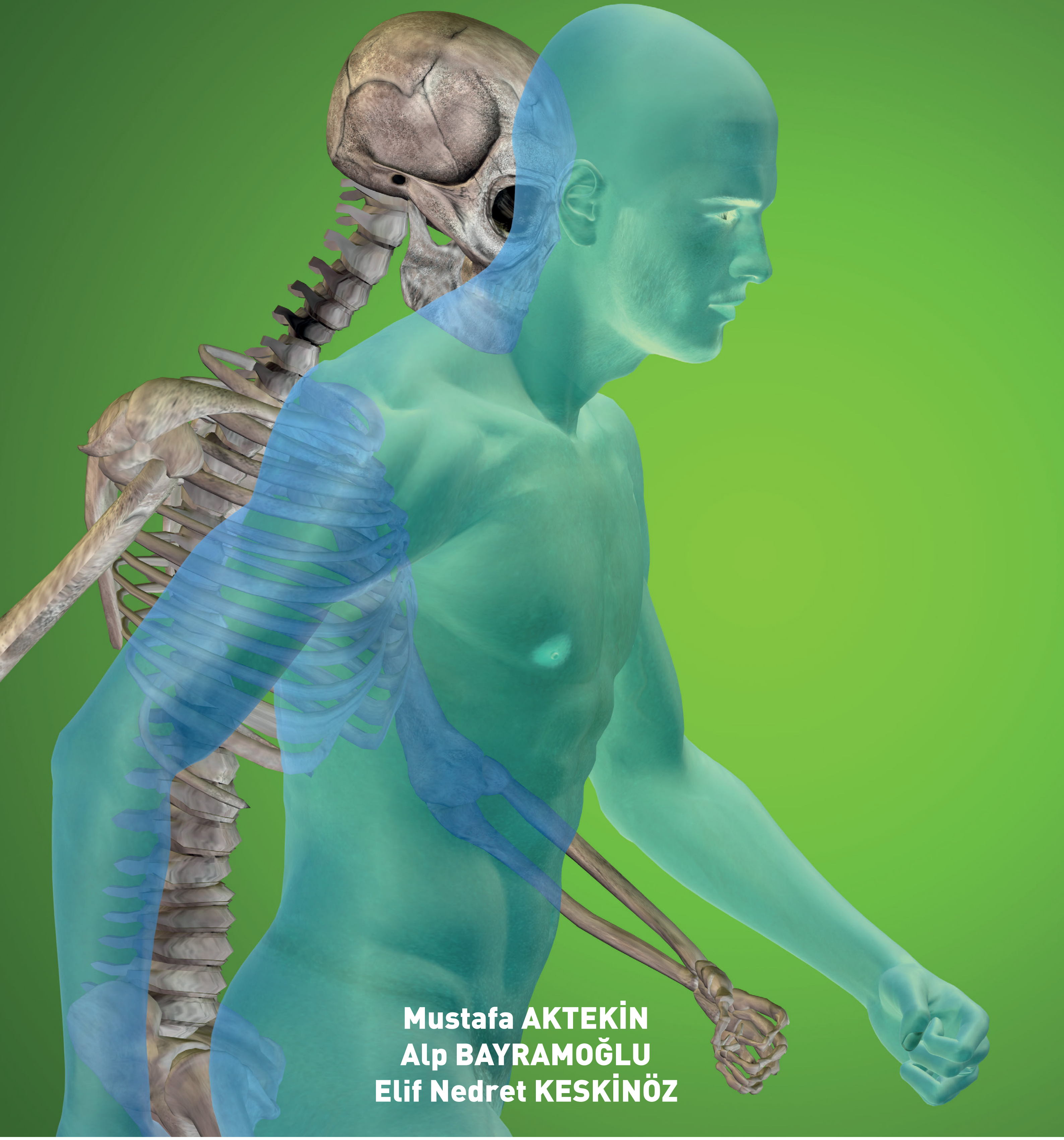
ESSENTIALS OF HUMAN ANATOMY

Illustrations, Clinical Relevance Boxes, and Review Questions



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ACIBADEM UNIVERSITY

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Acıbadem University Publication
Kerem Aydınlar Campus
Kayışdağı Cad. No: 32
Ataşehir – İstanbul, Türkiye

Publisher Certificate No: 51416

ISBN: 978-625-44490-7-9

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Photographs
Kerem AKTEKİN

Illustrations
www.shutterstock.com

Cover Design & Page Layout
Aslı Yavuz Özşengür

First Edition: İstanbul, September 2025

Prepared by:
Ege Reklam Basım Sanatları San. Tic. Ltd. Şti.
Esatpaşa Mah. Ziyapaşa Cad. No:4
34704 - Ataşehir / İSTANBUL
Tel: 0216 470 44 70
Faks: 0216 472 84 05
www.egebasim.com.tr

Printing Certificate No: 45604

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ACKNOWLEDGEMENTS

This book was written with the valuable contributions of my esteemed colleagues, Alp Bayramoğlu and Elif Nedret Keskinöz, with whom I have the privilege of working at the Department of Anatomy, School of Medicine, Acıbadem University. I sincerely thank them for their collaboration and efforts in creating a productive and harmonious team.

I would like to express my gratitude to Mehmet Ali Aydınlar, Chairman of the Board of Trustees of the Acıbadem Health and Education Foundation, for supporting the idea of the book being made available to a wide audience free of charge as a publication of Acıbadem University.

I am also grateful to Prof. Ahmet Şahin, Rector of Acıbadem University, and Prof. İrfan Güney, Vice Rector, for their support in the publication of this book.

Special thanks go to Yusuf Yıldız and Ali Rıza Derman, responsible for the Anatomy Laboratory of the School of Medicine, for their assistance in preparing the materials and supporting the photography process.

I also extend my thanks to Kerem Aktekin for his work on the photography as well as some figures featured in this book.

Finally, I would like to thank the staff of Ege Basım Printing House for their dedicated efforts to ensure the highest quality in the printing of this book.

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We dedicate this book to
OUR FAMILIES,
whose unconditional support, love, and patience have always been with us.

CONTENTS

PREFACE

This book, which you can view on your computer, mobile phone, or any other compatible electronic device, has been designed as an illustrated, **question-and-answer based** resource for learning human anatomy in a clear and engaging manner. Rich with original anatomical drawings and complemented by multiple-choice questions at the end of each section, it aims to support active learning and long-term retention of anatomical knowledge.

A key feature of this book is the "**Clinical Relevance**" boxes, which highlight the importance of anatomical structures in real-life clinical practice. These sections are intended to help readers connect theoretical knowledge with its practical applications in medicine.

What makes this book particularly significant and unique is that it is completely free to download, removing financial barriers to access. The book is available **exclusively as a free e-book in PDF format**, and can be accessed through the **library link of Acıbadem University**. This open-access approach reflects our belief in equitable education and the importance of making quality learning resources widely available.

I sincerely hope this book proves useful to students, trainees, and educators in anatomy and related fields. I would like to extend my heartfelt thanks to all who contributed to the preparation and improvement of this work through their insights and support.

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DEFINITIONS

DEFINITIONS

What is Anatomy?

Anatomy originates from two Greek words, “ana” and “tome.” “Ana” is a prefix in Greek that means upward or above, while “tome” means to cut. Human anatomy is the scientific discipline that studies the structure of the human body, as well as the relationships and connections between all tissues and organs it contains.

What are the sub-disciplines of Anatomy?

Anatomy is divided into subfields that examine organs, tissues, smaller structures, and their interrelations under various headings. These subfields can be listed as follows:

macroscopic anatomy: studies the structures of the body that are visible to the naked eye as distinct parts.

topographic anatomy: focuses on the body by regions. For example, the topographic anatomy of the neck involves the detailed examination of the structures and tissues in the neck region.

surface anatomy: examines the anatomical features of structures visible on the body’s surface. Surface anatomy is significant because the structures on the surface generally occupy the same location and maintain similar relationships in every individual. Using the surface as a guide, deeper structures can be accessed based on the knowledge provided by surface anatomy.

systemic anatomy: studies the structures of the body as separate systems, such as the circulatory, respiratory, excretory, and endocrine systems.

clinical anatomy: a sub-discipline that evaluates the condition of anatomical structures and the changes that occur in various clinical situations.

radiological anatomy: assesses the relationships between structures through images obtained using different radiological methods.

neuroanatomy: examines the structures and connections of the nervous system.

What is the Anatomical Position?

The anatomical position is the standard position used in all descriptions and applications related to the human body (Figure 1.1).

In this position:

The person stands upright with their head held straight and facing forward. The arms are positioned at the sides, with the palms facing forward. The lower limbs are parallel to each other, and the feet are slightly apart. All descriptions of structures, such as anterior-posterior, superior-inferior, and medial-lateral, are based on their arrangement in the anatomical position described above.

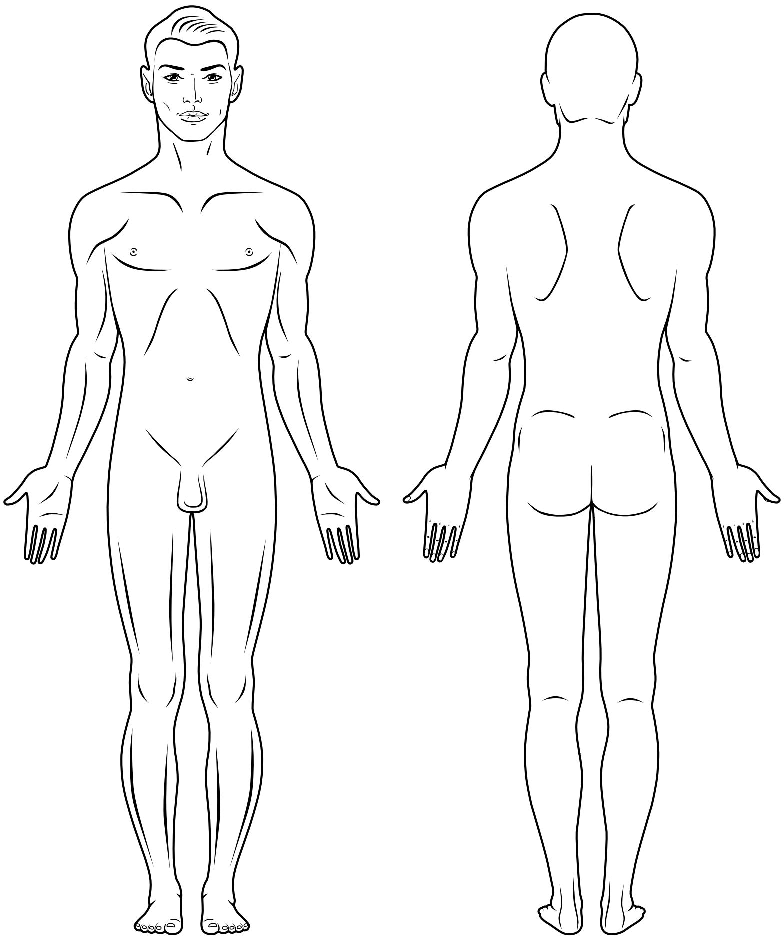


Figure 1.1 Anatomical position.

What are the anatomical planes?

In anatomy, descriptions are made using three imaginary planes that are perpendicular to each other. These are the **sagittal**, **coronal**, and **horizontal** planes (Figure 1.2).

Sagittal plane: A vertical plane that runs from top to bottom and front to back, dividing the body into right and left halves.

Coronal plane: A vertical plane that runs from top to bottom and side to side, dividing the body into front (anterior) and back (posterior) halves.

Horizontal (transverse) plane: A plane that runs parallel to the ground, dividing the body into upper (superior) and lower (inferior) parts.

With today's advanced imaging technologies, images can be obtained in these three planes, allowing for the evaluation of both normal and pathological anatomy.

There are also three axes corresponding to these planes: the **sagittal**, **coronal**, and **horizontal axes**. All bodily movements occur around one of these axes, depending on the characteristics of the joint involved.

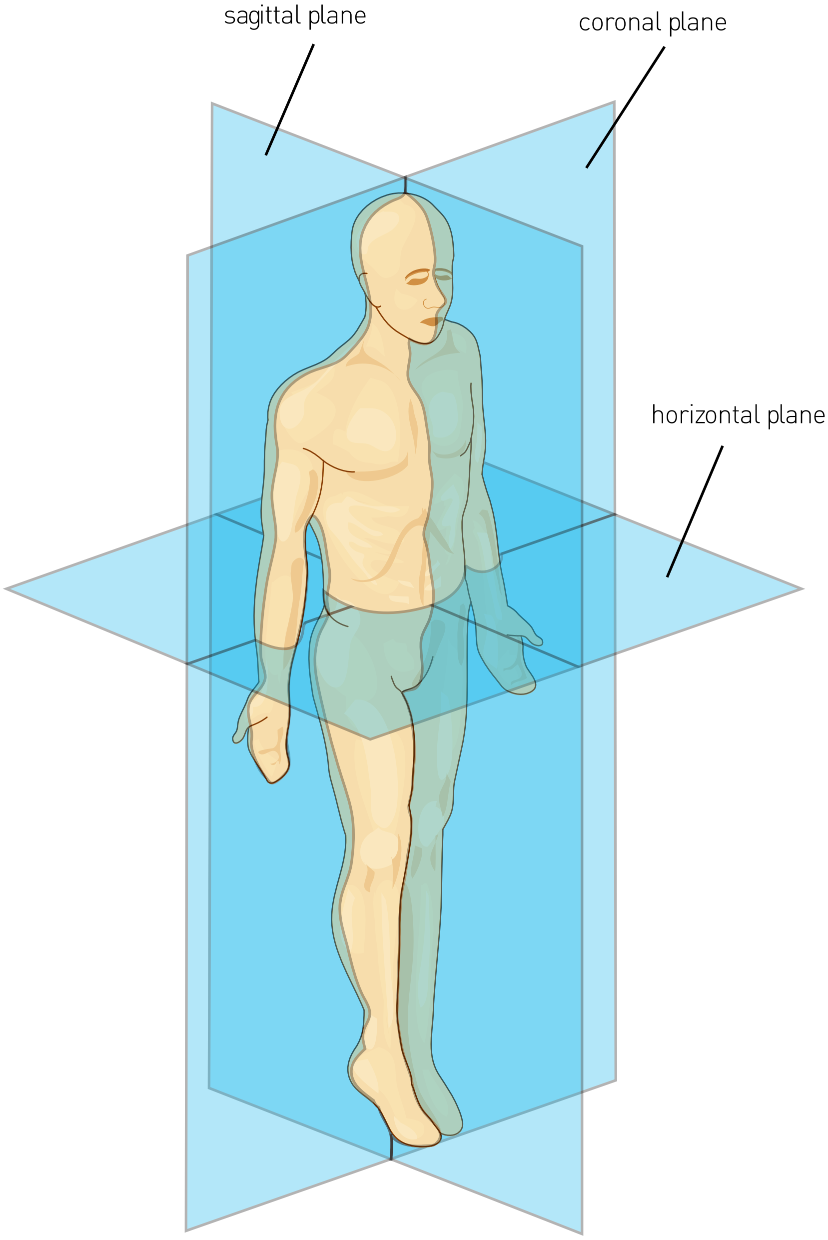


Figure 1.2. Anatomical planes.

CLINICAL RELEVANCE

The anatomical position is crucial in radiological imaging techniques because it provides a standardized reference point that ensures consistency and clarity when interpreting medical images. Anatomical position allows healthcare professionals to accurately describe and locate anatomical structures in relation to one another, regardless of the patient's actual positioning during imaging. By using the anatomical position as a reference, radiologists can avoid confusion and ensure precise communication of findings, whether in X-rays, CT scans, or MRIs. This consistency is essential for accurate diagnosis, treatment planning, and comparison of images over time.

Computed Tomography (CT) is a diagnostic imaging technique that uses X-rays and computer processing to create detailed cross-sectional images of the body. Unlike traditional X-rays, which produce a single image, CT scans generate multiple slices or "cuts" through the body, allowing for a more comprehensive view of internal structures. These images can be stacked to create 3D representations, offering detailed insights into organs, bones, and tissues. CT is commonly used to diagnose conditions such as tumors, infections, and internal injuries, providing faster and more accurate results than conventional imaging methods.

Magnetic Resonance Imaging (MRI) is a non-invasive imaging technique that uses strong magnetic fields and radio waves to create detailed images of internal structures within the body. Unlike X-rays or CT scans, MRI does not use ionizing radiation. It is particularly useful for visualizing soft tissues, such as the brain, muscles, and organs, with high clarity. MRI scans generate detailed cross-sectional images that can be used to diagnose a wide range of conditions, including brain disorders, joint injuries, and spinal problems.

FREQUENTLY USED TERMS AND ABBREVIATIONS IN ANATOMY

Frequently used terms:

Term	Meaning
angulus	angle, corner
apertura	aperture, opening
aponeurosis	the termination form of flat and thin muscles, flat tendon
arcus	arch, bow
caput	head
cauda	tail
cavum, cavitas	cavity
collum	neck
corpus	body, shaft
ductus	duct or tube
facies	face, surface
fascia	flat, thin tissue in the form of a sheet
foramen	hole
fossa	pit
plica	fold
incisura	notch
processus	process, protrusion
ramus	branch
recessus	recess, pouch
regio	region
septum	partition
sinus	sinus, cavity
spina	spine, sharp, spine-like projection
sulcus	groove
tuber, tuberculum	tubercle, bump, small bump
tuberositas	tuberosity, roughened area

Frequently used Abbreviations:

Abbreviation	Latin	English
a.	arteria	artery
aa.	arteriae	arteries
v.	vena	vein
vv.	venae	veins
n.	nervus	nerve
nn.	nervi	nerves
r.	ramus	branch
rr.	rami	branches
lig.	ligamentum	ligament
ligg.	ligamenta	ligaments
m.	musculus	muscle
mm.	musculi	muscles
art.	articulatio	joint
artt.	articulationes	joints
gl.	glandula	gland
gll.	glandulae	glands
proc.	processus	protrusion
gang.	ganglion	cluster of nerve cell bodies
ext.	externa	external
int.	interna	internal
dext.	dextra	right (on the right)
sin.	sinistra	left (on the left)

Terms indicating shape and size:

Latin	English
major	large
minor	small
maximus	the largest
minimus	the smallest
longus	long
brevis	short
semi	half
triangularis	triangular-shaped
quadrangularis	quadrangular-shaped
biceps	two-headed
triceps	three-headed
quadriceps	four-headed

Terms indicating location and direction:

Term	Meaning
superior	related to the upper part, above
inferior	related to the lower part, below
anterior (ventralis)	related to the front part, in front (on the belly side)
posterior (dorsalis)	related to the back part, behind (on the back side)
medialis	toward the inner side or midline
lateralis	toward the outer side
medianus	located on the midline
cranialis	related to the head, toward the head
caudalis	related to the tail, toward the tail
internus	internal, located inside
externus	external, located outside
superficialis	superficial, positioned near the surface
profundus	positioned deep, far from the surface
dexter	right
sinister	left
proximalis	closer to the body or point of origin
distalis	farther from the body or point of origin

Commonly used terms related to movements:

Term	Meaning
flexion	bending, decreasing the angle
extension	stretching, lengthening, increasing the angle
abduction	movement away from the midline around the sagittal axis
adduction	movement toward the midline around the sagittal axis
rotation	turning around the vertical axis
circumduction	circular movement performed by combining the above motions
supination	rotation of the hand and forearm to turn the palm forward (anteriorly)
pronation	rotation of the hand and forearm to turn the palm backward (posteriorly)
inversion	turning the sole of the foot inward
eversion	turning the sole of the foot outward
opposition	bringing the thumb closer to the other fingers
reposition	returning the thumb from the opposition position back to the anatomical position

INTRODUCTION TO THE MUSCULOSKELETAL SYSTEM

INTRODUCTION TO THE MUSCULOSKELETAL SYSTEM

STRUCTURES THAT MAKE UP THE SKELETAL SYSTEM

The skeletal system is composed of bone and cartilage tissues. Bones are structures that protect organs, produce blood cells, and store various minerals. Additionally, they serve as attachment points for muscles, enabling movement through muscle contraction.

How many parts does the skeleton have?

The skeleton is divided into two main parts:

axial skeleton: consists of the bones of the head, neck, and trunk.

appendicular skeleton: consists of the bones of the upper and lower limbs, which are attached to the axial skeleton (Figure 2.1).

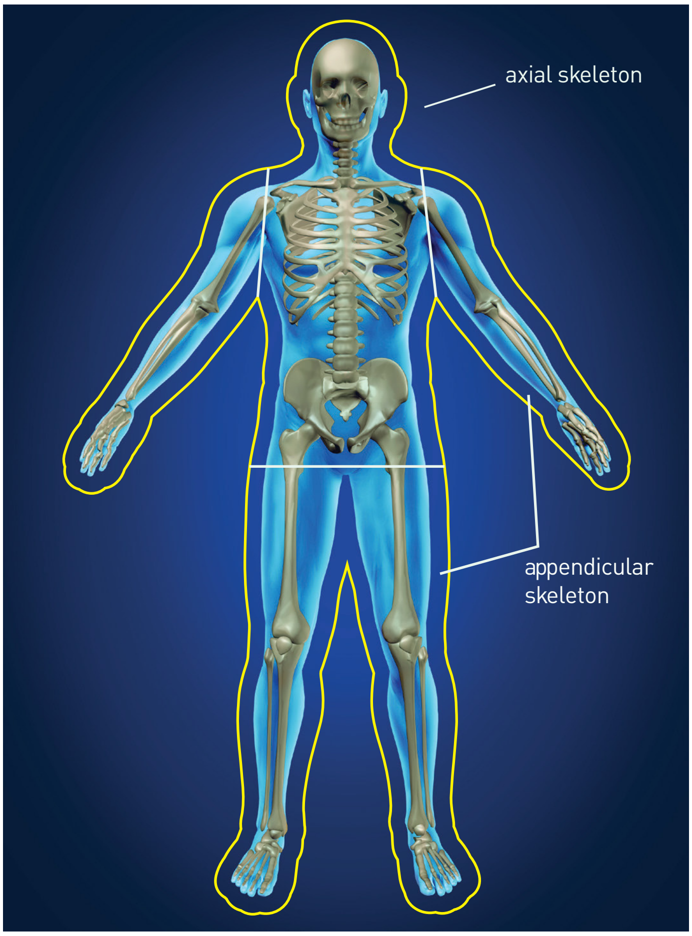


Figure 2.1. Axial and appendicular skeleton.

What is the structure of a bone?

The outer part of a bone is called the **compact portion**, while the inner spongy part is referred to as the **spongy portion**. The cavity inside the spongy portion is known as the **medullary cavity**, which contains bone marrow (Figure 2.2). The outer surface of the bone is covered by a connective tissue layer called the **periosteum** (Figure 2.2).

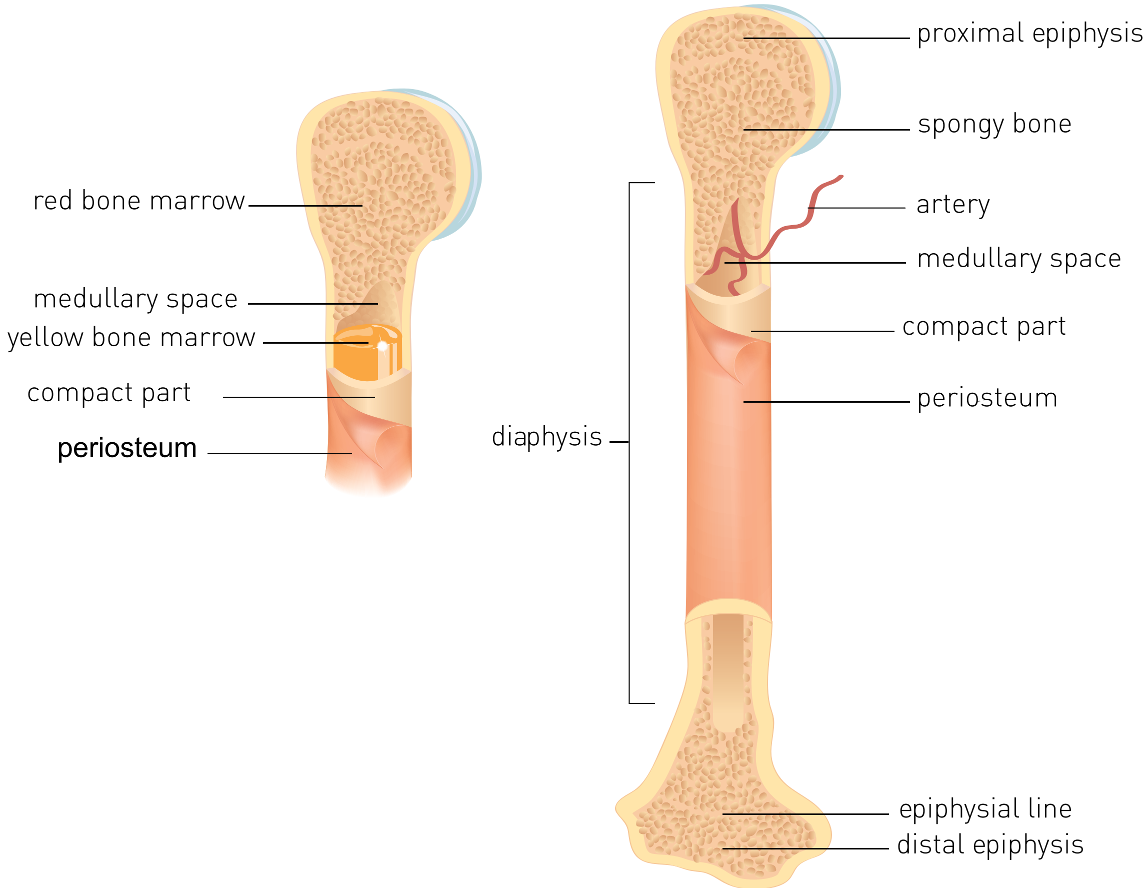


Figure 2.2. Structure of bone.

How are bones classified?

Bones are classified into four types based on their shape:

long bones

short bones

flat bones

irregular-shaped bones

Long bones: These are thin and elongated bones found in areas such as the arms and legs.

The shaft is called the **diaphysis**. Each end is called an **epiphysis**. The **epiphysis** is the region where the bone grows lengthwise, and the newly formed bone area in this zone is known as the **metaphysis**.

Short bones: These bones are located in the hands and feet.

Flat bones: Examples include the bones of the skull, ribs, and scapula (shoulder blade). These bones consist of a spongy tissue layer sandwiched between compact bone layers on the top and bottom.

Irregular-shaped bones: These are bones that do not fit into the other categories. Examples include the vertebrae and hip bones.

What is a sesamoid bone?

Sesamoid bones are small bones embedded within tendons or joint capsules. They are primarily found in the extremities. The largest sesamoid bone is the **patella**, located within the tendon on the front of the knee.

Commonly Used Latin Terms Related to Bones

Term	Meaning
os	bone
margo	margin, edge
foramen	hole
angulus	angle, corner
canalis	canal
fossa	pit
sulcus	groove
incisura	notch
spina	spine-like projection
processus	prominent extension
tuberositas	rough, elevated surface
tuberculum	small bump
fissura	fissure, crack
crista	ridge-like projection
linea	line
caput	head
collum	neck
corpus	body, shaft

CLINICAL RELEVANCE

Osteoporosis is a condition characterized by weakened bones that are more susceptible to fractures. It occurs when the body loses too much bone mass or doesn't produce enough new bone, leading to a decrease in bone density and strength. Commonly affecting older adults, particularly postmenopausal women, osteoporosis often develops without symptoms until a fracture occurs. It most commonly affects the spine, hips, and wrists. Risk factors include age, family history, low calcium intake, lack of physical activity, and certain medications. Preventive measures like a calcium-rich diet, weight-bearing exercise, and medications can help manage or slow the progression of osteoporosis.

What is a cartilage?

Cartilage is a durable yet flexible connective tissue. It covers the surfaces of bones that form joints and provides a smooth surface for movement.

THE JOINT SYSTEM

What is a joint?

A joint is the site where bones come together and are securely connected.

What are the types of joints?

Joints are classified into three types:

fibrous (immovable) joints: joints that have no movement or very limited movement, which is hard to observe. An example for this type of joint is the one between a tooth and its socket.

cartilaginous (slightly movable) joints: joints where only limited movement is possible. An example for this type of joint is the one between the discs and vertebrae in the spine.

synovial (freely movable) joints: joints that allow various movements in different axes.

What are the types of freely movable (synovial) joints?

Synovial joint types are named according to the shape of the bone surfaces that form the joint and are divided into the following types (Figure 2.3):

plane joint: A joint between two flat surfaces of bones where the surfaces can slide over each other, for example; the joints between the carpal bones.

hinge (trochlear) joint: A joint where one bone surface is shaped like a pulley and the other bone surface fits into it. In this type of joint, only flexion and extension movements are possible, for example; the elbow joint between the humerus and ulna, and the finger joints.

pivot joint: This type of joint has a vertical axis, with one bone surface being cylindrical and the other concave to fit into it. Rotational movement is possible in such joints, for example; the part of the elbow joint between the radius and ulna.

ellipsoid (oval) joint: One bone surface has an oval (elliptical) convex shape, and the other has an oval concave surface. Both flexion-extension and abduction-adduction movements are possible in this type of joint, for example; the wrist joint.

saddle joint: Both bone surfaces are shaped like a horse's saddle. In this type of joint, both flexion-extension and abduction-adduction movements are possible, for example; the carpometacarpal joint of the thumb.

ball-and-socket (spheroid) joint: One bone surface is spherical, and the other has a slightly concave surface that fits into it. This type of joint allows all six movements in three axes, and circumduction (circular motion), for example; the hip and shoulder joints.

CLINICAL RELEVANCE

Arthroscopy is a minimally invasive surgical procedure used to diagnose and treat joint problems. A small camera called an arthroscope is inserted into the joint through tiny incisions, allowing the surgeon to view the inside of the joint on a monitor. This technique is commonly used for joints like the knee, shoulder, and wrist to treat conditions such as torn cartilage, ligament damage, or arthritis. Arthroscopy typically requires smaller incisions, reduces recovery time, and causes less post-operative pain compared to traditional open surgery.

Commonly Used Latin Terms Related to Joints

Term	Meaning
articulatio	joint
facies	facet, joint surface
cartilago	cartilage
ligamentum	ligament
cavum, cavitas	cavity

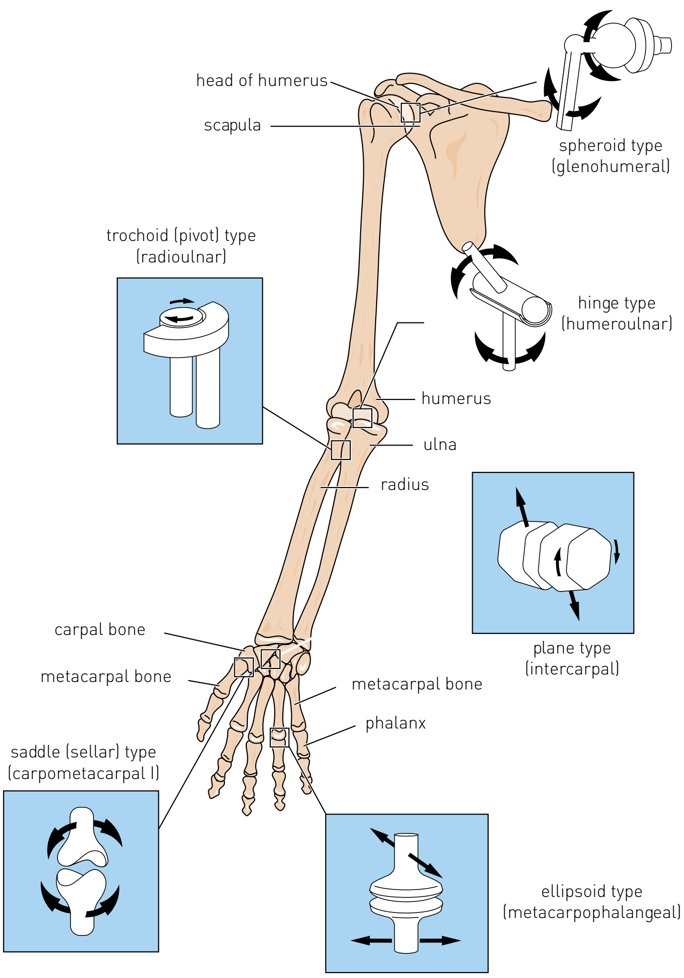


Figure 2.3. Types of movable (synovial) joints.

What are the common features of synovial (freely movable) joints?

All synovial joints have some common features (Figure 2.4). These are:

joint capsule: A strong sheath that holds the bones together in the joint.
joint cavity: The space within the joint that is enclosed by the joint capsule.
articular cartilage: The cartilage that covers the bone surfaces inside the joint.
synovial membrane: The membrane that lines the inner surface of the joint capsule and secretes synovial fluid.
synovial fluid: The fluid found in the joint cavity that allows for smooth and frictionless movement of the bone surfaces.
ligament: The connective tissue that strengthens and stabilizes the joint.

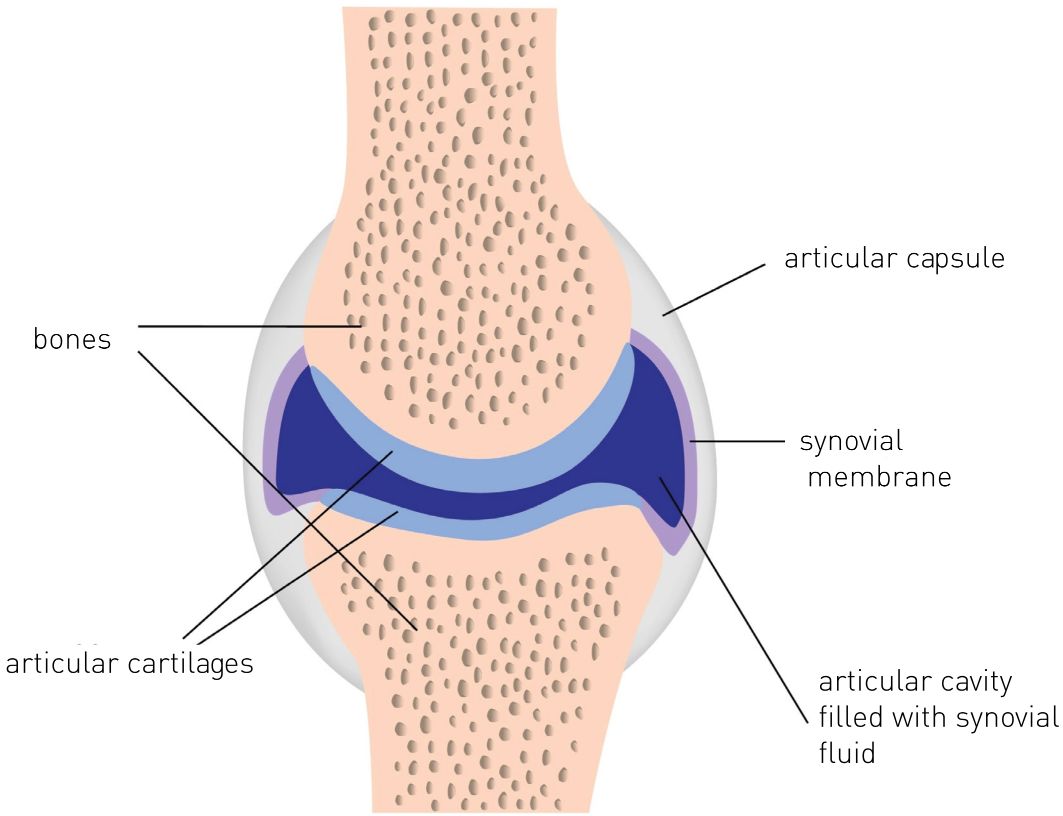


Figure 2.4. Common features of movable (synovial) joints.

In addition to these, some joints may have **internal ligaments**, or cartilage structures called **discus** or **meniscus** that increase the alignment between the joint surfaces.

What is the ligament?

A **ligament** is a strong band of connective tissue that connects bones to other bones at a joint, providing stability and helping to control the range of motion. Ligaments are composed mainly of collagen fibers, which give them strength and flexibility. They play a crucial role in preventing excessive movement that could lead to injury, while still allowing normal joint movement.

Ligaments are not just found around joints; they also play an important role in supporting internal organs. These ligaments are typically made of fibrous tissue and serve to hold organs in place, support their structure, and help prevent excessive movement. Some examples of ligaments around internal organs are: falciform, coronary, and triangular ligaments of liver, round and broad ligaments of the uterus, and gastrocolic and gastrosplenic ligaments of the stomach. These ligaments serve vital roles in maintaining the correct position and function of internal organs.

What is the bursa?

A **bursa** is a small, synovial fluid-filled sac found near joints. Its main function is to reduce friction and cushion pressure points between the bones and tendons or muscles around the joints. This helps make movements smoother and prevents damage to the tissues. Bursae are especially common in areas where movement and pressure are frequent, like the shoulders, elbows, and knees.

MUSCLE SYSTEM

Muscles are structures formed by specialized cells called muscle fibers that perform movement as a result of nerve stimulation. They are covered by a membrane called **fascia**. Fascia has two layers: the **superficial fascia**, which is made of fat and loose connective tissue and contains superficial blood vessels and nerves, and the **deep fascia**, which tightly surrounds the muscles to give their form and separates them from other muscles and the surrounding tissues.

What are the types of muscles?

There are three types of muscles in humans:

skeletal muscle (striated muscle): named for its microscopic striped appearance due to filaments called actin and myosin. This type of muscle cells has multiple nuclei. They are responsible for voluntary skeletal movements.

cardiac muscle: these muscles have a microscopic appearance similar to skeletal muscles but are controlled by the autonomic nervous system. The majority of the heart's structure consists of this muscle type.

smooth muscle (non-striated muscle): found in the walls of hollow (luminal) organs and blood vessels. They are controlled by the autonomic nervous system and operate involuntarily. They have single cell nucleus.

Commonly Used Latin Terms Related to Muscles

Term	Meaning
musculus	muscle
pars	part, section
venter	belly
tendo	tendon, muscle tendon
origo	origin of the muscle on the bone
insertio	insertion of the muscle on the bone
fascia	connective tissue covering muscles
septum	partition
aponeurosis	flat tendon, a flat and thin muscle attachment

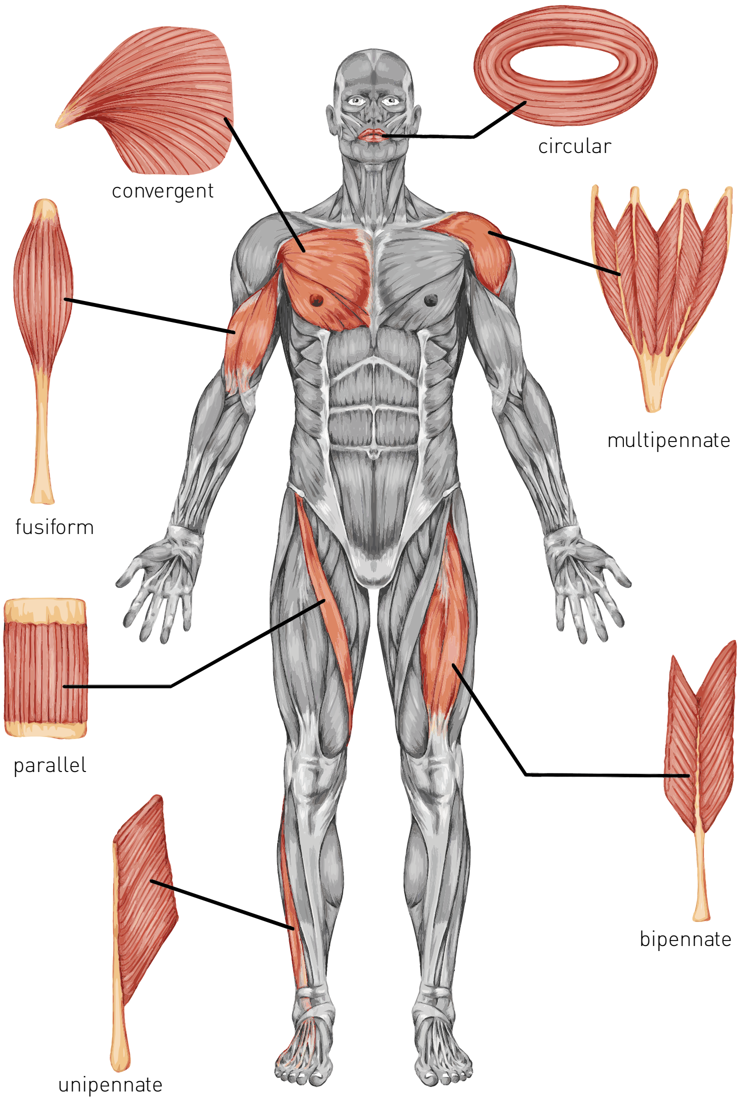


Figure 2.5. Skeletal muscle (striated muscle) types.

What are the general characteristics of skeletal muscles?

The fibers that make up skeletal muscles can appear in different types, which can sometimes influence the naming of the muscle (Figure 2.5). Some muscles are named based on their location or the movement they produce.

What are the sections of a skeletal muscle?

Skeletal muscles can be divided into the following sections:

Belly: the middle, body portion of the muscle where the muscle fibers are located.

Tendon: the part of the muscle consisting of dense connective tissue usually at the ends. Sometimes both ends of the muscle are tendons, but usually only one end is a tendon. Additionally, in some muscles (e.g., abdominal muscles), instead of forming tendons, the fibers may become thin and flat, forming an aponeurosis, which attaches to a broad area.

What do origin and insertion mean?

Origin: the origin of the muscle, typically the attachment point on the proximal bone, often described as the stationary part during movement.

Insertion: the insertion of the muscle, typically the attachment point on the distal bone, often described as the moving part during contraction.

What happens when a muscle contracts?

When a skeletal muscle contracts, its length shortens while its thickness increases, the origin and insertion points move closer to each other and the distance between them decreases, resulting in movement (Figure 2.6).

CLINICAL RELEVANCE

Electromyography (EMG) is a diagnostic procedure that measures the electrical activity of muscles at rest and during contraction. By using small electrodes placed on the skin or inserted into the muscle, EMG records electrical signals that reflect muscle function. It is commonly used to diagnose neuromuscular disorders, such as muscular dystrophy, nerve compression, or carpal tunnel syndrome, and to assess muscle weakness, spasms, or abnormal muscle activity. EMG helps doctors evaluate the health of muscles and the nerves controlling them.

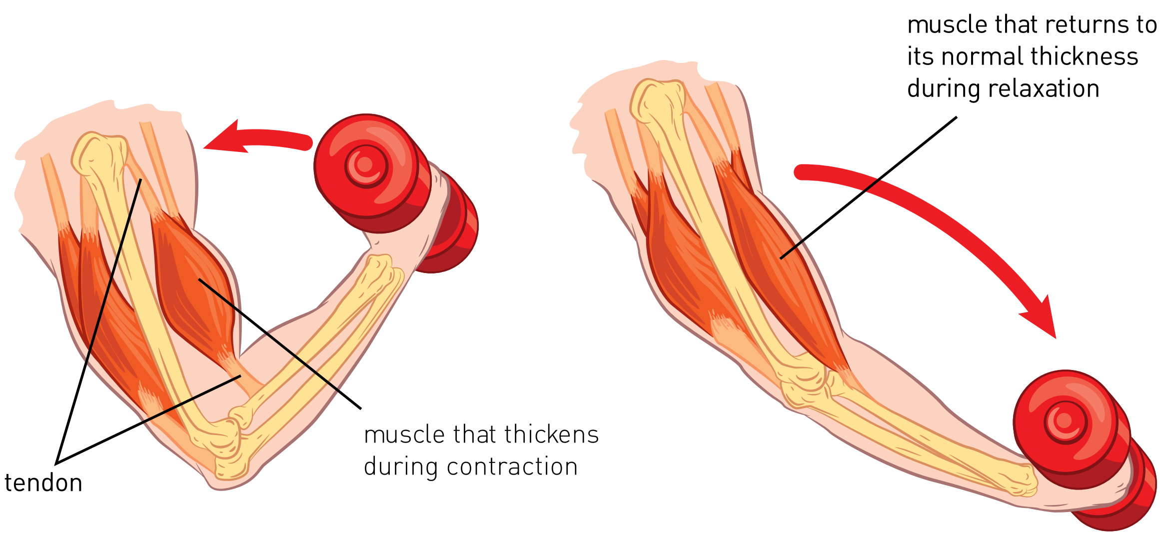


Figure 2.6. Change in the size of the muscle and movement formation as a result of muscle contraction.

Sample Questions about the Definitions and Introduction to the Musculoskeletal System

1. Which of the following is a term indicating "shape or size"?

   a) Superior
   b) Caudalis
   c) Longus
   d) Dexter
   e) Medialis

2. Which of the following is a term indicating "location or direction"?

   a) Maximus
   b) Triceps
   c) Brevis
   d) Externus
   e) Minor

3. What is the meaning of the term "cauda"?

   a) Gland
   b) Body
   c) Projection
   d) Tail
   e) Branch

4. What is the Latin equivalent of the term "head"?

   a) Cauda
   b) Corpus
   c) Collum
   d) Caput
   e) Cervix

5. Which of the following term definitions is correct?

   a) Profundus: located deep
   b) Proximalis: located far from the body or origin
   c) Dorsalis: related to the front side
   d) Abduction: moving towards the midline
   e) Extension: bending, reducing the angle

6. Which of the following is not a structure observed in bones?

   a) Processus
   b) Foramen
   c) Crista
   d) Spina
   e) Aponeurosis

7. Which of the following structures lines the surface of the bone?

   a) Diaphysis
   b) Metaphysis
   c) Epiphysis
   d) Medulla
   e) Periosteum

8. Which of the following is **not** observed in all synovial joints?

   a) Articular capsule
   b) Meniscus
   c) Synovia
   d) Articular cavity
   e) Synovial membrane

9. Which of the following joint types allows only rotational movement?

   a) Plane
   b) Ellipsoid
   c) Trochoid
   d) Spheroid
   e) Hinge

10. Which of the following structures surrounds and separates muscles into superficial and deep layers?

   a) Fascia
   b) Aponeurosis
   c) Head
   d) Tendon
   e) Septum

Answers: 1.C, 2. D, 3.B, 4.D, 5.A, 6.E, 7.E, 8.B, 9.C, 10.A

UPPER EXTREMITY

UPPER EXTREMITY

The **upper extremity** is an extension separated from the upper part of the trunk. It is a highly mobile region with sensitive and precise skills, consisting of the shoulder, arm, forearm, and hand regions.

BONES

What are the bones of the upper extremity?
The bones of the upper extremity are composed of:

Scapula and **Clavicle** in the shoulder region
Humerus in the arm
Radius and **Ulna** in the forearm
Carpal bones in the wrist
Metacarpal bones and **Phalanges (finger bones)** in the hand.

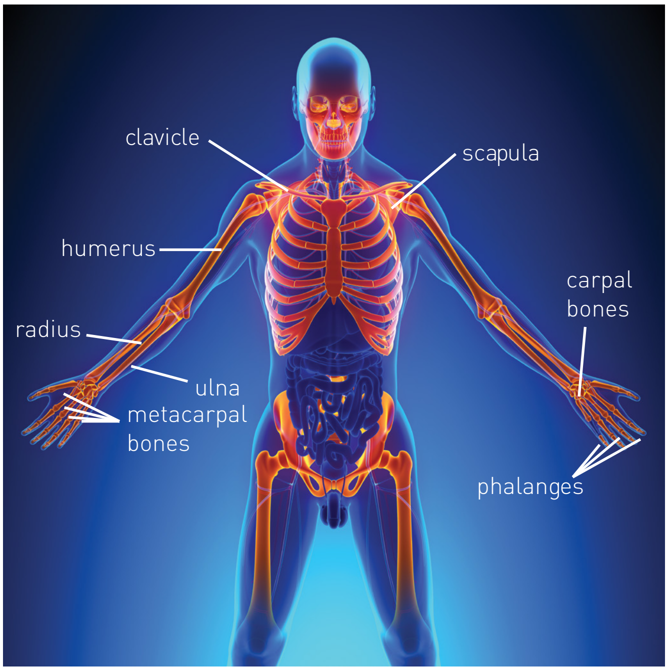


Figure 3.1. Upper extremity bones.

Shoulder Region Bones

Scapula (Shoulder Blade) The scapula is a flat, triangular-shaped bone with <u>three borders</u> (medial, lateral and upper) and <u>three angles</u> (superior, inferior and lateral) (Figure 3.2.). It has anterior and posterior surfaces; the anterior surface lies against the rib cage. The posterior surface features a prominent projection, the **spine**, which can be felt under the skin as it extends obliquely from the back towards the shoulder. Below the spine lies the **infraspinous fossa**, and above it, the **supraspinous fossa**, which house the muscles of the same name. The lateral end of the spine expands towards the shoulder and forms the **acromion**, which is easily palpable. Beneath the acromion, at the lateral angle of the scapula, is the slightly concave **glenoid fossa**, where the humerus articulates. Another projection, the **coracoid process**, extends forward from the upper lateral edge of the scapula.

