HUMAN ANATOMY LABORATORY MANUAL (HARTLINE)



Rosanna Hartline
West Hills College Lemoore

LibreTexts™

Human Anatomy Laboratory Manual

Compiled & Written by: Rosanna Hartline, Ph.D., *Lemoore College*

Cover image: "Air Force Women's Soccer vs Siena (48629694273).jpg" by U.S. Air Force/Joshua Armstrong is in the Public Domain

Created for: Lemoore College, Lemoore, CA

Special thanks to: Kelsey Smith and Amy Hartline

License: Human Anatomy Laboratory Manual by Rosanna Hartline, Ph.D., 2026 is licensed under CC BY-NC-SA 4.0

This text is disseminated via the Open Education Resource (OER) LibreTexts Project (https://LibreTexts.org) and like the thousands of other texts available within this powerful platform, it is freely available for reading, printing, and "consuming."

The LibreTexts mission is to bring together students, faculty, and scholars in a collaborative effort to provide an accessible, and comprehensive platform that empowers our community to develop, curate, adapt, and adopt openly licensed resources and technologies; through these efforts we can reduce the financial burden born from traditional educational resource costs, ensuring education is more accessible for students and communities worldwide.

Most, but not all, pages in the library have licenses that may allow individuals to make changes, save, and print this book. Carefully consult the applicable license(s) before pursuing such effects. Instructors can adopt existing LibreTexts texts or Remix them to quickly build course-specific resources to meet the needs of their students. Unlike traditional textbooks, LibreTexts' web based origins allow powerful integration of advanced features and new technologies to support learning.



LibreTexts is the adaptable, user-friendly non-profit open education resource platform that educators trust for creating, customizing, and sharing accessible, interactive textbooks, adaptive homework, and ancillary materials. We collaborate with individuals and organizations to champion open education initiatives, support institutional publishing programs, drive curriculum development projects, and more.

The LibreTexts libraries are Powered by NICE CXone Expert and was supported by the Department of Education Open Textbook Pilot Project, the California Education Learning Lab, the UC Davis Office of the Provost, the UC Davis Library, the California State University Affordable Learning Solutions Program, and Merlot. This material is based upon work supported by the National Science Foundation under Grant No. 1246120, 1525057, and 1413739.

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation nor the US Department of Education.

Have questions or comments? For information about adoptions or adaptions contact info@LibreTexts.org or visit our main website at https://LibreTexts.org.

This text was compiled on 06/08/2026

TABLE OF CONTENTS

Licensing

1: Introduction to Anatomy and Anatomical Terms

- 1.1: Introduction
- 1.2: Anatomical Position
- 1.3: Directional Terms
- 1.4: Planes/Sections
- 1.5: Anatomical Adjectives for Body Locations
- 1.6: Abdominopelvic Regions and Abdominopelvic Quadrants
- 1.7: Video Overview of Anatomical Position, Directional Terms, Planes/Sections, Anatomical Adjectives, Abdominal Regions, and Abdominal Quadrants
- 1.8: Body Cavities
- 1.9: Serosa (Serous Membranes)
- 1.10: Laboratory Activities and Assignment
- 1.11: Collaborative Study Activities

2: Introduction to Microscopes

- 2.1: Introduction
- 2.2: Introduction to the Metric System
- 2.3: Light Microscopy (LM)
- 2.4: Electron Microscopy (EM)
- 2.5: Use of Compound Light Microscopes for Anatomy Laboratories
- 2.6: Laboratory Activities and Assignment

3: Cell Structure and Cell Types

- 3.1: Introduction
- 3.2: Subcellular Structures
- 3.3: Cell-to-Cell Junctions Hold Cells Together In Tissues
- 3.4: Cell Structure Varies by Cell Type
- 3.5: Laboratory Activities and Assignment
- 3.6: Collaborative Study Activity

4: How Cells Divide (Mitotic Cell Division)

- 4.1: Introduction to Cell Division
- 4.2: The Life of a Cell
- 4.3: Mitotic Cell Division- Division of the Nucleus (Mitosis) + Division of the Cytoplasm (Cytokinesis)
- 4.4: Uncontrolled Cell Divisions Create Tumors including Cancers
- 4.5: Laboratory Activities and Assignment
- 4.6: Collaborative Study Activity

5: Tissues

- 5.1: Introduction
- 5.2: Epithelial Tissues
- 5.3: Connective Tissues
  - 5.3.1: Introduction to Connective Tissues

- 5.3.2: Connective Tissue Proper
- 5.3.3: Bone Tissue
- 5.3.4: Fluid Tissues
- 5.3.5: Cartilage Tissues
- 5.4: Muscle Tissues
- 5.5: Nervous Tissues
- 5.6: Laboratory Activities and Assignment
- 5.7: Collaborative Study Activity

6: Integumentary System

- 6.1: Introduction
- 6.2: Anatomy of the Skin
- 6.3: Secondary Structures of the Skin
- 6.4: Anatomy of the Nails
- 6.5: Laboratory Activities and Assignment
- 6.6: Collaborative Study Activity

7: Introduction to the Skeletal System

- 7.1: Introduction
- 7.2: Osseous Tissue (Bone Tissue)
- 7.3: Axial Skeleton and Appendicular Skeleton
- 7.4: Bone Shape Classifications
- 7.5: Anatomy of a Long Bone
- 7.6: Bone Markings
- 7.7: Cartilage
- 7.8: Laboratory Activities and Assignment

8: Axial Skeleton

- 8.1: Introduction
- 8.2: Skull
  - 8.2.1: Exterior of the Cranium
  - 8.2.2: Interior of the Cranium
  - 8.2.3: Markings of the Cranium
  - 8.2.4: Face
- 8.3: Hyoid Bone
- 8.4: Auditory Ossicles
- 8.5: Vertebral Column
  - 8.5.1: Introduction to the Vertebral Column
  - 8.5.2: Generalized Structure and Markings of Vertebrae
  - 8.5.3: Cervical Vertebrae
  - 8.5.4: Thoracic Vertebrae
  - 8.5.5: Lumbar Vertebrae
  - 8.5.6: Sacrum and Coccyx
  - 8.5.7: Intervertebral Foramina
  - 8.5.8: Intervertebral Discs
  - 8.5.9: Clinical Application - Whiplash
- 8.6: Thoracic Cage
- 8.7: Additional Reference Figures
- 8.8: Laboratory Activities and Assignment
- 8.9: Collaborative Study Activities

9: Appendicular Skeleton

- 9.1: Introduction
- 9.2: Shoulder Girdle/Pectoral Girdle
- 9.3: Upper Limb
- 9.4: Pelvic Girdle
- 9.5: Lower Limb
- 9.6: Additional Reference Figures
- 9.7: Laboratory Activities and Assignment
- 9.8: Collaborative Study Activities

10: Articulations (Joints) and Movements

- 10.1: Articulations (Joints)
- 10.2: Body Movements
- 10.3: Additional Reference Figures
- 10.4: Laboratory Activities and Assignment

11: Introduction to Skeletal Muscles

- 11.1: Introduction
- 11.2: Microscopic Anatomy of Skeletal Muscles
- 11.3: Macroscopic Anatomy of Skeletal Muscles
- 11.4: Laboratory Activities and Assignment

12: The Skeletal Muscles

- 12.1: Introduction
- 12.2: Muscles of the Head and Neck
- 12.3: Muscles of the Anterior Trunk
- 12.4: Muscles of the Posterior Trunk
- 12.5: Muscles of the Upper Limbs
- 12.6: Muscles of the Hips and Lower Limbs
- 12.7: Actions, Origins, and Insertions of the Skeletal Muscles
- 12.8: Laboratory Activities and Assignment
- 12.9: Collaborative Study Activities

13: Introduction to the Nervous System

- 13.1: Introduction
- 13.2: Neurons
- 13.3: Nerves are Bundles of Neuron Axons in the PNS
- 13.4: Glia (Neuroglia) Cells
- 13.5: Laboratory Activities and Assignment

14: Central Nervous System

- 14.1: Brain
- 14.2: Sheep Brain Dissection
- 14.3: Spinal Cord
- 14.4: Additional Reference Figures
- 14.5: Laboratory Activities and Assignment
- 14.6: Collaborative Study Activities

15: Peripheral Nervous System

- 15.1: Introduction
- 15.2: Cranial Nerves
- 15.3: Spinal Nerves
- 15.4: Additional Reference Figures
- 15.5: Laboratory Activities and Assignment
- 15.6: Collaborative Study Activities

16: Special Senses of the Nervous System

- 16.1: Introduction
- 16.2: Vision Anatomy
- 16.3: Auditory and Equilibrium Anatomy
- 16.4: Olfactory Anatomy
- 16.5: Taste Anatomy
- 16.6: Laboratory Activities and Assignment
- 16.7: Collaborative Study Activities

17: Cardiovascular System - The Heart

- 17.1: Introduction
- 17.2: Location, Size, and Shape of the Heart
- 17.3: Vessels of the Heart
- 17.4: Layers of the Heart
- 17.5: Internal Structures of the Heart
- 17.6: Circulation Through the Heart
- 17.7: Coronary Circulation
- 17.8: Heart Abnormalities and Treatments
- 17.9: Laboratory Activities and Assignment
- 17.10: Collaborative Study Activities

18: Cardiovascular System - The Blood Vessels

- 18.1: Introduction
- 18.2: Structures of Blood Vessels
- 18.3: Branches of the Aorta
- 18.4: Arteries of the Head and Neck
- 18.5: Arteries of the Upper Limb
- 18.6: Arteries of the Lower Limb
- 18.7: Branches of the Vena Cavae
- 18.8: Veins of the Head and Neck
- 18.9: Veins of the Upper Limb
- 18.10: Veins of the Lower Limb
- 18.11: Cadaver Images of Blood Vessels
- 18.12: Laboratory Activities and Assignment
- 18.13: Collaborative Study Activities

19: Respiratory System

- 19.1: Introduction
- 19.2: Upper Respiratory Tract
- 19.3: Lower Respiratory Tract
- 19.4: Laboratory Activities and Assignment
- 19.5: Collaborative Study Activities

20: Digestive System

- 20.1: Introduction
- 20.2: Histology of the Alimentary Canal
- 20.3: Serosa
- 20.4: Oral Cavity
- 20.5: Esophagus and Stomach
- 20.6: Duodenum, Pancreas, Liver, and Gallbladder
- 20.7: Small Intestine
- 20.8: Colon (Large Intestine), Rectum, and Anus
- 20.9: Laboratory Activities and Assignment
- 20.10: Collaborative Study Activities

21: Urinary System

- 21.1: Introduction
- 21.2: Kidneys
- 21.3: Microscopic Structures of the Kidneys - Nephrons
- 21.4: Ureters
- 21.5: Urinary Bladder
- 21.6: Urethra
- 21.7: Laboratory Activities and Assignment
- 21.8: Collaborative Study Activities

22: Reproductive Systems

- 22.1: Introduction
- 22.2: Female Reproductive System (Internal)
- 22.3: Female Reproductive System (External)
- 22.4: Male Reproductive System
- 22.5: Laboratory Activities and Assignment
- 22.6: Collaborative Study Activities

Index

Glossary

Detailed Licensing

Licensing

License: Human Anatomy Laboratory Manual by Rosanna Hartline, Ph.D., 2026 is licensed under CC BY-NC-SA 4.0

*A detailed breakdown of this resource's licensing can be found in **Back Matter/Detailed Licensing**.*

CHAPTER OVERVIEW

1: Introduction to Anatomy and Anatomical Terms

1.1: Introduction
1.2: Anatomical Position
1.3: Directional Terms
1.4: Planes/Sections
1.5: Anatomical Adjectives for Body Locations
1.6: Abdominopelvic Regions and Abdominopelvic Quadrants
1.7: Video Overview of Anatomical Position, Directional Terms, Planes/Sections, Anatomical Adjectives, Abdominal Regions, and Abdominal Quadrants
1.8: Body Cavities
1.9: Serosa (Serous Membranes)
1.10: Laboratory Activities and Assignment
1.11: Collaborative Study Activities

This page titled 1: Introduction to Anatomy and Anatomical Terms is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

1.1: Introduction

Introduction

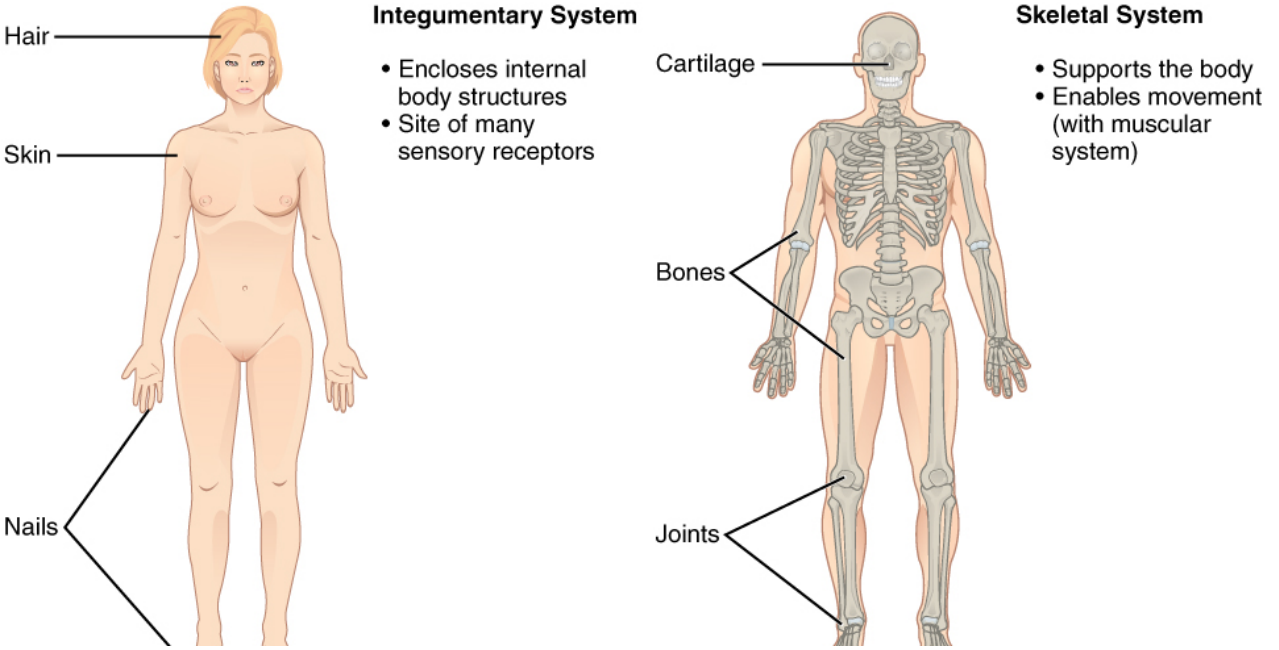
Anatomy is the study of biological structures. Biological structures may be examined and studied at levels visible to the human eye, **gross anatomy**, or at levels too small for the human eye to see, **microscopic anatomy**. Microscopic anatomy requires the use of microscopes and includes the study of cells, **cytology**, and the study of tissues, **histology**.

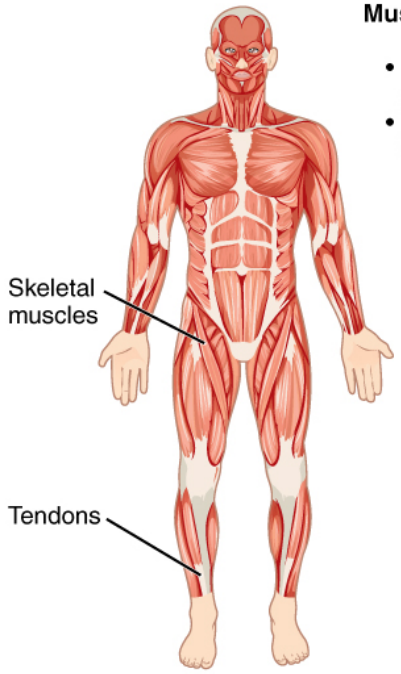
The structure of a human can be broken down based on levels of organization:

1. human
2. organ systems
3. organs
4. tissues
5. cells
6. molecules
7. atoms

Each level of structural organization is composed of the smaller levels below it. For example: cells are composed of molecules, tissues are composed of cells, and humans are composed of organ systems. In fact, humans are composed of eleven (11) organ systems:

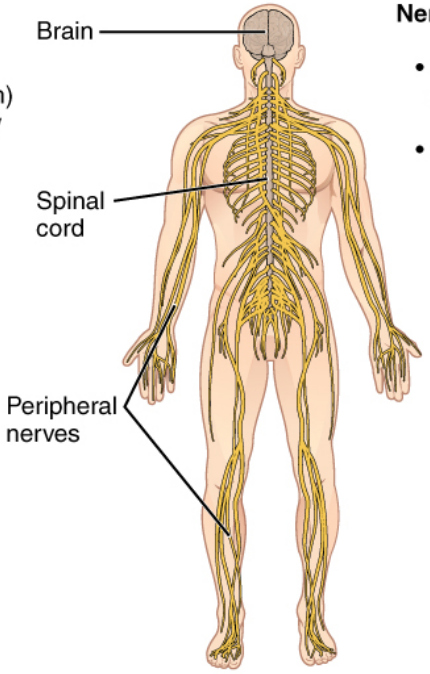
- **cardiovascular/circulatory system -** transports substances (e.g. oxygen [O_2], carbon dioxide [CO_2], glucose, hormones) throughout the body
- **integumentary system** – provides protecting coverings to the body
- digestive system – processes food to provide nutrients (energy, biological building blocks, and vitamins)
- **muscular system** – provides movement to the body
- **endocrine system** – produces hormones that signal cells, tissues, and organs throughout the body
- **lymphatic system -** cleanses and returns tissue fluid to the cardiovascular/circulatory system and provides adaptive immune responses
- **nervous system** – provides ability to interact with and interpret the environment (both the inside and outside environments)
- **skeletal system** – provides framework for movement and protection of the organs of the body
- **reproductive systems** (male and female) – produces offspring
- **respiratory system** – exchanges oxygen (O_2) for carbon dioxide (CO_2)
- **urinary/excretory system** – filters blood and discards waste products (wastes from metabolism, foreign substances, etc.)





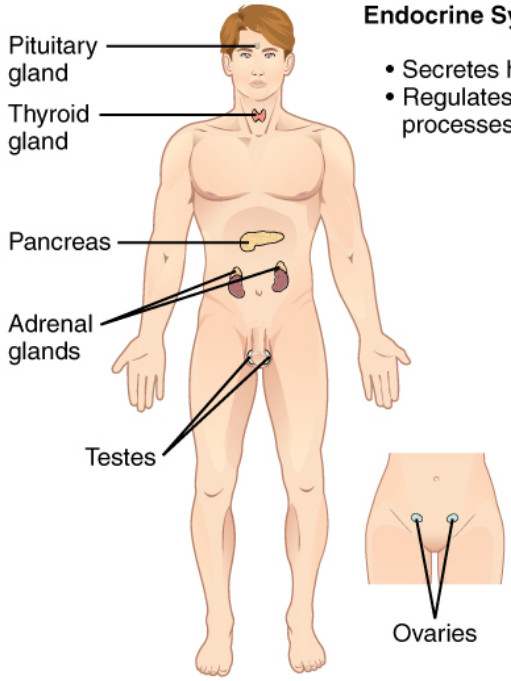
Muscular System

- Enables movement (with skeletal system)
- Helps maintain body temperature



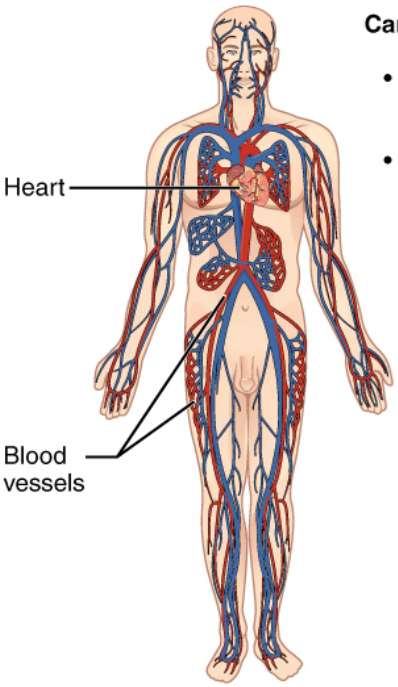
Nervous System

- Detects and processes sensory information
- Activates bodily responses



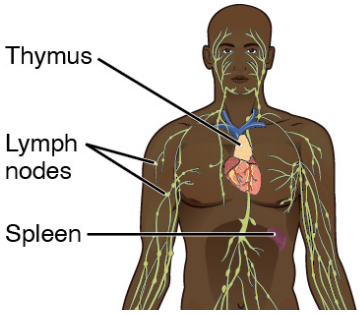
Endocrine System

- Secretes hormones
- Regulates bodily processes



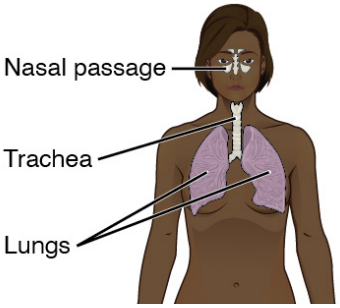
Cardiovascular System

- Delivers oxygen and nutrients to tissues
- Equalizes temperature in the body



Lymphatic System

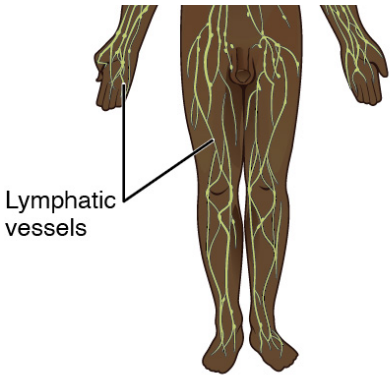
- Returns fluid to blood
- Defends against pathogens

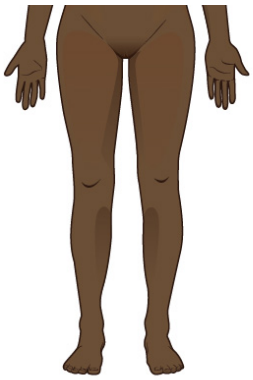


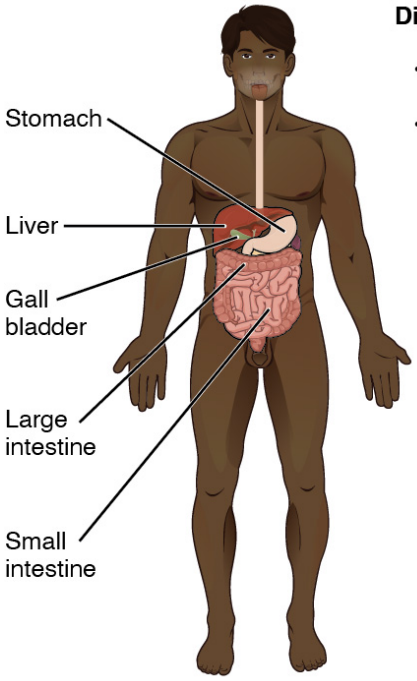
Respiratory System

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

https://bio.libretexts.org/@go/page/53506

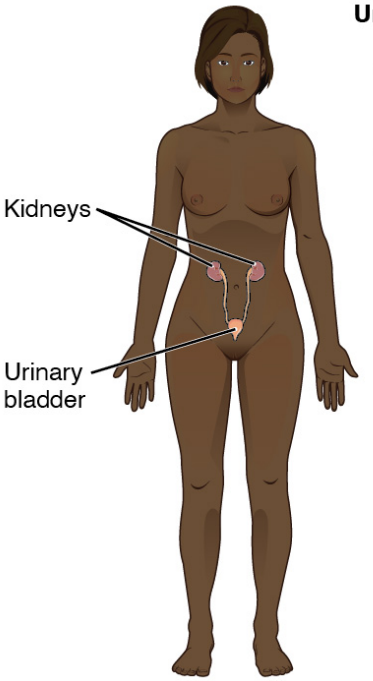






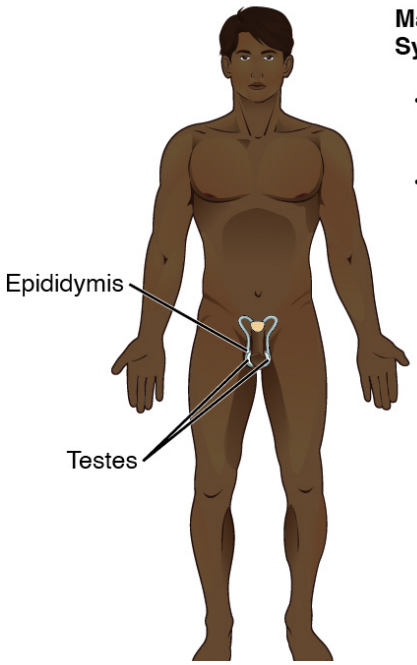
Digestive System

- Processes food for use by the body
- Removes wastes from undigested food



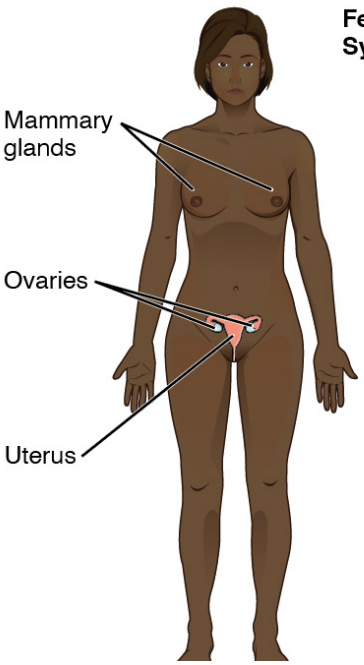
Urinary System

- Controls water balance in the body
- Removes wastes from blood and excretes them



Male Reproductive System

- Produces sex hormones and gametes
- Delivers gametes to female



Female Reproductive System

- Produces sex hormones and gametes
- Supports embryo/fetus until birth
- Produces milk for infant

https://bio.libretexts.org/@go/page/53506

There is overlap among these body systems with organs belonging to more than one organ system. For example, the ovaries are organs of the female reproductive system but they also produce hormones and are therefore considered to be endocrine organs also. There is also extensive interaction among these body systems. For example, the respiratory system brings oxygen (O_2) into the body and removes carbon dioxide (CO_2) from the body and works closely with the cardiovascular/circulatory system that takes O_2 from the respiratory system and transports it to body cells while removing CO_2 from body cells and transporting it to the respiratory system for removal.

Physiology is the study of biological functions and interactions and is often closely related to the anatomy since in biology, *structure dictates function*. Therefore, to best understand how a living thing functions (physiology), it is necessary to understand its structure (anatomy). Physiology may be studied from the molecular level to the organism level.

Attributions

- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0
- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0
- "UGA Anatomy and Physiology 1 Lab Manual, 3rd Edition" by DeLoris Hesse, Deanna Cozart, Brett Szymik, Rob Nichols, University of Georgia is licensed under CC BY 4.0

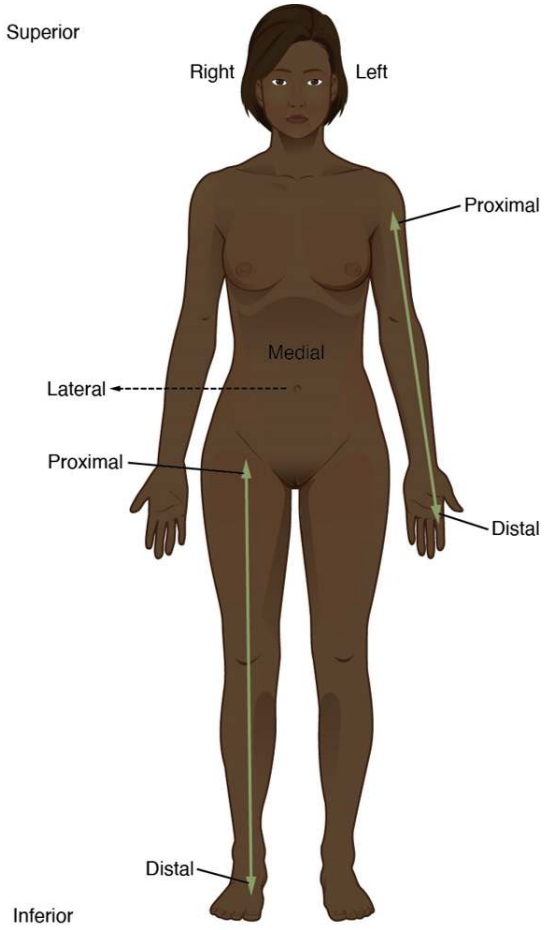
Updated 2025.

This page titled 1.1: Introduction is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

1.2: 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. All of the directional terms in the following section are used ***based on a human who is in anatomical position***. For example, if a human is doing a head stand, their head is still considered to be superior to their feet since directionality terms ALWAYS refer to anatomical position.



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

Attributions

- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0
- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0

Updated 2025.

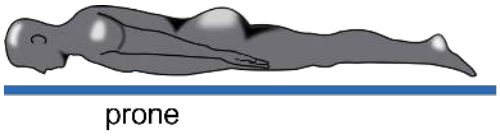
This page titled 1.2: Anatomical Position is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

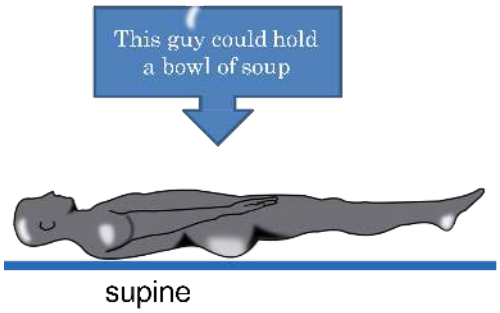
1.3: Directional Terms

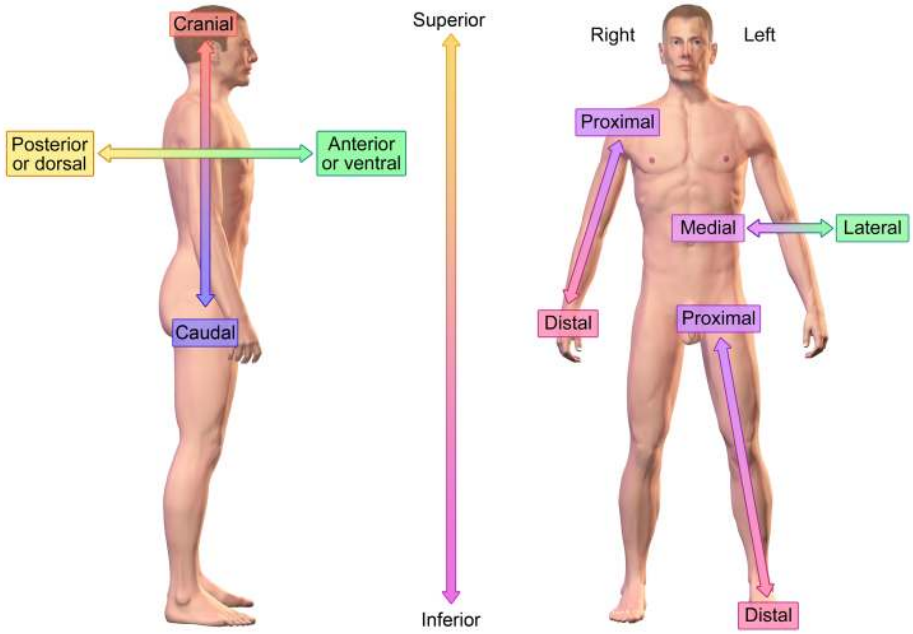
Directional Terms

With the body in anatomical position, there are specific terms to describe parts of the body with respect to each other. Please note that these terms are always used in reference to a body in anatomical position, regardless of that human body's actual position.

Directional Term	Meaning	Example
supine	lying face up	A person lying face up is in the supine position. "Person could hold a bowl of soup."
prone	lying face down	A person lying face down is in the prone position.
superior / cranial	above or higher up	The nose is superior (or cranial) to the chin.
inferior	below or lower down	The knees are inferior to the pelvis.
caudal	below or lower down - toward the tail bone from higher up	The pelvis is caudal to the stomach.
medial	toward the midline	The sternum is medial to the shoulders.
lateral	toward the side (right and/or left side)	The ears are lateral to the nose.
superficial	toward the body surface	The skin is superficial to the heart.
deep	toward the body core	The heart is deep to the ribs.
anterior / ventral	front or toward the front	The toes are anterior (or ventral) to the heel.
posterior / dorsal	back or toward the back	The spine is posterior (or dorsal) to the sternum.
proximal	**for limbs only:** closer to the shoulder (upper limb); closer to the hip (lower limb)	The elbow is proximal to the wrist.
distal	**for limbs only:** further from the shoulder (upper limb); further from the hip (lower limb)	The toes are distal to the knee.

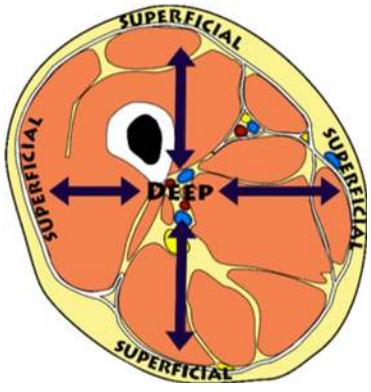






Directional References

Two or more directional terms may be technically correct, however only certain directional terms will convey the *most relevant* information for a specific situation. For example, when discussing a brain tumor relative to the nose, it may be deep, dorsal *and*, lateral. When we ask, "Can we take a scalpel, shove it up the patient's nasal cavity, and cut out the tumor?" it would *not* be appropriate to say, "No, it is too lateral," or "No, it is too dorsal." Instead, it would make the most sense to say, "No, it is too deep. We will have to cut through the skull to get to it."



Above: Cross section of the thigh.

Attributions

- "Anatomy and Physiology Lab Reference" by Laird C Sheldahl, OpenOregonEducational Resources, Mt. Hood Community College is licensed under CC BY-SA 4.0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- Blausen 0019 AnatomicalDirectionalReferences.png by Blausen.com staff (2014). "Medical gallery of Blausen Medical 2014". *WikiJournal of Medicine* **1** (2). DOI:10.15347/wjm/2014.010. ISSN 2002-4436

Updated 2025.

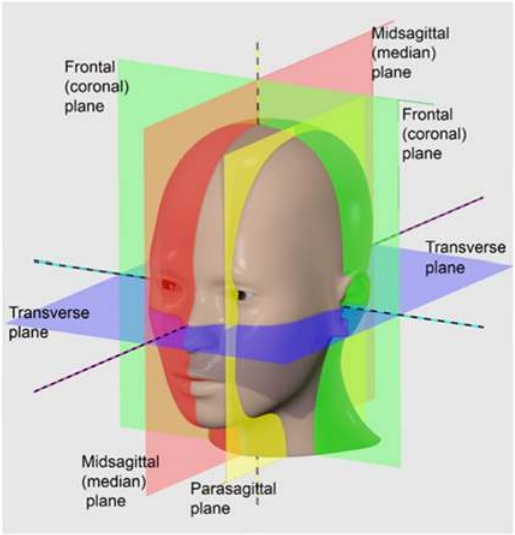
This page titled 1.3: Directional Terms is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

1.4: Planes/Sections

Planes/Sections

Anatomical figures are shown in different planes/sections (two-dimensional views). Medical imaging captures anatomy in specific planes/sections and microscopic anatomy requires that tissue is sectioned in a specific body plane to visualize microscopic structures. Additionally, medical staff discuss the planes/sections when discussing treatments and surgeries. The table below lists common anatomical planes/sections and describes each:

Plane / Section	Description	Example
horizontal / transverse / cross	separate the body into superior and inferior parts	
frontal / coronal	separate the body into anterior-posterior	
sagittal	separate the body into right and left portions	
midsagittal / median	separate the body into ***equal*** right and left portions	
parasagittal	separate the body into ***unequal*** right and left portions	
oblique	any plane other than at a 90° angle (right angle)	



Attributions

- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0
- "Anatomy and Physiology Lab Reference" by Laird C Sheldahl, OpenOregonEducational Resources, Mt. Hood Community College is licensed under CC BY-SA 4.0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0

Updated 2025.

This page titled 1.4: Planes/Sections is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

1.5: Anatomical Adjectives for Body Locations

Anatomical Adjectives for Body Locations

Like all areas of science, there is a lot of jargon associated with anatomy. Oftentimes the terms used in anatomy differ from what we would name things in everyday conversation. Most of the terms below also appear when studying structures in the various organ systems. For example, there is a frontal bone in the skull, there are axillary veins and axillary arteries in the cardiovascular system, and some pectoral (chest) muscles are called pectoralis major and pectoralis minor.

Anatomical Adjectives of the Head and Neck

Anatomical Adjective (click for pronunciation)	Common Name
cephalic	head
cranial	skull
facial	face
frontal	forehead
ocular	eye
orbital	eye socket
nasal	nose
buccal	cheek
oral	mouth
glossal	tongue
mental	chin
otic	ear
cervical	neck

Anatomical Adjectives of the Trunk

Anatomical Adjective (click for pronunciation)	Common Name
trunk	torso
thoracic / thorax	upper torso (anterior & posterior)
pectoral	chest
mammary	breast
sternal	breastbone (center chest)
clavicular	collarbone
acromial	shoulder
abdominal	belly
inguinal	fold between trunk and hip
pelvic	lower torso (below belly)
pubic	lowest abdominal region
perineal	between genitals and anus

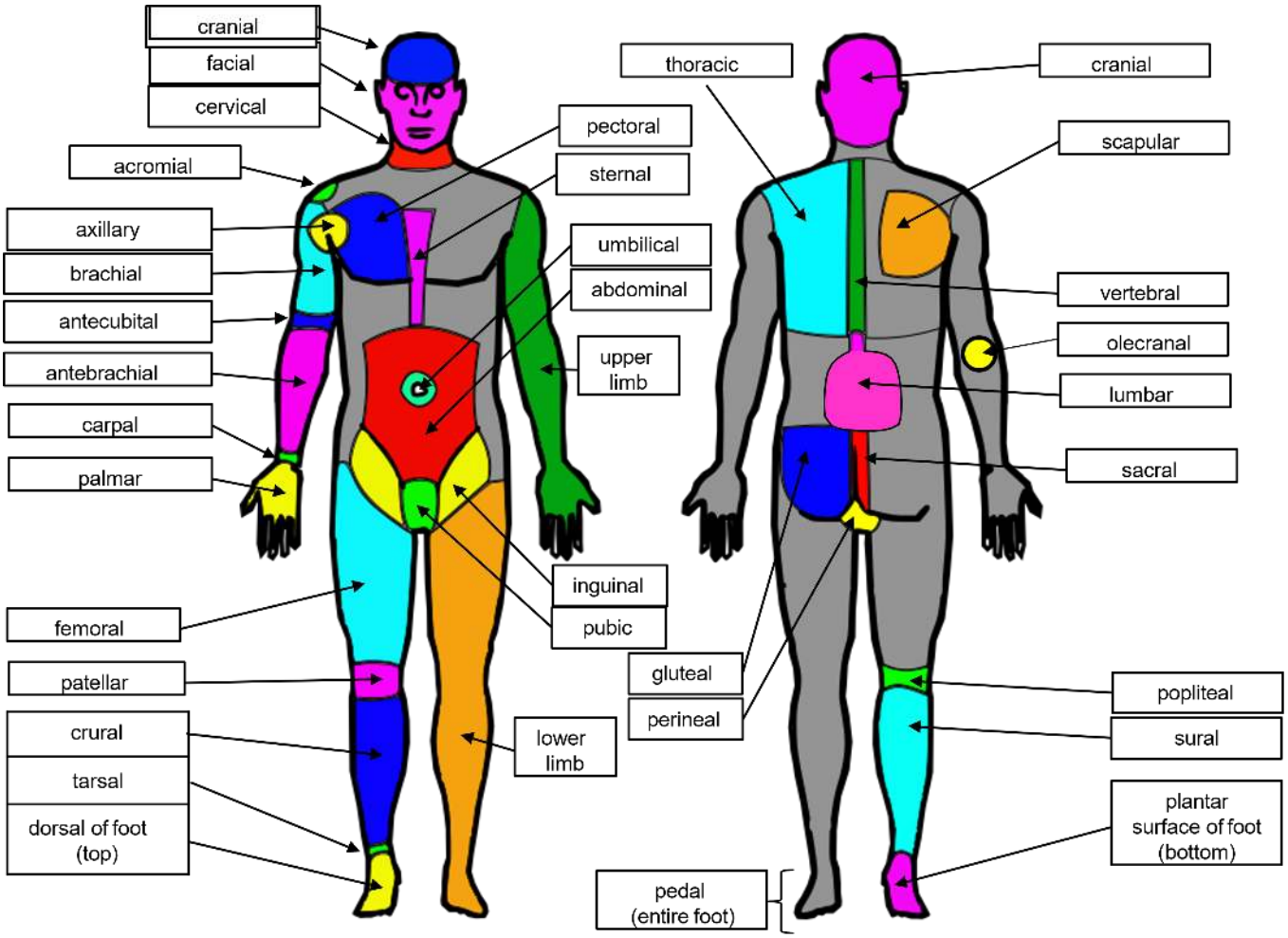
Anatomical Adjective (click for pronunciation)	Common Name
genital	sexual organs
coxal	hip
vertebral	spine
dorsal	back
scapular	shoulder blade
lumbar	lower back
sacral	extreme lower back (between butt cheeks)
gluteal	butt

Anatomical Adjectives of the Upper Limb

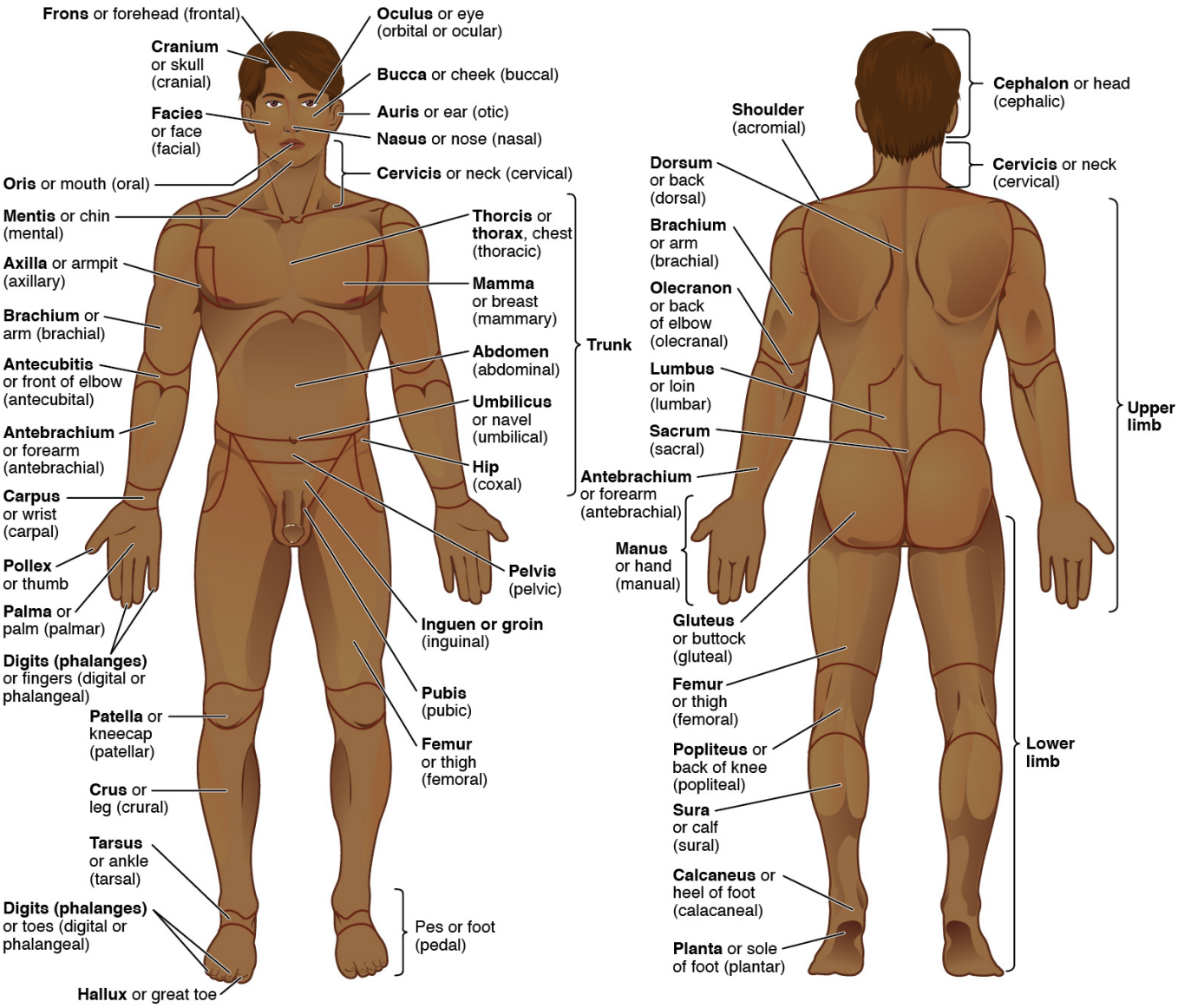
Anatomical Adjective	Common Name
axillary	armpit
brachial	shoulder to elbow
olecranal	elbow (posterior)
antecubital	front of the elbow
antebrachial	forearm
carpal	wrist
manual	hand
digital	fingers / toes
palmar	palm of the hand
pollex	thumb

Anatomical Adjectives of the Lower Limb

Anatomical Adjective	Common Name
femoral	thigh
popliteal	back of knee
patellar	kneecap
crural	shin
sural	calf
calcaneal	heel
tarsal	ankle
pedal	foot
digital	toes / fingers
hallux	big toe



https://bio.libretexts.org/@go/page/53510



Attributions

- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0
- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0
- "Anatomy and Physiology Lab Reference" by Laird C Sheldahl, OpenOregonEducational Resources, Mt. Hood Community College is licensed under CC BY-SA 4.0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0

Updated 2025.

This page titled 1.5: Anatomical Adjectives for Body Locations is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

1.6: Abdominopelvic Regions and Abdominopelvic Quadrants

Abdominopelvic Regions and Abdominopelvic Quadrants

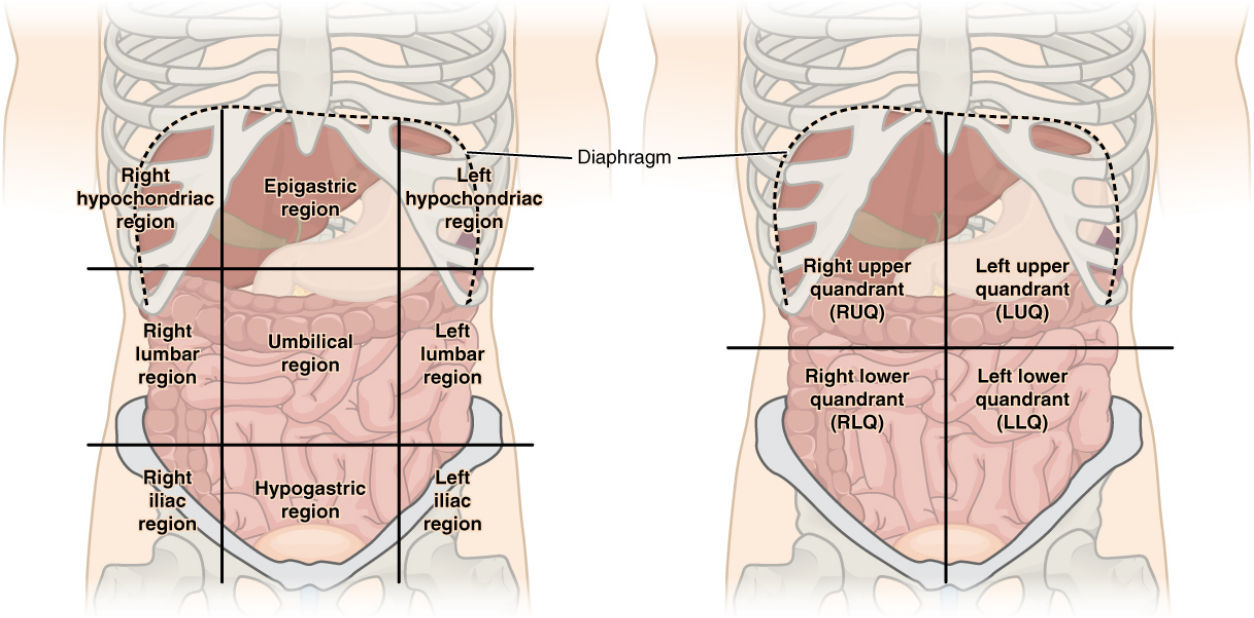
The abdominopelvic region can divided into **four abdominopelvic quadrants** or **nine abdominopelvic regions**. These are very important in clinical practice.

Four abdominopelvic quadrants:

- right-upper quadrant (RUQ)
- left-upper quadrant (LUQ)
- right-lower quadrant (RLQ)
- left-lower quadrant

Nine abdominopelvic regions:

- right hypochondriac
- epigastric
- left hypochondriac
- right lumbar
- umbilical
- left lumbar
- right iliac
- hypogastric
- left iliac



(a) Abdominopelvic regions

(b) Abdominopelvic quandrants

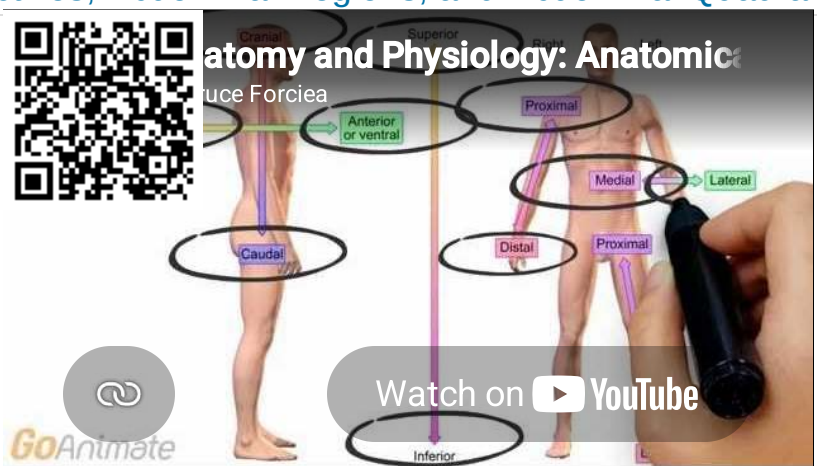
Attributions

- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0
- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0

Updated 2025.

This page titled 1.6: Abdominopelvic Regions and Abdominopelvic Quadrants is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

1.7: Video Overview of Anatomical Position, Directional Terms, Planes/Sections, Anatomical Adjectives, Abdominal Regions, and Abdominal Quadrants



Attribution

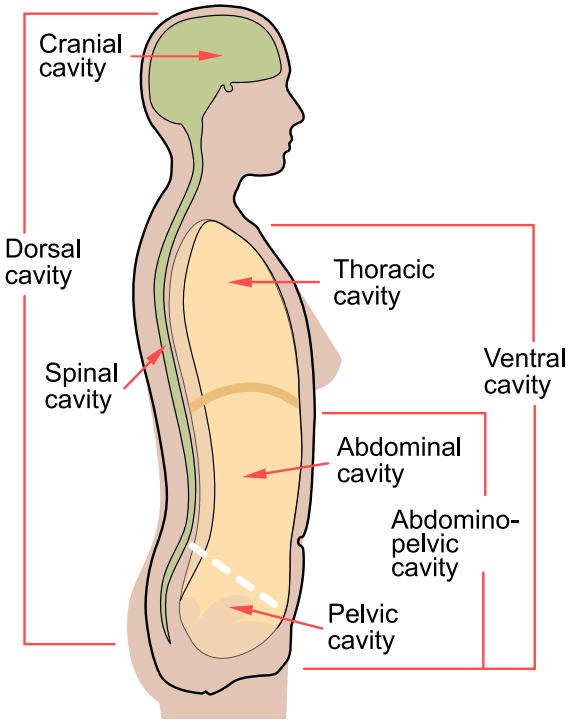
- "Anatomical Terminology Video" by Bruce Forciea is licensed under CC BY 4.0

This page titled 1.7: Video Overview of Anatomical Position, Directional Terms, Planes/Sections, Anatomical Adjectives, Abdominal Regions, and Abdominal Quadrants is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

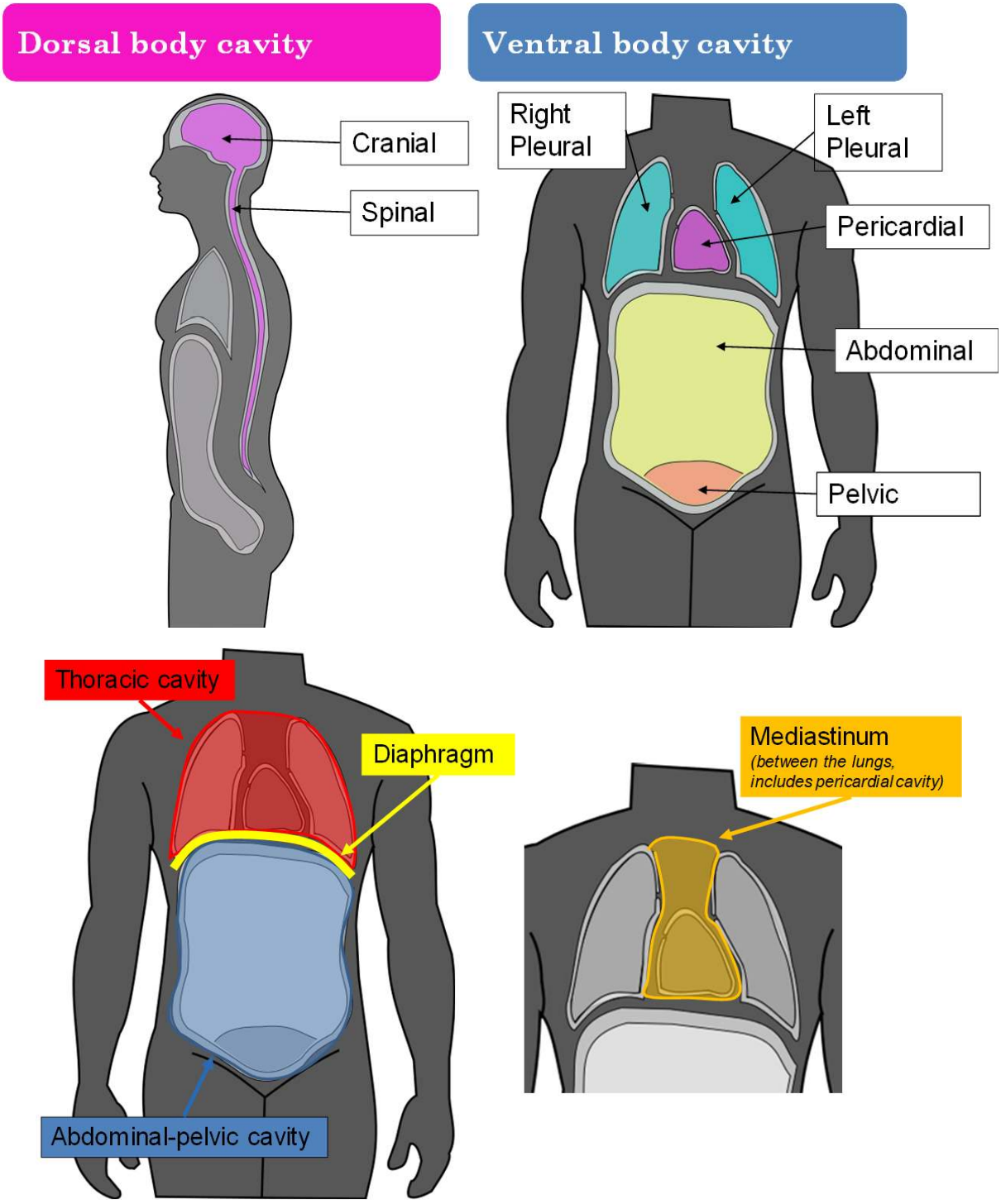
1.8: Body Cavities

Body Cavities

The major cavities of the human body are the spaces left over when the internal organs are removed. There are two main cavities: dorsal and ventral. The dorsal cavity is further divided into the cranial cavity and the vertebral/spinal cavity. The ventral body cavity is further divided into the thoracic and abdominopelvic cavities that are further subdivided into smaller cavities.



1. **dorsal body cavity**–the cranial cavity and the spinal cavity in combination.
    - **cranial cavity**–the space occupied by the brain, enclosed by the skull bones.
    - **vertebral/ spinal cavity**–the space occupied by the spinal cord enclosed by the vertebrae column making up the backbone. The spinal cavity is continuous with the cranial cavity.
2. **ventral body cavity**–the thoracic cavity, the abdominal cavity, and the pelvic cavity in combination.
    - **thoracic cavity**–the space occupied by the ventral internal organs superior to the diaphragm.
        - **right pleural cavity** and **left pleural cavity** - the space occupied by the right lung and the left lung, respectively.
        - **mediastinum** - the space located between the right pleural cavity and the left pleural cavity.
            - **pericardial cavity** - space inside of the mediastinum occupied by the heart.
    - **abdominopelvic cavity**–the abdominal cavity and the pelvic cavity in combination.
    - **abdominal cavity**–the space occupied by the ventral internal organs inferior to the diaphragm and superior to the pelvic cavity.
    - **pelvic cavity** - the space occupied by the internal organs inferior to the abdominal cavity and cradled by the pelvis.



Attributions

- "Anatomy and Physiology Lab Reference" by Laird C Sheldahl, OpenOregonEducational Resources, Mt. Hood Community College is licensed under CC BY-SA 4.0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- Scheme body cavities-en.svg by NCI and Mysid is in the public domain.

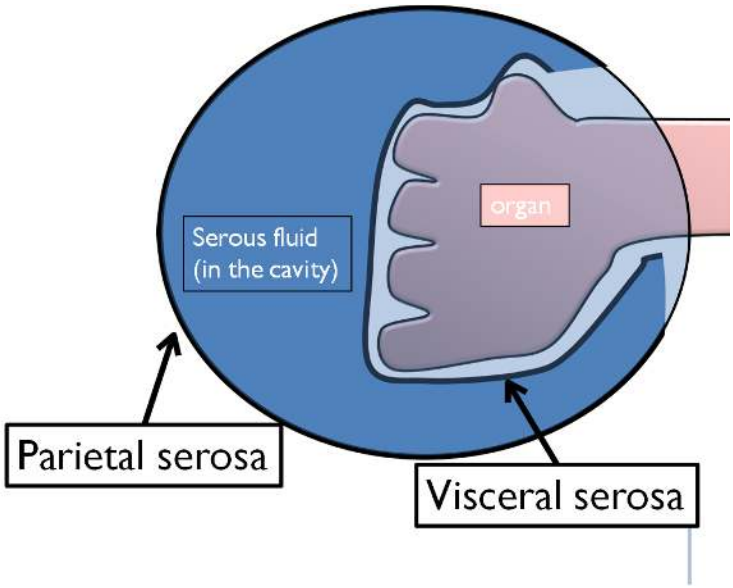
Updated 2025.

This page titled 1.8: Body Cavities is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

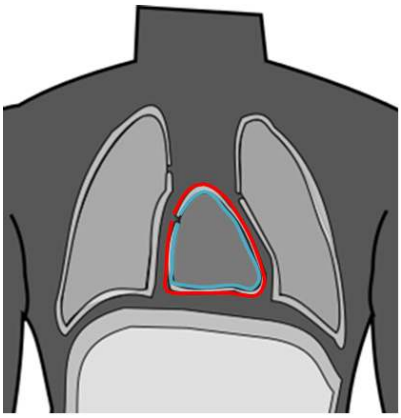
1.9: Serosa (Serous Membranes)

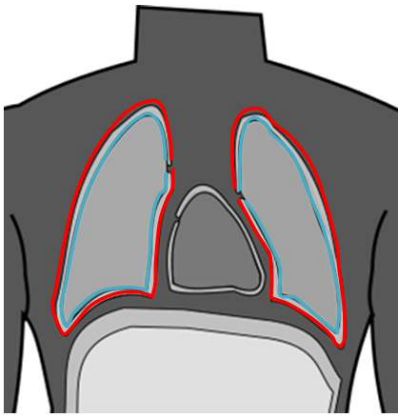
Serosa (Serous Membranes)

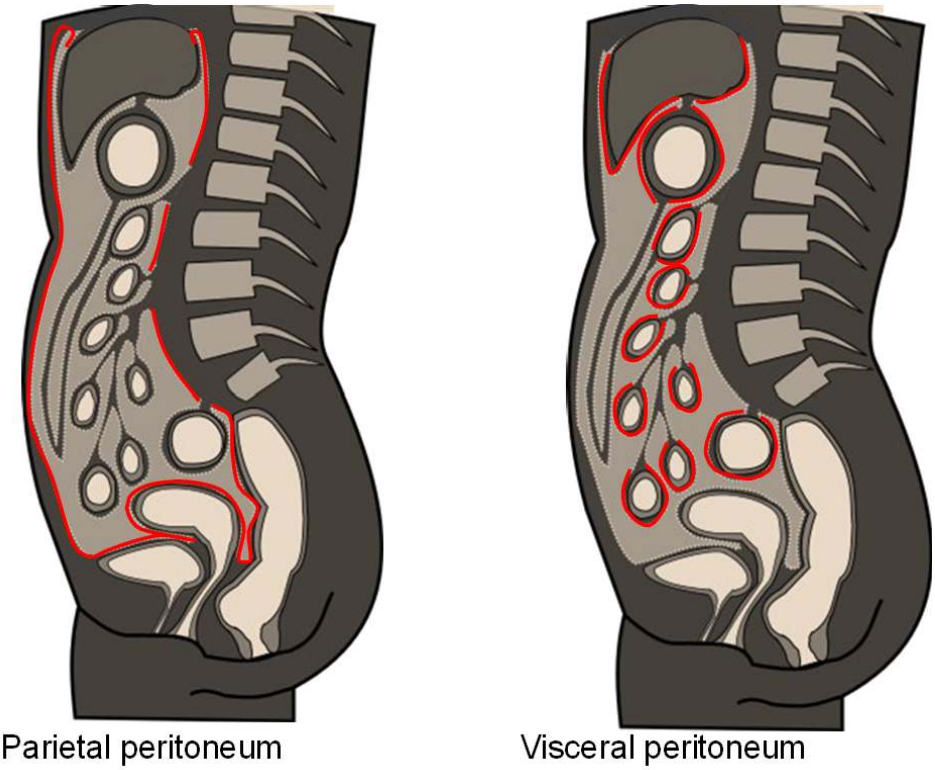
The ventral body cavities are enclosed inside **serous membranes** (**serosa**) that line the cavities and the organs inside them and create fluids that lubricate cushion the cavities to protect the organs prevent friction during movement. **Parietal** serosa line the body cavities and **visceral** serosa line the outer part of the organs within the body cavity. Therefore, parietal serous membranes are the outer membranes lining a body cavity and visceral serous membranes are the inner membranes lining a body cavity. Serous fluid produced by these membranes is located between the visceral and parietal layers.



Serous membranes are named not only using the terms "visceral" and "parietal", but also describing the body cavity where they are located. Serosa of the pleural cavities are called either **parietal pleural** or **visceral pleural**. Serosa of the pericardial cavity are called either **parietal pericardium** or **visceral pericardium**. Serosa of the abdominopelvic cavity are called either **parietal peritoneum** or **visceral peritoneum** but there are additional names given to the serous membranes of the abdominopelvic cavity that are covered more in depth in the digestive system chapter.







Attributions

- "Anatomy and Physiology Lab Reference" by Laird C Sheldahl, OpenOregonEducational Resources, Mt. Hood Community College is licensed under CC BY-SA 4.0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0

Updated 2025.

This page titled 1.9: Serosa (Serous Membranes) is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

1.10: Laboratory Activities and Assignment

Laboratory Activities and Assignment

Part 1: Human Organ Systems

The 11 human organ systems are listed below with an abbreviation for each. Put the letters relating to each body system to indicate the organ system each organ or structure listed below belongs to. There are more than one answer in some cases.

- cardiovascular (C)
- urinary (U)
- reproductive
  - male (MR)
  - female (FR)

- endocrine (E)
- muscular (M)
- skeletal (S)
- nervous (N)

- integumentary (I)
- respiratory (R)
- lymphatic (L)
- digestive (D)

_____ adrenal glands
_____ artery
_____ blood
_____ brain
_____ capillaries
_____ cartilage
_____ epididymis
_____ esophagus
_____ fingernails
_____ gall bladder
_____ hair
_____ heart
_____ joints
_____ kidney
_____ kneecap

_____ large intestines
_____ liver
_____ lungs
_____ lymph nodes
_____ lymphatic vessels
_____ mammary glands
_____ muscles
_____ nasal cavity
_____ nerves
_____ ovary
_____ pancreas
_____ pituitary gland
_____ ribs
_____ sense organs (e.g. eye)
_____ skin

_____ skull
_____ small intestines
_____ spinal cord
_____ spleen
_____ stomach
_____ tendons
_____ testes
_____ thymus
_____ thyroid gland
_____ trachea
_____ urinary bladder
_____ uterus

Part 2: Anatomical Position and Directional Terms

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

a. The heart is_____to the lungs.

b. The knee is_____to the hip.

c. The wrist is_____to the hand.

d. The mouth is_____to the nose.

e. The thorax is_____to the abdomen.

f. The thumb is_____to the ring finger.

g. The sternum is_____to the heart.

h. The skull is_____to the scalp.

i. The ears are_____to the nose.

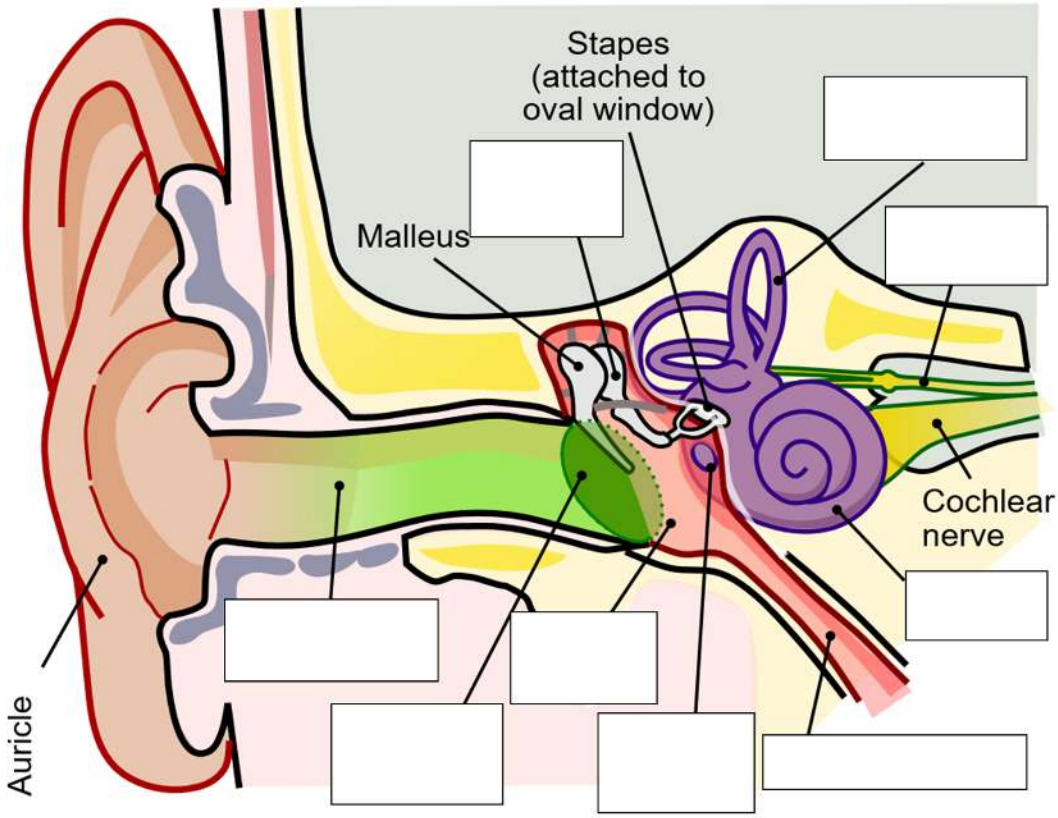
j. Dorsal refers to the_____of the human body, while ventral refers to the _____of the human body.

2. Use the information below to put "incus" in the correct white box on the figure below to label incus, a part of the human auditory system:

a. incus is superior to and lateral to the cochlear nerve

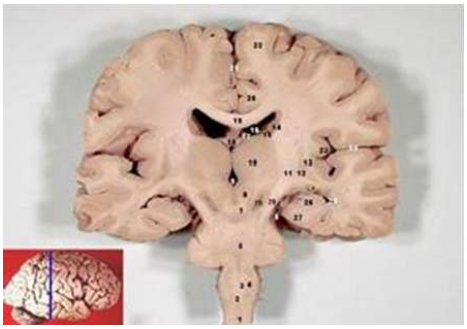
b. incus is medial to malleus

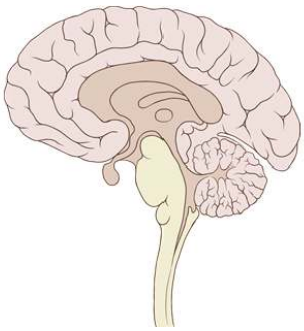
c. incus is lateral to stapes

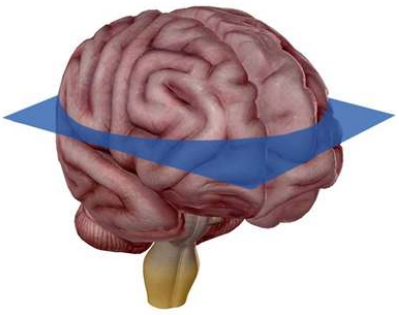


Part 3: Planes and Sections

1. Name the type of section performed in the brain shown. Write your answers on the lines given.







_____ _____ _____

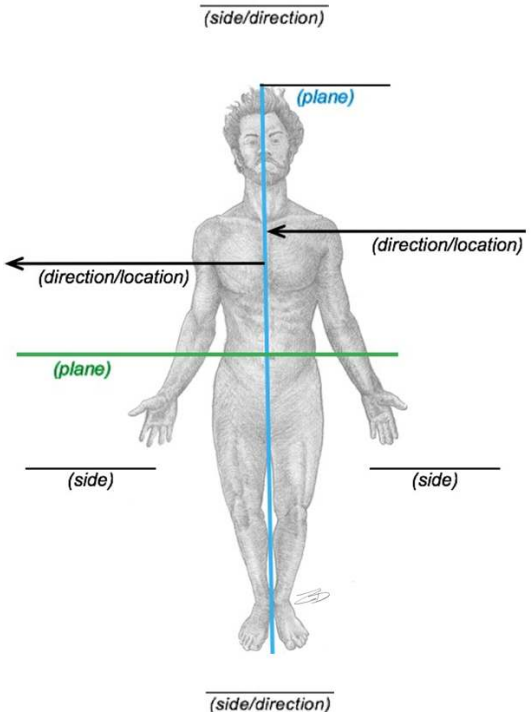
2. Use your knowledge of the different body planes/sections, fill in the blanks with the appropriate body plane for each of the following descriptions.

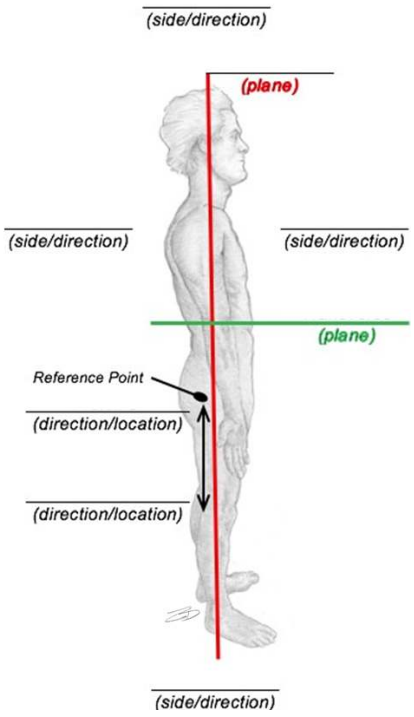
a. The plane that divides the body into anterior and posterior parts is the_____plane.

b. A transverse plane divides the body into _____and_____regions.

c. A_____or_____plane divides the body into right and left parts.

3. Label the two images below with the appropriate anatomical planes and directional terms:





Part 4: Anatomical Adjectives for Body Locations

1. Label the anatomical model of the muscle person below with the anatomical adjectives for body locations in the listed. ***Label BOTH the anterior view and the posterior view with as many of the labels as possible for each view.***

- abdominal
- acromial
- antebrachial
- antecubital
- axillary
- brachial
- buccal
- calcaneal
- carpal
- cephalic
- cervical
- clavicular
- coxal
- cranial
- crural
- ubital
- dorsal
- digital
- facial
- femoral
- frontal
- genital
- glossal
- gluteal
- hallux
- inguinal
- lumbar
- mammary
- manual
- mental
- nasal
- ocular
- olecranal
- oral
- orbital
- otic
- palmar
- palmar
- patellar
- pectoral
- pedal
- pelvic
- perineal
- pollex
- popliteal
- pubic
- sacral
- scapular
- sternal
- sural
- tarsal
- thoracic
- trunk
- umbilical
- vertebral

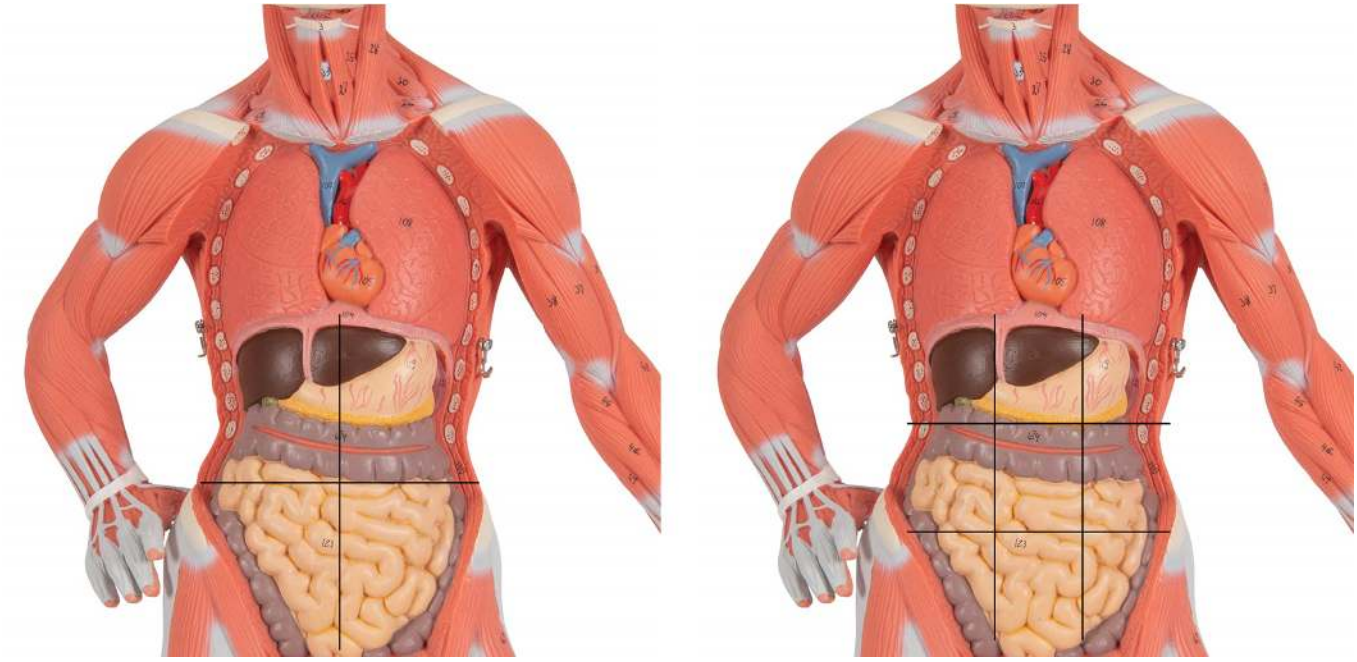


https://bio.libretexts.org/@go/page/53515



Part 5: Abdominopelvic Regions and Abdominopelvic Quadrants

1. Label the four abdominopelvic quadrants and the nine abdominopelvic regions on the anatomical models below as appropriate.



Part 6: Body Cavities and Serosa

1. Fill in the blank with the appropriate body cavity:

   a. The two main body cavities are the_____and the_____cavities.

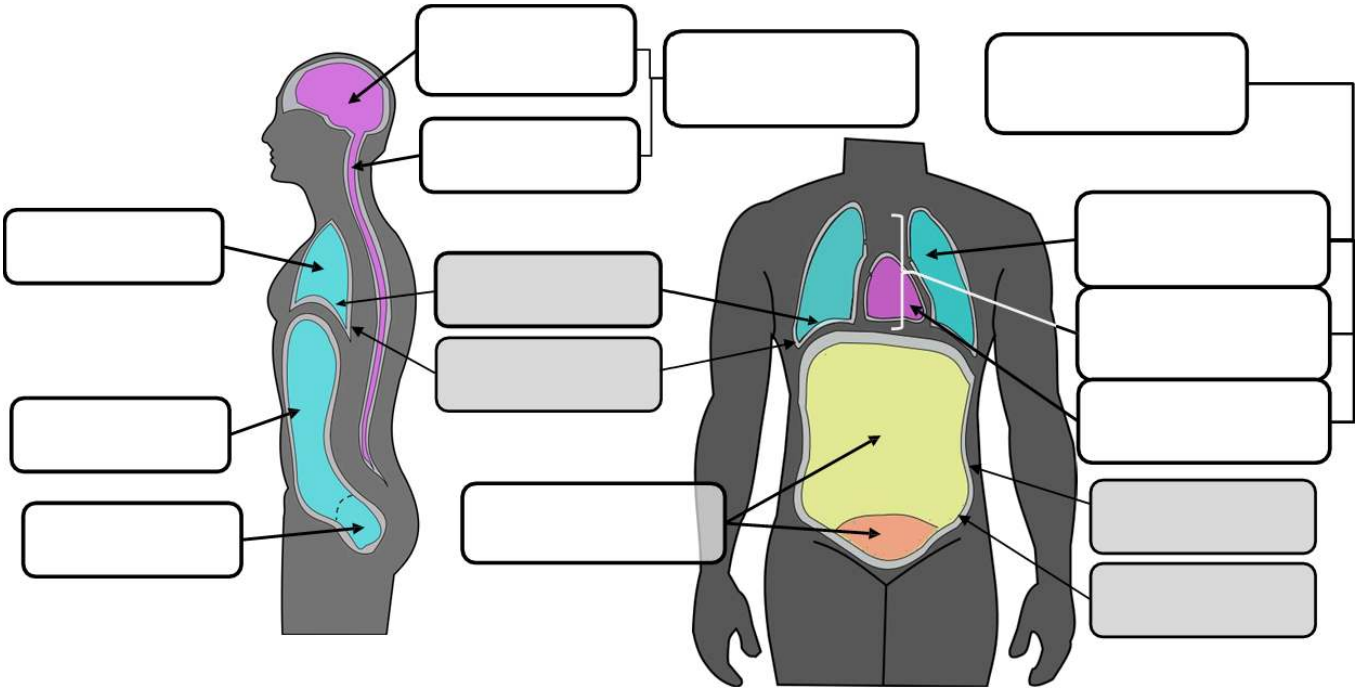
   b. The stomach is found in the_____cavity.

   c. The heart is found in the_____cavity, which is part of the larger_____cavity.

   d. The brain is found within the_____cavity which is part of the larger_____cavity

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

2. Fill in each box in the figure below with either the cavity shown (white boxes) or the name of the serous membrane (gray boxes).



Attributions

Part 2: Anatomical Position & Directional Terms

- "Anatomy of the Human Ear" by Lars Chittka; Axel Brockmann, Wikipedia Commons is licensed under CC BY-SA 4.0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0

Part 3: Planes & Sections

- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0

Part 4: Anatomical Adjectives for Body Locations

- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0

Part 5: Abdominopelvic Regions & Abdominopelvic Quadrants

- Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0

Part 6: Body Cavities & Serosa

- "Anatomy and Physiology Lab Homework" by Laird C Sheldahl is licensed under CC BY-SA 4.0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0

Updated 2025.

This page titled 1.10: Laboratory Activities and Assignment is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

1.11: Collaborative Study Activities

Collaborative Study Activities

This section contains collaborative laboratory activities intended for laboratory class on these topics. These activities are designed for students to use their laboratory class time to grasp the terms and anatomy and to work in groups to "test" each other, thereby beginning to study their anatomy while still in the classroom.

All of these activities are designed for student groups of two, but groups of 3-4 may also be used especially if a supplemental instructor is unavailable to assist the instructor to test groups on each section.

Part 1: Anatomical Position

1. ***Fully*** describe anatomical position in your own words:

2. **Put your body in anatomical position. Partners correct ANY differences between your partner's anatomical position and the correct anatomical position.**

3. A person is sitting in a chair with their legs crossed at the ankle. This person has their hands on a desk in front of them. They are sitting relaxed in the chair with their head turned to one side looking out the window or at a poster or sign on the wall. What does this person need to do to assume anatomical position? **Be specific.**

Important: All directional terms are in reference to anatomical position. This means, regardless of a person's actual position, directional terms are based on if that person was in anatomical position.

Part 2: Directional Terms

1. Discuss and describe the following body orientation/directional terms in a way that will help you know what they mean:

superior: _____

inferior: _____

cranial: _____

caudal: _____

anterior: _____

posterior: _____

ventral: _____

dorsal: _____

medial: _____

lateral: _____

proximal: _____

distal: _____

superficial: _____

deep: _____

2. Work with a partner. The first person stands roughly in anatomical position and they choose two body parts on the list below and they will either point to them on themselves or say them. The second person will use the directional terms above in a sentence with the two body parts given to them ***to describe the relationship*** between the two body parts. The people will switch roles and the second person will give the person two body parts from the list below. **Continue until both people have used each of the directional terms above *at least once*. Check off the boxes below when you have successfully used a directional term. Keep practicing with these terms until you are BOTH comfortable using all of them.**

• skin • shoulder • neck • ear • eye • belly button • thumb • index finger • elbow • wrist • hip • ribs (bones) • vertebrae (bones)	• nose • mouth • forehead • chin • knee • foot • big toe • little toe • leg (knee to ankle) • thigh (hip to knee) • ankle • heel • tailbone	• butt • back • shoulder blade • collar bone • esophagus • abdomen • right lung • eyebrows • head • sole of foot • cheek • temple • crown of the head

Check off the boxes when you have successfully used the term to describe the relationship between two anatomical structures.

☐ superior ☐ inferior ☐ cranial ☐ caudal ☐ anterior	☐ posterior ☐ ventral ☐ dorsal ☐ medial ☐ lateral	☐ proximal ☐ distal ☐ superficial ☐ deep

When you and your partner are comfortable using the terms above, request the assistance of your Instructor. They will test you on your use of these terms and initial ONLY when you are successful using these terms. Instructor: _____

Part 3: Planes/Sections

1. Describe the following body plane terms in a way that will help you know what they mean:

frontal (coronal) section/plane: _____

transverse (cross) section/plane: _____

sagittal: _____

midsagittal (median) section/plane: _____

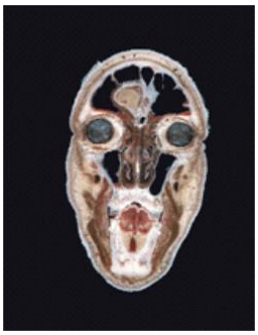
parasagittal section/plane: _____

oblique section/plane: _____

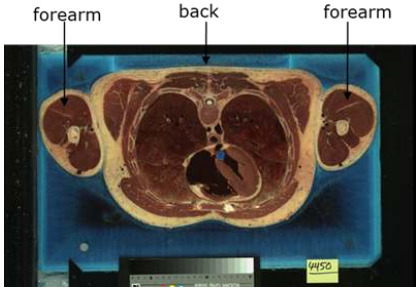
2. Discuss the images below and determine the section/plane of each image shown. Write the name(s) of each type of section on the lines below each image:



_____



_____



_____

https://bio.libretexts.org/@go/page/53522

Part 4: Anatomical Adjectives of Body Locations

1. Point to each body location corresponding with each anatomical adjective listed below on yourself and say the word out loud. Work out the pronunciations with your partner, the internet, and your instructor. Check off each word when you have done this for each.

☐ abdominal	☐ femoral	☐ palmar
☐ acromial	☐ frontal	☐ patellar
☐ antebrachial	☐ genital	☐ pectoral
☐ antecubital	☐ glossal	☐ pedal
☐ axillary	☐ gluteal	☐ pelvic
☐ brachial	☐ hallux	☐ perineal
☐ buccal	☐ inguinal	☐ pollex
☐ calcaneal	☐ lumbar	☐ popliteal
☐ carpal	☐ mammary	☐ pubic
☐ cephalic	☐ manual	☐ sacral
☐ cervical	☐ mental	☐ scapular
☐ clavicular	☐ nasal	☐ sternal
☐ coxal	☐ ocular	☐ sural
☐ cranial	☐ olecranal	☐ tarsal
☐ crural	☐ oral	☐ thoracic
☐ cubital	☐ orbital	☐ trunk
☐ dorsal	☐ otic	☐ umbilical
☐ digital	☐ palmar	☐ vertebral
☐ facial		

2. Work with a partner. Point to each anterior body landmark on yourself or an anatomical model and wait for your partner to say the correct anterior body landmark term. Check off each word below when your partner has successfully used each term. Your partner will do the same for you.

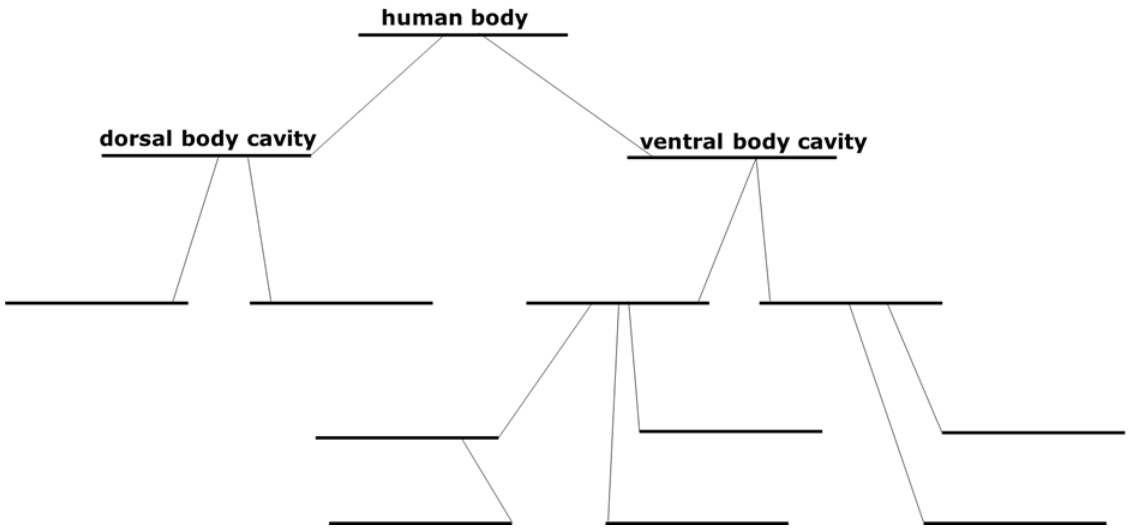
☐ abdominal	☐ femoral	☐ palmar
☐ acromial	☐ frontal	☐ patellar
☐ antebrachial	☐ genital	☐ pectoral
☐ antecubital	☐ glossal	☐ pedal
☐ axillary	☐ gluteal	☐ pelvic
☐ brachial	☐ hallux	☐ perineal
☐ buccal	☐ inguinal	☐ pollex
☐ calcaneal	☐ lumbar	☐ popliteal
☐ carpal	☐ mammary	☐ pubic
☐ cephalic	☐ manual	☐ sacral
☐ cervical	☐ mental	☐ scapular
☐ clavicular	☐ nasal	☐ sternal
☐ coxal	☐ ocular	☐ sural
☐ cranial	☐ olecranal	☐ tarsal
☐ crural	☐ oral	☐ thoracic
☐ cubital	☐ orbital	☐ trunk
☐ dorsal	☐ otic	☐ umbilical
☐ digital	☐ palmar	☐ vertebral
☐ facial		

When you and your partner are comfortable using the terms above, request the assistance of your Instructor. They will test you on your use of these terms and initial ONLY when you are successful using these terms. Instructor: _____

Part 5: Body Cavities

1. The tree below, once filled in, will show how body cavities are divided and subdivided. Use the figure and text above to help you complete the tree. Fill in the tree with the following:

• mediastinum • pelvic cavity • vertebral cavity • thoracic cavity	• cranial cavity • right pleural cavity • left pleural cavity	• abdominopelvic cavity • pericardial cavity • abdominal cavity



When you and your partner have completed the tree above, request the assistance of your Instructor. They will review your tree to make sure it is correct. Instructor: _____

2. Bring a torso model over to you and your partner. Identify the following body cavities on the torso model and check them off the list once you have identified them.

☐ ventral body cavity ☐ dorsal body cavity ☐ thoracic cavity ☐ abdominopelvic cavity ☐ vertebral cavity	☐ mediastinum ☐ pericardial cavity ☐ left pleural cavity ☐ right pleural cavity	☐ thoracic cavity ☐ pelvic cavity ☐ abdominal cavity ☐ cranial cavity

3. Test your partner by asking them to name each body cavity you point to. Check off each when your partner successfully names each. Your partner will also test you.

☐ ventral body cavity ☐ dorsal body cavity ☐ thoracic cavity ☐ abdominopelvic cavity ☐ vertebral cavity	☐ mediastinum ☐ pericardial cavity ☐ left pleural cavity ☐ right pleural cavity	☐ thoracic cavity ☐ pelvic cavity ☐ abdominal cavity ☐ cranial cavity

When you and your partner are comfortable using the terms above, request the assistance of your Instructor. They will test you on your use of these terms and initial ONLY when you are successful using these terms. Instructor: _____

Part 6: Nine Abdominopelvic Regions and Four Abdominopelvic Quadrants

1. Using a torso model identify each of the nine abdominal regions and check off the boxes below when you have identified them.

☐ right hypochondriac region ☐ left hypochondriac region ☐ epigastric region	☐ right lumbar region ☐ left lumbar region ☐ umbilical region	☐ right iliac region ☐ left iliac region ☐ hypogastric region

2. Test your partner by pointing to each abdominal region on the torso model and have your partner name each region. When your partner correctly names each region, check off the box below. Your partner will also test you.

☐ right hypochondriac region ☐ left hypochondriac region ☐ epigastric region	☐ right lumbar region ☐ left lumbar region ☐ umbilical region	☐ right iliac region ☐ left iliac region ☐ hypogastric region

3. Using a torso model identify each of the four abdominal quadrants and check off the boxes below when you have identified them.

☐ right upper quadrant ☐ right lower quadrant	☐ left upper quadrant	☐ left lower quadrant

4. Test your partner by pointing to each abdominal quadrant on the torso model and have your partner name each quadrant. When your partner correctly names each quadrant, check off the box below. Your partner will also test you.

☐ right upper quadrant ☐ right lower quadrant	☐ left upper quadrant	☐ left lower quadrant

When you and your partner are comfortable using the terms above, request the assistance of your Instructor. They will test you on your use of these terms and initial ONLY when you are successful using these terms. Instructor: _____

Part 7: Serosa (Serous Membranes)

For each of the serous membranes listed below, fill out the table to indicate the body cavity where each is found and if the membrane is in contact with the organ or the cavity wall.

Serous membranes (serosa)	Name the Body Cavity	This Serous Membrane Lines… (organ or body cavity)
visceral pericardium		
parietal pericardium		
visceral pleura		
parietal pleura		
visceral peritoneum		
parietal peritoneum		

Attribution

Part 3: Planes/Sections

- "Anatomy and Physiology Lab Reference" by Laird C Sheldahl, OpenOregonEducational Resources, Mt. Hood Community College is licensed under CC BY-SA 4.0

Updated 2025.

This page titled 1.11: Collaborative Study Activities is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

CHAPTER OVERVIEW

2: Introduction to Microscopes

2.1: Introduction
2.2: Introduction to the Metric System
2.3: Light Microscopy (LM)
2.4: Electron Microscopy (EM)
2.5: Use of Compound Light Microscopes for Anatomy Laboratories
2.6: Laboratory Activities and Assignment

This page titled 2: Introduction to Microscopes is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

2.1: Introduction

Introduction

Many important anatomical features, especially those that function at the tissue or cellular levels, are too small to be seen by the unaided eye. Cells vary in size. With few exceptions, individual cells cannot be seen with the naked eye, so scientists use **microscopes** (micro- = “small”; -scope = “to look at”) to study them. A microscope is an instrument that magnifies an object. Microscopes are valuable tools for magnifying small sections (cuts/slices - see Planes/Sections in Chapter 1) of biological material so that otherwise inaccessible details can be resolved (distinguished). Most photographs of cells are taken with a microscope, and these images can also be called **micrographs**.

The optics of microscope lenses changes the orientation (direction) of the image that the user sees. A specimen that is right-side up and facing right on the microscope slide will appear upside-down and facing left when viewed through a microscope, and vice versa. Similarly, if the slide is moved left while looking through the microscope, it will appear to move right, and if moved down, it will seem to move up. This occurs because microscopes use two sets of lenses to magnify the image. Because of the manner by which light travels through the lenses, this system of two lenses produces an inverted image.

Attributions

- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- "Biology 2e" by Mary Ann Clark, Matthew Douglas, Jung Choi, OpenStax is licensed under CC BY-NC 4.

Updated 2025.

This page titled 2.1: Introduction is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

2.2: Introduction to the Metric System

Introduction to the Metric System

Scientific measurements use the **metric system** - a system of measurement used worldwide that is very user-friendly since the units of measurement differ by magnitudes of 10. Since microscopes are concerned with the size (length) of structures and the magnification of these structures, we will consider the metric system as it relates to length. The base unit of length in the metric system is the **meter** (abbreviated as **m**). One meter is about 3.3 feet long. For units that are larger or smaller than meters, a prefix is added to the beginning of "meter" to indicate the magnitude of difference from the meter unit (base unit):

Prefix Name	Prefix Symbol	Size in relationship to the base unit (base unit =1)
kilo-	k	1,000
hecto-	h	100
deca-	da	10
base unit	none	1
deci-	d	0.1
centi-	c	0.01
milli-	m	0.001
micro-	µ	0.000001
nano-	n	0.000000001
pico-	p	0.000000000001

Using the table above that distinguishes units by prefix, to convert unit measurements back to the base unit, ***simply multiply the number you are converting with the number in the "size relationship to the base unit" column***. For example:

Using your microscope you measure a cell as 20 µm ("twenty micrometers"). To convert 20 µm to meters, multiply 20 µm by 0.000001:

$$20\ \mu m \times 0.000001 = 0.00002\ m$$

You measure the distance it takes you to get home from school as 19 km ("nineteen kilometers"). To convert 19 km to meters, multiply 19 km by 1,000:

$$19\ km \times 1{,}000 = 19{,}000\ m$$

Using the table above that distinguishes units by prefix, to convert the base unit to another unit, ***simply divide the number you are converting with the number in the "size relationship to the base unit" column***. For example:

You are told that a certain very large cell is 0.0003 m long. To convert 0.0003 m to micrometers (µm), divide 0.0003 m by 0.000001:

$$0.0003\ m \div 0.000001 = 300\ \mu m$$

You read that running a marathon means running 42,000 m. To convert 42,000 m to kilometers (km), divide 42,000 m by 1,000:

$$42{,}000\ m \div 1{,}000 = 42\ km$$

Cells are typically measured using the micrometer (µm) unit, but some subcellular structures may be reported in nanometers (nm) or even picometer (pm) measurements. To give you a sense of cell size, a typical human red blood cell is about eight millionths of a **meter** or eight **micrometers** (abbreviated as 8 µm) in diameter; the head of a pin of is about two thousandths of a meter (two mm) in diameter. That means about 250 red blood cells could fit on the head of a pin!

Check out this slider tool to get a sense of how big cells and cellular structures are in comparison to some familiar objects: Slider tool to see cell size

Attribution

- "Biology 2e" by Mary Ann Clark, Matthew Douglas, Jung Choi, OpenStax is licensed under CC BY-NC 4.0

Updated 2025.

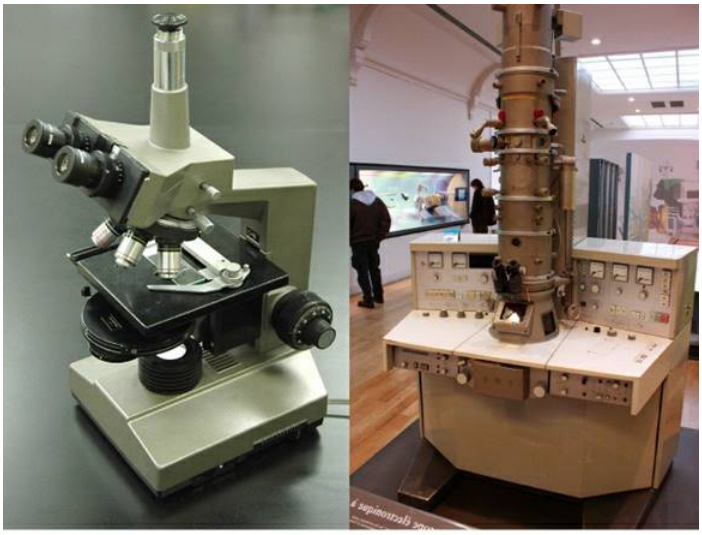
This page titled 2.2: Introduction to the Metric System is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

2.3: Light Microscopy (LM)

Light Microscopy (LM)

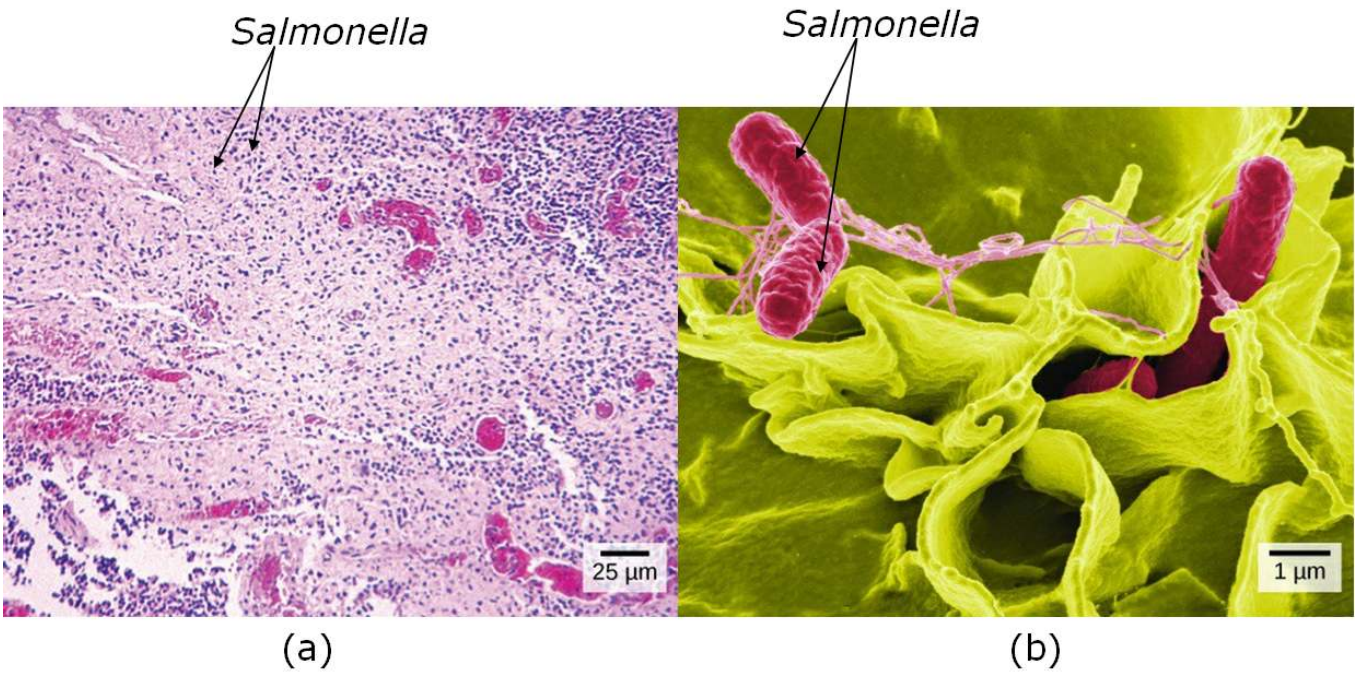
Most microscopes used in college biology laboratories are classified as **light microscopes** (see the figure, part (a) below) and may also be called **compound microscopes** since they use two lenses whose magnifications compound (multiply). Visible light passes through the specimen and is bent through the lens system to enable the user to see the specimen. Light microscopes are advantageous for viewing living organisms, but since individual cells are generally transparent, their components are not distinguishable unless they are colored with special **stains** (colored chemicals that makes cells appear to have color such as pink, blue, or purple). Because of this, when viewing a prepared slide, the specimens are usually colored (pink, purple, blue, black, green, etc.) Staining, however, usually kills the cells.

Light microscopes commonly used college classroom laboratories are used to magnify specimens up 400 times (400x), but oil immersion lenses can also be used with these microscopes for magnification of 1,000 times (1000x) to view very small structures or very small cells such as bacteria. Two parameters that are important in microscopy are **magnification** and **resolving power**. Magnification is the process of enlarging an object in appearance. Resolving power is the ability of a microscope to distinguish two adjacent structures as separate: the higher the resolution, the better the clarity and detail of the image. Due to the magnification limits of light microscopes, in order to gain a better understanding of cellular structure and function, scientists typically use **electron microscopes** (see image (b) in the figures below) that use electrons (subatomic particles) to carry images instead of light. To see the difference in magnification and detail possible when comparing light microscopes and electron microscopes, compare the images of *Salmonella* (a type of bacteria) in the figure below.



(a) (b)

Above: (a) Most light microscopes used in a college biology labs can magnify cells up to approximately 1000 times (1000x) and have a resolution of about 200 nanometers. (b) Electron microscopes provide a much higher magnification, 100,000x, and a have a resolution of 50 picometers.



Above: (a) These *Salmonella* bacteria appear as tiny purple dots when viewed with a light microscope. (b) This scanning electron microscope micrograph shows *Salmonella* bacteria (in red) invading human cells (yellow). Comparing *Salmonella* bacteria when using a light microscope (a), and *Salmonella* bacteria when using an electron microscope (b), observe the comparative increase in magnification with electron microscopy, the higher level of detail in electron microscopy, and the differences in appearance between light and electron microscopy.

Attribution

- "Biology 2e" by Mary Ann Clark, Matthew Douglas, Jung Choi, OpenStax is licensed under CC BY-NC 4.0

Updated 2025.

This page titled 2.3: Light Microscopy (LM) is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

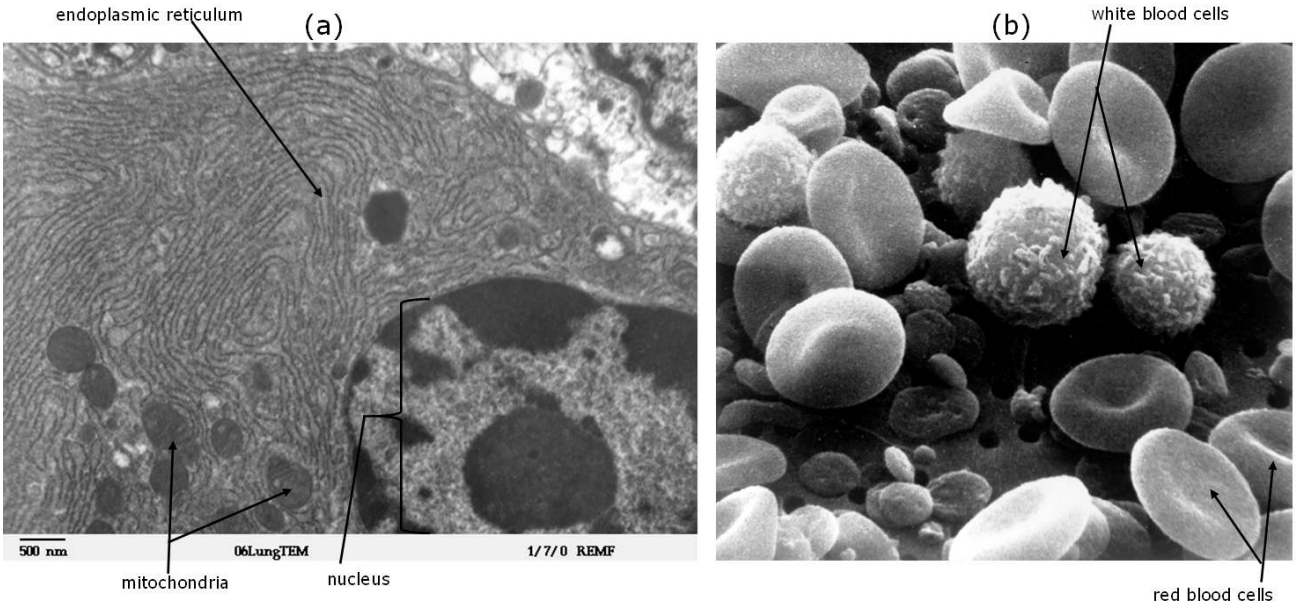
2.4: Electron Microscopy (EM)

Electron Microscopes (EM)

In contrast to light microscopes, **electron microscopes** (see the figure, part (b) on the previous page) use a beam of electrons instead of a beam of light. Not only does this allow for higher magnification and, thus, more detail, it also provides higher resolving power. The method used to prepare the specimen for viewing with an electron microscope kills the specimen. Electrons have short wavelengths (shorter than photons of light) that move best in a vacuum, so living cells cannot be viewed with an electron microscope.

The best type of EM to examine a cell's internal structures such as vesicles, storage granules, ribosomes, mitochondria, and nuclei is **transmission electron microscopy** (**TEM**) since it is designed to allow electrons to pass through a thin sample. Samples must be prepared for TEM by embedding the sample, such as a cell, in a tiny plastic block, and using either a glass knife or a diamond knife to thin-section the sample using a **microtome** (laboratory equipment that makes thin sections). As a result, thin slices of cells can be observed with TEM, exposing intracellular details. An example of a thin-sectioned skin cell magnified by TEM is shown in the figure, part (a) below.

Another common type of EM is **scanning electron microscopy** (**SEM**). SEM works much differently than TEM since SEM radiates electrons onto a sample's ***surface*** and these electrons are reflected back by the sample to elucidate the surface details of the sample. As a result, SEM is an excellent technique for examining the three-dimensional surface of an un-sectioned specimen and viewing only the external surfaces of cells and tissues. An example of an SEM image of skin cells with yeast infecting them is shown in the figure, part (b), below.



Above: (a) A lung cell that has been thin-sliced and **imaged with TEM**. Thin-slicing a cell with TEM exposes the internal structures such as the nucleus and mitochondria. (b) Exterior of blood cells **imaged with SEM**. SEM images only allow surface visualizations of cells and tissues.

Attributions

- "Biology 2e" by Mary Ann Clark, Matthew Douglas, Jung Choi, OpenStax is licensed under CC BY-NC 4.0
- "Clara cell lung - TEM" by Louisa Howard is in the Public Domain
- "SEM blood cells" by Bruce Wetzel, Harry Schaefer is in the Public Domain

Updated 2025.

This page titled 2.4: Electron Microscopy (EM) is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

2.5: Use of Compound Light Microscopes for Anatomy Laboratories

Use of the Compound Light Microscope for Anatomy Laboratories

Learning microscopy is necessary in human anatomy to 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.

Transport of a Compound Light Microscope

To take the microscope out of the cabinet or off of the cart use the following instructions:

1. Use your dominant hand to hold the arm of the microscope, and your non-dominant hand to hold the base of the microscope.
2. Carry the microscope upright. That way the ocular lenses located in the eyepiece do not fall out.
3. Make sure the electrical cord is wrapped or removed from the microscope, avoid tripping on the cord.

To return the microscope to the cabinet or to the cart use the following instructions:

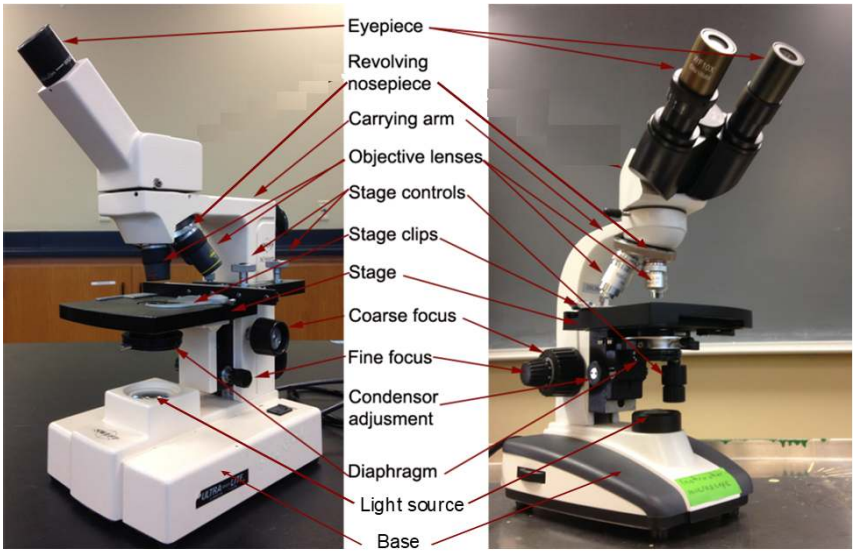
1. Turn off the microscope.
2. Turn the revolving nosepiece to have lowest magnification objective, usually 4X.
3. Disconnect from power source.
4. Wrap cord around the microscope.
5. If you used oil immersion, (the 100x objective), ***use lens paper only*** to remove any remnant of immersion oil on the 100x objective lens.
6. Place the microscope back in the cabinet or on the cart using the transport instructions above.

Focusing Procedure for a Compound Light Microscope

1. Place the microscope on a table in front of you and plug it in such that the cord does not create a trip hazard for you or others in the laboratory.
2. Turn the revolving nosepiece to have lowest magnification objective in place, usually 4x. The objective should click when properly in place.
3. Place the slide on the stage of the microscope and properly position the stage clips such that the clips "hug" the slide on either side and are NOT on top of the slide since this could crack the slide (NOTE: there are some models of microscopes where stage clips DO sit on top of the slide - ask your instructor about proper use of the stage clips for the model of microscope you are using).
4. Turn on the microscope and confirm that the light is on.
5. Move the stage control knobs to position the specimen on the slide directly over the path of the light.
6. ***With the 4x objective in place***, turn the coarse focus knob to bring the stage as close to the objective lens as possible.
7. Look through the microscope and use the coarse focus knob to focus on the sample. Make sure the slide is in very sharp focus before moving on. Check with your instructor if you are uncertain.
8. To focus on the specimen using higher magnification than 40x (use of the 4x objective magnifies the specimen by 40x), use the next steps:
9. With the specimen focused at 40x, re-center the specimen using the stage adjustment knobs. DO NOT CHANGE THE FOCUS!
10. Change to the next highest objective lens ***without changing any other settings on the microscope***.
11. Use ONLY the ***fine focus*** knob to modify the focus. The specimen should mostly be in focus and only minor adjustments should be necessary. Continue focusing until the image is sharp and clear.
12. Re-center the specimen using the stage adjustment knobs. DO NOT CHANGE THE FOCUS!
13. If moving to the next highest objective lens, change to the objective lens to the next highest ***without changing any other settings on the microscope***.
14. Use ONLY the fine ***focus knob*** to adjust the focus. Continue focusing until the image is sharp and clear.

If you get lost on your sample, go back to 40x magnification (objective says '4x'), re-focus, and follow the steps above again.

Parts of the Compound Light Microscope



Above: Parts of compound light microscopes. Some models are slightly different. Here, two different models are shown and labeled to indicate the parts of each.

Description and Function of the Parts of the Microscope

Microscope Part	Description and Function of Microscope Part
eyepiece	removable, holds o**cular 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
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
stage controls	moves the slide held by stage clips around the stage to position the specimen in the desired position
mechanical stage	holds the slide in place (with clamp), can be moved using the adjusting knobs
iris-diaphragm	located beneath the condenser, regulate the amount of light by opening or closing its aperture
light source	a light source, usually a bulb built in the base of the microscope - there may be a dial to regulate the intensity of light depending on the model of microscope
condenser	located below the stage, contains a lens that condense 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
head	upper part, contains the ocular lenses and the rotating nosepiece with the objective lenses
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

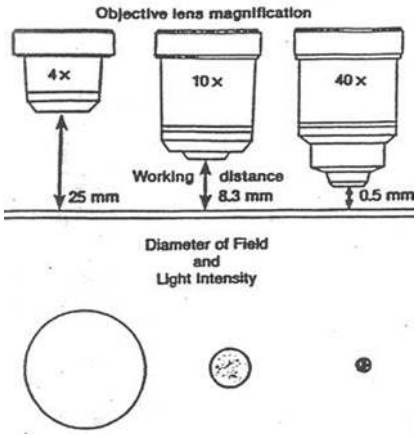
Calculating Magnification

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

Total Magnification = Ocular Magnification x Objective Magnification

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 below).



Above: Relationship between the objective lens magnification, working distance, and diameter of the field of view and light intensity.

Attributions

- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0

Updated 2025.

This page titled 2.5: Use of Compound Light Microscopes for Anatomy Laboratories is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

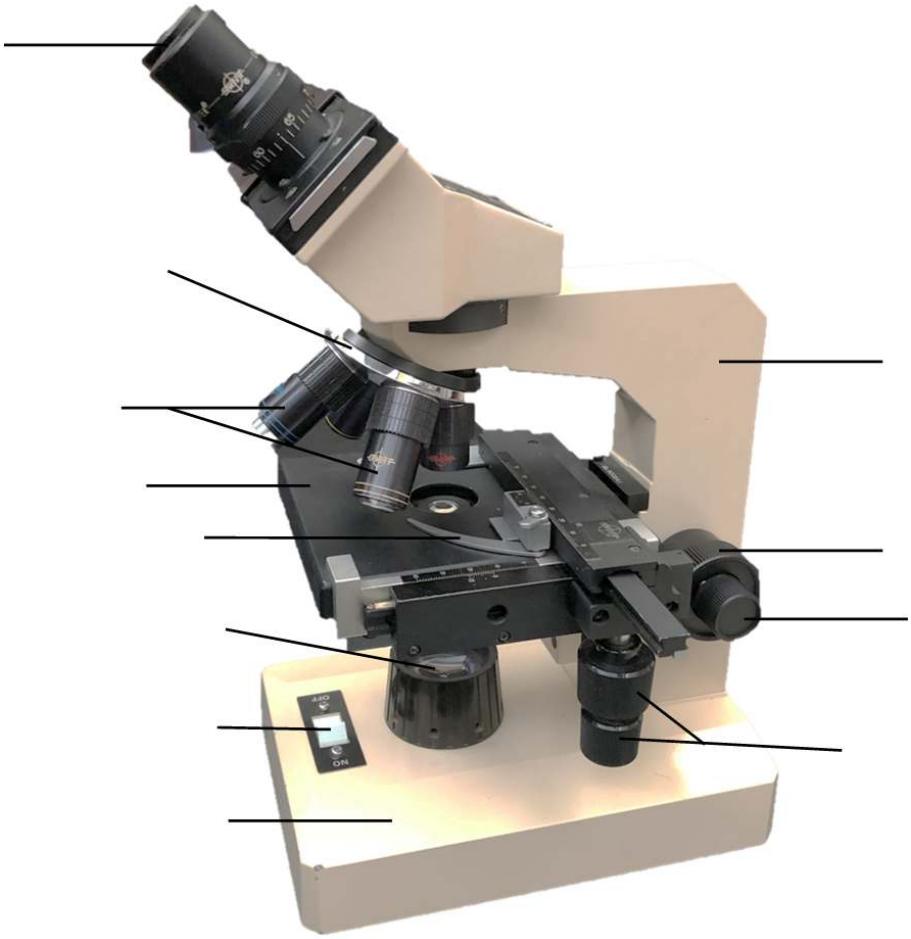
2.6: Laboratory Activities and Assignment

Laboratory Activities and Assignment

Part 1: Getting to Know the Microscope

1. Label the parts of the compound microscope below using the terms listed.

• light source • arm • fine focus (adjustment) knob • eyepiece (ocular)	• nosepiece • slide clip • base • power switch	• objective lenses • coarse focus (adjustment) knob • stage controls • stage



2. Match the names of the microscope parts with their descriptions:

___ coarse adjustment knob	A. Increases the light intensity
___ arm	B. Platform that supports the microscope slide
___ condenser	C. Concentrates light onto the specimen
___ eyepiece (ocular)	D. Shines through the specimen to carry the specimen image to the viewer
___ iris/diaphragm	E. Causes the stage to move upward or downward at a fast rate and is used to focus on a specimen
___ nosepiece	F. After the light passes through the specimen, it next enters this lens system
___ objective lens	G. Causes the stage to move upward or downward at a slow rate and is used to focus on a specimen
___ stage	H. Holds a microscope slide in position
___ light source	I. Contain a lens at the top of it
___ stage clip	J. Serves as a handle to carry the microscope
___ fine adjustment knob	K. Part of which the objective lenses are attached

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

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

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

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

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

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

9. Still looking down at the hole in the center of the stage, what happens when you slide the diaphragm lever counterclockwise?

Part 2: Magnifications of the Microscope

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

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

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

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

4. Write down the total magnification (ocular lens magnification x objective lens magnification) when using each objective on the microscope in front of you.

- Total magnification - objective one:
- Total magnification - objective two:
- Total magnification - objective three:
- Total magnification - objective four:

Magnified images in textbooks, activities, and assignments always refer to the ***TOTAL magnification*. To determine the objective lens you will need to use when given instructions in future labs, multiply the magnification written on each objective by the magnification of the ocular lens to determine the total magnification.**

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

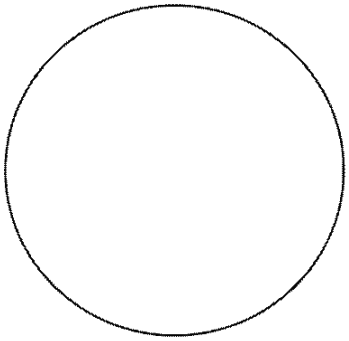
Part 3: Comparing the Real Image (Naked Eye) with the Magnified Virtual Image

1. Get an “e” slide. If it is already under your microscope, rotate the lowest-power objective into place, use the coarse focus to lower the stage, and remove the slide.

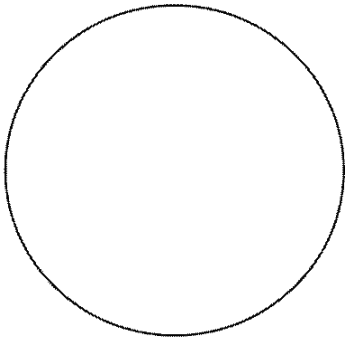
2. Look at the unmagnified “e” on the slide by eye. Rotate the slide around in your hand so that the “e” is right side up. Now clip the slide onto the microscope stage with the stage clips so that the “e” is facing you right side up when you look at it with your unaided eye.

3. In the right-hand circle below, draw what the “e” looks like when you are looking at it right side up with the unaided eye. Assume the circle below is the size of the entire coverslip. Draw the “e” you see unaided in the correct proportion to the coverslip. (The unmagnified “e” will take up a tiny portion of the coverslip area.)

magnified "e" "e" with the unaided eye



Total magnification: _____



Total magnification: _____

4. Position the slide into slide clips on your microscope stage so that the “e” is still facing you right side up. Get the “e” into your field of view and in focus.

5. In the left-hand circle above, draw what the “e” looks like when viewing it through the microscope under the lowest-power objective. Under the circle, write the total magnification of the image.

6. When viewed under a microscope, how is a specimen rotated?

7. Look at the stage and slide directly (not through the eyepieces). Move the stage control knob that causes the slide to move away from you on the stage, then move it back to its original position.

8. Now move the stage control knob the exact same way you just did, but view the “e” through the eyepiece. When the stage is moving away from you, what direction does the virtual image appear to be moving?

9. Again, look at the stage and slide directly (not through the eyepiece.) This time, move the stage control knob that causes the slide to move to your right, then move it back to its original position.

10.Now move the stage control knob the exact same way you just did, but view the “e” through the eyepiece. When the stage is moving to your right, what direction does the virtual image appear to be moving?

11.The **field of view** is the entire area you can see when looking through an eyepiece. Use the stage control knobs to move the virtual image of your “e” to one side of the field of view. Keep most of the “e” in the field of view, but move it to one side or the other.

12.Now switch to the next-power objective. Do not skip objectives. To get to the next-power objective, and not the highest-power objective, which way did you have to rotate the objectives, clockwise or counterclockwise?

13.Using only the fine focus knob (you do NOT use the coarse focus knob on any objective other than the lowest objective), get the “e” in focus.

14.Move away from the eyepieces and look at the distance between the slide and the bottom of the objective. Rotate back to the lowest power objective. Now rotate to the next objective (do not rotate to the highest-power objective by accident). Now rotate to the third-highest objective. What happens to the distance between the slide and the bottom of the objective as you rotate to higher power objectives?

15.With the third-highest power objective still in place, how much space is there between the slide and the bottom of the objective?

16.Notice there is a danger of smashing the objective lens into the slide if you were to use the coarse focus. Why are you instructed to only use the coarse focus with the lowest- power objective?

Part 4: Making Illustrations of Magnified Specimens

Instructions for Making Illustrations of Magnified Specimens

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

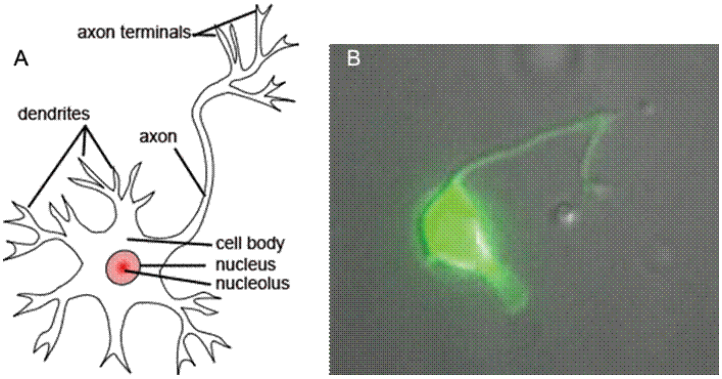
- Only draw what you actually see. Even if you expect to see something, if it is not there you should not draw it. Do not base your drawings on what the textbook or some other source tells you should be there. Do not draw things in the shapes that texts or other sources tell you to expect unless you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

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

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

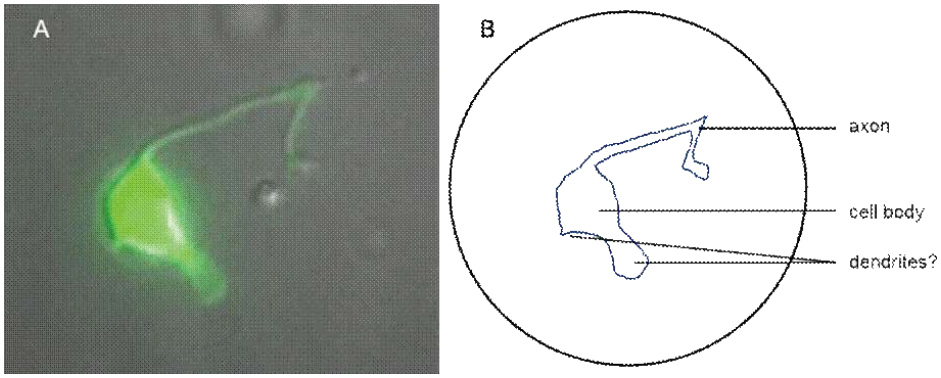
expectations.

For instance, in most textbooks, neurons, the most common cell found in nervous tissue, are drawn to look like variations of the drawing in the figure below:



Above: (A) Textbook illustration of a neuron. (B) Microscopic image of a neuron.

In the typical diagram of a neuron that appears in texts and on websites, there usually is a clear nucleus, and often a nucleolus visible, too. The dendrites are typically short and branched. There almost always is a single, easily-identifiable axon that is longer than all the dendrites and branches as it ends. An actual neuron as viewed through a microscope may look different from a "typical" neuron. In fact, often actual specimens look very little like their textbook counterparts. **Draw what you see, not what you think you are supposed to see.** Just make sure you are looking at what you are supposed to be finding (for instance, a neuron and not a piece of dirt or cell debris), and then draw it as it is.



Above: (A) Textbook illustration of a neuron. (B) Microscopic image of a neuron.

Most students feel they "cannot draw" and are reluctant to sketch what they are seeing under a microscope. Don't let ***what you believe to be*** a lack of artistic skills stop you! Use the following tips:

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

Practice Making Illustrations of Magnified Specimens

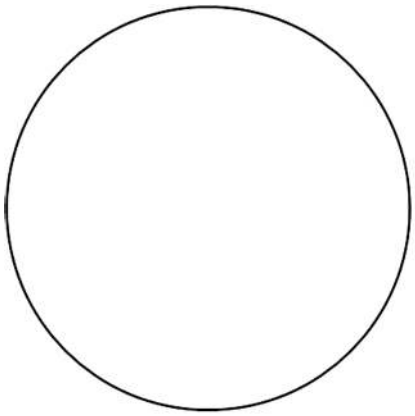
1. Get a human blood smear slide. Rotate your lowest power objective into place on your microscope.

2. Follow the directions for focusing on a sample until you are viewing the blood smear at 400x magnification (using the 40x objective).

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

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

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



Total magnification: _____

Part 5: Approximating the Size of a Magnified Specimen

Measure the Microscopic Fields of View

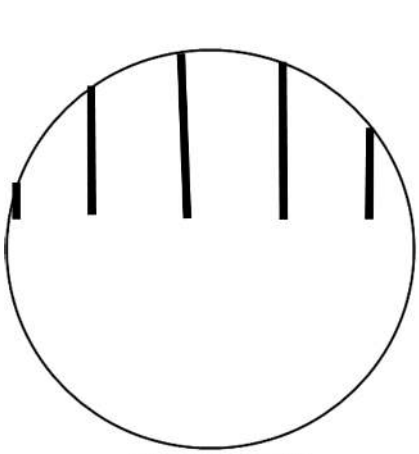
1. Set the TOTAL magnification of the microscope to 40x or the lowest magnification objective.

2. Place a transparent ruler across the stage of the microscope ***on top of the stage clips*** so that the metric side of the ruler is in the light (metric ruler lines can be seen when you look through the oculars).

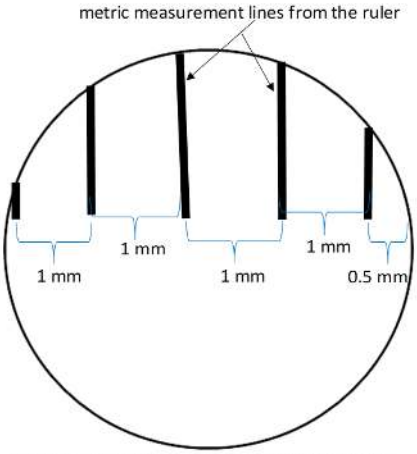
3. Use the course focus knob to focus on the ruler.

4. Count the number of spaces between the lines on the ruler (each space is a millimeter (mm)) to determine the length of the diameter of the field of view of the compound microscope (see figure below). Record this length in the table below.

5. Switch the microscope to the next highest magnification objective (commonly 100x TOTAL magnification) and adjust the focus using the fine focus knob.



Ruler magnified by 40x



How to measure the diameter of the field of view

6. Count the number of spaces between the lines on the ruler to determine the length of the diameter of the field of view of the compound microscope. Record this length in the table below.

7. Move to the next highest magnification (usually 400x total magnification) and adjust the focus using the fine focus knob. Can you see the spaces/lines on the ruler to measure the diameter?

8. Calculate the diameter at the magnification from step 7. The difference between 40x and 400x is a magnitude of 10, so there will be a magnitude of 10 difference between the diameter of the field of view at 40x and 400x. To calculate, the diameter of the field of view at 40x is divided by 10 to determine the field of view diameter at 400x:

field of view at 400x (mm) = field of view at 40x (mm) ÷ 10

9. Convert the field of view diameters from mm to µm and record in the table below.

TOTAL objective magnification	Field of view diameter (mm)	Field of view diameter (µm) There are 1,000 µm in each 1 mm.

10. Describe the relationship between the ***total magnification*** and the ***field of view diameter***. Use your answers from the table above.

Use Field of View Diameters to Approximate Sizes of Microscopic Objects

Imagine the black circle in the figure below is the field of view of the microscope. The blue line across shows the entire diameter of the field of view. There is no actual diameter line in the field of view, nor are there markings that show the percentage of the diameter as shown below - this is where your imagination must come into play to estimate the size of objects in the microscope.

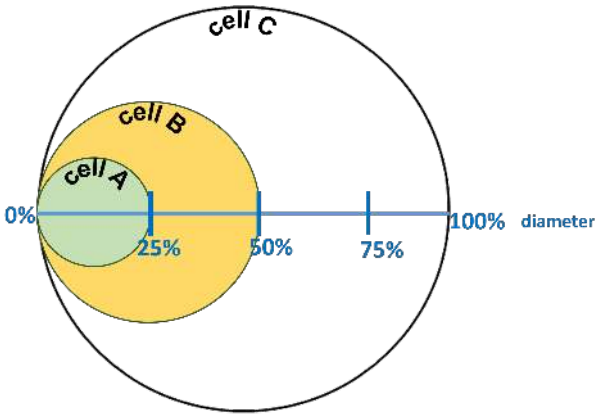
The yellow circle below represents some object magnified by the microscope that you wish to measure. You can see that the yellow circle takes up about 50% of the entire diameter at this magnification. To estimate the size of the yellow circle, use the table above with the diameters of the field of view using the following process:

1. Determine what the total magnification you are viewing the object with and use the table above to determine what the diameter of the field of view is ***at that total magnification***.

2. Estimate the percentage of the diameter of field of view the object you are measuring takes up.

3. Multiply the diameter of the field of view ***at that magnification*** in micrometers (µm) by the percentage you determined in part 2:

estimate of object size (µm) = % of field of view diameter x diameter of the field of view at that mag. (µm)



For example, let's say that the yellow circle is an object magnified by 400x (total magnification). Let's say that in the previous section you calculated the diameter of the field of view at 400x to be 0.5 mm or 500 µm (this value may or may not correspond with your actual measurements and calculations from above - this is for this example only). It is estimated that at 400x, the yellow circle takes up 50% of the diameter of the field of view. The size of the yellow circle is therefore calculated:

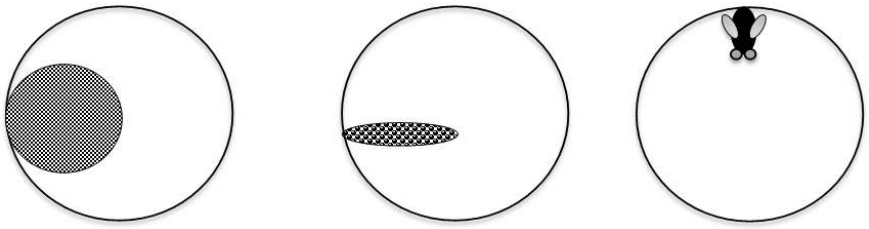
Yellow circle size (µm) = 50% x 500 µm = **250 µm**

Let's do one more example to show how the magnification changes the calculation.

Use the green circle above to represent another object that is viewed using the microscope at a lower magnification (100x). Let's say in the previous section, it was determined that the diameter of the field of view at 100x was 2 mm or 2,000 µm (this value may or may not correspond with your actual measurements and calculations from above - this is for this example only). It is estimated that at 100x, the green circle is 25% of the diameter of the field of view. The size of the green circle is therefore calculated:

Green circle size (µm) = 25% x 2,000 µm = **500 µm**

Use the instructions above to calculate estimated sizes for the objects below at the magnifications given with their corresponding fields of view:



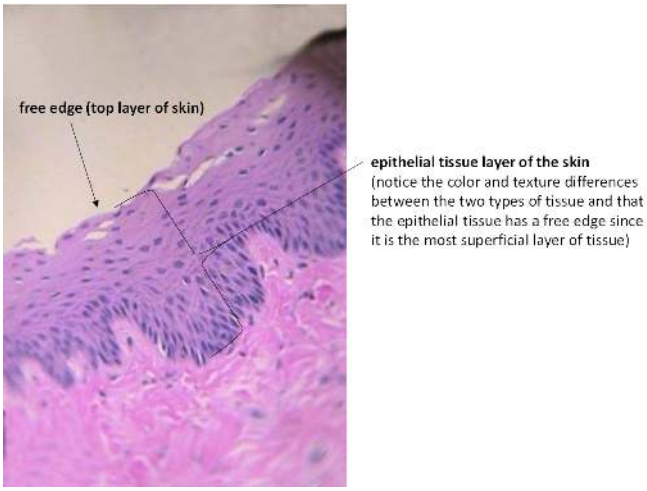
Magnification = 2,000x Diameter of field of view = 100 µm Approximate object size = _____µm	Magnification = 1,500x Diameter of field of view = 300 µm Approximate object size = _____µm	Magnification = 1,500x Diameter of field of view = 300 µm Approximate object size = _____µm

Part 6: Examining, Measuring, & Illustrating Magnified Specimens

Examine, Measure, and Illustration the Epithelial Tissue Layer of the Skin

1. Obtain a slide of skin and focus on the sample using the techniques you learned in this laboratory.

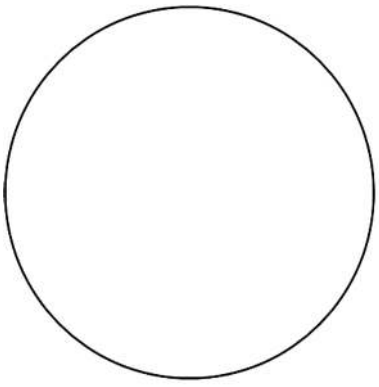
2. Identify the epithelial tissue layer of the skin (see figure below) on the slide.



3. Measure the thickness of the epithelial tissue layer of the skin in micrometers (µm) as you learned to do in the previous section. Write your calculation and put your estimated measurement in the space provided:

Estimated thickness of the epithelial tissue layer of the skin:_____ µm

4. Make an illustration of the sample in the space below and indicate the magnification of your illustration:



Total magnification: _____

Examine, Measure, and Illustrate Cheek Epithelial Cells

1. Make a wet mount of cheek epithelial cells. Watch this video for instructions for making a wet mount of cheek epithelial cells.

    a. Set a new slide on the benchtop.

    b. Put a very small drop of saline (0.85% - 0.9% NaCl) in the center of the slide.

    c. GENTLY scrape the inside of your cheek with a toothpick to obtain cheek epithelial cells.

    d. Swirl the same side of the toothpick that scraped the inside of your cheek in the drop of saline on the slide.

    e. Dispose of the toothpick in a biological waste container or in a container of bleach water.

    f. Place one small drop of methylene blue (stain) on top of the saline/cheek cell solution on the slide.

    g. Place one edge of a cover slip toward the edge of the fluid on the slide at about a 45 degree angle and dip in the fluid.

    h. Release the cover slip onto the fluid on the slide. The fluid should spread out underneath the cover slip.

    i. Use a paper towel or KimWipe at the edge of the cover slip to wick off excess fluid.

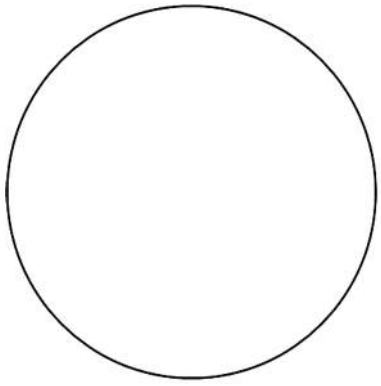
2. Focus on the cheek epithelial cell sample using the techniques you learned in this laboratory.

3. Identify the cheek epithelial cells on the slide. Make sure you are looking at cheek epithelial cells and not other debris on the slide. See the video linked above to examine what cheek epithelial cells should look like.

4. Measure the size of a cheek epithelial cell in micrometers (µm) as you learned to do in the previous section. Write your calculation and put your estimated measurement in the space provided:

    Estimated size of a cheek epithelial cell:_____ µm

5. Make an illustration of the sample in the space below and indicate the magnification of your illustration:



Total magnification: _____

Attributions

Part 1: Getting to Know the Microscope

- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0

Part 2: Magnifications of the Microscope

- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0

Part 3: Comparing the Real Image (Naked Eye) with the Magnified Virtual Image

- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0

Part 4: Making Illustrations of Magnified Specimens

- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0

Part 6: Examining, Measuring, & Illustrating Magnified Specimens

- "Anatomy and Physiology Lab Reference" by Laird C Sheldahl, OpenOregonEducational Resources, Mt. Hood Community College is licensed under CC BY-SA 4.0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0

Updated 2025.

This page titled 2.6: Laboratory Activities and Assignment is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

CHAPTER OVERVIEW

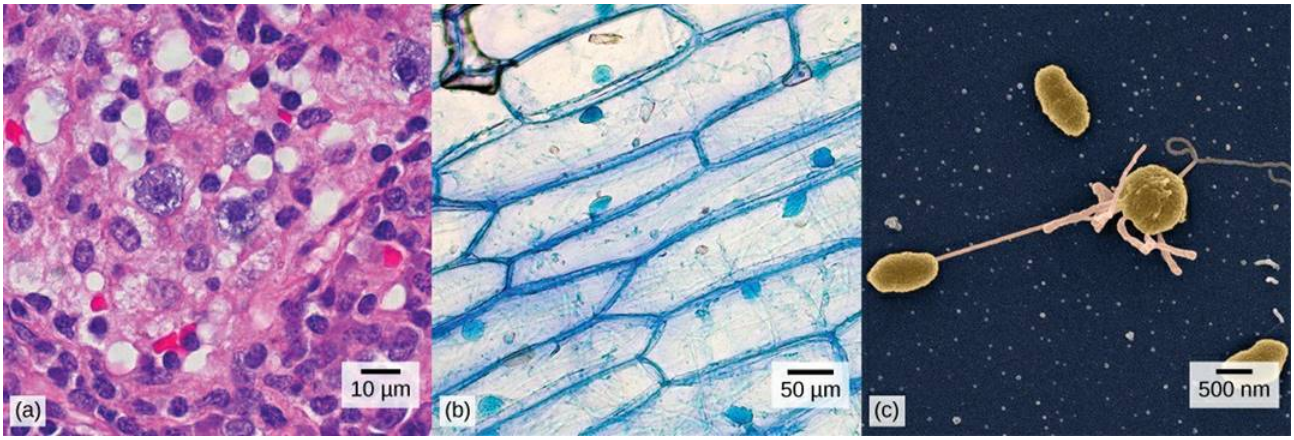
3: Cell Structure and Cell Types

3.1: Introduction
3.2: Subcellular Structures
3.3: Cell-to-Cell Junctions Hold Cells Together In Tissues
3.4: Cell Structure Varies by Cell Type
3.5: Laboratory Activities and Assignment
3.6: Collaborative Study Activity

This page titled 3: Cell Structure and Cell Types is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

3.1: Introduction

Introduction



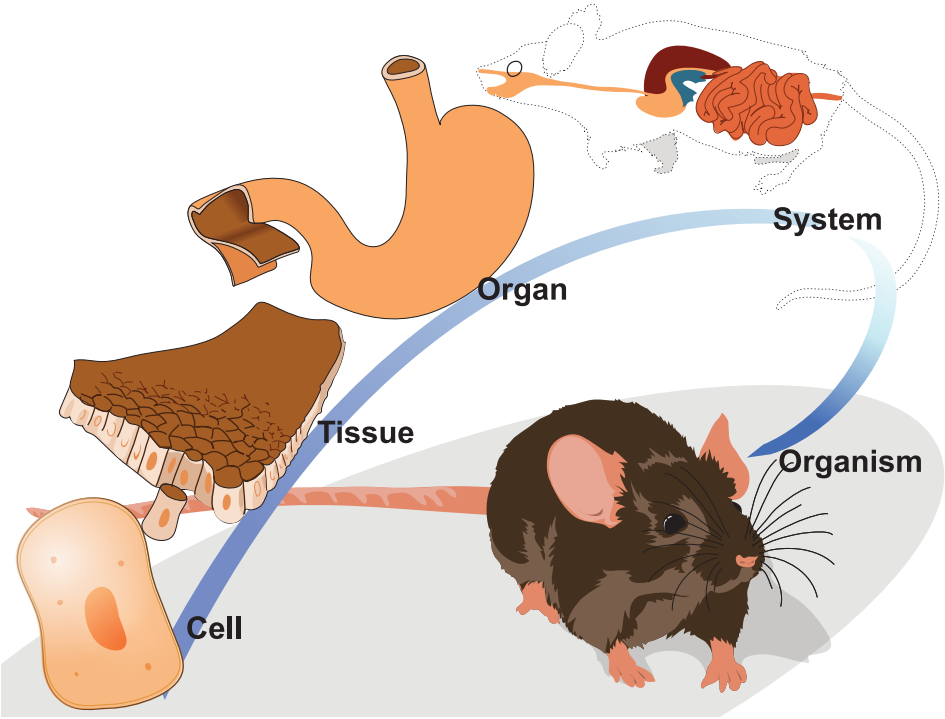
(a) Nasal sinus cells (viewed with a light microscope), (b) onion cells (viewed with a light microscope), and (c) *Vibrio tasmaniensis* bacterial cells (seen through a scanning electron microscope) are from very different organisms, yet all share certain characteristics of basic cell structure.

Close your eyes and picture a brick wall. What is the basic building block of that wall? A single brick, of course. Like a brick wall, your body is composed of basic building blocks, and the building blocks of your body are **cells**.

Your body has many kinds of cells, each specialized for a specific purpose. Just as a home is made from a variety of building materials, the human body is constructed from many cell types. For example, epithelial cells protect the surface of the body and cover the organs and body cavities within. Bone cells help to support and protect the body. Cells of the immune system fight invading bacteria. Additionally, blood and blood cells carry nutrients and oxygen throughout the body while removing carbon dioxide. Each of these cell types plays a vital role during the growth, development, and day-to-day maintenance of the body. In spite of their enormous variety, however, cells from all organisms—even ones as diverse as bacteria, onion, and human— share certain fundamental characteristics.

A cell is the smallest unit of a living thing. A living thing, whether made of one cell (like bacteria) or many cells (like a human), is called an **organism**. Thus, cells are the basic building blocks of all organisms.

Several cells of one kind that interconnect with each other and perform a shared function form **tissues**, several tissues combine to form an **organ** (your stomach, heart, or brain), and several organs make up an **organ system** (such as the digestive system, circulatory system, or nervous system). Several systems that function together form an **organism** (like a human being). Here, we will examine the structure and function of cells.



This diagram illustrates how cells build tissues, tissues build organs, organs build organ systems, and organ systems build organisms.

To understand the structures of human cells, the subcellular structures will be discussed including cellular **organelles**. The word “organelle” means “little organ,” and organelles have specialized cellular functions, just as your body's organs have specialized functions.

Although the generalized characteristics commonly found in **animal cells** (human cells are animal cells) are examined in the following sections, keep in mind that the diversity of cell types found in the human body, including red blood cells, white blood cells, bones cells, skeletal muscle cells, and sperm cells, means that the structures of these cells are different from each other to suit their specific functions. **Structure dictates function**. This means that not only are their shapes and sizes different, but the organelles found in each type of cell differ to suit the specific function of that cell type. All multitude of cell types within a single human contain identical DNA (with some exceptions, particularly sperm and egg cells), but they use different parts of that DNA to suit their specific functions (cells of different types express different genes even though these cells contain the same genes as each other).

Attribution

- "Biology 2e" by Mary Ann Clark, Matthew Douglas, Jung Choi, OpenStax is licensed under CC BY-NC 4.0
- Organization levels mouse.svg by LadyofHats is in the public domain

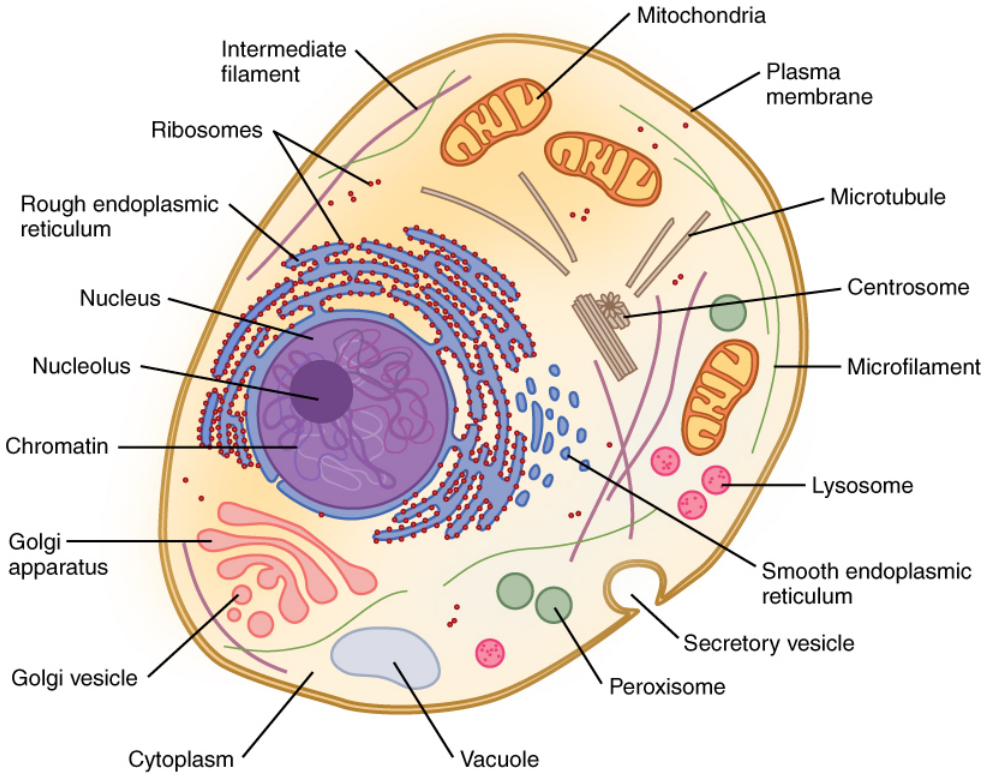
Updated 2025.

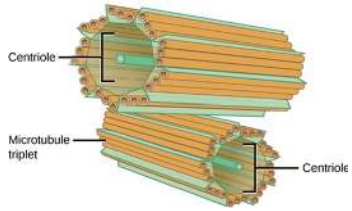
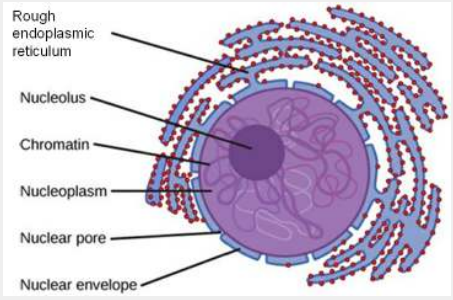
This page titled 3.1: Introduction is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

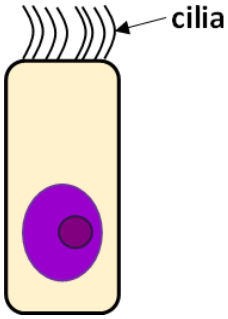
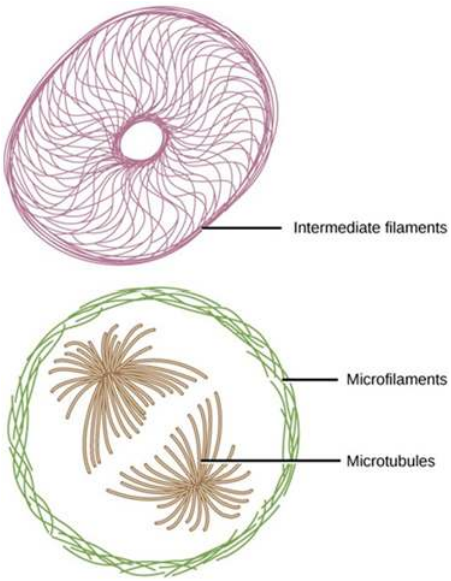
3.2: Subcellular Structures

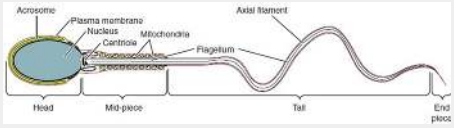
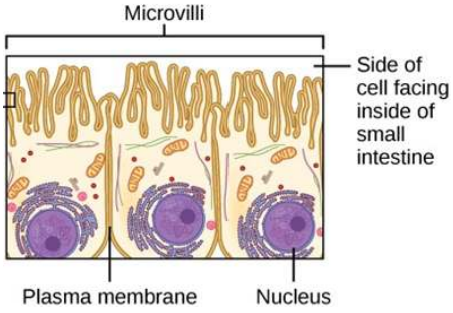
Subcellular Structures

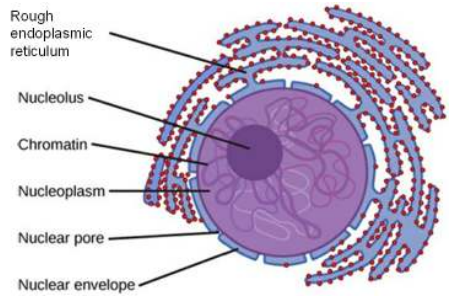
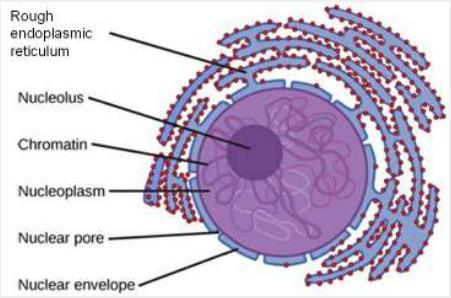
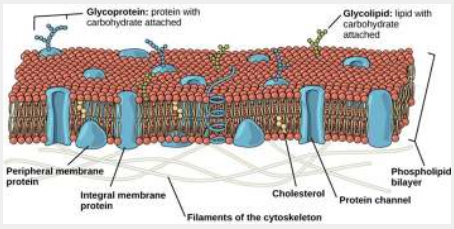
A generalized diagram of an animal cell is shown below. Different cell types will have different shapes. The organelles in a cell differ by cell type too. ***Structure dictates function*** and cells have structures and organelles that support their specific functions. Closely examine the shapes and locations of the organelles that may be found within animal cells and their functions:

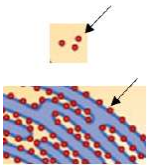
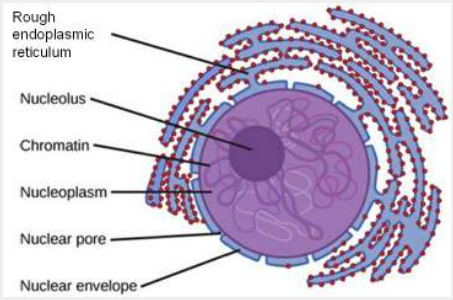


Subcellular Structure	Function of the Structure	Form of the Structure
centrosome 	The centrosome is a microtubule-organizing center found near the nuclei of animal cells. Centrosomes play a major role in cell division by organizing the microtubules that move and separate chromosomes into separate cells.	Two small barrel-like structures composed of straight fibers. These two barrels (each called a **centriole**) cross each other.
chromatin 	Chromatin describes the material that makes up the chromosomes both when condensed (packed into tight structures for cell division) and decondensed (loose; chromatin is loose most of the time).	Thin winding fibers located within the nucleus. Think of it as spaghetti within a bowl (the bowl is the nucleus).

Subcellular Structure	Function of the Structure	Form of the Structure
cilium (pl. cilia) 	Cilia are protein fibers anchored inside of a cell with the majority of these hair-like fibers on the exterior of a cell. In humans, cilia move substances along the cell's outer surface. For example, the cilia lining the Fallopian tubes move the ovum (egg) toward the uterus. Another example is the cilia on the cells lining the respiratory tract that moves mucus, and debris that gets trapped in the mucus, away from the lungs.	Small hairs lining the outside of the cell. Cilia differ from microvilli because they are hair-like fibers outside of the cell whereas microvilli describe a way the plasma membrane is wrapped.
cytoplasm	The cytoplasm is the cell's entire region between the plasma membrane and the nuclear envelope. It is comprised of organelles suspended in the gel-like **cytosol**, the cytoskeleton, and various chemicals. Even though the cytoplasm consists of 70 to 80 percent water, it has a semi- solid consistency, which comes from the proteins within it. Glucose and other simple sugars, polysaccharides, amino acids, nucleic acids, fatty acids, and derivatives of glycerol are also found in the cytoplasm. Many metabolic reactions, including protein synthesis, take place in the cytoplasm.	All of the semi-fluid surrounding all of the other organelles as well as the organelles except for the nucleus. If a cell is a swimming pool with the organelles being rafts in the pool, the cytoplasm is the water and the rafts and the cytosol is the water.
cytoskeleton 	A network of protein fibers creating support, structure, shape, and movement for cells. The cytoskeleton can be thought of as the "skeleton" of the cell. There are three types of fibers within the cytoskeleton: microfilaments, intermediate filaments, and microtubules. • **Microfilaments** function for cellular movement. They are comprised of two globular protein intertwined strands, which we call **actin**. For this reason, we also call microfilaments **actin filaments**. • **Intermediate filaments** are purely structural. They bear tension, thus maintaining the cell's shape, and anchor the nucleus and other organelles in place. • **Microtubules** help the cell resist compression, provide a track along which vesicles move through the cell, and pull replicated chromosomes to opposite ends of a dividing cell.	Long thin fibers scattered throughout the cytoplasm that attach to the plasma membrane and the organelles.

Subcellular Structure	Function of the Structure	Form of the Structure
flagellum (pl. flagella) 	Flagella are long, hair-like structures that extend from the plasma membrane and enable an entire cell to move. The only human cell type that has a flagellum is a sperm cell.	A long thin whip-like tail with one end embedded inside of the cell. The majority of a flagellum located outside of the cell.
Golgi apparatus / Golgi body / Golgi complex 	Sorting, tagging, packaging, and distributing lipids and proteins takes place in the Golgi apparatus. The Golgi can be thought of as the "post office" of a cell.	A series of roughly dumbbell-shaped membranes stacked next to each other.
lysosome 	Lysosomes are the cell's "garbage disposal." Enzymes within the lysosomes aid in breaking down proteins, polysaccharides, lipids, nucleic acids, and even worn-out organelles. These enzymes are active at a much lower pH than the cytoplasm's. Therefore, the pH within lysosomes is more acidic than the cytoplasm's pH. Many reactions that take place in the cytoplasm could not occur at a low pH.	A spherical structure smaller than Golgi and ER membranes.
microvillus (pl. microvilli) 	The plasma membranes of cells that specialize in absorption fold into fingerlike projections that we call microvilli. Such cells typically line the small intestine, the organ that absorbs nutrients from digested food. This is an excellent example of form following function. People with **celiac disease** have an immune response to gluten, which is a protein in what, barley, and rye. The immune response damages microvilli, and thus, afflicted individuals cannot absorb nutrients. This leads to malnutrition, cramping, and diarrhea.	The plasma membrane forms finger-like structures on one of the cell's surfaces. Microvilli resemble Bart Simpson's (the cartoon character's) hair.
mitochondrion (pl. mitochondria) 	Mitochondria are often called the "powerhouses" or "energy factories" of a cell because they are responsible for making adenosine triphosphate (ATP), the cell's main energy-carrying molecule. ATP represents the short-term stored energy of the cell. **Cellular respiration** is the process of making ATP using the chemical energy found in glucose and other nutrients. In mitochondria, this process uses oxygen and produces carbon dioxide as a waste product.	Often kidney-bean shaped structure with membranes pointing into its interior.

Subcellular Structure	Function of the Structure	Form of the Structure
nucleus (pl. nuclei) 	Houses the cell's DNA and directs the synthesis of proteins (**gene expression**) and the synthesis of ribosomes. Composed of the chromatin, nucleolus or nucleoli, a nuclear envelope, and nuclear pores. Nucleoplasm is essentially the cytoplasm of the nucleus.	A large and often prominent structure that may be roughly spherical, but not always.
nucleolus (pl. nucleoli) 	A darkly staining area within the nucleus called the nucleolus aggregates the ribosomal RNA with associated proteins to assemble the ribosomal subunits that are then transported out through the pores in the nuclear envelope to the cytoplasm.	A dark and dense region within the nucleus. There may be more than one nucleolus or none.
peroxisome 	Peroxisomes are small, round organelles enclosed by single membranes. They carry out oxidation reactions that break down fatty acids and amino acids. They also detoxify many poisons that may enter the body. (Many of these oxidation reactions release hydrogen peroxide, H_2O_2, which would be damaging to cells; however, when these reactions are confined to peroxisomes, enzymes safely break down the H_2O_2 into oxygen and water.) For example, alcohol is detoxified by peroxisomes in liver cells.	A spherical structure smaller than Golgi and ER membranes.
plasma membrane (cell membrane) 	The plasma membrane is a phospholipid bilayer with embedded proteins that separates the internal contents of the cell from its surrounding environment. The plasma membrane controls the passage of organic molecules, ions, water, and oxygen into and out of the cell. Wastes (such as carbon dioxide and ammonia) also leave the cell by passing through the plasma membrane. 	A sphere that surrounds the entire cell. It is shown as a line that separates the cell from its environment.

Subcellular Structure	Function of the Structure	Form of the Structure
ribosome 	Ribosomes are the cellular structures responsible for protein synthesis. When viewed through an electron microscope, ribosomes appear either as clusters (polyribosomes) or single, tiny dots that float freely in the cytoplasm. They may also be attached to the cytoplasmic side of the plasma membrane, the exterior of the rough endoplasmic reticulum and the outer membrane of the nuclear envelope.	Very small dot-like structures that are smaller than lysosomes, peroxisomes, and vesicles. Ribosomes may be found in the cytoplasm or attached to the RER.
rough endoplasmic reticulum (RER) 	Ribosomes attached to the RER transfer their newly synthesized proteins into the RER's interior where they undergo structural modifications, such as folding or acquiring side chains. These modified proteins incorporate into cellular membranes. The proteins synthesized with the RER can also be secreted from the cell (such as protein hormones and enzymes). The RER also makes phospholipids for cellular membranes.	Thin long ovals and circles of membrane that often stack irregularly on top of each other. RER has ribosomes attached to the outside giving it a "rough" appearance.
smooth endoplasmic reticulum (SER) 	SER functions include synthesis of carbohydrates, lipids, and steroid hormones; detoxification of medications and poisons; and storing calcium ions. In muscle cells, a specialized SER, called the **sarcoplasmic reticulum**, is responsible for storing calcium ions that are needed to trigger the muscle cells' coordinated contractions.	Thin long ovals and circles of membrane that often stack irregularly on top of each other. SER does not have ribosomes attached giving it a "smooth" appearance.
vacuole / vesicle / storage vesicles 	Vesicles and vacuoles are membrane-bound sacs that function in storage and transport. Other than the fact that vacuoles are somewhat larger than vesicles, there is a very subtle distinction between them: The membranes of vesicles can fuse with either the plasma membrane or other membrane systems within the cell and vacuoles cannot. Storage vesicles can store materials, such as lipid droplets in adipose cells (fat cells).	A spherical or irregularly shaped structure. Sizes vary widely.

Attributions

- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0
- "Biology 2e" by Mary Ann Clark, Matthew Douglas, Jung Choi, OpenStax is licensed under CC BY-NC 4.0

Updated 2025.

This page titled 3.2: Subcellular Structures is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

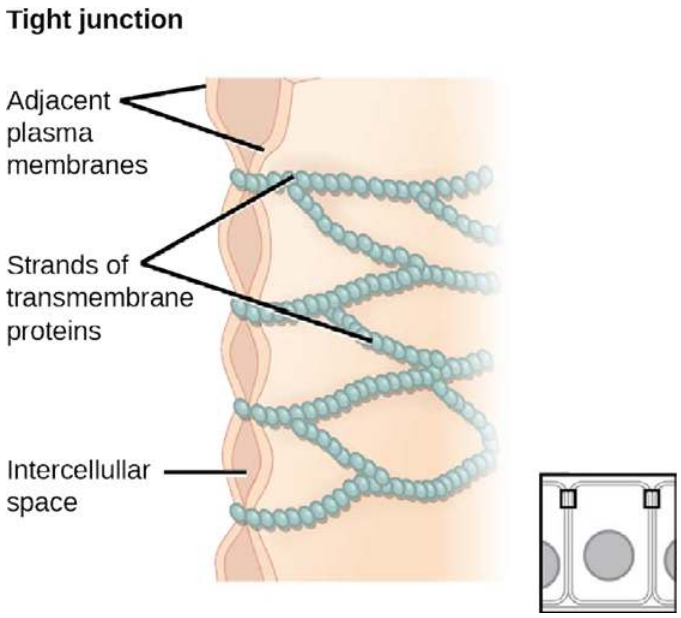
3.3: Cell-to-Cell Junctions Hold Cells Together In Tissues

Cell-to-Cell Junctions Hold Cells Together In Tissues

As stated in the introduction, a single cell is analogous to a single brick in a brick wall. Cells attach to one another to from tissues. There are different types of cell-to-cell attachments helping to hold cells together. The types of cell-to-cell attachments or junctions present in a tissue is related to the functions of that tissue. There are three main cell-to-cell junctions discussed below: **tight junctions**, **desmosomes**, and **gap junctions**.

Tight Junctions

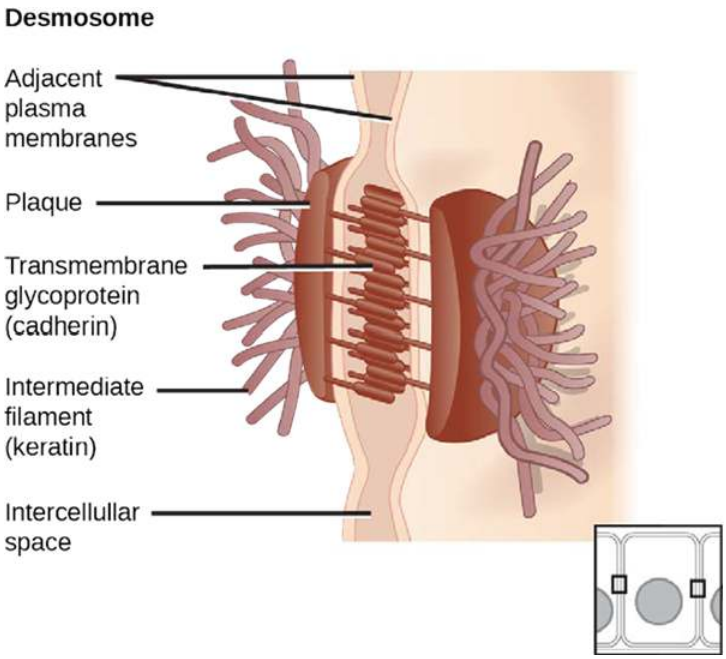
A **tight junction** is a watertight seal between two adjacent animal cells. The proteins that make up tight junctions tightly hold the cells against each other.



This tight adherence prevents materials from leaking between the cells; tight junctions are typically found in epithelial tissues that line internal organs and cavities, and comprise most of the skin. For example, the tight junctions of the epithelial cells lining your urinary bladder prevent urine from leaking out into the extracellular space.

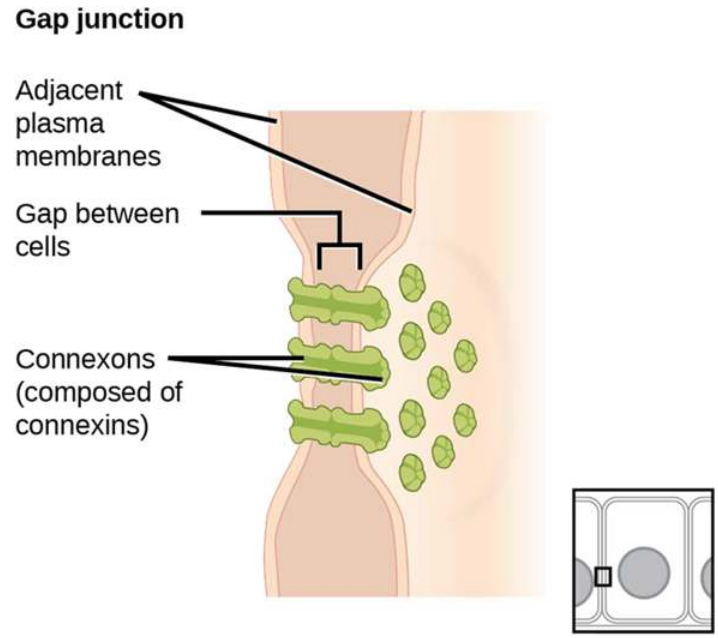
Desmosomes

Imagine two pieces of paper being held together with a staple. This is similar to how **desmosomes** hold two adjacent epithelial cells to each other. Cadherins, short proteins in the plasma membrane, connect to intermediate filaments to create desmosomes. The cadherins connect two adjacent cells to maintain the cells in a sheet-like formation in organs and tissues that stretch, like the skin, heart, and muscles.



Gap Junctions

Gap junctions are hollow channels (imagine a drinking straw) between adjacent cells that allow for transporting ions, nutrients, and other substances that enable cells to communicate. Gap junctions are particularly important in cardiac muscle. The electrical signal for the muscles to contract passes efficiently though gap junctions, allowing the heart muscle cells to contract in tandem.



Attribution

- "Biology 2e" by Mary Ann Clark, Matthew Douglas, Jung Choi, OpenStax is licensed under CC BY-NC 4.0

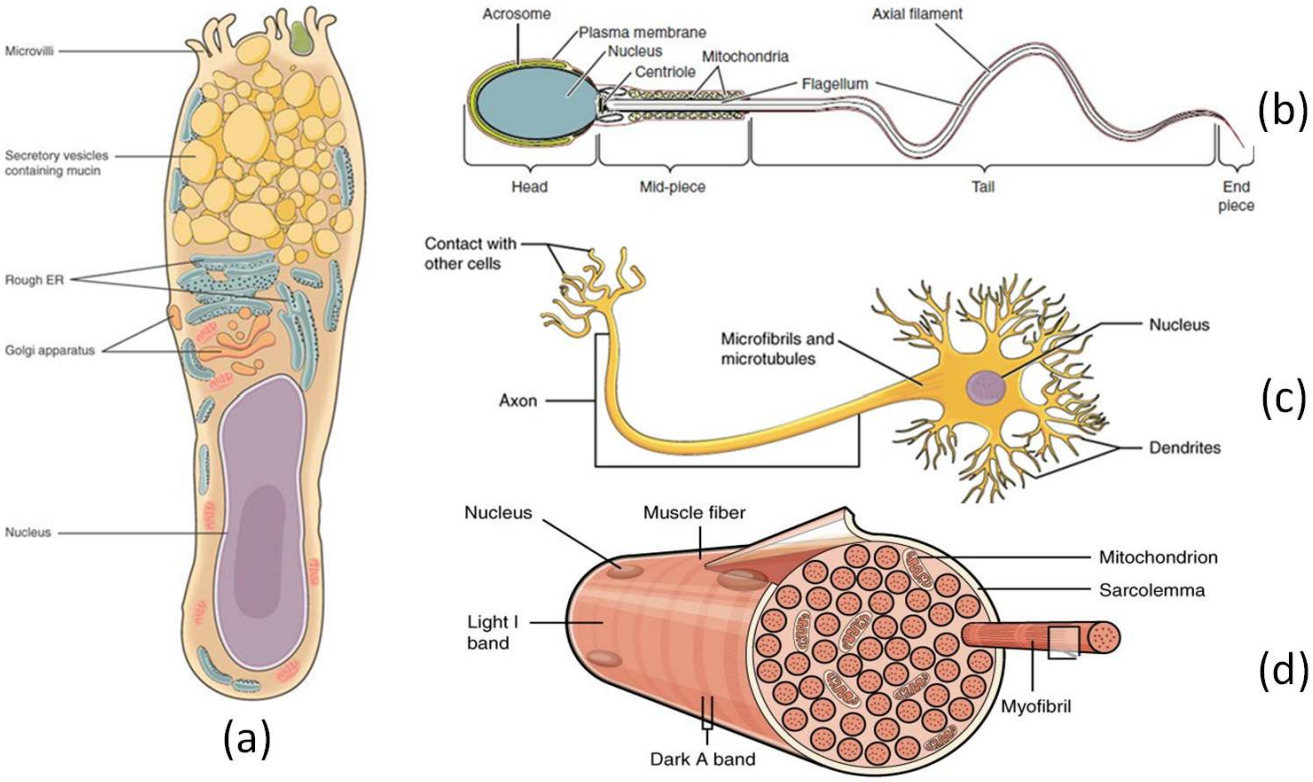
Updated 2025.

This page titled 3.3: Cell-to-Cell Junctions Hold Cells Together In Tissues is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

3.4: Cell Structure Varies by Cell Type

Cell Structure Varies by Cell Type

Cells, even within the same organism, are diverse. In the human body there are about 200 different types of cells. The size, shape, organelles and cell structures, and functions of these different cell types vary widely. To illustrate the cell diversity of the human body further, let's consider examples of four cell types: goblet cells, spermatozoa, neurons, and muscle fibers. Carefully examine the diagram and the table below to investigate how these four cells types differ. Please note that the diagram below presents the different cell types in a way that is ***not to scale*** when comparing the sizes of one cell type with another. See the table below to compare the typical sizes of these cell types.



Above: Four different types of human cells are shown above: (a) goblet cell, (b) spermatozoon, (c) neuron, and (d) muscle fiber. Please note that these cells are not to scale in relationship to their actual sizes. Of these cells, neurons can be the longest, followed by muscle fibers, spermatozoa, and goblet cells are the smallest of these cells.

Letter in the diagram above	Name of this cell type	Size of the cell type	Function of this cell type	How the cell's structure enables its function	Location(s) of this cell type
(a)	goblet cell	~10 µm	produces and secretes **mucin**, a protein that mixes with water after it is secreted to make mucus	contains lots of RER that produces and packages mucin; contains stored mucin in storage vesicles until secretion is initiated; microvilli increase surface area for increased secretion	mucus membranes (e.g. respiratory tract, digestive tract)
(b)	spermatozoon	head is 3-6 µm head to tail is ~60 µm	transports genetic information (DNA) to the female reproductive tract to fuse with an ovum for offspring production	contains a nucleus (DNA) carrying genetic information; contains mitochondria to power flagellar movement; has a flagellum to propel the cell through the female reproductive tract and to the ovum	produced in the testes
(c)	neuron	diameter is 5-150 µm can be as long as ~1 m (1 m is about 3.3 feet)	transmits information, sometimes long distances, for communication of sensory and motor information using electrical signals	dendrite branches collect information from other cells; axons transmit information sometimes long distances; axon terminal branches transmit information to the next cell in the information chain; microfilaments position ion channels and receptors along the axon; ion channels in the plasma membrane shifts electrical charges across the membrane to transmit information	brain, spinal cord, nerves (throughout the body)

Letter in the diagram above	Name of this cell type	Size of the cell type	Function of this cell type	How the cell's structure enables its function	Location(s) of this cell type
(d)	muscle fiber or skeletal muscle cell	100 µm-3 cm long (3 cm is about as long as an adult's thumbprint)	contract (shorten) to enable movement	contains an abundance of microfilaments for cellular movement; mitochondria provide energy required for movement; contains sarcoplasmic reticulum (a type of SER) which releases Ca^{2+} to initiate contraction	attached to the skeleton

Attribution

- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0

Updated 2025.

This page titled 3.4: Cell Structure Varies by Cell Type is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

3.5: Laboratory Activities and Assignment

Laboratory Activities and Assignment

Part 1: Cell Structures

1. Draw an animal cell in the space below. Draw the components of the cell using different colors. Color the parts of an animal cell using a color scheme you developed or on other words, match the color with the cell structure. Use a different color for each of the cell components if possible. Your cell will contain the following structures each labeled on the drawing:

• plasma membrane • cytoplasm • nucleus • nuclear envelope • nuclear pore • nucleolus • chromatin	• rough endoplasmic reticulum • smooth endoplasmic reticulum • Golgi body • mitochondria • lysosome • peroxisome • vesicle / vacuole	• cytoskeleton • centrosome • microvilli • flagellum • cilia • ribosomes

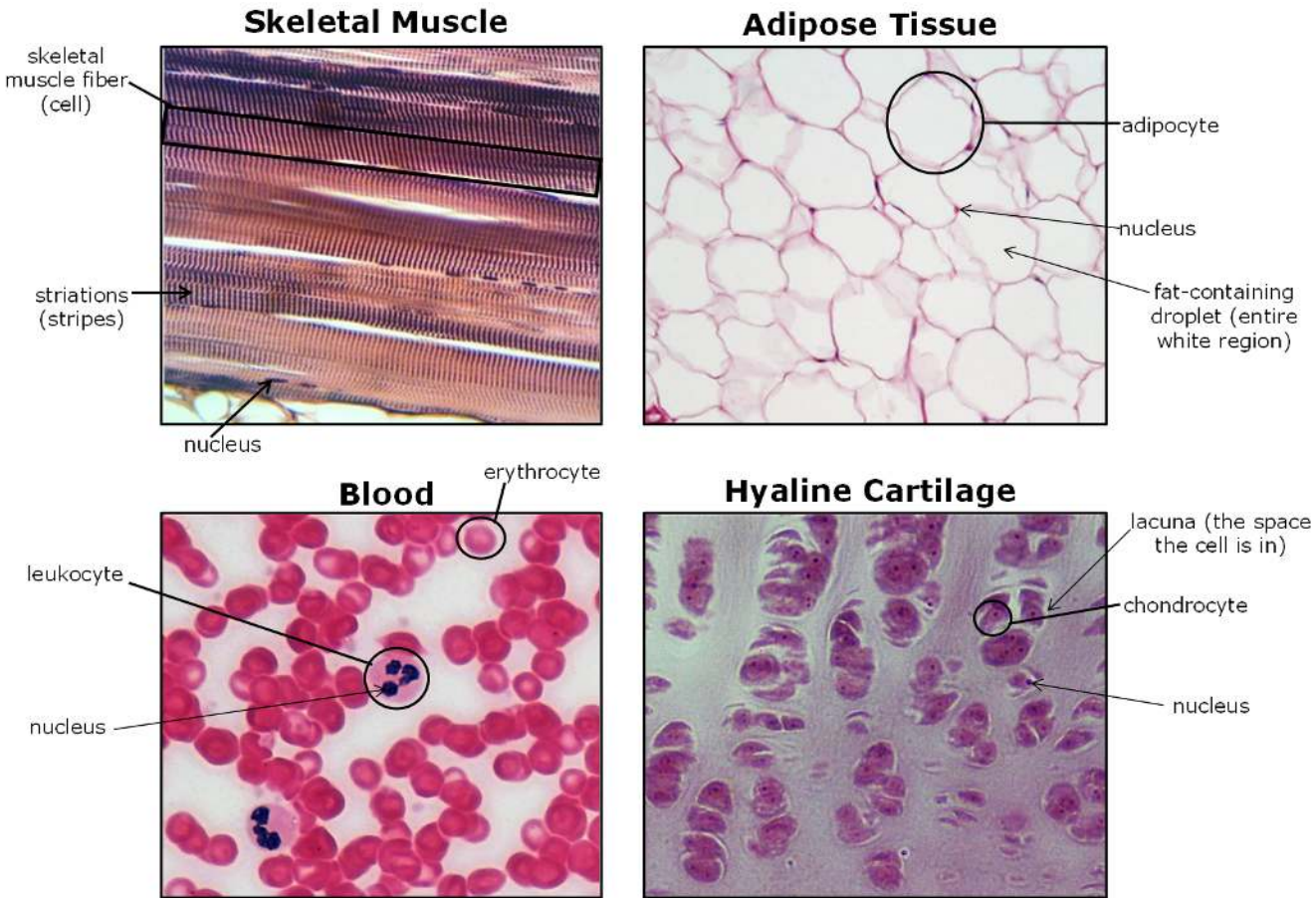
2. Label the 3D model of a cell below with the terms listed. Some structures in this model appear as closed 3D structures (as they would be in a living cell) and others appear as sliced flat (as they would be if we were observing these structures using an electron microscope (TEM, specifically). The colors in the model are significant. Everything that is orange for example is all the same type of structure, but it just may be shown in 3D versus sliced and therefore appears very differently in different spots on the model. Also, vesicles/vacuoles, peroxisomes, and lysosomes are very difficult to tell apart visually only, so don't stress about which one is which.

• plasma membrane • cytoplasm • nucleus • nuclear envelope • nuclear pore • nucleolus	• chromatin • rough endoplasmic reticulum • smooth endoplasmic reticulum • Golgi body • mitochondrion • lysosome	• peroxisome • vesicle / vacuole • centrosome • microvillus • ribosomes



Part 2: Observe, Illustration, and Label Cells of Different Types

Examine the images below of some of the more than 200 different cell types in the human body. Each image has a circle, rectangle, or other marker to indicate what a single cell of this cell type looks like. A few other labels are also included. Use these images for reference in this activity. Also note the scientific terms for different cells often include "-cyte" in their names (e.g. erythrocyte, adipocyte, etc.), which means "cell." So next time you come across a word you don't know that ends in "-cyte," you know that it is a type of cell.

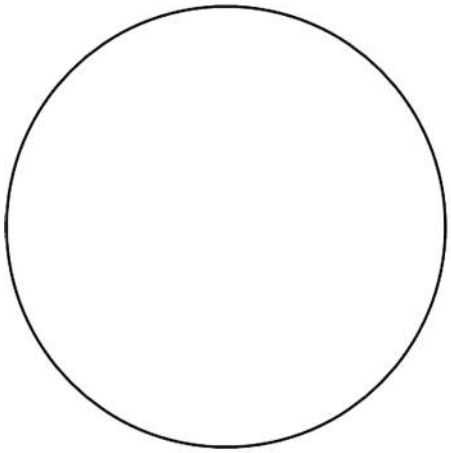


For each of the cell types listed below:

1. Examine a slide with the microscope to observe this cell type.
2. Identify a single cell in the sample.
3. Illustrate a single cell from the sample in the space provided below.
4. Indicate the ***total*** magnification (objective magnification x ocular magnification) used to observe and illustrate the cell.
5. Label your illustration of the cell type with the structures listed for each.

Skeletal Muscle Cell (Muscle Fiber)

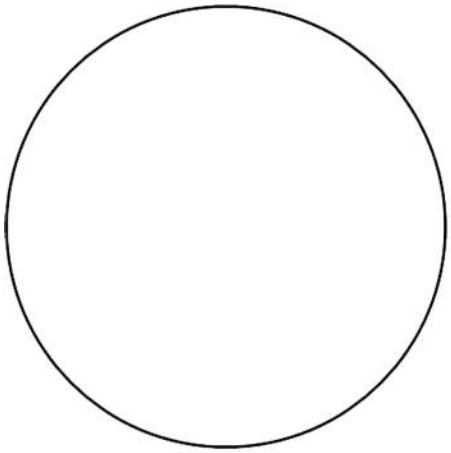
Label the cell with: nucleus, striations



Total magnification: _____

Adipose Cell (Fat Cell or Adipocyte)

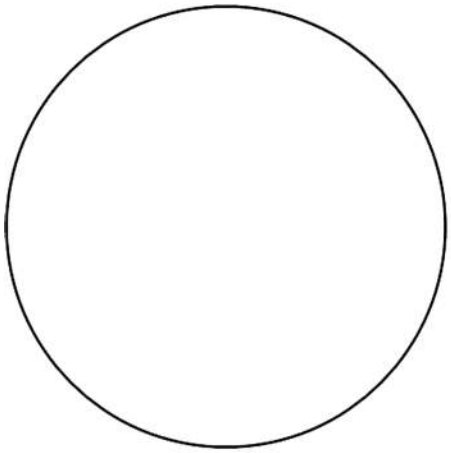
Label the cell with: nucleus, fat-containing droplet



Total magnification: _____

Red Blood Cell (Erythrocyte)

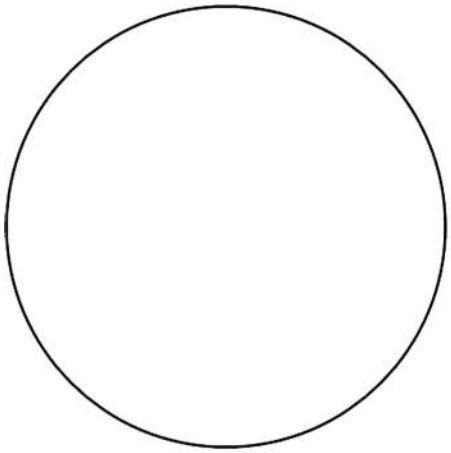
Label the cell with: n/a (lacks a nucleus)



Total magnification: _____

White Blood Cell (Leukocyte)

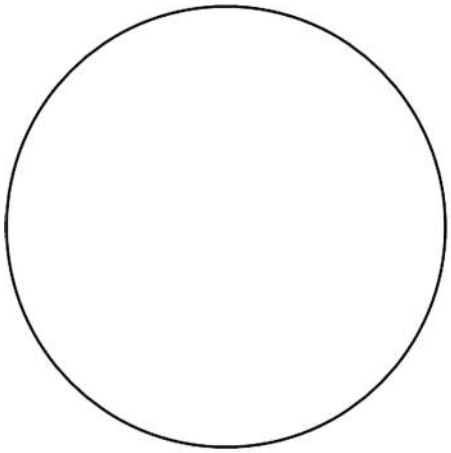
Label the cell with: nucleus



Total magnification: _____

Cartilage Cell (Chondrocyte)

Label the cell with: chondrocyte, nucleus, lacuna (a space surrounding the cell)



Total magnification: _____

Attributes

Part 1: Cell Structures

- Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0

Part 2: Observe, Illustrate, and Label Cells of Different Types

- "Anatomy and Physiology Lab Reference" by Laird C Sheldahl, OpenOregonEducational Resources, Mt. Hood Community College is licensed under CC BY-SA 4.0
- "Animal Tissues and Organs" by Berkshire Community College Bioscience Image Library is in the Public Domain, CC0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0

Updated 2025.

This page titled 3.5: Laboratory Activities and Assignment is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

3.6: Collaborative Study Activity

Collaborative Study Activity

This activity works best with student pairs of two, but groups of up to four can be created and students work in pairs within those groups. Having groups of four is better if there is no supplemental instructor present to help quiz the students after they practice in their pairs. In their pairs, students test each other to identify the structures of an animal cell on a cell model or using the flashcards linked below until they have mastered them, at which point the student pair will request the instructor come test them on the structures of the cell model/flashcard deck.

Cell Structures & Functions

1. Collect an animal cell model or access the cell model flashcard deck (in Quizlet).
2. Test your partner on the cell structures using the cell model or flashcard deck.
3. Have your partner test on the cell structures using the cell model or flashcard deck.
4. **When you and your partner have mastered the cell structures, request the assistance of your Instructor. They will test you using the cell model/flashcard deck and initial ONLY when you have successfully mastered the flashcard deck. Instructor: _____**

Attribution

- "Biology 2e" by Mary Ann Clark, Matthew Douglas, Jung Choi, OpenStax is licensed under CC BY-NC 4.0

Updated 2025.

This page titled 3.6: Collaborative Study Activity is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

CHAPTER OVERVIEW

4: How Cells Divide (Mitotic Cell Division)

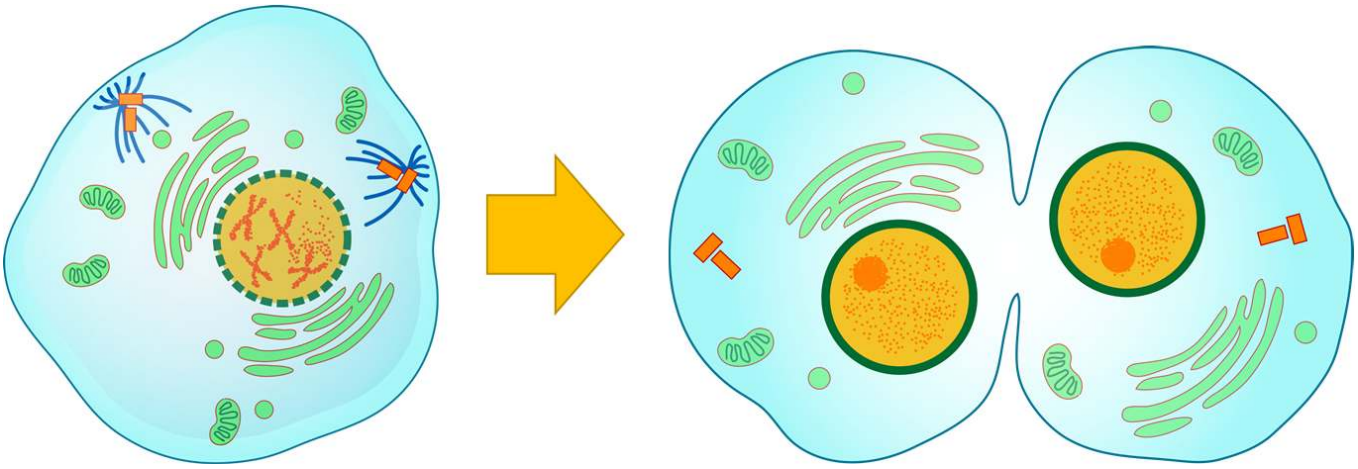
4.1: Introduction to Cell Division
4.2: The Life of a Cell
4.3: Mitotic Cell Division- Division of the Nucleus (Mitosis) + Division of the Cytoplasm (Cytokinesis)
4.4: Uncontrolled Cell Divisions Create Tumors including Cancers
4.5: Laboratory Activities and Assignment
4.6: Collaborative Study Activity

This page titled 4: How Cells Divide (Mitotic Cell Division) is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

4.1: Introduction to Cell Division

Introduction to Cell Division

Cells divide sometimes. This means that one cell splits into two cells. Humans would not exist without cell division. Every human starts life as one single cell, the result of an egg cell (**oocyte**) and sperm cell (**spermatocyte**) fusing during fertilization (the single cell formed through this fusion is called a **zygote**). Then, as the human develops, a series of cell divisions occurs to make an **embryo**.



One cell becomes two cells, two cells divide to produce four cells, four cells divide to produce eight cells, eight cells divide to produce sixteen cells, and so on. By the time a human is a fully grown adult, the human is composed of trillions of cells! Cell division does not end when a human is an adult since cell division is necessary to repair injuries and to replace old and worn out cells. Cells divide in humans for a variety of reasons including:

- **embryonic development** (zygote --> embryo --> fetus --> infant)
- **growth** (infant --> child --> adolescent --> young adult --> adult)
- **regeneration of dead and worn out cells**
- **repair of injuries** (e.g. broken bone, broken skin, etc.)
- **cell differentiation** (cells change from stem cells to specific cell types)
- **abnormal cell division** (benign tumors; cancers)

Another reason cells divide is to produce **gametes**, specialized sex cells that produce offspring (egg/ovum and sperm/spermatozoa). Although production of gametes requires cell division, the process of producing gametes is distinctly different from the type of cell division discussed in this chapter. See **Chapter 21: Reproductive Systems** to learn about cell division for gamete production (**meiosis**).

Attributions

- "Mitotic Prophase" by LadyofHats is in the Public Domain
- "Mitotic Cytokinesis" by LadyofHats is in the Public Domain

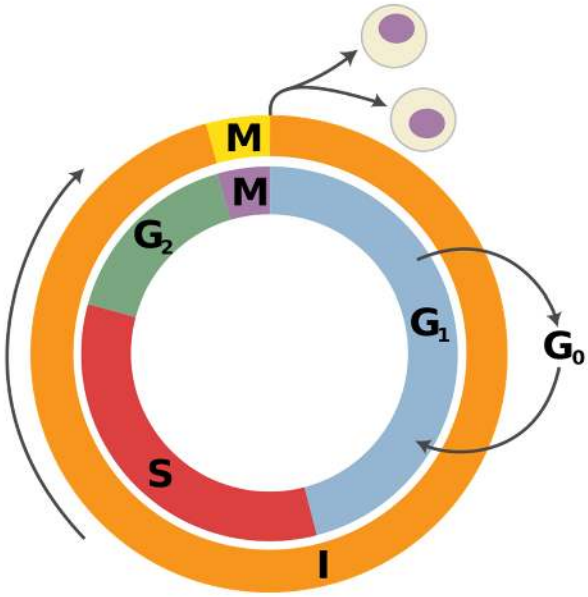
Updated 2025.

This page titled 4.1: Introduction to Cell Division is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

4.2: The Life of a Cell

The Life of a Cell

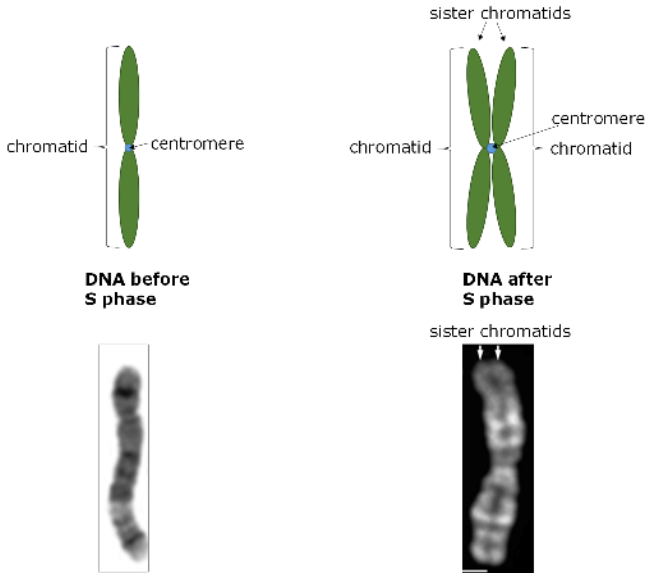
Cells go through different phases during their lives. These phases may involve preparing for cell division, or they may be in a phase where they are not moving toward a cell division. The sequence of phases or stages a cell goes through during its life is known as the **cell cycle**.



Above: This diagram summarizes the life phases a cell goes through (the cell cycle). The abbreviations are as follows: I= interphase, G_1 = G_1 phase, S = S phase, G_2 = G_2 phase, G_0 = G_0 phase, and M = mitotic cell division. The outer circle shows that G_1, G_0, S, and G_2 phases are all considered part of interphase. The inner circle shows the specific phases occurring during interphase. At the end of mitotic cell division, the cell divides into two. Both cells continue in the cell cycle after division - meaning that both cells are in the G_1 phase after completing mitotic cell division.

The bulk of the cell's life in the cell cycle is spent in the “living phase”, known as **interphase**, a phase when a cell is not dividing. The cell might not be progressing toward a cell division at all - a phase known as **G_0 phase** where cells do not move through the other stages of interphase preceding a cell division, but these cells typically are conducting **normal cellular processes** (undergoing metabolic reactions, conducting gene expression, responding to their environmental conditions etc.). If a cell in interphase *is* progressing toward cell division, then interphase involves normal cellular processes as well as three stages that prepare the cell for division. Preparation for cell division occurs in three phases occurring in the following order: **G_1 phase**, **S phase**, and **G_2 phase**:

- **G_1 phase:** a phase of growth when the cell is accumulating resources to live and grow. After attaining a certain size and having amassed enough raw materials, a checkpoint is reached where the cell uses biochemical markers to decide if the next phase should be entered.
- **S phase:** a phase when metabolism is shifted towards the replication (or synthesis) of the genetic material (**DNA replication**). During S phase, the amount of DNA in the nucleus is doubled and copied exactly in preparation for cell division. Before S phase, the chromosomes exist as single **chromatids**. At the end of S phase, each chromosome consists of two identical **sister chromatids** (identical twin sister chromatids) attached to each other at a **centromere**. These identical sister chromatids are separated from each during the cell division process to produce two genetically identical cells at the end of cell division.
- **G_2 phase:** a phase of growth and final preparation before the cell division process begins. Another checkpoint takes place at the end of G_2 to ensure the fidelity of the replicated DNA and to re- establish the success of the cell’s capacity to divide in the environment. If conditions are favorable, the cell continues on to **mitotic cell division**.



Above: The diagram and chromosome images above show the distinctions between single chromatids and two identical sister chromatids attached at a centromere. Please note that this figure shows the DNA in these chromatids as **condensed** (the DNA is tightly coiled and organized into the structures shown above). Throughout interphase, the DNA is **decondensed** (loose) in the nucleus and cannot be observed in this condensed structure until mitotic cell division begins.

Attributions

- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- "Biology 2e" by Mary Ann Clark, Matthew Douglas, Jung Choi, OpenStax is licensed under CC BY-NC 4.0
- "Cell Cycle 3-3" by Zephyris is licensed under CC BY-SA 3.0 / A derivative from the original work
- "SisterChromatid1" by Ascendinglotus2 is licensed under CC BY-SA 3.0
- "UCSC human chromosome colours" by HYanWong is in the Public Domain, CC0

Updated 2025.

This page titled 4.2: The Life of a Cell is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

4.3: Mitotic Cell Division- Division of the Nucleus (Mitosis) + Division of the Cytoplasm (Cytokinesis)

Mitotic Cell Division - Division of the Nucleus (Mitosis) + Division of the Cytoplasm (Cytokinesis)

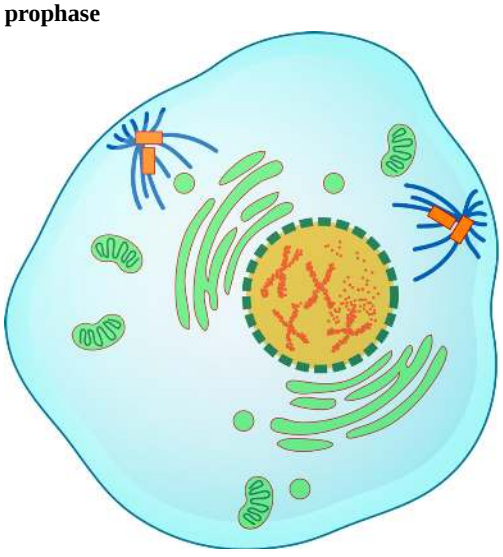
Human cells divide for embryonic development, growth of the human, injury repair, tumor and cancer development and spread, cell regeneration, and cell differentiation by a process called **mitotic cell division**. The word "mitotic" in "mitotic cell division" refers to **mitosis** (division of the nucleus). Mitosis is *a part* of the entire cell division process. After mitosis is complete, the cell is still a single cell, but now the DNA has been divided into two nuclei, with each nucleus containing a set of DNA (chromatids) identical to the other nucleus. Producing genetically identical nuclei is possible because the cell separates the sister chromatids from each other during mitosis and packages one chromatid of each pair of identical sister chromatids into a separate nucleus.

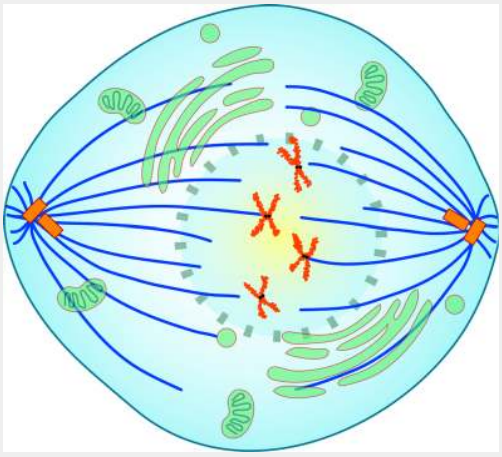
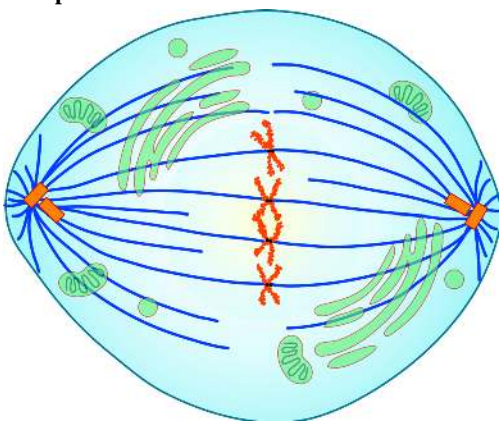
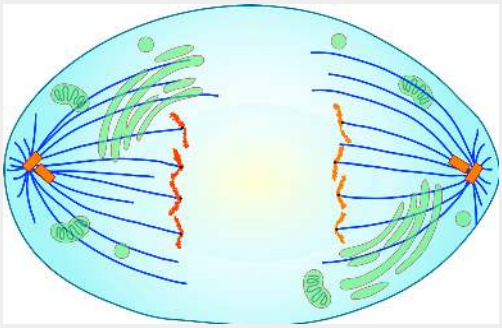
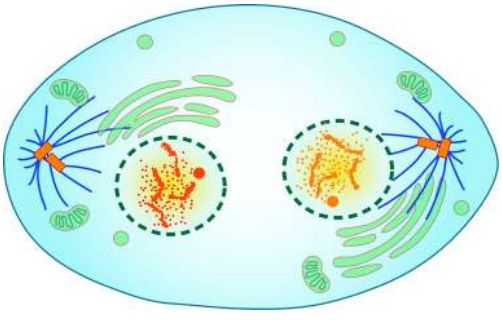
Mitotic cell division is only complete after the cell completely divides into two cells. After mitosis is complete, the cell with two nuclei undergoes **cytokinesis** to divide the cytoplasm, thereby completing mitotic cell division (mitotic cell division = mitosis + cytokinesis).

Cells proceeding through the steps of mitotic cell division have a lot going on. DNA condenses at the beginning and decondenses at the end, the nucleus breaks down and then reforms as two nuclei, sister chromatids are separated into two separate nuclei, the chromatids are moved around, organized, and pulled apart by microtubules, and the entire cell splits in a way that 1 nucleus ends up in each **daughter cell**. To better understand and describe the phases of mitotic cell division, mitosis is broken up into the following phases:

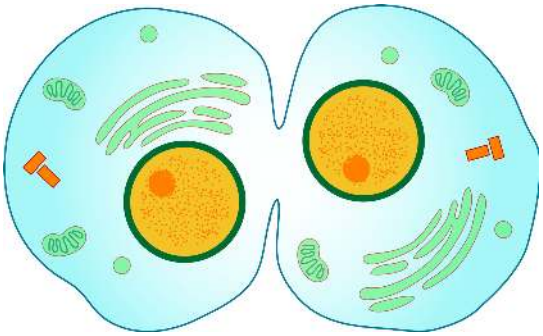
1. prophase
2. prometaphase
3. metaphase
4. anaphase
5. telophase

Cells leaving the G_2 phase of the cell cycle enter prophase first, the first stage of mitosis. The last phase of mitosis is telophase where the cell contains two separate nuclei. Cytokinesis follows telophase to create two separate cells. Examine the table below to investigate the appearance of a cell in each phase of mitosis and the major events occurring in each phase. Pay special attention to the chromatids through this process (shown as orange/red Xs representing sister chromatids, as single red lines in anaphase representing single chromatids, and as orange dots in prophase and telophase representing decondensed DNA) as well as the nuclear envelope (shown as a dark green circle - when this line is dashed it indicates the envelope is either breaking down or forming), the microtubules aka mitotic spindle (shown as blue lines) that move chromatids around the cell, and centrosomes (shown as a pair of orange rectangles) that organize the microtubules:

Phase of Mitosis	Major Events of this Phase
prophase 	• Chromatids condense and become visible as Xs with a microscope • Spindle fibers emerge from the centrosomes • Nuclear envelope breaks down • Nucleolus disappears

Phase of Mitosis	Major Events of this Phase
prometaphase 	• Chromatids continue to condense • Mitotic spindle microtubules attach to the chromatids • Centrosomes move toward opposite poles of the cell
metaphase 	• Mitotic spindle is fully developed • Centrosomes are at opposite poles of the cell • Chromatids are lined up in the center of the cell (also known as the **metaphase plate**) • Each sister chromatid is attached to a spindle fiber originating from opposite poles
anaphase 	• Sister chromatids (now called "chromatids" or "chromosomes" since the sister chromatids are separated) are pulled toward opposite poles of the cell • The cell elongates due to action of the spindle fibers
telophase 	• The single chromatids arrive at opposite poles of the cell • Nuclear envelope materials surround the two sets of chromatids and begins to assemble • Chromatids begin to decondense • The mitotic spindle begins to break down

After telophase is complete, mitosis is complete since the nucleus has now divided into two identical nuclei. Cytokinesis follows the end of mitosis to complete mitotic cell division:

Phase of Mitotic Cell Division	Major Events of this Phase
cytokinesis 	• A contractile ring of actin filaments pulls the equator of the cell inward, forming a fissure (this fissure is called a **cleavage furrow**) • The cleavage furrow continues to deepen as the actin ring continues to get smaller and eventually the membrane is cleaved into to two • Two **daughter cells** are produced • These daughter cells begin their lives in G_1 phase of interphase

Although the events of mitotic cell division are separated into phases, it is analogous to breaking up an entire day into morning, afternoon, evening, and night - it is all a part of the same day, but we describe the parts differently. As such mitotic cell division is a fluid process where one stage evolves into the next.

The length of the cell cycle is highly variable, even within the cells of a single organism. In humans, the frequency of cell turnover ranges from a few hours in early embryonic development, to an average of two to five days for epithelial cells, and to an entire human lifetime spent in G_0 by specialized cells, such as cortical neurons or cardiac muscle cells. There is also variation in the time that a cell spends in each phase of the cell cycle. When fast-dividing mammalian cells are grown in culture (outside the body under optimal growing conditions), the length of the cycle is about 24 hours. In rapidly dividing human cells with a 24-hour cell cycle, the G_1 phase lasts approximately nine hours, the S phase lasts 10 hours, the G_2 phase lasts about four and one-half hours, and the M phase lasts approximately one-half hour. In early embryos of fruit flies, the cell cycle is completed in about eight minutes. The timing of events in the cell cycle is controlled by mechanisms that are both internal and external to the cell.

Attributions

- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- "Biology 2e" by Mary Ann Clark, Matthew Douglas, Jung Choi, OpenStax is licensed under CC BY-NC 4.0
- "Mitotic Prophase" by LadyofHats is in the Public Domain
- "Mitotic Prometaphase" by LadyofHats is in the Public Domain
- "Mitotic Metaphase" by LadyofHats is in the Public Domain
- "Mitotic Anaphase" by LadyofHats is in the Public Domain
- "Mitotic Telophase" by LadyofHats is in the Public Domain
- "Mitotic Cytokinesis" by LadyofHats is in the Public Domain

Updated 2025.

This page titled 4.3: Mitotic Cell Division- Division of the Nucleus (Mitosis) + Division of the Cytoplasm (Cytokinesis) is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

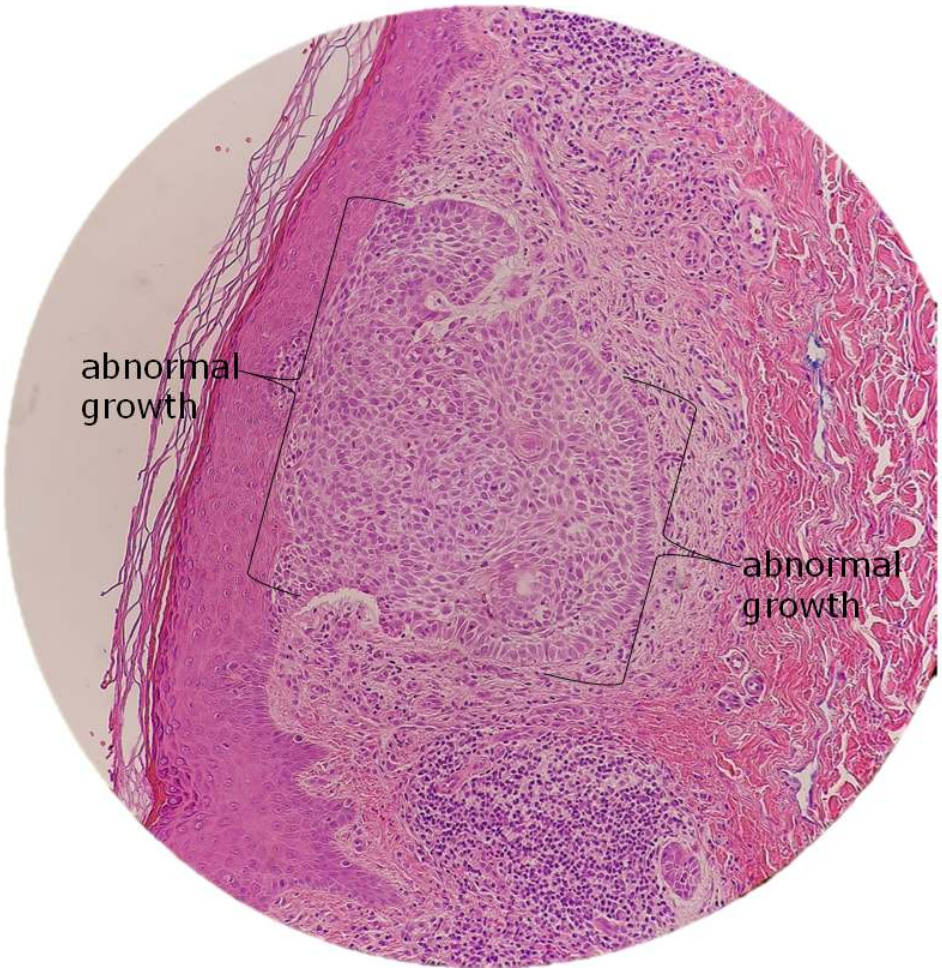
4.4: Uncontrolled Cell Divisions Create Tumors including Cancers

Uncontrolled Cell Divisions Create Tumors including Cancers

Tumors, including cancers, are caused by abnormal cells that multiply more rapidly than normal cells. If the abnormal cells continue to divide unstopped, they can damage the tissues around them, spread to other parts of the body (**malignancy**), and even result in death. In healthy cells, the tight regulation mechanisms of the cell cycle prevent this from happening (cell cycle **checkpoints** prevent movements to the next stages of the cell cycle), while failures of cell cycle control can cause unwanted and excessive cell division.

Failures of cell cycle control may be caused by inherited genetic abnormalities (**genetic predispositions**) that compromise the function of certain cell cycle “stop” and “go” signals. Cell cycle checkpoints may also be compromised due to exposures to environmental factors that mutate cellular DNA causing dysfunction in those "stop" and "go" signals controlling the cell cycle. Often, a combination of both genetic predisposition and environmental factors lead to cancer. Environmental factors causing DNA mutations that may lead to cancers can include:

- exposures to mutagenic chemicals (e.g. chemicals in cigarette smoke, pollutants, etc.)
- radiation (e.g. X-rays, ultraviolet light)
- some viruses (e.g. human papilloma virus [HPV])



Above: Light microscope image of a tissue cross-section from a patient with a type of basal cell cancer. The growth of abnormal cells is bracketed on either side, but the overall shape of the cancer tissue is roughly circular.

The process of a cell escaping its normal control system and becoming cancerous may actually happen throughout the body quite frequently. Fortunately, certain cells of the immune system are capable of recognizing cells that have become cancerous and destroying them. However, in certain cases the cancerous cells remain undetected and continue to proliferate. If the resulting tumor

does not pose a threat to surrounding tissues, it is said to be **benign** and can usually be easily removed. If capable of causing damage to surrounding tissues and spreading through the blood and/or lymph, the tumor is considered **malignant** and the patient is diagnosed with cancer.

Attributions

- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0
- "Biology 2e" by Mary Ann Clark, Matthew Douglas, Jung Choi, OpenStax is licensed under CC BY-NC 4.0
- "Palisading in basal cell cancer (original)" by Mikael Häggström, M.D. is in the Public Domain, CC0

Updated 2025.

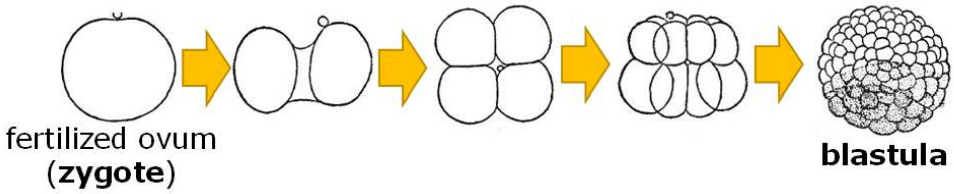
This page titled 4.4: Uncontrolled Cell Divisions Create Tumors including Cancers is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

4.5: Laboratory Activities and Assignment

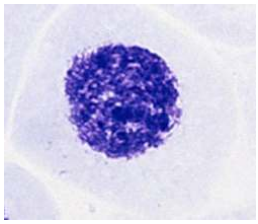
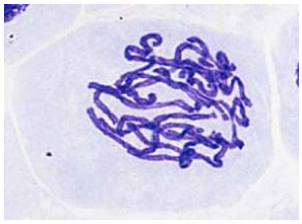
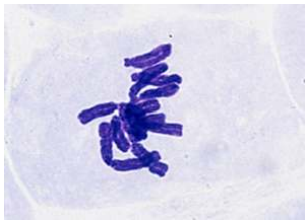
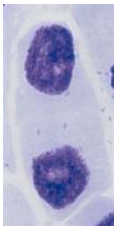
Laboratory Activities and Assignment

Introduction

In these laboratory activities, you will be examining real cells that have been frozen in time in the midst of undergoing the various phases of the cell cycle. To better examine the many cell cycle stages that occur with real cells, we use cells that are undergoing a high amount of cell division. One great source of rapidly dividing animal cells is in early embryonic development. A **blastula** is a ball of cells in an early embryonic phase and is continuing to undergo rapid cell divisions. After egg and sperm meet, the fertilized ovum rapidly begins to divide and will go through this blastula stage. Since we are interested in studying cell division in humans (a type animal), and it would be unethical to examine human blastula, fish blastula are commonly used.



Real cells can look quite different than the illustrated versions of cells in their cell cycle stages. To assist with recognizing these stages, examine the table above showing images of real animal cells. A description of features that can be used to identify cells in each stage is also provided. Note that these microscope slides are prepared using stains that stain the DNA (chromosomes/chromatids) a color that makes it more obvious such as purple, blue, or pink. The images above have the DNA stained dark purple.

Interphase	Prophase	Metaphase	Anaphase	Telophase
				
• Nucleus is present • Chromosomes are not condensed (cannot see individual thick strands) • Only one nucleus present	• Chromosomes are less confined in a circle structure (nucleus breaking down) • Chromosomes are condensed (can see individual thick strands) • Chromosomes are NOT in a line or pulling apart to opposite poles of the cell	• Chromosomes are condensed (can see individual thick strands) • Chromosomes are roughly lined up in a line • Chromosomes are NOT pulling apart to opposite poles of the cell	• Chromosomes are condensed (can see individual thick strands) • Chromosomes are pulling apart to opposite poles of the cell	• Two round nuclei inside one cell • Chromosomes are not condensed (cannot see individual thick strands)

Quantify Cells in Each Cell Cycle Phase in a Fish Blastula

Note: It is recommended students complete the Collaborative Study Activity for this chapter before beginning this section. This activity will better prepare students to identify the appearance of fish cells in each phase of the cell cycle.

1. Obtain a "fish blastula" or "fish mitosis" slide and setup a microscope.
2. Focus on a single blastula at low power and increase magnification incrementally, focusing at each power along the way. Do not skip objectives without re-centering and re-focusing the sample.
3. Carefully examine the blastula at 400x total magnification.
4. Count the number of cells in the entire blastula that are in interphase and record in the table below in the individual counts column.
5. Count the number of cells in the entire blastula that are in prophase and record in the table below in the individual counts column.
6. Count the number of cells in the entire blastula that are in metaphase and record in the table below in the individual counts column.
7. Count the number of cells in the entire blastula that are in anaphase and record in the table below in the individual counts column.
8. Count the number of cells in the entire blastula that are in telophase and record in the table below in the individual counts column.
9. Share your data with your instructor so they can compile class data.

Analyze Fish Blastula Data to Estimate Relative Durations of Each Phase of the Cell Cycle

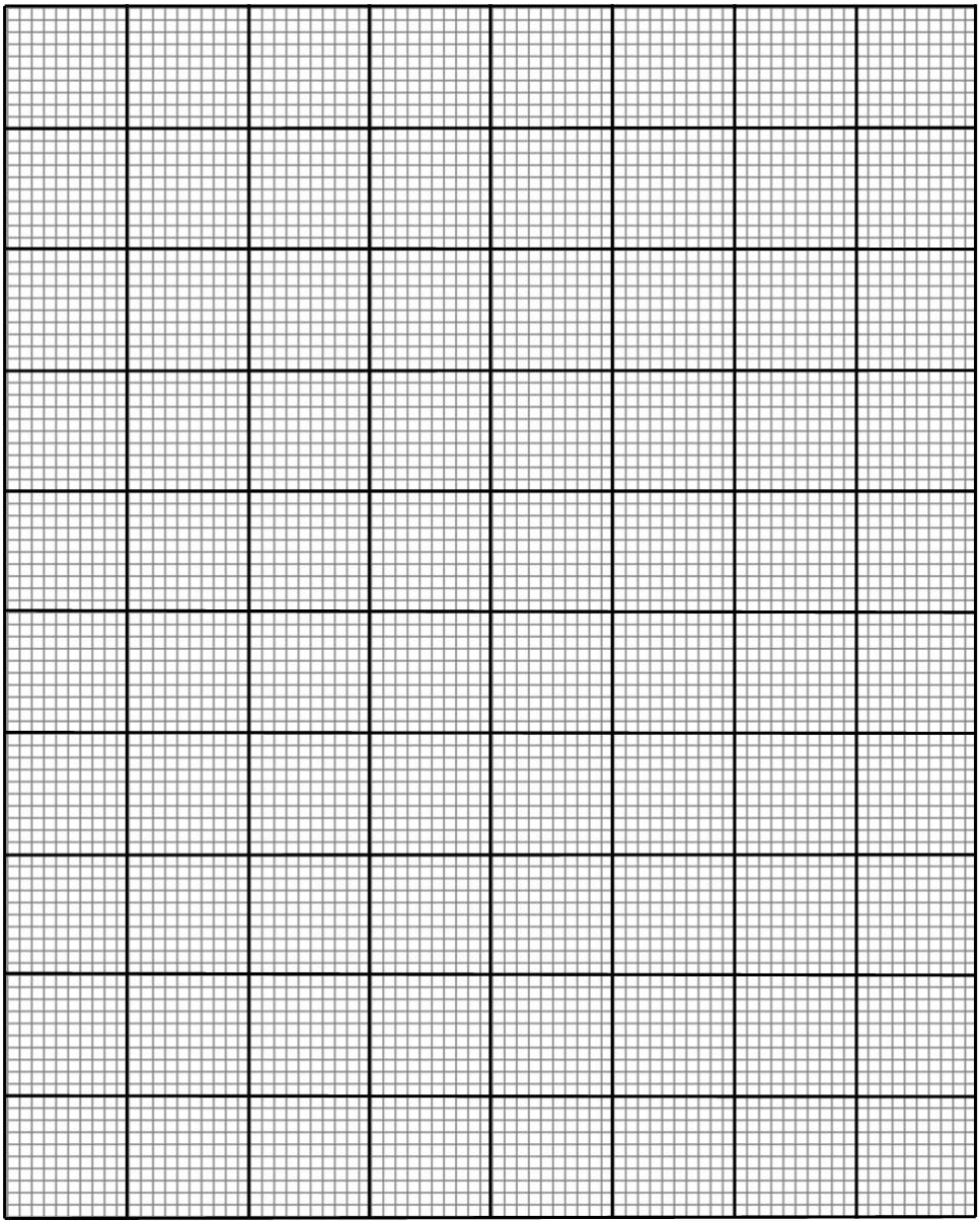
In the table below, record individual and class data indicating the number and percentages of cells in each phase of the cell cycle in fish blastula.

	Individual Counts		Class Counts	
	# Cells	**% Cells**	**Class # Cells**	**Class % Cells**
Interphase				
Prophase				
Metaphase				
Anaphase				
Telophase				
Total				

Calculate the percentage of cells in each phase of the cell cycle:

% cells = (cells in that stage ÷ total number of cells counted) x 100

1. Create a ***stacked*** bar graph presenting **class % cells** during the cell cycle for fish blastula cells. **Use a ruler** or a graphing software to make the graph neat and professional-looking. If using a graphing software, you could alternatively create a pie chart. Include in the graph the following:
    - Labels for the x-axis and y-axis:
        - Y-axis numbered corresponding the percentage of cells observed. The bottom of the y-axis is 0% and the top line of the y-axis is 100%. Each line up the y-axis is a specific increment (as determined by you) increasing up the y-axis.
        - Y-axis title to tell what the numbers mean: Percentage of cells in each stage.
        - X-axis label to tell what the bar shows (Fish Blastula).
    - Each of the two bars stretch from 0% to 100% but are divided into the stages of the cell cycle using different colors based on the % of cells in each stage. A key is needed to tell what each color shows. Bar sections should be colored in NEATLY so the graph looks professional.
    - Title for the graph.



2. Examine your graph. The percentage of cells observed in a specific stage the cell cycle is indicative of the length of time a cell requires for each stage (the greater the % cells, the longer the phase lasts during the cell cycle; the fewer the % cells, the shorter that phase is in the cycle cycle). Using your data, ***discuss the length of time each of the phases of the cell cycle lasts***. Which is the longest phase? Which phase is the shortest? How do all the phases compare with each other?

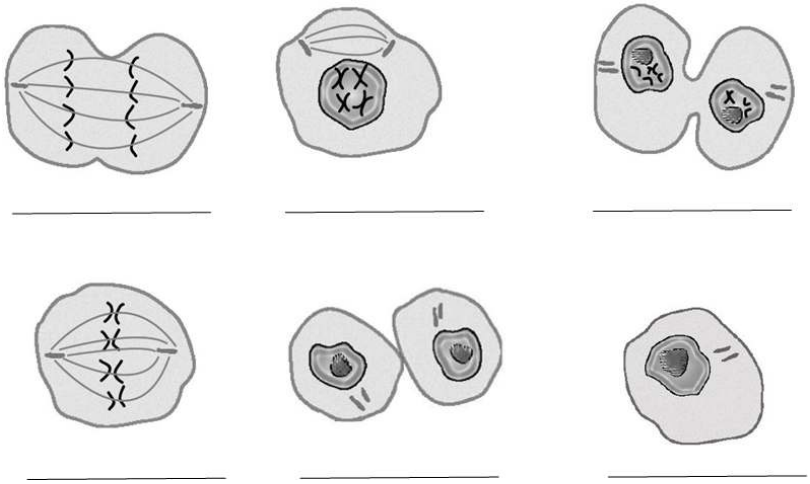
Additional Questions

1. Use the letters to match with the descriptions as appropriate. ***Some choices may be used more than once and some may not be used at all***.

A. mitosis B. interphase C. prophase D. homologous chromosomes E. telophase F. anaphase G. cytokinesis H. sister chromatids I. metaphase J. S phase	_____ A phase when chromosomes line up in the center of the cell. _____ A phase when the nuclear envelope begins to dissolve. _____ A phase between cell divisions. _____ A phase when chromosomes separate from one another. _____ Nuclear division. _____ A phase when DNA replication occurs. _____ A phase when the DNA decondenses. _____ Type of chromosomes that separate during mitosis. _____ Division of the cytoplasm to produce 2 separate cells. _____ A phase where the cell grows and organelles replicate. _____ A phase where DNA condenses. _____ A process that produces sister chromatids. _____ A phase when the nuclear envelope reforms.

2. Label the images of stages of the cell cycle using the choices below:

- interphase
- prophase
- metaphase
- anaphase
- telophase
- cytokinesis



Attributions

Introduction

- "Mitosis (261 01) Pressed; root meristem of Vicia faba" by Doc. RNDr. Josef Reischig, CSc. is licensed under CC BY-SA 3.0
- "Mitosis (261 02) Pressed; root meristem of Vicia faba (cells in prophase)" by Doc. RNDr. Josef Reischig, CSc. is licensed under CC BY-SA 3.0
- "Mitosis (261 03) Pressed; root meristem of Vicia faba (cells in prophase, metaphase)" by Doc. RNDr. Josef Reischig, CSc. is licensed under CC BY-SA 3.0
- "Mitosis (261 08) Pressed; root meristem of Vicia faba (cells in telophase)" by Doc. RNDr. Josef Reischig, CSc. is licensed under CC BY-SA 3.0
- "Mitosis (261 10) Pressed; root meristem of Vicia faba (cells in anaphase, prophase)" by Doc. RNDr. Josef Reischig, CSc. is licensed under CC BY-SA 3.0
- "PSM V84 D534 Facts and factors of development fig10" by Edwing Grant Conklin is in the Public Domain

Analyze Fish Blastula Data to Estimate Relative Lengths of Each Phase of the Cell Cycle

- "Graph paper inch Letter" by László Németh is in the Public Domain, CC0

Additional Questions

- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0

Updated 2025.

This page titled 4.5: Laboratory Activities and Assignment is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

4.6: Collaborative Study Activity

Collaborative Study Activity

This activity works best with student pairs of two, but groups of three or four can be created and students work in pairs within those groups. Having groups of three or four is better if there is no supplemental instructor present to help quiz the students after they practice in their pairs. In their pairs, students test each other using either cell models of mitotic cell division or the digital flashcards provided until they have mastered it, at which point the student pair will request the instructor come test.

Identifying Phases of the Cell Cycle

1. Access the mitotic cell division flashcard deck (in Quizlet) or use collect cell models of the stages of mitotic cell division.
2. Test your partner on the models or flashcard deck.
3. Have your partner test you on the models or flashcard deck.
4. **When you and your partner have mastered the flashcard deck, request the assistance of your Instructor. They will test you using the flashcard deck and initial ONLY when you have successfully mastered the flashcard deck. Instructor: _____**

Attributions

- "Mitosis (261 01) Pressed; root meristem of Vicia faba" by Doc. RNDr. Josef Reischig, CSc. is licensed under CC BY-SA 3.0
- "Mitosis (261 02) Pressed; root meristem of Vicia faba (cells in prophase)" by Doc. RNDr. Josef Reischig, CSc. is licensed under CC BY-SA 3.0
- "Mitosis (261 03) Pressed; root meristem of Vicia faba (cells in prophase, metaphase)" by Doc. RNDr. Josef Reischig, CSc. is licensed under CC BY-SA 3.0
- "Mitosis (261 08) Pressed; root meristem of Vicia faba (cells in telophase)" by Doc. RNDr. Josef Reischig, CSc. is licensed under CC BY-SA 3.0
- "Mitosis (261 10) Pressed; root meristem of Vicia faba (cells in anaphase, prophase)" by Doc. RNDr. Josef Reischig, CSc. is licensed under CC BY-SA 3.0
- "Mitosis Stages" by Ali Zifan is licensed under CC BY-SA 4.0
- "Mitotic Prophase" by LadyofHats is in the Public Domain
- "Mitotic Prometaphase" by LadyofHats is in the Public Domain
- "Mitotic Metaphase" by LadyofHats is in the Public Domain
- "Mitotic Anaphase" by LadyofHats is in the Public Domain
- "Mitotic Telophase" by LadyofHats is in the Public Domain
- "Mitotic Cytokinesis" by LadyofHats is in the Public Domain
- "SisterChromatid1" by Ascendinglotus2 is licensed under CC BY-SA 3.0
- "UCSC human chromosome colours" by HYanWong is in the Public Domain, CC

Updated 2025.

This page titled 4.6: Collaborative Study Activity is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

CHAPTER OVERVIEW

5: Tissues

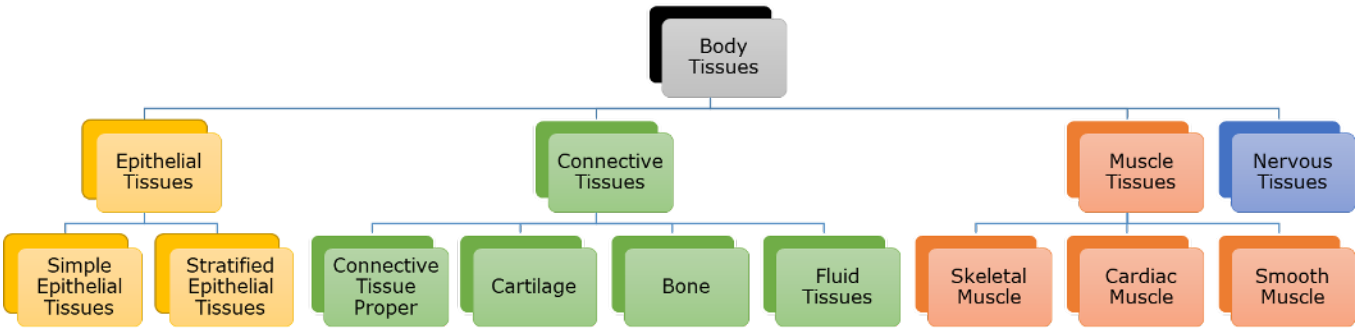
5.1: Introduction
5.2: Epithelial Tissues
5.3: Connective Tissues
5.3.1: Introduction to Connective Tissues
5.3.2: Connective Tissue Proper
5.3.3: Bone Tissue
5.3.4: Fluid Tissues
5.3.5: Cartilage Tissues
5.4: Muscle Tissues
5.5: Nervous Tissues
5.6: Laboratory Activities and Assignment
5.7: Collaborative Study Activity

This page titled 5: Tissues is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

5.1: Introduction

Introduction

Tissues are collections of cells and the extracellular substances surrounding them working together to perform a specific function. The microscopic study of tissues is called **histology**. There are four main types of tissue: **epithelial tissues**, **connective tissues**, **muscle tissues**, and **nervous tissues**. Most body structures and organs contain all four types of tissue with epithelial tissues lining surfaces, connective tissues often with structural roles, muscle tissues causing movement, and nervous tissues sending and receiving signals to and from tissues. Therefore, these four tissue types are found together and support and interact with each other. The diagram below shows how body tissues are categorized.



Attributions

- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0

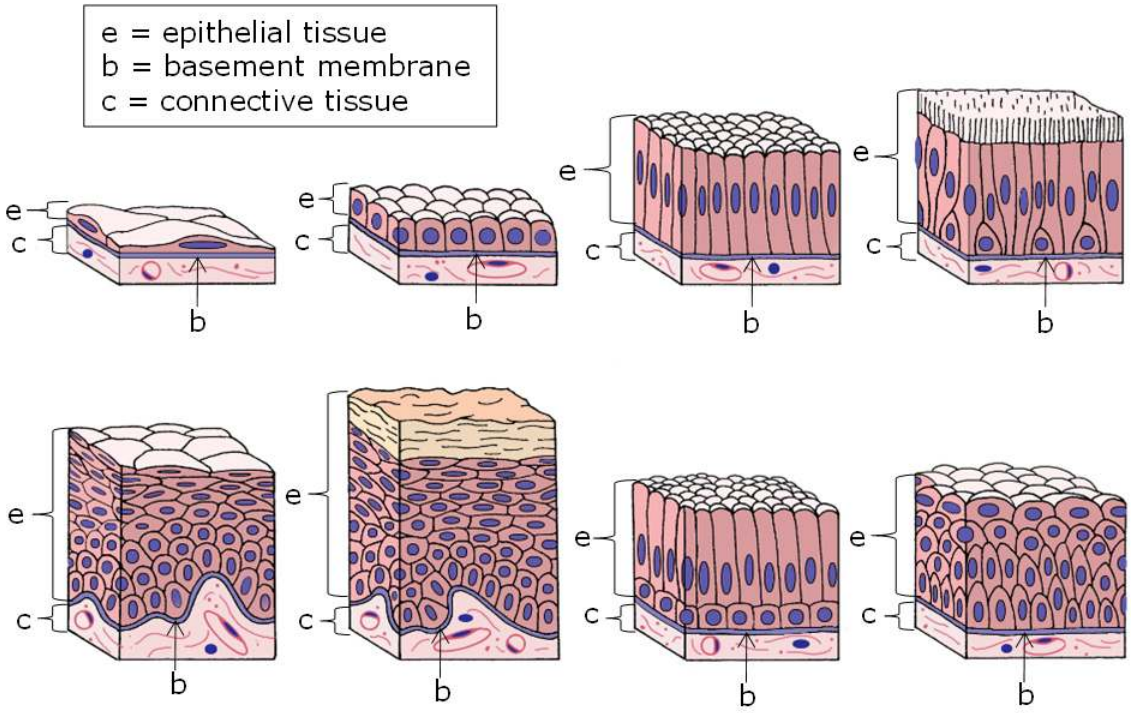
Updated 2025.

This page titled 5.1: Introduction is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

5.2: Epithelial Tissues

Epithelial Tissues

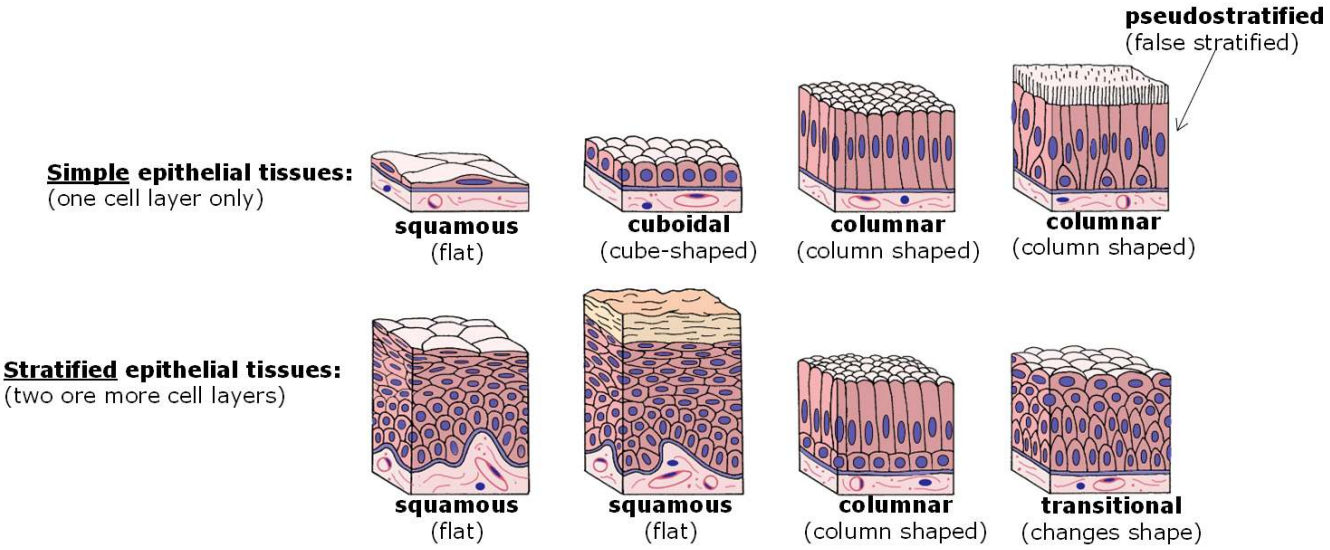
Epithelial tissues are found on the surfaces of all organs inside and out of the human body. As such, epithelial tissues have one edge not connected to other cells, the **apical surface**. The other end of an epithelial tissue (the **basal surface**) is attached to a **basement membrane** that is partly produced by the epithelial cells. Underlying the basement membrane are usually **connective tissues**. Carefully examine the diagram below to become familiar with recognizing different types of epithelial tissues and their positions in relationship to the basement membrane and the underlying connective tissues. Epithelial tissues do not contain blood vessels, that is they are **avascular**. Connective tissues are usually highly **vascular**, and so the nearby connective tissue provides essential nutrients (from the blood) to the epithelial tissue.



Epithelial tissues use a 2-word naming system:

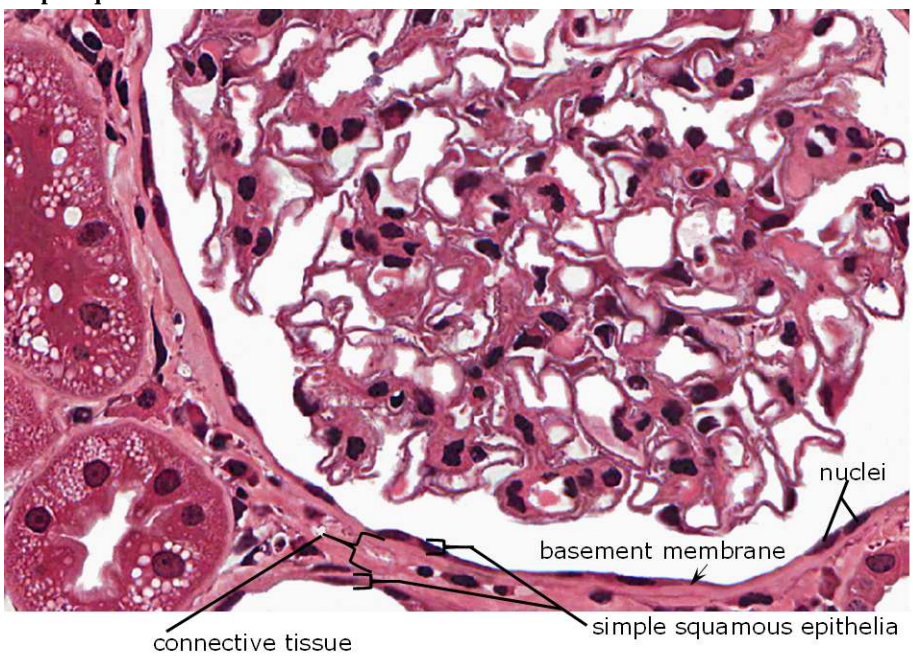
1. First word: **simple**, **stratified**, or **pseudostratified** (these terms indicate the number of cell layers)
   - **simple**: tissue only has one cell layer
   - **stratified**: tissue has 2+ cell layers
   - **pseudostratified**: tissue only has one cell layer, but *cells look like* they could be in more than one layer
2. Second word: **squamous**, **cuboidal**, **columnar**, or **transitional** (these terms indicates the cell shape)
   - **squamous**: cells are flat
   - **cuboidal**: cells are somewhat cube-shaped
   - **columnar**: cells are column-shaped
   - **transitional**: cells change shape (wide cells when not stretched; flat cells when stretched)

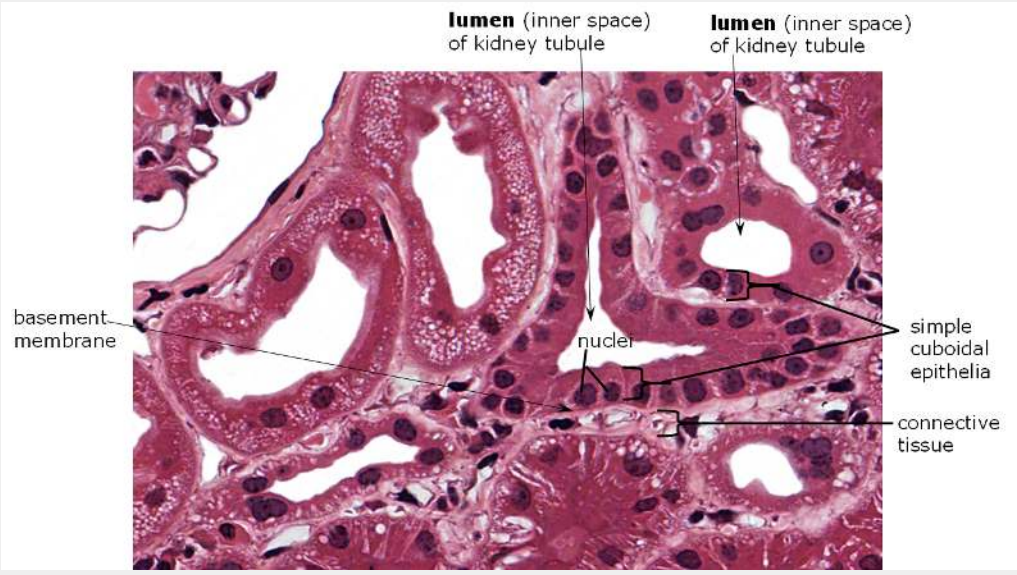
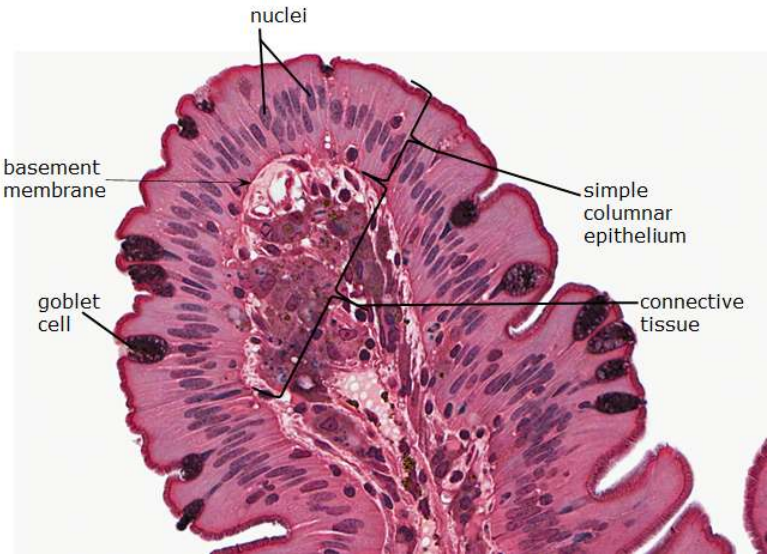
For example, examining the diagram below, the tissue shown in the bottom left corner would be called "stratified squamous" since the cells are flat (squamous) and there are more than two cell layers (stratified). The top second from the left on the diagram would be called, "simple cuboidal" since there is one cell layer (simple) and the cells are cube-shaped (cuboidal). There are some epithelial tissues that look like they are stratified, but they are in fact a single layer of cells - these tissues are called **pseudostratified** or "false/fake stratified." The tissue in the figure below on the top right is therefore called, "pseudostratified columnar." Simple epithelial tissues are only one cell layer thick to enable absorption, diffusion, or secretion of materials across the tissue. Stratified epithelial tissues have multiple cell layers primarily to protect the tissues underlying them.



Carefully examine the tables showing examples of different types of epithelial tissues and examples of where each type may be found:

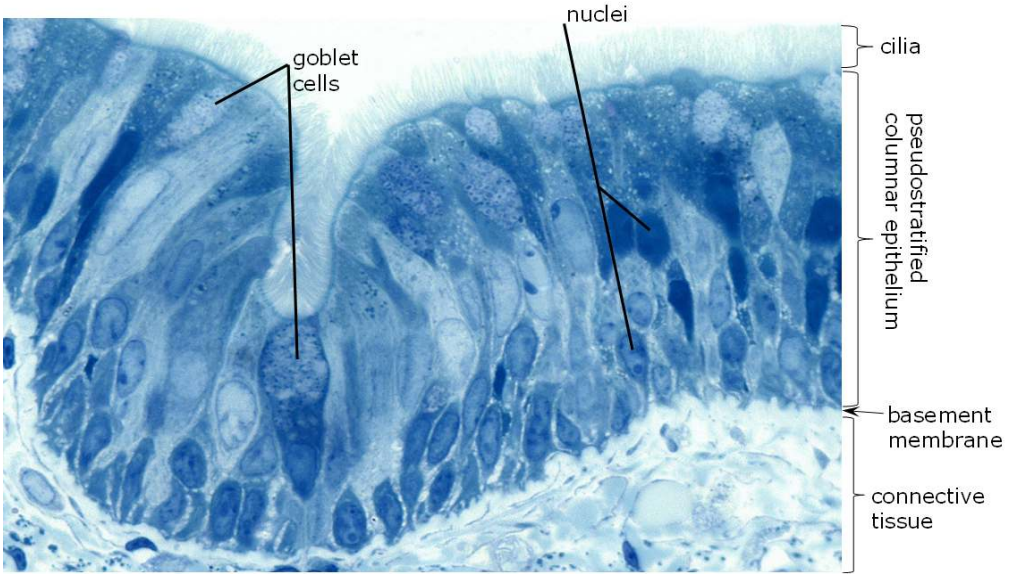
Simple Epithelial Tissues

Simple Epithelial Tissues	Examples of Where they are Found
simple squamous 	• inner lining of blood vessels • alveoli in the lungs • inner lining of lymphatic vessels • inner lining of the heart • inner lining of glomerular capsule in the kidneys • inner lining of some kidney tubules • serous membranes

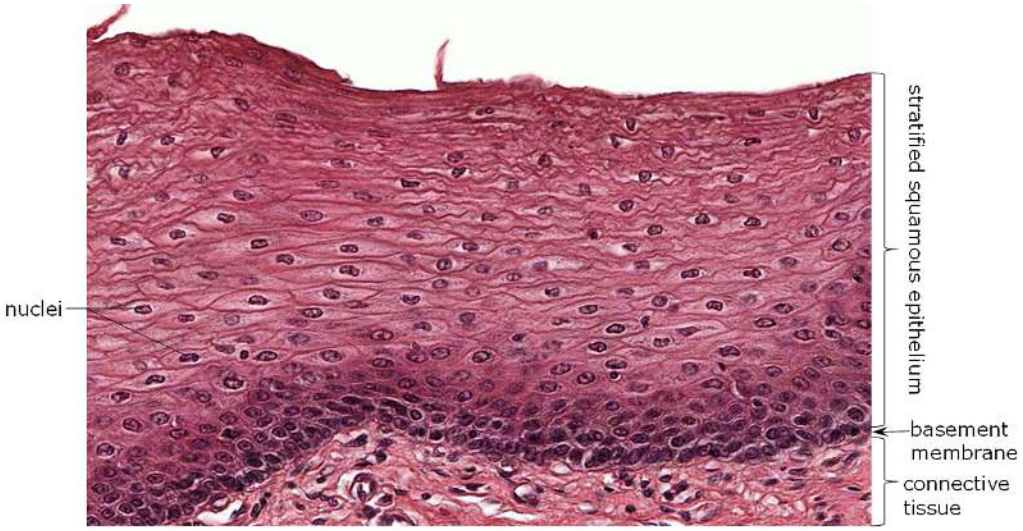
Simple Epithelial Tissues	Examples of Where they are Found
simple cuboidal  	• inner lining of some kidney tubules • inner lining of ducts
simple columnar  	• inner lining of the majority of the digestive tract • inner lining of ducts • lower respiratory tract

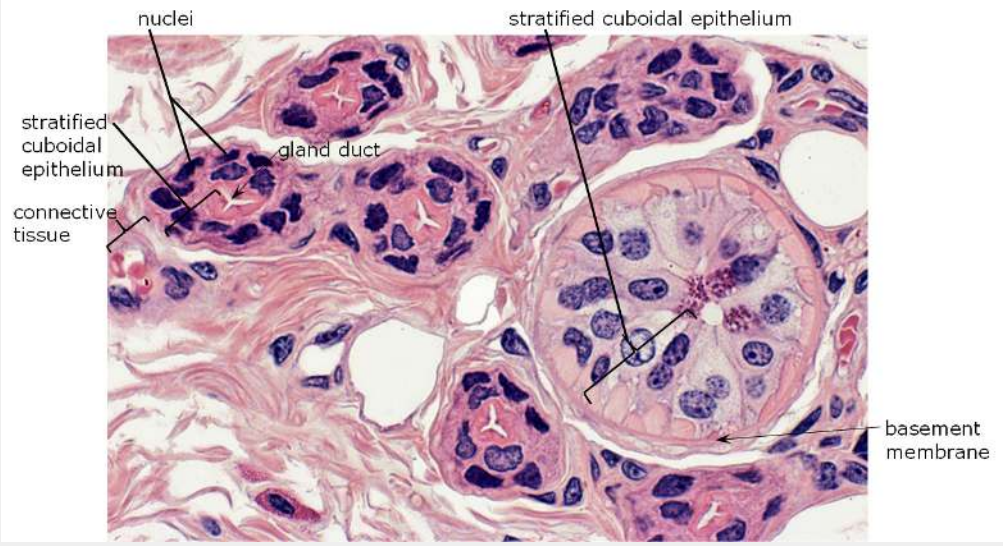
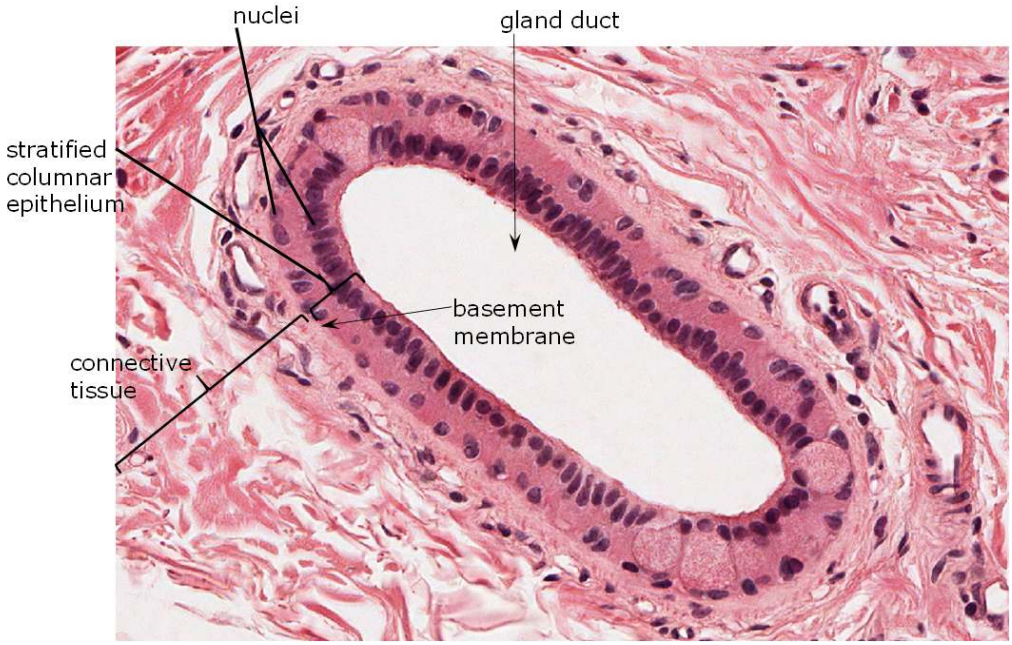
Pseudostratified Epithelial Tissue

Pseudostratified Epithelial Tissue	Examples of Where it is Found

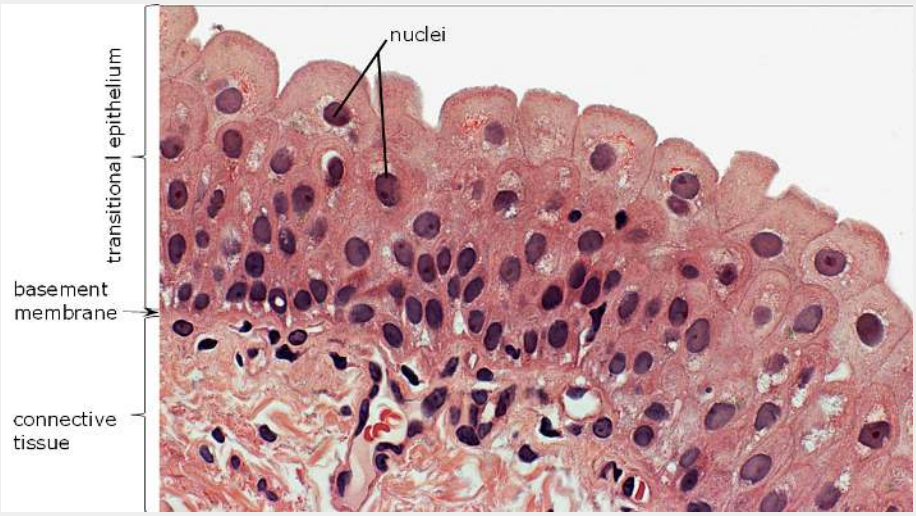
Pseudostratified Epithelial Tissue	Examples of Where it is Found
pseudostratified columnar  	• inner lining of the epididymis (tube that carries sperm) • inner lining of upper respiratory tract

Stratified Epithelial Tissues

Stratified Epithelial Tissues	Examples of Where they are Found
stratified squamous  	• skin surface • inner lining of the vagina • inner lining of the oral cavity and esophagus

Stratified Epithelial Tissues	Examples of Where they are Found
stratified cuboidal  	• uncommon • inner lining the ducts of some glands (e.g. sweat glands)
stratified columnar  	• uncommon • inner lining of the ducts of large glands

https://bio.libretexts.org/@go/page/53571

Stratified Epithelial Tissues	Examples of Where they are Found
transitional - broad cells as shown below when not stretched; cells become smaller when stretched (more like stratified squamous) 	• inner lining of urinary tract (ureters, urinary bladder, urethra)

Attributions

- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0

Updated 2025.

This page titled 5.2: Epithelial Tissues is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

5.3: Connective Tissues

5.3.1 Introduction to Connective Tissues

5.3.2 Connective Tissue Proper

5.3.3 Bone Tissue

5.3.4 Fluid Tissues

5.3.5 Cartilage Tissue

This page titled 5.3: Connective Tissues is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

5.3.1: Introduction to Connective Tissues

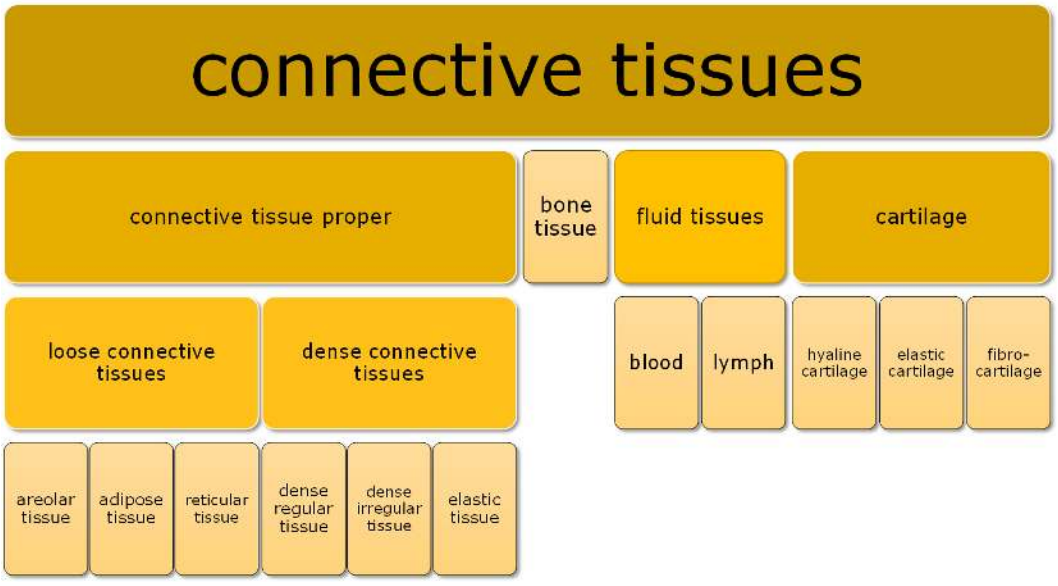
Introduction to Connective Tissues

Connective tissues connect one tissue to one another, acts as support, cushions and insulates, encloses organs, and in some cases stores compounds such as calcium, phosphorous, and fats. Most connective tissues are highly vascular (contain blood vessels). Connective tissue is the most diverse tissue category, and connective tissues can look very different, but they share their embryonic origins as well as 3 main structural characteristics:

1. **cells** - Connective tissues generally have cells that are not tightly connected to each other, the way the cells in epithelial and muscular tissues usually are. There is usually a fair amount of space between the connective tissue cells with one exception to this is adipose tissue (also known as fat tissue). Cells in these tissues are specialized and therefore are given different names such as adipocytes, chondrocytes, osteocytes, and erythrocytes.
2. **protein fibers** - Protein fibers (**collagen** fibers, **elastic** fibers, **reticular** fibers) are complexes of millions of individual proteins threaded into long fibrous structures that provide strength and elasticity to the tissue as a whole. The protein fibers are so large, they are longer than the cells they surround and enmesh. Blood and lymph, being liquid connective tissues, do not have these enmeshing protein fibers, but they still have an extensive liquid extracellular matrix.
3. **ground substance** - The materials between the cells and the protein fibers makes up the component of the tissue called ground substance. The ground substance varies widely by tissue type. For example, the ground substance of blood is the blood plasma or fluid that carries the cells and the protein fibers. Another example is bone that the ground substance is mainly composed of rigid calcium salts (**hydroxyapatite**).

Another term used to describe part of a connective tissue is **matrix**. The matrix is simply the non-cell part of the tissue, in other words, the matrix is composed of the protein fibers and the ground substance.

The diagram below describes the classification of connective tissues. You can see that the connective tissue category is subdivided into **connective tissue proper**, **fluid tissues**, and **cartilage** classifications as well as including **bone tissue**. The connective tissue proper classification is further subdivided based on how dense the cells and matrix are into the **loose connective tissues** and **dense connective tissues** subcategories. The dense connective tissues are further broken into **dense regular connective tissue** (fibers are parallel), **dense irregular connective tissue** (fibers are not parallel), and **elastic connective tissue** (contains a high amount of elastic fibers). There are three different types of cartilage: **hyaline cartilage**, **elastic cartilage**, and **fibrocartilage**. Fluid tissues include **blood** and **lymph**.



