed. Use a different color for each of the cell components if possible.

Laboratory Activity: The Animal Cell: Structure and Function

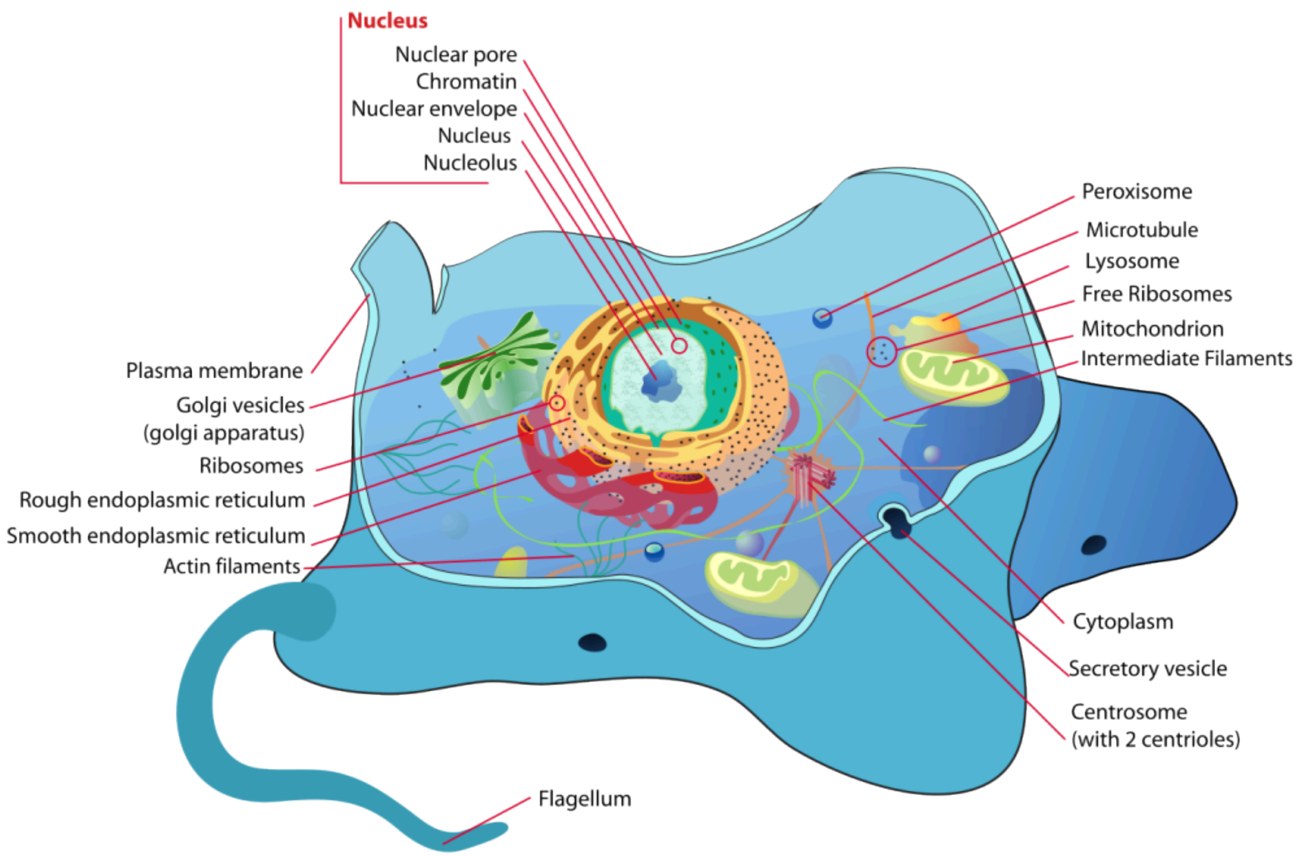


Figure 1: The animal cell

Introduction

The term cell comes from the Latin word "cella", meaning "small room". Cells were discovered by Robert Hooke in 1665, who named them for their resemblance to cells inhabited by Christian monks in a monastery.

The cells is a small container, it is the basic structural, functional, and biological unit of all known living organisms. A "cell" is the smallest unit of life known to man. Cells consist of a semi solid fluid, called cytoplasm and enclosed within a plasma membrane, which contains of biomolecules such as proteins, carbohydrates, lipids and nucleic acids as well as ions. Humans contain about 30 trillion (3013) cells. Cells size varies between 1 and 100 micrometers, therefore they are only visible only under a microscope.

The "Cell theory" was developed in 1839 by Matthias Jakob Schleiden and Theodor Schwann, it states that all organisms are composed of one or more cells, that cells are the fundamental unit of structure and function in all living organisms, and that all cells come from pre-existing cells.

It is believed that cells emerged on Earth at least 3.5 billion years ago, a common ancestor that has given rise to all organisms we have on earth.

Components of the Cell

Animal cells have a number of organelles and structures that perform specific functions inside the cell and allow them to communicate with other cells, to move or move particulate away from their surface.

Cells have evolved to perform different functions therefore they do not always all the organelles or structures we show here, but we will introduce you to most of the organelles present in animal cells.

PLASMA MEMBRANE

The plasma membrane is a membrane that surrounds an animal cell, it is the boundary between the inside and the outside of the cell. The plasma membrane is made of a double layer of phospholipids. Other compounds such as proteins and carbohydrates may be embedded into the plasma membrane and are responsible to receive cellular signals from other cells, and to allow passage of substances in and out of the cell by creating channels through the membrane.

NUCLEUS

The nucleus is an organelle found in eukaryotic cells. It is fully enclosed by nuclear membrane and it contains the majority of the cell's genetic material.

The nucleus consists of a nuclear envelope, chromatin, and a nucleolus. The nuclear envelope is composed of a set of double membranes with numerous pores (nuclear pores) to allow substances to move in and out of the nucleus. Chromatin contains the majority of a cell's DNA. It condenses to form chromosomes during cell division. The nucleolus is the center core of the nucleus. Nucleoli are made of proteins, DNA and RNA and it is responsible for ribosome biogenesis. The nucleolus makes ribosomal subunits from proteins and ribosomal RNA (rRNA). It then sends the subunits out to cytoplasm where they combine into complete ribosome units.

The main function of the cell nucleus is to control gene expression and mediate the replication of DNA during the cell cycle.

CYTOPLASM

The cytoplasm is the internal area of an animal cell. It consists of a jelly-like substance called 'cytosol' and allows organelles and cellular substances to move around the cell as needed.

ENDOPLASMIC RETICULUM (ER)

The endoplasmic reticulum is a network of membranes that originate from the nuclear envelope. The membranes are important for many cellular processes such as protein production and the metabolism of lipids and carbohydrates

The endoplasmic reticulum includes; the smooth ER and the rough ER. The smooth ER is a smooth membrane and has no ribosomes, whereas the rough ER has ribosomes that are used to produce proteins.

MITOCHONDRIA

They are the site of cellular respiration – the process that breaks down sugars and other compounds into cellular energy (ATP). It is in the mitochondria where oxygen is used as a final electron acceptor in the respiratory chain to generate many molecules of ATP.

GOLGI APPARATUS

The Golgi apparatus (or Golgi body) is a set of membranes found within the cell but is not attached to the nucleus of the cell. It serves many important functions including post-translational modification of proteins and lipids and transporting cellular substances inside and outside the cell.

RIBOSOMES

Ribosomes are involved in proteins synthesis. They can be either attached to the endoplasmic reticulum or floating freely in the cell's cytoplasm. They are formed by two subunits of ribosomal RNA.

PEROXISOMES

S organelles involved in the digestion of compounds such as fats, amino acids, and sugars. They also produce hydrogen peroxide.

LYSOSOMES

Lysosomes are essentially waste disposal units. They contain a range of enzymes that digest molecules such as lipids, carbohydrates, and proteins.

CENTROSOMES

Centrosomes are involved in cell division and the production of flagella and cilia. They consist of two centrioles that are the main hub for a cell's microtubules. As the nuclear envelope breaks down during cell division, microtubules interact with the cell's chromosomes and prepares them for cellular division.

VILLI

Villi are hair-like extensions of the plasma membrane. They are important for absorption of substances from their surrounding environment because they essentially increase the surface area of a cell.

FLAGELLA

Flagella are appendages that are involved in movement. Flagella (plural of flagellum) provide the mechanical ability for cells to move under their own power.

A flagellum is a long, thin extension of the plasma membrane and is driven by a cellular engine made from proteins. Flagella are particularly important for certain animal cells. In humans the only cell that contains flagella is the sperm cells,

DIFFERENT TYPES OF ANIMAL CELLS

There are many different types of animal cells. I will mention only a few here.

SKIN CELLS

The skin cells of animals mostly consist of keratinocytes and melanocytes

Melanocytes produce a compound called 'melanin' which gives skin its color.

MUSCLE CELLS

Also called myocytes, muscle fibers or muscle cells are long tubular cells responsible for moving an organism's limbs and organs. Muscle cells can be either skeletal muscle cells, cardiac muscle cells or smooth muscle cells.

BLOOD CELLS

Blood cells: red blood cells and white blood cells. Red blood cells make up around 99.9% of all blood cells and are responsible for delivering oxygen from the lungs to the rest of the body. Red blood cells do not have a nucleus. White blood cells are a vital part of an animal's immune system and help to battle infections by killing off damaging bacteria or damaged/infected cells.

NERVE CELLS

There are two types of nerve cells, neurons and neuroglia. There are many more neuroglia than neurons. Neuroglia are there to support, protect and nourish neurons. The human brain alone has ~ 100 billion neuron cells. They allow communication between cells. They contain a body, many dendrites and one axons. Dendrites and axons are extensions from the cell that receive and transport signals to and from the cell, respectively.

FAT CELLS

Fat cells, also known as adipocytes. They are used to store fat as energy reserves.

Materials

1. 24-color pencil set (students should bring their own set of color pencils)
2. Black sharpie
3. Labeling tape
4. Individual slides:
    1. Simple squamous epithelium (cheek cells)
    2. Columnar epithelium (isolated)
    3. Smooth muscle (teased)
    4. Skeletal muscle (teased)
    5. Human blood (smear)
    6. Fish blastocyst slide (mitosis)
5. Demonstration slides of organelles with special stains/treatments (these slides will be set up as demo stations at the instructor's bench).
    1. Sickle cell anemia
    2. Cardiac muscle (Intercalated disk stain)
    3. Lymphocytic leukemia
6. Anatomical models
    1. 3-D anatomical model of an animal cell (with key).
    2. 3-D model of mitosis (with key).

Note: the type of slides may vary depending on what is available in a laboratory.

Review the previous lab, the microscope as you will be using the microscope for this activity and for many others during the semester.

You will also need to review your textbook and any material your instructor has assigned as supplemental reading, as well as posted videos and animations related to the animal cell, the cell cycle and mitosis.

Objectives

1. Define the terms cell and cytology
2. List and identify the parts of an animal cell
3. List the functions of main components of an animal cell

Laboratory Activity – The animal cell and its components

A. Identify the following parts of the cell using a 3-D model of an animal cell

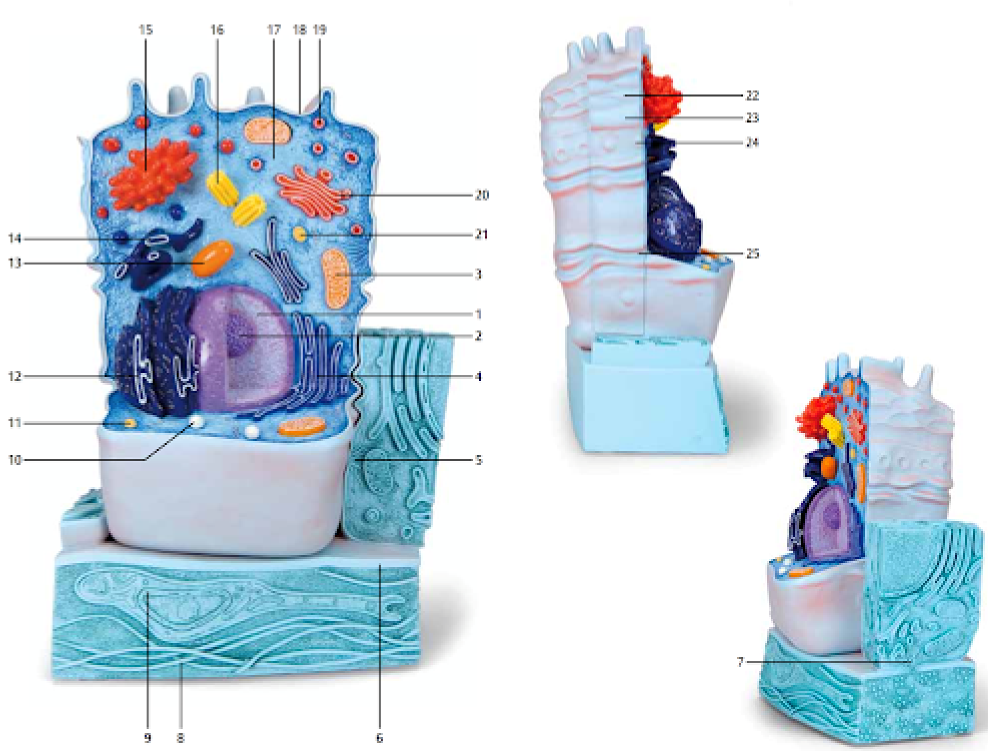


Figure 2: 3D Animal Cell

B. Cell types – observe and draw the following cells types.

Number	Part of the cell or organelle
1	
2	
3 (same as #13, l.s.)	
4 (same as #14, l.s.)	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	
20 (same as #15, l.s.)	
21	
22	
23	
24	
25	

Instructions: Using the microscope observe slides of simple columnar epithelium, skeletal muscle and a human blood smear.

Use scanning objective to locate the samples, then switch to low or high power to be able to see the cell morphology.

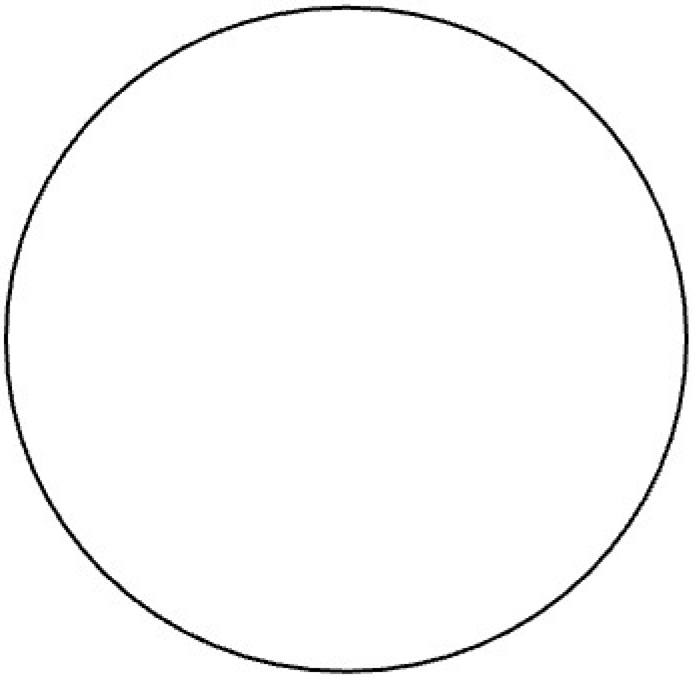
If these types of cells are not available use what your instructor provides for you.

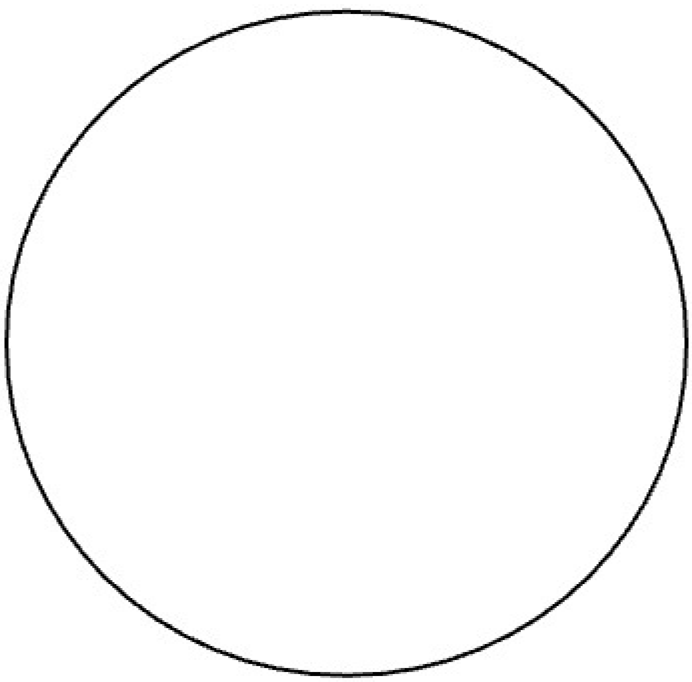
B1. Simple columnar epithelium

Observe tall rectangular cells with the nuclei oriented toward the base of the cells. Then draw what you see in the space provided. Make sure to write down the total magnification used.

B2. Skeletal Muscle Fiber

Observe long cells with a banding pattern and the nuclei oriented toward periphery. Then draw what you see in the space provided. Make sure to write down the total magnification used.





B3. Human blood smear

- Observe a human blood smear under the microscope. First use the scanning objective to locate the sample, then switch to higher objectives.
- To see the shape of the cells you need to use the high power objective (40X).
- You will see the formed elements of the blood, predominantly red blood cells (background) and a few white blood cells (cells with transparent cytoplasm and a dark purple nucleus). You may also see very

small fragments of cells called platelets (few).

- Then draw what you see in the space provided. Make sure to write down the total magnification used.

C. Demonstration slides (special stains/treatments or disease states)

- Sickle cell anemia
- Cardiac muscle (Intercalated disk stain)
- Lymphocytic leukemia

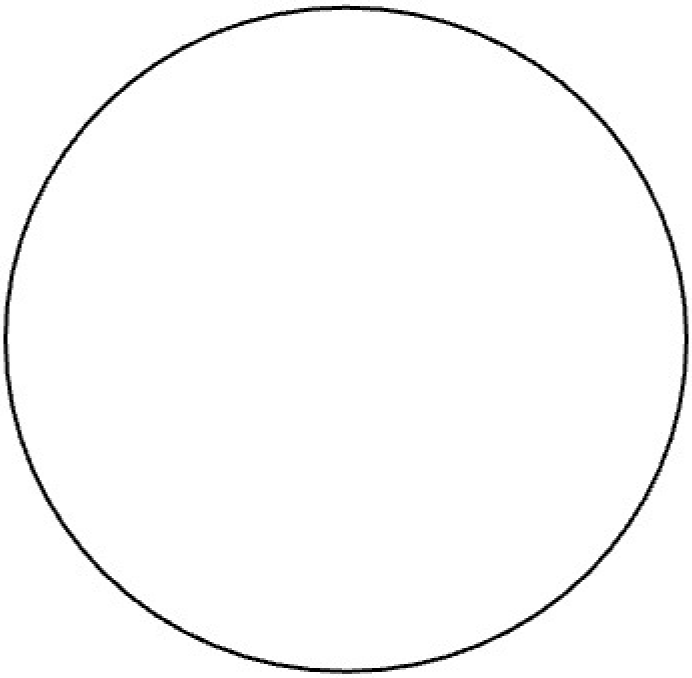
Observe the difference in cell morphology on the slides set as a demo on the instructor's bench.

Note: The type of slide may vary depending on what is available in the lab.

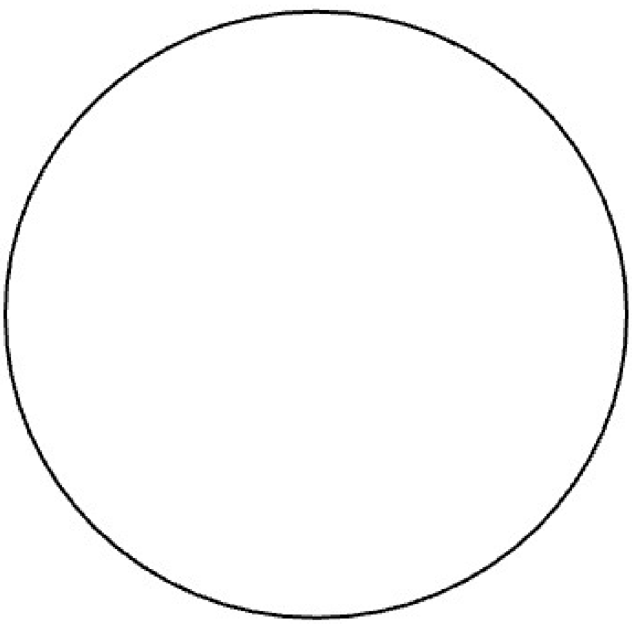
D. Mitosis

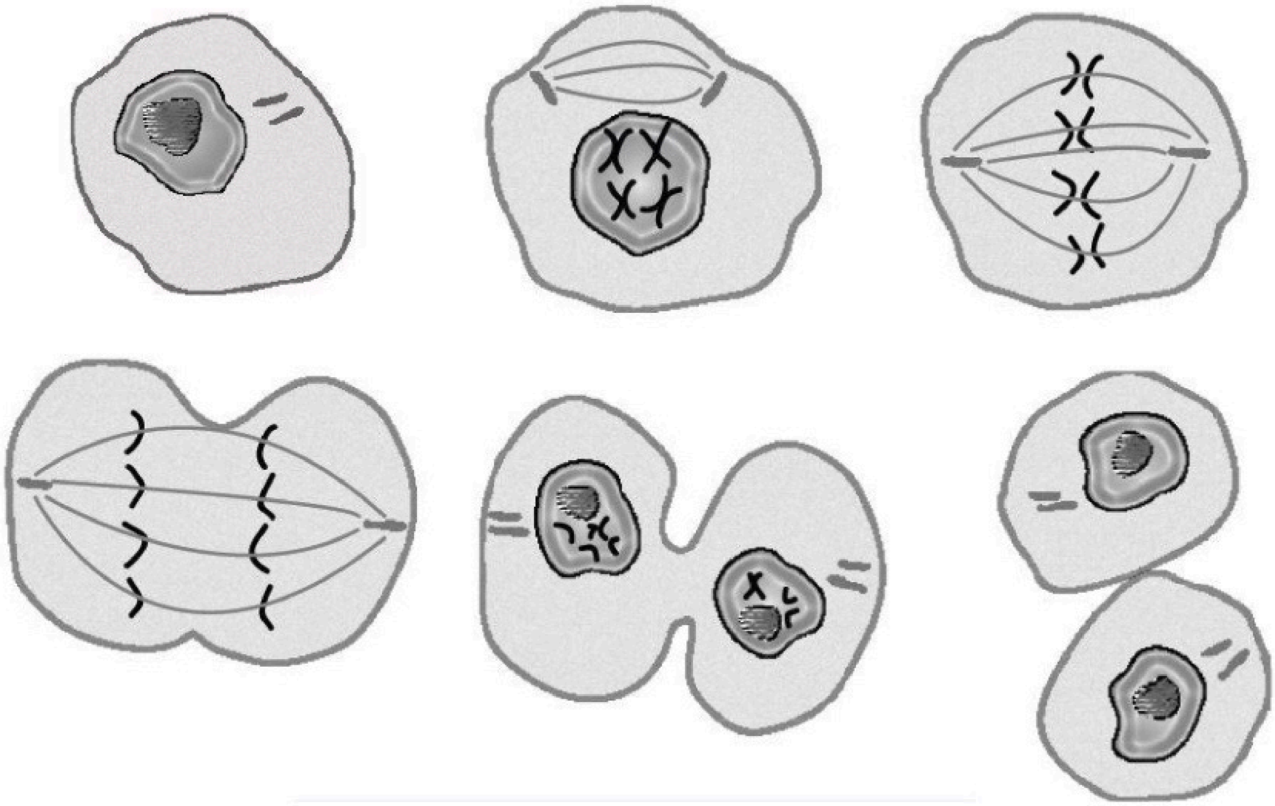
D1. Fish Blastocyst

Obtain a microscope slide of Fish Blastocyst and try to find and identify the different stages of mitosis. Then draw what you see in the space provided. Make sure to write down the total magnification used.



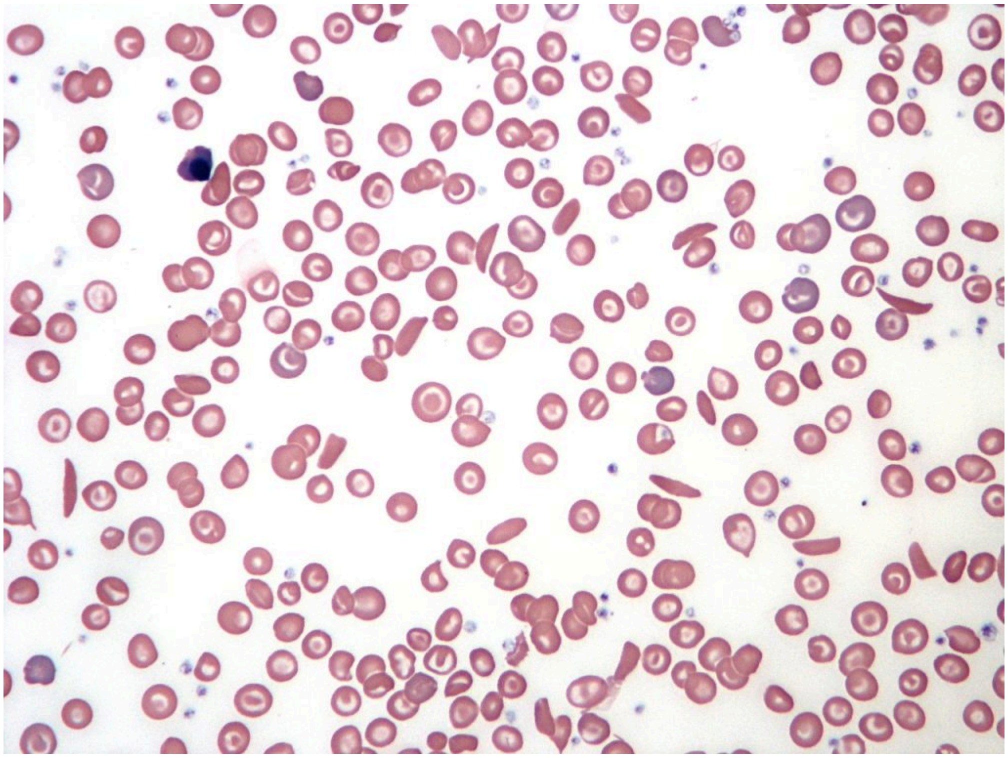
D2. Label the stages of Mitosis using the images shown here



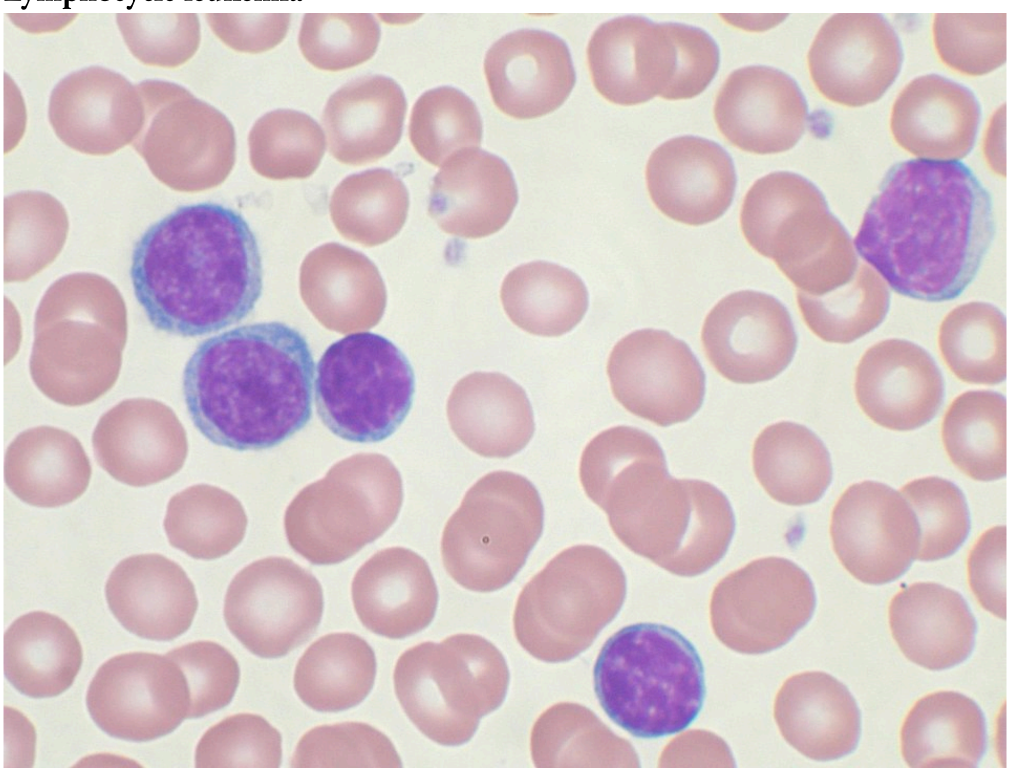


For 100% online labs use the following links:

- **Simple columnar epithelium** – UM Slide # 176: Colon, H&E, 40X (simple columnar epithelium)
- **Skeletal Muscle Fiber** – UM Slide #058L – Skeletal muscle, longitudinal section, H&E, 20X and 40X (banding pattern A I Z H [60787 x 18392, 34840 x 9034, 64339 x 17968])
- **Human blood smear** – UM Slide #086: Human blood smear, Giemsa stain, 86X scan from hematopathology normals collection (this slide contains 3 basophil cells)
- **Sickle cell anemia**



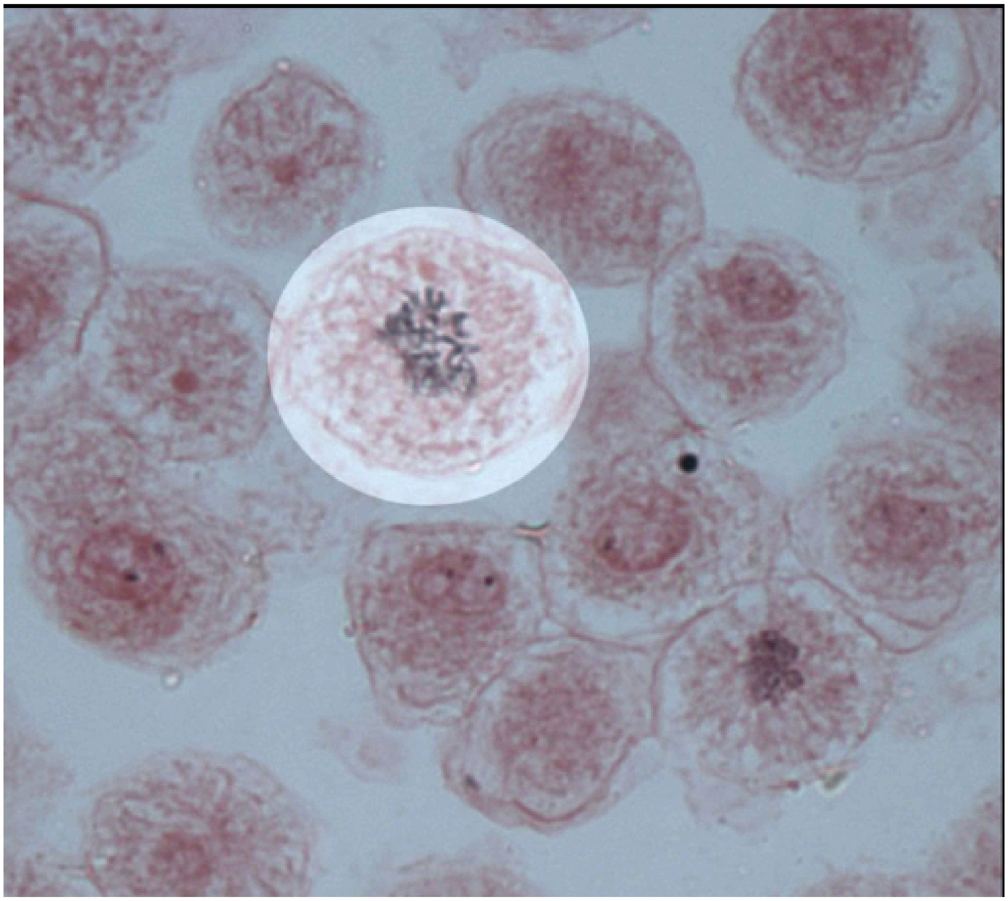
- **[Cardiac muscle (Intercalated disk stain)](#) – UM Slide #098-1: Heart, ventricle, H&E, 40X** (cardiac muscle, intercalated discs)
- **Lymphocytic leukemia**



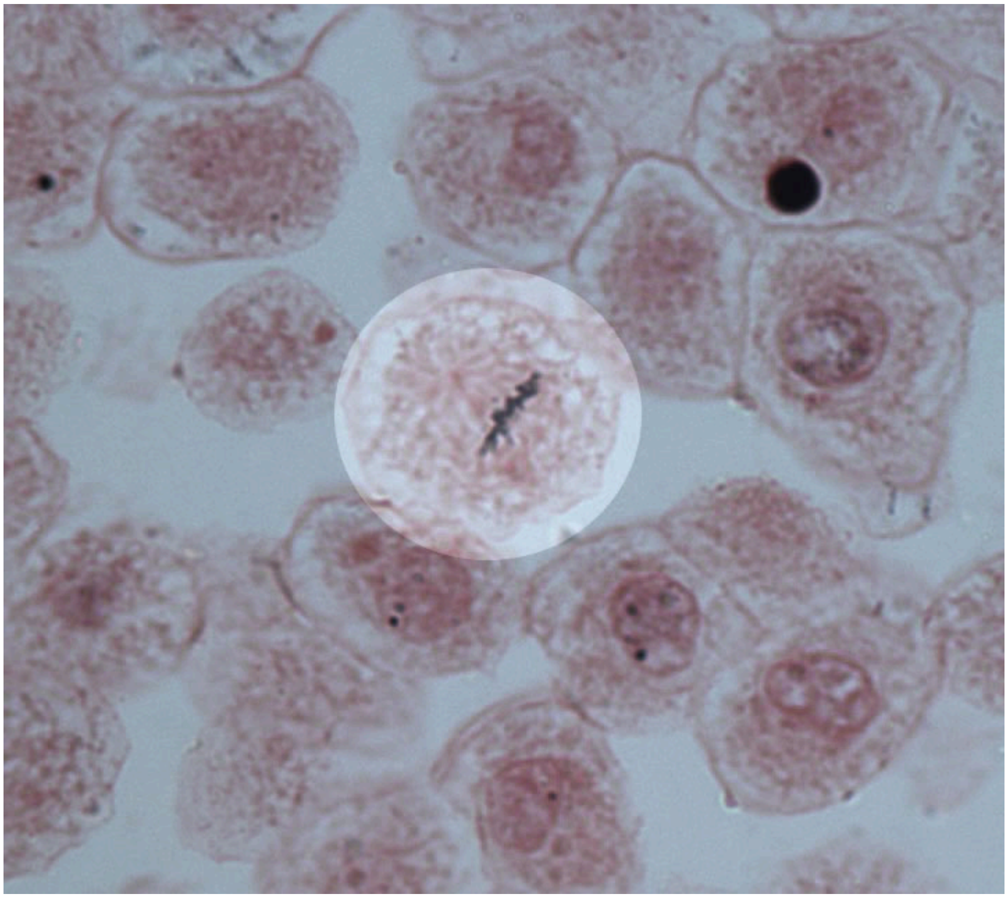
- **Fish Blastocyst**

Whitefish embryos are commonly used in the study of mitosis due to their rapid cell division and relatively large and transparent cells. Here are some images of mitosis in white fish blastocysts.

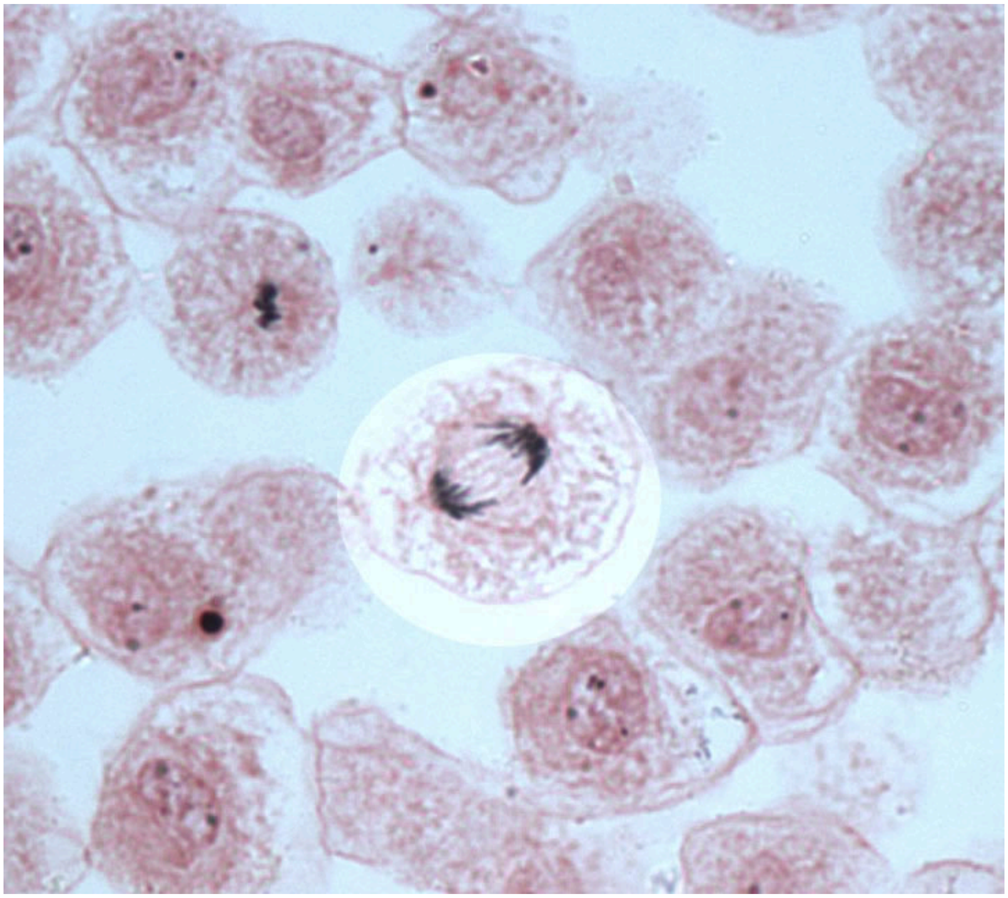
Visit the Biology Corner



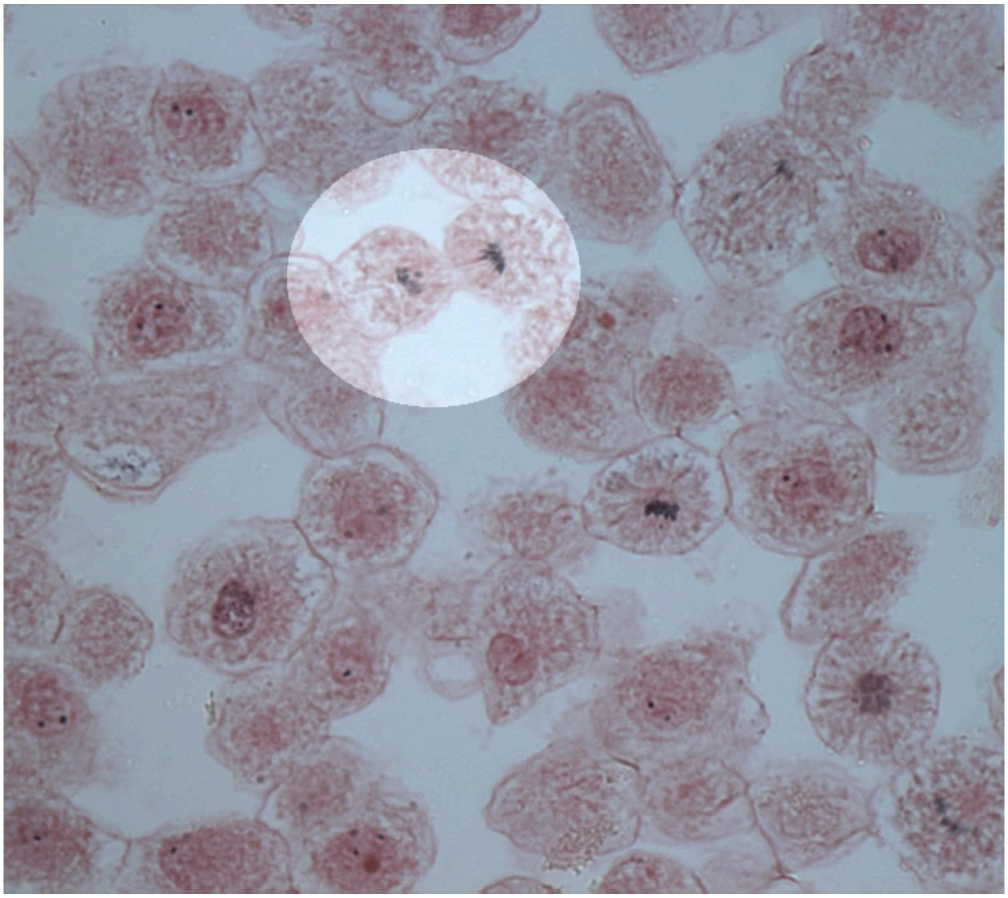
Prophase



Metaphase



Anaphase



Telophase

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THE STUDY OF TISSUES: HISTOLOGY

Laboratory Exercise – Tissues and Histology

Tissues are made of similar groups of cells that work together to carry out a specific function. Humans are multicellular organisms; the cells in our tissues work in a coordinated and synchronized effort in conjunction with other types of tissues. The human body has four main categories of tissues: epithelial, connective, muscular and neural tissues.

The branch of biology that studies the microscopic structure of tissues is called histology.

Compact bone, x.s. 400x

Learning Outcomes

1. List the 4 main types and characteristics of tissue found in the human body
2. Identify different types of epithelial tissue based on cell morphology and number of layers.
3. List the location and function of selected epithelial tissues in the human body

4. Identify different types of connective tissue.
5. List the location and function of selected connective tissues in the human body
6. Identify the three types of muscle tissue found in the human body.
7. List the location and function of three types of muscle tissue in the human body
8. Identify cell types in nervous tissue.
9. Describe the function of cells found in nervous tissue.

Laboratory supplies

Compound microscopes

Prepared slides:

Kidney – capsule of Bowman's – simple squamous epithelium
Lung – alveoli – simple squamous epithelium
Kidney – tubules x.s. and l.s – simple cuboidal epithelium
Small intestine – simple columnar epithelium
Esophagus – non keratinized stratified squamous epithelium
Thick Skin – keratinized stratified squamous epithelium
Thin skin – sweat glands – stratified cuboidal epithelium
Trachea – pseudostratified columnar ciliated epithelium
Urinary bladder – transitional epithelium
Areolar CT –
Adipose CT –
Reticular CT – lymph node
Dense regular connective tissue – Tendon
Dense irregular connective tissue – skin (dermis)
Elastic connective tissue – Aorta
Hyaline cartilage
Elastic cartilage
Fibrocartilage
Compact bone – ground
Human blood smear
Cardiac muscle – intercalated disk stain
Smooth muscle
Skeletal muscle

Neuronal smear
Notebook, pencil, eraser, color pencils

Pre-Laboratory Activities – Tissues and Histology Laboratory

It is expected that students read the corresponding chapter of the assigned textbook (Tissues), view videos/animations (if applicable) and then answer the questions shown below before coming to the laboratory.

Epithelial Tissue

View "Classification of Epithelia – Drawn & Defined" video from YouTube using the link shown below

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://rotel.pressbooks.pub/anatomyphysiology/?p=519#oembed-1

Complete the following questions

1. Draw a typical epithelial cell (at least two of them together) and label the apical portion, microvilli, nucleus, tight junctions, desmosomes, hemidesmosomes and basal portion.

2. List the three basic epithelial cell shapes

3. How is epithelial tissue classified?

4. Name the two types of epithelia that are not classified based on the characteristic you mentioned above?

5. Fill in the table shown below; epithelial tissue and its location. You will use it as reference during the lab activity.

Type of epithelial tissue	**Locations**
Simple squamous epithelium	
Simple cuboidal epithelium	
Simple columnar epithelium	
Pseudostratified columnar ciliated epithelium with goblet cells	
Stratified squamous epithelium (non-keratinized)	
Stratified squamous epithelium (keratinized)	
Stratified cuboidal epithelium	
Stratified columnar epithelium	
Transitional epithelium	

Connective Tissue

View "Tissues, Part 4 – Types of Connective Tissues: Crash Course Anatomy & Physiology #5" video from YouTube using the link shown below:

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://rotel.pressbooks.pub/anatomyphysiology/?p=519#oembed-2

Answer the following questions:

1. List the three shared characteristics of connective tissue.

2. Name 3 types of fibers found in connective tissue.

1. Define the following terms:
   1. Fibroblast

   2. Chondrocyte

   3. Osteocyte

4. Matrix

Muscular Tissue

View "Three types of muscle – Khan Academy" video from YouTube using the link shown below

> *One or more interactive elements has been excluded from this version of the text. You can view them online here: https://rotel.pressbooks.pub/anatomyphysiology/?p=519#oembed-3*

Answer the following questions

1. List the three types of muscular tissue

2. List the characteristics of skeletal muscle

3. List the characteristics of smooth muscle

4. List the characteristics of cardiac muscle

Nervous Tissue

View the following videos

1. "Introduction to neural cell types – Khan academy" video from YouTube using the link shown below:

> *One or more interactive elements has been excluded from this version of the text. You can view them online here: https://rotel.pressbooks.pub/anatomyphysiology/?p=519#oembed-4*

2. "The neuron" video from YouTube using the link shown below:

> *One or more interactive elements has been excluded from this version of the text. You can view them online here: https://rotel.pressbooks.pub/anatomyphysiology/?p=519#oembed-5*

Answer the following questions

1. Name the two types of cells present in nervous tissue. Describe their function.

2. Draw and label a typical motor neuron (include: dendrites, body, mitochondria, endoplasmic reticulum system, nucleus, axon, Schwan cells, telodendria)

Introduction to Tissues and Histology

Tissues are defined as collections of cells and the extracellular substances surrounding them that gather to perform a specific function. There are four main types of human tissue: epithelial, connective, muscular, and nervous. Histology is the microscopic study of tissues.

Epithelial Tissue

The epithelium consists of cells of diverse shapes that contain little extracellular matrix. The epithelium covers surfaces and lines the lumen of internal hollow organs, usually has an apical portion, a basement membrane for attachment, and it is avascular. The main function of epithelial tissue is to protect structures, it acts as barriers allowing only some substances to pass through epithelial layers. Epithelium also secretes and absorb substances depending on its location.

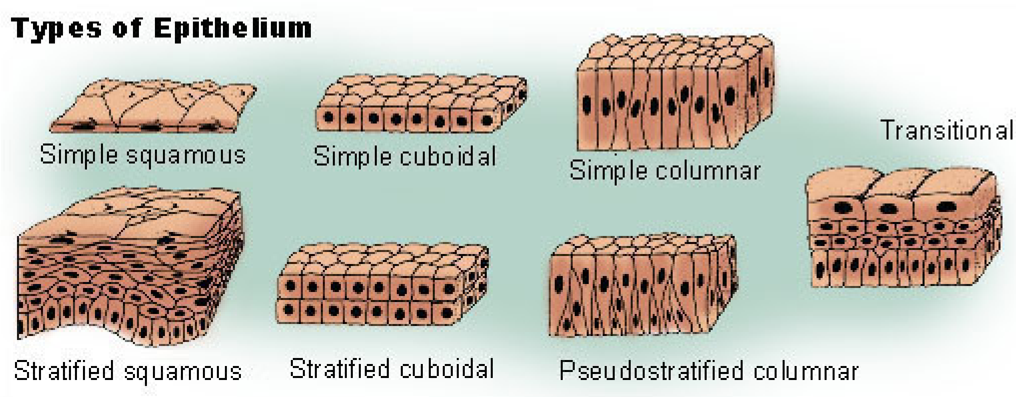
Epithelium is mostly classified based on the morphology of the cells and the number of cell layers present. The types of cells can be squamous (flat), cuboidal and columnar. Epithelium may be simple (one layer) or stratified (more than one layer of cells).

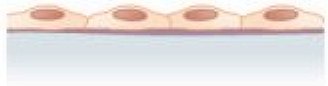
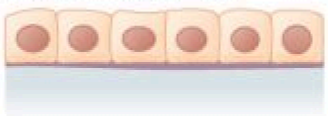
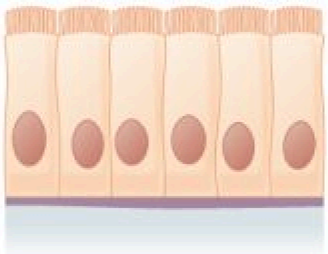
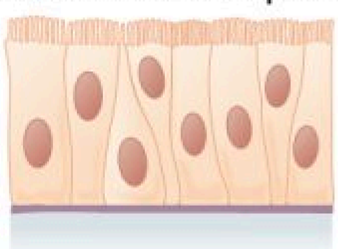
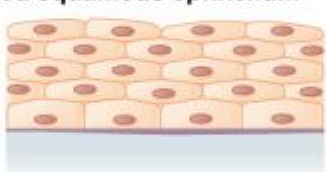
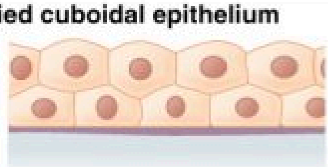
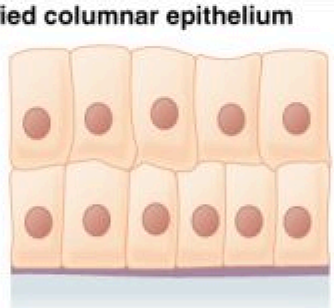
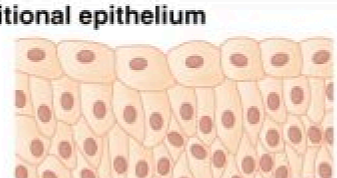
You can combine both cell shape and number of layers to have the following types of epithelium:

1. Simple squamous
2. Stratified squamous (nonkeratinized or keratinized)
3. Simple cuboidal
4. Stratified cuboidal
5. Simple columnar
6. Stratified columnar

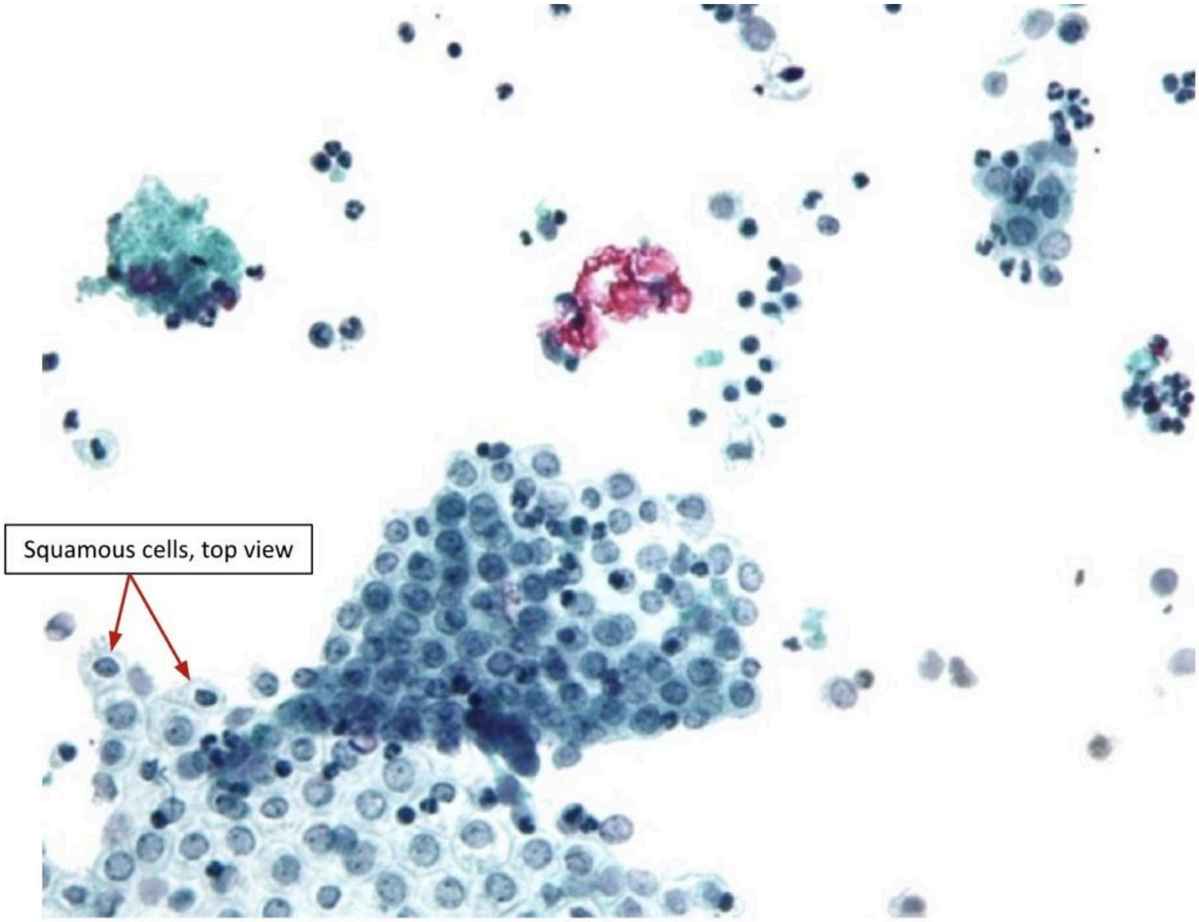
Besides those we also have other two types of epithelia that are not classified based on cell shape and number of layers:

7. Transitional epithelium (stratified, with cells that can change shape, cells have an apical dome shape),
8. Pseudostratified columnar ciliated epithelium – has a single layer of cells that appears stratified, because some cells do not reach the apical portion of the layer.



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

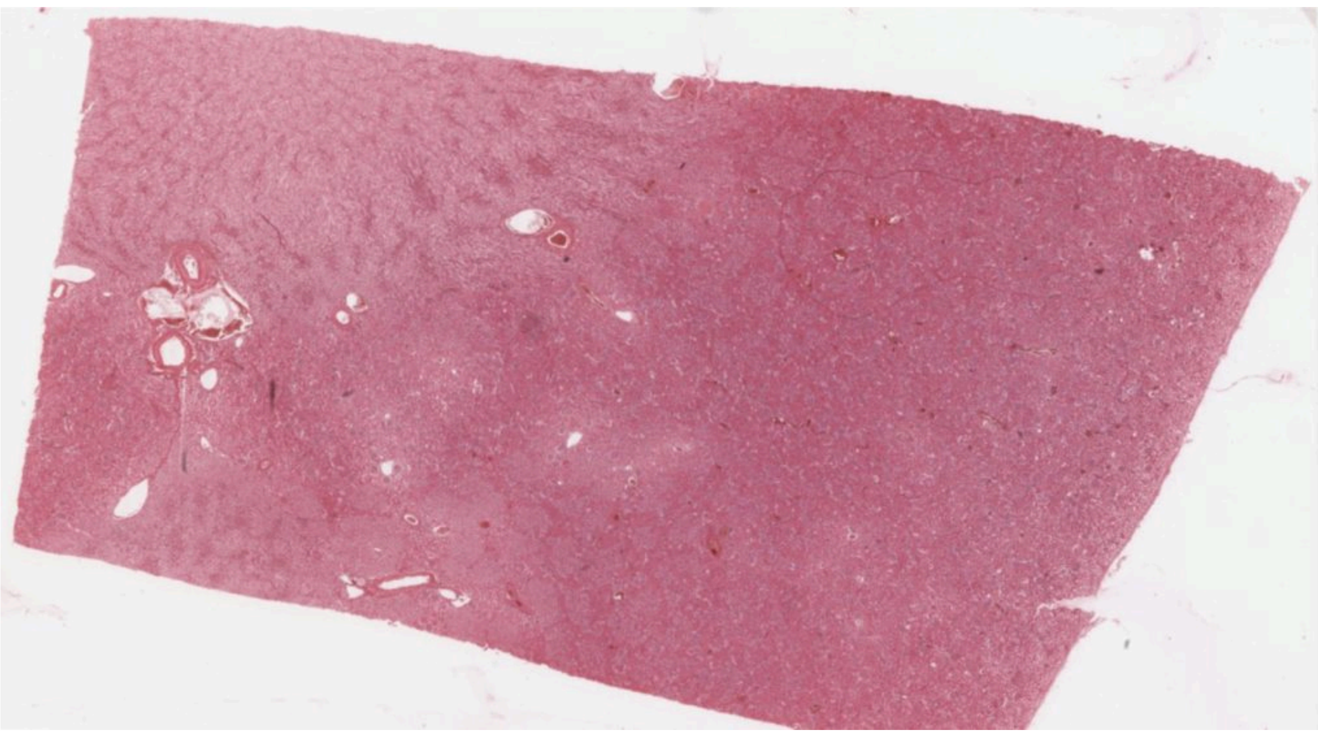
Selected histological images of Epithelial tissue



Virtual Microscope

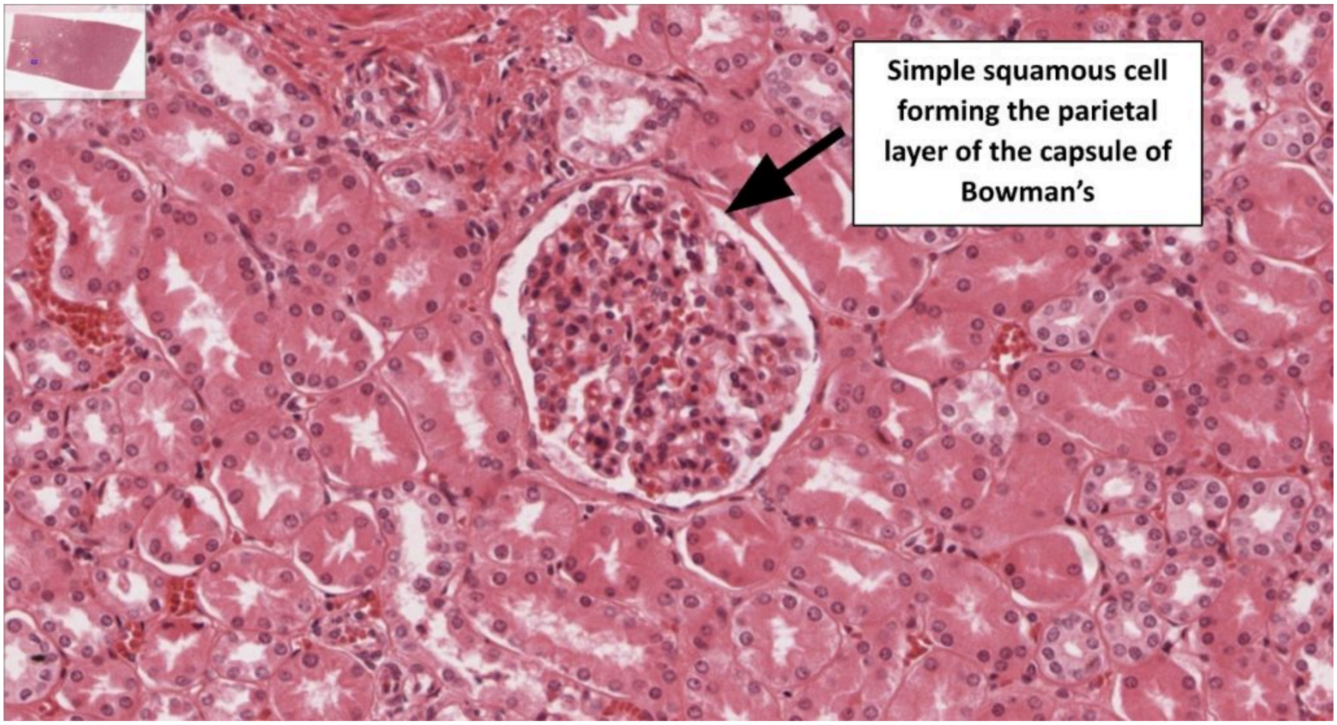
Use the QR code shown below to access the [Virtual Microscope from University of Michigan](). Use the +/- signs below the image to increase/decrease magnification. You may also scan the image – look at the top left of the main view, you will see a smaller window with a blue square, drag the square to change the area where you like to see. You can also move to a different area in the main view by dragging the small white hand shown there.

Simple cuboidal epithelium

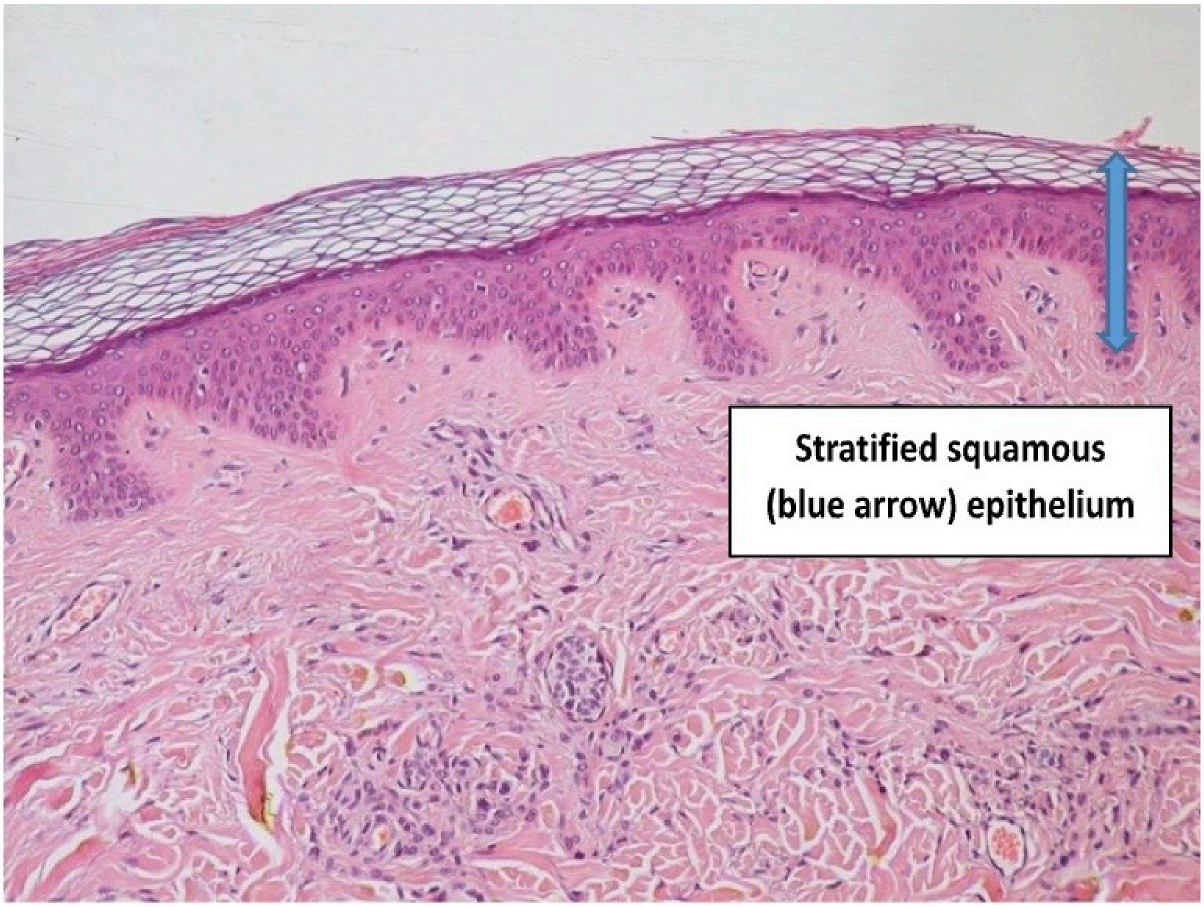


Kidney, H&E, 40X (simple cuboidal epithelium), #009-N1

Then, focus on the area shown below (capsule of Bowman's, parietal layer – containing simple squamous epithelium – flat cells:


Simple squamous cell
forming the parietal
layer of the capsule of
Bowman's

Stratified squamous epithelium (keratinized)

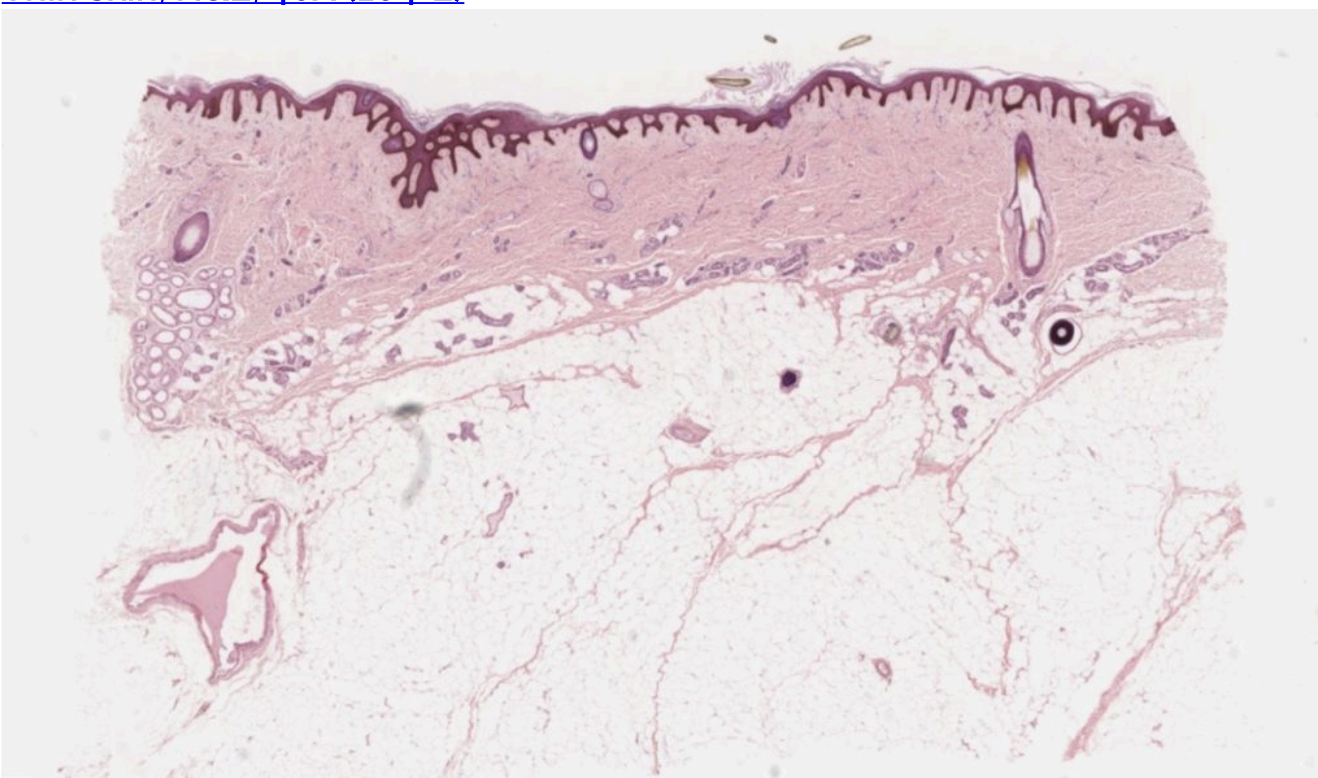


Normal Epidermis and Dermis with Intradermal Nevus 10x

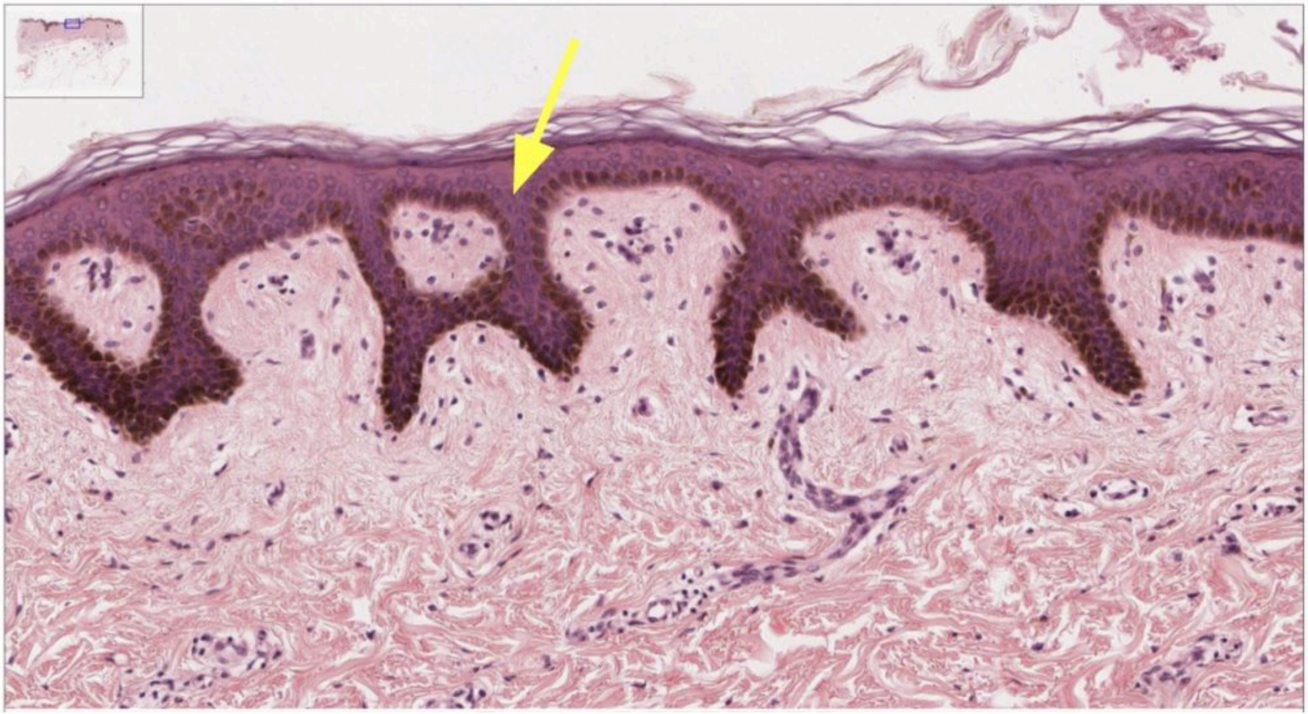
Virtual Microscope

Use the QR code shown below to access the [Virtual Microscope from University of Michigan](). Use the +/- signs below the image to increase/decrease magnification. You may also scan the image – look at the top left of the main view, you will see a smaller window with a blue square, drag the square to change the area where you like to see. You can also move to a different area in the main view by dragging the small white hand shown there.

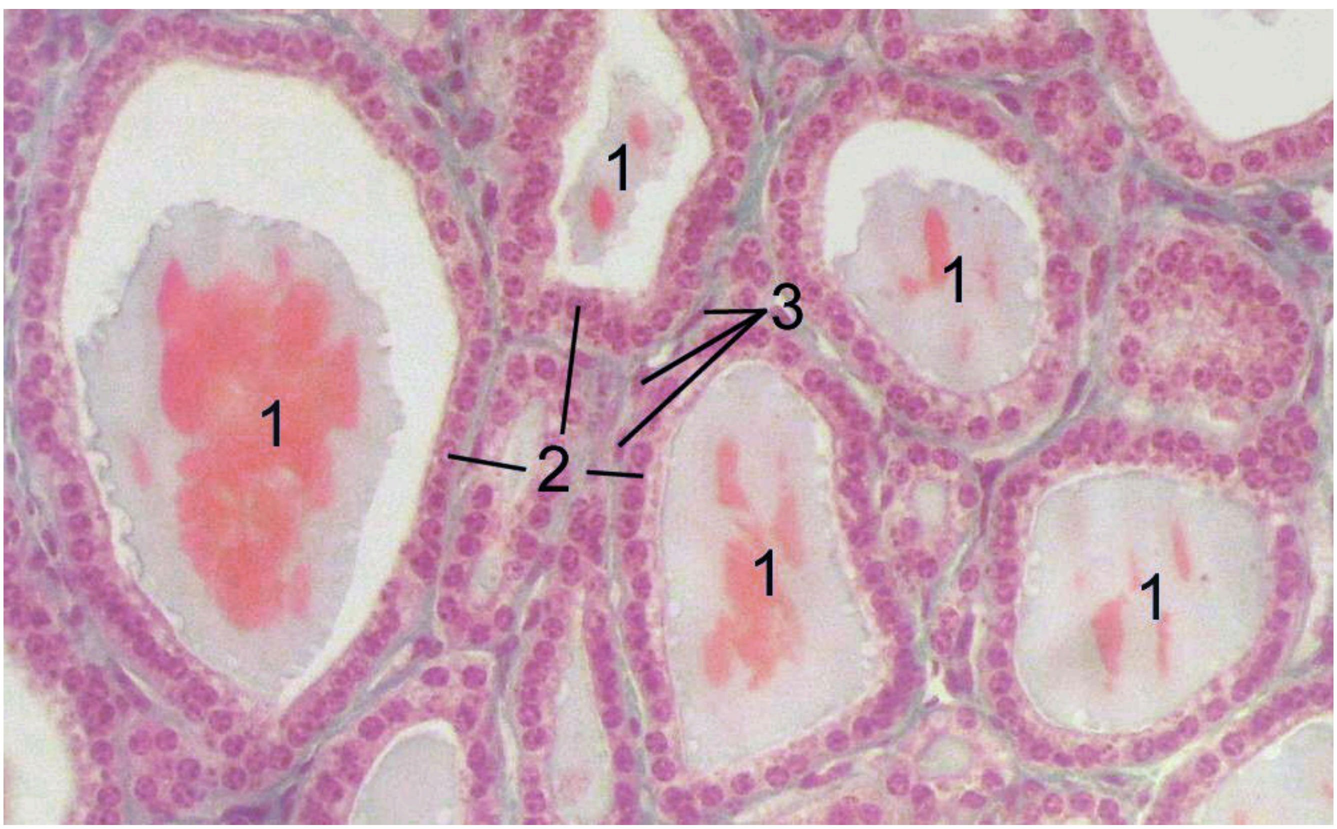
Thin skin, H&E, 40X (104-2)



Then focus on the epidermal layer – contains stratified squamous epithelium



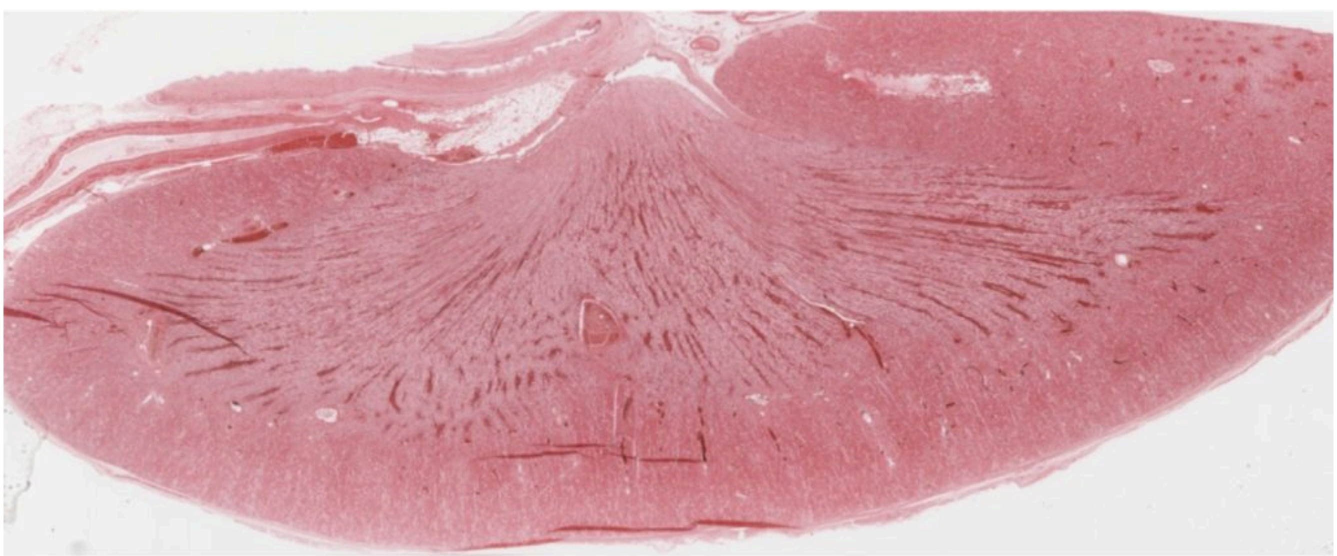
Simple cuboidal epithelium



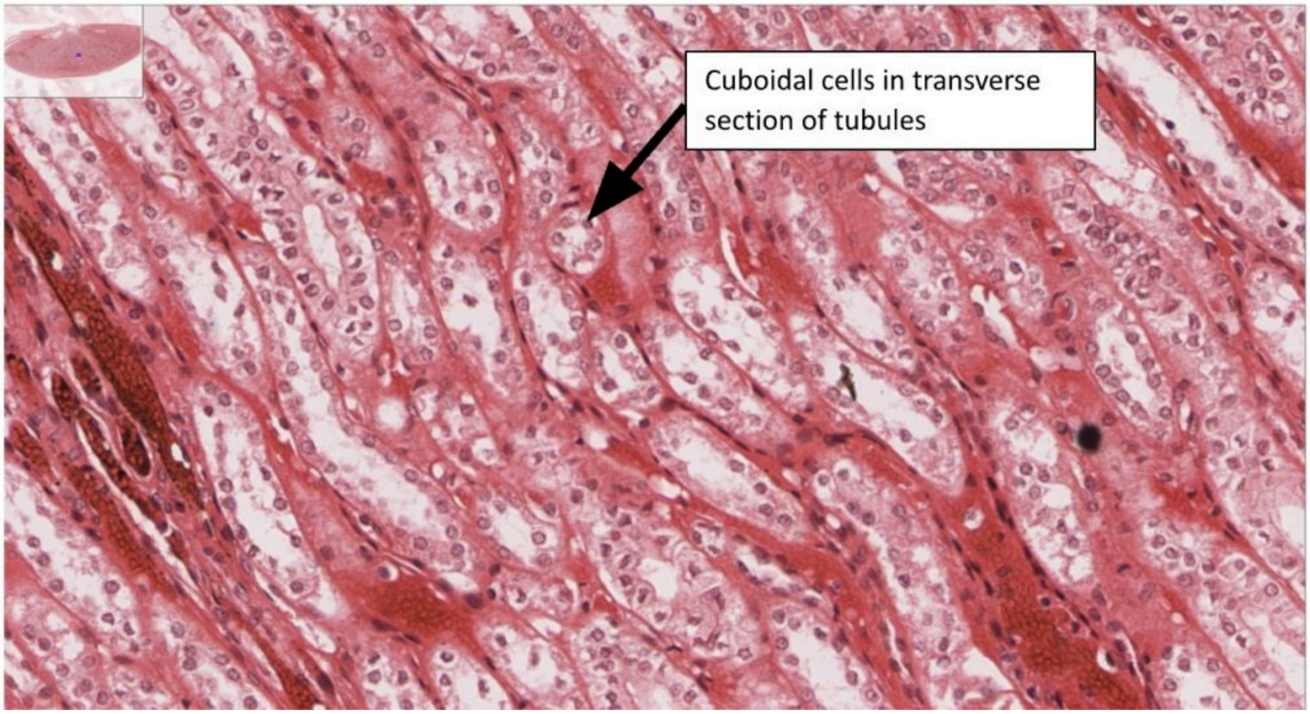
This is a microscope side of thyroid; showing follicles made of follicular cells (cuboidal shape), labeled #2 and filled with a colloid substance, labeled #1. The cells located between the follicles, labeled #3 are also of cuboidal shape and are called parafollicular cells.

Virtual Microscope – use the QR code shown below to access the Virtual Microscope from University of Michigan. Use the +/- signs below the image to increase/decrease magnification. You may also scan the image – look at the top left of the main view, you will see a smaller window with a blue square, drag the square to change the area where you like to see. You can also move to a different area in the main view by dragging the small white hand shown there.

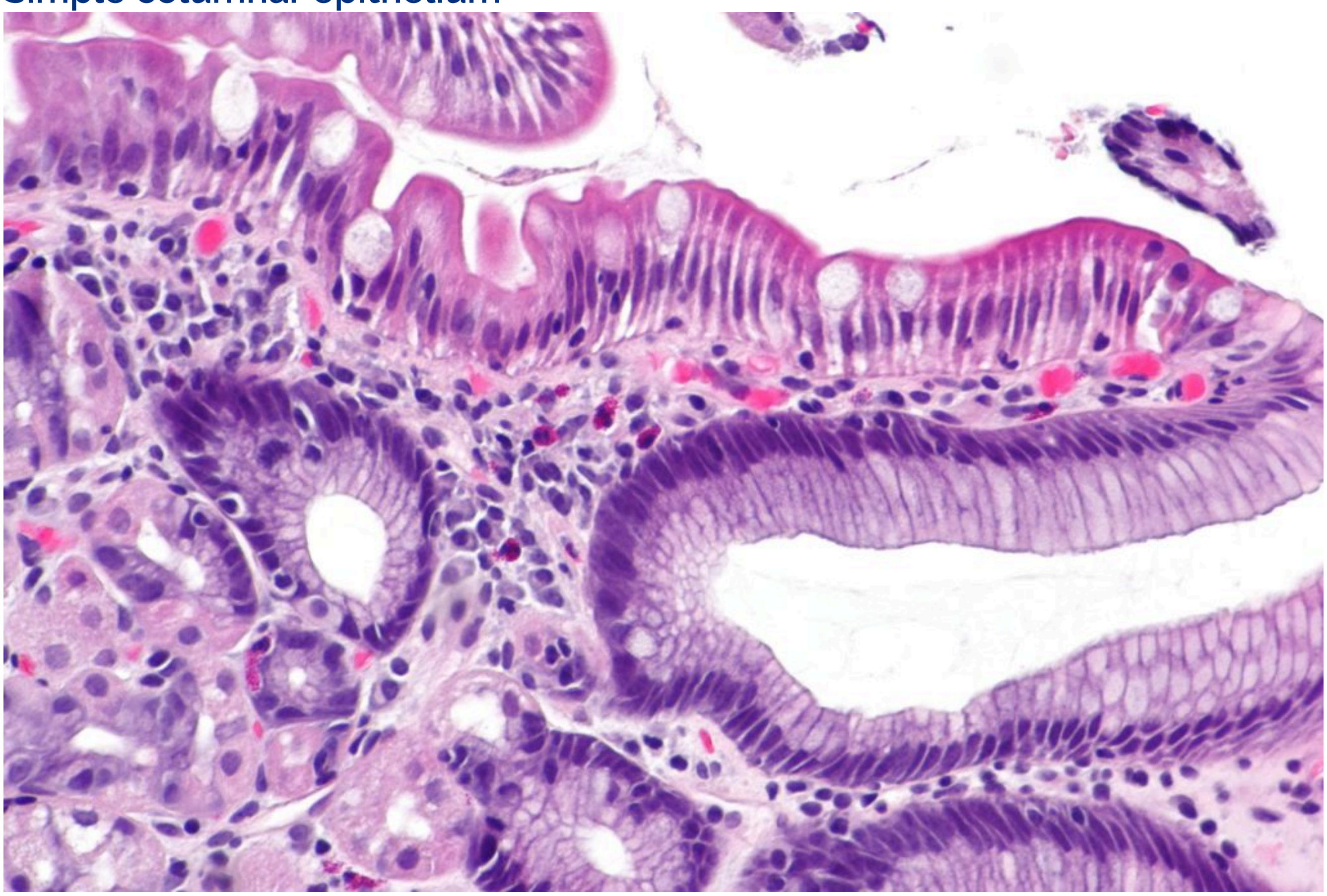
Kidney, human, H&E, 40X (cortex, glomerulus, proximal tubule, distal tubule, collecting duct, cortical labyrinth, medullary ray, medulla, vasa recta, loop of Henle, arcuate artery, interlobular arteries and veins). Cuboidal cells are located in the proximal tubule, distal tubule, collecting duct.



Then focus on the area where the tubules of the nephron are located to be able to see the simple cuboidal epithelium.



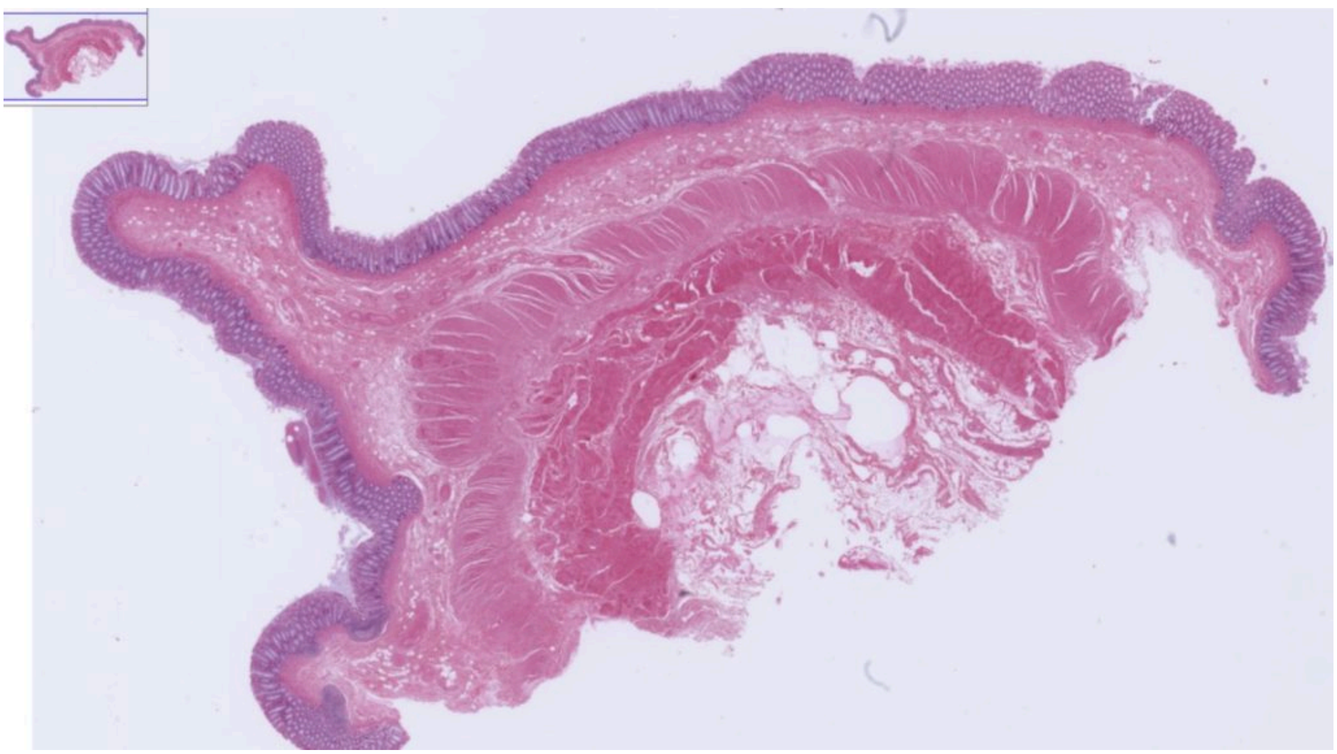
Simple columnar epithelium



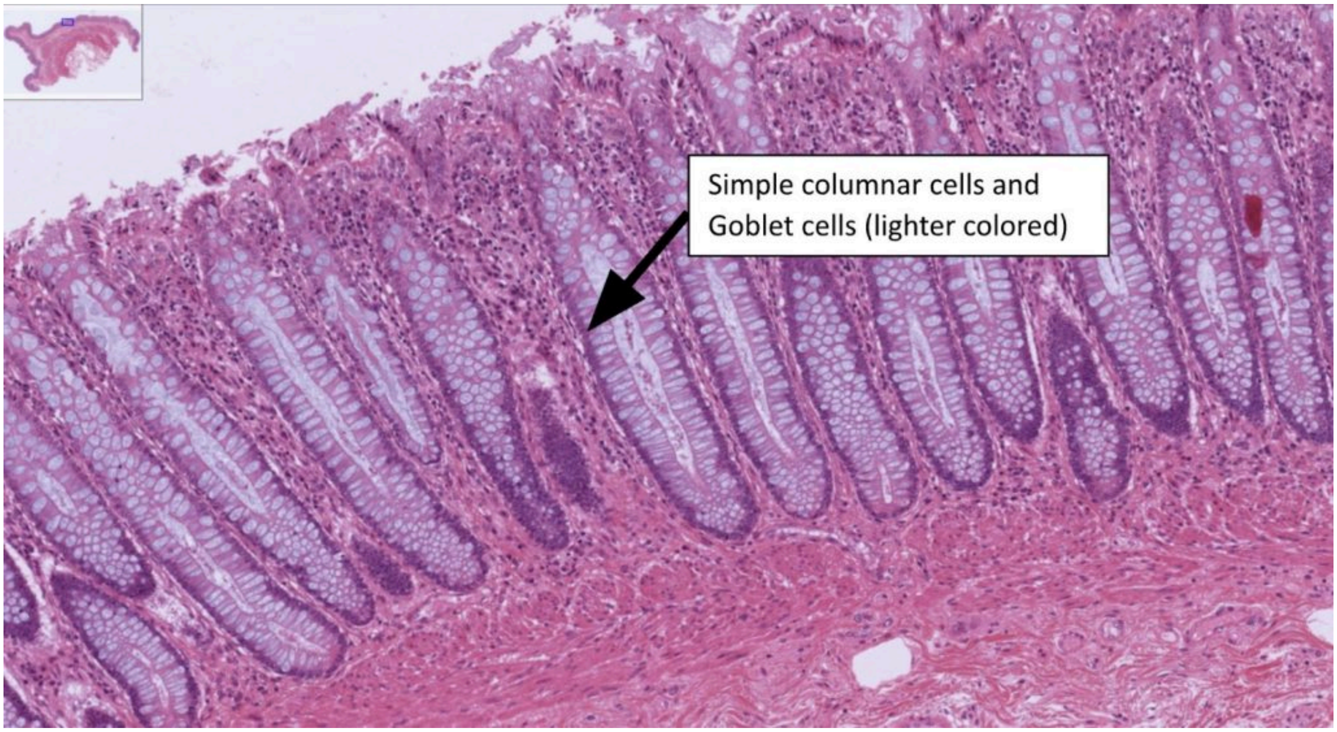
Virtual Microscope – use the QR code shown below to access the [Virtual Microscope from University of

Michigan. Use the +/- signs below the image to increase/decrease magnification. You may also scan the image – look at the top left of the main view, you will see a smaller window with a blue square, drag the square to change the area where you like to see. You can also move to a different area in the main view by dragging the small white hand shown there.

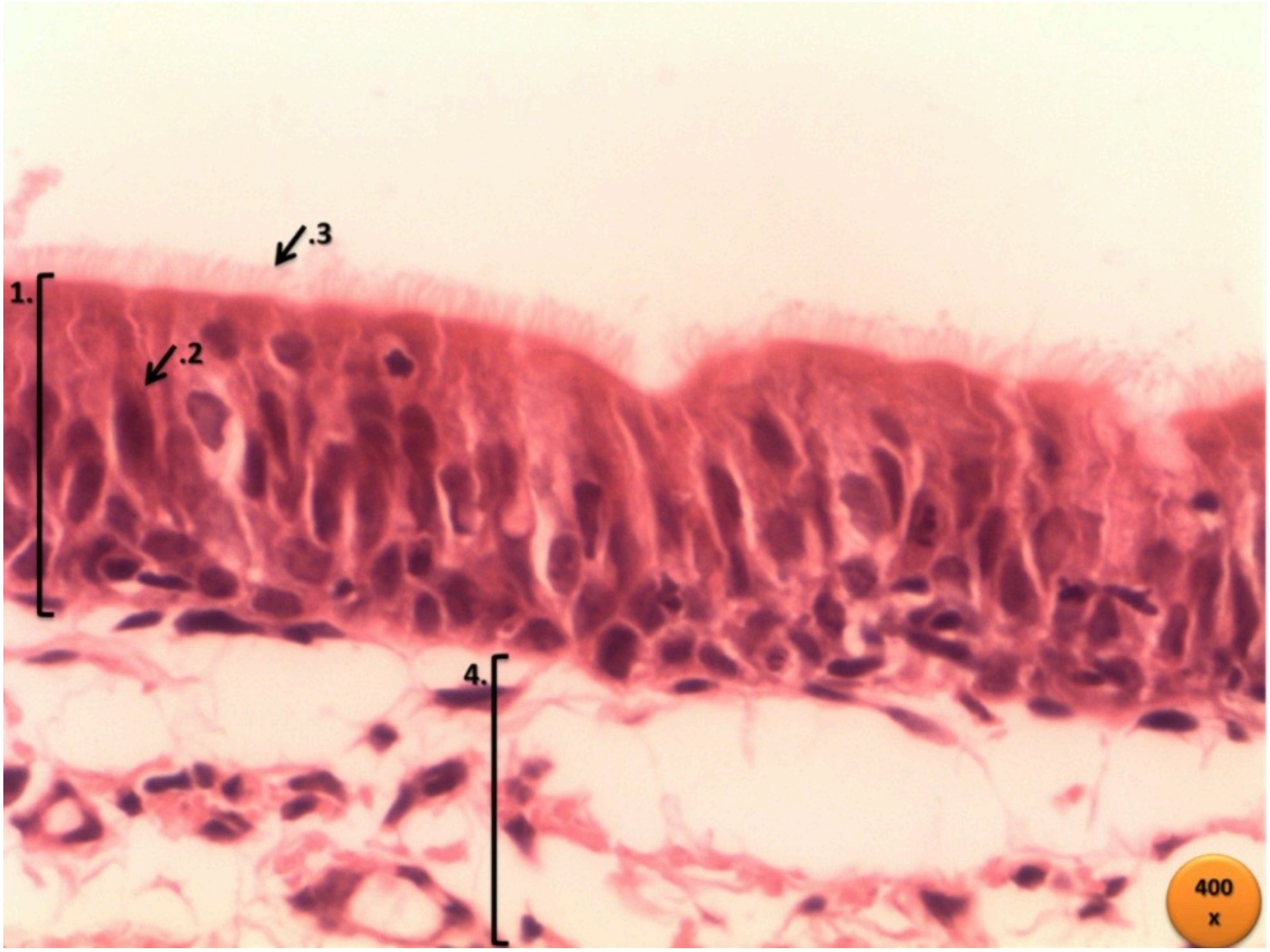
Colon, H&E, 40X (simple columnar epithelium) #176



Then focus on the layer that contains simple columnar cells

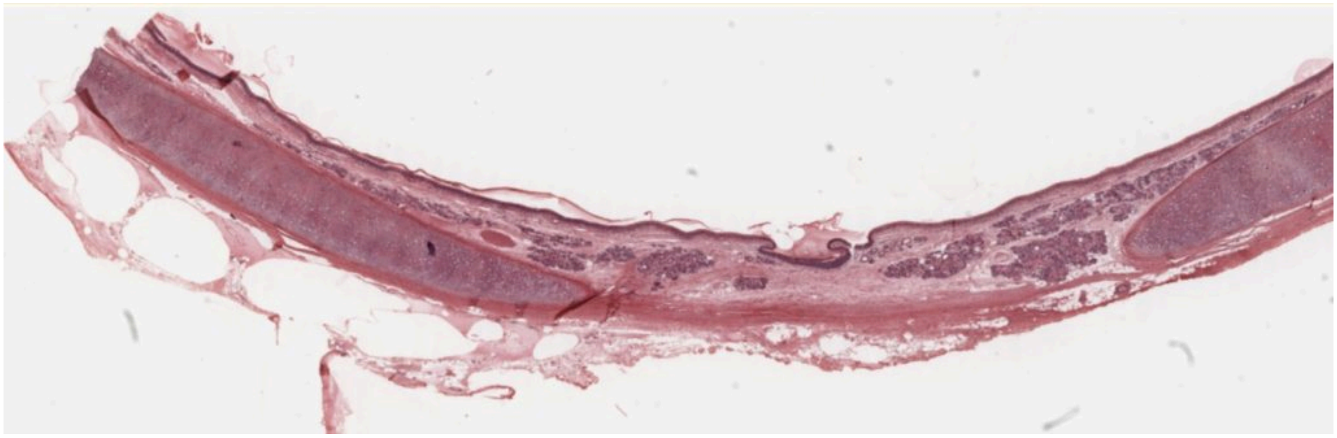

Simple columnar cells and
Goblet cells (lighter colored)

Pseudostratified columnar ciliated epithelium

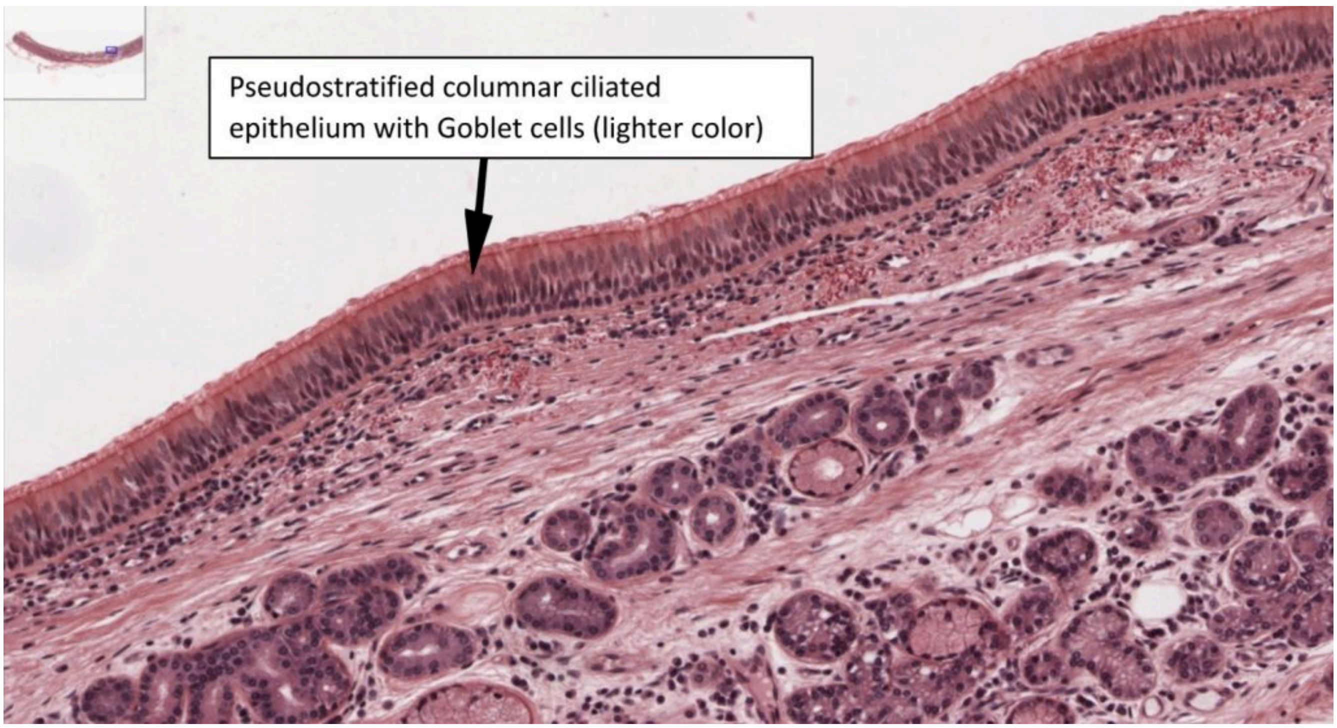


Virtual Microscope – use the QR code shown below to access the Virtual Microscope from University of Michigan. Use the +/- signs below the image to increase/decrease magnification. You may also scan then image – look at the top left of the main view, you will see a smaller window with a blue square, drag the square to change the area where you like to see. You can also move to a different area in the main view by dragging the small white hand shown there.

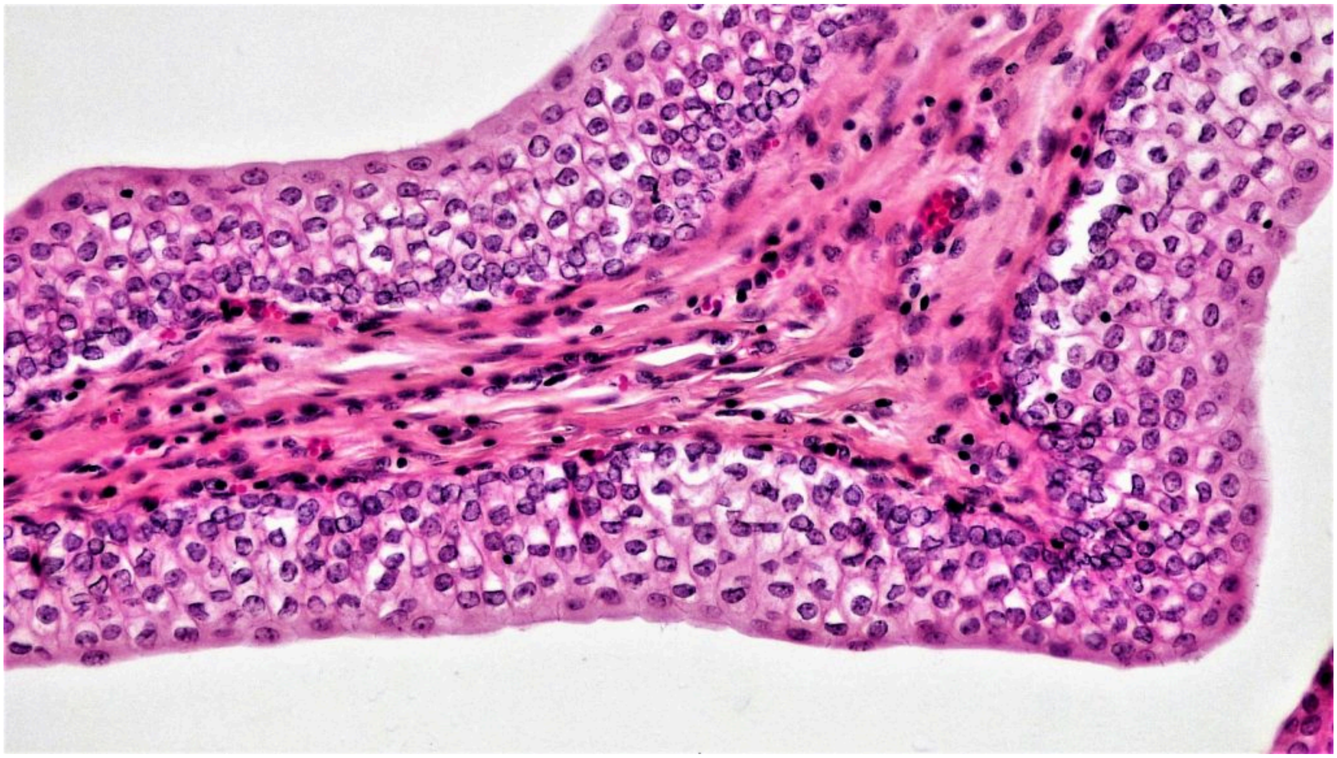
Trachea H&E, 40X (pseudostratified columnar epithelium), #040



Then focus on the layer that contains pseudostratified columnar ciliated epithelium.

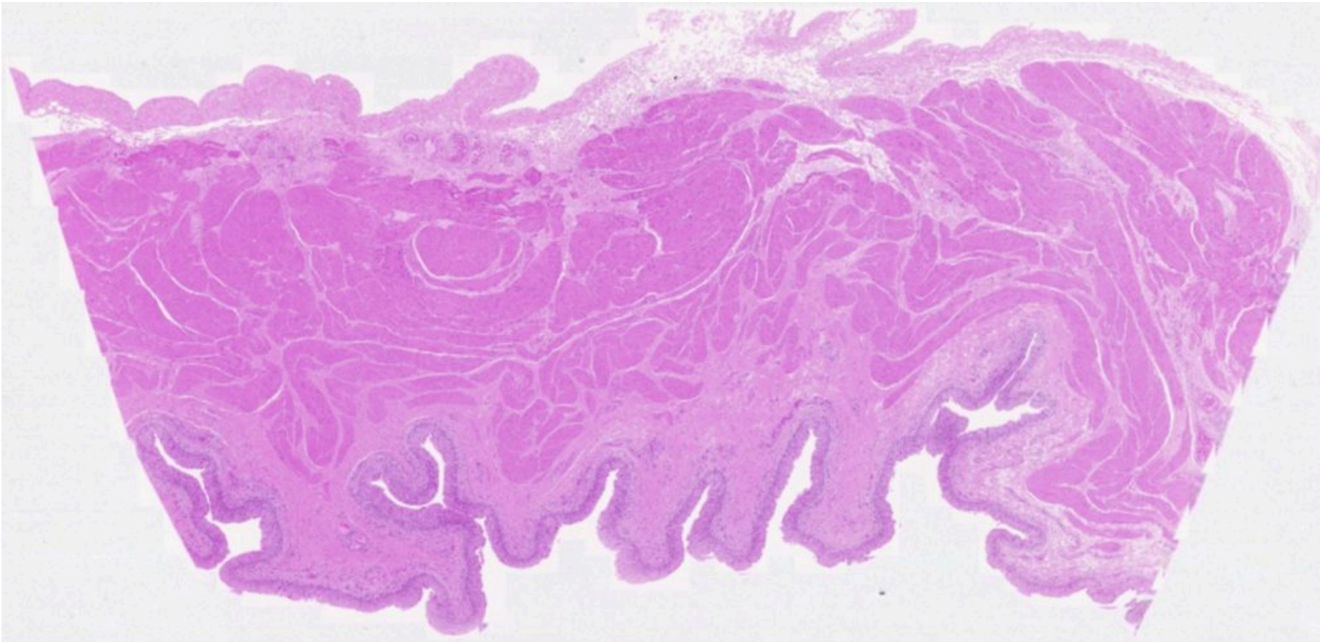


Transitional Epithelium

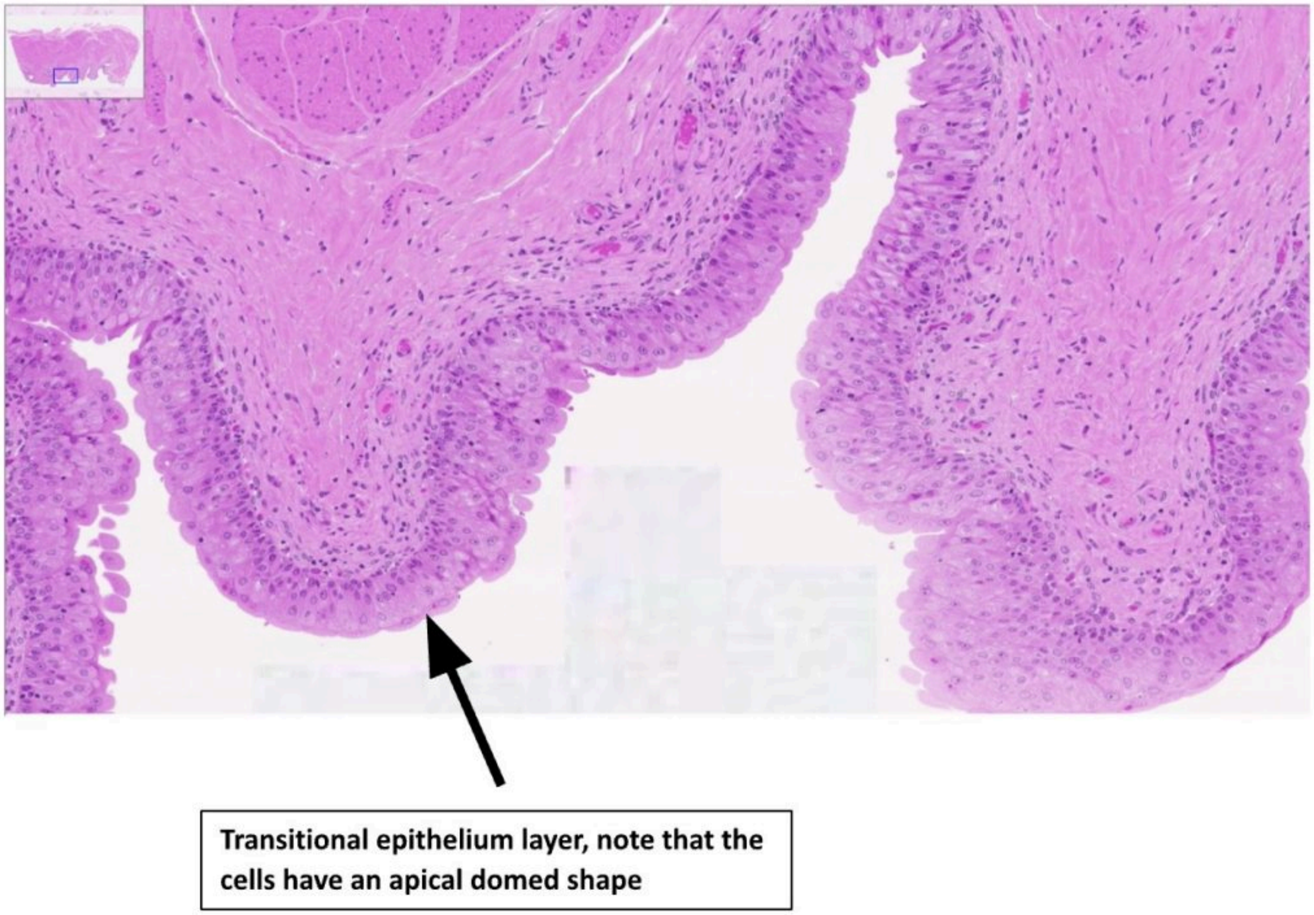


Virtual Microscope – use the QR code shown below to access the Virtual Microscope from University of Michigan. Use the +/- signs below the image to increase/decrease magnification. You may also scan the image – look at the top left of the main view, you will see a smaller window with a blue square, drag the square to change the area where you like to see. You can also move to a different area in the main view by dragging the small white hand shown there.

[Non-distended bladder, H&E, 40X (transitional epithelium), # Duke University 98.]

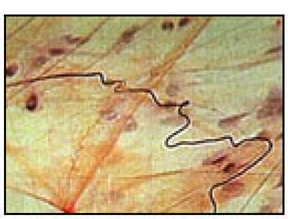


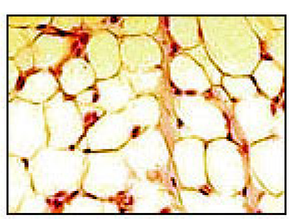
Then focus on the transitional epithelium layer

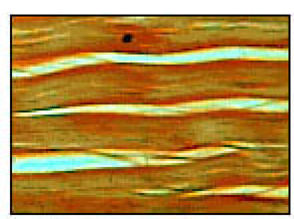


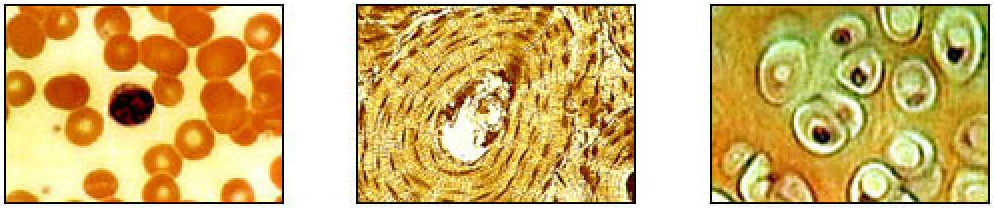
Connective Tissue

Connective tissues connect one tissue to one another; acts as support and participate in movement of body parts. It also stores compounds such as calcium and phosphorous; it cushions and insulate; and enclose organs. There are many types of connective tissue; they look very different, but they share their origin and 3 main characteristics; they contain ground substance, fibers (collagen, elastic, reticular) and specialized cells (adipose cells, chondrocytes, osteocytes, blood cells, macrophages, and mesenchymal cells cells). The combination of ground substance (Hyaluronic acid and proteoglycans) and fibers is also known as the Matrix.


Areolar connective tissue


Adipose tissue


Fibrous connective tissue



Sangre Tejido óseo Tejido cartilaginoso

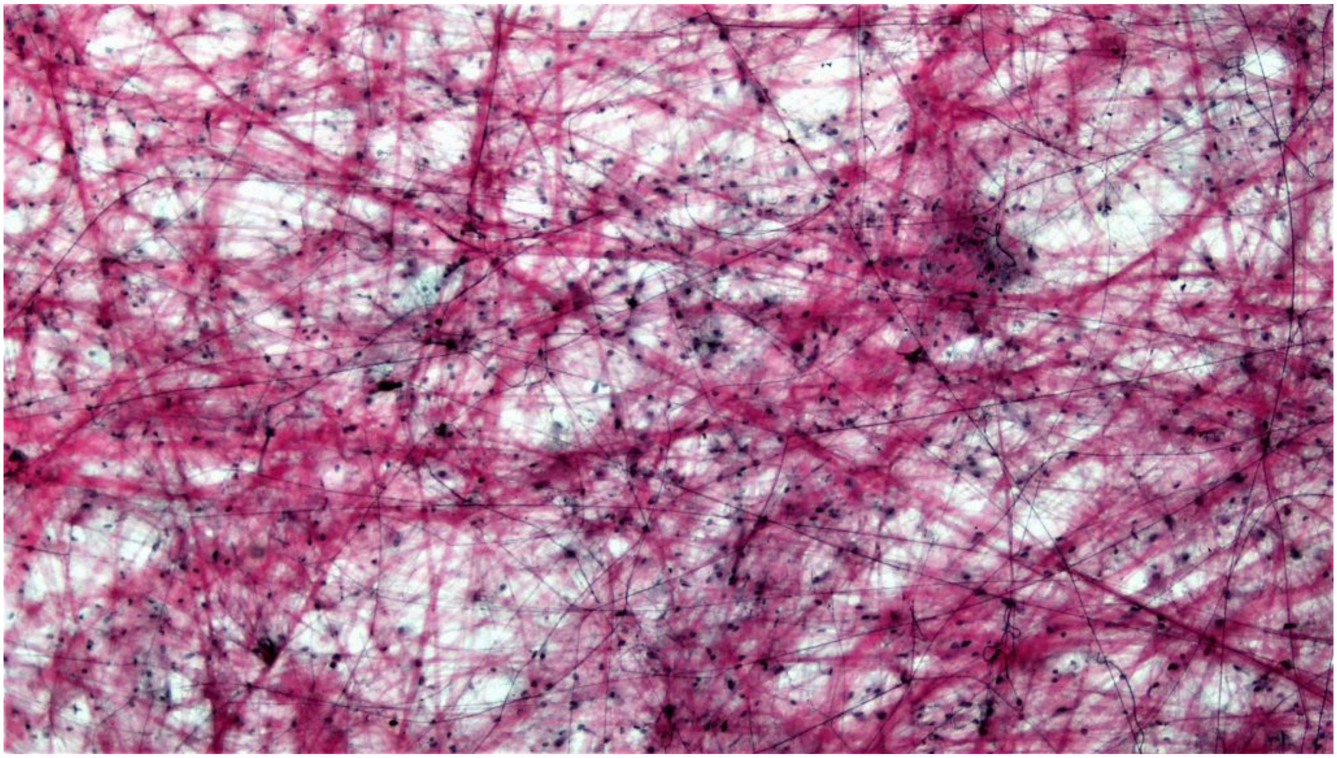
Connective tissue classification is based on the type specialized cells and the extracellular matrix. There are two main types of connective tissue:

1. Embryonic connective tissue is called mesenchyme, consists of irregularly shaped cells and abundant matrix, and gives rise to adult connective tissue.
2. Adult connective tissue consists of connective tissue proper, supporting connective tissue, and fluid connective tissue. The adult connective tissue is further subclassified as

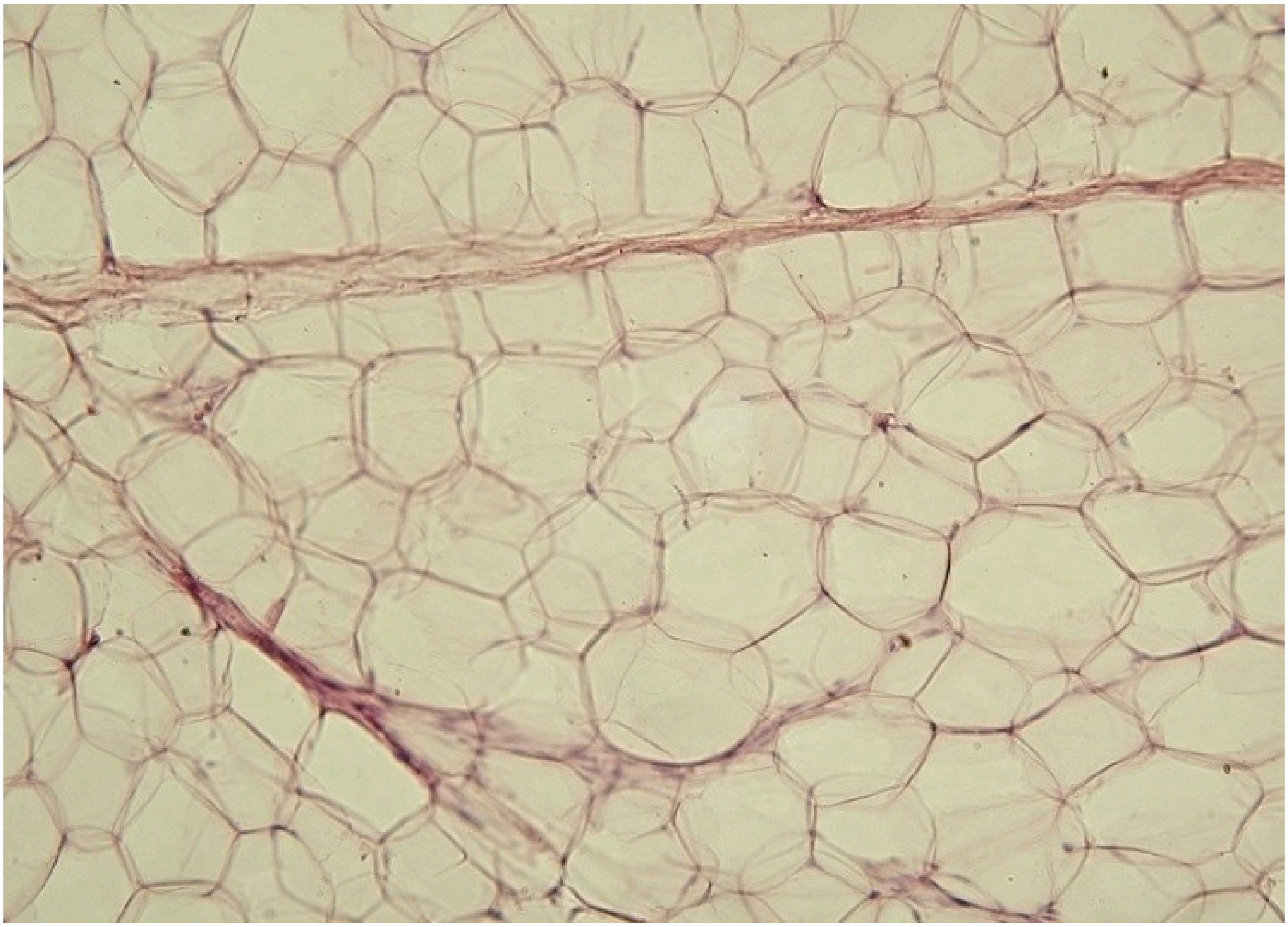
Connective Tissue Proper

1. Loose connective tissue

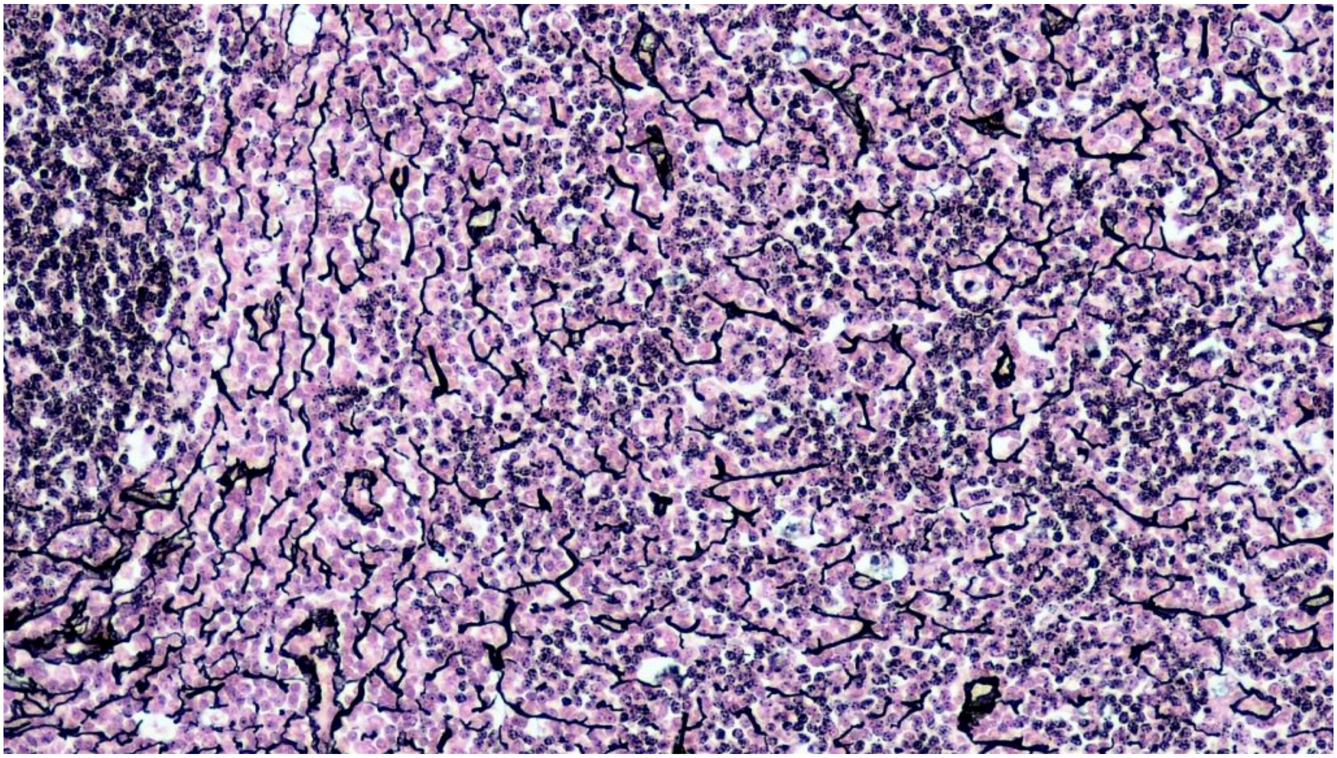
Loose Areolar connective tissue has many different cell types and a random arrangement of protein fibers with space between the fibers. This tissue fills spaces around the organs and attaches the skin to underlying tissues.