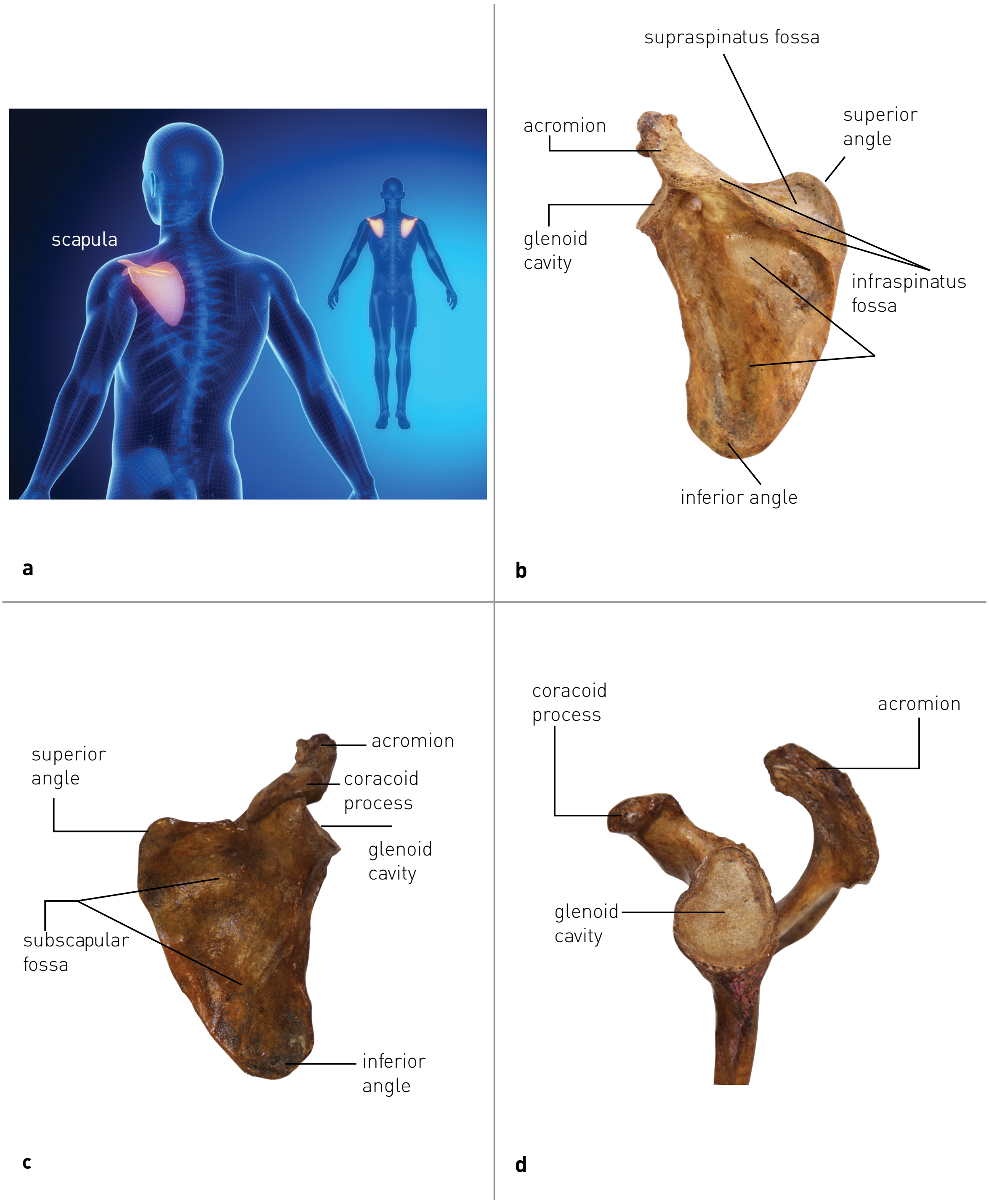
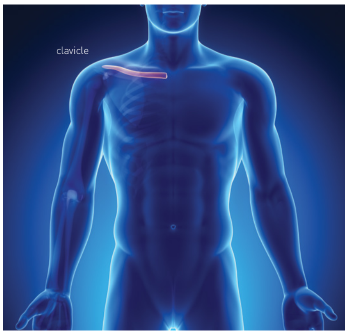


Figure 3.2. Scapula. **a.** location of scapula in the body. **b.** view of the posterior aspect of the scapula. **c.** view of the anterior aspect of the scapula. **d.** upper lateral view of the scapula.

Clavicle (Collarbone) The clavicle is located horizontally at the front and upper part of the chest (Figure 3.3.). It is the bone that connects the arm to the body, and plays a crucial role in supporting shoulder movement. It articulates medially with the sternum with its **sternal end** and laterally with the acromion of the scapula with its **acromial end**. Its medial portion curves forward, while the lateral part curves backward. The clavicle is prone to fracture because it is the last bone to ossify and is quite superficial.



b

c

Figure 3.3. Clavicle (collarbone). **a.** location of clavicle in the body. **b.** superior view of the clavicle. **c.** inferior view of the clavicle.

CLINICAL RELEVANCE

A **clavicle fracture** often occurs due to falls, especially onto an outstretched hand, or from high-impact sports like football, skiing, or cycling. It can also happen in car accidents. Symptoms of a clavicle fracture include pain, swelling, and bruising around the collarbone area. The shoulder may appear deformed or "bent," and there may be difficulty moving the arm, especially when lifting it. A grinding or popping sensation may be felt in the shoulder when moving it. In most cases, clavicle fractures can be treated without surgery. However, more severe fractures may require surgical intervention. The healing time for a clavicle fracture is usually 6 to 8 weeks. With proper treatment, most people recover fully from a clavicle fracture and return to their normal activities.

Humerus The humerus is the single bone of the arm (Figurre 3.4.). The proximal end features a rounded **head**, which articulates with the glenoid fossa of the scapula. Head is continuous with the **anatomical neck**. Below the anatomical neck there are two prominences: the one behind and lateral is the **greater tubercle** and the one at the front and medial is the **lesser tubercle**. Between these two is the **intertubercular sulcus**. Long head of the biceps brachii muscle lies in this groove. A little further down is the narrower **surgical neck** which is a common fracture site. Axillary nerve and circumflex humeral vessels are located here. It is continuous below with the body of the humerus. There is a prominent roughened area on the lateral aspect of the body: **deltoid tuberocity**. On the dorsal aspect of the body is a diagonal groove: **radial groove**. Radial nerve and deep brachial artery lie in this groove. At the distal end, the cylindrical shaped humeral body flattens to form two ridges on each side: **lateral** and **medial supracondylar ridges**. They extend distally toward the prominent **medial** and **lateral epicondyles**, with the medial one being easily palpable at the elbow. On the anterior surface, there are bony structures involved in the elbow joint: medially, the spool-shaped **trochlea**, and laterally, the spherical **capitulum**. There is a pit above the trochlea: **coronoid fossa**, and another one above the capitulum: **radial fossa**. On the posterior surface of the distal end of the humerus, there is a large concave area: the **olecranon fossa**.

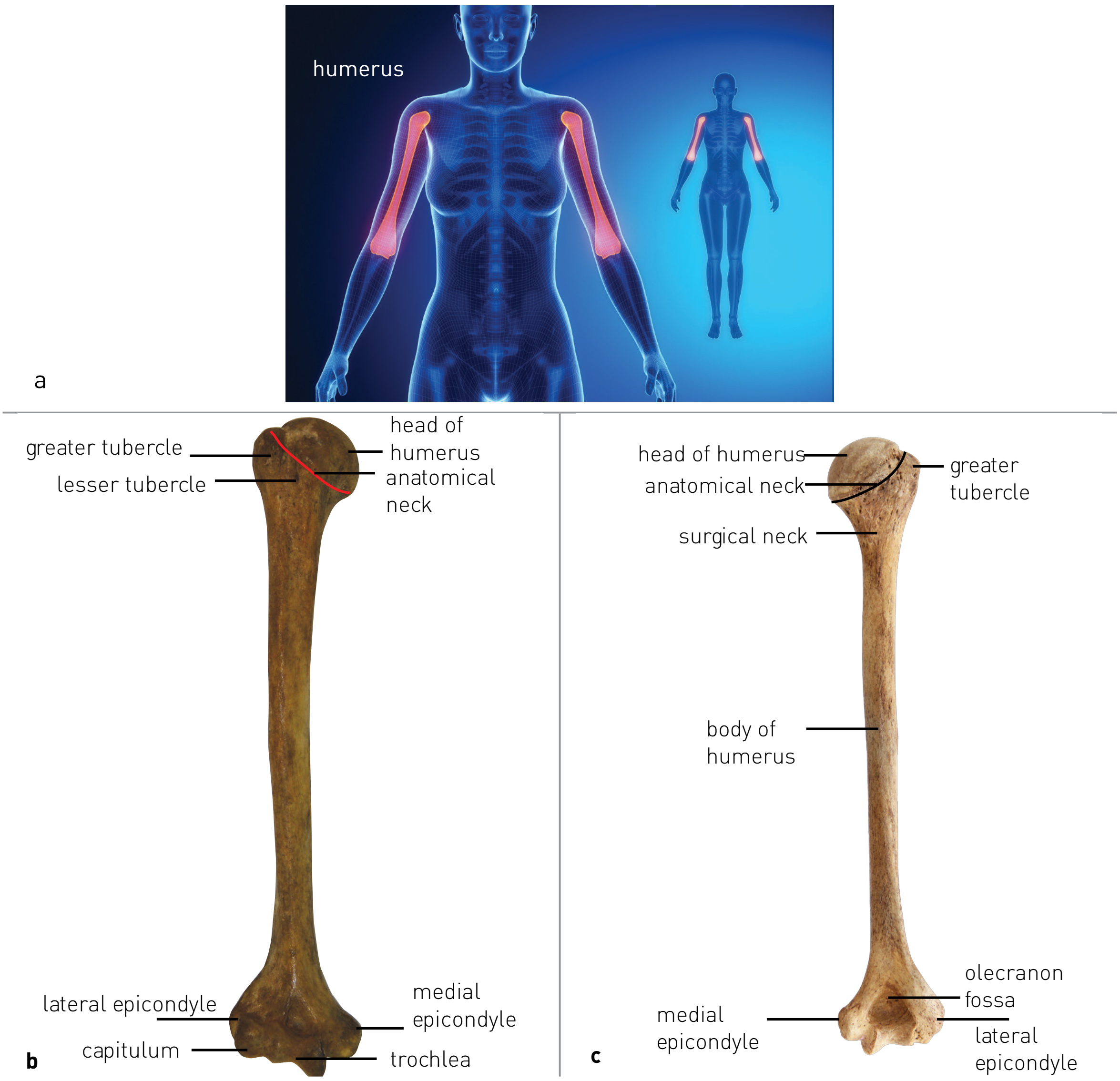


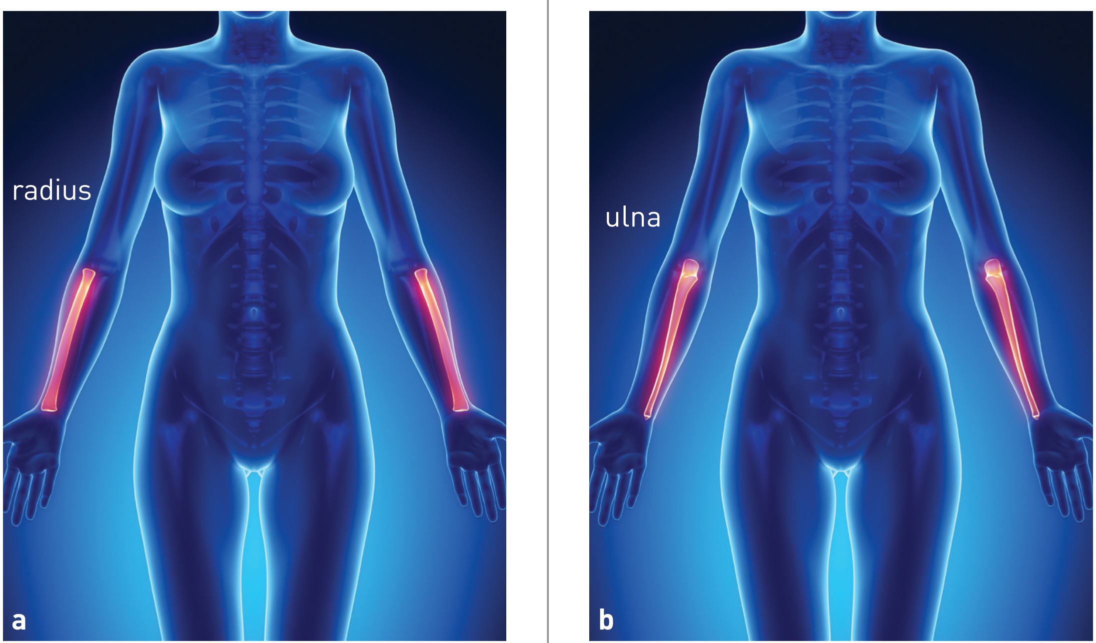
Figure 3.4. Humerus. **a.** location of humerus in the body. **b.** anterior view of the humerus. **c.** posterior view of the humerus.

Radius The radius is located laterally in the forearm. Its proximal end, thinner than the distal, contains the **head**. Below the head, featuring a roughened area: **radial tuberosity**. The body is long, triangular in shape with three borders. Medial border is thin and sharp and is called as the **interosseous border**, others are rough. The distal end has a pointed extension **styloid process**, which is palpable on the wrist's outer side.

CLINICAL RELEVANCE

A **Colles' fracture** is a type of fracture in the distal end of the radius. It typically occurs when a person falls onto an outstretched hand, causing the bone to break and often resulting in a noticeable deformity, with the wrist appearing bent. Symptoms include pain, swelling, bruising, and difficulty moving the wrist. Treatment usually involves immobilizing the wrist with a cast, though severe fractures may require surgery to realign the bones. Recovery generally takes 6-8 weeks, and physical therapy may be needed to regain strength and mobility.

Ulna The ulna lies medially in the forearm and has a thicker proximal end. Proximal end has a posterior projection called the **olecranon**. On the anterior side of the olecranon is the **trochlear notch**, which accommodates the trochlea on humerus. At the tip of the trochlear notch, there is a smaller projection: **coronoid process**. Lateral to the coronoid process, there is another notch to host the radial head: **radial notch**. Ulnar body has three borders, the lateral border is thin and sharp: **interosseus border**. Sharp interosseous borders of both radius and ulna is the site for the interosseous membrane which is located between the radius and ulna to separate the anterior and posterior compartments of the forearm. At the distal end, there is a small and rounded **head** located laterally and a pointed extension **styloid process** located medially, mirrors the one on the radius.



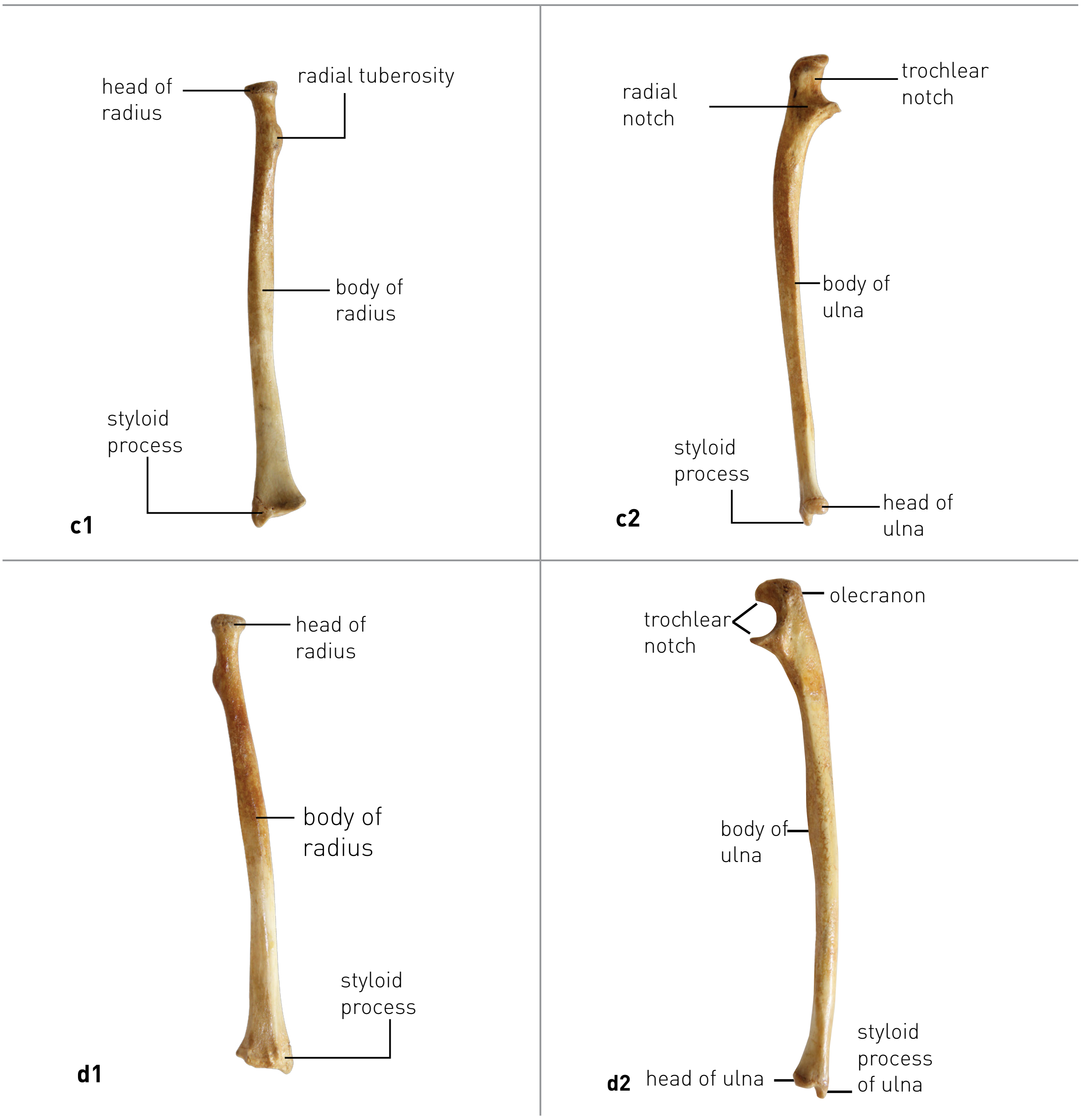


Figure 3.5. Forearm bones; radius and ulna. **a.** location of radius in the body. **b.** location of ulna in the body. **c.** anterior vies of radius (c1) and ulna (c2). **d.** posterior vies of radius (d1) and ulna (d2).

The hand is divided into the following subregions:

Carpal region (wrist area)

Metacarpal region (area of the metacarpal bones)

Phalangeal region (finger area)

The bones of the hand are also divided accordingly into the following subregions:

Carpal Bones (Wrist):

Proximal row (lateral to medial): **scaphoid**, **lunate**, **triquetrum**, **pisiform**

Distal row (lateral to medial): **trapezium**, **trapezoid**, **capitate**, **hamate**

Metacarpal Bones:

These are five elongated bones, numbered from lateral to medial as **metacarpal bone I-V**.

Phalanges (Finger Bones):

There are 14 phalanges in total: 2 in the thumb and 3 in each of the other fingers. These are classified as proximal phalanges, intermediate phalanges, and distal phalanges. (The thumb lacks the intermediate phalanx.)

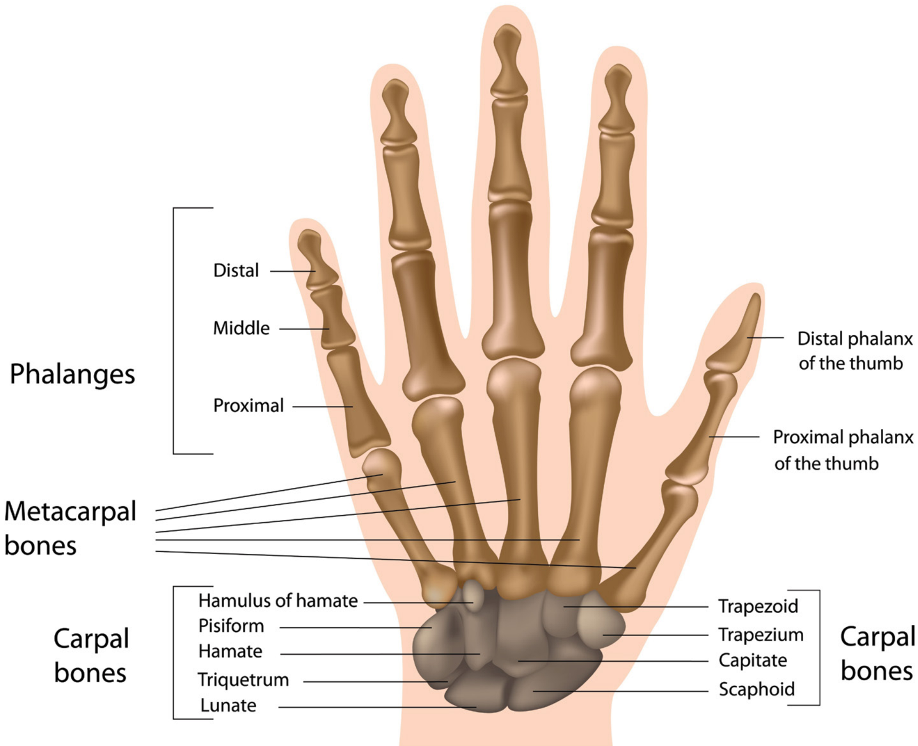


Figure 3.6. Bones of the hand.

JOINTS

What are the joints of the upper extremity?

The joints of the upper extremity include both the joints where the clavicle attaches to the thoracic cage and the joints of the free upper limb extending from the shoulder to the hand. Medially, the clavicle articulates with the sternum at the **sternoclavicular joint**. Laterally, it articulates with the acromion at the **acromioclavicular joint**.

The joints of the **free upper limb** are as follows:

Shoulder joint
Elbow joint
Joints between the radius and ulna
Wrist joint
Joints between the carpals, metacarpals, and phalanges

What are the features of the shoulder joint?

Shoulder joint is the most mobile joint of the body. It is between the glenoid fossa of the scapula and the head of humerus. It also comprises of the **glenoid labrum,** a ring of fibrocartilage that surrounds the glenoid fossa. It acts as a stabilizer, deepening the socket and helping to hold the head of the humerus in place. The labrum provides additional surface area for the attachment of ligaments and tendons, contributing to the overall stability of the shoulder joint.

What are the ligaments of the shoulder joint?

There are three ligaments related with the shoulder joint:

transverse humeral lig.: extends between the tubercles of the humerus and prevents the displacement of the long head of biceps brachii muscle tendon from the intertubercular groove.

coracohumeral lig.: extends between the coracoid process and the humerus and supports the joint superiorly.

glenohumeral lig.: has three parts as the **superior**, **middle** and the **inferior** which are formed by the thickening of the joint capsule to support the joint anteroinferiorly.

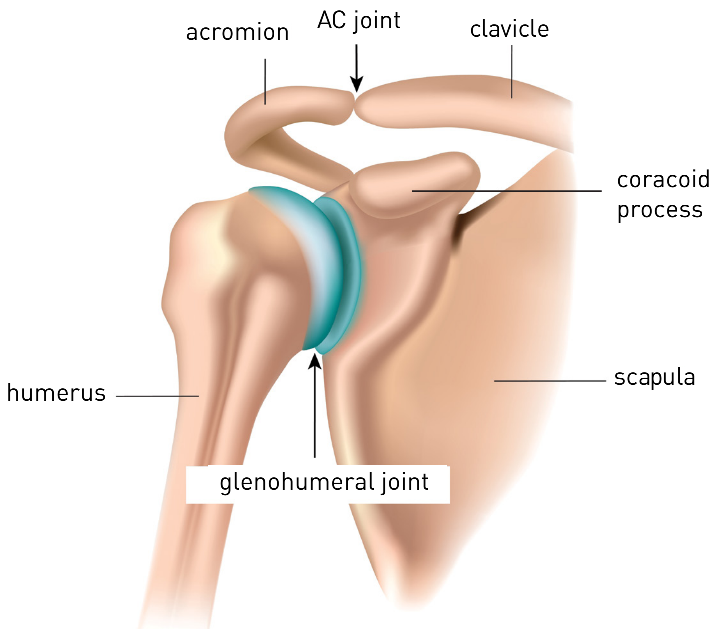


Figure 3.7. Shoulder joint.

What is the type of the shoulder joint and which movements are possible?

Shoulder joint is spheroid type joint, enabling movements like abduction-adduction, flexion-extension, internal and external rotation, and circumduction.

What are the main bursae around shoulder joint?

Main bursae around the shoulder joint are:

subscapular bursa: is located between the subscapularis tendon and the shoulder joint. This bursa is in connection with the shoulder joint cavity, which is quite atypical.
subacromial bursa: is located beneath the acromion and above the supraspinatus tendon.

subdeltoid bursa: is located deep to the deltoid muscle and coraco-acromial arch and above the shoulder joint.
subcoracoid bursa: is located between the coracoid process and the shoulder joint..

CLINICAL RELEVANCE

Shoulder displacement, or **shoulder dislocation**, occurs when the humerus pops out of the glenoid fossa due to trauma, such as a fall or sudden impact. This injury causes severe pain, limited range of motion, and visible deformity in the shoulder area. Treatment typically involves a healthcare professional manually realigning the bones, followed by rest, ice, and physical therapy to regain strength and mobility. In some cases, surgery may be required, especially if there are repeated dislocations or damage to surrounding tissues. Once the shoulder is dislocated, the joint can become more unstable, increasing the likelihood of future dislocations. Repeated dislocations can damage the ligaments, tendons, and cartilage around the shoulder, further compromising its stability.

Bursitis is the inflammation of a bursa. It typically occurs due to repetitive motion, overuse, or injury, leading to pain, swelling, and tenderness around the affected joint. Common areas for bursitis include the shoulder, elbow, and hip. Treatment often involves rest, ice, anti-inflammatory medications, and physical therapy. In more severe cases, corticosteroid injections or drainage of the bursa may be needed.

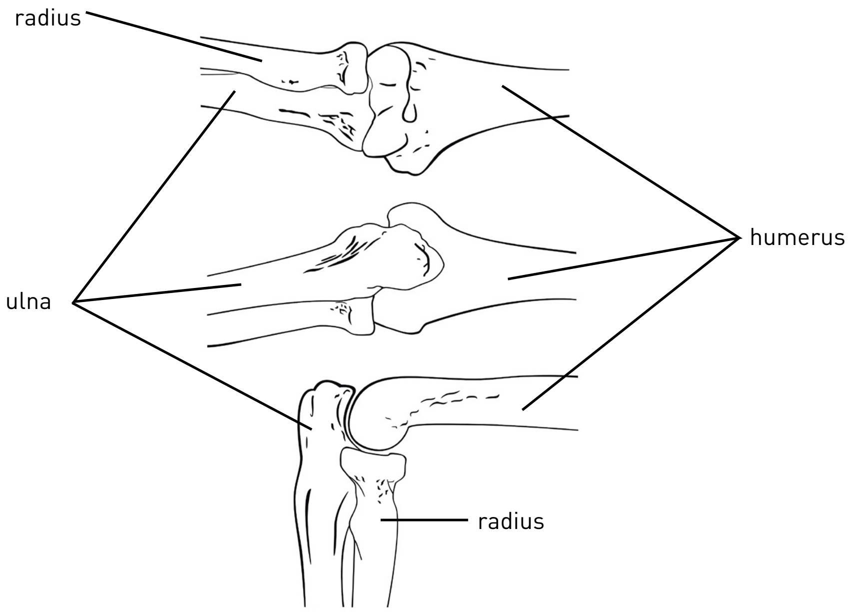


Figure 3.8. Elbow joint. Elbow extension (when straight) anterior view (at the top) and posterior view (in the middle), elbow flexion (when bent) lateral view (at the bottom).

What are the features of the elbow joint?

Elbow joint has two joints between three bones. One is between the capitulum of humerus and the head of radius (humeroradial joint), and the second one is between the trochlea of humerus and trochlear notch of ulna (humero-ulnar joint). Forearm bones radius and ulna are connected to each other at the **proximal** and **distal radio-ulnar joints**. Proximal radio-ulnar joint is between the head of radius and the radial notch of ulna and it is located within the same joint capsule of the elbow joint, as well. The distal radio-ulnar joint is located close to the wrist joint, between the ulnar notch of radius and the head of ulna.

What is the type of the elbow joint and which movements are possible?

The humeroradial and humeroulnar joints together form a hinge type joint, allowing only flexion and extension. The proximal radio-ulnar joint is pivot-type, which enables rotational movements.

What are the ligaments of the elbow joint?

Ligaments related with the elbow joint are

medial collateral ligament
lateral collateral ligament
annular ligament

The elbow joint capsule is strengthened by the collateral ligaments on both sides. Annular ligament is a ring shaped ligament around the head of radius and stabilizes the proximal radio-ulnar joint.

CLINICAL RELEVANCE

Nursemaid's elbow, also known as **pulled elbow**, is a common injury in young children, typically under the age of 5. The injury most commonly occurs in young children because their ligaments are still relatively loose and their bones are not fully developed, making the joint more prone to dislocation with sudden movements. It occurs when the radius slips out of its normal position at the elbow joint, usually due to a sudden pull on the child's arm, like when lifting them by the hand or wrist. The force causes the radial head to slip out from beneath the **annular ligament**, which normally holds the radial head in place. The child may cry out in pain, and their arm may be held in a bent position with limited movement. Treatment involves a healthcare provider gently popping the elbow back into place, which often relieves the pain immediately. With prompt treatment, children usually recover quickly and can move their arm normally again.

What are the features of the wrist joint?

Wrist joint is between the radius and the proximal row of carpal bones (excluding pisiform bone) (Figure 3.9).

Figure 3.9. X-ray image of the wrist joint. Note that only the radius is involved in the joint, and the ulna is distant from the joint.

What is the type of the wrist joint and which movements are possible?

Wrist joint is ellipsoid joint, enabling flexion-extension, abduction-adduction, and circumduction.

What type are the joints between the carpals, metacarpals, and phalanges, and what movements can be performed in these joint?

Within the hand region, there are numerous joints between the **carpal, metacarpal, and phalangeal bones**.

The joints between the carpal bones are generally **plane type**, allowing for slight gliding movements.

The joint between the first metacarpal bone (thumb) and the carpal bones is a **saddle type joint**, permitting flexion-extension and abduction-adduction.

In contrast, the joints between the carpal bones and the 2nd–5th metacarpals are plane type joints, allowing only limited gliding.

The first metacarpophalangeal joint is a hinge joint, permitting only flexion and extension.

The 2nd to 5th metacarpophalangeal joints are **ellipsoid** joints, allowing **f**lexion-extension, abduction-adduction, and circumduction (a combination of these movements).

The interphalangeal joints (between the phalanges) are also hinge type joints, and they permit only flexion and extension movements.

MUSCLES

What are the muscles of the upper extremity?

The muscles of the upper extremity include:

Shoulder muscles

Arm muscles

Forearm muscles

Hand muscles

The shoulder region muscles originate from the scapula and attach to the humerus, crossing the shoulder joint (Figure 3.10a-d). They are involved in arm movements. These muscles, their functions, and the nerves supplying them are given in the table below.

Muscle	Function	Nerve
deltoid m.	abduction of arm	axillary n.
supraspinatus m.	initiates arm abduction	suprascapular n.
infraspinatus m.	lateral rotation of the arm	
subscapularis m.	medial rotation and adduction of the arm	subscapular n.
teres major m.	lateral rotation and adduction of the arm	
teres minor m.	adduction of the arm	axillary n.

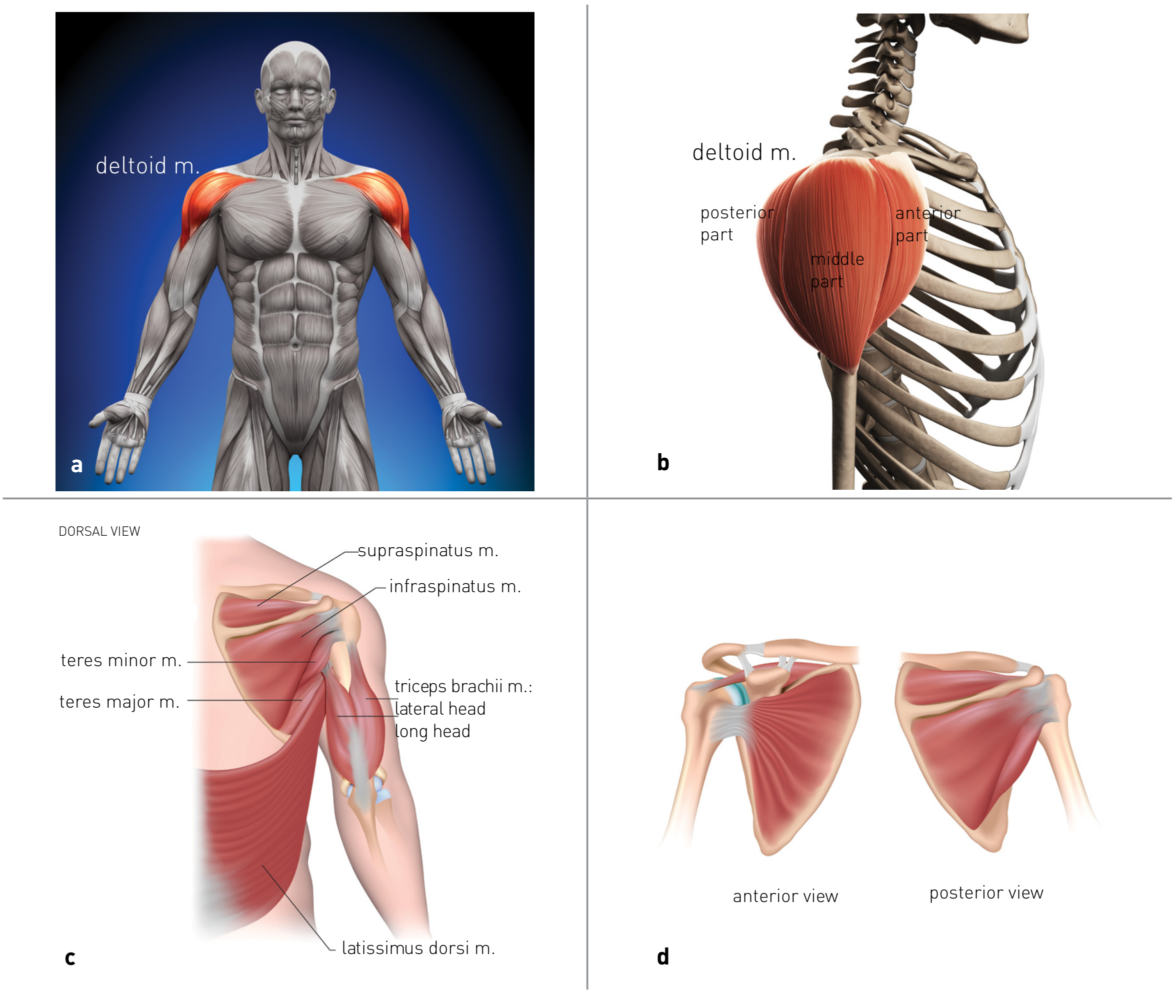


Figure 3.10. Shoulder region muscles. **a.** location of the deltoid m. in the body **b.** lateral view of the deltoid m. **c.** muscles on the back side of the shoulder region. **d.** the subscapularis m., located on the front part of the scapula and supporting the shoulder from the front.

What is the Rotator Cuff (Shoulder Girdle)?

Tendons of several shoulder muscles attach to the capsule of the shoulder joint, forming a strong structure known as the **rotator cuff**, which stabilizes and supports the joint capsule from above, behind, and in front. The muscles that contribute to the cuff are **supraspinatus m.**, **infraspinatus m.**, **subscapularis m.**, and **teres minor m.** While all these muscles, except **supraspinatus m.**, rotate the arm inward or outward, **supraspinatus m.** initiates the abduction of the arm. Because most of these muscles are involved in rotation of the arm, this structure is called the rotator cuff.

The **arm muscles** typically cross the elbow joint and terminate in the forearm, contributing to forearm movements. However, coracobrachialis muscle moves only the arm while biceps brachii muscle moves both the arm and forearm. These muscles, their functions, and the nerves supplying them are given in the table below (Figure 3.11a-e).

Muscle	Function	Nerve
biceps brachii m.	forearm flexion and supination, arm flexion	musculocutaneous n.
brachialis m.	forearm flexion	
coracobrachialis m.	arm flexion and adduction	
triceps brachii m.	forearm extension	radial n.

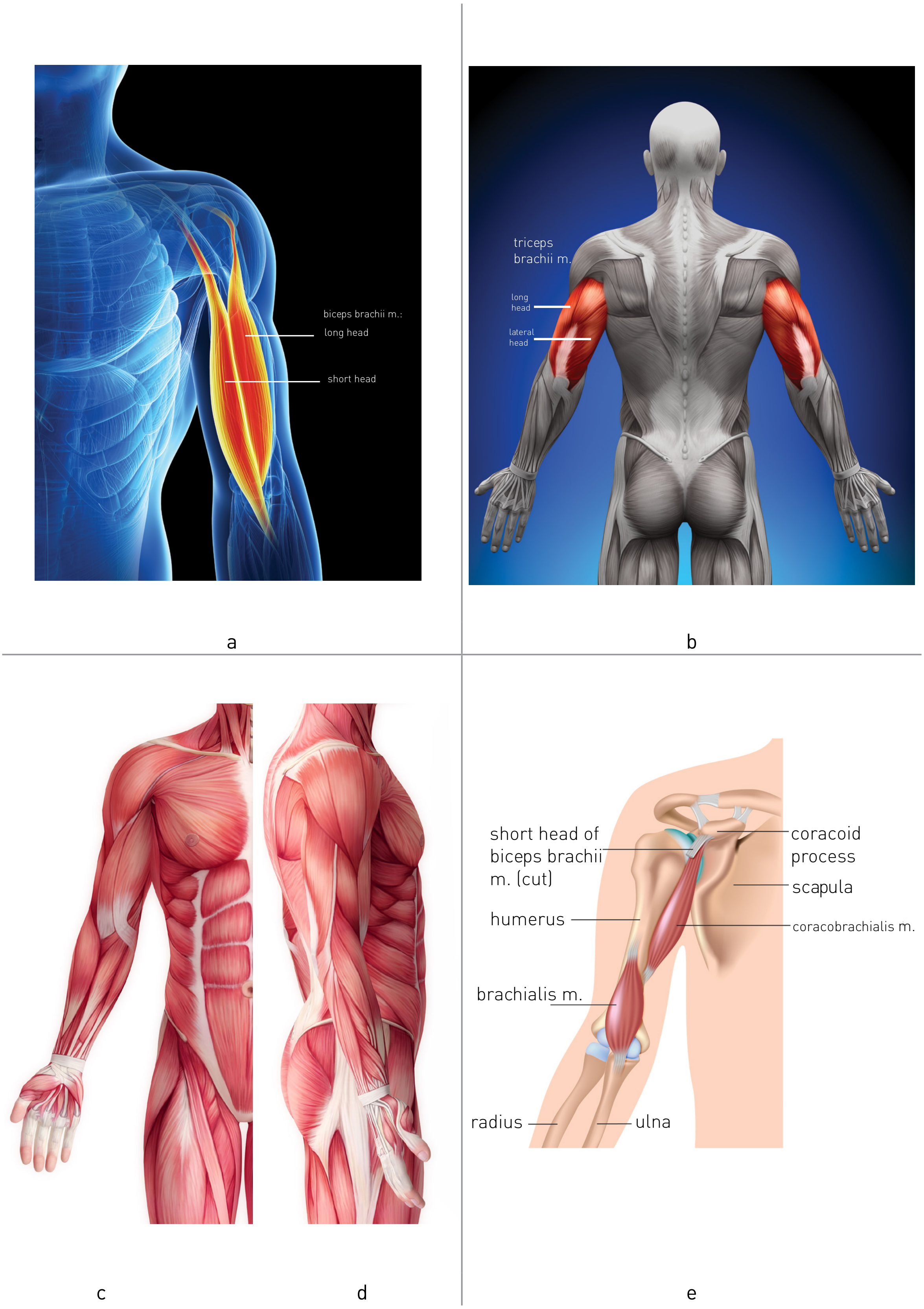


Figure 3.11. Arm muscles. **a.** the location of the biceps brachii m. in the body. **b.** the location of the triceps brachi m. in the body. **c.** anterior view of the biceps brachii m. **d.** lateral view of the biceps brachii m. and triceps brachii m. e. brachialis m. and coracobrachialis m.

The **forearm muscles** are divided into two groups: **anterior** and **posterior** (Figure 3.12). The anterior group muscles usually originate from the **medial epicondyle** and are responsible for wrist flexion. The posterior group muscles usually originate from the **lateral epicondyle** and are responsible for wrist extension.

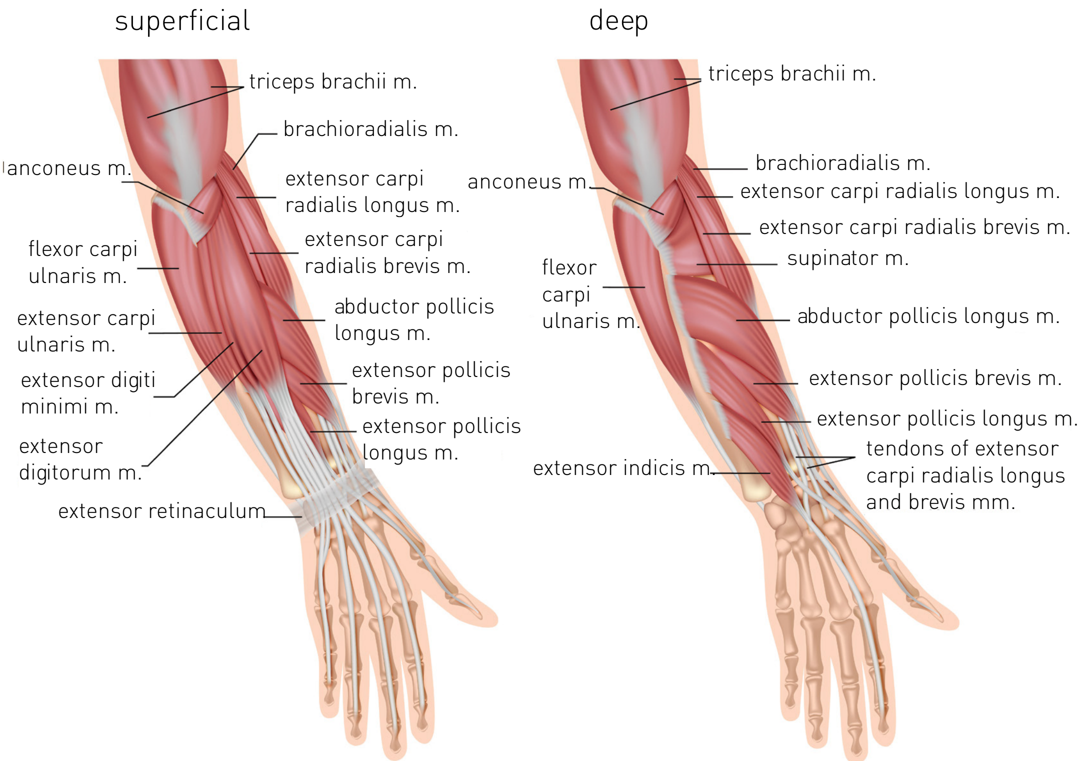


Figure 3.12. Forearm muscles, their functions and innervations. Superficial and deep group muscles in the dorsal aspects of forearm.

The anterior forearm muscles, their functions and the nerves supplying them are given in the table below.

Muscle	Function	Nerve
pronator teres m.	pronation of forearm and hand	median n.
pronator quadratus m.		
palmaris longus m.	flexion of wrist	median n.
flexor carpi radialis m.		median n.
flexor carpi ulnaris m.		ulnar n.
flexor digitorum superficialis m.	flexion of 2-5 digits	median n.
flexor digitorum profundus m.		median and ulnar nn.
flexor pollicis longus m.	flexion of thumb	median n.

The posterior forearm muscles, their functions and the nerves supplying them are given in the table below.

Muscle	Function	Nerve
brachioradialis m.	flexion of forearm	radial n. and its branches
extensor carpi radialis longus m.	extension of wrist	
extensor carpi radialis brevis m.		
extensor carpi ulnaris m.		
extensor digitorum m.	extension of wrist and fingers	
extensor digiti minimi m.	extension of 5th finger	
extensor pollicis longus m.	extension of thumb	
extensor pollicis brevis m.		
extensor indicis m.	extension of index finger	
abductor pollicis longus m.	abduction of thumb	
supinator m.	supination of hand	

On the hand, the puffy area on the thumb side of palmar face is called the **thenar region**, and the less puffy area on the little finger side is called the **hypothenar region** (Figure 3.13a-b). The thenar region muscles, their functions, and the nerves supplying them are given in the table below.

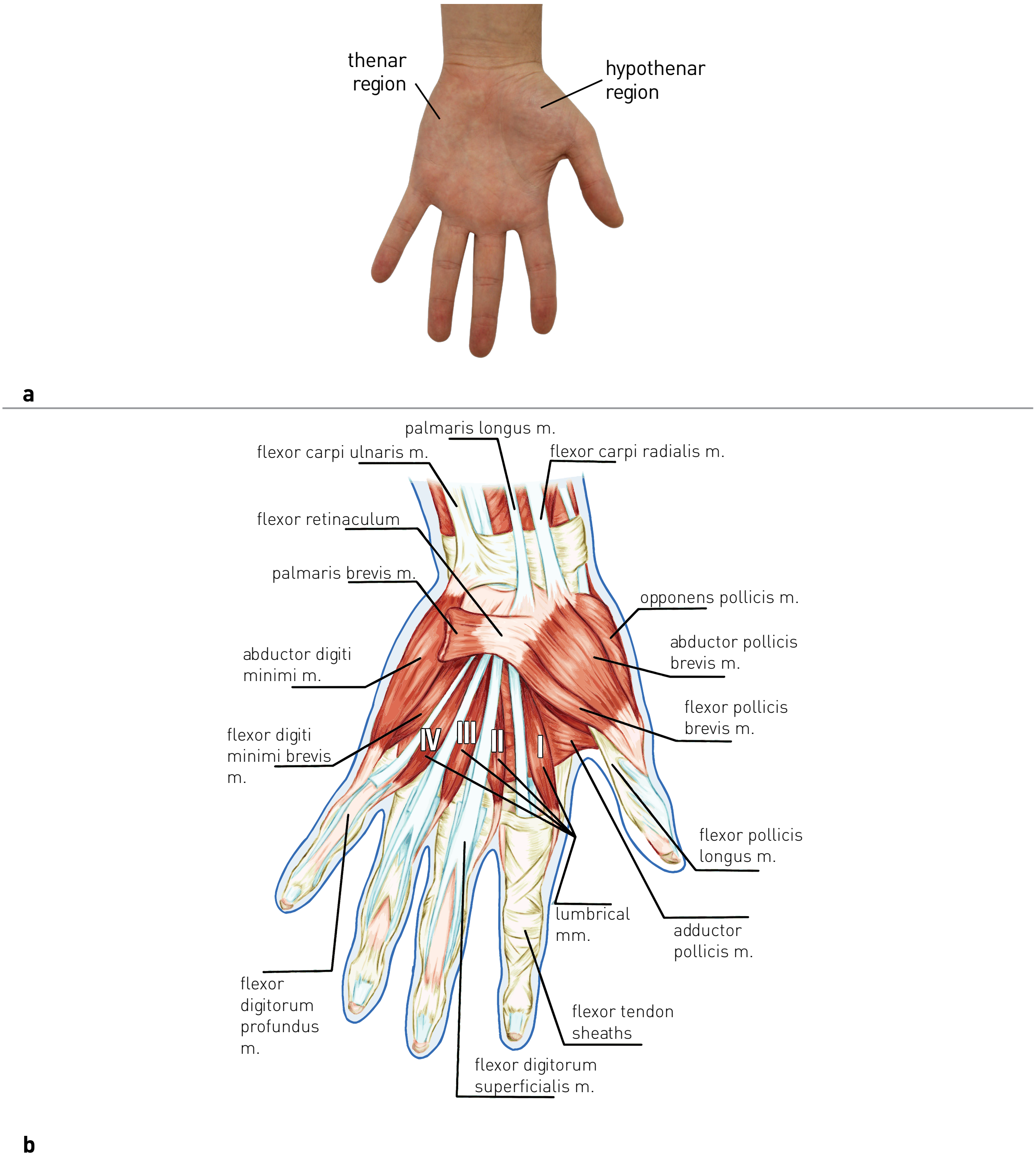


Figure 3.13. Hand region. **a.** thenar and hypothenar regions. **b.** hand region muscles.

The hypothenar region muscles, their functions and the nerves supplying them are given in the table below.

Muscle	Function	Nerve
abductor pollicis brevis m.	adduction of thumb	median n.
flexor pollicis brevis m.	flexion of thumb	
opponens pollicis m.	opposition of thumb	
adductor pollicis m.	adduction of thumb	ulnar n.

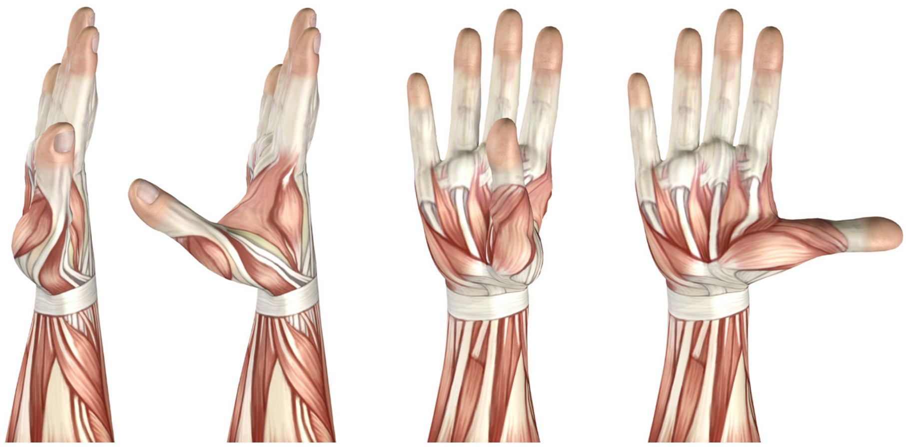
Apart from the thenar and hypothenar regions, deeper muscles in the hand, their functions and related nerves are provided in the table below.

Muscle	Function	Nerve
abductor digiti minimi m.	abduction of little finger	ulnar n.
flexor digiti minimi brevis m.	flexion of little finger	
opponens digiti minimi m.	opposition of little finger	
palmaris brevis m.	stretching the palmar aponeurosis	

Muscle	Function	Nerve
lumbrical mm.	flexion in 2nd-5th MCP joints, extension in PIP and DIP joints	median n. for the 1st-2nd lumbricals, ulnar n. for the 3rd-4th lumbricals
palmar interosseous mm.	adduction of fingers	ulnar n.
dorsal interosseous mm.	abduction of fingers	
MCP: metacarpophalangeal, PIP: proximal interphalangeal, DIP: distal interphalangeal		

The Thumb

The thumb is the most mobile of all the fingers and plays the largest role in the movements performed by the hand (Figure 3.14).



a. b. c. d

Figure 3.14. Thumb movements. **a.** adduction of the thumb. **b.** abduction of the thumb **c.** flexion of the thumb **d.** extension of the thumb.

What are the flexor retinaculum and extensor retinaculum?

The Latin term "retinaculum" means "restraining or holding device." The fibrous band that holds the tendons of the forearm muscles together, allowing them to function more effectively, is called as the **retinaculum**. The thickening of the deep fascia of the forearm at the wrist level forms the **flexor retinaculum** at the front (palmar side) and the **extensor retinaculum** at the back (dorsal side).

What is the carpal tunnel?

The **carpal tunnel** is the space formed between the flexor retinaculum and the carpal bones at the wrist level (Figure 3.15). Its significance lies in the fact that, apart from the tendons of the flexor muscles, the median nerve also passes through it.

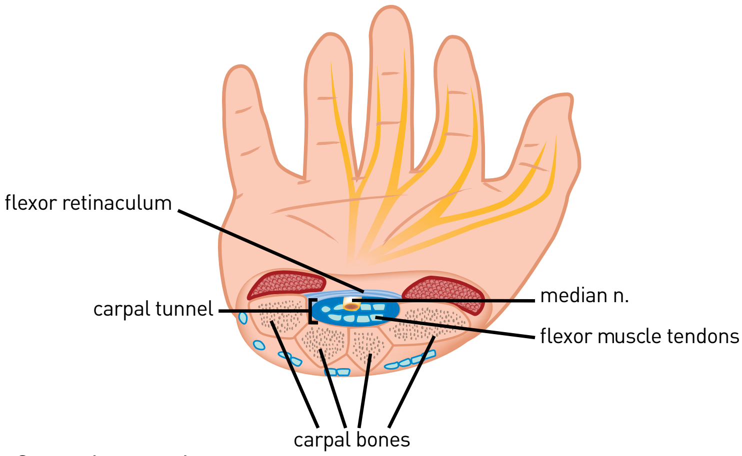


Figure 3.15. Carpal tunnel.