Attributions (All Connective Tissues Sections)

- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0
- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0
- "Animal Tissues and Organs" by Berkshire Community College Bioscience Image Library is in the Public Domain, CC0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0
- "Human eye iris 3" by Kamil Saitov is licensed under CC BY 4.0

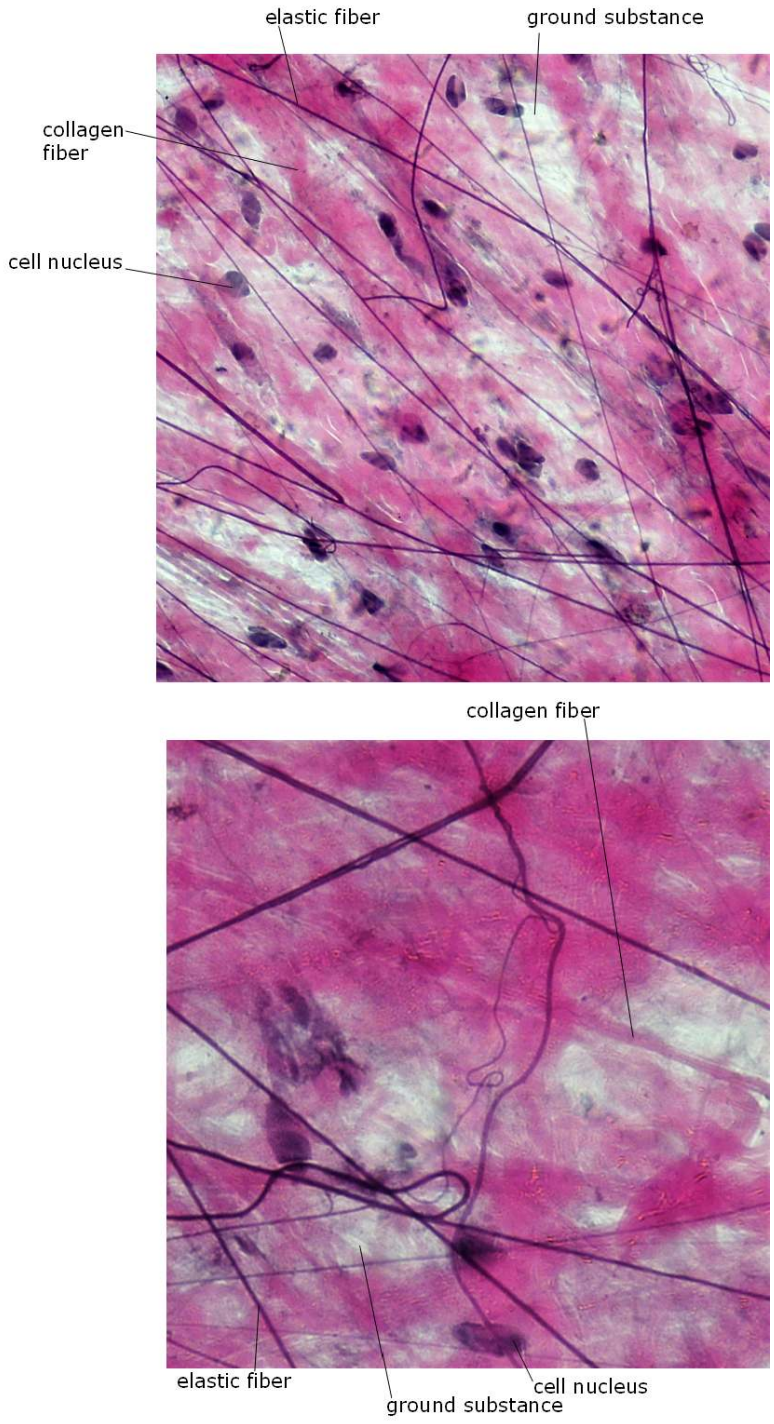
Updated 2025.

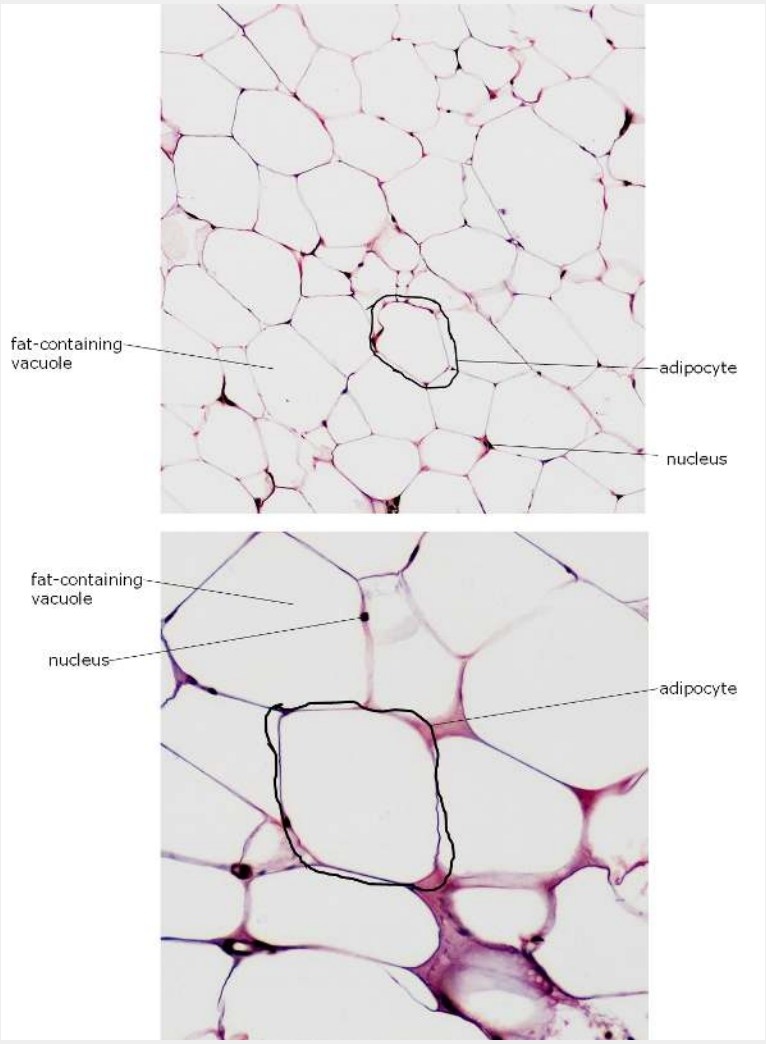
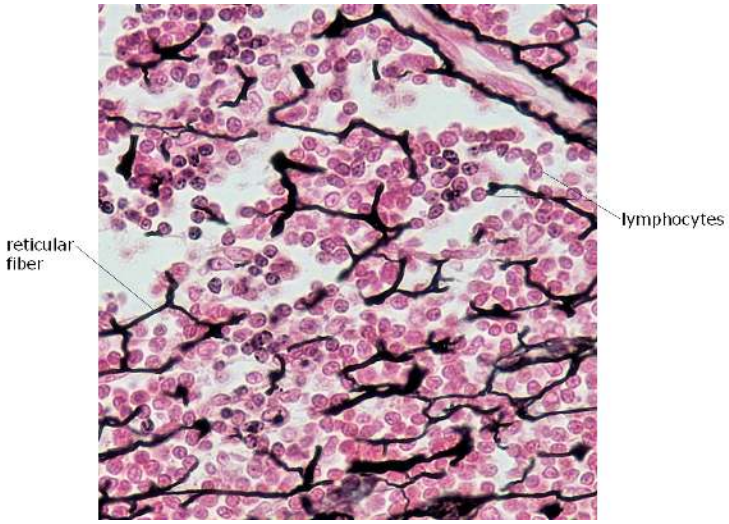
This page titled 5.3.1: Introduction to Connective Tissues is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

5.3.2: Connective Tissue Proper

Connective Tissue Proper

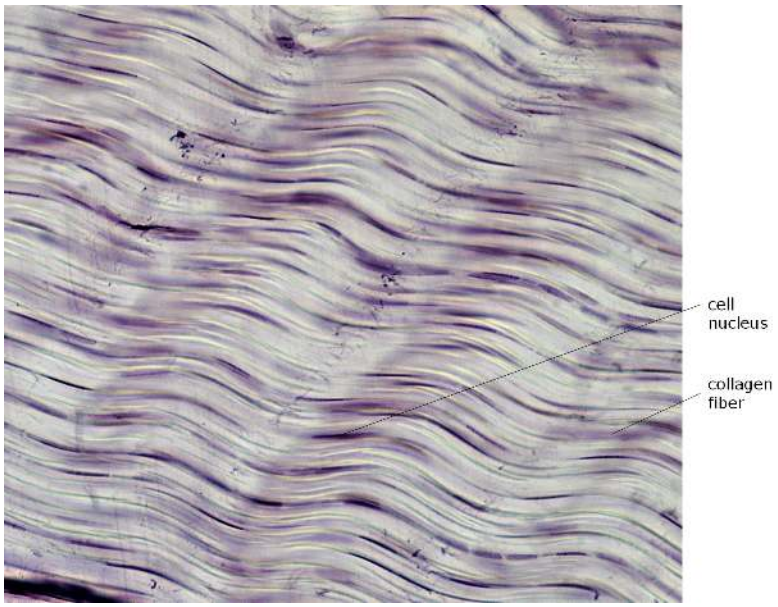
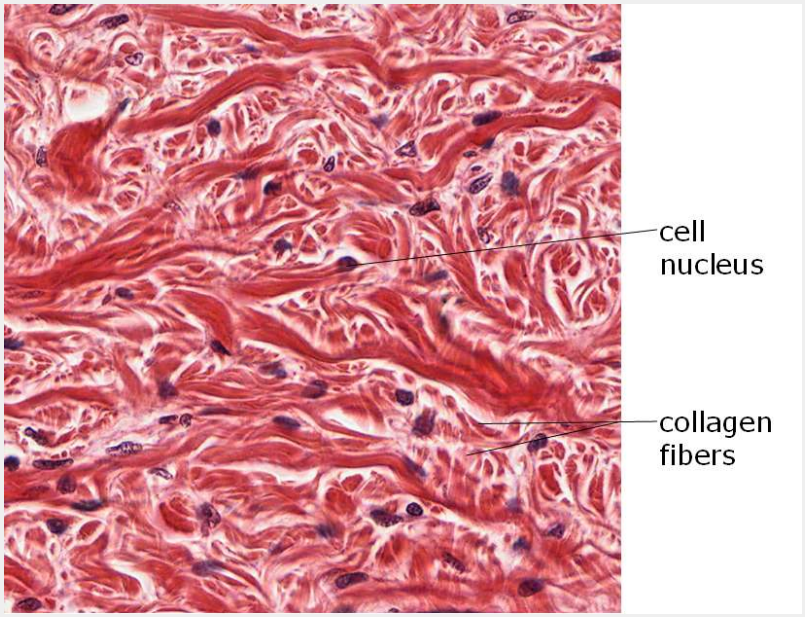
Connective Tissue Proper - Loose Connective Tissue

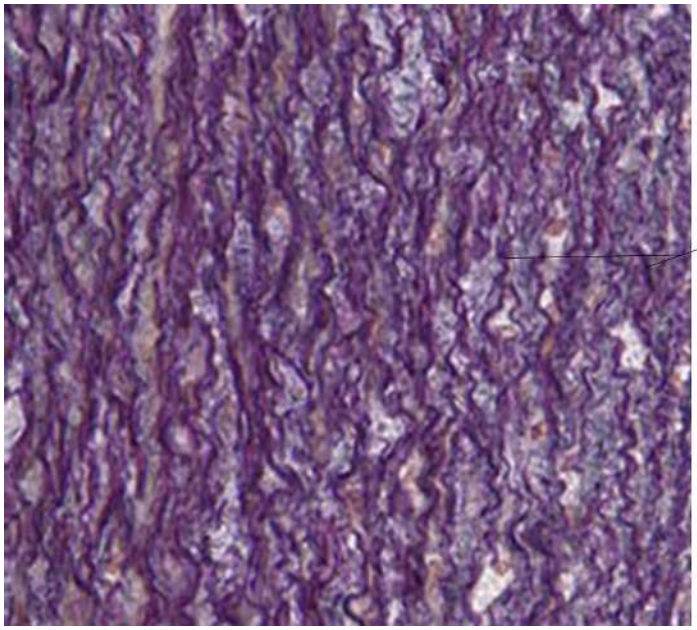
Type of Connective Tissue Proper - Loose	Features & Locations
areolar tissue 	Areolar tissue has many different cell types and a random arrangement of protein fibers with space between the fibers. This tissue fills spaces around the organs and attaches the skin to underlying tissues. Top image is magnified by 200x. Bottom image is magnified by 400x.

Type of Connective Tissue Proper - Loose	Features & Locations
adipose tissue 	Adipose tissue has **adipocytes** filled with very large **fat-containing vacuoles** and very little extracellular matrix. Adipose protects body structures, stores energy in the form of fats (lipids), and insulates. Top image is magnified by 200x. Bottom image is magnified by 400x.
reticular tissue 	Reticular tissue is composed of a network of reticular fibers and is found in lymphatic tissue, bone marrow, and the liver. Tissue is magnified by 400x.

https://bio.libretexts.org/@go/page/53903

Connective Tissue Proper - Dense Connective Tissue

Type of Connective Tissue Proper - Dense	Features & Locations
dense regular tissue  	Dense regular connective tissues are composed of fibers regularly arranged in one direction including tendons and most ligaments. Elastic fibers are more prevalent in the ligaments of the vertebrae. Tissue is of a tendon. Tissue is magnified by 200x.
dense irregular tissue  	Dense irregular connective tissues have fibers organized in many directions and is found as capsules of organs and in the dermis of skin. Tissue is magnified by 400x.

Type of Connective Tissue Proper - Dense	Features & Locations
elastic  	Dense elastic connective tissues contain elastic fibers providing more stretch. These tissues are found in the large arteries such as the aorta.

Attributions (All Connective Tissues Sections)

- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0
- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0
- "Animal Tissues and Organs" by Berkshire Community College Bioscience Image Library is in the Public Domain, CC0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0
- "Human eye iris 3" by Kamil Saitov is licensed under CC BY 4.0

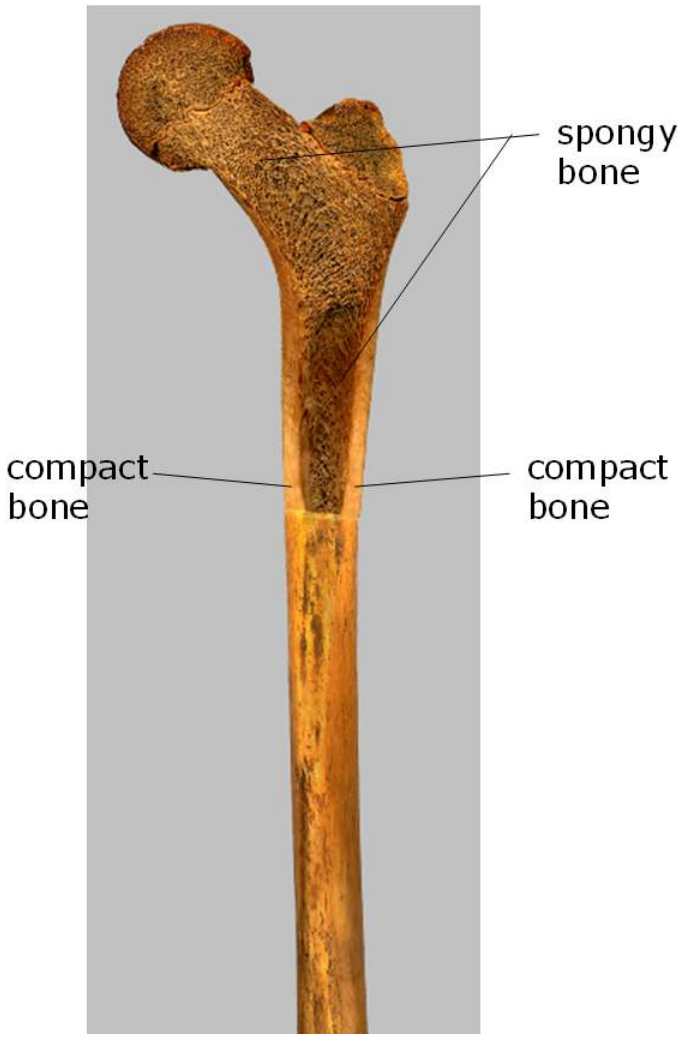
Updated 2025.

This page titled 5.3.2: Connective Tissue Proper is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

5.3.3: Bone Tissue

Bone Tissue

There are two types of bone: **spongy bone** has spaces between bony **trabeculae** (slender needle-like structures) filled with bone marrow, and **compact bone** which is more solid and composed of functional units called **osteons**.



Above: A femur (hip to knee) bone with a partial frontal section. Compact bone is located on the outer layers of the bone, particularly along the shaft. The interior of the bone is composed of spongy bone where bone marrow is located in the pockets between the trabeculae of bone.

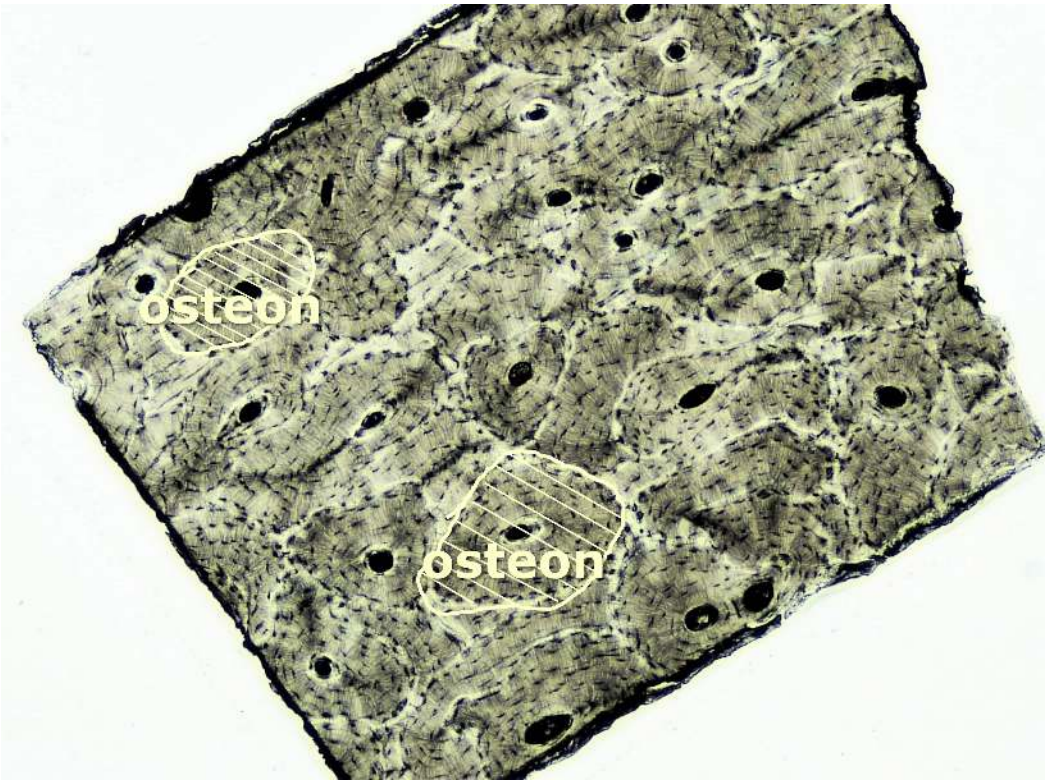
The bone cells, or **osteocytes**, are located in **lacunae** (a space or gap inside the tissue; sing. **lacuna**). Osteocytes are protected from the extracellular matrix that surrounds them by being housed in **lacunae**, which are spaces free of mineralized extracellular matrix. Bone has mainly collagen protein fibers in and a ground substance rich in a mineralized calcium phosphate compound known as **hydroxyapatite**. The hydroxyapatite that surrounds the mostly collagen protein fibers in the ground substance of bone is not soluble in water and forms a mineral solid in which both the bone cells and the collagen fibers are embedded. It is usually difficult to see the collagen fibers in the extracellular matrix of bone due to the density of the ground substance that surrounds them. There are four types of bone cells: **osteoprogenitor cells**, **osteoblasts**, **osteoclasts**, and **osteocytes**. **Osteocytes** are the most abundant and the only ones found throughout the bone.

Osteocytes have numerous cytoplasmic extensions that project off of the main cell body. These extension connect up with the extensions from other nearby osteocytes. These projections, like the osteocyte cell body, are in tiny spaces free of the mineralized

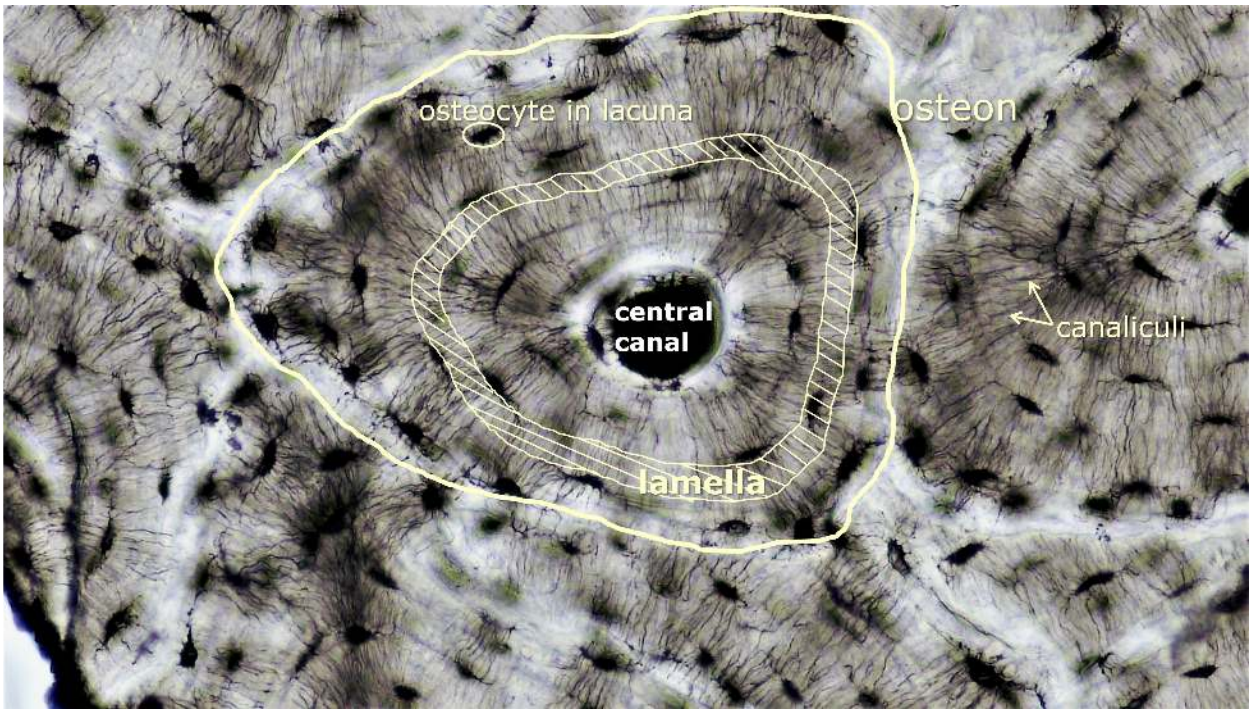
extracellular matrix. These spaces (but not the cytoplasmic projections themselves) are called **canaliculi** (singular: **canaliculum**) because, under the microscope, they look like tiny little canals.

Compact Bone

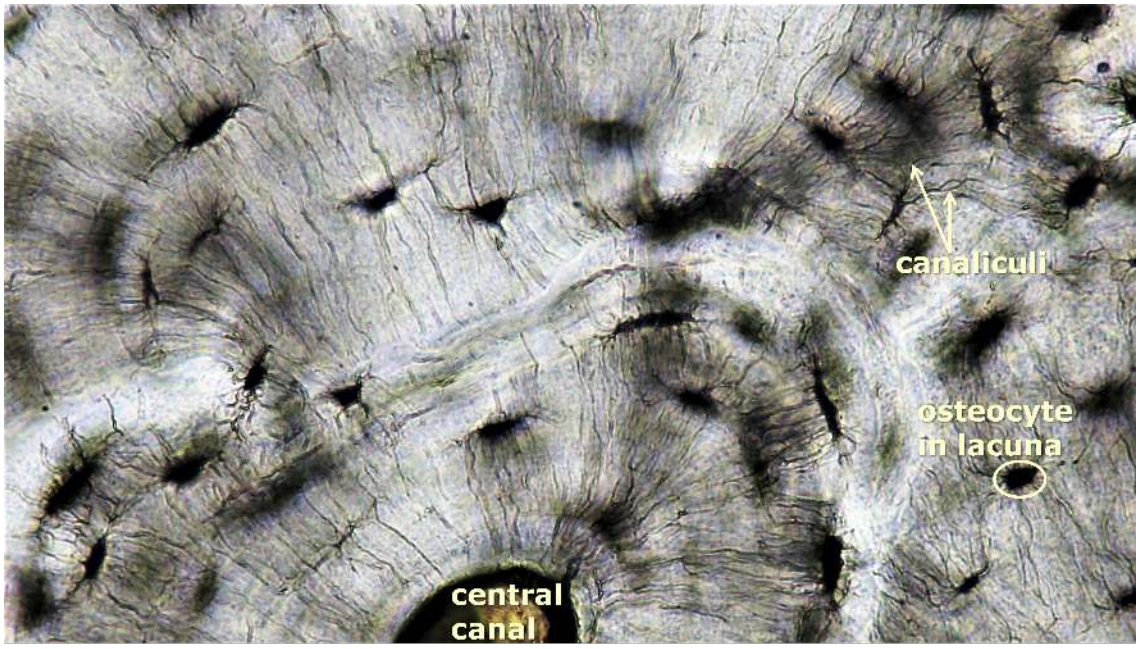
Osteocytes are inside of **lacunae** (hollow spaces) located in concentric circles of mineralized extracellular matrix. Each circle is called a **lamella** (plural: lamellae) and the osteocytes are found along the edges of each lamella. In compact bone, groups of lamellae and osteocytes are arranged into individual **osteons,** the cylindrical arrangement of material that makes up the fundamental building block of the compact bone. Each osteon has a hollow **central canal** in its center that blood vessels and nerves can travel through.



Above: Compact bone. Tissue is magnified by 40x.



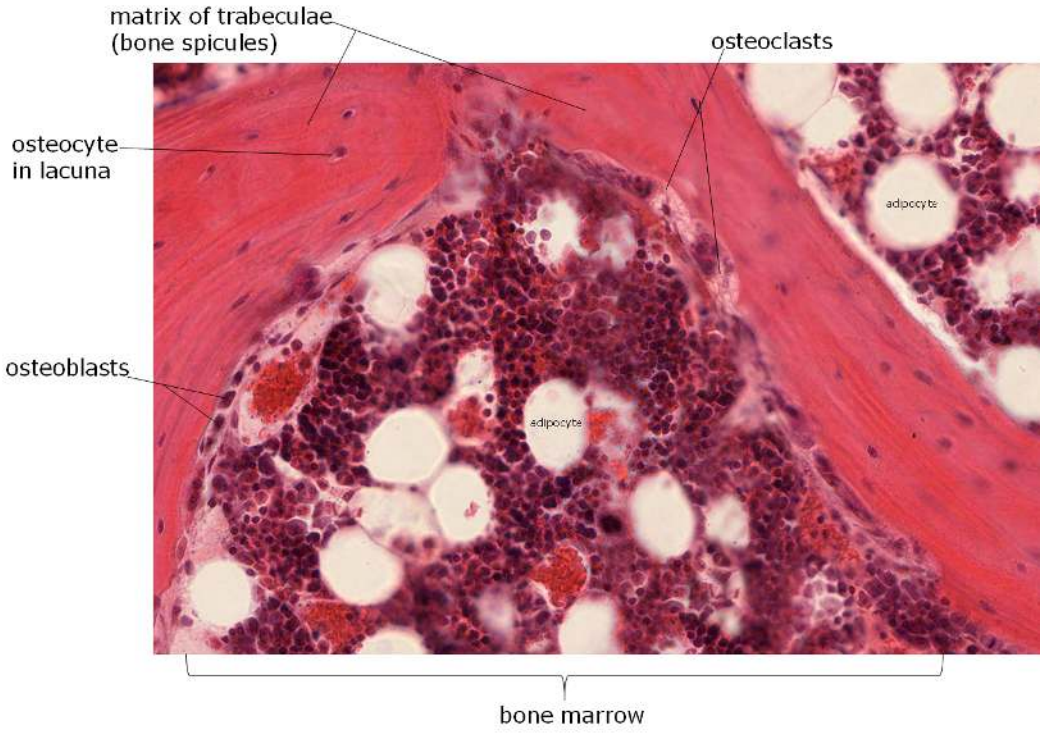
Above: Compact bone. Tissue magnified by 200x.



Above: Compact bone. Tissue is magnified by 400x.

Spongy Bone

In spongy bone, groups of lamellae are arranged into **trabeculae** (singular: trabecula), which are the individual projections of spongy bone. Trabeculae do not have central canals. Bone marrow surrounding the trabeculae store fats and produce new blood cells, a process called **hematopoiesis**.



Above: Spongy bone tissue (trabeculae) with pockets of bone marrow surrounding it. Tissue is magnified by 400x.

Attributions (All Connective Tissues Sections)

- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0
- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0
- "Animal Tissues and Organs" by Berkshire Community College Bioscience Image Library is in the Public Domain, CC0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0
- "Human eye iris 3" by Kamil Saitov is licensed under CC BY 4.0

Updated 2025.

This page titled 5.3.3: Bone Tissue is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

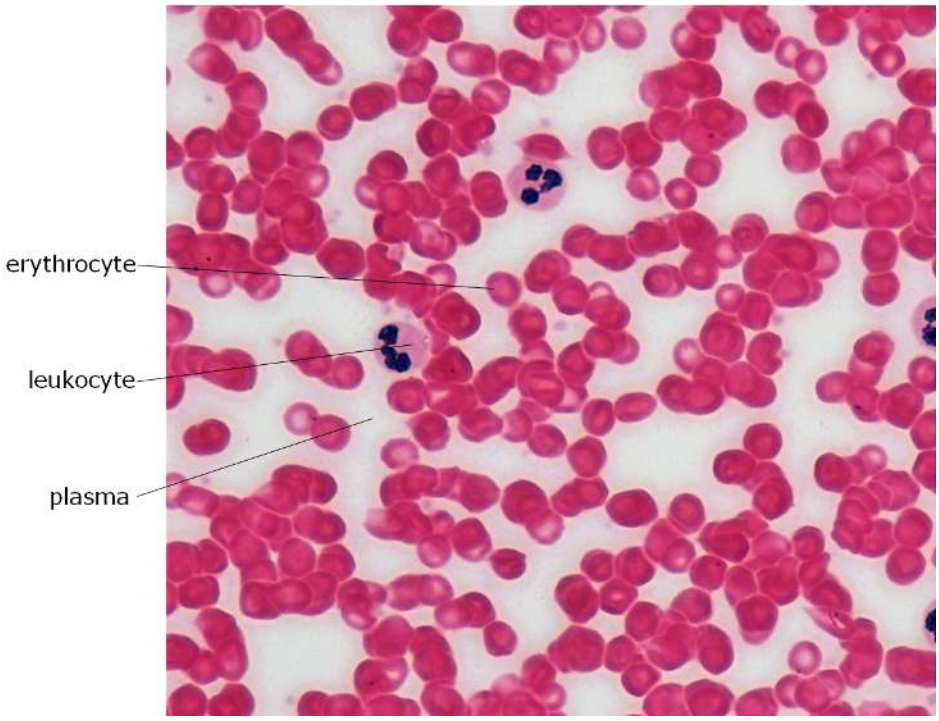
5.3.4: Fluid Tissues

Fluid Tissues

Blood and lymph are the two types of connective tissue in the "fluid tissues" sub-category. Both are fluid, rather than solid, and both lack the network of extracellular protein fibers found in the other types of connective tissue. As fluid tissues, these tissues circulate and move throughout the human body.

Blood

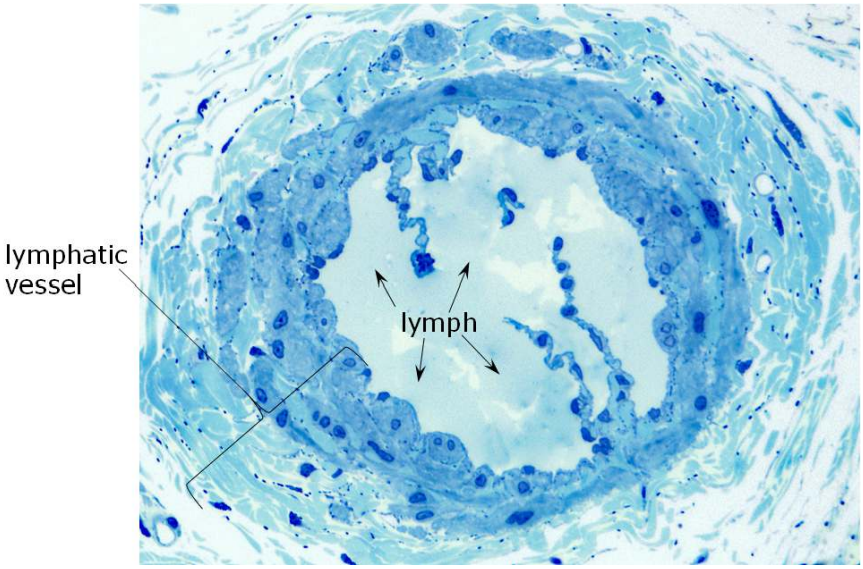
The blood has a fluid matrix (**plasma**) and specialized cells or formed elements of the blood: red blood cells (**erythrocytes**), white blood cells (**leukocytes**), and cell fragments called **platelets**. The primary function of blood is to deliver oxygen (O_2) and nutrients to and remove wastes from body cells, but that is only the beginning of the story. The specific functions of blood also include defense, distribution of heat, and maintenance of homeostasis. Mature erythrocytes lack organelles, including a nucleus, so they can accommodate a high concentration of **hemoglobin**, a protein that carries O_2 and CO_2. Hemoglobin carries O_2 from the lungs to body cells which use O_2 to make ATP (energy-rich molecule) in the process of cellular respiration. Hemoglobin also carries CO_2 from body cells to the lungs to dispose of this waste product of the cellular respiration process. Leukocytes are involved in immune responses and platelets are important for **blood clotting**.



Above: Blood. Tissue is magnified by 400x.

Lymph

Lymph is the fluid located in the lymphatic vessels and contain **lymphocytes**. Lymphocytes are the primary cells of adaptive immune responses. The two basic types of lymphocytes, B cells and T cells, are identical morphologically with a large central nucleus surrounded by a thin layer of cytoplasm. They are distinguished from each other by their surface protein markers, by the molecules they secrete, where they mature (B cells mature in the bone marrow; T cells mature in the thymus), and the functions they serve in the adaptive immune responses (B cells are involved in humoral immunity and T cells are involved in cell-mediated immunity).



Above: Cross section of a lymphatic vessel containing lymph. Lymphocytes are not distinguishable in this image. Tissue is magnified by 400x.

Attributions (All Connective Tissues Sections)

- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0
- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0
- "Animal Tissues and Organs" by Berkshire Community College Bioscience Image Library is in the Public Domain, CC0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0
- "Human eye iris 3" by Kamil Saitov is licensed under CC BY 4.0

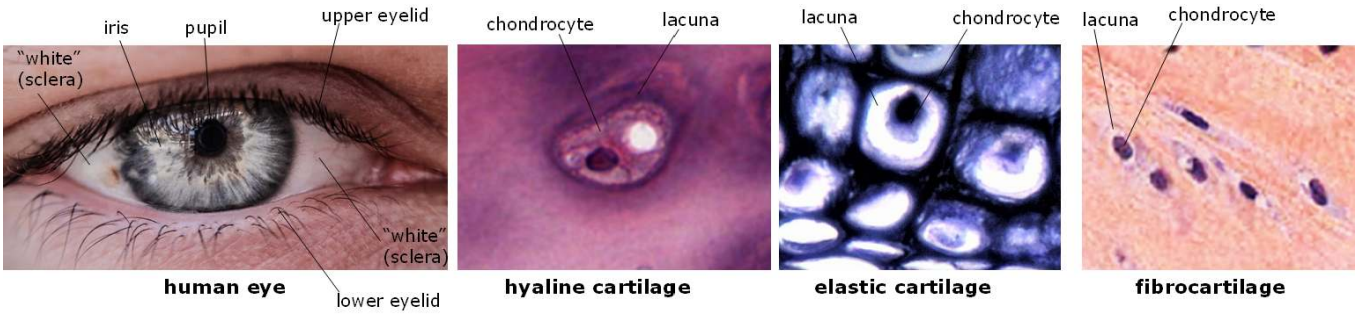
Updated 2025.

This page titled 5.3.4: Fluid Tissues is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

5.3.5: Cartilage Tissues

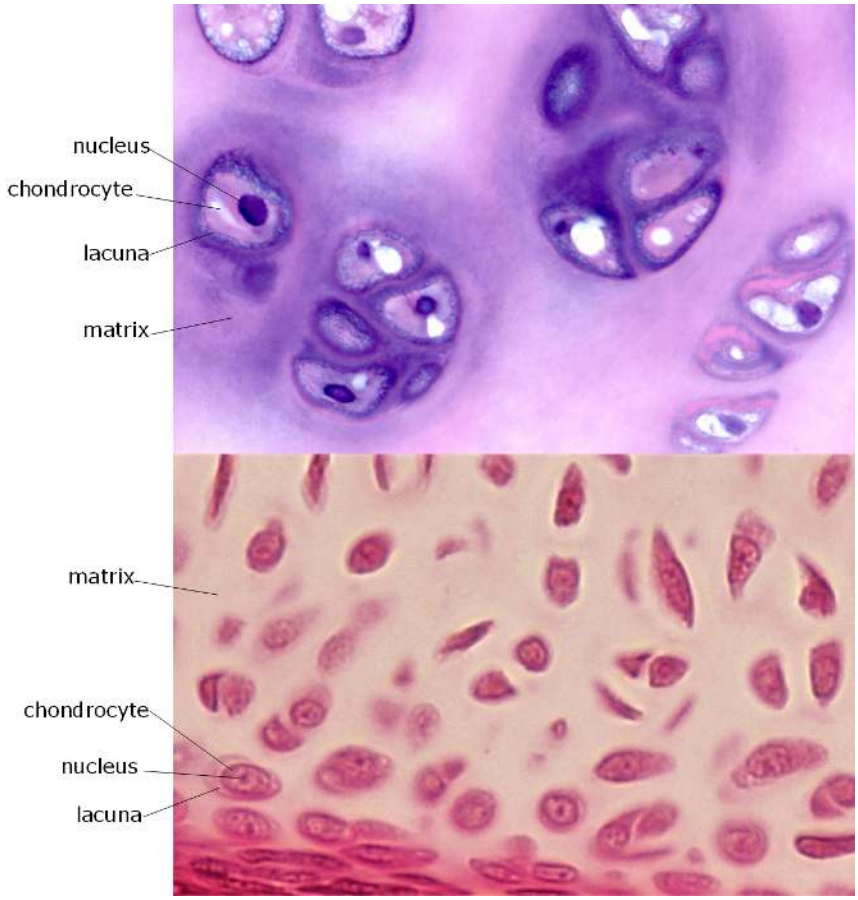
Cartilage Tissues

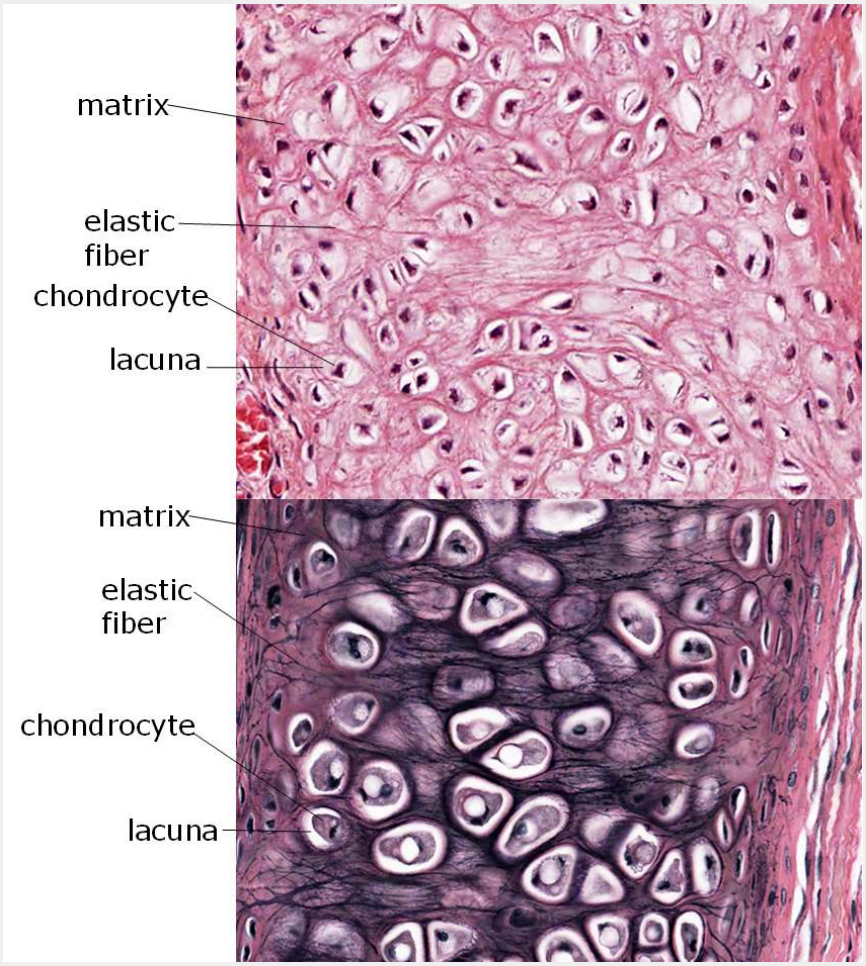
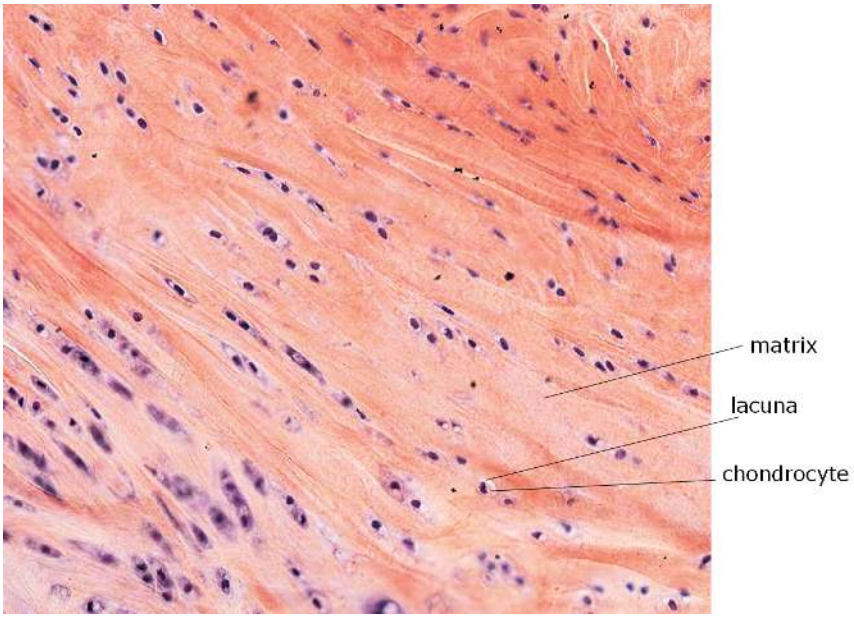
There is only one type of cell in cartilage, **chondrocytes**. They secrete and maintain the extracellular matrix of the tissue. Chondrocytes arise from **mesenchymal stem cells**, just like the fibroblasts of connective tissue proper do, but chondrocytes are specialized to produce just cartilage. The extracellular matrix produced by the chondrocytes is so tough and durable, the chondrocytes are in danger of being crushed by it. This is why chondrocytes always leave a region around themselves free of the cartilaginous extracellular matrix that makes up the rest of the tissue. These non-cartilaginous pockets around each chondrocyte are called **lacunae** and are clearly visible when examining cartilage under the microscope. Cartilage is distinctive compared to other types of connective tissues since the chondrocytes inside lacunae appear similar to a human eye. When examining a type of tissue, if you see an eye-like structure, it is probably a type of cartilage. Lacunae appear similar to the upper and lower eyelids and the white of a human eye and a chondrocytes appear as the iris and pupil of a human eye.



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

Type of Cartilage	Features & Locations

Type of Cartilage	Features & Locations
hyaline cartilage (two different stains shown) 	Hyaline cartilage is the most prevalent type, forming articular cartilages and the framework for parts of the nose, larynx, and trachea. The lack of blood vessels in hyaline cartilage means that nutrients and wastes must diffuse through the tissue, thus limiting the thickness of the hyaline cartilage. Top tissue is magnified by 1000x. Bottom tissue is magnified by 400x.
elastic cartilage (two different stains shown)	Elastic cartilage and its surrounding perichondrium form the cartilaginous, flexible framework in the pinna of the external ear. Elastic cartilage also forms the framework for the epiglottis and several of the smaller laryngeal cartilages. Chondrocytes in elastic cartilage are larger and more numerous than in hyaline cartilage and form fewer isogenous groups. The extracellular matrix of elastic cartilage is less abundant than in hyaline cartilage. With a special stain, elastic fibers are more readily visible (bottom image). Tissues are magnified by 400x.

Type of Cartilage	Features & Locations
	
fibrocartilage 	Fibrocartilage, the strongest of the cartilages, blends the strength of dense connective tissue with that of cartilage: obvious collagen fiber bundles (dense connective tissue) and a flexible, non-compressible ground substance (cartilage). Fibrocartilage exists in isolated pockets where extra strength is needed, rather than as an independent cartilage; therefore, it has no perichondrium. Fibrocartilage is frequently seen as a transition from dense connective tissue when greater strength is needed, as in the **pubic symphysis** and the **intervertebral discs**. Fibrocartilage forms a cushion between bones of the knee, where resistance to compression and to forces from multiple directions are needed. Under these conditions, collagen bundles are arranged irregularly, making this type of fibrocartilage easy to confuse with dense irregular connective tissue. Tissue magnified by 400x.

Attributions (All Connective Tissues Sections)

- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0
- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0
- "Animal Tissues and Organs" by Berkshire Community College Bioscience Image Library is in the Public Domain, CC0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0
- "Human eye iris 3" by Kamil Saitov is licensed under CC BY 4.0

Updated 2025.

This page titled 5.3.5: Cartilage Tissues is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

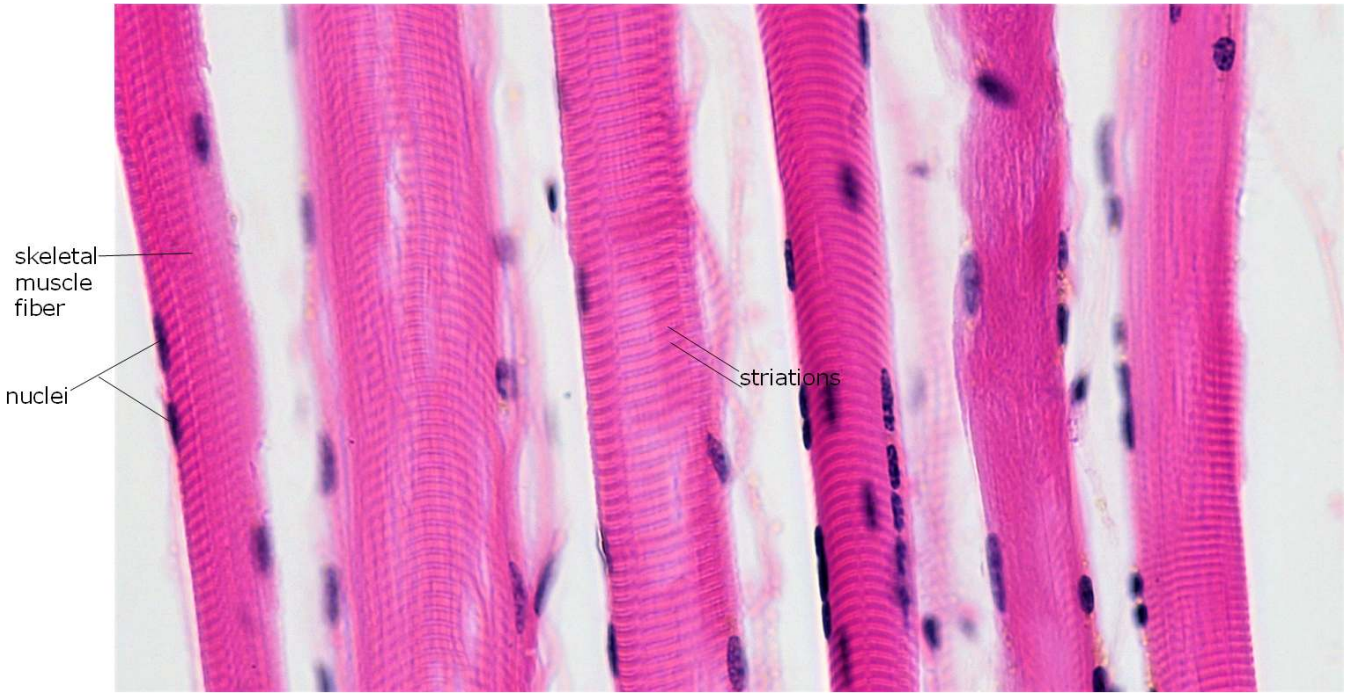
5.4: Muscle Tissues

Muscle Tissues

Muscle tissues are responsible for movements. Muscle tissue is subdivided into three broad categories: **skeletal** muscle, **cardiac** muscle, and **smooth** muscle. The three types of muscle can be distinguished by both their locations and their microscopic features.

Skeletal Muscle Tissue

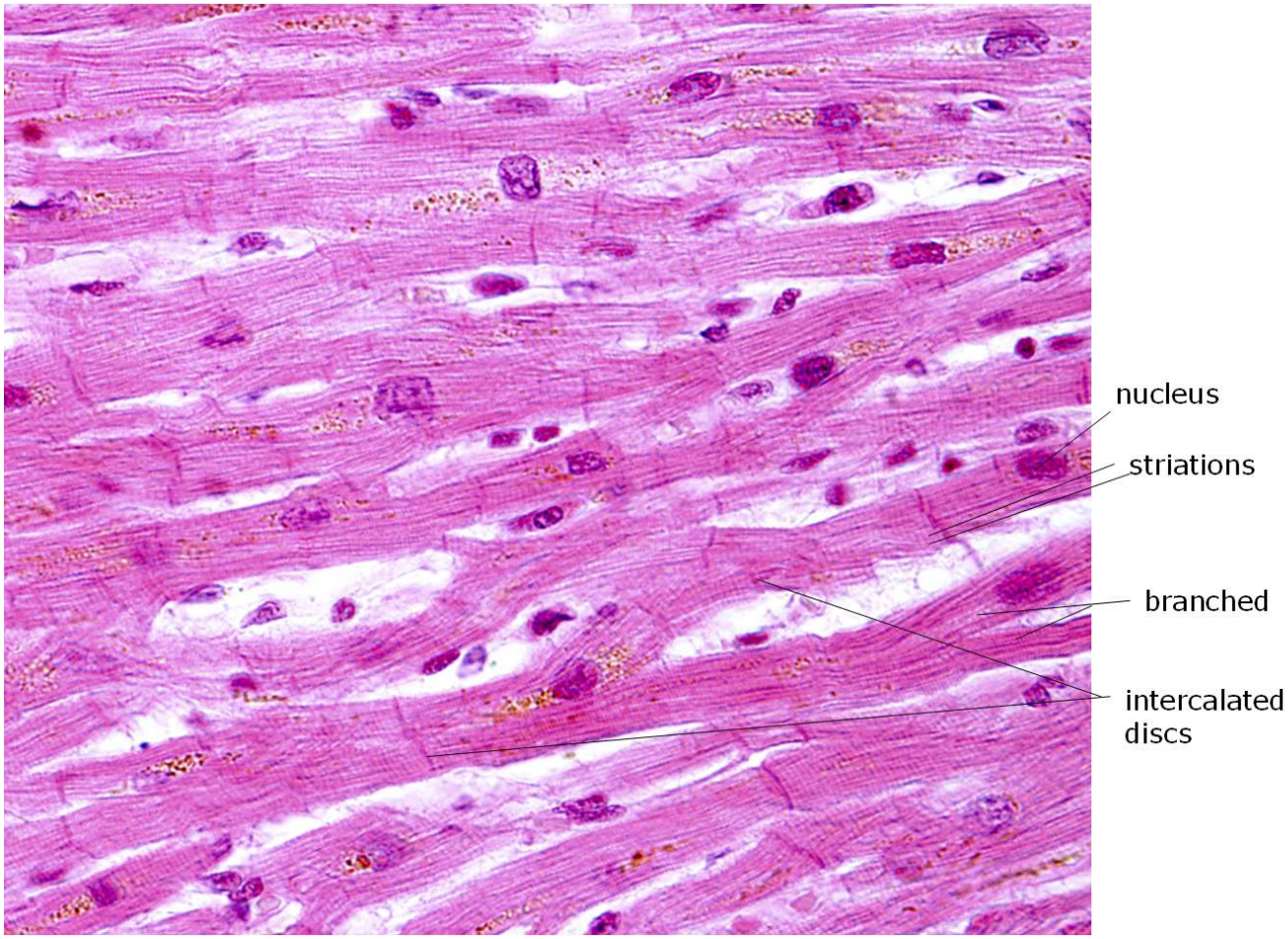
Skeletal muscle is largely found attached to bones. It consists of long **multinucleate** (cells that contain multiple nuclei) fibers. The fibers run the entire length of the muscle they come from and so are usually too long to have their ends visible when viewed under the microscope. The fibers are relatively wide and very long, but **unbranched**. The nuclei are usually up against the edge of the fiber. There are **striations** (different colored stripes) in skeletal muscle. These are alternating dark and light bands perpendicular to the edge of the fiber that are present all along the fiber.



Above: Skeletal muscle, teased, longitudinal view. Tissue magnified by 200x.

Cardiac Muscle Tissue

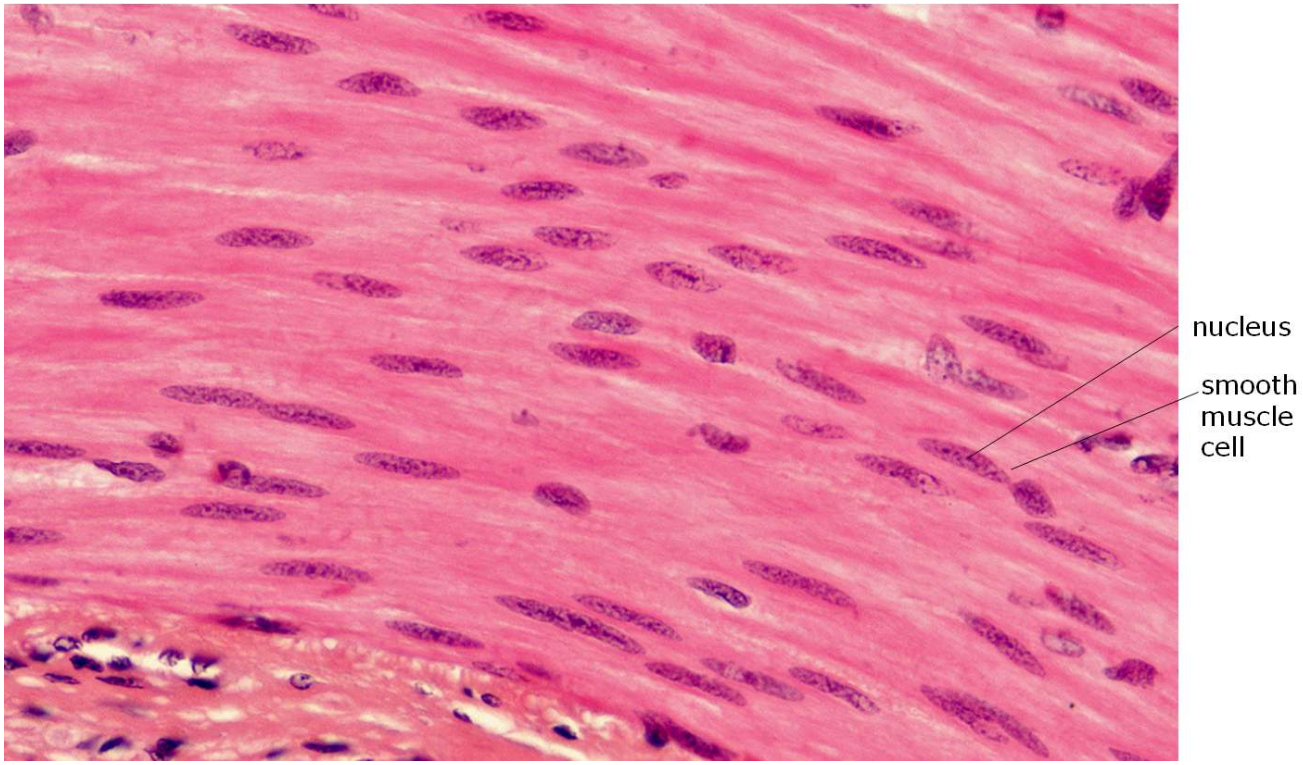
Cardiac muscle is only found in the heart. Its fibers are longer than they are wide, and they are **striated**, like skeletal muscle fibers. But, unlike skeletal muscle fibers, cardiac muscle fibers have distinct ends to them, called **intercalated discs**. These are dark lines that run from one side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



Above: Cardiac muscle, longitudinal view. Tissue magnified by 400x

Smooth Muscle Tissue

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



Above: Smooth muscle, longitudinal view. Tissue magnified by 1000x

Attributions

- "Animal Tissues and Organs" by Berkshire Community College Bioscience Image Library is in the Public Domain, CC0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0

Updated 2025.

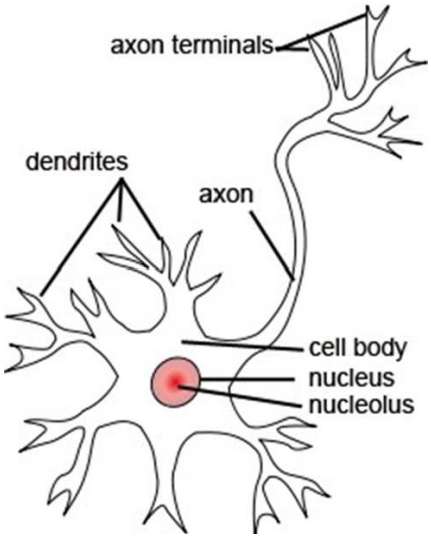
This page titled 5.4: Muscle Tissues is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

5.5: Nervous Tissues

Nervous Tissues

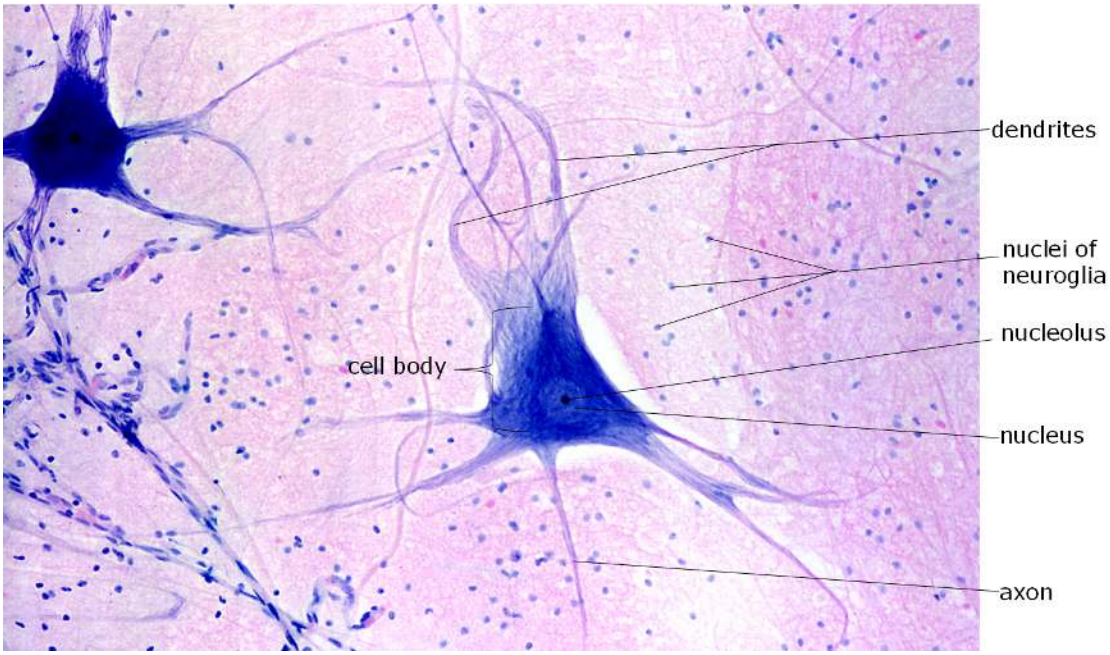
Nervous tissue is the last of the four major categories of human tissue. Nervous tissue comprises **neurons**, the cells specialized for sending signals to other neurons or cells receiving signals (e.g. muscles) through the propagation of electrochemical signals. **Neuroglia** are the so-called "supporting cells" in nervous tissue that support neurons in a variety of ways. There are multiple types of neuroglia cells (sometimes called just **glial cells**), and most of them do assist neurons, but recent research has discovered that some of the neuroglia cells play an active role by themselves in the proper functioning of the central and peripheral nervous systems. It is turning out that neuroglia do more than just support neurons.

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



Above: A generalized illustration of a neuron.

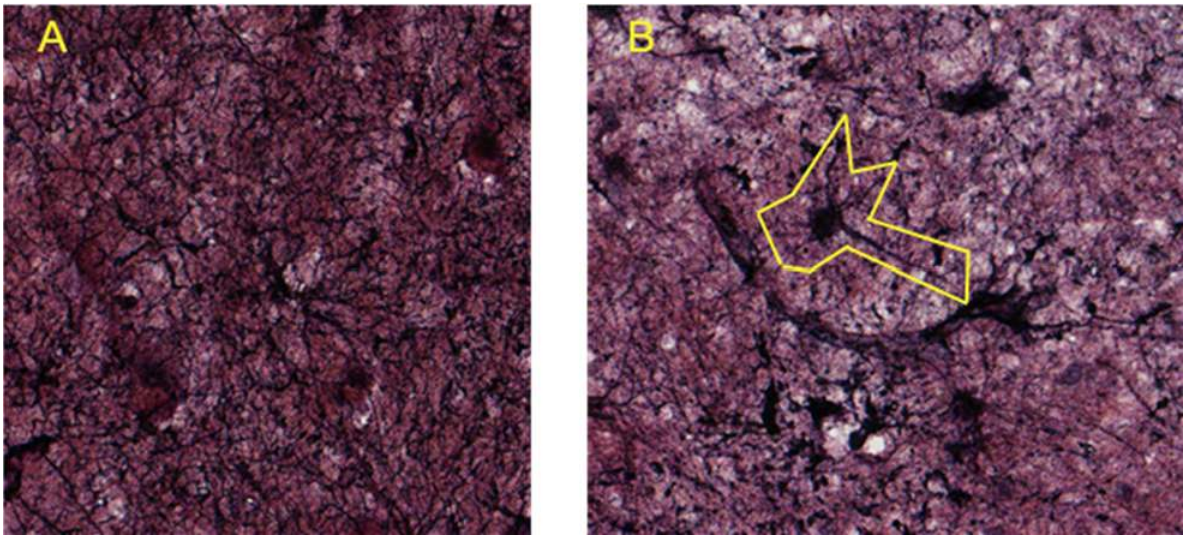
All of the structural features shown above are important to the functioning of neurons. The cell body is where most of the cellular processes of the neuron take place: protein synthesis, metabolism, etc. The dendrites contact and pick up signals coming in from other cells (other neurons or sensory cells).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



Above: Nervous tissue. Tissue is magnified by 200x.

What's more, nervous tissue is delicate and fragile. In creating preparations for slides to viewed under a microscope, some of the cells are squished together, damaged, truncated, or torn. Other times, the nervous tissue cells are simply too densely packed together to make out individual details. Much of what is visible is not useful to the student looking to find an intact and well-defined neuron. However, a bit of searching will often reveal some intact neurons. Often these are found at the edges of the preparation where the material is least dense. Keep in mind, you will often see neurons shaped distinctly different from those shown in the neuron illustration above.

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



Above: Two different areas from the same slide of a nervous tissue preparation. In A, the neurons are too crowded to see any one neuron clearly. In B, the neuron outlined in yellow illustrates a typical dendrite-cell body- axon arrangement.

Attributions

- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0

Updated 2025.

This page titled 5.5: Nervous Tissues is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

5.6: Laboratory Activities and Assignment

Laboratory Activities and Assignment

Part 1: Review of Tissues

Epithelial Tissues

1. Where will you always find epithelial tissues?

2. What functions do simple epithelial tissues have?

3. What functions do stratified epithelial tissues have?

4. Describe how to differentiate each type of epithelial tissue in the table below:

Type of epithelial tissue	Describe how to Differentiate this Tissue Type
simple squamous epithelium	
simple cuboidal epithelium	
simple columnar epithelium	
pseudostratified columnar epithelium	
stratified squamous epithelium (non-keratinized)	
stratified squamous epithelium (keratinized)	
stratified cuboidal epithelium	
stratified columnar epithelium	
transitional epithelium	

Connective Tissues

1. List 3 characteristic of connective tissue.

2. List the four categories of connective tissues.

Muscle Tissues

1. List the characteristics of skeletal muscle.

2. List the characteristics of smooth muscle.

3. List the characteristics of cardiac muscle.

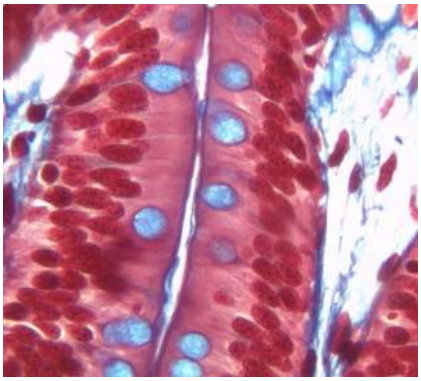
Nervous Tissues

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

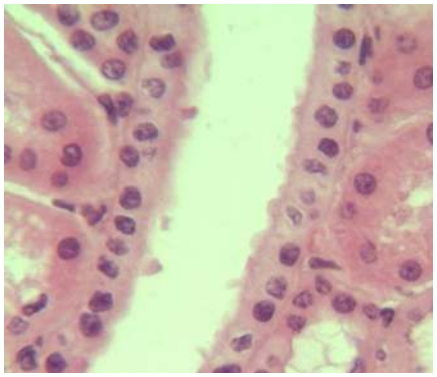
2. Create an illustration of a neuron from the images in Chapter 5. Label the cell body, axon, dendrites, and nucleus.

Tissue Identification

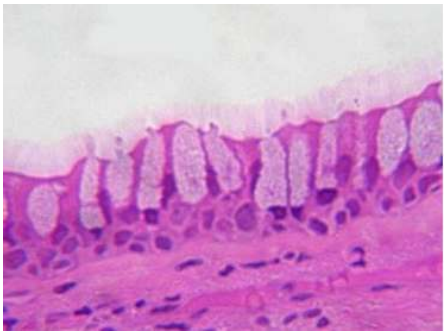
1. For each microscopic tissue image below, give the category of the tissue shown (epithelial, connective, muscle, or nervous) and give the name of the specific tissue shown.



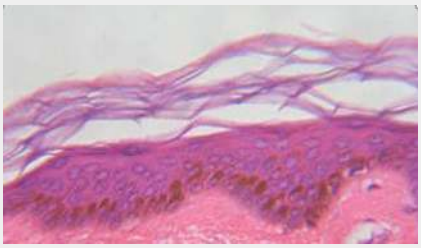
Tissue category:
Tissue name:



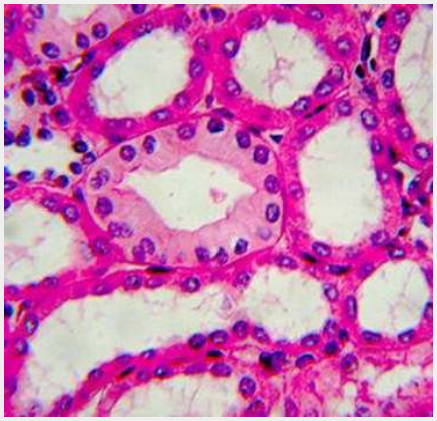
Tissue category:
Tissue name:



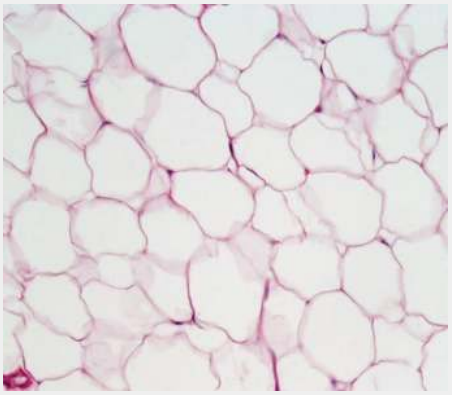
Tissue category:
Tissue name:



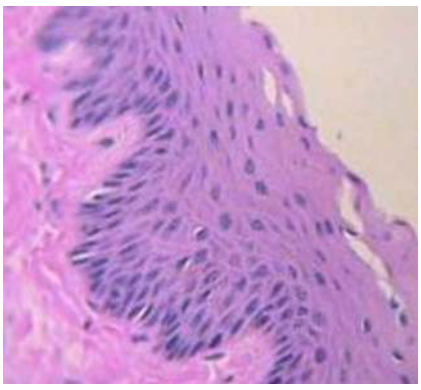
Tissue category:
Tissue name:



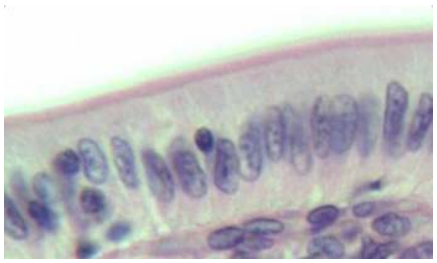
Tissue category:
Tissue name:



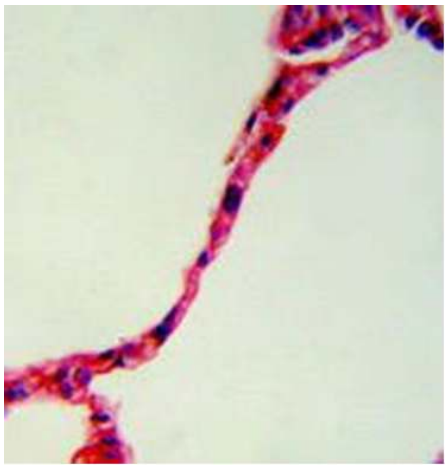
Tissue category:
Tissue name:



Tissue category:
Tissue name:

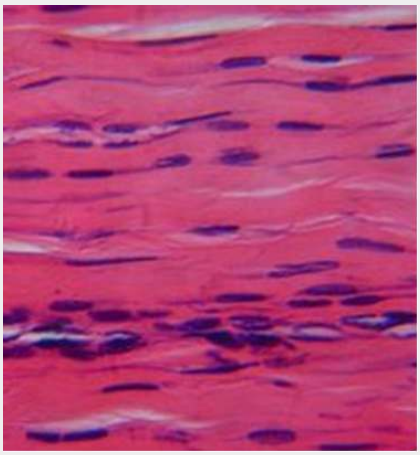


Tissue category:
Tissue name:

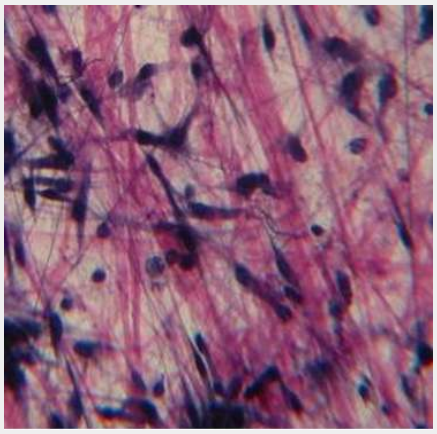


Tissue category:
Tissue name:

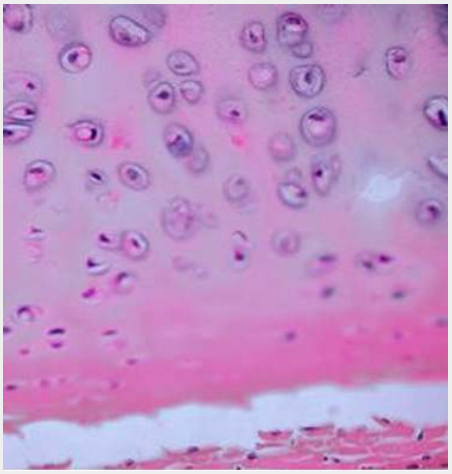
https://bio.libretexts.org/@go/page/53580



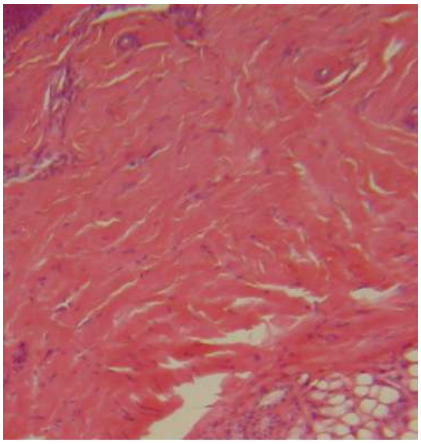
Tissue category:
Tissue name:



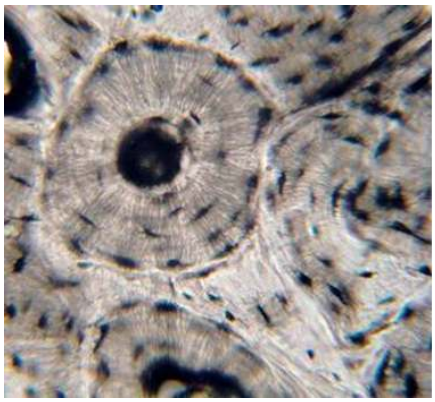
Tissue category:
Tissue name:



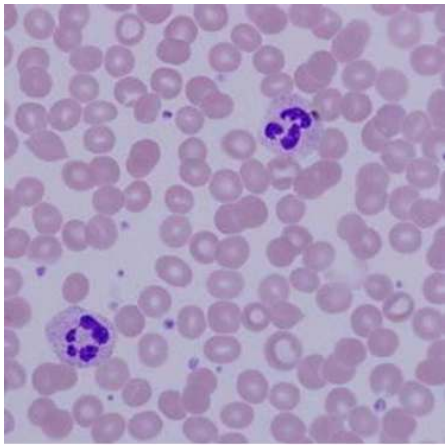
Tissue category:
Tissue name:



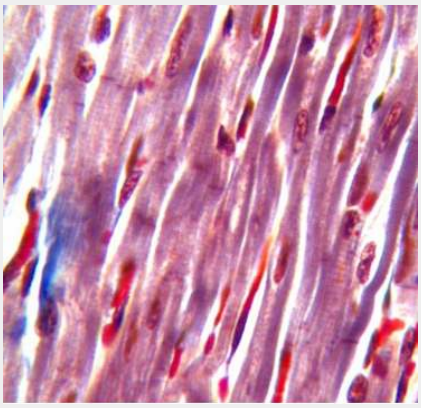
Tissue category:
Tissue name:



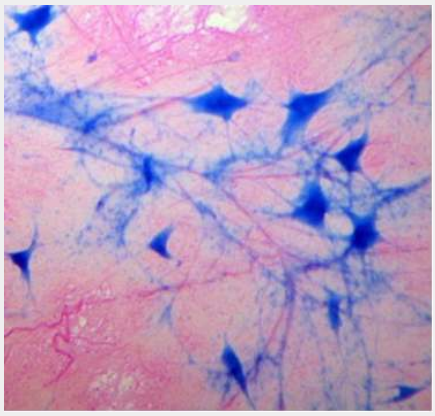
Tissue category:
Tissue name:



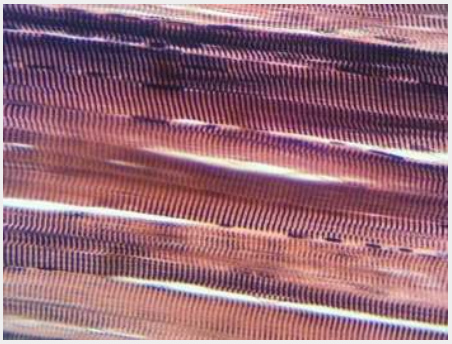
Tissue category:
Tissue name:



Tissue category:
Tissue name:



Tissue category:
Tissue name:



Tissue category:
Tissue name:

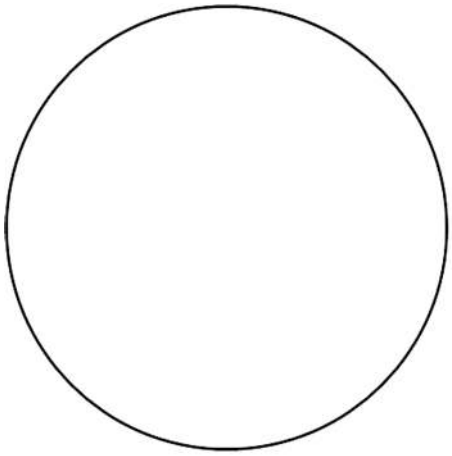
https://bio.libretexts.org/@go/page/53580

Part 2: Examining, Illustrating, and Labeling Epithelial Tissues

1. Obtain the slides listed below that are available for today's lab.
2. Focus on each sample and identify the structures listed for each type of tissue.
3. Indicate the **total** magnification you make each illustration at in the space provided.
4. Illustrate each tissue you observe with the microscope at the magnification you listed.
5. Label each illustration with the structures listed for each.

Simple Squamous Epithelium (Slide: Lung or Kidney)

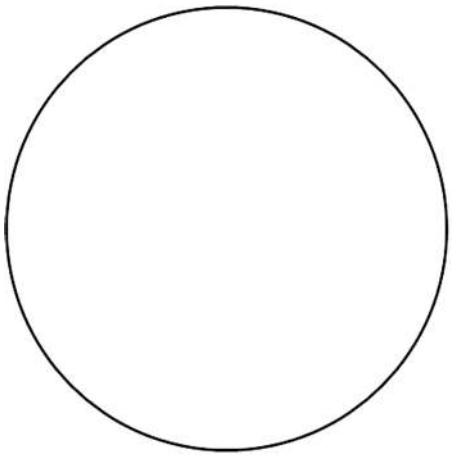
Label the tissue with: squamous cell, nucleus of squamous cell, simple squamous epithelium, basement membrane, connective tissue



Total magnification: _____

Stratified Squamous Epithelium (Slide: Skin or Stratified Squamous Epithelium

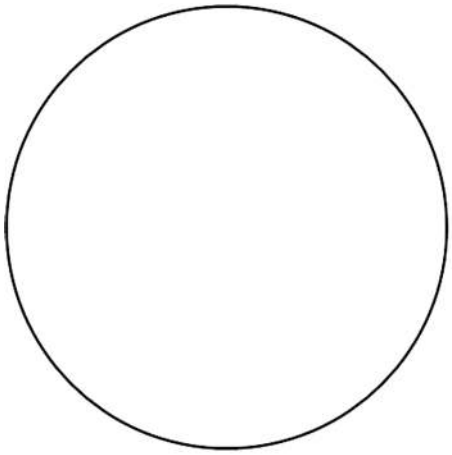
Label the tissue with: squamous cell, nucleus of squamous cell, stratified squamous epithelium, basement membrane, connective tissue



Total magnification: _____

Simple Cuboidal Epithelium (Slide: Simple Cuboidal Epithelium or Kidney Tubules)

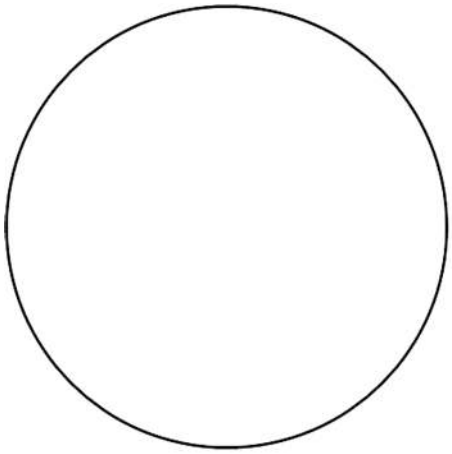
Label the tissue with: cuboidal cell, nucleus of cuboidal cell, simple cuboidal epithelium, basement membrane, connective tissue



Total magnification: _____

Simple Columnar Epithelium (Slide: Simple Columnar Epithelium or Small Intestine)

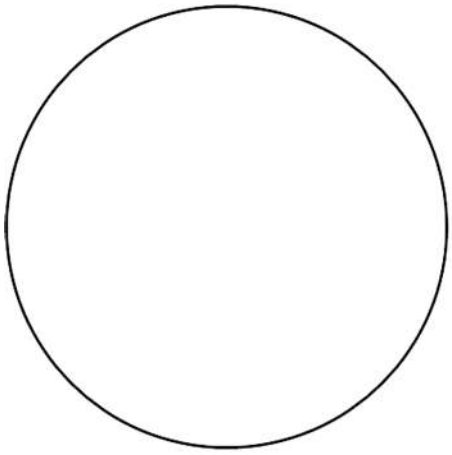
Label the tissue with: columnar cell, nucleus of columnar cell, simple columnar epithelium, basement membrane, goblet cell, connective tissue



Total magnification: _____

Pseudostratified Columnar Epithelium (Slide: Pseudostratified Ciliated Columnar Epithelium)

Label the tissue with: columnar cell, nucleus of columnar cell, pseudostratified columnar epithelium, cilia, basement membrane, connective tissue



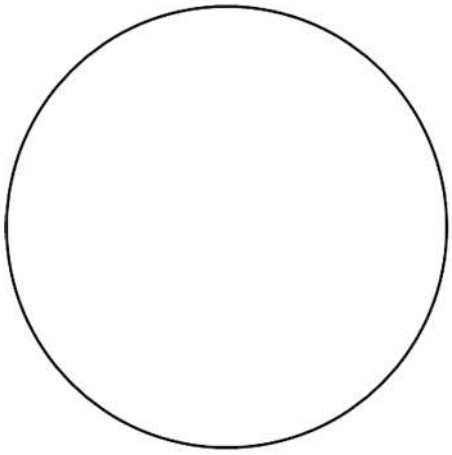
Total magnification: _____

Part 3: Examining, Illustrating, and Labeling Connective Tissues

1. Obtain the slides listed below that are available for today's lab.
2. Focus on each sample and identify the structures listed for each type of tissue.
3. Indicate the **total** magnification you make each illustration at in the space provided.
4. Illustrate each tissue you observe with the microscope at the magnification you listed.
5. Label each illustration with the structures listed for each.

Connective Tissue Proper - Loose - Areolar Tissue (Slide: Areolar Tissue)

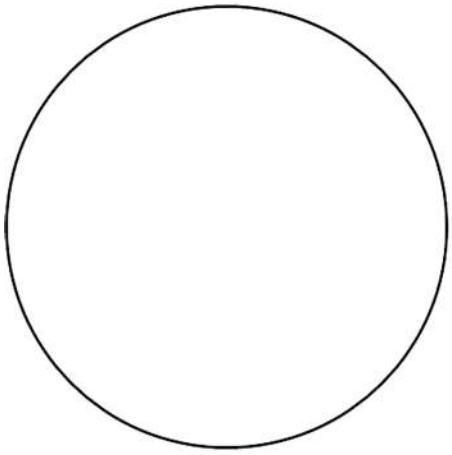
Label the tissue with: nucleus of fibroblast (cell type), collagen fibers, elastic fibers, ground substance



Total magnification: _____

Connective Tissue Proper - Loose - Adipose Tissue (Slide: Adipose Tissue)

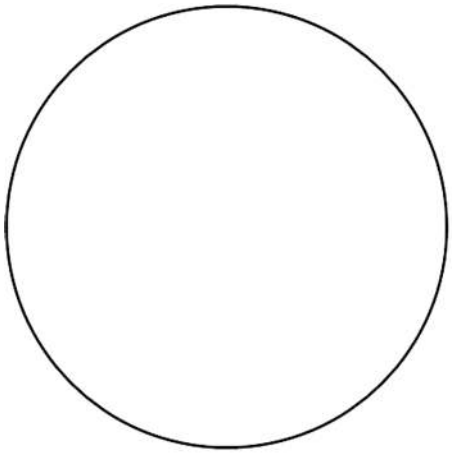
Label the tissue with: adipocyte, nucleus of adipocyte, fat-containing vacuole



Total magnification: _____

Connective Tissue Proper - Loose - Reticular Tissue (Slide: Reticular Tissue)

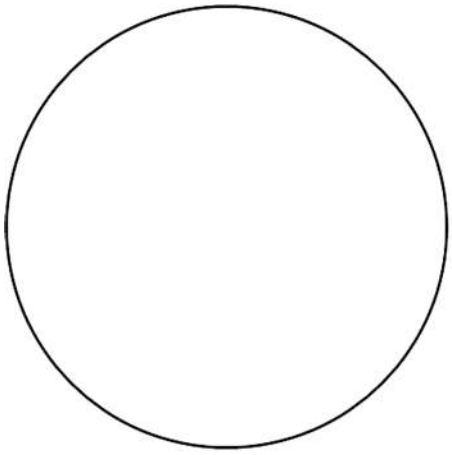
Label the tissue with: lymphocytes, reticular fibers



Total magnification: _____

Connective Tissue Proper - Dense - Regular (Slide: Tendon)

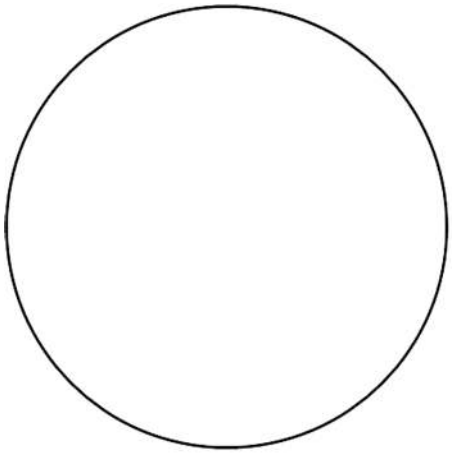
Label the tissue with: nucleus of fibroblast (cell), collagen fibers



Total magnification: _____

Connective Tissue Proper - Dense - Irregular (Slide: Skin)

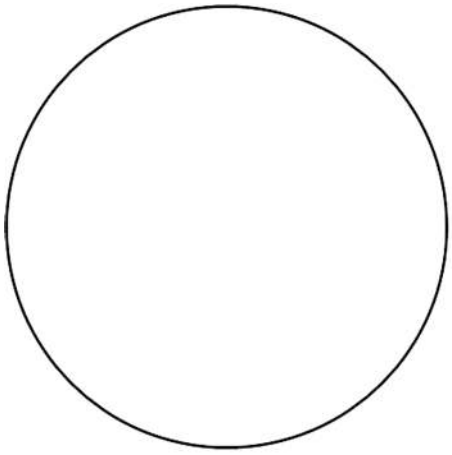
Label the tissue with: cell nucleus, collagen fibers



Total magnification: _____

Cartilage - Hyaline Cartilage (Slide: Hyaline Cartilage)

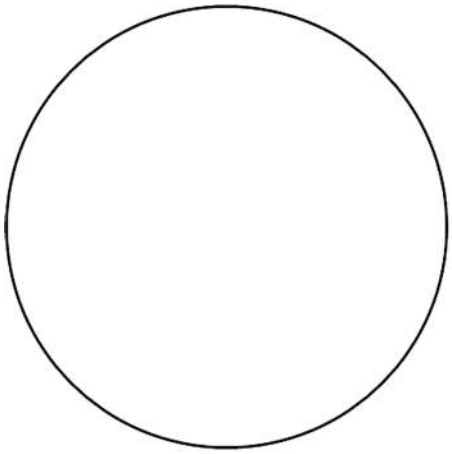
Label the tissue with: chondrocyte, lacuna, matrix



Total magnification: _____

Cartilage - Elastic Cartilage (Slide: Elastic Cartilage)

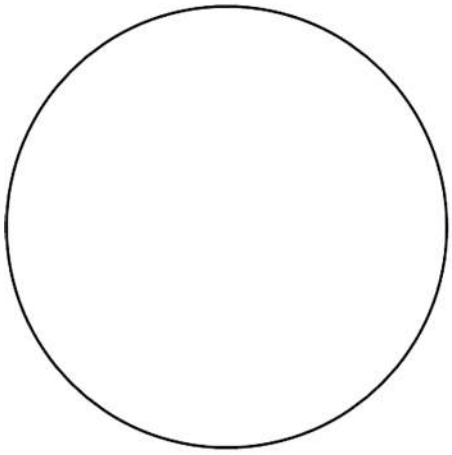
Label the tissue with: chondrocyte, lacuna, elastic fibers, matrix



Total magnification: _____

Cartilage - Fibrocartilage (Slide: Fibrocartilage)

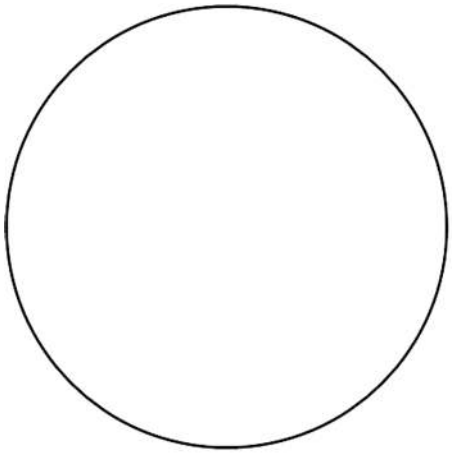
Label the tissue with: chondrocyte, lacuna, collagen fibers



Total magnification: _____

Compact Bone Tissue (Slide: Dry Bone Ground)

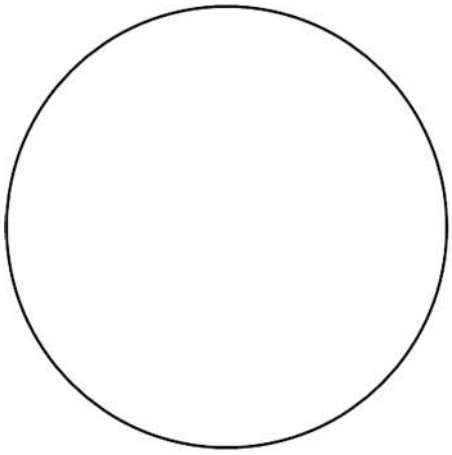
Label the tissue with: osteon, lamella, osteocyte in lacuna, central canal, canaliculi



Total magnification: _____

Fluid Tissue - Blood (Slide: Human Blood)

Label the tissue with: erythrocyte, plasma, leukocyte



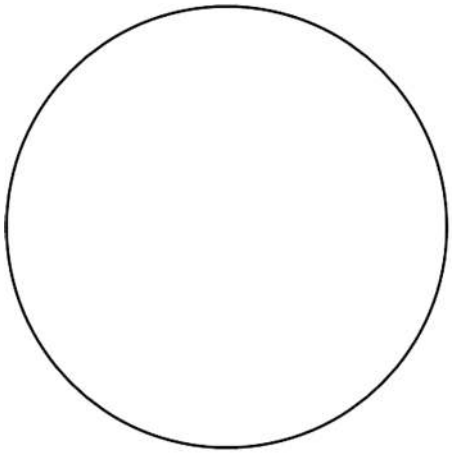
Total magnification: _____

Part 4: Examining, Illustrating, and Labeling Muscle Tissues

1. Obtain the slides listed below that are available for today's lab.
2. Focus on each sample and identify the structures listed for each type of tissue.
3. Indicate the **total** magnification you make each illustration at in the space provided.
4. Illustrate each tissue you observe with the microscope at the magnification you listed.
5. Label each illustration with the structures listed for each.

Skeletal Muscle (Slide: Skeletal Muscle)

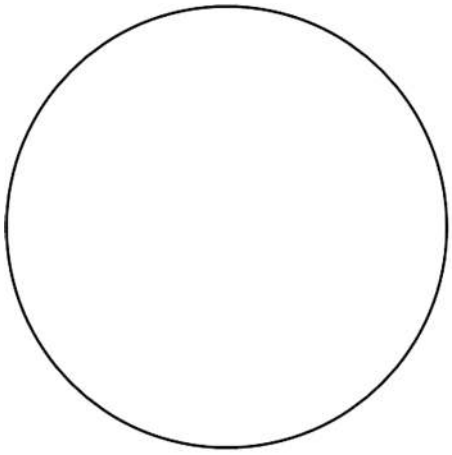
Label the tissue with: muscle fiber, nucleus, striations



Total magnification: _____

Cardiac Muscle (Slide: Cardiac Muscle)

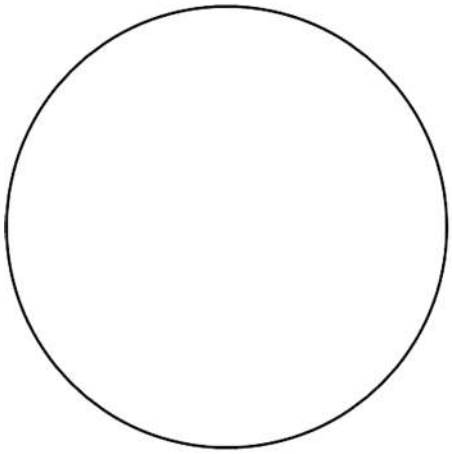
Label the tissue with: striations, cell nucleus, intercalated disc, branch



Total magnification: _____

Smooth Muscle (Slide: Smooth Muscle)

Label the tissue with: smooth muscle cell, cell nucleus



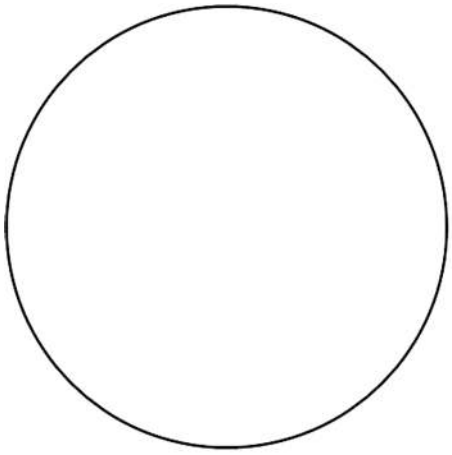
Total magnification: _____

Part 5: Examining, Illustrating, and Labeling Nervous Tissue

1. Obtain the slide listed below that is available for today's lab.
2. Focus on the sample and identify the structures listed for this type of tissue.
3. Indicate the **total** magnification you make the illustration at in the space provided.
4. Illustrate the tissue you observe with the microscope at the magnification you listed.
5. Label the illustration with the structures listed.

Nervous Tissue (Slide: Giant Multipolar Neuron Smear)

Label the tissue with: neuron, cell body of neuron, dendrites, axon, nucleus of neuron, nuclei of neuroglia



Total magnification: _____

Attributions

Part 1: Review of Tissues

- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0
- "Anatomy and Physiology Lab Homework" by Laird C Sheldahl is licensed under CC BY-SA 4.0

Part 2: Examining, Illustrating, and Labeling Epithelial Tissues

- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0

Part 3: Examining, Illustrating, and Labeling Connective Tissues

- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0

Part 4: Examining, Illustrating, and Labeling Muscle Tissues

- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0

Part 5: Examining, Illustrating, and Labeling Nervous Tissue

- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0

Updated 2025.

This page titled 5.6: Laboratory Activities and Assignment is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

5.7: Collaborative Study Activity

Collaborative Study Activity

This activity works best with student pairs of two, but groups of three or four can be created and students work in pairs within those groups. Having groups of four is better if there is no supplemental instructor present to help quiz the students after they practice in their pairs. Students will access the flashcard deck linked below as described. In their pairs, students test each other using the flashcards until they have mastered the flashcard deck, at which point the student pair will request the instructor come test them on the deck.

Epithelial Tissues

1. Click to access the epithelial tissues flashcard deck (in Quizlet).
2. Test your partner on the flashcard deck.
3. Have your partner test you on the flashcard deck.
4. **When you and your partner have mastered the flashcard deck, request the assistance of your Instructor. They will test you using the flashcard deck and *initial ONLY when you have successfully mastered the flashcard deck.* Instructor:**
   _____

Connective Tissues

1. Click to access the connective tissue flashcards deck (in Quizlet).
2. Test your partner on the flashcard deck.
3. Have your partner test you on the flashcard deck.
4. **When you and your partner have mastered the flashcard deck, request the assistance of your Instructor. They will test you using the flashcard deck and *initial ONLY when you have successfully mastered the flashcard deck.* Instructor:**
   _____

Muscle Tissues

1. Click to access the muscle tissue flashcards deck (in Quizlet).
2. Test your partner on the flashcard deck.
3. Have your partner test you on the flashcard deck.
4. **When you and your partner have mastered the flashcard deck, request the assistance of your Instructor. They will test you using the flashcard deck and *initial ONLY when you have successfully mastered the flashcard deck.* Instructor:**
   _____

Attributions

Epithelial Tissues

- "Animal Tissues and Organs" by Berkshire Community College Bioscience Image Library is in the Public Domain, CC0
- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0

Connective Tissues

- "Animal Tissues and Organs" by Berkshire Community College Bioscience Image Library is in the Public Domain, CC0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0

Muscle Tissues

- "Animal Tissues and Organs" by Berkshire Community College Bioscience Image Library is in the Public Domain, CC0
- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0

Updated 2025.

This page titled 5.7: Collaborative Study Activity is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

CHAPTER OVERVIEW

6: Integumentary System

6.1: Introduction
6.2: Anatomy of the Skin
6.3: Secondary Structures of the Skin
6.4: Anatomy of the Nails
6.5: Laboratory Activities and Assignment
6.6: Collaborative Study Activity

This page titled 6: Integumentary System is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

6.1: Introduction

Introduction

The integumentary system include the skin, and its accessory organs: hairs, nails, accessory glands, and sensory receptors. The roles of this body system includes protecting the body from dehydration, absorbing nutrients, excreting wastes, and regulating body temperature (temperature homeostasis). It is also the attachment site for certain muscles and contains sensory receptors that detect pain, sensation, pressure, and temperature. Additionally, the integument is involved in synthesis of vitamin D. The integumentary system relies on all four types of tissue, epithelial, connective, muscular, and nervous, to conduct its crucial functions.

Attribution

- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0

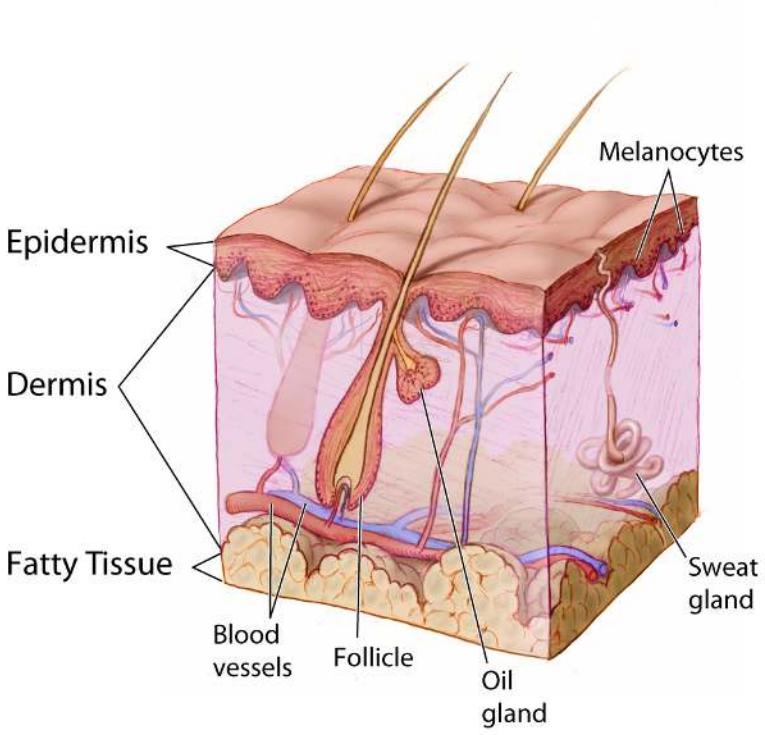
Updated 2025.

This page titled 6.1: Introduction is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

6.2: Anatomy of the Skin

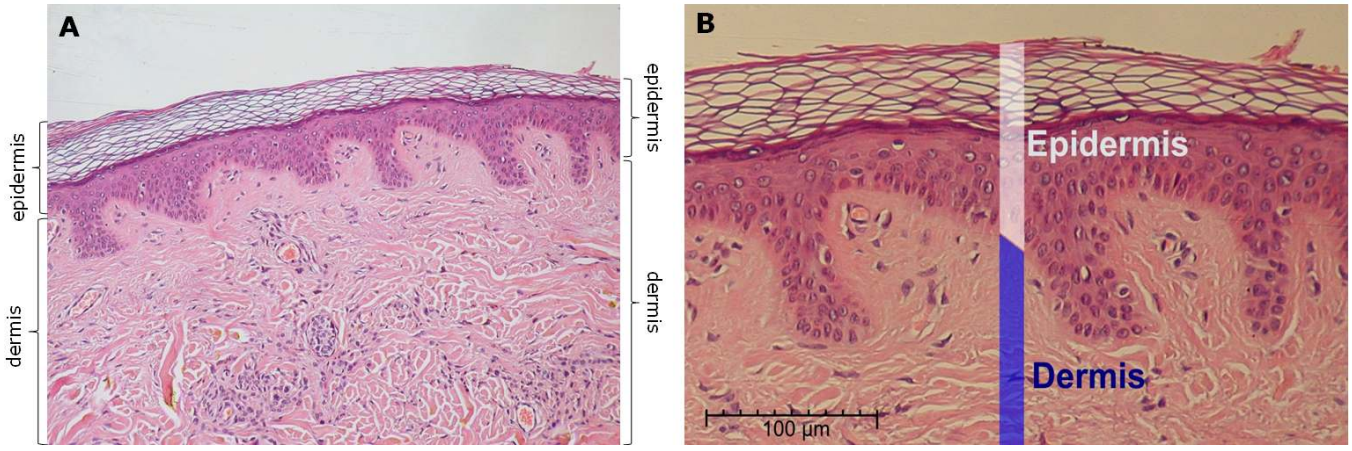
Anatomy of the Skin

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



Above: Skin cross section diagram showing the epidermis with melanocytes (pigment cells), dermis, and hypodermis (fatty tissue) layers as well as glands, hairs, and blood vessels embedded in these tissue layers.

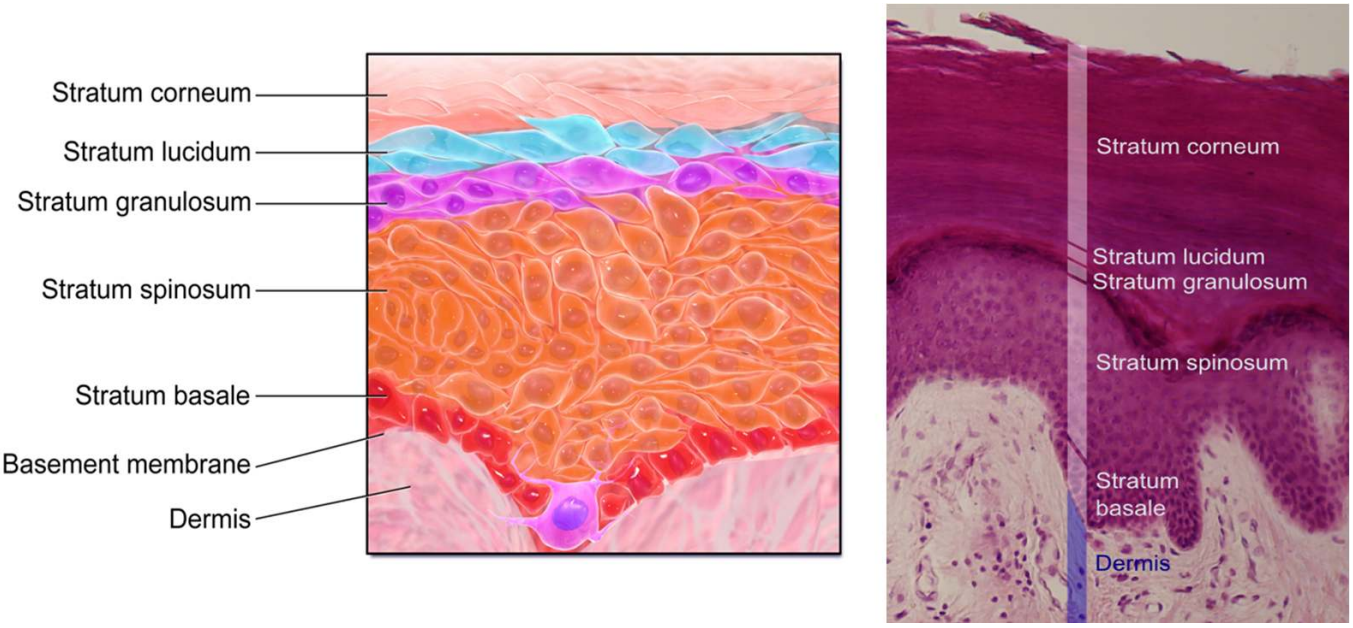
The skin is also called the **cutaneous membrane**. There are two types of skin: thin skin that is covered with hair (also contains sebaceous glands) and thick skin that has no hair. Thick skin, as the name suggests has extra tissue and cell layers in the epidermis compared to thin skin. The skin is composed of two main layers the **epidermis** and the **dermis**. Skin has an associated layer below the dermis called the **hypodermis**.



Above: Microscopic cross sections of the skin. Image A shows a skin cross section at lower magnification which shows that the dermis comprises a larger part of the skin than the epidermis. Image B shows a skin cross section at higher magnification. The divide between the epidermis and the dermis is based on the differences in tissue type. You can clearly see the difference between the stratified squamous epithelial tissue in the epidermis (darker pink) and the connective tissue in the dermis (lighter pink).

The Epidermis

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



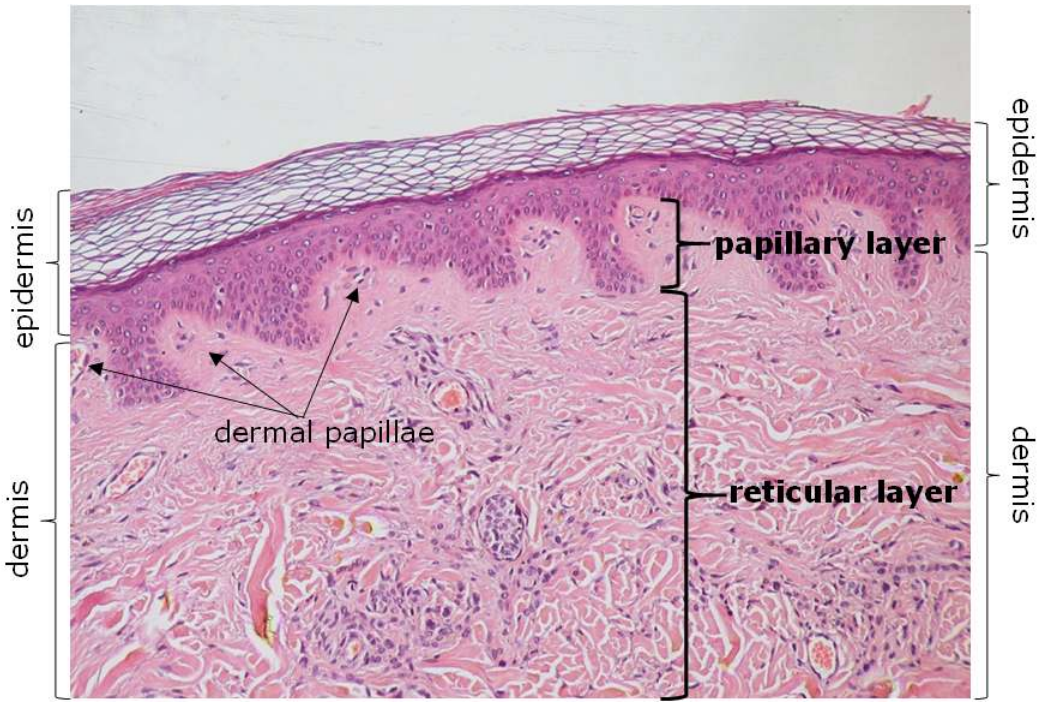
Above: This figure shows a diagram and microscopic tissue with labels indicating the five different layers that may be present in the epidermis of the skin. All five layers are present in thick skin, but in thin skin the stratum lucidum layer is absent. You can see that here we are zoomed in on the epidermis and only a small part of the underlying dermis is shown.

The layers of epidermis tissue are describe below from deep to superficial:

- **stratum basale**: This deepest layer of the epidermis is composed mainly of one layer of proliferating and non-proliferating **keratinocytes** (keratin-containing cells), attached to the basement membrane by hemidesmosomes. **Melanocytes** are present in this layer (melanin-containing cells aka pigment cells), 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 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**: A 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.

The Dermis

The **dermis** might be considered the “core” of the integumentary system (derma- = “skin”), as distinct from the epidermis (epi- = “upon” or “over”) and hypodermis (hypo- = “below”). It contains blood and lymph vessels, nerves, and other structures, such as hair follicles, **sebaceous glands** (oil glands), **sweat glands**, free nerve endings, pressure receptors (**Pacinnian corpuscles**), and **arrector pili** muscles capable of moving the hair follicles to make hair "stand on end." The dermis is made of two layers of connective tissue composed of an interconnected mesh of elastin and collagenous fibers, produced by fibroblasts. The **papillary layer** (superficial layer of the dermis) consists of areolar connective tissue. The **reticular layer** (deep layer of the dermis) consists of dense irregular connective tissue. These layers serve to give elasticity and flexibility to the integument.



Above: Microscopic image of the layers of the dermis. This stained slide shows the two components of the dermis—the papillary layer and the reticular layer. Both are made of connective tissue with fibers of collagen extending from one to the other, making the border between the two somewhat indistinct. The dermal papillae extending into the epidermis belong to the papillary layer, whereas the dense collagen fiber bundles below belong to the reticular layer.

Hypodermis

The hypodermis, also known as the subcutaneous layer, is a layer beneath the skin. It invaginates into the dermis and is attached to it with collagen and elastin fibers. It is largely composed of adipocytes that accumulate and store fats. These cells are grouped together in lobules separated by connective tissue. The hypodermis acts as an energy reserve. The energy-rich fats contained in the adipocytes can be brought into circulation via the venous route (through veins) during intense energy expenditure or when energy-rich molecules are in low supply. The hypodermis participates passively in thermoregulation since the fat stored in adipocytes act as a heat insulators.

Attributions

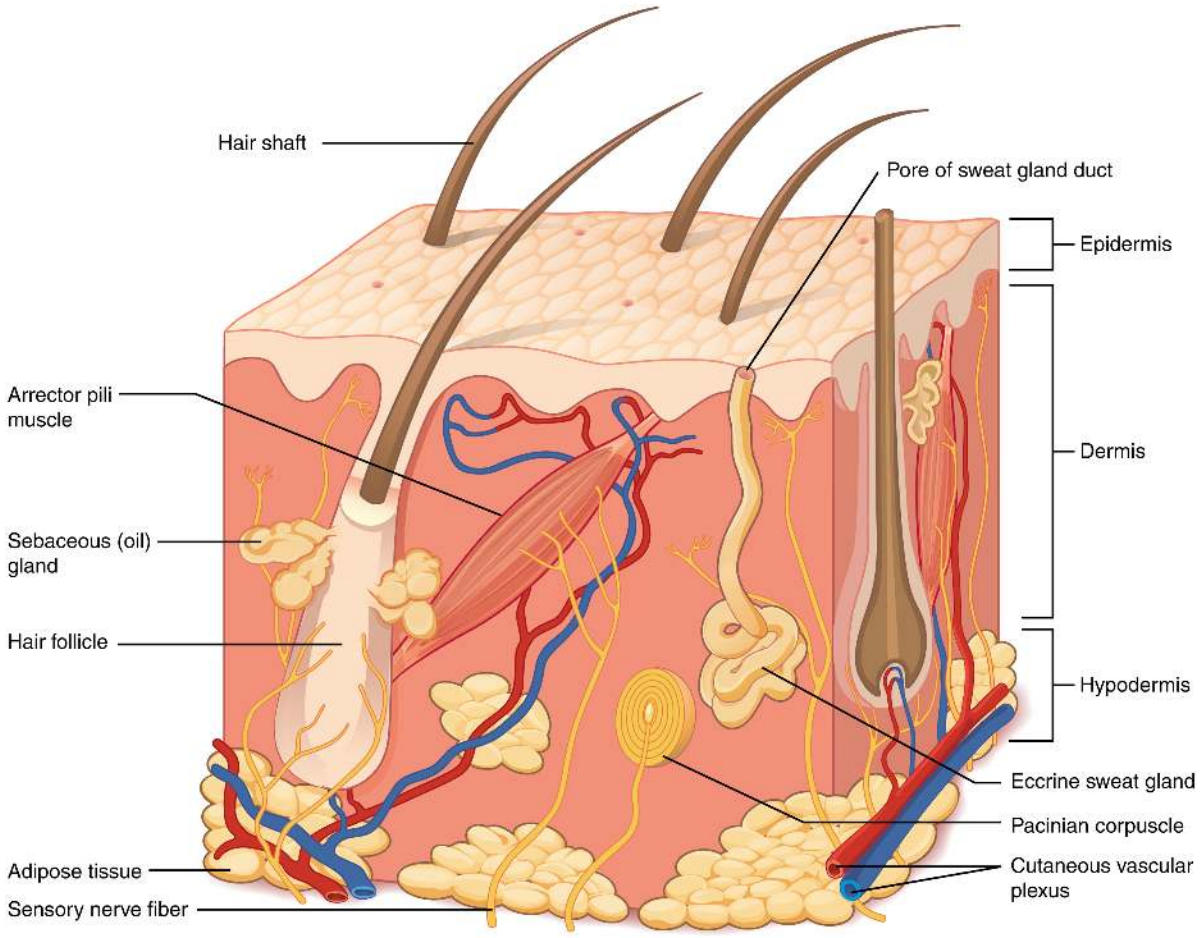
- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0
- Anatomy The Skin - NCI Visuals Online.jpg by National Institutes of Health and is in the public domain.
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0

Updated 2025.

This page titled 6.2: Anatomy of the Skin is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

6.3: Secondary Structures of the Skin

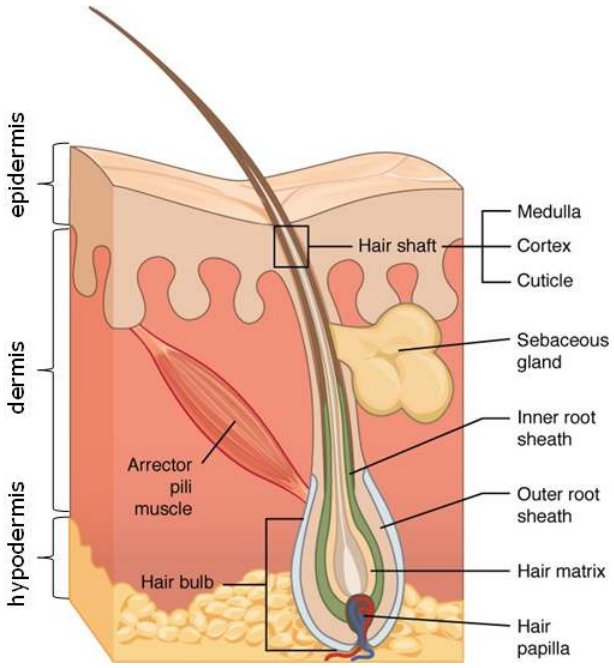
Secondary Structures of the Skin



Above: Illustrated diagram of the skin and underlying hypodermis with all of its associated secondary structures including hair, sweat glands, and sebaceous glands.

Hair

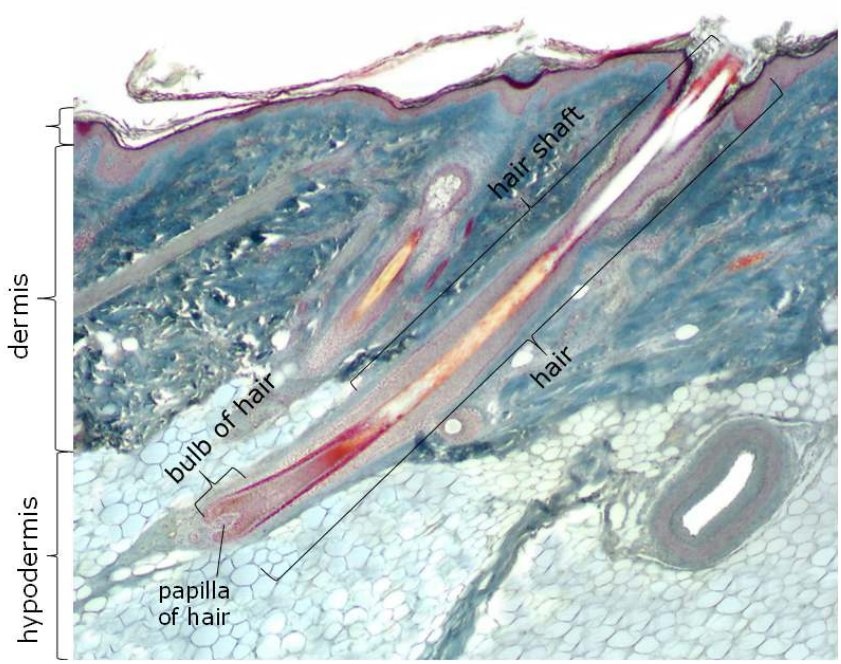
Hair is a keratinous (contains the protein keratin) filament growing out of the epidermis. It is primarily made of dead, keratinized cells. Strands of hair originate in an epidermal penetration of the dermis called the **hair follicle**. The **hair shaft** is the part of the hair not anchored to the follicle, and much of this is exposed at the skin's surface. The rest of the hair, which is anchored in the follicle, lies below the surface of the skin and is referred to as the **hair root**. The hair root ends deep in the dermis at the **hair bulb**, and includes a layer of mitotically active basal cells called the **hair matrix**. The hair bulb surrounds the **hair papilla**, which is made of connective tissue and contains blood capillaries and nerve endings from the dermis.



Above: Illustration of a hair and associated structures and tissues.

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

- **cuticle:** outer covering, which consists of several layers of flat, thin cells laid out overlapping one another as roof shingles
- **cortex:** which contains the keratin bundles in cell structures that remain roughly rod-like. The highly structural 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.
- **medulla:** a disorganized and open area at the fiber's center. The innermost region of the hair.



Above: Microscopic cross section of skin and hair. Tissue is magnified by 40x.

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.

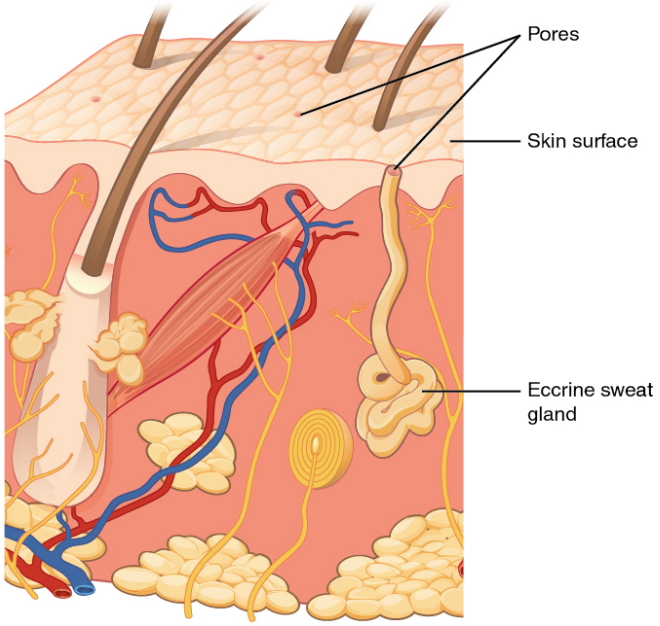
Sweat Glands

There are two types of sweat glands, each secreting slightly different products:

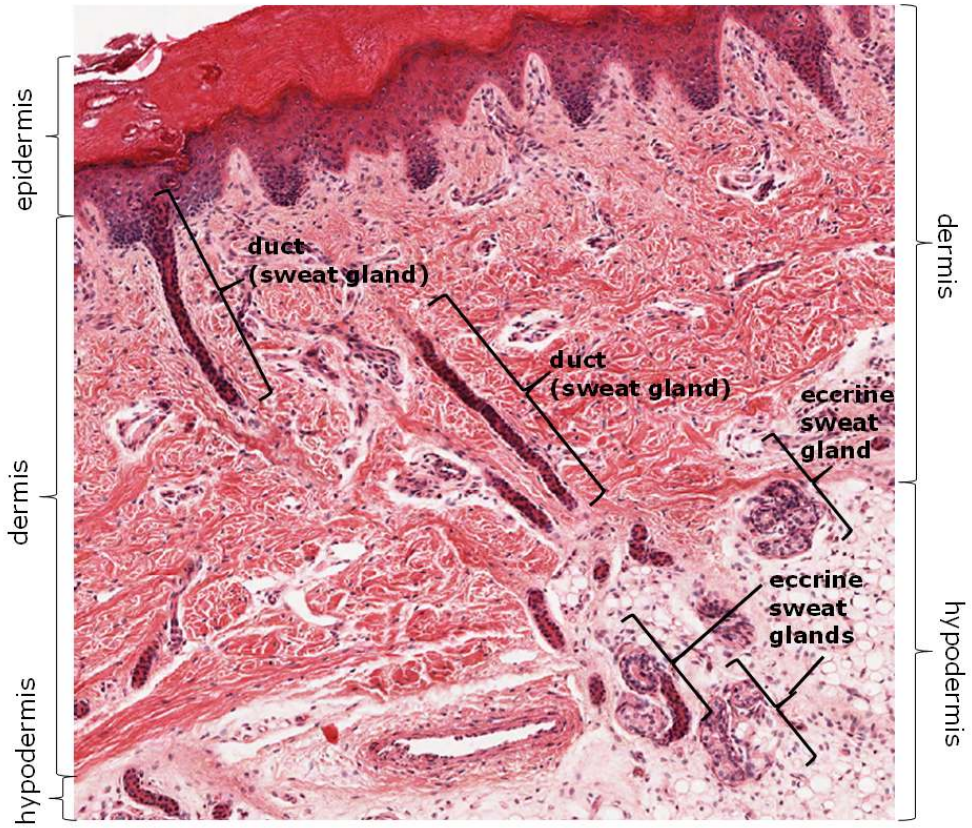
- eccrine sweat glands
- apocrine sweat glands

Eccrine Sweat Glands

The **eccrine sweat gland** is a type of gland that produces a hypotonic sweat for thermoregulation. These glands are found all over the skin's surface, bus are especially abundant on the palms of the hand, the soles of the feet, and the forehead. They are coiled glands lying deep in the dermis, with the duct rising to a pore on the skin surface, where sweat is released. This type of sweat, released by exocytosis, is hypotonic and composed mostly of water, with some salt, antibodies, traces of metabolic waste, and dermicidin, an antimicrobial peptide.



Above: Illustration of skin cross section showing an eccrine sweat gland in the dermis and its duct traveling through the dermis and epidermis to a pore on the skin surface.



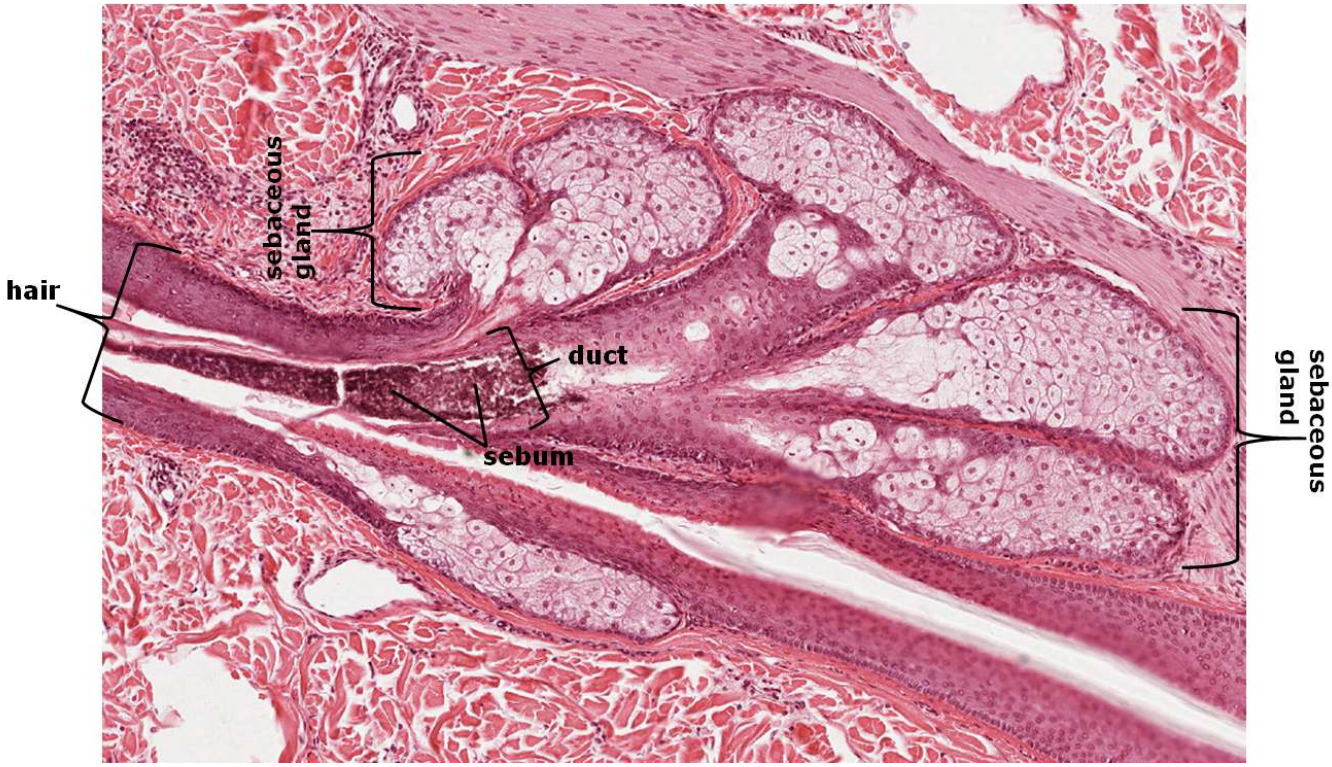
Above: Microscopic image of skin cross section showing eccrine sweat glands and ducts. Tissue is magnified by 100x.

Apocrine Sweat Glands

An **apocrine sweat gland** is usually associated with hair follicles in densely hairy areas, such as armpits and genital regions. Apocrine sweat glands are larger than eccrine sweat glands and lie deeper in the dermis, sometimes even reaching the hypodermis, with the duct normally emptying into the hair follicle. In additional to water and salts, apocrine sweat includes organic compounds that make the sweat thicker and subject to bacterial decomposition and subsequent smell. The release of this sweat is under both nervous and hormonal control, and plays a role in the poorly understood human pheromone response. Most commercial antiperspirants use an aluminum-based compound as their primary active ingredient to stop sweat. When the antiperspirant enters the sweat gland, the aluminum-based compounds precipitate due to a change in pH and form a physical block in the duct, which prevents sweat from coming out of the pore.

Sebaceous Glands

A **sebaceous gland** is a type of oil gland that is found all over the body and helps to lubricate and waterproof the skin and hair. Most sebaceous glands are associated with hair follicles. They generate and excrete **sebum**, a mixture of lipids, onto the skin surface, thereby naturally lubricating the dry and dead layer of keratinized cells on the stratum corneum keeping it pliable. The fatty acids of sebum also have antibacterial properties, and prevent water loss from thus kin in low-humidity environments. The secretion of sebum is stimulated by hormones, many of which do not become active until puberty. Thus, sebaceous glands are relatively inactive during childhood.



Above: Microscopic image of a sebaceous gland and its duct releasing sebum (oil secretion) onto a hair. Tissue is magnified by 100x.

Attributions

- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0
- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0

Updated 2025.

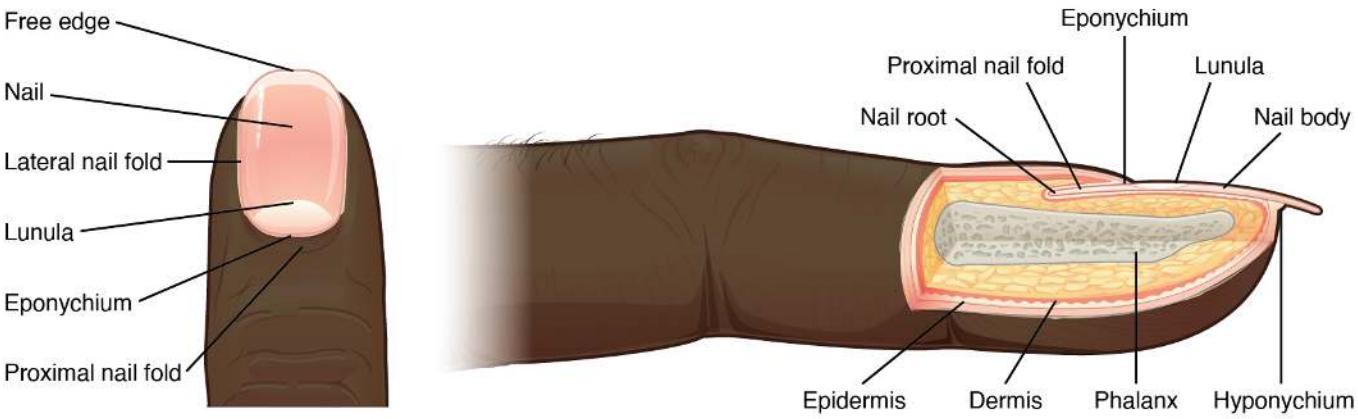
This page titled 6.3: Secondary Structures of the Skin is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

6.4: Anatomy of the Nails

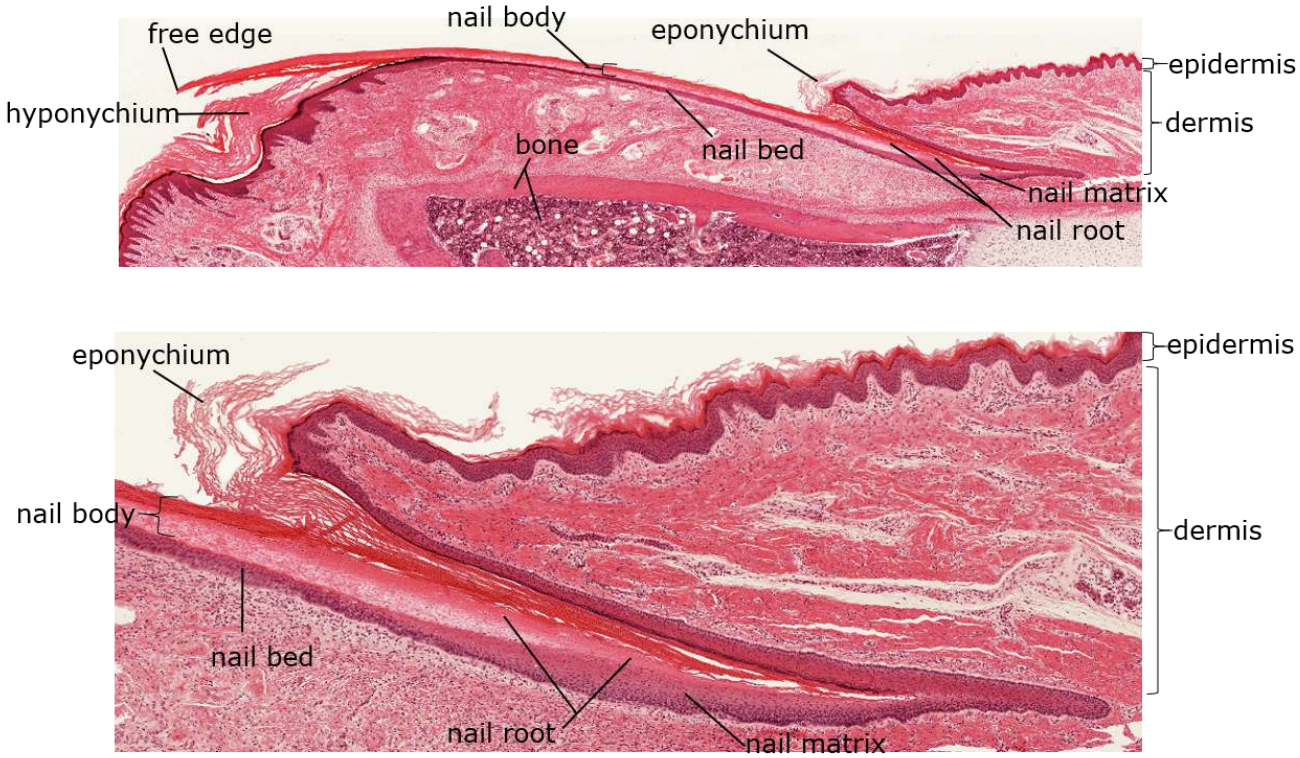
Anatomy of the Nails

The nail bed is a specialized structure of the epidermis that is found at the tips of our fingers and toes. The **nail body** is formed on the **nail bed**, and protects the tips of our fingers and toes as they are the farthest extremities and the parts of the body that experience the maximum mechanical stress. In addition, the nail body forms a back-support for picking up small objects with the fingers. The nail body is composed of densely packed dead keratinocytes.

The epidermis in this part of the body has evolved a specialized structure upon which nails can form. The nail body forms at the **nail root**, which has a matrix of proliferating cells from the stratum basale that enables the nail to grow continuously. The lateral **nail fold** overlaps the nail on the sides, helping to anchor the nail body. The nail fold that meets the proximal end of the nail body forms the **nail cuticle**, also called the **eponychium**. The nail bed is rich in blood vessels, making it appear pink, except at the base, where a thick layer of epithelium over the nail matrix forms a crescent-shaped region called the **lunula** (the "little moon"). The area beneath the free edge of the nail, furthest from the cuticle, is called the **hyponychium**. It consists of a thickened layer of stratum corneum.



Above: Illustrated diagram of the anatomy of a fingernail.



Above: Microscopic images of a fingernail cross section. The top image is magnified by 4x and the bottom image is the same tissue sample as the top image centered on the nail root and nail matrix magnified by 20x.

Attributions

- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0
- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0
- "Anatomy and Physiology Lab Reference" by Laird C Sheldahl, OpenOregonEducational Resources, Mt. Hood Community College is licensed under CC BY-SA 4.0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0

Updated 2025.

This page titled 6.4: Anatomy of the Nails is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

6.5: Laboratory Activities and Assignment

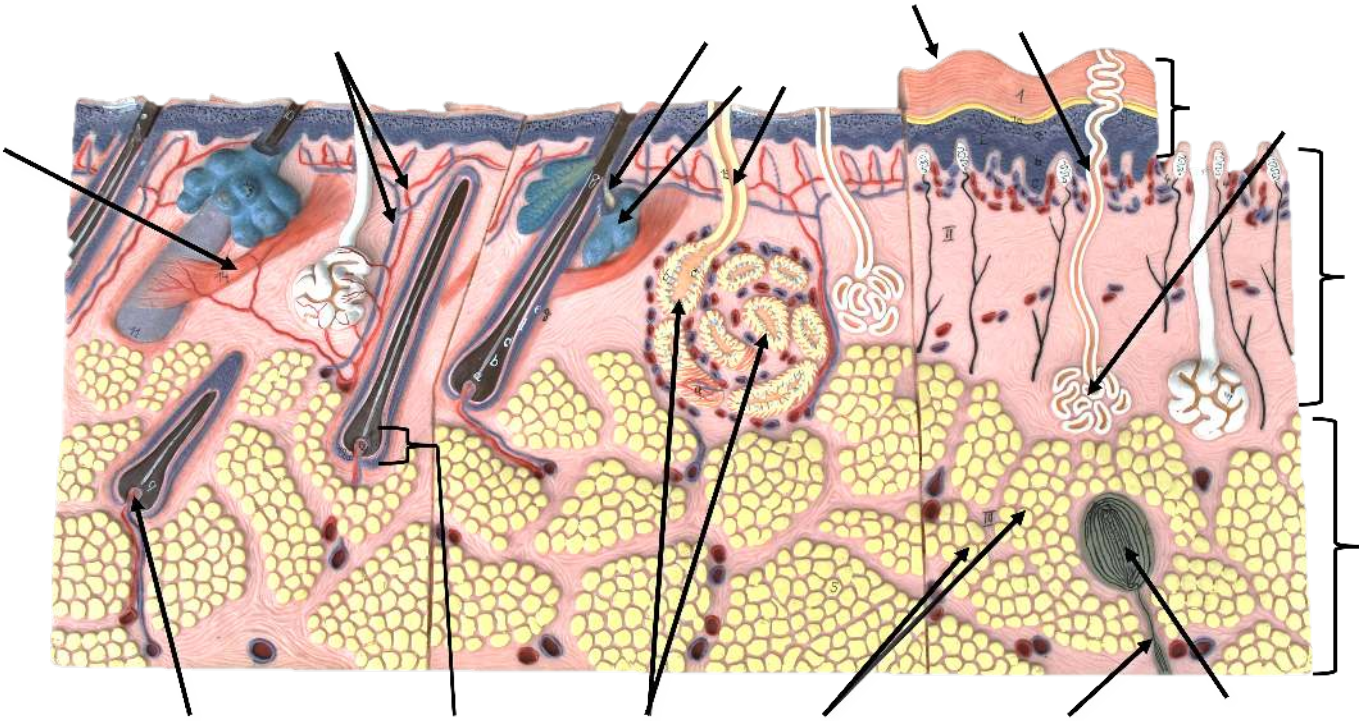
Laboratory Activities and Assignment

Part 1: Review of the Anatomy of the Integumentary System

1. Label the anatomical model of the skin below with the terms listed:

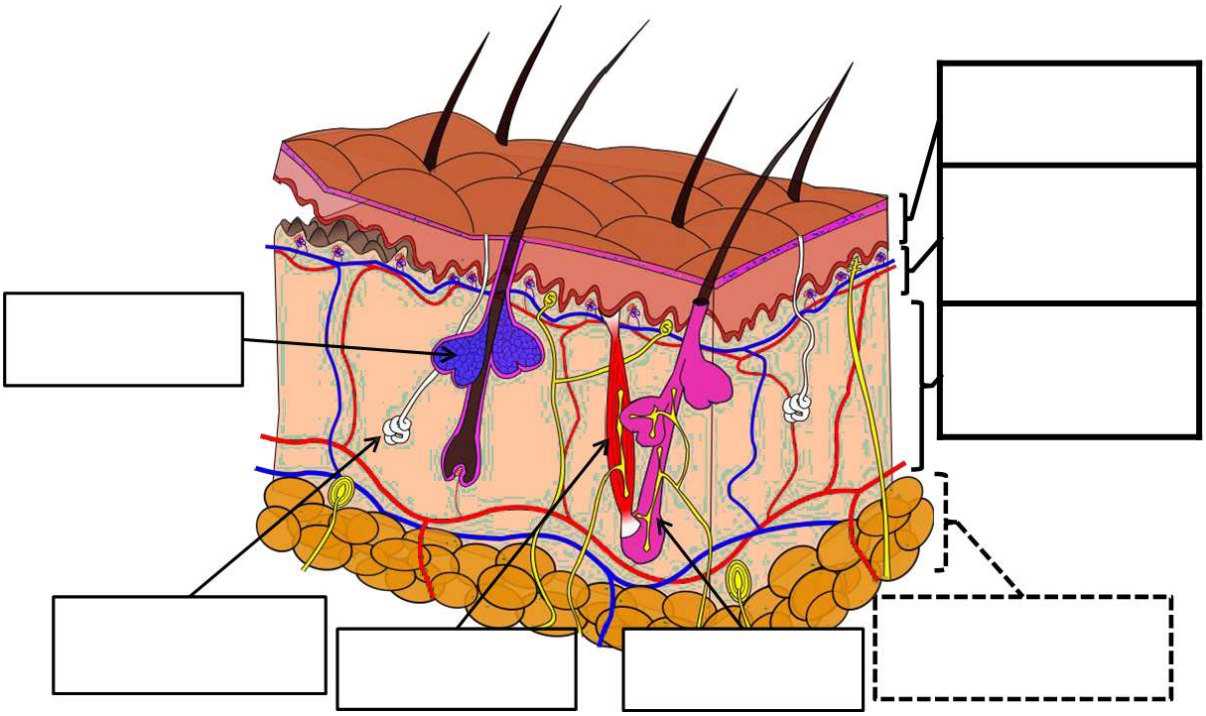
• epidermis • dermis • hypodermis • adipose tissue • apocrine sweat gland	• duct of apocrine sweat gland* • hair papilla • skin surface • sebaceous gland • duct of sebaceous gland	• arrector pili muscle • blood vessels • sensory nerve • hair bulb	• eccrine sweat gland • duct of eccrine sweat gland • hair bulb • Pacinian corpuscle

*note: these ducts typically release sweat onto hairs, but this is not shown in this model



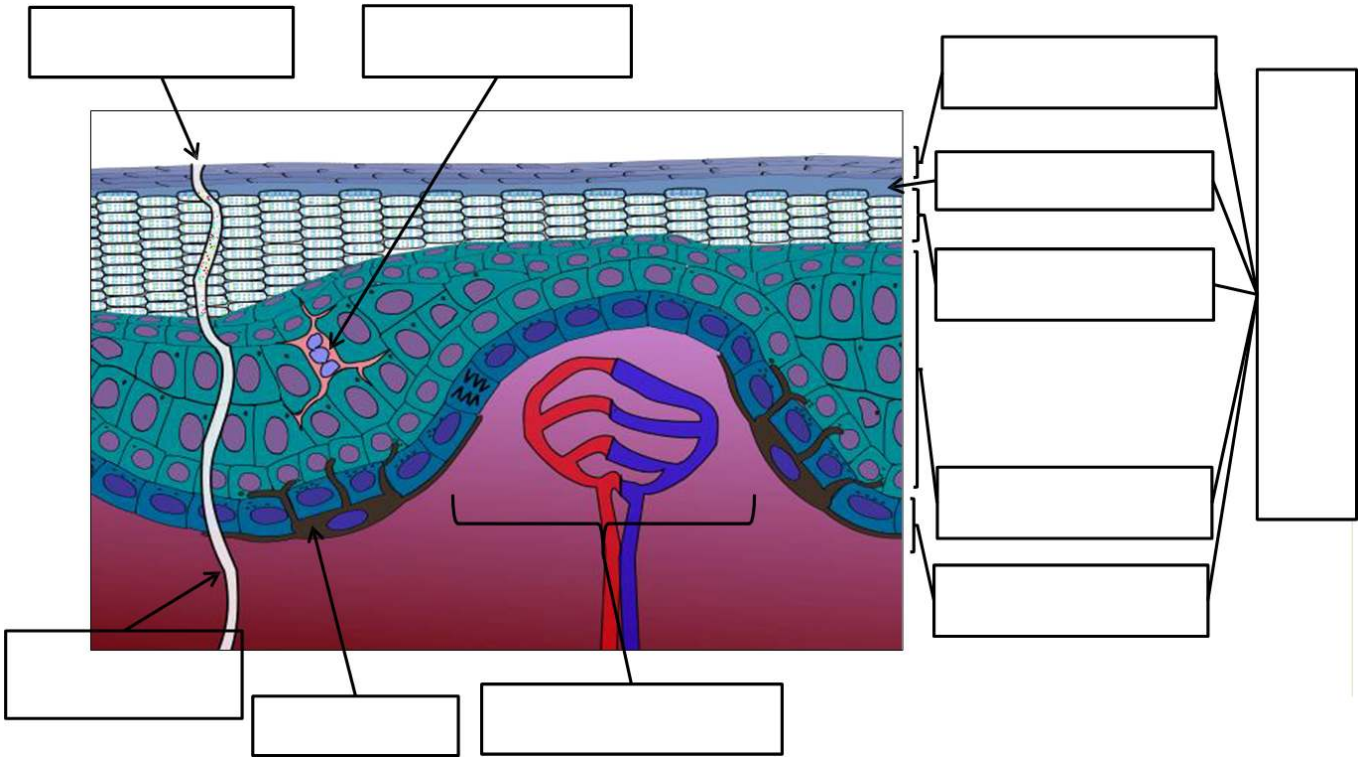
2. Label the diagram of the skin cross section below with the terms listed:

• hair follicle • sebaceous gland • epidermis	• dermis (papillary layer) • dermis (reticular layer)	• hypoderms • arrector pili muscle • sweat gland



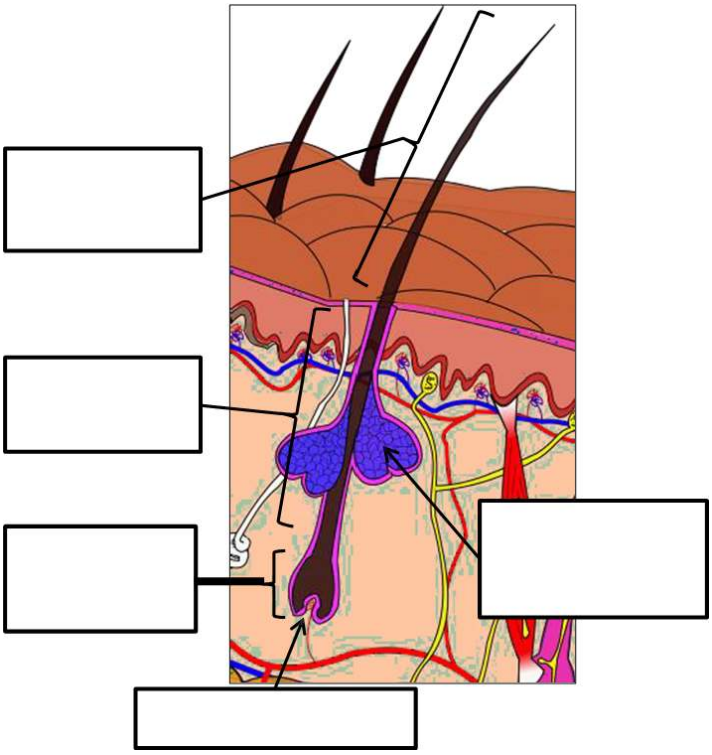
3. Label the diagram of the skin cross section below with the terms listed:

- stratum corneum
- stratum lucidum
- stratum granulosum
- stratum spinosum
- stratum basale
- dermal papilla
- sweat duct
- sweat pore
- stratified squamous epithelium
- dendritic cell
- melanocyte



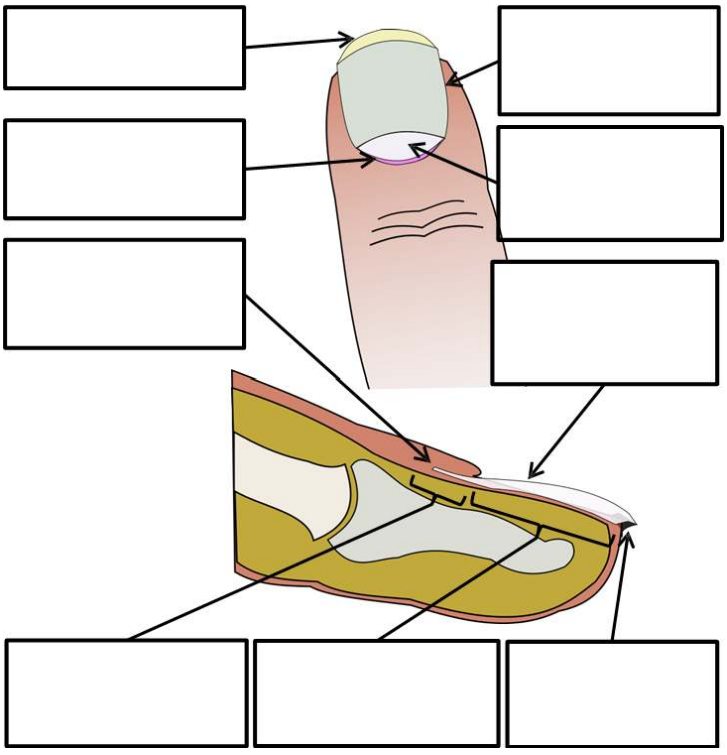
4. Label the diagram of the hair and skin cross section below with the terms listed:

• sebaceous gland • hair shaft	• hair bulb • hair root	• hair papilla



5. Label the diagram of the skin cross section below with the terms listed:

• free edge • hyponychium • lunula	• nail matrix • nail root • lateral nail fold	• nail bed • nail plate • eponychium



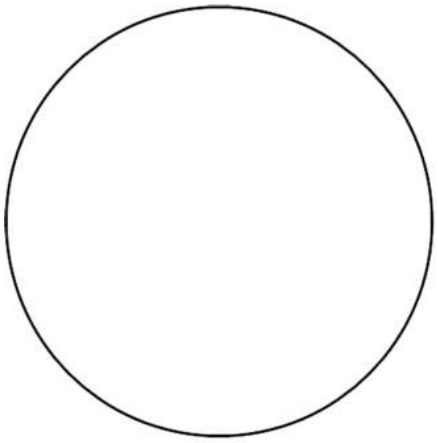
https://bio.libretexts.org/@go/page/53592

Part 2: Histology of the Integumentary System

1. Obtain the slides listed below that are available for today's lab.
2. Focus on each sample and identify the structures listed for each type of tissue.
3. Indicate the ***total*** magnification you make each illustration at in the space provided.
4. Illustrate each tissue you observe with the microscope at the magnification you listed.
5. Label each illustration with the structures listed for each.

Skin (cross section)

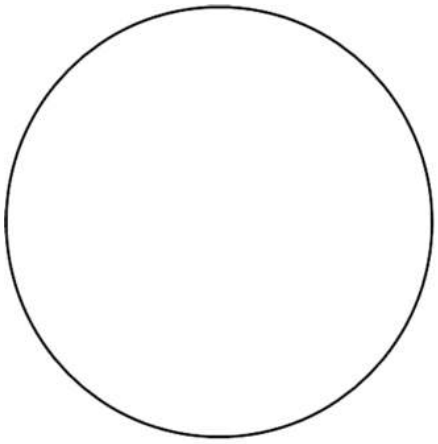
Label the tissue with: epidermis, dermis, papillary layer of the dermis, reticular layer of the dermis, basement membrane, stratum basale, stratum corneum, dermal papilla, epithelial tissue, areolar tissue, dense irregular connective tissue, skin surface



Total magnification: _____

Human Scalp with Hair Follicle

Label the tissue with: epidermis, dermis, arrector pili muscle, sebaceous gland, dermal papilla, hair follicle, hair bulb



Total magnification: _____

Attributions

Part 1: Review of the Anatomy of the Integumentary System

- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0
- "Anatomy and Physiology Lab Homework" by Laird C Sheldahl is licensed under CC BY-SA 4.0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- Skin cross section model.jpg by John Campbell is licensed under CC BY 2.0

Part 2: Histology of the Integumentary System

- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- "Human Anatomy Lab Manual" by Malgosia Wilk-Blaszczak, Mavs Open Press, University of Texas at Arlington is licensed under CC BY 4.

Updated 2025.

This page titled 6.5: Laboratory Activities and Assignment is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

6.6: Collaborative Study Activity

Collaborative Study Activity

This activity is designed for student groups of 2-4.

1. Identify the following structures on classroom anatomical models and/or unlabeled images/diagrams made available by your instructor. Work with your group to identify each structure and check them off the list once you have identified them.

☐ epidermis	☐ basement membrane	☐ sebaceous gland
☐ dermis	☐ hypodermis (subcutaneous layer)	☐ eccrine sweat gland
☐ dermal papilla	☐ thin (hair) skin	☐ nail body
☐ papillary layer (dermis)	☐ thick (hairless) skin	☐ free edge
☐ reticular layer (dermis)	☐ arrector pili muscle	☐ lunula
☐ stratum corneum	☐ hair shaft	☐ eponychium
☐ stratum lucidum	☐ hair root	☐ hyponychium
☐ stratum granulosum	☐ hair follicle	☐ nail bed
☐ stratum spinosum	☐ hair bulb	☐ nail matrix
☐ stratum basale	☐ hair papilla	☐ lateral nail fold

2. Test your group members by ***asking them to name each structure you point to***. Check off each when your group can successfully name each. Your group will also test you.

☐ epidermis	☐ basement membrane	☐ sebaceous gland
☐ dermis	☐ hypodermis (subcutaneous layer)	☐ eccrine sweat gland
☐ dermal papilla	☐ thin (hair) skin	☐ nail body
☐ papillary layer (dermis)	☐ thick (hairless) skin	☐ free edge
☐ reticular layer (dermis)	☐ arrector pili muscle	☐ lunula
☐ stratum corneum	☐ hair shaft	☐ eponychium
☐ stratum lucidum	☐ hair root	☐ hyponychium
☐ stratum granulosum	☐ hair follicle	☐ nail bed
☐ stratum spinosum	☐ hair bulb	☐ nail matrix
☐ stratum basale	☐ hair papilla	☐ lateral nail fold

When you and your group are comfortable identifying all the structures above, request the assistance of your Instructor. They will test you on your use of these terms and initial ONLY when you are successful using these terms. Instructor: _____

Attribution

- "Human Anatomy Lab Manual" by Malgosia Wilk-Blaszczak, Mavs Open Press, University of Texas at Arlington is licensed under CC BY 4.0

Updated 2025.

This page titled 6.6: Collaborative Study Activity is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

CHAPTER OVERVIEW

7: Introduction to the Skeletal System

7.1: Introduction
7.2: Osseous Tissue (Bone Tissue)
7.3: Axial Skeleton and Appendicular Skeleton
7.4: Bone Shape Classifications
7.5: Anatomy of a Long Bone
7.6: Bone Markings
7.7: Cartilage
7.8: Laboratory Activities and Assignment

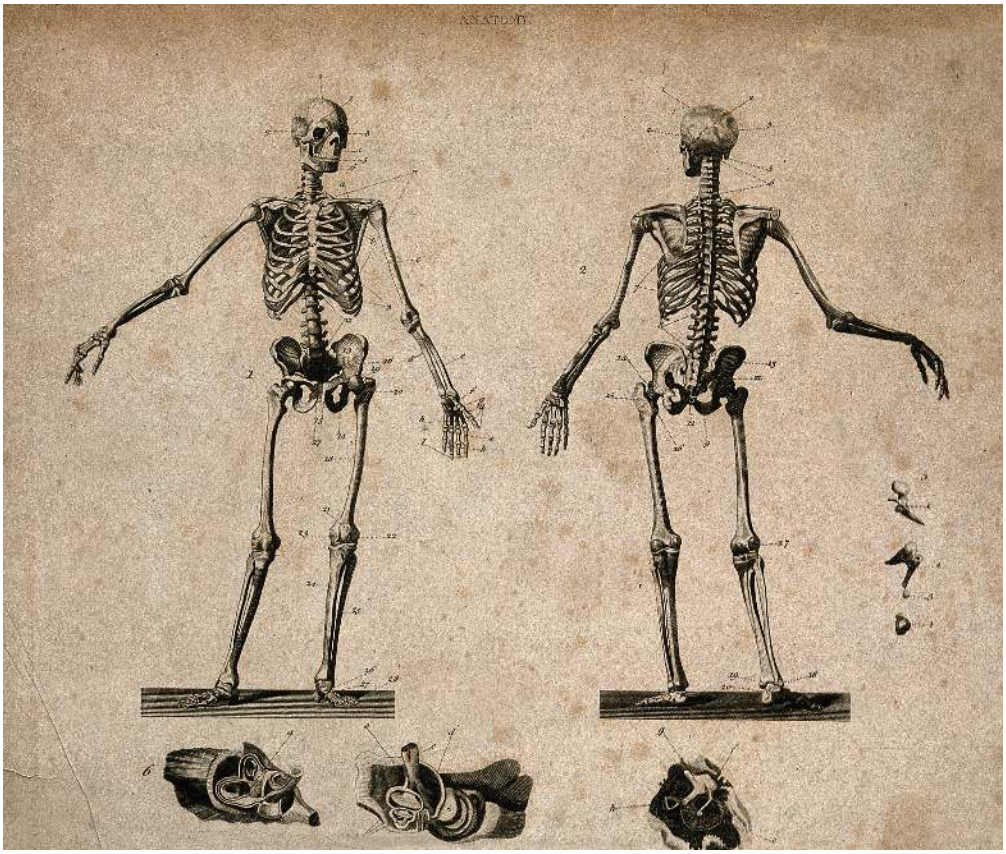
This page titled 7: Introduction to the Skeletal System is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

7.1: Introduction

Introduction

The skeletal system consists of bones, cartilages, and ligaments throughout the body. **Bones** are complex organs made up of different types of bone cells, protein fibers, and minerals as well as different types of tissues. The skeletal system provides 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 to 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.

Cartilage can be hyaline cartilage, fibrocartilage, or elastic cartilage (three different tissue types). Cartilage cushions joints, provides connections between bones in cartilaginous joints, and create structures (e.g. parts of the nose, outer ears, holding airways open). **Ligaments** are composed of dense regular connective tissue and connect bones to other bones, stabilizing joints.



Above: (Left) Anterior view of human skeleton. (Right) Posterior view of human skeleton. (Far right) Human auditory ossicles (bones of the middle ear). (Bottom) Views of the middle and inner ear showing auditory ossicles (bottom left) and semicircular canals of the inner ear (bottom right).

In the human body, at birth, there are over 300 bones. Many of these bones that exist at birth 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. The hyoid bone is the only bone in the human body that does not articulate (form a joint) with another bone. Instead, the hyoid is attached to a variety of soft tissues including cartilage and muscles.

Attribution

- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0
- Human skeleton with left arm extended; front and back views; Wellcome V0008044.jpg by the Wellcome Collection, a website operated by Wellcome Trust, a global charitable foundation based in the United Kingdom and is licensed under CC BY 4.0

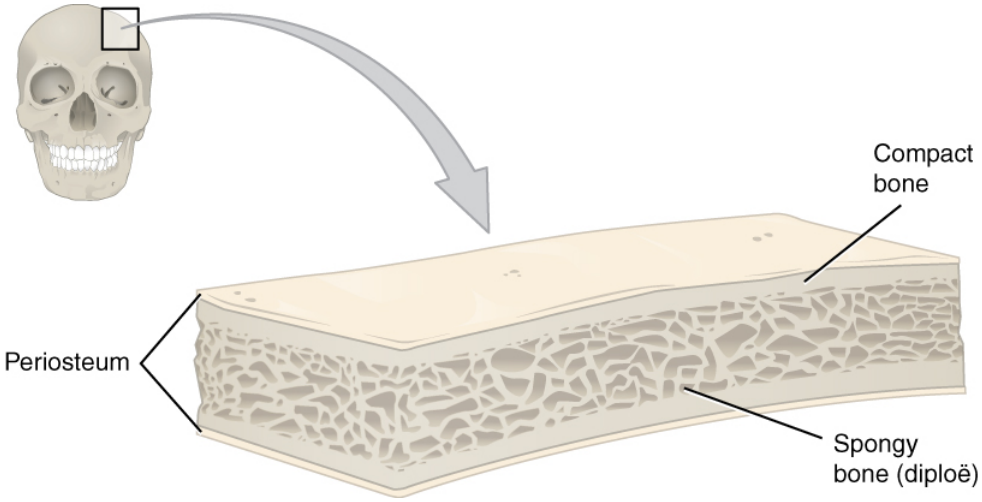
Updated 2025.

This page titled 7.1: Introduction is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

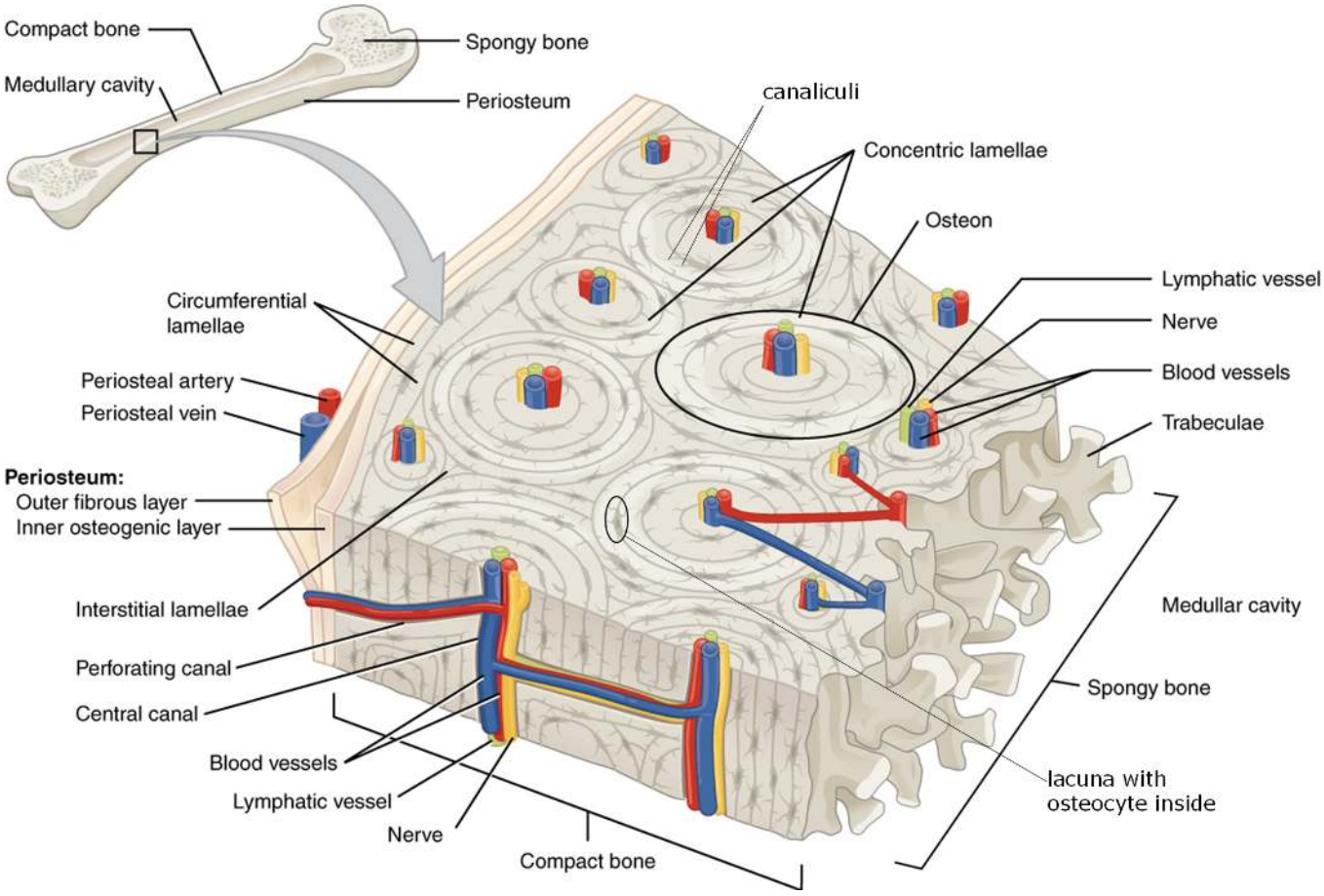
7.2: Osseous Tissue (Bone Tissue)

Osseous Tissue (Bone Tissue)

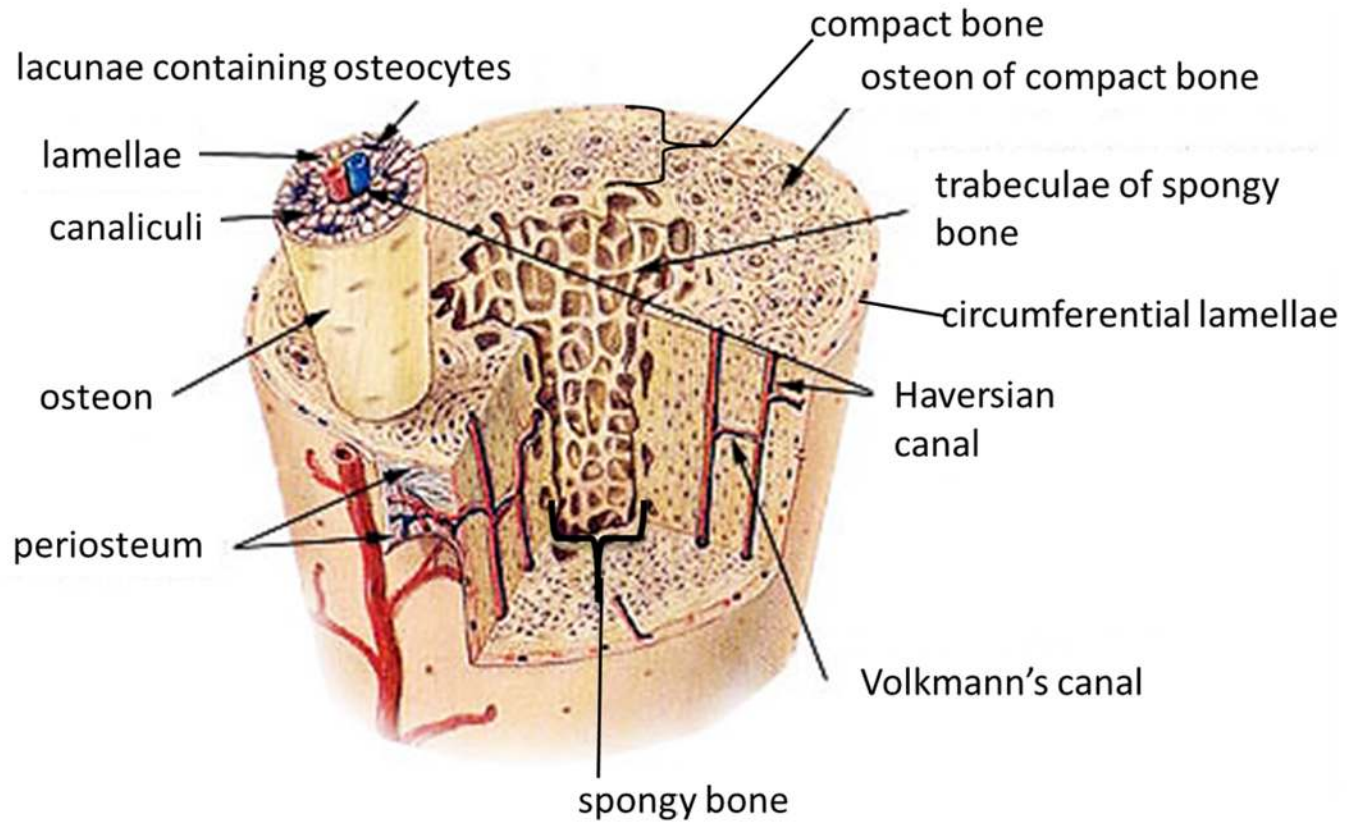
Bone tissue (**osseous tissue**) is a hard and mineralized connective tissue. Bone tissue is made up of different types of bone cells. **Osteoblasts** and **osteocytes** are involved in the formation and mineralization of bone; **osteoclasts** are involved in the resorption of bone tissue. Modified (flattened) 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. Bone tissue is a mineralized tissue of two types: **compact bone** (cortical) and **spongy bone** (trabecular or cancellous).



Above: A cross section of bone tissue shows the outer layers are composed of compact bone and the inner layers are composed of spongy bone. A membrane composed of dense connective tissue called the **periosteum** forms the outermost layer of bone.



https://bio.libretexts.org/@go/page/53598



Above: These illustrations of the structure of bone shows compact bone making up outer layers of bone and spongy bone making up the inner layers of bone. **Compact bone** is organized into **osteons**, circular structures surrounding a central canal where blood vessels (red and blue), nerves (yellow), and lymphatic vessels (green) can pass through the bone tissue. Circular rings called **lamellae** surround the **central canals** in each osteon. **Spongy bone** consists of slender bony projections called **trabeculae**. The trabeculae are surrounded by bone marrow tissues. The outermost layer of compact bone is surrounded by dense connective tissue called the **periosteum**. Between the periosteum and the osteons of compact bone are layers of **circumferential lamellae**, tissue that surround the entire bone in rings, similar to how the lamellae of an osteon surrounds the central canal.

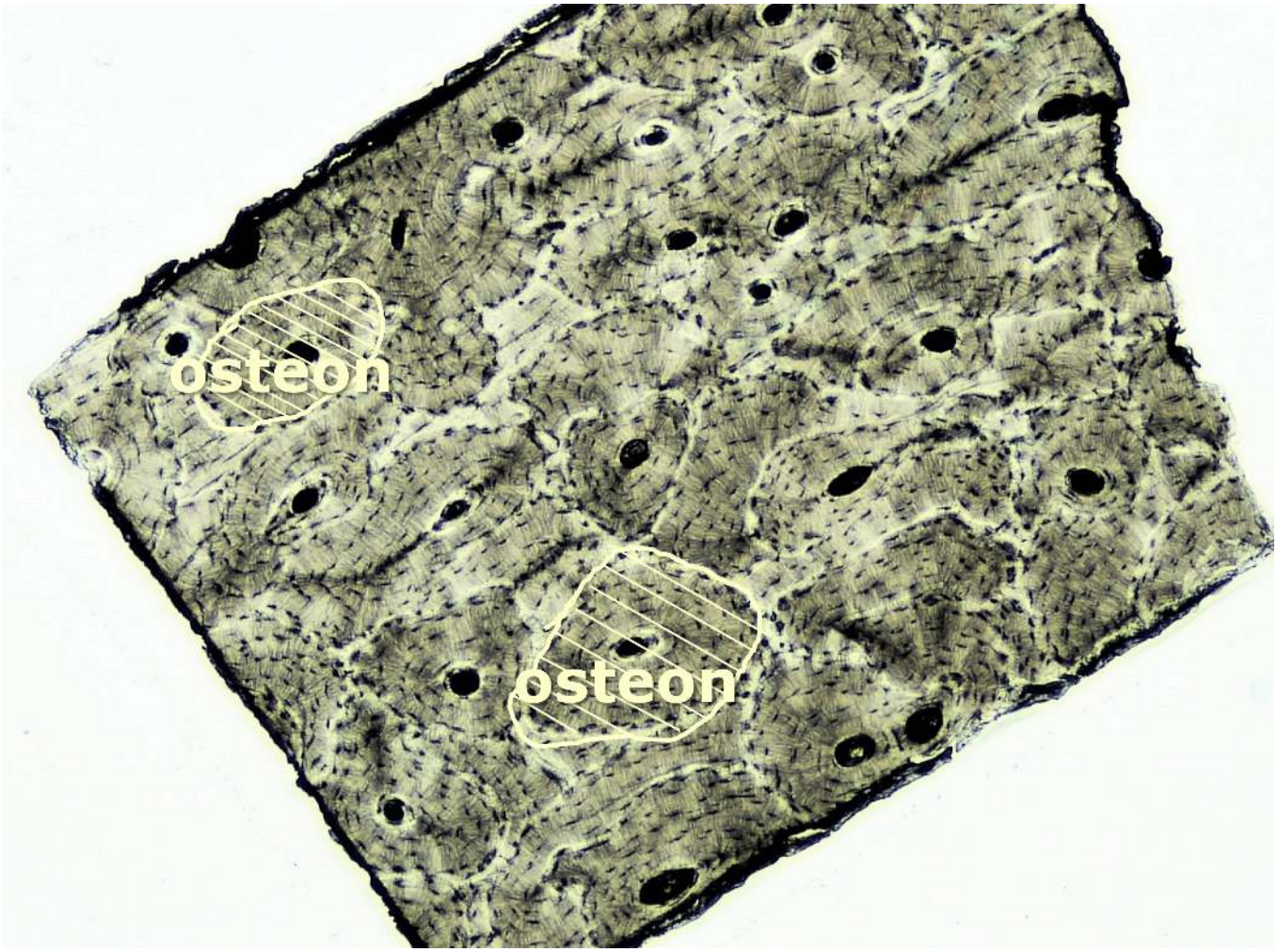
Bone is not uniformly solid, it consists of a flexible matrix and bound minerals, which are intricately woven and endlessly remodeled by a group of specialized bone cells. Their unique composition and design allow bones to be relatively hard and strong, while remaining lightweight. Bone matrix is 90 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 **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 compact bone and spongy bone, and each with different appearances and characteristics.

Compact Bone

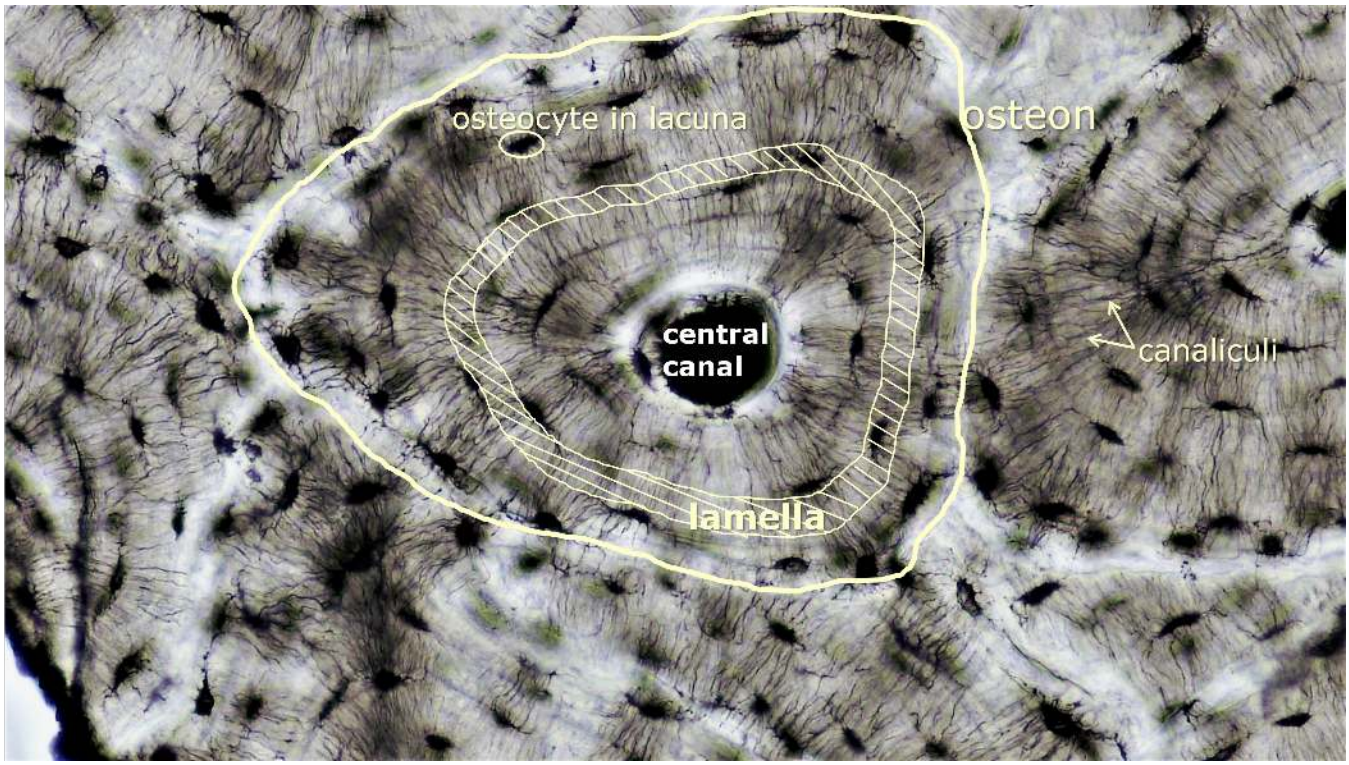
The hard, outer layer of bone is composed of compact bone also called **cortical bone** being much denser than spongy bone. The cortical bone gives bone its smooth, white, and solid appearance, and accounts for 80% of the total bone mass of an adult human skeleton. It facilitates bone's main functions: to support the whole body, protect organs, provide levers for movement, and store and release minerals, mainly calcium and phosphorous. It consists of multiple microscopic functional units, called an **osteon**. The osteons (tissue organizational structure known as the **Harvesian system**) are arrange as multiple layers of osteoblasts and

osteocytes around a **central canal** or **Haversian canal** where blood vessels, nerves, and lymphatic vessels pass through compact bone. The blood vessels, nerves, and lymphatic vessels passing through the central canals connect with other central canals of other osteons and with the periosteum through channels oriented at right angles known as **Volkmann's canals**.



Above: Compact bone. Tissue is magnified by 40x.

Osteons are metabolically active, and as bone is reabsorbed and created the nature and locations of the cells within the bone change. Compact bone is covered by a **periosteum** on its outer surface, and an **endosteum** on its inner surface. The endosteum is the boundary between the compact bone and the spongy bone. The periosteum is formed of two layers the outer fibrous layer made of dense irregular connective tissue. The outer layer of periosteum contains blood vessels and nerves and the inner layer of periosteum 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.

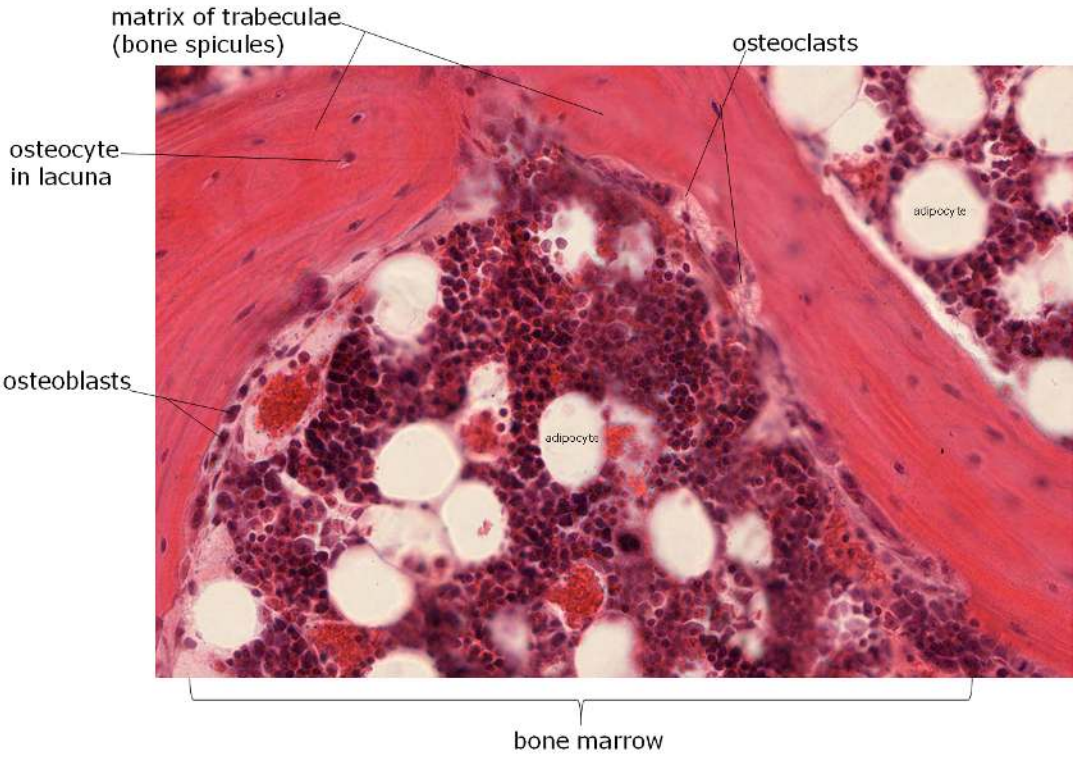


Above: Compact bone. Tissue magnified by 200x.

Spongy Bone

Spongy bone, also called **trabecular bone** or **cancellous bone**, is the internal tissue of bone and is an open cell porous network. Spongy bone has a higher surface-area-to-volume ratio than compact 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. Spongy bone is typically found at the ends of long bones, near joints and in the interior of vertebrae. Spongy 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 spongy bone is the **trabecula**. The trabeculae are aligned towards the mechanical load distribution that a bone experiences within long bones such as the femur.

Thin formations of osteoblasts, covered in endosteum, create an irregular network of spaces, known as trabeculae. The words spongy bone refers to a tiny lattice of boney extensions (trabeculae) that form the tissue. Within these spaces are bone marrow and hematopoietic stem cells that give rise to platelets, red blood cells (erythrocytes) and white blood cells (leukocytes). Trabecular marrow is composed of a network of rod- and plate-like elements that make the overall organ lighter and allows 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.



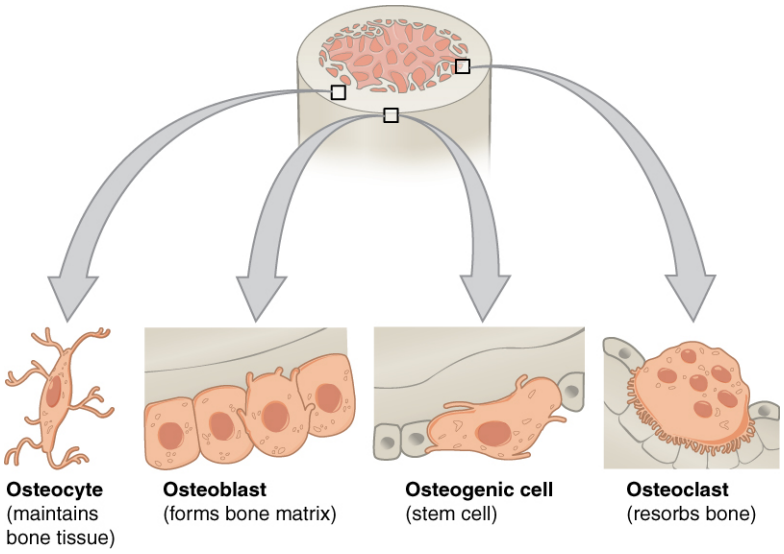
Above: Spongy bone tissue (trabeculae) with pockets of bone marrow surrounding it. Tissue is magnified by 400x.

Bone Marrow

Bone marrow, also known as **myeloid tissue** in red bone marrow, can be found in almost any bone that contains spongy 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 fraction called **marrow adipose tissue** (**MAT**) or **yellow bone marrow** 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 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.



Above: Illustration showing the different locations and appearances of the different types of bone cells.

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 phosphates which are 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 inside a space (**lacuna**), 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 connect to osteoblasts and other osteocytes for the purposes of communication. Osteocytes remain in contact with other cells in the bone through gap junctions—cell-to-cell attachments specialized for cell-to-cell communication—which pass through small channels in the bone matrix called the **canaliculi**.

Osteoblast

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 ($Ca_{10}(PO_4)_6(OH)_2$). 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.

Attributions

- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0
- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0
- "Animal Tissues and Organs" by Berkshire Community College Bioscience Image Library is in the Public Domain, CC0
- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0

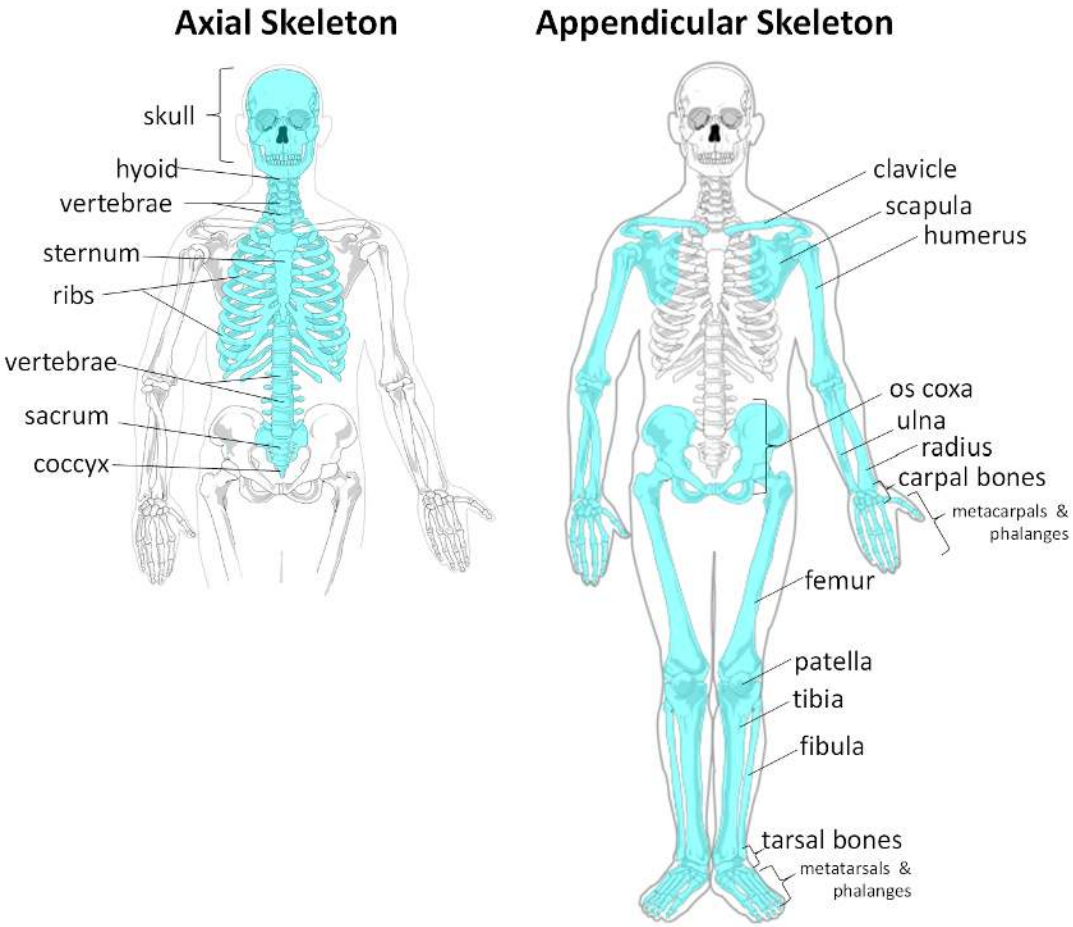
Updated 2025.

This page titled 7.2: Osseous Tissue (Bone Tissue) is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

7.3: Axial Skeleton and Appendicular Skeleton

Axial Skeleton and Appendicular Skeleton

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



Above: The bones of the axial skeleton make up the central axis of the body including the skull, hyoid, vertebrae, ribs, sternum, sacrum, and coccyx. The bones of the appendicular skeleton include those of the appendages and the joints with those appendages including the shoulder girdle (clavicle and scapula) and the hip joint (os coxae or hip bones).

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

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

Attribution

- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0

Updated 2025.

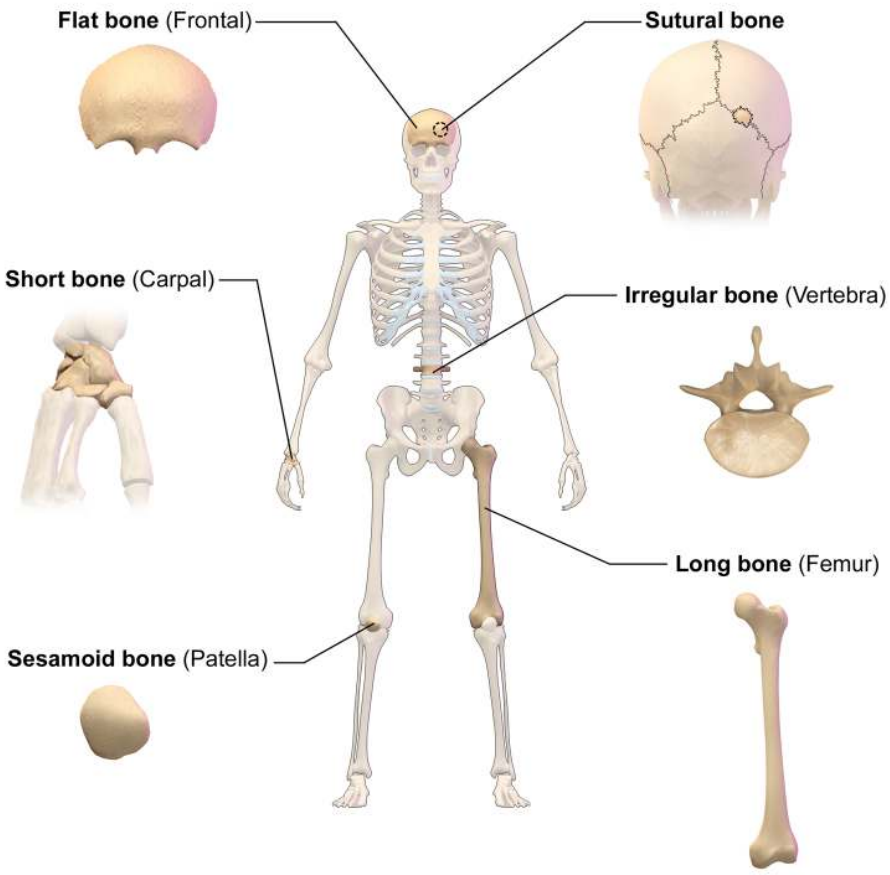
This page titled 7.3: Axial Skeleton and Appendicular Skeleton is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

7.4: Bone Shape Classifications

Bone Shape Classifications

There are six types of bones in the human body: long, short, flat, irregular, sesamoid and sutural.

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 (small irregular bones embedded in a cranial suture)



Above: The classifications of bone shapes with examples of each.

Attributions

- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0

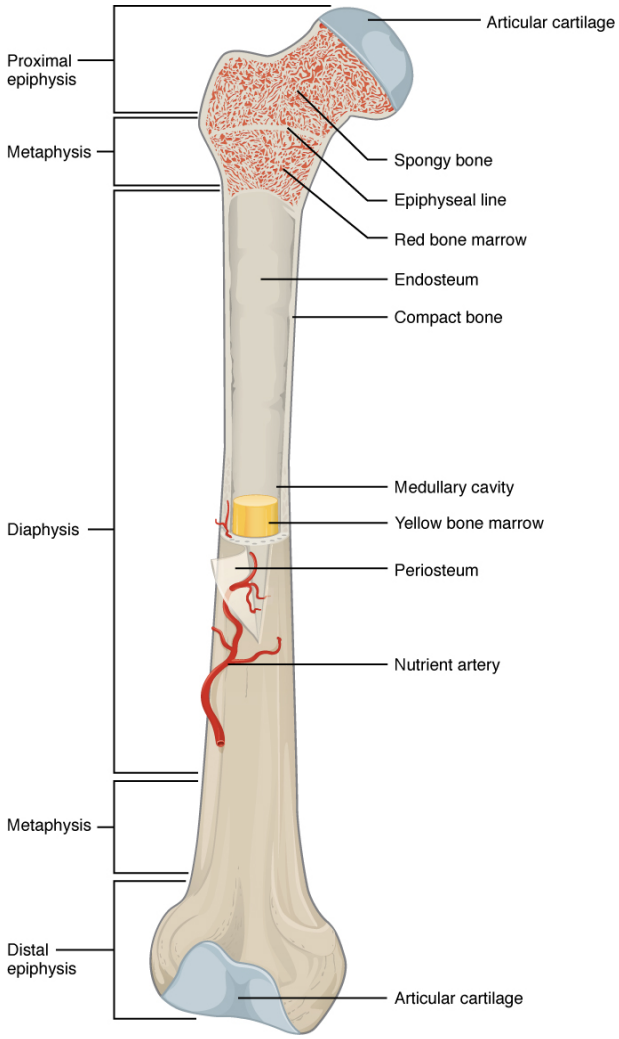
Updated 2025.

This page titled 7.4: Bone Shape Classifications is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

7.5: Anatomy of a Long Bone

Anatomy of a Long Bone

A long bone has two parts: the **diaphysis** and the **epiphysis**. The diaphysis is the tubular shaft that runs between the proximal and distal ends of the bone. The hollow region in the diaphysis is called the medullary cavity, which is filled with yellow marrow. The walls of the diaphysis are composed of dense and hard compact bone.



Above: Diagram illustrating the anatomy of a long bone.

The wider section at each end of the bone is called the epiphysis (plural = epiphyses), which is filled with spongy bone. Red marrow fills the spaces in the spongy bone. Each epiphysis meets the diaphysis at the metaphysis, the narrow area that contains the **epiphyseal plate** (growth plate), a layer of hyaline (transparent) cartilage in a growing bone. When the bone stops growing in early adulthood (approximately 18–21 years), the cartilage is replaced by osseous tissue and the epiphyseal plate becomes an epiphyseal line.

The medullary cavity has a delicate membranous lining called the **endosteum** (endo- = “inside”; oste- = “bone”), where bone growth, repair, and remodeling occur. The outer surface of the bone is covered with a fibrous membrane called the **periosteum** (peri- = “around” or “surrounding”). The periosteum contains blood vessels, nerves, and lymphatic vessels that nourish compact bone. Tendons and ligaments also attach to bones at the periosteum. The periosteum covers the entire outer surface except where

the epiphyses meet other bones to form joints. In this region, the epiphyses are covered with **articular cartilage**, a thin layer of cartilage that reduces friction and acts as a shock absorber

Attribution

- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0

Updated 2025.

This page titled 7.5: Anatomy of a Long Bone is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

7.6: Bone Markings

Bone Markings

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

The surface features of bones vary considerably, depending on the function and location in the body. There are three general classes of bone markings: (1) articulations, (2) projections, and (3) holes. As the name implies, an **articulation** is where two bone surfaces come together (articulus = "joint"). These surfaces tend to conform to one another, such as one being rounded and the other cupped, to facilitate the function of the articulation. A **projection** is an area of a bone that projects above the surface of the bone. These are the attachment points for tendons and ligaments. In general, their size and shape is an indication of the forces exerted through the attachment to the bone. A **hole** is an opening or groove in the bone that allows blood vessels and nerves to enter the bone. As with the other markings, their size and shape reflect the size of the vessels and nerves that penetrate the bone at these points.

Common bone markings include the following:

Type of Bone Marking	Description of Bone Marking Type
angle	Sharp bony angulations which may serve as bony or soft tissue attachments. *Examples: superior, inferior, and acromial angles of the scapula; superior, inferior, lateral angles of the occipital bone; angle of the mandible*
body	Usually refers to the largest most prominent segment of bone. *Examples: diaphysis or shaft of long bones like the femur and humerus; body of the mandible*
canal	Passageway through a bone. *Example: optic canal*
condyle	Refers to a large rounded prominence which often provides structural support to the overlying hyaline cartilage. *Examples: femoral lateral and medial condyles; tibial lateral and medial condyles; occipital condyles articulate with 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 is found on the ilium. *Example: median sacral crest*
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: femoral medial and lateral epicondyles; humeral medial and lateral epicondyles*
facet	A smooth, flat surface where two bones meet to forms a joint. *Example: articular facets 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: superior and inferior orbital fissures*
foramen (pl. foramina)	A hole in a bone through which nerves and blood vessels pass. *Examples: foramen magnum; supraorbital foramen; infraorbital foramen; mental foramen*
fossa (pl. fossae)	A shallow depression in a bone surface. *Examples: trochlear fossa; posterior, middle, and anterior cranial fossae*
fovea (pl. foveae)	Shallow pit that allow the attachment of a ligament. *Example: fovea capitis of the femur*
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. *Example: 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; the head of the femur*
line	Ridge along a bone that allows a muscle to attach to the bone. *Example: arcuate line (of the ilium)*
margin	The edge of any flat bone. *Example: edge of the temporal bone articulating with the occipital bone is the occipital margin of the temporal bone*
meatus (pl. meatuses)	A tube-like channel that extends within the bone, which may provide passage and protection to nerves, vessels, and sound. *Examples: external acoustic meatus; internal auditory meatus*
neck	The segment between the head and the shaft of a bone. *Example: anatomical neck of the humerus*
notch	A depression in a bone which often, provides stabilization to an adjacent articulating bone. *Examples: trochlear notch on the ulna; radial notch of the ulna; suprasternal notch; mandibular notch*
process (pl. processes)	Bony projection, allow for muscle attachment. *Examples: spinous process, acromial process, radial styloid process*
protuberance	A bump or outgrowth on a bone. *Example: external occipital protuberance*
ramus (pl. rami)	The curved part of a bone that gives structural support to the rest of the bone. *Example: ramus of the mandible*
sinus	A cavity within a bone. *Example: sphenoidal sinus*

Type of Bone Marking	Description of Bone Marking Type
sulcus (pl. sulci)	Same as groove. *Example: intertubercle sulcus of the humerus*
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. *Examples: greater and lesser trochanters of the femur*
tubercle	A small, rounded prominence where connective tissues attach. *Examples: 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: tibial tuberosity; deltoid tuberosity; ischial tuberosity*

Attributions

- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0
- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0

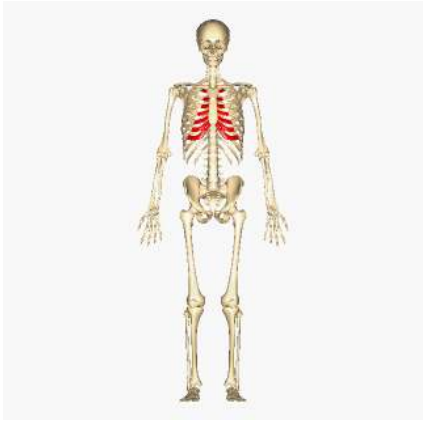
Updated 2025.

This page titled 7.6: Bone Markings is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

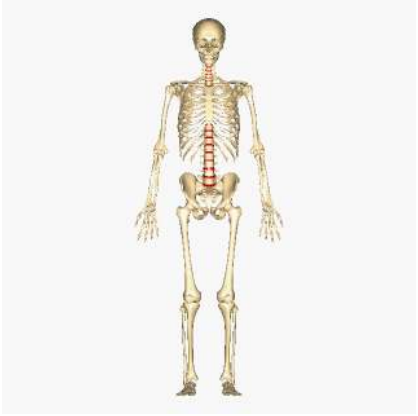
7.7: Cartilage

Cartilage

In additional to bone, cartilage is also an important part of the skeletal system creating structure, connecting bones, cushioning joints (**articulations**), protecting the ends of bones, and providing shock absorption. There are three different types of cartilage in the human body: **hyaline cartilage**, **elastic cartilage**, and **fibrocartilage** (see table below). For example, hyaline cartilage connects the ribs to the sternum and is called the **costal cartilage** (see image/gif animation below). Another example is the fibrocartilage is located between each vertebrae pair making up part of the **intervertebral discs**, which are crucial for separating the vertebrae, providing shock absorption, and better distributing pressure between the vertebrae (see image/gif animation below).

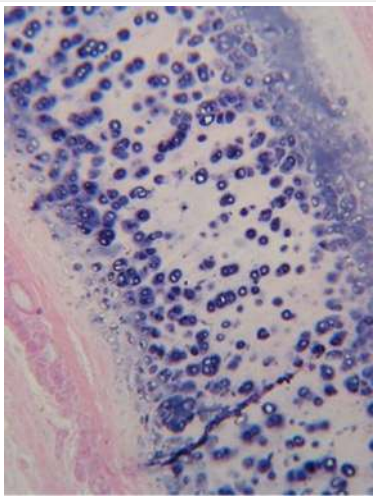


Above: The human skeleton highlighting the costal cartilage in red.



Above: The intervertebral discs containing fibrocartilage are shown in red (located between the vertebrae).

hyaline cartilage	elastic cartilage	fibrocartilage

	hyaline cartilage	elastic cartilage	fibrocartilage
Microscopic image of tissue			
Characteristics of tissue	• sturdy • cushioning • resilient • distributes pressure	• sturdy • flexible	• strong • flexible • compressible
Locations of tissue	• costal cartilage (connects ribs and sternum) • covering end of bones in free-moving joints • nose • outer lining of the larynx • outer lining of the trachea • outer lining of the bronchi	• external ear • epiglottis	• pubic symphysis • intervertebral discs • meniscus (in the knee joint)

Attributions

- "Anatomy and Physiology Lab Reference" by Laird C Sheldahl, OpenOregonEducational Resources, Mt. Hood Community College is licensed under CC BY-SA 4.
- "BodyParts3D/Anatomography" by The Database Center for Life Science is licensed under CC BY-SA 2.1
- "Costal cartilages animation" by Anatomography is licensed under CC BY-SA 2.0
- "Intervertebral discs - close-up - animation" by Anatomography is licensed under CC BY-SA 2.0

Updated 2025.

This page titled 7.7: Cartilage is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

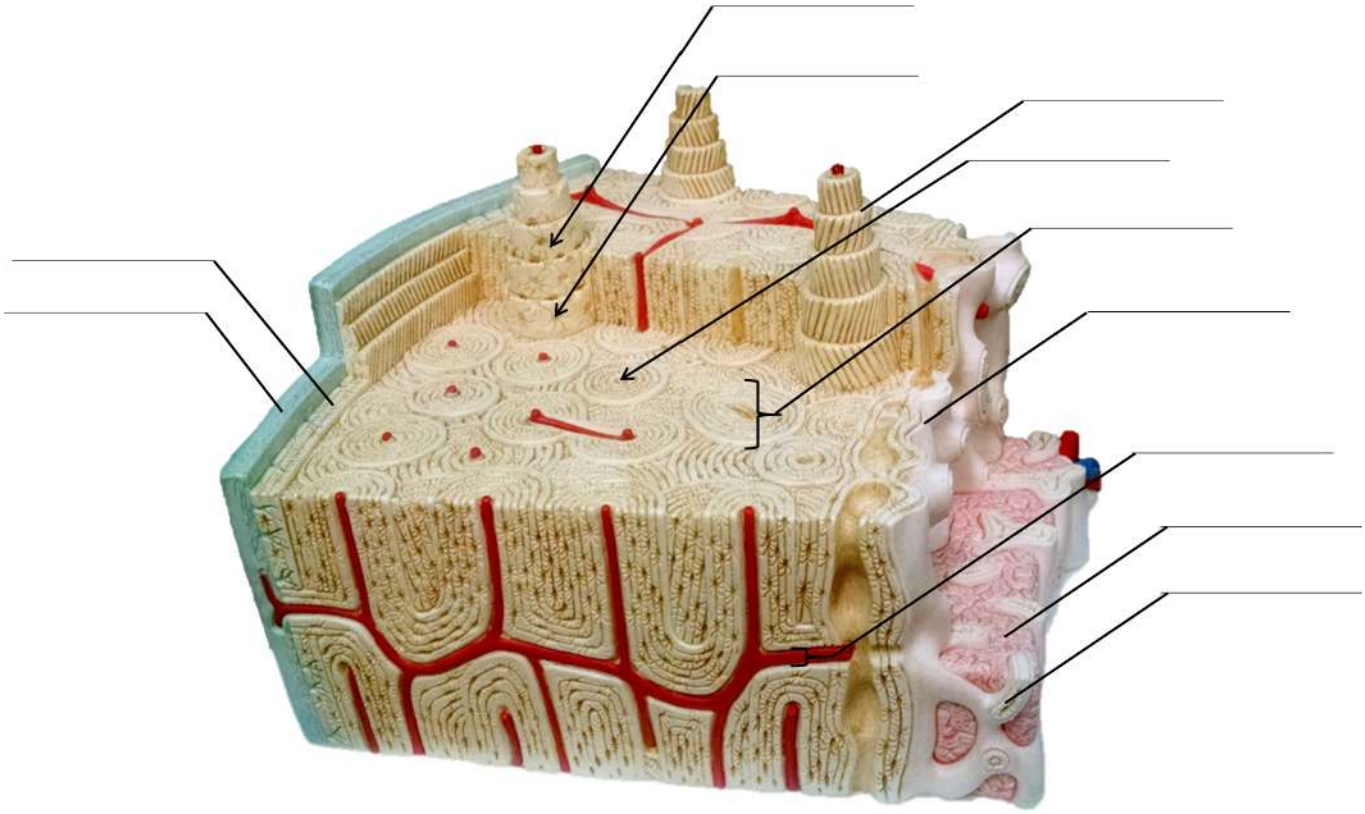
7.8: Laboratory Activities and Assignment

Laboratory Activities and Assignment

Part 1: Review of the Introduction to Skeleton Anatomy

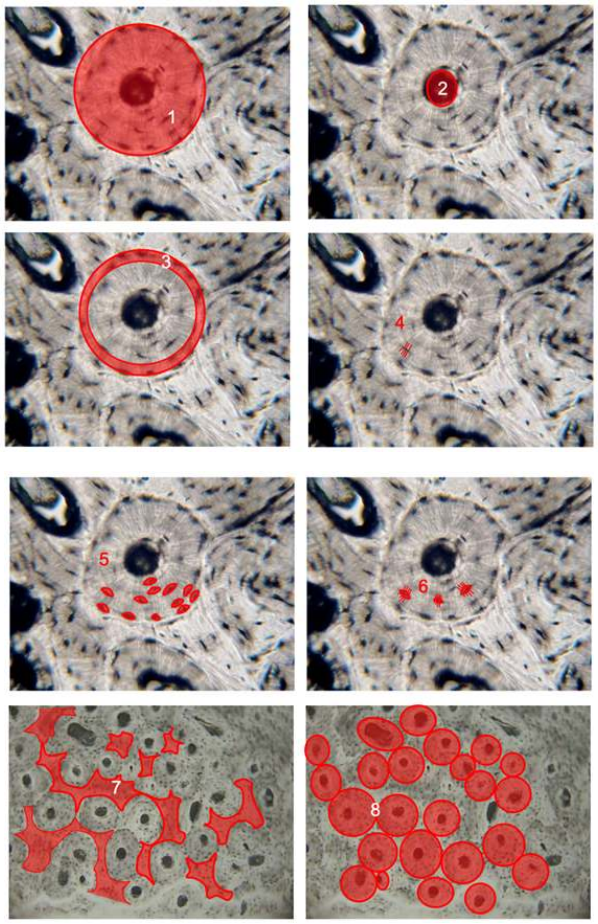
1. Identify and label the bone structures listed using the anatomical model of bone shown below:

• periosteum • endosteum • osteon	• central canal • osteocyte in lacuna • canaliculus	• Volkmann's canal • circumferential lamellae • concentric lamellae	• trabecula • bone marrow



2. Label the structures of compact bone shown in this microscopic images below in the table. Each image is labeled with the number. Place the corresponding anatomical name in the table below next to the number of the image highlighting that structure.

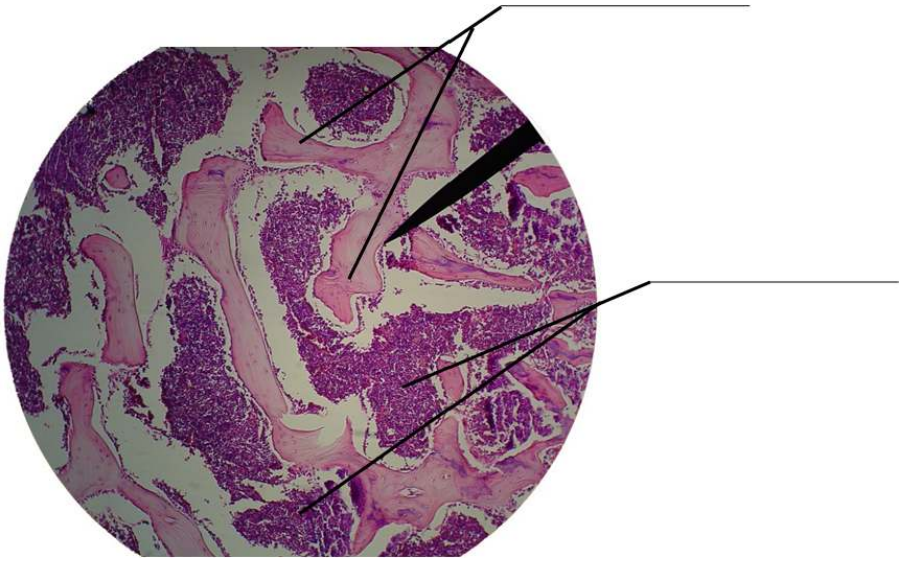
• interstitial lamella • canaliculi • osteocytes	• concentric lamella • osteons (multiple) • lacuna	• central canal • osteon (1)



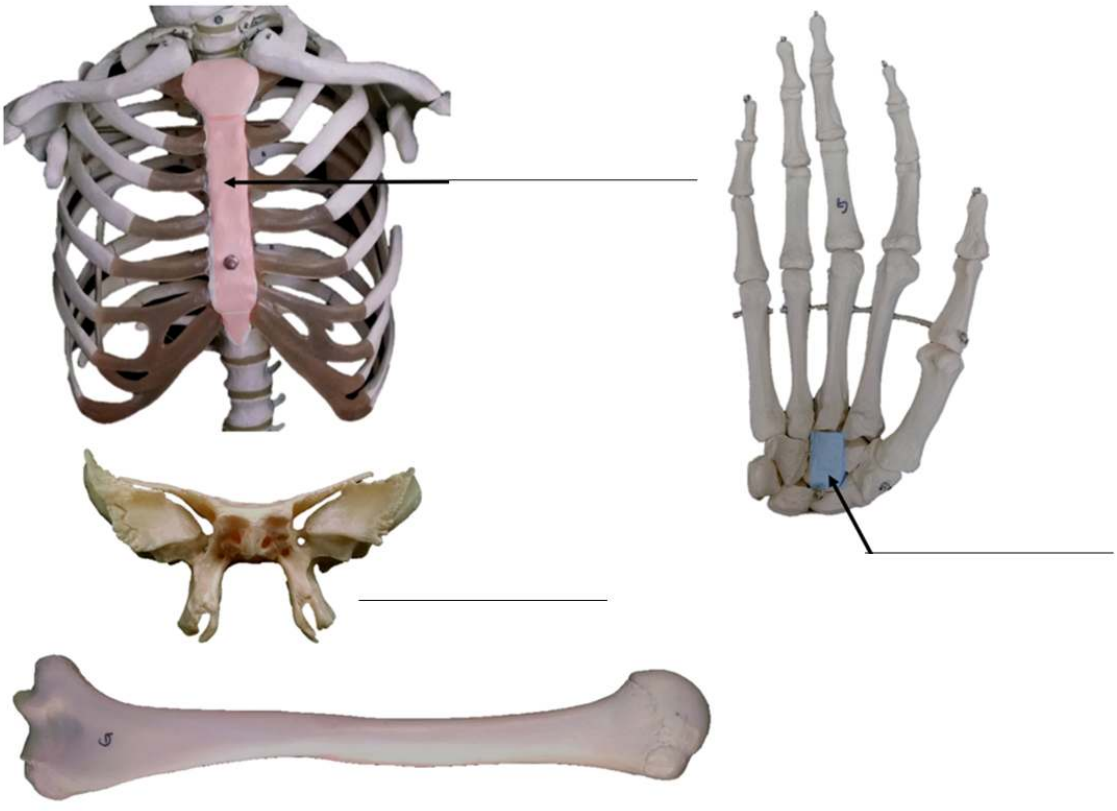
Structure #	Structure Name
1	
2	
3	
4	
5	
6	
7	
8	

3. Label spongy bone structures shown in this micrograph (arrows):

- trabecula
- bone marrow



4. Identify the shape of the bones shown below as: long, short, flat, sesamoid or irregular. Write your answers on the spaces provided.

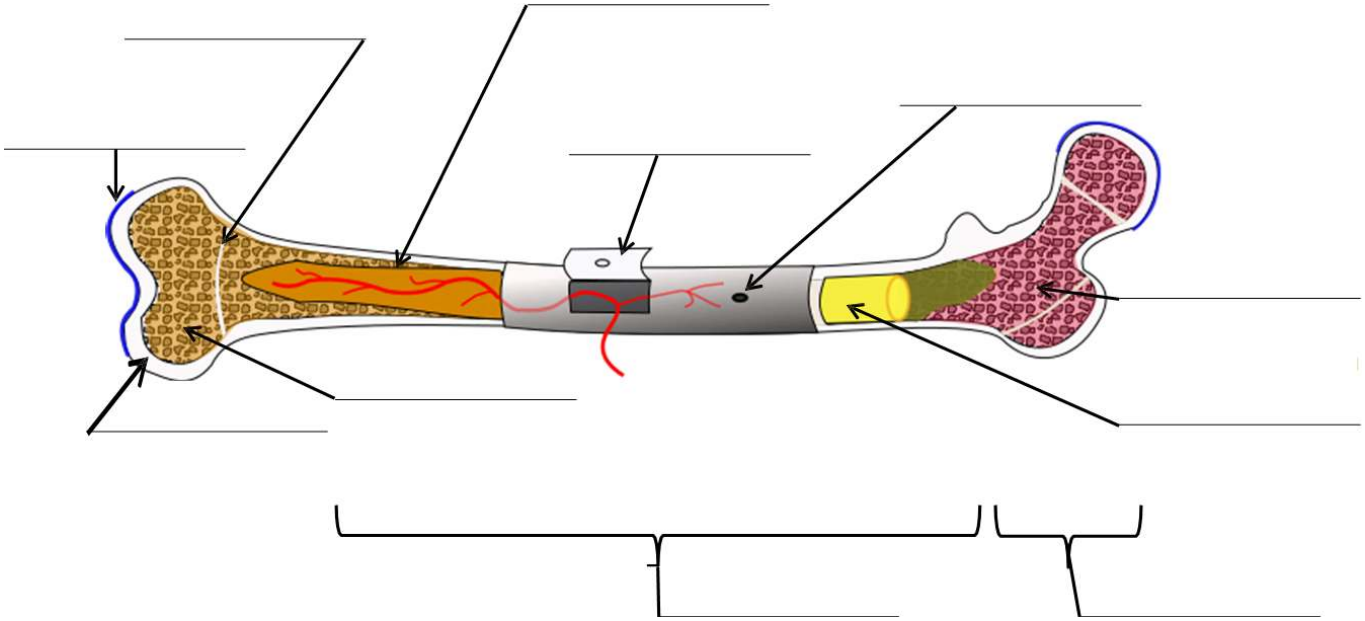


5. Name five bones of the axial skeleton and five bones of the appendicular skeleton.

Bones of the Axial Skeleton Include:	Bones of the Appendicular Skeleton Include:
1. 2. 3. 4. 5.	1. 2. 3. 4. 5.

6. Label the anatomy of a long bone with the terms listed below.

• epiphysis • diaphysis • articular cartilage • epiphyseal line	• red bone marrow • yellow bone marrow • periosteum • endosteum	• compact bone • spongy bone • nutrient foramen

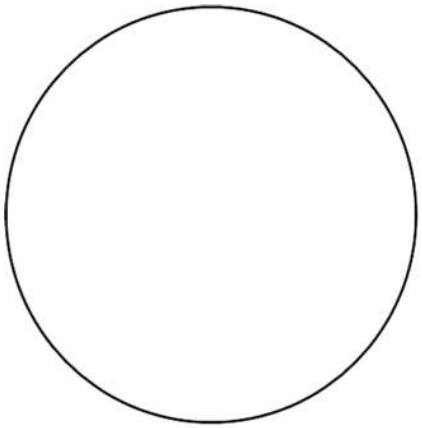


Part 2: Skeletal Histology

1. Obtain the slides listed below that are available for today's lab.
2. Focus on each sample and identify the structures listed for each type of tissue.
3. Indicate the **total** magnification you make each illustration at in the space provided.
4. Illustrate each tissue you observe with the microscope at the magnification you listed.
5. Label each illustration with the structures listed for each.

Compact Bone

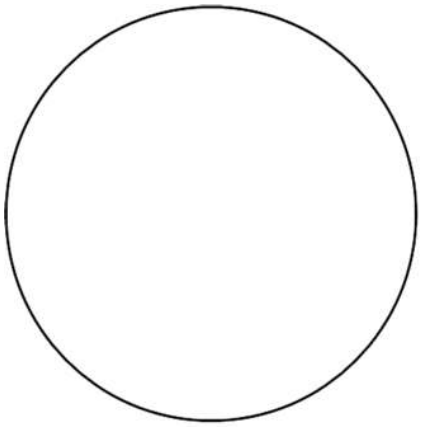
Label the tissue with: osteon, concentric lamella, osteocyte in lacuna, central canal, canaliculi



Total magnification: _____

Spongy Bone

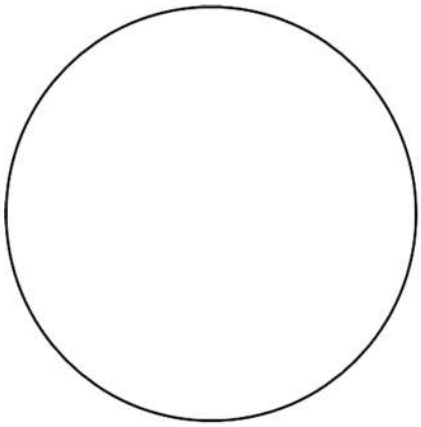
Label the tissue with: trabeculae, bone marrow



Total magnification: _____

Hyaline Cartilage

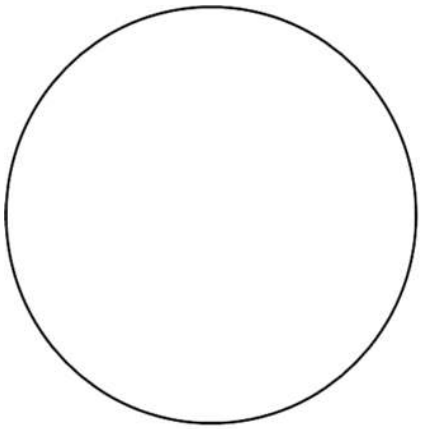
Label the tissue with: chondrocyte, lacuna, matrix



Total magnification: _____

Elastic Cartilage

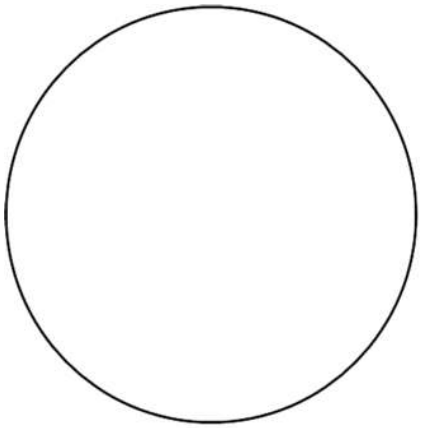
Label the tissue with: chondrocyte, lacuna, elastic fibers, matrix



Total magnification: _____

Fibrocartilage

Label the tissue with: chondrocyte, lacuna, collagen fibers



Total magnification: _____

Part 3: Bone Shape Classifications

Identify bone shapes

1. Work in groups of 2-4.
2. Obtain a disarticulated bone set.
3. Organize the bones according to shape.
4. Examine each bone listed below and discuss with your group which shape classification is appropriate for each. You may need to refer your textbook and/or laboratory manual for help identifying each bone.
5. Write the shape classification for each bone listed in the table below.

Bone Shapes

• flat bone • short bone	• irregular bone • long bone	• sesamoid bone

Bones	Bone Shape
frontal bone	
temporal bone	
parietal bone	

Bones	Bone Shape
hyoid bone	
vertebra	
mandible	
sternum	
clavicle	
scapula	
carpal bone	
metacarpal	
rib	
humerus	
patella	
radius	
ulna	
sacrum	
coccyx	
ilium	
ischium	
pubis	
femur	
tibia	
fibula	
calcaneus	
metatarsal	
phalanx	

Part 4: Bone Markings

Identify bone markings

1. Work in groups of 2-4.
2. Obtain a disarticulated bone set.
3. Organize the bones according to shape.
4. Examine each bone to find bone markings described in this lab exercise. You may need to refer your textbook and/or laboratory manual for help.
5. Write ***at least one bone marking*** found on each bone in the table below.

Some Common Types of Bone Markings

- angle
- canal
- condyle
- epicondyle
- facet
- fissure
- foramen
- fossa
- head
- meatus
- neck
- process
- protuberance
- ramus
- sulcus
- trochanter
- tubercle
- tuberosity

Bones	Markings on the bone
frontal bone	

Bones	Markings on the bone
occipital bone	
temporal bone	
vertebra	
mandible	
sternum	
clavicle	
scapula	
rib	
humerus	
radius	
ulna	
ilium	
ischium	
pubis	
femur	
tibia	
fibula	

Attributions

Part 1: Review of Introduction to Skeleton Anatomy

- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0
- "Human Anatomy Lab Manual" by Malgosia Wilk-Blaszczak, Mavs Open Press, University of Texas at Arlington is licensed under CC BY 4.0
- "Anatomy and Physiology Lab Reference" by Laird C Sheldahl, OpenOregonEducational Resources, Mt. Hood Community College is licensed under CC BY-SA 4.0

Part 2: Skeletal Histology

- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0

Part 3: Bone Shape Classifications

- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0

Part 4: Bone Markings

- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0

Updated 2025.

This page titled 7.8: Laboratory Activities and Assignment is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

CHAPTER OVERVIEW

8: Axial Skeleton

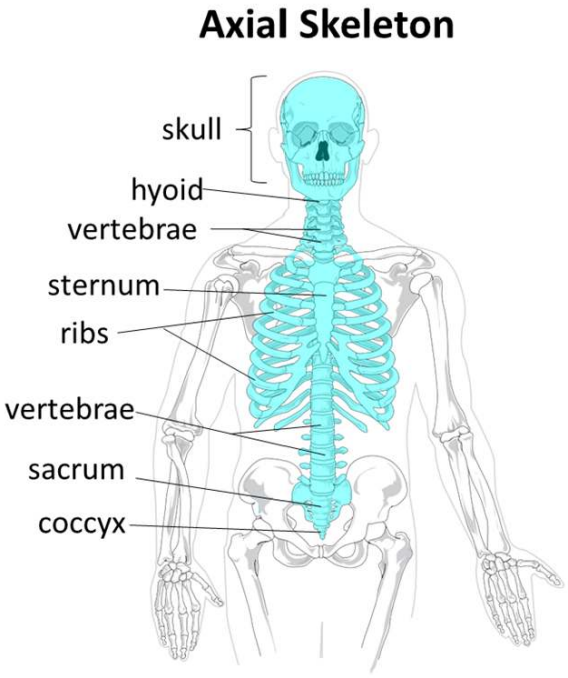
8.1: Introduction
8.2: Skull
8.2.1: Exterior of the Cranium
8.2.2: Interior of the Cranium
8.2.3: Markings of the Cranium
8.2.4: Face
8.3: Hyoid Bone
8.4: Auditory Ossicles
8.5: Vertebral Column
8.5.1: Introduction to the Vertebral Column
8.5.2: Generalized Structure and Markings of Vertebrae
8.5.3: Cervical Vertebrae
8.5.4: Thoracic Vertebrae
8.5.5: Lumbar Vertebrae
8.5.6: Sacrum and Coccyx
8.5.7: Intervertebral Foramina
8.5.8: Intervertebral Discs
8.5.9: Clinical Application - Whiplash
8.6: Thoracic Cage
8.7: Additional Reference Figures
8.8: Laboratory Activities and Assignment
8.9: Collaborative Study Activities

This page titled 8: Axial Skeleton is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

8.1: Introduction

Introduction

The axial skeleton consists of the bones of the **skull**, the bones of the **inner ear** (known as ossicles), the **hyoid bone** in the throat, and the bones of the **vertebral column**, including 24 **vertebrae** (7 cervical vertebrae, 12 thoracic vertebrae, and 5 lumbar vertebrae) and the **sacrum** and **coccyx** in the center of the pelvic girdle, and the bones of the **thoracic cage** (commonly known as the rib cage), comprised of 12 pairs of ribs and ther sternum.



Above: Illustration of of most of the human skeleton with the axial skeleton highlighted. The axial skeleton includes all the bones of the skull, the hyoid bone, all the vertebrae, the sacrum, the coccyx, all the ribs, the sternum.

Attributions

- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0

Updated 2025.

This page titled 8.1: Introduction is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

8.2: Skull

8.2.1 Exterior of the Cranium

8.2.2 Interior of the Cranium

8.2.3 Markings of the Cranium

8.2.4 Face

This page titled 8.2: Skull is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

8.2.1: Exterior of the Cranium

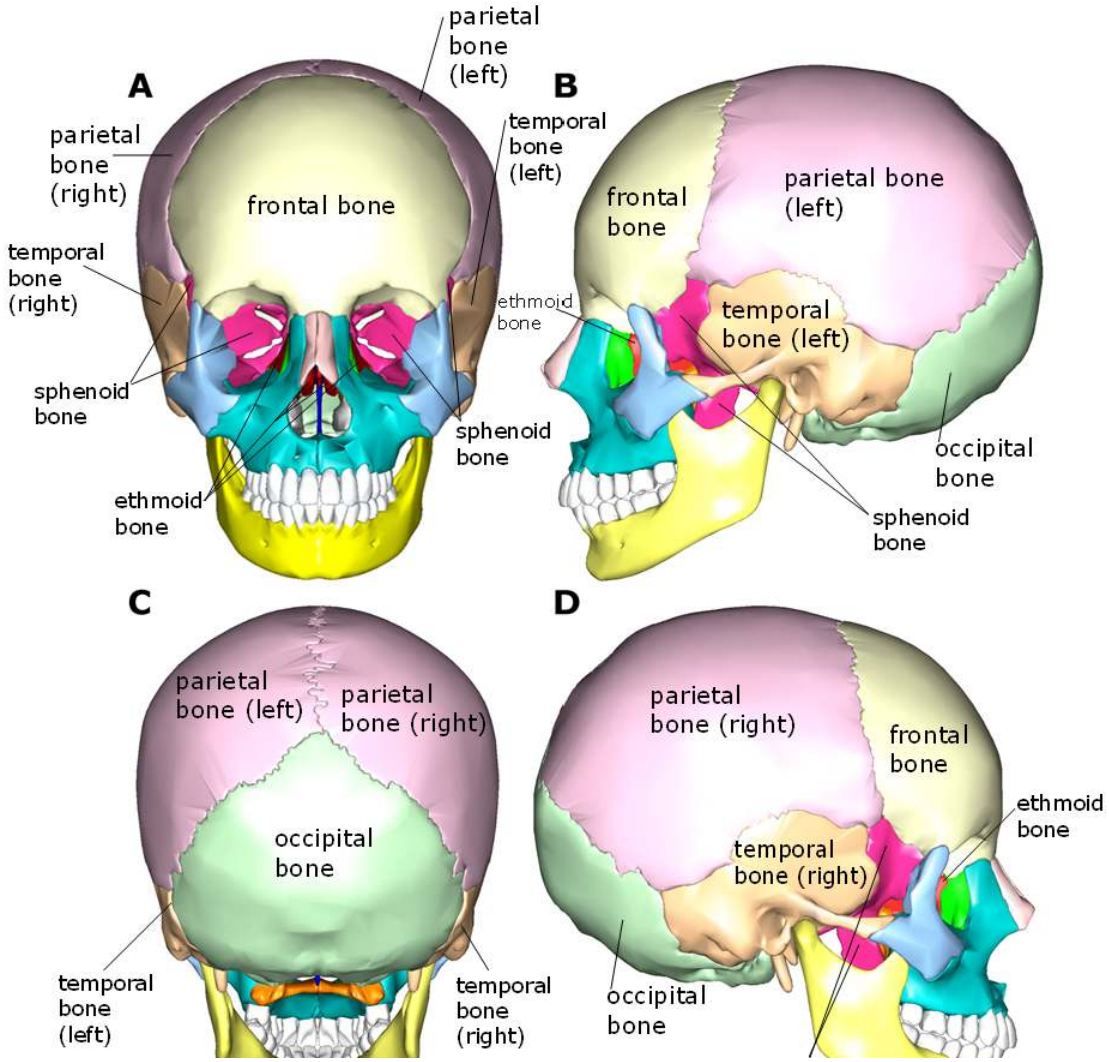
Skull

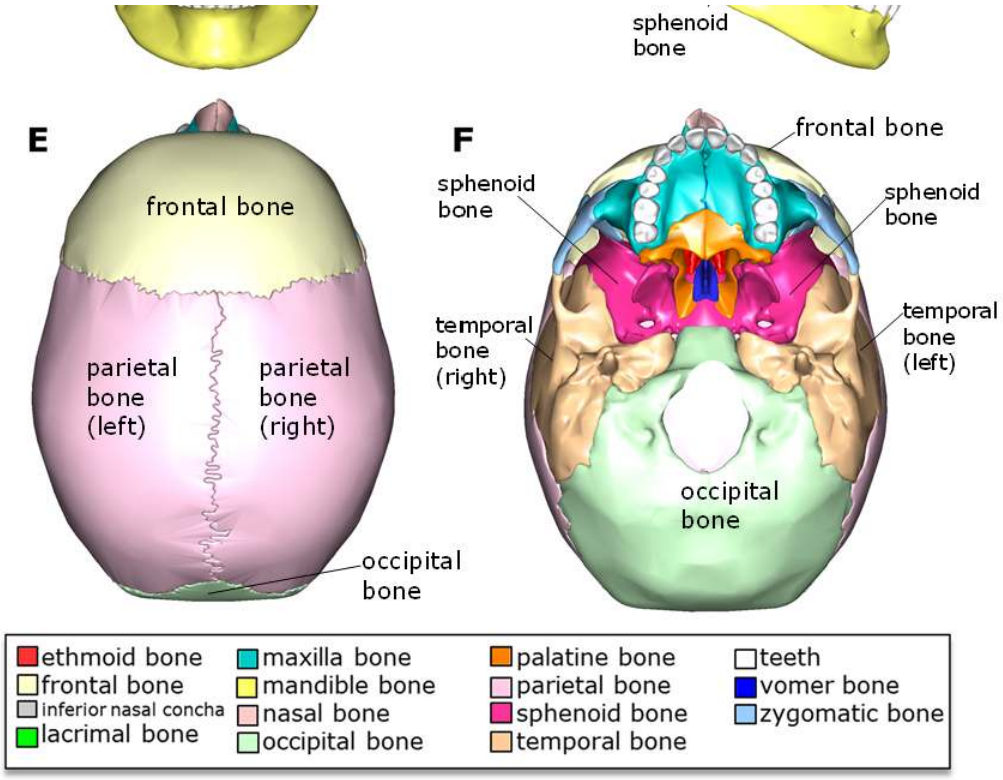
There is only one movable joint in the skull. That is the joint connecting the lower jaw, or mandible, to the rest of the skull. All the other bones in the skull are firmly attached to one another by **sutures**. Sutures are rigid immovable connections holding bones tightly to one another. Some of the sutures in the skull take a few months-to-years after birth to completely form. The brain is encased in the **cranium** of the skull. The bones that make up the cranium are called the **cranial bones**. The remainder of the bones in the skull are the **facial bones**.

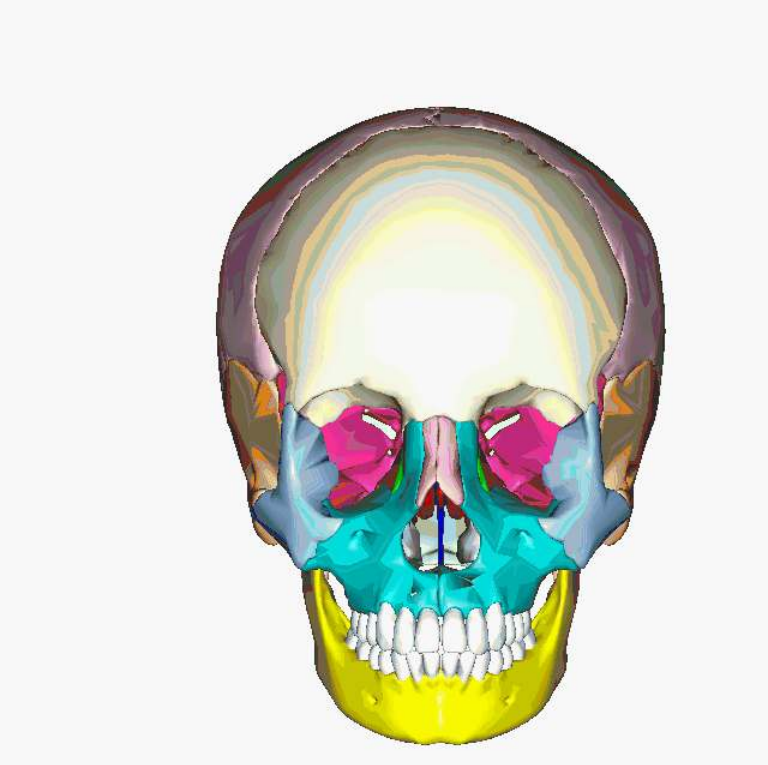
Exterior of the Cranium

The bones of the cranium include the **frontal bone** (1), **parietal bones** (2, one right and one left), **temporal bones** (2, one right and one left), **occipital bone** (1), **sphenoid bone** (1), and **ethmoid bone** (1). These bones enclose and protect the cranial cavity that contains the brain. All of these bones, except for the parietal bones, can also be observed when examining the interior superior view of the cranium (see the **Interior of the Cranium** section below). Both the sphenoid bone and the ethmoid bone are single, unpaired bones that form deeper parts of the skull and therefore, small portions of these bones can be viewed from the skull exterior (see the **Sphenoid Bone** and **Ethmoid Bone** sections below to examine the positions of these bones further).

Bones of the Exterior Cranium







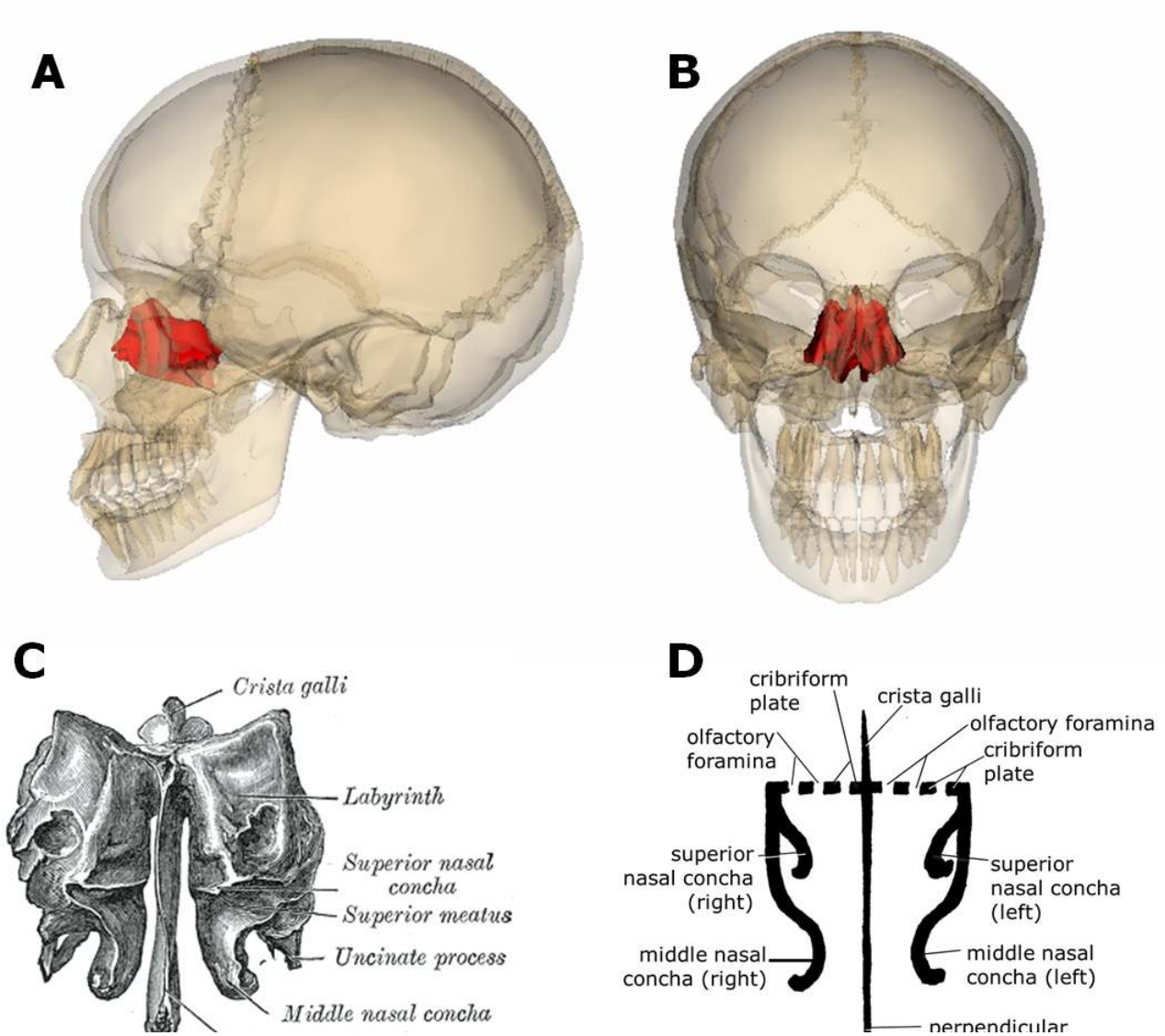
Above: The cranial bones. Figure A is the anterior skull view, figure B is the lateral view of the left side of the skull, figure C is the posterior view of the skull, figure D is the lateral view of the right side of the skull, figure E is the superior view of the skull with the anterior position being at the top of the diagram, and figure F is the inferior view of the skull with mandible removed; the anterior position is at the top of the diagram.

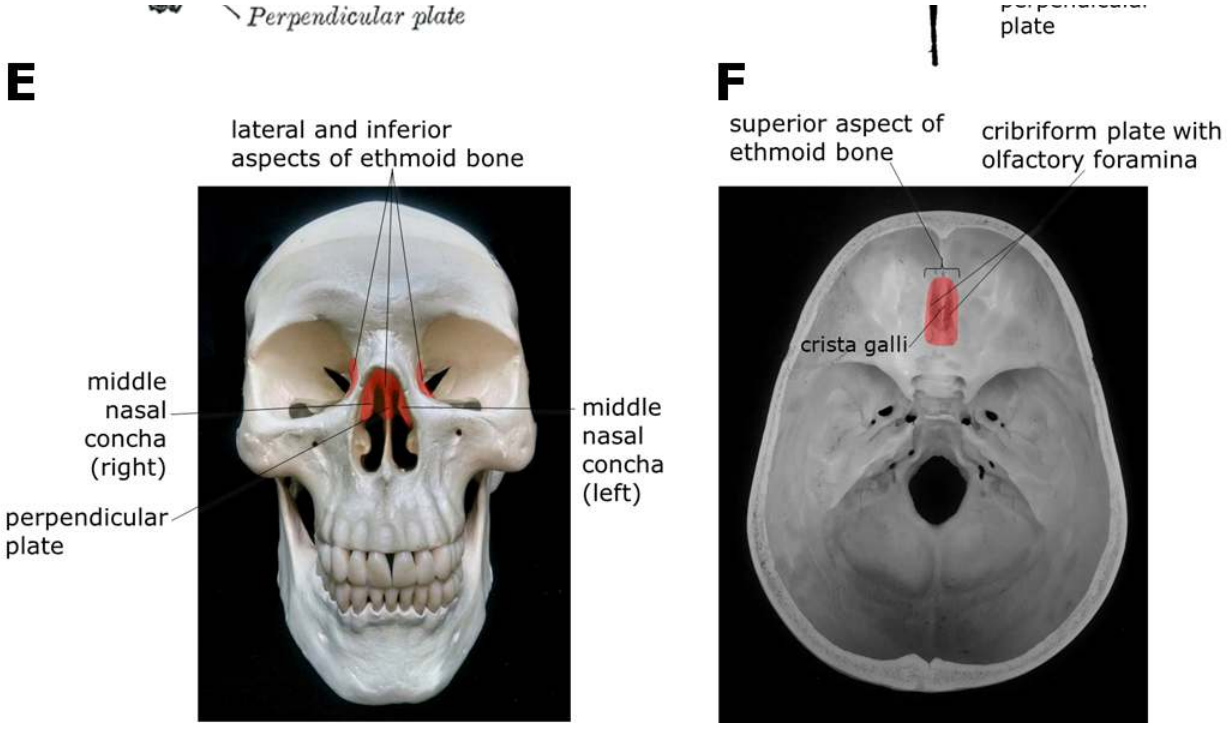
Ethmoid Bone

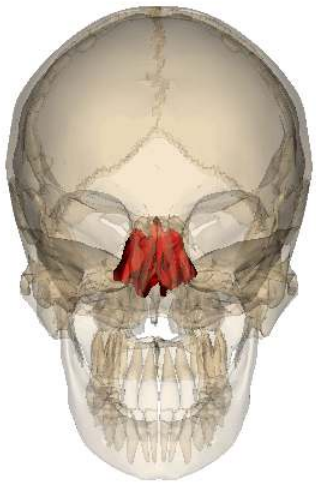
The ethmoid bone is located deep in the anterior of the skull forming part of the nasal cavity, including the paired **superior nasal conchae** (right and left) and **middle nasal conchae** (right and left), bony projections that point medially into the nasal cavities. These conchae form paired canals or passageways (right and left) in the nasal cavities for air passage called **nasal meatuses** (**superior**, **middle**, and **inferior nasal meatuses**). There are also paired medially-projecting **inferior nasal conchae**, but these are a part of the **maxilla bone**, a facial bone. A medial, inferior-pointing projection called the **perpendicular plate** of the ethmoid bone creates the superior aspect of the septum separating the right and left nasal cavities. The perpendicular plate articulates with part of the **vomer bone** which form the inferior portion of the nasal septum.

The ethmoid bone also creates separation between the nasal cavity and the cranial cavity. This separation is created by the **cribriform plates** of the ethmoid bone, two flat regions that house numerous pin-hole foramina called **olfactory foramina**. At the inferior aspects of the cribriform plates, **olfactory epithelia** are equipped with **olfactory sensory neurons** collecting scent information. The olfactory foramina are passageways where axons of these scent-sensing neurons can pass into the cranial cavity and bring olfactory (scent) information to the **olfactory bulbs** of cranial nerve I (**C.N. I olfactory nerve**), transmitting scent information to the brain. The two cribriform plates are separated by **crista galli**, a superior-pointing projection of the ethmoid bone that can be seen inside the cranial cavity. The olfactory bulbs of C.N. I are positioned on either side of crista galli on top of the two cribriform plates.

Small segments of the ethmoid bone also make up medial regions of each of the right and left **orbits** or eye sockets.





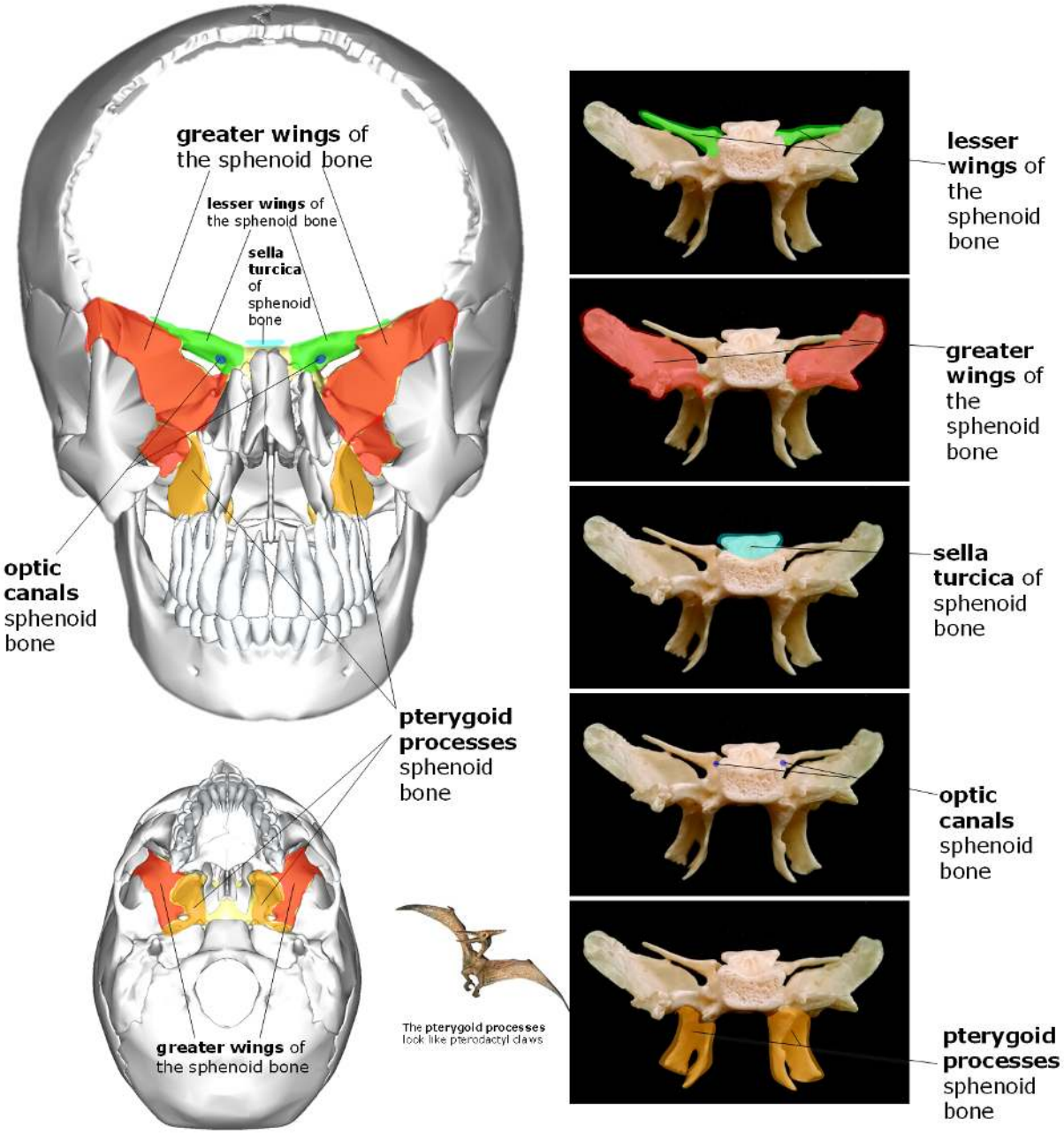


Above: This figure provides images depicting the location of the ethmoid bone and its structures. Image A highlights the ethmoid bone in red with a lateral view. Image B highlights the ethmoid bone in red with an anterior view. Diagram C is an illustration of the ethmoid bone alone with an anterior view. Crista galli, an upward projection of the ethmoid bone, can be observed in the interior of the cranium and the perpendicular plate and middle nasal concha in the nasal cavity. Diagram D shows a simplified version of the ethmoid bone from an anterior view. In this diagram, you can see the cribriform plates, containing olfactory foramina, are located on either side of crista galli. These structures are visible in the cranium interior. Images E and F highlight the ethmoid bone in red and point to important structures of the ethmoid bone. Image E shows the anterior view of the skull and image F shows the superior view of the cranium interior with the anterior of the skull at the top of the image.

https://bio.libretexts.org/@go/page/53617

Sphenoid Bone

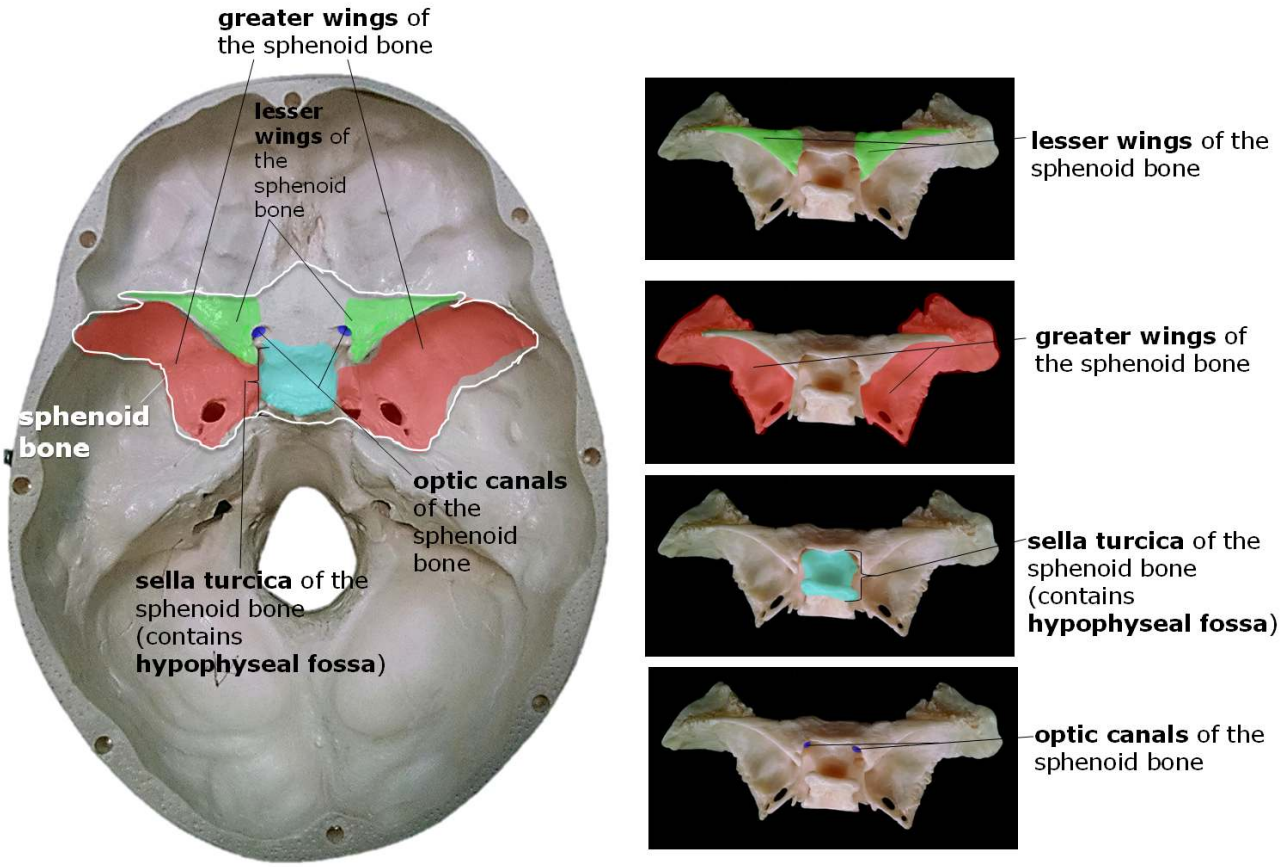
The sphenoid bone is a central bone in the skull located toward the anterior of the skull, but posterior to the ethmoid bone. The sphenoid bone creates some of the exterior of the cranium laterally on both the right and left sides between the temporal, parietal, and frontal bones. Inferiorly, the sphenoid bone is located posterior to the palatine bones (the palatine bone forms the posterior of the roof of the mouth). At this most inferior point of the sphenoid are pterygoid processes where chewing muscles attach.





Above: (Left top) Anterior view of the skull with the frontal bone and maxilla bone removed and the sphenoid bone highlighted in yellow. Parts of the sphenoid bone are further colored in green (**lesser wings**), red (**greater wings**), blue (**optic canals**), and orange (**pterygoid processes**). (Left bottom) Inferior view of the skull with the mandible and bottom teeth removed. The sphenoid bone is highlighted in yellow with the pterygoid processes highlighted orange and the greater wings in red. (Right) The sphenoid bone alone, anterior view. Structures of the sphenoid are highlighted the same colors as the other parts of the figure.

The sphenoid bone also forms the posterior aspect of the orbits (eye sockets) including the right and left pair of **superior orbital fissures** and the right and left pair of optic canals. These superior orbital fissures allow for the pairs (right and left) of cranial nerves III, IV, part of V, and VI (C.N. III oculomotor, C.N. IV trochlear, C.N. V trigeminal, and C.N. VI abducens) to pass from the brain to the eyes to control movements of the eyes. The **optic canals** provide a means for the right and left pair of cranial nerve II (C.N. II optic nerve) to pass from the eyes to the cranial cavity carrying sight information to the brain (one through the right optic canal and one through the left optic canal). One side of the optic canals can be see in the posterior aspects of the orbits and the other side of the optic canals can be seen as part of the sphenoid bone in the cranial cavity medial to the lesser wings of the sphenoid.



Above: (Left) Superior view of the interior of the cranium of the skull. (Right) The sphenoid bone alone, superior view. The sphenoid bone is shown highlighted with parts of the bone colored differently to describe its different parts. The lesser wings are colored green, the greater wings are colored red, sella turcica, a saddle-like structure with the hypophyseal fossa at the "seat" of the saddle, is colored light blue, and the optic canals are dark blue.

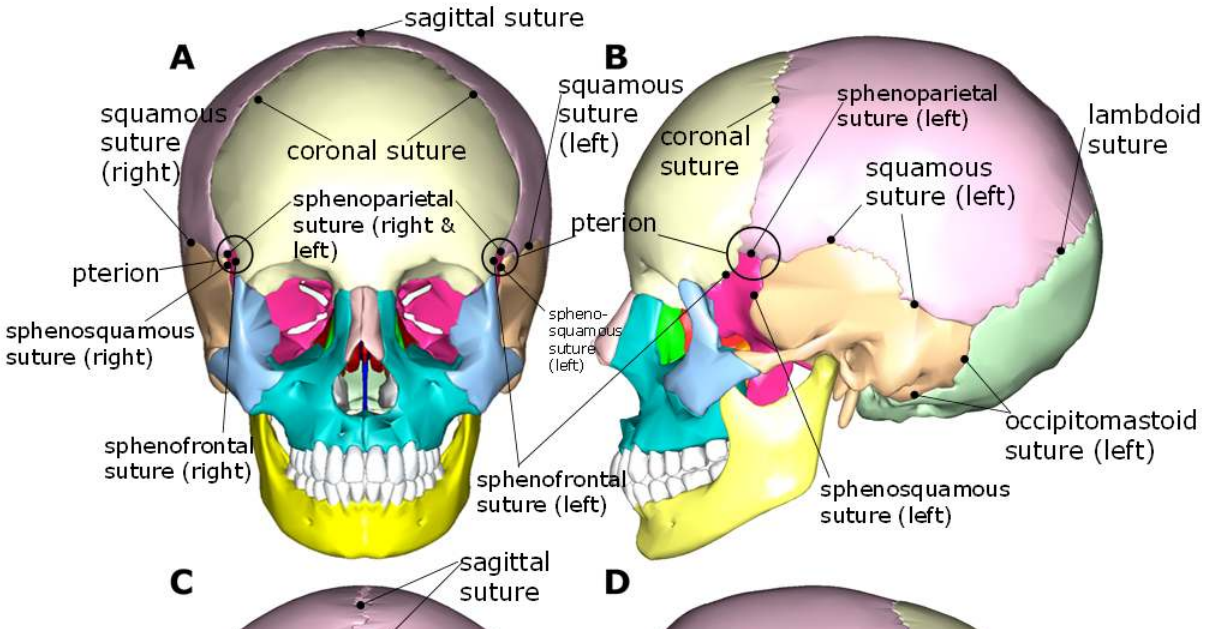
The sphenoid bone, from the outside, appears to contribute to only a small portion of the cranium, but when the parietal bones are removed and the interior of the cranial cavity (where the brain would be housed) is viewed, you can see the butterfly-like shape of the sphenoid bone makes a large contribution to the floor of the cranial cavity. The sphenoid bone appears to have two sets of wings, one larger, broader, and more inferior (the **greater wings**), and one smaller, shorter, and more superior (the **lesser wings**). The lesser wings contribute to the **anterior cranial fossa** with the frontal bone and the ethmoid bone and the greater wings contribute to the **middle cranial fossa** with the temporal bone. In the cranial cavity, the sphenoid bone forms a saddle-like structure medial to the greater wings called **sella turcica**. In the "seat" of the saddle of sella turcica is a basin-like structure called the **hypophyseal fossa** where the **pituitary gland** is positioned (note: **hypophysis** is another term for the pituitary gland).