Adipose tissue has adipocytes filled with lipid and very little extracellular matrix. It protects body structures, also serves as a place for energy storage, and insulation.



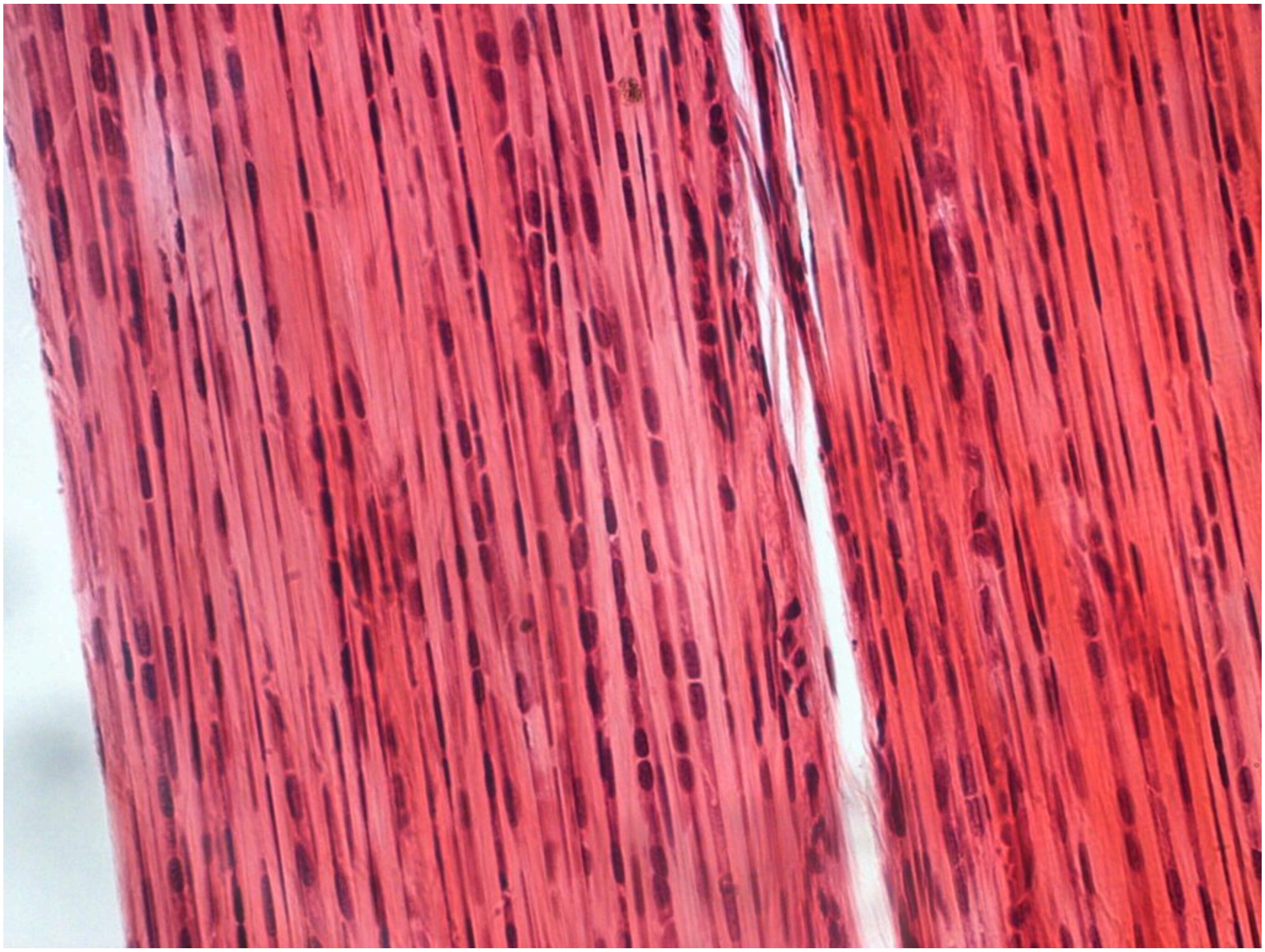
Reticular tissue is a network of reticular fibers, found in lymphatic tissue, bone marrow, and the liver.



Public Domain, 400x.

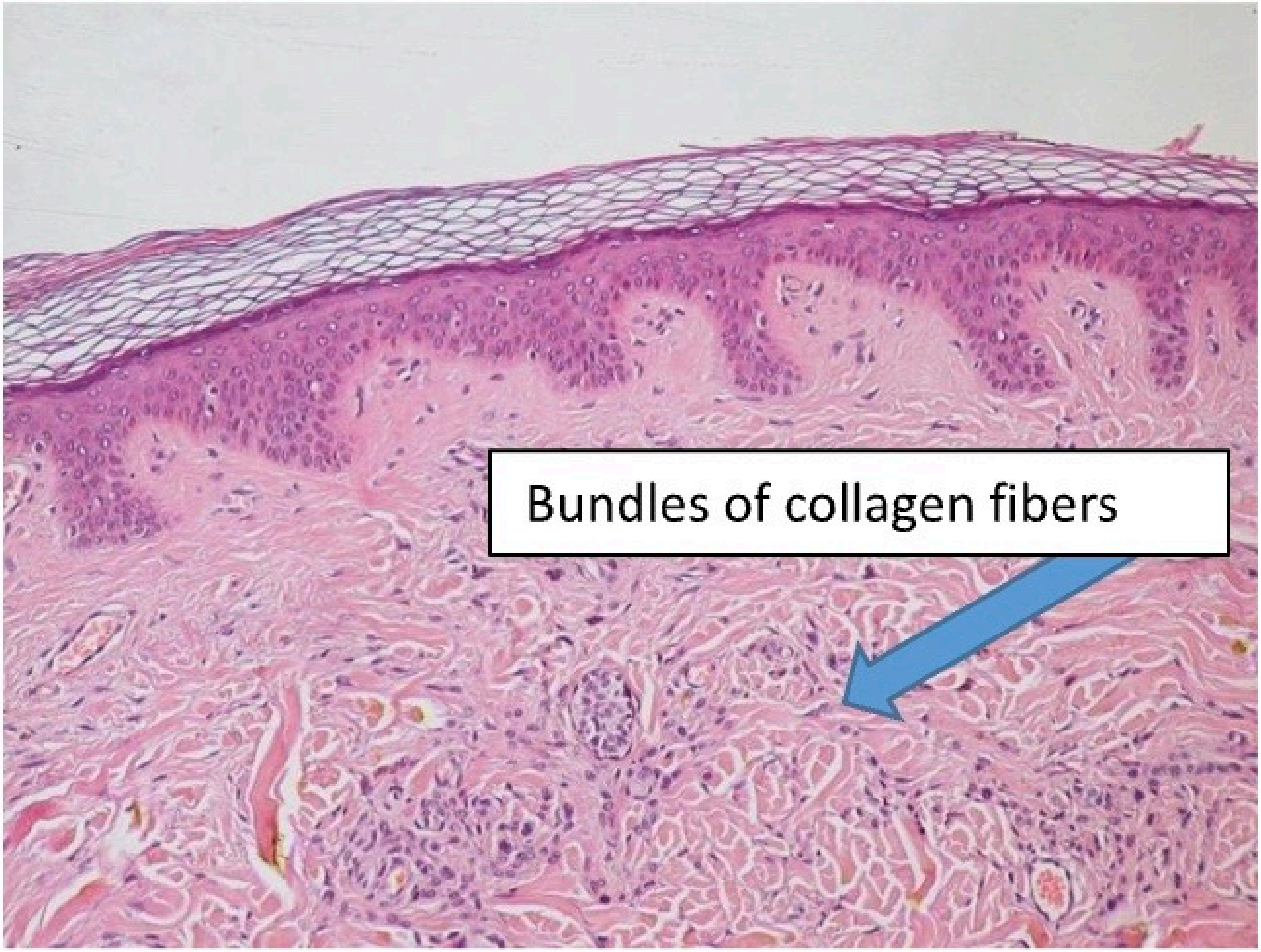
b. Dense connective tissue

Dense regular connective tissue is composed of fibers regularly arranged in one direction. There are two types of dense regular connective tissue; collagenous (tendons and most ligaments) and elastic (ligaments of vertebrae).

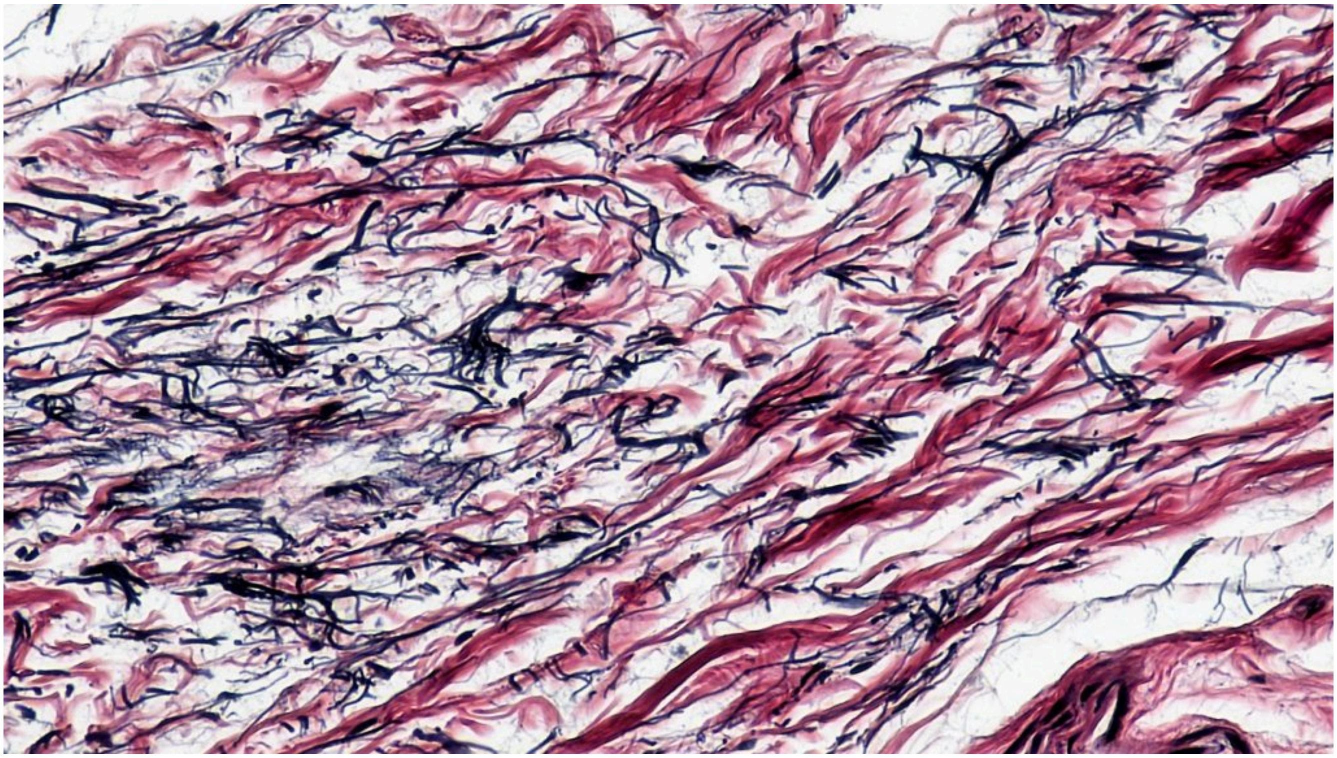


Dense irregular connective tissue has fibers organized in many directions, there are two types of dense irregular connective tissue: collagenous (found as capsules of organs and in the dermis of skin) and elastic (found in large arteries, such as the aorta).

Dense irregular connective tissue



Elastic connective tissue



Public domain, magnification 400x.

Supporting Connective Tissue

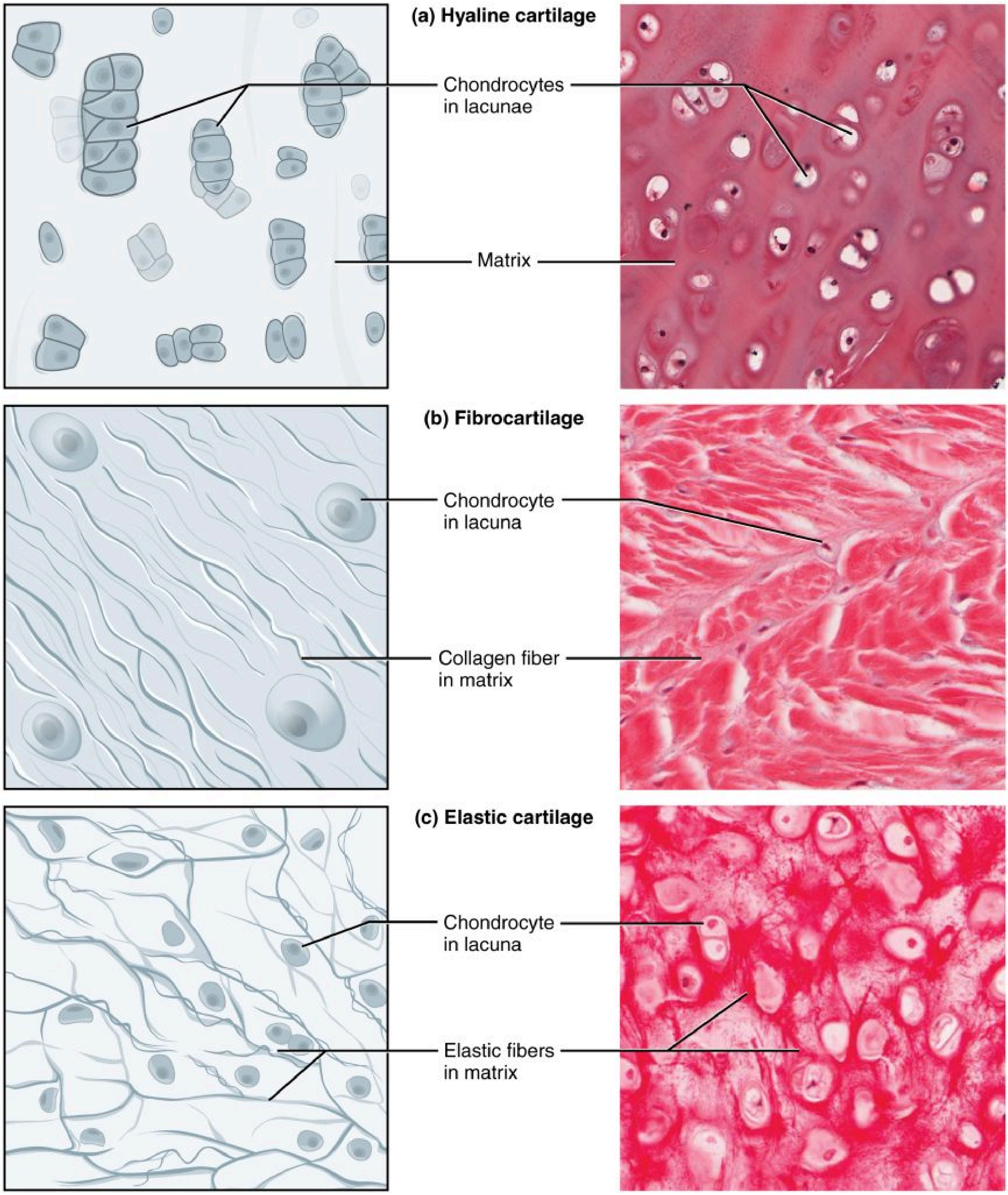
1. **Cartilage**

Cartilage has a relatively rigid matrix composed of protein fibers and proteoglycan aggregates. It contains mainly chondrocytes, within the lacunae. There are three types:

Hyaline cartilage with homogeneously distributed collagen fibers in the matrix and Chondrocytes in the lacunae

Fibrocartilage with homogeneously distributed collagen fibers but arranged in thick bundles and chondrocytes in the lacunae.

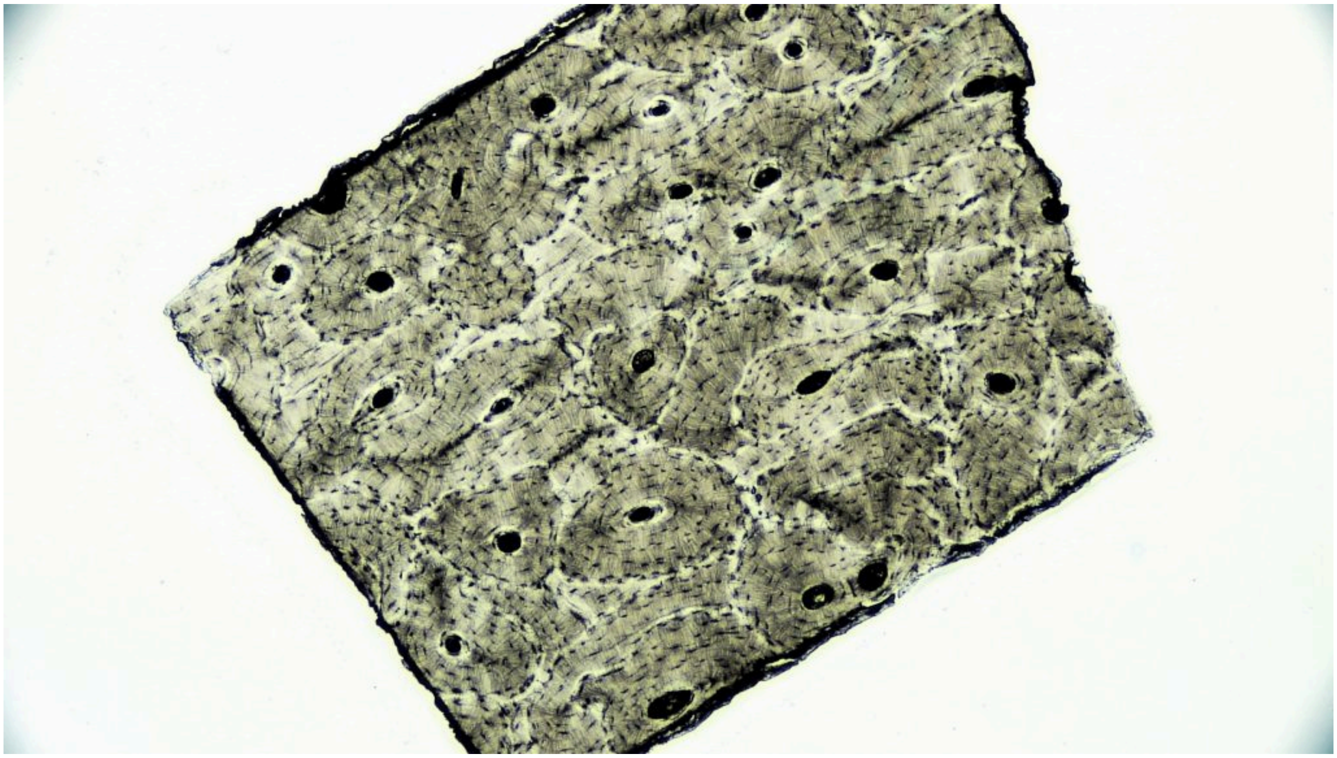
Elastic cartilage is similar to hyaline cartilage, but besides containing collagen fibers it also has elastin fibers.



2. Bone

The bone cells, or osteocytes, are located in lacunae and surrounded by a mineralized matrix (hydroxyapatite).

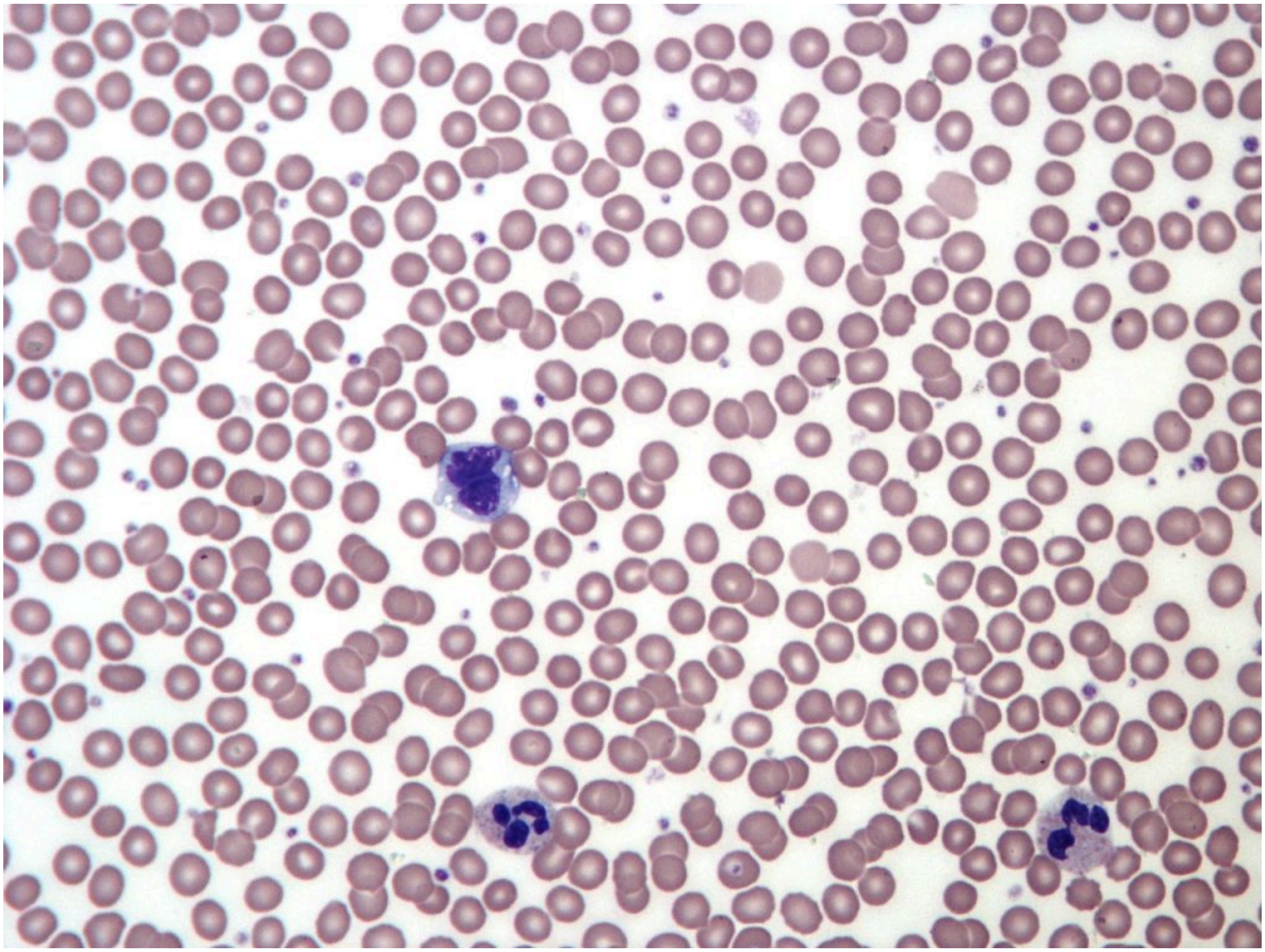
There are two types of bone; Spongy bone has spaces between bony trabeculae filled with bone marrow, and compact bone, which is more solid and composed of functional units called osteons.



3. Fluid Connective Tissue

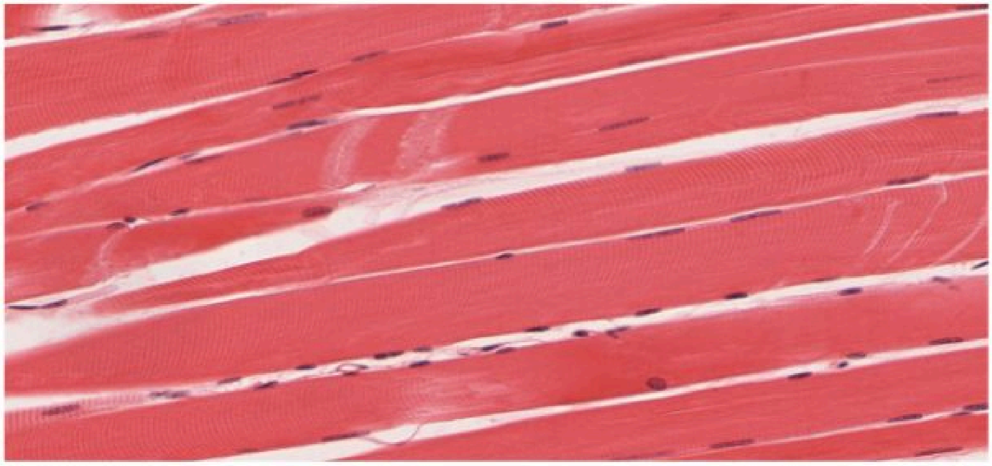
Blood

The blood has a fluid matrix and specialized cells or formed elements of the blood; red blood cells, white blood cells and platelets.

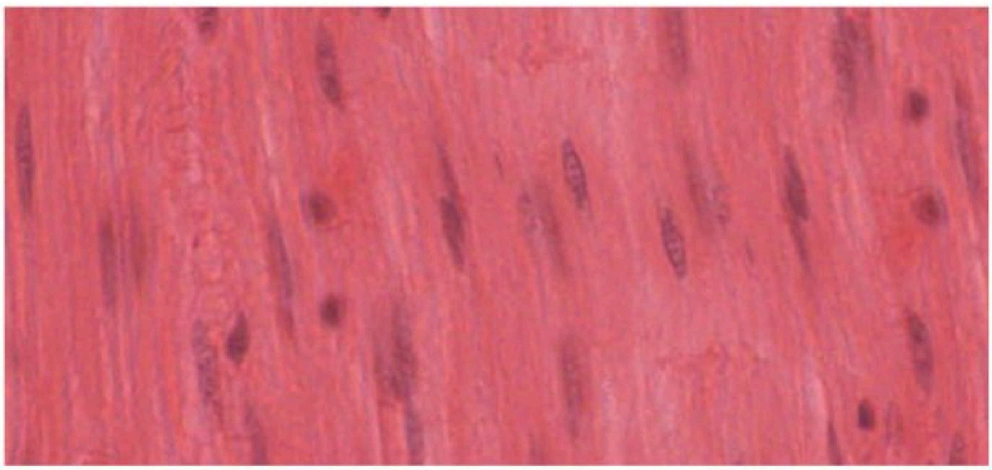


Muscular Tissue

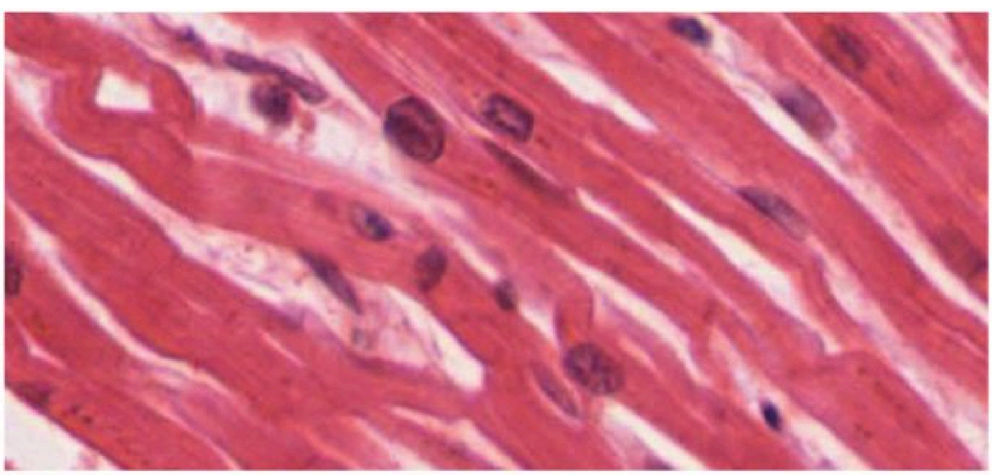
Muscle tissue has the ability to contract. There are three type of muscle tissue; Skeletal, smooth and cardiac muscle.



(a)



(b)



(c)

The body contains three types of muscle (x.s., 400x)

a. skeletal muscle
b. smooth muscle
c. cardiac muscle

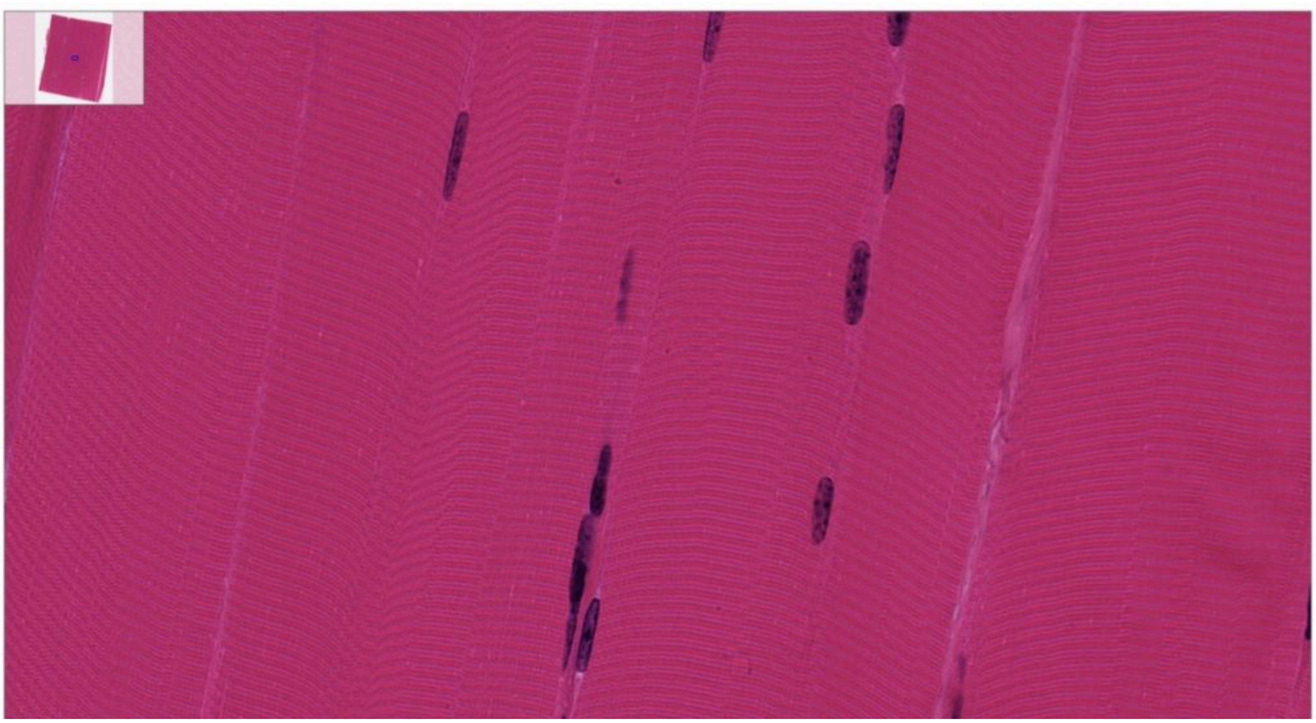
Virtual Microscope – use the QR code shown below to access the Virtual Microscope from University of Michigan. Use the +/- signs below the image to increase/decrease magnification. You may also scan the image – look at the top left of the main view, you will see a smaller window with a blue square, drag the square to change the area where you like to see. You can also move to a different area in the main view by dragging the small white hand shown there.

Skeletal Muscle

Skeletal muscle attaches to skeleton and is responsible for body movement. Skeletal muscle cells are long and cylindrically formed from fusion of many cells during development, therefore they contain many nuclei located at the periphery. This type of muscle has a banding pattern (striated) and is under voluntary control.

Slide: 058thin_HISTO_83X.htm

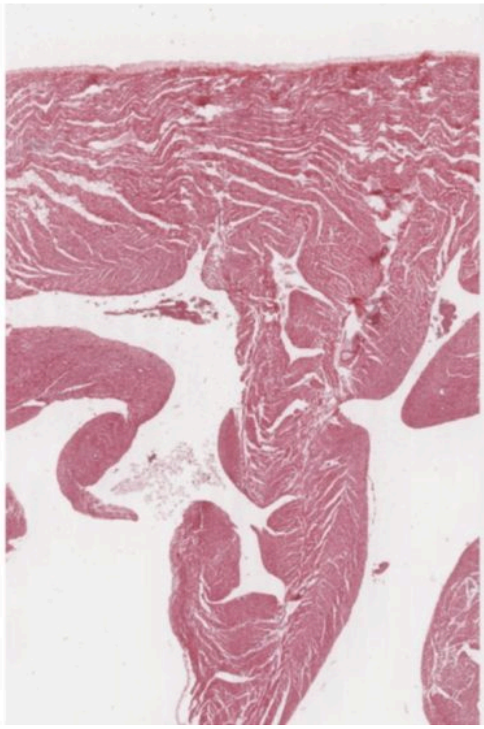
Then focus on the skeletal muscle fibers, long cylindrical, banded, multinucleated, nucleus located at the periphery.



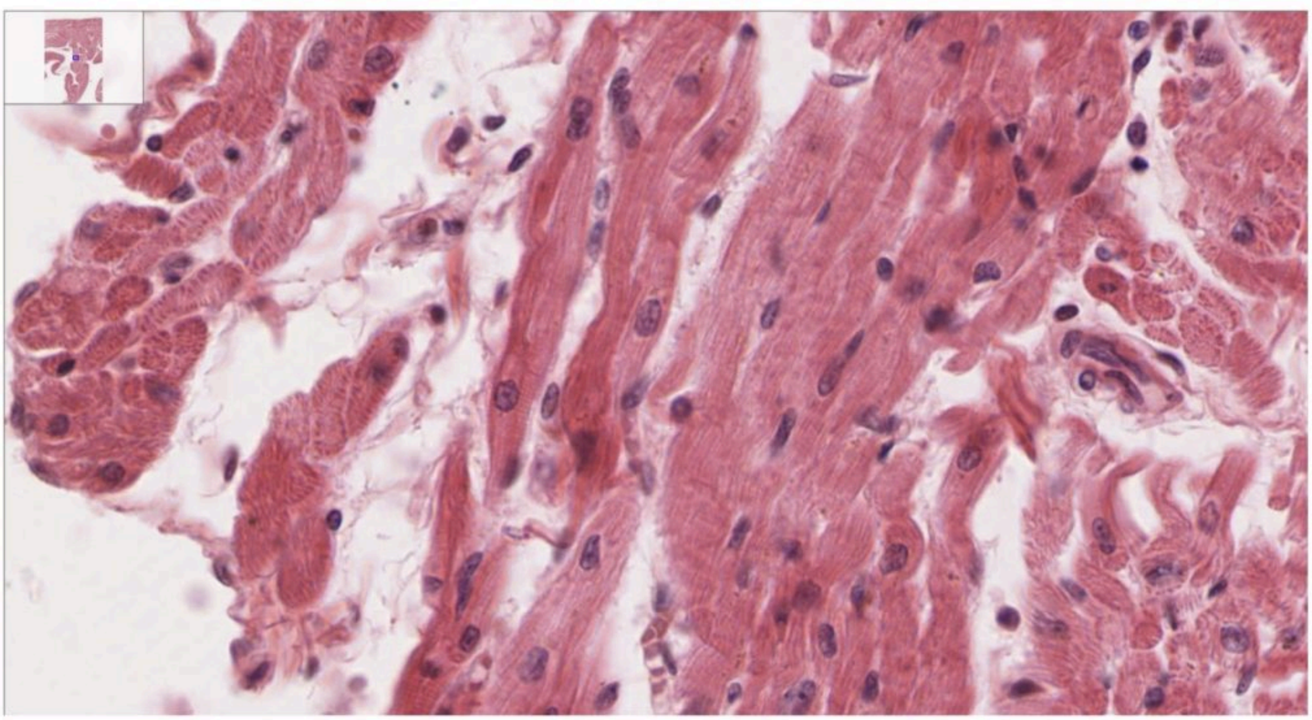
Cardiac Muscle

Cardiac muscle cells are short, branching cells with a single, central nucleus and gap junctions called intercalated disks. Cardiac muscle is only found in the heart and is responsible for pumping blood through the circulatory system. This type of muscle has a banding pattern (striated) and is under involuntary control.

Slide: 057_HISTO_40X



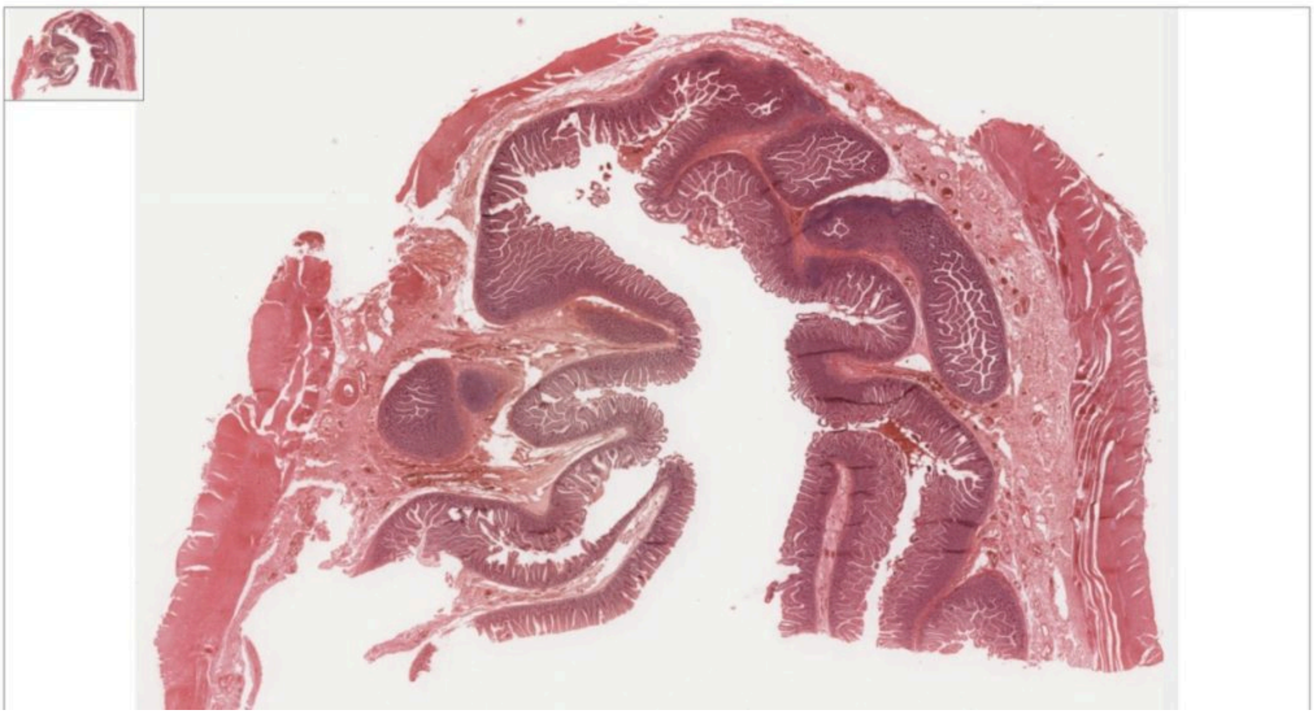
Then focus on cardiac cells



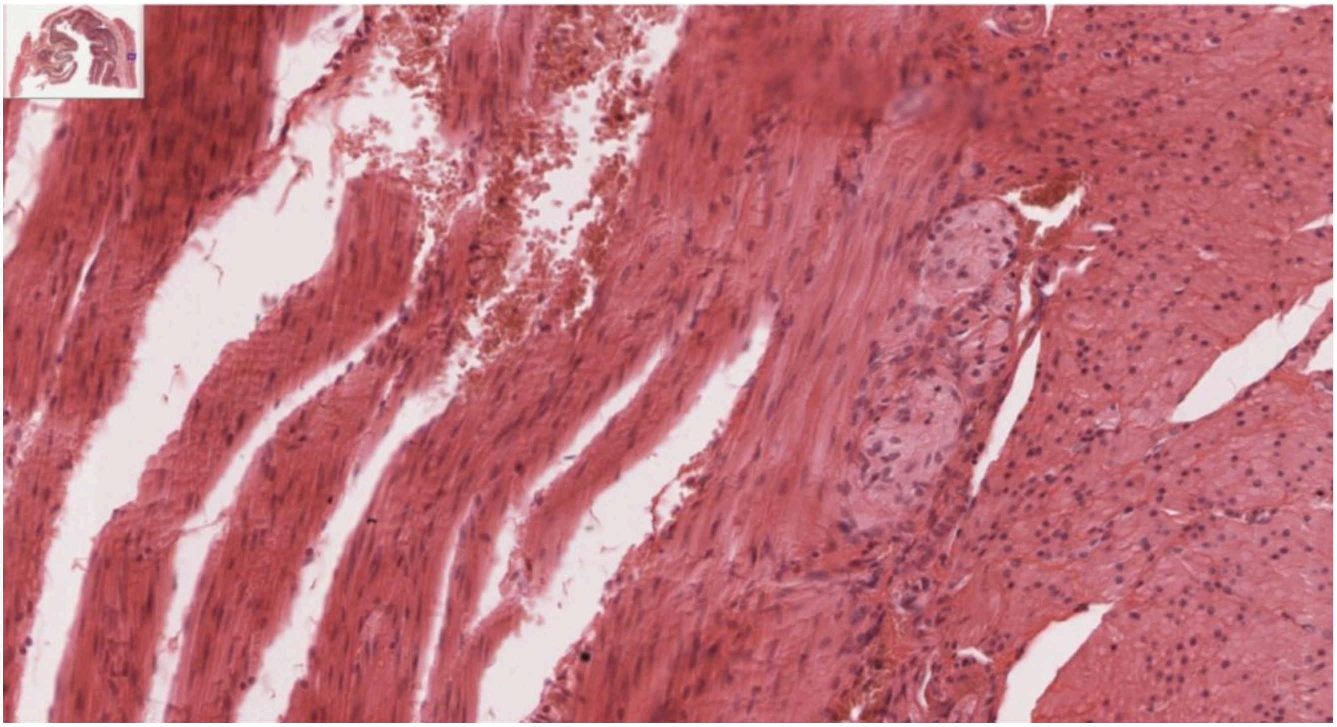
Smooth muscle

Smooth muscle is found in the walls of hollow organs, the iris of the eye, and other structures. The cells are tapered or spindle-shaped with a single, central nucleus. This type of muscle does not have a banding pattern (non-striated) and is under involuntary control.

Slide: 169_HISTO_40X



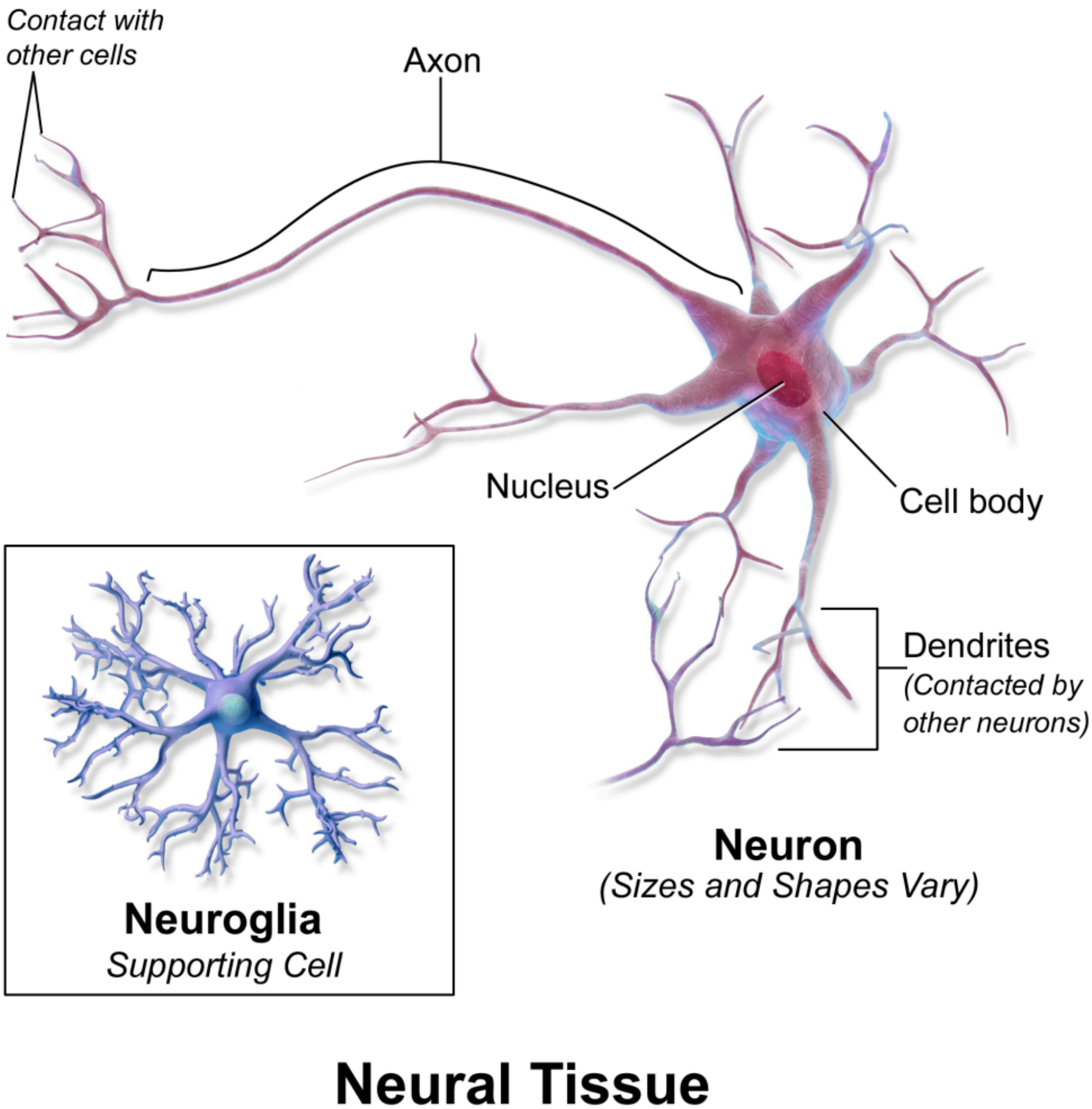
Focus on the smooth muscle, note tapered cells with central nucleus, no banding pattern.

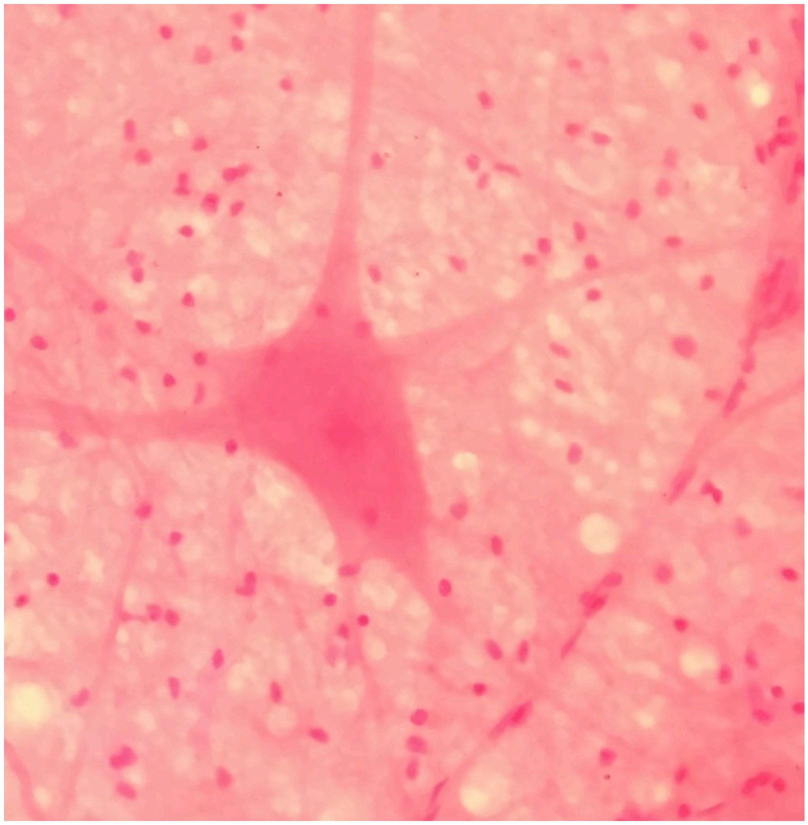


Nervous Tissue

The nervous tissue is composed of two types of cells, neurons (functional units, capable of transmitting an action potential) and neuroglia that support, nourish and monitor the neurons, they are found in an average ratio of 1: 9 (neuron: neuroglia). These cells are contained in the organs of the nervous system. The Central Nervous System (CNS) is composed of the brain and the spinal cord, the Peripheral Nervous System (PNS) is composed of all tissue located outside of the CNS, cranial and peripheral nerves.

Neurons have distinct type of cell processes; dendrites and axons. Dendrites are located on the body of the neuron, they receive electrical impulses, and axons conduct them.


Contact with other cells
Axon
Nucleus
Cell body
Dendrites
(Contacted by other neurons)
Neuron
(Sizes and Shapes Vary)
Neuroglia
Supporting Cell
Neural Tissue



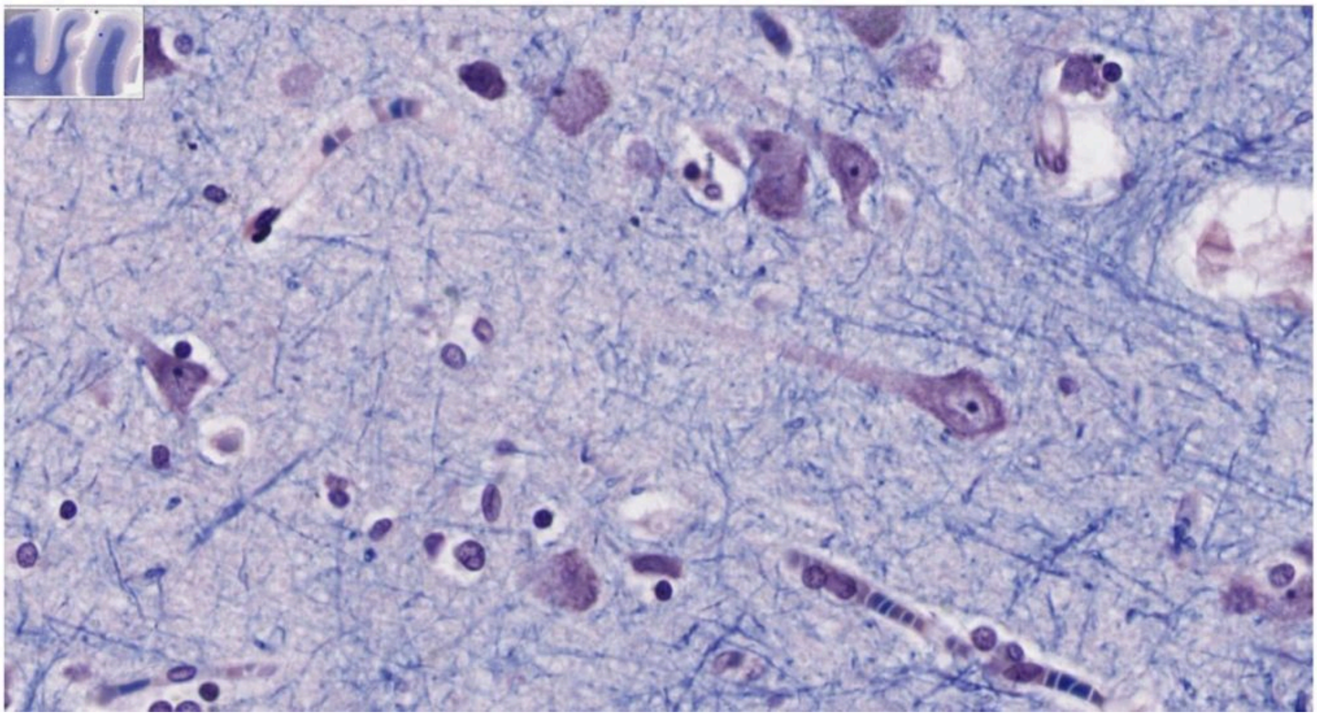
Multipolar neuronal smear, 400x

Virtual Microscope – use the QR code shown below to access the Virtual Microscope from University of Michigan. Use the +/- signs below the image to increase/decrease magnification. You may also scan the image – look at the top left of the main view, you will see a smaller window with a blue square, drag the square to change the area where you like to see. You can also move to a different area in the main view by dragging the small white hand shown there.

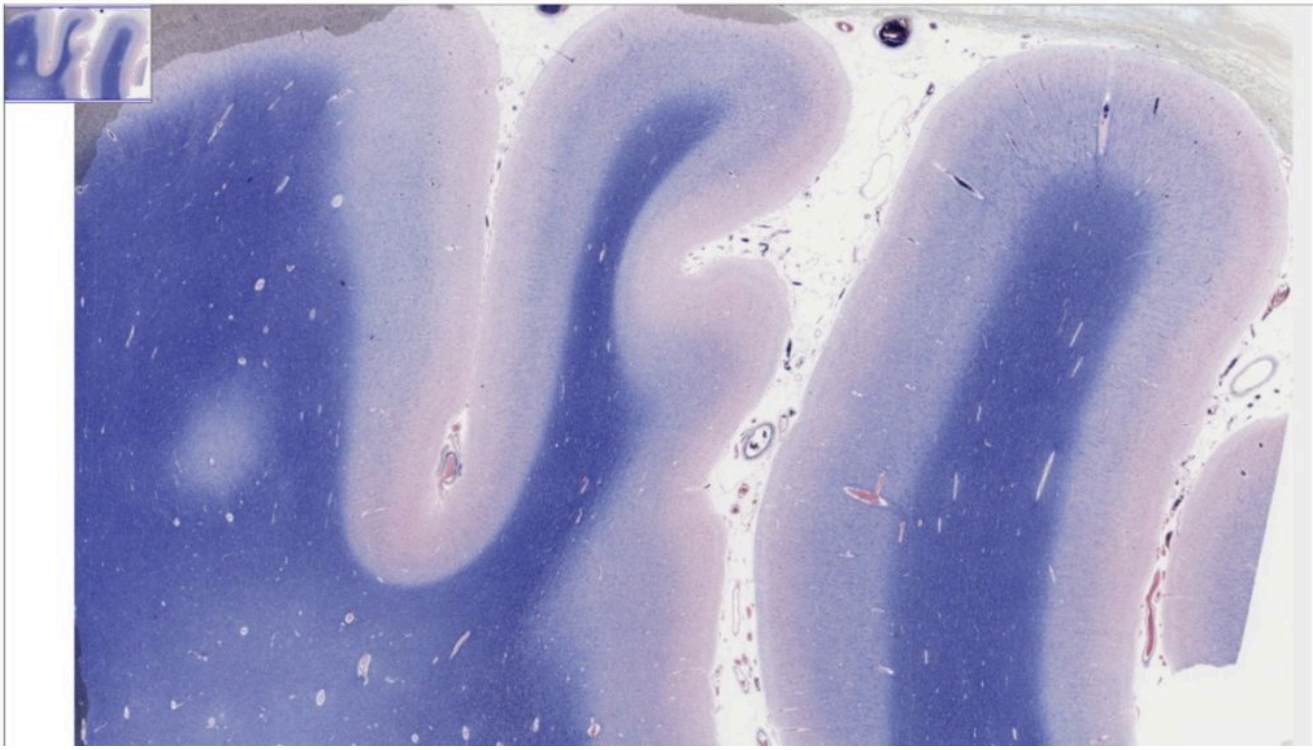
Neurons

Cerebrum, axons and neuron cell bodies stained blue, 40X (white matter [stained dark blue], cerebral cortex, pyramidal cells, pyramid shaped neuron cell bodies of various size, dendritic tree not visible, axon goes to white matter], glial cells, sulcus [white line from top to bottom of this section] between gyri.

Slide: 076_HISTO_40X.htm



Then focus on an area where you can find neurons



Laboratory Activities

Epithelial Tissue Activity – Draw and Identify

Use a compound light microscope to examine organ slides provided in the lab. Follow the rules of proper use and maintenance of a microscope explained to you at the beginning of the semester. You will first need to locate the epithelial tissue; remember the slides we use are sections of organs, they may contain other types of tissues as well. Remember, epithelium has a free apical side.

Observe the epithelial tissue slides under scanning power to locate the area where the epithelium is located, microscopes are parfocal, you will change magnification without having to focus again, just use the micro adjustment know to fine tune the focusing. You do not need 100X objective for this activity.

For 100% online courses, you will be using a virtual microscope. Instead of focusing using the coarse and fine adjustment knobs, you will use the +/- signs below the image to increase or decrease magnification.

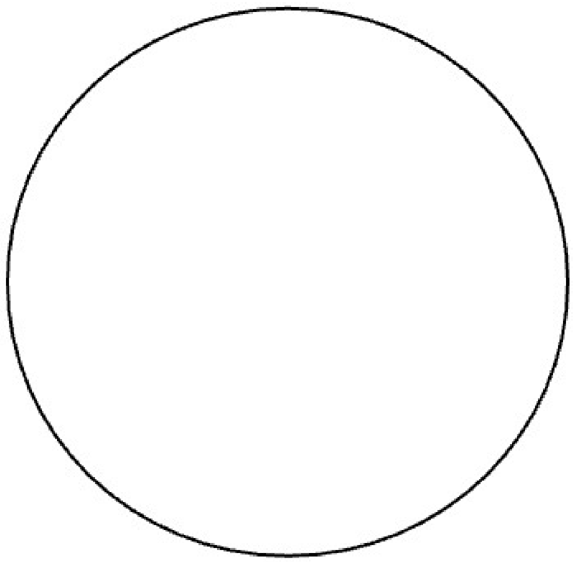
Observe and draw the following epithelial tissues slides:

1. Simple squamous epithelium – you may use lung, cheek cells, or kidney (bowman's capsule) slides.
2. Simple cuboidal epithelium – you may use kidney (tubules) or thyroid gland slides
3. Simple columnar epithelium – you may use stomach, duodenum, jejunum, ileum, colon or kidney slides.
4. Pseudostratified columnar ciliated epithelium with goblet cells, respiratory epithelium – use Trachea

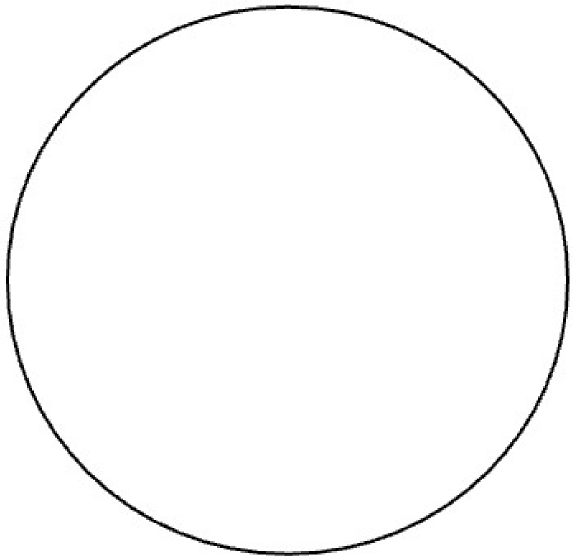
slides

5. Stratified squamous epithelium (non-keratinized) – you may use esophagus, vagina, or rectum slides
6. Stratified squamous epithelium (keratinized) – you may use thin or thick skin slides
7. Stratified cuboidal – use thin skin slides, locate the sebaceous glands and/or sweat glands in dermal layer.
8. Stratified columnar epithelium – rare. We do not have this slide to look at, instead look at an image in your textbook.
9. Transitional epithelium – you may use urinary bladder or ureter slides.

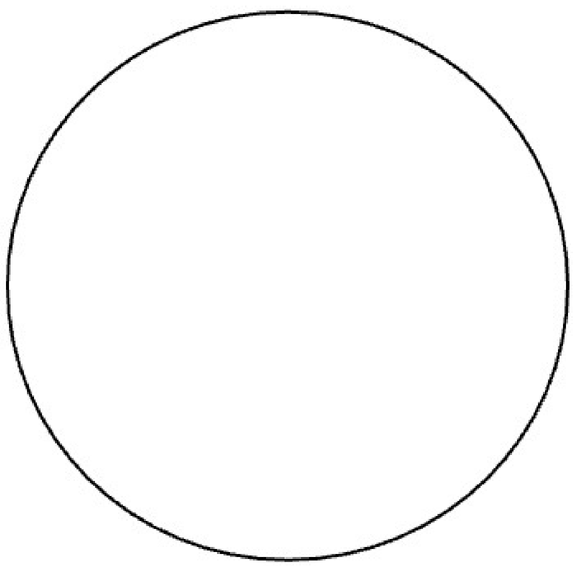
Note: Label the organelles you can identify, i.e, nucleus, cytoplasm, cell membrane, also label the basement membrane, and the free or luminal surface of the epithelium.



Simple squamous epithelium
Magnification __________X



Simple cuboidal epithelium
Magnification _______X



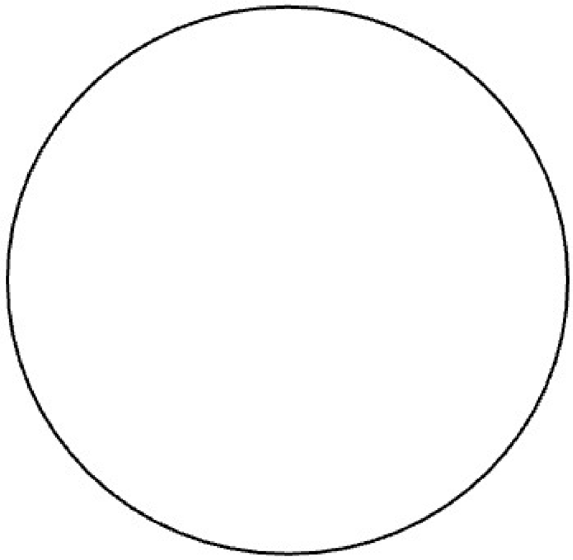
Simple columnar epithelium
Magnification _______X

Stratified squamous epithelium
Magnification _______X

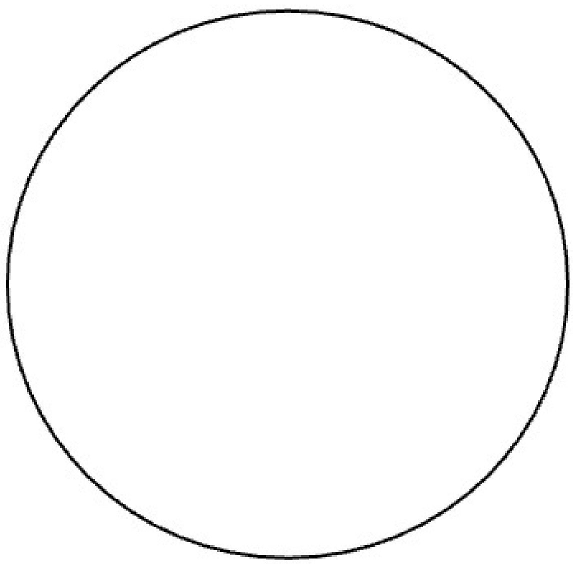
Stratified squamous epithelium (keratinized)
Magnification _______X

Pseudostratified columnar ciliated epithelium
Magnification _______X

Stratified cuboidal
Magnification _______X

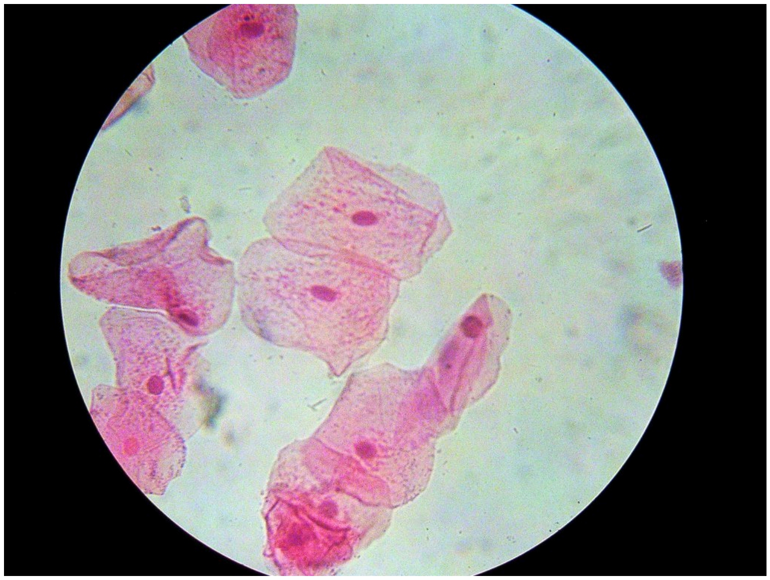


Stratified columnar epithelium
Magnification _______X



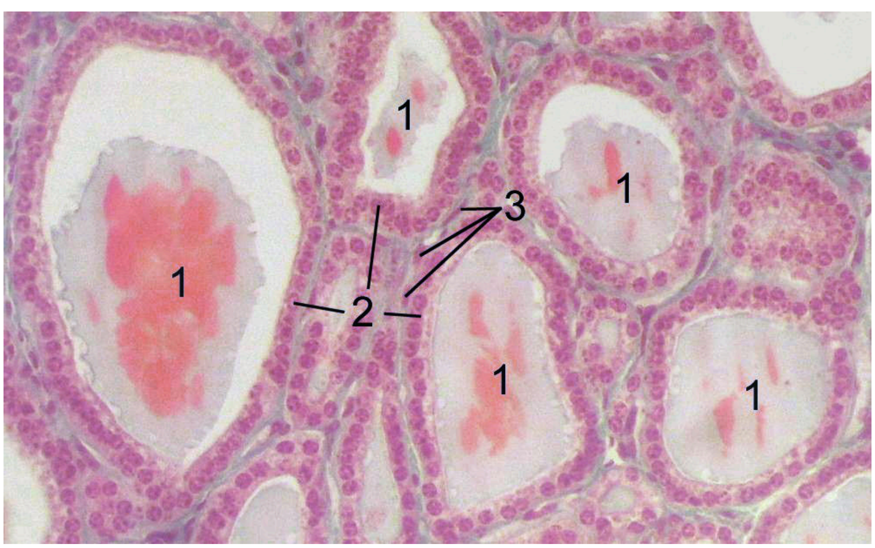
Transitional epithelium Magnification _______X

Identify the type of epithelial tissue seen under the microscopes



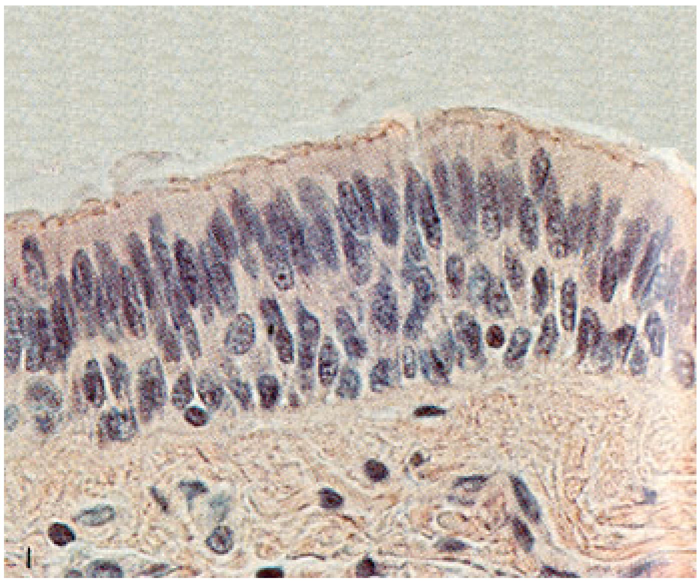
Tissue type:

Function:



Tissue type:

Function:



Tissue type:

Function:

Connective Tissue Activity – Draw and Identify

Use a compound light microscope to examine organ slides provided in the lab. Follow the rules of proper use and maintenance of a microscope explained to you at the beginning of the semester. You will first need to locate the connective tissue; remember the slides we use are sections of organs, they may contain other types of tissues as well.

Observe the connective tissue slides under scanning power to locate the area where the tissue microscopes are parfocal, you will change magnification without having to focus again, just use the micro adjustment know to fine tune the focusing. You do not need 100X objective for this activity.

Observe and draw the following connective tissues slides:

1. Loose Areolar tissue, packing material. You need to find and label the fibroblast cells, ground substance, collagen and elastic fibers
2. Adipose Tissue: Find cell membrane and nuclei.
3. Reticular connective Tissue – found in lymph nodes and liver, find and label the reticular fibers and cells.
4. Regular Dense CT- Collagenous tissue (or dense regular connective tissue), found in ligaments and tendons. You need to find and label collagen fibers and fibroblast cells
5. Elastic connective tissue – (large arteries). You need to find and label circular layer of elastic fibers.
6. Irregular Dense CT – found in dermis of skin. You need to find and label bundles of collagen fibers
7. Hyaline cartilage – Find and label chondrocytes, lacunae, matrix
8. Elastic cartilage – Find and label chondrocytes, lacunae, elastic fibers
9. Fibrocartilage – Find and label chondrocytes, lacunae, collagen fibers
10. Compact bone: Find and label – Osteons: lacunae, canaliculi, osteocyte, concentric lamellas
11. Human blood smear. Find and label the formed elements of blood; RBC, red blood corpuscles (erythrocytes), WBC, white blood cells (leukocytes), neutrophils, eosinophils, basophils, monocytes and lymphocytes. Platelets (Thrombocytes). As you observe a blood smear under the microscope, draw all formed elements of the blood. Note the absence or presence of the nucleus, the nuclear shape, amount of cytoplasm, and presence or absence of granules in the cytoplasm.

Note: You will need to use immersion oil and 100X objective to see details of formed elements of blood.

Tissue Type: , Magnification _______X

Tissue Type: , Magnification _______X

Tissue Type: , Magnification _______X

Tissue Type: , Magnification _______X

Tissue Type: , Magnification _______X

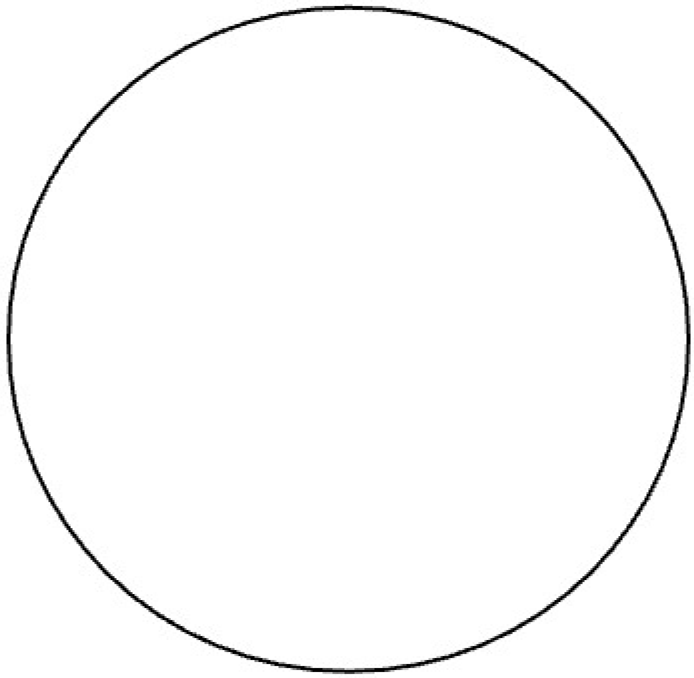
Tissue Type: , Magnification _______X

Tissue Type: , Magnification _______X

Tissue Type: , Magnification _______X

Tissue Type: , Magnification _______X

Tissue Type: , Magnification _______X



Tissue Type: , Magnification _______X

Answer the following questions

1. What are the 3 common characteristics of all connective tissue?

2. Where in the body is each type of connective tissue found? What is their function? Make a table.

Connective tissue type	**Location**

3. Name the formed elements of blood, state their function.

4. Why does the RBCs lose their nucleus?

5. What are the differences and similarities in WCBs types?

Muscle Tissue Activity – Draw and Identify

There are three types of muscle tissue, skeletal muscle, smooth muscle and cardiac muscle. You will learn how to identify each type of muscle tissue. You will first need to locate the muscle tissue; remember the slides we use are sections of organs, they may contain other types of tissues as well. Observe the muscle tissue slides under scanning power to locate the area where the tissue microscopes are parfocal, you will change magnification without having to focus again, just use the micro adjustment know to fine tune the focusing. You do not need 100X objective for this activity.

Observe and draw the following muscle tissues slides:

1. Skeletal muscle (teased)– Find and label the striations, nuclei and cylindrical muscle cells (fibers)
2. Smooth muscle (teased)– Find and label the nuclei and spindle shaped cells
3. Cardiac muscle (intercalated disk stain) – Find and label the intercalated disks, striations, nuclei and branched cells.

Tissue Type: , Magnification __________X

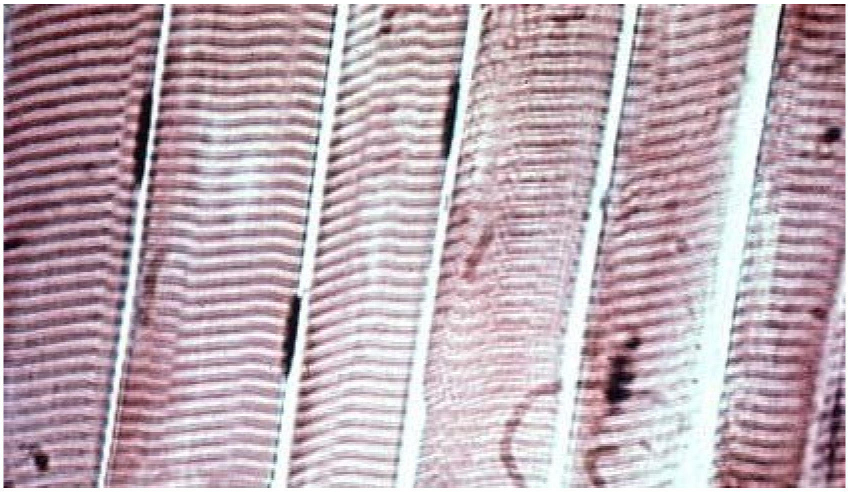
Tissue Type: , Magnification __________X

Tissue Type: , Magnification __________X

Identify the type of muscle tissue seen under the microscopes

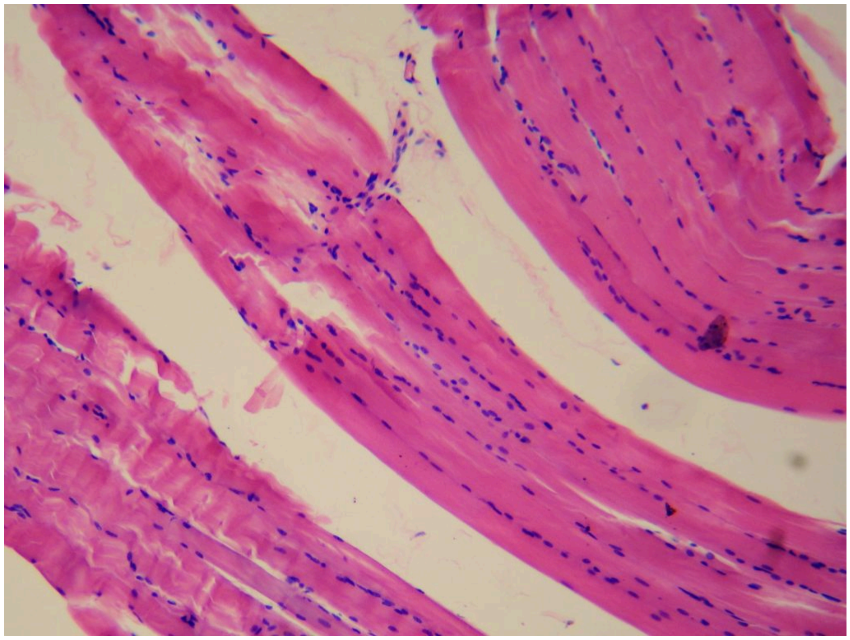
Demo Slide Activity

There are two microscopes set up at the instructor's bench, identify each of them. Be specific. What is the function of each type of epithelial tissue you identified?



Microscope 1 – Tissue type:

Microscope 1 – Function:



Microscope 2 – Tissue type:

Microscope 2 – Function:

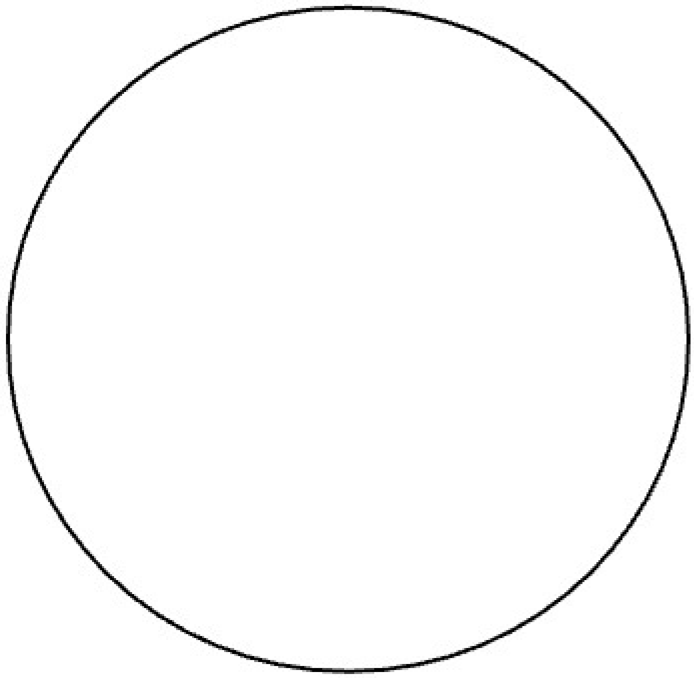
Nervous Tissue Activity – Draw and Identify

1. Microscopy

Use a compound light microscope to examine organ slides provided in the lab. You will first need to locate the nervous tissue; remember the slides we use are sections of organs, they may contain other types of tissues as well. Observe the nervous tissue slides under scanning power to locate the area where the tissue microscopes are parfocal, you will change magnification without having to focus again, just use the micro adjustment know to fine tune the focusing. You do not need 100X objective for this activity. Observe and draw a multipolar neuron smear slide or motor neuron, spinal cord smear, which ever one is available

Find and label the following structures:

1. Motor neurons, cell body, nucleus, Nissl bodies, dendrites and axons.
2. Neuroglia cell bodies

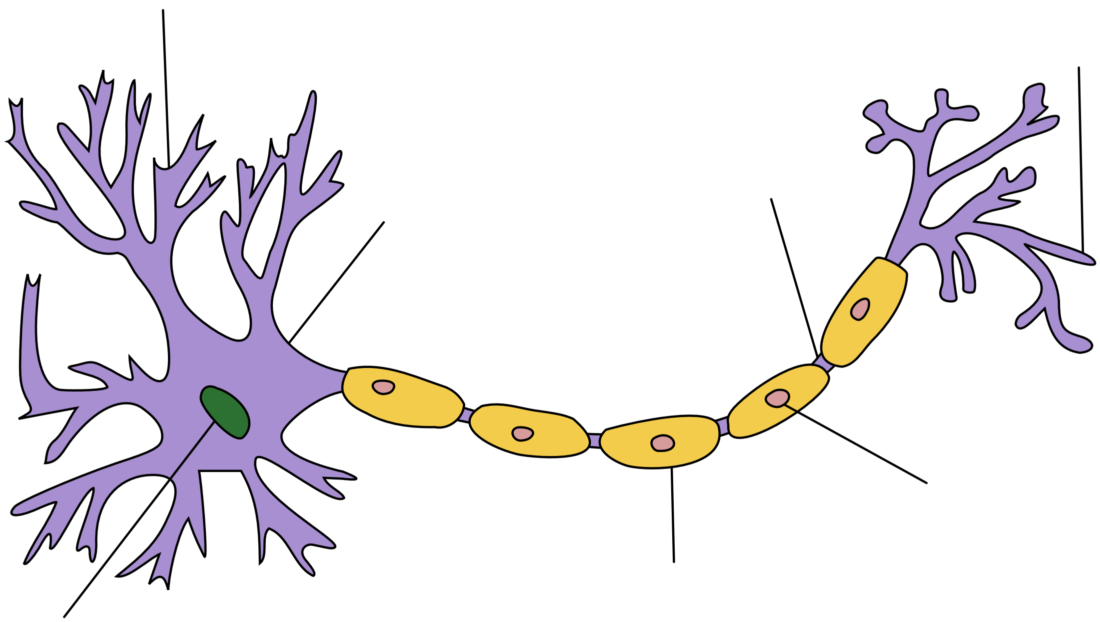


Tissue Type: , Magnification __________X

Identification of structures using the 3D neuron anatomical model. identify the following:

1. Cell body
2. Nucleus
3. Nissl bodies
4. Dendrites
5. Axons
6. Myelin sheath
7. Node of Ranvier
8. Internodes
9. Synaptic terminals – Telodendria

Label the components of a typical motor neuron



Review

Tissue type

Epithelium:	Comments	Location
Epithelium, simple squamous		
Epithelium, stratified squamous		
Epithelium, simple cuboidal		
Epithelium, pseudostratified ciliated columnar		
Epithelium, simple columnar		
Transitional epithelium		

Loose connective Tissue:	Comments	Location
Areolar tissue		
Adipose tissue		
Reticular tissuel		

Dense connective Tissue:	Comments	Location
Dense regular		
Dense irregular		

Supportive connective Tissue: Cartilage	Comments	Location
Fibrocartilage		
Elastic cartilage (yellow cartilage)		
Hyaline cartilage		

Supportive connective Tissue: Bone	Comments	Location
Compact		
Spongy bone		

Fluid connective Tissue:	Comments	Location
Blood		

Muscular Tissue:	Comments	Location
Skeletal muscle		
Cardiac muscle, intercalated disks		
Smooth muscle		

Nervous Tissue:	Comments	Location
Neuronal smear (neurons and neuroglia)		

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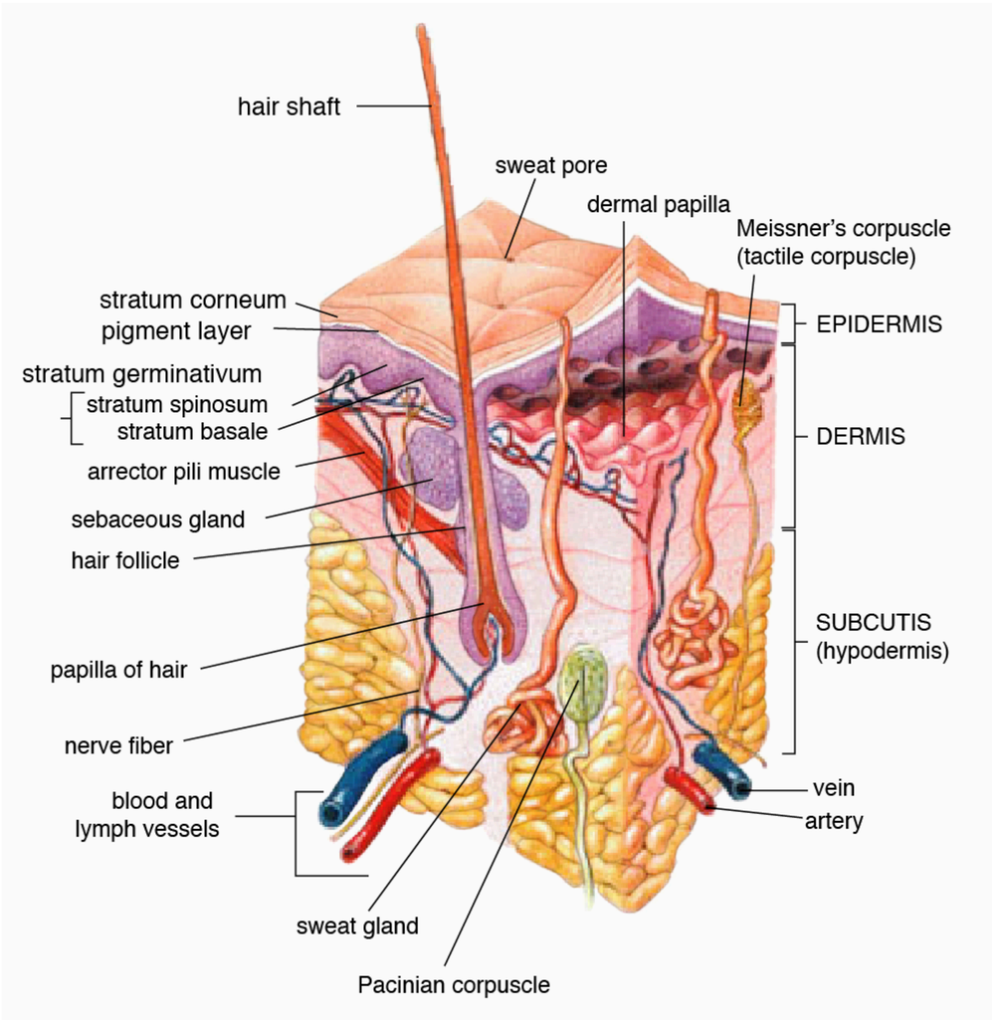
THE INTEGUMENTARY SYSTEM ANATOMY

The Integumentary System



Cross-section of skin

Objectives:

1. Identify components of the integumentary system
2. List the two types of skin
3. Describe macro and microscopic anatomy of both types of skin

4. List accessories structures of the skin
5. Associate the layers of skin and hypodermis with burn degrees

Introduction

The integumentary system is the largest organ of the human body. It is composed of four types of tissue, epithelial, connective, muscular and nervous tissues. The structures of the integumentary system include the skin, and its accessory organs; hairs, nails, accessory glands, sensory receptors. The integumentary system protects the body from dehydration, absorption of nutrients, excretion of wastes, and regulation of body temperature. It is also the attachment site of certain muscles and contains sensory receptors to detect pain, sensation, pressure, and temperature and it is also involved in synthesis of vitamin D.

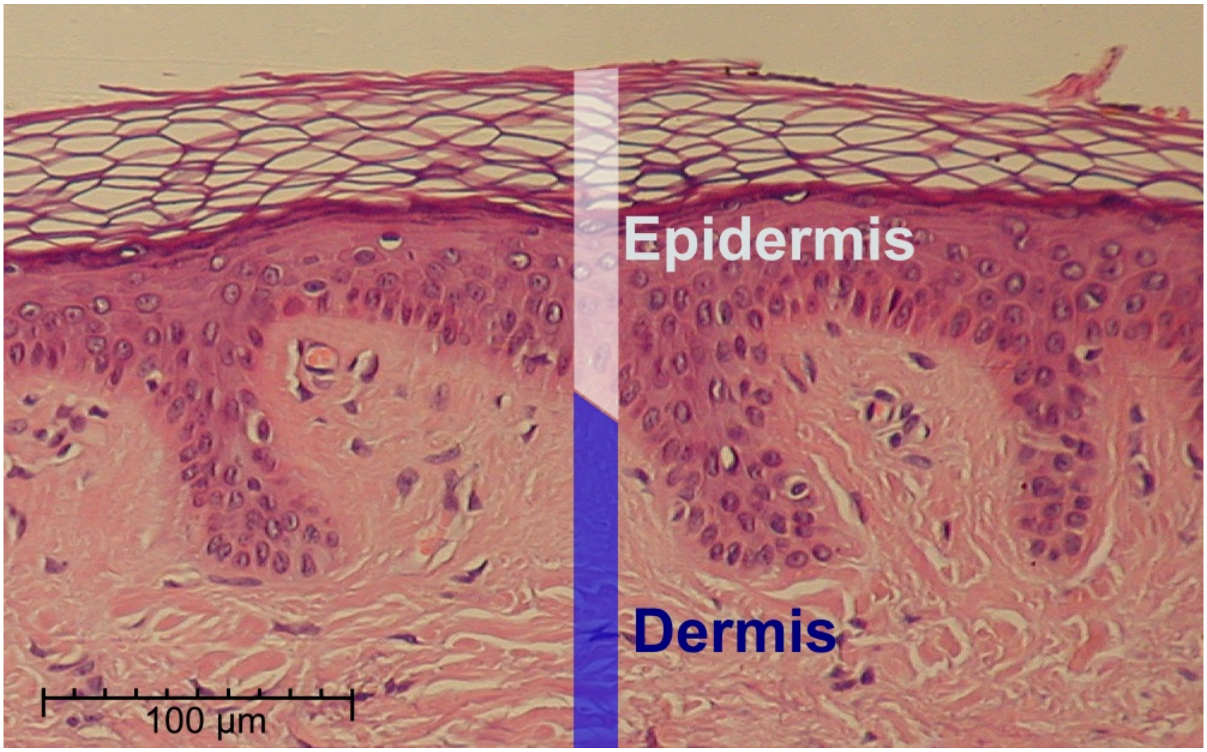
In this lab you will learn to identify the four types of tissues that compose the integumentary system and correlate them with their function.

Part 1 – Anatomy of the Skin

The skin is also called the cutaneous membrane. There are two types of skin, thin skin that is covered with hair (also contains sebaceous glands) and thick skin that has no hair.

The skin, regardless of the type is composed of two layers; the epidermis and the dermis. It has an associated layer below the dermis, called the hypodermis.

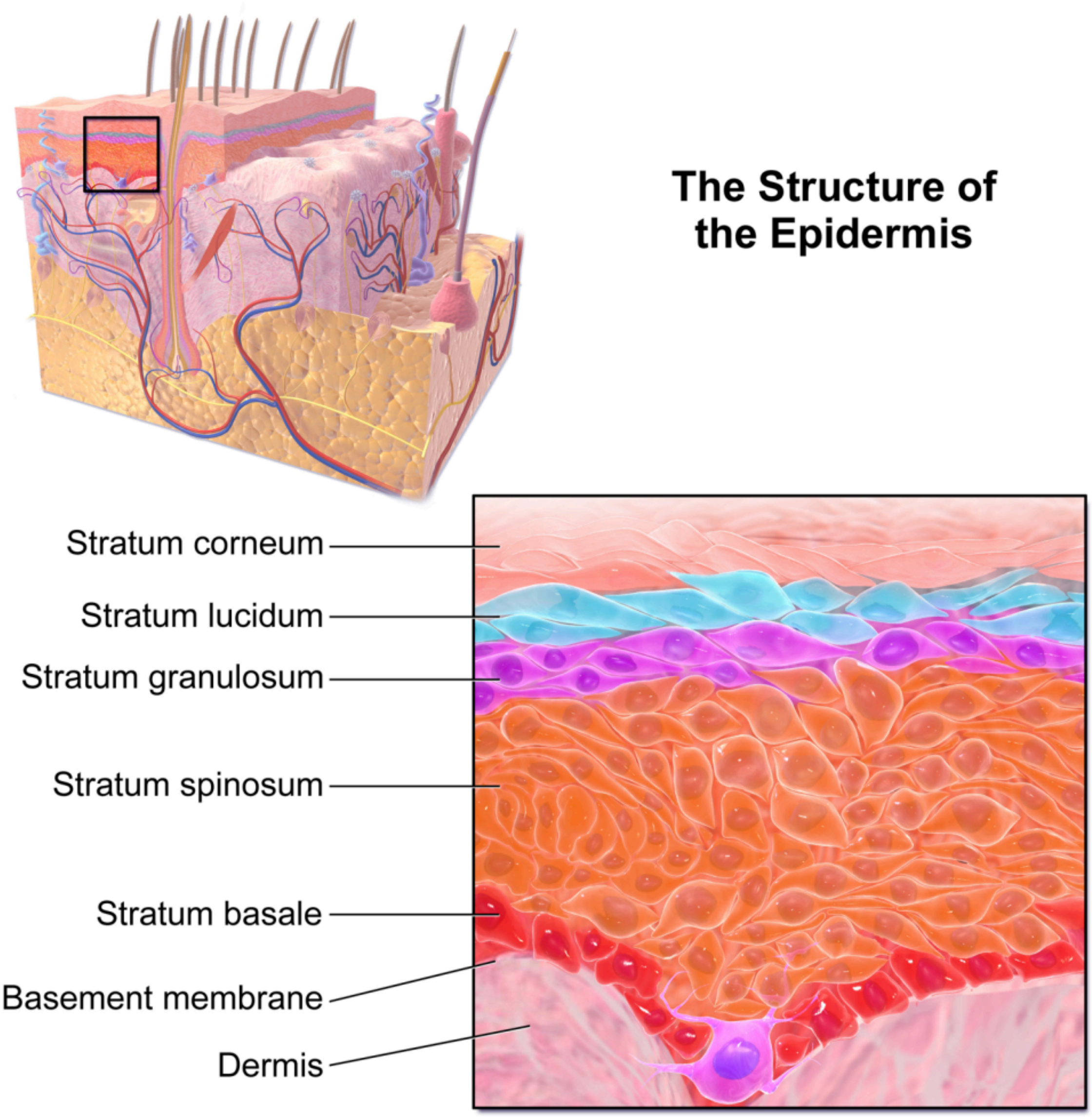
Human Skin, cross section



Layers of Skin

Epidermis

The epidermis is the top layer of skin. It is avascular, meaning, it does not contain blood vessels. It consists of layers of stratified squamous epithelium, and contains four types of cells (keratinocytes, melanocytes, Merkel cells, and Langerhans cells). The keratinocytes are the predominant cell type in the epidermis, they produce keratin, a fibrous protein that protects skin from mechanical stress. The majority of the skin on the body is keratinized. The only skin on the body that is non-keratinized is the lining of mucous membranes, such as the inside of the mouth.



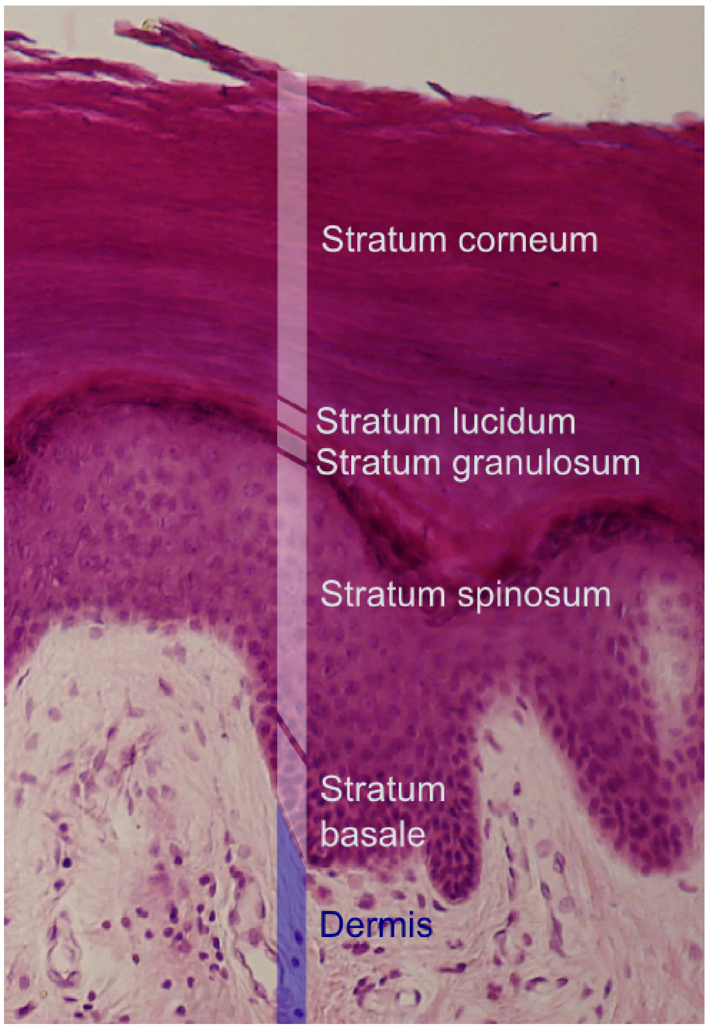
Epidermis structure

The epidermis contains 4-5 layers or strata of stratified squamous epithelium.
We will describe them from deep to superficial.

- Stratum basale: Deepest layer of the epidermis, it is composed mainly of one layer of proliferating and non-proliferating keratinocytes, attached to the basement membrane by hemidesmosomes. Melanocytes are present in this layer, connected to numerous keratinocytes through dendrites. Merkel cells are also found in the stratum basale (large numbers of touch-sensitive receptors are found in fingertips and lips).
- Stratum spinosum: Keratinocytes become connected through desmosomes and start to produce lamellar bodies, from within the Golgi, enriched in polar lipids, glycosphingolipids, free sterols, phospholipids

and catabolic enzymes. Langerhans cells (immunologically active cells) and melanin are found in the middle of this layer.

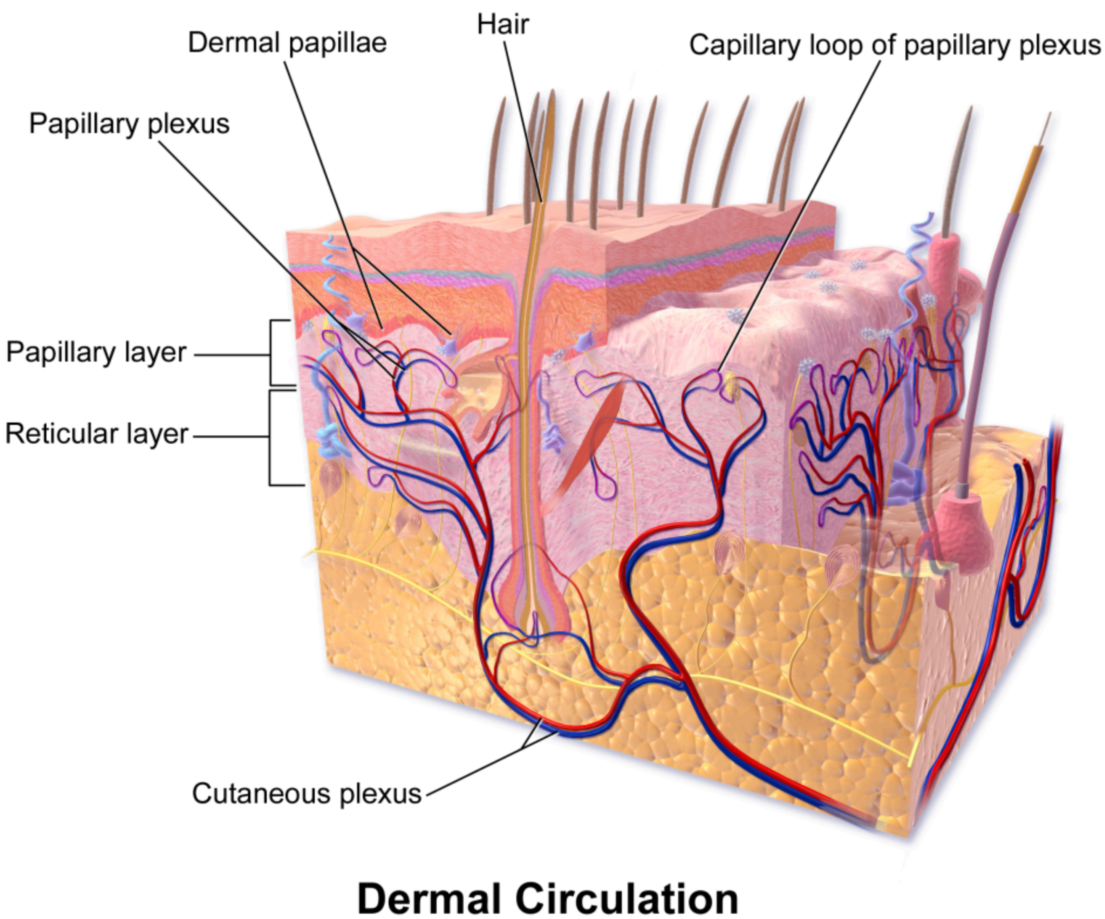
- Stratum granulosum: layer in which keratinocytes lose their nuclei and their cytoplasm appears granular. Lipids, contained into those keratinocytes within lamellar bodies, are released into the extracellular space through exocytosis to form a lipid barrier.
- Stratum lucidum: A clear/translucent layer of dead keratinocytes, only present in thick skin.
- Stratum corneum: Superficial layer of cells, composed of 10 – 30 layers anucleated keratinocyte, with the palms and soles having the most layers. Most of the barrier functions of the epidermis localize to this layer.



Layers of the epidermis, x.s. 400X

Dermis

The dermis is the middle layer of skin, composed of areolar connective tissue and dense irregular connective tissue. The dermis has two layers. The papillary layer (superficial) which consists of the areolar connective tissue. The reticular layer (deep) which consists of the dense irregular connective tissue. These layers serve to give elasticity and flexibility to the integument. The dermal layer provides a site for the blood vessels, free nerve endings, pressure receptors (Pacinian corpuscles), sweat glands, sebaceous glands, hair follicles, arrector pili muscles.



Dermal layers

Hypodermis

The hypodermis, also known as the subcutaneous layer, is a layer beneath the skin. It invaginates into the dermis and is attached to the latter, immediately above it, by collagen and elastin fibers. It is essentially composed of a type of cell known as adipocytes specialized in accumulating and storing fats. These cells are grouped together in lobules separated by connective tissue. The hypodermis acts as an energy reserve. The fat contained in the adipocytes can be brought into circulation, via the venous route, during intense effort or when there is a lack of energy providing a source for energy production. The hypodermis participates passively in thermoregulation because the fat stored in adipocytes acts as a heat insulator.

Part 2 – Anatomy of the accessory organs of the skin

Hair

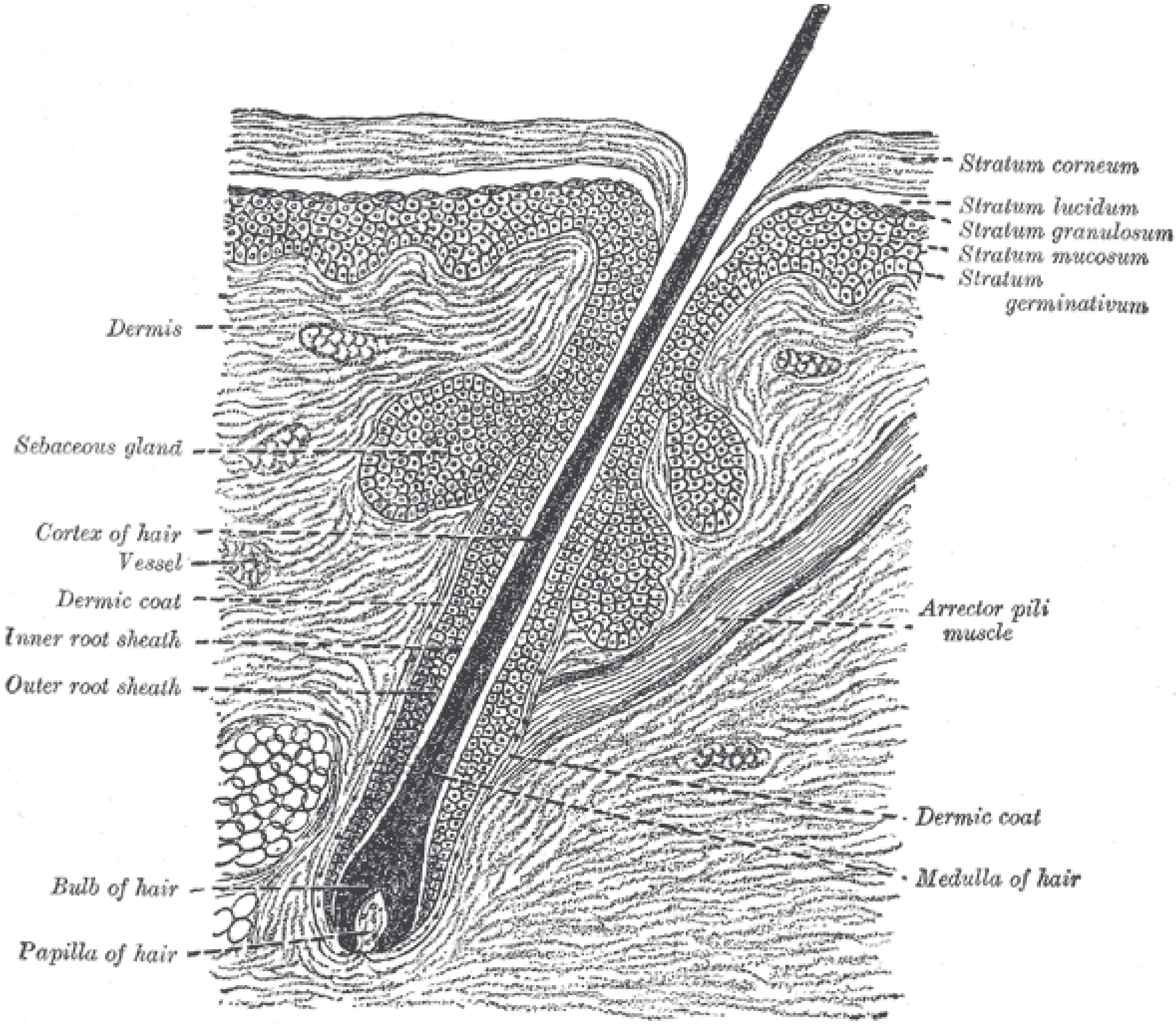
Hair is a protein filament that grows from follicles found in the dermis. The human body, apart from areas of glabrous skin, is covered in follicles which produce thick terminal and fine vellus hair.

Hair fibers have a structure consisting of several layers, starting from the outside:

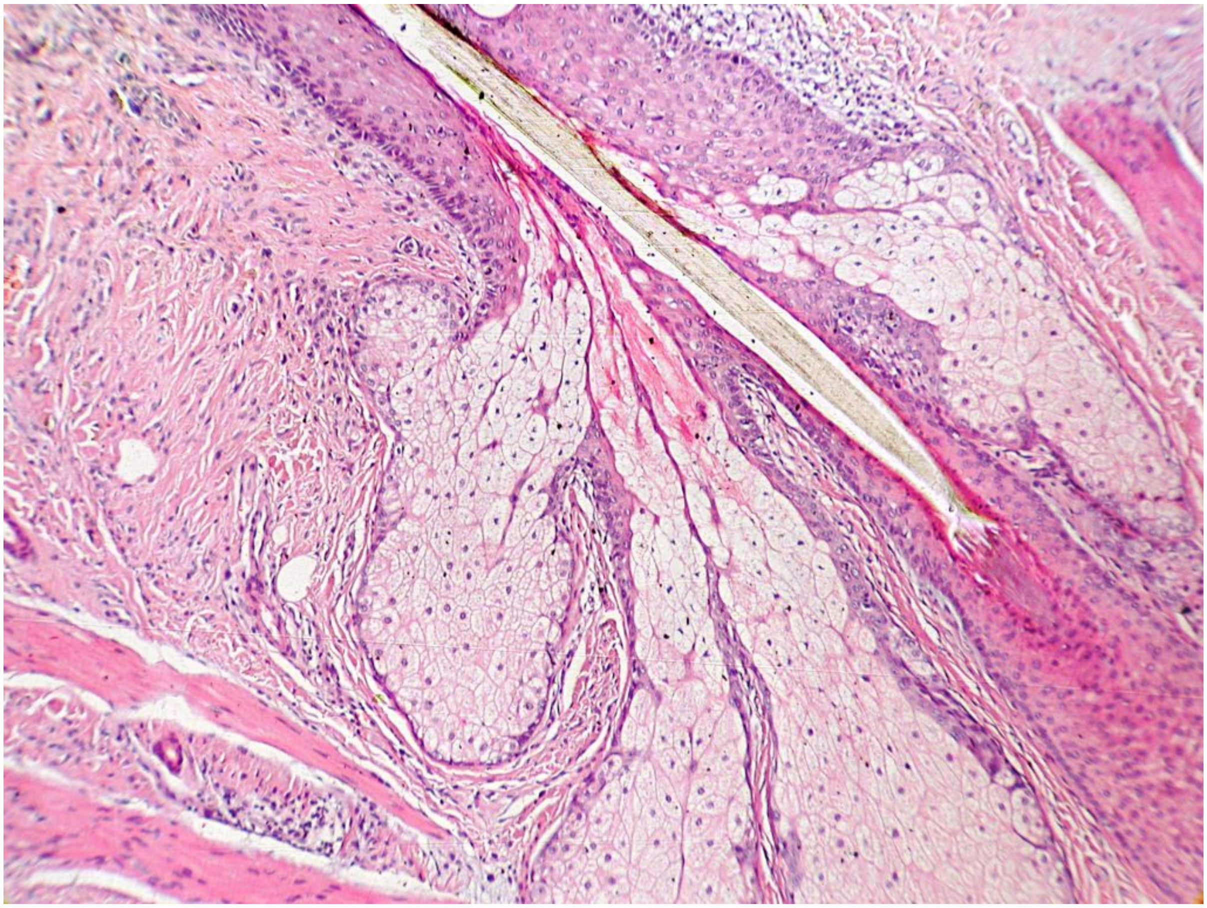
1. Cuticle, outer covering, which consists of several layers of flat, thin cells laid out overlapping one another as roof shingles
2. Cortex, which contains the keratin bundles in cell structures that remain roughly rod-like. The highly structured and organized cortex, or second of three layers of the hair, is the primary source of mechanical strength and water uptake. The cortex contains melanin, which colors the fiber based on the number, distribution and types of melanin granules. The shape of the follicle determines the shape of the cortex, and the shape of the fiber is related to how straight or curly the hair is. People with straight hair have round hair fibers. Oval and other shaped fibers are generally more wavy or curly.
3. Medulla, a disorganized and open area at the fiber's center. The innermost region of the hair.

Hair growth begins inside the hair follicle. The only "living" portion of the hair is found in the follicle. The hair that is visible is the hair shaft, which exhibits no biochemical activity and is considered "dead". The base of a hair's root (the "bulb") contains the cells that produce the hair shaft. Other structures of the hair follicle include the oil producing sebaceous gland which lubricates the hair and the arrector pili muscles, which are responsible for causing hairs to stand up. In humans with little body hair, the effect results in goose bumps.

Section of skin, showing the epidermis and dermis; a hair in its follicle; the Arrector pili muscle; sebaceous glands.



Section of skin, showing the epidermis and dermis; a hair in its follicle; the Arrector pili muscle; sebaceous glands.

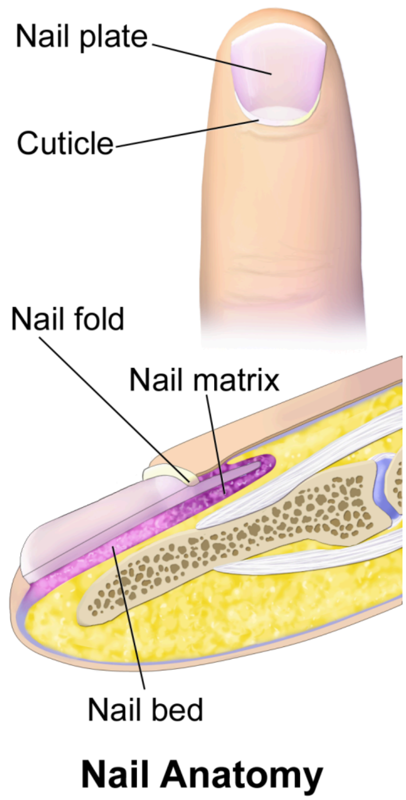


Thin skin with hair follicle, x.s., 400X

Nails

Nails are composed like hair mostly of dead keratinocytes, the protein keratin stiffens epidermal tissue to form fingernails. Nails grow from a thin area called the nail matrix at an average of 1 mm per week.

A nail is composed of a flat nail plate surrounded by nail folds. The proximal nail fold grows over the bail plate forms a structure called the cuticle or eponychium. Near the eponychium you can find a thickened area of the nail plate that looks like a half a moon (crescent-shape), this area is called the lunula.



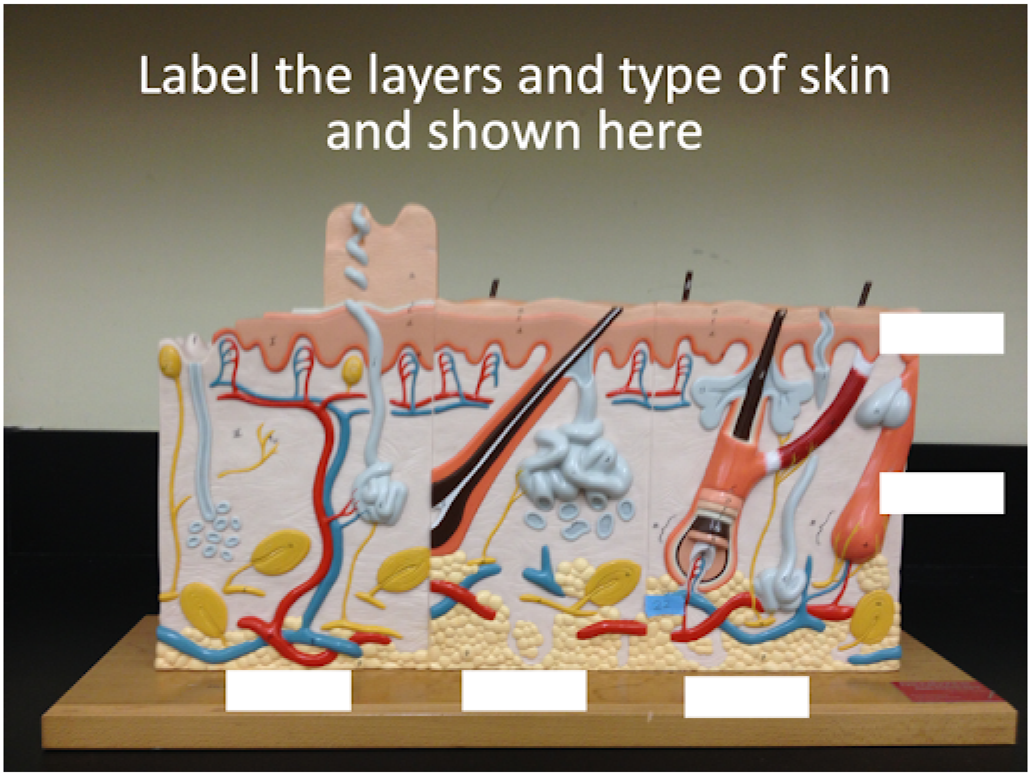
Finger nail anatomy

Laboratory Activity – Skin

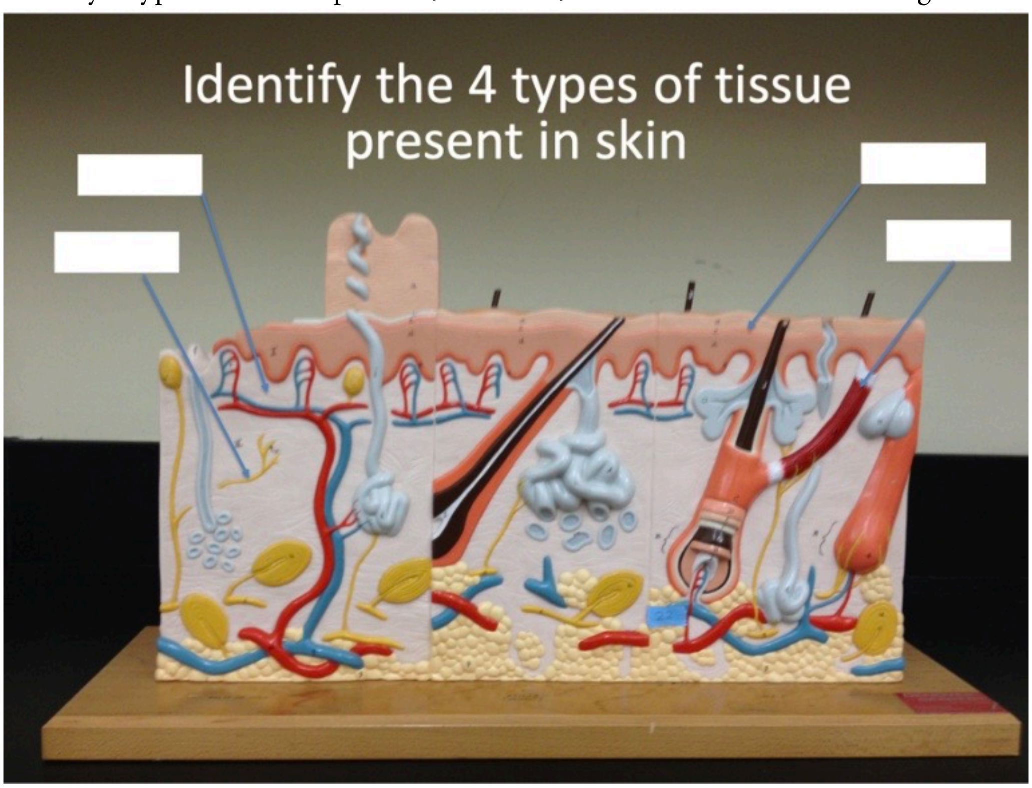
Macroscopic Anatomy of Skin

Use the Anatomical Model of Skin (Denoger Geppert #185) to identify parts of the skin (thick and thin skin):

1. Epidermis (with all layers), Dermis and the associated layer the hypodermis and types of skin (thin or thick). Highlighted in yellow needs to be added.