CLINICAL RELEVANCE

Carpal tunnel syndrome occurs when the median nerve, which runs from the forearm into the palm of the hand, becomes compressed at the carpal tunnel. This pressure causes symptoms like numbness, tingling, pain, and weakness in the hand and fingers, especially during activities like typing or using a mouse. It is often linked to repetitive wrist movements, wrong position for extended periods, previous injuries or underlying health conditions like arthritis. Treatment may include rest, wrist splints, anti-inflammatory medications, or in severe cases, surgery to relieve pressure on the nerve.

What is the axilla (armpit)?

The **axilla** is the hollow area between the chest wall and the upper arm. It is bounded anteriorly by the pectoralis major m. and posteriorly by the latissimus dorsi m. There is the upper thoracic wall medially and the upper part of humerus laterally. This area contains blood vessels, nerves, and lymph nodes related to the upper extremity, chest wall, and breast region (Figure 3.16).

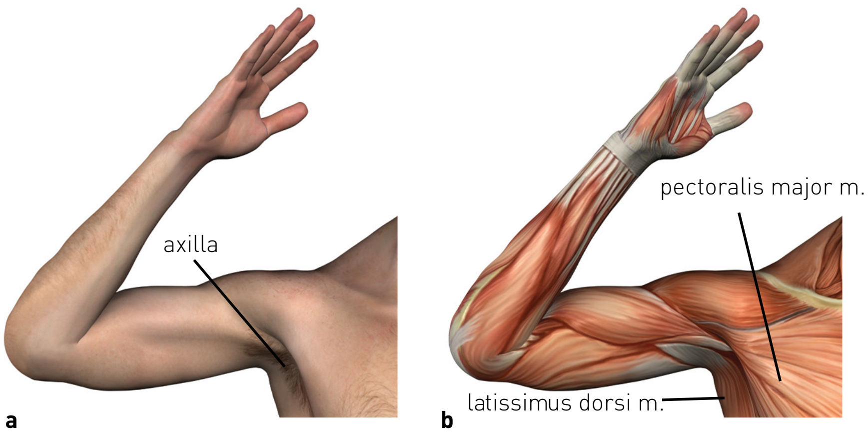


Figure 3.16. Axilla. **a.** superficial view of the axilla. **b.** muscles around the axilla.

What is the cubital fossa?

The **cubital fossa** is a triangular-shaped hollow area located in front of the elbow joint including the median n., radial n., brachial a., and the tendon of the biceps brachii m.

BLOOD VESSELS AND NERVES

What are the arteries of the arm and forearm?

The arteries of arm and forearm are as follows from proximal to distal (Figure 3.17):

In the axilla: **axillary a.**

In the arm: **brachial a.**

In the forearm: **radial a.** (lateral) and **ulnar a.** (medial)

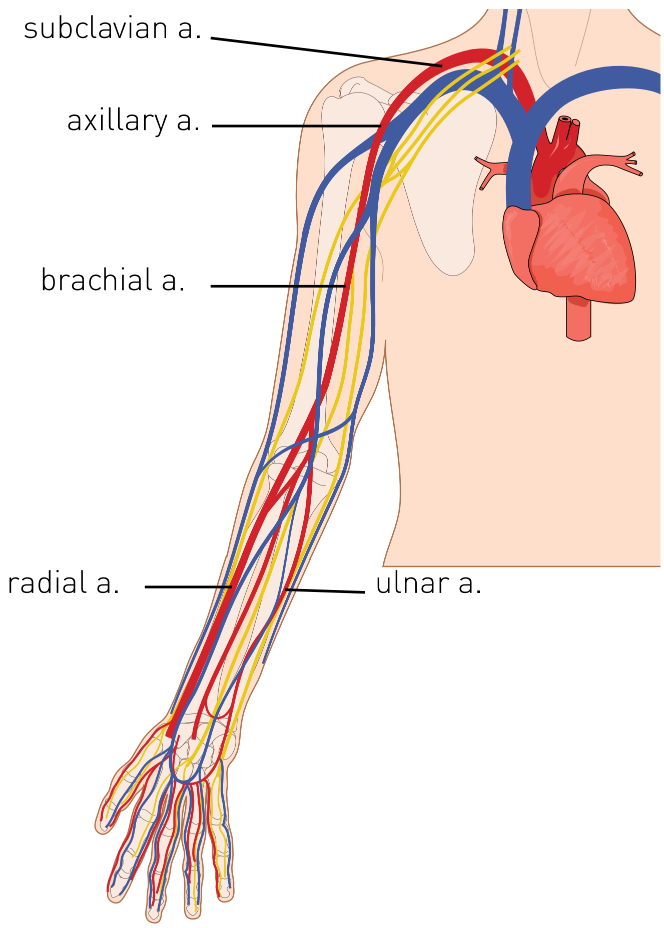


Figure 3.17. Arteries of the upper extremity.

What are the arteries of the hand and fingers?

The radial and ulnar arteries, coursing distally in the forearm, supply the hand and fingers through their branches. Together, they form an arterial network (rete carpale) on the palmar and dorsal sides to supply the wrist joint and neighboring structures. The radial artery, continuing distally, gives off the **princeps pollicis a.** for the thumb and the **radialis indicis a.** for the second finger. After giving these branches, the radial artery forms the **deep palmar arch**. From this arch, the **dorsal metacarpal aa.** branch off, and they further give the **dorsal digital aa.** to supply the fingers. The ulnar artery progresses distally from the rete carpale to form the **superficial palmar arch**. This arterial arch further gives the **common digital palmar aa.** and **proper digital palmar aa.** branches (Figure 3.18).

CLINICAL RELEVANCE

In the upper extremity, easily felt arterial pulses are at two sites where arteries are near the surface of the skin. These include:

radial artery pulse: is felt on the thumb side of the wrist, proximal to the wrist lines, and is located lateral to the tendon of the flexor carpi radialis m. which is quite prominent here.

brachial artery pulse: is felt on the inside of the elbow (cubital fossa), close to its midline where the brachial artery passes.

These pulses are used to assess circulation and detect potential vascular issues in the arms and hands.

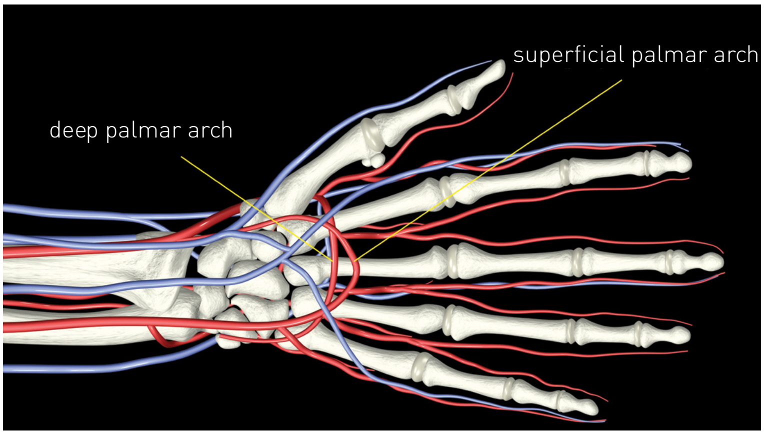


Figure 3.18. Superficial and deep arterial arches of the hand.

What are the veins of the upper extremity?

The veins of the upper extremity are classified into two groups:

Deep veins

In the forearm: **radial v.** (lateral) and **ulnar v.** (medial)

In the arm: **brachial v.**

In the axilla: **axillary v.**

These veins accompany the arteries of the same names.

Superficial veins (Figure 3.19):

On the lateral side: **cephalic v.**

On the medial side: **basilic v.**

On the anterior forearm: **median antebrachial v.**

In the cubital fossa (elbow): **median cubital v.**

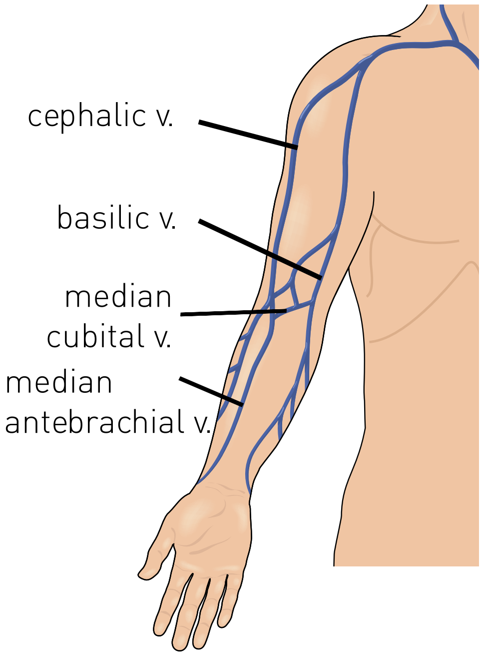


Figure 3.19. Superficial veins of the upper extremity.

Superficial veins are located within the superficial fascia formed by the subcutaneous adipose tissue. The **cephalic v.**, one of the superficial veins, runs along the lateral side of the forearm and arm, reaching the shoulder. It passes beneath the clavicle and drains into the **axillary v**. The **basilic v.** travels along the medial side of the forearm and arm and, as it approaches the axilla, it joins the **brachial v.** to form the **axillary v**. The **median antebrachial v.** is located in the forearm, between the **cephalic** and **basilic vv**. Last three veins connect via several branches in front of the elbow joint, which is quite superficial here, enabling venous blood samples collection (Figure 3.19).

What is the brachial plexus?

The **brachial plexus** is a network of nerves associated with the upper extremity (Figure 3.20). This network starts at the neck, near the edge of the spine, and extends downward and outward, passing behind the clavicle to reach the axilla. The nerves branching from the brachial plexus supply the muscles of the upper extremity and receive sensory input from the skin covering the upper extremity.

To form the **brachial plexus**, the anterior rami of the spinal nerves from levels C5 to T1 merge to create three trunks:

superior trunk,
medial trunk,
inferior trunk.

Each trunk then divides into anterior and posterior branches:

The posterior branches of all three trunks join to form the **posterior fascicle**.

The anterior branches of the **superior** and **medial trunks** unite to form the **lateral fascicle.**

The anterior branch of the **inferior trunk** forms the **medial fascicle**.

Since the trunks of the brachial plexus are located above the clavicle, this part is called the **supraclavicular part** of the brachial plexus, while the fascicles, which are located below the clavicle, are called the **infraclavicular part**.

Nerves Arising from the Brachial Plexus:

From the supraclavicular part:

- **dorsal scapular n.**
- **long thoracic n.**
- **subclavian n.**
- **suprascapular n.**

From the infraclavicular part:

From the lateral fascicle:

- **lateral pectoral n.**
- **musculocutaneous n.**
- **lateral root of median n.** (contributing to the median nerve)

From the medial fascicle:

- **ulnar n.**
- **medial pectoral n.**
- **medial brachial cutaneous n.**
- **medial cutaneous nerve of the forearm n.**
- **medial root of median n.** (contributing to the median nerve)

From the posterior fascicle:

- **radial n.**
- **axillary n.**
  - **subscapular n.** (as two separate branches)
  - **thoracodorsal n.**

Details about some major nerves of the brachial plexus:

radial n.: is the largest branch of the brachial plexus. It arises from the posterior fascicle and travels deeply, spiraling along the surface of the humerus toward the elbow. It innervates many muscles on the dorsal side of the upper extremity and provides sensory input from the skin.

axillary n.: is a branch of the **posterior fascicle**, like the radial nerve. It typically wraps around the neck of the humerus and innervates the **deltoid m.** and the **teres minor m**.

median n.: is formed by the merging of branches from the **medial** and **lateral fascicles**, it passes through the carpal tunnel at the wrist to reach the hand. It innervates some forearm and hand muscles and receives sensory input from the forearm and hand.

ulnar n.: is a branch of the **medial fascicle**, it typically passes superficially behind the **medial epicondyle** at the elbow. It innervates some muscles in the forearm and hand and provides sensory input from these regions.

musculocutaneous n.: is a branch of the **lateral fascicle**, it typically pierces the **coracobrachialis m.** as it travels through the arm. It innervates the muscles on the anterior side of the arm and receives sensory input from the lateral side of the forearm.

CLINICAL RELEVANCE

Peripheral nerve injury occurs when a nerve in the peripheral nervous system is damaged due to trauma, such as a cut, stretch, or compression, often from accidents, sports injuries, or repetitive movements. Symptoms include pain, numbness, tingling, weakness, or loss of movement in the affected area. Treatment varies depending on the severity of the injury, ranging from rest and physical therapy to surgery in more severe cases. With appropriate care, many peripheral nerve injuries improve over time, though recovery can be slow.

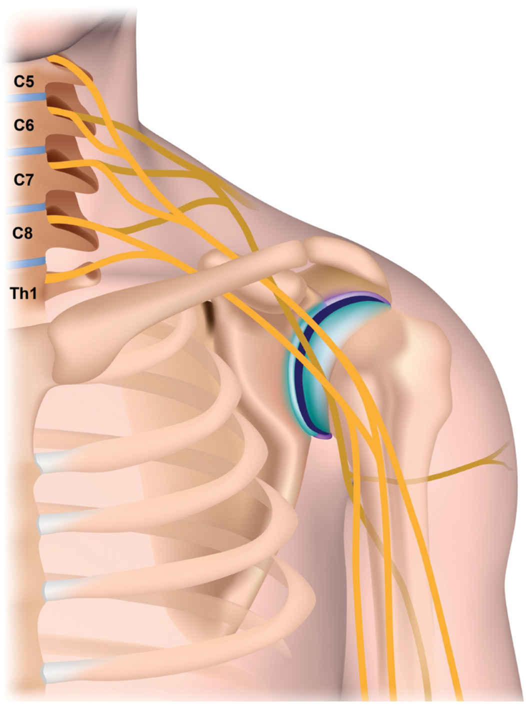


Figure 3.20. Brachial plexus..

Sample Questions about the Upper Extremity

1. Which of the following is **not** observed on the scapula?

   a) Spine
   b) Glenoid fossa
   c) Infraspinatus fossa
   d) Medial angle
   e) Acromion

2. Which of the following is **not** observed on the humerus?

   a) Head
   b) Surgical neck
   c) Olecranon fossa
   d) Medial epicondyle
   e) Trochlear notch

3. The shoulder joint is located between which two structures?

   a) Glenoid fossa – neck of humerus
   b) Glenoid fossa - head of humerus
   c) Neck of humerus - acromion
   d) Head of humerus - acromion
   e) Greater tubercle - glenoid fossa

4. Which of the following is **not** one of the muscles in the rotator cuff?

   a) Supraspinatus
   b) Infraspinatus
   c) Teres major
   d) Teres minor
   e) Subscapularis

5. Which of the following is innervated by the axillary n.?

   a) Teres minor m.
   b) Teres major m.
   c) Supraspinatus m.
   d) Infraspinatus m.
   e) Subscapularis m.

6. Which of the following is innervated by the radial n.?

   a) Deltoid m.
   b) Brachioradialis m.
   c) Supraspinatus m.
   d) Infraspinatus m.
   e) Coracobrachialis m.

7. Which of the following typically passes through the coracobrachialis m. to advance in the arm?

   a) Musculocutaneous n.
   b) Axillary n.
   c) Median n.
   d) Ulnar n.
   e) Radial n.

8. Which of the following muscles causes wrist flexion?

   a) Supinator m.
   b) Pronator teres m.
   c) Palmaris longus m.
   d) Pronator quadratus m.
   e) Abductor pollicis longus m.

9. Which nerve passes through the carpal tunnel at the wrist?

   a) Musculocutaneous n.
   b) Axillary n.
   c) Radial n.
   d) Ulnar n.
   e) Median n.

10. Which artery is located laterally in the forearm?

   a) Subclavian
   b) Axillary
   c) Brachial
   d) Radial
   e) Ulnar

Answers: 1.D, 2. E, 3.B, 4.C, 5.A, 6.B, 7.A, 8.C, 9.E, 10.D

LOWER EXTREMITY

LOWER EXTREMITY

The **lower extremity** is the extension that separates from the lower part of the body. It is the region consisting of the hip, thigh, leg, and foot (Figure 4.1).

BONES

What are the bones of the lower extremity?

The bones of the lower extremity are as follows:

Coxa, in the hip region,

Femur, in the thigh region,

Tibia and **Fibula** in the leg region,

Tarsal bones in the ankle, and

Metatarsal bones and **Phalanges** in the foot (Figure 4.1).

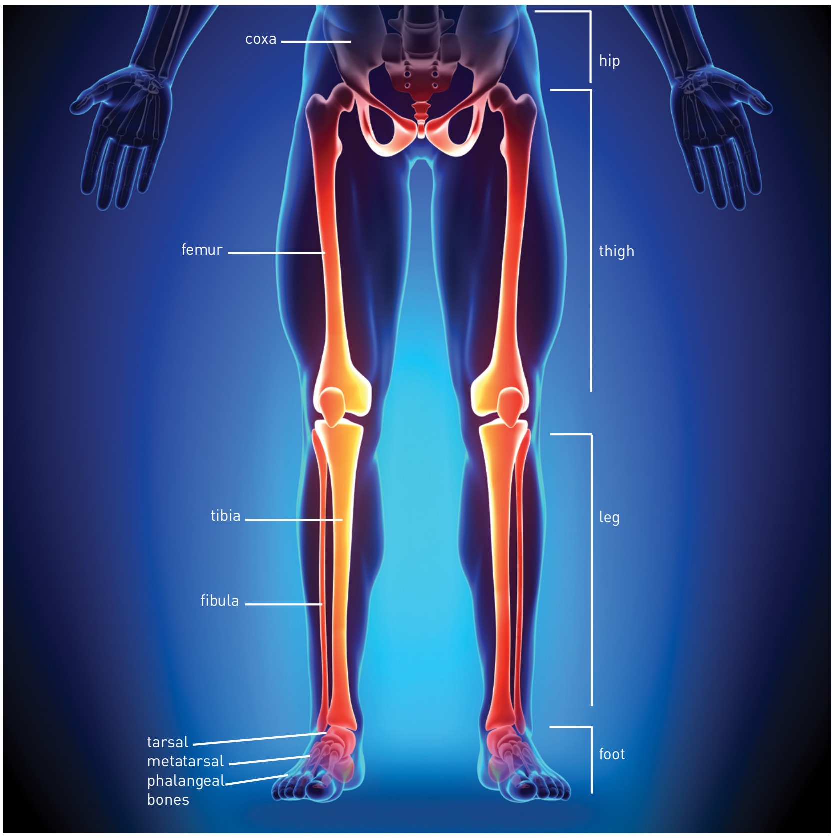


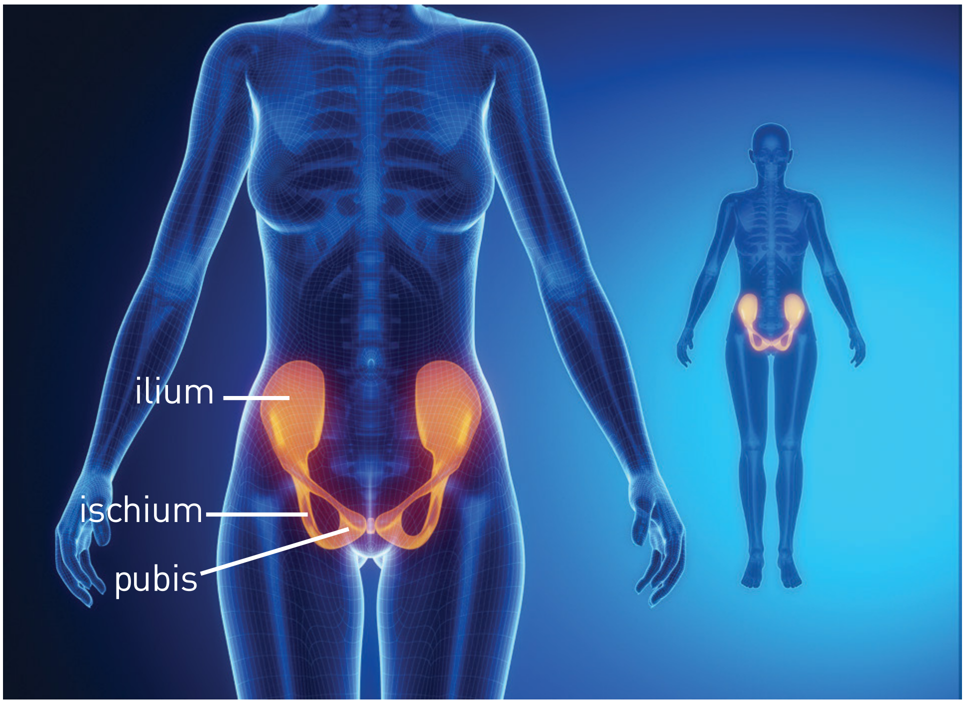
Figure 4.1. Bones of the lower extremity.

Coxa (Hip Bone): In the adult human, the coxa is a single bone formed by the fusion of three bones: the **ilium**, **ischium**, and **pubis**. It is a part of the pelvis (pelvic bone) and connects the body to the femur (Figure 4.2a,b).

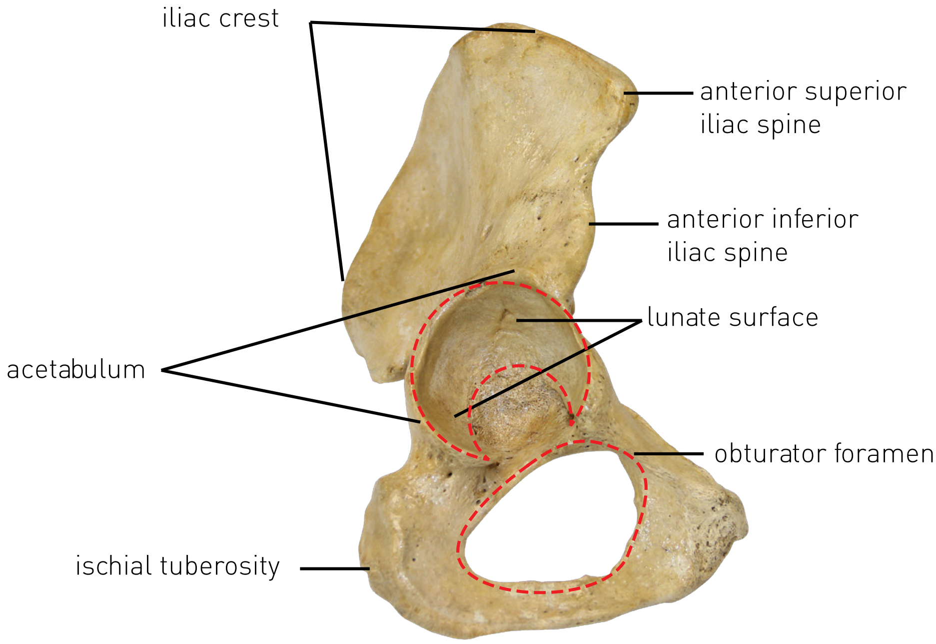
Ilium: The ilium forms the upper part of the coxa. It has a **body** and a **wing**. The body articulates with the ischium and pubis and contributes to the structure of the acetabulum. The thickened upper edge of the wing, known as the **iliac crest**, can be palpated. The anterior end of the iliac crest, called the **anterior superior iliac spine**, is an important reference point located on the lower outer side of the anterior abdominal wall. The posterior end of the crest is the **posterior superior iliac spine**. The gluteal muscles attach to the outer surface of the wing, while the inner surface is called the **iliac fossa**, where the iliac muscle is located. The inner surface also surrounds the major pelvic cavity. On the dorsal middle part of the body, there is a rough area that articulates with the sacrum, resembling an ear: **auricular facet**. Below this joint surface, there is a notch called the **greater sciatic notch**.

Ischium:The ischium is the bone that forms the lower posterior part of the hip bone. It consists of a **body** and a **ramus**. Joining with the ilium and pubis, ischium contributes to the acetabulum. At its lower end, there is a projection called the **ischial tuberosity**. While sitting, the body weight is supported by this bony prominence and can only be palpated in a sitting position. While standing, it is covered by the gluteal muscles. Above this prominence, there is a notch called the **lesser sciatic notch**. The ramus of the ischium extends forward and inward, joining with the inferior ramus of the pubic bone, thus closing the obturator foramen from below.

Pubis: The pubis forms the front part of the hip bone. It consists of a **body** and two **rami** (**superior** and **inferior**). Bodies of the pubic bones of both sides join at the midline to form the joint **pubic symphysis**. On the anterior part of the body there are two prominent parts: medially the **pubic crest** and laterally the **pubic tubercle**. The superior ramus joins with the ilium to contribute to the acetabulum, while the inferior ramus joins with the ischium, forming the obturator foramen.



a



b

Figure 4.2. Coxa. **a.** location of the coxa in the body **b.** lateral view of the coxa.

What is the acetabulum?

The acetabulum is the concave area on the outer surface of the coxa, formed by the fusion of the ilium, ischium, and pubis, and it faces downward and forward (Figure 4.2b). It contains a horseshoe-shaped joint surface, **lunate surface**, where the head of the femur fits to form a joint.

What is the obturator foramen?

The obturator foramen is a large opening formed by the bodies and rami of the ischium and pubis (Figure 4.2a,b). It is almost completely covered by the **obturator membrane**, except for the small groove on its upper side. Various muscles attach to the inner and outer surfaces of this membrane.

Femur (Thigh Bone) (Figure 4.3a-c):

The femur is the longest and heaviest bone in the body. It transmits the body weight from the hip to the leg. It is covered by muscles almost entirely. At the upper end, there is a spherical **head**, followed by a narrow **neck**, and two protrusions located, one large and external: **greater trochanter**, and the other smaller and internal: **lesser trochanter**. Below, there is a cylindrical **body**. At the lower end of the femur, there are two prominent areas: the **medial** and **lateral epicondyles**. Just below these prominences, there are joint surfaces that form part of the knee joint: the **medial** and **lateral condyles**. These joint surfaces are connected in the front, but a depression exists between them at the back: the **intercondylar fossa**.

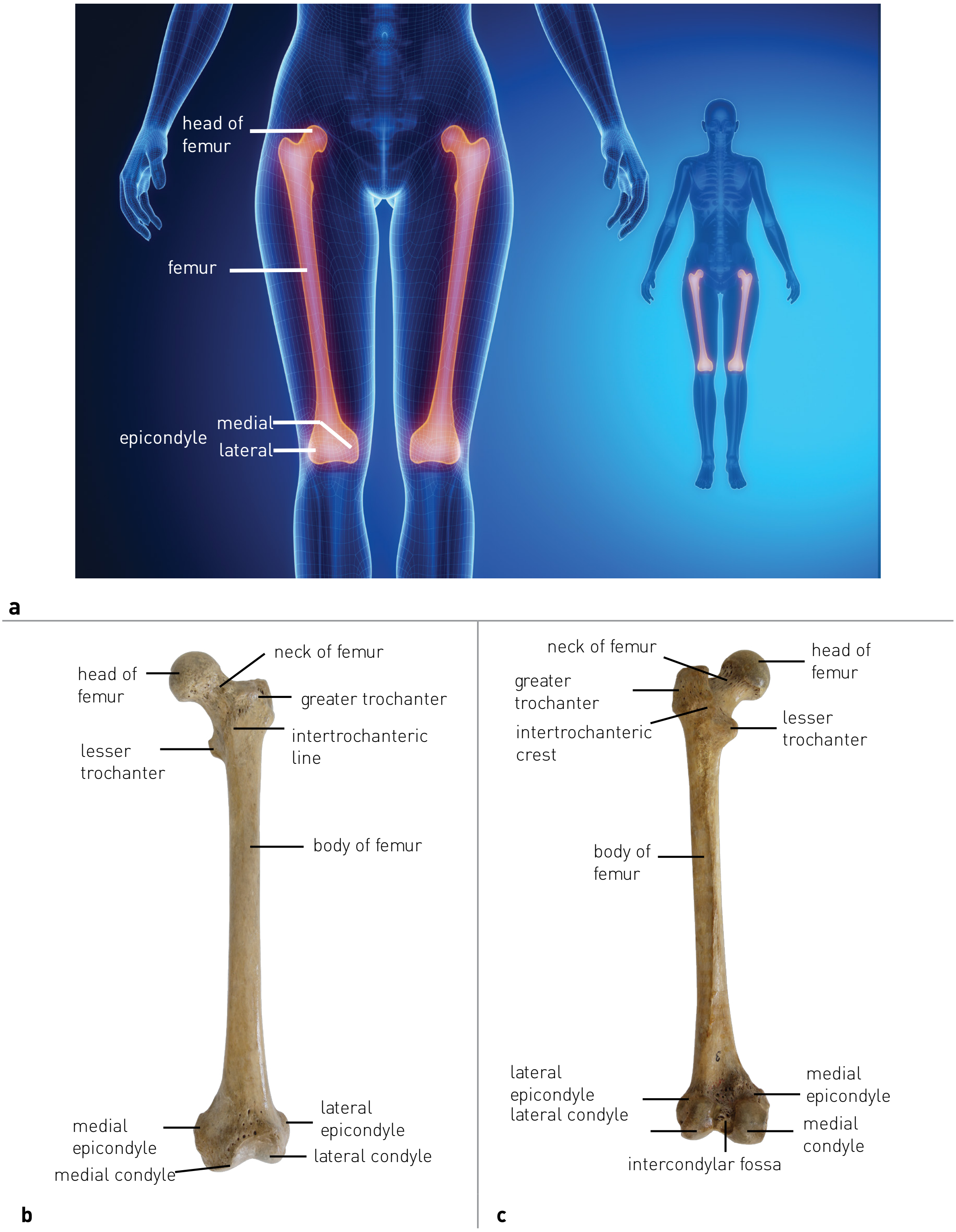


Figure 4.3. Femur. **a.** location of the femur **b.** anterior view of the left femur **c.** posterior view of the left femur.

Patella (Knee Cap Bone) (Figure 4.4a,b):

The patella is a sesamoid bone located in front of the knee. A part of the quadriceps femoris tendon passes in front of the bone and attaches to the tibia as the **patellar tendon**. The posterior surface of the patella forms a joint with the anterior surfaces of the medial and lateral condyles of the femur.

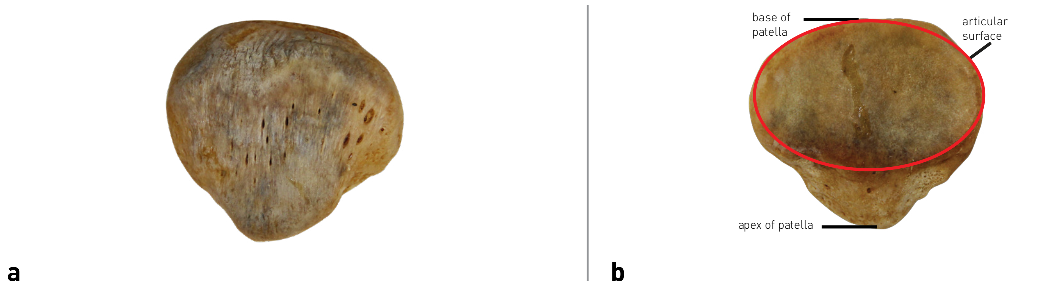


Figure 4.4. Patella. **a.** anterior surface **b.** articular facet on the posterior surface.

Leg Bones

Tibia (Shin Bone) (Figure 4.5a-c): The tibia is the thicker and medially located of the two bones in the leg. It transmits body weight from the leg to the foot. The upper end, which articulates with the femur, is broader and contains the prominent **medial** and **lateral condyles**. The upper surface of the tibia has the articular facets for the femoral condyles with the **intercondylar eminence** between the facets. Below, there is a raised area in the front and midline: the **tibial tuberosity**. This is the attachment point for the tendons of the anterior thigh muscles. The shaft of the tibia is triangular in shape, with medial, lateral, and posterior surfaces separated by sharp edges. The medial surface can be palpated along the inner side of the leg. The medial part of the lower end of the tibia features a prominent bump: the **medial malleolus**.

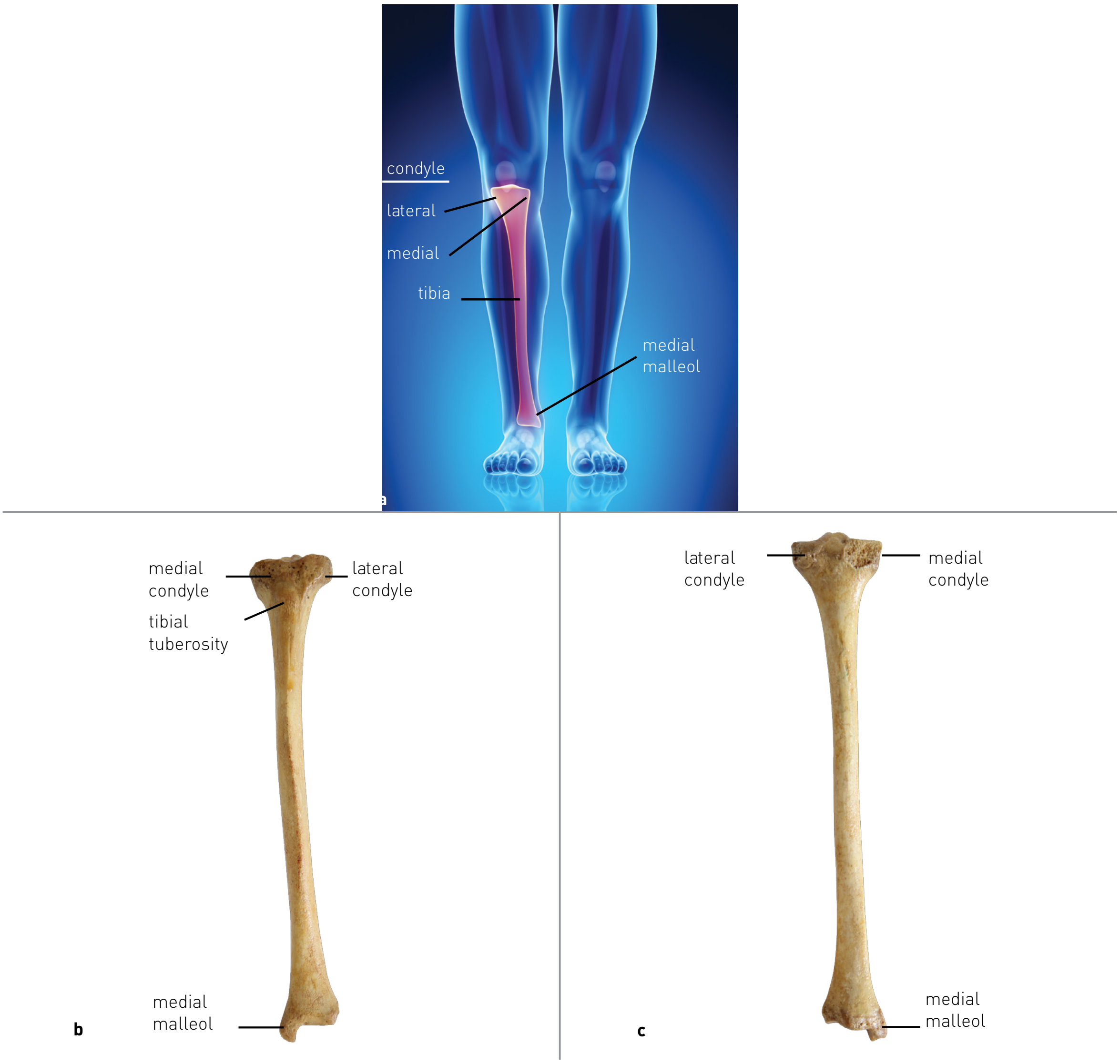
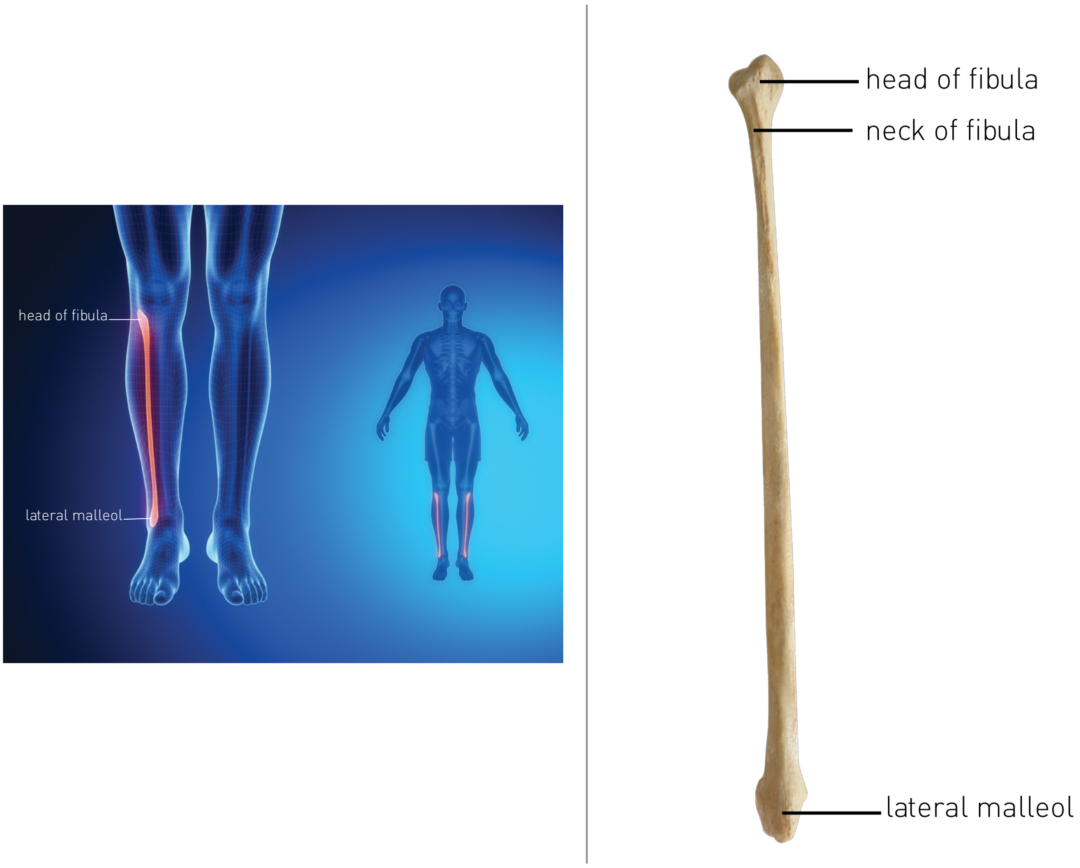


Figure 4.5. Tibia. **a.** location of the tibia **b.** anterior view of the left tibia **c.** posterior view of the left tibia.

Fibula (Figure 4.6a,b): The fibula is the thinner bone, located laterally in the leg. It does not play a role in the transmission of body weight. Almost throughout its length, fibula is connected to the tibia by a strong ligament called the **interosseous membrane**. At its distal end, it articulates with the tibia and with the talus, a tarsal bone. The proximal end has a broad part called the **head**, followed by the thinner **neck**, and at the distal end, there is a prominent bump: the **lateral malleolus**. This malleolus is located about 1 cm more distally than the medial malleolus of the tibia.



a **b**

Figure 4.6. Fibula. **a.** location of the fibula **b.** left fibula.

Ankle Bones (Figure 4.7a-c):

The ankle region (tarsus) consists of 7 bones:

- **talus**
- **calcaneus**
- **navicular bone**
- **medial cuneiform**
- **intermediate cuneiform**
- **lateral cuneiform**
- **cuboid bone**

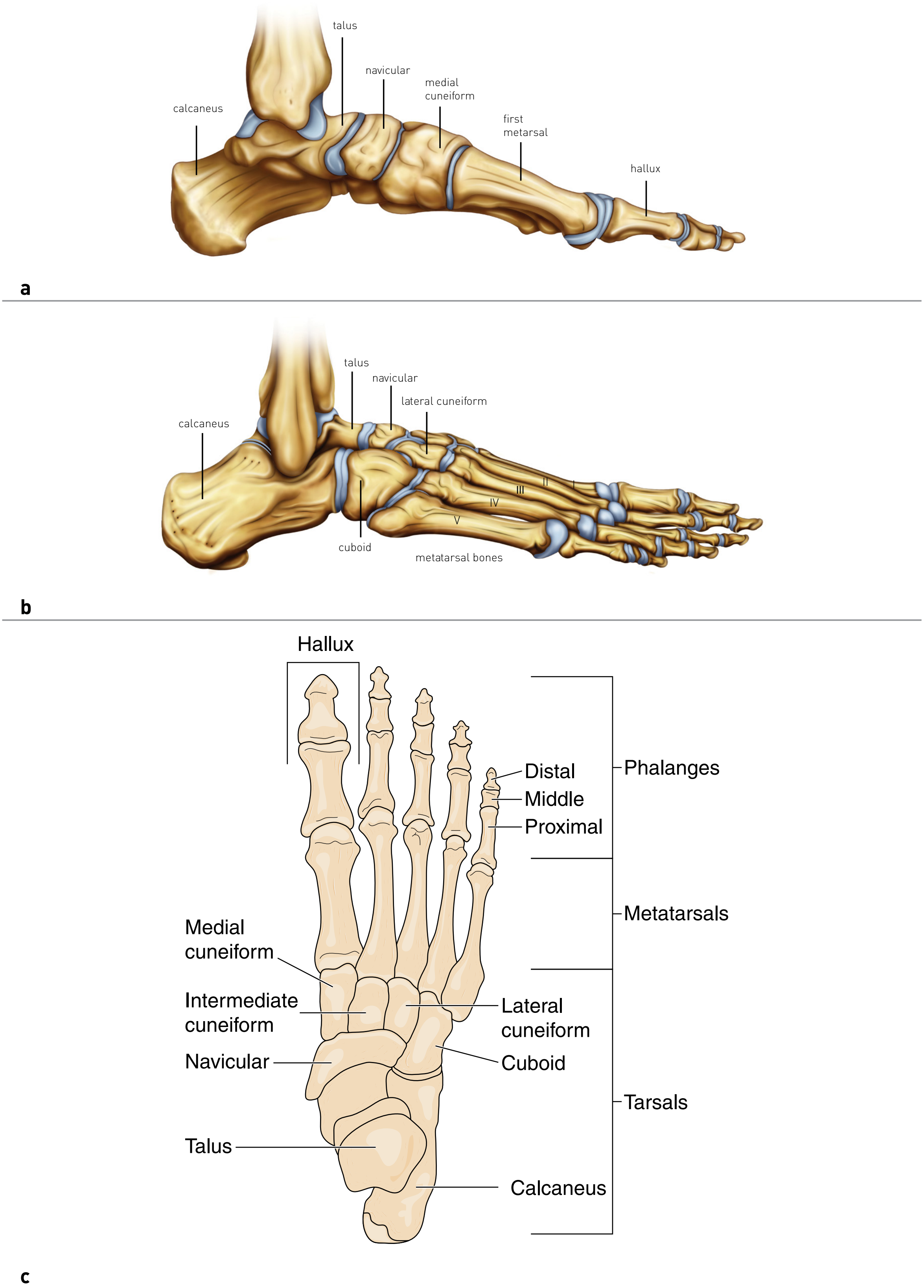


Figure 4.7. Bones of the foot. **a.** medial view. The medial longitudinal arch of the foot which is higher than the lateral **b.** lateral view. The lateral longitudinal arch of the foot **c.** upper view of the foot bones.

The **talus** forms a joint with the tibia through its **trochlea**, which is the joint surface. The **calcaneus** transmits the body weight received from the talus to the ground. The posterior projection, the **calcaneal tuberosity**, is where the Achilles tendon attaches. The **navicular bone** is located between the talus at the back and the three **cuneiform bones** in front. The cuneiform bones are located in front of the navicular bone and behind the first three metatarsal bones. The **cuboid bone** is located between the calcaneus at the back and the 4th and 5th metatarsals in front. The cuneiform bones and five metatarsal bones together form the **horizontal (transverse) arch of the foot**. Additionally, the foot has two longitudinal arches (Figure 4.7a,b): the **medial longitudinal arch** and the **lateral longitudinal arch**. The medial arch is higher.

Foot Bones

Metatarsal Bones and Phalanges: the metatarsals are 5 long and slender bones. Each has a base at the back that articulates with the tarsal bones, a **body**, and a **head** that articulates with the phalanges at the front. The base of the fifth metatarsal is typically wide and is noticeably prominent on the outer side of the foot. The big toe (hallux) has 2 phalanges, while the other toes have 3. The phalanges are named proximal, middle, and distal. Like the metatarsals, each phalanx has a base, body, and head.

JOINTS

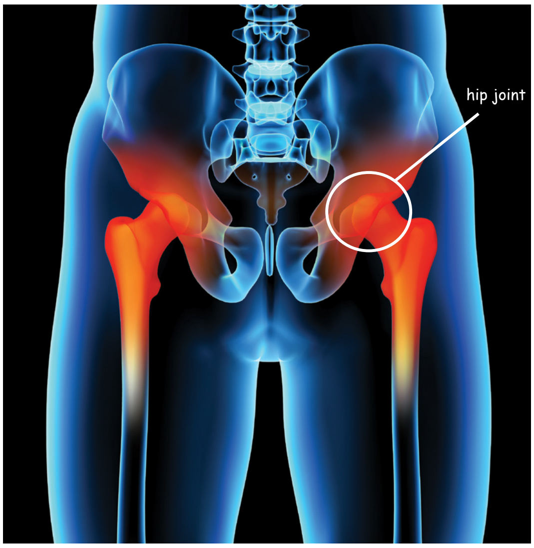
What are the joints of the lower extremity?

The joints of the lower extremity are:

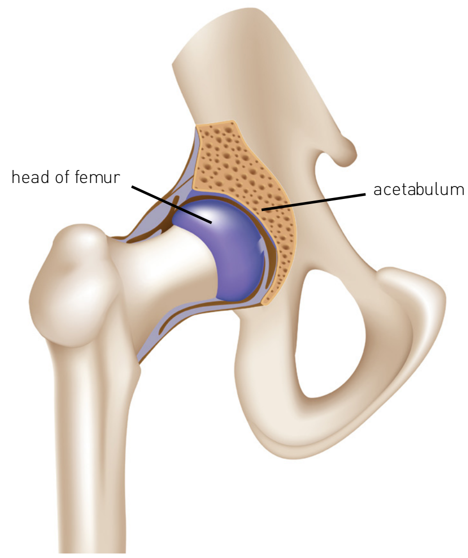
- Hip joint
- Knee joint
- The joints between the tibia and fibula
- Ankle joint
- The joints between the tarsal bones
- The joints between the tarsal and metatarsal bones
- The joints between the metatarsal bones and phalanges
- The joints between the phalanges

What structures are involved in the hip joint?

The hip joint is located between the lunate surface of the acetabulum on the lateral side of the coxa and the head of the femur (Figure 4.8a,b).



a



b

Figure 4.8. Hip joint. **a.** location of the hip joint in the body **b.** involved bony structures in a section passing through the hip joint

What type of joint is the hip joint, and what movements are possible?

The hip joint is a spheroid (ball-and-socket) joint. In this joint, six different movements are possible around all three axes, and the circumduction (the circular motion which is the combination of these six movements).

CLINICAL RELEVANCE

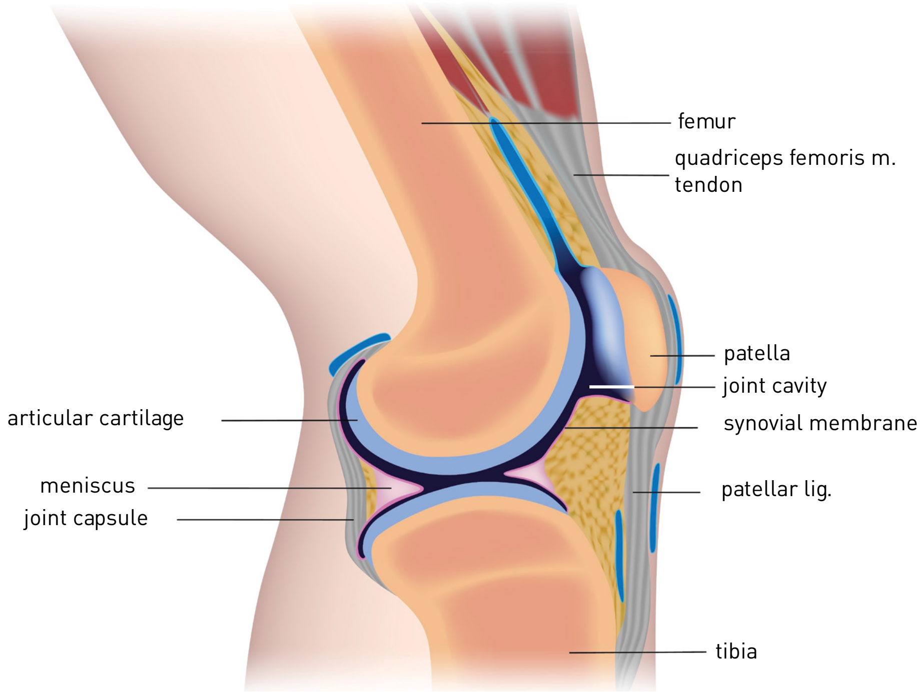
A **hip fracture** is a break in the upper part of the femur, typically occurring just below the ball-and-socket joint of the hip. It is most common in older adults, often due to a fall or weakened bones from conditions like osteoporosis. Symptoms include severe pain in the hip or groin, inability to bear weight on the affected leg, and difficulty moving the leg. Treatment usually involves surgery to repair or replace the hip joint, followed by physical therapy to regain mobility. Recovery time varies but often takes several months, depending on the severity of the fracture and the person's overall health.

Developmental Hip Dysplasia (DHD) is a condition where the hip joint doesn't form properly in infants or young children. In a healthy hip, the femoral head fits securely into the acetabulum of the pelvis. In DHD, the acetabulum may be too shallow or the head may not be properly aligned, leading to joint instability or dislocation. The exact cause is often unknown, but factors like family history, breech birth position, or low amniotic fluid can increase the risk. Early detection through physical exams and imaging is important.

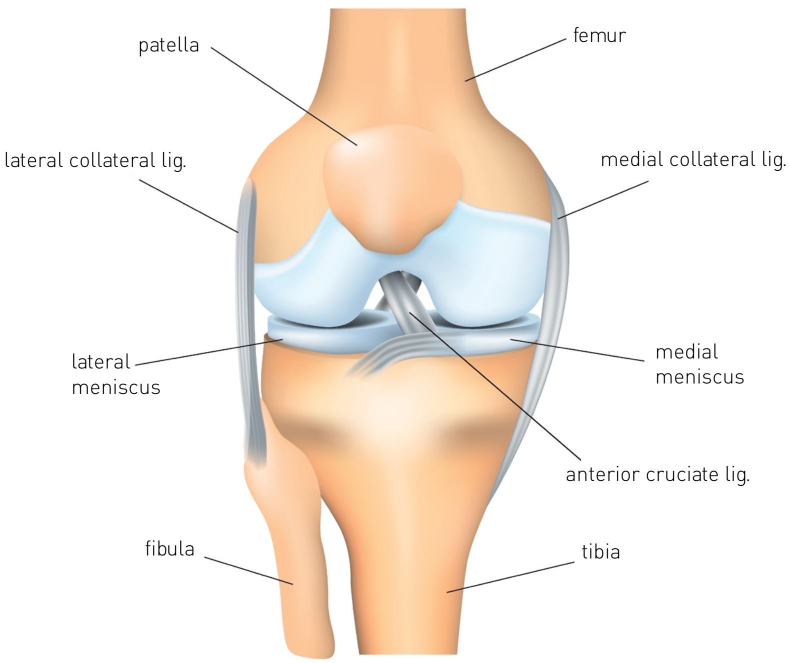
Congenital Hip Dislocation is a condition present at birth where the hip joint is dislocated or unstable due to abnormal development of the acetabulum or femoral head. This condition can result from factors like genetics, the baby's position in the uterus, or other environmental influences. Early diagnosis and treatment are crucial to prevent long-term joint problems and ensure normal hip function. Diagnosis is either by physical examination or radiography. Treatment often involves repositioning the hip into the acetabulum using a harness, brace, or in some cases, surgery.