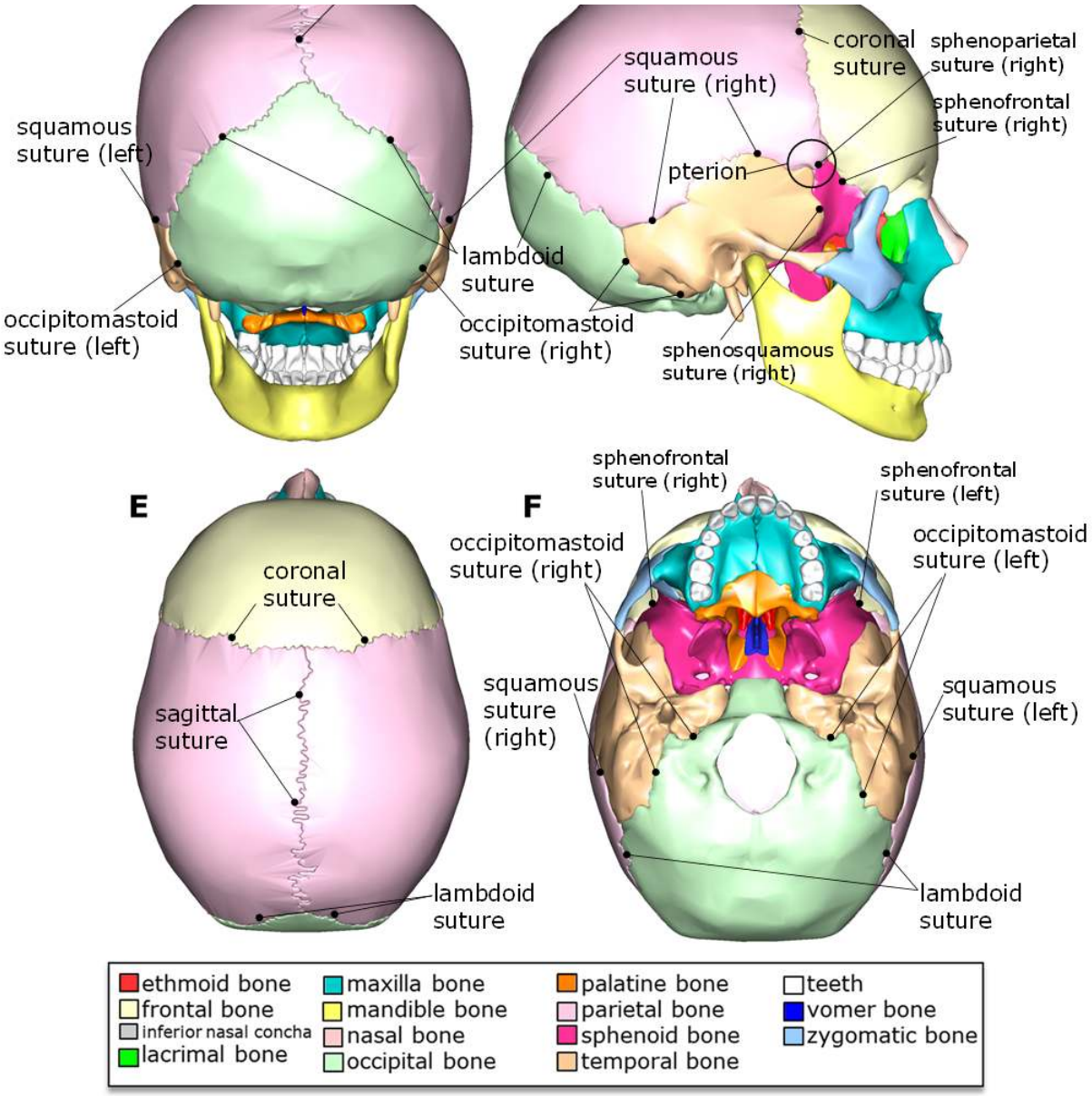
Sutures of the Cranium

The cranial bones are joined together with **sutures**, a type of unmoving joint or **articulation** between bones. Examine the table and figure below listing and showing the cranial sutures.

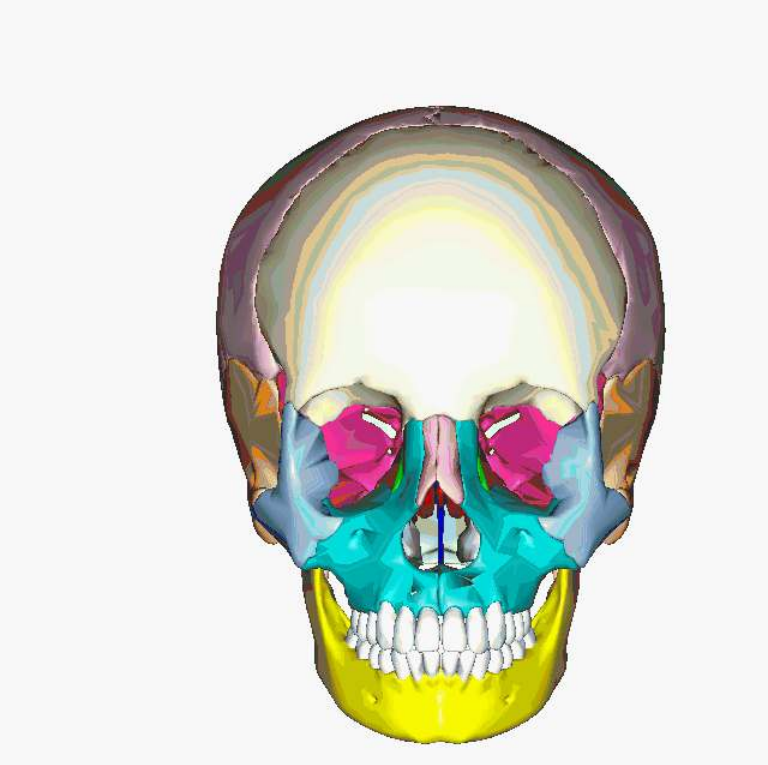
Suture	Articulating Bones
coronal suture	Frontal bone and the right/left parietal bones articulate at the **coronal suture**. This suture occurs in the coronal/frontal plane, hence where its name comes from.

Suture	Articulating Bones
lambdoid suture	Occipital bone and the right and left parietal bones articulate at the **lambdoid suture**. The suture shape is similar to the symbol for the uppercase Greek letter lambda (Λ), hence where the "lambd-" of the name comes from.
occipitomastoid suture	Occipital bone and the right and left temporal bones articulate at the **occipitomastoid suture**. This suture occurs near the mastoid process of the temporal bone, hence it is called "occipito-" for the occipital bone and "-mastoid" for the mastoid region of the temporal bone.
pterions (2, one right and one left)	Put your fingers on your **temples** and you are pointing to the two **pterions** of your skull. The junction between the parietal bone, temporal bone, frontal bone, and sphenoid bone forms this H-shaped suture configuration called **pterion**.
sagittal suture	Right and left parietal bones articulate at the **sagittal suture**. This suture occurs in the sagittal plane, hence where its name comes from.
sphenofrontal sutures (2, one right and one left)	Sphenoid bone and frontal bone articulate at these **sphenofrontal sutures**. The "spheno-" part comes from the sphenoid bone and the "-frontal" part comes from the frontal bone - the two bones articulating at this suture.
sphenoparietal sutures (2, one right and one left)	Sphenoid bone and one of the parietal bones form each of these paired sutures called **sphenoparietal sutures**. The "spheno-" part comes from the sphenoid bone and the "-parietal" part comes from the pareital bone - the two bones articulating at this suture.
spheno-squamous suture (2, one right and one left)	Sphenoid bone and squamous region of the temporal bones articulate at the **sphenosquamous sutures**. The "spheno-" part comes from the sphenoid bone. "-Squamous" comes from the fact that these regions of the right and left temporal bones are known as "pars squama" regions since they are roughly flat areas. Recall that epithelial tissues with flat cells are called **squamous**.
squamous sutures (2, one right and one left)	On the right side, the **squamous suture** occurs between the right parietal bone and the right temporal bone. On the left side, the **squamous suture** occurs between the left parietal bone and the left temporal bone. The squamous sutures gets their names because these regions of the right and left temporal bones are known as "pars squama" regions since they are roughly flat areas. Recall that epithelial tissues with flat cells are called **squamous**.



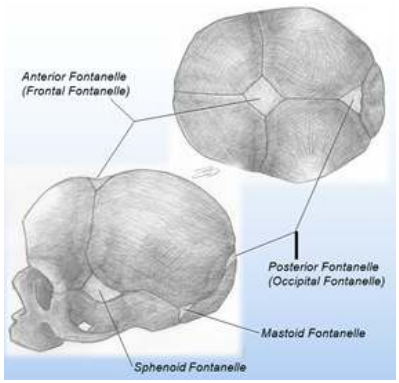


https://bio.libretexts.org/@go/page/53617



Above: The sutures of the cranial bones. Figure A is the anterior skull view, figure B is the lateral view of the left side of the skull, figure C is the posterior view of the skull, figure D is the lateral view of the right side of the skull, figure E is the superior view of the skull with the anterior position being at the top of the diagram, and figure F is the inferior view of the skull with the mandible removed; the anterior position is at the top of the diagram.

Clinical Application: Fontanelles



It is common to hear people talking about “soft spots” on the heads of newborn babies. These “soft spots,” otherwise called fontanelles, are areas between skull bones that have not yet fully ossified. The major fontanelles can be found where multiple cranial bones come together. Instead of protective bone, only a membrane and the scalp protect the newborn’s brain at the fontanelles until they ossify. These areas especially must be protected from blunt force until ossification is complete. In the above images, you can see the names fontanelles from a superior view (top right) and a lateral view (bottom left) on a newborn’s skull.

Attributions (All Skull Sections)

- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0

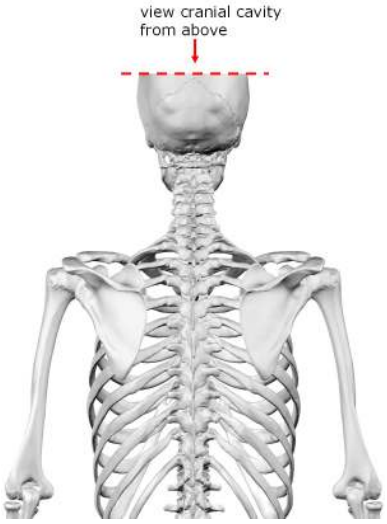
- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0
- "Anatomy and Physiology Lab Reference" by Laird C Sheldahl, OpenOregonEducational Resources, Mt. Hood Community College is licensed under CC BY-SA 4.0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- "BodyParts3D/Anatomography" by The Database Center for Life Science is licensed under CC BY-SA 2.1
- "Ethmoid.png" by Life Science Databases(LSDB) is licensed under CC BY-SA 2.0
- "Gray151.png" by Henry Vandyke Carter is in the Public Domain
- "Human Skeleton Upper Body Posterior View.jpg" by Andrewmeyerson is licensed under CC BY-SA 3.0
- "Rotation ethmoid.gif" by Life Science Databases(LSDB), animated by was a bee is licensed under CC BY-SA 2.0
- "Sphenoid bone - animation 02.gif" by Database Center for Life Science (DBCLS) is licensed under CC BY-SA 2.1

Updated 2025.

This page titled 8.2.1: Exterior of the Cranium is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

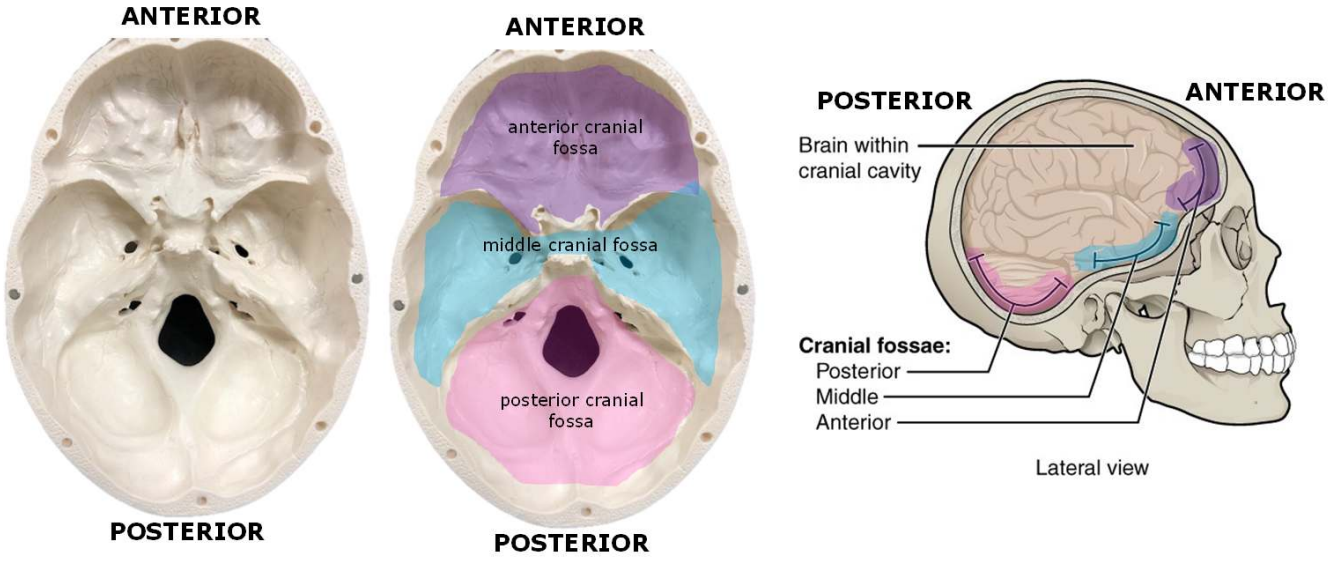
8.2.2: Interior of the Cranium

Interior of the Cranium



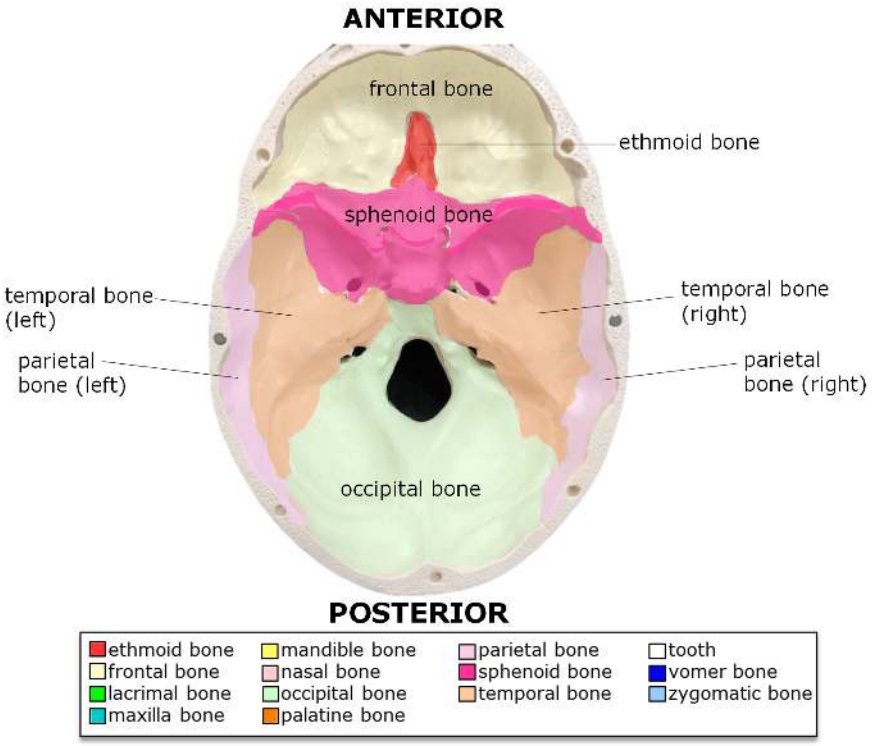
Above: Figure shows the view of the cranial cavity below.

If the skull were sliced in the transverse plane (separating superior and inferior) to expose the inferior aspect of the cranial cavity, where the underside of the brain is supported by the skull, and it was viewed from above (superior view), the skull would appear as the two images below. The base of the cranial cavity is composed of three main fossae (basin-like structures): the **anterior cranial fossa**, the **middle cranial fossa**, and the **posterior cranial fossa**.



Above: The fossae of the cranial cavity. (Left) Superior view of the cranial cavity of the skull unaltered. (Middle) Superior view of the cranial cavity of the skull colored to show the anterior cranial fossa, the middle cranial fossa, and the posterior cranial fossa. (Right) Lateral view of the skull showing that the anterior cranial fossa is more anterior and is more superior than the other cranial fossae (note that the the colors of the cranial fossae on the middle and right images match). The middle cranial fossa is inferior to the anterior cranial fossa but more superior to the posterior cranial fossa.

The base of the cranial cavity is created by the frontal bone, ethmoid bone, sphenoid bone, two temporal bones, and occipital bone.



Above: The bones of the cranial cavity.

Attributions (All Skull Sections)

- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0
- "Anatomy and Physiology Lab Reference" by Laird C Sheldahl, OpenOregonEducational Resources, Mt. Hood Community College is licensed under CC BY-SA 4.0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- "BodyParts3D/Anatomography" by The Database Center for Life Science is licensed under CC BY-SA 2.1
- "Ethmoid.png" by Life Science Databases(LSDB) is licensed under CC BY-SA 2.0
- "Gray151.png" by Henry Vandyke Carter is in the Public Domain
- "Human Skeleton Upper Body Posterior View.jpg" by Andrewmeyerson is licensed under CC BY-SA 3.0
- "Rotation ethmoid.gif" by Life Science Databases(LSDB), animated by was a bee is licensed under CC BY-SA 2.0
- "Sphenoid bone - animation 02.gif" by Database Center for Life Science (DBCLS) is licensed under CC BY-SA 2.1

Updated 2025.

This page titled 8.2.2: Interior of the Cranium is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

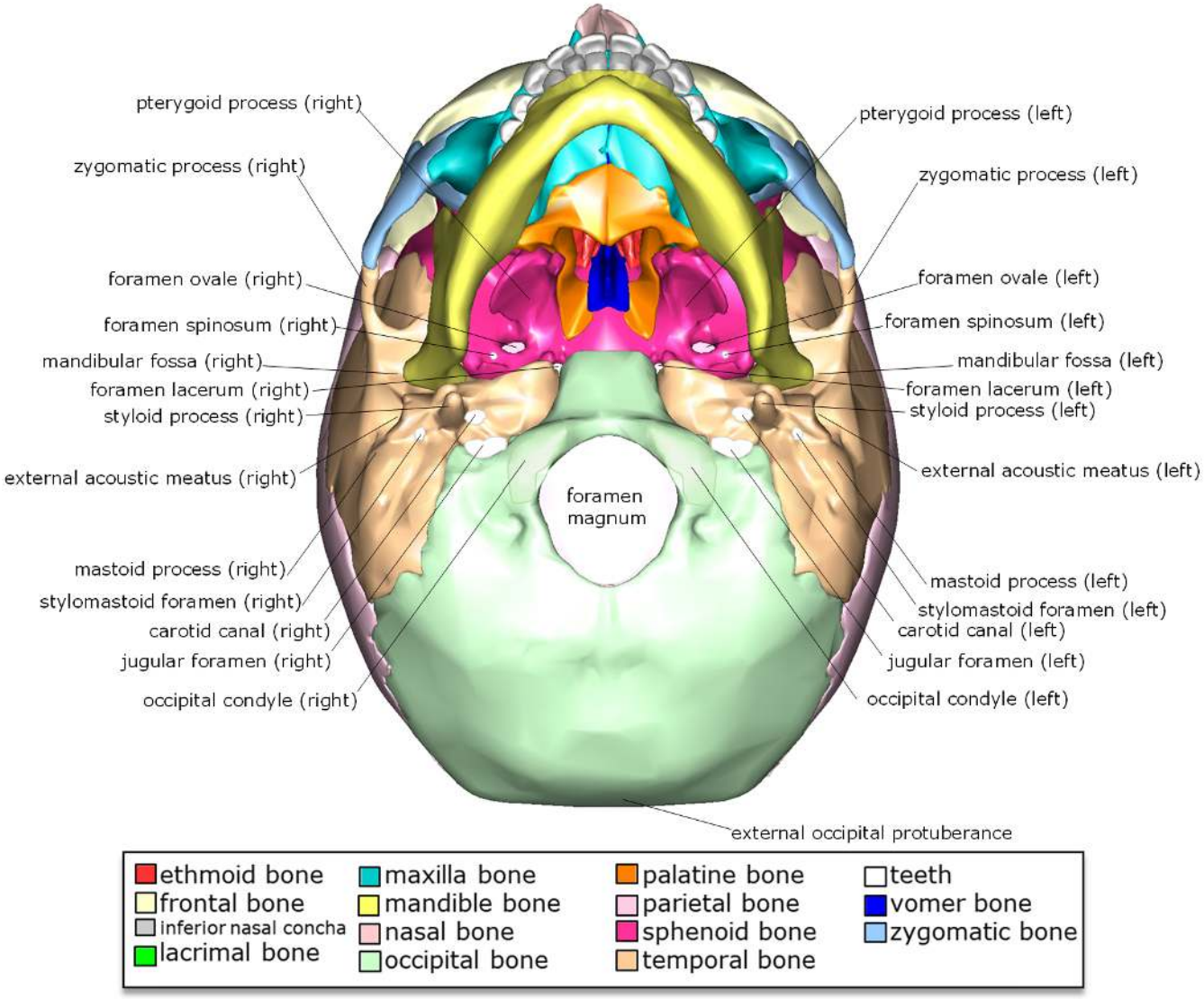
8.2.3: Markings of the Cranium

Markings of the Cranium

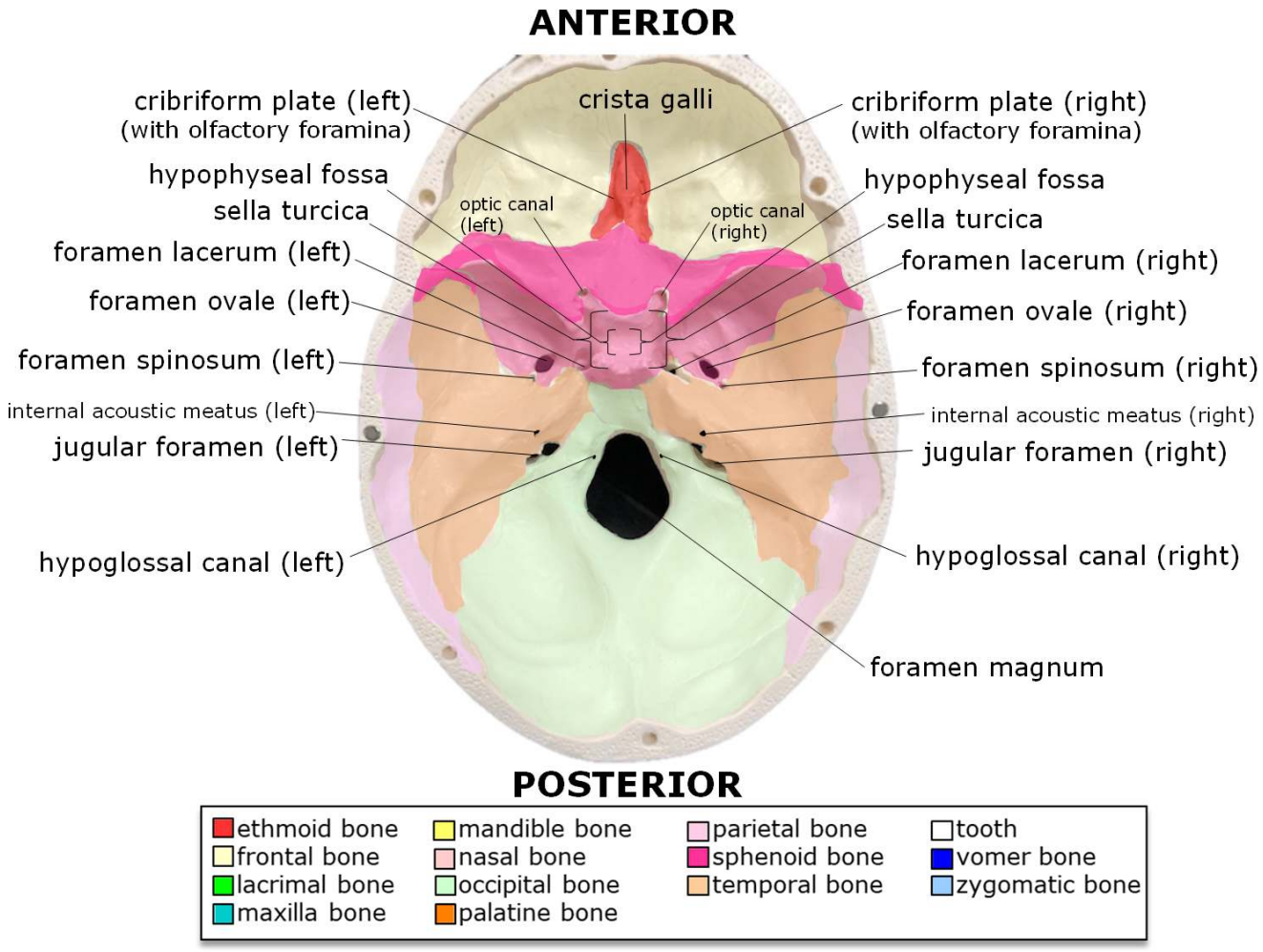
Recall from **Chapter 7: Introduction to the Skeletal System**, that bones have markings including holes, passageways, basins, and projections.

Before examining the specific markings of the cranium, review the pertinent types of markings we will see when we examine the cranium markings:

Type of Bone Marking	Description of Bone Marking Type
canal	Passageway through a bone. *Example: optic canal*
condyle	Refers to a large rounded prominence which often provides structural support to the overlying hyaline cartilage. *Examples: femoral lateral and medial condyles; tibial lateral and medial condyles; occipital condyles articulate with atlas (C1)*
foramen **(pl. foramina)**	A hole in a bone through which nerves and blood vessels pass. *Examples: foramen magnum; supraorbital foramen; infraorbital foramen; mental foramen*
fossa (pl. fossae)	A shallow depression in a bone surface. *Examples: trochlear fossa; posterior, middle, and anterior cranial fossae*
meatus **(pl. meatuses)**	A tube-like channel that extends within the bone, which may provide passage and protection to nerves, vessels, and sound. *Examples: external acoustic meatus; internal auditory meatus*
process **(pl. processes)**	Bony projection, allow for muscle attachment. *Examples: spinous process, acromial process, radial styloid process*
protuberance	A bump or outgrowth on a bone. *Example: external occipital protuberance*



Above: Markings of the cranium viewing the skull from the inferior view.

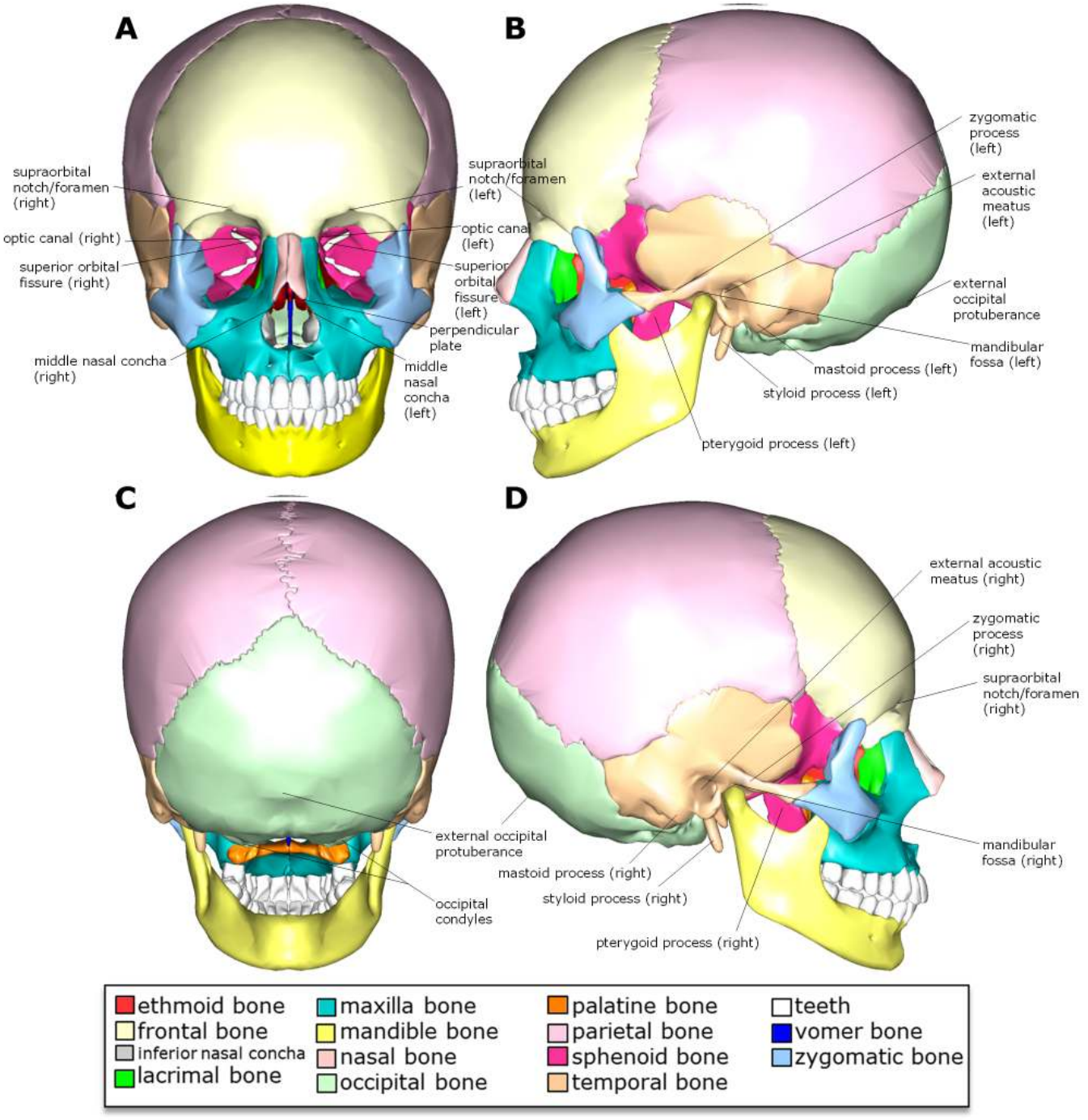


Above: Markings of the cranium viewing the skull from the superior view of the cranial cavity.

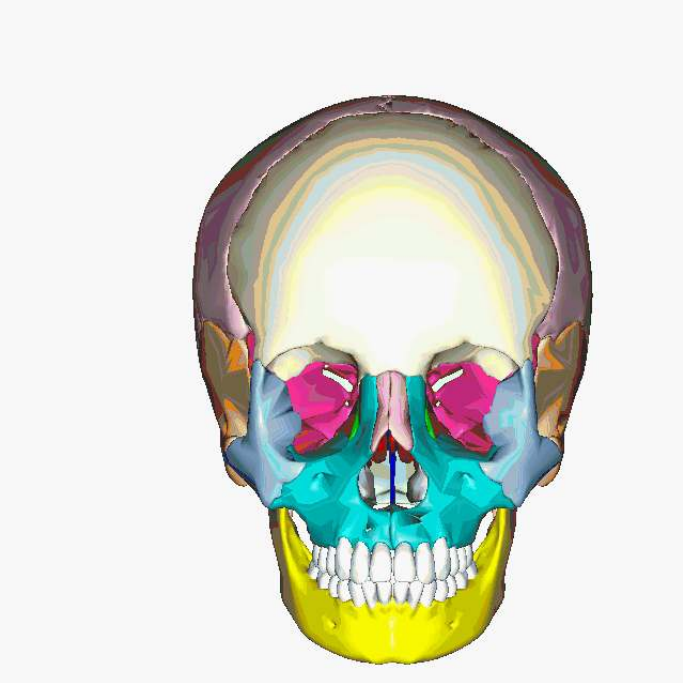
Marking	Bone Marking is Part of	Location	Function
carotid canal (2, one right & one left)	temporal bones	inferior skull	provides passage for the right and left internal carotid arteries
cribriform plate (2, one right & one left)	ethmoid bone	cranial cavity	forms the superior aspect of the nasal cavities; forms part of the anterior cranial fossa; plate contains olfactory foramina where sensory neurons carrying scent information pass through from the nasal cavities towards the brain
crista galli	ethmoid bone	cranial cavity	located between the cribriform plates; attaches to the dura mater, one of the meninges surrounding the brain
external acoustic meatus (2, one right & one left)	temporal bones	lateral skull	passageways (right and left) form canals to the middle ears
external occipital protuberance	occipital bone	posterior skull	a minor projection on the posterior of the skull
foramen lacerum (2, one right & one left)	temporal bones	inferior skull & cranial cavity	mostly blocked by cartilage, but some blood vessels and nerves pass through
foramen magnum	occipital bone	inferior skull & cranial cavity	this is the largest foramen of the skull; provides passage for the spinal cord to attach to the brain stem

Marking	Bone Marking is Part of	Location	Function
foramen ovale (2, one right & one left)	sphenoid bone	inferior skull & cranial cavity	these provide passage for branches of the paired (right and left) C.N. V trigeminal nerves
foramen spinosum (2, one right & one left)	sphenoid bone	inferior skull & cranial cavity	these provide passage for the middle meningeal arteries (right and left) which supplies blood to the dura mater of the brain
hypoglossal canal (2, one right & one left)	occipital bone	cranial cavity	provide passage for the pair (right and left) of C.N. XII hypoglossal nerves
hypophyseal fossa	sphenoid bone	cranial cavity	this fossa is the "seat" of the saddle-like sella turcica where the pituitary gland is positioned (another name for the pituitary gland is hypophysis)
internal acoustic meatus (2, one right & one left)	temporal bones	cranial cavity	provide passage for the right and left C.N. VIII vestibulocochlear nerves transmitting sensory information including auditory information
jugular foramen (2, one right & one left)	temporal bones	inferior skull & cranial cavity	provides passage for paired internal jugular veins (right and left) and right and left pairs of cranial nerves (C.N. IX, X, and XI)
mandibular fossa (2, one right & one left)	temporal bones	inferior skull	locations where the mandible articulates with the temporal bone creating hinges between the jaw and the rest of the skull; the condylar processes of the mandible (right and left) are positioned in these fossae
mastoid process (2, one right & one left)	temporal bones	inferior skull & lateral skull	location where neck muscles attach including the right and left sternocleidomastoid muscles
middle nasal concha (2, one right & one left)	ethmoid bone	anterior skull, nasal cavities	create passages for airflow through right and left nasal cavities
occipital condyle (2, one right & one left)	occipital bone	inferior skull	this pair of condyles is where the skull articulates with C_1, the first cervical vertebra, also known as atlas
olfactory foramina or **cribriform foramina** (many, found in right & left cribriform plates)	ethmoid bone	cranial cavity	provides passage for axons of olfactory sensory neurons from the nasal cavities to the olfactory cranial nerves (C.N. I) in the cranial cavity; enables transmission of scent information to the brain
optic canal (2, one right & one left)	sphenoid bone	anterior skull, posterior orbits & cranial cavity	these provide passage for the paired C.N. II optic nerves (right and left) to pass from the eyes to the brain carrying sight information
perpendicular plate	ethmoid bone	anterior skull, superior nasal septum	creates the superior part of the nasal septum separating the nasal cavities into right and left
pterygoid process (2, one right & one left)	sphenoid bone	inferior skull	pterygoid muscles attach to these processes connecting with the mandible to move the mandible for chewing
sella turcica	sphenoid bone	cranial cavity	a saddle-like structure creating a basin (fossa) where the pituitary gland is located; the "seat" of the sella turcica saddle is called the hypophyseal fossa (another name for the pituitary gland is hypophysis)
styloid process (2, one right & one left)	temporal bones	inferior skull & lateral skull	thin and narrow inferior-pointing projections (right and left) where neck muscles and ligaments attach
stylomastoid foramen (2, one right & one left)	temporal bones	inferior skull	provides passage for the right and left C.N. VII; each of these foramina are located between the styloid process and the mastoid process on that side of the skull
superior nasal concha (2, one right & one left)	ethmoid bone	inside the superior nasal cavities	create passages for airflow through right and left nasal cavities
superior orbital fissure (2, one right & one left)	sphenoid bone	anterior skull, posterior aspect of the orbits	paired cranial nerves (right and left) pass through to control eye movements (C.N.III, IV, part of V, and VI)

Marking	Bone Marking is Part of	Location	Function
supraorbital notch/foramen (2, one right & one left)	frontal bone	anterior skull, superior to orbits	passage for blood vessels and nerves
zygomatic process (of temporal bones) (2, one right & one left)	temporal bones	lateral skull & inferior skull	creates a bridge-like structure that connects the temporal bone with the zygomatic bone forming part of the zygomatic arch



https://bio.libretexts.org/@go/page/53619



Above: Markings of the cranium with the following views: (A) anterior view, (B) lateral view of the left side of the skull, (C) posterior view, and (D) lateral view of the right side of the skull.

Attributions (All Skull Sections)

- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0
- "Anatomy and Physiology Lab Reference" by Laird C Sheldahl, OpenOregonEducational Resources, Mt. Hood Community College is licensed under CC BY-SA 4.0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- "BodyParts3D/Anatomography" by The Database Center for Life Science is licensed under CC BY-SA 2.1
- "Ethmoid.png" by Life Science Databases(LSDB) is licensed under CC BY-SA 2.0
- "Gray151.png" by Henry Vandyke Carter is in the Public Domain
- "Human Skeleton Upper Body Posterior View.jpg" by Andrewmeyerson is licensed under CC BY-SA 3.0
- "Rotation ethmoid.gif" by Life Science Databases(LSDB), animated by was a bee is licensed under CC BY-SA 2.0
- "Sphenoid bone - animation 02.gif" by Database Center for Life Science (DBCLS) is licensed under CC BY-SA 2.1

Updated 2025.

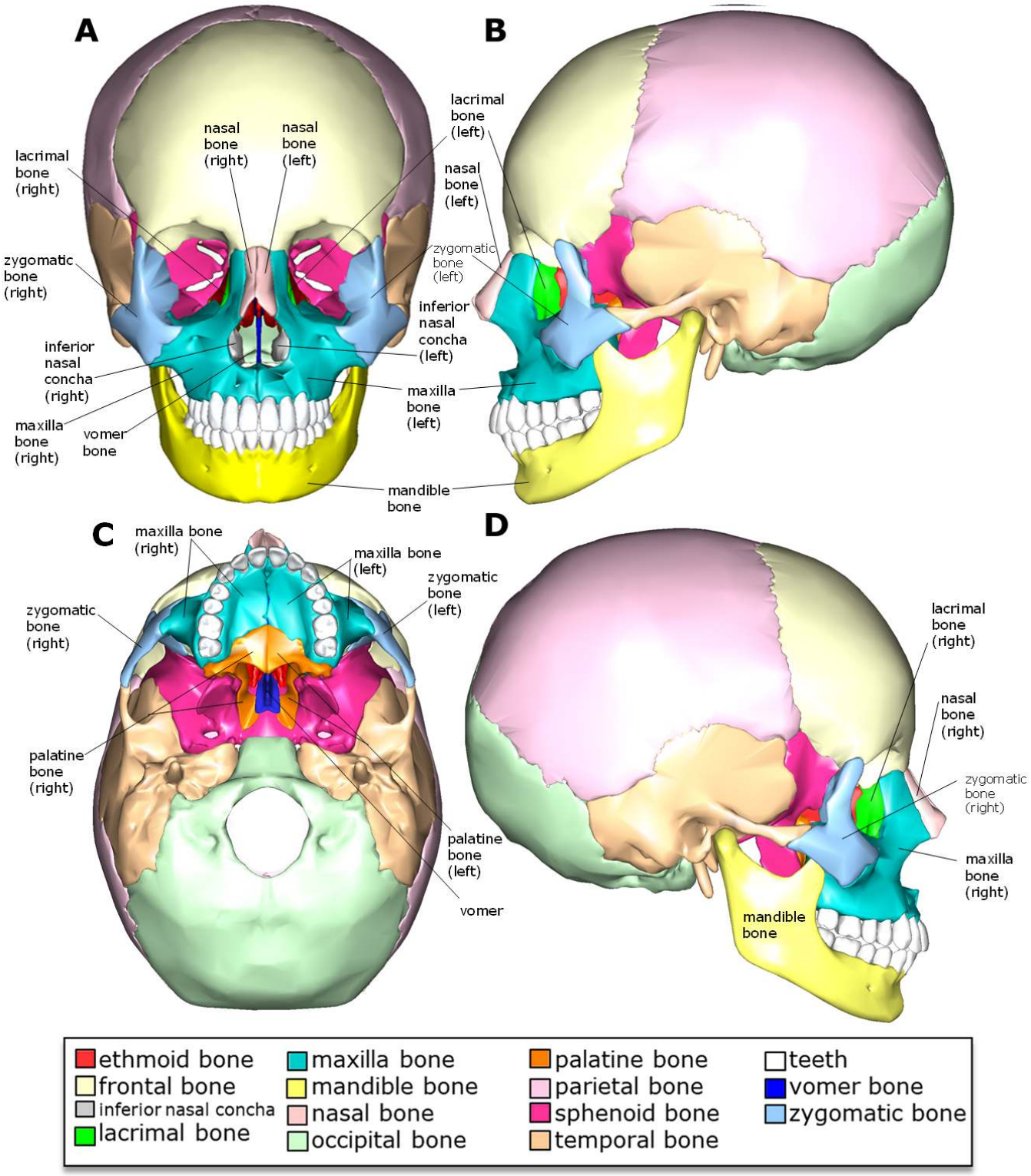
This page titled 8.2.3: Markings of the Cranium is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

8.2.4: Face

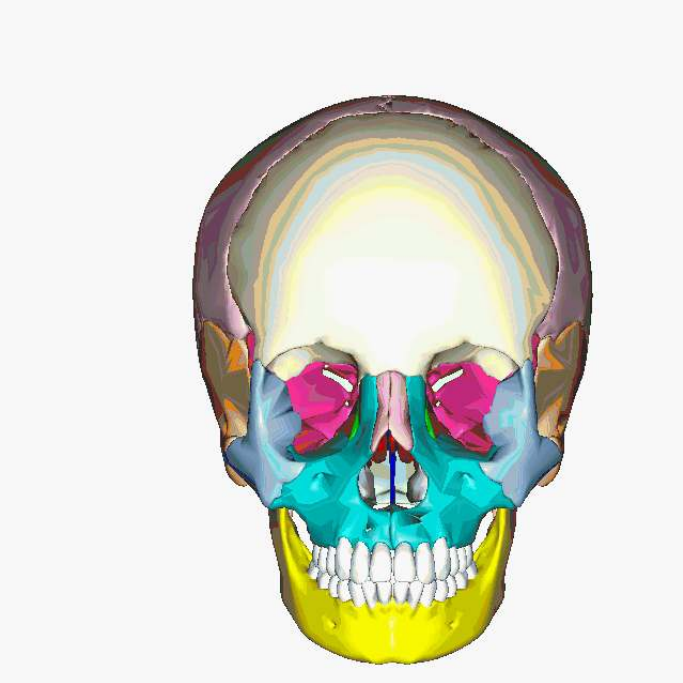
Face

Facial Bones

The facial bones include the **inferior nasal conchae** (2, one right and one left), the **lacrimal bones** (2, one right and one left), the **maxilla bones** (2, one right and one left), the **mandible bone** (1), the **nasal bones** (2, one right and one left), the **palatine bones** (2, one right and one left), **vomer bone** (1), and **zygomatic bones** (2, one right and one left). There are therefore a total of 14 bones making up the face, all of which are paired bones (one right and one left) except for the vomer bone and the mandible bone.



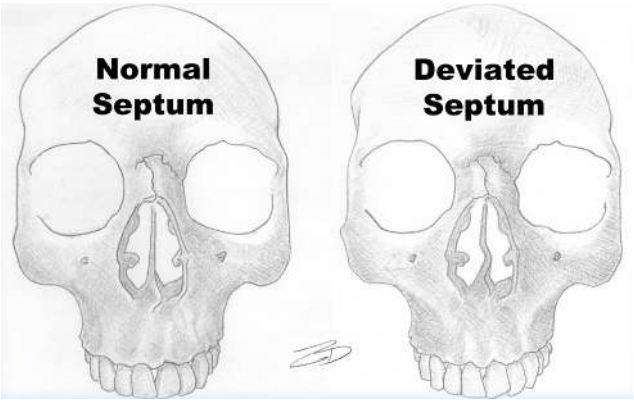
https://bio.libretexts.org/@go/page/53620



Above: Facial bones with the following views: (A) anterior view, (B) lateral view of the left side of the skull, (C) inferior view with the mandible removed, and (D) lateral view of the right side of the skull.

Clinical Application: Deviated Septum

Deviated septa are common. In more severe cases, a deviated septum can cause difficulty breathing, sinus infections, sleep apnea, snoring, repetitive sneezing, facial pain, nosebleeds, and mild to severe loss of the ability to smell. Although most commonly caused by impact trauma, it can also be a congenital disorder caused by compression of the nose during childbirth. Medications can temporarily relieve symptoms, but a minor surgical procedure, known as **septoplasty**, is necessary to completely cure the symptoms related to septal deviations.



Above: Illustration indicates the difference between a normal septum and a deviated septum. The septum is made up of the perpendicular plate of the ethmoid bone and the vomer bone.

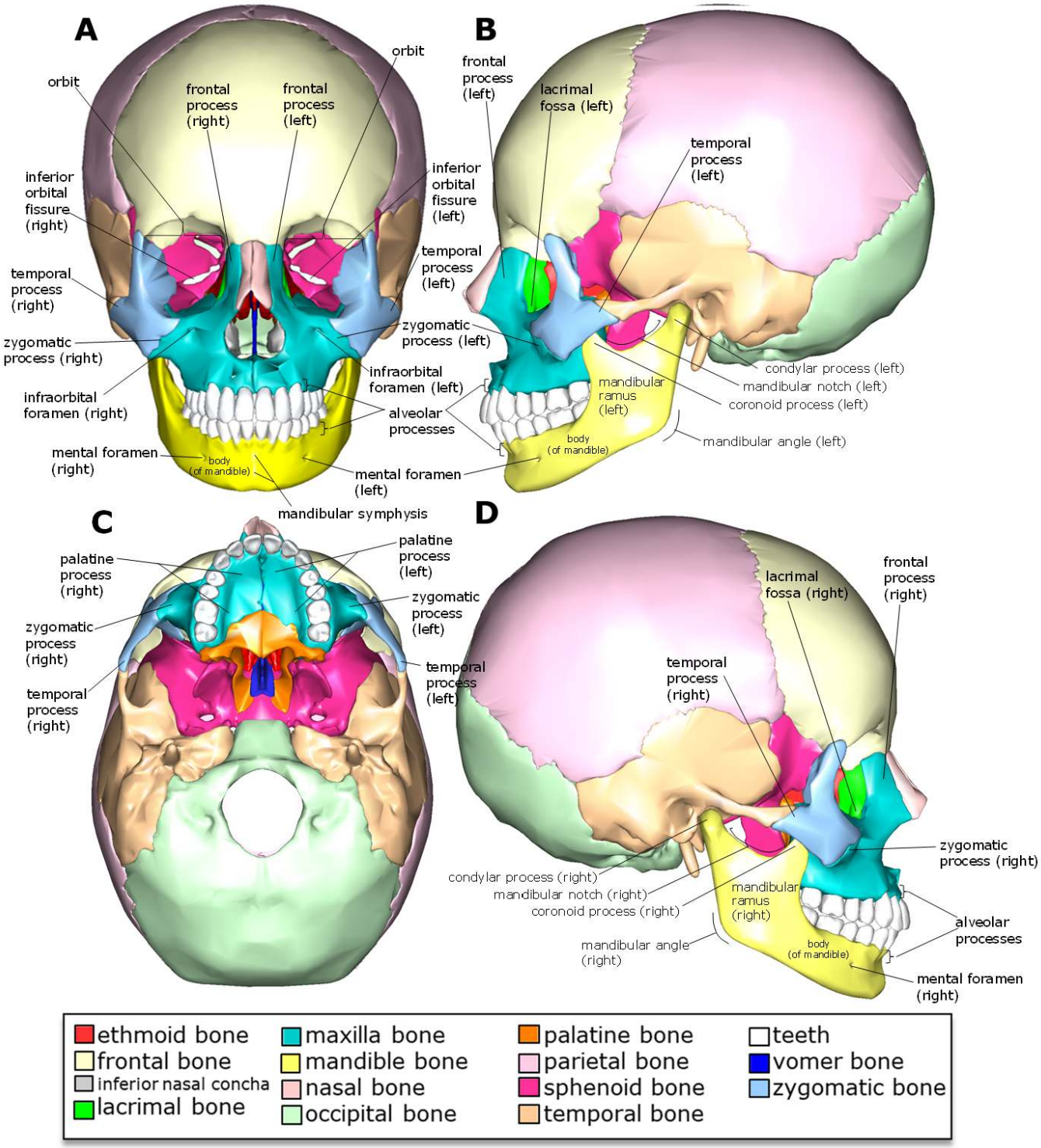
Markings of the Facial Bones

Recall from **Chapter 7: Introduction to the Skeletal System**, that bones have markings including holes, passageways, basins, and projections.

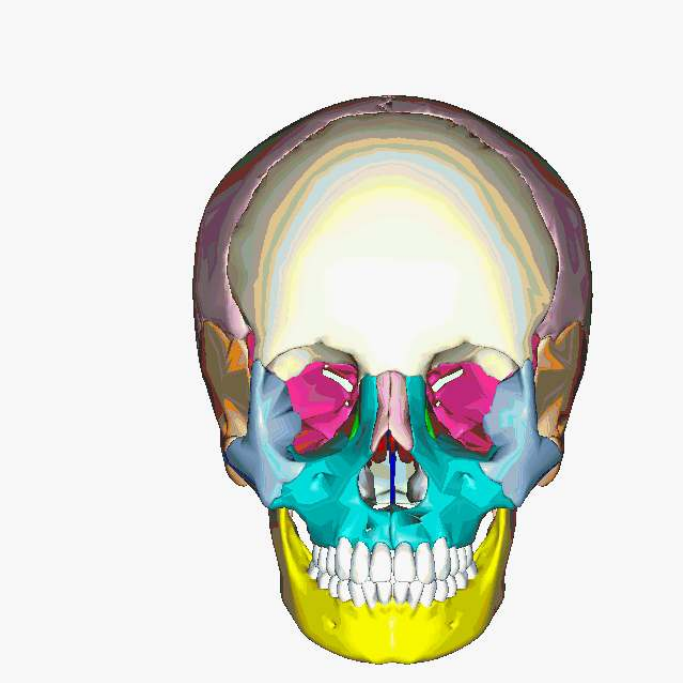
Before examining the specific markings of the facial bones, review the pertinent types of markings we will see when we examine the face markings:

Type of Bone Marking	Description of Bone Marking Type
angle	Sharp bony angulations which may serve as bony or soft tissue attachments.

Type of Bone Marking	Description of Bone Marking Type
body	Usually refers to the largest most prominent segment of bone.
foramen (pl. foramina)	A hole in a bone through which nerves and blood vessels pass.
fossa (pl. fossae)	A shallow depression in a bone surface.
notch	A depression in a bone which often, provides stabilization to an adjacent articulating bone.
process (pl. processes)	Bony projection, allow for muscle attachment.
ramus (pl. rami)	The curved part of a bone that gives structural support to the rest of the bone.



https://bio.libretexts.org/@go/page/53620



Above: Markings of the facial bones with the following views: (A) anterior view, (B) lateral view of the left side of the skull, (C) inferior view with the mandible removed, and (D) lateral view of the right side of the skull.

Marking	Bone Marking is Part of	Location	Function
alveolar process (3, one on each maxilla bone and one on the mandible)	maxilla bones & mandible bone	anterior skull & lateral skull	entire region of the bone that forms the sockets for the teeth
body (of the mandible)	mandible bone	anterior skull & lateral skull	connects the right and left rami of the mandible; holds the alveolar process; entire horizontal region of the mandible including the chin
condylar process (2, one right & one left)	mandible bone	lateral skull	creates the hinge where the mandible articulates with the temporal bone (within the mandibular fossa)
coronoid process (2, one right & one left)	mandible bone	lateral skull	superior-pointing process anterior to the condylar process; the temporalis muscle attaches here
frontal process (2, one right & one left)	maxilla bones	anterior skull & lateral skull	articulates with the nasal bones, lacrimal bones, and frontal bone forming lateral aspects of the nose
inferior orbital fissure	formed by maxilla, zygomatic, and sphenoid bones	anterior skull	provide passage for nerves and blood vessels
infraorbital foramen (2, one right & one left)	maxilla bones	anterior skull	provide passage for paired (right and left) blood vessels (infraorbital arteries) and nerves (infraorbital nerves)
lacrimal fossa (2, one right & one left)	lacrimal bones	lateral skull	involved in draining tears from the eyes into the nasal cavities
mandibular angle (2, one right & one left)	mandible bone	lateral skull	inferior and posterior aspects of the mandible (right and left) where the body meets the rami
mandibular notch (2, one right & one left)	mandible bone	lateral skull	indentation between the condylar process and the coronoid process
mandibular symphysis	mandible bone	anterior skull	a ridge located medially on the mandible

Marking	Bone Marking is Part of	Location	Function
mental foramen (2, one right & one left)	mandible bone	anterior skull & lateral skull	provides passage for blood vessels and nerves of the chin and lower lip; recall "mental" means "chin"
orbit (2, one right & one left)	formed by frontal, sphenoid, ethmoid, lacrimal, maxilla, and zygomatic bones	anterior skull	eye socket
palatine process (2, one right & one left)	maxilla bones	inferior skull	posterior-projecting processes of the maxilla bones forming the anterior aspect of the roof of the mouth; articulates with the palatine bones
ramus (of the mandible) (2, one right & one left)	mandible bone	lateral skull	regions of the mandible (right and left) connecting the body of the mandible, the condylar process, and the coronoid process
temporal process (2, one right & one left)	zygomatic bones	anterior skull & lateral skull	posterior-pointing process that articulates with the zygomatic process of the temporal bone
zygomatic process (of maxilla bones) (2, one right & one left)	maxilla bones	anterior skull & lateral skull	lateral-pointing processes that articulate with the right and left zygomatic bones

Attributions (All Skull Sections)

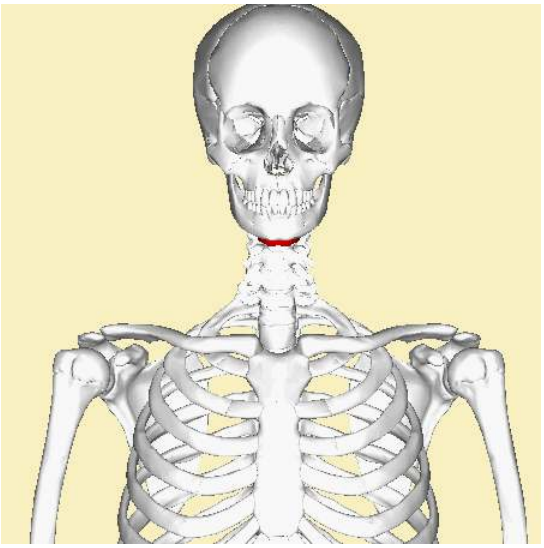
- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0
- "Anatomy and Physiology Lab Reference" by Laird C Sheldahl, OpenOregonEducational Resources, Mt. Hood Community College is licensed under CC BY-SA 4.0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- "BodyParts3D/Anatomography" by The Database Center for Life Science is licensed under CC BY-SA 2.1
- "Ethmoid.png" by Life Science Databases(LSDB) is licensed under CC BY-SA 2.0
- "Gray151.png" by Henry Vandyke Carter is in the Public Domain
- "Human Skeleton Upper Body Posterior View.jpg" by Andrewmeyerson is licensed under CC BY-SA 3.0
- "Rotation ethmoid.gif" by Life Science Databases(LSDB), animated by was a bee is licensed under CC BY-SA 2.0
- "Sphenoid bone - animation 02.gif" by Database Center for Life Science (DBCLS) is licensed under CC BY-SA 2.1

Updated 2025.

This page titled 8.2.4: Face is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

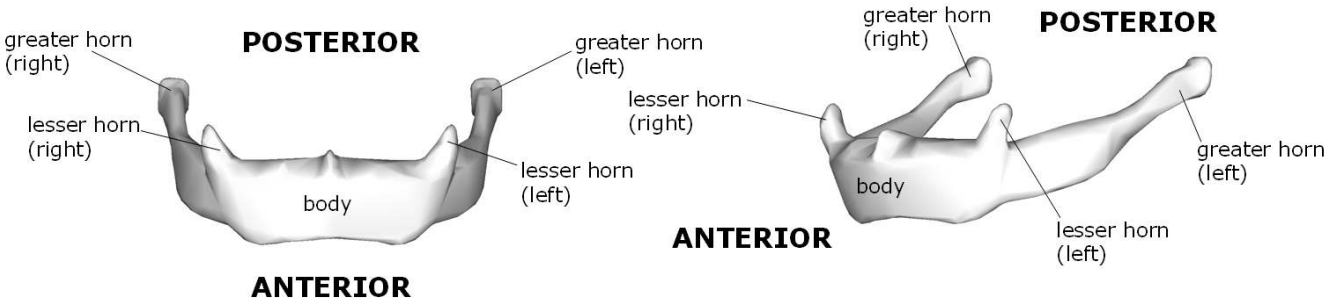
8.3: Hyoid Bone

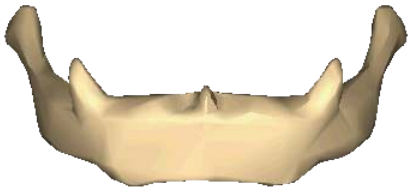
Hyoid Bone



Above: The upper skeleton with the hyoid bone highlighted in red. The hyoid is the only bone that does not articulate with any other bone of the skeleton.

The **hyoid** bone is located between the base of the mandible and the 3rd cervical vertebra. It is an attachment point for many muscles responsible for tongue movement and swallowing. The hyoid bone in the neck ***is the only bone in the body that does not articulate directly with at least one other bone***. It is U-shaped and is held in place by, and helps anchor, muscles that connect to the floor of the mouth and the tongue. It helps provide greater movement of the tongue and larynx, and so is crucial to human speech. The hyoid bone is commonly fractured (but not always) in strangulation fatalities, and therefore can be used as evidence of cause of death in some cases.





Above: Hyoid bone with an anterior view (top left) and an anterolateral view (top right).

Attributions

- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- "BodyParts3D/Anatomography" by The Database Center for Life Science is licensed under CC BY-SA 2.1
- "Hyoid bone - animation.gif" by Anatomography is licensed under CC BY-SA 2.1
- "Hyoid bone - close-up - animation.gif" by Anatomography is licensed under CC BY-SA 2.1

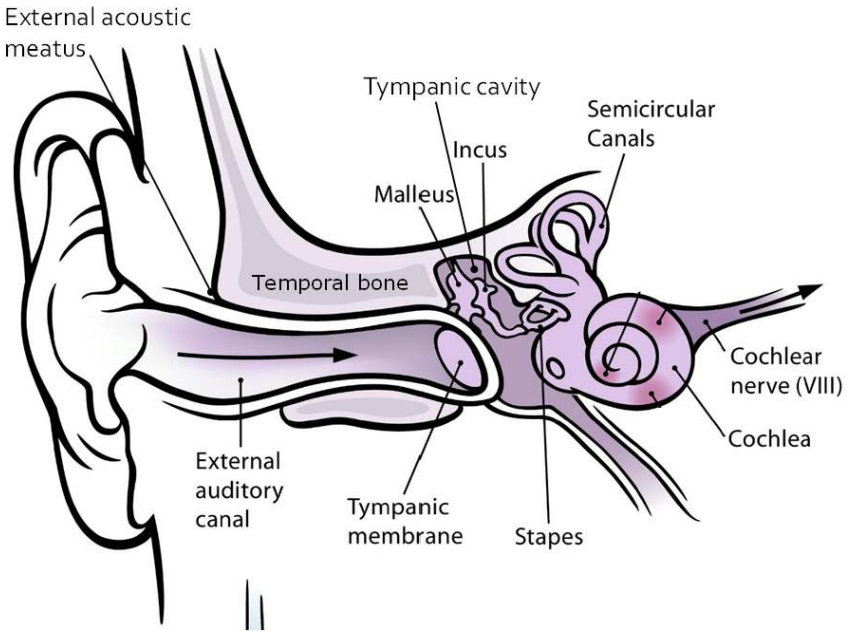
Updated 2025.

This page titled 8.3: Hyoid Bone is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

8.4: Auditory Ossicles

Auditory Ossicles

Within the external acoustic meatus of the temporal bone is the external auditory canal that carries sound into the middle ear. The tympanic membrane (ear drum) vibrates as it receives auditory information and transfers those vibrations to three small bones in the tympanic cavity of the middle ear: **malleus**, **incus**, and **stapes**, often known as the **auditory ossicles**.



Above: External, middle, and inner ear including the auditory ossicles.

Malleus, also known as the "hammer," articulates with **incus** (the "anvil"), which articulates with **stapes** (the "stirrup"). The aptly named stapes looks very much like a stirrup (the hole where a foot is placed in a horse's saddle). The three auditory ossicles are unique to mammals, and each plays a role in hearing. The malleus attaches at three points to the interior surface of the tympanic membrane. The incus attaches the malleus to the stapes. In humans, the stapes is not long enough to reach the tympanic membrane. If we did not have the malleus and the incus, then the vibrations of the tympanic membrane would never reach the inner ear. These bones also function to collect force and amplify sounds. These bones transfer the vibrations collected by the tympanic membrane to the **cochlea**, the specialized auditory sense organ. Auditory information in the cochlear is transferred to the **cochlear nerve**, part of the cranial nerve **C.N. VIII vestibulocochlear nerve**, that carries auditory information to the brain.

There are two sets of auditory ossicles in the human body, one set in the right middle ear and one set in the left middle ear.

Attributions

- "Biology 2e" by Mary Ann Clark, Matthew Douglas, Jung Choi, OpenStax is licensed under CC BY-NC 4.0
- "Frequency mapping in human ear and brain - 10.1371 journal.pbio.0030137.g001-L.jpg" by Chittka L. and Brockmann A. is licensed under CC BY 2.

Edited 2025.

This page titled 8.4: Auditory Ossicles is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

8.5: Vertebral Column

8.5.1 Introduction to the Vertebral Column

8.5.2 Generalized Structure and Markings of Vertebrae

8.5.3 Cervical Vertebrae

8.5.4 Thoracic Vertebrae

8.5.5 Lumbar Vertebrae

8.5.6 Sacrum and Coccyx

8.5.7 Intervertebral Foramina

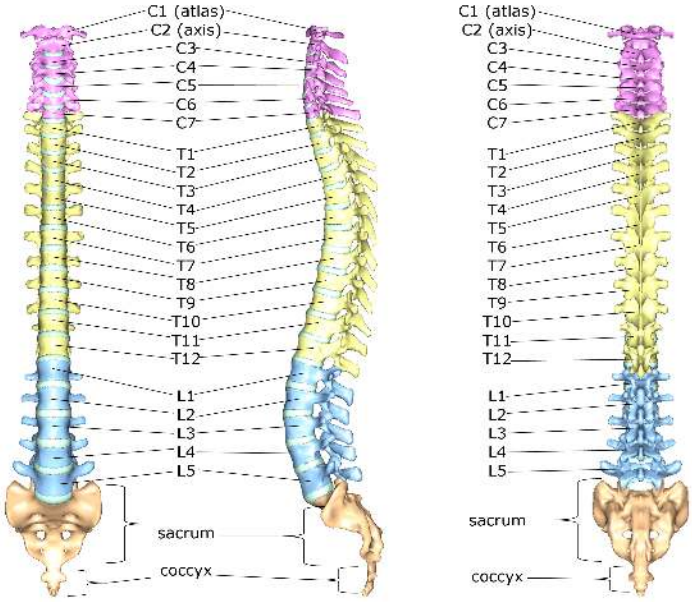
8.5.8 Intervertebral Discs

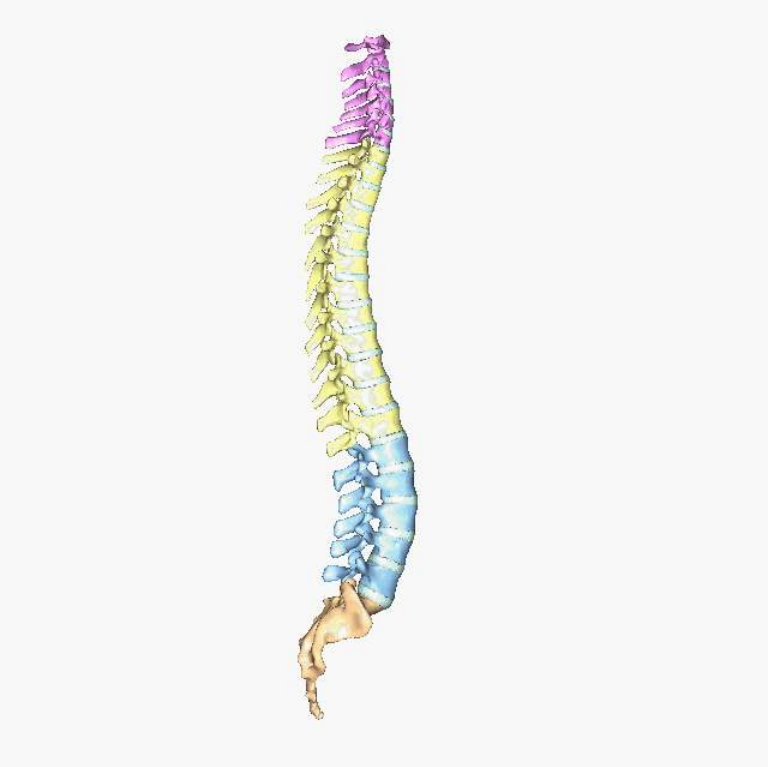
8.5.9 Clinical Application - Whiplash

This page titled 8.5: Vertebral Column is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

8.5.1: Introduction to the Vertebral Column

Introduction to the Vertebral Column



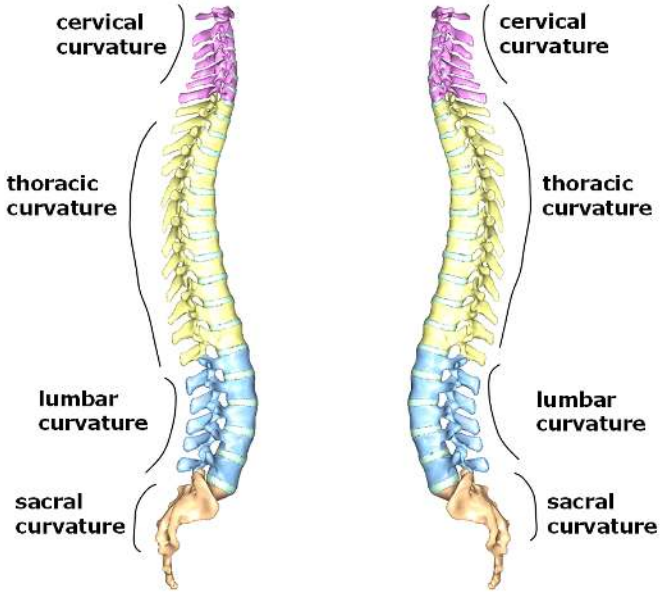


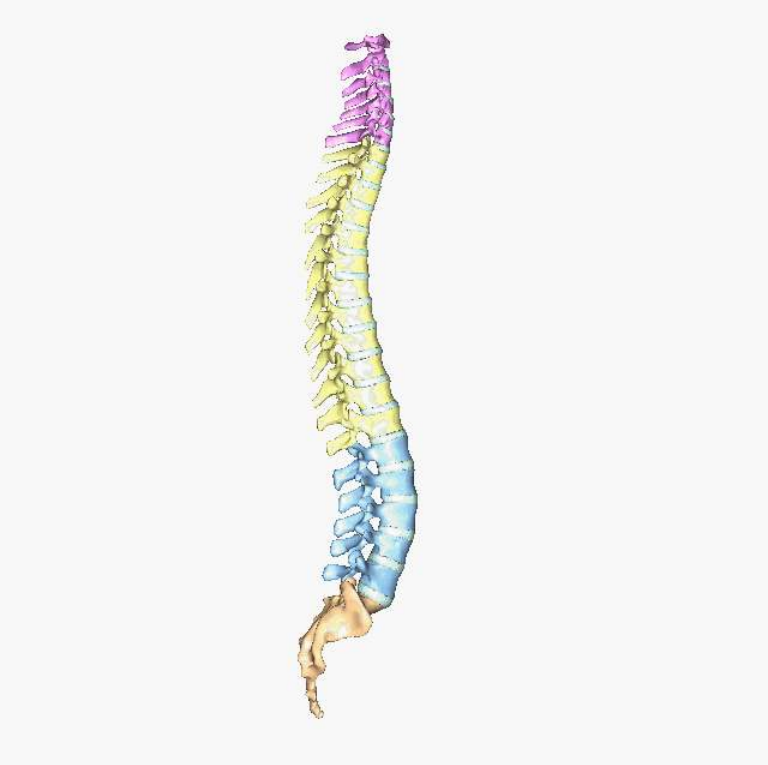
Above: Vertebral column. The vertebral column is composed of small, irregularly shaped bones called vertebrae stacked on top of each other. There are seven cervical vertebrae shown in pink (C-vertebrae, numbered C_1 through C_7), twelve thoracic vertebrae shown in yellow (T-vertebrae, numbered T_1 through T_{12}), and five lumbar vertebrae shown in blue (L-vertebrae, numbered L_1 through L_5). At the base of the vertebral column is the sacrum composed of five vertebrae that have been fused together. Inferior to the sacrum is the coccyx, or tailbone, that is composed of four fused vertebrae. The vertebral column is shown above (top left) in the anterior view, (top middle) in the lateral view of the left side of the column, and (top right) in the posterior view.

The vertebral column is more colloquially called the "backbone" or the "spine," which makes it sound like it is a single bone. In face, the vertebral column consists of 24 **vertebrae** bones, and two bones from the axial section of the pelvic girdle, the **sacrum** and the **coccyx**.

The vertebrae are divided into three groups: **cervical vertebrae** (neck), **thoracic vertebrae** (attach to the ribs; thoracic region), and **lumbar vertebrae** (lower back). There are seven cervical vertebrae (names C1 through C7), twelve thoracic vertebrae (named T1 through T12), and five lumbar vertebrae (named L1 through L5). You can use a meal-related mnemonic to remember them – imagine a crunchy breakfast at 7 am (7 cervical vertebrae), a tasty lunch at 12 noon (12 thoracic vertebrae), and a light dinner at 5 pm (5 lumbar vertebrae).

The vertebral column is not straight. There are four curvatures of the vertebral column, named for the vertebrae that form the curvatures: the **cervical curvature**, the **thoracic curvature**, the **lumbar curvature**, and the **sacral curvature**. The shapes of the curvatures can be described as being either *concave* (bending inward) or as *convex* (bending outward). Both the cervical and lumbar curvatures are concave and the thoracic and sacral curvatures are convex.

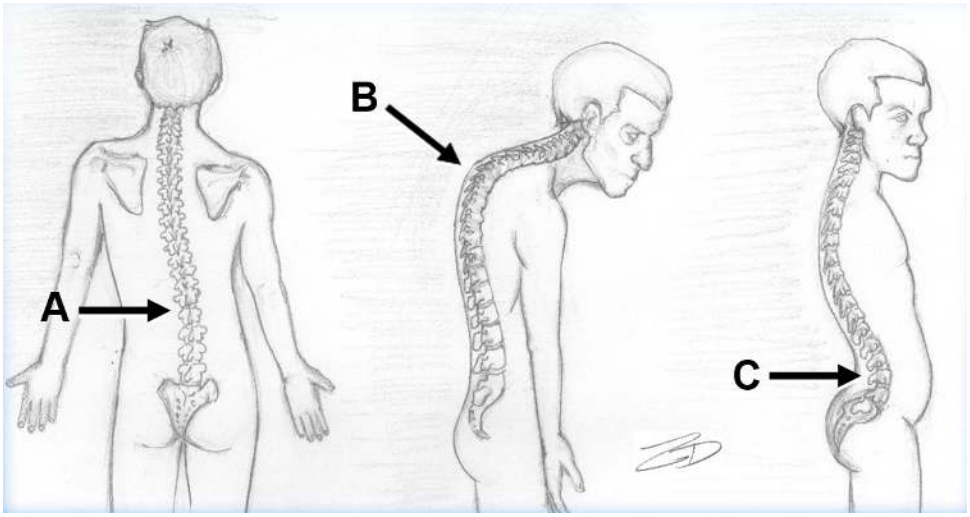




Above: The vertebrae are stacked into a column is such a way that there are four curvatures: cervical curvature, thoracic curvature, lumbar curvature, and sacral curvature. (Top left) Lateral view of the right side of the vertebral column. (Top right) Lateral view of the left side of the vertebral column.

Clinical Application: Scoliosis, Kyphosis, and Lordosis

When the vertebral column is positioned in such a way that its curvatures are abnormal, individuals may be diagnosed with **scoliosis**, **kyphosis**, or **lordosis**.



Above: The three abnormal curvatures of the spine are shown above. (A) **Scoliosis** is an abnormal lateral curvature of the spine. (B) **Kyphosis** is an exaggerated thoracic curvatire. (D) **Lordosis** is an exaggerated lumbar curvature.

Attributions (All Vertebral Column Sections)

- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- "BodyParts3D/Anatomography" by The Database Center for Life Science is licensed under CC BY-SA 2.1
- "Cervical vertebra english.png" by user:debivort is licensed under CC BY-SA 3.0
- "Sacrum - animation02.gif" by BodyParts3D is made by DBCLS is licensed under CC BY-SA 2.1

Updated 2025.

This page titled 8.5.1: Introduction to the Vertebral Column is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

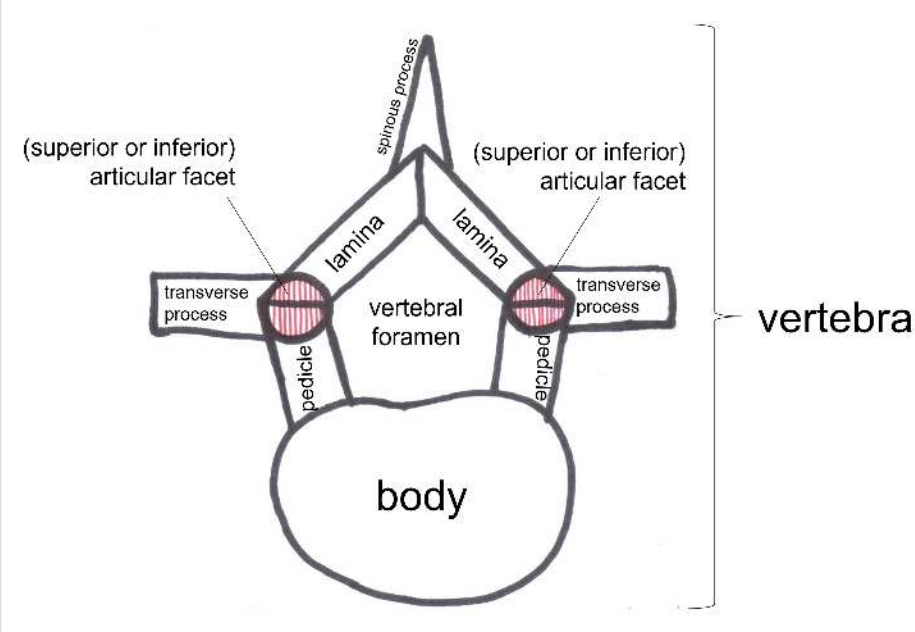
8.5.2: Generalized Structure and Markings of Vertebrae

Generalized Structure and Markings of Vertebrae

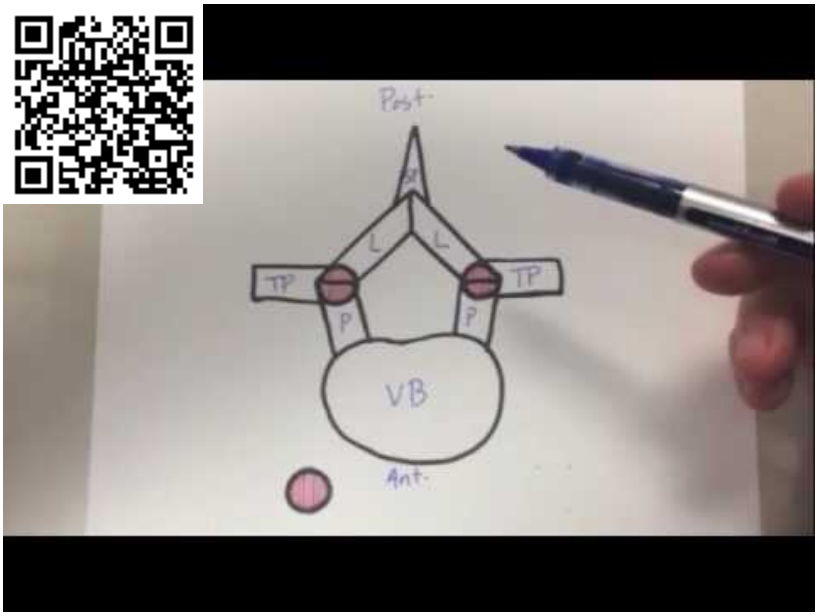
All three types of vertebrae have some structural features in common and some features that are distinctly different enabling you to readily distinguish vertebrae in one category (cervical, thoracic, or lumbar) from another.

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

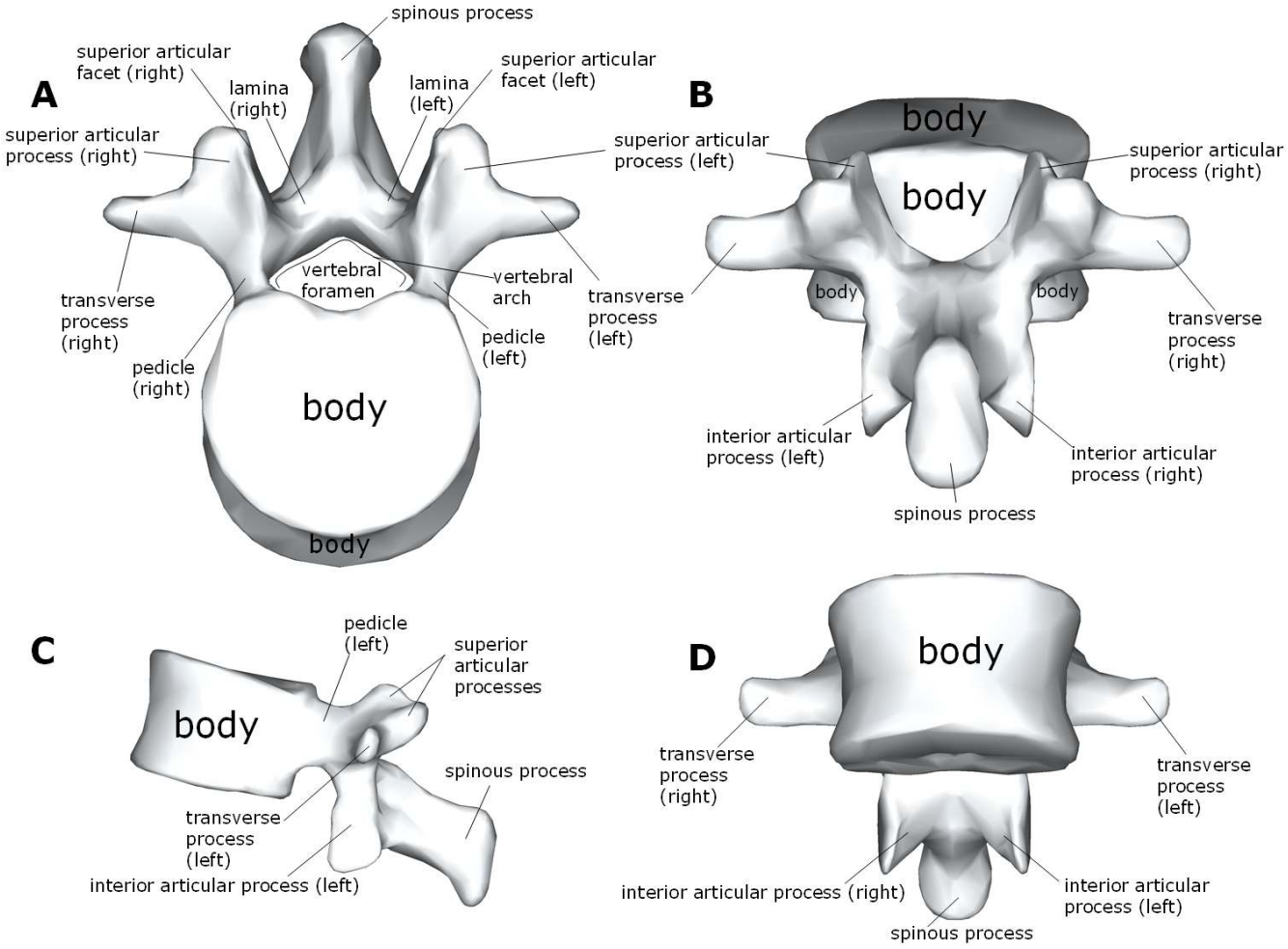
Two branches off of the body, known as **pedicles**, connect with two other branches, known as **laminae** (sing. **lamina**), to form a circle-like structure. Posterior to the vertebral body, this large, roughly circular opening in each vertebra is called the **vertebral foramen**. This is the hole through which the spinal cord passes. When the vertebrae are stacked in a column, these vertebral foramina align with each other to create the **spinal cavity** (part of the **dorsal body cavity**) where the spinal cord pass through the vertebral column.

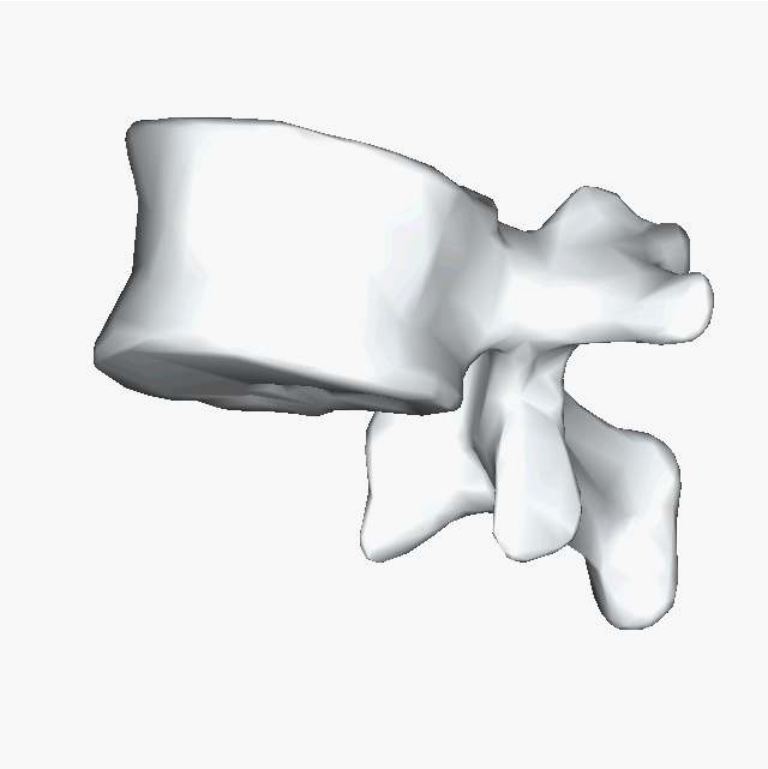


https://bio.libretexts.org/@go/page/53925



Above: This diagram is a simplified version of a generalized vertebra from either a superior view or an inferior view. This diagram can be labeled with the following terminologies: vertebral body, right pedicles, left pedicle, right lamina, left lamina, right transverse process, left transverse process, spinous process, right superior/inferior articular facet, left superior/inferior articular facet, vertebral arch, vertebral foramen.





https://bio.libretexts.org/@go/page/53925

Above: Markings of a vertebra with a (A) superior view (anterior at the bottom of the image), (B) posterior view, (C) lateral view of the left of a vertebra, and (D) anterior view.

Posterior to the vertebral foramen, projecting posteriorly from the laminae, is a single, central process known as the **spinous process**. Additionally, a pair of processes point roughly laterally away from the pedicles/laminae - these are called **transverse processes**. Paired, smooth facets are positioned at the superior and inferior aspects of each vertebra called **superior articular facets** and **inferior articular facets**, respectively. The superior facets articulate with the vertebra above and the inferior facets articulate with the vertebra below. These smooth facets are projected away from the pedicles/laminae on paired processes called **superior articular processes** and **inferior articular processes**.

Attributions (All Vertebral Column Sections)

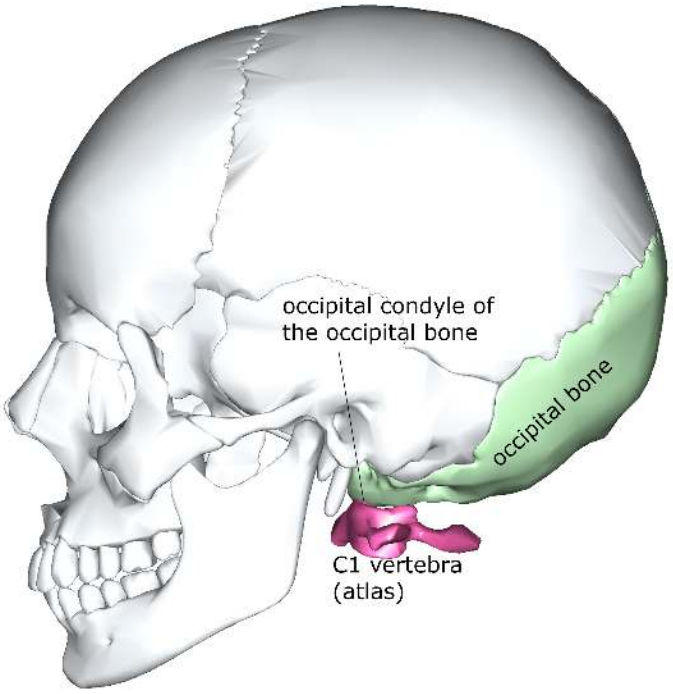
- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- "BodyParts3D/Anatomography" by The Database Center for Life Science is licensed under CC BY-SA 2.1
- "Cervical vertebra english.png" by user:debivort is licensed under CC BY-SA 3.0
- "Sacrum - animation02.gif" by BodyParts3D is made by DBCLS is licensed under CC BY-SA 2.1

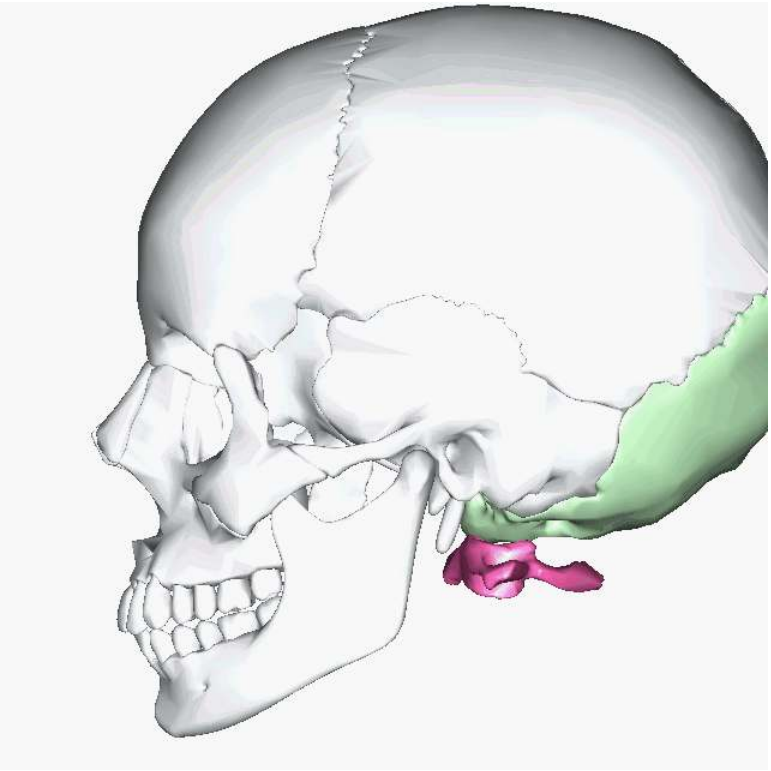
Updated 2025.

This page titled 8.5.2: Generalized Structure and Markings of Vertebrae is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

8.5.3: Cervical Vertebrae

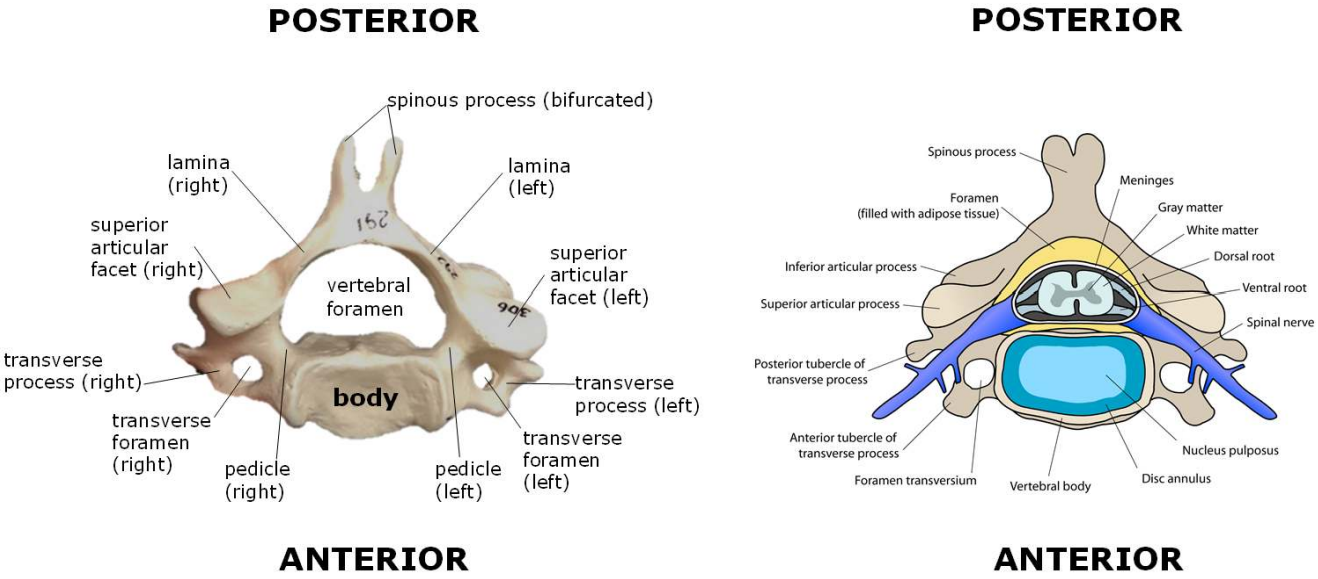
Cervical Vertebrae





Above: Lateral view of the skull with the occipital bone (and its occipital condyles) colored green and the first cervical vertebra or C1 (articulates with the occipital condyles) colored pink.

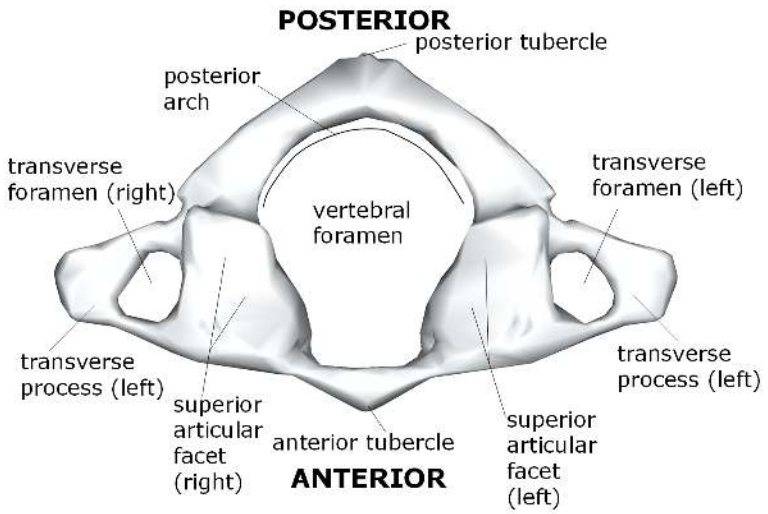
There are seven cervical vertebrae (C1 through C7). The skull articulates with C1 via the occipital condyles (rounded structures on the inferior portion of the occipital bone of the skull). The structures of C1 and C2 are distinctive and are covered below. All of the cervical vertebrae are smaller in size compared to thoracic vertebrae and lumbar vertebrae. The cervical vertebrae are easily distinguished from thoracic and lumbar vertebrae not only by their size, but also because they have foramina in their transverse processes, whereas the other vertebrae do not. These **transverse foramina** serve as passages for paired vertebral arteries (right and left) carrying blood to the head. Additionally, cervical vertebrae are roughly triangle-shaped and C3 through C6 have spinous processes that have two branches (**bifurcated**). The C7 vertebra however, has an unbranched spinous process that is so prominent that it can easily be observed and felt through the skin (feel on the posterior of your lower neck to see if you can find it on yourself), called **vertebra prominens**.

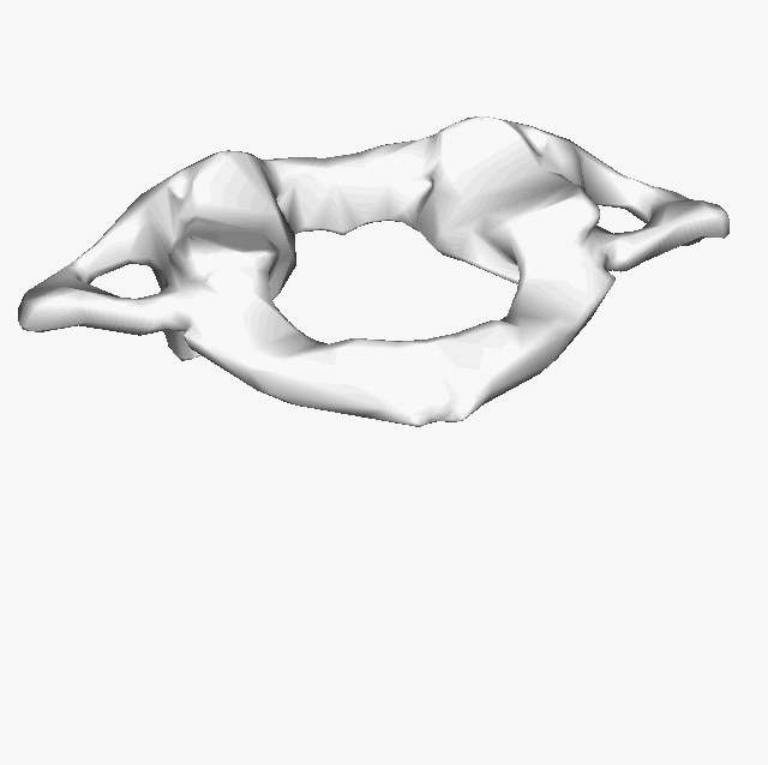


Above: A cervical vertebra, superior view. (Top) Anatomical model of a cervical vertebra. (Bottom) Illustration of a cervical vertebra showing the locations of the spinal cord in the vertebral foramen, spinal nerves, meninges surrounding the spinal cord, and intervertebral disc separating the bodies of articulating vertebrae.

C1 Vertebra (Atlas)

The first two cervical vertebrae have alternate names to C1 vertebra and C2 vertebra. The C1 vertebra is also called the **atlas**. In Greek mythology, Atlas was a titan who held the entire world on his shoulders. As the first vertebra in the column, atlas in a sense holds up the skull (similar in shape to Atlas holding up the world). The superior articular condyles form a joint (**articulation**) with the two occipital condyles of the occipital bone of the skull. It is this joint between the skull and the C1 vertebra that enables an individual to nod their head "yes." Unlike the other vertebrae, C1 has no body. The C1 vertebra also lacks a spinous process and instead has a small posterior tubercle (a small bump).

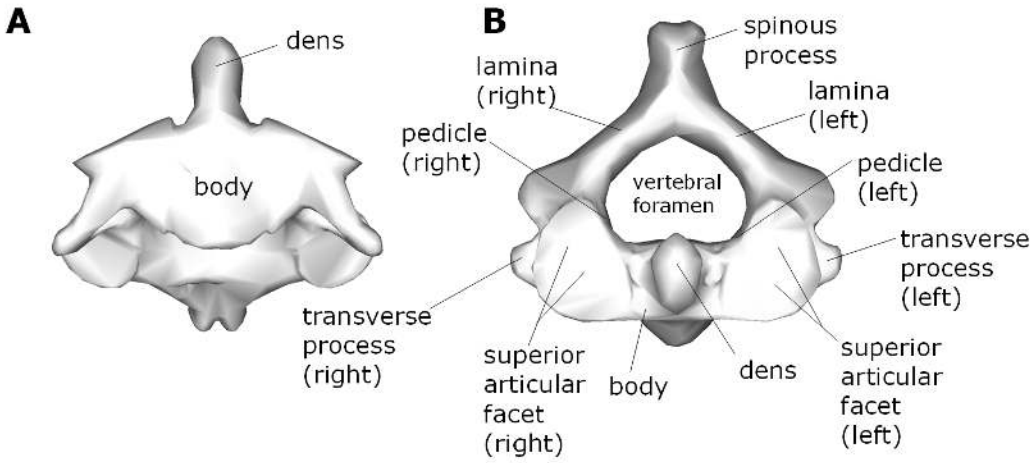


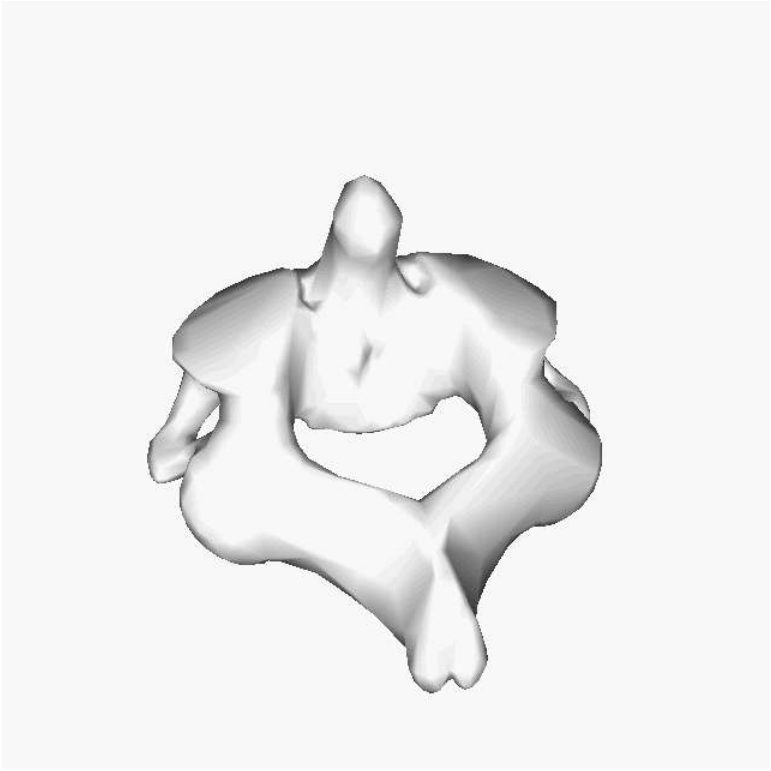


Above: C1 vertebra, also known as atlas with a superior view.

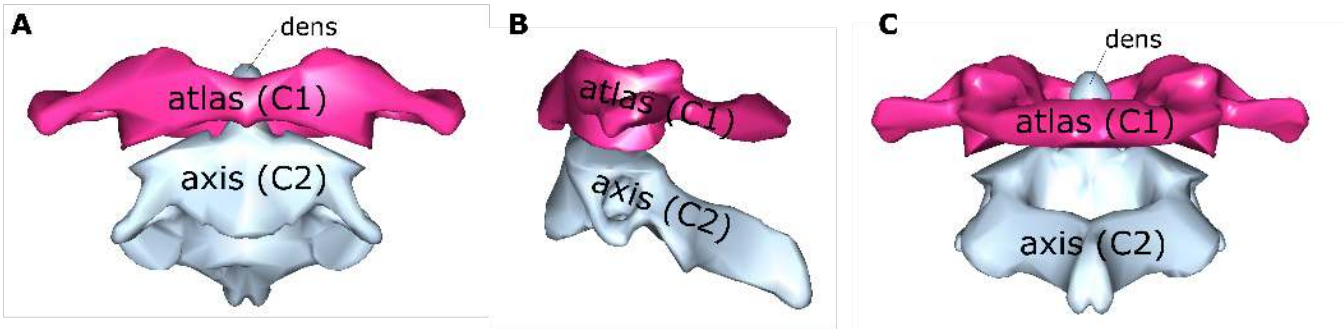
C2 Vertebra (Axis)

The C2 vertebra is also called **axis**. Axis allows both the skull and atlas (C1 vertebra) to rotate, so the head can be turned from side to side by neck muscles. Axis, or the C2 vertebra, also has a bulbous vertical process not found in any of the other vertebrae called the **dens**, and dens is what allows atlas (C1 vertebra) above it to rock right to left around dens. This rotation made possible with the C1-C2 articulation enables individuals to move their head side to side to shake their head "no."





Above: C2 vertebra, also known as axis, with (A) an anterior view and (B) a posterior view.





Above: Articulation of atlas (C1 vertebra) and axis (C2 vertebra). Atlas is shown in pink and axis is shown in light blue. (A) Anterior view of atlas and axis, (B) lateral view of the left side of atlas and axis, and (C) posterior view of atlas and axis.

Attributions (All Vertebral Column Sections)

- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- "BodyParts3D/Anatomography" by The Database Center for Life Science is licensed under CC BY-SA 2.1
- "Cervical vertebra english.png" by user:debivort is licensed under CC BY-SA 3.0
- "Sacrum - animation02.gif" by BodyParts3D is made by DBCLS is licensed under CC BY-SA 2.1

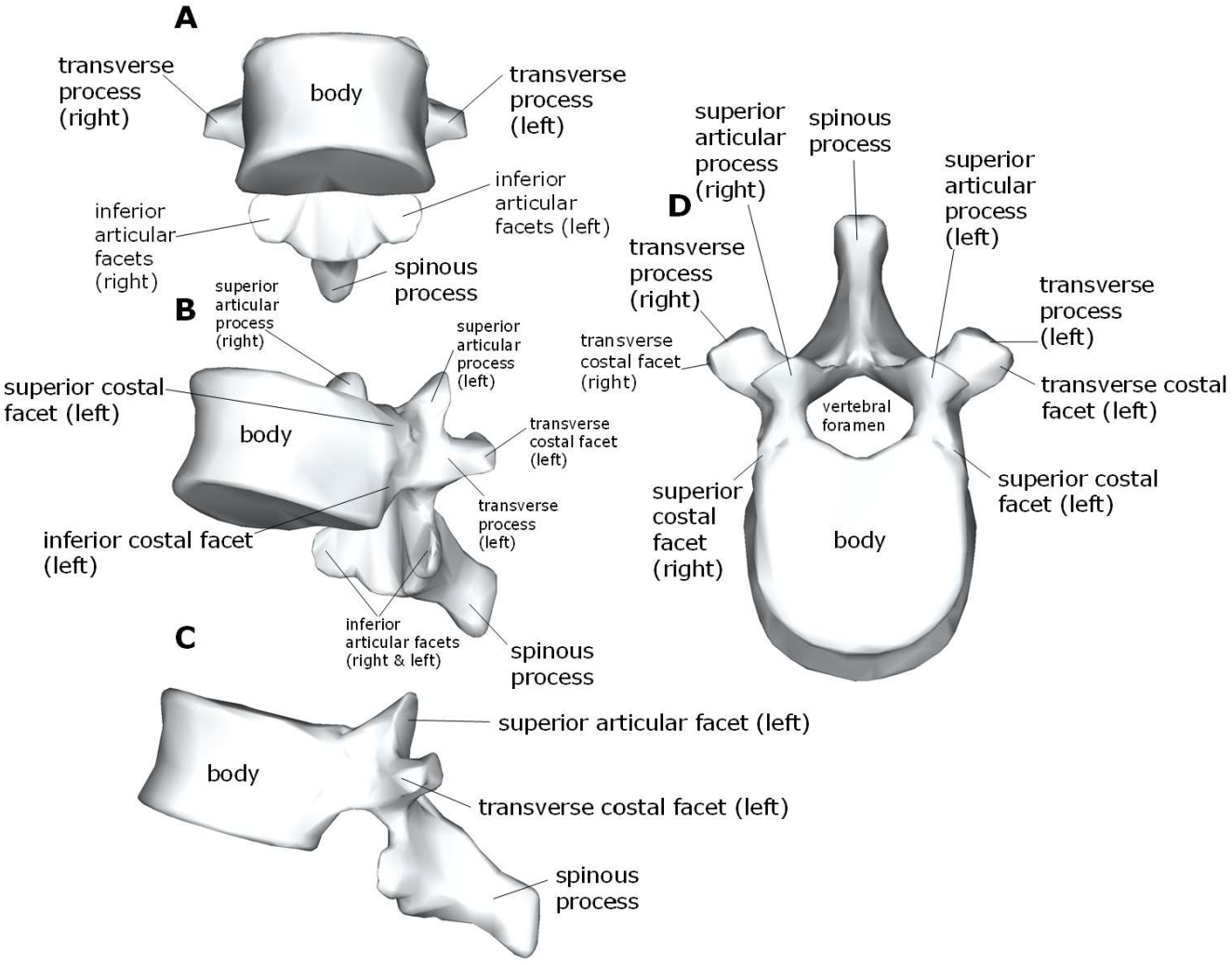
Updated 2025.

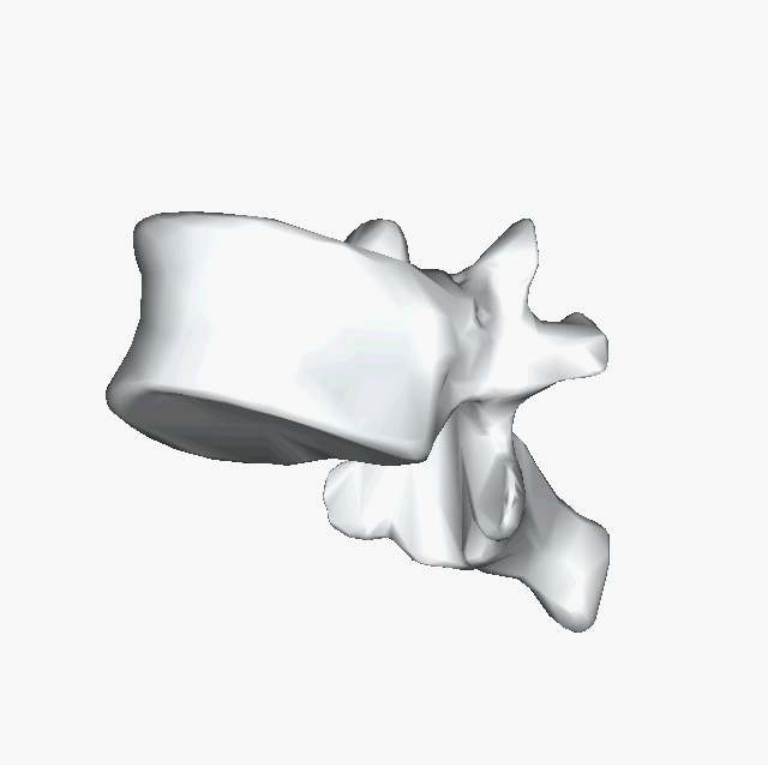
This page titled 8.5.3: Cervical Vertebrae is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

8.5.4: Thoracic Vertebrae

Thoracic Vertebrae

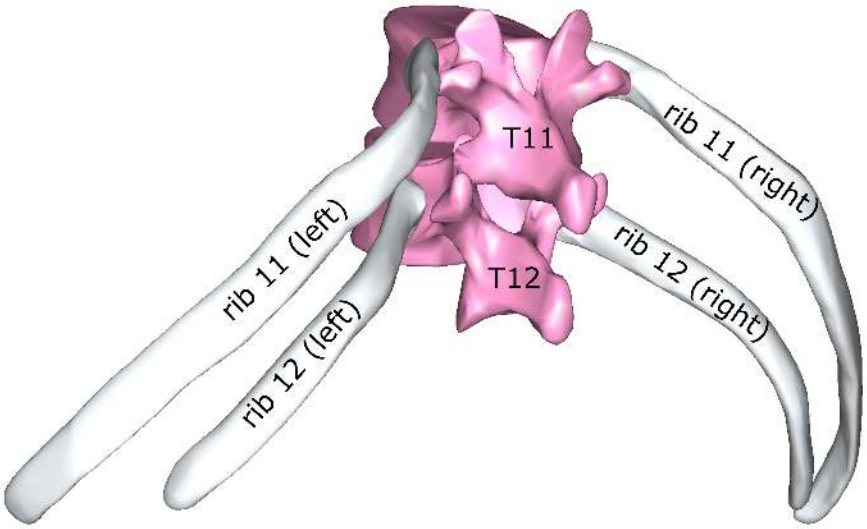
There are 12 **thoracic vertebrae** T1-T12 that are located inferior to the cervical vertebrae. Each thoracic vertebra has a body that is larger than the bodies of cervical vertebrae. The characteristic feature for a typical thoracic vertebra is the spinous process, which is long and most of them has a pronounced downward angle (point inferiorly) that causes it to overlap the next inferior vertebra. The superior articular processes of thoracic vertebrae face anteriorly and the inferior processes face posteriorly. These orientations are important determinants for the type and range of movements available to the thoracic region of the vertebral column.

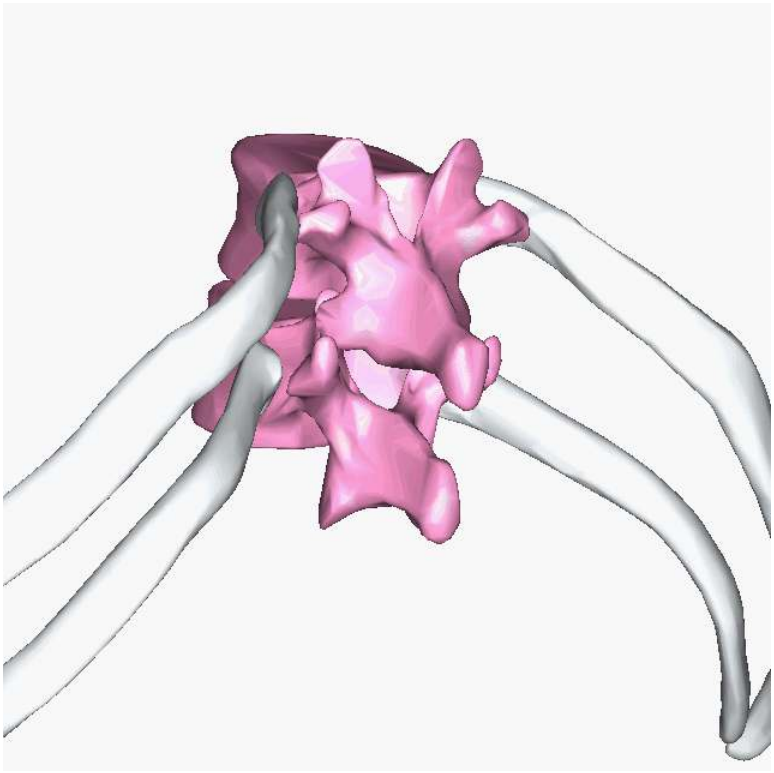




Above: A thoracic vertebra with (A) an anterior view, (B) an anterolateral view, (C) a lateral view of the left side of the vertebra, and (D) a superior view with anterior being at the bottom of the image.

Thoracic vertebrae have several additional articulation sites not found on cervical vertebrae or lumbar vertebrae where a rib is attached. Most thoracic vertebrae have two facets located on the lateral sides of the body, each of which is called a **costal facet** (costal = "rib"). These are for articulation with the head (end) of a rib. An additional facet is located on the transverse process for articulation with the tubercle of a rib.





Above: T11 vertebra and T12 vertebra (pink) articulating with right and left ribs 11 and ribs 12 (white), respectively. Ribs articulate with superior, inferior, and transverse costal facets located on the lateral aspects of each vertebra.

Attributions (All Vertebral Column Sections)

- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- "BodyParts3D/Anatomography" by The Database Center for Life Science is licensed under CC BY-SA 2.1
- "Cervical vertebra english.png" by user:debivort is licensed under CC BY-SA 3.0
- "Sacrum - animation02.gif" by BodyParts3D is made by DBCLS is licensed under CC BY-SA 2.1

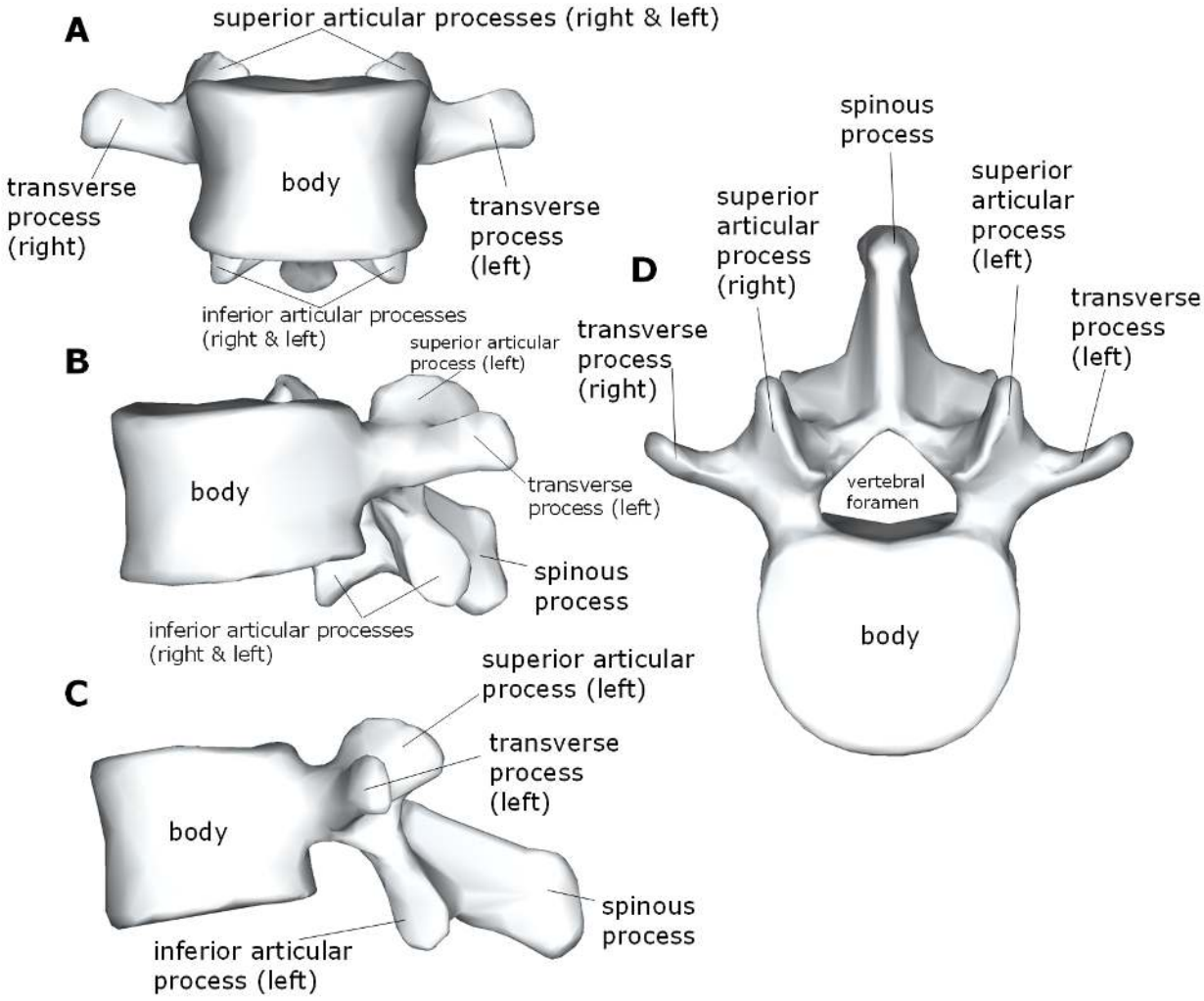
Updated 2025.

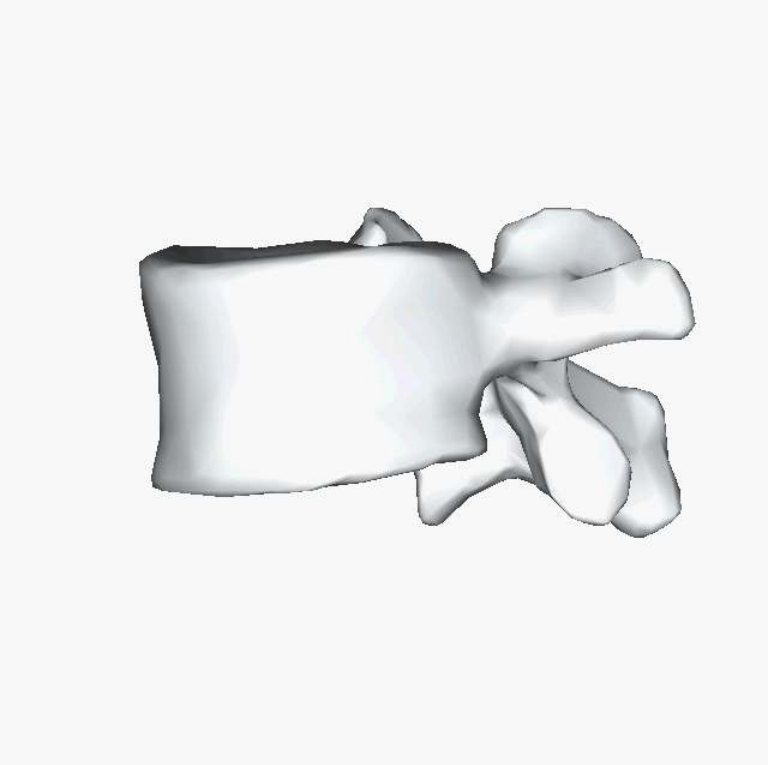
This page titled 8.5.4: Thoracic Vertebrae is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

8.5.5: Lumbar Vertebrae

Lumbar Vertebrae

Lumbar vertebrae (L1-L5 vertebrae) carry the greatest amount of body weight and are thus characterized by the large size and thickness of the vertebral body. They have short transverse processes and a short, thick, and blunt spinous process that projects posteriorly. The articular processes are large, with the superior process facing backward and the inferior facing forward.





Above: A lumbar vertebra with (A) an anterior view, (B) an anterolateral view, (C) a lateral view of the left side of the vertebra, and (D) a superior view with anterior being at the bottom of the image.

Attributions (All Vertebral Column Sections)

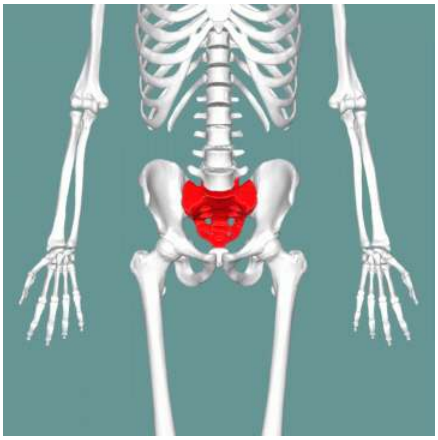
- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- "BodyParts3D/Anatomography" by The Database Center for Life Science is licensed under CC BY-SA 2.1
- "Cervical vertebra english.png" by user:debivort is licensed under CC BY-SA 3.0
- "Sacrum - animation02.gif" by BodyParts3D is made by DBCLS is licensed under CC BY-SA 2.1

Update 2025.

This page titled 8.5.5: Lumbar Vertebrae is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

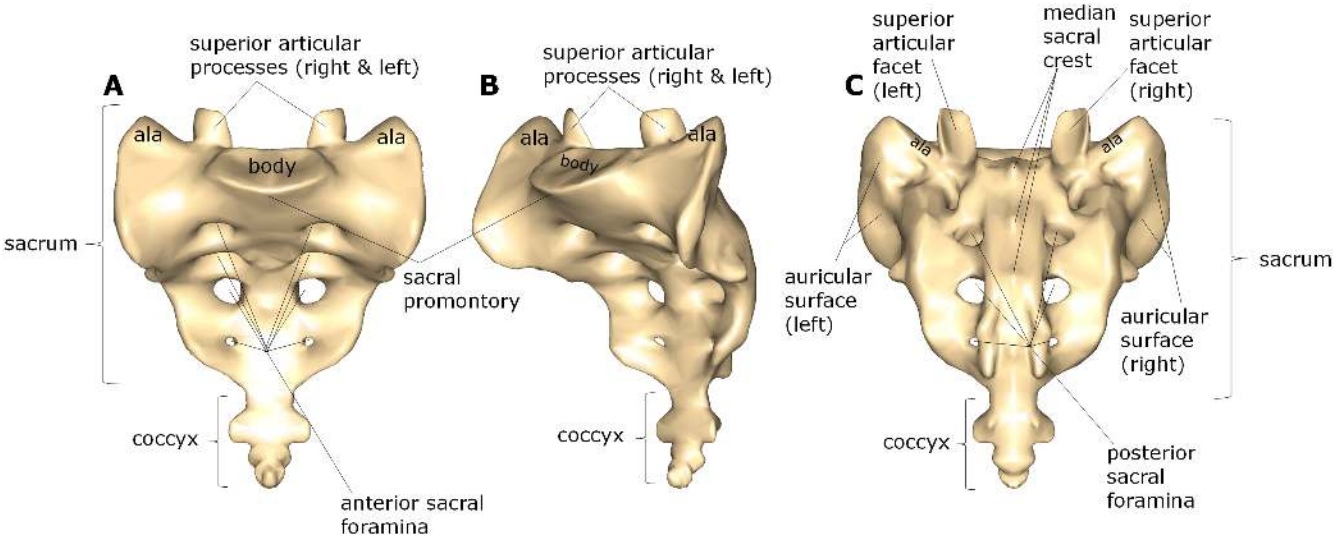
8.5.6: Sacrum and Coccyx

Sacrum and Coccyx



Above: The sacrum is shown in red. It is located in the posterior of the pelvic girdle and is the second-to-most inferior bone of the vertebral column (coccyx is the most inferior bone of the vertebral column).

The **sacrum** is part of both the vertebral column and the pelvic girdle. The sacrum articulates with the body of the L5 vertebra above it and articulates to the inferior articular processes and facets of L5 with the **superior articular processes and facets** of the sacrum. The sacrum also articulates with two coxal bones (hip bones) lateral to it at the **auricular surfaces**. In young people, the sacrum is actually five sacral vertebrae, but in late adolescence/early adulthood these sacral vertebrae fuse together to form one bone, the sacrum. This fusion is not complete until somewhere between the 18th and 30th year of life.



Above: The sacrum and coccyx from (A) anterior, (B) anterolateral, and (C) posterior views.

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

Attributions (All Vertebral Column Sections)

- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- "BodyParts3D/Anatomography" by The Database Center for Life Science is licensed under CC BY-SA 2.1
- "Cervical vertebra english.png" by user:debivort is licensed under CC BY-SA 3.0
- "Sacrum - animation02.gif" by BodyParts3D is made by DBCLS is licensed under CC BY-SA 2.1

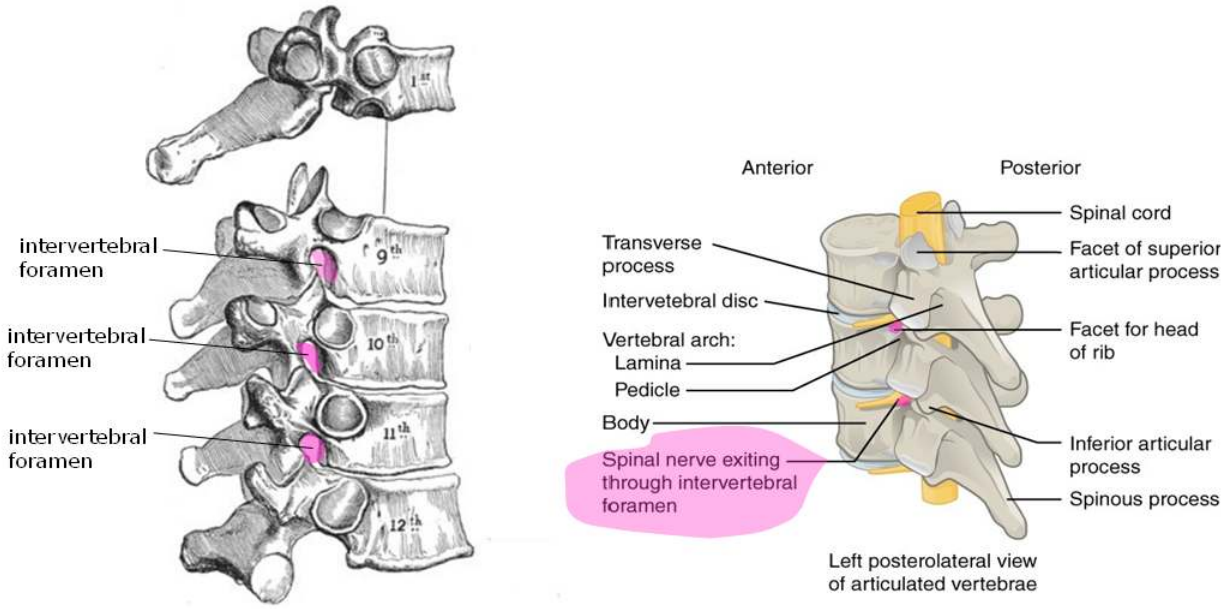
Updated 2025.

This page titled 8.5.6: Sacrum and Coccyx is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

8.5.7: Intervertebral Foramina

Intervertebral Foramina

When the vertebrae articulate on top of each other, **intervertebral foramina** are formed between the bodies of the vertebrae and the superior articulating processes and inferior articulating processes. These intervertebral foramina can be viewed from the lateral aspects of the vertebral column (right and left sides) and are important passageways providing means for spinal nerves to pass through the vertebrae and enables nerves to connect between body locations they innervate and the spinal cord (enables connections between the peripheral nervous system [nerves] and the central nervous system [brain and spinal cord]).



Above: Intervertebral foramina can be seen when vertebrae articulate from a lateral view. These foramina are important since spinal nerves attach to the spinal cord through these passageways. (Left) Vertebrae articulating with intervertebral foramina highlighted in pink. (Right) Articulating vertebrae with the spinal cord passing through the vertebral foramina of the vertebrae and spinal nerves passing through the intervertebral foramina.

Attributions (All Vertebral Column Sections)

- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- "BodyParts3D/Anatomography" by The Database Center for Life Science is licensed under CC BY-SA 2.1
- "Cervical vertebra english.png" by user:debivort is licensed under CC BY-SA 3.0
- "Sacrum - animation02.gif" by BodyParts3D is made by DBCLS is licensed under CC BY-SA 2.1

Updated 2025.

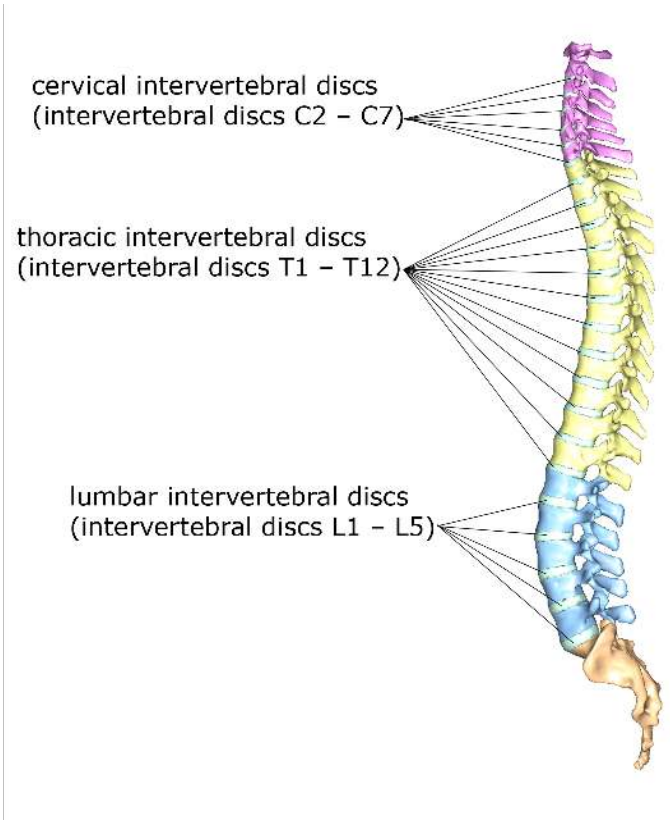
This page titled 8.5.7: Intervertebral Foramina is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

8.5.8: Intervertebral Discs

Intervertebral Discs

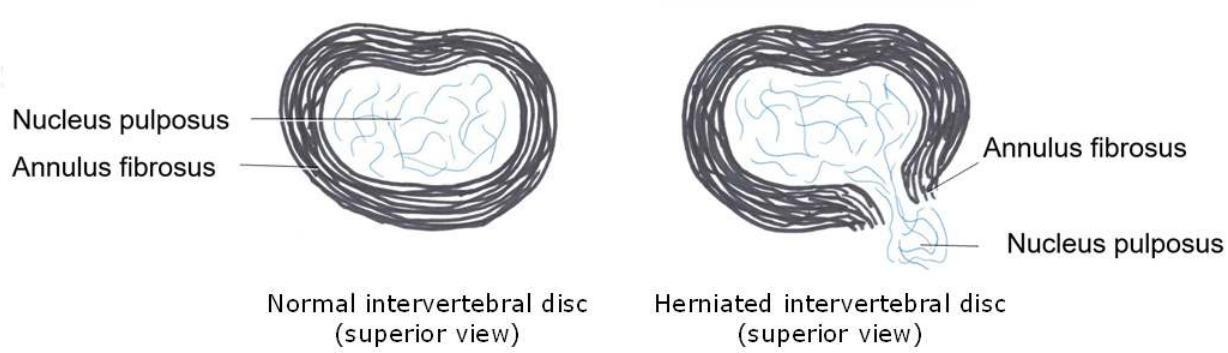
The **intervertebral discs** are fibrocartilaginous pads that fill the gaps between articulating vertebral bodies. Each disc is anchored to the bodies of the vertebrae superior and inferior to it, thus strongly uniting these. The discs also provide padding between vertebrae during weight bearing. Because of this, intervertebral discs are thin in the cervical region and thickest in the lumbar region, which carries the most body weight. In total, the intervertebral discs account for approximately 25 percent of your body height between the top of the pelvis and the base of the skull. Intervertebral discs are also flexible and can change shape to allow for movements of the vertebral column.

There is no intervertebral disc between the skull and atlas or between atlas and axis. There is also no intervertebral discs in between the sacral vertebrae or coccygeal vertebrae. Intervertebral discs are named according to the vertebra directly above them (i.e. the intervertebral disc between T3 and T4 vertebrae is the T3 intervertebral disc).



Above: Lateral view of the left side of the vertebral column with intervertebral discs labeled.

Each intervertebral disc consists of two parts. The **anulus fibrosus** is the tough, fibrous outer layer of the disc. It forms a circle (anulus = “ring” or “circle”) and is firmly anchored to the outer margins of the adjacent vertebral bodies. Inside is the **nucleus pulposus**, consisting of a softer, more gel-like material. It has a high water content that serves to resist compression and thus is important for weight bearing. With increasing age, the water content of the nucleus pulposus gradually declines. This causes the disc to become thinner, decreasing total body height somewhat, and reduces the flexibility and range of motion of the disc, making bending more difficult.



Above: Illustrations of intervertebral discs (right) that are normal and (left) that are herniated.

If the posterior anulus fibrosus is weakened due to injury or increasing age, the pressure exerted on the disc when bending forward and lifting a heavy object can cause the nucleus pulposus to protrude posteriorly through the anulus fibrosus, resulting in a **herniated disc** (“ruptured” or “slipped” disc). The posterior bulging of the nucleus pulposus can cause compression of a spinal nerve at the point where it exits through the intervertebral foramen, with resulting pain and/or muscle weakness in those body regions supplied by that nerve. The most common sites for disc herniation are the L4/L5 or L5/S1 intervertebral discs, which can cause sciatica, a widespread pain that radiates from the lower back down the thigh and into the leg. Similar injuries of the C5/C6 or C6/C7 intervertebral discs, following forcible hyperflexion of the neck from a collision accident or football injury, can produce pain in the neck, shoulder, and upper limb.

Attributions (All Vertebral Column Sections)

- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- "BodyParts3D/Anatomography" by The Database Center for Life Science is licensed under CC BY-SA 2.1
- "Cervical vertebra english.png" by user:debivort is licensed under CC BY-SA 3.0
- "Sacrum - animation02.gif" by BodyParts3D is made by DBCLS is licensed under CC BY-SA 2.1

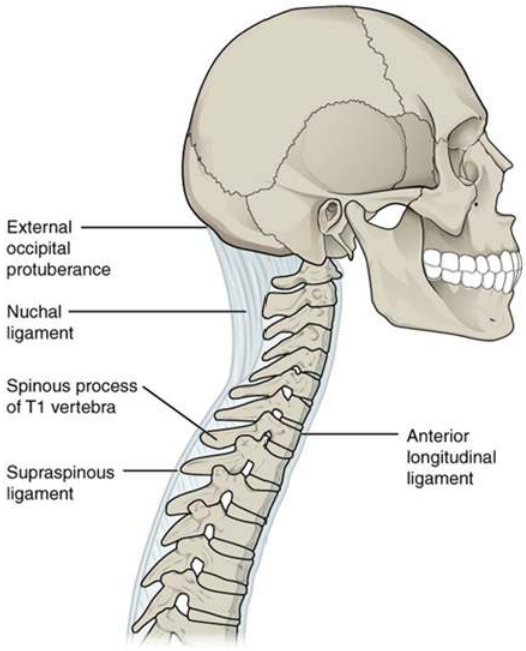
Updated 2025.

This page titled 8.5.8: Intervertebral Discs is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

8.5.9: Clinical Application - Whiplash

Clinical Application - Whiplash

Whiplash is an injury commonly associated with rear-end motor vehicle collisions. In a rear-end collision, the head of the person in the car being rear-ended will be thrown backward, causing hyperextension of the neck. This action can stretch and/or tear the **anterior longitudinal ligament**, resulting in pain and stiffness in the neck. Following the hyperextension injury in the same accident, the same person's head may then be thrown forward as a result of their vehicle and body being forced forward. This secondary action can cause hyperflexion of the neck and could jeopardize the integrity of the **posterior longitudinal ligament** and/or the **nuchal ligament**.



Above: Illustration of the skull and upper vertebral column showing the position of ligaments that may be damaged as a result of an accident (whiplash).

Attributions (All Vertebral Column Sections)

- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- "BodyParts3D/Anatomography" by The Database Center for Life Science is licensed under CC BY-SA 2.1
- "Cervical vertebra english.png" by user:debivort is licensed under CC BY-SA 3.0
- "Sacrum - animation02.gif" by BodyParts3D is made by DBCLS is licensed under CC BY-SA 2.1

Updated 2025.

This page titled 8.5.9: Clinical Application - Whiplash is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

8.6: Thoracic Cage

Thoracic Cage

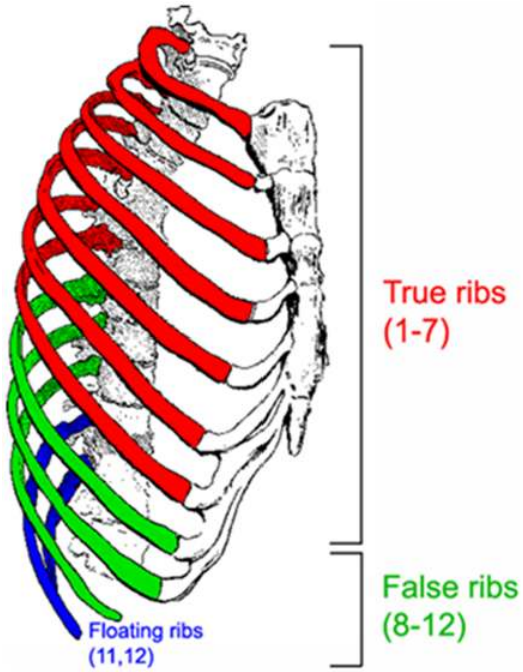
The thoracic cage, also called the rib cage, surrounds and protects the heart and lungs in the thoracic cavity. It consists of the **ribs**, the **sternum**, and the thoracic vertebrae, to which the ribs articulate.



Above: Bones (light tan) and cartilage (bright white) of the thoracic cage with the vertebral column, scapulae, clavicles, and humerii.

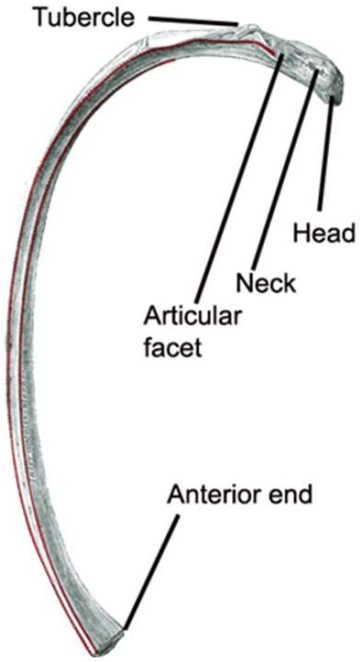
There are twelve pairs of ribs. Each pair of ribs articulates with a different thoracic vertebra on the posterior side of the body. The most superior rib is designated rib 1 and it articulates with the T1 thoracic vertebrae. The rib below that is rib 2, and it connects to the T2 thoracic vertebra, and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

Rib pairs 1-7 are considered **true ribs** because they attach to the sternum via their own separate costal cartilages. Rib pairs 8-12 are considered **false ribs** because they only attach to the sternum by attaching their combined costal cartilages with the costal cartilage of the 7th rib. Lastly, rib pairs 11-12 are considered **floating ribs** because they do not have any costal cartilages attaching them in any way to the sternum.

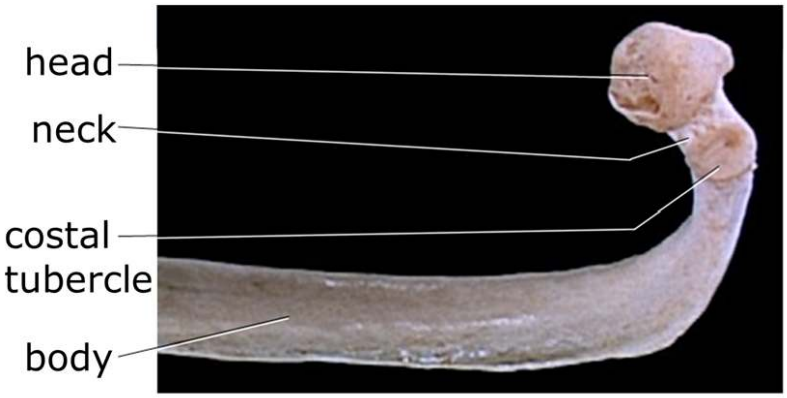


Above: The right side of the rib cage and the with the sternum. The true ribs are shown in red, the false ribs are shown in green and blue, and the floating ribs are blue. The sternum is the neck-tie shaped bone at the center of the chest shown in white. The white extensions of the ribs are costal cartilage connecting the ribs to the sternum.

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



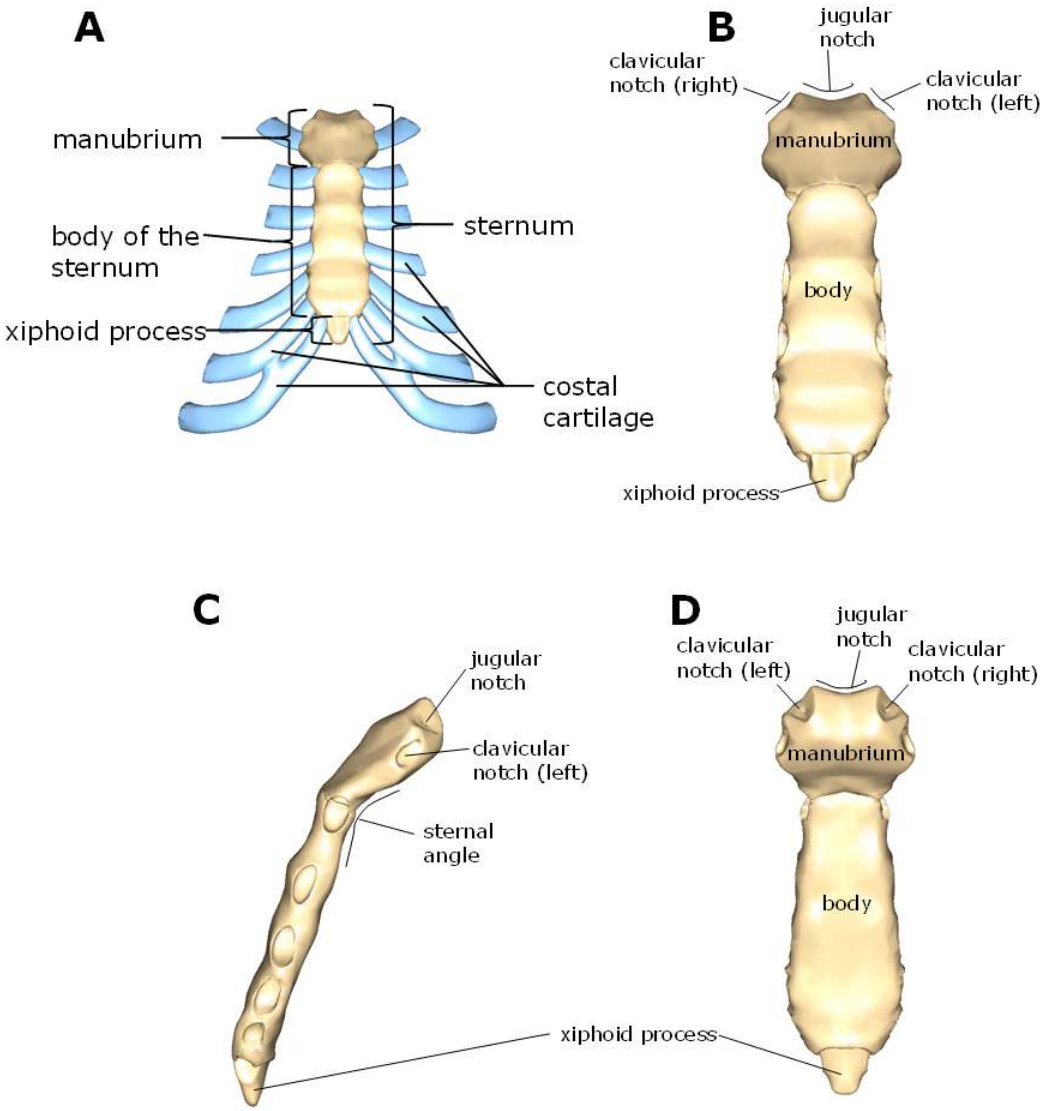
Above: The structure and markings of a rib.



Above: Markings of a rib (medial view).

The **articular facets** on the **head** and **costal tubercles** of the rib articulate posteromedially with **costal facets** on the thoracic vertebrae. The anterior aspects of the ribs (located medially) attach to **costal cartilages** which allow for elasticity of the thorax while linking the ribs to the costal notches on the sternum.

https://bio.libretexts.org/@go/page/53634



https://bio.libretexts.org/@go/page/53634



Above: The sternum. (A) The sternum with costal cartilage shown in blue, anterior view. (B) Anterior view of the sternum. (C) Lateral view of the left side of the sternum. (D) Posterior view of the sternum.

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

Attributions

- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- "BodyParts3D/Anatomography" by The Database Center for Life Science is licensed under CC BY-SA 2.1
- Thoracic Cage with Both Humerii.gif by DrJanaOfficial is licensed under CC BY-SA 4.0

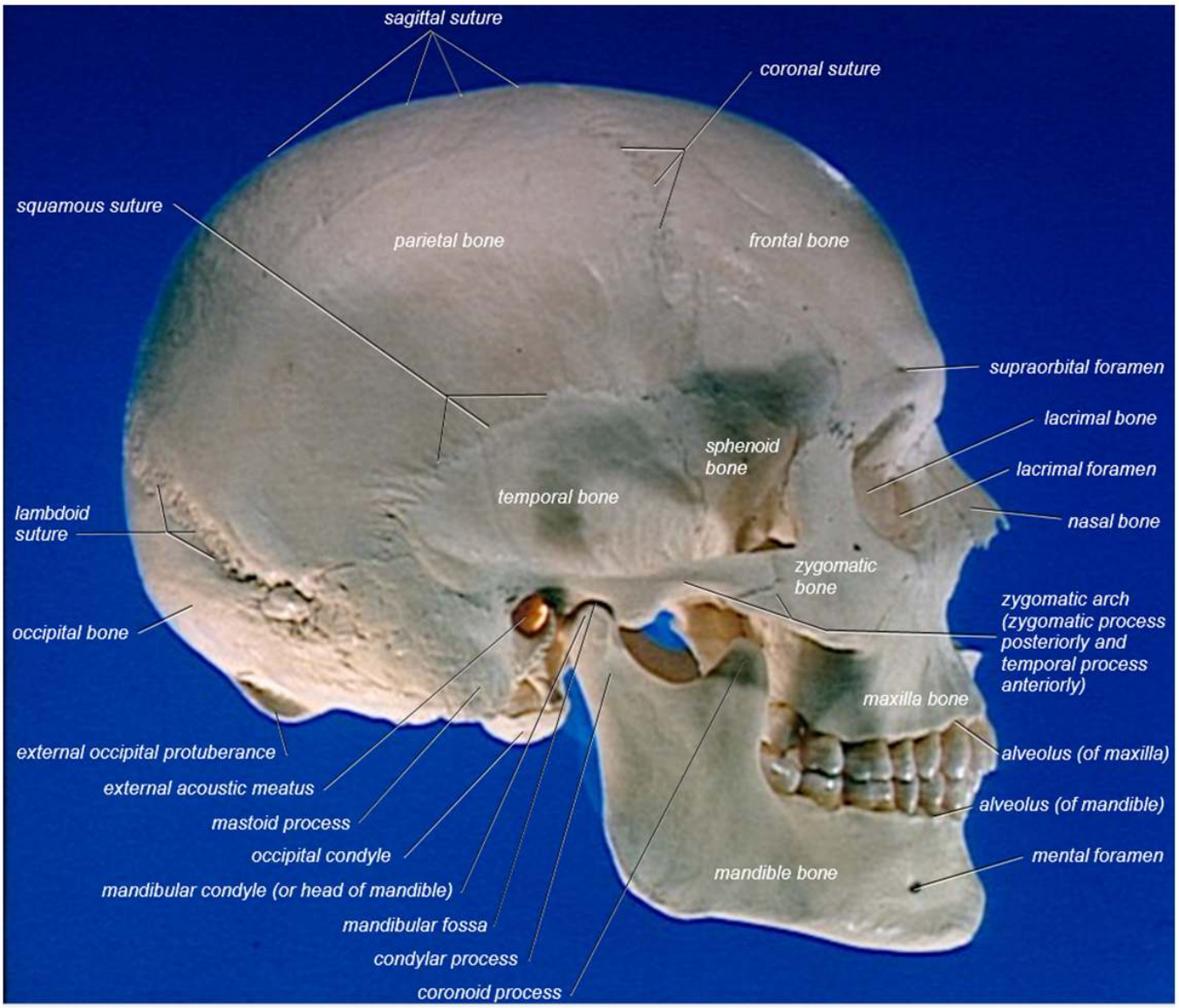
Updated 2025.

This page titled 8.6: Thoracic Cage is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

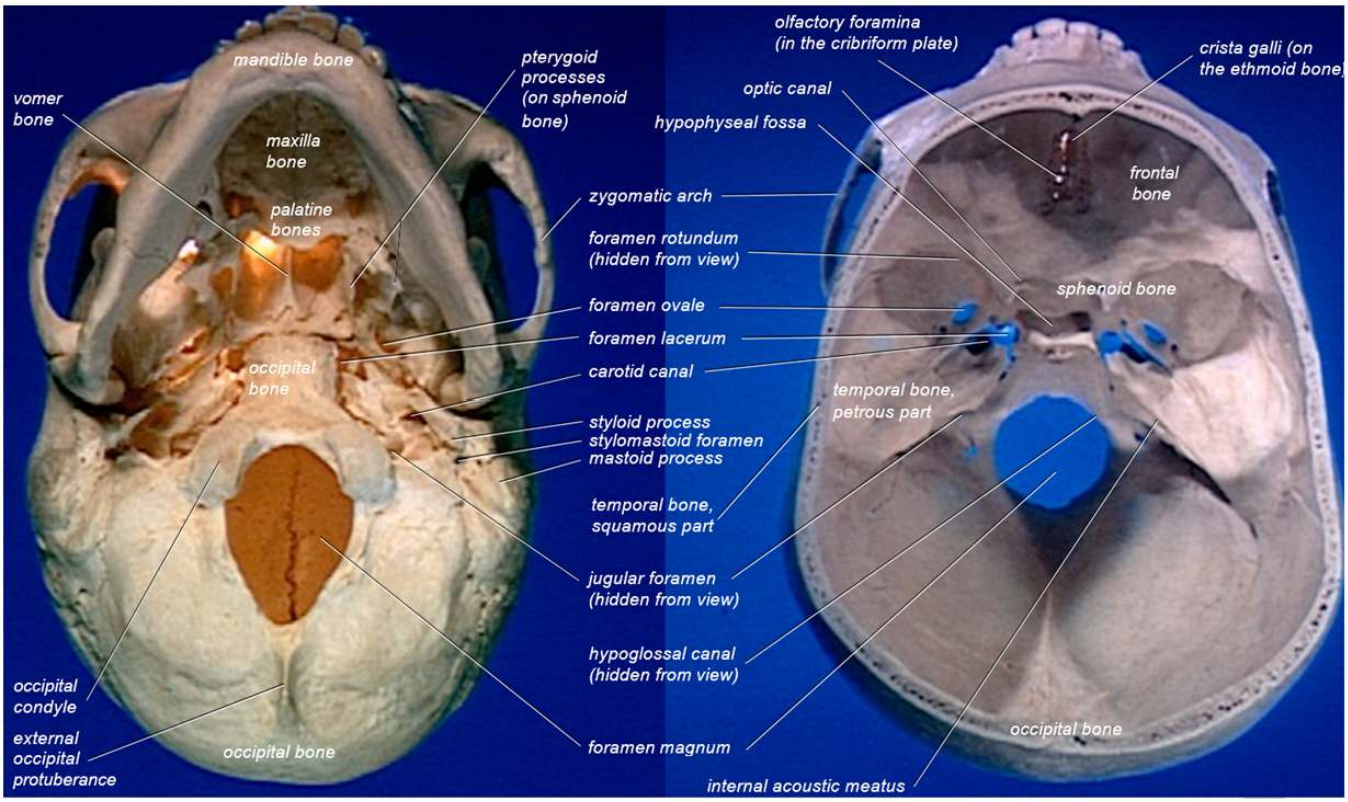
8.7: Additional Reference Figures

Additional Reference Figures

Skull

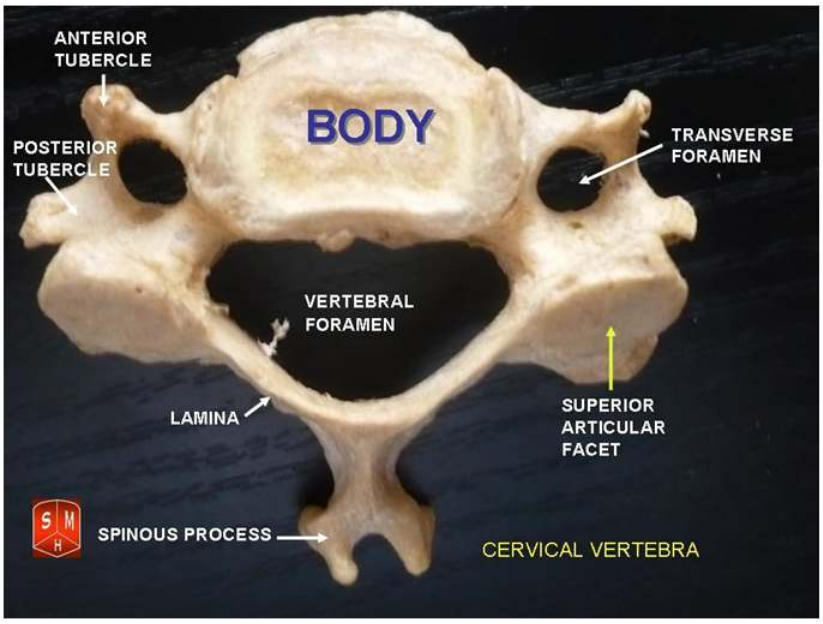


Above: Lateral view of a skull.

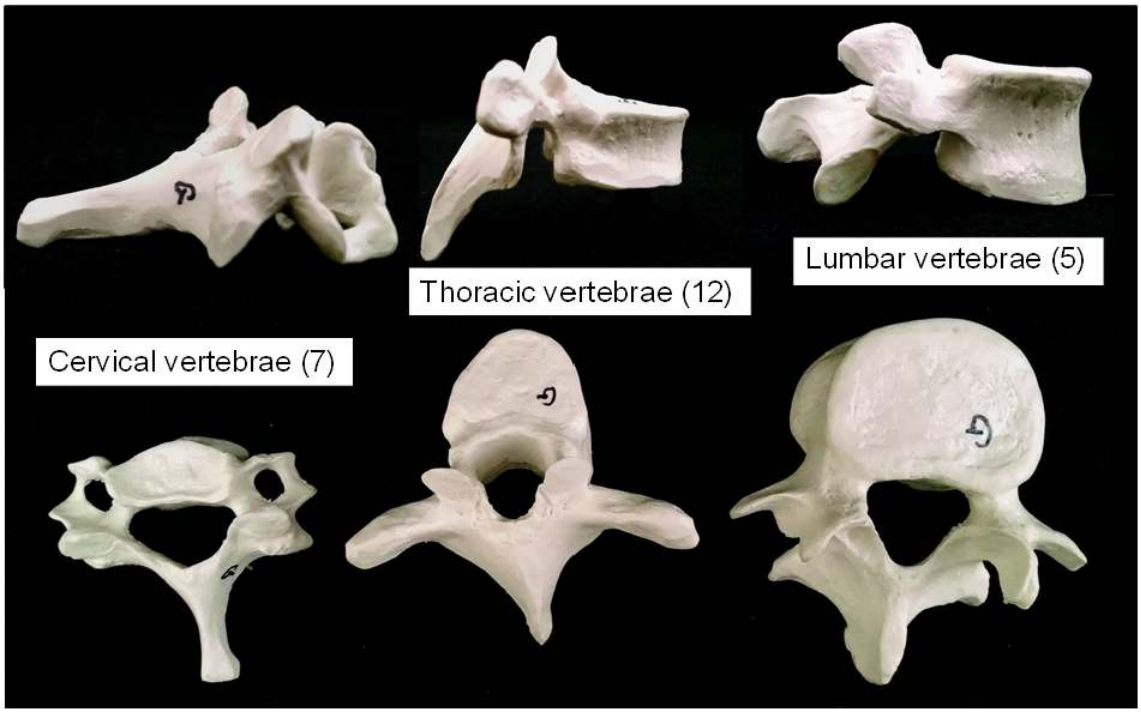


Above: (Left) Inferior view of a skull. (Right) Superior view of the cranial cavity.

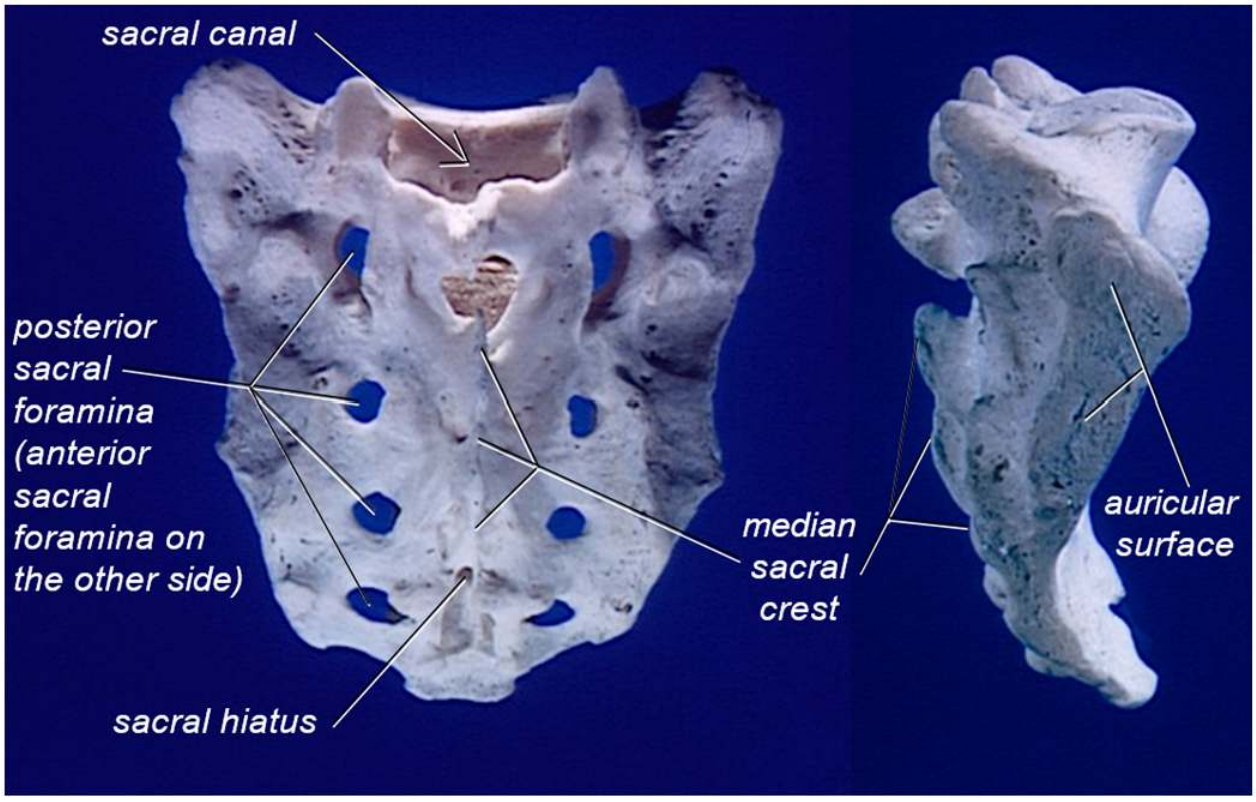
Vertebral Column



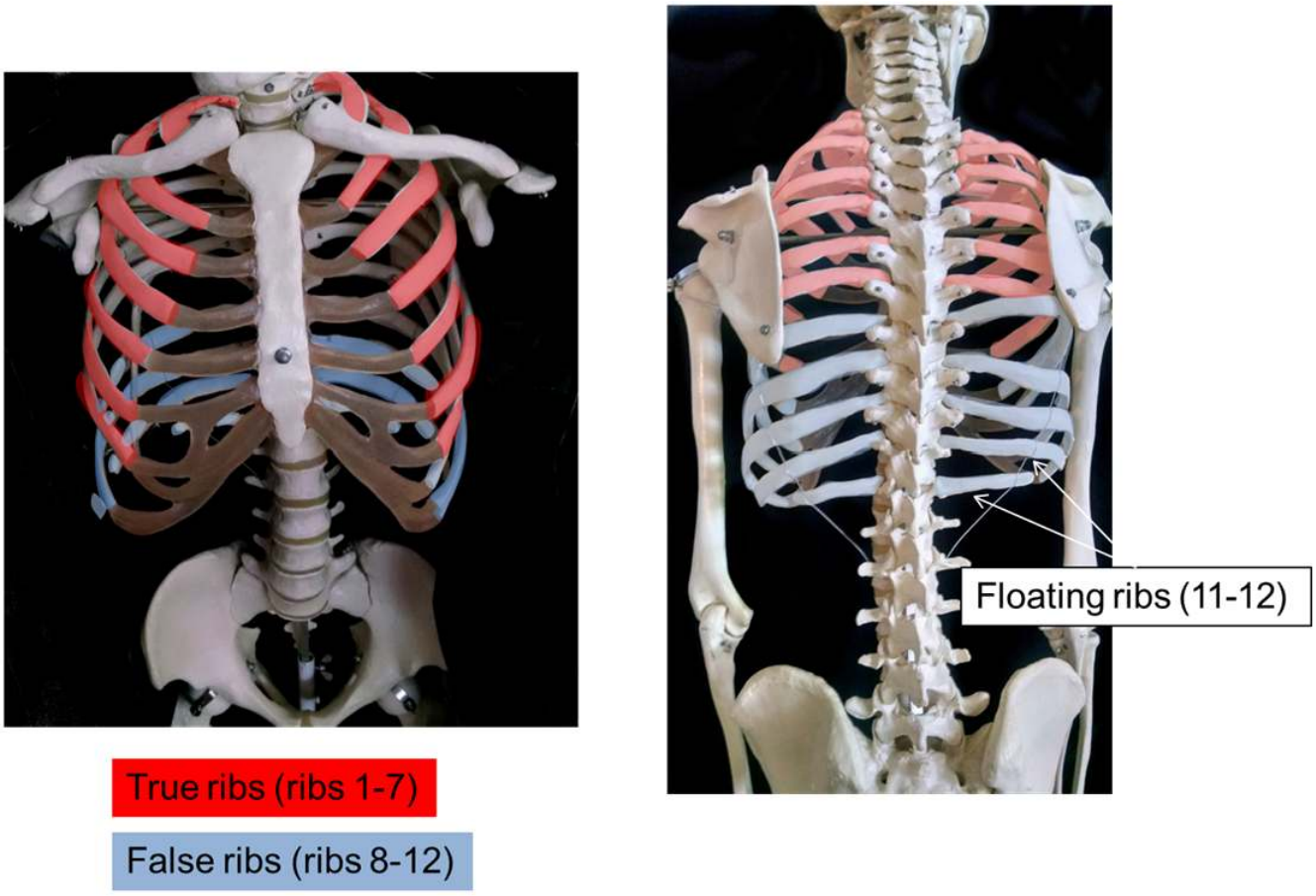
Above: A cervical vertebra. The top of the image is the anterior of the vertebra and the bottom of the image is the posterior of the vertebra. This is a superior view of the vertebra.



Above: A comparison of cervical vertebrae, thoracic vertebrae, and lumbar vertebrae. (Top) Lateral view of the right side of the vertebrae and (bottom) superior view of the vertebrae.



Above: The sacrum from a (left) posterior view and (right) lateral view of the right side of the sacrum.



Above: The thoracic cage on an anatomical model (right) anterior view and (left) posterior view.

Attributions

- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Anatomy and Physiology Lab Reference" by Laird C Sheldahl, OpenOregonEducational Resources, Mt. Hood Community College is licensed under CC BY-SA 4.0
- "Cervical vertebra.jpg" by Anatomist90 is licensed under CC BY-SA 3.

Updated 2025.

This page titled 8.7: Additional Reference Figures is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

8.8: Laboratory Activities and Assignment

Laboratory Activities and Assignment

Part 1: Review of the Skull

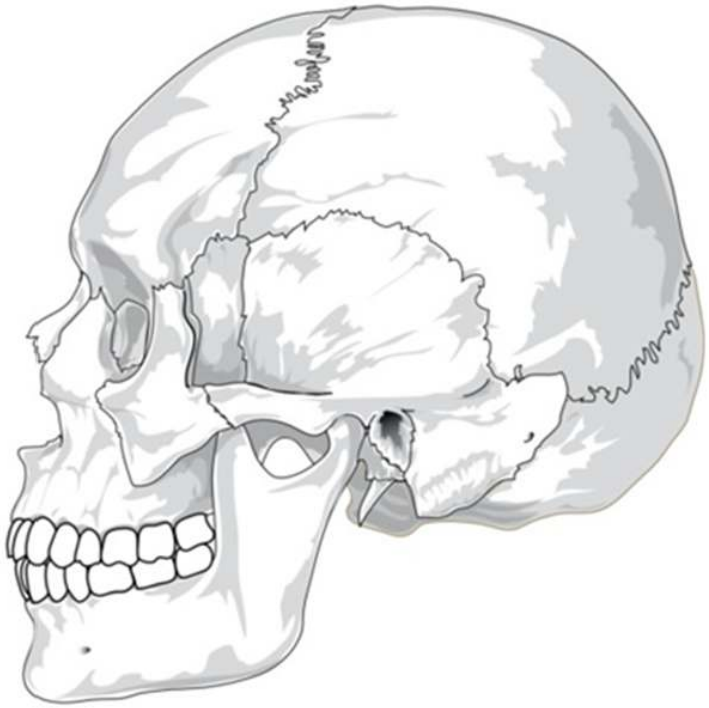
1. Match the following bone markings with their descriptions. Some choices may be used more than once.

____ foramen (pl. foramina)	A. A location where a bone turns suddenly and sharply
____ process (pl. processes)	B. A hole or passageway in a bone
____ fossa (pl. fossae)	C. A broad branch of a bone supporting other parts of that bone
____ meatus (pl. meatuses)	D. A large and/or main part of a bone
____ ramus (pl. rami)	E. A bony projection that is rounded at the end
____ body (pl. bodies)	F. A bulge or knob-like projection
____ condyle (pl. condyles)	G. A part of a bone that sticks outward from the rest
____ canal (pl. canals)	H. An edge of a bone that indents
____ protuberance (pl. protuberances)	I. A part of a bone that is shaped as a shallow basin
____ notch (pl. notches)	
____ angle (pl. angles)	

2. On the skull diagrams below, color the bones of the skull (listed below) with different colors with a key showing which color is for each bone. Also, label the sutures and markings listed below on the diagram.

Bones:	Sutures:	Markings:
▪ ethmoid ▪ frontal ▪ lacrimal ▪ mandible ▪ maxilla ▪ nasal ▪ occipital ▪ palatine (not visible) ▪ parietal ▪ sphenoid ▪ temporal ▪ vomer ▪ zygomatic	▪ coronal ▪ lambdoid ▪ occipitomastoid ▪ pterion ▪ sagittal ▪ sphenofrontal ▪ sphenoparietal ▪ sphenosquamous ▪ squamous	▪ alveolar processes ▪ body of mandible ▪ condylar process (of mandible bone) ▪ coronoid process (of mandible bone) ▪ external acoustic meatus ▪ external occipital protuberance ▪ frontal process (of maxilla bone) ▪ inferior orbital fissure ▪ infraorbital foramen ▪ lacrimal fossa ▪ mandibular angle ▪ mandibular fossa ▪ mandibular notch ▪ mandibular ramus ▪ mandibular symphysis ▪ mastoid process ▪ mental foramen ▪ orbital ▪ perpendicular plate ▪ styloid process ▪ superior orbital fissure ▪ supraorbital foramen ▪ temporal process (of zygomatic bone) ▪ zygomatic process (of temporal bone) ▪ zygomatic process (of maxilla bone)





3. On the skull images below, color the bones of the skull (listed below) with different colors with a key showing which color is for each bone. Also, label the sutures and markings listed below on the diagram.

Bones:	Sutures:	Markings:
▪ ethmoid ▪ frontal ▪ maxilla ▪ occipital ▪ palatine ▪ sphenoid ▪ temporal ▪ vomer ▪ zygomatic	▪ lambdoid suture ▪ occipitomastoid suture ▪ squamous suture	▪ anterior cranial fossa ▪ carotid canal ▪ cribriform plate ▪ crista galli ▪ external occipital protuberance ▪ foramen lacerum ▪ foramen magnum ▪ foramen ovale ▪ foramen spinosum ▪ greater wings of sphenoid ▪ hypoglossal canal ▪ hypophyseal fossa ▪ internal acoustic meatus ▪ lesser wings of sphenoid ▪ mandibular fossa ▪ mastoid process ▪ middle cranial fossa ▪ palatine process (of maxilla bone) ▪ posterior cranial fossa ▪ pterygoid processes ▪ occipital condyles ▪ olfactory foramina ▪ optic canals ▪ sella turcica ▪ stylomastoid foramen





Part 2: Review of the Vertebral Column

1. Label the following in the images below:

▪ C1 through C7	▪ thoracic curvature	▪ superior articular facets
▪ T1 through T12	▪ lumbar curvature	▪ transverse processes
▪ L1 through L5	▪ sacral curvature	▪ transverse foramina
▪ sacrum	▪ atlas	▪ spinous process
▪ coccyx	▪ axis	▪ pedicle
▪ occipital bone	▪ vertebral foramen	▪ lamina
▪ cervical curvature	▪ dens	▪ intervertebral foramina

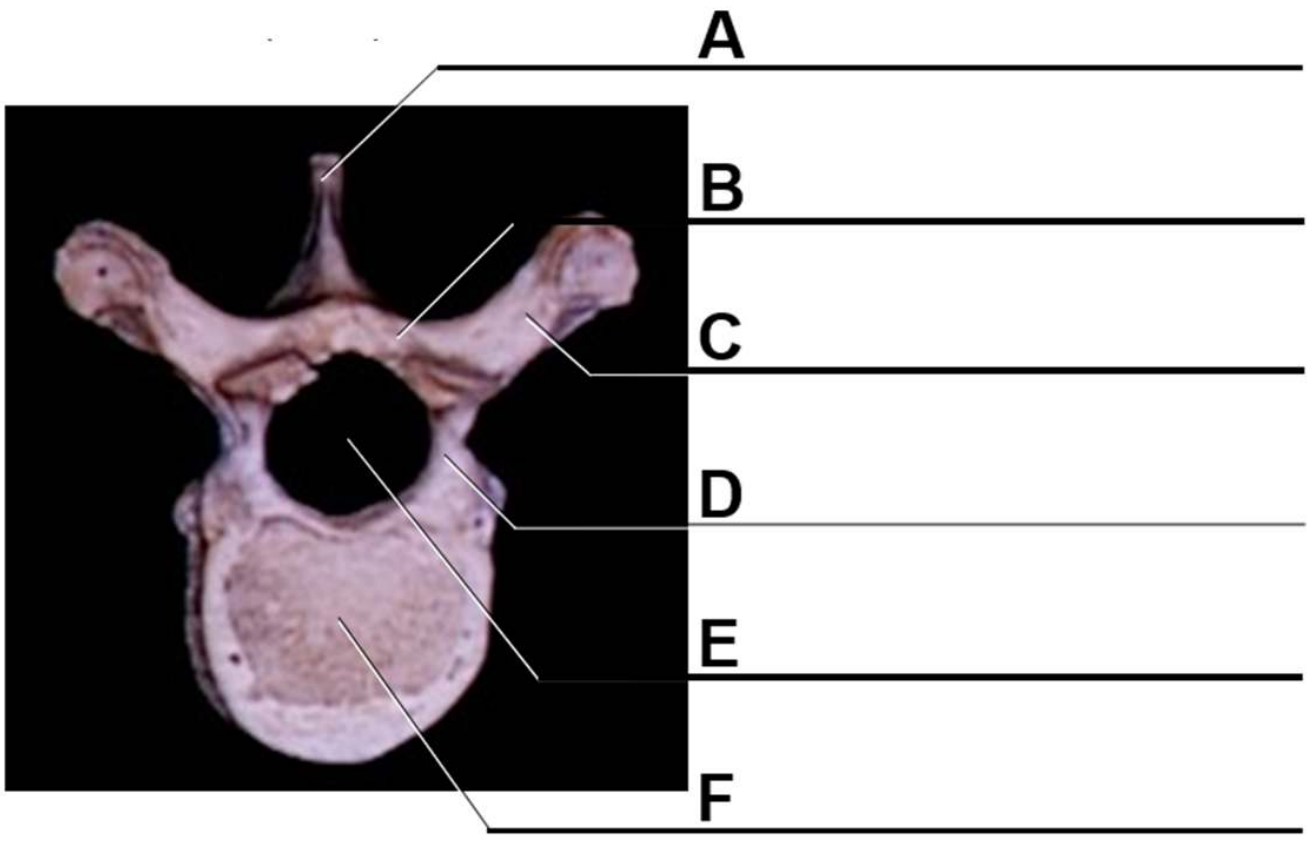


2. Label the following in the images of anatomical models below with the following:

▪ cervical vertebrae ▪ thoracic vertebrae ▪ lumbar vertebrae ▪ laminae ▪ pedicles	▪ transverse processes ▪ transverse foramina ▪ superior articular processes ▪ inferior articular processes	▪ vertebral foramina ▪ bodies ▪ costal facets (superior, inferior, transverse) ▪ spinous processes



3. Fill in the blanks to name the structures labeled on this thoracic vertebra below.



4. Label the images of the anatomical model below with the following:

▪ sacrum ▪ coccyx ▪ superior articular process ▪ superior articular facet	▪ anterior sacral foramina ▪ posterior sacral foramina ▪ ala ▪ auricular surface	▪ median sacral crest ▪ sacral promontory ▪ number the sacral segments S1-S5

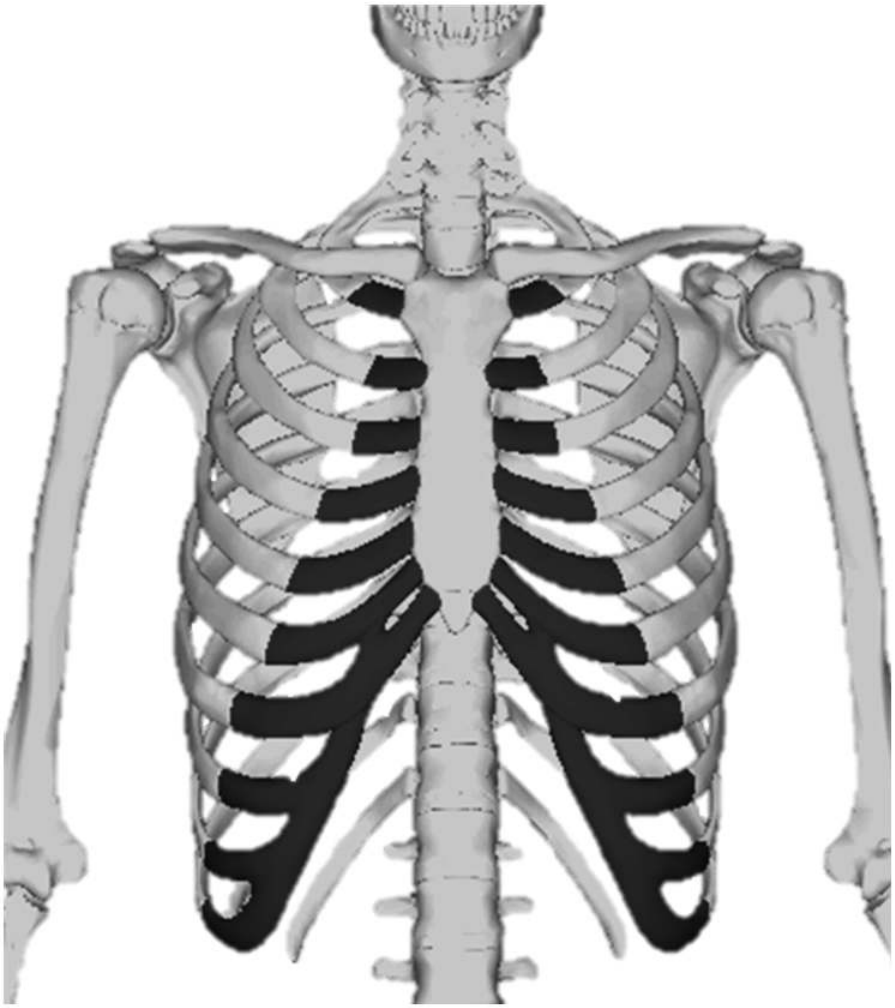




Part 3: Review of the Thoracic Cage

1. Label the image of the thoracic cage with the following:

▪ number the ribs 1 - 12 ▪ true ribs ▪ false ribs ▪ floating ribs	▪ sternum ▪ costal cartilage ▪ manubrium ▪ body of sternum	▪ xiphoid process ▪ clavicular notch ▪ jugular notch ▪ T11 & T12 vertebrae



Part 4: Skull Laboratory Activities

1. With your lab group, obtain an anatomical model of a skull. Collaborate with your group members to identify the structures listed below. For each, write each structure's name on masking tape or labeling tape (with correct spelling) and stick onto the model to label each structure.

Bones:	Sutures:	Markings:

Bones:	Sutures:	Markings:
ethmoid frontal inferior nasal conchae lacrimal mandible maxilla nasal occipital palatine parietal sphenoid temporal vomer zygomatic	coronal lambdoid occipitomastoid pterion sagittal sphenofrontal sphenoparietal sphenosquamous squamous	alveolar processes anterior cranial fossa body of mandible carotid canal condylar process (of mandible bone) coronoid process (of mandible bone) cribriform plate crista galli external acoustic meatus external occipital protuberance foramen lacerum foramen magnum foramen ovale foramen spinosum frontal process (of maxilla bone) greater wings of sphenoid hypoglossal canal hypophyseal fossa inferior orbital fissure infraorbital foramen internal acoustic meatus lacrimal fossa lesser wings of sphenoid mandibular angle mandibular fossa mandibular notch mandibular ramus mandibular symphysis mastoid process mental foramen middle cranial fossa middle nasal conchae orbital palatine process (of maxilla bone) perpendicular plate posterior cranial fossa pterygoid processes occipital condyles olfactory foramina optic canals sella turcica styloid process stylomastoid foramen superior orbital fissure supraorbital foramen temporal process (of zygomatic bone) zygomatic process (of temporal bone) zygomatic process (of maxilla bone)

2. When you are done, take photos of the labeled skull from different angles. Ask your instructor to verify the labeling is correct.

   Instructor Signature Confirming Correct Labeling: _____

3. Remove all tape from the anatomical model.

Part 5: Vertebral Column Laboratory Activities

1. With your lab group, obtain a complete set of vertebrae bone models (24 vertebrae + 1 sacrum/coccyx model). Collaborate with your group members to identify which are the atlas, axis, cervical vertebrae, thoracic vertebrae, and lumbar vertebrae.
2. What features enabled you to identify each of the following vertebrae:

   a. C1 atlas:

   b. C2 axis:

   c. C3 - C7:

   d. Thoracic vertebrae:

   e. Lumbar vertebrae:

3. Stack the vertebrae in the correct order and in the correct orientation (direction). When you are done, take a photo of the vertebral column your group assembled. Ask your instructor to verify the correct order and orientation of the vertebrae in the column.

   Instructor Signature Confirming Successful Assembly: _____

Part 6: Thoracic Cage Laboratory Activities

1. Obtain one anatomical model rib and one thoracic vertebra per person in your group.
2. As a group, identify the anterior and the posterior ends of the ribs.
3. Write each of the following structures on masking tape or labeling tape (with correct spelling) and stick onto the model to label each structure.

▪ anterior end ▪ posterior end	▪ head ▪ neck	▪ tubercle of the rib ▪ location where rib articulates with costal cartilage ▪ region where rib articulates with thoracic vertebra

4. Use the rib and thoracic vertebra to understand how ribs and T-vertebrae articulate. Use masking tape or labeling tape (with correct spelling) to label the transverse, superior, and inferior costal facets on the thoracic vertebra.
5. When you are done, take photos of your labeled rib and vertebra from different angles. Ask your instructor to verify the labeling is correct.

   Instructor Signature Confirming Correct Labeling: _____

6. Remove all tape from the anatomical model.

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

▪ true ribs ▪ false ribs ▪ rib numbers (1-12) ▪ costal cartilage	▪ sternum ▪ manubrium ▪ xiphoid process ▪ body of sternum	▪ jugular notch ▪ clavicular notches ▪ sternal angle ▪ T1 - T12

Attributions

Part 1: Review of the Skull

- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0
- "Anatomy and Physiology Lab Homework" by Laird C Sheldahl is licensed under CC BY-SA 4.0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0

Part 2: Review of the Vertebral Column

- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0
- "Anatomy and Physiology Lab Homework" by Laird C Sheldahl is licensed under CC BY-SA 4.0

Part 3: Review of the Thoracic Cage

- "Anatomy and Physiology Lab Homework" by Laird C Sheldahl is licensed under CC BY-SA 4.0
- "BodyParts3D/Anatomography" by The Database Center for Life Science is licensed under CC BY-SA 2.1

Part 5: Vertebral Column Laboratory Activities

- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0

Part 6: Thoracic Cage Laboratory Activities

- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0

Updated 2026.

This page titled 8.8: Laboratory Activities and Assignment is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

8.9: Collaborative Study Activities

Collaborative Study Activities

These activities are designed for student groups of 2-4. Larger groups will work better when there is no supplemental instructor present in the laboratory to assist in testing student groups on each section. Parts 1 and 2 require each group have an anatomical skull model and hyoid bone. For Part 3, each group will need cervical vertebrae, thoracic vertebrae, lumbar vertebrae, a sacrum and coccyx, C1 atlas, C2 axis, and access to an assembled vertebral column model. For Part 4, each group will need access to individual ribs, a sternum, and assembled models of the thoracic cage.

Part 1: Cranial Bones & Markings

Cranial Bones (External & Internal Views)

1. Identify the following structures on classroom anatomical models and/or unlabeled images/diagrams made available by your instructor. Work with your group to identify each structure and check them off the list once you have identified them.

☐ frontal bone (1) ☐ parietal bones (2)	☐ temporal bones (2) ☐ occipital bones (1)	☐ sphenoid bone (1) ☐ ethmoid bone (1)

2. Test your group members by ***asking them to name each structure you point to***. Check off each when your group can successfully name each. Your group will also test you.

☐ frontal bone (1) ☐ parietal bones (2)	☐ temporal bones (2) ☐ occipital bones (1)	☐ sphenoid bone (1) ☐ ethmoid bone (1)

Cranial Markings (External & Internal Views)

3. Identify the following structures on classroom anatomical models and/or unlabeled images/diagrams made available by your instructor. Work with your group to identify each structure and check them off the list once you have identified them.

☐ squamous suture ☐ coronal suture ☐ lambdoid suture ☐ sagittal suture ☐ sphenoparietal suture ☐ sphenosquamous suture ☐ sphenofrontal suture ☐ occipitomastoid suture ☐ supraorbital foramen/notch ☐ foramen lacerum ☐ foramen ovale ☐ foramen magnum ☐ foramen spinosum ☐ jugular foramen	☐ olfactory foramina ☐ stylomastoid foramen ☐ hypoglossal canal ☐ optic canal ☐ carotid canal ☐ external acoustic meatus ☐ internal acoustic meatus ☐ superior orbital fissure ☐ pterygoid process ☐ styloid process ☐ mastoid process ☐ zygomatic process (of temporal bone) ☐ middle nasal concha	☐ external occipital protuberance ☐ crista galli ☐ mandibular fossa ☐ hypophyseal fossa ☐ anterior cranial fossa ☐ middle cranial fossa ☐ posterior cranial fossa ☐ occipital condyles ☐ sella turcica ☐ cribriform plate ☐ greater wing of sphenoid ☐ lesser wing of sphenoid ☐ perpendicular plate

4. Test your group members by ***asking them to name each structure you point to***. Check off each when your group can successfully name each. Your group will also test you.

☐ squamous suture ☐ coronal suture ☐ lambdoid suture ☐ sagittal suture ☐ sphenoparietal suture ☐ sphenosquamous suture ☐ sphenofrontal suture ☐ occipitomastoid suture ☐ supraorbital foramen/notch ☐ foramen lacerum ☐ foramen ovale ☐ foramen magnum ☐ foramen spinosum ☐ jugular foramen	☐ olfactory foramina ☐ stylomastoid foramen ☐ hypoglossal canal ☐ optic canal ☐ carotid canal ☐ external acoustic meatus ☐ internal acoustic meatus ☐ superior orbital fissure ☐ pterygoid process ☐ styloid process ☐ mastoid process ☐ zygomatic process (of temporal bone) ☐ middle nasal concha	☐ external occipital protuberance ☐ crista galli ☐ mandibular fossa ☐ hypophyseal fossa ☐ anterior cranial fossa ☐ middle cranial fossa ☐ posterior cranial fossa ☐ occipital condyles ☐ sella turcica ☐ cribriform plate ☐ greater wing of sphenoid ☐ lesser wing of sphenoid ☐ perpendicular plate

5. When you and your group are comfortable identifying all the structures above (Cranial Bones & Cranial Markings), request the assistance of your Instructor. They will test you on your use of these terms and initial ONLY when you are successful using these terms. Instructor: _____

Part 2: Facial Bones & Markings

Facial Bones (Anterior, Lateral, and Inferior Views)

1. Identify the following structures on classroom anatomical models and/or unlabeled images/diagrams made available by your instructor. Work with your group to identify each structure and check them off the list once you have identified them.

☐ nasal bones (2) ☐ lacrimal bones (2) ☐ maxilla bones (2)	☐ mandible bone (1) ☐ zygomatic bones (2) ☐ inferior nasal conchae (2)	☐ palatine bones (2) ☐ vomer (1)

2. Test your group members by ***asking them to name each structure you point to***. Check off each when your group can successfully name each. Your group will also test you.

☐ nasal bones (2) ☐ lacrimal bones (2) ☐ maxilla bones (2)	☐ mandible bone (1) ☐ zygomatic bones (2) ☐ inferior nasal conchae (2)	☐ palatine bones (2) ☐ vomer (1)

Facial Markings (Anterior, Lateral, and Inferior Views)

3. Identify the following structures on classroom anatomical models and/or unlabeled images/diagrams made available by your instructor. Work with your group to identify each structure and check them off the list once you have identified them.

☐ orbit ☐ inferior orbital fissure ☐ infraorbital foramen ☐ mental foramen ☐ frontal process (of maxilla) ☐ temporal process (of zygomatic)	☐ zygomatic process (of maxilla) ☐ alveolar processes ☐ condylar process ☐ coronoid process ☐ palatine process (of maxilla)	☐ mandibular symphysis ☐ mandibular ramus ☐ body of mandible ☐ mandibular angle ☐ mandibular notch

4. Test your group members by ***asking them to name each structure you point to***. Check off each when your group can successfully name each. Your group will also test you.

☐ orbit ☐ inferior orbital fissure ☐ infraorbital foramen ☐ mental foramen ☐ frontal process (of maxilla) ☐ temporal process (of zygomatic)	☐ zygomatic process (of maxilla) ☐ alveolar processes ☐ condylar process ☐ coronoid process ☐ palatine process (of maxilla)	☐ mandibular symphysis ☐ mandibular ramus ☐ body of mandible ☐ mandibular angle ☐ mandibular notch

Hyoid Bone

1. Identify the following structures on classroom anatomical models and/or unlabeled images/diagrams made available by your instructor. Work with your group to identify each structure and check them off the list once you have identified them.

☐ hyoid bone ☐ body of hyoid	☐ greater horns	☐ lesser horns

2. Test your group members by ***asking them to name each structure you point to***. Check off each when your group can successfully name each. Your group will also test you.

☐ hyoid bone ☐ body of hyoid	☐ greater horns	☐ lesser horns

3. When you and your group are comfortable identifying all the structures above (Facial Bones, Facial Markings, & Hyoid), request the assistance of your Instructor. They will test you on your use of these terms and initial ONLY when you are successful using these terms. Instructor: _____

Part 3: Vertebral Column

Cervical, Thoracic, and Lumbar Vertebrae

1. Identify the following structures on classroom anatomical models and/or unlabeled images/diagrams made available by your instructor. Work with your group to identify each structure and check them off the list once you have identified them. **Structures found on all vertebrae should be identified on EACH type of vertebra.**

☐ atlas (C_1)	☐ spinous process	☐ intervertebral foramen
☐ axis (C_2)	☐ superior articular process	☐ vertebral arch
☐ cervical vertebra	☐ superior articular facet	☐ dens
☐ thoracic vertebra	☐ inferior articular process	☐ cervical curvature
☐ lumbar vertebra	☐ inferior articular facet	☐ thoracic curvature
☐ body	☐ lamina	☐ lumbar curvature
☐ transverse process	☐ transverse foramen	☐ sacral curvature
☐ vertebral foramen	☐ costal facets (superior, inferior, transverse)	
☐ pedicle		

2. Test your group members by ***asking them to name each structure you point to***. Check off each when your group can successfully name each. **Structures found on all vertebrae should be tested on EACH type of vertebra.** Your group will also test you.

☐ atlas (C1)	☐ spinous process	☐ intervertebral foramen
☐ axis (C2)	☐ superior articular process	☐ vertebral arch
☐ cervical vertebra	☐ superior articular facet	☐ dens
☐ thoracic vertebra	☐ inferior articular process	☐ cervical curvature
☐ lumbar vertebra	☐ inferior articular facet	☐ thoracic curvature
☐ body	☐ lamina	☐ lumbar curvature
☐ transverse process	☐ transverse foramen	☐ sacral curvature
☐ vertebral foramen	☐ costal facets (superior, inferior, transverse)	
☐ pedicle		

Sacrum & Coccyx

1. Identify the following structures on classroom anatomical models and/or unlabeled images/diagrams made available by your instructor. Work with your group to identify each structure and check them off the list once you have identified them.

☐ sacrum	☐ median sacral crest	☐ sacral promontory
☐ coccyx	☐ auricular surface (sacroiliac joint)	☐ anterior sacral foramina
☐ bodies of sacral vertebrae (S1-S5)	☐ superior articular process	☐ posterior sacral foramina
☐ ala	☐ superior articular facet	

2. Test your group members by ***asking them to name each structure you point to***. Check off each when your group can successfully name each. Your group will also test you.

☐ sacrum	☐ median sacral crest	☐ sacral promontory
☐ coccyx	☐ auricular surface (sacroiliac joint)	☐ anterior sacral foramina
☐ bodies of sacral vertebrae (S1-S5)	☐ superior articular process	☐ posterior sacral foramina
☐ ala	☐ superior articular facet	

3. When you and your group are comfortable identifying all the structures above (Cervical, Thoracic, and Lumbar Vertebrae & Sacrum & Coccyx), request the assistance of your Instructor. They will test you on your use of these terms and initial ONLY when you are successful using these terms. Instructor: _____

Part 4: Thoracic Cage

1. Identify the following structures on classroom anatomical models and/or unlabeled images/diagrams made available by your instructor. Work with your group to identify each structure and check them off the list once you have identified them.

☐ rib numbers ☐ true ribs ☐ false ribs ☐ floating ribs ☐ costal cartilage	☐ head (of rib) ☐ neck (of rib) ☐ tubercle (of rib) ☐ sternum ☐ manubrium	☐ body (of sternum) ☐ xiphoid process ☐ sternal angle ☐ jugular notch ☐ clavicular notches

2. Test your group members by ***asking them to name each structure you point to***. Check off each when your group can successfully name each. Your group will also test you.

☐ rib numbers ☐ true ribs ☐ false ribs ☐ floating ribs ☐ costal cartilage	☐ head (of rib) ☐ neck (of rib) ☐ tubercle (of rib) ☐ sternum ☐ manubrium	☐ body (of sternum) ☐ xiphoid process ☐ sternal angle ☐ jugular notch ☐ clavicular notches

3. When you and your group are comfortable identifying all the structures above, request the assistance of your Instructor. They will test you on your use of these terms and initial ONLY when you are successful using these terms. Instructor: _____

Updated 2026.

This page titled 8.9: Collaborative Study Activities is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

CHAPTER OVERVIEW

9: Appendicular Skeleton

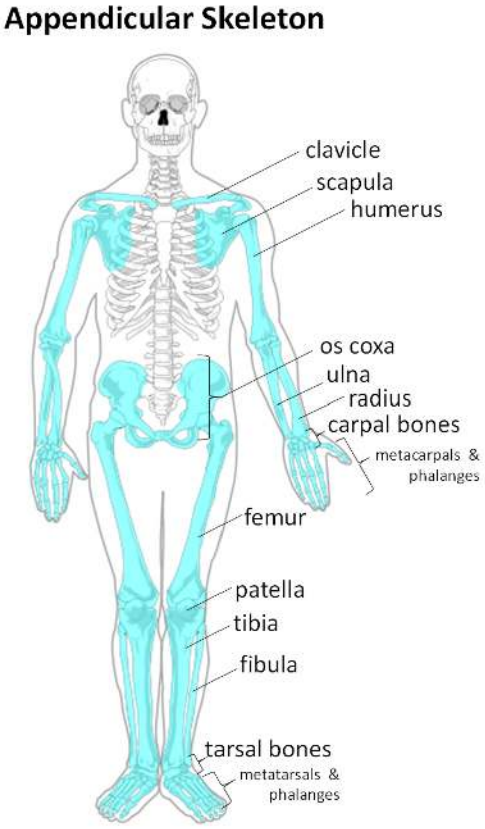
9.1: Introduction
9.2: Shoulder Girdle/Pectoral Girdle
9.3: Upper Limb
9.4: Pelvic Girdle
9.5: Lower Limb
9.6: Additional Reference Figures
9.7: Laboratory Activities and Assignment
9.8: Collaborative Study Activities

This page titled 9: Appendicular Skeleton is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

9.1: Introduction

Introduction

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



Attribution

- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0

Updated 2026.

This page titled 9.1: Introduction is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

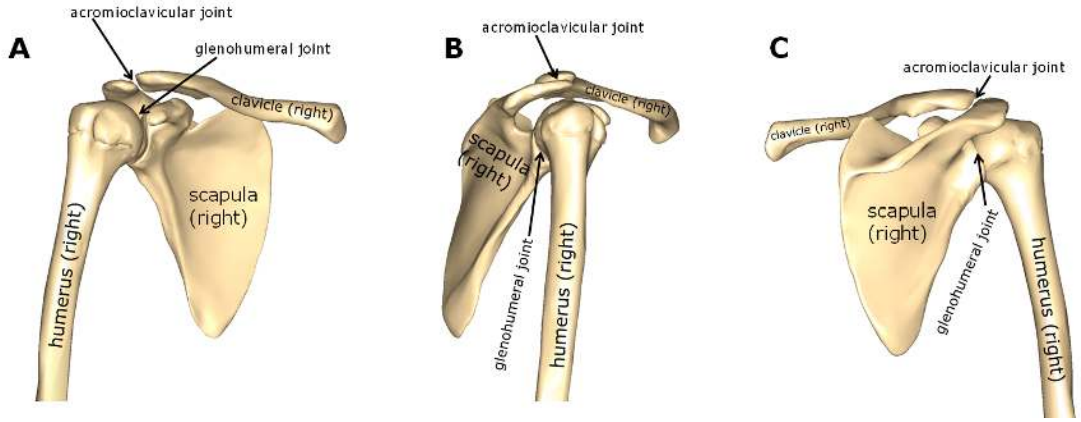
9.2: Shoulder Girdle/Pectoral Girdle

Shoulder Girdle/Pectoral Girdle



Above: The pectoral/shoulder girdle is shown in pink. Each has a scapula and a clavicle.

There is a pectoral girdle above each arm, consisting of a scapula (shoulder blade) and a clavicle (collar bone). The shoulder girdle, also known as the pectoral girdle, forms a socket and support system for the upper limb. Click here to see the positions of the shoulder/pectoral girdles.

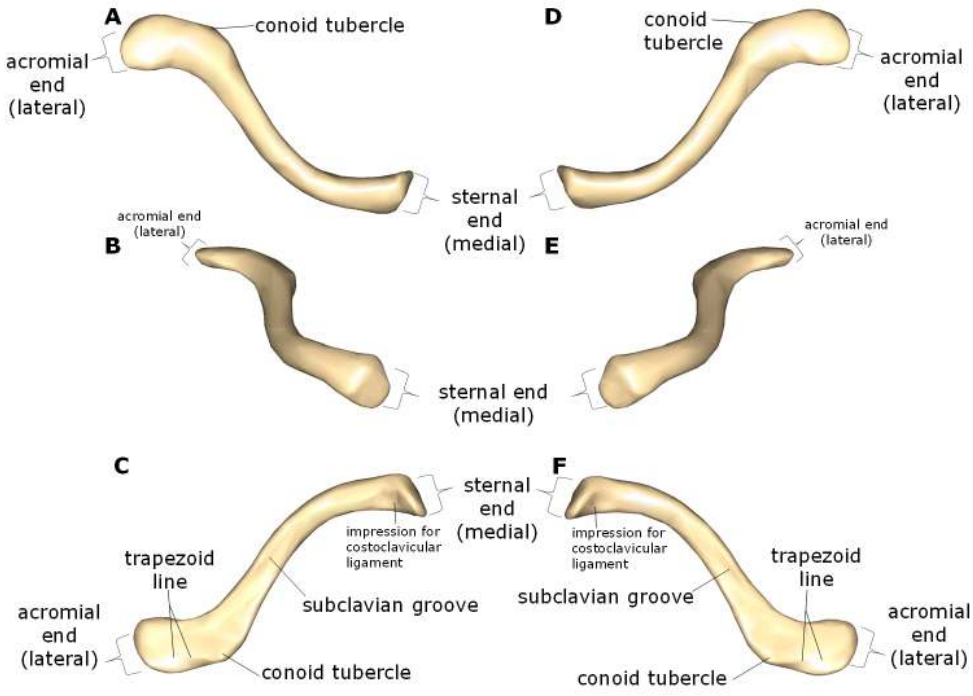




Above: The right shoulder/pectoral girdle show with the humerus (upper limb). (A) Anterior view, (B) lateral view, and (C) posterior view of the shoulder/pectoral girdle with the humerus. The joint between the humerus and the scapula is called the glenohumeral joint since the humerus ("humeral") articulates with the glenoid cavity ("gleno") of the scapula. The joint between the clavicle and the scapula is called the acromioclavicular joint since the clavicle ("clavicular") articulates with the acromial process ("acromio") of the scapula.

Clavicle

The **clavicle** is a vaguely S-shaped bone which articulates with the scapula at its lateral end and articulates with the sternum at its medial end. The flatter broader end is the **acromial end**, which articulates with the **acromion process** of the scapula. The superior surface of the acromial end is smoother than its inferior surface, which can help you determine whether a particular clavicle bone comes from the left or right. The more circular end is the **sternal end**, which articulates with one of the **sternal notches** on the manubrium of the sternum. The **conoid tubercle** found on the inferior, posterolateral aspect of the clavicle is an attachment point for the **conoid ligament** connecting the clavicle to the **coracoid process** of the scapula. Similarly, the **trapezoid line** of the clavicle also attaches a ligament (**trapezoid ligament**) joining the clavicle to the coracoid process of the scapula. An acromioclavicular ligament attaches the acromial end of the clavicle to the acromion process of the scapula.

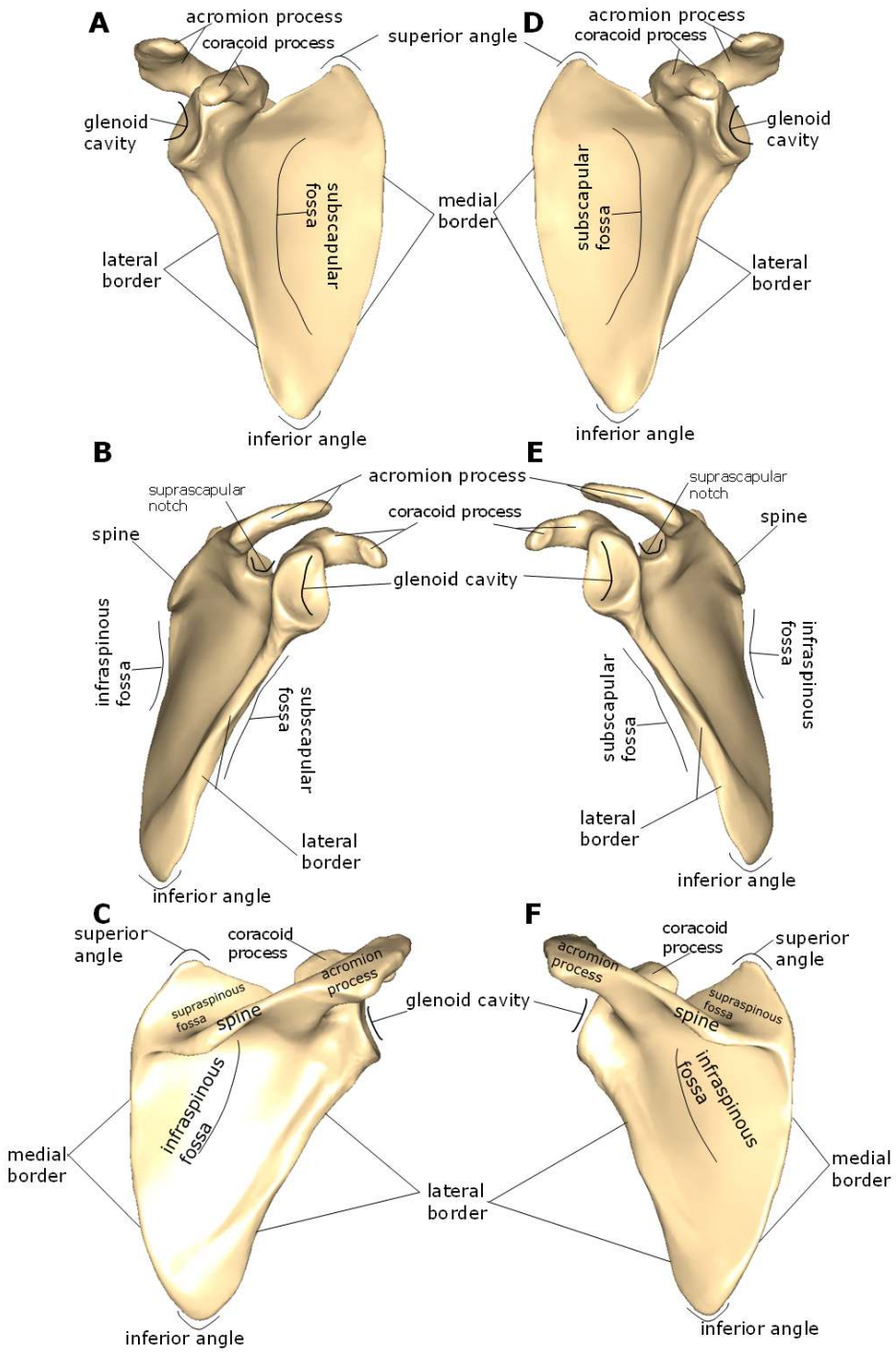


Above: A-C shows the right clavicle and D-F shows the left clavicle. A and D have a superior view, B and E have a superomedial view, and C and F have an inferior view.



Above: (Top) Position of the clavicles. (Middle) Right clavicle. (Bottom) Left clavicle.

Scapula



Above: A-C shows the right scapula and D-F shows the left scapula. A and D have a anterior views, B and E have a lateral views, and C and F have posterior views.

https://bio.libretexts.org/@go/page/53650





Above: (Top) Position of scapulae. (Bottom) Right scapula.

The smooth anterior surface (**subscapular fossa**) of the scapula is positioned facing the posterior lateral aspect of the thoracic cage. Rotator cuff muscles, that The **scapula**, commonly known as the shoulder blade, forms articulations with the clavicle and with the humerus. The scapula articulates with the clavicle at the **acromion process** and the **coracoid process** also creates attachments with ligaments attaching to the clavicle. The **glenoid cavity** of the scapula articulates with the head of the humerus of the upper limb forming the glenohumeral joint. stabilize the shoulder joint, attach scapula including **supraspinatus** (located in the **supraspinous fossa**), **infraspinatus** (located in the **infraspinous fossa**), **subscapularis** (located in the **subscapular fossa**), and **teres minor** (attached to the **lateral border** of the scapula).

Attributions

- "3d Scapula Rendered.gif" by DrJanaOfficial is licensed under CC BY-SA 4.0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- "BodyParts3D/Anatomography" by The Database Center for Life Science is licensed under CC BY-SA 2.1
- "Clavicle 3d Model.gif" by DrJanaOfficial is licensed under CC BY-SA 4.0

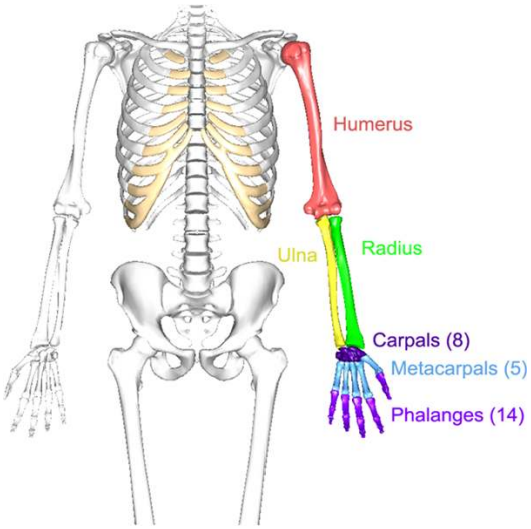
Updated 2026.

This page titled 9.2: Shoulder Girdle/Pectoral Girdle is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

9.3: Upper Limb

Upper Limb

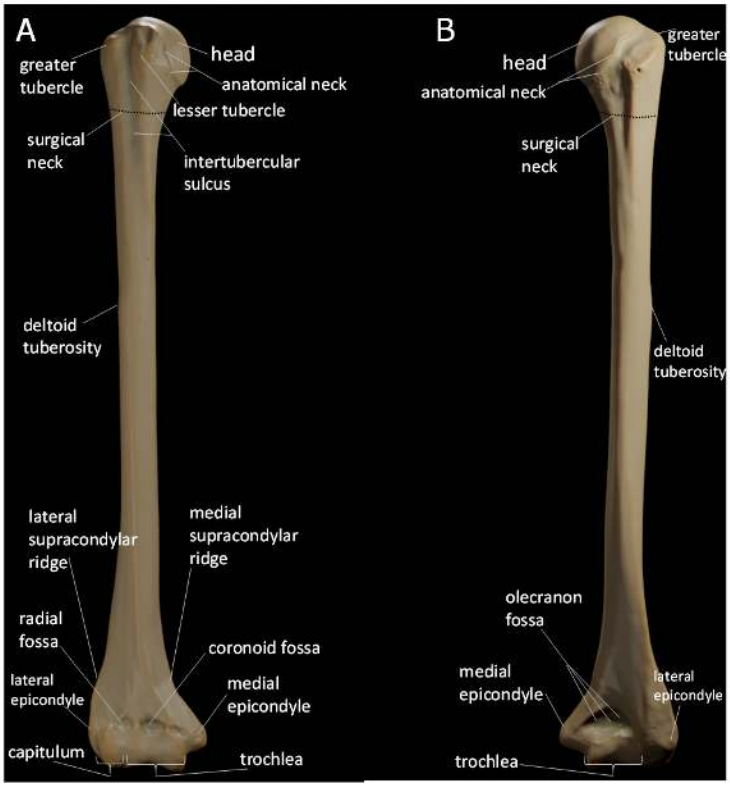
For anatomists, the upper limb consists of the **arm** or **brachium** (the upper arm), the **forearm** or **antebrachium** (the lower arm), and the hand, consisting of eight wrist bones or **carpal bones**, five hand bones or **metacarpals**, and fourteen **phalanges** (sing. **phalanx**) . The arm consists of a single bone, the **humerus**. The forearm consists of two bones, the **ulna** and **radius**. And the hand consists of 27 bones total.



Above: The left upper limb with its components highlighted red, green, yellow, violet, blue, and purple and labeled.

The Humerus

The **head of the humerus** articulates with the glenoid cavity of the scapular forming the glenohumeral joint. Positioned near the head of the humerus is the **greater tubercle** (lateral) and **lesser tubercle** (anterior) where rotator cuff muscles attached to the scapula attach to the humerus. The **deltoid tuberosity** located distal to the humeral head mid-way down the shaft is a site where the **deltoid muscle** attaches to the humerus. Between the greater and lesser tubercles is a groove called the **intertubercular sulcus**, a location where the **bicep** tendon is positioned.

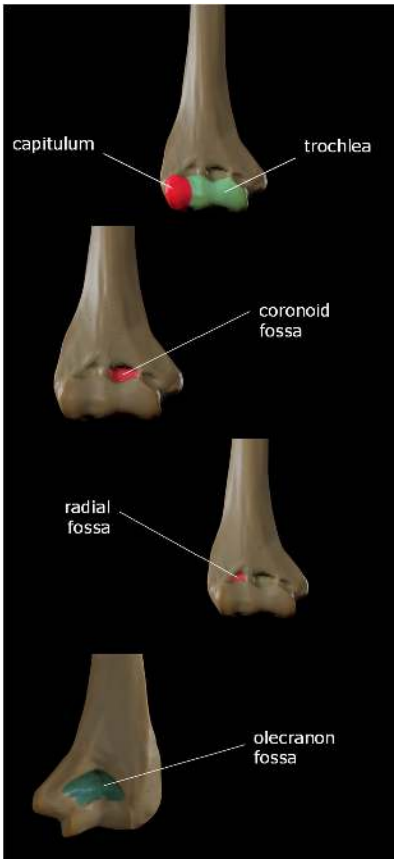


Above: The humerus (A) anterior view and (B) posterior view.



Above: Right humerus.

Many articulations are created by the radius and ulna, some between the two bones and others separately with the humerus. The **head of the radius** articulates with the **capitulum** of the humerus to create the rotating action of the forearm and hand. The action of rotating the forearm and hand so that the palm of the hand is facing posteriorly is called **pronation**; the action of rotating the forearm and hand so that the palm of the hand is facing anteriorly (as in normal **anatomical position**) is called **supination**.

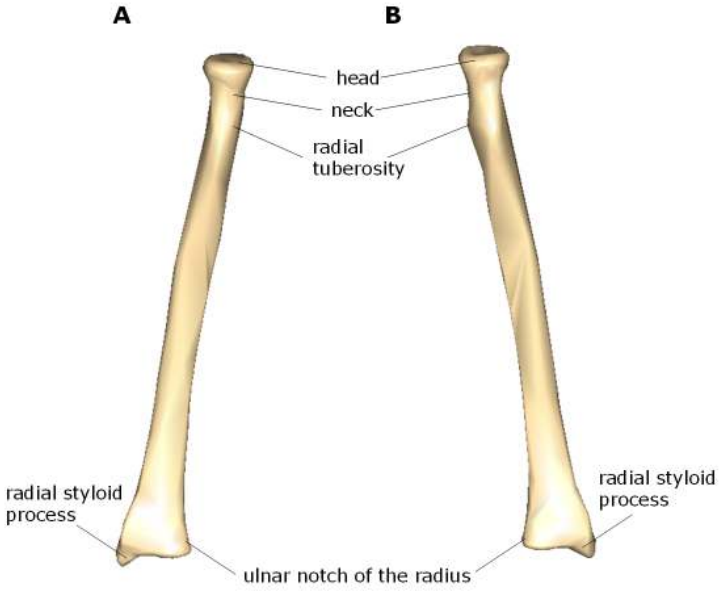


Above: Distal images of the humerus where the elbow joint is formed. The top three images show the anterior view of the distal humerus highlighting the **trochlea** (articulates with **trochlear notch** of the ulna), **capitulum** (articulates with the **head of the radius**), **coronoid fossa** (articulates with the **coronoid process of the ulna**), and **radial fossa** (articulates with the **head of the radius**). The bottom image shows the posterior aspect of the distal humerus with the **olecranon fossa** colored in (articulates with the **olecranon**, aka **olecranon process** of the ulna).

The Radius & Ulna



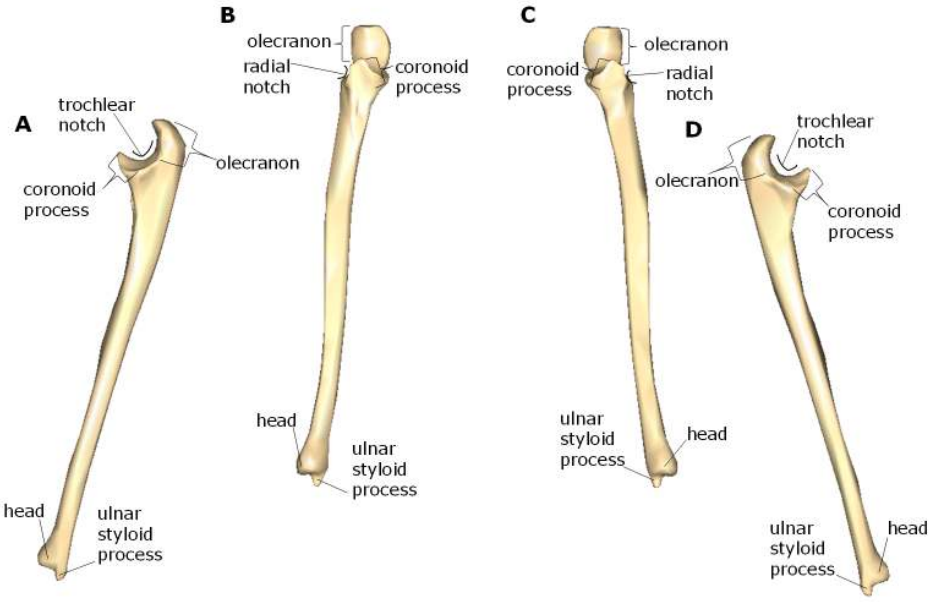
Above: Positions of radii.



Above: (A) Right radius and (B) left radius, anterior view.



Above: Position of ulnae.



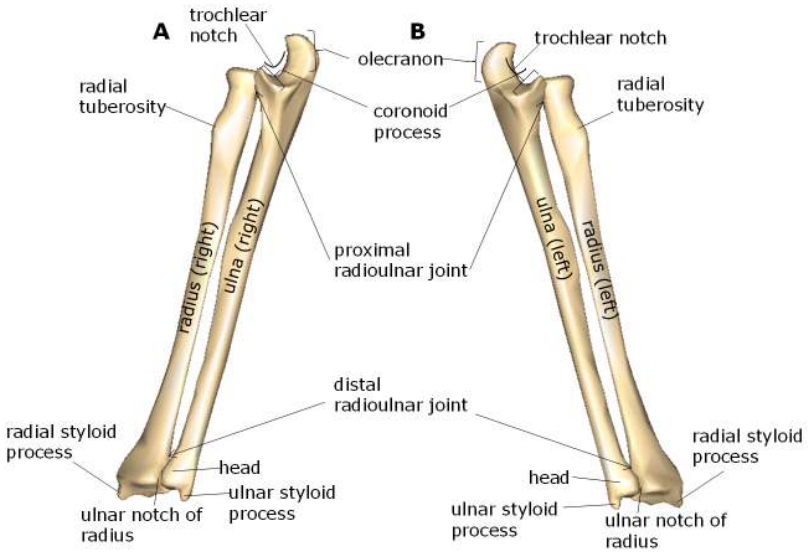
Above: (A) and (B) show the right ulna and (C) and (D) show the left ulna. (A) and (D) show medial views of the right and left ulnae, respectively. (B) and (C) shown anterior views of the right and left ulnae, respectively.

In order for the radius to rotate, it must also articulate with the ulna next to it. It does this in two places. Aside from articulating with the **capitulum**, the **head of the radius** also articulates with the **radial notch** (on the ulna) as it rotates. Similarly, at the distal end of the radius and ulna, the **head of the ulna** articulates with the **ulnar notch** (on the radius). Anatomical terms are usually named for their purpose, not necessarily what bone they are on; the **radial notch** is **FOR** the **radius**, so it is located **ON** the **ulna**, and the **ulnar notch** is **FOR** the **ulna**, so it is located **ON** the **radius**.

As for the ulna, the **trochlear notch** articulates with the **trochlea** on the humerus to allow a strong and stable flexing action at the elbow. Further, the **coronoid and olecranon processes** (on the ulna) articulate into the **coronoid and olecranon fossae** (on the humerus), respectively.



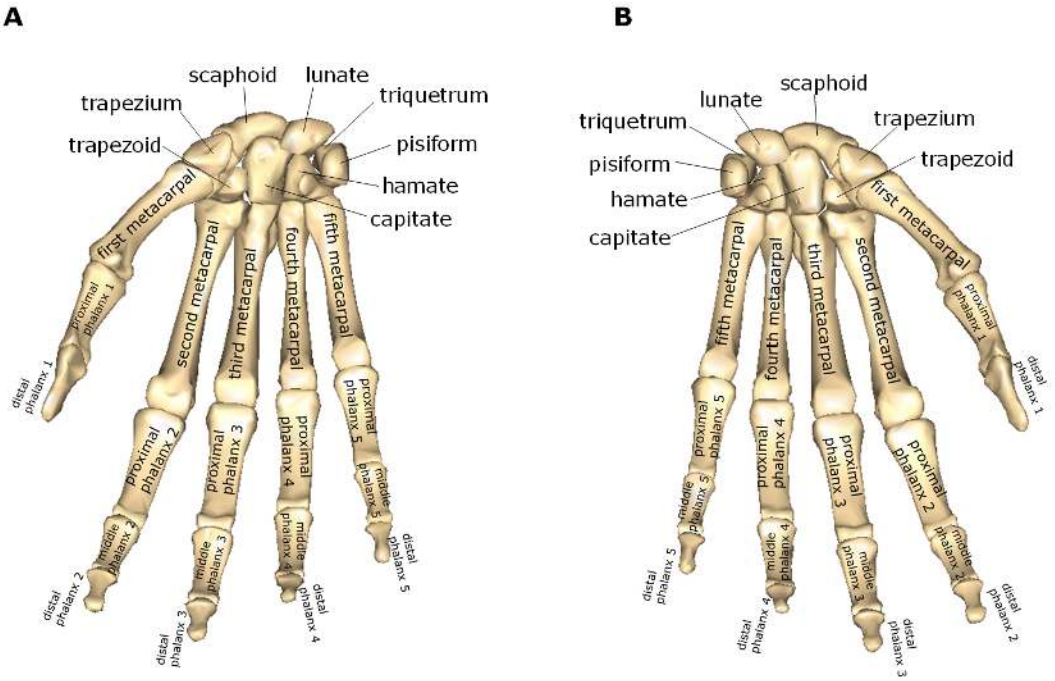
Above: Right humerus, radius, and ulna.



Above: (A) The right ulna and right radius articulating with an anteromedial view. (B) The left ulna and the left radius articulating with an anteromedial view.

The Bones of the Wrist and Hand

Each hand has eight **carpal**, or wrist, bones: **trapezoid**, **trapezium**, **scaphoid**, **capitate**, **lunate**, **hamate**, **pisiform**, and **triquetrum**. The hand is supported by five **metacarpal bones**, numbered one through five with one relating to the thumb and five relating to the little finger or pinky finger. The bones of the digits are called **phalanges** (sing. **phalanx**) where each is designated as being **proximal**, **middle**, or **distal**, depending on its position in relationship to the other phalanges, and given a number with the same system as the metacarpal numbering. The thumb only has two phalanges, **proximal phalanx #1** and **distal phalanx #1**, and therefore lacks a middle phalanx bone.



Above: The bones of the (A) right and (B) left hands, anterior views.

Attributions

- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "BodyParts3D/Anatomography" by The Database Center for Life Science is licensed under CC BY-SA 2.1
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- "Capitulum-and-trochlea.jpg" by DrJanaOfficial is licensed under CC BY-SA 4.0
- "Coronoid-Fossa.jpg" by DrJanaOfficial is licensed under CC BY-SA 4.0
- "Full Anterior View of Right Radius.png" by DrJanaOfficial is licensed under CC BY-SA 4.0
- "Full Lateral View of Right Radius.png" by DrJanaOfficial is licensed under CC BY-SA 4.0
- "Full Medial View of Right Radius.png" by DrJanaOfficial is licensed under CC BY-SA 4.0
- "Full Posterior View of Right Radius.png" by DrJanaOfficial is licensed under CC BY-SA 4.0
- "Humerus 3d Model.gif" by DrJanaOfficial is licensed under CC BY-SA 4.0
- "Humerus-views.png" by DrJanaOfficial is licensed under CC BY-SA 4.0
- "Neck-of-Humerus.jpg" by DrJanaOfficial is licensed under CC BY-SA 4.0
- "Olecranon-fossa.jpg" by DrJanaOfficial is licensed under CC BY-SA 4.0
- "Radial-Fossa.jpg" by DrJanaOfficial is licensed under CC BY-SA 4.0
- "Radius and Ulna - Forearm Bones.jpg" by DrJanaOfficial is licensed under CC BY-SA 4.0
- "Trochlea.jpg" by DrJanaOfficial is licensed under CC BY-SA 4.0

Updated 2026.

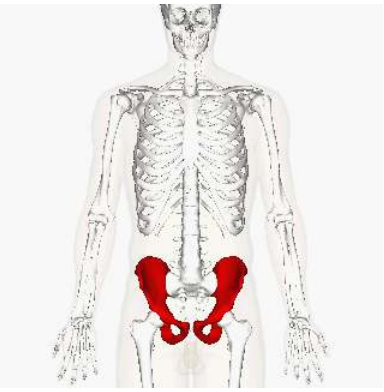
This page titled 9.3: Upper Limb is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

9.4: Pelvic Girdle

Pelvic Girdle

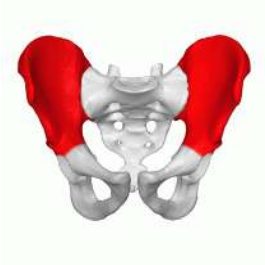
Coxal Bones (Os Coxae)

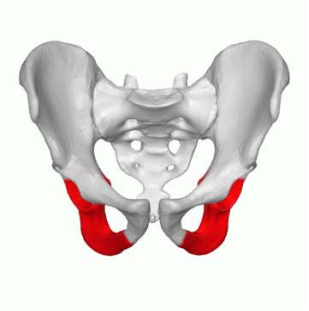
The pelvic girdle functions to connect and support the thighs to each side of the trunk of the body. The rest of the bones in the lower extremity form joints and regions of the lower limb (i.e. **hip, thigh, knee, leg, ankle,** and **foot**).



Above: Ox coxae highlighted in red.

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

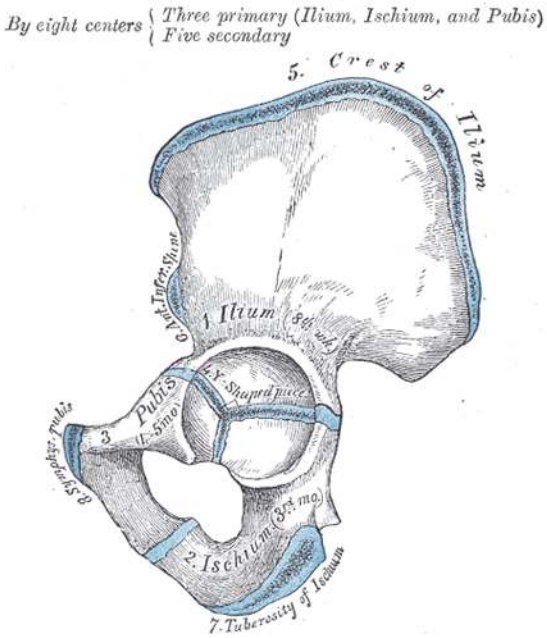




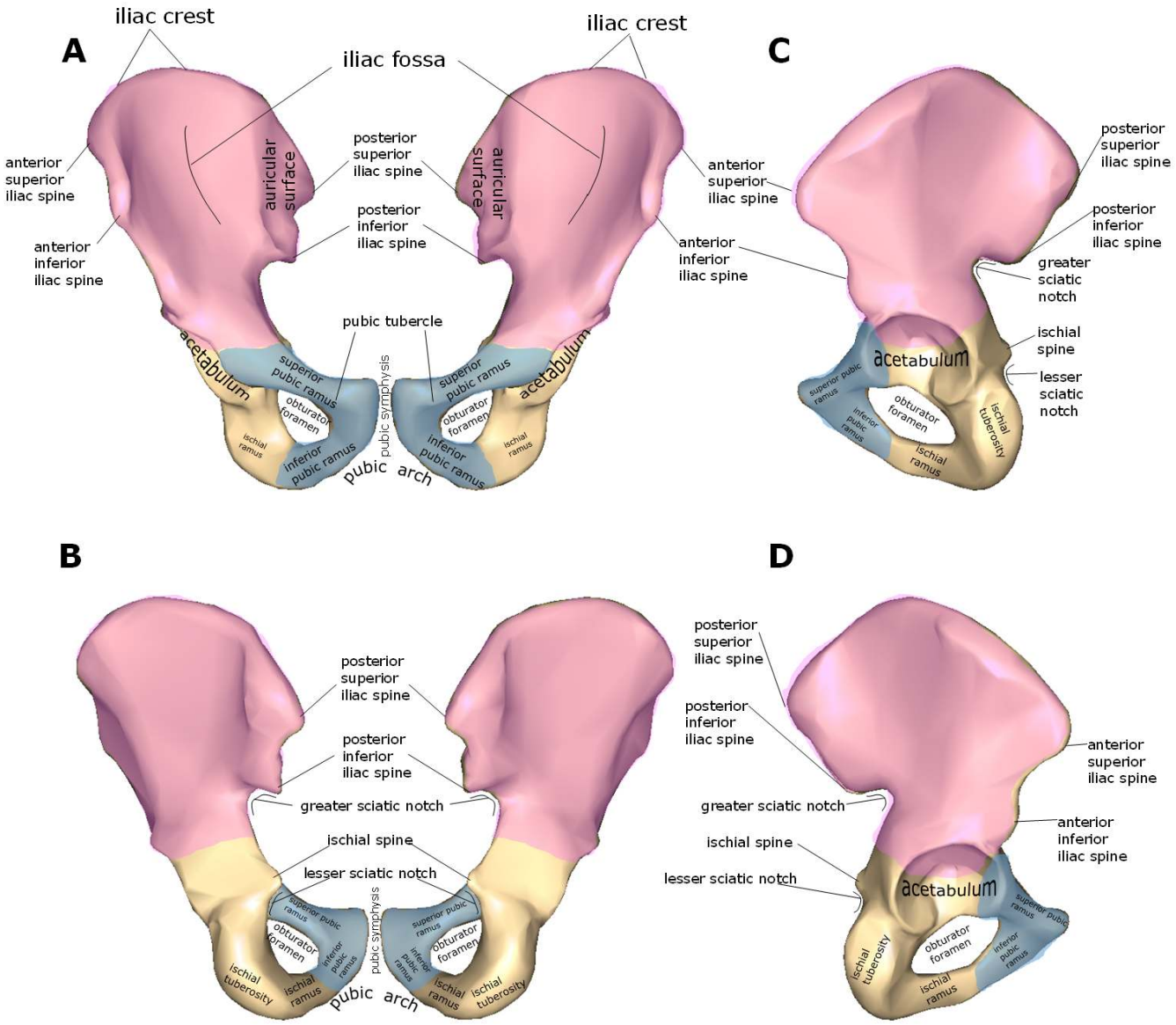


Above: The three regions of the os coxae: **ilium** (top), **ischium** (middle), and **pubis** (bottom).

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



Above: Lateral view of coxal bone (os coxa) prior to fusion of the ilium, ischium, and pubis.



Above: Os coxae, or **coxal bones**. (A) Anterior view of the right and left coxal bones. (B) Posterior view of the right and left coxal bones. (C) Lateral view of the left coxal bone. (D) Lateral view of the right coxal bone. **Ilium** is colored pink in all images, **pubis** is colored blue in all images, and **ischium** is colored yellow in all images.

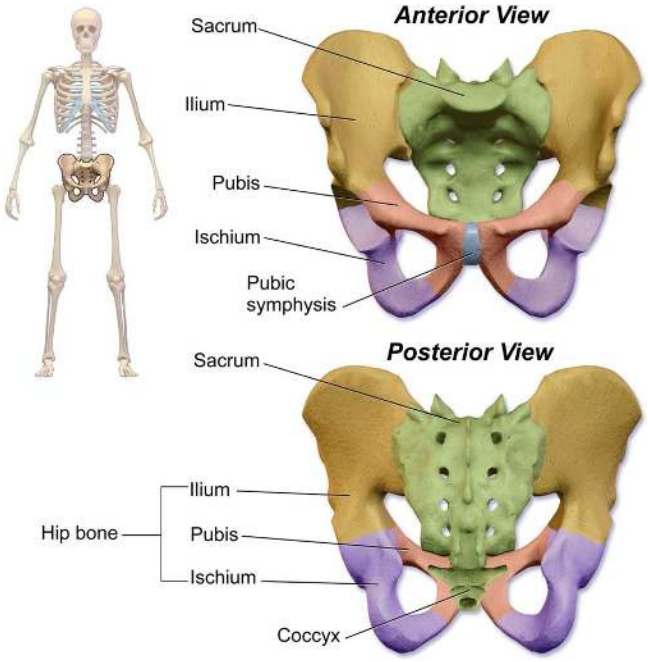
In a fully fused coxal bone, the ilium is the most superior portion, forming the "wing" that makes up the most prominent part of the coxal bone. The interior-facing side of this "wing" is called the **iliac fossa**. The ilium is where the sacrum attaches to each coxal bone to complete the pelvic bowl.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

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

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

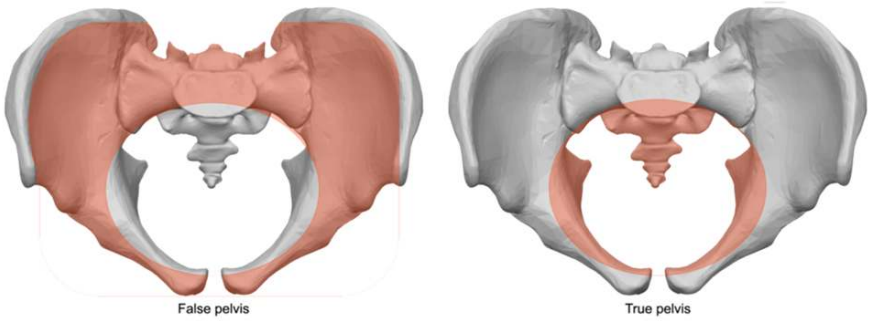
The Pelvis (Coxal Bones + Sacrum + Coccyx)

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

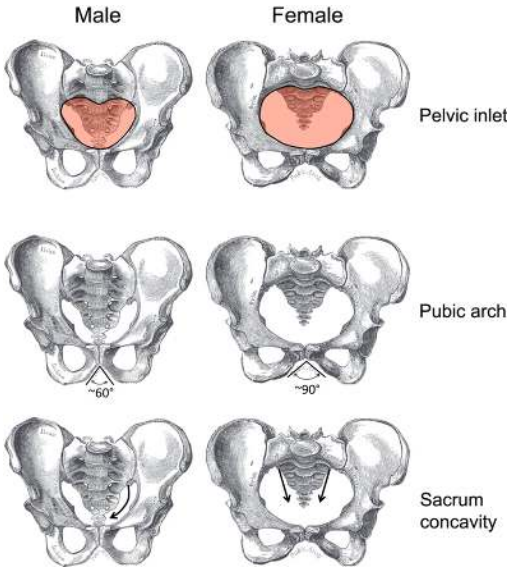


Above: The pelvis is composed of the sacrum and coccyx of the axial skeleton and the coxal bones including their component bones: ilium, pubis, and ischium.

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



Above: The false pelvis versus the true pelvis.



Above: Three features that distinguish male and female pelvises are (1) the pelvic inlet, (2) the pubic arch, and (3) sacrum concavity.

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

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

In female pelvises, both the pelvic inlet and the pelvic outlet are wider and more oval-shaped than those in male pelvises. The pelvic inlet in males tends to be more heart-shaped (narrower on the dorsal side) and the pelvic outlet tends to be more narrow. The pubic arch, found immediately inferior to the pubic symphysis, tends to form an angle closer to 90° in females, but forms an angle closer to 60° in males. The sacrum in female pelvises tends to be less curved; in male pelvises, the sacrum is more curved and tends to impinge upon the space of the pubic outlet.

Attributions

- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "BodyParts3D/Anatomography" by The Database Center for Life Science is licensed under CC BY-SA 2.1
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- "Gray237.png" by Henry Vandyke Carter is in the Public Domain
- "Hip bone animation.gif" by Anatomography is licensed under CC BY-SA 2.1
- "Ilium 03 animation.gif" by BodyParts3D is made by DBCLS is licensed under CC BY-SA 2.1
- "Ischium 03 animation.gif" by BodyParts3D is made by DBCLS is licensed under CC BY-SA 2.1
- "Pubis 03 animation.gif" by BodyParts3D is made by DBCLS is licensed under CC BY-SA 2.1

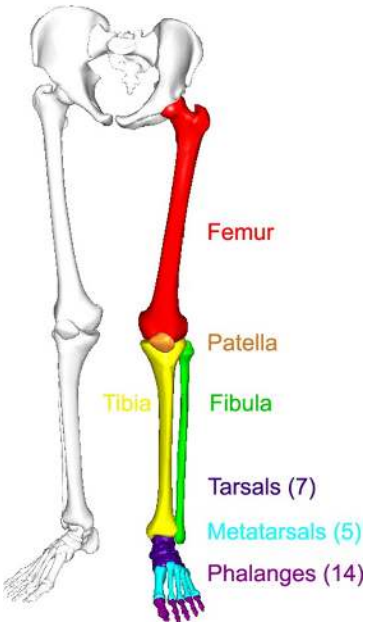
Updated 2026.

This page titled 9.4: Pelvic Girdle is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

9.5: Lower Limb

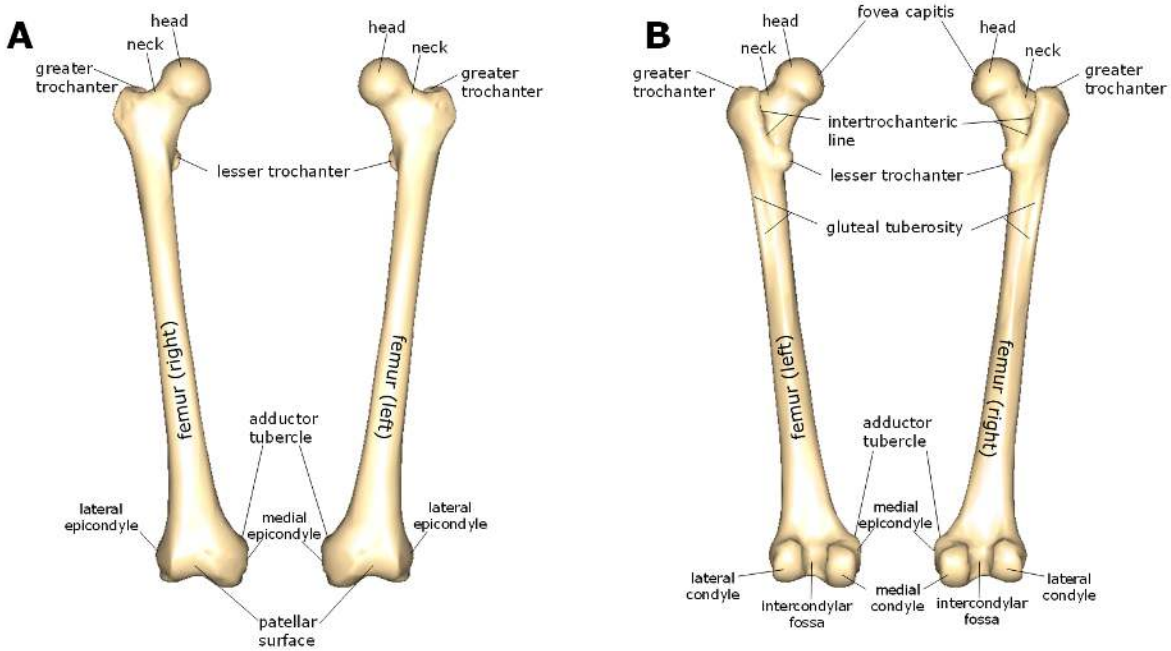
Lower Limb

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



Above: Diagram showing the components of a lower limb: 1 femur, 1 patella, 1 tibia, 1 fibula, 7 tarsal bones, 5 metatarsal bones, and 14 phalanges.

The Femur



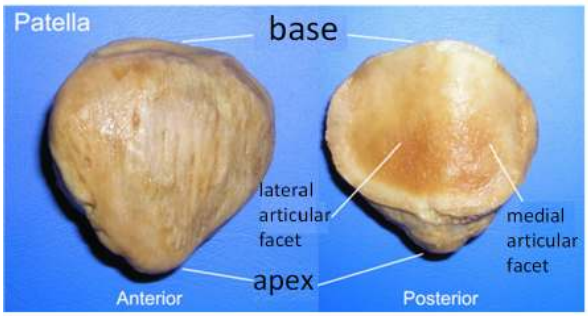
Above: The right and left femur (A) anterior view and (B) posterior view.

The **femur**, the thigh bone, is the strongest and heaviest bone in the human body. The head of the femur articulates with the acetabulum of a coxal bone. A dimple-like depression on the head of the femur, **fovea capitis**, is the site of attachment of a ligament securing the femur in the acetabulum (**ligamentum teres**). Although the femur is very strong, its weakest point is its **neck**, the most common site of femur fractures and usually called a "broken hip." The **greater trochanter**, **lesser trochanter**, and **gluteal tuberosity** are all markings of the femur where muscles attach.



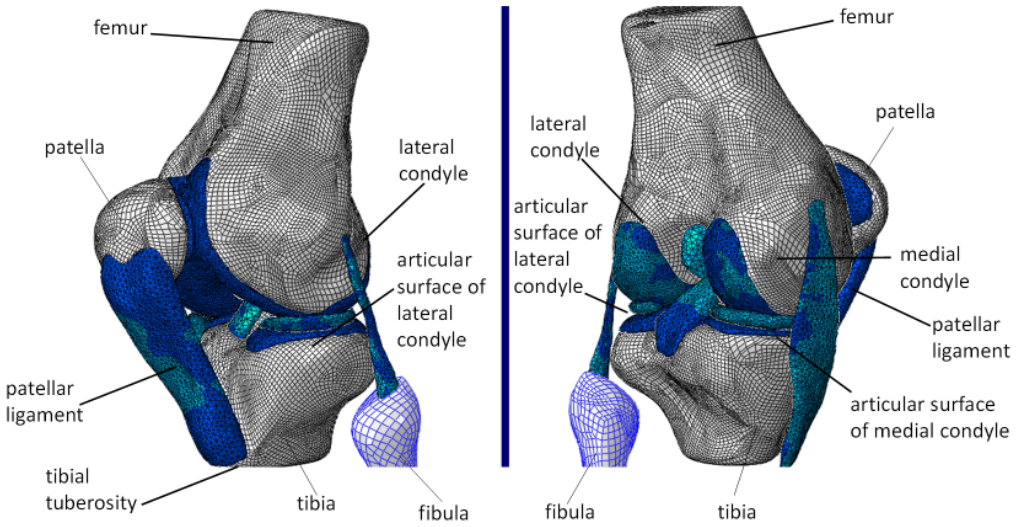
Above: Right femur.

The Patella & Knee Joint



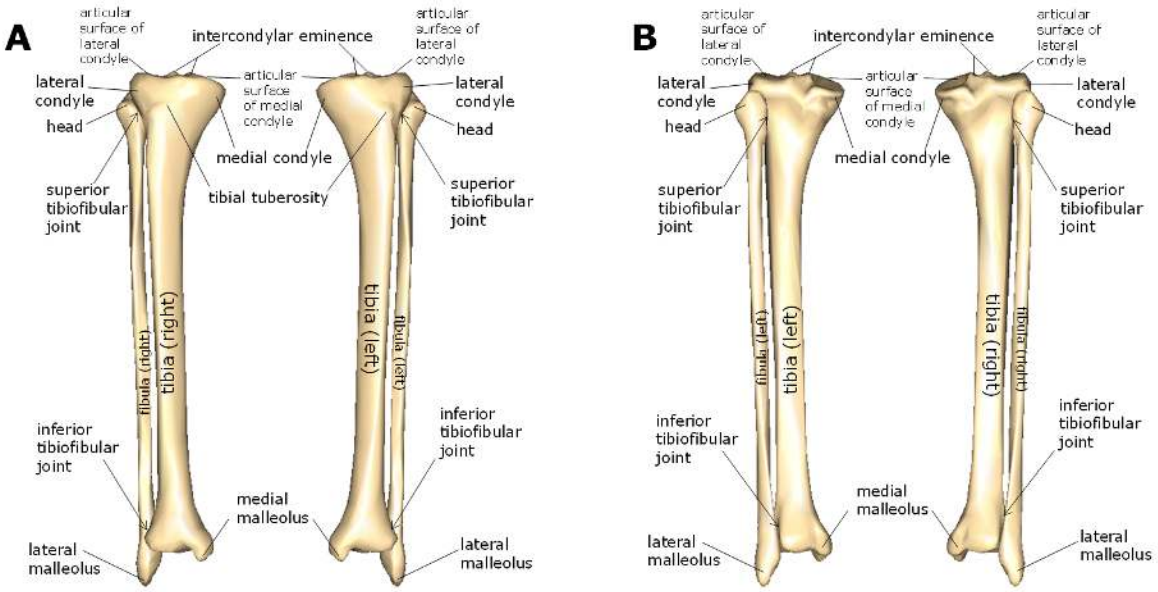
Above: Left patella (left) anterior view and (right) posterior view.

At the distal end of the femur are two condyles, a **medial condyle** and a **lateral condyle**, that articulate with the **tibia** at the **articulation surface of the medial condyle** and the **articulation surface of the lateral condyle**, respectively, forming the knee joint. A smooth surface called the **patellar surface** between the two condyles of the femur on the anterior aspect serves as a location where the **patella**, the knee cap, articulates with the femur in the knee joint.



Above: Articulation of the condyles of the femur with the articular surfaces of the tibia in the left knee joint. Articulation of the patella and fibula are also shown with some of the ligaments and cartilage of the knee joint.

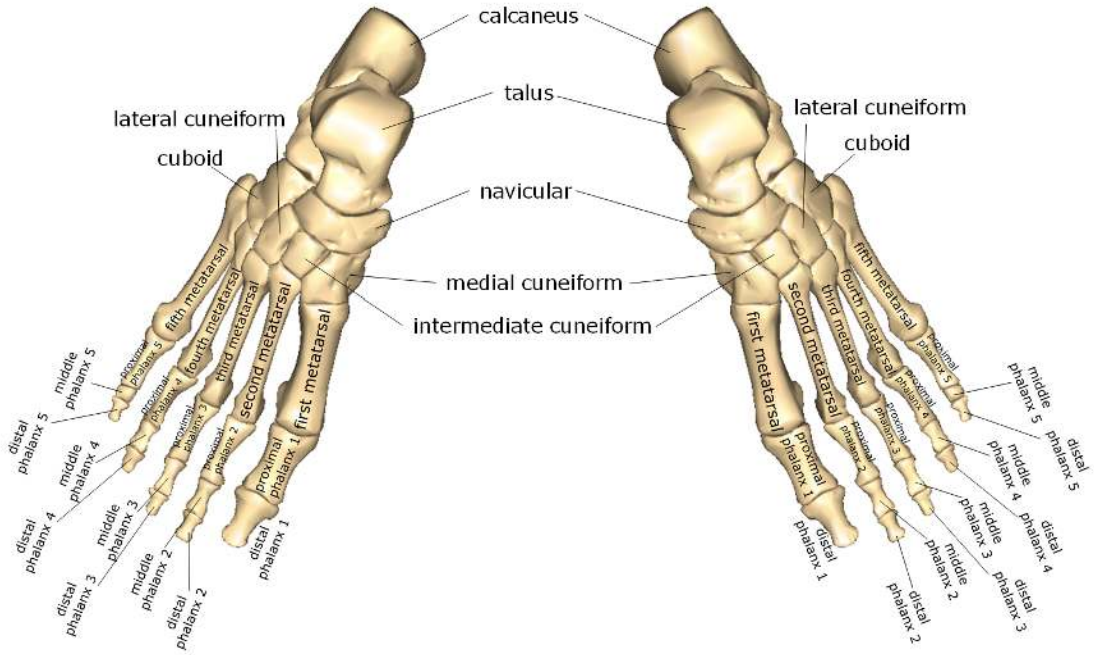
The Tibia & Fibula



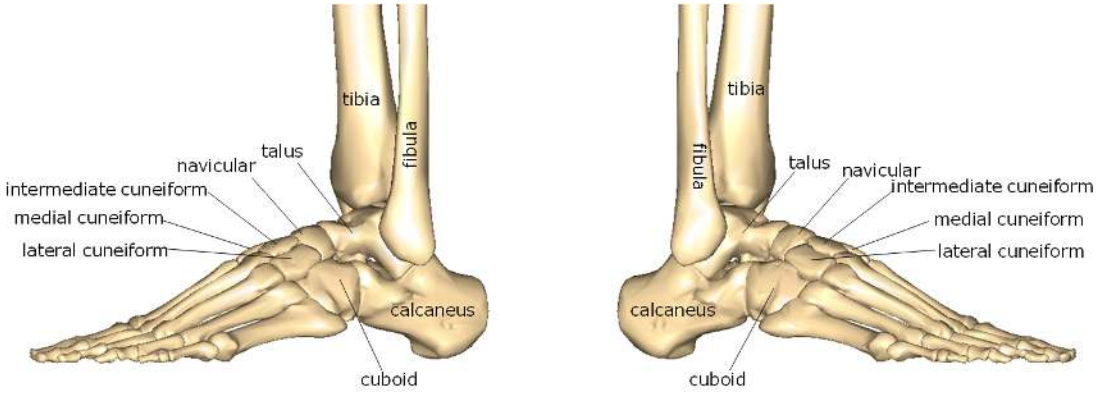
Above: Right and left tibia and fibula (A) anterior view and (B) posterior view.

The Bones of the Ankle & Foot

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



Above: The bones of the right and left feet, superior view. There are seven **tarsal** (ankle) bones: **calcaneus** (heel), **talus**, **navicular**, **medial cuneiform**, **intermediate cuneiform**, **lateral cuneiform**, and **cuboid**. The bones of the feet are **metatarsals** numbered one (medial) through five (lateral). The phalanges of the foot have the same numbering system as the metatarsals and also get designations of proximal, middle, and distal based on their positions. Phalanx #1 only has proximal and distal phalanges (no middle phalanx).



Above: The tarsal bones and their articulation with the tibial and fibula on the (left) left and (right) right foot viewed from their lateral aspects.

Attributions

- "BodyParts3D/Anatomography" by The Database Center for Life Science is licensed under CC BY-SA 2.1
- "Human knee joint FE model.png" by Hamid nbe is licensed under CC BY-SA 4.0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- "Femur - animation.gif" by Anatomography is licensed under CC BY-SA 2.1
- "Right femur - close-up - animation.gif" by Anatomography is licensed under CC BY-SA 2.1

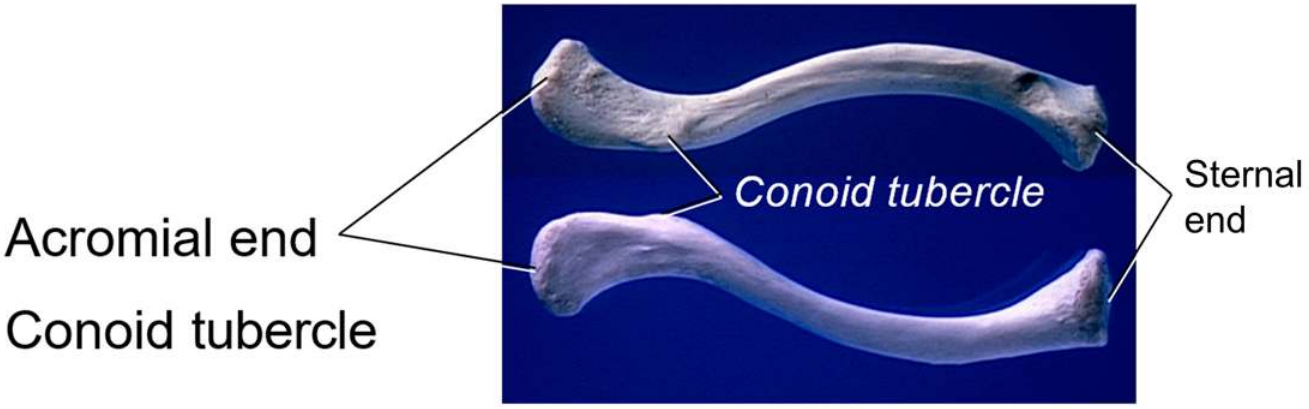
Updated 2026.

This page titled 9.5: Lower Limb is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

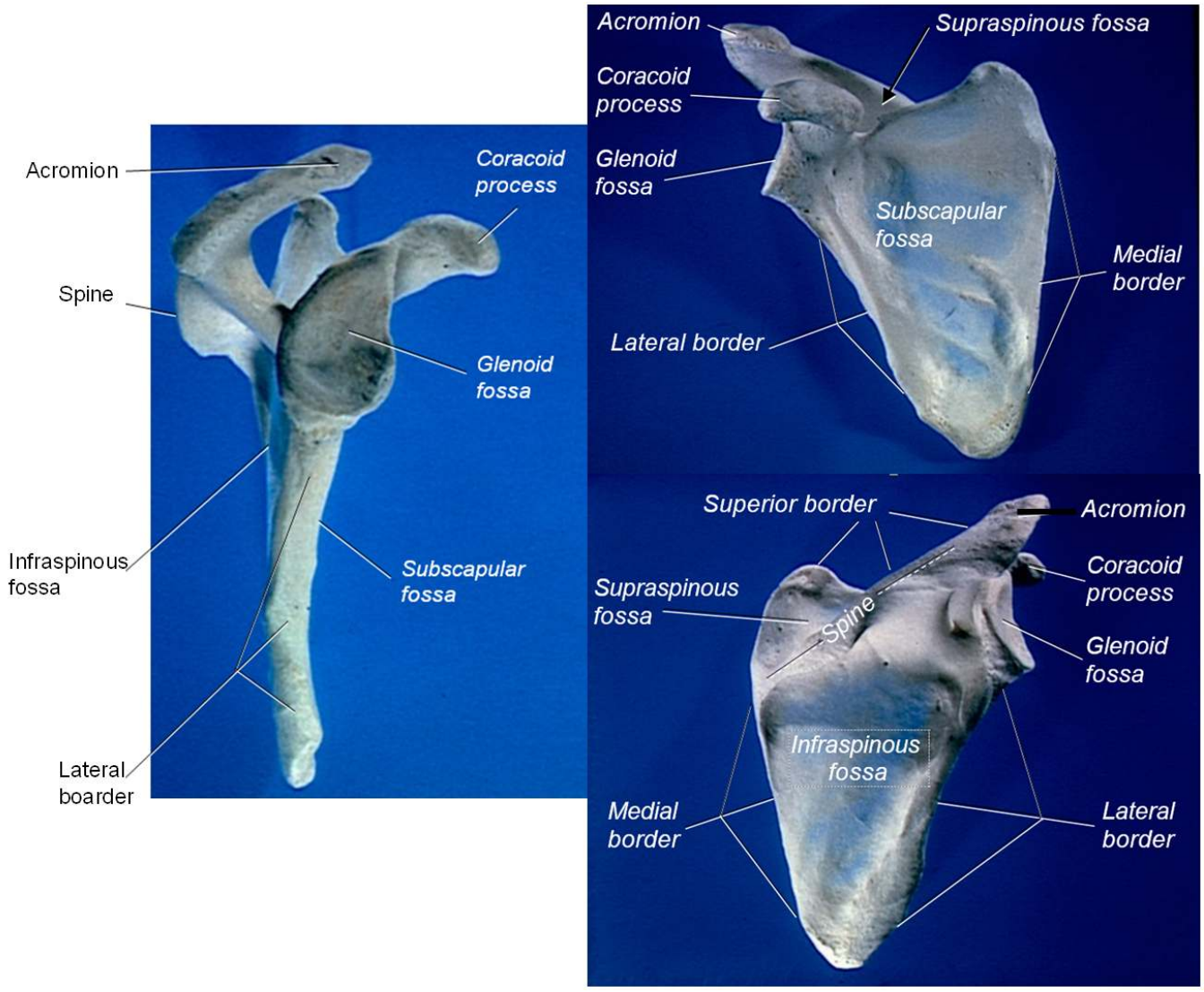
9.6: Additional Reference Figures

Additional Reference Figures

Shoulder Girdle/Pectoral Girdle

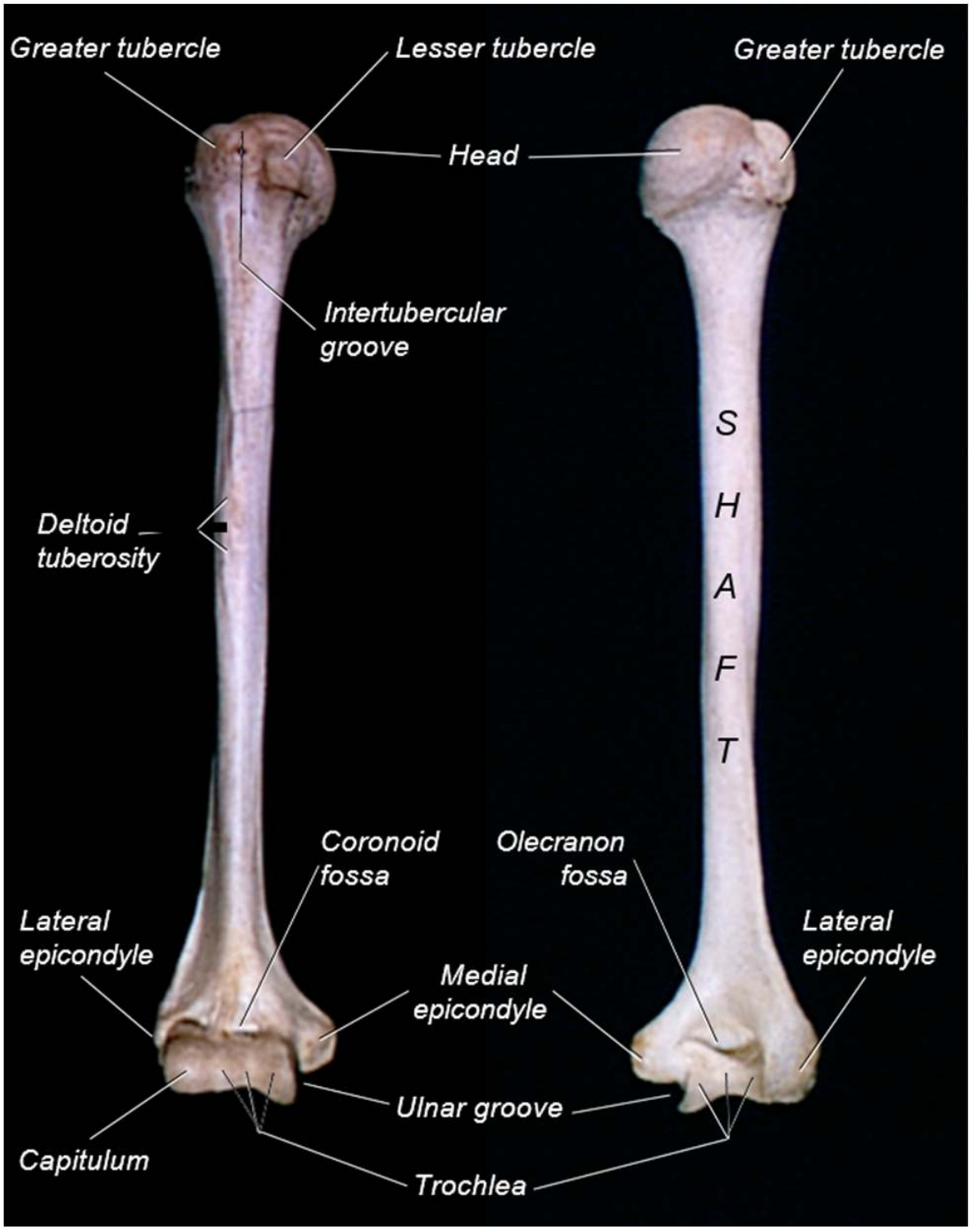


Above: Right clavicle (top) inferior view and (bottom) superior view.