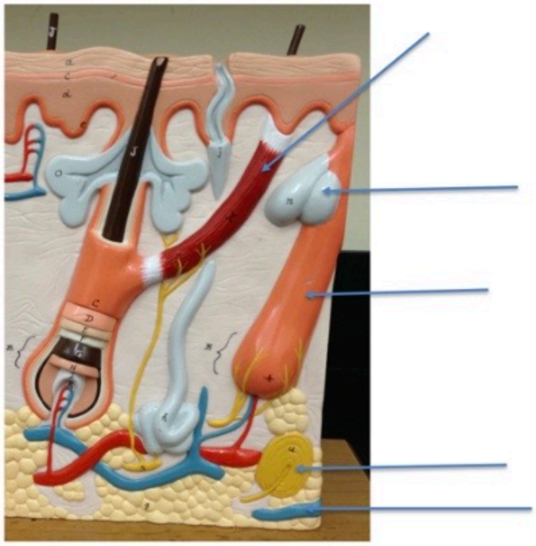


2. Identify 4 types of tissue: Epithelial, muscular, connective and nervous using this model.



3. Identify sweat glands, sebaceous glands, blood vessels, free nerve endings, Meisner corpuscles, arrector pili muscle, hair follicle, hair plexus.

Name the structures



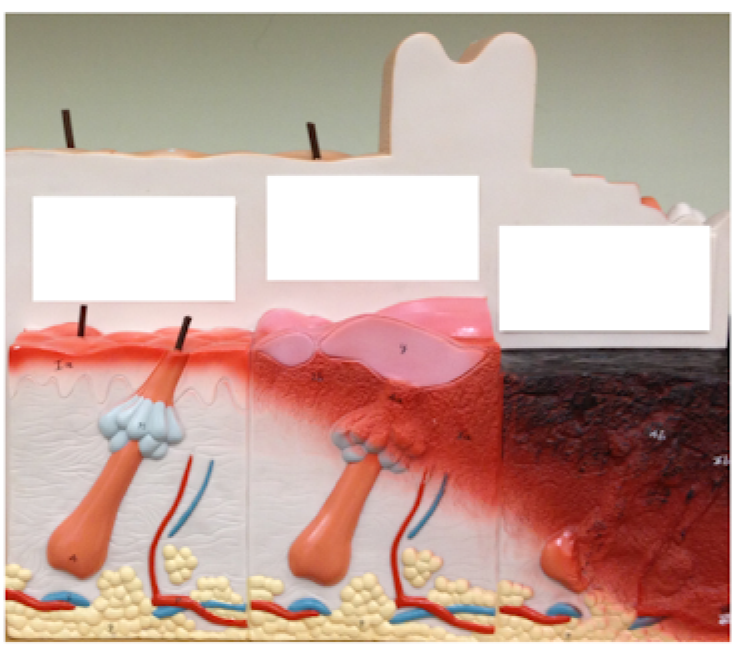
4. Describe burn degrees and associate them with layers of the skin and hypodermic layer.

   First degree:

   Second degree:

   Third degree:

Name the burn degrees shown here



Microscopy Anatomy of Skin

Observe microscope slides of different types of skin:

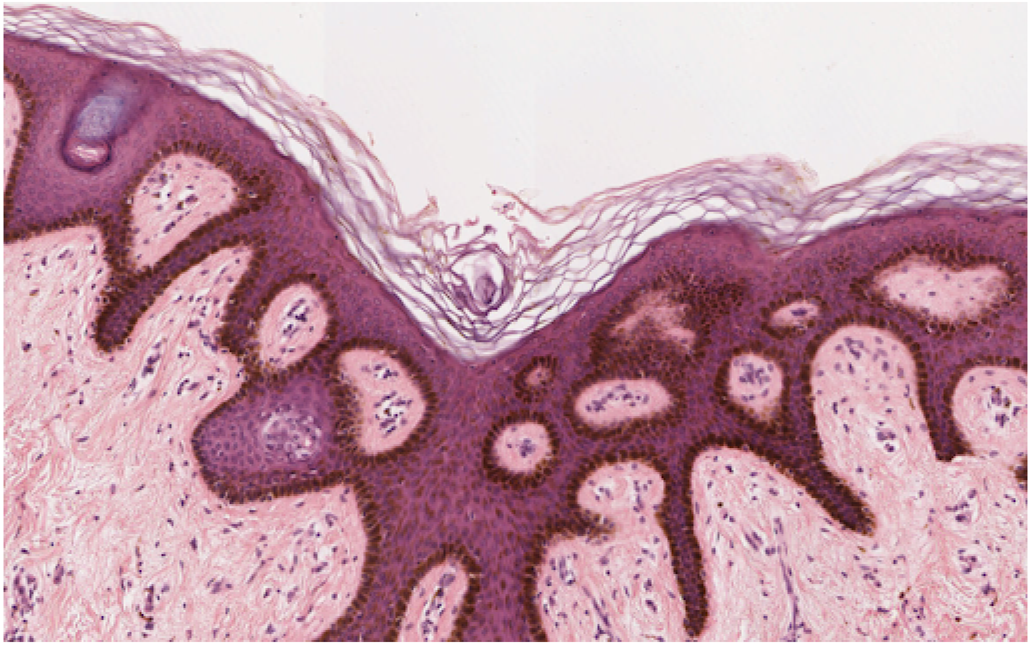
1. Human Thick Skin (Pigmented).

Draw what you see and label the following structures:

- Epidermis (all layers)
  - stratum corneum
  - stratum granulosum
  - stratum spinosum
  - stratum basale (note the pigmentation in this layer). What is the type of cells that produce the pigmentation seen here?
- Dermis
- Subcutaneous layer

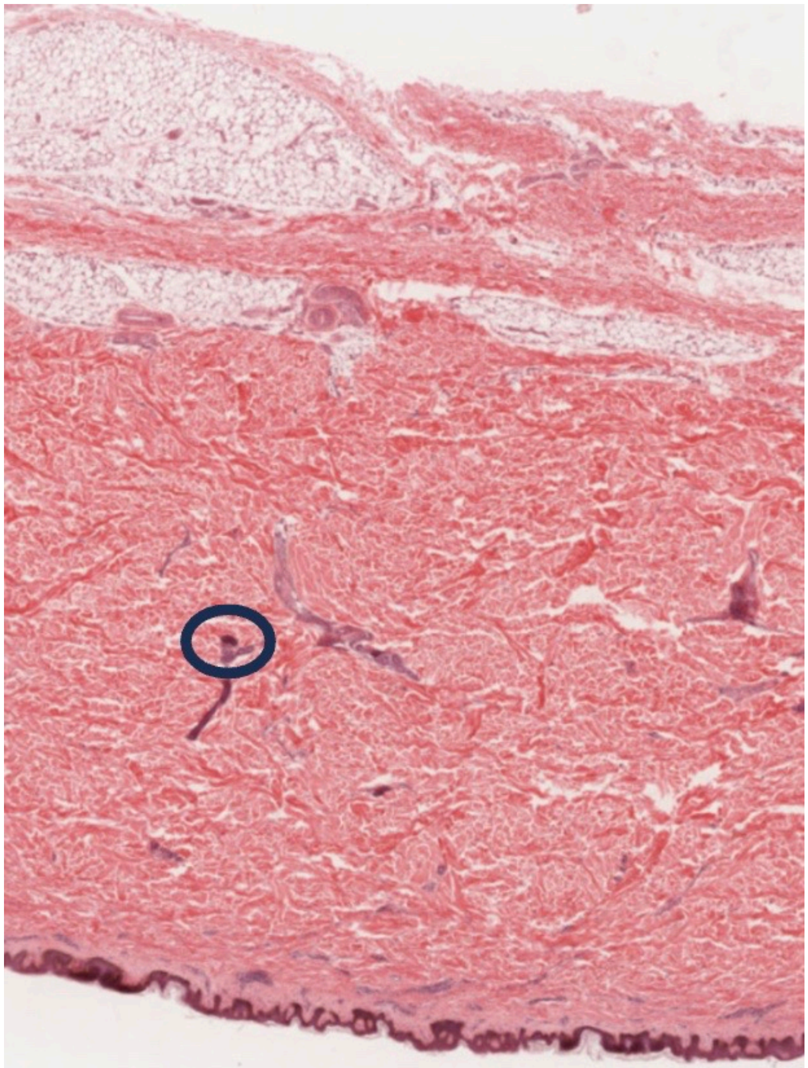
Note: for 100% online courses use UM Virtual Microscope.

slide # 104-2 or 105-2



Look at the slide with the lowest magnification possible, is this thin or thick skin? Why?

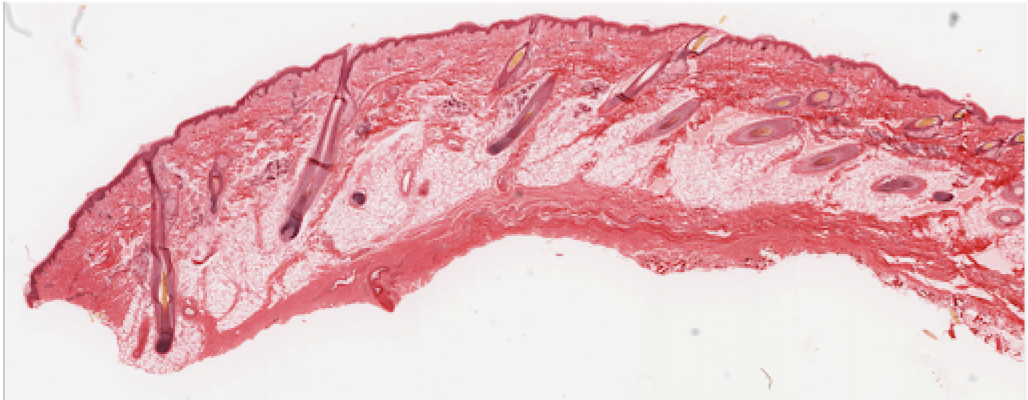
Now look at slide 105-2, Pigmented skin at lowest magnification and focus on the area of the dermis delineated with a circle, what type of tissue do you see? What do you think this is?



2. White human skin.
   Draw and label the following:

   - Epidermis (all layers)
     - stratum corneum
     - stratum granulosum
     - stratum spinosum
     - stratum basale
   - Dermis
   - Subcutaneous layer

Note: for 100% online courses use [UM Virtual Microscope.](#)
[slide #107](#)



Now Zoom in to high magnification and moving around locate draw and label the following structures:

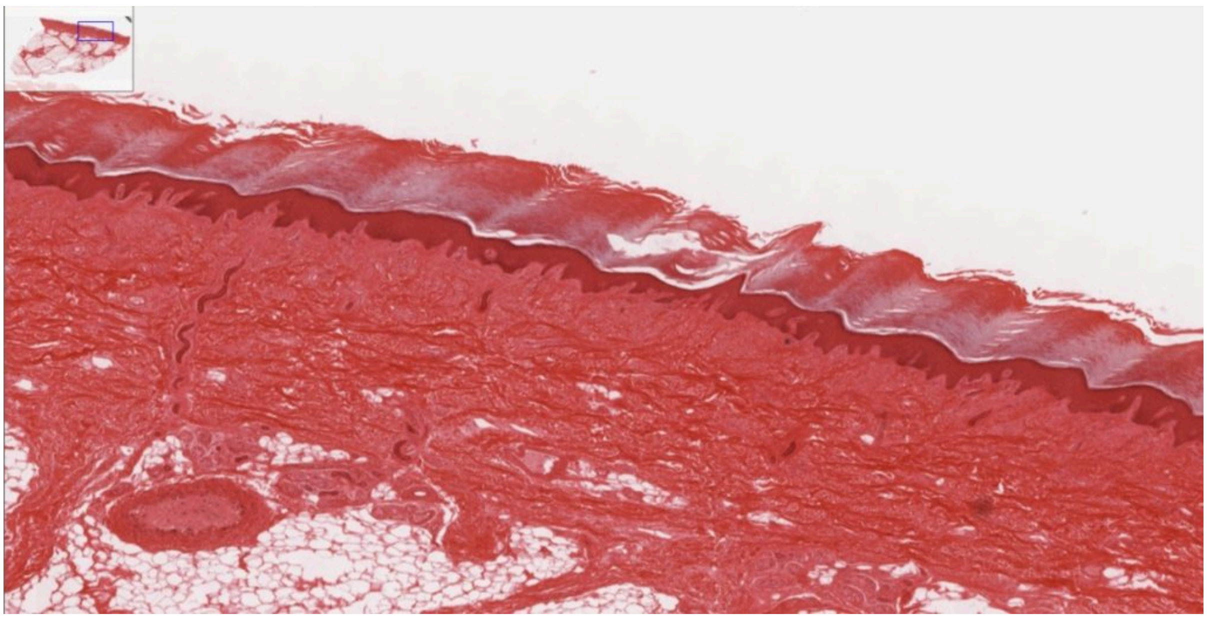
- hair follicles
- external root sheath
- Sebaceous glands
- Arrector pili
- Sweat gland ducts
- Adipose tissue

3. Thick Skin.
   Draw and label the following:

    - Epidermis
        - stratum corneum
        - stratum lucidum
        - stratum granulosum
        - stratum spinosum
        - stratum basale
    - Dermis
    - Ducts of sweat glands
    - Subcutaneous layer

Note: for 100% online courses use UM Virtual Microscope.

slide # 112N – Thick skin, sole of foot



Note: to be able to see the layers of the epidermis, you need to Zoom in.

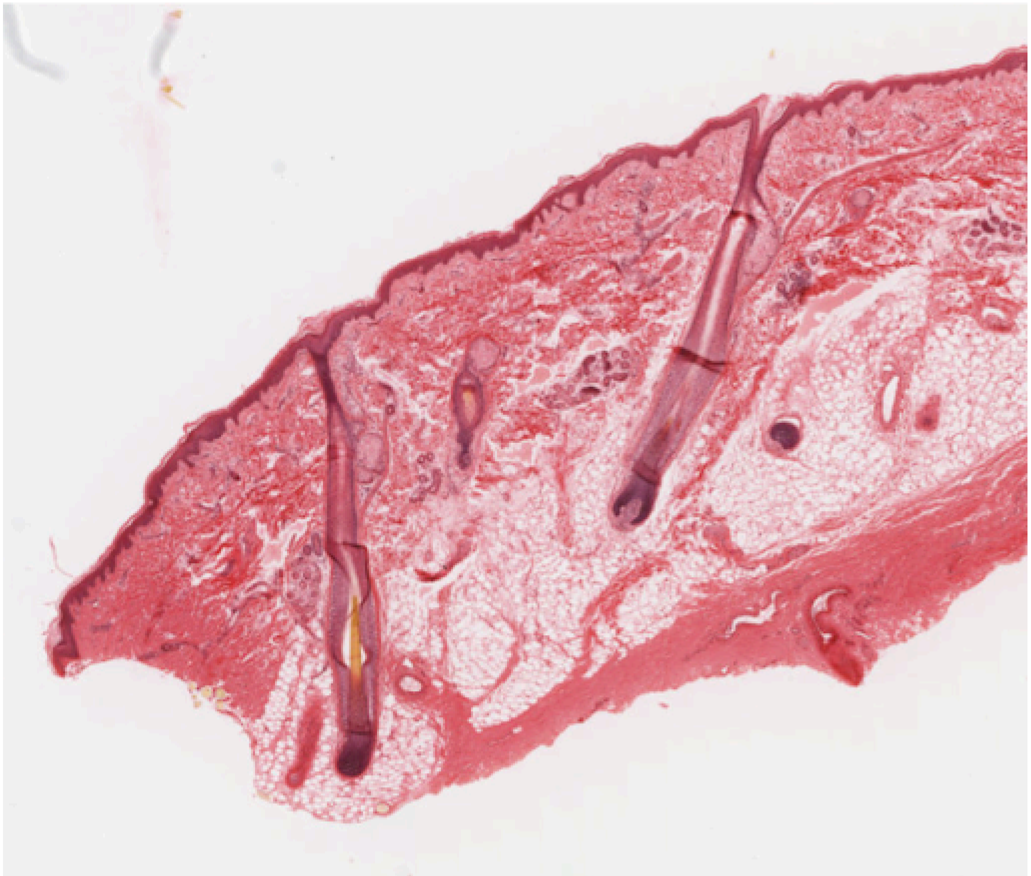
4. Human Scalp c.s – Examine a longitudinal section of a hair follicle
   Draw and label the following; hair shaft, hair follicle, bulb. dermal papilla, sebaceous gland, sweat gland and the region of cell division. Go to UM virtual microscope – Skin and Mammary glands section, Slide#107, Scalp, hair, H&E

   1. Download the image for labeling.

      - Using low power, locate and label the following structures:
      - Hair follicle
      - Sebaceous glands

2. Using high power locate the following structures:

    - External root sheath of the hair follicle
    - Root of hair follicle
    - Hair shaft
    - Arrector pili muscle



1. Anatomy of a nail
    1. Go to UM Virtual microscope slide # 108 20X– Fetal finger

    2. Label the following structures:

- Nail fold
- Nail matrix
- NAIL bed
- Distal medial and proximal phalanges

3. Zoom in and locate the following tissues:

    - hyaline cartilage
    - bone
    - epidermis
    - dermis

Apply what you have learned

Answer the following questions. You may need to use the textbook as reference to answer these questions.

1. What is the predominant tissue type in the epidermis?

2. What is the predominant tissue type in the dermis?

3. What is the predominant tissue type in the hypodermis?

4. Were you able to identify the melanocytes? In which layer do you see them? What is their function?

5. Which other structures can you identify within the dermis?

6. What type of tissue makes the ducts of the sweat glands? Did you find one?

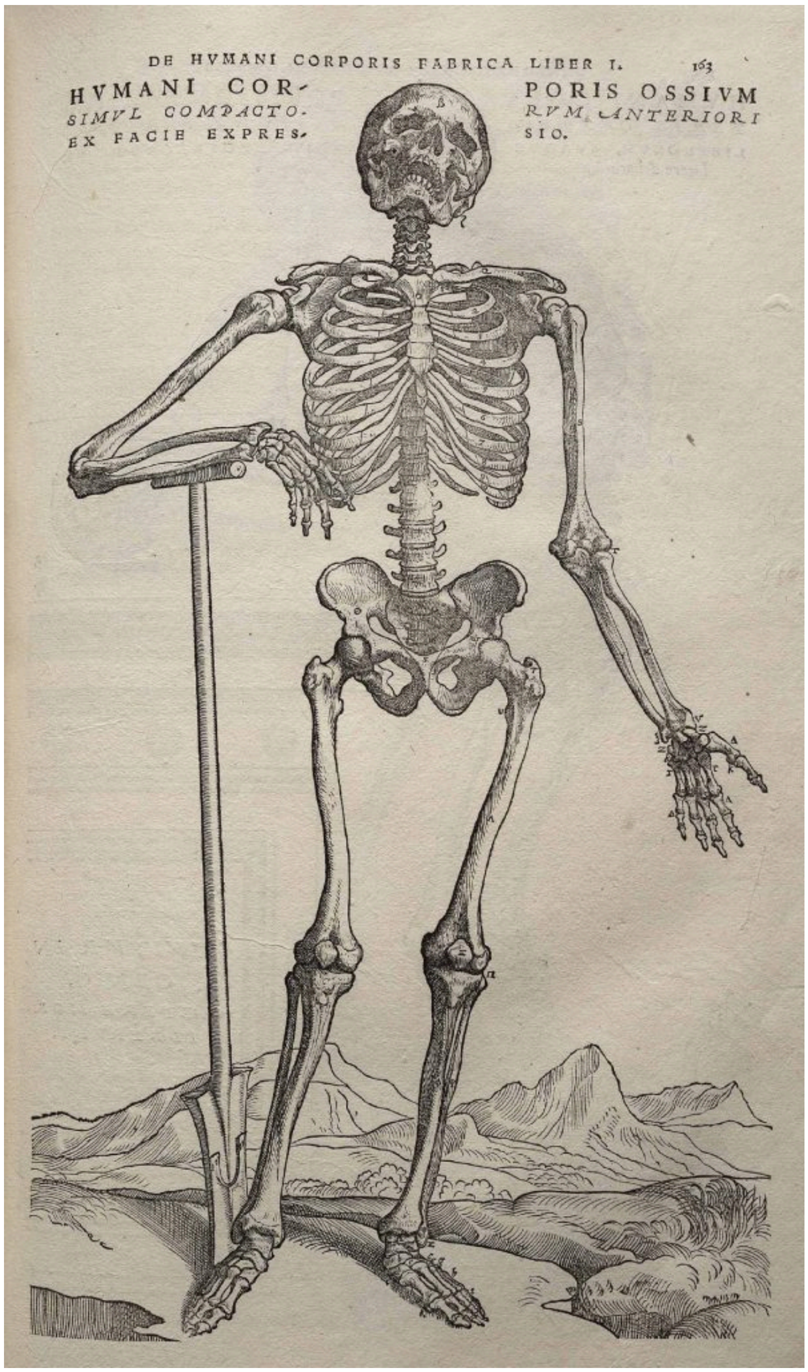
7. What type of tissue is present in the dermis of the skin?

8. List the layers of a hair, as seen from a cross section of hair.

Media Attributions

THE BONE TISSUE

Introduction to Skeletal System Laboratory Activity



Introduction

The skeletal system consists of bones and cartilages in the body.

Bones are complex organs, they are made up of bone cells, protein fibers, minerals, and other types of tissues. The main function of the skeletal system is to provide support and protection to the soft tissues that make up the rest of the body. The skeletal system also provides attachment for muscles to allow movements at the joints, it is a place where store fat and precious minerals such as calcium and phosphorous. Another function of bones is to house the bone marrow that is involved in the production of the formed element of blood.

In the human body at birth, there are over 300 bones, many of these bones fuse together during development, leaving a total of 206 separate bones in the adult, not counting numerous small sesamoid bones. The largest bone in the body is the femur or thigh-bone, and the smallest is the stapes in the middle ear.

This laboratory exercise will introduce you to the components of bone, its functional units and the skeletal system as a whole. You will also learn to identify the shape of bones that form the human skeleton and selected processes of the bones.

Objectives

- List major functions of the human skeletal system
- Describe and list types of bones
- Identify and label the structural and functional units of osseous tissue at the microscopic level
- Classify bones according to shape, and give examples of each
- Identify parts of long bones and flat bones
- List and describe the function of selected bone markings

Part 1 – Osseous Tissue

Bone tissue (osseous tissue) is a hard and mineralized connective tissue, it is made up of different types of bone cells: osteoblasts and osteocytes are involved in the formation and mineralization of bone; osteoclasts are involved in the resorption of bone tissue. Modified (flattened) osteoblasts become the lining cells that form a protective layer on the bone surface.

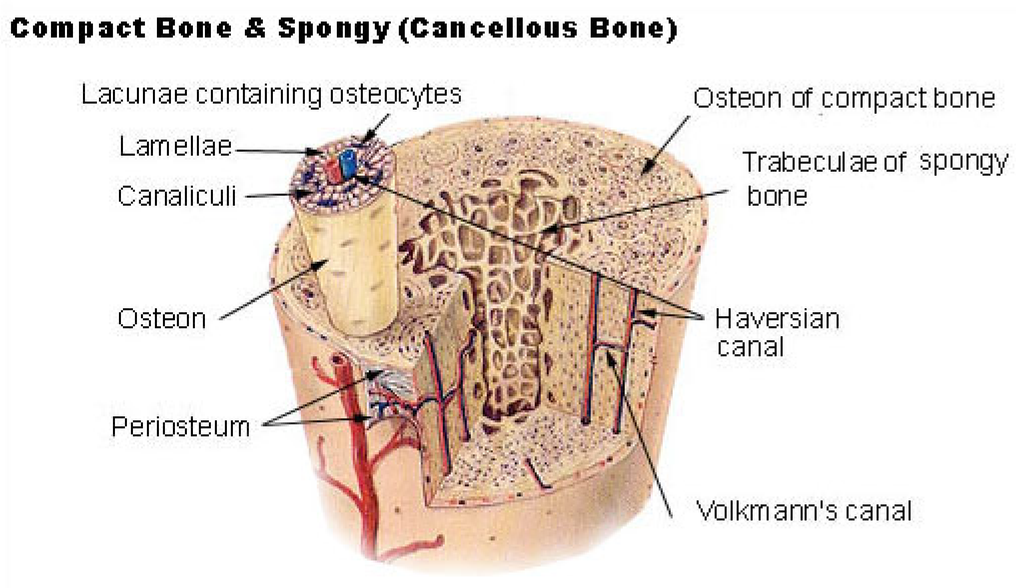
The mineralized matrix of bone tissue has an organic component of mainly collagen called ossein and an inorganic component of bone mineral made up of various salts . There are two types of mineralized bone; Compact bone (cortical) and Spongy (trabecular or cancellous) bone.

Bone is not uniformly solid, it consists of a flexible matrix and bound minerals, which are intricately woven and endlessly remodeled by a group of specialized bone cells. Their unique composition and design allow bones to be relatively hard and strong, while remaining lightweight.

Bone matrix is 90 to 95% composed of elastic collagen fibers, also known as ossein and the remainder is ground substance. The elasticity of collagen improves fracture resistance. The matrix is hardened by the binding of inorganic mineral salt calcium phosphate in a chemical arrangement known as calcium hydroxyapatite. It is the bone mineralization that give bones rigidity.

Bone is actively constructed and remodeled throughout life by special bone cells known as osteoblasts and osteoclasts. Within any single bone, the tissue is woven into two main patterns, known as cortical and cancellous bone, and each with different appearance and characteristics.

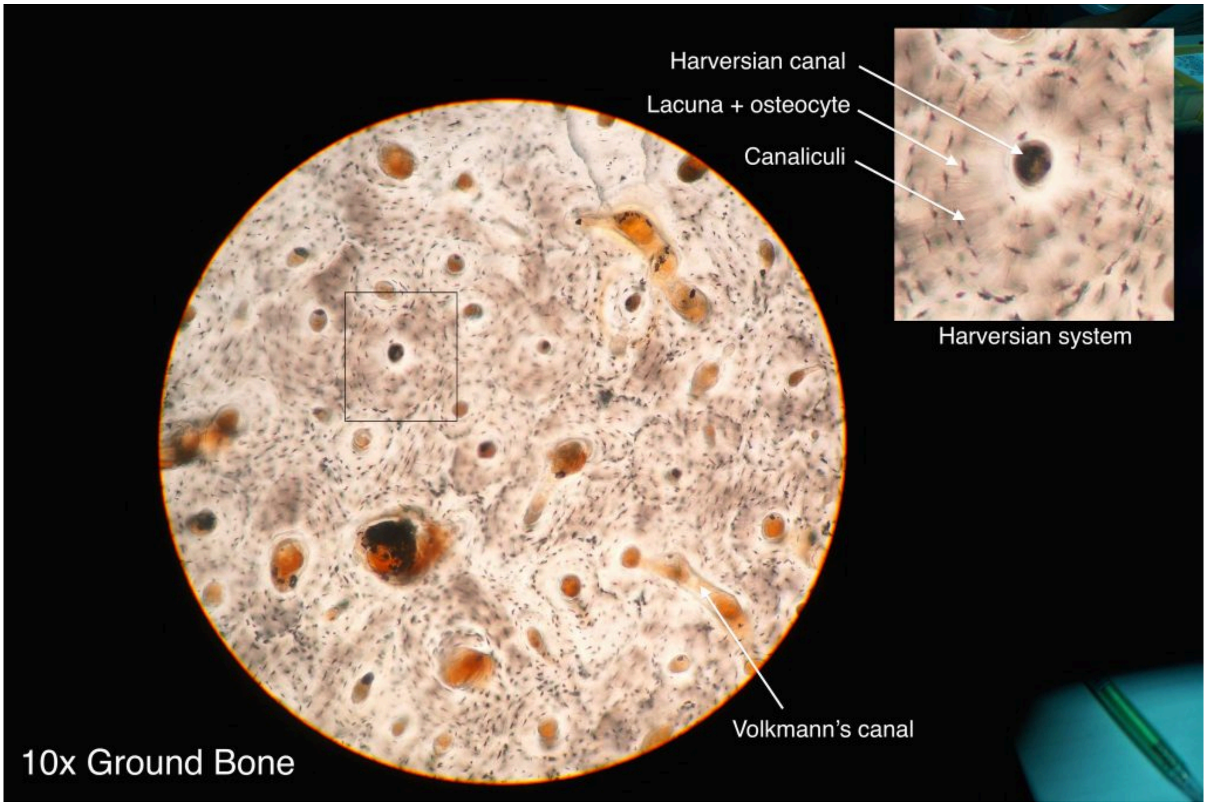
Compact or Cortical bone



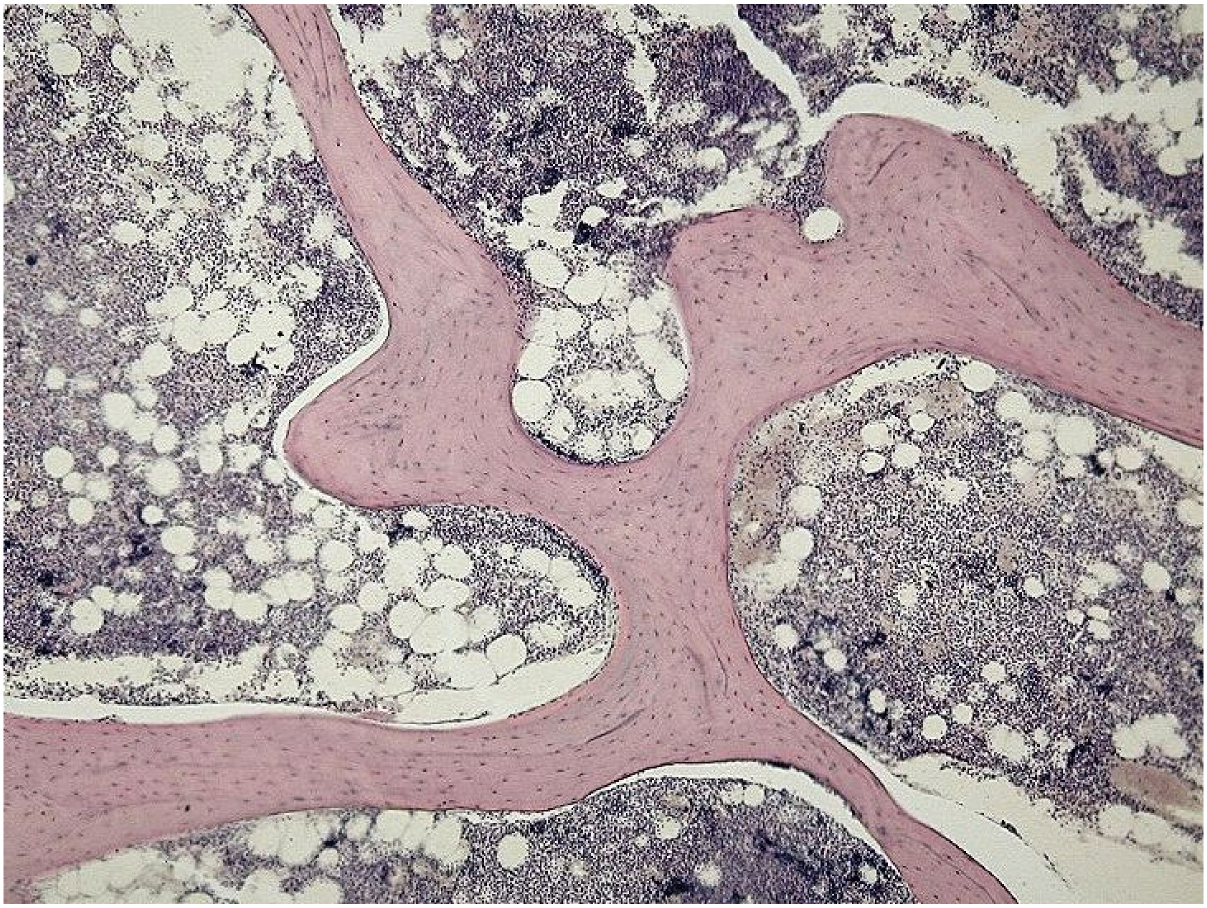
Cross-section details of a long bone

The hard, outer layer of bones is composed of cortical bone also called compact bone being much denser than cancellous bone. The cortical bone gives bone its smooth, white, and solid appearance, and accounts for 80% of the total bone mass of an adult human skeleton. It facilitates bone's main functions: to support the whole body, protect organs, provide levers for movement, and store and release minerals, mainly calcium and phosphorus. It consists of multiple microscopic functional units, called an osteon.

The osteons (Harvesian Systems) are arranged as multiple layers of osteoblasts and osteocytes around a central canal or Haversian canal. The osteons connect with each other at right angles via the perpendicular or Volkmann's canals. Osteons are metabolically active, and as bone is reabsorbed and created the nature and location of the cells within the bone will change. Cortical bone is covered by a periosteum on its outer surface, and an endosteum on its inner surface. The endosteum is the boundary between the cortical bone and the cancellous bone. The periosteum is formed of two layers: the outer fibrous layer made of dense irregular fibrous connective tissue where the blood vessels and nerves are located and the inner cellular layer of periosteum that contains osteogenic cells that become osteoblasts (build the matrix) and osteoclasts (reabsorb the matrix). The fibers of the periosteum extend to form Sharpey's fibers that anchor the periosteum to the bone.



Histology of compact bone showing osteon



Micrograph of cancellous bone

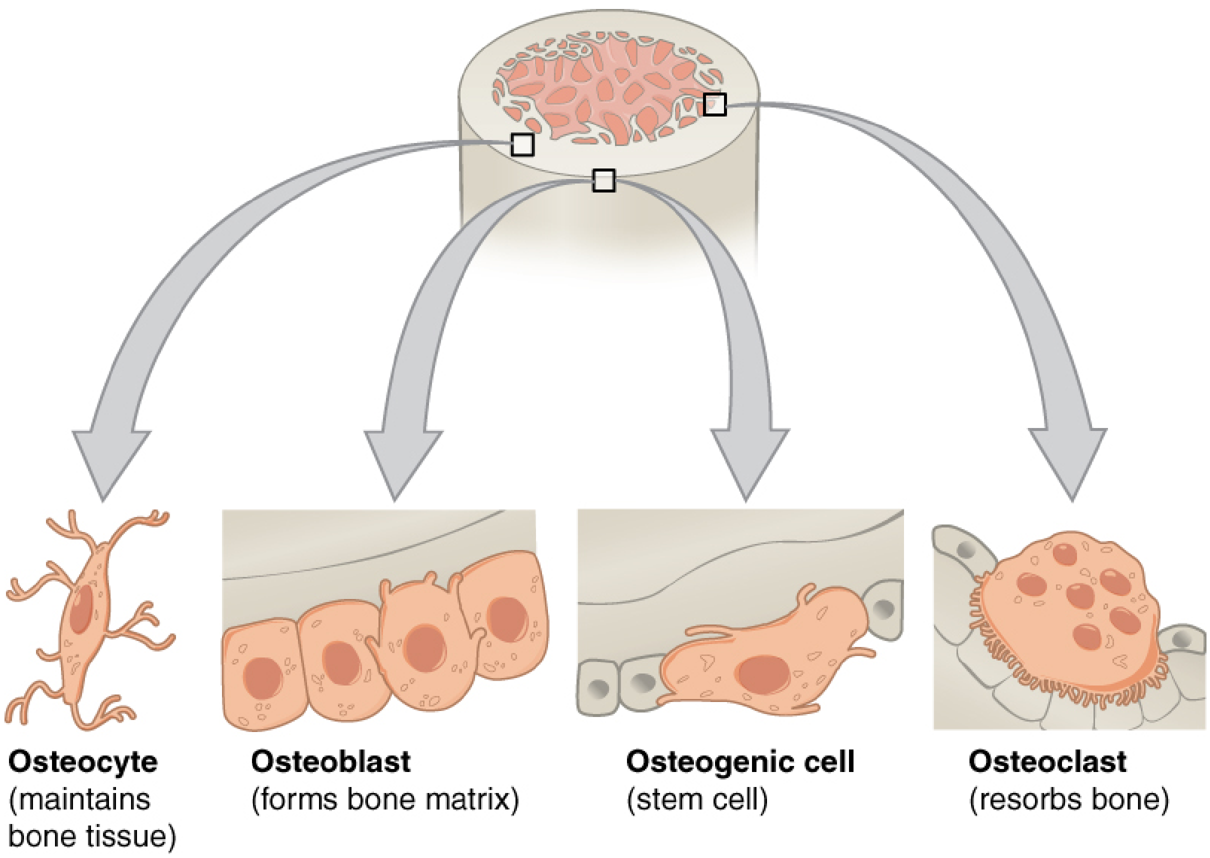
Cancellous bone, also called trabecular or spongy bone, is the internal tissue of the skeletal bone and is an open cell porous network. Cancellous bone has a higher surface-area-to-volume ratio than cortical bone because it is less dense. This makes it weaker and more flexible. The greater surface area also makes it suitable for metabolic activities such as the exchange of calcium ions. Cancellous bone is typically found at the ends of long bones, near joints and in the interior of vertebrae. Cancellous bone is highly vascular and often contains red bone marrow where hematopoiesis, the production of blood cells, occurs. The primary anatomical and functional unit of cancellous bone is the trabecula. The trabeculae are aligned towards the mechanical load distribution that a bone experiences within long bones such as the femur. As far as short bones are concerned, trabecular alignment has been studied in the vertebral pedicle. Thin formations of osteoblasts covered in endosteum create an irregular network of spaces, known as trabeculae. Within these spaces are bone marrow and hematopoietic stem cells that give rise to platelets, red blood cells and white blood cells. Trabecular marrow is composed of a network of rod- and plate-like elements that make the overall organ lighter and allow room for blood vessels and marrow. Trabecular bone accounts for the remaining 20% of total bone mass but has nearly ten times the surface area of compact bone.

The words cancellous and trabecular refer to the tiny lattice-shaped units (trabeculae) that form the tissue.

Bone marrow

Bone marrow, also known as myeloid tissue in red bone marrow, can be found in almost any bone that holds cancellous tissue. In newborns, all such bones are filled exclusively with red marrow, but as the child ages the hematopoietic fraction decreases in quantity and the fatty/ yellow fraction called marrow adipose tissue (MAT) increases in quantity. In adults, red marrow is mostly found in the bone marrow of the femur, the ribs, the vertebrae and pelvic bones.

Bone cells



Bone Cells

Bone is a metabolically active tissue composed of several types of cells. These cells include osteoblasts, which are involved in the creation and mineralization of bone tissue, osteocytes, and osteoclasts, which are involved in the reabsorption of bone tissue.

Osteoblast

Osteoblasts are mononucleate bone-forming cells. They are located on the surface of osteon seams and make a protein mixture known as osteoid, which mineralizes to become bone.

The osteoid seam is a narrow region of newly formed organic matrix, not yet mineralized, located on the surface of a bone. Osteoid is primarily composed of Type I collagen. Osteoblasts also manufacture hormones, such as prostaglandins, to act on the bone itself. The osteoblast creates and repairs new bone by actually building around itself. First, the osteoblast puts up collagen fibers. These collagen fibers are used as a framework for the osteoblasts' work. The osteoblast then deposits calcium phosphate which is hardened by hydroxide and bicarbonate ions. The brand-new bone created by the osteoblast is called osteoid. Once the osteoblast is finished working it is actually trapped inside the bone once it hardens. When the osteoblast becomes trapped, it becomes known as an osteocyte. Other osteoblasts remain on the top of the new bone and are used to protect the underlying bone, these become known as lining cells.

Osteocyte

Osteocytes are mostly inactive osteoblasts. Osteocytes originate from osteoblasts that have migrated into and become trapped and surrounded by bone matrix that they themselves produced. The spaces they occupy are known as lacunae. Osteocytes have many processes that reach out to meet osteoblasts and other osteocytes probably for the purposes of communication. Osteocytes remain in contact with other cells in the bone through gap junctions—coupled cell processes—which pass through small channels in the bone matrix called the canaliculi.

Osteoclast

Osteoclasts are very large multinucleate cells that are responsible for the breakdown of bones by the process of bone resorption. New bone is then formed by the osteoblasts. Bone is constantly remodeled by the resorption of osteoclasts and created by osteoblasts. Because the osteoclasts are derived from a monocyte stem-cell lineage, they are equipped with phagocytic-like mechanisms similar to circulating macrophages. Osteoclasts mature and/or migrate to discrete bone surfaces. Upon arrival, active enzymes, such as tartrate resistant acid phosphatase, are secreted against the mineral substrate. The reabsorption of bone by osteoclasts also plays a role in calcium homeostasis.

Extracellular matrix

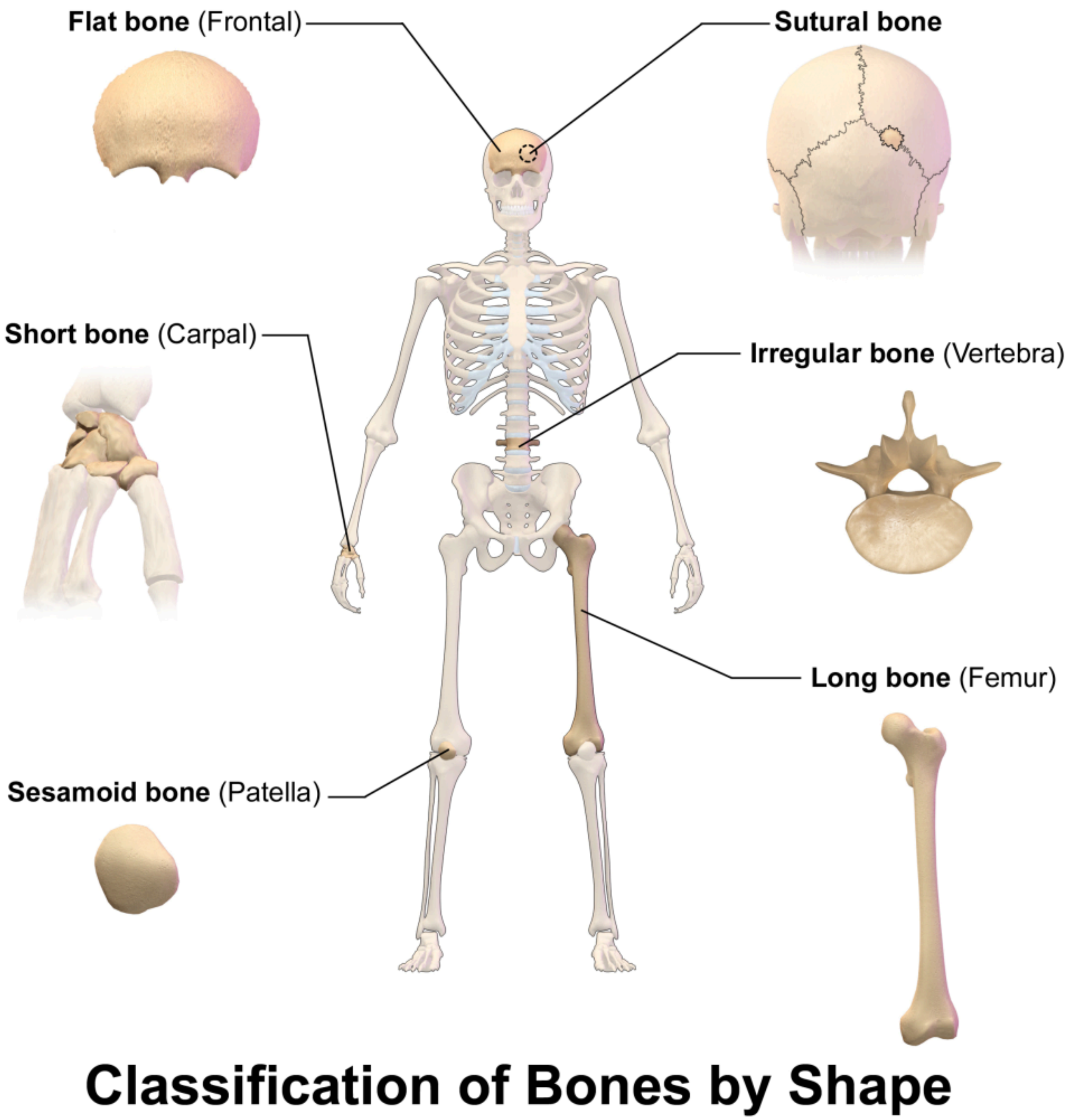
Bones consist of living cells embedded in a mineralized organic matrix. This matrix consists of organic components, mainly type I collagen – "organic" referring to materials produced as a result of the human body – and inorganic components, primarily hydroxyapatite and other salts of calcium and phosphate. Above 30%

of the acellular part of bone consists of the organic components, and 70% of salts. The collagen fibers give bone its tensile strength, and the interspersed crystals of hydroxyapatite give bone its compressive strength. These effects are synergistic.

The inorganic composition of bone (bone mineral) is primarily formed from salts of calcium and phosphate, the major salt being hydroxyapatite (Ca10(PO4)6(OH)2). The exact composition of the matrix may be subject to change over time due to nutrition and biomineralization, with the ratio of calcium to phosphate varying between 1.3 and 2.0 (per weight), and trace minerals such as magnesium, sodium, potassium and carbonate also being found.

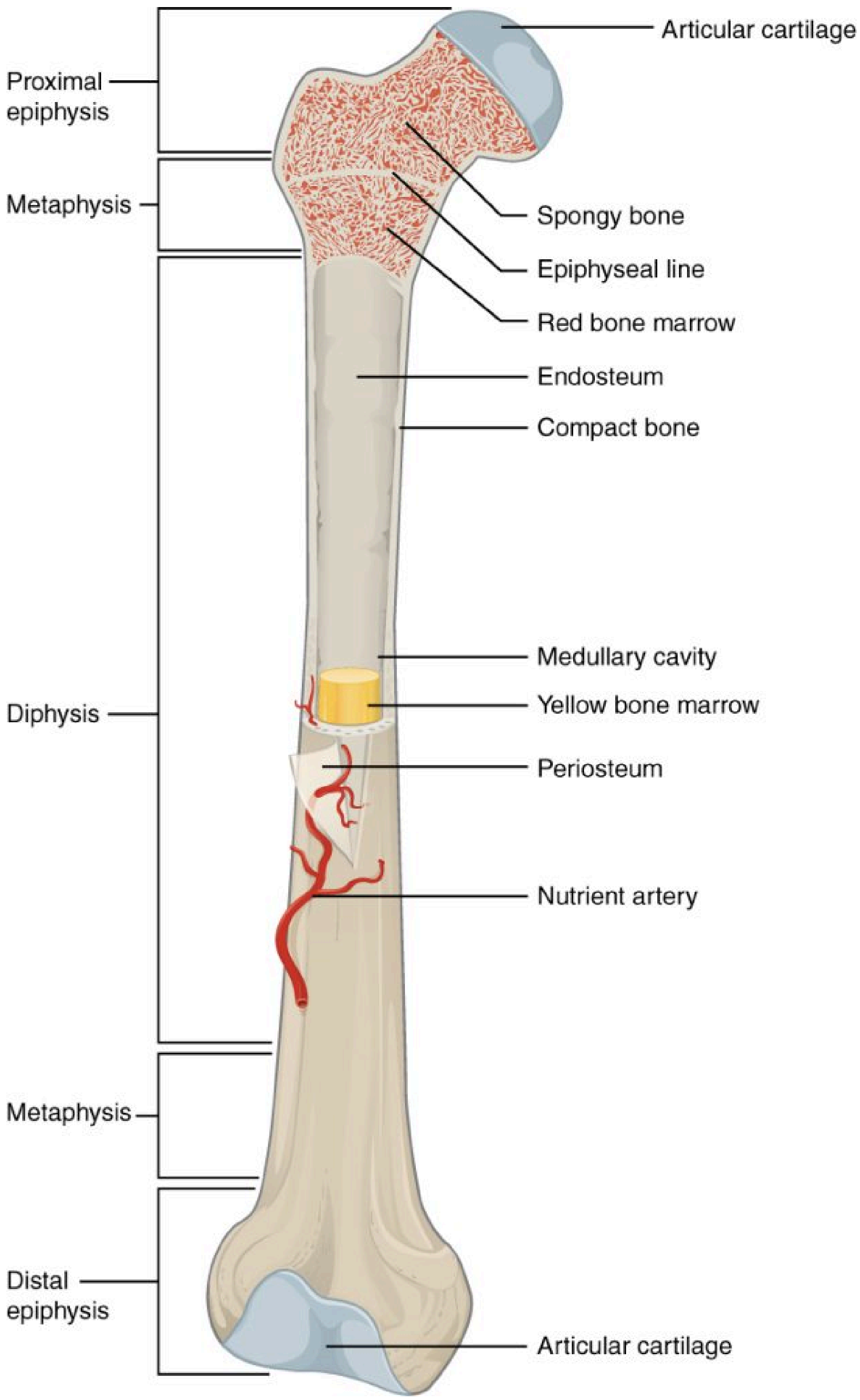
Type I collagen composes 90–95% of the organic matrix, with remainder of the matrix being a homogenous liquid called ground substance consisting of proteoglycans such as hyaluronic acid and chondroitin sulfate, as well as non-collagenous proteins such as osteocalcin, osteopontin or bone sialoprotein. Collagen consists of strands of repeating units, which give bone tensile strength, and are arranged in an overlapping fashion that prevents shear stress.

Part 2 – Classification of Bones Based on Shape



There are six types of bones in the human body: long, short, flat, irregular, sesamoid and sutural. Watch the following animation "Bone Shape – Drawn and Defined"

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://rotel.pressbooks.pub/anatomyphysiology/?p=523#oembed-1



Anatomy of a long bone (femur)

Long bones are characterized by a shaft, the diaphysis, that is much longer than its width; and by an epiphysis, a rounded head at each end of the shaft. They are made up mostly of compact bone, with lesser amounts of marrow, located within the medullary cavity, and areas of spongy, cancellous bone at the ends of the bones. Most bones of the limbs, including those of the fingers and toes, are long bones. The exceptions are the eight carpal bones of the wrist, the seven articulating tarsal bones of the ankle and the sesamoid bone of the kneecap. Long bones such as the clavicle, that have a differently shaped shaft or ends are also called modified long bones.

Short bones are roughly cube-shaped and have only a thin layer of compact bone surrounding a spongy interior. The bones of the wrist and ankle are short bones.

Flat bones are thin and generally curved, with two parallel layers of compact bones sandwiching a layer of spongy bone. Most of the bones of the skull are flat bones, as is the sternum.

Sesamoid bones are bones embedded in tendons. Since they act to hold the tendon further away from the joint, the angle of the tendon is increased and thus the leverage of the muscle is increased. Examples of sesamoid bones are the patella and the pisiform.

Irregular bones do not fit into the above categories. They consist of thin layers of compact bone surrounding a spongy interior. As implied by the name, their shapes are irregular and complicated. Often this irregular shape is due to their many centers of ossification or because they contain bony sinuses. The bones of the spine, pelvis, and some bones of the skull are irregular bones. Examples include the ethmoid and sphenoid bones.

Sutural bones are small bones located between flat bones of the skull at the suture.

Also called Wormian bones.

Watch the animation "Anatomy of long bones"

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://rotel.pressbooks.pub/anatomyphysiology/?p=523#oembed-2

Table 1 – Summary of Bone Shapes

Shape	Description	Example
Long bones	Longer that they are wide	Humerus, radius, ulna, femur, tibia fibula
Short bones	Length and wide are about the same	Bones of the wrist and ankle
Flat bones	They are flat	Bones of the skull, sternum, ribs, and hip
Irregular bones	Shape does not fit any of the other descriptions	Ethmoid, sphenoid bone, vertebra, sacrum
Sesamoid bones	Oval shaped bones located within tendons	Patella
Sutural bones	Small bones located between flat bones of the skull at the suture	Wormian bones of skull

Part 3 – Bone Markings

Bone markings are very important, they allow the identification of bones and bony pieces. Bone markings enable joints to form, to slide past each other, to lock bones in place, and to provide a place of attachment and structural support to muscle and connective tissue. They also provide stabilization, protection and a pathway to nerves, vessels, and other structures.

Bone markings consist of depressions, openings and projections.

Depressions provide pathways for blood vessels and nerves to travel to their target; they also allow two bones to form a joint. Opening houses and protecting structures. Projections provide points of attachment for muscles via tendons and bone to bone via ligaments.

Common Bone Markings Include the Following:

- **Angles** – Sharp bony angulations which may serve as bony or soft tissue attachments. Examples include the superior, inferior, and acromial angles of the scapula and the superior, inferior, lateral angles of the occipital bone, and the angle of the mandible.
- **Body** – Usually refers to the largest most prominent segment of bone. Examples include the diaphysis or shaft of long bones like the femur and humerus and the body of the mandible.
- **Canal** – passageway through a bone.
- **Condyle** – Refers to a large rounded prominence which often provides structural support to the overlying hyaline cartilage. Examples include the knee joint, formed by the femoral lateral and medial condyles, and the tibial lateral and medial condyles and occipital condyle which allows the articulation of the occipital bone and the atlas (C1).
- **Crest** – A raised or prominent part of the edge of a bone. Crests are often the sites where connective

tissue attaches muscle to bone. An example is the iliac crest found on the ilium.

- **Epicondyle** – A prominence that sits atop of a condyle. The epicondyle attaches muscle and connective tissue to bone, providing support to this musculoskeletal system. Examples include the femoral medial and lateral epicondyles, and humeral medial and lateral epicondyles.
- **Facet** – A smooth, flat surface where two bones meet to form a joint. Examples include the facet joints of the vertebrae for flexion and extension of the spine.
- **Fissure** – An open slit in or between bones. It usually houses nerves and blood vessels. Examples include superior and inferior orbital fissures.
- **Foramen** – A hole in a bone through which nerves and blood vessels pass. Examples include foramen magnum, supraorbital foramen, infraorbital foramen, and mental foramen.
- **Fossa** – A shallow depression in a bone surface. Examples include trochlear fossa, posterior, middle, and anterior cranial fossa.
- **Fovea** – Shallow pit that allows the attachment of a ligament.
- **Groove** – A long shallow depression on the bone surface that usually allows a blood vessel or nerve to travel along the length of the bone. Examples include a radial groove.
- **Head** – A rounded end of a bone, it is a prominent extension of bone that forms part of a joint. Example the head of the radius and the femur.
- Line – Ridge along a bone that allows a muscle to attach to the bone.
- **Margin** – The edge of any flat bone. For example, the edge of the temporal bone articulating with the occipital bone is called the occipital margin of the temporal bone.
- **Meatus** – A tube-like channel that extends within the bone, which may provide passage and protection to nerves, vessels, and sound. Examples include external acoustic meatus and internal auditory meatus.
- **Neck** – The segment between the head and the shaft of a bone. For example, the anatomical neck of the humerus.
- **Notch** – A depression in a bone which often provides stabilization to an adjacent articulating bone. Examples include the trochlear notch on the ulna, radial notch of the ulna, suprasternal notch, and the mandibular notch.
- **Process** – bony projection, allows for muscle attachment.
- **Protuberance** – A bump or outgrowth on a bone.
- **Ramus** – The curved part of a bone that gives structural support to the rest of the bone. Examples include the ramus of the mandible.
- **Sinus** – A cavity within a bone. Examples include paranasal sinuses.
- **Spinous Process** – A raised, sharp elevation of bone where muscles and connective tissue attach. Example spinous process of the vertebra.
- **Sulcus** – Same as groove
- **Trochanter** – A large prominence on the side of the bone. Some of the largest muscle groups and most dense connective tissues attach to the trochanter. The most notable examples are the greater and lesser

trochanters of the femur.

- **Tubercle** – A small, rounded prominence where connective tissues attach. Examples include the greater and lesser tubercle of the humerus.
- **Tuberosity** – A moderate prominence where muscles and connective tissues attach. Its function is similar to that of a trochanter. Examples include the tibial tuberosity, deltoid tuberosity, and ischial tuberosity.

Laboratory Activity

Part 1 – Osseous Tissue

1. Identify and label the structures of compact bone using the diagram of Anatomical Model of Bone.
    1. Structures: Periosteum, Sharpey's fibers, Circumferential lamellae, Osteon, Central Canal, Osteocytes, Lacunas, Canaliculi, Perforating canals, Concentric lamellae, Interstitial lamellae, Endosteum, Bone marrow.

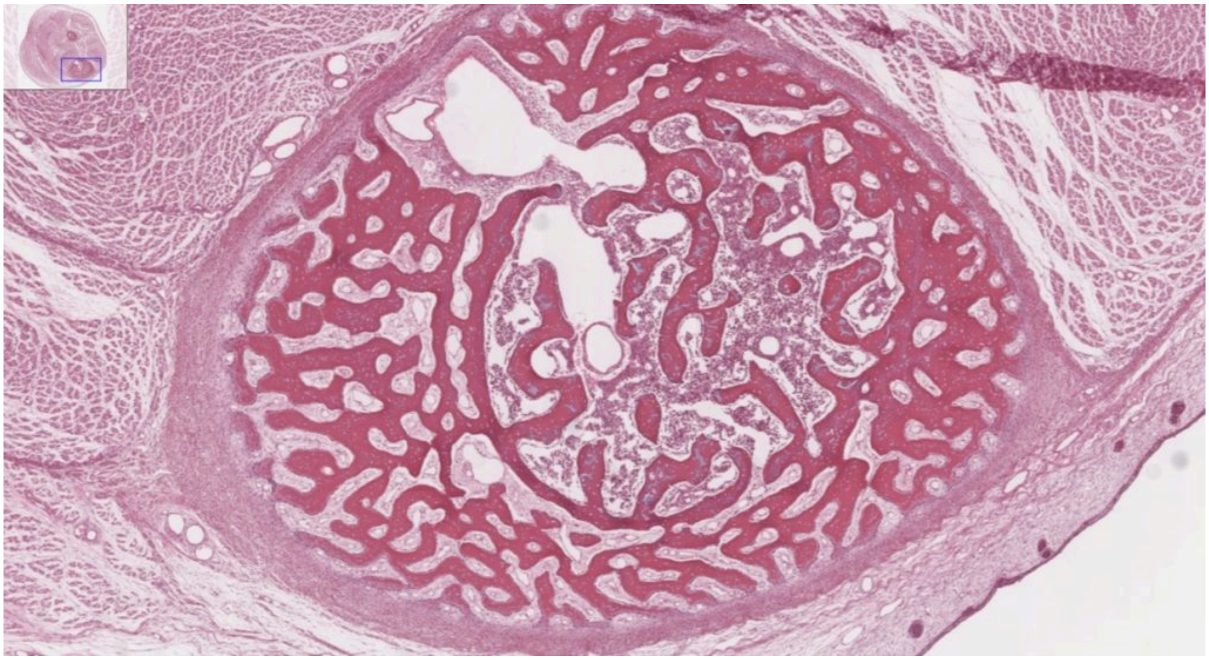
2. View a slide of spongy bone. In a standard face to face lab, use the microscope and available slides – spongy or trabecular bone.
3. 100% online mode – Instead of using the standard compound light microscope, you will use the University of Michigan (UM) "Virtual Microscope".
    1. Go to [University of Michigan Histology and Virtual Microscopy Learning Resources]
    2. Click on "Digital Microscopy" and review the instructions on how to use the Virtual Microscope

(Zoomify).

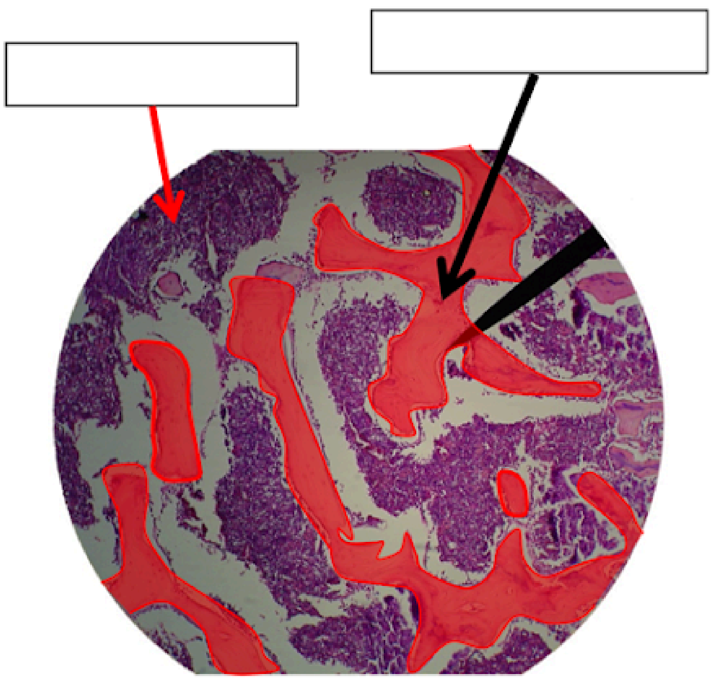
3. Next, go to Virtual Slide List
4. Search for "spongy bone"
5. Or you can click on the image shown below (links already embedded), scan for the tissue you need to see, then Zoomify using the +/- controls (below the image) and draw the tissues in your notebook or space provided.
6. You may also scan the image – look at the top left of the main view, you will see a smaller window with a blue square, drag the square to change the area where you like to see. You can also move to a different area in the main view by dragging the small white hand shown there.

Slide: 048_HISTO_40X

Focus on the area where spongy bone (blue arrow) is located and zoom in.



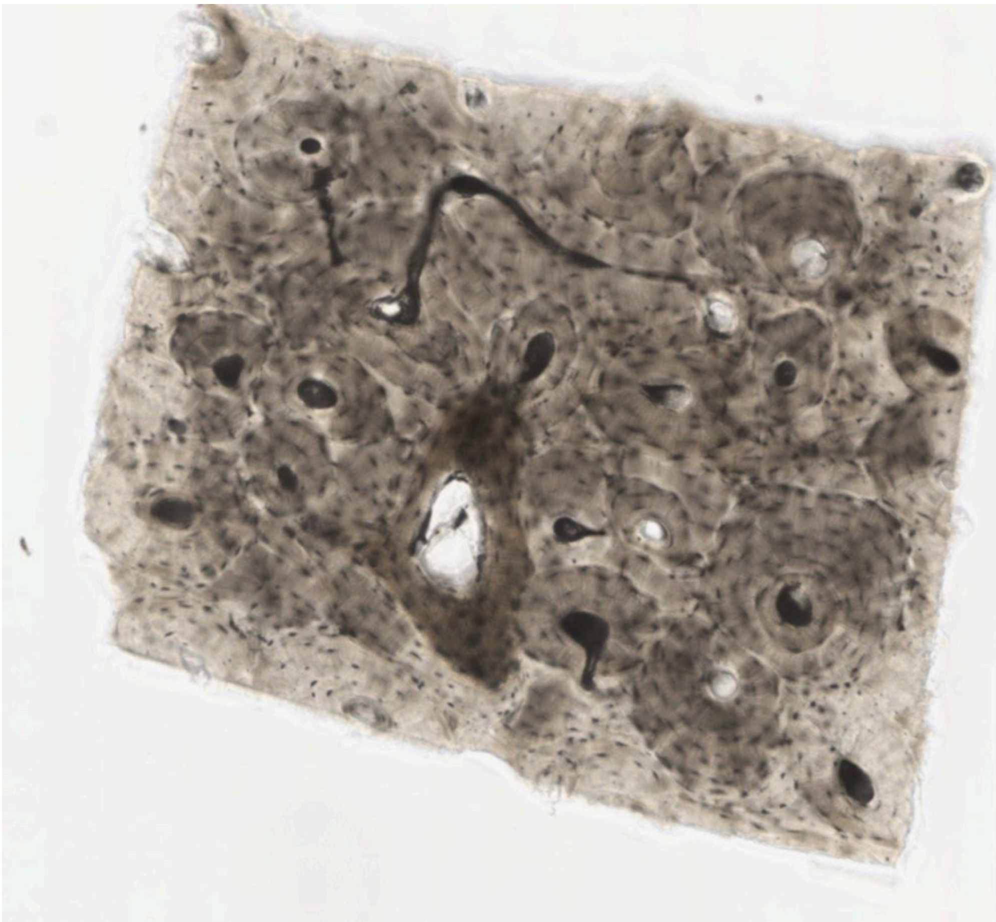
4. Label spongy bone structures shown in this micrograph (arrows): trabecula, bone marrow.



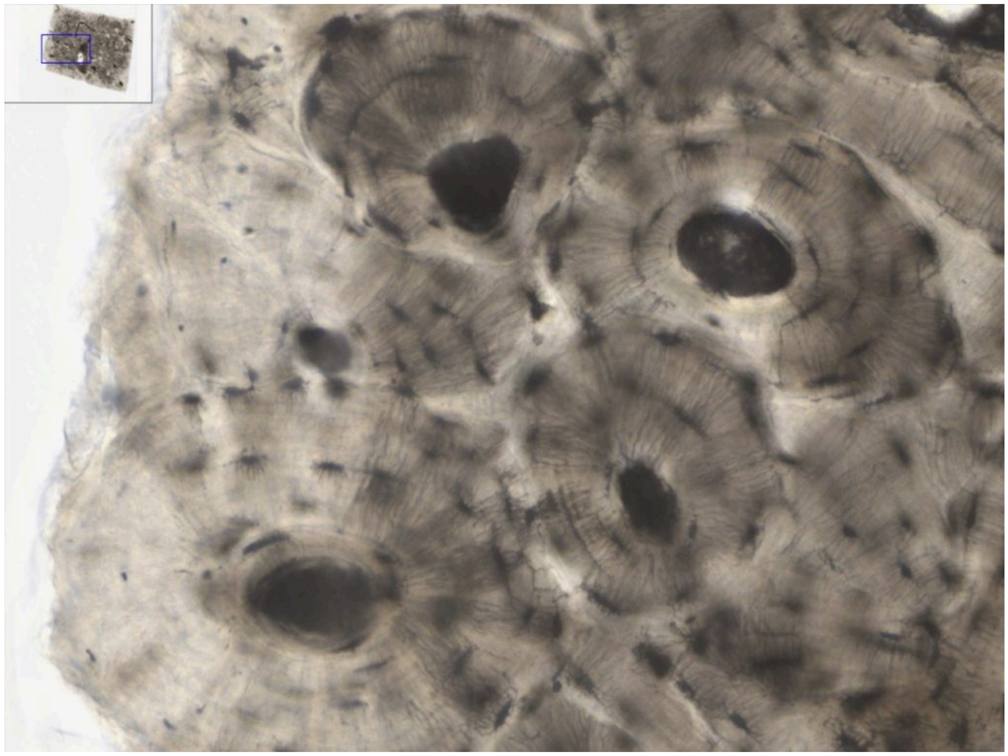
1. Compact bone – View a slide of compact bone. In a standard face to face lab, use the microscope and available slides – ground compact bone.
2. 100% online mode – Instead of using the standard compound light microscope, you will use the University of Michigan (UM) "Virtual Microscope".

1. Go to University of Michigan Histology and Virtual Microscopy Learning Resources or QR code below.
2. Click on "Digital Microscopy" and review the instructions on how to use the Virtual Microscope (Zoomify).
3. Next, go to Virtual Slide List
4. Search for "compact bone"
5. Or you can click on the image shown below (links already embedded), scan for the tissue you need to see, then Zoomify using the +/- controls (below the image) and draw the tissues in your notebook or space provided.
6. You may also scan the image – look at the top left of the main view, you will see a smaller window with a blue square, drag the square to change the area where you like to see. You can also move to a different area in the main view by dragging the small white hand shown there. You will use two images:
    1. Ground compact bone Thin section #093A
    2. Ground compact bone #093B

7. Slide: #093A

3. Use the following link to use the UM virtual microscope. You download the image at low and high-power magnification.
   Slide: #093B
4. Label the structures of compact bone shown in this micrograph (look for the numbers- some white others red)
   
5. At low magnification label the following:

   Osteon
   Circumferential lamella
   Interstitial Lamella,
   Central CanalAt high magnification label the following: Canaliculi, Osteocytes, Lacuna,



The image highlights the dense structure of compact bone, focusing on osteons and Haversian systems visible at high magnification.

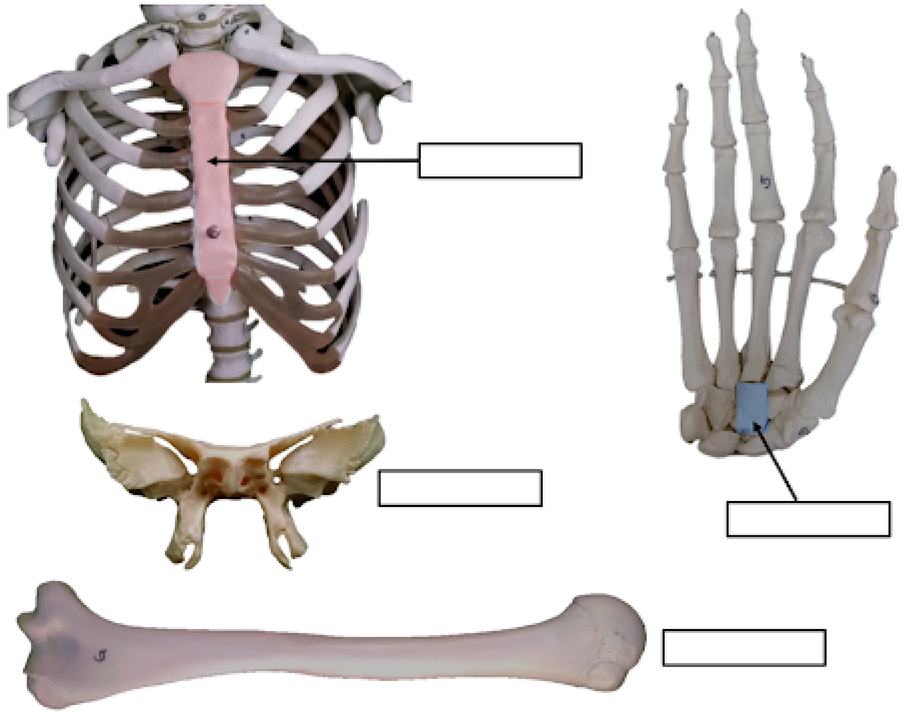
6. Use the following link to use the UM virtual microscope. You download the image at low and high-power magnification.
   [Slide: #051](#) – longitudinal section of compact bone

7. At low magnification label the following:

   Central Canal
   Volkman's canal

Part 2 – Identify Bones Shapes

1. Using your textbook, identify the shape of the bones shown here: long, short, flat, sesamoid or irregular.



An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://rotel.pressbooks.pub/anatomyphysiology/?p=523#h5p-8

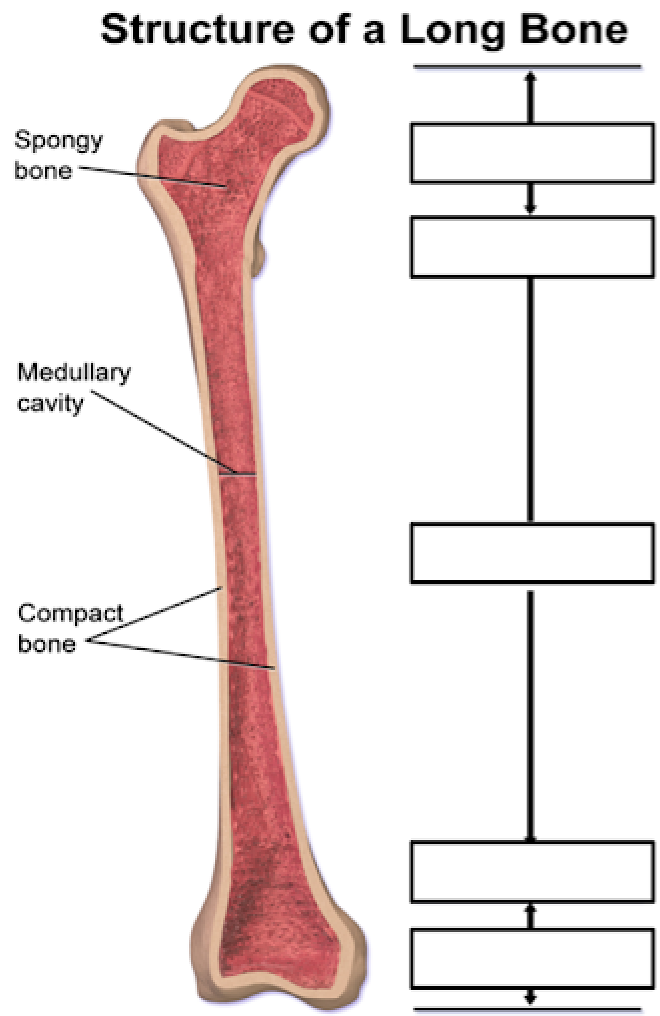
2. Fill in the table shown below and give at least 3 examples of each.

Table 2 – Bone Shapes

Shape	Description	Example
Long bones		
Short bones		
Flat bones		
Irregular bones		
Sesamoid bones		
Sutural bones		

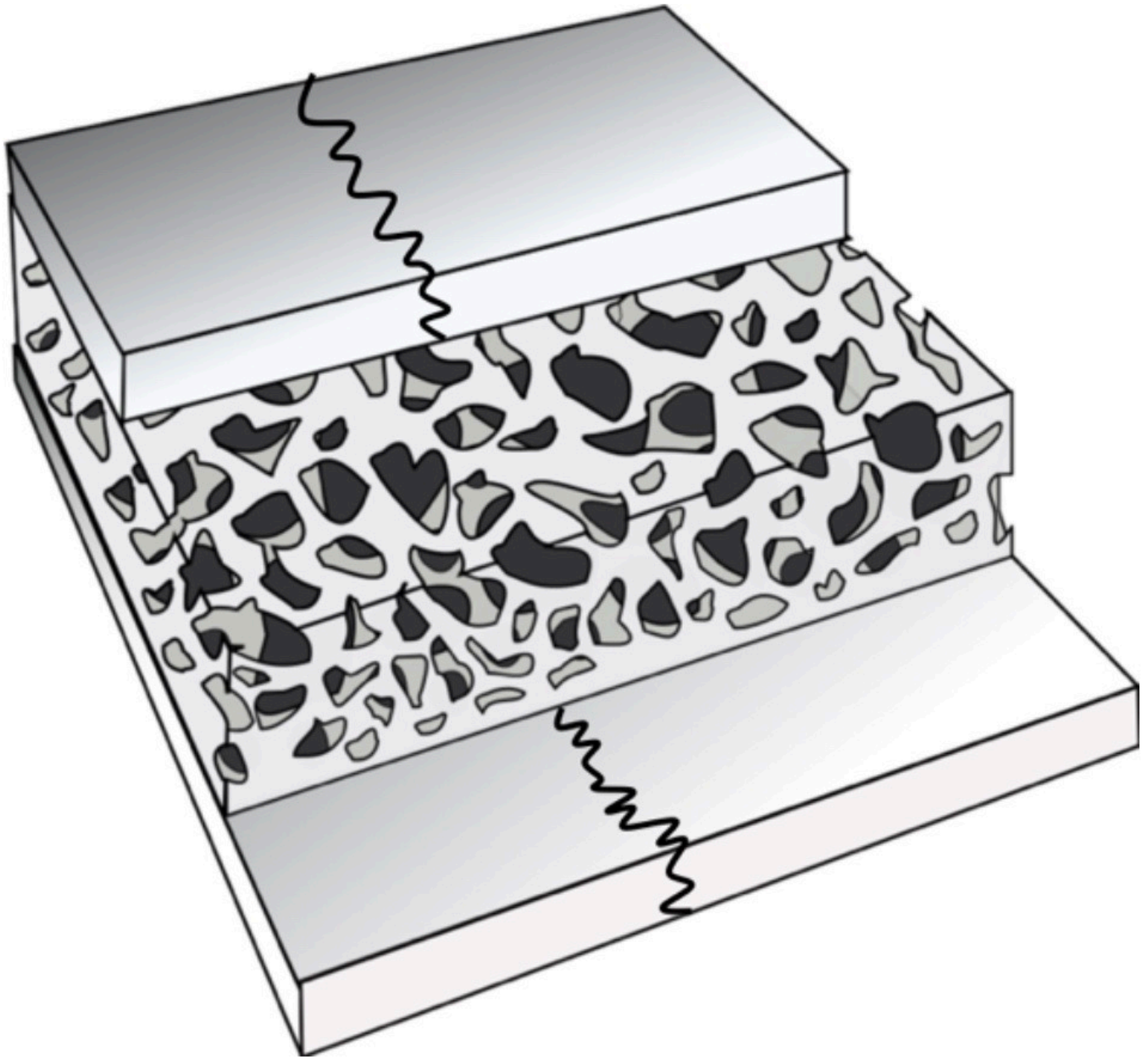
Part 3 – Anatomy of Long and Flat Bones

1. Label the structures of a long bone shown below



An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://rotel.pressbooks.pub/anatomyphysiology/?p=523#h5p-7

2. Label the structures of a flat bone show bellow: Trabeculae, spongy bone, compact bone, suture



Part 4 – Identifying Bone Markings

Identify bone markings

In a standard face to face lab, we will work in groups of two. In a 100% lab you will work individually.

Standard face to Face

- Obtain a disarticulated bone set.
- Organize the bones according to shape. Please note that you may have to look around the lab for missing bones from your box, or you may have more bones that you should, that is because the group that use the box before you were not very careful and organized, do not get discouraged, the bones are in the lab, you just need a few minutes to find them and make sure you have a complete set.
- Examine each bone and find one of the selected bone markings described in this lab exercise (pages 11-12), you may need to refer to your textbook for help.

- Write at least one bone marking found per selected bone, use the table provided to complete the activity.

100% online labs – look for images of all bones shown below, take a picture with your phone, download them and upload them here with their respective names and bone marking– see table below.

Table 3 – Bone markings

Bones	Markings of bone
Frontal bone	
Occipital bone	
Temporal bone	
Vertebra	
Mandible	
Sternum	
Clavicle	
Scapula	
Ribs	
Humerus	
Radius	
Ulna	
Ilium	
Ischium	
Pubis	
Femur	
Tibia	
Fibula	

Part 5 – Review Key Terms

At the end of this activity you should be able to identify the following:

1. Long bone anatomy:
    - Periosteum

- Endosteum
- Diaphysis (shaft)
- Epiphyses, proximal and distal
- Metaphyseal line
- Perforating fibers
- Nutrient artery
- Spongy bone
- Compact bone
- Medullary cavity
- Articular cartilage
- Red marrow
- Yellow marrow
- Epiphyseal line

2. Histology of Bone Tissue Models:

   Compact bone

   - Osteon
   - Concentric lamellae
   - Interstitial lamellae
   - Circumferential lamellae
   - Haversian canal
   - Osteocyte
   - Lacunae
   - Canaliculi
   - Perforating canal
   - Periosteum
   - Sharpey's fibers

   Spongy bone

   - Trabeculae
   - Endosteum
   - Lamella

   Hyaline cartilage

   - Perichondrium
   - Matrix
   - Chondrocyte
   - Lacunae

3. Bone Shapes

   - Long
   - Short
   - Flat
   - Irregular
   - Sesamoid
   - Sutural

4. Bone markings

   - Facet
   - Fossa
   - Fovea
   - Groove
   - Sulcus
   - Canal
   - Fissure
   - Foramen
   - Meatus
   - Condyle
   - Crest
   - Epicondyle
   - Head
   - Line
   - Protuberance
   - Trochanter
   - Tubercle
   - Tuberosity

Part 6 – Review of terms and Definitions

1. Define long bone, and give four examples
2. Define short bone, and give four examples
3. Define irregular bone, and give two examples
4. Define flat bone, and give two examples
5. Define sesamoid bone, and give an example
6. A raised rough surface on a bone where a muscle attaches to is called?
7. A round opening in a bone is called a ___________.
8. What are the components of the extracellular matrix of bone?
9. What is the function of the osteoclasts?
10. What is the difference between the distal and the proximal epiphysis?

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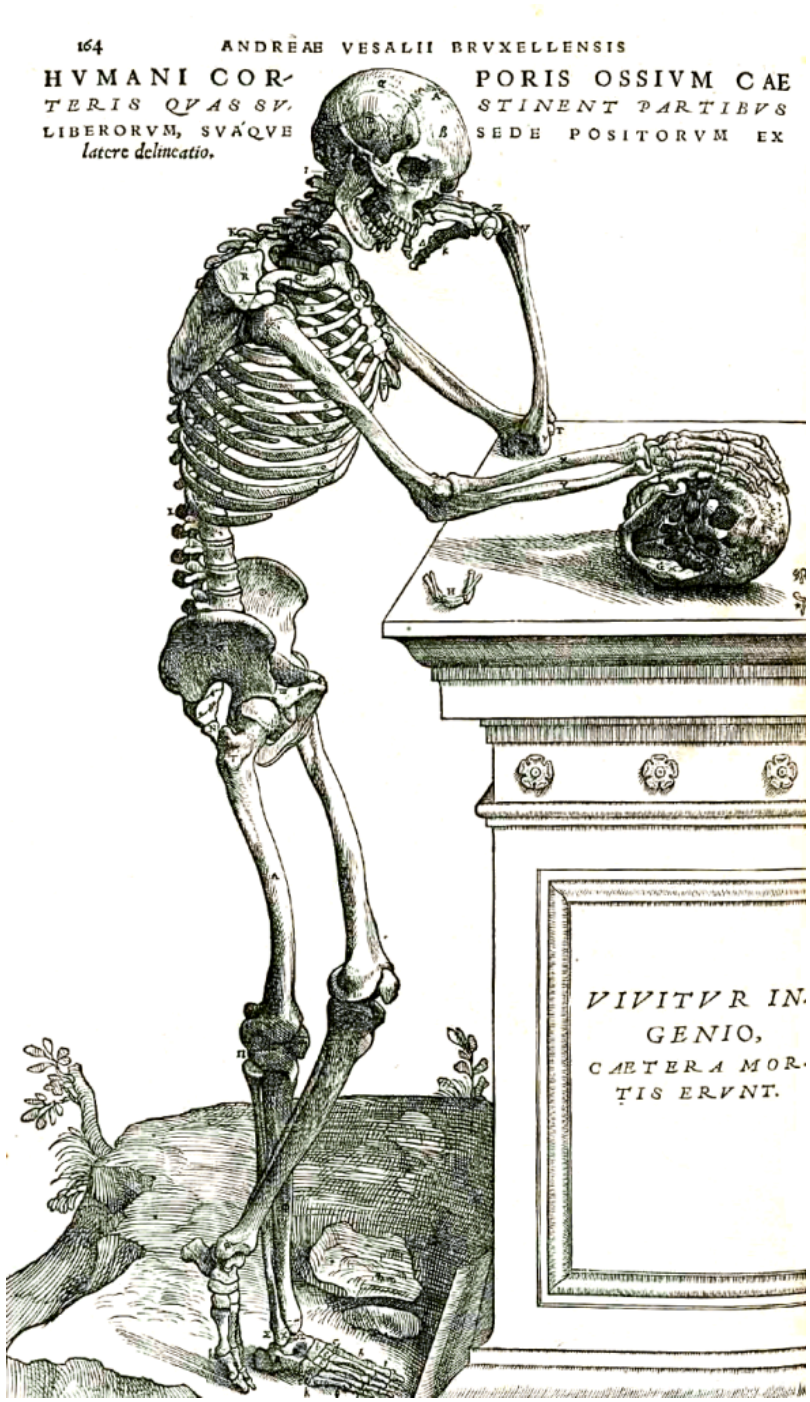
THE SKELETAL SYSTEM ANATOMY

The Skeletal System Laboratory Activity



Objectives

- Define and differentiate between the axial skeleton and the appendicular skeleton
- Identify the major bones and markings of the axial skeleton
- Identify the major bones and markings of the appendicular skeleton
- Build a skeleton using disarticulated bones

Introduction

This laboratory activity will introduce the students to the bones and structures that form the human skeleton. The skeleton is the internal framework of the human body. It is composed of 206 bones in the adult body.

The human skeleton can be divided into two portions: the axial skeleton and the appendicular skeleton.

The axial skeleton is formed by the rib cage (vertebral column, ribs, and sternum), the skull, mandible, hyoid bone and the three ossicles (inside the ear).

The appendicular skeleton, which is attached to the axial skeleton, is formed by the shoulder girdle, the pelvic girdle and the bones of the upper and lower limbs.

The human skeleton performs six major functions; support, movement, protection, production of blood cells, storage of minerals, and endocrine regulation.

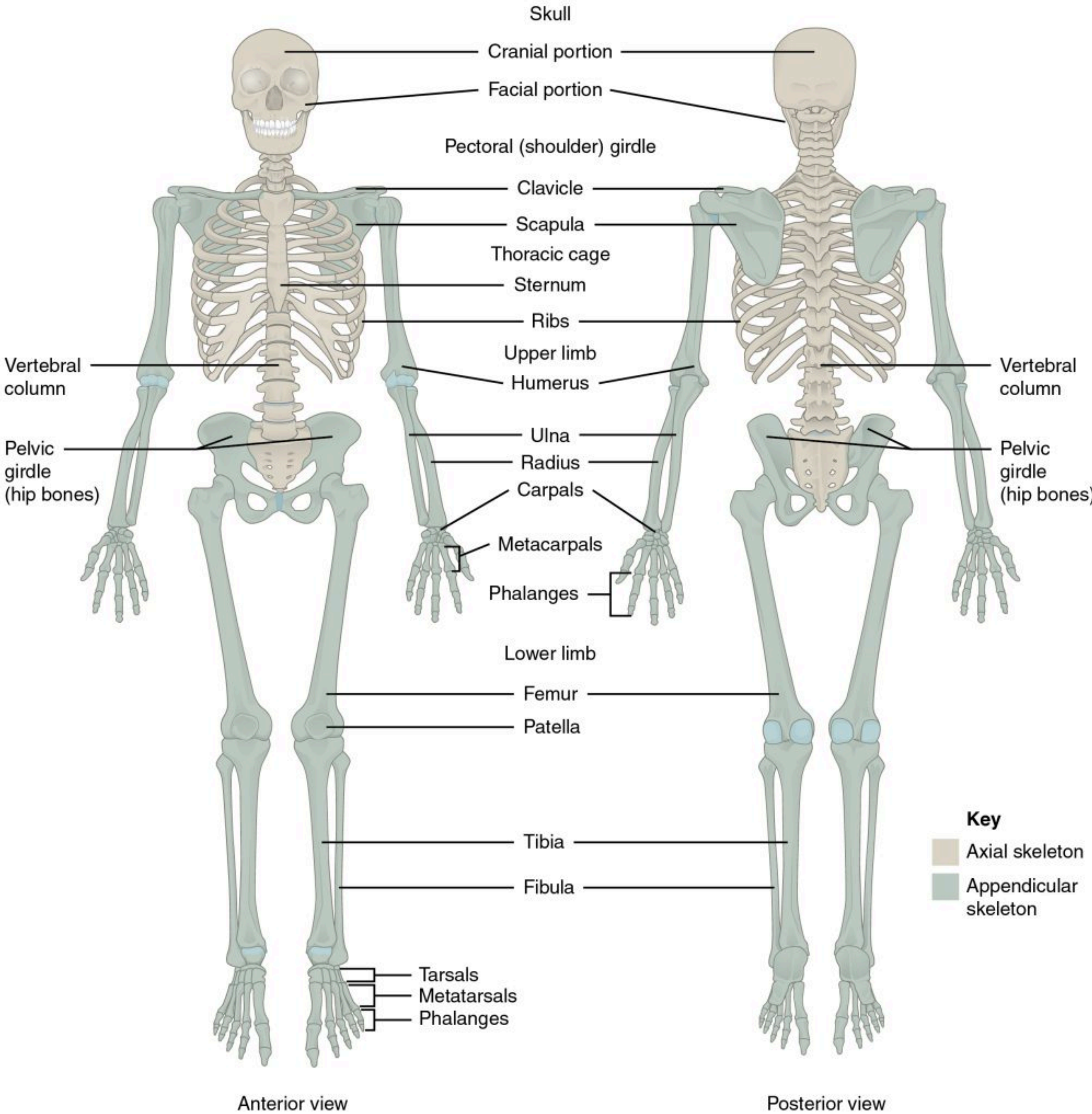


Figure 2: Axial vs. Appendicular skeletons

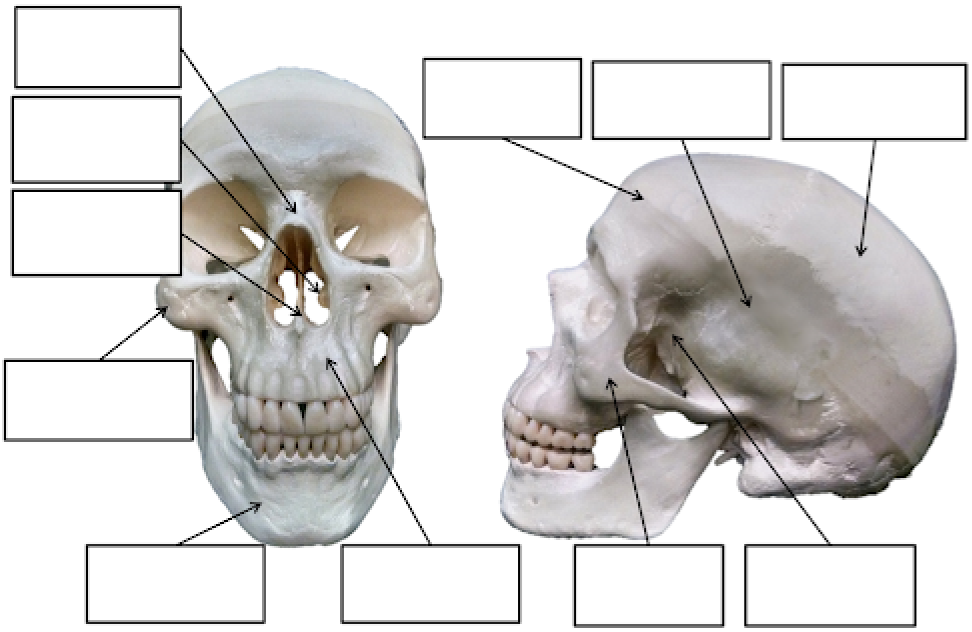
Laboratory Activity

In this lab, you will learn to identify the bones of the adult human skeleton, its processes, orientation and how they articulate with each other using sets of disarticulated and articulated skeletons.

Part 1 – Identify the bones of the human skeleton. Label the bones

using the images shown here.

1. Axial Skeleton – Identify bones and structures of the skull



Label the following:

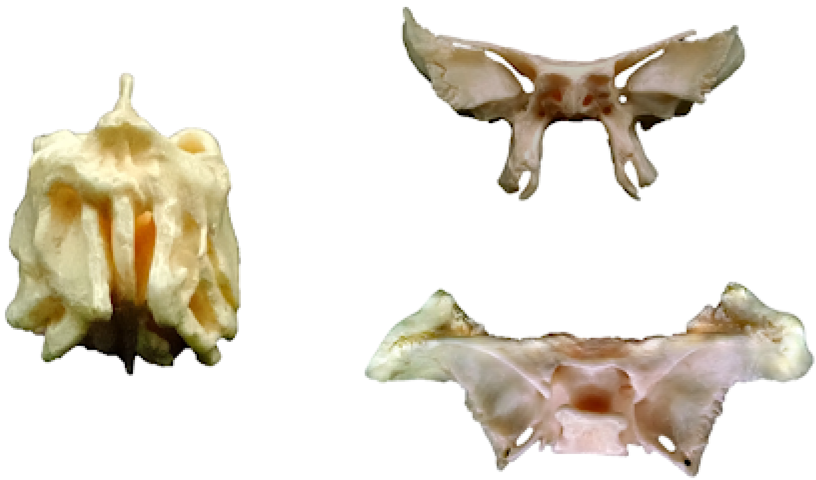
Zygomatic bones; Lacrimal bones, Occipital bone; Coronal suture; Sagittal suture; Superior orbital notch/ foramen; Inferior orbital foramen; Glabella; Superior orbital fissure; Inferior orbital fissure.

Label the following:

Occipital bone; Parietal bone; Temporal bone; Sphenoid bone; Maxilla; Mandible; Zygomatic bone; External acoustic meatus; Mastoid process; Styloid process; Lambdoid suture; Squamous suture; Zygomatic process of the temporal bone; Temporal process of the zygomatic bone; Wormian (or sutural) bones.

Label the following:

Zygomatic arch; Lesser wing of the sphenoid; Sella turcica; Foramen ovale; Foramen spinosum; Foramen lacerum; Jugular foramen; Carotid canal; Foramen magnum; Internal acoustic meatus; Occipital condyle; Mandibular fossa; Ethmoid bone; Crista galli; Optic canal; Anterior cranial fossa; Middle cranial fossa; Posterior cranial fossa.

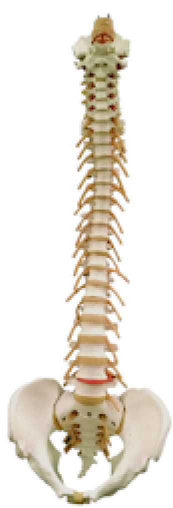


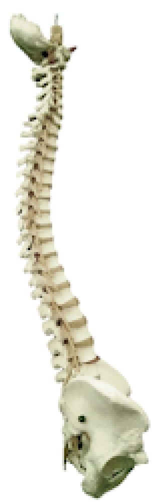
Label the following:

Ethmoid bone: Perpendicular plate; Crista galli; Lateral masses.
Sphenoid bone: Lesser wing; Greater wing; Sella turcica; Pterygoid plates; Hypophyseal fossa.

Label the following:

Maxilla; Palatine bone; Pterygoid plates; Vomer, Greater palatine foramen, Incisive foramen
Mandible; Condylar process; Coronoid process; Mental foramen; Body of mandible; Ramus of mandible; Mandibular notch.





Label the following:

Cervical vertebrae; Cervical curvature; Thoracic vertebrae; Thoracic curvature; lumbar vertebrae; Lumbar curvature; Sacrum; Coccyx; 7; 12; 5.
Atlas; Axis; Dens; C1; C2; Spinous process; Superior articular facet.

Label the following:

Cervical vertebrae; Thoracic vertebrae; Lumbar vertebrae; Transverse foramen; Superior articular process; Inferior articular process; Costal demifacet; Vertebral foramen; Body; Spine; Arch; Transverse process; Transverse facet

Label the following:

Sacrum: Sacral foramen; Ala (of the sacrum); Auricular surface.
Coccyx.
Sternum: Manubrium; Body; Xiphoid process; Jugular notch; Sternal angle.
True ribs; False ribs; Floating ribs; Costal cartilages.

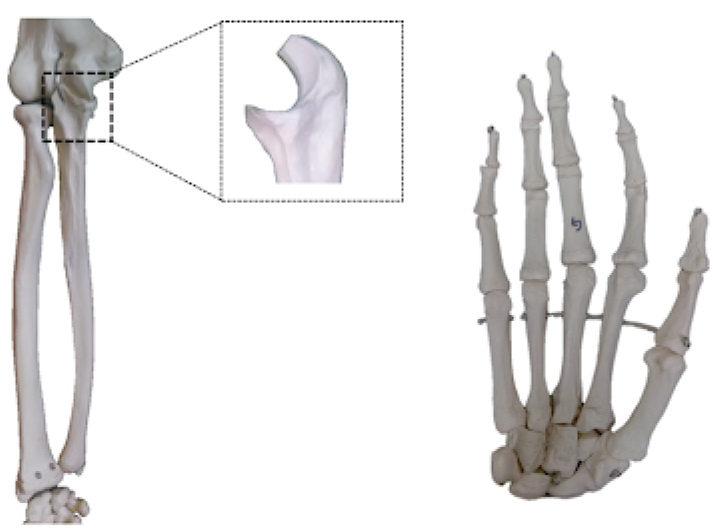
1. B. Appendicular Skeleton – Identify bones and structures of the appendicular skeleton

Label the following:

Label the following:

Scapula: Spine; Coracoid process; Acromion; Supra-spinous fossa; Infra-spinous fossa; Sub-scapular fossa; Glenoid cavity

Humerus: Head; Neck; (surgical and anatomical); Trochlea; Capitulum; Olecranon fossa; Coronoid fossa; Radial fossa; Medial epicondyle; Lateral epicondyle; Greater tubercle; Lesser tubercle



Label the following:

Radius: Styloid process; Radial head; Radial tuberosity.
Ulna: Olecranon; Trochlear notch; Coronoid process; Styloid process;
Carpals: Scaphoid; Lunate; Triquetral; Pisiform; Trapezium; Trapezoid; Capitate; Hamate.
Metacarpals
Phalanges: proximal; middle and distal
Pollex

Label the following:

Ilium; Ischium; Pubis.
Obturator foramen; Acetabulum; Iliac crest; Anterior superior iliac spine; Anterior inferior iliac spine; Posterior superior iliac spine; Posterior inferior iliac spine; Pubis symphisis; Greater sciatic notch; Ischial spine; Sacrum; (male or female pelvis).

Label the following:

Femur: Head; Neck; Greater trochanter; Lesser trochanter; Medial condyle; Lateral condyle; Medial epicondyle; Lateral epicondyle; Linea aspera.
Tibia: Medial malleolus; Tibial tuberosity.
Fibula: Lateral malleolus.

Label the following:

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

Appendix A – List of bone and its structures

This is the list of bones and structures that you must be able to identify after performing this lab activity. You should use the articulated and disarticulated skeletons available in the laboratory to practice identifying all structures listed here. It is recommended to work in groups of two and to test each other as you practice the identification of all structures listed here.

Axial Skeleton

Human Skull
Cranial Bones (bones that form the cranial cavity)

- Bones forming the calvarium (skull cap)
  - Frontal bone (1)
    - Supraorbital margins (ridges)
    - Supraorbital foramina (notches)
  - Parietal bone (2)
  - Occipital bone (1)
    - Foramen Magnum
    - Occipital Condyles
    - External occipital protuberance

Bones forming the Floor of the cranial cavity

- Frontal (1)
  - Frontal sinus
- ETHMOID BONE (1)
  - Cribriform plate
  - Crista galli
  - Olfactory foramina (passage for olfactory nerves)

  - Perpendicular plate (anterior and superior part of nasal septum, articulates with vomer)
  - Superior nasal conchae (turbinate bones)
  - Middle nasal conchae (turbinate bones)
  - Ethmoid sinus (air cells)
- SPHENOID BONE (1)
  - Lesser wings
  - Greater wings
  - Sella turcica
  - Sphenoid sinus
  - Optic foramina
- Temporal bone (2)
- Squamous portion – squamous suture, zygomatic process of the temporal bone (part of zygomatic arch), mandibular fossa
- Tympanic portion – external auditory meatus, styloid process and stylomastoid foramen
- Mastoid portion – mastoid process and mastoid air cells
- Petrous portion – internal auditory meatus, carotid foramen and canal, jugular foramen
- Occipital bone (1)

Other structures of the cranial floor

- Anterior, Middle and Posterior Fossae

Facial bones (bones of the face)

- Mandible (1)
  - Mental Protuberance
  - Alveolar process
  - Rami of mandible
  - Angle of mandible
  - Body of mandible
  - Mandibular condyles
  - Mental foramina
- Maxilla (2):
  - Maxillary sinus
  - Alveolar process
  - Palatine process (2/3 of hard palate)
- Palatine bone (2) (forms posterior 1/3 of hard palate)

- Zygomatic bone – ZYGOMA (2)
  - Temporal process of the zygomatic bone
- Lacrimal bone (2)
  - Lacrima fossae
- Nasal bone, also called Nasalis (2), they form the bridge of the nose
- Inferior nasal conchae (2)
- Vomer (1), forms inferior and posterior nasal septum, articulates with perpendicular plate of the ethmoid bone

BONES OF THE ORBIT

- Frontal
- Zygomatic
- Maxillary
- Sphenoid
- Ethmoid
- Palatine
- Lacrimal

OSSICLES (three bones in middle ear)

- Malleus
- Incus
- Stapes
- Hyoid bone (supports the tongue)

VERTEBRAL COLUMN

- Cervical vertebrae (7)
- C1 = Atlas
- C2 = Axis
  - Dens or odontoid process
- Thoracic vertebrae (12)
- Lumbar vertebrae (5).
- Sacrum (5, fused sacral vertebrae)
- Coccyx (4-6, fused coccygeal vertebrae) vestigial tail
- **VERTEBRA – Structures**

    - Body of Vertebra
    - Spinous process
    - Transverse process
    - Vertebral foramen
    - Superior articular facet
    - Inferior articular facet
    - Intervertebral foramen

THORACIC CAGE

- STERNUM
    - Manubrium
    - Body of sternum
    - Xiphoid process
- RIBS
    - Ribs 1-7 (true ribs)
    - Ribs 8-12 (false ribs)
    - Ribs 11-12 (floating ribs)
    - Ribs – Structures:
    - Head
    - Neck
    - Tubercle
    - Body
    - Costal groove
    - Sternal end

SUTURES

- Frontal or Coronal
- Sagittal
- Lambdoidal
- Squamous
- Sutural bones or Wormian bones

Fetal Skull

- Anterior fontanelle

- Posterior fontanelle
- Anterolateral fontanelle
- Posterolateral fontanelle

Appendicular Skeleton

GIRDLES AND LIMBS
PECTORAL GIRDLE

- Clavicle
  - Acromial end
  - Sternal End
- Scapula
  - Spine
  - Acromion
  - Glenoid cavity
  - Coracoid process
  - Supraspinous fossae
  - Infraspinous fossae
  - Subscapular fossae
  - Axillary border
  - Vertebral border
  - Superior border
  - Inferior border

UPPER LIMB (Humerus, radius, ulna, carpals, metacarpals, phalanges)

- Humerus (brachium – arm)
- Proximal end:
  - Head
  - Anatomical neck
  - Surgical neck
  - Greater tubercle
  - Lesser tubercle
- Shaft:
  - Deltoid tuberosity
- Distal end:
  - Capitulum

  - Trochlea
  - Lateral epicondyle
  - Medial epicondyle
  - Olecranon fossa
- Radius (antebrachium – forearm)
- Proximal end:
  - Head
  - Radial tuberosity
- Distal end:
  - Styloid process
  - Ulnar notch
- Ulna (antebrachium – forearm):
- Proximal end:
  - Olecranon
  - Radial notch
  - Trochlear notch
- Distal end:
  - Head
  - Styloid process
- Wrist (carpus) – carpal bones (8)
  - Scaphoid, lunate, triquetrum, pisiform, trapezium, trapezoid, capitate, hamate
- Hand (Manus – 19 bones):
  - Metacarpus
  - Metacarpal bones (I – V)
  - Phalanges (I – V)
    - Proximal, middle, distal phalanx

PELVIC GIRDLE (hip girdle, 2 innominate bones with sacrum)

- 2 coxal bones, also called innominate bones and os coxae.
- Ilium:
  - Iliac crest
  - Iliac fossa
  - Greater sciatic notch
  - Acetabulum (formed by the fusion of ilium, ischium and pubis)
- Ischium:
  - Ischial spine

    - Ischial tuberosity
    - Lesser sciatic notch
    - Acetabulum (formed by the fusion of ilium, ischium and pubis)
    - Obturator foramen
- Pubis:
    - Pubic symphysis
    - Acetabulum (formed by the fusion of ilium, ischium and pubis)
    - Obturator foramen

LOWER LIMB (femur, patella, tibia, fibula, tarsals, metatarsals, phalanges)

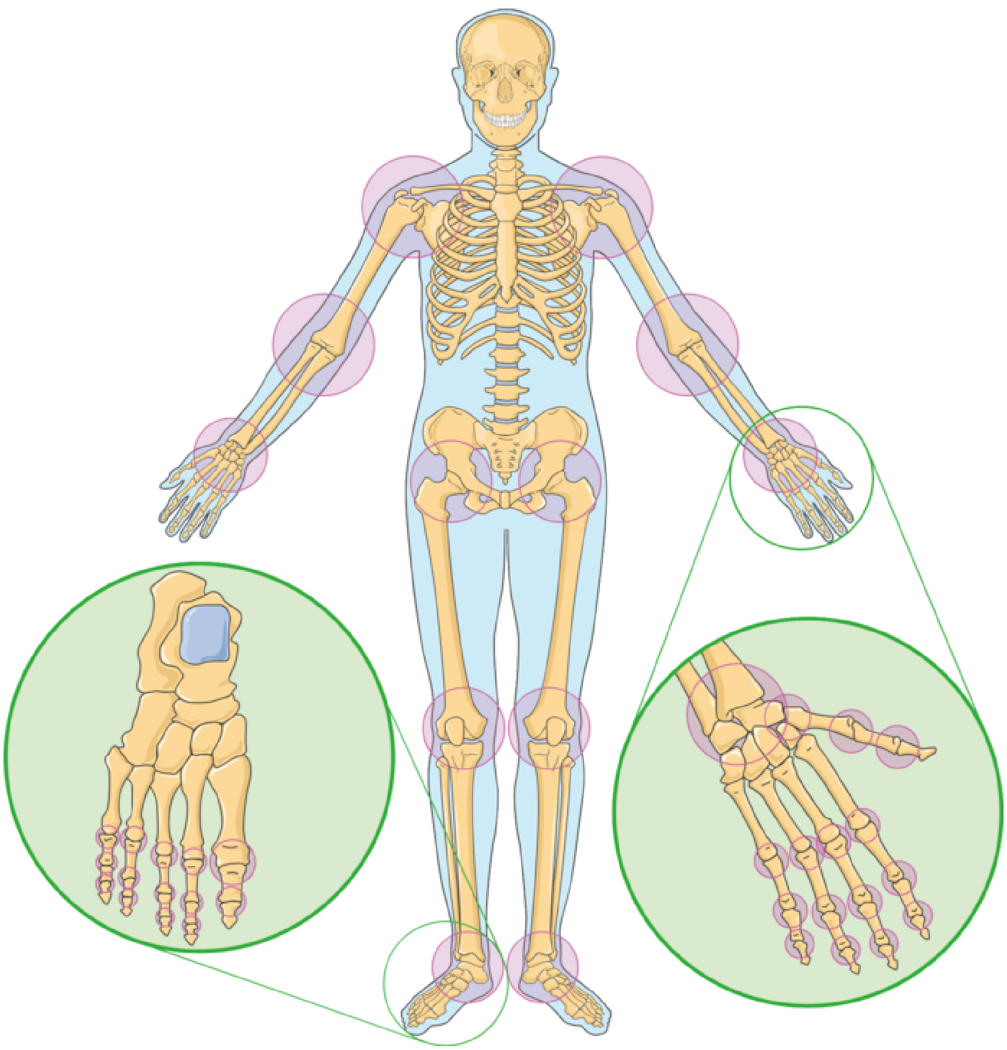
- Femur (thigh)
- Proximal end:
    - Head
    - Neck
    - Greater trochanter
    - Lesser trochanter
    - Gluteal tuberosity
- Shaft:
    - Linea aspera
- Distal end:
    - Patellar surface
    - Medial condyles
    - Lateral condyles
    - Medial epicondyles
    - Lateral epicondyles
- Patella (kneecap)
    - Base
    - Apex
- Tibia (leg, lower leg)
    - Proximal end:
        - Medial condyles
        - Lateral condyles
        - Tibial tuberosity
    - Shaft:
        - Anterior crest
    - Distal end:

        - Medial malleolus
- FIBULA (leg)
    - Proximal end:
        - Head
    - Distal end:
        - Lateral malleolus
- ANKLE (tarsus)
- 7 tarsal bones: talus, calcaneus, navicular, medial, intermediate and lateral cuneiformns, cuboid
- Foot (pes – 19 bones)
    - Metatarsus
    - Metatarsal bones (I-V)
    - Phalanges (I-V):
    - Proximal, middle, distal phalanx

Media Attributions

THE JOINTS

Joints and Articulations Laboratory Activity



Objectives

1. Define the term joint
2. List the types of joints based on structure and give an example.
3. List the names of joints based on structure and give an example.
4. List and identify the structural components of a synovial joint.
5. List types of synovial joints

6. Identify the sutures of the skull.
7. Identify the fontanelles.
8. Identify the components of the knee joint.
9. List type of movements in synovial joints.

Introduction

A joint or articulation is the connection made between 2 or more bones. They participate in degrees and types of movement. Joints may be classified based on function or structure.

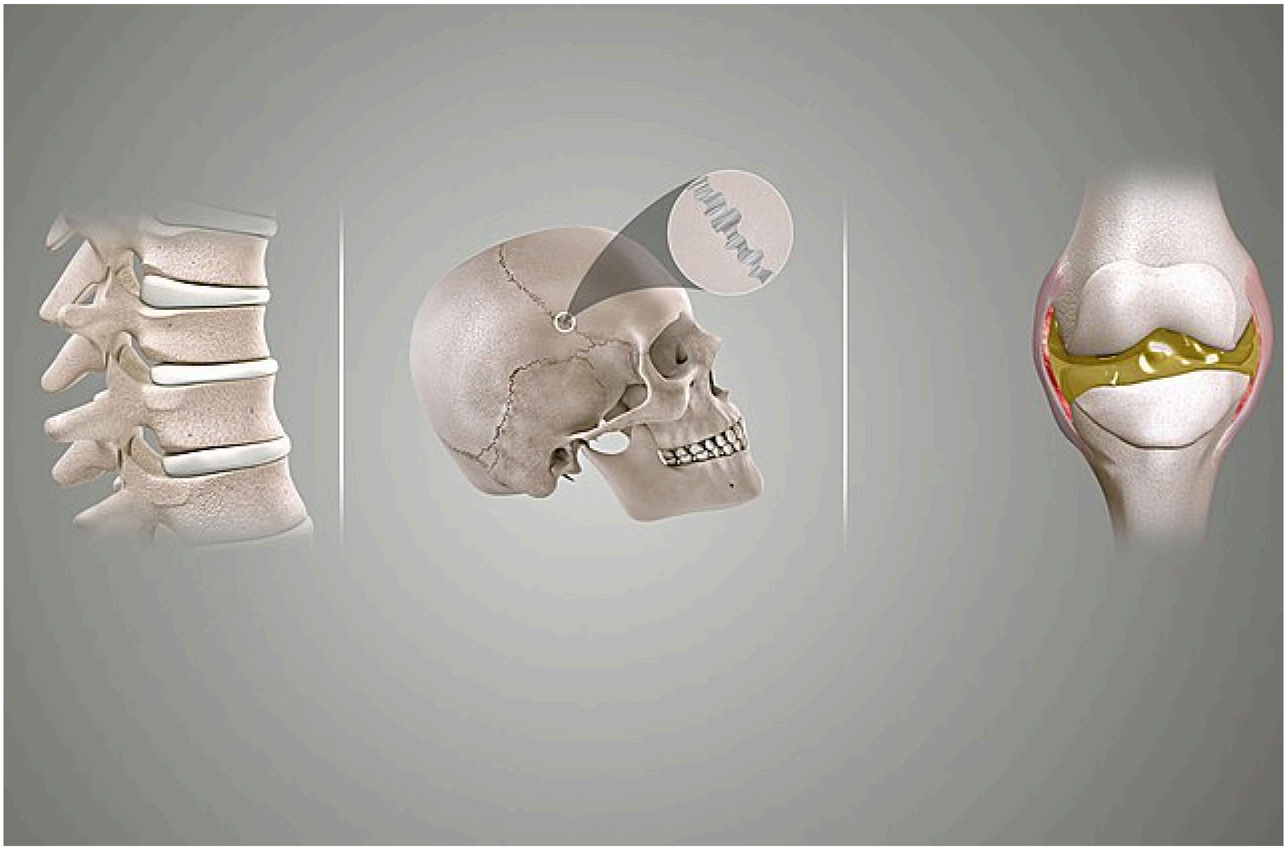
Functional classification (movement)

Joints can also be classified functionally according to the type and degree of movement they allow: Joint movements are described with reference to the basic anatomical planes.

There are three types:

- Synarthrosis – permits no mobility. Most synarthrosis joints are fibrous joints (e.g. sutures of the skull).
- Amphiarthrosis – permits slight mobility. Most amphiarthrosis joints are cartilaginous joints (e.g., intervertebral discs).
- Diarthrosis – freely movable joints.

Structural classification names and divides joints according to the type of tissue that connects the bones to each other.



Types of joints based upon their structure (L to R): Cartilaginous joint, Fibrous joint, and Synovial joint.

There are three structural classifications of joints:

- Fibrous joint: joined by dense regular connective tissue that is rich in collagen fibers.
- The subclasses of synarthrosis include:
  - Sutures – periosteum of articulating bones interdigitate making a very stable joint, for example sutures of the skull
  - Gomphosis – joint between the teeth and the alveolar process of the mandible or maxilla, it is held in place by the periodontal ligaments.
  - Syndesmosis – located between two parallel articulating bones, they are joined by a long fibrous membrane called the interosseous membrane, these joints are classified as amphiarthrosis, for example the joint between the radius and the ulna.
- Cartilaginous joint: bones joined by cartilage or fibrocartilage. Most of this type of joint allows for some movement, so they are amphiarthrosis.
- There are two types of cartilaginous joints:
  - Symphyses – bones are joint by a pad made of fibrocartilage (e.g. symphysis pubis)
  - Synchondroses – bones joint by hyaline cartilage (e.g. costochondral joints)
- Synovial joint: not directly joined, the bones have a synovial cavity filled with synovial fluid and are

united by the dense irregular connective tissue that forms the articular capsule that is normally associated with accessory ligaments. They are diarthroses as they allow for free movement.

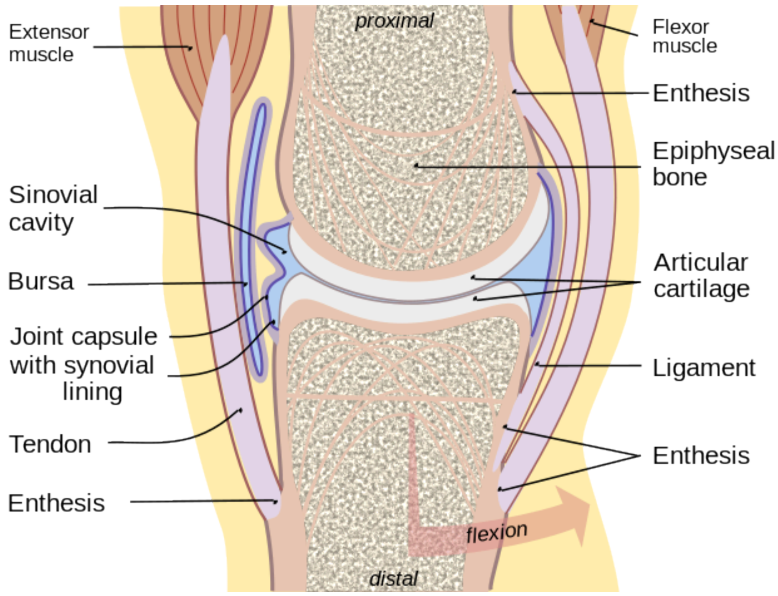


Diagram of a typical synovial joint

Synovial joints can in turn be classified into six groups according to the type of movement they allow:

- Plane joint – flat articular surfaces, allow for gliding movement.
- Ball and socket joint – where the convex of the end of one bone fits on the concave end of the other (e.g. shoulder joint).
- Hinge joint – a convex articular surface fits on the concave articular surface of the other, like a door hinge.
- Pivot joint – one bone rotates around another.
- Condyloid joint – one bone fits into the concave end of another (e.g. radiocarpal joint).
- Saddle joint – condyloid like but allow for more movement.

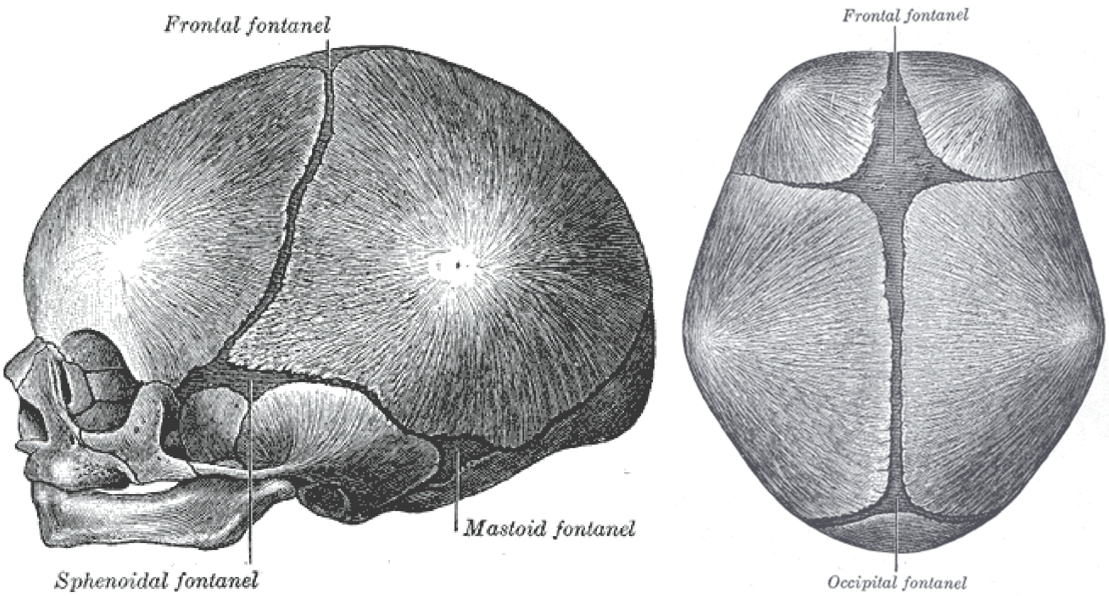
These are general terms that can be used to describe most movements the body makes. Most terms have a clear opposite, and so are treated in pairs.

Fontanelles

A fontanelle (or fontanel), colloquially known as soft spot, is an anatomical feature of the infant human skull comprising soft membranous gaps between the cranial bones that make up the calvaria of a fetus or an infant. Fontanelles allow for stretching and deformation of the neurocranium both during birth and later as the brain expands faster than the surrounding bone can grow.

The ossification of the bones of the skull causes the anterior fontanelle to close over by 9 to 18 months. The sphenoidal and posterior fontanelles close during the first few months of life. These closures eventually form the sutures of the neurocranium. Main fontanelles are the anterior and posterior fontanelles, the mastoid fontanelle and the sphenoidal fontanelle.

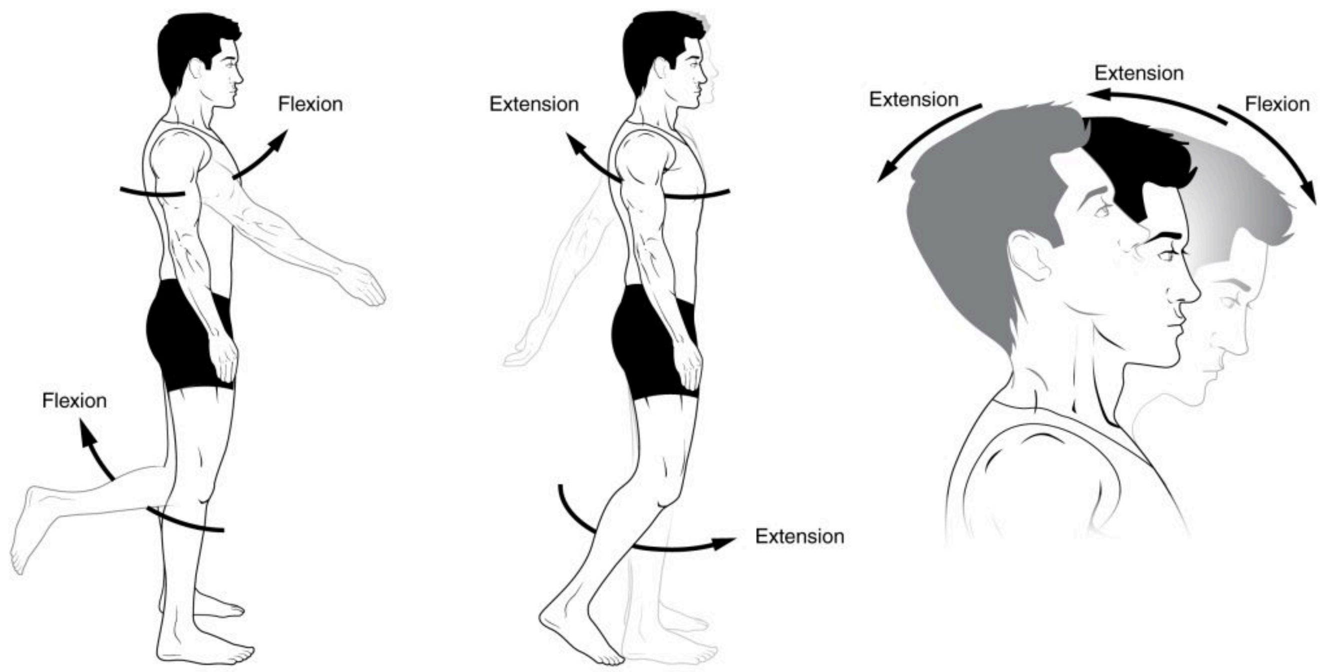
Premature complete ossification of the sutures is called craniosynostosis.