What structures are involved in the knee joint?

The knee joint is located between the femur, tibia, and patella (Figure 4.9a,b).



a



b

Figure 4.9. Knee joint. **a.** involved bony structures, the joint space and the location of the menisci in a sagittal section passing through the knee joint. **b.** anterior view of the knee joint. Some of the intra- and extra-articular ligaments are shown.

What type of joint is the knee joint, and what movements are possible?

The knee joint is a condylar-type joint, and it allows flexion-extension around the horizontal axis and limited rotation around the vertical axis.

What important structures are found inside the knee joint?

The knee joint contains some unique structures not found in other joints (Figure 4.10). These include:

the **medial** and **lateral menisci** (inner and outer menisci)

the **anterior** and **posterior cruciate ligaments**

the **anterior** and **posterior meniscofemoral ligaments**

What are the characteristics of the menisci?

The menisci are fibrocartilaginous structures located in the knee joint, between femur and the tibia. They serve as cushions and have shock-absorbing properties. The lateral meniscus is circular, and the medial meniscus is C-shaped. Their outer edges are thick, and the inner parts are thin.

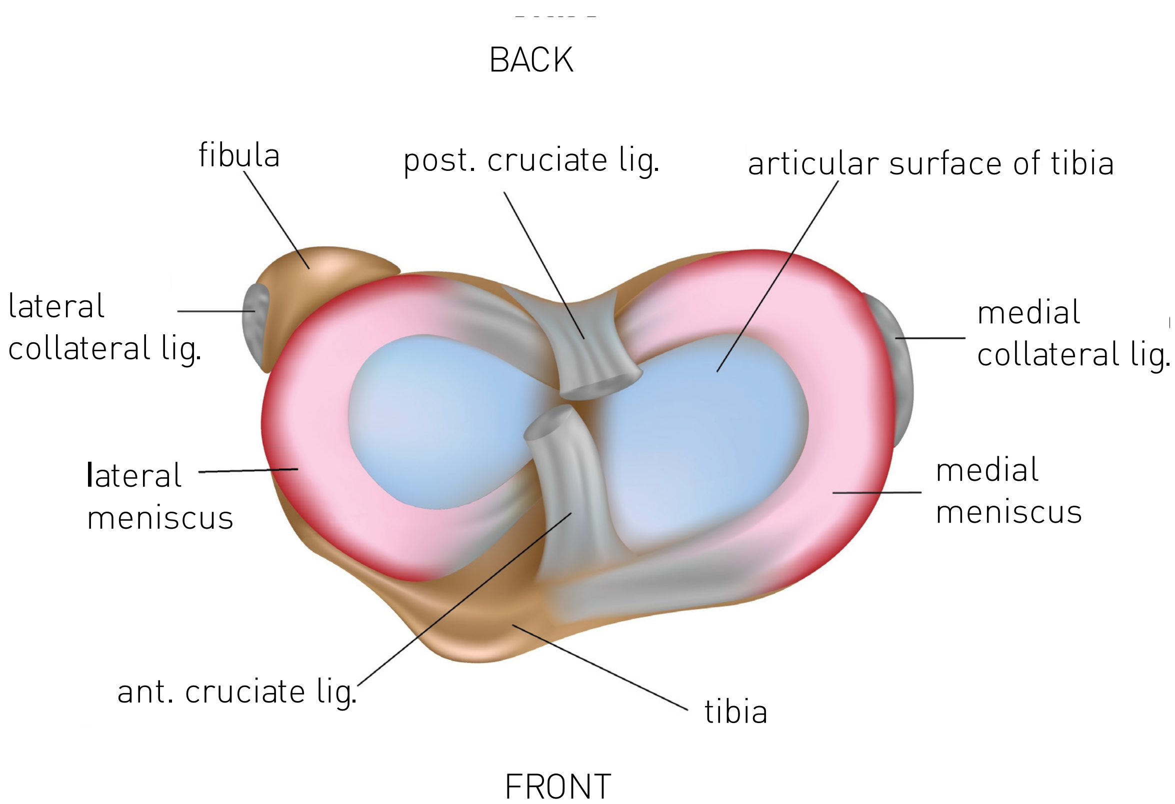


Figure 4.10. Knee joint. Upper view of the joint showing the location of the menisci and intra-articular ligaments.

CLINICAL RELEVANCE

Meniscus injury refers to damage to the meniscus. It commonly occurs during activities that involve twisting, turning, or sudden stops, such as sports. Symptoms can include pain, swelling, stiffness, and difficulty moving the knee. Treatment may involve rest, ice, physical therapy, or, in more severe cases, surgery to repair or remove the damaged part of the meniscus

What are the characteristics of the cruciate ligaments?

Both are located inside the knee joint and are crucial for stabilizing the knee during movement.

anterior cruciate ligament (ACL): runs diagonally in the middle of the knee, connecting the femur to the tibia. It prevents the tibia from sliding too far forward relative to the femur and helps control rotational movements of the knee. The ACL is most commonly injured during activities that involve quick direction changes or jumping.

posterior cruciate ligament (PCL): is located just behind the ACL, also connecting the femur to the tibia. It prevents the tibia from sliding too far backward relative to the femur and helps stabilize the knee when walking or running downhill.

CLINICAL RELEVANCE

Cruciate ligament injuries refer to damage to one of the two key ligaments in the knee: the anterior cruciate ligament (ACL) or the posterior cruciate ligament (PCL). The ACL is more commonly injured, often during sports that involve sudden stops, twists, or jumps. Symptoms can include pain, swelling, instability, and difficulty bearing weight on the leg. Treatment may vary depending on the severity of the injury, ranging from rest and physical therapy to surgery for complete tears.

What structures are involved in the ankle joint?

The ankle joint is formed between the tibia and the talus (Figure 4.11).

What type of joint is the ankle joint, and what movements can be performed in this joint?
The ankle joint is an ellipsoid-type joint. Both flexion-extension and abduction-adduction movements can be performed in this joint..

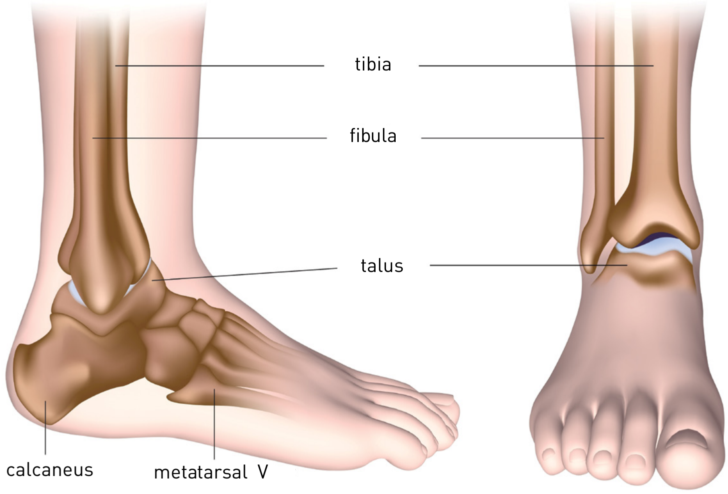


Figure 4.11. Ankle joint. Location of the involved bones.

CLINICAL RELEVANCE

An **ankle sprain** occurs when the ligaments surrounding the ankle are stretched or torn, usually due to a sudden twist, turn, or impact. It commonly happens during activities like running, jumping, or sports. Symptoms include pain, swelling, bruising, and difficulty moving the ankle. The severity of a sprain can range from mild (stretched ligaments) to severe (torn ligaments). Treatment often involves rest, ice, compression, elevation (R.I.C.E.), and in some cases, physical therapy or bracing to support recovery.

What are the arches of the foot?

The arches of the foot are structured to resist the body weight placed on them (Figure 4.7). These include two longitudinal arches, the **medial longitudinal arch** on the inner side of the foot and the **lateral longitudinal arch** on the outer side, as well as a transverse one, the **transverse arch**. The **medial longitudinal arch** of foot is located on the inner side of the foot and is the highest arch. It begins at the calcaneus in the back and continues forward through the talus, navicular bone, cuneiform bones, and the first three metatarsal bones. The highest point of this arch is at the head of the talus. The **lateral longitudinal arch** is located on the outer side of the foot and has a much shallower curvature. The **transverse arch** connects the two longitudinal arches. The stability of the arches of the foot is maintained through the shape of the bones, their arrangement, the ligaments between them, and the support from the muscles and tendons. Weakening of the arches leads to the clinical condition called **flatfoot**.

CLINICAL RELEVANCE

Hallux valgus, commonly known as a **bunion**, is a foot deformity where the big toe (hallux) tilts inward toward the second toe, causing a bony bump to form on the side of the foot at the base of the big toe. This misalignment can lead to pain, swelling, and difficulty wearing certain shoes. Hallux valgus can develop due to factors like genetics, poor footwear, or certain foot mechanics. In mild cases, it may be managed with padding, and proper footwear, but severe cases may require surgical correction.

What are the main bursae around synovial joints of the lower extremity?

Main bursae around synovial joints of the lower extremity:

- **iliopsoas (iliopectinate) bursa:** is located beneath the tendon of iliopsoas muscle and anterior to the hip joint capsule. It is the largest bursa around the hip joint.
- **trochanteric (subgluteus) bursa:** is located deep to the gluteus maximus m. around the greater trochanter of femur.
- **suprapatellar bursa**: is between the femur and the quadriceps femoris tendon.
- **prepatellar bursa:** is located between the skin and patella.
- **infrapatellar bursa:** is located behind the patella and tibia.

MUSCLES

What are the muscles of the lower extremity?

The muscles of the lower extremity are divided into hip muscles, thigh muscles, leg muscles, and foot muscles (Figure 4.12).

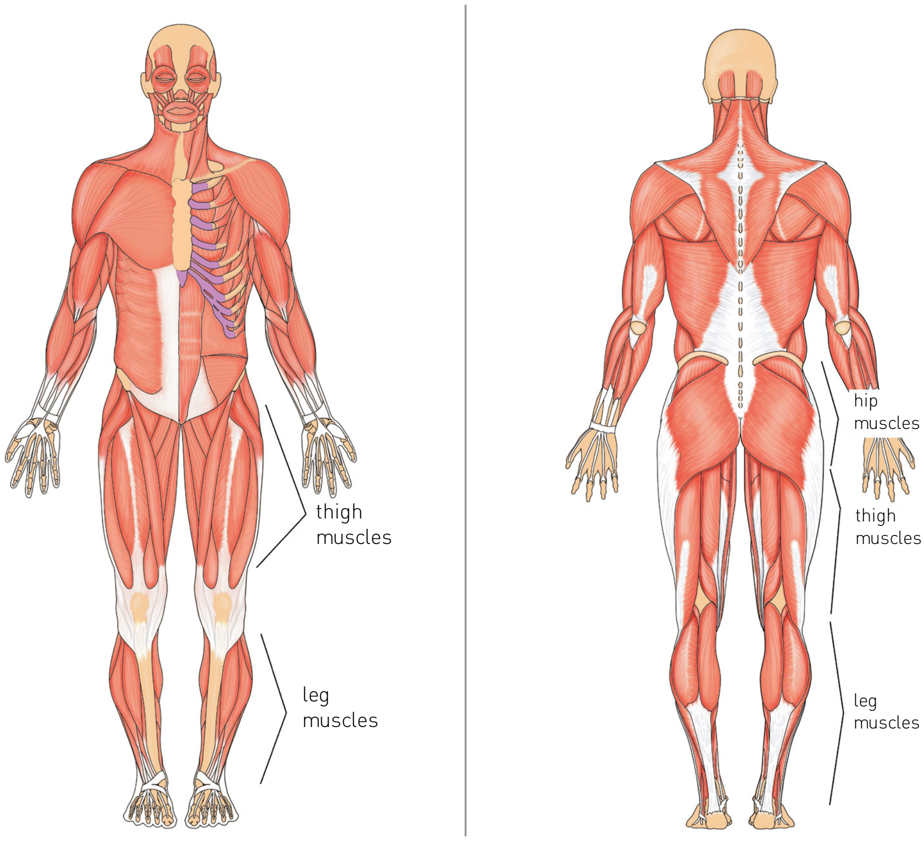


Figure 4.12. Lower extremity muscles **a.** anterior view and **b.** posterior view.

The hip muscles start from the coxa or sacrum and attach to the femur, allowing movement of the thigh. The deep fascia surrounding these muscles is called the **gluteal fascia**. The **gluteus maximus m.**, which creates the hip prominence and forms the thickest muscle mass of the body, is located here. The **gluteus medius m.** is located superiorly and deep to the gluteus maximus. The **gluteus minimus m.** lies beneath both of these muscles. The hip muscles, their functions, and the nerves supplying them are given in the table below (Figure 4.13a,b).

Muscle	Function	Nerve
gluteus maximus m.	extension and external rotation of the thigh	n. glutealis inferior
gluteus medius m.	abduction of the thigh	n. glutealis superior
gluteus minimus m.	abduction of the thigh	n. glutealis superior

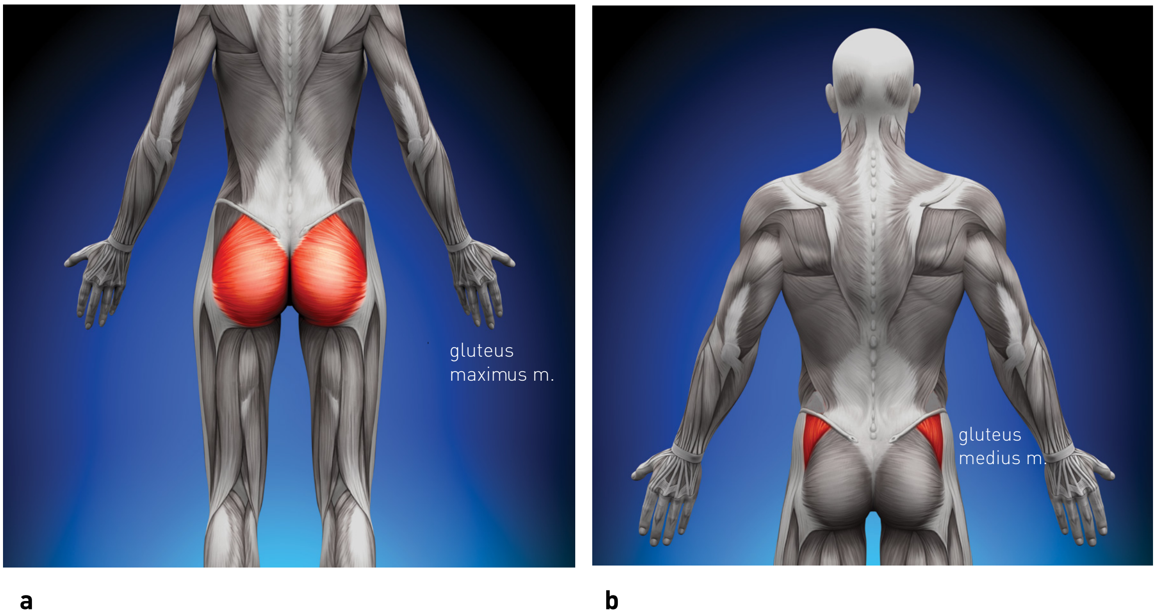


Figure 4.13. Hip (gluteal region) muscles. **a.** gluteus maximus m. **b.** gluteus medius m.

There is a group of small muscles deep in the hip region. Their functions and the nerves supplying them are given in the table below.

Muscle	Function	Nerve
piriformis m.	external rotation of the thigh	L5-S1,2
superior gemellus m.		L5-S1
inferior gemellus m.		L5-S1
obturator internus m.		L5-S1
quadratus femoris m.		L5-S1

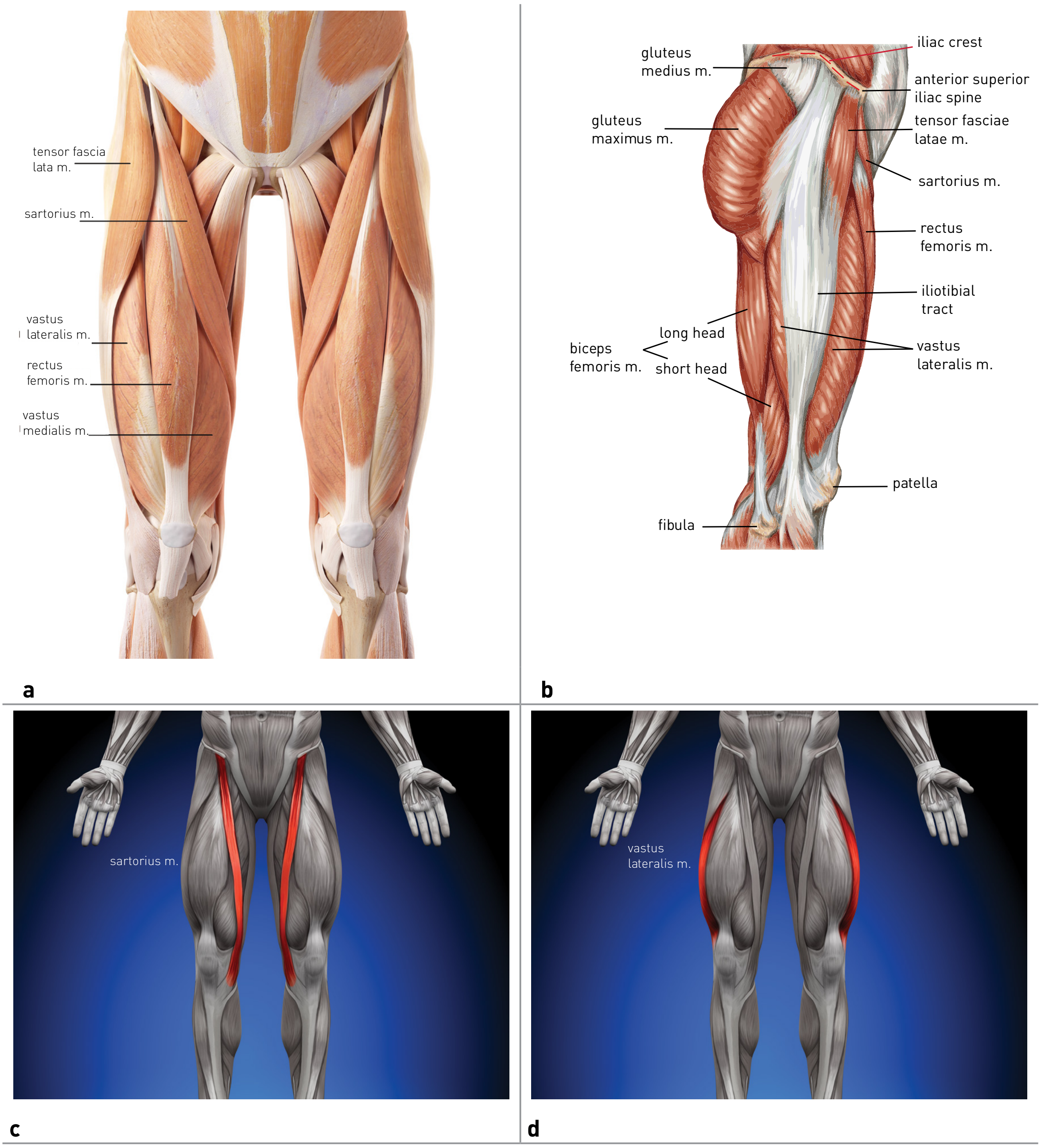
The fascia surrounding the thigh is called the **fascia lata**. The thickened and long extension of this fascia on the outer side of the thigh is called the **iliotibial tract** (Figure 4.14b).

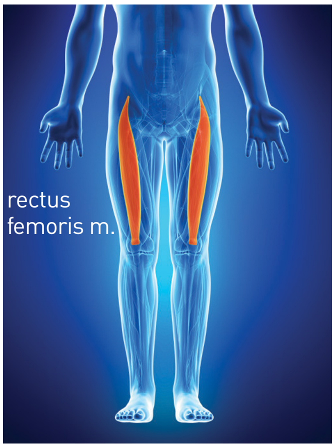
Thigh Muscles: The thigh muscles are categorized into three groups: anterior, posterior, and medial.

The largest muscle of the anterior thigh is the **quadriceps femoris m.**, which consists of four separate parts: the **rectus femoris m.**, **vastus lateralis m.**, **vastus medialis m.**, and **vastus intermedius m.** The **vastus intermedius m.** is deep to the other three and is not visible from the outside. The **patellar tendon** is the common tendon for the quadriceps femoris muscle which inserts to the patellar tuberostiy. Another muscle in this region, the **m. sartorius**, is the longest muscle in the body. It starts at the upper outer part of the thigh, moves inward, and crosses the thigh to attach to the inner part of the knee. The **iliopsoas m.** consists of two parts: the **iliacus m.** originating from the ilium, fills the iliac fossa and the **psoas major m.** originating from the spine. These two parts join via a common tendon and attach to the femur.

The anterior thigh muscles, their functions, and the nerves supplying them are given in the table below (Figure 4.14a-g).

Muscle	Function	Nerve
quadriceps femoris m.	extension of the leg	femoral n.
sartorius v	flexion of the thigh and leg	femoral n.
iliopsoas m.	flexion and external rotation of the thigh	L1-3 spinal n.
tensor fasciae latae m.	abduction and internal rotation of the thigh	sup. gluteal n.





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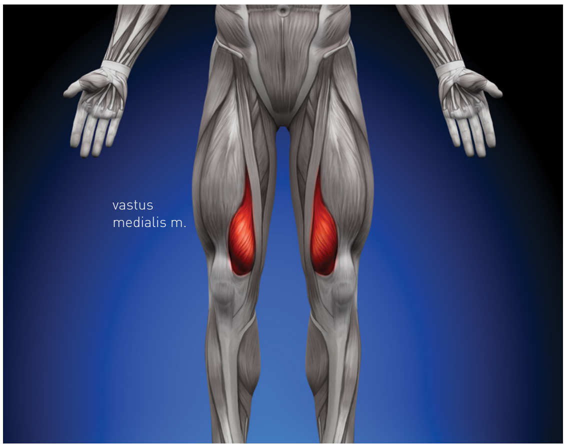

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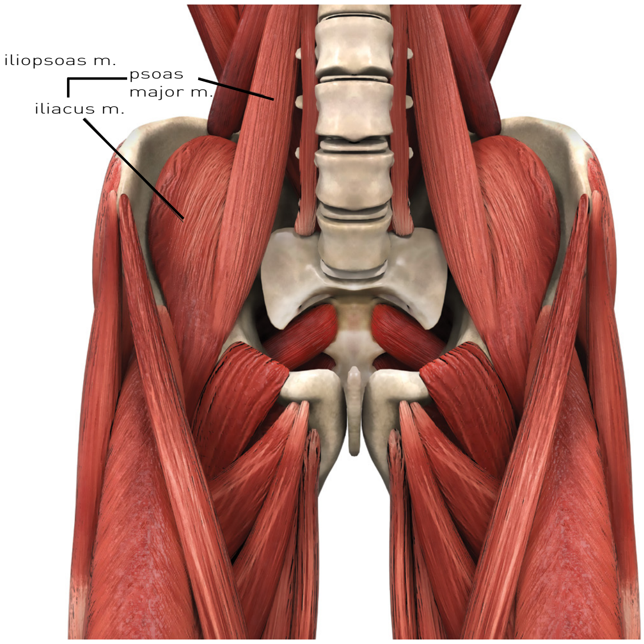

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Figure 4.14. Thigh muscles. **a.** anterior view **b.** lateral view **c.** sartorius m. **d.** vastus lateralis m. **e.** rectus femoris m. **f.** vastus medialis m. **g.** iliopsoas m.

The posterior thigh muscles are also known as the **hamstrings**. Their functions and the nerves supplying them are given in the table below (Figure 4.15).

CLINICAL RELEVANCE

The **patellar reflex**, also known as the **knee-jerk reflex**, is a simple, automatic response that occurs when the patellar tendon, located just below the kneecap, is tapped. This reflex helps assess the function of the L2, L3, and L4 spinal nerves. When the tendon is tapped, it stretches the quadriceps muscle, which causes it to contract, resulting in the leg kicking forward. This reaction is a normal, involuntary response that helps maintain posture and balance. A diminished or absent patellar reflex can indicate nerve damage or neurological issues, while an exaggerated reflex may suggest certain conditions like hyperthyroidism or upper motor neuron disorders.

Muscle	Function	Nerve
semimembranosus m.	extension of the thigh and flexion of the leg	sciatic n.
semitendinosus m.		
biceps femoris m.		

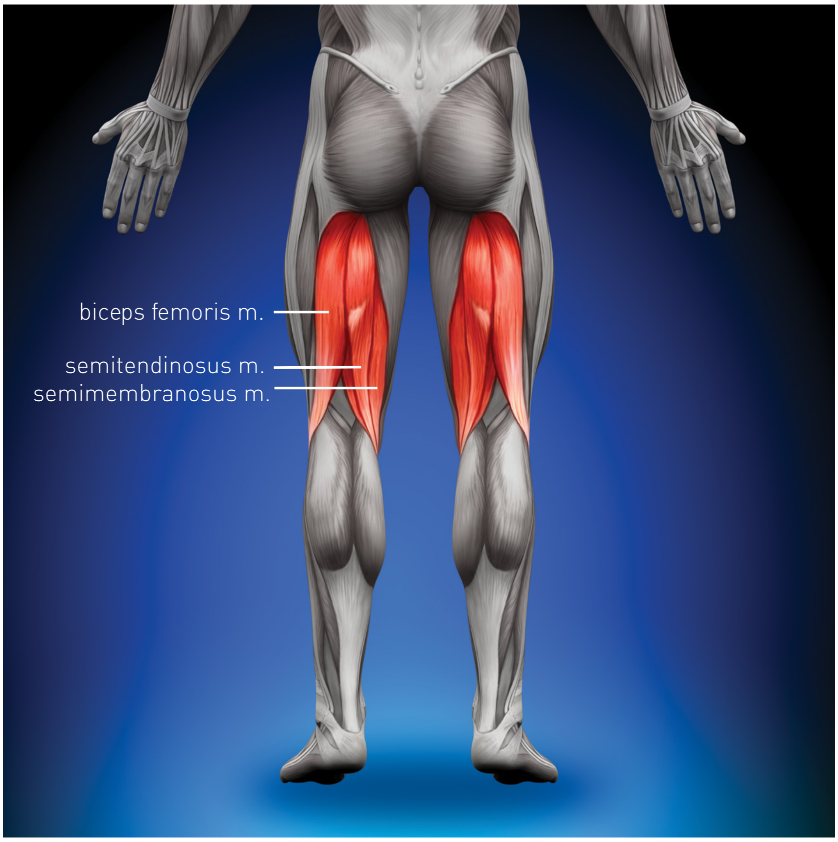


Figure 4.15. Posterior thigh muscles (Hamstring muscles).

The medial thigh muscles, also known as the thigh adductors. Their functions and the nerves supplying them are given in the table below (Figure 4.16).

Muscle	Function	Nerve
adductor magnus m.	adduction of thigh	obturator n. + sciatic n.
pectineus m.		femoral n.
gracilis m.		obturator n.
adductor longus m.		
adductor brevis m.		

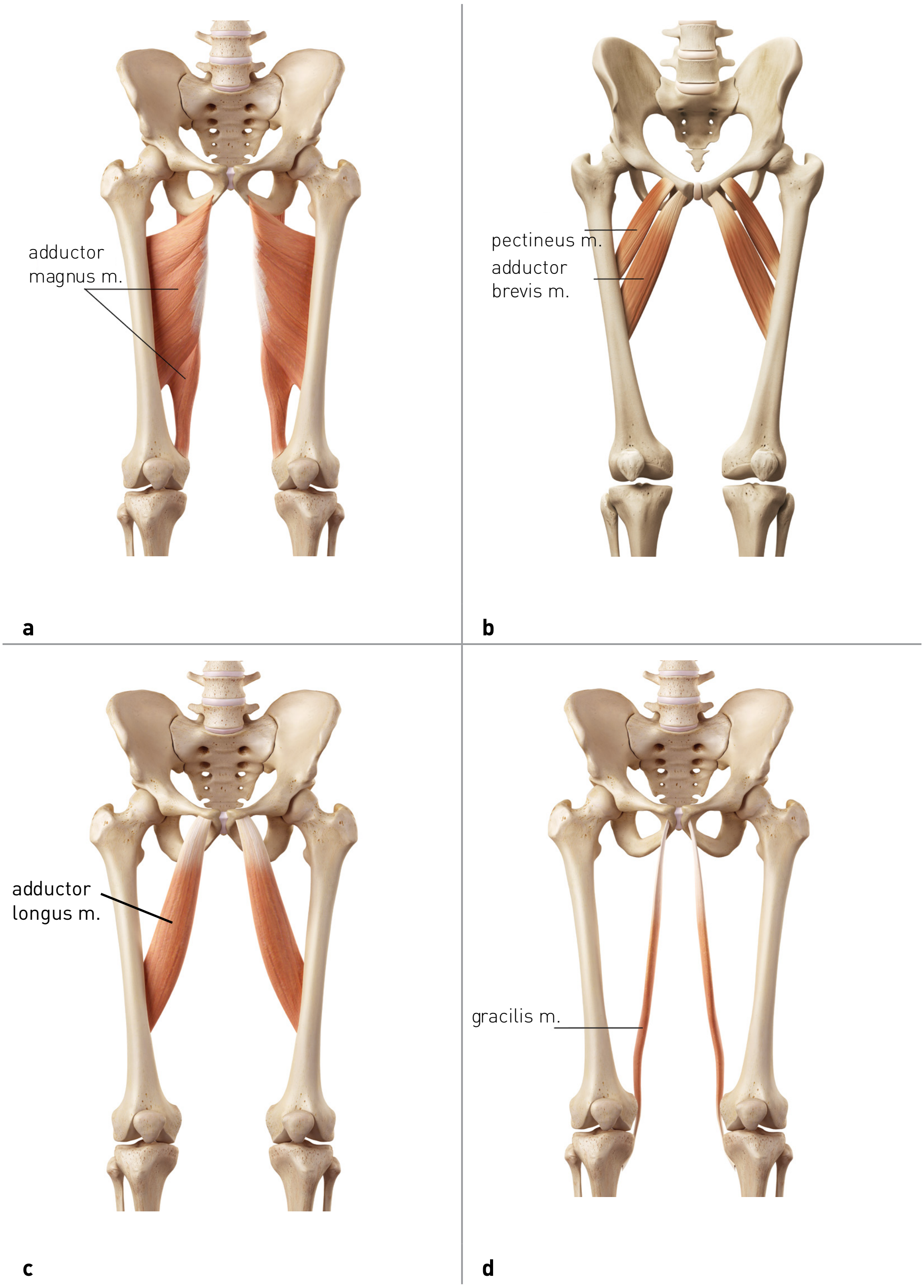


Figure 4.16. Medial thigh muscles (adductor group muscles). **a.** adductor magnus m. **b.** pectineus m. and adductor brevis **c.** adductor longus m. **d.** gracilis m.

Where is the femoral triangle?

It is situated on the top front portion of the thigh, an area through which vital blood vessels and nerves pass. Boundaries of this triangular area are formed by the **inguinal lig.** above, by the **sartorius m.** laterally, and by the **adductor longus m.** medially.

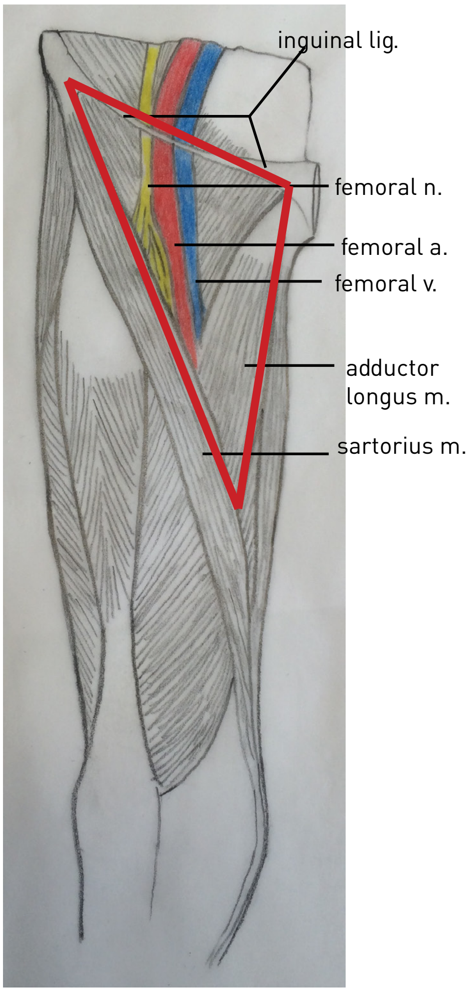


Figure 4.17. Femoral trigone.

What structures are present in the femoral triangle?

Inside, from medial to lateral, there are the **femoral v.**, **femoral a.**, and **femoral n.** (VAN).

What is the femoral canal?

The **femoral canal** is an inverted cone-shaped fascial space with four borders and an opening situated in the anterior thigh within the femoral triangle. It is bounded by the lacunar ligament medially, femoral vein laterally, inguinal ligament anteriorly and the pectineal ligament and the pectineus muscle posteriorly. The opening to the femoral canal is located at its superior edge, known as the **femoral ring**.

What is the adductor canal (Hunter's canal, subsartorial canal)?

Adductor canal is a narrow, 3-walled passage in the middle thigh. It begins at the apex of the femoral triangle and ends at the adductor hiatus. The boundaries of this canal are the vastus medialis m. anterolaterally, adductor longus and adductor magnus mm. posteriorly, and the sartorius m. and the vastoadductor membrane anteromedially. It transmits the femoral artery, femoral vein, saphenous nerve, and the nerve to vastus medialis.

CLINICAL RELEVANCE

A **femoral hernia** occurs when a part of the intestine pushes through the femoral canal. It is more common in women and may cause a bulge in the groin area, often accompanied by pain or discomfort, especially when lifting or straining. Femoral hernias can be serious if they become incarcerated (trapped) or strangulated (cut off from blood supply), requiring surgical intervention to repair the hernia and prevent complications.

Where is the popliteal fossa?

The popliteal fossa is a diamond-shaped area located at the back of the knee (Figure 4.22). The upper boundaries of the fossa are formed medially by the **semimembranosus** and **semitendinosus mm.**, and laterally by the **biceps femoris m.**, while the lower boundaries are formed by the **medial** and **lateral heads** of the **gastrocnemius m**.

What structures are present in the popliteal fossa?

Within this fossa, there are the branches of the **sciatic n.**, namely **tibial n.** and **common fibular n.**, which are embedded in adipose tissue, along with the **popliteal a.**, **popliteal v.**, **small saphenous v.**, and popliteal lymph nodes (Figure 4.22b). The deepest is the popliteal a., while the branches of the tibial n. and common fibular n. are the most superficial structures.

Leg muscles: The muscles of the leg are categorized into three groups: anterior, posterior, and lateral (Figure 4.18a-c).

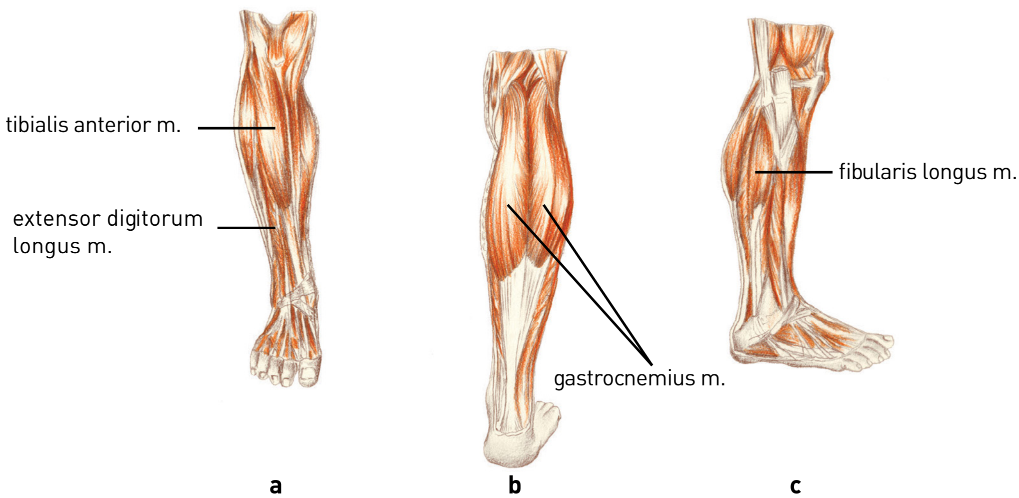


Figure 4.18. Leg muscles: **a.** anterior compartment, **b.** posterior compartment and **c.** lateral compartment.

The muscles of the anterior leg, their functions, and the nerves supplying them are given in the table below:

Muscle	Function	Nerve
tibialis anterior m.	dorsiflexion of the foot	deep fibular n.
extensor hallucis longus m.	dorsiflexion of the foot and big toe	
extensor digitorum longus m.	dorsiflexion of the foot and toes 2-5	
fibularis tertius m.	dorsiflexion of the foot	

The muscles of the posterior leg, their functions, and the nerves supplying them are given in the table below (Figures 4.18b, 4.19):

Muscle	Function	Nerve
Superficial group		
gastrocnemius m.	plantar flexion of the foot	tibial n.
soleus m.		
plantaris		
Deep group		
tibialis posterior m.	plantar flexion and inversion of the foot	tibial n.
flexor digitorum longus m.	plantar flexion of the foot and toes	
hallucis longus m.	plantar flexion and inversion of the foot	
popliteus m.	stabilization of the knee joint	

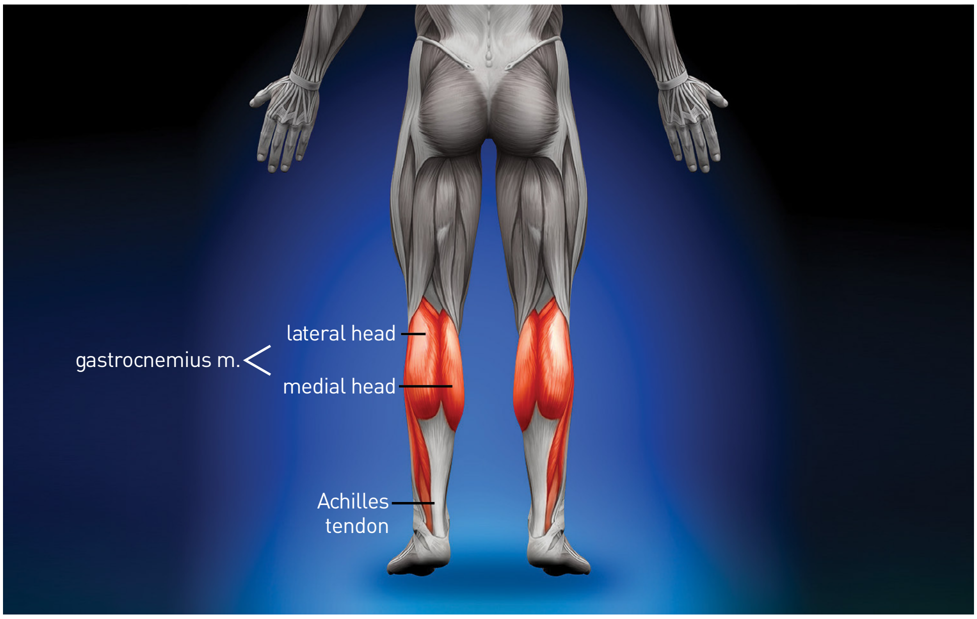


Figure 4.19. Leg posterior compartment muscles.

What is the popliteal fossa?

The **popliteal fossa** is a diamond-shaped area located at the back of the knee (Figure 4.22). Its upper boundaries are formed medially by the semimembranosus and semitendinosus muscles, and laterally by the biceps femoris muscle. The lower boundaries are formed by the medial and lateral heads of the gastrocnemius muscle**.**

What structures are found in the popliteal fossa?

Within this region, embedded in fat tissue, are the branches of the sciatic nerve- the **tibial nerve** and **common fibular (peroneal) nerve**, the **popliteal artery**, **popliteal vein**, **small saphenous vein**, and **popliteal lymph nodes** (Figure 4.22b). The popliteal artery is the deepest structure, while the tibial and common fibular nerves are the most superficial.

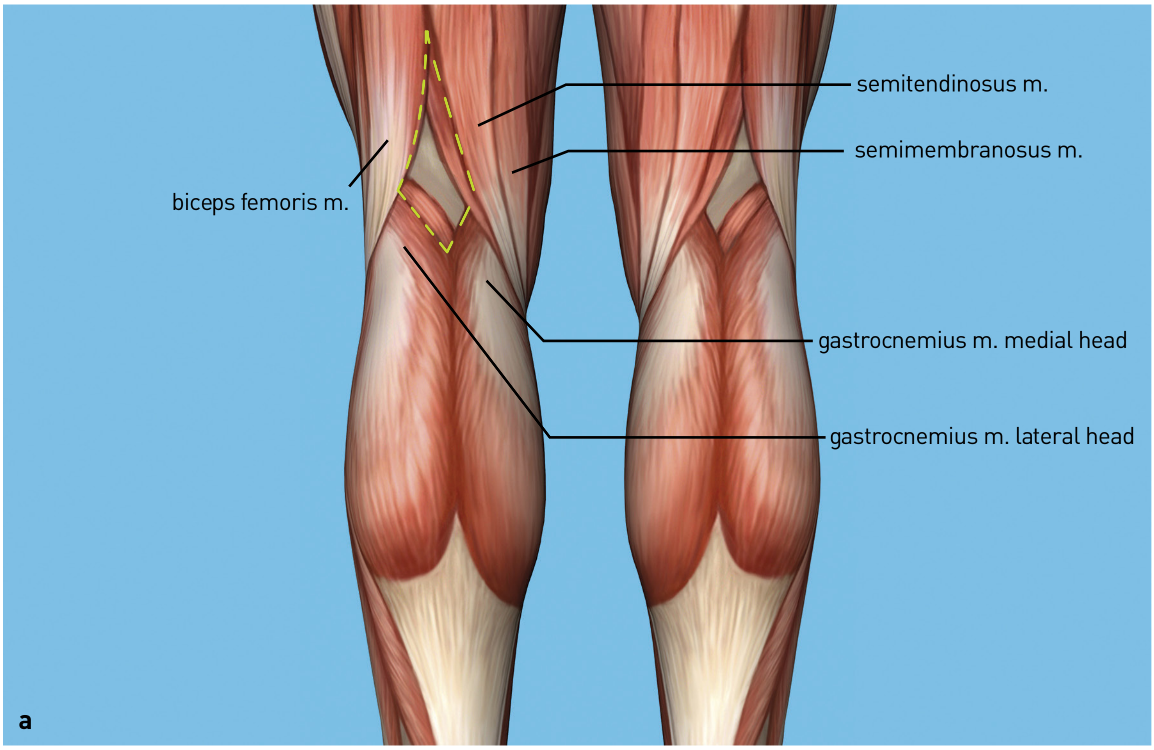
What is the Achilles tendon?

The Achilles tendon (**calcaneal tendon**) is the common tendon of the three large muscles in the superficial group of the posterior leg. It is the thickest and strongest tendon in the body, with the highest load-bearing capacity (Figures 4.18b, 4.19).

CLINICAL RELEVANCE

The **Achilles reflex**, is a deep tendon reflex that occurs when the Achilles tendon is tapped. This reflex tests the function of the **S1** and **S2** spinal nerves. When the tendon is tapped (typically while the patient is seated with their foot dangling), the calf muscles contract, causing the foot to point downward. This is an involuntary response that helps assess the integrity of the nerve pathways in the lower leg and the spinal cord. An absent or abnormal Achilles reflex can indicate issues with the nerves or spinal cord in the lower back.

Compartment syndrome is a serious condition that occurs when pressure builds up within a muscle compartment, a group of muscles, nerves, and blood vessels surrounded by the tough membrane; fascia. The increased pressure can restrict blood flow, leading to muscle and nerve damage. It often results from trauma or fractures. Symptoms include severe pain, swelling, tightness, numbness, and weakness in the affected area. If not treated promptly, compartment syndrome can cause permanent tissue damage. The main treatment is surgery to relieve pressure by opening the fascia (fasciotomy).



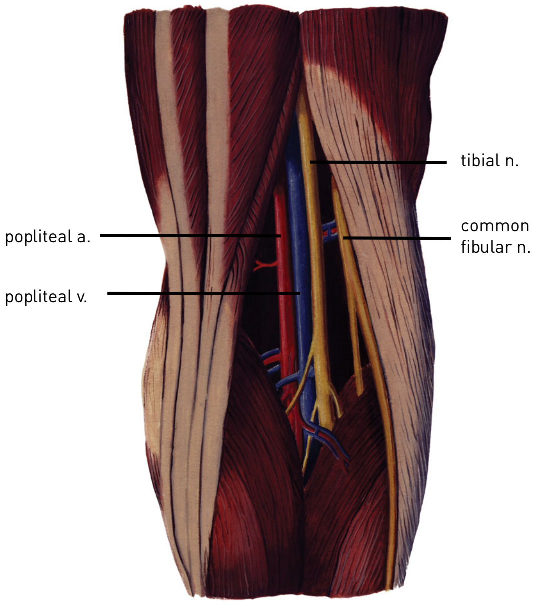


Figure 4.20. Popliteal fossa. **a.** muscular borders of the popliteal fossa **b.** neurovascular structures in the popliteal fossa.

The muscles of the lateral leg, their functions, and the nerves supplying them are given in the table below (Figures 4.18c, 4.20):

Muscle	Function	Nerve
fibularis longus m.	eversion of the foot	superficial fibular n.
fibularis brevis m.		

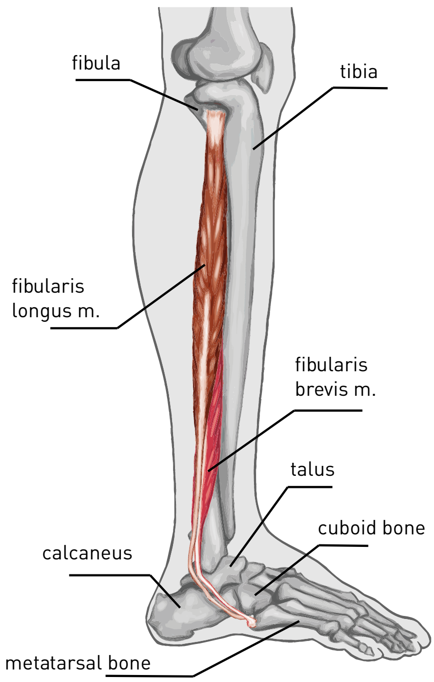


Figure 4.21. Leg lateral compartment muscles.

The muscles on the dorsum (top) of the foot, their functions, and the nerves supplying them are given in the table below:

Muscle	Function	Nerve
extensor digitorum brevis m.	extension of the toes	deep fibular n.

On the sole of the foot, there is a thick and strong band that protects the deep structures: the **plantar aponeurosis**. The foot muscles located deep to this structure, their functions, and innervations are listed in the table below.

CLINICAL RELEVANCE

Plantar fasciitis is a common cause of heel pain, occurring when plantar aponeurosis becomes inflamed. This band supports the arch of the foot and can become irritated from excessive pressure, overuse, or poor foot mechanics. The pain is typically felt on the bottom of the heel, especially with the first steps after waking up or after long periods of rest. It's often treated with rest, stretching, ice, and supportive footwear.

Layer	Muscle	Nerve	Function
1st layer	abductor hallucis m.	medial plantar n.	performs movements of the toes as their names suggest, generally plays a role in supporting the foot arches.
	abductor digiti minimi m.	lateral plantar n.	
	flexor digitorum brevis m.	medial plantar n.	
2nd layer	quadratus plantae m.	lateral plantar n.	
	lumbricals	medial and lateral plantar n.	
3rd layer	flexor hallucis brevis m.	medial plantar n.	
	adductor hallucis m.	lateral plantar n.	
	flexor digiti minimi brevis m.	lateral plantar n.	
4th layer	plantar interosseous m.	lateral plantar n.	
	dorsal interosseous m.		

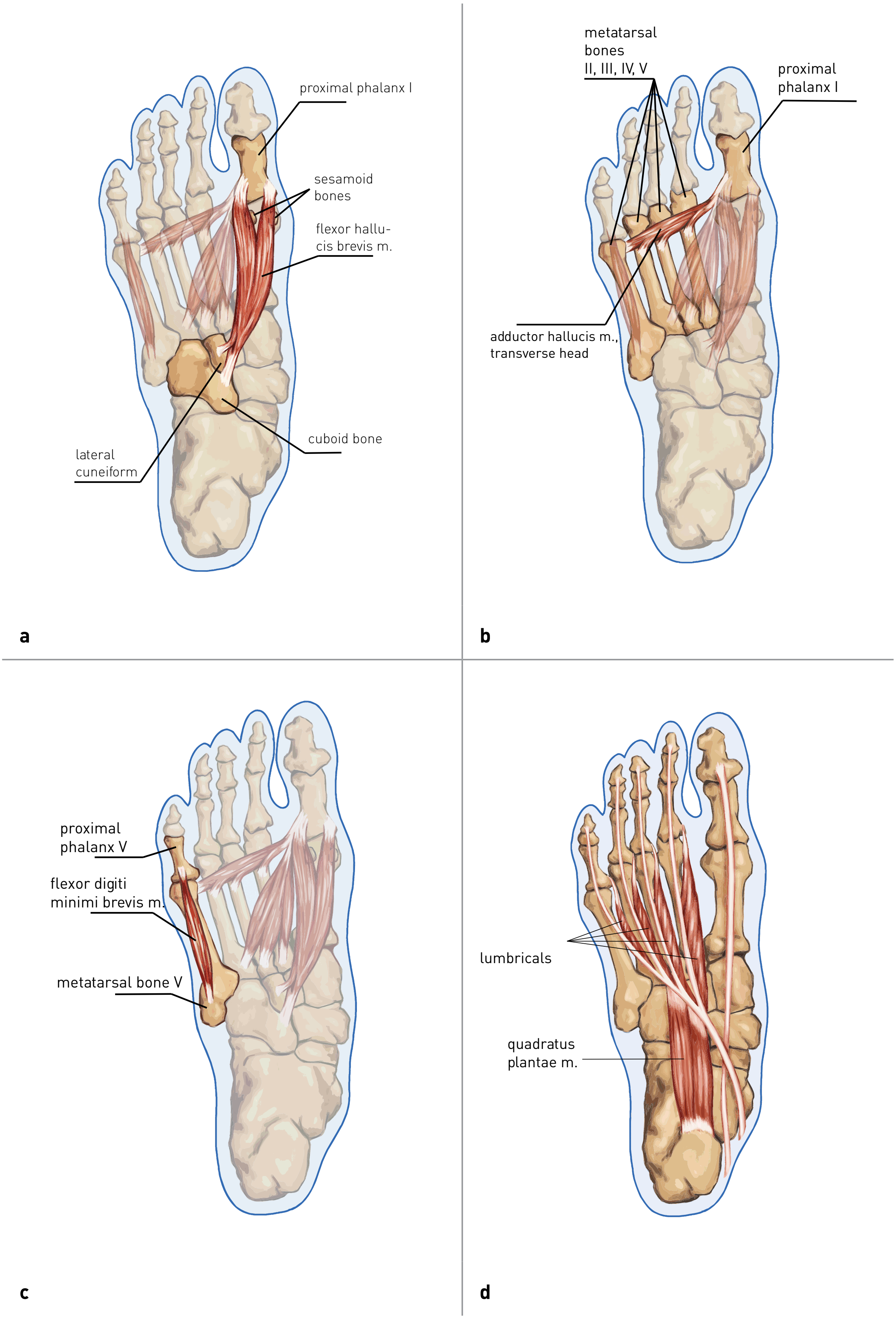


Figure 4.22. Some of the muscles in the different layers of the foot sole

VESSELS AND NERVES

What are the arteries of the lower extremity?