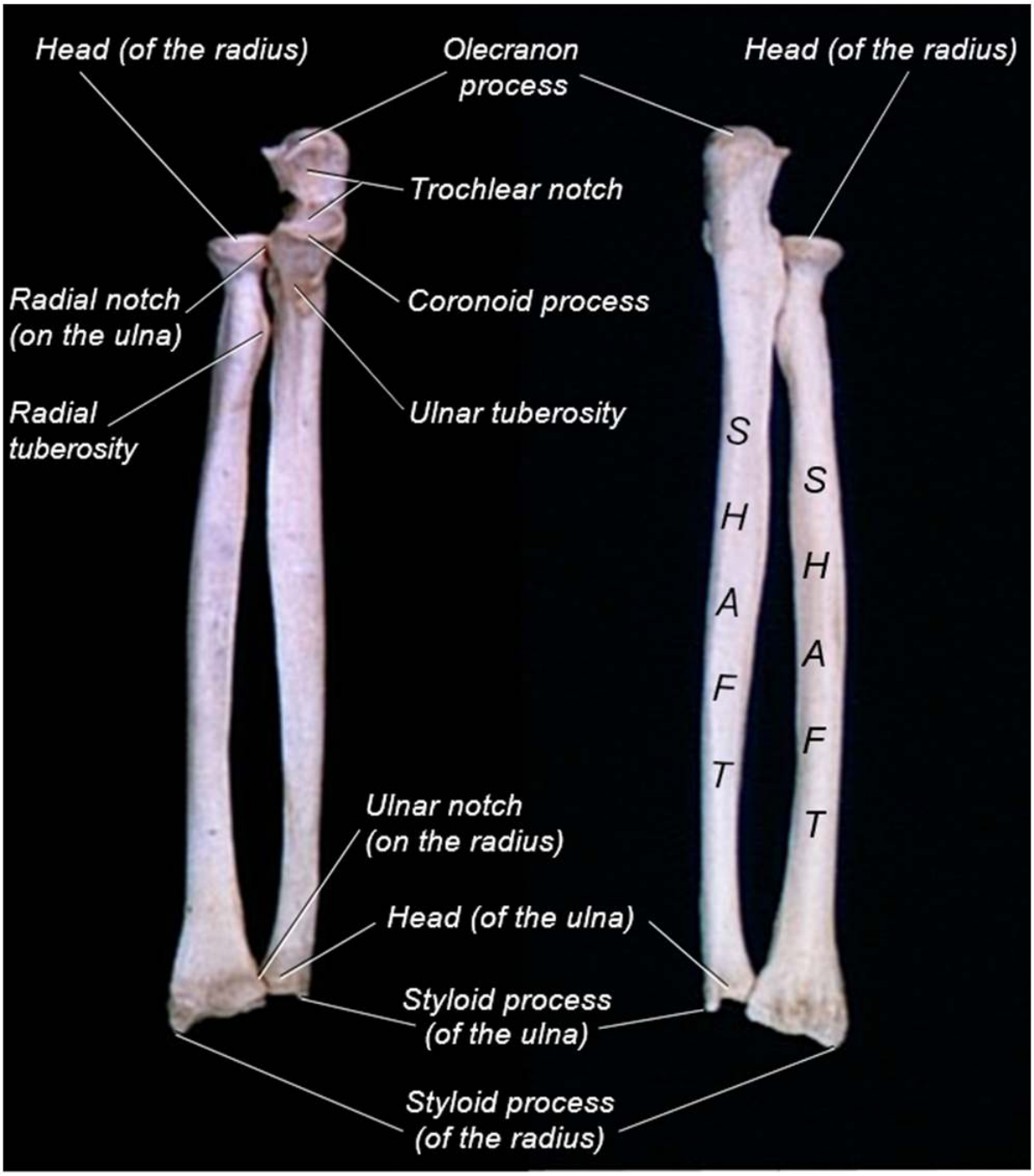


Above: Right scapula (left) lateral view, (right top) anterior view, and (right bottom) posterior view.

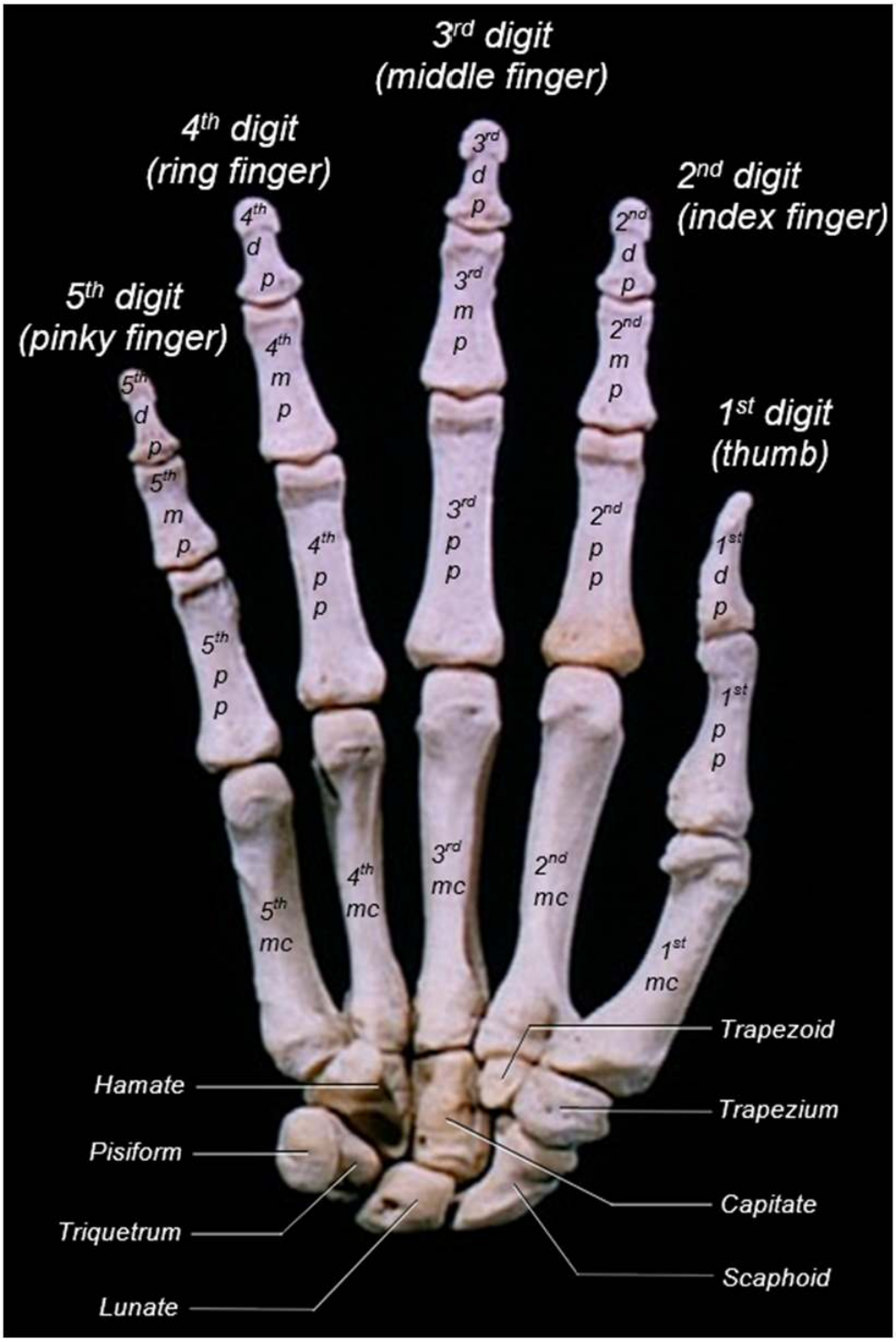
Upper Limb



Above: Right humerus (left) anterior view and (right) posterior view.

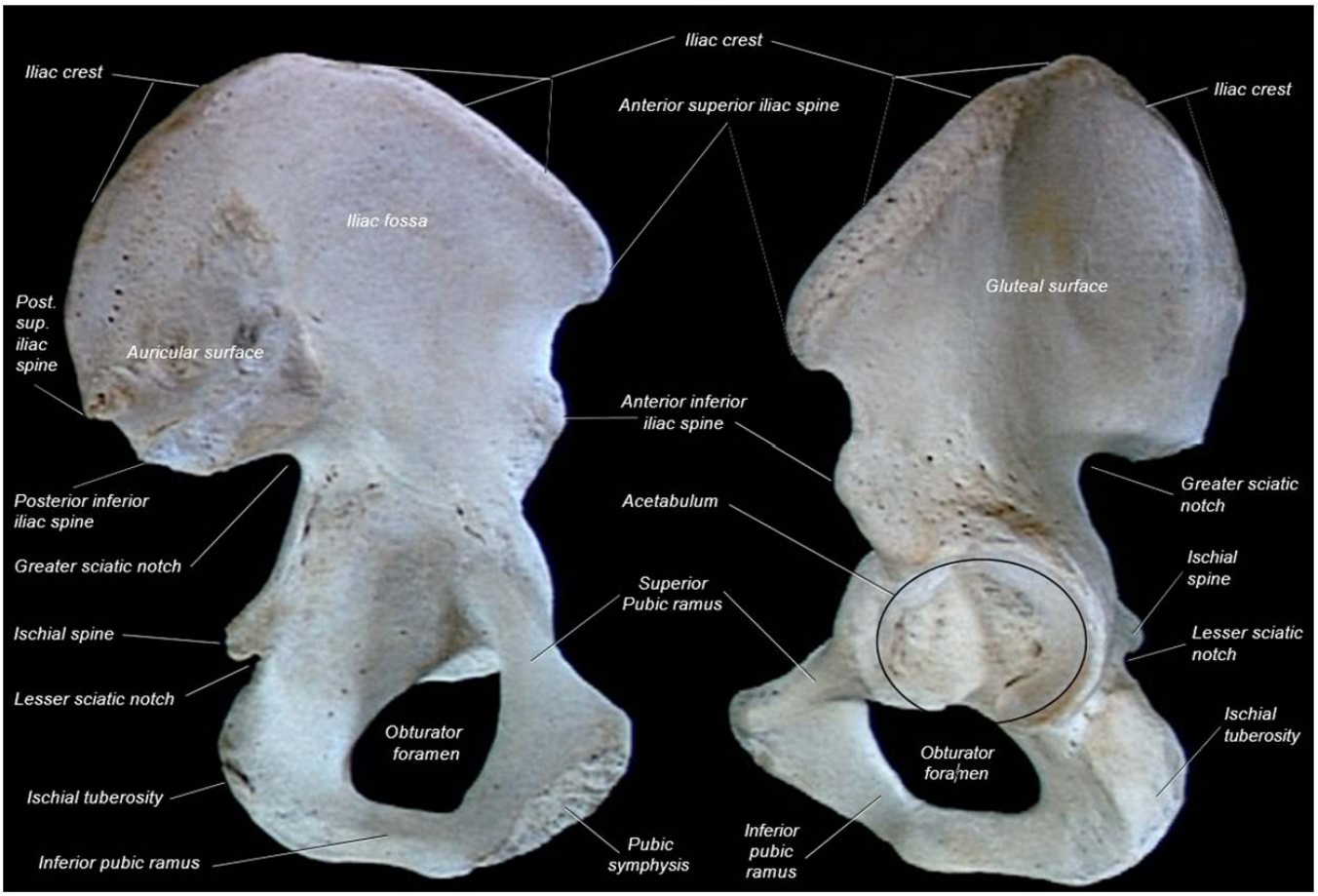


Above: Right radius and ulna (left) anterior view and (right) posterior view.



Above: Anterior view of right hand. Mc stands for metacarpal, pp stands for proximal phalanx, mp stands for middle phalanx, and dp stands for distal phalanx.

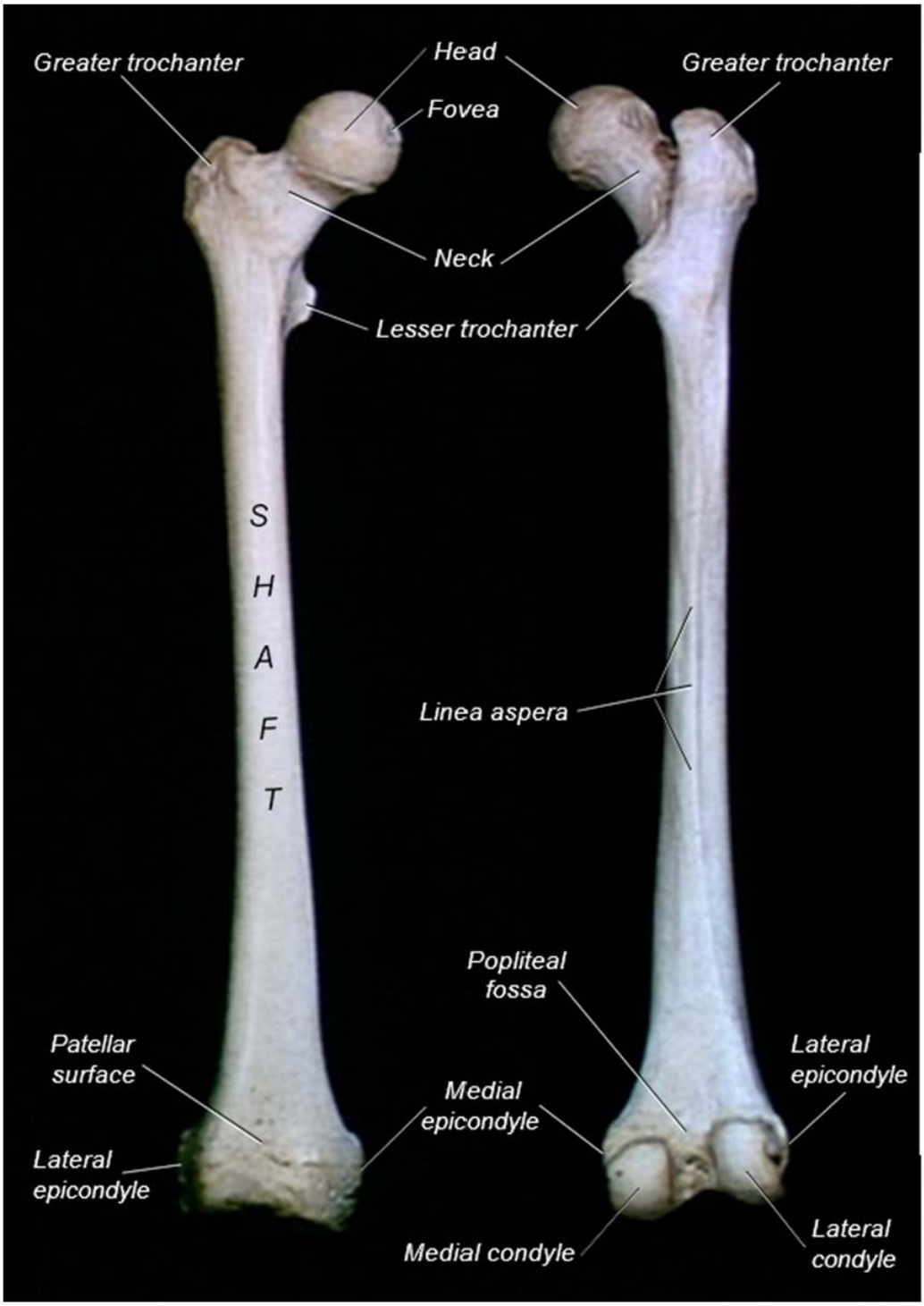
Pelvic Girdle



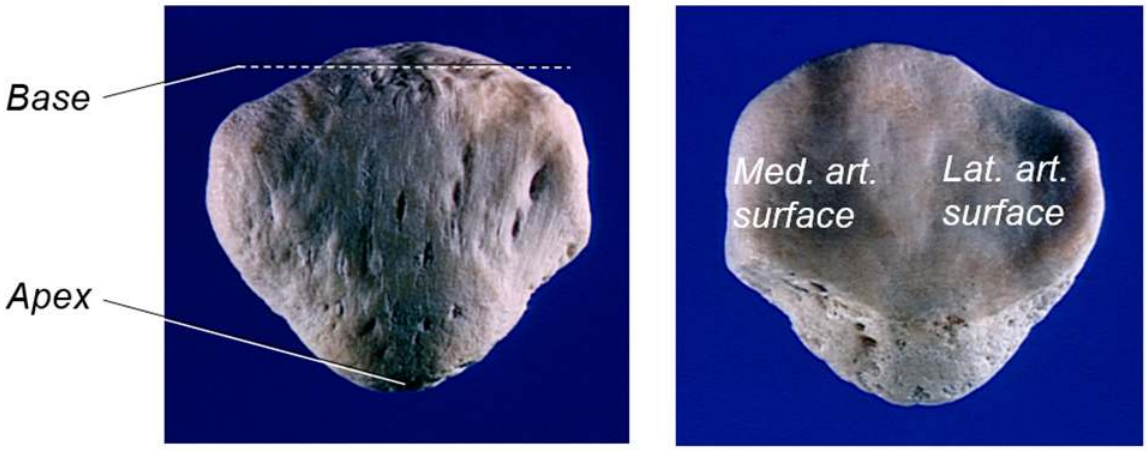
Above: Left coxal bone (left) anterior view and (right) posterior view.

Lower Limb

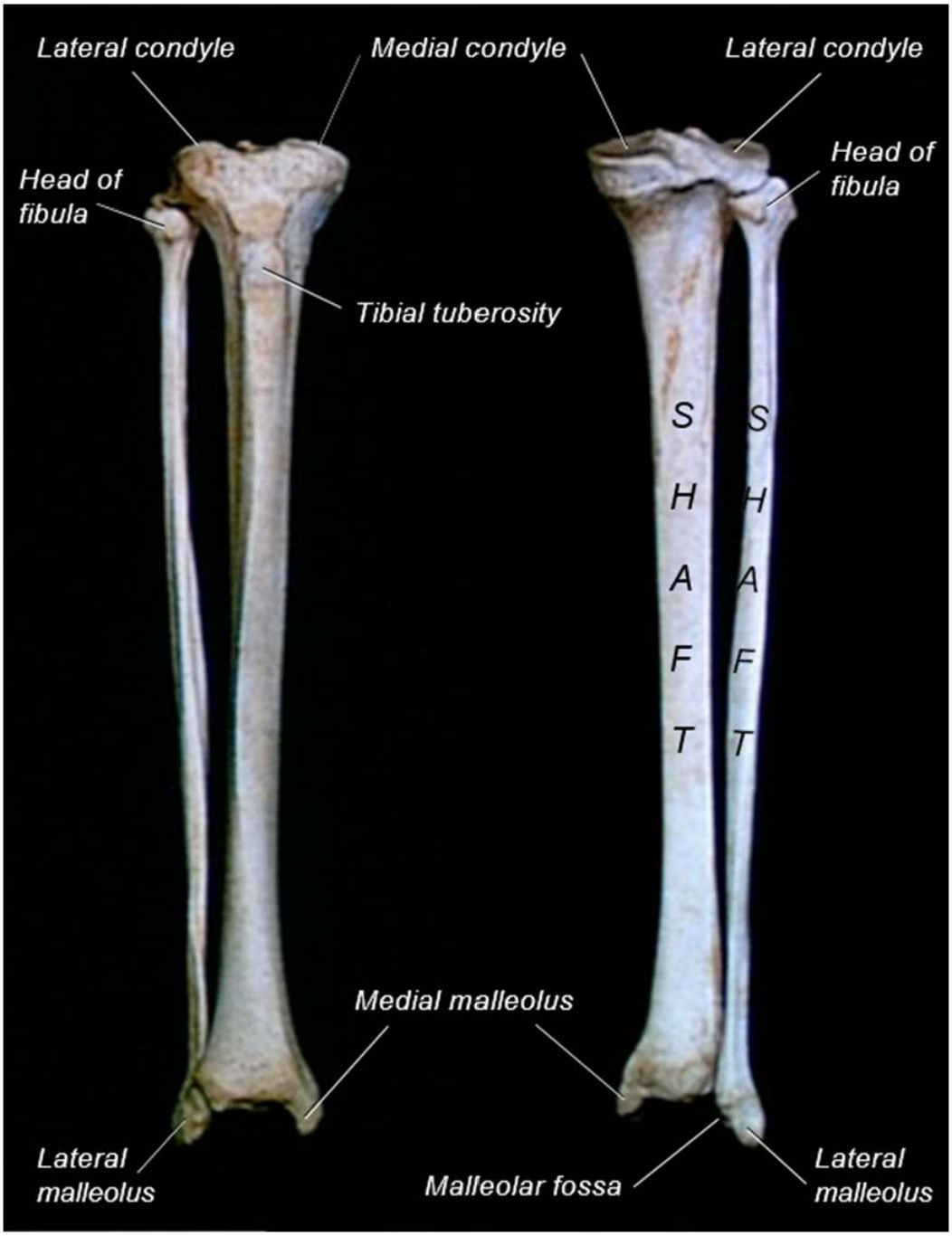
https://bio.libretexts.org/@go/page/53654



Above: Right femur (left) anterior view and (right) posterior view.



Above: Right patella (left) anterior view and (right) posterior view.



Above: Right tibia and fibula (left) anterior view and (right) posterior view.



Above: Left foot, superior view. Mt stands for metatarsal, pp stands for proximal phalanx, and dp stands for distal phalanx.

Attribution

- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0

Updated 2026.

This page titled 9.6: Additional Reference Figures is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

9.7: Laboratory Activities and Assignment

Laboratory Activities and Assignment

Part 1: Review of the Appendicular Skeleton

Pectoral/Shoulder Girdle

1. Label the following in the image of the anatomical model below:

• clavicle • anterior aspect • posterior aspect	• label the view (superior or inferior) • acromial end • sternal end	• conoid tubercle • subclavian groove • impression for costoclavicular ligament • right or left clavicle



2. Label the following in the image of the anatomical model below:

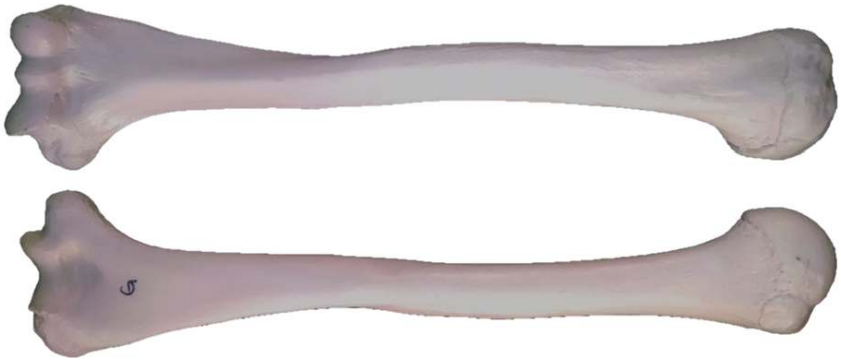
• scapula • anterior view • posterior view • spine • glenoid cavity	• infraspinous fossa • subscapular fossa • coracoid process • lateral border • medial border	• acromion • inferior angle • superior angle • right or left scapula



Upper Limb

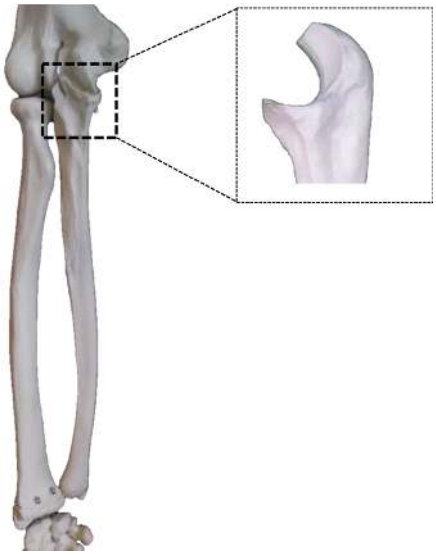
1. Label the following in the image of the anatomical model below:

- humerus
- head
- anatomical neck
- surgical neck
- greater tubercle
- lateral epicondyle
- medial epicondyle
- anterior aspect
- posterior aspect
- right or left humerus
- trochlea
- lesser tubercle
- capitulum
- olecranon fossa
- coronoid fossa
- radial fossa



2. Label the following in the image of the anatomical model below:

- radius
- ulna
- right or left
- anterior view or posterior view
- radial tuberosity
- radial styloid process
- ulnar styloid process
- radial head
- olecranon
- trochlear notch
- coronoid process
- distal radioulnar joint
- proximal radioulnar joint



3. Label the following in the image of the anatomical model below:

- carpals
- scaphoid
- lunate
- triquetral
- pisiform
- trapezium
- trapezoid
- capitate
- hamate
- metacarpals (with numbers)
- phalanges (proximal, middle, distal, with numbers)
- pollex



Pelvic Girdle

1. Label the following in the image of the anatomical model below:

• ilium • ischium • pubis • obturator foramen • acetabulum • iliac crest • pubic tubercle • inferior pubic ramus	• superior pubic ramus • anterior inferior iliac spine • anterior superior iliac spine • posterior superior iliac spine • posterior inferior iliac spine • greater sciatic notch • lesser sciatic notch	• ischial ramus • ischial spine • sacrum • iliac fossa • pubic arch • pubic symphysis • ischial tuberosity





Lower Limb

1. Label the following in the image of the anatomical model below:

• femur • anterior and posterior • head • neck • greater trochanter • lesser trochanter • intertrochanteric line • gluteal tuberosity	• right or left femur • medial condyle • lateral condyle • intercondylar fossa • patellar surface • patella • tibia • fibula	• medial malleolus • lateral malleolus • tibial tuberosity • articular surface for lateral condyle • articular surface for medial condyle • distal tibiofibular joint • proximal tibiofibular joint • head of the fibula







2. Label the following in the image of the anatomical model below:

• tarsals • talus • calcaneus • cuboid • navicular	• medial cuneiform • intermediate cuneiform • lateral cuneiform • metatarsal (with numbers)	• phalanges (proximal, middle and distal, with numbers) • hallux



Part 2: Laboratory Activities - Pectoral/Shoulder Girdle & Upper Limb

Pectoral/Shoulder Girdle

1. Using one of the full skeletons in the room, fill out the blanks for 1-4 below with steps to determine whether an individual scapula comes from the anatomical left or anatomical right. You must use any features that are already filled in. The clavicle was done as an example.
2. You can describe any features on that bone and which direction it has to face to allow you to determine whether that particular bone came from anatomical left or anatomical right.
3. Sample instructions for the clavicle are provided as an example for all subsequent exercises. Use proper anatomical terminology. Use terms which will make sense to anyone schooled in anatomy if they read it. Use as many steps as you need, not necessarily four.

Clavicle – Anatomical left from anatomical right

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

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

1. Glenoid cavity -

2.

3.

4.

Upper Limb

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

Humerus – Anatomical left from anatomical right

1. Olecranon fossa -

2.

3.

4.

Ulna – Anatomical left from anatomical right

1. Radial notch -

2.

3.

4.

Radius – Anatomical left from anatomical right

1. Styloid process -

2.

3.

4.

Part 3: Laboratory Activities - Pelvic Girdle & Lower Limb

Pelvic Girdle

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

1. Pubis -

2.

3.

4.

The Pelvis

Obtain an intact pelvis from the cabinet. Determine if the pelvis came from a male or female. Give three lines of evidence to support your conclusion.

Male or female?

- Evidence 1:
- Evidence 2:
- Evidence 3:

Lower Limb

1. Using one of the full skeletons in the room, fill out the list below with three or four steps to determine whether an individual bone comes from the anatomical left or anatomical right. You must use any features that are already filled in.

2. You can describe any features on that bone and which direction it has to face to allow you to determine whether that particular bone came from anatomical left or anatomical right.

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

Femur – Anatomical left from anatomical right

1. Head -

2.

3.

4.

Tibia – Anatomical left from anatomical right

1. Tibial tuberosity -

2.

3.

4.

Fibula – Anatomical left from anatomical right

1. Lateral malleolus -

2.

3.

4.

Calcaneus bone

1.

2.

3.

Talus bone

1.

2.

3.

Attributions

Part 1: Review of the Appendicular Skeleton

- "Anatomy and Physiology Lab Homework" by Laird C Sheldahl is licensed under CC BY-SA 4.0

Part 2: Laboratory Activities - Pectoral/Shoulder Girdle & Upper Limb

- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0

Part 3: Laboratory Activities - Pelvic Girdle & Lower Limb

- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0

Updated 2026.

This page titled 9.7: Laboratory Activities and Assignment is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

9.8: Collaborative Study Activities

Collaborative Study Activities

These activities are designed for student groups of 2-4. Larger groups will work better when there is no supplemental instructor present in the laboratory to assist in testing student groups on each section.

Part 1 each group will need a clavicle and a scapula. For Part 2, each group will need all the bones of the upper limb (hand articulated). For Part 3, each group will need a coxal bone or an assembled pelvis. For Part 4, each group will need the bones of the lower limb (foot articulated).

Part 1: Shoulder/Pectoral Girdle

1. Identify the following structures on classroom anatomical models and/or unlabeled images/diagrams made available by your instructor. Work with your group to identify each structure and check them off the list once you have identified them.

☐ scapula (R or L) ☐ spine ☐ supraspinous fossa ☐ infraspinous fossa ☐ superior angle	☐ inferior angle ☐ lateral border ☐ medial border ☐ subscapular fossa	☐ acromion/acromion process ☐ coracoid process ☐ glenoid cavity ☐ anterior/posterior
☐ clavicle (R or L) ☐ sternal end ☐ acromial end ☐ inferior aspect ☐ superior aspect	☐ conoid tubercle ☐ subclavian groove ☐ impression for costoclavicular ligament	☐ acromioclavicular joint ☐ sternoclavicular joint

2. Test your group members by ***asking them to name each structure you point to***. Check off each when your group can successfully name each. Your group will also test you.

☐ scapula (R or L) ☐ spine ☐ supraspinous fossa ☐ infraspinous fossa ☐ superior angle	☐ inferior angle ☐ lateral border ☐ medial border ☐ subscapular fossa	☐ acromion/acromion process ☐ coracoid process ☐ glenoid cavity ☐ anterior/posterior
☐ clavicle (R or L) ☐ sternal end ☐ acromial end ☐ inferior aspect ☐ superior aspect	☐ conoid tubercle ☐ subclavian groove ☐ impression for costoclavicular ligament	☐ acromioclavicular joint ☐ sternoclavicular joint

3. When you and your group are comfortable identifying all the structures above, request the assistance of your Instructor. They will test you on your use of these terms and initial ONLY when you are successful using these terms. Instructor: _____

Part 2: Upper Limb

1. Identify the following structures on classroom anatomical models and/or unlabeled images/diagrams made available by your instructor. Work with your group to identify each structure and check them off the list once you have identified them.

☐ humerus (R or L) ☐ head ☐ greater tubercle ☐ lesser tubercle ☐ anatomical neck	☐ surgical neck ☐ intertubercular sulcus ☐ deltoid tuberosity ☐ trochlea ☐ glenohumeral joint	☐ medial epicondyle ☐ lateral epicondyle ☐ olecranon fossa ☐ radial fossa

☐ radius (R or L) ☐ head	☐ radial styloid process ☐ radial tuberosity	☐ ulnar notch
☐ ulna (R or L) ☐ head ☐ ulnar styloid process ☐ olecranon process	☐ coronoid process ☐ trochlear notch ☐ radial notch	☐ proximal radioulnar joint ☐ distal radioulnar joint
☐ carpal bones ☐ how many carpal bones ☐ metacarpals (with numbers)	☐ phalanges (with numbers) ☐ proximal phalanges (with numbers)	☐ middle phalanges (with numbers) ☐ distal phalanges (with numbers)

2. Test your group members by ***asking them to name each structure you point to***. Check off each when your group can successfully name each. Your group will also test you.

☐ humerus (R or L) ☐ head ☐ greater tubercle ☐ lesser tubercle ☐ anatomical neck	☐ surgical neck ☐ intertubercular sulcus ☐ deltoid tuberosity ☐ trochlea ☐ glenohumeral joint	☐ medial epicondyle ☐ lateral epicondyle ☐ olecranon fossa ☐ radial fossa
☐ radius (R or L) ☐ head	☐ radial styloid process ☐ radial tuberosity	☐ ulnar notch
☐ ulna (R or L) ☐ head ☐ ulnar styloid process ☐ olecranon process	☐ coronoid process ☐ trochlear notch ☐ radial notch	☐ proximal radioulnar joint ☐ distal radioulnar joint
☐ carpal bones ☐ how many carpal bones ☐ metacarpals (with numbers)	☐ phalanges (with numbers) ☐ proximal phalanges (with numbers)	☐ middle phalanges (with numbers) ☐ distal phalanges (with numbers)

3. When you and your group are comfortable identifying all the structures above, request the assistance of your Instructor. They will test you on your use of these terms and initial ONLY when you are successful using these terms. Instructor: _____

Part 3: Pelvic Girdle

1. Identify the following structures on classroom anatomical models and/or unlabeled images/diagrams made available by your instructor. Work with your group to identify each structure and check them off the list once you have identified them.

☐ coxal bone (R or L) ☐ ilium ☐ iliac crest ☐ anterior superior iliac spine ☐ anterior inferior iliac spine ☐ posterior superior iliac spine ☐ posterior inferior iliac spine ☐ greater sciatic notch ☐ lesser sciatic notch ☐ iliac fossa	☐ acetabulum ☐ auricular surface ☐ ischium ☐ ischial spine ☐ ischial tuberosity ☐ ischial ramus ☐ obturator foramen	☐ pubis ☐ pubic tubercle ☐ pubic symphysis ☐ superior pubic ramus ☐ inferior pubic ramus ☐ pubic arch

2. Test your group members by ***asking them to name each structure you point to***. Check off each when your group can successfully name each. Your group will also test you.

☐ coxal bone (R or L) ☐ ilium ☐ iliac crest ☐ anterior superior iliac spine ☐ anterior inferior iliac spine ☐ posterior superior iliac spine ☐ posterior inferior iliac spine ☐ greater sciatic notch ☐ lesser sciatic notch ☐ iliac fossa	☐ acetabulum ☐ auricular surface ☐ ischium ☐ ischial spine ☐ ischial tuberosity ☐ ischial ramus ☐ obturator foramen	☐ pubis ☐ pubic tubercle ☐ pubic symphysis ☐ superior pubic ramus ☐ inferior pubic ramus ☐ pubic arch

3. When you and your group are comfortable identifying all the structures above, request the assistance of your Instructor. They will test you on your use of these terms and initial ONLY when you are successful using these terms. Instructor: _____

Part 4: Lower Limb

1. Identify the following structures on classroom anatomical models and/or unlabeled images/diagrams made available by your instructor. Work with your group to identify each structure and check them off the list once you have identified them.

☐ femur (R or L) ☐ head ☐ fovea capitis ☐ neck	☐ greater trochanter ☐ lesser trochanter ☐ intertrochanteric crest ☐ lateral condyle	☐ medial condyle ☐ intercondylar fossa ☐ patellar surface ☐ gluteal tuberosity
☐ patella ☐ apex	☐ facet for medial condyle of femur ☐ facet for lateral condyle of femur	☐ anterior/posterior of patella
☐ tibia ☐ intercondylar eminence	☐ medial condyle ☐ lateral condyle	☐ tibial tuberosity ☐ medial malleolus
☐ fibula ☐ head	☐ lateral malleolus ☐ proximal tibiofibular joint	☐ distal tibiofibular joint
☐ tarsal bones ☐ talus ☐ calcaneus ☐ how many tarsal bones?	☐ metatarsals (with numbers) ☐ phalanges (with numbers) ☐ proximal phalanges (with numbers	☐ middle phalanges (with numbers) ☐ distal phalanges (with numbers)

2. Test your group members by ***asking them to name each structure you point to***. Check off each when your group can successfully name each. Your group will also test you.

☐ femur (R or L) ☐ head ☐ fovea capitis ☐ neck	☐ greater trochanter ☐ lesser trochanter ☐ intertrochanteric crest ☐ lateral condyle	☐ medial condyle ☐ intercondylar fossa ☐ patellar surface ☐ gluteal tuberosity
☐ patella ☐ apex	☐ facet for medial condyle of femur ☐ facet for lateral condyle of femur	☐ anterior/posterior of patella
☐ tibia ☐ intercondylar eminence	☐ medial condyle ☐ lateral condyle	☐ tibial tuberosity ☐ medial malleolus
☐ fibula ☐ head	☐ lateral malleolus ☐ proximal tibiofibular joint	☐ distal tibiofibular joint
☐ tarsal bones ☐ talus ☐ calcaneus ☐ how many tarsal bones?	☐ metatarsals (with numbers) ☐ phalanges (with numbers) ☐ proximal phalanges (with numbers	☐ middle phalanges (with numbers) ☐ distal phalanges (with numbers)

3. When you and your group are comfortable identifying all the structures above, request the assistance of your Instructor. They will test you on your use of these terms and initial ONLY when you are successful using these terms. Instructor: _____

Updated 2026.

This page titled 9.8: Collaborative Study Activities is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

CHAPTER OVERVIEW

10: Articulations (Joints) and Movements

10.1: Articulations (Joints)
10.2: Body Movements
10.3: Additional Reference Figures
10.4: Laboratory Activities and Assignment

This page titled 10: Articulations (Joints) and Movements is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

10.1: Articulations (Joints)

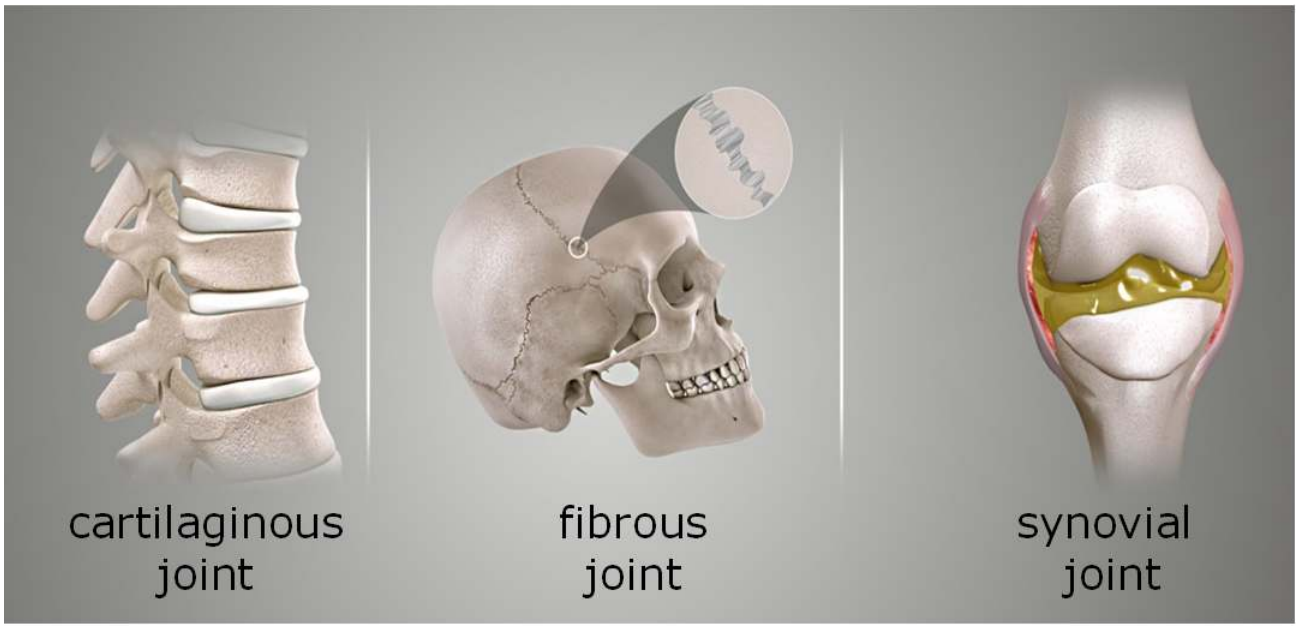
Articulations (Joints)

Introduction

A joint, also known as an **articulation**, is a location where two or more bones meet. Most joints contain a single articulation. Each articulation contains the **names of two bones** (or sockets). For example, the hip joint is known as the **acetabulofemoral joint** since it is where the acetabulum ("acetabulo-") of a coxal bone articulates with the head of the femur ("-femoral"). Another example is the shoulder joint, which is known as the **glenohumeral joint** since it is where the glenoid cavity ("gleno-") of the scapula articulates with the head of the humerus ("-humeral").

Some joints have more than one articulation (where more than two bones articulate with each other). These include the knee and the elbow joints. The knee includes articulation between the femur and tibia (**tibiofemoral joint**) and the femur and patella (**patellofemoral joint**). The elbow joint has three articulations: the **humeroradial joint** (articulation of the humerus and radius), the **humeroulnar joint** (articulation of the humerus and ulna), and the **proximal radioulnar joint** (the proximal articulation of the radius and the ulna).

Articulations vary in the amounts of movement they allow as well as their structures. Joints are classified based on function, the amount of movement they allow, into three categories: **synarthrosis**, **amphiarthrosis**, and **diarthrosis**. Additionally, joints are classified based on their structures into three categories: **fibrous joints**, **cartilaginous joints**, and **synovial joints**.



Above: Types of joints based upon their structure (L to R): cartilaginous joint, fibrous joint, and synovial joint.

Functional classifications (movement) of joints:

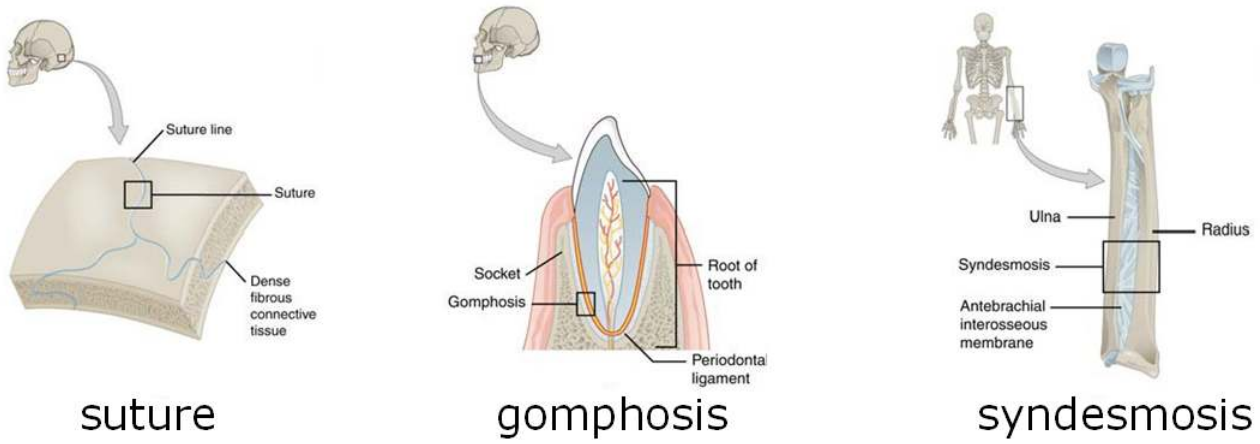
1. **synarthrosis** – permits no mobility. Most synarthrosis joints are **fibrous joints** (e.g. sutures of skull).
2. **amphiarthrosis** – permits slight mobility. Most amphiarthrosis joints are **cartilaginous joints** (e.g. intervertebral discs).
3. **diarthrosis** – freely movable joints, including all **synovial joints**.

Structural classification (according to the type of tissue that connects the bones to each other) of joints:

1. fibrous joint: bones are joined by dense regular connective tissue that is rich in collagen fibers. The subclasses of synarthroses include:

- **sutures** – periosteum of articulating bones interdigitate making a very stable joint, for example sutures of the skull

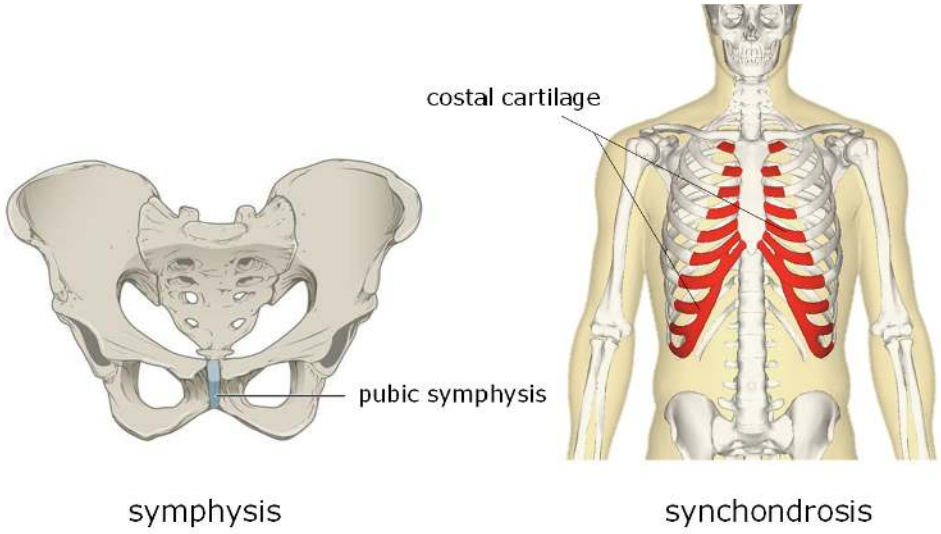
- **gomphosis** – joint between the teeth and the alveolar process of the mandible or maxilla, it is held in place by the periodontal ligaments
- **syndesmosis** – located between two parallel articulating bones, they are joined by a long fibrous membrane called the interosseous membrane. These joints are classified as amphiarthroses including articulation of the radius and the ulna



Above: The categories of fibrous joints with examples.

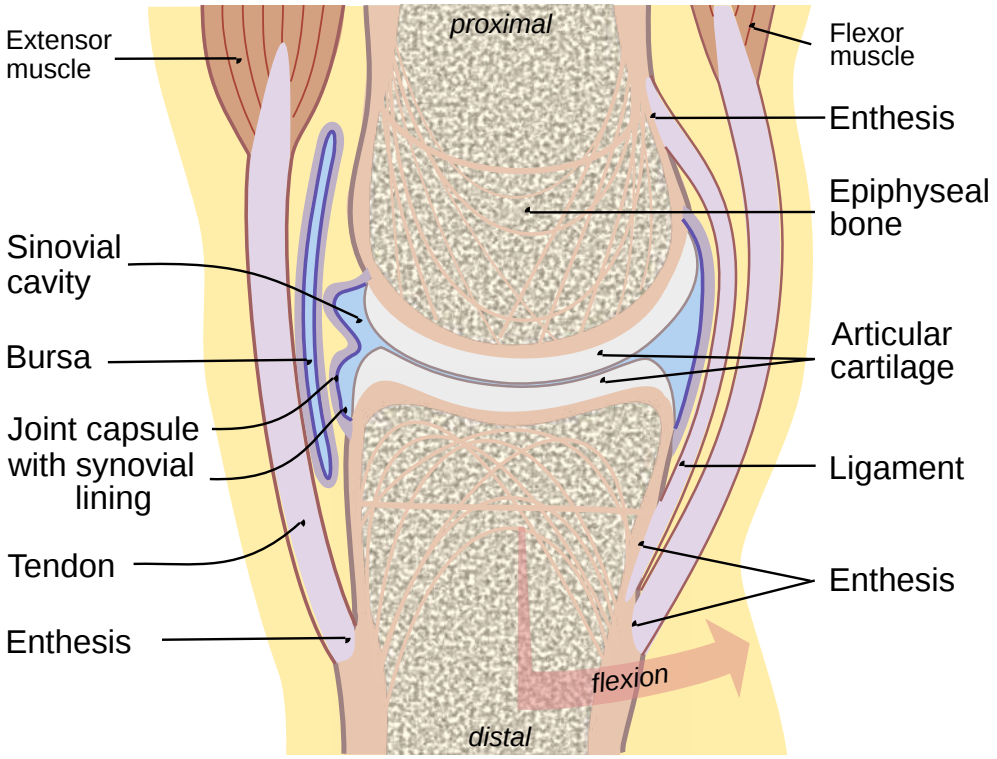
2. cartilaginous joint: bones are joined by cartilage. Most of this type of joint allow for some movement, so they are amphiarthrosis. There are two types of cartilaginous joints:

- **symphysis** – bones are joined by a pad made of fibrocartilage (e.g. pubic symphysis; articulation between the bodies of two vertebrae - intervertebral discs)
- **synchondrosis** – bones are joined by hyaline cartilage (e.g. costochondral joints)



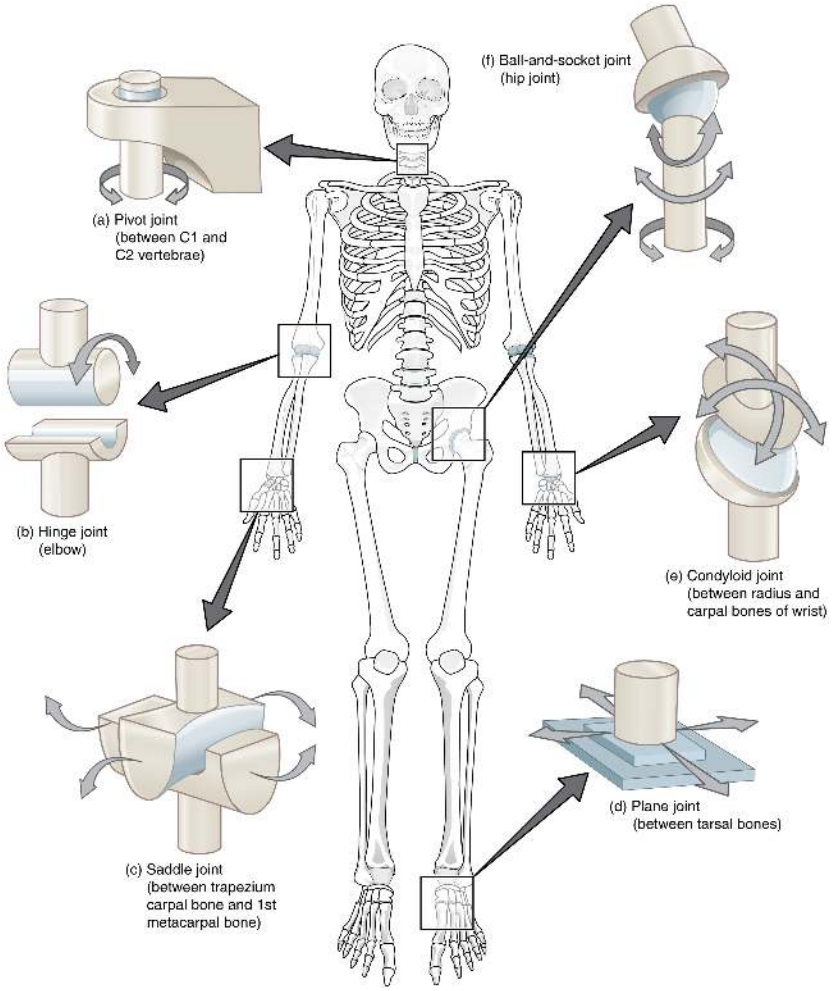
Above: The categories of cartilaginous joints.

3. synovial joint: bones are 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 diarthrosis as they allow for free movement. Synovial joints can in turn be classified into six groups according to the type of movement they allow:



Above: Structure of a synovial joint.

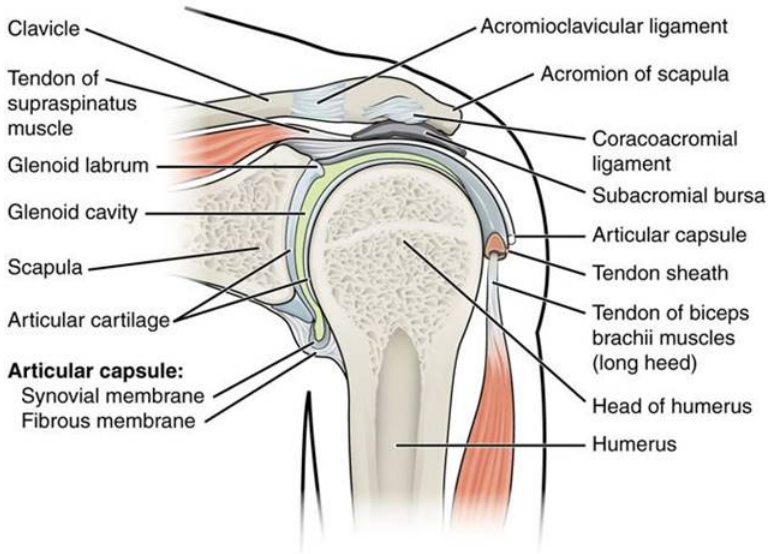
- **plane joint** – flat articular surfaces, allow for gliding movement
- **ball and socket joint** – where the convex of the end of one bone fits on the concave end of the other (e.g. shoulder joint)
- **hinge joint** – a convex articular surface fits on the concave articular surface of the other, like a door hinge
- **pivot joint** – one bone rotates around another
- **condyloid joint** (aka **ellipsoid joint**) – one bone fits into the concave end of another (e.g. radiocarpal joint)
- **saddle joint –** condyloid-like but allow for more movement



Above: The structures of different synovial joint classifications and examples of each type.

Shoulder Joint

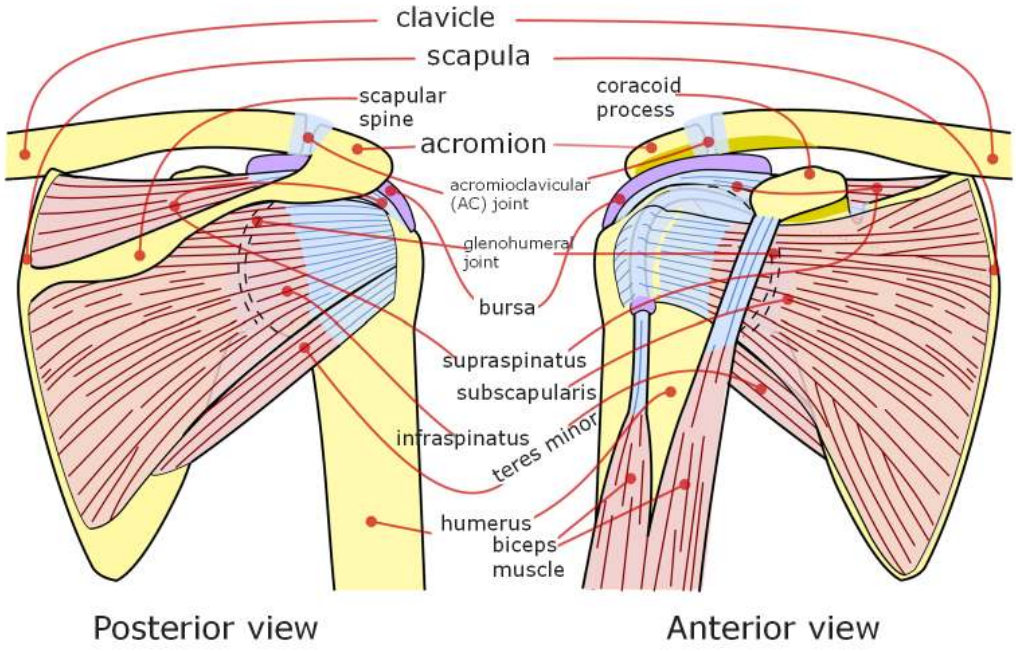
The shoulder joint is called the **glenohumeral joint**. This is a ball-and-socket joint formed by the articulation between the head of the humerus and the glenoid cavity of the scapula. This joint has the largest range of motion of any joint in the body. However, this freedom of movement is due to the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



Above: The glenohumeral joint. The glenohumeral (shoulder) joint is a ball-and-socket joint that provides the widest range of motions. It has a loose articular capsule and is supported by ligaments and the rotator cuff muscles.

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

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



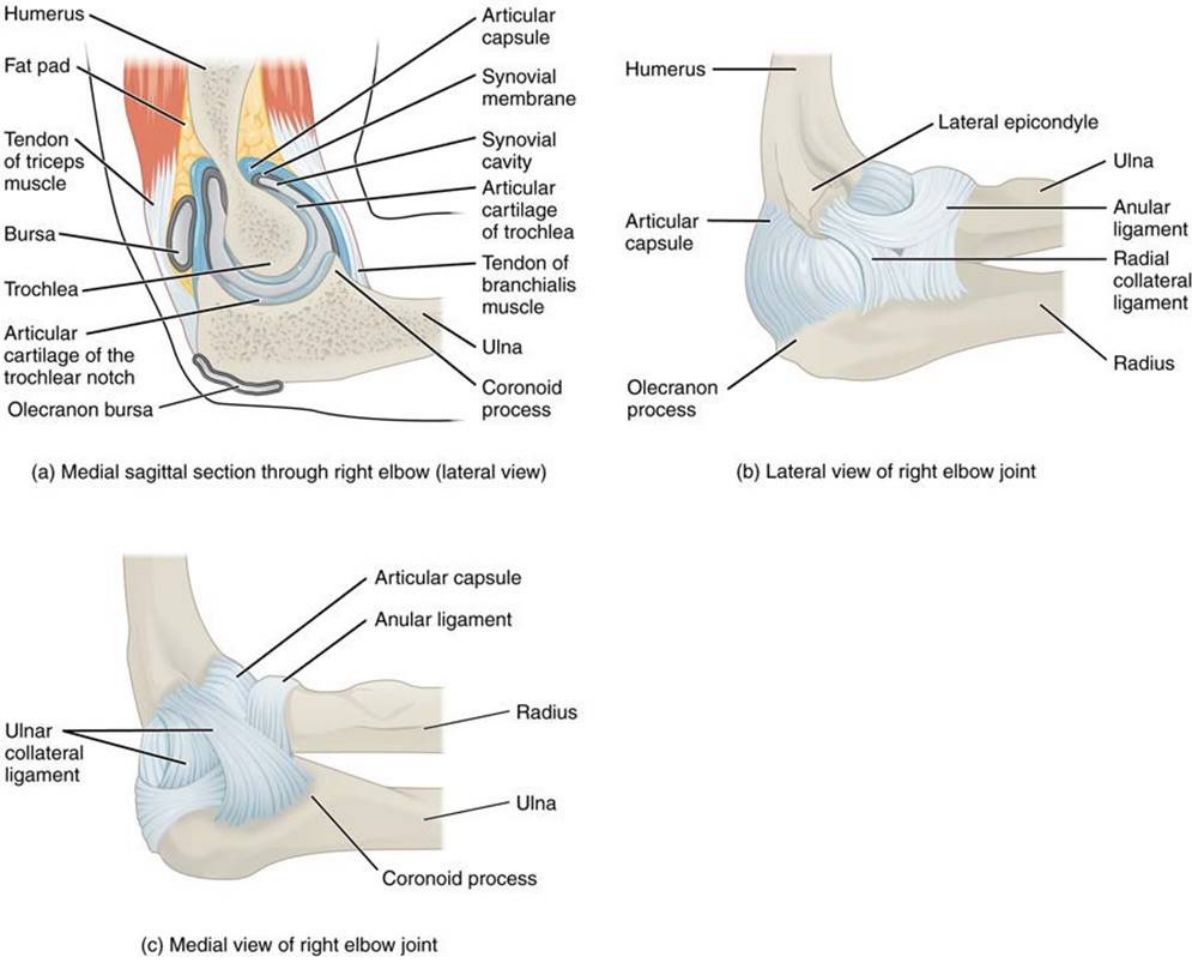
Above: Joints of the shoulder. This diagram includes the rotator cuff muscles: suprasinatus, subscapularis, infraspinatus, and teres minor.

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

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

Elbow Joint

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



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

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

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

Knee Joint

The knee joint is the largest joint of the body. It actually consists of three articulations. The **femoropatellar joint** is found between the patella and the distal femur. The **medial tibiofemoral joint** and **lateral tibiofemoral joint** are located between the medial and lateral condyles of the femur and the medial and lateral condyles of the tibia. All of these articulations are enclosed within a single articular capsule. The knee functions as a hinge joint, allowing flexion and extension of the leg. This action is generated by both

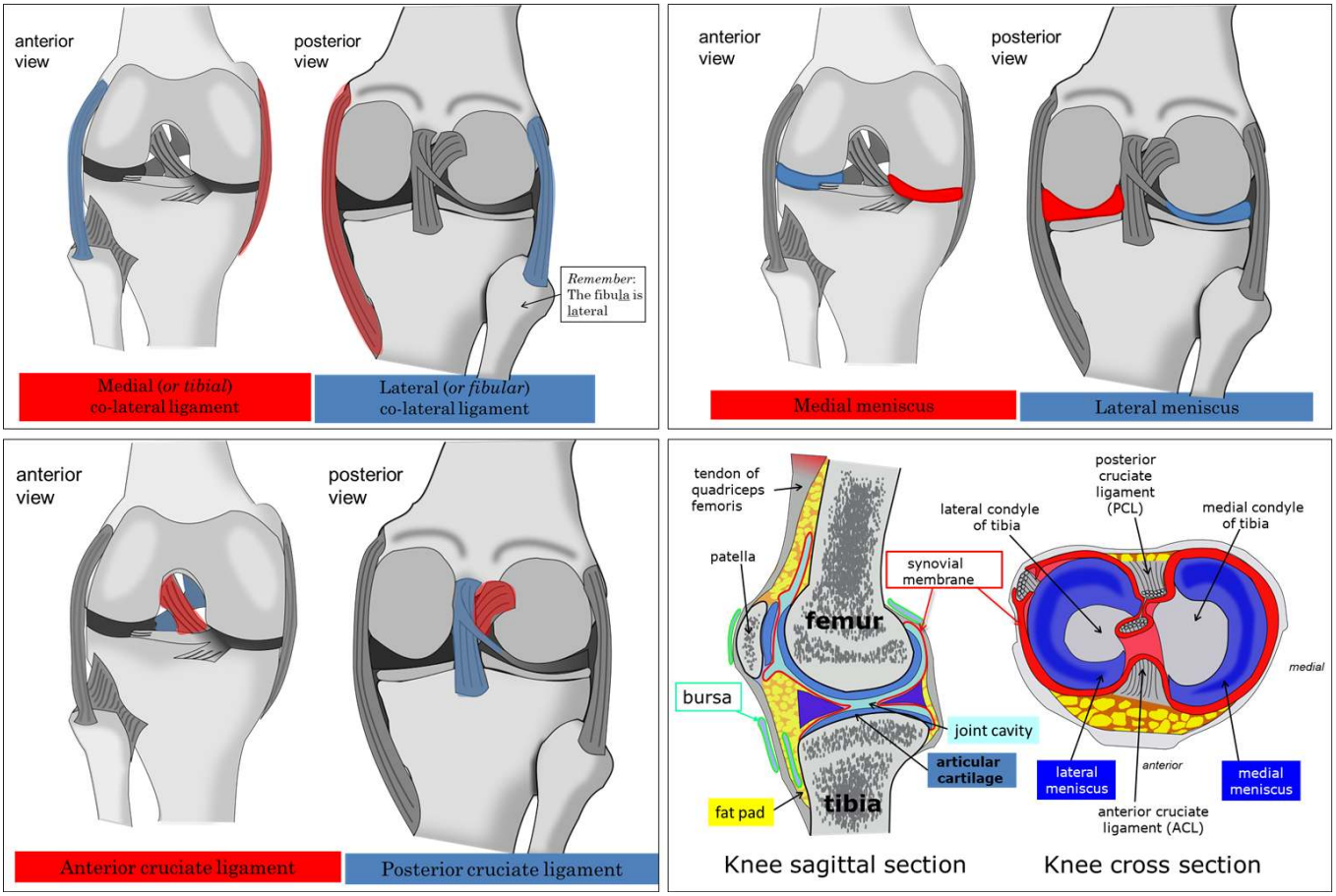
rolling and gliding motions of the femur on the tibia. In addition, some rotation of the leg is available when the knee is flexed, but not when extended. The knee is well constructed for weight bearing in its extended position, but is vulnerable to injuries associated with hyperextension, twisting, or blows to the medial or lateral side of the joint, particularly while weight bearing.

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

The medial and lateral tibiofemoral joints are the articulations between the rounded condyles of the femur and the relatively flat condyles of the tibia. During flexion and extension motions, the condyles of the femur both roll and glide over the surfaces of the tibia. The rolling action produces flexion or extension, while the gliding action serves to maintain the femoral condyles centered over the tibial condyles, thus ensuring maximal bony, weight-bearing support for the femur in all knee positions. As the knee comes into full extension, the femur undergoes a slight medial rotation in relation to tibia. The rotation results because the lateral condyle of the femur is slightly smaller than the medial condyle. Thus, the lateral condyle finishes its rolling motion first, followed by the medial condyle. The resulting small medial rotation of the femur serves to "lock" the knee into its fully extended and most stable position. Flexion of the knee is initiated by a slight lateral rotation of the femur on the tibia, which "unlocks" the knee. This lateral rotation motion is produced by the popliteus muscle of the posterior leg.

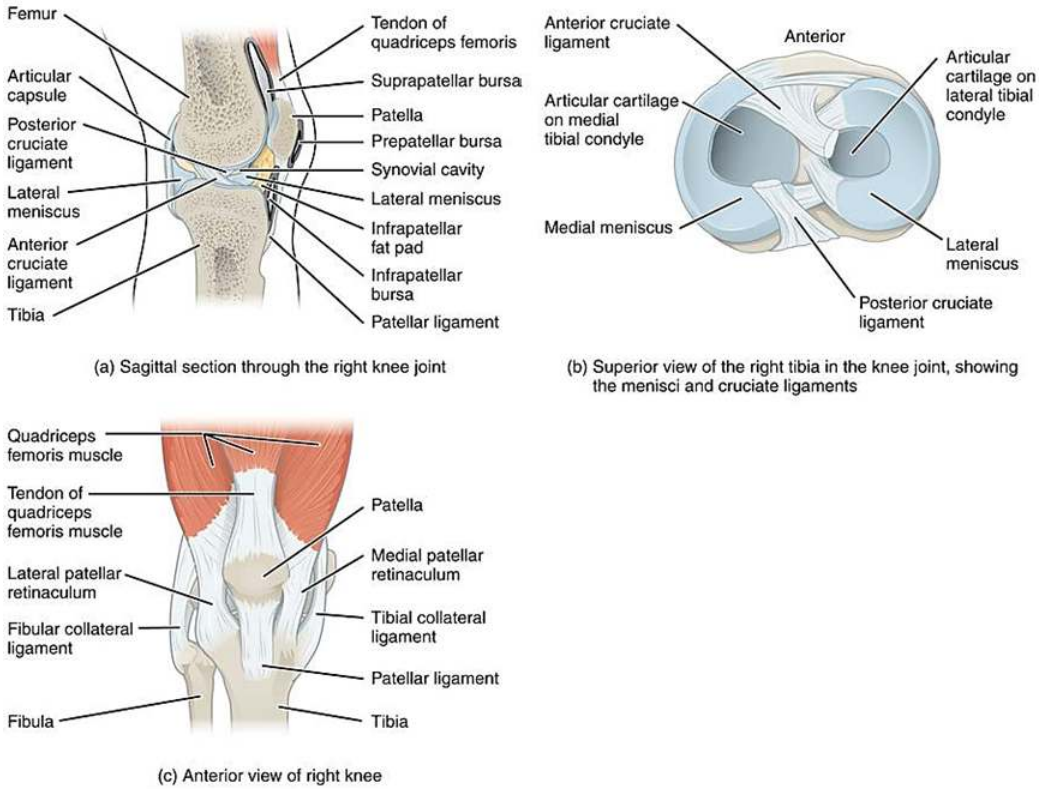
Located between the articulating surfaces of the femur and tibia are two articular discs, the **medial meniscus** and **lateral meniscus**. Each is a C-shaped fibrocartilage structure that is thin along its inside margin and thick along the outer margin. They are attached to their tibial condyles, but do not attach to the femur. While both menisci are free to move during knee motions, the medial meniscus shows less movement because it is anchored at its outer margin to the articular capsule and tibial collateral ligament. The menisci provide padding between the bones and help to fill the gap between the round femoral condyles and flattened tibial condyles. Some areas of each meniscus lack an arterial blood supply and thus these areas heal poorly if damaged.

The knee joint has multiple ligaments that provide support, particularly in the extended position. Outside of the articular capsule, located at the sides of the knee, are two extrinsic ligaments. The **fibular collateral ligament** (lateral collateral ligament) is on the lateral side and spans from the lateral epicondyle of the femur to the head of the fibula. The **tibial collateral ligament** (medial collateral ligament) of the medial knee runs from the medial epicondyle of the femur to the medial tibia. As it crosses the knee, the tibial collateral ligament is firmly attached.



Above: Diagrams highlight the structures of the knee joint.

on its deep side to the articular capsule and to the medial meniscus, an important factor when considering knee injuries. In the fully extended knee position, both collateral ligaments are taut (tight), thus serving to stabilize and support the extended knee and preventing side-to-side or rotational motions between the femur and tibia.



Above: Knee Joint (a) The knee joint is the largest joint of the body. (b)–(c) It is supported by the tibial and fibular collateral ligaments located on the sides of the knee outside of the articular capsule, and the anterior and posterior cruciate ligaments found inside the capsule. The medial and lateral menisci provide padding and support between the femoral condyles and tibial condyles.

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

Attributions

- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0
- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0
- "Anatomy and Physiology Lab Reference" by Laird C Sheldahl, OpenOregonEducational Resources, Mt. Hood Community College is licensed under CC BY-SA 4.0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- "Costal cartilages frontal.png" by Anatomography is licensed under CC BY-SA 2.1
- Joint.svg by Madhero88 is licensed under CC BY-SA 3.0
- "Shoulder joint bf.svg" by Jmarchn is licensed under CC BY-SA 3.0

Updated 2026.

This page titled 10.1: Articulations (Joints) is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

10.2: Body Movements

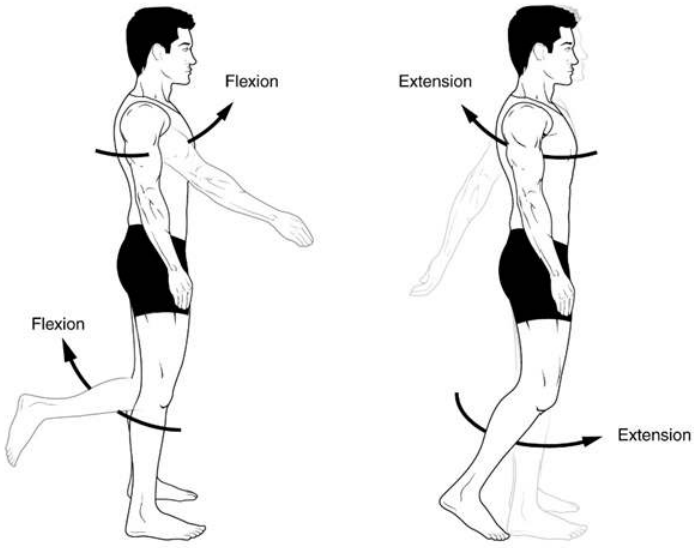
Body Movements

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

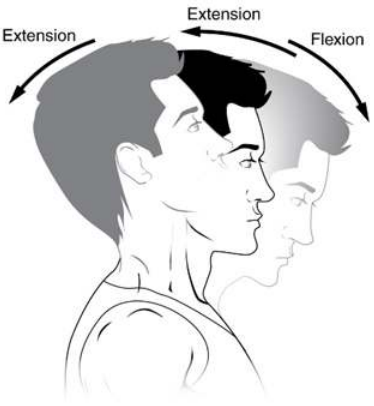
- flexion - extension
- abduction - adduction
- circumduction (no opposite)
- elevation - depression
- internal/medial rotation - external/lateral rotation
- dorsiflexion - plantar flexion
- pronation - supination
- inversion - eversion
- protrusion/protraction - retrusion/retraction
- opposition - reposition

Flexion & Extension

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



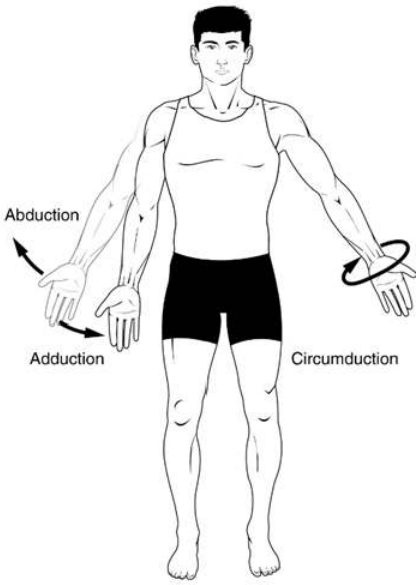
(a) and (b) Angular movements: flexion and extension at the shoulder and knees



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

Abduction & Adduction

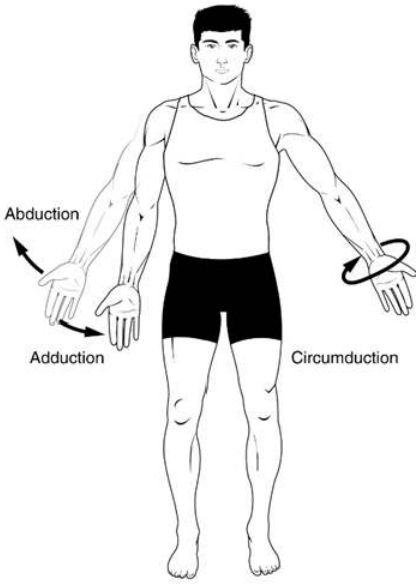
Abduction is the motion of a structure away from the midline while **adduction** refers to motion towards the center of the body. The center of the body is defined as the midsagittal plane. These terms come from Latin words with similar meanings, ab- being the Latin prefix indicating "away," ad- indicating "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.



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

Circumduction

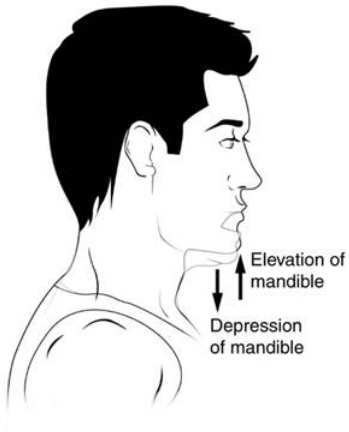
Circumduction refers to a conical movement of a body part, such as a ball and socket joint or the eye. Circumduction is a combination of flexion, extension, adduction and abduction. Circumduction can be best performed at ball and socket joints, such as the hip and shoulder, but may also be performed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

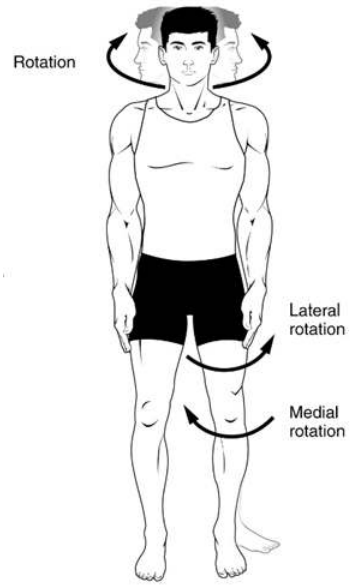
Elevation & Depression

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.



Internal/Medial Rotation & External/Lateral 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.



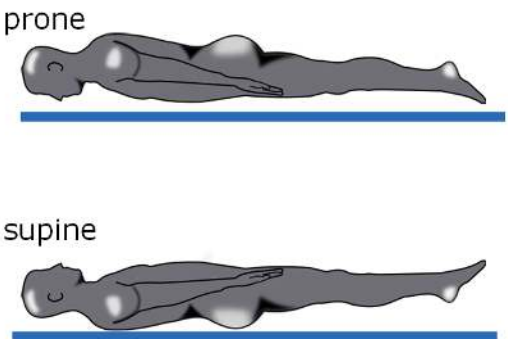
(f) Rotation of the head, neck, and lower limb

Dorsiflexion & Plantar Flexion

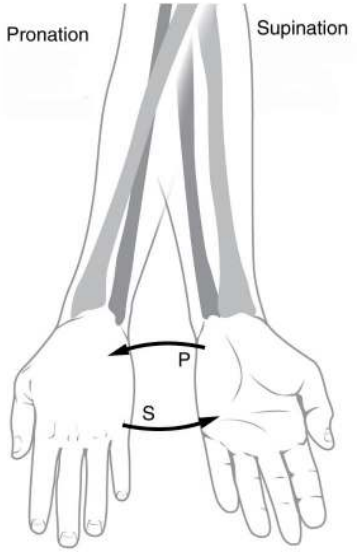
Dorsiflexion and **plantar flexion** refer to extension or flexion of the foot at the ankle. These terms refer to flexion in direction of the "back" of the foot, dorsum pedi, which is the upper surface of the foot when standing, and flexion in direction of the sole of the foot, plantar pedi. These terms 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 & Supination



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.



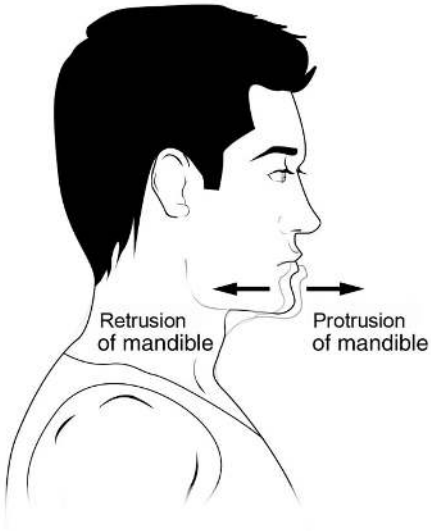
Inversion & Eversion

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/Protraction & Retrusion/Retraction

Protrusion and **retrusion** are sometimes used to describe the anterior (protrusion) and posterior (retrusion) movement of the jaw. **Protraction** and **retraction** refer to an anterior (protraction) or posterior (retraction) movement, such as of the arm at the shoulders, and the mandible.



Opposition & Reposition

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



Attributions

- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0
- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0

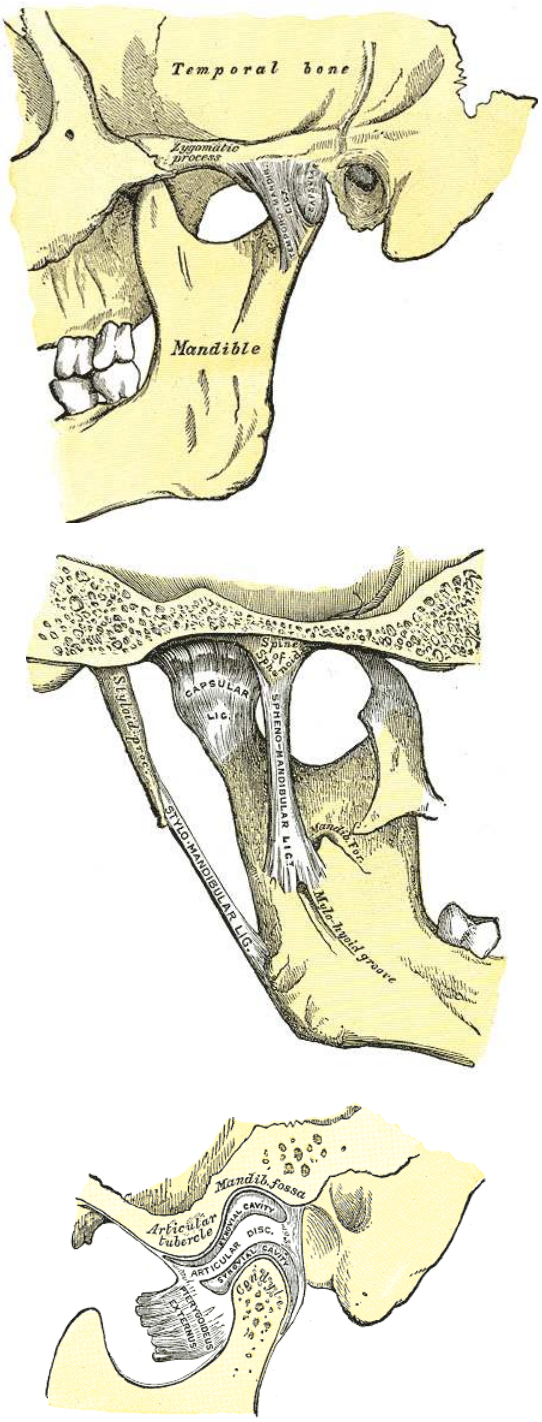
Updated 2026.

This page titled 10.2: Body Movements is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

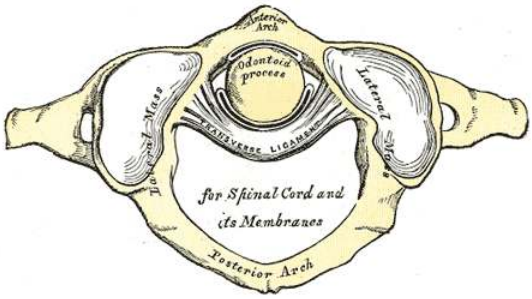
10.3: Additional Reference Figures

Additional Reference Figures

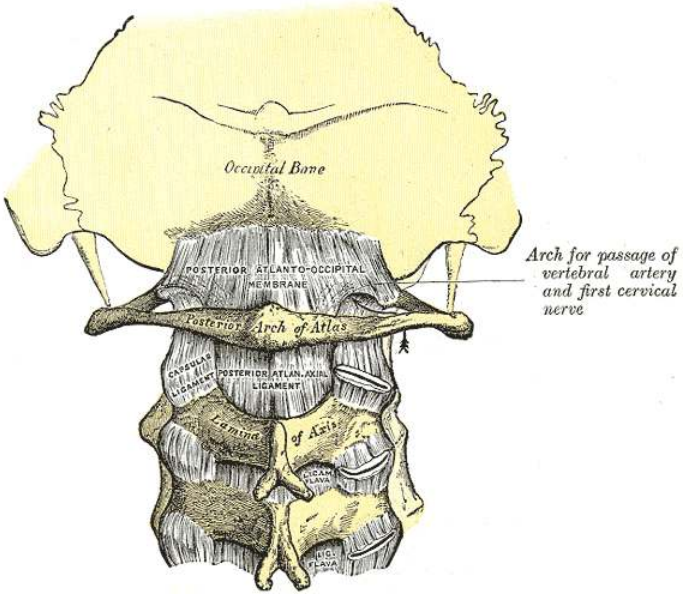
Mandible Joints



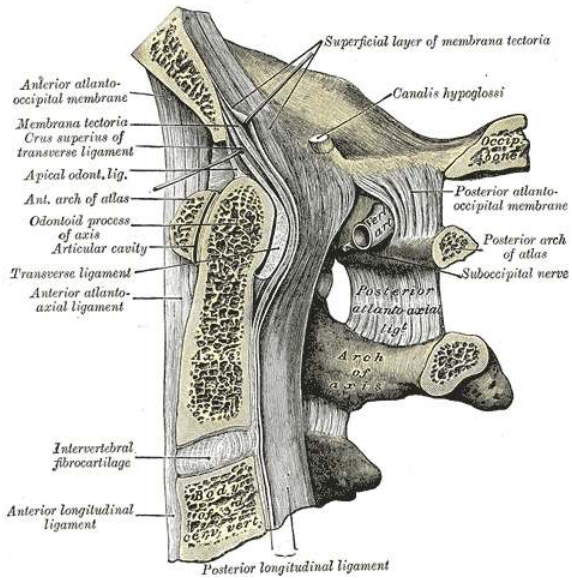
Above: Articulation of the mandible. (Top) Lateral aspect of the left side of the mandible. (Middle) Medial aspect of the left side of the mandible. (Bottom) Sagittal section of the articulation of the mandible.



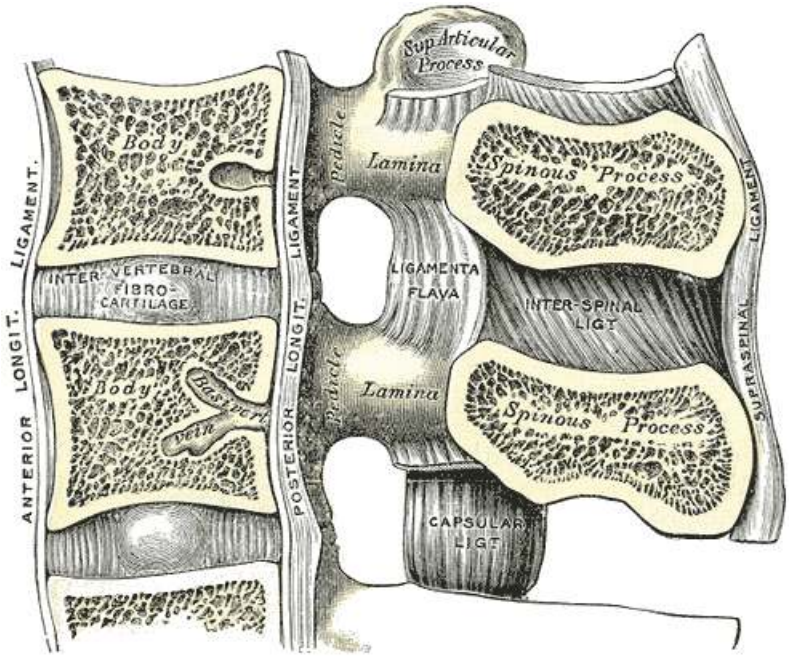
Above: Articulation between odontoid process (dens of C_2 or axis) and atlas (C_1). Anterior is at the top of the illustration and posterior is at the bottom.



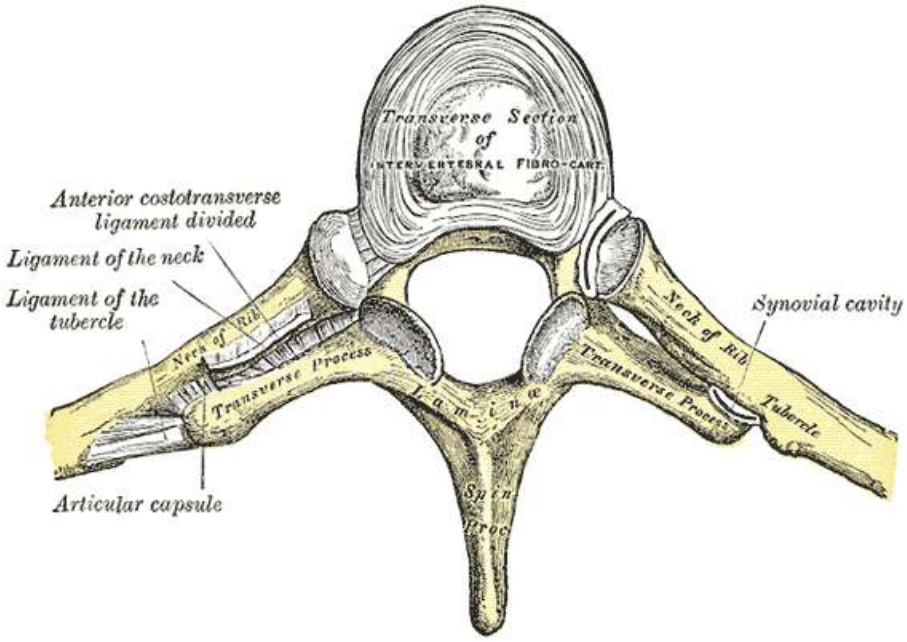
Above: Posterior atlantooccipital membrane and atlantoaxial ligament. Posterior view of the occipital bone of the skull and the vertebral column.



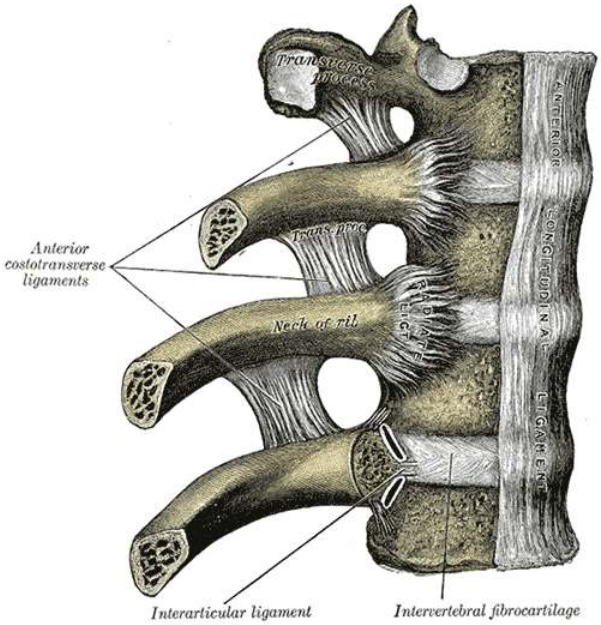
Above: Median sagittal section through the occipital bone and first three cervical vertebrae. The left side of this illustration is anterior and the right side is posterior.



Above: Median sagittal section of two lumbar vertebrae and their ligaments. Anterior is at the left of the illustration and posterior is at the right of the illustration.



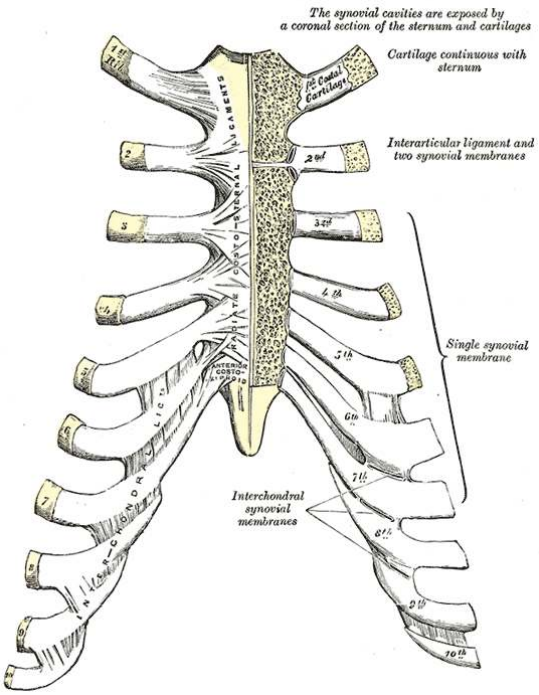
Above: Costotransverse articulation. Seen from above. Anterior is at the top of the illustration and posterior is at the bottom.



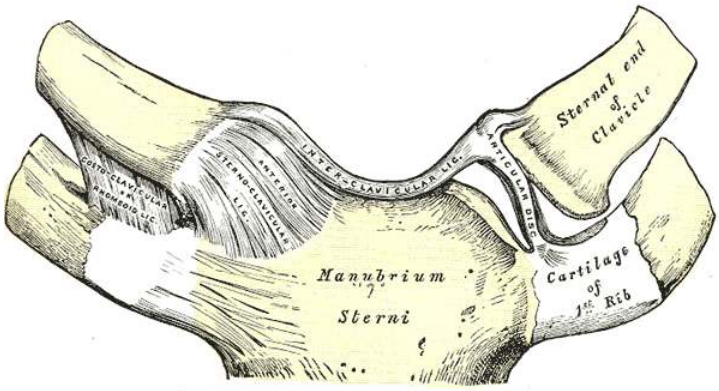
Above: Costovertebral articulations. Anterior view.

Sternal Joints

https://bio.libretexts.org/@go/page/53671



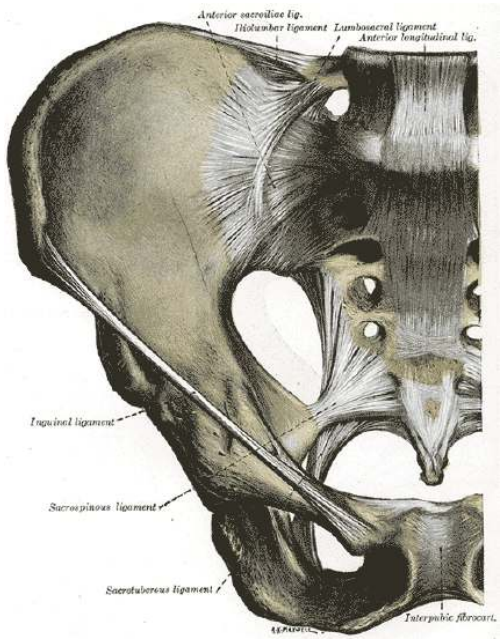
Above: Sternocostal and interchondral articulations. Anterior view.



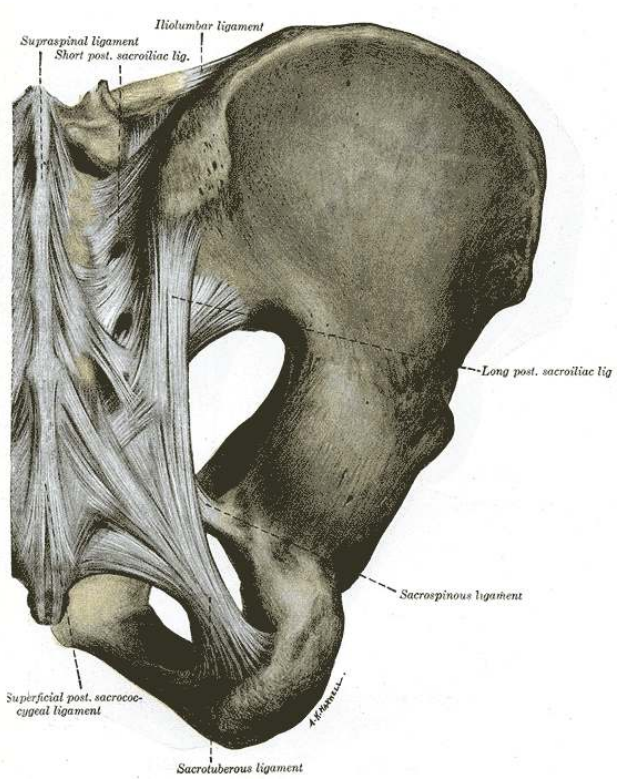
Above: Sternoclavicular articulation. Anterior view.

Pelvic Joints

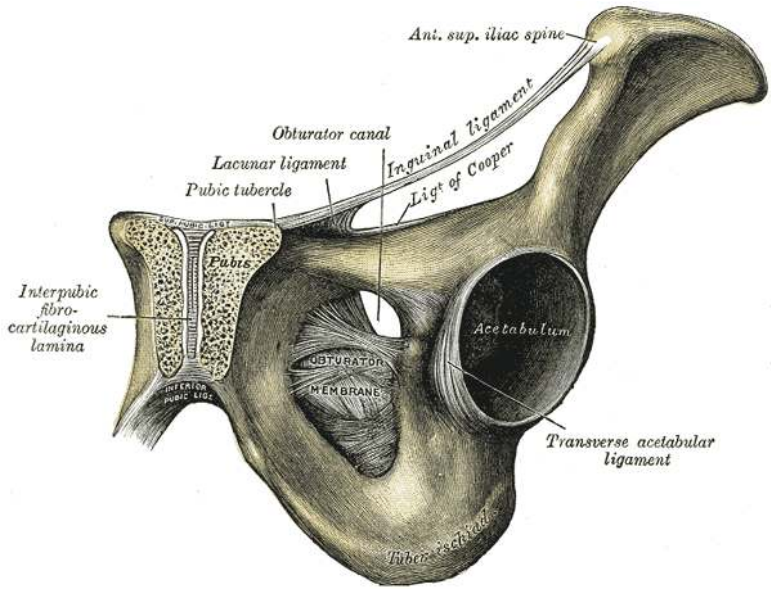
https://bio.libretexts.org/@go/page/53671



Above: Anterior articulations of pelvis.

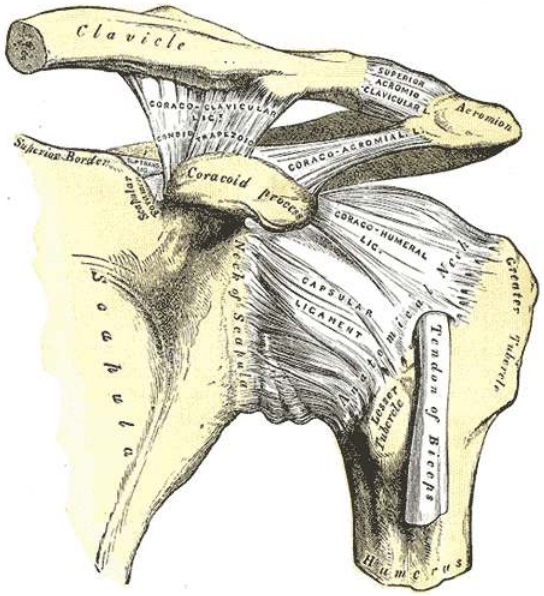


Above: Posterior articulations of pelvis.

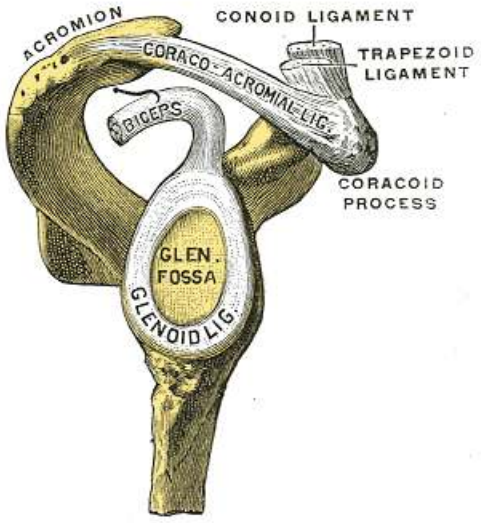


Above: Symphysis pubis exposed by a coronal section.

Shoulder Joints

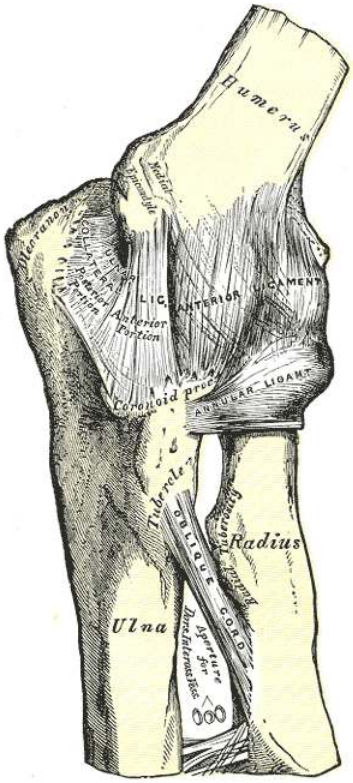


Above: The left shoulder and acromioclavicular joints, and the proper ligaments of the scapula.

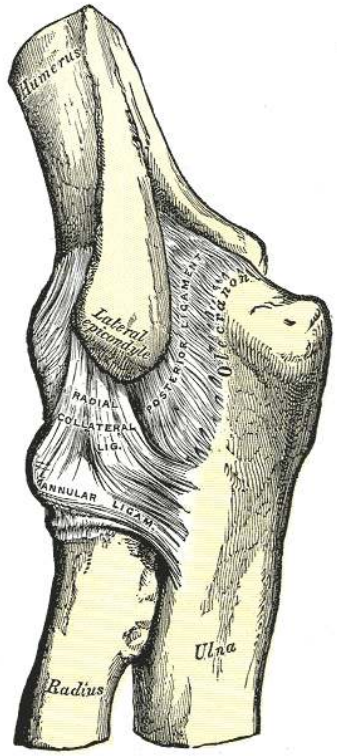


Above: Glenoid fossa of the right scapula. Lateral view.

Elbow Joint

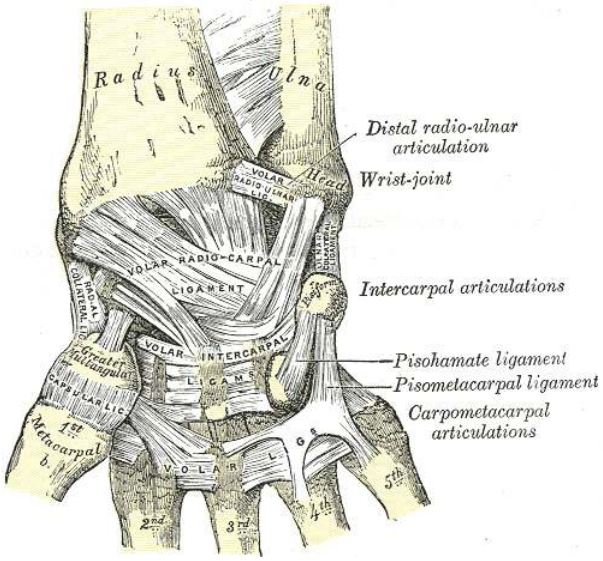


Above: Left elbow joint, showing anterior and internal ligaments

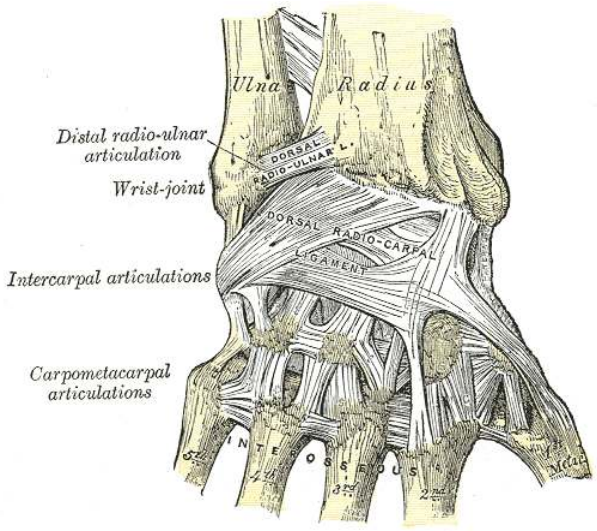


Above: Left elbow joint, showing posterior and external ligaments.

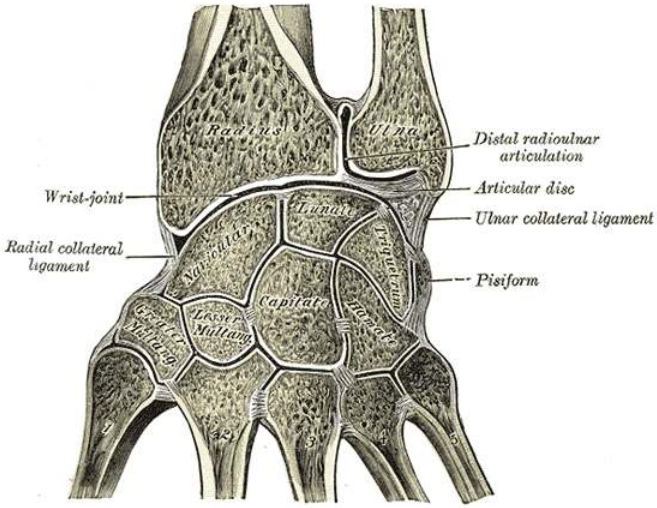
Hand Joints



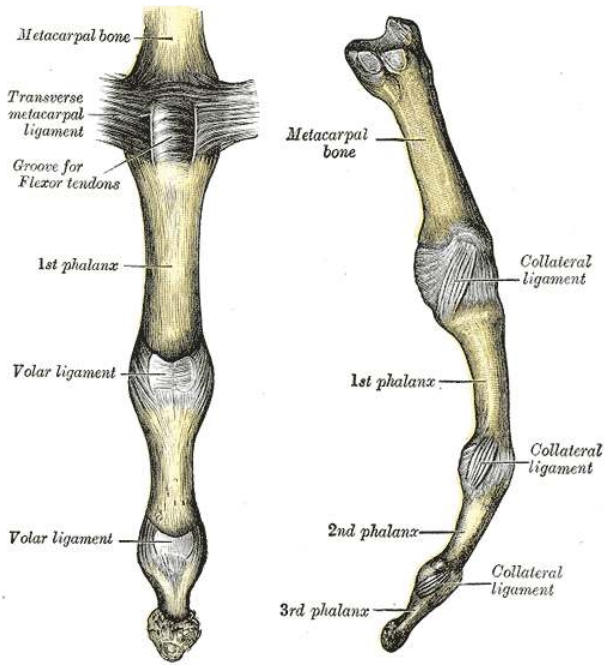
Above: Ligaments of the right wrist. Anterior view.



Above: Ligaments of the right wrist. Posterior view.

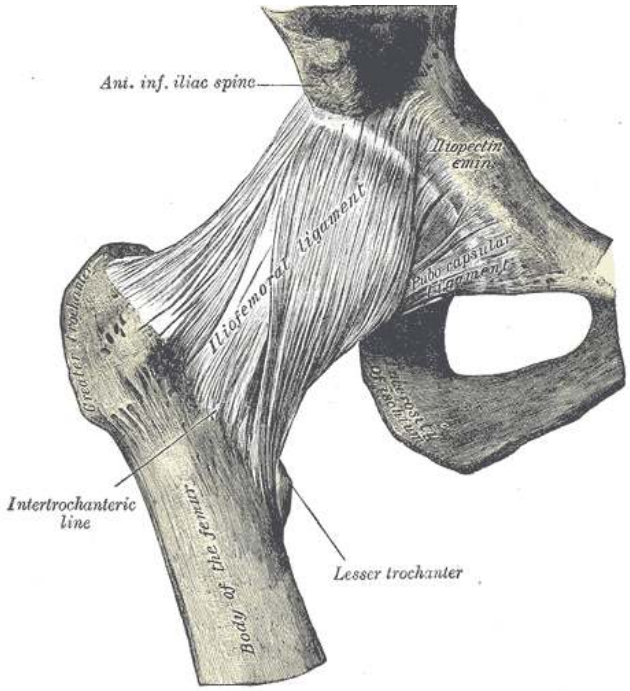


Above: Vertical section through the articulations at the wrist, showing the synovial cavities.

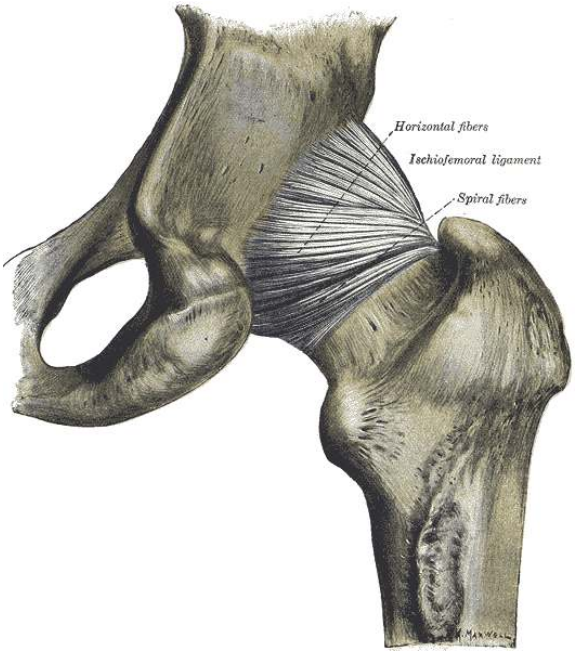


Above: Metacarpophalangeal articulation and articulations of digit. (Left) Volar aspect and (right) ulnar aspect.

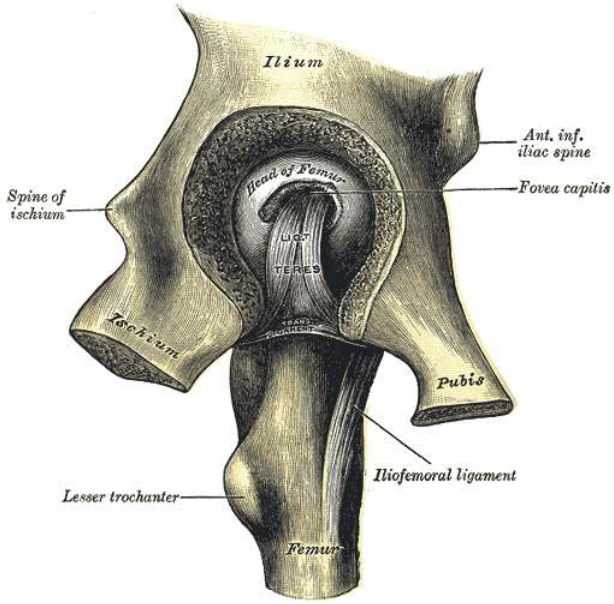
Hip Joint



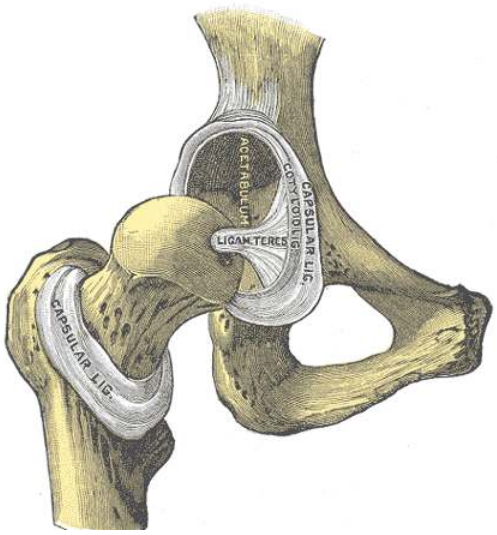
Above: Right hip-joint from the front.



Above: The hip-joint from behind.

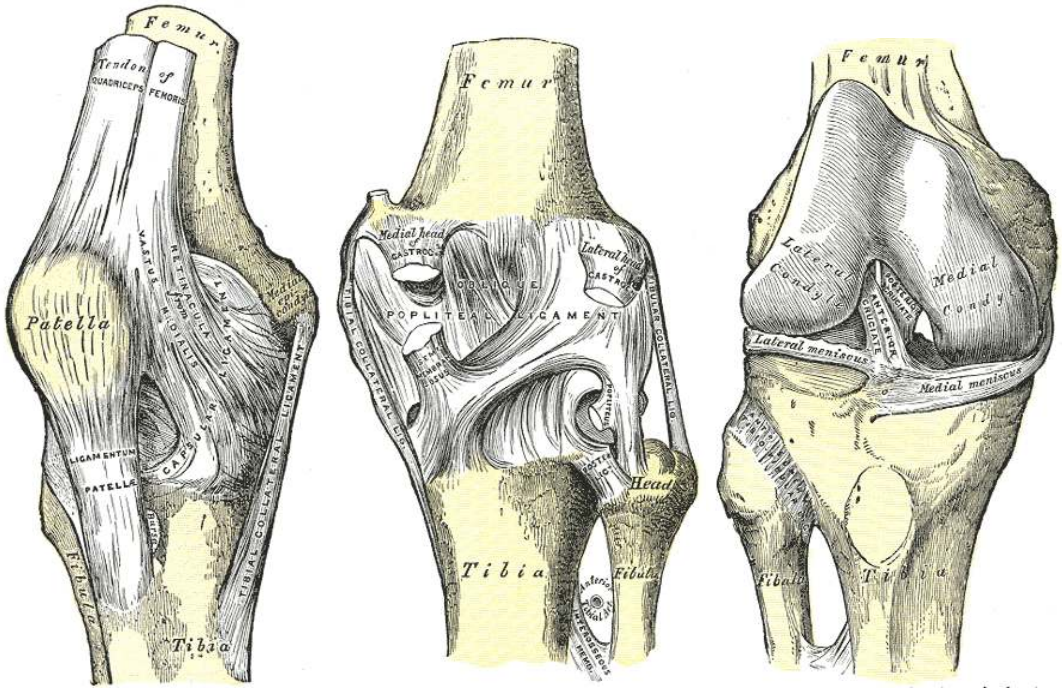


Above: Left hip-joint, opened by removing the floor of the acetabulum from within the pelvis.

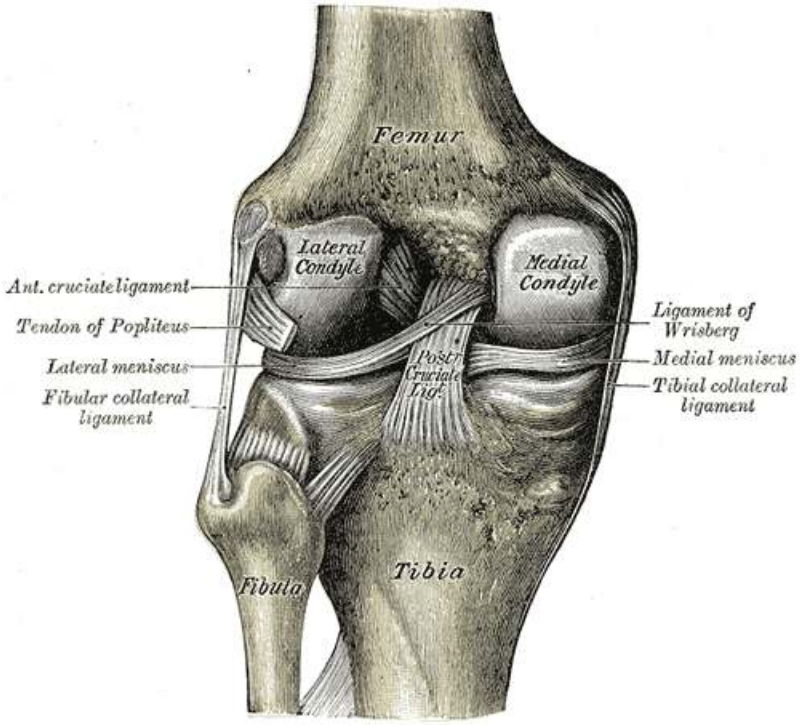


Above: Hip-joint, front view. The capsular ligament has been largely removed.

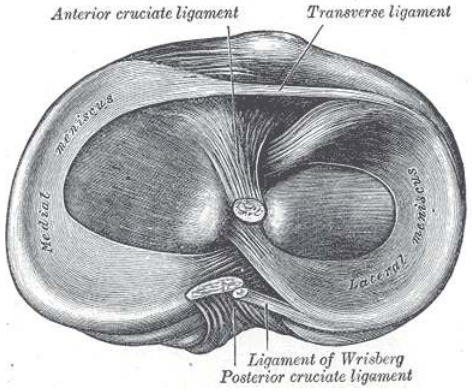
Knee Joint



Above: Right knee-joint. (Left) Anterior view, (middle and right) posterior view).

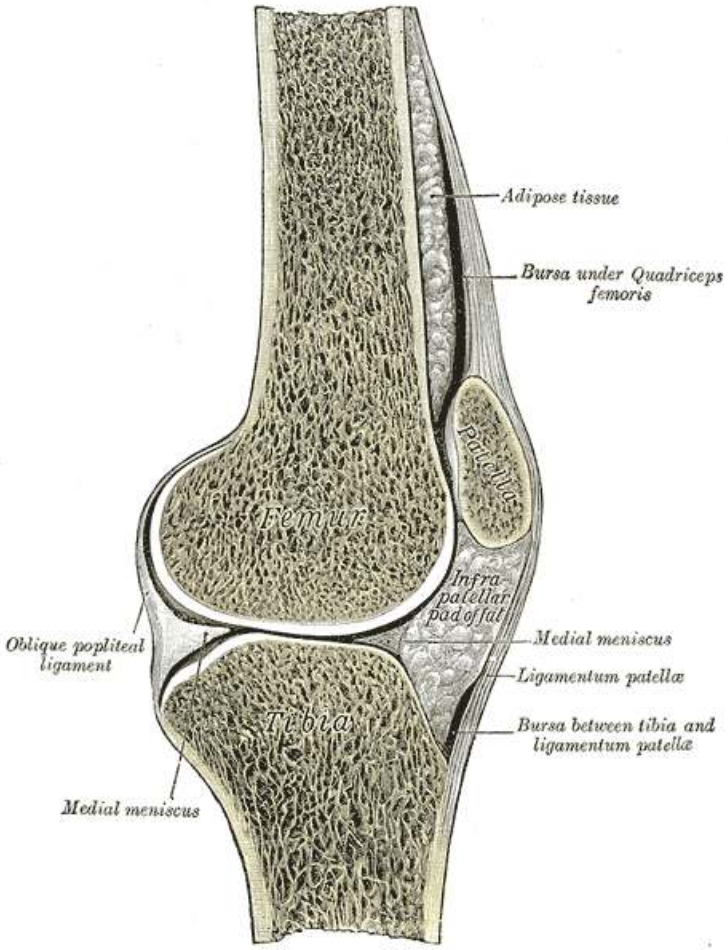


Above: Left knee-joint from behind, showing interior ligaments.



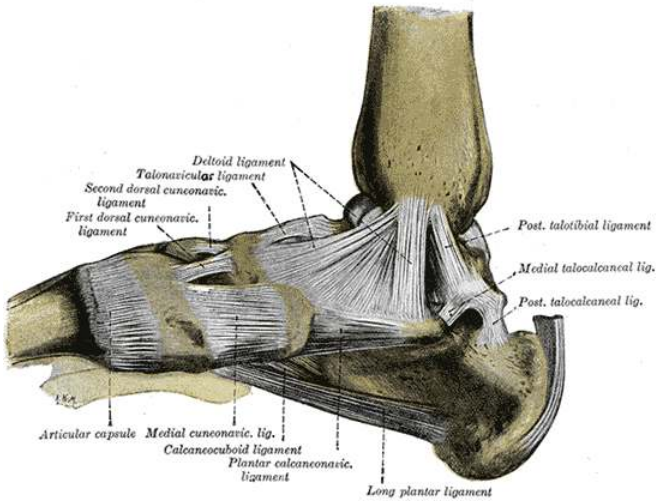
Above: Head of right tibia seen from above, showing menisci and attachments of ligaments.

https://bio.libretexts.org/@go/page/53671



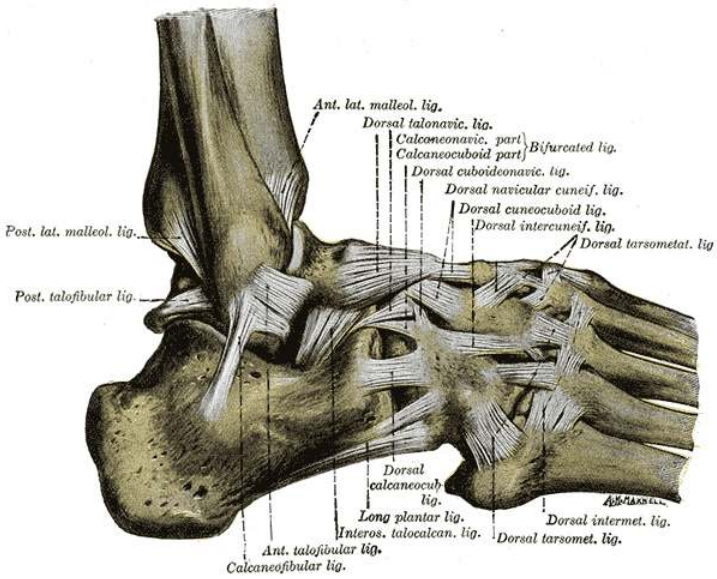
Above: Sagittal section of right knee-joint.

Foot Joints

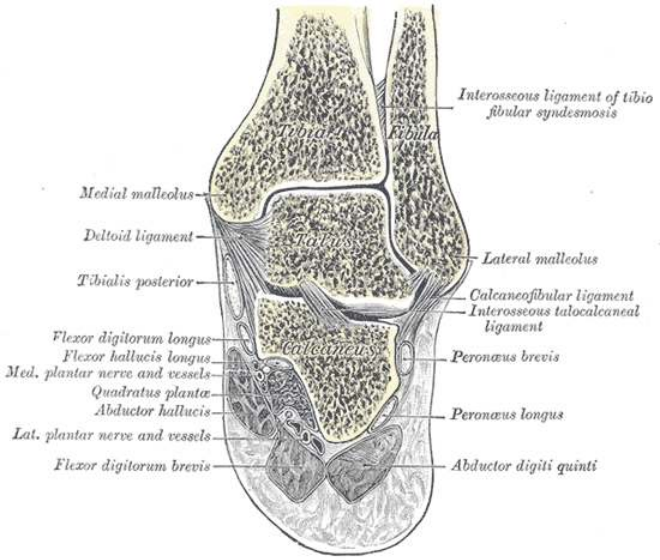


Above: Ligaments of the medial aspect of the foot.

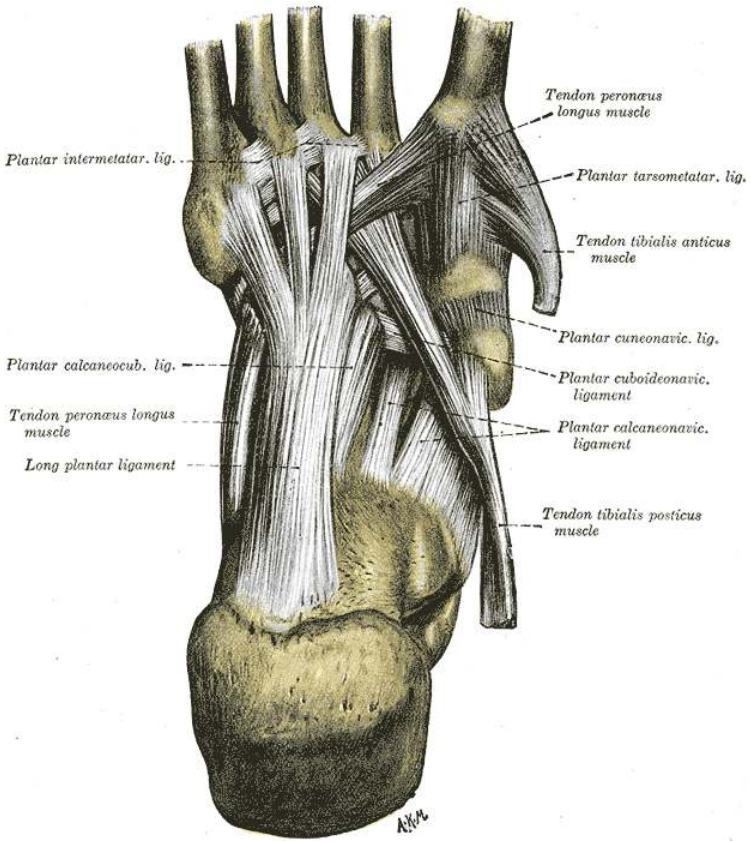
https://bio.libretexts.org/@go/page/53671



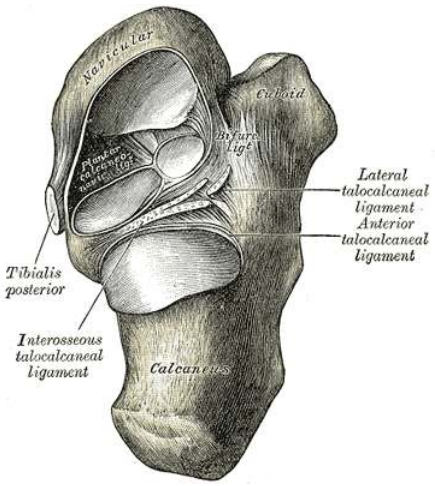
Above: The ligaments of the foot from the lateral aspect.



Above: Coronal section through right talocrural and talocalcaneal joints.

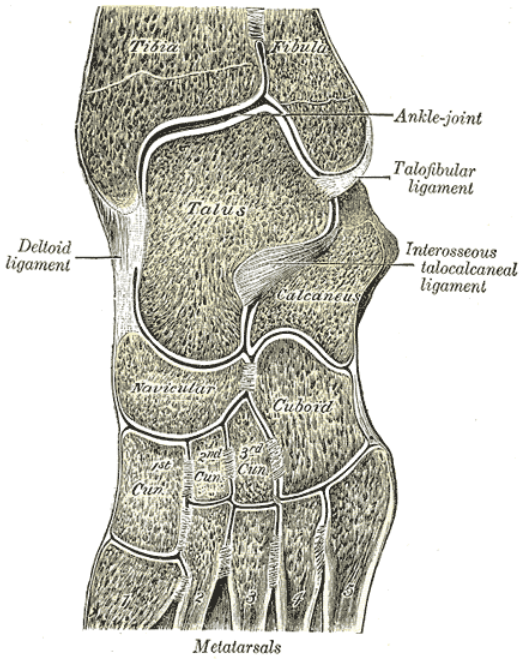


Above: Ligaments of the sole of the foot, with the tendons of the peroneus longus, tibialis posterior and tibialis anterior muscles.



Above: Talocalcaneal and talocalcaneonavicular articulations exposed from above by removing the talus.

https://bio.libretexts.org/@go/page/53671



Above: Oblique section of left intertarsal and tarsometatarsal articulations, showing the synovial cavities.

Attributions

- "Gray's Anatomy plates" by Henry Vandyke Carte is in the Public Domain

Updated 2026.

This page titled 10.3: Additional Reference Figures is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

10.4: Laboratory Activities and Assignment

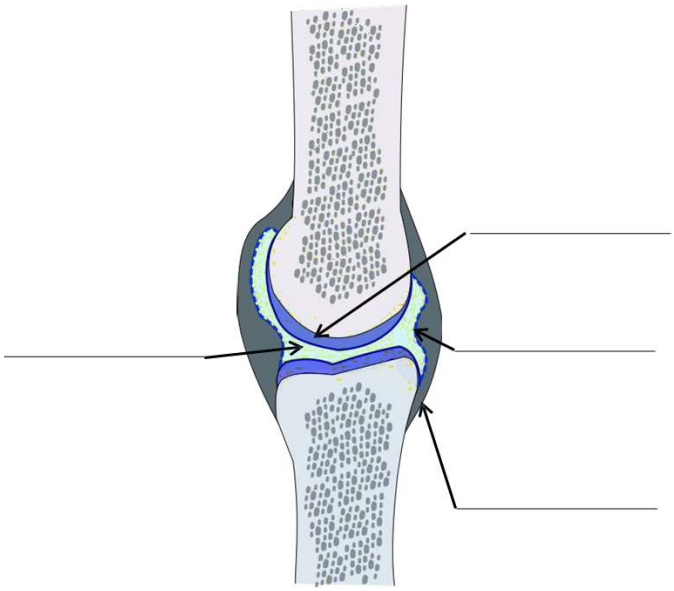
Laboratory Activities and Assignment

Part 1: Review of Articulations & Movements

Articulations

1. On the diagram below of a synovial joint, label the figure with the terms listed below:

• joint cavity • articular cartilages	• fibrous capsule • synovial membrane

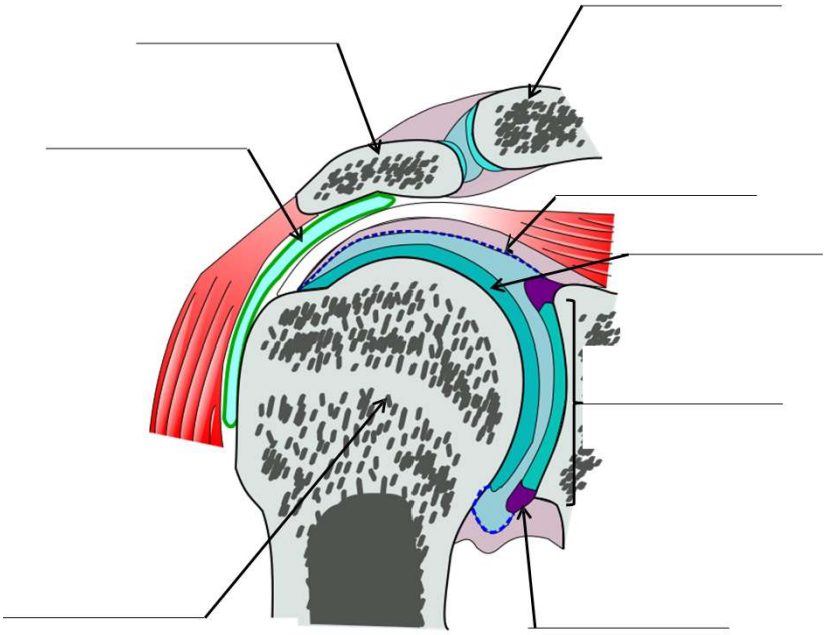


2. Create a diagram showing the relationships (i.e. show in diagram form which types of joints belong to the same categories and which ones do not) between the following types of joints:

• ball and socket • cartilaginous • condylar • fibrous • gomphosis	• hinge • pivot • plane • syndesmosis • saddle	• suture • synovial • synchondrosis • symphysis

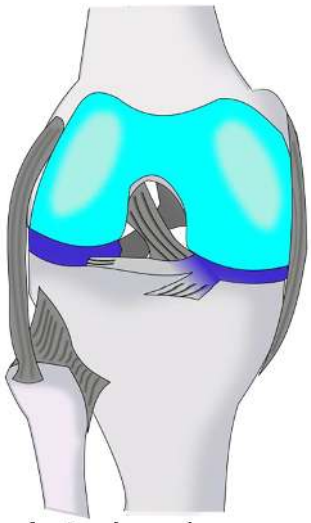
3. On the diagram below of the glenohumeral joint (shoulder), label the figure with the terms listed below:

• articular cartilage • clavicle • bursa	• glenoid labrum • synovial membrane • head of humerus	• glenoid cavity of scapula • acromion of scapula



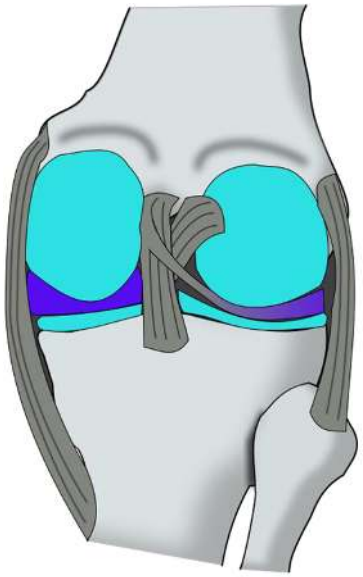
4. On the diagram below of the knee joint (anterior view), label the figure with the terms listed below:

• medial condyle • lateral condyle • medial collateral ligament	• lateral collateral ligament • medial meniscus • lateral meniscus	• anterior cruciate ligament • posterior cruciate ligament



5. On the diagram below of the knee joint (anterior view), label the figure with the terms listed below:

• anterior cruciate ligament • posterior cruciate ligament • medial collateral ligament	• lateral collateral ligament • medial meniscus • lateral meniscus	• medial condyle • lateral condyle

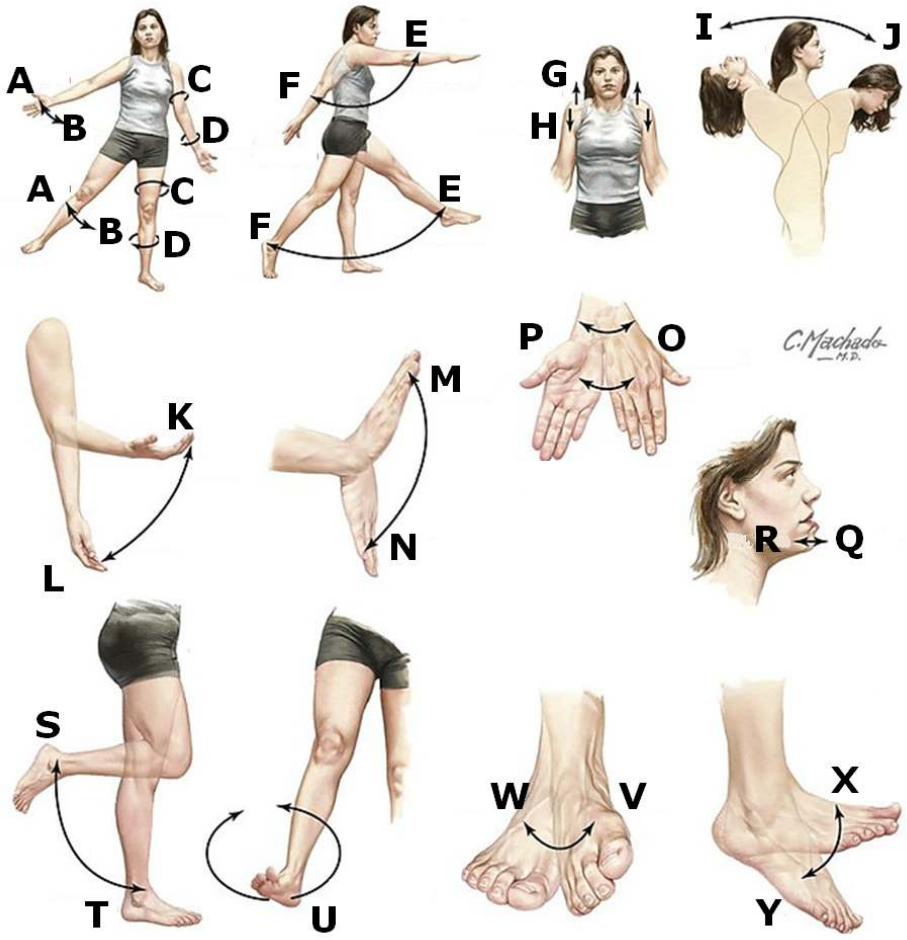


Posterior view

Movements

1. For each letter on the figure below, indicate the type of motion shown from the choices below. Some choices are used multiple times.

• abduction • adduction • circumduction • depression • dorsiflexion • elevation	• eversion • extension • flexion • inversion • lateral rotation • medial rotation	• plantar flexion • pronation • protrusion • retrusion • supination



A: _____	J: _____	R: _____
B: _____	K: _____	S: _____
C: _____	L: _____	T: _____
D: _____	M: _____	U: _____
E: _____	N: _____	V: _____
F: _____	O: _____	W: _____
G: _____	P: _____	X: _____
H: _____	Q: _____	Y: _____
I: _____		

Part 2: Articulation Laboratory Activities

1. Classify joints by structure and function. Inspect the anatomical models available to you. Classify the joints by structure and function. Also add the structural subcategory to your answers. Write your answers in the table provided below.

Structural Classifications & Subcategories:	**Functional Classifications:**

Structural Classifications & Subcategories:	Functional Classifications:
1. fibrous • suture • gomphosis • syndesmosis 2. cartilaginous • symphysis • synchondrosis 3. synovial • plane • ball and socket • hinge • pivot • condyloid • saddle	1. synarthrosis 2. amphiarthrosis 3. diarthrosis

Joint	Structural classification & Subcategories	Functional classification
atlantoaxial joint (C_1 and C_2)		
atlantooccipital joint (C_1 and occipital bone)		
coronal suture		
costochondral joint		
glenohumeral joint (shoulder)		
intervertebral joint		
knee joint		
radioulnar joint		
sagittal suture		
tibiofibular joint		
tooth joint		

2. Examine an anatomical model of a knee joint. Identify the following structures on the model.

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)	

Structure	Identified (✓/X)
synovial membrane	
tendon of rectus femoris	
tibia	

3. Use the anatomical model of a knee joint to label the images below with the structures listed:

- anterior cruciate ligament (ACL)
- bursae
- femur
- 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
- tendon of rectus femoris
- tibia



Part 3: Movement Laboratory Activities

1. Collaborating with your lab group, choose a body part for each of the movement terminologies below and physically move your body in this way. Describe how you moved for each below:

a. flexion:

b. extension:

c. circumduction:

d. elevation:

e. depression:

f. medial rotation:

g. lateral rotation:

h. dorsiflexion:

i. plantar flexion:

j. pronation:

k. supination:

l. inversion:

m. eversion:

n. protrusion:

o. retrusion:

p. opposition:

q. reposition:

2. With your lab group, move your body in each of the ways described below. Discuss these movements with your lab group and describe these movements using anatomical movement terminologies. You will need to use multiple movement terms for each:

a. Walking:

b. Stand and pivot your entire body to stand facing the direction to your right:

c. Beginning in a normal standing position, move your arms as if you were doing a jumping jack:

d. Simulate the movements you would do to grab a frying pan from a counter and move it to the stove:

Attributions

Part 1: Review of Articulations & Movements

- "Anatomy and Physiology Lab Homework" by Laird C Sheldahl is licensed under CC BY-SA 4.0
- "Anatomy and Physiology Lab Reference" by Laird C Sheldahl, OpenOregonEducational Resources, Mt. Hood Community College is licensed under CC BY-SA 4.0
- "Introduction to Anatomy" by Paul Hudson is licensed under CC BY-NC-SA 4.0

Part 2: Articulation Laboratory Activities

- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0

Updated 2026.

This page titled 10.4: Laboratory Activities and Assignment is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

CHAPTER OVERVIEW

11: Introduction to Skeletal Muscles

11.1: Introduction
11.2: Microscopic Anatomy of Skeletal Muscles
11.3: Macroscopic Anatomy of Skeletal Muscles
11.4: Laboratory Activities and Assignment

This page titled 11: Introduction to Skeletal Muscles is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

11.1: Introduction

Introduction

The best-known feature of skeletal muscle is its ability to contract and cause movement. Skeletal muscles act not only to produce movement but also to stop movement, such as resisting gravity to maintain posture. Small, constant adjustments of the skeletal muscles are needed to hold a body upright or balanced in any position. Muscles also prevent excess movement of the bones and joints, maintaining skeletal stability and preventing skeletal structure damage or deformation. Joints can become misaligned or dislocated entirely by pulling on the associated bones; muscles work to keep joints stable. Skeletal muscles are located throughout the body at the openings of internal tracts to control the movement of various substances. These muscles allow functions, such as swallowing, urination, and defecation, to be under voluntary control. Skeletal muscles also protect internal organs (particularly abdominal and pelvic organs) by acting as an external barrier or shield to external trauma and by supporting the weight of the organs.

Below are some important terminologies to be familiar with when learning about the skeletal muscles:

- **innervation**: nerves present in the tissue (in this case, stimulating a muscle to contract)
- **contraction**: the process of a muscle becoming shorter and tighter; caused by activated nerves
- **relaxation**: the process of a muscle becoming longer and looser; caused by lack of activated nerves
- **action**: a movement caused by muscle contraction
- **origin**: the end of the muscle attached to a fixed (stabilized) bone
- **insertion:** the end of the muscle that attaches to the bone being pulled/moved
- **tendon**: strong fibrous tissue that attaches muscle to bone
- **prime mover / agonist**: the principle muscle involved in a movement

Attributions

- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0

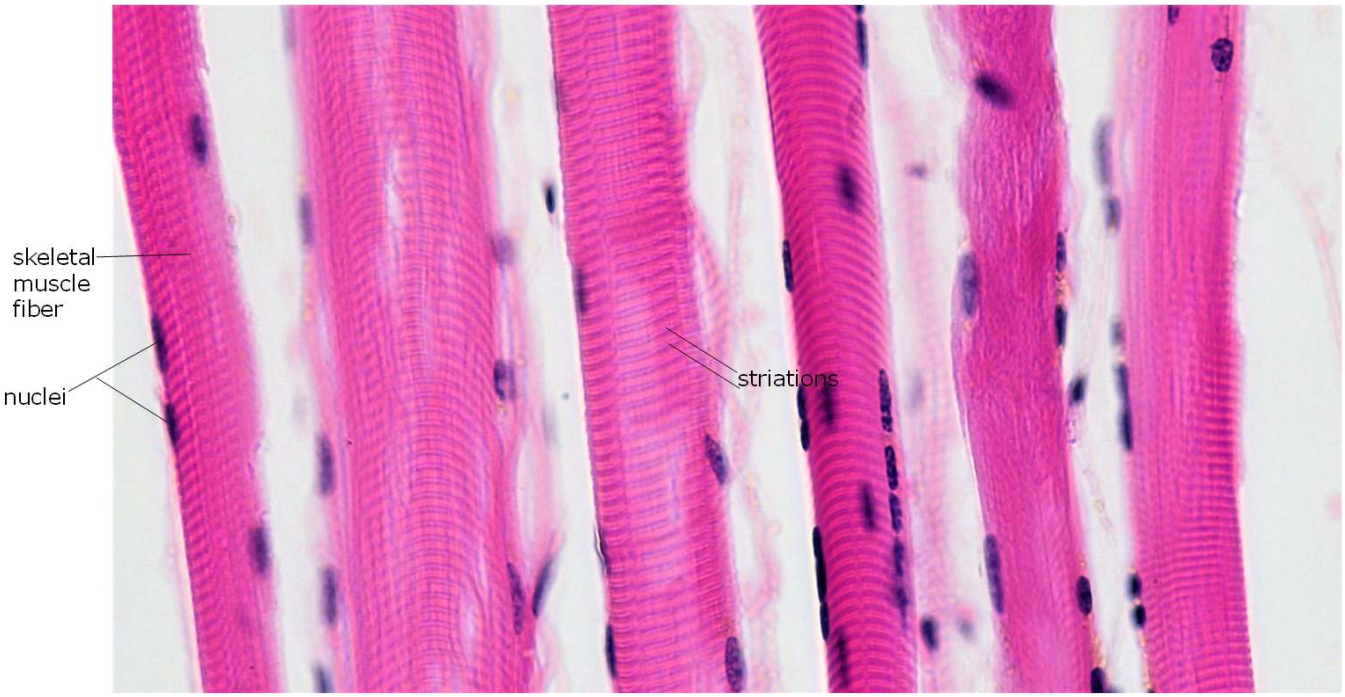
Updated 2026.

This page titled 11.1: Introduction is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

11.2: Microscopic Anatomy of Skeletal Muscles

Microscopic Anatomy of Skeletal Muscles

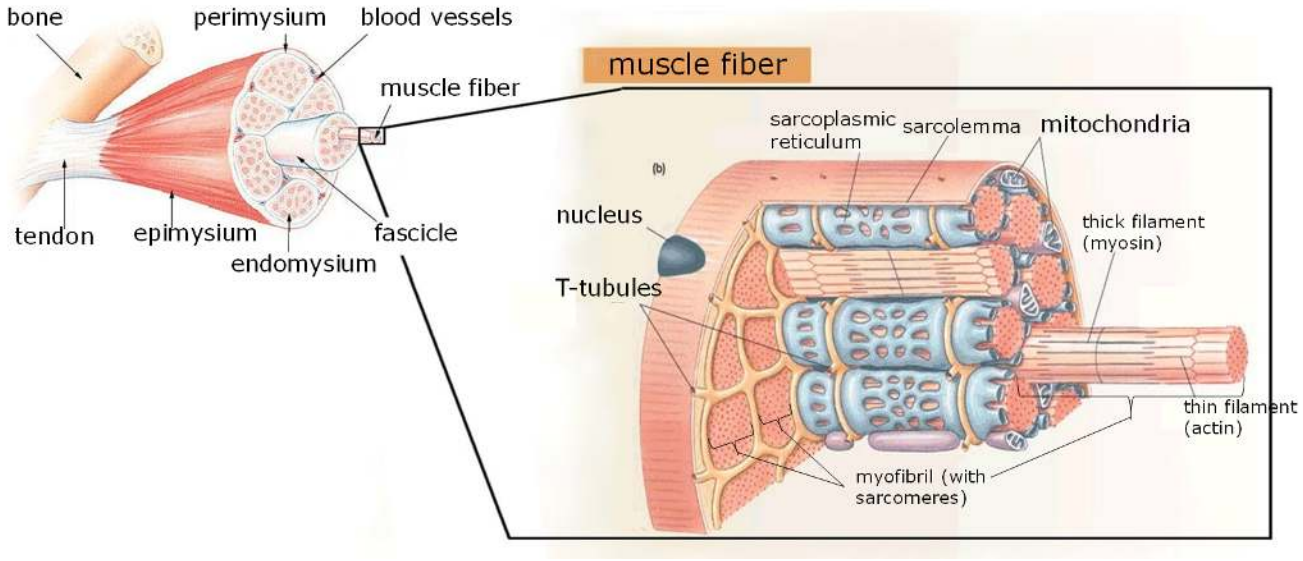
Skeletal muscle is found attached to bones. It consists of long **multinucleate** fibers. The fibers run the entire length of the muscle they come from and so are usually too long to have their ends visible when viewed under the microscope. The fibers are relatively wide and very long, but **unbranched**. Fibers are formed from the fusion of thousands of precursor cells. This is why they are so long and why individual fibers are multinucleate (a single fiber has many nuclei). The nuclei are usually up against the edge of the fiber. There are **striations** in skeletal muscle. These are alternating dark and light bands perpendicular to the edge of the fiber that are present all along the fiber.



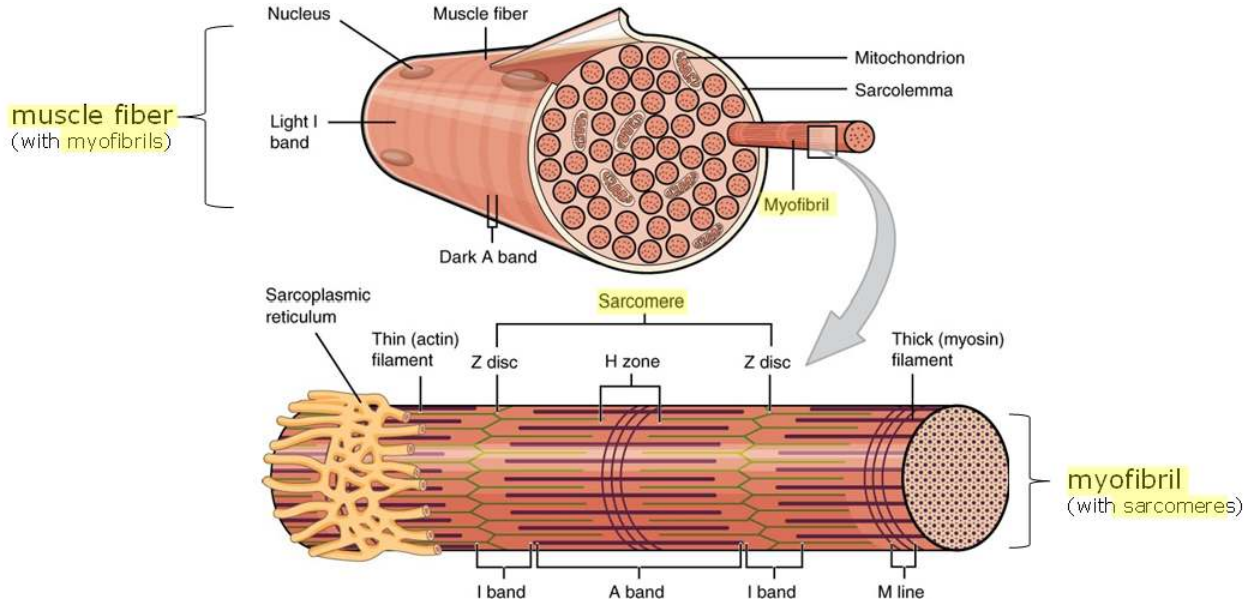
Above: Skeletal muscle fibers, teased, longitudinal view. Tissue magnified by 200x.

Skeletal muscles are bundles of **fascicles** (bundles of muscle fibers) surrounded by **epimysium** (fibrous elastic tissue). Fascicles are bundles of **muscle fibers** surrounded by **perimysium** (connective tissue). A single muscle fiber is surrounded by a layer of endomysium (areolar connective tissue). The plasma membrane of a muscle fiber is called the **sarcolemma** and these cells contain specialized endoplasmic reticulum called **sarcoplasmic reticulum**. Each muscle fiber is a multinucleated structure composed **myofibrils**, long cylinder-shaped cell structures composed of **actin** and **myosin** filaments, protein fibers capable of contraction. Myofibrils have repeating **sarcomeres** causing the **striations** (banding pattern) observed with a microscope. Sarcomeres are the functional units of skeletal muscles enabling contraction to occur when actin and myosin filaments cross-link and the myosin heads bend in a power stroke causing an increased overlap in the actin and myosin filaments resulting in shortening of the sarcomere (contraction).

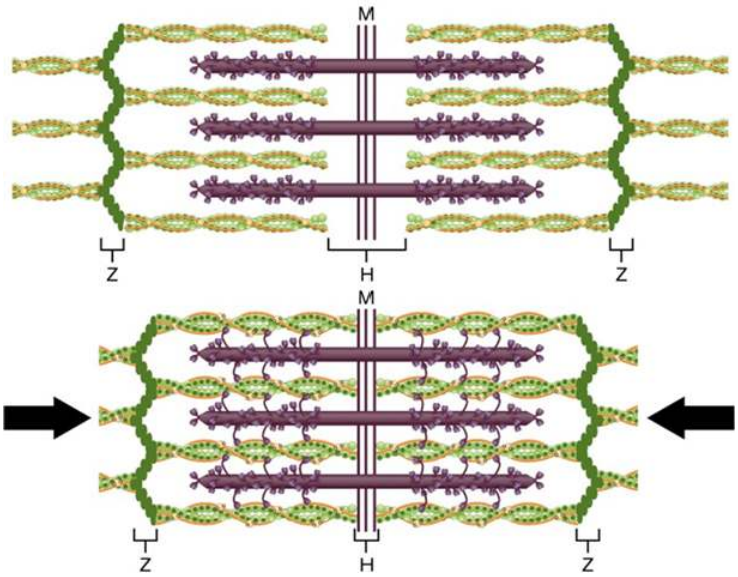
Muscle contraction occurs as a result of many sarcomeres within many myofibrils cross-linking and pulling on each other to shorten the sarcomere. The dark region of a striation (made of a sarcomere) is composed of the thicker myosin filaments with some actin overlap (the **A band**). The lighter region of a striation is where only actin filaments, the thinner filaments, are present (the **I band**). Myosin filaments connect with each other at the **M line** and actin filaments connect with each other at the **Z disc**. A single sarcomere unit begins at one Z disc and ends at another Z disc with the M line in the center of the sarcomere. The **H zone** in the center of the A band is a region where only myosin filaments, and no actin filaments, are present. For this reason, the H zone appears as a light band in the center of each dark band in the striations of skeletal muscle (see microscopic image of skeletal muscle below).



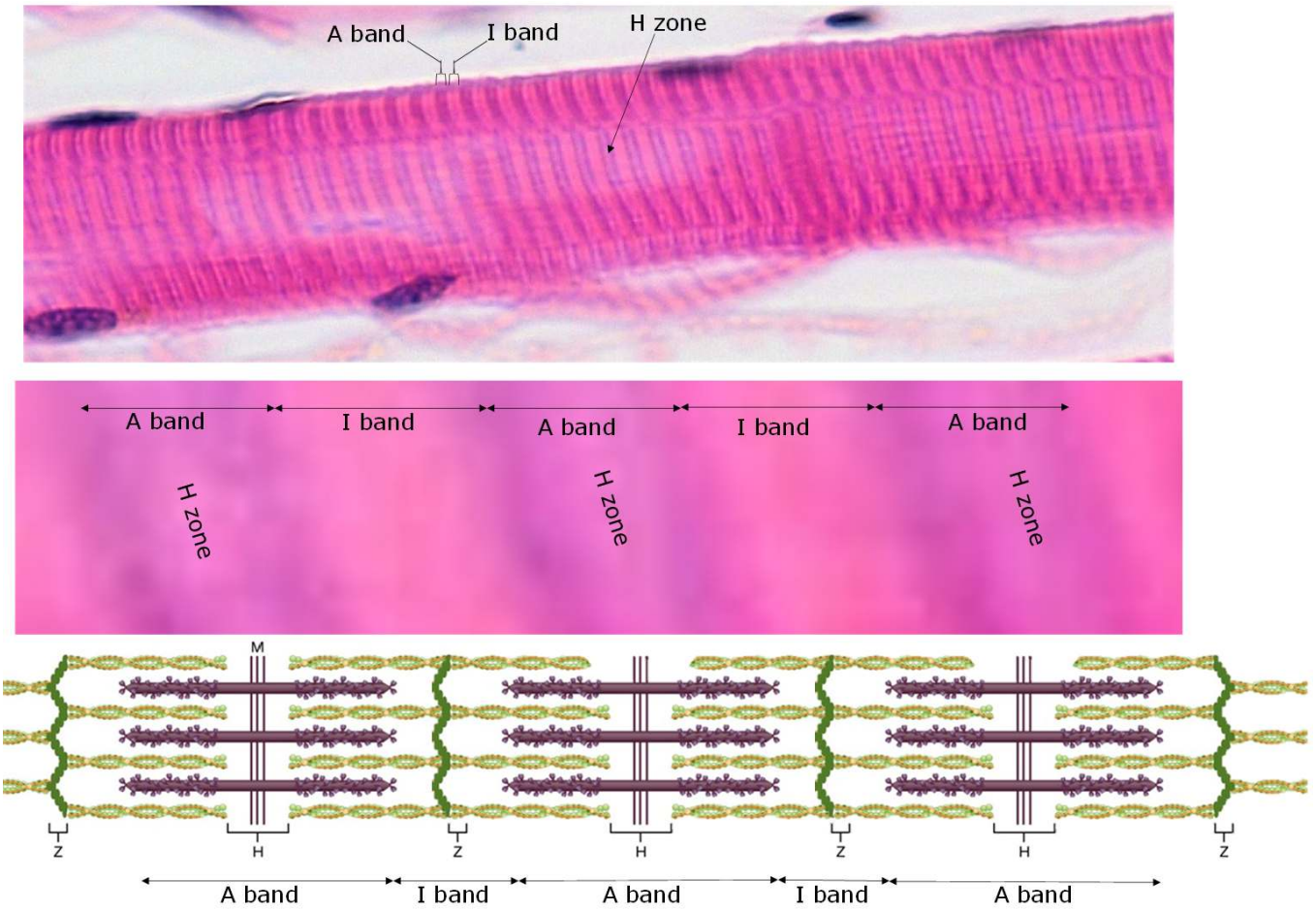
Above: The structure of a skeletal muscle and its muscle fibers.



Above: Muscle fibers are cells composed of multiple myofibrils, bundles of actin and myosin filaments that cross-link for contraction. Each myofibril is composed of units called sarcomeres, repeating structures of actin and myosin responsible for muscular contraction. In this diagram, myosin is shown in purple and actin is shown in green.

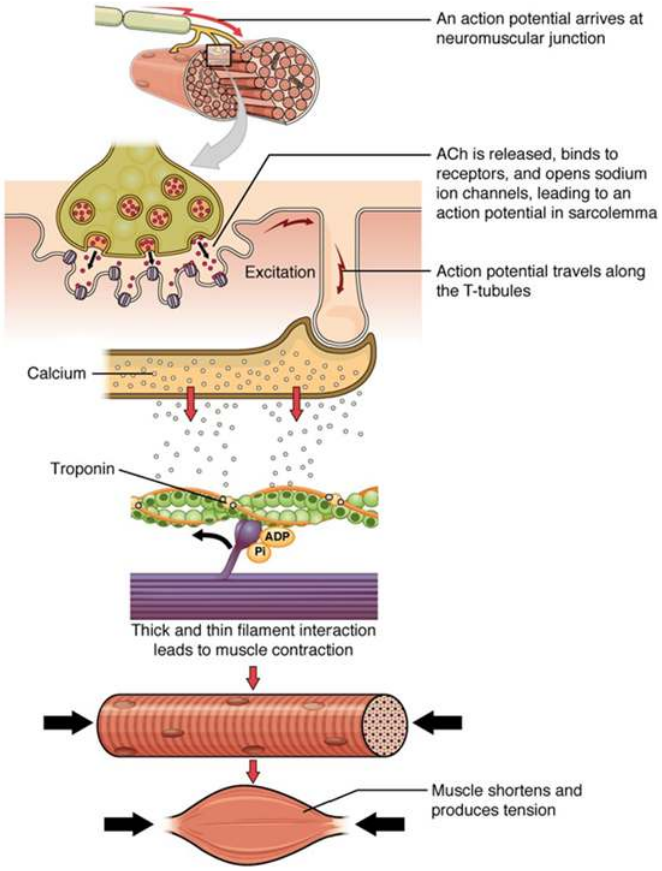


Above: A single sarcomere (top) relaxed and (bottom) contracted. The purple filaments are myosin and the green are actin. When the myosin heads cross-link with actin and undergo the power stroke (myosin heads move), the overlap between actin and myosin increases and the entire sarcomere structure becomes smaller (contraction).

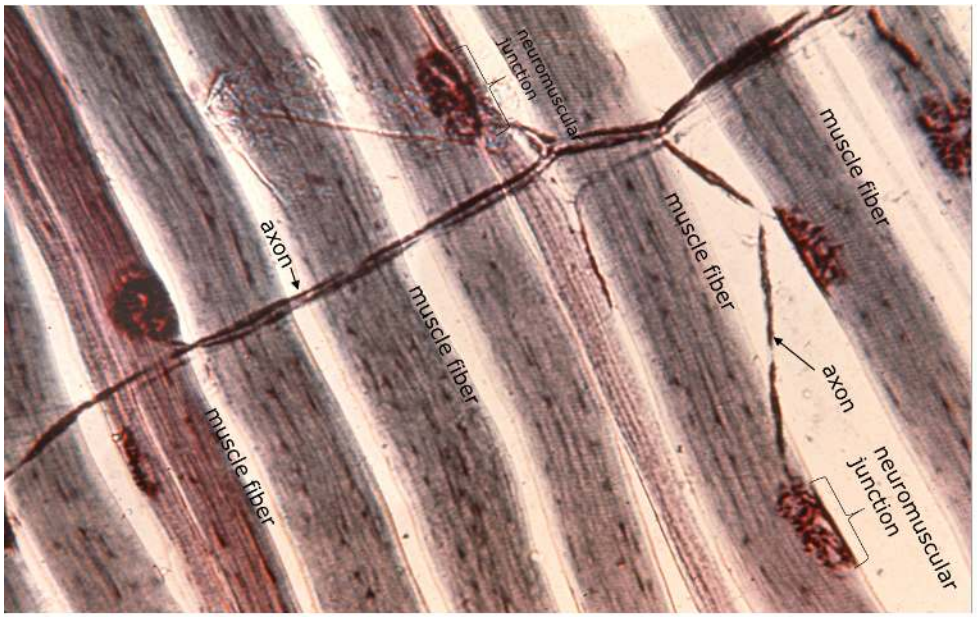


Above: (Bottom) Diagram shows the structure of a myofibril with repeating sarcomeres and how this corresponds with the striations of skeletal muscle (top and middle; middle is top image highly zoomed into striations).

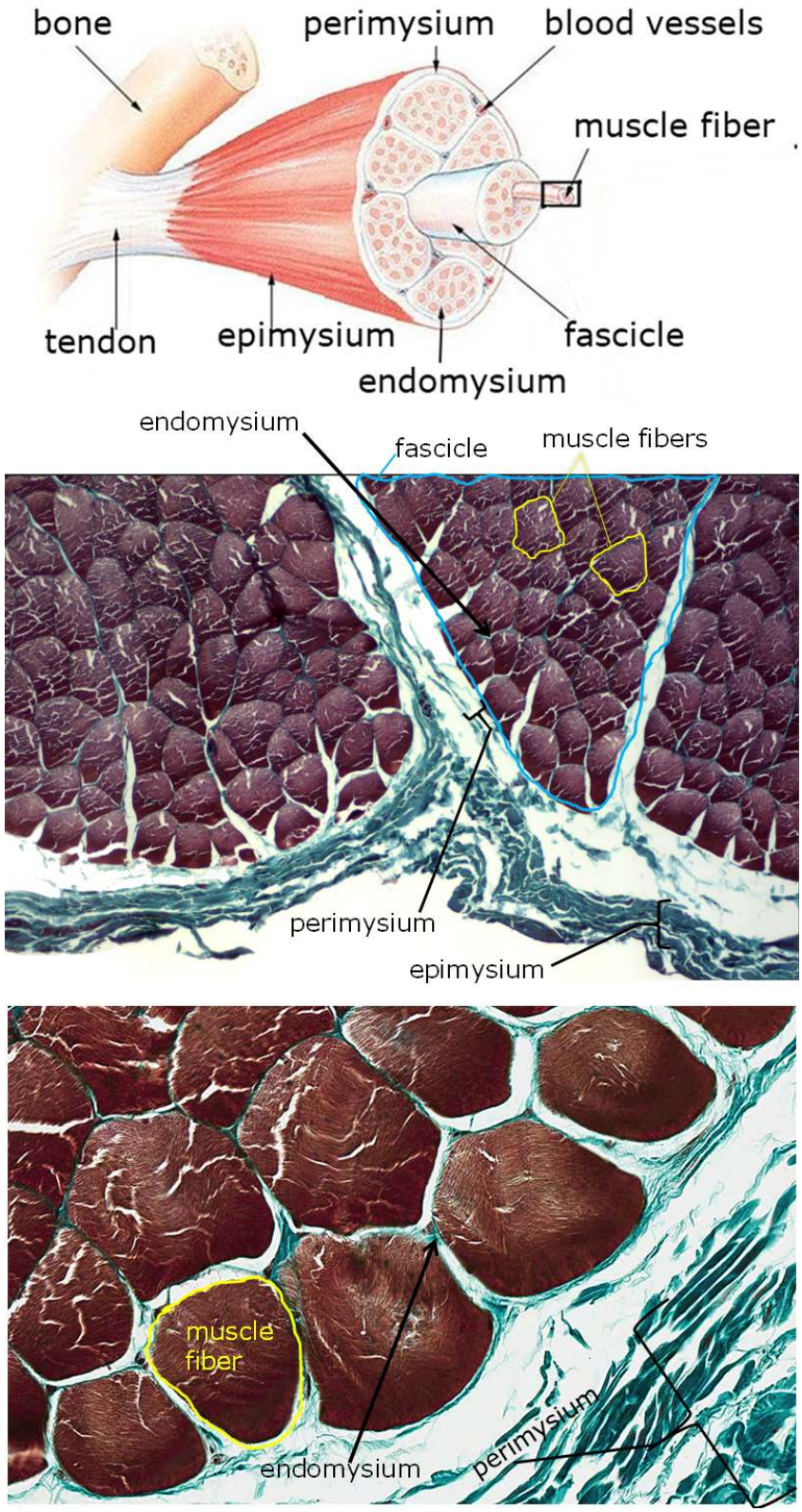
A series of events resulting in muscular contraction begins with an **action potentia**l from a **motor neuron** at a **neuromuscular junction**. When the action potential reaches the synaptic terminal at the neuromuscular junction, acetylcholine, a **neurotransmitter**, is released from vesicles from the neuron triggering a chain reaction that orchestrates sodium channels in the **sarcolemma** (plasma membrane of a muscle fiber) to trigger release of calcium from sarcoplasmic reticulum enabling myosin heads to crosslink with actin to initiate contraction. This causes the sarcomeres in nearby myofibrils to crosslink and initiate the power stroke causing the myofibrils to become shorter, thereby pulling the entire muscle and causing it to become shorter.



Above: Sequence of events beginning with an action potential from a neuron resulting in muscular contraction.



Above: Microscopic image of skeletal muscle fibers with multiple axons and neuromuscular junctions.



Above: (Middle and bottom) Microscopic images of muscle cross sections at 100x (middle) and at 400x (bottom). The structures in these microscopic images correspond with the illustration showing structures of skeletal muscle (top).

Attributions

- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0
- "Anatomy and Physiology Lab Homework" by Laird C Sheldahl is licensed under CC BY-SA 4.0
- "Animal Tissues and Organs" by Berkshire Community College Bioscience Image Library is in the Public Domain, CC0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0
- "Skeletal muscle and fiber.jpg" by Abdulrahman112 is in the Public Domain, CC0 / A derivative from the original work

Updated 2026.

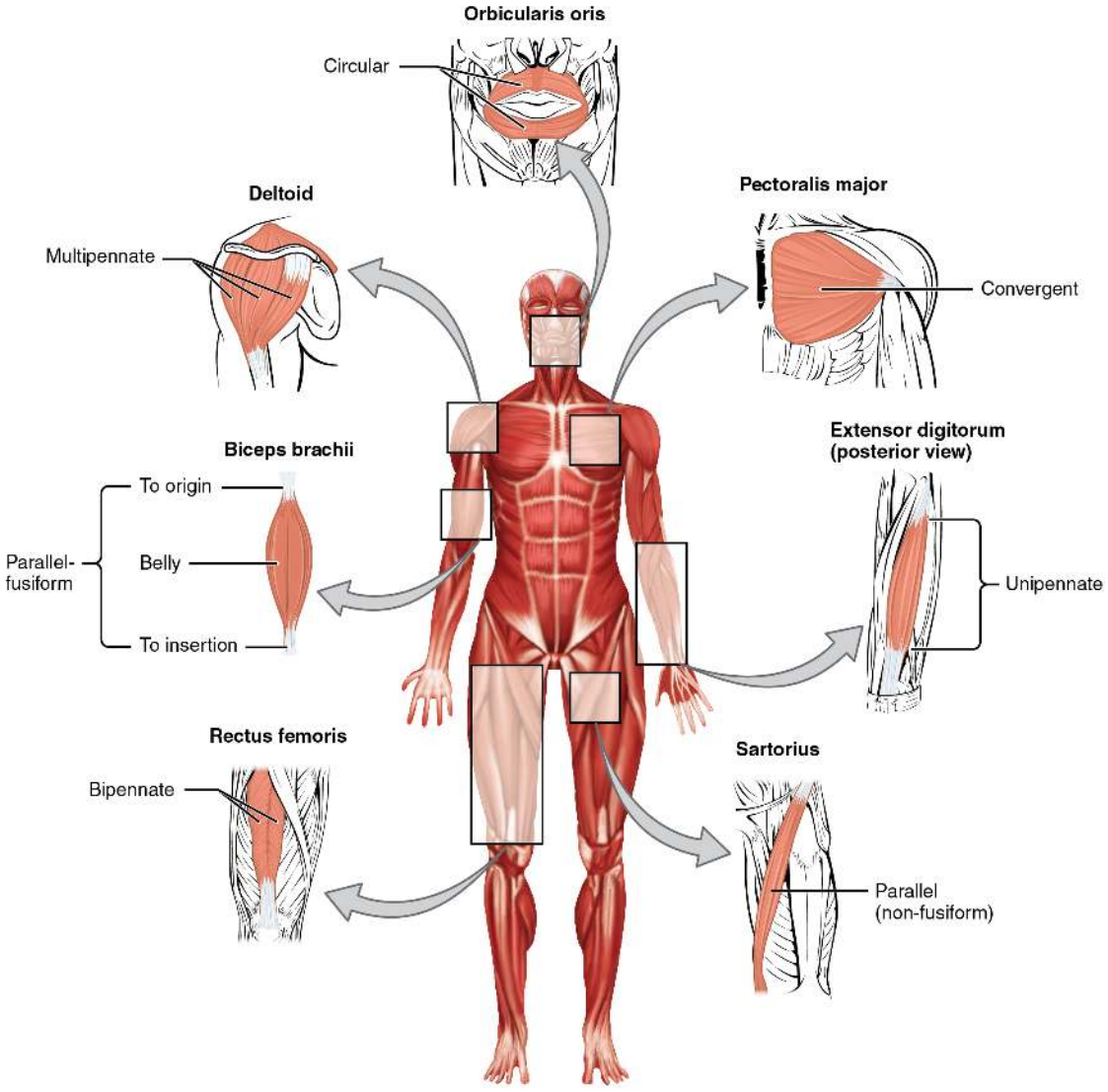
This page titled 11.2: Microscopic Anatomy of Skeletal Muscles is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

11.3: Macroscopic Anatomy of Skeletal Muscles

Macroscopic Anatomy of Skeletal Muscles

Arrangement of the fascicles in skeletal muscles have certain patterns and arrangements including:

- **circular muscle:** fascicles arranged in a circle (also called **sphincters**)
- **convergent muscle:** broad muscle with fascicles converging in a single point of attachment
- **parallel fusiform muscle:** muscle with rounded middle with the fascicles parallel to each other
- **parallel non-fusiform muscle:** flat muscle with the fascicles parallel to each other
- **unipennate muscle:** fascicles branch off a central tendon like one side of a feather
- **bipennate muscle:** fascicles branch off a central tendon on two sides like a feather
- **multipennate muscle:** fascicles branch off a central tendon on more than two sides in a feather-like pattern



Above: Shape and arrangement patterns of fascicles in different skeletal muscles.

Names of skeletal muscles are diverse and may be based on the shape of the muscle, its origin and insertion, its action, its location, its size, or its direction. Here are some terms you will see when learning the skeletal muscles and their meanings:

- **adductor:** causes adduction
- **brevis:** short muscle
- **extensor:** causes extension

- **flexor:** causes flexion
- **longus:** long muscle
- **major:** larger muscle than another (the **minor**)
- **maximus:** the largest
- **minimus:** the smallest
- **minor:** smaller muscle than another (the **major**)
- **oblique:** fascicles travel at an oblique angle (large angle)
- **pronator:** causes pronation
- **rectus:** "rectus" means "straight" and therefore refers to a straight shape where fascicles are parallel
- **transverse:** fascicles travel at a right angle (90°)
- **vastus:** "great" or larger muscle

Attributions

- "Fascicle Muscle Shapes.jpg" by OpenStax College is licensed under CC BY-SA 3.0

Updated 2026.

This page titled 11.3: Macroscopic Anatomy of Skeletal Muscles is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

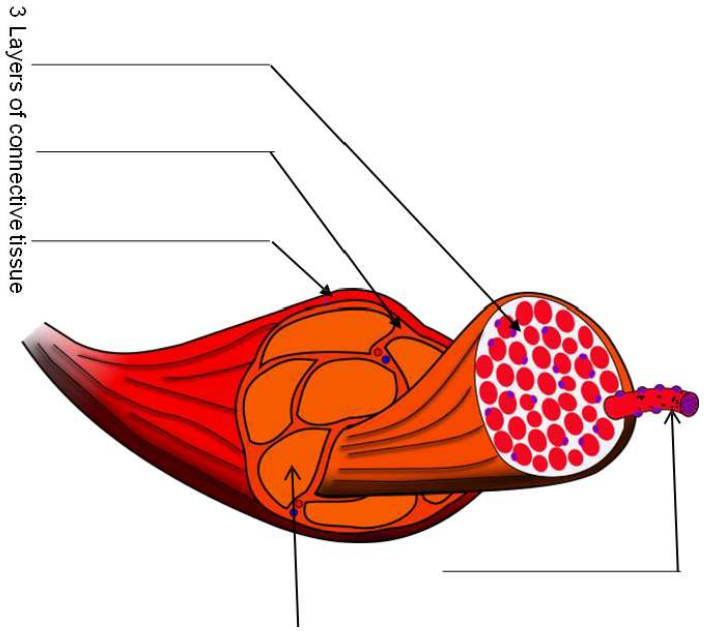
11.4: Laboratory Activities and Assignment

Laboratory Activities and Assignment

Part 1: Review of Introduction to Skeletal Muscles

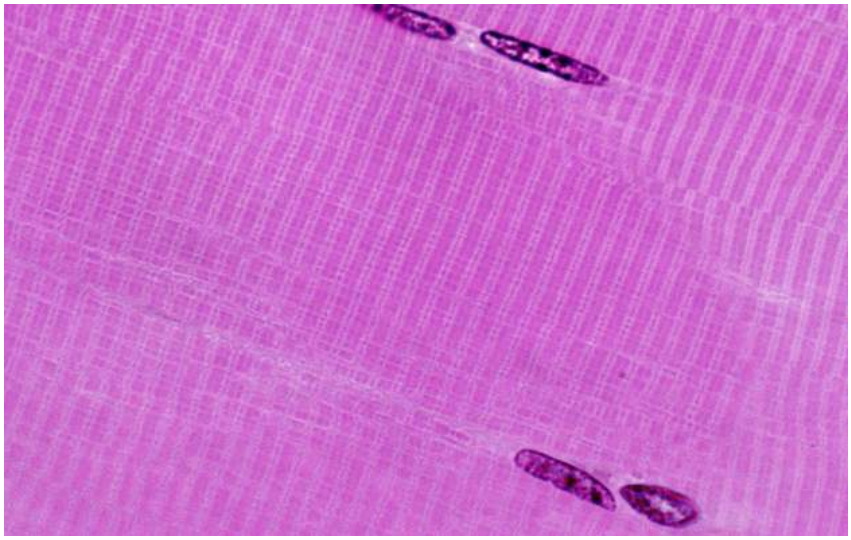
1. Label the figure showing the structure of a skeletal muscle below with the following terms:

• epimysium • perimysium	• endomysium • fascicle	• muscle fiber



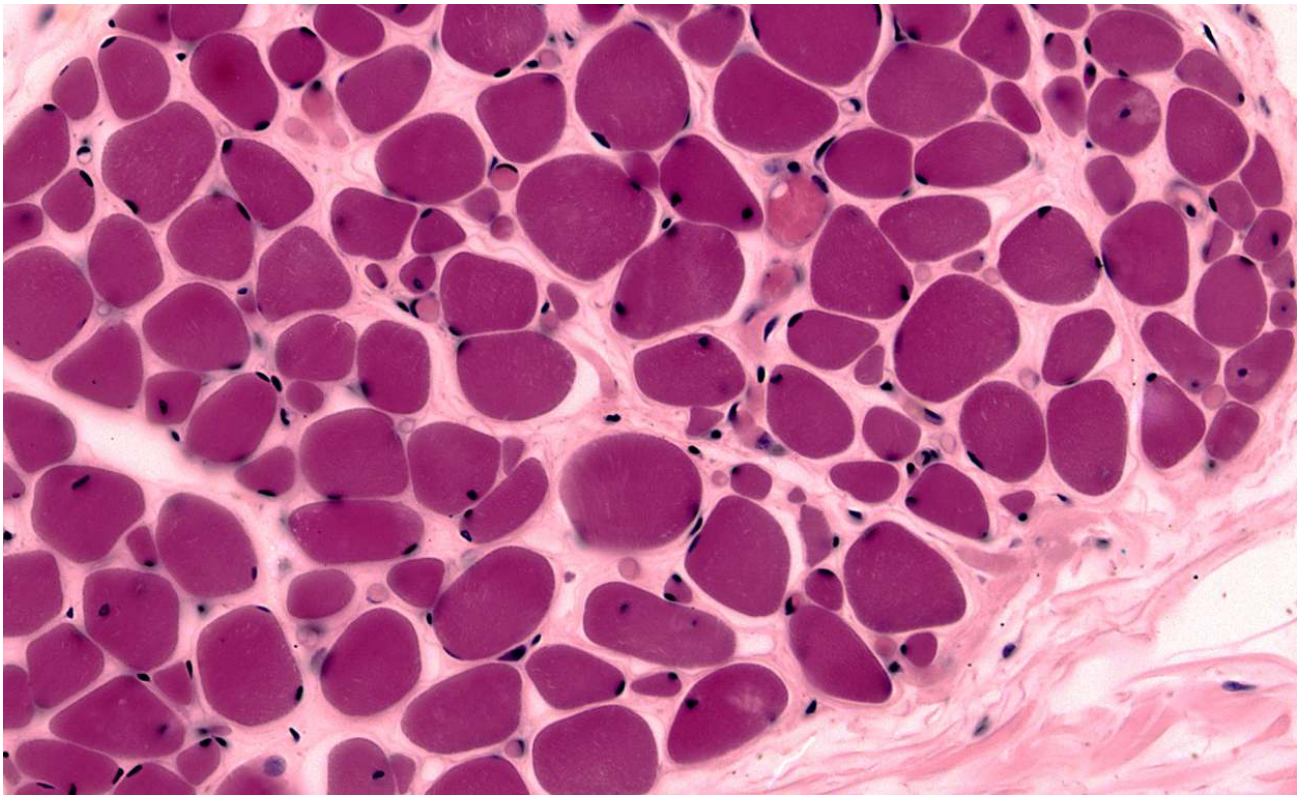
2. Below is a microscopic image of a longitudinal view of muscle fibers magnified by 1000x. Label the following structures on the image:

• muscle fiber • striations	• nuclei • A band	• I band • H zone • Z disc (challenge)



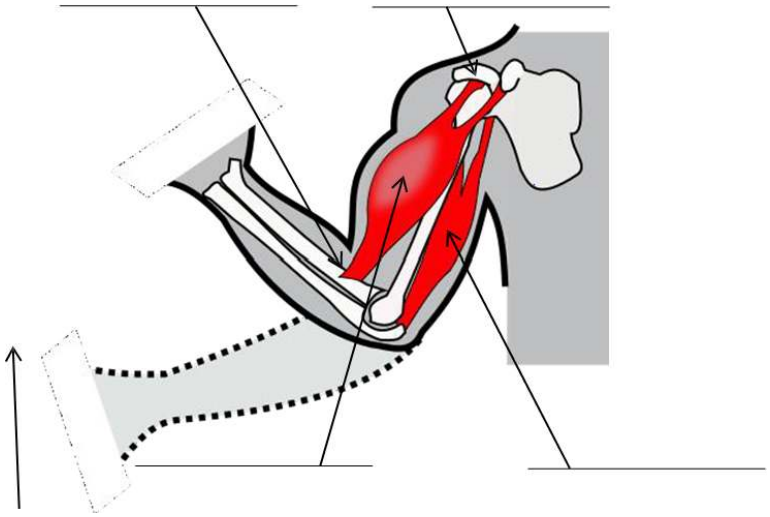
3. Below is a microscopic image of a cross section of muscle fibers magnified by 200x. Label the following structures on the image:

• muscle fiber • nuclei	• endomysium • fascicle	• perimysium



4. Label the figure showing examples of skeletal muscles below with the following terms:

• origin • insertion	• extensor	• flexor

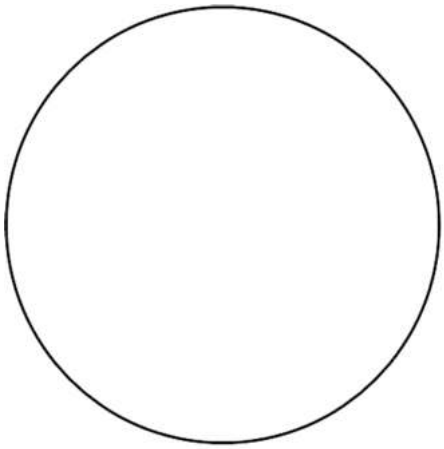


Part 2: Introduction to Skeletal Muscles Laboratory Activities

1. Examine a slide of skeletal muscle viewing muscle fibers with a longitudinal view. Illustrate the tissue and label the following structures. Indicate the total magnification of the view you illustrate in the space provided.

- muscle fiber
- striations
- nuclei
- A band
- I band
- H zone (challenge)

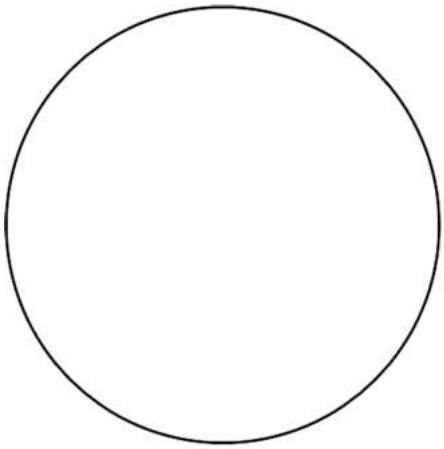
- Z disc (challenge)



Total magnification: _____

2. Examine a slide of skeletal muscle that has been cross-sectioned. Illustrate the tissue and label the following structures. Indicate the total magnification of the view you illustrate in the space provided.

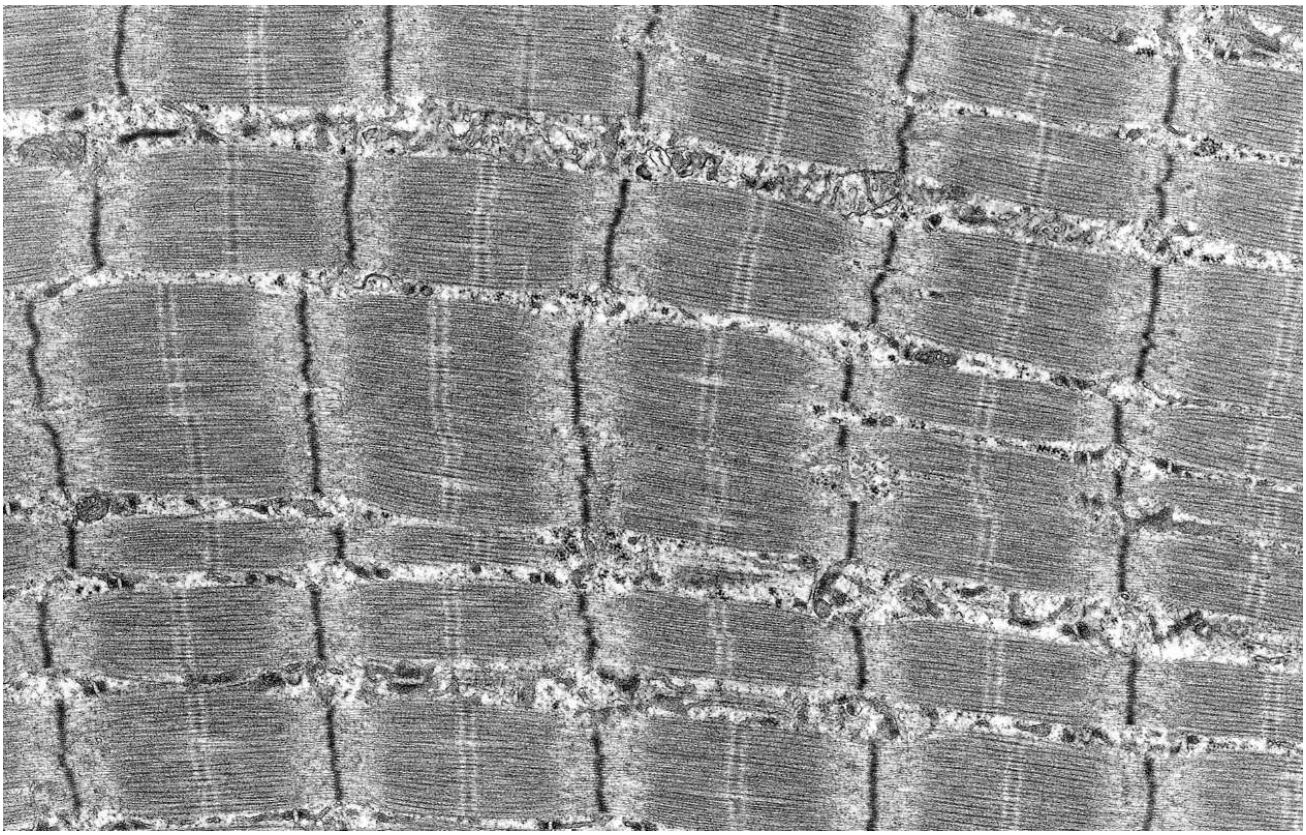
- epimysium
- fascicle
- perimysium
- muscle fiber
- endomysium
- nuclei



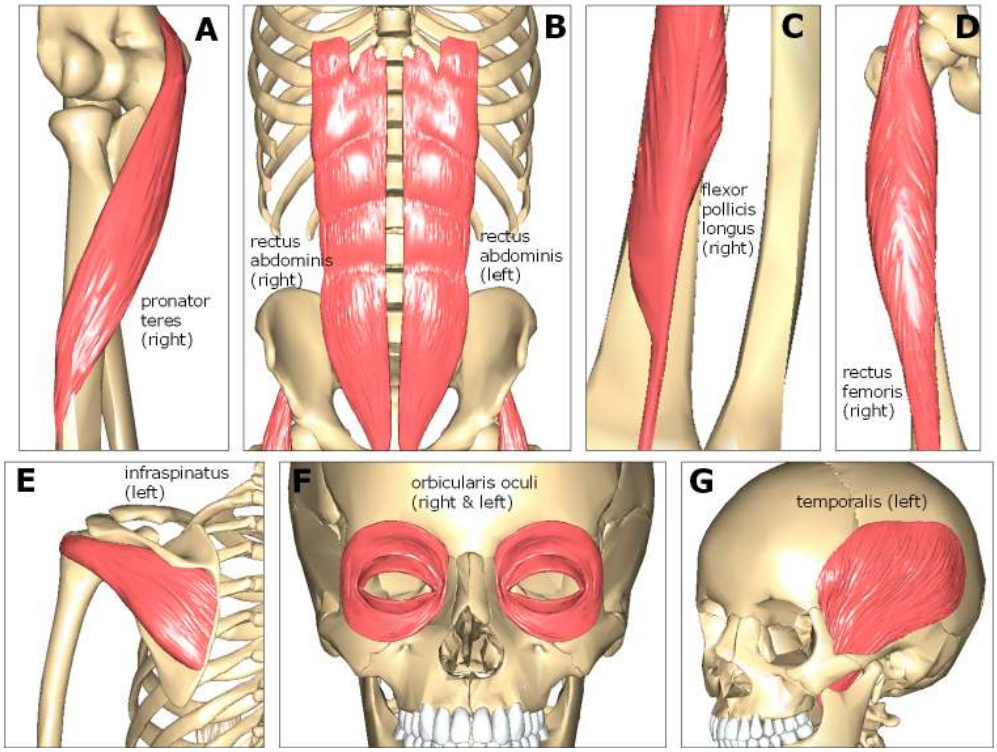
Total magnification: _____

3. Below is electron micrograph (very high magnification - 15,000x magnification in this image) of a longitudinal view of multiple myofibrils (structures found inside of a single muscle fiber) stacked top to bottom and their component sarcomeres lined up (left to right). Work with your group to label the following structures:

• myofibril • sarcomere • dark band of striation	• light band of striation • M line • H zone	• A band • I band • Z disc



4. Examine the following images of the some examples of skeletal muscles. If possible, identify these muscles on anatomical models available to you. Discuss with your group the shapes and fascicle arrangements of each of these muscles. Match each of these muscles with its shape/fascicle arrangement description from the choices given:



https://bio.libretexts.org/@go/page/53680

_____ circular _____ convergent _____ parallel fusiform	_____ parallel non-fusiform _____ unipennate	_____ bipennate _____ multipennate

5. Below is a list of muscles (continued on the next page). Discuss each ***muscle name*** with your group and match with the following descriptions ***based on the <u>name</u> of the muscle***.

_____ supraspinatus	A. Causes pronation of the forearm
_____ trapezius	B. A two-headed muscle located along the femur
_____ flexor carpi ulnaris	C. Causes extension of the digits, a long muscle
_____ triceps brachii	D. Causes flexion, origin includes the ulna, insertion includes carpal bones
_____ adductor magnus	E. A straight shaped muscle located abdominally
_____ vastus lateralis	F. Has a shape similar to a trapezoid
_____ extensor digitorum longus	G. A small muscle located at the gluteal (butt) region
_____biceps femoris	H. Causes adduction of the thigh
_____ pronator teres	I. A rhombus-shaped muscle that is larger than another rhombus-shaped muscle
_____ rectus abdominis	J. Located on the posterior aspect of the tibia
_____ tibialis posterior	K. Located in the supraspinous fossa of the scapula
_____ gluteus minimus	L. Has an origin at the sternum and inserts on the hyoid
_____ extensor carpi radialis brevis	M. A large muscle located laterally
_____ rhomboid major	N. Causes extension of the wrist, located along the radius
_____ sternohyoid	O. A three-headed muscle along the brachium (arm)

Attributions

Part 1: Review of Introduction to Skeletal Muscles

- "Anatomy and Physiology Lab Homework" by Laird C Sheldahl is licensed under CC BY-SA 4.0
- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0

Part 2: Introduction to Skeletal Muscles Laboratory Activities

- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- "BodyParts3D/Anatomography" by The Database Center for Life Science is licensed under CC BY-SA 2.1
- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0

Updated 2026.

This page titled 11.4: Laboratory Activities and Assignment is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

CHAPTER OVERVIEW

12: The Skeletal Muscles

12.1: Introduction
12.2: Muscles of the Head and Neck
12.3: Muscles of the Anterior Trunk
12.4: Muscles of the Posterior Trunk
12.5: Muscles of the Upper Limbs
12.6: Muscles of the Hips and Lower Limbs
12.7: Actions, Origins, and Insertions of the Skeletal Muscles
12.8: Laboratory Activities and Assignment
12.9: Collaborative Study Activities

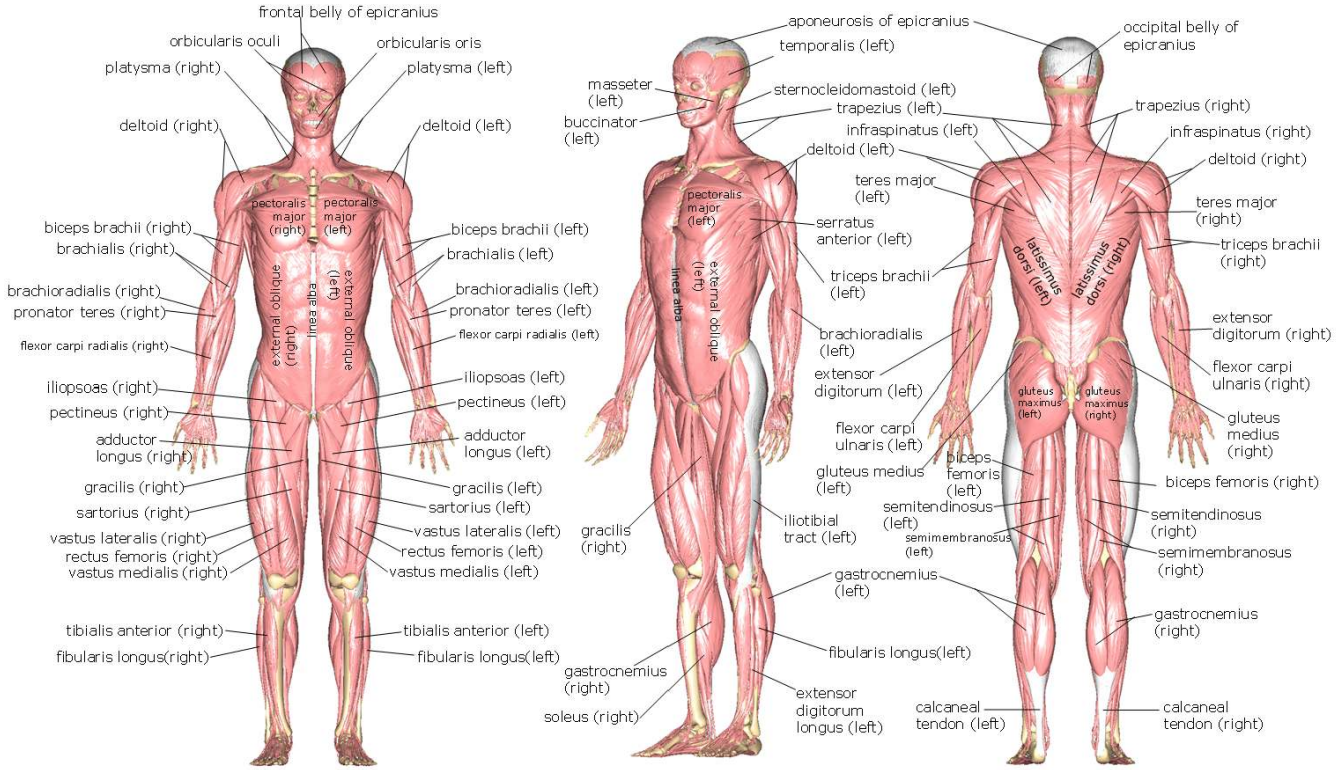
This page titled 12: The Skeletal Muscles is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

12.1: Introduction

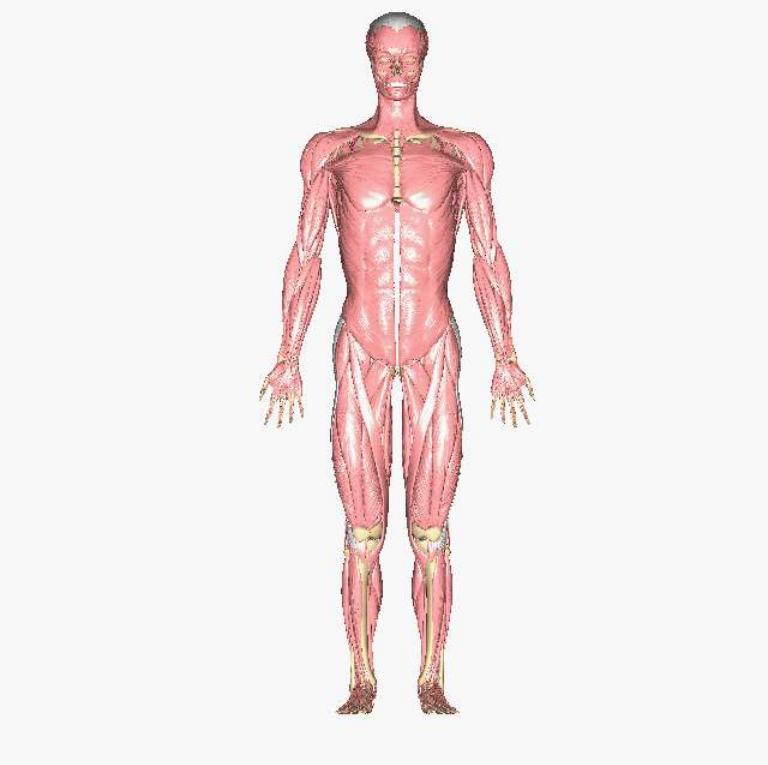
Introduction

The skeletal muscles are the movers of the skeleton. Most of the skeletal muscles are paired, one right and one left, with the right and left muscles appearing as mirror images on opposite sides of the body. There are multiple layers of muscle in each body region with different fascicle directions, origins, and insertions to enable the diverse movements humans are capable of. Recall from **Chapter 11: Introduction to Skeletal Muscles** that muscles are named for their locations (often relates to the bones and their markings or positions such as medial and lateral), shapes ("biceps" for a two-lobed muscle, trapezoid-shaped, etc.), their actions (flexion, extension, pronation, adduction, etc.), their fascicle directions (rectus, oblique, transverse, etc.), and their sizes relative to other muscles (major, minor, maximus, medius, minimus).

As you use this chapter to understand the relative positions of each of the muscles, be aware that some figures show superficial muscles and other figures show deeper muscles by showing the model with more superficial muscles removed. To better understand the relative positions of these muscles, be sure to read the captions carefully to identify which muscles have been removed, where applicable. Details about the actions, origins, and insertions of the skeletal muscles are listed in the tables at the end of this chapter.



https://bio.libretexts.org/@go/page/53684



Above: Overview of superficial skeletal muscles.

Attribution

- "BodyParts3D/Anatomography" by The Database Center for Life Science is licensed under CC BY-SA 2.1

Updated 2026.

This page titled 12.1: Introduction is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

12.2: Muscles of the Head and Neck

Muscles of the Head and Neck

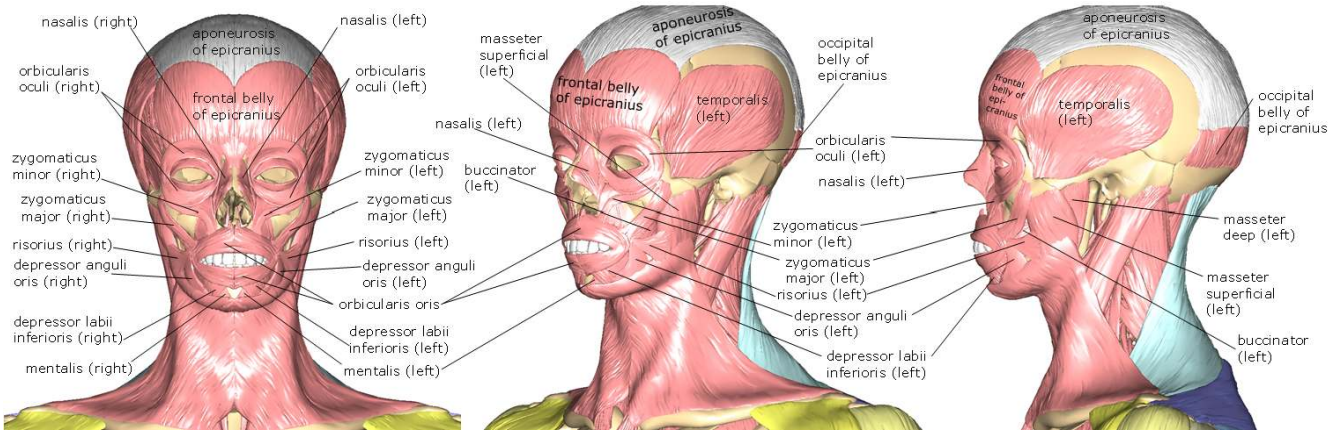
Head

The **epicranius** muscle is also very broad and covers most of the top of the head. The epicranius muscle includes a middle section which is all **aponeurosis** (white, fibrous, flat, tendon-like tissue). The actual muscle tissue is only found over the forehead (the portion of the muscle called the **epicranius frontalis**, or **frontal belly of epicranius**) and the back of the head (the portion of the muscle called the **epicranius occipitalis**, or o**ccipital belly of the epicranius**).

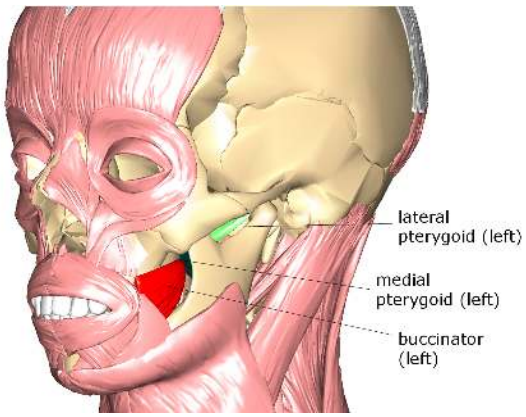
The **buccinator** muscles, one on each side of the face, compress the cheeks when contracted. The name is from the Latin for trumpet, which requires blowing air out of the cheeks to play, and also reflects the anatomical adjective for the cheek, buccal.

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

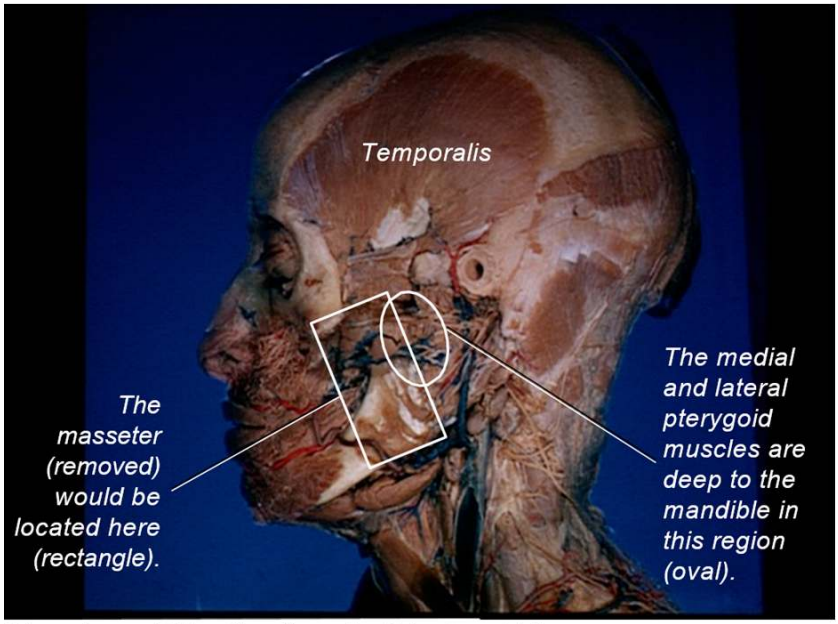
The **zygomaticus major** muscles and the **zygomaticus minor** muscles are found on each side of the face both have their origins on the zygomatic bone. They both can change the shape of the mouth by elevating it.



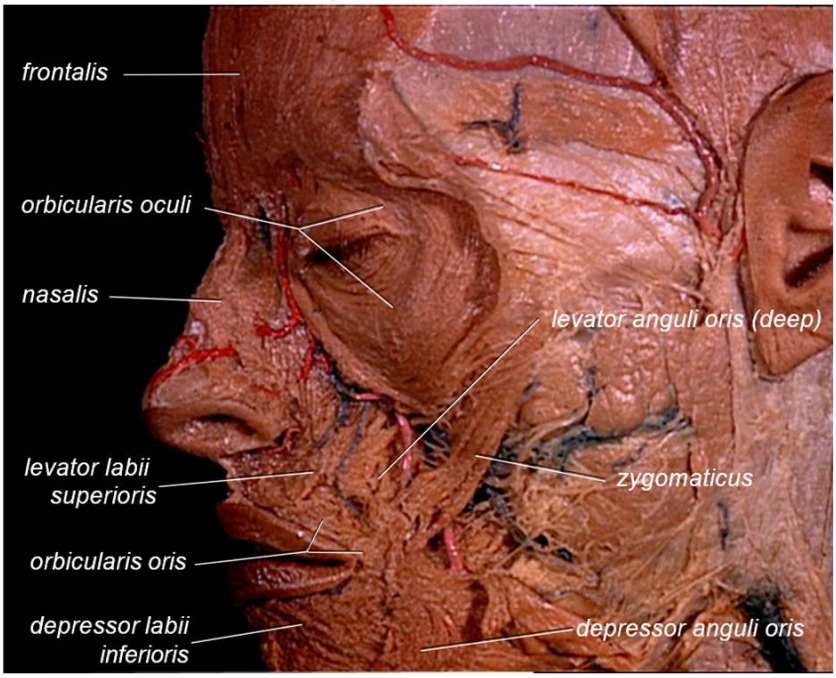
Above: Muscles of the head.



Above: Deeper muscles of the head. This diagram shows the masseter removed (superficial and deep), temporalis removed, risorius removed, and zygmaticus major removed. Buccinator is shown in red, lateral pterygoid in green, and medial pterygoid in black.



Muscles of Mastication, Left Lateral View



Muscles of Facial Expression, Left Lateral View

Above: Cadaver images of the muscles of the head.

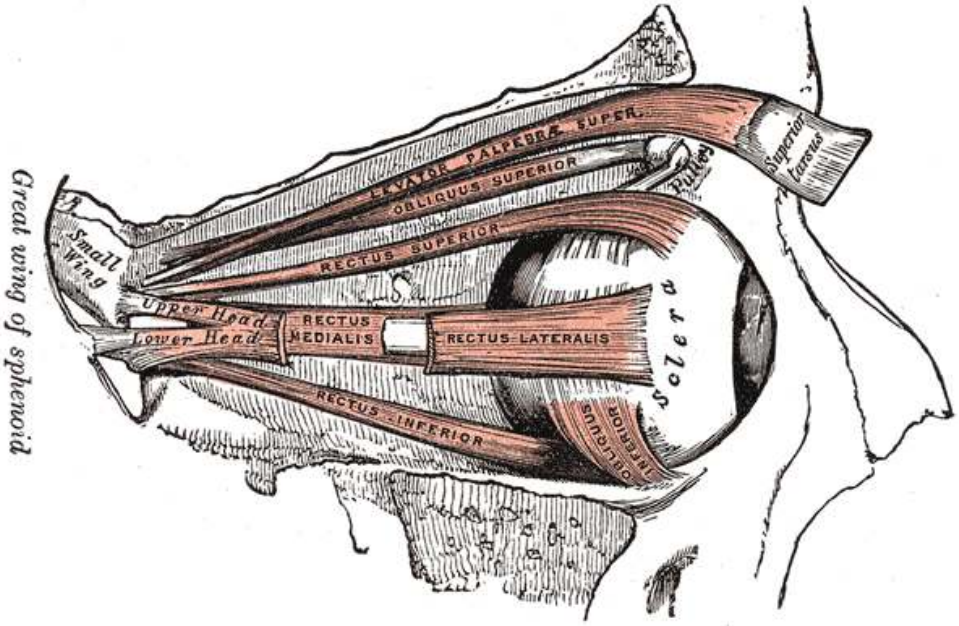
Clinical Application: The Buccinator Muscle

The **buccinator muscle** is a deep muscle of the cheek. Its primary role is to **assist in mastication (chewing) by keeping food between upper and lower teeth**. If you've ever **bitten your cheek** bad enough, you may have bitten down on your buccinator (although under most instances, you only bite down on the epithelium and superficial fascia that lines the innermost surfaces of your cheeks). The buccinator muscle also assists **infants with suckling** and **adults with whistling.**

Eye

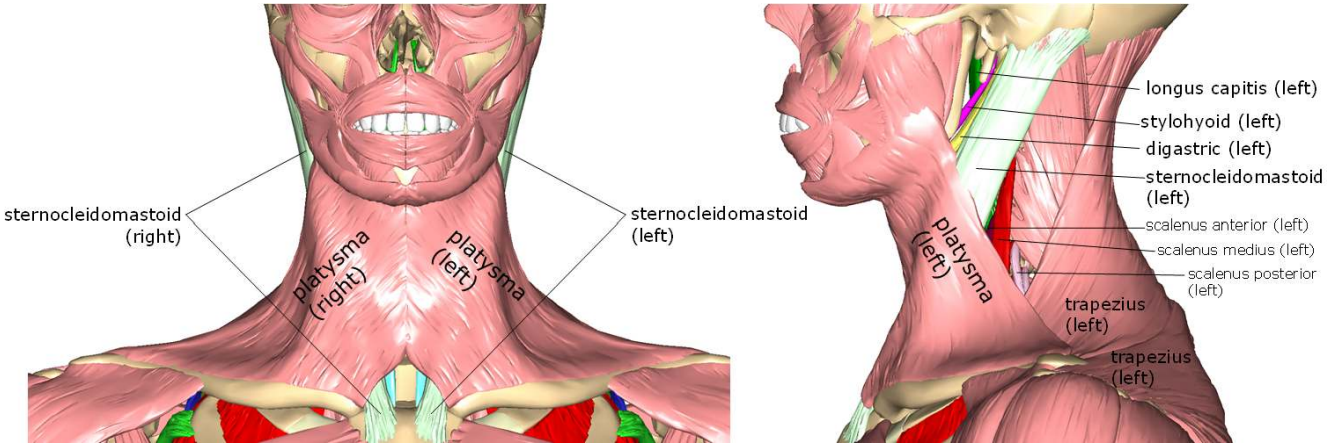
The movements of the eyeball are controlled by six muscles. The muscles "rectus" are straight muscles and the "oblique" muscles are positioned at an angle in relationship to the straight muscles. Each of the ocular muscles are named for their positions (superior,

inferior, lateral and medial): **superior rectus**, **superior oblique**, **inferior rectus**, **inferior oblique**, **lateral rectus**, and **medial rectus**. Additionally, **levator palpebrae superioris**, located superiorly to the eye, raises the eyelid.



Above: Diagram of the ocular muscles of the right eye. The lateral rectus is shown as broken only to allow view of medial rectus.

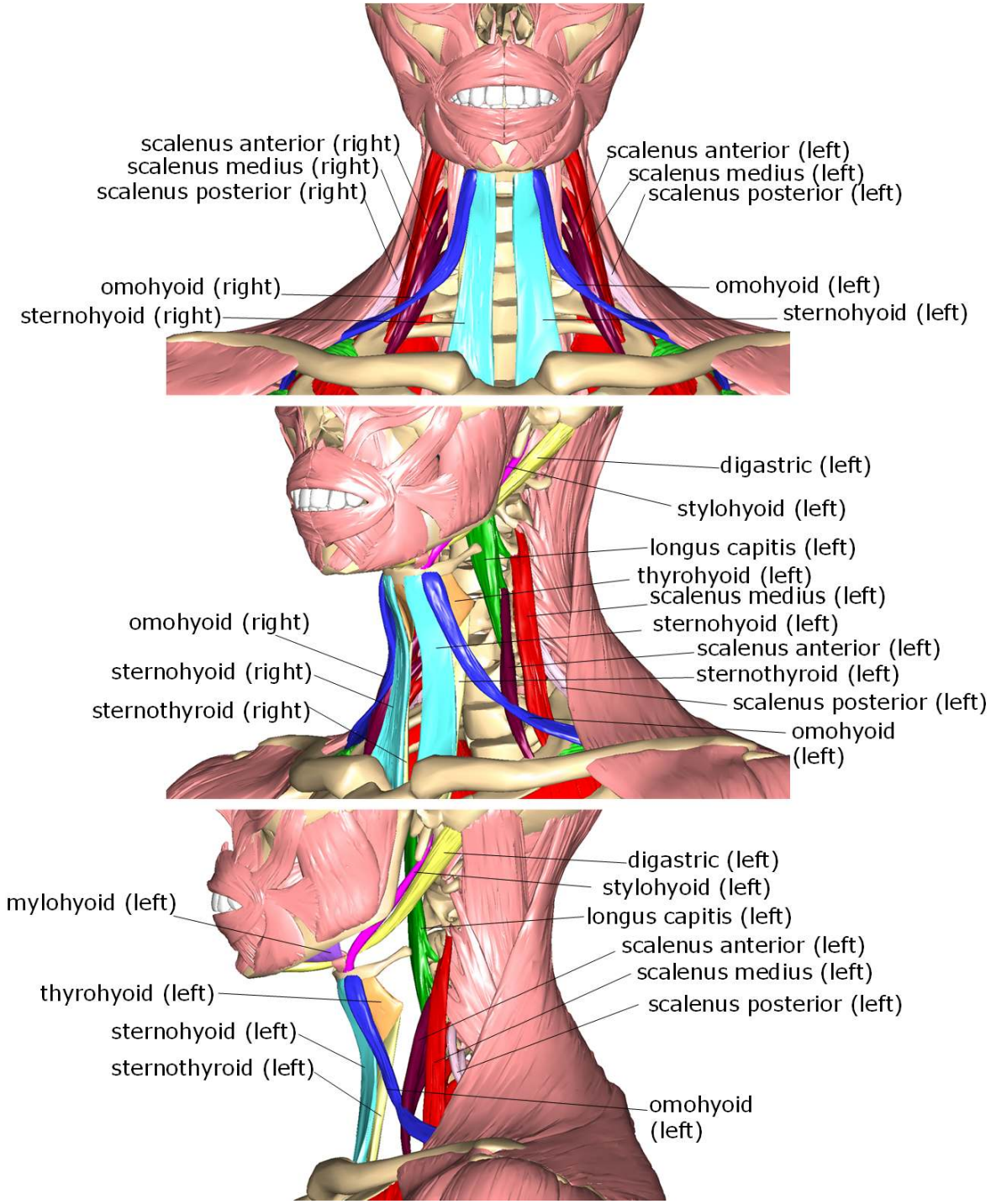
Anterior Neck

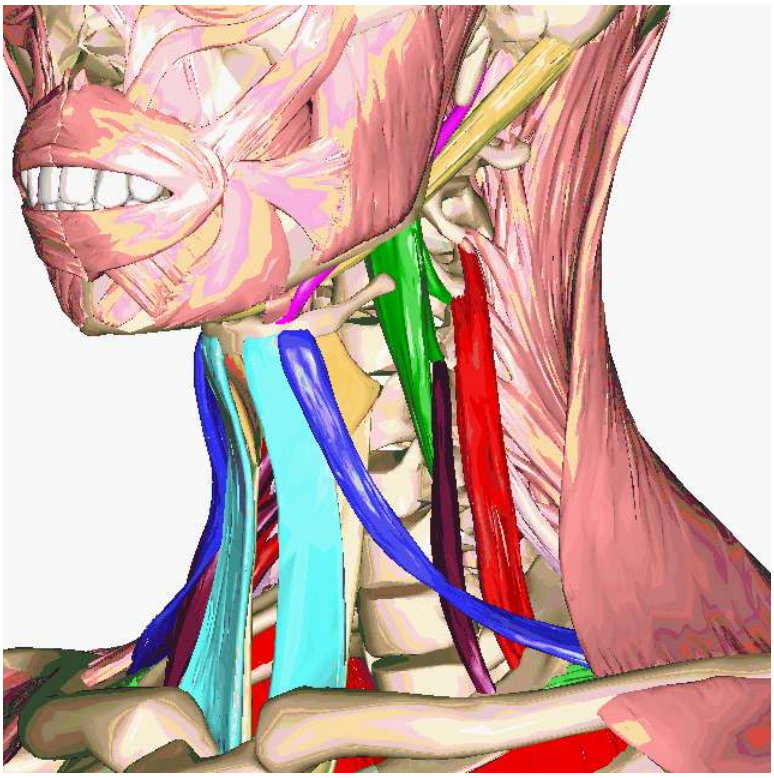


Above: (Left) Anterior and (right) lateral views of superficial neck muscles with deeper anterior neck muscles shown in different colors.

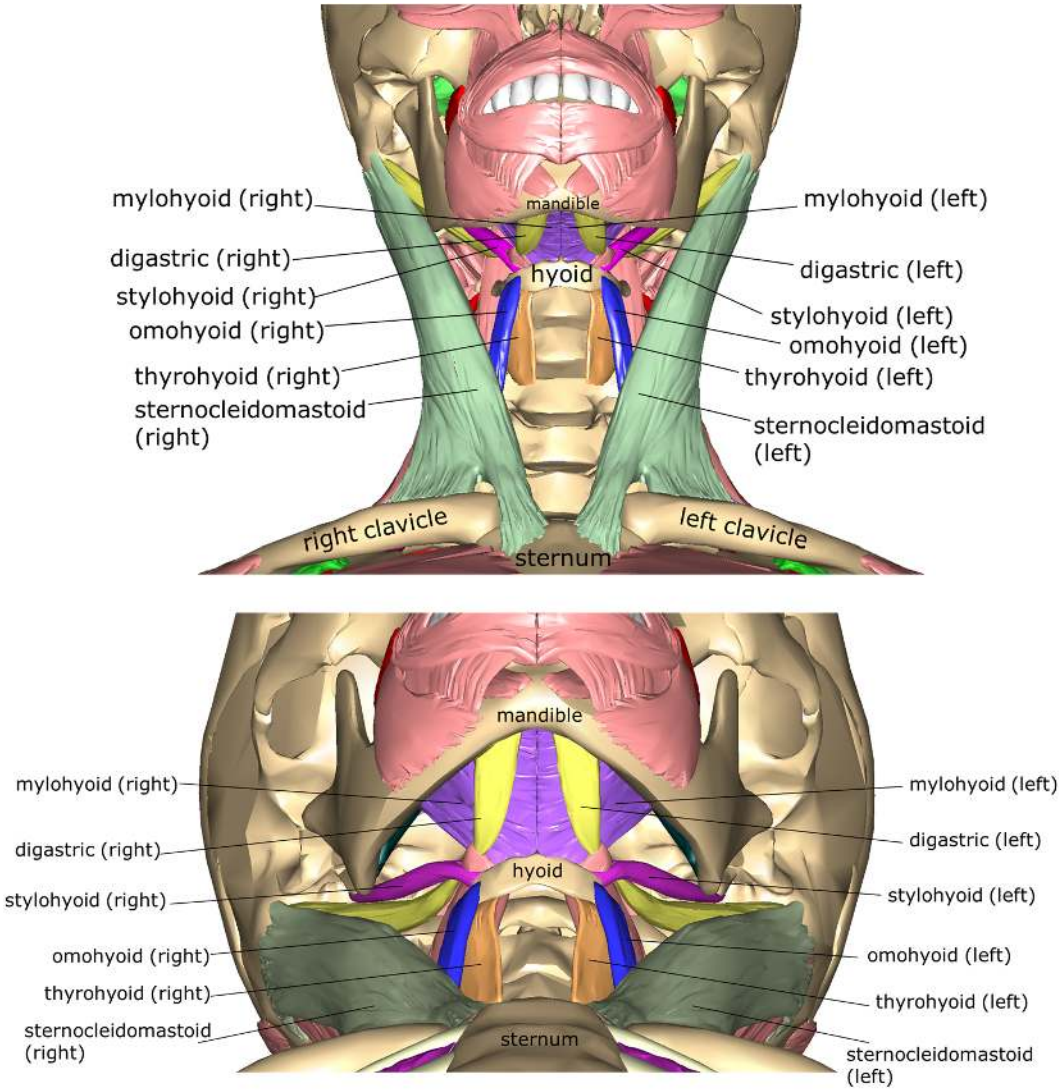
A single **platysma** muscle is only shown in the lateral view of the head muscles in. There are two platysma muscles, one on each side of the neck. Each is a broad sheet of a muscle that covers most of the anterior neck on that side of the body. The other anterior neck muscles are below them, and most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

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


scalenus anterior (right)
scalenus medius (right)
scalenus posterior (right)
omohyoid (right)
sternohyoid (right)
scalenus anterior (left)
scalenus medius (left)
scalenus posterior (left)
omohyoid (left)
sternohyoid (left)
digastric (left)
stylohyoid (left)
longus capitis (left)
thyrohyoid (left)
scalenus medius (left)
sternohyoid (left)
scalenus anterior (left)
sternothyroid (left)
scalenus posterior (left)
omohyoid (left)
omohyoid (right)
sternohyoid (right)
sternothyroid (right)
digastric (left)
stylohyoid (left)
longus capitis (left)
scalenus anterior (left)
scalenus medius (left)
scalenus posterior (left)
omohyoid (left)
mylohyoid (left)
thyrohyoid (left)
sternohyoid (left)
sternothyroid (left)

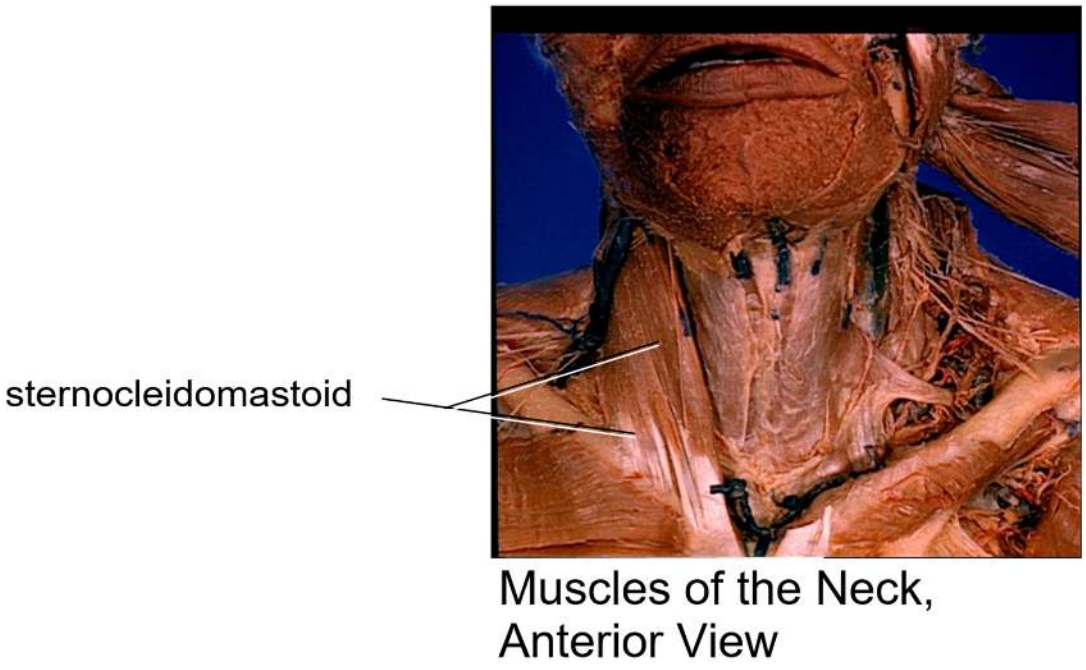


Above: Deep anterior neck muscles shown with platysma and sternocleidomastoid removed (top) anterior, (middle) anterolateral, and (bottom) lateral views.



Above: Muscles of the anterior neck, platysma, sternohyoid, and sternothyroid removed. (Top) Anterior and slightly inferior view of deep neck muscles. (Bottom) Inferior view of the deep muscles of the neck.

https://bio.libretexts.org/@go/page/53685



Above: Cadaver image of the muscles of the anterior neck.

Attributions

- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- "BodyParts3D/Anatomography" by The Database Center for Life Science is licensed under CC BY-SA 2.1
- "Gray's Anatomy plates" by Henry Vandyke Carte is in the Public Domain

Updated 2026.

This page titled 12.2: Muscles of the Head and Neck is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

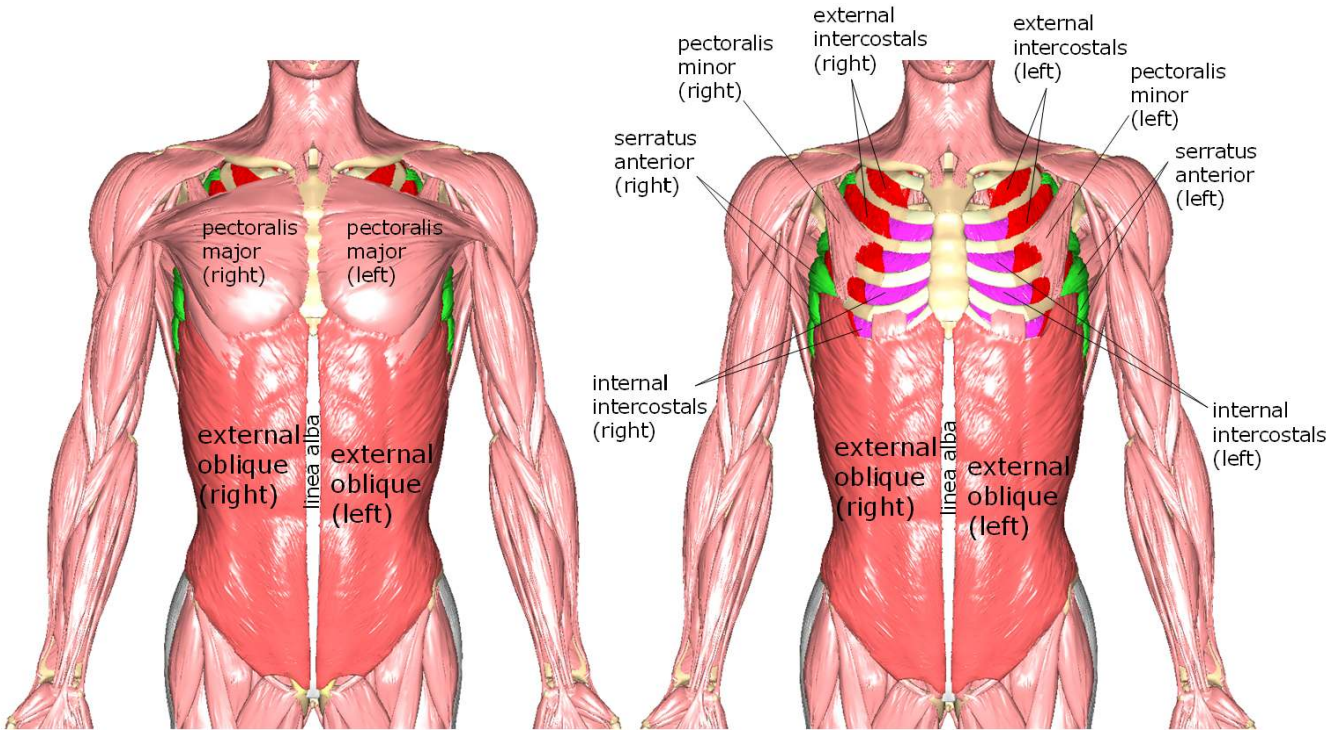
12.3: Muscles of the Anterior Trunk

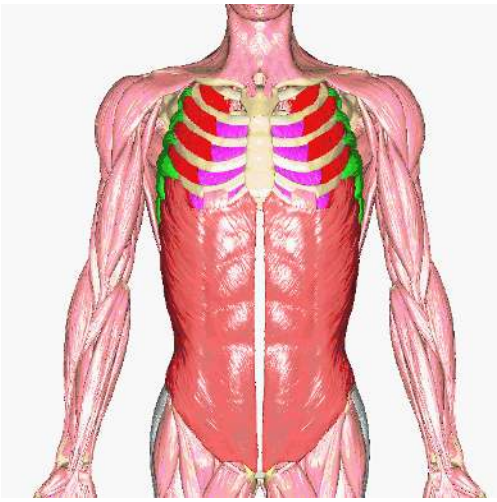
Muscles of the Anterior Trunk

Some of the trunk muscles have been given nicknames by gym rats. For instance, the "pecs" are the **pectoralis major** muscles at each breast. Deep to pectoralis major are the paired pectoralis minor muscles. Between the ribs are three layers of intercostal muscles: **external intercostals** (most superficial), **inner intercostals** (intermediate), and **innermost intercostals** (deepest intercostal muscles).Although the internal intercostal muscles are deep to the external intercostal muscles, paying attention to the direction of muscle fibers for each muscle can help you identify them correctly. From an anterior view, internal intercostal muscle fibers run in an inferolateral direction from superior to inferior, whereas external intercostal muscle fibers run in an inferomedial direction from superior to inferior.

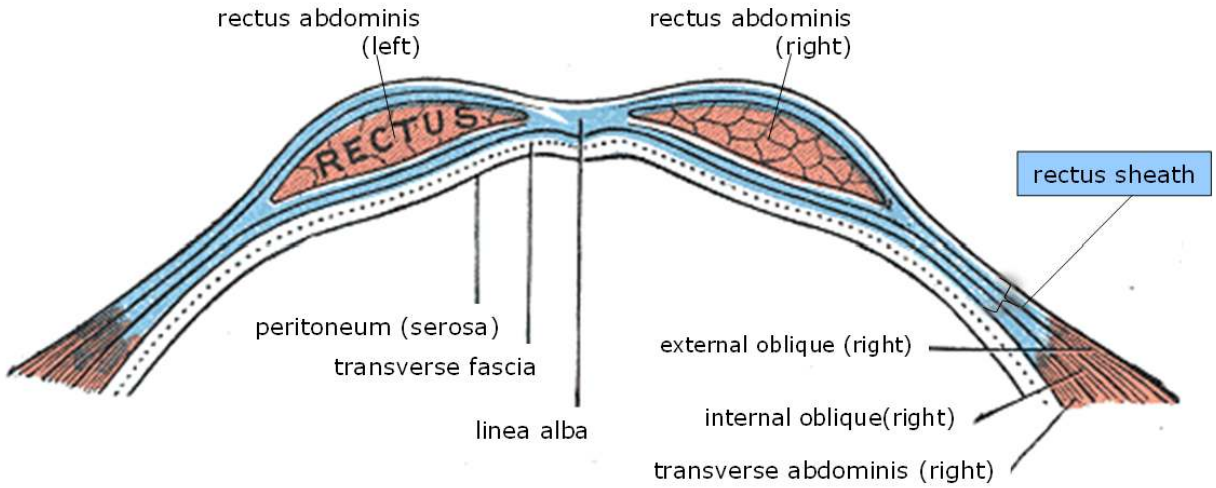
Extending from the back and wrapping around the sides of the rib cage are the paired **serratus anterior** muscles. This muscle's anterior edges are serrated like the teeth of a saw because this muscle's origins are on ribs 1 through 8 and each serration is the attachment point to another rib.

Rectus abdominis, the medial, paired muscles that can create an abdominal "six-pack," is enclosed by the **rectus sheath**, also known as the **rectus fascia**. The rectus sheath is formed by **aponeuroses** (white, fibrous, flat, tendon-like tissue) from the **external oblique**, **internal oblique**, and **transverse abdominis** muscles. The rectus sheath fuses along a medial line called the **linea alba**, literally meaning the "white line." Linea alba is a fibrous tissue attached to the pubic symphysis and the xiphoid process of the sternum and is a point of insertion for abdominal muscle.

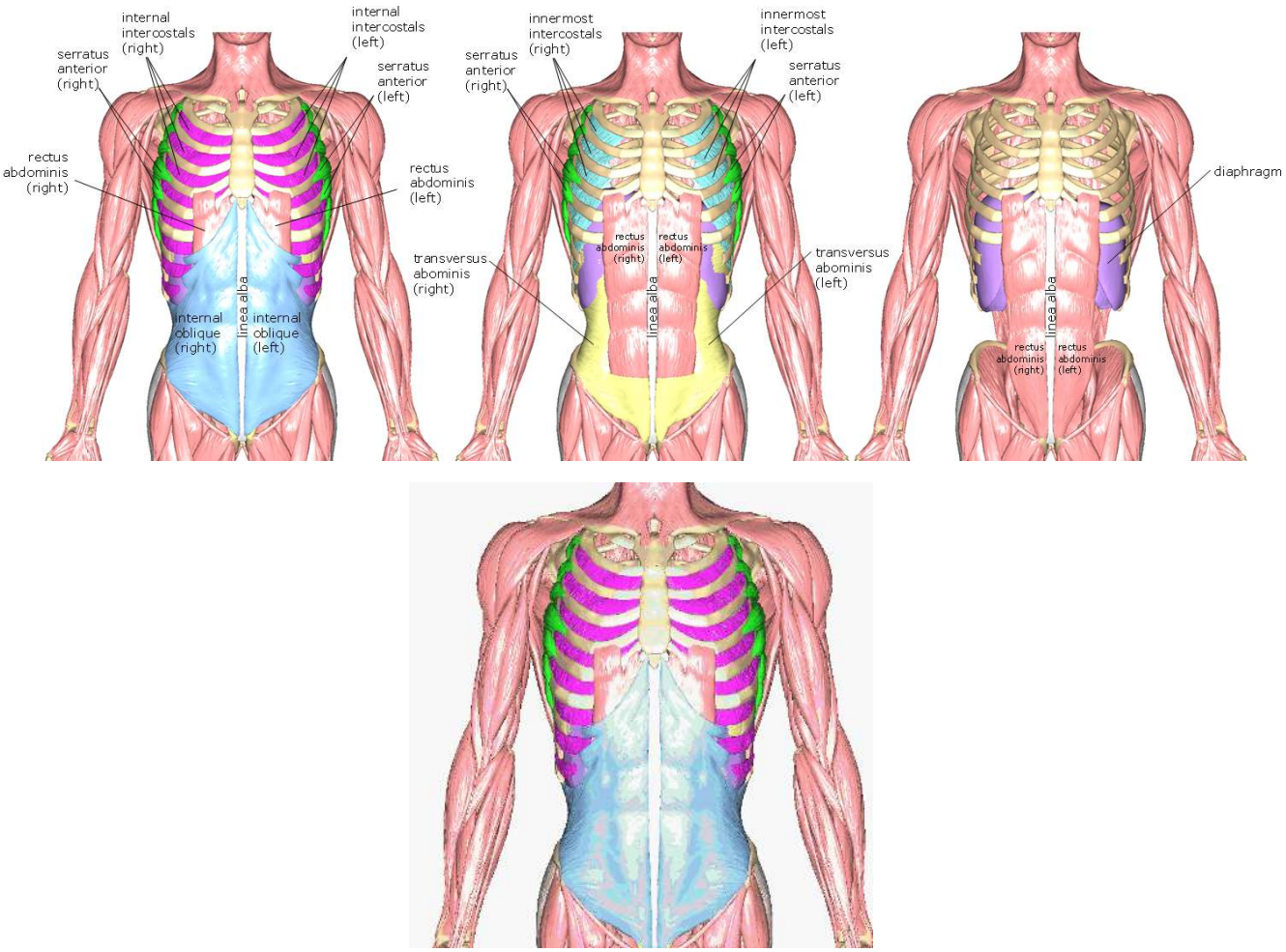




Above: Superficial anterior trunk muscles (top left and middle) with all muscles and (top right and bottom) with pectoralis major removed. External obliques are shown in light red, external intercostals are shown in bright red, serratus anterior is shown in green, and internal intercostals are shown in magenta.



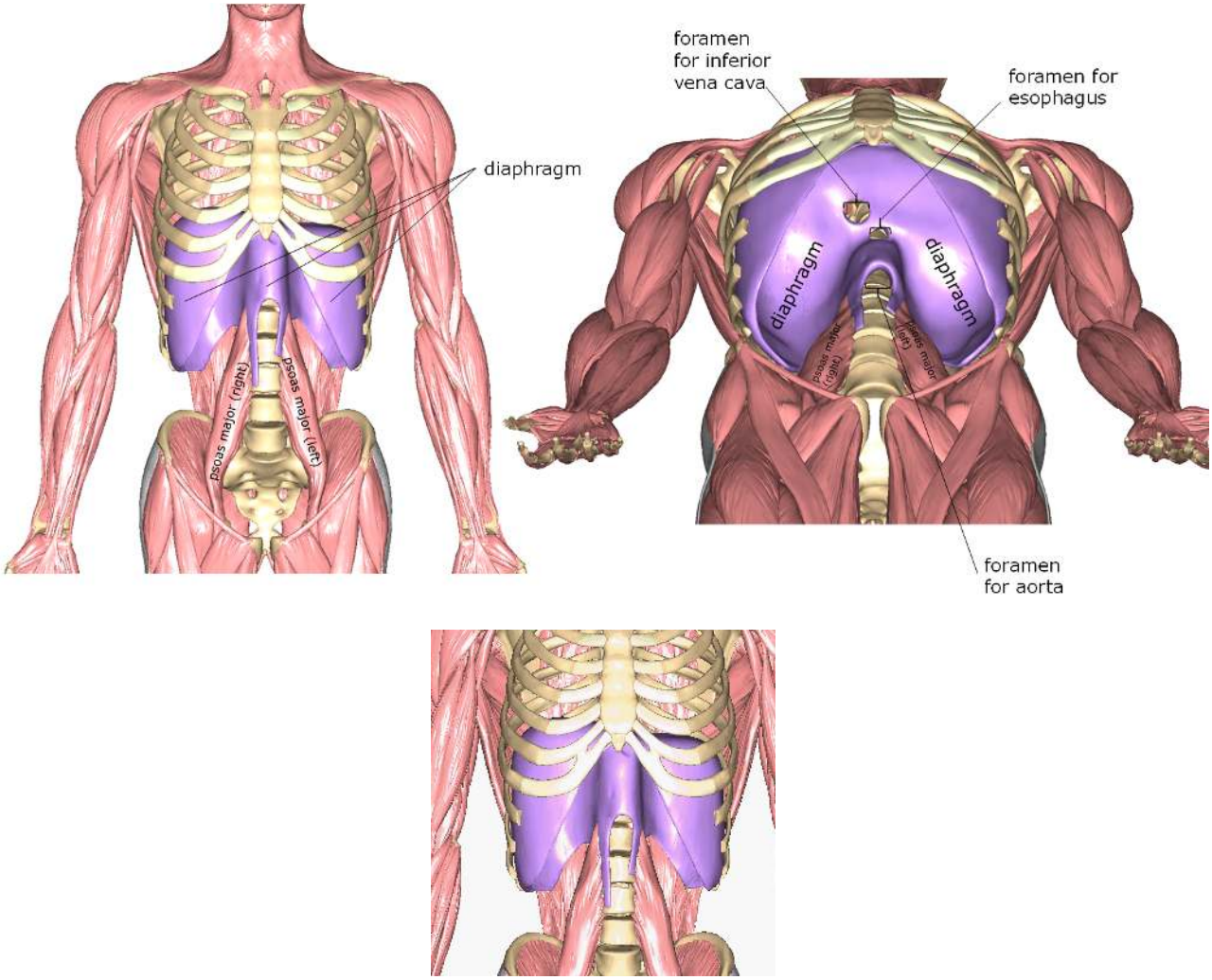
Above: Cross section of abdominal muscles, superior view, with anterior at the top of the image and posterior at the bottom of the image. The rectus sheath, the aponeuroses of the external obliques, internal obliques, and transverse abdominis, and enclosing the rectus abdominis muscles is shown in blue.



Above: Deeper anterior trunk muscles (top left and middle) without pectoralis major, pectoralis minor, and the external obliques (top middle and bottom) also without internal intercostals and internal obliques, and (right) also without innermost intercostals, serratus anterior, and transversus abdominis. External intercostals are shown in bright red, serratus anterior is shown in green, internal intercostals are shown in magenta, internal obliques are shown in light blue, transversus abdominis in light yellow, innermost intercostals in cyan, and the diaphragm in lilac.

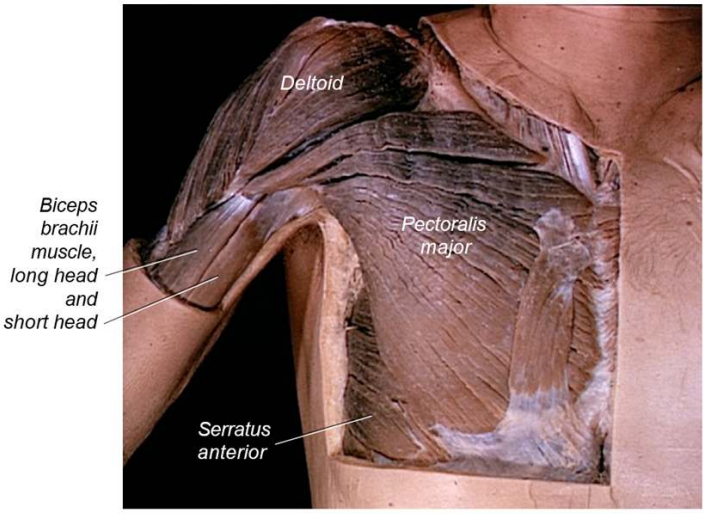
What gym rats call the "core muscles" are three layers of muscle that sit over the abdomen. The outer layer is the **external oblique** muscle, with its aponeurosis covering the medial abdomen. Under the external oblique are the **internal obliques** on the sides of the abdomen and the **rectus abdominis**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

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

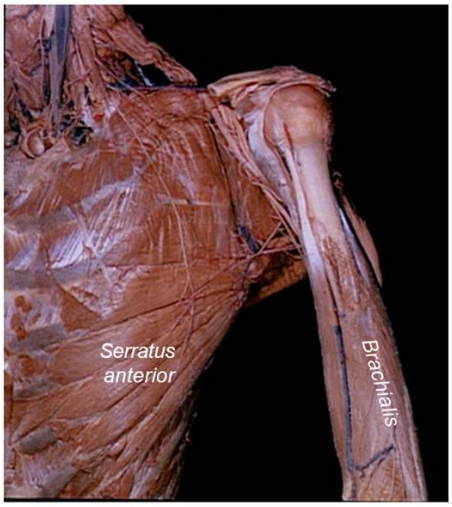


Above: The diaphragm.

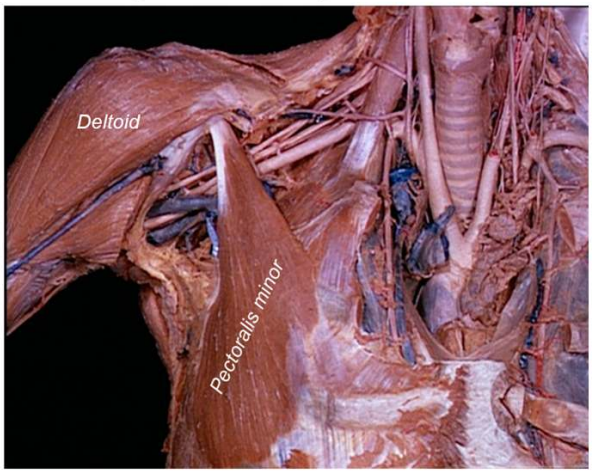
https://bio.libretexts.org/@go/page/53686



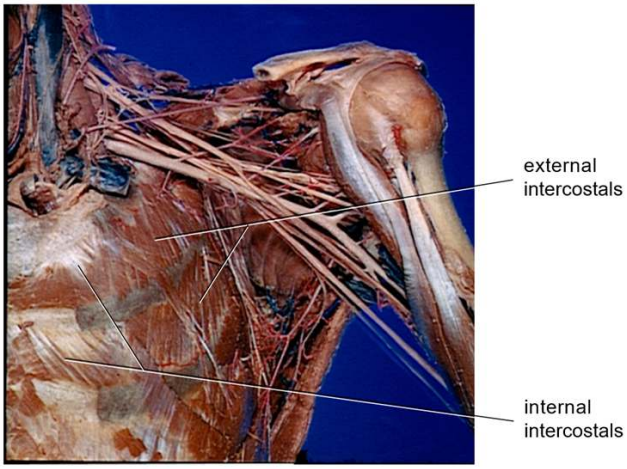
Right Pectoralis Major, Anterior View



Left Serratus Anterior and Brachialis, Anterior View

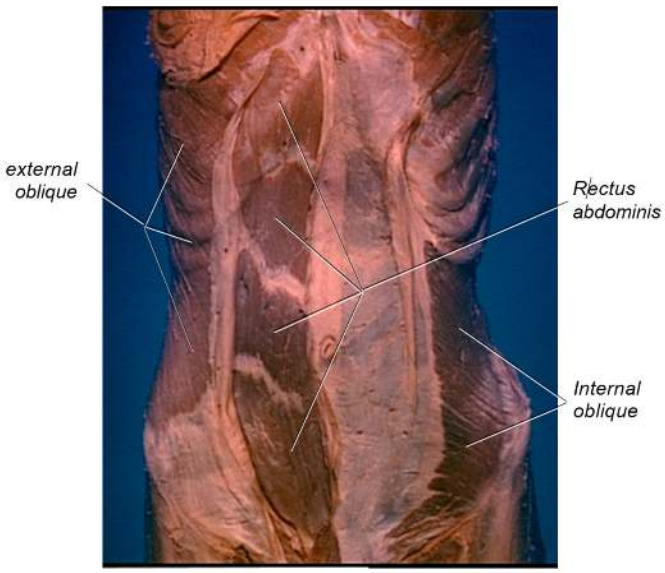


Right Pectoralis Minor, Anterior View



Muscles of the Thorax, Anterior View

Above: Cadaver images of the muscles of the anterior thorax.



Muscles of the Abdomen, Anterior View

Above: Cadaver image of the muscles of the abdominal region.

Attributions

- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- "BodyParts3D/Anatomography" by The Database Center for Life Science is licensed under CC BY-SA 2.1
- "Gray's Anatomy plates" by Henry Vandyke Carte is in the Public Domain

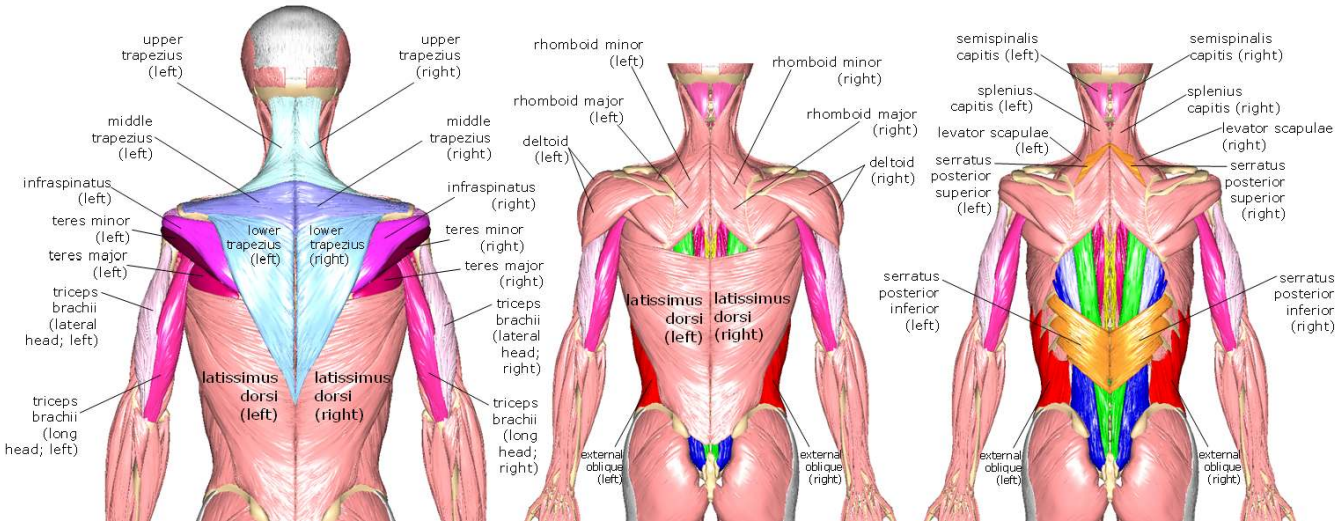
Updated 2026.

This page titled 12.3: Muscles of the Anterior Trunk is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

12.4: Muscles of the Posterior Trunk

Muscles of the Posterior Trunk

Posterior Neck & Back

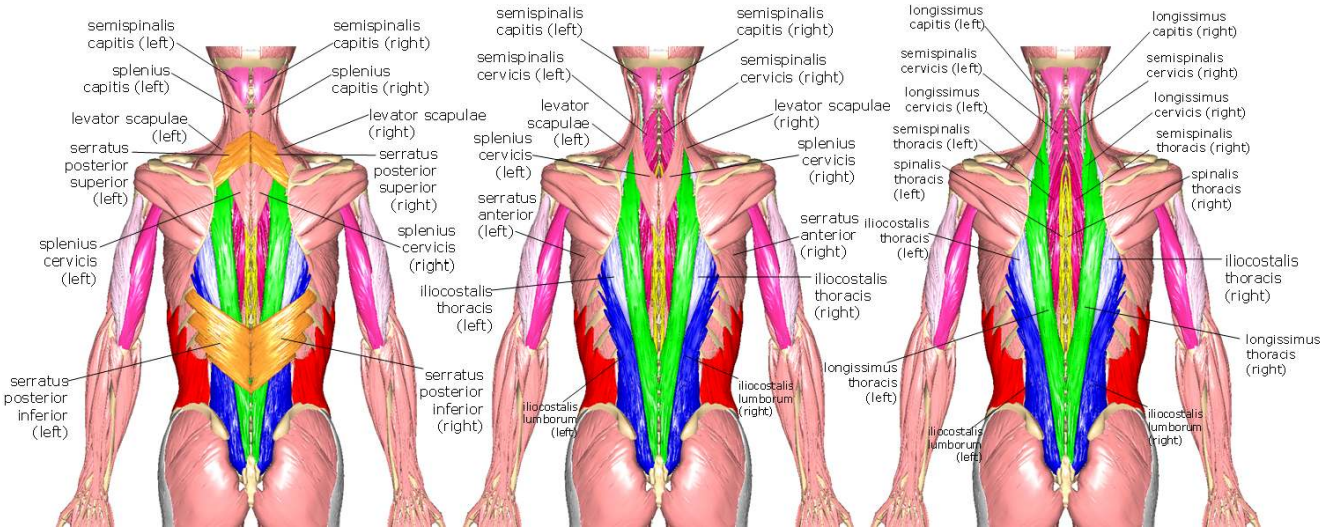


Above: Posterior trunk (left) superficial muscles without the deltoids, (middle) superficial muscles without the trapezius, and latissimus dorsi.

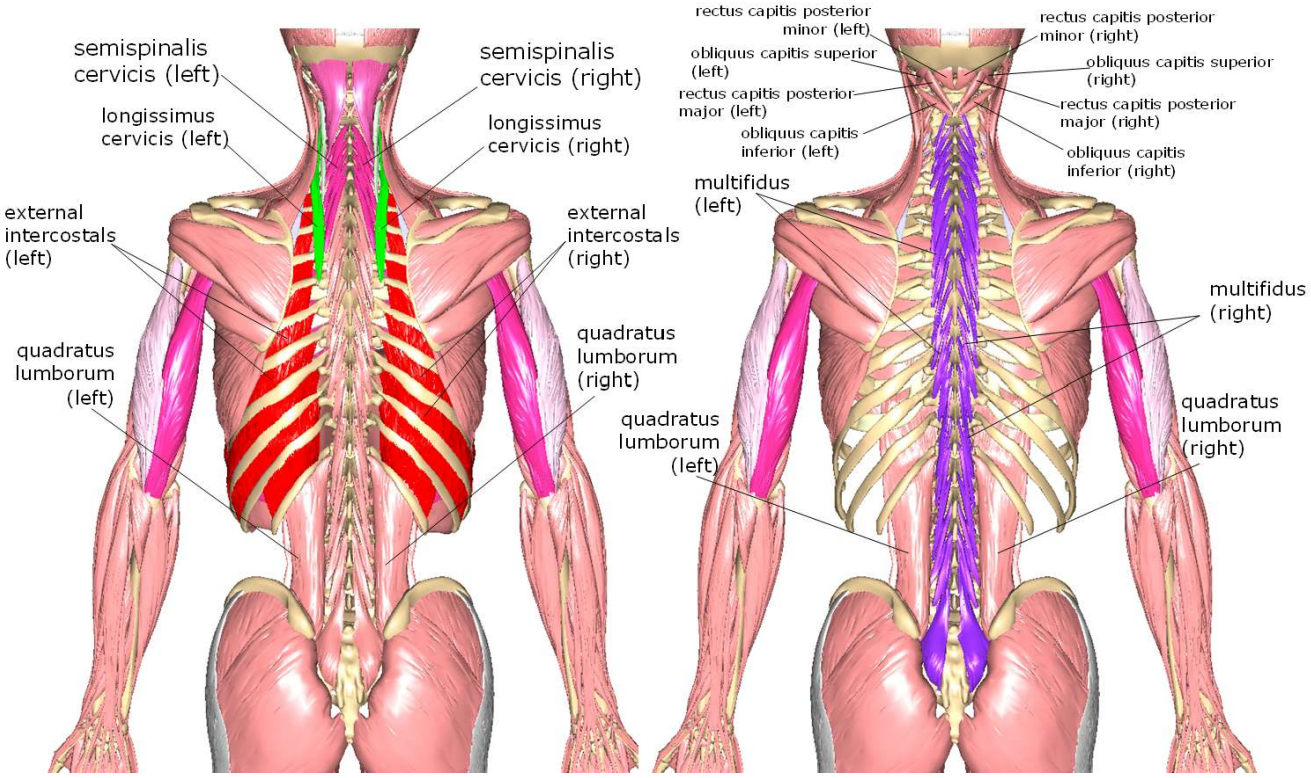
In an exercise setting, "lats" refers to the **latissimus dorsi**, a paired muscle that covers most of the lower back with its lateral fibers. The upper back is covered by the large **trapezius** muscle (aka "traps") that is almost diamond-shaped as it extends from the neck, out to the shoulders, then tapers in midway down the back. There are three sections of trapezius: upper (descending) trapezius, middle (transverse) trapezius, and lower (ascending) trapezius.

Similar to serratus anterior on the anterior trunk, the **serratus posterior** muscles resemble a serrated knife. There are two serratus posterior muscles - one superior and one inferior.

There are sets of muscles associated with the vertebral column with different regions. Those named with "capitis" attach to the head, "cervicis" relates to the cervical vertebrae, "thoracis" relates to the thoracic vertebrae, and "lumborum" relates to the lumbar vertebrae. These muscles from medial to lateral are called **spinalis** (shown in yellow), **semispinalis** (shown in pink shades along the vertebrae), **longissimus** (shown in green shades), and **iliocostalis** (shown in blue shades). These muscles act to flex and extend the vertebral column. Even deeper muscles associated with the vertebral column include **quadratus lumborum** and **multifidus**.

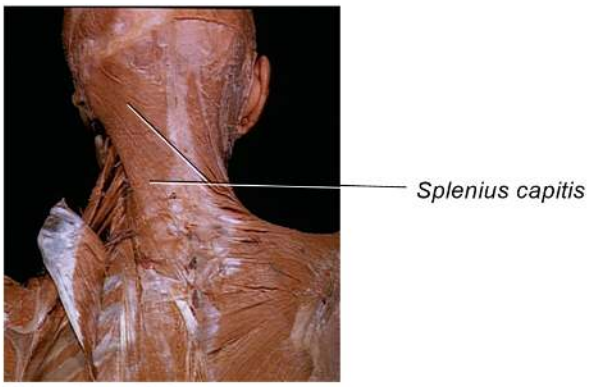


Above: Deeper muscles of the posterior trunk. (Left) Posterior trunk without trapezius, deltoids, latissimus dorsi, rhomboid major, and rhomboid minor. (Middle) Posterior trunk as shown at left except without serratus posterior superior, serratus posterior inferior, and splenius capitis.

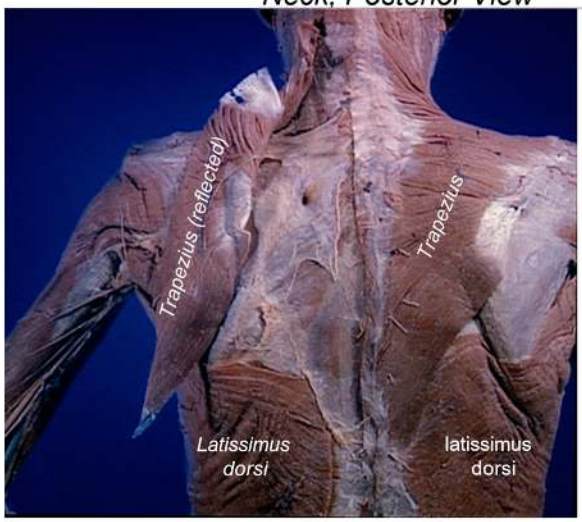


Above: The deepest muscles of the posterior trunk (left) without trapezius, deltoids, latissimus dorsi, rhomboid major, rhomboid minor, serratus posterior superior, serratus posterior inferior, splenius capitis, all iliocostalis muscles, longissimus thoracis, semispinalis thoracis, all spinalis muscles, and abdominal muscles. (Right) The posterior trunk shown at left without intercostal muscles, semispinalis capitis, and longissimus cervicus with multifidus colored in purple.