The skull at birth, showing the lateral fontanelles, anterior and posterior fontanelles

Types of Movements

Flexion and extension describe movements that affect the angle between two parts of the body. Flexion describes a bending movement that decreases the angle between a segment and its proximal segment. Extension is the opposite of flexion, describing a straightening movement that increases the angle between body parts

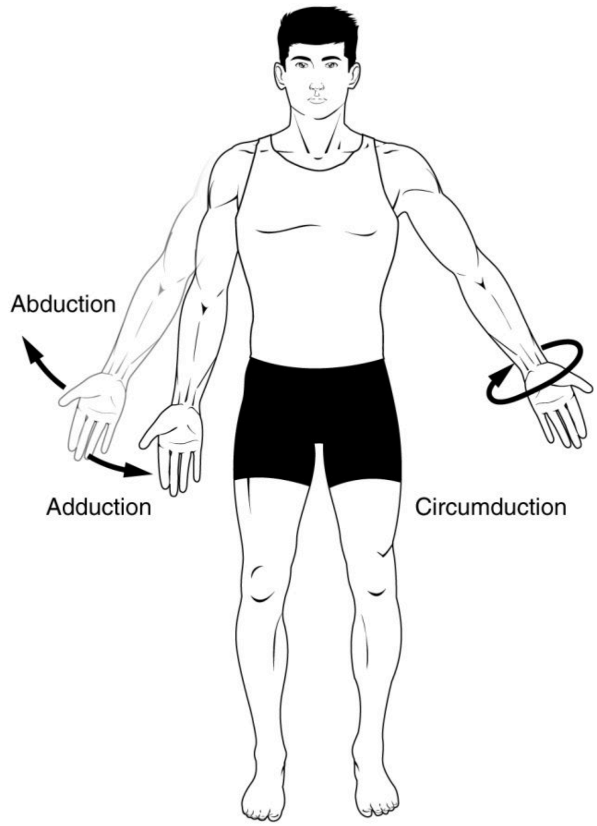


(a) and (b) Angular movements: flexion and extension at the shoulder and knees

(c) Angular movements: flexion and extension of the neck

Abduction is the motion of a structure away from the midline while adduction refers to motion towards the center of the body. The center of the body is defined as the midsagittal plane. These terms come from Latin words with similar meanings, ab- being the Latin prefix indicating "away," ad- indicating "toward," and ducere meaning "to draw or pull" (cf. English words "duct," "conduct," "induction"). Abduction refers to a motion that pulls a structure or part away from the midline of the body. In the case of fingers and toes, it refers to spreading the digits apart, away from the centerline of the hand or foot. Adduction refers to a motion that pulls a structure or part toward the midline of the body, or towards the midline of a limb.

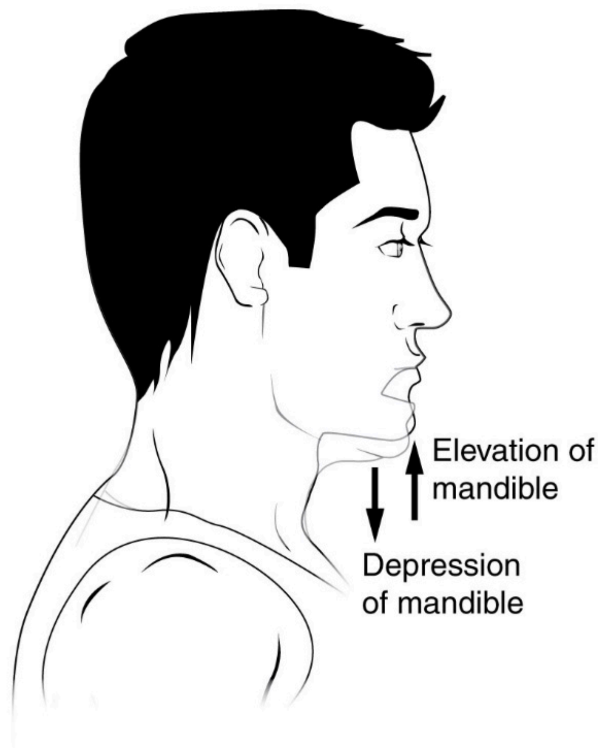
Circumduction refers to a conical movement of a body part, such as a ball and socket joint or the eye. Circumduction is a combination of flexion, extension, adduction and abduction. Circumduction can be best performed at ball and socket joints, such as the hip and shoulder, but may also be performed by other parts of the body such as fingers, hands, feet, and head.



(e) Angular movements: abduction, adduction, and circumduction of the upper limb at the shoulder

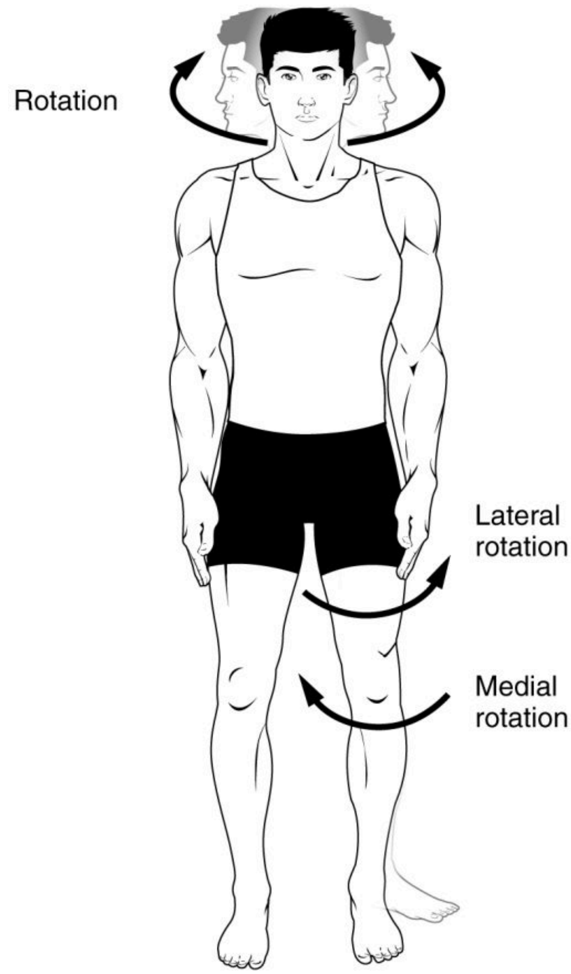
Elevation and depression

The terms elevation and depression refer to movement above and below the horizontal. Elevation refers to movement in a superior direction. Depression refers to movement in an inferior direction, the opposite of elevation.



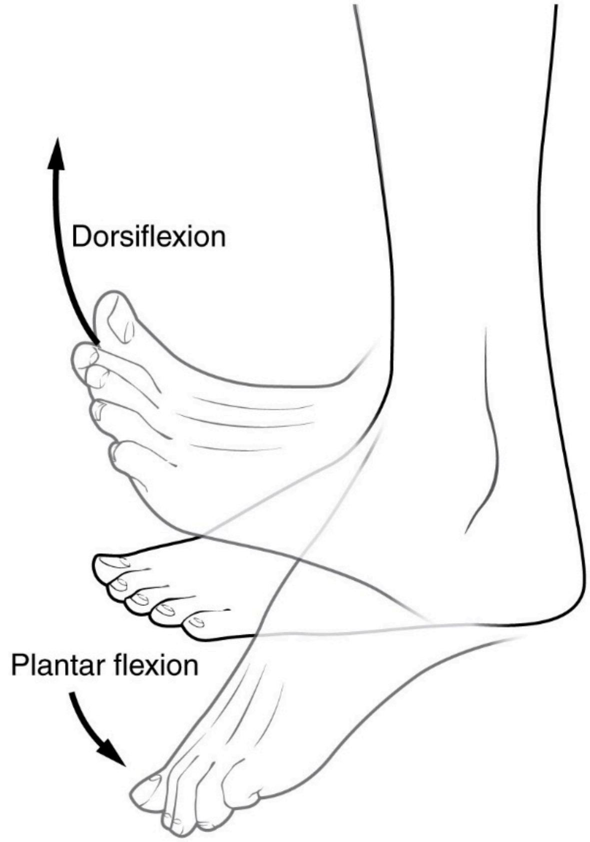
Rotation

Rotation of body parts is referred to as internal or external, referring to rotation towards or away from the center of the body. Internal rotation (or medial rotation) refers to rotation towards the axis of the body. External rotation (or lateral rotation) refers to rotation away from the center of the body.

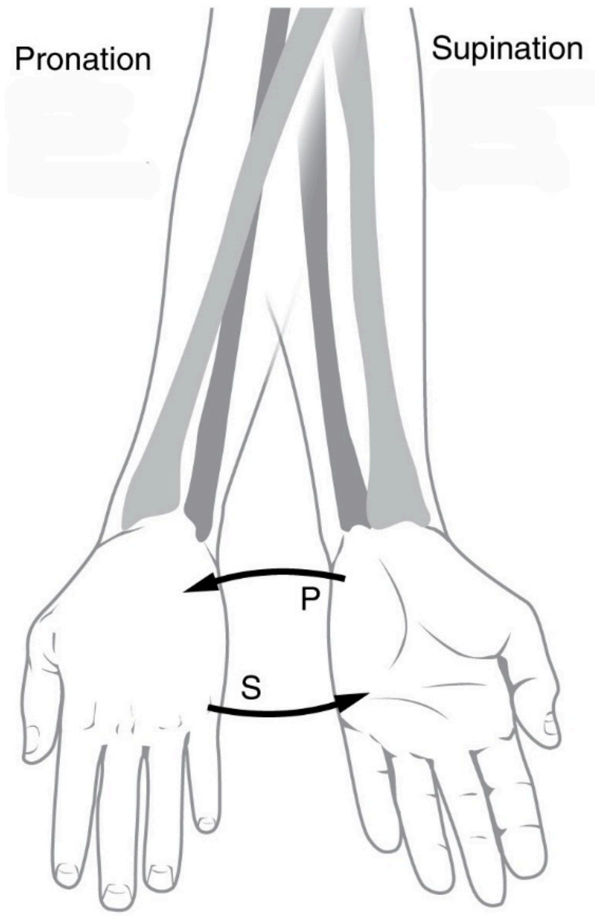


f) Rotation of the head, neck, and lower limb

Dorsiflexion and plantar flexion refer to extension or flexion of the foot at the ankle. These terms refer to flexion in direction of the "back" of the foot, dorsum pedi, which is the upper surface of the foot when standing, and flexion in direction of the sole of the foot, plantar pedi. These terms are used to resolve confusion, as technically extension of the joint refers to dorsiflexion, which could be considered counter-intuitive as the motion reduces the angle between the foot and the leg. Dorsiflexion is where the toes are brought closer to the shin. This decreases the angle between the dorsum of the foot and the leg. Plantar flexion or plantarflexion is the movement which decreases the angle between the sole of the foot and the back of the leg.

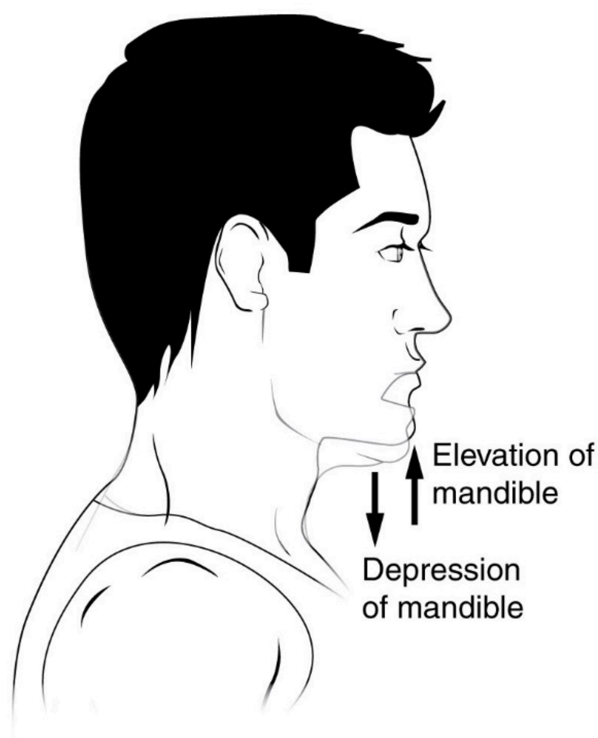


Pronation and supination refer most generally to assuming prone or supine positions, but often they are used in a specific sense referring to rotation of the forearm or foot so that in the standard anatomical position the palm or sole is facing anteriorly (supination) or posteriorly (pronation). Pronation at the forearm is a rotational movement where the hand and upper arm are turned inwards. Pronation of the foot refers to turning of the sole outwards, so that weight is borne on the medial part of the foot. Supination of the forearm occurs when the forearm or palm are rotated outwards. Supination of the foot refers to turning of the sole of the foot inwards, shifting weight to the lateral edge.

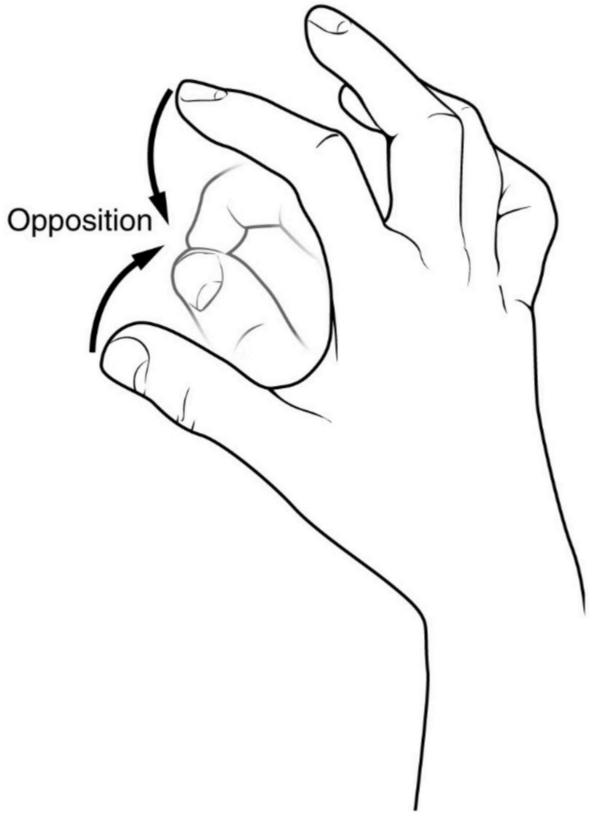


Inversion and eversion refer to movements that tilt the sole of the foot away from (eversion) or towards (inversion) the midline of the body. Eversion is the movement of the sole of the foot away from the median plane. Inversion is the movement of the sole towards the median plane.

Protrusion and retrusion are sometimes used to describe the anterior (protrusion) and posterior (retrusion) movement of the jaw.



Opposition refers to the movement that involves grasping of the thumb and fingers. Reposition refers to restoring an object to its natural condition.



Protraction and Retraction refer to an anterior (protraction) or posterior (retraction) movement, such as of the arm at the shoulders, and the mandible.

Lastly, we have selected one of the joints to study in detail for this lab activity, the Knee Joint. The other elbow, shoulder and hip joint will be shown superficially, make sure to pay attention to the structures that compose the knee joint, it is the most complex of all of them and it will give you a good idea of how a synovial joint functions.

The knee joins the thigh with the leg and consists of two joints: tibiofemoral joint (between femur and tibia), and patellofemoral joint (between femur and patella). It is the largest joint in the human body.

The knee is a modified hinge joint, which permits flexion and extension as well as slight internal and external rotation. The joint is bathed in synovial fluid which is contained inside the synovial membrane called the joint capsule.

The articular bodies of the knee joint include the articular bodies of the femur (lateral and medial condyles), a pair of tibial condyles are separated by the intercondylar eminence and the patella.

The articular capsule has a synovial and a fibrous membrane separated by fatty deposits. Anteriorly, the synovial membrane is attached on the margin of the cartilage both on the femur and the tibia, but on the femur, the suprapatellar bursa or recess extends the joint space proximally. The suprapatellar bursa is prevented from being pinched during extension by the Articularis genus muscle. Behind, the synovial membrane is attached to the margins of the two femoral condyles which produces two extensions similar to the anterior recess. Between these two extensions, the synovial membrane passes in front of the two cruciate ligaments at the center of the joint, thus forming a pocket directly inward.

There are numerous bursae surround the knee joint. The largest communicative bursa is the suprapatellar bursa described above. Four considerably smaller bursae are located on the back of the knee. Two non-communicative bursae are located in front of the patella and below the patellar tendon, and others are sometimes present.

The cartilage ensures supple knee movement. There are two types of joint cartilage in the knees: fibrous cartilage (the meniscus) and hyaline cartilage. Fibrous cartilage has tensile strength and can resist pressure. Hyaline cartilage covers the surface along which the joints move. There are no blood vessels inside of the hyaline cartilage, the alimentation is performed per diffusion. Synovial fluid and the subchondral bone marrow serve both as nutrition sources for the hyaline cartilage. Lack of at least one source induces a degeneration. Cartilage will wear over the years. Cartilage has a very limited capacity for self-restoration. The newly formed tissue will generally consist of a large part of fibrous cartilage of lesser quality than the original hyaline cartilage. As a result, new cracks and tears will form in the cartilage over time.

The articular discs of the knee-joint are called menisci because they only partly divide the joint space. These two disks, the medial meniscus and the lateral meniscus, consist of connective tissue with extensive collagen fibers containing cartilage-like cells. The menisci are flattened at the center of the knee joint, fused with the synovial membrane laterally, and can move over the tibial surface. The menisci serve to protect the ends of the bones from rubbing on each other and to effectively deepen the tibial sockets into which the femur attaches. They also play a role in shock absorption, and may be cracked, or torn, when the knee is forcefully rotated and/or bent.

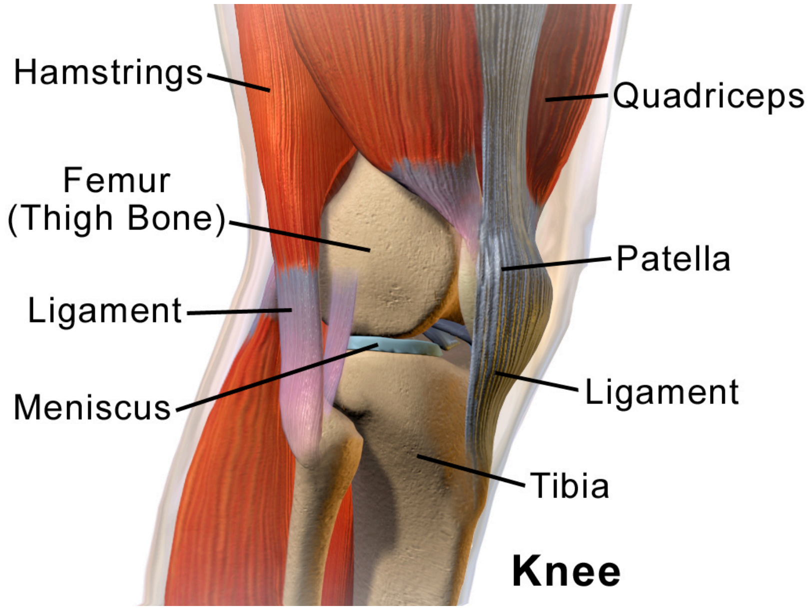
The ligaments surrounding the knee joint offer stability by limiting movements and, together with the menisci and several bursae, protect the articular capsule.

There are two types of ligaments in the knee joint, the intracapsular and extracapsular ligaments. The intracapsular ligaments include a pair of cruciate ligaments, transverse ligament, meniscofemoral ligaments, and the menisco-tibial ligaments that stabilize the knee.

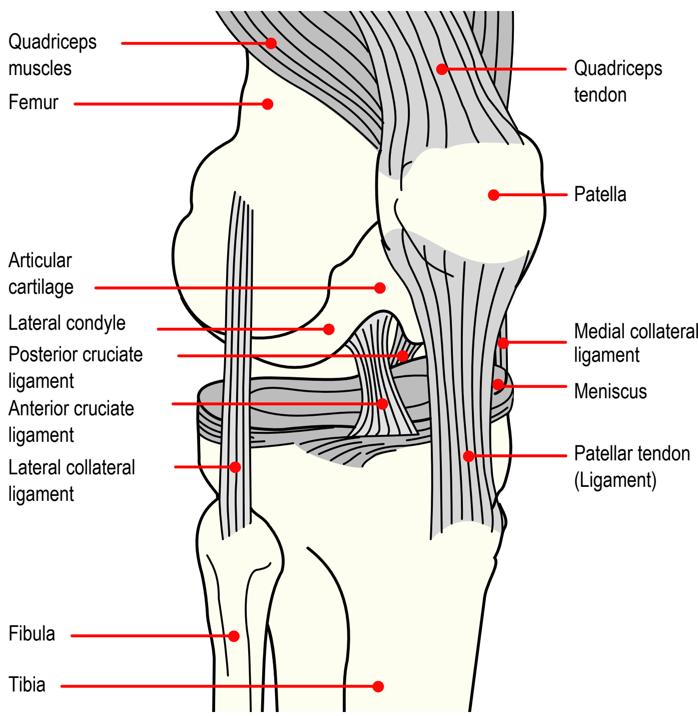
The anterior cruciate ligament (ACL) stretches from the lateral condyle of femur to the anterior intercondylar area. The ACL is critically important because it prevents the tibia from being pushed too far anterior relative to the femur. It is often torn during twisting or bending of the knee. The posterior cruciate ligament (PCL) stretches from the medial condyle of femur to the posterior intercondylar area. Injury to this ligament is uncommon but can occur as a direct result of forced trauma to the ligament. This ligament prevents posterior displacement of the tibia relative to the femur. The transverse ligament stretches from the lateral meniscus to the medial meniscus. It passes in front of the menisci. The two menisci are attached to each other anteriorly by the ligament. The posterior and anterior meniscofemoral ligaments stretch from the posterior horn of the lateral meniscus to the medial femoral condyle. They pass posteriorly behind the posterior cruciate ligament. The posterior meniscofemoral ligament is more commonly present (30%); both ligaments are present less often. The menisco-tibial ligaments (or "coronary") stretches from inferior edges of the mensici to the periphery of the tibial plateaus. The extracapsular ligaments include the patellar ligament, medial and lateral collateral ligaments, oblique popliteal ligament and arcuate popliteal ligament.

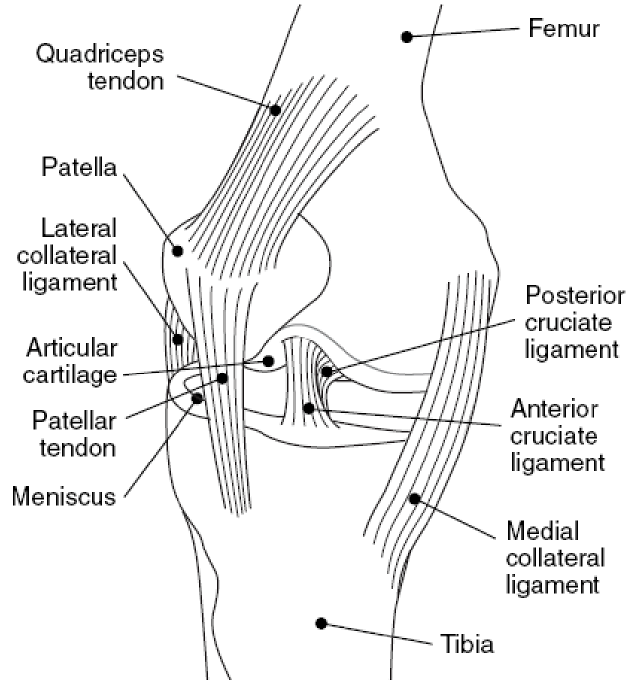
The patellar ligament connects the patella to the tuberosity of the tibia. It is also occasionally called the patellar tendon because there is no definite separation between the quadriceps tendon (which surrounds the patella) and the area connecting the patella to the tibia, it mat be more appropriate even though there is no physical division between the two, to call the upper portion the rectus femoris tendon and the lower portion the patellar ligament. This very strong ligament helps give the patella its mechanical leverage and also functions as a cap for the condyles of the femur. Laterally and medially to the patellar ligament the lateral and medial retinacula connect fibers from the vasti lateralis and medialis muscles to the tibia. Some fibers from the iliotibial tract radiate into the lateral retinaculum and the medial retinaculum receives some transverse fibers arising on the medial femoral epicondyle. The medial collateral ligament (MCL a.k.a. "tibial") stretches from the medial epicondyle of the femur to the medial tibial condyle. It is composed of three groups of fibers, one stretching between the two bones, and two fused with the medial meniscus. The MCL is partly covered by the pes anserinus and the tendon of the semimembranosus passes under it. It protects the medial side of the knee from being bent open by a stress applied to the lateral side of the knee (a valgus force). The fibular collateral ligament (LCL a.k.a. "fibular") stretches from the lateral epicondyle of the femur to the head of fibula. It is separate from both the joint capsule and the lateral meniscus. It protects the lateral side from an inside bending force. Lastly, there are two ligaments on the dorsal side of the knee. The oblique popliteal ligament is a radiation of the tendon of the semimembranosus on the medial side, from where it is direct laterally and proximally. The arcuate popliteal ligament originates on the apex of the head of the fibula to stretch proximally, crosses the tendon of the popliteus muscle, and passes into the capsule.

Note: On the anatomical model of the knee we have in the lab, we can't identify all of the intra and extracapsular ligaments, they usually a few of them only.



Right knee seen from the right side





Anterolateral and anteromedial aspects of the knee

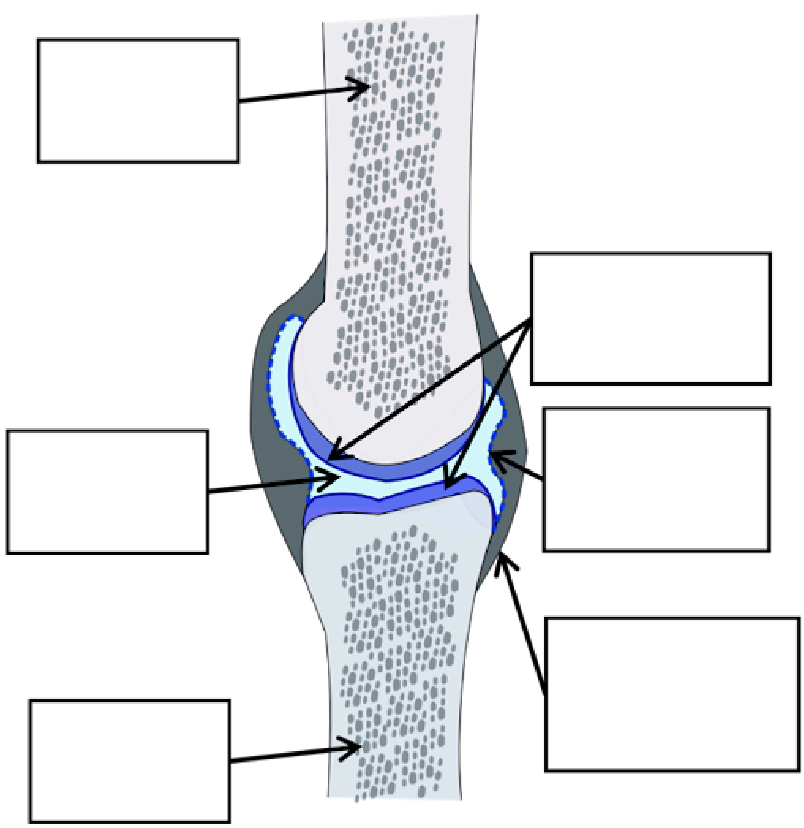
Laboratory activity

1. **Classification of JointsProcedure**Procedure
    1. Classify joints by structure and function. Inspect the anatomical models your instructor placed on the lab bench. Classify the joints by structure and function. You may also add the structural subcategory and the amount of motion that the joint allows to your answers. Write your answers in the table provided below.

Table No. 1 – Classification of Joints

Joint	Structural classification	Functional classification
Atlantoaxial joint		
Atlantooccipital joint		
Coronal suture		
Costochondral joint		
Glenohumeral joint (shoulder)		
Intervertebral joint		
Knee joint		
Radioulnar joint		
Sagittal suture		
Tibiofibular joint		
Tooth joint		

2. **Identify the structures of a synovial joint.**



3. **Identify structures of the knee joint.**

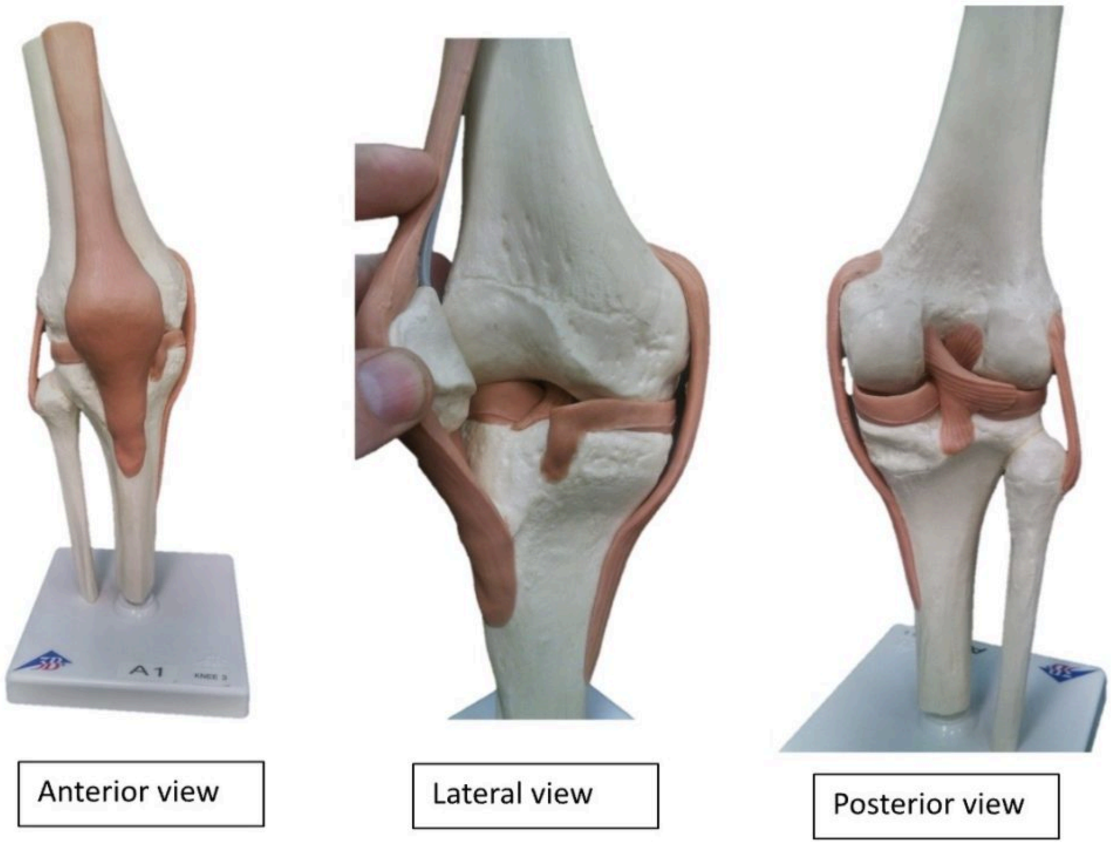
Procedure

Using the Anatomical model of the knee and the diagrams shown above, identify the following structures:

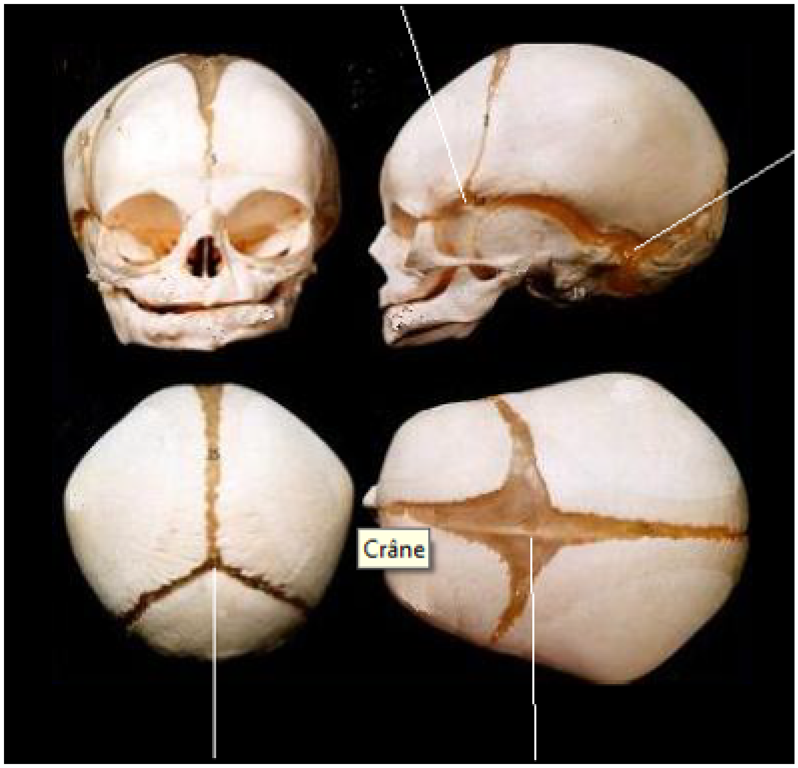
Table No. 2 – Structures of the knee

Structure	Identified (√/X)
Anterior cruciate ligament (ACL)	
Articular surface of the femur	
Bursae	
Femur	
Joint capsule	
Lateral collateral ligament	
Lateral condyle of femur	
Lateral meniscus	
Medial collateral ligament	
Medial condyle of femur	
Medial meniscus	
Patella	
Patellar ligament	
Posterior cruciate ligament (PCL)	
Quadriceps muscle	
Synovial cavity (with synovial fluid)	
Synovial membrane	
Tendon of the rectus femoris	
Tibia	

4. **Label the structures of the knee using the knee anatomical model (for 100% online, use the images provided here).**



5. **Using the anatomical model of a newborn skull, label the main fontanelles, anterior, posterior, sphenoid and mastoid fontanelles. For 100% online courses, use the image provided here.**



Motions of Synovial Joints

Define the following terms using the table provided here:

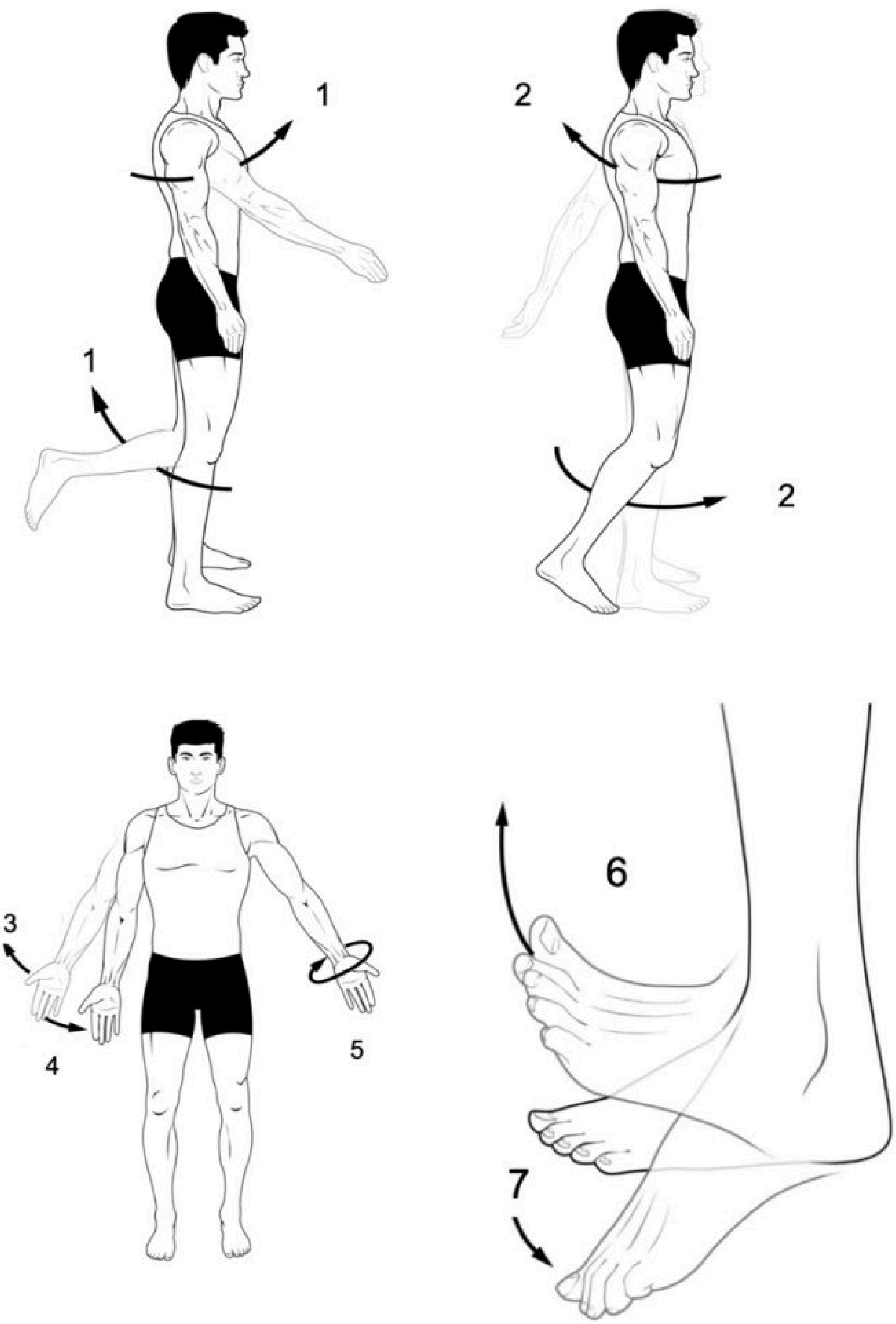
Table No. 3 – Definitions

Movement	Definition
Abduction	
Adduction	
Circumduction	
Depression	
Dorsiflexion	
Eversion	
Elevation	
Extension	
Flexion	
Inversion	
Opposition	
Plantar flexion	
Protraction	
Retraction	
Rotation	
Supination	

6. **Determine the type of Movement at synovial joints**

Using the images shown below, determine the type of movement shown. Write your answers on the table provided below.

Movements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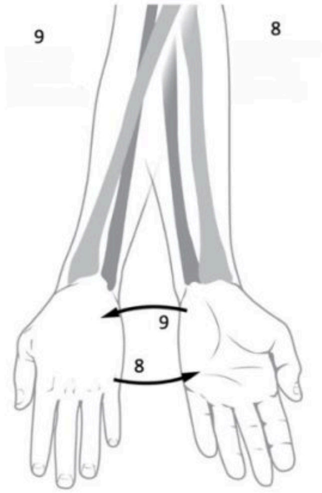
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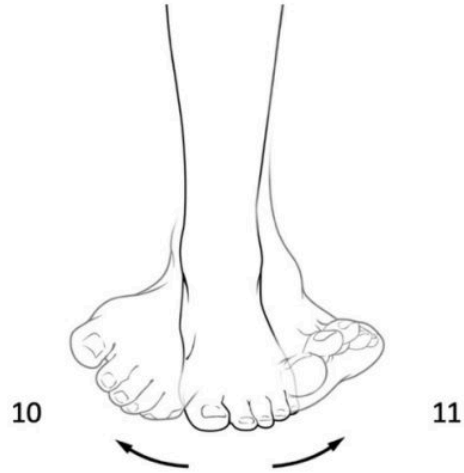
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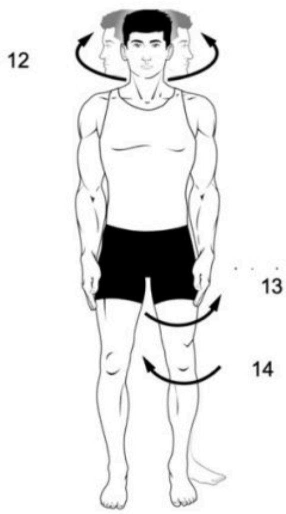
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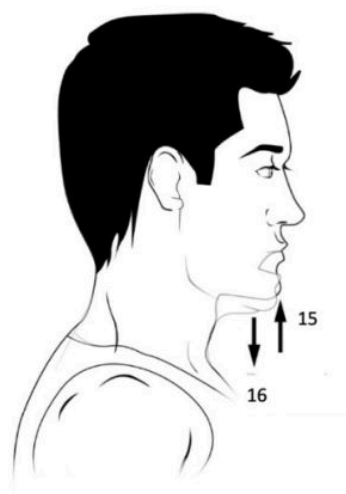
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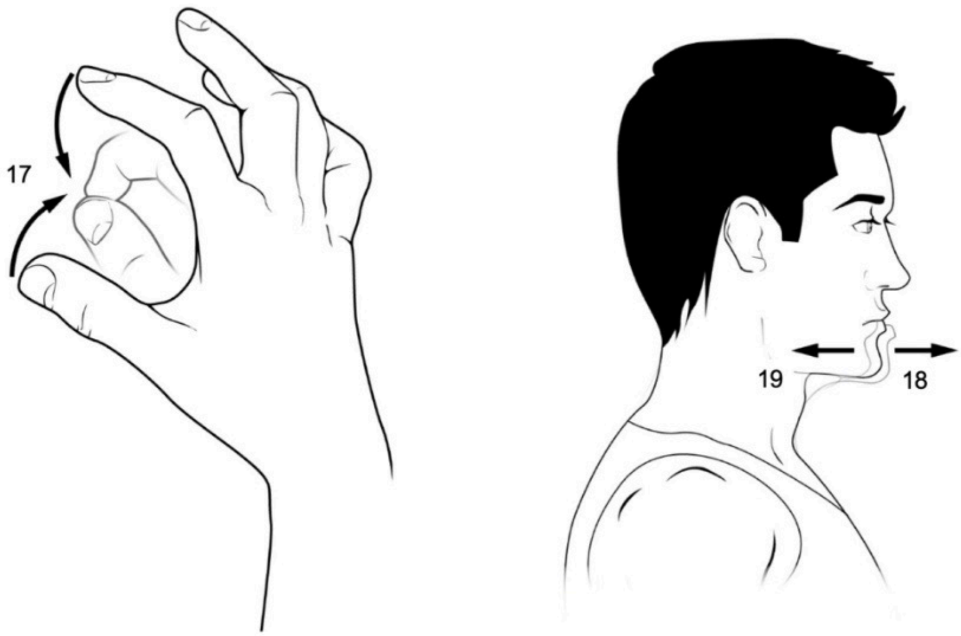

Table No. 4 – Types of Movement

Figure #	Type of movement
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Word bank: Abduction, Adduction, Circumduction, Depression, Dorsiflexion, Eversion, Elevation, Extension, Flexion, Inversion, Opposition, Plantar flexion, Protraction, Retraction, Rotation, Rotation (lateral), Rotation (medial), Supination.

Review the Following Structures:

Sutures

Coronal
Sagittal
Lambdoidal
Squamous suture
Fontanelles
Anterior fontanelle

Posterior fontanelle

Anterolateral fontanelle (sphenoidal)

Posterolateral fontanelle (mastoid)

Syndesmoses

- Radioulnar joint
- Tibiofibular joint

Gomphoses

Synchondroses

- Sternocostal

Symphysis

- Symphysis pubis

Synovial joints

- Bursa
- Articular Capsule
  - Fibrous capsule
  - Synovial membrane
- Synovial cavity

Knee Joint

Femur

- Medial condyle + Articular cartilage
- Lateral condyle + Articular cartilage

ACL, Anterior cruciate ligament

PCL, Posterior cruciate ligament

Lateral collateral ligament

Medial collateral ligament

Lateral meniscus

Medial meniscus

Tibia

- Medial Condyle + Articular cartilage
- Lateral Condyle + Articular cartilage

Patella

- Patellar ligament
- Tendon of quadriceps femoris

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THE MUSCULAR TISSUE

Muscle Tissue Laboratory Activity

Objectives

1. Describe the three types of muscle tissue and describe the basic function of each.
2. Describe the histological appearance of the 3-muscle tissue types; skeletal, smooth and cardiac muscle.
3. Identify each type of muscle tissue in microscope preparations and identify the microanatomy of the skeletal muscle fibers.

Introduction:

Muscle tissue is composed of cells that have the ability to shorten/contract in order to produce movement. The muscle cells, also called muscle fibers are long and slender. They are arranged in bundles or layers that are surrounded by connective tissue. Actin and myosin are the main contractile proteins in muscular tissue. Muscle tissue formed during embryonic development through a process known as myogenesis.

Muscle tissue is categorized into skeletal muscle tissue (attached to the skeleton), smooth muscle tissue (found inside of hollow organs and blood vessels, and cardiac muscle tissue (only found in the heart).

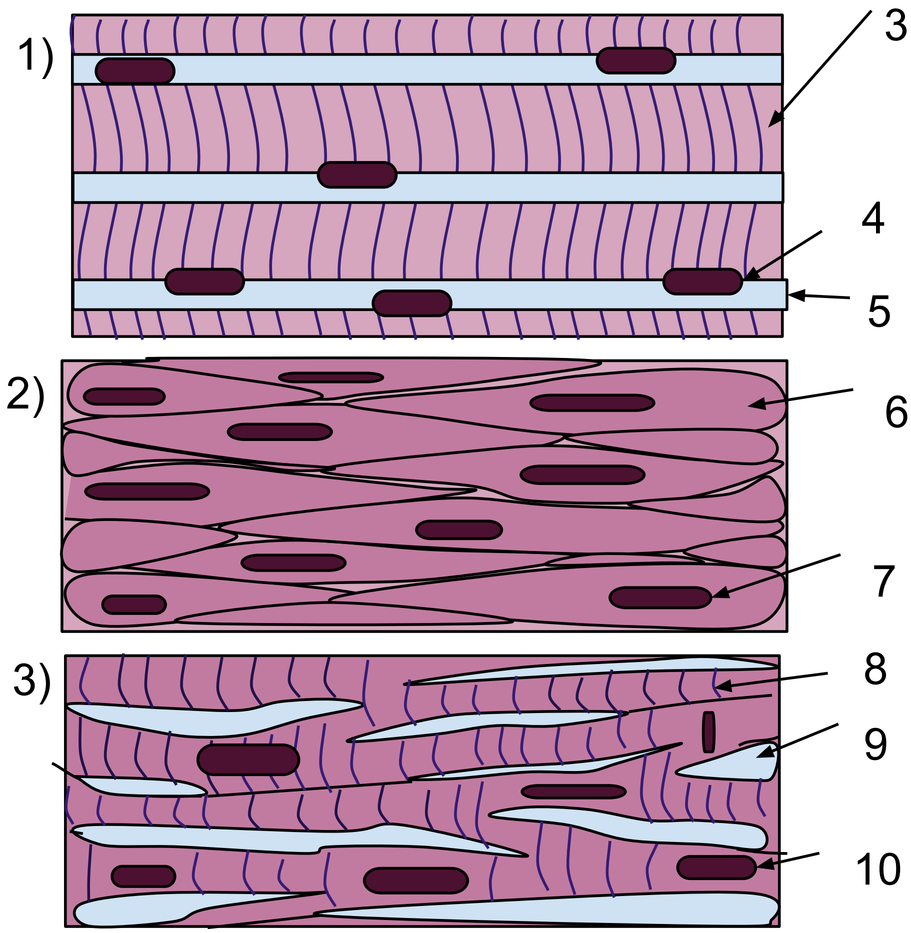
Skeletal muscle fibers are long, cylindrical, multinucleated (due to fusion of many cells during development), showing a banding pattern or striations, and are under voluntary control.

Smooth muscle cells are shorter, tapered or spindle shaped, have a central single, and lack striations. They are under involuntary control.

Cardiac muscles are short branched, one-two nucleus per cell, with striations, and modified gap junctions called intercalated disks. They are under involuntary control.

These muscle types are activated both through interaction of the central nervous system and endocrine (hormonal) activation. Skeletal muscle only contracts voluntarily, upon influence of the central nervous system. Reflexes are a form of nonconscious activation of skeletal muscles, but nonetheless arise through activation of the central nervous system, albeit not engaging cortical structures until after the contraction has occurred.

A schematic diagram of the different types of muscle cells



1) Skeletal muscle cells are long tubular cells with striations (3) and multiple nuclei (4). The nuclei are embedded in the cell membrane (5) so that they are just inside the cell. This type of tissue occurs in the muscles that are attached to the skeleton. Skeletal muscles function in voluntary movements of the body.

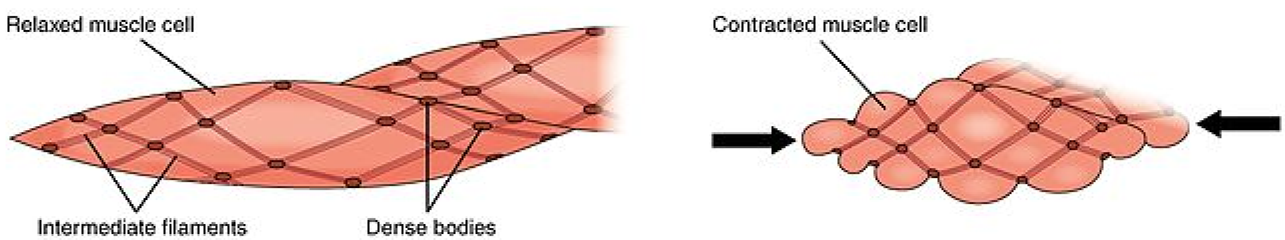
2) Smooth muscle cells are spindle shaped (6), and each cell has a single nucleus (7). Unlike skeletal muscle, there are no striations. Smooth muscle acts involuntarily and functions in the movement of substances in the lumens. They are primarily found in blood vessel walls and walls along the digestive tract.

3) Cardiac muscle cells branch off from each other, rather than remaining along each other like the cells in the skeletal and smooth muscle tissues. Because of this, there are junctions between adjacent cells (9). The cells have striations (8), and each cell has a single nucleus (10). This type of tissue occurs in the wall of the heart and its primary function is for pumping blood

Smooth Muscle

Smooth muscle is an involuntary non-striated muscle. It is divided into two subgroups: the single-unit (unitary) and multiunit smooth muscle. Within single-unit cells, the whole bundle or sheet contracts as a syncytium (i.e. a multinucleate mass of cytoplasm that is not separated into cells). Multiunit smooth muscle tissues innervate individual cells; as such, they allow for fine control and gradual responses, much like motor unit recruitment in skeletal muscle.

Smooth muscle is found within the walls of blood vessels (such smooth muscle specifically being termed vascular smooth muscle) such as in the tunica media layer of large (aorta) and small arteries, arterioles and veins. Smooth muscle is also found in lymphatic vessels, the urinary bladder, uterus (termed uterine smooth muscle), male and female reproductive tracts, gastrointestinal tract, respiratory tract, arrector pili of skin, the ciliary muscle, and iris of the eye. The structure and function is basically the same in smooth muscle cells in different organs, but the inducing stimuli differ substantially, in order to perform individual effects in the body at individual times. In addition, the glomeruli of the kidneys contain smooth muscle-like cells called mesangial cells.

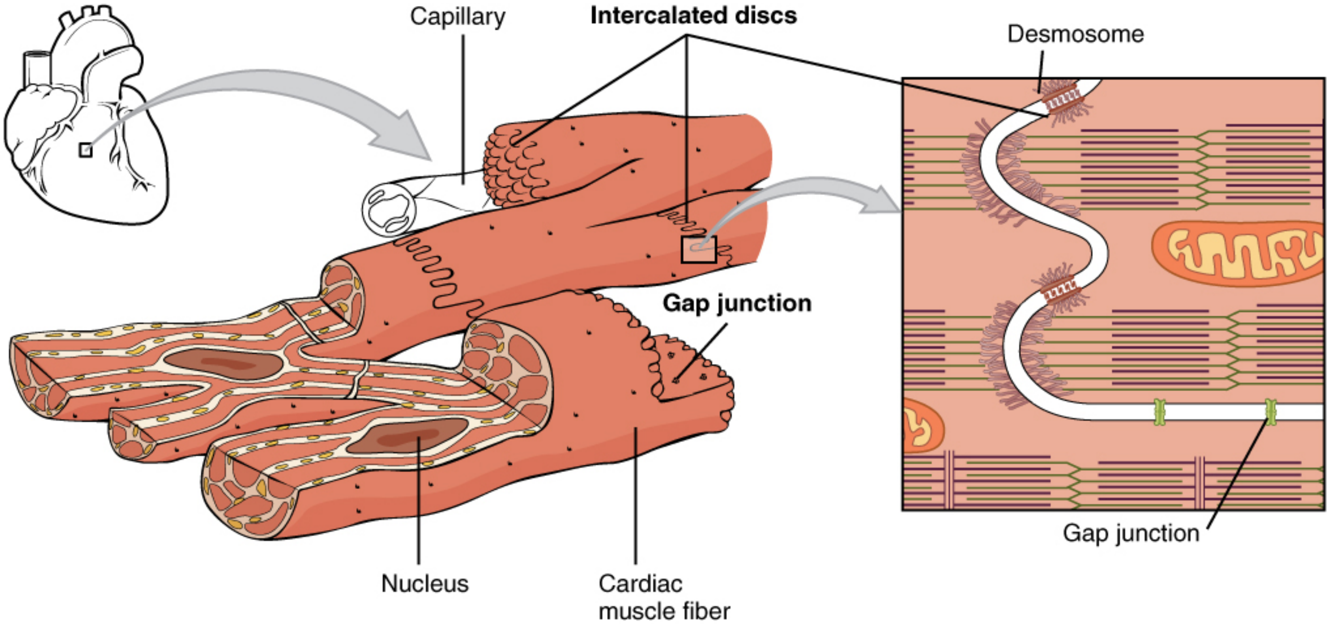


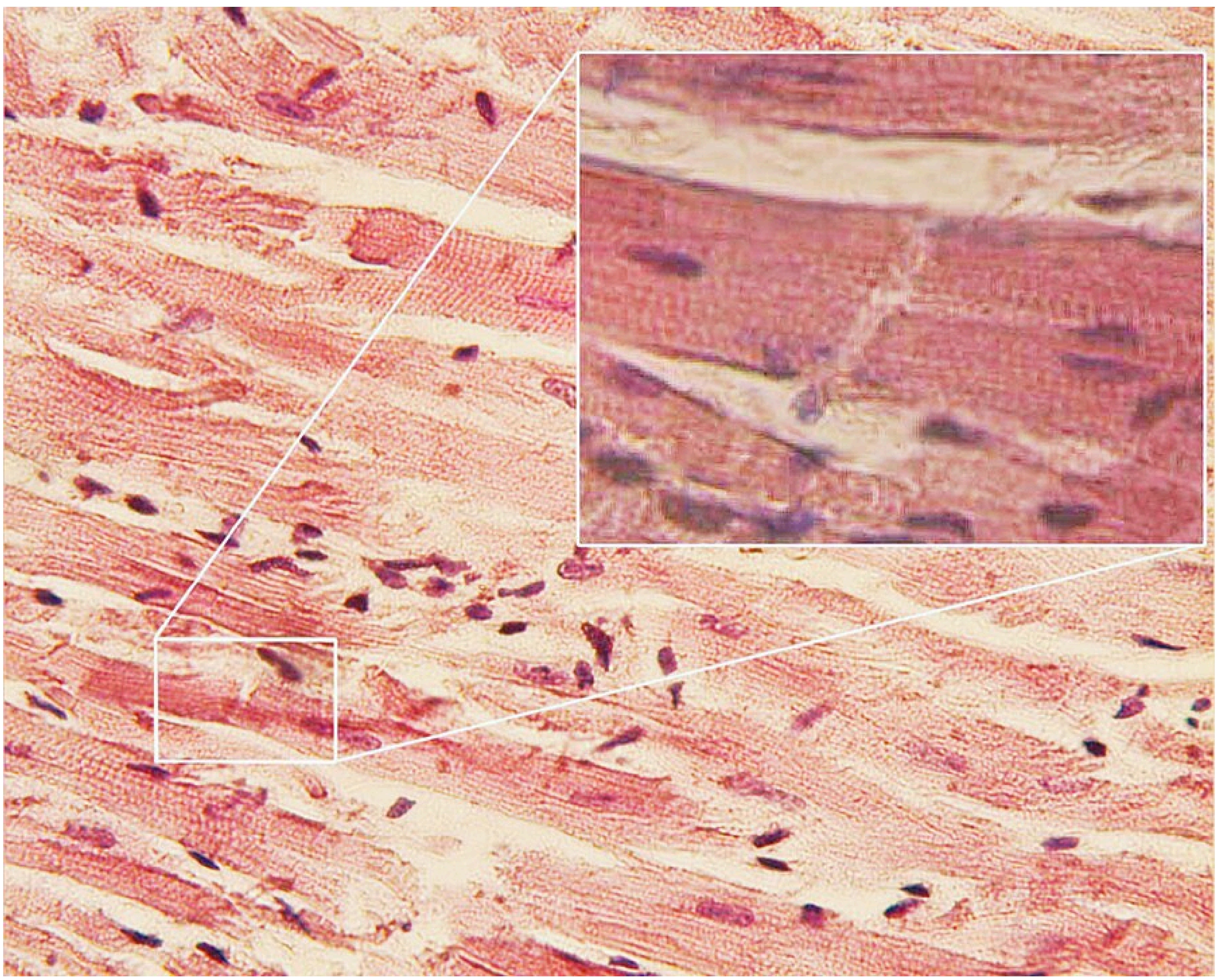
The dense bodies and intermediate filaments are networked through the sarcoplasm, which cause the muscle fiber to contract.

Cardiac Muscle

Cardiac muscle (also called heart muscle or myocardium) is one of three types of vertebrate muscles, with the other two being skeletal and smooth muscles. It is an involuntary, striated muscle that constitutes the main tissue of the walls of the heart. The myocardium forms a thick middle layer between the outer layer of the heart wall (the epicardium) and the inner layer (the endocardium), with blood supplied via the coronary circulation. It is composed of individual heart muscle cells (cardiomyocytes) joined together by intercalated discs, encased by collagen fibres and other substances that form the extracellular matrix.

Cardiac muscle contracts in a similar manner to skeletal muscle, although with some important differences. An electrical stimulation in the form of an action potential triggers the release of calcium from the cell's internal calcium store, the sarcoplasmic reticulum. The rise in calcium causes the cell's myofilaments to slide past each other in a process called excitation contraction coupling.


Capillary
Intercalated discs
Desmosome
Gap junction
Gap junction
Nucleus
Cardiac
muscle fiber

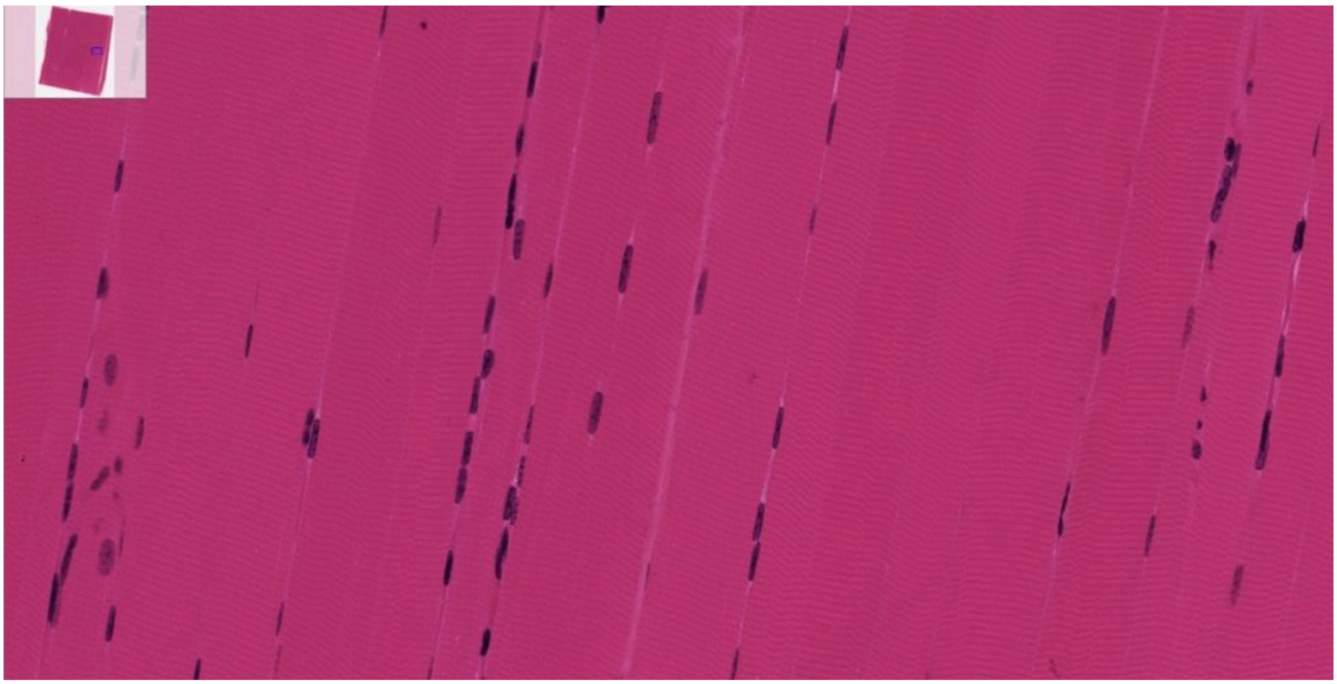


Muscle tissue type Activities

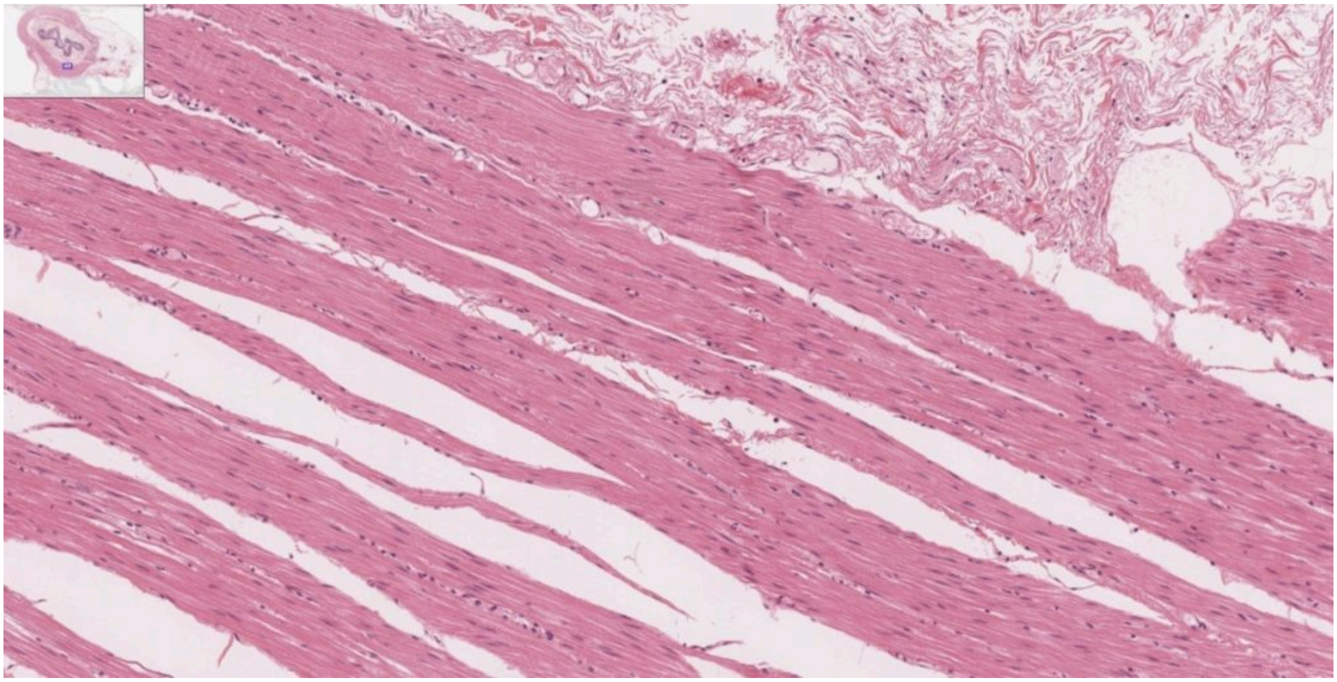
Virtual Microscopy (for 100% online courses)

Go to University of Michigan Virtual Microscope, search for muscles, then choose the following slides:

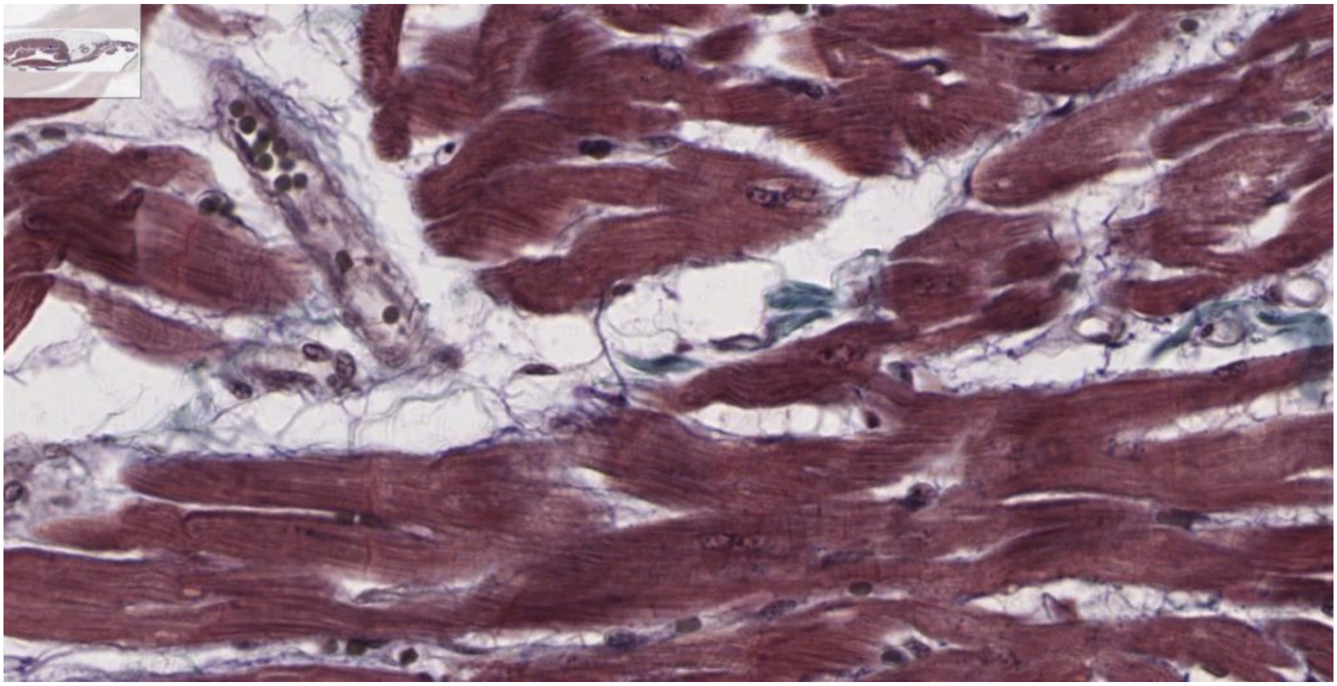
1. Skeletal Muscle – Slide: #058 Thin section



2. Smooth Muscle – Slide: # 029-1



3. Cardiac Muscle – Slide: #098-N



Instructions:

Once you have searched for the muscle's slides, click on the slide number described above.

The first image you see is at scanning power level, you will need to increase magnification using the plus/minus signs until you see the area shown here.

Remember, these are slides of organs and contain more than one type of tissue, you need to locate the specific tissue, i.e. muscles (skeletal, smooth and cardiac). Locate the area where each of the muscle tissues (individual slides) are located draw and label them.

1. Skeletal muscle – Slide: #058 Thin sectionDraw what you see in the space provided. Find and label the striations, peripheral nuclei and cylindrical muscle cells (fibers).

2. Smooth muscle – Slide: # 029-1Draw what you see in the space provided. Find nuclei and spindle shaped cells.

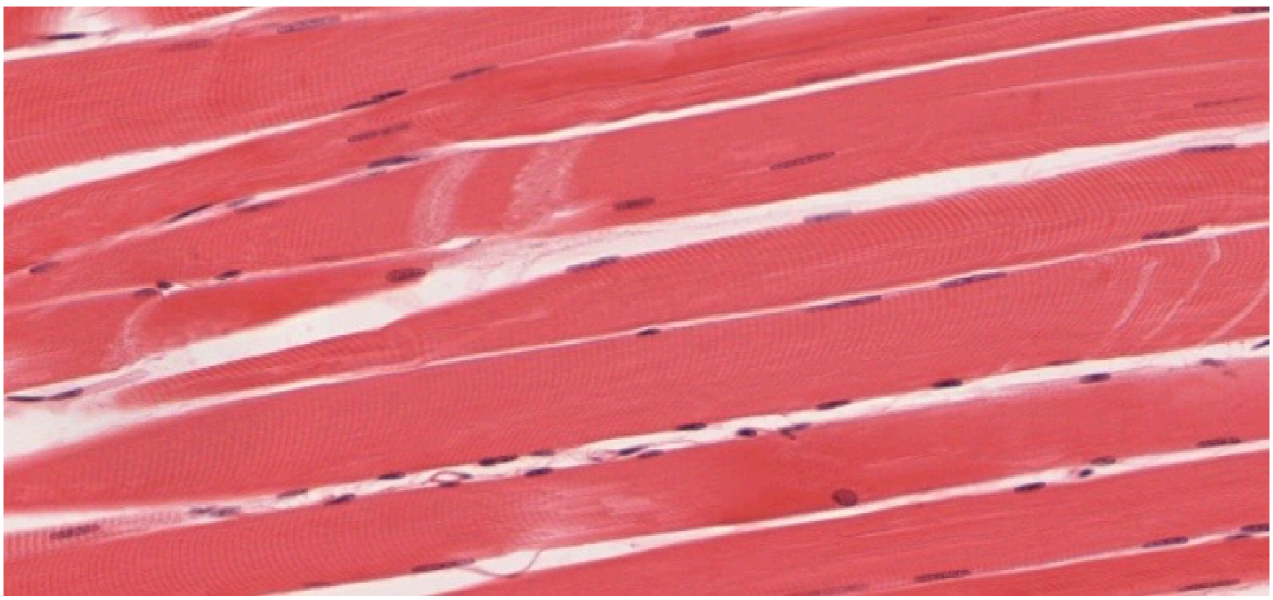
3. Cardiac muscle – Slide: #098-NDraw what you see in the space provided. Find intercalated disks, striations, nuclei and branched cells.

Light Microscopy (for hybrid and F-to-F courses)

Obtain muscle slides from your instructor. Look under the microscope at scanning (to locate the tissue), the change to low power and high power. Draw and label the structures of the following muscular tissues slides:

1. Skeletal muscle (teased)Move around the microscope slide (move the mechanical stage once you have placed the slide in it and secure it with the clip) to locate the area where skeletal muscle is located (remember you are looking at organ slides, made of more than one type of tissue).

   You should look for an area that looks like this:

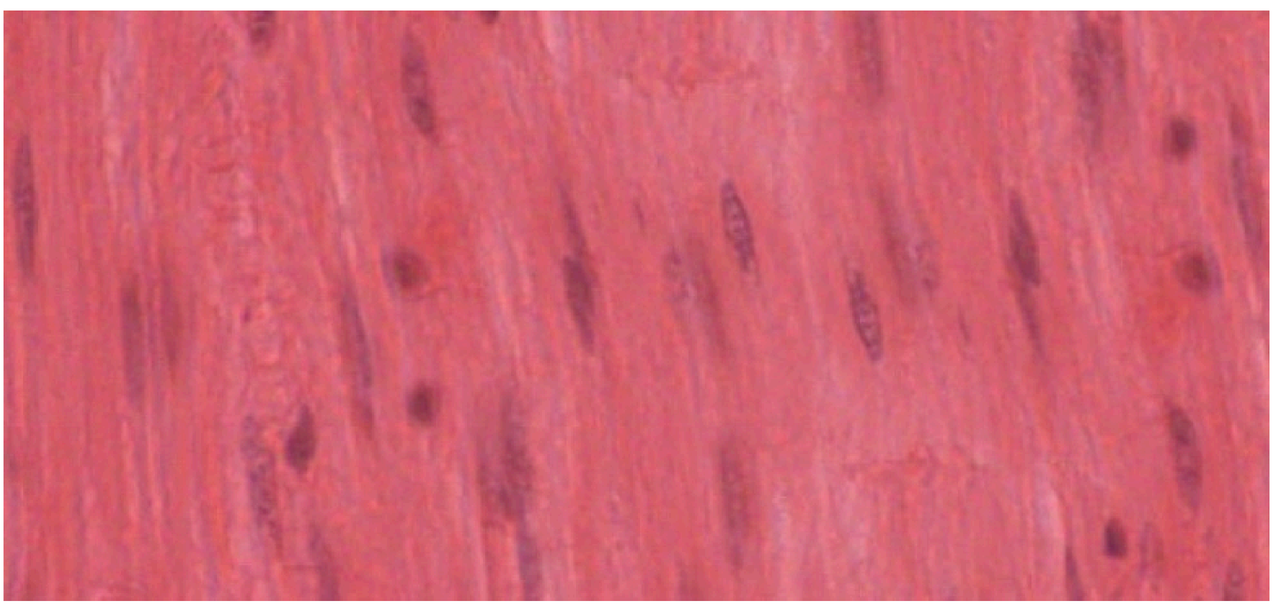
   

   (a) skeletal muscle, LM × 1600.

   Draw what you see in the space provided. Find and label the striations, peripheral nuclei and cylindrical muscle cells (fibers).

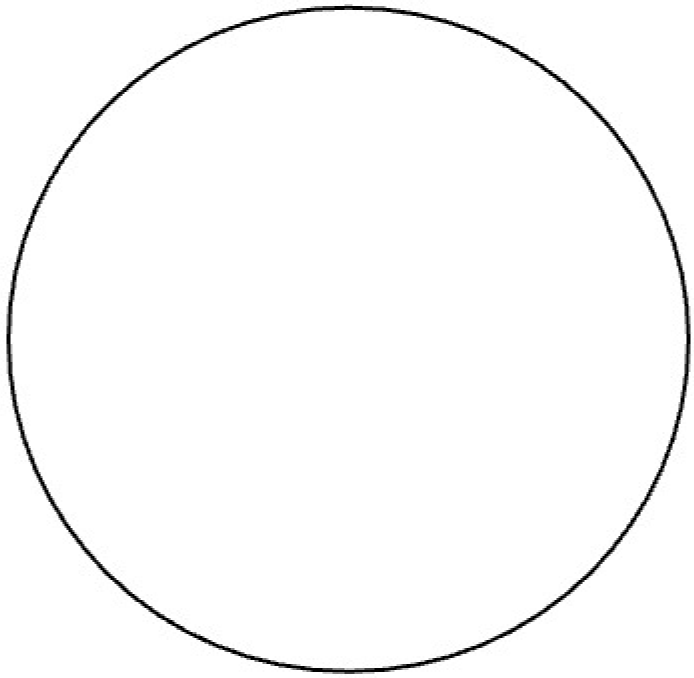
2. Smooth muscle (teased)Move around the microscope slide (move the mechanical stage once you have placed the slide in it and secure it with the clip) to locate the area where skeletal muscle is located (remember you are looking at organ slides, made of more than one type of tissue).

   You should look for an area that looks like this:

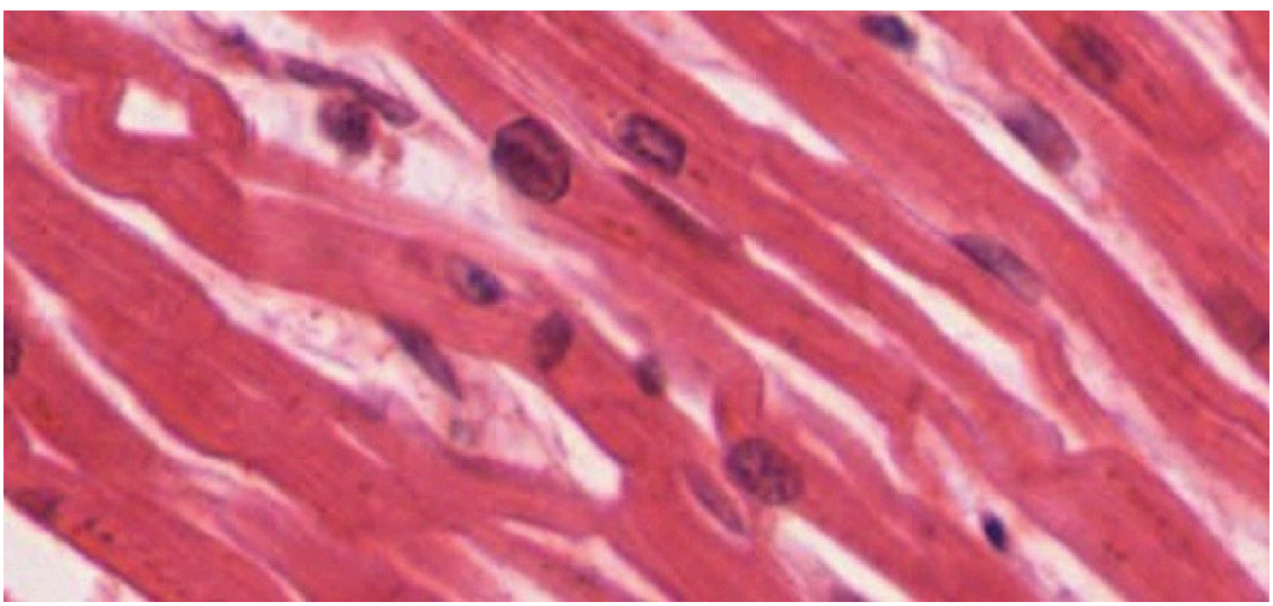
   Smooth muscle, LM × 1600.

Draw what you see in the space provided. Find nuclei and spindle shaped cells.



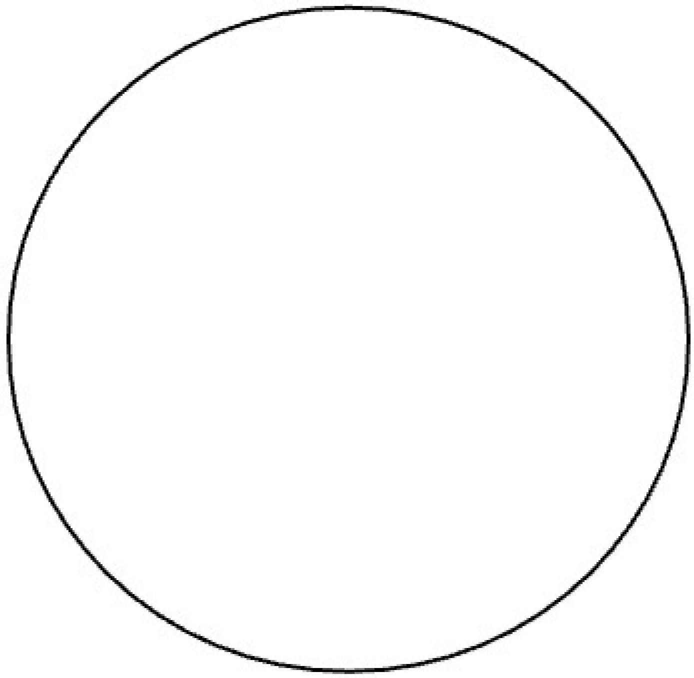
3. Cardiac muscle (intercalated disk stain)Move around the microscope slide (move the mechanical stage once you have placed the slide in it and secure it with the clip) to locate the area where skeletal muscle is located (remember you are looking at organ slides, made of more than one type of tissue).

   You should look for an area that looks like this:

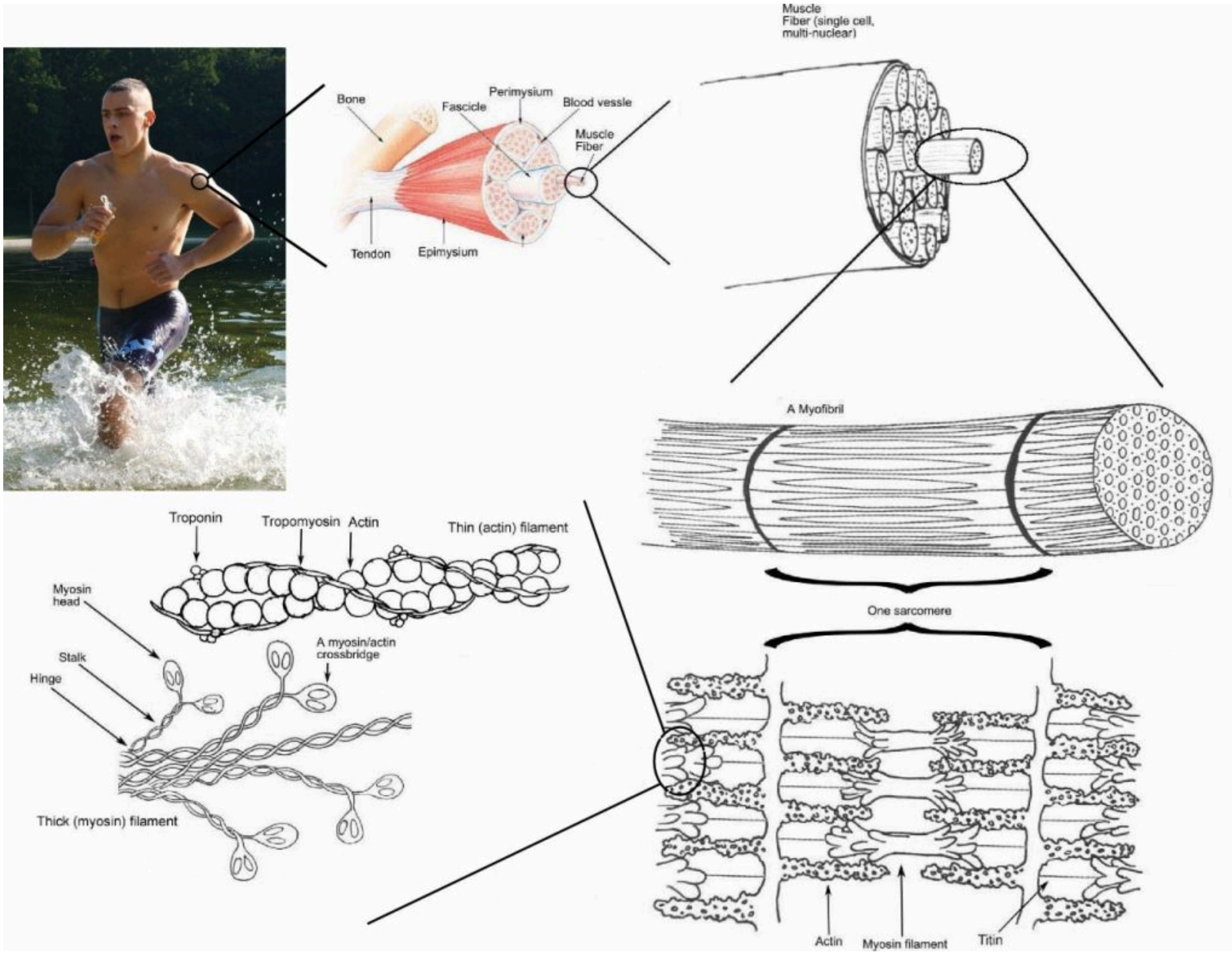
   

   Cardiac muscle, LM × 1600.

   Draw what you see in the space provided. Find intercalated disks, striations, nuclei and branched cells.



The Sarcomere



Use the anatomical Model of Skeletal muscle available in the lab.
Identify the following areas of the sarcomere:
I band, A band, H band, Z line, M line, thin and thick filaments and Zone of overlap.

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THE MUSCULAR SYSTEM ANATOMY

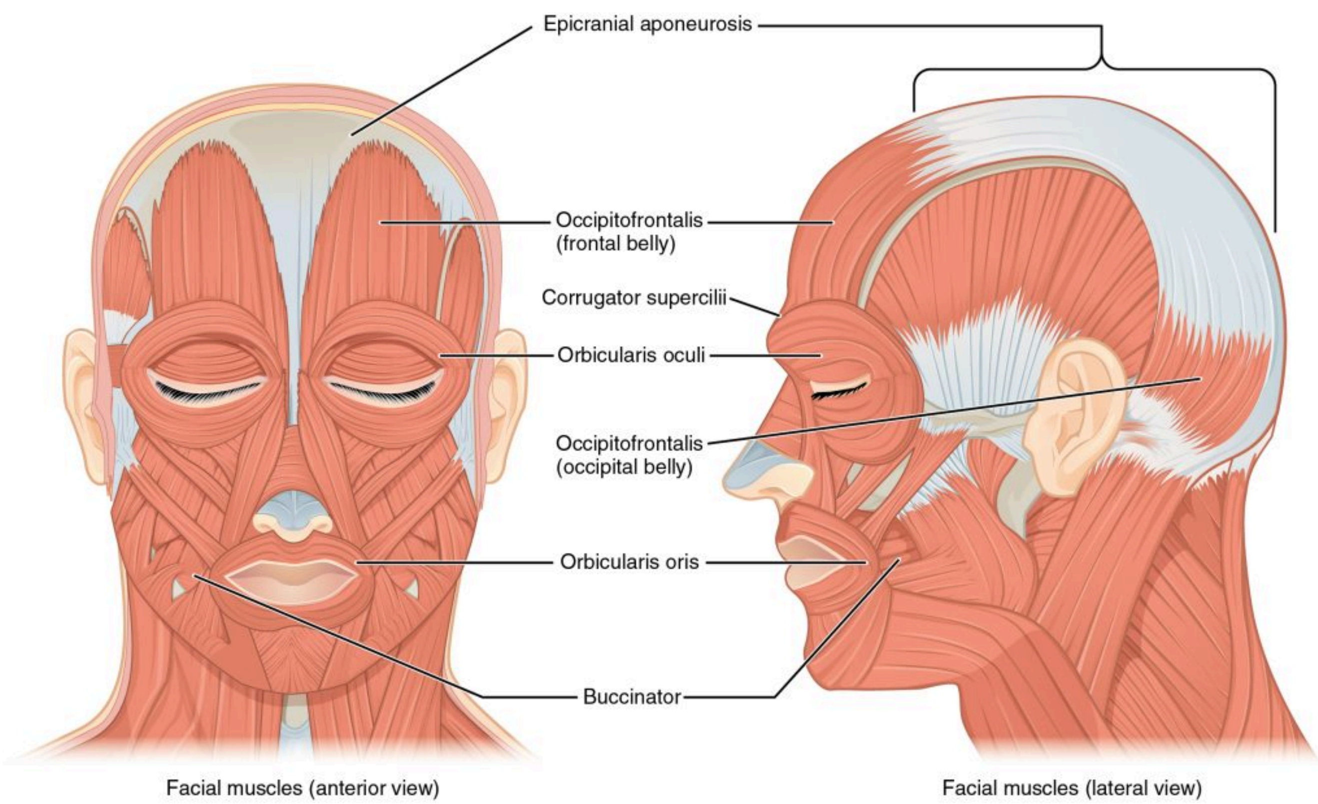
Muscles of the Head, Neck & Back

Objectives

1. Locate the muscles of the head, neck & back on laboratory charts and models.
2. Recognize on the models the origin, insertion, and action of the muscles of the head, neck & back.
3. Describe and demonstrate the action of the muscles of the head, neck & back.

Muscles of Facial Expression

The muscles of facial expression originate from the surface of the skull or the fascia (connective tissue) of the face. The insertions of these muscles have fibers intertwined with connective tissue and the dermis of the skin. Because the muscles insert in the skin rather than on bone, when they contract, the skin moves to create facial expressions.



Brow

Muscle	Origin	Insertion	Action	Innervation
Occipitofrontalis, frontal belly	Epicraneal aponeurosis	Underneath skin of forehead	Furrowing brow	Facial nerve
Occipitofrontalis, occipital belly	Occipital bone; mastoid process (temporal bone)	Epicraneal aponeurosis	Unfurrowing brow	Facial nerve
Corrugator supercilii	Frontal bone	Skin underneath eyebrow	Draws eyebrows medially and downward; frowning	Facial nerve

Nose

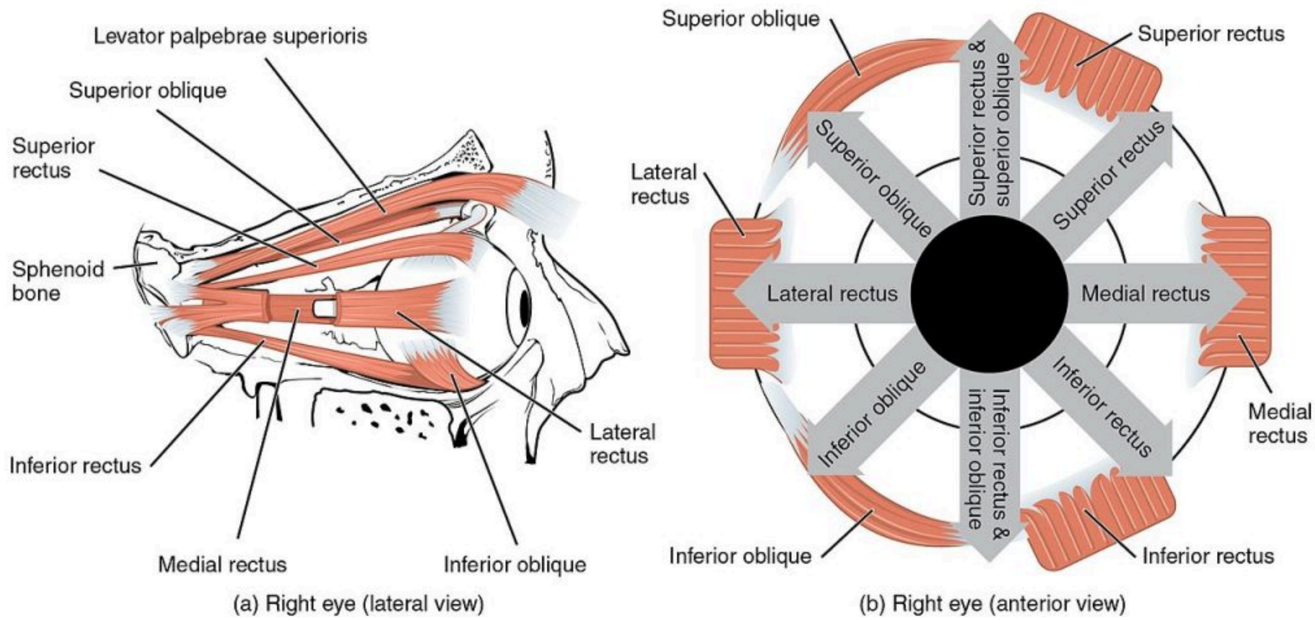
Muscle	Origin	Insertion	Action	Innervation
Nasalis	Maxilla	Nasal bone	Widens nostrils	Facial nerve

Mouth

Muscle	Origin	Insertion	Action	Innervation
Levator labii superioris	Maxilla	Underneath skin at corners of the mouth; orbicularis oris	Elevates upper lip	Facial nerve
Depressor labii inferioris	Mandible	Underneath skin of lower lip	Draws lower lip downward	Facial nerve
Depressor angulus oris	Mandible	Underneath skin at corners of the mouth	Opening mouth and sliding lower jaw left and right	Facial nerve
Zygomaticus major	Zygomatic bone	Underneath skin at corners of the mouth (dimple area); orbicularis oris	Draws angle of mouth upward and laterally; smiling	Facial nerve
Orbicularis oris	Tissue surrounding lips	Underneath skin at corners of the mouth	Shaping of lips (as during speech)	Facial nerve
Buccinator	Maxilla, mandible; sphenoid bone (via pterygomandibular raphae)	Orbicularis oris	Lateral movement of cheeks (e.g., sucking on a straw; also used to compress air in mouth while blowing)	Facial nerve
Risorius	Fascia of parotid salivary gland	Underneath skin at corners of the mouth	Draws angle of mouth laterally.	Facial nerve
Mentalis	Mandible	Underneath skin of chin	Elevates and protrudes lower lip ands skin of the chin	Facial nerve

Muscles of the Eye

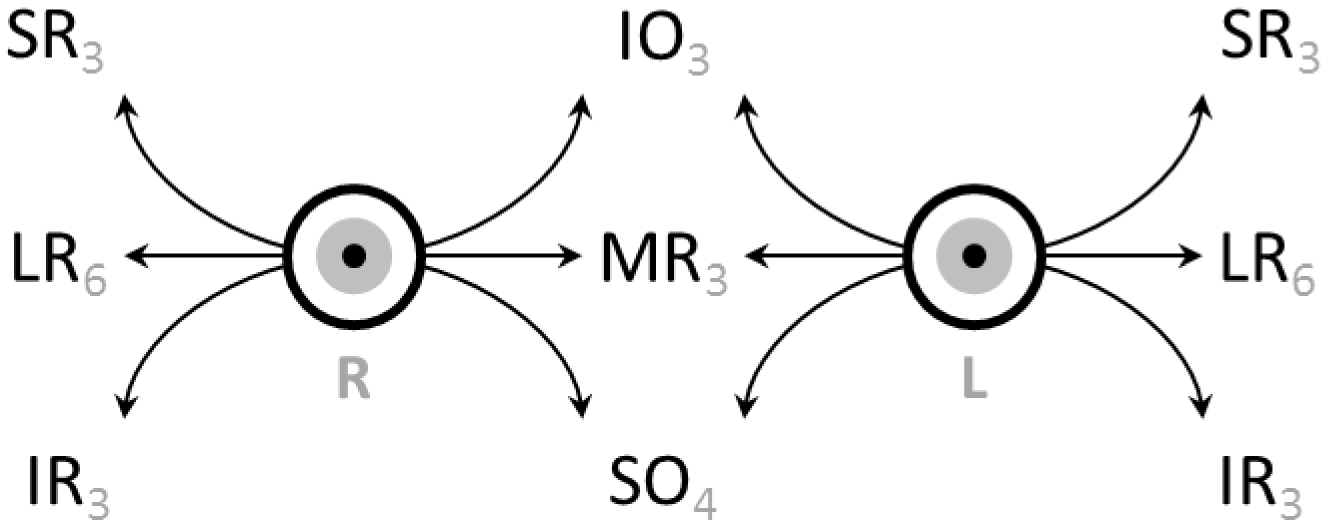
The movement of the eyeball is under the control of the extra ocular (extrinsic) eye muscles, which originate from the bones of the orbit and insert onto the outer surface of the white of the eye. These muscles are located inside the eye socket and cannot be seen on any part of the visible eyeball. If you have ever been to a doctor who held up a finger and asked you to follow it up, down, and to both sides, he or she is checking to make sure your eye muscles are acting in a coordinated pattern.



Muscles of the Eyes

(a) The extraocular eye muscles originate outside of the eye on the skull. (b) Each muscle inserts onto the eyeball.

Muscle	**Origin**	**Insertion**	**Action/Movement**	**Innervation**
Inferior rectus	Sphenoid around optic canal (Annulus of Zinn)	Inferior, medial surface of the eyeball	Eye looks down, depression.	Oculomotor nerve (N II)
Medial rectus	Sphenoid around optic canal (Annulus of Zinn)	Medial surface of eyeball	Eye looks medially, adduction	Oculomotor nerve (N II)
Superior rectus	Sphenoid around optic canal (Annulus of Zinn)	Superior, anterior surface of eyeball	Eye looks up, elevation	Oculomotor nerve (N II)
Lateral rectus	Sphenoid around optic canal (Annulus of Zinn)	Lateral, anterior surface of eyeball	Eye looks laterally, abduction	Abducens nerve (N VI)
Inferior oblique	Maxilla, anterior area of orbit	Inferior, lateral surface of eyeball	Eye rolls, looks up and laterally, excyclotorsion	Oculomotor nerve (N III)
Superior oblique	Sphenoid at optic canal	Superior, lateral surface of eyeball	Eye rolls, looks down and laterally, incyclotorsion	Trochlear nerve (N VI)
Levator palpebrae superioris	Sphenoid	Tarsal plate of upper eyelid	Elevates, retracts upper eyelid	Oculomotor nerve (N III)



Schematic demonstrating the actions and cranial nerve innervation (in subscript) of extraocular muscles.

Movement Coordination

Intermediate directions are controlled by simultaneous actions of multiple muscles. When one shifts the gaze horizontally, one eye will move laterally (toward the side) and the other will move medially (toward the midline). This may be neurally coordinated by the central nervous system, to make the eyes move together and almost involuntarily. This is a key factor in the study of strabismus, namely, the inability of the eyes to be directed to one point.

There are two main kinds of movement: conjugate movement (the eyes move in the same direction) and disjunctive (opposite directions). The former is typical when shifting gaze right or left, the latter is convergence of the two eyes on a near object. Disjunction can be performed voluntarily, but is usually triggered by the nearness of the target object. A "see-saw" movement, namely, one eye looking up and the other down, is possible, but not voluntarily; this effect is brought on by putting a prism in front of one eye, so the relevant image is apparently displaced. To avoid double vision from non-corresponding points, the eye with the prism must move up or down, following the image passing through the prism. Likewise conjugate torsion (rolling) on the anteroposterior axis (from the front to the back) can occur naturally, such as when one tips one's head to one shoulder; the torsion, in the opposite direction, keeps the image vertical.

The muscles show little inertia – a shutdown of one muscle is not due to checking of the antagonist, so the motion is not ballistic.

Eye Examination

The initial clinical examination of the extra-occular eye muscles is done by examining the movement of the globe of the eye through the six cardinal eye movements. When the eye is turned out (temporally) and horizontally, the function of the lateral rectus muscle is tested. When the eye is turned in (nasally) and horizontally, the function of the medial rectus muscle is being tested. When turning the eye down and in, the inferior rectus is contracting. When turning it up and in the superior rectus is contracting. Paradoxically, turning the eye up and out uses the inferior oblique muscle, and turning it down and out uses the superior oblique. All of these six movements can be tested by drawing a large "H" in the air with a finger or other object in front of a patient's face and having them follow the tip of the finger or object with their eyes without moving their head. Having them focus on the object as it is moved in toward their face in the midline will test convergence, or the eyes' ability to turn inward simultaneously to focus on a near object.

To evaluate for weakness or imbalance of the muscles, a penlight is shone directly on the corneas. Expected normal results of the corneal light reflex is when the penlight's reflection is located in the center of both corneas, equally.

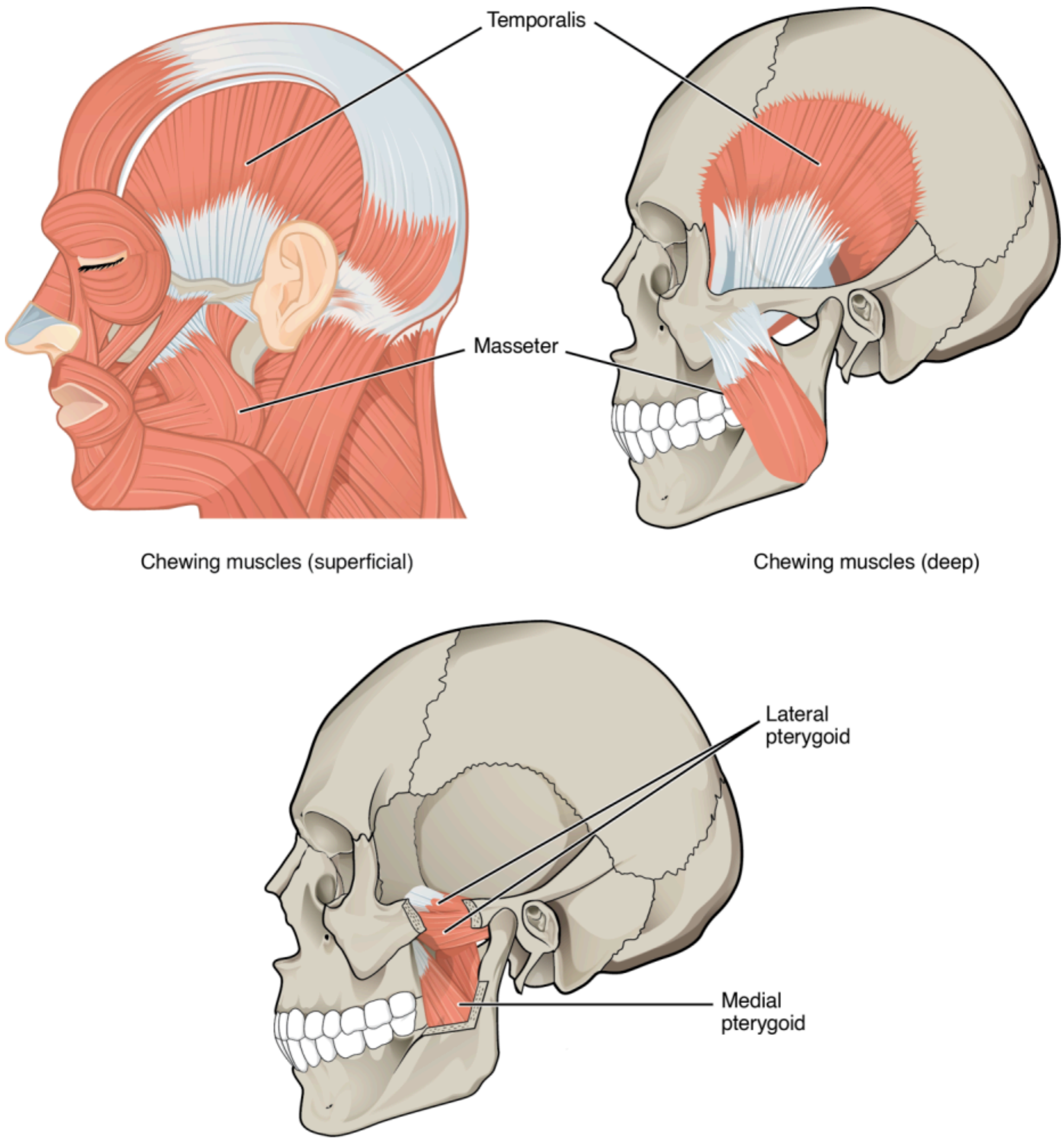
Extraocular muscles

In The Lab

1. Review the muscles of the eye in the images and tables provided
2. Examine the eye model and eye muscles charts provided in lab, locate each muscle (origin, insertion & innervation) and describe its action.
3. Review the movement and action of each eye muscle using your eyes and your lab partners.

Muscles That Move the Lower Jaw/ Mastication

In anatomical terminology, chewing is called mastication. Muscles involved in chewing must be able to exert enough pressure to bite through and then chew food before it is swallowed. The masseter muscle is the prime mover muscle for chewing because it elevates the mandible (lower jaw) to close the mouth, and it is assisted by the temporalis muscle, which retracts the mandible. You can feel the temporalis move by putting your fingers to your temple as you chew. The medial pterygoid and lateral pterygoid muscles provide assistance in chewing and moving food within the mouth by moving the mandible laterally and medially to grind food between the molars.



Muscles That Move the Lower Jaw

The muscles that move the lower jaw are typically located within the cheek and originate from processes in the skull. This provides the jaw muscles with the large amount of leverage needed for chewing.

Muscle	Origin	Insertion	Action	Innervation
Masseter	Zygomatic arch	Lateral surface of mandibular arch	Elevates mandible and closes jaw, aids chewing	Mandibular branch of Trigeminal nerve (N V)
Temporalis	Temporal lines of skull	Coronoid process of mandible	Elevates mandible, pulls lower jaw in under upper jaw	Mandibular branch of Trigeminal nerve (N V)
Medial pterygoid	Lateral pterygoid plate	Medial area of mandibular ramus	Elevates the mandible & closes jaw, pushes lower jaw out under upper jaw; moves lower jaw side-to-side	Mandibular branch of Trigeminal nerve (N V)
Lateral pterygoid	Lateral pterygoid plate	Medial area of mandibular ramus	Protrudes the mandible, opens jaw, pushes lower jaw out under upper jaw; moves lower jaw side-to-side	Mandibular branch of Trigeminal nerve (N V)

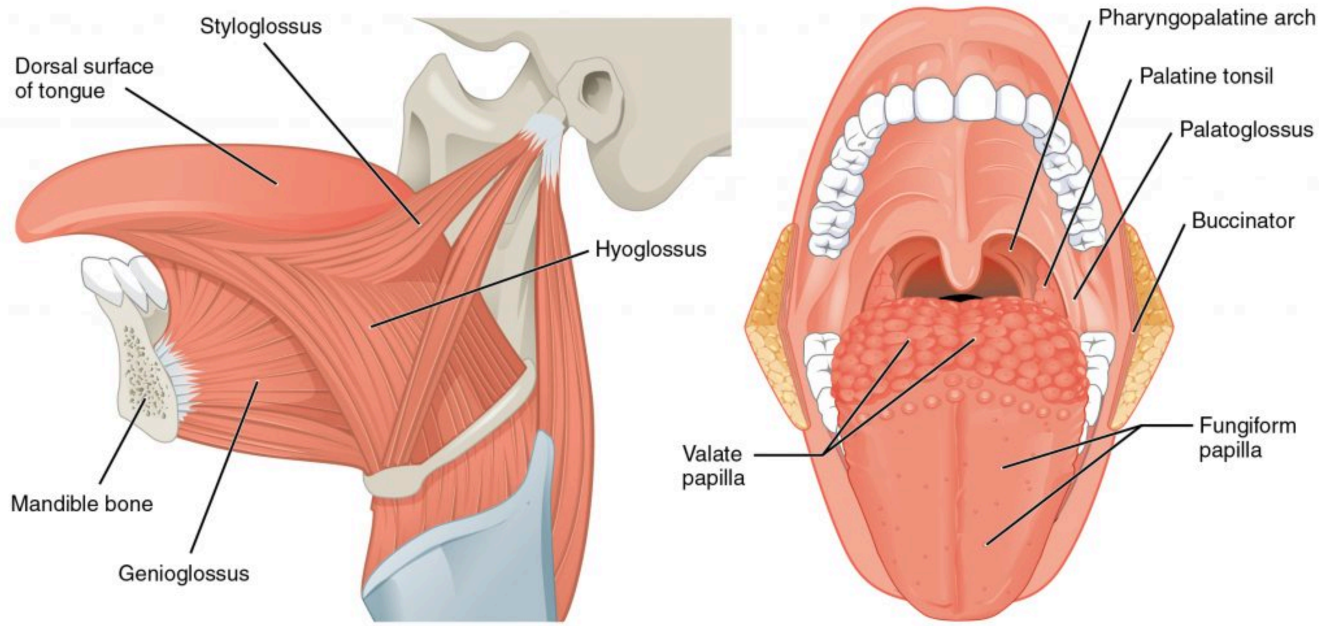
In The Lab

1. Review the muscles of mastication in the images and tables provided
2. Examine the model and muscles charts provided in lab, locate each muscle (origin, insertion & innervation) and describe its action.
3. Review the movement and action of each muscle using yours and your lab partners.

Muscles of the Tongue

Although the tongue is obviously important for tasting food, it is also necessary for mastication, **deglutition**(swallowing), and speech. Because of its mobility, the tongue facilitates complex speech patterns and sounds.Tongue muscles can be extrinsic or intrinsic. Extrinsic tongue muscles insert into the tongue from outside origins, and the intrinsic tongue muscles insert into the tongue from origins within it. The extrinsic muscles move the whole tongue in different directions, whereas the intrinsic muscles allow the tongue to change its shape (such as, curling the tongue in a loop or flattening it).

The extrinsic muscles all include the word root glossus (glossus = "tongue"), and the muscle names are derived from where the muscle originates. The genioglossus (genio = "chin") originates on the mandible and allows the tongue to move downward and forward. The styloglossus originates on the styloid process of the temporal bone, and allows upward and backward motion. The palatoglossus originates on the soft palate to elevate the back of the tongue, and the hyoglossus originates on the hyoid bone to move the tongue downward and flatten it.



(a) Extrinsic tongue muscles

(b) Palatoglossus and surface of tongue

Muscles that Move the Tongue

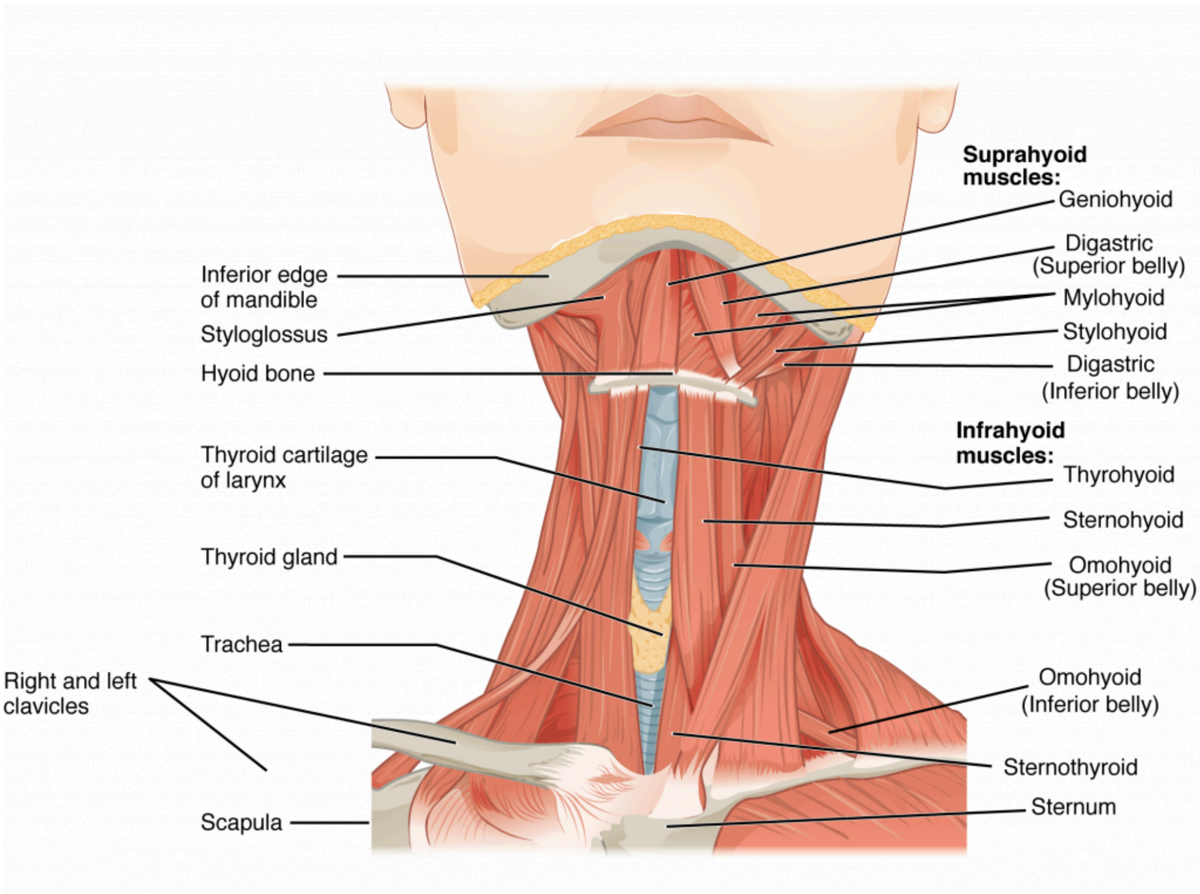
Muscle	Origin	Insertion	Action	Innervation
Genioglossus	Medial surface of mandible	Hyoid bone, body of tongue	Depresses & protracts tongue	Hypoglossal nerve (N XII)
Hyoglossus	Greater horn and body of hyoid bone	Side of tongue	Depresses & retracts tongue	Hypoglossal nerve (N XII)
Palatoglossus	Anterior surface of soft palate	Side of tongue	Elevates tongue, depresses soft palate	Internal branch of accessory nerve (N XI)
Styloglossus	Styloid process of temporal bone	Side to tip of tongue base	Retracts tongue, elevates side of tongue	Hypoglossal nerve (N XII)

Muscle of the Anterior Neck

The muscles of the anterior neck assist in deglutition (swallowing) and speech by controlling the positions of the larynx (voice box), and the hyoid bone, a horseshoe-shaped bone that functions as a foundation on which the tongue can move. The muscles of the neck are categorized according to their position relative to the hyoid bone. Suprahyoid muscles are superior to it, and the infrahyoid muscles are located inferiorly.

The suprahyoid muscles raise the hyoid bone, the floor of the mouth, and the larynx during deglutition. These include the digastric muscle, which has anterior and posterior bellies that work to elevate the hyoid bone and larynx when one swallows; it also depresses the mandible. The stylohyoid muscle moves the hyoid bone posteriorly, elevating the larynx, and the mylohyoid muscle lifts it and helps press the tongue to the top of the mouth. The geniohyoid depresses the mandible in addition to raising and pulling the hyoid bone anteriorly.

The strap-like infrahyoid muscles generally depress the hyoid bone and control the position of the larynx. The omohyoid muscle, which has superior and inferior bellies, depresses the hyoid bone in conjunction with the sternohyoid and thyrohyoid muscles. The thyrohyoid muscle also elevates the larynx's thyroid cartilage, whereas the sternothyroid depresses it.



Muscles of the Anterior Neck

The anterior muscles of the neck facilitate swallowing and speech. The suprahyoid muscles originate from above the hyoid bone in the chin region. The infrahyoid muscles originate below the hyoid bone in the lower neck.

Muscle	Origin	Insertion	Action	Innervation
Digastric	Mandible at chin and temporal bone	Hyoid bone	Depresses mandible / elevates larynx	Anterior belly: mandibular branch of Trigeminal nerve (N V) Posterior belly: Facial nerve (N VII)
Geniohyoid	Mandible medial surface	Hyoid bone	Depresses mandible / elevates larynx & pulls hyoid bone anteriorly	Spinal nerve C1 via Hypoglossal nerve (N XII)
Mylohyoid	Mandible	Hyoid bone; line of raphe	Elevates hyoid bone & floor of mouth. Depresses mandible	Mandibular branch of Trigeminal nerve (N V)
Omohyoid	Superior border of scapula	Hyoid bone	Depresses larynx & hyoid bone	Cervical spine nerves (C2-C3)
Sternohyoid	Clavicle & manubrium	Hyoid bone	Depresses larynx & hyoid bone	Cervical spine nerves (C1-C3)
Sternothyroid	Dorsal surface of manubrium & first costal cartilage	Thyroid cartilage of larynx	Depresses larynx & hyoid bone	Cervical spine nerves (C1-C3)
Stylohyoid	Temporal bone; styloid process	Hyoid bone	Elevates larynx	Facial nerve (N VII)
Thyrohyoid	Larynx; thyroid cartilage	Hyoid bone	Elevates thyroid, depresses hyoid bone	Spinal nerve C1- C2, via Hypoglossal nerve (N XII)
Sternocleidomastoid	Clavicular head; to sternal end of clavicle Sternal head; to manubrium	Mastoid area of skull & superior nuchal line	Rotates and tilts head to the side, tilts head forward	Accessory nerve (N XII) & cervical spinal nerves C2-C3)

Muscles of the Posterior Neck and Back

The posterior muscles of the neck are primarily concerned with head movements, like extension. The back muscles stabilize and move the vertebral column, and are grouped according to the lengths and direction of the fascicles.

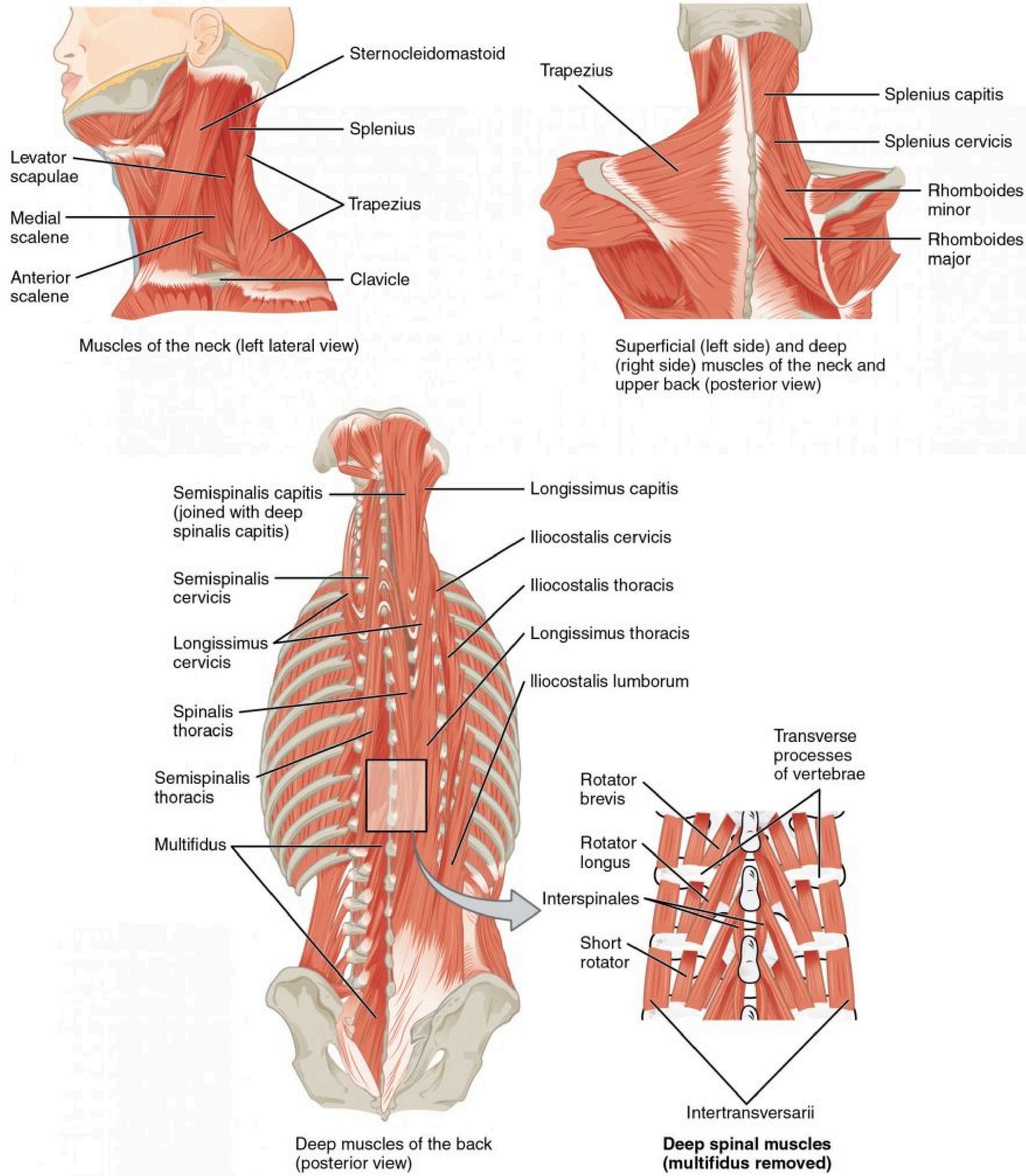
The splenius muscles originate at the midline and run laterally and superiorly to their insertions. From the sides and the back of the neck, the splenius capitis inserts onto the head region, and the splenius cervicis extends onto the cervical region. These muscles can extend the head, laterally flex it, and rotate it

The erector spinae group forms the majority of the muscle mass of the back and it is the primary extensor of the vertebral column. It controls extension, lateral flexion, and rotation of the vertebral column, and maintains the lumbar curve. The erector spinae comprises the iliocostalis (laterally placed) group, the longissimus (intermediately placed) group, and the spinalis (medially placed) group.