The arteries of the lower extremity, from proximal to distal, are as follows (Figure 4.23):

- in the gluteal region: **superior gluteal a.** and **inferior gluteal a.**
- in the thigh: **femoral a.** and its branch, **deep femoral a.**
- in the popliteal region: **popliteal a.**
- in the leg, anterior compartment: **anterior tibial a.**
- in the posterior compartment: **posterior tibial a.** + **fibular a.**
- on the foot, dorsum: **dorsalis pedis a.** + **arcuate a.**
- on the plantar surface: **medial plantar a.** + **lateral plantar a.**

In the lower extremity, arterial pulses are felt at several key sites where arteries are close to the surface of the skin. These include:

- **femoral pulse**: located in the groin area, just below the inguinal crease, where the femoral artery passes.
- **popliteal pulse**: felt behind the knee, in the popliteal fossa, where the popliteal artery is located.
- **dorsalis pedis pulse**: found on the top of the foot, between the first and second toes, where the dorsalis pedis artery runs.
- **posterior tibial pulse**: located just behind the medial malleolus where the posterior tibial artery passes.

These pulses are important for assessing blood flow and detecting potential circulatory problems in the lower limbs.

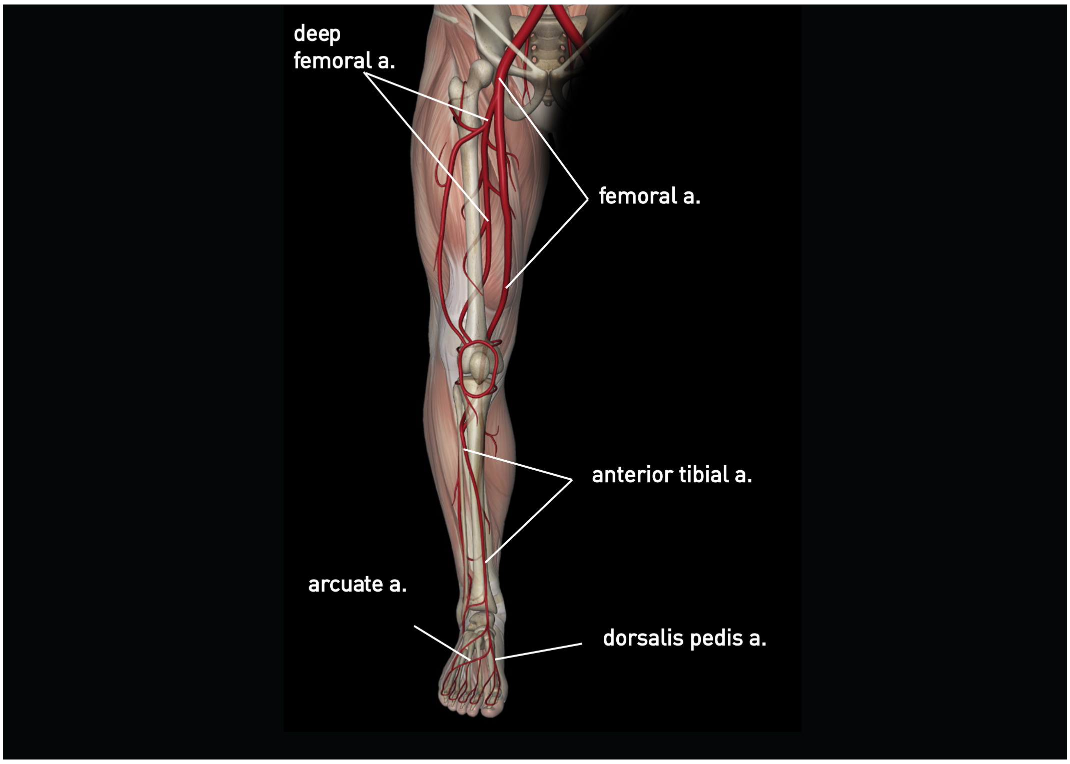


Figure 4.23. Arteries of the lower extremity.

What are the veins of the lower extremity?

The veins of the lower extremity are classified into two groups: **deep veins** and **superficial veins**.

Deep veins: These veins accompany the arteries and have the same names but with blood flow in the opposite direction.

in the leg (anterior compartment): **anterior tibial v.**

in the posterior compartment: **posterior tibial v.** + **fibular v.**

at the knee: **popliteal v.**

in the thigh: **femoral v.**

Superficial veins (Figure 4.24):

on the dorsum of the foot: **dorsal venous arch**

on the plantar surface: **plantar venous arch**

in the leg (on the side of the big toe): **great saphenous v.**

in the leg (on the side of the little toe): **small saphenous v.**

in the thigh: **great saphenous v.**

The **great saphenous v.**, which begins on the dorsum of the foot near the big toe, passes in front of the **medial malleolus**, continues along the medial side of the leg, knee, and thigh, and then drains into the **femoral v.** at the **femoral triangle**. The **small saphenous v.**, starting on the side of the little toe on the dorsum of the foot, passes behind the **lateral malleolus**, continues up the lateral side of the leg to the knee, and drains into the **popliteal v.** in the **popliteal fossa**.

CLINICAL RELEVANCE

Varices are enlarged, twisted veins that usually occur in the legs but can also develop in other areas. They result from weakened or damaged vein walls and valves, which cause blood to pool and the veins to stretch. The most common type is **varicose veins**, which are visible under the skin and often cause discomfort, swelling, or a feeling of heaviness. Risk factors include aging, prolonged standing, pregnancy, and a family history of vein problems. Treatment options vary from lifestyle changes and compression stockings to procedures like sclerotherapy, laser therapy, or surgery in more severe cases.

Deep vein thrombosis (DVT) is a condition where a blood clot forms in a deep vein, usually in the legs. The clot can cause swelling, pain, and redness in the affected area. DVT is dangerous because if the clot breaks loose, it can travel to the lungs, causing a pulmonary embolism, which can be life-threatening. Risk factors for DVT include prolonged immobility, surgery, pregnancy, and certain medical conditions. Treatment often involves blood thinners to prevent the clot from growing or traveling.

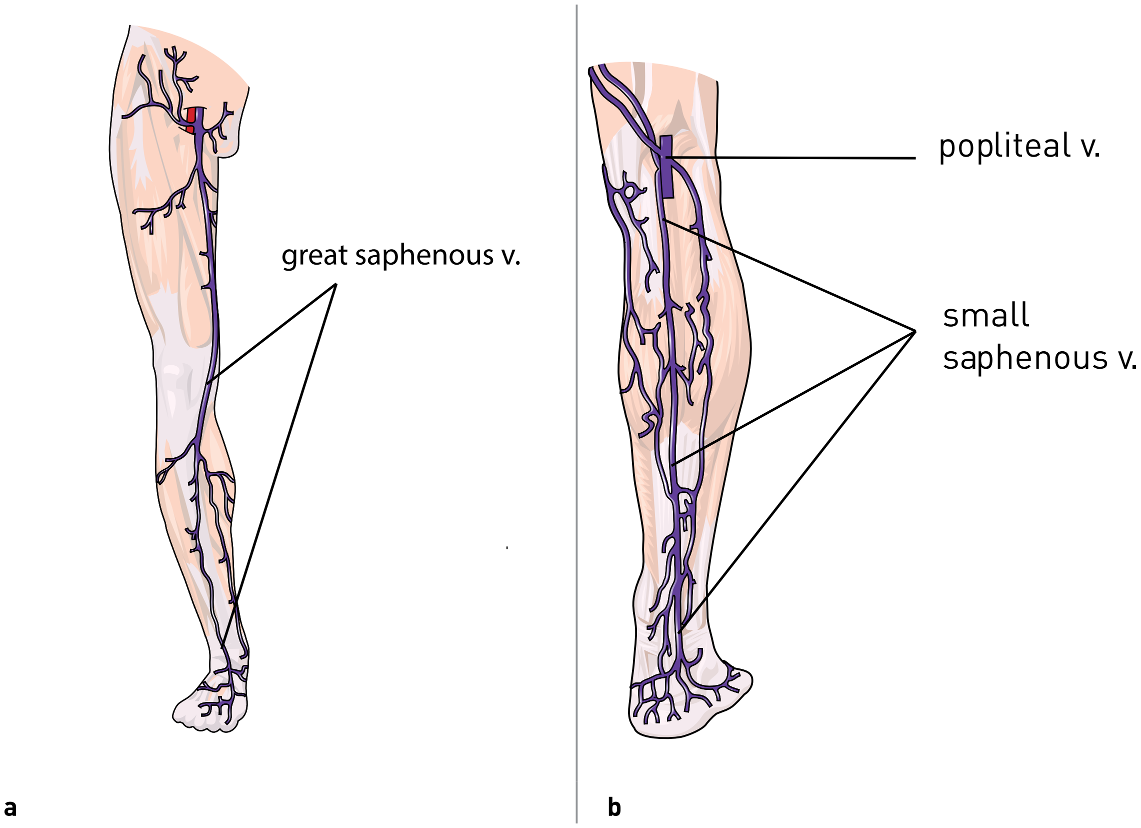


Figure 4.24. Superficial veins of the lower extremity. **a.** anterior view of the superficial veins of the thigh and leg **b.** view of the superficial veins on the dorsal aspect of the leg.

What is the lumbosacral plexus (lumbar and sacral nerve plexus)?

The lumbar plexus is located in the posterior abdominal wall, deep to the psoas major m., formed by the fibers coming from the spinal segments Th12, L1, L2, L3, and L4 (Figure 4.25a). It provides sensory nerves for the skin of the lower abdomen and lower extremity, as well as motor nerves for some of the muscles in the lower extremity. The nerves that emerge from this plexus are as follows:

iliohypogastric n. (L1): Passes from the posterior abdominal wall, behind the kidneys, and proceeds towards the lateral and anterior abdominal wall. It provides sensory branches to the posterior lateral gluteal area and the suprapubic region. Its motor branches innervate the transversus abdominis m. and obliquus internus abdominis m.

ilioinguinal n. (L1): Follows a path similar to the iliohypogastric n., advancing toward the anterior abdominal wall. It enters the inguinal canal near the anterior superior iliac spine and emerges from the superficial inguinal ring. In males, it provides sensory branches to the upper inner thigh, root of the penis, and scrotum. In females, it supplies the mons pubis and major labia. Its motor branches innervate the transversus abdominis m. and obliquus internus abdominis m. before entering the inguinal canal.

genitofemoral n. (L1, L2): After forming in the posterior abdominal wall, it typically passes through the psoas major m., continuing downward on its anterior surface, and splits into two branches: **genital** and **femoral**. The genital branch enters the inguinal canal, innervates the cremaster m., and provides sensory innervation to the external genitalia. The femoral branch continues downward and enters the thigh, providing sensory innervation to the anterior upper thigh.

lateral femoral cutaneous n. (L2, L3): Passes laterally to the psoas major m., goes beneath the inguinal lig., and enters the thigh, providing sensory innervation to the anterior and lateral aspects of the thigh up to the knee.

femoral n. (L2,3,4): Passes along the outside of the psoas major m., continues downward between psoas major and iliacus m., and enters the thigh by passing beneath the inguinal lig. It gives numerous sensory and motor branches. Its sensory branches provide sensation to the anterior thigh, and the saphenous n., a sensory branch, provides sensation to the inner part of the lower leg. Its motor branches supply the iliacus m., pectineus m., sartorius m., and quadratus femoris m.

obturator n. (L2,3,4): Passes along the inner surface of the psoas major m., continues downward, and exits the pelvis through the obturator canal to reach the medial thigh. It provides sensory branches to the medial thigh and motor branches to the adductor muscles.

The sacral plexus is a nerve network that provides sensory innervation to a portion of the lower extremity and innervates some muscles of the pelvis and lower extremity. It is formed by fibers from the spinal segments L4, L5, S1, S2, S3, and S4, located in front of the piriformis m. in the posterior pelvis. The nerves emerging from this plexus include:

sciatic n. (L4, L5, S1, S2, S3): The thickest nerve in the body, formed in front of the piriformis m., passes below it, moves from the pelvis to the gluteal region, and then enters the posterior thigh. It splits into the tibial n. and common fibular n. in the popliteal fossa. It innervates the muscles of the posterior thigh, leg, and foot, and provides sensory innervation to the lateral side of the leg and the entire foot.

pudendal n. (S2, S3, S4): Formed on the lower front side of the piriformis m., passes below it, travels around the sacrospinous lig., and reaches the perineum. It innervates the sphincter ani externus m., sphincter urethrae externus m., and other muscles of the perineum, and provides sensory innervation to the skin of the perineum.

superior gluteal n. (L4, L5, S1): Passes above the piriformis m. and innervates the following muscles: gluteus medius m., gluteus minimus m., and tensor fasciae latae m.

inferior gluteal n. (L5, S1, S2): Passes below the piriformis m. and innervates the gluteus maximus m.

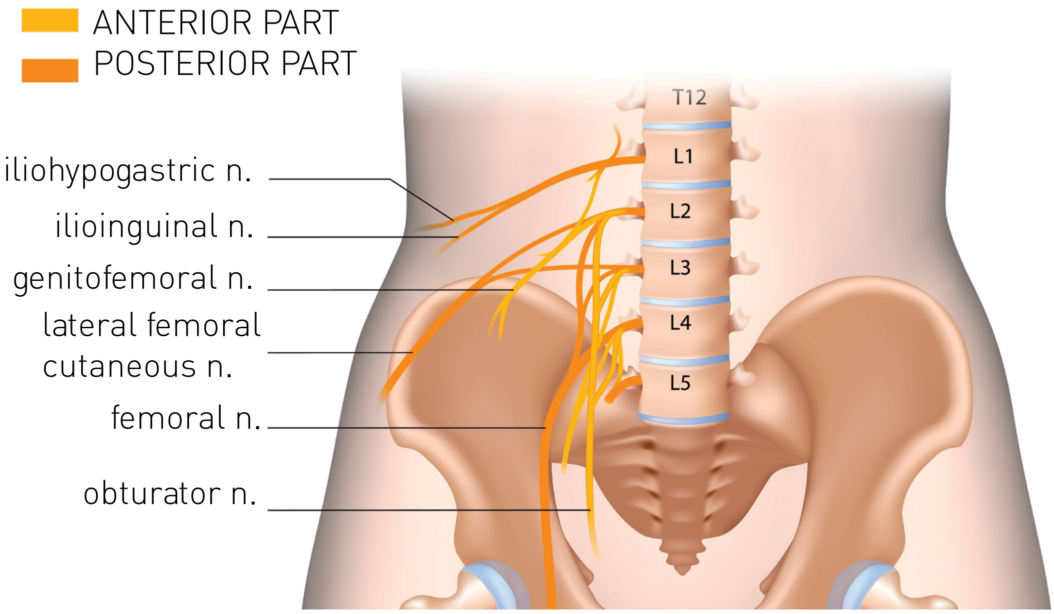
posterior femoral cutaneous n. (S1, S2, S3): Passes below the piriformis m., travels down the posterior thigh, and reaches the upper posterior leg. It provides sensory innervation to the gluteal region, posterior thigh, and upper posterior leg.

muscular branches: A group of motor branches from the sacral plexus innervates small muscles around the gluteal region, such as the piriformis m., gemellus superior m., gemellus inferior m., obturator internus m., and quadratus femoris m.

CLINICAL RELEVANCE

Sciatic pain is a pain that starts in the lower back and radiates down the legs. This pain is usually caused by compression or irritation of the sciatic nerve. The sciatic nerve is the longest nerve in the body, extending from the lower back to the hips and down the legs. Sciatic pain can result from conditions like a herniated disc, muscle strain, or nerve compression. Symptoms may include burning, tingling, weakness, and severe pain in the leg. Treatment may involve rest, pain relievers, physical therapy, and in some cases, surgical intervention.

A **common fibular nerve injury** due to a fibular head fracture occurs when the fibular nerve, which runs near the fibula just below the knee, is damaged as a result of a break in the fibula near the knee. The fracture can directly compress or stretch the nerve, leading to symptoms such as **foot drop** (lack of dorsiflexion, inability to lift the foot), weakness in the muscles controlling the foot and ankle, numbness, or tingling along the outer lower leg and foot. This type of injury is often seen in fractures caused by trauma, like a fall or impact.



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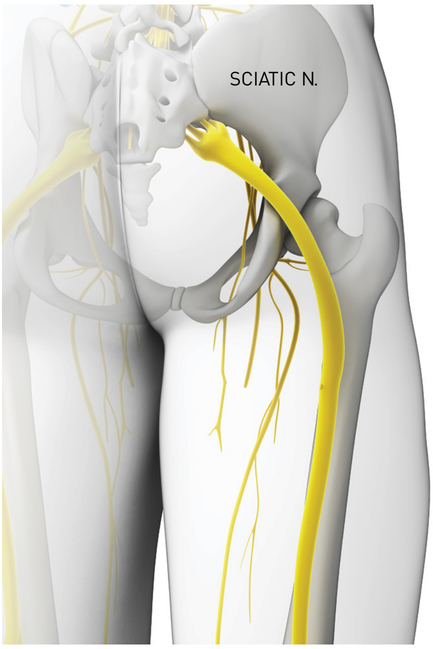

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Figure 4.25. Nerve plexuses of the lower extremity. **a.** lumbar plexus and its branches **b.** sciatic n.

Sample Questions about the Lower Extremity:

1. Which of the following is **not** observed on the coxa?

   a) Ischial tuberosity

   b) Greater trochanter

   c) Iliac crest

   d) Acetabulum

   e) Obturator foramen

2. Which of the following can be observed on the femur?

   a) Pubic ramus

   b) Lunate surface

   c) Intercondylar fossa

   d) Ischial spine

   e) Lesser sciatic notch

3. Between which two structures is the hip joint located?

   a) Femoral head - lunate surface

   b) Femoral head - obturator foramen

   c) Femoral neck - pubic symphysis

   d) Femoral neck - lunate surface

   e) Femoral neck – acetabulum

4. Which of the following is **not** related to the knee joint?

   a) Anterior cruciate lig.

   b) Posterior cruciate lig.

   c) Lateral collateral lig.

   d) Medial meniscus

   e) Lesser sciatic notch

5. Which of the following muscles performs extension of the thigh?

   a) Gluteus maximus m.

   b) Gluteus medius m.

   c) Quadratus femoris m.

   d) Piriformis m.

   e) Sartorius m.

6. Which of the following muscles is innervated by the femoral?

   a) Gluteus medius m.

   b) Adductor longus m.

   c) Gracilis m.

   d) Sartorius m.

7. Which of the following is located in front of the thigh?

   a) Gluteus maximus m.
   b) Gluteus medius m.
   c) Gastrocnemius m.
   d) Quadriceps femoris m.
   e) Fibularis longus m.

8. Which of the following is **not** a branch of the lumbar plexus?

   a) Ilioinguinal n.
   b) Genitofemoral n.
   c) Sciatic n.
   d) Femoral n.
   e) Obturator n.

9. Which of the following is located most medially in the femoral triangle?

   a) Femoral n.
   b) Femoral a.
   c) Femoral v.
   d) Sciatic n.
   e) Popliteal a.

10. Which of the following is one of the muscles of the lateral compartment of the leg?

    a) Flexor digitorum longus m.
    b) Fibularis longus m.
    c) Tibialis anterior m.
    d) Gastrocnemius m.
    e) Soleus m.

Answers: 1.B, 2. C, 3.A, 4.E, 5.A, 6.E, 7.D, 8.C, 9.C, 10.B

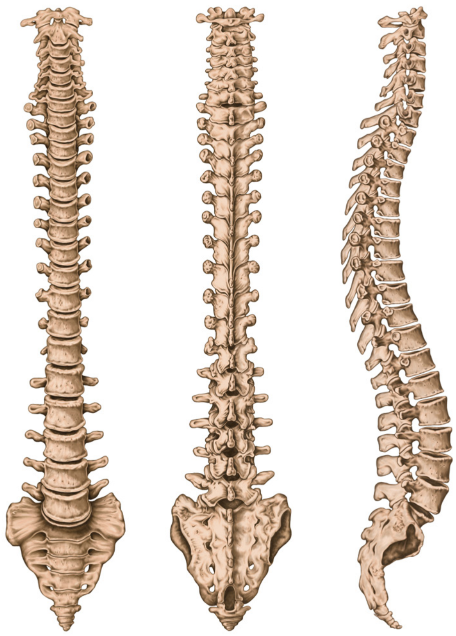
SPINE (VERTEBRAL COLUMN)

SPINE (VERTEBRAL COLUMN)

What is the vertebral column?

Vertebral column is the bony structure known as **spine**. It extends from the base of the skull to the coccyx (tailbone). It is composed of a total of 33-34 vertebrae that are stacked on top of one another to form this structure. (Figure 5.1a,b)

a



a

Figure 5.1. The vertebral column. **a.** Position of the vertebral column in the body. **b.** Anterior, posterior, and right lateral views of the vertebral column.

What are the names of vertebrae that constitute the regions of the vertebral column?

The neck region contains 7 small vertebrae, known as the **cervical vertebrae**. Inferior to them, 12 vertebrae, called the **thoracic vertebrae**, are located in the back of the chest wall and partially abdominal wall. Below the thoracic vertebrae, 5 vertebrae form the **lumbar vertebrae** in the lower back region. Posterior to the pelvic region, 5 vertebrae fuse to create a triangular-shaped bone known as the **sacrum**. Inferior to the sacrum, four to five small vertebrae fuse to form the tailbone, referred to as the **coccyx** (Figure 5.2).

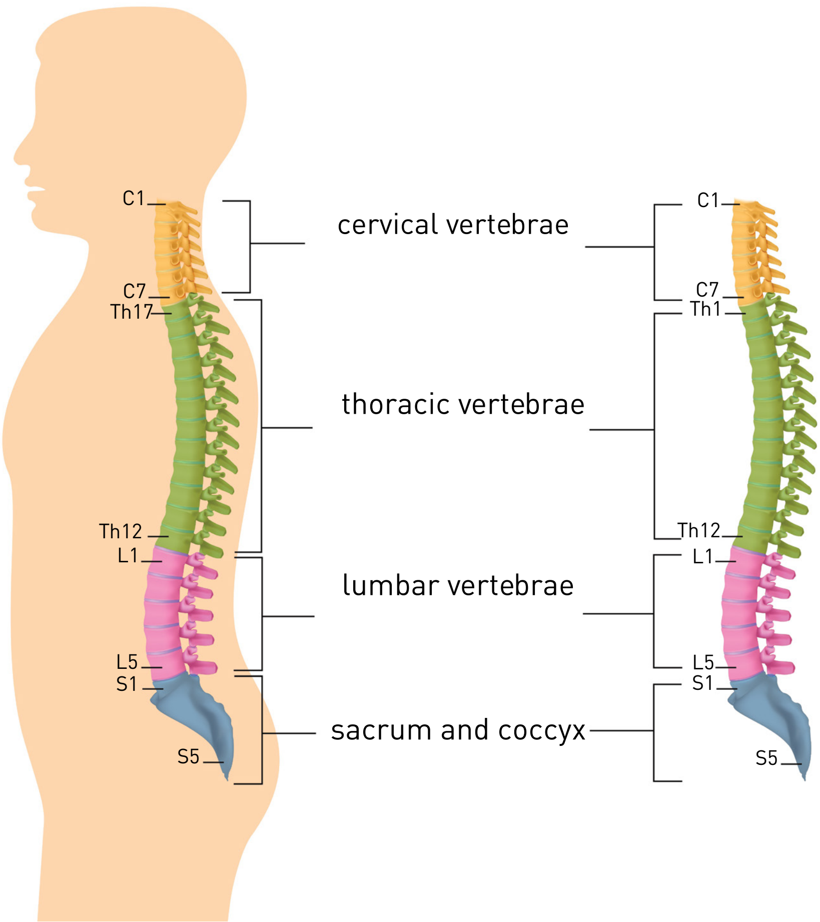


Figure 5.2. Parts of the vertebral column.

How is the appearance and alignment of the vertebral column?

When viewed from the front or back, the vertebral column appears straight, extending vertically from top to bottom. However, when observed from the side, four distinct anatomical curvatures can be identified. These curvatures are located in the cervical, thoracic, lumbar, and sacral regions. The curvatures in the cervical and lumbar regions protrude anteriorly, while those in the thoracic and sacral regions protrude posteriorly.

These curvatures are normal and essential in healthy individuals, as they help to support the body's weight and maintain an upright posture. However, in certain pathological or diseased conditions, the degree of these curvatures may either increase or decrease (Figure 5.3a,b).

CLINICAL RELEVANCE

Scoliosis is a condition characterized by an abnormal sideways curvature of the spine, which can be congenital, idiopathic, or secondary to neuromuscular disorders. Scoliosis can vary in severity, and in more extreme cases, it may cause pain or affect breathing. Treatment options include observation while Severe cases may require bracing or surgical correction.

Kyphosis is an exaggerated thoracic curvature of the spine, leading to hunched back, commonly associated with osteoporosis, poor posture, or developmental conditions. Mild kyphosis may not cause symptoms, but more severe cases can lead to pain, stiffness, and difficulty with movement. Treatment options range from physical therapy and exercises to bracing or surgery, depending on the severity.

Lordosis is a condition where there is an excessive inward curve of the lower spine, often referred to as a "swayback." It can result from factors like poor posture, obesity, or muscle imbalances, and may also be caused by certain conditions, such as spondylolisthesis or congenital disorders. While a mild curve is normal in the lower back, excessive lordosis can cause discomfort, pain, and sometimes affect movement. Treatment may include exercises, physical therapy, or in severe cases, surgery to correct the spinal alignment.

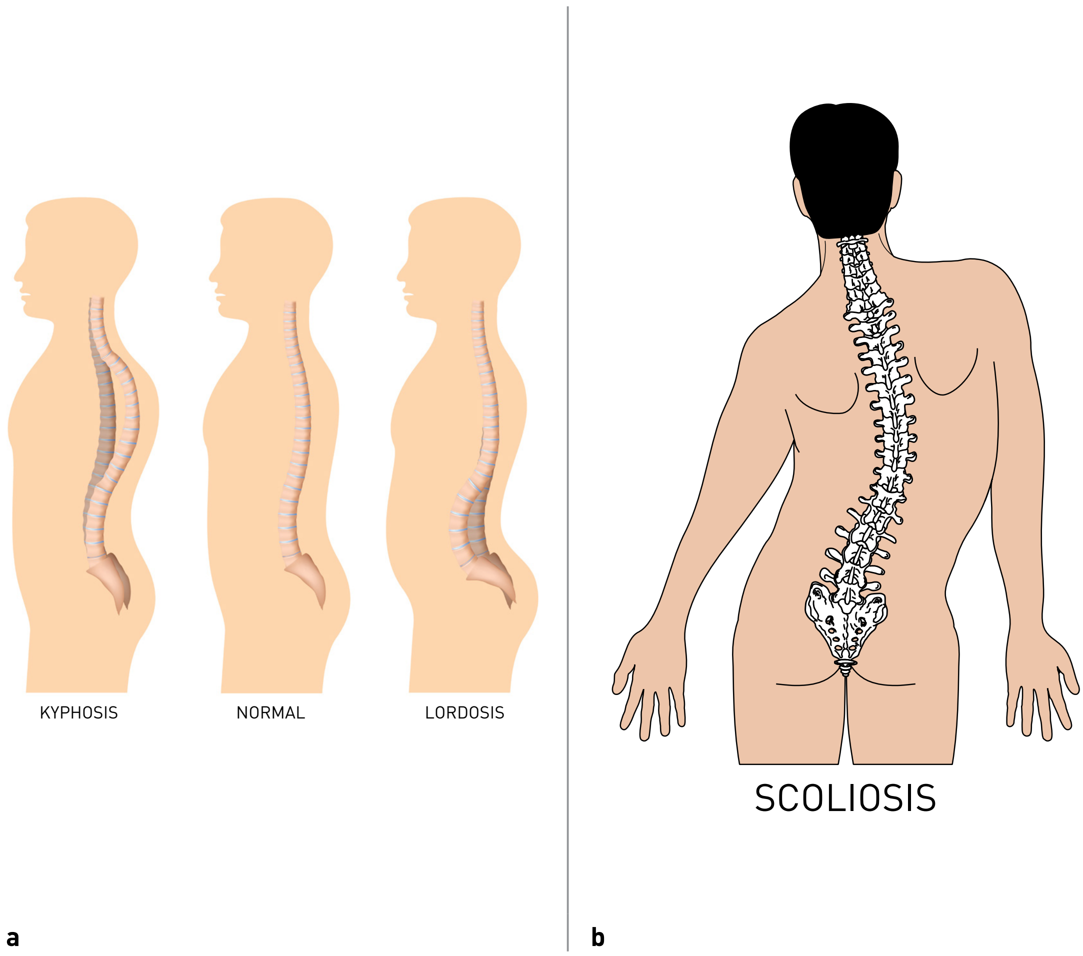


Figure 5.3. Curvature changes observed in the spine in various conditions. **a.** kyphosis and lordosis **b.** scoliosis.

VERTEBRAE

What is a vertebra?

Vertebrae are 33-34 bony structures that are stacked on top of each other in the midline at the posterior part of the body, forming the vertebral column.

What are the common structural components of a typical vertebra?

Each vertebra typically consists of the following parts (Figure 5.4):

body: anteriorly located, the main weight-bearing part of the vertebra

arch: a curved structure posterior to the body. The arch is made up of a **pedicle** attached to the posterior part of the body on each side and a **lamina** posteriorly.

transverse processes: lateral projections extending to either side of the vertebra.

spinous process: a single posterior projection located in the midline

superior and inferior articular processes: projections that articulate with the vertebrae above and below. Each side has one superior and one inferior articular process, making a total of four.

superior and inferior articular surfaces: articular surfaces located on the superior and inferior articular processes.

vertebral foramen: the space between the body and arch.

superior and inferior vertebral notches: notches located between the body and articular processes.

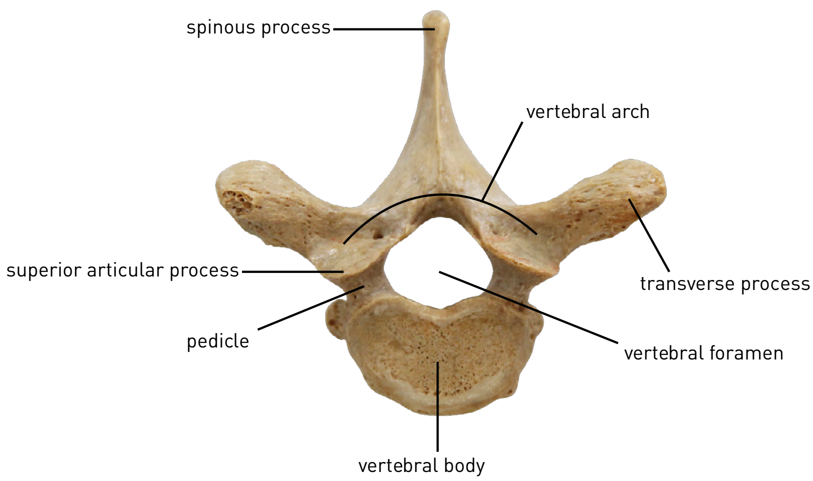


Figure 5.4. Parts of a typical vertebra.

What is the vertebral canal?

The **vertebral canal** is formed when all vertebrae align and articulate with each other to create the vertebral column. As a result, the vertebral foramina, surrounded by the body and arch of each vertebra, combine to form a continuous canal throughout the vertebral column. This canal houses the spinal cord.

CLINICAL RELEVANCE

A **compression fracture** is a type of bone fracture where a vertebra in the spine collapses or breaks due to pressure or stress. This often occurs in the elderly, especially those with osteoporosis, as their bones become weak and fragile. Compression fractures can also result from trauma or injury. Symptoms may include back pain, a decrease in height, or a stooped posture. Treatment options range from pain management and physical therapy to more severe cases requiring surgery, such as vertebroplasty or kyphoplasty, to stabilize the spine.

What is the intervertebral foramen?

Intervertebral foramina are openings formed between adjacent vertebrae, formed by the inferior vertebral notch of the vertebra above and the superior vertebral notch of the vertebra below. Since these notches are located on both sides of each vertebra, two intervertebral foramina are formed at each vertebral level—one on the right and one on the left. These openings allow the passage of spinal nerves as they exit the vertebral column.

Do vertebrae have the same characteristics at all levels of the vertebral column?

The general features of vertebrae vary among the regions of the vertebral column. For instance; the body of the vertebra is smaller and thinner in the cervical region, while it becomes larger and thicker in the lower regions to support increasing body weight. Similarly, the spinous process which extends posteriorly, is slender and long in the upper regions, but it becomes thicker and shorter in the lower regions.

What are the typical characteristics of vertebrae observed in different regions?

Typical features of **cervical vertebrae** are as follows (Figure 5.5):

the **body** is small and quadrangular in shape

the **transverse processes** contain a hole called the **foramen transversarium**

spinous process is bifurcated (bifid)

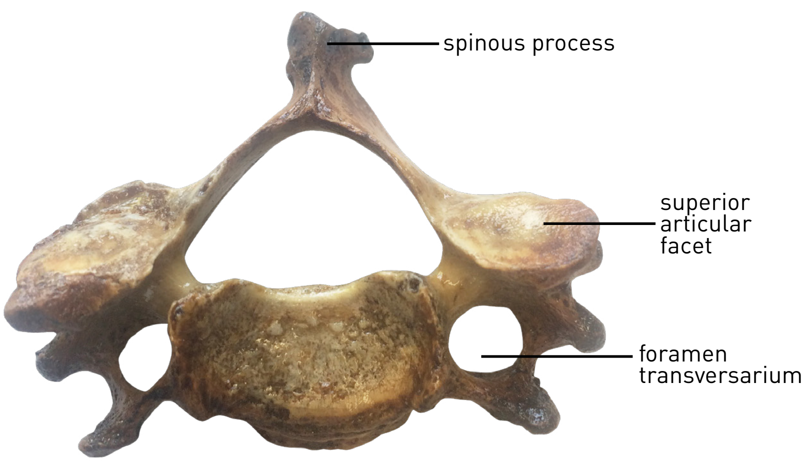
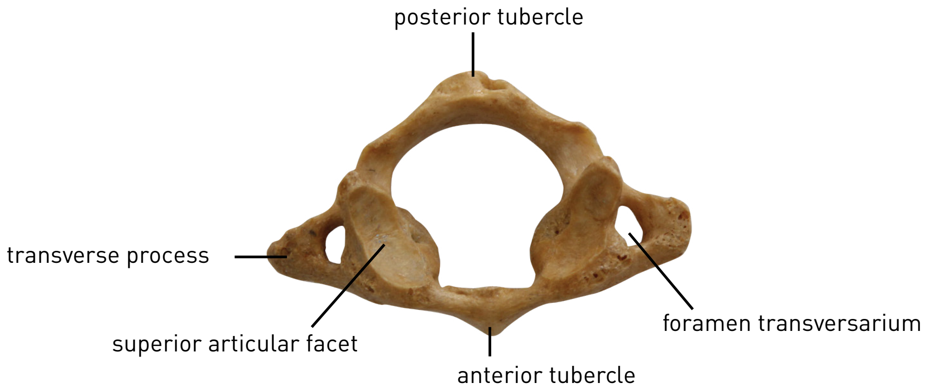
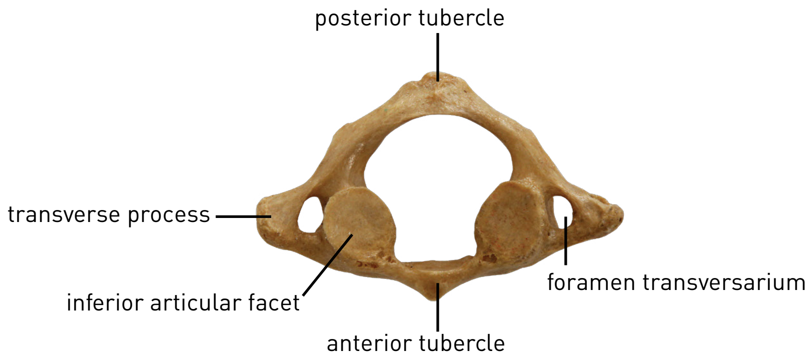


Figure 5.5. Superior view of a typical cervical vertebra.

Cervical vertebrae that do not exhibit these typical features are referred to as **atypical cervical vertebrae**, which include the 1st, 2nd, and 7th cervical vertebrae. The first cervical vertebra is specifically named **atlas** (Figure 5.6a, b). The uniqueness of the atlas is the absence of a body and spinous process. Instead, it has two small projections, the **anterior tubercle** and **posterior tubercle**. Additionally, it has articular surfaces superiorly on both sides for articulation with the base of the skull.



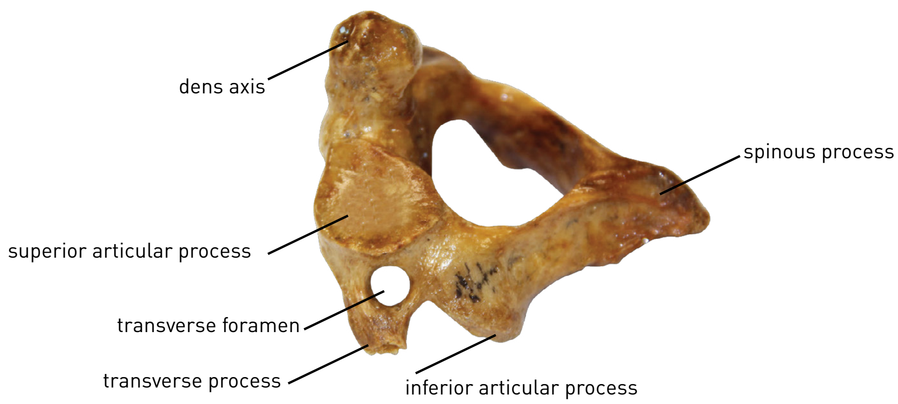
a



b

Figure 5.6. Atlas**. a.** superior view **b.** Inferior view.

The second cervical vertebra is specifically called the **axis** (Figure 5.7a-c). The unique feature of the axis is the presence of a tooth-like projection (**dens axis** or **odontoid process**) extending upward from the body to articulate with atlas.



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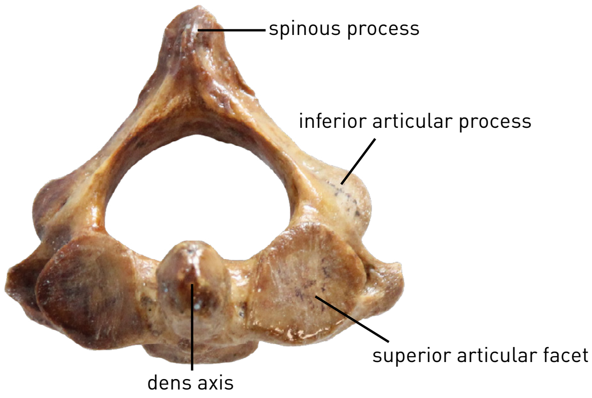

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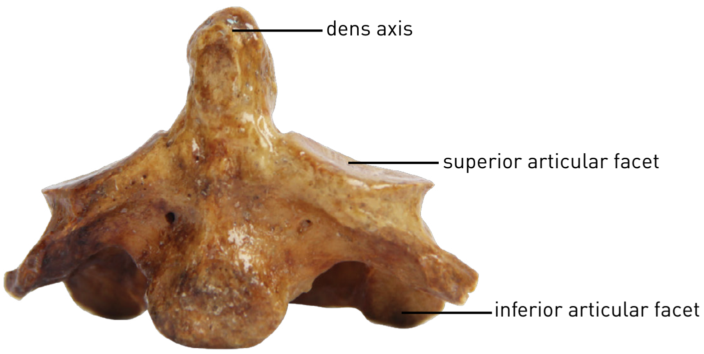


c

Figure 5.7. Axis**. a.** superior lateral view **b.** superior view **c.** anterior view.

The seventh cervical vertebra is specifically called **vertebra prominens** (Figure 5.8). Its distinguishing feature is that, its **spinous process** is the longest among the cervical vertebrae and, unlike the other cervical vertebrae, it is not bifid. This projection can be clearly observed and palpated at the lower neck.

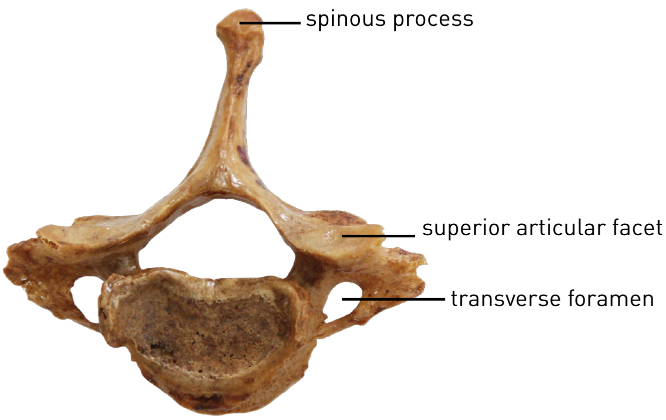
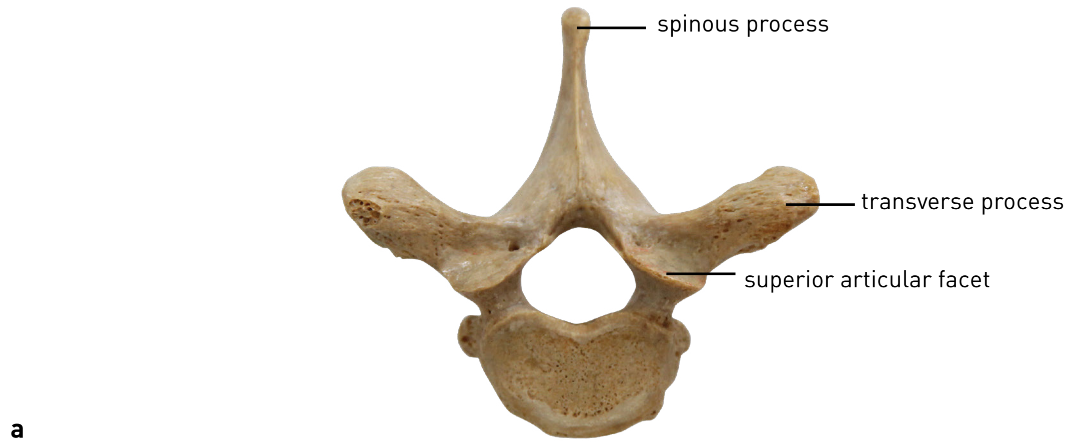


Figure 5.8. Vertebra prominens.

Typical characteristics of **thoracic vertebrae** (Figure 5.9):

the **body** is heart-shaped and on its lateral sides, there are articular surfaces for head of the ribs located on both the superior and inferior edges (**superior** and **inferior costal facets**).

the **transverse processes** also contain articular surfaces for the ribs, called **transverse costal facets.**



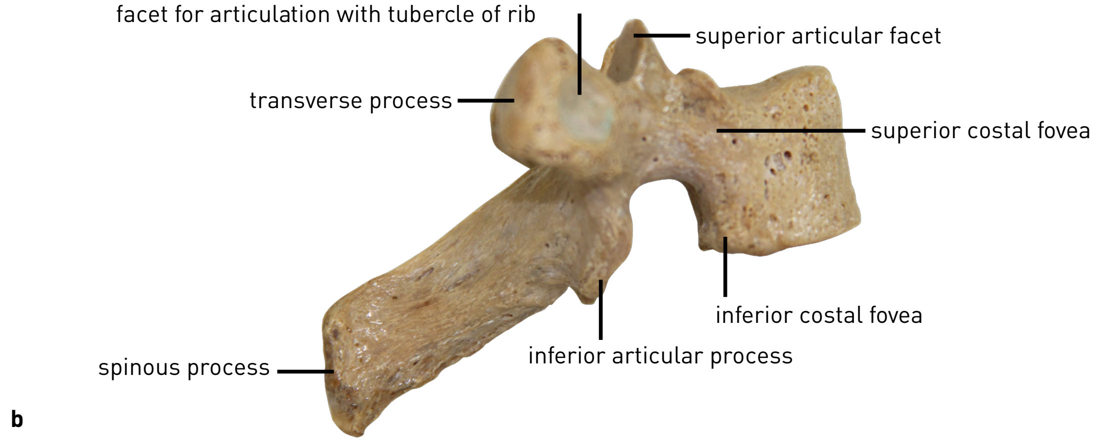


Figure 5.9. A typical thoracic vertebra. **a.** superior view **b.** lateral view.

Typical characteristics of **lumbar vertebrae** (Figure 5.10a, b):

the **body** is relatively large and kidney-shaped.

the **spinous processes** are thick and blunt.

they have additional projections called **mammillary process** and **accessory process.**

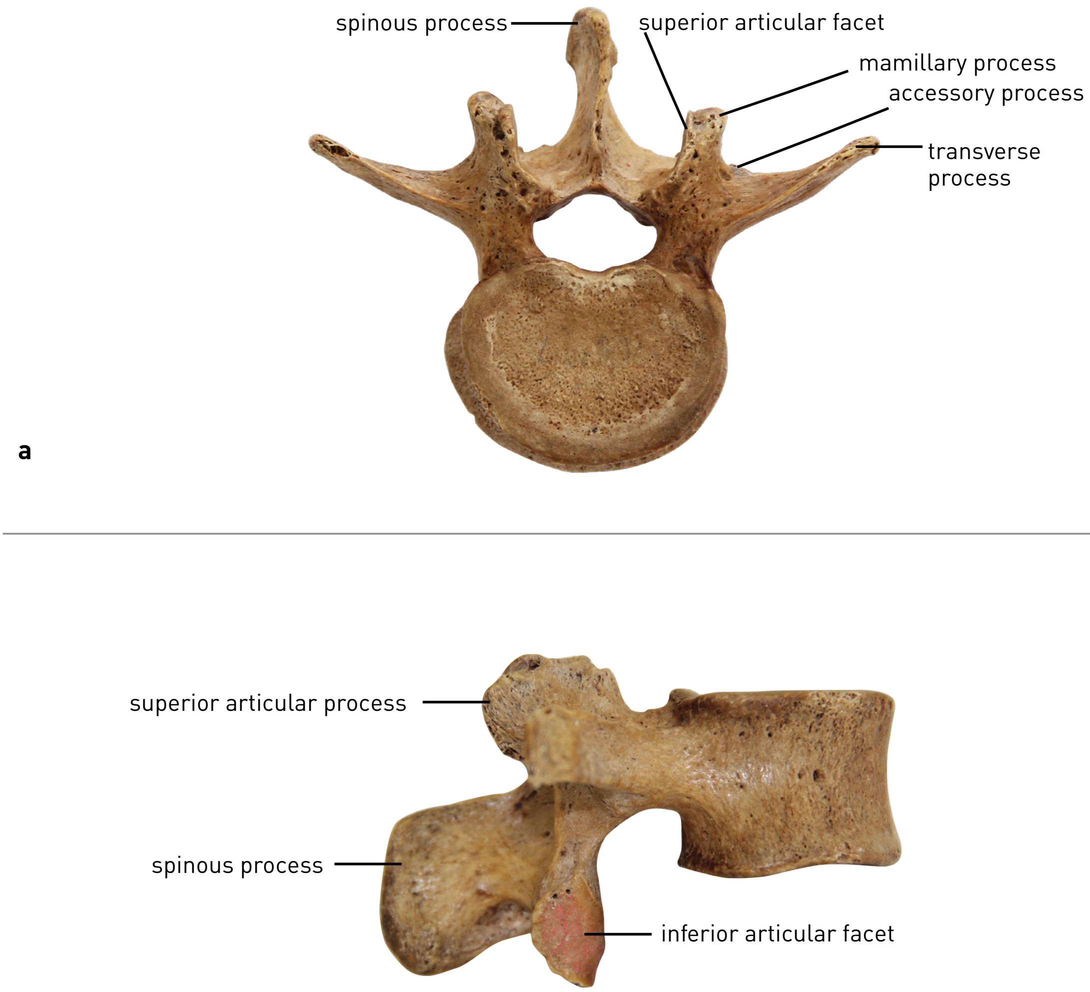


Figure 5.10. A typical lumbar vertebra**. a.** superior view **b.** lateral view.

Sacrum (Figure 5.11a-d):

The sacrum is a triangular-shaped bone with the apex pointed inferiorly. It is formed by the fusion of 5 sacral vertebrae. It constitutes the posterior part of the pelvis. On its anterior and posterior surfaces, there are 4 pairs of openings; **anterior sacral foramina** and **posterior sacral foramina**, through which the sacral spinal nerves pass.

On the posterior surface, the sacrum features the **sacral hiatus**, which is the lowest opening of the vertebral canal. Additionally, the fusion of the sacral vertebrae results in the formation of bony ridges known as the **median, medial**, and **lateral sacral crests**. On its lateral sides, the sacrum has articular surfaces called **auricular surface**, which articulate with the coxa (hip bone).