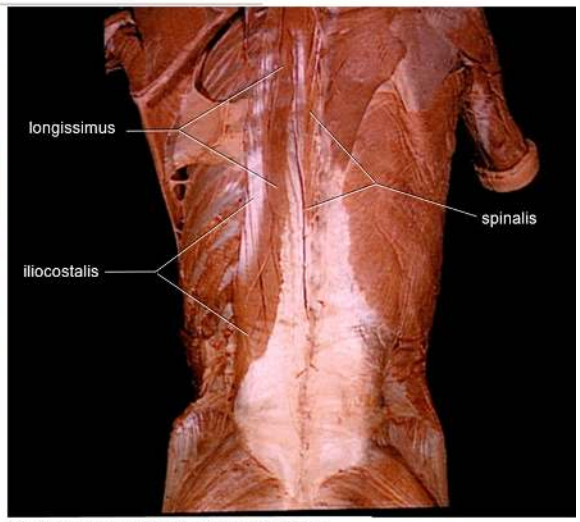
https://bio.libretexts.org/@go/page/53687



Muscles of the Neck, Posterior View



Trapezius and Latissimus Dorsi, Posterior View



Muscles of the Back, Posterior View

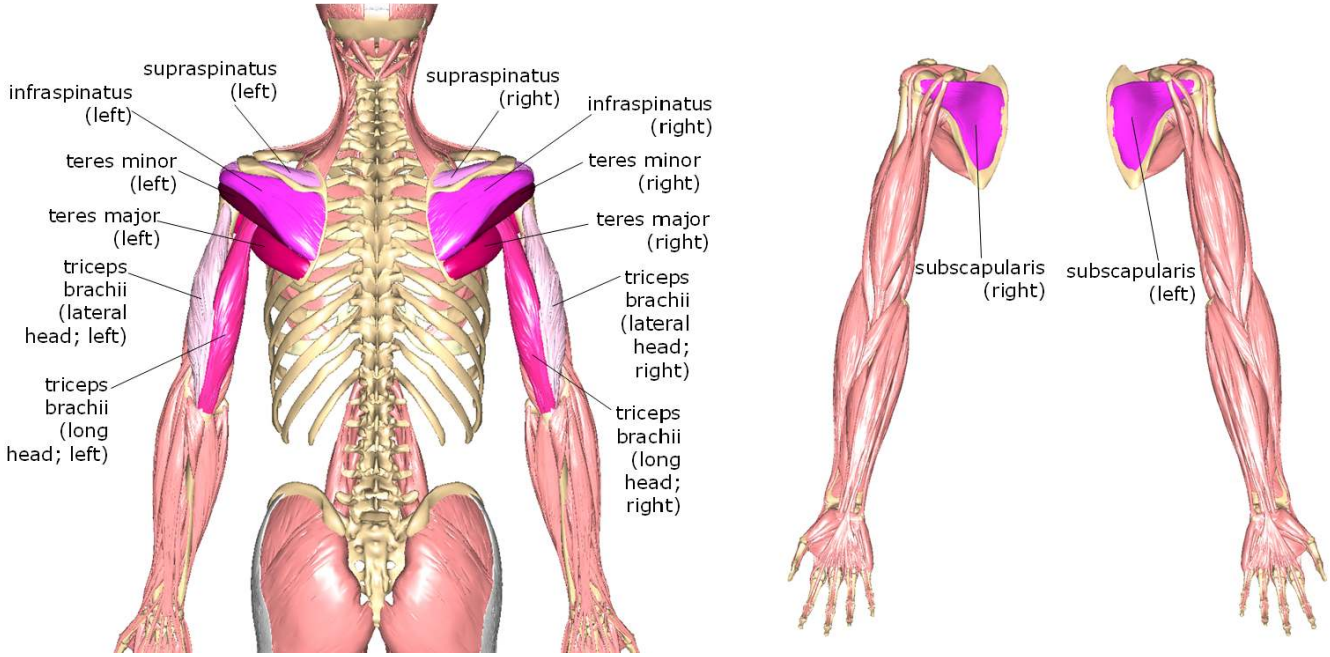
Above: Cadaver images of the muscles of the posterior trunk and neck.

Rotator Cuff

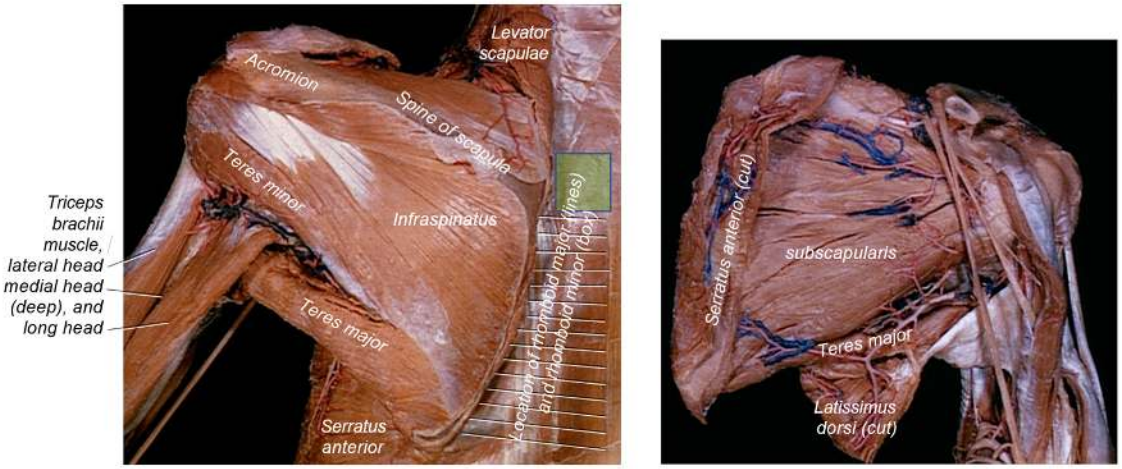
The rotator cuff is the name given to the group of four muscles that are largely responsible for the ability to rotate the arm: **supraspinatus**, **infraspinatus**, **subscapularis**, and **teres minor**. Three of the four rotator cuff muscles are deep to the deltoid and trapezius muscles and cannot be seen unless those muscles are first removed and one is on the anterior side of the scapula bone and cannot be seen from the surface. On the anterior side of scapula bone is the subscapularis. It is triangular in shape and covers the entire anterior aspect of the scapula. Its origin is along the subscapular fossa that makes up most of the anterior "wing" of the scapula and it inserts on the lesser tubercle of the humerus bone.

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

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



Above: Muscles of the rotator cuff. (Top left) Posterior muscles of the rotator cuff and (top right) anterior view of the scapulae showing the subscapularis muscles on the anterior aspects of the subscapular fossae of the scapulae. (Top right and bottom) The subscapularis muscles are shown without the rest of the body since they are positioned at the posterior of the thoracic cage and are difficult to see.



Above: Cadaver images of the muscles of the rotator cuff.

Attributions

- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- "BodyParts3D/Anatomography" by The Database Center for Life Science is licensed under CC BY-SA 2.1

Updated 2026.

This page titled 12.4: Muscles of the Posterior Trunk is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

12.5: Muscles of the Upper Limbs

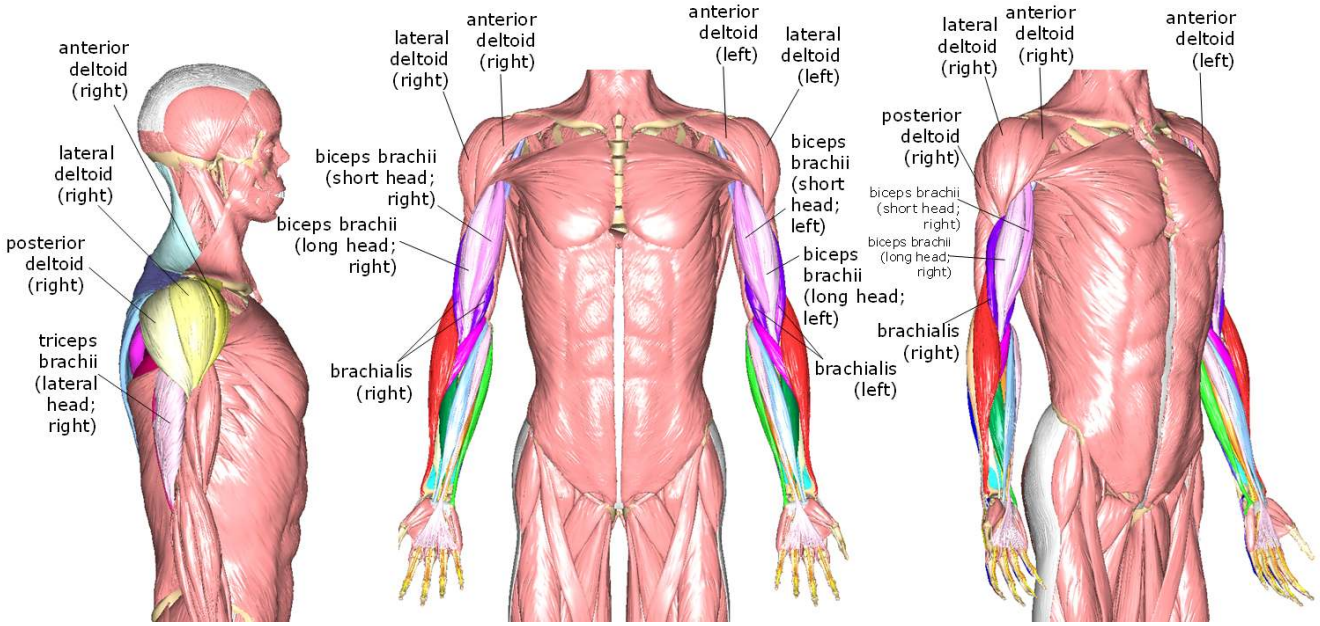
Muscles of the Upper Limbs

Arm (Shoulder to Elbow)

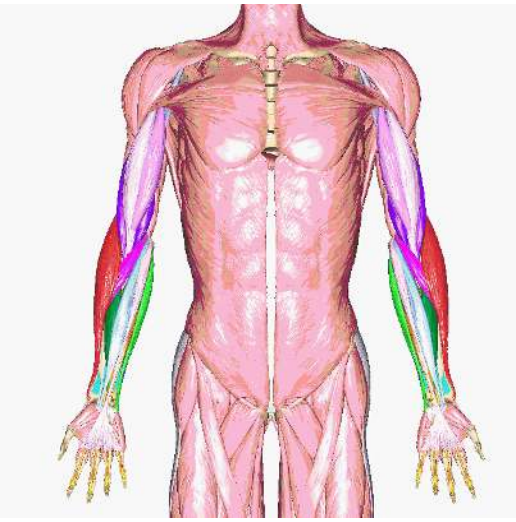
Anatomists refer to the upper arm as just the arm or the brachium. (The lower arm is the forearm or antebrachium.) There are three muscles on the upper arm that are parallel to the long axis of the humerus, the biceps brachii, the brachialis, and the triceps brachii.

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

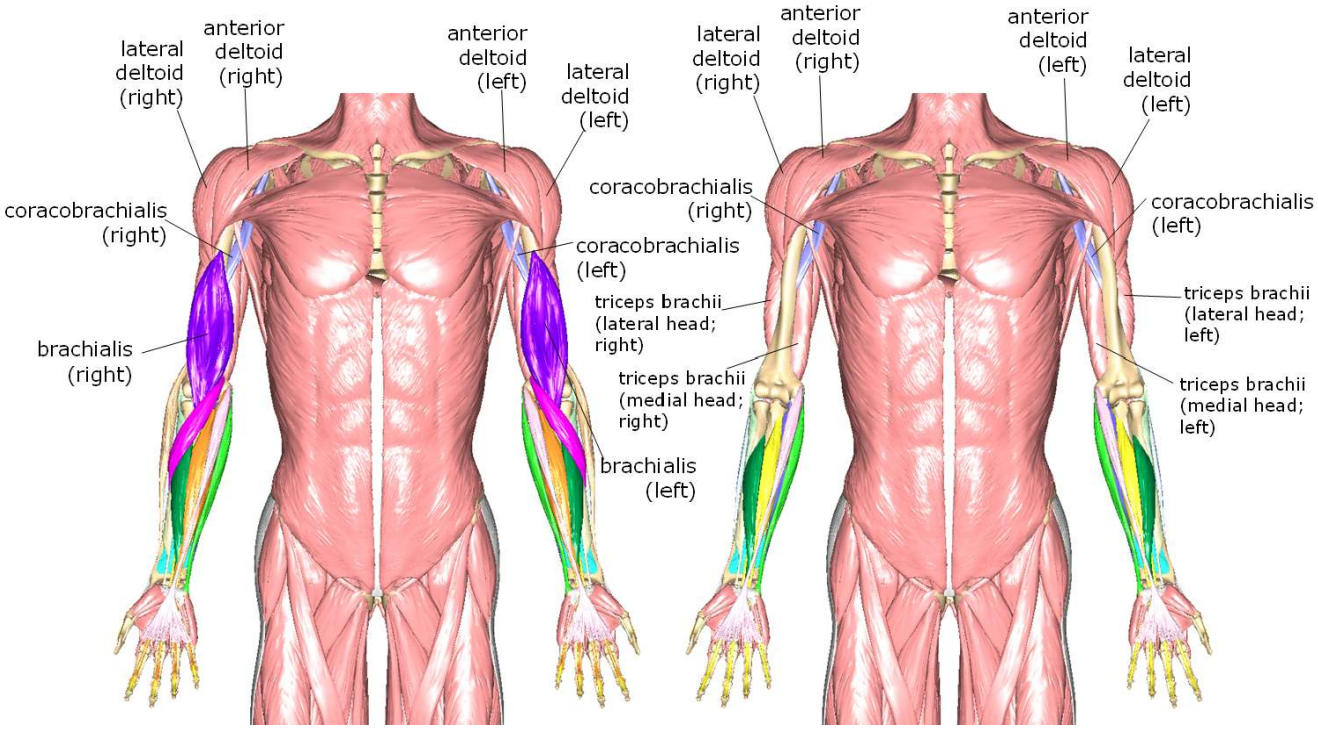
On the posterior side of the arm is the **triceps brachii** muscle. It the antagonist to the biceps brachii. When the triceps brachii contracts it extends the forearm, undoing any flexing brought about by contractions of the biceps brachii. As a result, when the triceps brachii is contracted, the biceps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



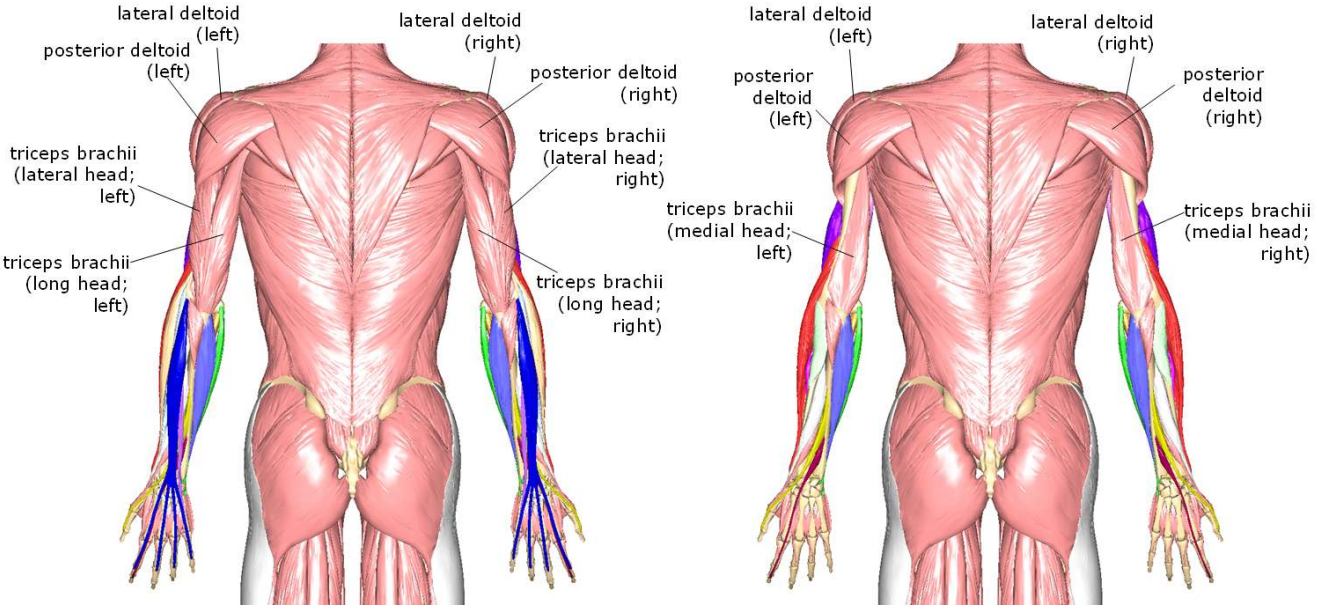
https://bio.libretexts.org/@go/page/53688



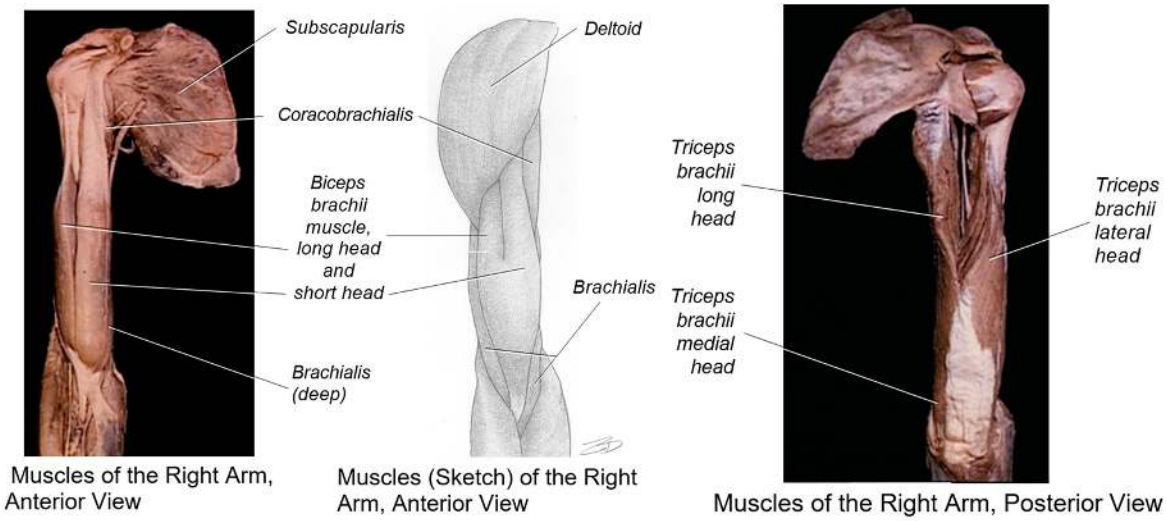
Above: Superficial muscles of the arm (shoulder to elbow) with a (left) lateral view, (middle) anterior view, and (right) anterolateral view.



Above: Anterior upper limb with some muscles removed and deep muscles of the arm labeled (left) without biceps brachii and (right) without biceps brachii and brachialis.



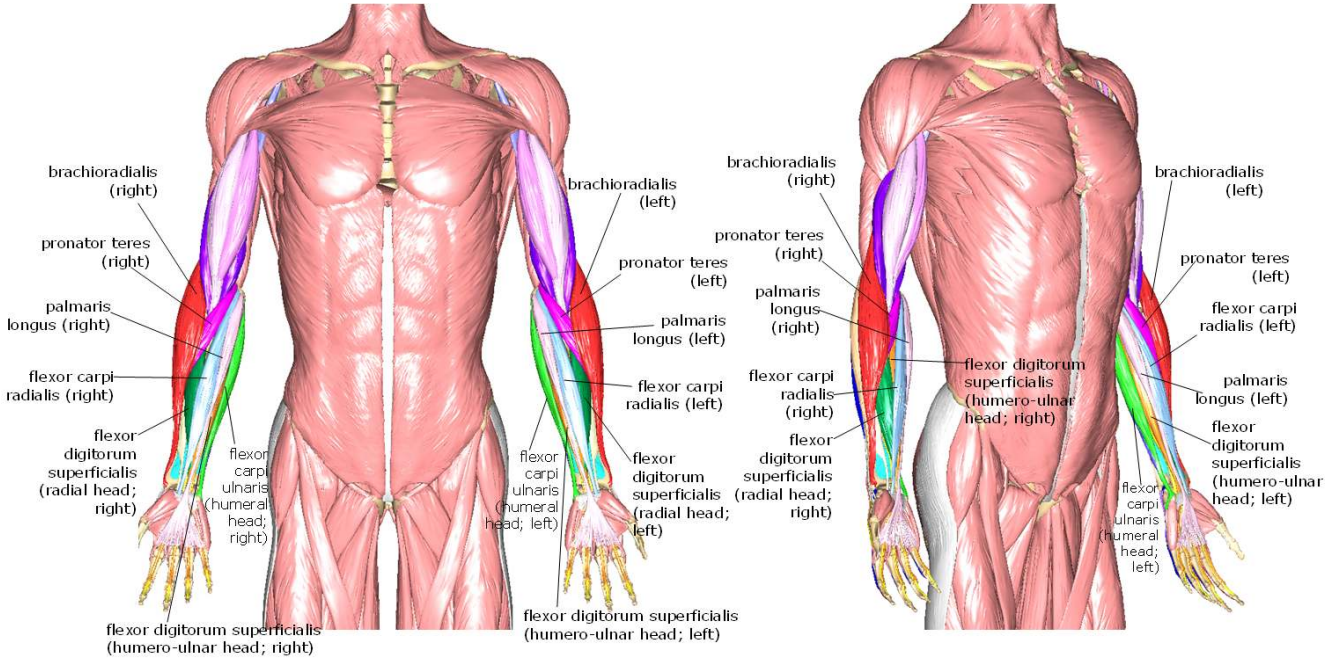
Above: Posterior upper limb with muscles of the arm labeled. (Left) The superficial muscles of the posterior arm and (right) muscles of the posterior arm without the lateral head and long head of triceps brachii.



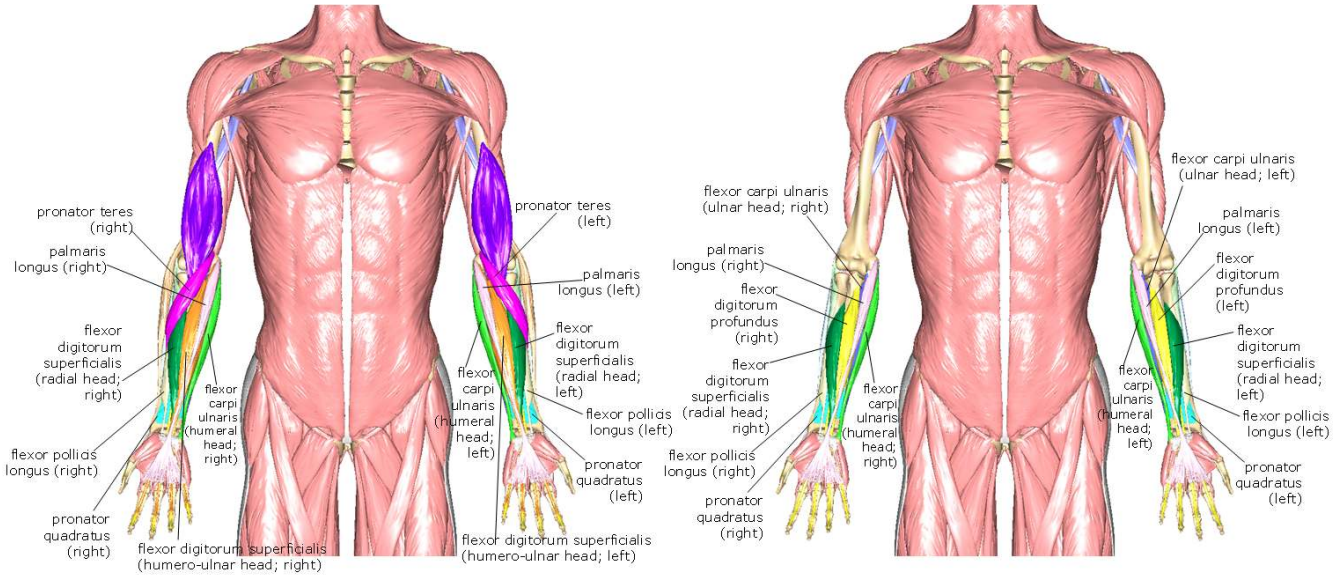
Above: Cadaver images of the muscles of the arm.

Forearm

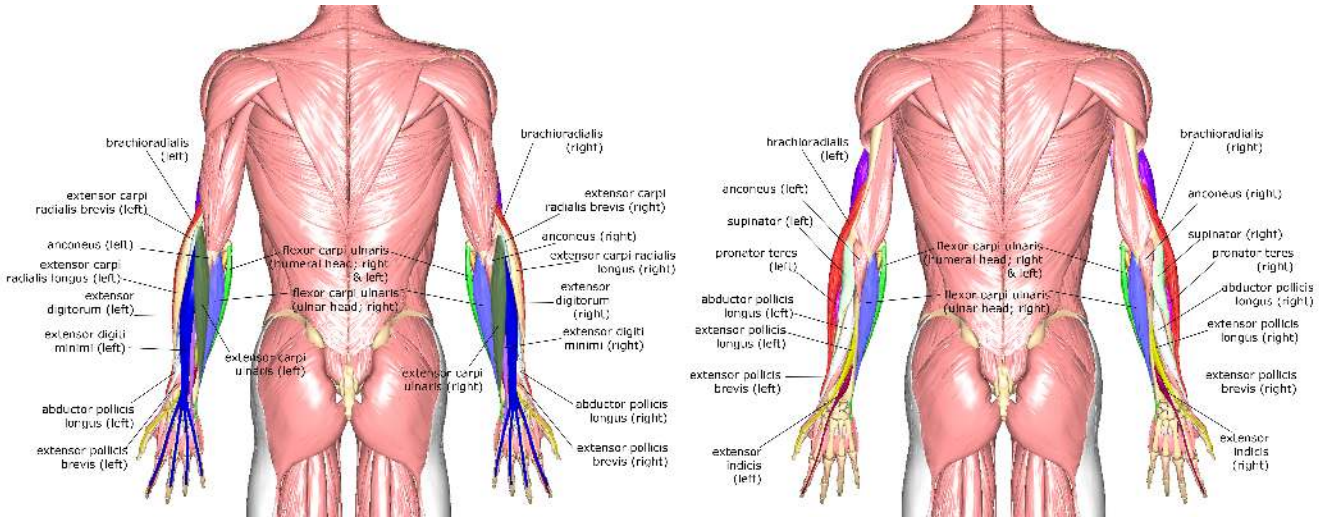
Anatomists refer to the lower arm as the forearm or antebrachium. The musculature of the forearm is complicated in order to provide the dexterity possible with the forearm and some of the movements of the hand. Many of the muscles of the anterior forearm are "flexor" muscles since they cause flexion. Likewise, many of the muscles of the posterior forearm are "extensor" muscles since they cause extension. The names of the forearm muscles reflect attachments, locations, and actions they cause including "digitorum" (mover of the digits aka fingers), "carpi" (relating to the carpals/wrist bones), "radialis" (relating to the radius), "ulnaris" (relating to the ulna), "pronator" (causes pronation), "supinator" (causes supination), "pollicis" (relating to the thumb/pollex) and "abductor" (causing abduction).



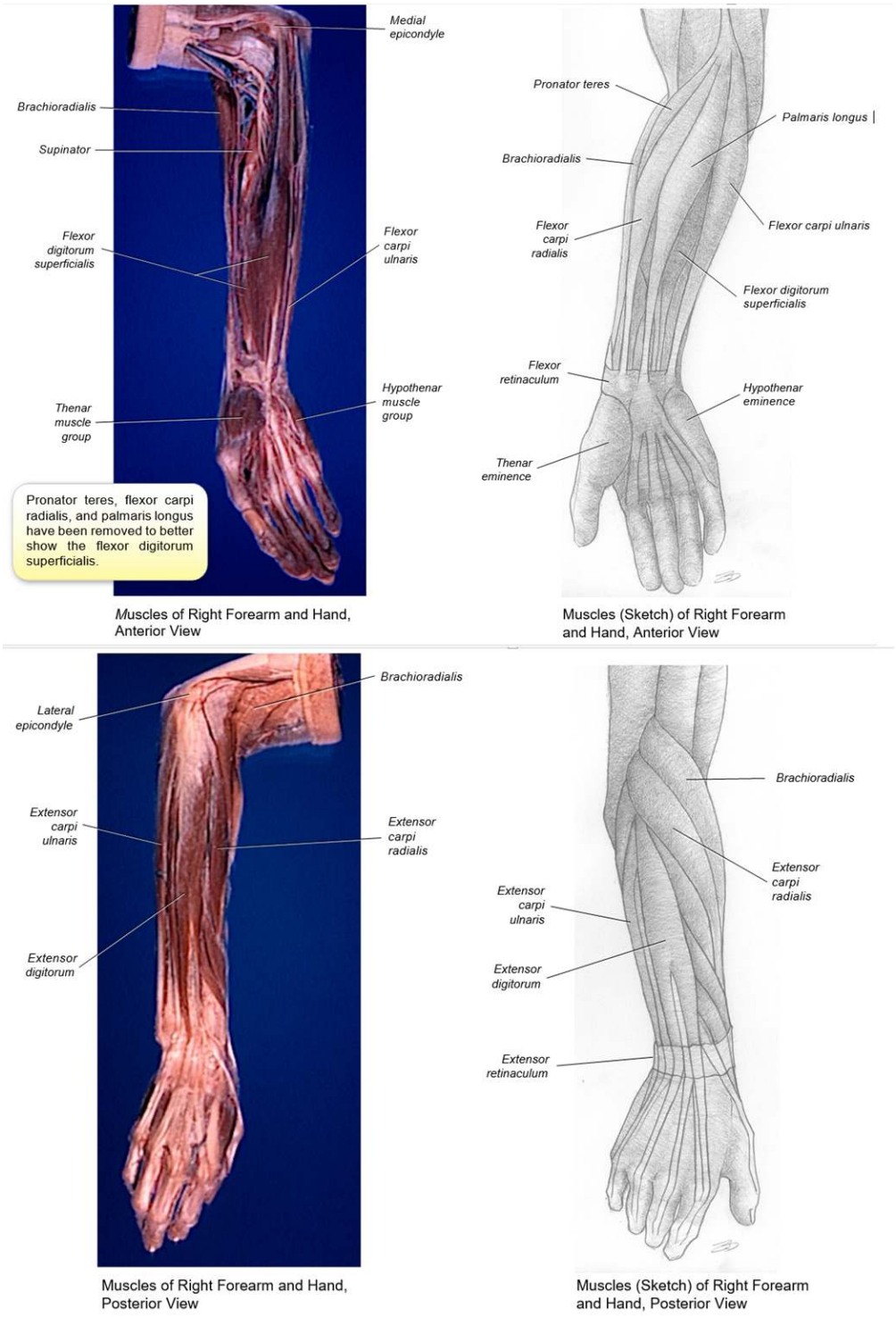
Above: Superficial muscles of the forearm (elbow to wrist) with a (left) lateral view, (middle) anterior view, and (right) anterolateral view.



Above: Anterior upper limb with some muscles removed with deep muscles of the forearm labeled. (Left) without brachioradialis and flexor carpi radialis and (right) without muscles in the left figure and also without pronator teres, humero-ulnar head of flexor digitorum, and extensor carpi radialis longus.



Above: Posterior upper limb with muscles of the forearm labeled. (Right) The posterior forearm and (left) without extensor digitorum, extensor carpi radialis longus, extensor carpi radialis brevis, extensor carpi ulnaris, and extensor digiti minimi.



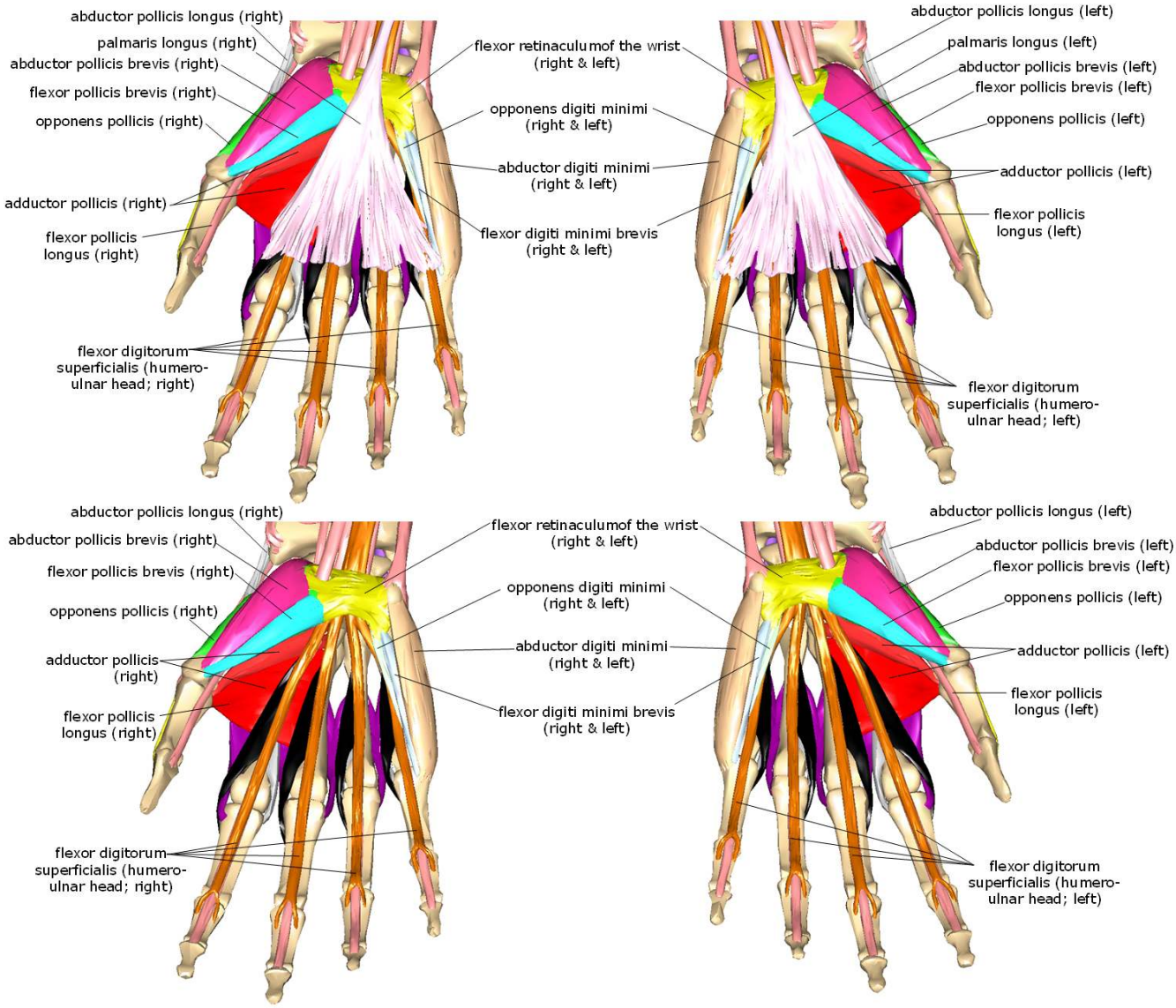
Above: Cadaver images of the muscles of the forearm.

Hand

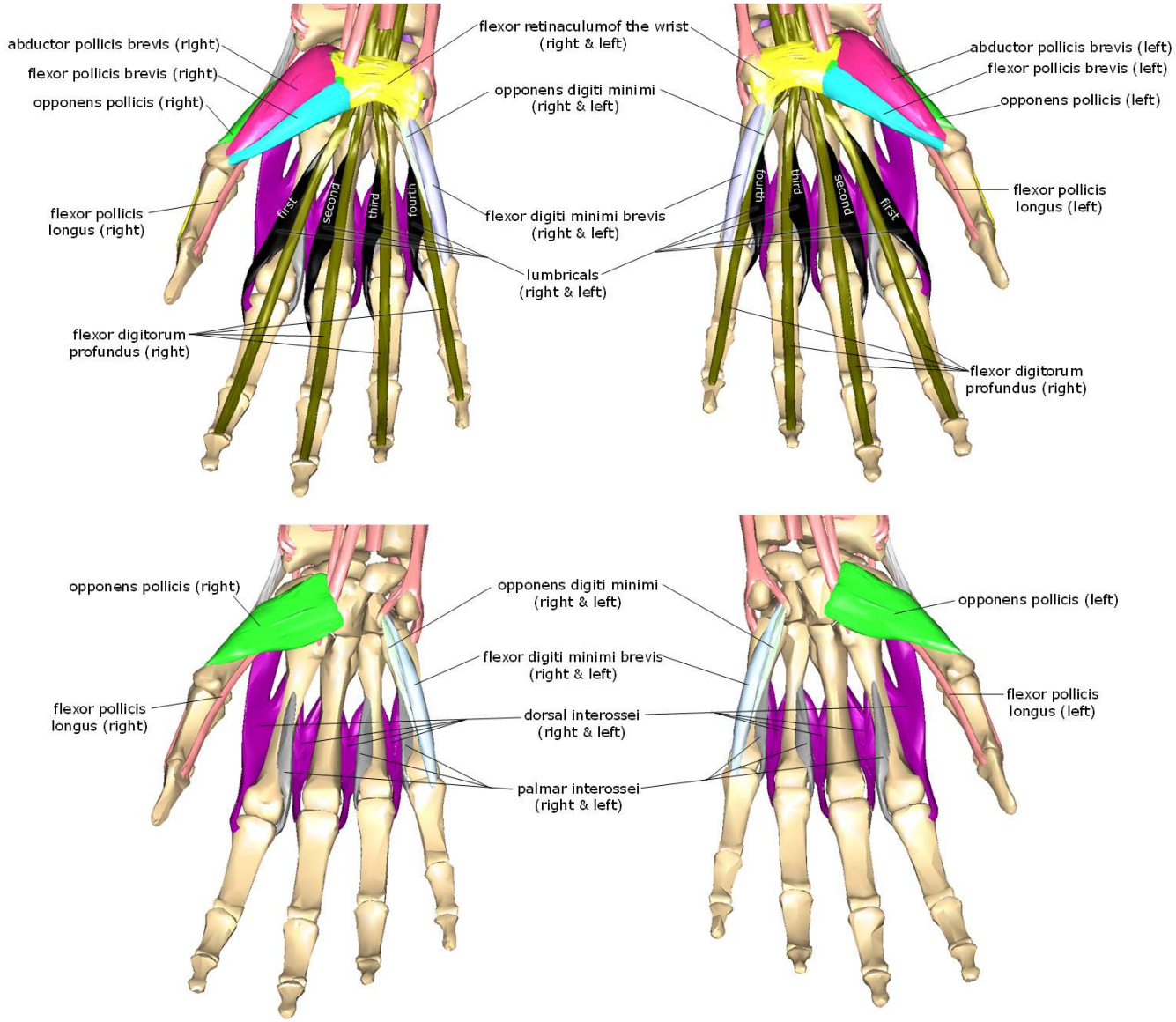
Humans are capable of very fine movements as well as powerful movements with their hands in a variety of directions. These abilities require a host of muscles to create the high amount of dexterity possible with the hands. A number of muscles of the forearm attach to the hands including palmaris longus, flexor digitorum (humero-ulnar head), and flexor pollicis longus. These attachments may be seen in the figure below.

Lateral muscles of the palm include **abductor pollicis brevis**, **opponens pollicis**, **flexor pollicis brevis**, and **adductor pollicis**. The medial muscles of the palm include **palmaris brevis**, **flexor digiti minimi brevis**, **abductor digiti minimi**, and **opponens digiti minimi**.

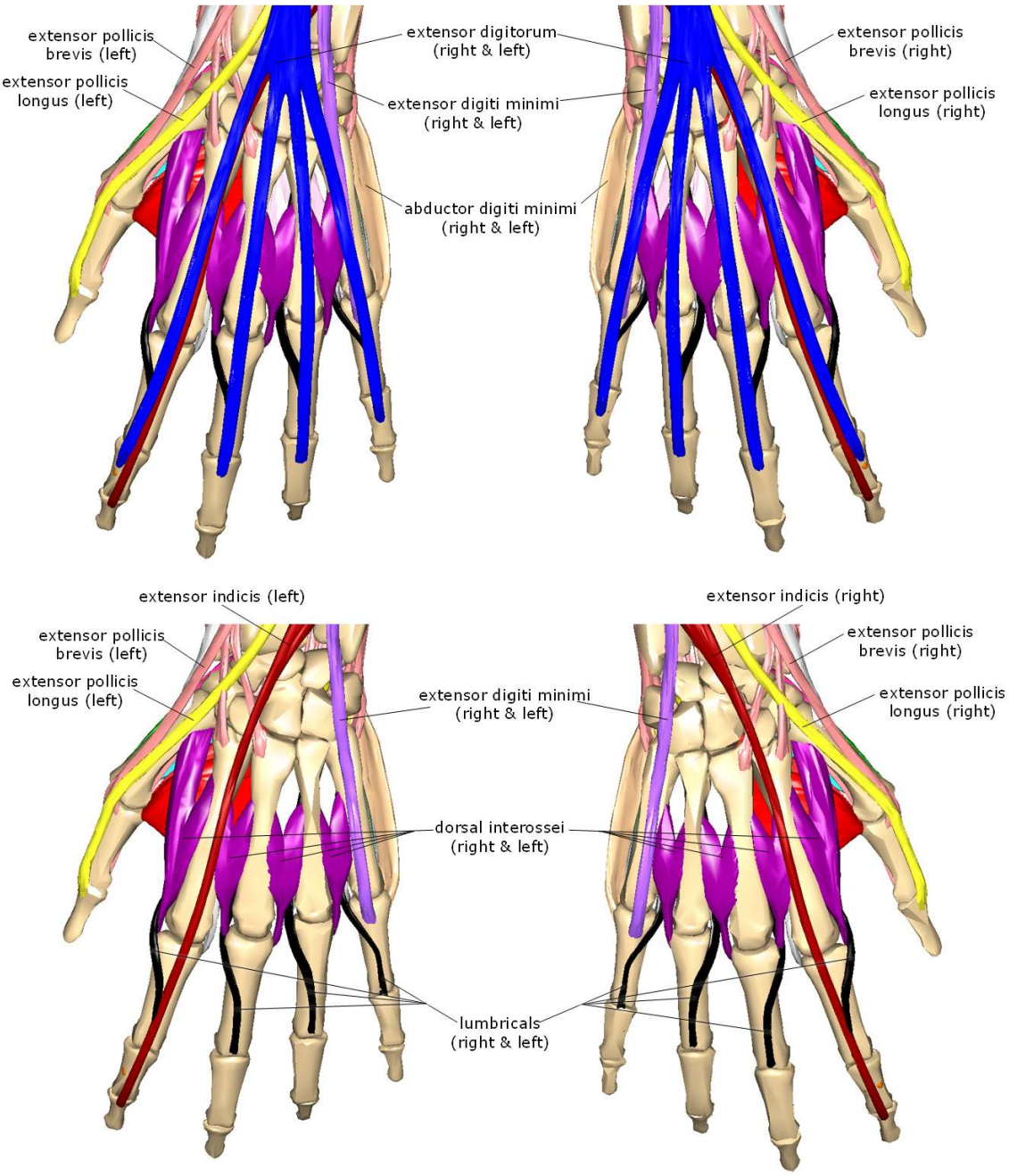
There are multiple **lumbricals** and **interossei** are muscles that are intermediate in the hand with palmar interossei located on the palmar or anterior aspect of the hand and dorsal interossei located on the dorsal aspect of the hand. The lumbricals are named **first lumbrical** (lateral edge of the second phalanx), **second lumbrical** (lateral edge of the third phalanx), **third lumbrical** (lateral edge of the fourth phalanx), and **fourth lumbrical** (lateral edge of the fifth phalanx)



Above: Palm of the hand (anterior aspect) (top) with all the muscles and (bottom) without palmaris longus.



Above: Deeper muscles of the palm of the hand (anterior aspect) (top) without palmaris longus, flexor digitorum (humero-ulnar head), abductor digiti minimi, adductor pollicis, and abductor pollicis brevis. (Bottom) The palm without the muscles in the top diagram and also without flexor digitorum profundus, lumbricals, flexor retinaculum of the wrist, abductor pollicis brevis, and opponens pollicis.



Above: Muscles of the posterior hand. (Top) All of the muscles of the posterior hand and (bottom) without extensor digitorum.

Attributions

- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0
- "Anatomy of the Human Body" by Henry Gray is in the Public Domain
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- "BodyParts3D/Anatomography" by The Database Center for Life Science is licensed under CC BY-SA 2.1
- "Gray's Anatomy plates" by Henry Vandyke Carte is in the Public Domain

Updated 2026.

This page titled 12.5: Muscles of the Upper Limbs is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

12.6: Muscles of the Hips and Lower Limbs

Muscles of the Hips and Lower Limbs

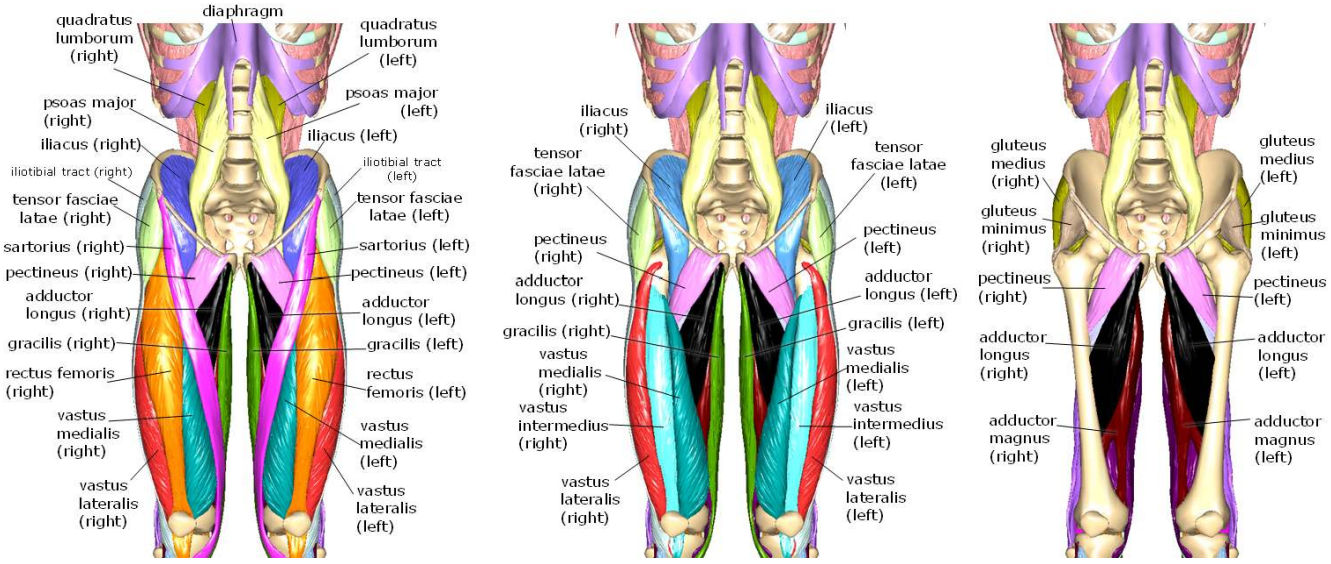
Hip & Thigh

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

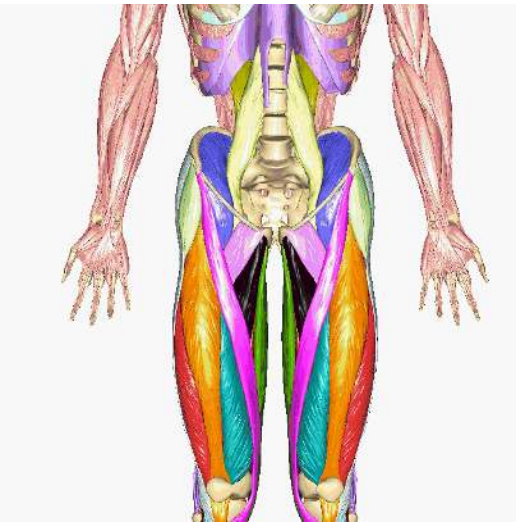
The quadriceps sounds like it should be just one muscle, akin to the triceps brachii (one muscle with three heads), but it is a group of four separate muscles, three visible on the surface, and the fourth obscured. The three surface muscles of the quadriceps are the **rectus femoris** in the center, the **vastus medialis** on the medial side, and the **vastus lateralis** on the lateral side. Deep to rectus femoris and largely hidden by it is the **vastus intermedius**. The four muscles of the quadriceps all extend the leg (knee to ankle), and the rectus femoris additionally can flex the thigh at the hip. The **sartorius** muscle is a distinctively long and thin muscle that crosses the thigh diagonally. Sartorius comes from the Latin for "tailor," and this is sometimes called the tailor’s muscle, although the reasons for the nickname are obscure. It may be because the shape of the muscle is thin and long, like a tailor’s measuring tape; it may be because it is close to the inseam a tailor measures when tailoring pants, or it may be because it helps bring about the cross-legged position that tailors often adopt when working.

There are three layers of gluteal muscles on the posterior hips, just like there are three layers of muscles in the abdominal trunk. The largest of them is the most superficial muscle, the **gluteus maximus.** Its origin is on the ilium of the coxal bone, and it inserts part-way down the shaft of the femur. It helps maintain erect posture, abducts the thigh, and rotates the thigh outward. Below the gluteus maximus is the smaller **gluteus medius**. The gluteus medius muscle helps abducts the thigh along with the gluteus maximus, but can rotate the thigh inward where the gluteus maximus rotates the thigh outward. The below the gluteus medius are several muscles, one of which is the **gluteus minimus**, the smallest of the gluteal muscles. It is a synergist for the gluteus medius.

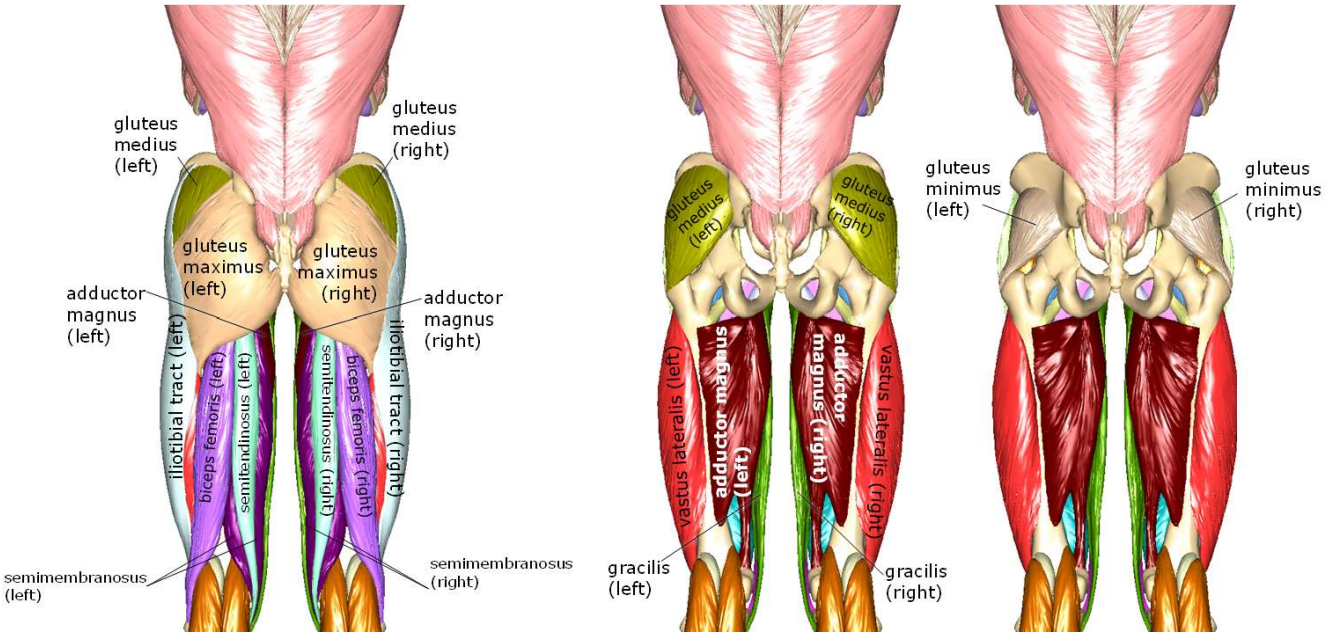
In the posterior thigh the bulk of the musculature is made up of three long muscles that are collectively called the "hamstrings." The origin of this nickname is obscure, but it may have to do with the practice of butchers of hanging the thighs of butchered animals such as pig (the “hams”) by the tendons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

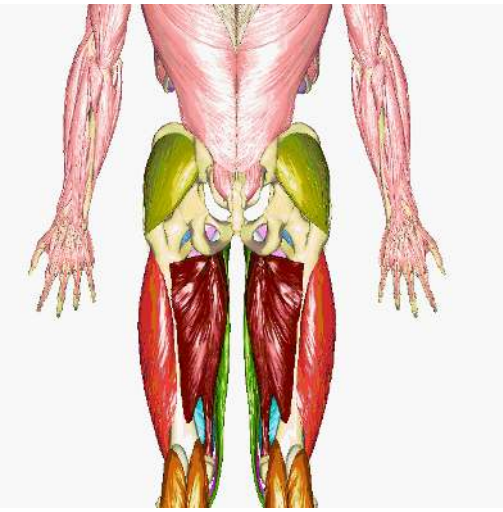


https://bio.libretexts.org/@go/page/53689

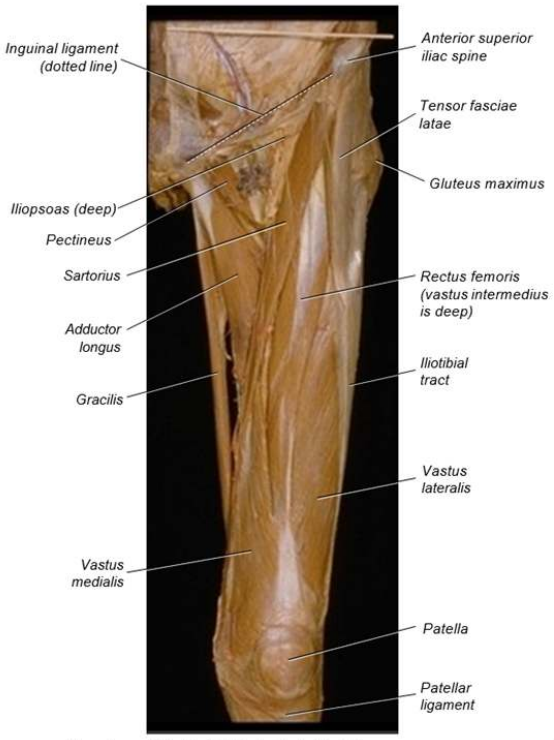


Above: Anterior aspect of the hip and thigh (hip to knee) with the arms absent and without the abdominal muscles with all hip and thigh muscles (top left and rotating diagrams), without sartorius, and rectus femoris muscles (middle diagram), and without the same muscles as the middle diagram and also without iliacus, vastus lateralis, vastus medialis, vastus intermedius, gracilis, tensor fasciae latae, and the iliotibial tract (left diagram).

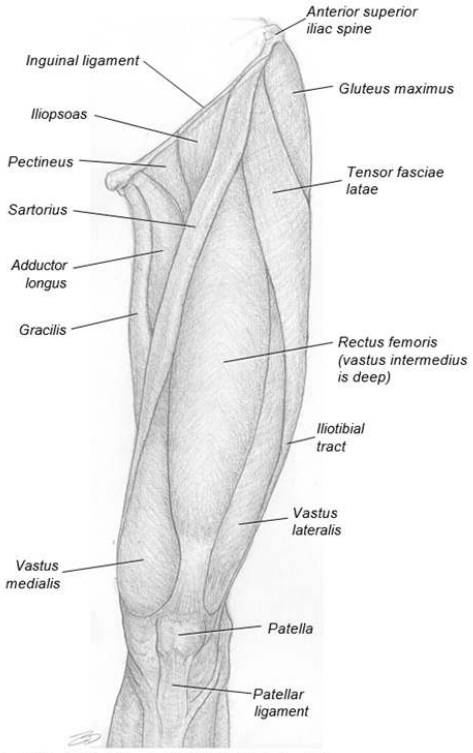




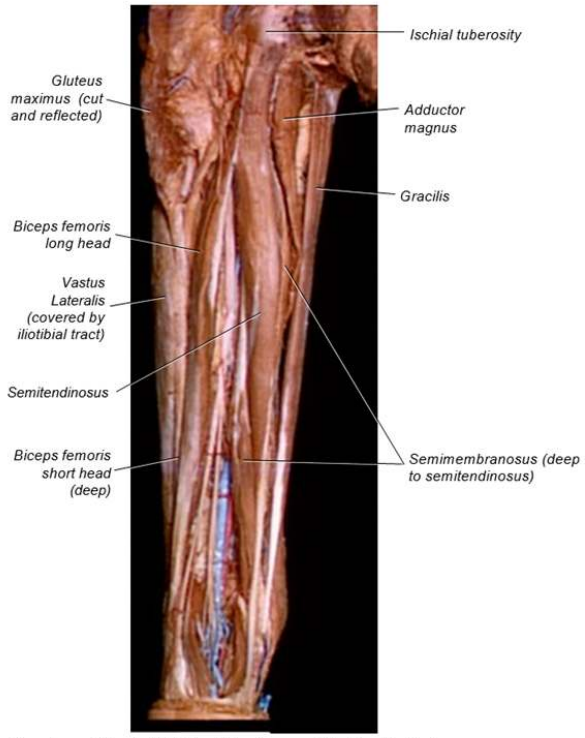
Above: Posterior aspect of the hip and thigh (hip to knee) with abdominal muscles absent (top left) with all muscles and (top middle and bottom) without gluteus maximus, semitendinosus, semimembranosus, biceps femoris and (right) without the same muscles as the middle figure and also without gluteus medius.



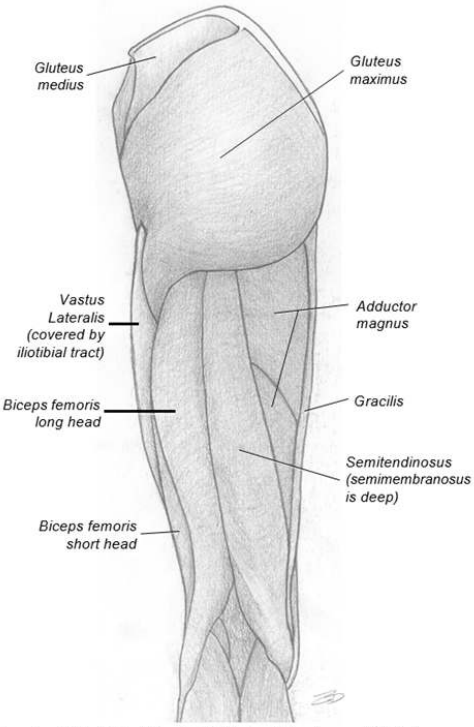
Muscles of the Left Thigh, Anterior View



Muscles (Sketch) of the Left Thigh, Anterior View

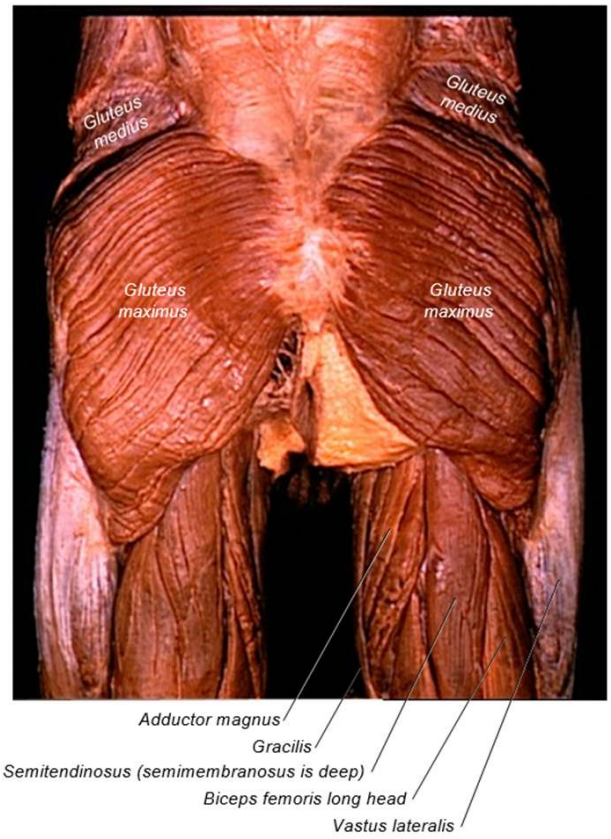


Muscles of the Left Gluteal Region and Thigh, Posterior View

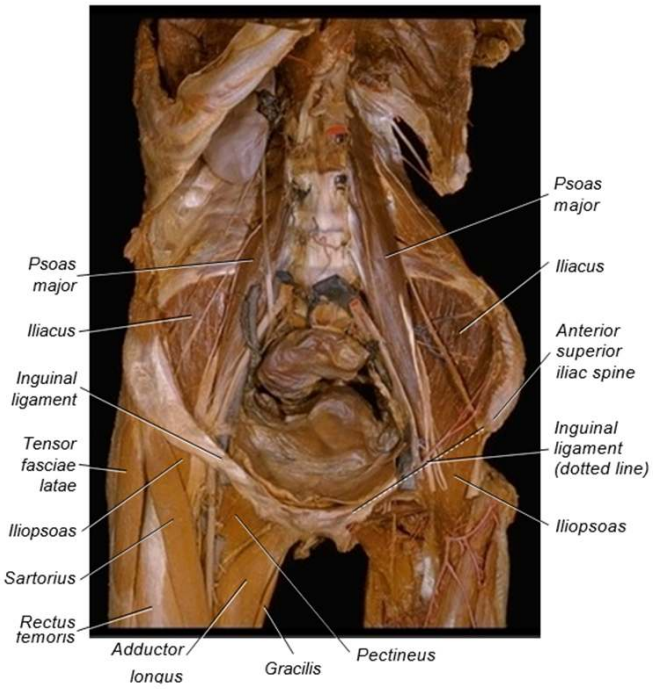


Muscles (Sketch) of the Left Gluteal Region and Thigh, Posterior View

Above: Cadaver images of the muscles of the thigh.



Muscles of the Gluteal Region and Proximal Thigh, Posterior View



Muscles of the Pelvis and Proximal Thigh, Anterior View

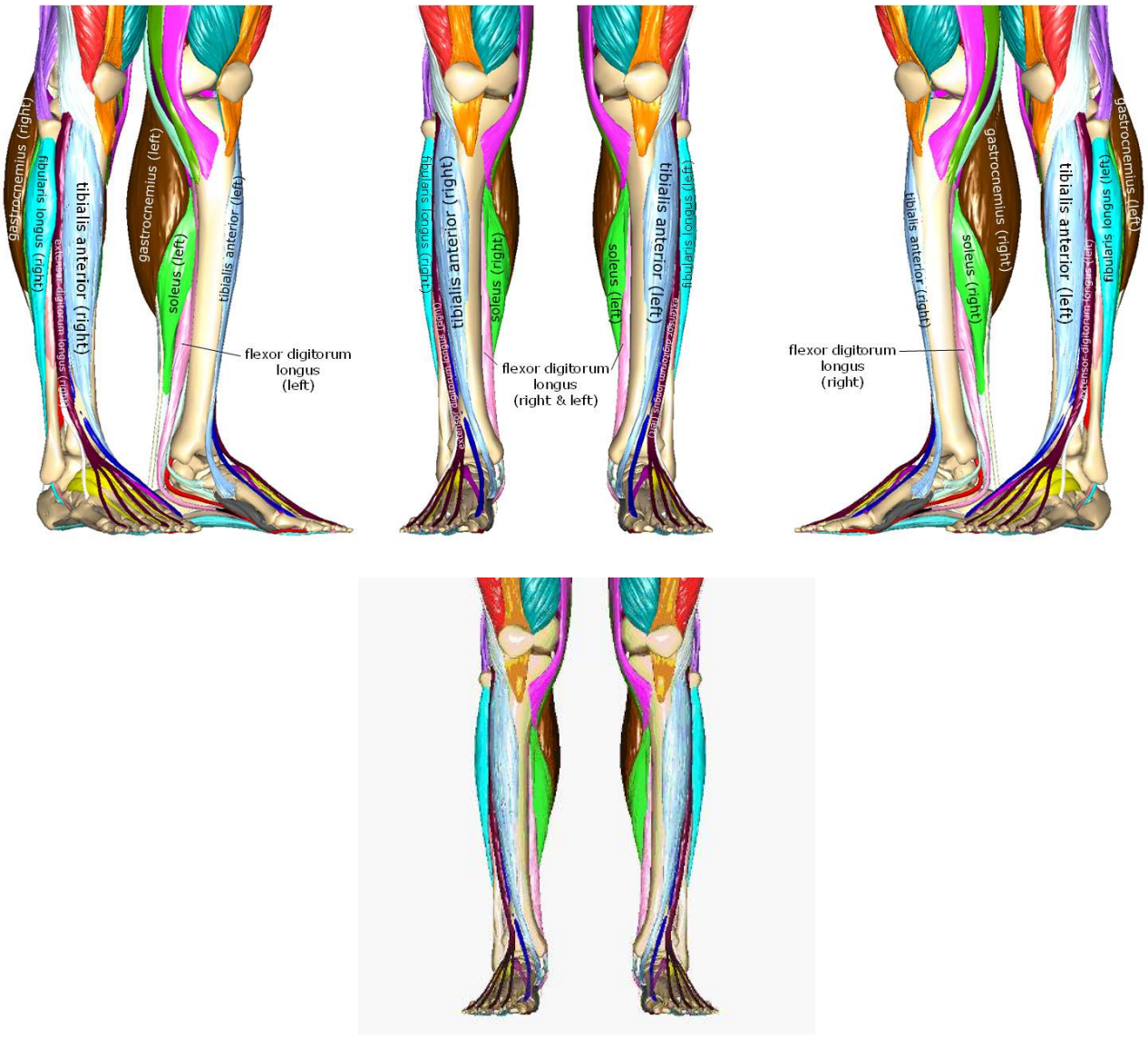
Above: Cadaver images of the muscles of the butt and hip.

Clinical Application: "Groin Pull"

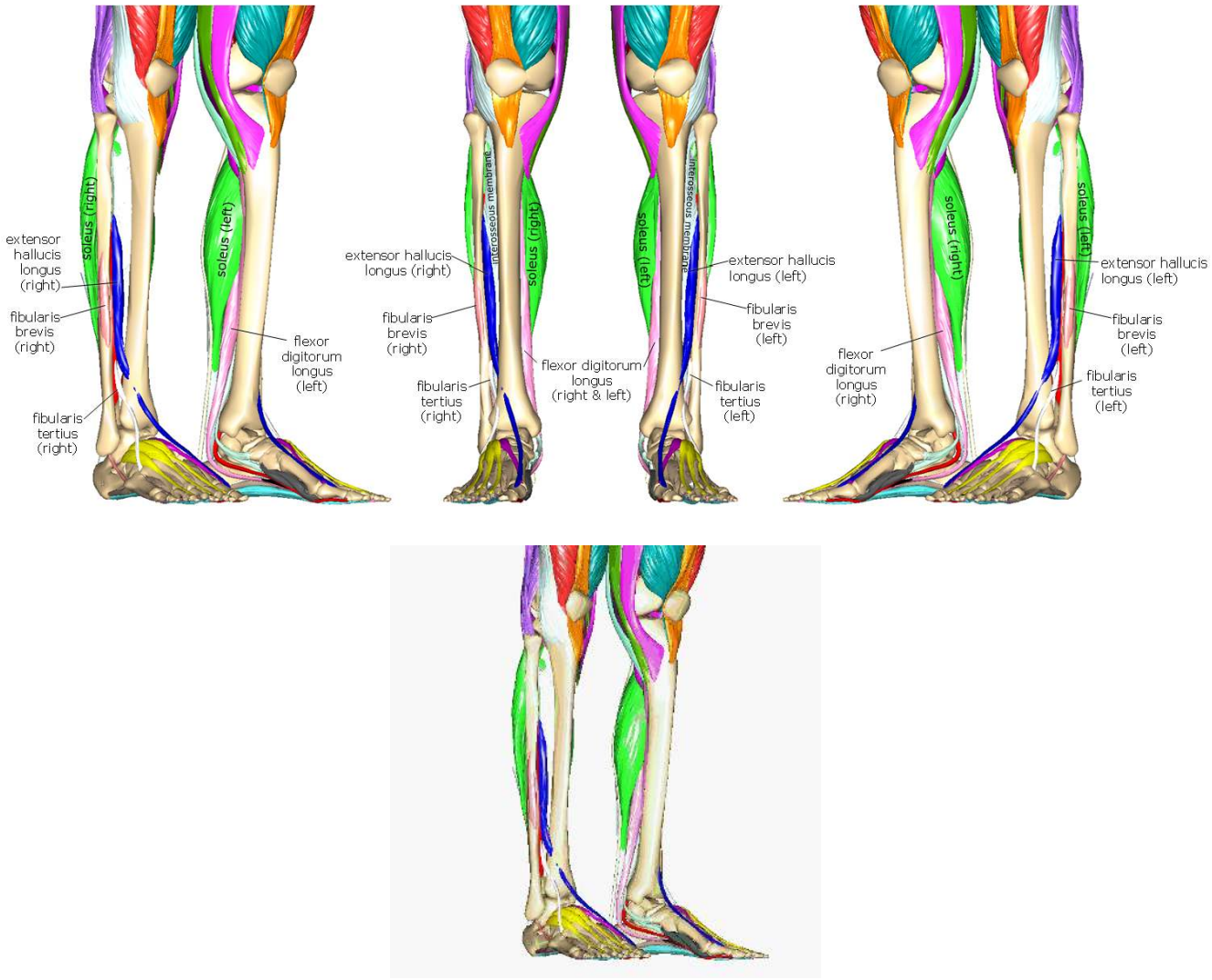
There are many muscles that adduct your thighs, including but not limited to the **adductors**, **gracilis**, and **pectineus** muscles. When these muscles are strained, the resulting pain and discomfort is often diagnosed as a “groin pull.” This pain and discomfort can range from mild to severe depending on how strained the muscles are. Severe groin strains can include swelling, bruising, and muscle spasms, making even light walking painful. Groin pulls are especially common among hockey, football, and soccer athletes who generate tremendous force from their adductor muscles. Proper conditioning and stretching of adductor muscles are two of the most effective ways to prevent groin pulls.

Leg (Knee to Ankle)

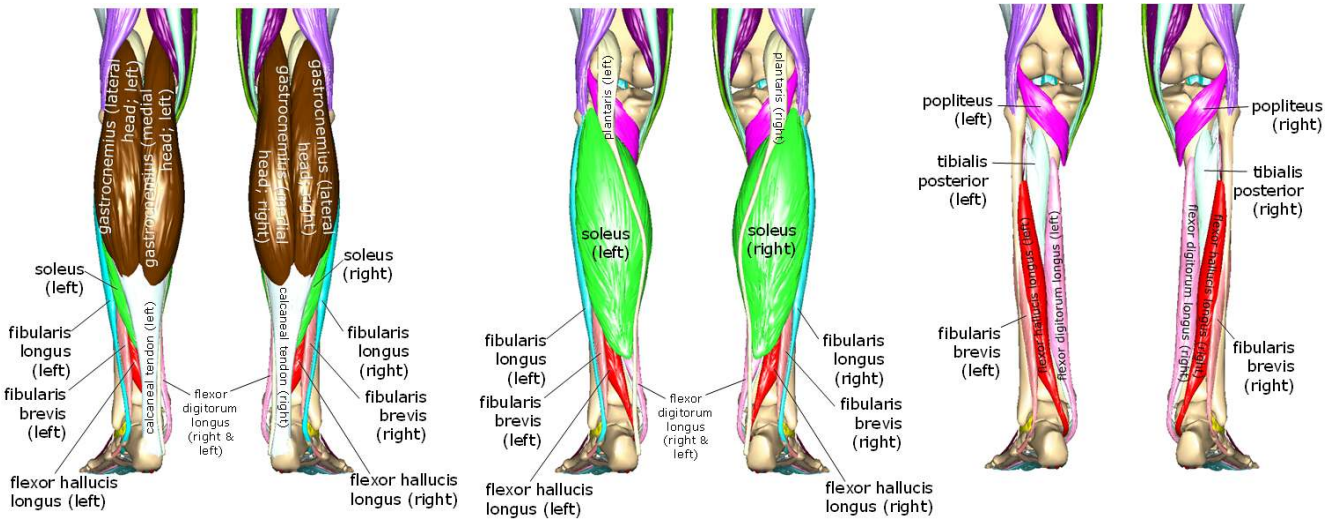
The muscles of the lower leg, called simply the "leg" by anatomists, largely move the foot and toes. The **gastrocnemius** muscle has two large bellies, called the medial head (on the medial aspect of the leg) and the lateral head (on the lateral aspect of the leg), and inserts into the calcaneus bone of the foot via its **calcaneal tendon** (also known as the "Achilles tendon"). The **soleus** muscle is deep to the gastrocnemius, and the two muscles serve together as the calf of the leg. Many of the muscles of the leg are named for their locations, origins, insertions, and actions. "Tibialis" relates to the tibia, "fibularis" relates to the fibula, "hallucis" relates to the hallux or big toe, and "digitorum" relates to the digits or phalanges of the foot.



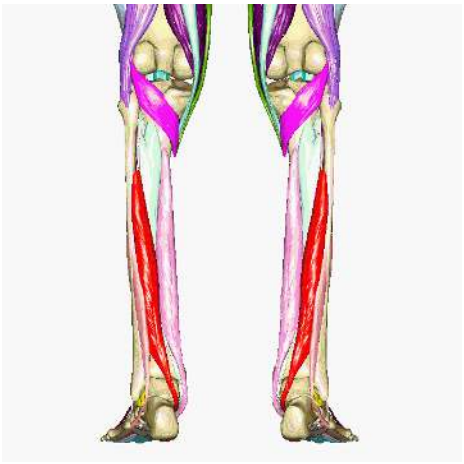
Above: The superficial muscles of the leg (left) with an anterolateral view of the right side, (middle) an anterior view, and (right) with an anterolateral view of the left side.



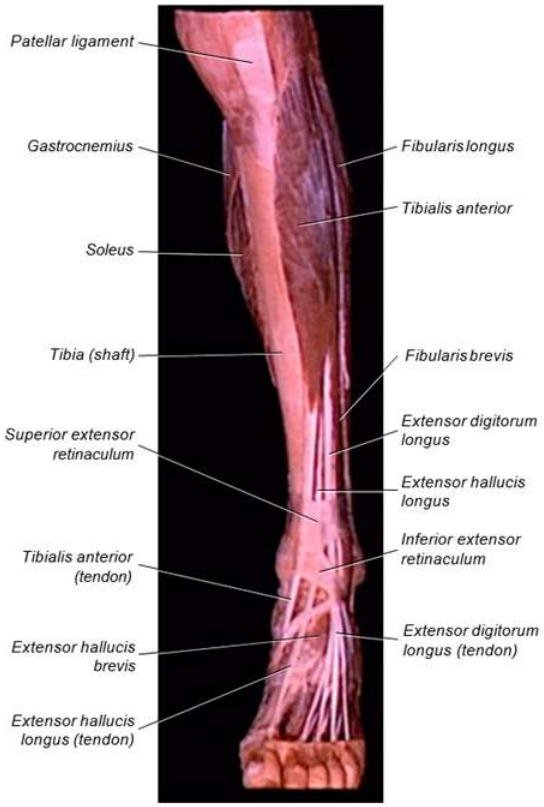
Above: The deeper muscles of the anterior and lateral leg without tibialis anterior, fibularis longus, extensor digitorum longus, and gastrocnemius (left) with an anterolateral view of the right side, (middle) an anterior view), and (right) with an anterolateral view of the left side.



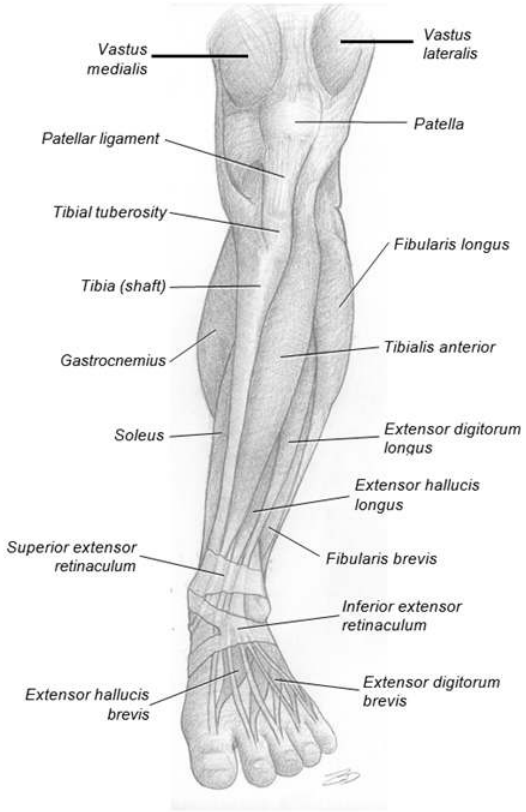
https://bio.libretexts.org/@go/page/53689



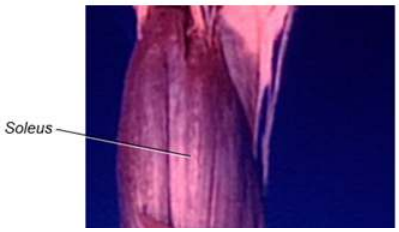
Above: Posterior view of the muscles of the leg (top left) with all muscles present, (top middle) without gastrocnemius and the calcaneal tendon, and (top right and bottom) without gastrocnemius, the calcaneal tendon, soleus, fibularis longus, and plantaris.

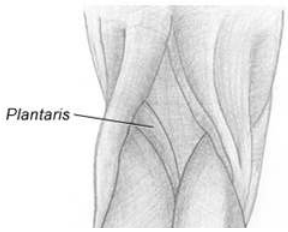


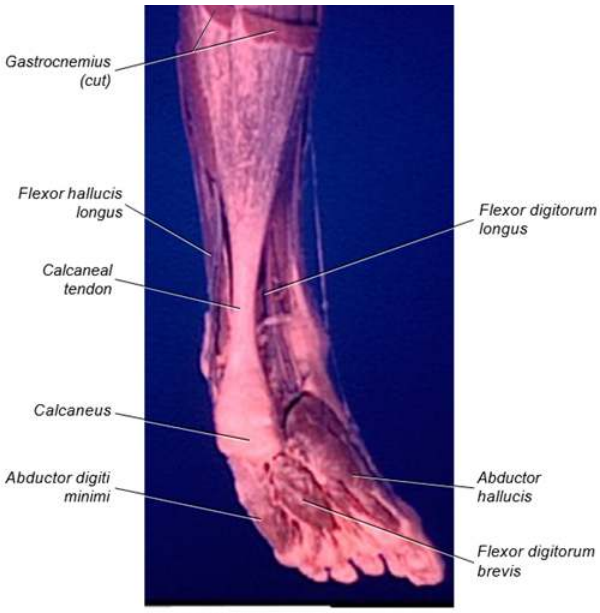
Muscles of the Left Leg, Anterior View



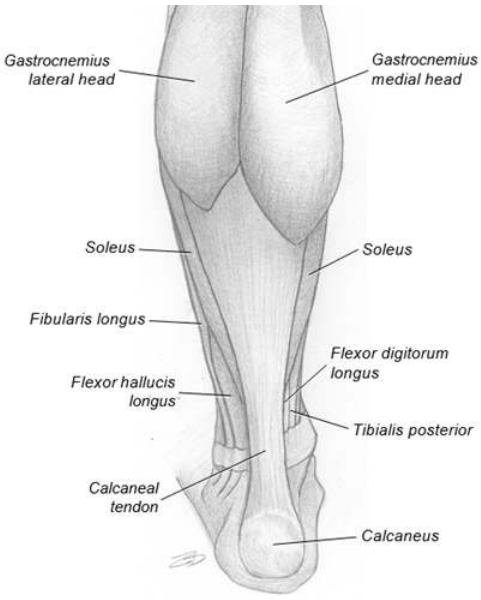
Muscles (Sketch) of the Left Leg, Anterior View







Muscles of the Left Leg, Posterior View

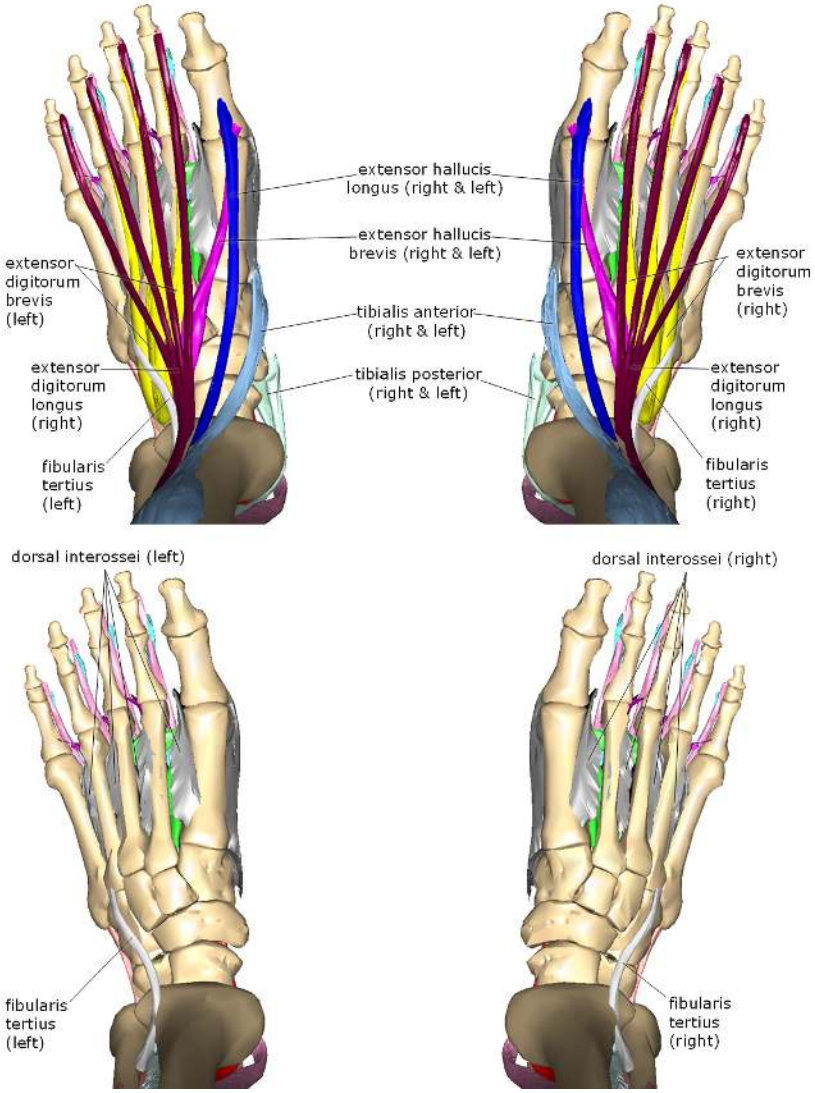


Muscles (Sketch) of the Left Leg, Posterior View

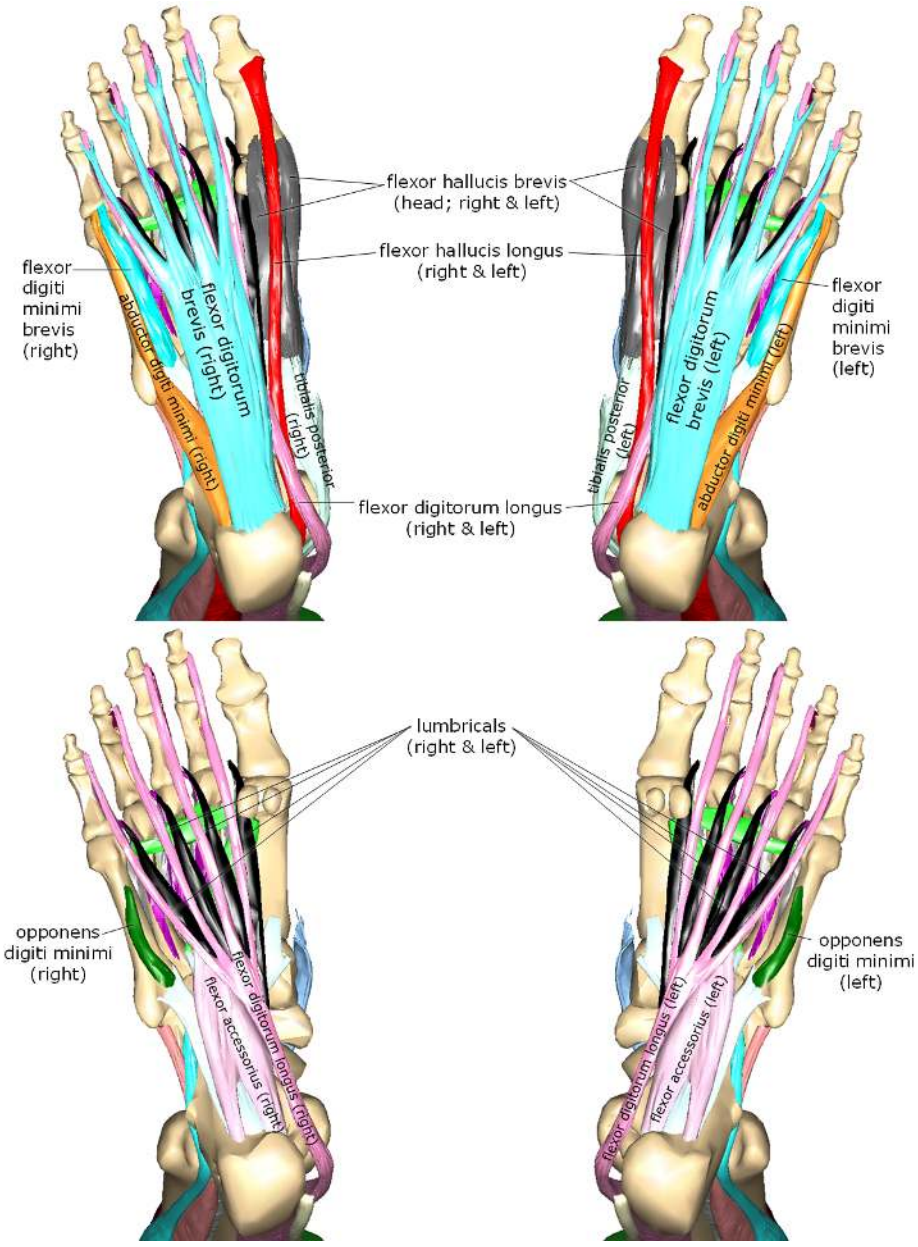
Above: Cadaver images of the muscles of the leg.

Foot

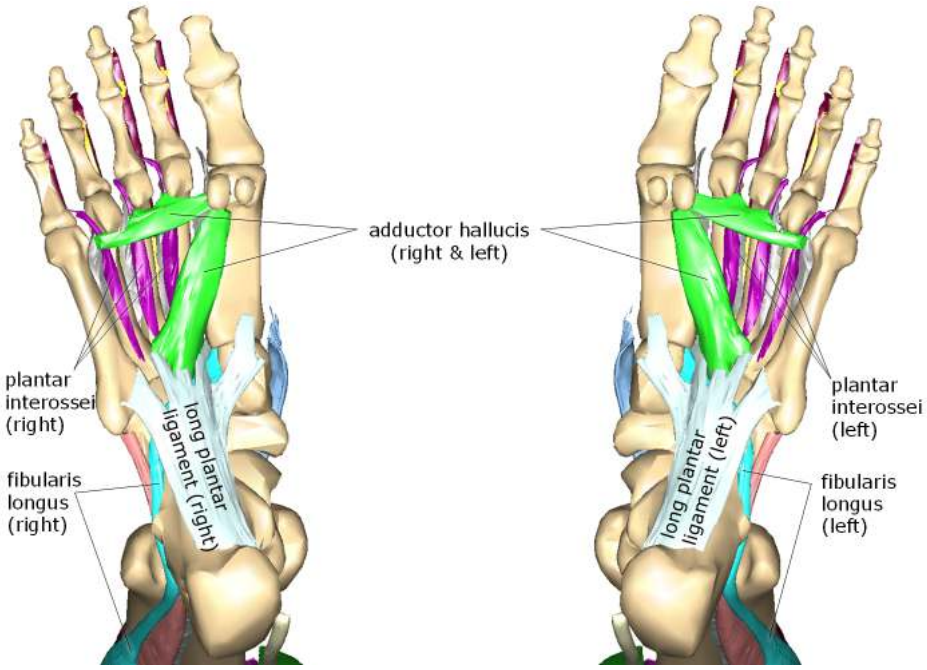
Muscles of the leg, including extensors hallucis longus and brevis, extensors digitorum longus and brevis, tibialis anterior and tibialis posterior, fibularis tertius, flexor digitorum longus, and flexor hallucis longus attach to the dorsal and plantar aspects of the foot. Deeper foot muscles include interossei between the metatarsals, one set on the dorsal aspect (**dorsal interossei**) and one set on the plantar aspect (**plantar interossei**). Lumbricals are also present between the metatarsals on the plantar aspect of the foot.



Above: Dorsal (back) of the foot from a superior view. (Top) Superficial muscles of the dorsal foot and (bottom) deep muscles of the dorsal foot without tibialis anterior, tibialis posterior, extensor hallucis longus, extensor hallucis brevis, extensor digitorum longus, and extensor digitorum brevis.



Above: Plantar (sole of the foot) muscles from an inferior view. (Top) Superficial plantar muscles and (bottom) deep plantar muscles without flexor digitorum brevis, flexor hallucis brevis, flexor hallucis longus, tibialis posterior, flexor digiti minimi brevis, abductor digiti minimi.



Above: Deep plantar (sole of the foot) muscles from an inferior view without flexor digitorum brevis, flexor hallucis brevis, flexor hallucis longus, tibialis posterior, flexor digiti minimi brevis, abductor digiti minimi, flexor accessorius, flexor digitorum longus, lumbricals, and opponens digiti minimi.

Attributions

- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0
- "BodyParts3D/Anatomography" by The Database Center for Life Science is licensed under CC BY-SA 2.1

Updated 2026.

This page titled 12.6: Muscles of the Hips and Lower Limbs is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

12.7: Actions, Origins, and Insertions of the Skeletal Muscles

Actions, Origins, and Insertions of the Skeletal Muscles

Head and Face

Muscle	Action	Origin	Insertion
buccinator	pressing cheek inward, compressing air while blowing	maxilla bone, mandible bone	orbicularis oris
depressor anguli oris	opening the mouth, sliding the lower jaw right and left	mandible bone	corners of the mouth
depressor labii inferioris	drawing the lip downward	mandible bone	lower lip
epicranius	raising eyebrows, wrinkling forehead, pulling scalp posteriorly	frontal belly, occipital belly, temporal bone	skin of brow, epicranial aponeurosis
lateral pterygoid	protruding the mandible, opening the jaw, moving the mandible outward and right and left	pterygoid plate of sphenoid bone	mandible bone
masseter (superficial & deep)	elevating the mandible (lower jaw)	zygomatic arch	mandible bone
medial pterygoid	elevating the mandible, moving the mandible outward and right and left	pterygoid plate of sphenoid bone	mandible bone
mentalis	elevating and protruding lower lip and chin	mandible bone	chin
nasalis	widening the nostrils	maxilla bone	nasal bone
orbicularis oculi	closing the eye	margin of orbit	eyelid
orbicularis oris	closing the mouth, shaping lips	maxilla bone, mandible bone	corners of the mouth
risorius	pulling mouth laterally	fascia of parotid salivary gland	corners of the mouth
temporalis	elevating the mandible (lower jaw)	temporal bone	mandible bone
zygomaticus major	smiling/raising corners of the mouth	zygomatic bone	corners of the mouth (dimple region), orbicularis oris
zygomaticus minor	smiling/raising corners of the mouth	zygomatic bone	corners of the mouth

Eye

Muscle	Action	Origin	Insertion
levator palpebrae superioris	elevating and retracting the upper eyelid	sphenoid bone	upper eyelid
inferior oblique	looking up and laterally (eye roll)	maxilla bone	eyeball (inferior, lateral)
inferior rectus	looking down (depression)	sphenoid bone	eyeball (inferior, medial)
lateral rectus	looking laterally (abduction)	sphenoid bone	eyeball (lateral, anterior)
medial rectus	looking medially (adduction)	sphenoid bone	eyeball (medial)
superior oblique	looking down and laterally (eye roll)	sphenoid bone	eyeball (superior, lateral)
superior rectus	looking up (elevation)	sphenoid bone	eyeball (superior, anterior)

Anterior Neck

Muscle	Action	Origin	Insertion
digastric	depressing the mandible, elevating the larynx	mandible bone, temporal bone	hyoid bone
longus capitis	flexing the head and neck, rotating the head	cervical vertebrae	occipital bone
mylohyoid	elevating hyoid bone, elevating the floor of the mouth, depressing the mandible	mandible bone	hyoid bone
omohyoid	depressing the hyoid bone, depressing the larynx	scapula	hyoid bone
platysma	tensing skin of the neck, depressing the mandible, pulling down and back the lower lip	thoracic fascia	mandible bone, corners of mouth
scalenus anterior	flexing the neck and elevating the ribs	cervical vertebrae	first two ribs
scalenus medius	flexing the neck and elevating the ribs	cervical vertebrae	first two ribs
scalenus posterior	flexing the neck and elevating the ribs	cervical vertebrae	first two ribs
sternocleidomastoid	flexing the neck, rotating the neck, elevating the ribs	sternum, clavicle	mastoid process of temporal bone
sternohyoid	elevating the larynx	sternum, clavicle	hyoid bone
sternothyroid	depressing the hyoid bone, depressing the larynx	sternum, first costal cartilage	thyroid cartilage
stylohyoid	elevating the larynx	styloid process of temporal bone	hyoid bone
thyrohyoid	depressing the hyoid bone, elevating the thyroid	thyroid cartilage, larynx	hyoid bone

Thorax

Muscle	Action	Origin	Insertion
diaphragm	increasing thoracic volume (for inhalation)	sternum, ribs, lumbar vertebrae	central tendinous sheet
external intercostals	elevating ribs	inferior aspects of ribs	superior aspects of ribs
innermost intercostals	adducting the ribs, decreasing thoracic volume (for exhalation)	inferior aspects of ribs	superior aspects of ribs
internal intercostals	depressing ribs	superior aspects of ribs	inferior aspects of ribs
pectoralis major	flexing, adducting, and medially rotating the arm at the shoulder	sternum, clavicle	humerus
pectoralis minor	elevating the ribs, moving scapula anterior and inferior, protracting and elevating the shoulder	ribs	scapula
serratus anterior	moving and fixing scapula anteriorly, protracting the shoulder	ribs	scapula

Abdomen

Muscle	Action	Origin	Insertion
external oblique	flexing vertebral column, rotating vertebral column, compressing the abdomen	lower ribs	ilium, pubis, linea alba
internal oblique	flexing vertebral column, rotating vertebral column, compressing the abdomen	lumbar vertebrae, ilium	pubis, linea alba, lower ribs, sternum
rectus abdominis	flexing vertebral column, compressing the abdomen	pubis	lower ribs, sternum
transversus abdominis	compressing the abdomen	lower ribs, ilium, lumbar vertebrae	pubis, linea alba

Posterior Trunk

Muscle	Action	Origin	Insertion
iliocostalis (thoracis, lumborum)	flexing the vertebral column laterally, extending the vertebral column	thoracic and lumbar vertebrae, ilium, sacrum	ribs
latissimus dorsi	extending, adducting, and medially rotating arm at the shoulder	thoracic and lumbar vertebrae, ribs	humerus
levator scapulae	elevating the scapula and extending the neck	cervical vertebrae	scapula
longissimus (capitis, cervicis, thoracis)	flexing the head and neck laterally, extending the vertebral column	cervical, thoracic, and lumbar vertebrae	cervical, thoracic, and lumbar vertebrae
multifidus	extending backwards, bending vertebral column laterally, rotating vertebral column, collecting sensory information	cervical, thoracic, and lumbar vertebrae	cervical, thoracic, and lumbar vertebrae
obliquus capitis inferior	rotating the head and the neck	axis (C_2)	atlas (C_1)
obliquus capitis superior	extending and flexing the head	atlas (C_1)	occipital bone
quadratus lumborum	depress ribs, laterally flexes vertebral column	ilium, iliolumbar ligament	lumbar vertebrae, last rib
rectus capitis posterior major	extending and rotating the head	axis (C_2)	occipital bone
rectus capitis posterior minor	extending the head and neck, collecting sensory information	atlas (C_1)	occipital bone
rhomboid (major, minor)	elevating and adducting scapula	cervical and thoracic vertebrae	scapula
semispinalis (capitis, cervicis, thoracis)	extending the head and vertebral column, rotating head and vertebral column	cervical and thoracic vertebrae	occipital bone, cervical and thoracic vertebrae
serratus posterior inferior	depressing lower ribs, decreasing thoracic volume (for exhalation)	thoracic and lumbar vertebrae	lower ribs
serratus posterior superior	elevating upper ribs	cervical and thoracic vertebrae, nuchal ligament	upper ribs
spinalis thoracis	extending the neck, raising the neck and rotating it laterally	thoracic vertebrae	cervical and thoracic vertebrae
splenius capitis	extending the head, laterally flexing the head	cervical vertebrae	temporal bone, occipital bone
splenius cervicis	extending the head and neck, laterally flexing and rotating the head and neck	thoracic vertebrae	cervical vertebrae
teres major	extending and medially rotating the arm	scapula	humerus
trapezius (lower, middle, upper)	elevating, retracting, depressing, and upwardly rotating the scapula, extending the neck	occipital bone, thoracic vertebrae	scapula

Rotator Cuff

Muscle	Action	Origin	Insertion
infraspinatus	laterally rotating the shoulder	scapula	humerus
subscapularis	medially rotating the shoulder, stabilizes shoulder joint	scapula	humerus
supraspinatus	abducting the shoulder, stabilizes shoulder joint	scapula	humerus
teres minor	laterally rotating the shoulder	scapula	humerus

Arm (Shoulder to Elbow)

Muscle	Action	Origin	Insertion
biceps brachii	flexing the arm at the elbow	scapula	radius
brachialis	flexing the arm at the elbow	humerus	ulna
coracobrachialis	flexing and adducting the arm	scapula	humerus
deltoid	abducting the arm at the shoulder, flexing and extending arm at the shoulder	clavicle, scapula	humerus
triceps brachii	extending the arm at the elbow	humerus, scapula	ulna

Forearm (Elbow to Wrist)

Muscle	Action	Origin	Insertion
abductor pollicis longus	abduction and extension of the thumb	radius, ulna, interosseous membrane	first metacarpal, trapezium
anconeus	extending the elbow	humerus	ulna
brachioradialis	flexing the arm at the elbow	humerus	radius
extensor carpi radialis brevis	extending and abducting the hand	humerus	third metacarpal
extensor carpi radialis longus	extending and abducting the hand	humerus	second metacarpal
extensor carpi ulnaris	extending and adducting the hand at the wrist	humerus	carpal bones
extensor digiti minimi	extends the little finger (phalanx 5)	humerus	fifth phalanx
extensor digitorum	extending the fingers	humerus	digits
extensor indicis	extending the index finger (phalanx 2), extending the wrist	ulna, interosseous membrane	tendon of extensor digitorum of index finger
extensor pollicis brevis	extending the thumb	radius, ulna, interosseous membrane	first proximal phalanx
extensor pollicis longus	extending the thumb	radius, ulna, interosseous membrane	first proximal phalanx
flexor carpi radialis	flexing and abducting the hand at the wrist	humerus	carpal bones
flexor carpi ulnaris	flexing and adducts the hand at the wrist	humerus	carpal bones
flexor digitorum profundus	flexing distal interphalangeal joints	ulna, interosseous membrane	phalanges 2-5
flexor digitorum superficialis	flexing the wrist, flexing the phalanges 2-5	humerus, ulna, radius	phalanges 2-5
flexor pollicis longus	flexing the thumb	first distal phalanx	radius, interosseous membrane
palmaris longus	flexing the hand at the wrist	humerus	carpal bones
pronator quadratus	pronating the forearm	ulna	radius
pronator teres	pronating the forearm	humerus, ulna	radius
supinator	supinating the forearm	humerus, ulna	radius

Hand

Muscle	Action	Origin	Insertion
abductor digiti minimi	abducting and flexing the little finger (phalanx 5)	pisiform	fifth phalanx
abductor pollicis brevis	abducting the thumb	transverse carpal ligament, carpal bones	first phalanx (thumb)
abductor pollicis longus	abduction and extension of the thumb	radius, ulna, interosseous membrane	first metacarpal, trapezium
dorsal interossei	abducting and flexing metacarpal-phalanx joints	metacarpals	proximal phalanges 2-4
extensor digiti minimi	extends the little finger (phalanx 5)	humerus	fifth phalanx
extensor digitorum	extending the fingers	humerus	digits
extensor indicis	extending the index finger (phalanx 2), extending the wrist	ulna, interosseous membrane	tendon of extensor digitorum of index finger
extensor pollicis brevis	extending the thumb	radius, ulna, interosseous membrane	first proximal phalanx
extensor pollicis longus	extending the thumb	radius, ulna, interosseous membrane	first proximal phalanx
flexor digiti minimi brevis	flexing the little finger (phalanx 5)	hamate	fifth proximal phalanx
flexor digitorum superficialis	flexing the wrist, flexing the phalanges 2-5	humerus, ulna, radius	phalanges 2-5

Muscle	Action	Origin	Insertion
flexor digitorum profundus	flexing distal interphalangeal joints	ulna, interosseous membrane	phalanges 2-5
flexor pollicis brevis	abducting and flexing the thumb	first metacarpal, carpal bones	first proximal phalanx
flexor pollicis longus	flexing the thumb	first distal phalanx	radius, interosseous membrane
flexor retinaculum of the wrist (a tendinous sheath)	no actions - fibrous band over carpal bones, forms carpal tunnel	n/a	n/a
lumbricals	extending the proximal and distal interphalangeal joints	tendons of flexor digitorum profundus	phalanges 2-5, tendons of extensor digitorum
opponens digiti minimi	opposition of the fifth metacarpal	flexor retinaculum, trapezium	fifth metacarpal
opponens pollicis	opposition of the thumb	flexor retinaculum, trapezium	first metacarpal
palmar interossei	adducting and flexing metacarpal-phalanx joints	metacarpals 2, 4, 5	phalanges 2, 4, 5
palmaris longus	flexing the hand at the wrist	humerus	carpal bones

Hip & Thigh

Muscle	Action	Origin	Insertion
adductor longus	adducting the thigh at the hip	pubis	femur
adductor magnus	adducting the thigh at the hip	pubis, ischium	femur
biceps femoris	flexing the leg at the knee, extending the thigh at the hip	ischium, femur	tibia, fibula
gluteus maximus	extending the thigh at the hip, rotating the thigh laterally	ilium, sacrum, coccyx	femur, iliotibial tract (iliotibial band)
gluteus medius	abducting the thigh at the hip, rotating the thigh medially	ilium	femur
gluteus minimus	abducting and medially rotating the thigh	ilium	femur
gracilis	adducting the thigh at the hip	pubis	tibia
iliacus	flexing the thigh at the hip	ilium	femur
pectineus	adducting the thigh, flexing and medially rotating the leg	pubis	femur
psoas major	flexing the thigh at the hip, flexing the vertebral column	thoracic and lumbar vertebrae	femur
quadratus lumborum	depress ribs, laterally flexes vertebral column	ilium, iliolumbar ligament	lumbar vertebrae, last rib
rectus femoris	extending the leg at the knee, flexing the thigh at the hip	ilium	tibia
sartorius	flexing the leg at the knee, flexing and rotating the thigh at the hip	ilium	tibia
semimembranosus	flexing the leg at the knee, extending the thigh at the hip	ischium	tibia
semitendinosus	flexing the leg at the knee, extending the thigh at the hip	ischium	tibia
tensor fascia latae	tensing the iliotibial band, supporting the knee	ilium	iliotibial tract (iliotibial band)
vastus intermedius	extending the leg at the knee	femur	tibia
vastus lateralis	extending the leg at the knee	femur	tibia
vastus medialis	extending the leg at the knee	femur	tibia

Leg

Muscle	Action	Origin	Insertion
extensor digitorum longus	extending the toes	tibia, fibula	digits
extensor hallucis longus	extending hallux (big toe), dorsiflexing foot	fibula, interosseous membrane	first distal phalanx
fibularis brevis	plantar flexing, everting the foot	fibula	fifth metatarsal
fibularis longus	plantarflexing	tibia, fibula	first metatarsal
fibularis tertius	dorsiflexing the foot, eversion of the foot	fibula, interosseous membrane	fifth metatarsal
flexor digitorum longus	flexing the toes	tibia	digits
flexor hallucis longus	flexing hallux (big toe)	fibula	big toe
gastrocnemius	plantarflexing	femur	calcaneus
popliteus	flexing and rotating the left medially, laterally rotates thigh	femur, lateral meniscus	tibia
soleus	plantarflexing	femur, tibia	calcaneus
tibialis anterior	dorsiflexing the foot at the ankle, inverting the foot	tibia	first metatarsal
tibialis posterior	inverting and plantar flexing the food, stabilizing longitudinal foot arch	tibia, fibula, interosseous membrane	tarsals, metatarsals 2-4

Foot

Muscle	Action	Origin	Insertion
abductor digiti minimi	abducting and flexing the small toe (phalanx 5)	calcaneus	fifth proximal phalanx
adductor hallucis	abducting and flexing hallux (big toe)	calcaneus, flexor retinaculum	first proximal phalanx
dorsal interossei	abducting and flexing middle toes at metatarsophalangeal joints, extending middle toes at interphalangeal joints	metatarsals	phalanges
extensor digitorum brevis	extending toes 2-5	calcaneus, extensor retinaculum	first proximal phalanx, extensor expansions on phalanges 2-5
extensor digitorum longus	extending the toes	tibia, fibula	digits
extensor hallucis brevis	extending hallux (big toe)	calcaneus	first proximal phalanx
extensor hallucis longus	extending hallux (big toe), dorsiflexing foot	fibula, interosseous membrane	first distal phalanx
fibularis longus	plantar flexing	tibia, fibula	first metatarsal
fibularis tertius	dorsiflexing the foot, eversion of the foot	fibula, interosseous membrane	fifth metatarsal
flexor accessorius	flexing interphalangeal joints	calcaneus, long plantar ligament	tendons of flexor digitorum longus
flexor digiti minimi brevis	flexing the small toe (phalanx 5)	Fifth metatarsal, tendon sheath of fibularis longus	fifth proximal phalanx
flexor digitorum brevis	flexing toes 2-4	calcaneus	middle phalanges 2-4
flexor digitorum longus	flexing the toes	tibia	digits
flexor hallucis brevis	flexing hallux (big toe)	tarsal bones	first proximal phalanx
flexor hallucis longus	flexing hallux (big toe)	fibula	big toe
lumbricals	extending toes 2-5 at interphalangeal joints, flexing the small toes at metatarsophalangeal joints	tendons of flexor digitorum longus	proximal phalanges 2-5
opponens digiti minimi	adducting and opposing the small toe (phalanx 5)	fifth metatarsal, long plantar ligament	fifth metatarsal
plantar interossei	abducting toes 3-5, flexing proximal phalanges, extending distal phalanges	metatarsals	phalanges
tibialis anterior	dorsiflexing the foot at the ankle, inverting the foot	tibia	first metatarsal
tibialis posterior	inverting and plantar flexing the food, stabilizing longitudinal foot arch	tibia, fibula, interosseous membrane	tarsals, metatarsals 2-4

Attributions

- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0
- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0
- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0

Updated 2026.

This page titled 12.7: Actions, Origins, and Insertions of the Skeletal Muscles is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

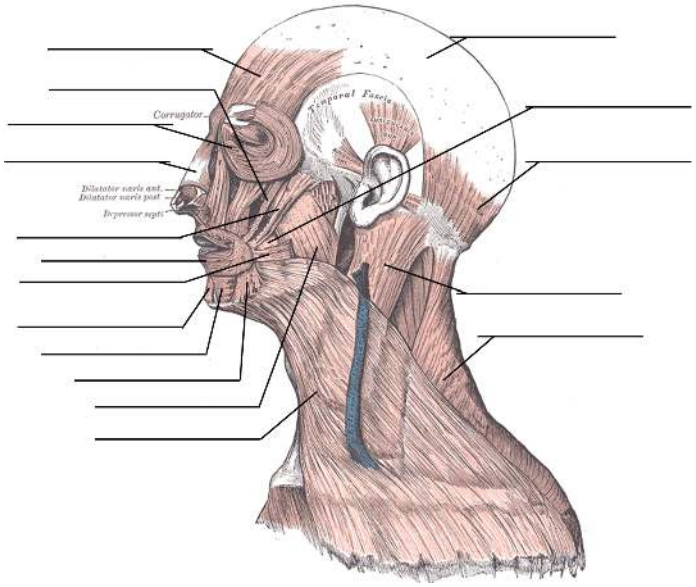
12.8: Laboratory Activities and Assignment

Laboratory Activities and Assignment

Part 1: Review of the Head and Anterior Neck Muscles

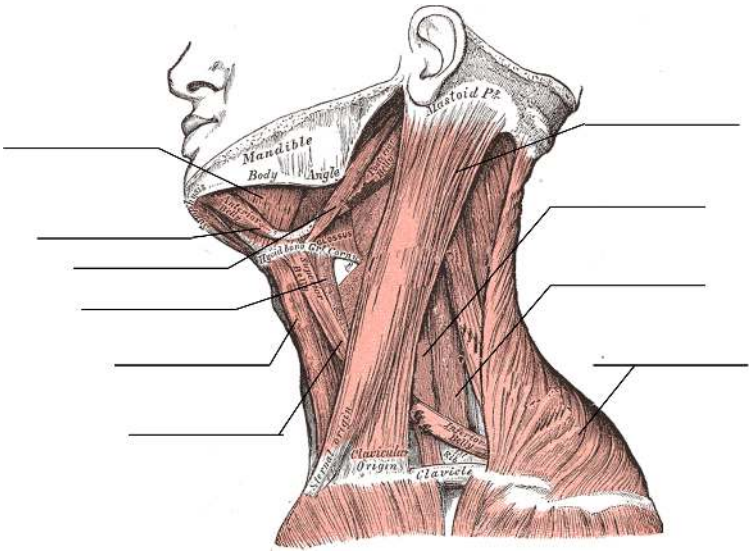
1. Label the muscles in the diagram below by placing the name of each muscle listed below in the corresponding blank space on the figure below.

- aponeurosis of epicranius
- buccinator
- depressor anguli oris
- depressor labii inferioris
- frontal belly of epicranius
- occipital belly of epicranius
- orbicularis oculi
- orbicularis oris
- mentalis
- masseter
- nasalis
- platysma
- risorius
- sternocleidomastoid
- trapezius
- zygomaticus major
- zygomaticus minor



2. Label the muscles in the diagram below by placing the name of each muscle listed below in the corresponding blank space on the figure below.

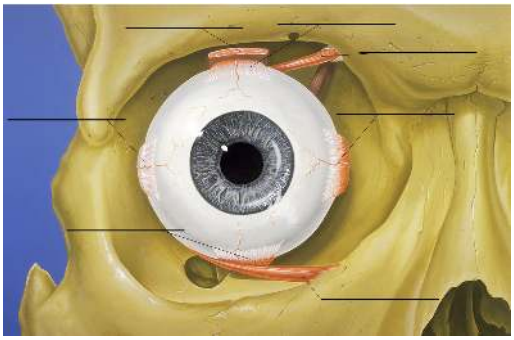
- digastric
- mylohyoid
- omohyoid
- scalenus anterior
- scalenus medius
- sternocleidomastoid
- sternohyoid
- stylohyoid
- thyrohyoid
- trapezius



3. Label the muscles that move the eye and eyelid by placing the name of each muscle listed below in the corresponding blank space on the figure below.

https://bio.libretexts.org/@go/page/53691

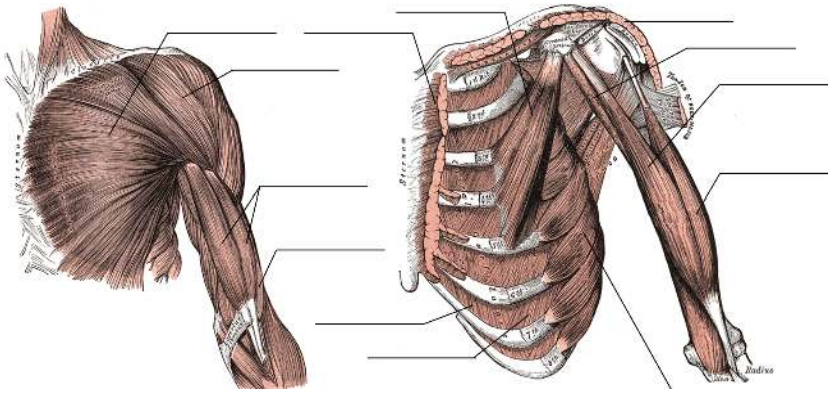
• superior rectus • inferior rectus • levator palpebrae superioris	• lateral rectus • medial rectus	• superior oblique • inferior oblique



Part 2: Review of Trunk and Posterior Neck Muscles

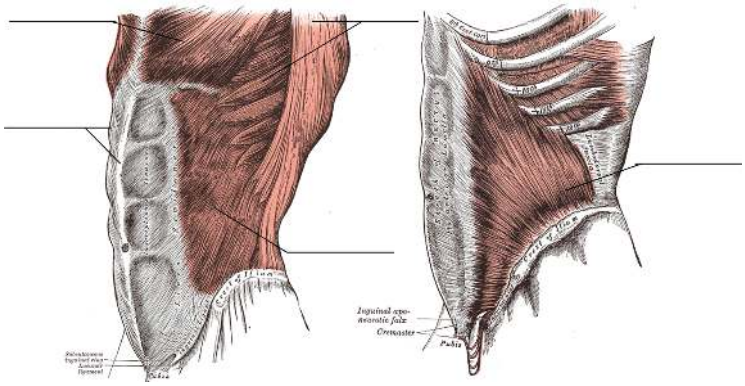
1. Label the muscles in the diagram below by placing the name of each muscle listed below in the corresponding blank space on the figure below (left shows superficial muscles of anterior thorax and arm and right shows deeper muscles of anterior thorax and arm).

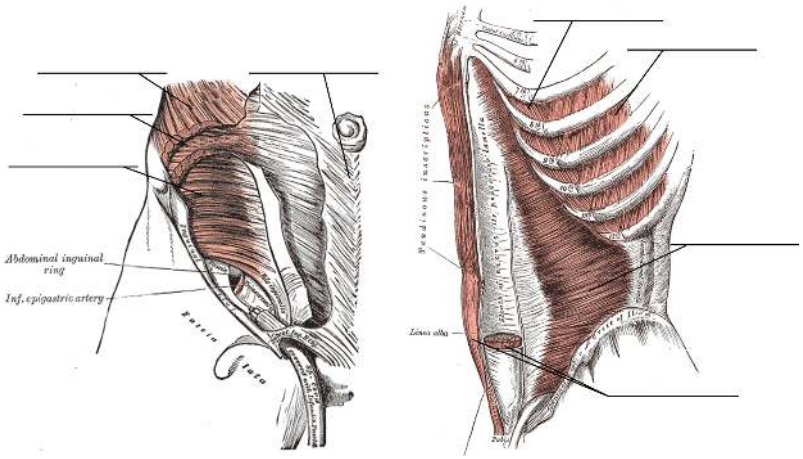
• biceps brachii (both heads) • biceps brachii (short head) • biceps brachii (long head) • coracobrachialis	• brachialis • deltoid (2 places) • external intercostal • internal intercostal	• pectoralis major (2 places) • pectoralis minor • serratus anterior



2. Label the muscles in the diagram below by placing the name of each muscle listed below in the corresponding blank space on the figure below (top left shows superficial anterior abdominal muscles, top right is one layer deeper than top left, bottom right shows one layer deeper than top right, and bottom left shows a cut through the multiple abdominal layers).

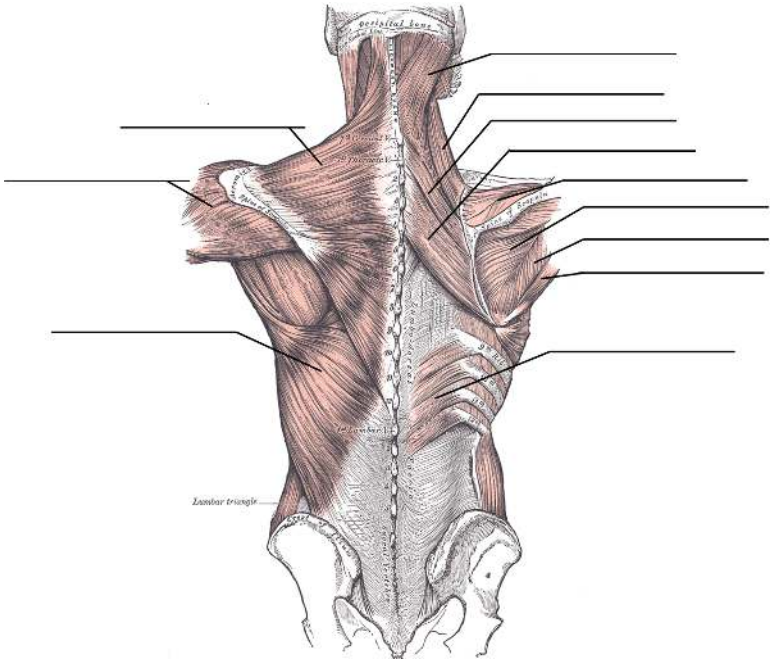
• external intercostal • external oblique (2 places) • internal intercostal	• internal obliques (2 places) • linea alba (2 places) • pectoralis major	• rectus abdominis • serratus anterior • transversus abdominis (2 places)





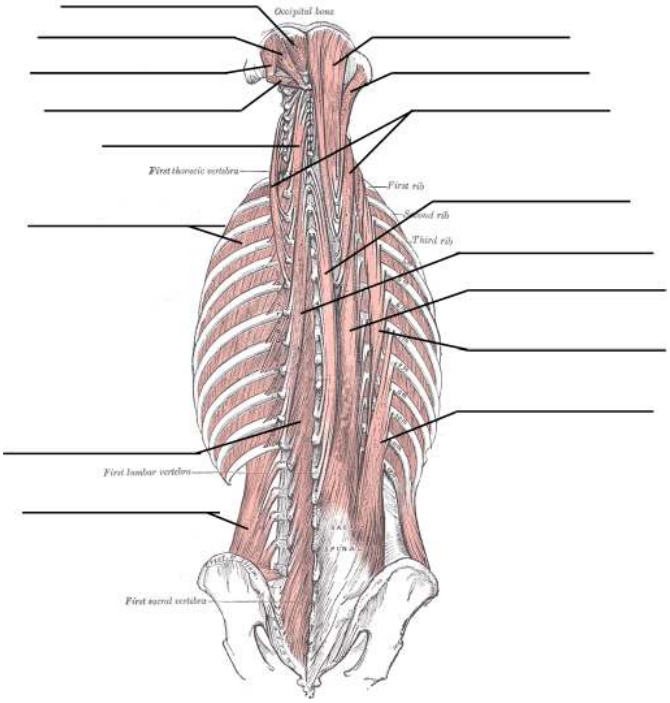
3. Label the muscles in the diagram below by placing the name of each muscle listed below in the corresponding blank space on the figure below (left side shows superficial muscles and right side shows deeper muscles of the posterior trunk and neck).

• deltoid • infraspinatus • latissimus dorsi • levator scapulae	• rhomboid major • rhomboid minor • serratus posterior inferior • splenius capitis	• supraspinatus • teres major • teres minor • trapezius



4. Label the muscles in the diagram below by placing the name of each muscle listed below in the corresponding blank space on the figure below (figure mostly shows only one of each of the paired muscles of the deep posterior trunk - focus on lateral positions of the long vertebral muscles in relation to each other and whether the muscles are associated with the cervical vertebrae, thoracic vertebrae, lumbar vertebrae, or the skull).

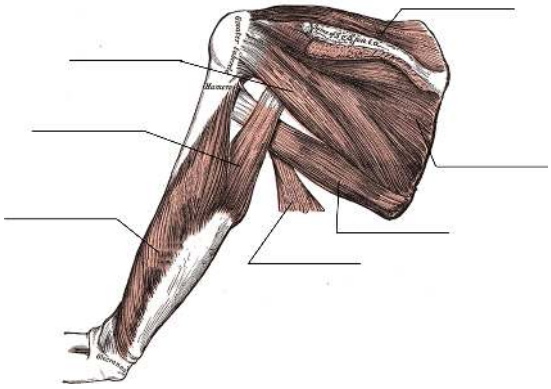
• external intercostal • iliocostalis lumborum • iliocostalis thoracis • longissimus capitis • longissimus cervicis • longissimus thoracis	• multifidus • obliquus capitis inferior • obliquus capitis superior • quadratus lumborum • rectus capitis posterior major	• rectus capitis posterior minor • semispinalis capitis • semispinalis cervicis • semispinalis thoracis • spinalis thoracis



Part 3: Review of Rotator Cuff and Upper Limb Muscles

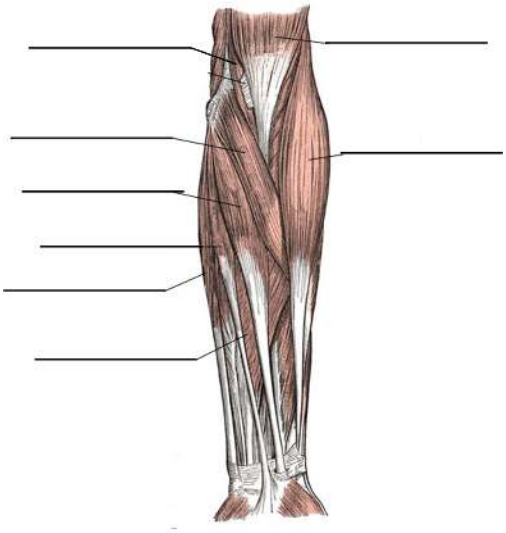
1. Label the muscles in the diagram below by placing the name of each muscle listed below in the corresponding blank space on the figure below (figure shows posterior view of the arm and the scapula).

• infraspinatus • latissimus dorsi • supraspinatus	• teres major • teres minor	• triceps brachii (lateral head) • triceps brachii (long head)



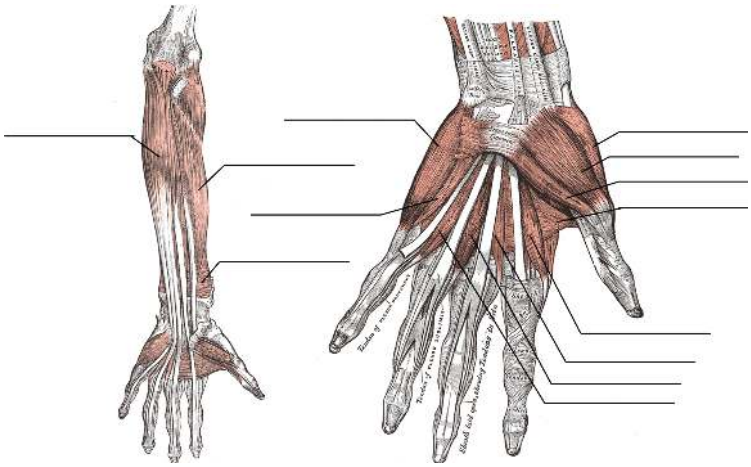
2. Label the muscles of the left superficial anterior antebrachium (forearm) by placing the name of each muscle listed below in the corresponding blank space on the figure below.

• biceps brachii • brachialis • brachioradialis	• flexor carpi radialis • flexor carpi ulnaris • flexor digitorum superficialis	• palmaris longus • pronator teres



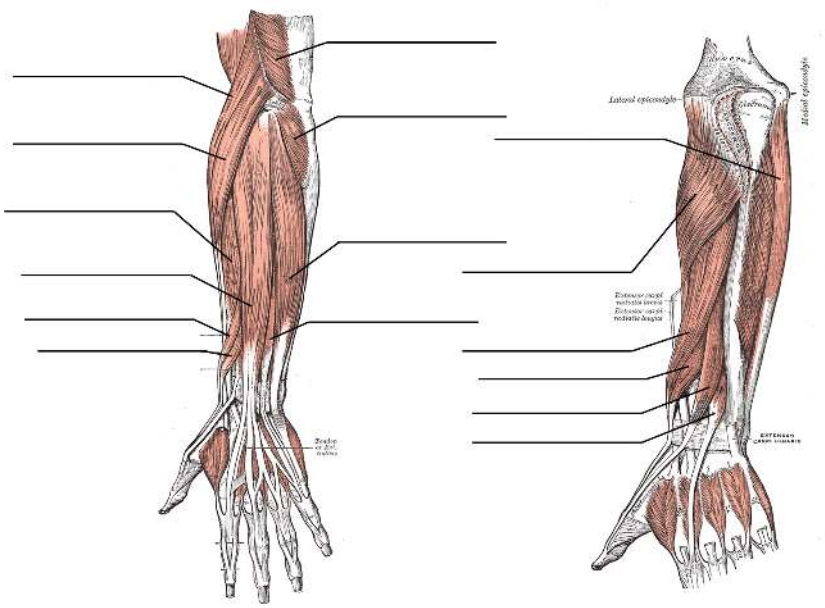
3. Label the muscles in the diagram below by placing the name of each muscle listed below in the corresponding blank space on the figure below (diagrams show the deeper muscles of the anterior left forearm and superficial palmar muscles of the left hand).

- abductor digiti minimi
- abductor pollicis brevis
- adductor pollicis
- first lumbrical
- flexor digiti minimi brevis
- flexor digitorum profundus
- flexor pollicis brevis
- flexor pollicis longus
- fourth lumbrical
- opponens pollicis
- pronator quadratus
- second lumbrical
- third lumbrical



4. Label the muscles in the diagram below by placing the name of each muscle listed below in the corresponding blank space on the figure below.

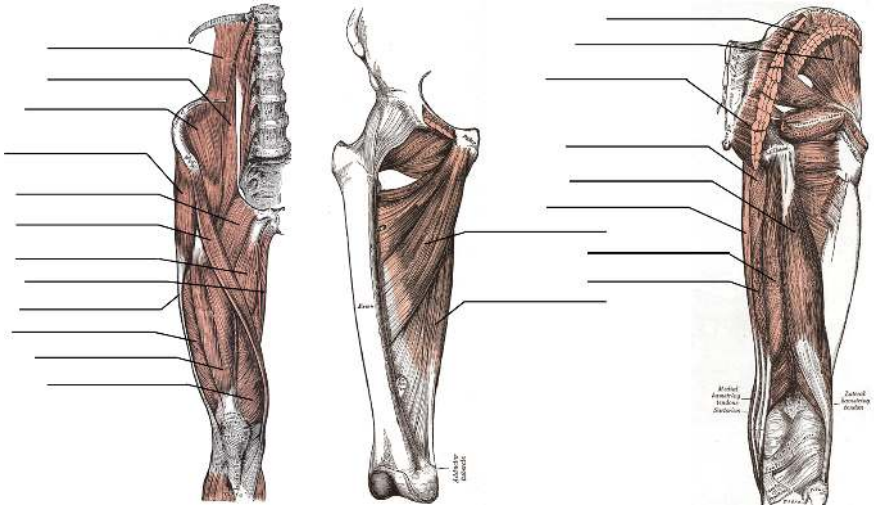
- abductor pollicis longus (2 places)
- anconeus
- brachioradialis
- extensor carpi radialis brevis
- extensor carpi radialis longus
- extensor carpi ulnaris
- extensor digiti minimi
- extensor digitorum
- extensor indicis
- extensor pollicis brevis (2 places)
- extensor pollicis longus
- flexor carpi ulnaris
- supinator
- triceps brachii



Part 4: Review of Hip and Lower Limb Muscles

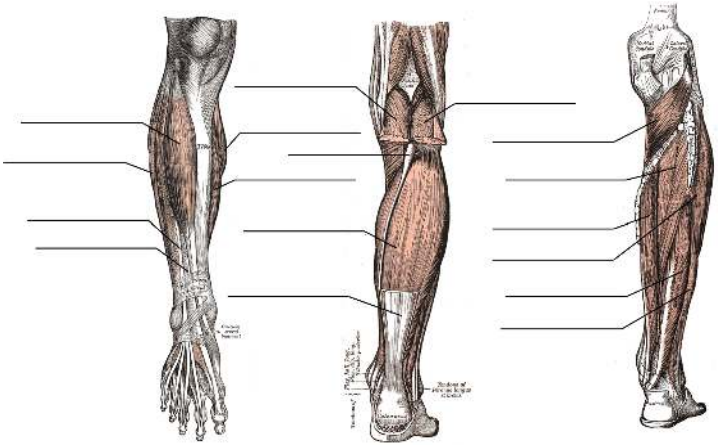
1. Label the muscles in the diagram below by placing the name of each muscle listed below in the corresponding blank space on the figure below (left shows superficial muscles of the anterior right hip and thigh, middle shows the deep muscles of the anterior right thigh, and right shows the superficial and deep muscles of the posterior thigh with superficial gluteal muscles cut away).

- adductor longus (2 places)
- adductor magnus (2 places)
- biceps femoris
- gluteus maximus
- gluteus medius
- gluteus minimus
- gracilis (2 places)
- iliacus
- iliotibial tract/band (ITB)
- pectineus
- psoas major
- quadratus lumborum
- rectus femoris
- sartorius
- semimembranosus
- semitendinosus
- tensor fasciae latae
- vastus lateralis
- vastus medialis



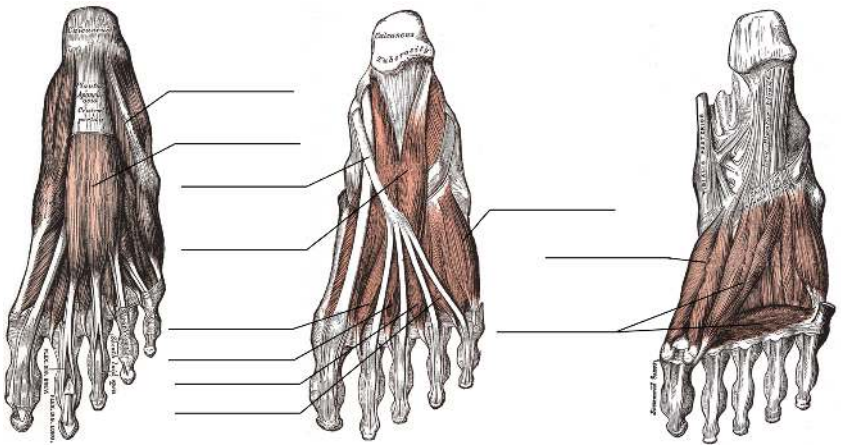
2. Label the muscles in the diagram below by placing the name of each muscle listed below in the corresponding blank space on the figure below.

- calcaneal tendon
- extensor digitorum longus
- extensor hallucis longus
- fibularis brevis
- fibularis longus (2 places)
- flexor digitorum longus
- flexor hallucis longus
- gastrocnemius
- gastrocnemius (lateral head)
- gastrocnemius (medial head)
- plantaris
- popliteus
- soleus (2 places)
- tibialis anterior
- tibialis posterior



3. Label the muscles in the diagram below by placing the name of each muscle listed below in the corresponding blank space on the figure below (figure shows left to right superficial to deep muscles of plantar (sole of the foot)).

- abductor digiti minimi
- adductor hallucis
- first lumbrical
- flexor accessorius
- flexor digiti minimi brevis
- flexor digitorum brevis
- flexor digitorum longus
- flexor hallucis brevis
- fourth lumbrical
- second lumbrical
- third lumbrical



Part 5: Head and Anterior Neck Muscles Laboratory Activities

1. The following are muscles of **facial expression**. For each, identify it on a laboratory model, give its location, and describe its action when it contracts.

Muscle	Location	Action when contracted
epicranius frontal belly		
epicranius occipital belly		
orbicularis oculi		
zygomaticus major		
zygomaticus minor		
buccinator		
orbicularis oris		
platysma		
depressor labii inferioris		
depressor anguli oris		
risorius		
nasalis		

2. The following are muscles of **mastication** (chewing). For each, identify it on a laboratory model (where possible), give its location, and describe its action when it contracts.

Muscle	Location	Action when contracted
masseter		
temporalis		
medial pterygoid		
lateral pterygoid		

3. Navigate to zygotebody.com. Use the slide bar on the left of the screen to remove the skin but leave the superficial layers of muscle. Click the following head and neck muscles on the ZygoteBody model. For each, indicate whether this muscle is superficial, deep, or intermediate to other muscles (hold ctrl on the keyboard [or command on a Mac] and click on a muscle to make it disappear – when you then click without holding control, it will restore all of the hidden items). Describe each muscle as being "superficial" (no muscles on top of it), "intermediate" (muscles on top of it and deep to it), or "deep" (muscles on top of it but none underneath it). List the muscles that are either superficial or deep to each of these muscles in the table below as applicable.

Muscle	Superficial, intermediate, or deep	Muscle(s) Deep to This Muscle	Muscle(s) Superficial to This Muscle
platysma			
masseter			
sternocleidomastoid			
trapezius			
temporalis			
zygomaticus			
orbicularis oculi			
orbicularis oris			

Part 6: Trunk and Posterior Neck Muscles Laboratory Activities

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

Muscle	Location	Action when contracted
trapezius		
pectoralis minor		
serratus anterior		

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

Muscle	Location	Action when contracted
pectoralis major		
latissimus dorsi		
deltoid		

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

Muscle	Location	Action when contracted
rectus abdominis		
external oblique		
internal oblique		
transversus abdominis		

4. Navigate to zygotebody.com. Use the slide bar on the left of the screen to remove the skin but leave the superficial layers of muscle. Click the following anterior trunk muscles on the ZygoteBody model. For each, indicate whether this muscle is superficial, deep, or intermediate to other muscles (hold ctrl on the keyboard [or command on a Mac] and click on a muscle to make it disappear – when you then click without holding control, it will restore all of the hidden items). Describe each muscle as being "superficial" (no muscles on top of it), "intermediate" (muscles on top of it and deep to it), or "deep" (muscles on top of it but none underneath it). List the muscles that are either superficial or deep to each of these muscles in the table below as applicable.

Muscle	Superficial, intermediate, or deep	Muscle(s) Deep to This Muscle	Muscle(s) Superficial to This Muscle
pectoralis major			

Muscle	Superficial, intermediate, or deep	Muscle(s) Deep to This Muscle	Muscle(s) Superficial to This Muscle
pectoralis minor			
serratus anterior			
external intercostal			
internal intercostal			
innermost intercostal			
transverse abdominis			
external oblique			
internal oblique			
psoas major			

5. Navigate to zygotebody.com. Use the slide bar on the left of the screen to remove the skin but leave the superficial layers of muscle. Click the following posterior trunk muscles on the ZygoteBody model. For each, indicate whether this muscle is superficial, deep, or intermediate to other muscles (hold ctrl on the keyboard [or command on a Mac] and click on a muscle to make it disappear – when you then click without holding control, it will restore all of the hidden items). Describe each muscle as being "superficial" (no muscles on top of it), "intermediate" (muscles on top of it and deep to it), or "deep" (muscles on top of it but none underneath it). List the muscles that are either superficial or deep to each of these muscles in the table below as applicable.

Muscle	Superficial, intermediate, or deep	Muscle(s) Deep to This Muscle	Muscle(s) Superficial to This Muscle
trapezius			
latissimus dorsi			
spinalis thoracis			
levator scapularis			
longissimus thoracis			
iliocostalis			
supraspinatus			
multifidus			
infraspinatus			
teres major			
teres minor			
longissimus capitis			
rhomboid major			
rhomboid minor			
serratus posterior superior			
serratus posterior inferior			
splenius capitis			
splenius cervicis			
semispinalis capitis			
semispinalis thoracis			

Part 7: Rotator Cuff and Upper Limb Muscles Laboratory Activities

1. The following are muscles of **arm rotation and adduction**. For each, identify it on a laboratory model, give its location, action when contracted, and whether or not it is part of the rotator cuff.

Muscle	Location	Action when contracted	Part of rotator cuff?
subscapularis			
supraspinatus			
infraspinatus			
teres major			
teres minor			
deltoid			

2. The following are muscles of **arm rotation and adduction**. For each, identify it on a laboratory model, give its location, and its action when contracted.

Muscle	Location	Action when contracted
biceps brachii		
brachialis		
triceps brachii		

3. Write down the muscles of the forearm selected by your instructor and, for each, identify it on a laboratory model, give the location of that muscle, and what effect contracting that muscle has.

Muscle	Location	Action when contracted

4. Navigate to zygotebody.com. Use the slide bar on the left of the screen to remove the skin but leave the superficial layers of muscle. Click the following upper limb and rotator cuff muscles on the ZygoteBody model. For each, indicate whether this muscle is superficial, deep, or intermediate to other muscles (hold ctrl on the keyboard [or command on a Mac] and click on a muscle to make it disappear – when you then click without holding control, it will restore all of the hidden items). Describe each muscle as being "superficial" (no muscles on top of it), "intermediate" (muscles on top of it and deep to it), or "deep" (muscles on top of it but none underneath it). List the muscles that are either superficial or deep to each of these muscles in the table below as applicable.

Muscle	Superficial, intermediate, or deep	Muscle(s) Deep to This Muscle	Muscle(s) Superficial to This Muscle
subscapularis			
supraspinatus			
infraspinatus			
teres minor			
deltoid			
biceps brachii			
brachialis			

Muscle	Superficial, intermediate, or deep	Muscle(s) Deep to This Muscle	Muscle(s) Superficial to This Muscle
tricep (long head)			
tricep (lateral head)			
tricep (medial head)			
brachioradialis			
extensor carpi radialis longus			
extensor carpi radialis brevis			
extensor digitorum			
extensor carpi ulnaris			
pronator teres			
flexor carpi radialis			
flexor digitorum superficialis			
palmaris longus			
flexor carpi ulnaris			

Part 8: Hip and Lower Limb Muscles Laboratory Activities

1. Write down the muscles of the hip, thigh, and gluteal regions in the table below and, for each, identify it on a laboratory model, give the location of that muscle, and what effect contracting that muscle has.

Muscle	Location	Action when contracted
rectus femoris		
vastus intermedius		
vastus medialis		
vastus lateralis		
sartorius		
gracilis		
semimembranosus		
semitendinosus		
biceps femoris		
gluteus maximus		
gluteus medius		
gluteus minimus		
iliacus		
psoas major		
quadratus lumborum		
tensor fascia latae		

2. For each of the muscles of the leg, identify it on a laboratory model, give the location of that muscle, and what effect contracting that muscle has.

Muscles	Location	Action when contracted
gastrocnemius		
soleus		
tibialis anterior		
fibularis longus		
flexor digitorum longus		
extensor digitorum longus		

3. Navigate to zygotebody.com. Use the slide bar on the left of the screen to remove the skin but leave the superficial layers of muscle. Click the following lower limb and gluteal muscles on the ZygoteBody model. For each, indicate whether this muscle is superficial, deep, or intermediate to other muscles (hold ctrl on the keyboard [or command on a Mac] and click on a muscle to make it disappear – when you then click without holding control, it will restore all of the hidden items). Describe each muscle as being "superficial" (no muscles on top of it), "intermediate" (muscles on top of it and deep to it), or "deep" (muscles on top of it but none underneath it). List the muscles that are either superficial or deep to each of these muscles in the table below as applicable.

Muscle	Superficial, intermediate, or deep	Muscle(s) Deep to This Muscle	Muscle(s) Superficial to This Muscle
gluteus maximus			
gluteus medius			
gluteus minimus			
rectus femoris			
vastus medialis			
vastus lateralis			
vastus intermedius			
sartorius			
gracilis			
pectineus			
adductor longus			
adductor magnus			
biceps femoris (longus)			
biceps femoris (short)			
semitendinosus			
semimembranosus			
gastrocnemius			
soleus			
tibialis anterior			
extensor digitorum			
fibularis (peroneus) longus			
tibialis posterior			

Attributions

Part 1: Review of Head and Anterior Neck Muscles

- "Eye orbit anatomy anterior2.jpg" by Patrick J. Lynch is licensed under CC BY 2.5
- "Gray's Anatomy plates" by Henry Vandyke Carte is in the Public Domain

Part 2: Review of Trunk and Posterior Neck Muscles

- "Gray's Anatomy plates" by Henry Vandyke Carte is in the Public Domain

Part 3: Review of Rotator Cuff and Upper Limb Muscles

- "Gray's Anatomy plates" by Henry Vandyke Carte is in the Public Domain
- "Sup. forearm.jpg" by Rafael Di Marco Barros is in the Public Domain / A derivative from the original work

Part 4: Review of Hip and Lower Limb Muscles

- "Gray's Anatomy plates" by Henry Vandyke Carte is in the Public Domain

Part 5: Head and Anterior Neck Muscles Laboratory Activities

- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0

Part 6: Trunk and Posterior Neck Muscles Laboratory Activities

- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0

Part 7: Rotator Cuff and Upper Limb Muscles Laboratory Activities

- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0

Part 8: Hip and Lower Limb Muscles Laboratory Activities

- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0

Updated 2026.

This page titled 12.8: Laboratory Activities and Assignment is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

12.9: Collaborative Study Activities

Collaborative Study Activities

These activities are designed for student groups of 2-4. Larger groups will work better when there is no supplemental instructor present in the laboratory to assist in testing student groups on each section.

Head and Neck Muscles

1. Identify the following structures on classroom anatomical models and/or unlabeled images/diagrams made available by your instructor. Work with your group to identify each structure and check them off the list once you have identified them.

☐ platysma ☐ masseter ☐ sternocleidomastoid ☐ trapezius ☐ temporalis ☐ sternohyoid ☐ mylohyoid	☐ orbicularis oculi ☐ orbicularis oris ☐ frontal belly of epicranius ☐ occipital belly of epicranius ☐ aponeurosis of epicranius ☐ sternothyroid	☐ zygomaticus major ☐ zygomaticus minor ☐ risorius ☐ mentalis ☐ nasalis ☐ digastric

2. Test your group members by ***asking them to name each structure you point to***. Check off each when your group can successfully name each. Your group will also test you.

☐ platysma ☐ masseter ☐ sternocleidomastoid ☐ trapezius ☐ temporalis ☐ sternohyoid ☐ mylohyoid	☐ orbicularis oculi ☐ orbicularis oris ☐ frontal belly of epicranius ☐ occipital belly of epicranius ☐ aponeurosis of epicranius ☐ sternothyroid	☐ zygomaticus major ☐ zygomaticus minor ☐ risorius ☐ mentalis ☐ nasalis ☐ digastric

3. When you and your group are comfortable identifying all the structures above, request the assistance of your Instructor. They will test you on your use of these terms and initial ONLY when you are successful using these terms. Instructor: _____

Anterior Trunk Muscles

1. Identify the following structures on classroom anatomical models and/or unlabeled images/diagrams made available by your instructor. Work with your group to identify each structure and check them off the list once you have identified them.

☐ pectoralis major ☐ pectoralis minor ☐ serratus anterior ☐ external intercostals	☐ internal intercostals ☐ rectus abdominis ☐ transversus abdominis ☐ external oblique	☐ internal oblique ☐ linea alba ☐ psoas major

2. Test your group members by ***asking them to name each structure you point to***. Check off each when your group can successfully name each. Your group will also test you.

☐ pectoralis major ☐ pectoralis minor ☐ serratus anterior ☐ external intercostals	☐ internal intercostals ☐ rectus abdominis ☐ transversus abdominis ☐ external oblique	☐ internal oblique ☐ linea alba ☐ psoas major

3. When you and your group are comfortable identifying all the structures above, request the assistance of your Instructor. They will test you on your use of these terms and initial ONLY when you are successful using these terms. Instructor: _____

Posterior Neck and Trunk Muscles

1. Identify the following structures on classroom anatomical models and/or unlabeled images/diagrams made available by your instructor. Work with your group to identify each structure and check them off the list once you have identified them.

☐ trapezius	☐ rhomboid major	☐ splenius capitis
☐ latissimus dorsi	☐ rhomboid minor	☐ levator scapulae
☐ spinalis thoracis	☐ teres major	☐ quadratus lumborum
☐ longissimus thoracis	☐ semispinalis capitis	☐ serratus posterior inferior
☐ iliocostalis thoracis		

2. Test your group members by ***asking them to name each structure you point to***. Check off each when your group can successfully name each. Your group will also test you.

☐ trapezius	☐ rhomboid major	☐ splenius capitis
☐ latissimus dorsi	☐ rhomboid minor	☐ levator scapulae
☐ spinalis thoracis	☐ teres major	☐ quadratus lumborum
☐ longissimus thoracis	☐ semispinalis capitis	☐ serratus posterior inferior
☐ iliocostalis thoracis		

3. When you and your group are comfortable identifying all the structures above, request the assistance of your Instructor. They will test you on your use of these terms and initial ONLY when you are successful using these terms. Instructor: _____

Upper Limb Muscles

1. Identify the following structures on classroom anatomical models and/or unlabeled images/diagrams made available by your instructor. Work with your group to identify each structure and check them off the list once you have identified them.

☐ deltoid	☐ brachioradialis	☐ pronator teres
☐ biceps brachii	☐ extensor carpi radialis longus	☐ flexor carpi radialis
☐ brachialis	☐ extensor carpi radialis brevis	☐ flexor digitorum superficialis
☐ triceps brachii (long head)	☐ extensor digitorum	☐ palmaris longus
☐ triceps brachii (lateral head)	☐ extensor carpi ulnaris	
☐ triceps brachii (medial head)	☐ flexor carpi ulnaris	

2. Test your group members by ***asking them to name each structure you point to***. Check off each when your group can successfully name each. Your group will also test you.

☐ deltoid	☐ brachioradialis	☐ pronator teres
☐ biceps brachii	☐ extensor carpi radialis longus	☐ flexor carpi radialis
☐ brachialis	☐ extensor carpi radialis brevis	☐ flexor digitorum superficialis
☐ triceps brachii (long head)	☐ extensor digitorum	☐ palmaris longus
☐ triceps brachii (lateral head)	☐ extensor carpi ulnaris	
☐ triceps brachii (medial head)	☐ flexor carpi ulnaris	

3. When you and your group are comfortable identifying all the structures above, request the assistance of your Instructor. They will test you on your use of these terms and initial ONLY when you are successful using these terms. Instructor: _____

Lower Limb Muscles

1. Identify the following structures on classroom anatomical models and/or unlabeled images/diagrams made available by your instructor. Work with your group to identify each structure and check them off the list once you have identified them.

☐ gluteus maximus ☐ gluteus medius ☐ gluteus minimus ☐ rectus femoris ☐ vastus medialis ☐ vastus lateralis ☐ vastus intermedius ☐ sartorius	☐ gracilis ☐ pectineus ☐ adductor longus ☐ adductor magnus ☐ biceps femoris ☐ semitendinosus ☐ semimembranosus	☐ gastrocnemius (medial head) ☐ gastrocnemius (lateral head) ☐ soleus ☐ tibialis anterior ☐ extensor digitorum ☐ popliteus ☐ fibularis longus

2. Test your group members by ***asking them to name each structure you point to***. Check off each when your group can successfully name each. Your group will also test you.

☐ gluteus maximus ☐ gluteus medius ☐ gluteus minimus ☐ rectus femoris ☐ vastus medialis ☐ vastus lateralis ☐ vastus intermedius ☐ sartorius	☐ gracilis ☐ pectineus ☐ adductor longus ☐ adductor magnus ☐ biceps femoris ☐ semitendinosus ☐ semimembranosus	☐ gastrocnemius (medial head) ☐ gastrocnemius (lateral head) ☐ soleus ☐ tibialis anterior ☐ extensor digitorum ☐ popliteus ☐ fibularis longus

When you and your group are comfortable identifying all the structures above, request the assistance of your Instructor. They will test you on your use of these terms and initial ONLY when you are successful using these terms. Instructor: _____

Updated 2026.

This page titled 12.9: Collaborative Study Activities is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

CHAPTER OVERVIEW

13: Introduction to the Nervous System

13.1: Introduction
13.2: Neurons
13.3: Nerves are Bundles of Neuron Axons in the PNS
13.4: Glia (Neuroglia) Cells
13.5: Laboratory Activities and Assignment

This page titled 13: Introduction to the Nervous System is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

13.1: Introduction

Introduction



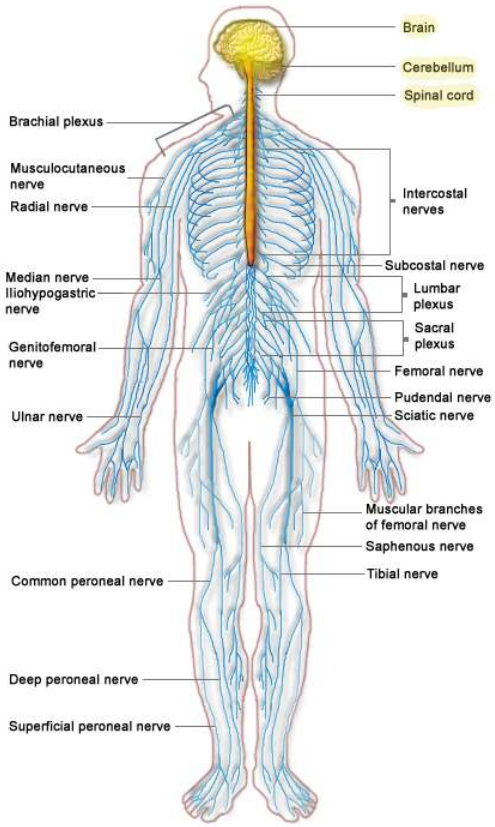
Above: A traditional Cambodian dance called the Golden Mermaid Dance.

A dancer's nervous system is hard at work during the planning and execution of their movements. Parts of the nervous system are involved in determining how much to flex the hand and when to turn, as well as controlling the muscles throughout the body that make complicated movements possible.

While you are reading this, your nervous system is performing several functions simultaneously. The visual system is processing what is seen on the page, the motor system controls the movement of the eyes and the turning of the pages (or clicks of the mouse), and the prefrontal cortex maintains attention. Even fundamental functions, like breathing and regulation of body temperature, are controlled by the nervous system. A nervous system is an organism's control center: it processes sensory information from outside (and inside) the body and controls all behaviors—from eating to sleeping to finding a mate.

Organization of the Nervous System

The nervous system is divided into two subsections: the **central nervous system (CNS)** and the **peripheral nervous system (PNS)**. The central nervous system is made up of the **brain** and **spinal cord.** The peripheral nervous system is the connection between the central nervous system and the rest of the body. The CNS is like the power plant of the nervous system. It creates the signals that control the functions of the body. The PNS is like the wires that go to individual houses. Without those "wires," the signals produced by the CNS could not control the body (and the CNS would not be able to receive sensory information from the body either).



Above: The nervous system. The central nervous system (CNS), consisting of the brain and spinal cord are highlighted in yellow. The peripheral nervous system (PNS), consisting of the nerves are shown in blue.

The PNS can be broken down into the **autonomic nervous system** (involuntary), which controls bodily functions without conscious control, and the **sensory-somatic nervous system** (voluntary), which transmits sensory information from the skin, muscles, and sensory organs to the CNS and sends motor commands from the CNS to the muscles.

Types of Nervous System Cells

The nervous system is made up of **neurons**, specialized cells that can receive and transmit chemical or electrical signals, and **glia** or **neuroglia**, cells that provide support functions for the neurons by playing an information processing role that is complementary to neurons. A neuron can be compared to an electrical wire—it transmits a signal from one place to another. Glia can be compared to the workers at the electric company who make sure wires go to the right places, maintain the wires, and take down wires that are broken. Although glia have been compared to workers, recent evidence suggests that also usurp some of the signaling functions of neurons.

There is great diversity in the types of neurons and glia that are present in different parts of the nervous system. Most neurons contain dendrites, which receive these signals, and axons that send signals to other neurons or tissues. Glia are non-neuronal cells in the nervous system that support neuronal development and signaling. There are several types of glia that serve different functions.

Attributions

- "2016 Phnom Penh, Tradycyjny Kambodżański Pokaz Tańca (137).jpg" by Marcin Konsek is licensed under CC BY-SA 4.0
- "Neurons & Nervous System" by Mohamed Awad is licensed under CC BY-NC-SA 4.0
- "Nervous system diagram.png" by Persian Poet Gal is in the Public Domain

- "Principles of Biology I and II lab manuals" by Dalton State University is licensed under CC BY-SA 4.0

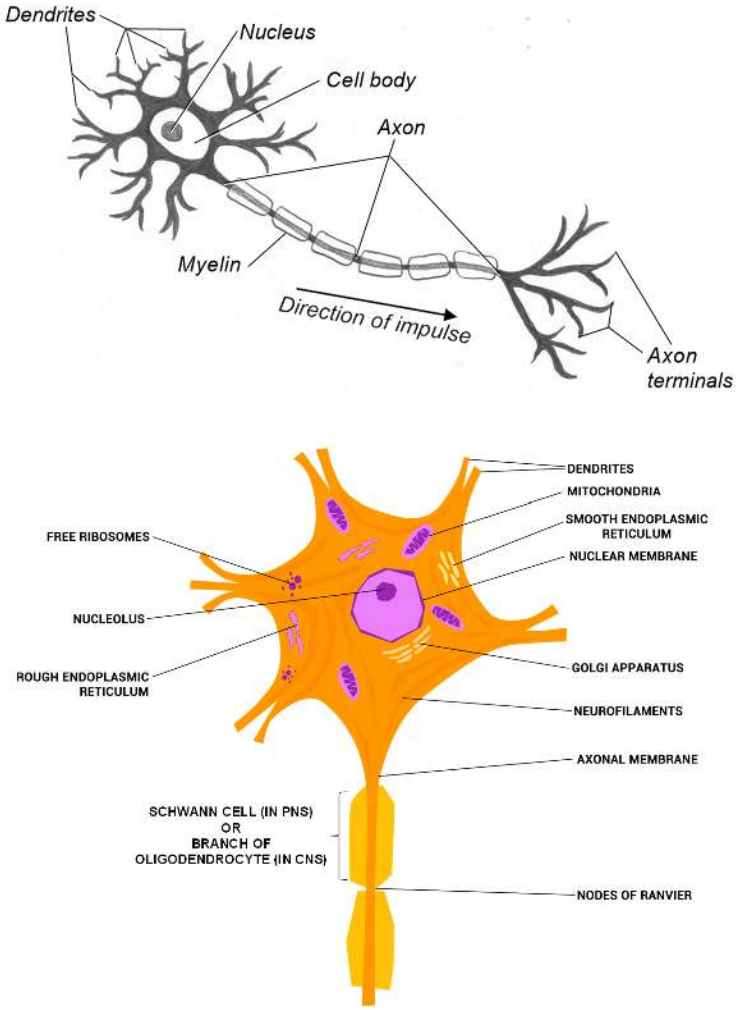
Updated 2026.

This page titled 13.1: Introduction is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

13.2: Neurons

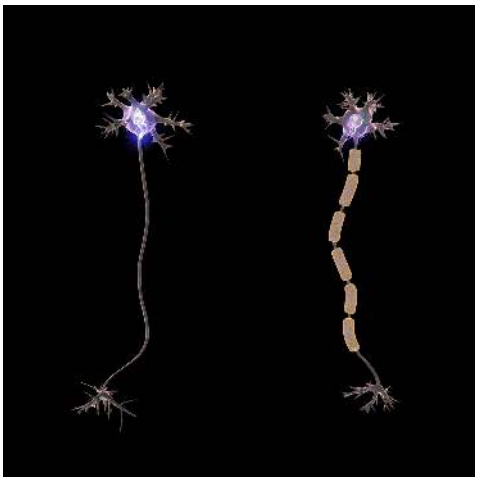
Neurons

The nervous system is composed of more than 100 billion cells known as *neurons*. A **neuron** is *a cell in the nervous system whose function it is to receive and transmit information*. Neurons are made up of three major parts: a **cell body**, or **soma**, which *contains the nucleus of the cell and keeps the cell alive*; a branching tree-like fiber known as the **dendrite**, which *collects information from other cells and sends the information to the cell body (soma)*; and a long, segmented fiber known as the **axon**, which *transmits information away from the cell body toward other neurons or to the muscles and glands*. An excited neuron transmits signals down its axon toward the **axon terminals** through a wave of electricity known as an **action potential**. Think of an axon as being an electric wire transmitting electricity from one place to another.



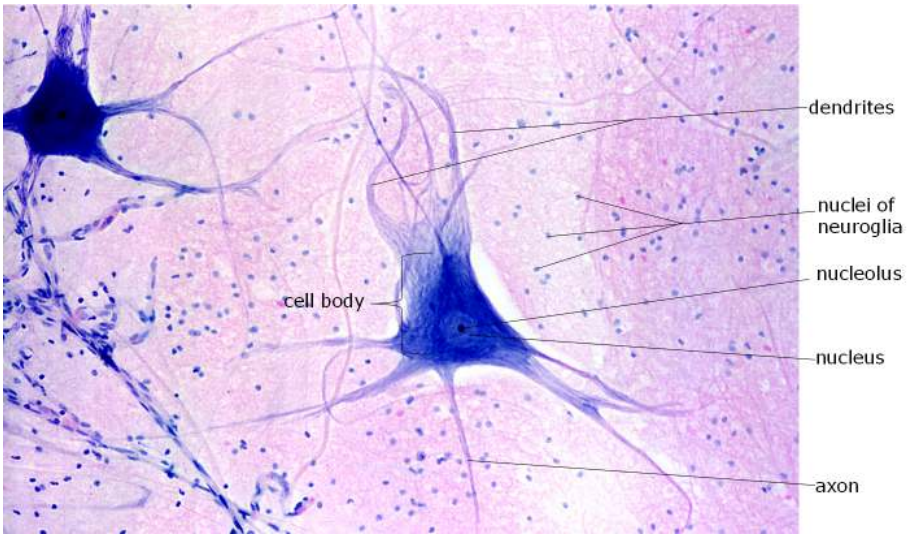
Above: Generalized structure of a neuron.

Once a signal is received by the dendrite, it then travels to the cell body that may be excited enough to stimulate an action potential down the axon. An axon is a tube-like structure that propagates (increases) the integrated signal to specialized endings called **axon terminals**. These terminals in turn synapse on other neurons, or other cells such as muscle cells. Chemicals released at axon terminals allow signals to be communicated to these other cells.



Above: Animation comparing the speed of action potentials along myelinated and unmyelinated neurons.

Some axons are covered with myelin, which acts as an insulator to minimize dissipation of the electrical signal as it travels down the axon, greatly increasing the speed on conduction. This insulation is important as the axon from a human **motor (efferent) neuron** can be as long as a meter (100 cm)—from the base of the spine to the toes - and therefore some signals have long distances to travel, making the speed of the action potential particularly important. The myelin sheath is not actually part of the neuron. Myelin is produced by specific types of glial cells. Along the axon there are periodic gaps in the myelin sheath. These gaps are called **nodes of Ranvier** and are sites where the **signal is "recharged" as it travels along the axon**.

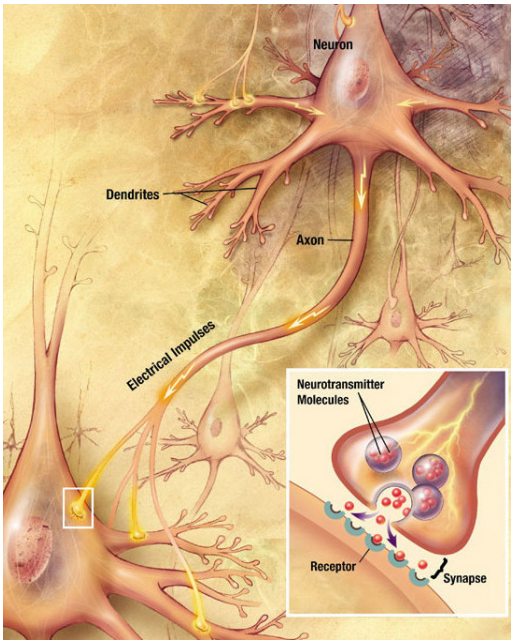


Above: Nervous tissue. Tissue is magnified by 200x.

It is important to note that a single neuron does not act alone—neuronal communication depends on the connections that neurons make with one another (as well as with other cells, like muscle cells). Dendrites from a single neuron may receive synaptic contact from many other neurons.

Synapses are physical junctions between two neurons, as well as between neurons and other cells (e.g. neuron-muscle cell, neuron-sensory receptor cell), that allow for communication. **Chemical synapses** (most common type) use an action potential to signal the exocytosis of **neurotransmitter** chemicals (over 100 different neurotransmitters known in humans). Each neurotransmitter requires a **receptor protein** (multiple subtypes known for each different neurotransmitter). **Electrical synapses** are direct membrane

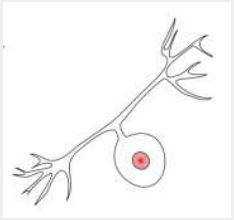
junctions between cells that allow continuations of action potentials. A neuron passes signals to another neuron or cell through synapses at its axon terminals. Neurons receive signals from other neurons or cells through synapses at its cell body or dendrites.

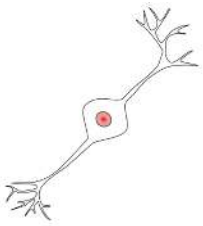
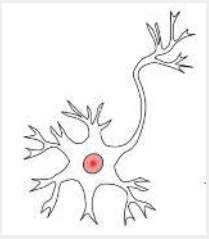


Above: Illustration of a synapse between two neurons. A chemical synapse is depicted here.

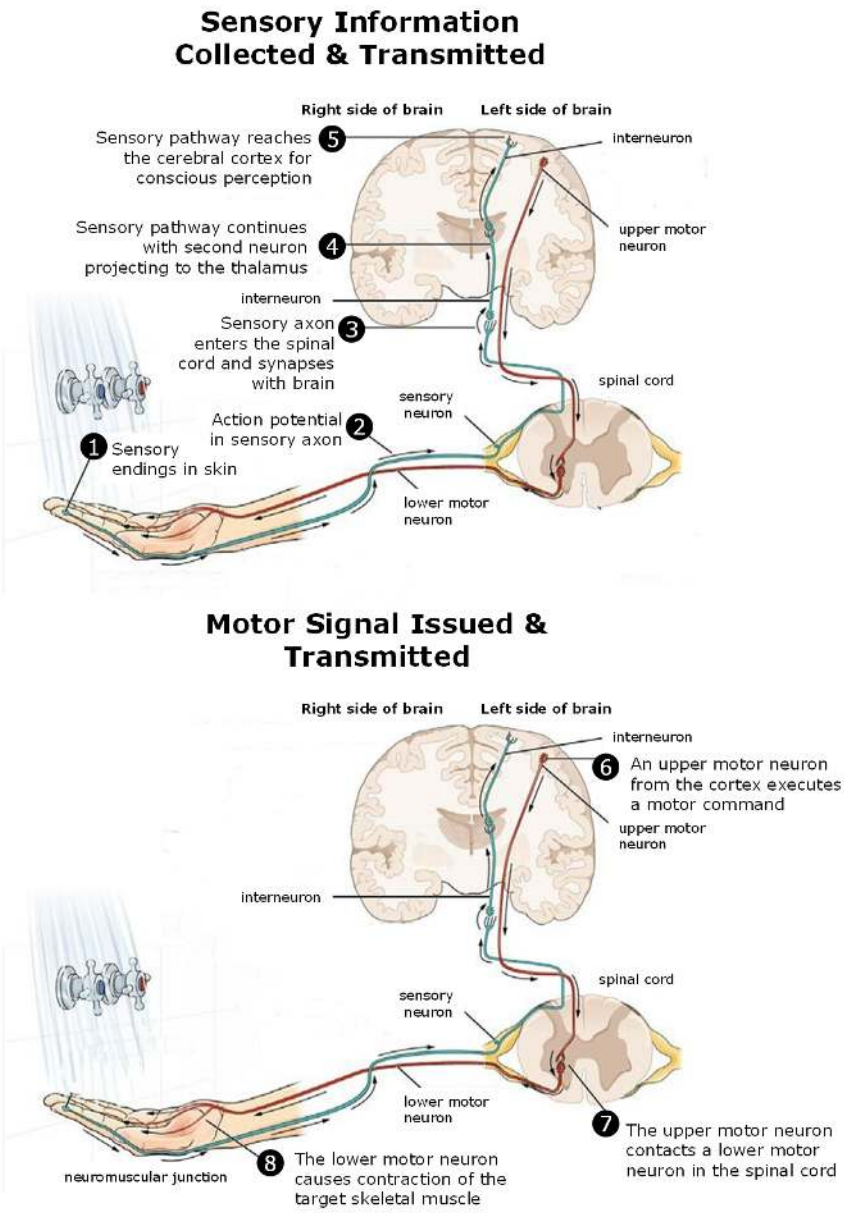
Structural Classifications of Neurons

A neuron is composed of one cell body, one axon, and usually one or more dendrites, but there are different ways these components may be organized resulting is some structural differences among neurons. There are four main structural classifications of neurons: **multipolar**, **bipolar**, **unipolar**, and **pseudounipolar**.

Neuron Structural Type	Number of Branches off Cell Body	Description of Branches off Cell Body	Function/Info
unipolar 	1	1 neurite (functions as dendrite and axon)	not present in humans found in invertebrate animals
pseudounipolar 	1, splits into two later	branch connects to axon branching two directions (has no dendrites)	**sensory neurons** (signals from PNS to CNS) one axon end branches to CNS; the other axon end branches to PNS

Neuron Structural Type	Number of Branches off Cell Body	Description of Branches off Cell Body	Function/Info
bipolar 		2	1 axon + 1 dendrite
multipolar 	3+	1 axon + 2 or more dendrites	**motor neurons** (signals from CNS to PNS) or **interneurons** (pass signals between two neurons) most common type of neuron in humans

Sensory Neurons, Motor Neurons, & Interneurons



Above: Sensory neurons collect sensory information about the environment in the PNS and transmit information to the CNS. Motor neurons transmit signals from the CNS to the PNS to stimulate a change. In this example, a person tests the water temperature before getting in the shower (sensed by sensory neurons) and adjusts the water temperature accordingly using motor neurons to cause skeletal muscle contractions.

Within the nervous system, there are 3 fundamental ***functional*** types of neurons:

- **sensory (afferent) neurons** conduct signals from receptors to the CNS
- **motor (efferent) neurons** conduct signals from the CNS to effectors such as muscles and glands (PNS)
- **interneurons (association neurons)** are confined to the CNS

Sensory information such as touch, temperature, smell, sight, sounds, vibrations, and pain is received by **sensory neurons**, also called **afferent neurons**, in the PNS and transmitted to the CNS. The example in the diagram below shows how a sensory neuron in the hand senses the temperature of shower water and transmits that information to the CNS.

Motor neurons, also called **efferent neurons**, give commands from the CNS to cause changes including muscular contractions (skeletal, cardiac, and smooth) and gland secretions. Continuing the example diagramed below, motor neurons cause the muscles of

the hand and forearm to contract to adjust the shower temperature knobs based on the sensory information received from the sensory neurons.

Mediating communication between sensory neurons and motor neurons are **interneurons**. Interneurons are found in the CNS and are neither sensory nor motor, they act as intermediaries between sensory neurons and motor neurons.

Clinical Application: Neurogenesis

At one time, scientists believed that people were born with all the neurons they would ever have. Research performed during the last few decades indicates that **neurogenesis**, the birth of new neurons, continues into adulthood. Neurogenesis was first discovered in songbirds that produce new neurons while learning songs. For mammals, new neurons also play an important role in learning: about 1,000 new neurons develop in the hippocampus (a brain structure involved in learning and memory) each day. While most of the new neurons will die, researchers found that an increase in the number of surviving new neurons in the hippocampus correlates with how well rats learn a new task. Interestingly, both exercise and some antidepressant medications also promote neurogenesis in the hippocampus. Stress has the opposite effect. While neurogenesis is quite limited compared to regeneration in other tissues, research in this area may lead to new treatments for disorders such as Alzheimer's, stroke, and epilepsy.

Attributions

- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0
- "Chemical synapse schema cropped.jpg" by Officer or employee of the United States is in the Public Domain
- "Introduction to Psychology" by University of Minnesota is licensed under CC BY-NC-SA 4.0
- "Neuron or Nerve cell - Labelled Image.png" by DrJanaOfficial is in the Public Domain, CC0
- "Neurons & Nervous System" by Mohamed Awad is licensed under CC BY-NC-SA 4.0
- "Neurons uni bi multi pseudouni.svg" by Juoj8 is licensed under CC BY-SA 3.0 / A derivative from the original work
- "Principles of Biology I and II lab manuals" by Dalton State University is licensed under CC BY-SA 4.0
- "Saltatory Conduction.gif" by DrJanaOfficial is in the Public Domain, CC0
- "UGA Anatomy and Physiology 1 Lab Manual, 3rd Edition" by DeLoris Hesse, Deanna Cozart, Brett Szymik, Rob Nichols, University of Georgia is licensed under CC BY 4.0

Updated 2026.

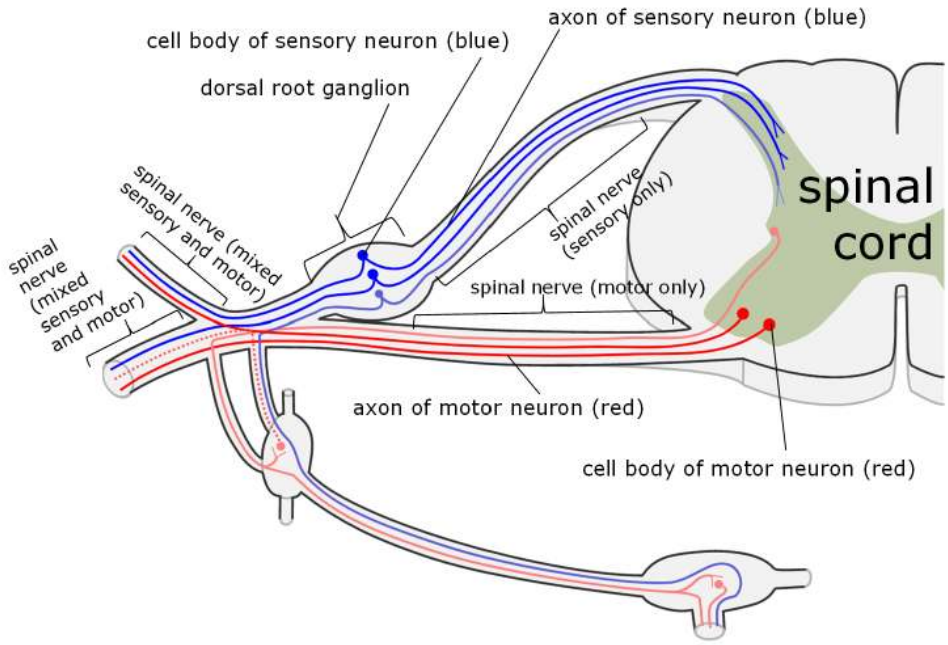
This page titled 13.2: Neurons is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

13.3: Nerves are Bundles of Neuron Axons in the PNS

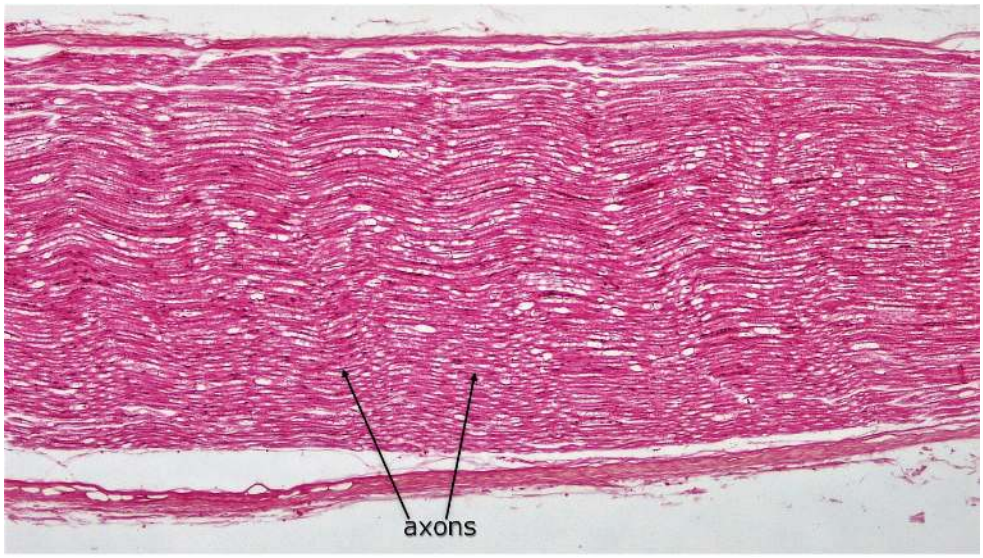
Nerves are Bundles of Neuron Axons in the Peripheral Nervous System (PNS)

Nerves are bundles of axons in the peripheral nervous system (PNS). Nerves can be classified as **sensory (afferent)** for signals coming into the central nervous system (CNS) from the PNS, or **motor (efferent)** for signals from the CNS to the PNS. Most nerves are **mixed**, and therefore carry both sensory and motor information.

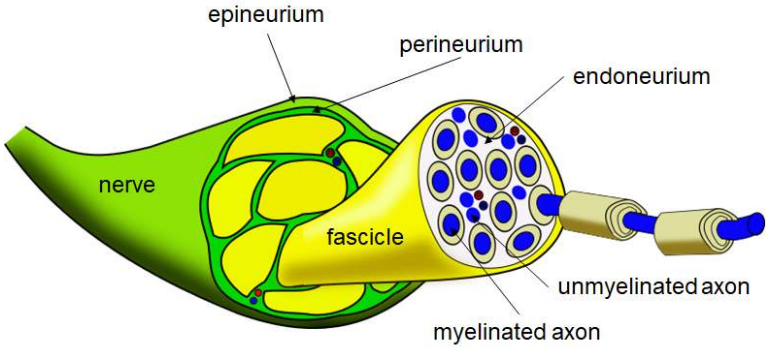
Ganglia are clusters of neuron cell bodies in the nerves of the PNS. Ganglia have various functions controlling and monitoring body functions. For example, **dorsal root ganglia** are sensory neurons clustered lateral to the spinal cord.



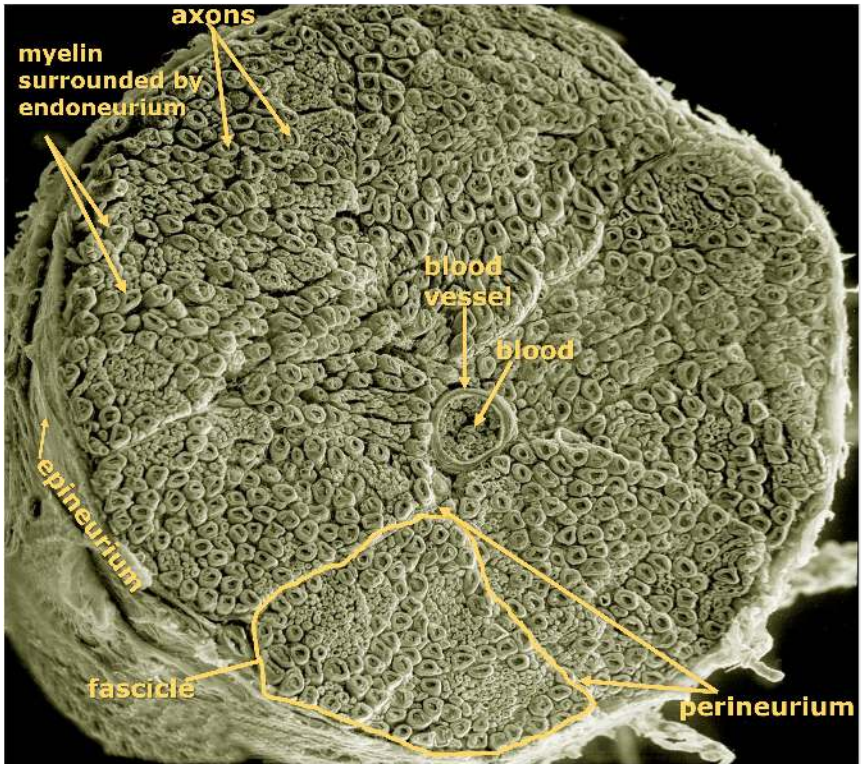
Above: Nerves (bundles of axons in the PNS) connect with the spinal cord in the CNS at spinal cord (spinal nerves) or at the brain (cranial nerves). The diagram above shows the structure of spinal nerves. Notice that nerves are composed of axons of both sensory and motor neurons (mixed nerves) and then are organized sensory neurons at the dorsal root of the spinal cord and motor neurons at the ventral root. Cell bodies of sensory neurons are bundled together in an enlarged region of the dorsal root called dorsal root ganglion.



Above: Microscopic image of a nerve with a longitudinal view. Axons appear as long strands in this view. Tissue is magnified by 40x.

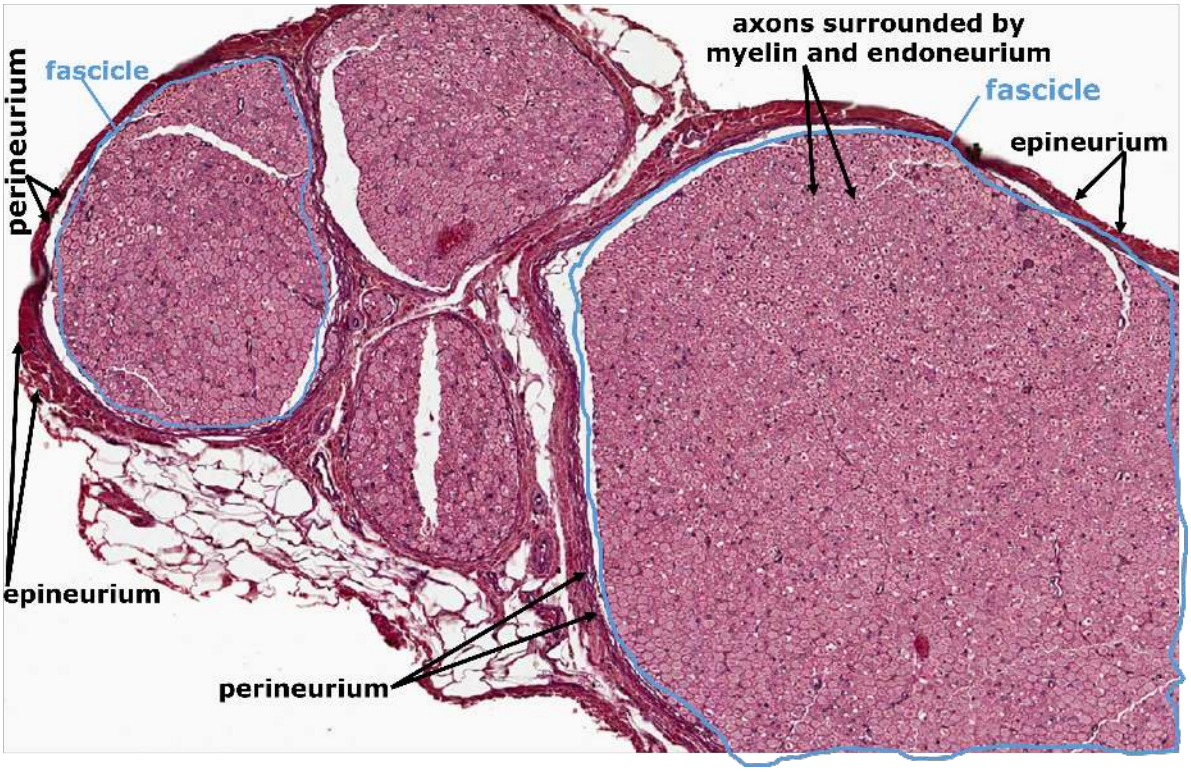


Above: Structure of a nerve.



Above: SEM image of a spinal nerve cross section.

The arrangements of axons in a nerve is similar to the organization of muscle fibers in a skeletal muscle (see **Chapter 11: Introduction to Skeletal Muscles**). Each axon is surrounded by a sheath of tissue called **endoneurium**. The axons surrounded by endoneurium are bundled together into sections called **fascicles**. Each fascicle is surrounded by a sheath of tissue called **perineurium**. Multiple fascicles, each surrounded by perineurium, are bundled together and wrapped with **epineurium** to for a nerve.



Above: Light microscope cross section of a nerve. Tissue is magnified 100x.

Attributions

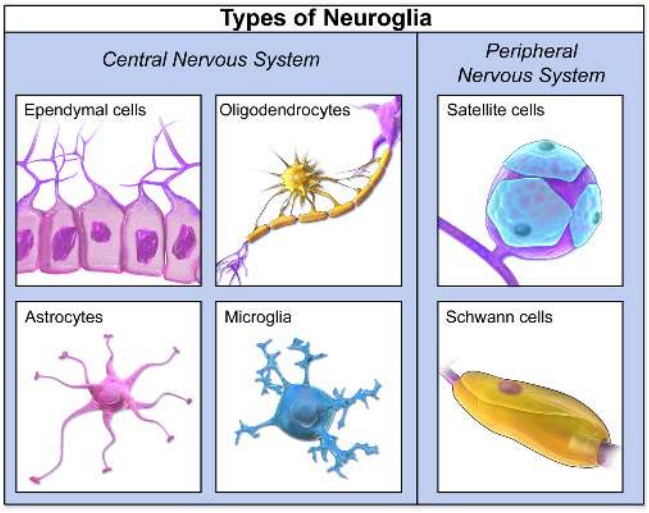
- "Anatomy and Physiology Lab Reference" by Laird C Sheldahl, OpenOregonEducational Resources, Mt. Hood Community College is licensed under CC BY-SA 4.0
- "Animal Tissues and Organs" by Berkshire Community College Bioscience Image Library is in the Public Domain, CC0
- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0
- "NCMIR human spinal nerve" by Mark Ellisman and Tom Deerinck is licensed under CC BY-NC-SA 3.0
- "Principles of Biology I and II lab manuals" by Dalton State University is licensed under CC BY-SA 4.0
- "Spinal nerve no text.svg" by jmarchn is licensed under CC BY-SA 3.0

Updated 2026.

This page titled 13.3: Nerves are Bundles of Neuron Axons in the PNS is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

13.4: Glia (Neuroglia) Cells

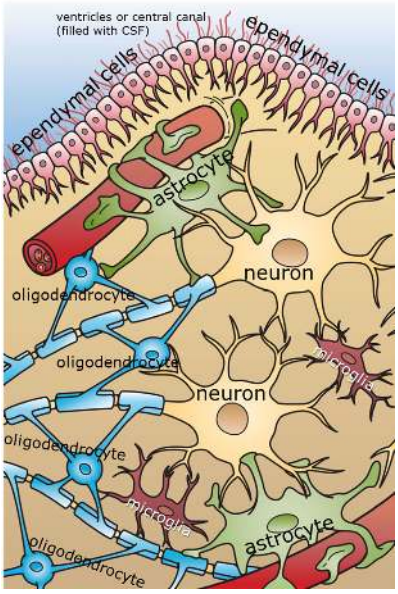
Glia (Neuroglia) Cells



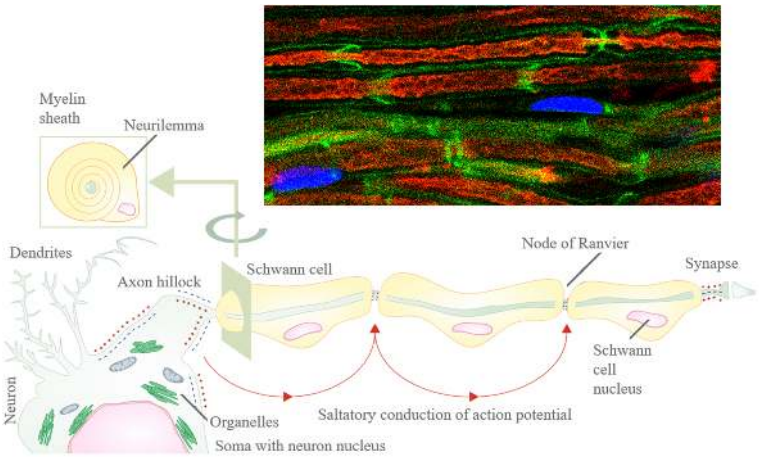
Above: Illustrations of the six types of glia cells. **Ependymal cells**, **oligodendrocytes**, **astrocytes**, and **microglia** are found in the CNS only. **Satellite cells** and **Schwann cells** are found in the PNS only. Both oligodendrocytes and Schwann cells wrap around axons of neurons forming myelin sheaths. Both astrocytes and satellite cells protect cell bodies from chemicals found in other tissues such as the blood. Ependymal cells protect neurons by producing cerebrospinal fluid (CSF). Microglia protect neurons by removing debris from nervous tissue.

Neurons are central to the functionality of the nervous system since they carry signals, thereby enabling collection of sensory information, processing of information, and transmission of motor commands. However, neurons are sensitive cells that need protection and support from glia cells. Examine the table below describing the six different types of glia cells, their functions, and whether they are found in the CNS or in the PNS.

Glia Cells	Function	Cells in CNS	Cells in PNS
oligodendrocytes, **Schwann cells**	cells that wrap axons in **myelin sheaths** (glial membrane extensions) that increase action potential velocity	oligodendrocytes (one cell branches to wrap around multiple axons)	Schwann cells (one cell wraps around one axon segment)
astrocytes, **satellite cells**, **ependymal cells**	cells that form borders between nervous tissues and other body tissues (protection)	astrocytes ependymal cells (make CSF)	satellite cells
microglia	immune cells that clear cellular debris from nervous tissues	microglia	--



Above: Diagram above shows the four types of glia cells of the central nervous system with neurons. Oligodendrocytes have multiple branches to myelinate multiple axon segments. Astrocytes wrap around blood vessels to protect neurons from substances that might interfere with neuron function. Microglia are mobile and patrol around nervous tissue to remove debris. Ependymal cells line the ventricles in the brain and the central canal in the spinal cord to create cerebrospinal fluid (CSF)



Above: (Bottom) Diagram showing Schwann cells wrapped around the axon of a neuron in the PNS. Schwann cells create myelin sheaths insulating the axon to increase the rate of propagation of an action potential. A cross section of the Schwann cell with its axon segment shows that the Schwann cell coils around the axon with its nucleus at a peripheral location. (Top) Microscopic image of axons (red) within a nerve (in the PNS). Wrapped around the axons are Schwann cells (green) creating myelin sheaths. The nuclei of Schwann cells are shown in blue.

Attributions

- "Blausen 0870 TypesofNeuroglia.png" by BruceBlaus is licensed under CC BY 3.0
- "Glial Cell Types.png" by Holly Fischer is licensed under CC BY 3.0
- "Principles of Biology I and II lab manuals" by Dalton State University is licensed under CC BY-SA 4.0
- "Propagation of action potential along myelinated nerve fiber en.svg" by Helixitta is licensed under CC BY-SA 4.0

Updated 2026.

This page titled 13.4: Glia (Neuroglia) Cells is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

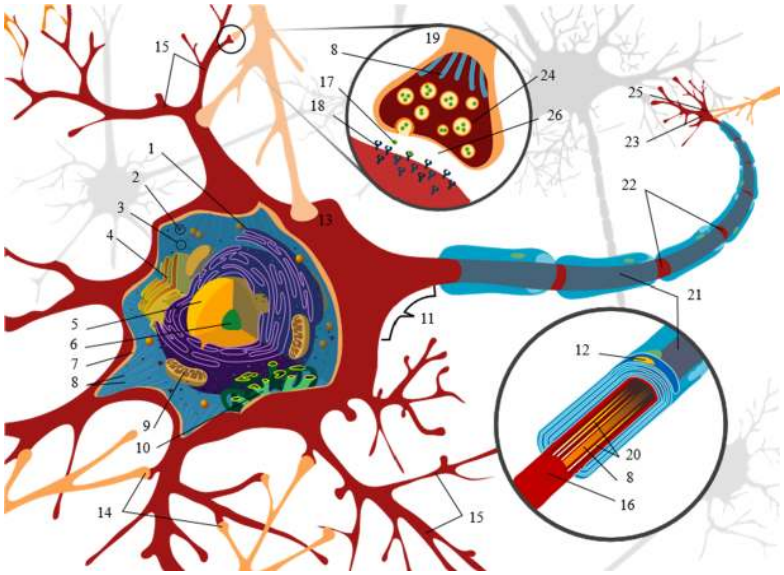
13.5: Laboratory Activities and Assignment

Laboratory Activities and Assignment

Part 1: Review of Introduction to the Nervous System

1. The diagram below shows a neuron with other neurons connected to it. In the blanks below, write the appropriate term for each numbered item from the choices listed below:

• axon • axon terminal • dendrites • neuron cell membrane • neuron nucleus	• neurotransmitter • node of Ranvier • nucleolus • receptor	• rough ER (Nissl body) • Schwann cell nucleus • Schwann cell with myelin sheath • synapse

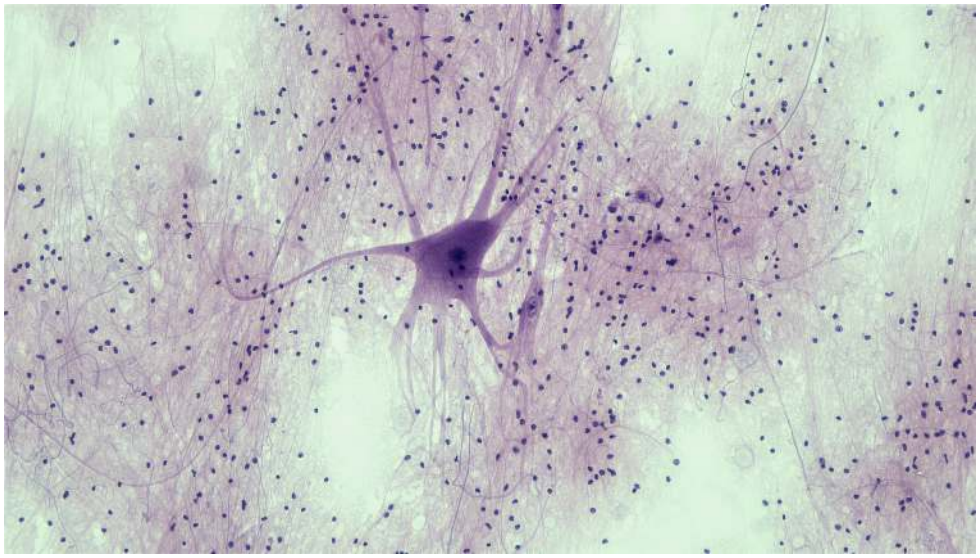


1. _____	16._____
5. _____	17. _____
6. _____	18. _____
7. _____	21. _____
12. _____	22. _____
13., 14., 19., 25. _____	23. _____
15. _____	

2. Below is a microscopic image of neural tissue. What structural classification of neuron is this (pseudo unipolar, bipolar, or multipolar)? How do you know?

3. On the microscopic image of neural tissue below, label the following structures:

• cell body (of neuron) • nucleus (of neuron)	• dendrites • synapse	• nuclei (of glia cells)



4. For each of the descriptions below, indicate whether it refers to a sensory neuron or a motor neuron by writing either "sensory" or "motor" in the spaces provided.

a. _____ Neurons that carry olfactory (scent) information from the nose to the brain.

b. _____ Neurons that increase glandular secretions.

c. _____ Neurons that cause muscles controlling the jaw to contract during chewing.

d. _____ Neurons that transmit pain when stung by a bee.

e. _____ Also known as efferent neurons.

f. _____ Also known as afferent neurons.

g. _____ Neurons causes heart beats.

h. _____ Neurons causing diaphragm contractions to enable breathing.

i. _____ Neurons transmitting light information from the eyes to the brain.

j. _____ Neurons that cause smooth muscle in the blood vessels close to the skin to contract in cold weather to prevent heat loss through the skin.

k. _____ Neurons that collect and transmit auditory (sound) information to the brain.

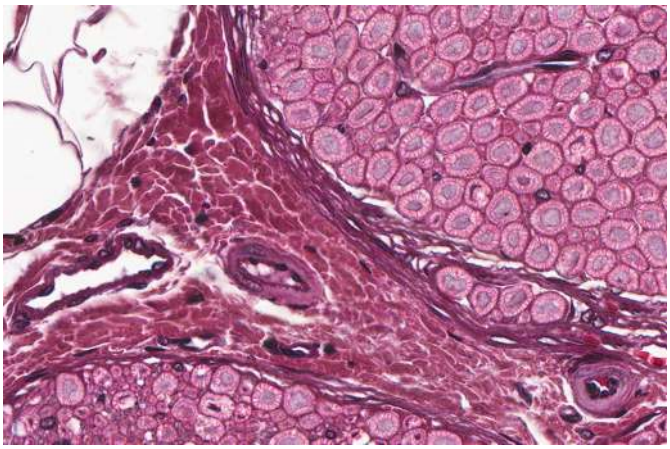
l. _____ Neurons that sense the touch of an insect that lands on the skin.

m. _____ Neurons that sense an itchy feeling after being bitten by a mosquito.

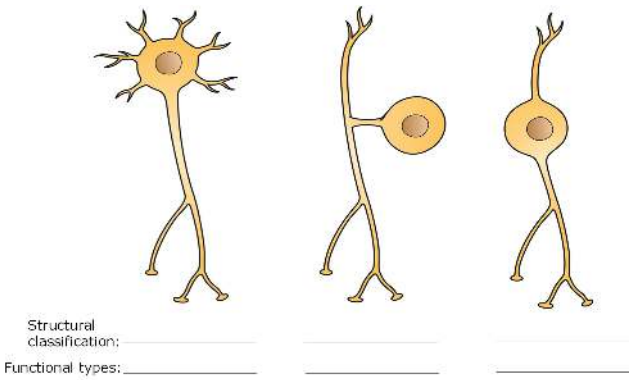
n. _____ Neurons that cause the eyes to blink.

5. Below is an image of part of a cross section of a nerve. Note that this image is at a much higher magnification (400x) than the one shown in the chapter (100x). Identify the following structures in the image and label the image accordingly:

• epineurium • perineurium	• axons • Schwann cells with myelin sheaths	• nuclei of Schwann cells • blood vessels

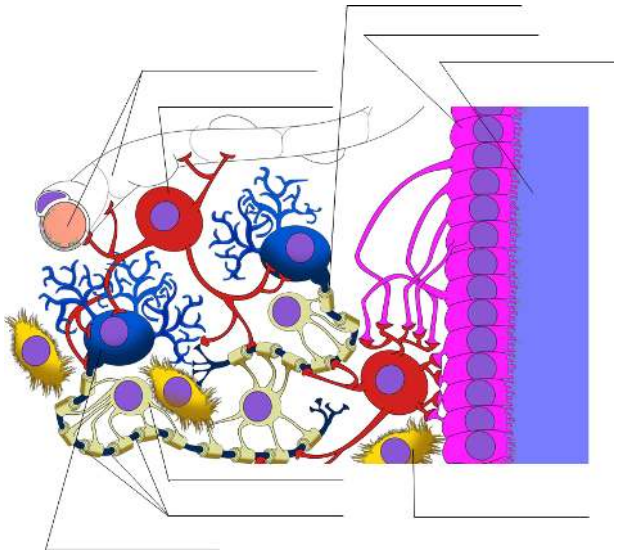


6. Below are three different neurons. For each, indicate its structural classification (pseudounipolar, bipolar, or multipolar), and the types of functions each have in the human body (sensory neurons, motor neurons, or interneurons - some may have more than one).



7. Below is an illustration of neurons and glia in the CNS. Label each of the following:

• astrocyte • axon • blood vessel	• cerebrospinal fluid-filled space (ventricles or central canal) • ependymal cell • microglia	• myelin sheath • neuron • oligodendrocyte



8. In the illustration above, there are two types of glia cells not shown.

   a. Name the two types of glia cells that are not shown.

   b. Why do these glia cells not belong in this illustration?

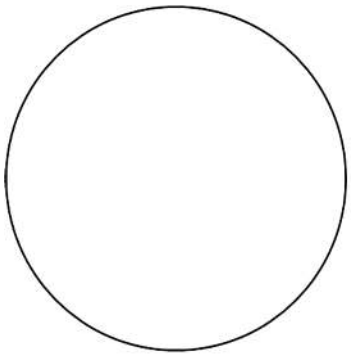
9. Multiple sclerosis is a demyelinating disease affecting the central nervous system. What type of cell would be the most likely target of this disease? Why?

Part 2: Introduction to the Nervous System Laboratory Activities

1. Obtain the slides listed below that are available for today's lab.
2. Focus on each sample and identify the structures listed for each type of tissue.
3. Indicate the **total** magnification you make each illustration at in the space provided.
4. Illustrate each tissue you observe with the microscope at the magnification you listed.
5. Label each illustration with the structures listed for each.

Central Nervous Tissue

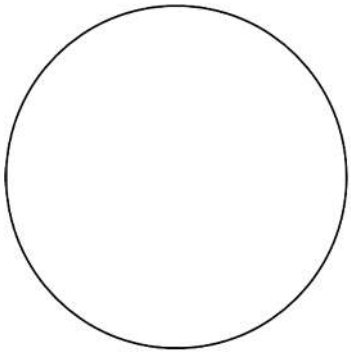
Label the tissue with: neuron, cell body (neuron), nucleus (neuron), dendrite, axon, synapse, nuclei (glia), [pseudounipolar, bipolar, or multipolar, as appropriate for each neuron]



Total magnification: _____

Dorsal Root Ganglion

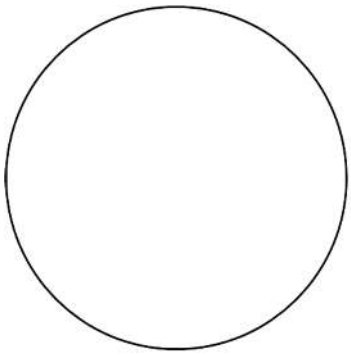
Label the tissue with: cell body (neuron), nucleus (neuron), axons, Schwann cell nuclei, satellite cell nuclei, whether the neurons are sensory neurons or motor neurons



Total magnification: _____

Peripheral Nerve (Cross Section)

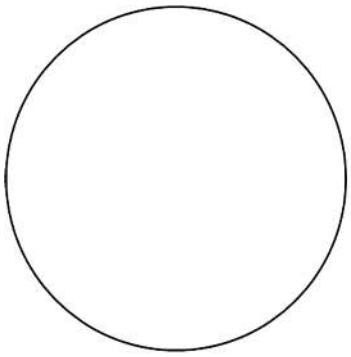
Label the tissue with: epineurium, perineurium, fascicle, myelin sheath, axon



Total magnification: _____

Neuromuscular Junction

Label the tissue with: muscle fiber, axon terminal, synapse



Total magnification: _____

Attributions

Part 1: Review of Introduction to the Nervous System

- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0
- "Anatomy and Physiology Lab Homework" by Laird C Sheldahl is licensed under CC BY-SA 4.0
- "Animal Tissues and Organs" by Berkshire Community College Bioscience Image Library is in the Public Domain, CC0
- "Bipolar Interneuron.png" by Holly Fischer is licensed under CC BY 3.0
- "Complete neuron cell diagram numbered.svg" by LadyofHats is in the Public Domain
- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0
- "Multipolar Motor Neuron.png" by Holly Fischer is licensed under CC BY 3.0
- "Unipolar Sensory Neuron.png" by Holly Fischer is licensed under CC BY 3.0

Part 2: Introduction to the Nervous System Laboratory Activities

- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0

Updated 2026.

This page titled 13.5: Laboratory Activities and Assignment is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

CHAPTER OVERVIEW

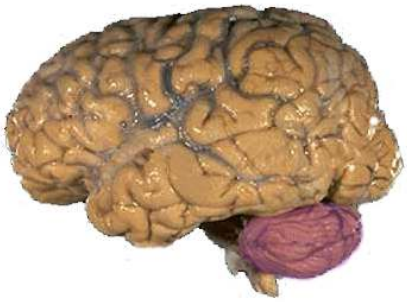
14: Central Nervous System

14.1: Brain
14.2: Sheep Brain Dissection
14.3: Spinal Cord
14.4: Additional Reference Figures
14.5: Laboratory Activities and Assignment
14.6: Collaborative Study Activities

This page titled 14: Central Nervous System is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

14.1: Brain

Brain

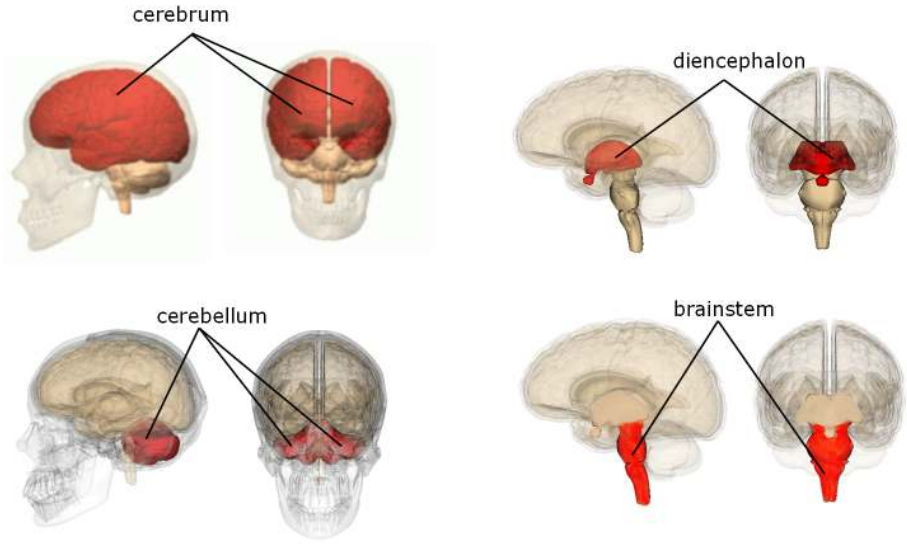


Above: A human brain, lateral view of the left side.

The brain is a complex organ with integrated parts. It contains over 100 billion neurons that are specialized to form different regions of the brain. As the brain develops, its neurons develop in complexity, become specialized into specific brain areas and functions, create circuits or pathways based on repeated experiences with some pathways fading away when they are not used.

Anatomy of the Brain

The brain can be subdivided into four different regions (listed superior to inferior): the **cerebrum**, the **diencephalon**, the **cerebellum**, and the **brainstem**.



Above: Subdivisions of the brain (left) lateral view of the left side of the brain and (right) anterior view of the brain.

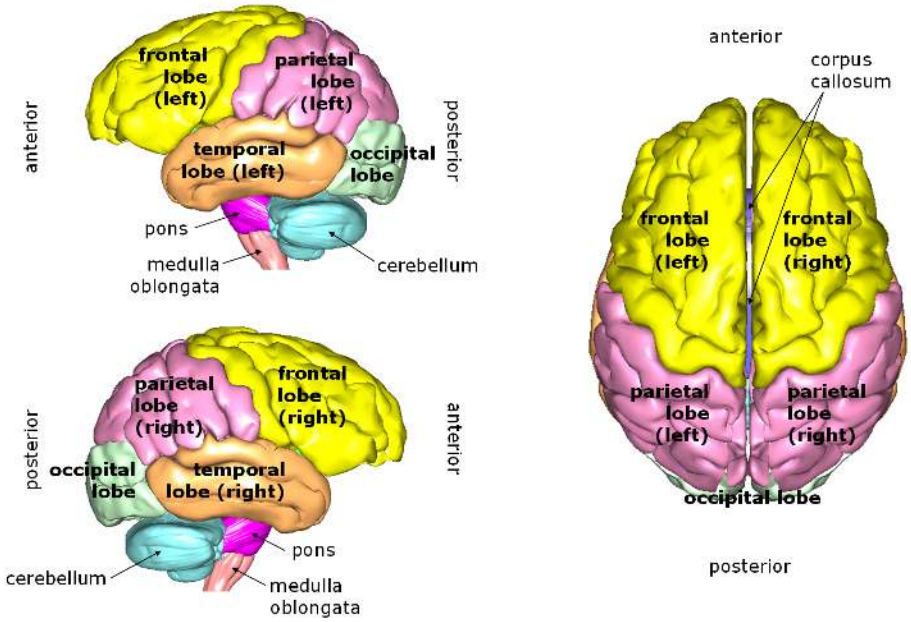
Structures of the brain, divided into each of the four brain subdivisions: cerebrum, diencephalon, cerebellum, and brain stem.

Brain structure	Location / Associations	Function
	cerebrum	
amygdala	cerebrum, limbic system	emotions, memories, and decision-making

Brain structure	Location / Associations	Function
caudate nucleus	cerebrum, basal nuclei	regulation of movements
cerebral cortex (frontal, temporal, parietal, & occipital lobes)	cerebrum	receiving and processing sensory information, processing and issuing motor commands, personality, reasoning, decision-making, language interpretation, language formation, memory
fornix	cerebrum, limbic system	involved in memory
globus pallidus	cerebrum, basal nuclei	regulation of movements
hippocampus	cerebrum, limbic system	stores and retrieves long-term explicit memories
insula	cerebrum, cerebral cortex	receiving visceral (organ) sensation and taste sensation
putamen	cerebrum, basal nuclei	regulation of movements
uncus	cerebrum	receiving olfactory (scent) sensory information, forming memories, and emotions
diencephalon		
hypothalamus	diencephalon, limbic system	regulates homeostasis for body temperature, heart rate, thirst, blood pressure, influencing pituitary gland, sleep cycle, fluid balance; the hypothalamus is both nervous and endocrine
pineal gland	diencephalon	controls sleep cycles, circadian rhythm, and seasonal cycles; produces melatonin; endocrine gland
thalamus	diencephalon, limbic system	a "gate" between sensory and motor neurons and relaying these signals to the cerebral cortex, regulating alertness, sleep, and consciousness
cerebellum		
cerebellum	cerebellum	outgoing motor commands are coordinated; maintaining balance, posture and coordination
brainstem		
cerebral crus (cerebral peduncle)	brainstem, midbrain	location where motor neuron tracts pass from the cerebral cortex to pons and then ultimately to the spinal cord
inferior colliculi	brainstem, midbrain	receiving auditory (sound) information
medulla oblongata	brainstem	causing reflexes such as swallowing, coughing, sneezing, and vomiting, regulates breathing, regulates heart rate, regulates blood pressure
midbrain / mesencephalon	brainstem	regulating alertness and sleep, involved in processing sensory perception (hearing, vision), and relaying motor controls
pons	brainstem	contains tracts of neurons regulating motor reflexes such as swallowing, crying, and bladder control as well as breathing, sleep, posture, and facial expressions; tracts carry equilibrium sensation and auditory sensation signals
pyramids of medulla oblongata	brainstem, medulla oblongata	contains tracts of motor neurons
superior colliculi	brainstem, midbrain	producing behavioral responses to stimuli in the environment

Note: The limbic system governs emotion, motivation, memory, and learning.

The **cerebral cortex** is a prominent part of the cerebrum that forms the outer layers of the brain located more superior and superficial to the rest of the brain. It is mainly composed of four lobes: the **frontal lobe**, **parietal lobe**, **temporal lobe**, and **occipital lobe**. The cerebral cortex has two hemispheres, the **right hemisphere** and the **left hemisphere**, divided by the **longitudinal fissure** . Each hemisphere receives sensory information and gives motor commands to the opposite side of the body, that is, the right hemisphere senses the left side of the body and issues motor commands to the left side of the body. This happens because most axons of sensory and motor neurons cross over from right to left or from left to right, often as they ascend up the spinal cord. The right and left hemispheres are connected by tracts of neural tissue located between them called the **corpus callosum** allowing communication between the two hemispheres.

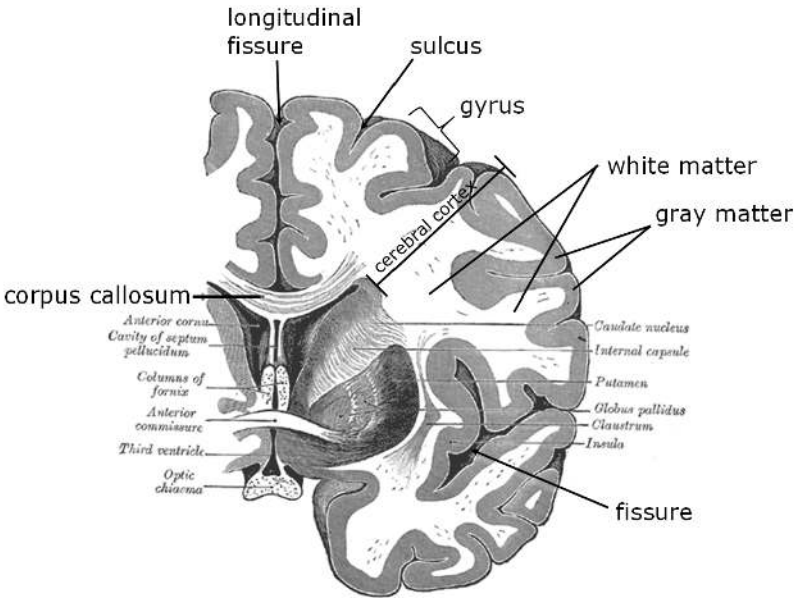


Above: Superficial view of the brain showing the lobes of the cerebral cortex (frontal, parietal, temporal, and occipital). The frontal lobe is shown in yellow, parietal lobe in pink, temporal lobe in orange, occipital lobe in mint green, cerebellum in teal, pons in magenta, medulla oblongata in light red, and corpus callosum in blue. (Top) Lateral view of the left side of the brain, (bottom) lateral view of the right side of the brain, and (right) superior view of the brain.

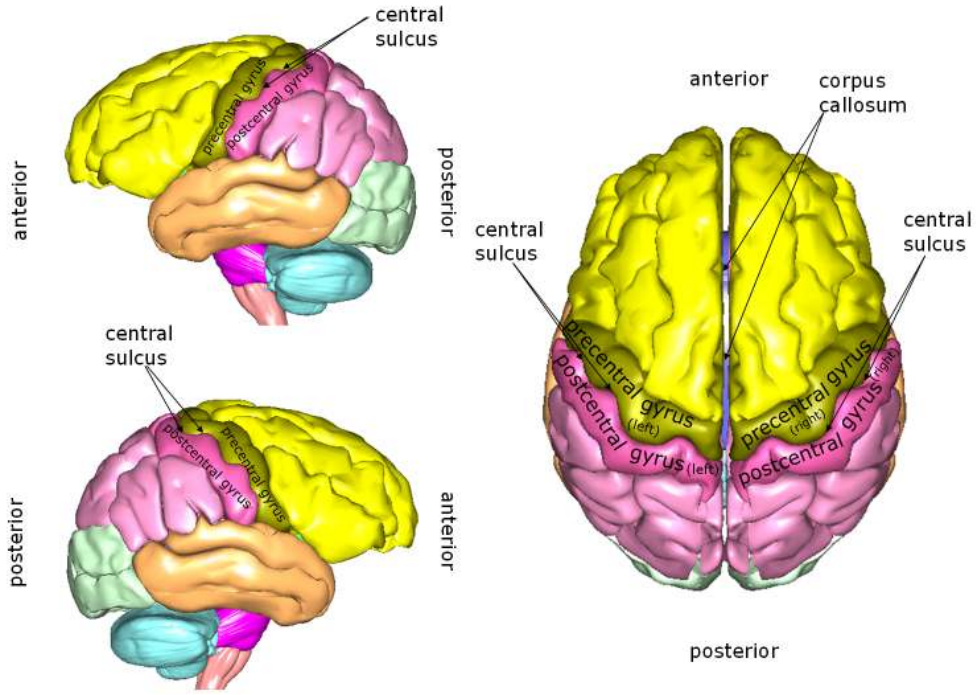
Lobe of the Cerebral Cortex	Location	Function Regions in this Lobe
frontal lobe	medial, anterior cerebral cortex	prefrontal cortex, premotor cortex, primary motor cortex (precentral gyrus), Broca's area (speech production)
parietal lobe	medial, intermediate cerebral cortex	primary sensory cortex (postcentral gyrus), somatic sensory association area
temporal lobe	lateral cerebral cortex	auditory association area, auditory cortex, Wernicke's area (understanding speech)
occipital lobe	medial, posterior cerebral cortex	visual association area, visual cortex

Each rounded ridge on the surface of the cerebral cortex is called a **gyrus** (pl. **gyri**) and are separated by indentations called **sulci** (sing. **sulcus**) if they are shallow indentations and called **fissures** if they are deep indentations. A slice through the cerebral cortex (see figure below) reveals that it is composed of both **white matter** and **gray matter**, neural tissues that have distinctly lighter and

darker colorations, respectively. The gray matter of the cerebral cortex contains the cell bodies (part of the neuron with its nucleus and organelles) of neurons involved in the specific functions of that brain region and the white matter contains axons, surrounded by myelin sheaths, bringing signals to and from the cerebral cortex. There are additional islands of gray matter, positioned within the white matter of the cerebral cortex, that are called **basal nuclei** (not shown in the figure below).

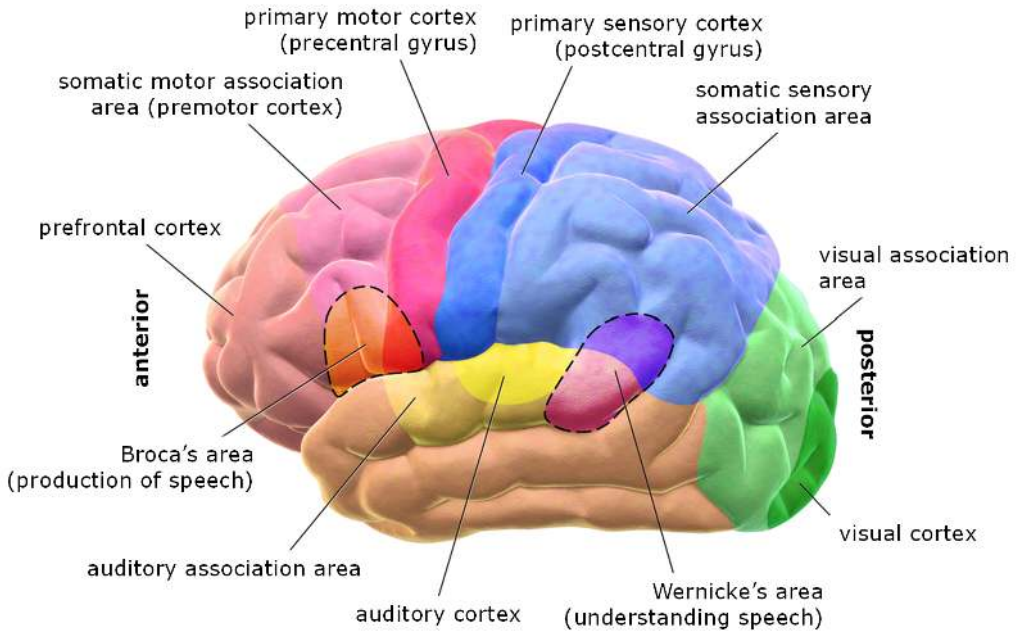


Above: Frontal section of the cerebrum showing the gray and white matter of the cerebral cortex, the two hemispheres separated by the longitudinal fissure and the corpus callosum connecting them, and the distinctions between a gyrus, sulcus, and fissure.



Above: Superficial view of the brain showing the lobes of the cerebral cortex and the precentral gyri, postcentral gyri, and the central sulcus. (Top) Lateral view of the left side of the brain, (bottom) lateral view of the right side of the brain right, and (right) superior view.

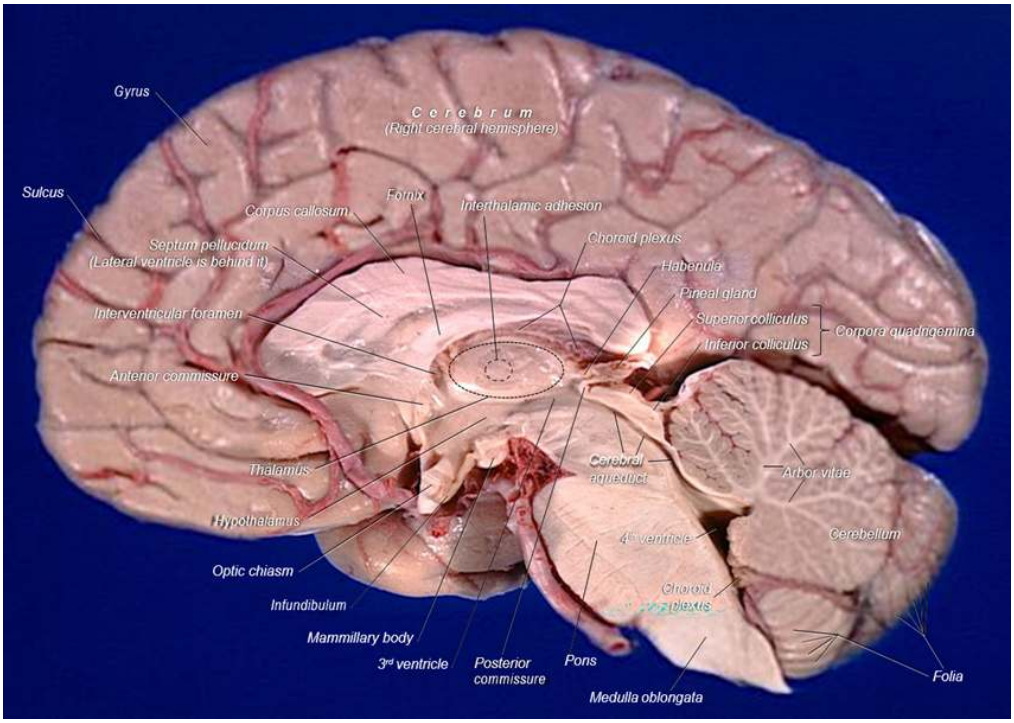
Separating the frontal lobe and the parietal lobe is the **central sulcus**. The gyri on either side of the central sulcus are called the **precentral gyrus** anterior to the central sulcus and the **postcentral gyrus** posterior to the central sulcus. The precentral gyrus is also known as the **primary motor cortex** since it is responsible for movements of the skeletal muscle under conscious control of the individual. This means that raising your right arm will be controlled by the precentral gyrus in the left hemisphere and kicking your left leg will be controlled by the precentral gyrus in the right hemisphere. The postcentral gyrus is also known as the **primary somatosensory cortex** ("somato-" comes from the Greek "soma" referring to "the body") that receives sensory information (touch, temperature, pain, vibration, etc.) from the body including the skin and muscles.



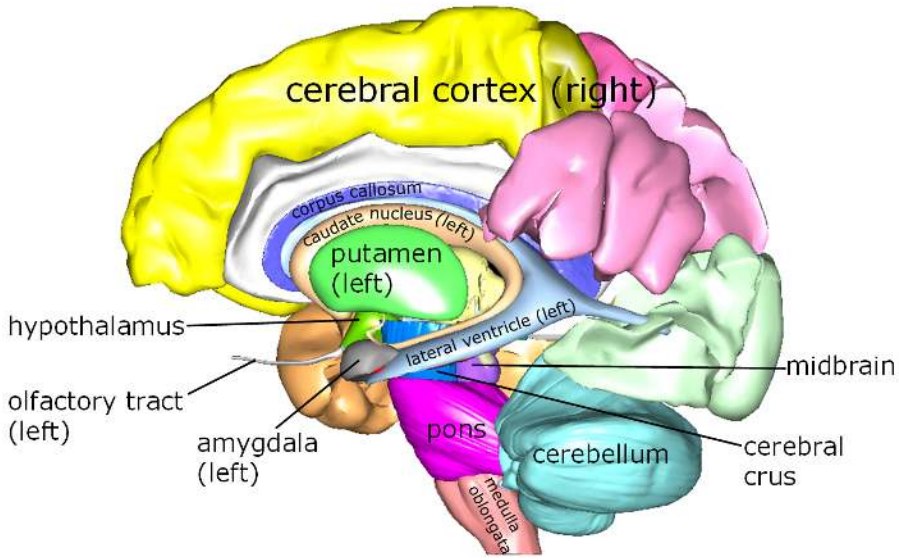
Above: Functional regions of the cerebral cortex with a lateral view of the left side of the brain. Wernicke's area and Broca's area are found only in the dominant hemisphere of the cerebral cortex (usually the left hemisphere, but may be in the right hemisphere instead, especially if an individual is left-handed).

Functional Areas of the Cerebral Cortex	Location in the Cerebral Cortex	Functions
auditory association area	temporal lobe	processing auditory (sound) information and auditory memory
auditory cortex	temporal lobe	receiving auditory (sound) information from the ears
Broca's area	frontal lobe	producing speech; located in the left temporal lobe only in most individuals; in some individuals located *instead* in the right temporal lobe
prefrontal cortex	frontal lobe	executing executive and higher cognitive functions including decision-making, planning, memory, and social behaviors
primary motor cortex	frontal lobe, precentral gyrus	causing voluntary movements of the skeletal muscles
primary sensory cortex	parietal lobe, postcentral gyrus	receiving sensory information from the body
somatic motor association area (premotor cortex)	frontal lobe	involved in timing and spatial relationships of movements

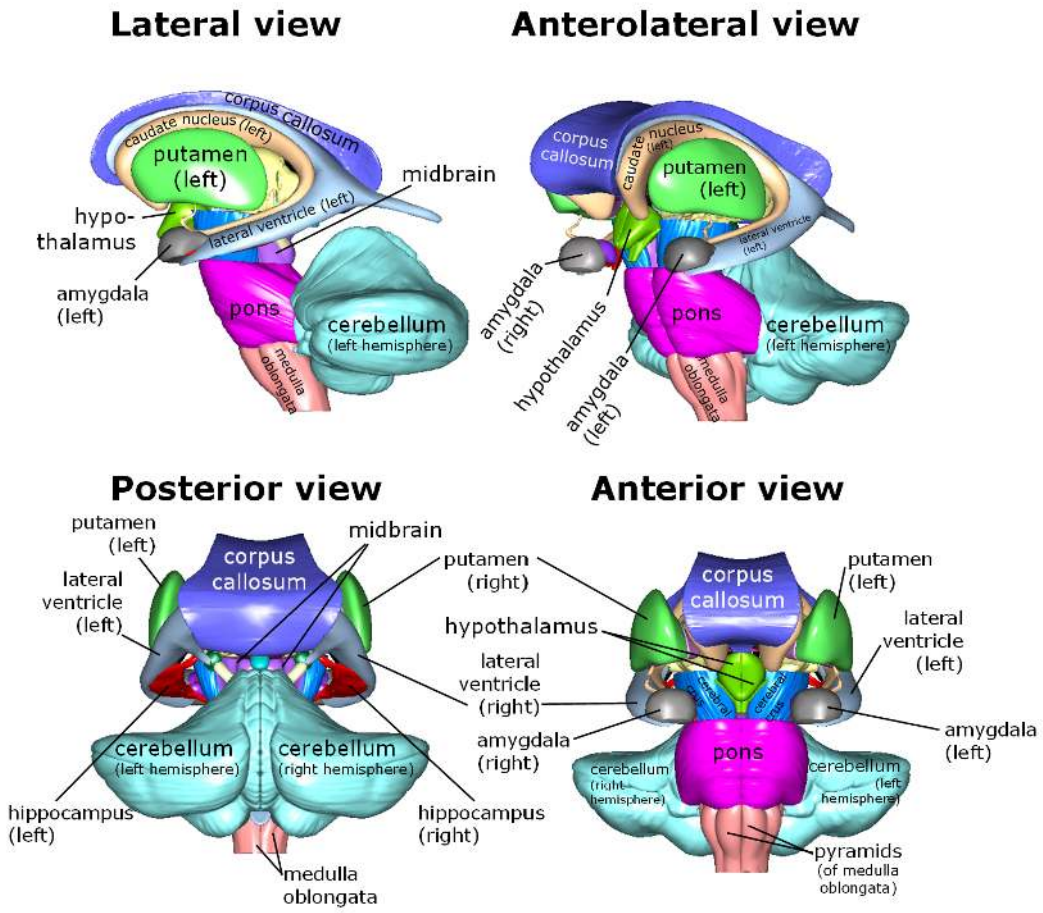
Functional Areas of the Cerebral Cortex	Location in the Cerebral Cortex	Functions
somatic sensory association area	parietal lobe	combines multiple sensory signals
visual association area	occipital lobe	processing visual information
visual cortex	occipital lobe	receiving visual information
Wernicke's area	temporal lobe	understanding language (both written and verbal); located in the left temporal lobe only in most individuals; in some individuals located *instead* in the right temporal lobe



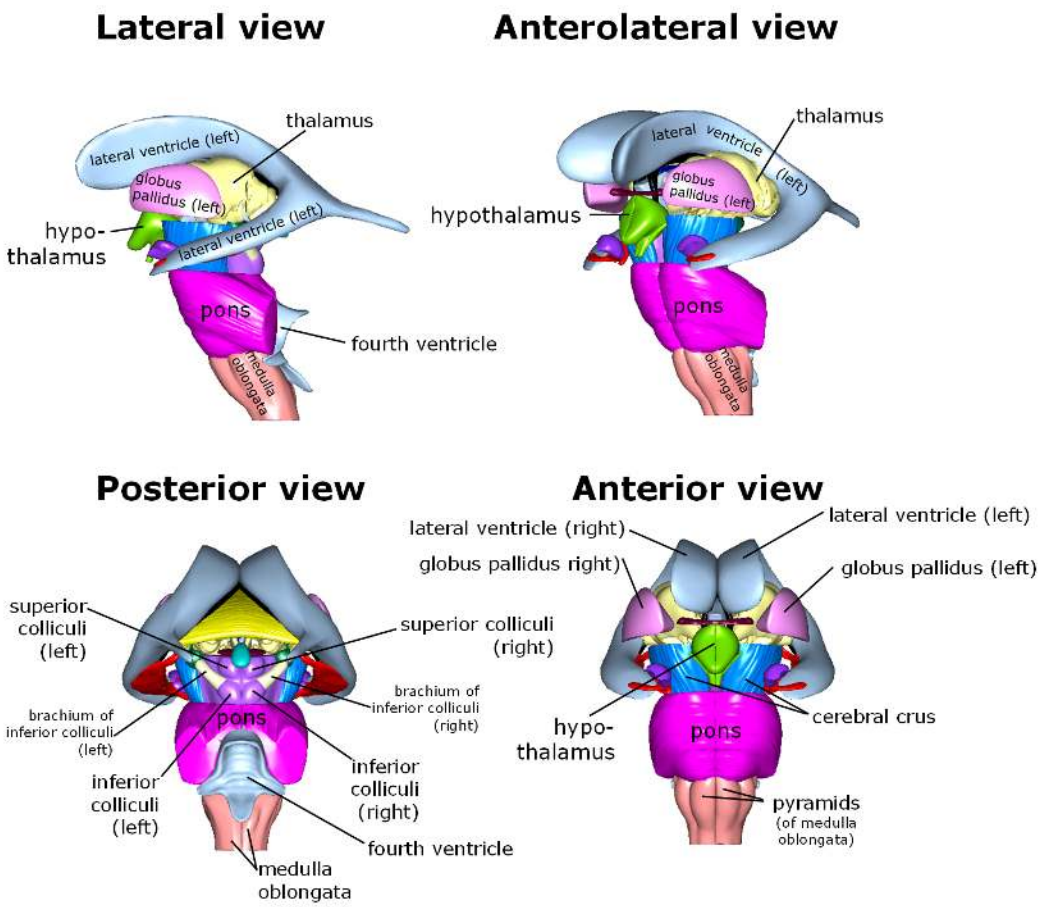
Above: Midsagittal view of a human brain.

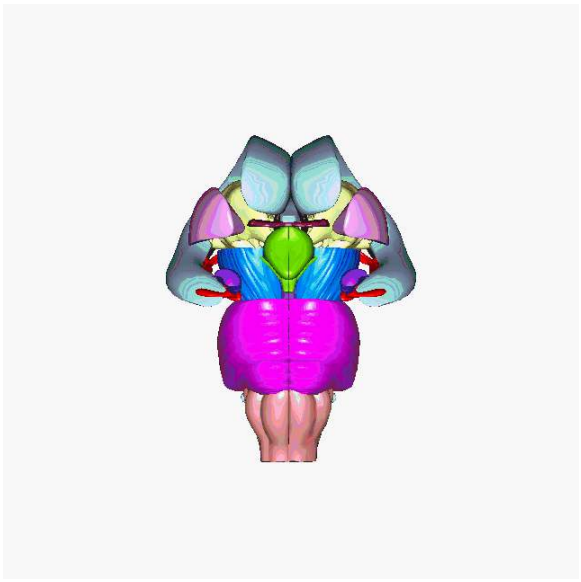


Above: Structures deeper in the brain with some of the left hemisphere of the cerebral cortex removed and a lateral view of the left side of the brain.

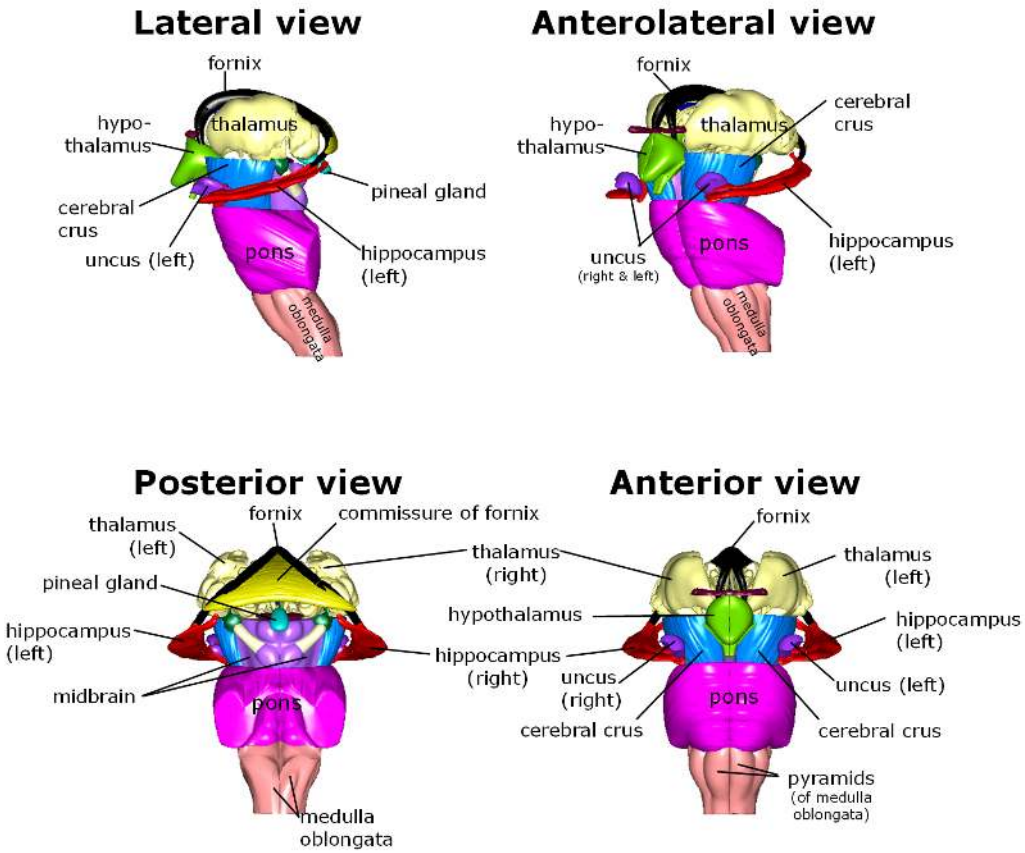


Above: The brain with the entire cerebral cortex removed (frontal lobe, parietal lobe, temporal lobe, and occipital lobe) to show deeper structures of the brain.





Above: The brain without the cerebral cortex, corpus callosum, cerebellum, amygdalae, caudate nuclei, and putamina.



Above: The brain without the cerebral cortex, corpus callosum, cerebellum, amygdalae, caudate nuclei, putamina, all of the ventricles (right and left lateral ventricles, third ventricle, fourth ventricle, and cerebral aqueduct), and globus pallidi.

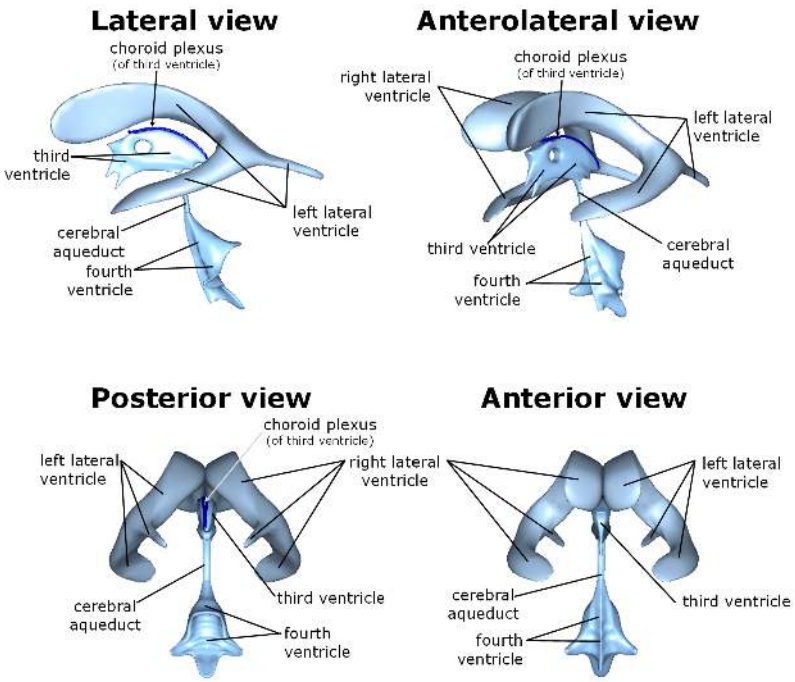
Clinical Application: Memory

There are three main subdivisions of memory, each of which is processed in a different areas of the brain:

- **Working memory** happens in the front of the brain, in the prefrontal cortex. This type of memory coordinates long-term memories with sights, sounds, and feelings so you can respond to events as they happen.
- **Short-term memory** involves retaining information for short periods of time, such as a mental "to do" list. Short-term memory involves coordination between the prefrontal cortex and the parietal lobes.
- **Long-term memory** accesses an amazing range of information - from knowledge of yourself to your understanding of the world. Long-term memory for events and experiences are processed deep in the brain, in a spired area called the **hippocampus**. It is here that the brain transfers newly gained information into permanent memory. For example, when repeatedly saying a new anatomy term while you are studying, you are passing this information through your hippocampus over and over again which strengthens the associations in the brain with the anatomy term. After repeating it over and over, eventually the pathways in the brain become strong enough to form long-term memories.

Ventricles, Choroid Plexuses, and Cerebrospinal Fluid

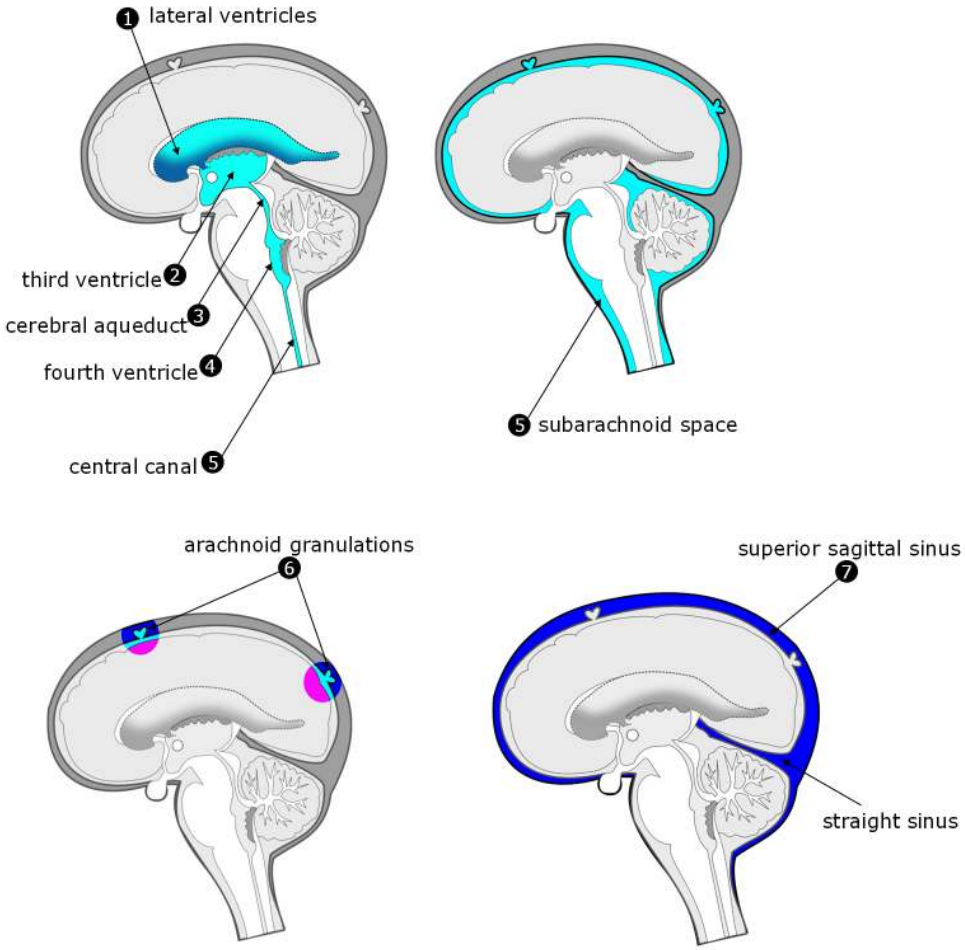
The ventricles are a system of structures in the brain that produce and circulate cerebrospinal fluid (CSF). Each of the four ventricles (**left lateral ventricle**, **right lateral ventricle**, **third ventricle**, and **fourth ventricle**) contain regions called **choroid plexuses** with ependymal cells (glia cells) responsible for creating CSF. CSF is a clear fluid that cushions the delicate tissues of the central nervous system and is found circulating throughout the ventricles, central canal of the spinal cord, through the subarachnoid space surrounding the brain and spinal cord, and ultimately leaves the subarachnoid space and into the blood in the superior sagittal sinus and straight sinus (blood vessels). CSF also is extremely important in maintaining biochemical homeostasis throughout the central nervous system. It is 99% water but also contains ions, proteins, neurotransmitters, and glucose.





Above: Ventricles of the brain shown without other brain structures.

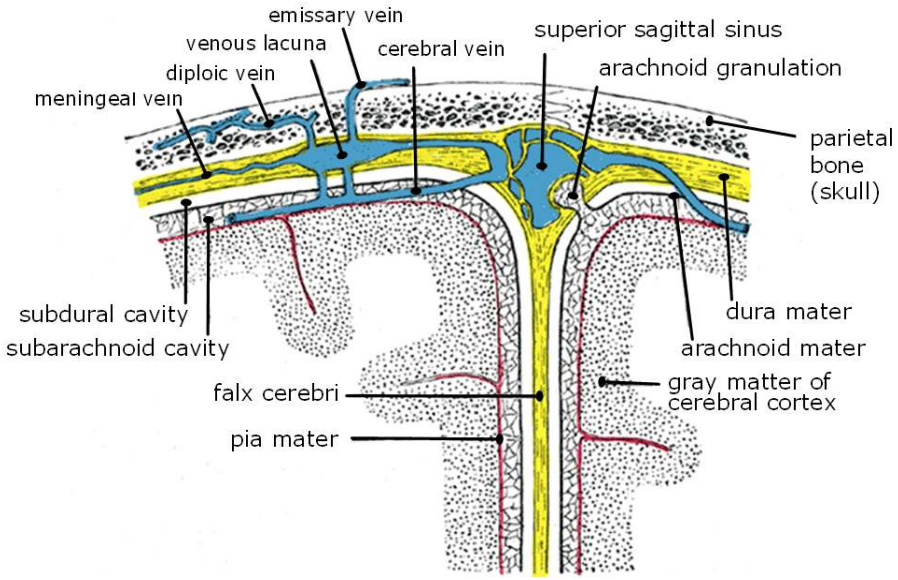
https://bio.libretexts.org/@go/page/53716



Above: The flow of CSF in and around the central nervous system. There are two step 5's since CSF can flow into the central canal, although most travels to the subarachnoid space.

Meninges

There are three layers of connective tissue of the central nervous system called meninges. These tissue layers from superficial to deep are: **dura mater**, **arachnoid mater**, and **pia mater**. The brain and spinal cord both are both covered with these same meningeal layers. That is, the dura mater of the brain is continuous with the dura mater of the spinal cord, the arachnoid mater of the brain is continuous with the arachnoid mater of the spinal cord, and the pia mater of the brain is continuous with the pia mater of the spinal cord. Inflammation of the meninges, in either the spinal cord, the brain, or both, is called **meningitis**.



Above: Frontal section of the skull, meninges, and superficial cerebral cortex. The three layers of meninges (dura mater, arachnoid mater, and pia mater) and their associated spaces (subdural cavity and subarachnoid cavity) are shown.

The dura mater in the brain forms a large fold, positioned within the longitudinal fissure of the cerebral cortex. This prominent fold largely separating the right and left hemispheres of the brain is called **falx cerebri**. Some of the large veins of the cranial cavity carrying blood back towards the heart, the **superior sagittal sinus** and **straight sinus**, are positioned within the falx cerebri.

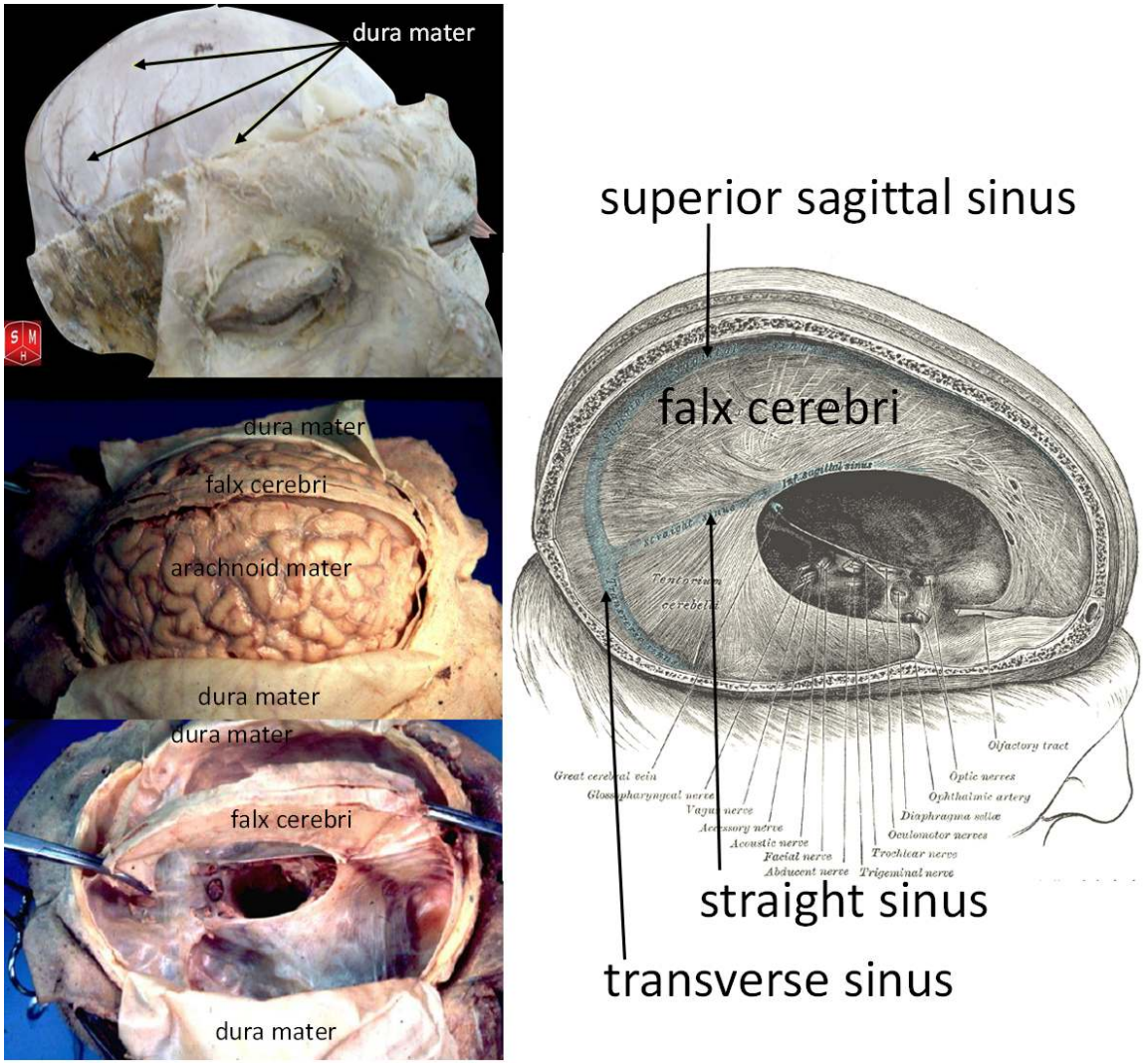
Dura Mater

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.

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.



Above: Cadaver images of the **dura mater**, **arachnoid mater**, two of the meningeal layers, and **falx cerebri** with an anatomical illustration of the falx cerebri with the large venous sinuses superior sagittal sinus, straight sinus, and transverse sinus that carry blood from the brain towards the heart.

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.

Attributions

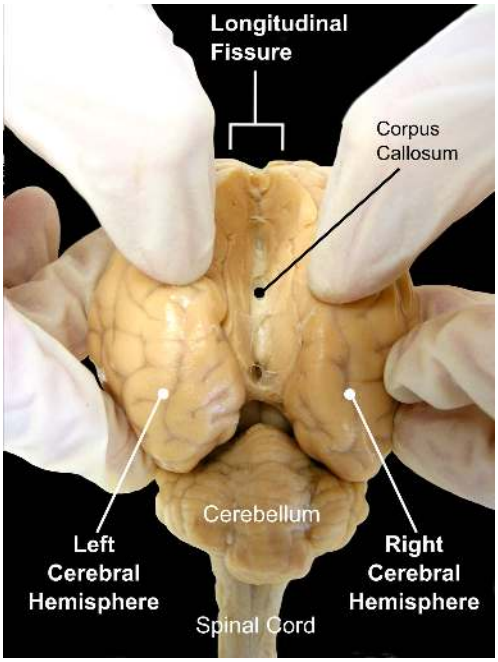
- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0
- "Anatomy and Physiology Lab Reference" by Laird C Sheldahl, OpenOregonEducational Resources, Mt. Hood Community College is licensed under CC BY-SA 4.0
- "Blausen 0102 Brain Motor&Sensory.png" by BruceBlaus is licensed under CC BY 3.0
- "BodyParts3D/Anatomography" by The Database Center for Life Science is licensed under CC BY-SA 2.1
- "Brain dura-mater 1.jpg" by Anatomist90 is licensed under CC BY-SA 3.0
- "Cerebellum NIH.png" by NIH is in the Public Domain
- "Cerebellum small.gif" by Life Science Databases(LSDB) is licensed under CC BY-SA 2.1
- "Cerebrum animation small.gif" by Database Center for Life Science(DBCLS) is licensed under CC BY-SA 2.1
- "Diencephalon.png" by Life Science Databases(LSDB) is licensed under CC BY-SA 2.1
- "Gray's Anatomy plates" by Henry Vandyke Carte is in the Public Domain
- "Human brain arachnoid.JPG" by John A Beal, PhD is licensed under CC BY 2.5
- "Human brain dura mater (reflections).JPG" by John A Beal, PhD is licensed under CC BY 2.5
- "Memory" by Exploratorium is licensed under CC BY-NC-SA 4.0
- "Neurobiology of Trauma" by California Social Work Education Center (CalSWEC) is licensed under CC BY-NC-SA 3.0

Updated 2026.

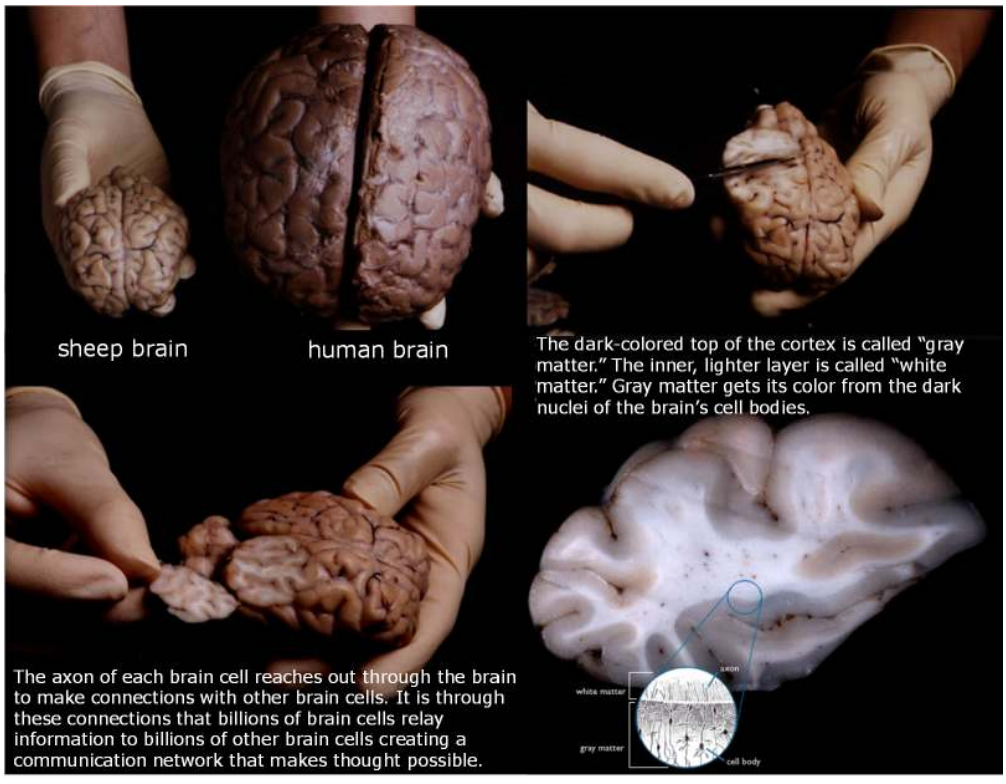
This page titled 14.1: Brain is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

14.2: Sheep Brain Dissection

Sheep Brain Dissection



Above: Posterior view of a sheep brain

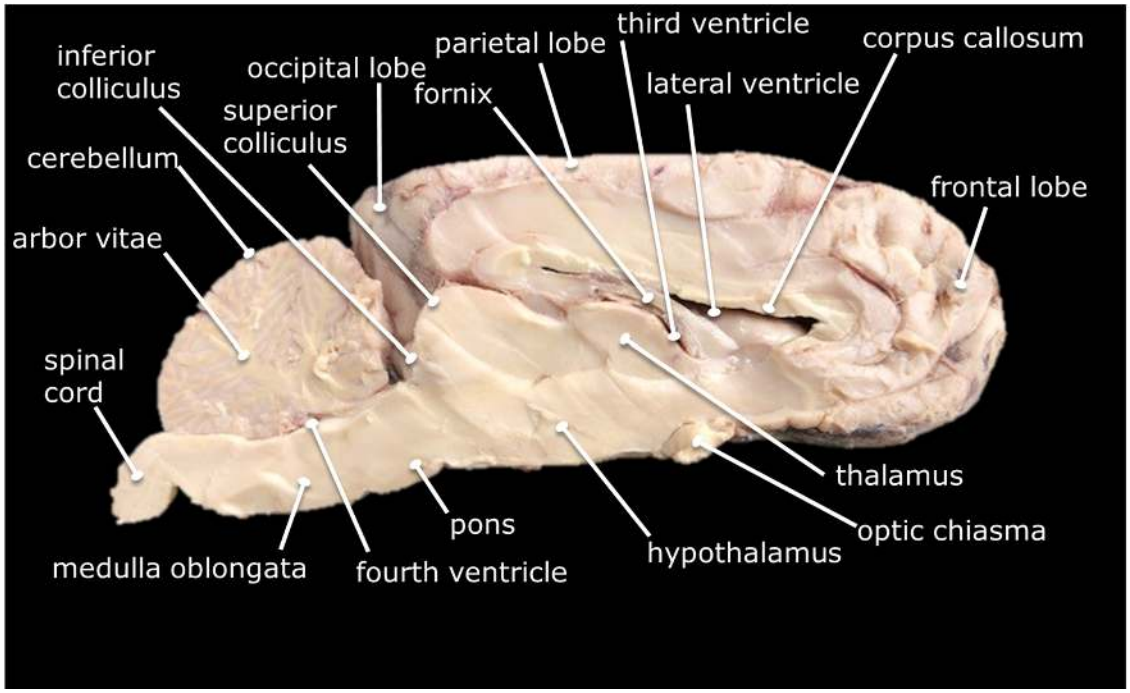


Above: Difference in size and appearance between a human brain and a sheep brain. A slice of the cerebral cortex of the sheep brain is taken to reveal the pattern of gray matter and white matter.



Above: A midsagittal slice of the sheep brain is made to reveal structures within the brain including the cerebellum.