The iliocostalis group includes the iliocostalis cervicis, associated with the cervical region; the iliocostalis thoracis, associated with the thoracic region; and the iliocostalis lumborum, associated with the lumbar region. The three muscles of the longissimus group are the longissimus capitis, associated with the head region; the longissimus cervicis, associated with the cervical region; and the longissimus thoracis, associated with the thoracic region. The third group, the spinalis group, comprises the spinalis capitis (head region), the spinalis cervicis (cervical region), and the spinalis thoracis (thoracic region).

The transversospinales muscles run from the transverse processes to the spinous processes of the vertebrae. Similar to the erector spinae muscles, the semispinalis muscles in this group are named for the areas of the body with which they are associated. The semispinalis muscles include the semispinalis capitis, the semispinalis cervicis, and the semispinalis thoracis. The multifidus muscle of the lumbar region helps extend and laterally flex the vertebral column.

Important in the stabilization of the vertebral column is the segmental muscle group, which includes the interspinales and intertransversarii muscles. These muscles bring together the spinous and transverse processes of each consecutive vertebra. Finally, the scalene muscles work together to flex, laterally flex, and rotate the head. They also contribute to deep inhalation. The scalene muscles include the anterior scalene muscle (anterior to the middle scalene), the middle scalene muscle (the longest, intermediate between the anterior and posterior scalenes), and the posterior scalene muscle (the smallest, posterior to the middle scalene).



Muscles of the Neck and Back.

The large, complex muscles of the neck and back move the head, shoulders, and vertebral column.

In The Lab

1. Review the muscles of the tongue, anterior neck and back in the images and tables provided
2. Examine the model and muscles charts provided in lab, locate each muscle (origin, insertion & innervation) and practice & describe the action of each muscle.

Review

Muscles are either axial muscles or appendicular. The axial muscles are grouped based on location, function, or both. Some axial muscles cross over to the appendicular skeleton. The muscles of the head and neck are all axial. The muscles in the face create facial expression by inserting into the skin rather than onto bone. Muscles that move the eyeballs are extrinsic, meaning they originate outside of the eye and insert onto it. Tongue muscles are both extrinsic and intrinsic. The genioglossus depresses the tongue and moves it anteriorly; the styloglossus lifts the tongue and retracts it; the palatoglossus elevates the back of the tongue; and the hyoglossus depresses and flattens it. The muscles of the anterior neck facilitate swallowing and speech, stabilize the hyoid bone and position the larynx. The muscles of the neck stabilize and move the head. The sternocleidomastoid divides the neck into anterior and posterior triangles.

The muscles of the back and neck that move the vertebral column are complex, overlapping, and can be divided into five groups. The splenius group includes the splenius capitis and the splenius cervicis. The erector spinae has three subgroups. The iliocostalis group includes the iliocostalis cervicis, the iliocostalis thoracis, and the iliocostalis lumborum. The longissimus group includes the longissimus capitis, the longissimus cervicis, and the longissimus thoracis. The spinalis group includes the spinalis capitis, the spinalis cervicis, and the spinalis thoracis. The transversospinales include the semispinalis capitis, semispinalis cervicis, semispinalis thoracis, multifidus, and rotatores. The segmental muscles include the interspinales and intertransversarii. Finally, the scalenes include the anterior scalene, middle scalene, and posterior scalene.

In The Lab

1. Review the muscles of the head using table & figure provided on previous pages.
2. Examine and study the head model using the muscle chart provided in lab, locate each muscle (origin, insertion, action & innervation) and describe its action.
3. Find the approximate location of the muscles of facial expression on your own face and study & observe their action.
4. Explain the difference between axial and appendicular muscles.
5. Describe the muscles of the anterior neck.
6. Why are the muscles of the face different from typical skeletal muscle?

Muscles of the Abdominal Wall & Thorax

Objectives

4. Locate the muscles of the abdominal wall and thorax on laboratory charts and models.
5. Recognize on the models the origin, insertion, and action of the muscles of the abdominal wall and thorax.
6. Describe and demonstrate the action of the muscles of the abdominal wall and thorax.

It is a complex job to balance the body on two feet and walk upright. The muscles of the vertebral column, thorax, and abdominal wall extend, flex, and stabilize different parts of the body's trunk. The deep muscles of the body's core help maintain posture as well as provide stability for movement of the limbs.

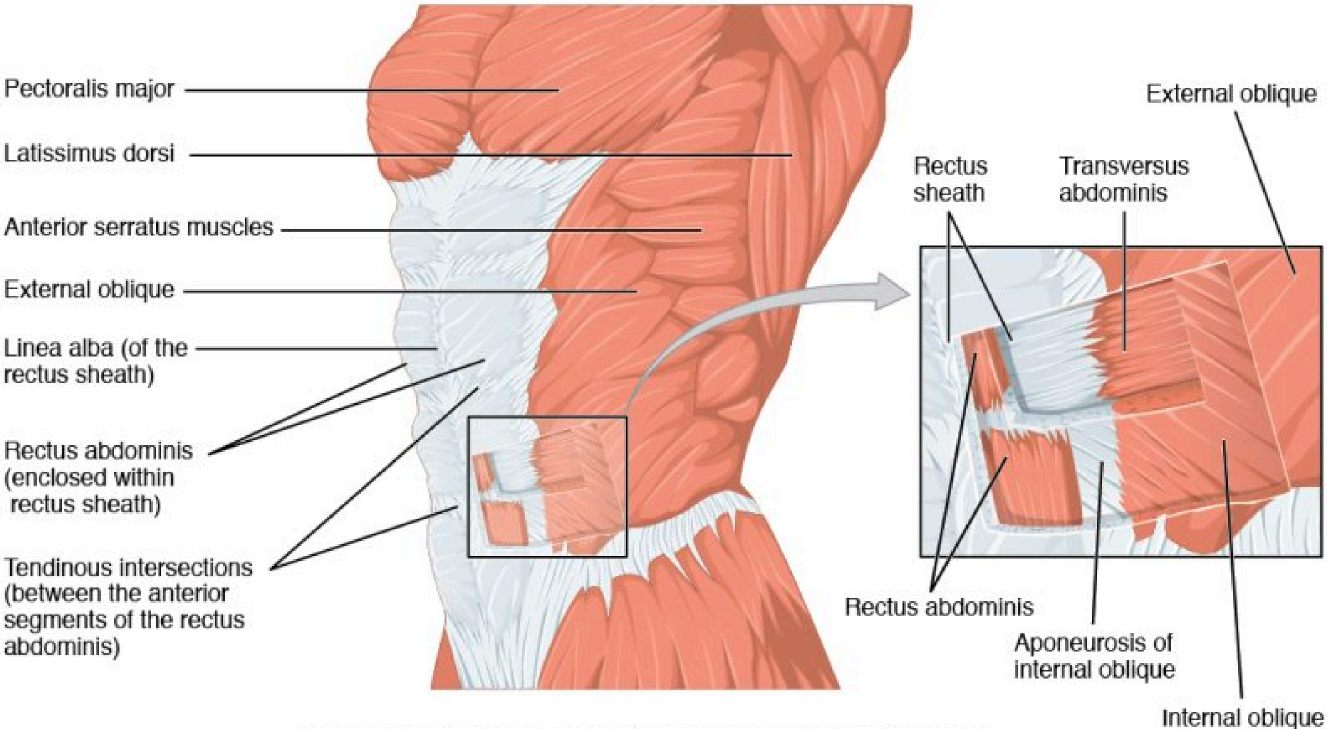
Muscles of the Abdomen

There are four pairs of abdominal muscles that make up the abdominal wall: the rectus abdominis, the external abdominal obliques, the internal abdominal obliques and the transverse abdominis.

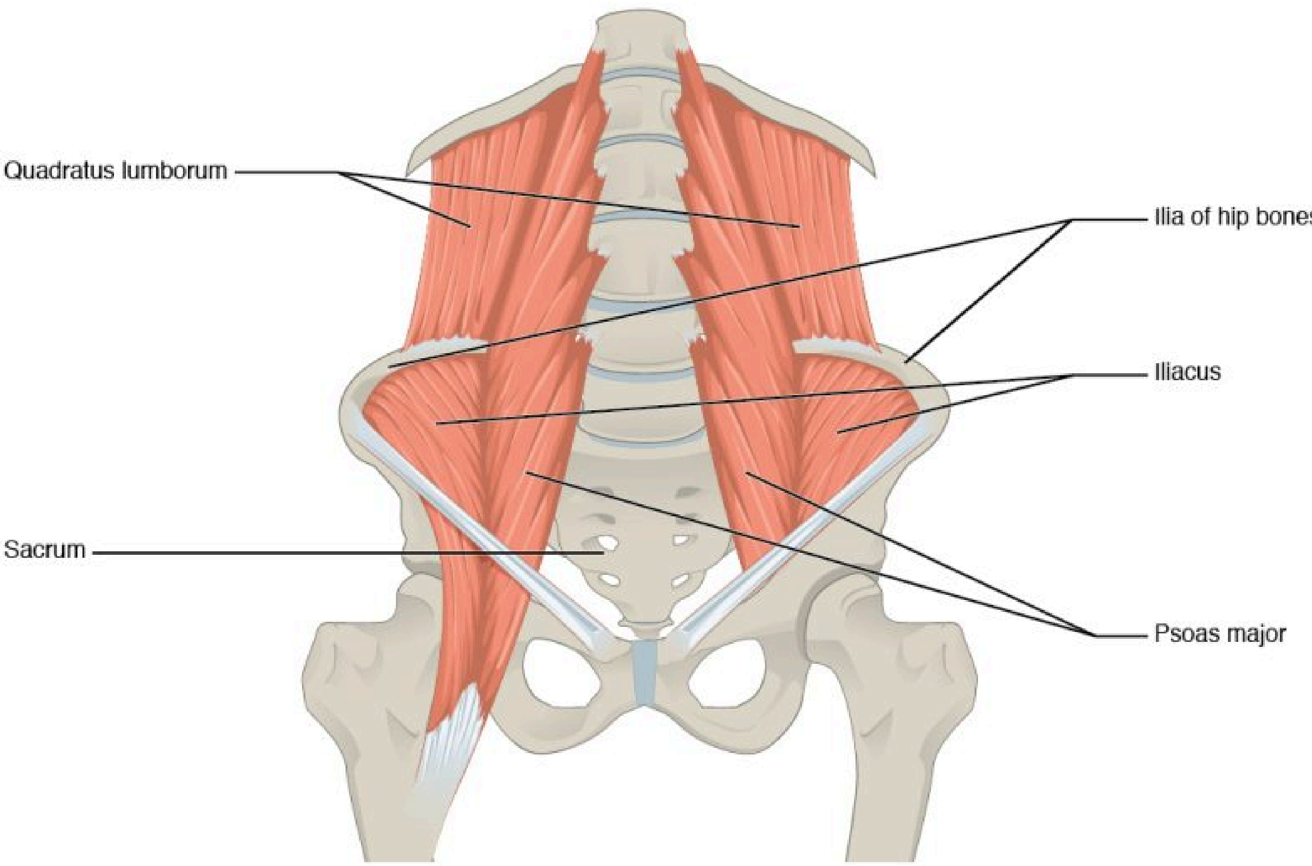
There are three flat skeletal muscles in the antero-lateral wall of the abdomen. The external oblique, closest to the surface, extend inferiorly and medially, in the direction of sliding one's four fingers into pants pockets. Perpendicular to it is the intermediate internal oblique, extending superiorly and medially, the direction the thumbs usually go when the other fingers are in the pants pocket. The deep muscle, the transverse abdominis, is arranged transversely around the abdomen, similar to a belt. This arrangement of three bands of muscles in different orientations allows various movements and rotations of the trunk. The three layers of muscle also help to protect the internal abdominal organs in an area where there is no bone.

The linea alba is a white, fibrous band that is made of the bilateral rectus sheaths that join at the anterior midline of the body. These enclose the rectus abdominis muscles that originate at the pubic crest and symphysis, and extend the length of the body's trunk. Each muscle is segmented by three transverse bands of collagen fibers called the tendinous intersections resulting in the look of "six-pack abs".

The posterior abdominal wall is formed by the lumbar vertebrae, parts of the ilia of the hip bones, psoas major and iliacus muscles, and quadratus lumborum muscle. This part of the core plays a key role in stabilizing the rest of the body and maintaining posture.



(a) Superficial and deep abdominal muscles (anterior lateral view)



(b) Posterior abdominal muscles (anterior view)

Muscles of the Abdomen

(a) The anterior abdominal muscles include the medially located rectus abdominis, which is covered by a sheet of connective tissue called the rectus sheath. On the flanks of the body, medial to the rectus abdominis, the abdominal wall is composed of three layers. The external oblique muscles form the superficial layer, while the internal oblique muscles form the middle layer, and the transverses abdominus forms the deepest layer.

b) The muscles of the lower back move the lumbar spine but also assist in femur movements.

Muscle	Origin	Insertion	Action	Innervation
External oblique	External & inferior borders of ribs 5-12	Iliac crest & Linea alba	Bends/flexes spine, compresses abdomen, depresses ribs	Ilioinguinal intercostal, iliohypogastric nerves
Internal oblique	Iliac crest, thoracolumbar fascia	Linea alba, xyphoid process, inferior ribs	Bends/flexes spine, compresses abdomen, depresses ribs	Ilioinguinal intercostal, iliohypogastric nerves
Transversus abdominis	Ribs 6-12 cartilages, thoracolumbar fascia, iliac crest	Pubis & linea alba	Compresses abdomen	Ilioinguinal intercostal, iliohypogastric nerves
Rectus abdominis	Pubis symphysis; superior surface	Ribs 5-7; inferior surfaces of costal cartilages & xiphoid process	Bends/flexes spine, compresses abdomen, depresses ribs	Intercostal nerves (T7-T12)
Quadratus lumborum	Iliolumbar ligament & iliac crest	Transverse processes of lumbar vertebrae & last rib	Depress ribs, laterally flexes vertebral column	Thoracic & lumbar spinal nerves

In The Lab

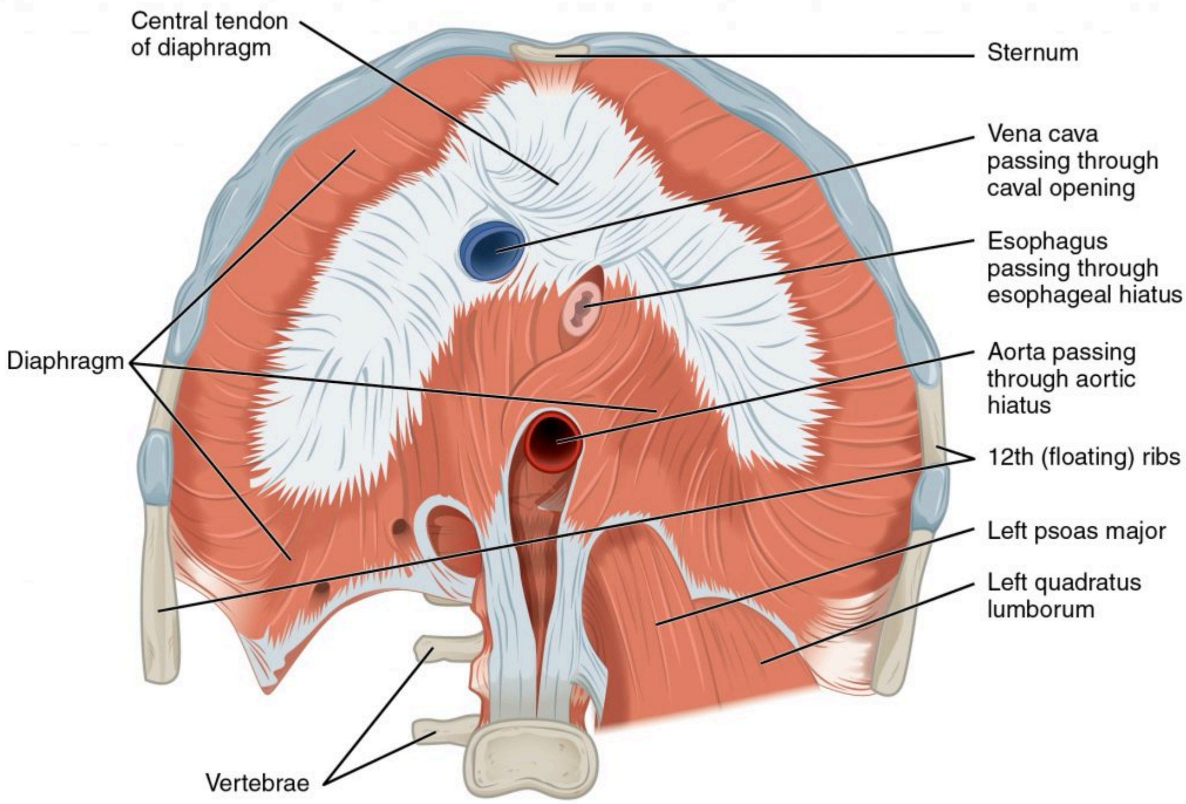
1. Review the muscles of the abdominal wall & thorax in the images and tables provided
2. Examine the model and muscles charts provided in lab, locate each muscle (origin, insertion & innervation) and describe its action.
3. Review the movement and action of each muscle with your lab partners.

Muscle of the Thorax

The muscles of the chest serve to facilitate breathing by changing the volume of the thoracic cavity. When you inhale your chest rises increasing the volume of the thoracic cavity. Alternately, when you exhale, your chest falls decreasing the volume of the thoracic cavity.

The Diaphragm

The change in volume of the thoracic cavity during breathing is due to the alternate contraction and relaxation of the diaphragm. It separates the thoracic and abdominal cavities, and is dome-shaped at rest. The superior surface of the diaphragm is convex, creating the elevated floor of the thoracic cavity. The inferior surface is concave, creating the curved roof of the abdominal cavity.



Diaphragm (inferior view)

Muscles of the Diaphragm

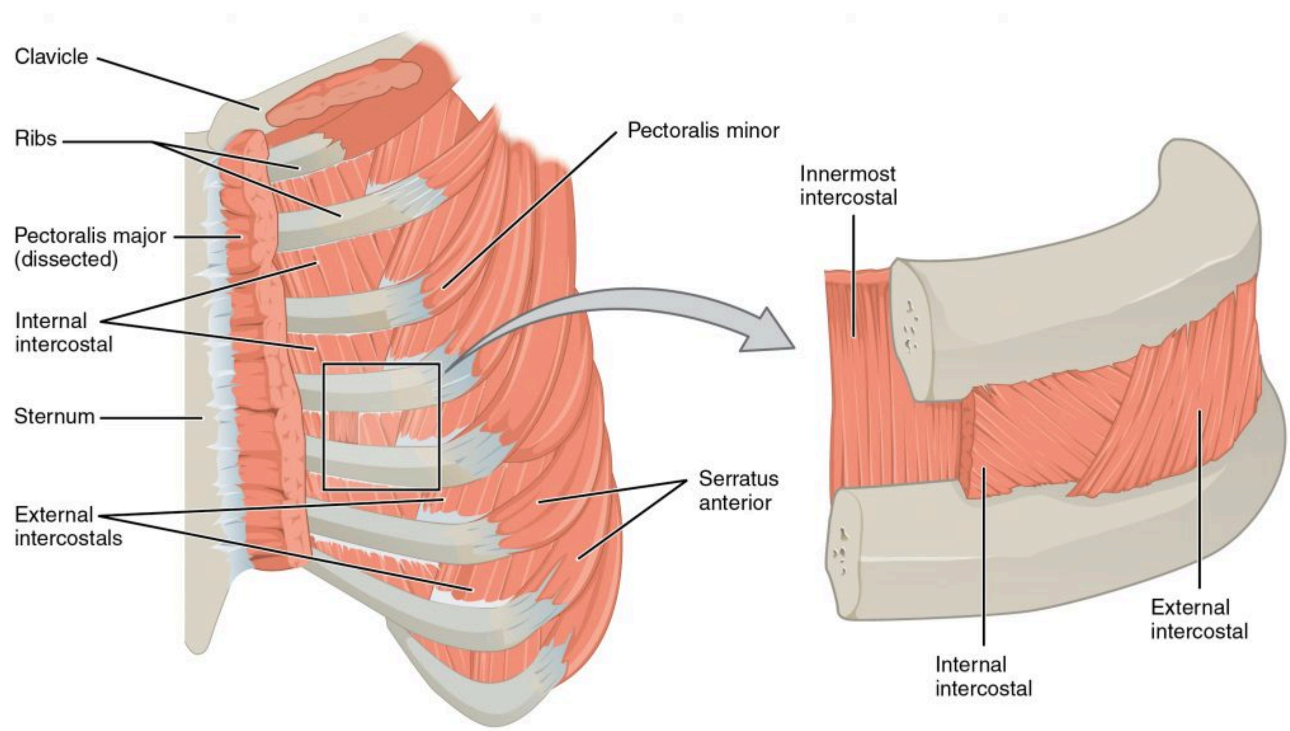
The diaphragm separates the thoracic and abdominal cavities. Defecating, urination, and even childbirth involve cooperation between the diaphragm and abdominal muscles (this cooperation is referred to as the "Valsalva maneuver"). While you hold your breath the diaphragm and abdominal muscles contract increasing the pressure of the peritoneal cavity and stabilizing the core. When the abdominal muscles contract, the pressure cannot push the diaphragm up, so it increases pressure on the intestinal tract (defecation), urinary tract (urination), or reproductive tract (childbirth).

The inferior surface of the pericardial sac and the inferior surfaces of the pleural membranes (parietal pleura) fuse onto the central tendon of the diaphragm. To the sides of the tendon are the skeletal muscle portions of the diaphragm, which insert into the tendon while having a number of origins including the xiphoid process of the sternum anteriorly, the inferior six ribs and their cartilages laterally, and the lumbar vertebrae and 12th ribs posteriorly.

The diaphragm also includes three openings for the passage of structures between the thorax and the abdomen. The inferior vena cava passes through the caval opening, and the esophagus and attached nerves pass through the esophageal hiatus. The aorta, thoracic duct, and azygous vein pass through the aortic hiatus of the posterior diaphragm.

Intercostal Muscles

There are three sets of muscles, called intercostal muscles, which span each of the intercostal spaces. The principal role of the intercostal muscles is to assist in breathing by changing the dimensions of the rib cage. The 11 pairs of superficial external intercostal muscles aid in inspiration of air during breathing because when they contract, they raise the rib cage, which expands it. The 11 pairs of internal intercostal muscles, just under the externals, are used for expiration because they draw the ribs together to constrict the rib cage. The innermost intercostal muscles are the deepest, and they act as synergists for the action of the internal intercostals.



Intercostal Muscles.

The external intercostals are located laterally on the sides of the body. The internal intercostals are located medially near the sternum. The innermost intercostals are located deep to both the internal and external intercostals.

Muscle	Origin	Insertion	Action	Innervation
Diaphragm	Cartilages of ribs 4-10, anterior surfaces of lumbar vertebrae & xyphoid process	Central tendinous sheet	Contracts to expand thoracic cavity	Phrenic nerve (C3-C5)
External intercostals	Inferior border of each rib/ intercostal muscle	Superior border of each rib/ intercostal muscle	Elevates ribs/ Elevation (expands thoracic cavity)	Intercostal nerves/branches of thoracic nerves
Internal intercostals	Superior border of each rib/ intercostal muscles	Inferior border of each rib/ intercostal muscle	Depress ribs, Movement along superior/inferior axis to bring ribs closer together	Intercostal nerves/branches of thoracic nerves
Transversus thoracis	Sternum/posterior surface	Rib cartilages	Depress ribs	Intercostal nerves/branches of thoracic nerves

In The Lab

1. Review the muscles of the thorax in the images and tables provided
2. Examine the model and muscles charts provided in lab, locate each muscle (origin, insertion & innervation) and describe its action.
3. Review the movement and action of each muscle with your lab partners.

Appendicular Muscles: Pectoral Girdle & Upper Limb

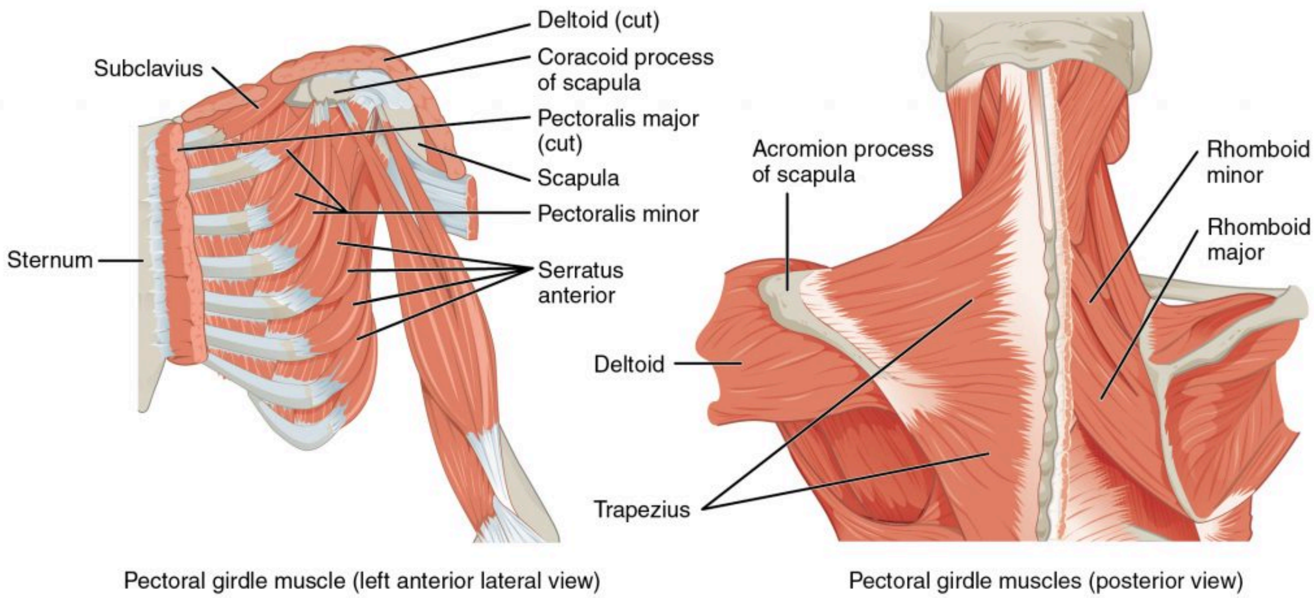
Objectives

7. Locate the muscles of the pectoral girdle & upper limb on laboratory charts and models.
8. Recognize on the models the origin, insertion, and action of the muscles of the pectoral girdle & upper limb.
9. Describe and demonstrate the action of the muscles of the pectoral girdle & upper limb.

Muscles of the shoulder and upper limb can be divided into four groups: muscles that stabilize and position the pectoral girdle, muscles that move the arm, muscles that move the forearm, and muscles that move the wrists, hands, and fingers.

Muscles That Position the Pectoral Girdle

The pectoral girdle, or shoulder girdle, consists of the lateral ends of the clavicle and scapula, along with the proximal end of the humerus, and the muscles covering these three bones to stabilize the shoulder joint. The girdle creates a base from which the head of the humerus, in its ball-and-socket joint with the glenoid fossa of the scapula, can move the arm in multiple directions. Muscles that position the pectoral girdle are located either on the anterior thorax or on the posterior thorax. The anterior muscles include the subclavius, pectoralis minor, and serratus anterior. The posterior muscles include the trapezius, rhomboid major, and rhomboid minor. When the rhomboids are contracted, your scapula moves medially, which can pull the shoulder and upper limb posteriorly.



Muscles That Position the Pectoral Girdle.

The muscles that stabilize the pectoral girdle make it a steady base on which other muscles can move the arm. Note that the pectoralis major and deltoid, which move the humerus, are cut here to show the deeper positioning muscles.

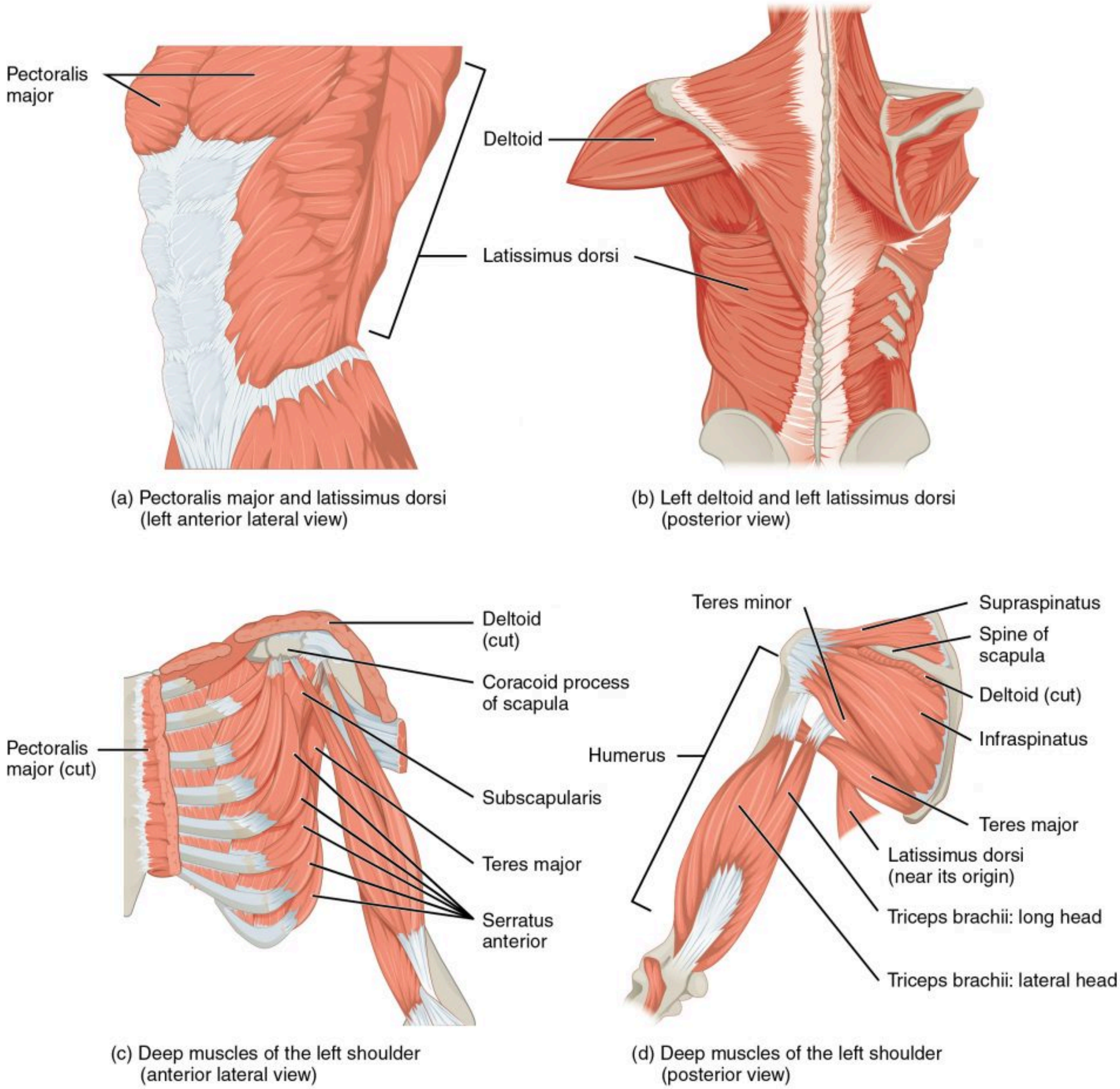
Muscles	**Origin**	**Insertion**	**Action**	**Innervation**
Serratus anterior	Superior & anterior margins of ribs 1-8/9	Anterior surface of vertebral border of scapula	Rotates scapula for glenoid cavity to move upward, protracts shoulder	Long thoracic nerve (C 5-7)
Subclavius	Rib #1	Inferior border of clavicle	Protracts & depresses shoulder	Subclavius nerve (C 5-6)
Trapezius	Spinous process of thoracic vertebrae, ligament nuchae, occipital bone	Scapular spine and acromion, clavicle	Extend neck Elevate, retract, depress, rotate scapula, Elevate clavicle	Accessory Nerve (N XI) Cervical spinal nerves (C 3-4)
Pectoralis minor	Superior & anterior surface of rubs 3-5	Scapula; coracoid process	Protracts/elevates shoulder Rotates scapula to allow glenoid cavity to rotate downward	Medial pectoral nerve (C 8 ,T 1)
Rhomboid major	Spinous process of superior thoracic vertebrae	Scapula;vertebral border, from spine to inferior angle	Adducts scapula Downward rotation of scapula	Dorsal scapular nerve C 5
Rhomboid minor	Spinous process of vertebrae C 7 – T 1	Scapula;vertebral border	Adducts scapula Downward rotation of scapula	Dorsal scapular nerve C
Levator scapulae	Cervical vertebrae 1-4 (transverse processes)`	Scapula; vertebral border	Elevates scapula	Cervical nerves C 3 – 4 & dorsal scapular nerve; C 5

In The Lab

4. Review the muscles of the pectoral girdle in the images and tables provided
5. Examine the model and muscles charts provided in lab, locate each muscle (origin, insertion & innervation) and describe its action.
6. Review the movement and action of each muscle with your lab partners

Muscles That Move the Humerus

Similar to the muscles that position the pectoral girdle, muscles that cross the shoulder joint and move the humerus bone of the arm include both axial and scapular muscles. The two axial muscles are the pectoralis major and the latissimus dorsi. The pectoralis major is thick and fan-shaped, covering much of the superior portion of the anterior thorax. The broad, triangular latissimus dorsi is located on the inferior part of the back and has multiple points of origin including the lumbosacral fascia attached to the inferior 6 thoracic vertebrae, the inferior 3 ribs, the iliac crest and inferior angle of the scapula.



Muscles That Move the Humerus

(a, c) The muscles that move the humerus anteriorly are generally located on the anterior side of the body and originate from the sternum (e.g., pectoralis major) or the anterior side of the scapula (e.g., subscapularis). (b) The muscles that move the humerus superiorly generally originate from the superior surfaces of the scapula and/or the clavicle (e.g., deltoids). (c) The muscles that move the humerus inferiorly generally originate from middle or lower back (e.g., latissiumus dorsi). (d) The muscles that move the humerus posteriorly are generally located on the posterior side of the body and insert into the scapula (e.g., infraspinatus).

Axial muscles

Muscle	Origin	Insertion	Action	Innervation
Pectoralis major	Clavicle; sternum; cartilage of certain ribs (1-6 or 1-7); aponeurosis of external oblique muscle	Greater tubercle of humerus	Adducts and medially rotates the arm	Lateral and medial pectoral nerve
Latissimus dorsi	Thoracic vertebrae (T17-T12); lumbar vertebrae; lower ribs (9-12); iliac crest	Intertubercular sulcus of humerus	Adducts the arm; Rotates the arm medially at the shoulder	Thoracodorsal nerve (C6-C8)

Scapular muscles

Muscle	Origin	Insertion	Action	Innervation
Deltoid	Trapezius; clavicle; acromion; spine of scapula	Nasal bone	Abducts the arm	Axillary nerve
Subscapularis	Subscapular fossa of scapula	Lesser tubercle of humerus	Medially rotates the arm; stabilizes shoulder joint during movement of the pectoral girdle	Upper and lower subscapular nerves
Supraspinatus	Supraspinous fossa of scapula	Greater tubercle of humerus	Abducts the arm; stabilizes shoulder joint	Suprascapular nerve
Infraspinatus	Infraspinous fossa of scapula	Greater tubercle of humerus	Rotates elbow laterally, as during a tennis swing	Suprascapular nerve
Teres major	Posterior surface of scapula	Intertubercular sulcus of humerus	Extends, medially rotates and adducts arm	Lower subscapular nerve
Teres minor	Lateral border of dorsal scapular surface	Greater tubercle of humerus	Rotates elbow laterally	Lower and upper subscapular nerve
Coracobra chialis	Coracoid process of scapula	Medial surface of humerus shaft	Flexes and adducts arm	Musculocutaneuous nerve

The rest of the shoulder muscles originate on the scapula and help to move the arm. The deltoid is the major abductor of the arm but also facilitates flexing and medial rotation, as well as extension and lateral rotation. The subscapularis originates on subscapular fossa and medially rotates the arm. Named for their locations, the supraspinatus (originating from the supraspinous fossa) and the infraspinatus (originating from the infraspinous fossa) abduct the arm, and laterally rotate the arm, respectively. The thick and flat teres major is inferior to the teres minor and extends the arm, and assists in its adduction and medial rotation. The long teres minor laterally rotates the arm. Finally, the coracobrachialis flexes and adducts the arm.

The tendons of the subscapularis, supraspinatus, infraspinatus, and teres minor connect the scapula to the humerus, forming the rotator cuff (musculotendinous cuff), the circle of tendons around the shoulder joint. Although the shoulder joint allows a great deal of freedom of movement due to the shallow glenoid cavity it is extremely vulnerable to downward dislocation. The muscles and tendons of the rotator cuff provide stability to the joint. When baseball pitchers undergo shoulder surgery it is usually on the rotator cuff, which becomes pinched and inflamed, and may tear away from the bone due to the repetitive motion of bringing the arm overhead to throw a fast pitch.

Movements

- Flexion and extension of the shoulder joint in the (sagittal plane).
- Flexion is carried out by the anterior fibres of the deltoid, pectoralis major and the coracobrachialis.
- Extension is carried out by the latissimus dorsi and posterior fibres of the deltoid.

- Abduction and adduction of the shoulder (frontal plane).
- Abduction is carried out by the deltoid and the supraspinatus in the first 90 degrees.
- From 90-180 degrees it is the trapezius and the serratus anterior.
- Adduction is carried out by the pectoralis major, lattisimus dorsi, teres major and the subscapularis.

- Horizontal abduction and horizontal adduction of the shoulder (transverse plane)
- Medial and lateral rotation of shoulder (also known as internal and external rotation).
- Medial rotation is carried out by the anterior fibres of the deltoid, teres major, subscapularis, pectoralis major and the lattissimus dorsi.
- Lateral rotation is carried out by the posterior fibres of the deltoid, infraspinatus and the teres minor.

- Circumduction of the shoulder (a combination of flexion/extension and abduction/adduction).

Shoulder joint

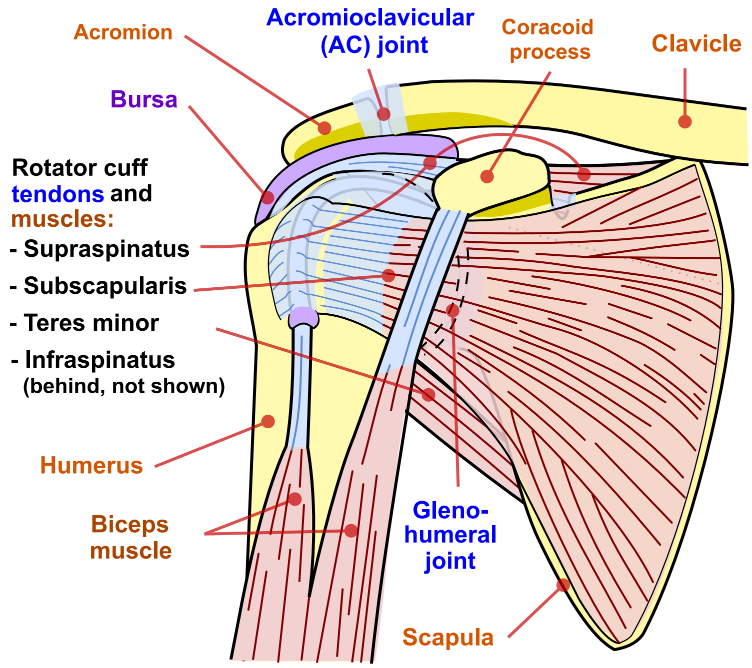
Clinical Significance

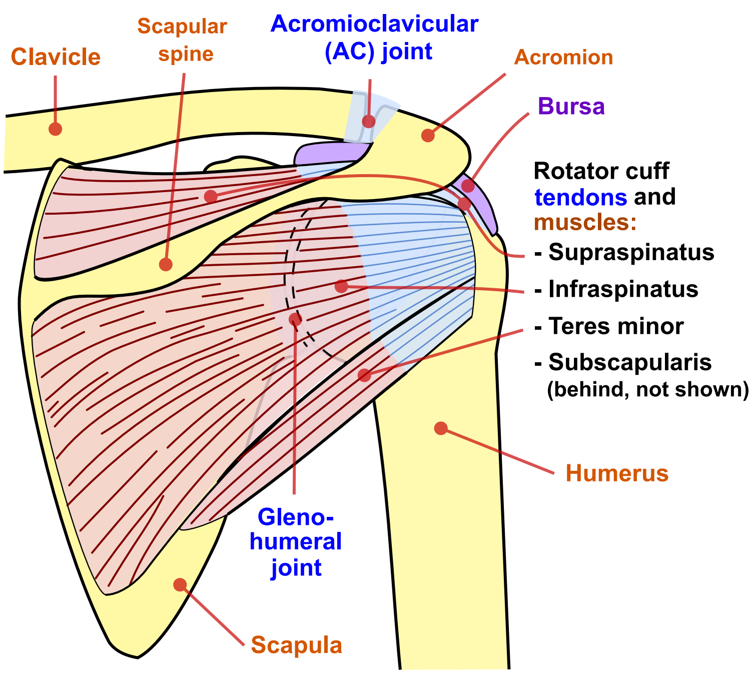
The capsule can become inflamed and stiff, with abnormal bands of tissue (adhesions) growing between the joint surfaces, causing pain and restricting movement of the shoulder, a condition known as frozen shoulder or adhesive capsulitis.

A SLAP tear (superior labrum anterior to posterior) is a rupture in the glenoid labrum. SLAP tears are characterized by shoulder pain in specific positions, pain associated with overhead activities such as tennis or overhand throwing sports, and weakness of the shoulder. This type of injury often requires surgical repair.

Anterior dislocation of the glenohumeral joint occurs when the humeral head is displaced in the anterior direction. Anterior shoulder dislocation often is a result of a blow to the shoulder while the arm is in an abducted position. In younger people, these dislocation events are most commonly associated with fractures on the humerus and/or glenoid and can lead to recurrent instability. In older people, recurrent instability is rare but people often suffer rotator cuff tears.[citation needed] It is not uncommon for the arteries and nerves (axillary nerve) in the axillary region to be damaged as a result of a shoulder dislocation; which if left untreated can result in weakness, muscle atrophy, or paralysis.

Subacromial bursitis is a painful condition caused by inflammation which often presents a set of symptoms known as subacromial impingement.

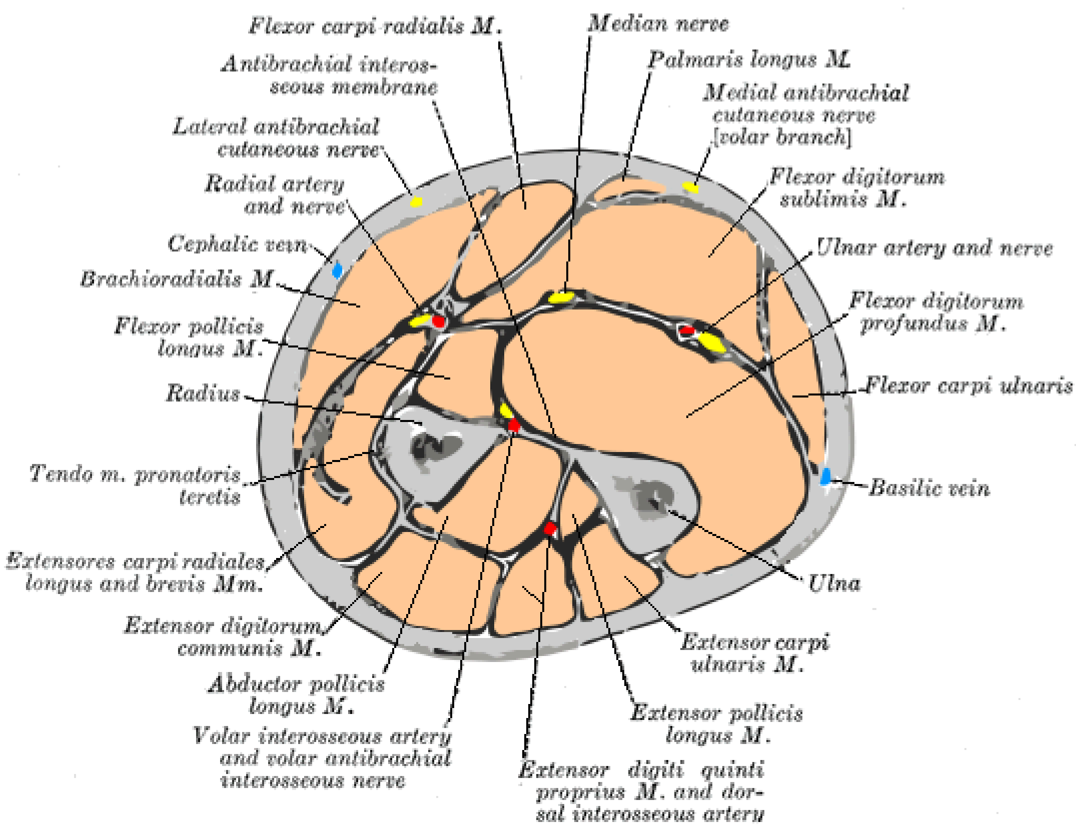




Muscles of the Forearm

The forearm, made of the radius and ulna bones, has four main types of action at the hinge of the elbow joint: flexion, extension, pronation, and supination. When the forearm faces anteriorly, it is supinated. When the forearm faces posteriorly, it is pronated. The forearm flexors include the biceps brachii, brachialis, and brachioradialis. The extensors are the triceps brachii and anconeus. The pronators are the pronator teres and the pronator quadratus, and the supinator turns the forearm anteriorly.

The biceps brachii, brachialis, and brachioradialis flex the forearm. The two-headed biceps brachii crosses the shoulder and elbow joints to flex the forearm, also taking part in supinating the forearm at the radioulnar joints and flexing the arm at the shoulder joint. Deep to the biceps brachii, the brachial is a synergist in forearm flexion. Finally, the brachioradialis can flex the forearm quickly or help lift a load slowly. These muscles and their associated blood vessels and nerves form the anterior compartment of the arm (anterior flexor compartment of the arm)



Anterior muscles (flexion)

Muscle	Origin	Insertion	Action	Innervation
Biceps brachii	Coracoid process; tubercle above glenoid cavity	Radial tuberosity	Flexes and supinates forearm	Musculocutaneous nerve
Brachialis	Front of distal humerus	Coronoid process of ulna	Flexes the elbow	Musculocutaneous nerve; radial nerve
Brachioradialis	Lateral supracondylar ridge at distal end of humerus	Base of styloid process of radius	Flexes the forearm	Radial nerve

Posterior muscles (extension)

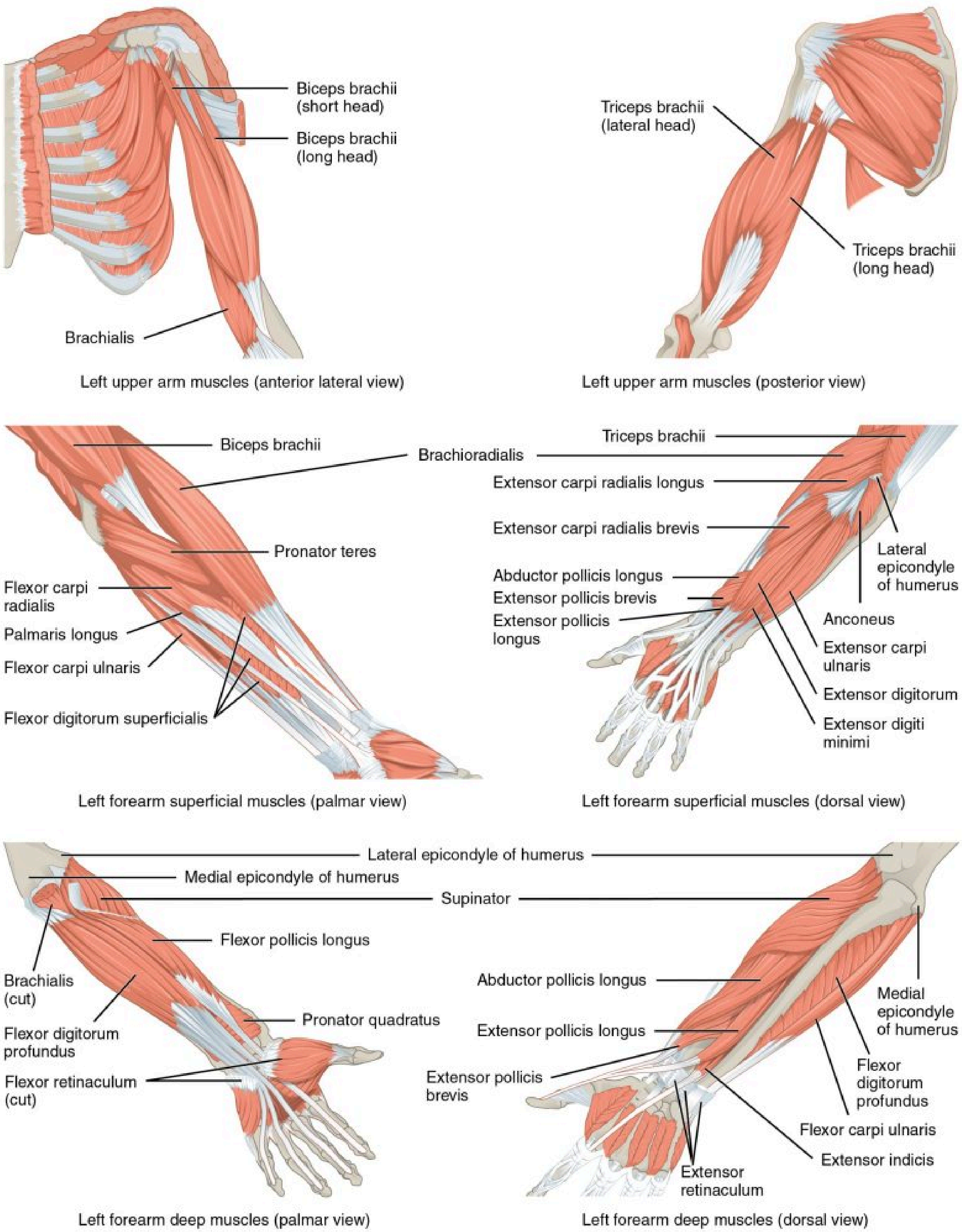
Muscle	Origin	Insertion	Action	Innervation
Triceps brachii	Infraglenoid tubercle of scapula; posterior shaft of humerus; posterior humeral shaft distal to radial groove	Olecranon process of ulna	Extends the forearm	Radial nerve
Anconeus	Lateral epicondyle of humerus	Lateral aspect of olecranon process of ulna	Extends elbow	Radial nerve

Anterior muscles (pronation)

Muscle	Origin	Insertion	Action	Innervation
Pronator teres	Medial epicondyle of humerus; coronoid process of ulna	Lateral radius	Pronates forearm	Median nerve
Pronator quadratus	Distal portion of anterior ulnar shaft	Distal surface of anterior radius	Assists in pronation forearm	Median nerve

Posterior muscles (supination)

Muscle	Origin	Insertion	Action	Innervation
Supinator	Lateral epicondyle of humerus; proximal ulna	Proximal end of radius	Supinates forearm	Posterior interosseous nerve



Left upper arm muscles (anterior lateral view)

Left upper arm muscles (posterior view)

Left forearm superficial muscles (palmar view)

Left forearm superficial muscles (dorsal view)

Left forearm deep muscles (palmar view)

Left forearm deep muscles (dorsal view)

Muscles That Move the Forearm

The muscles originating in the upper arm flex, extend, pronate, and supinate the forearm. The muscles originating in the forearm move the wrists, hands, and fingers.

Muscles that Move the Hand, Wrist & Fingers

Wrist, hand, and finger movements are facilitated by two groups of muscles. The forearm is the origin of the extrinsic muscles of the hand. The palm is the origin of the intrinsic muscles of the hand.

Extrinsic Muscles of the Hand

The muscles in the anterior compartment of the forearm (anterior flexor compartment of the forearm) originate on the humerus and insert onto different parts of the hand. These make up the bulk of the forearm. From lateral to medial, the superficial anterior compartment of the forearm includes the flexor carpi radialis, palmaris longus, flexor carpi ulnaris, and flexor digitorum superficialis. The flexor digitorum superficialis flexes the hand as well as the digits at the knuckles, which allows for rapid finger movements, as in typing or playing a musical instrument. However, repetitive movement with poor ergonomics can irritate the tendons of these muscles as they slide back and forth with the carpal tunnel of the anterior wrist and pinch the median nerve, which also travels through the tunnel, causing Carpal Tunnel Syndrome. The deep anterior compartment produces flexion and bends fingers to make a fist. These are the flexor pollicis longus and the flexor digitorum profundus.

The muscles in the superficial posterior compartment of the forearm (superficial posterior extensor compartment of the forearm) originate on the humerus. These are the extensor radialis longus, extensor carpi radialis brevis, extensor digitorum, extensor digiti minimi, and the extensor carpi ulnaris.

The muscles of the deep posterior compartment of the forearm originate on the radius and ulna. These include the abductor pollicis longus, extensor pollicis brevis, extensor pollicis longus, and extensor indicis.

The tendons of the forearm muscles attach to the wrist and extend into the hand. Fibrous bands called retinacula sheath the tendons at the wrist. The flexor retinaculum extends over the palmar surface of the hand while the extensor retinaculum extends over the dorsal surface of the hand.

Superficial anterior compartment of forearm

Muscle	Origin	Insertion	Action	Innervation
Flexor carpi radialis	Medial epicondyle of humerus	Base of second and third metacarpals	Flexes and abducts the hand	Median nerve
Palmaris longus	Medial epicondyle of humerus	Palmar aponeurosis; skin and fascia of palm	Tenses skin and fascia of palm. Aids in flexion of wrist and elbow	Median nerve
Flexor carpi ulnaris	Medial epicondyle of humerus; olecranon process; posterior surface of ulna	Pisiform, hamate bones, and base of fifth metacarpal	Flexes and abducts the hand	Ulnar nerve
Flexor digitorum superficialis	Medial epicondyle of humerus; coronoid process of ulna; shaft of radius	Middle phalanges of fingers 2-5	Flexes wrist and middle phalanges of second to fifth fingers	Median nerve

Deep anterior compartment of forearm

Muscle	Origin	Insertion	Action	Innervation
Flexor pollicis longus	Anterior surface of radius; interosseous membrane	Distal phalanx of thumb	Flexes distal phalanx of thumb	Median nerve
Anconeus	Coronoid process; anteromedial surface of ulna; interosseous membrane	Distal phalanges of fingers 2-5	Flexes distal interphalangeal joints	Median nerve; ulner nerve

Superficial posterior compartment of forearm

Muscle	Origin	Insertion	Action	Innervation
Extensor carpi radialis longus	Lateral supracondylar ridge of humerus	Base of second metacarpal	Extends and abducts the hand	Radial nerve
Extensor carpi radialis brevis	Lateral epicondyle of humerus	Base of third metacarpal	Extends and abducts the hand	Posterior interosseus nerve
Extensor digitorum	Lateral epicondyle of humerus	Extensor expansions; distal phalanges of fingers	Extends the hand and abducts the finger	Posterior interosseus nerve
Extensor digiti minimi	Lateral epicondyle of humerus	Extensor expansion; distal phalanx of finger 5	Extends little finger	Posterior interosseus nerve
Extensor carpi ulnaris	Lateral epicondyle of humerus; posterior border of ulna	Base of fifth metacarpal	Extends and abducts the hand	Posterior interosseus nerve

Deep posterior compartment of forearm

Muscle	Origin	Insertion	Action	Innervation
Abductor pollicis longus	Posterior surface of radius and ulna; interosseous membrane	Base of first metacarpal; trapezium	Abducts and extends the thumb	Posterior interosseus nerve
Abductor pollicis longus	Dorsal shaft of radius and ulna; interosseous membrane	Base of proximal phalanx of thumb	Extends thumb	Posterior interosseus nerve
Abductor pollicis longus	Dorsal shaft of radius and ulna; interosseous membrane	Base of distal phalanx of thumb	Extends thumb	Posterior interosseus nerve
Extensor indicis	Posterior surface of distal ulna; interosseous membrane	Tendon of extensor digitorum of index finger	Extends index finger; aids in extending the wrist	Posterior interosseus nerve

Muscles That Move the Wrist, Hands, and Forearm

Intrinsic Muscles of the Hand

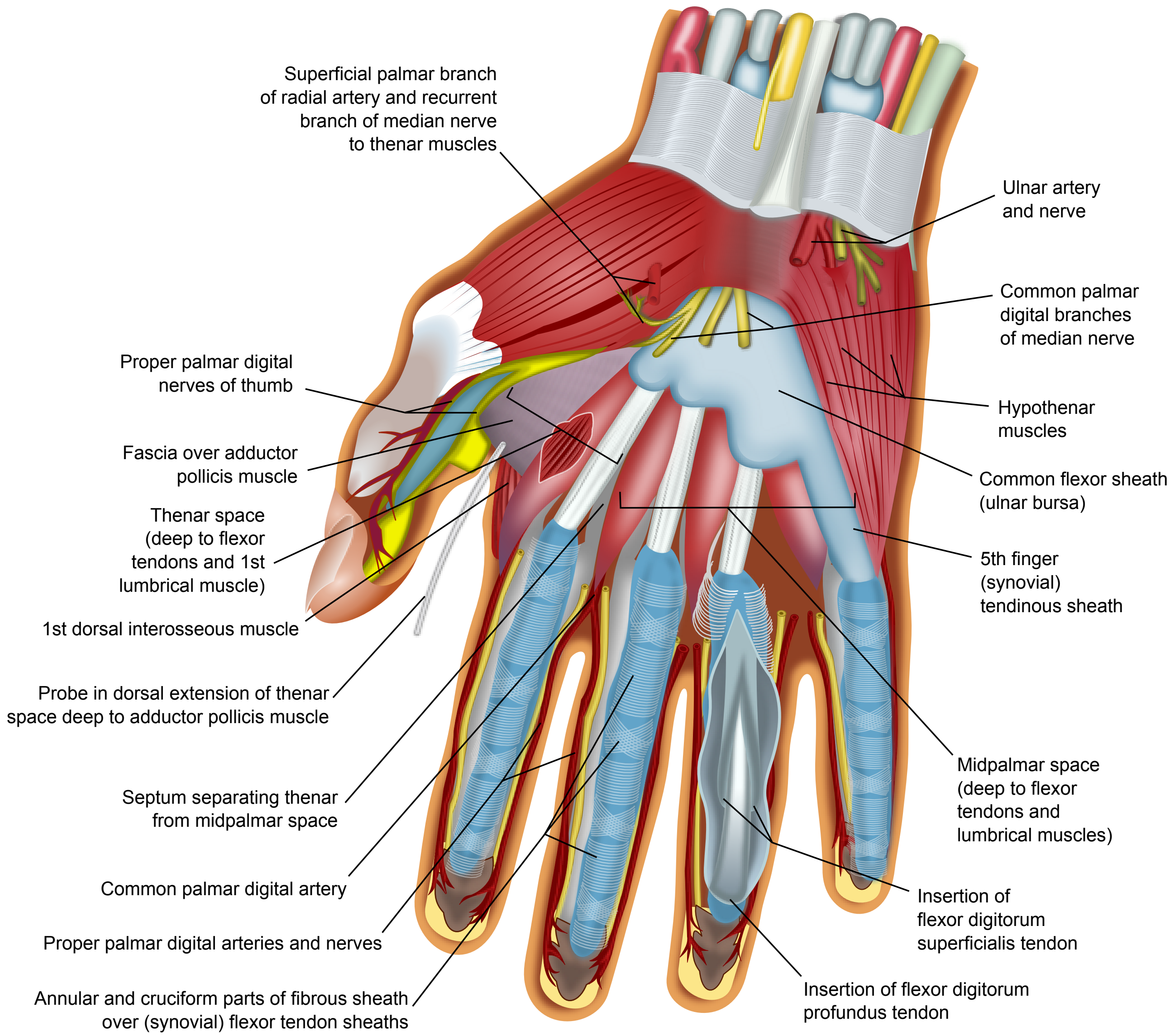
The intrinsic muscles of the hand both originate and insert within it. These muscles allow your fingers to make precise movements for actions, such as typing or writing. These muscles are divided into three groups. The thenar muscles are on the radial aspect of the palm. The hypothenar muscles are on the ulnar aspect of the palm, and the intermediate muscles are midpalmar.

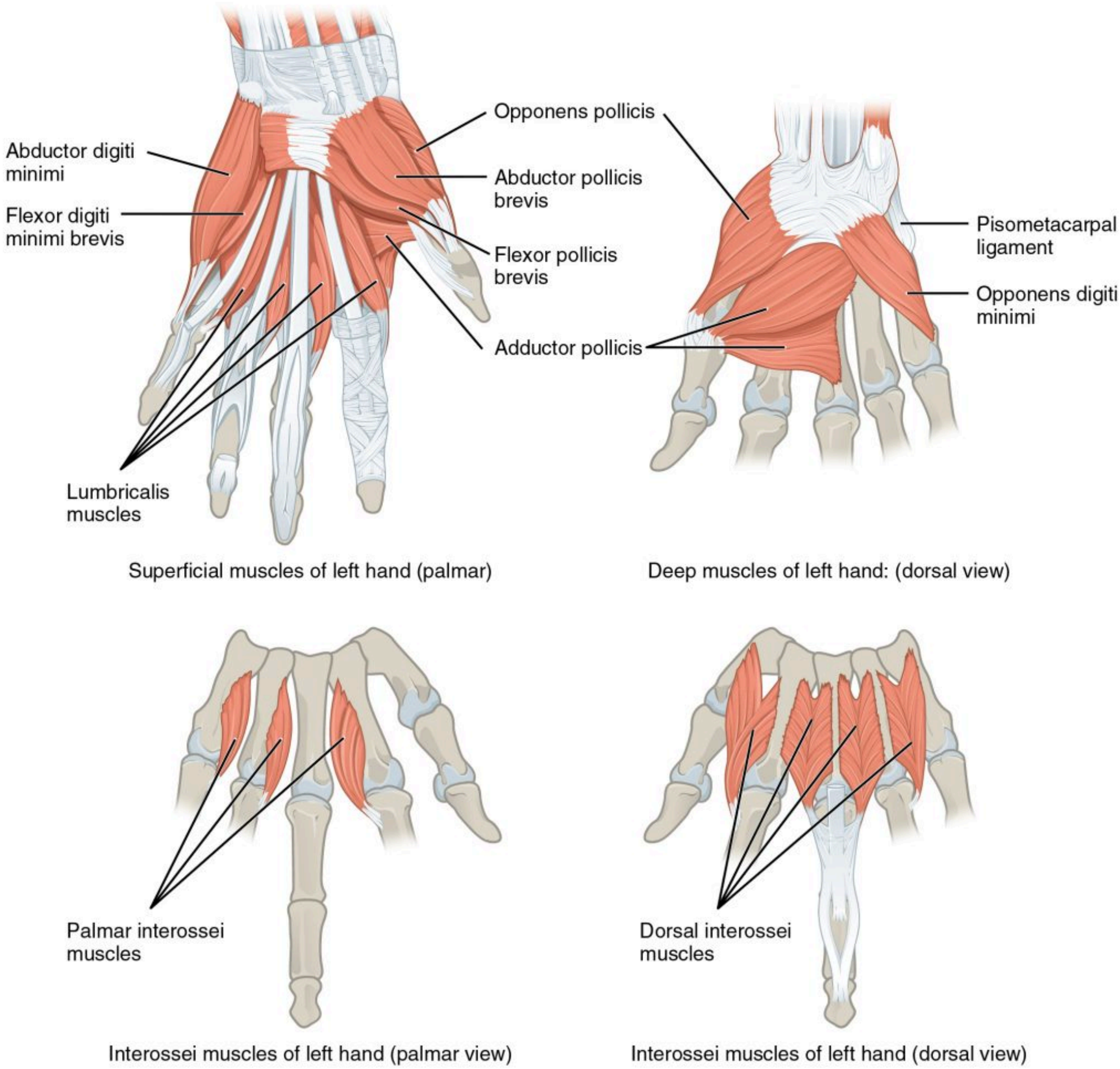
The thenar muscles include the abductor pollicis brevis, opponens pollicis, flexor pollicis brevis, and the adductor pollicis. These muscles form the thenar eminence, the rounded contour of the base of the thumb, and all act on the thumb. The movements of the thumb play an integral role in most precise movements of the hand.

The hypothenar muscles include the abductor digiti minimi, flexor digiti minimi brevis, and the opponens digiti minimi. These muscles form the hypothenar eminence, the rounded contour of the little finger, and as such, they all act on the little finger. Finally, the intermediate muscles act on all the fingers and include the lumbrical, the palmar interossei, and the dorsal interossei.

Wrist and Hand

Deeper Palmar up Dissection at Right Hand





Intrinsic Muscles of the Hand

The intrinsic muscles of the hand both originate and insert within the hand. These muscles provide the fine motor control of the fingers by flexing, extending, abducting, and adducting the more distal finger and thumb segments.

Muscle	Origin	Insertion	Action	Innervation
Palmaris brevis	Aponeurosis of palmar	Medial border of hand skin	Medial border of skin moved to midline	Ulnar nerve, superficial branch C 8
Adductor pollicis	Carpal & metacarpal bones	Thumb proximal phalanx	Adduction of thumb	Ulnar nerve, deep branch (C 8 – T 1)
Palmar interosseous (3-4)	Metacarpal bones (II, IV, V)	Proximal phalanges bases of fingers 2, 4, 5	Adduction of metacarpophalangeal joints of 2, 4, 5. Flexion at metacarpophalangeal joints. Extension at interphalangeal joints	Ulnar nerve, deep branch (C 8 – T 1)
Abductor pollicis brevis	Transverse carpal ligament Scaphoid, trapezium	Base of proximal phalanx/thumb ; radial side	Abduction of thumb	Median nerve (C6 – C7)
Dorsal interosseous	Sides of metacarpals; originates from opposing faces of two metacarpal bones	Proximal phalanges of fingers 2-4	Abduction at metacarpophalangeal joints of fingers 2&4. Flexion at metacarpophalangeal joints. Extension at interphalangeal joints.	Ulnar nerve, deep branch (C 8 – T 1)
Abductor digiti minimi	Pisiform	Little finger; proximal phalanx	Abduction & flexion of little finger.	Ulnar nerve, deep branch (C 8 – T 1)
Flexor pollicis brevis	Ulnar side of first metacarpal bone, flexor retinaculum, trapezium, capitate	Ulnar & radial sides of proximal phalanx of the thumb	Abduction & flexion of thumb	Branches of median & ulnar nerve
Flexor digiti minimi brevis	Hamate	Proximal phalanx of little finger	Little finger' flexion of joints	Ulnar nerve, deep branch (C 8 – T 1)
Lumbricals	Tendons of flexor digitorum profundus	Digits 2-5; tendons of extensor digitorum	Digits; 2-5. Extension at proximal & distal interphalangeal joints.	Lumbricals 1 & 2; median nerve. Lumbricals 3 & 4; ulnar nerve (deep branch)
Opponens pollicis	Flexor retinaculum & trapezium	1st metacarpal bone	Thumb opposition	Median nerve C 6 _ C7_

Muscle	Origin	Insertion	Action	Innervation
Opponens digiti minimi	Flexor retinaculum & trapezium	5th metacarpal bone	5th metacarpal bone opposition	Ulnar nerve C8 – T1

In The Lab

1. Review the muscles of the humerus/shoulder/forearm/hand/wrist/fingers in the images and tables provided
2. Examine the model and muscles charts provided in lab, locate each muscle (origin, insertion & innervation) and describe its action.
3. Review the movement and action of each muscle with your lab partners

Appendicular Muscles: Pelvic Girdle & Lower Limb

Objectives

10. Locate the muscles of the pelvic girdle & lower limb on laboratory charts and models.
11. Recognize on the models the origin, insertion, and action of the muscles of the pelvic girdle & lower limb
12. Describe and demonstrate the action of the muscles of the pelvic girdle & lower limb.

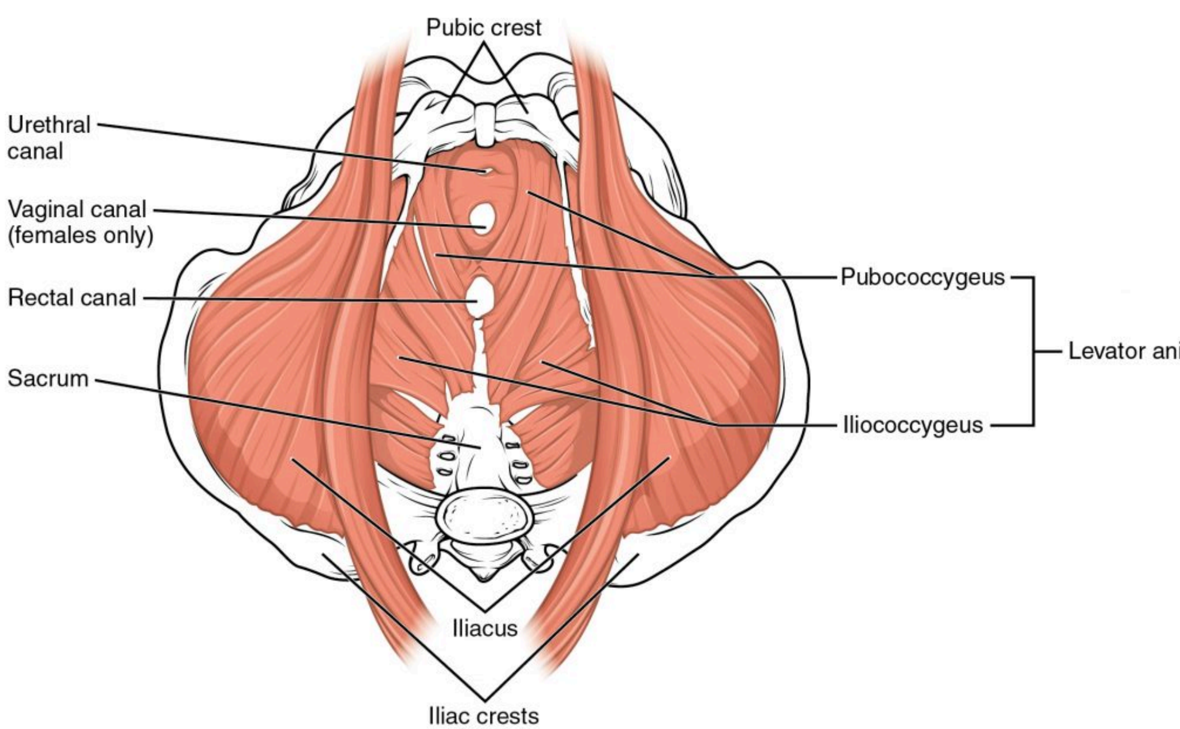
The appendicular muscles of the lower body position and stabilize the pelvic girdle, which serves as a foundation for the lower limbs. Comparatively, there is much more movement at the pectoral girdle than at the pelvic girdle. There is very little movement of the pelvic girdle because of its connection with the sacrum at the base of the axial skeleton and because the deep acetabulum provides a stable point of articulation with the head of the femur. The pelvic girdle's lack of range of motion allows it to stabilize and support the body. The body's center of gravity is in the area of the pelvis. If the center of gravity were not to remain fixed, standing up would be difficult. Therefore, what the leg muscles lack in range of motion and versatility, they make up for in size and power, facilitating the body's stabilization, posture, and movement.

Muscles of the Pelvic Floor and Perineum

The pelvic floor (also referred to as the pelvic diaphragm) is a muscular sheet that defines the inferior portion of the pelvic cavity. The pelvic floor extends anteriorly to posteriorly from the pubis to the coccyx and is comprised of the levator ani and the ischiococcygeus. Its openings include the anal canal and urethra, and the vagina in women.

The large levator ani consists of two skeletal muscles, the pubococcygeus and the iliococcygeus. The levator ani is considered the most important muscle of the pelvic floor because it supports the pelvic viscera. It resists the pressure produced by contraction of the abdominal muscles so that the pressure is applied to the colon to aid in defecation and to the uterus to aid in childbirth (assisted by the ischiococcygeus, which pulls the coccyx anteriorly). This muscle also creates skeletal muscle sphincters at the urethra and anus.

The perineum is the diamond-shaped space between the pubic symphysis (anteriorly), the coccyx (posteriorly), and the ischial tuberosities (laterally), lying just inferior to the pelvic diaphragm (levator ani and ischiococcygeus). Divided transversely into triangles, the anterior is the urogenital triangle, which includes the external genitals and the posterior is the anal triangle containing the anus. The perineum is also divided into superficial and deep layers with some of the muscles common to men and women. Women also have the compressor urethrae and the sphincter urethrovaginalis, which function to close the vagina. In men, the deep transverse perineal muscle plays a role in ejaculation.



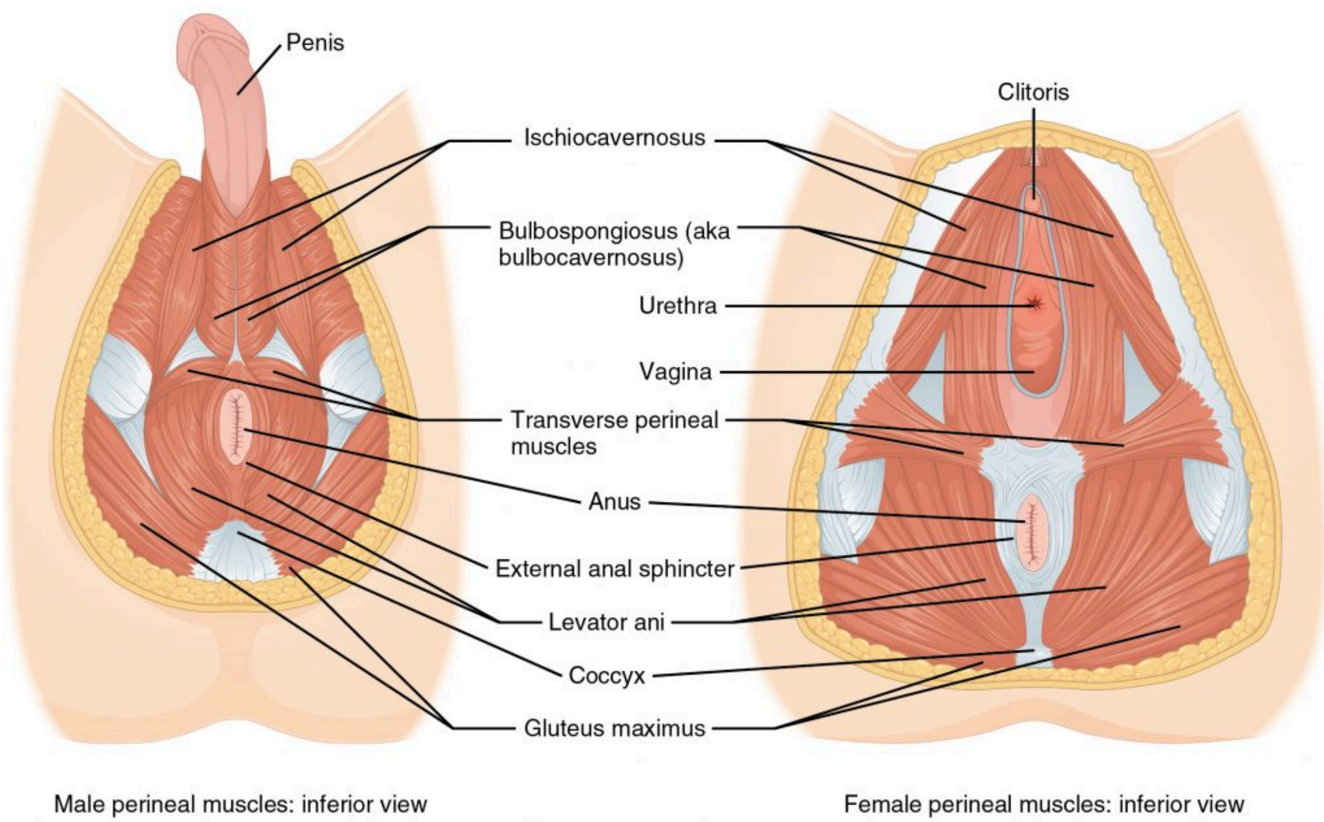
Pelvic diaphragm (superior view)

Muscles of the Pelvic Floor

The pelvic floor muscles support the pelvic organs, resist intra-abdominal pressure, and work as sphincters for the urethra, rectum, and vagina.

In The Lab

4. Review the muscles of the pelvic floor & perineum in the images and tables provided
5. Examine the pelvic floor & perineum muscles charts provided in lab, locate each muscle (origin, insertion & innervation) and describe its action.
6. Review the movement and action of each pelvic floor & perineum muscle using your and your lab partners.



Muscles of the Perineum.

The perineum muscles play roles in urination in both sexes, ejaculation in men, and vaginal contraction in women.

Muscles of the Perineum Common to Men and Women

Muscle	Origin	Insertion	Action	Innervation
Levator ani pubococcygeus; levator ani iliococcygeus	Pubis; Ischium	Urethra; anal canal; perineal body; coccyx	Compresses anal canal; Defecation; urination; birth; coughing	Pudendal nerve; Spinal nerves S2-S3

Superficial muscles

Muscle	Origin	Insertion	Action	Innervation
Flexor pollicis longus	Anterior surface of radius; interosseous membrane	Distal phalanx of thumb	Flexes distal phalanx of thumb	Median nerve
Bulbospongiosus	Perineal body	Perineal body membrane; corpus spongiosum of penis; deep fascia of penis; clitoris in female	Involuntary response that compresses urethra when excreting urine in both sexes or while ejaculating in male; also aids in erection of penis in males	Pudendal nerve
Ischiocavernosus	Ischium; ischial rami; pubic rami	Pubic symphysis; corpus cavernosum of penis in male; clitoris of female	Compresses veins to maintain erection of penis in males; erection of clitoris in females	Pudendal nerve

Deep muscles

Muscle	Origin	Insertion	Action	Innervation
External urethral sphincter	Ischial rami; pubic rami	Male: median raphe; female: vaginal wall	Voluntarily compresses urethra during urination	Pedendal nerve spinal nerves S2-S4; pelvic splanchnic nerve
External anal sphincter	Anoccoccygeal ligament	Perineal body	Closes anus	Pedendal nerve spinal nerves S2-S4; pelvic splanchnic nerve

Appendicular Muscles Of The Pelvic Girdle And Lower Limbs

The appendicular muscles of the lower body position and stabilize the pelvic girdle, which serves as a foundation for the lower limbs. Comparatively, there is much more movement at the pectoral girdle than at the pelvic girdle. There is very little movement of the pelvic girdle because of its connection with the sacrum at the base of the axial skeleton and because the deep acetabulum provides a stable point of articulation with the head of the femur. The pelvic girdle's lack of range of motion allows it to stabilize and support the body. The body's center of gravity is in the area of the pelvis. If the center of gravity were not to remain fixed, standing up would be difficult. Therefore, what the leg muscles lack in range of motion and versatility, they make up for in size and power, facilitating the body's stabilization, posture, and movement.

Gluteal Region Muscles That Move the Thigh

Most muscles that insert on the femur (the thigh bone) and move it, originate on the pelvic girdle. The major flexors of the hip are the psoas major and iliac which make up the iliopsoas group. Some of the largest and most powerful muscles in the body are the gluteal muscles or gluteal group. The gluteus maximus, one of the major extensors of the thigh at the hip, is the largest; deep to the gluteus maximus is the gluteus medius, and deep to the gluteus medius is the gluteus minimus, the smallest of the trio.

The tensor fascia latae is a thick, squarish muscle in the superior aspect of the lateral thigh. It acts as a synergist of the gluteus medius and iliopsoas in flexing and abducting the thigh. It also helps stabilize the lateral aspect of the knee by pulling on the iliotibial tract (band), making it taut. Deep to the gluteus maximus, the piriformis, obturator internus, obturator externus, superior gemellus, inferior gemellus, and quadratus femoris laterally rotate the thigh at the hip.

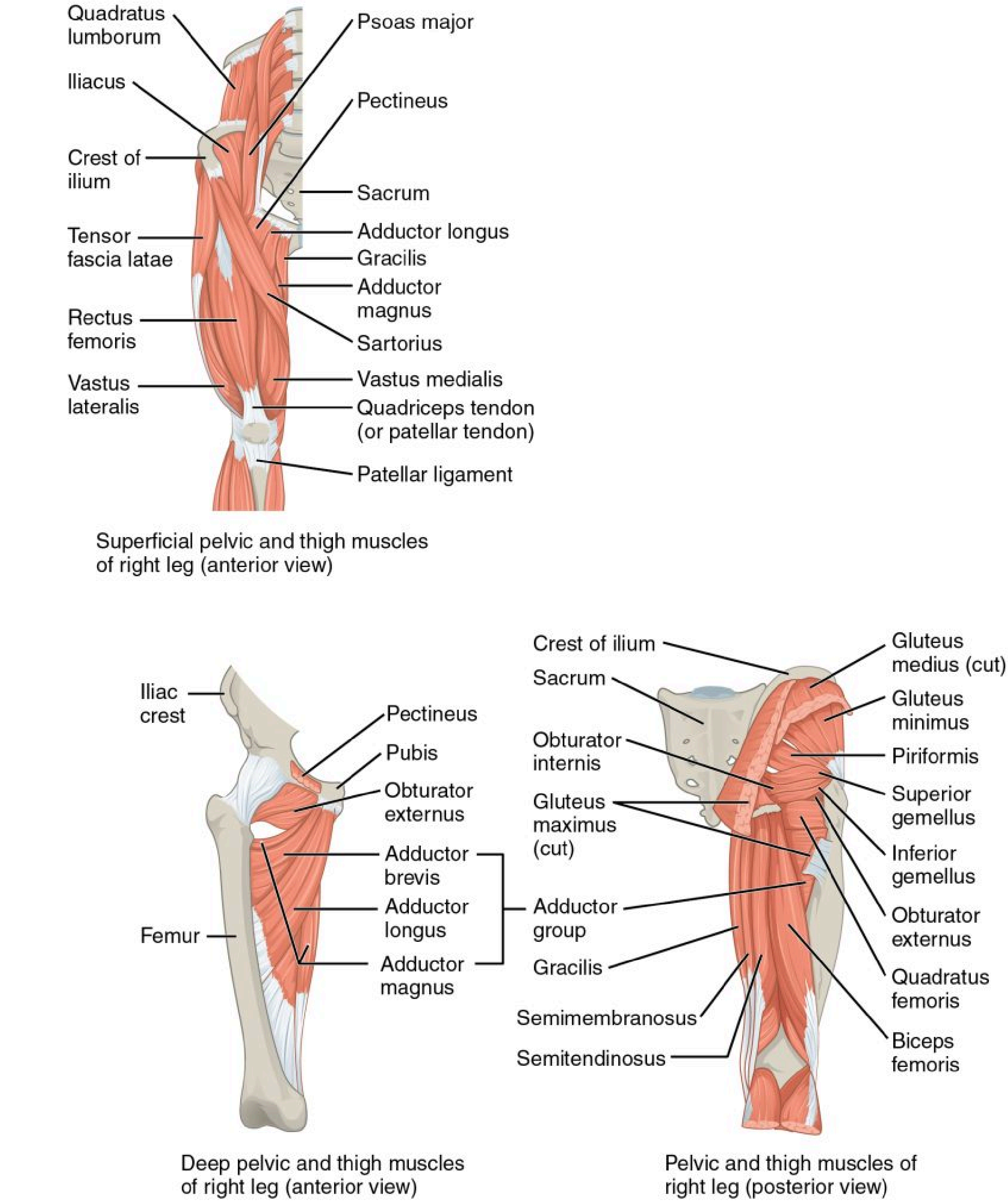
Deep fascia in the thigh separates it into medial, anterior, and posterior compartments. The muscles in the medial compartment of the thigh responsible for adducting the femur at the hip are the adductor group including the adductor longus, adductor brevis, and adductor magnus which all adduct and medially rotate the thigh. The adductor longus also flexes the thigh, whereas the adductor magnus extends it. Like the adductor longs, the pectineus adducts and flexes the femur at the hip. The pectineus is located in the femoral triangle, which is formed at the junction between the hip and the leg and includes the femoral nerve, the femoral artery, the femoral vein, and the deep inguinal lymph nodes. The strap-like gracilis adducts the thigh in addition to flexing the leg at the knee.

The muscles of the anterior compartment of the thigh flex the thigh and extend the leg. This compartment contains the quadriceps femoris group, which is comprised of four muscles that extend the leg and stabilize the knee. Within the compartment the rectus femoris is on the anterior aspect of the thigh, the vastus lateralis is on the lateral aspect of the thigh, the vastus medialis is on the medial aspect of the thigh, and the vastus intermedius is between the vastus lateralis and vastus medialis and deep to the rectus femoris. The tendon common to all four is the quadriceps tendon (patellar tendon), which inserts into the patella and continues below it as the patellar ligament. The patellar ligament attaches to the tibial tuberosity. In addition to the quadriceps femoris, the sartorius is a band-like muscle that extends from the anterior superior iliac spine to the medial side of the proximal tibia. This versatile muscle flexes the leg at the knee and flexes, abducts, and laterally rotates the thigh at the hip. This muscle allows us to sit cross-legged.

The posterior compartment of the thigh includes muscles that flex the leg and extend the thigh. The three long muscles on the back of the thigh are the hamstring group, which flexes the knee. These are the biceps femoris, semitendinosus, and semimembranosus. The tendons of these muscles form the upper border of the popliteal fossa, the diamond-shaped space at the back of the knee.

In The Lab

4. Review the muscles of muscles of the pelvic girdle in the images and tables provided
5. Examine the model and muscles charts provided in lab, locate each muscle (origin, insertion & innervation) and describe its action.
6. Review the movement and action of each muscle using yours and your lab partners.



Hip and Thigh Muscles

The large and powerful muscles of the hip that move the femur generally originate on the pelvic girdle and insert into the femur. The muscles that move the lower leg typically originate on the femur and insert into the bones of the knee joint. The anterior muscles of the femur extend the lower leg but also aid in flexing the thigh. The posterior muscles of the femur flex the lower leg but also aid in extending the thigh. A combination of gluteal and thigh muscles also adduct, abduct, and rotate the thigh and lower leg.

Gluteal Region Muscles That Move the Femur

Iliopsoas group

Muscle	Origin	Insertion	Action	Innervation
Psoas major	Lumbar verlebrae (L1-L5); thoracic vertebra (T1 2)	Lesser trochanter of femur	Flexes the thigh and vertebral column laterally	Anterior rami of lumbar spinal nerves
lliacus	Iliac fossa: iliac crest; lateral sacrum	Lesser trochanter of femur	Flexes the trunk and thigh	Femoral nerve

Gluteal group

Muscle	Origin	Insertion	Action	Innervation
Gluteus maximus	Dorsal ilium; sacrum; coccyx	Gluteal tuberosity of femur; Iliotibial tract	Extends the thigh	Inferior gluteal nerve
Gluteus medius	Lateral surface of ilium	Greater trochanter of femur	Abducts and medially rotates thigh	Superior gluleal nerve
Gluteus minimus	External surface of ilium	Greater trochanter of femur	Abducts and medially rotates thigh	Superior gluleal nerve
Tensor fascia lata	Anterior aspect of iliac crest; anterior superior iliac spine	Iliotibial tract	Steadies leg and trunk; rotates thigh medially; maintains posture by stabilizing the iliotibal track, which connects to the knee	Superior gluleal nerve

Lateral rotators

Muscle	Origin	Insertion	Action	Innervation
Piriformis	Anterolateral surface of sacrum	Greater trochanter of femur	Rotates extended thigh laterally; Slabilizes hip joint; Aids in abduction of thigh	Spinal nerves L5-S2
Obutrator internus	Inner surface of obturator membrane; greater sciatic notch; margins of obturator foramen	Greater trochanter in front of piriformis	Rotates extended thigh laterally; Stabilizes hip joint; Aids in abduction of thigh	Nerve lo obturator infernus
Obturator externus	Outer surfaces of obturator membrane, pubic, and ischium; margins of obturator foramen	Trochanteric fossa of posterior femur	Rotates extended thigh laterally; Stabilizes hip joint; Aids in abduction of thigh	Obturator nerve
Superior gemellus	lschial spine	Greater trochanter of femur	Rotates extended thigh laterally; Stabilizes hip joint; Aids in abduction of thigh	Nerve lo obturator infernus
Inferior gemellus	Ischial tuberosity	Greater trochanter of femur	Rotates extended thigh laterally; Stabilizes hip joint; Aids in abduction of thigh	Nerve to quadratus femoris
Quadratus femoris	Ischial tuberosity	Trochanteric crest of femur	Extends and stabilizes leg; flexes thigh at hip	Nerve to quadratus femoris

Adductors

Muscle	Origin	Insertion	Action	Innervation
Adductor longus	Pubis near pubic symphysis	Linea aspera	Adducts, flexes and medially rotates thigh	Obturator nerve
External anal sphincter	Body of pubis; inferior ramus of pubis	Linea aspera above adductor longus	Adducts, flexes and medially rotates thigh	Obturator nerve
Adductor magnus	lschial rami; pubic rami; lschial tuberosity	Linea aspera; adductor tubercle of femur	Adducts and medially rotates flexes thigh. Aids in thigh extension	Obturator nerve; tibial nerve
Pectineus	Pedineal line of pubis	Lesser trochanter to linea aspera of posterior aspect of femur	Adducts thigh, flexes and medially rotates leg	Femoral nerve

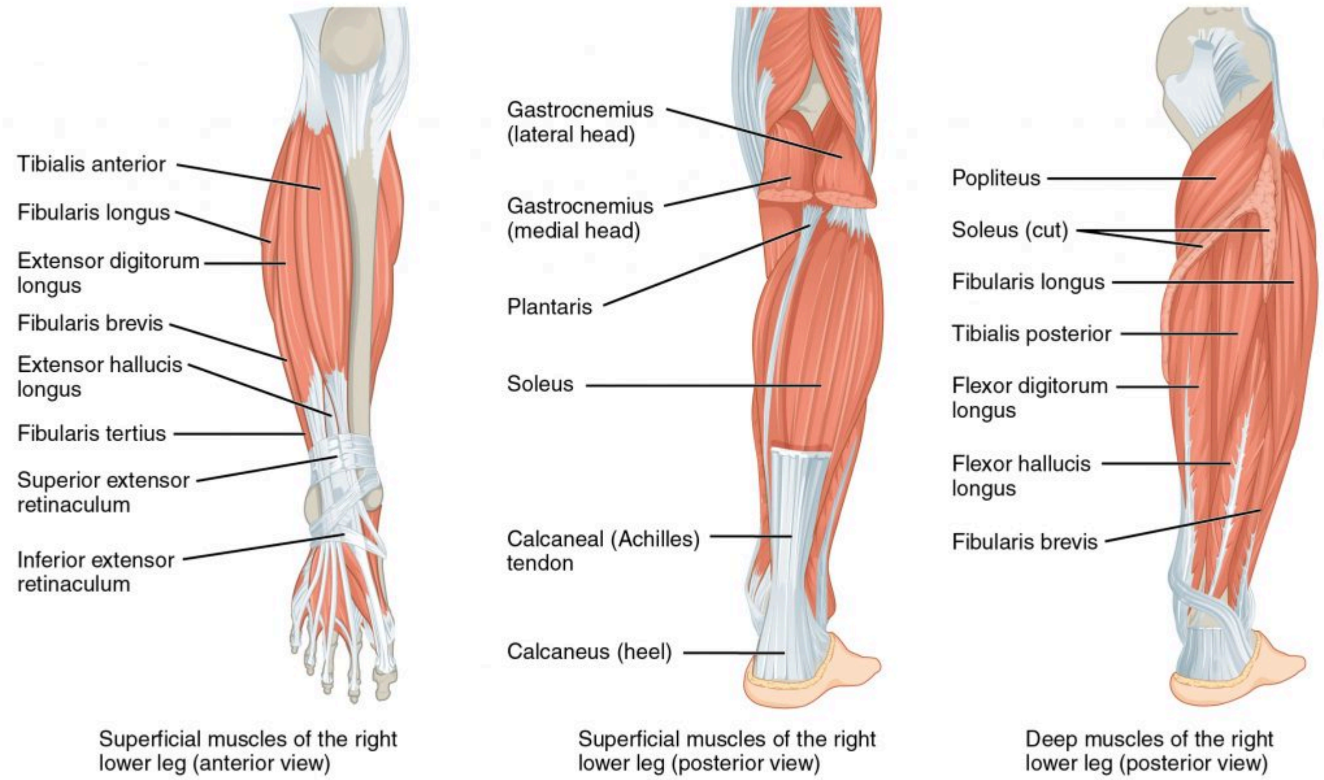
Muscles That Move the Feet and Toes

Similar to the thigh muscles, the muscles of the leg are divided by deep fascia into compartments, although the leg has three: anterior, lateral, and posterior.

The muscles in the anterior compartment of the leg all contribute to dorsiflexion: the tibialis anterior, a long and thick muscle on the lateral surface of the tibia, the extensor hallucis longus, deep under it, and the extensor digitorum longus, lateral to it. The fibularis tertius, a small muscle that originates on the anterior surface of the fibula, is associated with the extensor digitorum longus and sometimes fused to it, but is not present in all people. Thick bands of connective tissue called the superior extensor retinaculum (transverse ligament of the ankle) and the inferior extensor retinaculum, hold the tendons of these muscles in place during dorsiflexion.

The lateral compartment of the leg includes two muscles which contribute to eversion and plantar flexion: the fibularis longus (peroneus longus) and the fibularis brevis (peroneus brevis). The superficial muscles in the posterior compartment of the leg all insert onto the calcaneal tendon (Achilles tendon), a strong tendon that inserts into the calcaneal bone of the ankle, all contribute to plantar flexion. The muscles in this compartment are large and strong and keep humans upright. The most superficial and visible muscle of the calf is the gastrocnemius. Deep to the gastrocnemius is the wide, flat soleus. The plantaris runs obliquely between the two; some people may have two of these muscles, whereas no plantaris is observed in about seven percent of other cadaver dissections. The plantaris tendon is a desirable substitute for the fascia lata in hernia repair, tendon transplants, and repair of ligaments. There are four deep muscles in the posterior compartment of the leg as well: the popliteus, flexor digitorum longus, flexor hallucis longus, and tibialis posterior all contribute to plantar flexion or inversion of the foot.

The foot also has intrinsic muscles, which originate and insert within it (similar to the intrinsic muscles of the hand). These muscles primarily provide support for the foot and its arch, and contribute to movements of the toes (Figure 6 and Figure 7). The principal support for the longitudinal arch of the foot is a deep fascia called plantar aponeurosis, which runs from the calcaneus bone to the toes (inflammation of this tissue is the cause of "plantar fasciitis," which can affect runners. The intrinsic muscles of the foot include the extensor digitorum brevis on the dorsal aspect and a plantar group, which consists of four layers.



Muscles of the Lower Leg

The muscles of the anterior compartment of the lower leg are generally responsible for dorsiflexion, and the muscles of the posterior compartment of the lower leg are generally responsible for plantar flexion. The lateral and medial muscles in both compartments invert, evert, and rotate the foot.

Anterior compartment of leg

Muscle	Origin	Insertion	Action	Innervation
Tibialis anterior	Lateral condyle and upper tibial shaft; interosseous membrane	Interior surface of medial cuneiform; First metatarsal bone	Dorsiflexes the foot; inverts foot; aids in support of medial longitudinal arch of foot	Deep fibular (peroneal) nerve
Extensor hallucis longus	Anteromedial fibula shaft; interosseous membrane	Distal phalanx of big toe	Extends big toe; aids in dorsiflexion of the foot	Deep fibular (peroneal) nerve
Extensor digitorum longus	Lateral condyle of tibia; proximal portion of fibula; interosseous membrane	Middle and distal phalanges of toes 2-5	Extends toes; dorsiflexes the foot	Deep fibular (peroneal) nerve

Lateral compartment of leg

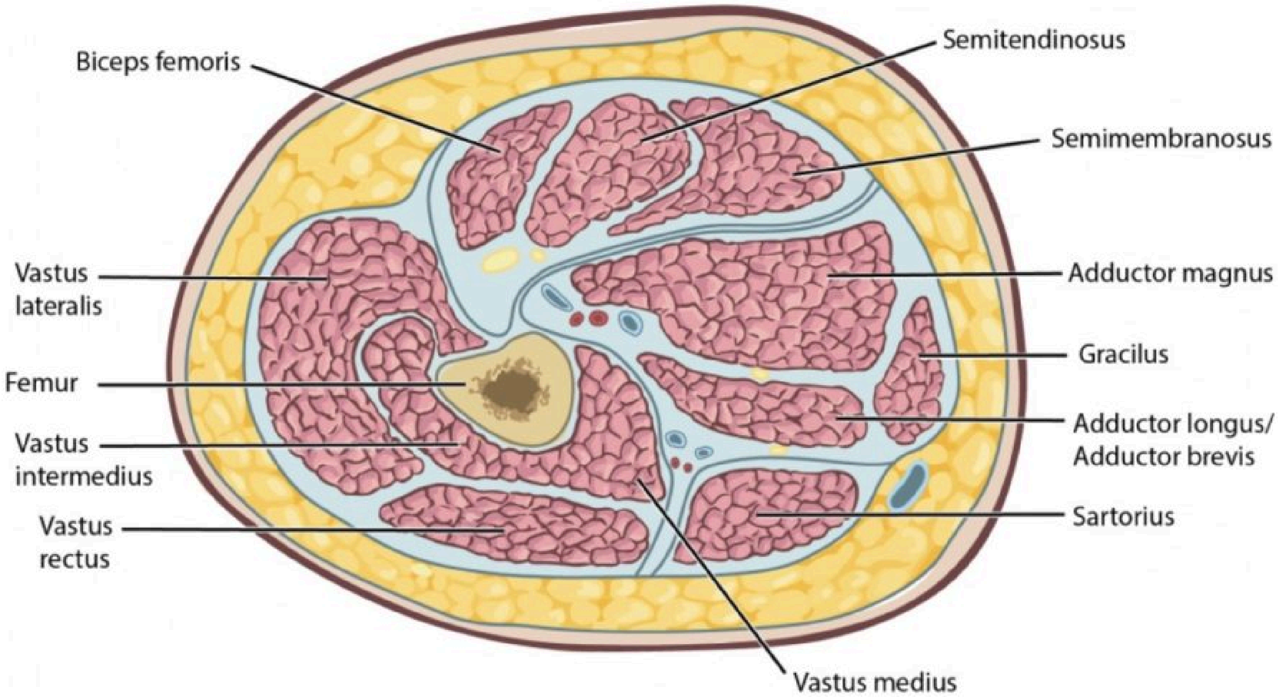
Muscle	Origin	Insertion	Action	Innervation
Fibularis longus	Upper portion of lateral fibula	First metatarsal medial cuneiform	Plantar Rexes and everts foot	Superficial fibular (peroneal) nerve
Fibularis (peroneus) brevis	Distal fibula shaft	Proximal end of fifth metatarsal	Plantar Rexes and everts foot	Superficial fibular (peroneal) nerve

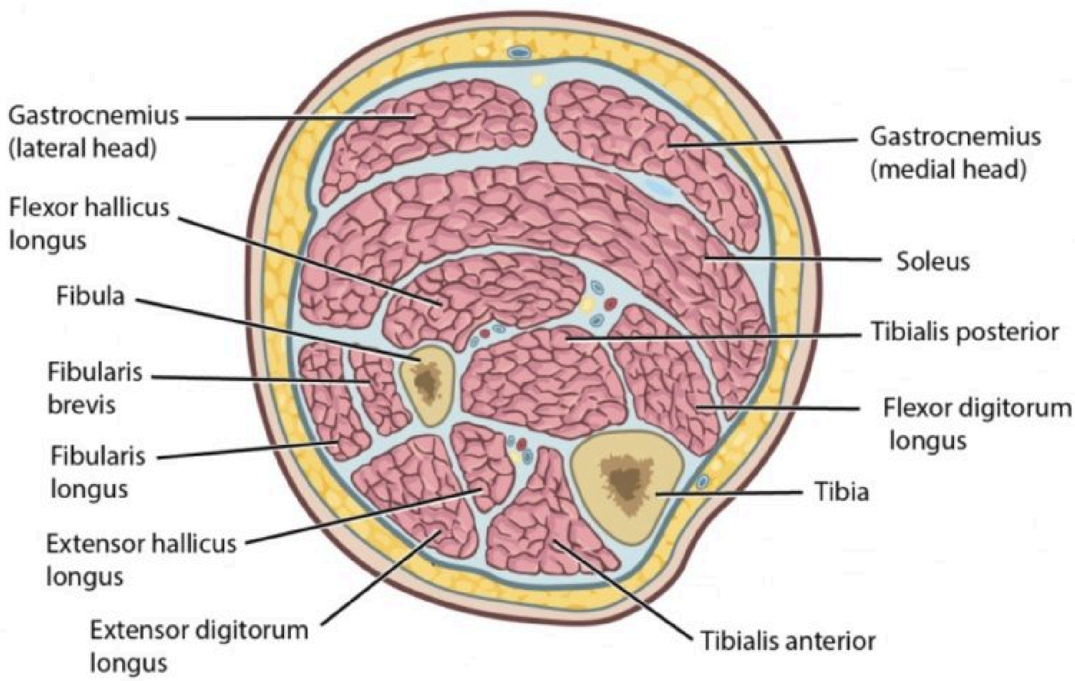
Posterior compartment of leg: Superficial muscles

Muscle	Origin	Insertion	Action	Innervation
Gastrocnemius	Medial and lateral condyles of femur	Posterior calcaneus	Plantar flexes the foot; flexes knee when foot is dorsiflexed	Tibial nerve
Soleus	Superior tibia; fibula; interosseous membrane	Posterior calcaneus	Plantar flexes foot	Tibial nerve
Plantaris	Posterior femur above lateral condyle	Calcaneus or calcaneus tendon	Aids in flexing the leg and plantar flexing the foot	Tibial nerve from anterior rami of S1-S2
Tibialis posterior	Superior tibia and fibula; interosseous membrane	Several tarsals and metatarsals 2-4	Inverts and plantar flexes foot; aids in stabilizing medial longitudinal arch of foot	Tibial nerve

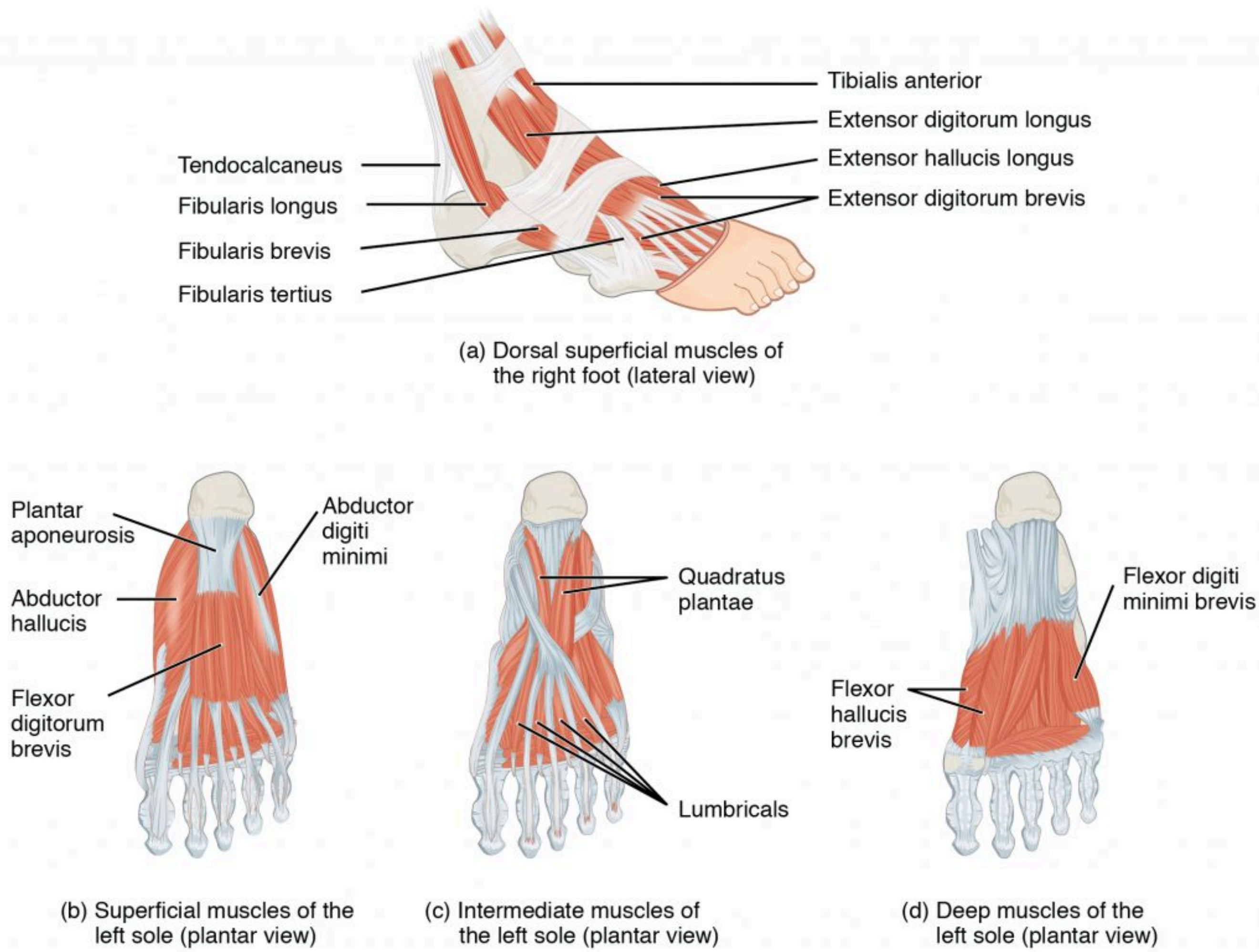
Posterior compartment of leg: Deep muscle

Muscle	Origin	Insertion	Action	Innervation
Poplileus	Lateral condyle of femur; lateral meniscus	Proximal tibia	Flexes and rotates leg medially to unlock extended knee when flexion begins; laterally rotates thigh	Tibial nerve
Flexor digitorum longus	Posterior tibia	Distal phalanges of toes 2-5	Plantar flexes and inverts foot; flexes toes	Tibial nerve
Flexor hallucis longus	Midshaft of fibula; interosseous membrane	Distal phalanx of big, toe	Plantar flexes and inverts foot; flexes toes	Tibial nerve


Biceps femoris
Semitendinosus
Semimembranosus
Vastus lateralis
Adductor magnus
Gracilus
Femur
Adductor longus/ Adductor brevis
Vastus intermedius
Sartorius
Vastus rectus
Vastus medius


Gastrocnemius (lateral head)
Gastrocnemius (medial head)
Flexor hallicus longus
Soleus
Fibula
Tibialis posterior
Fibularis brevis
Flexor digitorum longus
Fibularis longus
Tibia
Extensor hallicus longus
Extensor digitorum longus
Tibialis anterior

Compartments of the leg.



Intrinsic Muscles of the Foot

The muscles along the dorsal side of the foot (a) generally extend the toes while the muscles of the plantar side of the foot (b, c, d) generally flex the toes. The plantar muscles exist in three layers, providing the foot the strength to counterbalance the weight of the body. In this diagram, these three layers are shown from a plantar view beginning with the bottom-most layer just under the plantar skin of the foot (b) and ending with the top-most layer (d) located just inferior to the foot and toe bones.

In The Lab

7. Review the muscles of the lower limb in the images and tables provided
8. Examine the model and muscles charts provided in lab, locate each muscle (origin, insertion & innervation) and describe its action.