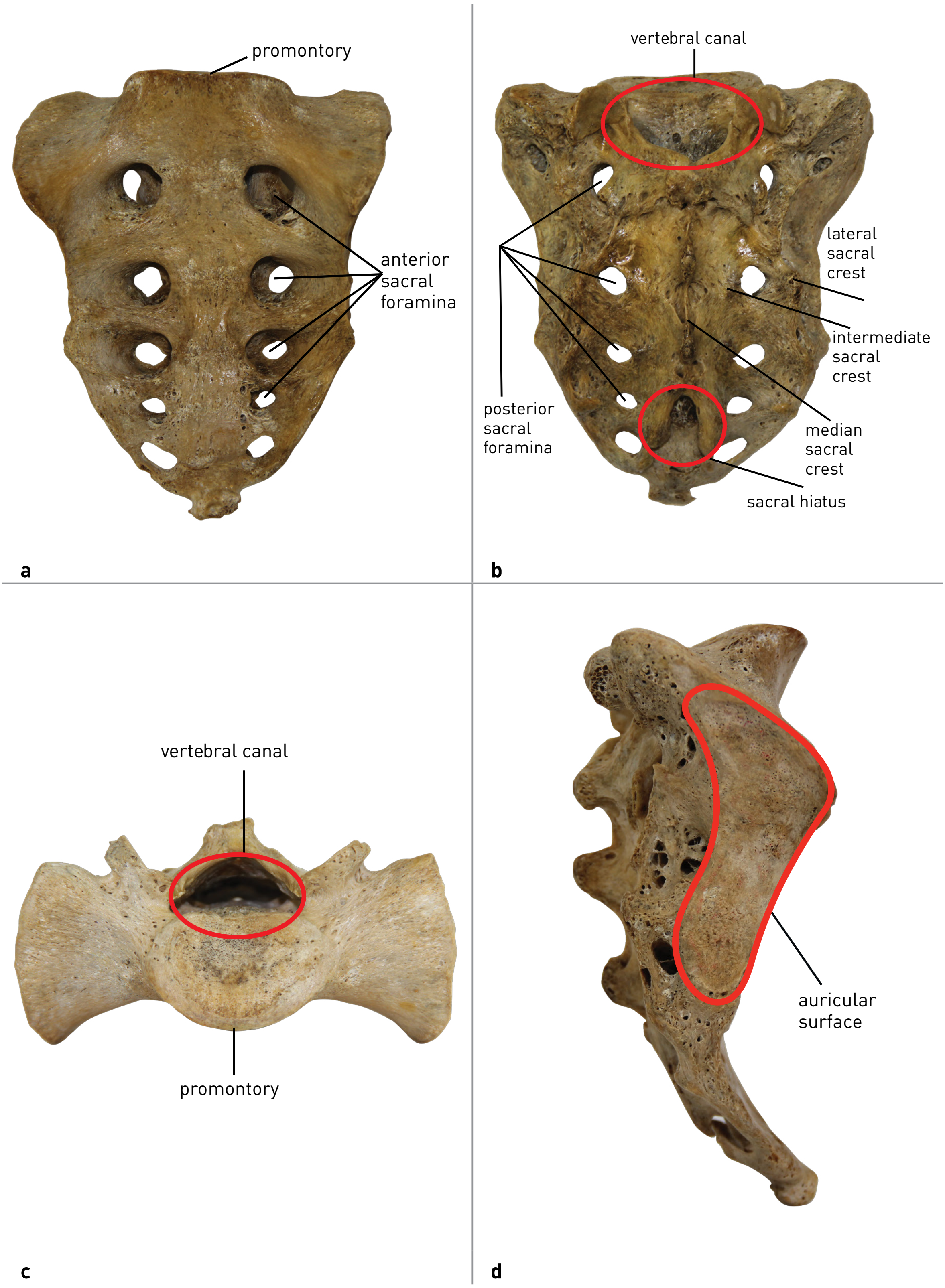


Figure 5.11. Sacrum and coccyx**. a.** anterior view showing four pairs of foramina for sacral spinal nerves at the top and one pair of foramina for coccygeal spinal nerves at the bottom. **b.** posterior view displaying a total of five pairs of foramina for sacral and coccygeal spinal nerves. **c.** superior view. **d.** lateral view.

Coccyx:

Also known as the **tailbone**, the coccyx is formed by the fusion of 4-5 vertebrae. It articulates with the sacrum at its superior end.

JOINTS OF THE VERTEBRAL COLUMN

What are the joints that constitute the vertebral column?

The following parts of the vertebrae join each other to form the vertebral column:

joints between the vertebral bodies
joints between the vertebral arches (articular processes)
joints between the atlas and the axis
joints between the atlas and the skull
joints between the vertebrae and the ribs
joints between the sacrum and the pelvic bones

What are the joints between the vertebral bodies?

Between the vertebral bodies are elastic structures called **intervertebral discs**, which serve to provide support and resist compression (Figure 5.12a, b). The outer layer of these discs, known as the **anulus fibrosus**, consists of a fibrous structure, while the inner core is filled with a gelatinous substance called the **nucleus pulposus**.

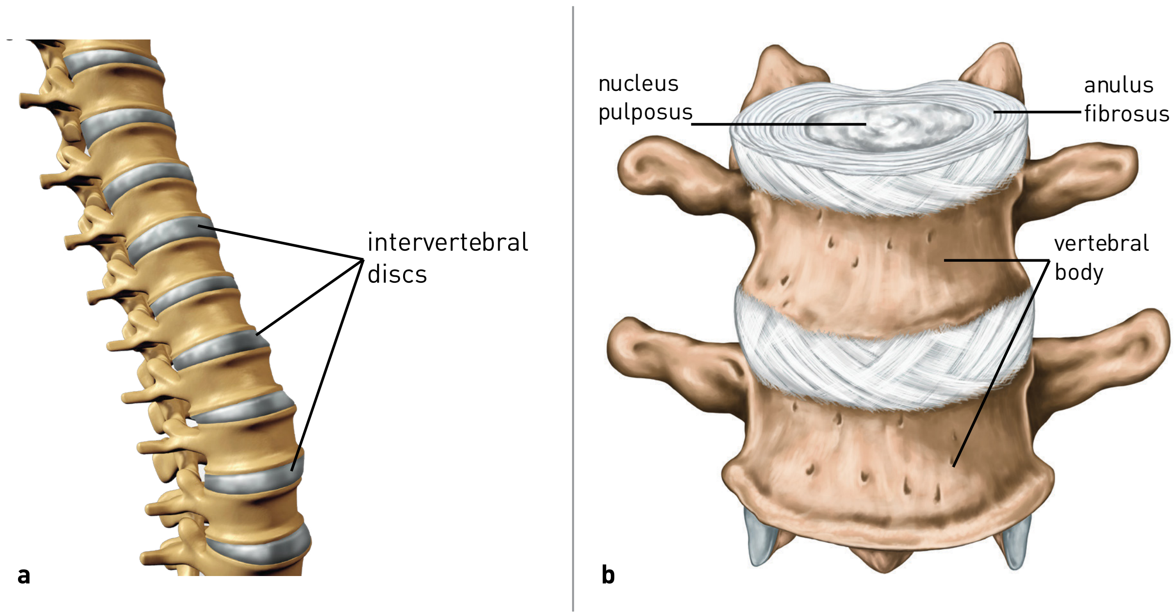


Figure 5.12. Intervertebral discs.

CLINICAL RELEVANCE

Herniated Disc (Disc Prolapse) is a condition where the intervertebral disc's nucleus pulposus protrudes through the annulus fibrosus, often compressing nearby nerves. It can cause pain, numbness, and weakness, particularly in the lower back or neck (lumbar disc hernia, cervical disc hernia, respectively). Treatment may involve rest, physical therapy, pain medications, or, in severe cases, surgery to remove or repair the damaged disc.

What are the ligaments which stabilize the vertebral bodies?

Ligaments which interconnect the vertebral column joints, creating a strong and stable structure include (Figure 5.13a-c):

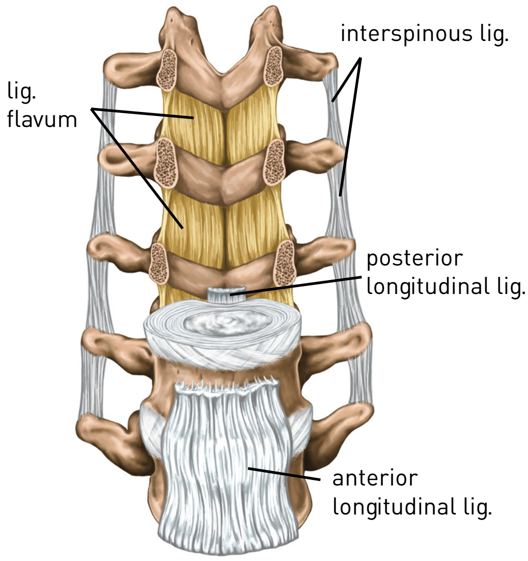
anterior longitudinal ligament: located on the anterior surface of the vertebral bodies, extending along the most of the vertebral column

posterior longitudinal ligament: located on the posterior surface of the vertebral bodies extending along the most of the vertebral column

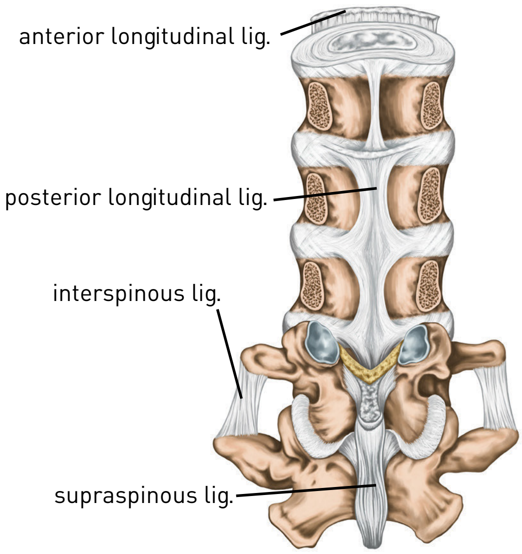
ligamentum flavum: extending between the vertebral arches

interspinous ligament: located between the spinous processes

supraspinous ligament: extends vertically along the posterior tips of the spinous processes



a



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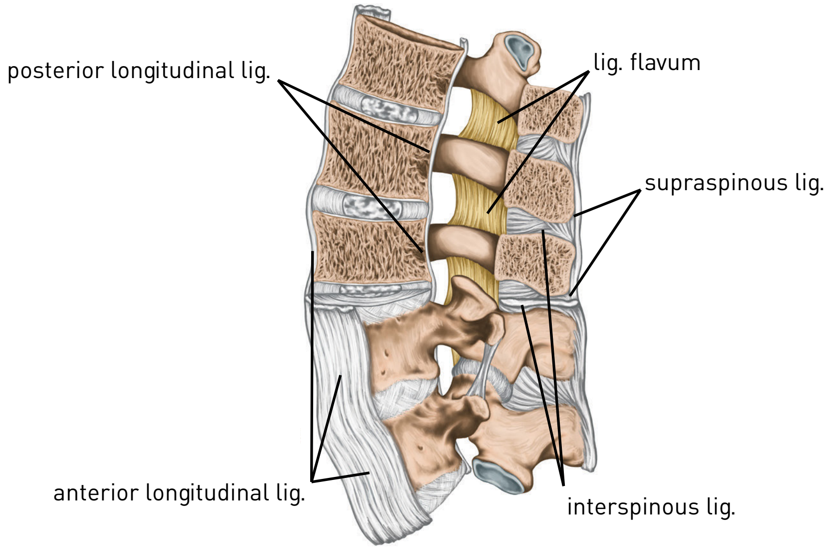


c

Figure 5.13. Ligaments of vertebral column. **a.** anterior view **b.** vertebral arches removed to reveal the posterior aspect of the vertebral bodies **c.** lateral view.

VESSELS OF THE VERTEBRAL COLUMN

What are the joints between the atlas and axis (atlanto-axial joint)?

There are three joints between the atlas and the axis: two lateral joints and one median joint. These joints do not contain intervertebral discs. The primary movement at these joints is rotation, which allows us to turn our head to the right and left.

What are the joints between the atlas and the skull (atlanto-occipital joint)?

The atlanto-occipital joint is the articulation between the atlas and the occipital bone. The primary movements at this joint are flexion and extension, allowing us to nod our head forward and backward.

What are the ligaments supporting the joints between the atlas, axis, and occipital bone?

anterior atlanto-occipital membrane: located between the atlas and the anterior edge of the foramen magnum.

posterior atlanto-occipital membrane: located between the atlas and the posterior edge of the foramen magnum.

transverse ligament of atlas: a ligament that supports the dens of the axis from behind.

alar ligaments: connect the dens of the axis to the foramen magnum.

tectorial membrane: upper part of posterior longitudinal ligament, attaching to intracranial aspect of base of the skull.

What are the vessels of the vertebral column?

The arteries that supply the vertebral column are segmental, meaning that each level is supplied by a spinal branch originating from different arteries depending on the region:

in the cervical region: spinal branches from **vertebral artery** and **ascending cervical artery**.

in the **thoracic region**: from the **posterior intercostal artery** branches.
in the **lumbar region**: from the **lumbar arteries**.
in the **pelvic region**: from the **iliolumbar artery**, **lateral** and **median sacral arteries.**

The veins of the vertebral column form rich venous networks both inside and outside the vertebral canal: the **internal vertebral venous plexus** and **external vertebral venous plexus**. Veins draining from these networks, similar to arteries, open segmentally into different veins.

BACK REGION

Which muscles are located in the back region?

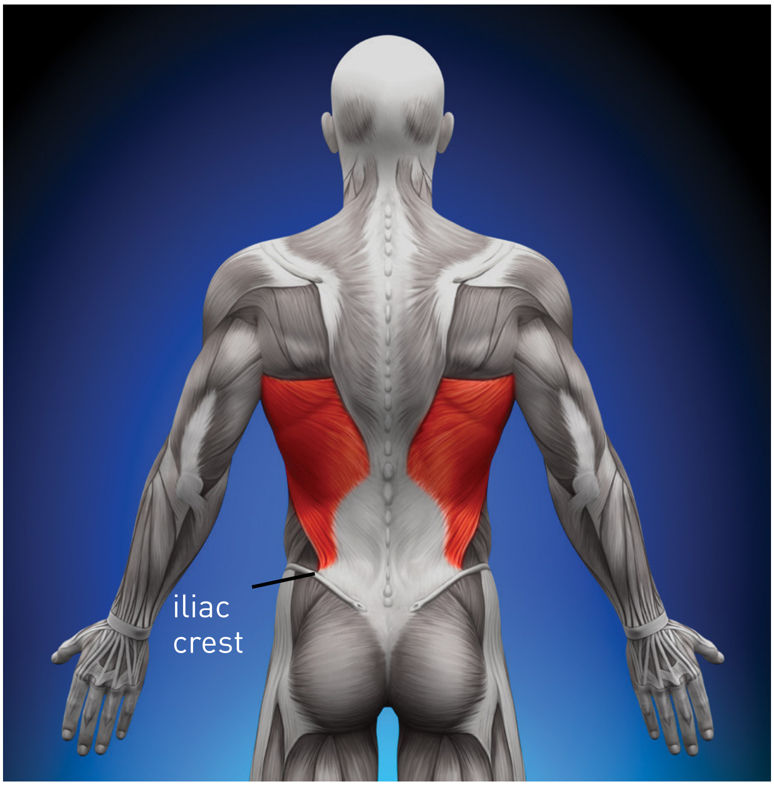
The back region refers to the posterior part of the body, extending from the neck to the buttock. The muscles in this region are categorized into superficial, intermediate, and deep groups.

In the **superficial group**, the following muscles are included:

trapezius m. (Figure 5.14a)
latissimus dorsi m. (Figure 5.14b, c)
levator scapulae m. (Figure 5.14c)
rhomboideus major m. (Figure 5.14c)
rhomboideus minor m. (Figure 5.14c)

These muscles are primarily involved in the movement of the upper extremities.

a



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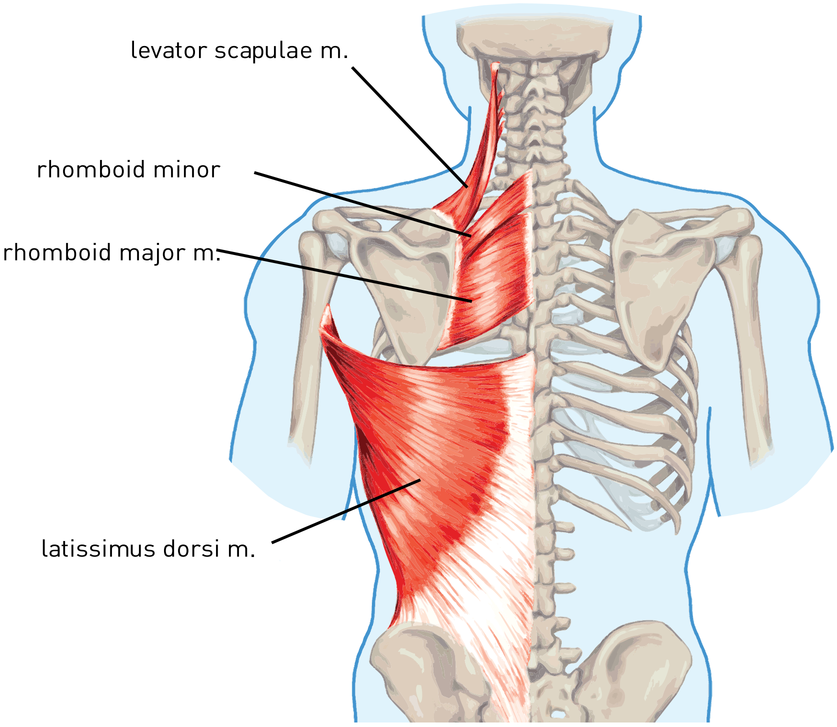


c

Figure 5.14. Superficial Back Muscles**. a.** trapezius muscle **b.** latissimus dorsi muscle **c.** levator scapulae, rhomboid major, and rhomboid minor muscles.

The superficial back muscles and their functions are presented in the table below.

Muscle	Function
trapezius	elevates and rotates the scapula.
latissimus dorsi	extends, adducts, and internally rotates the arm.
levator scapulae	elevates and rotates the scapula.
rhomboideus major	pulls the scapula inward and upward.
rhomboideus minor	

In the **intermediate group**, the following muscles are present:

serratus posterior superior m.

serratus posterior inferior m.

These muscles have functions related to respiration.

The **deep group** includes several muscle groups that extend from the posterior part of the skull to the vertebral column, from the vertebral column to the pelvis, and between various sections of the vertebral column. These muscles are responsible for maintaining an upright posture, preserving the body's posture, and enabling movements of the vertebrae.

The deep back muscles are further divided into three subgroups: superficial, intermediate, and deep. Within the intermediate group, the **erector spinae muscle** is located on either side of the vertebral column, forming two vertical columns. This muscle is primarily responsible for keeping the vertebral column upright (extension).

Spine Anatomy Sample Questions:

1. Which of the following is observed only in cervical vertebrae?
   a) Transverse process
   b) Articular facet on the transverse process
   c) Bifid spinous process (bifid)
   d) Articular facet on the side of the vertebral body
   e) Kidney-shaped vertebral body

2. Which of the following is NOT a part of a typical vertebra?
   a) Corpus
   b) Arcus
   c) Spinous process
   d) Vertebral foramen
   e) Foramen transversarium

3. How many vertebrae are there in the cervical region?
   a) 5
   b) 7
   c) 9
   d) 10
   e) 12

4. What is the name of the wide articular surface on the lateral side of the sacrum?
   a) Articular surface of superior articular processes
   b) Articular surface of inferior articular processes
   c) Dorsal surface
   d) Auricular surface
   e) Pelvic surface

5. What is the name of the upper part of the sacrum projecting anteriorly towards pelvic cavity?
   a) Promontorium
   b) Median sacral crest
   c) Sacral horn
   d) Sacral canal
   e) Sacral foramina

6. Which ligament connects the anterior surfaces of the vertebrae along the spine?
   a) Anterior longitudinal
   b) Posterior longitudinal
   c) Ligamentum flavum
   d) Interspinous
   e) Supraspinous

7. Which ligament is located between the vertebral arches along the spine?
   a) Anterior longitudinal lig
   b) Posterior longitudinal lig
   c) Lig. flavum
   d) Interspinous lig
   e) Supraspinous lig

8. Which of the following is a typical feature observed only in the C1 vertebra (atlas)?
   a) Transverse foramen
   b) Bifid spinous process
   c) Presence of a projection called dens
   d) Absence of a vertebral body
   e) Presence of an articular surface on the vertebral body

9. Which of the following is referred to as the "vertebra prominens"?
   a) C1
   b) C2
   c) C7
   d) T12
   e) L5

10. How many pairs of openings are observed on the anterior surface of the sacrum?
   a) 1
   b) 2
   c) 3
   d) 4
   e) 5

Answers: 1.C, 2. E, 3.B, 4.D, 5.A, 6.A, 7.C, 8.D, 9.C, 10.D

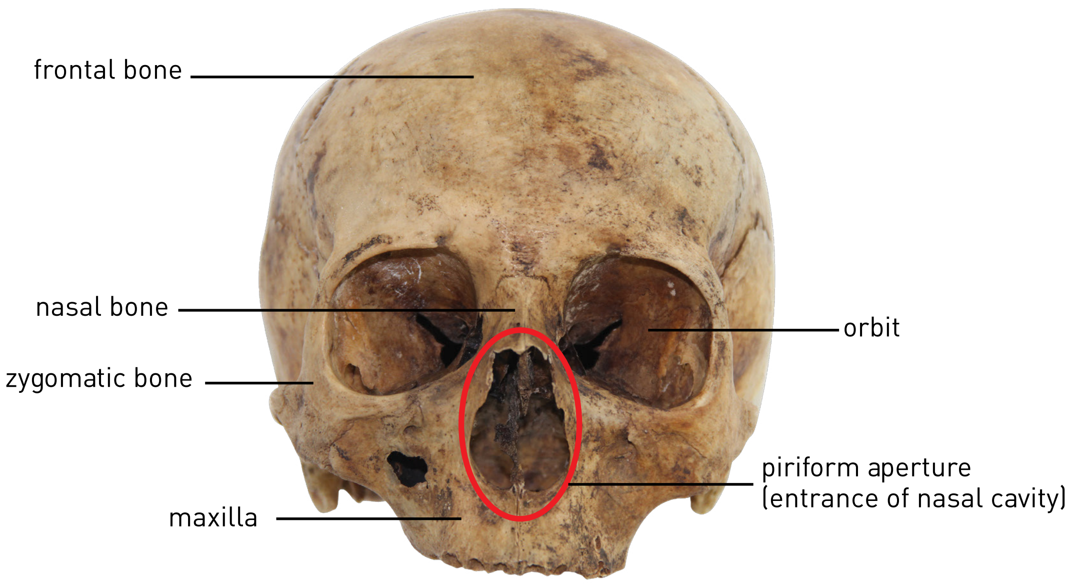
HEAD AND NECK REGION

HEAD AND NECK REGION

SKULL (Cranium)

The skull is a bony structure formed by the fusion of multiple bones, enclosing part of the central nervous system and housing various organs (Figure 6.1a-d). Anatomically, the skull is divided into two parts:

neurocranium: the portion that surrounds and protects the brain
splanchnocranium: the portion that forms the facial region



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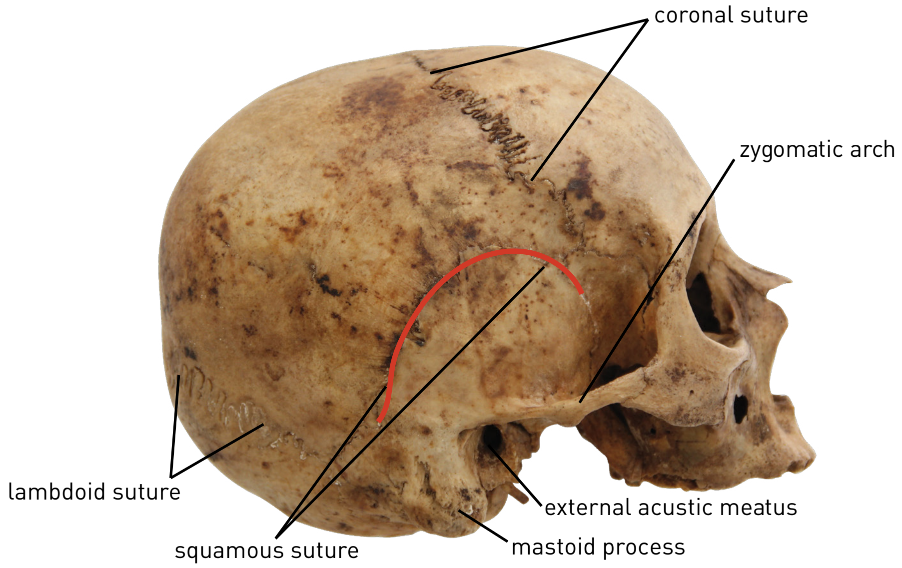

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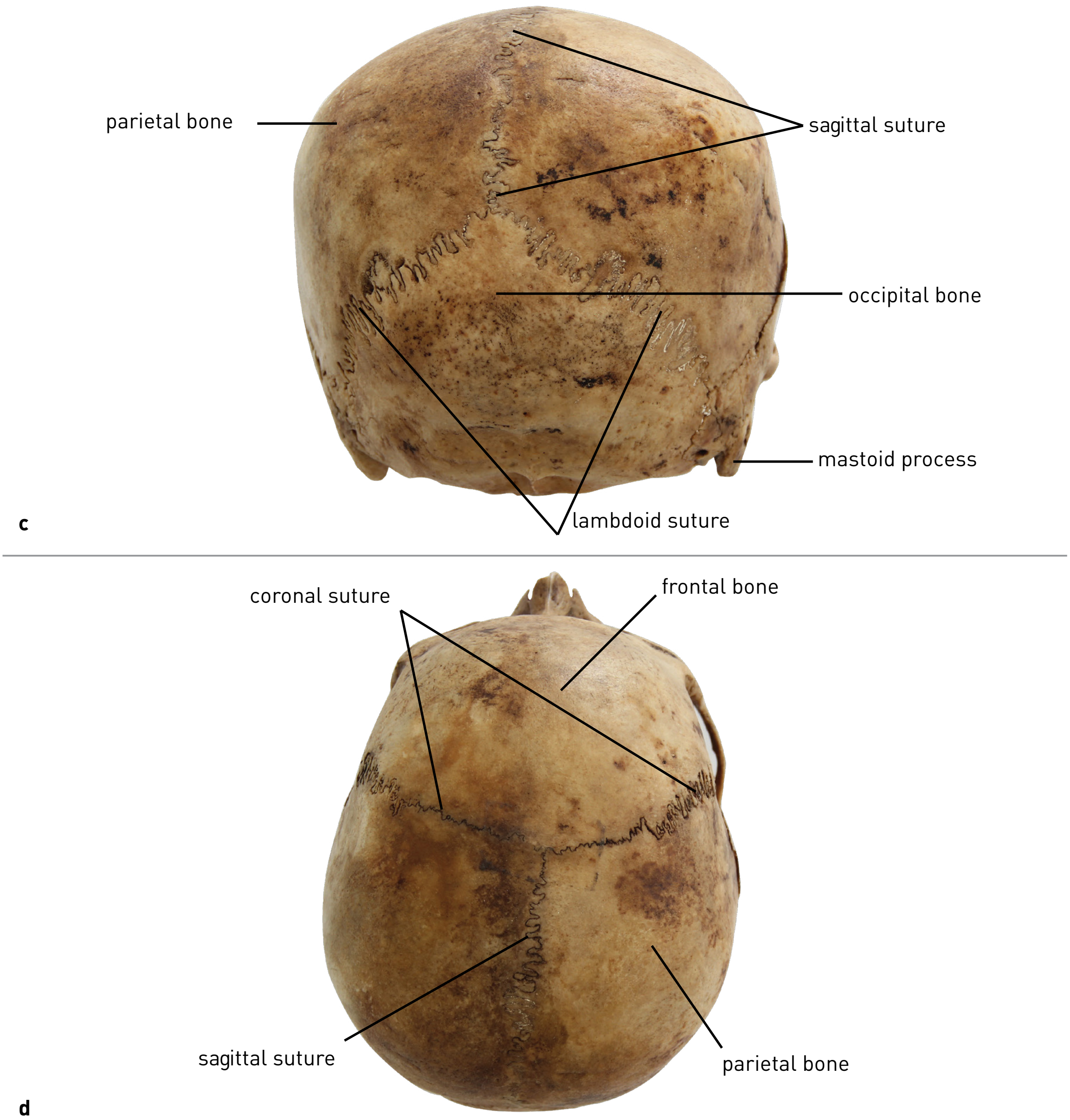


Figure 6.1. Cranium**. a.** anterior view **b.** lateral view **c.** posterior view **d.** superior view.

Which bones form the neurocranium?

The neurocranium is composed of the following bones:

- **frontal bone** (single)
- **parietal bones** (double)
- **temporal bones** (double)
- **occipital bone** (single)
- **sphenoid bone** (single)
- **ethmoid bone** (single).

The **frontal bone** is located in the forehead region. It covers the anterior part of the brain and forms the upper portion of the eye sockets (orbit). It also contains an air-filled cavity called the **frontal sinus**.

The **parietal bone** is a pair of flat, broad bones located on the upper lateral sides of the skull, posterior to the frontal bone.

The **temporal bone** is located inferior to the parietal bone on each side of the skull. Its flat portion forms the bony structure around the ear, while the pyramidal portion extends medially from the flat and contributes to the base of the skull. This pyramidal portion houses structures related to hearing and balance. The temporal bone also features the **zygomatic process**, a projection that extends anteriorly toward the cheek. The **mastoid process** is a conical bony prominence of the temporal bone located posterior to the auricle, which can be easily palpated here. Anterior to the mastoid process, a spinous projection, called **styloid process**, extends inferiorly. The facial nerve, which innervates all the mimic muscles of the face, travels through a canal in the temporal bone, exits the skull at its base, and reaches the facial region. The foramen located between the mastoid and styloid processes, known as the **stylomastoid foramen**, serves as the exit point for the facial nerve.

The **occipital bone** is located at the posterior part of the skull. A small portion of the occipital bone contributes to the posterior aspect of skull base. It contains the **foramen magnum**, the largest opening in the skull, through which the spinal cord passes. Inferiorly, it articulates with the first cervical vertebra (atlas). The bony prominence on the back of the head, which is a bony landmark that can be palpated easily, is the **external occipital protuberance** located on this bone.

The **sphenoid bone**, located at the base of the skull, is a single bone resembling a butterfly or a bat with outstretched wings. Due to its central position, it articulates with numerous bones and contributes to the structure of regions such as the orbit and nasal cavity. It contains an air-filled cavity called the **sphenoidal sinus**. The **hypophyseal fossa**, which houses the pituitary gland, is also located within the sphenoid bone.

The **ethmoid bone** is located at the anterior part of the skull and forms the upper portion of the nasal cavity. Its **cribriform plate** contains numerous small openings through which nerves related to the sense of smell pass. The **perpendicular plate** forms part of the nasal septum, dividing the nasal cavity into two. One of the paranasal sinuses, the **ethmoidal air cells**, consists of multiple small cavities within this bone.

What is the cranial base?

The **cranial base** is the inferior part of the neurocranium, formed by the union of various parts of the cranial bones. It contains numerous openings of varying sizes that allow the passage of cranial nerves and blood vessels. When the **calvaria** (the upper part of the skull) is removed and the internal part of the cranial base is viewed from above, three distinct depressions can be identified: the **anterior cranial fossa**, **middle cranial fossa**, and **posterior cranial fossa** (Figure 6.2).

anterior cranial fossa (Figure 6.2, pink area): the inferior surface of the frontal lobe sits here. In the midline, there is a bony projection called the **crista galli**. The **cribriform plate**, containing numerous small openings, situated on either side of crista galli, forms the roof of the nasal cavity. At the posterior edge of anterior cranial fossa, close to the midline, the **optic canal** is located on each side.

middle cranial fossa (Figure 6.2, blue area): slightly deeper than the anterior fossa, it accommodates the temporal lobes. In the midline, a depression called the **sella turcica** houses the pituitary gland. On either side of the sella turcica, there are several foramina located on the greater wing of ethmoid bone: **foramen ovale**, **foramen rotundum**, **foramen spinosum**, and **foramen lacerum**. Anteriorly, the **superior orbital fissure**, which connects middle cranial fossa to the orbit, can be observed.

posterior cranial fossa (Figure 6.2, green area): this is the largest fossa and contains the cerebellum and pons. The **foramen magnum** is located centrally within this fossa. Laterally, the **internal acoustic meatus**, **jugular foramen**, and **hypoglossal canal** are present.

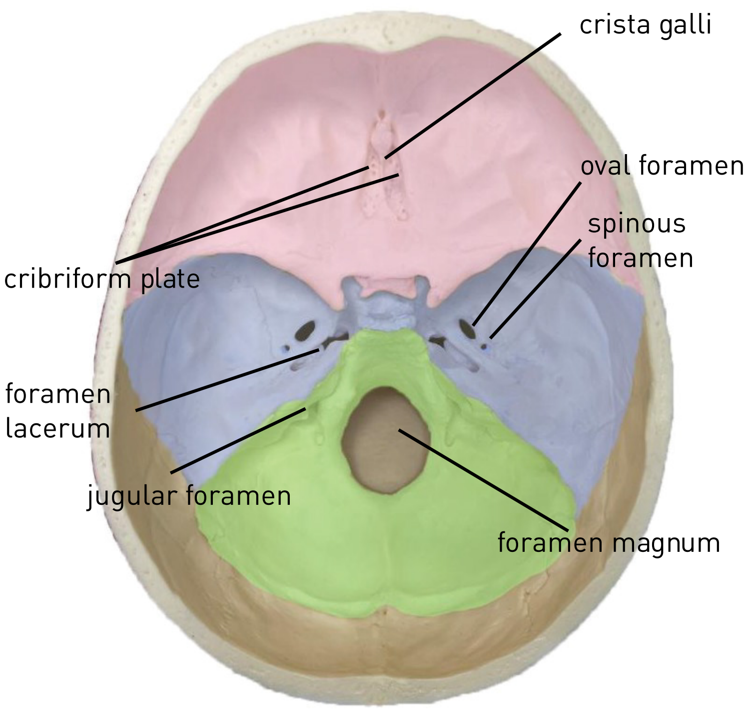


Figure 6.2. superior view of the cranial base, showing the cranial fossae and various foramina.

What is a suture?

A **suture** is an immovable joint between the bones of the skull, resembling a seam or stitch (Figure 6.1b-d).

What sutures are found in the skull?

sagittal suture: located between the two parietal bones and positioned along the sagittal axis (Figure 6.1c, d).

coronal suture: found between the posterior edge of the frontal bone and the anterior edges of the two parietal bones (Figure 6.1d).

lambdoid suture: located between the posterior edges of the parietal bones and the occipital bone (Figure 6.1c).

squamous suture: located on each side of the cranium between the parietal and temporal bones (Figure 6.1b).

What is a fonticulus (fontanel)?

In newborns, ossification of the skull is not yet complete, leaving the intersection points of the sutures open. These regions, composed of cartilage during this stage and feel soft to the touch. These areas are called **fonticulus** or **fontanels** (Figure 6.3)

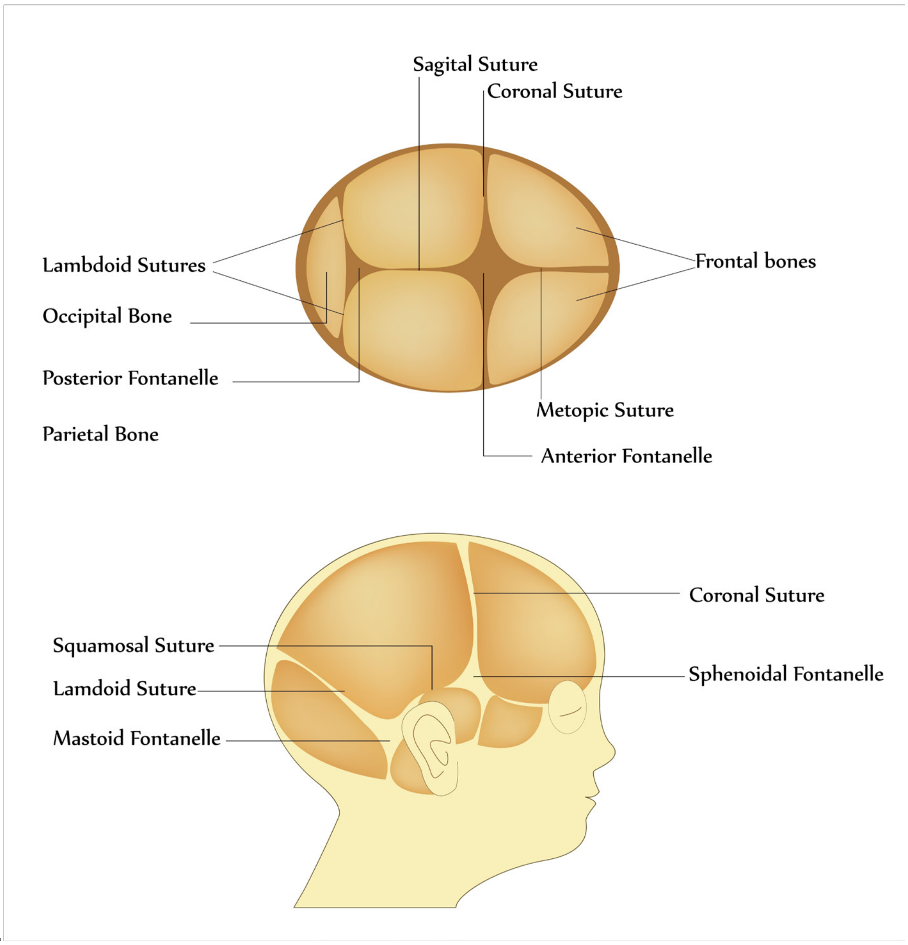


Figure 6.3. Fontanelles.

Fontanels are named as follows:

anterior fontanel
posterior fontanel
anterolateral fontanel
posterolateral fontanel

The largest and most prominent fontanel is the **anterior fontanel**, located at the intersection of the sagittal and coronal sutures. By approximately 1.5 years of age, ossification is complete, and it can no longer be felt.

Which bones form the splanchnocranium?

The splanchnocranium is formed by the following paired bones located on each side, except for the last two, which are single bones (Figure 6.1a-d):

maxilla
zygomatic bone
nasal bone
lacrimal bone
palatine bone
inferior nasal concha
vomer (single)
mandible (single)

Maxilla The maxilla forms the upper jaw. It also contributes to the structure of the orbit and nasal cavity. One of the paranasal sinuses, the **maxillary sinus** is located within the maxilla.

Zygomatic bone Also known as the **cheekbone**. It forms the inferolateral part of orbit.

Nasal bone The paired nasal bones are small, flat bones that form the bridge of the nose. They are located in the anterior portion of the upper wall of the nasal cavity, positioned superior to the cartilaginous part of the nose.

Lacrimal bone The lacrimal bone is a very small bone located in the medial wall of the orbit. It houses the **lacrimal sac** (tear sac).

Palatine bone The palatine bone, shaped like the letter "L," forms the posterior part of the bony palate.

Inferior nasal concha The inferior nasal concha is located in the lower part of the lateral wall of the nasal cavity.

Vomer The vomer is a single bone that contributes to the formation of nasal septum.

The **mandible** is the lower jawbone (Figure 6.4a-c). It consists of two main parts: the **body** where the lower teeth are located, and the **ramus**, which extends on either side toward the temporomandibular joint. The angle formed at the junction of the corpus and ramus is called the **mandibular angle**.

At the upper end of the ramus, there are two projections: the **coronoid process** in the front and the **condylar process** at the back. The **mandibular head**, located at the tip of the condylar process, articulates with the temporal bone to form the temporomandibular joint.

On the inner surface of the mandible, there is an opening called the **mandibular foramen**, which is the entry to a canal carrying nerves and vessels related to the lower teeth and gums. On each side of the body of the mandible, another opening, **mental foramen** is present.

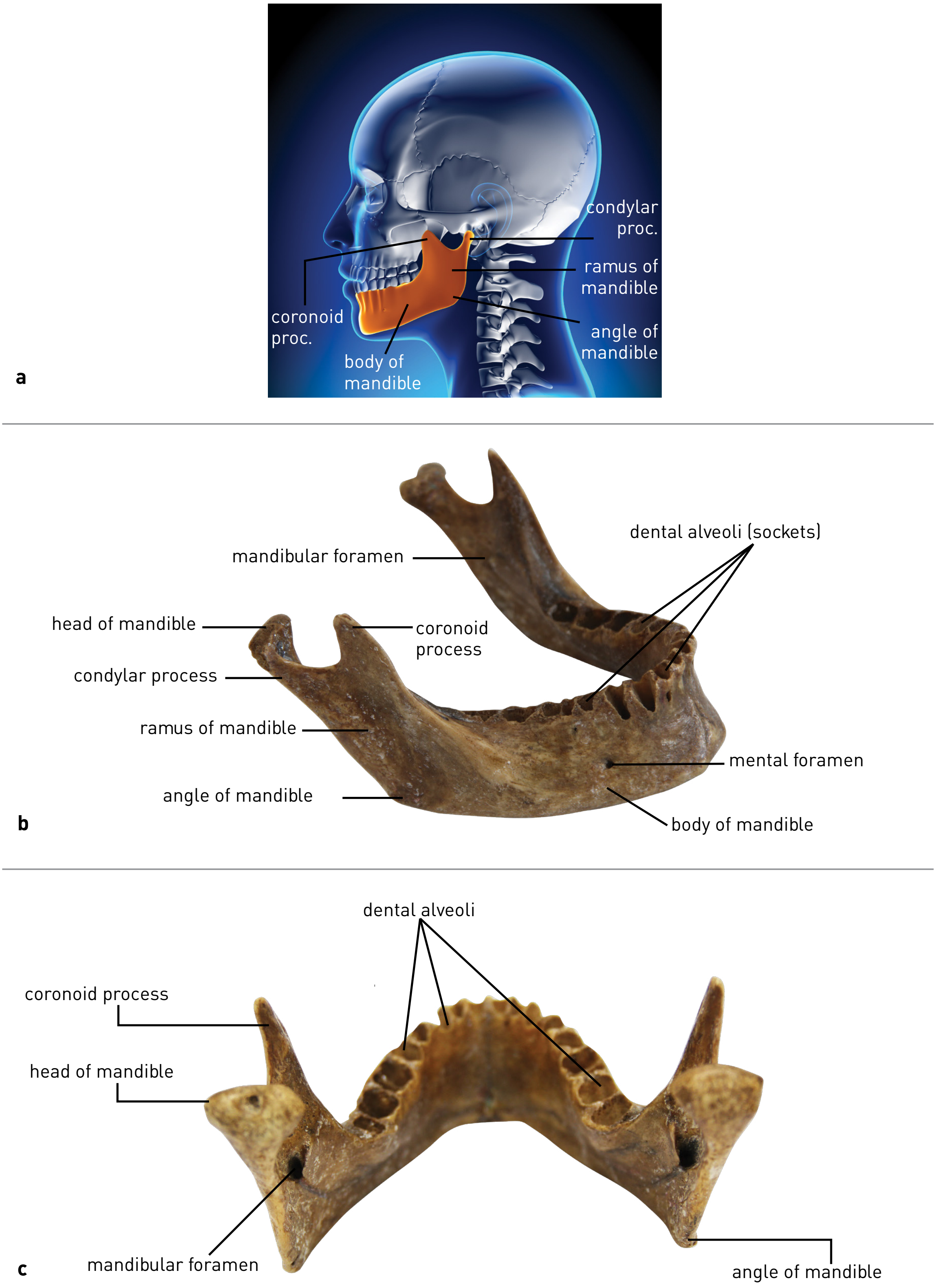


Figure 6.4. Mandible. **a.** position of the mandible **b.** lateral view **c.** posterior view

SCALP

The scalp is a continuation of the skin from the facial region and consists of five layers. These layers can be remembered using the acronym **SCALP**, where each letter corresponds to one of the layers, listed from superficial to deep.

1. **S**kin
2. **C**onnective tissue (subcutaneous tissue)
3. **A**poneurotic layer (galea aponeurotica)
4. **L**oose connective tissue
5. **P**eriosteum

The first three layers are tightly adhered to each other by the connective tissue and are separate from the periosteum by the loose connective tissue. Thus, the outer three layers of the scalp move freely over the periosteum, that lines the cranial skeleton.

The aponeurotic layer contains a thin and flat muscle called the **occipitofrontalis muscle**. The frontal belly of this muscle is located in the forehead region, while the occipital belly is situated posteriorly at the back of the skull. Actually, thick aponeurotic layer connects these bellies.

When contracted, the muscle shortens, wrinkling the skin above it. Thus, contraction of the frontal part creates horizontal wrinkles on the forehead, while contraction of the occipital part causes horizontal wrinkles at the back of the neck.

What are the nerves of the scalp?

The nerves that innervate the scalp are:

trigeminal nerve (5th cranial nerve)

branches of the **cervical spinal nerves**

What are the blood vessels of the scalp?

The arterial supply of the scalp is primarily provided by branches of the **external carotid artery** (Figure 6.5):

superficial temporal artery

posterior auricular artery

occipital artery

Additionally, the anterior part of the scalp is supplied by the **supraorbital** and **supratrochlear arteries**. Unlike other scalp arteries, these two are branches of the ophthalmic artery, which itself is a branch of the **internal carotid artery**. These arteries travel through the orbit and exit via openings located at the medial aspect of the eyebrow to supply the forehead and scalp regions.

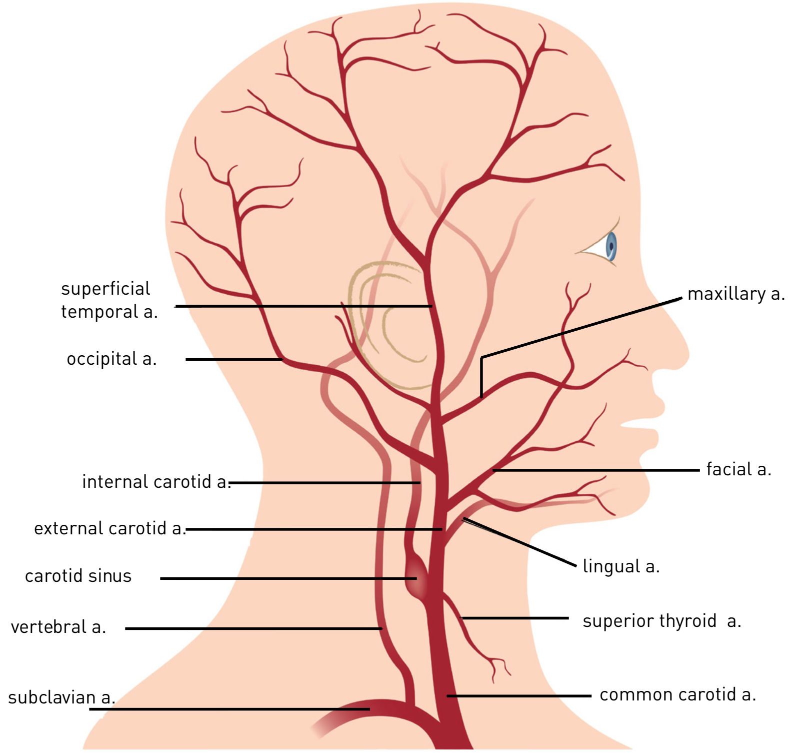


Figure 6.5. Arteries of the head and neck region.

What is the venous and lymphatic drainage of the scalp?

Venous drainage occurs via veins accompanying the arteries of the scalp, which share the same names. These veins drain into the **external jugular vein** and **internal jugular vein** via the **retromandibular vein**.

Lymph is mainly drained via the postauricular and occipital nodes into the deep cervical lymph nodes. (Figure 6.7)

FACIAL REGION

Beneath the skin of the face lies the **superficial fascia**. However, there is no **deep fascia** in the face. The facial mimic muscles attach directly to the superficial fascia, allowing them to create facial expressions (mimics) when contracted.

Which nerves are responsible for the sensory innervation of the face?

The sensory innervation of the face is provided by the **trigeminal nerve** (Figure 6.6), which has three branches:

ophthalmic nerve: supplies sensation to the forehead, upper eyelid, nasal bridge, and temple region

maxillary nerve: supplies the lower eyelid, upper lip, nasal wings, and the area around the cheekbone

mandibular nerve: supplies the lower lip, chin, and the lower portion of the cheek

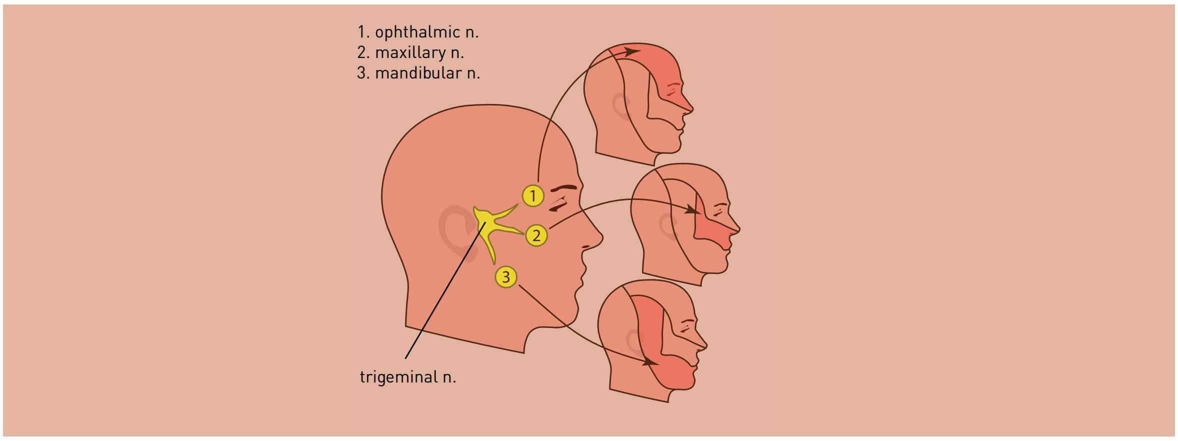


Figure 6.6. Distribution of the trigeminal nerve branches on the face.

What is the arterial supply of the face?

The face is supplied by the following arteries:

- **facial artery**
- **transverse facial artery**
- **infraorbital artery**
- **supratrochlear artery**
- **supraorbital artery**

What is the venous drainage of the face?

The venous drainage of the face occurs through veins that accompany the arteries and share the same names. The **superficial temporal vein** and the **maxillary vein** join to form the **retromandibular vein**. The **facial vein** combines with the anterior branch of the retromandibular vein and drains into the **internal jugular vein** (Figure 6.7).

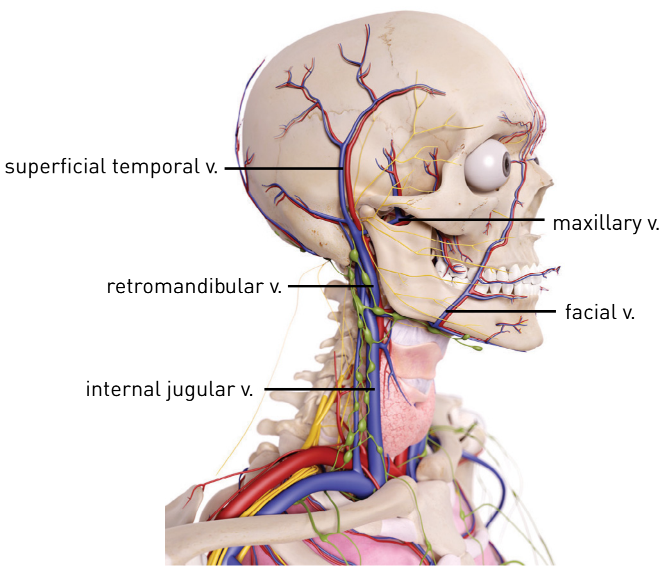


Figure 6.7. Veins of the head and neck region.

What are the lymph nodes of the face?