Dissection of sheep brains is an excellent way to become more familiar with mammalian brain anatomy. As you can see below, sheep brains are considerably smaller than human brains, weighing about ten times less. Even though there are obvious differences, we can observe much of the anatomy present in a human brain by dissecting a sheep brain, which is much more readily available for use in anatomy laboratories.



Above: Midsagittal section of a sheep brain.

Attributions

- "Memory" by Exploratorium is licensed under CC BY-NC-SA 4.0
- "Sheep Brain Dissection 2 - black background with labels.png" by aaronbflickr is licensed under CC BY 2.0 / A derivative from the original work

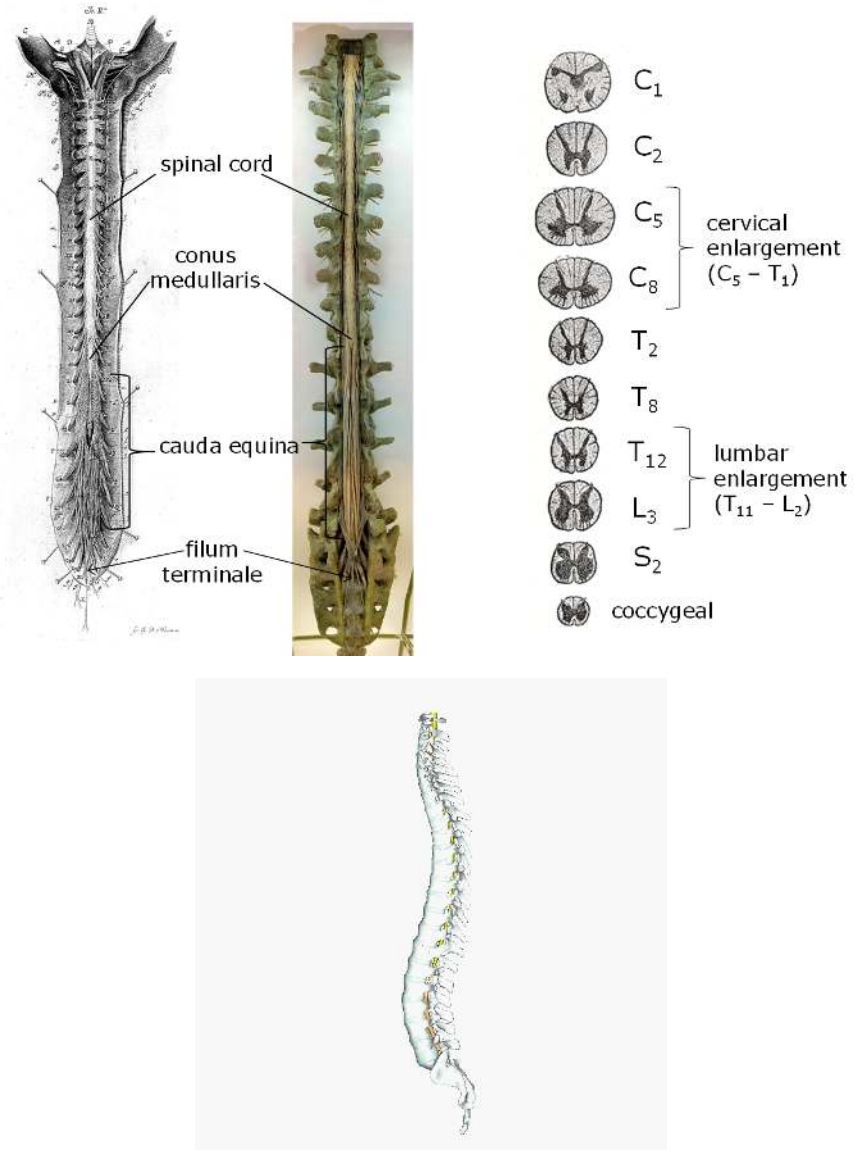
Spring 2026.

This page titled 14.2: Sheep Brain Dissection is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

14.3: Spinal Cord

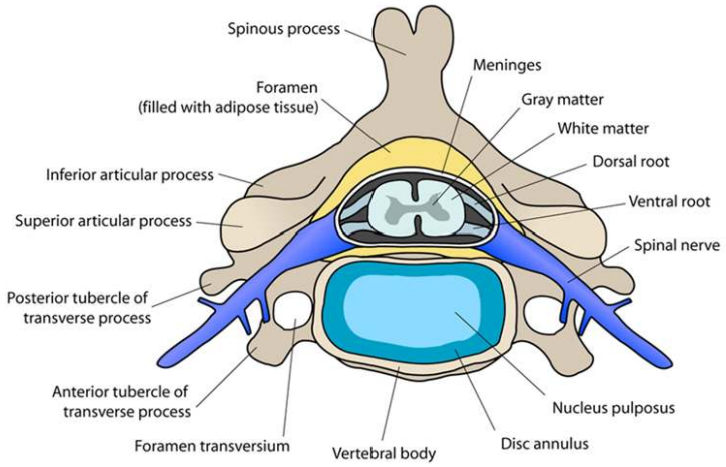
Spinal Cord

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. 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 tapers to from the **conus medullaris** near the second lumbar vertebra as it spreads out into a horse tail-like structure called **cauda equina** and terminating in a fibrous extension known as the **filum terminale**. 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.



Above: The spinal cord. (Top left) Illustration and (top middle) image from a cadaver of the spinal cord without or with only part of the bones of the vertebral column present. (Top right) Transverse sections of the spinal cord show a butterfly-pattern in the neural tissue of the spinal cord and the shape and width of the cord differs as the spinal cord descends through the vertebral

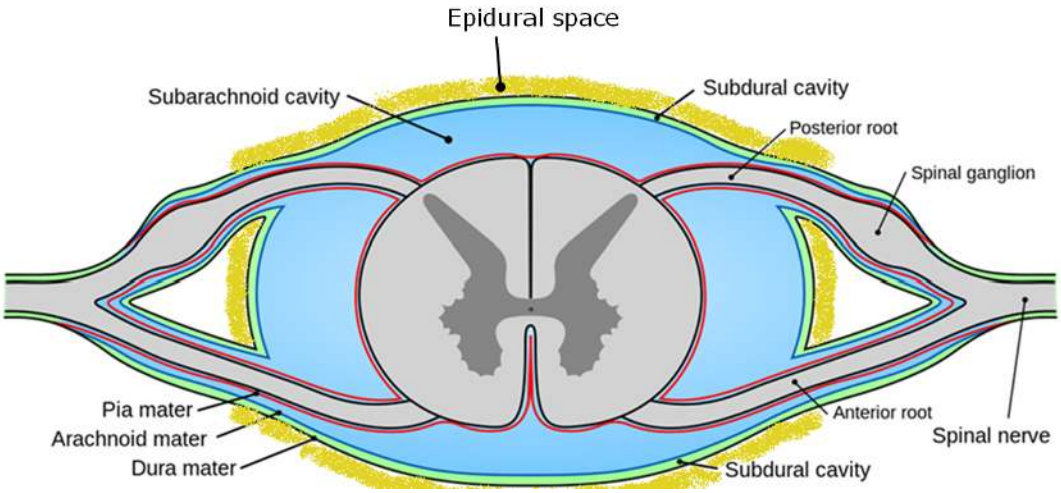
foramina of the vertebral column. (Bottom) Within the vertebral foramina of the vertebrae, the condensed spinal cord can be seen shown in yellow with cauda equina shown in orange.



Above: Superior view of a cervical vertebra with the spinal cord located in the vertebral foramen surrounded by the three layers of meninges: the dura mater, arachnoid mater, and the pia mater.

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.

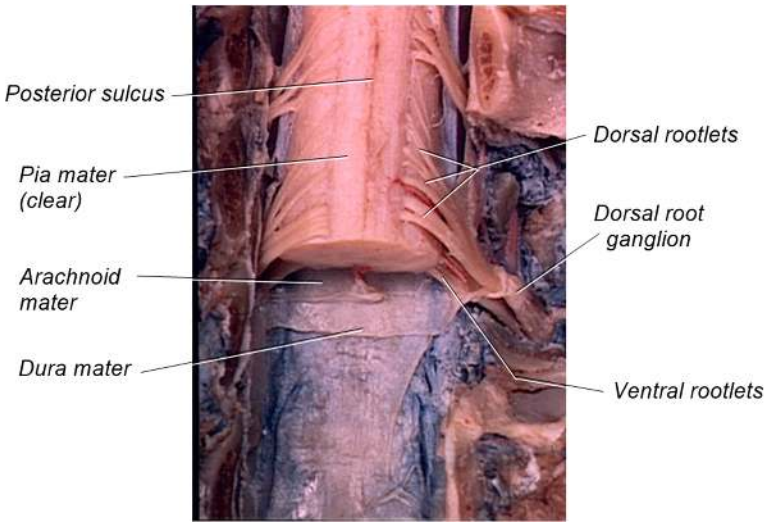
Meninges



Above: Illustration of the meninges surrounding the spinal cord, transverse section with a superior view.

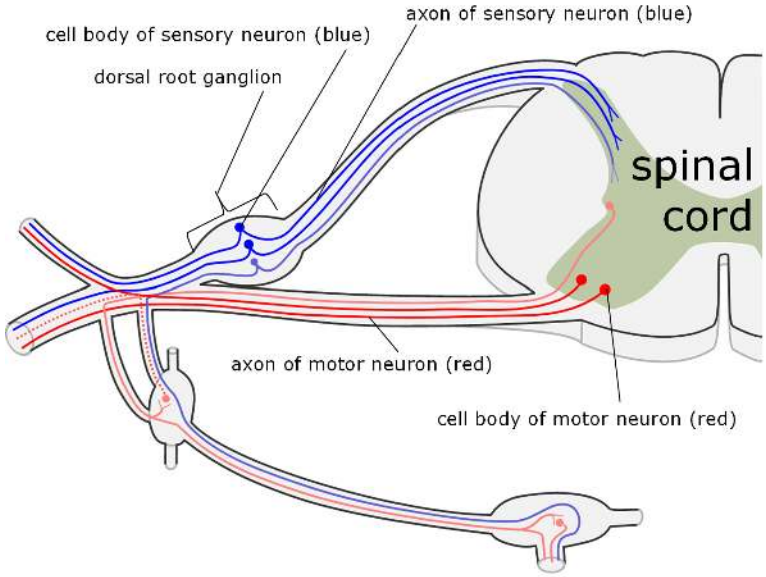
The spinal cord (and brain) are protected by three layers of connective tissue or membranes called **meninges**. The dura mater is the outermost layer, and it forms a tough protective coating. Between the dura mater and the surrounding bone of the vertebrae is a

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.



Above: Cadaver image of the spinal cord shown cut in the transverse plane, posterior view. The dura mater and arachnoid mater on the anterior of the spinal cord are shown and the transparent pia mater can be seen on the posterior of the spinal cord.

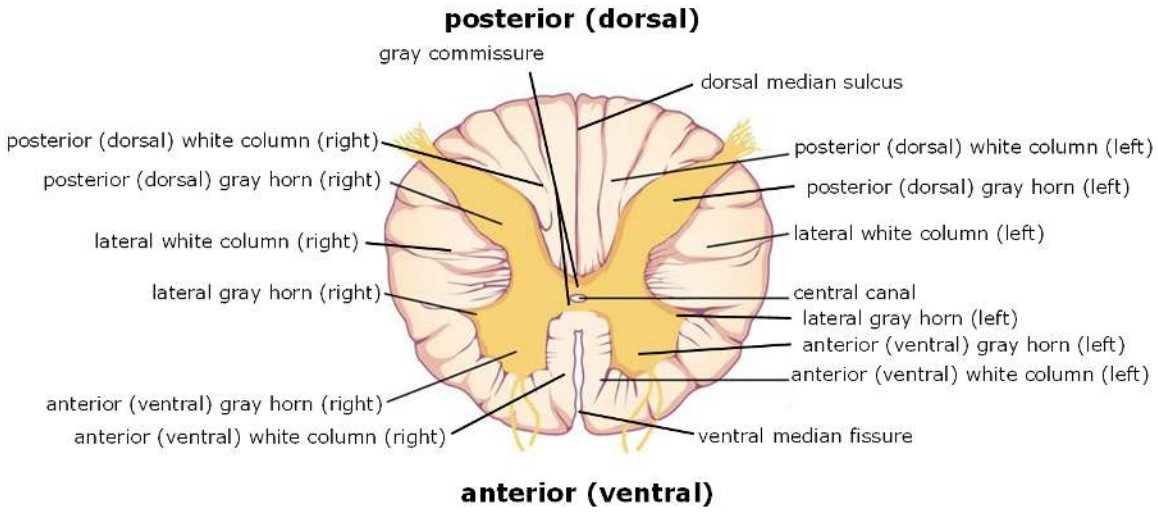
Organization of the Spinal Cord



Above: Transverse section of the spinal cord and spinal nerve. The blue lines represent axons of sensory neuron and blue dots are cell bodies of sensory neurons. The red lines represent axons of motor neurons. You can see that motor neurons exit the spinal cord from the ventral root (anteriorly) and sensory neurons enter the spinal cord at the dorsal root (posteriorly).

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 gray matter, which contains the nerve cell bodies arranged in the three gray 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.

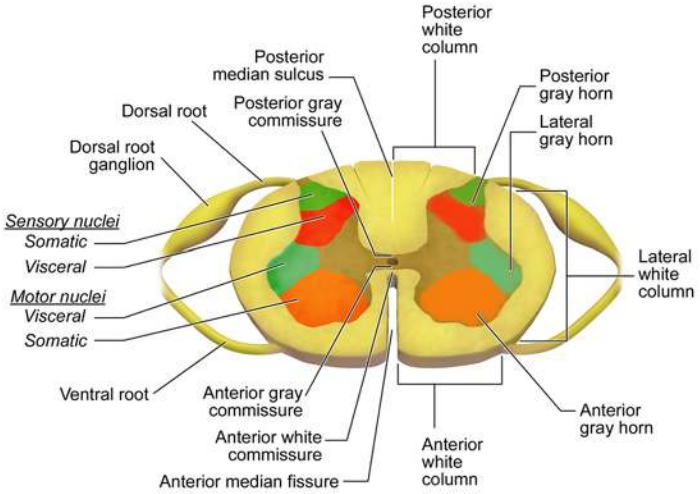


Above: the structures of the spinal cord, transverse section with a superior view.

The gray matter is divided into **posterior (dorsal) gray horns** which contain sensory neurons, and **lateral gray horns** and **anterior (ventral) gray horns** that contain the cell bodies of motor neurons. The surrounding white matter is divided into **anterior (ventral) white columns**, **lateral white columns**, and **posterior (dorsal) white columns**. The **gray commissure** is the gray matter posterior to the central canal where the neurons from either side of the spinal cord crossover. The same principle applies to the **white commissure** which lies anteriorly to the gray matter.

Gray Matter of the Spinal Cord

In cross-section, the gray matter of the spinal cord has the appearance of an ink-blot test, with the spread of the gray matter on one side replicated on the other—a shape reminiscent of a bulbous capital “H” or a butterfly. The gray matter is subdivided into regions that are referred to as horns. The posterior gray horn is responsible for sensory processing. The anterior gray horn sends out motor signals to the skeletal muscles. The lateral gray horn, which is only found in the thoracic, upper lumbar, and sacral regions, is the central component of the sympathetic division of the autonomic nervous system.

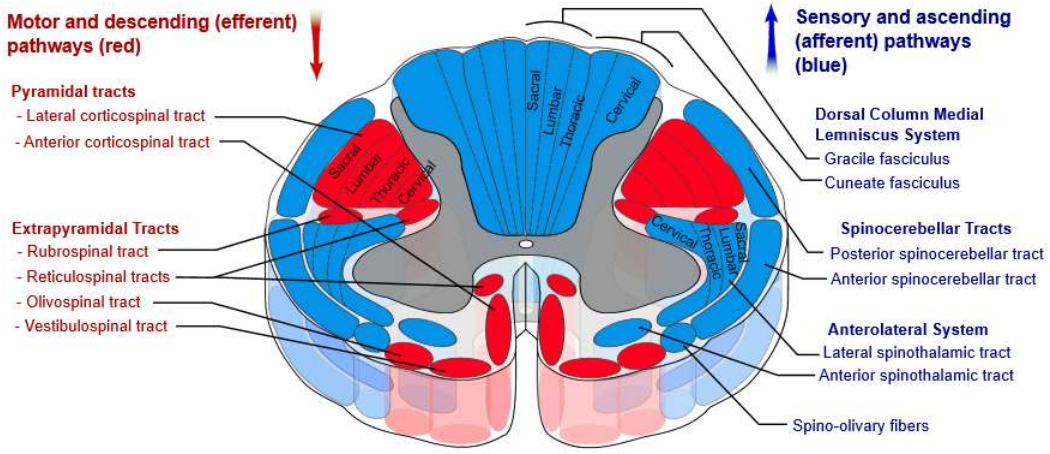


Above: The gray matter of the spinal cord is organized such that the posterior gray horns contain sensory nuclei and the anterior gray horns and lateral gray horns contain motor nuclei. These are further subdivided into visceral and sensory. Somatic sensory located in the posterior aspects of the posterior gray horns (green), visceral sensory located in the anterior aspects of the posterior gray horns (red), somatic motor located in the anterior aspects of the anterior gray horns (orange), and visceral motor located in the lateral gray horns (light green).

Some of the largest neurons of the spinal cord are the multipolar motor neurons in the anterior horn. The fibers that cause contraction of skeletal muscles are the axons of these neurons. The motor neuron that causes contraction of the big toe, for example, is located in the sacral spinal cord. The axon that has to reach all the way to the belly of that muscle may be a meter in length. The neuronal cell body that maintains that long fiber must be quite large, possibly several hundred micrometers in diameter, making it one of the largest cells in the body.

White Matter of the Spinal Cord

Just as the gray matter is separated into horns, the white matter of the spinal cord is separated into columns. **Ascending tracts** of nervous system fibers in these columns carry sensory information up to the brain, whereas **descending tracts** carry motor commands from the brain. Looking at the spinal cord longitudinally, the columns extend along its length as continuous bands of white matter. Between the two posterior horns of gray matter are the **posterior columns**. Between the two anterior horns, and bounded by the axons of motor neurons emerging from that gray matter area, are the **anterior columns**. The white matter on either side of the spinal cord, between the posterior horn and the axons of the anterior horn neurons, are the **lateral columns**. The posterior columns are composed of axons of ascending tracts. The anterior and lateral columns are composed of many different groups of axons of both ascending and descending tracts—the latter carrying motor commands down from the brain to the spinal cord to control output to the periphery.



Above: Functional organization of the tracts of white matter in the spinal cord.

Attributions

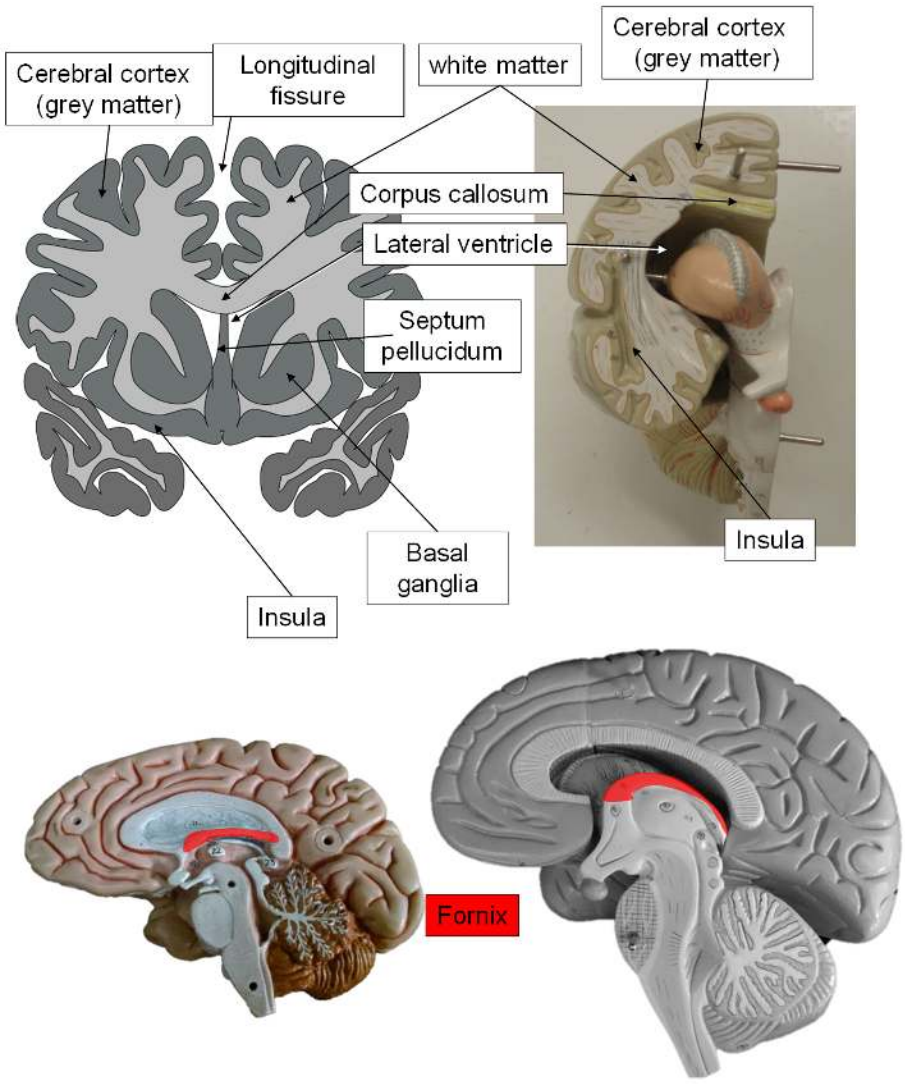
- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0
- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0
- "Gray's Anatomy plates" by Henry Vandyke Carte is in the Public Domain
- "Human Anatomy Lab Manual" by Malgosia Wilk-Blaszczak, Mavs Open Press, University of Texas at Arlington is licensed under CC BY 4.0
- "Spinal Cord - 4742.jpg" by Amada44 is licensed under CC BY-SA 3.0
- "Spinal cord and roots and dural tube which covers them. Wellcome L0002010.jpg" by Wellcome Images is licensed under CC BY 4.0
- "Spinal cord tracts - English.svg" by Polarlys and Mikael Häggström is licensed under CC BY-SA 3.0
- "Spinal dura mater 1.jpg" by Anatomist90 is licensed under CC BY-SA 3.0

Updated 2026.

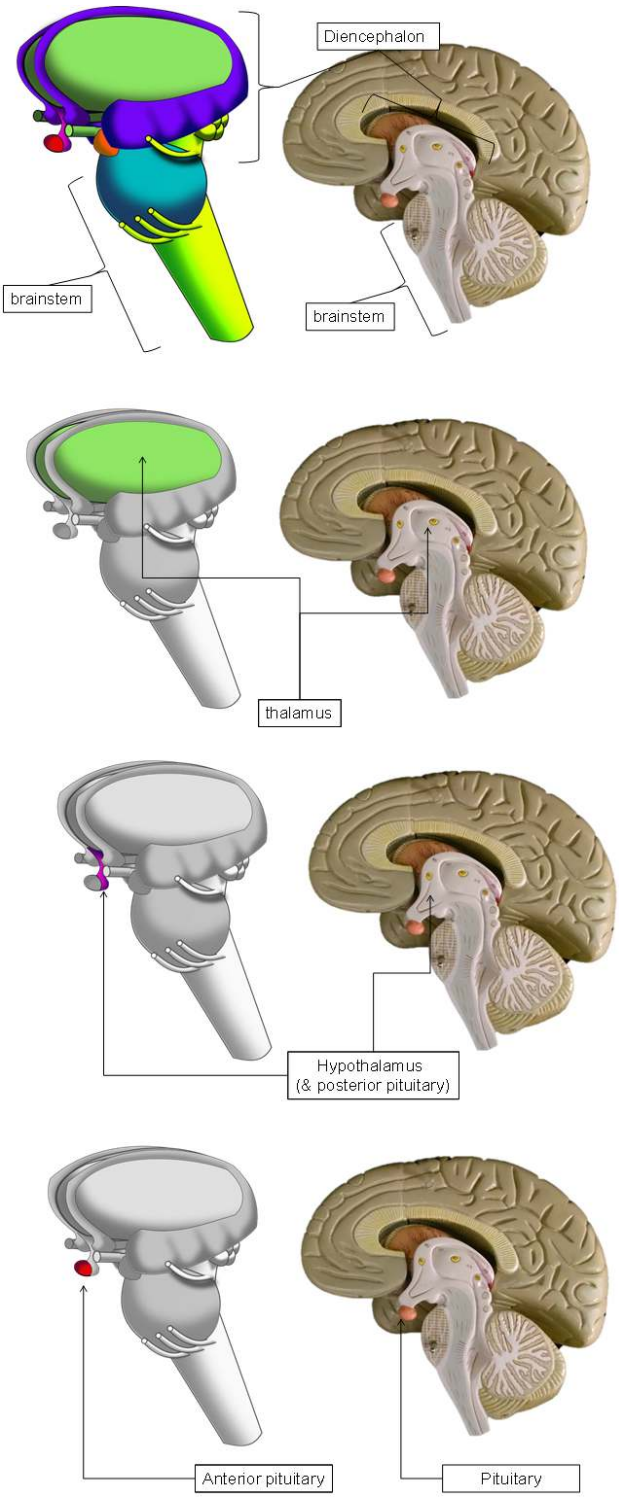
This page titled 14.3: Spinal Cord is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

14.4: Additional Reference Figures

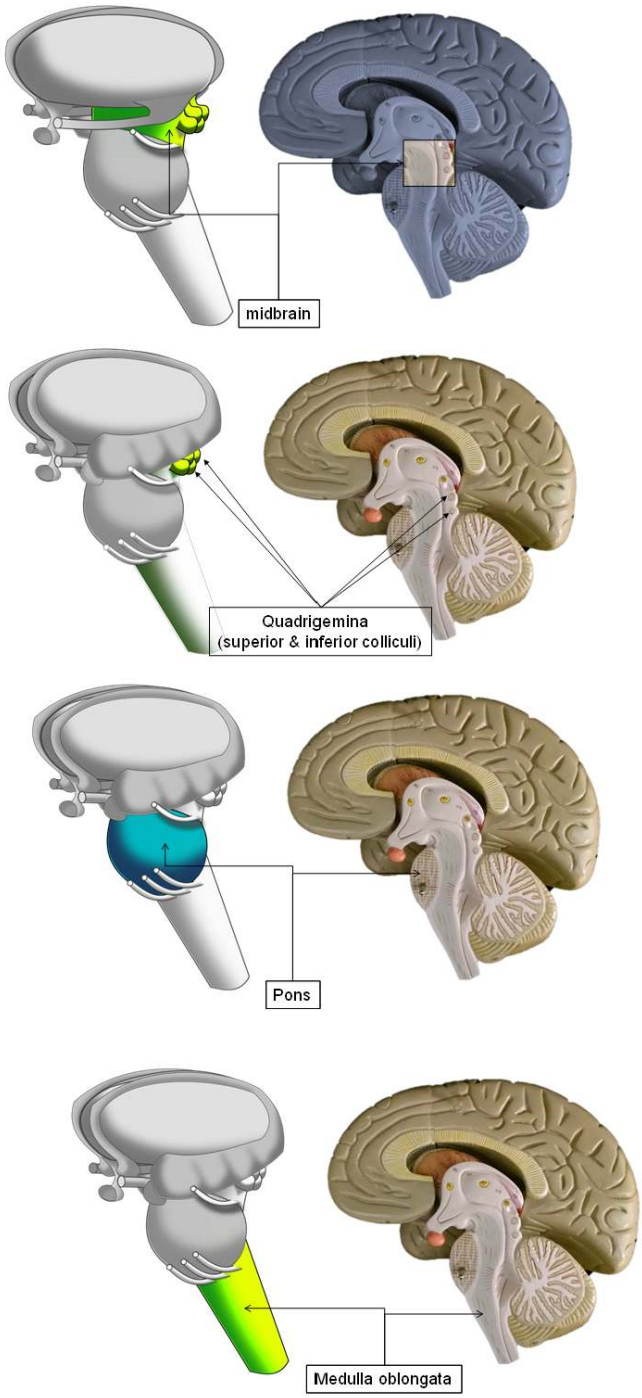
Additional Reference Figures



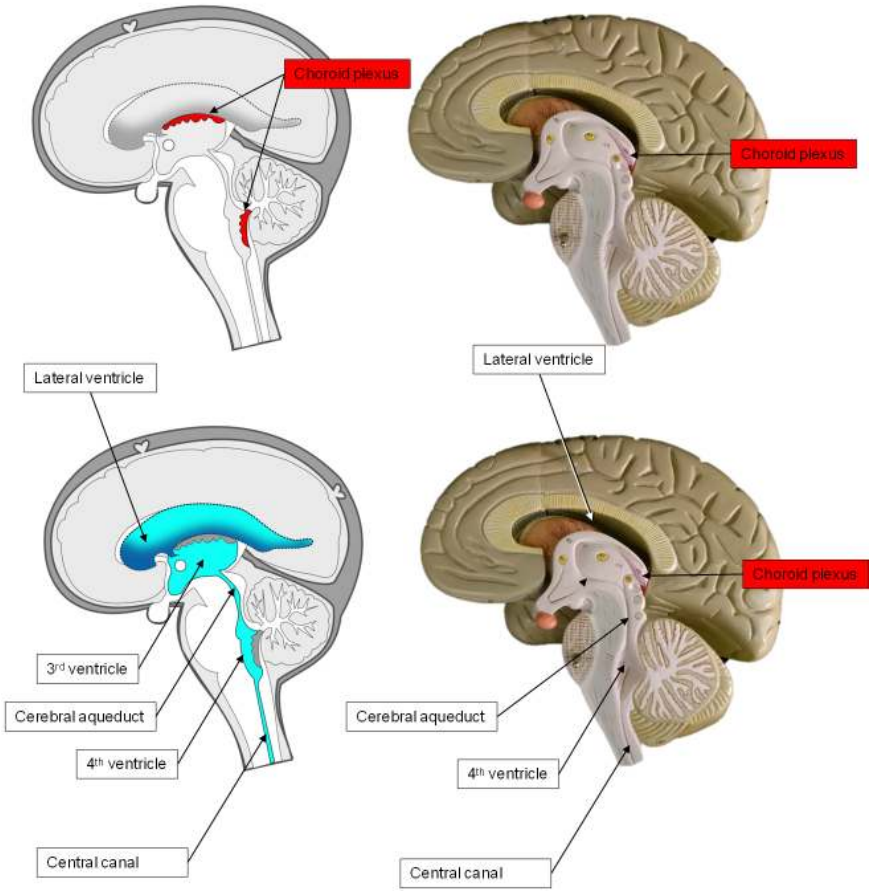
Above: Some of the structures of the brain on an anatomical model.



Above: Structures of the diencephalon on an anatomical model.



Above: Structures of the brainstem on an anatomical model.



Above: Ventricles and choroid plexuses on an anatomical model.

Attributions

- "Anatomy and Physiology Lab Reference" by Laird C Sheldahl, OpenOregonEducational Resources, Mt. Hood Community College is licensed under CC BY-SA 4.0

Updated 2026.

This page titled 14.4: Additional Reference Figures is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

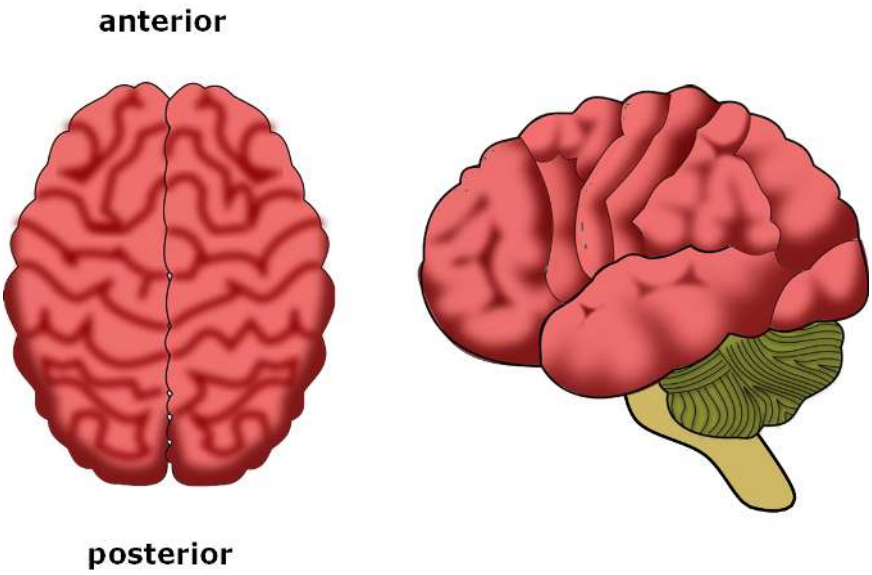
14.5: Laboratory Activities and Assignment

Laboratory Activities and Assignment

Part 1: Review of Brain Anatomy

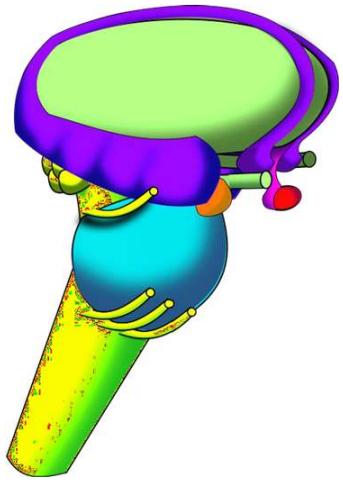
1. Label the following structures on the diagrams below.

• brainstem • central sulcus • cerebellum • cerebrum • frontal lobe	• left hemisphere • longitudinal fissure • medulla oblongata • occipital lobe • parietal lobe	• pons • postcentral gyrus • precentral gyrus • right hemisphere • temporal lobe



2. Label the following structures on the diagram below.

• amygdala • brainstem • diencephalon • hippocampus	• hypothalamus • inferior colliculi • medulla oblongata • midbrain / mesencephalon	• pituitary gland • pons • superior colliculi • thalamus



3. Label the following structures on the diagram below.

https://bio.libretexts.org/@go/page/53729

• arbor vitae • brain stem • cerebral aqueduct • choroid plexus • corpus callosum • cerebellum • cerebral cortex • cerebrum	• diencephalon • fornix • fourth ventricle • frontal lobe • gyrus • hypothalamus • inferior colliculus • interthalamic adhesion	• lateral ventricle • medulla oblongata • midbrain / mesencephalon • pituitary gland • pons • sulcus • superior colliculus • thalamus



4. Label the following structures on the diagram below.

• arachnoid granulations • central canal • cerebral aqueduct • choroid plexus of fourth ventricle	• choroid plexus of lateral ventricle • fourth ventricle • lateral ventricle	• subarachnoid space • superior sagittal sinus • third ventricle



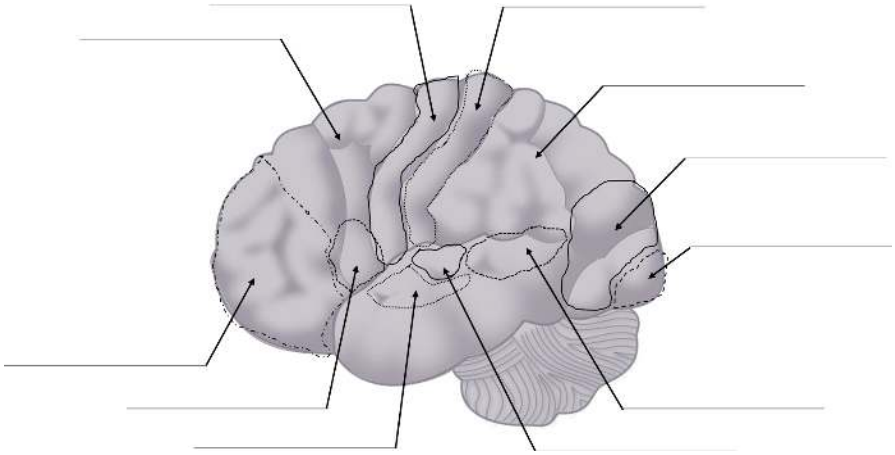
5. Rank the following structures to indicate the flow of CSF through the ventricle system beginning with the creation of CSF (1.) and ending with CSF entering the blood stream.

• arachnoid granulations • cerebral aqueduct • choroid plexus	• fourth ventricle • lateral ventricle • subarachnoid space	• superior sagittal sinus • third ventricle

1. _____	5. _____
2. _____	6. _____
3. _____	7. _____
4. _____	8. _____

6. Label the following functional areas of the cerebral cortex on the diagram below.

• auditory association area • auditory cortex • Broca's area • prefrontal cortex	• primary motor cortex • primary sensory cortex • somatic motor association area • somatic sensory association area	• visual association area • visual cortex • Wernicke's area



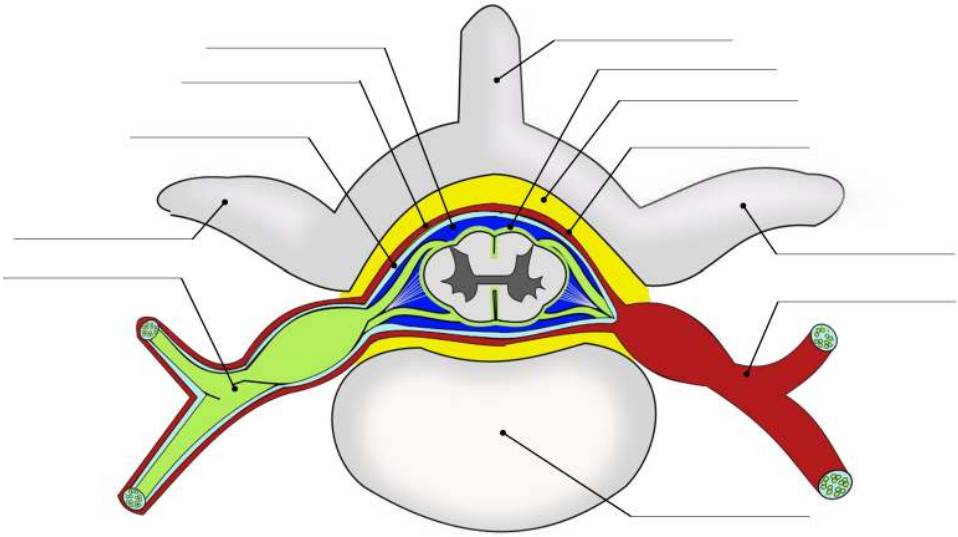
7. Match each structure with its description.

_____ Broca's area	A. Sends out signals causing contractions in voluntary skeletal muscles
_____ dura mater	B. Middle meningeal layer
_____ prefrontal cortex	C. Emotion center
_____ thalamus	D. A fold in the dura mater positioned between the right and left hemispheres
_____ hippocampus	E. The speech center; where speech is formed
_____ Wernicke's area	F. The deepest meningeal layer, found lining the immediate surface of the brain
_____ visual cortex	G. Personality traits and social interaction center
_____ primary motor cortex	H. Center for automated muscular contractions such as sneezing, swallowing, and breathing
_____ hypothalamus	I. Formation and storage of long-term memory
_____ cerebellum	J. Understanding writing or speech
_____ pia mater	K. Collects visual information
_____ falx cerebri	L. Outermost meningeal layer
_____ arachnoid mater	M. Governs transmission of sensory and motor information to and from the cerebral cortex
_____ pineal gland	N. Maintenance of a relatively constant internal body environment including blood pressure, heart rate, and body temperature
_____ amygdala	O. Contributes to balance and coordination, smoothing out multiple motor signals from the primary motor cortex
_____ medulla oblongata	P. Produces melatonin to regulate sleep cycles

Part 2: Review of Spinal Cord Anatomy

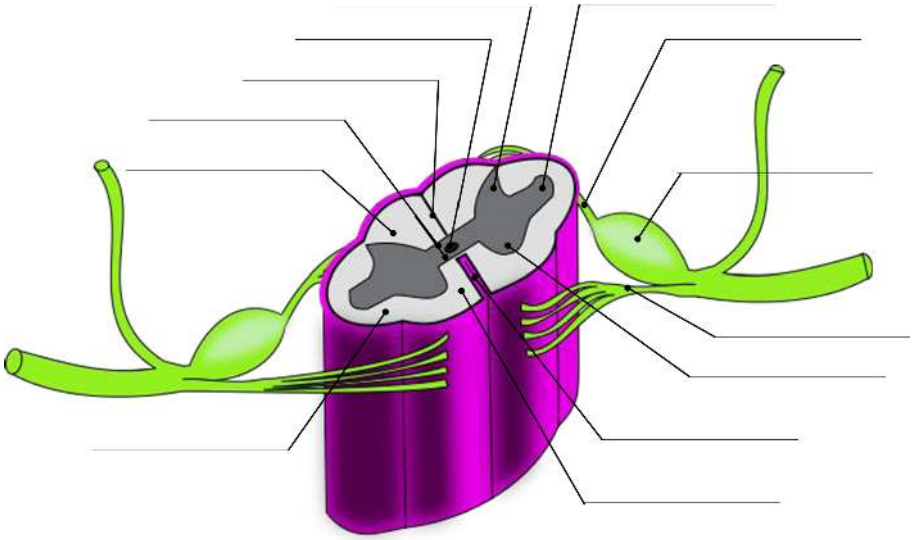
1. Label the following structures of the spinal cord and vertebra on the diagram below.

• arachnoid mater • body (of vertebra) • dura mater • epidural space	• pia mater • spinal nerve (left) • spinal nerve (right) • spinous process	• subarachnoid space/cavity • subdural space/cavity • transverse process (left) • transverse process (right)



2. Label the following structures of the spinal cord and vertebra on the diagram below.

• anterior (ventral) gray horn • anterior (ventral) white column • central canal • dorsal median sulcus • dorsal root	• dorsal root ganglion • gray commissure • lateral gray horn • lateral white column	• posterior (dorsal) gray horn • posterior (dorsal) white column • ventral median fissure • ventral root



3. Match the functional regions of the regions of the gray horns.

_____ visceral sensory	A. Lateral gray horns
_____ visceral motor	B. Posterior aspect of posterior gray horn
_____ somatic sensory	C. Anterior aspect of posterior gray horn
_____ somatic motor	D. Anterior gray horn

Part 3: Sheep Brain Dissection

Background Information

The sheep brain is remarkably similar to the human brain. One major difference, however, is in proportion. For example, the sheep brain has a proportionately smaller cerebrum. Another difference is in orientation of the spinal cord. The sheep spinal cord is orientated anterior to posterior, as in any four-legged animal. The human spinal cord is orientated superior to inferior. This orientation difference has a major affect on the location of the brain stem. The sheep brain stem is located more towards the rear (posteriorly). The sheep skull, in order to compensate for this, has the foramen

magnum located more towards the rear of the skull. In humans, since we walk upright (bipedalism), the spinal cord is in a more vertical plane, thus the foramen magnum is located centrally on the bottom of the skull (inferiorly). By observing the movement of this major skull feature from the rear (as in very early human ancestors) to the current location (modern humans), scientists have been able to determine when the human species began to walk upright on two legs.

Dissection Instructions

1. Collect a dissection tray, scalpel, scissors, probes, and gloves.
2. Obtain a preserved sheep brain and place it on your dissection tray.
3. Make a transverse section of the spinal cord (below the medulla oblongata) and set aside for **Part 4: Sheep Spinal Cord Dissection**.
4. The sheep brain may be is enclosed in a tough outer covering called the dura mater. You can still see some structures on the brain before you remove the dura mater. Take special note of the pituitary gland and the **optic chiasma**. These two structures will likely be pulled off when you remove the **dura mater**.
5. Make illustrations of the external sheep brain in the space below (alternatively, you may take photos and label the photos on the computer). Label the following structures on your illustrations or photos:

• brain stem • cerebellum • cerebrum • corpus callosum • frontal lobe • gyrus	• longitudinal fissure • medulla oblongata • midbrain / mesencephalon • parietal lobe • pineal gland • pituitary gland	• pons • occipital lobe • spinal cord • sulcus • temporal lobe

5. Using a scalpel and the **longitudinal fissure** as a guide, the brain is separated into the left and the right hemispheres. Sharp scalpels work best for this procedure. Always leave the specimen in the dissecting tray when cutting it, DO NOT hold it in your hand! If you are very careful, you will cleanly cut the brain into two halves and can see the internal structures, the most visible of them being the **corpus callosum**, which divides the left and right hemispheres. The cerebrum will still be visible as a wrinkled structurer, and you can even locate the "bumps" of the **superior and inferior colliculi**. These structures are located by pulling down the cerebellum. The cerebellum, when cut will have a very distinct tree-like white area within it. This is called the **arbor vitae**, or the tree of life. Once the brain is cut this way, the colliculi can also be seen from the inside and the pineal gland is revealed only if you made a very careful incision. Finally, a section of the brain is cut to examine the difference between white matter and gray matter.

6. Make illustrations of the dissected medial section of your sheep brain in the space below (alternatively, you may take photos and label the photos on the computer). Label the following structures on your illustrations or photos:

• arbor vitae • brain stem • cerebellum • cerebrum • corpus callosum • fornix • fourth ventricle • frontal lobe	• gyrus • hypothalamus • inferior colliculus • lateral ventricle • medulla oblongata • midbrain / mesencephalon • parietal lobe • pineal gland	• pituitary gland • pons • occipital lobe • optic chiasma • thalamus • spinal cord • sulcus • superior colliculus

Part 4: Sheep Spinal Cord Dissection

Dissection Instructions

1. Use transverse section of the spinal cord produced in step 3 of **Part 3: Sheep Brain Dissection**.
2. Make an illustration of the superior view of the transverse section of your sheep spinal cord slice in the space below (alternatively, you may take a photo and label the photo on the computer). Label the following structures on your illustration or photo:

• anterior (ventral) gray horn • anterior (ventral) white column • dorsal median sulcus	• gray commissure • posterior (dorsal) gray horn matter	• posterior (dorsal) white column • ventral median fissure

Attributions

Part 1: Review of Brain Anatomy

- "Anatomy and Physiology Lab Homework" by Laird C Sheldahl is licensed under CC BY-SA 4.0

Part 2: Review of Spinal Cord Anatomy

- "Anatomy and Physiology Lab Homework" by Laird C Sheldahl is licensed under CC BY-SA 4.0

Part 3: Sheep Brain Dissection

- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0

Updated 2026.

This page titled 14.5: Laboratory Activities and Assignment is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

14.6: Collaborative Study Activities

Collaborative Study Activities

These activities are designed for student groups of 2-4. Larger groups will work better when there is no supplemental instructor present in the laboratory to assist in testing student groups on each section.

Brain Anatomy

1. Identify the following structures on classroom anatomical models and/or unlabeled images/diagrams made available by your instructor. Work with your group to identify each structure and check them off the list once you have identified them.

☐ arbor vitae	☐ gray matter	☐ pons
☐ auditory cortex	☐ gyrus	☐ postfrontal cortex
☐ brainstem	☐ hypothalamus	☐ prefrontal cortex
☐ Broca's area	☐ inferior colliculi	☐ primary motor cortex
☐ central sulcus	☐ interthalamic adhesion	☐ primary sensory cortex
☐ cerebellum	☐ lateral ventricle	☐ right hemisphere
☐ cerebral aqueduct	☐ left hemisphere	☐ spinal cord
☐ cerebrum	☐ longitudinal fissure	☐ sulcus
☐ choroid plexus	☐ medulla oblongata	☐ superior colliculi
☐ corpus callosum	☐ midbrain / mesencephalon	☐ temporal lobe
☐ diencephalon	☐ occipital lobe	☐ thalamus
☐ fornix	☐ parietal lobe	☐ visual cortex
☐ fourth ventricle	☐ pineal gland	☐ Wernicke's area
☐ frontal lobe	☐ pituitary gland	☐ white matter

2. Test your group members by ***asking them to name each structure you point to***. Check off each when your group can successfully name each. Your group will also test you.

☐ arbor vitae	☐ gray matter	☐ pons
☐ auditory cortex	☐ gyrus	☐ postfrontal cortex
☐ brainstem	☐ hypothalamus	☐ prefrontal cortex
☐ Broca's area	☐ inferior colliculi	☐ primary motor cortex
☐ central sulcus	☐ interthalamic adhesion	☐ primary sensory cortex
☐ cerebellum	☐ lateral ventricle	☐ right hemisphere
☐ cerebral aqueduct	☐ left hemisphere	☐ spinal cord
☐ cerebrum	☐ longitudinal fissure	☐ sulcus
☐ choroid plexus	☐ medulla oblongata	☐ superior colliculi
☐ corpus callosum	☐ midbrain / mesencephalon	☐ temporal lobe
☐ diencephalon	☐ occipital lobe	☐ thalamus
☐ fornix	☐ parietal lobe	☐ visual cortex
☐ fourth ventricle	☐ pineal gland	☐ Wernicke's area
☐ frontal lobe	☐ pituitary gland	☐ white matter

3. When you and your group are comfortable identifying all the structures above, request the assistance of your Instructor. They will test you on your use of these terms and initial ONLY when you are successful using these terms. Instructor: _____

Spinal Cord Anatomy

1. Identify the following structures on classroom anatomical models and/or unlabeled images/diagrams made available by your instructor. Work with your group to identify each structure and check them off the list once you have identified them.

☐ anterior (ventral) gray horn	☐ gray commissure	☐ somatic sensory (gray)
☐ anterior (ventral) white column	☐ lateral gray horn	☐ spinal nerve
☐ central canal	☐ lateral white column	☐ ventral median fissure
☐ dorsal median sulcus	☐ posterior (dorsal) gray horn	☐ ventral root
☐ dorsal root	☐ posterior (dorsal) white column	☐ visceral motor nuclei (gray)
☐ dorsal root ganglion	☐ somatic motor nuclei (gray)	☐ visceral sensory (gray)

2. Test your group members by ***asking them to name each structure you point to***. Check off each when your group can successfully name each. Your group will also test you.

☐ anterior (ventral) gray horn	☐ gray commissure	☐ somatic sensory (gray)
☐ anterior (ventral) white column	☐ lateral gray horn	☐ spinal nerve
☐ central canal	☐ lateral white column	☐ ventral median fissure
☐ dorsal median sulcus	☐ posterior (dorsal) gray horn	☐ ventral root
☐ dorsal root	☐ posterior (dorsal) white column	☐ visceral motor nuclei (gray)
☐ dorsal root ganglion	☐ somatic motor nuclei (gray)	☐ visceral sensory (gray)

When you and your group are comfortable identifying all the structures above, request the assistance of your Instructor. They will test you on your use of these terms and initial ONLY when you are successful using these terms. Instructor: _____

Updated 2026.

This page titled 14.6: Collaborative Study Activities is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

CHAPTER OVERVIEW

15: Peripheral Nervous System

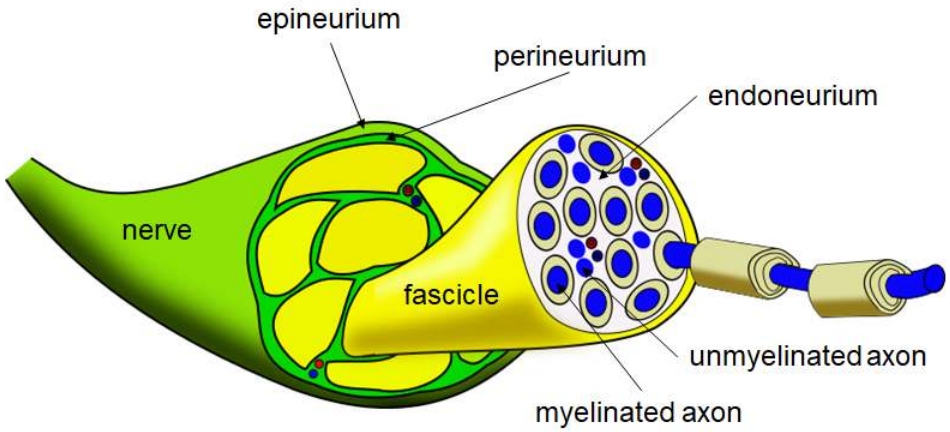
15.1: Introduction
15.2: Cranial Nerves
15.3: Spinal Nerves
15.4: Additional Reference Figures
15.5: Laboratory Activities and Assignment
15.6: Collaborative Study Activities

This page titled 15: Peripheral Nervous System is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

15.1: Introduction

Introduction

Bundles of axons in the PNS are referred to as nerves. These structures in the periphery are different than the central counterpart, called a tract. Nerves are composed of more than just nervous tissue. They have connective tissues invested in their structure, as well as blood vessels supplying the tissues with nourishment. The outer surface of a nerve is a surrounding layer of fibrous connective tissue called the **epineurium**. Within the nerve, axons are further bundled into **fascicles**, which are each surrounded by their own layer of fibrous connective tissue called **perineurium**. Finally, individual axons are surrounded by loose connective tissue called the **endoneurium**. These three layers are similar to the connective tissue sheaths for muscles. Nerves are associated with the region of the CNS to which they are connected, either as **cranial nerves** connected to the brain or **spinal nerves** connected to the spinal cord.



Above: Structure of a nerve.

Attributions

- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0
- "Anatomy and Physiology Lab Reference" by Laird C Sheldahl, OpenOregonEducational Resources, Mt. Hood Community College is licensed under CC BY-SA 4.0

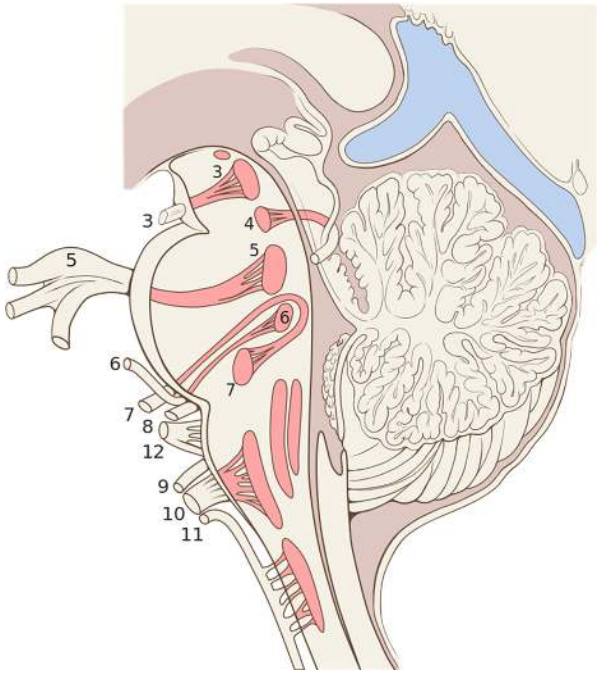
Updated 2026.

This page titled 15.1: Introduction is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

15.2: Cranial Nerves

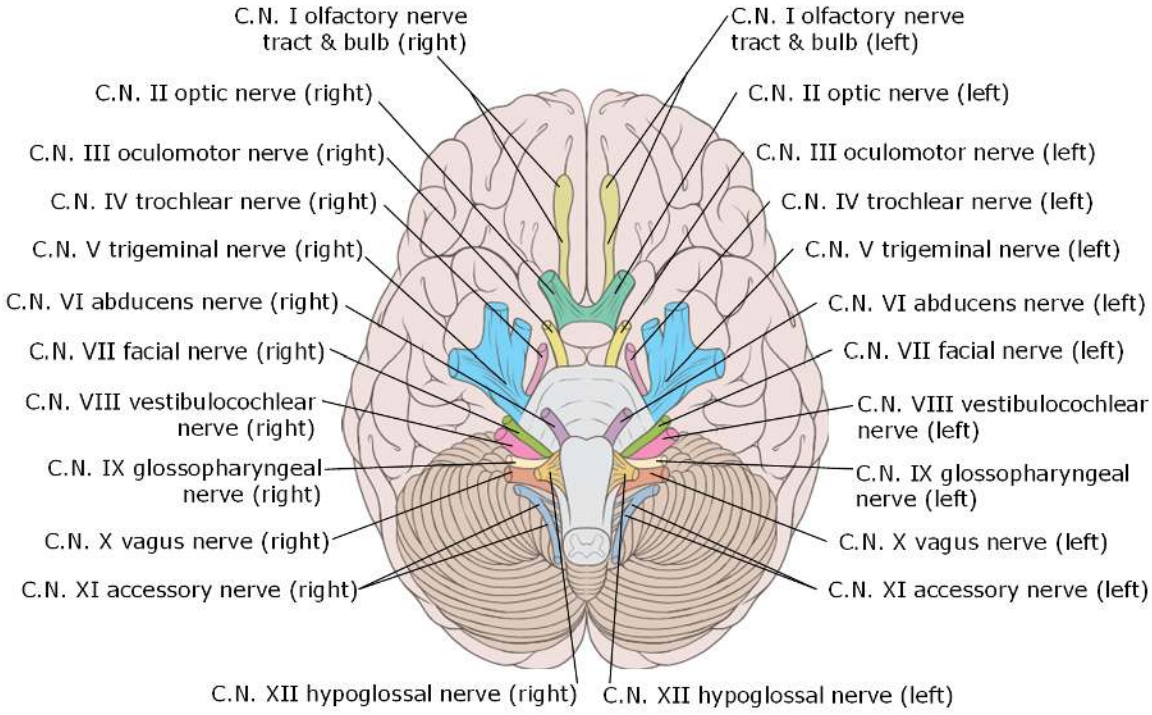
Cranial Nerves

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. In humans there are twelve cranial nerves pairs, which are assigned Roman numerals I–XII. ***The numbering of the cranial nerves is based on the order in which they emerge from the brain, front to back (brainstem)***.



Above: Lateral view of the brain stem showing the locations of the cranial nerves III - XII.

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.



Above: Inferior view of the brain with the pairs of cranial nerves labeled.

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)**.

C.N. #	C.N. Name	Associated Opening(s)	Nerve Type	Innervation
C.N. I	olfactory nerve	olfactory foramina (cribriform plate of the ethmoid bone)	special sensory	olfaction (smell) - olfactory epithelium
C.N. II	optic nerve	optic canals	special sensory	retina of the eye (sight)
C.N. III	oculomotor nerve	superior orbital fissure	motor	inferior oblique, medial rectus, superior rectus, and inferior recuts muscles of the eye
C.N. IV	trochlear nerve	superior orbital fissure	motor	superior oblique muscle of the eye
C.N. V	trigeminal nerve			
	C.N. V, branch 1: ophthalmic nerve	superior orbital fissure, supraorbital foramen	sensory	skin on the upper third of the face
	C.N. V, branch 2: maxillary nerve	foramen rotundum, infraorbital foramen	sensory	skin on the middle third of the face

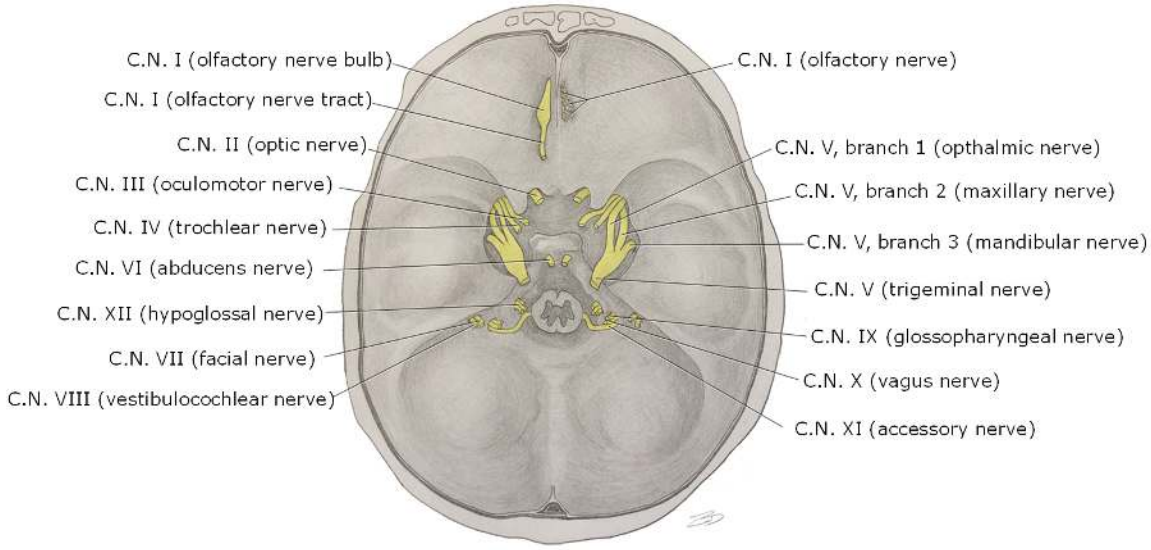
C.N. #	C.N. Name	Associated Opening(s)	Nerve Type	Innervation
	C.N. V, branch 3: mandibular nerve	foramen ovale, mandibular foramen, mental foramen	sensory	skin on the lower third of the face, pain from the tongue
C.N. VI	abducens nerve	superior orbital fissure	motor	lateral recuts muscle of the eye
C.N. VII	facial nerve	internal acoustic meatus, stylomastoid foramen	motor, special sensory	*motor:* muscles of facial expression *special sensory:* taste buds on the anterior two-thirds of the tongue
C.N. VIII	vestibulocochlear nerve	internal acoustic meatus	special sensory	auditory (hearing), balance, and equilibrium - inner ear (cochlear and vestibular apparatus)
C.N. IX	glossopharyngeal nerve	jugular foramen	motor, special sensory	*motor:* pharynx muscles *special sensory:* taste buds on the posterior third of the tongue
C.N. X	vagus nerve	jugular foramen	motor, sensory, special sensory	*motor:* heart, smooth muscle of pharynx and organs of the gut *sensory:* skin across the throat and the external acoustic meatus *special sensory:* taste, gag reflex
C.N. XI	accessory nerve	jugular foramen, foramen magnum	motor	trapezius, sternocleidomastoid, muscles of the pharynx
C.N. XII	hypoglossal nerve	hypoglossal canal	motor	muscles of the tongue

Mnemonic phrases can be helpful to remember the order of the cranial nerves. Here are two popular mnemonics for the order of the cranial nerves (I-XII):

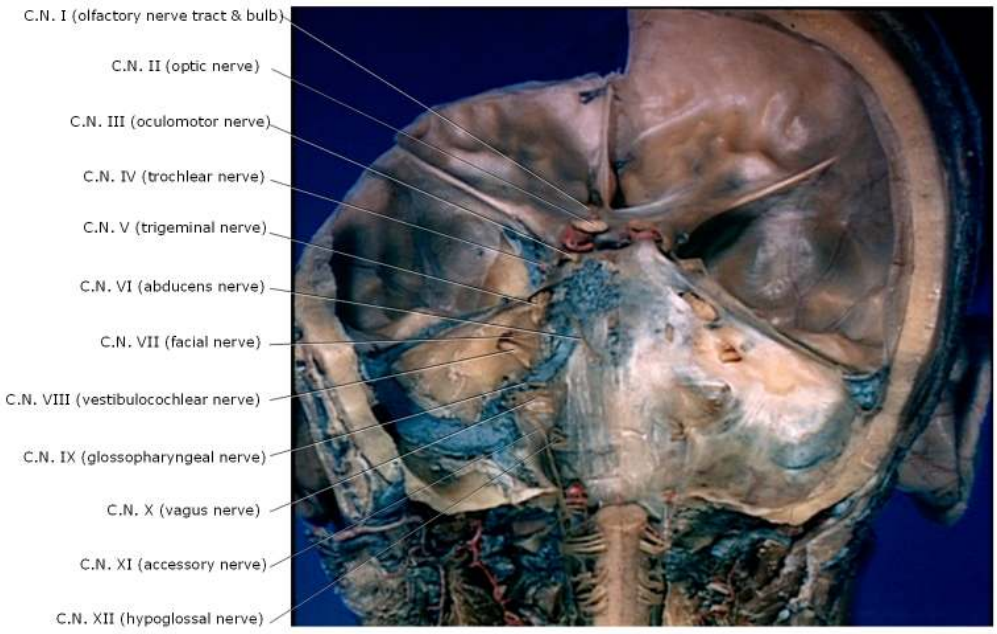
- **O**h **O**nce **O**ne **T**akes **T**he **A**natomy **F**inal, **V**ery **G**ood **V**acations **A**re **H**eavenly
- **O**h, **O**h, **O**h, **T**o **T**ouch **A**nd **F**eel **V**ery **G**ood **V**elvet, **A**-**H**

The cranial nerves carry motor, sensory, and/or special sensory signals. **Motor** signals innervate muscles/tissues, **sensory** signals send information to the CNS from sensory receptors, and **special sensory** signals send information to the CNS from the special senses (vision, hearing and balance, and taste). Some cranial nerves carry more than one type of signal; one cranial nerve even carries all three types of signals.

To enter/exit the skull, cranial nerves pass through **openings** in the base of the skull.



Above: Diagram showing how the cranial nerves enter/exit the cranial cavity through the skull.



Above: Image of cadaver with the left cranial nerves labeled.

Attributions

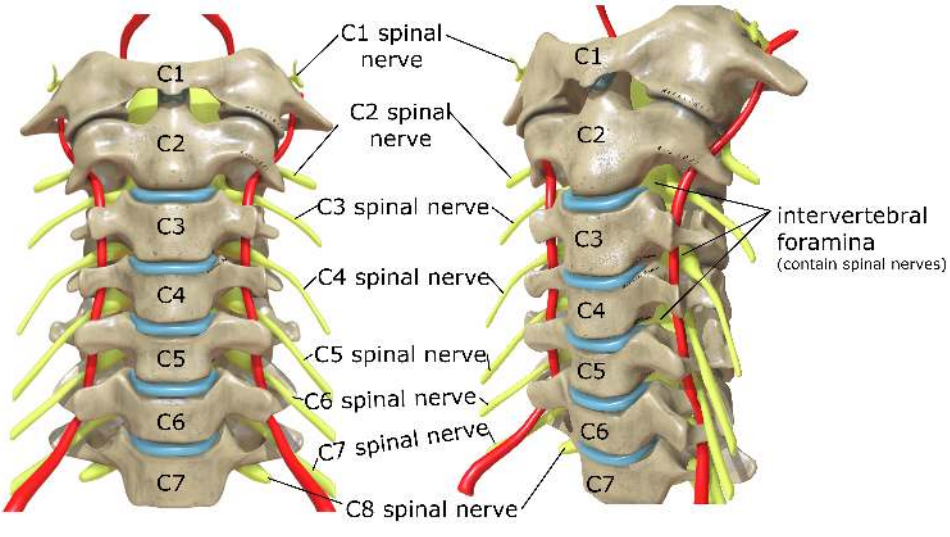
- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0
- "Brain human normal inferior view.svg" by Patrick J. Lynch, medical illustrator is licensed under CC BY 2.5

Updated 2026.

This page titled 15.2: Cranial Nerves is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

15.3: Spinal Nerves

Spinal Nerves



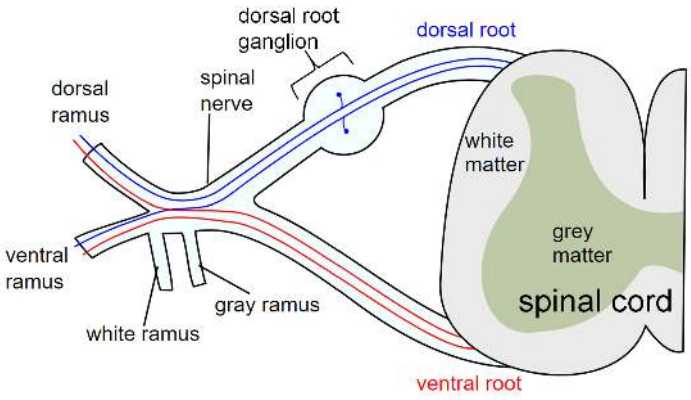
Above: Position and numbering of the cervical spinal nerves.

There are 31 pairs (right and left) of spinal nerves:

- 8 pairs of cervical spinal nerves
- 12 pairs of thoracic spinal nerves
- 5 pairs of lumbar spinal nerves
- 5 pairs of sacral spinal nerves
- 1 pair of coccygeal spinal nerves

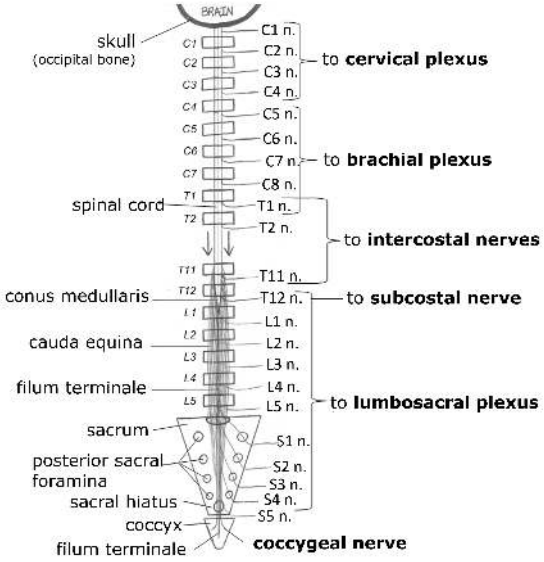
All spinal nerves, *except for the first pair and last six pairs*, exit the vertebral column through **intervertebral foramina**. The first pair of spinal nerves (C1 spinal nerves) exit the vertebral column between the occipital bone and atlas (C1).

The ventral and dorsal rami of sacral nerves 1- 4 exit the vertebral column through the **anterior and posterior sacral foramina** respectively, and the 5th pair of sacral nerves and the one pair coccygeal nerves exits the vertebral column through the **sacral hiatus**.



Above: Branches of spinal nerves. Blue represents sensory neurons and red represents motor neurons.

A **plexus** is a network of nerves. The three biggest nerve plexuses in the body are the **cervical plexus** (paired, right and left) which serves the head and neck, the **brachial plexus** (paired, right and left) which serves the upper limb, and the **lumbosacral plexus** (paired, right and left) which serves the pelvis, genitalia, and lower limb.

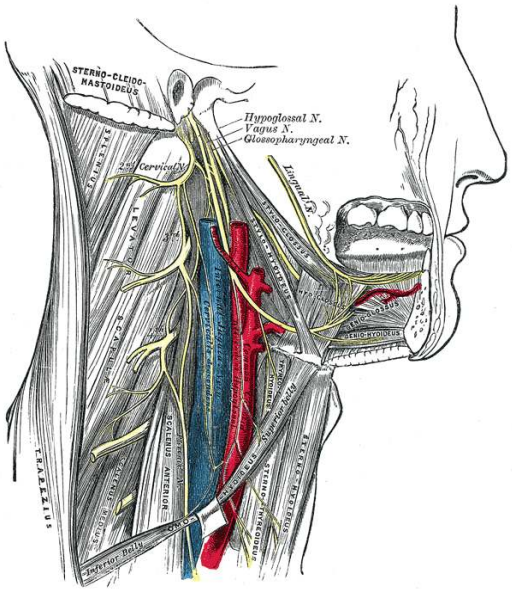


Above: Diagram numbering each spinal nerve (those with "n." after are the spinal nerves) and the nerve plexuses.

Cervical Plexus

The **cervical plexus** is a plexus of the ventral rami of the first four cervical spinal nerves (C1 through C4). They are located laterally to the transverse processes between prevertebral muscles from the medial side and vertebral from lateral side. There is **anastomosis** (cross-connection) with **accessory nerve**, **hypoglossal nerve** and **sympathetic trunk**.

It is located in the neck, deep to sternocleidomastoid. 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 dorsal ramus of C2 greater occipital nerve arises.



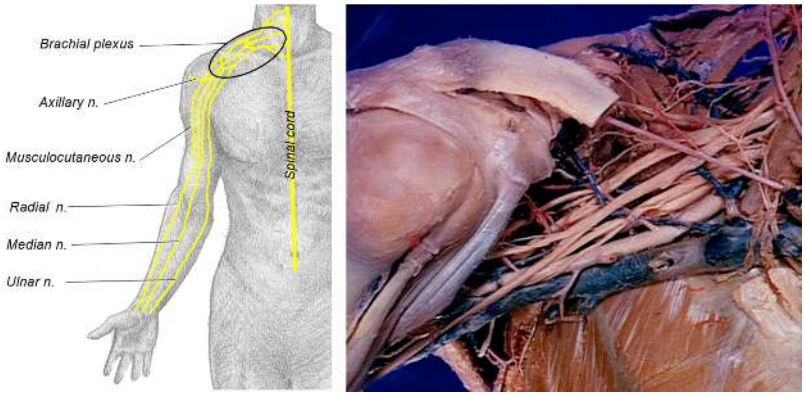
Above: Nerves of the cervical plexus shown with some of cranial nerves (C.N. IX glossopharyngeal nerve, C.N. X vagus nerve, and XII hypoglossal nerve).

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

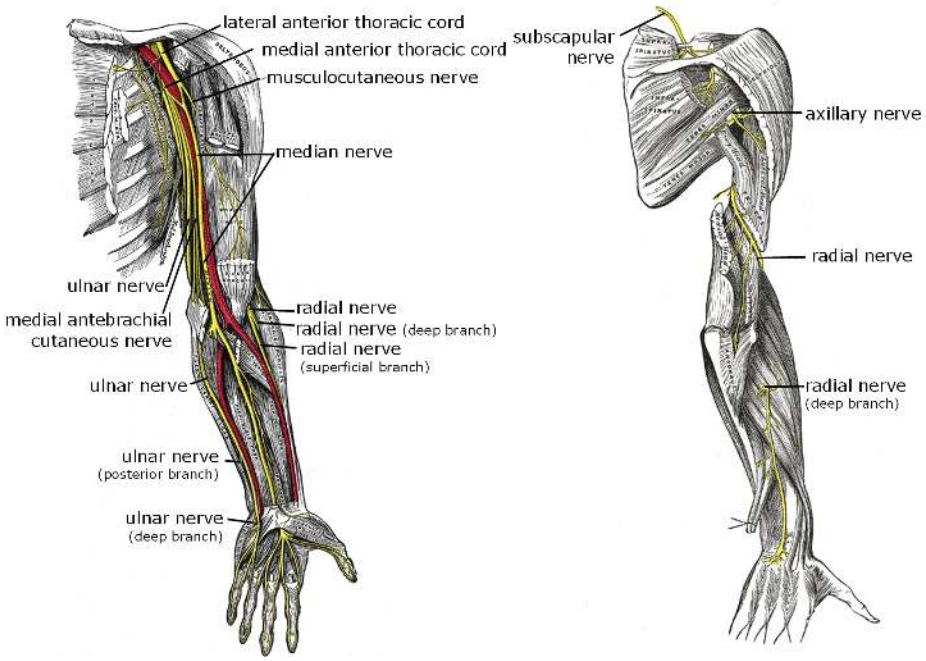
Nerve Name	Nerves Involved	Innervation

Nerve Name	Nerves Involved	Innervation
Cutaneous branch		
greater auricular nerve	ventral rami C2 and C3 spinal nerves	Skin near the outer ear and external acoustic meatus (ear canal)
lesser occipital nerve	ventral rami of C2 spinal nerve	Skin and the scalp posterosuperior to the outer ear
supraclavicular nerves (lateral, intermediate, and medial)	ventral rami C3 and C4 spinal nerves	Skin below the clavicle
transverse cervical nerve	ventral rami C2 and C3 spinal nerves	Anterior region of the neck
Muscular branch		
ansa cervicalis nerve	A loop formed from ventral rami of C1, C2, and C3 spinal nerves	thyrohyoid, sternothyroid, sternohyoid, and omohyoid muscles
phrenic nerve	ventral rami of C3 through C5 spinal nerves	Diaphragm, pericardium
segmental branches	ventral rami of C1 through C4 spinal nerves	Anterior and middle scalenes muscles

Brachial Plexus



Above: (Left) Diagram and (right) cadaver image of the right brachial plexus, anterior view

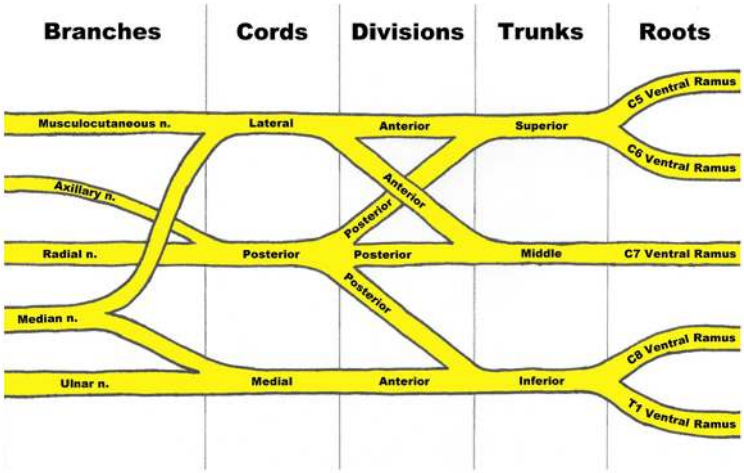


https://bio.libretexts.org/@go/page/53740

Above: Nerves of the upper limb (left) anterior left upper limb and (right) posterior right upper limb.

The **brachial plexus** is divided into **roots**, **trunks**, **divisions**, **cords**, and **branches**:

- **roots:** ventral roots of spinal nerves C5, C6, C7, C8, and T1
- **trunks:** superior, middle, and inferior trunks
- **divisions:** each of the superior, middle, and inferior trunks have an anterior division and a posterior division (6 divisions total)
- **cords:**
  - **lateral cord:** the anterior divisions from the superior and middle trunks combine to form the lateral cord
  - **posterior cord:** the posterior divisions from the superior, middle, and inferior trunks combine to form the posterior cord
  - **medial cord:** comprised of the anterior division of the inferior trunk
- **branches: musculocutaneous nerve**, **axillary nerve**, **radial nerve**, **median nerve**, and **ulnar nerve**



Above: Diagram of the structure of the brachial plexus.

The terminal branches of the brachial plexus are the nerves that will innervate the muscles of the upper limb. Some muscles are listed under the nerve that innervates them.

Nerve Name	Nerves Involved	Cutaneous Innervation	Muscular Innervation
axillary nerve	ventral rami of C5 and C6 spinal nerves	skin of the shoulder	deltoid and teres minor muscles
dorsal scapular nerve	ventral rami of C5 spinal nerve	--	levator scapulae, rhomboid major, and rhomboid minor muscles
long thoracic nerve	ventral rami of C_5 through C_7 spinal nerve	--	serratus anterior muscles
median nerve	ventral rami of C5 through T1 spinal nerves	some skin of the hand	anterior forearm flexor, palm, and digit muscles
musculocutaneous nerve	ventral rami of C5 through C7 spinal nerves	some skin of the forearm	biceps brachii, brachialis, and coracobrachialis muscles
pectoral nerve	ventral rami of C5 through T1 spinal nerves	--	pectoralis major and pectoralis minor muscles
radial nerve	ventral rami of C5 through T1 spinal nerves	posterolateral skin of the upper limb	triceps brachii, brachioradialis, and posterior forearm muscles
subscapular nerve	ventral rami of C5 and C6 spinal nerves	--	subscapularis and teres major muscles
suprascapular nerve	ventral rami of C5 and C6 spinal nerves	--	supraspinatus and infraspinatus muscles

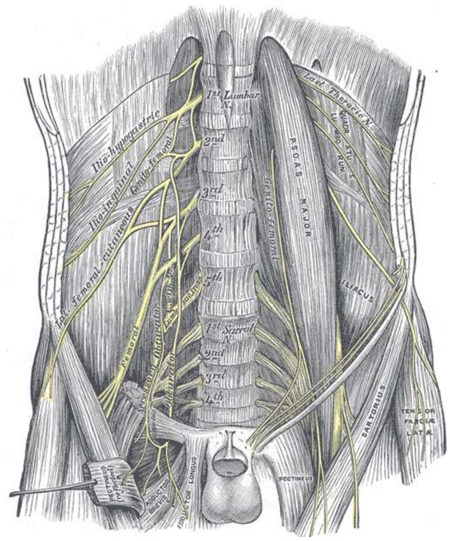
Nerve Name	Nerves Involved	Cutaneous Innervation	Muscular Innervation
ulnar nerve	ventral rami of C8 and T1 spinal nerves	some skin of the hand	anterior forearm flexor and hand muscles

Intercostal Nerves

Intercostal nerves are not part of a plexus; they are simply **ventral rami** from thoracic spinal nerves that travel directly to the region they innervate. Intercostal nerves are found between ribs and between the external and internal intercostal muscles (ventral rami of spinal nerves T1 through T11). Notice how there are only 11 *inter*costal nerves, but there are 12 pair of ribs. This is because for a nerve to be an *inter*costal nerve, it must be *between* two ribs. The 12th thoracic spinal nerve is not *between* two ribs; it is *below* the last rib, which is why this nerve is called the *sub*costal nerve.

Lumbosacral Plexus

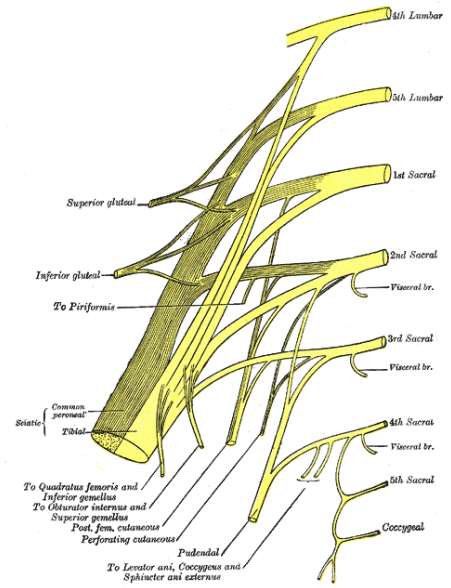
The lumbosacral plexus involves ventral rami from spinal nerves T12 through S4.



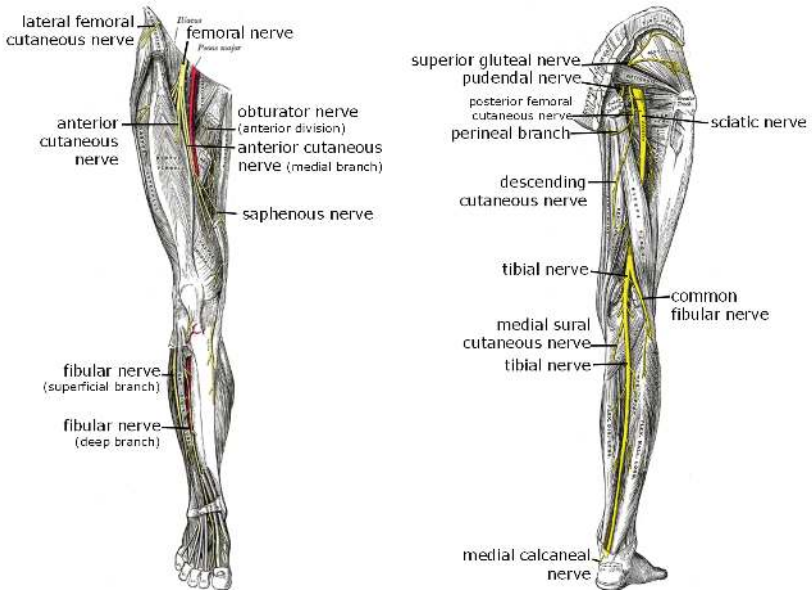
Above: Nerves of the lumbosacral plexus, anterior view.

Nerve Name	Nerves Involved	Cutaneous Innervation	Muscular Innervation
common fibular nerve (superficial and deep branches)	ventral rami of L4 through S2 spinal nerves	skin of the anterolateral leg and foot	tibialis anterior, extensor digitorum longus, fibularis longus and fibularis brevis muscles
femoral nerve	ventral rami of L2 through L4 spinal nerves	skin of the medial lower limb and anterior thigh	iliacus, sartorius, pectineus, rectus femoris, vastus lateralis, vastus medialis, and vastus intermedius muscles
genitofemoral nerve	ventral rami of L1 and L2 spinal nerves	skin of external genitalia	cremasteric muscles (males only)
iliohypogastric nerve	ventral rami of L1 spinal nerves	skin of the hip and inferior abdomen	internal oblique and transversus abdominis muscles
ilioinguinal nerve	ventral rami of L1 spinal nerves	skin of the medial thigh and external genitalia	internal oblique and Transversus abdominis muscles
inferior gluteal nerve	ventral rami of L5 through S2 spinal nerves	--	gluteus maximus muscles
lateral femoral cutaneous nerve	ventral rami of L2 and L3 spinal nerves	skin of the anterolateral thigh and knee	--
obturator nerve	ventral rami of L2 through L4 spinal nerves	skin of thigh (medial)	gracilis, adductor magnus, adductor longus, and adductor brevis muscles
posterior femoral cutaneous nerve	ventral rami of S1 through S3 spinal nerves	skin of the posterior lower limb	--

Nerve Name	Nerves Involved	Cutaneous Innervation	Muscular Innervation
pudendal nerve	ventral rami of S2 through S4 spinal nerves	skin of external genitalia	external anal sphincter, external urethral sphincter, and pelvic muscles
sciatic nerve (branches into tibial and common fibular nerves)	ventral rami of L4 through S3 spinal nerves	skin of the leg and foot	semitendinosus, semimembranosus, and biceps femoris muscles
superior gluteal nerve	ventral rami of L4 through S1 spinal nerves	--	gluteus medius, gluteus minimus, and tensor fasciae latae muscles
tibial nerve	ventral rami of L4 through S3 spinal nerves	skin of the sole of the foot and posterior leg	flexor digitorum longus, gastrocnemius, and soleus muscles



Above: Arrangement of nerves in the right side of the lumbosacral plexus, anterior view.



Above: Nerves of the lower limb (left) anterior right lower limb and (right) posterior right lower limb.

Clinical Application: Epidural (Childbirth)

An **epidural** is a medical procedure commonly done to relieve pain during labor and delivery. In this procedure, a needle is inserted into the vertebral canal without puncturing the dura mater. With the tip of the needle/catheter *above* the *dura mater* (**epi-** = above; **-dural**= of the dura mater), anesthetics are injected into the epidural space. The anesthetics then pass through the meninges and block neuronal impulses, thus inhibiting the transmission of sensation (in this case, pain) to the brain. Just like in a lumbar puncture, the epidural needle can be inserted between L3/L4 vertebrae, but because the pain impulses from the uterus reach the spinal cord at levels between T10-L1, epidurals are more commonly placed more superiorly. A common location for epidural placement is T7, which is easily identifiable at about the level of the inferior border of the scapula. When the drugs are injected, gravity can pull the drugs downward, blocking everything below the epidural location. Therefore, administering an epidural above the level of T10 can relieve labor pain from uterine contractions as well as pain from the pelvic floor transmitted by the pudendal nerve (from S2, S3, and S4 spinal nerves).

Attributions

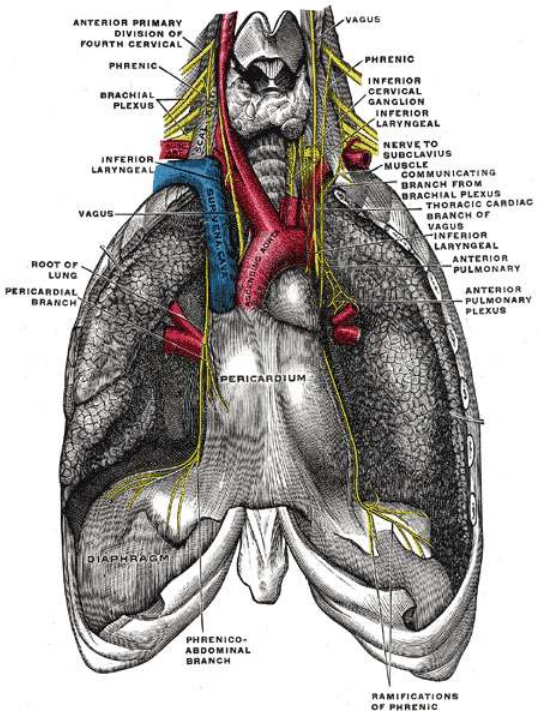
- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0
- "Cervical Spine Anterior View.png" by DrJanaOfficial is licensed under CC BY-SA 4.0
- "Cervical Spine Oblique View.png" by DrJanaOfficial is licensed under CC BY-SA 4.0
- "Gray's Anatomy plates" by Henry Vandyke Carte is in the Public Domain
- "Spinal nerve-es.svg" by Tristanb and Mysid is licensed under CC BY-SA 3.0

Updated 2026.

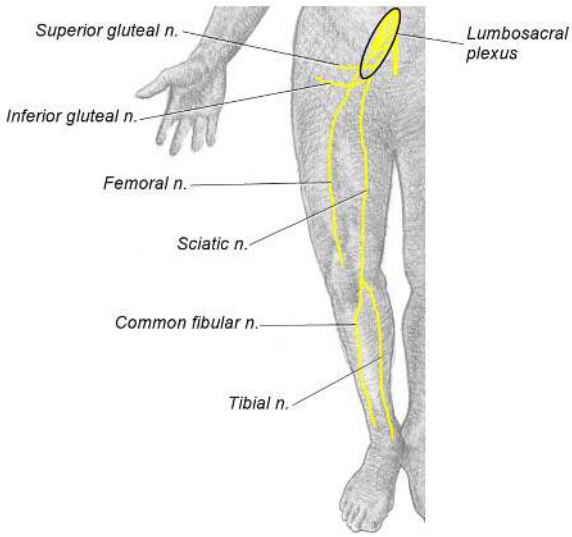
This page titled 15.3: Spinal Nerves is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

15.4: Additional Reference Figures

Additional Reference Figures



Above: Paths of some cranial and spinal nerves including the phrenic nerve (cervical plexus), vagus nerve (C.N. X).



Above: Diagram of the right lumbosacral plexus and the path of some of its nerves, anterior view.

Attributions

- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Gray's Anatomy plates" by Henry Vandyke Carte is in the Public Domain

Updated 2026.

This page titled 15.4: Additional Reference Figures is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

15.5: Laboratory Activities and Assignment

Laboratory Activities and Assignment

Part 1: Review of Cranial Nerves

1. Provide the ***name and number*** of the cranial nerves involved in each of the following activities, sensations or disorders.

    a. Rotating the head

    b. Smelling coffee

    c. Elevating the eyelids; pupillary constriction

    d. Slowing the heart; swallowing

    e. Involved in Bell's palsy (facial paralysis); crying

    f. Chewing food; feeling a toothache

    g. Listening to music; seasickness

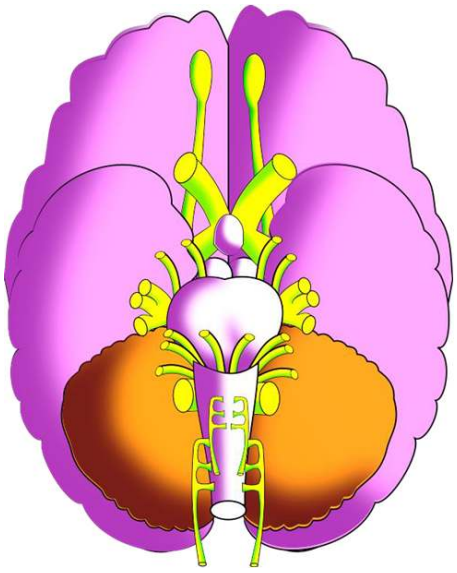
    h. Secretion of saliva; tasting well-seasoned food

    i. Involved in "rolling" the eyes (three nerves; give numbers)

    j. Swallowing; speaking (motor only)

    k. Seeing the notes during lecture

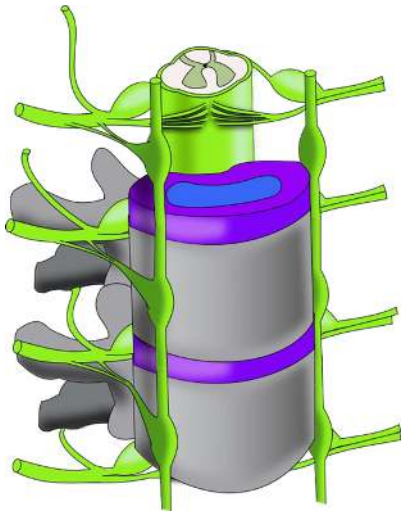
2. Label the ***number and name*** for ALL of the cranial nerves (left and right) on this inferior view of the brain.



Part 2: Review of Spinal Nerves

1. Label the following structures on the diagram below.

• dorsal ramus • dorsal root • dorsal root ganglion	• spinal cord • spinal nerve	• ventral ramus • ventral root



2. Match the following nerves to their nerve plexuses (give the nerve plexus each nerve arises from).

a. _____ sciatic nerve

b. _____ phrenic nerve

c. _____ axillary nerve

d. _____ radial nerve

e. _____ femoral nerve

f. _____ pudendal nerve

g. _____ ansa cervicalis nerve

h. _____ musculocutaneous nerve

i. _____ inferior gluteal nerve

j. _____ obturator nerve

k. _____ superior gluteal

l. _____ pectoral nerve

m. _____ greater auricular nerve

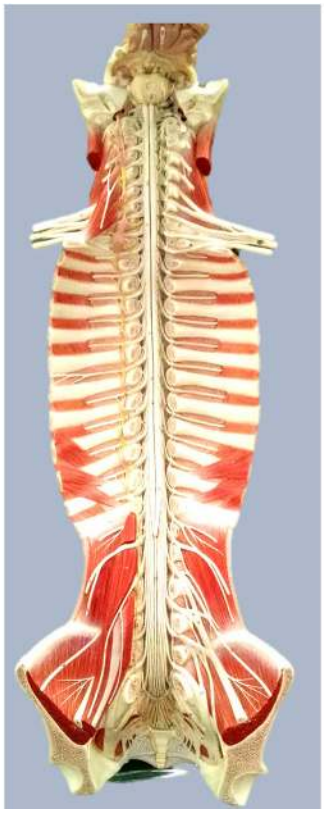
n. _____ common fibular nerve

o. _____ median nerve

p. _____ genitofemoral nerve

3. Label **EACH** of the spinal nerves (C1 – S5) on the image of an anatomical model below. Also, label the items listed below.

• brachial plexus • cervical plexus	• intercostal nerves • lumbosacral plexus



4. Label the following nerves of the upper limb on the diagram below.

- axillary nerve
- median nerve
- musculocutaneous nerve
- radial nerve
- ulnar nerve



5. Label the following nerves on the lower limb diagram below.

- femoral nerve
- sciatic nerve



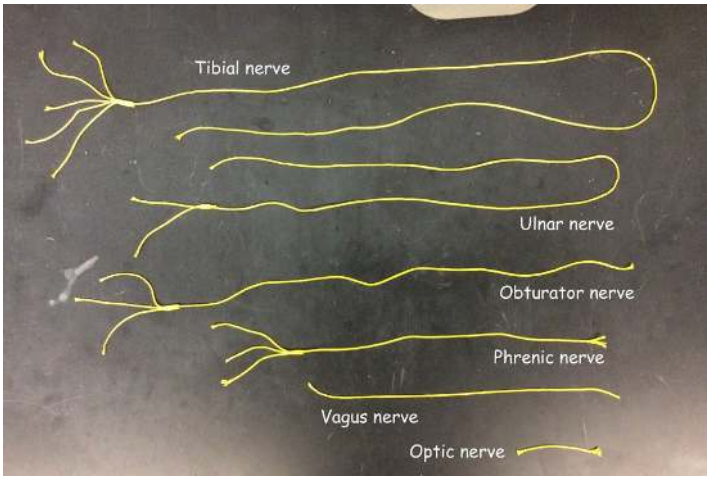
Part 3: Laboratory Activity Plotting Cranial and Spinal Nerve Pathways

In this activity, you will work in small groups of 3-5 and use string or twine to model the pathways of nerves on human skeleton models and thus are able to better learn the origins, pathways, and innervation points of these nerves.

Materials Required

- Human skeleton models (life-size models are best, but smaller ones would work too)
- Human brain model (one that fits into the skull of the skeleton)
- Human eyeball model (one that fits into the orbital socket of the skeleton)
- String / rope / twine – try to find a product that does not fray or unwind easily
- Tape (masking or lab tape is best)
- Measuring tape / ruler
- Scissors
- Envelopes

Instructor Preparation



Above: Completed set of six nerves used in this lesson.

For the first time through this lesson, you will need to make the six “nerves” from the string. Each group of students will need one set of six nerves, so you will need to repeat the following process for however many groups you will have. Depending on how carefully students use the nerves, you may need to make new ones every time, or fix them as needed.

1. First you will need to make the nerves using the string. Table 2 (page 4) lists the lengths of string and number of spinal nerve attachment points to be used for the nerves emerging from nerve plexuses.

2. To make a nerve, cut the required length of string from Table 2 (page 4), and then attach the number of spinal nerve attachment points to one end using tape. NOTE: These lengths are approximate and work well for the specific model of skeleton that I used to develop this lesson. If you have a different-sized model, you will want to adjust the lengths of your nerves as needed.
3. Each spinal nerve attachment point can be a 3 to 4" piece of string (pieces of pipe cleaners can be used as well and may be more effective). The spinal nerve attachment points will be taped or otherwise attached to the spinal nerves that emerge from the skeleton model (or onto the neighboring vertebrae if the model does not have spinal nerves), so these are the parts that will be subjected to the most damage from students. Figure 1 shows examples of the completed set of six nerves. As described in the Teaching Discussion section, the instructor can choose to use different colored strings to represent different nerves or other materials (pipe cleaners, Velcro-backed adhesive, Bendaroo, etc) to make the nerve attachment points.
4. Place one set of six nerves into an envelope. Each group completing the lesson will be given one envelope.
5. Repeat steps 2 to 4 for however many groups you have in your class.

Plotting Nerve Pathways-Details for the preparation of the six nerves used in this lesson.

Nerve	Length of String (Inches)	Number of Spinal Nerve Attachment Points
optic (C.N. II)	4	N/A
vagus (C.N. X)	15	N/A
phrenic	15	3
ulnar	30	2
obturator	18	3
tibial	40	5

Activity Instructions

Getting Started

1. In your lab envelope you have many pieces of yellow mason line – these will be used to model the pathways that nerves travel through the body. PLEASE be careful with them, as the ends fray easily and other groups will need to use them!
2. There are six total nerves; two cranial and four major nerves that are parts of the nerve plexuses of the body. Some of the nerves have more than one ending – these will represent attachment points to spinal nerves. Those that have multiple endings thus are spinal nerves, and those with a single ending are cranial nerves. It is up to you to figure out which nerve to use for the following exercises. Examine their lengths and number of endings to figure out which is which.
3. **NOTE:** this model will not be completely accurate, as we are not modeling the nerve plexuses; rather the nerves will attach directly to the spinal nerves. Also remember that each nerve is paired – there is a left and right of each nerve. You are only going to model the left or the right, not both.
4. Spread your six nerves out on your lab bench and compare their lengths and number of spinal nerve attachment points. Can you tell which ones are cranial nerves and which ones are spinal nerves?

Optic Nerve (C.N. II)

1. Take the brain from the torso and identify the origination point of the optic nerve.

2. Identify the optic nerve from the envelope of nerves and tape one end to the attachment point on the brain.

    Where does the optic nerve originate from the brain? _____

3. Remove the skullcap from the human skeleton skull model, and identify the foramen that the optic nerve passes through.

    What foramen does the optic nerve pass through? _____

4. Carefully place the brain in the cranial fossa and thread the cranial nerve through its foramen.

5. Remove the left eye from the torso and carefully place it in the left orbital socket of the skull. The optic nerve is now "attached" to the eye!

Vagus nerve (C.N. X)

1. Remove the brain from the skull and identify the origination point of the vagus nerve. (leave the optic nerve attached!)

    Where does the vagus nerve originate from the brain? _____

2. Identify the vagus nerve from the envelope of nerves and tape one end to the attachment point on the brain.

3. In the skull model, identify the foramen that the vagus nerve passes through.

    What foramen does the vagus nerve pass through? _____

4. Carefully place the brain in the cranial fossa and thread the cranial nerve and vagus nerve through their foramina.

5. Thread the vagus nerve to the approximate location where it would innervate the heart.

Show your instructor your optic and vagus nerves before moving on. Do not remove the nerves until the end of the lesson.

Instructor Initials: _____

Phrenic nerve

1. Identify the phrenic nerve from the envelope of nerves.

    Which spinal nerves make up the phrenic nerve? _____

    What plexus does the phrenic nerve originate from? _____

2. On the human skeleton model, identify the spinal nerves that make up the phrenic nerve.

3. Tape the ends of the phrenic nerve to its appropriate spinal nerves.

4. Thread the phrenic nerve from its attachment points at the spinal nerves to its most distal point – use tape to help keep it in place.

Ulnar nerve

1. Identify the ulnar nerve from the envelope of nerves.

    Which spinal nerves make up the ulnar nerve? _____

    What plexus does the ulnar nerve originate from? _____

2. On the human skeleton model, identify the spinal nerves that make up the ulnar nerve.

3. Tape the ends of the ulnar nerve to its appropriate spinal nerves.

4. Thread the ulnar nerve from its attachment points at the spinal nerves to its most distal point – use tape to help keep it in place.

Show your instructor your phrenic and ulnar nerves before moving on. Do not remove the nerves until the end of the lesson.

Instructor Initials: _____

Obturator nerve

1. Identify the obturator nerve from the envelope of nerves.

    Which spinal nerves make up the obturator nerve? _____

    What plexus does the obturator nerve originate from? _____

2. On the human skeleton model, identify the spinal nerves that make up the obturator nerve.

3. Tape the ends of the obturator nerve to its appropriate spinal nerves.

4. Thread the obturator nerve from its attachment points at the spinal nerves to its most distal point – use tape to help keep it in place.

Tibial nerve

1. Identify the tibial nerve from the envelope of nerves.

    Which spinal nerves make up the tibial nerve? _____

    What plexus does the tibial nerve originate from? _____

2. On the human skeleton model, identify the spinal nerves that make up the tibial nerve.

3. Tape the ends of the tibial nerve to its appropriate spinal nerves.

4. Thread the tibial nerve from its attachment points at the spinal nerves to its most distal point – use tape to help keep it in place.

Show your instructor your obturator and tibial nerves before moving on. Take a photo of your completed skeleton model before removing your nerves. Instructor Initials: _____

Part 4: Plotting Cranial and Spinal Nerve Pathways Post-Activity Questions

Answer the following questions about the nerves of the body:

1. Describe the path that the vagus nerve takes through the body, including its origination point, the foramen it passes through, and what structures it innervates.

2. What type(s) of rami make up nerve plexuses?

3. What muscle(s) does the phrenic nerve innervate? What plexus does the phrenic nerve originate from?

4. What plexus does the obturator nerve originate from? What spinal nerves contribute to it? What muscle groups does it innervate? What cutaneous regions does it innervate?

5. Describe the path of the tibial nerve through the body, including what spinal nerves contribute to it, what plexus it originates from, how it passes through the body (using correct anatomical relationships) and

6. Take a photo of your completed skeleton model and submit it to your instructor with your answers.

Attributions

Part 1: Review of Cranial Nerves

- "Anatomy and Physiology Lab Homework" by Laird C Sheldahl is licensed under CC BY-SA 4.0
- "Human Anatomy Lab Manual" by Malgosia Wilk-Blaszczak, Mavs Open Press, University of Texas at Arlington is licensed under CC BY 4.0

Part 2: Review of Spinal Nerves

- "Anatomy and Physiology Lab Homework" by Laird C Sheldahl is licensed under CC BY-SA 4.0

Part 3: Laboratory Activity Plotting Cranial and Spinal Nerve Pathways

- "Plotting Cranial and Spinal Nerve Pathways in a Human Anatomy Lab" by Justin F. Shaffer is licensed under CC BY-NC-SA 4.0

Part 4: Plotting Cranial and Spinal Nerve Pathways Post-Activity Questions

- "Plotting Cranial and Spinal Nerve Pathways in a Human Anatomy Lab" by Justin F. Shaffer is licensed under CC BY-NC-SA 4.0

Updated 2026.

This page titled 15.5: Laboratory Activities and Assignment is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

15.6: Collaborative Study Activities

Collaborative Study Activities

These activities are designed for student groups of 2-4. Larger groups will work better when there is no supplemental instructor present in the laboratory to assist in testing student groups on each section.

Cranial Nerves

1. Identify the following structures on classroom anatomical models and/or unlabeled images/diagrams made available by your instructor. Work with your group to identify each structure and check them off the list once you have identified them.

☐ abducens nerve ☐ accessory nerve ☐ facial nerve ☐ cranial nerves I - XII ☐ glossopharyngeal nerve	☐ hypoglossal nerve ☐ oculomotor nerve ☐ olfactory nerve ☐ optic nerve	☐ trigeminal nerve ☐ trochlear nerve ☐ vagus nerve ☐ vestibulocochlear nerve

2. Test your group members by ***asking them to name each structure you point to***. Check off each when your group can successfully name each. Your group will also test you.

☐ abducens nerve ☐ accessory nerve ☐ facial nerve ☐ cranial nerves I - XII ☐ glossopharyngeal nerve	☐ hypoglossal nerve ☐ oculomotor nerve ☐ olfactory nerve ☐ optic nerve	☐ trigeminal nerve ☐ trochlear nerve ☐ vagus nerve ☐ vestibulocochlear nerve

3. When you and your group are comfortable identifying all the structures above, request the assistance of your Instructor. They will test you on your use of these terms and initial ONLY when you are successful using these terms. Instructor: _____

Spinal Nerves

1. Identify the following structures on classroom anatomical models and/or unlabeled images/diagrams made available by your instructor. Work with your group to identify each structure and check them off the list once you have identified them.

☐ axillary nerve ☐ brachial plexus ☐ cervical plexus ☐ cervical spinal nerves (C1-C8) ☐ femoral nerve ☐ intercostal nerves	☐ lumbar spinal nerves (L1-L5) ☐ lumbosacral plexus ☐ median nerve ☐ musculocutaneous nerve ☐ pudendal nerve ☐ radial nerve	☐ sciatic nerve ☐ spinal nerves C1 - S5 ☐ subcostal nerve ☐ thoracic spinal nerves (T1-T12) ☐ ulnar nerve

2. Test your group members by ***asking them to name each structure you point to***. Check off each when your group can successfully name each. Your group will also test you.

☐ axillary nerve ☐ brachial plexus ☐ cervical plexus ☐ cervical spinal nerves (C1-C8) ☐ femoral nerve ☐ intercostal nerves	lumbar spinal nerves (L1-L5) ☐ lumbosacral plexus ☐ median nerve ☐ musculocutaneous nerve ☐ pudendal nerve ☐ radial nerve	☐ sciatic nerve ☐ spinal nerves C1 - S5 ☐ subcostal nerve ☐ thoracic spinal nerves (T1-T12) ☐ ulnar nerve

3. When you and your group are comfortable identifying all the structures above, request the assistance of your Instructor. They will test you on your use of these terms and initial ONLY when you are successful using these terms. Instructor: _____

Updated 2026.

This page titled 15.6: Collaborative Study Activities is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

CHAPTER OVERVIEW

16: Special Senses of the Nervous System

16.1: Introduction
16.2: Vision Anatomy
16.3: Auditory and Equilibrium Anatomy
16.4: Olfactory Anatomy
16.5: Taste Anatomy
16.6: Laboratory Activities and Assignment
16.7: Collaborative Study Activities

This page titled 16: Special Senses of the Nervous System is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

16.1: Introduction

Introduction

In anatomy, special senses are the senses that have nervous system organs specifically devoted to them such as **vision**, **gustation** (taste), **olfaction** (smell), **audition** (sound), and **equilibrioception** (balance and proprioception). These senses have specialized organs that detect and process stimuli and send signals to the brain which lead to the perception of that stimulus. These specialized organs include the tongue, the nose, the eyes and the ears.

Updated 2026.

This page titled 16.1: Introduction is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

16.2: Vision Anatomy

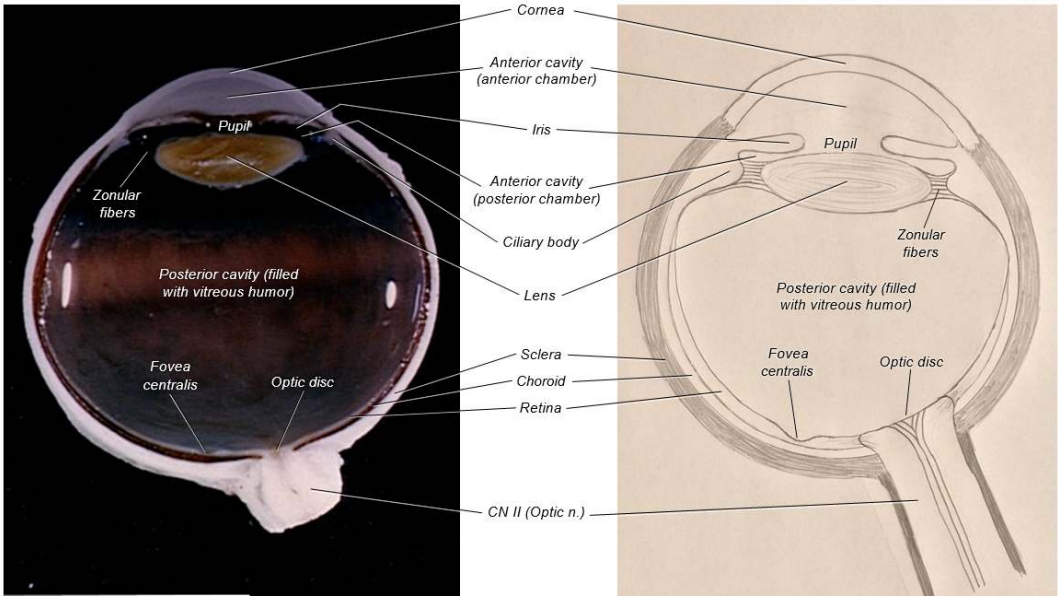
Vision Anatomy

Vision (sight) is perception of light emitted or reflected from objects in the environment. **Visible light** is electromagnetic radiation with wavelengths from **400 to 750nm.** Light must cause a photochemical reaction in order to produce a nerve signal that is sent to the occipital lobes of the brain for processing. Radiation below 400 nm has so much energy it kills cells (ultraviolet or UV light). Radiation above 750 nm has too little energy to cause photochemical reaction (it only warms the tissue) (infrared).

Macroscopic Anatomy of the Eye

The human eye is an organ that reacts to light and allows vision. The eye is the specialized organ of sight which has three principal layers, the **fibrous tunic** (**tunica fibrosa**), the **vascular tunic** (**tunica vasculosa**) and the **neural tunic** (**tunica interna**). Furthermore, there are two main chambers, the **anterior chamber**, containing **aqueous humor** and the **posterior chamber**, that contains **vitreous humor**. In the neural tunic of the **retina**, light propagates from the ganglionic cells through the **bipolar cells** to the **rods cells** and **cone cells**, which, somewhat paradoxically hyperpolarize opposite the direction of light.

Tunic of the Eyeball	Layer Type	Structures	Function
tunica fibrosa (fibrous tunic)	fibrous layer	sclera, cornea	provides protection
tunica vasculosa (vascular tunic)	vascular layer (contains blood vessels)	choroid, ciliary body, iris	provides nourishment
tunica interna (neural tunic)	internal layer	retina, optic nerve	converts light to nerve signal and sends to the occipital lobes of the brain



Above: Transverse section of the eye with a superior view (left) image of eye section and (right) illustration of eye structures.

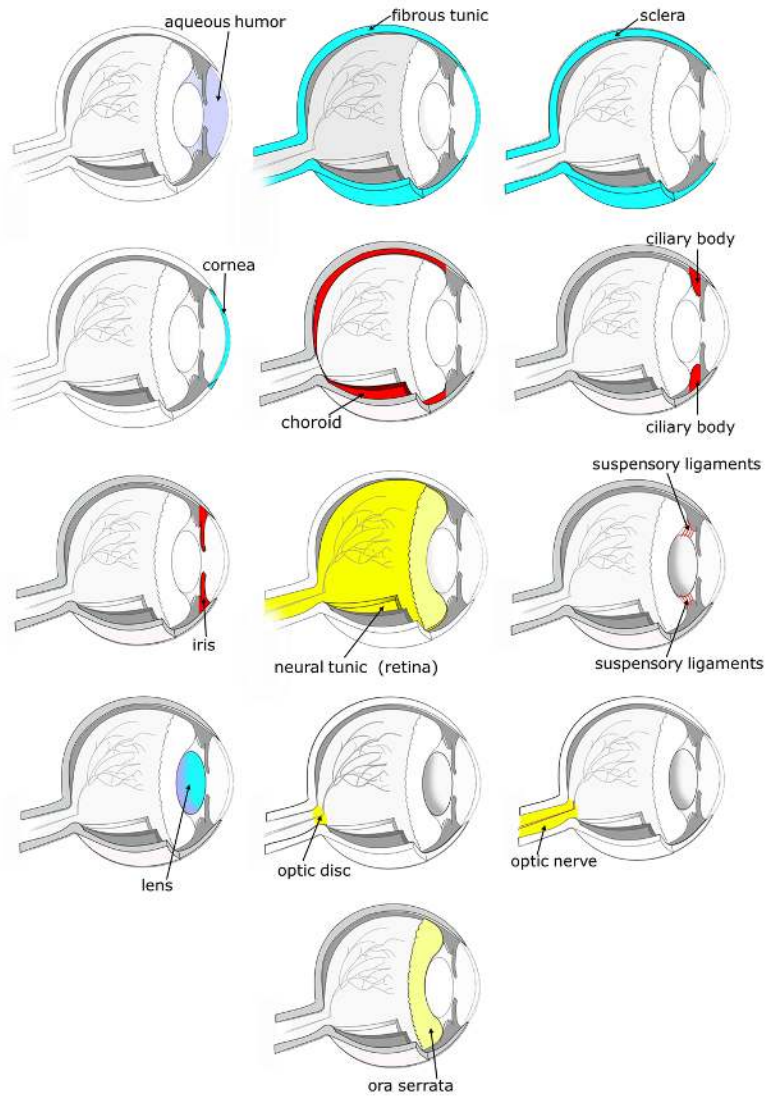
Cavity of the Eye	Location	Fluid (Humor)	Function
anterior cavity	anterior to the lens of the eye (cornea to lens)	aqueous humor (watery fluid)	aqueous humor helps to maintain the intraocular pressure and supply of nutrients to the lens and the cornea
posterior cavity	posterior to the lens of the eye (between the lens to retina)	vitreous humor (jelly-like substance)	vitreous humor holds the retina against the choroid layer and prevents the eyeball from collapsing

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, is more curved, and is linked to the larger posterior segment, composed of the vitreous humor, 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.

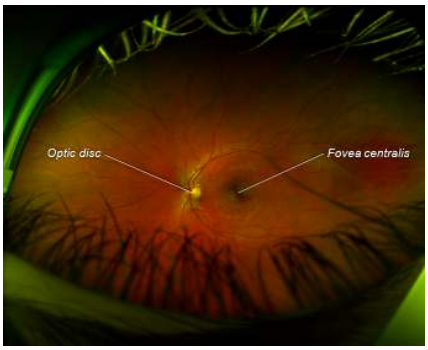
Light enters the eye through the cornea, through the pupil and then through the lens. The lens shape is changed for near focus (accommodation) and is controlled by the ciliary muscle. Photons of light falling on the light-sensitive cells of the retina (photoreceptor cone cells and rod cells) are converted into electrical signals that are transmitted to the brain by the **C.N. II optic nerve** and interpreted as sight and vision.

Structure	Location	Function
choroid	posterior portion of tunica vasculosa	contains melanin (pigment) that absorbs light to prevent reflection back into the eyeball, which could cause blurred vision; provides nourishment to the retina
ciliary body	composed of ciliary process and ciliary muscle, connected by suspensory ligaments	helps in adjusting the shape of the lens for near and far vision; produces aqueous humor
conjunctiva (bulbar/ocular)	covers the sclera (white part of the eye)	lubrication and protection by producing fluid and mucus; monitors microorganisms present to prepare immune response
conjunctiva (palpebral)	thin mucus membrane that lines the inside of the eyelids	secretes mucus to reduce friction and moisten the eyeball surface
cornea	the transparent, curved coat of the eyeball that covers the iris and pupil	admits light to the interior; responsible for bending light to focus toward the back of the eye; dense fibrous nature provides protection
fovea centralis	a small depression in the macula lutea	area of the sharpest vision because of the abundance of cone cells
iris	pigments portion around the central aperture (the pupil)	constrictor and dialator muscle of the iris change the diameter of the pupil to regulate the amount of light striking the retina
lens	posterior to the iris and pupil	fine-tunes bending of light to focus image on the retina; divides the eyeball into two cavities/chambers: anterior cavity/chamber and posterior cavity/chamber
macula lutea	oval-shaped central region of the retina containing higher concentration of photoreceptors; fovea centralis is located in its center	region of highest-quality vision due to the presence of lots of photoreceptors
optic disc	location where the optic nerve exits the eyeball; lacks photoreceptors	the blind spot of the eye where no photoreceptors are located due to the presence of the optic nerve
optic nerve (C.N. II)	exits the eyeball at the optic disc, through the optic canal of the skull, into the cranial cavity (optic chiasma, to optic tract, to occipital lobe which contains the visual cortex)	transmits light information from the eye to the visual cortex in the occipital lobe of the brain
ora serrata	where the retina meets the ciliary body; has a serrated (jagged) appearance	location where photosensitive tissue transitions into non-photosensitive tissue
plica semilunaris	a semilunar (crescent-shaped) fold in the bulbar/ocular conjunctiva in the medial corner of the eye	aids in movement of lacrimal fluid across the eye (for lubrication of the eye)
pupil	contractile hole located in the center of the iris of the eye	allows light to enter the retina
retina	innermost layer of the posterior eye; contains two layers (outer pigmented layer and inner neuronal layer)	outer pigmented layer prevents light scattering and absorbs light; inner neuronal layer contains two types of photoreceptors, rod cells and cone cells, that collect light information and transmit to neurons
sclera	covers the eyeball except at the cornea; covered by the bulbar/ocular conjunctiva; white part of the eye	resists punctures and protects the eye; helps maintain pressure in the eye to keep its shape and keep the retina adhered to the back of the eye; attachment point of extrinsic eye muscles



Above: Structures of the eye.

Clinical Application: "Blind Spot"



Above: Photograph of left human retina, anterior view.

There are **no rods or cones** (visual receptors) at the **optic disc** (the structure formed from where **CN II (Optic n.)** connects to the retina) because that space is being occupied up by the optic nerve fibers and retinal vasculature. Therefore, as light passes through the eye and onto the retina for visual processing, the light that shines on the optic disc is not processed into eyesight, causing a “blind spot” in each eye’s normal field of vision. You can “see” your blind spot for yourself using the image below. Close your right eye and look directly at the center of the plus sign with your left eye (don’t look away or at the circle). Hold the image about one foot away from your face (how close you need to view the image will depend on the size of the image (whether in print or digital format which is dependent on the zoom in your view)). While looking

directly at the plus sign with your left eye, the white circle should disappear from your peripheral vision because that area in your field of vision is shining on your optic disc. You typically don't notice your blind spots because your brain takes vision from your other eye and "fills in" your blind spots for a full field of view. Unlike the optic disc, the **fovea centralis**, a structure on the retina near the optic disc, has the highest concentration of cones and processes the most acute vision necessary for reading, driving, etc.



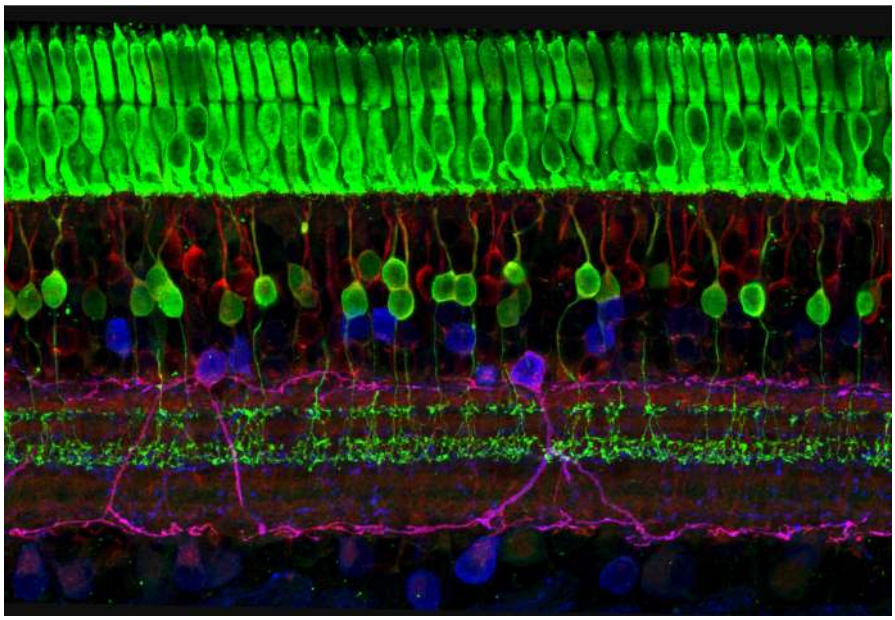
Above: Diagram for "seeing" your blind spot.

Clinical Application: Conjunctivitis

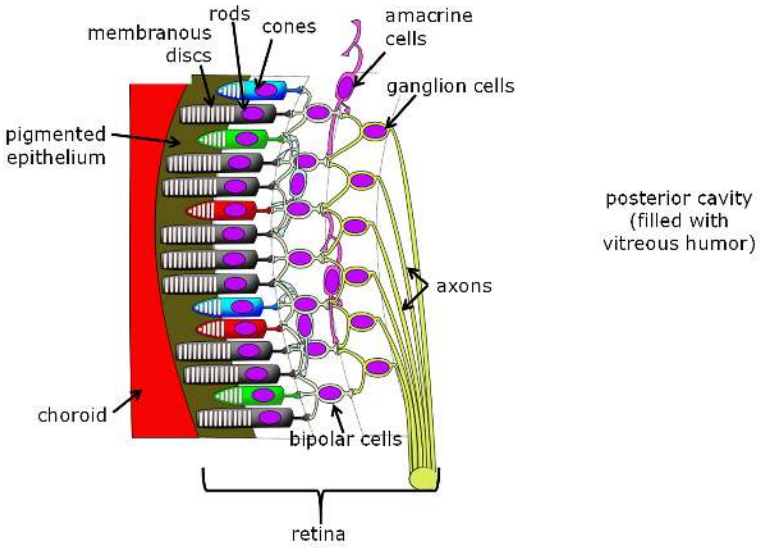
Conjunctivitis (or **pink eye**) is a common inflammation of the **conjunctiva** of the eye. Symptoms typically include redness, itching, increased tear production, and crusting around the eyes. It is highly contagious, and can be spread by direct contact (i.e. handshake or hug) or indirect contact (i.e. touching a contaminated pencil or doorknob). Although the inflammation is usually not severe and will resolve on its own, the process can be sped up with antibiotic eye drops.

Microscopic Anatomy of the Eye

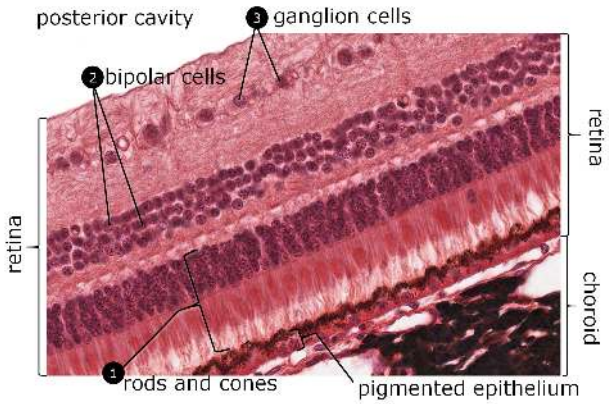
The human eye can differentiate between about 10 million colors and is possibly capable of detecting a single photon. **Rod** and **cone cells** in the retina allow conscious light perception and vision including color differentiation and the perception of depth.



Above: This image captures the many layers of nerve cells in the retina. The top layer (green) is made up of cells called photoreceptors that convert light into electrical signals to relay to the brain. The two best-known types of photoreceptor cells are rod- and cone-shaped. Rods help us see under low-light conditions but can't help us distinguish colors. Cones don't function well in the dark but allow us to see vibrant colors in daylight. The top of the image is the posterior of the retina and the bottom of the image is positioned toward the posterior cavity filled with vitreous humor.

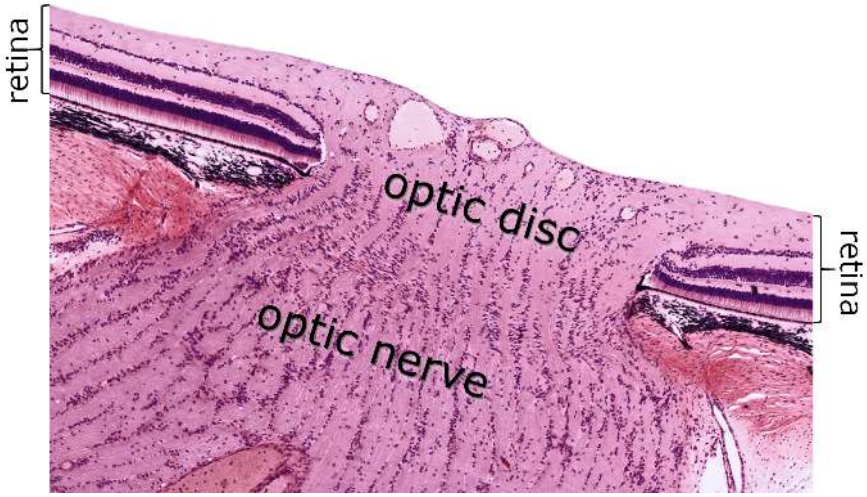


Above: Diagram of the cells of the retina. Light would enter the eye from the right of the figure and strike the retina and be detected by the rods and cones which send light information to bipolar cells and ganglion cells.



Above: Tissue of the retina magnified by 400x. The top of the image shows the posterior cavity of the eye where light is coming in toward the retina. Light is sensed by the rods and cones that pass the information to bipolar cells and then to ganglion cells. The axons of ganglion cells are bundled in C.N. II optic nerve.

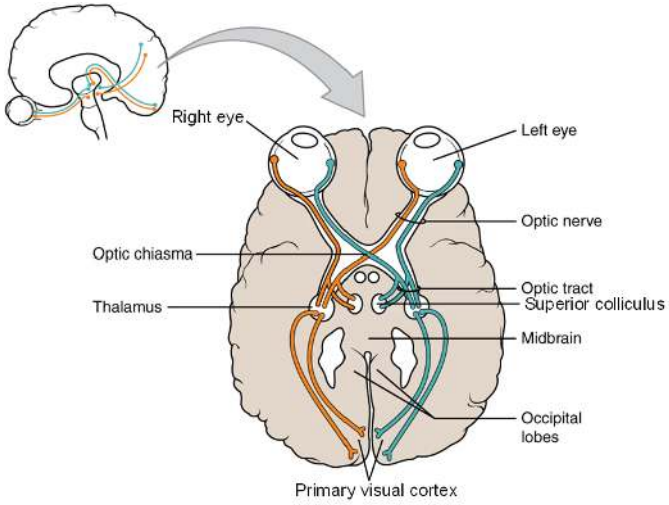
Structure	Location	Function
amacrine cells	retina, inner neuronal layer	inhibit some light signals from being transmitted (inhibitory neurons); interneurons
bipolar cells	retina, inner neuronal layer	transmit light information from rod and cone cells to ganglion cells; interneurons
cone cells	retina, inner neuronal layer	a type of photoreceptor; detects color vision and visual acuity; used in bright light
ganglion cells	retina, inner neuronal layer, optic nerve	transmit light information from bipolar cells and amacrine cells; axons are bundled in the optic nerve (C.N. II); sensory neurons
rod cells	retina, inner neuronal layer	a type of photoreceptor; determines motion and general shape of objects in dim light; black and white vision



Above: Microscopic image of the tissue of the optic disc (blind spot), magnified by 100x.

Vision Neuron Pathway

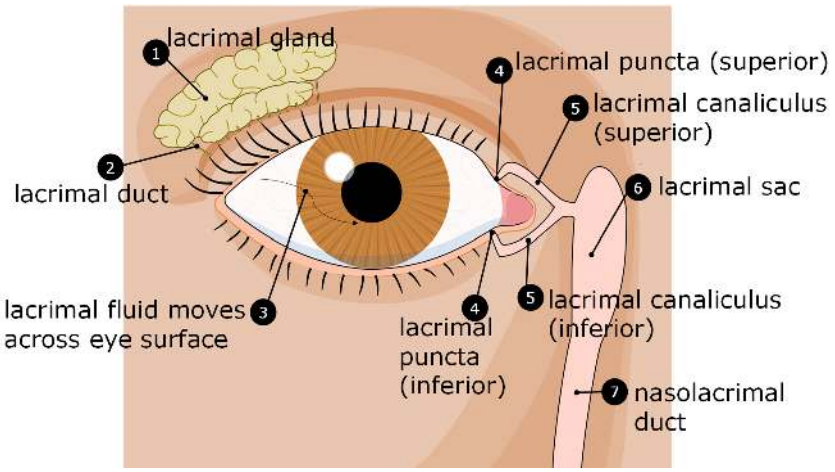
Axons of ganglion cells in the retina are bundled into the optic nerve (C.N. II). The path of these axons is dependent on which part of the eye they come from. Axons of ganglion cells arising from the lateral retinas remain on the same side of the brain as the eye the they came from. The axons of medial ganglion cells however cross to the opposite side of the brain as that eye in the **optic chiasma**. Axons of ganglion cells terminate in the thalamus which filters out unneeded or extraneous visual information, aiding the cerebral cortex in focusing on important visual signals. Light information that pass through the "gate" of the thalamus is transmitted to the **primary visual cortex** in the occipital lobe, a region of the brain that processes visual information. Additionally, some of the ganglion cell axons terminate in the superior colliculi of the midbrain which collects visual information and modifies movements of the eyes.



Above: Diagram showing the path of axons of ganglion cells of the retina.

Lacrimal Apparatus

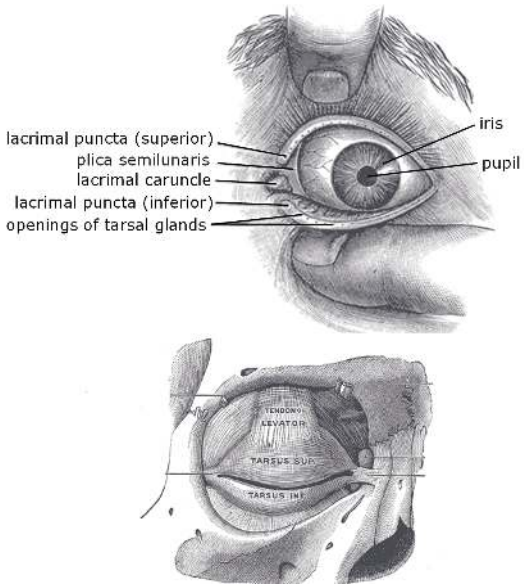
The **lacrimal apparatus** frames the eye and coats the sclera and cornea in **lacrimal fluid**, a bactericide, which lubricates and protects them. Lacrimal fluid is produced consistently to maintain lubrication and protection for the eye, but increases production when the eye is irritated or when an individual is emotional (tears). The lacrimal apparatus is made of the **lacrimal gland**, **lacrimal canaliculi**, **lacrimal sac** and **nasolacrimal duct**. This network of structures allows tears produced by the **lacrimal gland** to cover the eye, drain through the **lacrimal puncta** into the lacrimal canaliculi, collect in the lacrimal sac, travel down the nasolacrimal duct and finally empty into the nose. This is why crying leads to a runny nose.



Above: Structures of the lacrimal apparatus of the right eye showing the passage of lacrimal fluid (1-7).

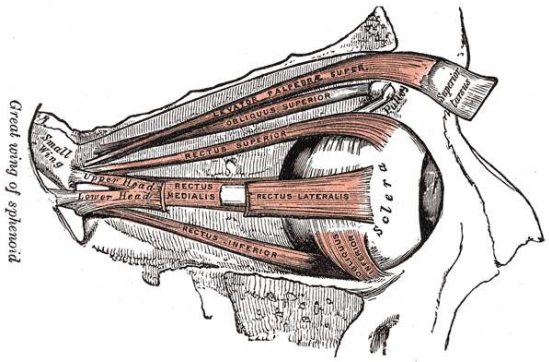
Structure	Location	Function
lacrimal canaliculi (superior duct and inferior duct)	paired canals (superior duct and inferior duct) at the medial aspect of the eye between the lacrimal puncta and nasolacrimal duct	transfers lacrimal fluid from lacrimal puncta to the nasolacrimal duct
lacrimal caruncle	red fleshy globe-like nodule in the medial commissure of the eye that contains sebaceous glands and sweat glands	eye lubrication; dried secretions forms sandy residue
lacrimal ducts	small passageways connecting the lacrimal gland with the surface of the eye	carries newly-formed lacrimal fluid to the eye's surface
lacrimal fluid	produced in the lacrimal gland and travels to the eye surface through lacrimal ducts and then across the eye from lateral to medial before draining into the lacrimal puncta, then lacrimal canaliculi, to the nasolacrimal duct, and into the nasal cavity	lubricates the eye and protects it from debris and bacteria; aids in O_2 and CO_2 diffusion; creates tears during emotional response
lacrimal gland	superior lateral edge of the orbit	production of lacrimal fluid (tears) to lubricate and protect the eye (fluid contains lysozyme, an antibiotic, antibodies, and mucus)
lacrimal puncta	paired openings at the medial aspect of the eye leading to the lacrimal canaliculi (superior duct and inferior duct)	collection of lacrimal fluid from the eye's surface into lacrimal canaliculi (draining fluid)
lacrimal sac	a broad region of the nasolacrimal duct, located at the superior aspect of the nasolacrimal duct	receives lacrimal fluid from the lacrimal canaliculi
nasolacrimal duct	a passage connecting the lacrimal canaliculi with the nasal cavity	carries lacrimal fluid from lacrimal canaliculi into the nasal cavity
palpebrae (eyelids)	one superior and one inferior per eye	blinking the palpebrae spreads lacrimal fluid and protects the eye

Other Accessory Eye Structures



Above: Structures of the eye. (Top) Left eye. (Bottom) Closed right eye without skin to show the tarsal plates.

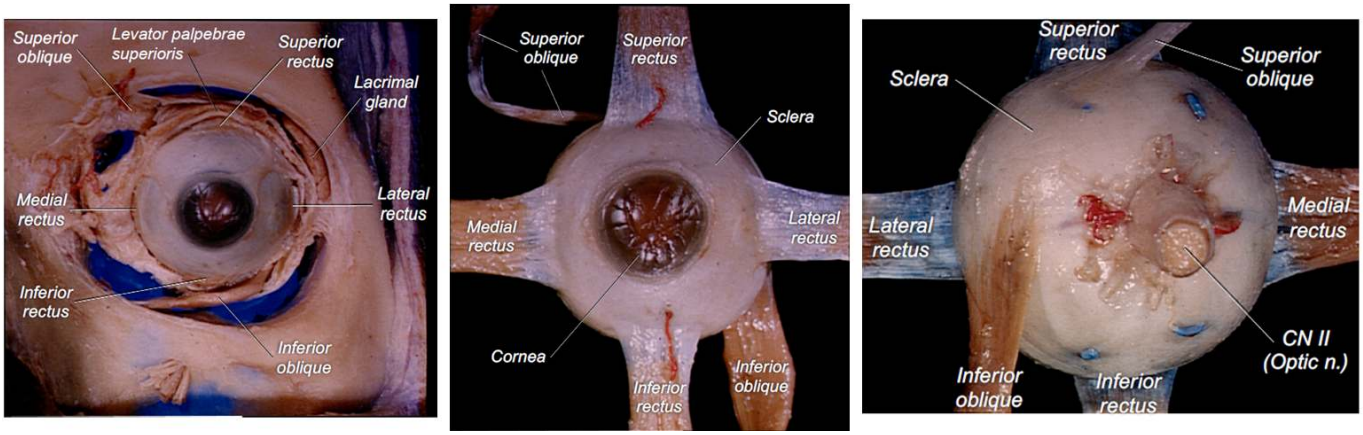
Structure	Details
ciliary gland / Moll's gland	glands located at the base of the eyelashes producing sebum to lubricate the eyelashes; when infection of a ciliary gland occurs it results in a sty
eyebrows	hair superior to the eye, protection from light and sweat
lateral commissure	lateral corner of the eye
levator palpebrae superioris muscle	lifts the upper palpebra (eyelid)
medial commissure	medial corner of the eye, houses the lacrimal caruncle
tarsal glands / Meibomian glands	glands found in the tarsal plate, produce oily substance to prevent eyes from drying out
tarsal plates	located within the superior and inferior palpebrae (eyelids); comparatively thick, elongated plates of dense connective tissue that contribute to eyelids form and support



Above: Diagram of the ocular muscles of the right eye. The lateral rectus is shown as broken only to allow view of medial rectus.

Extrinsic Eye Muscles	Location	Action	Innervation
inferior oblique	originating at the inferior medial aspect of the orbit and extending laterally and posteriorly to the eyeball	looking up and laterally (eye roll)	C.N. III oculomotor nerve
inferior rectus	inferior aspect of the eyeball approximately in the sagittal plane	looking down (depression)	C.N. III oculomotor nerve
lateral rectus	lateral aspect of the eyeball approximately in the sagittal plane	looking laterally (abduction)	C.N. VI abducens nerve

Extrinsic Eye Muscles	Location	Action	Innervation
medial rectus	medial aspect of the eyeball approximately in the sagittal plane	looking medially (adduction)	C.N. III oculomotor nerve
superior oblique	originates medial to the eyeball approximately along the sagittal plane and then loops obliquely through a pully (**trochlea of superior oblique**) to from a v-like shape	looking down and laterally (eye roll)	C.N. IV trochlear nerve
superior rectus	superior aspect of the eyeball approximately in the sagittal plane	looking up (elevation)	C.N. III oculomotor nerve



Above: Human eye and its extrinsic muscles (left) anterior view of the left eye with surrounding tissues including the lacrimal gland, (middle) anterior view of the left eyeball and its extrinsic eye muscles, and (right) posterior view of the left eyeball and its extrinsic eye muscles.

Attributions

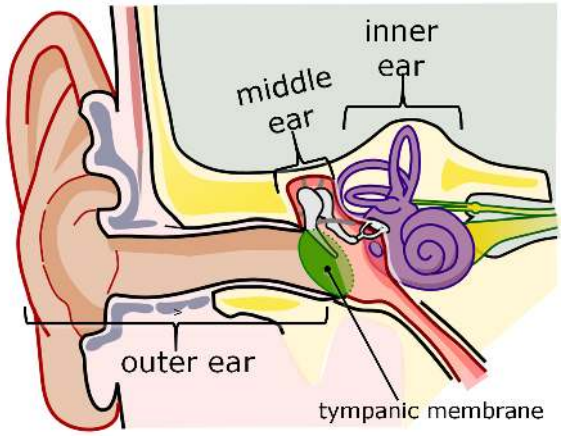
- "1204 Optic Nerve vs Optic Tract.jpg" by OpenStax is licensed under CC BY 4.0
- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0
- "Anatomy and Physiology Lab Reference" by Laird C Sheldahl, OpenOregonEducational Resources, Mt. Hood Community College is licensed under CC BY-SA 4.0
- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0
- "Gray's Anatomy plates" by Henry Vandyke Carte is in the Public Domain
- "Human Anatomy Lab Manual" by Malgosia Wilk-Blaszczak, Mavs Open Press, University of Texas at Arlington is licensed under CC BY 4.0
- "Special Senses – Anatomy of the Eye" by Dongho Kim is licensed under CC BY-NC-SA 4.0
- "Tear system-pt.svg" by Jmarchn is licensed under CC BY-SA 3.0
- "The eye uses many layers of nerve cells to convert light into sight" by Wei Li is licensed under CC BY-NC-SA 3.0

Updated 2026.

This page titled 16.2: Vision Anatomy is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

16.3: Auditory and Equilibrium Anatomy

Auditory and Equilibrium Anatomy



Above: The outer, middle, and inner ear.

The ear is a complex organ which houses special structures that allow us to hear, balance and orientate ourselves. Sound waves are collected by the **auricle** (outer ear) and funneled into the **external acoustic meatus**. The ear is divided into three sections, the **outer**, **middle**, and **inner ear**. The outer ear consists of the auricle which extends through the external auditory canal and terminates at *t*he **tympanic membrane**.

Outer Ear

The **auricle** or **pinna** (external ear) consists of a core of elastic cartilage covered by thin skin. Skeletal muscle fibers of the auricular muscle have little, but variable, function in humans. Numerous hair follicles with their accompanying sebaceous glands are also present.

Thin skin covering the external acoustic meatus possesses small dermal papillae and epithelial pegs to anchor the epidermis with the dermis. The sebaceous glands are large. Additionally, **ceruminous glands**, specialized coiled, tubular, apocrine sweat glands, secret **cerumen**, a waxy secretion. Skeletal muscle is also present. Elastic cartilage and the temporal bone form the support for the auricle.

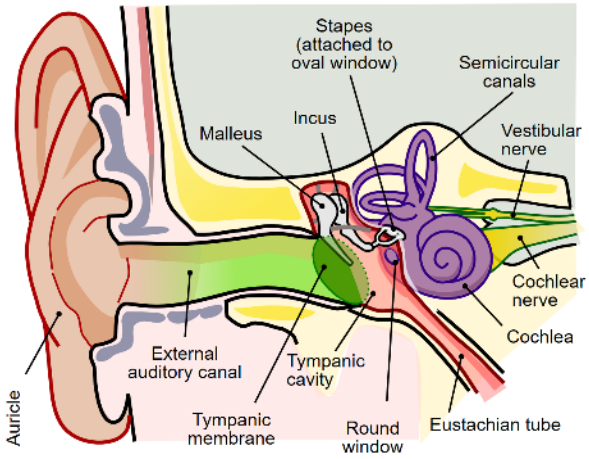
Outer Ear Structure	Location	Function
auricle (pinna)	paired (right and left) external ear structure composed of elastic cartilage and skin	collecting sound and funneling it into the external auditory canal
ceruminous glands	located under the skin along the external auditory canal	produce and secrete cerumen (ear wax); cerumen lubricates the external auditory canal and is antibacterial
external acoustic meatus	paired (right and left) canal in the bone of the skull, specifically the temporal bone	creates passage within the skull for the external auditory canal
external auditory canal	paired (right and left) skin-covered canal positioned within the external acoustic meatus (sometimes used synonymously with external acoustic meatus)	passageway carrying sound collected by the auricle to the middle ear
tympanic membrane	paired (right and left) membranes in the external auditory canal separating the outer ear from the middle ear	ear drum; sound causes vibration of the tympanic membrane; vibrations of the tympanic membrane are transferred to the middle ear and then ultimately the inner ear for detection of sound

Middle Ear

The main structures of the middle ear are the **auditory ossicles**, **Eustachian tube** (also known as the **pharyngotympanic tube**), **oval window** and **round window**. The auditory ossicles inward from the tympanic membrane, are the **malleus**, **incus**, and **stapes**. The base of the stapes covers the oval window which allows sound waves to pass from the tympanic membrane, into the cochlea of the inner ear.

Middle Ear Structure	Location	Function
Eustachian tube (pharyngotympanic tube)	passage between the middle ear and the nasopharynx (paired, one right and one left)	equalizes the pressure of the middle ear with external air pressure (ear popping)
incus	middle auditory ossicles, anvil-shaped bone	receives vibrations from malleus and transmits them to stapes

Middle Ear Structure	Location	Function
malleus	between the tympanic membrane and incus, hammer-shaped bone	receives vibrations from the tympanic membrane and transmits them to incus
oval window	between stapes and the cochlea, membrane-covered opening	transfers vibrations from stapes to the cochlea
round window	inferior to the oval window on the exterior of the cochlea, membrane-covered opening	creates space for the fluid within the cochlea to move with the vibrations of the auditory ossicles
stapes	between incus and the oval window, stirrup-shaped bone, smallest bone in the human body	receives vibrations from stapes and transmits them to the oval window

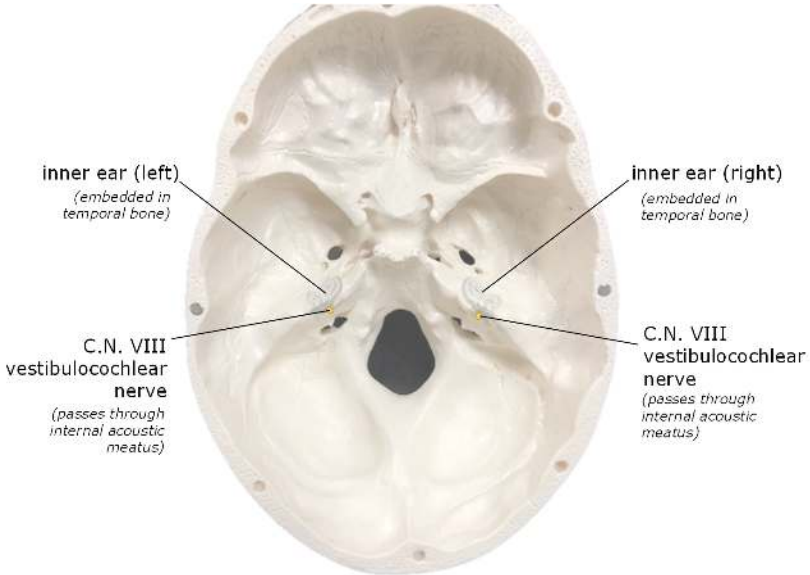


Above: Structures of the outer, middle, and inner ear.

The middle ear, or tympanic cavity, is an air-filled space in the temporal bone that is lined by a mucosa. Three **auditory ossicles** span the cavity between the tympanic membrane and an opening in the wall of the inner ear, the **oval window**. The middle ear communicates with the mastoid air cells posteriorly and with the pharynx anteriorly through the Eustachian tube.

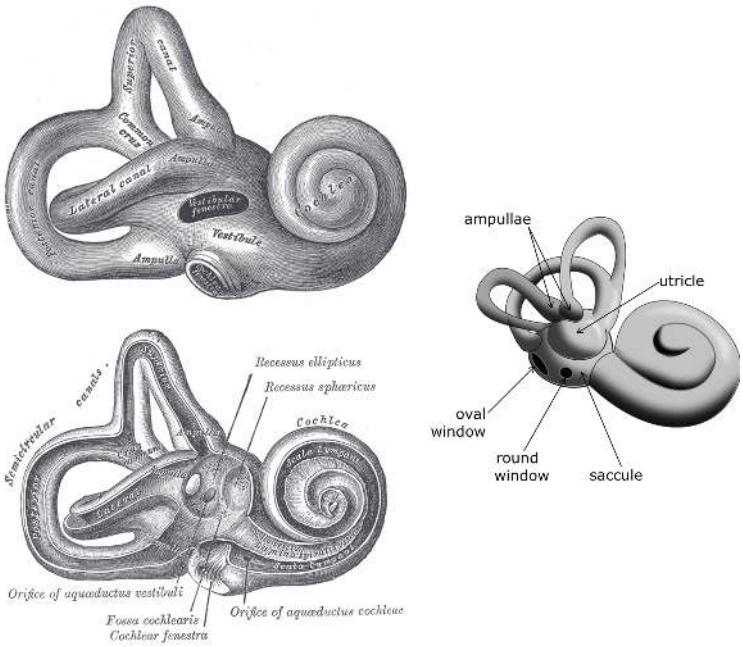
Vibrations of the vestibular membrane are transmitted through the malleus and incus to the stapes. The stapes is seated in the oval window between the middle ear and the vestibule of the inner ear. Inward movement of the stapes creates pressure on the **perilymph** filling the **osseous labyrinth** (inner ear), initiating responses in neural receptors of the **cochlear duct**.

Inner Ear



Above: Superior view of the cranial cavity (skull) showing where the inner ear is embedded in the temporal bone and how C.N. VIII vestibulocochlear nerve passes through the internal acoustic meatus into the cranial cavity.

The inner ear, located in the **petrous portion of the temporal bone** (between the external acoustic meatus and the internal acoustic meatus), houses receptors that monitor changes in sound, gravity and movement. These receptors are located in a series of membranous tubes and sacs, collectively termed the **membranous labyrinth**, which are suspended in a series of bony spaces, the **osseous labyrinth**. The osseous labyrinth can be subdivided into three regions: the **cochlea**, **vestibule**, and **semicircular canals**. The cochlea, vestibule, and semicircular canals are responsible for hearing, static and dynamic equilibrium respectively.

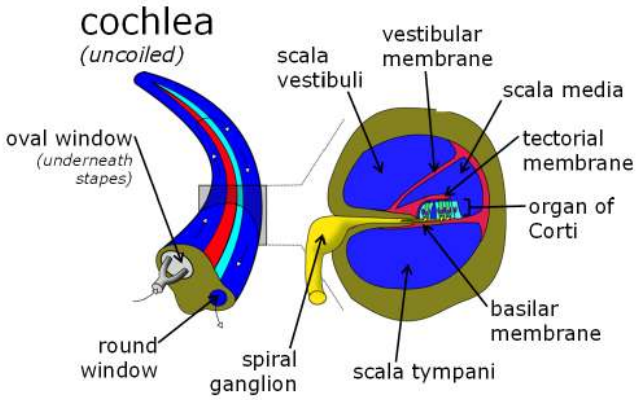


Above: Osseous labyrinth of the inner ear. (Top) The bony labyrinth and its components, the cochlea (auditory sense), the vestibule (sense of gravity and acceleration), and the semicircular canals (sense of balance). (Bottom) A look inside the osseous labyrinth reveals passageways inside called the membranous labyrinth that is filled with endolymph, which moves with vibrations from auditory ossicles in the cochlea, or with movements of the head in the vestibule and semicircular canals. Changes sensed in the endolymph is transmitted to neurons in C.N. VIII. (Right) The utricle and saccule of the vestibule, specialized sensory regions.

The osseous labyrinth is lined with periosteum and filled with a fluid, **perilymph** surrounding the **membranous labyrinth**. Within the membranous labyrinth is endolymph, specialized fluid, as well as epithelia and its underlying connective tissue, containing receptors for hearing and for static and kinetic senses. C.N. VIII, the vestibulocochlear nerve, innervates the receptors in the membranous labyrinth. The cochlear division of the nerve supplies the **organ of Corti** in the **cochlear duct**. The vestibulocochlear nerve passes into the cranial cavity through the internal acoustic meatus.

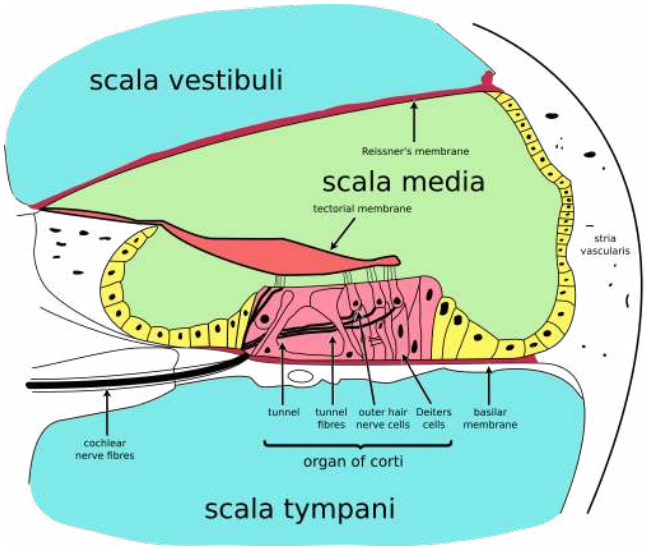
Inner Ear Structure	Location	Function
cochlea	inner ear, spiral part of the osseous labyrinth	contains receptor cells (hair cells)
cochlear nerve	nerve connected to the cochlea, a branch of C.N. VIII vestibulocochlear nerve	carries auditory signals to the brain
endolymph	inside the membranous labyrinth, produced from perilymph	this fluid moves in response to movements and vibrations; fluid movements are detected by hair cells
hair cells	inside the membranous labyrinth of the cochlea, vestibule, and ampullae of the semicircular canals	receptor cells detect movements in the fluids inside the membranous labyrinth and transmit to sensory neurons of the vestibulocochlear nerve
membranous labyrinth	ducts located inside the osseous labyrinth of the inner ear (cochlea, vestibule, and semicircular canals)	contains endolymph and hair cells for detecting vibrations and changes in position
osseous labyrinth	bony structure in the inner ear surrounding the membranous labyrinth, composed of the cochlea, vestibule, and semicircular canals	contains the membranous labyrinth where auditory, gravitational, balance, and acceleration information is sensed
perilymph	fluid between the osseous labyrinth and the membranous labyrinth	transfers vibrations to the endolymph
saccule	a region of the vestibule containing receptor cells (hair cells)	senses head tilting and accelerations
semicircular canals		
utricle	a region of the vestibule containing receptor cells (hair cells)	senses balance, orientation, and motion

Inner Ear Structure	Location	Function
vestibular nerve	nerve connected to the vestibule, a branch of C.N. VIII vestibulocochlear nerve	carries balance, orientation, motion, head tilting, and acceleration sensory information to the brain
vestibule	central region of the osseous labyrinth	senses balance, orientation, motion, head tilting, and acceleration
vestibulocochlear nerve (C.N. VIII)	between the inner ear and the brain, passes into the cranial cavity through the internal acoustic meatus	carries special sensory signals to the brain including auditory, balance, equilibrium, and acceleration signals



Above: The cochlear duct (scala media), vestibular duct (scala vestibuli), and tympanic duct (scala tympani) of the cochlea. Cross section of part of the cochlea to reveal the internal structure of the cochlea, the cochlear duct, including the organ of Corti, where endolymph fluid movements in the cochlea are detected and transferred to sensory neurons of C.N. VIII vestibulocochlear nerve.

Cochlear Structure	Location	Function
basilar membrane	inside the cochlea, structure between scala media and scala tympani	separates scala media and scala tympani
cochlear duct / scala media	a duct inside the cochlea filled with endolymph	contains organ of Corti for sensing auditory information
hair cells	inside the membranous labyrinth of the cochlea, vestibule, and ampullae of the semicircular canals	receptor cells detect movements in the fluids inside the membranous labyrinth and transmit to sensory neurons of the vestibulocochlear nerve
organ of Corti (spiral organ)	inside the cochlea, within scala media	contains receptor cells (hair cells) that detect vibration movements in the endolymph as auditory signals
scala tympani / tympanic duct	inside the cochlea, a cavity inside the cochlea	contains perilymph, transmits vibration information to endolymph in scala media
scala vestibuli / vestibular duct	inside the cochlea, a cavity inside the cochlea	contains perilymph, transmits vibration information to endolymph in scala media
spiral ganglion	inside the cochlea, bundle of neuron cell bodies	these neurons collect auditory information from the hair cells and transfer auditory sensory information
tectorial membrane	inside the cochlea, attached to hair cells in the cochlear duct	transfers movements of the endolymph to the hair cells
vestibular membrane (Reissner's membrane)	inside the cochlea, between the cochlear duct and the vestibular duct	separates the cochlear duct from the vestibular duct



Above: Structure of the organ of Corti with its hair cells attached to the tectorial membrane. Endolymph in the scala media (cochlear duct) moves with vibrations from the auditory ossicles and transfers motion to the tectorial membrane. These movements are sensed by the hair cells that transfer these sensory signals to cochlear nerve fibers.

Attributions

- "Anatomy and Physiology Lab Reference" by Laird C Sheldahl, OpenOregonEducational Resources, Mt. Hood Community College is licensed under CC BY-SA 4.0
- "Anatomy of the Human Ear.svg" by Lars Chittka; Axel Brockmann is licensed under CC BY 2.5
- "Cochlea-crosssection.svg" by Fred the Oyster is licensed under CC BY-SA 3.0 / A derivative from the original work
- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0
- "Gray's Anatomy plates" by Henry Vandyke Carte is in the Public Domain
- "Human Anatomy Lab Manual" by Malgosia Wilk-Blaszczak, Mavs Open Press, University of Texas at Arlington is licensed under CC BY 4.0
- "Inner ear.png" by Sheldahl is licensed under CC BY-SA 4.0

Updated 2026.

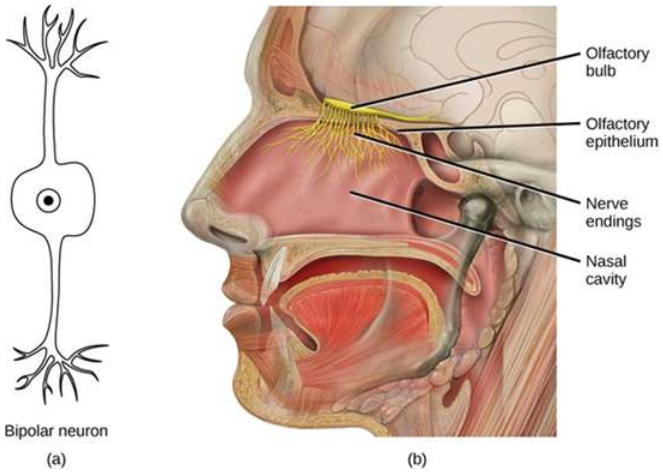
This page titled 16.3: Auditory and Equilibrium Anatomy is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

16.4: Olfactory Anatomy

Olfactory Anatomy

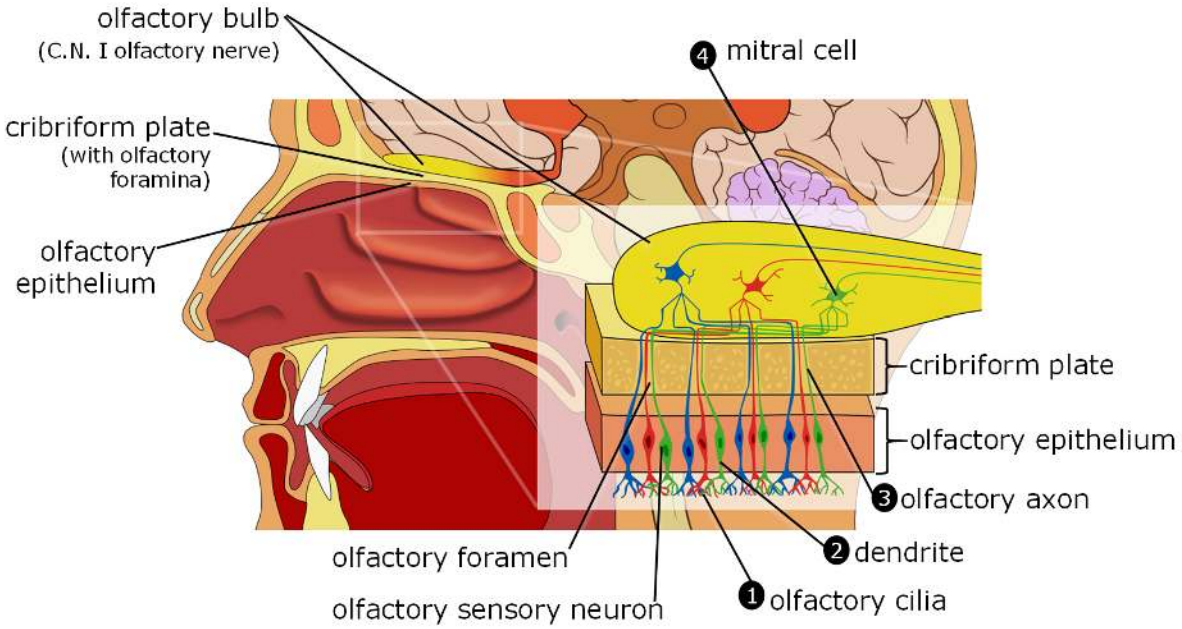
All odors that we perceive are molecules in the air we breathe. If a substance does not release molecules into the air from its surface, it has no smell. And if a human or other animal does not have a receptor that recognizes a specific molecule, then that molecule has no smell.

Odorants (odor molecules) enter the nose and dissolve in the olfactory epithelium, the mucosa at the back of the nasal cavity. The **olfactory epithelium** is a collection of specialized olfactory receptors in the back of the nasal cavity. An **olfactory receptor**, which is a dendrite of a specialized neuron, responds when it binds certain molecules inhaled from the environment by sending impulses directly to the olfactory bulb (part of **C.N. I olfactory nerve**) of the brain. Humans have about 12 million olfactory receptors, distributed among hundreds of different receptor types that respond to different odors. Twelve million seems like a large number of receptors, but compare that to other animals: rabbits have about 100 million, most dogs have about 1 billion, and bloodhounds—dogs selectively bred for their sense of smell—have about 4 billion. The overall size of the olfactory epithelium also differs between species, with that of bloodhounds, for example, being many times larger than that of humans.



Above: In the human olfactory system, (a) bipolar olfactory neurons extend from (b) the olfactory epithelium, where olfactory receptors are located, to the olfactory bulb.

Olfactory neurons are **bipolar neurons** (neurons with two processes from the cell body). Each neuron has a single dendrite buried in the olfactory epithelium, and extending from this dendrite are 5 to 20 receptor-laden, hair-like **olfactory cilia** that trap odorant molecules. When an odorant binds with a receptor that recognizes it, the sensory neuron associated with the receptor is stimulated. Unlike any of the following special senses, neurons from the olfactory bulb bypass the thalamus and synapse directly with the olfactory cortex.



Above: Diagram of olfactory anatomy. Olfactory sensory neurons embedded in the olfactory epithelium have olfactory cilia with receptors that attach to odor molecules and send a signal along the olfactory sensory neuron from 1. the olfactory cilia, 2. to the dendrite, 3. to the olfactory axon, and then 4. the signal is passed to another neuron called a mitral cell in the olfactory bulb of C.N. I. The signal is then transfered to the olfactory cortex in the brain.

Attributions

- "Biology 2e" by Mary Ann Clark, Matthew Douglas, Jung Choi, OpenStax is licensed under CC BY-NC 4.0
- "Human Anatomy Lab Manual" by Malgosia Wilk-Blaszczak, Mavs Open Press, University of Texas at Arlington is licensed under CC BY 4.0
- "Olfactory system.svg" by Chabacano is licensed under CC BY-SA 2.5

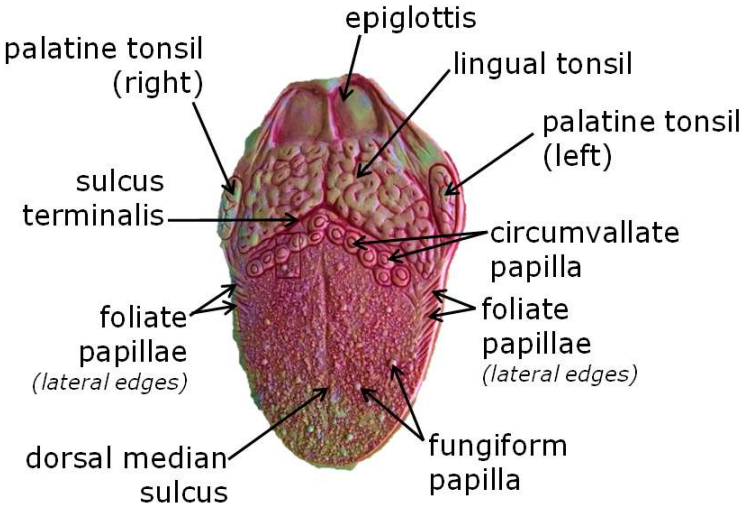
Updated 2026.

This page titled 16.4: Olfactory Anatomy is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

16.5: Taste Anatomy

Taste Anatomy

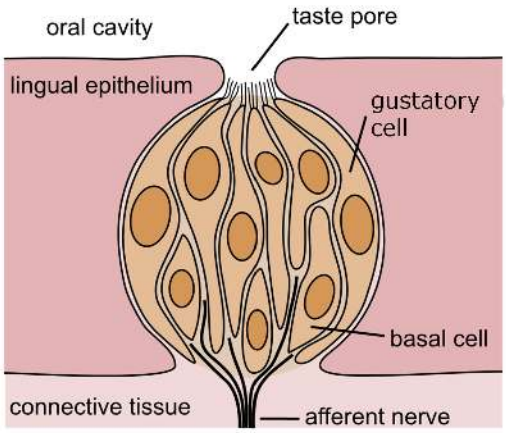
The primary tastes detected by humans are sweet, sour, bitter, salty, and umami. The first four tastes need little explanation. The identification of **umami** as a fundamental taste occurred fairly recently—it was identified in 1908 by Japanese scientist Kikunae Ikeda while he worked with seaweed broth, but it was not widely accepted as a taste that could be physiologically distinguished until many years later. The taste of umami, also known as savoriness, is attributable to the taste of the amino acid L-glutamate. In fact, monosodium glutamate, or MSG, is often used in cooking to enhance the savory taste of certain foods. What is the adaptive value of being able to distinguish umami? Savory substances tend to be high in protein.



Above: Structures of the tongue.

Detecting a taste (**gustation**) is fairly similar to detecting an odor (olfaction), given that both taste and smell rely on chemical receptors being stimulated by certain molecules. The **tongue** is a crucial organ in mechanical digestion and taste. Taste buds contain taste receptor cells which are the smallest functional unit in gustation. Taste buds can be found throughout the length of the upper digestive tract. On the surface of the tongue are protrusions called papillae. **Circumvallate papillae** are arranged in a v-shape pattern on toward the base of the tongue, on the dorsal aspect, and contain more than 100 taste buds each. The **fungiform papillae** are found all over the dorsal aspect of the tongue and contain only about 5 taste buds each. The **foliate papillae** are found on the lateral aspects of the tongue and only contain taste buds during childhood. Finally, there are the **filiform papillae** which, like the fungiform papillae, are found all over the tongue, however, they do not contain taste buds. Instead, their barbed shape provides the friction for moving food around during mastication.

Chemical are detected by **gustatory cells** in taste buds in the papillae of the tongue that relay these sensory signals to neurons in cranial nerves VII, IX, and X (facial nerve, glossopharyngeal nerve, and vagus nerve, respectively). Each taste bud's taste cells are replaced every 10 to 14 days. These are elongated cells with hair-like processes called microvilli at the tips that extend into the taste bud pore. Food molecules (**tastants**) are dissolved in saliva, and they bind with and stimulate the receptors on the microvilli. The receptors for tastants are located across the outer portion and front of the tongue, outside of the middle area where the filiform papillae are most prominent.



Above: Diagram of the microscopic anatomy of a taste bud. Many taste buds are present within papillae of the tongue.

Taste neurons project from taste cells in the tongue, esophagus, and palate to the medulla, in the brainstem. From the medulla, taste signals travel to the thalamus and then to the primary gustatory cortex. Information from different regions of the tongue is segregated in the medulla, thalamus, and cortex.

Attributions

- "Anatomy and Physiology Lab Reference" by Laird C Sheldahl, OpenOregonEducational Resources, Mt. Hood Community College is licensed under CC BY-SA 4.0
- "Biology 2e" by Mary Ann Clark, Matthew Douglas, Jung Choi, OpenStax is licensed under CC BY-NC 4.0
- "Human Anatomy Lab Manual" by Malgosia Wilk-Blaszczak, Mavs Open Press, University of Texas at Arlington is licensed under CC BY 4.0
- "Taste bud.svg" by NEUROtiker is licensed under CC BY-SA 3.0

Updated 2026.

This page titled 16.5: Taste Anatomy is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

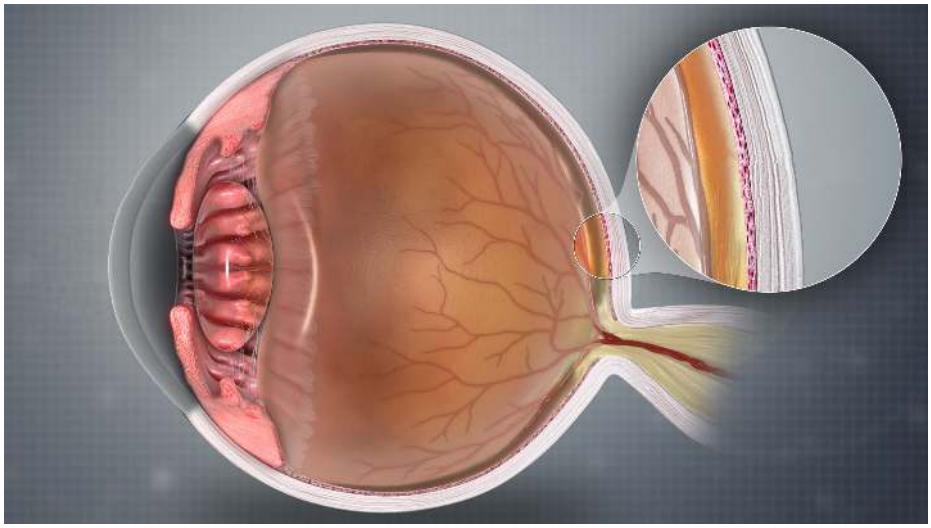
16.6: Laboratory Activities and Assignment

Laboratory Activities and Assignment

Part 1: Review of Vision Anatomy

1. Label the diagram of the eye below with the following structures:

- anterior cavity
- aqueous humor
- choroid
- ciliary body
- cornea
- fovea centralis
- iris
- lens
- optic disc
- optic nerve
- ora serrata
- posterior cavity
- pupil
- retina
- sclera
- suspensory ligaments
- vitreous humor



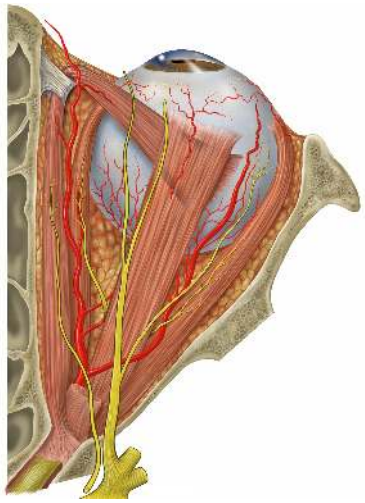
2. Below is a image of a microscopic section of the eye, magnified by 10x. Label the following structures:

- anterior cavity
- aqueous humor
- choroid
- ciliary body
- C.N. II optic nerve
- cornea
- lens
- optic disc
- posterior cavity
- retina
- sclera
- suspensory ligaments
- vitreous humor



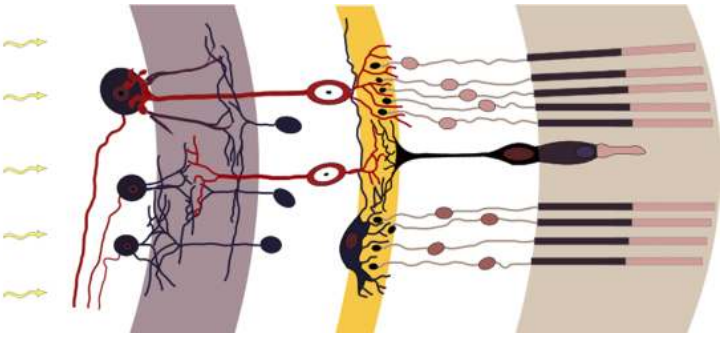
3. Label the following structures of the eye on the diagram below (superior view of the right eye).

• cornea • C.N. II optic nerve • C.N. III oculomotor nerve • C.N. IV trochlear nerve • iris	• lateral rectus • levator palpebrae superioris • medial rectus • optic canal • pupil	• sclera • superior oblique • superior rectus • trochlea of superior oblique



4. Below is a diagram of the cells in the retina. Label the following:

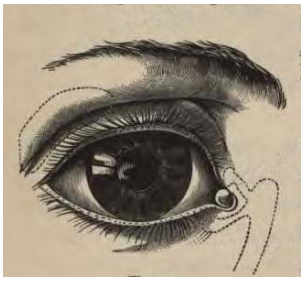
• bipolar cells • choroid • cone cells	• ganglion cells • posterior cavity of the eye	• retina • rod cells



5. On the diagram above, number the structures light information is processed through beginning with the photoreceptors and ending with the cells carrying light sensory information to the thalamus in the optic nerve.

6. On the diagram of the lacrimal apparatus below, label the following structures:

• inferior palpebra • lacrimal canaliculi • lacrimal caruncle	• lacrimal ducts • lacrimal gland • lacrimal puncta	• lacrimal sac • nasolacrimal duct • superior palpebra



7. On the diagram above, number the sequential path of lacrimal fluid.

8. In the boxes of the diagram below, place the appropriate letters with each labeled structure of the vision neural pathway.

A. Conscious visual sensation

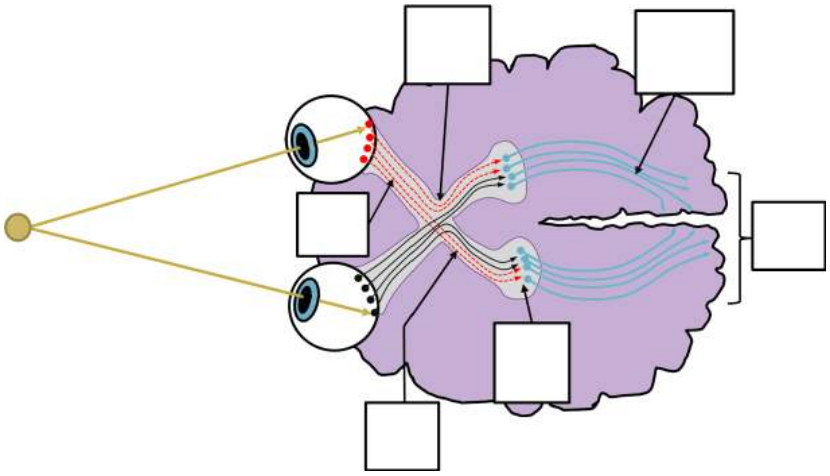
B. Beginning of axons of retinal ganglion cells

C. Third order neuron

D. Synapse between second and third order neuron in (in thalamus)

E. Half of nerve fibers decussate here

F. First region with axons from only the left side of both eyes



Part 2: Review of Auditory and Equilibrium Anatomy

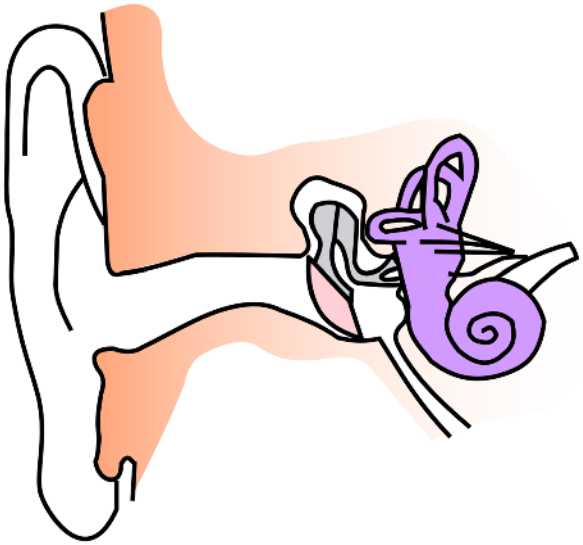
1. Match the following items to their proper location.

• auricle • cochlea • cochlear duct • endolymph • external auditory canal • hair cells	• incus • malleus • organ of Corti • oval window • round window	• semicircular canals • stapes • tympanic membrane • vestibule • vestibulocochlear nerve

Outer ear	Middle ear	Inner ear

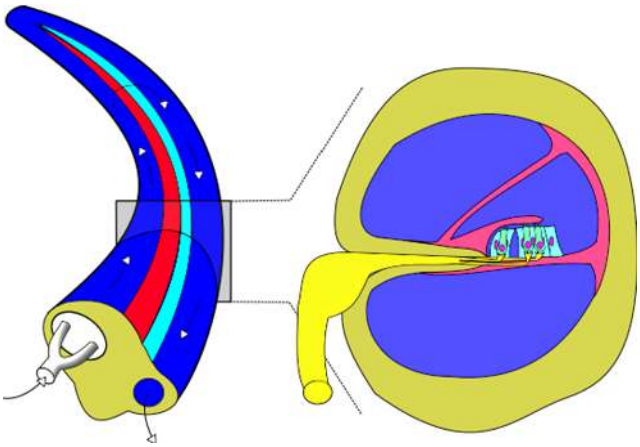
2. Label the following diagram with the structures listed below.

• auricle • cochlea • Eustachian tube • external acoustic meatus • external auditory canal • incus	• inner ear • malleus • middle ear • osseous labyrinth • outer ear • semicircular canals	• stapes • temporal bone • tympanic membrane • vestibule • vestibulocochlear nerve



3. Label the following diagram showing a section of the cochlea with the structures listed.

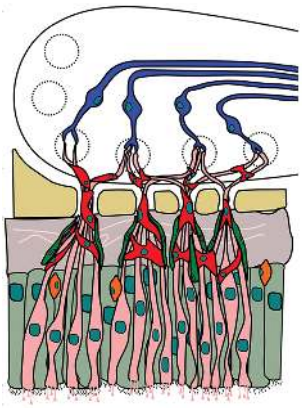
• basilar membrane • cochlea (uncoiled) • cochlear nerve • endolymph • hair cells	• organ of Corti • perilymph (2 places) • round window • scala media (cochlear duct) • scala tympani	• scala vestibuli • stapes • tectorial membrane • vestibular membrane



Part 3: Review of Olfactory Anatomy

1. Label the figure below with the following microstructures of olfaction:

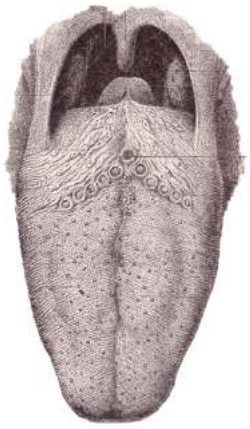
• axon of olfactory sensory neuron • C.N. I olfactory nerve • cribriform plate • mitral cell	• nasal cavity • olfactory bulb • olfactory cilia	• olfactory epithelium • olfactory foramina • olfactory sensory neuron



Part 4: Review of Taste Anatomy

1. On the figure below, label the following structures:

• circumvallate papillae • dorsal median sulcus	• epiglottis • foliate papillae	• fungiform papillae • lingual tonsil



2. Explain the role of the following structures in gustation:

   a. papillae:

   b. gustatory cells

   c. taste pore

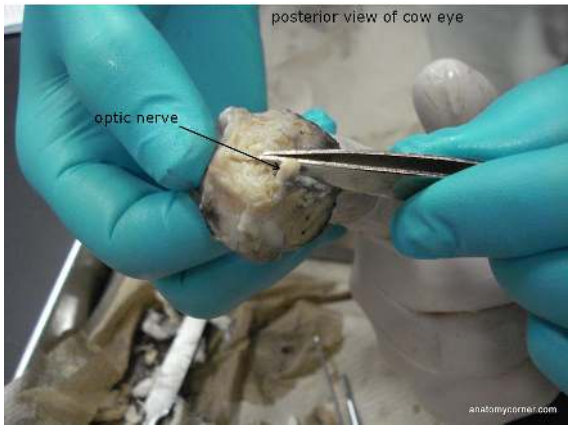
   d. taste bud:

3. Give the three cranial nerves that transmit taste sensory signals.

Part 5: Cow Eye Dissection

Instructions

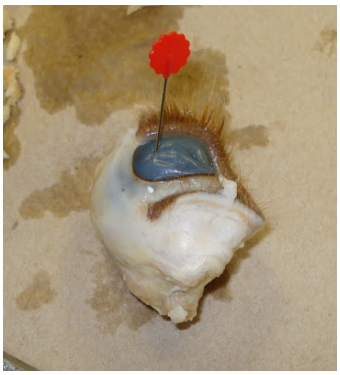
1. Collect a dissection tray, scalpel, scissors, probes, and gloves.
2. Obtain a preserved cow eye and place it on your dissection tray.
3. Examine the outside of the eye. You should be able to find the **sclera,** or the whites of the eye. This tough, outer covering of the eyeball has fat and muscle attached to it.
4. Locate the covering over the front of the eye, the **cornea**. When the cow was alive, the cornea was clear. In your cow's eye, the cornea may be cloudy or blue in color.
5. Illustrate the outer eye in the space below. Label the following structures on your illustration (alternatively, you may take a photo and label it on the computer).
   - adipose tissue (fat)
   - cornea
   - sclera
6. Cut the fat around the eye and remove it.
7. Identify the optic nerve. It can be seen on the back of the eye. The nerve is usually buried in fat, so it will take some work to expose it.



Above: Posterior view of a cow eye with adipose tissue cut away to reveal the optic nerve.

8. Puncture the cornea (pinned in the image below) with scissors or scalpel. Liquid should leak out.

What is the name of the fluid that leaked out when the cornea was punctured? _____ *(Hint: Which cavity of the eye did you open?)*

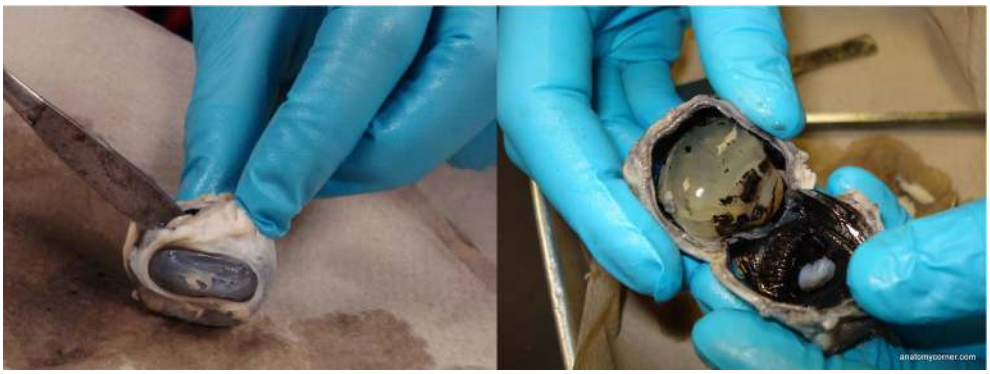


Above: Cow eye with the cornea pinned

9. Cut the eye in a frontal section (separating anterior and posterior). See image below. This cut will open another cavity of the eye.

Name the cavity of the eye that was opened when making the frontal section: _____

What is the name of the gelatinous fluid inside this cavity of the eye? _____



Above: Making a frontal section of a cow eye.

10.Open the eye (as shown in the image above).

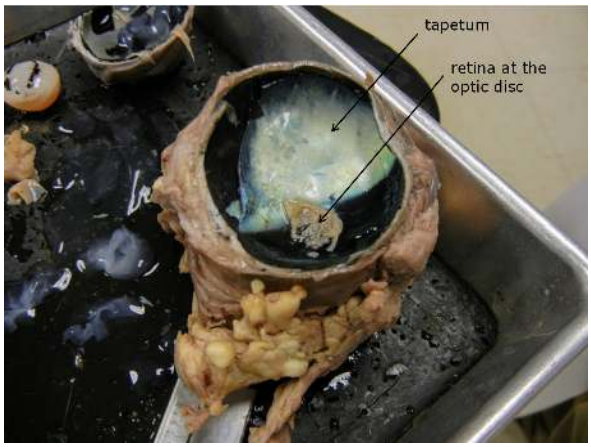
11.Separate the parts of the eye. The lens is the hard, sphere-shaped structure sitting in or on the liquid in this cavity.

12.Find the cornea (which you punctured in step 8) and then the disk-shaped **iris** behind it.

13.The iris will be dark in color and contain a center opening, the **pupil.**

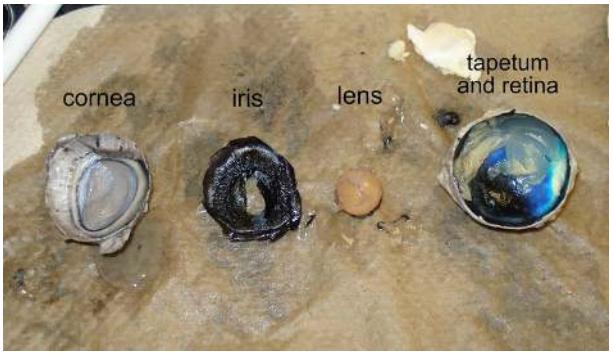
14.On the back of the eye, the thin layer of cells of the **retina** can be seen. It is very thin and easy to pull away. The spot where they remain attached is the optic disk which connects the retina to the optic nerve.

15.The **tapetum** (a layer of the choroid that is highly reflective in animals) is clearly visible when the retina is removed. It is blue and shiny and will reflect light. This helps the cow to see in the dark



Above: Cow eye showing the tapetum and a small portion of retina remaining at the optic disc.

16.The image below shows how each part of the eye appears when it has been separated.



Above: Isolated structures of a dissected cow eye.

17.Illustrate the structures of your dissected cow eye and label the following structures in the space below. Alternatively, you can take a photo and label the image.

- cornea
- iris
- lens
- pupil
- retina
- tapetum

18.[Optional] Take a photo of your dissected cow eye and share it on social media. #coweyedissection

Part 6: Sound Localization Activity

Materials Required

- tuning forks (1 per group)

Instructions

1. Have a subject sit with their eyes closed.
2. Using a tuning fork, strike the fork so it makes a sound and move it to the front, back, side and top of head at a constant distance.
3. The subject will use their figure to continue pointing out the location they believe the sound is coming from as the tuning fork moves.
4. Note the accuracy at each position of their pointing, and determine the most and least accurate positions for localization.
5. Repeat with another subject.

In the table below, write a check mark when the subject accurately pointed out the position of the tuning fork. Write an X when the subject inaccurately pointed out the position of the tuning fork.

Subject #	Anterior to head	Posterior to head	Lateral (right) to head	Lateral (left) to head	Superior to head
1					
2					
3					

Subject #	Anterior to head	Posterior to head	Lateral (right) to head	Lateral (left) to head	Superior to head
4					
5					
6					

6. Were there any positions of the tuning fork where sound localization was most accurate? If so, which ones?

7. Were there any positions of the tuning fork where sound localization was least accurate? If so, which ones?

8. Consider the anatomy of the auditory sense (macroscopic and microscopic). What features of the anatomy might account for the observations you made in 6. and 7.?

Part 7: Olfaction Threshold

Material Required

- Serial dilutions of odorant oils in sealed containers (lowest concentration should be less than micromolar concentrations) - may use spearmint, orange, anise, etc.

Instructions

Humans consistently recognize certain odorants when their olfactory epithelium detects inhaled chemicals. In this activity, you will test your olfactory sensitivity for each by starting with a series at the low end of the concentrations.

1. Unseal the lowest concentration solution and smell it. If you smell an odor from the solution, put a check mark in the table below for "concentration 1." If you do not smell an odor, write an X.
2. Repeat this procedure for all five solutions, each with an increasing concentration of odorant.

	Concentration 1	Concentration 2	Concentration 3	Concentration 4	Concentration 5
Result					

3. Inform your instructor of the lowest concentration that you first smelled the odorant. They will compile class results.

4. Record the class results shared by your instructor below.

	Number of Students at this Detection Level	Percentage of the Class
Concentration 1		
Concentration 2		
Concentration 3		
Concentration 4		
Concentration 5		
Total		

5. Discuss the macroanatomy and microanatomy of olfaction with your lab group and how chemical molecules are detected through olfaction. What individual anatomical differences might account for the ability to detect smells at lower concentrations than others?

Part 8: Are You a Super-Taster?

Materials Required

- dark-colored food coloring liquid or power
- clean spoons (1 per student)
- paper squares with 1 cm diameter holes in them (1 per student)
- camera phones

Instructions

1. Use a spoon to put a ***small amount*** of dark food coloring liquid or powder on the surface of the tongue. Your goal is to stain the surface of your tongue.
2. Align your paper square with a hole above the stained part of your tongue.
3. Have another student take a clear, close-up image of your tongue in the circle.
4. The papillae on the surface of your tongue will be obvious since their color will contrast the color of the food coloring. Count the number of papillae on your tongue using the image taken.
5. Record the number of papillae in the circle on your tongue in the table and share this number with your instructor who will compile all of the data from the rest of the class.

Data Collection and Analysis

1. Number of papillae on my tongue in a 1 cm diameter circle: _____

The number of papilla in the circle indicates whether you are an "average-taster," a "hypo-taster" with fewer papilla than average, or a "hyper-taster" with more papilla than average.

- 0 - 5 papillae = "hypo-taster"
- 6 - 15 papillae = "average taster"

- 16+ papillae = "hyper-taster"

A "hypo-taster" is more tolerant of bitter tastes. A hyper-taster is more sensitive to bitter tastes.

2. What type of taster are you based on your data? _____

3. Collect class data below and calculate the percentages of the class that are "hypo-tasters," "average tasters," and "hyper-tasters."

Taster type	Number of students	Percentage of Students
hypo		
average		
hyper		
Total		

Activity Questions

1. Explain how the number of papillae on your tongue relates to your taste sensitivity. Relate the anatomy of taste (including the microscopic anatomy of taste) with your answer.

2. Does your experience validate the data collected in this experiment? For example, if you are a "hypo-taster" do you notice that bitter tasting foods seem to bother you less than other people?

Attributions

Part 1: Review of Vision Anatomy

- "3D Medical Animation Eye Structure.jpg" by https://www.scientificanimations.com is licensed under CC BY-SA 4.0
- "Anatomy and Physiology Lab Homework" by Laird C Sheldahl is licensed under CC BY-SA 4.0
- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0
- "Eye orbit anatomy superior.jpg" by Patrick J. Lynch, medical illustrator is licensed under CC BY 2.5
- "Physiology for Young People - 1884 - The eye.png" by Alonzo Benjamin Palmer; Ezra M. Hunt, et al is in the Public Domain
- "Retina-diagram.svg" by Ramón y Cajal is licensed under CC BY-SA 3.0 / A derivative from the original work

Part 2: Review of Auditory and Equilibrium Anatomy

- "Anatomy and Physiology Lab Homework" by Laird C Sheldahl is licensed under CC BY-SA 4.0
- "Ear-anatomy-notext-small.svg" by Iain is licensed under CC BY-SA 3.0

Part 3: Review of Olfactory Anatomy

- "Location of olfactory ensheathing cells (OECs) within the olfactory system.png" by A. A. Wright, M. Todorovic, J. Tello-Velasquez, A. J. Rayfield, J. A. St John, J. A. Ekberg is licensed under CC BY 4.0

Part 4: Review of Taste Anatomy

- "The Tongue.jpg" by Frederick M. Rossiter is in the Public Domain

Part 5: Cow Eye Dissection

- "Anatomy and Physiology I Lab" by Victoria Vidal is licensed under CC BY 4.0
- "Cow Eye Virtual Dissection " by biologycorner is licensed under CC BY-NC-SA 4.0

Part 6: Sound Localization Activity

- "Principles of Biology II Lab Manual (BIOL 1108) " by Dalton State is licensed under CC BY-SA 4.0

Part 7: Olfaction Threshold

- "Principles of Biology II Lab Manual (BIOL 1108) " by Dalton State is licensed under CC BY-SA 4.0

Part 8: Are You a Super-Taster?

- "Human Anatomy Lab Manual" by Malgosia Wilk-Blaszczak, Mavs Open Press, University of Texas at Arlington is licensed under CC BY 4.0

Updated 2026.

This page titled 16.6: Laboratory Activities and Assignment is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

16.7: Collaborative Study Activities

Collaborative Study Activities

These activities are designed for student groups of 2-4. Larger groups will work better when there is no supplemental instructor present in the laboratory to assist in testing student groups on each section.

Vision Anatomy

1. Identify the following structures on classroom anatomical models and/or unlabeled images/diagrams made available by your instructor. Work with your group to identify each structure and check them off the list once you have identified them.

☐ anterior cavity	☐ inferior rectus	☐ superior palpebra
☐ aqueous humor	☐ iris	☐ posterior cavity
☐ choroid	☐ lacrimal caruncle	☐ pupil
☐ ciliary body	☐ lacrimal gland	☐ retina
☐ C.N. II optic nerve	☐ lacrimal puncta	☐ trochlea of superior oblique
☐ cornea	☐ lateral rectus	☐ sclera
☐ fovea centralis	☐ lens	☐ superior oblique
☐ inferior oblique	☐ medial rectus	☐ superior rectus
☐ inferior palpebra	☐ ora serrata	☐ vitreous humor

2. Test your group members by ***asking them to name each structure you point to***. Check off each when your group can successfully name each. Your group will also test you.

☐ anterior cavity	☐ inferior rectus	☐ superior palpebra
☐ aqueous humor	☐ iris	☐ posterior cavity
☐ choroid	☐ lacrimal caruncle	☐ pupil
☐ ciliary body	☐ lacrimal gland	☐ retina
☐ C.N. II optic nerve	☐ lacrimal puncta	☐ trochlea of superior oblique
☐ cornea	☐ lateral rectus	☐ sclera
☐ fovea centralis	☐ lens	☐ superior oblique
☐ inferior oblique	☐ medial rectus	☐ superior rectus
☐ inferior palpebra	☐ ora serrata	☐ vitreous humor

3. When you and your group are comfortable identifying all the structures above, request the assistance of your Instructor. They will test you on your use of these terms and initial ONLY when you are successful using these terms. Instructor: _____

Auditory and Equilibrium Anatomy

1. Identify the following structures on classroom anatomical models and/or unlabeled images/diagrams made available by your instructor. Work with your group to identify each structure and check them off the list once you have identified them.

☐ ampullae of semicircular canals	☐ inner ear	☐ round window
☐ auditory ossicles	☐ malleolus	☐ saccule
☐ auricle	☐ membranous labyrinth	☐ semicircular canals
☐ cochlea	☐ middle ear	☐ stapes
☐ cochlear duct	☐ organ of Corti	☐ tympanic membrane
☐ Eustachian tube	☐ osseous labyrinth	☐ utricle
☐ external acoustic meatus	☐ outer ear	☐ vestibule
☐ external auditory canal	☐ oval window	☐ vestibular nerve
☐ endolymph	☐ perilymph	☐ vestibulocochlear nerve
☐ incus		

2. Test your group members by ***asking them to name each structure you point to***. Check off each when your group can successfully name each. Your group will also test you.

☐ ampullae of semicircular canals ☐ auditory ossicles ☐ auricle ☐ cochlea ☐ cochlear duct ☐ Eustachian tube ☐ external acoustic meatus ☐ external auditory canal ☐ endolymph ☐ incus	☐ inner ear ☐ malleolus ☐ membranous labyrinth ☐ middle ear ☐ organ of Corti ☐ osseous labyrinth ☐ outer ear ☐ oval window ☐ perilymph	☐ round window ☐ saccule ☐ semicircular canals ☐ stapes ☐ tympanic membrane ☐ utricle ☐ vestibule ☐ vestibular nerve ☐ vestibulocochlear nerve

3. When you and your group are comfortable identifying all the structures above, request the assistance of your Instructor. They will test you on your use of these terms and initial ONLY when you are successful using these terms. Instructor: _____

Olfactory Anatomy

1. Identify the following structures on classroom anatomical models and/or unlabeled images/diagrams made available by your instructor. Work with your group to identify each structure and check them off the list once you have identified them.

☐ C.N. I olfactory nerve ☐ cribriform plate	☐ olfactory bulb ☐ olfactory epithelium	☐ olfactory foramina

2. Test your group members by ***asking them to name each structure you point to***. Check off each when your group can successfully name each. Your group will also test you.

☐ C.N. I olfactory nerve ☐ cribriform plate	☐ olfactory bulb ☐ olfactory epithelium	☐ olfactory foramina

Taste Anatomy

1. Identify the following structures on classroom anatomical models and/or unlabeled images/diagrams made available by your instructor. Work with your group to identify each structure and check them off the list once you have identified them.

☐ circumvallate papilla ☐ dorsal median sulcus ☐ epiglottis	☐ foliate papillae ☐ fungiform papilla	☐ lingual tonsil ☐ palatine tonsil

2. Test your group members by ***asking them to name each structure you point to***. Check off each when your group can successfully name each. Your group will also test you.

☐ circumvallate papilla ☐ dorsal median sulcus ☐ epiglottis	☐ foliate papillae ☐ fungiform papilla	☐ lingual tonsil ☐ palatine tonsil

3. When you and your group are comfortable identifying all the structures above, request the assistance of your Instructor. They will test you on your use of these terms and initial ONLY when you are successful using these terms. Instructor: _____

Updated 2026.

This page titled 16.7: Collaborative Study Activities is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

CHAPTER OVERVIEW

17: Cardiovascular System - The Heart

17.1: Introduction
17.2: Location, Size, and Shape of the Heart
17.3: Vessels of the Heart
17.4: Layers of the Heart
17.5: Internal Structures of the Heart
17.6: Circulation Through the Heart
17.7: Coronary Circulation
17.8: Heart Abnormalities and Treatments
17.9: Laboratory Activities and Assignment
17.10: Collaborative Study Activities

This page titled 17: Cardiovascular System - The Heart is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

17.1: Introduction

Introduction

The cardiovascular system is composed of the heart and the blood vessels. The main function of this body system is to distribute materials throughout the body, including oxygen and energy-rich nutrients. The heart is the muscular pump of the cardiovascular system and the blood vessels are a delivery system. To understand how the heart functions, it is necessary to also study the large blood vessels that deliver blood directly into the heart and carry blood immediately out of the heart. In the cardiovascular system, there are two major categories of large vessels: **arteries** and **veins**. Arteries ("a" for "away") carry blood ***away*** from the heart. Veins carry blood ***toward*** the heart.

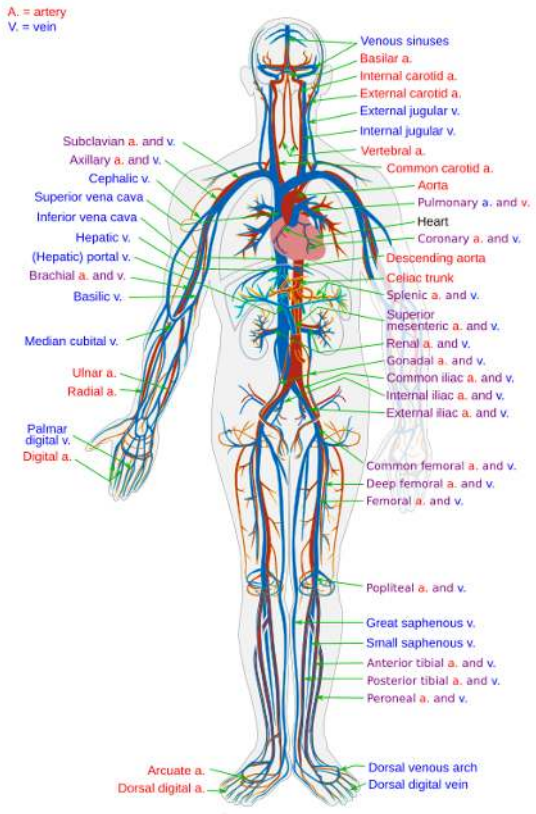


Figure 1: Anatomy of the cardiovascular system.

When considering blood flow, the amount of oxygen in the blood is of great importance. Oxygen, acquired from the lungs, is transported in the blood and used by body cells to conduct **cellular respiration**, a metabolic process that makes the body's main energy molecule: ATP. ATP is such an important source of energy in the body that if there is not enough oxygen to make ATP, an individual will die.

When showing blood flow in anatomical diagrams, vessels that are colored blue carry oxygen-poor blood and vessels that are colored red carry oxygen-rich blood. Most of the time, arteries are shown as red in anatomical diagrams because they usually carry oxygen-rich blood (*exceptions*: the **pulmonary trunk** and the **pulmonary arteries** that carry oxygen-poor blood from the heart to the lungs). Most of the time, veins are shown as blue in anatomical diagrams because they usually carry oxygen-poor blood (*exception:* the **pulmonary veins** that carry oxygen-rich blood from the lungs to the heart).

Attributions

- "Anatomy and Physiology Lab Reference" by Laird C Sheldahl, OpenOregonEducational Resources, Mt. Hood Community College is licensed under CC BY-SA 4.0
- "Circulatory System en.svg" by LadyofHats is in the public domain
- "Heart Anatomy" by Dongho Kim is licensed under CC BY-NC-SA 4.0

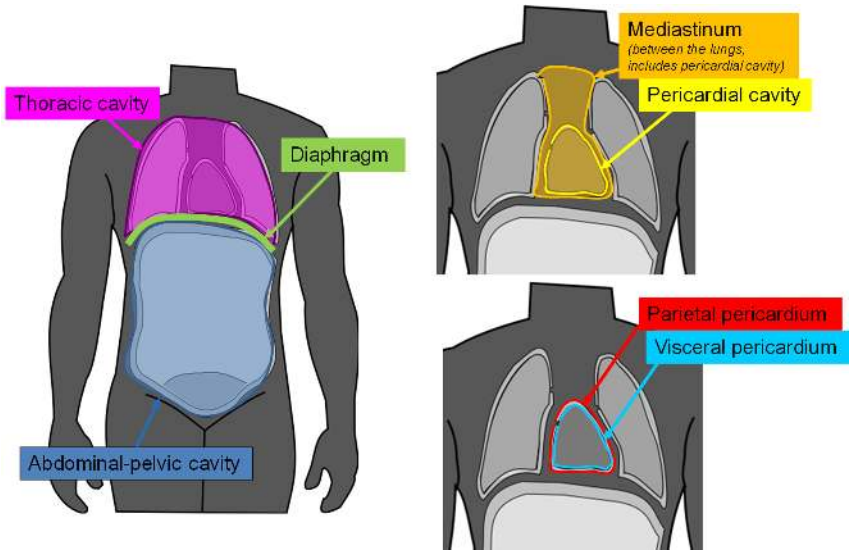
Updated 2026.

This page titled 17.1: Introduction is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

17.2: Location, Size, and Shape of the Heart

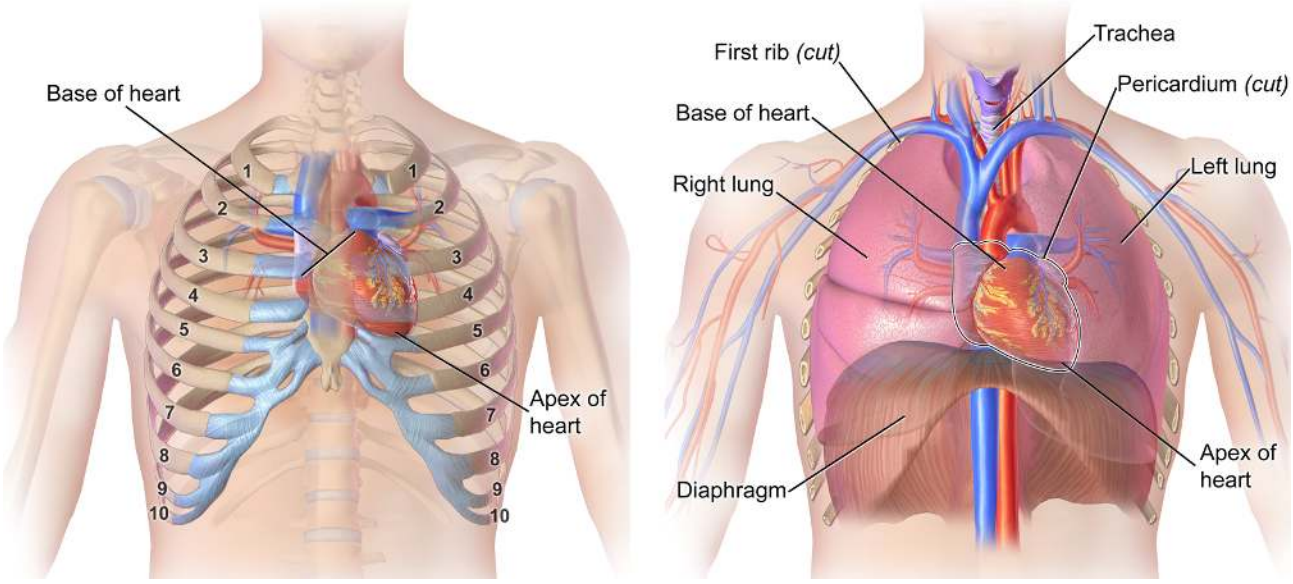
Location, Size, and Shape of the Heart

The heart is located within the **ventral body cavity**. Recall that the ventral body cavity is further subdivided into the **thoracic cavity** and the **abdominopelvic cavity**, separated by the diaphragm. The heart is located within the thoracic cavity. Between the two lungs and their cavities (pleural cavities) is a central cavity called the **mediastinum**. The heart is located inside of the mediastinum in an inner cavity called the **pericardial cavity**. Serous membranes form the pericardial cavity with the outer layer being the **parietal pericardium** and the inner layer being the **visceral pericardium** (also known as the **epicardium**). Between these serous membranes is the pericardial cavity filled with a small amount **pericardial fluid** produced by these membranes to allow the heart to move and reducing friction. In some cases, too much pericardial fluid will build up in the cavity; this is called **pericardial effusion**.

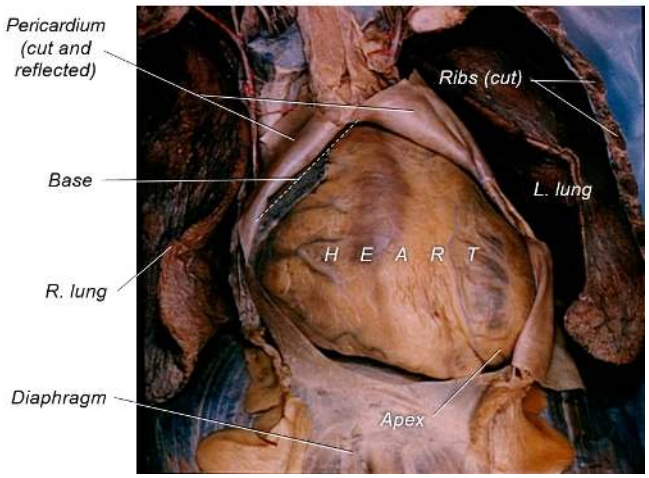


Above: Diagram of the ventral body cavity, mediastinum, pericardial cavity, and the serosa of the pericardial cavity.

The shape of the heart is similar to a pinecone, broad at the superior surface (called the **base**) and tapering to the **apex**. A typical heart is approximately the size of your fist: 12 cm (5 in) in length, 8 cm (3.5 in) wide, and 6 cm (2.5 in) in thickness. Given the size difference between most members of the sexes, the weight of a female heart is approximately 250–300 grams and the weight of a male heart is approximately 300–350 grams. For comparison sake, a typical apple is about 100 grams. Therefore, the weight of a human heart would be about the same weight as two and a half to three and a half apples.



Above: Diagram showing the position of the heart in relationship to the ribs, lungs and diaphragm. The base of the heart and the apex of the heart are also labeled.



Above: Cadaver image of the human heart, anterior view.

Attributions

- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Heart Anatomy" by Dongho Kim is licensed under CC BY-NC-SA 4.0
- "Medical gallery of Blausen Medical 2014" by Blausen.com staff is licensed under CC BY 3.0

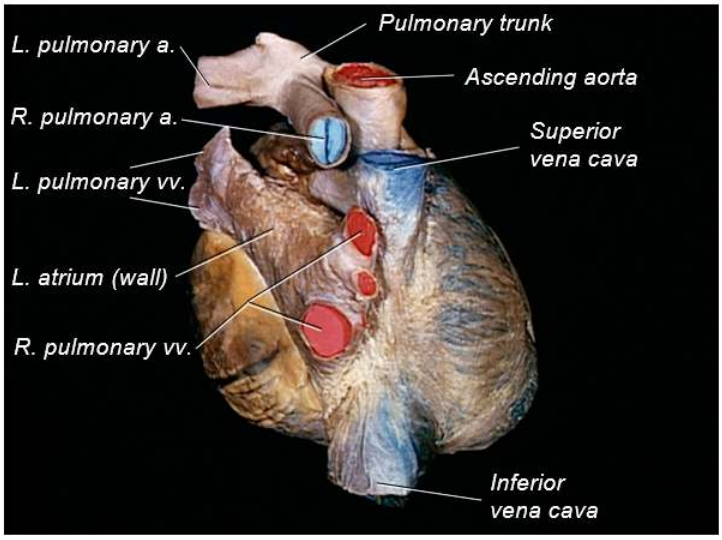
Updated 2026.

This page titled 17.2: Location, Size, and Shape of the Heart is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

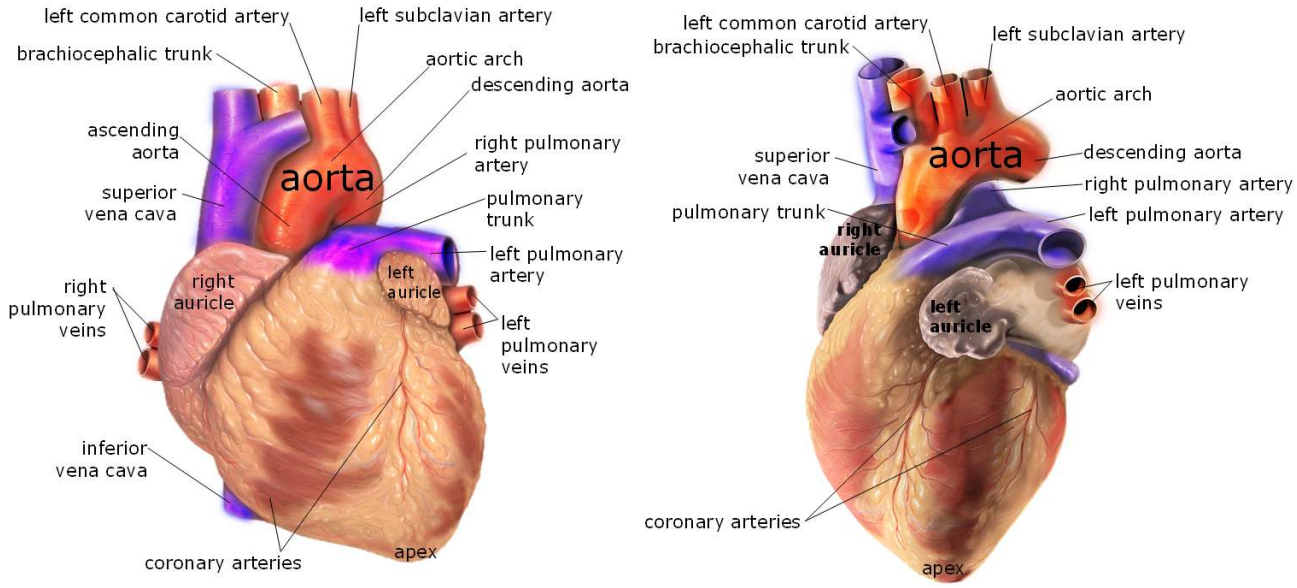
17.3: Vessels of the Heart

Vessels of the Heart

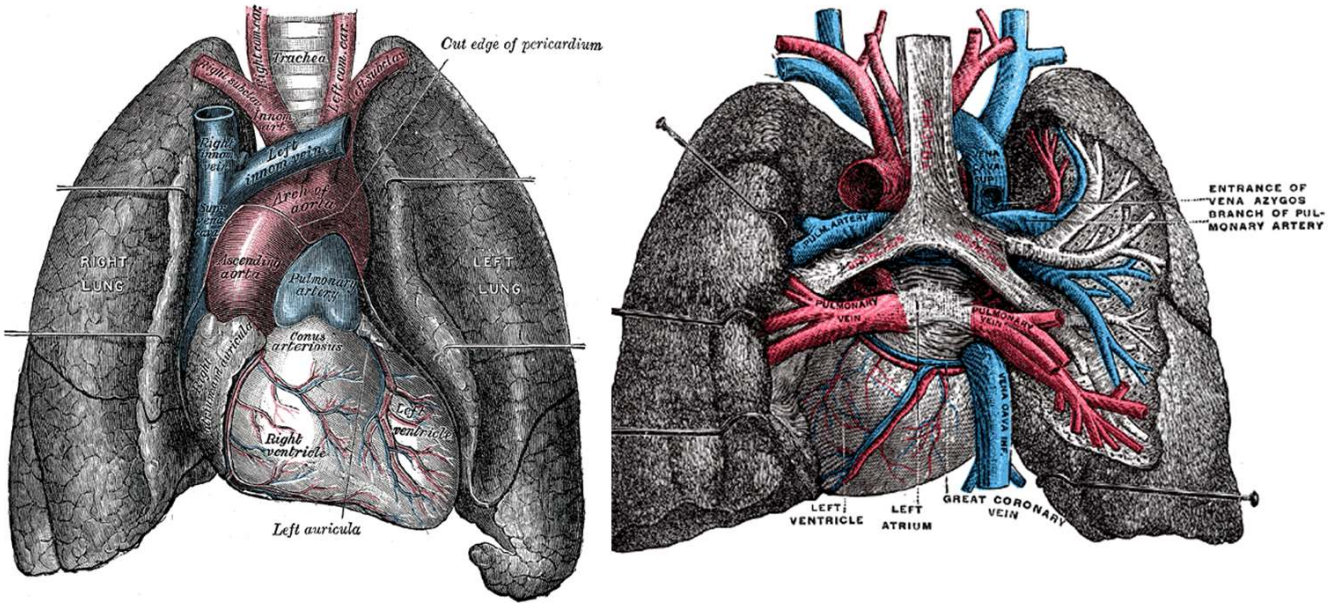
The major vessels carrying blood away from the heart are the **aorta** and the **pulmonary trunk** which splits into the **right** and **left pulmonary arteries**. The aorta has different regions (**ascending aorta**, **aortic arch**, and **descending aorta**). The descending aorta is shown in the figures as being cut, but would continue to descend along the posterior aspect of the heart through the thoracic and abdominal cavities. The right and left pulmonary arteries travel to the right and left lungs, respectively.



Above: Lateral view of the right side of a heart with blood vessels colored to indicate the oxygenation of blood passing through these vessels.



Above: Large vessels of the heart (left) anterior view and (right) lateral view of the left side of the heart.



Above: External view of the heart and its large vessels (left) anterior view and (right) posterior view. In the posterior view, the trachea and bronchi block the view of the ascending aorta, aortic arch, and pulmonary trunk, but the descending aorta and right and left pulmonary arteries can be seen.

The major vessels carrying blood toward the heart are the **superior vena cava** (vena= vein), **inferior vena cava**, **left pulmonary veins**, and **right pulmonary veins**. The superior vena cava and inferior vena cava carry blood to the heart from the superior and inferior regions of the body, respectively. The right and left pulmonary veins carry blood back to the heart from the right and left lungs, respectively.

Coronary arteries are found along the surface of the heart. These arteries provide nutrients to the heart tissue. The individual coronary arteries have specific names - see the **Coronary Circulation** section in this chapter.

Attributions

- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Heart anterior exterior view.jpg" by Patrick J. Lynch, medical illustrator is licensed under CC BY 2.5
- "Heart oblique external.jpg" by Patrick J. Lynch, medical illustrator is licensed under CC BY 2.5

Updated 2026.

This page titled 17.3: Vessels of the Heart is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

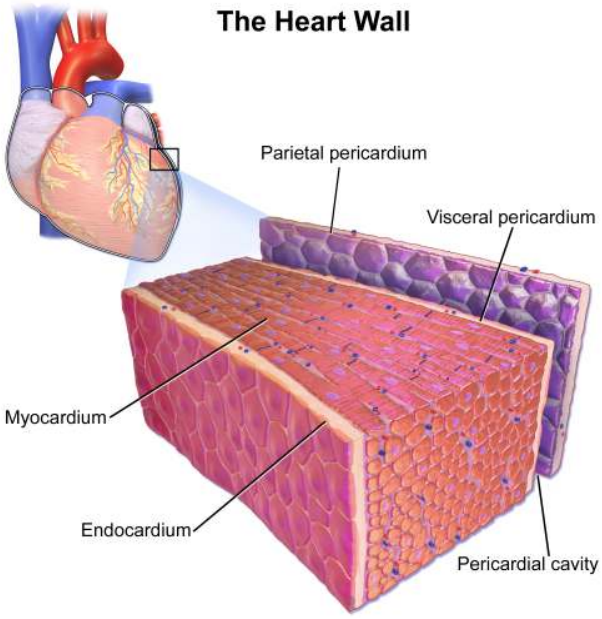
17.4: Layers of the Heart

Layers of the Heart

As mentioned in the previous section, the heart is located in the pericardial cavity formed by the serous membranes of the pericardium. There are two layers of serous membranes (parietal and visceral) with the outer layer being the parietal pericardium which attaches the heart to the mediastinum and has fibrous tissue so the heart does not over-expand. The inner visceral layer is also called the **epicardium** and it lines the surface of the heart. Between these two membranes is a space, the pericardial cavity, containing a small amount of fluid to reduce friction as the heart moves. Both layers have mesothelium which produces serous fluid.

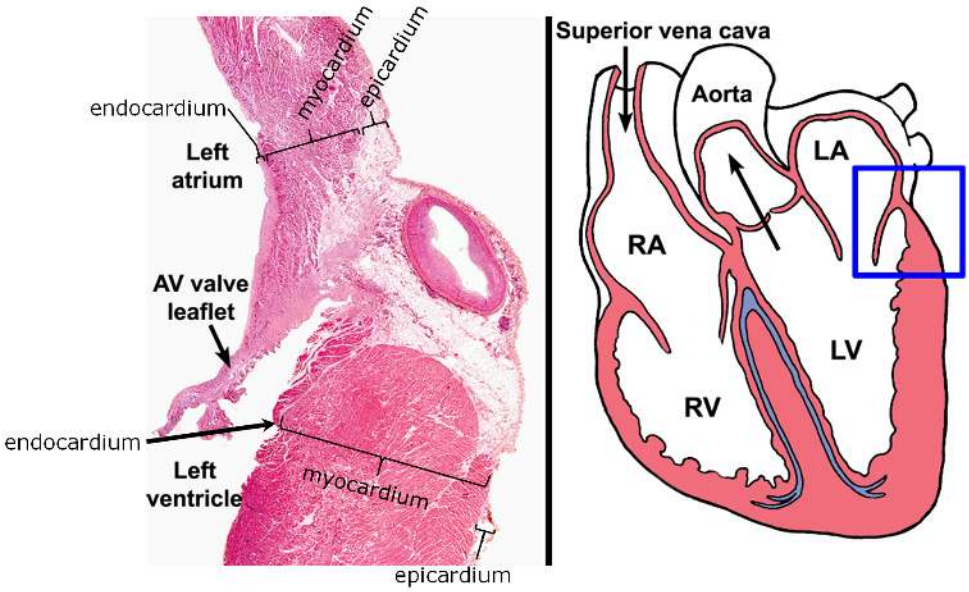
The heart wall is composed of three layers (from outside to inside):

1. **epicardium** - the same tissue as the visceral pericardium
2. **myocardium** - makes up most of heart wall, composed of cardiac muscle tissue (which is made of uninucleated cardiac muscle cells
3. **endocardium** - a thin layer of endothelial tissue that lines the heart chambers



Above: Tissue layers of the heart wall and the pericardium.

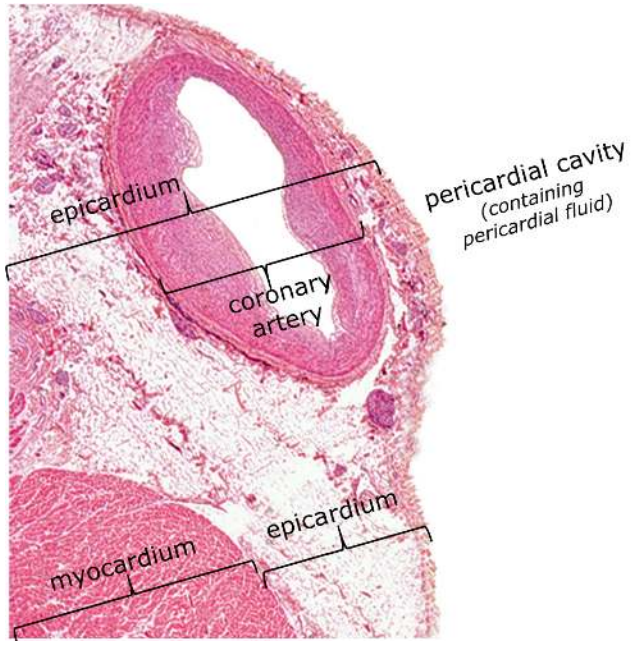
https://bio.libretexts.org/@go/page/53778



Above: Tissue layers of the wall of the heart (epicardium, myocardium, and endocardium). (Left) Tissues of the heart magnified by 10x. The region of the heart wall magnified is depicted in the diagram on the right inside the blue box.

Epicardium

The epicardium (visceral pericardium) is a serous membrane (serosa) of variable thickness, forming the outermost tunic of the heart. The connective tissue portion of this layer lies adjacent to the myocardium and is covered by a simple squamous epithelium (mesothelium) that faces the pericardial space. Coronary vessels, nerves and adipocytes are located in this layer.



Above: Epicardium (aka visceral pericardium), magnified 100x.

Myocardium

The myocardium is the middle layer of the heart and is composed of cardiac muscle with connective tissue and blood vessels. The single nucleus of each muscle cell is centrally located, frequently surrounded by a clear space where organelles are located. In a cross section, the myofibrils can be easily distinguished.

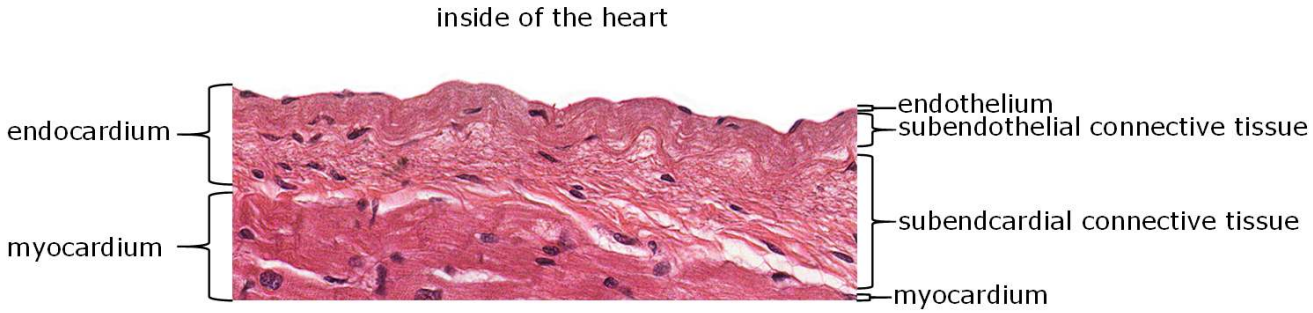
Diagnostic features of cardiac muscle fibers are central nuclei, branching fibers and **intercalated discs**. Intercalated discs, appearing as thick lines, are specialized communication junctions between fibers enabling synchronized contraction of these muscle cells; each is composed of interdigitating plasma membranes, myofilaments and cell junctions. The striations and banding pattern of cardiac muscle are not very obvious in this longitudinal section.



Above: Tissue of the myocardium. (Left) Cross section of myocardial tissue, magnified 1000x. (Right) Longitudinal section of myocardial tissue, magnified 400x.

Endocardium

The endocardium lines the heart chambers and is continuous with the tunica intima of blood vessels. It consists of a simple squamous epithelium (endothelium), an underlying layer of subendothelial connective tissue that may contain smooth muscle fibers, and a deeper layer of subendocardial connective tissue. Elements of the conducting system of the heart, **Purkinje fibers**, are located in the subendocardial connective tissue. The endocardium is thicker in the atria than in the ventricles. **Endocarditis** is a medical condition involving the endocardium that occurs when the tissue of the endocardium becomes inflamed, typically caused by a bacterial infection of the endocardium near the heart valves.



Above: Tissue of the endocardium, magnified by 400x.

Attributions

- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0
- "Heart Anatomy" by Dongho Kim is licensed under CC BY-NC-SA 4.0
- "Medical gallery of Blausen Medical 2014" by Blausen.com staff is licensed under CC BY 3.0

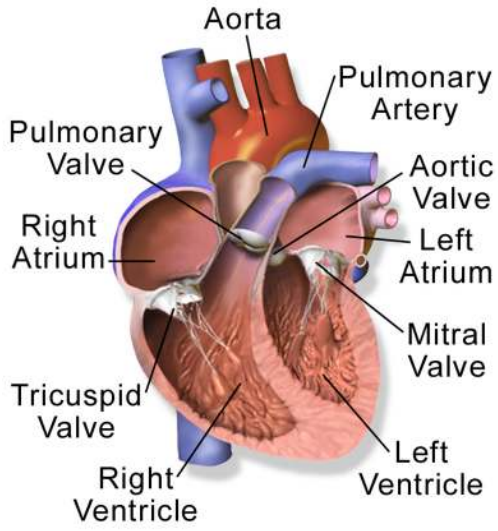
Updated 2026.

This page titled 17.4: Layers of the Heart is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

17.5: Internal Structures of the Heart

Internal Structures of the Heart

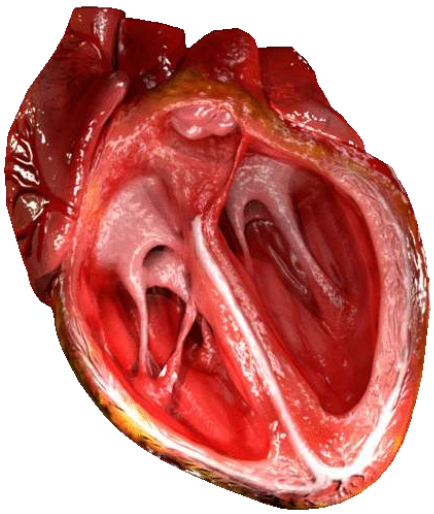
The heart is divided into four chambers: **right atrium**, **right ventricle**, **left atrium**, and **left ventricle**. The atria are the two superior chambers of the heart and the ventricles are the two inferior chambers of the heart. The right side of the heart and the left side of the heart are isolated from each other (each belongs to a separate circuit - see the **Circulation Through the Heart** section below). The right and left sides are separated by septa. Between the right and left atria is tissue called the **interatrial septum** and between right and left ventricles is tissue called the **interventricular septum**.



Above: Chambers and valves of the heart.

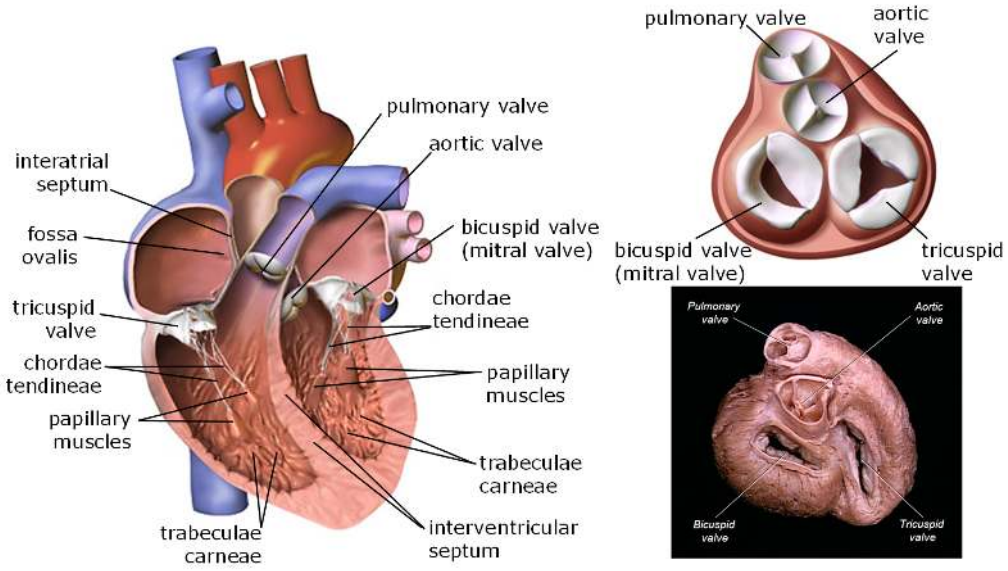
Heart Chamber	Location	Blood flowing into this chamber	Blood flowing out of this chamber	Associated valves
left atrium	superior left side of the heart	from pulmonary veins; oxygen-rich blood	to the left ventricle	**mitral valve** (aka **left atrioventricular valve**; aka **bicuspid valve**) drains blood from the left atrium when it is open during ventricular diastole
left ventricle	inferior left side of the heart	from left atrium; oxygen-rich blood	to the aorta	blood moves into this chamber through the **mitral valve** (aka **left atrioventricular valve**; aka **bicuspid valve**) during ventricular diastole; blood moves out of this chamber through the **aortic valve** during ventricular systole
right atrium	superior right side of the heart	from superior vena cava and inferior vena cava; oxygen-poor blood	to the right ventricle	**tricuspid valve** (aka **right atrioventricular valve**) drains blood from the right atrium when it is open during ventricular diastole
right ventricle	inferior right side of the heart	from right atrium; oxygen-poor blood	to the pulmonary trunk	blood moves into this chamber through the **tricuspid valve** (aka **right atrioventricular valve**) during ventricular diastole; blood moves out of this chamber through the **pulmonary valve** during ventricular systole

There are four valves in the heart: two that separate the atria from the ventricles on both the right and left sides (**atrioventricular [AV] valves**), and two that separate the ventricles from their associated arteries (**aortic valve** and **pulmonary valve**). The aortic valve and pulmonary valve are sometimes called **semilunar valves** since they are composed of three crescent-shaped cusps. The AV valves are also called the **tricuspid valve** and the **bicuspid valve** (aka the **mitral valve**); these names describe the number of cusps that make them up (tri= 3 cusps; bi= 2 cusps). Heart valves are either open or they are closed based on whether the heart muscle of the ventricles is contracting, **ventricular systole**, or the heart muscle of the ventricles is not contracting, **ventricular diastole**. Both systole and diastole are equally important for moving blood effectively though the heart and through the blood circulation circuits.



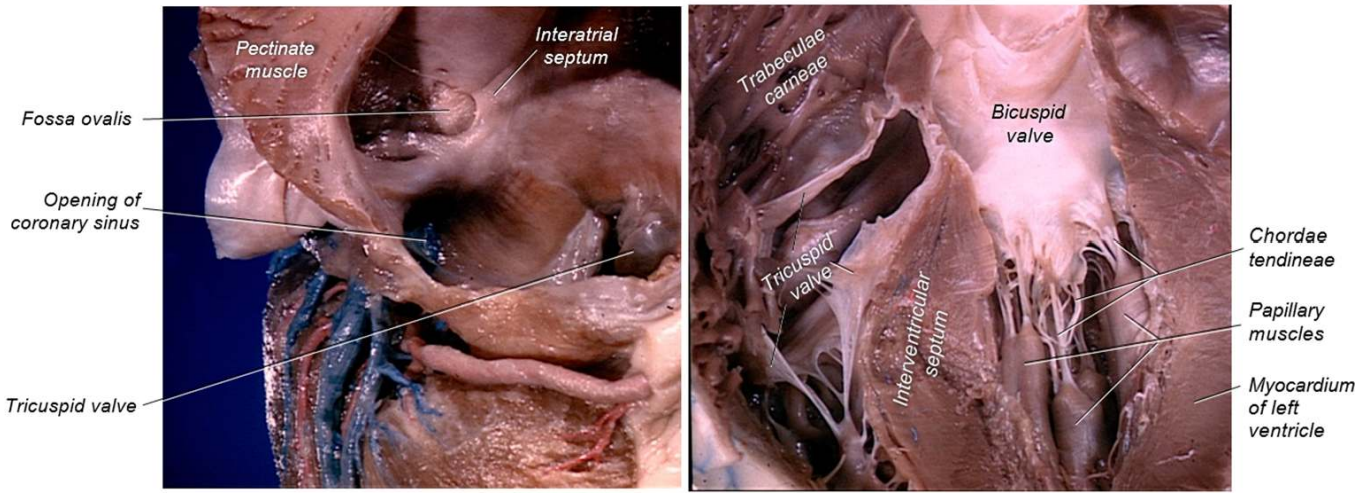
Above: Animated heart pumping with the ventricles shown open.

Heart Valve	Location	During ventricular systole	During ventricular diastole	How it Works
aortic valve	between the left ventricle and the aorta	open	closed	valve is closed unless pressure inside the ventricle pushes it open
mitral valve (left atrioventricular [AV] valve; bicuspid valve)	between the left atrium and the left ventricle	closed	open	valve is open unless pressure inside the ventricle pushes it closed; papillary muscles and chordae tendineae prevent the valves from flipping open during ventricular systole (prolapse)
pulmonary valve	between the right ventricle and the pulmonary trunk	open	closed	valve is closed unless pressure inside the ventricle pushes it open
tricuspid valve (right atrioventricular [AV] valve)	between the right atrium and the left ventricle	closed	open	valve is open unless pressure inside the ventricle pushes it closed; papillary muscles and chordae tendineae prevent the valves from flipping open during ventricular systole (prolapse)



Above: Internal structures of the heart. (Left) Anterior view of the internal heart and (right) superior view of the valves of the heart with the atria removed.

Internal Heart Structure	Location	Function/Description
chordae tendineae	connecting the cusps of AV valves with the papillary muscles	"heart strings" aid in holding AV valves closed to prevent valve from flipping open during ventricular systole
fossa ovalis	indentation in the right atrium along the interatrial septum	location where a hole used to be during fetal development (**foramen ovale**); since fetal lungs are non-functional, the pulmonary circuit of circulation is extraneous and therefore blood is allowed to pass through foramen ovale from the right atrium to the left atrium; a flap closes over foramen ovale after birth and eventually seals up
interatrial septum	tissue between the right and left atria	separate the right and left atria; keeps oxygen-poor blood on the right side of the heart from mixing with oxygen-rich blood on the left side of the heart
interventricular septum	tissue between the right and left ventricles	separate the right and left ventricles; keeps oxygen-poor blood on the right side of the heart from mixing with oxygen-rich blood on the left side of the heart
papillary muscles	muscles on the internal heart wall connected to chordae tendineae	aid in holding AV valves closed to prevent valve from flipping open during ventricular systole (prolapse)
trabeculae carneae	ridges along the inside wall of the ventricles	aid in holding AV valves closed to prevent valve from flipping open during ventricular systole (prolapse)



Above: (Right) Inside of the right atrium of the heart, superolateral view. (Left) Inside the left ventricle, anterior view.

Attributions

- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "CG Heart.gif" by DrJanaOfficial is licensed under CC BY-SA 4.0
- "Heart Anatomy" by Dongho Kim is licensed under CC BY-NC-SA 4.0
- "Medical gallery of Blausen Medical 2014" by Blausen.com staff is licensed under CC BY 3.0

Updated 2026.

This page titled 17.5: Internal Structures of the Heart is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

17.6: Circulation Through the Heart

Circulation Through the Heart

When the ventricles of the heart contract (ventricular systole), it pumps blood into two different circuits: the **pulmonary circuit** and the **systemic circuit**. Pulmonary circulation carries blood from the right side of the heart to the alveoli of the lungs and back to the left side of the heart, while the systemic circulation carries blood from the left side of the heart to all the organs and tissues of the body, before returning to the right side of the heart.



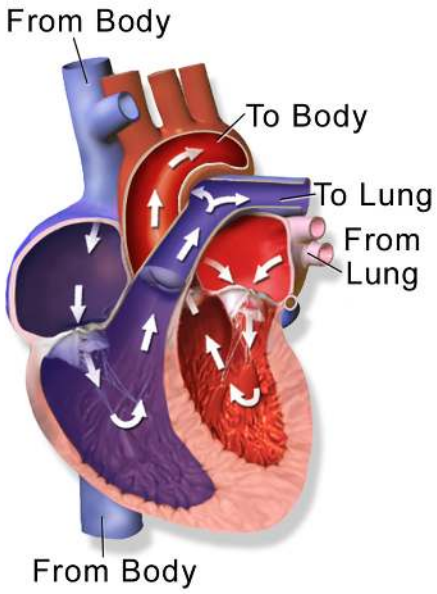
Above: Animated heart pumping with the ventricles shown open.

The Pulmonary Circuit

The function of the pulmonary circuit is to oxygenate (add oxygen to) the blood by transferring low-oxygen blood to the lungs to acquire oxygen. Once oxygenated, blood in the blood vessels of the pulmonary circuit returns to the heart to complete the circuit.

The right side of the heart pumps blood through the systemic circuit. Blood entering the right side of the heart is returning to the heart from the systemic circuit. This blood has had much of its oxygen depleted since oxygen is transferred to the cells of the body in the systemic circuit. Blood enters the right side of the heart through the superior vena cava and the inferior vena cava.

1. Blood enters the right atrium by way of the superior vena cava and the inferior vena cava.
2. From the right atrium, the blood flows through the tricuspid AV valve into the right ventricle.
3. After the ventricle contracts, the blood flows through the pulmonary semilunar valve and into the pulmonary arteries.
4. The pulmonary arteries deliver the blood to the lungs where it is enriched with oxygen and exits by way of the pulmonary veins.
5. The oxygenated blood is delivered to the left atrium by way of the pulmonary veins.



Above: Diagram showing the movement of blood into, out of, and through the heart.

The Systemic Circuit

The function of the systemic circuit is to carry oxygen-rich blood to the organs and tissues throughout the body. Blood returning to the heart from the pulmonary circuit enters the systemic circuit in the left atrium. Blood transfers from the left atrium to the left ventricle, and then exits the left ventricle when pressure forces blood into the aorta. The aorta branches to all the other arteries of the systemic circuit traveling to the head, thorax, upper limbs, abdominopelvic region, and lower limbs. After oxygen is transferred from the blood in the smallest blood vessels of the systemic circuit (capillaries), veins return low-oxygen blood back to the heart through the superior vena cava and inferior vena cava to enter the pulmonary circuit.

1. The oxygenated blood is delivered to the left atrium by way of the pulmonary veins.
2. Blood moves through the bicuspid (or mitral) AV valve into the left ventricle.
3. From here the blood is pushed through the systemic semilunar valve (aortic valve) into the aorta and then out into the body.
4. Oxygen-depleted blood returns to the right atrium by way of the superior vena cava and the inferior vena cava.

Attributions

- "CG Heart.gif" by DrJanaOfficial is licensed under CC BY-SA 4.0
- "Heart Anatomy" by Dongho Kim is licensed under CC BY-NC-SA 4.0
- "Medical gallery of Blausen Medical 2014" by Blausen.com staff is licensed under CC BY 3.0
- "Human Anatomy Lab Manual" by Malgosia Wilk-Blaszczak, Mavs Open Press, University of Texas at Arlington is licensed under CC BY 4.0

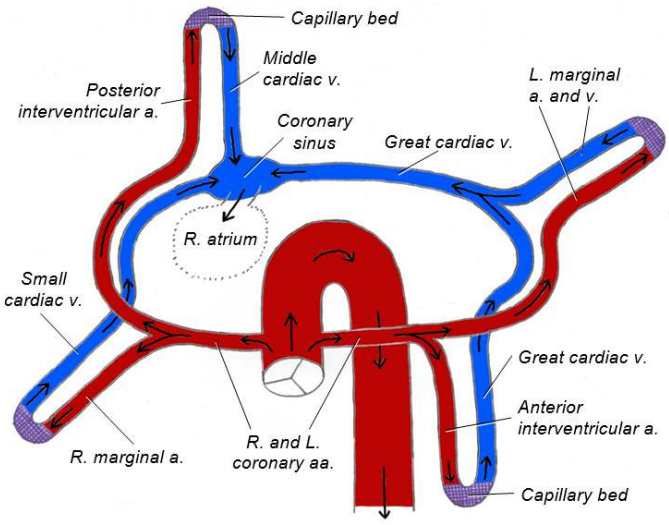
Updated 2026.

This page titled 17.6: Circulation Through the Heart is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

17.7: Coronary Circulation

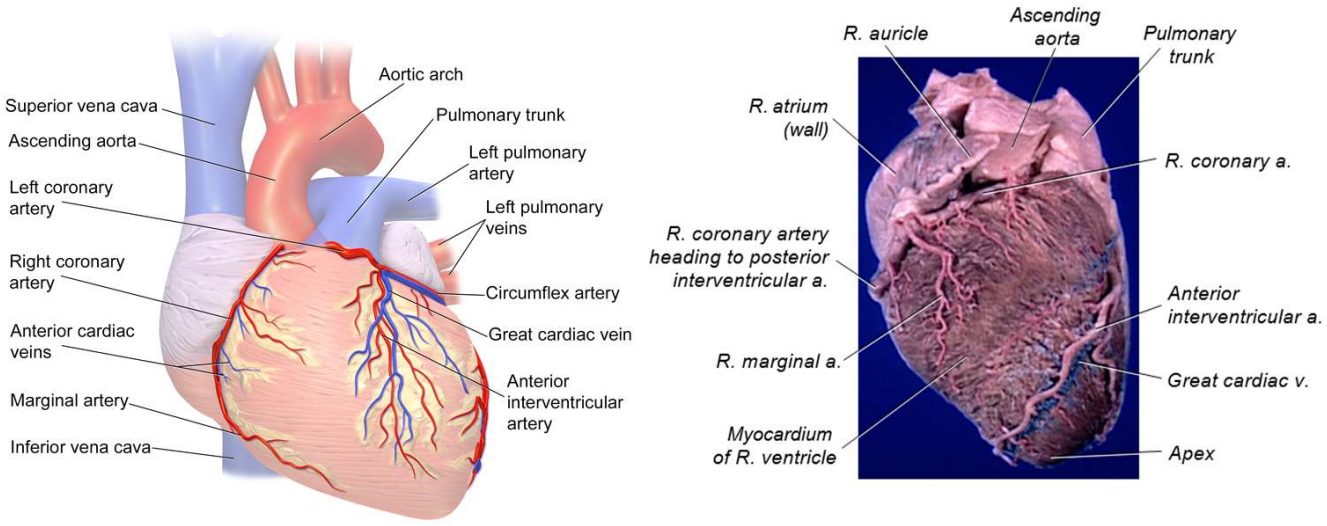
Coronary Circulation

Coronary arteries supply the myocardium with the nutrients and oxygen the tissue needs to survive and continue functioning. Some of the oxygen-rich blood in the aorta enters the **right coronary artery** and the **left coronary artery**. The right coronary artery then splits into two main branches: the **right marginal artery** and the **posterior interventricular artery**.

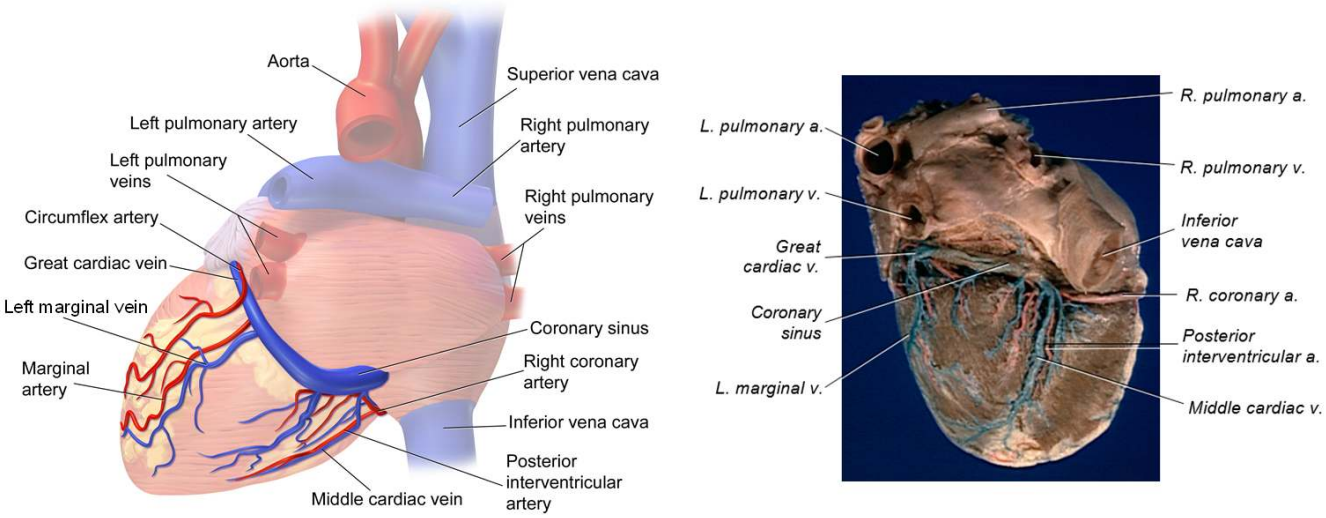


Above: Simplified diagram of the circulation through the coronary blood vessels serving the myocardium.

The left coronary artery also splits into two main branches: **anterior interventricular artery** and the **left marginal artery**. After oxygen and nutrient transfer occurs in the capillaries serving the myocardium, deoxygenated blood is pooled into the **coronary sinus**, an enlarged blood vessel that transfers blood into the right atrium of the heart. A series of coronary veins carry blood to the coronary sinus (including the **small cardiac vein**, **middle cardiac vein**, **great cardiac vein**, and **left marginal vein**).



Above: Anterior coronary vessels (left) diagram and (right) cadaver image.



Above: Posterior coronary vessels (left) diagram and (right) cadaver image.

Attributions

- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Heart Anatomy" by Dongho Kim is licensed under CC BY-NC-SA 4.0
- "Medical gallery of Blausen Medical 2014" by Blausen.com staff is licensed under CC BY 3.0

Updated 2026.

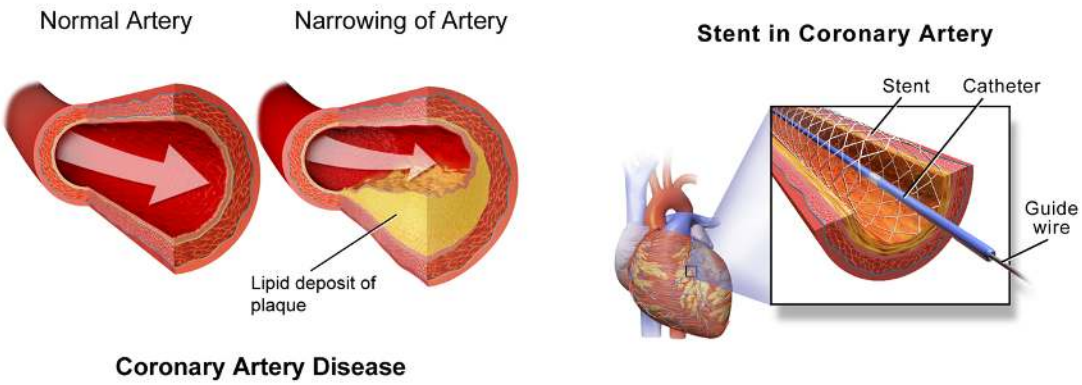
This page titled 17.7: Coronary Circulation is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

17.8: Heart Abnormalities and Treatments

Heart Abnormalities and Treatments

Coronary Artery Disease

Coronary artery disease is the leading cause of death worldwide. It occurs when there is a buildup of plaque (a fatty material including cholesterol, connective tissue, white blood cells, and some smooth muscle cell) within the walls of the arteries that serve the myocardium of the heart. This buildup obstructs the flow of blood and decreases the flexibility or compliance of the blood vessels serving the heart tissue. This condition is called **atherosclerosis**, a hardening of the arteries that involves the accumulation of plaque. As the coronary blood vessels become occluded, the flow of blood to the tissues of the heart becomes restricted, a condition called **ischemia** that causes the cells to receive insufficient amounts of oxygen, called **hypoxia**. If untreated, coronary artery disease can lead to **myocardial infarction**, also known as a heart attack (death of cardiac muscle as a result of ischemia and hypoxia).

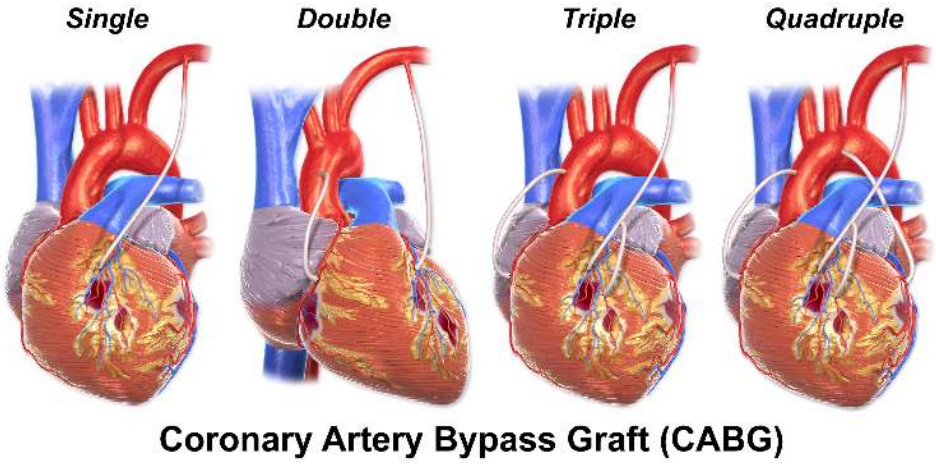


Above: (Left) Illustration of normal blood flow through the coronary arteries versus abnormal blood flow through coronary arteries with coronary artery disease. (Right) Following an angioplasty procedure to remove plague blockage from a coronary artery, a stent is often used to hold the artery open to maximize blood flow through the vessel to prevent ischemia, hypoxia, and myocardial infarction.

Angioplasty is a procedure in which the occlusion is mechanically widened with a balloon. A specialized catheter with an expandable tip is inserted into a superficial vessel, normally in the leg, and then directed to the site of the occlusion. At this point, the balloon is inflated to compress the plaque material and to open the vessel to increase blood flow. Then, the balloon is deflated and retracted. A stent consisting of a specialized mesh is typically inserted at the site of occlusion to reinforce the weakened and damaged walls. Stent insertions have been routine in cardiology for more than 40 years.

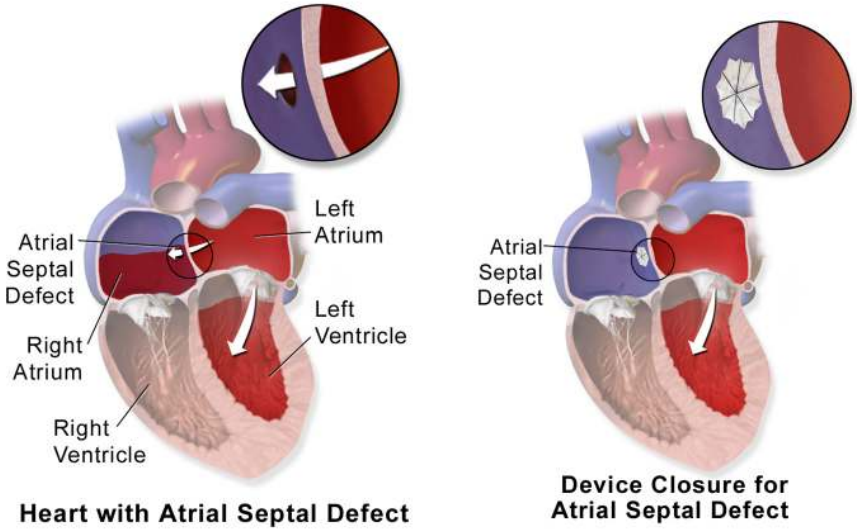
Coronary Artery Bypass

Another treatment for coronary artery disease is coronary bypass surgery. This surgical procedure grafts a replacement vessel obtained from another, less vital portion of the patient's body to bypass the occluded area. This procedure is clearly effective in treating patients experiencing myocardial infarction, but overall does not increase longevity. Nor does it seem advisable in patients with stable although diminished cardiac capacity since frequently loss of mental acuity occurs following the procedure.



Above: Diagram of single, double, triple, and quadruple coronary artery bypass grafts.

Atrial Septal Defect



Above: (Left) Diagram of patent foramen ovale where foramen ovale is not fully covered at birth and (right) a catheter procedure can be used to insert a device to cover foramen ovale.

One very common form of interatrial septum pathology is **patent foramen ovale**, which occurs when foramen ovale does not close at birth, and the fossa ovalis is unable to fuse. The word "patent" is from the Latin root patens for “open.” It may be benign or asymptomatic, perhaps never being diagnosed, or in extreme cases, it may require surgical repair to close the opening permanently. As much as 20–25% of the general population may have a patent foramen ovale, but fortunately, most have the benign, asymptomatic version. Patent foramen ovale is normally detected by auscultation of a heart murmur (an abnormal heart sound) and confirmed by imaging with an echocardiogram. Despite its prevalence in the general population, the causes of patent ovale are unknown, and there are no known risk factors. In nonlife-threatening cases, it is better to monitor the condition than to risk heart surgery to repair and seal the opening.

Where medical interventions are necessary to correct patent foramen ovale, a catheter procedure may be used to implant a device to close the foramen in the interatrial septum. Device closure involves threading the device, attached to a catheter, into a vein in the groin and through the blood vessels until it reaches the heart and can be implanted over the foramen. Another more invasive procedure would involve surgically opening the heart and stitching up the foramen in the interatrial septum.

Attributions

- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0
- "Medical gallery of Blausen Medical 2014" by Blausen.com staff is licensed under CC BY 3.0

Updated 2026.