9. Review the movement and action of each muscle with your lab partners

Dorsal group

Prime mover	Origin	Insertion	Action	Innervation
Extensor digitorum brevis	Calcaneus; extensor retinaculum	Base of proximal phalanx of big toe; extensor expansions on toes 2-5	Extends toes 2-5	Posterior interosseous nerve

Plantar group (layer 1)

Prime mover	Origin	Insertion	Action	Innervation
Abductor hallucis	CalcaneaJ tuberosity; flexor retinaculum	Proximal phalanx of big toe	Abducts and flexes big toe	Medial plantar nerve
Flexor digitorum brevis	Calcaneal tuberosity	Middl'e phalanx of toes 2-4	Flexes toes 2-4	Superficial branch of the lateral plantar nerve
Abductor digiti minimi	Calcaneal tuberosity	Proximal phalanx of little toe	Abducts and flexes small toe	superficial branch of the lateral plantar nerve

Plantar group (layer 2)

Prime mover	Origin	Insertion	Action	Innervation
Quadratus plantae	Medial and lateral sides of calcaneus	Tendon of flexor digitorum longus	Flexes and rotates leg medially to unlock extended knee when flexion begins; laterally rotates thigh	Lateral plantar nerve (S1-S2)
Lumbricals	Tendons of flexor digitorum longus	Medial side of proximal phalanx of toes 2-5	Extends toes 2-5 at the interphalangeal joints; flexes the small toes at the metatarsophalangeal joints	Medial and lateral plantar nerves (S3)

Plantar group (layer 3)

Prime mover	Origin	Insertion	Action	Innervation
Flexer hallucis brevis	Lateral cuneiform; cuboid bones	Base of proximal phalanx of big toe	Flexes big toe	Medial plantar nerve
Adductor hallucis	Bases of metatarsals 2-4; fibular,is longus tendon sheath; ligament across metatarsophalangeal joints	Base of proximal phalanx of big toe	Adducts and flexes big toe	Lateral plantar nerve
Flexor digiti minimi brevis	Base of metatarsal 5; tendon sheath of fibularis longus	Base of proximal phalanx of little toe	Flexes small toe	Superficial branch of the lateral plantar nerve

Plantar group (layer 4)

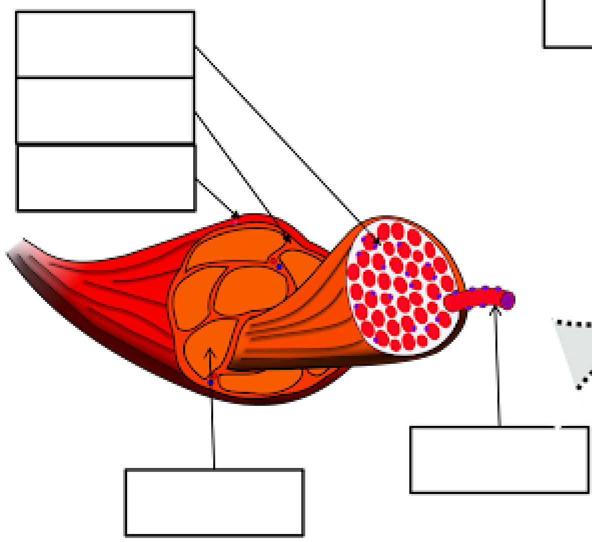
Prime mover	Origin	Insertion	Action	Innervation
Dorsal interossei	Sides of metatarsals	Both sides of toe 2; for each other toe, extensor expansion over first phalanx on side opposite toe 2	Abducts and flexes middle toes at metatarsophalangeal joints; extends middle toes at interphalangeal joints	Lateral plantar nerve
Plantar interossei	Sides of metatarsal that faces metatarsal 2 (absent from metatarsal 2)	Extensor expansion on first phalanx of each toe (except to 2) on side facing toe 2	Abducts toes 3-5; flexes proximal phalangeal and extends distal phalanges	Lateral plantar nerve

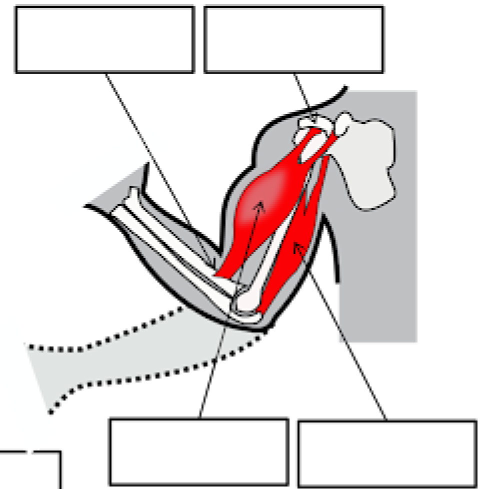
Intrinsic Muscles in the Foot

Laboratory Activity

1. Muscle Terminology

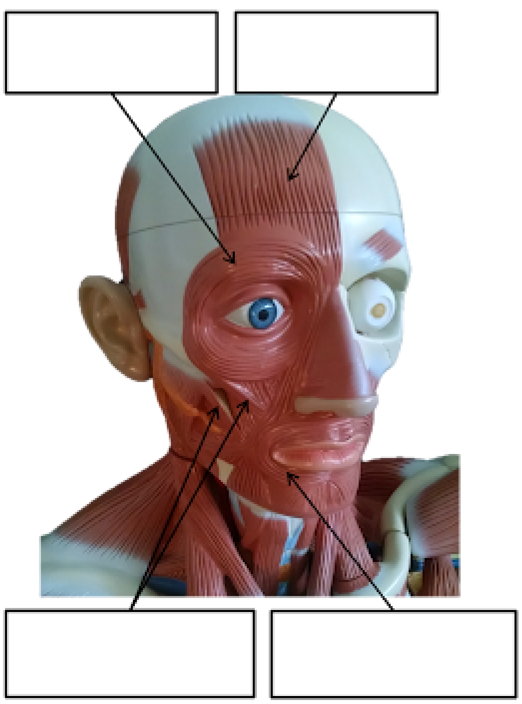
Label the following:

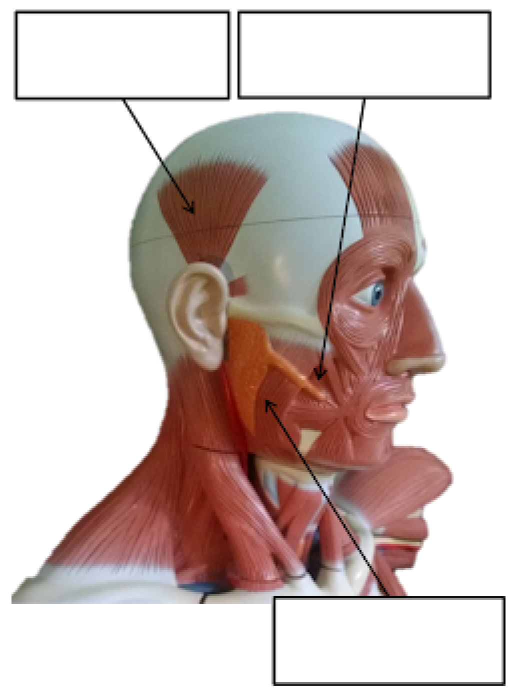




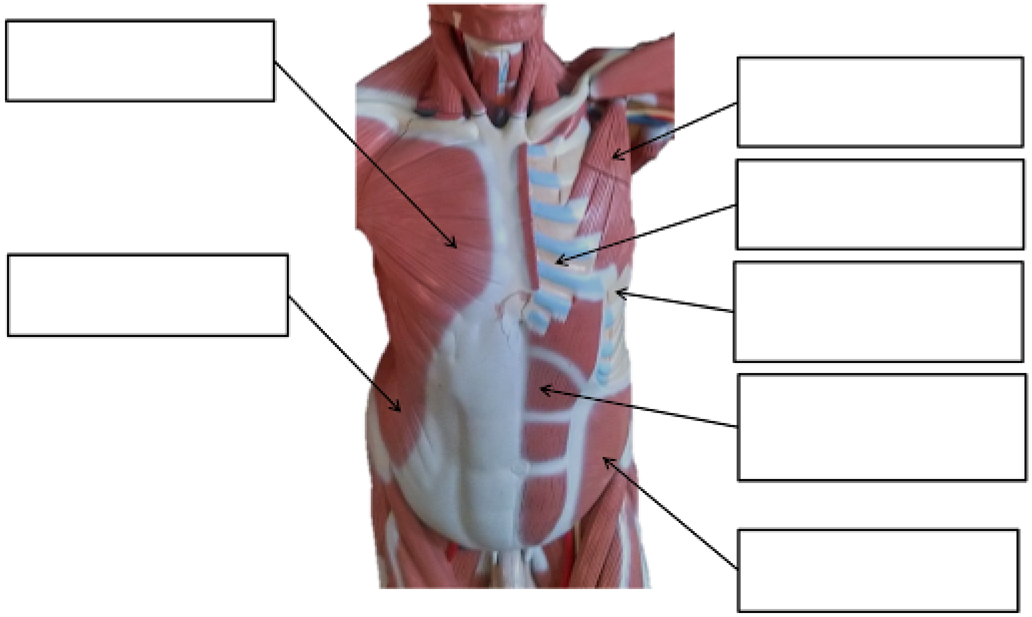
B. Gross Anatomy of the Muscular System

Head & Neck

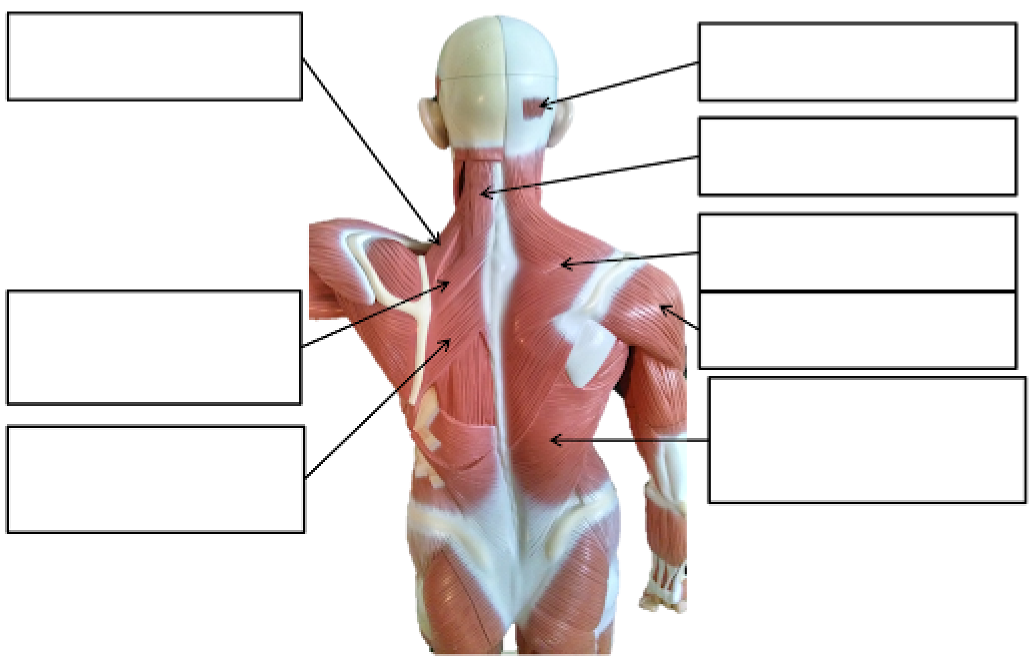




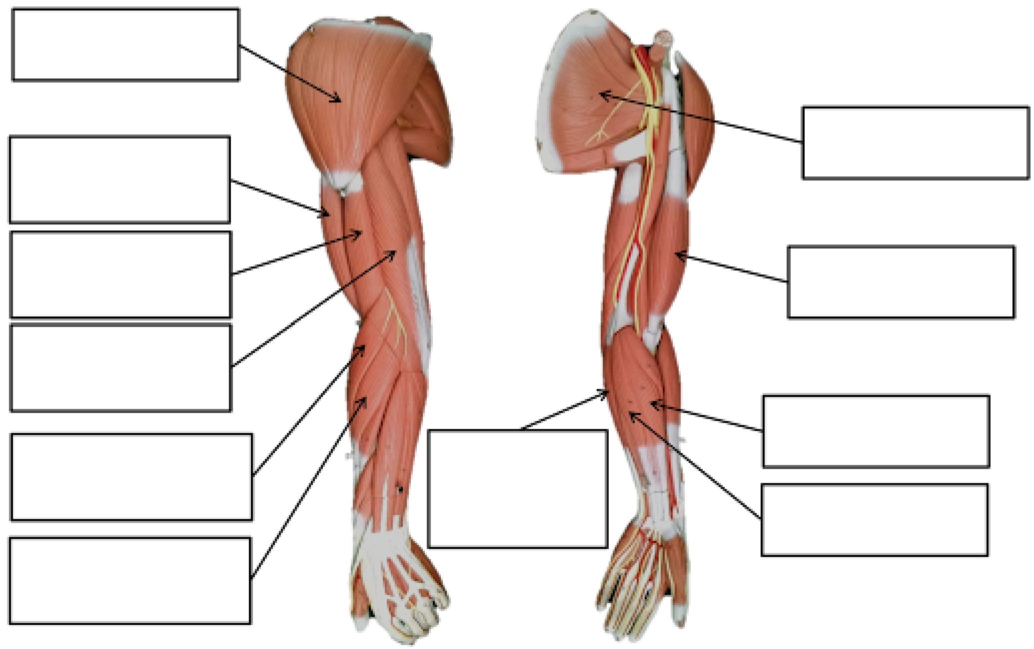
Torso – Anterior view

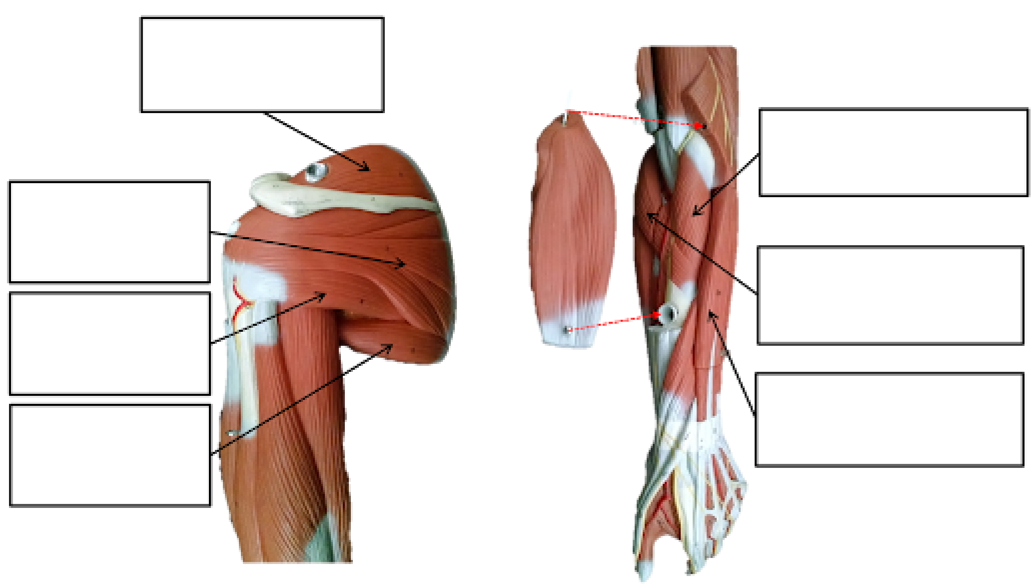


Torso posterior view

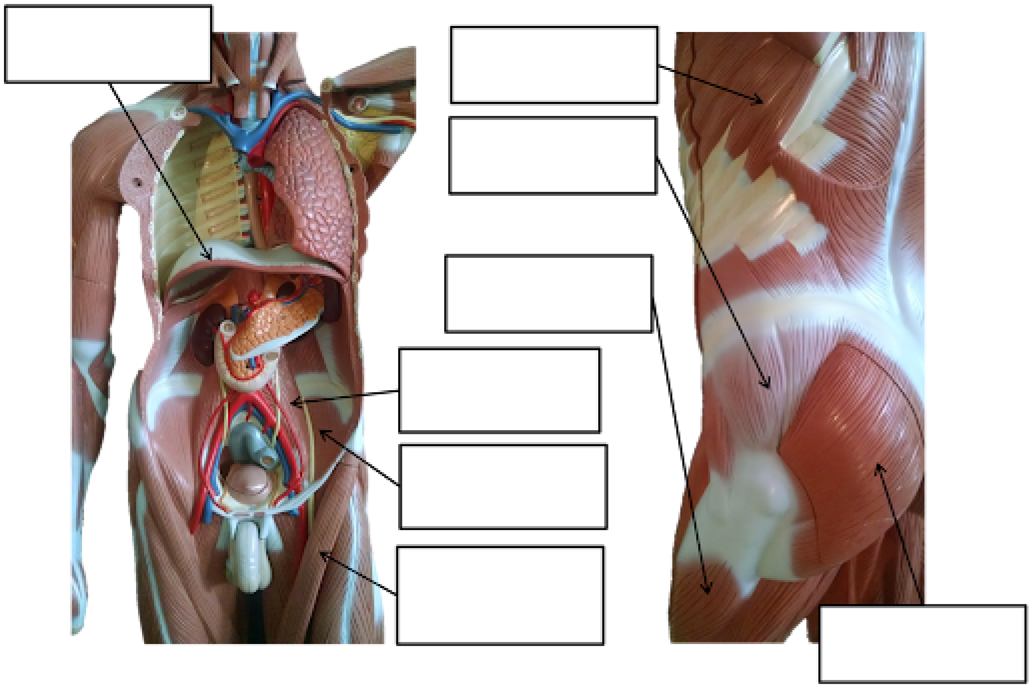


Arm

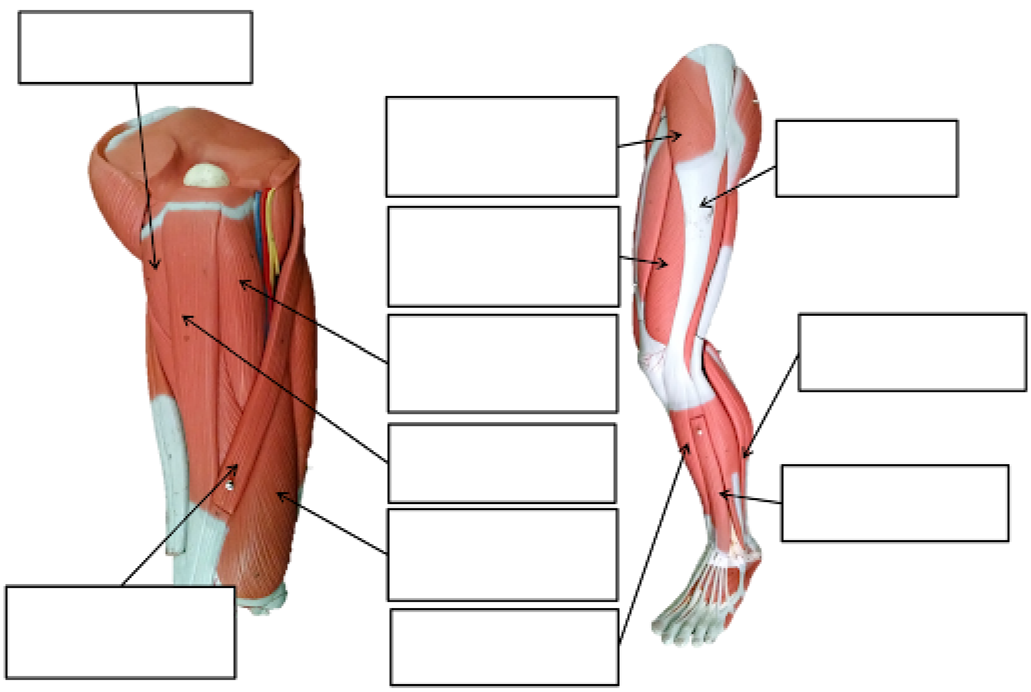




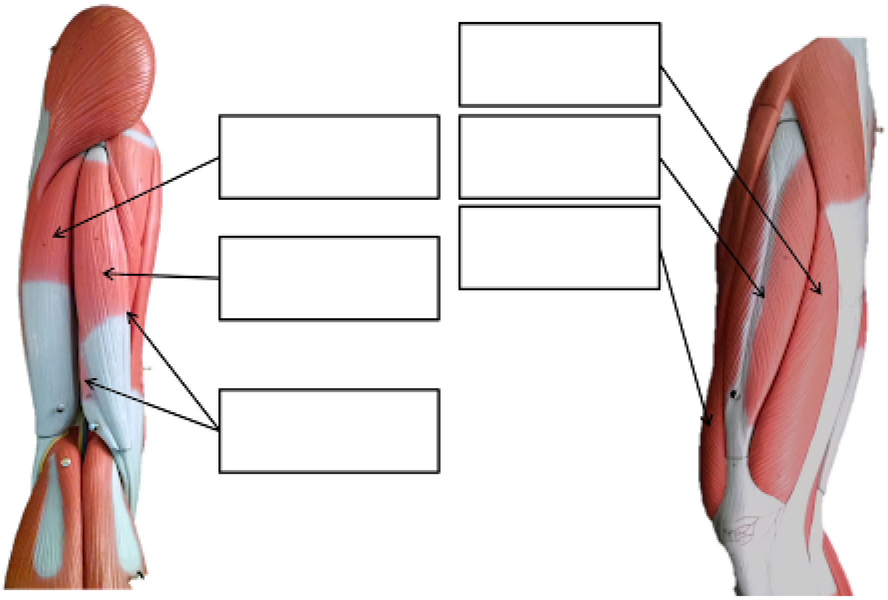
Torso and Leg



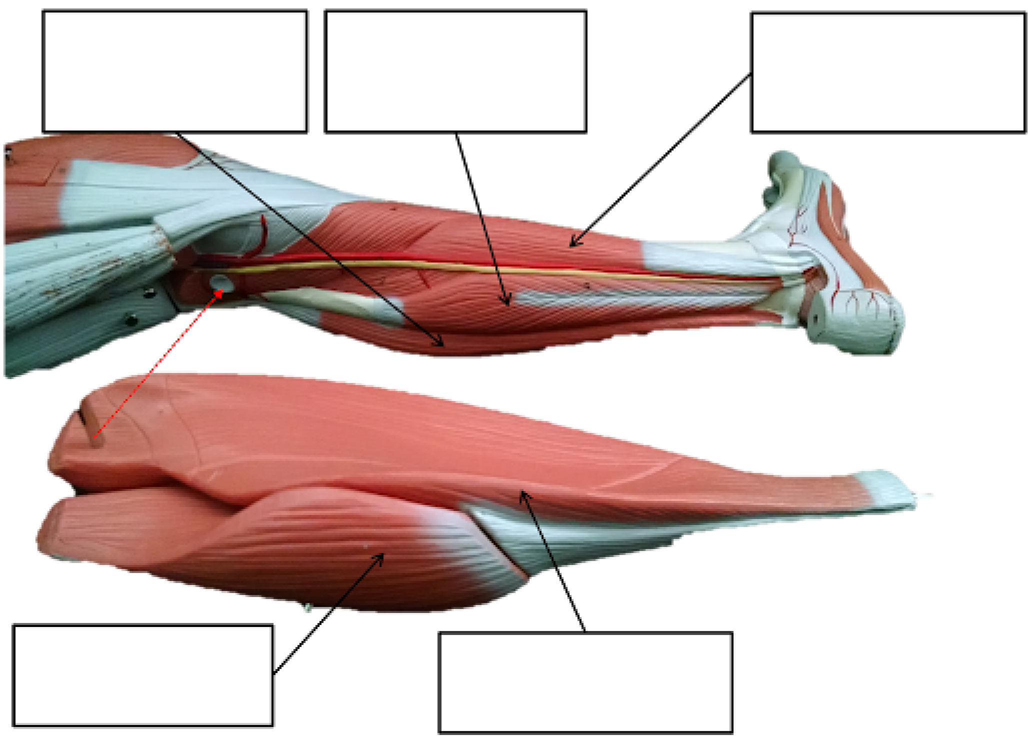
Leg



Leg



Leg



List of Muscles to Identify in the lab using Anatomical Models

Muscles of facial expression

Name	Action	Origin	Insertion
Frontalis	Raises eyebrows, wrinkles forehead	Frontal Bone	Skin of the brow
Occipitalis	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

Name	Action	Origin	Insertion
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

Thoracic & shoulder muscles

Name	Action	Origin	Insertion
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

Name	Action	Origin	Insertion
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

Name	Action	Origin	Insertion
Infraspinatus	Laterally rotates shoulder	Scapula	Humerus
Supraspinatus	Abducts shoulder	Scapula	Humerus
Subscapularis	Medially rotates shoulder	Scapula	Humerus
Teres minor	Laterally rotates shoulder	Scapula	Humerus

Forearm movers

Name	Action	Origin	Insertion
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

Muscles of the leg & thigh

Name	Action	Origin	Insertion
Psoas major	Flexes thigh at hip and 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

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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THE NERVOUS TISSUE

Neuron Anatomy & Physiology

Introduction

The nervous system is one of the two major communicating systems of the body. It works together with the endocrine system to control, regulate, all system in the body to maintain homeostasis.

It is the center of all mental activity including thought, learning, and memory. Through its receptors, the nervous system keeps us in touch with our internal and external environments.

The nervous system is composed of organs, principally the brain, spinal cord, nerves, and ganglia. These, in turn, consist of various tissues, including nervous, epithelial, and connective tissue. Together these carry out the complex activities of the nervous system.

The activities of the nervous system can be grouped as three general overlapping functions; sensory, integrative and motor.

The nervous tissue is composed of two types of cells, neurons (functional units, capable of transmitting an action potential) and neuroglia that support and nourish the neurons, usually they are found in a ratio of 1:9 (neuron:neuroglia).

These cells are contained in the organs of the nervous system.

The Central Nervous System (CNS) is composed of the brain and the spinal cord, and the Peripheral Nervous System (PNS) is composed of all tissue located outside of the CNS, cranial and peripheral nerves.

Objectives:

1. Distinguish functions of the neurons and neuroglia
2. Identify the anatomical characteristics of a neuron
3. Classify neurons based on structure and function
4. Describe the structure of a nerve and the connective tissue coverings

Procedures

A. Gross Anatomy of a Neuron

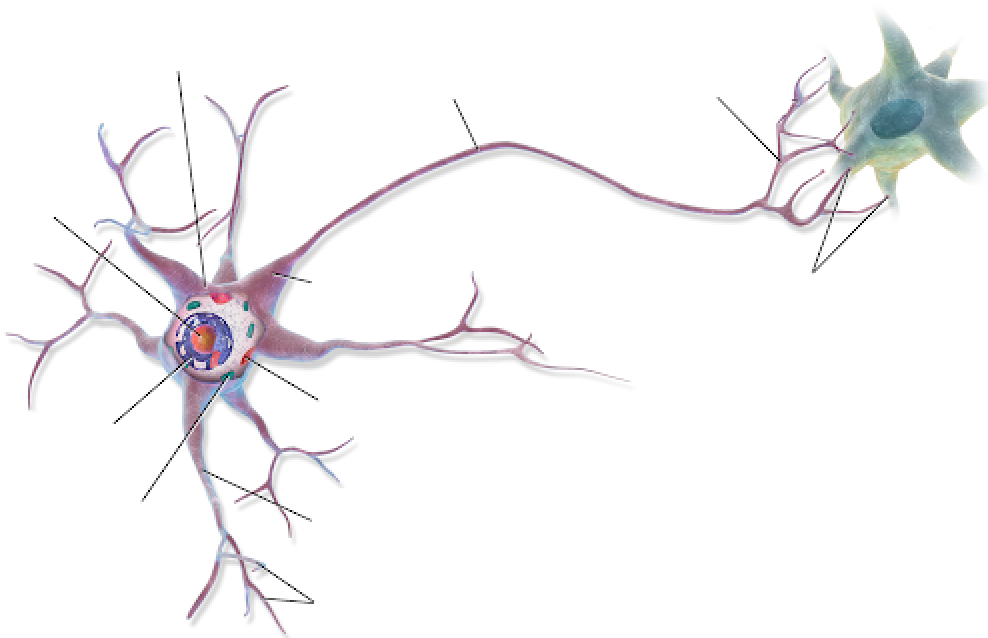
Use a 3D model of a neuron (Somso, BS35) to identify the following structures:

1. Perikaryon (nerve cell)
2. Peripheral Nerve with sheaths
    1. Neurite cone
    2. Nucleus of nerve cell with nucleolus
    3. BS35: Endoplasmic reticulum, BS35-1 Nissl's granules
    4. Neurofibrils
    5. Synaptic terminals
    6. Neuroaxon
    7. Schwan cells with nucleus
    8. Schwan sheath
    9. Linked Schwan cells at node of Ranvier
    10. Mitochondria
    11. Medullary myelin sheath
    12. Perineural sheath of connective tissue
    13. Mesaxon
    14. Dendrites
    15. Lysosome
    16. Neurotubules
    17. Golgi Apparatus

Use the following diagram to label and draw any missing structure of a neuronal network

1. Cell body
2. Nucleus
3. Nissl bodies
4. Mitochondria
5. Axon Hilock
6. Dendrites
7. Axons
8. Myelin sheath
9. Node of Ranvier

10. Internodes
11. Synaptic terminals – Telodendria
12. Pre-synaptic cell
13. Post-synaptic cell
14. Synaptic cleft



B. Microscopic Anatomy of a Neuron

Use the slides or a virtual microscope (link provided) to draw and label the microscopic structures of a neuron:

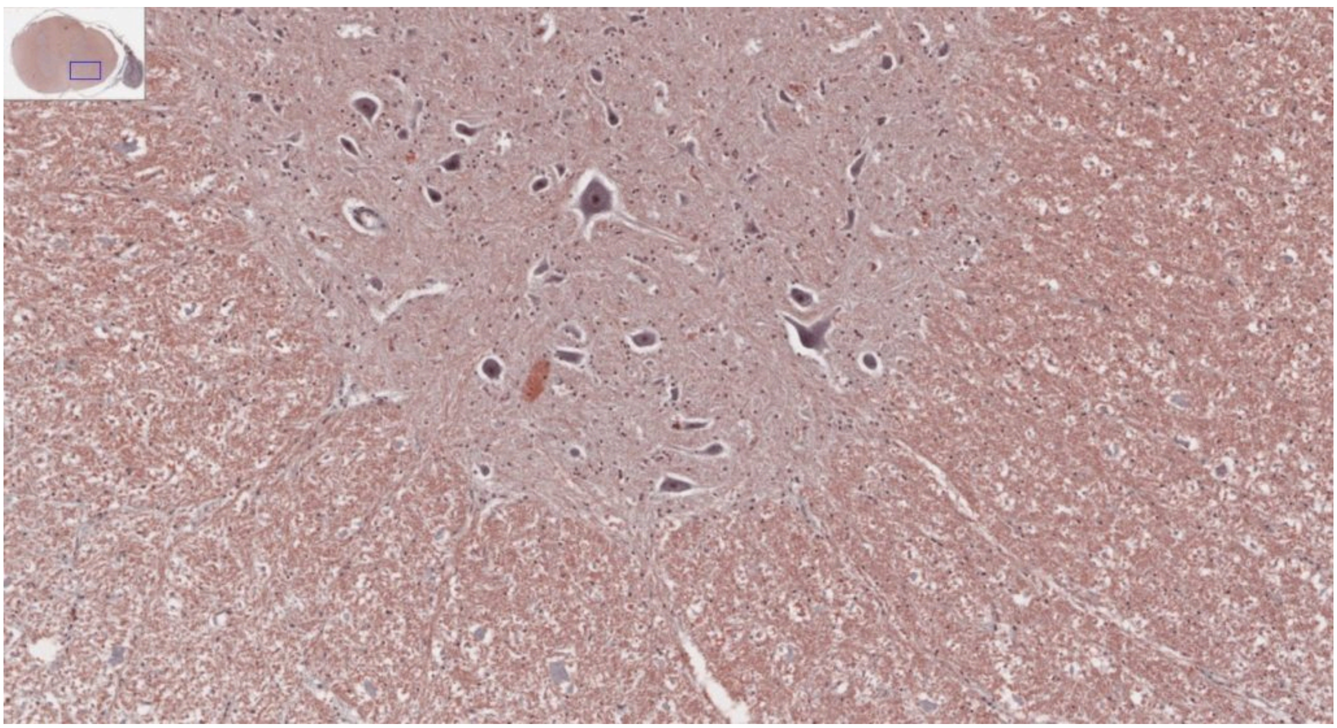
- Motor neuron
- Spinal cord smear

Find/label the following structures:

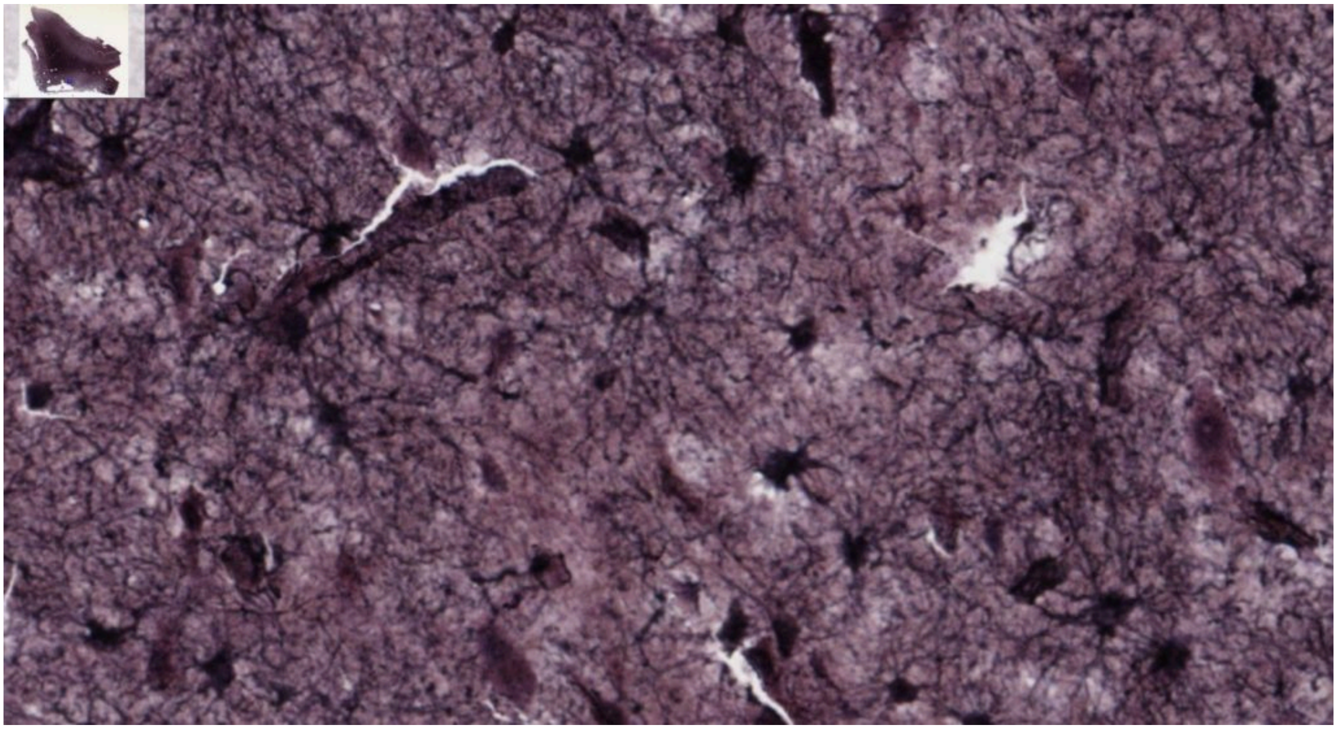
- Motor neurons, cell body, nucleus, dendrites, axons and Nissl bodies (this may not be visible in all slides)

[Virtual Microscopy, UM Virtual Microscope](#) or QR code below.

- Slide: # 65-1 Spinal cord and dorsal root ganglion, H&E, 20X (white matter [pinkish], gray matter [grayish], dorsal horn, ventral horn, ventral horn cells [large motor neuron cell bodies], neuropil, dorsal root ganglion [at right], sensory neurons, capsular cells, sensory axon tracts).



- Neuroglia cell bodies (Astrocytes), Slide # 13270, Astrocytes, Gold-staining



C. Neuron Classification

Draw, label and describe the function of the following types of neurons:

1. Multipolar

2. Bipolar

3. Unipolar

D. Structure of a nerve

Using your textbook and/or the internet, draw and name the three connective tissue coverings of a nerve.

Identify & label the parts of a Synapse.

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THE NERVOUS SYSTEM ANATOMY

The Brain and Cranial Nerves

Objectives

1. Identify the three meninges that cover the brain.
2. Identify the major regions of the brain and the basic function of each region.
3. Describe the vessels that supply the CNS.
4. Name the components of the ventricular system and the regions of the brain in which each is located.
5. Explain the production of cerebrospinal fluid and its flow through the ventricles.
6. Identify and describe the function of the cranial nerves.

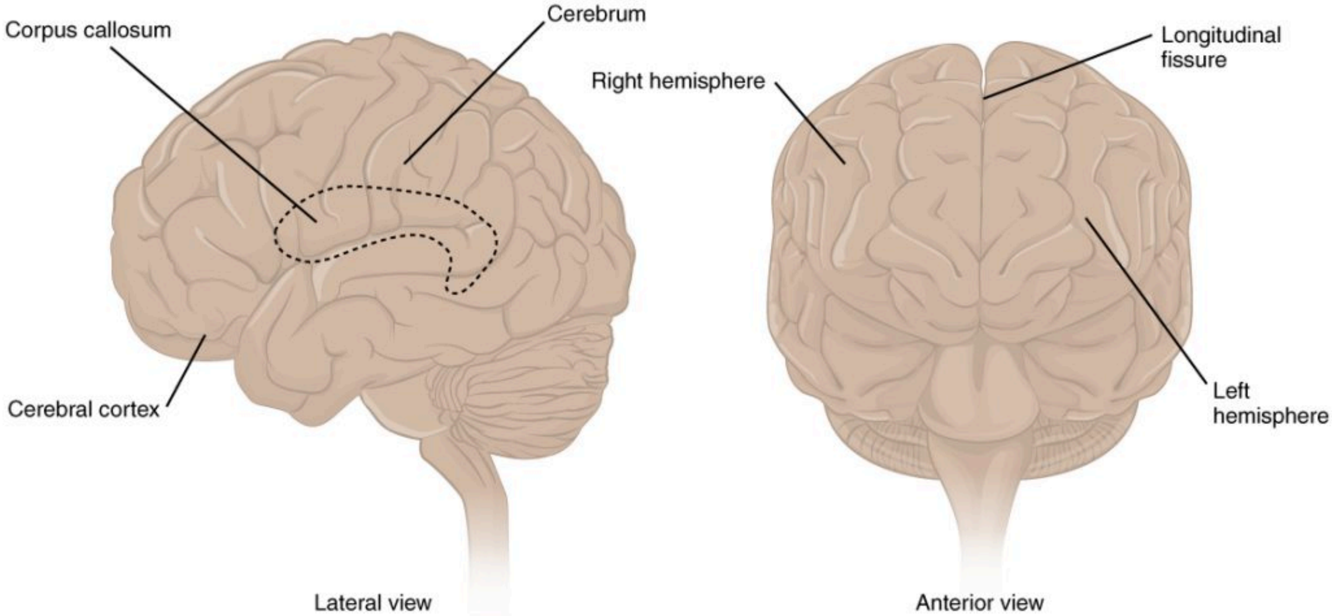
The Central Nervous System (CNS) is composed of the brain and the spinal cord. The adult brain has two hemispheres attached by a structure called the corpus callosum and it is further described by four major regions: the cerebrum, the diencephalon, the brainstem, and the cerebellum. As the brain extends posteriorly and passes through the foramen magnum becomes the spinal cord.

Regulation of homeostasis is governed by two systems: namely, the Nervous system and the Endocrine system. They work in association to coordinate all functions of our organ systems. The nervous system sends electrical signals (action potentials) between cells and the endocrine system chemical signals (hormones) via the circulatory system.

Let’s describe the regions of the brain and its functions.

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. 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.



The Cerebrum: The cerebrum is a large component of the CNS in humans, and the most obvious aspect of it is the folded surface called the cerebral cortex.

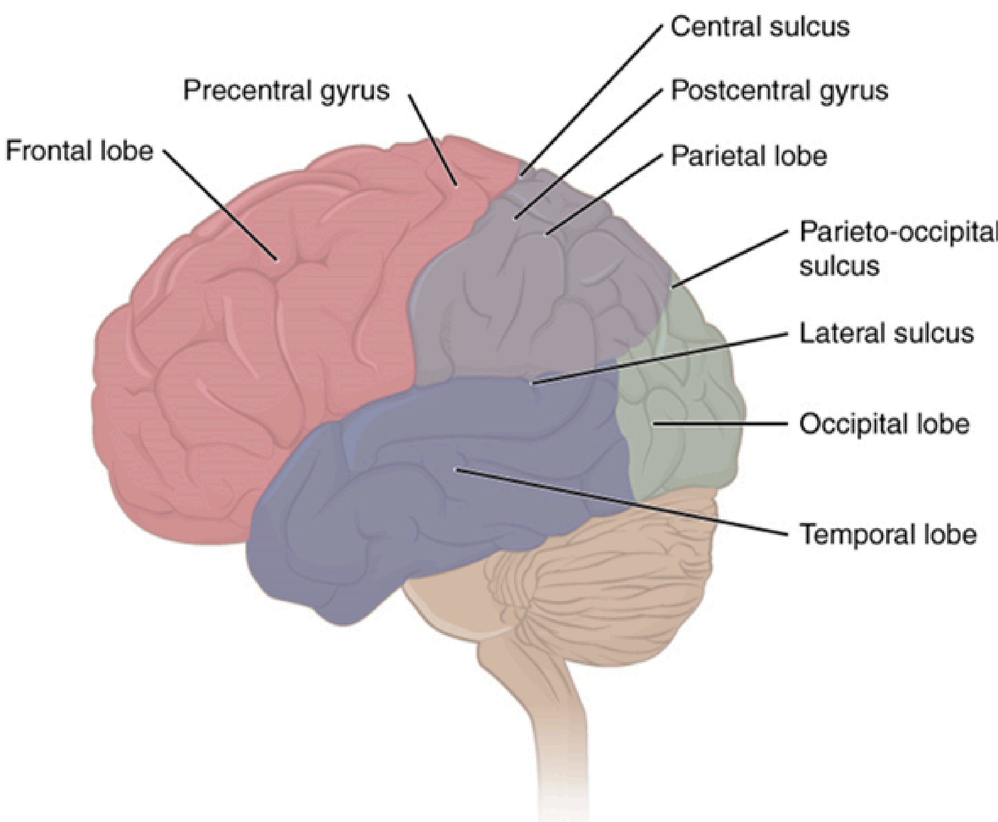
Many of the higher neurological functions, such as memory, emotion, and consciousness, are the result of cerebral function. The complexity of the cerebrum is different across vertebrate species. The cerebrum of the most primitive vertebrates is not much more than the connection for the sense of smell. In mammals, the cerebrum comprises the outer gray matter that is the cortex (from the Latin word meaning "bark of a tree") and several deep nuclei that belong to three important functional groups. The basal nuclei are responsible for cognitive processing, the most important function being that associated with planning movements. The basal forebrain contains nuclei that are important in learning and memory. The limbic cortex is the region of the cerebral cortex that is part of the limbic system, a collection of structures involved in emotion, memory, and behavior.

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. 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.



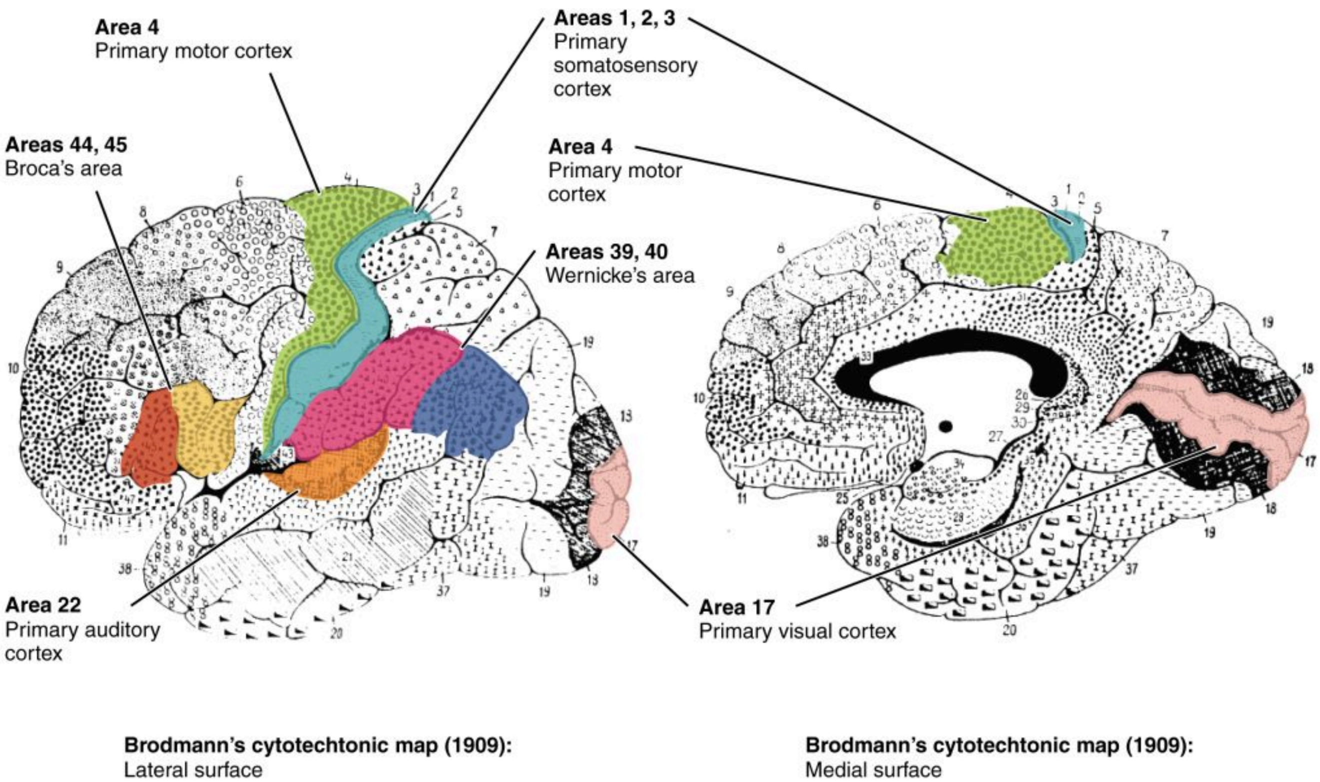
Lobes of the Cerebral Cortex: The cerebral cortex is divided into four lobes. Extensive folding increases the surface area available for cerebral functions.

Different regions of the cerebral cortex can be associated with particular functions, a concept known as localization of function. In the early 1900s, a German neuroscientist named Korbinian Brodmann performed an extensive study of the microscopic anatomy—the cytoarchitecture—of the cerebral cortex and divided the cortex into 52 separate regions on the basis of the histology of the cortex. His work resulted in a system of classification known as Brodmann's areas, which is still used today to describe the anatomical distinctions within the cortex. The results from Brodmann's work on the anatomy align very well with the functional differences within the cortex. Areas 17 and 18 in the occipital lobe are responsible for primary visual perception. That visual information is complex, so it is processed in the temporal and parietal lobes as well.

The temporal lobe is associated with primary auditory sensation, known as Brodmann's areas 41 and 42 in the superior temporal lobe. Because regions of the temporal lobe are part of the limbic system, memory is an important function associated with that lobe. Memory is essentially a sensory function; memories are recalled sensations such as the smell of Mom's baking or the sound of a barking dog. Even memories of movement are really the memory of sensory feedback from those movements, such as stretching muscles or the movement of the skin around a joint. Structures in the temporal lobe are responsible for establishing long-term memory, but the ultimate location of those memories is usually in the region in which the sensory perception was processed.

The main sensation associated with the parietal lobe is somatosensation, meaning the general sensations associated with the body. Posterior to the central sulcus is the postcentral gyrus, the primary somatosensory cortex, which is identified as Brodmann's areas 1, 2, and 3. All of the tactile senses are processed in this area, including touch, pressure, tickle, pain, itch, and vibration, as well as more general senses of the body such as proprioception and kinesthesia, which are the senses of body position and movement, respectively.

Anterior to the central sulcus is the frontal lobe, which is primarily associated with motor functions. The precentral gyrus is the primary motor cortex. Cells from this region of the cerebral cortex are the upper motor neurons that instruct cells in the spinal cord and brainstem (lower motor neurons) to move skeletal muscles. Anterior to this region are a few areas that are associated with planned movements. The premotor area is responsible for storing learned movement algorithms which are instructions for complex movements. Different algorithms activate the upper motor neurons in the correct sequence when a complex motor activity is performed. The frontal eye fields are important in eliciting scanning eye movements and in attending to visual stimuli. Broca's area is responsible for the production of language, or controlling movements responsible for speech; in the vast majority of people, it is located only on the left side. Anterior to these regions is the prefrontal lobe, which serves cognitive functions that can be the basis of personality, short-term memory, and consciousness. The prefrontal lobotomy is an outdated mode of treatment for personality disorders (psychiatric conditions) that profoundly affected the personality of the patient.



Brodmann's Areas of the Cerebral Cortex: Brodmann mapping of functionally distinct regions of the cortex was based on its cytoarchitecture at a microscopic level.

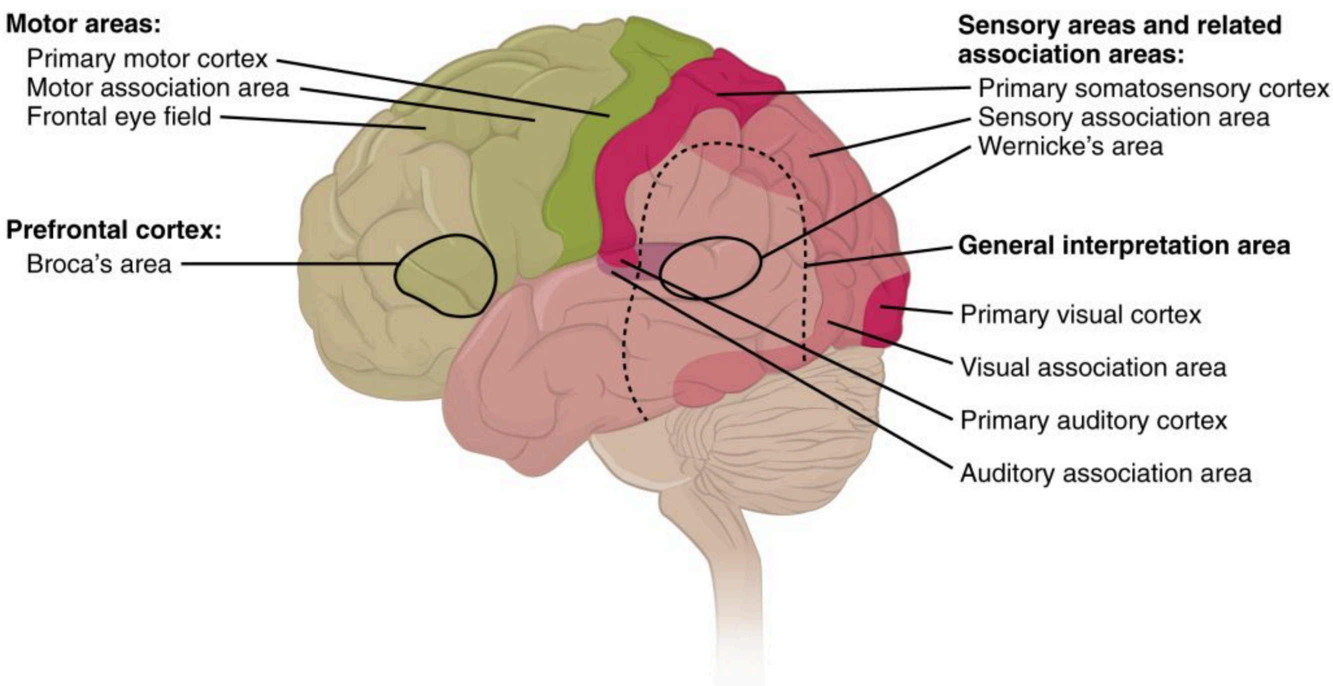
Area 17, as Brodmann described it, is also known as the primary visual cortex. Adjacent to that are areas 18 and 19, which constitute subsequent regions of visual processing. Area 22 is the primary auditory cortex, and it is followed by area 23, which further processes auditory information. Area 4 is the primary motor cortex in the precentral gyrus, whereas area 6 is the premotor cortex. These areas suggest some specialization within the cortex for functional processing, both in sensory and motor regions. The fact that Brodmann's areas correlate so closely to functional localization in the cerebral cortex demonstrates the strong link between structure and function in these regions.

Areas 1, 2, 3, 4, 17, and 22 are each described as primary cortical areas. The adjoining regions are each referred to as association areas. Primary areas are where sensory information is initially received from the thalamus for conscious perception, or—in the case of the primary motor cortex—where descending commands are sent down to the brainstem or spinal cord to execute movements.

Functions of the Cerebral Cortex

The cerebrum is the seat of many of the higher mental functions, such as memory and learning, language, and conscious perception, which are the subjects of subtests of the mental status exam. The cerebral cortex is the thin layer of gray matter on the outside of the cerebrum. It is approximately a millimeter thick in most regions and highly folded to fit within the limited space of the cranial vault. These higher functions are distributed across various regions of the cortex, and specific locations can be said to be responsible for particular functions. There is a limited set of regions, for example, that are involved in language function, and they can be subdivided on the basis of the particular part of language function that each governs.

A number of other regions, which extend beyond these primary or association areas of the cortex, are referred to as integrative areas. These areas are found in the spaces between the domains for particular sensory or motor functions, and they integrate multisensory information, or process sensory or motor information in more complex ways. Consider, for example, the posterior parietal cortex that lies between the somatosensory cortex and visual cortex regions. This has been ascribed to the coordination of visual and motor functions, such as reaching to pick up a glass. The somatosensory function that would be part of this is the proprioceptive feedback from moving the arm and hand. The weight of the glass, based on what it contains, will influence how those movements are executed.



Types of Cortical Areas: The cerebral cortex can be described as containing three types of processing regions: primary, association, and integration areas. The primary cortical areas are where sensory information is initially processed, or where motor commands emerge to go to the brainstem or spinal cord. Association areas are adjacent to primary areas and further process the modality-specific input. Multimodal integration areas are found where the modality-specific regions meet; they can process multiple modalities together or different modalities on the basis of similar functions, such as spatial processing in vision or somatosensation.

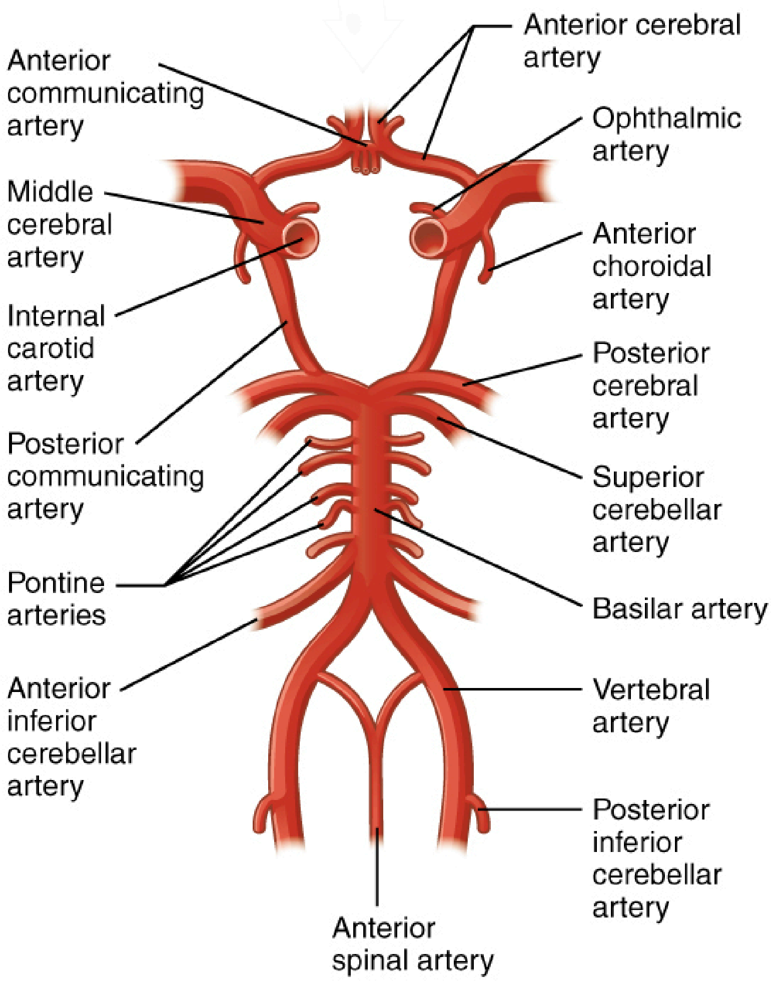
Blood Supply to the Brain

A lack of oxygen to the CNS can be devastating, and the cardiovascular system has specific regulatory reflexes to ensure that the blood supply is not interrupted. There are multiple routes for blood to get into the CNS, with specializations to protect that blood supply and to maximize the ability of the brain to get an uninterrupted perfusion.

Arterial Supply

The major artery carrying recently oxygenated blood away from the heart is the aorta. The very first branches off the aorta supply the heart with nutrients and oxygen. The next branches give rise to the common carotid arteries, which further branch into the internal carotid arteries. The external carotid arteries supply blood to the tissues on the surface of the cranium. The bases of the common carotids contain stretch receptors that immediately respond to the drop in blood pressure upon standing. The orthostatic reflex is a reaction to this change in body position, so that blood pressure is maintained against the increasing effect of gravity (orthostatic means “standing up”). Heart rate increases—a reflex of the sympathetic division of the autonomic nervous system—and this raises blood pressure.

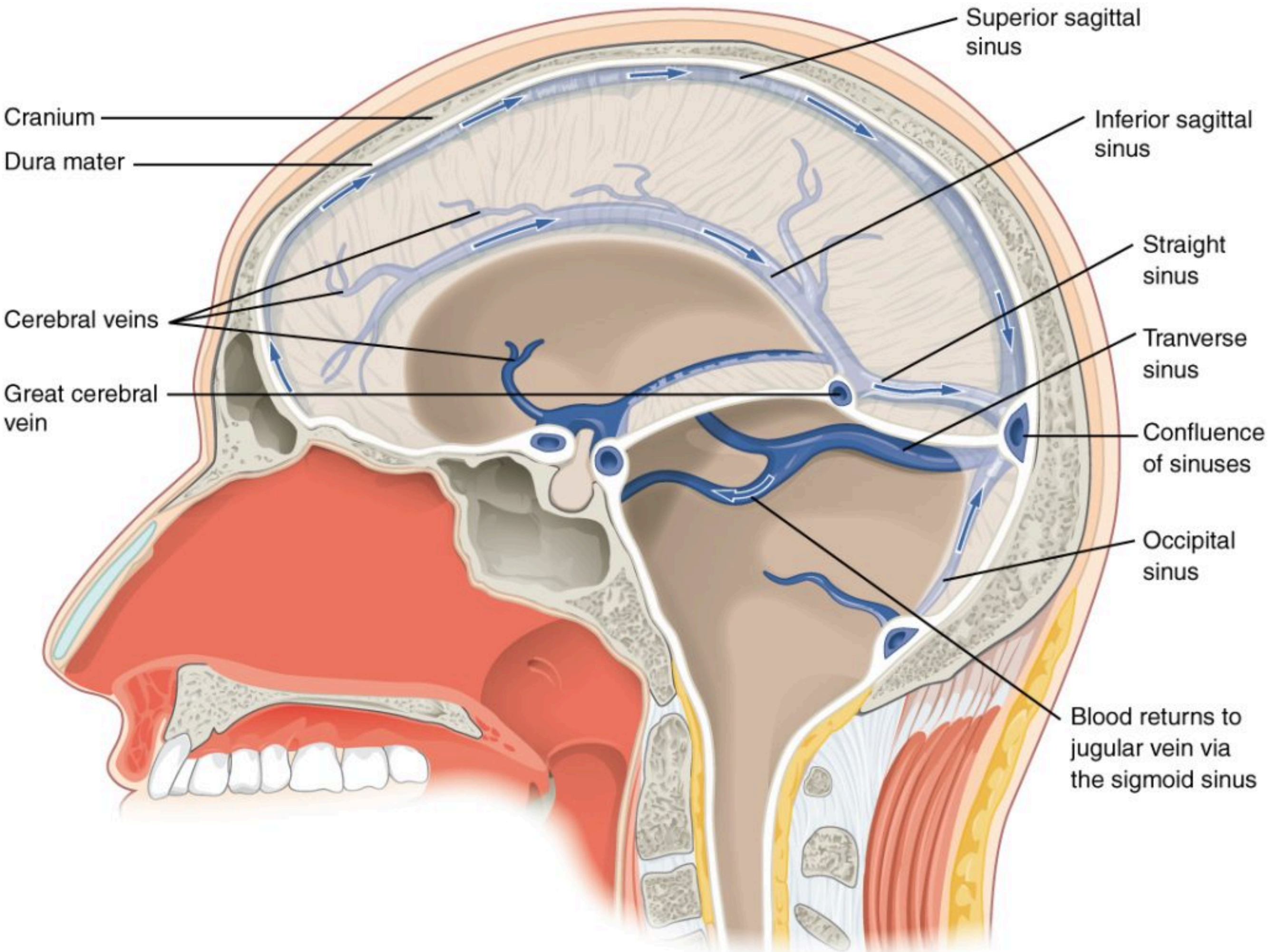
The internal carotid artery enters the cranium through the carotid canal in the temporal bone. A second set of vessels that supply the CNS are the vertebral arteries, which are protected as they pass through the neck region by the transverse foramina of the cervical vertebrae. The vertebral arteries enter the cranium through the foramen magnum of the occipital bone. Branches off the left and right vertebral arteries merge into the anterior spinal artery supplying the anterior aspect of the spinal cord, found along the anterior median fissure. The two vertebral arteries then merge into the basilar artery, which gives rise to branches to the brainstem and cerebellum. The left and right internal carotid arteries and branches of the basilar artery all become the circle of Willis, a confluence of arteries that can maintain perfusion of the brain even if narrowing or a blockage limits flow through one part.



Circle of Willis: The blood supply to the brain enters through the internal carotid arteries and the vertebral arteries, eventually giving rise to the circle of Willis.

Venous Return

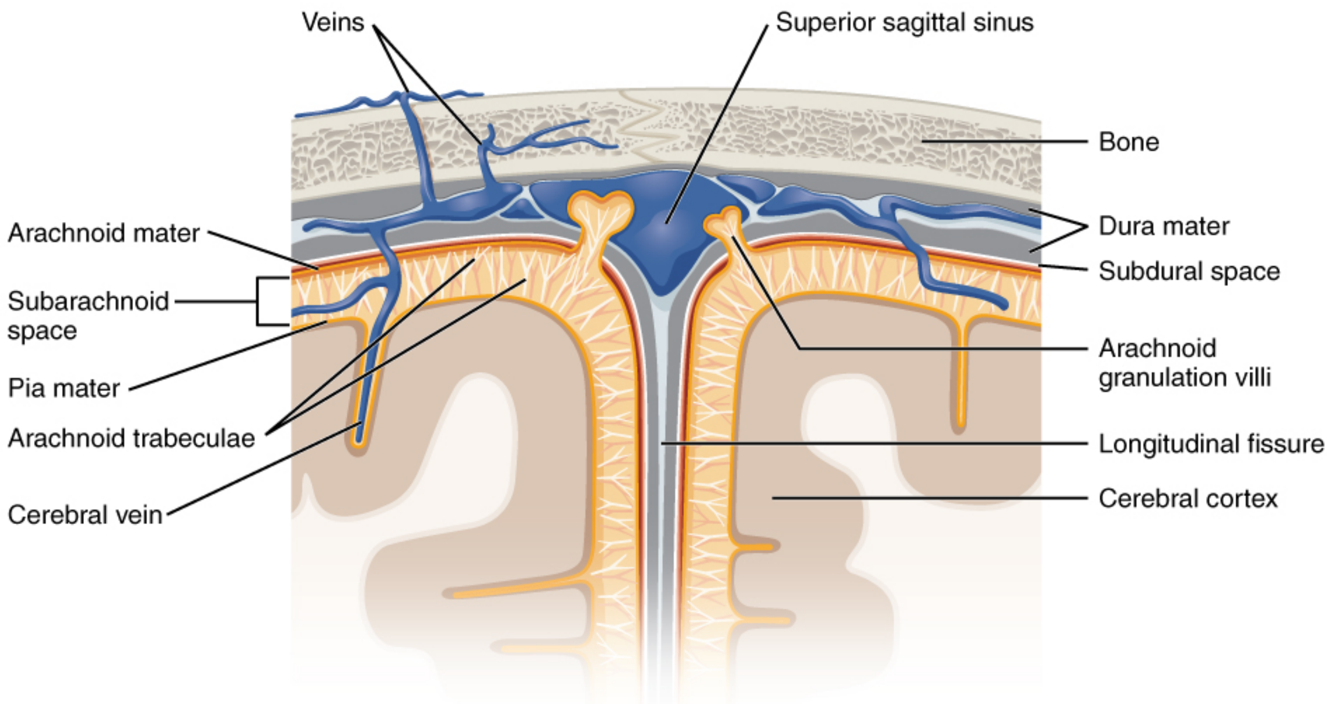
After passing through the CNS, blood returns to the circulation through a series of dural sinuses and veins. The superior sagittal sinus runs in the groove of the longitudinal fissure, where it absorbs CSF from the meninges. The superior sagittal sinus drains to the confluence of sinuses, along with the occipital sinuses and straight sinus, to then drain into the transverse sinuses. The transverse sinuses connect to the sigmoid sinuses, which then connect to the jugular veins. From there, the blood continues toward the heart to be pumped to the lungs for reoxygenation.



Dural Sinuses and Veins: Blood drains from the brain through a series of sinuses that connect to the jugular veins.

Protective Coverings of the Brain and Spinal Cord

The outer surface of the CNS is covered by a series of membranes composed of connective tissue called the meninges, which protect the brain. The dura mater is a thick fibrous layer and a strong protective sheath over the entire brain and spinal cord. It is anchored to the inner surface of the cranium and vertebral cavity. The arachnoid mater is a membrane of thin fibrous tissue that forms a loose sac around the CNS. Beneath the arachnoid is a thin, filamentous mesh called the arachnoid trabeculae, which looks like a spider web, giving this layer its name. Directly adjacent to the surface of the CNS is the pia mater, a thin fibrous membrane that follows the convolutions of gyri and sulci in the cerebral cortex and fits into other grooves and indentations.



Meningeal Layers of Superior Sagittal Sinus: The layers of the meninges in the longitudinal fissure of the superior sagittal sinus are shown, with the dura mater adjacent to the inner surface of the cranium, the pia mater adjacent to the surface of the brain, and the arachnoid and subarachnoid space between them. An arachnoid villus is shown emerging into the dural sinus to allow CSF to filter back into the blood for drainage.

Dura Mater

Like a thick cap covering the brain, the dura mater is a tough outer covering. The name comes from the Latin for "tough mother" to represent its physically protective role. It encloses the entire CNS and the major blood vessels that enter the cranium and vertebral cavity. It is directly attached to the inner surface of the bones of the cranium and to the very end of the vertebral cavity.

There are infoldings of the dura that fit into large crevasses of the brain. Two infoldings go through the midline separations of the cerebrum and cerebellum; one forms a shelf-like tent between the occipital lobes of the cerebrum and the cerebellum, and the other surrounds the pituitary gland. The dura also surrounds and supports the venous sinuses.

Arachnoid Mater

The middle layer of the meninges is the arachnoid, named for the spider-web–like trabeculae between it and the pia mater. The arachnoid defines a sac-like enclosure around the CNS. The trabeculae are found in the subarachnoid space, which is filled with circulating CSF. The arachnoid emerges into the dural sinuses as the arachnoid granulations, where the CSF is filtered back into the blood for drainage from the nervous system.

The subarachnoid space is filled with circulating CSF, which also provides a liquid cushion to the brain and spinal cord. Similar to clinical blood work, a sample of CSF can be withdrawn to find chemical evidence of neuropathology or metabolic traces of the biochemical functions of nervous tissue.

Pia Mater

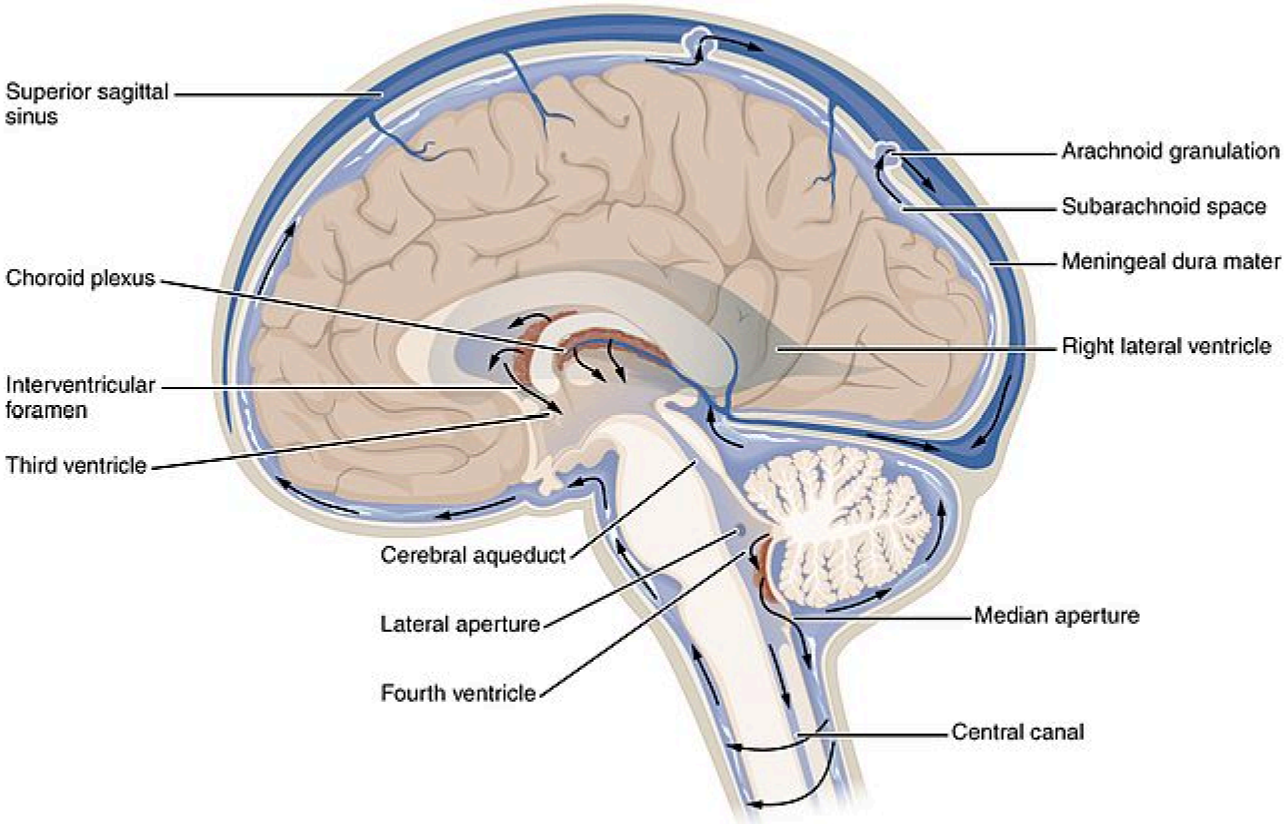
The outer surface of the CNS is covered in the thin fibrous membrane of the pia mater. It is thought to have a continuous layer of cells providing a fluid-impermeable membrane. The name pia mater comes from the Latin for "tender mother," suggesting the thin membrane is a gentle covering for the brain. The pia extends into every convolution of the CNS, lining the inside of the sulci in the cerebral and cerebellar cortices. At the end of the spinal cord, a thin filament extends from the inferior end of CNS at the upper lumbar region of the vertebral column to the sacral end of the vertebral column. Because the spinal cord does not extend through the lower lumbar region of the vertebral column, a needle can be inserted through the dura and arachnoid layers to withdraw CSF. This procedure is called a lumbar puncture and avoids the risk of damaging the central tissue of the spinal cord. Blood vessels that are nourishing the central nervous tissue are between the pia mater and the nervous tissue.

The Ventricular System

Cerebrospinal fluid (CSF) circulates throughout and around the CNS. In other tissues, water and small molecules are filtered through capillaries as the major contributor to the interstitial fluid. In the brain, CSF is produced in special structures to perfuse through the nervous tissue of the CNS and is continuous with the interstitial fluid. Specifically, CSF circulates to remove metabolic wastes from the interstitial fluids of nervous tissues and return them to the blood stream. The ventricles are the open spaces within the brain where CSF circulates. In some of these spaces, CSF is produced by filtering of the blood that is performed by a specialized membrane known as a choroid plexus. The CSF circulates through all of the ventricles to eventually emerge into the subarachnoid space where it will be reabsorbed into the blood.

The Ventricles

There are four ventricles within the brain, all of which developed from the original hollow space within the neural tube, the central canal. The first two are named the lateral ventricles and are deep within the cerebrum. These ventricles are connected to the third ventricle by two openings called the interventricular foramina. The third ventricle is the space between the left and right sides of the diencephalon, which opens into the cerebral aqueduct that passes through the midbrain. The aqueduct opens into the fourth ventricle, which is the space between the cerebellum and the pons and upper medulla.



Cerebrospinal Fluid Circulation: The choroid plexus in the four ventricles produce CSF, which is circulated through the ventricular system and then enters the subarachnoid space through the median and lateral apertures. The CSF is then reabsorbed into the blood at the arachnoid granulations, where the arachnoid membrane emerges into the dural sinuses.

Cranial Nerves

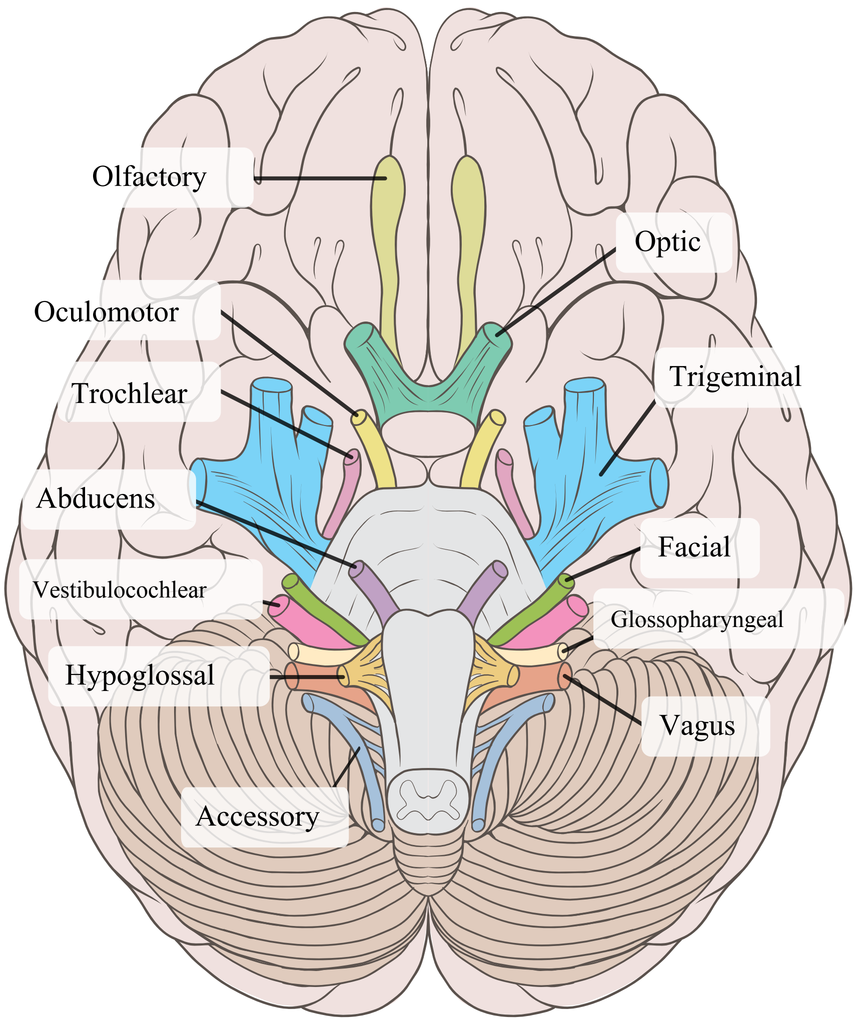
Cranial nerves are the nerves that emerge directly from the brain (including the brainstem), in contrast to spinal nerves (which emerge from segments of the spinal cord). Ten of the cranial nerves originate in the brainstem. Cranial nerves relay information between the brain and parts of the body, primarily to and from regions of the head and neck.

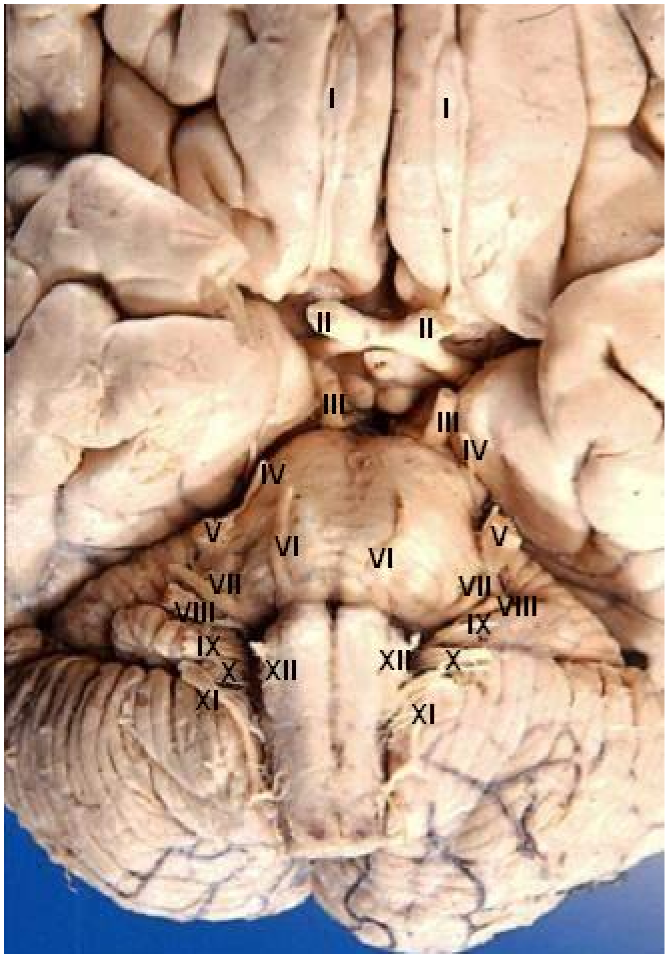
Spinal nerves emerge sequentially from the spinal cord with the spinal nerve closest to the head (C1) emerging in the space above the first cervical vertebra. The cranial nerves, however, emerge from the central nervous system above this level. Each cranial nerve is paired and is present on both sides. Depending on definition in humans there are twelve or thirteen cranial nerves pairs, which are assigned Roman numerals I–XII, sometimes also including cranial nerve zero. The numbering of the cranial nerves is based on the order in which they emerge from the brain, front to back (brainstem).

The, olfactory nerves (I) and optic nerves (II) emerge from the cerebrum or forebrain, and the remaining ten pairs arise from the brainstem, which is the lower part of the brain.

The cranial nerves are considered components of the peripheral nervous system (PNS), although on a structural level the olfactory (I), optic (II), and trigeminal (V) nerves are more accurately considered part of the central nervous system (CNS).

Humans are considered to have twelve pairs of cranial nerves (I–XII). They are: the olfactory nerve (I), the optic nerve (II), oculomotor nerve (III), trochlear nerve (IV), trigeminal nerve (V), abducens nerve (VI), facial nerve (VII), vestibulocochlear nerve (VIII), glossopharyngeal nerve (IX), vagus nerve (X), accessory nerve (XI), and hypoglossal nerve (XII).




I
I
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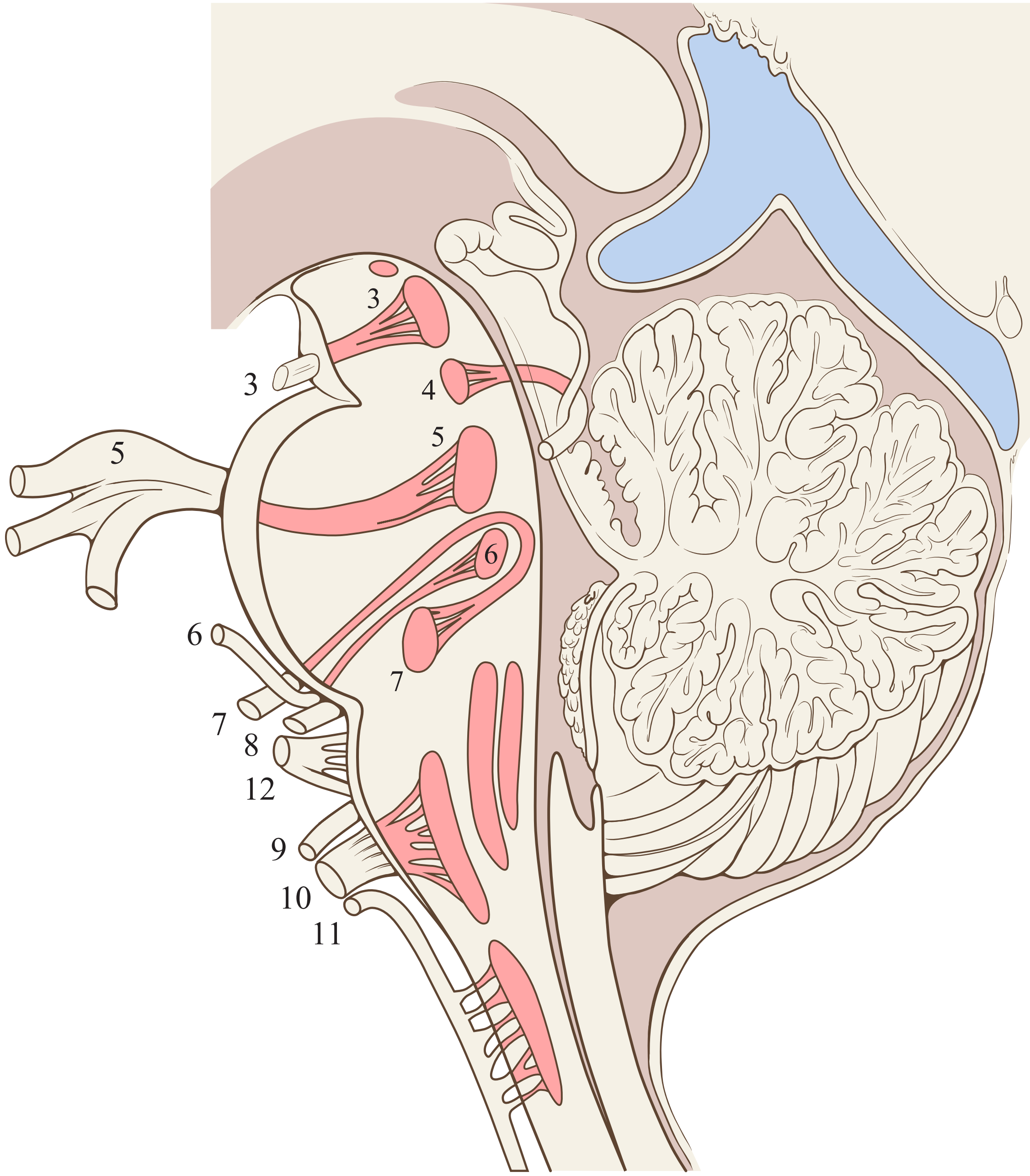


The brainstem, with cranial nerve nuclei and tracts shown in red

The Spinal Cord & Spinal Nerves

Objectives

1. Recognize and describe the major surface features of the spinal cord & minges.
2. Recognize and describe the sectional anatomy of the spinal cord.
3. Recognize and describe the organization of spinal nerves.

The Spinal Cord

The spinal cord is a long, thin, tubular structure made up of nervous tissue, which extends from the medulla oblongata in the brainstem to the lumbar region of the vertebral column. It encloses the central canal of the spinal cord, which contains cerebrospinal fluid. The brain and spinal cord together make up the central nervous system (CNS). In humans, the spinal cord begins at the occipital bone, passing through the foramen magnum and entering the spinal canal at the beginning of the cervical vertebrae. The spinal cord extends down to between the first and second lumbar vertebrae, where it ends. The enclosing bony vertebral column protects the relatively shorter spinal cord. It is around 45 cm (18 in) in men and around 43 cm (17 in) long in women. The diameter of the spinal cord ranges from 13 mm (1⁄2 in) in the cervical and lumbar regions to 6.4 mm (1⁄4 in) in the thoracic area.

The spinal cord functions primarily in the transmission of nerve signals from the motor cortex to the body, and from the afferent fibers of the sensory neurons to the sensory cortex. It is also a center for coordinating many reflexes and contains reflex arcs that can independently control reflexes. It is also the location of groups of spinal interneurons that make up the neural circuits known as central pattern generators. These circuits are responsible for controlling motor instructions for rhythmic movements such as walking.

Structure

The spinal cord is the main pathway for information connecting the brain and peripheral nervous system. Much shorter than its protecting spinal column, the human spinal cord originates in the brainstem, passes through the foramen magnum, and continues through to the conus medullaris near the second lumbar vertebra before terminating in a fibrous extension known as the filum terminale.

It is about 45 cm (18 in) long in men and around 43 cm (17 in) in women, ovoid-shaped, and is enlarged in the cervical and lumbar regions. The cervical enlargement, stretching from the C5 to T1 vertebrae, is where sensory input comes from and motor output goes to the arms and trunk. The lumbar enlargement, located between L1 and S3, handles sensory input and motor output coming from and going to the legs.

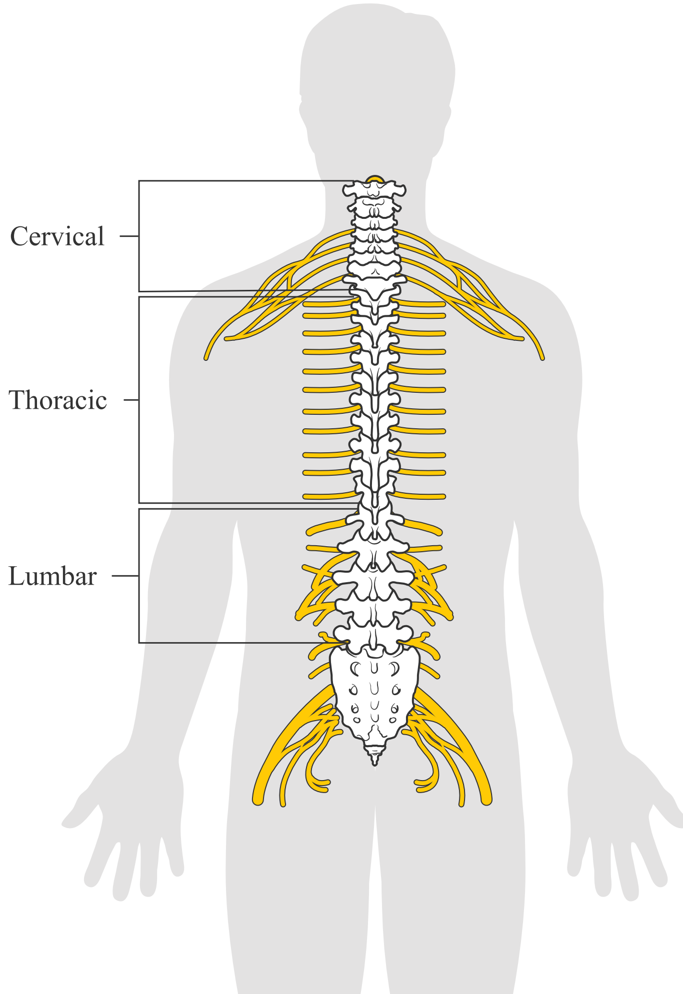
The spinal cord is continuous with the caudal portion of the medulla, running from the base of the skull to the body of the first lumbar vertebra. It does not run the full length of the vertebral column in adults. It is made of 31 segments from which branch one pair of sensory nerve roots and one pair of motor nerve roots. The nerve roots then merge into bilaterally symmetrical pairs of spinal nerves. The peripheral nervous system is made up of these spinal roots, nerves, and ganglia.

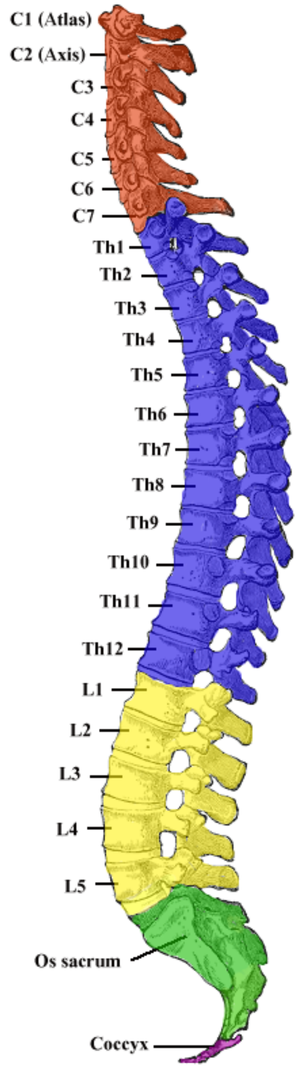
The dorsal roots are afferent fascicles, receiving sensory information from the skin, muscles, and visceral organs to be relayed to the brain. The roots terminate in dorsal root ganglia, which are composed of the cell bodies of the corresponding neurons. Ventral roots consist of efferent fibers that arise from motor neurons whose cell bodies are found in the ventral (or anterior) gray horns of the spinal cord.

The spinal cord (and brain) are protected by three layers of tissue or membranes called meninges, that surround the canal. The dura mater is the outermost layer, and it forms a tough protective coating. Between the dura mater and the surrounding bone of the vertebrae is a space called the epidural space. The epidural space is filled with adipose tissue, and it contains a network of blood vessels. The arachnoid mater, the middle protective layer, is named for its open, spiderweb-like appearance. The space between the arachnoid and the underlying pia mater is called the subarachnoid space. The subarachnoid space contains cerebrospinal fluid (CSF), which can be sampled with a lumbar puncture, or "spinal tap" procedure. The delicate pia mater, the innermost protective layer, is tightly associated with the surface of the spinal cord. The cord is stabilized within the dura mater by the connecting denticulate ligaments, which extend from the enveloping pia mater laterally between the dorsal and ventral roots. The dural sac ends at the vertebral level of the second sacral vertebra.

In cross-section, the peripheral region of the cord contains neuronal white matter tracts containing sensory and motor axons. Internal to this peripheral region is the grey matter, which contains the nerve cell bodies arranged in the three grey columns that give the region its butterfly-shape. This central region surrounds the central canal, which is an extension of the fourth ventricle and contains cerebrospinal fluid.

The spinal cord is elliptical in cross section, being compressed dorsolaterally. Two prominent grooves, or sulci, run along its length. The posterior median sulcus is the groove in the dorsal side, and the anterior median fissure is the groove in the ventral side.


Cervical
Thoracic
Lumbar


C1 (Atlas)
C2 (Axis)
C3
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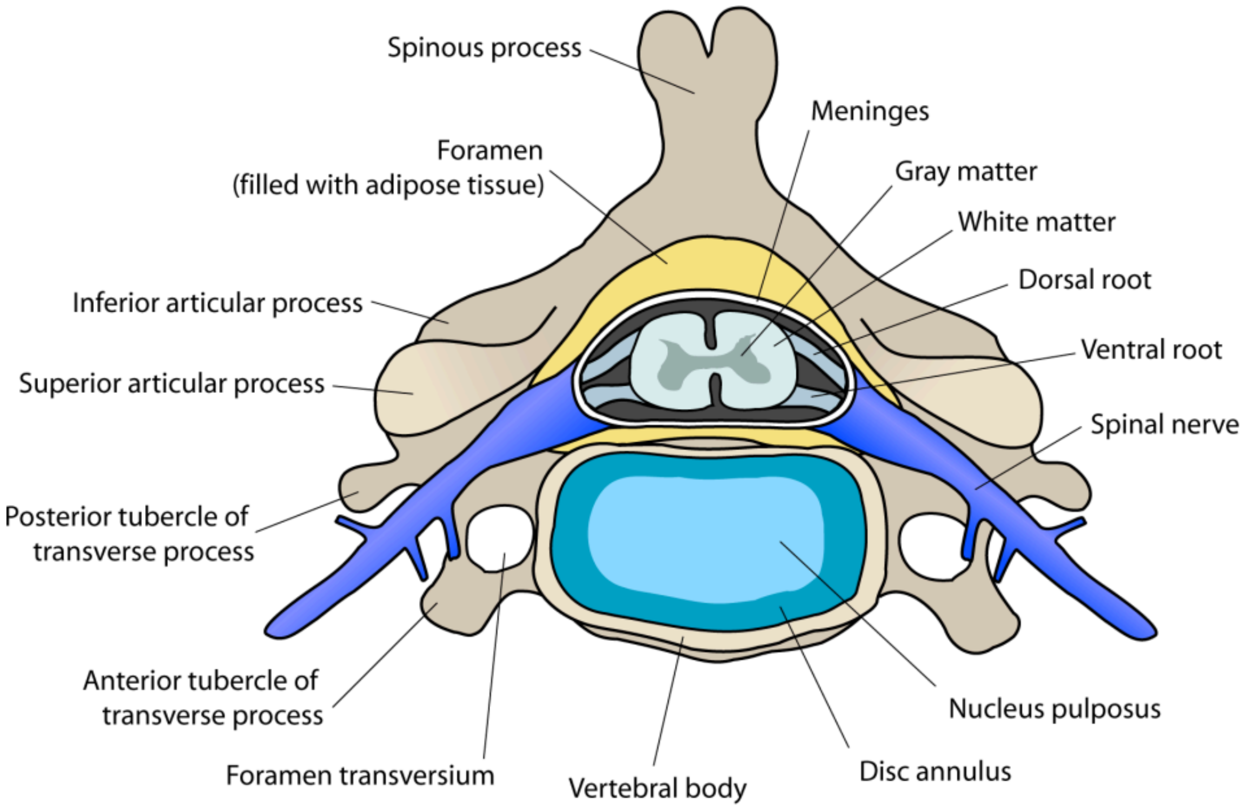
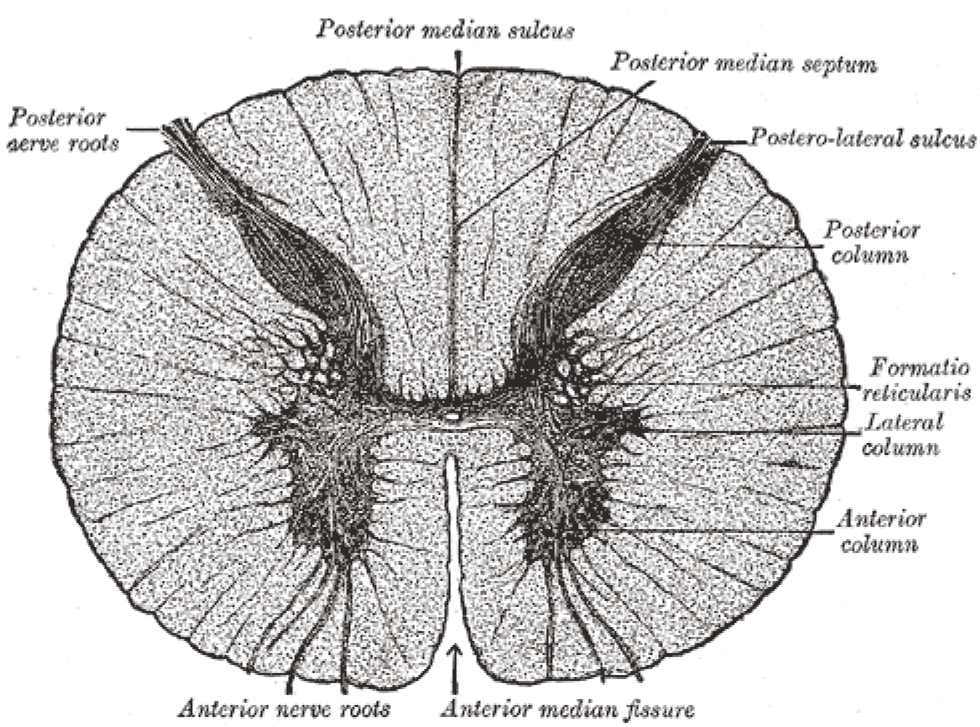
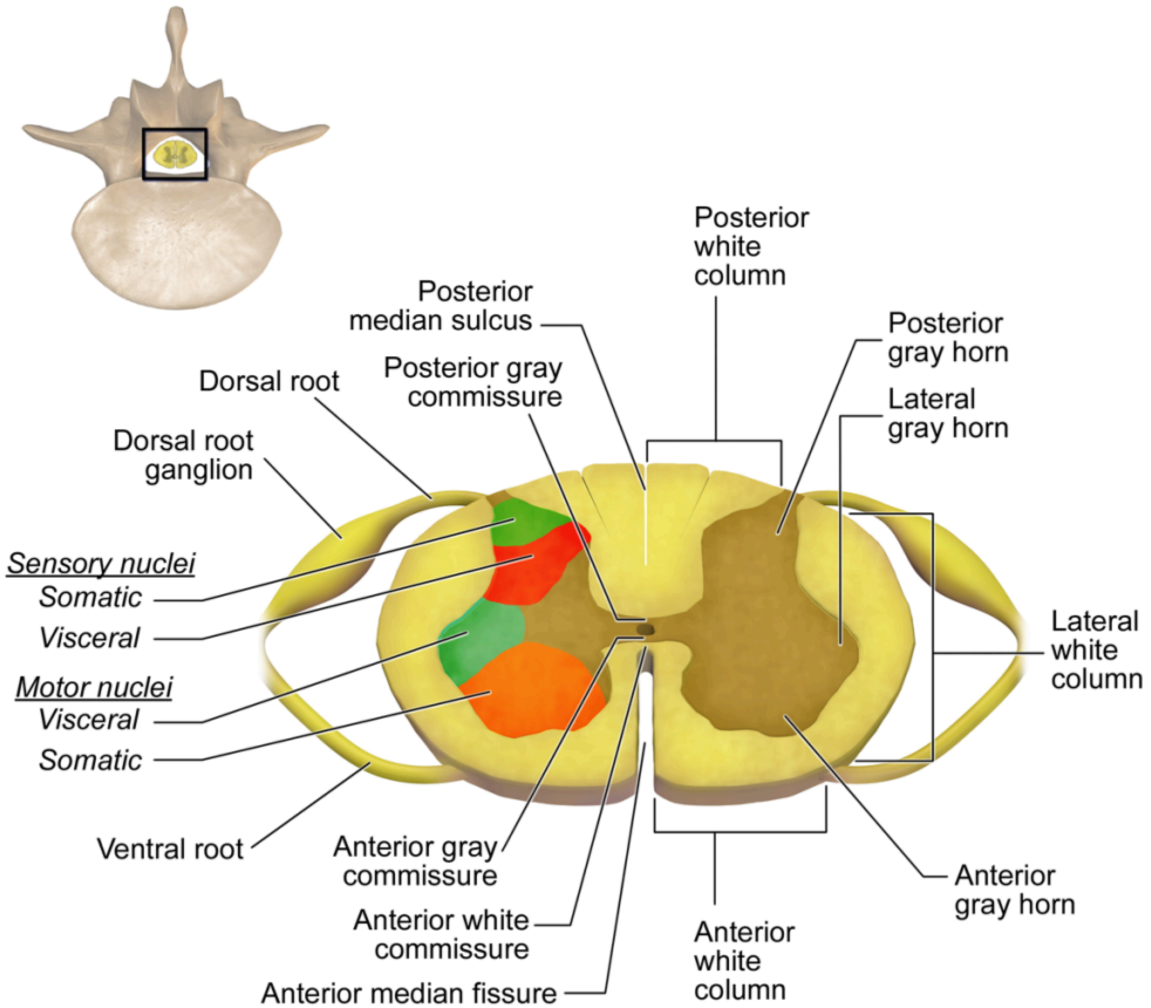
Os sacrum
Coccyx



Spinous process
Meninges
Foramen
(filled with adipose tissue)
Gray matter
White matter
Dorsal root
Inferior articular process
Ventral root
Superior articular process
Spinal nerve
Posterior tubercle of
transverse process
Anterior tubercle of
transverse process
Nucleus pulposus
Foramen transversium
Vertebral body
Disc annulus



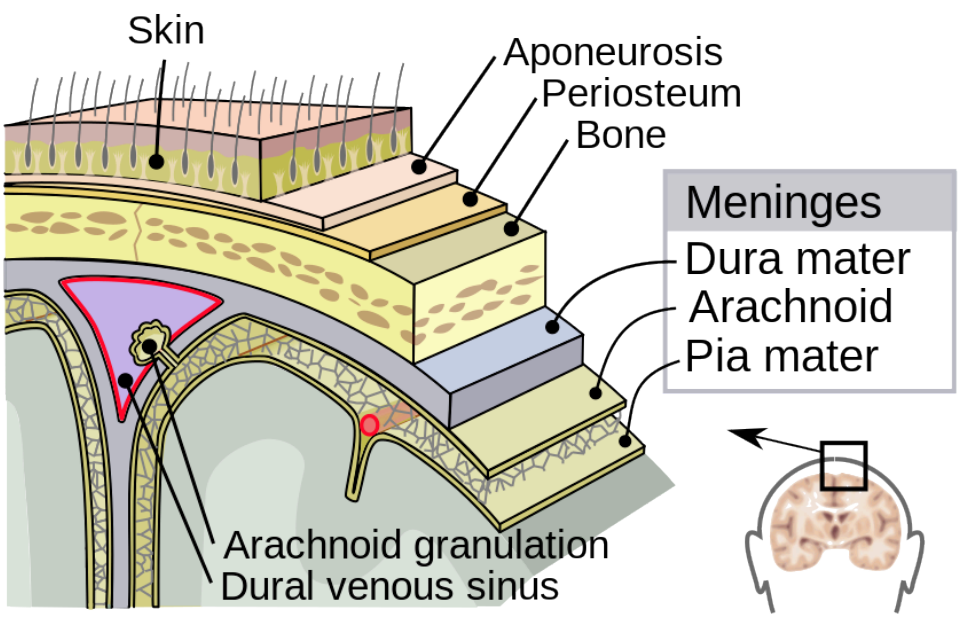
Posterior median sulcus
Posterior median septum
Posterior
nerve roots
Postero-lateral sulcus
Posterior
column
Formatio
reticularis
Lateral
column
Anterior
column
Anterior nerve roots
Anterior median fissure



Sectional Organization of the Spinal Cord

Meninges

The meninges are the three membranes that envelop the brain and spinal cord. In mammals, the meninges are the dura mater, the arachnoid mater, and the pia mater. Cerebrospinal fluid is located in the subarachnoid space between the arachnoid mater and the pia mater. The primary function of the meninges is to protect the central nervous system.



Dura mater

The dura mater is a thick, durable membrane, closest to the skull and vertebrae. The dura mater, the outermost part, is a loosely arranged, fibroelastic layer of cells, characterized by multiple interdigitating cell processes, no extracellular collagen, and significant extracellular spaces. The middle region is a mostly fibrous portion. It consists of two layers: the endosteal layer, which lies closest to the calvaria (skullcap), and the inner meningeal layer, which lies closer to the brain. It contains larger blood vessels that split into the capillaries in the pia mater. It is composed of dense fibrous tissue, and its inner surface is covered by flattened cells like those present on the surfaces of the pia mater and arachnoid mater. The dura mater is a sac that envelops the arachnoid mater and surrounds and supports the large dural sinuses carrying blood from the brain toward the heart.

The dura has four areas of infolding:

- Falx cerebri, the largest, sickle-shaped, separates the cerebral hemispheres. Starts from the frontal crest of frontal bone and the crista galli running to the internal occipital protuberance.
- Tentorium cerebelli, the second largest, crescent-shaped; separates the occipital lobes from cerebellum. The falx cerebri attaches to it giving a tentlike appearance.
- Falx cerebelli, vertical infolding; lies inferior to the tentorium cerebelli, separating the cerebellar hemispheres.
- Diaphragma sellae, smallest infolding; covers the pituitary gland and sella turcica.

Arachnoid Mater

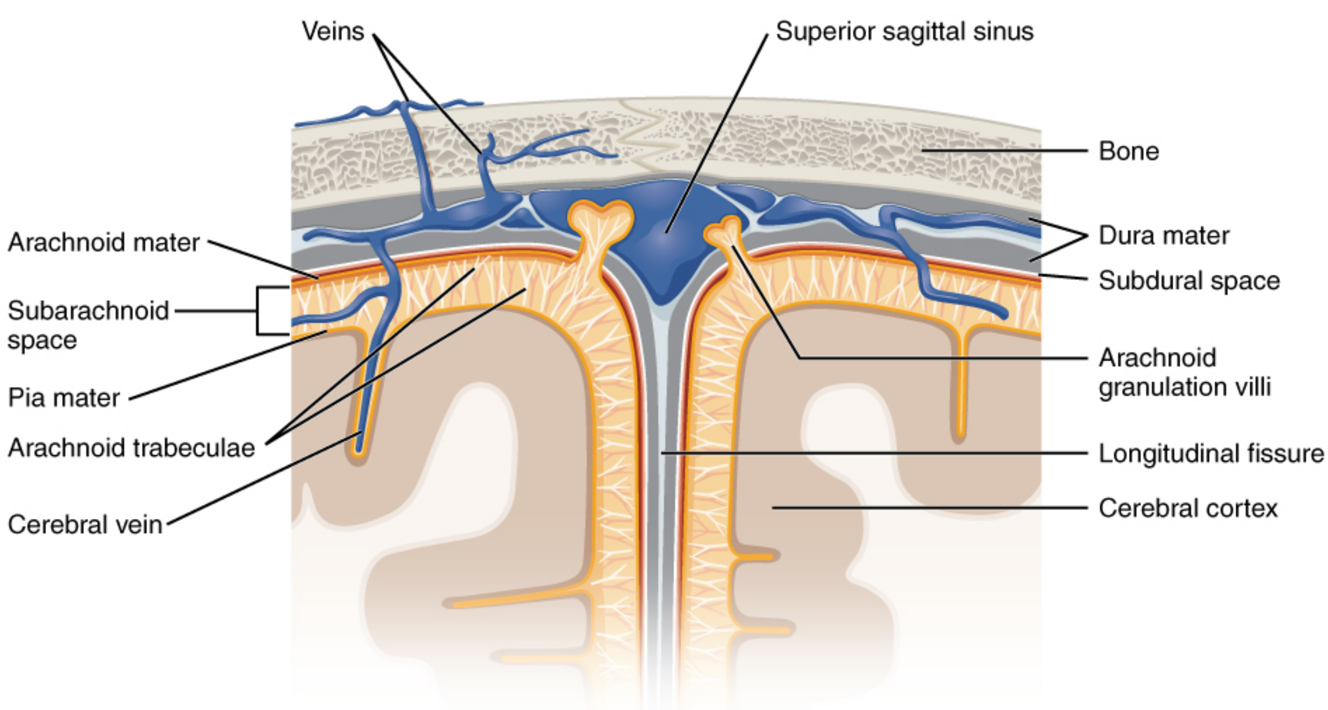
The middle element of the meninges is the arachnoid mater, so named because of its spider web-like appearance. It cushions the central nervous system. This thin, transparent membrane is composed of fibrous tissue and, like the pia mater, is covered by flat cells also thought to be impermeable to fluid.

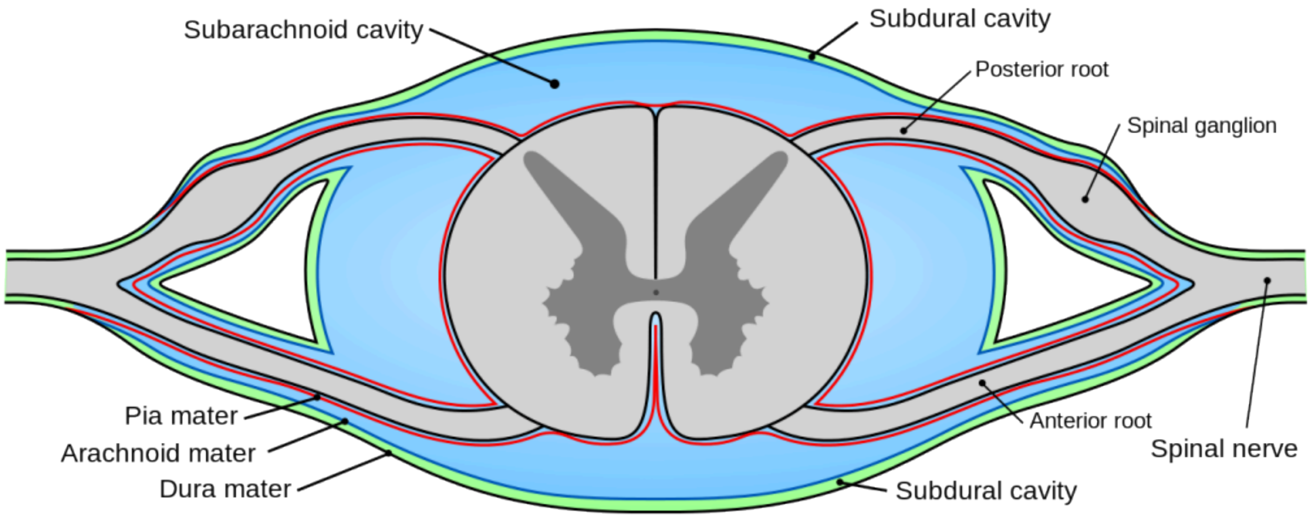
The shape of the arachnoid does not follow the convolutions of the surface of the brain and so looks like a loosely fitting sac. In particular, in the region of the brain a large number of fine filaments called arachnoid trabeculae pass from the arachnoid through the subarachnoid space to blend with the tissue of the pia mater. The arachnoid is composed of an outermost portion (arachnoid barrier cell layer) with tightly packed cells and no extracellular collagen; that is why it is considered to represent an effective morphological and physiological meningeal barrier between the cerebrospinal fluid and subarachnoid space and the blood circulation in the dura.

The arachnoid barrier layer is characterized by a distinct continuous basal lamina on its inner surface toward the innermost collagenous portion of the arachnoid reticular layer

Pia Mater

The pia mater is a very delicate membrane. It is the meningeal envelope that firmly adheres to the surface of the brain and spinal cord, following all of the brain's contours (the gyri and sulci). It is a very thin membrane composed of fibrous tissue covered on its outer surface by a sheet of flat cells thought to be impermeable to fluid. The pia mater is pierced by blood vessels to the brain and spinal cord, and its capillaries nourish the brain.





Subarachnoid Space

The subarachnoid space is the space that normally exists between the arachnoid and the pia mater, which is filled with cerebrospinal fluid, and continues down the spinal cord. Spaces are formed from openings at different points along the subarachnoid space; these are the subarachnoid cisterns, which are filled with cerebrospinal fluid.

The dura mater is attached to the skull, whereas in the spinal cord, the dura mater is separated from the vertebrae by a space called the epidural space, which contains fat and blood vessels. The arachnoid is attached to the dura mater, while the pia mater is attached to the central nervous system tissue. When the dura mater and the arachnoid separate through injury or illness, the space between them is the subdural space. There is a subpial space underneath the pia mater that separates it from the glia limitans.

Spinal Cord Segments

The human spinal cord is divided into segments where pairs of spinal nerves (mixed; sensory and motor) form. Six to eight motor nerve rootlets branch out of right and left ventro lateral sulci in a very orderly manner. Nerve rootlets combine to form nerve roots. Likewise, sensory nerve rootlets form off right and left dorsal lateral sulci and form sensory nerve roots. The ventral (motor) and dorsal (sensory) roots combine to form spinal nerves (mixed; motor and sensory), one on each side of the spinal cord. Spinal nerves, with the exception of C1 and C2, form inside the intervertebral foramen (IVF). These rootlets form the demarcation between the central and peripheral nervous systems.

The grey column, (as three regions of grey columns) in the center of the cord, is shaped like a butterfly and consists of cell bodies of interneurons, motor neurons, neuroglia cells and unmyelinated axons. The anterior and posterior grey column present as projections of the grey matter and are also known as the horns of the spinal cord. Together, the grey columns and the gray commissure form the “grey H.”

The white matter is located outside of the grey matter and consists almost totally of myelinated motor and sensory axons. “Columns” of white matter carry information either up or down the spinal cord.

The spinal cord proper terminates in a region called the conus medullaris, while the pia mater continues as an extension called the filum terminale, which anchors the spinal cord to the coccyx. The cauda equina (“horse’s tail”) is a collection of nerves inferior to the conus medullaris that continue to travel through the vertebral column to the coccyx. The cauda equina forms because the spinal cord stops growing in length at about age four, even though the vertebral column continues to lengthen until adulthood. This results in sacral spinal nerves originating in the upper lumbar region.

Within the CNS, nerve cell bodies are generally organized into functional clusters, called nuclei. Axons within the CNS are grouped into tracts.

There are 31 spinal cord nerve segments in a human spinal cord:

- 8 cervical segments forming 8 pairs of cervical nerves (C1 spinal nerves exit the spinal column between the foramen magnum and the C1 vertebra; C2 nerves exit between the posterior arch of the C1 vertebra and the lamina of C2; C3–C8 spinal nerves pass through the IVF above their corresponding cervical vertebrae, with the exception of the C8 pair which exit between the C7 and T1 vertebrae)
- 12 thoracic segments forming 12 pairs of thoracic nerves
- 5 lumbar segments forming 5 pairs of lumbar nerves
- 5 sacral segments forming 5 pairs of sacral nerves
- 1 coccygeal segment

Somatosensory Organization

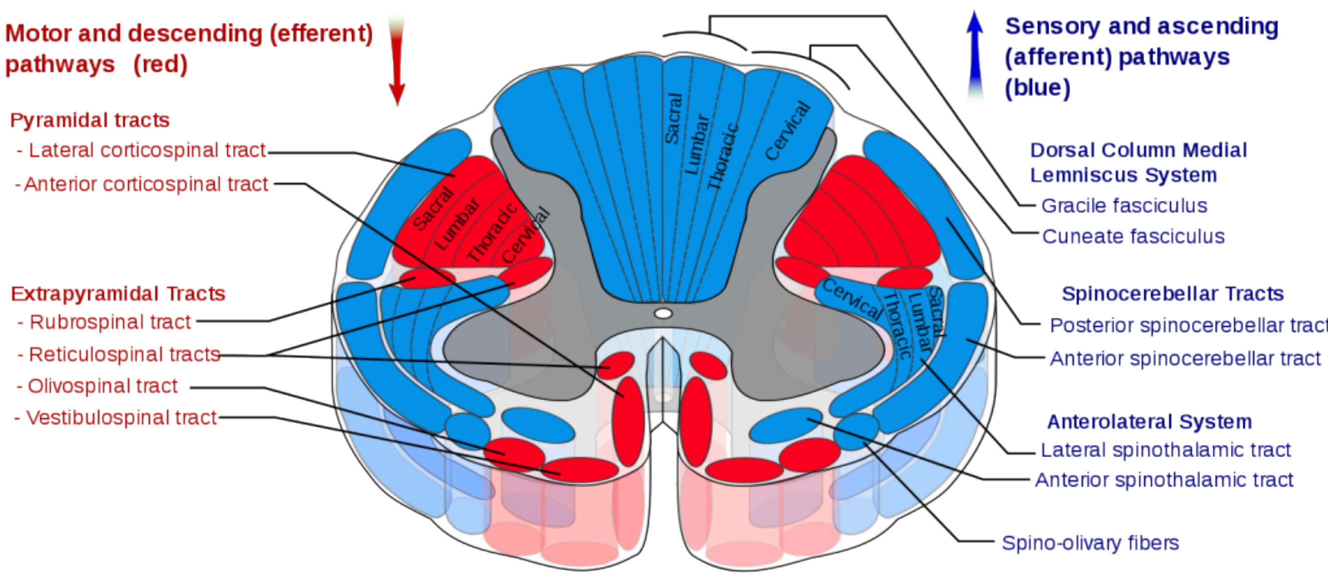
Somatosensory organization is divided into the dorsal column-medial lemniscus tract (the touch/proprioception/vibration sensory pathway) and the anterolateral system, or ALS (the pain/temperature sensory pathway). Both sensory pathways use three different neurons to get information from sensory receptors at the periphery to the cerebral cortex. These neurons are designated primary, secondary and tertiary sensory neurons. In both pathways, primary sensory neuron cell bodies are found in the dorsal root ganglia, and their central axons project into the spinal cord.

In the dorsal column-medial leminiscus tract, a primary neuron’s axon enters the spinal cord and then enters the dorsal column. If the primary axon enters below spinal level T6, the axon travels in the fasciculus gracilis, the medial part of the column. If the axon enters above level T6, then it travels in the fasciculus cuneatus, which is lateral to the fasciculus gracilis. Either way, the primary axon ascends to the lower medulla, where it leaves its fasciculus and synapses with a secondary neuron in one of the dorsal column nuclei: either the nucleus gracilis or the nucleus cuneatus, depending on the pathway it took. At this point, the secondary axon leaves its nucleus and passes anteriorly and medially. The collection of secondary axons that do this are known as internal arcuate fibers. The internal arcuate fibers decussate and continue ascending as the contralateral medial lemniscus. Secondary axons from the medial lemniscus finally terminate in the ventral posterolateral nucleus (VPLN) of the thalamus, where they synapse with tertiary neurons. From there, tertiary neurons ascend via the posterior limb of the internal capsule and end in the primary sensory cortex.

The proprioception of the lower limbs differs from the upper limbs and upper trunk. There is a four-neuron pathway for lower limb proprioception. This pathway initially follows the dorsal spino-cerebellar pathway. It is arranged as follows: proprioceptive receptors of lower limb → peripheral process → dorsal root ganglion → central process → Clarke's column → 2nd order neuron → medulla oblongata (Caudate nucleus) → 3rd order neuron → VPLN of thalamus → 4th order neuron → posterior limb of internal capsule → corona radiata → sensory area of cerebrum.

The anterolateral system works somewhat differently. Its primary neurons axons enter the spinal cord and then ascend one to two levels before synapsing in the substantia gelatinosa. The tract that ascends before synapsing is known as Lissauer's tract. After synapsing, secondary axons decussate and ascend in the anterior lateral portion of the spinal cord as the spinothalamic tract. This tract ascends all the way to the VPLN, where it synapses on tertiary neurons. Tertiary neuronal axons then travel to the primary sensory cortex via the posterior limb of the internal capsule.

Some of the "pain fibers" in the ALS deviate from their pathway towards the VPLN. In one such deviation, axons travel towards the reticular formation in the midbrain. The reticular formation then projects to a number of places including the hippocampus (to create memories about the pain), the centromedian nucleus (to cause diffuse, non-specific pain) and various parts of the cortex. Additionally, some ALS axons project to the periaqueductal gray in the pons, and the axons forming the periaqueductal gray then project to the nucleus raphes magnus, which projects back down to where the pain signal is coming from and inhibits it. This helps control the sensation of pain to some degree.



Motor Organization

The corticospinal tract serves as the motor pathway for upper motor neuronal signals coming from the cerebral cortex and from primitive brainstem motor nuclei.

Cortical upper motor neurons originate from Brodmann areas 1, 2, 3, 4, and 6 and then descend in the posterior limb of the internal capsule, through the crus cerebri, down through the pons, and to the medullary pyramids, where about 90% of the axons cross to the contralateral side at the decussation of the pyramids. They then descend as the lateral corticospinal tract. These axons synapse with lower motor neurons in the ventral horns of all levels of the spinal cord. The remaining 10% of axons descend on the ipsilateral side as the ventral corticospinal tract. These axons also synapse with lower motor neurons in the ventral horns. Most of them will cross to the contralateral side of the cord (via the anterior white commissure) right before synapsing.

The midbrain nuclei include four motor tracts that send upper motor neuronal axons down the spinal cord to lower motor neurons. These are the rubrospinal tract, the vestibulospinal tract, the tectospinal tract and the reticulospinal tract. The rubrospinal tract descends with the lateral corticospinal tract, and the remaining three descend with the anterior corticospinal tract.

The function of lower motor neurons can be divided into two different groups: the lateral corticospinal tract and the anterior corticospinal tract. The lateral tract contains upper motor neuronal axons which synapse on dorsal lateral (DL) lower motor neurons. The DL neurons are involved in distal limb control. Therefore, these DL neurons are found specifically only in the cervical and lumbosacral enlargements within the spinal cord. There is no decussation in the lateral corticospinal tract after the decussation at the medullary pyramids.

The anterior corticospinal tract descends ipsilaterally in the anterior column, where the axons emerge and either synapse on lower ventromedial (VM) motor neurons in the ventral horn ipsilateral or decussate at the anterior white commissure where they synapse on VM lower motor neurons contralaterally . The tectospinal, vestibulospinal and reticulospinal descend ipsilaterally in the anterior column but do not synapse across the anterior white commissure. Rather, they only synapse on VM lower motor neurons ipsilateral. The VM lower motor neurons control the large, postural muscles of the axial skeleton. These lower motor neurons, unlike those of the DL, are located in the ventral horn all the way throughout the spinal cord.

Cervical Plexus

The cervical plexus is a plexus of the anterior rami of the first four cervical spinal nerves which arise from C1 to C4 cervical segment in the neck. They are located laterally to the transverse processes between prevertebral muscles from the medial side and vertebral (m. scalenus, m. levator scapulae, m. splenius cervicis) from lateral side. There is anastomosis with accessory nerve, hypoglossal nerve and sympathetic trunk.

It is located in the neck, deep to sternocleidomastoid m. Nerves formed from the cervical plexus innervate the back of the head, as well as some neck muscles. The branches of the cervical plexus emerge from the posterior triangle at the nerve point, a point which lies midway on the posterior border of the sternocleidomastoid. Also from the posterior ramus of C2 greater occipital nerve arises

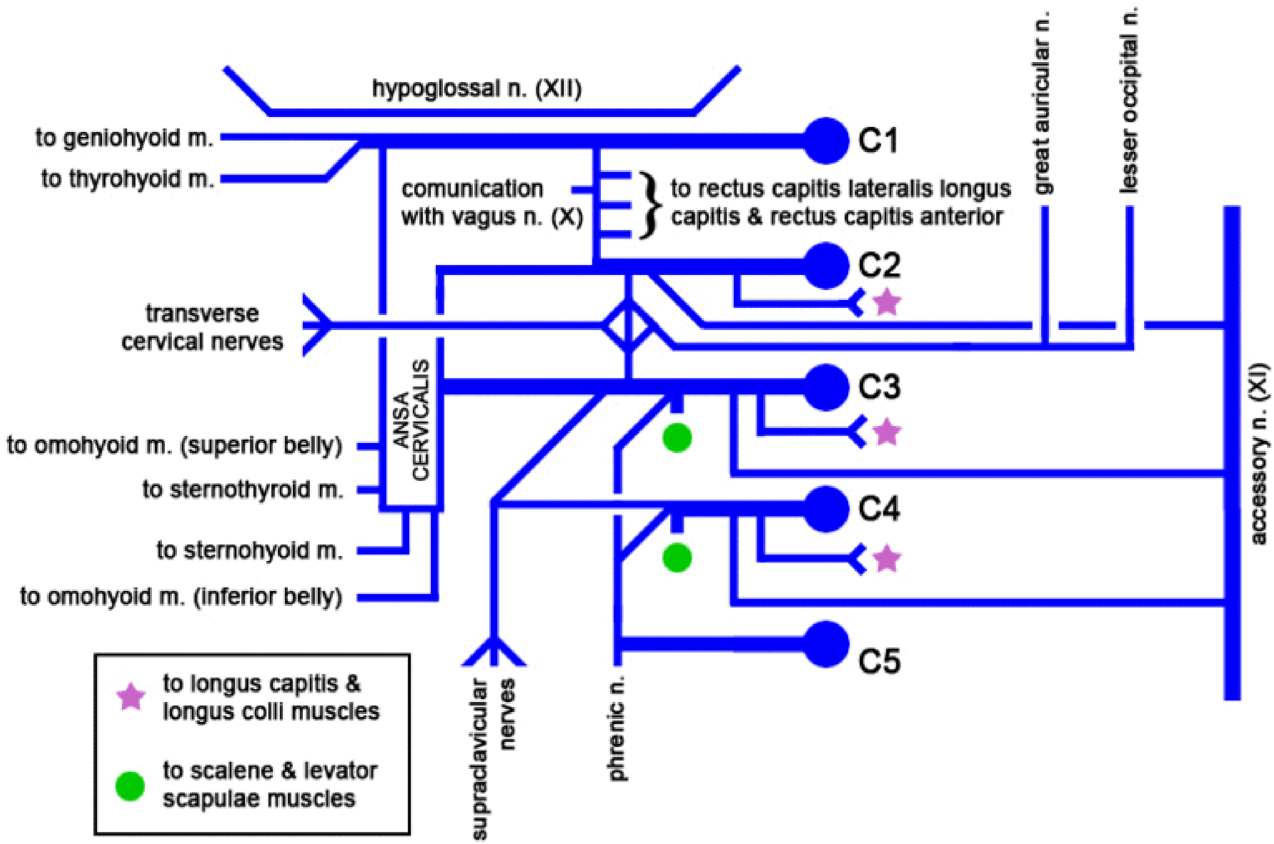
The cervical plexus has two types of branches: cutaneous and muscular.

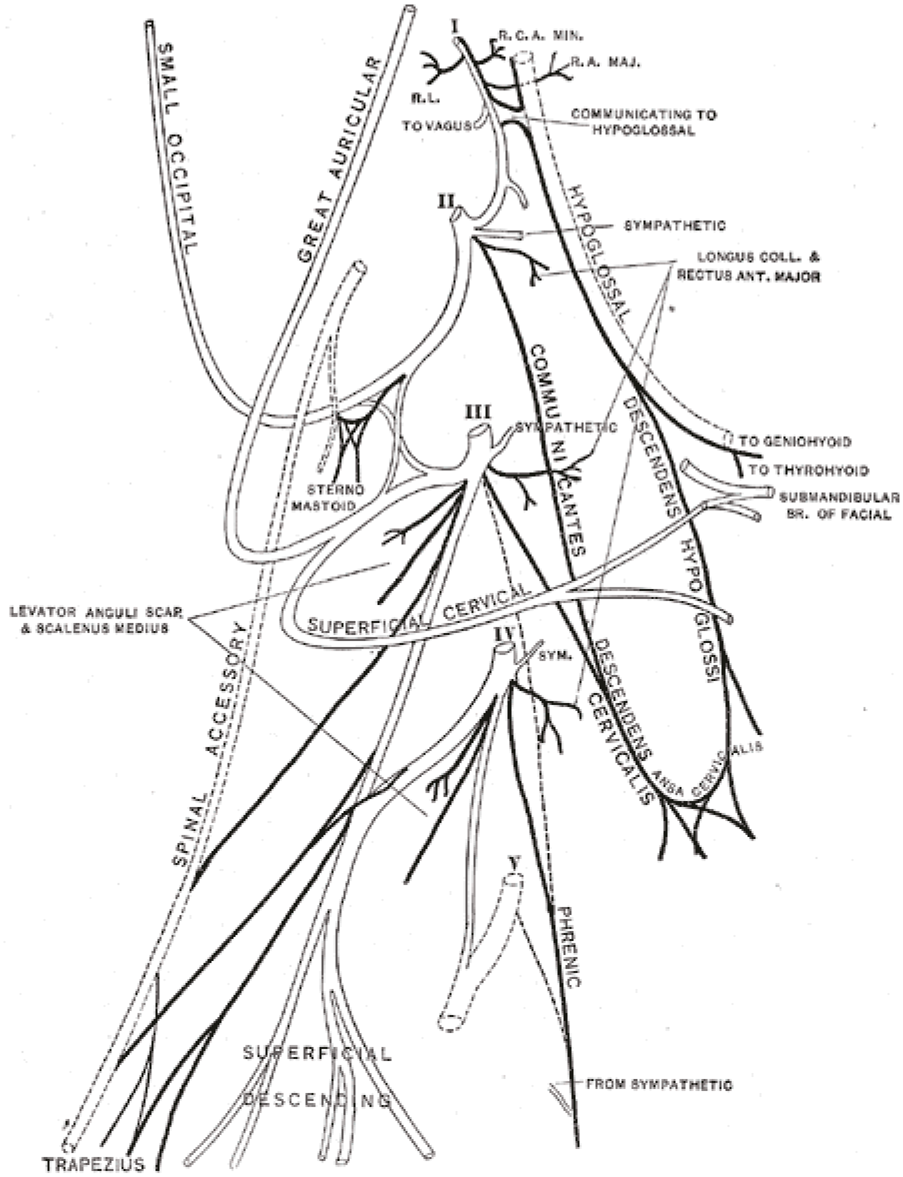
Cutaneous (4 branches):

1. Lesser occipital – innervates the skin and the scalp posterosuperior to the auricle (C2)
2. Great auricular nerve – innervates skin near concha auricle (outer ear) and external acoustic meatus (ear canal) (C2&C3)
3. Transverse cervical nerve – innervates anterior region of neck (C2&C3)
4. Supraclavicular nerves – innervate the skin above and below the clavicle (C3,C4) [1]

Muscular

1. Ansa cervicalis (This is a loop formed from C1-C3 which supplies the four infrahyoid aka strap muscles), etc. (thyrohyoid (C1 only), sternothyroid, sternohyoid, omohyoid)
2. Phrenic (C3-C5 (primarily C4))-innervates diaphragm and the pericardium
3. Segmental branches (C1-C4)- innervates anterior and middle scalenes
4. Additionally, there are two branches formed by the posterior roots of spinal nerves:
    1. Preauricular nerve (from the posterior roots of C2–C3)[2][3]
    2. Postauricular nerve (from the posterior roots of C3–C4)[3]


hypoglossal n. (XII)
to geniohyoid m.
to thyrohyoid m.
C1
comunication
with vagus n. (X)
to rectus capitis lateralis longus
capitis & rectus capitis anterior
great auricular n.
lesser occipital n.
C2
transverse
cervical nerves
ANSA
CERVICALIS
C3
to omohyoid m. (superior belly)
to sternothyroid m.
C4
to sternohyoid m.
to omohyoid m. (inferior belly)
C5
accessory n. (XI)
to longus capitis &
longus colli muscles
to scalene & levator
scapulae muscles
supraclavicular
nerves
phrenic n.



Brachial Plexus

The brachial plexus is a network (plexus) of nerves (formed by the ventral ramus of the lower four cervical nerves and first thoracic nerve (C5, C6, C7, C8, and T1). This plexus extends from the spinal cord, through the cervicoaxillary canal in the neck, over the first rib, and into the armpit. It supplies afferent and efferent nerve fibers to the chest, shoulder, arm and hand.

The brachial plexus is divided into five roots, three trunks, six divisions (three anterior and three posterior), three cords, and five branches. There are five "terminal" branches and numerous other "pre-terminal" or "collateral" branches, such as the subscapular nerve, the thoracodorsal nerve, and the long thoracic nerve,[1] that leave the plexus at various points along its length. A common structure used to identify part of the brachial plexus in cadaver dissections is the M or W shape made by the musculocutaneous nerve, lateral cord, median nerve, medial cord, and ulnar nerve.