The lymph nodes of the face are:

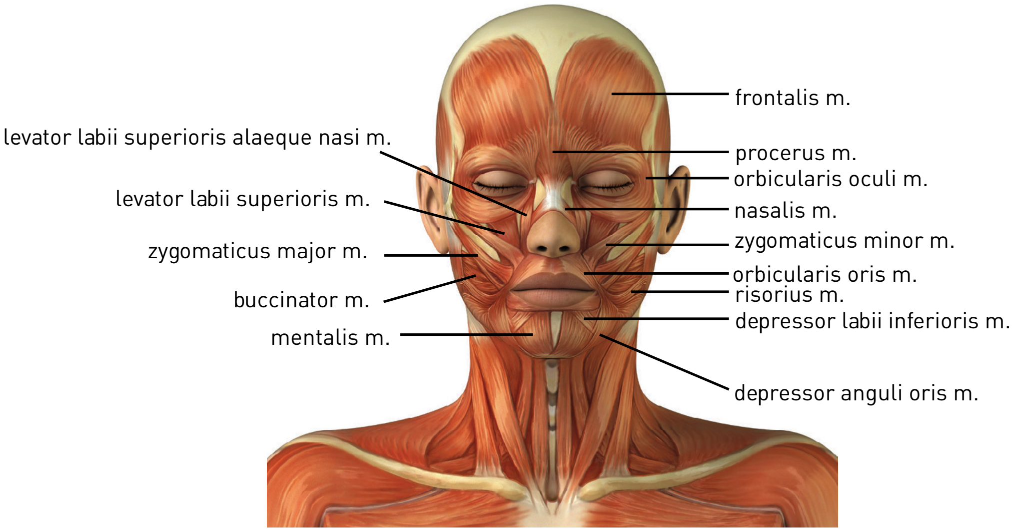
parotid nodes
submandibular nodes
submental nodes

These drain into the deep cervical lymph nodes.

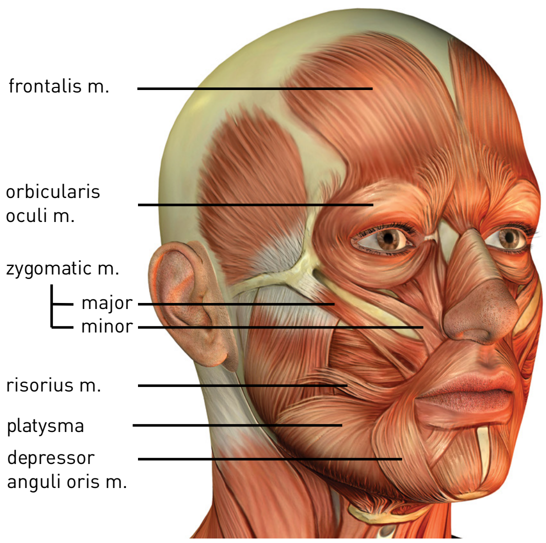
What are the facial expression (mimic) muscles?

The facial (mimic) muscles are thin, superficially located muscles that attach to the skin of the face (Figure 6.8a, b). These muscles are arranged around the openings of the skull, such as the orbit, mouth, and nose.

All the facial mimic muscles are innervated by the **facial nerve**. Below is a list of these muscles and their functions:



a



b

Figure 6.8. Facial expression (mimic) muscles. **a.** anterior view **b.** anterolateral view.

Muscles around the mouth

Muscle	Function	Resulting Facial Expression
orbicularis oris	closes the lips tightly	expressions of strain or distress
depressor labii inferioris	pulls the lower lip downward	sadness, melancholy, doubt
depressor anguli oris	pulls the corners of the mouth downward	sadness
mentalis	elevates the lower lip	doubt, disdain
levator labii superioris	elevates the upper lip, turning it outward	seriousness, sadness
levator anguli oris	elevates the corners of the mouth	smiling
zygomaticus major	pulls the corners of the mouth upward and outward	smiling
zygomaticus minor	elevates the upper lip	arrogance, disdain
risorius	pulls the corners of the mouth laterally	grinning, smiling
buccinator	tenses the cheeks, active during blowing	
platysma	tenses the neck and pulls the corners of the mouth downward	

Muscles around the eyelids

Muscle	Function	Resulting Facial Expression
orbicularis oculi	closes the eyes gently or tightly	-
depressor supercilii	functions as part of the m. orbicularis oculi	-
corrugator supercilii	pulls the eyebrows inward and downward	frowning, scowling

Muscles around the nose

Muscle	Function	Resulting Facial Expression
nasalis	widens the nostrils	-
procerus	pulls the inner part of the eyebrows downward	frowning
depressor septi	pulls the nasal septum downward	frowning, scowling

Muscles in the forehead region

Muscle	Function	Resulting Facial Expression
frontalis	raises the eyebrows, creating horizontal lines on the forehead	surprise

Muscles in the neck

Muscle	Function	Resulting Facial Expression
platysma	tenses the skin of the neck	stress and tension

NECK

Where is the neck region?

The neck region is the part of the body located between the head and the chest (Figure 6.9). It contains arteries that originate from aorta and supply the head and upper extremities, veins that return blood from the head and upper extremities to the thoracic cavity, nerves, and structures belonging to various systems like the esophagus, larynx, thyroid gland.

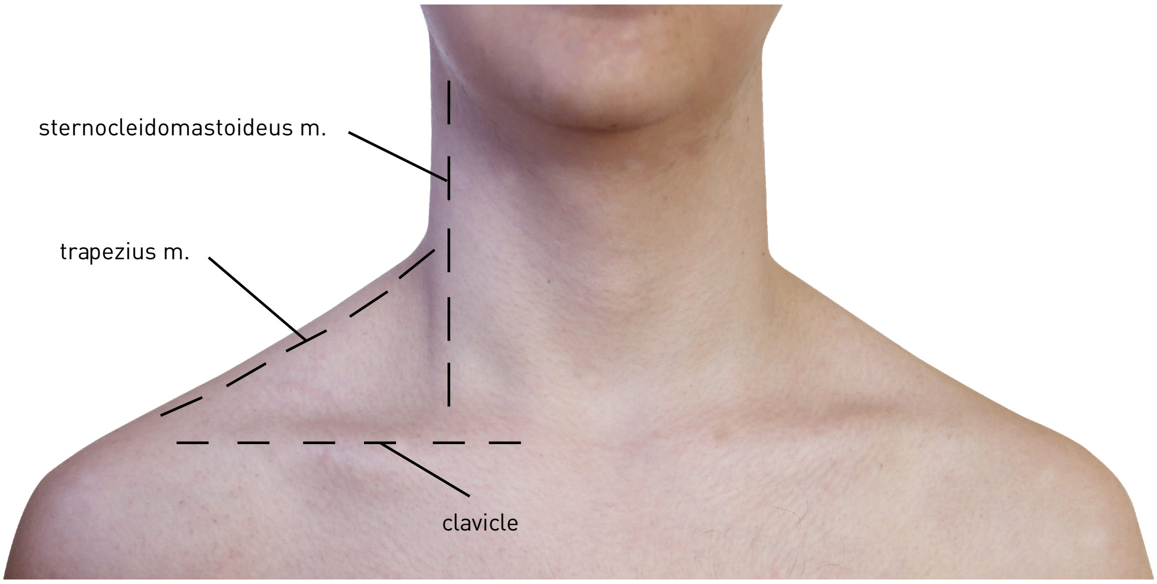


Figure 6.9. Anterior view of the neck region. The inferior border is formed by the clavicle, and posteriorly, the trapezius muscle is located. The sternocleidomastoid muscle is one of the most prominent structures.

What forms the skeleton of the neck?

The skeleton of the neck is formed by 7 cervical vertebrae located posteriorly in the neck region.

What structures are found in the neck region?

The neck contains muscles, blood vessels, nerves, and organs belonging to the endocrine, respiratory, and digestive systems.

What are the muscles located in the neck region?

The most prominent muscle in this region is the **sternocleidomastoid muscle** (Figures 6.10, 6.11). This muscle is considered a landmark structure in the neck.

It originates from the upper end of the sternum (sternal head) and the clavicle (clavicular head). It travels upward and outward, attaching to the mastoid process behind the ear.

When contracted unilaterally, it rotates the neck to the same side and turns the face to the opposite side. When contracted bilaterally, it flexes the head, extending the chin upward and forward.

The sternocleidomastoid is innervated by the **accessory nerve**.

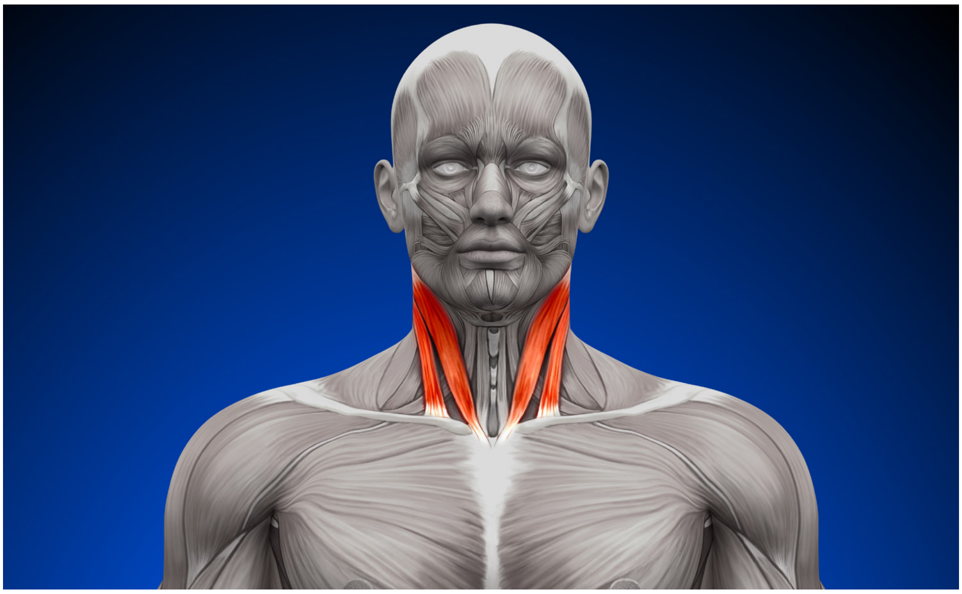


Figure 6.10. Sternocleidomastoid muscle.

The second most prominent muscle in the neck region is the **trapezius muscle** (Figures 5.14a, 6.9). It is a large, triangular muscle covering the region between the external occipital protuberance, the shoulder, and the T12 spinous process.

Its functions include rotating the scapula and stabilizing it against the chest wall. The trapezius is innervated by the **accessory nerve**.

What are the other muscles in the neck region?

In the neck, a group of muscles is classified as **suprahyoid muscles** (located above the hyoid bone) and **infrahyoid muscles** (located below the hyoid bone).

These muscles, which attach to the hyoid bone, move the hyoid bone and the larynx as a unit, particularly during swallowing and speaking.

What are the suprahyoid muscles?

The suprahyoid muscle group includes the following:

digastric m.
stylohyoid m.
mylohyoid m.
geniohyoid m.

What are the infrahyoid muscles?

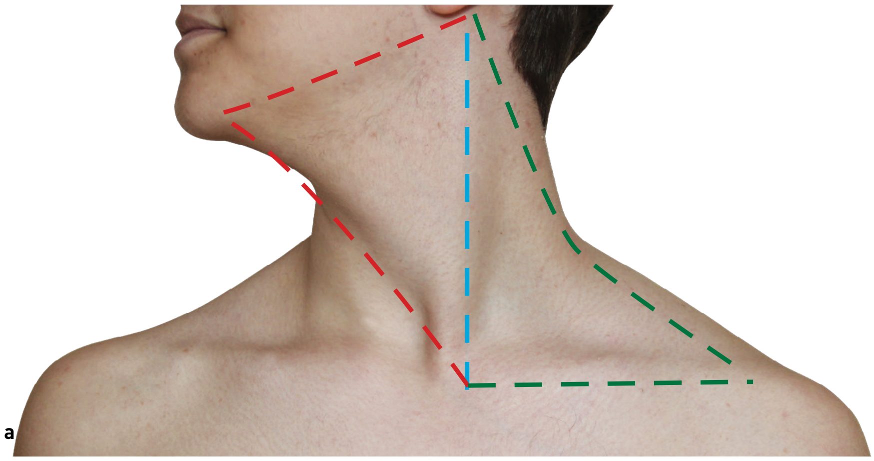
The infrahyoid muscle group includes the following:

sternohyoid m.
sternothyroid m.
thyrohyoid m.
omohyoid m.

What are the triangles of the neck?

The muscles in the neck region divide the neck into various triangles. Primarily, the neck is divided into two large triangular regions: **anterior triangle** and **posterior triangle**. Each of these triangles is further subdivided into smaller triangles.

Each triangle contains structures belonging to different systems. The neck triangles are significant in identifying the location of these structures and organs, as well as facilitating clinical access to them.



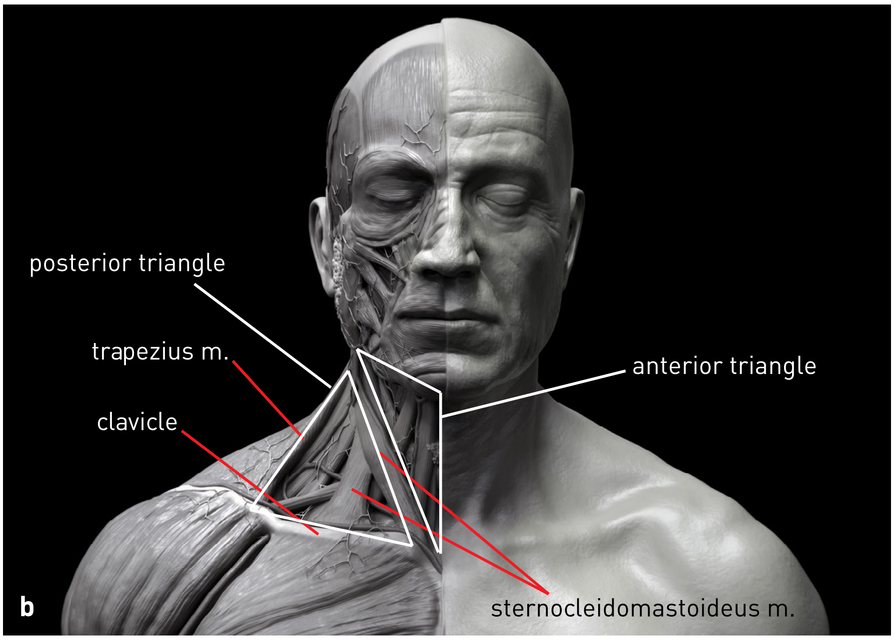


Figure 6.11. Neck triangles**. a.** anterior and posterior triangles **b.** inferior part of the posterior triangle and part of the anterior triangle.

How are the neck triangles classified?

When the neck is divided by an imaginary vertical line passing through the midline of the body, each half forms a quadrangular region (Figure 6.11a). This region is further divided by the sternocleidomastoid muscle into two main triangles:

anterior triangle

posterior triangle

What is the anterior triangle of the neck?

The anterior triangle is bounded by the **sternocleidomastoid muscle**, the **inferior border of the mandible**, and the **midline of the body**. It is further subdivided into four smaller triangles:

submandibular triangle: contains the submandibular gland, submandibular ganglion, lymph nodes, hypoglossal nerve and facial artery.

carotid triangle: contains the common carotid artery and its branches, internal jugular vein and vagus nerve.

submental triangle: contains lymph nodes.

muscular triangle: contains the sternothyroid muscle, sternohyoid muscle and the thyroid gland.

What is the posterior triangle of the neck?

The posterior triangle of the neck is bounded by the **sternocleidomastoid muscle**, the **upper border of the clavicle**, and the **trapezius muscle**. It is further subdivided into two smaller triangles:

occipital triangle: contains branches of the cervical plexus, the upper part of the brachial plexus, and the accessory nerve.

supraclavicular triangle: contains the subclavian artery, the subclavian vein, and lymph nodes.

What are the blood vessels in the neck region?

The neck region contains vital arteries and veins.

Arteries (Figure 6.12):

The **common carotid artery** and its branches:

external carotid artery which supplies blood to the superficial structures of the face and head.

internal carotid artery which supplies blood to the intracranial structures

subclavian artery which supplies blood to the upper extremities and intracranial structures (only on the right).

Veins (Figure 6.12):

internal jugular vein, which carries venous blood from the brain.

external jugular vein, which drains venous blood from the superficial structures of the face.

anterior jugular vein, a small vein located in the anterior midline of the neck.

brachiocephalic vein, formed by the junction of the **internal jugular vein** and the **subclavian vein**.

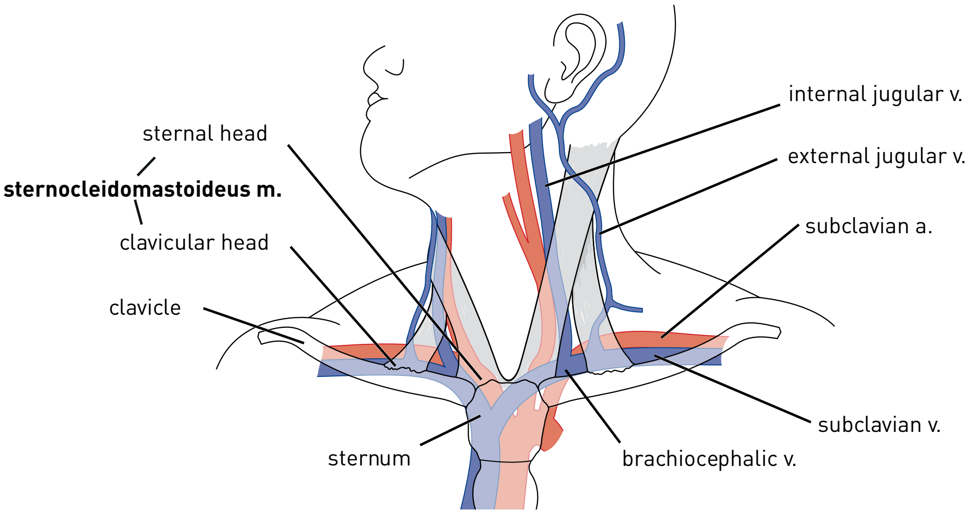


Figure 6.12. Blood vessels of the neck region..

What are the lymph nodes in the neck region?

The lymphatic drainage of structures in the neck region occurs through the following groups of lymph nodes:

- **deep cervical nodes**
- **superficial cervical nodes**
- **occipital nodes**
- **submandibular nodes**
- **submental nodes**

What are the nerves in the neck region?

The neck region contains nerve plexuses formed by spinal nerves and their branches, as well as certain cranial nerves that emerge from the base of the skull and extend to various parts of the body (Figures 6.13a, b). Nerve plexuses are:

cervical plexus: is a network of nerves formed by the anterior branches of spinal nerves originating from the first four cervical segments (C1–C4) of the spinal cord. It innervates many muscles in the neck and provides sensory innervation to the skin in the neck region. The nerves forming this plexus also create a loop known as the **ansa cervicalis**, from which branches supply all the infrahyoid muscles except the thyrohyoid muscle.

brachial plexus (discussed in the upper extremity section).

phrenic nerve, which innervates the diaphragm, originates from the C3–C5 segments and is sometimes considered part of the cervical plexus.

Cranial nerves in the neck region:

mandibular nerve: a branch of the fifth cranial nerve (trigeminal nerve).

facial nerve: the seventh cranial nerve (VII).

glossopharyngeal nerve: the ninth cranial nerve (IX).

vagus nerve: the tenth cranial nerve (X).

accessory nerve: the eleventh cranial nerve (XI).

hypoglossal nerve: the twelfth cranial nerve (XII).

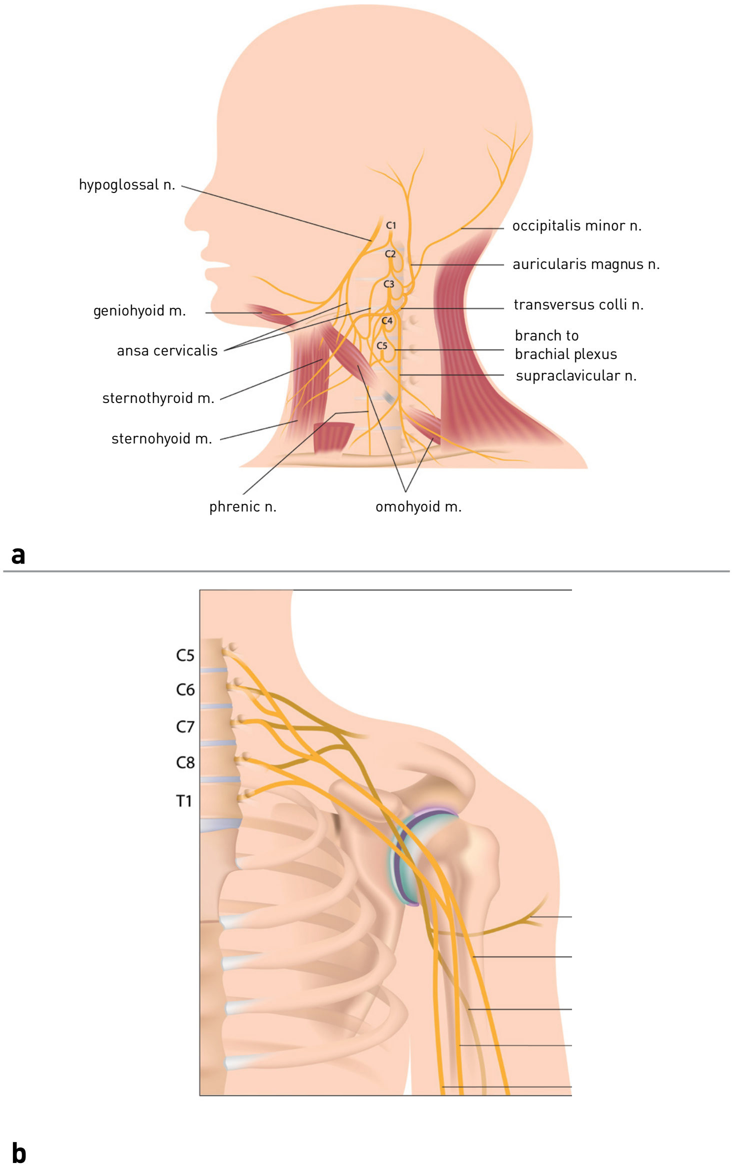


Figure 6.13. Nerve plexuses in the neck. **a.** cervical plexus **b.** formation and terminal branches of the brachial plexus.

What are the organs in the neck region?

The neck region contains organs belonging to the endocrine, respiratory, and digestive systems.

Organs of the endocrine system:

thyroid gland

parathyroid gland

Organs of the respiratory system:

trachea (windpipe)

larynx (voice box)

Organs of the digestive system:

pharynx (throat)

esophagus

submandibular salivary gland

Sample Questions on Head and Neck Anatomy

1. Which suture is located between the frontal and parietal bones?

   a) Coronal
   b) Sagittal
   c) Lambdoid
   d) Squamous
   e) Metopic

2. Which of the following arteries supplies the scalp in the forehead region?

   a) Facial
   b) Posterior auricular
   c) Occipital
   d) Supraorbital
   e) Maxillary

3. Which nerve receives the sensation when a hot object touches the forehead?

   a) Mandibular
   b) Maxillary
   c) Ophthalmic
   d) Facial
   e) Hypoglossal

4. Which facial muscle allows the eyelids to close tightly?

   a) Corrugator supercilii
   b) Procerus
   c) Orbicularis oculi
   d) Frontalis
   e) Depressor septi

5. Which muscle raises the eyebrows and creates horizontal lines on the forehead?

   a) Corrugator supercilii
   b) Procerus
   c) Orbicularis oculi
   d) Frontalis
   e) Depressor septi

6. Which nerve innervates the facial mimic muscles?

a) Maxillary

b) Facial

c) Mandibular

d) Vagus

e) Hypoglossal

7. Which of the following is NOT one of the suprahyoid muscles?

a) Digastric

b) Stylohyoid

c) Mylohyoid

d) Geniohyoid

e) Omohyoid

8. Which muscle divides the neck into anterior and posterior triangles?

a) Digastric

b) Stylohyoid

c) Omohyoid

d) Trapezius

e) Sternocleidomastoid

9. The cervical plexus originates from which segments of the spinal cord?

a) C1–C4

b) C1–C5

c) C2–C5

d) C2–C7

e) C3–C5

10. Which nerve innervates the sternocleidomastoid muscle?

a) Phrenic

b) Accessory

c) Axillary

d) Facial

e) Ansa cervicalis

Answers: 1.A, 2. D, 3.C, 4.C, 5.D, 6.B, 7.E, 8.E, 9.A, 10.B

CIRCULATORY SYSTEM

CIRCULATORY SYSTEM

The circulatory system is responsible for delivering essential substances, such as oxygen, to all tissues in the body via blood. It also returns deoxygenated blood to the heart after it has been utilized by the tissues.

What organs and structures make up the circulatory system?

The circulatory system consists of the **heart**, **blood vessels**, and the **blood** they contain. Additionally, the **lymphatic system**, which transports interstitial fluid (fluid found in the spaces around the cells) and fluids derived from the gastrointestinal system, is considered part of the circulatory system.

Blood is produced in the bone marrow of adults and is pumped throughout the body by the heart.

It delivers oxygen and nutrients to all tissues and returns deoxygenated blood to the heart.

What are arteries and veins?

Artery: is the blood vessel that carries blood away from the heart to the tissues. It is typically abbreviated as **"a."** in anatomical nomenclature.

Arteries carry oxygen-rich blood, with one exception: the **pulmonary artery**, which carries oxygen-poor blood from the right ventricle of the heart to the lungs for oxygenation.

Vein: is the blood vessel that carries blood from tissues back to the heart. It is abbreviated as **"v."** in anatomical terminology.

Veins typically carry oxygen-poor blood, with one exception: the **pulmonary veins**, which carry oxygen-rich blood from the lungs to the heart.

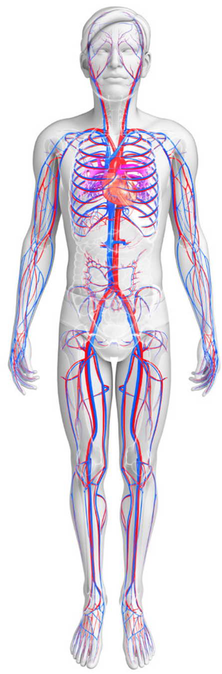


Figure 7.1. The circulatory system, showing the arterial component (red) originating from the heart and the venous component (blue) returning to the heart.

What are systemic and pulmonary circulation, and what structures are involved?

Two large veins, the **superior vena cava** and the **inferior vena cava**, carry deoxygenated blood from the entire body to the **right atrium**. From there, the blood flows into the **right ventricle**, which pumps it to the lungs via the **pulmonary trunk** and the **pulmonary arteries**.

In the lungs, the blood is oxygenated and then returned to the **left atrium** via the **pulmonary veins**. Then, it flows into the **left ventricle**, which pumps it to the body through the **aorta**.

The transport of oxygenated blood from the left ventricle to the body's tissues and its return to the right atrium after oxygen and nutrients have been utilized is called the **systemic circulation (greater circulation)**.

The transport of blood from the right ventricle to the lungs, and its return to the left atrium after oxygenation, is referred to as the **pulmonary circulation (lesser circulation)**.

CLINICAL RELEVANCE

ECG (Electrocardiogram) is a test that records the electrical activity of the heart. It helps detect heart rhythm problems, heart attacks, and other cardiac conditions. It's quick, non-invasive, and often done as a routine test.

ECHO (Echocardiography) is an ultrasound-based imaging test that shows the heart's structure and function. It helps evaluate heart valves, chambers, and pumping ability. It is also non-invasive and commonly used in diagnosing heart disease.

Angiography is a medical imaging technique that uses X-rays and contrast dye to visualize the blood vessels, especially in the heart (**coronary angiography**). This invasive procedure is used to detect blockages or narrowing in the arteries and often guides treatment like stenting or bypass surgery.

An **aneurysm** is a bulge or swelling in the wall of a blood vessel. It can occur in any artery but is most common in the brain, heart, or aorta. Aneurysms may develop slowly over time and often have no symptoms, but if they rupture, they can cause life-threatening internal bleeding. Risk factors include high blood pressure, smoking, and genetic conditions. Treatment depends on the size and location and may involve monitoring, medications, or surgery to repair or remove the aneurysm.

Hypertension, or **high blood pressure**, is a condition where the force of blood against the walls of the arteries is consistently too high. Over time, this increased pressure can damage blood vessels and lead to serious health issues such as heart disease, stroke, and kidney damage. Hypertension often has no obvious symptoms, which is why it is often called the "silent killer." Risk factors include a poor diet, lack of exercise, smoking, and a family history of the condition. It can be managed with lifestyle changes, medications, and regular monitoring.

Atherosclerosis is a condition where the arteries become narrowed and hardened due to a buildup of plaque, which is made up of fat, cholesterol, and other substances. This plaque restricts blood flow and can lead to serious health problems, such as heart attack, stroke, or peripheral artery disease. The process develops over time and is often caused by risk factors like high cholesterol, high blood pressure, smoking, and diabetes. Treatment focuses on managing these risk factors through lifestyle changes and medications, and in some cases, surgery may be necessary to remove blockages.

HEART

What are the size and location of the heart?

In a healthy individual, the heart is approximately the size of the fist and weighs around 250–300 grams (Figure 7.2). It is located between the lungs on either side, with the diaphragm below, the esophagus and vertebral column behind, and the sternum along with the left 4th to 6th costal cartilages in front.

It is positioned within the thoracic cavity, slightly to the left of the midline with its right side anteriorly and its left side posteriorly. Thus, the right ventricle is the most anterior chamber, while the left atrium is the most posterior chamber.

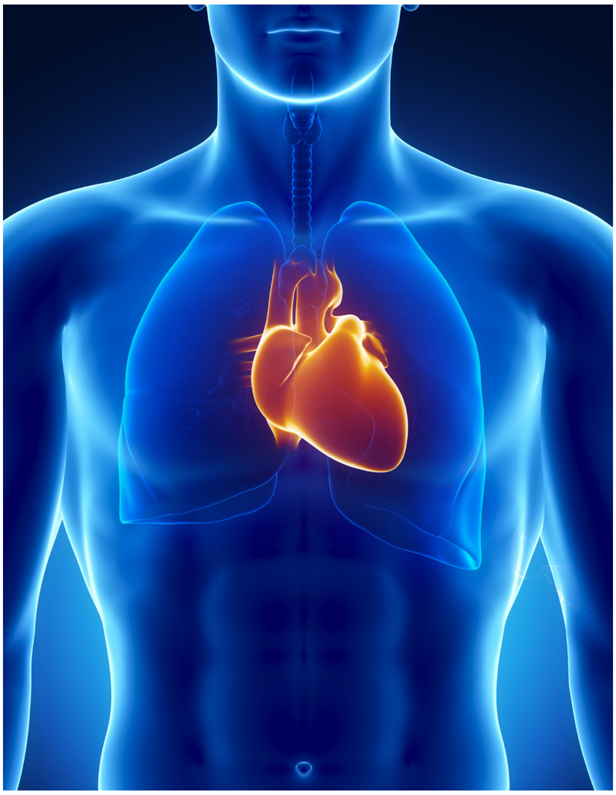


Figure 7.2. Position of the heart within the body.

What is the external appearance of the heart?

The heart can be compared to a triangular pyramid. The tip of the pyramid, referred to as the **apex**, is located downward and to the left, while its posterior aspect, called the **base**, is positioned to the right, upward, and posteriorly (Figure 7.3)

The heart's three surfaces are named based on the structures they are related to:

sternocostal surface: the surface facing the sternum and ribs

pulmonary surface: the surface facing the lungs

diaphragmatic surface: the surface resting on the diaphragm

The edges of the heart separating these surfaces are not sharp, making the boundaries between surfaces indistinct. The three edges are:

right border

left border

inferior border

The **atriums** and **ventricles** are separated externally by a groove called the **coronary sulcus**. This groove houses the **coronary arteries**, which supply blood to the heart itself, and the **coronary sinus**, which carries venous blood from the heart tissue.

Additionally, two grooves extend from the **coronary sulcus** toward the **apex** on the anterior and posterior surfaces of the heart, marking the boundary between the two ventricles:

anterior interventricular sulcus
posterior interventricular sulcus (Figure 7.3).

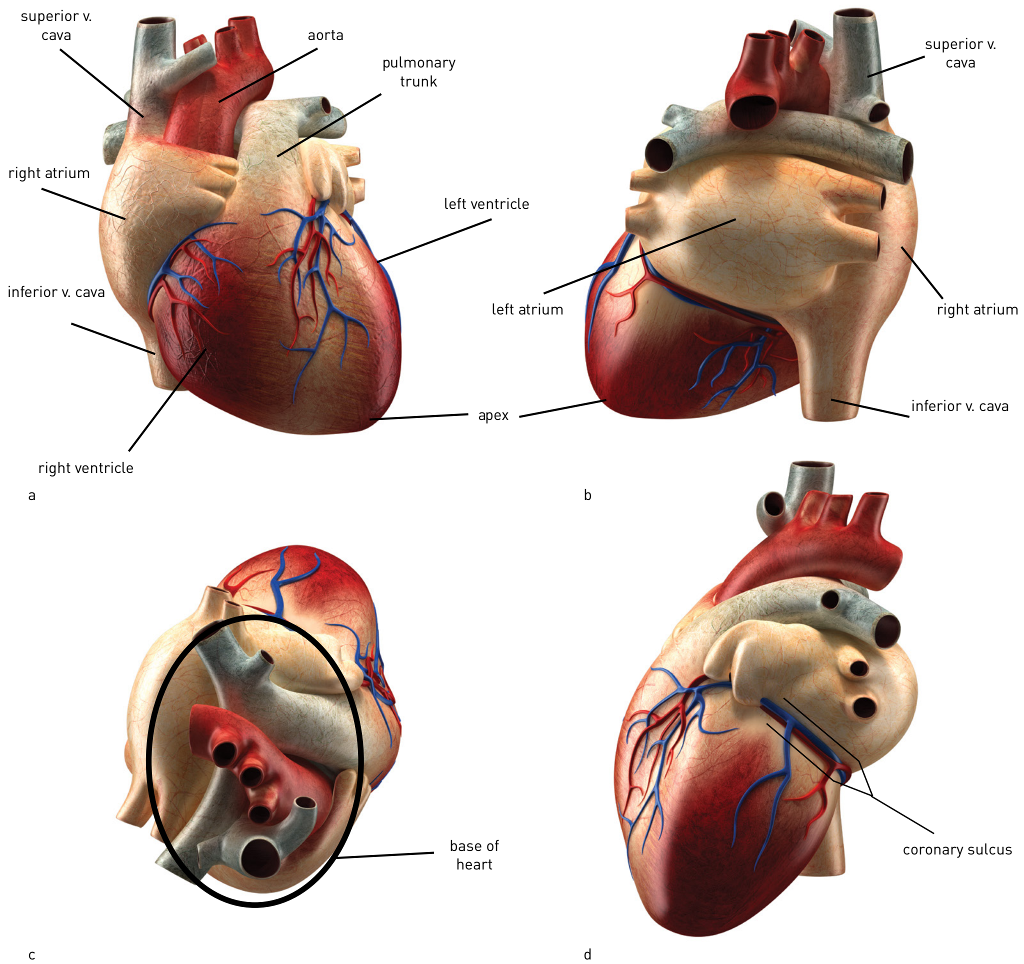


Figure 7.3. External view of the heart. **a.** anterior view **b.** posterior view **c.** superior view **d.** left lateral view

What is the structure of the heart?

The heart is composed of three layers: **pericardium**, **myocardium**, **endocardium**.

Pericardium: is the outer, fibroserous sac that surrounds the heart. It consists of two parts;

fibrous pericardium: the outer, tougher part that attaches to surrounding structures (e.g., the sternum and diaphragm).

serous pericardium: the inner part, which is smoother and more delicate. The serous pericardium has two layers:

parietal layer (parietal lamina): outer layer of serous pericardium, lines the inner surface of the fibrous pericardium.

visceral layer (visceral lamina): inner layer of the serous pericardium that covers the surface of the heart, also known as the **epicardium**.

The space between parietal and visceral layers is called the **pericardial cavity**, which contains a small amount of pericardial fluid. This fluid reduces friction between the layers during the heart's movements.

Myocardium: is the middle layer, which is composed of cardiac muscle tissue and forms the majority of the heart's structure. It is responsible for contracting and pumping blood throughout the body. It is composed of cardiac muscle tissue and is the most important layer for heart function.

Endocardium: is the innermost, very thin layer lining the interior of the heart chambers and valves. It helps to provide a smooth surface for blood flow and prevents blood clots from forming within the heart.

CLINICAL RELEVANCE

Myocardial infarction (heart attack) occurs due to blockage of coronary arteries, leading to ischemia and necrosis of cardiac muscle. Common symptoms include chest pain (angina), shortness of breath, sweating, nausea, and radiating pain to the left arm or jaw. Prompt treatment is critical to restore blood flow and minimize heart damage. Treatment may involve medications, procedures like angioplasty, or surgery, depending on the severity.

Congestive Heart Failure (CHF) is a condition where the heart fails to pump blood efficiently, leading to fluid accumulation in the lungs (pulmonary edema) and body (peripheral edema). This can cause symptoms such as shortness of breath, fatigue, swelling in the legs, and fluid retention. CHF can result from various heart conditions, including coronary artery disease, high blood pressure, or heart valve problems. While it is a chronic condition, treatment focuses on managing symptoms, improving heart function, and preventing further damage through medications, lifestyle changes, and sometimes medical procedures.

Pericarditis is the inflammation of the pericardium. It can be caused by infections (viral, bacterial), autoimmune diseases, trauma, or certain medications. Common symptoms include sharp chest pain, which may worsen with breathing or coughing, and sometimes fever or difficulty breathing. The inflammation can lead to fluid accumulation around the heart, known as **pericardial effusion**, which can affect the heart's function. Treatment typically includes anti-inflammatory medications, pain relief, and addressing the underlying cause. In severe cases, procedures may be required to drain excess fluid or prevent complications.

What are the chambers of the heart?

The heart has four chambers: the blood-receiving chambers, the right and left **atria** (singular: **atrium**), and the blood-pumping chambers, the right and left **ventricles**. The atria form the base of the heart (Figure 7.4).

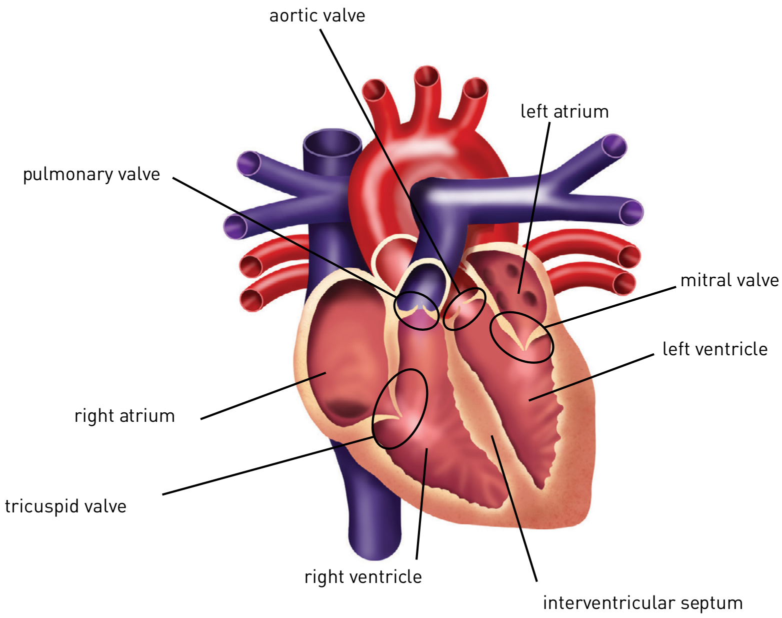


Figure 7.4. Chambers and valves of the heart.

Right atrium: is the heart chamber where the superior and inferior vena cava open. Most of its surface is smooth. The smaller, narrow anterior part is called the **auricle**, which appears ridged due to the presence of **pectinate muscles**. The right atrium is separated from the left atrium by a partition called the **interatrial septum**. On this septum, an embryological remnant of **oval foramen**, the **oval fossa**, can be observed. At the lower part of the right atrium is the **opening of the coronary sinus,** which carries venous blood from the heart tissue itself.

During fetal life, blood flows directly from the right atrium to the left atrium through the oval foramen**.** This occurs because the fetal lungs are not yet functional for gas exchange. Consequently, oxygenated blood from the placenta, entering the right side of the fetal heart, bypasses the lungs and is directed to the left side of the heart, allowing it to be pumped into the systemic circulation to supply the body.

Left atrium: is the chamber of the heart that receives oxygenated blood from the lungs via the pulmonary veins. These veins drain into the left atrium, delivering oxygen-rich blood to be pumped into systemic circulation. Similar to the right atrium, its walls are smooth except for a small portion, the auricle, which is ridged.

Right ventricle: is connected to the right atrium through an opening called the **right atrioventricular orifice**. This opening is guarded by the **tricuspid valve**. Most of the inner surface of the right ventricle has a ridged appearance due to muscular structures called **trabeculae carneae**. Only the area near the pulmonary valve has a smooth surface. Near the lower part of the ventricle, a more prominent structure of the trabeculae carneae, known as the **septomarginal trabecula (moderator band)**, contains fibers of the heart's conduction system.

The right ventricle also has **2-3 papillary muscles**, which extend from the ventricular wall to the leaflets of the tricuspid valve. These muscles are connected to the valve leaflets by thin, white, string-like structures called **chordae tendineae**.

Left ventricle: is connected to the left atrium through an opening called the **left atrioventricular orifice**. This opening is guarded by the **mitral valve**. Similar to the right ventricle, the inner surface of the left ventricle has ridges formed by **trabeculae carneae**.

The left ventricle also contains **2-3 papillary muscles**, which extend from the ventricular wall to the leaflets of the mitral valve. These are also connected to the mitral valve leaflets by **chordae tendineae**.

Since the blood pressure in systemic circulation is higher than in pulmonary circulation, the left ventricle needs to contract more forcefully. As a result, the wall of the left ventricle is significantly thicker than that of the right ventricle.

What are the valves of the heart?

The heart contains **4** valves (Figure 7.5):

- **atrioventricular valves:**
  - **right atrioventricular valve (tricuspid valve)**
  - **left atrioventricular valve (mitral valve)**
- **semilunar valves**:
  - **right pulmonary valve**
  - **left aortic valve**

Blood from systemic circulation enters the right atrium and passes into the right ventricle through the tricuspid valve. When the right ventricle contracts, blood is ejected through the pulmonary valve into the pulmonary trunk and pulmonary arteries, which transport it to the lungs. Oxygenated blood from the lungs is carried to the left atrium, then passes into the left ventricle through the mitral valve, and is then pumped through the aortic valve into the aorta and systemic circulation.

During the heart's functioning, blood must flow from the atria to the ventricles and then from the ventricles to the major vessels (aorta and pulmonary trunk). The valves function to prevent the backflow of blood. **Atrioventricular valves** prevent blood from flowing back into the atria when the ventricles contract. **Semilunar valves** prevent blood from flowing back into the ventricles from the aorta or pulmonary artery.

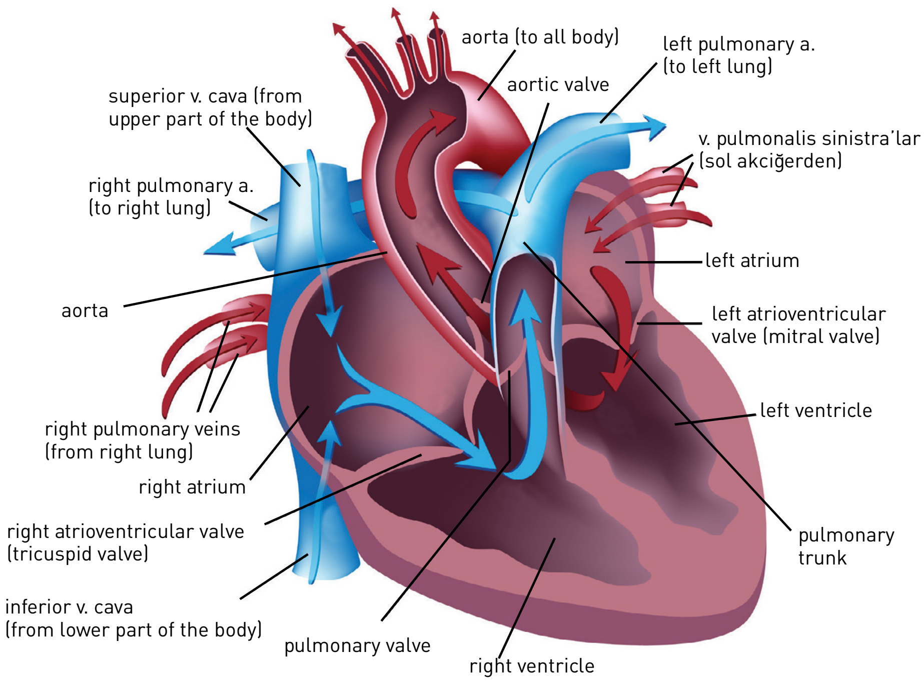


Figure 7.5. Chambers and valves of the heart and the direction blood circulation.

What is the interatrial septum?

The **interatrial septum** is the partition that separates the right and left atria. On its surface, there is a slightly depressed region called the **oval fossa** (oval foramen in fetal life) (Figure 7.4).

What is the interventricular septum?

The **interventricular septum** is the partition that separates the two ventricles. Except for a very small area at its uppermost part, the entire septum is composed of cardiac muscle (Figure 7.4).

CLINICAL RELEVANCE

Atrial Septal Defect (ASD) is a congenital heart condition where there is a hole in the septum between the two atria of the heart. This allows oxygen-rich blood to mix with oxygen-poor blood, which can strain the heart and lungs. Symptoms can range from none to shortness of breath and fatigue, and treatment may involve monitoring or surgery.

Ventricular Septal Defect (VSD) is another congenital defect, but it involves a hole in the septum between the two ventricles. This causes blood to flow abnormally between the heart's chambers, which can lead to heart failure if left untreated. Treatment depends on the size of the hole and may involve surgery.

Valve diseases refer to conditions where one or more of the heart valves (such as the mitral, aortic, tricuspid, or pulmonic valves) don't function properly. This can include valve stenosis (narrowing), regurgitation (leakage), or prolapse (improper closure). These conditions can affect blood flow, leading to symptoms like shortness of breath, fatigue, and chest pain. Treatment options vary from medications to surgery, depending on the severity.

What are the great vessels that bring blood to the heart?

The vessels that bring blood to the heart open into its atria (Figures 7.3, 7.4, and 7.5).

Vessels opening into the right atrium:

superior vena cava: drains venous blood from the head, neck, upper extremities, and chest wall into the heart.

inferior vena cava: carries venous blood from the lower extremities, pelvis, abdominal organs, and abdominal wall to the heart.

Vessels opening into the left atrium:

pulmonary veins: are 3 or 4 veins that carry oxygenated blood from the lungs to the heart.

What are the major vessels leaving the heart?

The major vessels leaving the heart originate from the ventricles (Figures 7.3, 7.4, 7.5).

From the right ventricle:

The only major artery leaving the right ventricle is the **pulmonary trunk**. Shortly after its origin, it divides into two branches:

right pulmonary artery carries venous blood to the right lung.

left pulmonary artery carries venous blood the left lung.

CLINICAL RELEVANCE

Pulmonary Embolism (PE) occurs when a blood clot, often from the legs (deep vein thrombosis), travels to the lungs and blocks a pulmonary artery. This disrupts blood flow to the lungs, causing symptoms like sudden shortness of breath, chest pain, coughing, and dizziness. PE can be life-threatening if not treated promptly. Treatment typically involves blood thinners, clot-dissolving medications, or surgery to remove the clot, depending on the severity of the blockage.

From the left ventricle:

The only major artery leaving the left ventricle is the **aorta** (Figure 7.6). Immediately after exiting the heart, the aorta gives off two branches that supply blood to the heart muscle itself:

- **right coronary artery**
- **left coronary artery**

Afterward, the aorta is referred to by different names along its course:

- **ascending aorta**
- **aortic arch**
- **descending aorta (thoracic aorta)**

What are the branches of the aortic arch?

The aortic arch gives off three major branches in the following order:

- **brachiocephalic trunk**: later divides into the right subclavian artery and the right common carotid artery.
- **left common carotid artery**
- **left subclavian artery**

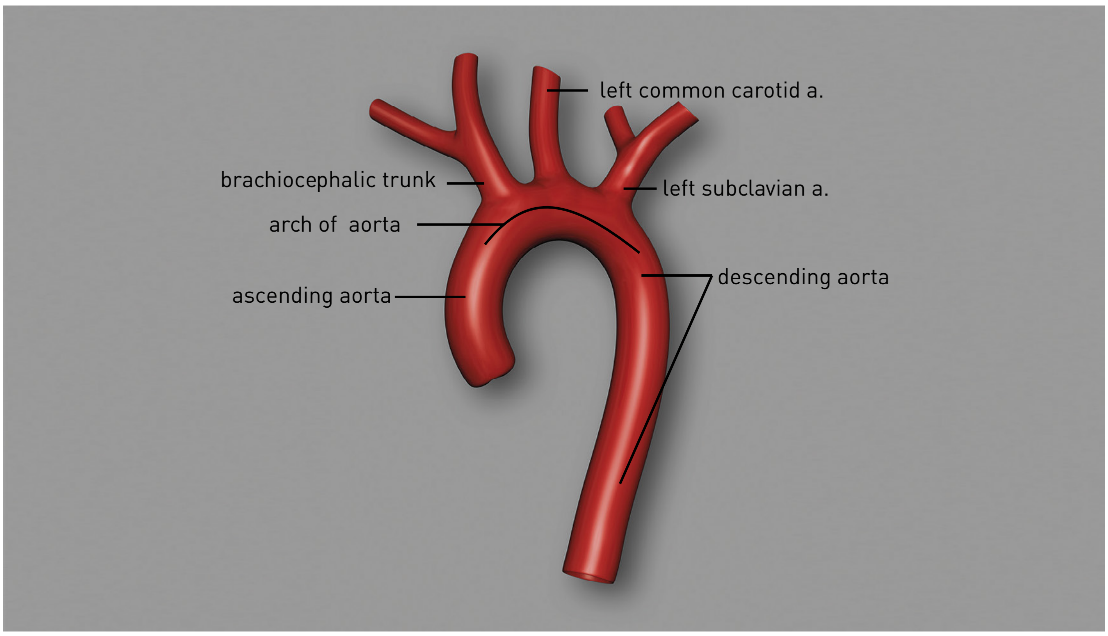


Figure 7.6. Ascending aorta, aortic arch and its branches, and the descending aorta.

These three main branches supply blood to the head, neck, and both upper extremities.

CLINICAL RELEVANCE

Aortic Coarctation is a congenital condition where a part of the aorta is narrowed, reducing blood flow to the lower body. This narrowing causes the heart to work harder to pump blood, potentially leading to high blood pressure and heart failure if untreated. Symptoms may include high blood pressure in the arms, weak pulses in the legs, and shortness of breath. Treatment often involves surgery or balloon angioplasty to widen the narrowed section.