This page titled 17.8: Heart Abnormalities and Treatments is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

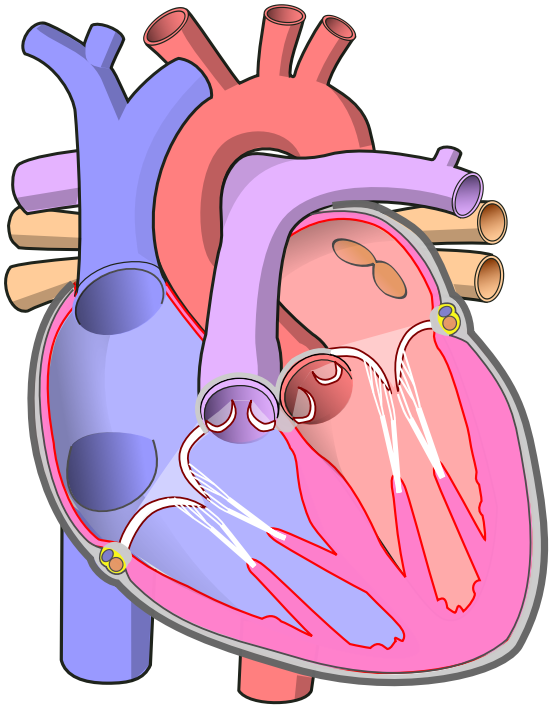
17.9: Laboratory Activities and Assignment

Laboratory Activities and Assignment

Part 1: Review of the Heart

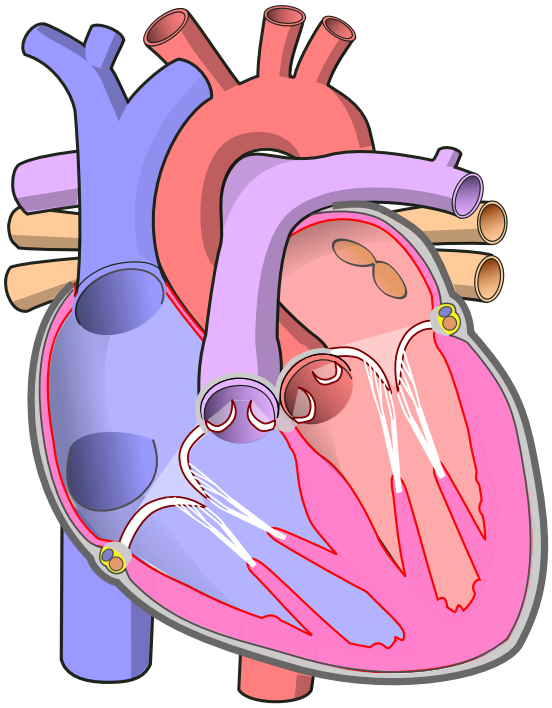
1. On the diagram of the heart below, label the following structures:

- aortic arch
- ascending aorta
- brachiocephalic trunk
- descending aorta
- endocardium
- epicardium
- inferior vena cava
- left atrium
- left common carotid artery
- left pulmonary artery
- left pulmonary veins
- left subclavian artery
- left ventricle
- myocardium
- right atrium
- right pulmonary artery
- right pulmonary veins
- right ventricle
- superior vena cava
- thoracic aorta



2. On the diagram of the heart below, label the following structures:

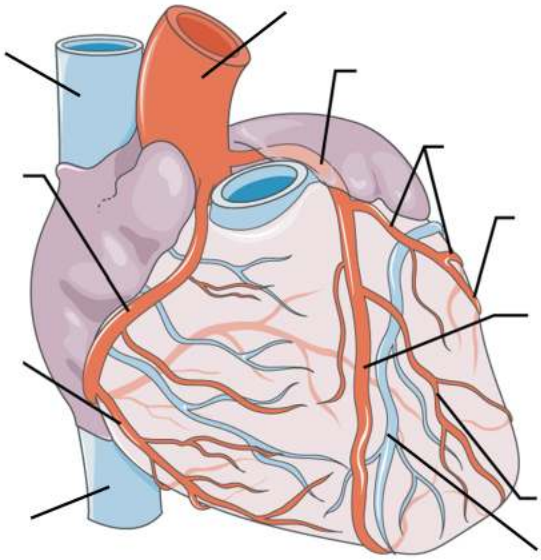
- aortic semilunar valve
- apex
- base
- chordae tendineae
- coronary artery
- fossa ovalis (draw in)
- interatrial septum
- interventricular septum
- left atrium
- left ventricle
- mitral valve
- papillary muscles
- pulmonary semilunar valve
- right atrium
- right ventricle
- trabeculae carneae (draw in)
- tricuspid valve

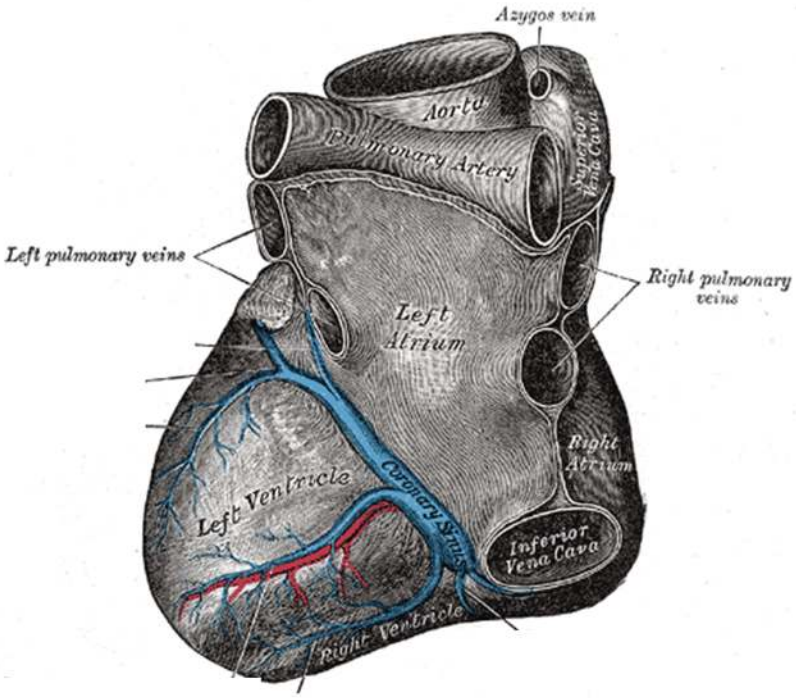


3. On the diagram above, number the blood vessel(s) where oxygen-poor blood enters the heart as #1. Then continue numbering each chamber, valve, and blood vessel sequentially to follow blood through both circuits of circulation through the heart.

4. On the anterior view of the heart (top) and posterior view of the heart (bottom) below, label the following coronary vessels, plus the aorta (not a coronary vessel):

• anterior interventricular artery • aorta • circumflex artery • great cardiac vein	• left coronary artery • left marginal artery • left marginal vein	• middle cardiac vein • right coronary artery • right marginal artery





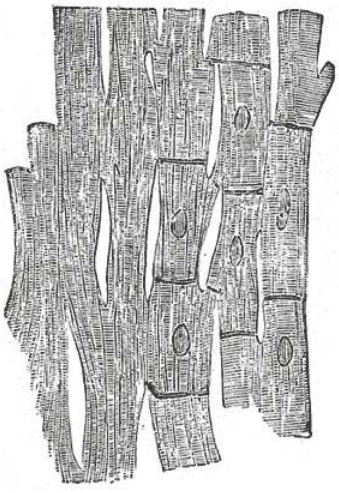
5. The illustration below is of a type of tissue of the heart. Name the tissue layer where this type of tissue is found.

6. If the tissue below does not get enough oxygen, what can happen to the tissue?

7. Where does the type of tissue below get its oxygen and nutrients from?

8. On the diagram of tissue below, label the following structures:

• branches • intercalated discs	• nuclei	• striations



Part 2: Sheep Heart Dissection

The heart dissection can be challenging. Part of the reason is because the heart is not perfectly symmetrical, but it is so close that it becomes challenging to discern which side you are looking at (posterior, anterior, left or right). Finding the vessels is directly related to being able to orient the heart correctly and figuring out which side you are looking at. ***A great landmark to find the***

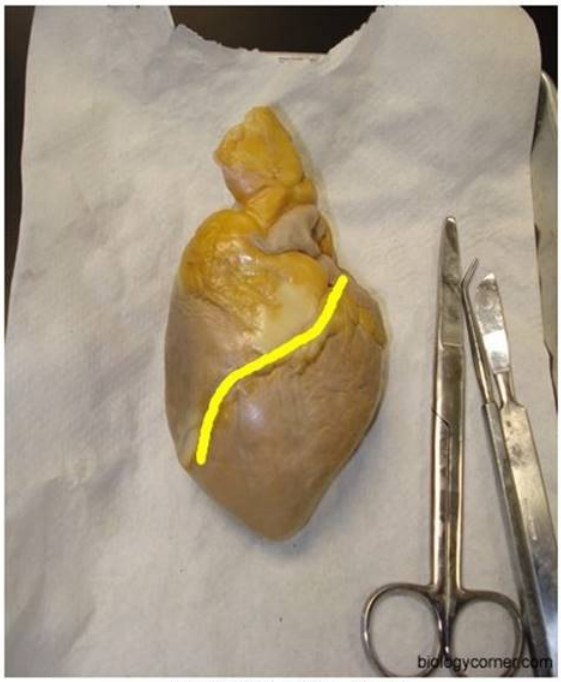
anterior of the heart is looking for the distinct anterior interventricular artery (it crosses the anterior of the heart diagonally with some fat surrounding it).

The heart may also pose challenges because the fatty tissue that surrounds the heart can obscure the openings to the vessels. This means that you really must experience the heart with your hands and feel your way to find the openings. Don't be shy with the heart. Use your fingers and tools to feel your way through the dissection.

Step 1: Orientation

When you first remove your heart from the bag, you will see a lot of fatty tissue surrounding it. It is usually a waste of time to try to remove this tissue. Grab some colored pencils to help you identify and mark the vessels you find.

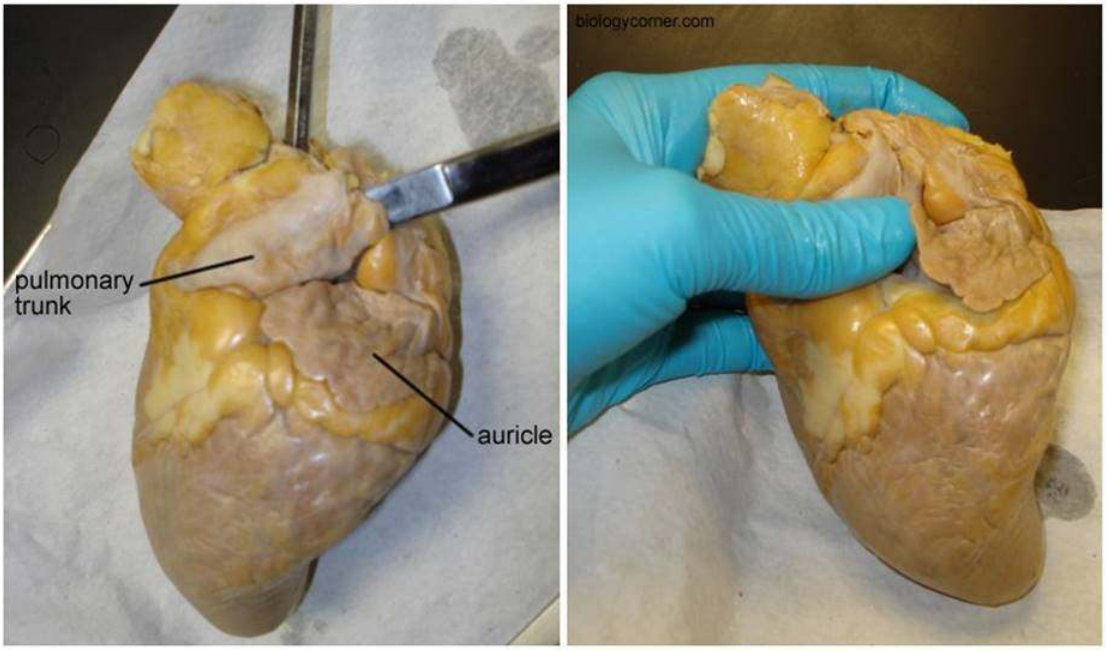
There are a few clues to help you figure out the left and the right side, but often the packaging and preserving process can cause the heart to be misshapen. If you are lucky, the heart will be nicely preserved and you will see that the front (anterior) side of the heart has a couple of key features: 1) a large pulmonary trunk that extends off the top of it 2) the flaps of the auricles covering the top of the atria. 3) the curve of the entire front side, whereas the backside is much flatter.



Front Side of the Heart

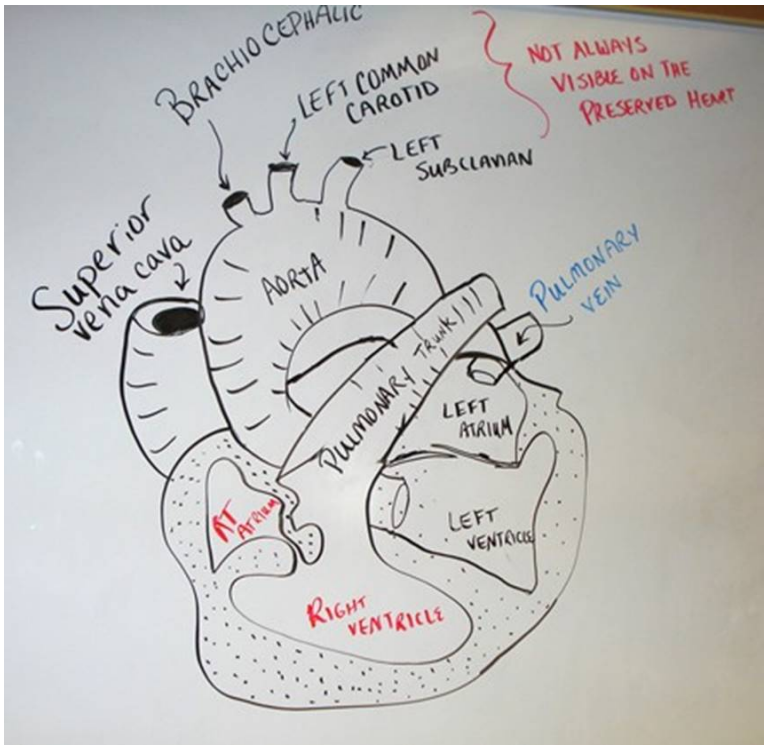

Back Side of the Heart

Above: The first image shows the front side of the heart, often identified by the anterior interventricular artery that runs cross it at an angle (yellow).



Above: The auricle is the flap that covers the atrium, it looks like an ear. The pulmonary trunk is the located at the front of the heart and enters at an angle.

Step 2: Locate the Aorta

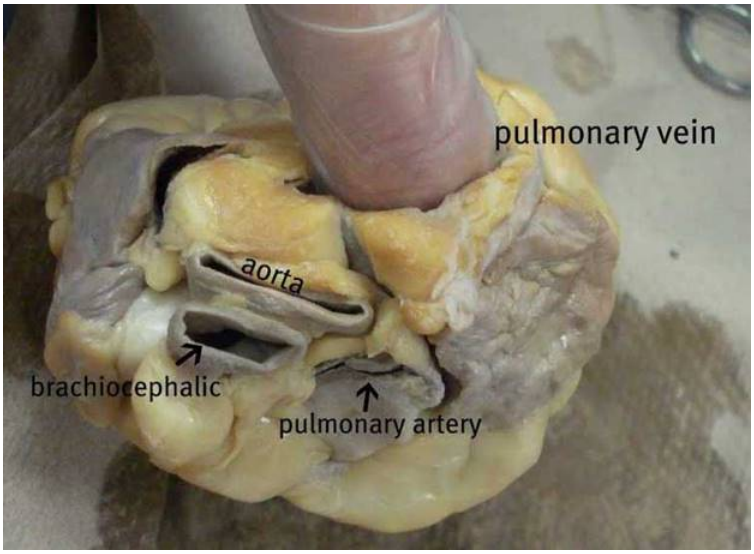


Above: Diagram of the position of heart blood vessels and chambers.

Use your fingers to probe around the top of the heart. Four major vessels can be found entering the heart: the pulmonary trunk, aorta, superior vena cava, and the pulmonary vein. Remember that if you are looking at the back of the heart, then the right and left

sides are the same as your right and left hand. This picture was on the board the day of the dissection so that you could glance up and recall which vessel entered which part of the heart.

If you find the pulmonary vein, the aorta should be situated a little bit behind it. It may be covered by fat, so use your fingers to poke around until you find the opening. Push your finger all the way in and you will feel inside of the left ventricle. The left ventricle has a very thick wall, unlike the right ventricle. Insert your finger through the pulmonary vessel to feel the left ventricle and you will notice and feel that it is much thinner than the left side of the heart.

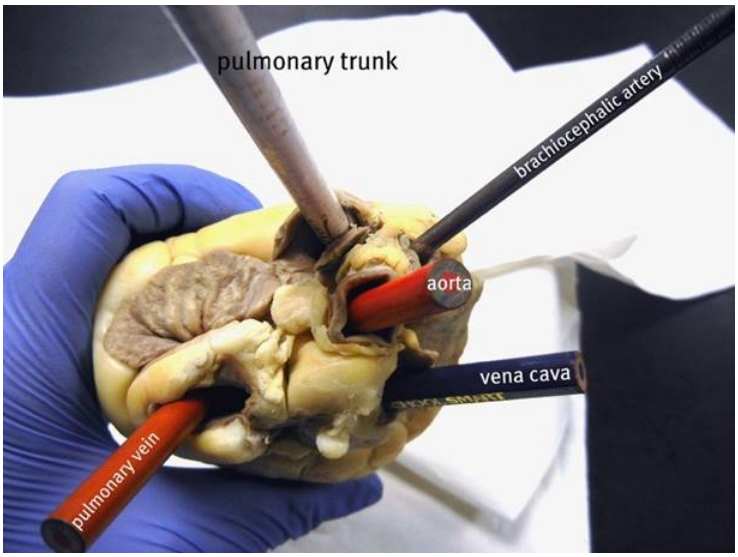


Above: The major blood vessels of the superior aspect of the heart.

With your fingers or probes in the aorta and the pulmonary trunk you should notice that they crisscross each other, with the pulmonary trunk in the front. At this point, you may want to use your colored pencils to mark these vessels so that you don't get them confused when you are searching for the other two openings that top of the heart.

Step 3: Locate the Veins

The two major veins that enter the heart can be found on the backside, as both enter the atria. On the left side, you should be able to find the opening of the pulmonary vein as it enters the left atrium. The superior vena cava enters the right atrium. In many preserved hearts, the heart was cut at these points, so you won't see the vessels themselves, you will just find the openings. Again, use your fingers to feel around the heart to find the openings. If you've marked the aorta and pulmonary then you won't mistake them for the veins you are looking for. This picture shows all of the vessels labeled.

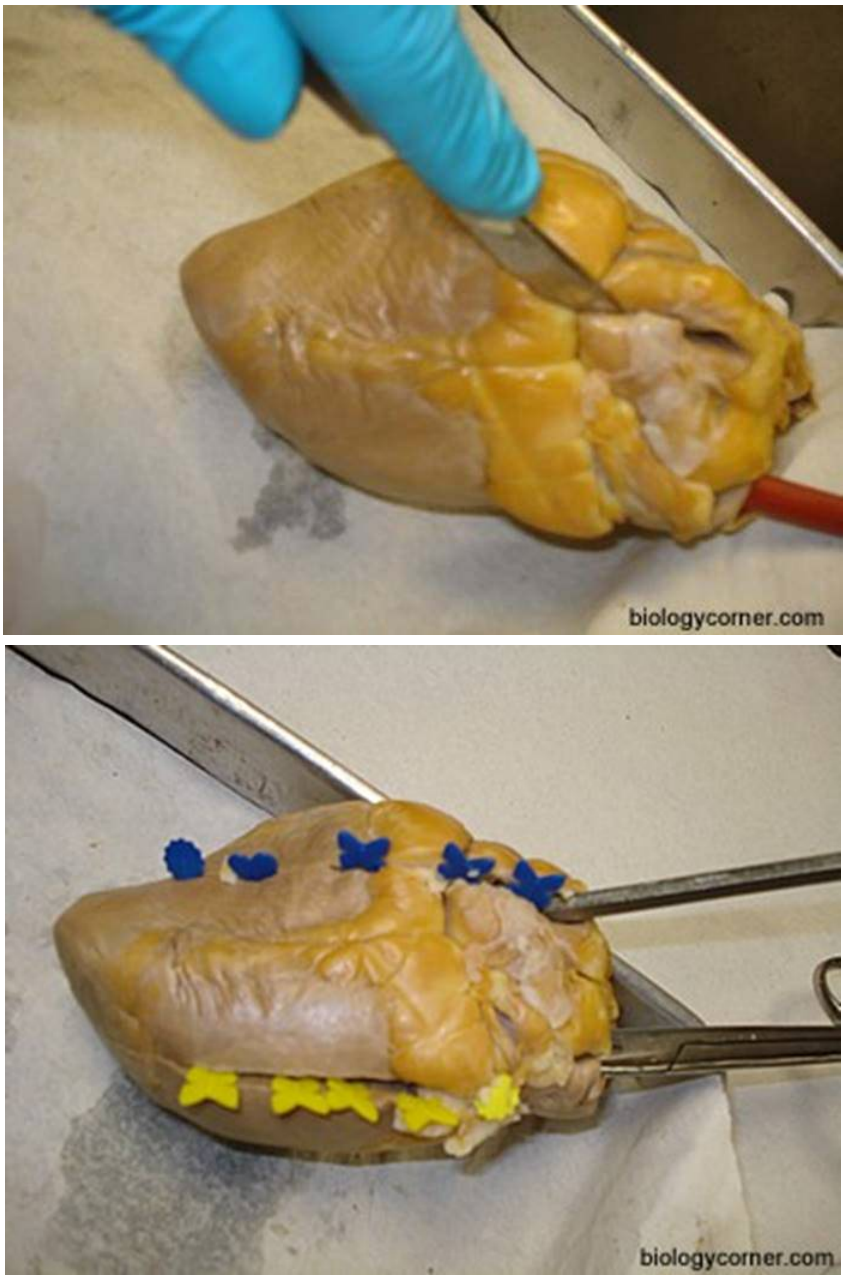


Above: The major blood vessels of the superior aspect of the heart.

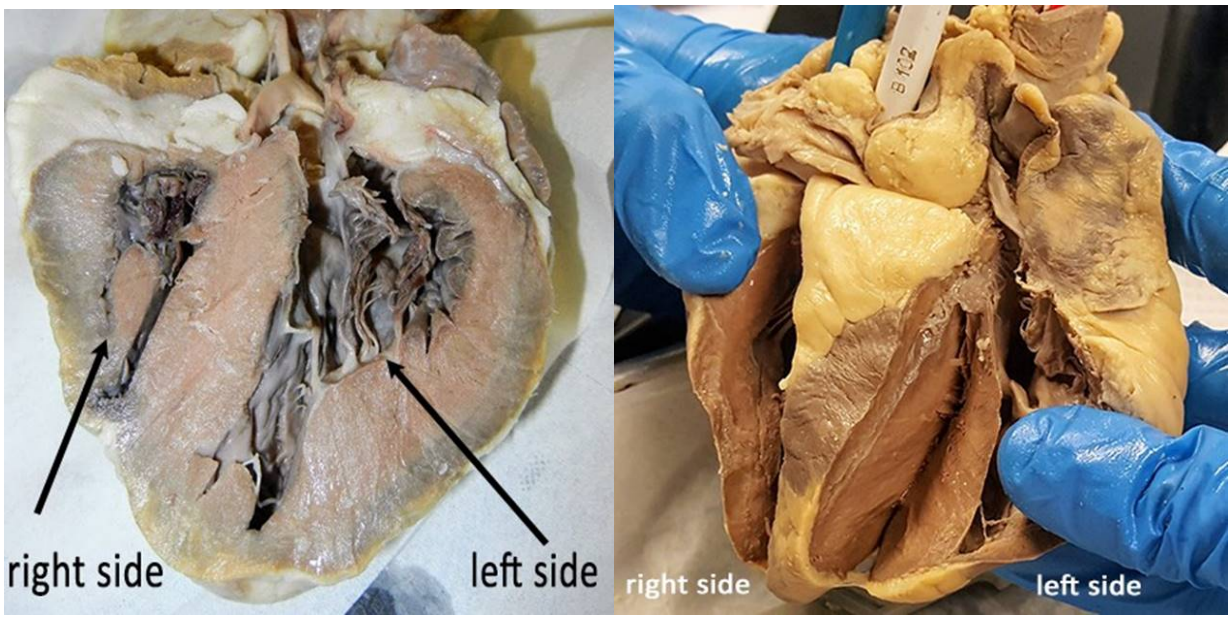
Sometimes, the aorta still has its branches attached to it. There are three vessels that branch from the aorta: the brachiocephalic, left common carotid and the left subclavian. The majority of the time, these vessels are not visible because the aorta was cut too close to the main part of the heart when the heart was removed from the animal. Occasionally, you can find the brachiocephalic artery attached, as it is in this photo.

Step 4: Make the Incisions

Now that you have all of the vessels located and marked, you can now open the heart to view the inner chambers. Use the superior vena cava and pulmonary vein as guides for where to cut. You are basically going to be cutting each side of the heart so that you can look inside. (Some dissections will ask you to make a coronal cut where a single cut opens the entire back side of the heart). The heart below is marked below to show you where the two incisions should be made.



Above: (Top) Using a scalpel to make an incision on the sheep heart. (Bottom) Heart with pins showing the locations where incisions should be made.

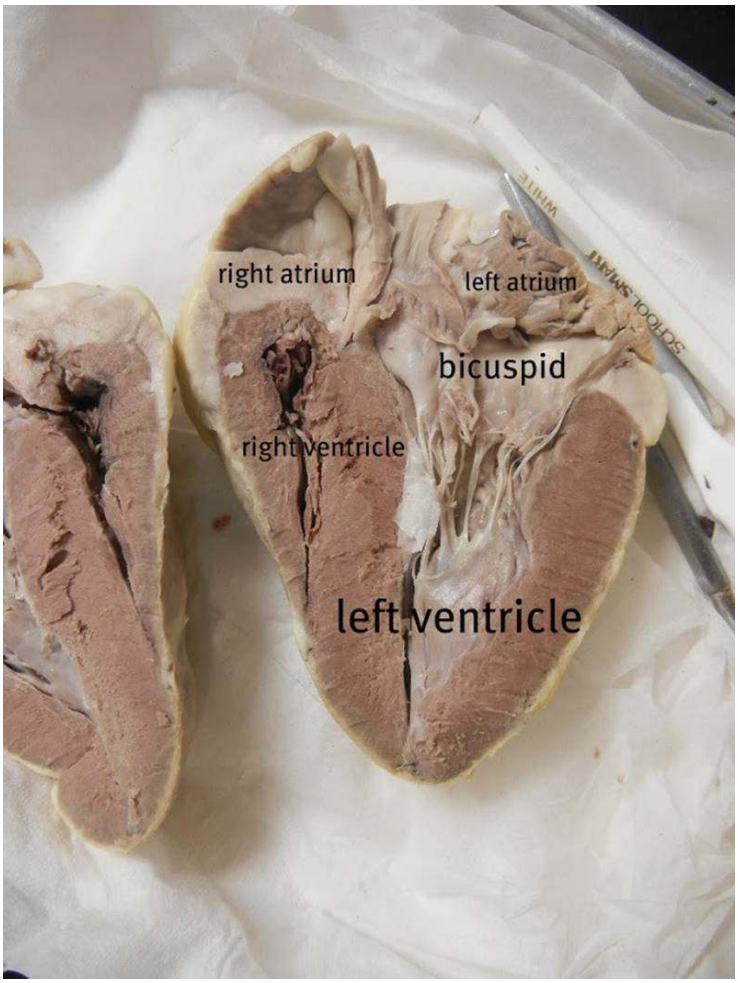


Above: Dissected heart, anterior view.

Step 5: Viewing the Chambers

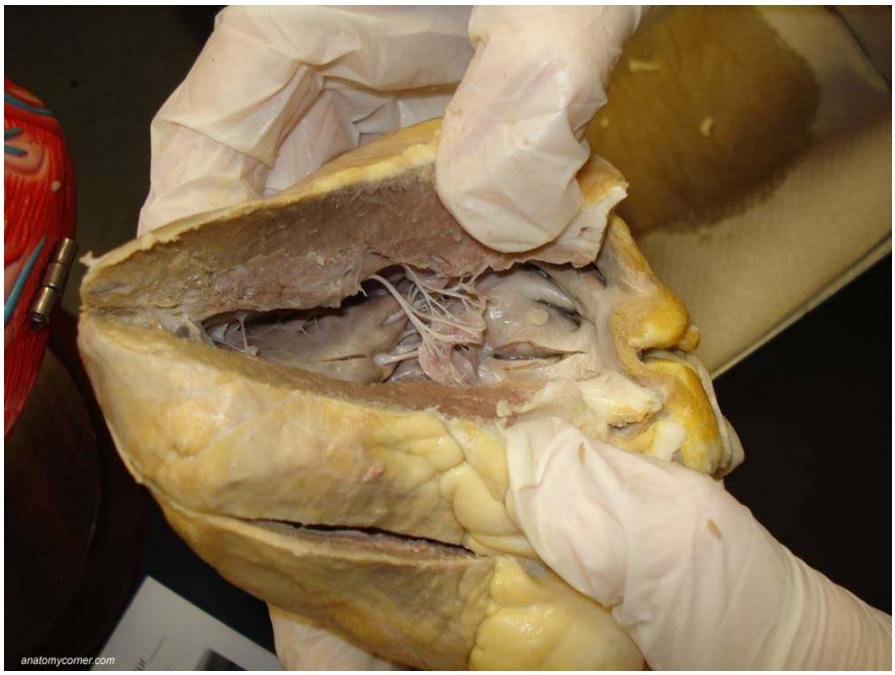
At this point it is helpful to have two hands, one to hold the heart apart so you can take a peak inside of it and another to use a probe to locate the specific parts. Your colored pencils you used to mark the heart in step 2 can also now be used to see where those vessels connect within the heart. For instance, the aorta pencil can now be seen ending in the left ventricle.

You can also now see how much thicker the walls of the left ventricle are compared to the right ventricle.



Above: Dissected heart.

The other obvious structures seen within the heart are the chordae tendineae which are attached to papillary muscles. These tendons hold the heart valves in place, sometimes they are called the "heartstrings". The valves were probably cut when the heart was opened, but if you follow the "cords" they should lead you to a thin flap that is the atrioventricular (bicuspid) valve. You can find a similar valve on the right side of the heart (tricuspid).



Above: Image shows the left atrioventricular valve (bicuspid) and the chordae tendineae.

Step 6: Illustrate and Label

1. Illustrate your dissected heart (alternatively, take photos and label these) and label with the structures listed in the space below:

• aorta • aortic semilunar valve • apex • base • chordae tendineae • endocardium • epicardium • interatrial septum	• interventricular septum • left atrium • left ventricle • mitral valve • myocardium • papillary muscles • pulmonary trunk	• pulmonary semilunar valve • right atrium • right ventricle • superior vena cava • trabeculae carneae • tricuspid valve

Attributions

Part 1: Review of the Heart

- "Coronary vessels, with annotated arteries.svg" by Mikael Häggström, M.D. is licensed under CC BY 3.0
- "Diagram of the human heart (no labels).svg" by Stenemo is licensed under CC BY-SA 4.0
- "Gray's Anatomy plates" by Henry Vandyke Carte is in the Public Domain

Part 2: Heart Dissection

- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0

Updated 2025.

This page titled 17.9: Laboratory Activities and Assignment is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

17.10: Collaborative Study Activities

Collaborative Study Activities

These activities are designed for student groups of 2-4. Larger groups will work better when there is no supplemental instructor present in the laboratory to assist in testing student groups on each section.

1. Identify the following structures on classroom anatomical models and/or unlabeled images/diagrams made available by your instructor. Work with your group to identify each structure and check them off the list once you have identified them.

☐ anterior interventricular artery ☐ aorta ☐ aortic arch ☐ aortic semilunar valve ☐ ascending aorta ☐ apex ☐ base ☐ chordae tendineae ☐ circumflex artery ☐ coronary sinus ☐ descending aorta ☐ endocardium ☐ great cardiac vein ☐ inferior vena cava	☐ interatrial septum ☐ interventricular septum ☐ left atrium ☐ left auricle ☐ left coronary artery ☐ left marginal artery ☐ left ventricle ☐ middle cardiac vein ☐ mitral valve / left atrioventricular valve ☐ myocardium ☐ papillary muscles ☐ posterior interventricular artery	☐ pulmonary arteries ☐ pulmonary semilunar valve ☐ pulmonary trunk ☐ pulmonary veins ☐ right atrium ☐ right auricle ☐ right coronary artery ☐ right marginal artery ☐ right ventricle ☐ superior vena cava ☐ trabeculae carneae ☐ tricuspid valve / right atrioventricular valve

2. Test your group members by ***asking them to name each structure you point to***. Check off each when your group can successfully name each. Your group will also test you.

☐ anterior interventricular artery ☐ aorta ☐ aortic arch ☐ aortic semilunar valve ☐ ascending aorta ☐ apex ☐ base ☐ chordae tendineae ☐ circumflex artery ☐ coronary sinus ☐ descending aorta ☐ endocardium ☐ great cardiac vein ☐ inferior vena cava	☐ interatrial septum ☐ interventricular septum ☐ left atrium ☐ left auricle ☐ left coronary artery ☐ left marginal artery ☐ left ventricle ☐ middle cardiac vein ☐ mitral valve / left atrioventricular valve ☐ myocardium ☐ papillary muscles ☐ posterior interventricular artery	☐ pulmonary arteries ☐ pulmonary semilunar valve ☐ pulmonary trunk ☐ pulmonary veins ☐ right atrium ☐ right auricle ☐ right coronary artery ☐ right marginal artery ☐ right ventricle ☐ superior vena cava ☐ trabeculae carneae ☐ tricuspid valve / right atrioventricular valve

3. When you and your group are comfortable identifying all the structures above, request the assistance of your Instructor. They will test you on your use of these terms and initial ONLY when you are successful using these terms. Instructor: _____

Updated 2026.

This page titled 17.10: Collaborative Study Activities is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

CHAPTER OVERVIEW

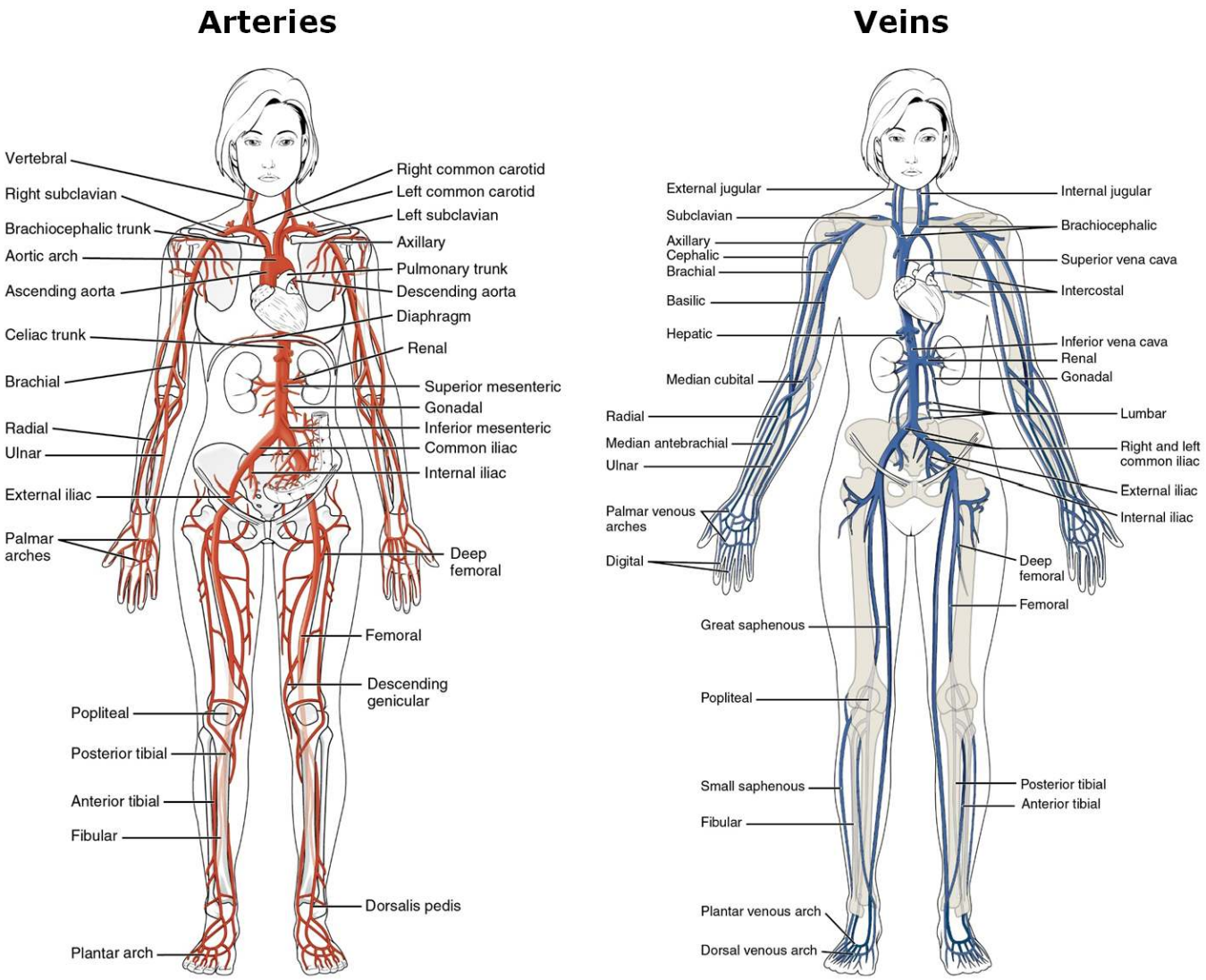
18: Cardiovascular System - The Blood Vessels

18.1: Introduction
18.2: Structures of Blood Vessels
18.3: Branches of the Aorta
18.4: Arteries of the Head and Neck
18.5: Arteries of the Upper Limb
18.6: Arteries of the Lower Limb
18.7: Branches of the Vena Cavae
18.8: Veins of the Head and Neck
18.9: Veins of the Upper Limb
18.10: Veins of the Lower Limb
18.11: Cadaver Images of Blood Vessels
18.12: Laboratory Activities and Assignment
18.13: Collaborative Study Activities

This page titled 18: Cardiovascular System - The Blood Vessels is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

18.1: Introduction

Introduction



Above: Overview of the systemic arteries and veins.

The cardiovascular system is responsible for transporting oxygen, nutrients, and waste materials around the body. These substances are dissolved or suspended in the blood tissue and carried around a system of tubes called blood vessels. If it were possible to stretch out all of the blood vessels in the body, they would measure 60,000 to 100,000 miles, enough circle the earth roughly four times.

As discussed in **Chapter 17: Cardiovascular System - The Heart**, there are two circuits of circulation from the heart: the pulmonary circuit and the systemic circuit. The pulmonary circuit transfers deoxygenated blood from the heart to the lungs and the oxygenated blood from the lungs back to the heart. The systemic circuit transports oxygenated blood from the heart to all of the body tissues and returns deoxygenated blood from the tissues to the heart. In anatomical diagrams, blood vessels carrying oxygenated blood are usually shown red and blood vessels carrying deoxygenated blood are usually shown blue. It is for this reason that blood vessels in the systemic circuit that are shown as red in anatomical diagrams are either **arteries** or **arterioles** (carrying oxygen-rich blood away from the heart and toward the body tissues) and blood vessels in the systemic circuit that are

shown blue are either **veins** or **venules** (carrying oxygen-poor blood toward the heart from the body tissues). The terms arteriole and venule are terms used to describe blood vessels that are smaller in size than arteries and veins, respectively.

The smallest blood vessels of the body are the **capillaries**. This is where transfer of oxygen, nutrients, and waste materials occurs between the blood and the body tissues.

Attributions

- "Blood vessels" by Professor Philip Cowley is licensed under CC BY-NC-SA 4.0
- "Human Anatomy Lab Manual" by Malgosia Wilk-Blaszczak, Mavs Open Press, University of Texas at Arlington is licensed under CC BY 4.0

Updated 2026.

This page titled 18.1: Introduction is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

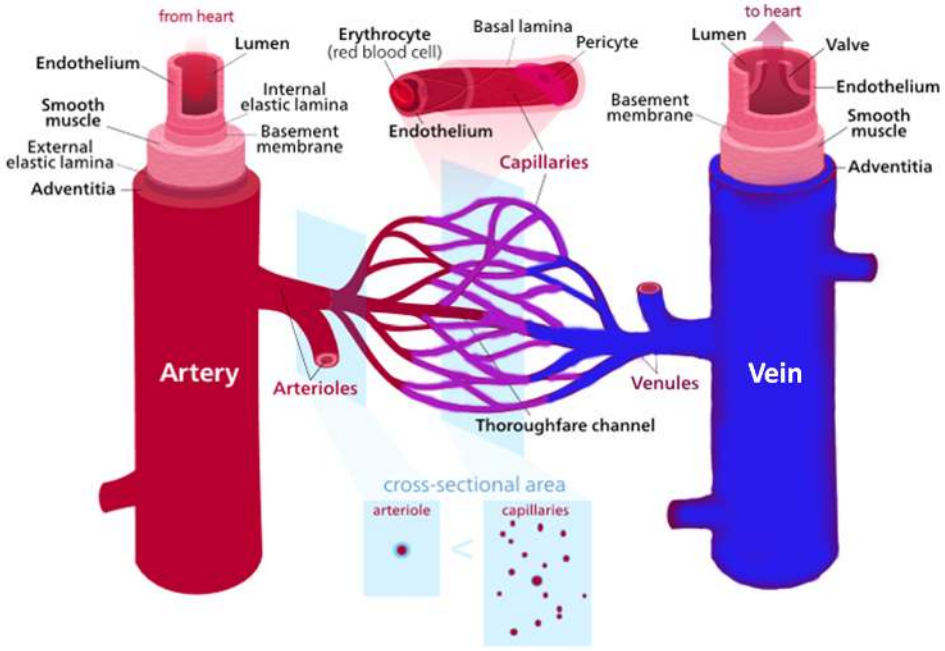
18.2: Structures of Blood Vessels

Structures of Blood Vessels

Blood vessels leaving the heart are large in size and gradually decrease in size until they become capillaries in the tissues where exchanges occur. Capillaries drain into larger blood vessels and these vessels gradually increase until they are large in size and connect with the heart. From the heart and then back again, blood vessels occur in the following order: 1. arteries, 2. arterioles, 3. capillaries, 4. venules, 5. veins. The word **lumen** is used to describe an internal space within an organ. As it applies to blood vessels, the lumen is the space inside a blood vessel where blood flows through the vessel.

Blood vessels are composed of three layers, although in veins and smaller blood vessels these may be so narrow to be indistinguishable. The exact structure of the blood vessel depends on its location and function. The three layers of blood vessels are (from inside to outside):

1. **tunica intima** - This is the innermost layer which is made of a single layer of endothelial cells (the **endothelium**) lined up in the direction of blood flow. These cells provide a smooth internal surface which is important in allowing the free flow of blood without clotting. The endothelial cells lie on a basement membrane which contains collagen and occasionally elastic fibers. In large blood vessels, these elastic fibers may be aggregated at the lower end of the intima to form the **internal elastic lamina**.
2. **tunica media** - This is the middle layer of the blood vessel consisting of smooth muscle collagen, and elastic fibers. It is particular prominent in arteries although less obvious in veins and non-existent in capillaries.
3. **tunica adventitia** - The outermost layer is composed largely of collagen. In arteries, the elastic fibers form a distinct layer between the tunica adventitia and tunica media known as the **external elastic lamina**. Within the adventitia of vessels with thick walls lie the **vasa vasorum**, small blood vessels which supply the walls of the vessel with the nutrients and waste removal the tissues of the vessel requires.



Above: The structures of blood vessels are modified depending on their type and location. These structural modifications reflect different functional properties of the vessels. Capillaries are shown as purple since this is where exchange of materials occurs in tissues and therefore they are between an oxygenated and deoxygenated state.

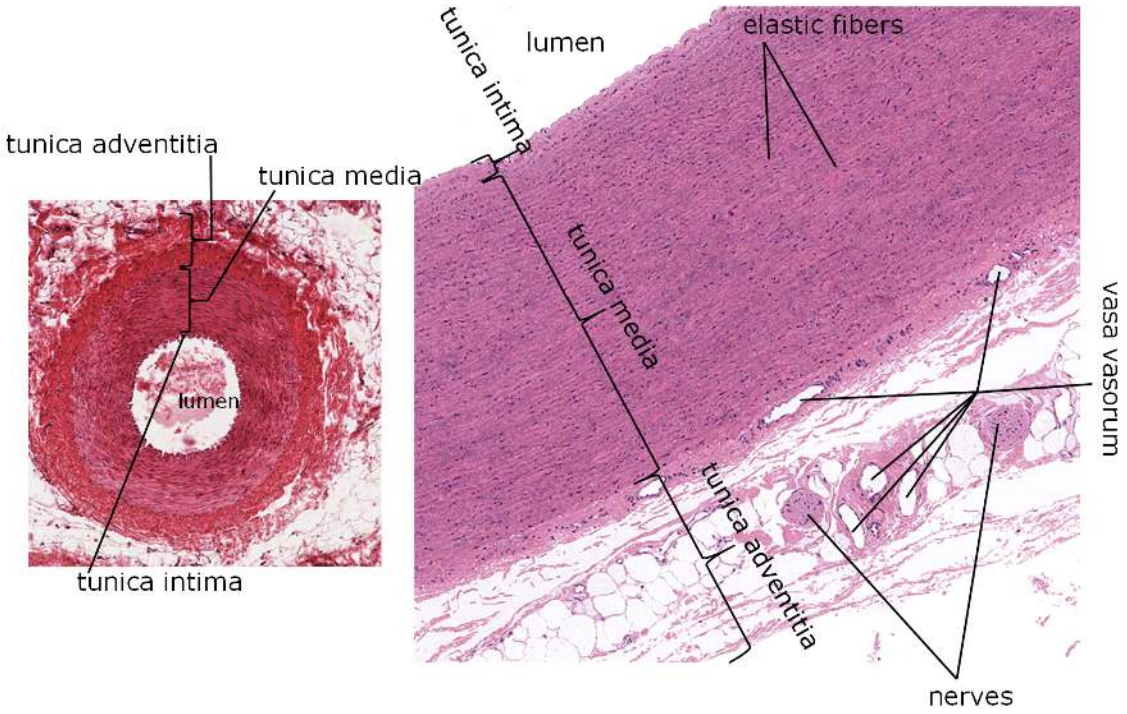
Arteries and Arterioles

The aorta is the largest artery in the body. In the tunica media of the aorta, there is a large amount of elastic tissue. This is essential for the aorta to stretch to accommodate the output of blood from the left ventricle and then to recoil to maintain an adequate

diastolic pressure and generate a more continuous flow of blood. The aorta is therefore an example of an **elastic artery**.

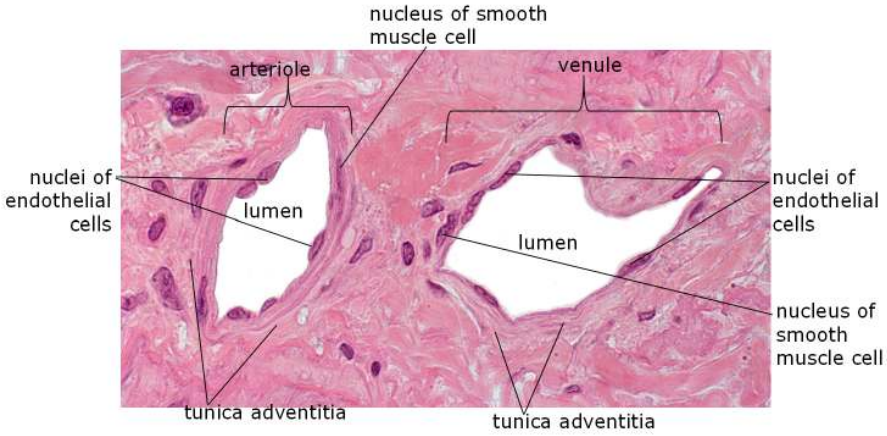
The transition from an elastic artery to a muscular one is gradual, so **transitional arteries** may show features of both arterial types. The tunica media of these arteries have characteristics of a medium, muscular artery (inner portion of smooth muscle) and large, elastic artery (outer portion with elastic lamellae).

Muscular arteries, such as the femoral artery in the thigh, occur as the elastic arteries gradually merge into muscular arteries. The tunica media of the muscular arteries contains few elastic fibers and large amounts of smooth muscle. The tunica media has a layer of elastic tissue on its internal and external aspects; they are known as the **internal elastic lamina** and **external elastic lamina**, respectively.



Above: Cross sections of (left) a medium artery and (right) a large elastic artery, both at the same magnification of 40x.

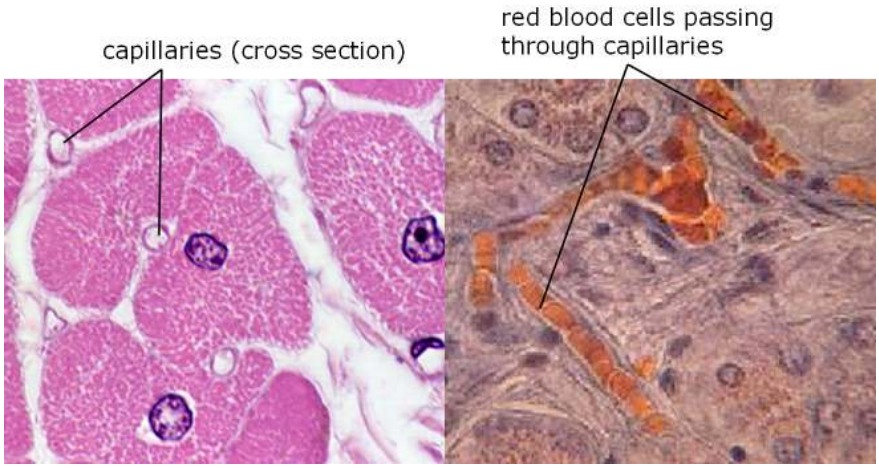
Arterioles vary in diameter from 30 nm to 400 nm. The tunica media is composed of one or two layers of smooth muscle cells. These layers become fragmented as arterioles decrease in size. Arterioles make a big contribution to resistance to blood flow in tissues. This is important for maintaining blood pressure.



Above: Cross section of (left) an arteriole (right) and a venule side by side in the same tissue, magnified by 400x.

Capillaries

The walls of **capillaries** are composed of a simple squamous epithelium, called endothelium, and its basal lamina. Since they are so thin and small, capillaries are difficulty to see longitudinally using a microscope, but may appear as small circular structures in cross section. The presence of capillaries may sometimes be seen as a single line of red blood cells within a capillary Capillaries are too small to be seen with the naked eye - over 100 of them would sit side by side across a pinhead. Capillaries is some areas such as the gastrointestinal mucosa and renal glomeruli contain pores called **fenestrations** in the endothelium. These fenestrations enhance the passage of substances into and out of the capillary.



Above: (Left) Cross section of cardiac muscle with cross sections of capillaries. (Right) Tissue showing longitudinal view of capillaries made more apparent by the red blood cells inside them.

Veins and Venules

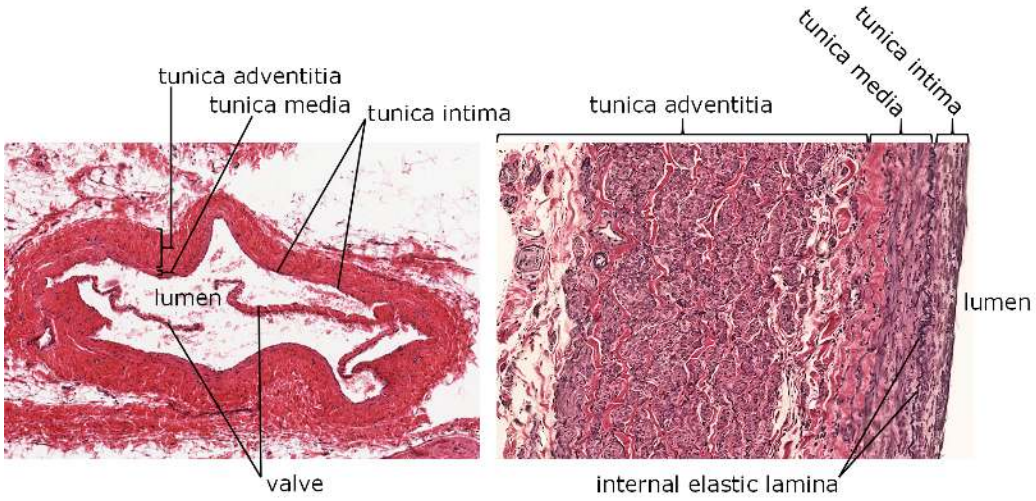
Unlike arteries and arterioles, venous vessels contain **valves**. The valves themselves do not propel the blood forward but prevents the blood from flowing backwards under the effect of gravity, particularly in the arms and legs. The composition of the walls of veins is the most variable of all vessels, and the three tunics are not always well demarcated.

The smallest venules, resembling large-diameter capillaries, are composed of endothelial cells and pericytes, which are multipotential cells with contractile properties. As venules enlarge, they acquire smooth muscle in the tunica media. Surrounding

these venules is loose connective tissue with elastic fibers. In larger venules, the tunica media contains one to two layers of smooth muscle cells.

Venules continue into **small veins**, which possess a thin tunica media, composed of scattered smooth muscle, and a prominent tunica adventitia. Like venules, veins also possess valves. The walls of small veins are much thinner and less regular than that of small arteries.

Medium veins demonstrate differences apparent in their walls. Lumens of medium veins are wider and their tunics are thinner and less organized than the arteries they accompany. Smooth muscle forms a more definitive and continuous tunica media in medium veins compared with small veins. Most named veins are medium veins. Valves continue to be present in medium veins.



Above: Cross section of (left) a medium vein and (right) a large vein, specifically the vena cava. Both images are shown at the same magnification, 100x.

A feature of **large veins**, like the vena cavae, is a significant amount of smooth muscle in the tunica adventitia. Smooth muscle fibers in the adventitia are oriented longitudinally, thus they usually are seen in cross section. In the tunica intima, smooth muscle fibers are present in the connective tissue beneath the endothelium. Large collagen bundles and circularly arranged smooth muscle comprise the tunica media. The tunica adventitia contains longitudinally oriented smooth muscle fibers and collagen. The wall of a large vein is variable depending on its location.

Attributions

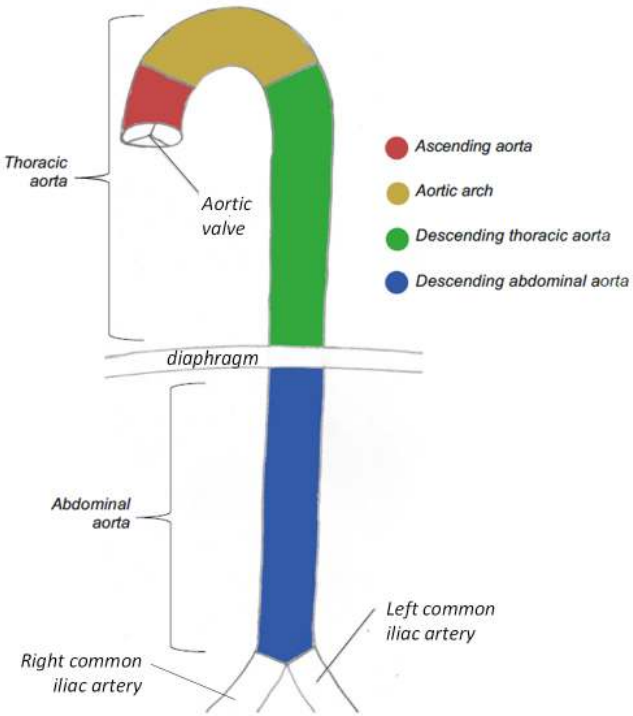
- "Blood vessels" by Professor Philip Cowley is licensed under CC BY-NC-SA 4.0
- "Blood vessels (retouched) -en.svg" by Kelvinsong is licensed under CC BY-SA 3.0 / A derivative from the original work
- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0

Updated 2026.

This page titled 18.2: Structures of Blood Vessels is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

18.3: Branches of the Aorta

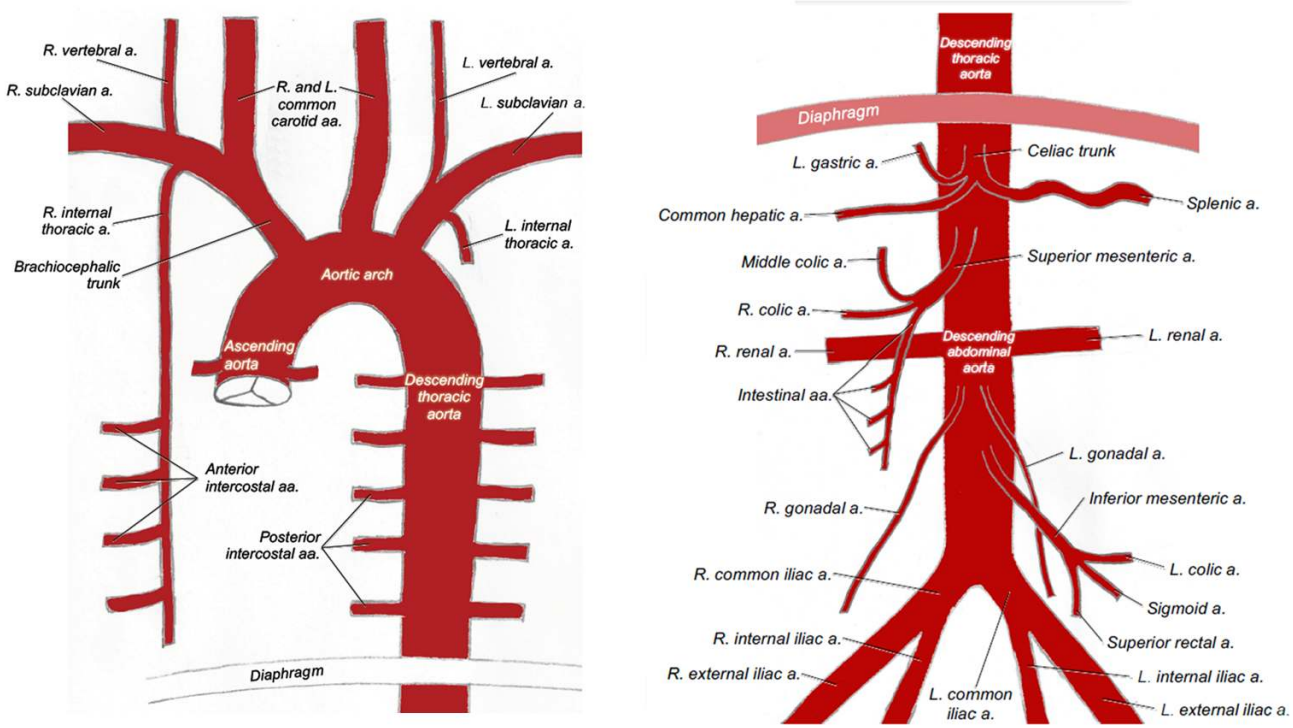
Branches of the Aorta



Above: Generalized illustration of the structure of the aorta.

The **aorta**, the largest artery in the body, is separated from the heart by the aortic valve. The aorta ascends (**ascending aorta**), arches (**aortic arch**), and then descends (**descending aorta**) posterior to the heart through the thoracic cavity (**thoracic aorta**), through the diagram and then through the abdominal cavity (**abdominal aorta**). In the pelvic cavity, the aorta splits right and left and now is called the **right common iliac artery** and the **left common iliac artery**. All of the oxygenated blood leaving the heart leaves through the aorta and then enters the multiple arteries branching off of the aorta to reach all the tissues and organs of the body.

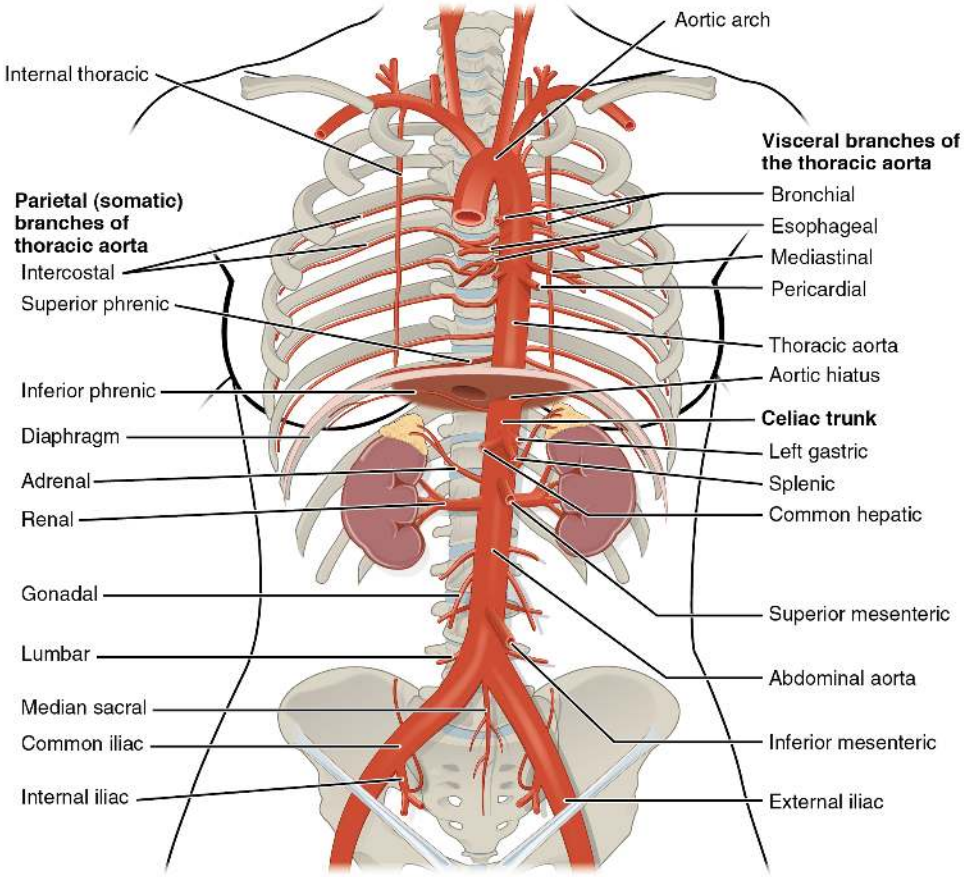
Along the aortic arch, arteries branch including the **brachiocephalic trunk**, the **left common carotid artery**, and the **left subclavian artery**. The brachiocephalic trunk (brachial = arm, cephalic = head) branches into the **right common carotid artery** bringing blood to the head and the **right subclavian artery** bringing blood to the right arm. When "common" is a part of a vessel's name, it means it splits into internal and external parts. For example, the right and left common carotid arteries both branch into **internal carotid arteries** and **external carotid arteries**. The descending thoracic aorta continues branching into eleven pairs (right and left) of **posterior intercostal arteries**. A pair of **superior phrenic arteries** (right and left) branch from the aorta to serve the superior diaphragm. The thoracic aorta continues to descend through a foramen in the diaphragm and into the abdominal cavity (inferior of the diaphragm, the aorta is now called the **abdominal aorta**).



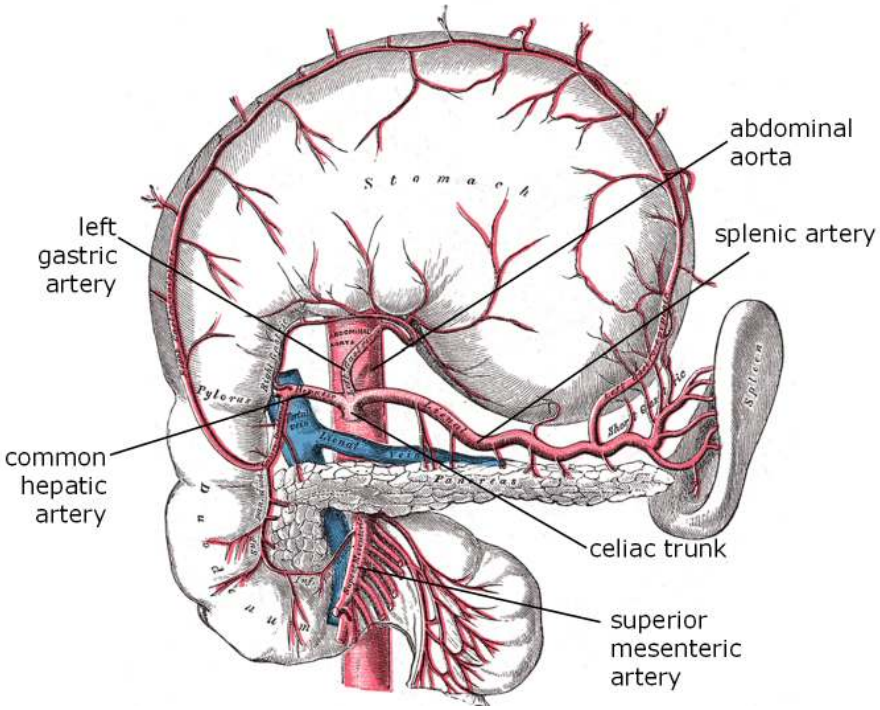
Above: (Left) Diagram of the branches of the aorta located in the thoracic cavity. (Right) Diagram of the arteries branching from the abdominal aorta. The abbreviations are "a." for "artery" and "aa." for "arteries."

A pair of **inferior phrenic arteries** serve the inferior aspect of the diaphragm. The descending abdominal aorta has a large anterior branch called the **celiac trunk** which branches into three arteries: **left gastric artery** (superior branch, to the stomach), **common hepatic artery** (right branch, to the liver), and **splenic artery** (left branch, to the spleen and pancreas). A pair of **adrenal arteries** branch off the aorta (right and left, to the adrenal glands), followed by an anterior branch called the **superior mesenteric artery** (to the small intestine and colon) and then a pair of renal arteries traveling to the kidneys (right and left). Additional paired right and left branches occur including **gonadal arteries** (to reproductive organs) and the **lumbar arteries** (to the body wall of the posterior trunk) as well as an anterior branch called the **inferior mesenteric artery** (to the small intestine and colon). Finally, in the pelvic region, the aorta splits into two large arteries: the **right common iliac artery** and the **left common iliac artery** to provide blood to the pelvic organs (**internal iliac arteries**) and to the lower limbs (**external iliac arteries**).

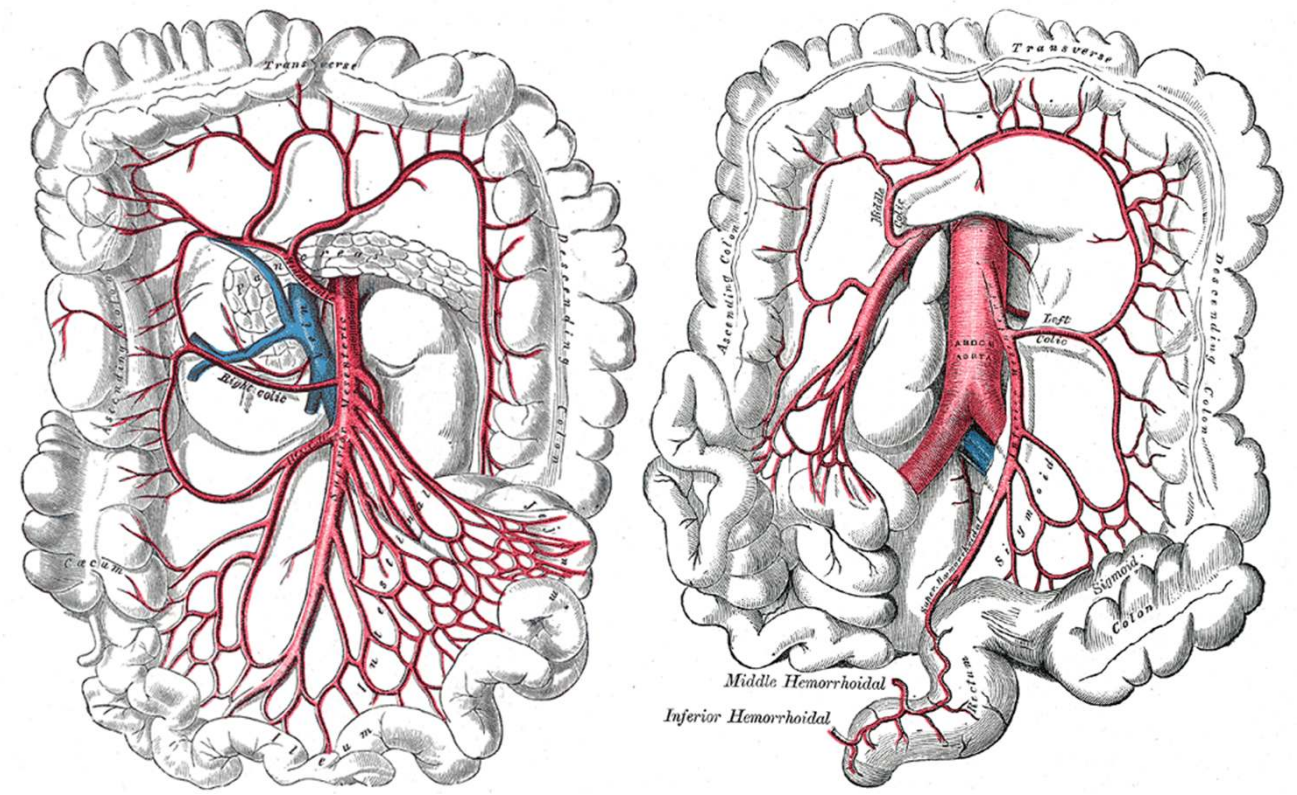
https://bio.libretexts.org/@go/page/53790



Above: Arteries of the trunk, anterior view.



Above: Arteries of the celiac trunk shown with the stomach flipped up above of its normal position.



Above: (Left) Superior mesenteric artery and (right) inferior mesenteric artery.

Attributions

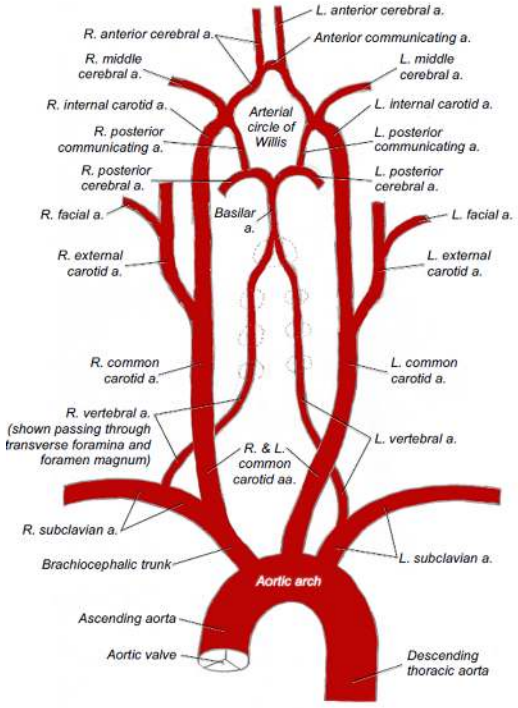
- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0
- "Gray's Anatomy plates" by Henry Vandyke Carte is in the Public Domain

Updated 2026.

This page titled 18.3: Branches of the Aorta is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

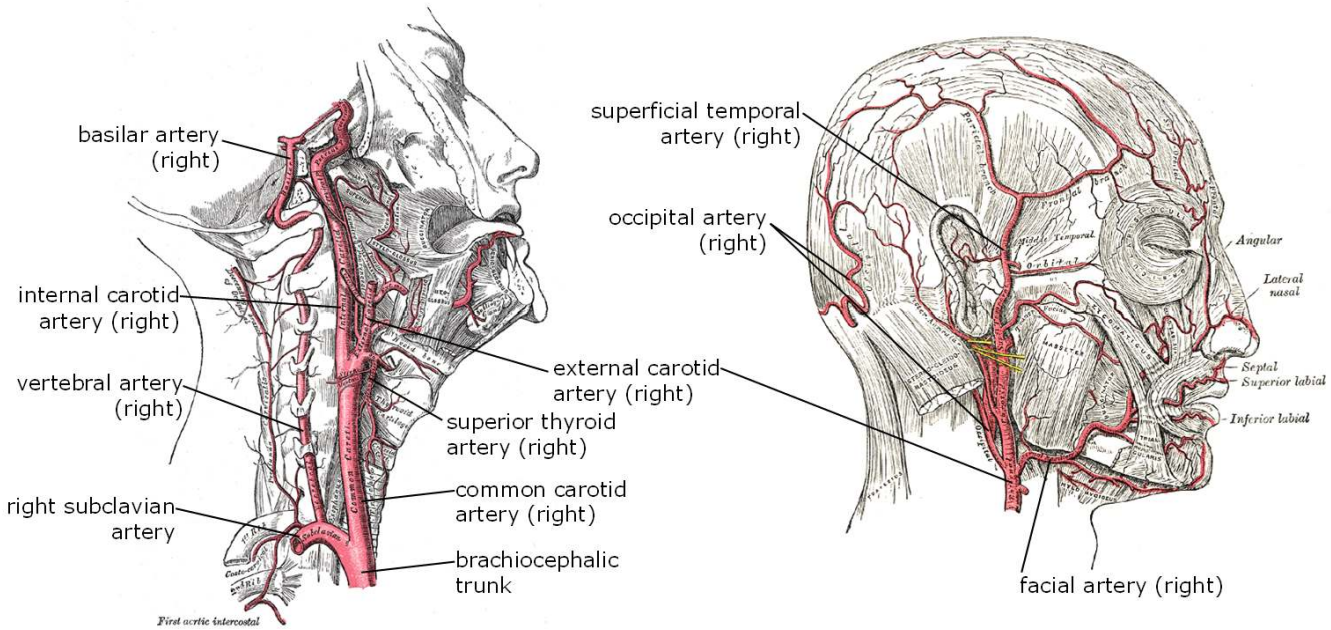
18.4: Arteries of the Head and Neck

Arteries of the Head and Neck

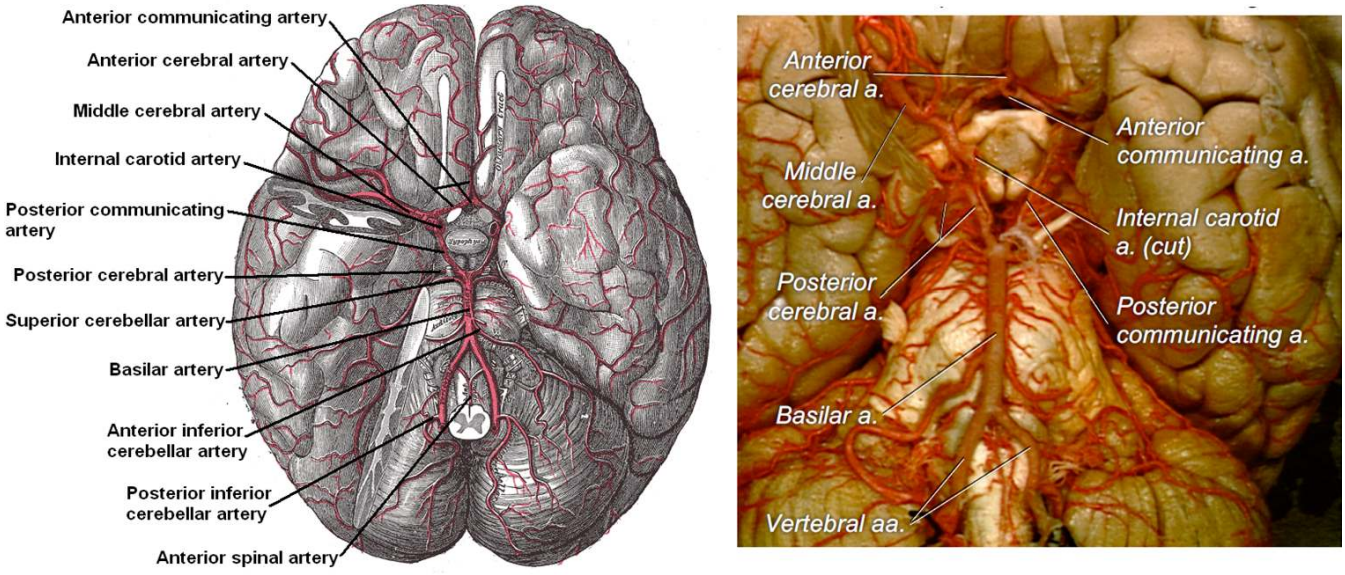


Above: Diagram of the arteries serving the head and neck. Abbreviations "a." is for "artery" and "aa." for "arteries."

Arteries of the head and neck branch from the **common carotid arteries** (right and left) and the **vertebral arteries** (right and left) that pass through the transverse foramina of the cervical vertebrae. The common carotid arteries branch into the **internal carotid arteries** and the **external carotid arteries**. The internal carotid arteries pass into the cranial cavity through the right and left foramen lacerum and then branch multiple times and rejoin to form an arterial circle at the inferior aspect of the brain called the **circle of Willis**. Branches of the external carotid arteries serve the face (**fascial arteries**) and superficial anatomy of the head including **superficial temporal arteries** and **occipital arteries**.



Above: Arteries of the right head and neck.



Above: (Left) Diagram and (right) cadaver image of the arteries of the brain, inferior view

Clinical Application: Cerebrovascular Accident

A cerebrovascular accident (CVA), or stroke, happens when blood flow is occluded to an area of the brain, causing the death of brain cells (neurons) in that area. There are two main types of CVAs: **ischemic stroke** and **hemorrhagic stroke**. In an ischemic stroke, a blood clot blocks the flow of blood in a vessel, preventing blood and oxygen from reaching the brain. In a hemorrhagic stroke, a blood vessel ruptures preventing blood and oxygen from getting to part of the brain. Symptoms vary on location of tissue death, but typical (sudden) symptoms can include dizziness, loss of balance and coordination, difficulty speaking, localized numbness/paralysis, and/or sudden headache accompanied by vomiting. Medical help should be sought right away if a stroke is assumed.

Attributions

- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Arteries beneath brain.png" by User:Mikael Häggström and Wikid77 is in the Public Domain / A derivative from the original work
- "Gray's Anatomy plates" by Henry Vandyke Carte is in the Public Domain

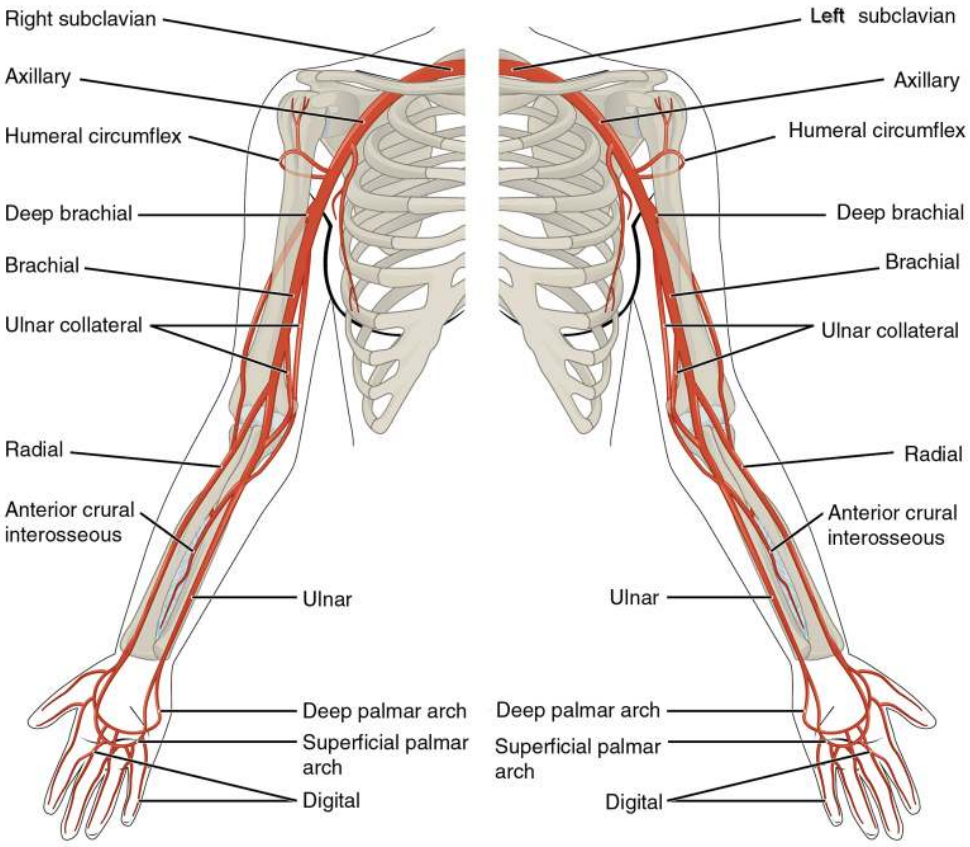
Updated 2026.

This page titled 18.4: Arteries of the Head and Neck is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

18.5: Arteries of the Upper Limb

Arteries of the Upper Limb

The **right** and **left subclavian arteries** serve the upper limbs. Branches from the subclavian arteries occur (not shown in the figure below) and in the armpit regions, the main arteries serving the upper limbs (continuous with the subclavian arteries) are called the **axillary arteries**. The arteries of the upper limbs branch into arteries named for landmarks where they are found and the regions they serve including the **brachial arteries**, **radial arteries**, **ulnar arteries**, **deep** and **superficial palmar arches**, and **digital arteries**.



Above: Arteries of the upper limbs.

Attributions

- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0

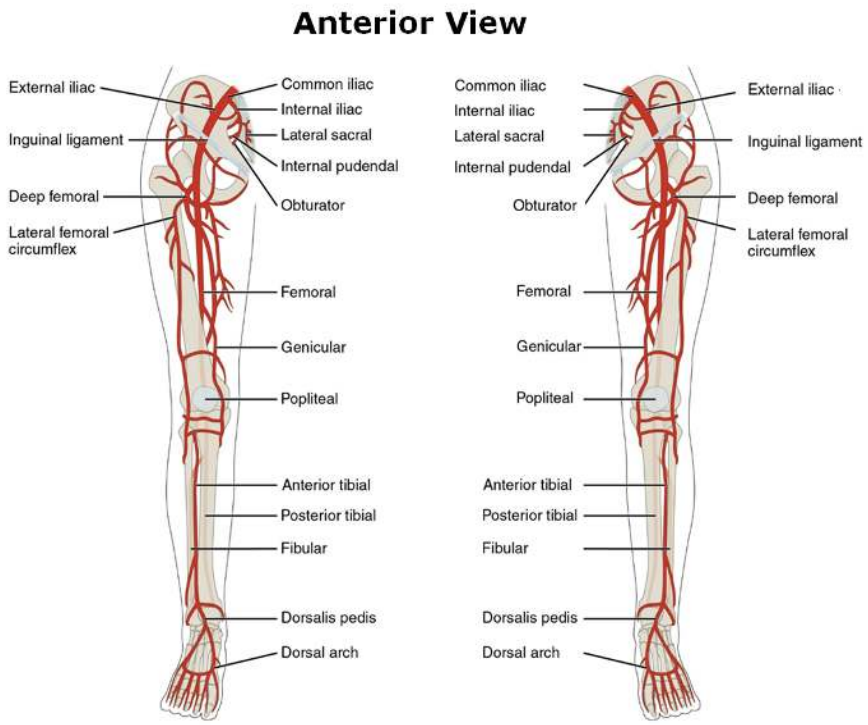
Updated. 2026.

This page titled 18.5: Arteries of the Upper Limb is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

18.6: Arteries of the Lower Limb

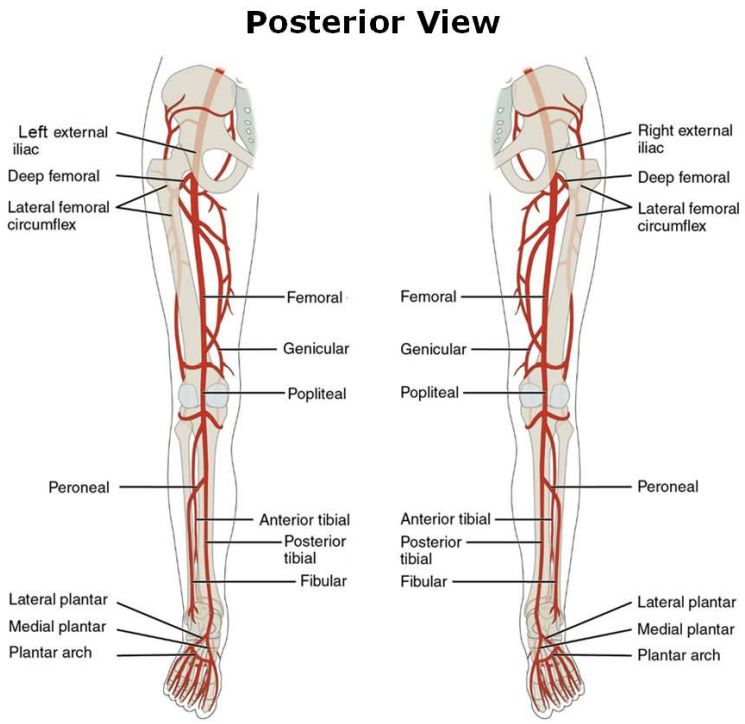
Arteries of the Lower Limb

The external iliac arteries (right and left) carry blood to the other arteries of the lower limbs. Similar to the upper limbs, the arteries of the lower limbs are named for landmarks where they are found and the regions they serve including the **femoral arteries**, **popliteal arteries**, **anterior** and **posterior tibial arteries**, **fibular arteries**, **dorsal arches** of the foot and **plantar arches** of the foot.



Above: Arteries of the anterior lower limb.

https://bio.libretexts.org/@go/page/53793



Above: Arteries of the posterior lower limb.

Attributions

- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0

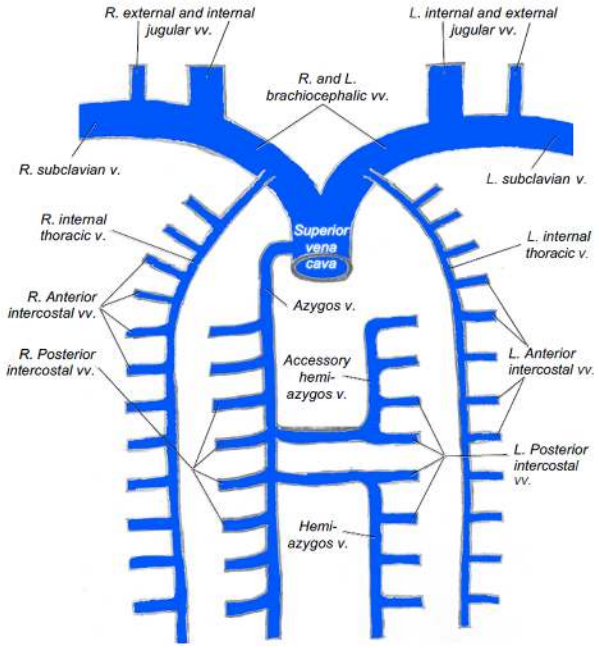
Updated 2026.

This page titled 18.6: Arteries of the Lower Limb is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

18.7: Branches of the Vena Cavae

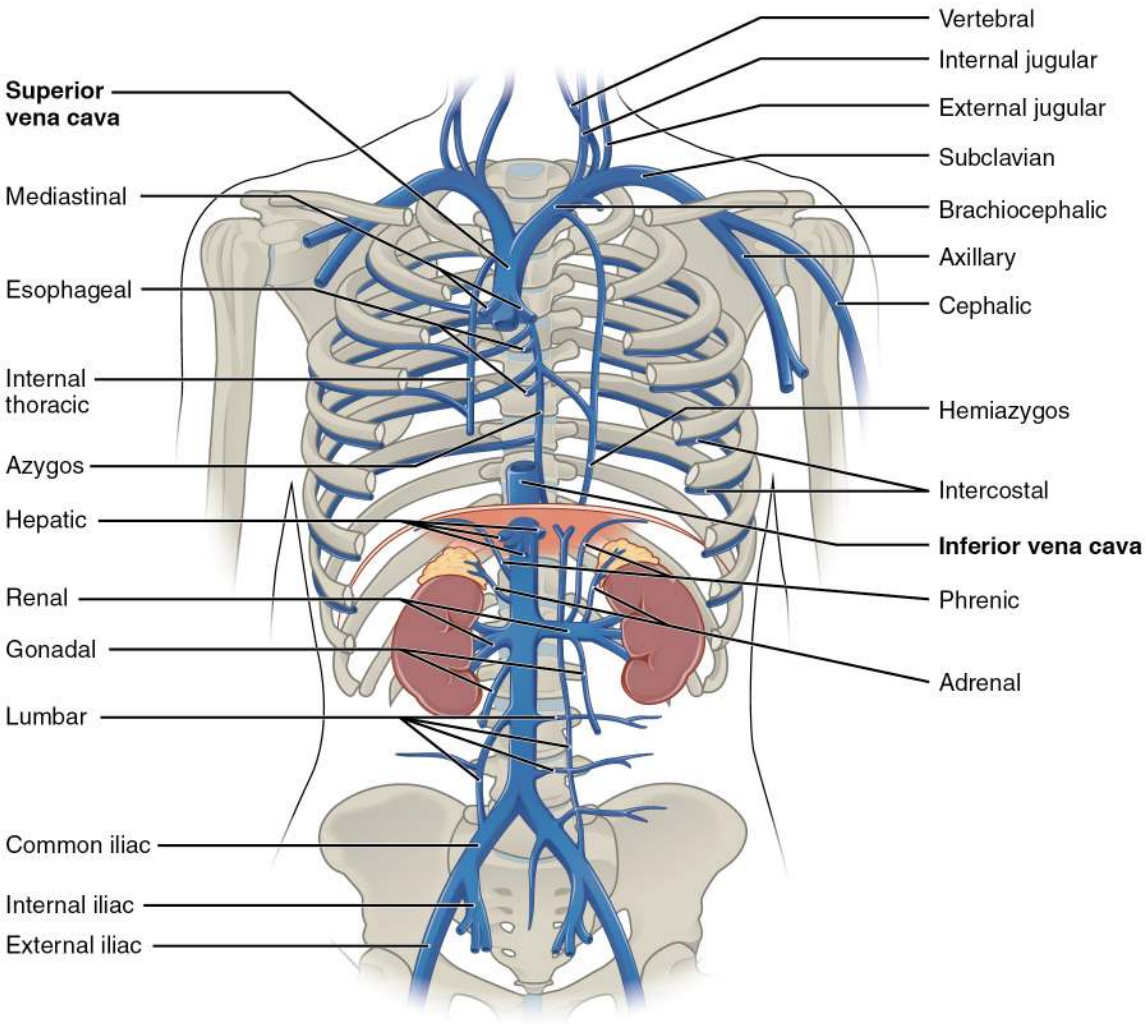
Branches of the Vena Cavae

The **superior** and **inferior vena cavae** receive all of the blood returning from the systemic circuit. The superior vena cava collects deoxygenated blood from the upper limbs from the **right** and **left subclavian veins** and from the head from the **right** and **left internal** and **external jugular veins**. Additionally, the **anterior intercostal veins** drain into the **right** and **left brachiocephalic veins** that both merge into the superior vena cava. The **azygous vein** collects blood from the **posterior intercostal veins** and drains directly into the superior vena cava.



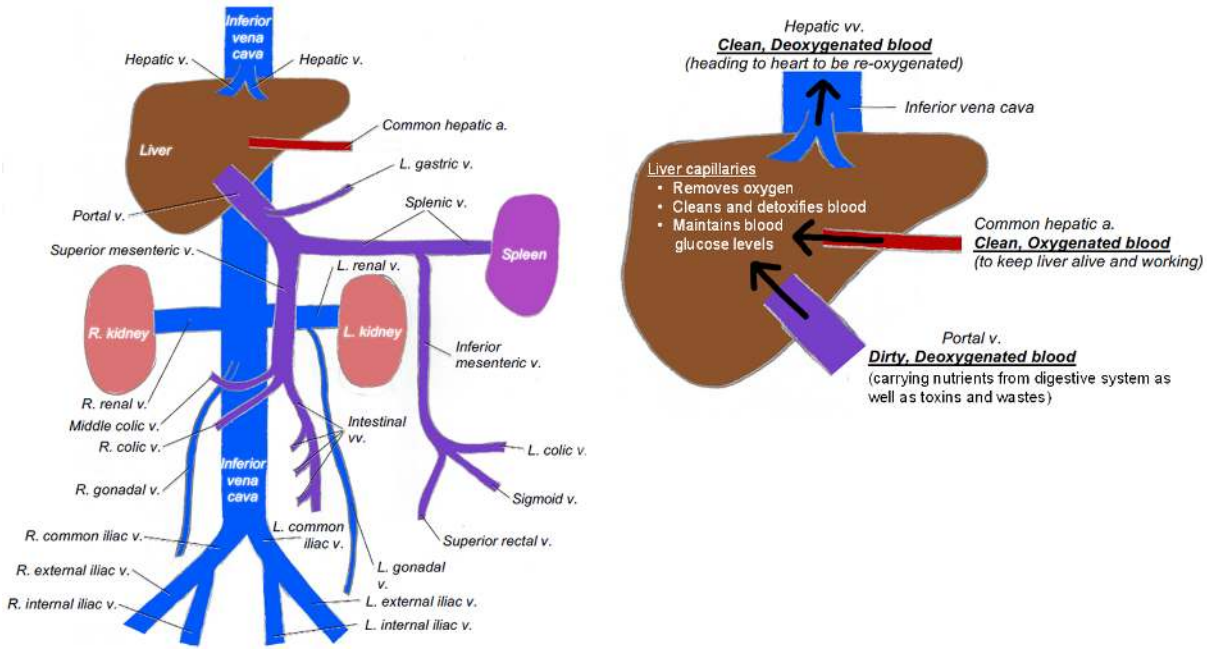
Above: Diagram of the veins draining blood into the superior vena cava. The abbreviations are "v." for "vein" and "vv." for "veins."

https://bio.libretexts.org/@go/page/53794



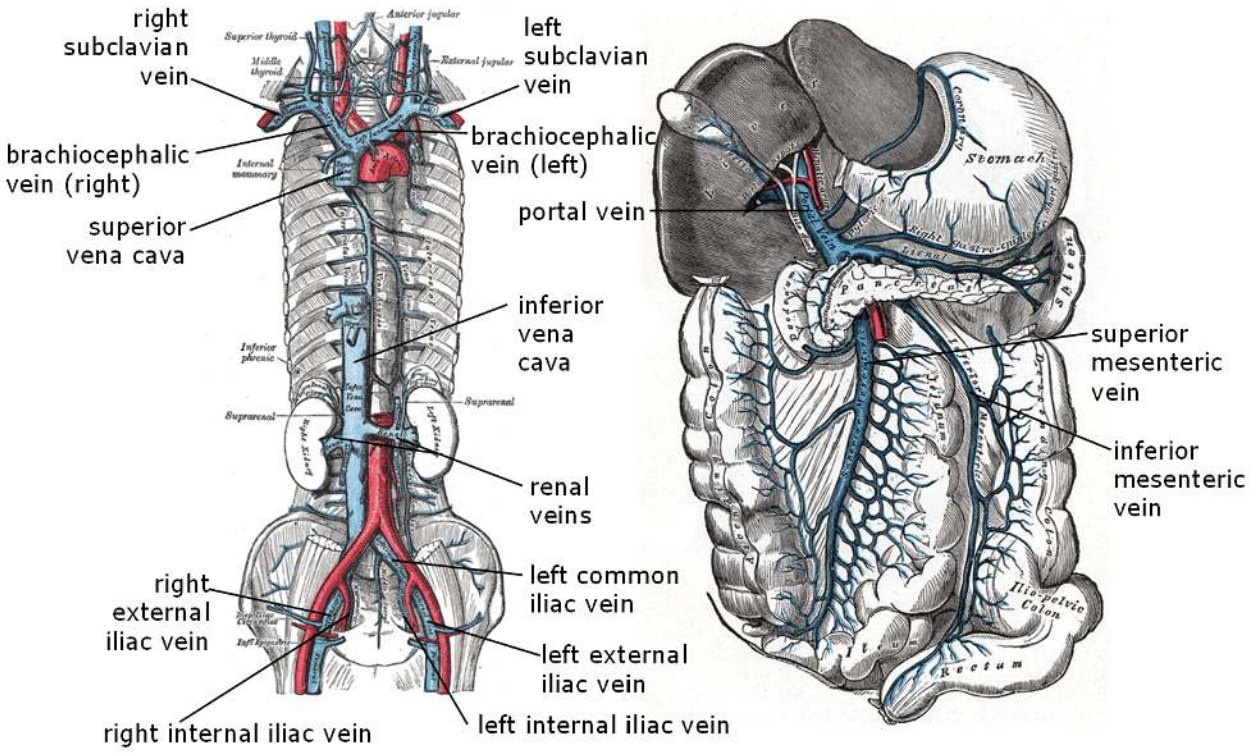
Above: Veins of the trunk.

The inferior vena cava collects blood from the lower limbs and pelvic organs by way of the **right** and **left common iliac veins**. **Lumbar veins**, **gonadal veins**, **renal veins**, **adrenal veins**, and **phrenic veins** carry blood to the inferior vena cava from the posterior body wall, reproductive organs, kidneys, adrenal glands, and diaphragm respectively. **Hepatic veins** pool blood from the liver into the inferior vena cava.



Above: Diagram of the veins draining blood into the inferior vena cava. The abbreviations are "v." for "vein," "vv." for "veins," and "a." for "artery."

The **splenic vein**, **inferior mesenteric vein**, **superior mesenteric vein**, and **left gastric vein** do not directly bring blood to the inferior vena cava. First, all these veins drain into the **hepatic portal vein**, a large vein carrying blood from the digestive tract to the liver. If food is being digested in the digestive tract, the blood in the hepatic portal vein will carry nutrients from food as well as any toxins ingested (e.g. ethanol aka drinking alcohol), and wastes from the tissues where the blood was carried from. The liver adjusts the content of the blood to maintain constant blood-glucose levels as well as balance other nutrient components in the blood (e.g. amino acids and fatty acids). Additionally, this pit-stop in the liver allows the liver to detoxify blood passing through it before draining into the inferior vena cava through the hepatic veins.



Above: (Left) Veins of the trunk and (right) hepatic portal vein system.

Attributions

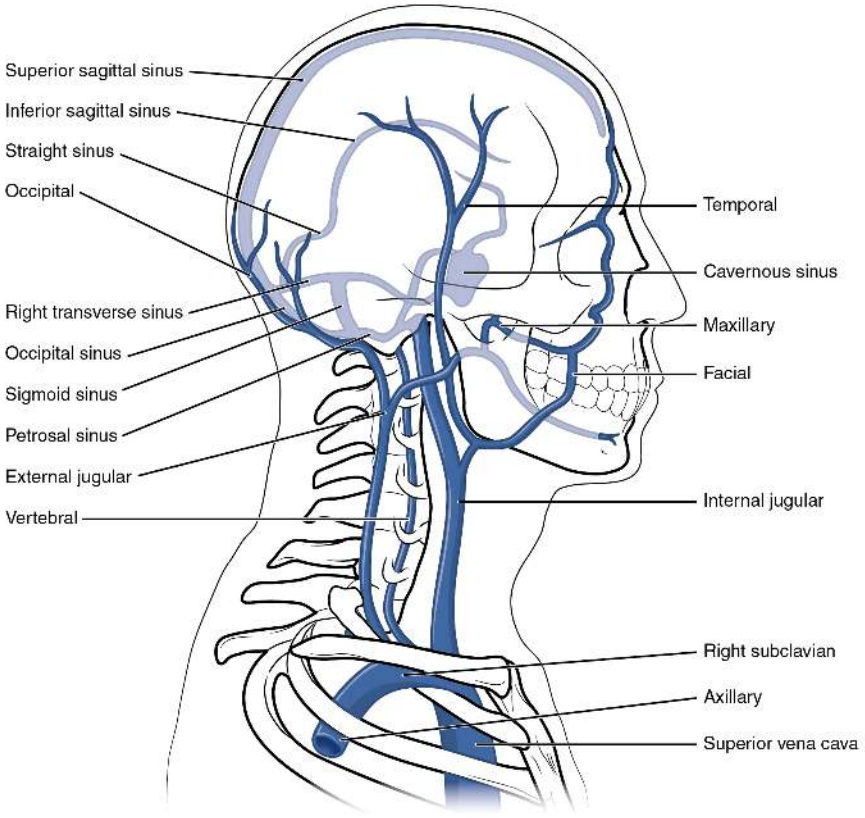
- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0
- "Gray's Anatomy plates" by Henry Vandyke Carte is in the Public Domain

Updated 2026.

This page titled 18.7: Branches of the Vena Cavae is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

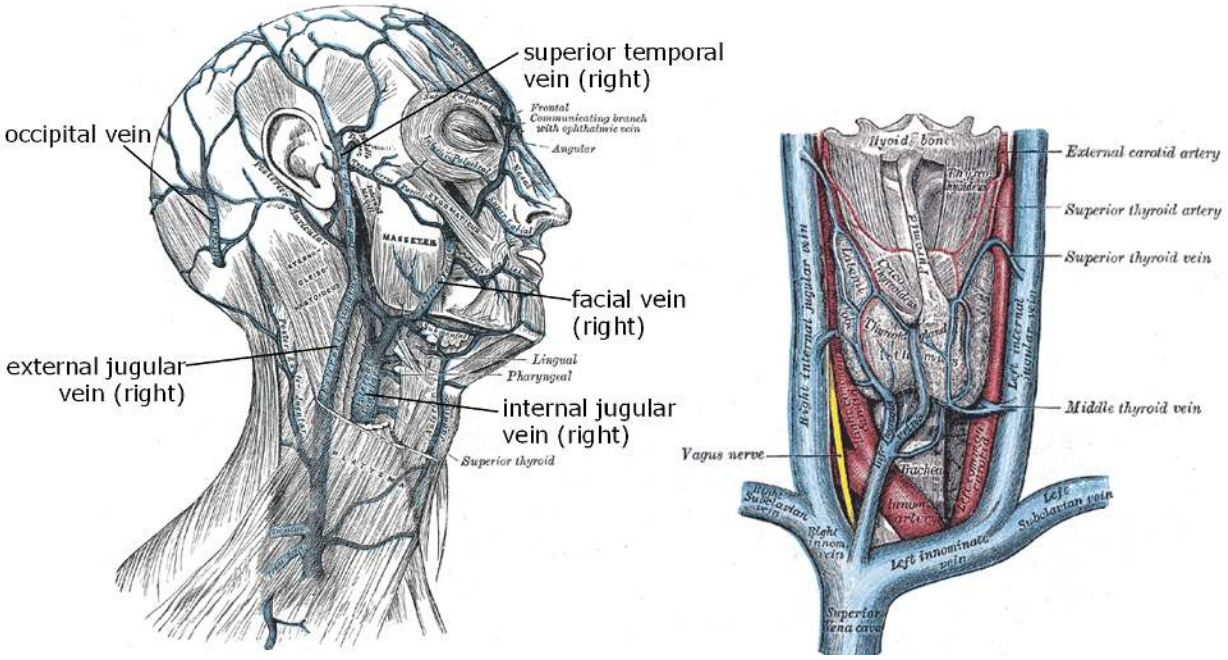
18.8: Veins of the Head and Neck

Veins of the Head and Neck

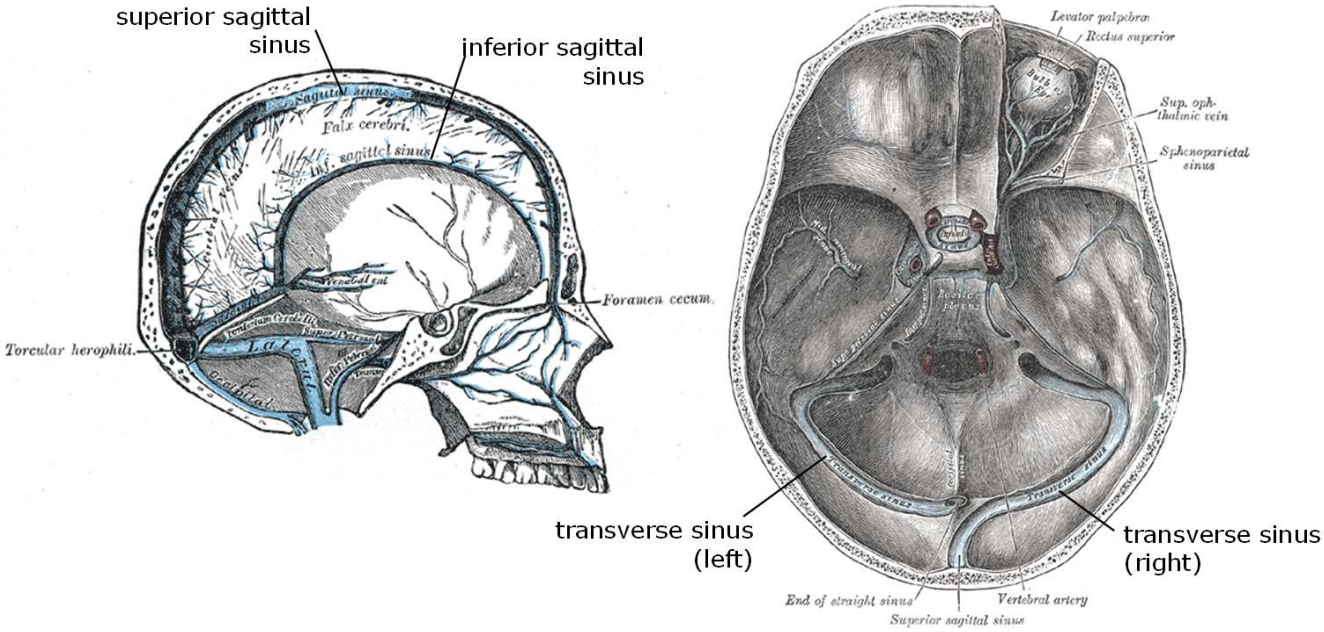


Above: Veins of the head and neck.

Blood from the brain is drained through the **superior sagittal sinus** and **inferior sagittal sinus**, through the **sigmoid sinus** and to the **internal jugular veins** (right and left) and the **vertebral veins** (right and left) passing through the transverse foramina of the cervical vertebrae. Deoxygenated blood from superficial structures of the head drains into the **external jugular veins** (right and left) by way of the **facial veins**, **temporal veins**, and **occipital veins** (right and left).



Above: Veins of the head and neck.



Above: Veins of the cranial cavity.

Attributions

- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0
- "Gray's Anatomy plates" by Henry Vandyke Carte is in the Public Domain

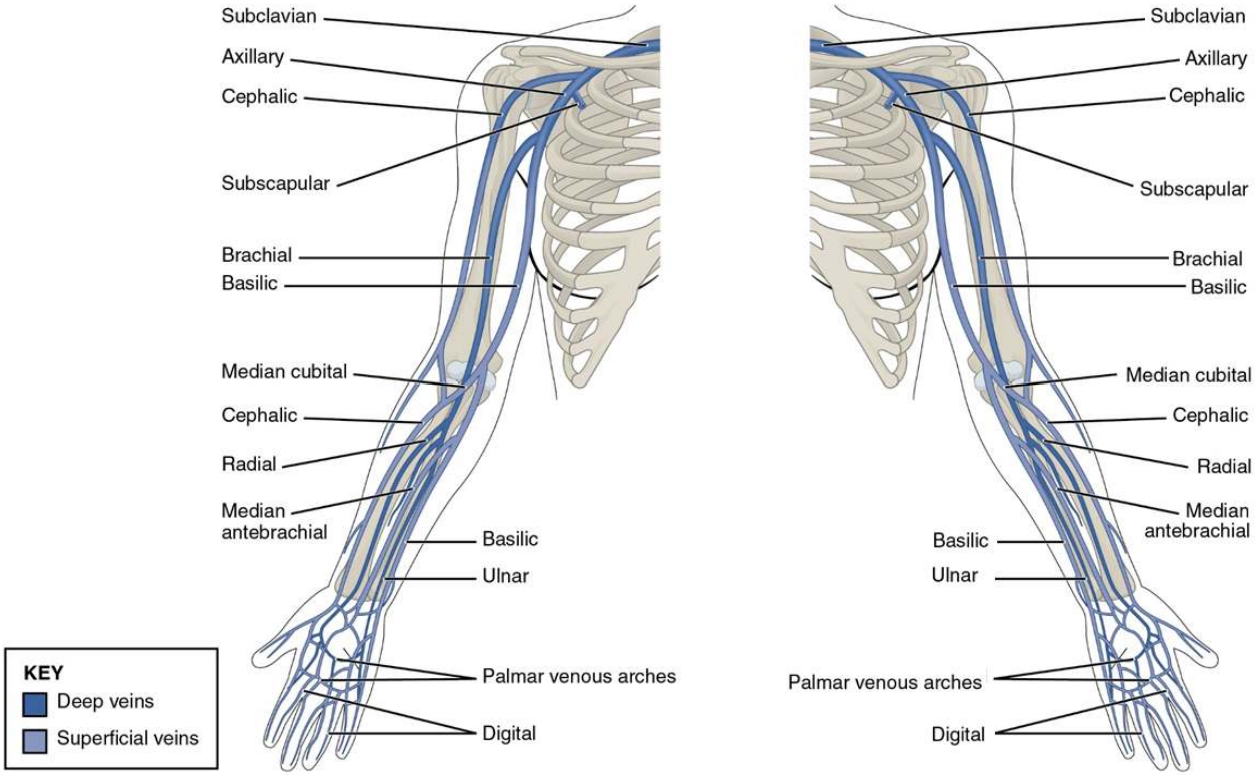
Updated 2026.

This page titled 18.8: Veins of the Head and Neck is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

18.9: Veins of the Upper Limb

Veins of the Upper Limb

Blood returning to the superior vena cava from the upper limbs is collected through the **subclavian veins** (right and left). Veins of the upper limbs are named as they relate to and the landmarks and regions they drain. The **median cubital vein**, located on the anterior aspect of the elbow, is one of the most common locations where blood draws are taking due to its position close to the surface of the skin.



Above: Veins of the upper limb.



Above: Army Pfc. Suzie Johnson, a health care specialist with the 525th Military Police Battalion assigned to Joint Task Force Guantanamo's Joint Troop Clinic, draws a blood sample for lab tests from the median cubital vein.

Attributions

- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0
- "Joint Troop Clinic Blood Draw DVIDS282299.jpg" by Petty Officer 3rd Class Joshua Nistas is in the Public Domain

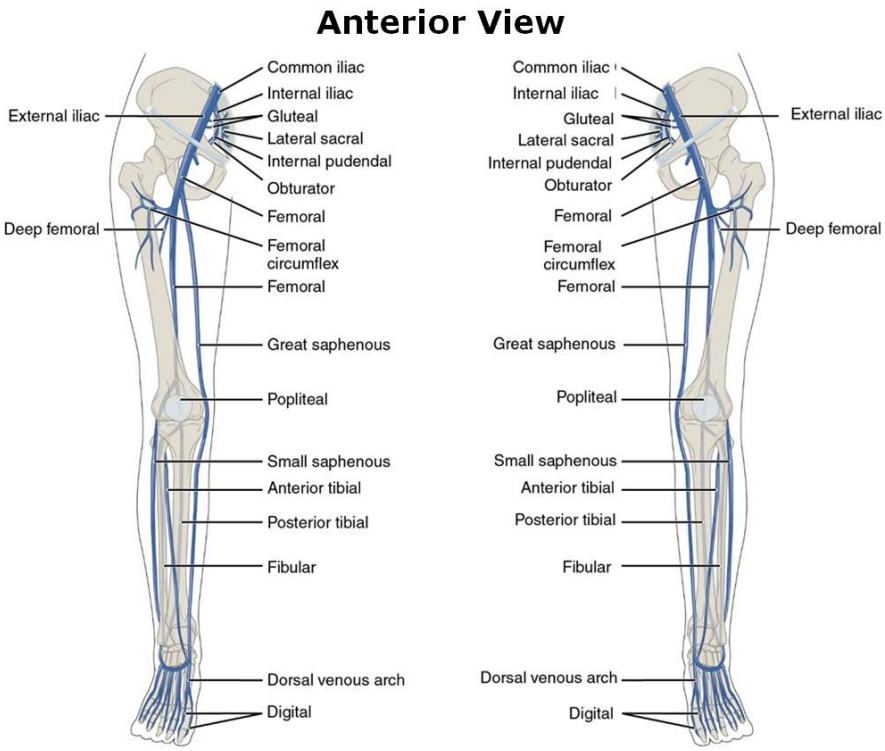
Updated 2026.

This page titled 18.9: Veins of the Upper Limb is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

18.10: Veins of the Lower Limb

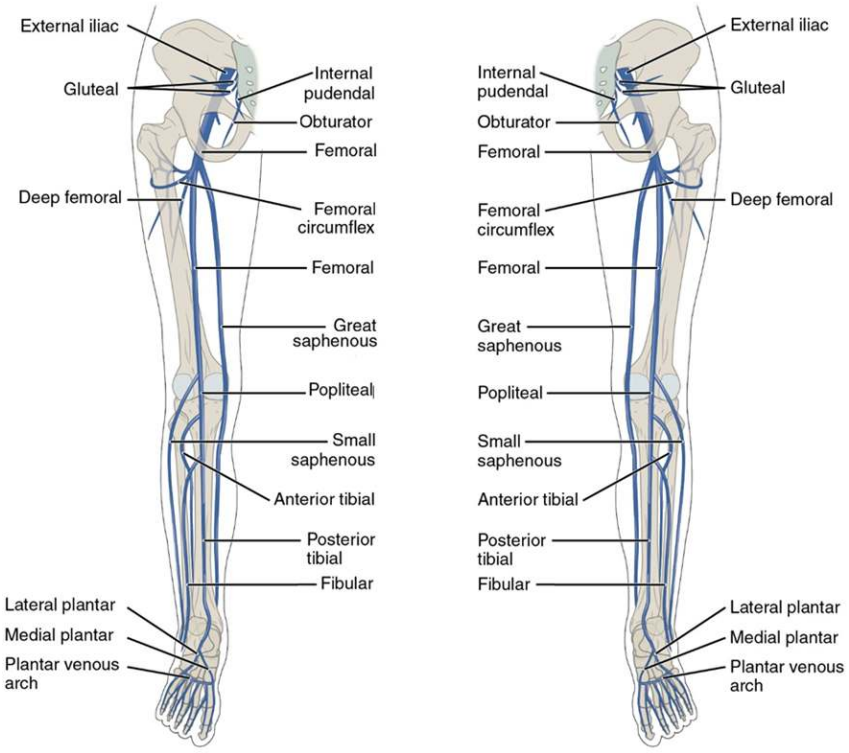
Veins of the Lower Limb

Deoxygenated blood returning to the heart from the lower limbs drain into the **external iliac veins** (right and left). The veins of the lower limb are named for the landmarks and regions they serve such as the **femoral veins**, the **popliteal veins**, and the **anterior** and **posterior tibial veins**. Among the veins of the lower limb are the longest blood vessels in the body, the **great saphenous veins** (right and left), which run the entire lengths of the lower limbs.



Above: Anterior veins of the lower limb.

Posterior View



Above: Veins of the posterior lower limb.

Attributions

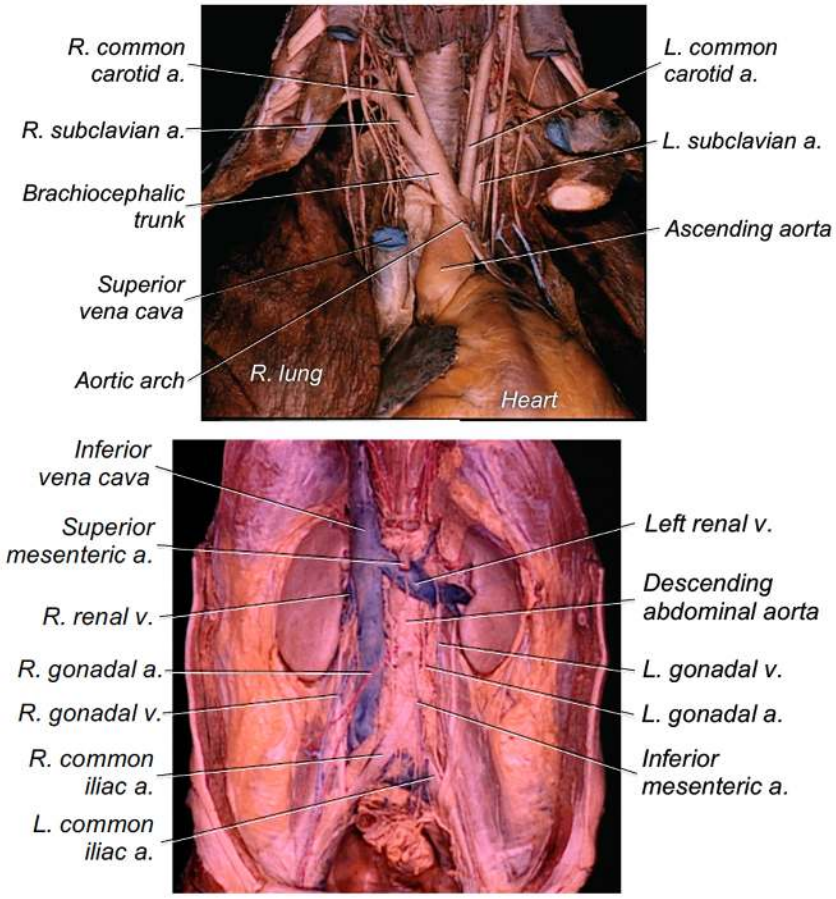
- "Anatomy and Physiology" by J. Gordon Betts et al., OpenStax is licensed under CC BY 4.0

Updated 2026.

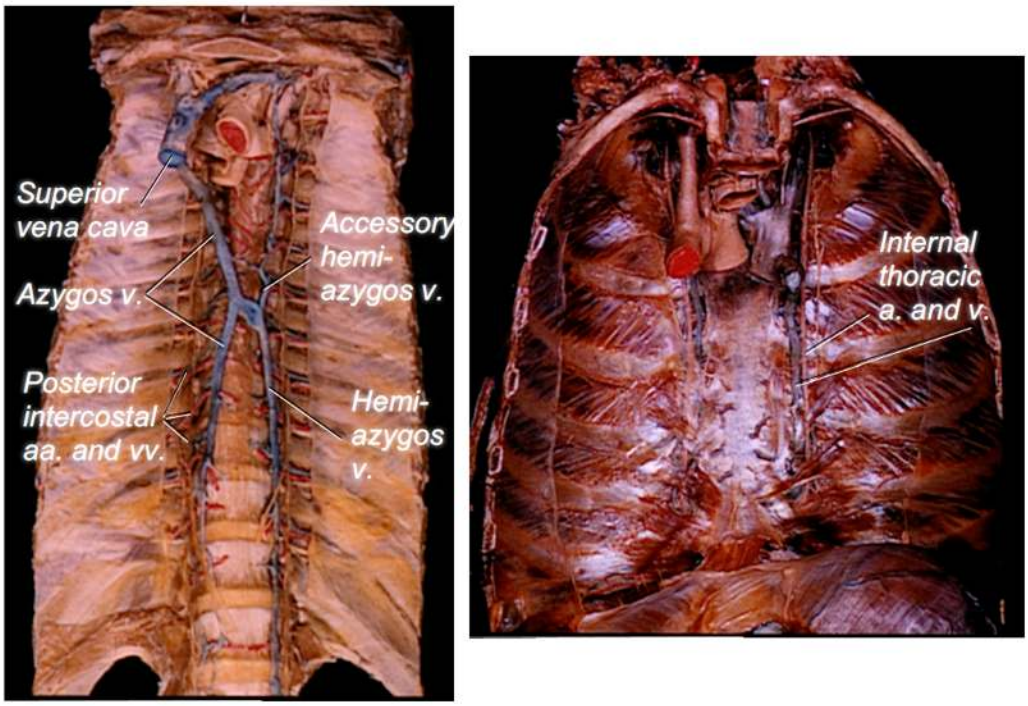
This page titled 18.10: Veins of the Lower Limb is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

18.11: Cadaver Images of Blood Vessels

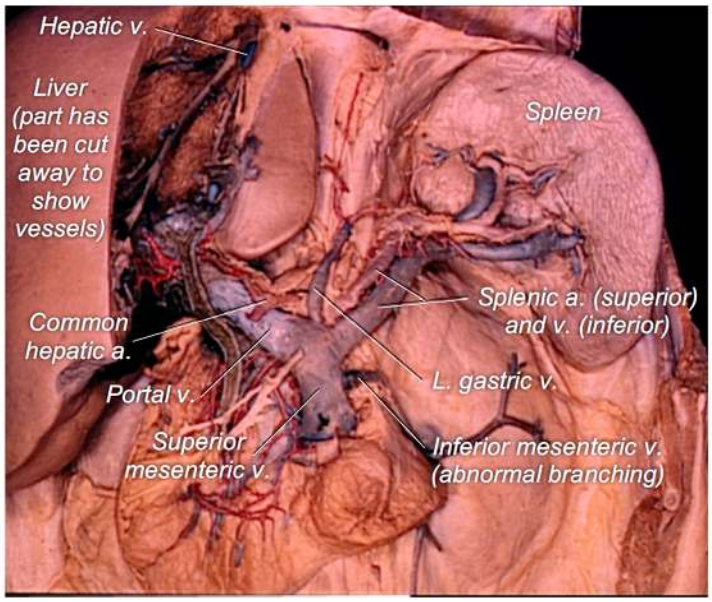
Cadaver Images of Blood Vessels



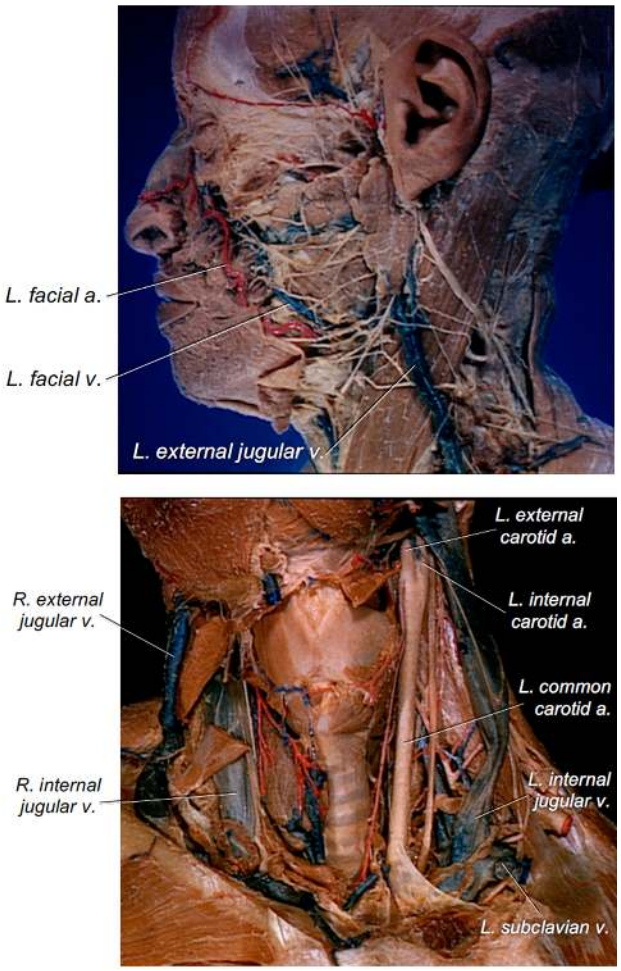
Above: Cadaver image of blood vessels (top) of the anterior superior thorax and neck and (bottom) abdominopelvic. The abbreviations are "a." for "artery" and "v." for "vein."



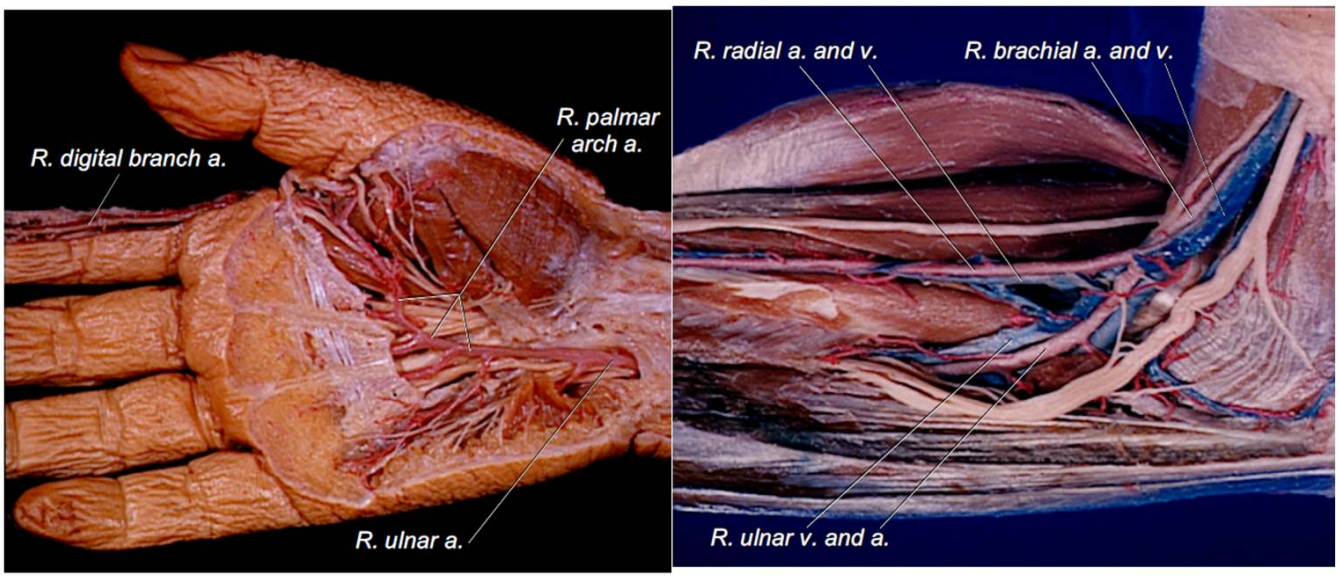
Above: Veins of the superior thorax. The abbreviations are "a." for "artery," "v." for "vein," "aa." for "arteries," and "vv." for "veins."



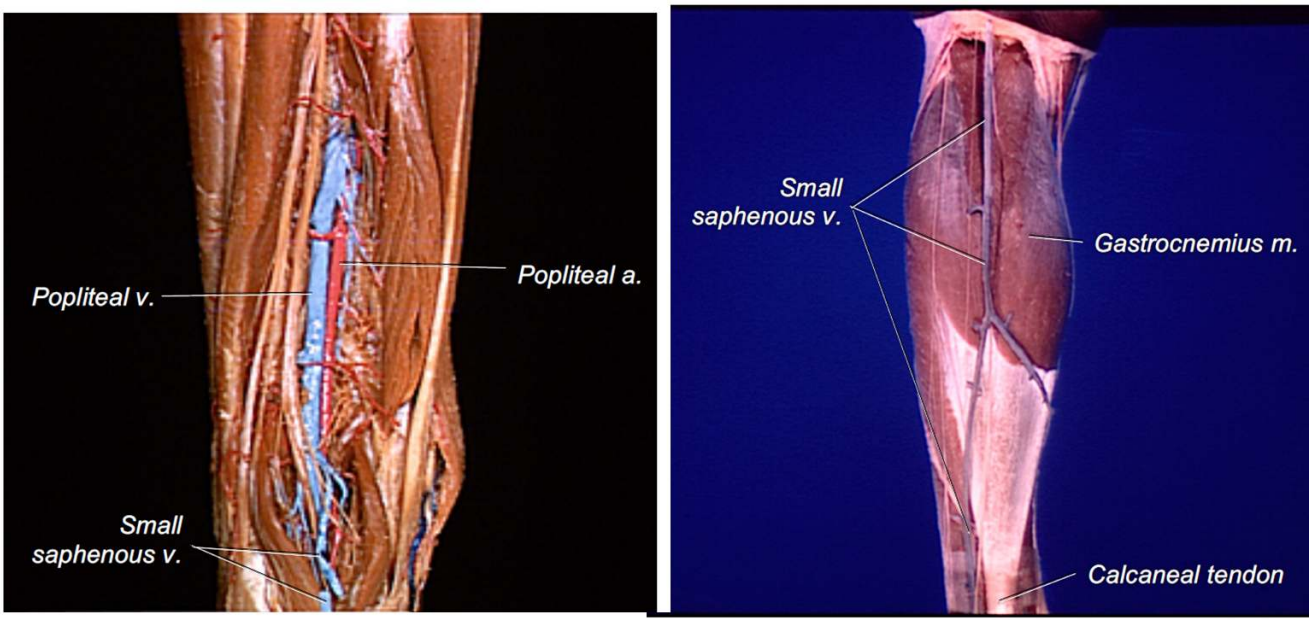
Above: Vasculature of the portal system, anterior view. The abbreviations are "a." for "artery" and "v." for "vein."



Above: Vasculature of the head and neck of a cadaver. The abbreviations are "a." for "artery" and "v." for "vein."



Above: Vasculature of the (left) right hand and (right) antebrachium. The abbreviations are "a." for "artery" and "v." for "vein."



Above: Vasculature of the posterior knee (left) and posterior leg (right). The abbreviations are "a." for "artery," "v." for "vein," and "m" for "muscle."

Attributions

- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0

Updated 2026.

This page titled 18.11: Cadaver Images of Blood Vessels is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

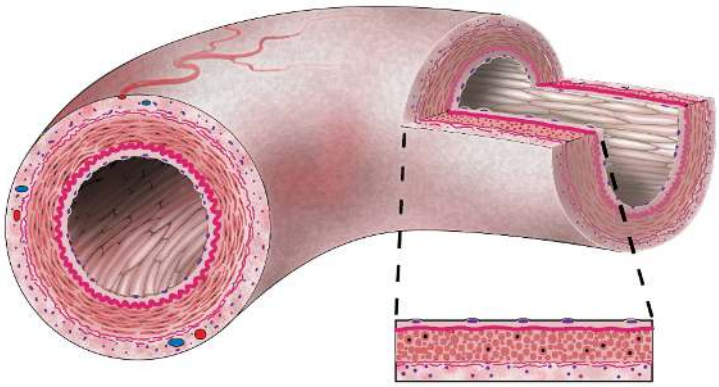
18.12: Laboratory Activities and Assignment

Laboratory Activities and Assignment

Part 1: Review of Blood Vessels

1. On the diagram of a blood vessel below, label the following:

• endothelium • external elastic lamina • internal elastic lamina	• lumen • smooth muscle • tunica adventitia	• tunica intima • tunica media • vasa vasorum



2. For each description below, write one of the choices below in the blank spaces provided. Choices can be used more than once.

- arteries
- arterioles
- capillaries
- veins
- venules

a. _____ These large blood vessels carry blood to the heart.

b. _____ & _____ These blood vessels contain valves.

c. _____ These large blood vessels carry blood away from the heart.

d. _____ These smaller blood vessels carry blood from the vessels of where materials are transferred between the blood and the tissues to the large blood vessels carrying blood to the heart.

e. _____ These are the smallest blood vessels in the body.

f. _____ These smaller blood vessels carry blood to the vessels where materials are transferred between the blood and the tissues.

g. _____ The inferior vena cava is one of these.

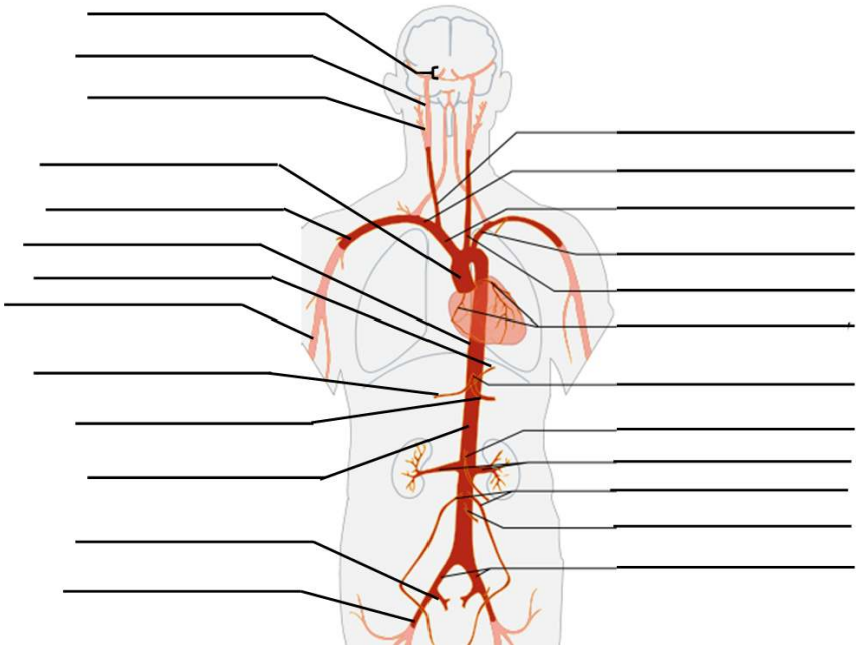
h. _____ The aorta is one of these.

i. _____ The vessels where materials are transferred between the blood and the tissues.

j. _____, _____, & _____ Blood vessels that do not have valves.

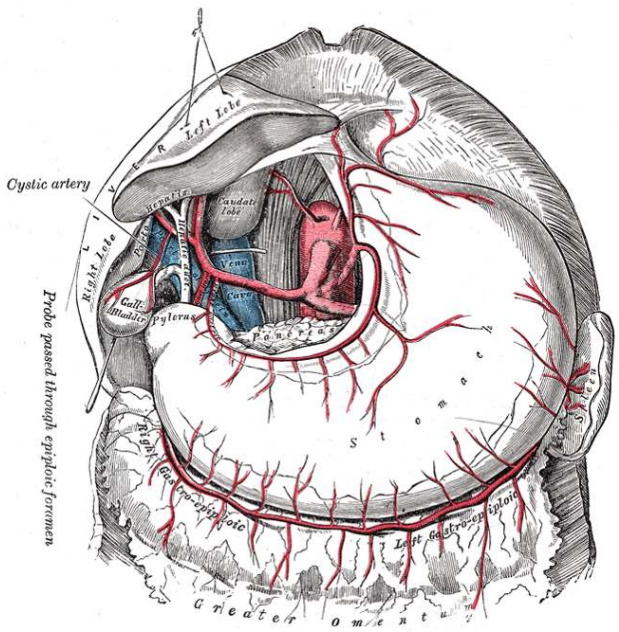
3. Name the arteries on the diagram below. Use the choices given to fill in each blank.

- ascending aorta
- axillary artery
- brachial artery
- brachiocephalic trunk
- celiac trunk
- circle of Willis
- common carotid artery (right and left)
- common hepatic artery
- common iliac arteries
- descending abdominal aorta
- descending thoracic aorta
- external carotid artery
- external iliac artery
- gonadal arteries
- inferior mesenteric artery
- internal carotid artery
- internal iliac artery
- left gastric artery
- renal arteries
- right and left coronary arteries
- splenic artery
- subclavian artery (right and left)
- superior mesenteric artery



3. Label the following arteries on the diagram below:

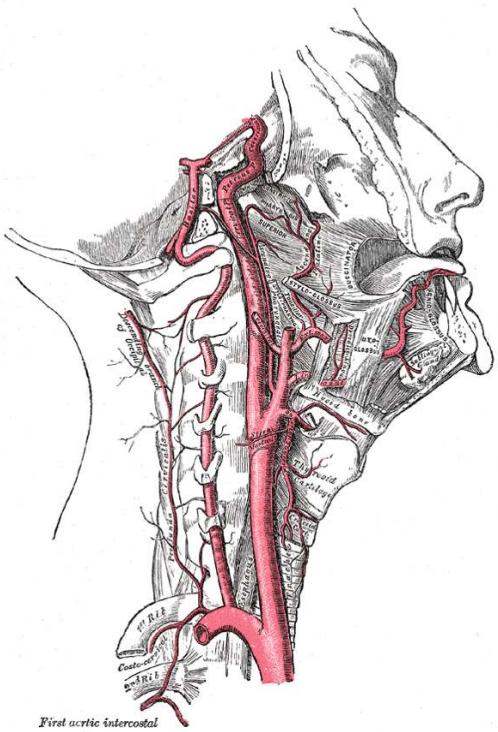
- celiac trunk
- common hepatic artery
- descending abdominal aorta
- inferior phrenic artery
- left gastric artery
- splenic artery



https://bio.libretexts.org/@go/page/53799

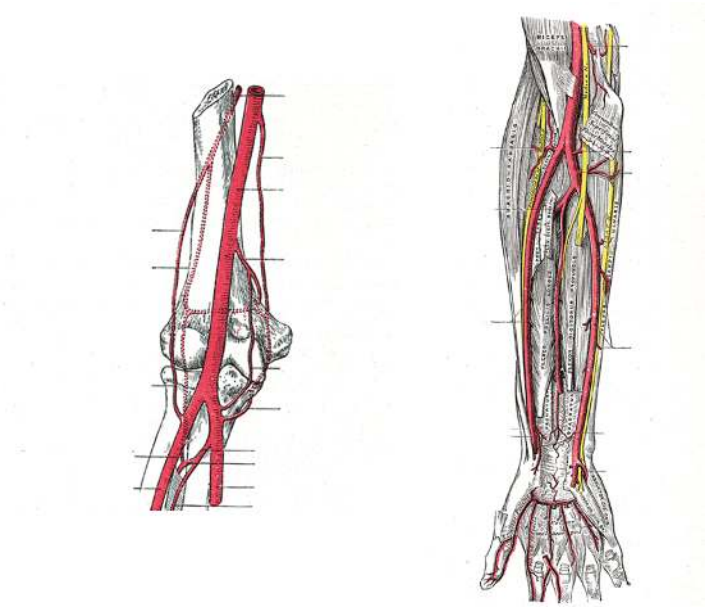
4. Label the following arteries on the diagram below:

- brachiocephalic trunk
- external carotid artery
- internal carotid artery
- right subclavian artery
- vertebral artery



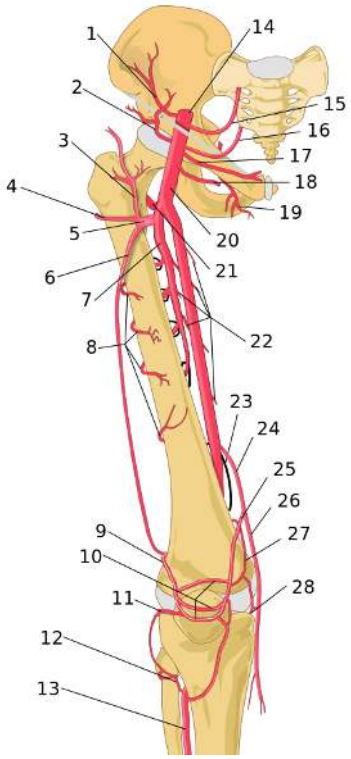
5. Label the following arteries on the diagram below:

- anterior crural interosseous
- brachial artery (on both diagrams)
- deep palmar arch (on both diagrams)
- digital arteries
- inferior ulnar collateral (on both diagrams)
- radial artery (on both diagrams)
- superior ulnar collateral
- ulnar artery (on both diagrams)



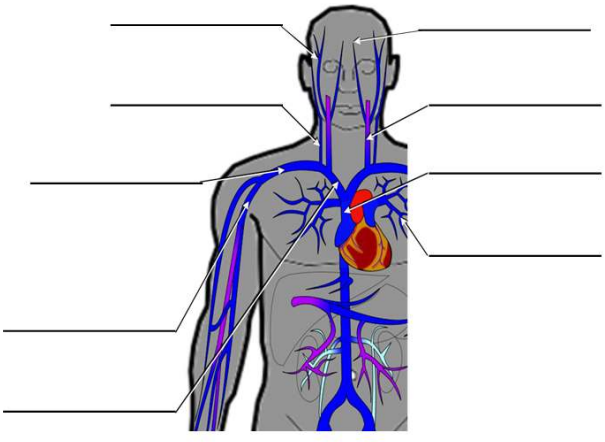
6. Write the number in each blank that corresponds with the name of each artery in the diagram.

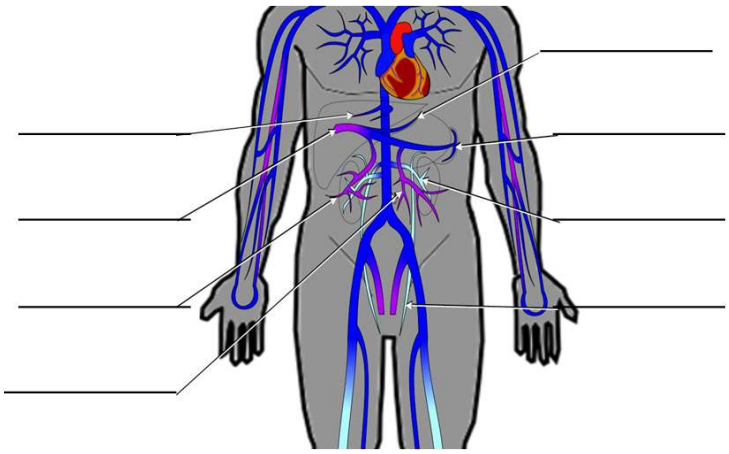
_____ anterior tibial artery _____ deep femoral artery _____ external iliac artery	_____ femoral artery _____ genicular artery _____ lateral femoral circumflex artery



7. Label the following veins on the diagrams below:

• axillary vein • brachiocephalic vein • external jugular vein • facial vein • gastric vein • hepatic portal vein	• inferior mesenteric vein • internal jugular vein • left gonadal vein • left renal vein • pulmonary artery • right hepatic vein	• splenic vein • subclavian vein • superior vena cava • superficial temporal vein • superior mesenteric vein

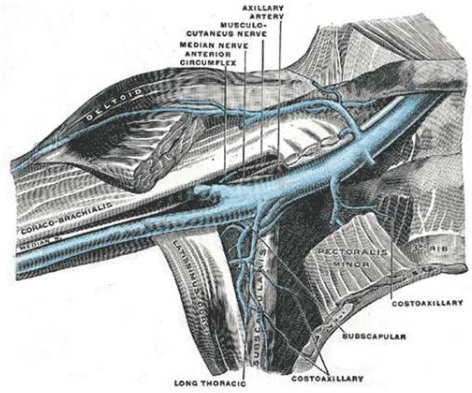


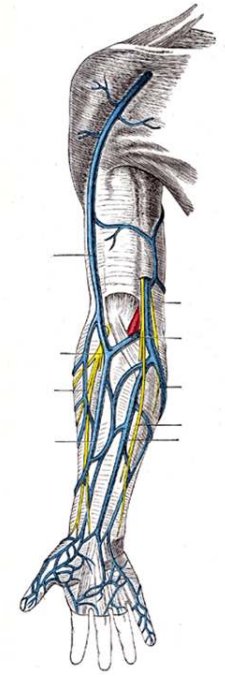


6. Label the following veins on the diagrams below:

https://bio.libretexts.org/@go/page/53799

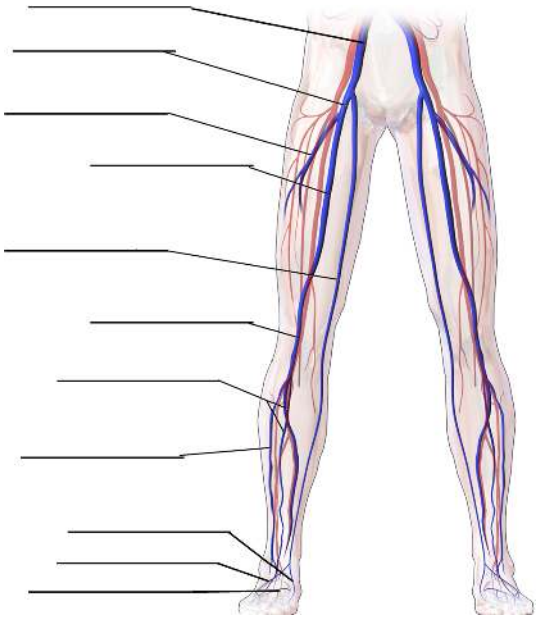
- axillary vein
- basilic vein (on both diagrams
- brachial vein
- cephalic vein (on both diagrams)
- digital veins
- median antebrachial vein
- median cubital vein
- palmar venous arches





7. Label the following veins on the diagrams below:

- common femoral vein
- deep femoral vein
- external iliac vein
- femoral vein
- great saphenous vein
- lateral plantar vein
- medial plantar vein
- plantar venous arch
- popliteal vein
- small saphenous vein
- tibial veins

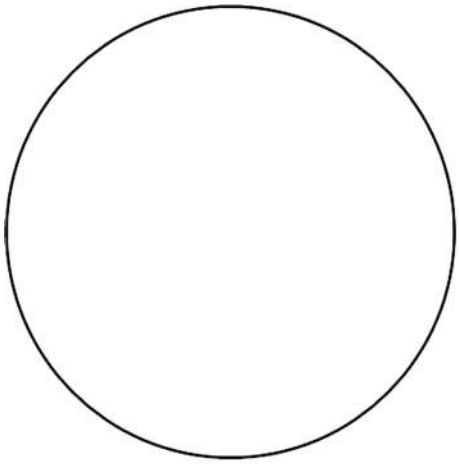


Part 2: Examining the Histology of the Blood Vessels

1. Obtain the slides listed below that are available for today's lab.
2. Focus on each sample and identify the structures listed for each type of tissue.
3. Indicate the **total** magnification you make each illustration at in the space provided.
4. Illustrate each tissue you observe with the microscope at the magnification you listed.
5. Label each illustration with the structures listed for each.

Large Elastic Artery Cross Section

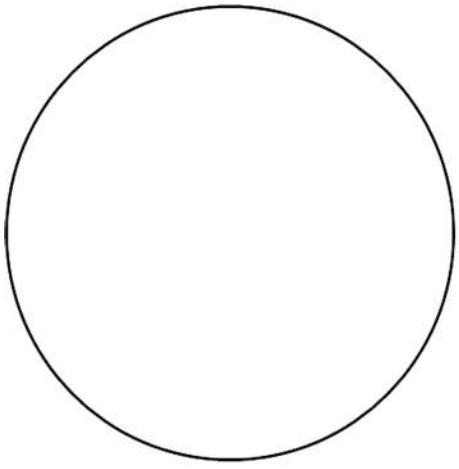
Label the tissue with: tunica intima, tunica media, tunica adventitia, smooth muscle, elastic fibers, vasa vasorum



Total magnification: _____

Capillary-Containing Tissue

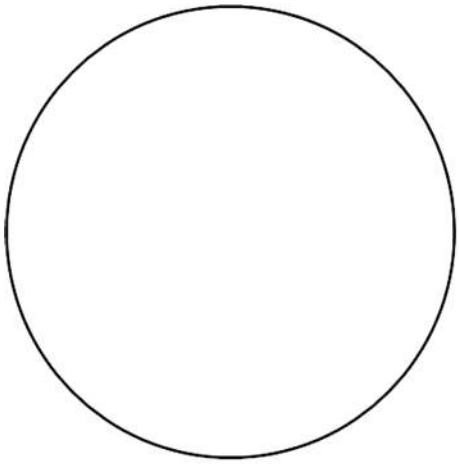
Label the tissue with: capillary, nucleus of endothelial cell



Total magnification: _____

Vein Cross Section

Label the tissue with: tunica intima, tunica media, tunica adventitia, nucleus of endothelial cell, valve



Total magnification: _____

Part 3: The Arteries and Veins of the Systemic Circuit

1. For each blood vessel in the table below, identify it on anatomical models, anatomical diagrams provided by your instructor, or on the virtual model at www.zygotebody.com.
2. Fill out the table to tell the location of the blood vessel.
3. Indicate whether this blood vessel supplies blood or drains it by checking the appropriate box.
4. Tell what organs or body regions are supplied or drained by the blood vessel.
5. Indicate whether this blood vessel is paired (right and left) or if there is only one by checking the appropriate box.

Blood Vessels of the Trunk

Blood Vessel	Location	Supplies	Drains	Organ(s) Supplied/Drained	Paired	Unpaired
abdominal aorta						
azygous vein						
brachiocephalic trunk						
brachiocephalic vein						
common carotid artery						
common hepatic artery						
common iliac artery						
common iliac vein						
coronary arteries						
hemiazygous vein						
hepatic portal vein						
hepatic veins						
external jugular vein						
gonadal artery						
gonadal vein						
inferior mesenteric artery						
inferior mesenteric vein						
intercostal arteries						

Blood Vessel	Location	Supplies	Drains	Organ(s) Supplied/Drained	Paired	Unpaired
intercostal veins						
internal jugular vein						
left gastric artery						
renal artery						
renal vein						
splenic artery						
splenic vein						
subclavian artery						
subclavian vein						
superior mesenteric artery						
superior mesenteric vein						
superior vena cava						
thoracic aorta						

Blood Vessels of the Head and Neck

Blood Vessel	Location	Supplies	Drains	Organ(s) Supplied/Drained	Paired	Unpaired
basilar artery						
brachiocephalic trunk						
brachiocephalic vein						
cerebral arterial circle (aka circle of Willis)						
common carotid artery						
external carotid artery						
external jugular vein						
facial artery						
internal carotid artery						
internal jugular vein						
superficial temporal artery						
superior vena cava						
vertebral artery						
vertebral vein						

Blood Vessels of the Upper Limbs

Blood Vessel	Location	Supplies	Drains	Organ(s) Supplied/Drained	Paired	Unpaired
axillary artery						
axillary vein						

Blood Vessel	Location	Supplies	Drains	Organ(s) Supplied/Drained	Paired	Unpaired
basilic vein						
brachial artery						
brachial vein						
brachiocephalic trunk						
brachiocephalic vein						
cephalic vein						
deep palmar (arterial) arch						
digital arteries (of the hand)						
digital veins (of the hand)						
median cubital vein						
radial artery						
radial vein						
subclavian artery						
subclavian vein						
superficial (arterial) palmar arch						
ulnar artery						
ulnar vein						

Blood Vessels of the Lower Limbs

Blood Vessel	Location	Supplies	Drains	Organ(s) Supplied/Drained	Paired	Unpaired
common iliac artery						
common iliac vein						
deep femoral artery						
digital arteries (of the foot)						
digital veins (of the foot)						
external iliac artery						
external iliac vein						
femoral artery						
femoral vein						
fibular artery						
great saphenous vein						
plantar artery						
plantar venous arch						
dorsal venous arch						
popliteal artery						

Blood Vessel	Location	Supplies	Drains	Organ(s) Supplied/Drained	Paired	Unpaired
popliteal vein						

Attributions

Part 1: Review of Blood Vessels

- "Anatomy and Physiology Lab Homework" by Laird C Sheldahl is licensed under CC BY-SA 4.0
- "Aorta branches.svg" by Mikael Häggström is licensed under CC BY-SA 3.0 / A derivative from the original work
- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0
- "Gray's Anatomy plates" by Henry Vandyke Carte is in the Public Domain
- "Medical gallery of Blausen Medical 2014" by Blausen.com staff is licensed under CC BY 3.0
- "Thigh arteries schema numbered.svg" by Jecowa is licensed under CC BY 3.0 / A derivative from the original work

Part 2: Examining the Histology of the Blood Vessels

- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0

Part 3: The Arteries and Veins of the Systemic Circuit

- "Systemic Blood Vessels" by Dongho Kim is licensed under CC BY-NC-SA 4.0

Updated 2026.

This page titled 18.12: Laboratory Activities and Assignment is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

18.13: Collaborative Study Activities

Collaborative Study Activities

These activities are designed for student groups of 2-4. Larger groups will work better when there is no supplemental instructor present in the laboratory to assist in testing student groups on each section.

Systemic Arteries

1. Identify the following structures on classroom anatomical models and/or unlabeled images/diagrams made available by your instructor. Work with your group to identify each structure and check them off the list once you have identified them.

☐ anterior tibial arteries	☐ descending thoracic aorta	☐ left gastric artery
☐ aortic arch	☐ digital arteries	☐ palmar arch arteries
☐ ascending aorta	☐ external carotid arteries	☐ popliteal arteries
☐ axillary arteries	☐ external iliac arteries	☐ posterior tibial arteries
☐ celiac trunk	☐ femoral arteries	☐ radial arteries
☐ common hepatic artery	☐ gonadal arteries	☐ renal arteries
☐ common iliac arteries	☐ inferior mesenteric artery	☐ splenic artery
☐ brachial arteries	☐ inferior phrenic arteries	☐ subclavian arteries
☐ brachiocephalic trunk	☐ intercostal arteries	☐ superior mesenteric artery
☐ common carotid arteries	☐ internal carotid arteries	☐ ulnar arteries
☐ descending abdominal aorta	☐ internal iliac arteries	☐ vertebral arteries

2. Test your group members by ***asking them to name each structure you point to***. Check off each when your group can successfully name each. Your group will also test you.

☐ anterior tibial arteries	☐ descending thoracic aorta	☐ left gastric artery
☐ aortic arch	☐ digital arteries	☐ palmar arch arteries
☐ ascending aorta	☐ external carotid arteries	☐ popliteal arteries
☐ axillary arteries	☐ external iliac arteries	☐ posterior tibial arteries
☐ celiac trunk	☐ femoral arteries	☐ radial arteries
☐ common hepatic artery	☐ gonadal arteries	☐ renal arteries
☐ common iliac arteries	☐ inferior mesenteric artery	☐ splenic artery
☐ brachial arteries	☐ inferior phrenic arteries	☐ subclavian arteries
☐ brachiocephalic trunk	☐ intercostal arteries	☐ superior mesenteric artery
☐ common carotid arteries	☐ internal carotid arteries	☐ ulnar arteries
☐ descending abdominal aorta	☐ internal iliac arteries	☐ vertebral arteries

3. When you and your group are comfortable identifying all the structures above, request the assistance of your Instructor. They will test you on your use of these terms and initial ONLY when you are successful using these terms. Instructor: _____

Systemic Veins

1. Identify the following structures on classroom anatomical models and/or unlabeled images/diagrams made available by your instructor. Work with your group to identify each structure and check them off the list once you have identified them.

- [ ] anterior tibial veins
- [ ] axillary veins
- [ ] azygous vein
- [ ] basilic veins
- [ ] brachial veins
- [ ] brachiocephalic veins
- [ ] cephalic veins
- [ ] common iliac veins
- [ ] digital veins
- [ ] dorsal venous arches
- [ ] external iliac veins
- [ ] external jugular veins
- [ ] femoral veins
- [ ] great saphenous veins
- [ ] hemiazygous vein
- [ ] hepatic portal vein
- [ ] hepatic veins
- [ ] inferior sagittal sinus
- [ ] inferior mesenteric vein
- [ ] inferior vena cava
- [ ] intercostal veins
- [ ] internal jugular veins
- [ ] left gastric vein
- [ ] popliteal veins
- [ ] posterior tibial veins
- [ ] radial veins
- [ ] renal veins
- [ ] splenic vein
- [ ] subclavian veins
- [ ] superior mesenteric vein
- [ ] superior sagittal sinus
- [ ] superior vena cava
- [ ] sigmoid sinus
- [ ] transverse sinus
- [ ] ulnar veins

2. Test your group members by ***asking them to name each structure you point to***. Check off each when your group can successfully name each. Your group will also test you.

- [ ] anterior tibial veins
- [ ] axillary veins
- [ ] azygous vein
- [ ] basilic veins
- [ ] brachial veins
- [ ] brachiocephalic veins
- [ ] cephalic veins
- [ ] common iliac veins
- [ ] digital veins
- [ ] dorsal venous arches
- [ ] external iliac veins
- [ ] external jugular veins
- [ ] femoral veins
- [ ] great saphenous veins
- [ ] hemiazygous vein
- [ ] hepatic portal vein
- [ ] hepatic veins
- [ ] inferior sagittal sinus
- [ ] inferior mesenteric vein
- [ ] inferior vena cava
- [ ] intercostal veins
- [ ] internal jugular veins
- [ ] left gastric vein
- [ ] popliteal veins
- [ ] posterior tibial veins
- [ ] radial veins
- [ ] renal veins
- [ ] splenic vein
- [ ] subclavian veins
- [ ] superior mesenteric vein
- [ ] superior sagittal sinus
- [ ] superior vena cava
- [ ] sigmoid sinus
- [ ] transverse sinus
- [ ] ulnar veins

3. When you and your group are comfortable identifying all the structures above, request the assistance of your Instructor. They will test you on your use of these terms and initial ONLY when you are successful using these terms. Instructor: _____

Updated 2026.

This page titled 18.13: Collaborative Study Activities is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

CHAPTER OVERVIEW

19: Respiratory System

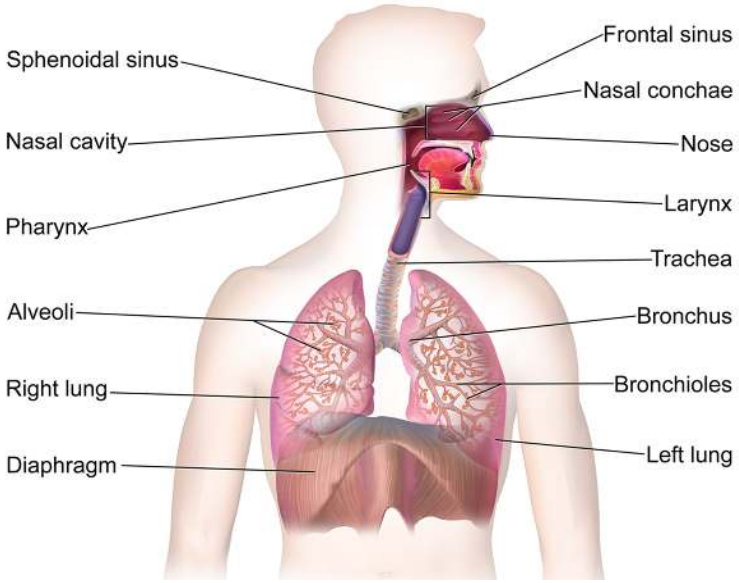
19.1: Introduction
19.2: Upper Respiratory Tract
19.3: Lower Respiratory Tract
19.4: Laboratory Activities and Assignment
19.5: Collaborative Study Activities

This page titled 19: Respiratory System is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

19.1: Introduction

Introduction

The respiratory system is responsible for the gas exchange of oxygen (O_2) and carbon dioxide (CO_2), pulling oxygen into the body and getting rid of carbon dioxide. The main specialized organs of this process are the lungs which house clusters of sac-like structures known as **alveoli**. There are from 480 to 790 million alveoli which increase the efficiency of gas exchange by increasing surface area to around 118 m^2 in men and 91 m^2 in women. The respiratory system consists of the **nasal cavity**, **pharynx**, **larynx**, **trachea**, **lungs**, **bronchi**, **bronchioles**, and **alveoli**, along with their accessory structures. These structures are divided into the **upper respiratory tract** and the **lower respiratory tract**, with the lower portion beginning at the trachea. Functionally, the respiratory system can be divided into the **conducting zone**, terminating at the **terminal bronchioles**; then air flows into the **respiratory zone**, where the actual gas exchange occurs.



Above: Structures of the respiratory system.

Attributions

- "1.1 Anatomy and Physiology of Respiratory System" by Paul Hudson is licensed under CC BY-NC 4.0
- "Medical gallery of Blausen Medical 2014" by Blausen.com staff is licensed under CC BY 3.0

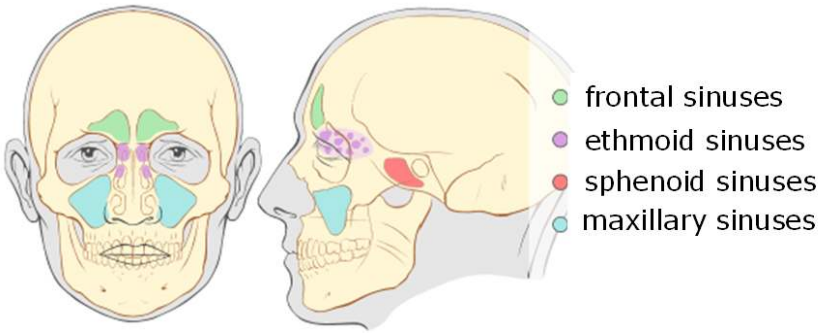
Updated 2026.

This page titled 19.1: Introduction is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

19.2: Upper Respiratory Tract

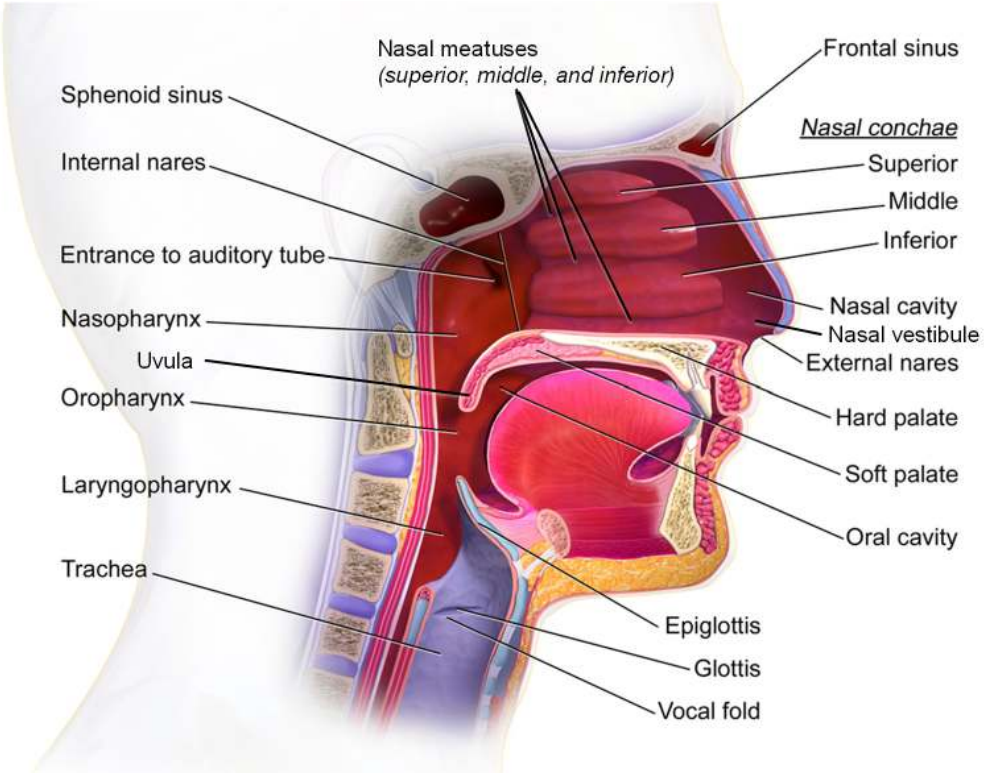
Upper Respiratory Tract

When you breathe in air flows through the nostrils and enters the nasal cavity which is lined by **goblet cells** that release mucus. That mucus is salty sticky and has lysozyme, enzymes that help kill bacteria. Nose hairs at the entrance of the nasal cavity get coated with that mucus and are able to trap large particles of dust and pollen as well as bacteria forming tiny clumps in the nose. The nasal cavity is connected to four sinuses, which are air-filled spaces inside the bones that surround the nose called the **paranasal sinuses**. Maxillary sinus helps the inspired air to circulate for a bit so it has time to get warm and moist. They also act like tiny echo chambers that help amplify the sound of your voice, this is why you sound so different when you plug your nose.



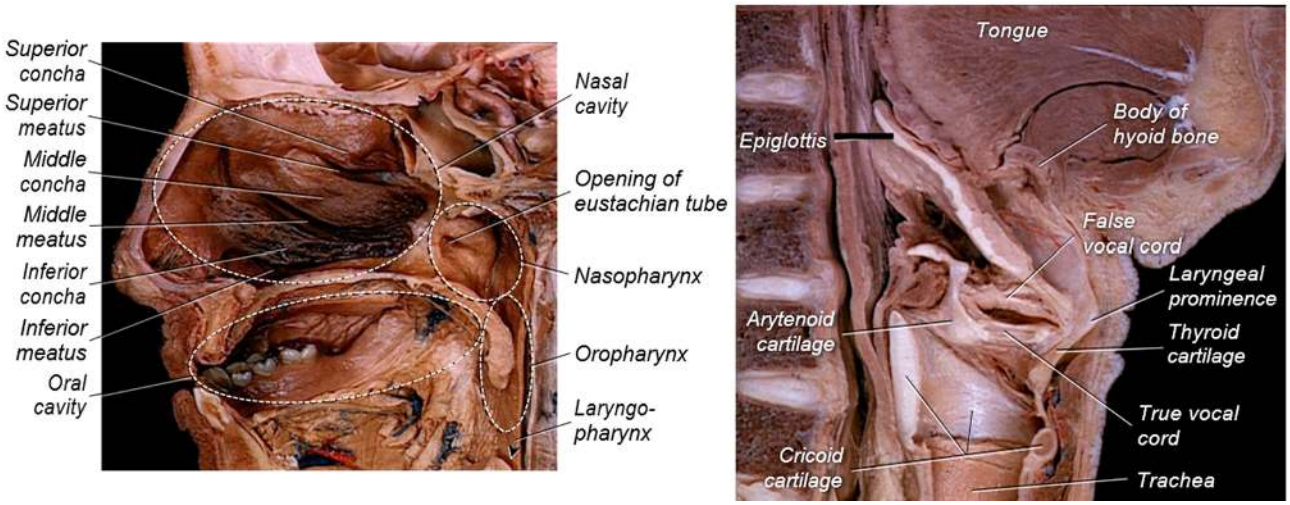
Above: Paranasal sinuses.

That relatively clean warm and moist air goes from the nasal cavity into the **pharynx**, composed of three regions (listed from superior to inferior): **nasopharynx** (posterior to the nasal cavity), **oropharynx** (posterior to the oral cavity), and **laryngopharynx** (at the pharynx-larynx transition). The **soft palate** which is the softer portion of the roof of your mouth behind the **hard palate** which is the part you can feel with your tongue and the pendulum-like **uvula** hanging at its end move together to form a flap or valve that closes the nasal pharynx off when you eat to prevent food from going up into the nasal pharynx. Finally there's the laryngopharynx the part of the pharynx that's continuous with the larynx or the voice box up to this point.

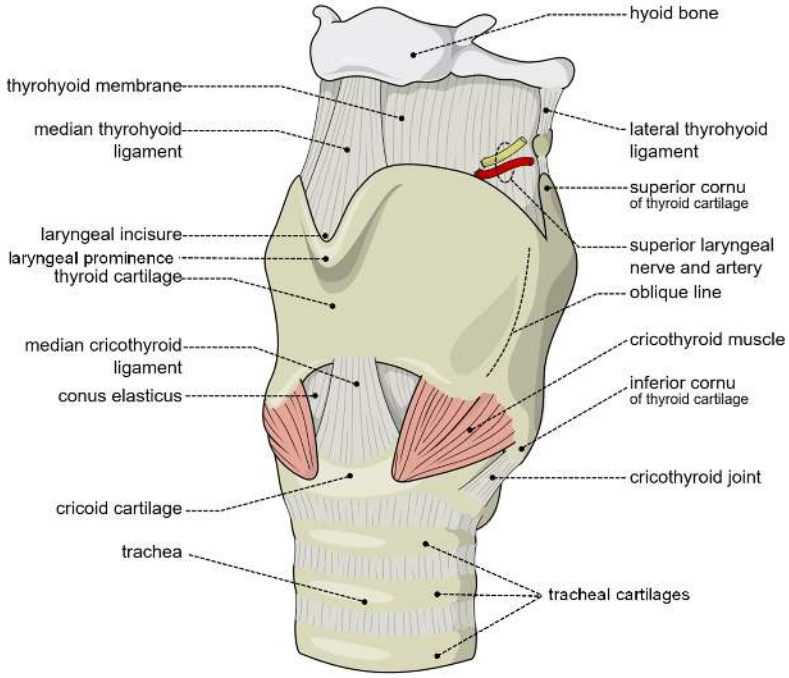


Above: Structures of the upper respiratory tract, lateral view.

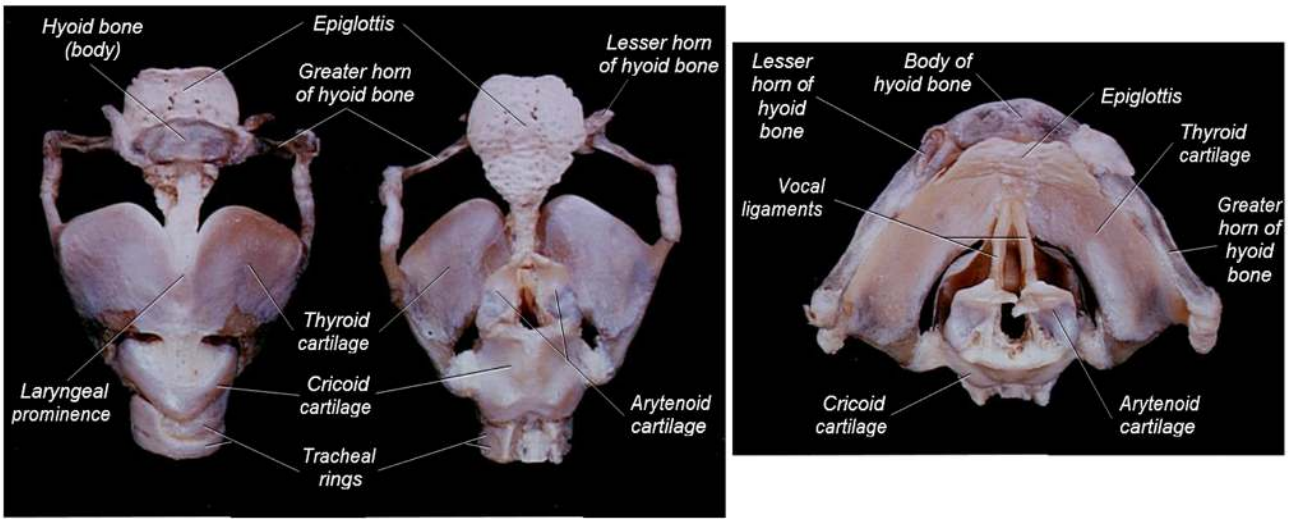
Food and air share a common path but at the top of the larynx, a spoon shaped flap of cartilage called the **epiglottis** acts like a lid that seals off the airway when you are eating so that food can only go one way down the esophagus and towards the stomach. If anything other than air gets into the larynx then you have a cough reflex that kicks it right back out.



Above: Cadaver images of upper respiratory structures (left) lateral view from the left side of the nasal and oral cavities and(right) lateral view from the right side of the larynx.



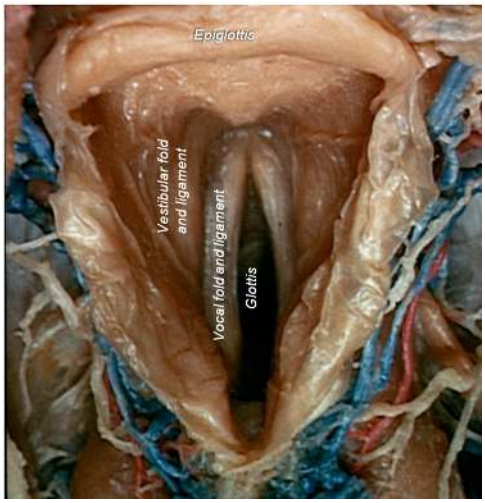
Above: External structure of the larynx, anterolateral view of the left anterior of the larynx and superior trachea.



Above: Images of larynx from a cadaver (left) anterior view, (middle) posterior view, and (right) superior view.

Upper Respiratory Tract Structure	Location	Function
epiglottis	an elastic cartilage flap capable of moving to covering the boundary between the laryngopharynx and the larynx when swallowing	when swallowing, the hyoid bone lifts causing the epiglottis to lower to protect the airways and prevent food and liquid from entering the larynx
external nares	the nostrils	primary route for entering air; hair in the vestibule removes airborne particles

Upper Respiratory Tract Structure	Location	Function
vestibular folds (false vocal cords)	a pair of folds in the mucous membranes of the glottis (within the larynx); each fold contains one of a pair of vestibular ligaments	prevents food and liquid from entering the airways; prevents vocal hoarseness
glottis	part of the larynx that contains the vocal folds	producing vocal sounds
laryngopharynx	inferior to the oropharynx and superior to the larynx and esophagus	passageway for food, water, and air; lined with stratified squamous epithelium
larynx	structure surrounded in cartilage located anterior to the esophagus between the laryngopharynx and the trachea; has nine different types of cartilage: 1 thyroid cartilage (Adam's apple), 1 cricoid cartilage, 1 epiglottis, 2 arytenoid cartilages, 2 corniculate cartilages, 2 cuneiform cartilages	voice box; conducts air to the lower respiratory tract
nasal conchae (superior, middle, and inferior)	medial-projecting bony protrusions in the nasal cavity; between the conchae are passageways called nasal meatuses	cause the air to swirl in the nasal cavity and come in contact with mucous membranes that catch dust and debris in the incoming air; heat and humidify the air for respiration to allow diffusion of gases in the lungs
nasal septum	between the right and left nostril and nasal cavities; the body portion is composed of the perpendicular plate of the ethmoid bone and the vomer bone; bone and cartilage together form the septum	divides the nasal cavity into right and left
nasopharynx	passageway posterior to the nasal cavity and superior to the oropharynx	passageway for airflow from nasal cavity; has pseudostratified ciliated columnar epithelium, pharyngeal tonsils, and Eustachian tubes equalizing pressure with the middle ear
oropharynx	passageway posterior to the oral cavity, inferior to the nasopharynx, and superior to the laryngopharynx	common passageway for food, water, and air; lined with stratified squamous epithelium; contains palatine and lingual tonsils
paranasal sinuses (frontal, ethmoid, sphenoid, and maxillary sinuses)	air-filled cavities within bones of the skull; connect to the nasal cavity	make the head lighter; heat and humidify the air for respiration to allow diffusion of gases in the lungs
vocal folds (true vocal cords)	folds of tissue in the glottis of the larynx; each fold is attached to one of a pair of vocal ligaments	responsible for sound production; only produces sound when air is exhaled over them; sound change when cords are stretched or relaxed



Above: Superior view of the glottis. The bottom of the photo is posterior and the top of the photo is anterior.

Attributions

- "1.1 Anatomy and Physiology of Respiratory System" by Paul Hudson is licensed under CC BY-NC 4.0
- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Anatomy of the Respiratory System" by Dongho Kim is licensed under CC BY-NC-SA 4.0
- "Larynx external en.svg" by Olek Remesz is licensed under CC BY-SA 2.5 / A derivative from the original work
- "Medical gallery of Blausen Medical 2014" by Blausen.com staff is licensed under CC BY 3.0
- "Paranasal sinuses numbers.svg" by Patrick J. Lynch, medical illustrator is licensed under CC BY 2.5

Updated 2026.

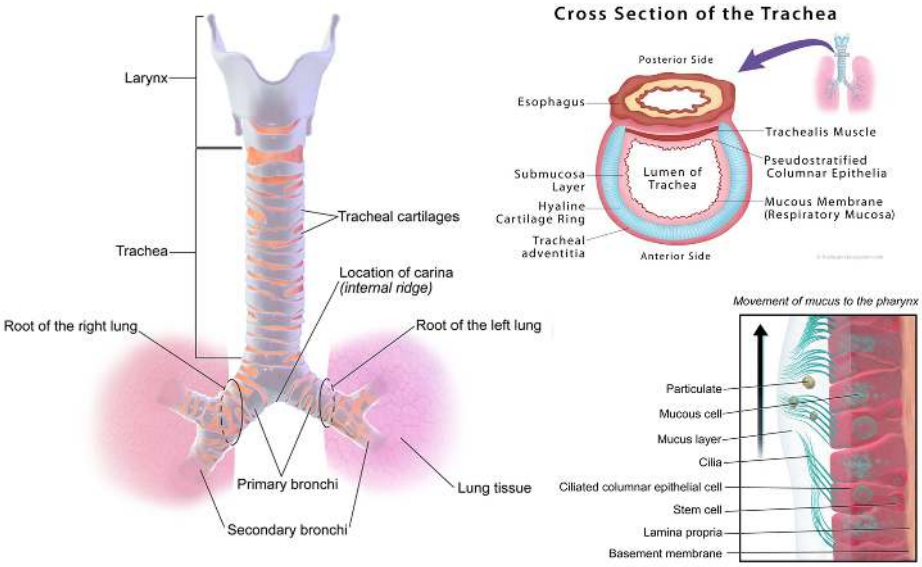
This page titled 19.2: Upper Respiratory Tract is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

19.3: Lower Respiratory Tract

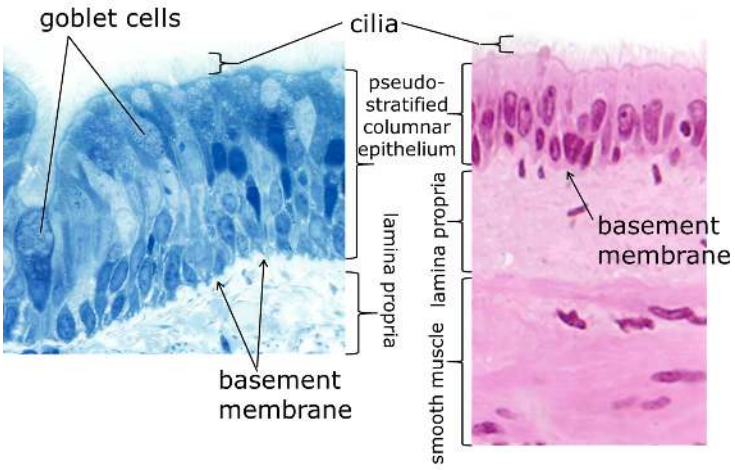
Lower Respiratory Tract

Once air makes its way into the larynx it then continues down the **trachea** (commonly known as the windpipe) which ultimately splits into two main stems towards the right and left lungs, respectively: the **right primary bronchus** and the **left primary bronchus**. The right primary bronchus is wider than the left primary bronchus and it is also has a more vertical angle than the left primary bronchus. Due to these structural differences, if a foreign object is accidently inhaled, it is more likely to become lodged in the right primary bronchus than the left primary bronchus.

The large airways are lined mostly by pseudostratified ciliated columnar epithelium with mucus-secreting goblet cells, **respiratory mucosa**. Mucus helps trap particles and then the ciliated columnar cells beat rhythmically to move the mucus and any trapped particles from the air towards the pharynx where they can either be spit out or swallowed. This mechanism is known as the **mucociliary escalator**.

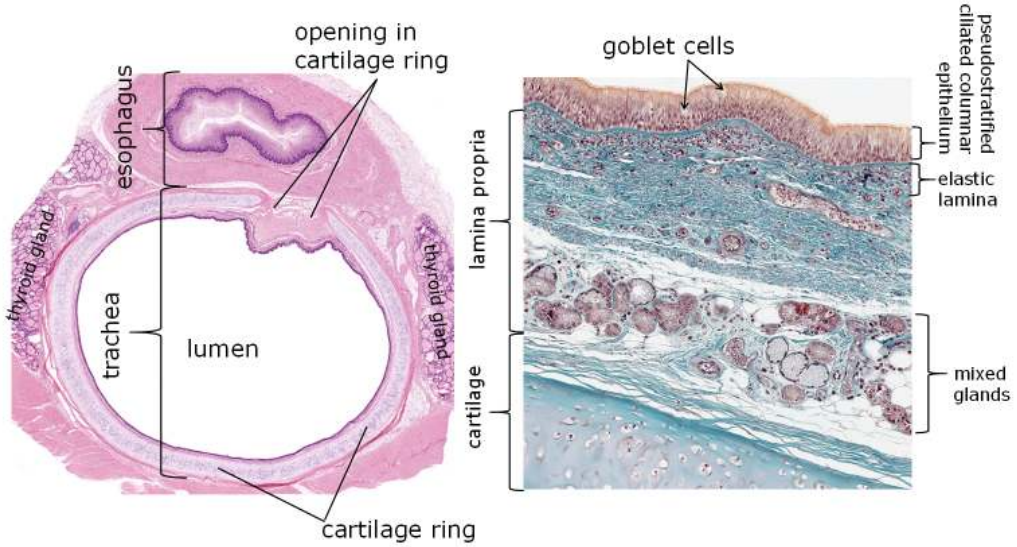


Above: (Left) The larynx, trachea, large bronchi, and lungs (only part shown). (Top right) Cross section of the trachea, located anterior to the esophagus. (Bottom right) The respiratory mucosa lining the inside of most of the large airways and creates the mucociliary escalator.



Above: Pseudostratified ciliated columnar epithelia that line the inside of large airways and are responsible for creating the mucociliary escalator.

https://bio.libretexts.org/@go/page/53809

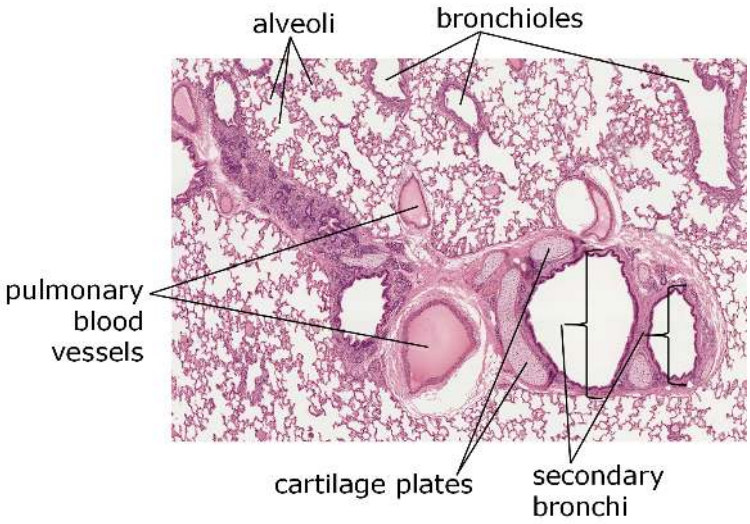


Above: (Left) The trachea, magnified by 10x. The trachea, continuing inferiorly from the larynx, lies anterior to the esophagus. The patency of the trachea and primary bronchi respiratory organs is maintained by C-shaped cartilage rings, whose openings face the esophagus. The two main lobes of the thyroid gland are located at the lateral boundaries of the trachea. (Right) The walls of the trachea and primary bronchi are identical, resembling the pattern typical for most respiratory passageways. Longitudinally oriented elastic fibers are numerous in the lamina propria, sometimes forming an obvious elastic lamina. Bundles of interlacing smooth muscle lie external to the elastic fibers. The trachea and primary bronchi are extrapulmonary and are part of the conducting portion of the respiratory system. Magnified by 100x.

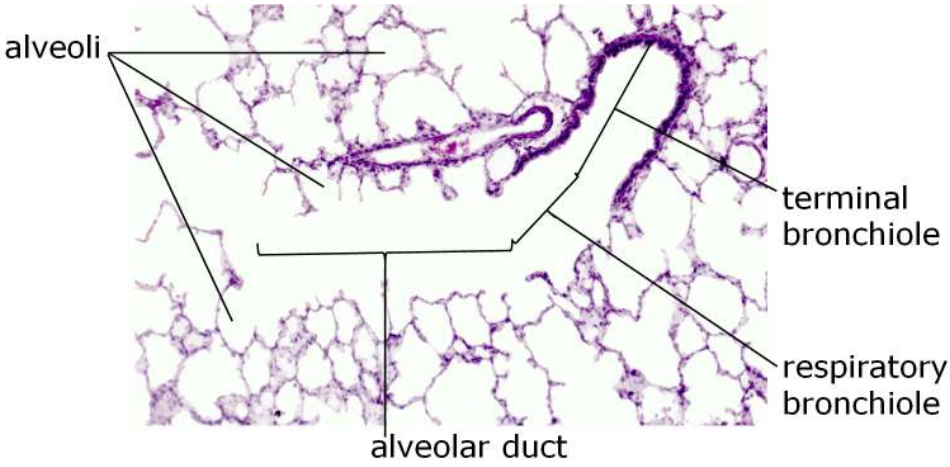
The bronchi are the largest airways of the lungs and they branch again and again becoming smaller and smaller. At each branch point, they get a different name. The **primary bronchi** branch into **secondary bronchi** which branch into **tertiary bronchi**. The first three generations of bronchi are all pretty wide and have cartilage rings for support. After the first three generations of bronchi though the airwaves get more narrow called **bronchioles** meaning "little bronchi" and these can stay open without the need for cartilage air is conducted through smaller and smaller bronchioles for about 15 to 20 generations and collectively these are known as conducting bronchioles. These conducting bronchioles are also lined by ciliated columnar cells. Mucus-secreting goblet cells are present as well as a new type of cell called a **club cell**. These club cells secrete glycosaminoglycans which protect a bronchial or epithelium, that can also transform into ciliated columnar cells so they help regenerate and replace damaged cells, if needed.

Lower Respiratory Tract Structure	Location	Function
alveolar duct	thin-walled passages at the end of respiratory bronchioles leading to alveolar sacs containing alveoli	conducting air to/from the alveolar sacs and alveoli
alveolar macrophages	mobile cells in the alveoli	big eater cells that patrol alveoli for debris and engulf it to remove it (dust, bacteria, etc.)
alveolar sac	a structure resembling a bunch of grapes off of an alveolar duct; contains alveoli	conducting air to/from alveoli; assemblage of alveoli that allow gas transfer with the pulmonary capillaries wrapped around the outside of alveoli
alveoli	spherical thin-tissue structures assembled into bunches (alveolar sacs)	assemblage of alveoli that allow gas transfer with the pulmonary capillaries wrapped around the outside of alveoli
bronchial tree	successive branches of airways wrapped in cartilage; primary bronchi (first branches), secondary bronchi (second branches), and tertiary bronchi	conducting air to/from bronchioles
bronchioles	airway branches off of tertiary bronchi in the lungs; smaller passages than bronchi; have a layer of smooth muscle; have cilia; lead to terminal bronchioles which lead to respiratory bronchioles; divide into 2-10 alveolar ducts	conducting air to/from alveolar ducts
lungs	paired organs within pleural cavities	conduct air and enable gas exchange to occur between the air in the lungs and blood in the pulmonary capillaries
parietal pleura	serous membranes forming the outer layers of the pleural cavities	forms outer aspects of the pleura cavities; produces pleura fluid to lubricate the pleural cavities

Lower Respiratory Tract Structure	Location	Function
trachea	tube between the larynx and the primary bronchi; wrapped in tracheal cartilage to keep airways open	conducting air to/from the lungs
type I alveolar cell	form about 95% of alveoli surfaces; simple squamous epithelial cells	gas exchange with capillaries
type II alveolar cell	very small cuboidal cells in the alveoli	produce and secrete pulmonary surfactant to maximize gas exchange
visceral pleura	serous membranes on the external surface of the lung	forms inner aspects of the pleura cavities; produces pleura fluid to lubricate the pleural cavities

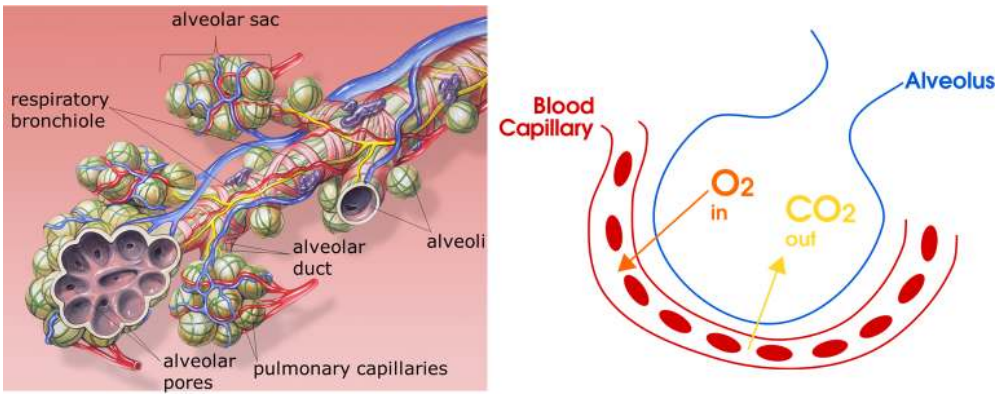


Above: Secondary bronchi, bronchioles, and alveoli in the lungs. Pulmonary blood vessels are also present. Tissue is magnified by 40x.



Above: A respiratory bronchiole is formed from a terminal bronchiole by the addition of alveoli and by a decrease in its diameter and in the thickness of its wall. The accumulation of additional alveoli to a respiratory bronchiole reduces the wall area of this bronchiole and forms an alveolar duct. Tissue is magnified by 100x.

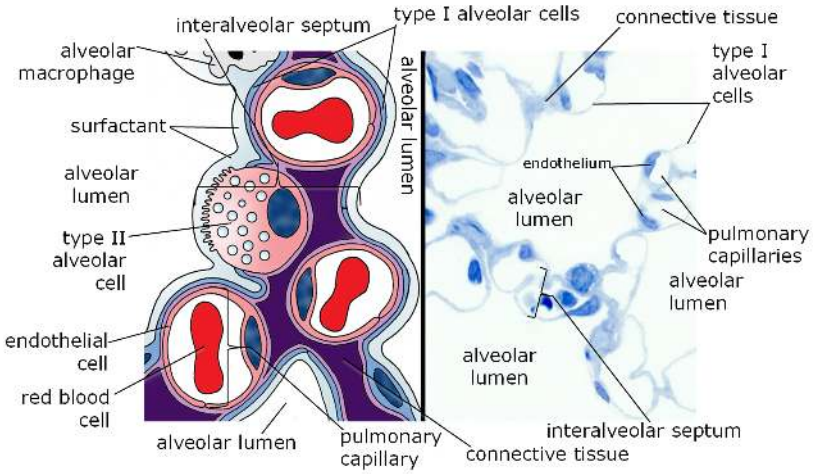
Now all these cells of the bronchioles receive oxygenated blood from the bronchial arteries of the systemic circulation. The last conducting bronchioles are the **terminal bronchioles** and then after that air moves into the **respiratory bronchioles**. Eventually the respiratory bronchioles end at **alveolar ducts** leading to **alveolar sacs** containing bunches of **alveoli**.



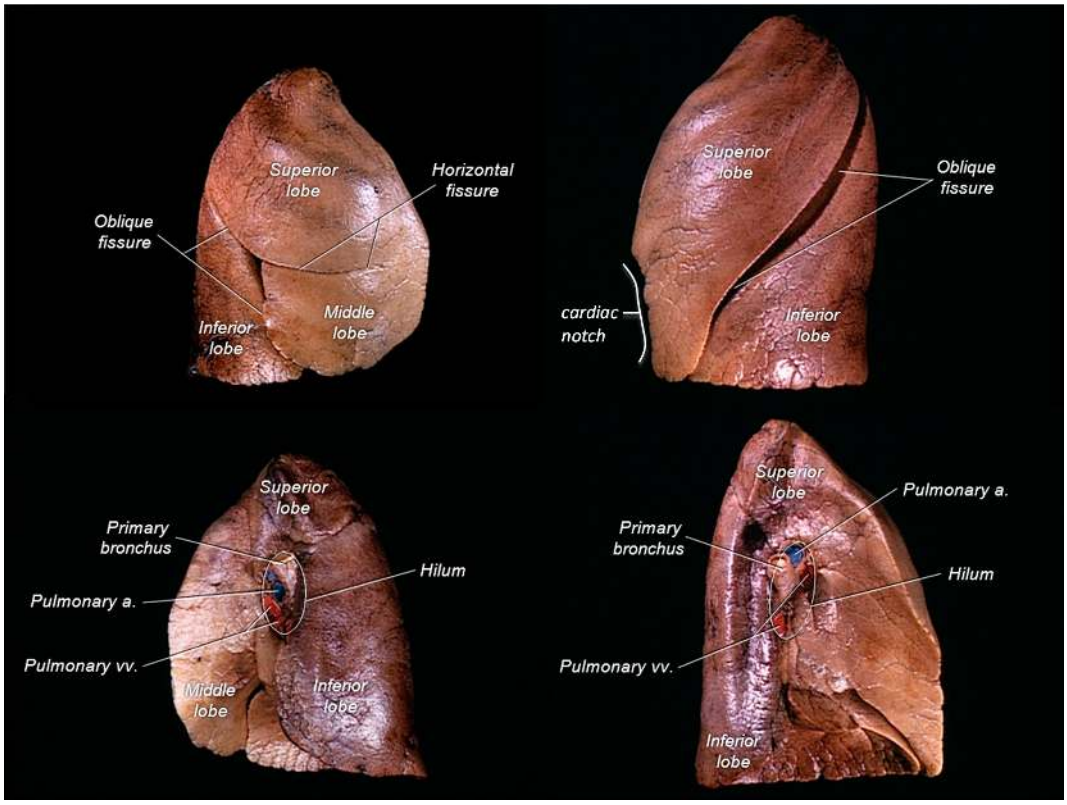
Above: (Left) Alveoli arranged in alveolar sacs at the end of alveolar ducts. (Right) Diagram showing how gas exchange occurs between an alveolus and the passing blood in a capillary.

There are hundreds of millions of alveoli in the lungs. The alveoli are where gas exchange occurs between the lungs and the blood. There are no cilia or smooth muscle and instead the walls lined by thin epithelial cells called alveolar cells. Most of the alveolar surface is covered by **type I alveolar cells** where gas exchange occurs. The type I alveolar cells form a **respiratory membrane** where O_2 (necessary to make ATP) passes from the lungs into the blood and CO_2 (a waste product from ATP production) passes from the blood and into the lungs for exhalation. Other alveolar cells called **type II alveolar cells** have the ability to secrete a substance called **surfactant** helps decrease the surface tension within the alveoli and therefore helps gases to pass across the respiratory membrane more efficiently. Finally if foreign particles make it deep into the lungs there are **alveolar macrophages** that can "eat" (phagocytize) the particles up to remove them.

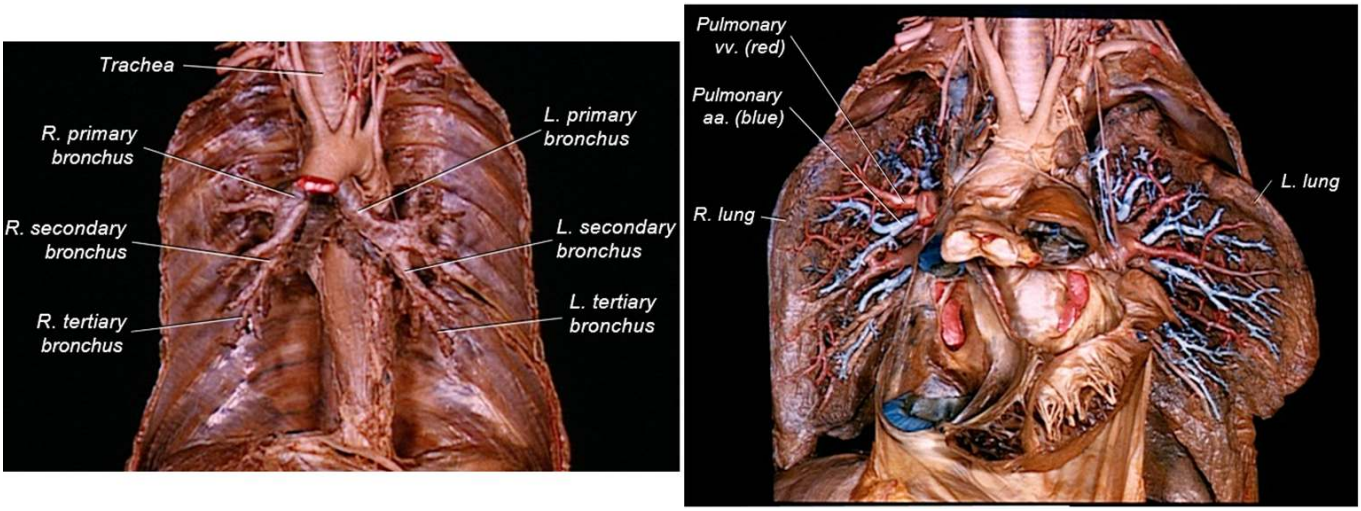
On the other side of the type I alveolar cells are endothelial cells that line the pulmonary capillary walls. Carbon dioxide diffuses out from the deoxygenated blood in the pulmonary capillaries and into the air of the alveoli which will be breathed out upon exhalation. With each breath in, oxygen enters the alveoli and freely diffuses into the blood in the pulmonary capillaries. This blood is now oxygenated and will return to the heart to complete the pulmonary circuit of blood circulation. This newly oxygenated blood is then pumped through the systemic circuit to provide oxygen to the body tissues. This oxygen is used in a metabolic process called **cellular respiration**, a process conducted by cells throughout the body to produce the energy-rich molecule **ATP**. It is because of ATP, and the process of making it (cellular respiration), that oxygen is vital for human life.



Above: (Left) Diagram of the structure of the alveolar-pulmonary capillary junction. (Right) Most of the same structures present in the diagram to the left are shown in the microscopic image of alveoli.

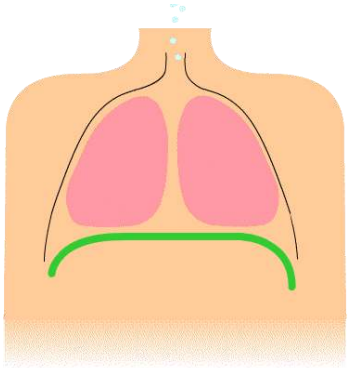


Above: (Left) Left lung from an (top) anterior view and (bottom) medial view. (Right) Right lung from an (top) anterior view and (bottom) medial view. The abbreviations are "a." for "artery" and "vv." for "veins."



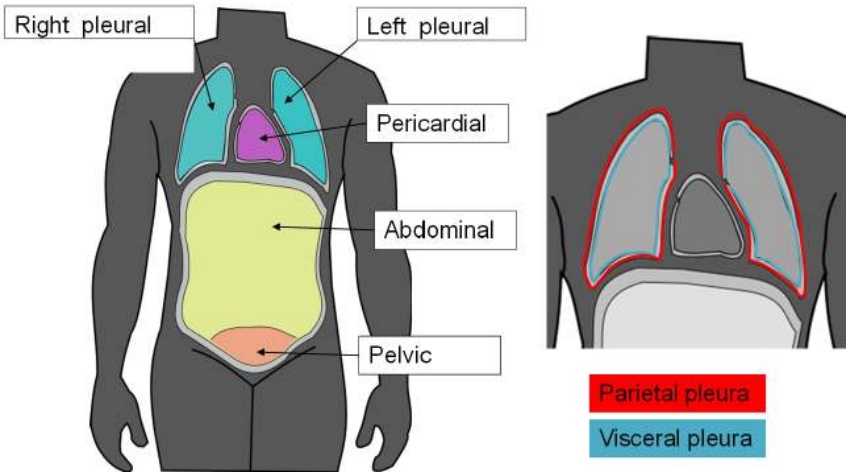
Above: Cadaver images of (left) the bronchial tree and (right) the branches of pulmonary arteries and pulmonary veins within the lungs. The abbreviations are "aa." for "arteries," "vv." for "veins," "L." for "left" and "R." and "right."

The right lung has three lobes, the **superior lobe**, **middle lobe** and **inferior lobe**, separated by two fissures, a **horizontal fissure** and an **oblique fissure**. The **left lung** just has two lobes the **superior lobe** and the **inferior lobe**, separated by an **oblique fissure**.



Above: Animation of diaphragm contraction and relaxation resulting in inhalation and exhalation, respectively.

During inhalation, the diaphragm contracts to pull downward while the thorax muscles contract to pull open the chest which both help reduce the pressure inside of the lungs causing gases from the higher pressure air outside of the body to rush into the lungs (gases move from high pressure to low pressure). During an exhalation, the muscles of the diaphragm and thorax relax allowing the lungs to spring back to their normal size which increases internal pressure in the lungs such that the pressure becomes higher inside the lungs than outside the body. The result is that air moves out of the lungs (gases move from high pressure to low pressure).



Above: The lungs are located in the pleural cavities surrounded by parietal pleura and visceral pleura (serosa).

Clinical Application: Pneumonia

Pneumonia is an **infection** of the lungs that can be acquired by breathing in bacteria or viruses. The infection causes the alveoli to fill with fluid/pus, which can make breathing difficult or labor-some because the body may not be able to get the oxygen it needs from the alveoli walls as easily. Other typical symptoms of pneumonia can include fever, coughing up sputum, chills, nausea, vomiting, and diarrhea, among others. Sometimes symptoms can be mild, causing people to refer to their illness as "**walking pneumonia**". Because types of pneumonia are caused by bacteria, **antibiotics** are commonly used to treat many forms of pneumonia within a reasonable time period. However, viral pneumonias will not improve with the use of antibiotics since antibiotics only kill bacteria. Pneumonia should be taken seriously; it can be **severe and deadly** for **infants**, the **elderly**, and others with an already **compromised immune system**.

Attributions

- "1.1 Anatomy and Physiology of Respiratory System" by Paul Hudson is licensed under CC BY-NC 4.0
- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Anatomy and Physiology Lab Reference" by Laird C Sheldahl, OpenOregonEducational Resources, Mt. Hood Community College is licensed under CC BY-SA 4.0
- "Anatomy of the Respiratory System" by Dongho Kim is licensed under CC BY-NC-SA 4.0
- "Bronchial anatomy.jpg" by Patrick J. Lynch, medical illustrator is licensed under CC BY 2.5
- Diaphragmatic breathing.gif by John Pierce is in the Public Domain
- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0
- "Gas exchange in the aveolus simple (en).svg" by domdomegg is licensed under CC BY 4.0
- "Medical gallery of Blausen Medical 2014" by Blausen.com staff is licensed under CC BY 3.0

Updated 2026.

This page titled 19.3: Lower Respiratory Tract is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

19.4: Laboratory Activities and Assignment

Laboratory Activities and Assignment

Part 1: Review of the Respiratory System

1. Put the following structures in order as indicated by each part a. and b. below:

• alveolar duct • alveolar sac • alveoli • bronchioles • laryngopharynx • larynx	• external nares • nasal meatuses • nasal vestibule • nasopharynx • oropharynx • primary bronchi	• respiratory bronchioles • respiratory membrane • secondary bronchi • terminal bronchioles • tertiary bronchi • trachea

a. Put the structures in order air passes through from entry into the respiratory system to the point of gas exchange with the blood (this order follows the path of O_2 into the body):

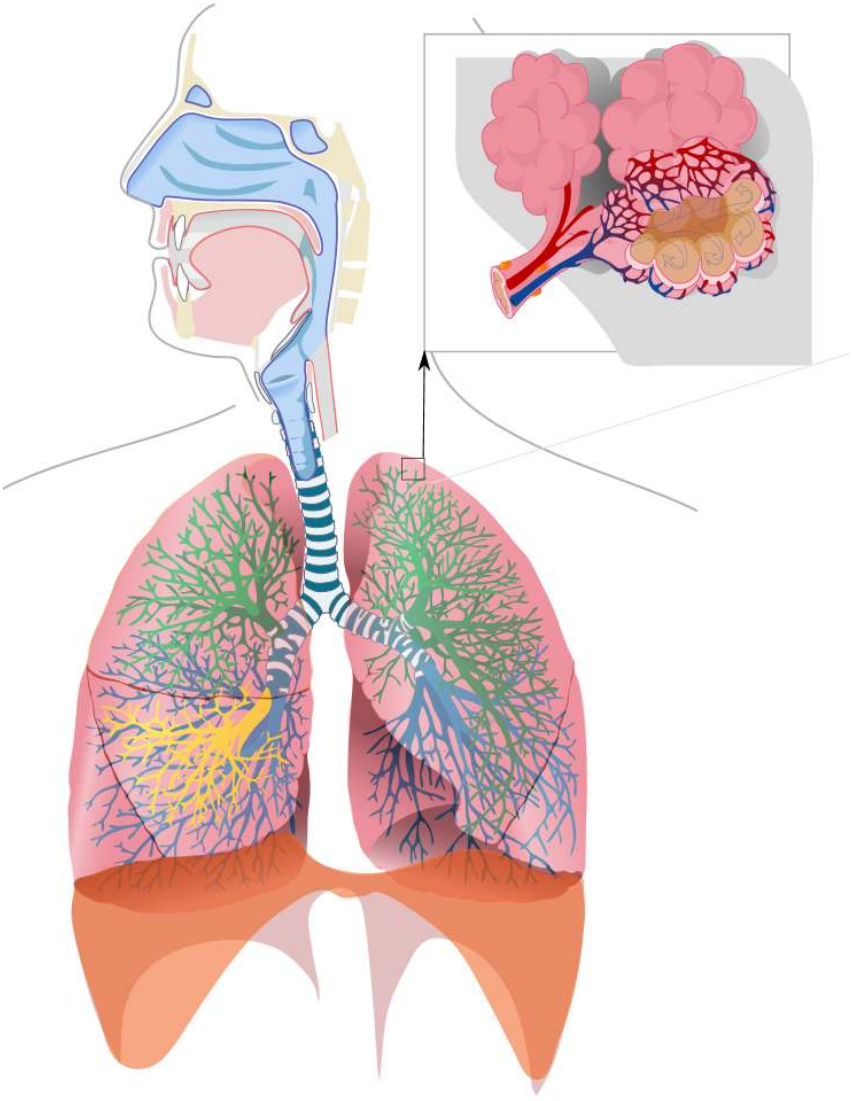
1. _____	10._____
2. _____	11._____
3. _____	12._____
4. _____	13._____
5. _____	14._____
6. _____	15._____
7. _____	16._____
8. _____	17._____
9. _____	18._____

b. Put the structures in order air passes through from gas exchange with the blood to its exit from the respiratory system (this order follows the path of CO_2 out of the body):

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

2. Label the diagram below with the following structures:

- alveolar duct
- alveolar sac
- alveoli
- bronchioles
- diaphragm
- epiglottis
- esophagus
- external nares
- frontal sinus
- hard palate
- entrance to auditory tube
- inferior lobe (2 places)
- inferior nasal concha
- inferior nasal meatus
- internal nares
- laryngopharynx
- larynx
- left lung
- left primary bronchus
- middle lobe
- middle nasal concha
- middle nasal meatus
- nasal vestibule
- nasopharynx
- oral cavity
- oropharynx
- pulmonary capillaries
- respiratory bronchioles
- right lung
- right primary bronchus
- secondary bronchi
- soft palate
- sphenoid sinus
- superior lobe (2 places)
- superior nasal concha
- superior nasal meatus
- terminal bronchioles
- tertiary bronchi
- trachea
- tracheal cartilages
- uvula



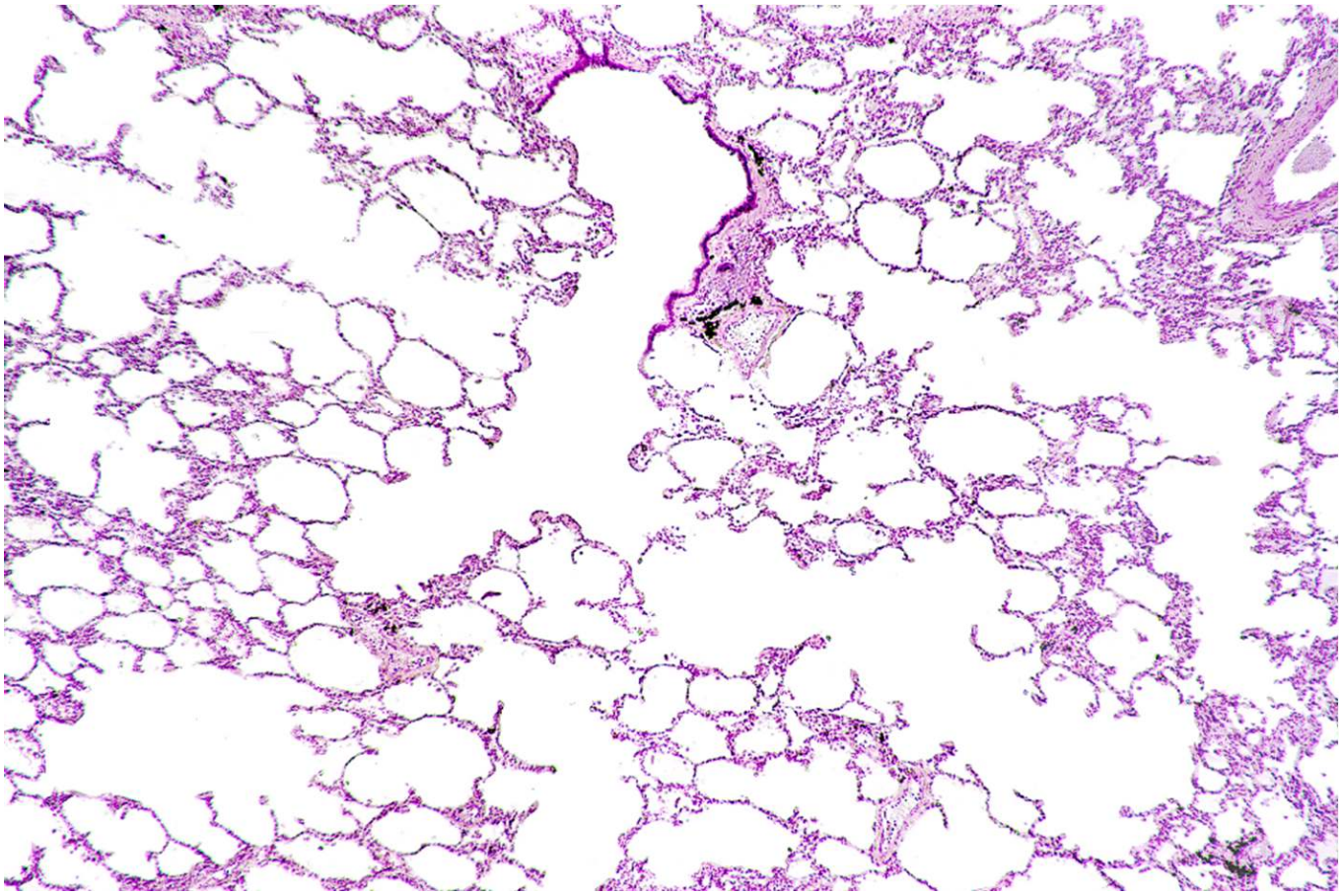
2. Label the diagram of the respiratory mucosa lining much of the large airways of the respiratory tract with the structures listed below.

• basement membrane • cilia • goblet cell	• lamina propria • lumen	• pseudostratified columnar epithelium • smooth muscle



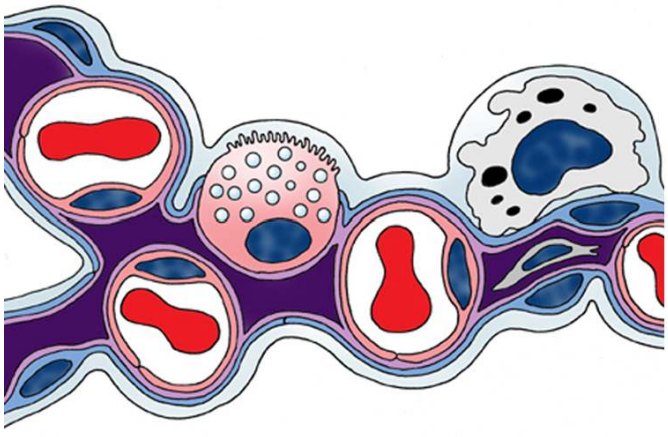
3. Below is a microscopic image of lung tissue magnified by 100x. Label the following structures:

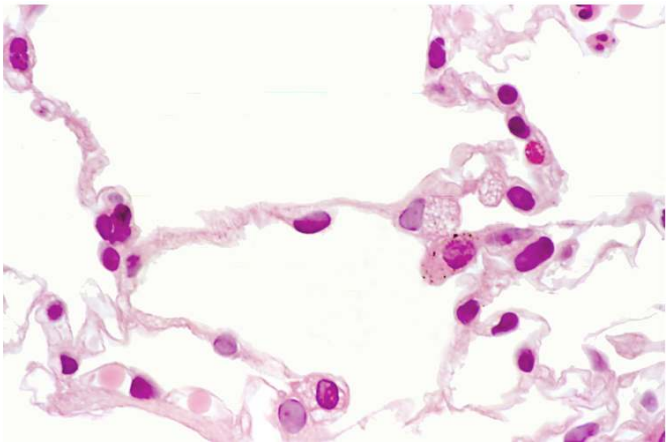
• alveolar ducts (multiple) • alveoli	• respiratory bronchiole • terminal bronchiole



4. Below is a diagram of alveolar structures with a tissue section showing some of those alveolar structures. Label the following on both the figure and the microscopic tissue section where possible.

- alveolar lumen
- alveolar macrophage
- connective tissue
- endothelial cells / endothelium
- interalveolar septum
- pulmonary capillaries
- red blood cells
- surfactant
- type I alveolar cell
- type II alveolar cell





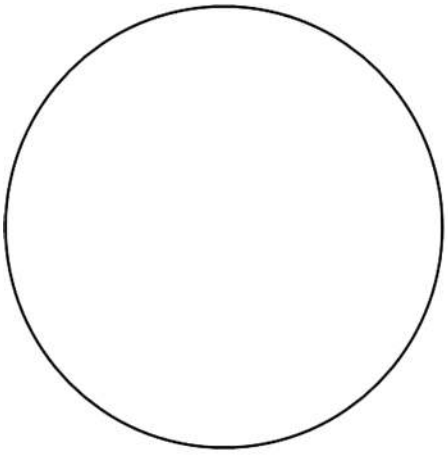
Part 2: Examining the Histology of the Respiratory System

1. Obtain the slides listed below that are available for today's lab.
2. Focus on each sample and identify the structures listed for each type of tissue.
3. Indicate the **total** magnification you make each illustration at in the space provided.
4. Illustrate each tissue you observe with the microscope at the magnification you listed.
5. Label each illustration with the structures listed for each.

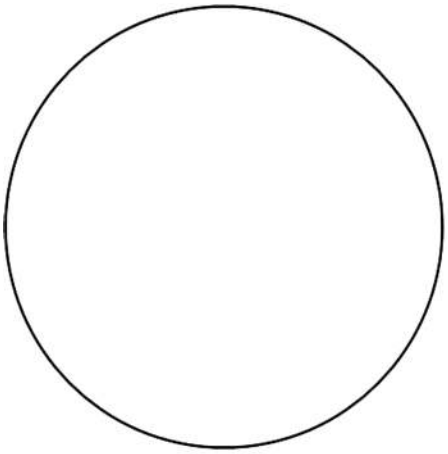
Trachea Cross Section

Illustrations at more than one magnification will be required.

Label the tissue with: trachea, esophagus, cartilage ring, opening in cartilage ring, lumen, pseudostratified ciliated columnar epithelium, goblet cells, cilia, basement membrane, lamina propria, elastic lamina, mixed glands, hyaline cartilage



Total magnification: _____

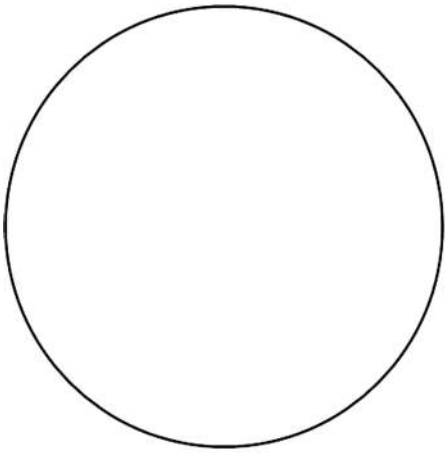


Total magnification: _____

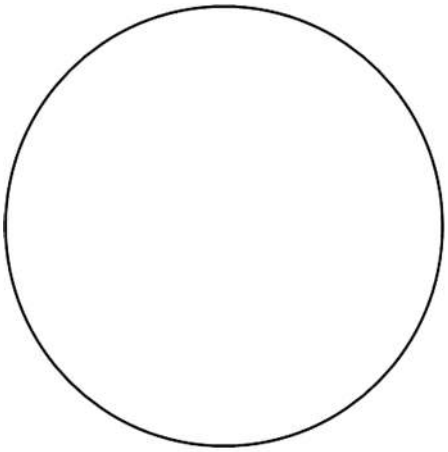
Lung Tissue

More than one illustration will required with more than one magnification.

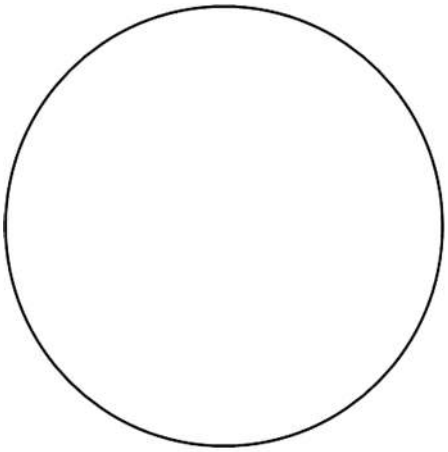
Label the tissue with: secondary bronchi, cartilage plates, pulmonary blood vessels, bronchioles, terminal bronchiole, respiratory bronchiole, alveolar ducts, alveoli, type I alveolar cells, interalveolar septum, endothelium, pulmonary capillary, connective tissue, alveolar lumen



Total magnification: _____



Total magnification: _____

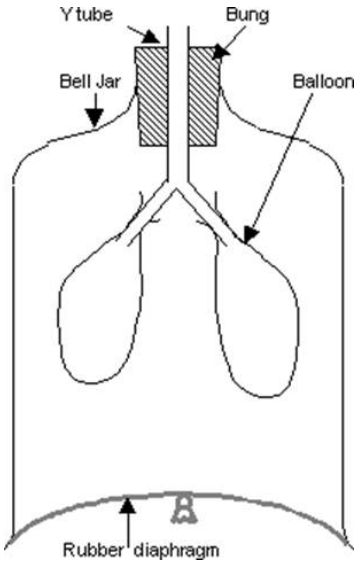


Total magnification: _____

Part 3: Mechanism of Breathing (Balloon-and-Bell Jar Model)

Materials

- Balloon-and-bell jar



Instructions & Questions

1. Pull down the rubber sheet. What happens to the balloons?____.
2. This represents the downward movement of the human___, which causes the chest cavity to become_____(larger/smaller). This, in turn, causes the human _____to expand and fill with air.
3. Release the rubber sheet. What happens to the balloons?_____.
4. This represents relaxed_____(inhaling/exhaling), when the chest cavity becomes smaller and the lungs deflate. Note that this is a passive process.
5. What organs do the balloons represent? _____
6. What does the rubber sheet you pulled on represent? _____

Attributions

Part 1: Review of the Respiratory System

- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0
- "Respiratory system complete no labels.svg" by Bibi Saint-Pol, Jmarch is licensed under CC BY-SA 3.0

Part 2: Examining the Histology of the Respiratory System

- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0

Part 3: Mechanism of Breathing (Balloon-and-Bell Jar Model)

- "Principles of Biology II Lab Manual (BIOL 1108) " by Dalton State is licensed under CC BY-SA 4.0

Updated 2026.

This page titled 19.4: Laboratory Activities and Assignment is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

19.5: Collaborative Study Activities

Collaborative Study Activities

This activity is designed for student groups of 2-4. Larger groups will work better when there is no supplemental instructor present in the laboratory to assist in testing student groups on each section.

1. Identify the following structures on classroom anatomical models and/or unlabeled images/diagrams made available by your instructor. Work with your group to identify each structure and check them off the list once you have identified them.

☐ bronchioles	☐ left lung	☐ right lung
☐ cardiac notch	☐ median cricothyroid ligament	☐ right primary bronchus
☐ cricoid cartilage	☐ middle lobe	☐ secondary bronchi
☐ external nares	☐ middle nasal concha	☐ soft palate
☐ hard palate	☐ middle nasal meatus	☐ superior lobe (2 places)
☐ horizontal fissure	☐ nasal cavity	☐ superior nasal concha
☐ inferior lobe (2 places)	☐ nasal vestibule	☐ superior nasal meatus
☐ inferior nasal concha	☐ nasopharynx	☐ tertiary bronchi
☐ inferior nasal meatus	☐ oblique fissure (2 places)	☐ thyrohyoid membrane
☐ internal nares	☐ oral cavity	☐ thyroid cartilage
☐ laryngeal prominence	☐ oropharynx	☐ trachea
☐ laryngopharynx	☐ pulmonary arteries	☐ tracheal cartilage
☐ larynx	☐ pulmonary veins	☐ uvula
☐ left primary bronchus		

2. Test your group members by ***asking them to name each structure you point to***. Check off each when your group can successfully name each. Your group will also test you.

☐ bronchioles	☐ left lung	☐ right lung
☐ cardiac notch	☐ median cricothyroid ligament	☐ right primary bronchus
☐ cricoid cartilage	☐ middle lobe	☐ secondary bronchi
☐ external nares	☐ middle nasal concha	☐ soft palate
☐ hard palate	☐ middle nasal meatus	☐ superior lobe (2 places)
☐ horizontal fissure	☐ nasal cavity	☐ superior nasal concha
☐ inferior lobe (2 places)	☐ nasal vestibule	☐ superior nasal meatus
☐ inferior nasal concha	☐ nasopharynx	☐ tertiary bronchi
☐ inferior nasal meatus	☐ oblique fissure (2 places)	☐ thyrohyoid membrane
☐ internal nares	☐ oral cavity	☐ thyroid cartilage
☐ laryngeal prominence	☐ oropharynx	☐ trachea
☐ laryngopharynx	☐ pulmonary arteries	☐ tracheal cartilage
☐ larynx	☐ pulmonary veins	☐ uvula
☐ left primary bronchus		

3. When you and your group are comfortable identifying all the structures above, request the assistance of your Instructor. They will test you on your use of these terms and initial ONLY when you are successful using these terms. Instructor: _____

Updated 2026.

This page titled 19.5: Collaborative Study Activities is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

CHAPTER OVERVIEW

20: Digestive System

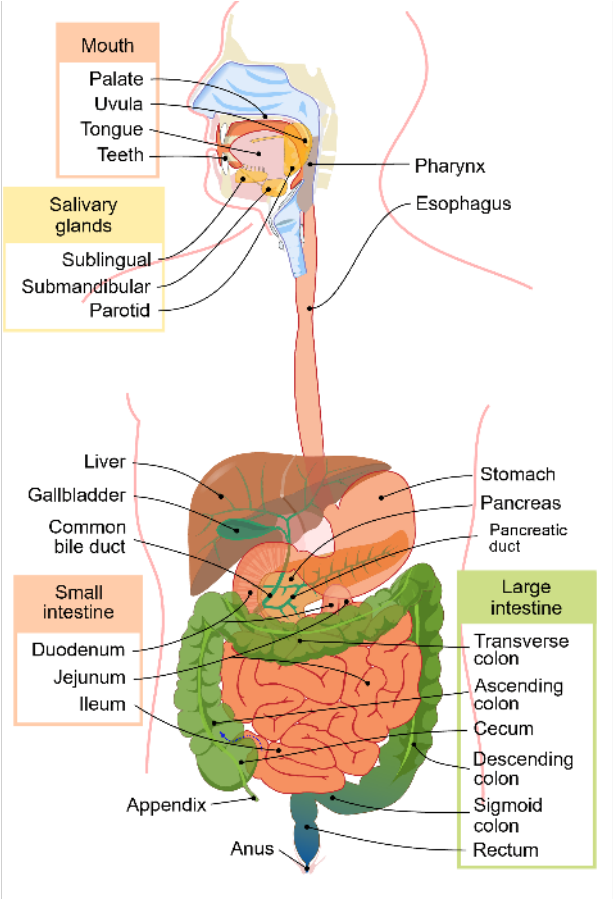
20.1: Introduction
20.2: Histology of the Alimentary Canal
20.3: Serosa
20.4: Oral Cavity
20.5: Esophagus and Stomach
20.6: Duodenum, Pancreas, Liver, and Gallbladder
20.7: Small Intestine
20.8: Colon (Large Intestine), Rectum, and Anus
20.9: Laboratory Activities and Assignment
20.10: Collaborative Study Activities

This page titled 20: Digestive System is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

20.1: Introduction

Introduction

The digestive system consists of the **gastrointestinal tract** (also known as the **alimentary canal**), a hollow muscular tube extending from the mouth to the anus, and accessory organs, including the **liver** and **pancreas**. Nutrient absorption primarily occurs in the **small intestine**. To promote absorption of nutrients, the intestines have **circular folds** (large folds in the tissue), **villi** (small fold in the tissue) and **microvilli** (folds in the cell membranes) along the inner surface to increase surface area, thereby maximizing the potential for absorption. Like the alveoli of the lungs, microvilli substantially increase the surface area of the intestines to between 180 to 300 m^2 (the size of the average American home). Major structures of the gastrointestinal tract include the **oral cavity**, **pharynx**, **esophagus**, **stomach**, **small intestine**, **large intestine**, **rectum**, and **anus**. These structures and organs form a hollow space from mouth to anus and function to chemically and mechanically catabolize and absorb nutrients. Along the way, organs such as the **salivary glands**, **liver**, **gallbladder** and **pancreas** release enzymes to aid digestion and are known collectively as **accessory structures**.



Above: Overview of the anatomy of the digestive system.

Attributions

- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Digestive system diagram en.svg" by Mariana Ruiz (LadyofHats) is in the public domain
- "Human Anatomy Lab Manual" by Malgosia Wilk-Blaszczak, Mavs Open Press, University of Texas at Arlington is licensed under CC BY 4.0

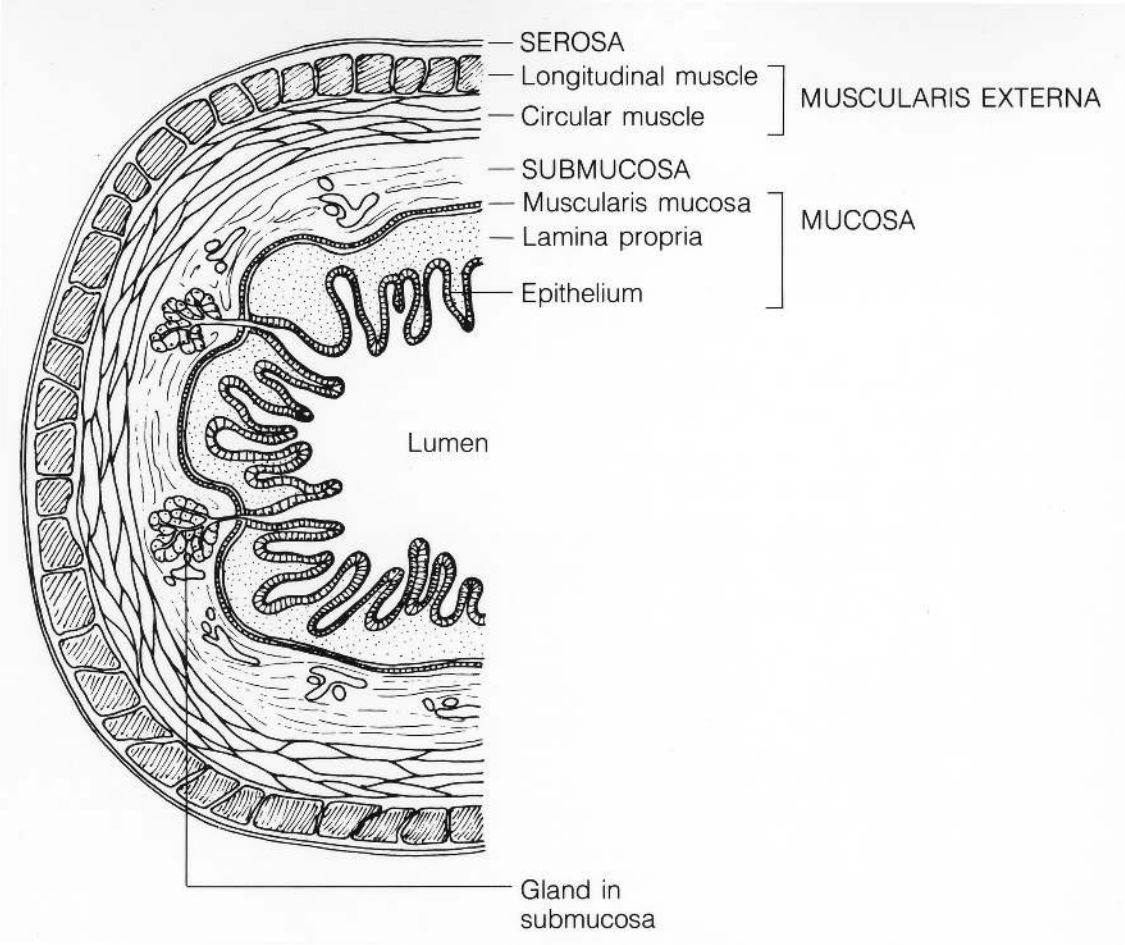
Updated 2026.

This page titled 20.1: Introduction is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

20.2: Histology of the Alimentary Canal

Histology of the Alimentary Canal

The organs of the GI tract are made from four layers, the inner lining or **mucosa**, the **submucosa** containing blood vessels and lymphatics, the **muscularis externa** or smooth muscle layer, and the outermost layer or **serosa/adventitia**. Each tissue layer plays a vital role in the digestive system ranging in their capacity to form a protective barrier from the highly acidic contents of the stomach to supplying hormones, producing muscular contractions and draining lymph. For example, specialized cells found the in epithelium lining the inside of the stomach are supporting cells which produce a protective layer of mucus and gastric acid for digestion. Additionally, other supporting cells, in the stomach and the **acinar cells** of the pancreas, release **zymogens**, inactive forms of digestive enzymes that become triggered to become active digestive enzymes.



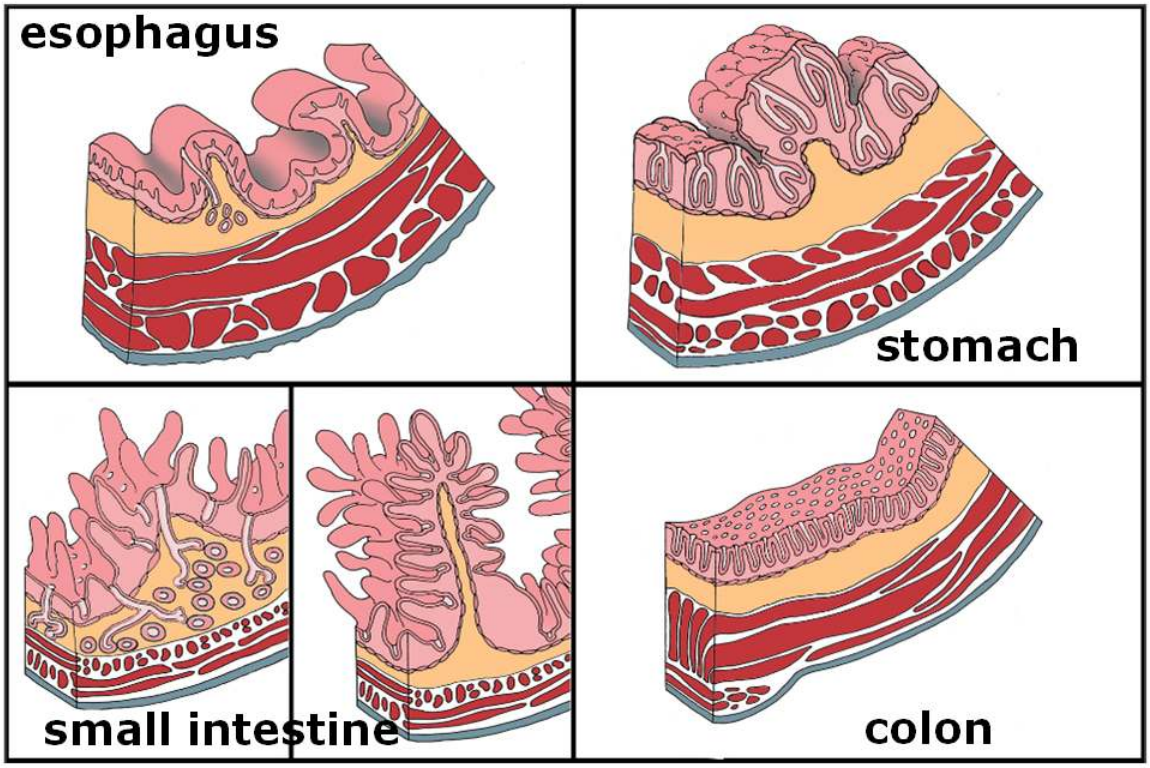
Above: Tissue layers of the organs of the alimentary canal.

Layer of the Alimentary Tissue	Location	Substructures	Functions
mucosa	innermost layer; lines the alimentary canal	1. epithelium (mostly simple columnar) 2. lamina propria (connective tissue; may contain MALT; may contain lacteal capillaries) 3. muscularis mucosa (smooth muscle)	produces mucus, digestive enzymes, digestive zymogens, hormones and specialized materials necessary for digestion; protects from infectious agents; absorption of nutrients from food

Layer of the Alimentary Tissue	Location	Substructures	Functions
submucosa	between the mucosa and muscularis externa	contains blood and lymphatic vessels (may contain lacteals) and nerves	provides structure; absorption of nutrients in blood vessels and lacteals
muscularis externa	between the submucosa and the serosa / adventitia	1. circular layer, 2. longitudinal layer; deep to the circular layer is a third layer in the stomach only, the oblique layer	contractions and relaxations in the canal that push digesting food through the canal (peristalsis) breaking it up [click here to see a gif of peristalsis]
serosa / visceral peritoneum / adventitia	outermost layer; lines the outside of the alimentary canal	1. areolar connective tissue, 2. epithelium (simple squamous)	production of peritoneal fluid to reduce friction between the organs during movements

MALT = mucosa-associated lymphatic tissue; immune functions

lacteal = fat-absorbing lymphatic vessels in the small intestine



Above: The major diagnostic features of the components of the tubular digestive tract are highlighted in these drawings. All images show the tubular digestive organs cut in cross section, except for the small intestine illustrated in the two smaller panels located in the lower left quadrant. These small intestine sections depict longitudinal sections of this organ. Mucosae are pink, submucosae are orange, muscularis externa are red, and serosa / adventitia are blue-gray.

The esophagus is lined by stratified squamous moist epithelium. Scattered glands are present in lamina propria of the upper and lower esophagus and in the submucosa. Muscularis externa begins as skeletal muscle, transitions to skeletal plus smooth muscle and finally to only smooth muscle in the lower portion. An adventitia surrounds the organ.

The stomach is characterized by a thick mucosa lined by a surface sheet gland. The lamina propria is filled with gastric glands, each opening into a gastric pit. The muscularis externa is very thick with three, rather than the usual two, subdivisions. The stomach is covered by a serosa.

Villi are prominent features of small intestine. Intestinal glands open at the bases of villi and extend to muscularis mucosae. Glands in submucosa distinguish duodenum from the remainder of small intestine. Most of the organ is covered by a serosa, although a portion of duodenum is retroperitoneal and possesses an adventitia.

The large intestine (colon) lacks villi and possesses very straight intestinal glands in lamina propria. No submucosal glands are present. Most of the outer longitudinal subdivision of muscularis externa is relegated to three longitudinal strips termed the taeniae coli. The large intestine is covered by either an adventitia or a serosa, depending on its location.

Attributions

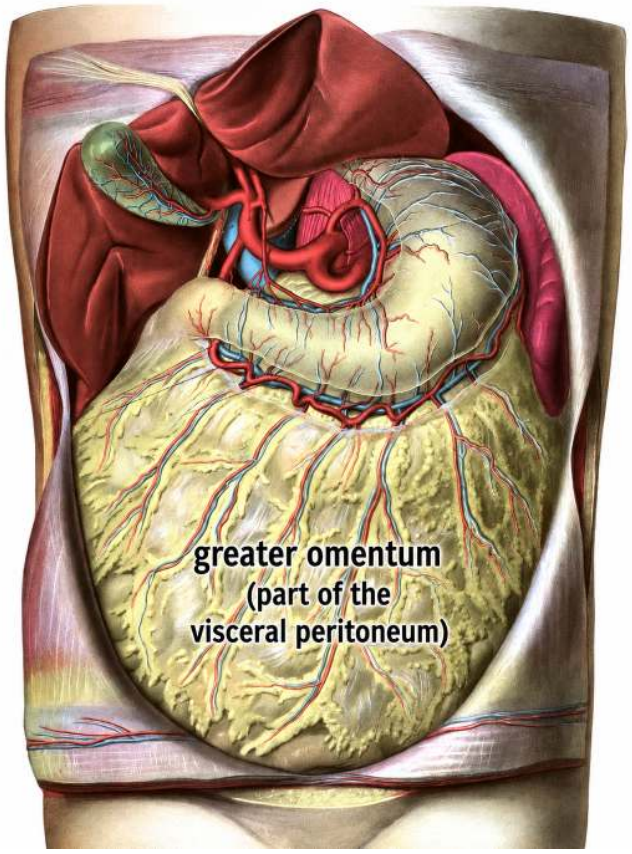
- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0
- "Human Anatomy Lab Manual" by Malgosia Wilk-Blaszczak, Mavs Open Press, University of Texas at Arlington is licensed under CC BY 4.0
- "Mucosa.jpg" by National Cancer Institute is in the Public Domain
- "Peristalsis.gif" by Auawise is licensed under CC BY-SA 4.0

Updated 2026.

This page titled 20.2: Histology of the Alimentary Canal is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

20.3: Serosa

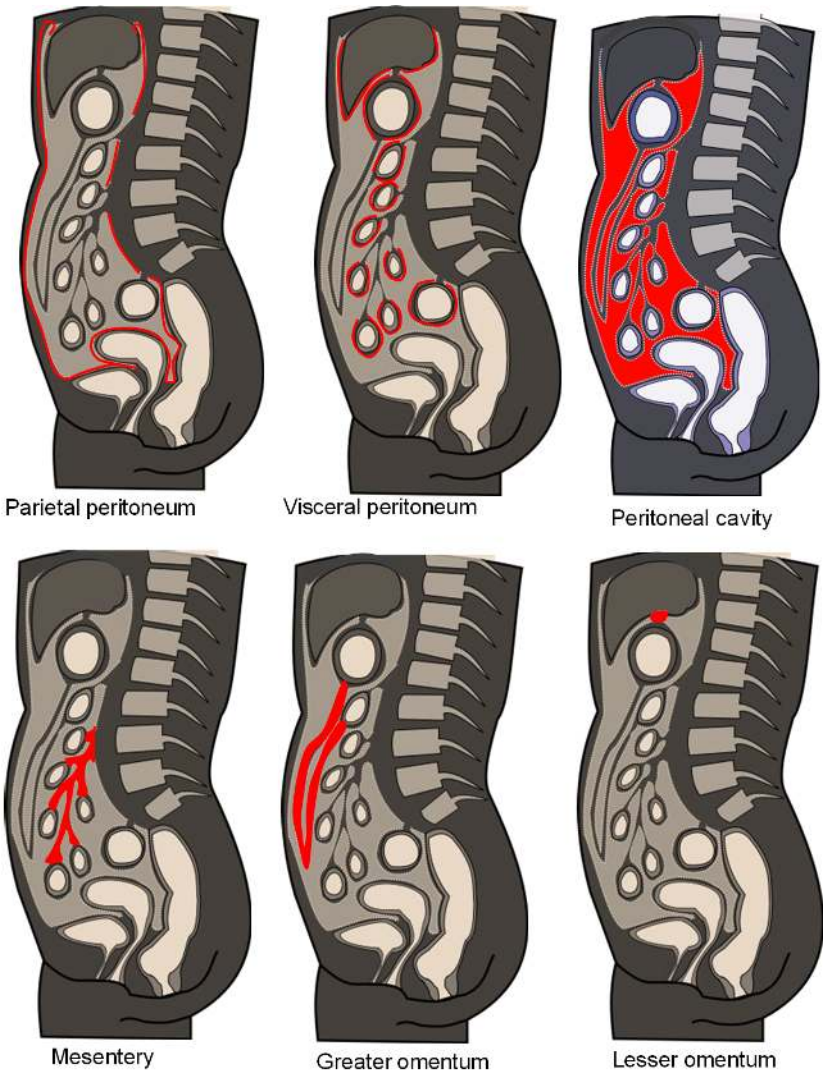
Serosa



Above: The greater omentum, part of a network of peritoneum (serosa of the abdomen) attaching and positioning the abdominal organs to each other and to body walls.

The **peritoneum** is a large serous membrane network which lines the abdominal cavity and coverers most of the digestive organs. some organs are only partially covered by the peritoneum while others are entirely uncovered. These organs are referred to as being **retroperitoneal**.

There are **visceral peritoneum** layers lining the surface of abdominal organs and **parietal peritoneum** layers lining the cavity wall. Serosa produce serous fluid (in this case **peritoneal fluid**) to lubricate the organs, thereby preventing friction between the organs allowing them to slide around during movement.



Above: Structures of the peritoneum and peritoneal cavity.

Peritoneum Structure	Location
falciform ligament	Peritoneum extending between the liver and the anterior body wall
greater omentum	large fold of the visceral peritoneum that covers the anterior aspect of the small intestine like an apron; attached to the greater curvature of the stomach, covers the small intestine and folds upward, ultimately attaching to the posterior body wall; site where adipose tissue can build up in the abdomen
lesser omentum	peritoneum extending between the liver and the lesser curvature of the stomach
mesentery	Peritoneum extending between the posterior body wall and the small intestine; contains blood vessels, lymphatic vessels, nerves, and adipose tissue
mesocolon (ascending, transverse, descending, and sigmoid)	peritoneum extending between the posterior body wall and the colon

Attributions

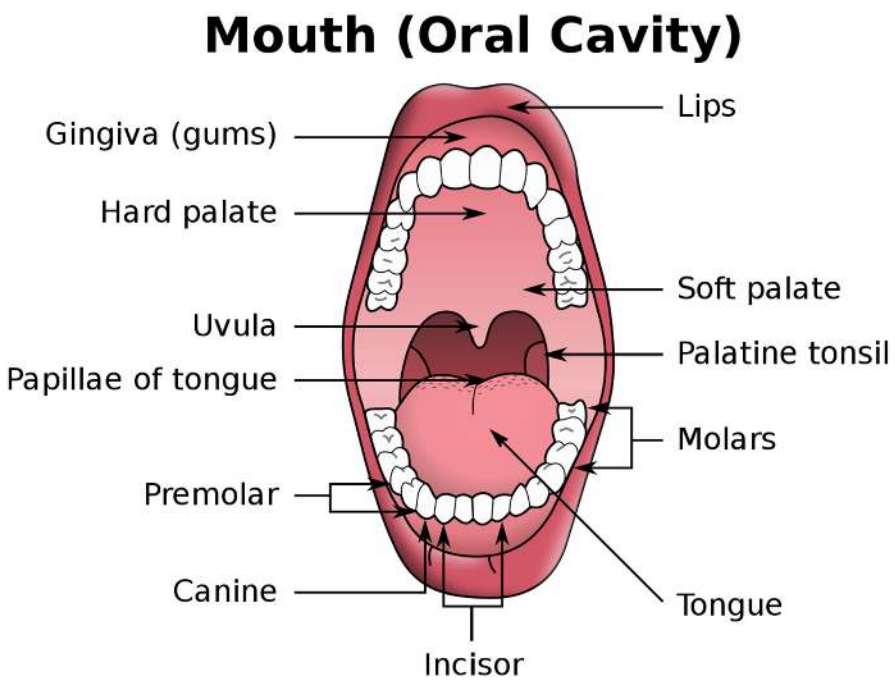
- "Anatomy and Physiology Lab Reference" by Laird C Sheldahl, OpenOregonEducational Resources, Mt. Hood Community College is licensed under CC BY-SA 4.0
- "Sobo 1909 564.png" by Dr. Johannes Sobotta is in the Public Domain

Updated 2026.

This page titled 20.3: Serosa is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

20.4: Oral Cavity

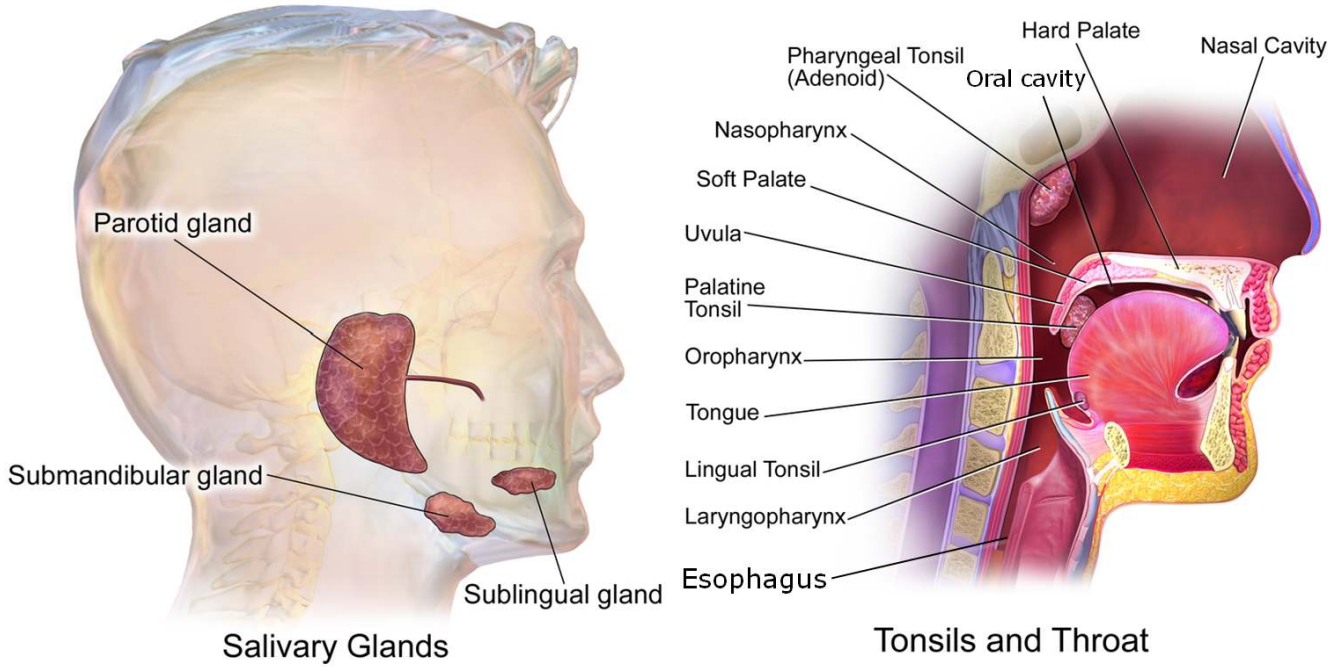
Oral Cavity



Above: Anatomy of the oral cavity.

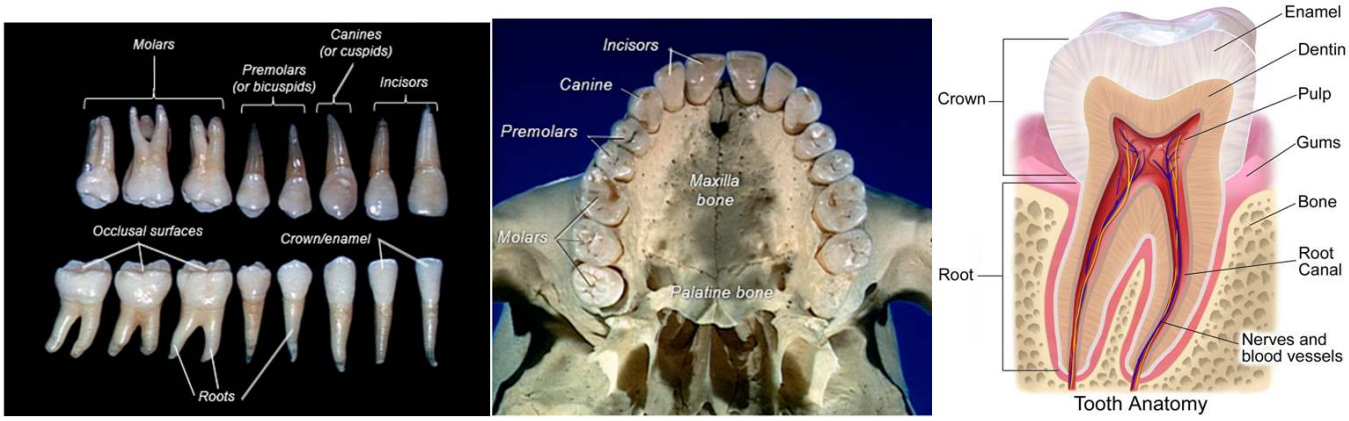
The oral cavity is the entry point into the digestive system. It is equipped with teeth and a tongue to grind up and break apart foodstuffs to begin physical digestion. Chemical digestion also begins in the mouth with enzymes produced and secreted by three pairs (right and left) of salivary glands: **sublingual salivary glands**, **submandibular salivary glands**, and **parotid salivary glands**. Salivary glands secrete fluid saliva containing **amylase**, an enzyme that breaks down starch, a long-chain carbohydrate found in foods such as pasta and potatoes. Amylase breaks starch into sugars, thereby beginning chemical digestion. Saliva also contains lysozyme, an enzyme that kills some bacteria.

Tonsils are present along in the posterior oral cavity, which collect information about possible infectious agents entering the body and begins preparing the adaptive immune response to those infectious agents. Tonsils include the **pharyngeal tonsil** at the posterior aspect of the nasal cavity, a pair of **palatine tonsils** on the right and left of the oropharynx, and a pair of **lingual tonsils** at the posterior and inferior aspect of the tongue.

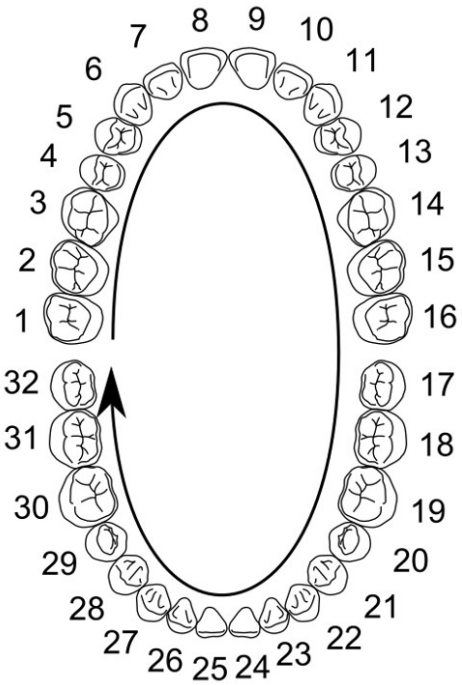


Above: Anatomy of the salivary glands, oral cavity, tonsils, and throat.

Adults (that have all of their teeth) have 32 teeth: 4 incisors, 4 canines/cuspids, 8 premolars/bicuspids, and 12 molars. Each tooth is designated with a number 1-32 beginning with 1 on the upper right posterior molar and then numbering each tooth successively from right to left on the top. Tooth 17 is the posterior molar on the lower left and the numbering continues from left to right such that the posterior lower right molar is number 32.

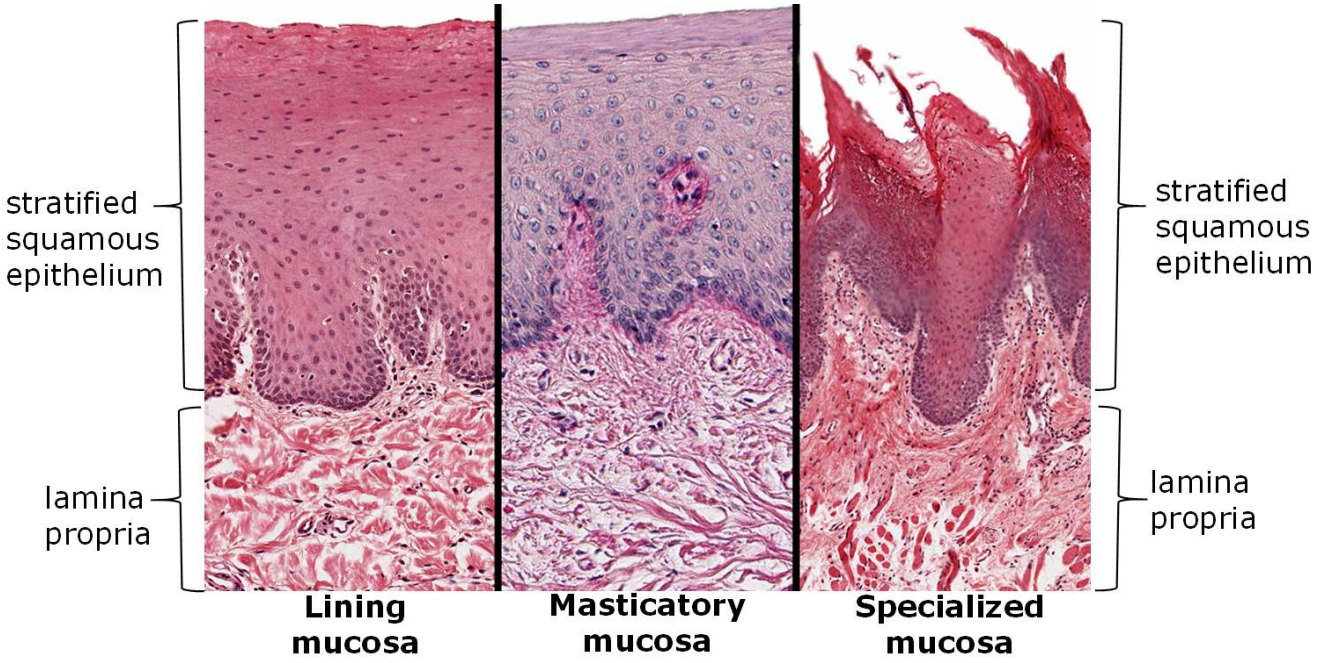


Above: Anatomy of the teeth.



Above: Diagram of the universal tooth numbering system. The top of the diagram shows the upper teeth with tooth number 1 being the most posterior right upper tooth (most posterior right upper molar) and numbering sequentially through the upper left most posterior tooth (tooth 16) and continuing numbering at the lower posterior left molar and numbering sequentially to the lower right most posterior molar (tooth 32).

After **mastication** (chewing) and swallowing food, it passes into the oropharynx, to the laryngopharynx, and the closing of the epiglottis when swallowing diverts the food into the esophagus, posterior to the larynx and trachea. After the food has been chewed and is being swallowed, we now refer to it as a **bolus**.



Above: Tissues lining the oral cavity. The lining mucosa lines all of the oral cavity except for the gingiva (gums), hard palate and the dorsal surface of the tongue. The masticatory mucosa lines the gingiva and hard palate, areas that undergo abrasive forces

during mastication. Specialized mucosa lines the dorsal surface of the tongue. The epithelium of the tongue mucosa is keratinized, but is modified into three types of papillae, only one type is shown. Some papillae serve mechanical functions, while others possess taste buds.

Attributions

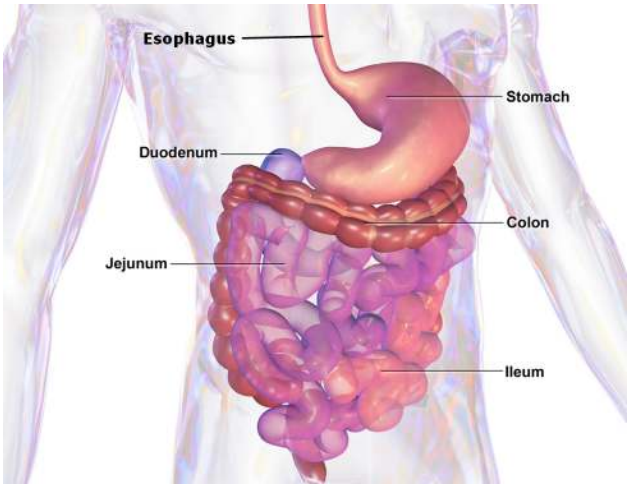
- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0
- "Illu mouth.jpg" by An officer or employee of the United States Government is in the Public Domain

Updated 2026.