Roots

The five roots are the five anterior rami of the spinal nerves, after they have given off their segmental supply to the muscles of the neck. The brachial plexus emerges at five different levels; C5, C6, C7, C8, and T1. C5 and C6 merge to establish the upper trunk, C7 continuously forms the middle trunk, and C8 and T1 merge to establish the lower trunk. Prefixed or postfixed formations in some cases involve C4 or T2, respectively. The dorsal scapular nerve comes from the superior trunk and innervates the rhomboid muscles which retract the scapula. The subclavian nerve originates in both C5 and C6 and innervates the subclavius, a muscle that involves lifting the first ribs during respiration. The long thoracic nerve arises from C5, C6, and C7. This nerve innervates the serratus anterior, which draws the scapula laterally and is the prime mover in all forward-reaching and pushing actions.

Trunks

These roots merge to form the trunks:

- "superior" or "upper" (C5–C6)
- "middle" (C7)
- "inferior" or "lower" (C8, T1)

Divisions

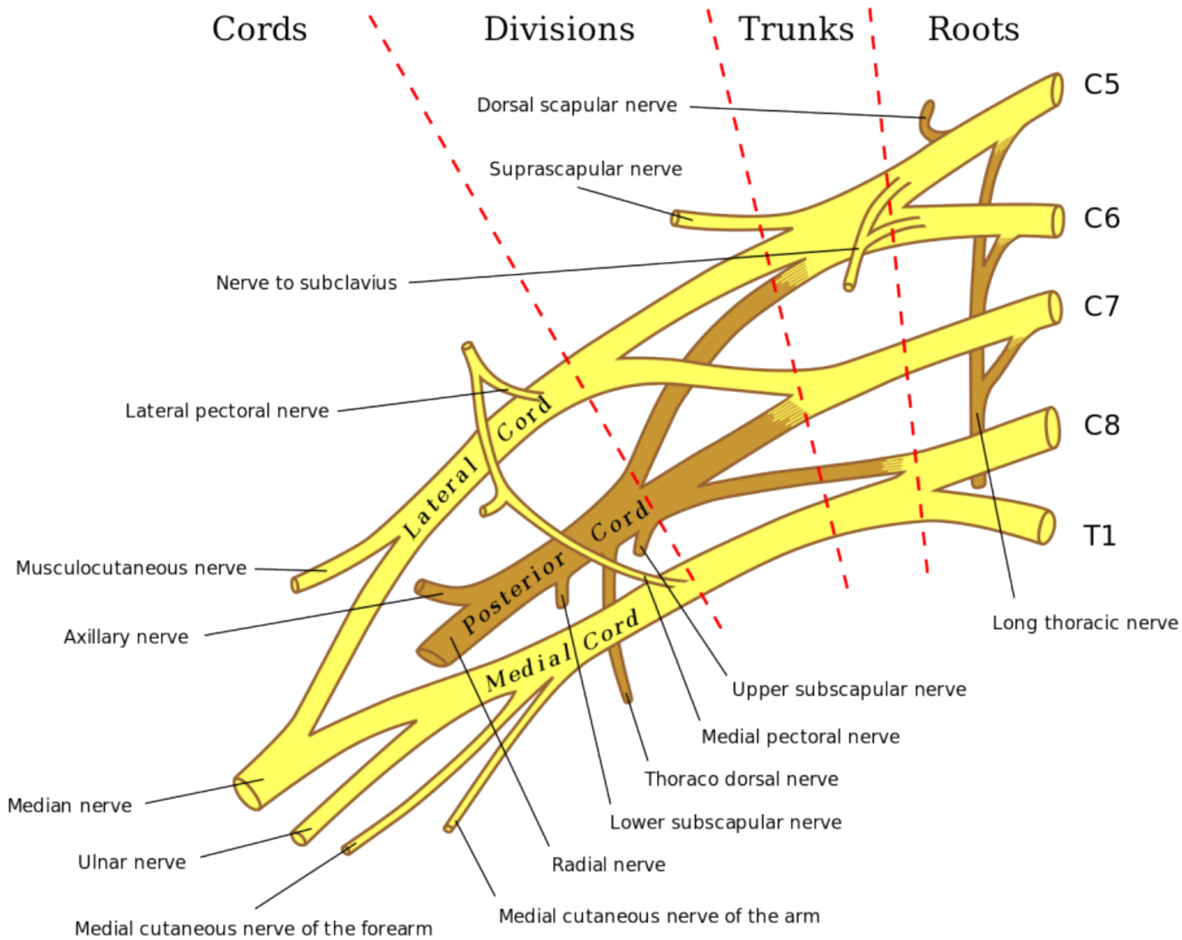
Each trunk then splits in two, to form six divisions:

- anterior divisions of the upper, middle, and lower trunks
- posterior divisions of the upper, middle, and lower trunks
- when observing the body in the anatomical position, the anterior divisions are superficial to the posterior divisions

Cords

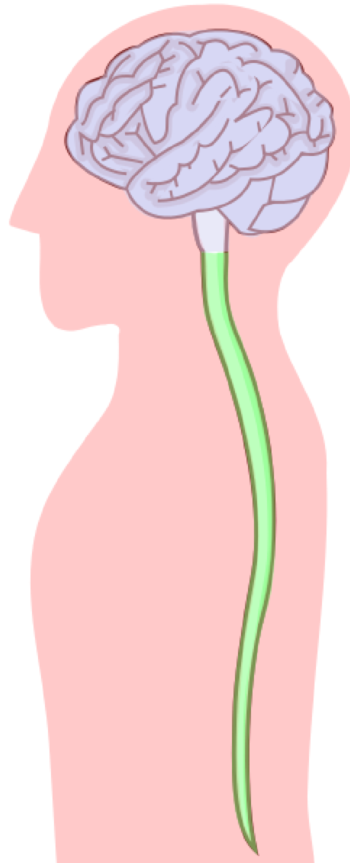
These six divisions regroup to become the three cords or large fiber bundles. The cords are named by their position with respect to the axillary artery.

- The posterior cord is formed from the three posterior divisions of the trunks (C5-C8, T1)
- The lateral cord is formed from the anterior divisions of the upper and middle trunks (C5-C7)
- The medial cord is simply a continuation of the anterior division of the lower trunk (C8, T1)

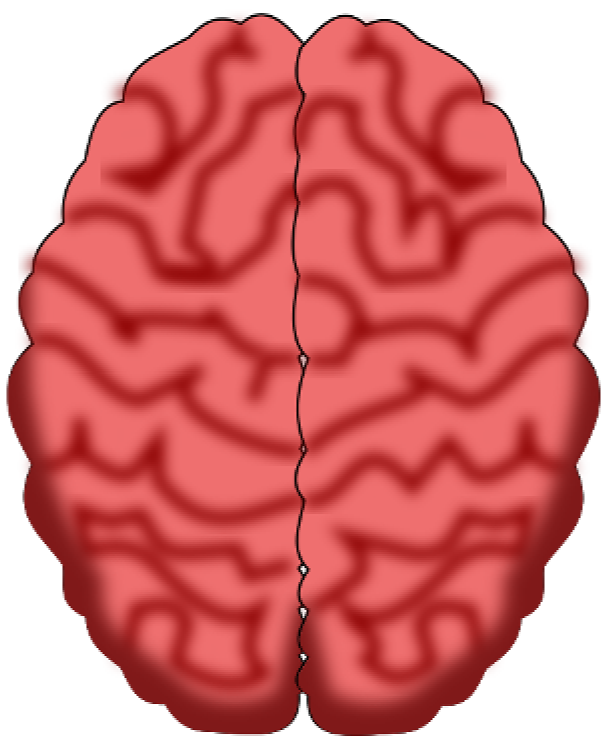


Laboratory Activity

Label the main part of the Central Nervous System

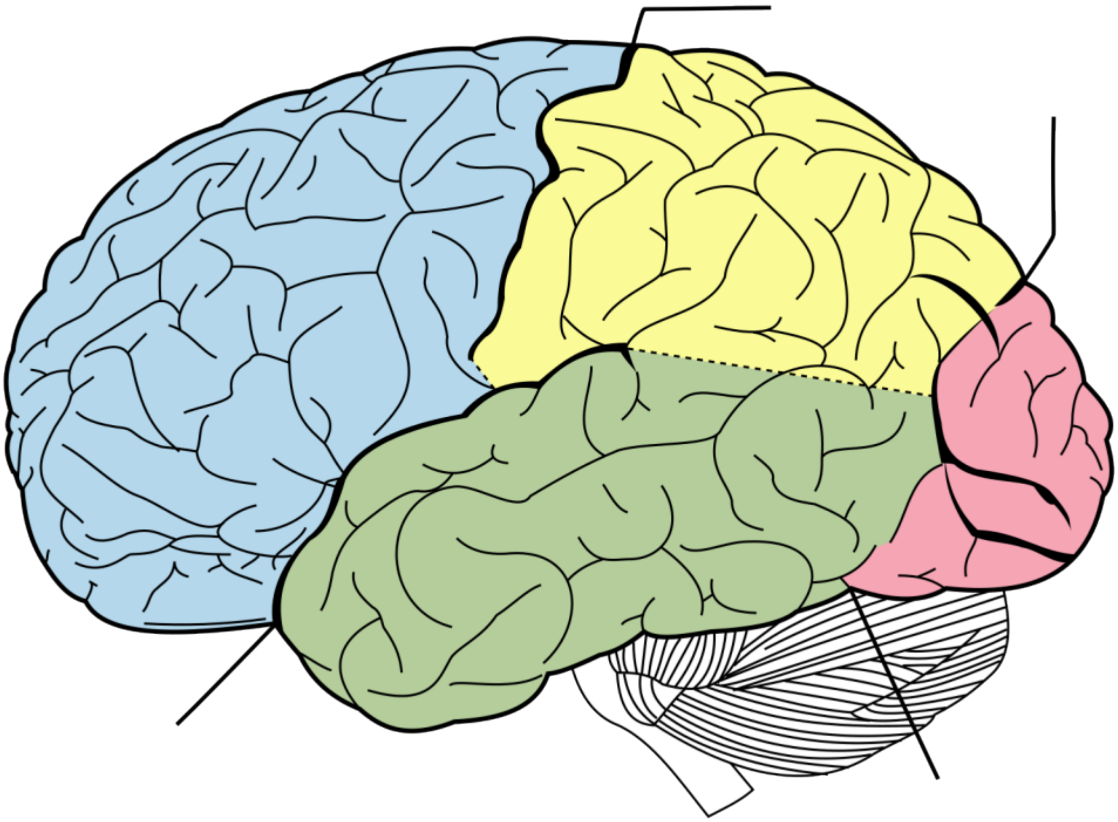


Label the hemispheres of the brain and the longitudinal fissure.

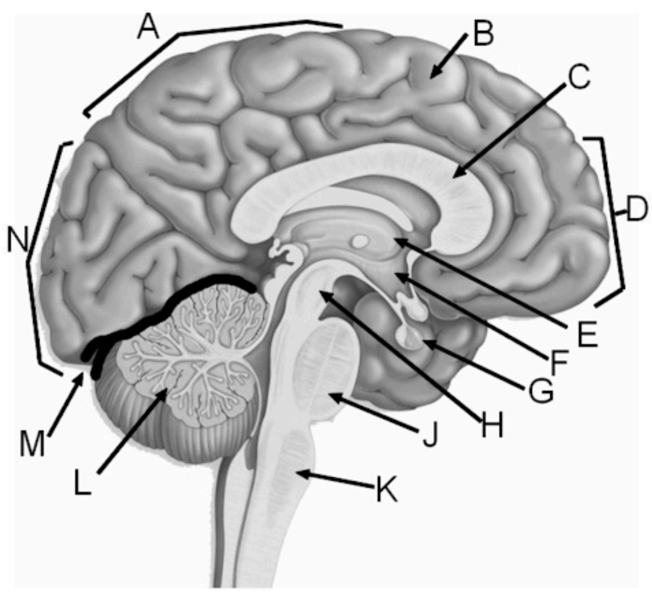


The brain

Label the main regions of the brain.



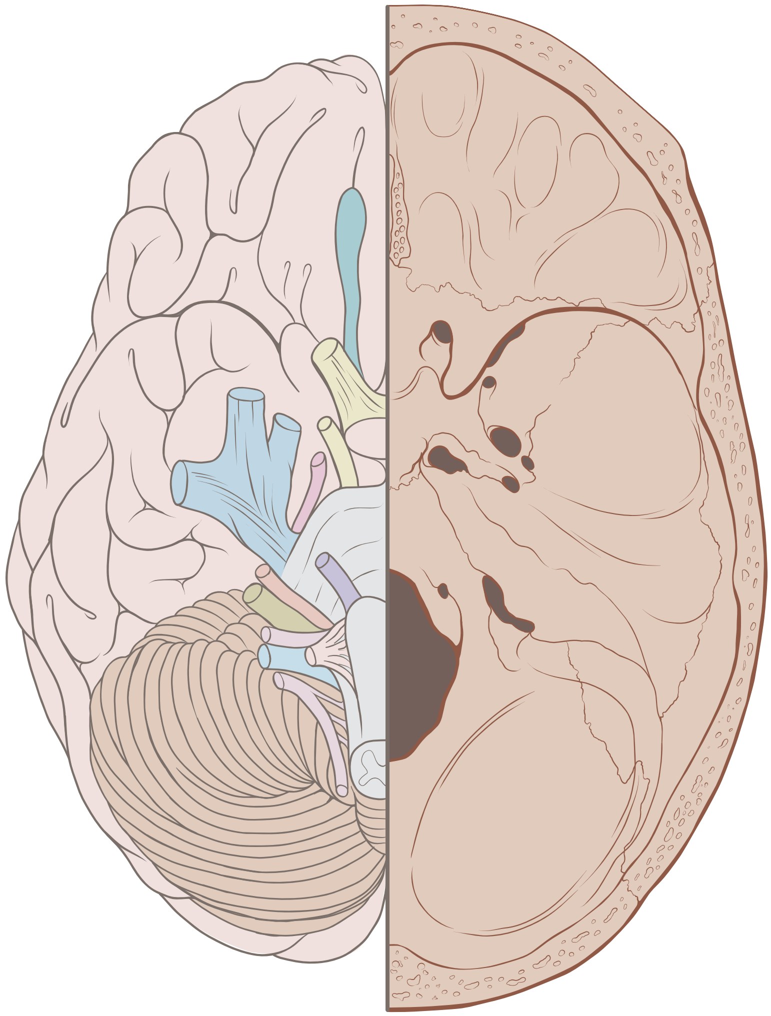
The brain



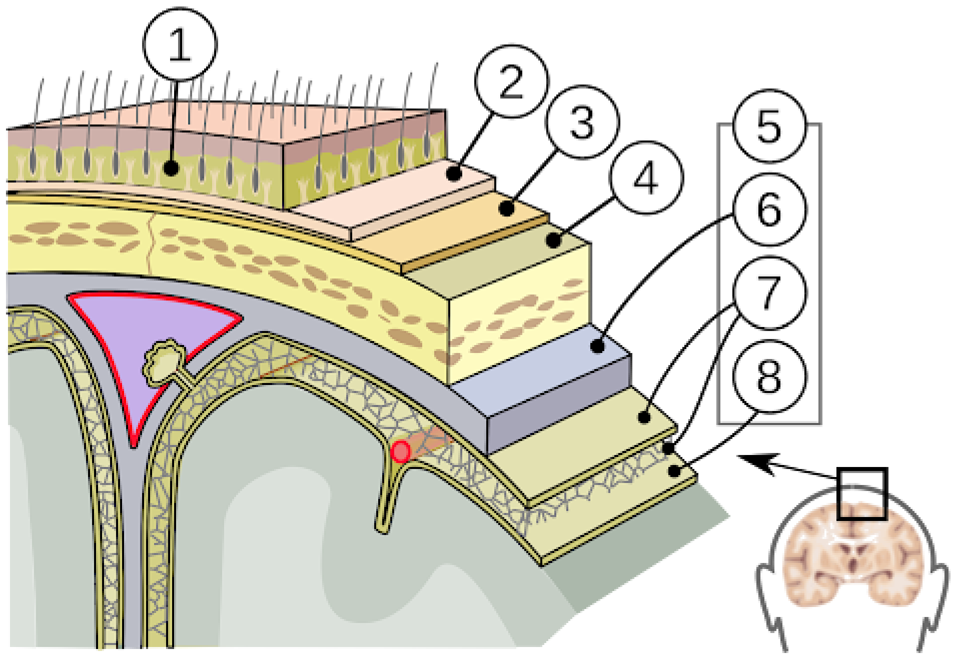
Sagittal section of brain

Letter	Structure
A	
B	
C	
D	
E	
F	
G	
H	
I	
J	
K	
L	
M	

Label the 12 pairs of Cranial Nerves



Left View of the human brain from below, showing origins of cranial nerves. Right Juxtaposed skull base with foramina in which many nerves exit the skull.



#	**Structure**
1	
2	
3	
4	
5	
6	
7	
8	

Label the parts of the human spinal cord and the spinal nerve roots

Word bank:

central canal

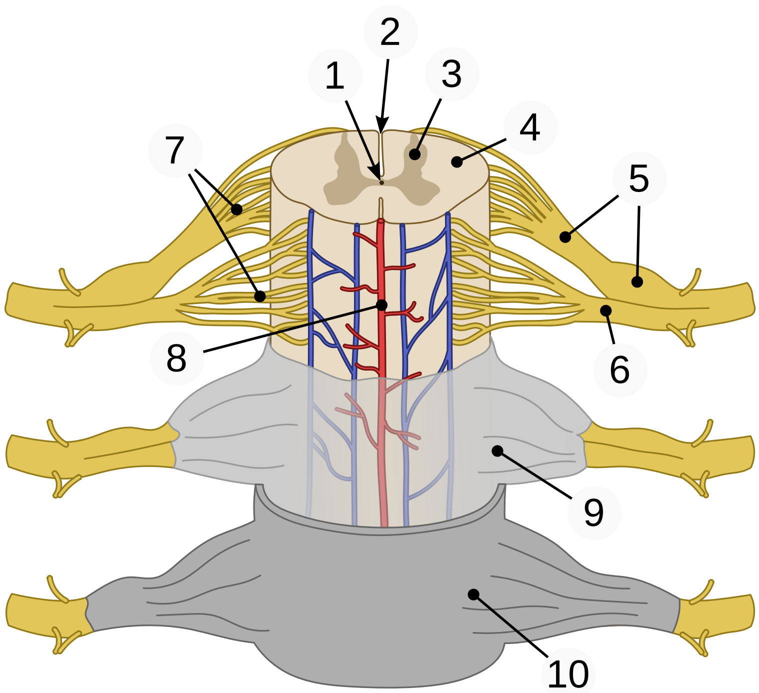
posterior median sulcus

gray matter

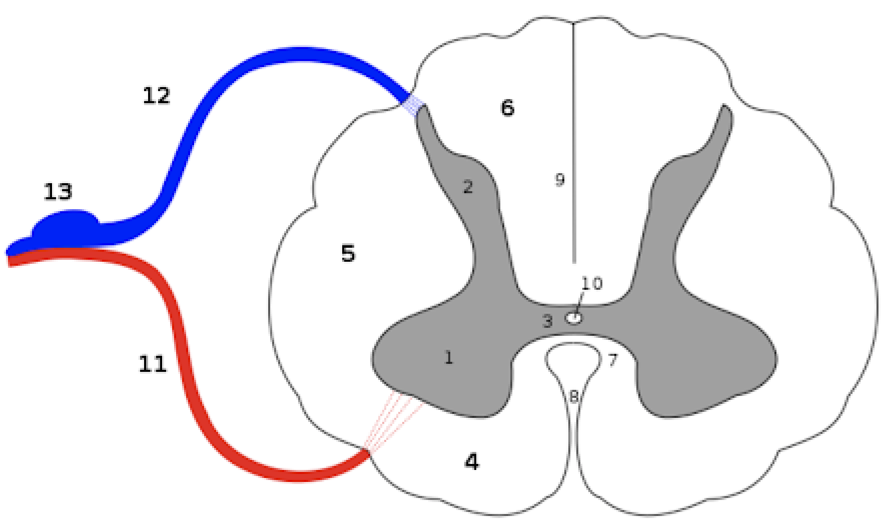
white matter

dorsal root (left)

dorsal root ganglion (right)
ventral root
fascicles
anterior spinal artery
arachnoid mater
dura mater



Label the parts of the human spinal cord and the spinal nerve roots



Transverse section of spinal cord

#	Structure
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	

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THE GENERAL AND SPECIAL SENSES

The human body has two basic types of senses: general and special senses. Special senses have specialized sense organs and include vision (eyes), hearing (ears), balance (ears), taste (tongue), and smell (nasal passages). General senses are all associated with touch, they lack special sense organs, but they have sensory receptors, which are specialized nerve cells that respond to stimuli (from internal or external environment) by generating a nerve impulse.

Objectives

1. Differentiate between general and special senses
2. Identify cutaneous sensory receptors
    1. Pacinian corpuscles
    2. Meissner corpuscles
    3. Merkel cells
    4. Free nerve endings
3. Identify structures of the eye
4. Identify extraocular muscles of the eye
5. Compare functions of rods and cones
6. Identify the structures of the ear
7. Identify structures of the olfactory and taste senses

General Senses

General senses are all associated with touch and lack special sense organs. These receptors allow us to react to stimuli.

There are different types of sensory receptors that respond to stimuli:

- Mechanoreceptors respond to mechanical forces, such as pressure, vibration, and stretching. They are usually found in the skin as they are needed for the sense of touch. They may also be found in muscle and in the inner ear, where they serve a special function for the senses of hearing and balance.
- Thermoreceptors respond to variations in temperature. They are found mostly in the skin and detect temperatures that are above or below body temperature.

Nociceptors respond to potentially damaging stimuli, which are generally perceived as pain. They are found in internal organs, as well as on the surface of the body. Different nociceptors are activated depending on the particular stimulus. Some detect damaging heat or cold, others detect excessive pressure, and still others detect painful chemicals (such as very hot spices in food).

Photoreceptors detect and respond to light. Most photoreceptors are found in the eyes and are needed for the sense of vision.

Chemoreceptors respond to certain chemicals. They are found mainly in taste buds on the tongue — where they are needed for the sense of taste — and in nasal passages, where they are needed for the sense of smell.

Special Senses

Special senses have specialized sense organs and include vision (eyes), hearing (ears), balance (ears), taste (tongue), and smell (nasal passages).

The Eye

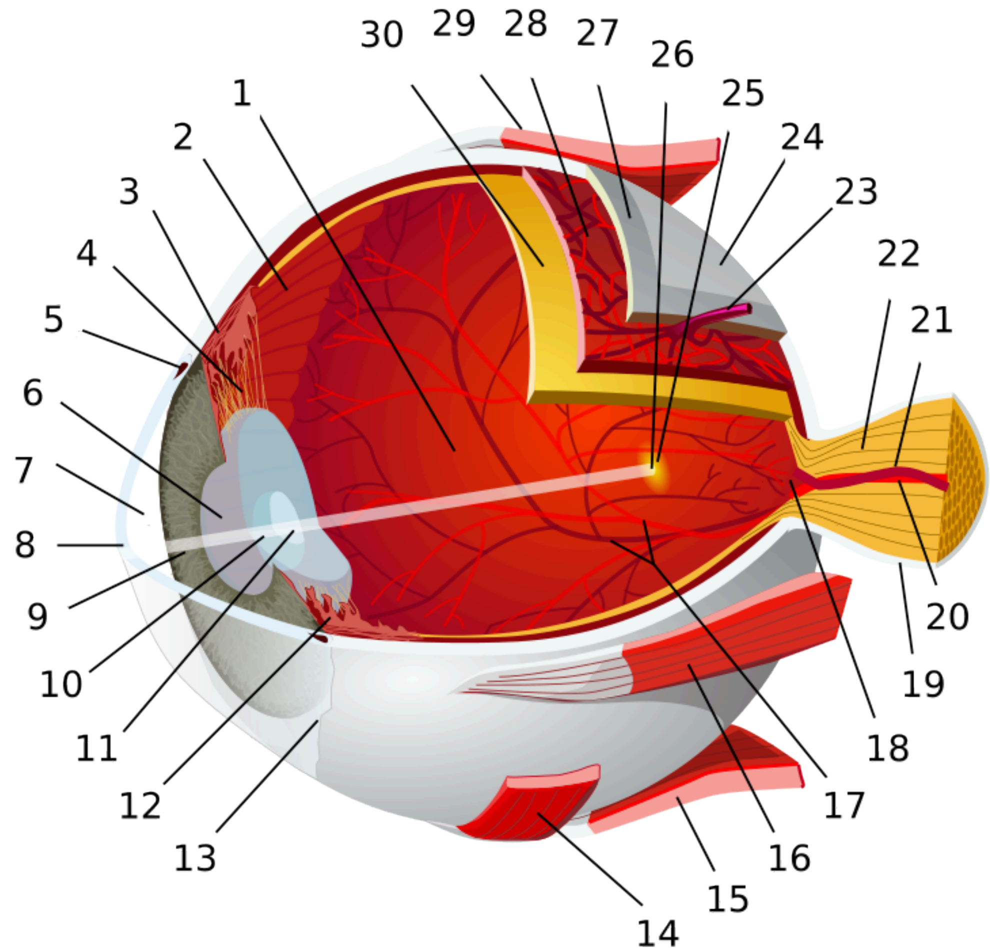
The human eye is an organ that reacts to light and allows vision. Rod and cone cells in the retina allow conscious light perception and vision including color differentiation and the perception of depth. The human eye can differentiate between about 10 million colors and is possibly capable of detecting a single photon. The eye is part of the sensory nervous system.

Similar to the eyes of other mammals, the human eye's non-image-forming photosensitive ganglion cells in the retina receive light signals which affect adjustment of the size of the pupil, regulation and suppression of the hormone melatonin and entrainment of the body clock.

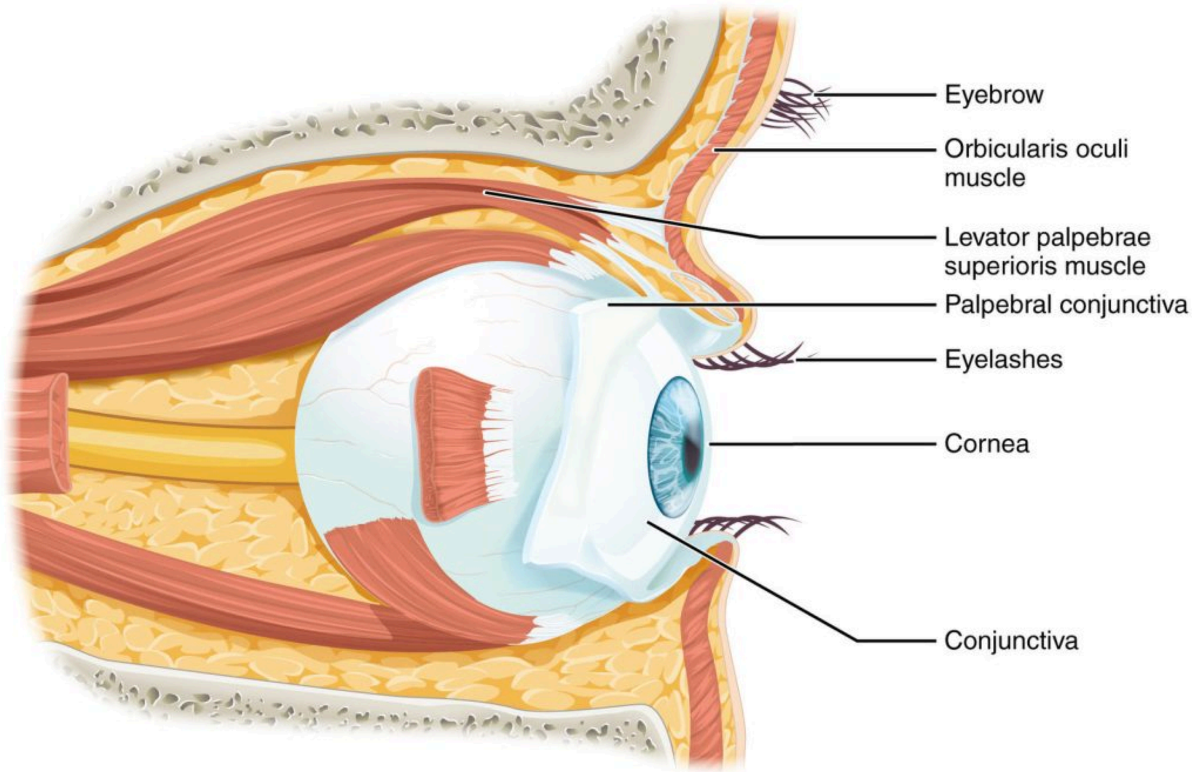
The eye is not shaped like a perfect sphere, rather it is a fused two-piece unit, composed of the anterior segment and the posterior segment. The anterior segment is made up of the cornea, iris and lens. The cornea is transparent and more curved, and is linked to the larger posterior segment, composed of the vitreous, retina, choroid and the outer white shell called the sclera.

The cornea is typically about 11.5 mm (0.3 in) in diameter, and 0.5 mm (500 μm) in thickness near its center. The posterior chamber constitutes the remaining five-sixths; its diameter is typically about 24 mm. The cornea and sclera are connected by an area termed the limbus. The iris is the pigmented circular structure concentrically surrounding the center of the eye, the pupil, which appears to be black. The size of the pupil, which controls the amount of light entering the eye, is adjusted by the iris' dilator and sphincter muscles.

Light energy enters the eye through the cornea, through the pupil and then through the lens. The lens shape is changed for near focus (accommodation) and is controlled by the ciliary muscle. Photons of light falling on the light-sensitive cells of the retina (photoreceptor cones and rods) are converted into electrical signals that are transmitted to the brain by the optic nerve and interpreted as sight and vision.

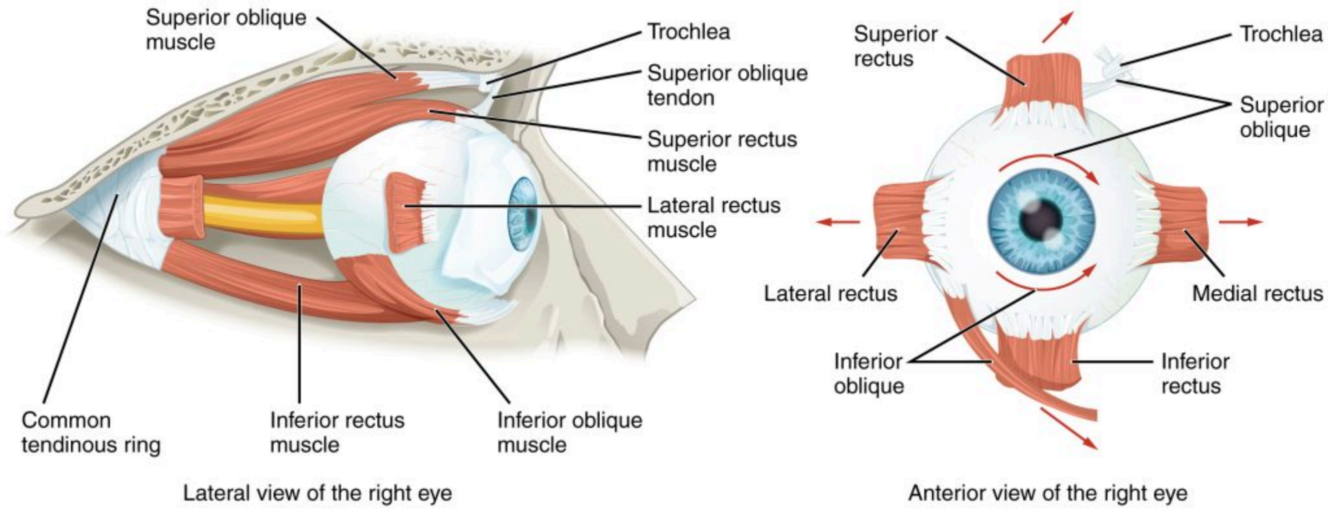


1:posterior segment of eyeball 2:ora serrata 3:ciliary muscle 4:ciliary zonules 5:canal of Schlemm 6:pupil 7:anterior chamber 8:cornea 9:iris 10:lens cortex 11:lens nucleus 12:ciliary process 13:conjunctiva 14:inferior oblique muscle 15:inferior rectus muscle 16:medial rectus muscle 17:retinal arteries and veins 18:optic disc 19:dura mater 20:central retinal artery 21:central retinal vein 22:optic nerve 23:vorticose vein 24:bulbar sheath 25:macula 26:fovea 27:sclera 28:choroid 29:superior rectus muscle 30:retina

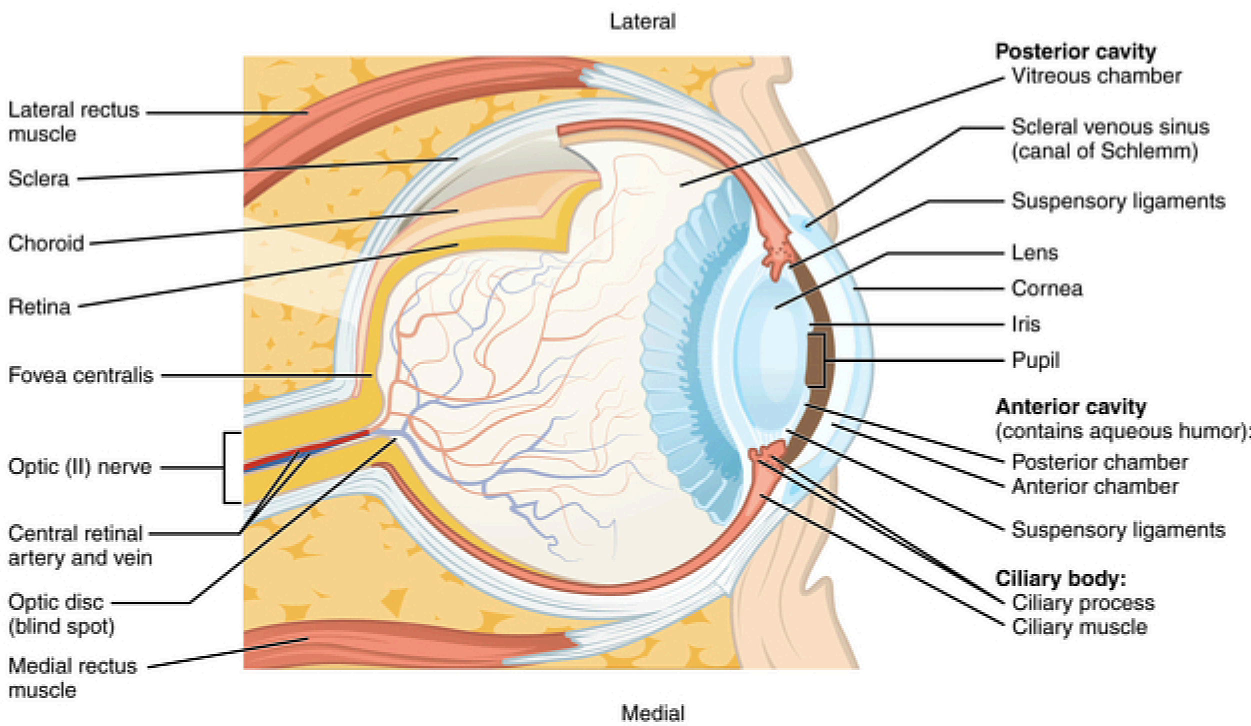


The Eye in the Orbit: The eye is located within the orbit and surrounded by soft tissues that protect and support its function. The orbit is surrounded by cranial bones of the skull.

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. 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 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. The extraocular muscles are innervated by three cranial nerves. The lateral rectus, which causes abduction of the eye, is innervated by the abducens nerve. The superior oblique is innervated by the trochlear nerve. All of the other muscles are innervated by the oculomotor nerve, as is the levator palpebrae superioris. The motor nuclei of these cranial nerves connect to the brain stem, which coordinates eye movements.



Extraocular Muscles: The extraocular muscles move the eye within the orbit.



Structure of the Eye: The sphere of the eye can be divided into anterior and posterior chambers. The wall of the eye is composed of three layers: the fibrous tunic, vascular tunic, and neural tunic. Within the neural tunic is the retina, with three layers of cells and two synaptic layers in between. The center of the retina has a small indentation known as the fovea.

Identify the Structures of the Eye

Eyelids (Palpebrae) – Cover the eye

Meibomian glands – oily secretions – lubricate Medial and Lateral canthi

Conjunctiva – mucous membrane that covers the internal surface of the eyelids and much of the anterior eyeball

Eyeball

- Fibrous tunic – Dense irregular CT, avascular
- Sclera (white)
- Cornea – clear, refractory media of eyeball – bend light rays
- Vascular tunic, also called UVEA – carries blood to tissues of the eye
- Chroroid – posterior, brown, prevents light scattering in the eye
- Ciliary body – anterior, made mostly of ciliary muscle to control the shape of the lens
- Iris – most anterior portion – consist of muscle fibers around the pupil
- Sensory tunic b- Consist of
- Retina – contains photoreceptors
- Rods – shades of gray
- Cones – color
- Optic Nerve
- Lens – Divides the eyeball into
- Anterior Chamber – aqueous fluid = aqueous humors
- Posterior Chamber – viscous fluid = vitreous humor

Accessory structures

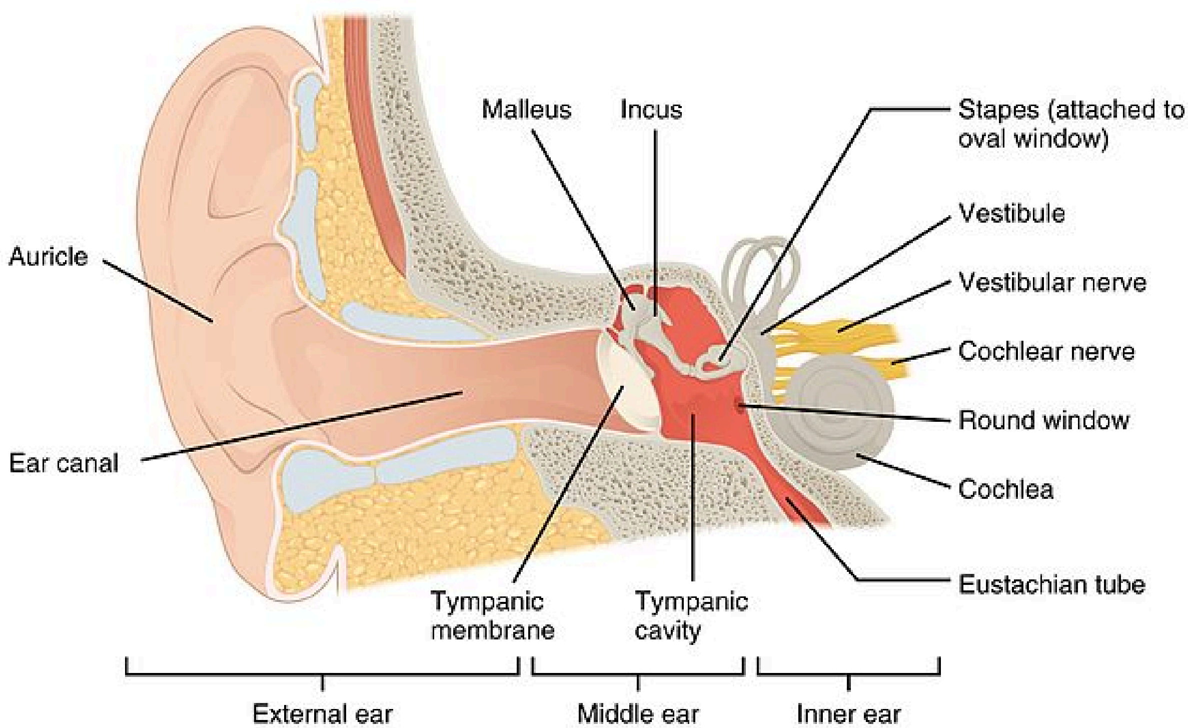
- Lacrimal apparatus
- Lacrimal glands
- Ducts – drain tears

Extraocular muscles – move eyeball

- Superior Rectus
- Inferior Rectus
- Medial Rectus
- Lateral Rectus
- Inferior Oblique
- Superior Oblique
- Innervation of the extraocular muscle of the eye

Ear

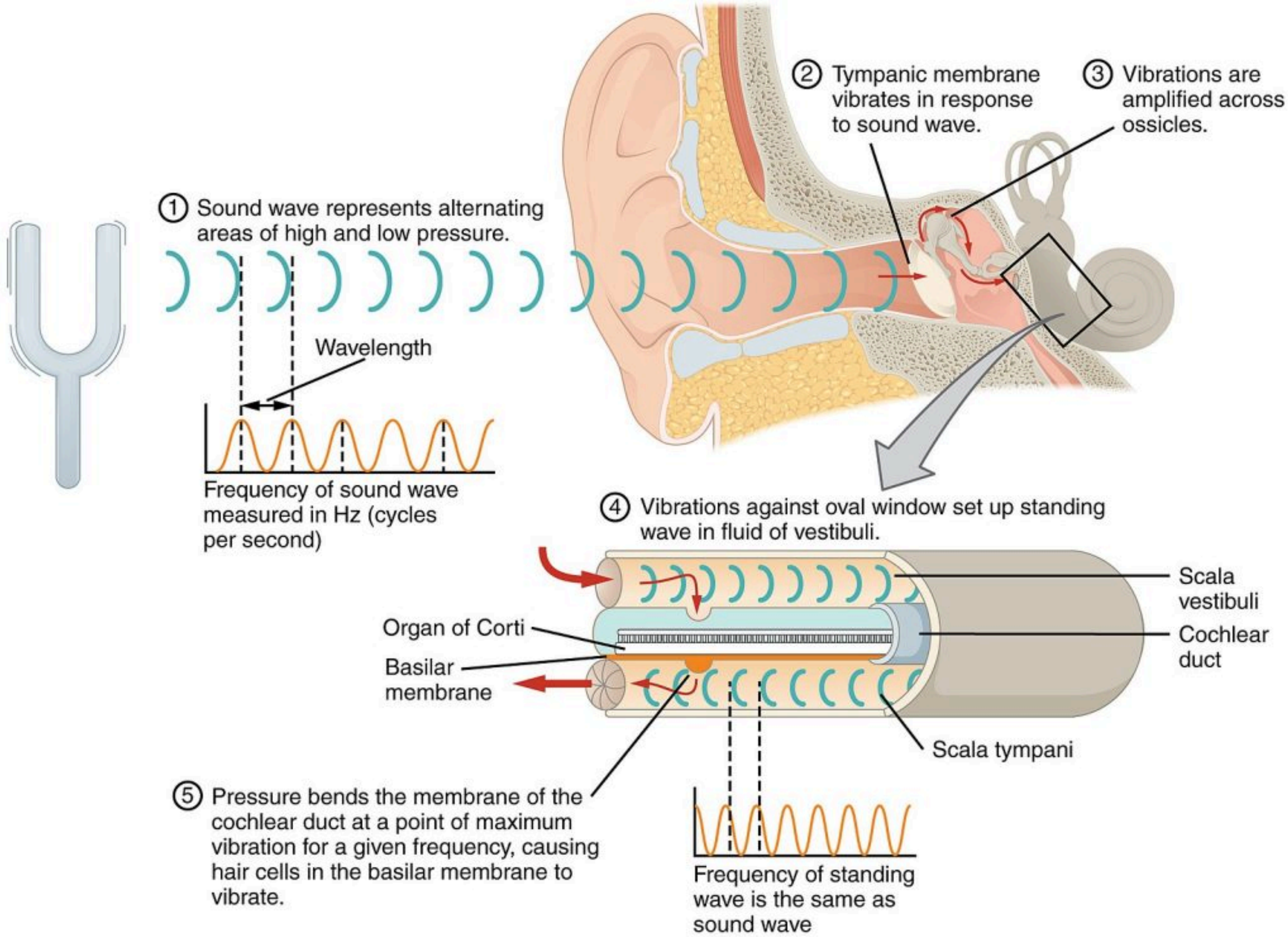
Hearing, or audition, is the transduction of sound waves into a neural signal that is made possible by the structures of the ear. The large, fleshy structure on the lateral aspect of the head is known as the auricle. Some sources will also refer to this structure as the pinna, though that term is more 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.



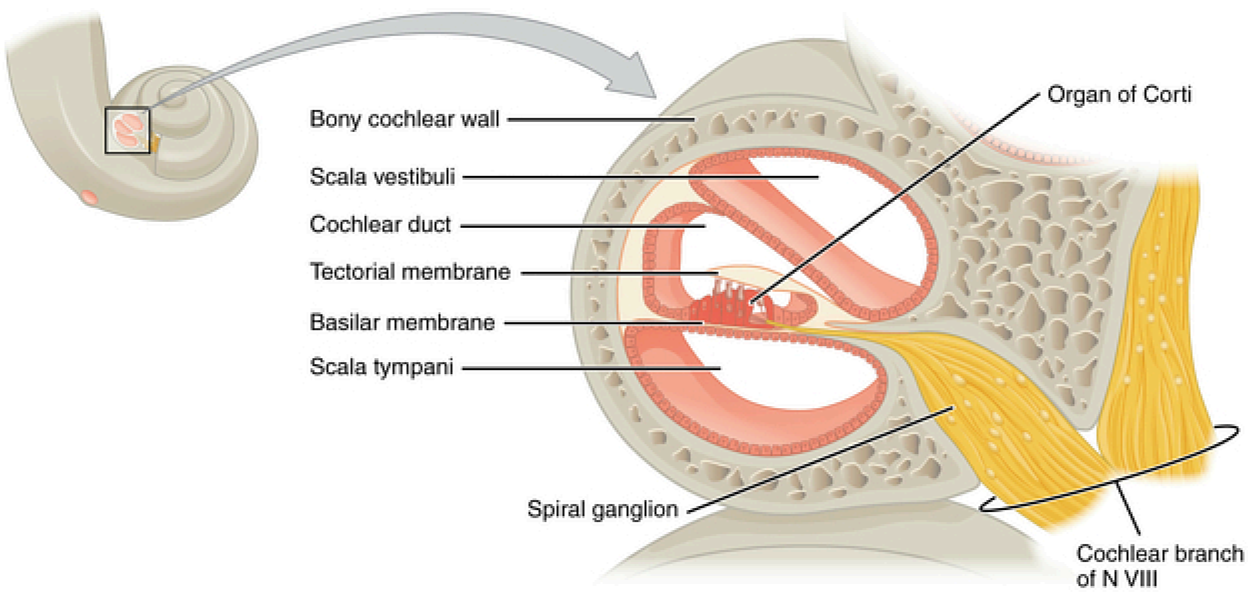
Structures of the Ear: The external ear contains the auricle, ear canal, and tympanic membrane. The middle ear contains the ossicles and is connected to the pharynx by the Eustachian tube. The inner ear contains the cochlea and vestibule, which are responsible for audition and equilibrium, respectively.

The inner ear is often described as a bony labyrinth, as it is composed of a series of canals embedded within the temporal bone. It has two separate regions, the cochlea and the vestibule, which are responsible for hearing and balance, respectively. The neural signals from these two regions are relayed to the brain stem through separate fiber bundles. However, these two distinct bundles travel together from the inner ear to the brain stem as the vestibulocochlear nerve. Sound is transduced into neural signals within the cochlear region of the inner ear, which contains the sensory neurons of the spiral ganglia. These ganglia are located within the spiral-shaped cochlea of the inner ear. The cochlea is attached to the stapes through the oval window.

The oval window is located at the beginning of a fluid-filled tube within the cochlea called the scala vestibuli. The scala vestibuli extends from the oval window, traveling above the cochlear duct, which is the central cavity of the cochlea that contains the sound-transducing neurons. At the uppermost tip of the cochlea, the scala vestibuli curves over the top of the cochlear duct. The fluid-filled tube, now called the scala tympani, returns to the base of the cochlea, this time traveling under the cochlear duct. The scala tympani ends at the round window, which is covered by a membrane that contains the fluid within the scala. As vibrations of the ossicles travel through the oval window, the fluid of the scala vestibuli and scala tympani moves in a wave-like motion. The frequency of the fluid waves match the frequencies of the sound waves. The membrane covering the round window will bulge out or pucker in with the movement of the fluid within the scala tympani.



Transmission of Sound Waves to Cochlea: A sound wave causes the tympanic membrane to vibrate. This vibration is amplified as it moves across the malleus, incus, and stapes. The amplified vibration is picked up by the oval window causing pressure waves in the fluid of the scala vestibuli and scala tympani. The complexity of the pressure waves is determined by the changes in amplitude and frequency of the sound waves entering the ear.



Cross Section of the Cochlea: The three major spaces within the cochlea are highlighted. The scala tympani and scala vestibuli lie on either side of the cochlear duct. The organ of Corti, containing the mechanoreceptor hair cells, is adjacent to the scala tympani, where it sits atop the basilar membrane.

A cross-sectional view of the cochlea shows that the scala vestibuli and scala tympani run along both sides of the cochlear duct. 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.

Procedures

Plastic Anatomy – Identify structures.

1. Review the muscles of the eye & ear in the images and tables provided using anatomical models available in the lab.
2. Examine and label the eye & ear model and using images provided and anatomical models in the lab.
3. Review the movement and action of each eye muscle using your eyes and your lab partners.
4. Perform a Dissection of Cow eyeball – Watch the following video before coming to the lab.

You will need: lab coat, eye protection, dissection kit.

Media Attributions

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THE ENDOCRINE SYSTEM ANATOMY

Introduction

The endocrine system is the collection of ductless glands that produce hormones that regulate metabolism, growth and development, tissue function, sexual function, reproduction, sleep, and mood.

The term "endocrine" comes from Greek, endo- 'within' + krinein 'sift', that means that the secretion produced by the gland is secreted inside the gland and then diffused to the capillaries that surround the gland to be distributed via circulation throughout the body where it will reach its target cell.

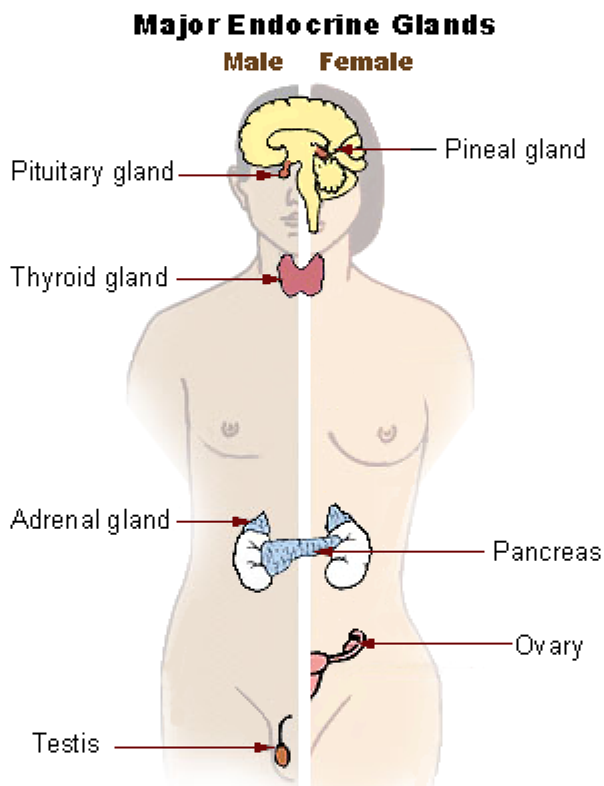


Figure 1. Major components of the Endocrine System

Learning Objectives

1. To identify the major endocrine glands using an anatomical model or diagram.

    1. Pituitary gland; anterior and posterior pituitary glands
    2. Thyroid and parathyroid glands
    3. Adrenal gland
    4. Pancreas
    5. Testes
    6. Ovaries
2. Identify major endocrine glands and its components at the microscopic level
    1. Pituitary gland – distinguish between the anterior and posterior lobes
    2. Thyroid – Identify the thyroid follicles, colloid and parafollicular cells
    3. Adrenal Glands – Identify the zona glomerulosa, zona fasciculata, zona reticularis, and adrenal medulla
    4. Pancreas – Identify pancreatic islets and acinar tissue
3. To list the hormones secreted by each endocrine gland identified, and discuss the actions of each hormone identified
4. Describe the nature of feedback loops that regulate the activity of the hypothalamus, pituitary and other endocrine glands

Before the lab

- Read "The Endocrine System" chapter from your textbook
- View assigned videos and animations
- Complete the pre-lab activities assigned by your instructor

Laboratory Activities

Gross and Microscopic Anatomy of the Endocrine System

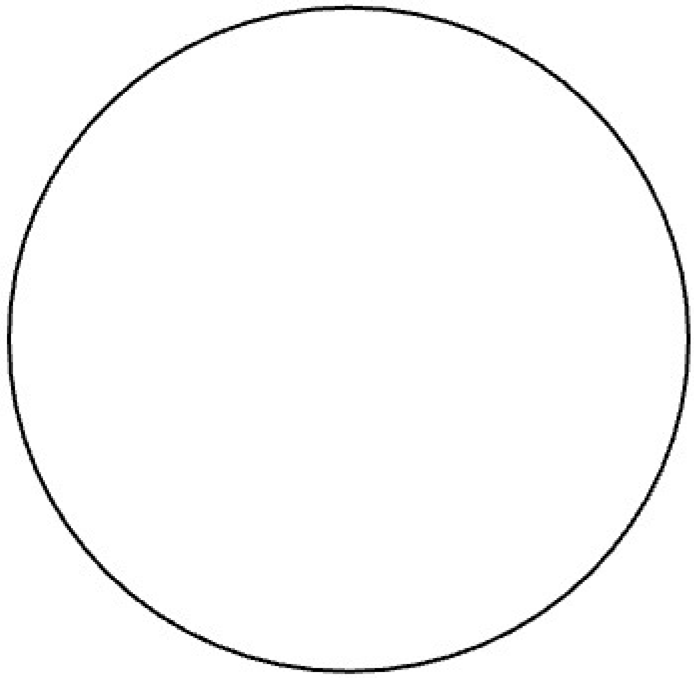
1. Identify the major endocrine organs. Use anatomical models available in the lab and Figure 1 as reference.Use the table shown below and the space provided for drawings to complete this activity.

Identify the following organs using:	**Identified**
A. Anatomical Models	
Hypothalamus	
Infundibulum	
Pituitary gland (Hypophysis)	
Anterior Pituitary – Pars distalis (Adenohypophysis)	
Posterior Pituitary – Pars nervosa (Neurohypophysis)	
Pineal gland	
Thyroid Gland	
Isthmus	
Right and left lobes	
Parathyroid glands	
Oxyphil and chief cells (if visible)	
Thymus Gland	
Pancreas	
Head	
Neck	
Body	
Tail	
Adrenal Gland	
Capsule	
Cortex	
Medulla	
Ovaries	
Testes	

2. Identify the microscopic components of major endocrine glands. Use microscope slides available in the lab to complete this activity. Draw each of them.

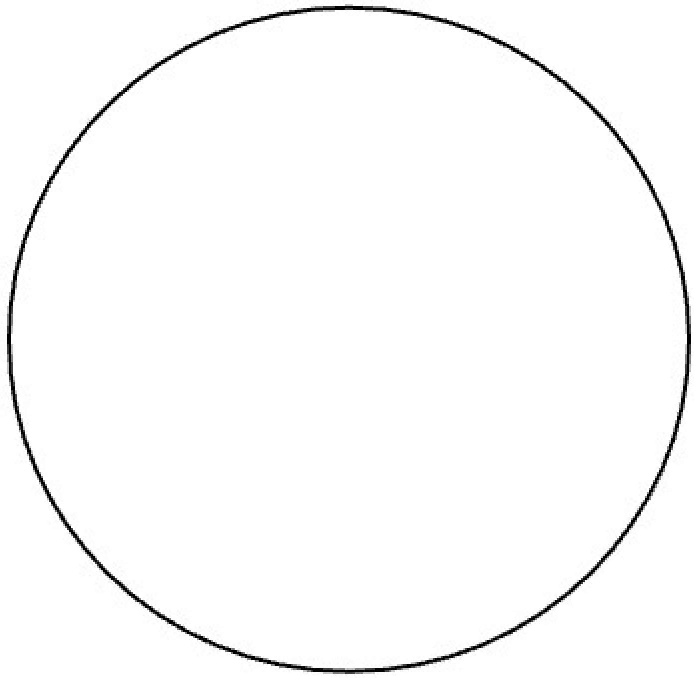
B. Microscope slides	**Identified**
Thyroid gland	
Follicles	
Follicular cells	
Colloid	
Parafollicular cells	
Adrenal gland	
Capsule	
Zona glomerulosa	
Zona fasciculata	
Zona reticularis	
Medulla	
Pancreas	
Acinar cells	
Islets of Langerhans	
Pancreatic ducts	
Ovaries	
*distinguish between oocytes and follicles	
Primordial follicles	
Primary follicles	
Secondary follicles	
3rtiary, Vesicular or Graafian follicle	
Antrum	
Ovum	
Corpus Luteum	
Corpus Albicans	
Medulla and cortex	
Testis	
Seminiferous tubule	
Interstitial cell (Leydig cell)	

3. Obtain prepared microscope slides of the major endocrine glands. Place the slides on the microscope stage, scan the slide using the scanning objective, once you have located the sample increase the magnification by using the low power objective to view the sample. Then use the high-power objective to see the cells associated with each of the endocrine glands and draw them in the space provided.
    1. Pituitary gland – make sure to label the anterior and posterior lobe



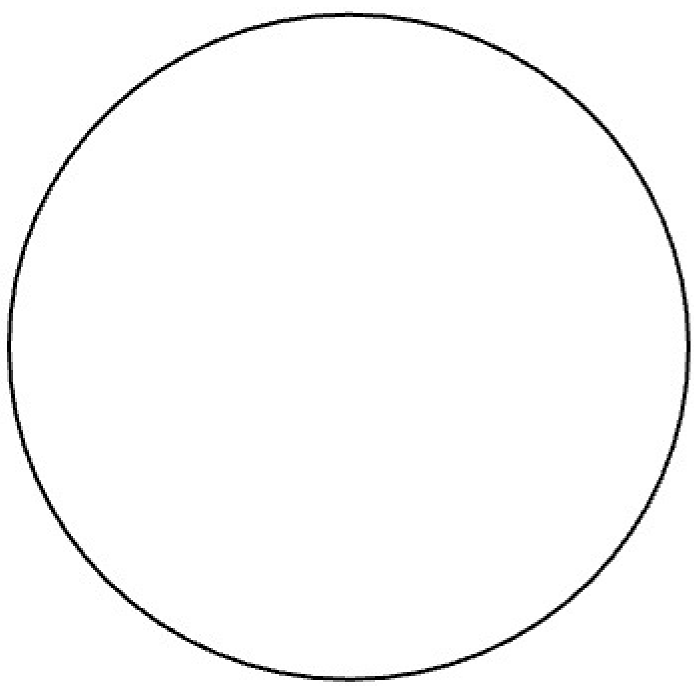
Total Magnification:

    2. Thyroid – make sure to label the thyroid follicles, colloid and parafollicular cells



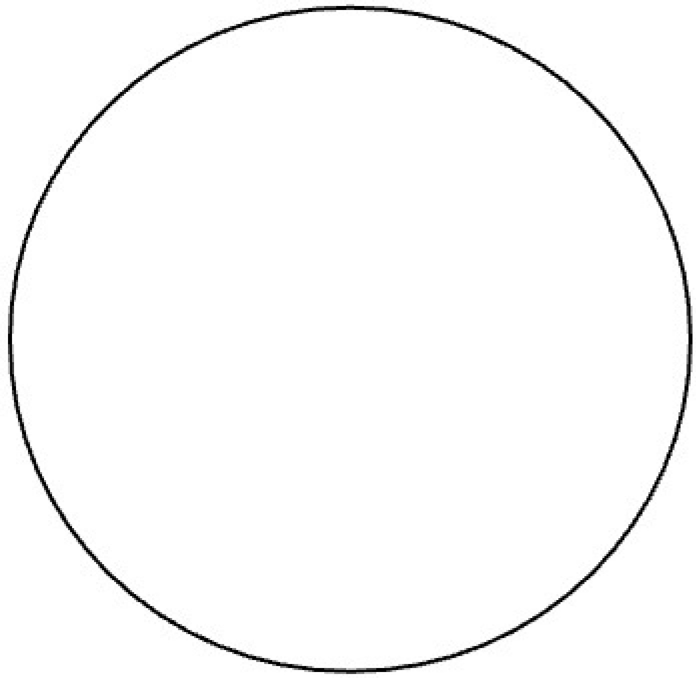
Total Magnification:

3. Adrenal Glands – Identify the zona glomerulosa, zona fasciculata, zona reticularis, and adrenal medulla



Total Magnification:

4. Pancreas – Identify pancreatic islets and acinar tissue



Total Magnification:

4. List the hormones secreted by each endocrine gland identified, and discuss the actions of each hormone identified

Table 2: Hormones and their actions

Organ	Hormones Secreted	Action of Hormones
Pineal Gland	Melatonin	
Anterior Pituitary Gland (Adenohypophysis)	Follicle-stimulating hormone (FSH)	
	Luteinizing hormone (LH)	
	thyroid-stimulating hormone (thyrotropin) (TSH)	
	Adrenocorticotropic hormone (ACTH)	
	Prolactin (PRL)	
	Growth Hormone (GH)	
Posterior Pituitary Gland (Neurohypophysis)	Antidiuretic Hormone (ADH)	
	Oxytocin	
Thyroid Gland (Colloid)	Triiodothyronine (T3)	
	Thyroxine (T4)	
	Calcitonin	
Parathyroid Gland	Parathyroid Hormone (PTH)	
Thymus	Thymosin	
Pancreas	Insulin	
	Glucagon	
	Somatostatin	
Adrenal Gland (cortex)	Corticosteroid Hormones	
zona glomerulosa	Mineralocorticoids (aldosterone)	
zona fasciculata	Glucocorticoids (cortisol/hydrocortisone)	
zona reticularis	Gonadocorticoids (Androstenedione and dehydroepiandrosterone (DHEA))	
Adrenal Gland (Medulla)	Epinephrine and Norepinephrine	
Testes	Testosterone and Inhibin	

Organ	Hormones Secreted	Action of Hormones
Ovaries	Estrogen, Progesterone and Inhibin	

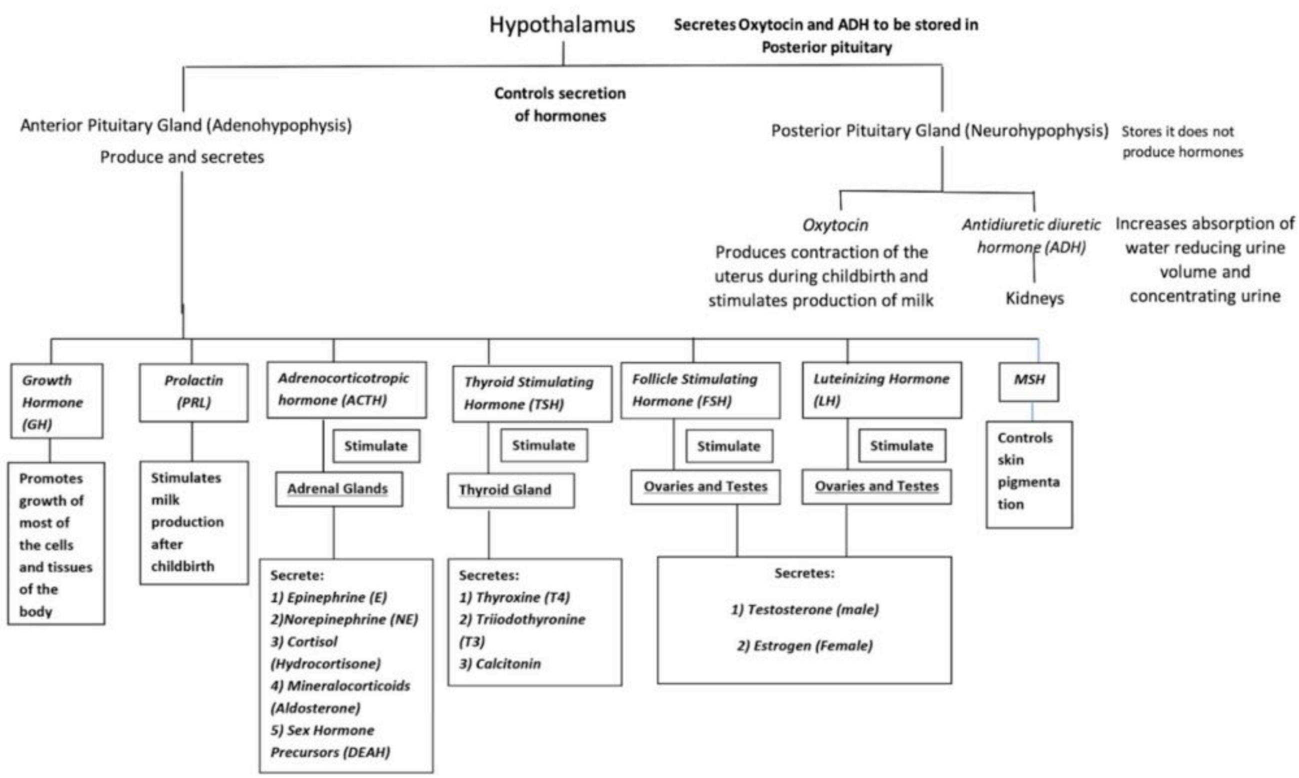
5. Describe the nature of feedback loops that regulate the activity of the hypothalamus, pituitary and other endocrine gland.

Additional Questions

You should also be able to answer the following questions:

1. What is the general name for the types of organs that produce hormones?
2. What name is given to cells or tissues receptive to hormones?
3. Melatonin is secreted by which gland?
4. Where is ADH stored?
5. What is the effect of TSH, and where is it produced?
6. What connects the two lobes of the thyroid gland?
7. Does parathormone increase or decrease calcium levels in the blood?
8. What does glucagon do as a hormone, and where is it produced?
9. Which hormones in the adrenal gland control water and electrolyte balance?
10. Which is the primary gland that secretes epinephrine?
11. Where is growth hormone produced?
12. What is another name for T3?
13. Interstitial cells of the testis produce which hormone?
14. What structures are responsible for the production of estrogen?

Appendix 1 – Hormone Flow Chart



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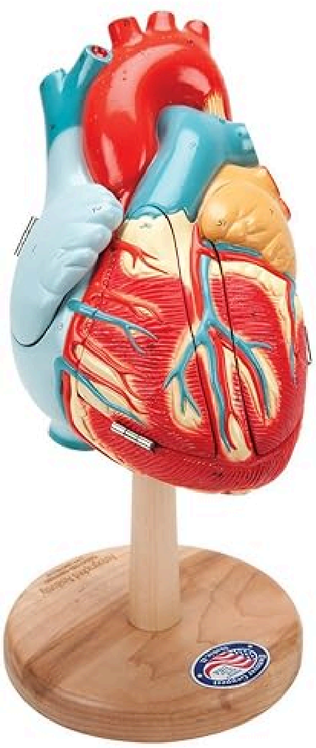
- Hormone Flow Chart © Maria Carles is licensed under a CC BY-SA (Attribution ShareAlike) license

THE CARDIOVASCULAR SYSTEM ANATOMY

Cardiovascular System Laboratory Activity

The Heart and Associated Vessels



The heart is a muscular organ that pumps blood through the blood vessels of the circulatory system. The pumped blood carries oxygen and nutrients to the body, while carrying metabolic waste such as carbon dioxide to the lungs.

In humans, the heart is approximately the size of a closed fist and is located between the lungs, in the middle compartment of the chest, called the mediastinum. The heart is enclosed in a protective sac, the pericardium, which also contains a small amount of fluid. The wall of the heart is made up of three layers: epicardium, myocardium, and endocardium.

The heart pumps blood with a rhythm determined by a group of pacemaker cells in the sinoatrial node. These generate a current that causes the heart to contract, traveling through the atrioventricular node and along the conduction system of the heart. In humans, deoxygenated blood enters the heart through the right atrium from the superior and inferior venae cavae and passes to the right ventricle. From here it is pumped into pulmonary circulation to the lungs, where it receives oxygen and gives off carbon dioxide. Oxygenated blood then returns to the left atrium, passes through the left ventricle and is pumped out through the aorta into systemic circulation, traveling through arteries, arterioles, and capillaries—where nutrients and other substances are exchanged between blood vessels and cells, losing oxygen and gaining carbon dioxide—before being returned to the heart through venules and veins.[8] The heart beats at a resting rate close to 72 beats per minute.

Laboratory Activity

1. Gross Anatomy of the heart and its blood vesselsUse anatomical models available in the lab to identify the following structures. Use the empty column to keep track of your progress.

Structures	
Right Atrium	
Right auricle	
Opening from coronary sinus	
Opening from superior vena cava	
Opening from inferior vena cava	
Left Atrium	
Left auricle	
Openings from pulmonary veins	
Right Ventricle	
Left Ventricle	
Tricuspid valve	
Bicuspid Valve	
Interatrial septum	
Aortic semilunar valve	
Pulmonary semilunar valve	
Interventricular septum	
Chorda tendinea	
Papillary muscles	
Pectinate muscles	
Trabecula carnae	
Pulmonary trunk	
Right Pulmonary artery	
Left Pulmonary artery	
Ligamentum arteriosum	
Ascending aorta	
Aortic arch	
Brachiocephalic trunk	
Left common carotid artery	
Left subclavian artery	

Structures	
Descending Aorta	
Superior vena cava	
Inferior vena cava	
Coronary sulcus	
Great cardiac vein	
Right coronary artery	
Left coronary artery	
Circumflex branch of left coronary artery	
Apex of the heart	
Base of the heart	

2. Microscopic anatomy of the human heart. Obtain a human heart slide from your instructor, focus at high power then identify, draw and label the following structures:

    - Heart cells – cardiomyocytes
    - Nucleus
    - Striations
    - Intercalated disks

3. Heart Dissection:

   For 100% online courses, watch the sheep heart dissection video posted here. For Hybrid and face to face courses, we will perform a sheep heart dissection in the lab.

   > *One or more interactive elements has been excluded from this version of the text. You can view them online here: https://rotel.pressbooks.pub/anatomyphysiology/?p=541#oembed-1*

Cardiovascular System Laboratory: Blood

Blood is a body fluid in the circulatory system of humans and other vertebrates that delivers necessary substances such as nutrients and oxygen to the cells and transports metabolic waste products away from those same cells. Blood in the circulatory system is also known as peripheral blood, and the blood cells it carries, peripheral blood cells.

Blood is composed of blood cells suspended in blood plasma. Plasma, which constitutes 55% of blood fluid, is mostly water (92% by volume), and contains proteins, glucose, mineral ions, hormones, carbon dioxide (plasma being the main medium for excretory product transportation), and blood cells themselves. Albumin is the main protein in plasma, and it functions to regulate the colloidal osmotic pressure of blood. Formed elements of blood include red blood cells (RBCs or erythrocytes), white blood cells (WBCs or leukocytes), and platelets (thrombocytes). RBCs are the most abundant cells. These contain hemoglobin, an iron-containing protein, which facilitates oxygen transport by reversibly binding to this respiratory gas thereby increasing its solubility in blood. In contrast, carbon dioxide is mostly transported extracellularly as bicarbonate ion transported in plasma.

Objectives:

- Identify the formed elements of the blood
- Determine differential WBC blood count
- Perform AB0 and Rh blood typing using simulated blood
- Explain basis for blood donation
- Determine appropriate donors for a given recipient

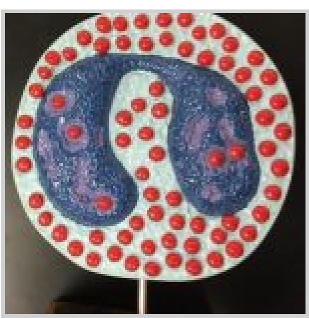
Activities

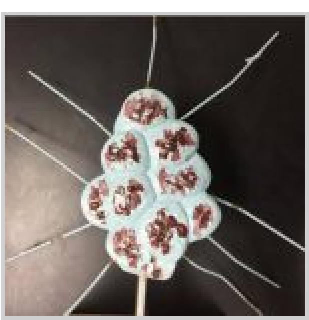
Identify the "Formed Elements" of the blood.

Procedure 1: Using the anatomical models available in the lab, identify the formed elements of blood.

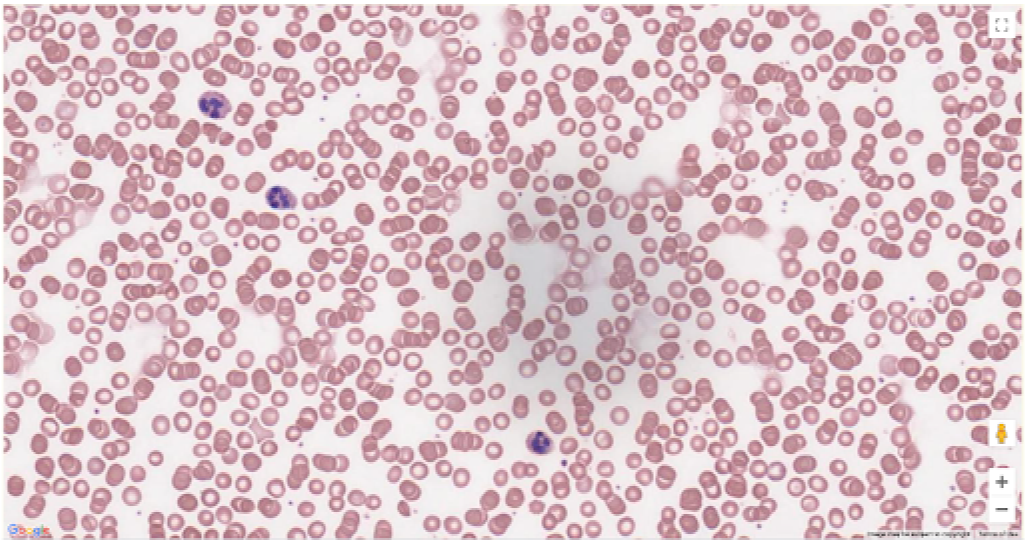
- Red blood cells
- White blood cells
    - Neutrophils
    - Eosinophils
    - Basophils
    - Lymphocytes
    - Monocytes
- Platelets



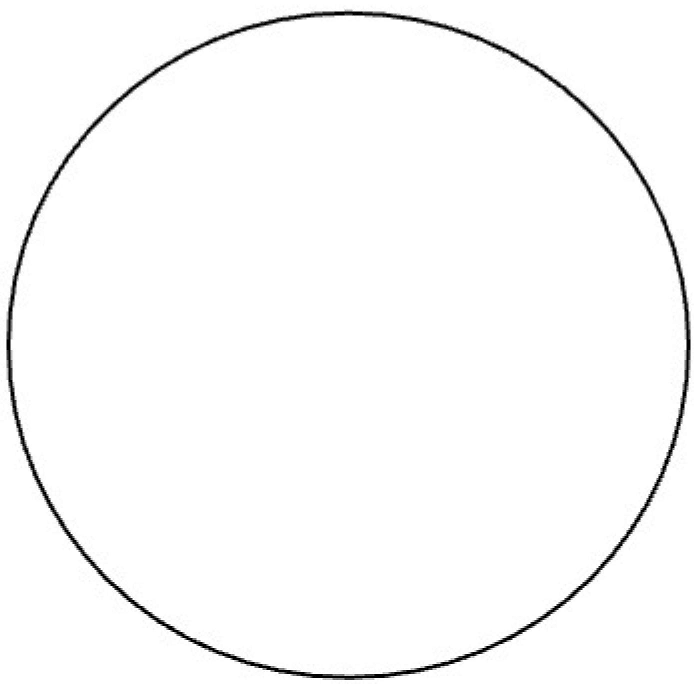



Procedure 2: Microscopy of Peripheral Blood Smear



Human blood smear, Giemsa stain, 86X scan from hematopathology normals collection (this slide contains 3 basophil cells)

Use a human blood smear slide, focus under high power, then draw and label the formed elements of blood. It should look similar to what you see here. For online courses, use the University of Michigan Virtual Microscope, search for Human blood smear and complete the procedure as described for a regular microscope.



Procedure 3: Performing a Differential White Blood Cell Count

Obtain a human blood smear slide, focus under high power, count the number of white blood cells you see per field. Note and differentiate the type of WBC. Record your findings on the table provided. Calculate the % of each WBC present. For online courses, use the University of Michigan Virtual Microscope, search for Human blood smear and complete the procedure as described for a regular microscope.

Cell type	**Number of cells**	**% of WBC**
Lymphocytes		
Monocytes		
Eosinophils		
Basophils		
Neutrophils		

Testing Simulated blood

Using a perform blood typing using a "Blood Typing Simulated Blood Kit". Follow the instructions of the manufacturer.

For 100% online courses, please watch the blood typing simulation video.

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://rotel.pressbooks.pub/anatomyphysiology/?p=541#oembed-2

Blood Vessels Lab

Introduction

The human circulatory system is a closed system composed of blood vessels, the heart and blood.

Recall what you learned about the directionality of blood in the unit of the heart, deoxygenated blood enters the right atrium via vena cava, and oxygenated blood enters the left atrium via pulmonary veins then the blood passes through the atrioventricular canals – to the right ventricle and to the left ventricle. When the ventricles of the heart contract, blood gets pushed in two different directions; from the right ventricle deoxygenated goes to the lungs – via the pulmonary trunk (artery) and return to the left atrium of the heart via pulmonary veins, then and from the left ventricle oxygenated blood is sent to the rest of the body via the aorta.

The blood will move into smaller arteries and finally into the capillaries (arterial end) in tissues, where exchange of materials will occur. The blood is then drain into the capillary bed (venous end) then into venules which will then empty into larger veins that will eventually reach the Vena Cava that enters the heart and completes the cycle.

The arteries are the ones that carry blood away from the heart and the veins will carry blood back to the heart. You usually see them colored in diagrams in red, blue and purple. The colors mean the following:

Red = blood vessels that carry oxygenated blood

Blue = blood vessels that carry deoxygenated blood

Purple = site for exchange where there is a mixture of oxygenated and deoxygenated blood or blood vessels that carry a mixture of both.

In this exercise we will examine and the gross and microscopic anatomy of selected blood vessels. We will identify mayor arteries and veins and learn which organs they are supplying or draining blood.

Learning Objectives

- Identify and label the components of blood vessels, arteries and veins.
- Identify selected arteries and veins.
- Describe the organs and regions supplied and drained by each artery and vein.
- Describe the blood flow patterns through portal systems.
- Trace the pathway of blood through pulmonary, cardiac, and systemic circuits.
- Describe the histological features of arteries, veins, and capillaries.
- Locate selected pulse points and identify locations for venipuncture.

Keywords

- macrovasculature
- microvasculature
- lumen
- tunica intima
- tunica media
- tunica adventitia
- elastic artery
- muscular artery
- continuous endothelium

- fenestrated endothelium
- discontinuous endothelium
- sinusoid
- artery
- arteriole
- vein
- venule
- capillary
- vasa vasorum
- portal system

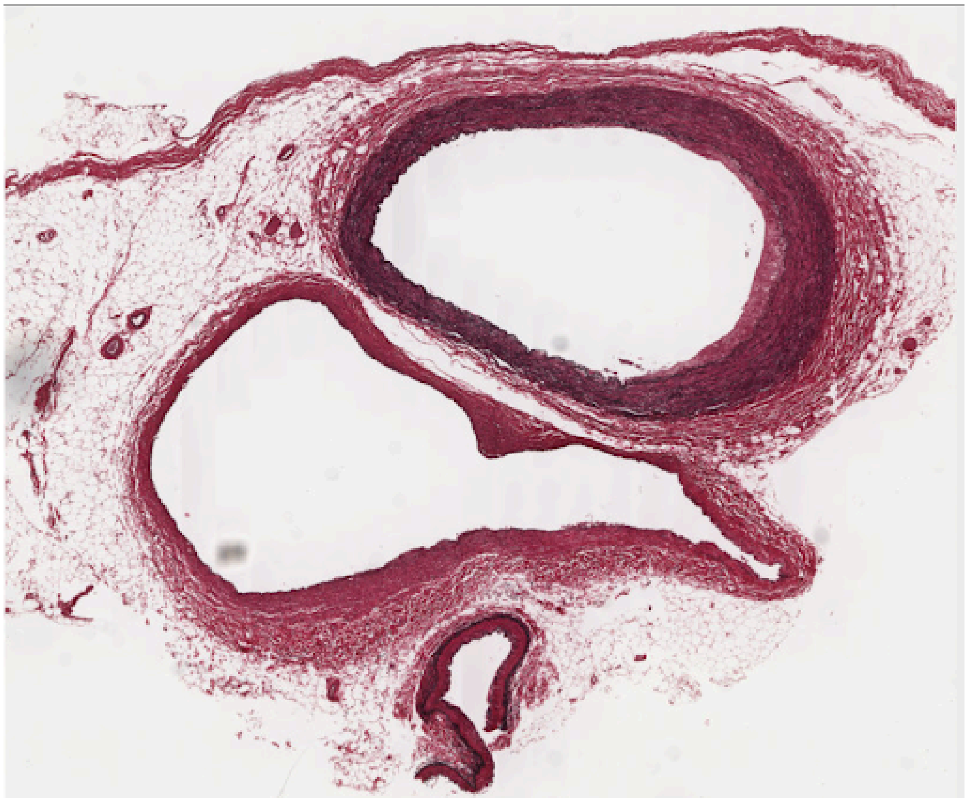
Materials

- Anatomical models of the human circulatory system
- Anatomical Charts of human blood vessels (major arteries and veins)
- Diagrams of pulmonary, coronary and systemic circulation
- Anatomical model of a fetus with placenta
- Anatomical model of the brain – Arterial supply to the brain and sinuses
- Microscope slides:
- Cross section of artery and vein
- Heart muscle – intercalated disk preparation (capillaries)
- UM Virtual Microscope slide # 303, Artery & vein, Verhoeff stain, 40X.

Procedure 1 – Microscopic anatomy of blood vessels

Except for capillaries the walls of arteries and veins have several layers, these layers are called tunicas. There are three distinct tissue layers making up the walls of arteries and veins:

1. Tunica interna or intima. It consists of a simple squamous epithelium (endothelium). It contains an adjacent basement membrane, the subendothelial connective tissue, and the internal elastic lamina. 2. Tunica media. Composed of smooth muscle tissue (innervated by the sympathetic nervous system) and elastic fibers, the elastic lamellae, where the elastic fibers allow the vessel to expand and recoil without damaging the walls of the arteries. 3. Tunica externa nor adventicia. The outermost layer of the blood, consists of dense irregular collagenous connective tissue with abundant collagen fibers, macrophages, mast cells, fibroblasts, nerves and vessels that supply large blood vessels.
   1. The image shown below was taken from the University of Michigan (UM) virtual Microscope, slide #303. Identify the artery and the vein.



UM slide #303; Artery & vein, Verhoeff stain, 40X

Procedure 2 – Classification of Blood vessels

Blood vessels are divided into two broad categories:

1. Macrovasculature – composed of blood vessels that can be seen with the naked eye.
2. Microvasculature – composed of blood vessels that are smaller than 100 microns may only be seen with the aid of a microscope.

Blood vessels can be classified as: elastic arteries (conducting arteries), muscular arteries (distributing arteries), arterioles, capillaries (4 to 10 microns in diameter), venules, and veins (small, medium, and large), and portal systems. Veins of small and medium size are characterized by a thin media containing only a few layers of smooth muscle cells and a large tunica adventitia, considerably thicker than the tunica media. The vasa vasorum, is a network of small vessels that supplies the cells of larger blood vessels, present in their adventitia layer.

Types of Capillaries

Continuous – Capillaries with a continuous endothelium are less permeable and are present in muscles, lung, connective tissue, and skin.

Fenestrated – Capillaries with a fenestrated endothelium have gaps between endothelial cells, but the basement membrane is still continuous. These are found in the renal glomeruli, endocrine glands, intestinal villi, and exocrine pancreas.

Discontinuous – Capillaries with a discontinuous endothelium have large gaps between cells and a discontinuous basement membrane. Such capillaries are called sinusoids and are found in the liver and in blood-forming and lymphoid organs. These capillaries play an important role in blood/interstitial fluid exchanges and explain the high degree of capillary permeability for water and water-soluble molecules, as well as plasma protein and hormones.

- Complete the following table

Type of blood vessel	Name an example of each
Elastic arteries	
Muscular arteries – Torso	
Muscular arteries – Head	
Muscular arteries – Arm	
Veins – large (torso)	
Veins – Large (leg)	
Veins – Large (arm)	
Portal System (brain)	
Portal System (abdomen)	
Fenestrated capillaries	Location:
Discontinuous capillaries	Location:

Procedure 3 – Blood Vessels Identification

Use the anatomical models available in the laboratory to identify following arteries. For 100% online courses use the diagrams provided.

Arteries of the Trunk

1. Aorta
    1. Ascending aorta
    2. Aortic arch

    3. descending aorta
    4. Thoracic aorta
    5. Abdominal aorta
2. Brachiocephalic trunk
3. Subclavian artery
4. Celiac trunk
    1. Common hepatic artery
    2. Splenic artery
    3. Left gastric artery
5. Middle suprarenal arteries
6. Renal arteries
7. Superior mesenteric artery
8. Gonadal arteries
9. Inferior mesenteric artery
10. Common iliac artery
    1. Internal iliac artery
    2. External iliac artery

Arteries of the Head and Neck

1. Common carotid arteries
    1. Right common carotid artery
    2. Left common carotid artery
2. External carotid artery
    1. Superficial temporal artery
3. Internal carotid artery
4. Vertebral artery
5. Basilar artery
6. Cerebral arterial circle
    1. Anterior communicating artery
    2. Posterior communicating arteries

Arteries of the Upper Limbs

1. Axillary artery
2. Brachial artery
3. Radial artery

4. Ulnar artery

Arteries of the Lower Limbs

1. Femoral artery
2. Popliteal artery
    1. Anterior tibial artery
    2. Posterior tibial artery

Veins of the Trunk

1. Superior vena cava
2. Inferior vena cava
3. Azygos system
    1. Azygos vein
    2. Hemiazygos vein
    3. Accessory hemiazygos vein
4. Renal vein
5. Gonadal veins
6. Suprarenal vein
7. Splenic vein
8. Gastric veins
9. Superior mesenteric vein
10. Inferior mesenteric vein
11. Hepatic portal vein
12. Hepatic veins

Veins of the Head and Neck

1. Vertebral vein
2. External jugular vein
3. Internal jugular vein
4. Dural sinuses
    1. Superior sagittal sinus
    2. Inferior sagittal sinus
    3. Straight sinus
    4. Transverse sinus
    5. Sigmoid sinus

6. Cavernous sinus

Veins of the Upper Limbs

1. Radial vein
2. Ulnar vein
3. Brachial vein
4. Cephalic vein
5. Median antebrachial vein
6. Basilic vein
7. Median cubital vein
8. Axillary vein
9. Subclavian vein
10. Brachiocephalic vein

Veins of the Lower Limbs and Pelvis

1. Anterior tibial vein
2. Posterior tibial vein
3. Popliteal vein
4. Small saphenous vein
5. Great saphenous vein
6. Femoral vein
7. Common iliac vein
8. Internal iliac vein
9. External iliac vein

Procedure 4 – Trace the path of blood

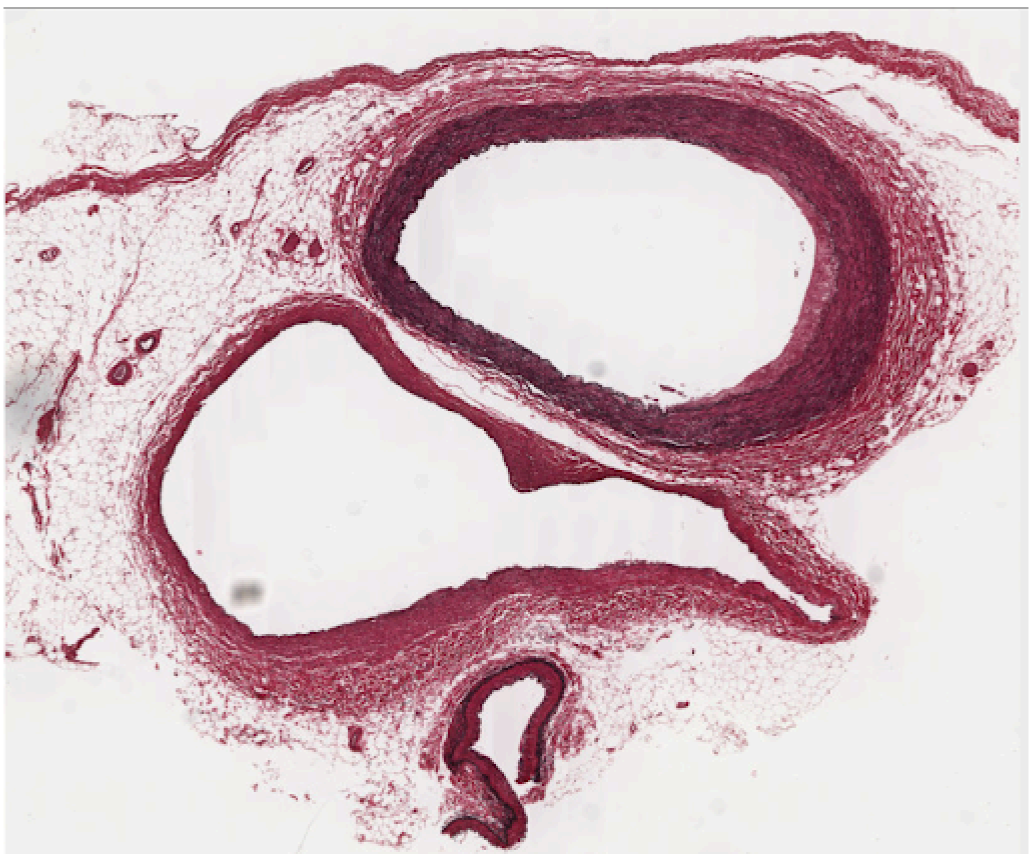
Trace the path of blood on each of the vascular circuits shown below. Use arrows.

1. Systemic Circuit

2. Pulmonary Circuit

3. Coronary Circuit

Procedure 5 – Histology of the Blood Vessels



UM slide #303; Artery & vein, Verhoeff stain, 40X

For 100% online courses, go to University of Michigan Virtual Microscope, search for slide #303 or use the image shown here.

For standard face to face or hybrid classes, obtain a prepared microscope slides of artery, vein and capillaries. Note – for capillaries use a heart slide (intercalated disk stain).

Use colored pencils to draw and label the following:

1. Artery
    1. Tunica interna (endothelium)
    2. Tunica media: Smooth muscle & Elastic fibers
    3. Tunica externa
    4. Lumen
2. Capillary
    1. Tunica interna
    2. Blood cell(s), if present
    3. Lumen
3. Vein
    1. Tunica interna
    2. Tunica media
    3. Tunica externa
    4. Lumen

Procedure 6 – Pulse Palpation

Pulse palpation is the process of using your fingertips to feel pulse points. You will be able to assess the rate, rhythm, and regularity of the heartbeat. Common pulse points are radial, ulnar, brachial, carotid, temporal, femoral, popliteal, posterior tibial, and dorsalis pedis arteries.

1. Wash your hands
2. Lightly place your index finger and middle finger over the artery, increase the pressure slightly, but be careful not to press too hard, because you could cut off blood flow.
3. Start with the radial, ulnar, brachial, carotid, temporal, femoral, popliteal, posterior tibial, and dorsalis pedis arteries. Do the exercise only to one side of the body at the time,
4. The superficial veins of the arm, forearm, and hand provide multiple places that are relatively easy to access to blood. When performing a venipuncture, the most commonly used veins are the median cubital vein, the cephalic vein, or the basilic vein. When placing an intravenous catheter, generally one of the posterior veins of the hand is used.
5. Locate the most common places to perform venipuncture in your lab partner. We will not do the actual venipuncture.

Pre-Lab Quiz

1. List, in order, the specific segmental variations of blood vessels that a red blood cell would travel through on a continuous circuit beginning in the left ventricle and ending in the right atrium of the heart.

2. The blood-brain barrier (BBB) separates the brain and spinal cord from the contents of the bloodstream. What type of endothelium would you expect to see in the capillaries of the BBB?

3. As you move through the arterial system from large to small arteries, what change would you expect to see in the relative amounts of elastic tissue and smooth muscle cells?

4. As you move from arteries to veins, what change would you expect to see in the relative sizes of the tunica intima, media, and adventitia?

5. Which of the following is a common pulse point? (check all that apply)
    1. Subclavian artery.
    2. Femoral artery.
    3. Brachial artery.
    4. Dorsalis pedis artery.
    5. Temporal artery

Fill in the blanks

1. __________ carry blood away from the heart to supply tissues
2. __________ drain tissues and bring blood back to the heart
3. One layer of ______________ epithelium forms the walls of capillaries
4. The __________ is the largest artery of the body

5. The ________________ is the longest vein of the human body
6. The ______________ is a branch of the abdominal aorta that supplies most of the small intestine and the final first half of the large intestine
7. In the developing fetus the umbilical __________ carry rich blood in nutrients and oxygen to the fetus.
8. In the developing fetus there is a connection between the right and the left atria called ___________.
9. And minutes after a baby is born that closes and becomes _______________.

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Pre-Lab Quiz (Online Version)

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An interactive H5P element has been excluded from this version of the text. You can view it online here:
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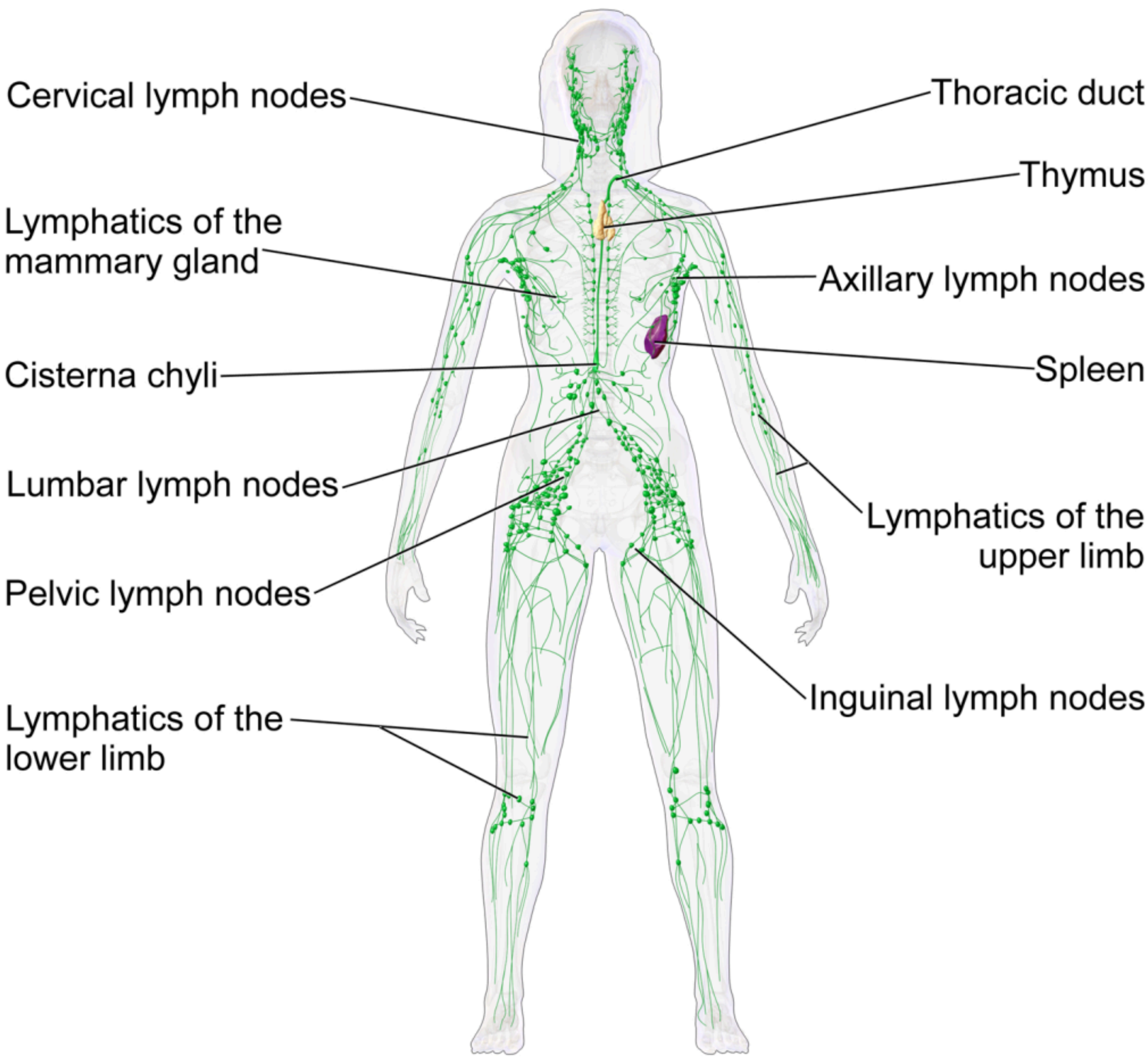
- Blank circle © Maria Carles is licensed under a CC BY-SA (Attribution ShareAlike) license
- Private: Artery and the vein label © Michigan Medical School adapted by Maria Carles is licensed under a CC BY-SA (Attribution ShareAlike) license

THE LYMPHATIC AND IMMUNE SYSTEM ANATOMY

Human Lymphatic System



Introduction

The lymphatic system was first described in the 17th century independently by Olaus Rudbeck and Thomas Bartholin.

The lymphatic system is an organ system closely associated with the immune system, and complementary to the circulatory system. It consists of a large network of lymphatic vessels, lymph nodes, lymphoid organs, lymphoid tissues and lymph.

Lymph (Latin, lympha, it refers to the deity of fresh water, "Lympha"), is a clear fluid very similar in chemical composition to plasma, that is carried by the lymphatic vessels to the vena cava then into the heart for re-circulation. Lymph contains waste products and cellular debris, together with bacteria and proteins. The cells of the lymph are mostly lymphocytes.

The lymphoid organs include the lymph nodes (where the highest lymphocyte concentration is found), spleen, thymus, and tonsils. They are composed of lymphoid tissue and are the sites either of lymphocyte production or of lymphocyte activation. Lymphocytes are initially produced in the bone marrow and reach lymphoid organs via circulation. Lymphoid tissue may also be associated with the mucosa, mucosa-associated lymphoid tissue (MALT).

Fluid from circulating blood leaks into the tissues of the body by capillary action, carrying nutrients to the cells. The fluid bathes the tissues as interstitial fluid, collecting waste products, bacteria, and damaged cells, and then drains as lymph into the lymphatic capillaries and lymphatic vessels. These vessels carry the lymph throughout the body, passing through numerous lymph nodes which filter out unwanted materials such as bacteria and damaged cells. The lymph then passes into much larger lymph vessels known as lymphatic ducts; the right lymphatic duct drains the right side of the head and right arm and the larger left lymphatic duct, known as the thoracic duct, drains the left side of the body. The ducts empty into the subclavian veins, then to the superior vena cava to return to the fluid to the circulation. Lymph is moved through the system by muscle contractions.

Primary Lymphoid Organs

The primary lymphoid organs generate lymphocytes from immature progenitor cells. The thymus and the bone marrow constitute the primary lymphoid organs involved in the production and early clonal selection of lymphocyte tissues.

Bone Marrow

Bone marrow is responsible for both the creation of T cell precursors and the production and maturation of B cells, which are important lymphocyte types of the immune system. From the bone marrow, B cells immediately join the circulatory system and travel to secondary lymphoid organs in search of pathogens. T cells, on the other hand, travel from the bone marrow to the thymus, where they develop further and mature.

Thymus

The thymus increases in size from birth in response to postnatal antigen stimulation. It is most active during the neonatal and pre-adolescent periods. The thymus is located between the inferior neck and the superior thorax. At puberty, by the early teens, the thymus begins to atrophy and regress, with adipose tissue mostly replacing the thymic stroma. However, residual T cell lymphopoiesis continues throughout adult life, providing some immune response. The thymus is where the T lymphocytes mature and become immunocompetent. The loss or lack of the thymus results in severe immunodeficiency and subsequent high susceptibility to infection. In most species, the thymus consists of lobules divided by septa which are made up of epithelium which is often considered an epithelial organ. T cells mature from thymocytes, proliferate, and undergo a selection process in the thymic cortex before entering the medulla to interact with epithelial cells.

Secondary lymphoid organs

The secondary (or peripheral) lymphoid organs, which include lymph nodes and the spleen, maintain mature naive lymphocytes and initiate an adaptive immune response. The secondary lymphoid organs are the sites of lymphocyte activation by antigens. Activation leads to clonal expansion, and affinity maturation. Mature lymphocytes recirculate between the blood and the secondary lymphoid organs until they encounter their specific antigen.

Spleen

The main functions of the spleen are:

- to produce immune cells to fight antigens
- to remove particulate matter and aged blood cells, mainly red blood cells
- to produce blood cells during fetal life.

Lymph nodes

A lymph node is an organized collection of lymphoid tissue, through which the lymph passes on its way back to the blood. Lymph nodes are located at intervals along the lymphatic system. Several afferent lymph vessels bring in lymph, which percolates through the substance of the lymph node, and is then drained out by an efferent lymph vessel. Of the nearly 800 lymph nodes in the human body, about 300 are located in the head and neck. Many are grouped in clusters in different regions, as in the underarm and abdominal areas. Lymph node clusters are commonly found at the proximal ends of limbs (groin, armpits) and in the neck, where lymph is collected from regions of the body likely to sustain pathogen contamination from injuries. Lymph nodes are particularly numerous in the mediastinum in the chest, neck, pelvis, axilla, inguinal region, and in association with the blood vessels of the intestines.

The substance of a lymph node consists of lymphoid follicles in an outer portion called the cortex. The inner portion of the node is called the medulla, which is surrounded by the cortex on all sides except for a portion known as the hilum. The hilum presents as a depression on the surface of the lymph node, causing the otherwise spherical lymph node to be bean-shaped or ovoid. The different lymph vessel directly emerges from the lymph node at the hilum. The arteries and veins supplying the lymph node with blood enter and exit through the hilum. The region of the lymph node called the paracortex immediately surrounds the medulla. Unlike the cortex, which has mostly immature T cells, or thymocytes, the paracortex has a mixture of immature and mature T cells. Lymphocytes enter the lymph nodes through specialized high endothelial venules found in the paracortex.

A lymph follicle is a dense collection of lymphocytes, the number, size, and configuration of which change in accordance with the functional state of the lymph node. For example, the follicles expand significantly when encountering a foreign antigen. The selection of B cells, or B lymphocytes, occurs in the germinal center of the lymph nodes.

Secondary lymphoid tissue provides the environment for the foreign or altered native molecules (antigens) to interact with the lymphocytes. It is exemplified by the lymph nodes, and the lymphoid follicles in tonsils, Peyer's patches, spleen, adenoids, skin, etc. that are associated with the mucosa-associated lymphoid tissue (MALT).

In the gastrointestinal wall, the appendix has mucosa resembling that of the colon, but here it is heavily infiltrated with lymphocytes.

Lymphatic vessels

The lymphatic vessels, also called lymph vessels, are thin-walled vessels that conduct lymph between different parts of the body. They include the tubular vessels of the lymph capillaries, and the larger collecting vessels–the right lymphatic duct and the thoracic duct (the left lymphatic duct). The lymph capillaries are mainly responsible for the absorption of interstitial fluid from the tissues, while lymph vessels propel the absorbed fluid forward into the larger collecting ducts, where it ultimately returns to the bloodstream via one of the subclavian veins.

The tissues of the lymphatic system are responsible for maintaining the balance of the body fluids. Its network of capillaries and collecting lymphatic vessels work to efficiently drain and transport extravasated fluid, along with proteins and antigens, back to the circulatory system. Numerous intraluminal valves in the vessels ensure a unidirectional flow of lymph without reflux. Two valve systems, a primary and a secondary valve system, are used to achieve this unidirectional flow. The capillaries are blind-ended, and the valves at the ends of capillaries use specialized junctions together with anchoring filaments to allow a unidirectional flow to the primary vessels. The collecting lymphatics, however, act to propel the lymph by the combined actions of the intraluminal valves and lymphatic muscle cells.

Lab Activity: Gross Anatomy of the Lymphatic System

Objectives

1. List the main functions of the lymphatic system.
2. List the components of the lymphatic system.
3. Describe the relationship between the lymphatic system and the cardiovascular system.
4. Describe the relationship between the lymphatic system and the immune system.
5. Identify lymphatic organs and lymphatic nodules in the human body.
6. Describe the microscopic structure of selected lymphatic structures. Describe the anatomy of an antibody molecule.
7. Explain the basis of the ELISA test.

Purpose:

The goal of this lab is to examine the organization of the components of the lymphatic system. By the end of the lab, you should be able to describe and distinguish lymph, lymph nodes, tonsils, lymphatic tissue, thymus, and spleen.

Materials

- Torso
- Head and neck models
- Lymphatic system model
- Intestinal villus model (with lacteals)

Instructions

1. 1. Obtain a model of the head and neck (midsagittal), identify the pharyngeal, lingual and palatine tonsils.
2. Obtain a torso model, identify the thymus, spleen, ileum, and vermiform appendix.
3. On a torso model, identify networks of lymphatic vessels in the axillary and inguinal regions, the right lymphatic duct, thoracic duct and cisternae chyli.
4. Using a lymph node model, identify the afferent and efferent vessels, cortex and medulla.
5. Using a lymphatic system model identify, cervical, axillary, inguinal, mediastinal, mesenteric lymph nodes, thoracic trunk, right lymphatic trunk, cisternae chili.

Microscopic Anatomy of the Lymphatic System Components

Materials

Microscope slides:

1. Lymphatic vessels, l.s.
2. Tonsils
3. Thymus
4. Lymph node
5. Spleen
6. Ilium (Peyer's Patches)

Instructions

Lymphatic vessel, l.s.

1. Obtain a slide of the lymphatic vessel, make sure it is a l.s. section.
2. View the slide with the scanning objective to locate the sample, then change to low power. Identify the valves of the lymphatic vessels.

Tonsils

1. Obtain a slide of the Tonsils.
2. View the slide with the scanning objective to locate the sample, then change to low power. Identify the septa, germinal centers, cortex and medulla.

Thymus

1. Obtain a slide of the thymus.
2. View the slide with the scanning objective to locate the sample, then change to low power, then high power. Identify the capsule (connective tissue), and trabecula that subdivide each lobe of the thymus into lobules, cortex, medulla and germinal centers.

Lymph node

1. Obtain a slide of the Lymph node.
2. View the slide with the scanning objective to locate the sample, then change to low power and eventually

to high power, 400X. Identify the capsule (connective tissue), cortex and medulla, germinal centers, afferent and efferent vessels, and septa.

Spleen

1. Obtain a slide of the spleen.
2. View the slide with the scanning objective to locate the sample, then change to low power, then high power. Identify the capsule and septa.
3. Identify the two functional tissue components of the spleen; red pulp, and white pulp and the capsule.

Ilium patches

1. Obtain a slide of Ilium.
2. View the slide with the scanning objective to locate the sample, then change to low power. Identify the epithelium, the submucosa and the Peyer Patches

Anatomy of an Antibody

Draw and label an IgG molecule in the space provided.

Media Attributions

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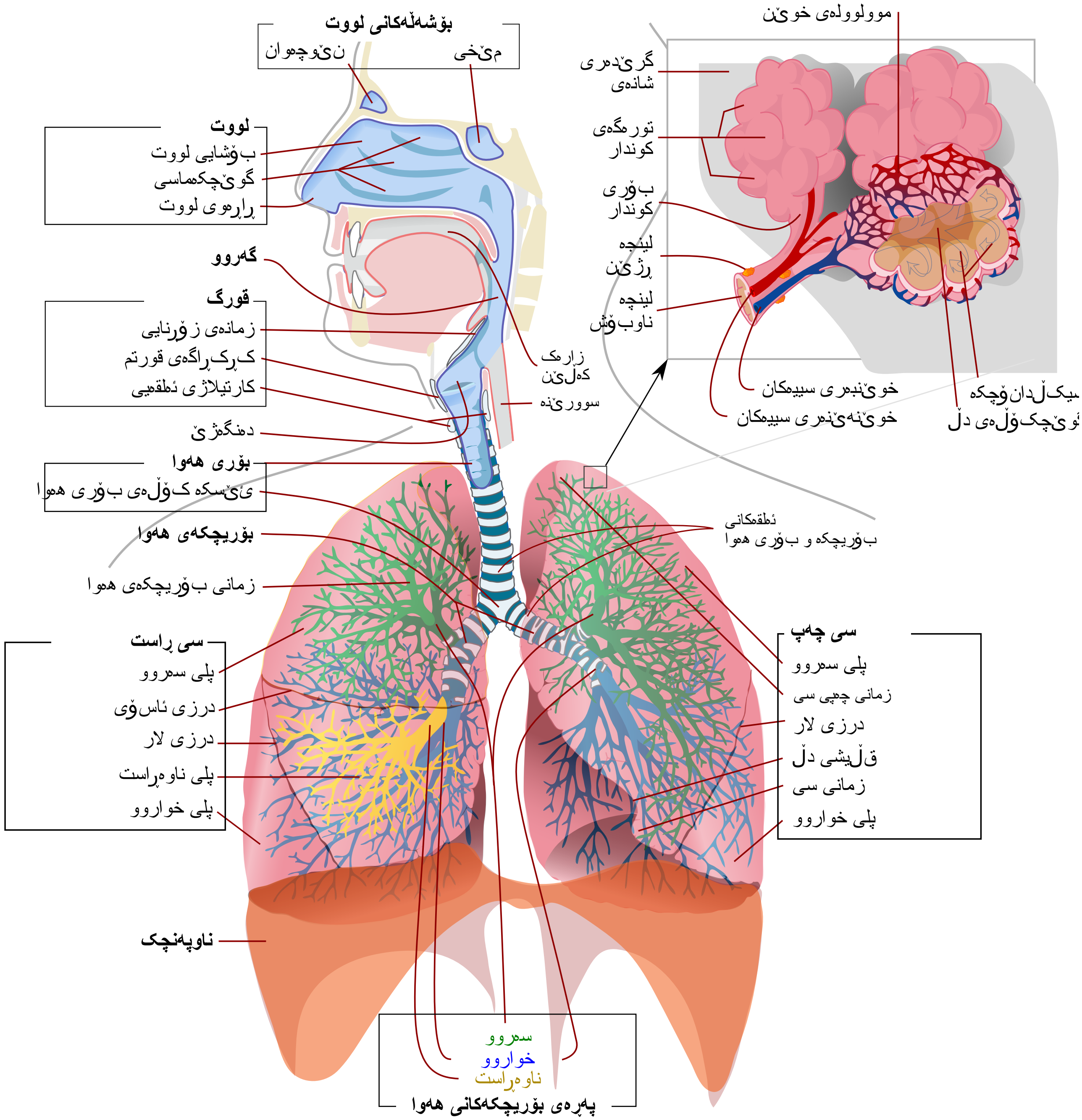
THE RESPIRATORY SYSTEM ANATOMY

The Respiratory System Laboratory Activity



A complete, schematic view of the human respiratory system with their parts and functions.

Introduction

The respiratory system is a biological system consisting of specific organs and structures used for gas exchange. Gas exchange in the lungs occurs in millions of small air sacs; in mammals called alveoli. These microscopic air sacs have a very rich blood supply, thus bringing the air into close contact with the blood. These air sacs communicate with the external environment via a system of airways, or hollow tubes, of which the largest is the trachea, which branches in the middle of the chest into the two main bronchi. These enter the lungs where they branch into progressively narrower secondary and tertiary bronchi that branch into numerous smaller tubes, the bronchioles. In birds the bronchioles are termed parabronchi. It is the bronchioles, or parabronchi that generally open into the microscopic alveoli in mammals and atria in birds. Air has to be pumped from the environment into the alveoli or atria by the process of breathing which involves the muscles of respiration.

In humans the respiratory tract is divided into an upper and a lower respiratory tract. The upper tract includes the nose, nasal cavities, sinuses, pharynx and the part of the larynx above the vocal folds. The lower tract includes the lower part of the larynx, the trachea, bronchi, bronchioles and the alveoli.

The branching airways of the lower tract are often described as the respiratory tree or tracheobronchial tree. The first bronchi to branch from the trachea are the right and left main bronchi. Second, only in diameter to the trachea (1.8 cm), these bronchi (1 -1.4 cm in diameter) enter the lungs at each hilum, where they branch into narrower secondary bronchi known as lobar bronchi, and these branch into narrower tertiary bronchi known as segmental bronchi. Further divisions of the segmental bronchi (1 to 6 mm in diameter)[7] are known as 4th order, 5th order, and 6th order segmental bronchi, or grouped together as subsegmental bronchi

Complete Lab Activities for the Respiratory System:

Exercise 1: Respiratory System Anatomy

- Practice – 3D Model Activity – Use Anatomical models of the Respiratory System – available in the lab to identify the following structures:
- Anatomical models available in the lab include: Torsos, Tracheobronchial tree, Giant nose.
- To supplement the lab view the respiratory system anatomical model explained:

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Exercise 2: Histology of the Respiratory Tract

University of Michigan – Full Slide List or scan QR code below.

Directions:

1. Click to link shown above to use the microscope simulation – Microscope slide of Trachea (Trachea H&E, 40X) and lung
    1. Trachea – slide #127 (it also contains the esophagus, locate the area where you see hyaline cartilage and pseudostratified columnar ciliated epitheliumn)
    2. Lung – slide # 130 (zoom in and locate the alveoli of the lung and bronchioles (there is cartilage around it)

Instructions to use the simulation:

1. Click to zoom-in and double-click to zoom-out
2. Use the “+” or “-+ to Zoom in or out

3. Click-drag to pan.
4. Alt-click to zoom-in 100% and alt-double-click to zoom-out completely.
5. To return to a prior view simply Alt-click the Reset button on the Toolbar. (On Mac, Option-click rather than Alt-click.)

Note: There are more images you can use in the lab folder for the respiratory system.

Exercise 3: Lung inflation model – Watch the following videos/simulations

Inflation model videos:

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THE DIGESTIVE SYSTEM ANATOMY

The Digestive System Laboratory Activity

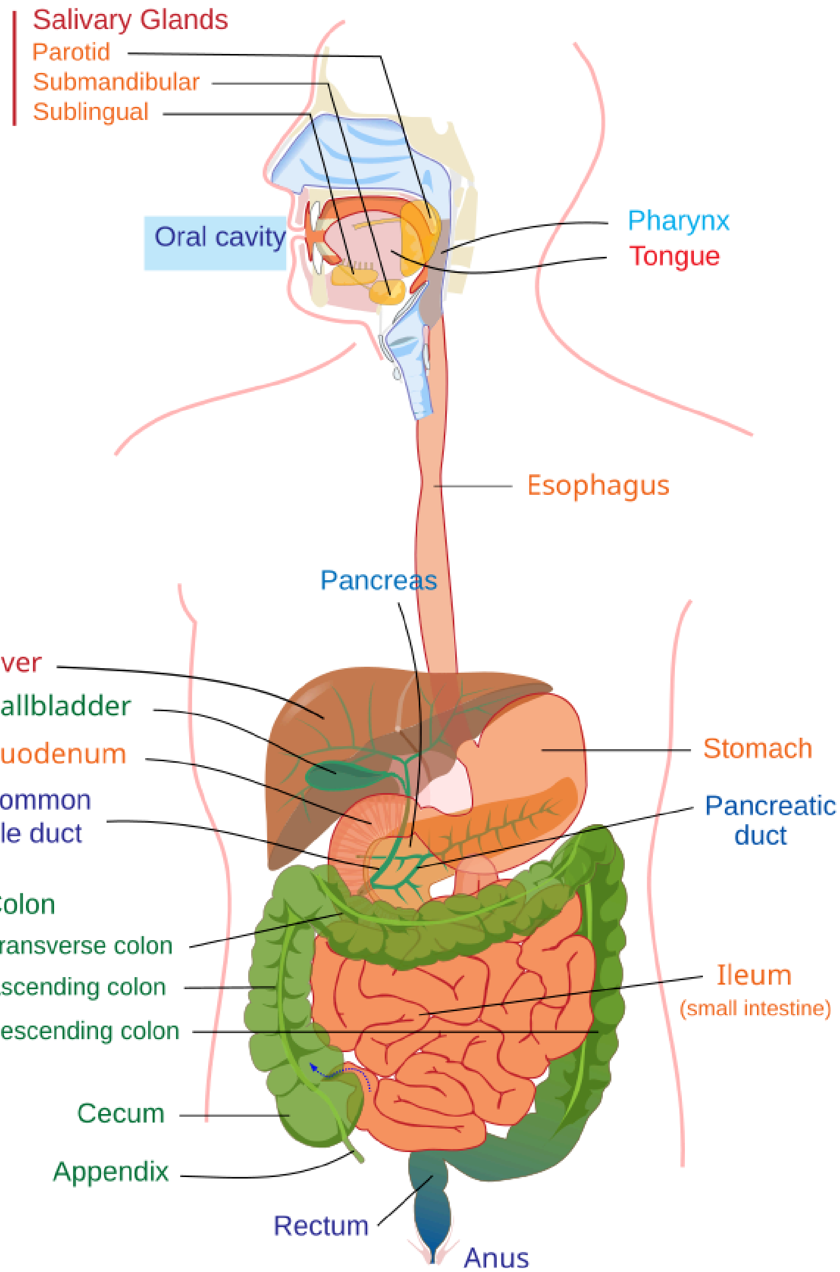
The digestive system is made up of a series of hollow organs that form a tube that twists and convolutes (~30 meters long) and the main functions are to convert food into fuel.

Food enters the digestive tract at the mouth where digestion begins and continues along the digestive tract, processes such as absorption and production of waste also happen here. The digestive system contains accessory organs such as the liver, gallbladder and pancreas that help break down and absorb food.

The organs that make up the digestive tract are: the mouth (oral cavity), esophagus, stomach, and small intestine (duodenum, jejunum, and ileum), large intestine (colon, rectum, and anus). These hollow organs are composed of several layer of tissue, the mucosa contains glands that produce substances to help digest food and lubricate (lines the lumen), sub mucosa, the smooth muscle layer (middle layer) helps break down food and move it along the tract and a serosa layer, protective connective tissue layer (adventitia).

The liver and the pancreas produce digestive secretions that reach the intestine through small tubes called ducts. The gallbladder stores the bile (produced in the liver) until needed in the intestine. Parts of the nervous (plexuses) and circulatory systems play major roles in the digestive system.

Let's examine the structure and function of each of the organs that form the digestive system.



The Digestive System

Mouth (Oral Cavity)

Movement: Mastication

Secretions (Fluid/Enzymes/Hormones/Mucus)

- Saliva (H_2O, HCO_3^-)
- R-protein (protection of B-12)
- Salivary amylase (ptyalin = α-amylase) to maltose, maltriose
- *Greek ptyalon saliva, from ptyein to spit
- Serous Mucus (lubrication), helps soften the food and form it into a bolus.
- Lingual lipase, hydrolyzes long-chain triglycerides into partial glycerides and free fatty acids.

Digestion: Beginning carbohydrate and lipid breakdown
Absorption: Very little
Reflexes: Chewing or Mastication Reflexes
Innervation:

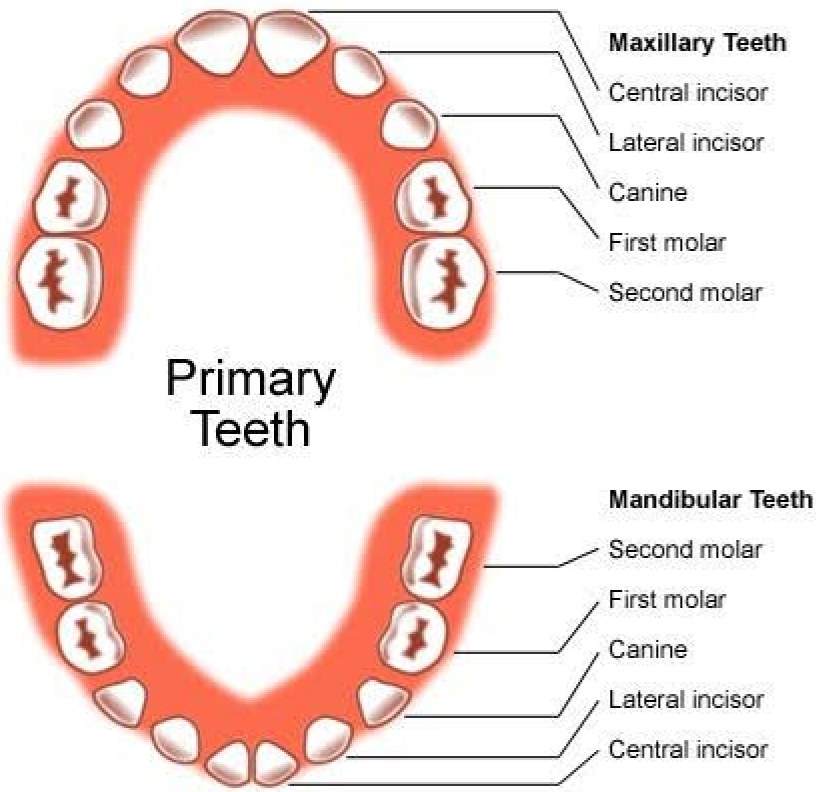
- Cranial nerves
- Sympathetic
- Parasympathetic

Disorders

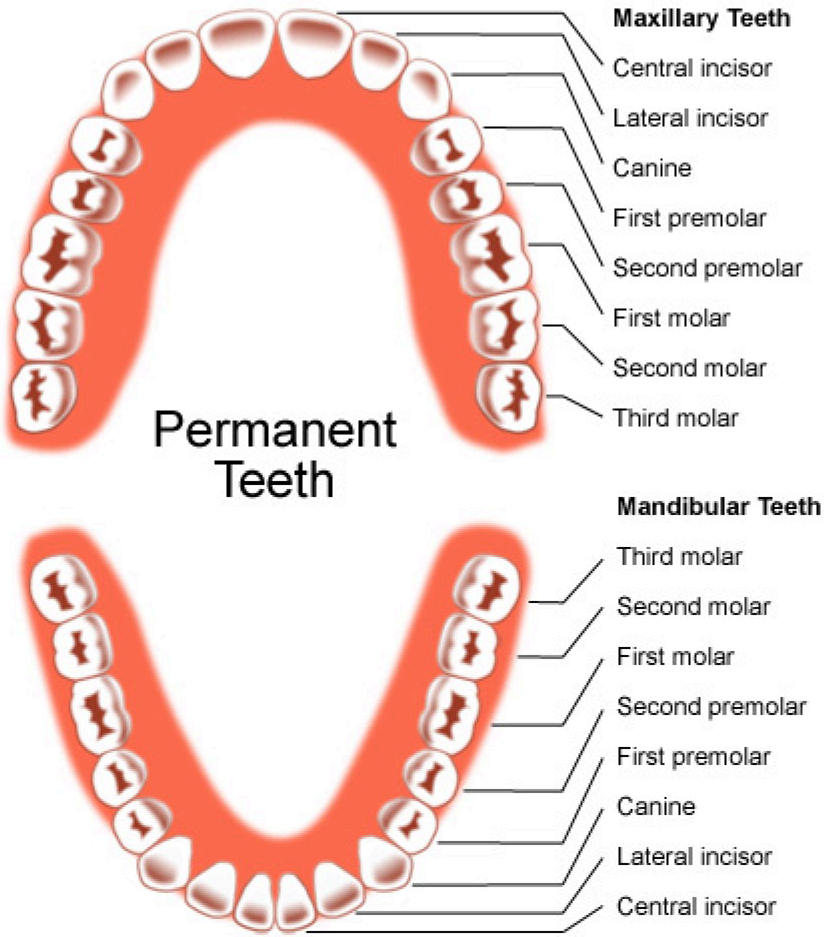
- Cleft lip/palate
- Dental decal
- Tooth loss
- Tone damage
- TMJ
- Paralysis/ spinal cord injury
- Sjorngren's syndrome�inability to produce saliva or tears

Teeth

- Primary teeth are the first set of teeth that erupt through the gums at regular intervals between the ages of six months and two and one-half years. There are twenty primary teeth – ten in each jaw.



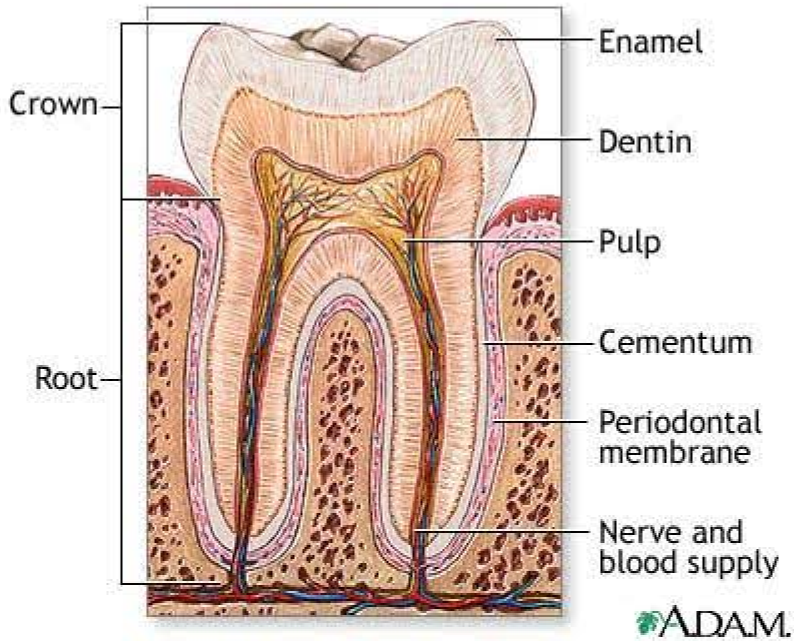
- Secondary teeth begin to appear about age six but may not be completed until age twenty-five.
  - There are thirty-two secondary teeth – sixteen in each jaw.
  - The incisors are chisel-shaped, and their sharp edges bite off relatively large pieces of food.
  - The cuspids (canine) are cone-shaped, and they grasp and tear food.
  - The bicuspids (premolars) and molars have somewhat flattened surfaces and are specialized for grinding food particles.



Permanent Teeth

[Permanent teeth (adult teeth)](#)

Each tooth consists of two main portions called the crown and the root. The crown is the portion above the gum and is covered by glossy white enamel. Beneath the enamel is the bulk of the tooth, which is made up of dentin. Dentin surrounds the central cavity, which houses the blood vessels, nerves and connective tissue. The root is enclosed by cementum, which is surrounded by the periodontal ligament. The region where the crown and root meet is called the neck. The cementum and the periodontal ligaments anchor the tooth to the alveolar bone.



The Histological Structure of a Tooth

Pharynx

The pharynx is the part of the neck and throat situated behind the mouth and nasal cavity, and cranial, or superior, to the esophagus.

It is part of the digestive system and respiratory system. Because both food and air pass through the pharynx, a flap of connective tissue, the epiglottis closes over the trachea when food is swallowed to prevent choking or asphyxiation.

The pharynx is composed of:

The nasopharynx located above the soft palate, lies behind the nasal cavity and like the nasal passages is lined with ciliated columnar pseudostratified epithelium.

The oropharynx located behind the soft palate and projects downward to the upper border of the epiglottis, is that part of the pharynx behind the oral cavity. It is lined with stratified squamous epithelium.

The laryngopharynx (hypopharynx) located from the upper border of the epiglottis downward to the lower border of the cricoid cartilage of the larynx, where the respiratory and digestive pathways diverge. At that point, the laryngopharynx is continuous with the esophagus. It serves as a passageway for food and air, during swallowing, food has the “right of way”, and air passage temporarily stops. It is lined with a stratified squamous epithelium.

Swallowing

The steps in the mechanism of swallowing are:

1. The soft palate rises, preventing food from entering the nasal cavity.
2. The hyoid bone and the larynx are elevated; the epiglottis closes off the top of the trachea so that food is less likely to enter.
3. The tongue is pressed against the soft palate, sealing off the oral cavity from the pharynx.
4. The longitudinal muscles in the pharyngeal wall contract, pulling the pharynx upward toward the food.
5. The lower portion of the inferior constrictor muscles relaxes, opening the esophagus.
6. The superior constrictor muscles contract, stimulating a peristaltic wave to begin in the pharyngeal muscles. This wave forces the food into the esophagus.

Esophagus

The esophagus is a narrow and hollow muscular tube about 20-30 centimeters long, closed proximally and distally by muscular sphincters.

The esophagus functions as a tube that transports substances from the pharynx to the stomach.

The upper esophageal sphincter (UES) and proximal one third of the esophageal body is composed of striated muscle. There is then a transition zone where striated and smooth muscles intermix. The lower esophageal sphincter (LES) and the distal one half to two thirds of the esophageal body are composed of smooth muscle

The esophageal wall is composed of distinct layers:

1. The inner mucosal layer consists of stratified squamous epithelium and underlying connective tissue, within which lies a longitudinally oriented muscle layer called the muscularis mucosa (unknown function)
2. The muscularis propria, involved in bolus transport and consists of an inner layer of circularly oriented muscle fibers and an outer layer of longitudinally oriented fibers.
3. In between these two muscle layers lies the myenteric plexus, which controls the motor function of these muscles.

The main function of the esophagus is to propel swallowed food or fluid into the stomach.

The peristaltic velocity averages about 3 cm/sec in the upper esophagus, then accelerates to about 5 cm/sec in the mid-esophagus, and slows again to approximately 2.5 cm/sec distally.

The duration and amplitude of individual pressure waves also varies along the esophagus. The duration of the wave is shortest in the proximal esophagus (approximately 2 seconds) and longest distally (approximately 5 to 7 seconds). In average, it takes about seven seconds for food to pass through the esophagus.

Movements:

- Peristalsis: rhythmic propelling movements that occur in the alimentary canal
- Receptive relaxation is where the muscular wall ahead of peristaltic contraction relaxes. This allows the tubular contents to be pushed along the canal.
- Secretions (Fluid/Enzymes/Hormones/Mucus): Lubricating Mucus
- Digestion: Starch continued from above
- Absorption: None
- Reflexes: Receptive relaxation
- Innervation: Cranial nerves, Parasympathetic, Sympathetic

Disorders:

- Achalasia—lower esophageal sphincter fails to relax during the swallowing mechanism—damage to lower 2/3 of the esophagus, may lead to megaesophagus—excessive distension of the esophagus; heartburn (GERD); esophagitis (inflammation of the esophagus); paralysis; hernia, diverticula, and atresia

Stomach

The **stomach** is a J-shaped, pouch-like organ. Thick folds called rugae mark its inner lining. Its mucous membrane lining contains the gastric pits that are the openings for the gastric glands that secrete digestive enzymes.

Movement: Peristalsis, Retropropulsion/ mixing

Secretions (Fluid/Enzymes/Hormones/Mucus):

- Gastric fluid, intrinsic factor, and HCl/Pepsin, Tributerase, and collagenase/Gastrin and Histamine/ thick, viscous, basic mucous.
- Chief cell-Pepsinogen
- Parietal cell-HCl (convert pepsinogen to pepsin) and intrinsic factor (for absorption of B-12)
- Neck cell-Mucus (protection)
- Surface epithelial cell- Bicarbonate (protects mucosa)
- Mucosal cells- Histamine (↑ acid production)
- G-cells- Gastrin (↑ acid production, ↑ intestinal motility, pyloric contraction, ↑ secretion of Secretin, and relax ileocecal valve)

- **Pepsin**—is a protein-splitting enzyme. The chief cells secrete **pepsinogen** (the precursor of pepsin) that then combines with **hydrochloric acid** to form pepsin.
- **Intrinsic factor**—aids in the absorption of vitamin B12

Digestion:

- Starch continued from above until pH reaches ~4.
- Beginning of protein breakdown to proteases, peptones, and poly-peptides by pepsin.
- **Absorption:** Some lipid-soluble substances such as alcohol (20%) and aspirin.

Reflexes:

- Regulation of gastric secretions
- Parasympathetic impulses and the hormone gastrin enhance the gastric secretions. The presence of the food in the small intestine� inhibits the gastric secretions.

Mechanism that controls the emptying of the stomach.

The chyme accumulates near the pyloric sphincter. This muscle begins to relax. The pyloric region of the stomach then pumps the chyme a little at a time into the small intestine. The rate at which the stomach empties is dependent upon the fluidity of the chyme and the type of food present.

- **Gastrocholic reflex**—signals from the stomach cause evacuation of the colon.
- **Enterogastric reflex**— inhibits the gastric peristalsis and secretion when the food enters the small intestine. The small intestine tells the stomach to slow down (negative feedback).

Innervation: Vagal nerves (Parasympathetic) Sympathetic

Disorders

Peptic ulcer disease (PUD) gastric ulcers in the stomach

- Gastritis— inflammation of the gastric mucosa,
- Gastric atrophy—in people with chronic gastritis, the mucosa becomes atrophic until little or no gastric gland activity remains.

Autoimmunity, may lead to:

- **Achlorhydria**—no HCl secretion, [can be due to chronic use of antacids, no carbonic anhydrase].
- **Hypochlorhydria**—diminished HCl secretion,
- **Pernicious anemia**-no intrinsic factor (B-12 absorption problem)� failure to synthesize RBC's

Hiatal Hernia

Pyloric stenosis (esp. in children)

Small intestine

is the part of the gastrointestinal tract following the stomach and followed by the large intestine, and is where much of the digestion and absorption of food takes place. It receives bile juice and pancreatic juice through hepato-pancreatic duct, controlled by Sphincter of Oddi

The primary function of the small intestine is the absorption of nutrients and minerals found in food.

The average length of the small intestine in an adult human male is 6.9 m (22 feet 6 inches), and in an adult female 7.1 m (23 feet 4 inches). It can vary greatly, from as short as 4.6 m (15 feet) to as long as 9.8 m (32 feet). It is approximately 2.5–3 cm in diameter.

The small intestine is divided into three structural parts:

1. **Duodenum**—the first twenty-five centimeters of the small intestine, it lies behind the parietal peritoneum. It is the most fixed portion of the small intestine.
2. **Jejunum**—the proximal two-fifths of the remainder of the small intestine.
3. **Ileum**—the remainder of the small intestine

The three sections of the small intestine look similar to each other at a microscopic level, but there are some important differences. The parts of the intestine are as follows:

Histology

The small intestine is divided into duodenum (25-30 cm), jejunum (about first two-fifths of the rest) and ileum. The three segments merge imperceptibly and have the same basic histological organization.

The Mucosa

The mucosa of the small intestine has various structural features which considerably increase the luminal surface area and consequently support the main function of the small intestine – the absorption of the degraded components of the food.

Plicae circulares (of Kerkering) are macroscopically visible, crescent-shaped folds of the mucosa and submucosa. Plicae circulares extend around one-half to two-thirds of the circumference of the lumen of the small intestine.

Plicae circulares

- Are permanent structures, i.e. their presence does not depend on the state of distension of the small intestine.
- Are absent from the first few centimeters of the duodenum and the distal part of the ileum.
- Are particularly well developed in the jejunum.

- Increase the surface area of the mucosa by a factor of ~ three.

The entire intestinal mucosa forms intestinal villi (about one mm long), which increase the surface area by a factor of ~ ten. The surface of the villi is formed by a simple columnar epithelium. Each absorptive cell or enterocyte of the epithelium forms numerous microvilli (1 μm long and about 0.1 μm wide). Microvilli increase the surface area by a factor of ~ 20.

Between the intestinal villi we see the openings of simple tubular glands, the crypts of Lieberkühn. They extend through the lamina propria down to the muscularis mucosae. Undifferentiated cells close to the bottom of the crypts regenerate the epithelium (epithelial cell turnover time is less than one week). Other epithelial cells in the crypts correspond largely to those in the epithelium of the intestinal villi. One exception is Paneth cells, which are located at the bottom of the crypts. They release a number of antibacterial substances, among them lysozyme, and are thought to be involved in the control of infections.

One function of the crypts of Lieberkühn is the secretion of "intestinal juice" (about 2 liter/day), which in its composition closely resembles extracellular fluid and which is rapidly reabsorbed. The only enzymes which can be demonstrated in the intestinal juice are enteropeptidase (or enterokinase), which activates the pancreatic enzyme trypsin, and small amounts of amylase. In addition to enterocytes, the epithelium is composed of mucus-secreting goblet cells and endocrine cells.

In addition to gastrin- and somatostatin-producing cells, we also find endocrine cells secreting cholecystokinin and secretin. Cholecystokinin stimulates the secretion of digestive enzymes in the pancreas and the contraction of the gall bladder. Secretin stimulates the pancreas to release "pancreatic juice", which is rich in bicarbonate ions. Secretin also amplifies the effects of cholecystokinin.

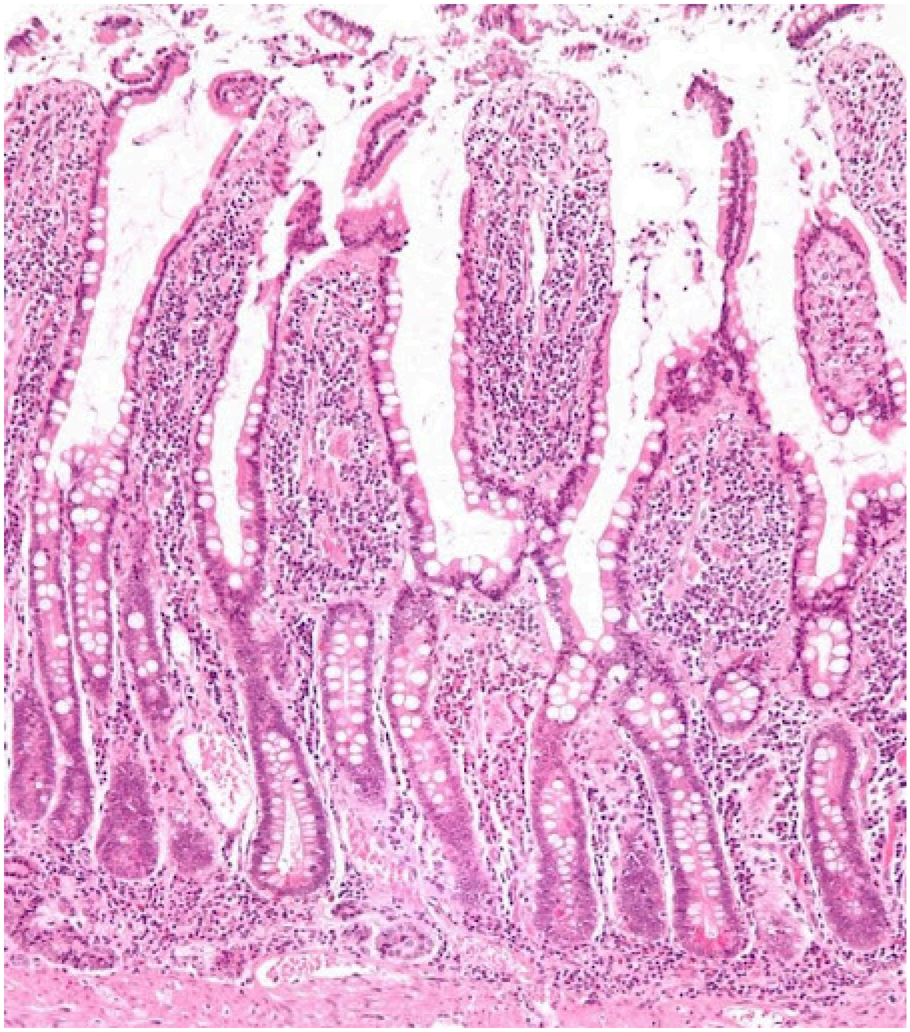
The lamina propria is, similar to the lamina propria of the stomach, unusually cell rich. Lymphocytes often invade the epithelium or form solitary lymphoid nodules in the lamina propria. Lymph nodules may form longitudinal aggregations of 30-50 nodules in the lamina propria of the ileum. These large aggregations are called Peyer's patches.

The muscularis mucosae has two layers and extends into the intestinal villi, where the smooth muscle cells form a longitudinal bundle in the center of the villi.

The Submucosa

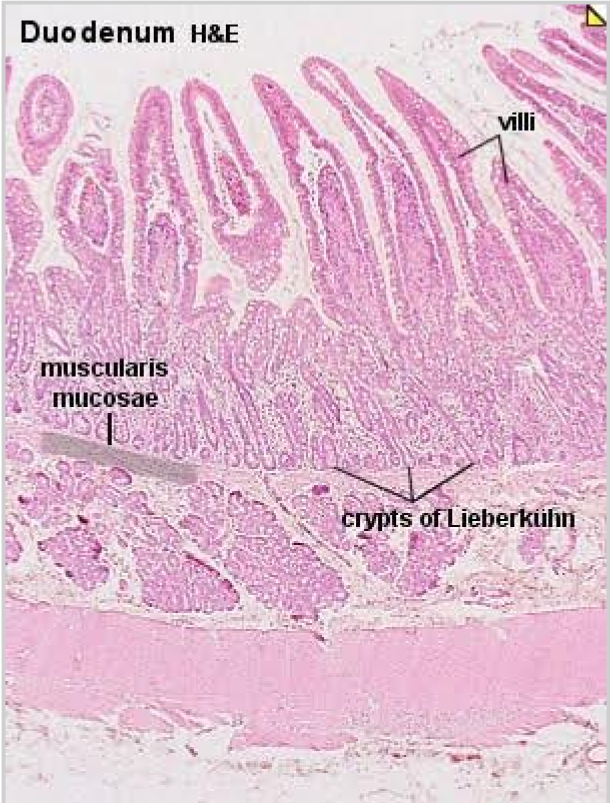
The submucosa contains glands only in the duodenum. Submucosal glands of the duodenum are also called Brunner's glands. Their secretion is mucous and slightly alkaline due to bicarbonate ions (pH 7-8). The amount of bicarbonate is however too low to neutralize the acidic contents of the duodenal lumen. Instead, the secretion of Brunner's glands protects the duodenal mucosa – similar to the mucus which protects the gastric mucosa.

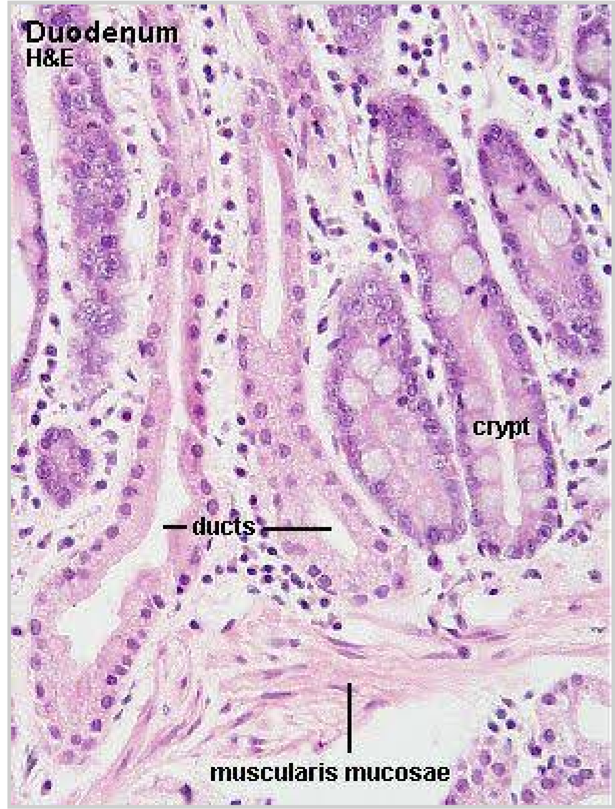
Layer	Duodenum	Jejunum	Ileum
Serosa	1st part serosa, 2nd – 4th adventitia	normal	normal
Muscularis externa	Longitudinal and circular layers, with Auerbach's (myenteric) plexus in between	same as duodenum	same as duodenum
Submucosa	Brunner's glands and Meissner's (submucosal) plexus	no BG	no BG
mucosa: muscularis mucosae	normal	normal	normal
Mucosa: lamina propria	no Peyer's patches	no Peyer's patches	Peyer's patches
Mucosa: intestinal epithelium	simple columnar. Contains goblet cells, Paneth cells	Similar to duodenum Villi very long	Similar to duodenum Villi very short

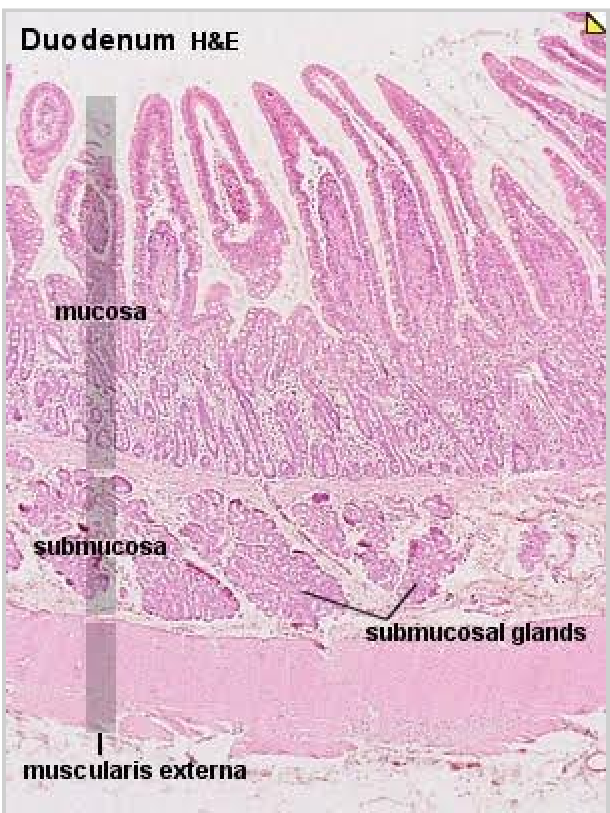


Small intestine mucosa showing the intestinal villi and crypts of Lieberkühn, low magnification.

Duodenum







Duodenum – H&E

Take a close look at the epithelium lining the villi and crypts of the duodenum, and note the absence of plicae circulares.

Look at tall columnar epithelium composed of enterocytes, goblet cells and endocrine cells throughout the remainder of the GIT.

Identify the lamina propria and muscularis mucosae and the "packages" of glandular tissue (Brunner's glands) in the connective tissue between the muscularis mucosae and muscularis externa, i.e. in the submucosa. Occasionally you will see ducts of Brunner's gland which penetrate the muscularis mucosae and ascend through the lamina propria.

Note that goblet cells are absent from these ducts.

Jejunum – H&E

Look at the images and identify plicae circulares, muscularis externa and villi.

Next identify surface epithelium (simple columnar with goblet cells), crypts, and muscularis mucosae, submucosa and muscularis externa. Crypts will probably be smaller than you expect them from schematic drawings. They are fairly short and narrow.

Accumulations of lymphocytes are common in the mucosa of the GIT, and they occur frequently in the small intestine. They can form very large aggregates in particular in the ileum, where they may be covered by a specialized epithelium which facilitates their immune function (defense of the body against possible pathogens) in the lumen of the intestine. These specialized parts of the small intestine are called Peyer's patches.

Movement: Peristalsis Segmentation MMC

The major mixing movement is segmentation, in which small, ringlike, contractions occur periodically, cutting the chyme into segments moving it back and forth. Peristaltic waves propel the chyme through the small intestine. These are weak waves so that the chyme moves slowly through the small intestine.

Secretions (Fluid/Enzymes/Hormones/Mucus):

- Dipeptidase, Aminopeptidase
- Crypts of Lieberkühn – water
- [Brunner's glands]
- Alkaline mucus (protection)
- Epithelial cells- Crypts of Lieberkühn
- Mucus (lubricates and protect)

Disaccharidases:

- Lactase: lactose glucose + galactose
- Sucrase: sucrose glucose + fructose
- Maltase: maltose glucose+glucose
- Intestine lipase: fats glycerol + fatty acids
- Gastric inhibitory peptide: ↓ gastrin secretion and ↓ speed of gastric emptying (aka GIP)
- Enterokinase (trypsinogen trypsin, chymotrypsinogen chymotrypsin, and procarboxypolypeptidase carboxypolypeptidase)
- Bulbogastrone: ↓ parietal cell acid secretion
- S-cells: respond to ↓ pH, undigested fats
- Secretin: ↓gastrin secretion and motility, ↑bile salt secretion, ↑ pancreatic bicarbonate secretion, and ↓GI motility; protective function.
- I-cells: respond to undigested PRO's and fats

Cholecystokinin

Cholecystokinin – abbreviated as CCK or CCK-PZ;

The word cholecystokinin comes from Greek chole, “bile”; cysto, “sac”; kinin, “move” � move the bile-sac.

Functions:

↓gastric motility, ↑ pancreatic enzyme to stimulate acinar cells, and bicarbonate secretion, and ↑gallbladder contraction, which stimulate bile; protective function.

Synthesized by I-cells in the mucosal epithelium of the small intestine and secreted in the duodenum, the first segment of the small intestine, and causes the release of pancreatic digestive enzymes and bile from the gallbladder. It also acts as a hunger suppressant.

The secretions of the intestinal mucosa are stimulated by the direct contact with chyme, which provides both chemical and mechanical stimuli, and by reflexes triggered by distention of the intestinal wall. It is inhibited by the lack of chyme in the small intestine.

Digestion

α-amylase from the pancreas almost totally converts all starches into maltose and other small glucose polymers.

All sugars such as lactose, sucrose, and maltose are broken down by their respective enzymes.

Peptidases in the cell membranes (aminopeptidase and dipeptidases) split the remainder of the larger polypeptides into tripeptides, dipeptides, and amino acids.

Phospholipids, cholesterol, and cholesterol esters are emulsified by bile (bile salts and lecithin)-lipase attacks the fat globules on their surfaces (pancreatic lipase and enteric lipase in enterocytes).

Absorption:

- Water by diffusion/ osmosis
- Sodium by Active Transport
- Chloride ions dragged by electrical gradient of:
- All monosaccharides except for fructose absorbed by secondary active transport w/Na+ mechanism dependent on sodium, fructose by facilitated diffusion.
- Amino Acids/peptides by the same route as monosaccharides (secondary active transport via Na+–5 transport proteins found.)
- Monoglycerides and free fatty acids diffuse immediately into the enterocytes.

Reflexes:

- Enterogastric reflex—the small intestine tells the stomach to slow down (negative feedback).
- Colonoilcal reflex

Innervation:

- Myenteric plexus (Auerbach's plexus)
- Submucosal plexus (Meissner's plexus)
- Parasympathetic
- Sympathetic

Disorders

- Abnormal digestion due to pancreatitis or blockage of pancreatic duct.
- Sprue—tropical—inflammation of the intestinal mucosa due to infectious bacterial agent/protozoan. (Treatment is difficult due to cyst form, eukaryote)
- Idiopathic/Celiac disease/gluten enteropathy—toxic effect of gluten present in certain types of grains and has a destructive effect on the enterocytes � steatorrhea and absorption impaired.
- Crohn's Disease (esp. in ileum)
- Cystic fibrosis
- Hornip's Disease
- Obstruction: interception, volvulus
- Disaccharide (lactose) intolerance
- Meconium Ileus: assoc. w/ pancreatic deficiency (precursor to CF)

Summary of each major type of digestive product and absorption site.

1. Monosaccharides are absorbed by the villi by diffusion, facilitated diffusion, or active transport. The blood then carries them away.
2. Amino acids are absorbed by the villi by means of active transport. The blood then carries them away.
3. Fatty acids and glycerol are absorbed by diffusion into the lacteals of the villi. They are then carried away by lymph.
4. Diffusion and active transport into the villi absorb electrolytes.
5. Water is absorbed by osmosis into the villi.

Large Intestine

The cecum is a dilated, pouch like structure that hangs slightly below the ileocecal opening. This represents the beginning of the large intestine. The colon is divided into four parts. The ascending colon begins at the cecum and travels upward against the posterior abdominal wall to a point just below the liver. It turns sharply to the left and becomes the transverse colon. This is the longest and most movable part of the large intestine.

As the transverse colon approaches the spleen, it turns abruptly downward and becomes the descending colon. At the brim of the pelvis, the descending colon makes an S-shaped curve, called the sigmoid colon, and then becomes the rectum. The rectum is firmly attached to the sacrum and it ends about five centimeters below the tip of the coccyx. It now is known as the anal canal. The anal canal is the last two and one-half to four centimeters of the large intestine. It ends at the anus, which opens to the outside of the body.

Functions of the large intestine

- It has little or no digestive function.
- It secretes mucous.
- Absorption is generally limited to water and electrolytes.
- Formation and storage of feces.
- Movement: Peristalsis-mass movement, Huastral (mixing)
- Secretions (Fluid/Enzymes/Hormones/Mucus)
- [Crypts of Lieberkühn]
- Mucus (lubrication, protection, solidification)
- Bicarbonate (neutralize bacterial products)

Digestion: None

Absorption: Water

Ions—Na+, K+, products of Vitamin K, intestinal Biotin, flora, (Almost no nutrients)

Reflexes

- Colonolileal reflex — the large intestine tells the small intestine to slow down (negative feedback).
- Gastrocolic reflex — signal from the stomach cause evacuation of the colon.
- Defecation reflex
- A person holds a deep breath and contracts the abdominal wall muscles. This increases the internal abdominal pressure and forces the feces into the rectum. As the rectal wall distends, this triggers the defecation reflex. Peristaltic waves in the descending colon are stimulated, and the internal anal sphincter relaxes. The external sphincter relaxes and the feces are forced to the outside.

Innervation:

- Parasympathetic
- Sacral
- Some Sympathetic
- (relax sphincter)
- Enteric nervous system

- Voluntary muscle contraction

Disorders:

- Constipation–anything that can obstruct the intestinal movements, irregular bowl habits, or spasm of the sigmoid colon.
- Megacolon/Hirschsprung's disease — build-up of large quantity of fecal matter, lack of ganglion cells of the myenteric plexus in a segment of the sigmoid colon.
- Diarrhea- enteritis
- Crohn's Disease
- Ulcerative Colitis
- Bacillary Dysentery
- Salivary glands—located in the oral cavity
- Saliva is secreted in large amounts (1-1.5 liters/day) by three pairs of exocrine salivary glands (parotid, submandibular, and sublingual) in the oral cavity, and is mixed with the chewed food by the tongue.
- The serous cells found in the salivary glands produce a watery fluid that contains amylase. Amylase is a digestive enzyme that splits starch and glycogen molecules into disaccharides. This is the first step of carbohydrate digestion.
- The parotid glands secrete a clear, watery fluid that is rich in amylase.
- The submandibular glands secrete a serous fluid with some mucous, making it more viscous than the parotid gland secretion.
- The sublingual glands secrete a thick and stringy mucous fluid

Liver

The liver is enclosed in a fibrous capsule and divided into lobes by connective tissue. Each lobe is further subdivided into hepatic lobules. These are the functional units of the liver. Each lobule consists of hepatic cells (hepatocytes) that radiate outward from a central vein.

Movement: None

Secretions (Fluid/Enzymes/Hormones/Mucus): Bile (emulsifies fats)

Digestion: None

Absorption: None

Reflexes: None

Innervation: Several

Disorders:

- Cirrhosis

- Hepatitis
- Storage diseases (all involve jaundice)
- Hemolytic/obstructive
- Cancer

Liver Functions:

- Metabolism
- Carbohydrate Metabolism
- Conversion of glucose to glycogen
- Breakdown of glycogen to glucose
- Protein Metabolism
- Deamination of amino acids & nucleic acids
- Lipid Metabolism
- Cholesterol metabolism
- Fat formation (glucose & amino acids)
- Fat breakdown
- Storage
- Glucose, stored as glycogen
- Bile storage in gallbladder
- Storage of Vitamins A, D, E, K, B1, B2, B12
- Fats & Fatty acids
- Water volume (blood volume)

Minerals: Iron & copper

Secretion & Synthesis

Secretion of bile salts into bile Bile is composed of bile salts, bile pigments (bilirubin and biliverdin), cholesterol, and electrolytes path of bile from a bile canal to the small intestine. The bile flows from the bile canal into hepatic ducts. The ducts then merge to form the common hepatic duct. It then can flow into the gallbladder for storage. The common hepatic and cystic duct form the common bile duct. This then empties into the duodenum. Bile salts emulsify fats and aid in the absorption of fatty acids, cholesterol, and certain vitamins.

Blood clotting factors

- Blood proteins
- Elaborates heparin
- Erythrocyte before birth

- Excretory Function
- Breakdown of hemoglobin
- Drug detoxification
- Breakdown of sterols
- Formation of urea from amino acids
- Blood buffering
- Detoxification
- Gallbladder
- Movement
- Contraction/constriction � stimulated by cholecystokinin, inhibited by Vagus nerve

Secretions (Fluid/Enzymes/Hormones/Mucus): Concentrated bile

Digestion: None

Absorption: None

Reflexes:

Innervation:

Disorders: Gallbladder stones

Gallstones form as a result of cholesterol precipitating out of solution and crystallizing. This can result if the bile becomes too concentrated, the hepatic cells secrete too much cholesterol, or the gallbladder is inflamed.

Pancreas

The pancreas is an elongated, somewhat flattened organ that is posterior to the stomach and behind the parietal peritoneum. It is attached to the duodenum by the pancreatic duct, which runs the length of the pancreas.

Movement: None

Secretions (Fluid/Enzymes/Hormones/Mucus):

- Bicarbonate and water
- Insulin and glucagon
- Enzymes & functions in pancreatic juice:
- Pancreatic amylase —digest carbohydrates
- Pancreatic lipase — digest triglycerides
- Trypsin — digest protein
- Chymotrypsin —digest protein
- Carboxypeptidase — digest protein

- Nucleases—break nucleic acids into nucleotides

Absorption: none

Reflexes:

- Secretin stimulates the release of pancreatic juice that has a high bicarbonate ion concentration.
- Cholecystokinin stimulates the release of pancreatic juice that has a high concentration of digestive enzymes.
- Acidic chyme in the duodenum triggers the release of pancreatic juice. As the chyme moves through the intestine the pancreatic juice is inhibited.

Innervation:

Disorders:

- Pancreatitis
- Pancreatic cancer
- Mechanism of vomiting

Sensory impulses travel from the site of stimulation to the vomiting center in the medulla oblongata, and a number of motor responses follow. These include taking a deep breath, raising the soft palate and thus closing the nasal cavity, closing the opening to the trachea (glottis), relaxing the circular muscle fibers at the base of the esophagus, contracting the diaphragm so that it moves downward over the stomach, and contracting the abdominal wall muscles so that pressure inside the abdominal cavity increases. As a result, the stomach is squeezed from all sides, forcing its contents upward and out through the esophagus, pharynx, and mouth.

Effects of Aging on the Digestive Tract

Altered rates of absorption in the small intestine

Because the small intestine is the site of absorption of nutrients, it is here that noticeable signs of aging on digestion arise. Subtle shifts in the microbial species that inhabit the small intestine alter the rates of absorption of particular nutrients. With age, the small intestine becomes less efficient at absorbing vitamins A, D, and K and the mineral zinc. This raises the risk of deficiency symptoms—effects on skin and vision due to a lack of vitamin A; weakened bones from inadequate vitamin D; impaired blood clotting seen in vitamin K deficiency; and slowed healing, decreased immunity, and altered taste evidenced in zinc deficiency.

Digestive function

- Older people sometimes do not chew food thoroughly because thinning enamel makes teeth more

sensitive to hot and cold foods, gums recede, and teeth may loosen.
- Slowing peristalsis in the digestive tract may cause heartburn and constipation.
- Aging affects nutrient absorption in the small intestine.
- Accessory organs to digestion also age, but not necessarily in ways that affect health.

Laboratory Activity: Macroscopic Anatomy

Use the anatomical models available in the lab to identify the following structures:

STRUCTURES	✔	X
Mouth		
Tongue		
Papilla		
Hard palate		
Soft palate		
Lingual frenulum		
Upper lip		
Lower lip		
Maxillary teeth		
Mandibular teeth		
Salivary glands		
Parotid gland		
Submandibular gland		
Sublingual gland		
Pharynx		
Esophagus		
Stomach		
Cardia		
Greater curvature		
Lesser Curvature		
Fundus		
Body		
Pylorus		
Stomach rugae		
Gastric pits – microscope slides		
Simple columnar epithelium		
Small Intestine – villi		
Duodenum		
Jejunum		

STRUCTURES	✔	X
Ileum		
Cecum		
Vermiform appendix		
Ascending colon		
Transverse colon		
Descending colon		
Sigmoid colon		
Rectum		
Anus		
Anal sphincter		
Liver		
Right lobe		
Left Lobe		
Caudate lobe		
Quadrate lobe		
Hepatic portal vein		
Hepatic artery		
Right hepatic duct		
Left hepatic duct		
Common hepatic duct		
Cystic duct		
Common bile duct		
Gallbladder		
Pancreas		
Pancreatic duct		
Tooth		
Crown		
Neck		
Root		

STRUCTURES	✔	X
Gingiva		
Enamel		
Dentin		
Cementum		

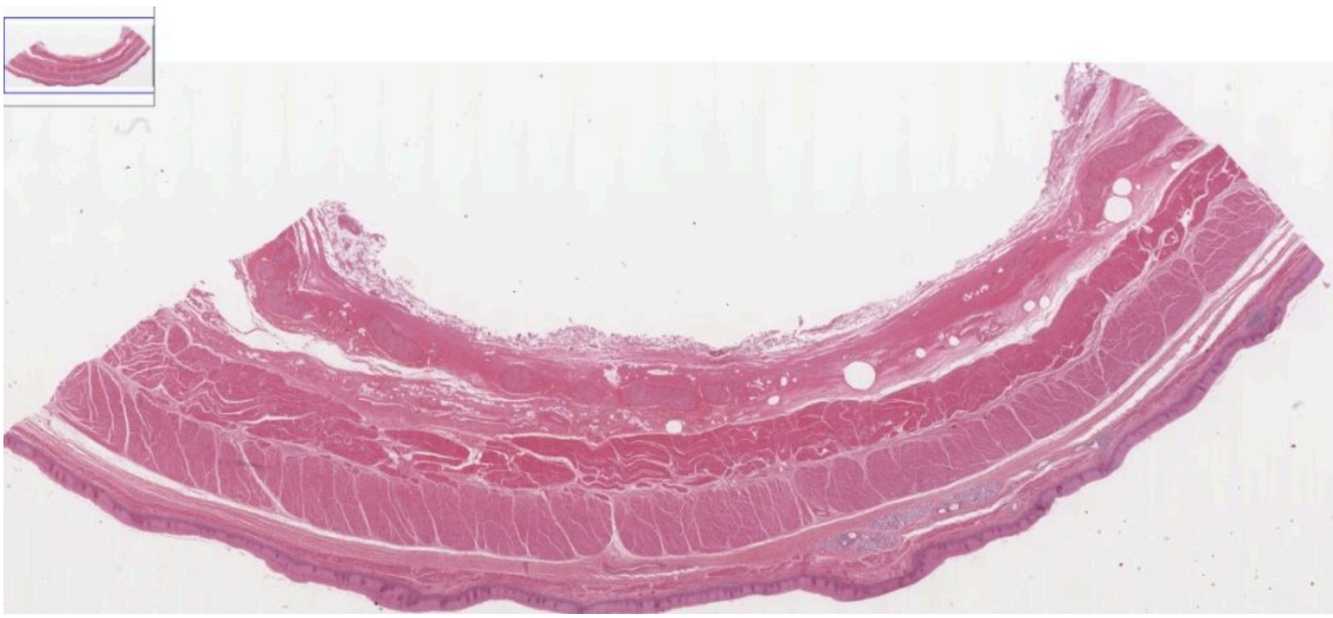
Microscopic Anatomy

Obtain microscope slides from your instructor. View them under scanning power to locate the sample, then increase magnification up to 40X. Draw and label each of them.

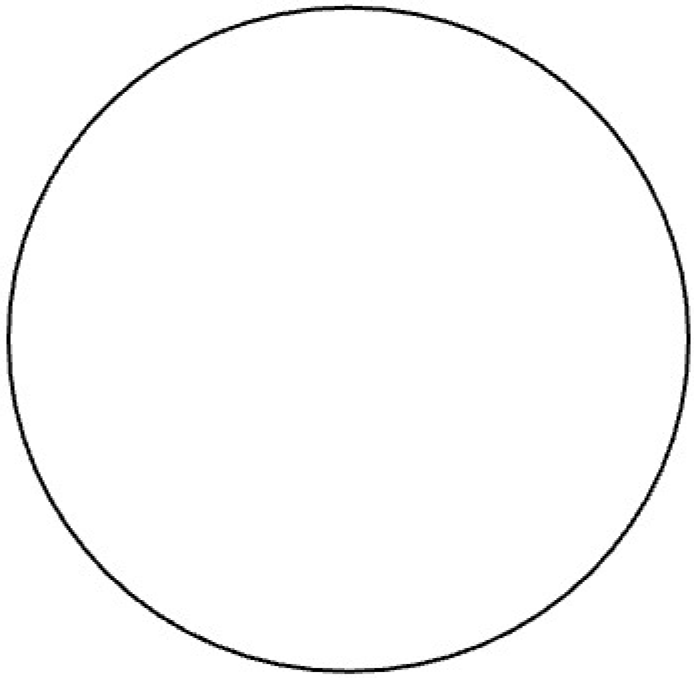
1. **Esophagus:** identify the lumen, non- keratinized stratified squamous epithelium, lamina propria, muscularis mucosae, submucosa, submucosal mucous glands, muscularis externa (all smooth muscle), and adventitia layer.

Simple squamous epithelium Magnification ___________X

For online labs, go to University of Michigan, virtual microscope: Full Slide List or scan the QR code.

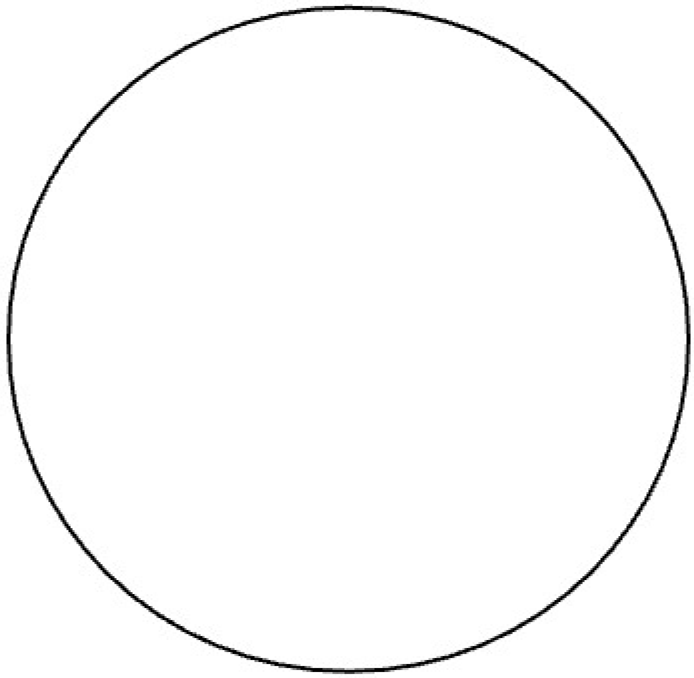


Search for slide #153 – Esophagus, H&E, 20X.



Simple squamous epithelium Magnification ___________X

2. **Stomach:** identify the gastric glands, simple columnar epithelium, smooth muscle layers.

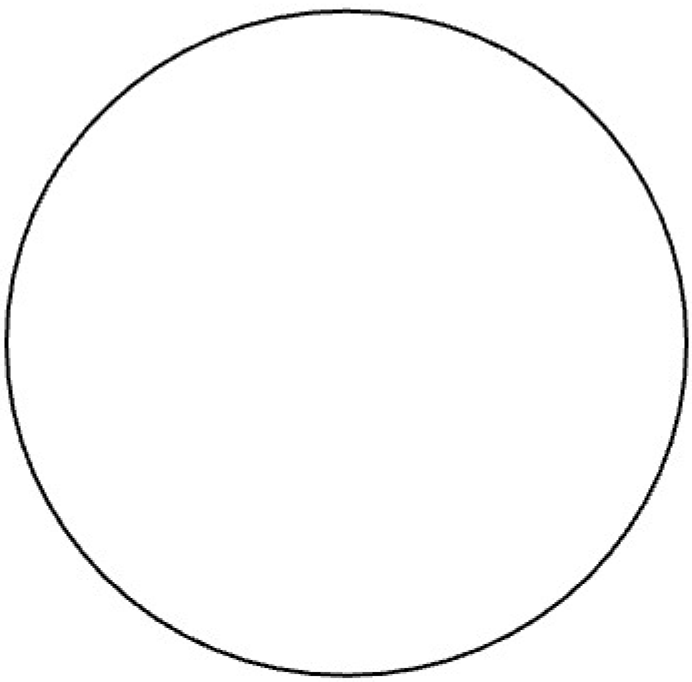


Simple squamous epithelium Magnification ___________X

For online labs, go to University of Michigan, virtual microscope: Full Slide List or scan the QR code.

Search for slide #156 – Stomach, H&E, 20X.

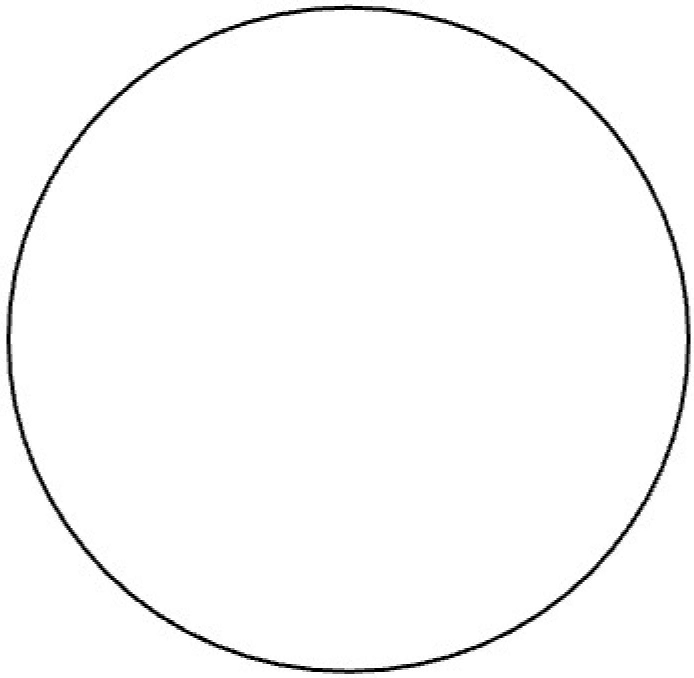
Pits, glands, mucous cells, parietal cells [acid], chief cells [pepsinogen], muscularis mucosae, submucosa, muscularis).



Simple squamous epithelium Magnification ___________X

Small intestines: duodenum, identify the duodenal glands, plica, simple columnar epithelium with Goblet cells, smooth muscle layers

Slide 162 – Small intestine, duodenum [right side of section], H&E, 40X (villi very poorly preserved, glands [crypts of Lieberkühn], muscularis mucosae, submucosal glands).



Simple squamous epithelium Magnification ___________X

Small intestines – jejunum, identify, plica, simple columnar epithelium with Goblet cells, smooth muscle layers

Small intestines – ileum, identify the Peyer Patches, plica, simple columnar epithelium with Goblet cells, smooth muscle layers

Large intestines, identify the epithelium, simple columnar epithelium with Goblet cells, intestinal crypts.

Media Attributions

THE URINARY SYSTEM ANATOMY

Introduction

The urinary system consists of the two kidneys, two ureters, one urinary bladder, and one urethra.

The main functions of the urinary system and its components are to remove metabolic waste, regulate blood volume and composition (e.g., electrolytes, sodium, potassium, and calcium), regulate blood pressure, regulate pH of the blood, produce erythropoietin to signal production of red blood cells, and synthesize calcitriol (Vitamin D3).

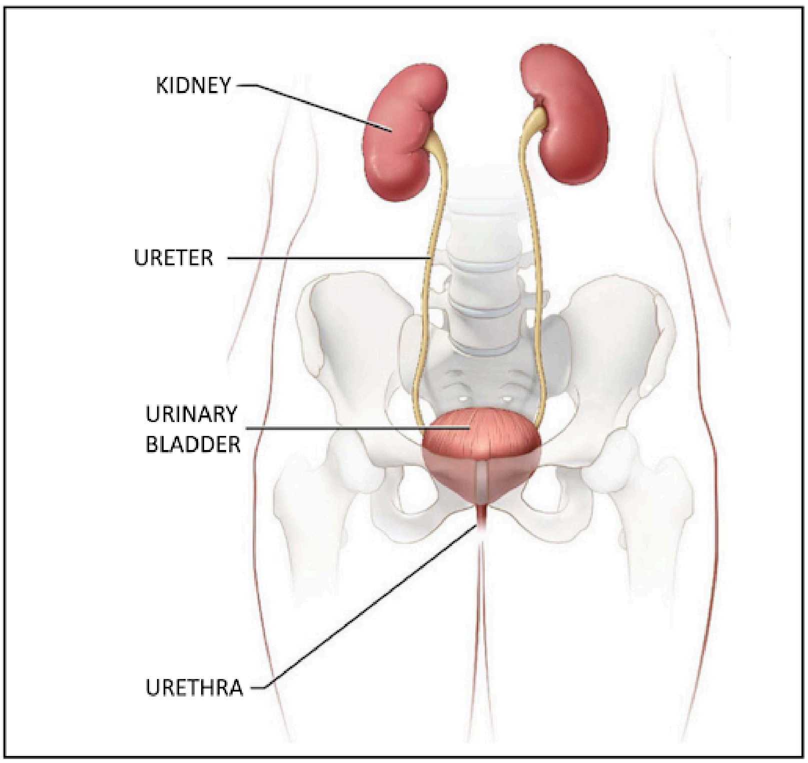


Figure 1. A Diagram of the Urinary System

Each kidney consists of about one million functional units called nephrons, which are composed of a renal corpuscle (Bowman's capsule and the glomerulus), a proximal convoluted tubule, a loop of Henle, and a distal convoluted tubule.

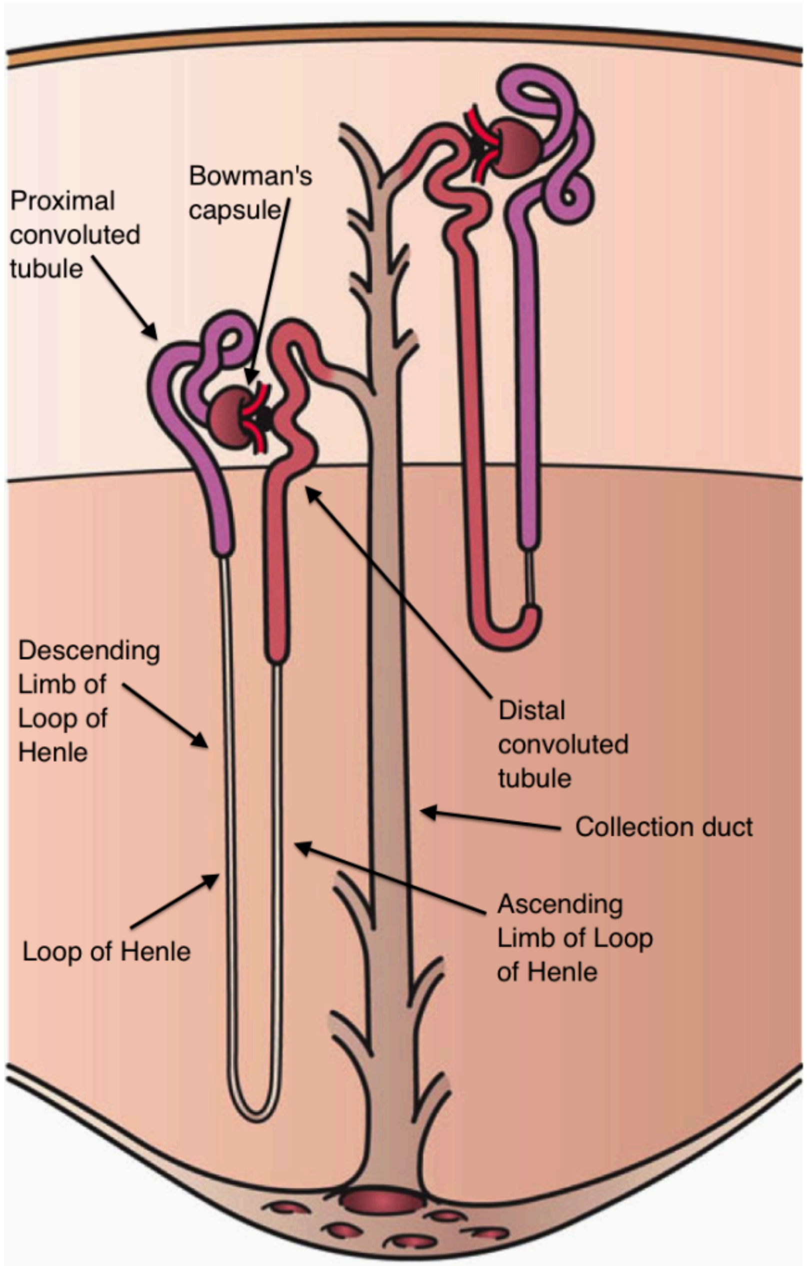


Figure 2. A diagram of the nephron.

Kidneys are highly vascularized; blood enters the kidney via renal arteries (a branch from the abdominal aorta) and branches into the segmental, interlobar, arcuate, interlobular, and afferent arterioles. The afferent arterioles bring blood to the glomerulus (composed or fenestrated capillaries), where filtration occurs and blood exits the glomerulus via efferent arterioles. The efferent arterioles join the peritubular capillaries at the arterial end of the capillary bed, from there, blood continues to the venous end of the capillary bed that joins to the interlobular, arcuate, interlobar, segmental, and renal veins that bring blood to the inferior vena cava.

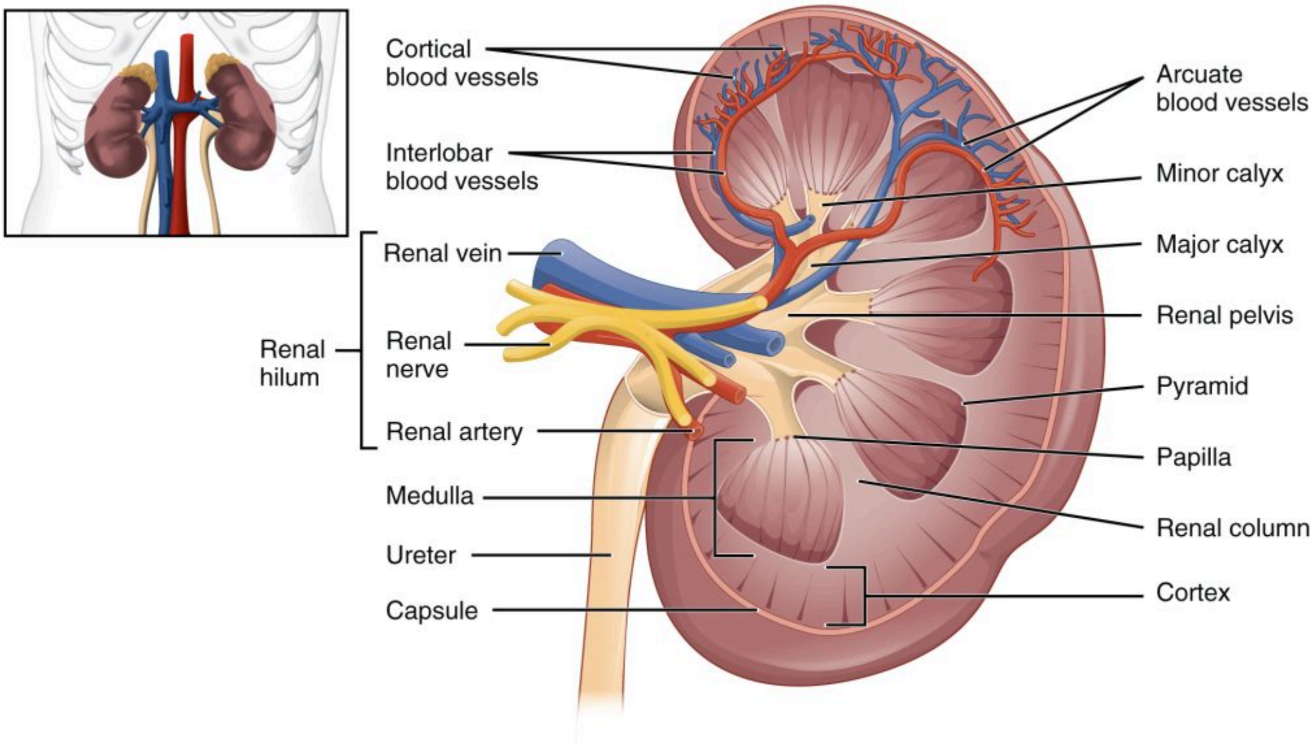


Figure 3. Vascularity of the human kidney.

Processes of the Nephron

The nephrons are the functional units of the kidney and perform a series of processes. Filtration (1) starts at the glomerulus forming the filtrate will then pass to the proximal convoluted, loop of Henle, distal convoluted tubule, as the filtrate is passing through the tubules, reabsorption is taking place (2) as soon as the filtrate enters the proximal convoluted tubule, reabsorption begins and continues the length of the tubules including the collecting ducts. Most of the fluid is reabsorbed and the remaining secretion (3) is called urine. The urine is then transferred to the collecting ducts. Urine passes from the collecting duct to the minor calyces, then mayor calices, renal pelvis, and the ureter. The ureters (muscular tubes lined with transitional epithelium) propel urine towards the urinary bladder, the urine enter the posterior part of urinary bladder (two openings), where urine is stored until it is time to urinate. The urethra conveys the urine outside the body (4). The female and male urinary system are very similar in structure but differ in length, male urethra is about 4-5 times longer than the female urethra. An average of 800–2,000 milliliters (mL) of urine are normally produced every day in an adult; the final volume of urine varies according to fluid intake and kidney function.

In summary, the kidneys filtrate, reabsorb, secrete, and excrete waste products from our body.

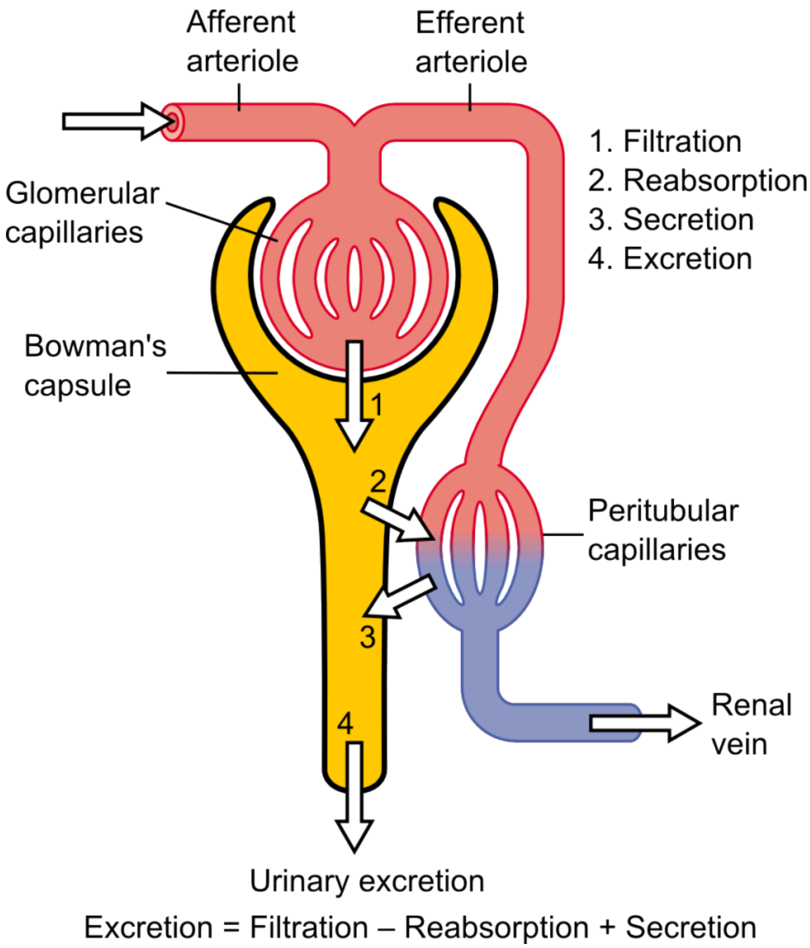


Figure 4. Physiology of a nephron.

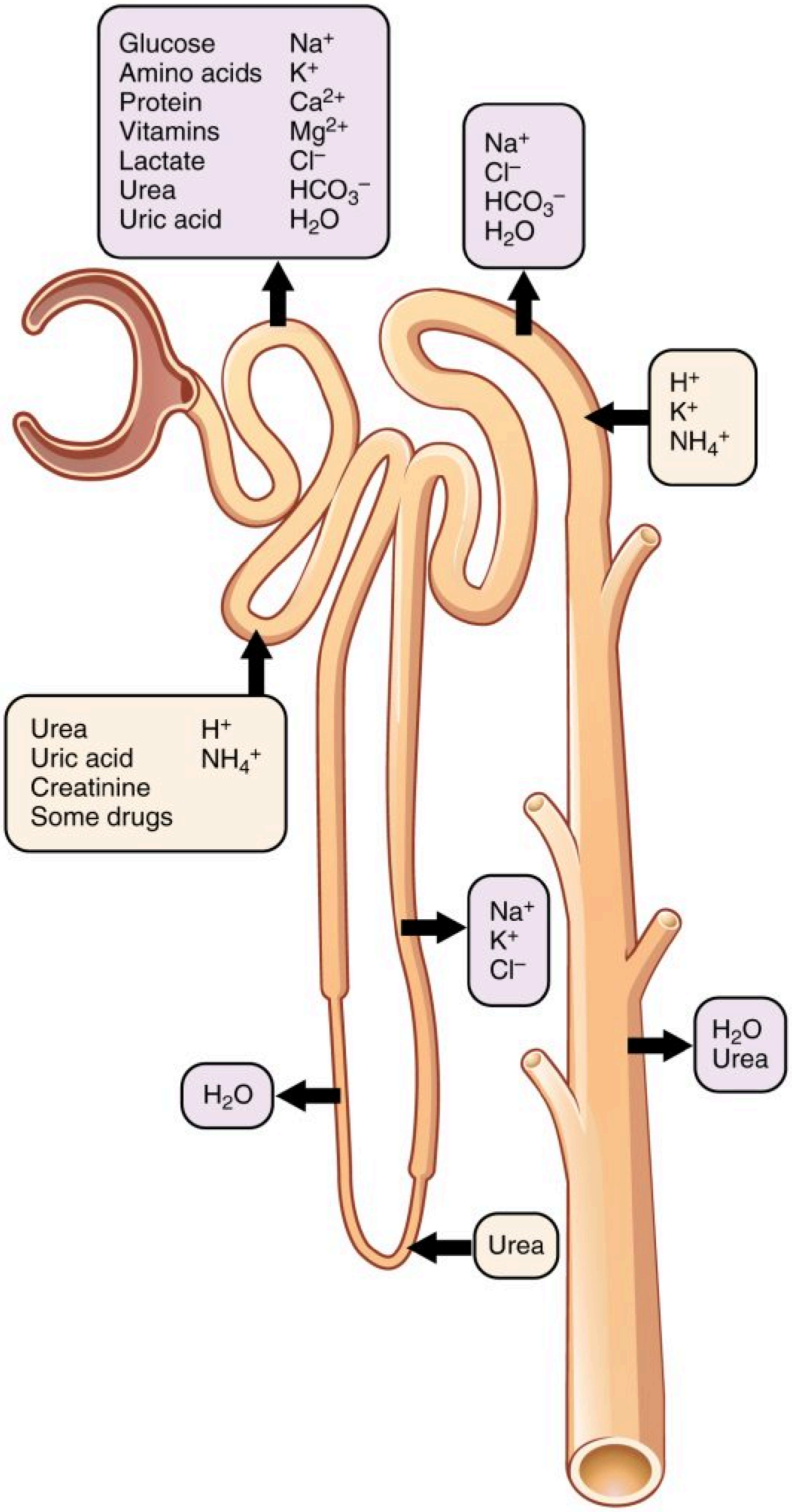


Figure 5. Reabsorption and secretion by the kidney tubules

Activity 1 – Introduction to the Urinary System Anatomy

Use the information shown in this YouTube video about the urinary system to complete this laboratory activity on the Urinary System. It may be helpful to pause the video to allow time to finish each part.

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://rotel.pressbooks.pub/anatomyphysiology/?p=549#oembed-1

Activity 2 – Gross Anatomy of the Urinary System

Obtain a urinary system model from your instructor and identify the organs of the urinary system. You may use labeling tape and a black sharpie to label them. Please remember to remove the labels after you have shown it to your instructor.

Use this image shown below to label the organs of the urinary system. Enter the information on Table 1.

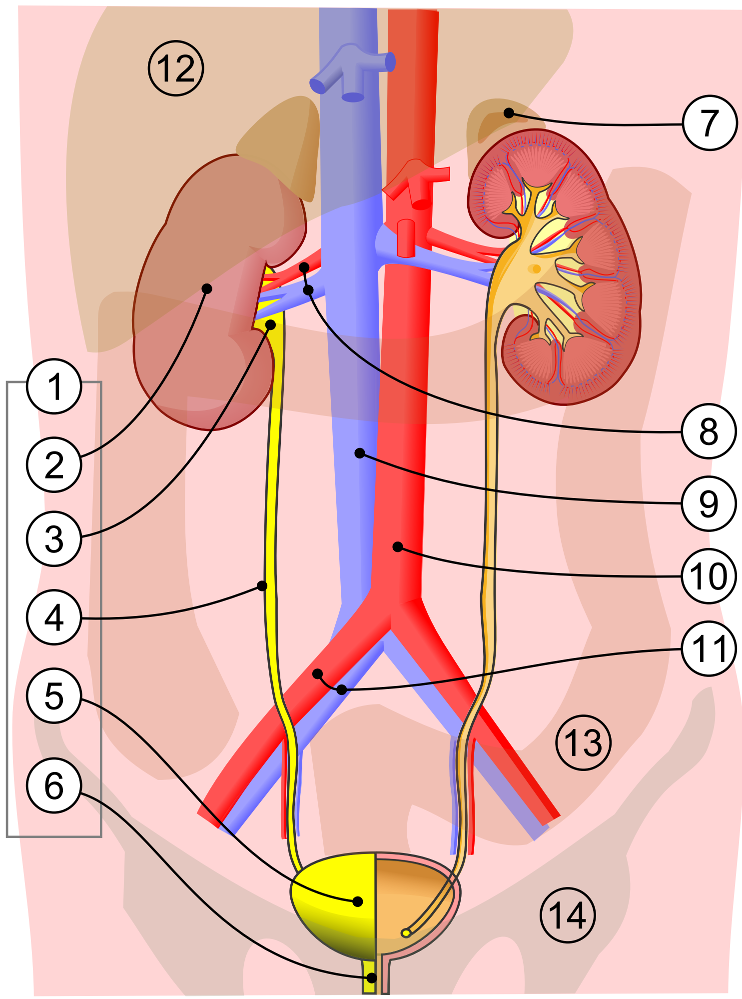


Figure 6. The urinary System

Table 1

Number	Structure	Number	Structure
1		8	
2		9	
3		10	
4		11	
5		12	
6		13	
7		14	

For 100% online courses, skip using the urinary system model and use the drag and drop activity provided below to complete the labeling activities.

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://rotel.pressbooks.pub/anatomyphysiology/?p=549#h5p-11

Kidneys are bean shaped structures located between the abdominal wall and the peritoneum; therefore, they are called retroperitoneal. They are attached to the abdominal wall

Use this image to label structures of the kidney. Enter the information on Table 2.

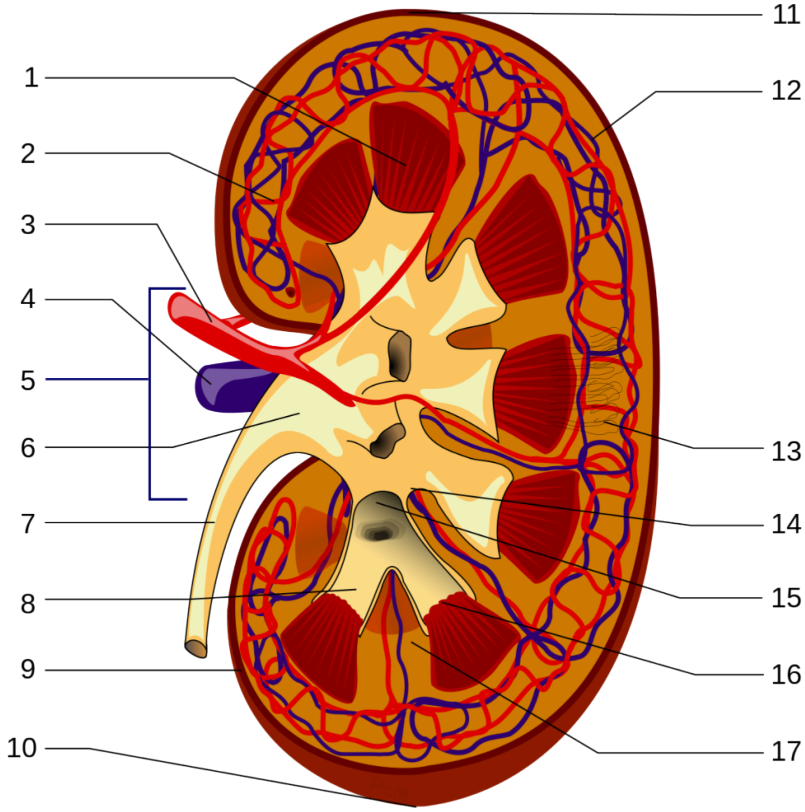


Table 2

Number	Structure	Number	Structure
1		10	
2		11	
3		12	
4		13	
5		14	
6		15	
7		16	
8		17	
9			

For 100% online courses, skip using the structures of the kidney image and use the drag and drop activity provided below to complete the labeling activities.

An interactive H5P element has been excluded from this version of the text. You can view it online here:
https://rotel.pressbooks.pub/anatomyphysiology/?p=549#h5p-12

Activity 3 – Microscopic Anatomy of the Urinary System

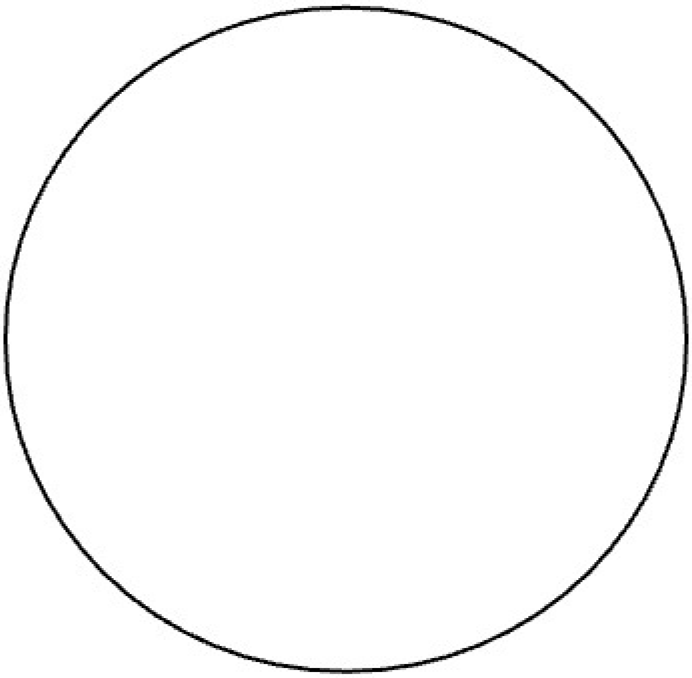
1. For face to face or hybrid courses, obtain prepared slides of kidney, ureter and urinary bladder from our instructor. Draw and label them at 40X and a high magnification using the space provided (steps 5-7). For 100% online courses, use the Virtual Microscope by following the instructions shown below:
2. Navigate to University of Michigan Virtual Microscope. – Full Slide List,
3. In “Slide Category,” choose Urinary system.
4. Chose slide #204 Kidney, human, H&E, 40X.
5. Using scanning view locate the cortex and the medulla of the kidney.
6. Increase magnification and locate the following:

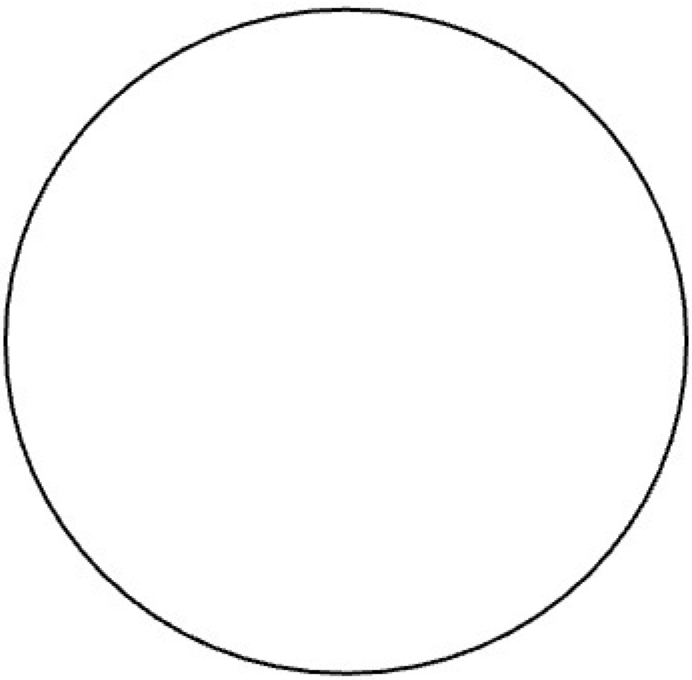
    - Glomerulus

- Proximal tubule
- Distal tubule
- Collecting duct

7. Draw and label the kidney at 40X and a high magnification using the space provided.

8. Chose slide #211 Ureter, adult human, H&E, 40X (transitional epithelium, smooth muscle).
9. Using scanning view, locate the lumen and smooth muscle layer of the ureter.
10. Increase magnification and locate the following:
    - Lumen
    - Mucosa (Transitional epithelium)
    - Lamina propria
    - Muscularis (smooth muscle; circular and longitudinal layers)
    - Tunica adventitia (Fibrous connective tissue)
    - Adipose tissue
11. Draw and label the ureter at 40X and a high magnification using the space provided.





Chose slide #212 Bladder, human, H&E, 40X (transitional epithelium, smooth muscle).

12. Navigate to https://histologyslides.med.umich.edu/Histology/Urinary%20System/212N_HISTO_40X.htm
13. Using scanning view, locate the lumen and smooth muscle layer of the urinary bladder.
14. Increase magnification and locate the following:

- Lumen
- Mucosa (Transitional epithelium)
- Lamina propria
- Detrusor muscle

15. Draw and label the ureter at 40X and a high magnification using the space provided.

Answer the following questions:

1. What is the composition of urine? (10 points)?

2. Describe the four basic processes in the formation of urine (16 points).

Questions

1. What is the composition of urine? (10 points)

2. Describe the four basic processes in the formation of urine

Media Attributions

THE REPRODUCTIVE SYSTEM ANATOMY

Introduction

The reproductive system in humans is complex. To our eyes the male and female reproductive systems very different but in reality, they are similar, they share the following characteristics:

- Both are derived from the same tissues during development.
- Contain gonads that produce gametes; two ovaries in females produce oocytes and two testes in males produce spermatozoids.
- Contain a system of ducts; to transport gametes to the site of fertilization; the epididymis, vas deferens and urethra in males and the oviducts in females.
- Contain accessory glands that secrete materials that aid in the transport of gametes to the site of fertilization. Seminal vesicles, prostate gland and bulbourethral gland in males and the greater vestibular glands in females.
- Their external genitalia contain similar structures, i.e. penis (male) and clitoris (female) and scrotal sac (males) and labial folds (female).
- Both sexes use the same hormones to regulate the reproductive process; Follicular stimulating hormone (FSH) and Luteinizing hormone (LH), both produced in the anterior pituitary. In males, interstitial cells from testes produce testosterone and in females, cells in the ovaries produce estrogen, both of these hormones are derived from cholesterol and have very similar chemical structure.

Even though these systems share many characteristics, they are fundamentally different and have different functions but they complement each other and work in close association for us to be able to generate the genetic diversity needed to perpetuate our species.

The male produces spermatozoids that contain half the number of chromosomes and the female produces oocytes that also contain half the number of chromosomes of human species. Through the process of fertilization, the genetic material will be combined as the oocyte and the sperm join to form a zygote. The zygote will then contain a complete set of chromosomes, half coming from the mother and the other half from the father. Once fertilization has occurred inside the female reproductive system, the zygote will implant in the innermost lining of the uterus, the endometrium where it will develop through numerous cell divisions into an embryo and then a fetus. The first stage of human development occurs around 6 days after fertilization and it is referred as pre-embryonic development (from zygote, 2-cell stage, 4-cells stage, morula, blastocyst) then it will continuous to develop into a fetus until the birth of a newborn.

Objectives

- Identify structures of the male reproductive system
- Identify structures of the female reproductive system
- Describe the histology of the testis (seminiferous tubules) and spermatozoa
- Describe the histology of the ovary
- Identify the stages of meiosis. Describe differences between mitosis and miosis

Laboratory Activities
Exercise 1: Define the following terms

Male Reproductive System

1. Testes
2. Seminiferous tubules
3. Epididymis
4. Ductus deferens
5. Spermatic cord
6. Seminal vesicle
7. Prostate gland
8. Corpus spongiosum
9. Corpora cavernosa
10. Testosterone
11. Spermatogenesis

Female Reproductive System

1. Ovaries
2. Ovarian follicles
3. Uterine tubes
4. Uterus
5. Cervix
6. Vagina
7. Vulva
8. Mammary Glands
9. Estrogen

10. Oogenesis

Exercise 2 – Meiosis vs. Mitosis

1. Draw and describe the stages of Meiosis
2. List the differences between Mitosis and Meiosis

Exercise 3 – Identify reproductive organs using the anatomical models available in the laboratory

Use coronal and sagittal male pelvis models to identify the following structures:

Male Reproductive System

1. Scrotum
2. Testes
    1. Epididymis
3. Seminiferous tubules
4. Vas deferens
5. Ejaculatory Tract
6. Seminal Vesicle
7. Bulbourethral gland
8. Prostate
    1. Prostatic Urethra
9. Membranous Urethra
10. Penis
    1. Prepuce
    2. Glans Penis
    3. Spongy Urethra

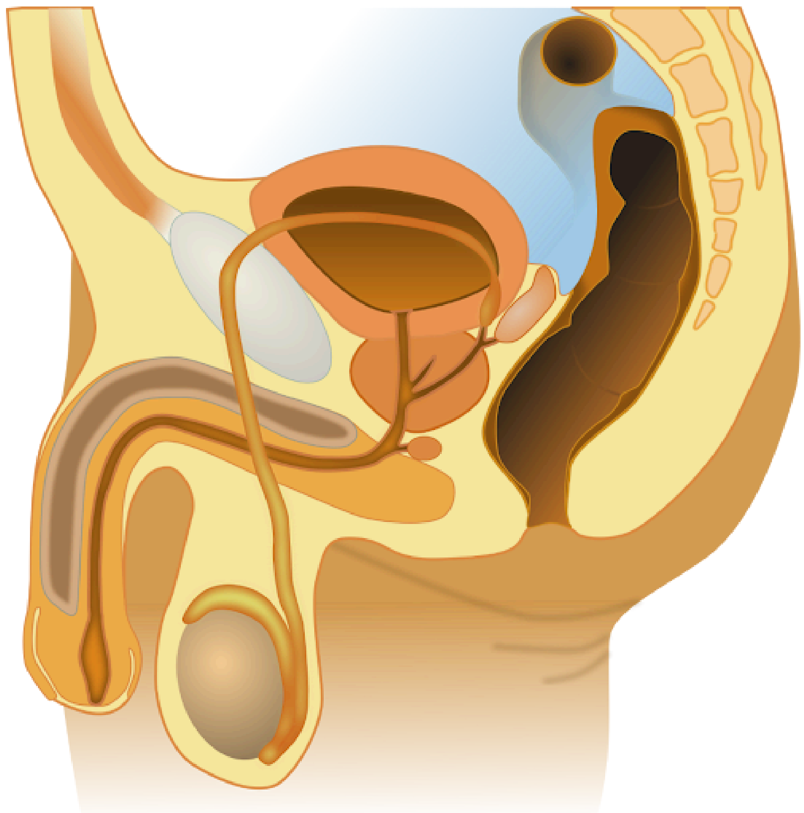
Female Reproductive System

1. Ovaries (2)
2. Uterine tubes (2)
3. Uterus
4. Vagina
5. External genital organs – VULVA

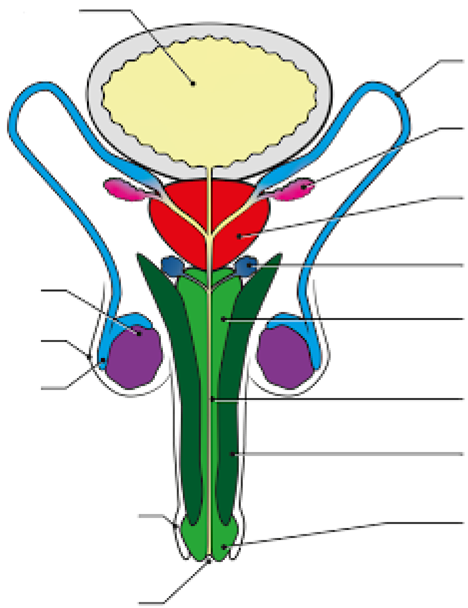
6. Mammary glands
7. Mons Pubis

Exercise 4 – Label and color the structures

Male Reproductive System



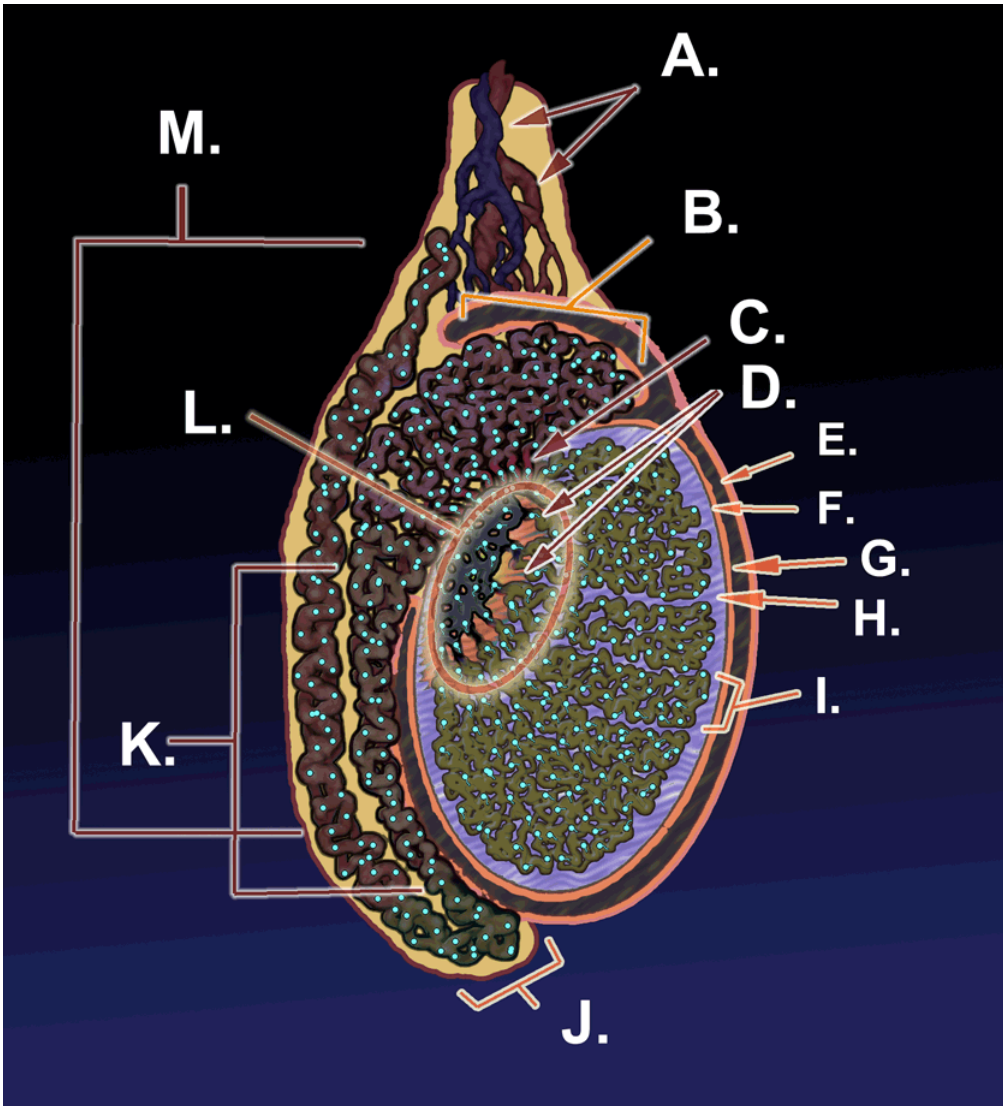
Midsagittal section of male pelvis



Male genital system front view

Label the male genital system using the following test bank

- Urinary bladder
- Vas deferens
- Seminal vesicle
- Prostate gland
- Bulbourethral gland or Cowper's gland
- Bulb of penis (corpus spongiosum)
- Spongy Urethra
- Corpus Cavernosum
- Glans penis
- Urethral opening
- Foreskin or prepuce
- Epididymis
- Scrotum
- Testis

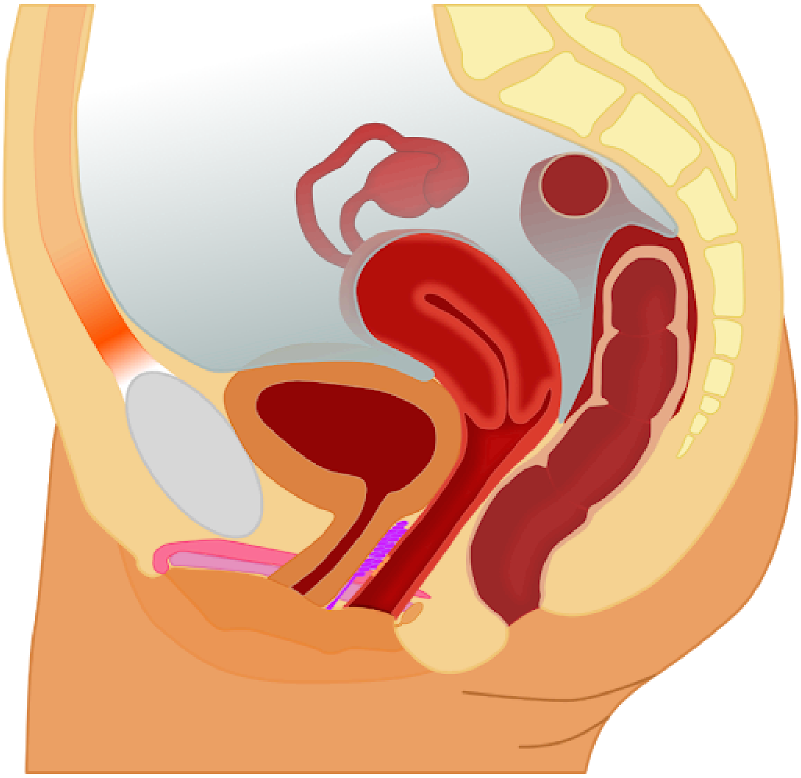


Midsagittal section through testis

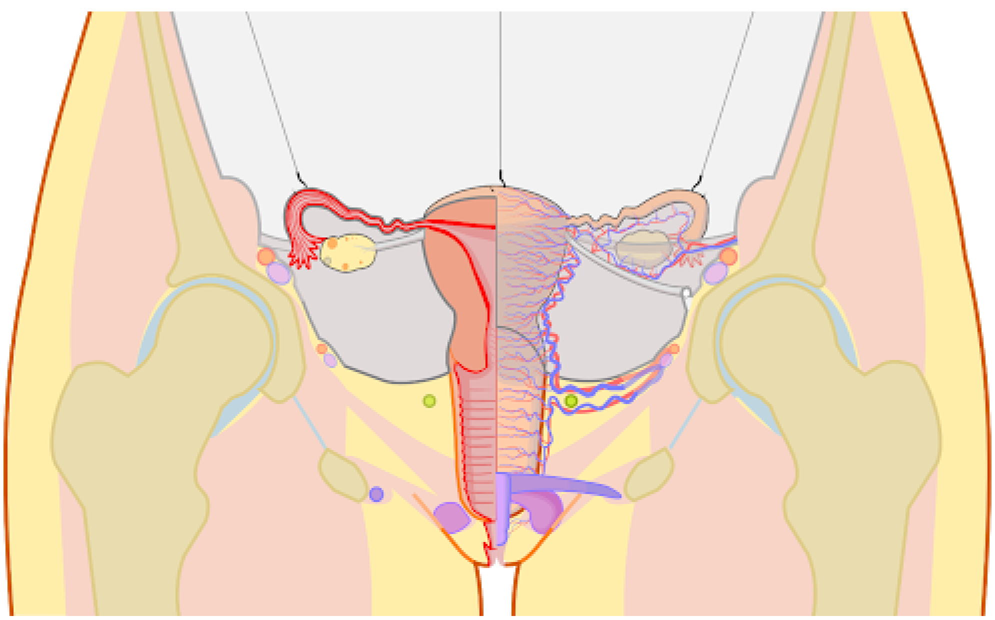
Label the structures of the Testis

Letter	Structure
A	
B	
C	
D	
E	
F	
G	
H	
I	
J	
K	
L	
M	

Female Reproductive System



Midsagittal section of female pelvis



Frontal section female reproductive organs

Label the structures using the word bank shown here:

- Vulva
- Labia majora
- Uterus
- Cervix
- Body Fundus
- Uterine cavity
- Endometrium
- Myometrium and Perimetrium
- Fallopian tube
- Isthmus; Ampulla
- Infundibulum
- Fimbria
- Ovary
- Broad ligament
- Round ligament
- Ovarian ligament
- Suspensory ligament of ovary

Exercise 5 – Microscopic Anatomy of Testes

Face-to-face Laboratories

Obtain a microscope slide of testes from your instructor and view using a standard light microscope. Identify, draw and label the following structures:

Seminiferous tubules

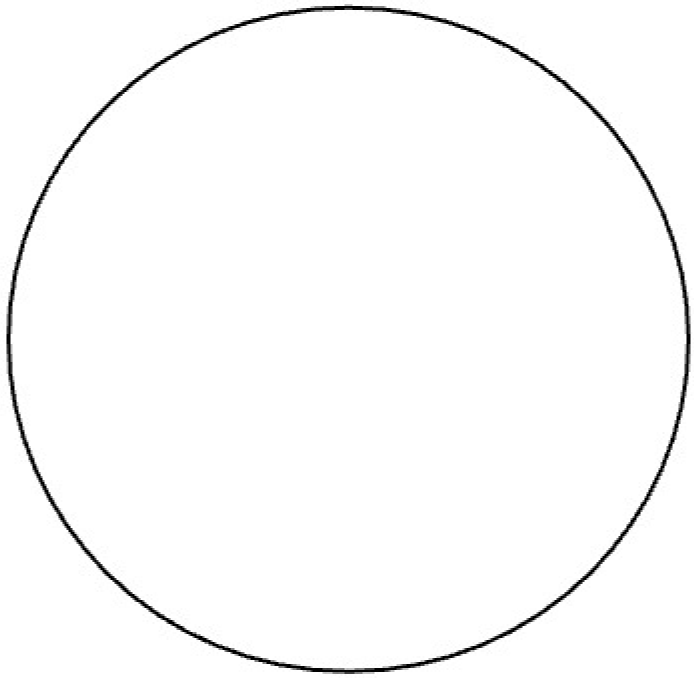
Interstitial cells (Leydig Cells)

Spermatogonia Sertoli cells

Spermatids

Lumen

Sperm in lumen of seminiferous tubules

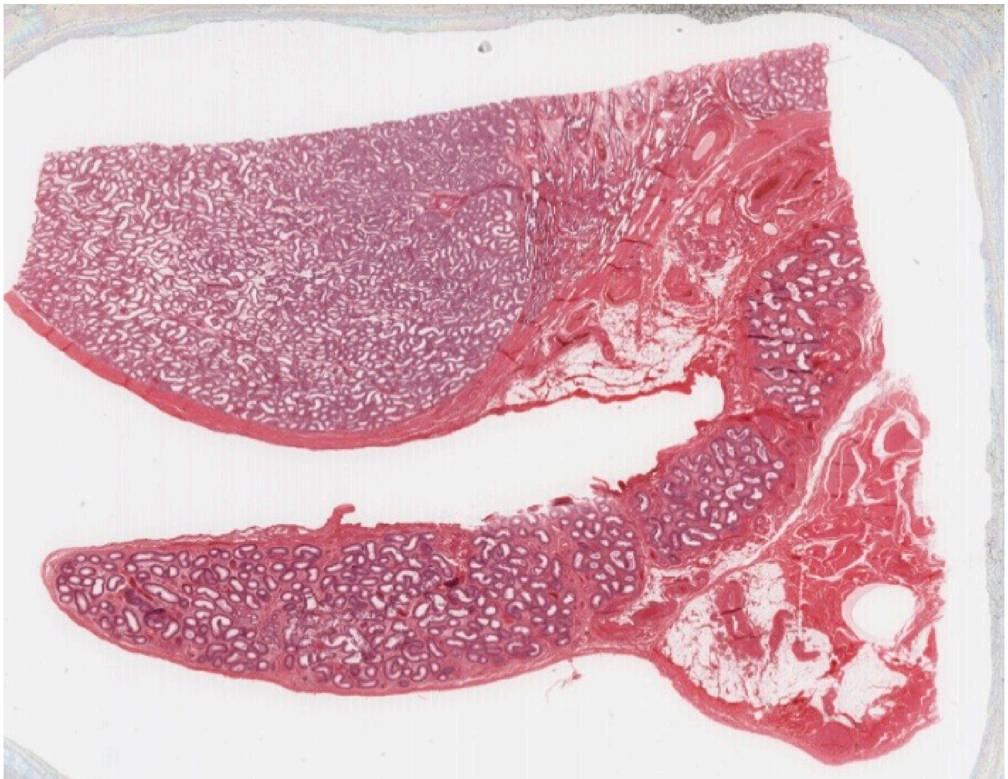


Note: face to face labs should also take advantage of open educational resources, such as the virtual microscopes and review the images assigned to 100% onion labs.

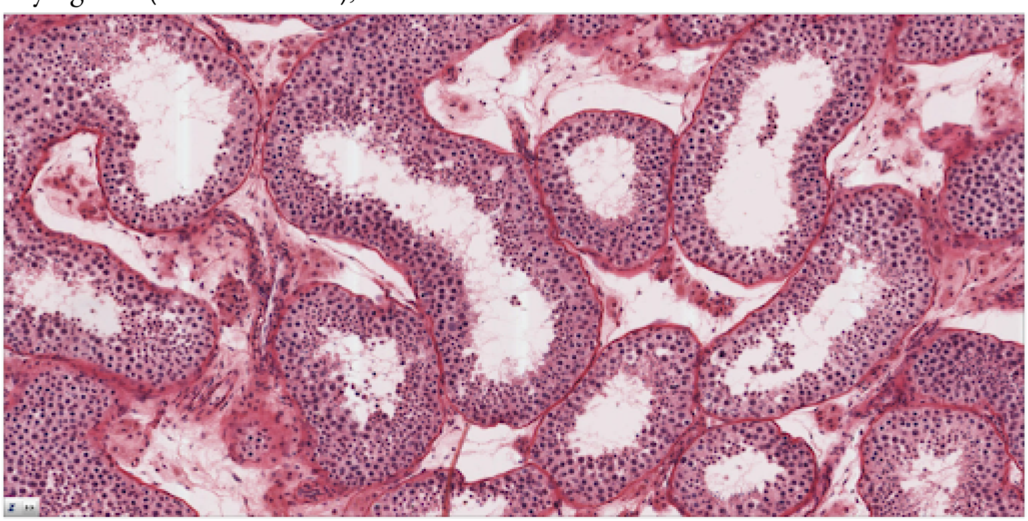
100% online labs – University of Michigan Virtual Microscope – use the following link:

Full Slide List

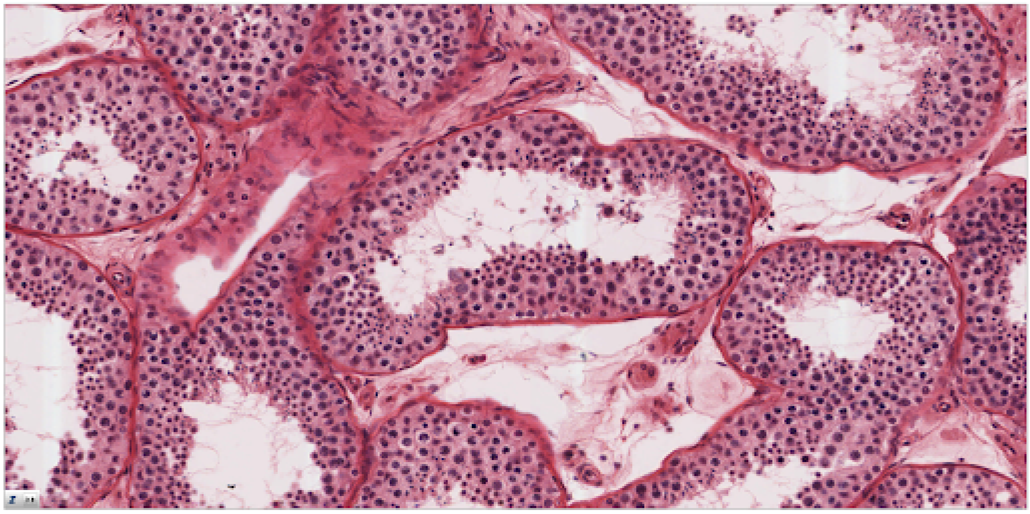
1. Search for slide #70 Testis, human, H&E, 40X, you should see the following image at low magnification



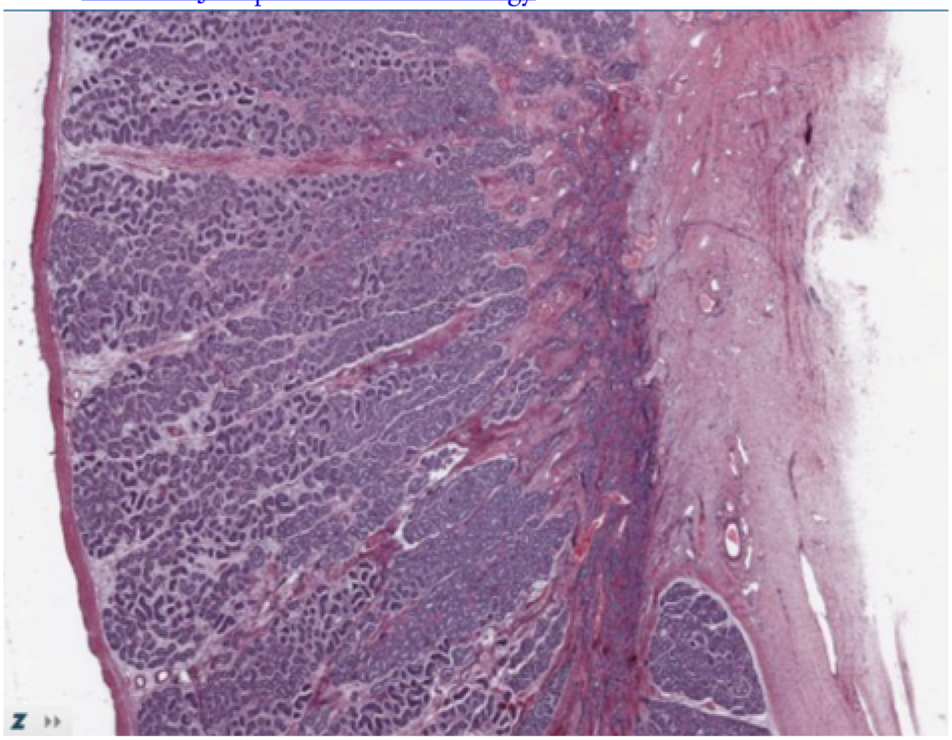
2. Using the +/- controls, magnify the image to be able to identify and label the seminiferous tubules, Leydig cells (interstitial cells), lumen of the seminiferous tubules



3. Using the +/- controls, magnify even more the image to be able to identify and label the Leydig cells, Seminiferous tubules, Spermatogonia, Sertoli cells, spermatogonia, spermatids, sperm in lumen



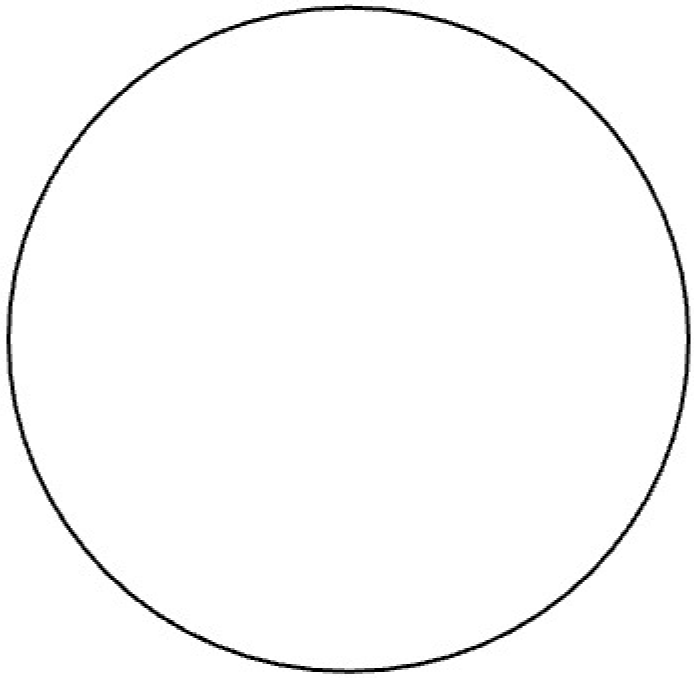
4. Go to [Slides for Junqueira's Basic Histology]()



Slide No. 119, Testis, human H&E

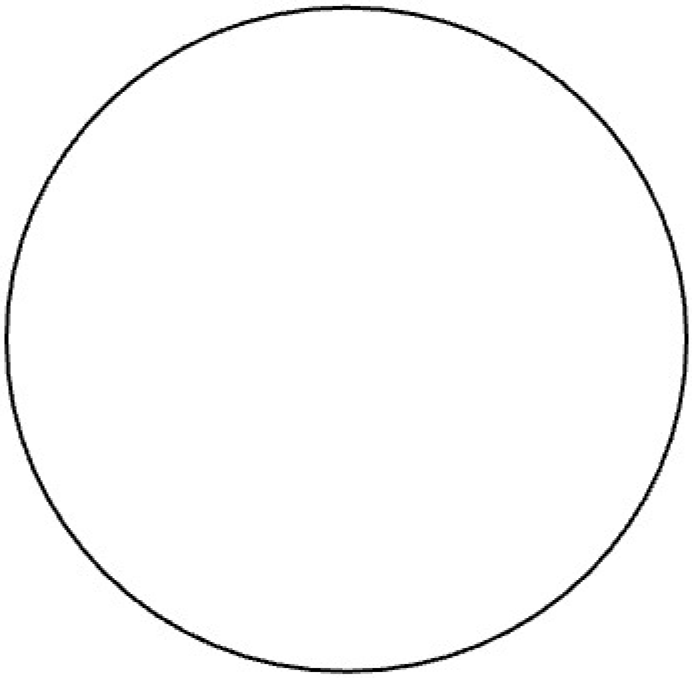
Choose slide 119, testis, human H&E. Use the controls (+/-) to increase magnification. First scan the sample at low power and draw and label the structures of the testis:

- Capsule
- Lobules
- Convoluted seminiferous tubules

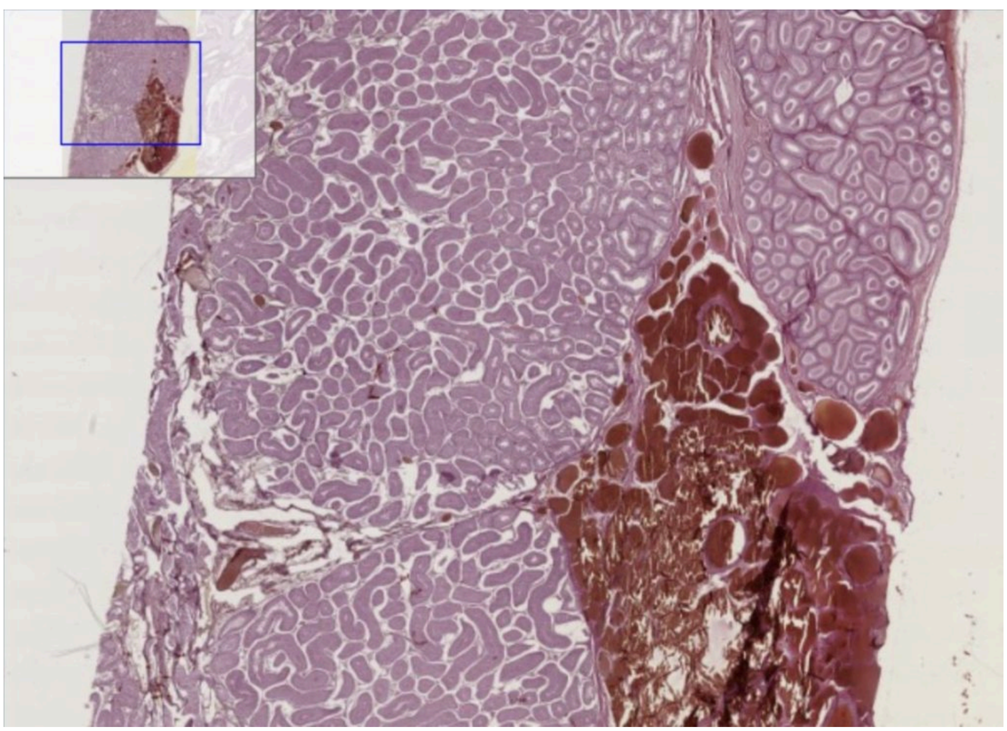


Increase magnification and draw and label the structures of the testis:

- Convoluted seminiferous tubules, x.s.
- Clusters of interstitial cells or Leydig Cells
- Spermatogonia
- Sertoli cells
- Spermatids
- Lumen
- Sperm (at lumen)



5. Go to [Slides for Junqueira's Basic Histology]



Choose slide 155, testis, dog. Use the controls (+/-) to increase magnification. First scan the area at low magnification, then increase magnification close to the maximum and draw and label the structures of the testis/seminiferous tubules:

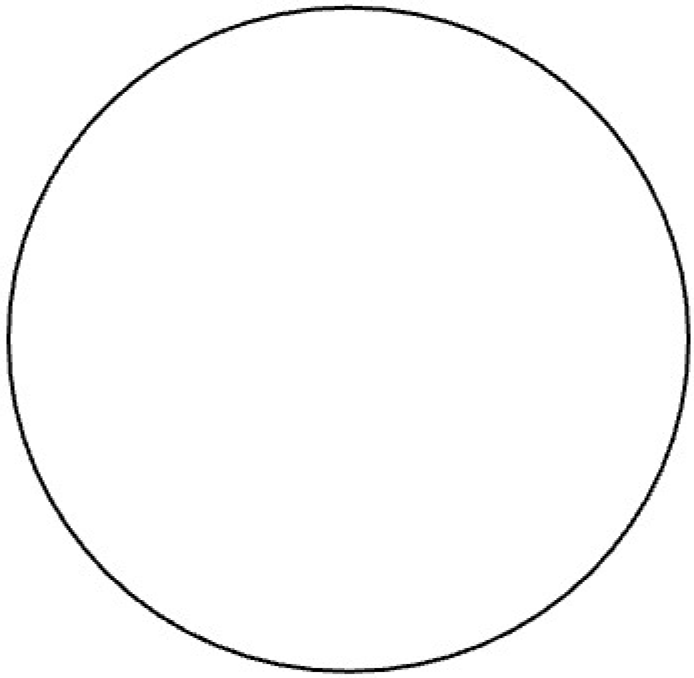
- Seminiferous tubules (transverse section)
- Clusters of interstitial cells or Leydig Cells – between the seminiferous tubules
- Spermatogonia
- Sertoli cells
- Lumen
- Spermatids
- Sperm (at lumen)

Exercise 6 – Microscopic Anatomy of Ovaries

Face-to-face Laboratories

Obtain a microscope slide of ovary from your instructor and view using a standard light microscope. Identify, draw and label the following structures:

1. Ovary
2. Primordial Follicles
3. Primary follicles
4. Secondary follicles (sometimes these are hard to see)
5. Tertiary Follicles
    1. Antrum
    2. Cumulative mass
    3. Oocyte
6. Corpus luteum (if present)



Note: face to face labs should also take advantage of open educational resources, such as the virtual microscopes and review the images assigned to 100% onion labs.

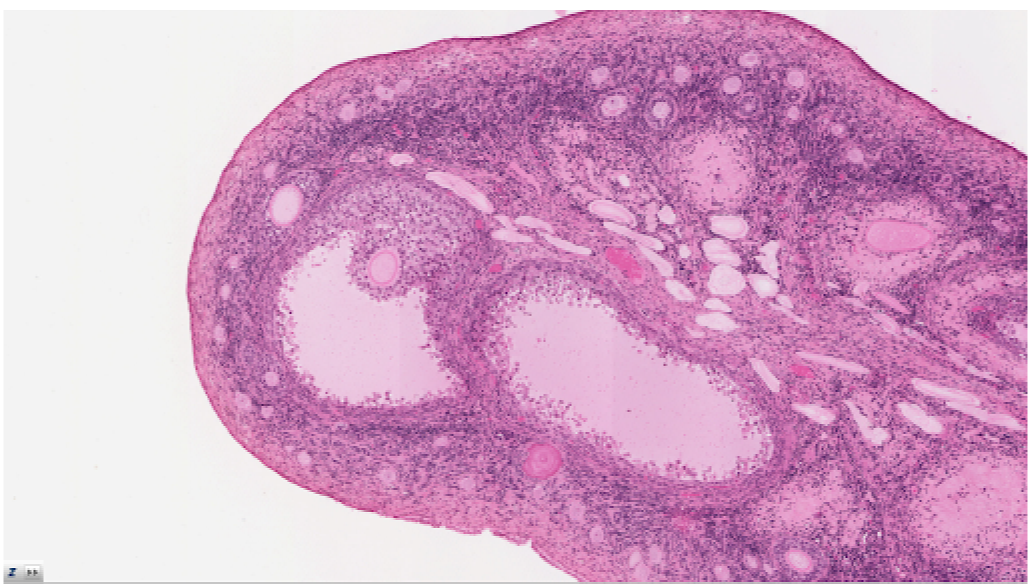
100% online labs – University of Michigan Virtual Microscope – use the following link:

[Full Slide List]

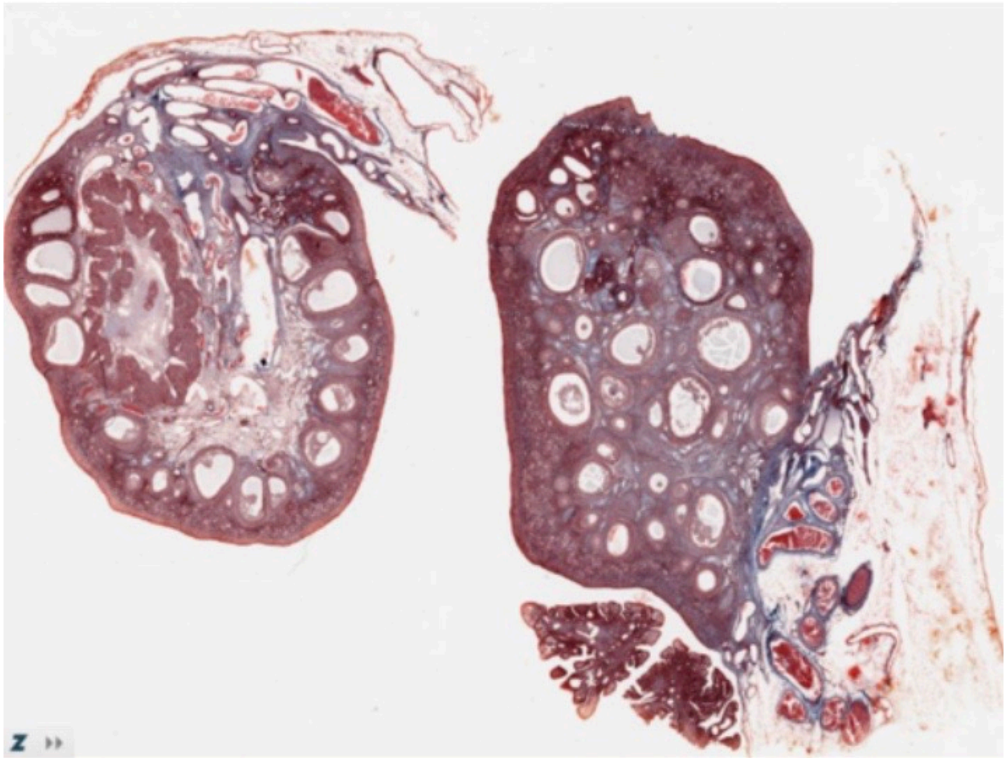
1. Search for slide #239 Ovary, monkey, H&E, 40X, you should see the following image at low magnification

2. Using the +/- controls, magnify the image to be able to identify and label the following structures: hilus, mesovarium, medulla, cortex, tunica albuginea, primordial follicles, ovum, granulosa

[follicular] cells, primary follicles, secondary follicles, antrum, mature [Graafian] follicles, theca interna, zona pellucida, cumulus oophorus, corona radiata, atresia, glassy membrane, corpus luteum, granulosa lutein cells, theca lutein cells, corpus albicans.

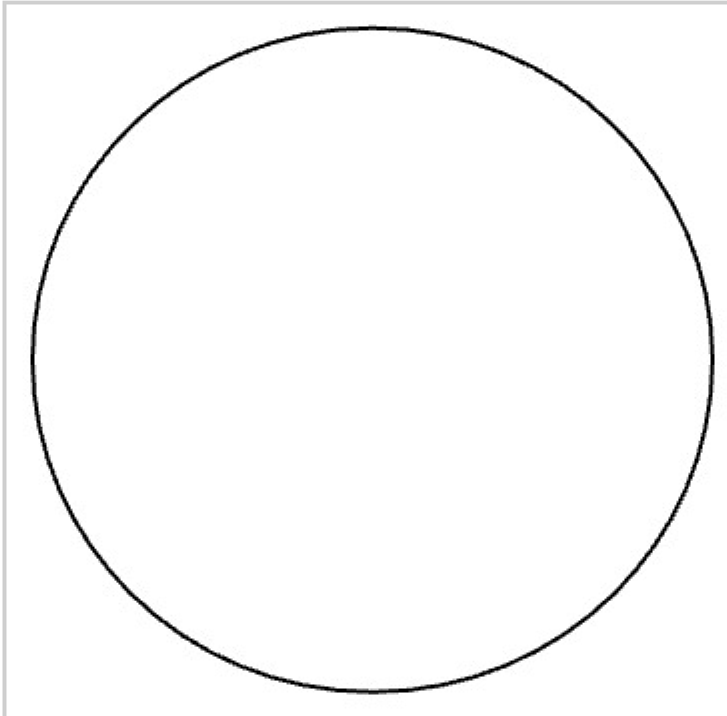


3. Go to [Slides for Junqueira's Basic Histology]()



Choose slide 13, Ovary, Monkey, Masson Trichrome. Use the control (+/-) to magnify the image. Draw, and label the following structures:

1. Primordial follicles
2. Primary follicles
3. Secondary follicles
4. Graafian follicles
5. Oocyte
6. Antrum
7. Corpus luteum
8. Corpus albicans



Simple squamous epithelium Magnification ___________x

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