This page titled 20.4: Oral Cavity is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

20.5: Esophagus and Stomach

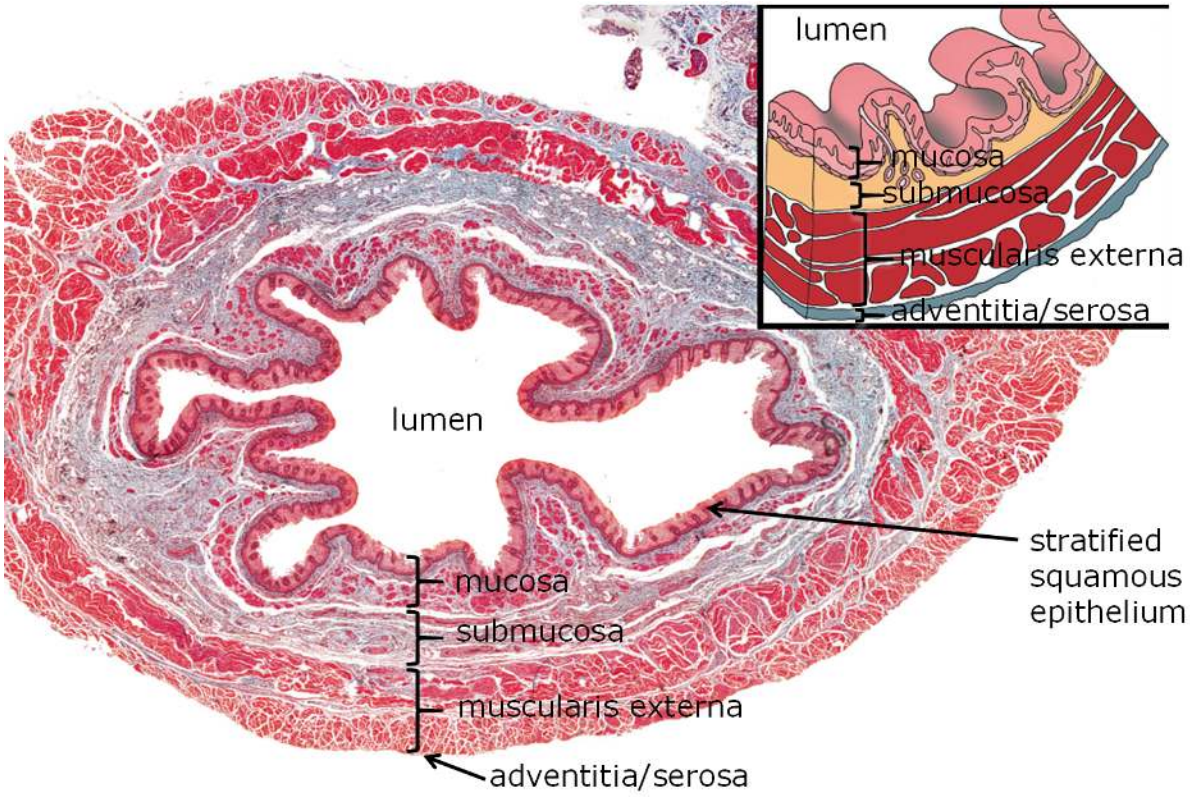
Esophagus and Stomach



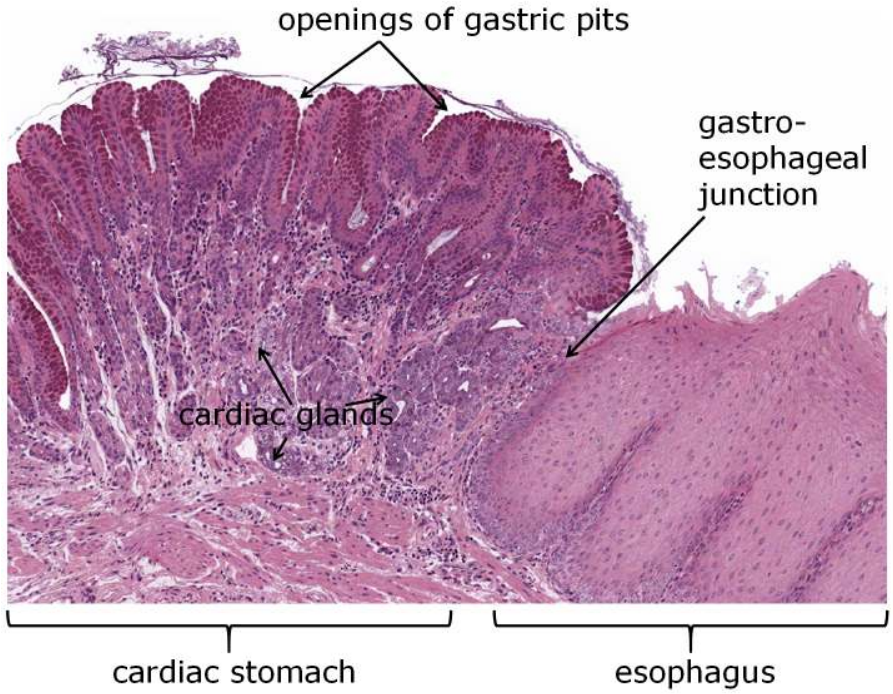
Above: After the oral cavity and pharynx, the gastrointestinal tract (alimentary canal) is next comprised of the esophagus, stomach, and small intestine (duodenum, jejunum, and ileum).

The Esophagus

Sphincters, typically composed of a circular muscle, regulate the movement of digesting materials through the alimentary canal. The first sphincter the bolus passes through is the **upper esophageal sphincter** at the pharynx-esophageal transition. This sphincter prevents air from entering the esophagus and prevents reflux of materials within the esophagus into the pharynx. A **lower esophageal sphincter** is present where the esophagus meets the stomach. The lower esophageal sphincter relaxes to let a bolus into the stomach and contracts to prevent regurgitation of stomach contents into the esophagus.



Above: Histology of the esophagus, magnified by 10x.

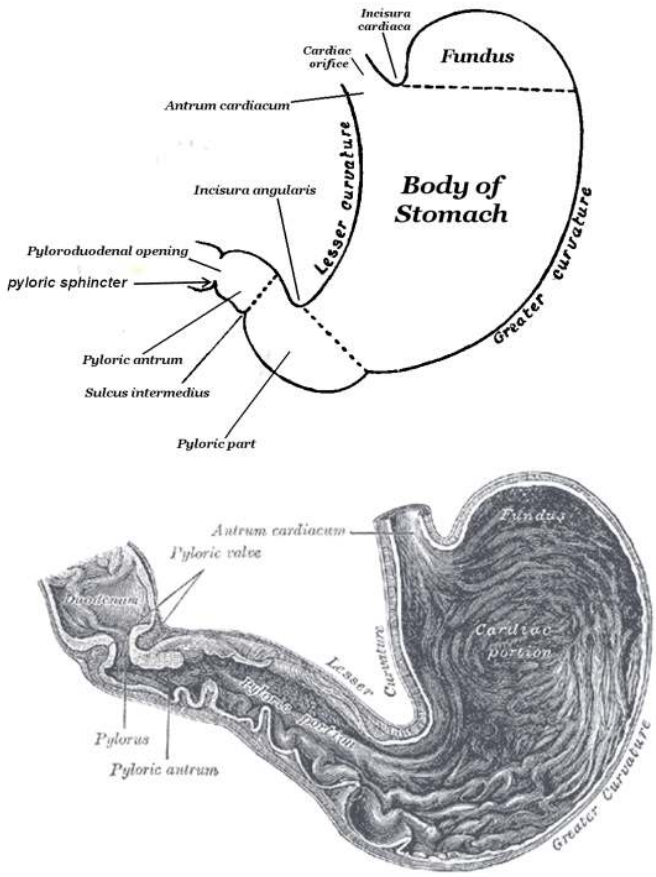


Above: A sharp transition in the mucosal epithelium, from stratified squamous moist (esophagus) to simple columnar (cardiac stomach), marks the transition of these two organs. Additional features of the stomach include the presence of gastric pits

extending from the surface to the gastric glands in the lamina propria. This region can also be referred to as the **gastro-esophageal junction**. Tissue is magnified by 40x.

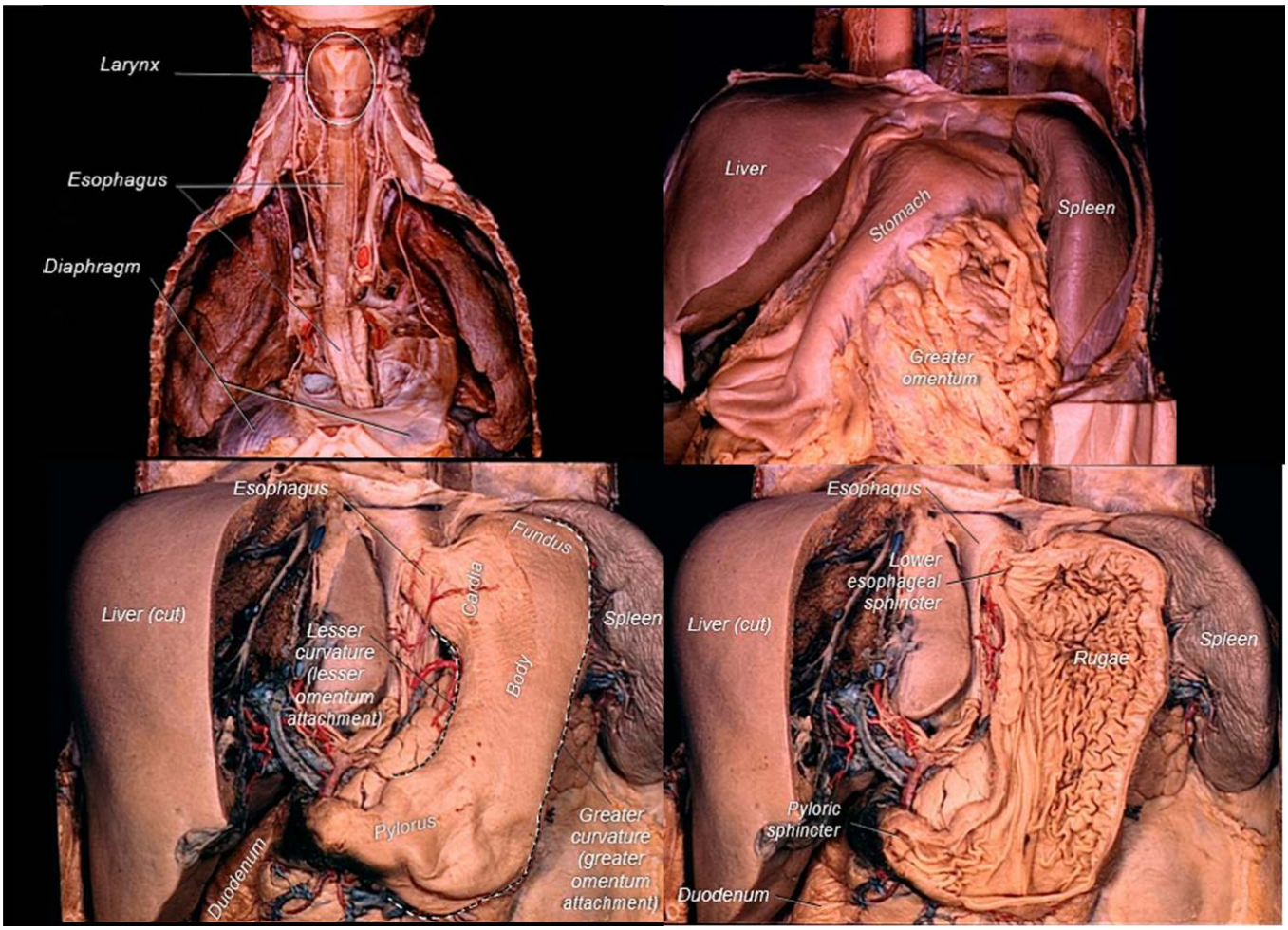
The Stomach

Muscularis externa is formed of inner circular and outer longitudinal layers. In the upper third of the esophagus, these layers are formed of skeletal muscle, which is involved with swallowing, a voluntary action. In the middle one-third, skeletal and smooth muscles are intermixed. In the lower one-third, only smooth muscle is present.



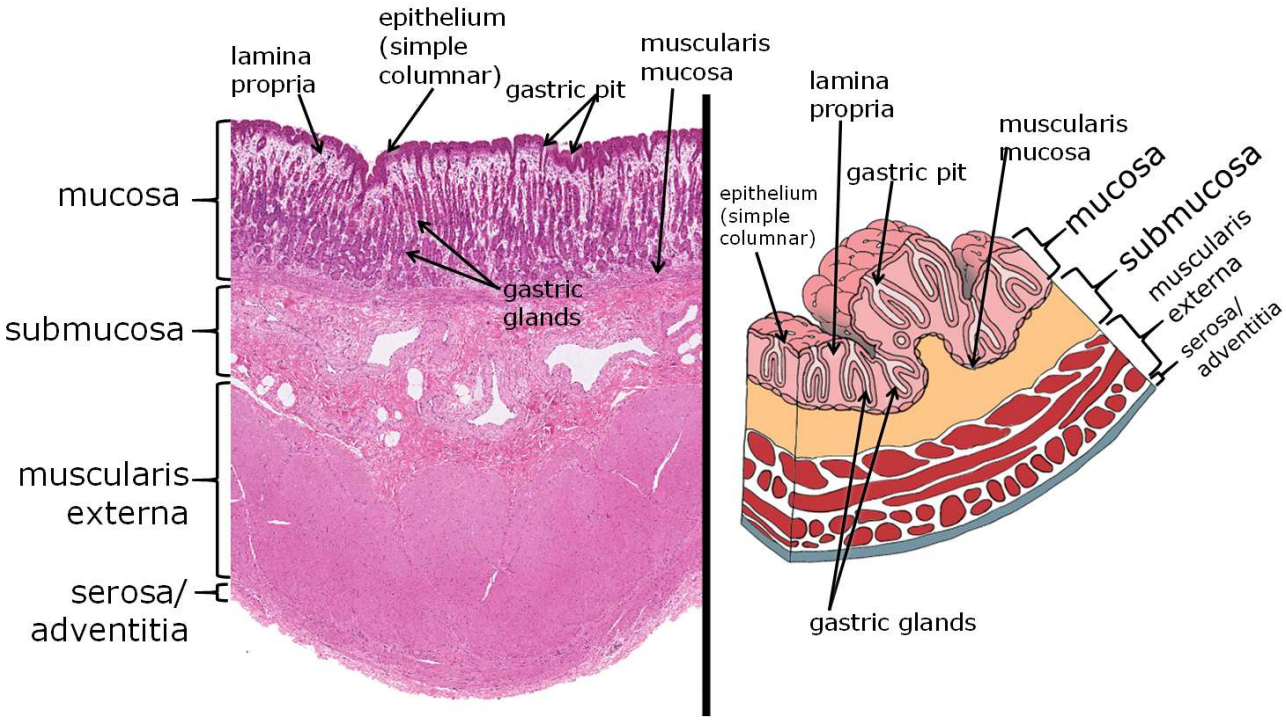
Above: Stomach.

The stomach is composed of four main parts: the **cardia**, **fundus**, **body**, and **pylorus**. The cardiac region is where the esophagus meets the stomach. The fundus is a the dome-like region of the stomach, the main part is the body, and then the funnel-shaped area leading to the duodenum is called the pylorus. The pylorus leads to the **pyloric sphincter** that separates the stomach from the **duodenum** (first compartment of the small intestine). Inside the stomach are folds called **rugae**. When a large meal is eaten and the stomach is really full, the rugae stretch, becoming smoother to enable the stomach to stretch to accommodate the large meal. There are two curvatures of the stomach: the **greater curvature** and the **lesser curvature**. Unlike other regions of the alimentary canal, the stomach has three layers of muscularis externa (listed from inside out): **oblique layer** (fibers are diagonally-oriented), **circular layer** (fibers are oriented to form circle around the stomach), and **longitudinal layer** (fibers are oriented along the long axis of the stomach).



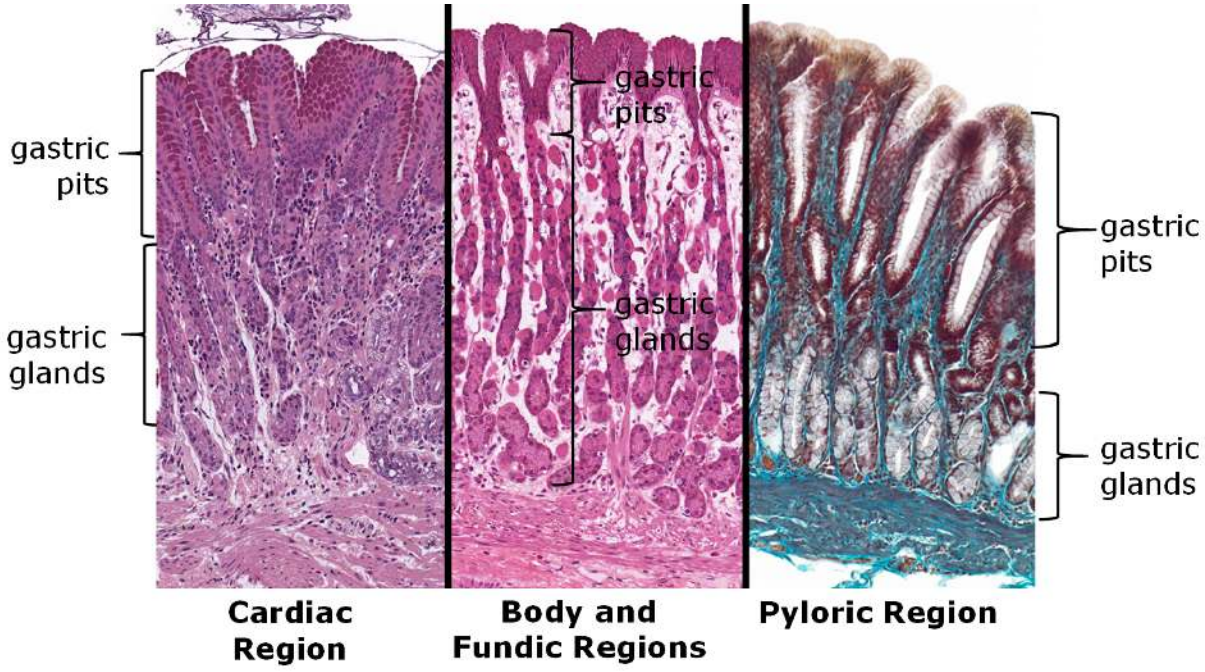
Above: Cadaver images showing the esophagus and stomach as well as other nearby abdominal organs.

The mucosal epithelium of the stomach is modified to form a **sheet gland** that invaginates into lamina propria, forming **gastric pits**. **Gastric glands** begin at the bases of these pits and extend to muscularis mucosae. The submucosa is composed of dense connective tissue. The gastric muscularis externa is composed of three layers of smooth muscle instead of the usual two; however, the additional internal oblique layer is inconsistently present. The stomach is covered on its exterior surface by a serosa because this organ protrudes into the peritoneal cavity.



Above: Histology of the stomach wall magnified by 10x.

The simple columnar epithelium lining the stomach is modified to form a sheet gland, with each cell in the sheet actively producing mucus that protects the stomach from its acidic environment. **Mucin** (a glycoprotein that mixes with water to form mucus) accumulates in the apex of each cell while the cytoplasm and nucleus are squeezed into the slender stem of the cell.



Above: The three regions of the stomach can be distinguished by the ratio of the length of the gastric pits to the length of the gastric glands. In the cardiac region (left), pits and glands are roughly equal in length; in the body and fundic regions (middle), the

pits are much shorter than the glands; in the pyloric region, the pits are longer than the glands (right). Tissues are magnified by 100x.

The stomach continues digestion by secreting **pepsin** to aid in protein digestion, producing an acidic fluid, and churning via the thick muscularis externa. Hormones secreted by **enteroendocrine cells** modulate digestion.

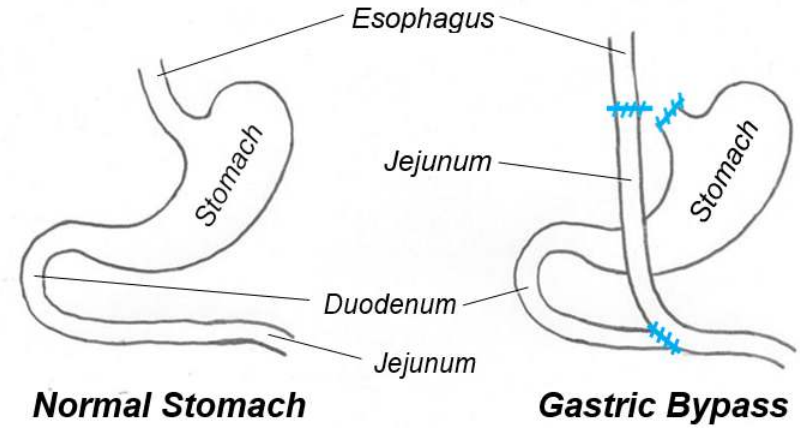
Gastric pits contain specialized cells including **goblet cells** producing and secreting mucus, **parietal cells** producing and secreting hydrochloric acid, and **G cells** producing and secrete gastrin which stimulate the parietal cells to produce and secrete hydrochloric acid.

The gastric glands contain cells including parietal cells and G cells as well as **chief cells** and **foveolar cells**. Chief cells produce pepsinogen (pepsinogen is a zymogen and precursor to pepsin). Foveolar cells produce mucus. Mucus is essential for protecting the stomach tissues from the highly acidic environment of the stomach. Within the protective mucus, the stomach acids would eat away at the stomach tissues.

When the bolus transitions from the stomach to the small intestine, it is now called **chyme**.

Clinical Application: Gastric Bypass

Gastric bypass is a surgical procedure where the stomach is divided into a smaller upper portion and larger lower portion, and then both portions are reconnected to the small intestine. Because the functional volume of the usable portion of the stomach is significantly reduced, the physical and physiological response to consuming food is also altered. In effect, patients will feel full from consuming less food, and less calories will be absorbed by the body because a significant part of the gastrointestinal tract has been bypassed. The need to lose/control weight is the typical reason for gastric bypass surgery, and physicians often prescribe this surgery as treatment for patients fighting and struggling with morbid obesity.



Above: Diagram of gastric bypass.

Attributions

- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0
- "Gray's Anatomy plates" by Henry Vandyke Carte is in the Public Domain
- "Medical gallery of Blausen Medical 2014" by Blausen.com staff is licensed under

Updated 2026.

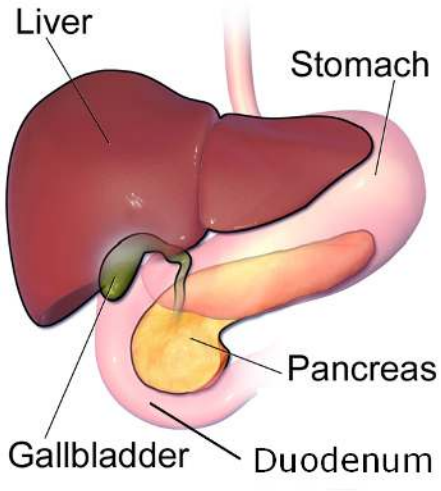
This page titled 20.5: Esophagus and Stomach is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

20.6: Duodenum, Pancreas, Liver, and Gallbladder

Duodenum, Pancreas, Liver, and Gallbladder

Duodenum

Chyme passing through the pyloric sphincter moves into the duodenum which needs to neutralizes the highly acidic solution from the stomach, continue chemical digestion, and begin absorption of nutrients. In the duodenum there is a papilla (a small rounded protuberance) called the **major duodenal papilla** where secretions from the pancreas, liver, and gallbladder enter the duodenum to neutralize stomach acid, continue chemical digestion, and aid in absorption of nutrients.



Above: The duodenum, part of the small intestine, receives chyme from the stomach and neutralizes the gastric juices and continues chemical digestion with secretions from the pancreas.

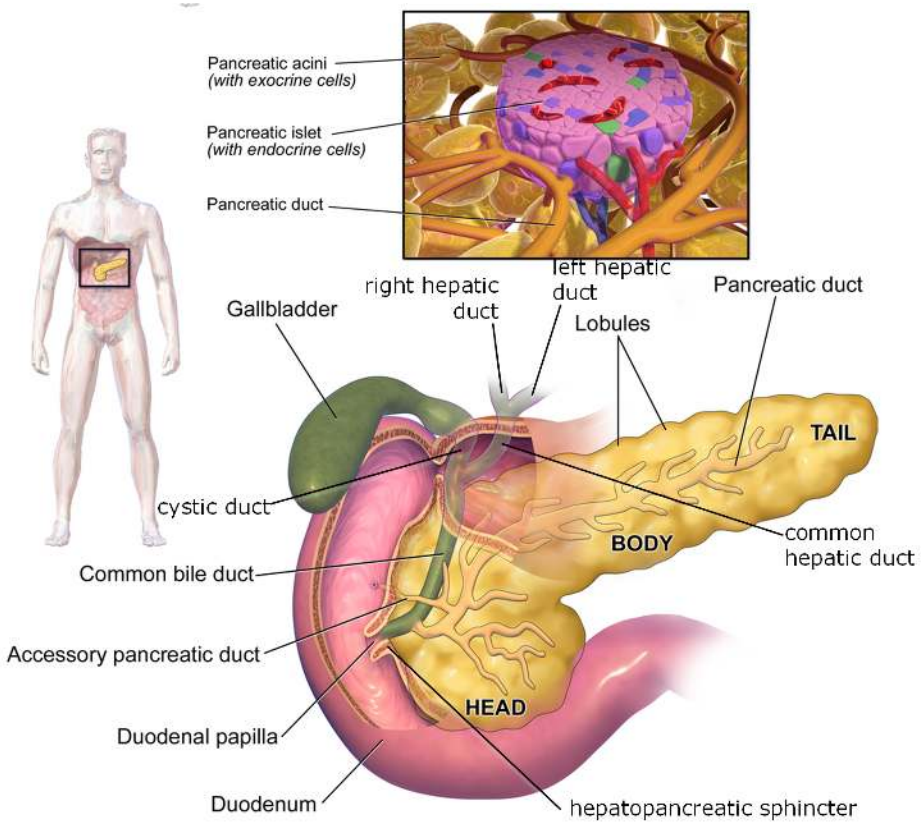
Pancreas

The pancreas has both endocrine and exocrine functions: it produces **glucagon** and **insulin** to regulate blood sugar levels (endocrine hormones) and digestive enzymes to aide in digestion (exocrine). There are three main regions of the pancreas: The **head**, **body** and **tail**.

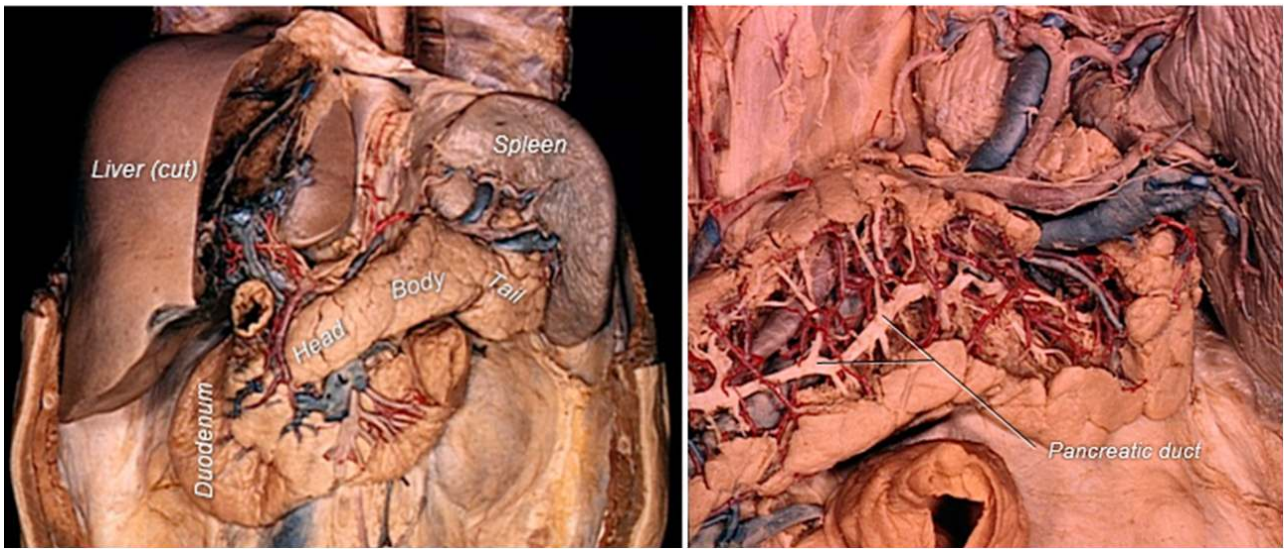
The **main pancreatic duct** combines with the **common bile duct** to form the **hepatopancreatic ampulla**. The **hepatopancreatic sphincter** controls the flow of bile and pancreatic juices through the ampulla and out the **major duodenal papilla**. The **accessory pancreatic duct** leads to the **minor duodenal papilla**.

Exocrine secretions containing digestive enzymes from the pancreas follow the following path:

1. pancreatic digestive enzymes produced in pancreatic acinar cells
2. pancreatic duct
3. common bile duct
4. through the hepatopancreatic sphincter
5. through the duodenal papilla
6. into the duodenum



Above: The duodenum, pancreas, and gall bladder including the common bile duct where secretions from the liver and gall bladder combine with pancreatic secretions and are released into the duodenum through the duodenal papilla. Release of secretions is controlled by the hepatopancreatic sphincter.



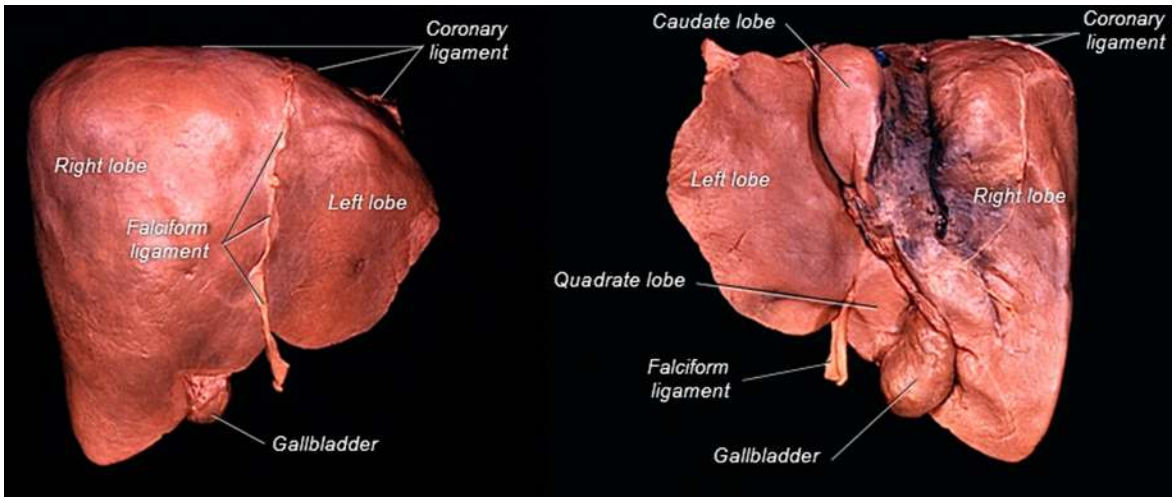
Above: Cadaver images of pancreas and duodenum.

Liver

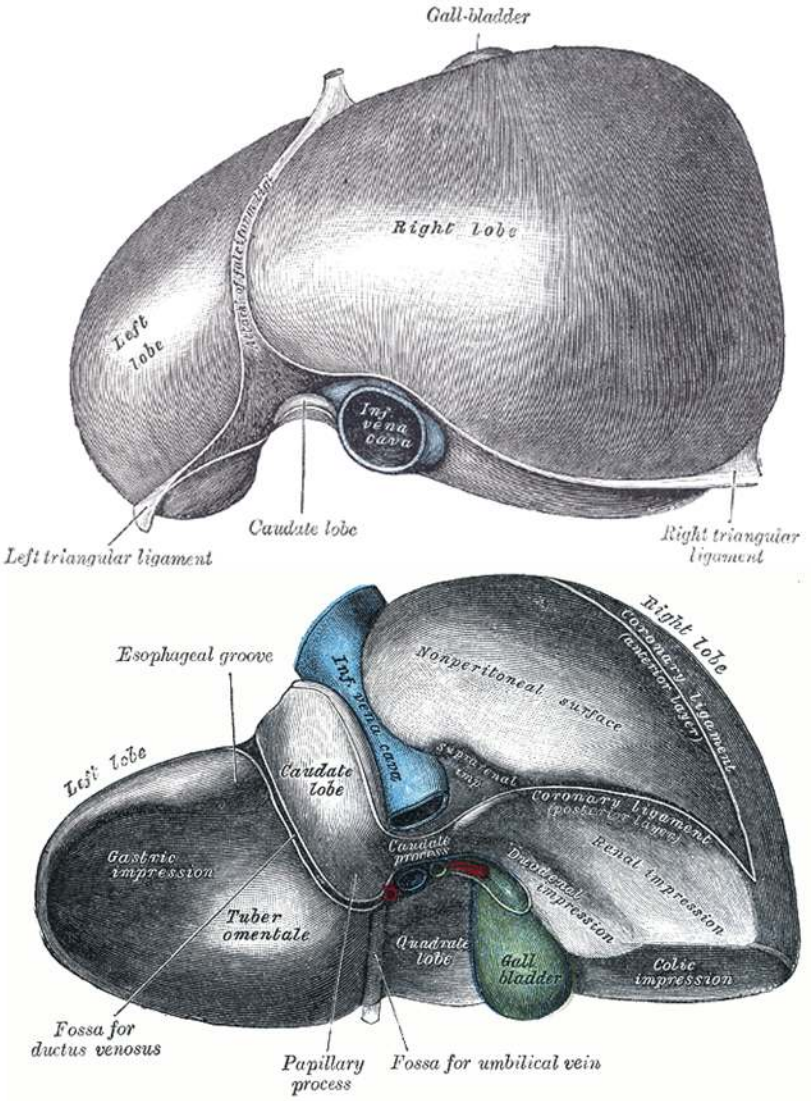
The liver cleans and detoxifies blood entering it from the hepatic portal vein, balances the amount of nutrients in the blood including glucose and amino acids, and produces **bile**. Bile is a greenish-brown alkaline fluid that aids in digestion by emulsifying fats.

Bile produced in the liver follows the following path into the duodenum:

1. bile is produced in the liver
2. right/left hepatic ducts
3. common hepatic duct
4. common bile duct
5. through the hepatopancreatic sphincter
6. through the duodenal papilla
7. into the duodenum

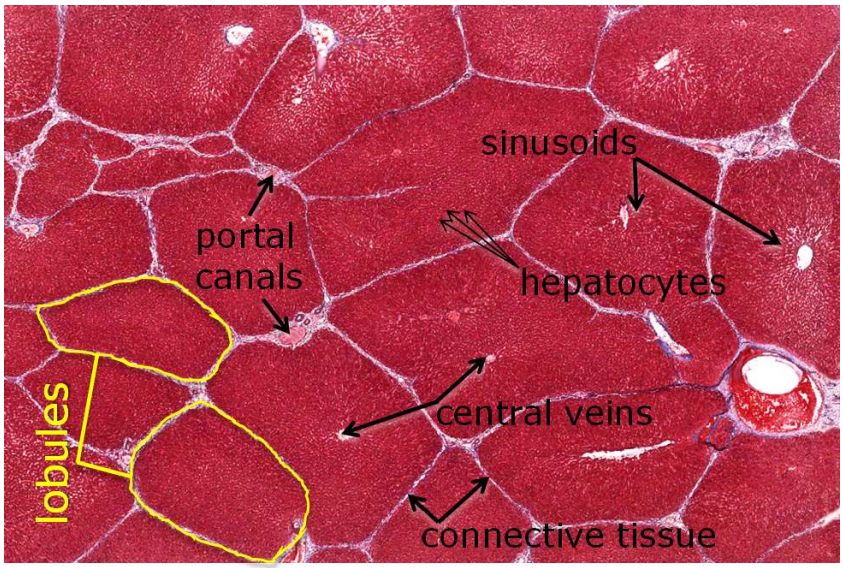


Above: Cadaver images of liver and gallbladder. (Left) Anterior view of the liver and (right) posterior view of the liver.



Above: (Top) Superior view of the liver with the top of the image being anterior and the bottom of the image being posterior. (Bottom) Inferoposterior view of the liver.

The liver is composed of four lobes: **right lobe**, **left lobe**, **quadrate lobe**, and **caudate lobe**. Between the right and left lobes is the **falciform ligament**, a fold of the peritoneum (serosa) which also attaches the liver to the anterior body wall and diaphragm. The **coronary ligament** is a ligament composed of peritoneum along the coronal plane of the superior aspect of the liver, attaching it to the diaphragm and the right kidney.



Above: The **lobule**, the basic structure of the liver, is formed by anastomosing rows of **hepatocytes** and intervening **sinusoids**, which extend from the periphery of the lobule toward a **central vein**. **Portal canals**, located at the marginal angles around the perimeter of the lobule, contain branches of the **hepatic portal vein**, **hepatic artery** and **bile duct**. Blood enters the liver in the hepatic portal vein or hepatic artery; branches of both vessels are located in a portal canal. From these branches, blood enters hepatic sinusoids between plates of hepatocytes and is carried into the central vein. Bile, the exocrine liver product, is released into tiny tunnel-like passageways called bile canaliculi. Canaliculi are located between the boundaries of adjacent hepatocytes and are continuous with bile ducts in the hepatic portal canals. Bile drains from the canaliculi to the bile duct, passing through an enlarging duct system and finally opening into the duodenum. This image of pig liver tissue shows bands of connective tissue outlining lobules; these distinctions are not so obvious in the human. Tissue is magnified by 40x.

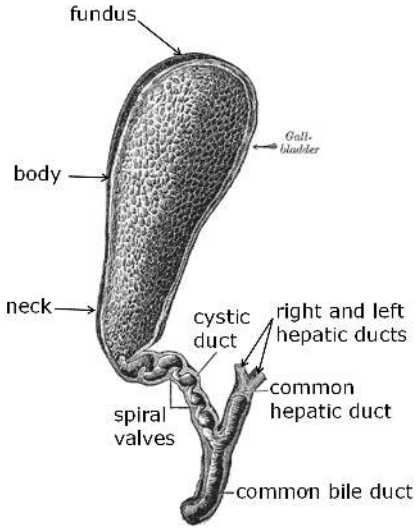
Gallbladder

The **gallbladder** stores and concentrates bile. Bile is produced in the liver and is transported into the gallbladder for storage through the right and left hepatic ducts, to the common hepatic duct, then through the cystic duct. The gallbladder has different regions called the **fundus** (dome-shaped), **body** (main region), and **neck** (narrow region leading to the cystic duct).

Some of the bile produced by the liver is stored in the gallbladder. Stored bile follows the following path:

1. bile is produced in the liver
2. right/left hepatic ducts
3. common hepatic duct
4. cystic duct
5. gallbladder for storage

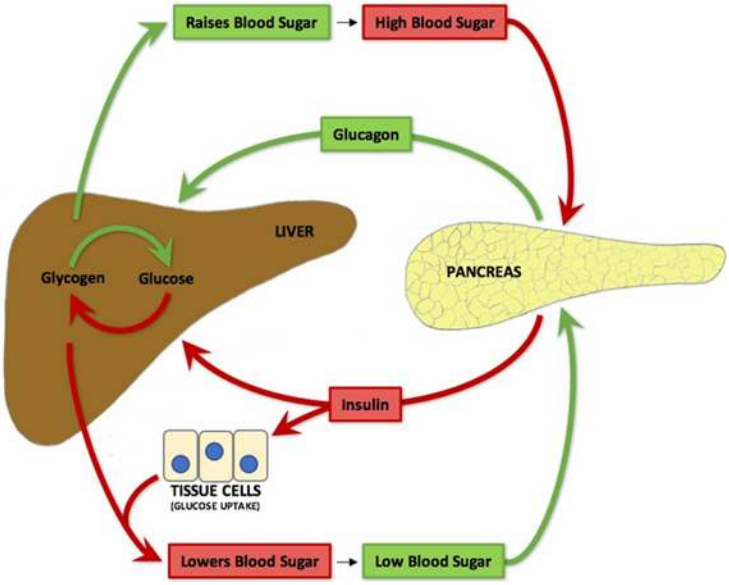
Since bile is important for the digestion of fats, individuals who have had their gallbladders removed do not have a lot of bile stored to help with fat digestion. Therefore, these individuals have to carefully monitor their diet since they cannot tolerate consuming a large amount of fat at one time.



Above: The gallbladder.

Clinical Application: Blood Sugar and Diabetes

After you consume a meal, your body digests that food to break down the **sugars**, nutrients, vitamins, minerals, proteins, etc. into usable and readily-absorbed forms. The **sugar** (in the form of **glucose**) is absorbed **into the circulatory system** and taken **first** to the **liver** (via the **portal v.**) to be processed and then to the rest of the body. When the **blood sugar level** is **high**, the **pancreas** produces **insulin**, a **hormone** that stimulates the **liver** to convert **glycose to glycogen** (**the storage form of glucose**) and body **tissues** to **uptake glucose** from the blood. Both of these actions will cause the level of sugar in the blood to **lower**. After some time has passed and your body has a **low blood sugar level from using the glucose that was in your blood for energy**, the **pancreas** will produce **glucagon**, a **hormone** that stimulates the **liver** to convert **previously made glycogen back into glucose** and release it into circulation for transportation. This action will cause the level of sugar in the blood to **raise**. The figure below represents the communication between the pancreas, liver, and tissue cells to maintain **homeostatic** blood sugar levels.



Above: Diagram showing how the liver and pancreas work together to maintain blood glucose levels.

Diabetes is a disease that causes abnormal blood sugar levels. There are **three main types of diabetes**. **Type 1 diabetes** is a condition where the **pancreas** produces little to no insulin. **Type 2 diabetes** is a condition where the **liver** is unable to adequately convert glucose into glycogen. **Prediabetes** is a condition where **high blood sugar is caused by hindered glucose processing**, but it is **not severe enough to be Type 2 diabetes** because it can be **controllable by diet modification.**

Attributions

- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0
- "Gray's Anatomy plates" by Henry Vandyke Carte is in the Public Domain
- "Medical gallery of Blausen Medical 2014" by Blausen.com staff is licensed under CC BY 3.0

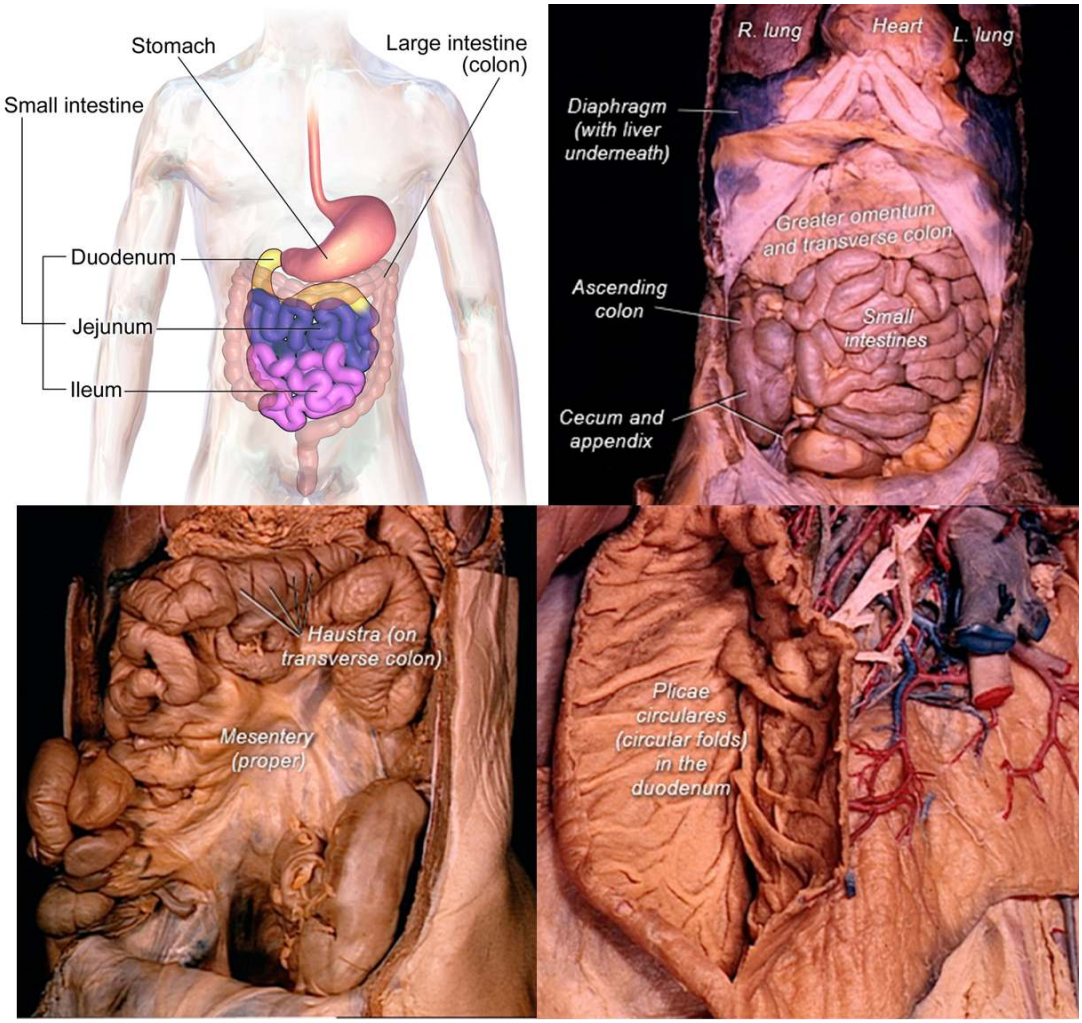
Updated 2026.

This page titled 20.6: Duodenum, Pancreas, Liver, and Gallbladder is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

20.7: Small Intestine

Small Intestine

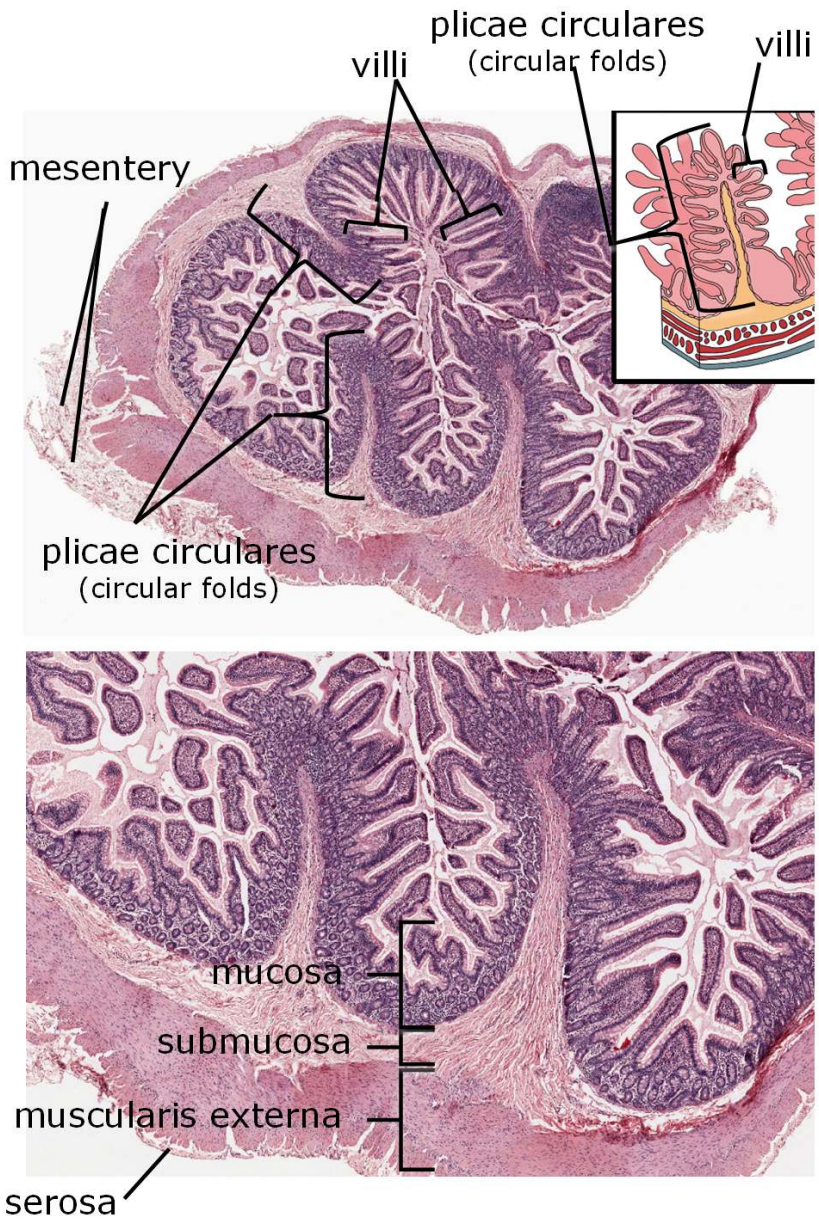
The small intestine has three regions (in the order in which they occur in the alimentary canal): the **duodenum**, the **jejunum**, and the **ileum**. The duodenum is the shortest segment of the small intestine and receives chyme from the stomach where the gastric juices are neutralized and bile and digestive enzymes are injected into the small intestine at the hepatopancreatic ampulla. Secretions into the duodenum are not continuous and their release is controlled by the hepatopancreatic sphincter. The jejunum is longer than the duodenum and shorter than the ileum. The ileum carries cyme to the **cecum**, part of the **large intestine** (also known as the **colon**). Passage from the ileum to the cecum is controlled by the **ileocecal valve**.



Above: (Top left) The three regions of the small intestine: duodenum, jejunum, and ileum. (Top right and bottom) Cadaver images of small intestine, mesentery connecting the small intestine to the posterior body wall, and plicae circulares, aka circular folds, in the small intestine which increase surface area to maximize nutrient absorption.

The small intestine continues chemical digestion and is the main organ of the alimentary canal responsible for nutrient absorption. The inner surface of the small intestine is structured to maximize surface area, since more surface area provides more opportunities for nutrient absorption. The tissue inside the small intestine is wrapped in large folds called **plicae circulares** (also known as **circular folds**) that increase the surface area of the small intestine. The plicae circulares are most prominent in the duodenum and

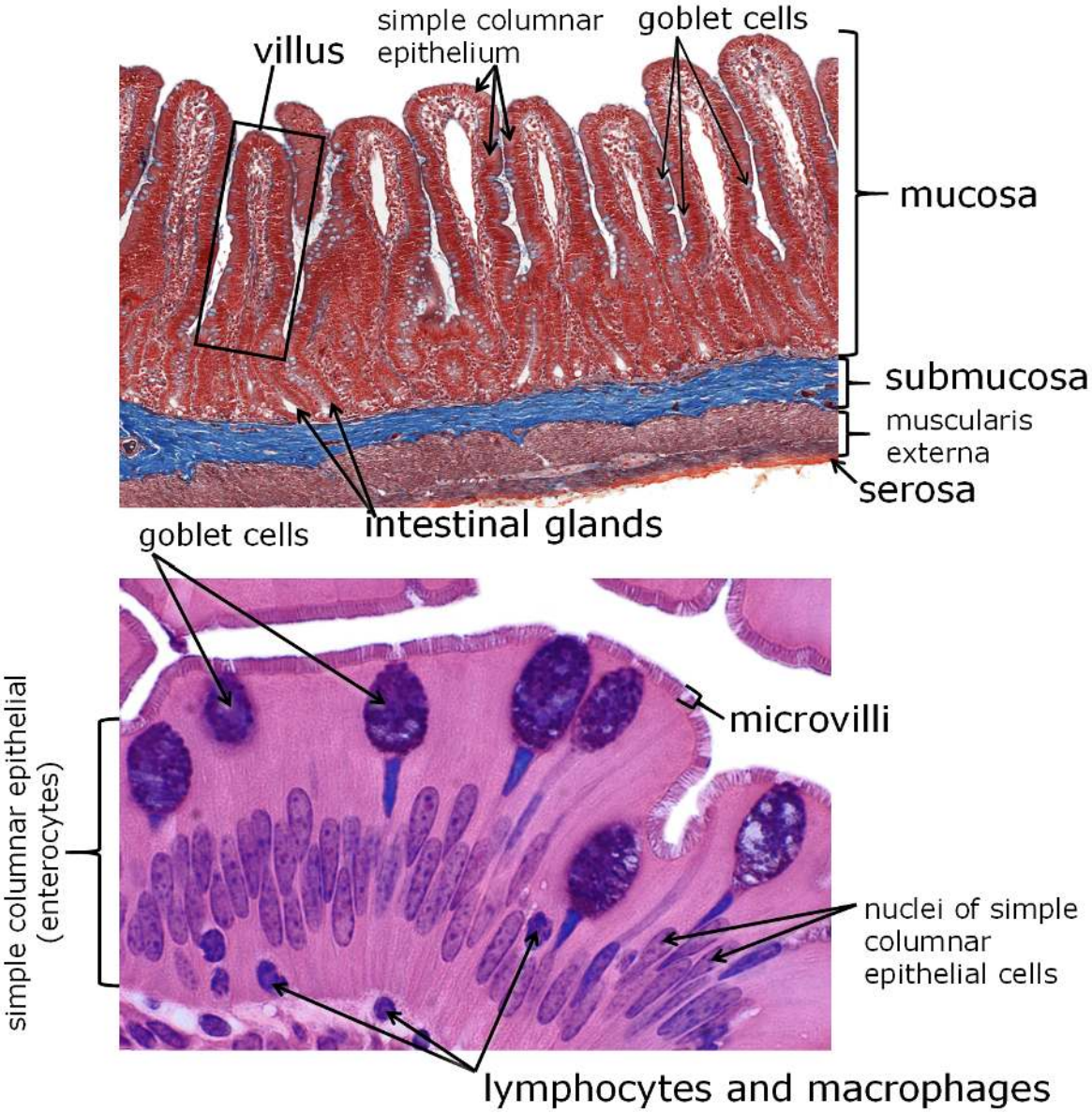
progressively thin out and transition to the smoother wall of the distal ileum. Within each plica circulare are **villi**, finger-like folds in the tissue lining the inside of the small intestine that increase surface area further. Closely examining the cells lining the inside of small intestine, tiny finger-like extensions of the cell membranes of these cells can be seen. These are folds formed within the individual cells of the epithelium lining the inside of the small intestine and are called **microvilli**. These microvilli further increase surface area to maximize nutrient absorption in the small intestine.



Above: Microscopic images of a cross section of small intestine (top) magnified by 10x and (bottom) magnified by 100x. Each plica has a core of submucosa that is overlain by all mucosal layers, including villi.

Nutrients are absorbed through the mucosa and into blood vessels and **lacteal capillaries** (lymphatic vessels that absorb fats) in the tissue lining the inside of the small intestine. Blood vessels collecting nutrients from digesting materials in the small intestine enter the **superior mesenteric vein**, that drains into the **hepatic portal vein** to reach the liver. The liver adjust and balances the nutrient levels in the blood before the blood drains from the liver. Fats absorbed in the lacteal capillaries drain into **lacteals**, larger

lymphatic vessels in the villi of the small intestine that collect digested fats. Lacteals carry the absorbed fats through the lymphatic system into the thoracic duct, which ultimately drains into the left subclavian vein where these absorbed fats enter the blood stream.



Above: (Top) This innermost layer of the small intestine is the mucosa. The mucosa is composed of three layers: a simple columnar epithelium with microvilli and goblet cells; a lamina propria of loose connective tissue in which intestinal glands are located; and a thin muscularis mucosae of smooth muscle. Beneath the mucosa is the submucosa followed by the muscularis externa and the serosa. Tissue is magnified by 100x. (Bottom) Simple columnar epithelium with microvilli lines the small intestine, possessing both absorptive (**enterocytes**) and mucus-secreting goblet cells. Wandering lymphocytes and macrophages provide immune surveillance. Tissue is magnified by 1000x.

Attributions

- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0

- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0
- "Medical gallery of Blausen Medical 2014" by Blausen.com staff is licensed under CC BY 3.0

Updated 2026.

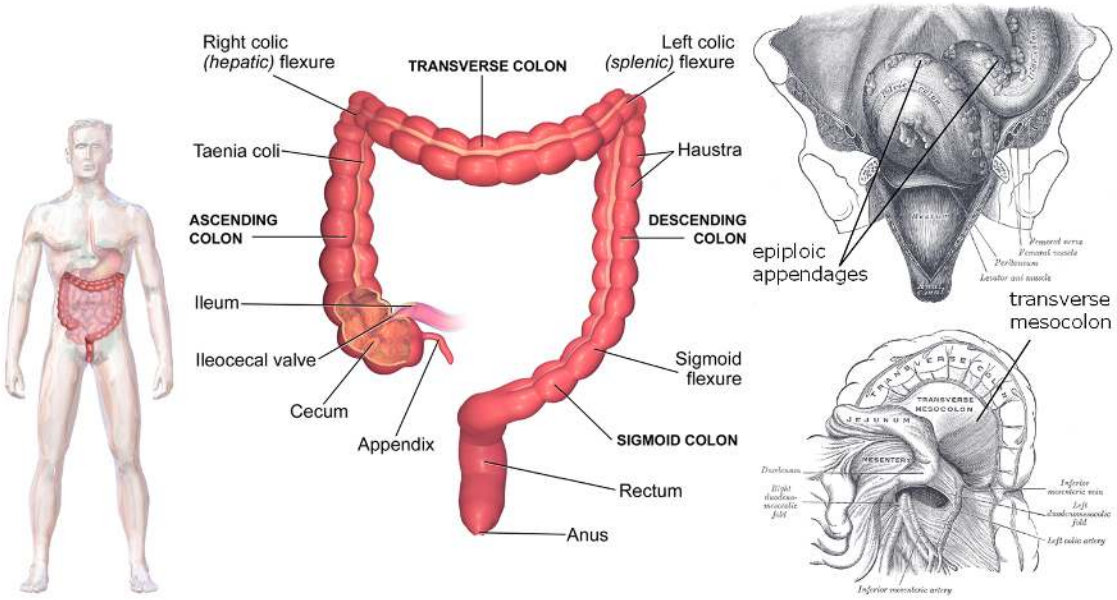
This page titled 20.7: Small Intestine is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

20.8: Colon (Large Intestine), Rectum, and Anus

Colon (Large Intestine), Rectum, and Anus

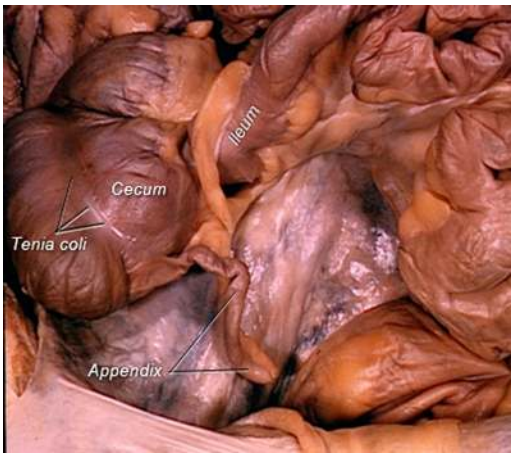
This **ileocecal valve** controls the flow of chyme from the ileum into the **cecum**. Once chyme enters the large intestine, the "food" substance is then called **feces**.

The **colon**, also called the **large intestine**, processes feces after the majority of the nutrients have been absorbed in the small intestine. This organ is responsible for absorbing the water and electrolytes remaining in the feces in addition to absorbing vitamins, including B vitamins and vitamin K that are produced by **colonic bacteria** living in the colon. In fact, there are trillions of bacteria living in the colon that produce vitamins absorbed in the colon. These bacteria also have important immune roles, protecting the colon from infection. The colon also helps to store and propel waste from the body.



Above: Structures of the colon. (Left) Diagram of the different regions and structures of the colon. (Top right) some of the epiploic appendages are shown on the surface of the colon. (Bottom right) The colon is attached to the posterior body wall with serosa called mesocolon. The mesocolon is named for regions of colon it is attached to: **ascending mesocolon**, **transverse mesocolon**, **descending mesocolon**, and **sigmoid mesocolon**.

There are five regions of the colon. In order from the ileocecal valve to the rectum: **cecum**, **ascending colon**, **transverse colon**, **descending colon**, and **sigmoid colon**. The cecum is a pouch where feces enter the colon and the **appendix** is attached and in the inferior aspect of the cecum. The terms ascending, transverse, and descending refer to the movements feces take as they move toward the rectum.

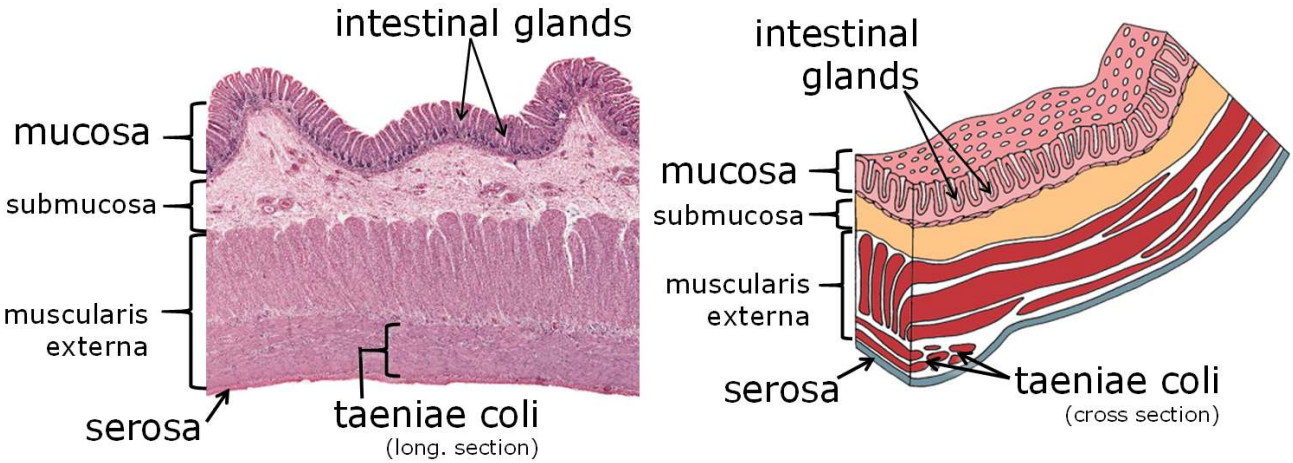


Above: Cadaver image of the cecum and appendix.

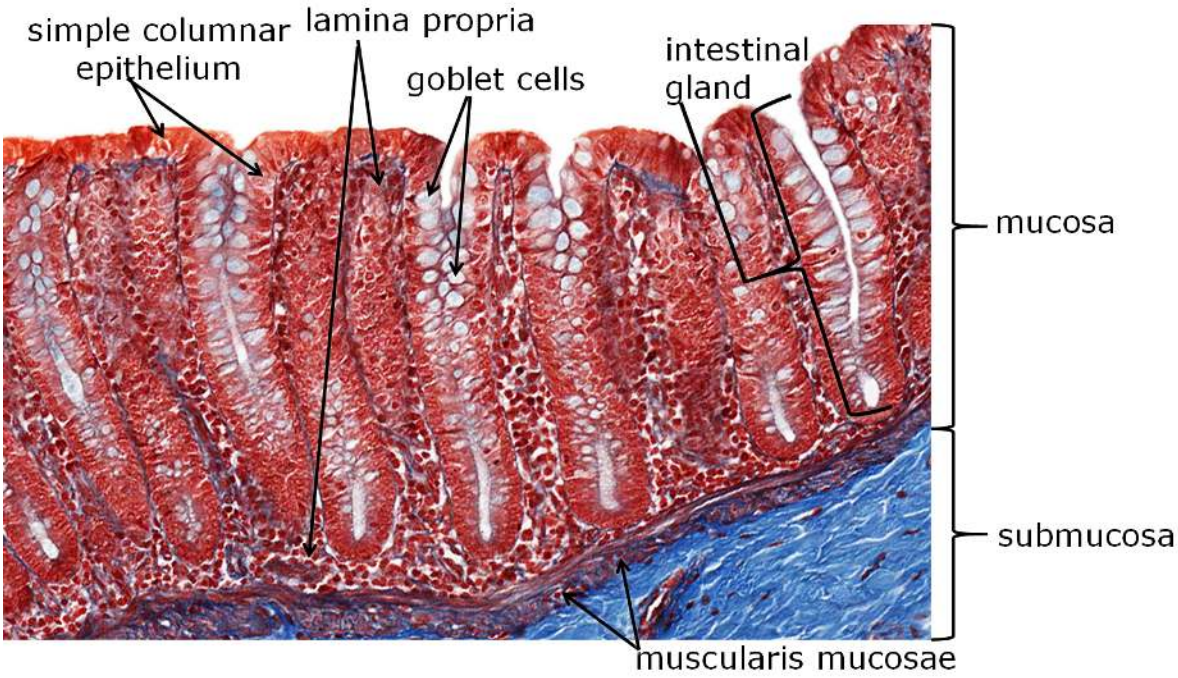
The colon has rounded pouches called **haustra**, each divided by indentations called **haustral folds**. Along the exterior surface of the colon are fatty appendages formed of peritoneum called **epiploic appendages**.

There are three **flexures** (a fancy way to say a bend or curve) in of the colon: **right colic flexure** (also called the **hepatic flexure** for its proximity to the liver), **left colic flexure** (also called the **splenic flexure** for its proximity to the spleen), and the **sigmoid flexure** (sigmoid = "S" or "C" shaped structure).

The tenia coli is a longitudinal band of muscle that spans the entire length of the large intestine. It helps move feces through the large intestine. There are a total of three tenia coli.

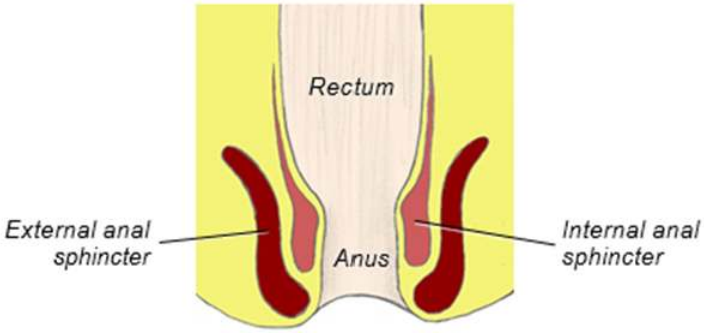


Above: The large intestine, composed of the four basic tunics, is differentiated from small intestine by the lack of villi, straight intestinal glands and taeniae coli. The large intestine was cut longitudinally through a taenia coli in the bottom left image. Tissue is magnified by 10x.



Above: The mucosa of the large intestine is lined by absorptive and goblet cells forming a simple columnar epithelium with microvilli. Goblet cells increase in number from the beginning to the termination of the large intestine, providing lubrication. A reduced number of enteroendocrine cells is present. Straight intestinal glands are typical of the large intestine. Tissue is magnified by 400x.

The descending colon, sigmoid colon, and rectum store feces until expelled. The sigmoid colon additionally aids in forcing feces from the body. For feces to pass from the body through the anus, it needs to pass through two sphincters: the **internal anal sphincter** and the **external anal sphincter**. The autonomic nervous system (involuntarily) controls your internal anal sphincter (smooth muscle), and there is voluntary control over the external anal sphincter (skeletal muscle).



Above: Diagram showing the position of the internal anal sphincter (smooth muscle, involuntary) and external anal sphincter (skeletal muscle, voluntary).

Clinical Application: Appendicitis

The **appendix** is a tube of tissue about the size of a pinky finger (exact thickness and length varies) attached to the cecum. The **lumen** of the appendix is continuous with that of the cecum, which allows fecal matter to fill the appendix. When the appendix is agitated (typically caused by a component of fecal matter getting stuck in the lumen), it becomes **inflamed** and is known as

appendicitis. **Symptoms** of appendicitis include **severe pain in the lower right quadrant of the abdomen** (where the appendix is located), **vomiting**, and **fever**. **Blood**, **urine**, and **radiographic tests** can help verify the **diagnosis**. If left untreated, the inflamed appendix may **perforate** or **rupture**, allowing fecal matter and bacteria to spill into the **abdominal cavity**. This can cause **peritonitis** (inflammation of the **peritoneum**), which can be fatal. Therefore, medical attention should be sought immediately if appendicitis is suspected. Typical treatment includes consists of an **emergency surgical procedure** called an **appendectomy** to remove the appendix. Because they are sharp and do not digest, one of the most common things that become lodged in the appendix and cause appendicitis is **fingernails**!

Attributions

- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0
- "Gray's Anatomy plates" by Henry Vandyke Carte is in the Public Domain
- "Medical gallery of Blausen Medical 2014" by Blausen.com staff is licensed under CC BY 3.0

Updated 2026.

This page titled 20.8: Colon (Large Intestine), Rectum, and Anus is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

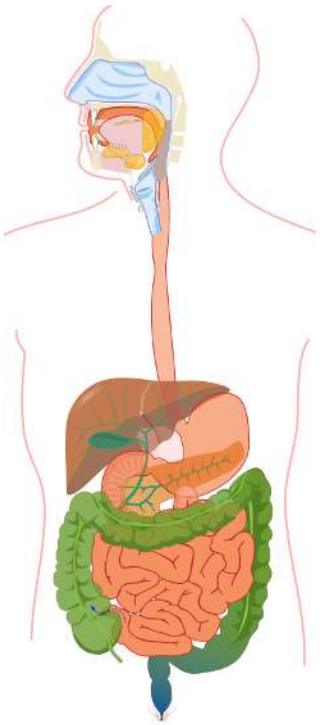
20.9: Laboratory Activities and Assignment

Laboratory Activities and Assignment

Part 1: Review of the Digestive System

1. On the diagram below, label the following structures:

- anus
- appendix
- ascending colon
- cardia of the stomach
- cecum
- common bile duct
- common hepatic duct
- descending colon
- duodenum
- esophagus
- falciform ligament
- fundus of the stomach
- gallbladder
- hard palate
- haustra
- ileocecal valve
- ileum
- jejunum
- left colic flexure
- left hepatic duct
- left lobe of the liver
- lower esophageal sphincter
- oral cavity
- pancreas
- parotid salivary gland
- pyloric sphincter
- pylorus of the stomach
- rectum
- right colic flexure
- right hepatic duct
- right lobe of the liver
- sigmoid colon
- soft palate
- stomach
- sublingual salivary gland
- submandibular salivary gland
- taenia coli
- transverse colon
- upper esophageal sphincter
- uvula



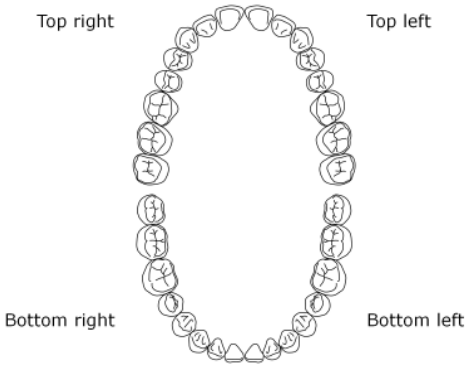
2. On the diagram below, label the following structures:

- blood vessels
- crown
- dentin
- enamel
- nerves
- pulp
- root
- root canal



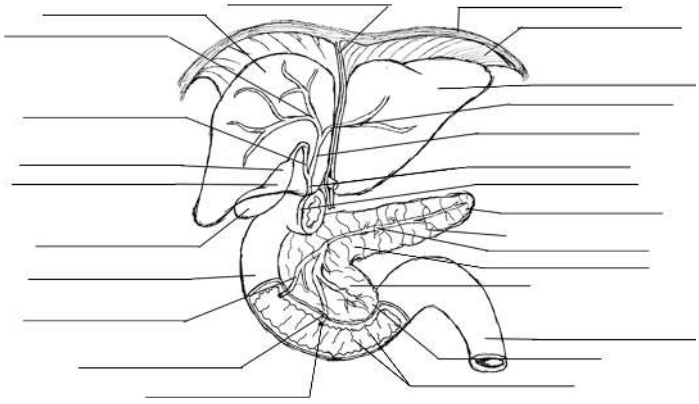
3. On the diagram below, label the following structures:

• canines • incisors • molars	• numbers (1-32) • premolars



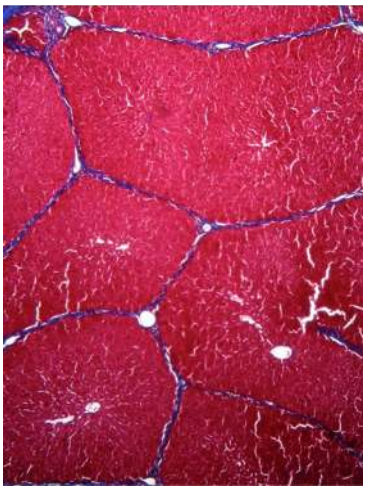
4. On the diagram below, label the following structures:

• accessory pancreatic duct • body of gallbladder • body of pancreas • common bile duct • common hepatic duct • coronary ligament • cystic duct • diaphragm	• duodenum • falciform ligament • fundus of gallbladder • head of pancreas • hepatopancreatic ampulla • hepatopancreatic sphincter • jejunum • left hepatic duct	• left lobe of liver • neck of gallbladder • pancreatic duct • plicae circulares • pyloric sphincter • right hepatic duct • right lobe of liver • tail of pancreas



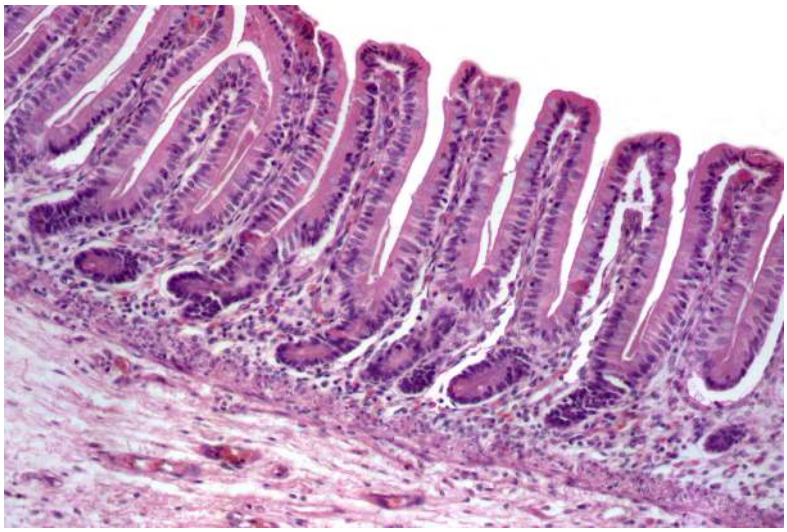
5. On the diagram below, label the following structures:

• central veins • connective tissue	• hepatocytes • lobules	• portal canals • sinusoids



6. Below is a microscopic image of the tissue lining the inside of the large intestine, magnified by 400x. Label the following structures on the image:

• goblet cells • intestinal glands • lamina propria	• mucosa • muscularis mucosa	• simple columnar epithelium • submucosa

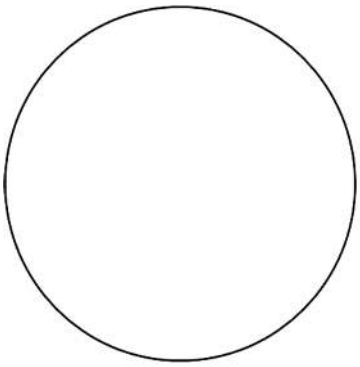


Part 2: Histology of the Digestive System

1. Obtain the slides listed below that are available for today's lab.
2. Focus on each sample and identify the structures listed for each type of tissue.
3. Indicate the **total** magnification you make each illustration at in the space provided.
4. Illustrate each tissue you observe with the microscope at the magnification you listed.
5. Label each illustration with the structures listed for each.

Oral Cavity

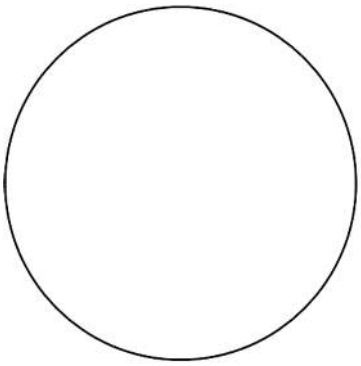
Label the tissue with: stratified squamous epithelium, mucosa, lamina propria



Total magnification: _____

Esophagus

Label the tissue with: mucosa, submucosa, muscularis externa, serosa, lumen, stratified squamous epithelium, lamina propria

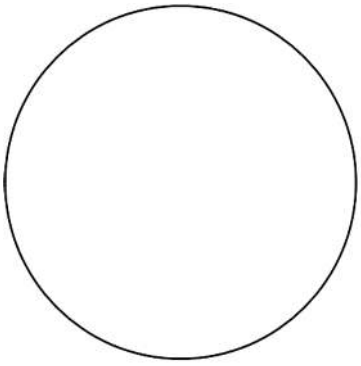


Total magnification: _____

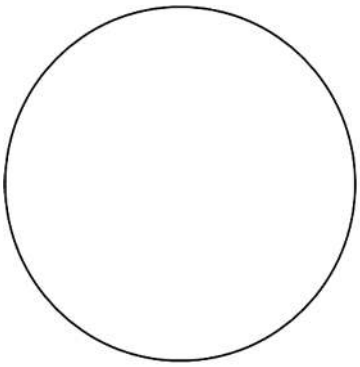
Stomach

Make one illustration at a low magnification and another at a higher magnification to view structures in the mucosa.

Label the tissue with: mucosa, submucosa, muscularis externa, serosa, goblet cells, simple columnar epithelium lamina propria, gastric pits, gastric glands



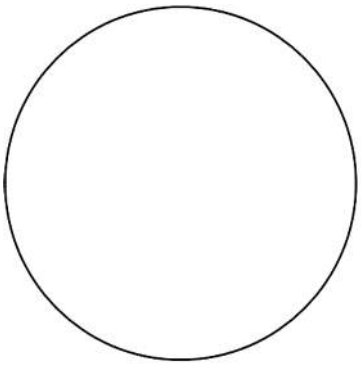
Total magnification: _____



Total magnification: _____

Liver

Label the tissue with: lobule, portal canals, central veins, hepatocytes, sinusoids

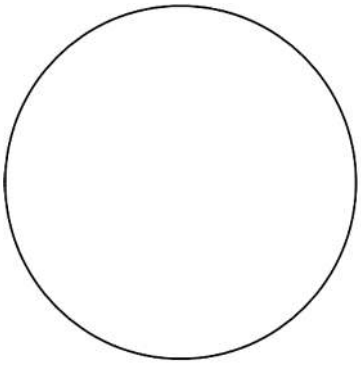


Total magnification: _____

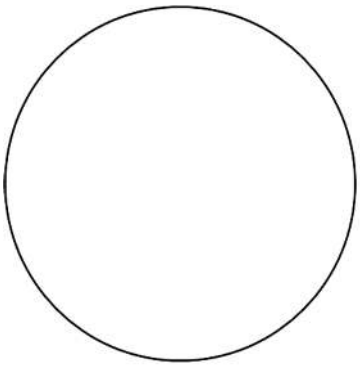
Small Intestine

Make one illustration at a low magnification and another at a higher magnification to view structures in the mucosa.

Label the tissue with: mucosa, submucosa, muscularis externa, serosa, plicae circulares (circular folds), villi, simple columnar epithelium, lamina propria, goblet cells, microvilli



Total magnification: _____

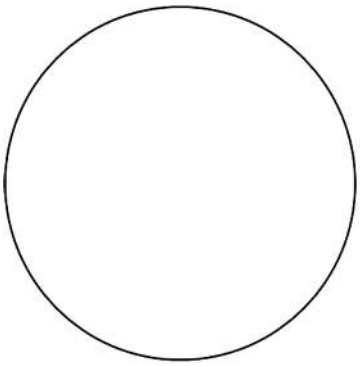


Total magnification: _____

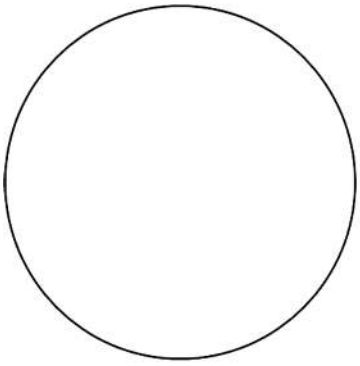
Large Intestine

Make one illustration at a low magnification and another at a higher magnification to view structures in the mucosa.

Label the tissue with: mucosa, submucosa, muscularis externa, serosa, simple columnar epithelium, lamina propria, goblet cells, intestinal glands, muscularis mucosa



Total magnification: _____



Total magnification: _____

Part 3: Digestive System Laboratory Activities

Oral Cavity, Esophagus, and Stomach

1. Use the anatomical models provided to your group in your group.
2. As a group, identify the structures listed below.
3. Write each of the following structures on masking tape or labeling tape (with correct spelling) and stick onto the model to label each structure.

- #1 molar
- #15 incisor
- #16 canine
- #17 premolar
- #18 molar
- attachment of greater omentum
- attachment of lesser omentum
- body (of stomach)
- cardia (of stomach)
- circular muscle (of stomach)
- crown (of tooth)
- dentin (of tooth)
- enamel (of tooth)
- esophagus
- fundus (of stomach)
- gingiva
- greater curvature (of stomach)
- hard palate
- longitudinal muscle (of stomach)
- lesser curvature (of stomach)
- lower esophageal sphincter
- oblique muscle (of stomach)
- parotid salivary gland
- pyloric sphincter
- pylorus (of stomach)
- rugae
- soft palate
- sublingual salivary gland
- submandibular salivary gland
- tongue
- upper esophageal sphincter
- uvula

4. When you are done, take photos of your labeled anatomical model(s). Ask your instructor to verify the labeling is correct.

Instructor Signature Confirming Correct Labeling: _____

Liver, Gallbladder, and Pancreas

1. Use the anatomical models provided to your group in your group.
2. As a group, identify the structures listed below.
3. Write each of the following structures on masking tape or labeling tape (with correct spelling) and stick onto the model to label each structure.

- accessory duct
- body (of gallbladder)
- body (of pancreas)
- common bile duct
- common hepatic duct
- cystic duct
- falciform ligament
- fundus (of gallbladder)
- head (of pancreas)
- left hepatic duct
- left lobe (of liver)
- neck (of gallbladder)
- pancreatic duct
- right hepatic duct
- right lobe (of liver)
- tail (of pancreas)

4. When you are done, take photos of your labeled anatomical model(s). Ask your instructor to verify the labeling is correct.

Instructor Signature Confirming Correct Labeling: _____

Small Intestine and Colon

1. Use the anatomical models provided to your group in your group.
2. As a group, identify the structures listed below.
3. Write each of the following structures on masking tape or labeling tape (with correct spelling) and stick onto the model to label each structure.

- appendix
- ascending colon
- ascending mesocolon
- attachment of mesentery
- cecum
- descending colon
- descending mesocolon
- duodenum
- external anal sphincter
- hepatopancreatic ampulla
- hepatopancreatic sphincter
- ileocecal valve
- ileum
- internal anal sphincter
- jejunum
- left colic flexure
- rectum
- right colic flexure
- sigmoid colon
- sigmoid mesocolon
- transverse colon
- transverse mesocolon

4. When you are done, take photos of your labeled anatomical model(s). Ask your instructor to verify the labeling is correct.

Instructor Signature Confirming Correct Labeling: _____

Flow of the Gastrointestinal Tract

1. As a group, determine the route a bolus/chyme/feces take through the digestive tract. List each structure of the alimentary canal in order. When the list is complete, show when it is called "bolus," when it is called "chyme," and when it is called "feces," by adding labels to your list.

Attributions

Part 1: Review of the Digestive System

- "Anatomy and Physiology Lab Homework" by Laird C Sheldahl is licensed under CC BY-SA 4.0
- "Digestive system without labels.svg" by Mariana Ruiz, Jmarchn is in the Public Domain
- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0
- "Human Anatomy Lab Manual" by Malgosia Wilk-Blaszczak, Mavs Open Press, University of Texas at Arlington is licensed under CC BY 4.0
- "Human dental arches.svg" by Kaligula is licensed under CC BY-SA 3.0

Part 2: Histology of the Digestive System

- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0

Part 3: Digestive System Laboratory Activities

- "Human Anatomy Lab Manual" by Malgosia Wilk-Blaszczak, Mavs Open Press, University of Texas at Arlington is licensed under CC BY 4.0

Updated 2026.

This page titled 20.9: Laboratory Activities and Assignment is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

20.10: Collaborative Study Activities

Collaborative Study Activities

This activity is designed for student groups of 2-4. Larger groups will work better when there is no supplemental instructor present in the laboratory to assist in testing student groups on each section.

1. Identify the following structures on classroom anatomical models and/or unlabeled images/diagrams made available by your instructor. Work with your group to identify each structure and check them off the list once you have identified them.

☐ appendix	☐ hard palate	☐ parotid salivary gland
☐ ascending colon	☐ head of pancreas	☐ pylorus (stomach)
☐ body (gallbladder)	☐ ileum	☐ rectum
☐ body (stomach)	☐ internal anal sphincter	☐ right hepatic duct
☐ cardia (stomach)	☐ jejunum	☐ right lobe (liver)
☐ cecum	☐ large intestine	☐ rugae (stomach)
☐ common bile duct	☐ left hepatic duct	☐ sigmoid colon
☐ cystic duct	☐ left lobe (liver)	☐ small intestine
☐ descending colon	☐ lesser curvature (stomach)	☐ soft palate
☐ duodenum	☐ liver	☐ stomach
☐ esophagus	☐ mesentery	☐ sublingual salivary gland
☐ external anal sphincter	☐ mesocolon	☐ submandibular salivary gland
☐ fundus (gallbladder)	☐ neck (gallbladder)	☐ tail of pancreas
☐ fundus (stomach)	☐ oral cavity	☐ tongue
☐ gallbladder	☐ oropharynx	☐ transverse colon
☐ greater curvature (stomach)	☐ pancreas	☐ uvula

2. Test your group members by ***asking them to name each structure you point to***. Check off each when your group can successfully name each. Your group will also test you.

☐ appendix	☐ hard palate	☐ parotid salivary gland
☐ ascending colon	☐ head of pancreas	☐ pylorus (stomach)
☐ body (gallbladder)	☐ ileum	☐ rectum
☐ body (stomach)	☐ internal anal sphincter	☐ right hepatic duct
☐ cardia (stomach)	☐ jejunum	☐ right lobe (liver)
☐ cecum	☐ large intestine	☐ rugae (stomach)
☐ common bile duct	☐ left hepatic duct	☐ sigmoid colon
☐ cystic duct	☐ left lobe (liver)	☐ small intestine
☐ descending colon	☐ lesser curvature (stomach)	☐ soft palate
☐ duodenum	☐ liver	☐ stomach
☐ esophagus	☐ mesentery	☐ sublingual salivary gland
☐ external anal sphincter	☐ mesocolon	☐ submandibular salivary gland
☐ fundus (gallbladder)	☐ neck (gallbladder)	☐ tail of pancreas
☐ fundus (stomach)	☐ oral cavity	☐ tongue
☐ gallbladder	☐ oropharynx	☐ transverse colon
☐ greater curvature (stomach)	☐ pancreas	☐ uvula

3. When you and your group are comfortable identifying all the structures above, request the assistance of your Instructor. They will test you on your use of these terms and initial ONLY when you are successful using these terms. Instructor: _____

Updated 2026.

This page titled 20.10: Collaborative Study Activities is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

CHAPTER OVERVIEW

21: Urinary System

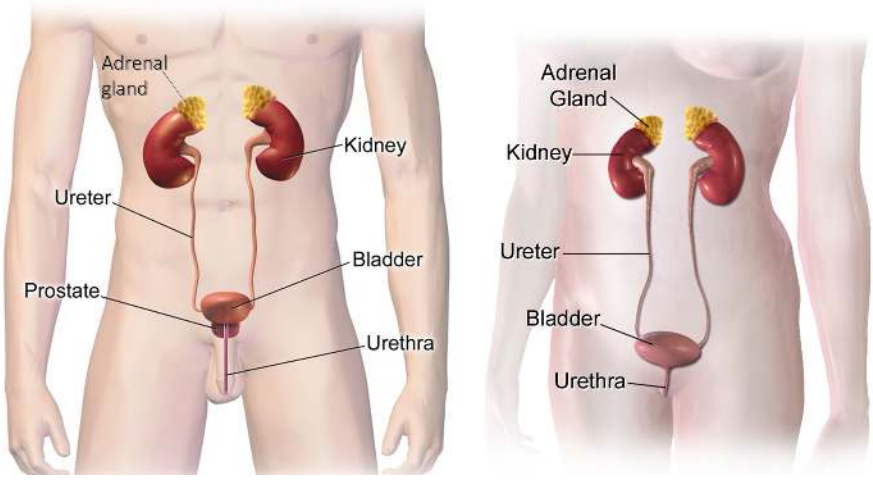
21.1: Introduction
21.2: Kidneys
21.3: Microscopic Structures of the Kidneys - Nephrons
21.4: Ureters
21.5: Urinary Bladder
21.6: Urethra
21.7: Laboratory Activities and Assignment
21.8: Collaborative Study Activities

This page titled 21: Urinary System is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

21.1: Introduction

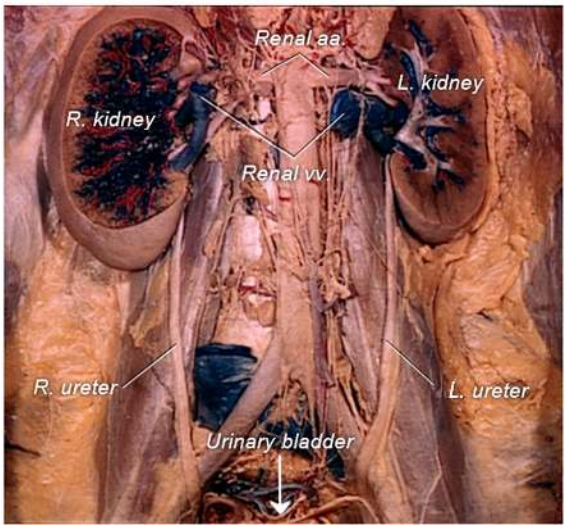
Introduction

The urinary system is one of excretion, elimination and reabsorption. It is made from four organs, only one of which produces urine (the **kidney**). **Nephrons**, the smallest functional unit of the kidneys, are found in numbers of one to two million within the kidney and can filter up to 400 gallons of cycled blood, daily! The kidneys receive more blood than the heart, liver, or even the brain and have vital functions such as the regulation of pH, blood pressure, concentration of blood solutes and concentration of red blood cells. The remaining three organs (**ureters**, **urinary bladder**, and **urethra**) facilitate urine storage and secretion. Of these organs, only the urethra is anatomically distinct between males and females.



Above: Overview of the anatomy of the urinary system with (left) male anatomy and (right) female anatomy.

The kidneys execute many of the urinary system functions including the formation of urine. The other urinary organs, the ureters, urinary bladder, and urethra, function primarily as a means of eliminating urine from the body.



Above: Cadaver image of urinary anatomy. Kidneys are shown sectioned. The abbreviations are "R." for "right,""L." for "left," "aa." for "arteries," and "vv." for "veins."

Attributions

- "Human Anatomy Lab Manual" by Malgosia Wilk-Blaszczak, Mavs Open Press, University of Texas at Arlington is licensed under CC BY 4.0
- "Urinary System (Female).png" by BruceBlaus is licensed under CC BY-SA 4.0
- "UrinarySystemMale.jpg" by BruceBlaus is licensed under CC BY-SA 4.0 / A derivative from the original work

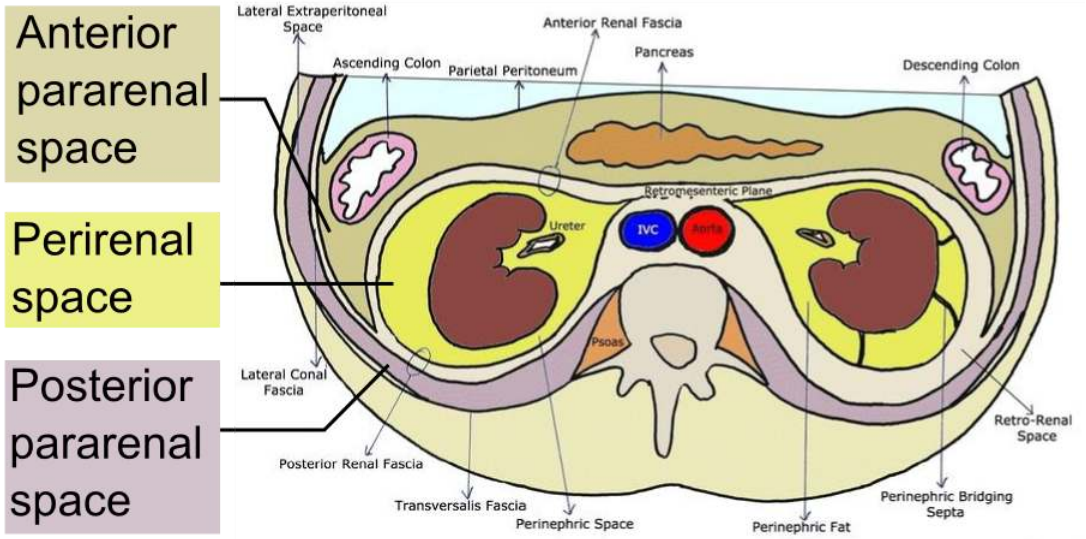
Updated 2026.

This page titled 21.1: Introduction is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

21.2: Kidneys

Kidneys

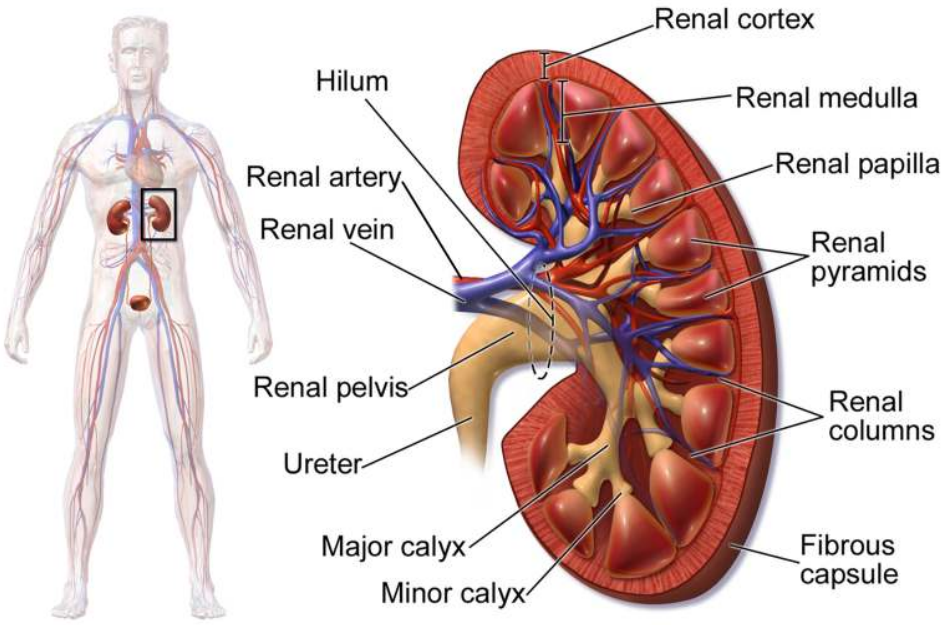
There are two kidneys, one right and one left. They are **retroperitoneal** (posterior to peritoneum) and encased in protective layers of adipose tissue along the posterior body wall of the abdomen.



Above: Transverse section with the bottom of the diagram posterior and the top of the diagram anterior showing the position of the kidneys as retroperitoneal (outside of the abdominal cavity located posterior to it). The kidneys are surrounded by perinephric fat and surrounded by an anterior renal fascia and posterior renal fascia.

The kidneys filter dissolved materials from the blood, including metabolic wastes, regulate electrolytes, regulate fluid volume (thereby influencing blood pressure), concentrates and stores waste products in the form of urine, and reabsorbs metabolically important substances back into the circulatory system. The following are specific functions of the kidneys:

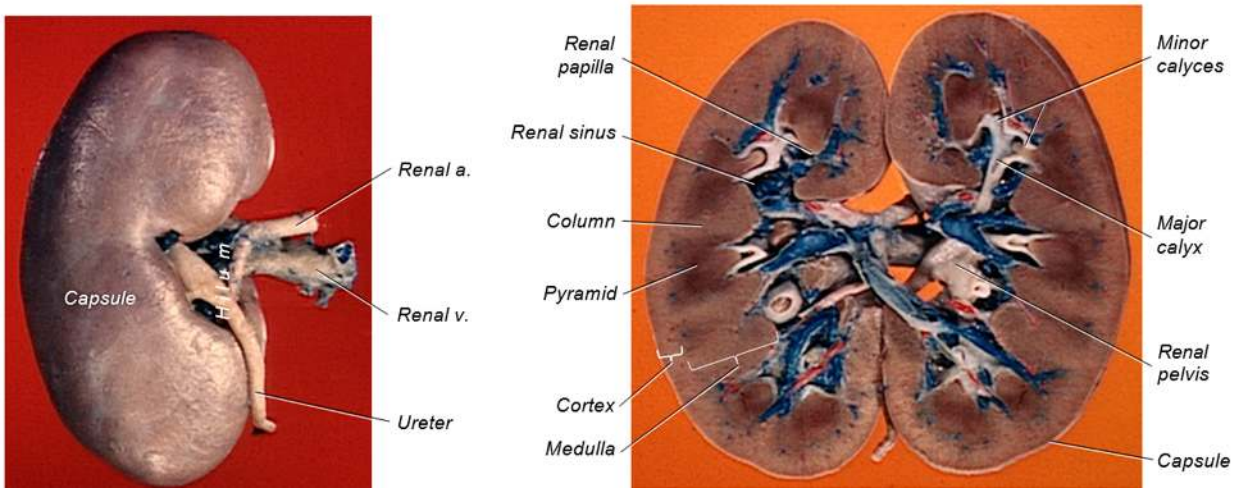
1. **Remove waste:** The kidneys filter waste products and excess fluid out of the blood and remove them from the body in the form of urine. (nitrogenous wastes such as **urea** and **ammonium**)
2. **Maintain the right balance of chemicals in the body:** The kidneys keep the right balance of chemicals,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



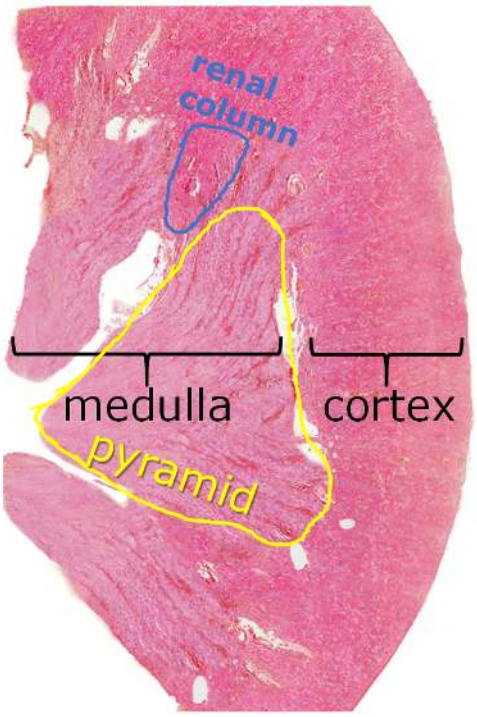
Above: Anatomy of a kidney. Left kidney shown with frontal section.

Kidney Structure	Location	Function
columns (renal)	tissue-filled areas between the pyramids	anchor the medulla to the cortex and provide a place for blood vessels to travel
cortex (renal)	a region of the kidney where nephrons are mostly located	region of the kidney where blood is filtered and urine is formed; contain nephrons
fibrous capsule	fibrous layer on the lining the outside of the kidney	Protects and supports the kidney
glomerulus	microscopic bundle of capillaries in the cortex of the kidney; part of a nephron	high-pressure leaky capillaries create raw filtrate (fluid that will become urine); fluid and solutes are pushed out of these capillaries from the blood and into the Bowman's capsule / glomerular capsule
hilum	a central, medial fissure in the kidney	location where ureters, blood vessels, and nerves enter the kidney
major calyx	large divisions of the renal pelvis; where minor calyces fuse together	collects urine from the minor calyces and transfer it to the renal pelvis
minor calyx	smaller divisions of the major calyces; between major calyces and renal papillae	collects urine from the renal papillae and transfers it to the major calyces
medulla (renal)	a region of the kidney between the cortex and the minor calyces	contain nephron loops of juxtamedullary nephrons; balancing water and salt concentrations in the blood
nephron	microscopic structures mostly found in the renal cortex, but some components found in the medulla; composed of kidney tubules	filters the blood to remove wastes and fluid; produces urine
papilla (renal)	between the pyramids and the minor calyces	collects urine from the collecting ducts and transfers to the minor calyces
pyramids (renal)	triangular-shaped regions of the medulla	transfer of urine from nephrons to the calyces

Kidney Structure	Location	Function
renal pelvis	between the major calyces and the ureter	collects urine from the major calyces and transfers it to the ureter



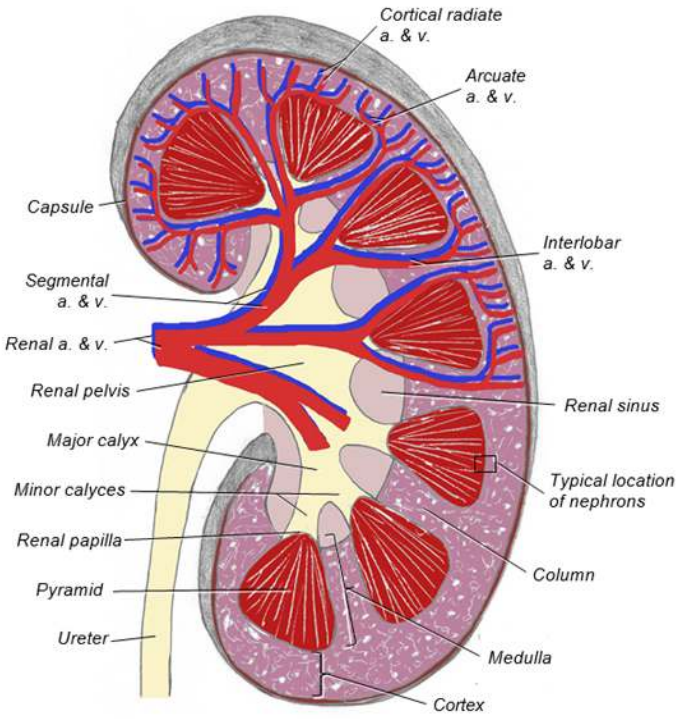
Above: Cadaver kidney (left) right kidney, unsectioned and (right) kidney, frontal sectioned. The abbreviations are "a." for "artery" and "v." for "vein."



Above: Microscopic image of kidney tissue, magnified by 10x.

In order for the kidney to work properly, blood vessels must carry blood to the **glomerulus** for **filtration**, then to the **peritubular capillaries** to drop off oxygen (and pick up carbon dioxide and reabsorb water and electrolytes), and then to the renal vein to head back to the heart. Below are the vessels that make this special circulation happen. They are listed in the order that blood flows through them.

1. descending abdominal aorta
2. renal artery
3. segmental artery
4. interlobar artery
5. arcuate artery
6. cortical radiate artery
7. afferent arteriole
8. glomerulus
9. efferent arteriole
10. peritubular capillaries
11. cortical radiate vein
12. arcuate vein
13. interlobar vein
14. renal vein
15. inferior vena cava



Above: Blood vessel network of the kidney. The abbreviations are "a." for "artery" and "v." for "vein."

Attributions

- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0
- "Medical gallery of Blausen Medical 2014" by Blausen.com staff is licensed under CC BY 3.0
- "Renal Anatomy" by Dongho Kim is licensed under CC BY-NC-SA 4.0
- "Retroperitoneal spaces.png" by Goran Mitreski and Tom Sutherland is licensed under CC BY 4.0 / A derivative from the original work

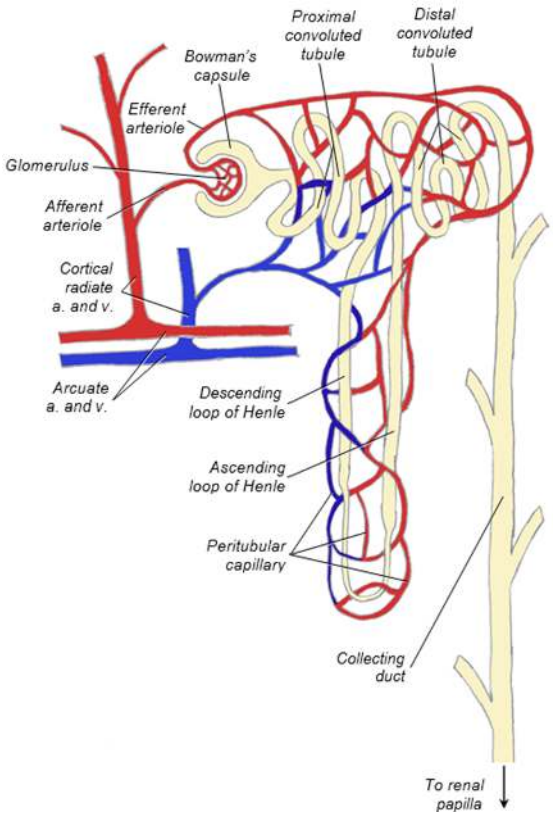
Updated 2026.

This page titled 21.2: Kidneys is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

21.3: Microscopic Structures of the Kidneys - Nephrons

Microscopic Structures of the Kidneys - Nephrons

Nephrons are functional units located in the kidneys responsible for forming urine. Nephrons are complexes of a few components: a filtration unit, the **renal corpuscle** (composed of a **glomerulus** and **Bowman's capsule/glomerular capsule**) that filters the blood, **kidney tubules** that allow adjustment of urine contents and opportunities for reabsorption of materials into the blood, and blood vessels that bring blood to and from the nephron and reabsorb materials from the **filtrate** (fluid in the process of becoming urine) that had been filtered out of the blood.



Above: Structure of a nephron.

The kidneys maintain the chemical balance of body fluids by removing metabolic wastes, excess water and electrolytes. Three physiological process occur in **nephrons** to produce urine:

1. **Filtration** - blood is initially filtered in the glomerulus

2. **Reabsorption**

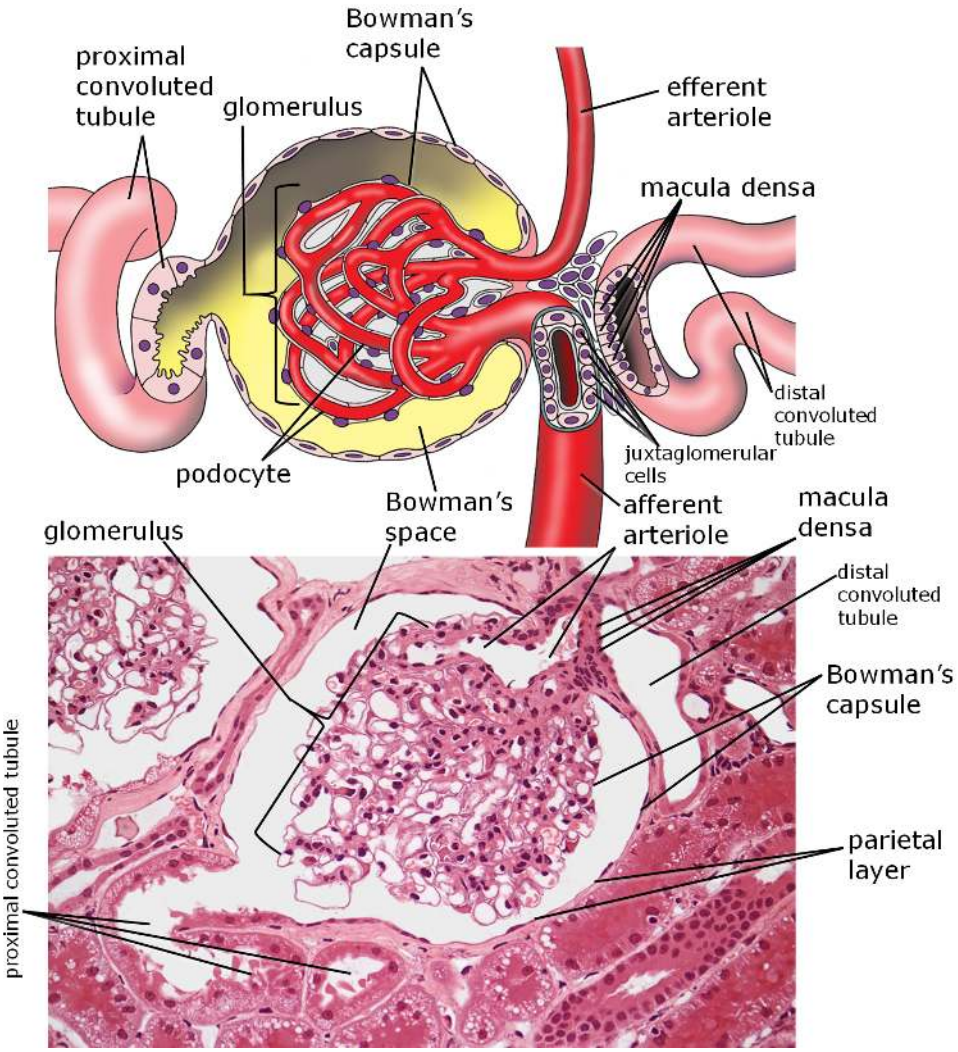
- as the filtrate moves through the proximal convoluted tubule, 60-70% of water and 100% of the organic nutrients (glucose, amino acids) are reabsorbed into the blood
- the loop of Henle conserves water and salt while concentrating the filtrate for modification by the distal convoluted tubule
- reabsorption in the distal convoluted tubule is controlled by two hormones, aldosterone and antidiuretic hormone (ADH)

3. **Secretion** - most secretion takes place in the distal convoluted tubule

Microscopic Kidney Structure	Location	Function

Microscopic Kidney Structure	Location	Function
Bowman's capsule / glomerular capsule	microscopic structure in the cortex of the kidney; part of a nephron; surrounds the glomerulus	collects the waste fluid filtered out of the glomerulus. The waste fluid then travels through a series of tubules where water and electrolytes will be reabsorbed into the body.
collecting ducts	ducts traveling through the renal cortex, to the renal medulla, and ending at the renal papilla	carries filtrate from the nephrons to the renal papilla and minor calyx; reabsorbs a small amount of water and solutes; mainly, secretes solutes from the blood into the filtrate
cortex (renal)	a region of the kidney where nephrons are mostly located	region of the kidney where blood is filtered and urine is formed; contain nephrons
glomerulus	microscopic bundle of capillaries in the cortex of the kidney; part of a nephron	high-pressure leaky capillaries create raw filtrate (fluid that will become urine); fluid and solutes are pushed out of these capillaries from the blood and into the Bowman's capsule / glomerular capsule
juxtaglomerular cells	modified in the afferent arteriole	regulates blood pressure and blood volume
macula densa	modified cells in the wall of the distal convoluted tubule located adjacent to the afferent arteriole	regulates blood pressure and blood volume
medulla (renal)	a region of the kidney between the cortex and the minor calyces	contain nephron loops of juxtamedullary nephrons; balancing water and salt concentrations in the blood
nephron	microscopic structures mostly found in the renal cortex, but some components found in the medulla; composed of kidney tubules	filters the blood to remove wastes and fluid; produces urine
peritubular capillaries	surrounding the kidney tubules of cortical nephrons and the proximal and distal convoluted tubules of juxtamedullary nephrons	the peritubular capillaries surround the loop of Henle to reabsorb water, concentrating the waste fluid.
podocyte	cells on the surface of the glomerulus	create filtration slits that aid in filtration of the blood as fluid pushes out of the glomerular capillaries into the Bowman's capsule
renal corpuscle	microscopic structures in the renal cortex; composed of the glomerulus and Bowman's capsule	filters blood to produce raw filtrate; filtrate composed of water, nitrogenous waste, and nutrients; blood cells and platelets are NOT filtered and remain in the blood
renal tubules (proximal and distal convoluted tubules; loop of Henle)	• **proximal convoluted tubule** occurs between renal corpuscle and descending limb of the nephron loop • **loop of Henle** consists of descending limb and ascending limb; occurs between the proximal convoluted tubule and the distal convoluted tubule • **distal convoluted tubule** occurs between the ascending limb of the loop of Henle and the collecting duct	modifies the filtrate through reabsorption and secretion to form urine • **proximal convoluted tubule:** the major site for reabsorption of water and solutes from the filtrate into the interstitial fluid and then into blood capillaries; reabsorb 100% of most organic solutes (amino acid, glucose, etc.); 65% of water, sodium ions, and potassium ions; and 50% of chloride ions • **descending limb of nephron loop:** the nephron loop is also called the loop of Henle; 15% of the water in the filtrate is reabsorbed by osmosis into the interstitial fluid; the descending limb is impermeable to solutes • **ascending limb of nephron loop:** reabsorbs solutes; impermeable to water • **distal convoluted tubule:** reabsorbs a small amount of water and solutes; mainly, secretes solutes from the blood into the filtrate; drains into a collecting duct

Microscopic Kidney Structure	Location	Function
vasa recta	capillaries surrounding the loop of Henle in juxtamedullary nephrons	water reabsorption from filtrate in juxtamedullary nephrons



Above: Renal corpuscles (formed by the glomerulus and Bowman's capsule) are located in the convoluted regions of the cortex and are composed of a capillary tuft, the glomerulus, surrounded by a double-walled capsule, Bowman's capsule. The space between the capsular walls, Bowman's space, receives the fluid passing through the filtration barrier. The distal convoluted tubule associated with this renal corpuscle loops back to its own vascular pole, where it lies adjacent to the afferent arteriole. Modified cells in the wall of the tubule, the macula densa, and cells in the wall of the afferent arteriole, juxtaglomerular cells, comprise the juxtaglomerular apparatus, which regulates blood pressure and blood volume. The tissue in the bottom image is magnified by 400x.

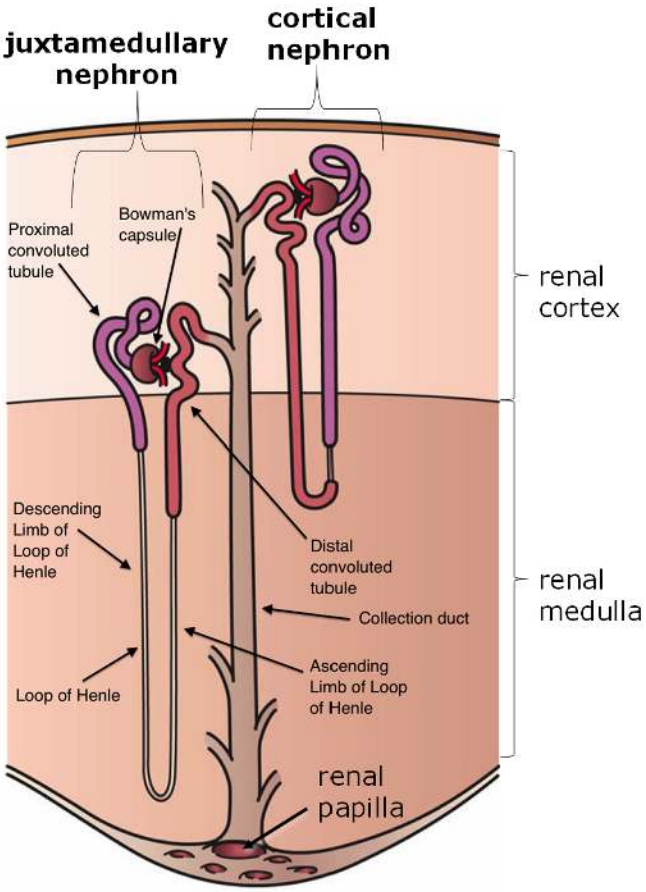
The following are the structures filtrate passes through from its creation to its passage from the kidney as urine:

1. Filtrate is created in the renal corpuscle
2. Proximal convoluted tubule
3. Descending limb of nephron loop
4. Ascending limb of nephron loop
5. Distal convoluted tubule
6. Collecting duct
7. Renal papilla
8. Minor calyx

9. Major calyx
10. Renal pelvis
11. Ureter

The following list gives the order of blood vessels that blood passes through in the cortex to reach a nephron and then to exit the renal cortex:

1. Arcuate artery
2. Cortical radiate artery
3. Afferent arteriole
4. Efferent arteriole
5. Peritubular capillaries
6. Cortical radiate vein
7. Arcuate vein



Above: Structure and position of cortical nephrons versus juxtamedullary nephrons. Note that blood vessels are not shown in this figure, only the renal corpuscles and kidney tubules.

There are two different types of nephrons: **cortical nephrons** and **juxtamedullary nephrons**. Cortical nephrons are primarily located in the cortex of the kidneys, although the nephron loops may cross into the medulla. Cortical nephrons make up about 85% of all nephrons in a kidney. Juxtamedullary nephrons are located closer to the medulla (juxta = near to) and they have longer nephron loops that are largely in the medulla and travel deep within it. Juxtamedullary nephrons make up about 15% of the nephrons in a kidney. Juxtamedullary nephrons enable a greater amount of water reabsorption by the blood from the filtrate, thereby producing more concentrated urine. Additionally, the capillaries networking around the loop of Henle in juxtamedullary nephrons are not connected to the peritubular capillaries as in the cortical nephrons and are instead associated with blood vessels of the renal medulla. As such, the capillaries surrounding the juxtamedullary nephron loop are not called peritubular capillaries and instead are called **vasa recta**.

Attributions

- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0
- "Kidney Nephron.png" by Holly Fischer is licensed under CC BY 3.0
- "Renal Anatomy" by Dongho Kim is licensed under CC BY-NC-SA 4.0

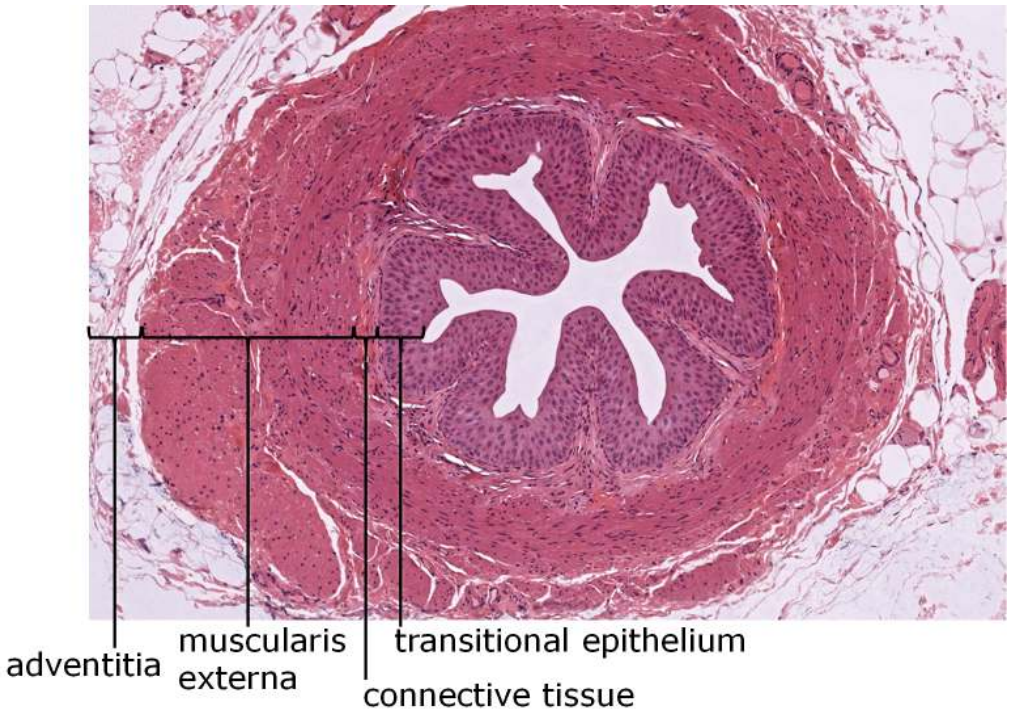
Updated 2026.

This page titled 21.3: Microscopic Structures of the Kidneys - Nephrons is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

21.4: Ureters

Ureters

The **ureters** are a pair (right and left) of narrow, long muscular tubes between the kidneys and the urinary bladder. The ureters contain smooth muscle and move urine from the kidney to the urinary bladder peristalsis.



Above: Cross section of a ureter. The ureter connects the renal pelvis with the urinary bladder. It is composed of a transitional epithelium, connective tissue layer, muscularis externa and adventitia. Tissue is magnified by 100x.

The ureter is lined by **transitional epithelium** overlying a connective tissue layer. For most of the ureter's length, the muscularis externa is divided into **inner longitudina**l and **outer circular** layers (the reverse of the digestive tract). However, near the urinary bladder, an additional outer longitudinal layer is added.

Attributions

- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0
- "Renal Anatomy" by Dongho Kim is licensed under CC BY-NC-SA 4.0

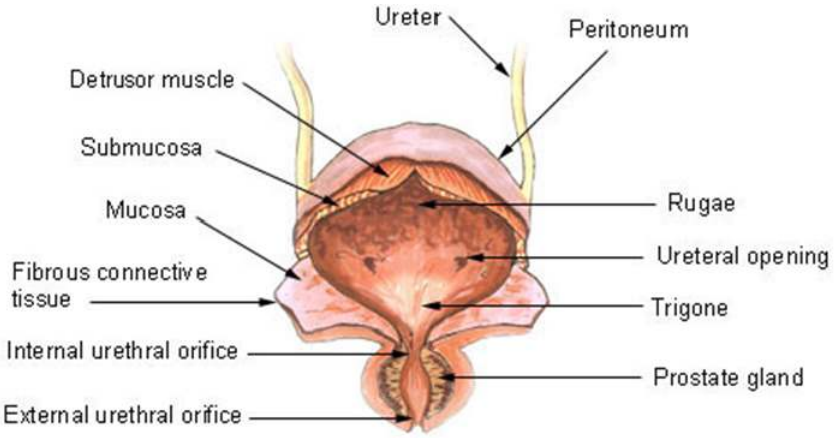
Updated 2026.

This page titled 21.4: Ureters is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

21.5: Urinary Bladder

Urinary Bladder

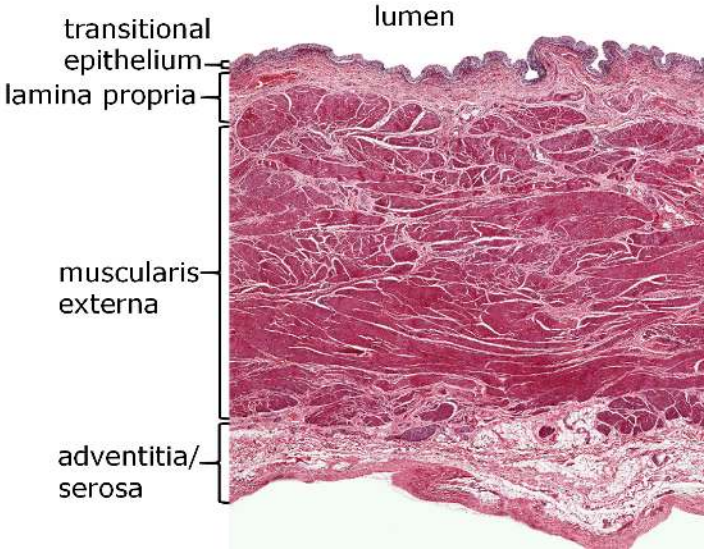
The urinary bladder stores urine until it is expelled from the body. Its inner lining is **transitional epithelium**, tissue that expands when not stretched and becomes thinner, similar to stratified squamous epithelium, when stretched. This allows the bladder to expand to provide more room for storing urine. The inner lining of the urinary bladder also has folds of tissue called **rugae** that similarly can stretch to enable the organ to expand and stretch when filled with urine.



Above: Urinary bladder in a male (females do not have a prostate gland).

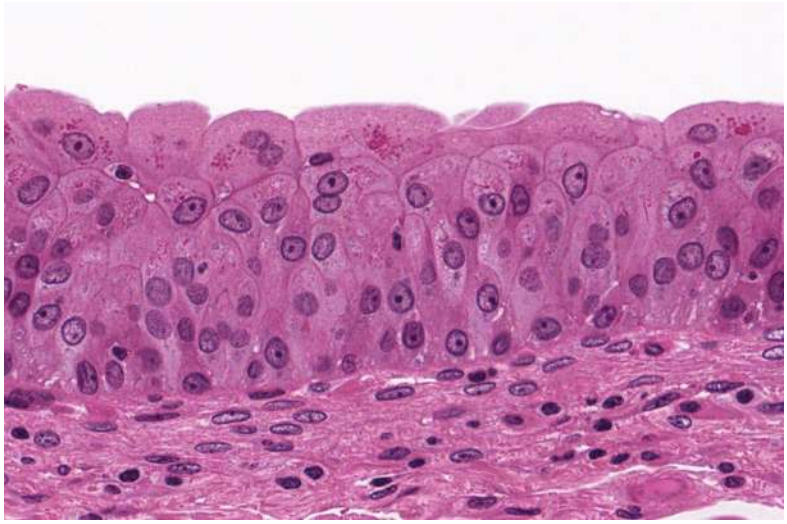
A triangular structure, called the **trigone**, is found on the posterior wall of the urinary bladder. The trigone as three openings: on the right, the right ureteral opening, on the left, the left ureteral opening, and inferiorly, the **internal urethral orifice** leading to the urethra.

Detrusor muscles are present in the walls of the bladder. When contracted, the detrusor muscle pushes urine from the urinary bladder and into the urethra to expel urine during urination.



Above: The bladder is lined by transitional epithelium. The underlying lamina is composed of a thinner, highly cellular portion adjacent to the epithelium and a thicker region of dense connective tissue closer to muscularis externa. The muscularis externa is

composed of three ill-defined layers of smooth muscle (inner and outer longitudinal and middle circular layers). An adventitia is present beyond the muscularis externa. Tissue is magnified by 100x.



Above: The mucosa of the bladder has a histologic appearance very similar to that of the ureter. Transitional epithelium has characteristic dome-shaped cells at the surface when the bladder is not distended with urine. Dome cells are often bi-nucleated and become flattened when the bladder is distended. A connective tissue layer (lamina propria continuous with submucosa) underlies this epithelium. Tissue is magnified by 400x.

Attributions

- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0
- "Illu bladder.jpg" by U.S. National Cancer Institute's Surveillance, Epidemiology and End Results (SEER) Program is in the Public Domain
- "Renal Anatomy" by Dongho Kim is licensed under CC BY-NC-SA 4.0

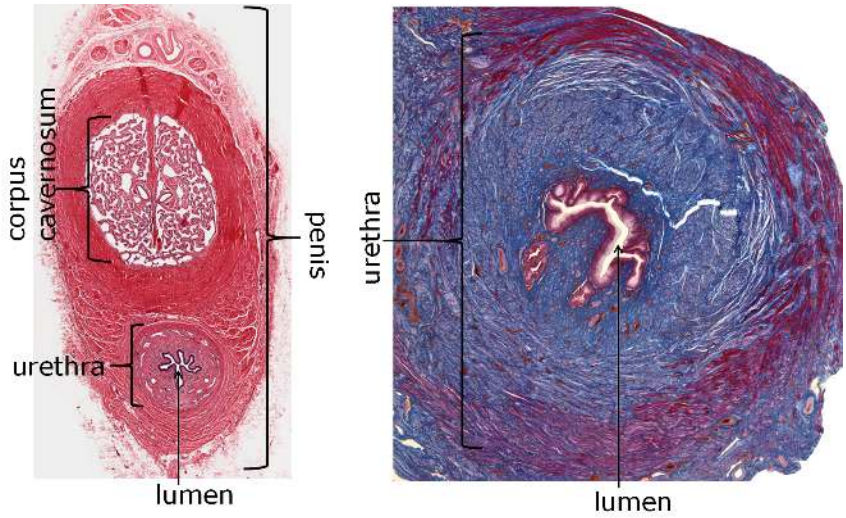
Updated 2026.

This page titled 21.5: Urinary Bladder is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

21.6: Urethra

Urethra

The urethra carries urine from the internal urethral orifice (opening of the urethra from the bladder) to the **external urethral orifice** to exit the body. There are basic differences in the lengths of the urethra between males and females with males having a longer urethra since it passes through the penis. Another difference between males and females is the types of fluid passing through the urethra. In females, the urethra is designed for urine transport only. In males however, the urethra carries urine and is also linked in with reproductive structures to carry semen (fluid containing sperm) outside of the body upon ejaculation.



Above: Cross sections of the male and female urethra, shown at two different magnifications. Male magnified by 40x and female magnified by 200x. (Left) Cross section of the penile urethra. The urethra is a fibromuscular tube that conveys urine from the bladder to the external urethra orifice. In males, the urethra is about 20 cm long and begins with the prostatic region at the neck of the bladder. Subsequent subdivisions are a short membranous urethra, which leads into the long penile (spongy) urethra. The penile urethra travels in the corpus spongiosum on the ventral side of the penis. (Right) Cross section of the female urethra. The female urethra is much shorter than in males (3-5 cm in length), and its mucosa is thrown into longitudinal folds. The transitional epithelium present as the urethra exits the bladder transitions to stratified squamous, such as seen here. The lamina propria contains a venous plexus similar to the male corpus spongiosum. In addition to two layers of smooth muscle (inner longitudinal and outer circular), an outermost layer of circular, skeletal muscle is present at the distal end.

Attributions

- "Renal Anatomy" by Dongho Kim is licensed under CC BY-NC-SA 4.0
- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0

Updated 2026.

This page titled 21.6: Urethra is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

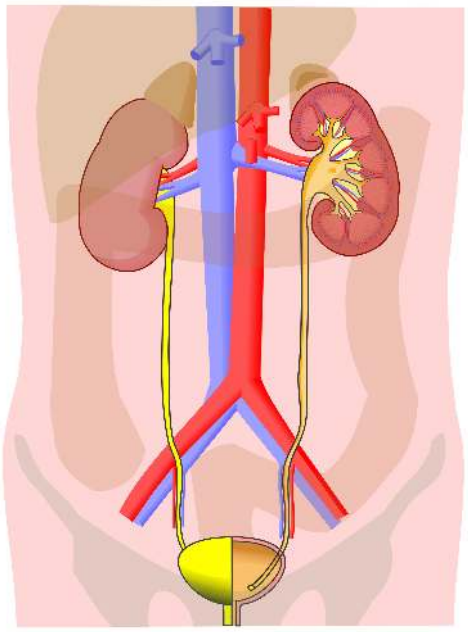
21.7: Laboratory Activities and Assignment

Laboratory Activities and Assignment

Part 1: Review of the Urinary System

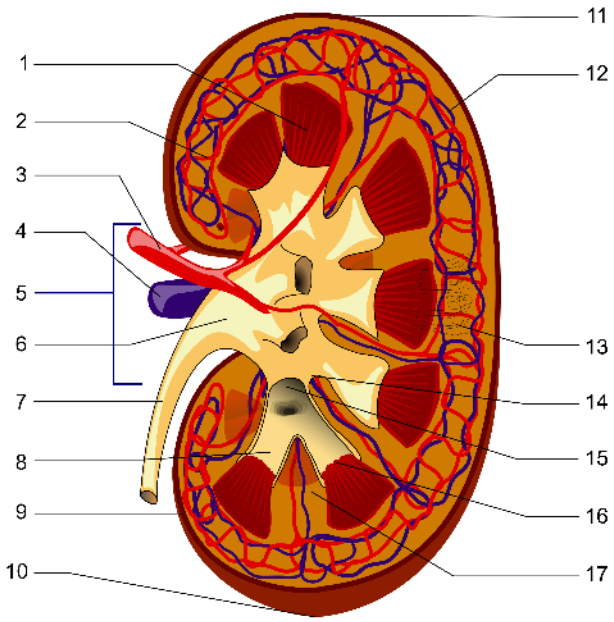
1. On the diagram below, label the following structures:

- inferior vena cava
- descending thoracic aorta
- external urethral orifice
- internal urethral orifice
- left adrenal gland
- left kidney
- left ureter
- major calyx
- minor calyx
- right adrenal gland
- right kidney
- right ureter
- renal artery
- renal pelvis
- renal vein
- urethra
- urinary bladder



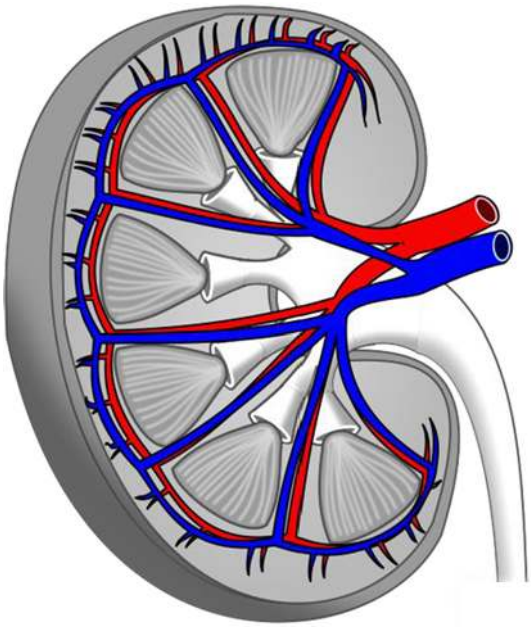
2. On the diagram below, match the numbers on the diagram with the following structures (not all numbers will be used):

____ fibrous capsule
____ hilum
____ location of adrenal gland (not shown)
____ major calyx
____ minor calyx
____ nephrons
____ papilla
____ pyramid
____ renal artery
____ renal column
____ renal pelvis
____ renal vein
____ ureter



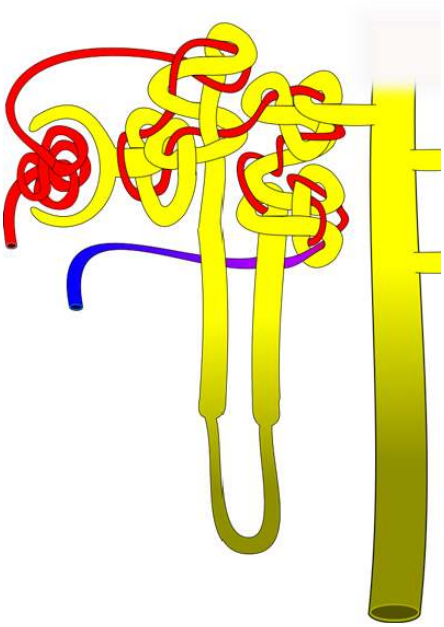
3. On the diagram below, label the following structures:

• arcuate artery • arcuate vein • fibrous capsule • interlobar artery	• interlobar vein • location(s) of nephrons • renal artery • renal cortex	• renal medulla • renal vein • segmental artery

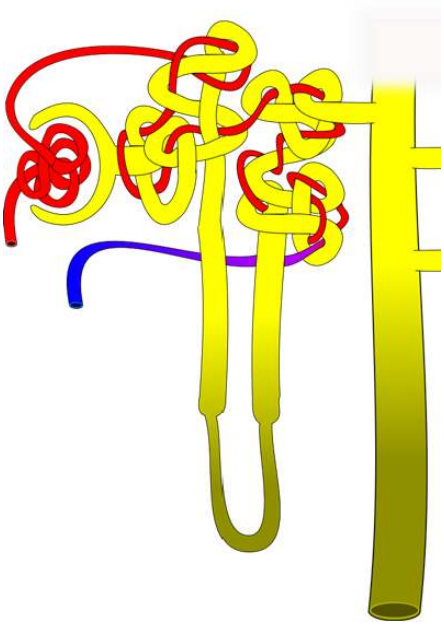


4. On the diagram below, label the following structures:

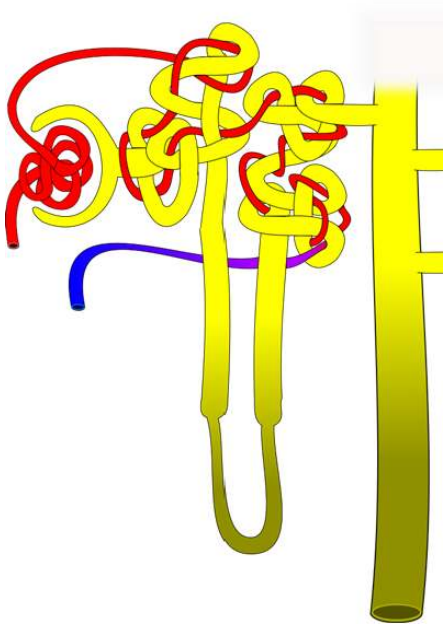
• afferent arteriole • ascending limb of nephron loop • Bowman's capsule • collecting duct	• cortical radiate artery • cortical radiate vein • descending limb of nephron loop • distal convoluted tubule	• efferent arteriole • glomerulus • peritubular capillaries • proximal convoluted tubule



5. On the diagram below, number the path of filtrate through the nephron, beginning with the location where it is created (#1) and follow its path as it becomes urine and is transported toward the ureter (you will have 6-8 steps total, depending on how you label the figure).

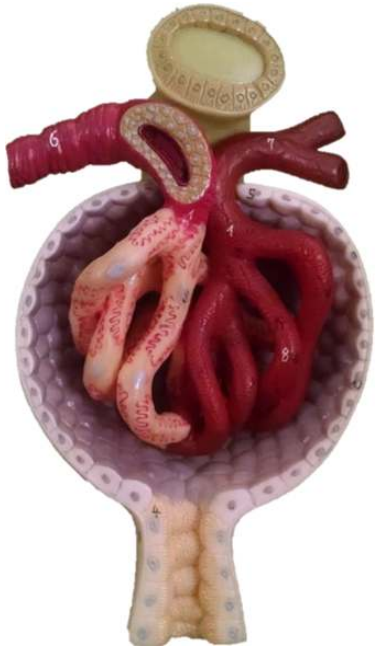


6. On the diagram below, number the path of blood through the nephron, beginning with the blood vessel bringing blood to the nephron (#1) and follow its path until it exits the nephron and moves back toward the heart (you should have 6 steps total and include cortical radiate blood vessels).



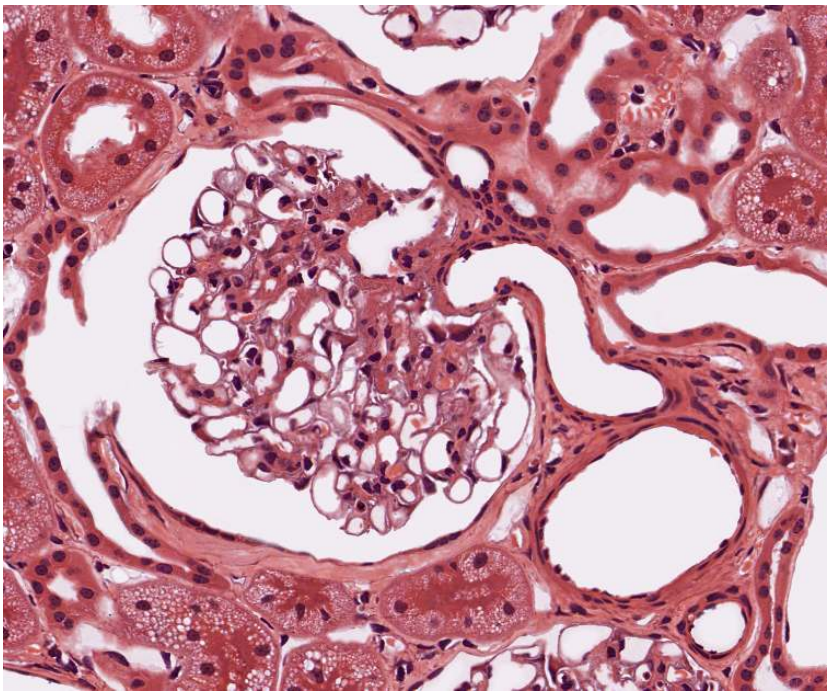
7. On the diagram below, label the following structures:

• afferent arteriole • Bowman's capsule • Bowman's space • distal convoluted tubule	• efferent arteriole • glomerulus • juxtaglomerular cells • macula densa	• parietal layer • podocyte • proximal convoluted tubule • renal corpuscle



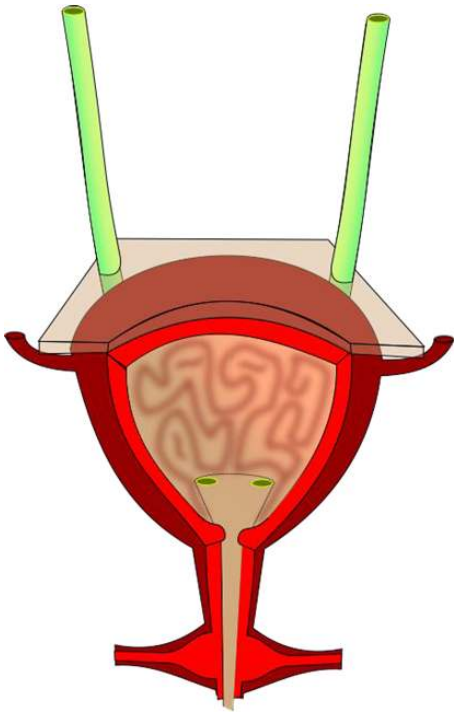
8. On the microscopic image of cortical tissue of the kidney, label the following structures:

• afferent arteriole • Bowman's capsule • Bowman's space • efferent arteriole	• glomerulus • distal convoluted tubule • macula densa • parietal layer	• podocyte • proximal convoluted tubule • renal corpuscle



9. On the diagram below, label the following structures:

• detrusor muscle • external urethral opening • internal urethral opening • left ureter	• left ureteral opening • peritoneum • right ureter • right ureteral opening	• rugae • trigone • urethra

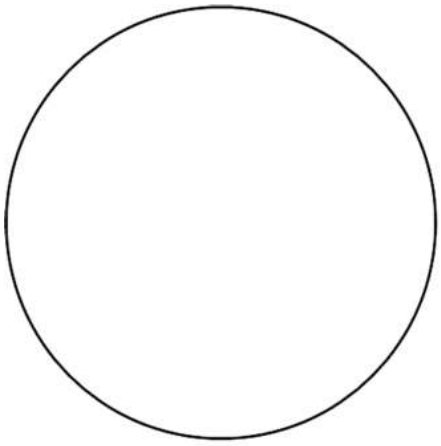


Part 2: Histology of the Urinary System

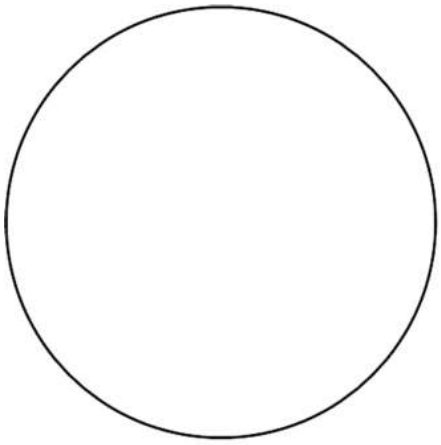
Kidney

Make one illustration at a low magnification and another at a higher magnification to view structures of the nephron.

Label the tissue with: cortex, medulla, renal column, pyramid, glomerulus, Bowman's capsule, Bowman's space, parietal layer, podocytes, afferent arteriole, efferent arteriole, macula densa, juxtaglomerular cells (if possible), proximal convoluted tubule, distal convoluted tubule, simple cuboidal epithelium lining kidney tubules



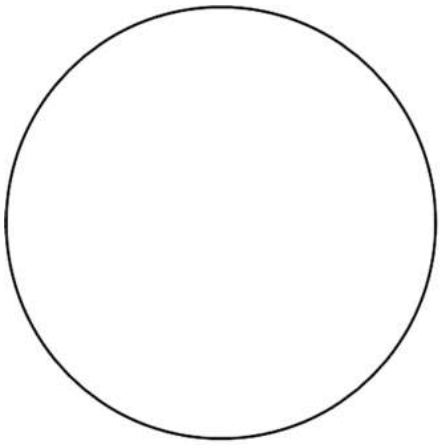
Total magnification: _____



Total magnification: _____

Ureter

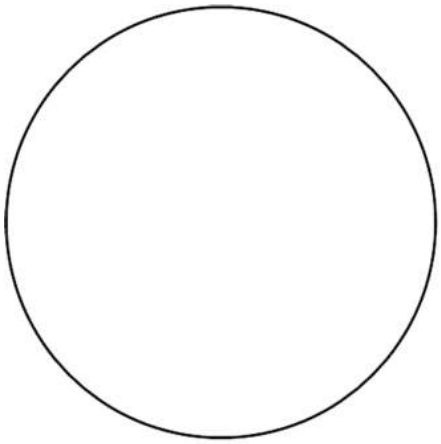
Label the tissue with: lumen, transitional epithelium, connective tissue, muscularis externa, adventitia



Total magnification: _____

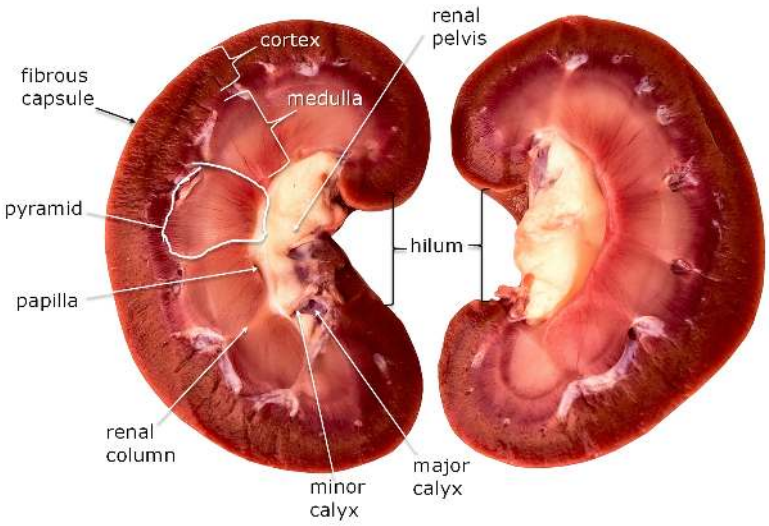
Urinary Bladder

Label the tissue with: lumen, transitional epithelium, lamina propria, muscularis externa, adventitia/serosa



Total magnification: _____

Part 3: Sheep Kidney Dissection



Above: Dissected sheep kidney (frontal section).

1. Collect a dissection tray, scalpel, scissors, probes, and gloves.
2. Obtain a preserved cow eye and place it on your dissection tray.
3. Identify the renal hilum. What three prominent structures enter/exit the kidney at the renal hilum? _____, _____, & _____
4. Carefully slide the scalpel from the lateral aspect of the kidney to the medial aspect of the kidney to create a frontal section of the kidney, separating anterior and posterior. **DO NOT** make sawing motions with the scalpel. If the scalpel is sharp enough for the dissection, it should slide across the tissue without sawing.
5. Identify the following structures on your dissected kidney. Illustration and label the dissected kidney in the space below. Alternatively you can take a photo and label the photo of your dissected kidney.

- cortex
- fibrous capsule
- hilum
- major calyx
- medulla
- minor calyx
- papilla
- pyramid
- renal artery (if present)
- renal column
- renal pelvis
- renal vein (if present)
- ureter (if present)

Part 4: Urinary System Laboratory Activities

Labeling Models

1. Use the anatomical models provided to your group in your group.
2. As a group, identify the structures listed below.
3. Write each of the following structures on masking tape or labeling tape (with correct spelling) and stick onto the model to label each structure.

- adipose capsule
- afferent arteriole
- arcuate artery
- arcuate vein
- ascending loop of Henle
- Bowman's capsule
- Bowman's space
- collecting duct
- cortical nephron
- cortical radiate artery
- cortical radiate vein
- descending loop of Henle
- detrusor muscle
- distal convoluted tubule
- efferent arteriole
- external urethral orifice
- external urethral sphincter
- glomerular capillaries
- glomerulus
- interlobar artery
- interlobar vein
- internal urethral orifice
- internal urethral sphincter
- juxtamedullary cells
- juxtamedullary nephron
- left ureter
- peritubular capillaries
- podocytes
- proximal convoluted tubule
- renal artery
- macula densa
- major calyx
- minor calyx
- renal column
- renal corpuscle
- renal cortex
- renal fascia
- renal hilum
- renal papilla
- renal pelvis
- renal pyramid
- renal medulla
- right ureter
- renal vein
- rugae (bladder)
- segmental artery
- urethra
- urinary bladder
- urinary trigone
- vasa recta

4. Ask your instructor to verify the labeling is correct.

Instructor Signature Confirming Correct Labeling: _____

5. Take a photo of your anatomical model for future reference for studying.

Filtrate Path and Blood Flow Path through Kidney

1. As a group, determine the route of filtrate/urine through the various ducts of the kidney on an anatomical model, originating at the glomerulus and ending with the urethra. Be sure to identify where along that path each of the structures on the vocabulary list are located.

2. Write sequential numbers on masking tape or labeling tape to show the sequence of filtrate/urine movement and attach to an anatomical model.

3. As a group, on an anatomical model, determine the course of blood through the blood vessels from the heart, to the kidney, through the kidney, and back to the heart.

4. Using a different color tape or a different color marker than step 2, write sequential numbers on masking tape or labeling tape and adhere to an anatomical model to show the sequence of blood flow from the heart, into and through the kidney, and back to the heart.

5. Ask your instructor to verify the labeling is correct.

Instructor Signature Confirming Correct Labeling: _____

6. Take a photo of your anatomical model for future reference for studying.

Attributions

Part 1: Review of the Urinary System

- "Anatomy and Physiology Lab Homework" by Laird C Sheldahl is licensed under CC BY-SA 4.0
- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0
- "KidneyStructures PioM.svg" by Piotr Michał Jaworski is licensed under CC BY-SA 3.0
- "Urinary System Large Unlabeled.jpg" by Andrewmeyerson is licensed under CC BY-SA 3.0

Part 2: Histology of the Urinary System

- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0

Part 3: Sheep Kidney Dissection

- "Human Anatomy Lab Manual" by Malgosia Wilk-Blaszczak, Mavs Open Press, University of Texas at Arlington is licensed under CC BY 4.0

Part 4: Urinary System Laboratory Activities

- "Human Anatomy Lab Manual" by Malgosia Wilk-Blaszczak, Mavs Open Press, University of Texas at Arlington is licensed under CC BY 4.0
- "Kidney of lamb 6.jpg" by Jurfeld is licensed under CC BY 4.0

Updated 2026.

This page titled 21.7: Laboratory Activities and Assignment is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

21.8: Collaborative Study Activities

Collaborative Study Activities

This activity is designed for student groups of 2-4. Larger groups will work better when there is no supplemental instructor present in the laboratory to assist in testing student groups on each section.

Urinary System Anatomy

1. Identify the following structures on classroom anatomical models and/or unlabeled images/diagrams made available by your instructor. Work with your group to identify each structure and check them off the list once you have identified them.

☐ aorta	☐ internal urethral orifice	☐ right renal vein
☐ arcuate artery	☐ internal urethral sphincter	☐ right ureter
☐ arcuate vein	☐ left kidney	☐ renal column
☐ cortical radiate artery	☐ left renal artery	☐ renal cortex
☐ cortical radiate vein	☐ left renal vein	☐ renal medulla
☐ detrusor muscle	☐ left ureter	☐ renal pelvis
☐ external urethral orifice	☐ major calyx	☐ renal pyramid (of medulla)
☐ external urethral sphincter	☐ minor calyx	☐ rugae (of bladder)
☐ inferior vena cava	☐ renal hilum	☐ urethra
☐ interlobular artery	☐ right kidney	☐ urinary bladder
☐ interlobular vein	☐ right renal artery	

2. Test your group members by ***asking them to name each structure you point to***. Check off each when your group can successfully name each. Your group will also test you.

☐ aorta	☐ internal urethral orifice	☐ right renal vein
☐ arcuate artery	☐ internal urethral sphincter	☐ right ureter
☐ arcuate vein	☐ left kidney	☐ renal column
☐ cortical radiate artery	☐ left renal artery	☐ renal cortex
☐ cortical radiate vein	☐ left renal vein	☐ renal medulla
☐ detrusor muscle	☐ left ureter	☐ renal pelvis
☐ external urethral orifice	☐ major calyx	☐ renal pyramid (of medulla)
☐ external urethral sphincter	☐ minor calyx	☐ rugae (of bladder)
☐ inferior vena cava	☐ renal hilum	☐ urethra
☐ interlobular artery	☐ right kidney	☐ urinary bladder
☐ interlobular vein	☐ right renal artery	

3. When you and your group are comfortable identifying all the structures above, request the assistance of your Instructor. They will test you on your use of these terms and initial ONLY when you are successful using these terms. Instructor: _____

Nephron Anatomy

1. Identify the following structures on classroom anatomical models and/or unlabeled images/diagrams made available by your instructor. Work with your group to identify each structure and check them off the list once you have identified them.

☐ afferent arteriole	☐ descending limb of loop of Henle	☐ parietal layer
☐ ascending limb of loop of Henle	☐ distal convoluted tubule	☐ peritubular capillaries
☐ Bowman's capsule	☐ efferent arteriole	☐ podocytes
☐ Bowman's space	☐ glomerular capillaries	☐ proximal convoluted tubule
☐ collecting duct	☐ glomerulus	☐ renal corpuscle
☐ cortex-medulla junction	☐ juxtamedullary nephron	☐ renal cortex
☐ cortical nephron	☐ juxtamedullary cells	☐ renal medulla
☐ cortical radiate artery	☐ macula densa	☐ vasa recta
☐ cortical radiate vein		

2. Test your group members by ***asking them to name each structure you point to***. Check off each when your group can successfully name each. Your group will also test you.

☐ afferent arteriole	☐ descending limb of loop of Henle	☐ parietal layer
☐ ascending limb of loop of Henle	☐ distal convoluted tubule	☐ peritubular capillaries
☐ Bowman's capsule	☐ efferent arteriole	☐ podocytes
☐ Bowman's space	☐ glomerular capillaries	☐ proximal convoluted tubule
☐ collecting duct	☐ glomerulus	☐ renal corpuscle
☐ cortex-medulla junction	☐ juxtamedullary nephron	☐ renal cortex
☐ cortical nephron	☐ juxtamedullary cells	☐ renal medulla
☐ cortical radiate artery	☐ macula densa	☐ vasa recta
☐ cortical radiate vein		

3. When you and your group are comfortable identifying all the structures above, request the assistance of your Instructor. They will test you on your use of these terms and initial ONLY when you are successful using these terms. Instructor: _____

Updated 2026.

This page titled 21.8: Collaborative Study Activities is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

CHAPTER OVERVIEW

22: Reproductive Systems

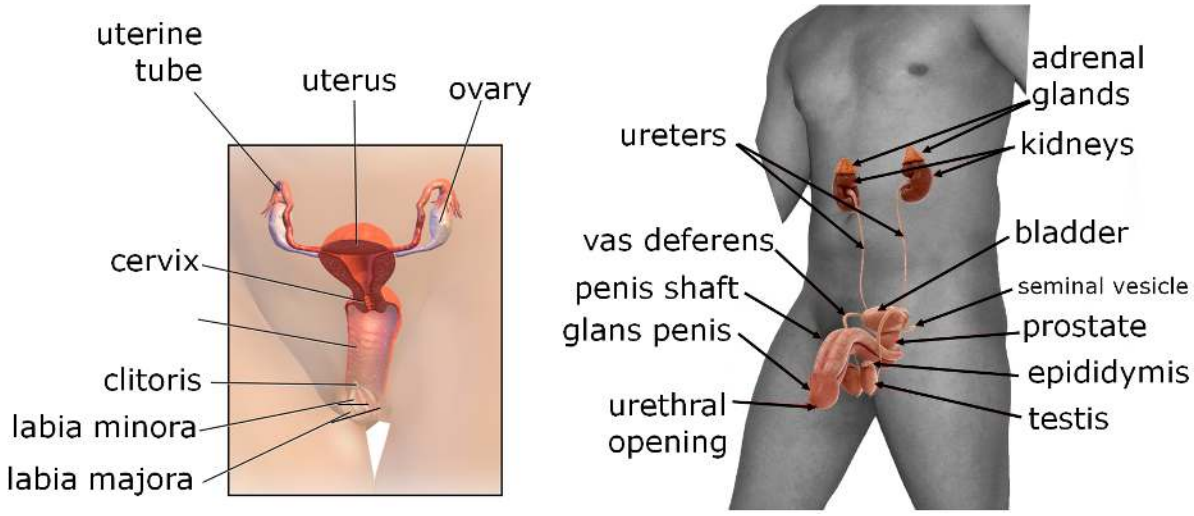
22.1: Introduction
22.2: Female Reproductive System (Internal)
22.3: Female Reproductive System (External)
22.4: Male Reproductive System
22.5: Laboratory Activities and Assignment
22.6: Collaborative Study Activities

This page titled 22: Reproductive Systems is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

22.1: Introduction

Introduction

The reproductive system is designed to propagate the human species (make more humans) and therefore has two primary functions: the production of **gametes** (egg and sperm cells) and the production of **sex hormones**. Male gametes are referred to as **spermatozoa** (aka sperm), whereas female gametes are called **ova** (aka egg). Reproduction is very metabolically taxing especially for the female. The role of the male reproductive system is to produce spermatozoa and transfer them to the female reproductive tract. Although they originate from similar primordial tissues, the female and male reproductive systems differ in gonad type, ducts, accessory glands, and external genitalia. Male gonads are the **testes** while the female gonads are the **ovaries**; both are the sites of their respective **gametogenesis** (production of the gametes, i.e. spermatozoa production and ova production). The hormones produced by the gonads are crucial to the reproductive system and sexual development, including primary and secondary sexual development, tissue regeneration, and production of gametes.



Above: Overview of the anatomy of the (left) female and (right) male reproductive system. Note that the male diagram also shows the kidneys, ureters, bladder, and adrenal glands, which are not part of the reproductive system.

Reproductive anatomy remains undefined in a developing fetus until at some point of gestation, the fetus will develop both Wolffian and Müllerian ducts, the basic structures of both the male and female reproductive systems. As a result, there are several elements of the male and female reproductive systems which are **homologous** (structurally related to each other and derived from the same type of fetal tissues). Such structures share developmental and evolutionary origins but are not necessarily similar in function. The following are the homologous structures of the male and female reproductive system:

Female homologous structure	Male homologous structure
ovary	testis
labia major	scrotum
labia minora	shaft of the penis
clitoris	glans penis
prepuce (aka clitoral hood)	prepuce (aka foreskin)
paraurethral gland	prostate gland
greater vestibular gland	bulbourethral gland

Humans have variation in their anatomies. While this is true for a variety of anatomical structures, it is also true for the reproductive system. This chapter will explore human anatomy defined as "male reproductive anatomy" and "female reproductive anatomy" as traditionally defined in educational and clinical settings, however, reproductive anatomies vary. For example, some people are born (1 in every 2,000-4,500 births) with a variation of sex characteristics that do not fully fit the traditional definitions of "male" or "female" reproductive anatomies (**intersex people**). There are also people (1.6%-5% of adults) who identify as a gender different from what they were assigned at birth (**transgender people** including **nonbinary people**). Not all individuals' anatomies will fit into the traditional definitions of "male reproductive anatomy" and "female reproductive anatomy" categories.

Attributions

- "Human Anatomy Lab Manual" by Malgosia Wilk-Blaszczak, Mavs Open Press, University of Texas at Arlington is licensed under CC BY 4.0
- "Human Urinary and reproductive system (Labelled).jpg" by Baresh25 is licensed under CC BY-SA 4.0
- "Medical gallery of Blausen Medical 2014" by Blausen.com staff is licensed under CC BY 3.0

Updated 2026.

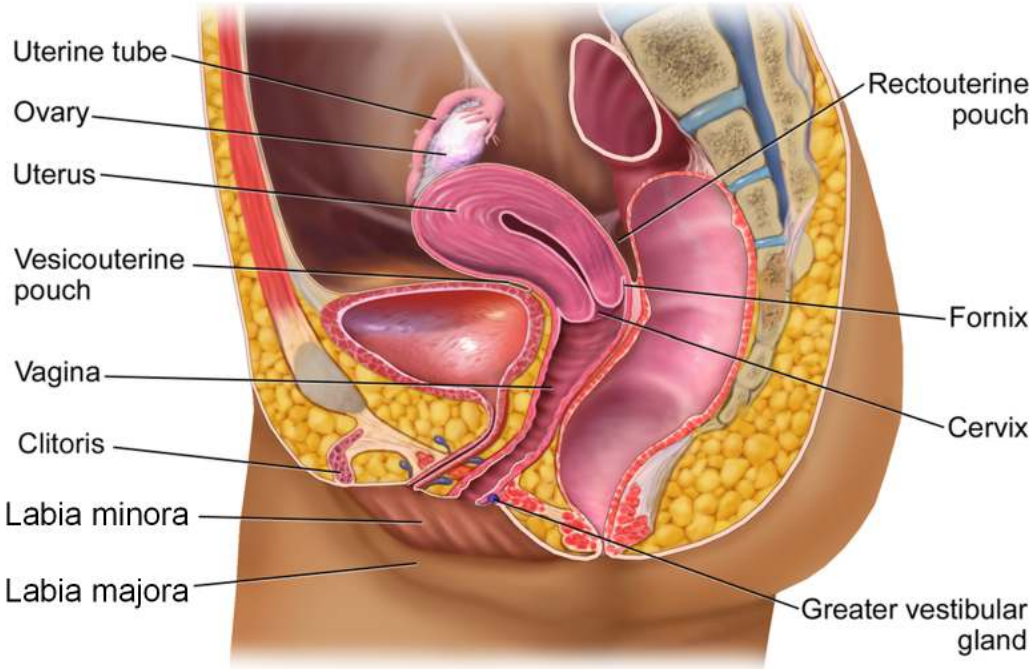
This page titled 22.1: Introduction is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

22.2: Female Reproductive System (Internal)

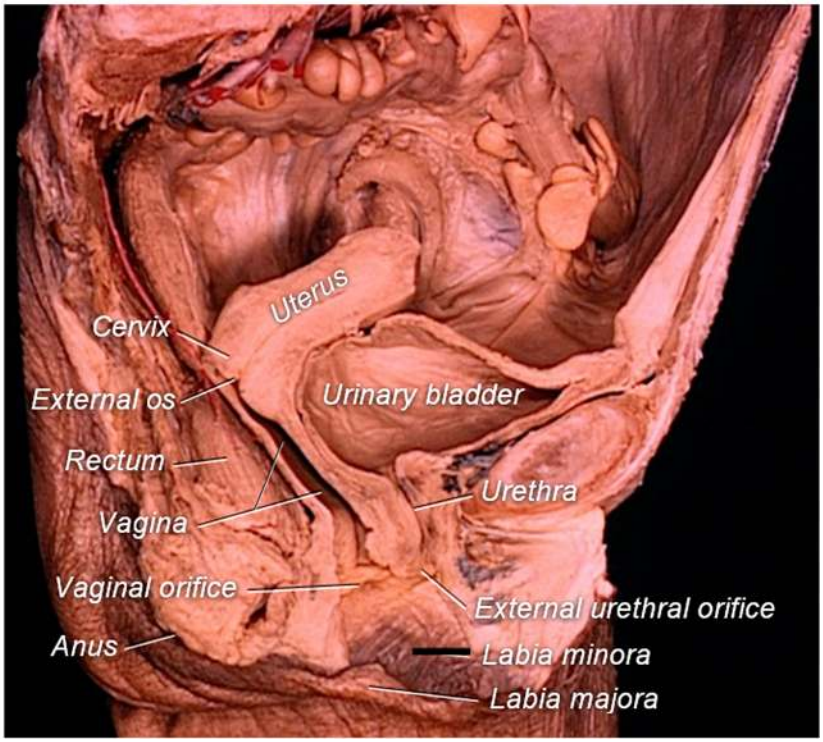
Female Reproductive System (Internal)

Internal Female Genitalia

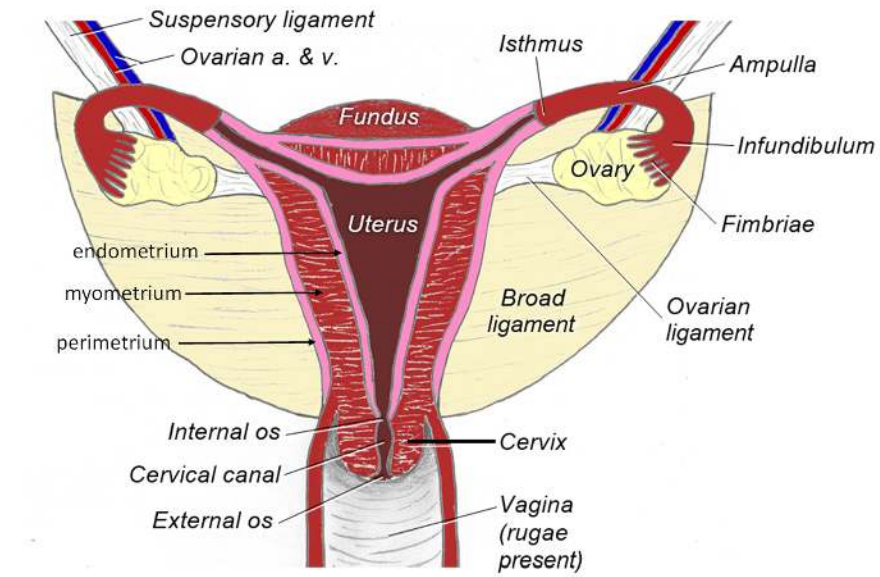
The female reproductive system includes both internal and external organs. Collectively these organs function to produce female gametes (ova), receive male gametes (spermatozoa), transport the female gametes, provide a location for fertilization to occur, protect and nourish a developing embryo, and deliver a child.

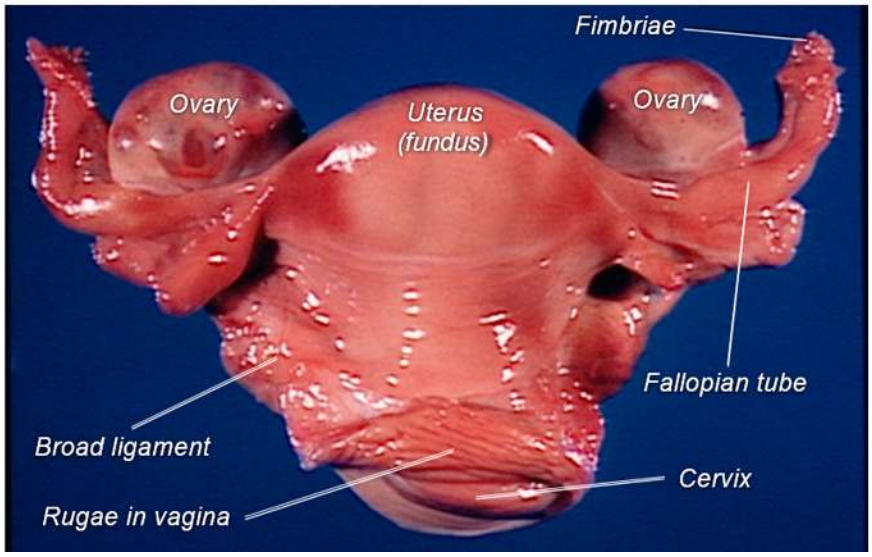


Above: Lateral view of the left side of a female pelvic cavity with the body wall open and organs shown with sagittal sections.



Above: Cadaver image of internal female genitalia, lateral view of the right side with body wall open and pelvic organs with sagittal sections.

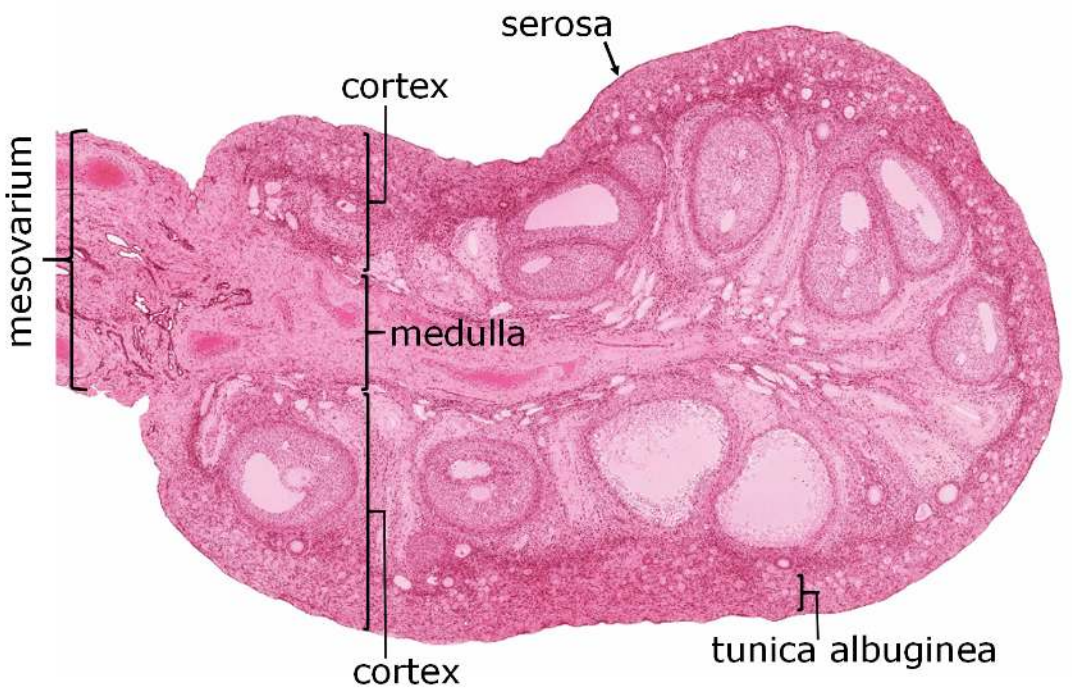




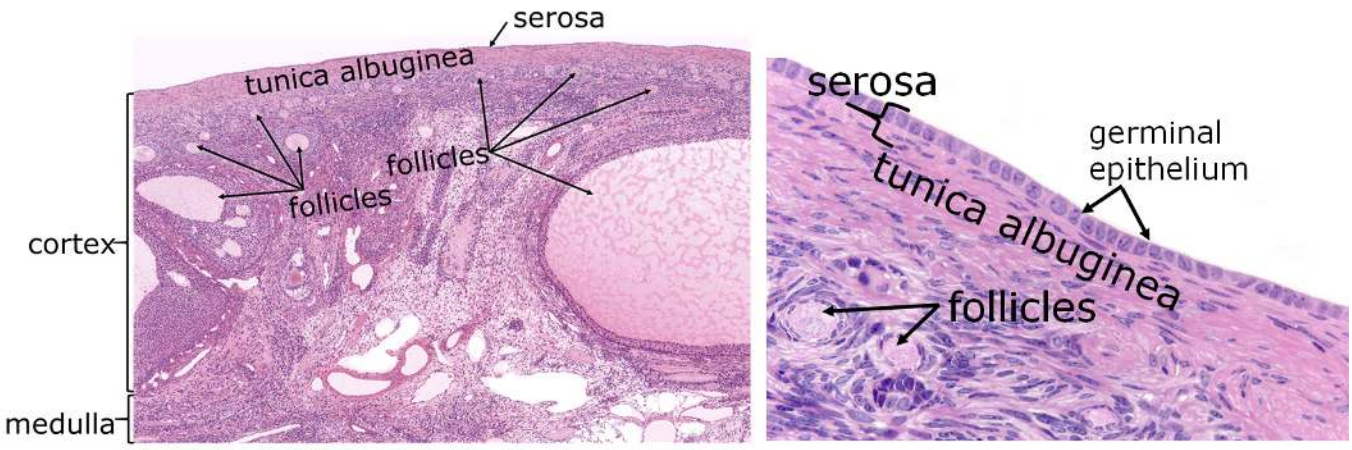
Above: Anterior view of internal female reproductive anatomy.

Each ovary is both an exocrine (production of **oocytes**, immature ova) and an endocrine (production of estrogen and progesterone) organ. The gland can be divided into an outer **cortex** and inner **medulla**.

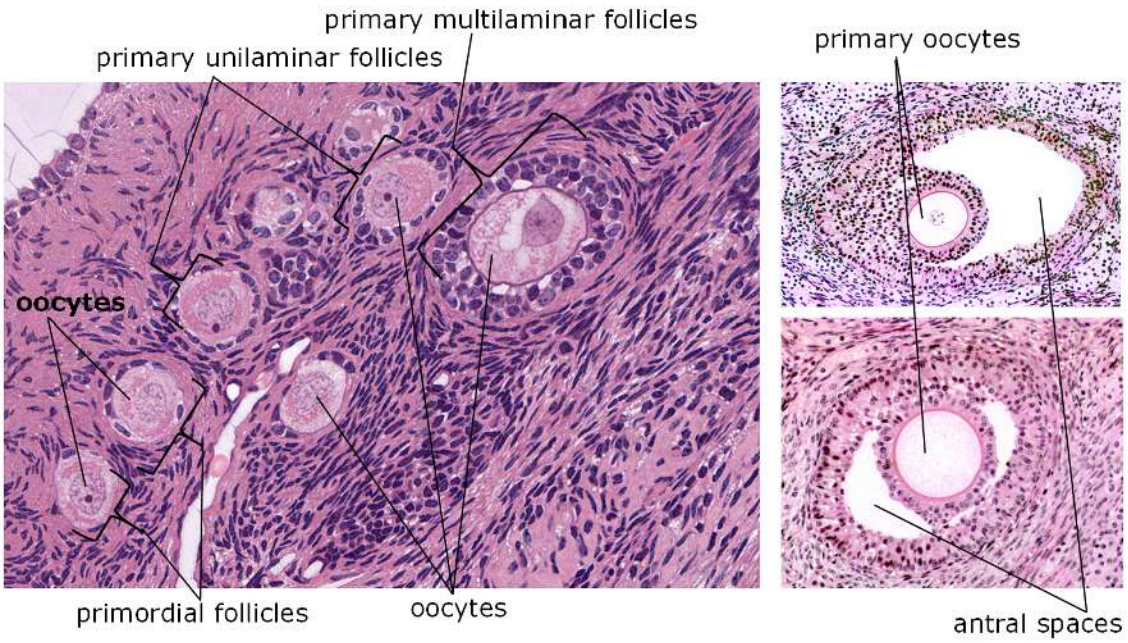
The cortex forms the outer zone of the ovary. The cortex contains **follicles**, the **corpus luteum**, and the degenerating elements of these two structures, **atretic follicles** and **corpora albicantia** (sing. **corpus albicans**), respectively. Follicles are epithelial structures that house developing oocytes, the germ cells. **Primordial follicles** are the smallest follicles, with their follicular cells forming a simple squamous layer surrounding the oocyte. A **primary oocyte** is housed within each follicle. Primary oocytes can undergo the process of **oogenesis** (meiotic division process) to become ova.



Above: Thin section of an ovary, magnified by 10x.



Above: (Left) Thin section of an ovary, magnified by 40x. Small follicles are clustered beneath the tunica albuginea, while larger follicles are located deeper in the cortex. (Right) The ovary is covered by a serosa of epithelium overlying a thin connective tissue layer. However, rather than the expected simple squamous epithelium, the epithelium of this serosa is simple cuboidal and is called by the misnomer **germinal epithelium**. A dense connective tissue layer, tunica albuginea, lies beneath the serosa. Small follicles are located in the cortex beneath the tunica albuginea. Tissue is magnified by 400x.

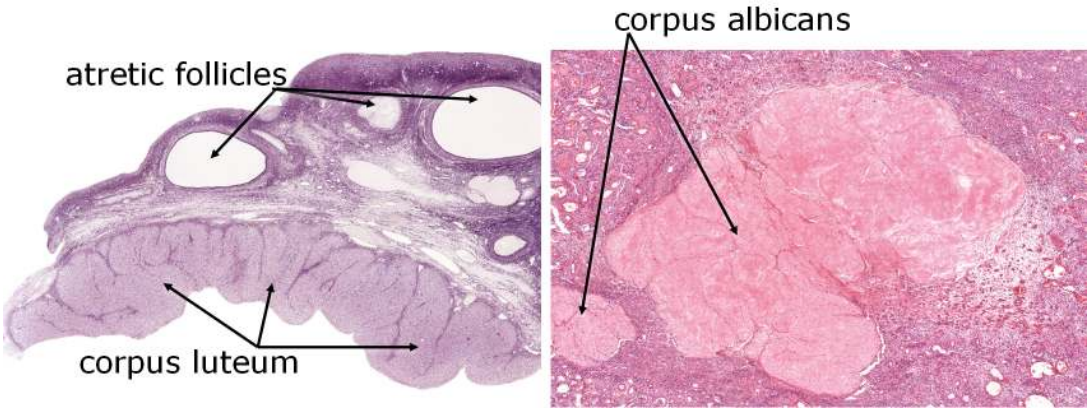


Above: (Left) Primordial follicles are the smallest follicles, with their follicular cells forming a simple squamous layer. A primary oocyte is housed within each follicle. Primary unilaminar follicles are larger than primordial follicles; their follicular cells have increased in height to form a simple cuboidal or columnar epithelium. The primary oocyte has also increased in size from that present in the primordial follicle. Follicular cells continue to increase in volume and number, becoming a stratified epithelial layer and forming a primary multilaminar follicle. Each primordial and primary follicle contains a primary oocyte. Each oocyte increases in diameter as the follicular cells increase in size and number. Tissue is magnified by 400x. (Right) Secondary follicles form as **antral fluid** accumulates in spaces among the proliferating follicle (granulosal) cells. (Right bottom) Tissue is magnified by 200x. (Right top) The primary oocyte remains arrested in prophase of the first meiotic division. It is surrounded by a ring of granulosal cells (the cumulus oophorus) and protrudes into the antral space. Tissue is magnified by 400x.

Atretic follicles are the degenerating remains of follicles. Approximately two million primordial follicles, containing primary oocytes, are present at birth, but only 400-450 secondary oocytes are ovulated from Graafian follicles during the reproductive life of a woman; the remaining follicles undergo **atresia**. The process of atresia can occur at all stages of follicular development.

An ovum is released from a follicle during the process of **ovulation** (usually one ovum is released every approximately 28 days during reproductive years). The now empty follicle becomes a corpus luteum. The corpus luteum actively secretes progesterone and estrogen from day 15 to day 26 of the menstrual cycle.

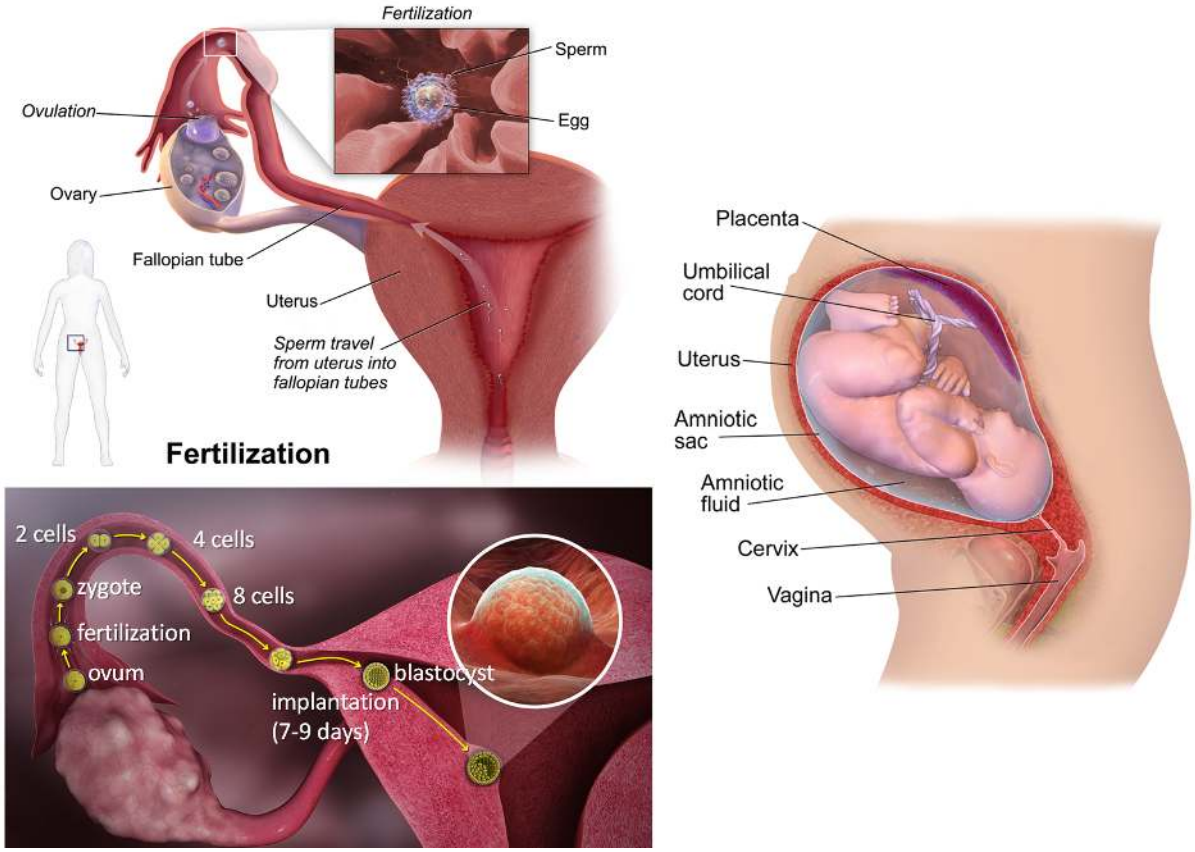
The medulla occupies the center of the ovary and is composed of connective tissue containing blood vessels, lymphatic vessels, and nerves that supply the ovary. The exterior of the ovary is covered by a serosa with a simple cuboidal epithelium (mesothelium) overlying a band of dense connective tissue, the **tunica albuginea**. The ovary is suspended from the **broad ligament** of the uterus by the **mesovarium**, through which blood vessels enter and leave the ovary.



Above: (Left) The **corpus luteum** is present and actively secreting progesterone and estrogen from days 15-26 of the menstrual cycle. A portion of a corpus luteum extends across the bottom of this image of the ovary. This portion of the corpus luteum represents approximately 25-30% of its total volume. Tissue is magnified by 10x. (Right) A **corpus albicans** is the scar tissue remains of the corpus luteum; its size decreases with age. The corpus albicans is composed of inactive fibroblasts and scar tissue, which gives the corpus albicans its distinctive white appearance in fresh tissue and eosinophilic staining in typical slide preparations. Tissue is magnified by 100x.

Structure	Location	Function
broad ligament	flat sheet of peritoneum covering internal genitalia anteriorly and posteriorly	provides support for internal genitalia, holding the organs in place
cervix	"neck" between the vagina and the uterus; cervical canal provides passage into the uterus	passage for menstrual fluid to exit the uterus; passage of spermatozoa into the uterus; expands for childbirth
endometrium	inner lining of the uterus; two layers	tissue builds up to prepare for embryo implantation; supports development of an embryo/fetus; built up tissue sheds during menstruation
fimbriae	finger-like projections of the uterine tube extending toward the ovaries	"wave" the egg down the uterine tubes toward the uterus
myometrium	Middle tissue layer of the uterus	three layers of smooth muscle; responsible for labor contractions during childbirth
ovarian ligament	pair of ligaments (right and left) between the ovaries and the uterus	attaches the ovaries to the uterus
ovaries	paired organs with passageways to the uterus by way of uterine tubes; suspended by suspensory ligament and attached to the uterus by ovarian ligament	primary reproductive organ; produces hormones (estrogen and progesterone), storage and development of ova
perimetrium	outer tissue layer of the uterus	continuous with the visceral peritoneum (serosa)
suspensory ligament	pair of ligaments (right and left) between the ovaries and the pelvic wall	supports and holds ovaries in place
urethra	tube between the urinary bladder and the external urethral orifice	removal of urine

Structure	Location	Function
uterine tube (fallopian tube)	pair (right and left) of tubes between the uterus and the ovaries; three parts: infundibulum (expansion near ovary, ciliated epithelium moves ova down the tube), ampulla (widened area of tube; where fertilization usually occurs), isthmus (last point of tube; narrow; connects to uterus)	transport of ova and developing embryo to the uterus; site of fertilization; passage for spermatozoa to ova; embryo can implant in uterine tube - called **ectopic pregnancy** (dangerous condition; endangers mother's life)
uterus	organ located between the bladder and the rectum; dome-shaped **fundus**; main region called the **body**	implantation of embryo; development of placenta; fetal development; muscular contractions result in childbirth; buildup and shedding of endometrial lining results in menstruation
vagina	passage from external genitalia to the cervix; lined with stratified squamous epithelium; walls have rugae for stretch/expansion	copulation, childbirth, passageway for menstruation



Above: (Top left) Path of sperm and location of fertilization are shown. (Bottom left) Diagram show the events occurring following fertilization to implantation of the embryo in the uterus. (Right) Internal female genitalia during pregnancy. A specialized organ, the placenta, forms during pregnancy to facilitate transfer of nutrients and waste to and from, respectively, the fetus. The expansion of the uterus during pregnancy causes the other abdominal organs to shift. Vaginal childbirth necessitates passage of the of the fetus through the cervix and vagina.

Fertilization requires spermatozoa to travel through the uterus and to the uterine tube (aka fallopian tube) to reach an ovum (if present). If an ovum is present and spermatozoa are present, a single sperm cell can break through outer layers of the ovum to fertilize it producing a **zygote** (fertilized ovum). Fertilization occurs in the uterine tube. A zygote begins dividing as it travels

through the uterine tube to the uterus. By the time it reaches the uterus, it is a ball of cells called a **blastocyst**. Implantation of the embryo in the endometrium of the uterus typically occurs 7 to 9 days after fertilization.

Clinical Application: Menstruation

Ova are released from ovaries with the intent for possible fertilization. If a released ovum is not fertilized, the ovum will exit through the vagina and the inner lining of the uterus will be flushed out. This process is called **menstruation** and occurs about every 28 days. At the beginning of the menstrual cycle, the inner lining of the uterus sheds if the previously released ovum was not fertilized by spermatozoa and implanted to the endometrium. The shedding of endometrium causes vaginal bleeding and is commonly referred to as the "period." After shedding, the endometrium regrows and thickens in preparation for the next ovum that might be fertilized and implanted in the uterus. This cycle of menstruation is controlled by **luteinizing hormone** (**LH**) and **follicle-stimulating hormone** (**FSH**) which are produced by the **pituitary gland**.

Attributions (All Female Reproductive Sections)

- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0
- "Female Areola.jpg" by Electric one is licensed under CC BY-SA 3.0
- "Female Reproductive System" by Dongho Kim is licensed under CC BY-NC-SA 4.0
- "Medical gallery of Blausen Medical 2014" by Blausen.com staff is licensed under CC BY 3.0
- "Wiki Images" by https://www.scientificanimations.com/wiki-images/ is licensed under CC BY-SA 4.0

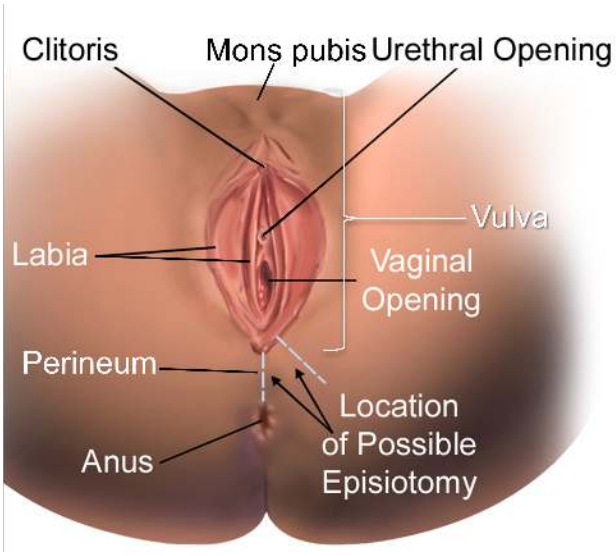
Updated 2026.

This page titled 22.2: Female Reproductive System (Internal) is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

22.3: Female Reproductive System (External)

Female Reproductive System (External)

External Female Genitalia

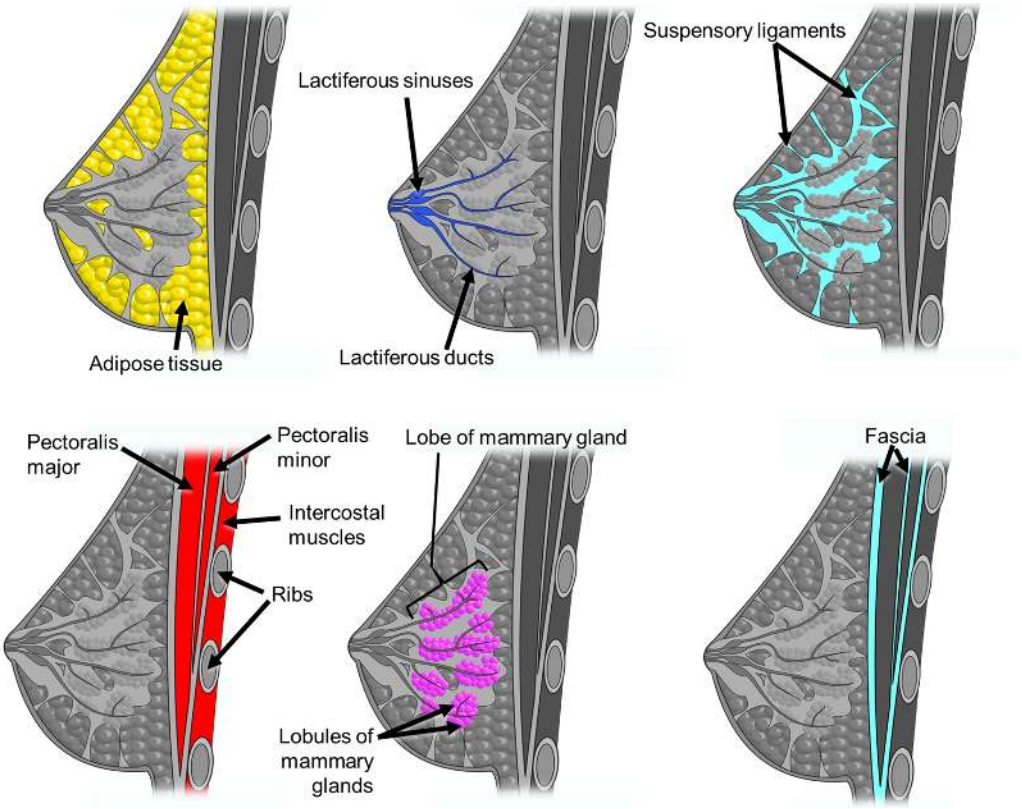


Above: External female genitalia with locations of possible episiotomies are shown. An episiotomy is a surgical cut made to widen the vaginal opening during a difficult childbirth to prevent tissues from tearing.

Structure	Location	Function
anus	posterior to the vulva	removal of feces
clitoris	medial structure; superior to urethral opening; covered by clitoral hood; made of highly sensitive erectile tissue	a highly sensitive bulbous erectile structure; covered by the **prepuce** (aka **clitoral hood**); homologous to glans penis in male
labia majora	two fatty folds that extend posteriorly from the mons pubis; lateral to urethral opening and vaginal opening	homologous to the male scrotum; contain pubic hair, sudoriferous and sebaceous glands
labia minora	two smaller parallel folds; lateral to urethral opening and vaginal opening but medial to labia majora	contain sebaceous glands but no hair, covers clitoris
mons pubis	fatty pad superior to the rest of the vulva	cushions and protects pubic symphysis during sexual intercourse
perineum	region between the vulva and the anus	supports urinary, genital, and gastrointestinal structures
urethral opening	medially located; inferior of clitoris and superior of vaginal opening	removal of urine
vagina orifice (opening)	entry point into internal female genitalia	entry point for copulation and exit for childbirth
vulva	the external female genitalia	removal of urine, copulation, childbirth

Breasts

The female reproductive system is designed not only to nurture developing embryos/fetuses in utero, but also to provide nutrients after childbirth. The breasts contain specialized **mammary glands** for providing nutrients to continue nurturing offspring.

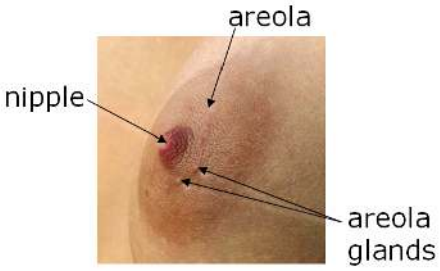


Above: Structures of breasts, mammary glands, and lactiferous ducts.

Human breast milk contains a variety of nutrient compounds, including proteins, fats, sugars, amino acids, nucleotides, vitamin A, B vitamins, and vitamin D, as well as non-nutritive, but biologically important, components such as hormones, growth factors, antibodies, cytokines, chemokines, stem cells, and macrophages. Alveoli cells are specialized cells that are primarily responsible for producing and secreting a large proportion of the components of breast milk. Alveoli cells are clustered into lobules, which are further clustered into lobes. During **lactation** (the process of secreting breast milk), milk travels from the lobes, to the lactiferous ducts, to the lactiferous sinuses, and to the nipple for delivery to the offspring. **Areolar glands** are present surrounding the nipple on the areola to help lubricate and protect the nipple during breastfeeding.

Structure	Description/Function
alveoli	milk-secreting cells
areola	pigmented tissue surrounding the nipple; muscles within the areola aid in lactation and milk delivery
areolar glands (Montgomery glands)	these are sebaceous glands; protect the nipple; lubricates the nipple
lactiferous ducts	drain milk from lobules
lactiferous sinus	empty milk into nipples
lobes of mammary glands	bunches of lobules of mammary glands
lobules of mammary glands	small divisions of lobes of mammary glands that contain alveoli

Structure	Description/Function
mammary glands	modified sweat glands that produce milk in a process called lactation
nipple	surrounded by pigmented areola
suspensory ligaments	connective tissue; provides structure/support for breast tissues



Above: External breast structures.

Attributions (All Female Reproductive Sections)

- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0
- "Female Areola.jpg" by Electric one is licensed under CC BY-SA 3.0
- "Female Reproductive System" by Dongho Kim is licensed under CC BY-NC-SA 4.0
- "Medical gallery of Blausen Medical 2014" by Blausen.com staff is licensed under CC BY 3.0
- "Wiki Images" by https://www.scientificanimations.com/wiki-images/ is licensed under CC BY-SA 4.0

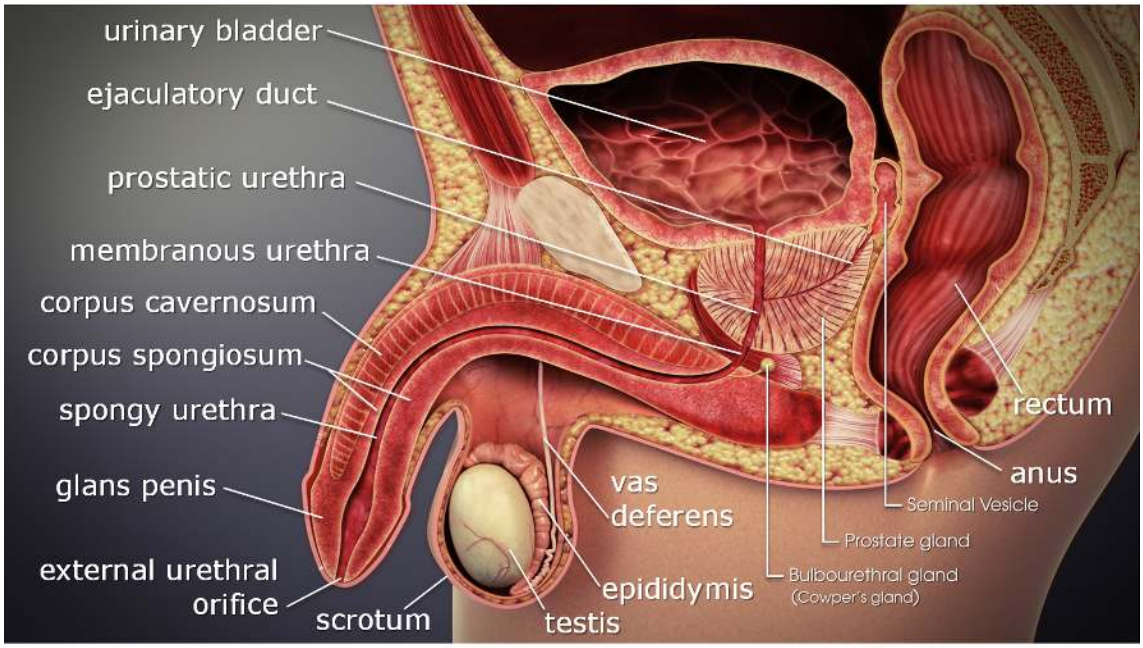
Updated 2026.

This page titled 22.3: Female Reproductive System (External) is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

22.4: Male Reproductive System

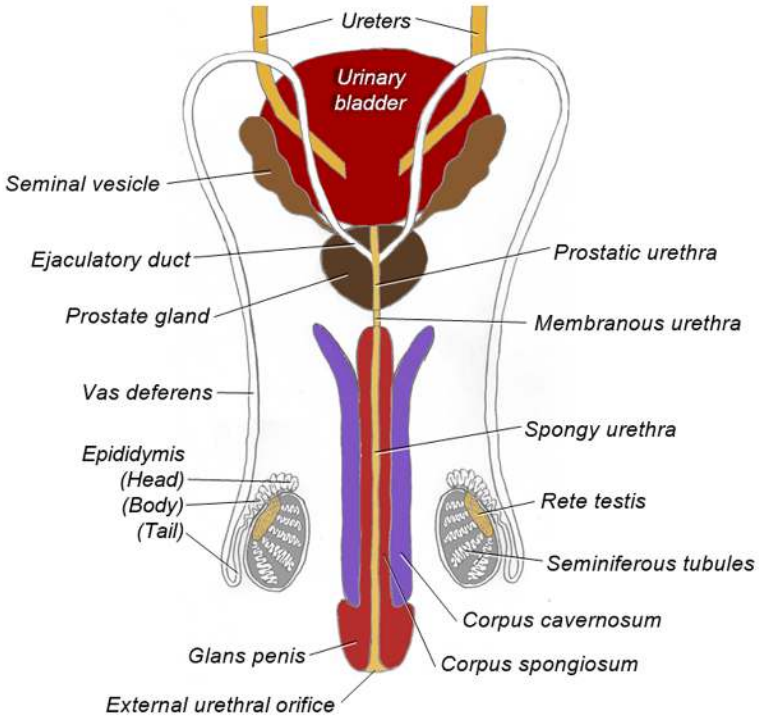
Male Reproductive System

The **testes** produce spermatozoa (sperm), the male reproductive cells. Spermatozoa are produced in the **seminiferous tubules** and collected by the **rete testis** (rete = net). Spermatozoa travels from the rete testis to the head of the **epididymis** where they mature and are stored until ejaculation. The **vas deferens** transports spermatozoa from the tail of the epididymis to the **prostate gland**. Seminal glands, the prostate gland, and the bulbourethral glands add fluid secretions to spermatozoa to form semen. These additional fluids support the spermatozoa and their survival as well as facilitate their transfer to the female reproductive tract.



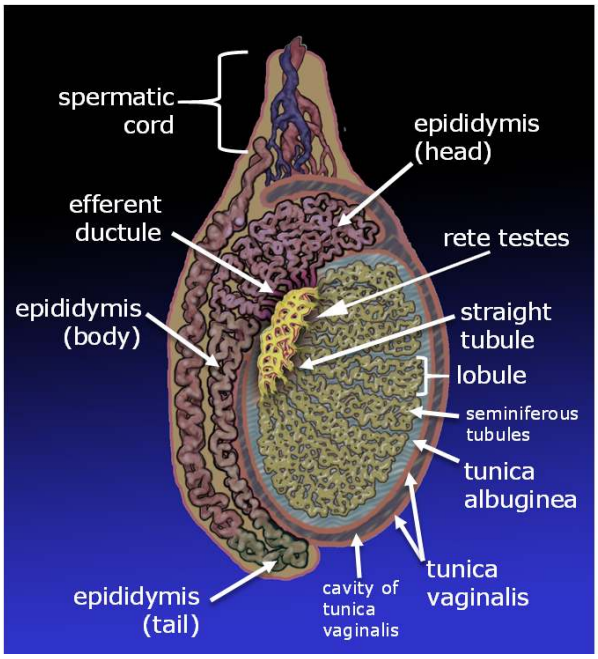
Above: Male reproductive system, lateral view of the left side with structures shown with sagittal sections.

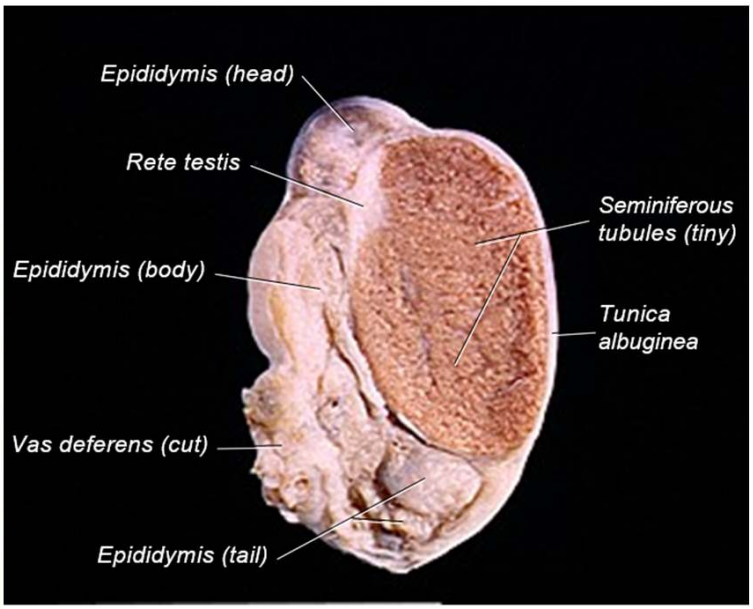
The epididymis, vas deferens, ejaculatory duct and urethra form a system of tubules for the transport of spermatozoa from testes to the pelvic cavity. There they will be combined with the secretions of the accessory glands to form semen.



Above: Structures of the male genitalia.

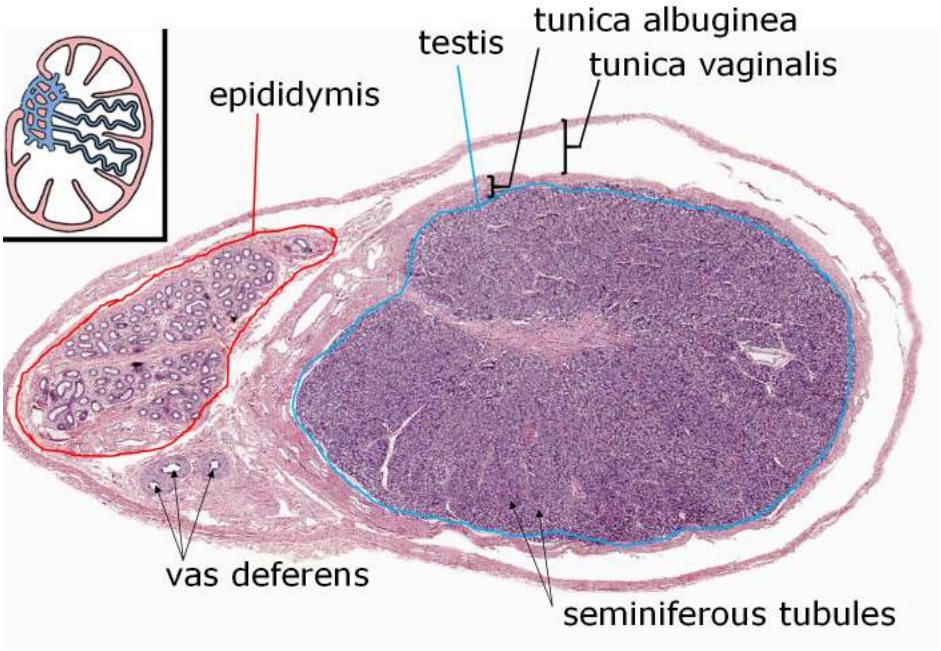
In order for proper and efficiently development of spermatozoa, the testes must be cooler than core body temperature (95°F is optimal for **spermatogenesis** and 98.6°F is core body temperature). The testes cool some just from being suspended away from the body, but the core temperature arterial blood from the **gonadal artery** must also be cooled before reaching the testis capillary beds. As blood is cooled in the peripheral capillary beds of the scrotal walls**,** it collects into a network of gonadal veins called the **pampiniform plexus** (pampiniform = shaped like a vine or tendril). As it ascends to the abdomen, this venous plexus wraps around the gonadal artery, cooling the arterial blood to sufficient temperature.



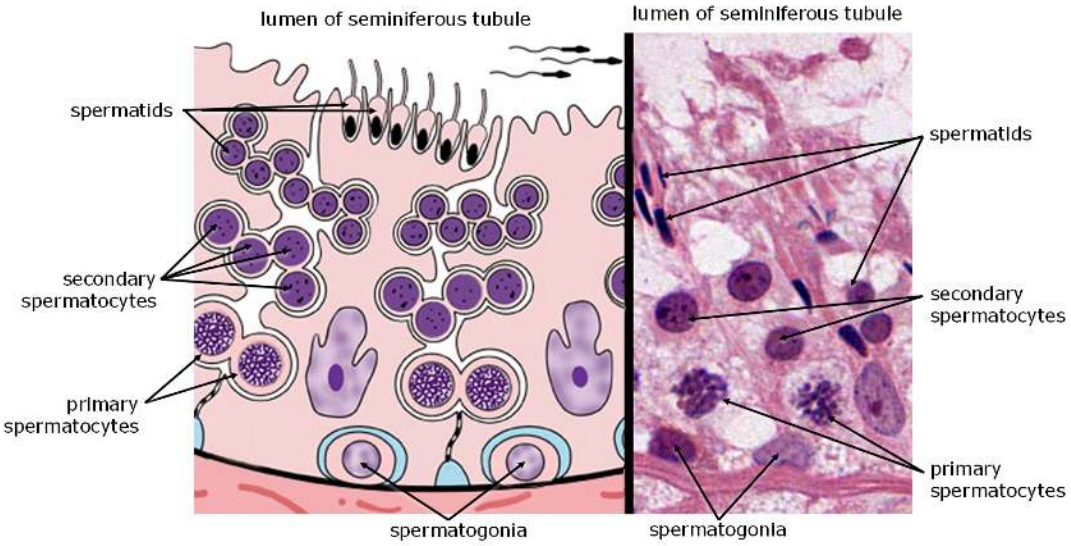


Above: Internal structure of the testis and epididymis.

Sperm cells are produced in the seminiferous tubules in the testes. A cross section through the process of **spermatogenesis** (a type of meiosis). Close examination of a cross section of a seminiferous tubule shows that sperm cells develop beginning close to the inner lining of the seminiferous tubule, beginning with specialized stem cells called **spermatogonia**, and develop as they move closer to the lumen of the seminiferous tubules. **Primary spermatocytes** (cells that undergo the first meiotic division) and **secondary spermatocytes** (cells that undergo the second meiotic division) are intermediate cells produced as spermatozoa develop. Spermatogenesis produces immature **spermatids** that ultimately mature into spermatozoa.

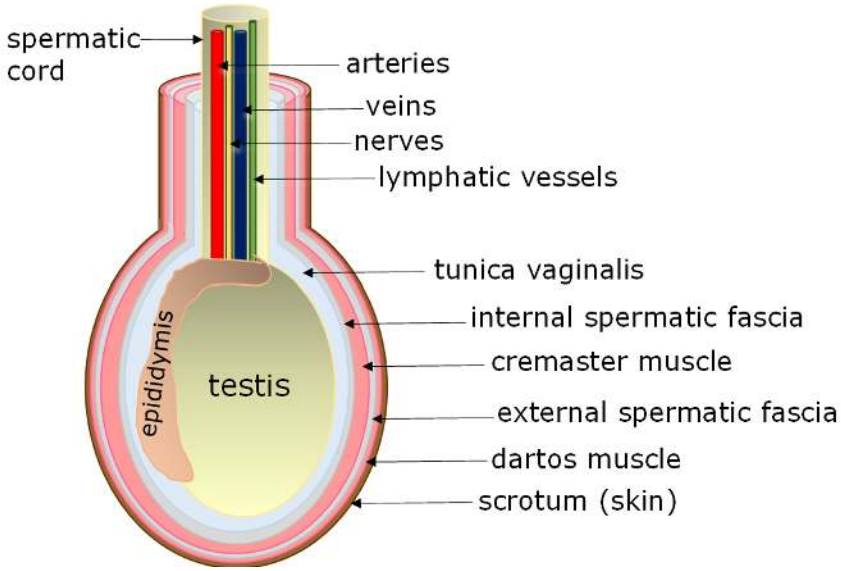


Above: The testis is both an exocrine (producing spermatozoa) and an endocrine (producing androgens) gland. This immature testis, cut in cross section, provides an overview of the testis proper, its enclosing tunics, and its location in the scrotum. Also seen are the epididymis and the ductus deferens lying posterior to the testis. Tissue is magnified by 10x.



https://bio.libretexts.org/@go/page/53847

Above: The exocrine function of the testis is performed by the epithelium lining the convoluted portions of seminiferous tubules. Each convoluted tubule is lined by a stratified epithelium composed of two cell types. Germ cells divide and cytodifferentiate to form haploid spermatozoa. Sertoli cells nourish and protect germ cells during their formation before releasing them into the lumen of the tubule. Tissue is magnified by 1000x.

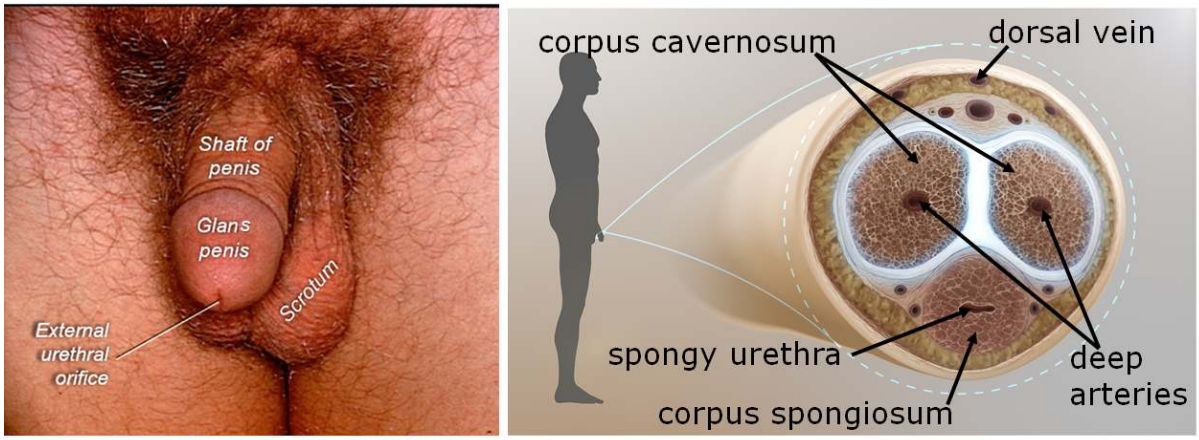


Above: Structures of the spermatic cord and structures enveloping the testis.

Structure	Location	Function
bulbourethral glands (Cowper's glands)	pair (right and left) of glands posterior to the bulb of the penis and membranous urethra	produce ~1% of the total volume of semen; produce a thick mucus that cleans and neutralizes the urethra of residual urine and increases the mobility of sperm in the vagina
corpus cavernosum	two of the three bodies of erectile tissue bodies in the penis	become engorged with blood, causing an erection
corpus spongiosum	one of the three bodies of erectile tissue in the penis; the spongy urethra passes through the corpus spongiosum	become engorged with blood, causing an erection
cremasteric muscle	very thin muscle that surrounds the spermatic cord and testes	elevate the testes to warm them when the testes become too cold for optimal sperm production and development
dartos muscle	a very thin muscle in the walls of the scrotum	elevate the scrotum to warm it when the testes are too cold for optimal sperm production and development
ejaculatory ducts	channels in the prostate gland formed when vas deferens joins with duct from the seminal vesicle	spermatozoa and semen fluids flow through toward the prostatic urethra
epididymis	paired organ (right and left) located on the posterior aspect of the testes; consists of head, body and tail regions	location where spermatids mature and become spermatozoa; store spermatozoa until ejaculation; spermatozoa account for about 3% of semen volume; an average of 200 – 500 million sperm released from an ejaculation

Structure	Location	Function
external urethral orifice	urethral opening on the penis	location where urine and semen leave the body
glans penis	the highly sensitive bulbous structure at the end of the corpus spongiosum and tip of the penis	contains the external urethral orifice and is covered by the prepuce in uncircumcised males
membranous urethra	short segment of the urethra that passes through the floor of the pelvis	transports urine and semen
penis	external genitalia composed of shaft and glans penis	male copulatory organ
prepuce (foreskin)	loose skin of the penis which covers the glans and is often removed by a process called circumcision	protects glans penis
prostate gland	gland inferior to the urinary bladder; prostatic urethra and ejaculatory ducts pass through	contributes ~26% to the volume of semen; secretes fluid that stabilizes sperm and protects them from the acidic environment of the vagina
prostatic urethra	region of the urethra that passes through the prostate; occurs from the bladder to the membranous urethra	transports urine and semen
scrotum	skin surrounding the testis	protection of the testis and associated tissues
seminal vesicles	pair (right and left) of tubular glands; posterior to the urinary bladder	produce fluid that mixes with spermatozoa in the vas deferens just before the prostate gland; fluid from the seminal vesicles contributes the majority (~70%) of the volume of semen (**semen** = the mixture of sperm and supporting fluids); fluid from the seminal vesicles contains a lot of fructose, a sugar that is used by spermatozoa as their main energy source
seminiferous tubules	tubules within the testes	site of spermatogenesis (production of spermatozoa); produce millions of spermatozoa per day
spermatic cord	bundle of vessels (blood and lymphatic vessels) and nerves traveling from the trunk to the testes	a connective tissue sheath consisting of blood vessels, nerves and the cremaster muscle
spongy urethra	region of the urethra between the membranous urethra and the external urethral orifice; passes through the corpus spongiosum	transports urine and semen
testis (pl. testes)	pair of organs within the scrotum; located outside of the abdominopelvic cavity; covered with tunica albuginea ("white tunic")	produces spermatozoa and testosterone (a hormone)
tunica albuginea	a dense connective tissue capsule or "white tunic" that covers the testes; inward extensions of the tunica albuginea divides the seminiferous tubules into lobes	

Structure	Location	Function
vas deferens (ductus deferens)	Passes from the epididymis, through the spermatic cord, through the inguinal canal, into the pelvic cavity and superiorly over the bladder	upon ejaculation, sperm is received here from the epididymis by peristalsis



Above: (Left) External male genitalia. (Right) Cross section of the penis.

Attributions

- "Anatomy 204L: Laboratory Manual (Second Edition)" by Ethan Snow, University of North Dakota is licensed under CC BY-NC 4.0
- "Anatomy and Physiology Lab Reference" by Laird C Sheldahl, OpenOregonEducational Resources, Mt. Hood Community College is licensed under CC BY-SA 4.0
- "Digital Histology" by Department of Anatomy and Neurobiology and the Office of Faculty Affairs, Virginia Commonwealth University School of Medicine and the ALT Lab at Virginia Commonwealth University is licensed under CC BY 4.0
- "Male Reproductive System" by Dongho Kim is licensed under CC BY-NC-SA 4.0
- "Rete testis.jpg" by KDS444 is licensed under CC BY-SA 3.0
- "Wiki Images" by https://www.scientificanimations.com/wiki-images/ is licensed under CC BY-SA 4.0

Updated 2026.

This page titled 22.4: Male Reproductive System is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

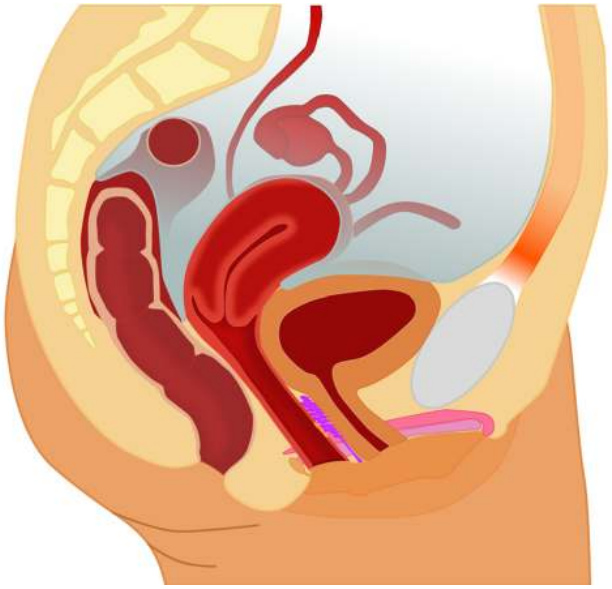
22.5: Laboratory Activities and Assignment

Laboratory Activities and Assignment

Part 1: Review of the Reproductive Systems

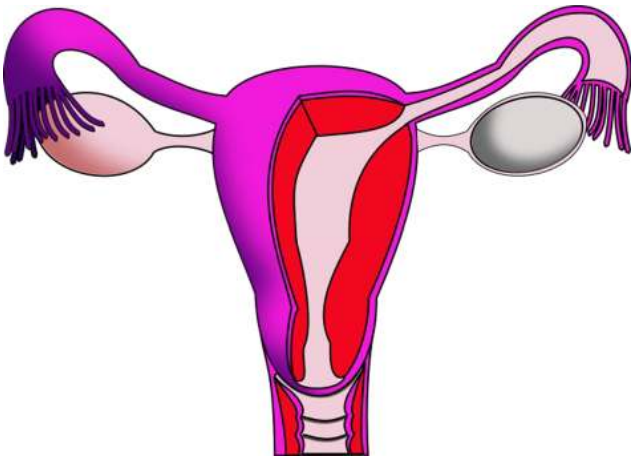
1. Label the structures listed below on the diagram of the female genitalia below.

- anus
- cervix
- clitoris
- external os
- fornix
- greater vestibular gland
- labia majora
- labia minora
- ovarian ligament
- ovary
- rectum
- urethra
- urethral opening
- uterine tube
- uterus
- vagina
- vaginal opening



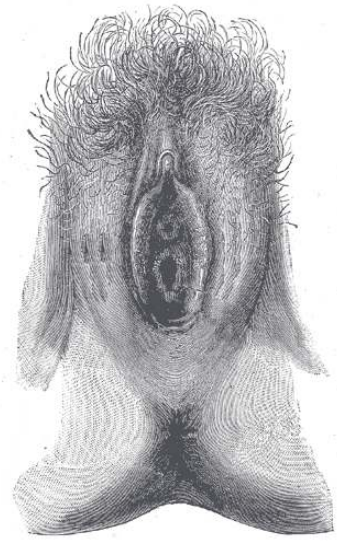
2. Label the structures listed below on the diagram of internal female genitalia below.

- cervical canal
- cervix
- endometrium
- external os
- fimbriae
- fundus of the uterus
- internal os
- left ampulla of uterine tube
- left infundibulum of uterine tube
- left isthmus of uterine tube
- left ovarian ligament
- left ovary
- left uterine tube
- myometrium
- perimetrium
- right ampulla of uterine tube
- right infundibulum of uterine tube
- right isthmus of uterine tube
- right ovarian ligament
- right ovary
- right Uterine tube
- rugae of vagina
- uterus
- vagina



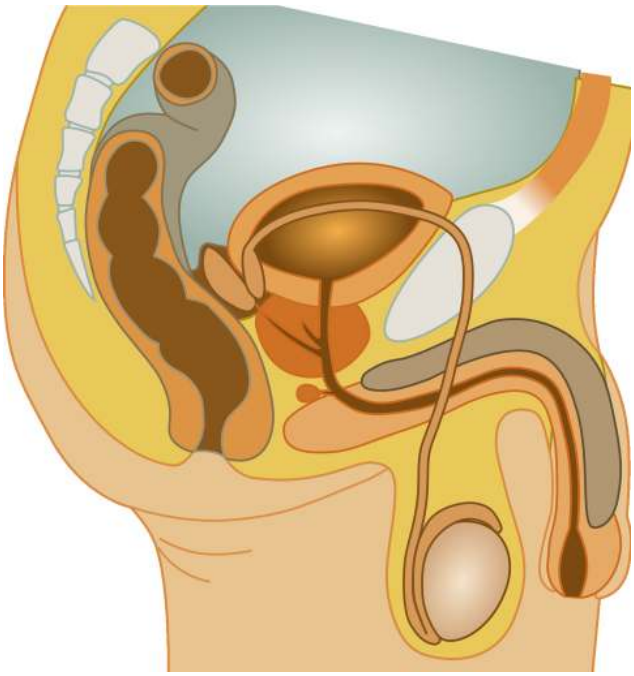
3. Label the structures listed below on the diagram of the external female genitalia.

• anus • clitoris • clitoral hood • labia majora	• labia minora • mons pubis • perineum	• urethral opening • vaginal opening • vulva



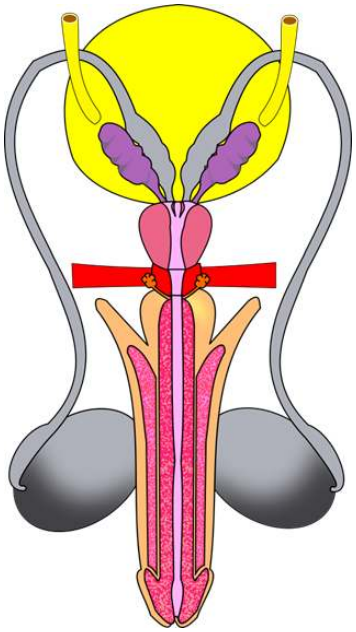
4. Label the structures listed below on the diagram of the male genitalia below.

• anus • bulb of the penis • bulbourethral gland • corpus cavernosum • corpus spongiosum • ejaculatory duct • epididymis	• external urethral orifice • glans penis • membranous urethra • prostate gland • prostatic urethra • rectum	• scrotum • seminal vesicle • shaft of the penis • spongy urethra • urinary bladder • vas deferens



5. Label the structures listed below on the diagram of the male genitalia below.

• bulbourethral gland • corpus cavernosum • corpus spongiosum • ejaculatory duct • epididymis	• external urethral orifice • glans penis • membranous urethra • prostate gland • prostatic urethra	• seminal vesicle • shaft of the penis • spongy urethra • urinary bladder • vas deferens

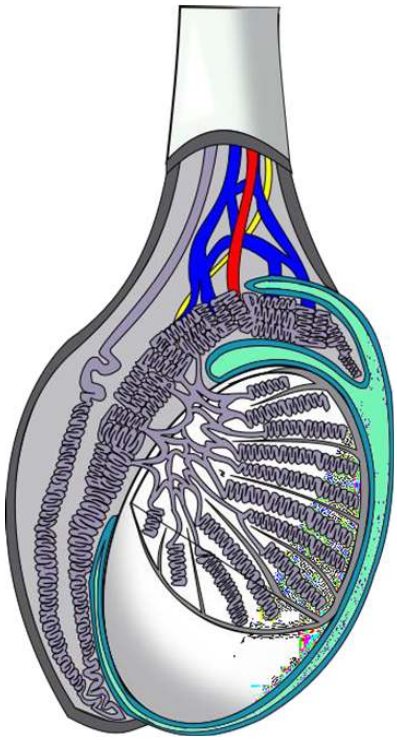


7. On the figure above, number the structures spermatozoa pass through to exit the male reproductive system from where spermatids are created (#1) to the point where they exit the body.

8. On the figure above, add a star (*) next to the name of each structure that contributes to semen.

9. Label the structures listed below on the diagram of the male genitalia below.

• body of epididymis • efferent ductule • head of epididymis • lobule of seminiferous tubules • rete testes	• seminiferous tubules • spermatic cord • spermatic/testicular arteries • spermatic/testicular nerves • spermatic/testicular veins	• straight tubules • tail of epididymis • tunica albuginea • tunica vaginalis • vas deferens



10.Match the structure listed in the table below with its corresponding description.

Name of Structure	Description
_____ vas deferens	1. produce sperm and testosterone
_____ areola	2. small convoluted tubules and site of spermatogenesis
_____ testes	3. conduct sperm to the urethra during ejaculation
_____ mammary gland	4. produces an ovum, estrogen, and progesterone
_____ fimbriae	5. a gland in mammals that produces milk
_____ corpus cavernosum and corpus spongiosum	6. ducts that carry milk from the mammary glands to the nipple
_____ labia major	7. pigmented area around the nipple
_____ seminiferous tubules	8. the larger outer folds of the vulva surrounding the inner folds; contain adipose tissue and hair
_____ ovaries	9. erectile tissues that form the bulk of the penis
_____ lactiferous ducts	10. small fingerlike projections at the end of the fallopian tubes

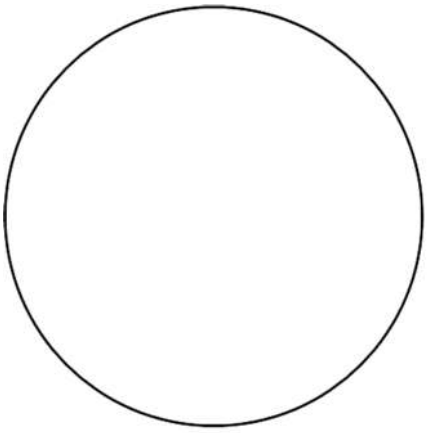
Part 2: Histology of the Reproductive Systems

1. Obtain the slides listed below that are available for today's lab.
2. Focus on each sample and identify the structures listed for each type of tissue.
3. Indicate the **total** magnification you make each illustration at in the space provided.
4. Illustrate each tissue you observe with the microscope at the magnification you listed.
5. Label each illustration with the structures listed for each.

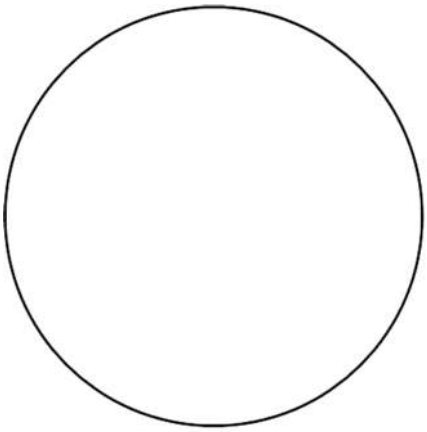
Ovary

More than one illustration at more than one magnification will be required to illustrate and label all structures

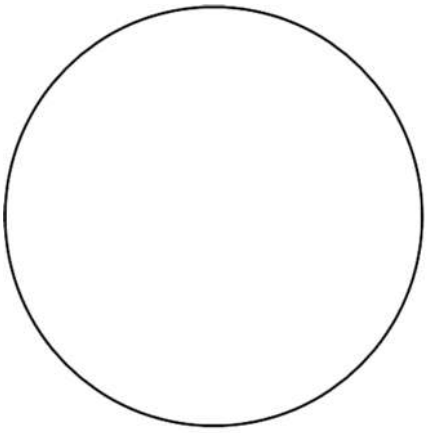
Label the tissue with: serosa, medulla, cortex, tunica albuginea, follicles, primordial follicles, primary follicles, secondary follicles, antral spaces, primary oocytes, corpus luteum, atretic follicles



Total magnification: _____



Total magnification: _____

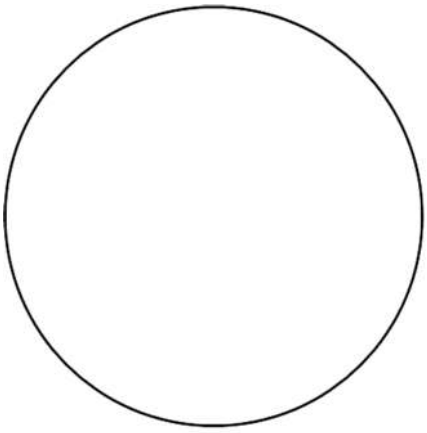


Total magnification: _____

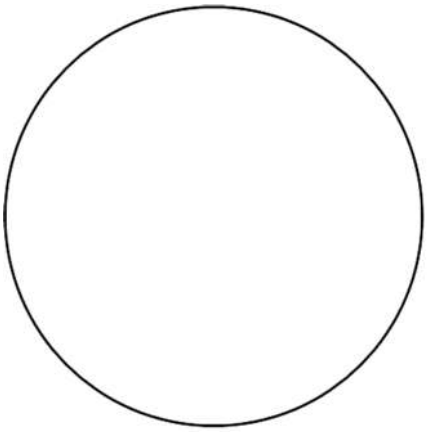
Testis

More than one illustration at different magnifications and possibly of different slides will be necessary to illustrate and label all structures listed.

Label the tissue with: testis, epididymis, vas deferens, tunica albuginea, tunica vaginalis, seminiferous tubules, lumen of seminiferous tubule, spermatogonia, primary spermatocyte, secondary spermatocyte, spermatid



Total magnification: _____



Total magnification: _____

Part 3: Reproductive Systems Laboratory Activities

Labeling Male Reproductive Anatomical Model(s)

1. Use the anatomical model(s) provided to your group.
2. As a group, identify the structures listed below.
3. Write each of the following structures on masking tape or labeling tape (with correct spelling) and stick onto the model to label each structure.

- bulb of the penis
- bulbourethral gland
- corpus cavernosum
- corpus spongiosum
- cremaster muscle
- dartos muscle
- ejaculatory duct
- epididymis
- external urethral orifice
- glans penis
- lobules
- membranous urethra
- prepuce
- prostate gland
- prostatic urethra
- rete testes
- scrotum
- scrotal septum
- seminal vesicle
- seminiferous tubules
- shaft of the penis
- spermatic cord
- spongy urethra
- straight tubules
- testis
- vas deferens

4. When you are done, ask your instructor to verify the labeling is correct.

Instructor Signature Confirming Correct Labeling: _____

5. Take a photo of your anatomical model for future reference for studying.

Labeling Female Reproductive Anatomical Model(s)

1. Use the anatomical model(s) provided to your group.
2. As a group, identify the structures listed below.
3. Write each of the following structures on masking tape or labeling tape (with correct spelling) and stick onto the model to label each structure.

- ampulla of uterine tube
- areola
- breast
- broad ligament
- cervical canal
- cervix
- clitoris
- clitoral hood
- endometrium
- external os
- external urethral orifice
- fimbriae
- fornix
- infundibulum of uterine tube
- internal os
- isthmus of uterine tube
- labia majora
- labia minora
- lactiferous duct
- lactiferous sinus
- lobe of mammary gland
- lobule of mammary gland
- mammary glands
- mons pubis
- myometrium
- nipple
- ovarian ligament
- ovary
- perimetrium
- rugae of the vagina
- uterine tube
- uterus
- vagina
- vaginal orifice
- vulva

4. When you are done, ask your instructor to verify the labeling is correct.

Instructor Signature Confirming Correct Labeling: _____

5. Take a photo of your anatomical model for future reference for studying.

Attributions

Part 1: Review of Reproductive Systems

- "Anatomy and Physiology Lab Homework" by Laird C Sheldahl is licensed under CC BY-SA 4.0
- "Female anatomy with g-spot-nb.svg" by Tsaitgaist is licensed under CC BY-SA 3.0
- "Gray's Anatomy plates" by Henry Vandyke Carte is in the Public Domain
- "Human Anatomy Lab Manual" by Malgosia Wilk-Blaszczak, Mavs Open Press, University of Texas at Arlington is licensed under CC BY 4.0
- "Male reproductive system.png" by User:Ningyou is licensed under CC BY-SA 3.0
- "Male reproductive tract.png" by Sheldahl is licensed under CC BY-SA 4.0

Part 2: Histology of the Reproductive Systems

- "BIOL 250 Human Anatomy Lab Manual SU 19" by Yancy Aquino, Skyline College is licensed under CC BY-NC-SA 4.0

Part 3: Reproductive Systems Laboratory Activities

- "Human Anatomy Lab Manual" by Malgosia Wilk-Blaszczak, Mavs Open Press, University of Texas at Arlington is licensed under CC BY 4.0

Updated 2026.

This page titled 22.5: Laboratory Activities and Assignment is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

22.6: Collaborative Study Activities

Collaborative Study Activities

This activity is designed for student groups of 2-4. Larger groups will work better when there is no supplemental instructor present in the laboratory to assist in testing student groups on each section.

Female Reproductive System

1. Identify the following structures on classroom anatomical models and/or unlabeled images/diagrams made available by your instructor. Work with your group to identify each structure and check them off the list once you have identified them.

☐ ampulla (of uterine tube)	☐ fornix	☐ ovarian blood vessels
☐ broad ligament	☐ fundus of uterus	☐ ovarian ligament
☐ cervical canal	☐ infundibulum (of uterine tube)	☐ perimetrium
☐ cervix	☐ internal os	☐ right ovary
☐ endometrium	☐ isthmus (of uterine tube)	☐ uterine tube
☐ external os	☐ left ovary	☐ uterus
☐ fimbriae	☐ myometrium	☐ vagina

2. Test your group members by ***asking them to name each structure you point to***. Check off each when your group can successfully name each. Your group will also test you.

☐ ampulla (of uterine tube)	☐ fornix	☐ ovarian blood vessels
☐ broad ligament	☐ fundus of uterus	☐ ovarian ligament
☐ cervical canal	☐ infundibulum (of uterine tube)	☐ perimetrium
☐ cervix	☐ internal os	☐ right ovary
☐ endometrium	☐ isthmus (of uterine tube)	☐ uterine tube
☐ external os	☐ left ovary	☐ uterus
☐ fimbriae	☐ myometrium	☐ vagina

3. When you and your group are comfortable identifying all the structures above, request the assistance of your Instructor. They will test you on your use of these terms and initial ONLY when you are successful using these terms. Instructor: _____

Male Reproductive System

1. Identify the following structures on classroom anatomical models and/or unlabeled images/diagrams made available by your instructor. Work with your group to identify each structure and check them off the list once you have identified them.

☐ bulb of the penis		
☐ corpus cavernosum	☐ membranous urethra	☐ seminal gland
☐ corpus spongiosum	☐ prepuce (foreskin)	☐ spongy urethra
☐ ejaculatory duct	☐ prostate gland	☐ testis
☐ epididymis	☐ prostatic urethra	☐ urinary bladder
☐ external urethral orifice	☐ scrotum	☐ vas deferens
☐ glans penis		

2. Test your group members by ***asking them to name each structure you point to***. Check off each when your group can successfully name each. Your group will also test you.

☐ bulb of the penis ☐ corpus cavernosum ☐ corpus spongiosum ☐ ejaculatory duct ☐ epididymis ☐ external urethral orifice ☐ glans penis	☐ membranous urethra ☐ prepuce (foreskin) ☐ prostate gland ☐ prostatic urethra ☐ scrotum	☐ seminal gland ☐ spongy urethra ☐ testis ☐ urinary bladder ☐ vas deferens

When you and your group are comfortable identifying all the structures above, request the assistance of your Instructor. They will test you on your use of these terms and initial ONLY when you are successful using these terms. Instructor: _____

Updated 2026.

This page titled 22.6: Collaborative Study Activities is shared under a CC BY-NC-SA 4.0 license and was authored, remixed, and/or curated by Rosanna Hartline.

Index

C

cartilage
7.7: Cartilage

cranial nerves
15.2: Cranial Nerves

H

hyoid bone
8.3: Hyoid Bone

S

spinal nerves
15.3: Spinal Nerves

Glossary

Sample Word 1 | Sample Definition 1

https://bio.libretexts.org/@go/page/53859

Detailed Licensing

Overview

Title: Human Anatomy Laboratory Manual (Hartline)

Webpages: 210

Applicable Restrictions: Noncommercial

All licenses found:

- CC BY-NC-SA 4.0: 98.6% (207 pages)
- Undeclared: 1.4% (3 pages)

By Page

- Human Anatomy Laboratory Manual (Hartline) - *CC BY-NC-SA 4.0*
  - Front Matter - *CC BY-NC-SA 4.0*
    - TitlePage - *CC BY-NC-SA 4.0*
    - InfoPage - *CC BY-NC-SA 4.0*
    - Table of Contents - *Undeclared*
    - Licensing - *Undeclared*
  - 1: Introduction to Anatomy and Anatomical Terms - *CC BY-NC-SA 4.0*
    - 1.1: Introduction - *CC BY-NC-SA 4.0*
    - 1.2: Anatomical Position - *CC BY-NC-SA 4.0*
    - 1.3: Directional Terms - *CC BY-NC-SA 4.0*
    - 1.4: Planes/Sections - *CC BY-NC-SA 4.0*
    - 1.5: Anatomical Adjectives for Body Locations - *CC BY-NC-SA 4.0*
    - 1.6: Abdominopelvic Regions and Abdominopelvic Quadrants - *CC BY-NC-SA 4.0*
    - 1.7: Video Overview of Anatomical Position, Directional Terms, Planes/Sections, Anatomical Adjectives, Abdominal Regions, and Abdominal Quadrants - *CC BY-NC-SA 4.0*
    - 1.8: Body Cavities - *CC BY-NC-SA 4.0*
    - 1.9: Serosa (Serous Membranes) - *CC BY-NC-SA 4.0*
    - 1.10: Laboratory Activities and Assignment - *CC BY-NC-SA 4.0*
    - 1.11: Collaborative Study Activities - *CC BY-NC-SA 4.0*
  - 2: Introduction to Microscopes - *CC BY-NC-SA 4.0*
    - 2.1: Introduction - *CC BY-NC-SA 4.0*
    - 2.2: Introduction to the Metric System - *CC BY-NC-SA 4.0*
    - 2.3: Light Microscopy (LM) - *CC BY-NC-SA 4.0*
    - 2.4: Electron Microscopy (EM) - *CC BY-NC-SA 4.0*
    - 2.5: Use of Compound Light Microscopes for Anatomy Laboratories - *CC BY-NC-SA 4.0*
    - 2.6: Laboratory Activities and Assignment - *CC BY-NC-SA 4.0*
  - 3: Cell Structure and Cell Types - *CC BY-NC-SA 4.0*
    - 3.1: Introduction - *CC BY-NC-SA 4.0*
    - 3.2: Subcellular Structures - *CC BY-NC-SA 4.0*
    - 3.3: Cell-to-Cell Junctions Hold Cells Together In Tissues - *CC BY-NC-SA 4.0*
    - 3.4: Cell Structure Varies by Cell Type - *CC BY-NC-SA 4.0*
    - 3.5: Laboratory Activities and Assignment - *CC BY-NC-SA 4.0*
    - 3.6: Collaborative Study Activity - *CC BY-NC-SA 4.0*
  - 4: How Cells Divide (Mitotic Cell Division) - *CC BY-NC-SA 4.0*
    - 4.1: Introduction to Cell Division - *CC BY-NC-SA 4.0*
    - 4.2: The Life of a Cell - *CC BY-NC-SA 4.0*
    - 4.3: Mitotic Cell Division- Division of the Nucleus (Mitosis) + Division of the Cytoplasm (Cytokinesis) - *CC BY-NC-SA 4.0*
    - 4.4: Uncontrolled Cell Divisions Create Tumors including Cancers - *CC BY-NC-SA 4.0*
    - 4.5: Laboratory Activities and Assignment - *CC BY-NC-SA 4.0*
    - 4.6: Collaborative Study Activity - *CC BY-NC-SA 4.0*
  - 5: Tissues - *CC BY-NC-SA 4.0*
    - 5.1: Introduction - *CC BY-NC-SA 4.0*
    - 5.2: Epithelial Tissues - *CC BY-NC-SA 4.0*
    - 5.3: Connective Tissues - *CC BY-NC-SA 4.0*
      - 5.3.1: Introduction to Connective Tissues - *CC BY-NC-SA 4.0*
      - 5.3.2: Connective Tissue Proper - *CC BY-NC-SA 4.0*
      - 5.3.3: Bone Tissue - *CC BY-NC-SA 4.0*
      - 5.3.4: Fluid Tissues - *CC BY-NC-SA 4.0*
      - 5.3.5: Cartilage Tissues - *CC BY-NC-SA 4.0*
    - 5.4: Muscle Tissues - *CC BY-NC-SA 4.0*
    - 5.5: Nervous Tissues - *CC BY-NC-SA 4.0*
    - 5.6: Laboratory Activities and Assignment - *CC BY-NC-SA 4.0*

- 5.7: Collaborative Study Activity - *CC BY-NC-SA 4.0*

- 6: Integumentary System - *CC BY-NC-SA 4.0*
  - 6.1: Introduction - *CC BY-NC-SA 4.0*
  - 6.2: Anatomy of the Skin - *CC BY-NC-SA 4.0*
  - 6.3: Secondary Structures of the Skin - *CC BY-NC-SA 4.0*
  - 6.4: Anatomy of the Nails - *CC BY-NC-SA 4.0*
  - 6.5: Laboratory Activities and Assignment - *CC BY-NC-SA 4.0*
  - 6.6: Collaborative Study Activity - *CC BY-NC-SA 4.0*
- 7: Introduction to the Skeletal System - *CC BY-NC-SA 4.0*
  - 7.1: Introduction - *CC BY-NC-SA 4.0*
  - 7.2: Osseous Tissue (Bone Tissue) - *CC BY-NC-SA 4.0*
  - 7.3: Axial Skeleton and Appendicular Skeleton - *CC BY-NC-SA 4.0*
  - 7.4: Bone Shape Classifications - *CC BY-NC-SA 4.0*
  - 7.5: Anatomy of a Long Bone - *CC BY-NC-SA 4.0*
  - 7.6: Bone Markings - *CC BY-NC-SA 4.0*
  - 7.7: Cartilage - *CC BY-NC-SA 4.0*
  - 7.8: Laboratory Activities and Assignment - *CC BY-NC-SA 4.0*
- 8: Axial Skeleton - *CC BY-NC-SA 4.0*
  - 8.1: Introduction - *CC BY-NC-SA 4.0*
  - 8.2: Skull - *CC BY-NC-SA 4.0*
    - 8.2.1: Exterior of the Cranium - *CC BY-NC-SA 4.0*
    - 8.2.2: Interior of the Cranium - *CC BY-NC-SA 4.0*
    - 8.2.3: Markings of the Cranium - *CC BY-NC-SA 4.0*
    - 8.2.4: Face - *CC BY-NC-SA 4.0*
  - 8.3: Hyoid Bone - *CC BY-NC-SA 4.0*
  - 8.4: Auditory Ossicles - *CC BY-NC-SA 4.0*
  - 8.5: Vertebral Column - *CC BY-NC-SA 4.0*
    - 8.5.1: Introduction to the Vertebral Column - *CC BY-NC-SA 4.0*
    - 8.5.2: Generalized Structure and Markings of Vertebrae - *CC BY-NC-SA 4.0*
    - 8.5.3: Cervical Vertebrae - *CC BY-NC-SA 4.0*
    - 8.5.4: Thoracic Vertebrae - *CC BY-NC-SA 4.0*
    - 8.5.5: Lumbar Vertebrae - *CC BY-NC-SA 4.0*
    - 8.5.6: Sacrum and Coccyx - *CC BY-NC-SA 4.0*
    - 8.5.7: Intervertebral Foramina - *CC BY-NC-SA 4.0*
    - 8.5.8: Intervertebral Discs - *CC BY-NC-SA 4.0*
    - 8.5.9: Clinical Application - Whiplash - *CC BY-NC-SA 4.0*
  - 8.6: Thoracic Cage - *CC BY-NC-SA 4.0*
  - 8.7: Additional Reference Figures - *CC BY-NC-SA 4.0*
  - 8.8: Laboratory Activities and Assignment - *CC BY-NC-SA 4.0*
  - 8.9: Collaborative Study Activities - *CC BY-NC-SA 4.0*
- 9: Appendicular Skeleton - *CC BY-NC-SA 4.0*
  - 9.1: Introduction - *CC BY-NC-SA 4.0*
  - 9.2: Shoulder Girdle/Pectoral Girdle - *CC BY-NC-SA 4.0*
  - 9.3: Upper Limb - *CC BY-NC-SA 4.0*
  - 9.4: Pelvic Girdle - *CC BY-NC-SA 4.0*
  - 9.5: Lower Limb - *CC BY-NC-SA 4.0*
  - 9.6: Additional Reference Figures - *CC BY-NC-SA 4.0*
  - 9.7: Laboratory Activities and Assignment - *CC BY-NC-SA 4.0*
  - 9.8: Collaborative Study Activities - *CC BY-NC-SA 4.0*
- 10: Articulations (Joints) and Movements - *CC BY-NC-SA 4.0*
  - 10.1: Articulations (Joints) - *CC BY-NC-SA 4.0*
  - 10.2: Body Movements - *CC BY-NC-SA 4.0*
  - 10.3: Additional Reference Figures - *CC BY-NC-SA 4.0*
  - 10.4: Laboratory Activities and Assignment - *CC BY-NC-SA 4.0*
- 11: Introduction to Skeletal Muscles - *CC BY-NC-SA 4.0*
  - 11.1: Introduction - *CC BY-NC-SA 4.0*
  - 11.2: Microscopic Anatomy of Skeletal Muscles - *CC BY-NC-SA 4.0*
  - 11.3: Macroscopic Anatomy of Skeletal Muscles - *CC BY-NC-SA 4.0*
  - 11.4: Laboratory Activities and Assignment - *CC BY-NC-SA 4.0*
- 12: The Skeletal Muscles - *CC BY-NC-SA 4.0*
  - 12.1: Introduction - *CC BY-NC-SA 4.0*
  - 12.2: Muscles of the Head and Neck - *CC BY-NC-SA 4.0*
  - 12.3: Muscles of the Anterior Trunk - *CC BY-NC-SA 4.0*
  - 12.4: Muscles of the Posterior Trunk - *CC BY-NC-SA 4.0*
  - 12.5: Muscles of the Upper Limbs - *CC BY-NC-SA 4.0*
  - 12.6: Muscles of the Hips and Lower Limbs - *CC BY-NC-SA 4.0*
  - 12.7: Actions, Origins, and Insertions of the Skeletal Muscles - *CC BY-NC-SA 4.0*
  - 12.8: Laboratory Activities and Assignment - *CC BY-NC-SA 4.0*
  - 12.9: Collaborative Study Activities - *CC BY-NC-SA 4.0*

- 13: Introduction to the Nervous System - *CC BY-NC-SA 4.0*
  - 13.1: Introduction - *CC BY-NC-SA 4.0*
  - 13.2: Neurons - *CC BY-NC-SA 4.0*
  - 13.3: Nerves are Bundles of Neuron Axons in the PNS - *CC BY-NC-SA 4.0*
  - 13.4: Glia (Neuroglia) Cells - *CC BY-NC-SA 4.0*
  - 13.5: Laboratory Activities and Assignment - *CC BY-NC-SA 4.0*
- 14: Central Nervous System - *CC BY-NC-SA 4.0*
  - 14.1: Brain - *CC BY-NC-SA 4.0*
  - 14.2: Sheep Brain Dissection - *CC BY-NC-SA 4.0*
  - 14.3: Spinal Cord - *CC BY-NC-SA 4.0*
  - 14.4: Additional Reference Figures - *CC BY-NC-SA 4.0*
  - 14.5: Laboratory Activities and Assignment - *CC BY-NC-SA 4.0*
  - 14.6: Collaborative Study Activities - *CC BY-NC-SA 4.0*
- 15: Peripheral Nervous System - *CC BY-NC-SA 4.0*
  - 15.1: Introduction - *CC BY-NC-SA 4.0*
  - 15.2: Cranial Nerves - *CC BY-NC-SA 4.0*
  - 15.3: Spinal Nerves - *CC BY-NC-SA 4.0*
  - 15.4: Additional Reference Figures - *CC BY-NC-SA 4.0*
  - 15.5: Laboratory Activities and Assignment - *CC BY-NC-SA 4.0*
  - 15.6: Collaborative Study Activities - *CC BY-NC-SA 4.0*
- 16: Special Senses of the Nervous System - *CC BY-NC-SA 4.0*
  - 16.1: Introduction - *CC BY-NC-SA 4.0*
  - 16.2: Vision Anatomy - *CC BY-NC-SA 4.0*
  - 16.3: Auditory and Equilibrium Anatomy - *CC BY-NC-SA 4.0*
  - 16.4: Olfactory Anatomy - *CC BY-NC-SA 4.0*
  - 16.5: Taste Anatomy - *CC BY-NC-SA 4.0*
  - 16.6: Laboratory Activities and Assignment - *CC BY-NC-SA 4.0*
  - 16.7: Collaborative Study Activities - *CC BY-NC-SA 4.0*
- 17: Cardiovascular System - The Heart - *CC BY-NC-SA 4.0*
  - 17.1: Introduction - *CC BY-NC-SA 4.0*
  - 17.2: Location, Size, and Shape of the Heart - *CC BY-NC-SA 4.0*
  - 17.3: Vessels of the Heart - *CC BY-NC-SA 4.0*
  - 17.4: Layers of the Heart - *CC BY-NC-SA 4.0*
  - 17.5: Internal Structures of the Heart - *CC BY-NC-SA 4.0*
  - 17.6: Circulation Through the Heart - *CC BY-NC-SA 4.0*
  - 17.7: Coronary Circulation - *CC BY-NC-SA 4.0*
  - 17.8: Heart Abnormalities and Treatments - *CC BY-NC-SA 4.0*
  - 17.9: Laboratory Activities and Assignment - *CC BY-NC-SA 4.0*
  - 17.10: Collaborative Study Activities - *CC BY-NC-SA 4.0*
- 18: Cardiovascular System - The Blood Vessels - *CC BY-NC-SA 4.0*
  - 18.1: Introduction - *CC BY-NC-SA 4.0*
  - 18.2: Structures of Blood Vessels - *CC BY-NC-SA 4.0*
  - 18.3: Branches of the Aorta - *CC BY-NC-SA 4.0*
  - 18.4: Arteries of the Head and Neck - *CC BY-NC-SA 4.0*
  - 18.5: Arteries of the Upper Limb - *CC BY-NC-SA 4.0*
  - 18.6: Arteries of the Lower Limb - *CC BY-NC-SA 4.0*
  - 18.7: Branches of the Vena Cavae - *CC BY-NC-SA 4.0*
  - 18.8: Veins of the Head and Neck - *CC BY-NC-SA 4.0*
  - 18.9: Veins of the Upper Limb - *CC BY-NC-SA 4.0*
  - 18.10: Veins of the Lower Limb - *CC BY-NC-SA 4.0*
  - 18.11: Cadaver Images of Blood Vessels - *CC BY-NC-SA 4.0*
  - 18.12: Laboratory Activities and Assignment - *CC BY-NC-SA 4.0*
  - 18.13: Collaborative Study Activities - *CC BY-NC-SA 4.0*
- 19: Respiratory System - *CC BY-NC-SA 4.0*
  - 19.1: Introduction - *CC BY-NC-SA 4.0*
  - 19.2: Upper Respiratory Tract - *CC BY-NC-SA 4.0*
  - 19.3: Lower Respiratory Tract - *CC BY-NC-SA 4.0*
  - 19.4: Laboratory Activities and Assignment - *CC BY-NC-SA 4.0*
  - 19.5: Collaborative Study Activities - *CC BY-NC-SA 4.0*
- 20: Digestive System - *CC BY-NC-SA 4.0*
  - 20.1: Introduction - *CC BY-NC-SA 4.0*
  - 20.2: Histology of the Alimentary Canal - *CC BY-NC-SA 4.0*
  - 20.3: Serosa - *CC BY-NC-SA 4.0*
  - 20.4: Oral Cavity - *CC BY-NC-SA 4.0*
  - 20.5: Esophagus and Stomach - *CC BY-NC-SA 4.0*
  - 20.6: Duodenum, Pancreas, Liver, and Gallbladder - *CC BY-NC-SA 4.0*
  - 20.7: Small Intestine - *CC BY-NC-SA 4.0*
  - 20.8: Colon (Large Intestine), Rectum, and Anus - *CC BY-NC-SA 4.0*
  - 20.9: Laboratory Activities and Assignment - *CC BY-NC-SA 4.0*

- 20.10: Collaborative Study Activities - *CC BY-NC-SA 4.0*

- 21: Urinary System - *CC BY-NC-SA 4.0*
  - 21.1: Introduction - *CC BY-NC-SA 4.0*
  - 21.2: Kidneys - *CC BY-NC-SA 4.0*
  - 21.3: Microscopic Structures of the Kidneys - Nephrons - *CC BY-NC-SA 4.0*
  - 21.4: Ureters - *CC BY-NC-SA 4.0*
  - 21.5: Urinary Bladder - *CC BY-NC-SA 4.0*
  - 21.6: Urethra - *CC BY-NC-SA 4.0*
  - 21.7: Laboratory Activities and Assignment - *CC BY-NC-SA 4.0*
  - 21.8: Collaborative Study Activities - *CC BY-NC-SA 4.0*
- 22: Reproductive Systems - *CC BY-NC-SA 4.0*
  - 22.1: Introduction - *CC BY-NC-SA 4.0*
  - 22.2: Female Reproductive System (Internal) - *CC BY-NC-SA 4.0*
  - 22.3: Female Reproductive System (External) - *CC BY-NC-SA 4.0*
  - 22.4: Male Reproductive System - *CC BY-NC-SA 4.0*
  - 22.5: Laboratory Activities and Assignment - *CC BY-NC-SA 4.0*
  - 22.6: Collaborative Study Activities - *CC BY-NC-SA 4.0*
- Back Matter - *CC BY-NC-SA 4.0*
  - Index - *CC BY-NC-SA 4.0*
  - Glossary - *CC BY-NC-SA 4.0*
  - Detailed Licensing - *Undeclared*