Dissecting Aortic Aneurysm occurs when there is a tear in the inner lining of the aorta, causing blood to flow between the layers of the aortic wall. This can lead to a rupture, which is a life-threatening emergency. Symptoms include severe chest or back pain, dizziness, and fainting. Immediate medical intervention, such as surgery, is usually required to repair the tear and prevent rupture.

What are the coronary arteries?

Coronary arteries are the vessels that supply blood to the heart's own tissue. These arteries are the first branches of the ascending aorta. There are two coronary arteries (right and left), both of which originate from the ascending aorta and travel through the coronary sulcus toward the right and left sides of the heart, where they branch out to supply blood to the heart (Figure 7.7):

- **Right Coronary Artery (RCA):** runs through the coronary sulcus along the right side of the heart toward the posterior surface. Along its course, it gives off the **right marginal branch** which travels along the right border of the heart. It continues in the posterior interventricular sulcus as the **posterior interventricular artery** which extends to the apex of the heart and terminates there.
- **Left Coronary Artery (LCA):** divides into two major branches just after originating from the aorta:
  - **circumflex branch (Cx):** travels through the coronary sulcus on the left side of the heart and curves around to the posterior surface.
  - **anterior interventricular artery (LAD: left anterior descending artery):** runs down the anterior interventricular sulcus toward the apex of the heart.

CLINICAL RELEVANCE

Bypass surgery, also known as coronary artery bypass graft (CABG) surgery, is a procedure used to treat blocked or narrowed coronary arteries. During the surgery, a healthy blood vessel from another part of the body (often the leg, chest, or arm) is used to create a bypass around the blocked artery, allowing blood to flow freely to the heart. This surgery helps improve blood supply to the heart muscle, relieve chest pain (angina), and reduce the risk of heart attack.

Angioplasty is a medical procedure used to open narrowed or blocked blood vessels, typically arteries, to restore normal blood flow. During the procedure, a small balloon is inserted into the affected artery through a catheter and inflated at the site of the blockage. This helps to compress the plaque and widen the artery. In some cases, a stent (a small mesh tube) may be placed to keep the artery open. Angioplasty is commonly used to treat conditions like coronary artery disease and is less invasive than traditional surgery.

Which veins drain the heart's own tissue?

The venous blood from the heart's own tissue is collected by veins that accompany the arteries. These veins include:

great cardiac vein: begins at the apex, travels along the anterior interventricular sulcus, and joins the left marginal vein.

left marginal vein: runs along the left border of the heart.

small cardiac vein: is the continuation of the right marginal vein, traveling along the right side of the heart and draining into the coronary sinus.

right marginal vein: travels along the prominent right border of the heart.

middle cardiac vein: starts at the apex, runs along the posterior interventricular sulcus, and drains into the coronary sinus.

smallest cardiac veins (Thebesian veins): are small veins that open directly into the right atrium and ventricle.

All of these veins (except the Thebesian veins) ultimately drain into the **coronary sinus**, which empties into the right atrium.

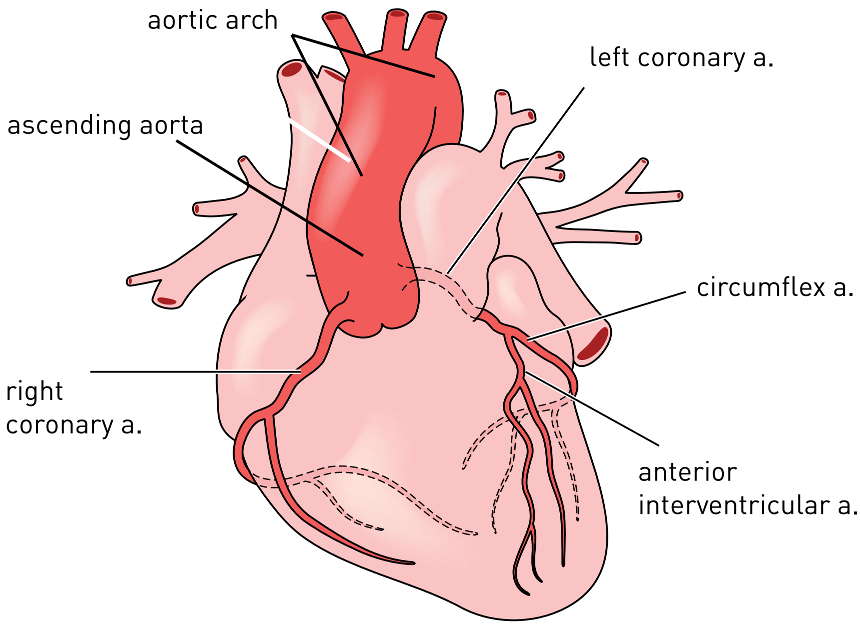


Figure 7.7. Coronary arteries.

What is the conduction system of the heart?

The conduction system of the heart consists of specialized structures that regulate the rhythm of cardiac contraction and ensure the transmission of electrical impulses. It includes:

nodes (pacemakers): These are structures that generate rhythmic impulses:

Sinoatrial (SA) node: located in the right atrium, it acts as the primary pacemaker of the heart, generating impulses that cause the heart to contract 60–80 times per minute.

Atrioventricular (AV) node: found in the lower part of the interatrial septum within the right atrium, it transmits signals from the atria to the ventricles.

specialized muscle fibers: these fibers conduct impulses between nodes and across the heart muscle:

atrioventricular bundle (His bundle): a pathway that transmits impulses from the AV node to the ventricles.

right and left bundle: are the branches of the His bundle that deliver impulses to the respective ventricles.

Purkinje fibers: located beneath the endocardium, distribute impulses throughout the ventricular myocardium, ensuring coordinated contraction.

The SA node initiates an electrical impulse that spreads through the atrial myocardium via specialized fibers, causing the atria to contract. This impulse reaches the AV node, which slows it down to allow complete atrial contraction and ventricular filling. From the AV node, the impulse travels through the His bundle and its right and left branches, eventually spreading into the ventricles via Purkinje fibers, causing them to contract.

The conduction system operates under the control of the brainstem's autonomic centers to adjust the heart's rhythm as needed.

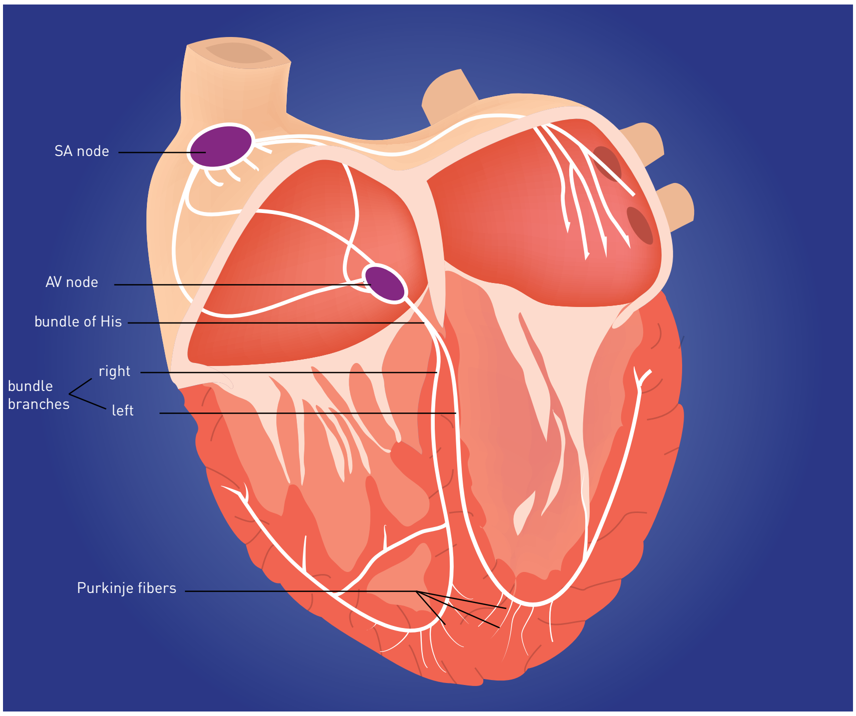


Figure 7.8. Conducting system of the heart.

CLINICAL RELEVANCE

Cardiac rhythm disorders, also known as **arrhythmias**, are conditions where the heart's normal rhythm is disrupted. This can result in the heart beating too fast (tachycardia), too slow (bradycardia), or irregularly. Arrhythmias can occur in the atria or ventricles of the heart and may lead to symptoms such as palpitations, dizziness, shortness of breath, or even fainting. In severe cases, arrhythmias can cause heart failure or increase the risk of stroke. Treatment options vary depending on the type and severity of the arrhythmia and may include medications, lifestyle changes, or procedures like pacemaker implantation or ablation.

LYMPHATIC SYSTEM

How is the lymphatic system defined?

The lymphatic system is a network of vessels, tissues, and organs that serves the following functions:

- **protection and defense:** as a part of the immune system, it contributes the protection of the body against foreign substances and pathogens.
- **fluid balance:** facilitates the return of interstitial fluid (fluid found between cells) to the bloodstream.
- **nutrient transport:** transports fats absorbed from the digestive system.

What structures comprise the lymphatic system?

The lymphatic system includes the following components:

- **lymph**
- **lymphatic vessel network**
- **lymph nodes (lymphatic nodules)**
- **tonsils**
- **spleen**
- **thymus**
- **bone marrow**

What is lymph?

Lymph is a fluid derived from interstitial fluid (tissue fluid between cells) and is rich in white blood cells. It plays a key role in immune defense and the maintenance of fluid balance.

What is the lymphatic vessel network?

The lymphatic vessel network begins at the level of **lymphatic capillaries**, which are located alongside blood capillaries in tissues. These highly permeable capillaries collect interstitial fluid. The smaller lymphatic capillaries merge to form larger lymphatic vessels.

What are the main lymphatic trunks?

The primary lymphatic trunks and the areas they drain are as follows:

- **jugular:** drains lymph from the neck.
- **subclavian:** drains lymph from the upper extremities.
- **lumbar:** drains lymph from the lower extremities.
- **bronchomediastinal:** drains lymph from the thoracic cavity.
- **intestinal:** drains lymph from abdominal organs.

CLINICAL RELEVANCE

Lymphedema is a condition where excess lymph fluid builds up in tissues, causing swelling, usually in the arms or legs. It occurs when the lymphatic system, which helps drain excess fluid from the body, is damaged or blocked. This can happen due to surgery, radiation therapy, infections, or congenital conditions. Lymphedema can cause discomfort, limited movement, and skin changes. While there is no cure, treatment options like compression garments, manual lymphatic drainage, exercise, and skin care can help manage the swelling and prevent complications.

What is the thoracic duct?

The **thoracic duct** is the largest lymphatic vessel in the body (Figure 7.9). It begins anterior to the **12th thoracic vertebra** and ascends along the anterior surface of the spine. It collects lymph from:

- both lower extremities
- the entire abdominal cavity
- the left side of the head and neck
- the left thorax
- left upper extremity

The thoracic duct empties into the **left venous angle**, which is the junction of the **left internal jugular** and the **left subclavian veins** in the neck.

Lymph from the right upper extremity, as well as the right side of the thorax, head, and neck, is collected by the **right lymphatic duct**, which empties into the **right venous angle**.

What is the cisterna chyli?

The **cisterna chyli** is a lymphatic sac typically located anterior to the L1-L2 vertebrae. Lymph from both lower extremities and the digestive system converges here before continuing upward as the thoracic duct. The cisterna chyli narrows superiorly to continue as the thoracic duct.

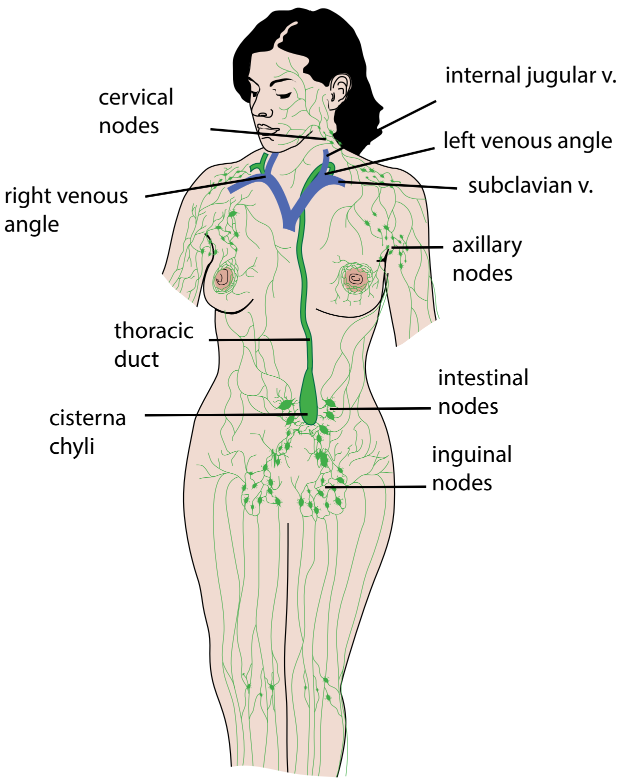


Figure 7.9. Major lymph nodes and lymphatic pathways.

What are lymph nodes?

Lymph nodes are oval-shaped masses of lymphatic tissue arranged in clusters along lymphatic vessels at specific locations in the body. As lymph flows through these nodes, it is filtered before being returned to the systemic circulation.

What is the function of lymph nodes?

Lymph nodes filter lymph, removing harmful substances and microorganisms carried by lymphatic vessels. Lymph nodes produce antibodies that help macrophages recognize and destroy pathogens which is called as **phagocytosis**.

Where are the lymph nodes located?

Some examples of areas where lymph nodes are located:

neck region (cervical nodes)

groin region (inguinal nodes)

armpit region (axillary nodes)

abdominal region (intestinal nodes)

CLINICAL RELEVANCE

Lymphadenopathy refers to the swelling or enlargement of lymph nodes, which are part of the lymphatic system and help fight infection. It can be caused by various factors, including infections, autoimmune diseases, or cancers. Swollen lymph nodes are often tender and can be felt under the skin, especially in the neck, armpits, or groin. Lymphadenopathy may resolve on its own if caused by an infection, but if persistent or associated with other symptoms, it may require medical evaluation to determine the underlying cause.

What is a tonsil?

Tonsils are large clusters of lymph nodes located around the oral cavity and pharynx. They play a vital role in defending the body against microorganisms entering through the mouth and nose.

What are the lymphatic organs?

The lymphatic organs include the spleen and thymus.

What is spleen (Lien)?

The spleen is the largest lymphatic organ, located in the upper left quadrant of the abdominal cavity, beneath the diaphragm.

It has an upper border (superior margin), which typically features notches, and a lower border (inferior margin). The surface facing the abdominal cavity is called visceral surface and contains the hilum, where the splenic artery and vein enter and exit. Anterior to the hilum, spleen is in contact with the stomach (gastric surface), posteriorly it is related to left kidney (renal surface) and inferiorly it is associated with the left colic flexure (colic surface).

What is the function of spleen?

Spleen,

acts like a large lymph node, filtering blood.

removes bacteria and damaged blood cells.

plays a role in the immune system by producing immune cells.

stores blood for release when needed.

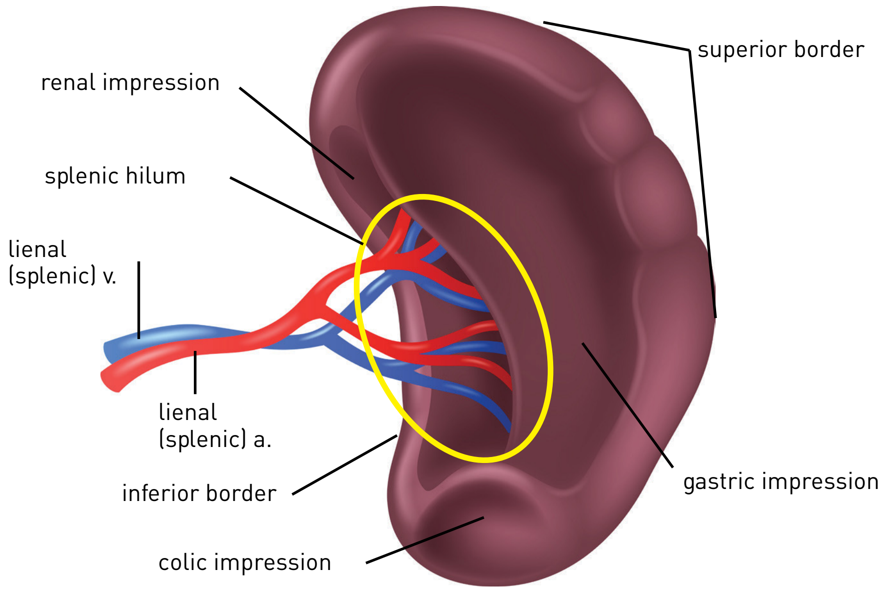


Figure 7.10. Hilum on the visceral surface of the spleen and contact areas with adjacent organs.

CLINICAL RELEVANCE

Splenomegaly is the enlargement of the spleen, often due to infections, liver disease, or hematological disorders. It can lead to increased red blood cell destruction, thrombocytopenia, and susceptibility to infections. Symptoms may include abdominal pain, a feeling of fullness, or swelling in the abdomen. Treatment depends on the underlying cause, and in some cases, the spleen may need to be removed (splenectomy) if the enlargement is severe or causing complications.

What is the function of thymus and where is it located?

The thymus is located in the thoracic cavity, posterior to the sternum, anterior to the trachea, and inferior to the thyroid gland.

It is active before puberty, after which it decreases in size and becomes inactive.

The thymus plays a role in the immune system by supporting the maturation of T lymphocytes (T cells), which then enter the bloodstream to perform their immune functions.

What is the function of bone marrow?

Bone marrow is a connective tissue located within bones that produces blood cells.

In addition to other blood cells, bone marrow produces macrophages and plasma cells, which are associated with the lymphatic system.

Some cells produced in the bone marrow are transported to the thymus, spleen, and lymph nodes, where they mature and perform their immune functions.

Circulatory System Anatomy Sample Questions:

1. Which of the following is located posterior to the heart?
   a) Lung
   b) Diaphragm
   c) Sternum
   d) Esophagus
   e) Trachea

2. What is the name of the innermost layer of the heart?
   a) Endometrium
   b) Endocardium
   c) Myocardium
   d) Pericardium
   e) Peritoneum

3. Which artery originates from the right ventricle?
   a) Pulmonary trunk
   b) Ascending aorta
   c) Aortic arch
   d) Descending aorta
   e) Brachiocephalic trunk

4. Which of the following structures is NOT related to the right atrium?
   a) Auricle
   b) Opening of the coronary sinus
   c) Fossa ovalis
   d) Pectinate muscles
   e) Papillary muscle

5. Which of the following valves is located between the left atrium and the left ventricle?
   a) Aortic
   b) Pulmonary
   c) Mitral
   d) Tricuspid
   e) Semilunar

6. Which of the following structures can be observed on the interatrial septum?
   a) Auricle
   b) Opening of the coronary sinus
   c) Fossa ovalis
   d) Pectinate muscles
   e) Papillary muscle

7. The coronary arteries are branches of which structure?
   a) Aortic arch
   b) Ascending aorta
   c) Descending aorta
   d) Common carotid artery
   e) Brachiocephalic trunk

8. Which of the following vessels carries oxygen-rich blood from the lungs to the heart?
   a) Pulmonary vein
   b) Pulmonary trunk
   c) Inferior vena cava
   d) Superior vena cava
   e) Internal jugular vein

9. Which of the following structures is not related to the conduction system of the heart?
   a) SA node
   b) AV node
   c) Bundle of His
   d) Coronary sinus
   e) Purkinje fibers

10. Which part of the heart is located most anteriorly in anatomical position?
    a) Right atrium
    b) Right ventricle
    c) Left atrium
    d) Left ventricle
    e) Aortic arch

Answers: 1.D, 2. B, 3.A, 4.E, 5.C, 6.C, 7.B, 8.A, 9.D, 10.B

RESPIRATORY SYSTEM

RESPIRATORY SYSTEM

The respiratory system is a network of organs responsible for the process of breathing, which involves the exchange of oxygen and carbon dioxide (Figure 8.1). The system consists of the following organs:

nose
pharynx (throat)
larynx (voice box)
trachea (windpipe)
bronchus and bronchioles
lungs
respiratory muscles

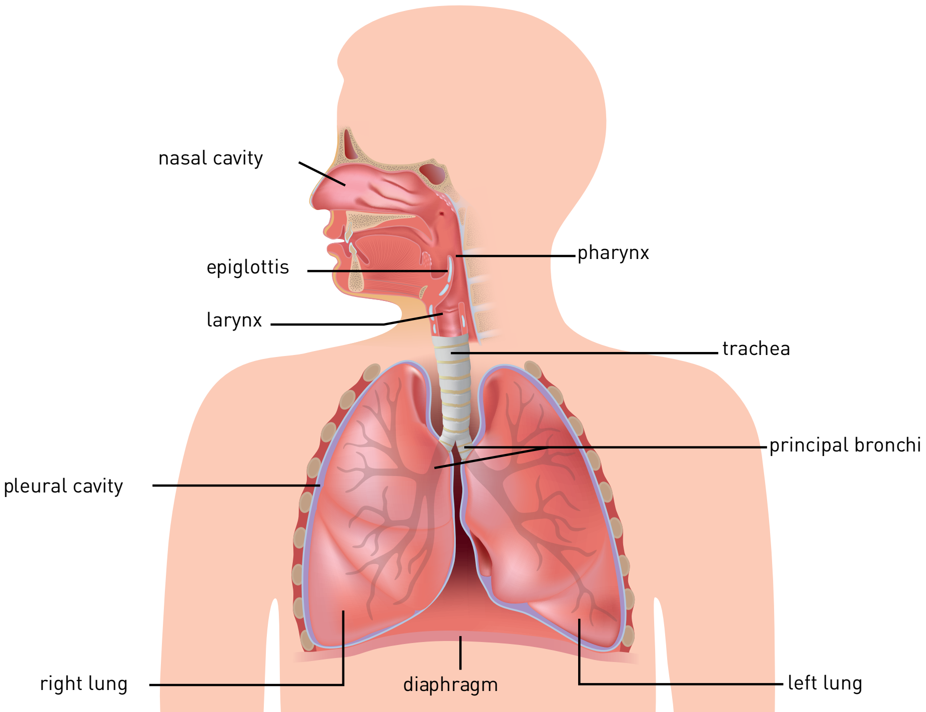


Figure 8.1. Structures related with the respiratory system.

NOSE

The nose forms the entry point of the respiratory system and is supported by a structure made of bone and cartilage. The **nasal cavity** is a narrow passage and lined by mucosa. The mucus secreted by the glands here helps warm and humidify the air before it passes further into the system. Additionally, the hairs at the entrance trap foreign particles and filter the air entering the respiratory system. The nose also plays a role in the sense of smell (olfaction).

Which bones surround the entrance of the nasal cavity?

The entrance of the nasal cavity is surrounded by the **maxilla** and the **nasal bones**. They form the **piriform aperture** at the entrance of the nasal cavity.

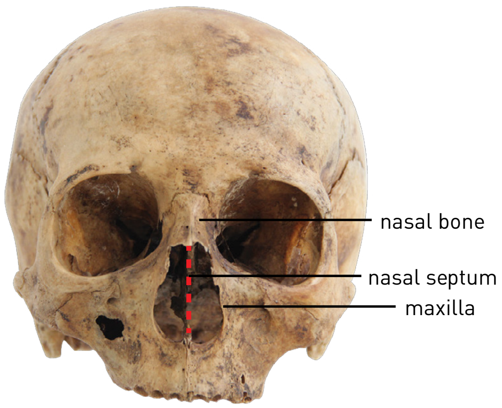


Figure 8.2. Anterior view of the nasal skeleton.

What are the boundaries of the nasal cavity?

The nasal cavity is bounded by the following structures:

roof (superior wall): composed of the nasal, frontal, ethmoid, and sphenoid bones. The posterior part of the roof forms the bony wall between the inferior surface of the brain and the nasal cavity.

floor (inferior wall): formed by the maxilla and palatine bones, creating the bony separation, hard palate, between the nasal cavity and the oral cavity (Figure 8.2).

What are the cartilages of the nose?

The cartilages of the nose include the following (Figure 8.3):

major alar cartilage: consists of the medial and lateral crura.

lateral nasal cartilage

septal nasal cartilage

minor nasal cartilages

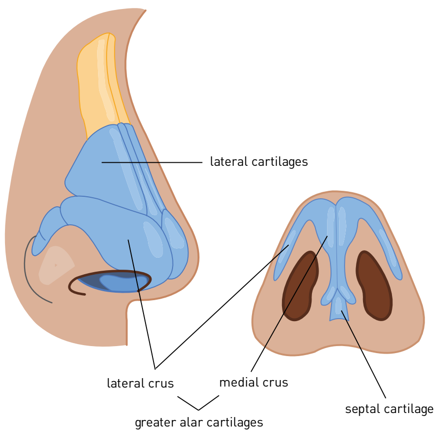


Figure 8.3. Nasal cartilages.

What is the nasal septum?

The nasal septum is a partition that divides the nasal cavity into two halves.

What structures form the nasal septum?

The nasal septum is formed by the following structures:

a part of the ethmoid bone (**perpendicular plate**)

the **vomer**

the **septal nasal cartilage**

CLINICAL RELEVANCE

Nasal septum deviation occurs when the thin wall of cartilage and bone that divides the two sides of the nasal cavity is displaced to one side. This can lead to difficulty breathing through the nose, nasal congestion, and frequent sinus infections. The condition can be congenital or result from injury. In some cases, it may cause little to no symptoms, but severe deviations may require treatment, such as medications to relieve symptoms or surgery (septoplasty) to correct the alignment of the septum.

What is the nasal concha?

The nasal concha refers to bony projections located on the lateral wall of the nasal cavity. Each half of the nasal cavity contains three conchae arranged from top to bottom (Figure 8.4b):

- **superior nasal concha**: part of the ethmoid bone
- **middle nasal concha**: part of the ethmoid bone
- **inferior nasal concha**: a separate bone

What is the nasal meatus?

The nasal meatus refers to the passage located beneath each nasal concha. Therefore, in each half of the nasal cavity, there are totally three meatus, one under each concha (Figure 8.4b):

- **superior nasal meatus**
- **middle nasal meatus**
- **inferior nasal meatus**

The paranasal sinuses, which are air-filled spaces within the bones surrounding the nasal cavity, open into these meatus. Consequently, the mucus secreted by the sinuses drains in here.

What are the arteries of nose?

The nose has a very rich arterial supply, originating from both the external and internal carotid arteries. Branches from the external carotid artery are the **sphenopalatine, greater palatine, superior labial** and **lateral nasal arteries** while the branches of the internal carotid artery are the **anterior** and **posterior ethmoidal arteries**. Many of the external and internal carotid arterial branches anastomose at the antero-inferior part of the nasal septum which is called as the **Little's area (Kiesselbach's plexus).** This particular area is the site where most of the nosebleeding happens.

What is choana?

The choana refers to the posterior boundary of the nasal cavity where it connects with the pharynx (throat).

What are paranasal sinuses?

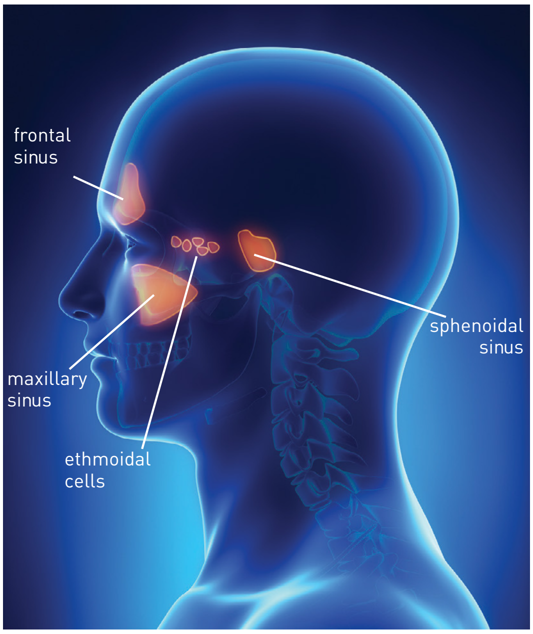
Some of the bones surrounding the nasal cavity contain air-filled spaces connected to the nasal cavity, known as paranasal sinuses (Figure 8.4a, b). These sinuses include:

- **maxillary sinus**: located within the maxilla, it is the largest paranasal sinus. It drains into the middle nasal meatus.
- **frontal sinus**: located within the frontal bone, it drains into the middle nasal meatus.
- **sphenoidal sinus**: found in the sphenoid bone, it opens above the superior nasal meatus into the spheno-ethmoidal recess.
- **ethmoidal air cells**: these are not a single large cavity but rather multiple small air-filled spaces within the ethmoid bone. They open into the middle and superior nasal meatus.

CLINICAL RELEVANCE

Epistaxis is the medical term for a **nosebleed**. It occurs when the small blood vessels inside the nose break and bleed, often due to dry air, nose picking, injury, or high blood pressure. Most nosebleeds are minor and stop on their own, but severe or frequent episodes may require medical attention.

Sinusitis is the inflammation or infection of the sinuses. It often occurs when the sinuses become blocked due to a cold, allergies, or other factors, leading to symptoms like nasal congestion, facial pain, headache, fever, and thick nasal discharge. Sinusitis can be acute, lasting for a few weeks, or chronic, lasting for months. Treatment typically includes decongestants, nasal sprays, pain relievers, and, in some cases, antibiotics if a bacterial infection is present.



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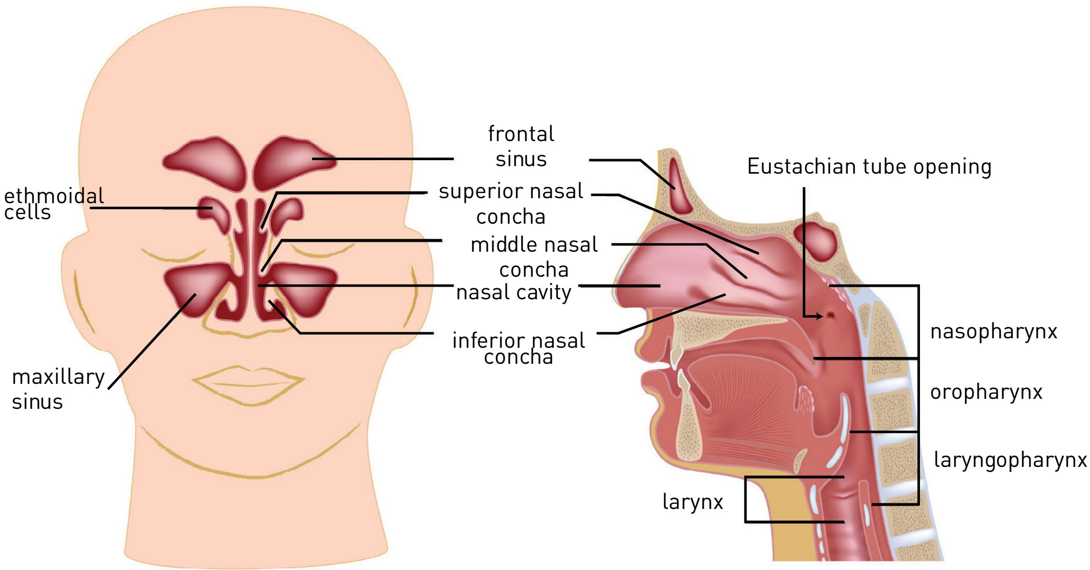
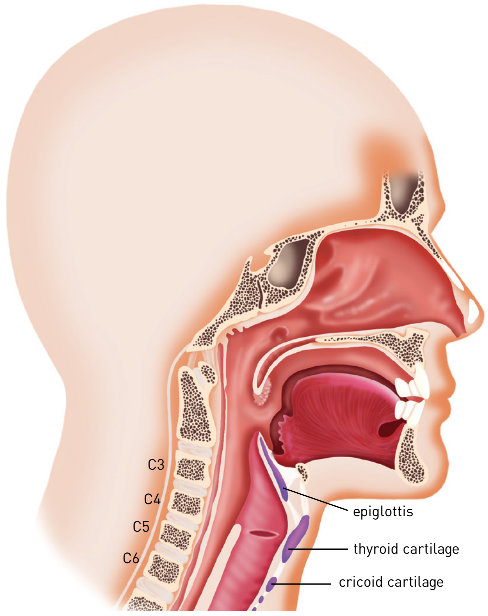


a

Figure 8.4. Paranasal sinuses. **a.** location of the paranasal sinuses. **b.** relationship of the paranasal sinuses with the nasal cavity and nasal conchae.

LARYNX (Voice Box)

The larynx is a passageway in the respiratory system that allows air from the nasal or oral cavity to enter the trachea (windpipe). Its structure is made up of cartilages, ligaments (that connect the cartilages), and muscles that facilitate movement and control of its parts (Figure 8.5a, b).



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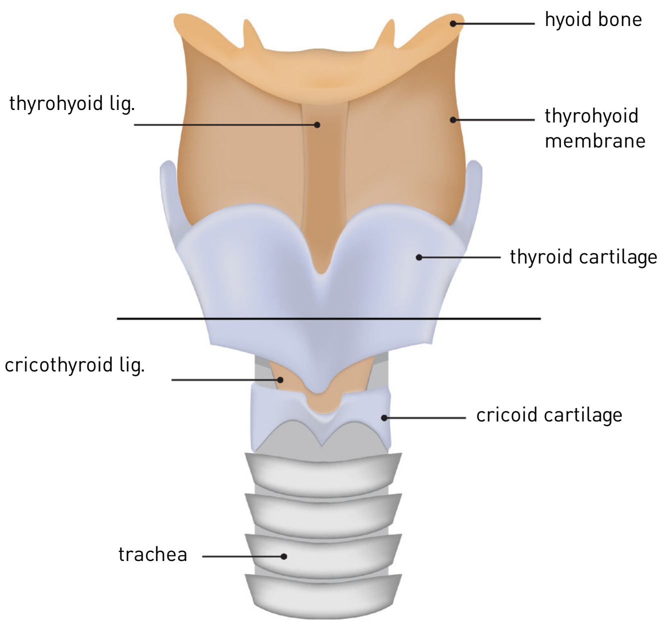


b

Figure 8.5. Larynx. **a.** sagittal section view. **b.** anterior view of the laryngeal cartilages and ligaments.

What is the function of the larynx?

The primary functions of the larynx are:

maintaining an open airway: ensuring a clear passage for air during breathing.

sound production: enabling the formation of sounds for speech and vocalization.

Where is the larynx located?

The larynx is positioned at the level of the C3–C6 cervical vertebrae in the neck. It is approximately 4 cm in length.

What are the structures surrounding the larynx?

superiorly: connected to the hyoid bone

inferiorly: connected to the trachea

anteriorly: lies directly beneath the skin

posteriorly: adjacent to the pharynx

laterally (on both sides): surrounded by the carotid sheath, infrahyoid muscles, sternocleidomastoid muscle, and the thyroid gland.

What are the cartilages of larynx?

The larynx consists of **three unpaired (single) cartilages** and **three paired cartilages** (Figures 8.5b, 8.6).

Unpaired cartilages are:

Epiglottis: Leaf-shaped cartilage attaches to the inner surface of the thyroid cartilage at its stem. During swallowing, it bends backward to close the laryngeal inlet, preventing food from entering the airway.

Thyroid cartilage: Formed by the fusion of two rectangular plates (laminae). The union of two laminae, anteriorly forms the **laryngeal prominence** (commonly known as the "Adam's apple"), a visible and palpable structure in the midline of the neck. This prominence is more distinct in males and moves up and down during swallowing. It has a pair of extensions on each side: **superior horns,** extending upward and **inferior horns,** extending downward. The thyroid cartilage is connected to the hyoid bone superiorly via the thyrohyoid membrane.

Cricoid cartilage: Resembles a signet ring, with the thin part (**arch**) positioned anteriorly and the thicker part (**lamina**) positioned posteriorly. Located at the level of the C6 vertebra, its arch can be felt beneath the skin at the front of the neck. Inferiorly, it is connected to the first cartilage of the trachea.

Paired cartilages are:

Arytenoid cartilage

Cuneiform cartilage

Corniculate cartilage

These paired cartilages are relatively small and are located on the superior posterior part of the cricoid cartilage.

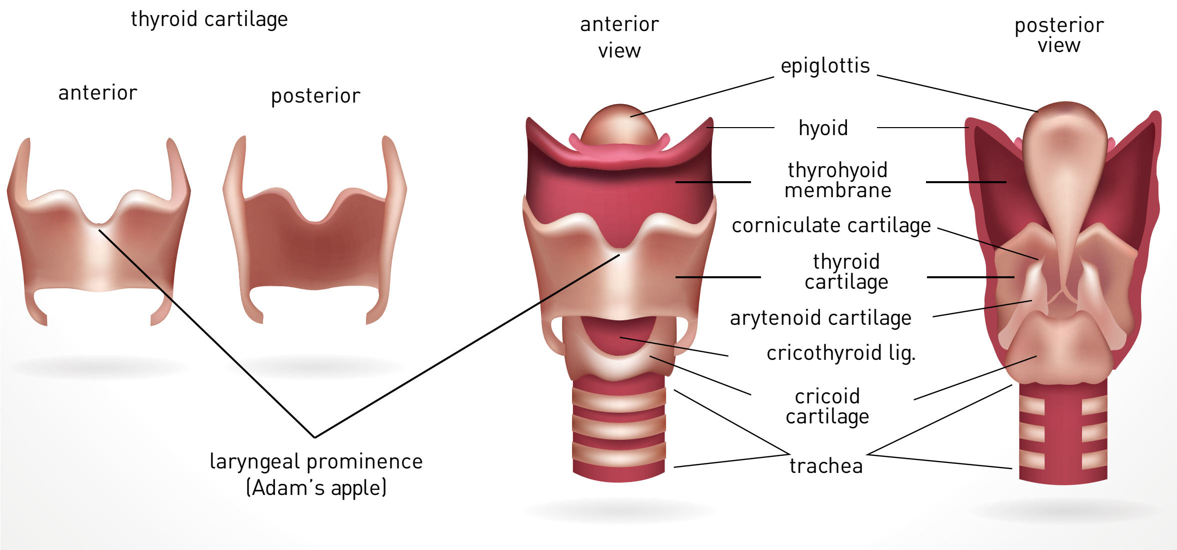


Figure 8.6. Laryngeal cartilages.

What are the ligaments of the larynx?

The ligaments of the larynx connect the cartilages that form its skeleton (Figure 8.5b). Depending on their thickness, they are named either membrane (thinner) or ligament (thicker). These ligaments are named after the two structures they connect. The most prominent ligaments are as follows:

thyrohyoid membrane: located between the thyroid cartilage and the hyoid bone. There is an opening on each side of the membrane, through which the internal laryngeal nerve and the superior laryngeal artery and vein pass. The central thickened part of the membrane is called the thyrohyoid ligament.

cricothyroid ligament: connects the cricoid cartilage and the thyroid cartilage.

vocal ligament (vocal cord): extends from the posterior aspect of the point where the laminae of the thyroid cartilage meet anteriorly, to the vocal process of the arytenoid cartilage posteriorly.

vestibular ligament: forms the lower free edge of the submucosal layer that extends from the epiglottis down to the arytenoid cartilages. It is located above and runs parallel to the vocal ligament.

hyoepiglottic ligament: connects the anterior surface of the epiglottis to the hyoid bone

What are the quadrangular membrane and the conus elasticus?

Beneath the mucosa of the larynx lies an elastic and durable connective tissue that plays a vital role in the function of the larynx. The upper part of this connective tissue is called the **quadrangular membrane**, while the lower part is called the **conus elasticus**. The free upper edge of the conus elasticus forms the **vocal ligament** and the free lower edge of quadrangular membrane forms the **vestibular ligament**. Between these two, the mucosa of the larynx forms a recess called the **laryngeal ventricle**.

What are the muscles of larynx?

Muscle	Function
cricothyroid muscle	stretches and tenses the vocal cords, altering the pitch of the voice.
lateral cricoarytenoid muscle	brings the vocal cords closer together (adduction), narrowing the rima glottidis (as during speaking).
posterior cricoarytenoid muscle	widens the rima glottidis by abducting the vocal cords (as during breathing).
thyroarytenoid muscle	relaxes and shortens the vocal cords.
vocalis muscle	fine-tunes tension in the vocal cords for precise pitch modulation.
transverse arytenoid muscle	brings the posterior parts of the vocal cords closer together (adduction).
oblique arytenoid muscle	tilts the epiglottis backward to partially close the laryngeal inlet, aiding in airway protection.
aryepiglottic muscle	works with the oblique arytenoid muscle to bend the epiglottis backward, closing the laryngeal inlet.

The **posterior cricoarytenoid muscle** is the only muscle responsible for widening the rima glottidis, allowing air passage (Figure 8.7).

All laryngeal muscles, except one, are innervated by branches of the **recurrent laryngeal nerve**. Only the **cricothyroid muscle** is innervated by the **external branch of the superior laryngeal nerve**.

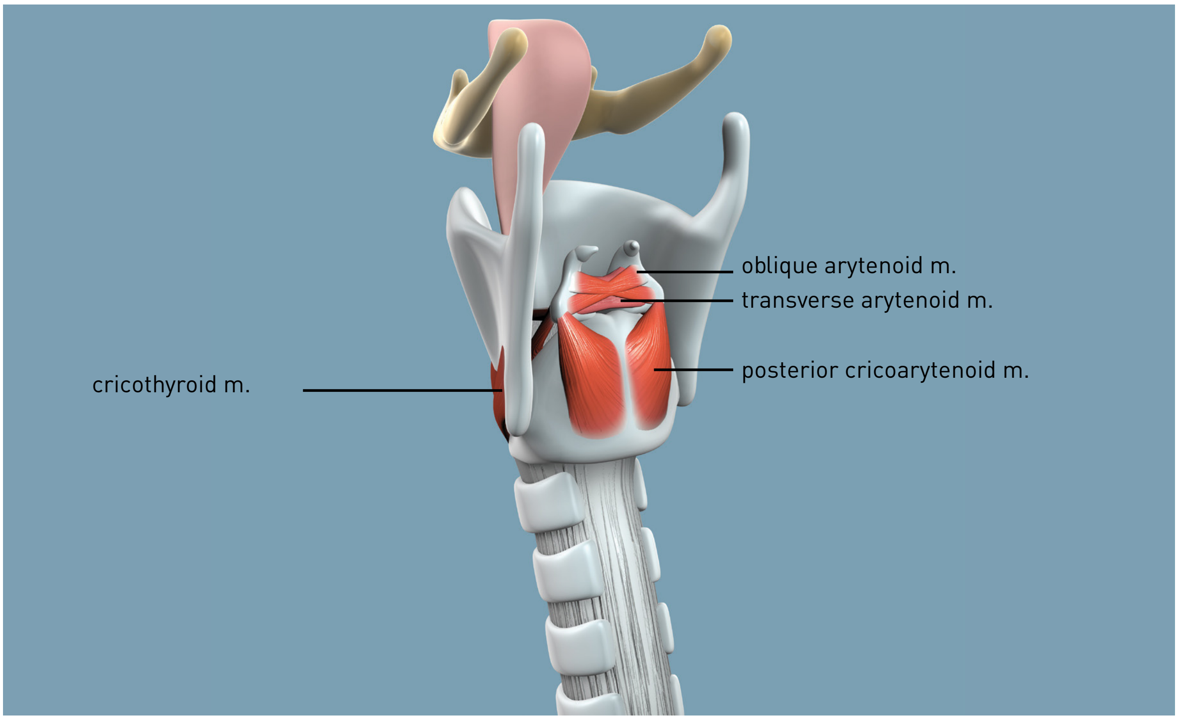


Figure 8.7. Posterior-lateral view of selected laryngeal muscles.

What are the divisions of the laryngeal cavity?

The laryngeal cavity is divided into three sections:

vestibule: the space between the laryngeal inlet and the vestibular folds.

ventricle: the space between the vestibular folds and the vocal folds.

infraglottic cavity: the space below the vocal folds extending to the trachea.

The narrowest part of the laryngeal cavity is the **rima glottidis**, located between the two vocal folds. Above the vocal folds, the **vestibular folds** are situated. The vocal folds control the passage of air through the rima glottidis and play a critical role in sound production.

What is the laryngeal inlet?

The **laryngeal inlet** is an oval-shaped opening that serves as the entrance to the larynx. It is wider at the anterior side and narrows toward the posterior. Its boundaries are:

anteriorly: the upper edge of the epiglottis

laterally: the aryepiglottic folds

posteriorly: the interarytenoid fold

What is the rima glottidis?

The **rima glottidis** is the opening between the vocal folds. The shape and size of the rima glottidis change with the movements of the arytenoid cartilages. During respiration, the rima glottidis is wide, while during speech, it becomes narrower. Air passes through this opening to flow downward to the lungs or upward to the nasal/oral cavity. For sound production, the vocal folds must be nearly parallel with a very small gap between them. As air flows outward from the lungs, it causes the vocal folds to vibrate, producing sound.

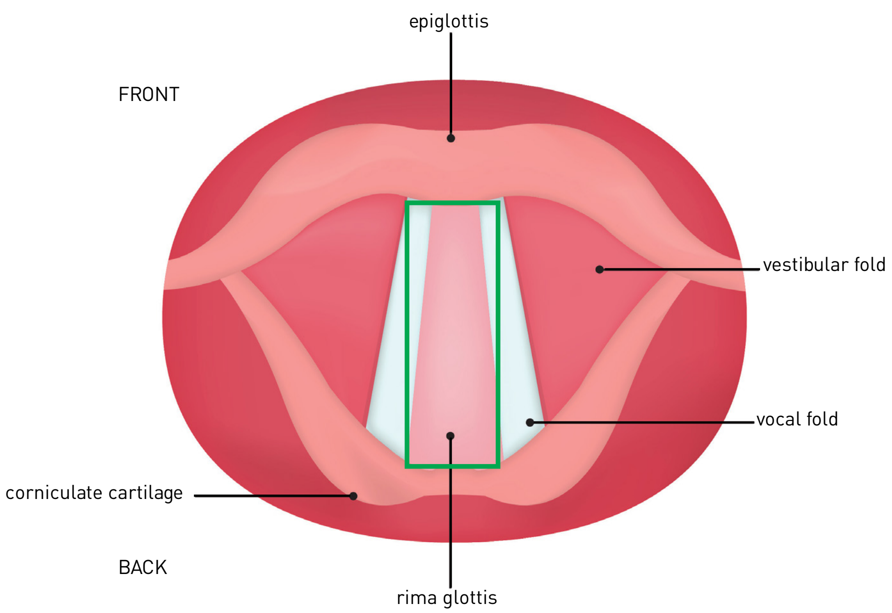


Figure 8.8. Superior view of the laryngeal cavity showing the rima glottidis (indicated in green). The right and left vestibular folds are positioned more superiorly and farther apart, while the vocal folds are situated lower and closer together (shown in white).

What is the vocal fold?

The **vocal fold** is a mucosal fold formed by the laryngeal mucous membrane as it encloses the vocal ligament (Figure 8.8).

What is the vestibular fold?

The **vestibular fold** or false vocal fold, is a mucosal fold formed by the laryngeal mucous membrane as it encloses the vestibular ligament (Figure 8.8).

TRACHEA (Windpipe)

The trachea is a tube-shaped structure that begins at the lower end of the larynx at the level of the C6 vertebra and continues down into the thoracic cavity, where it branches into (bifurcation of trachea) right and left main bronchi at the level of the T4 vertebra. Its primary function is to conduct air (Figure 8.9).

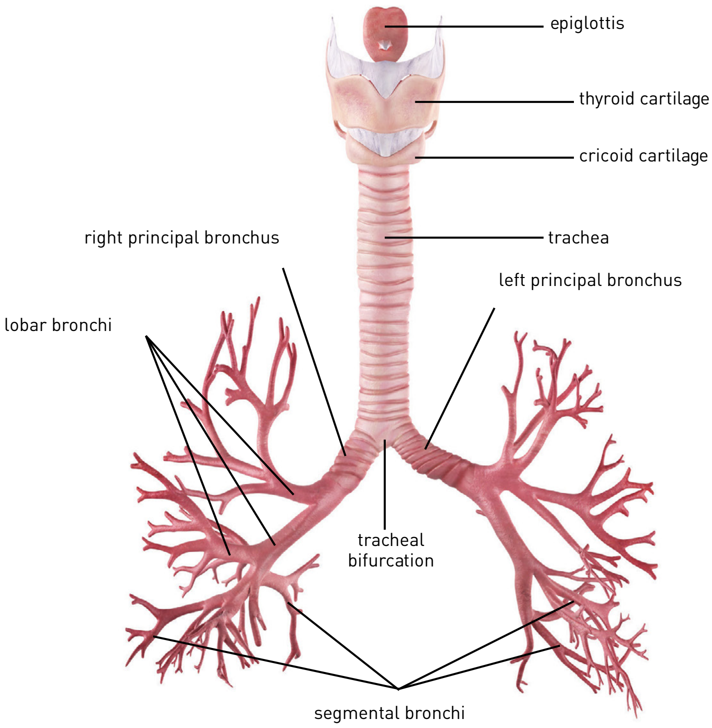


Figure 8.9. Trachea and bronchial system.

What are the dimensions of the trachea?

The trachea is approximately 10–12 cm in length. Its external diameter is about 2 cm in adult males and 1.5 cm in adult females.

What structures form the framework of the trachea?

The framework of the trachea is composed of 16–20 C-shaped cartilaginous rings or structures resembling a horseshoe. These cartilage rings are connected to each other by ligaments and are stacked to form a column. The open ends of the cartilages face posteriorly and are covered by smooth muscle and fibroelastic tissue. This cartilaginous structure ensures that the trachea remains open, providing a constant airway passage.

What are the neighboring structures of the trachea?

posteriorly: the esophagus.

anteriorly: the infrahyoid muscles, isthmus of the thyroid gland, blood vessels related to the thyroid gland, and remnants of the thymus gland.

laterally: the lateral lobes of the thyroid gland, common carotid artery, inferior thyroid artery, and recurrent laryngeal nerve.

In the thoracic cavity, the trachea is adjacent to the lungs on both sides. It is also associated with the azygos vein, hemiazygos vein, superior vena cava, brachiocephalic trunk, arch of the aorta, subclavian artery, and vagus nerve.

CLINICAL RELEVANCE

Laryngoscope is a medical instrument used to examine the larynx and vocal cords. It is commonly used during intubation to secure the airway or to diagnose laryngeal disorders.

Laryngitis is the inflammation of the larynx, often caused by viral infections, excessive use of the voice, or irritants like smoke. It leads to symptoms such as hoarseness, loss of voice, sore throat, and coughing. Most cases of laryngitis are viral and resolve on their own with rest and hydration. In more persistent cases, treatment may involve medication to reduce inflammation or address underlying causes. Avoiding irritants and vocal strain can help prevent the condition.

A **tracheotomy** is a surgical procedure in which an incision is made in the neck to create an opening directly into the trachea (windpipe). A tube is usually inserted to allow air to flow into the lungs, bypassing any obstruction or narrowing in the upper airway. This procedure is typically done in emergency situations or when long-term airway support is needed. After performing a tracheotomy procedure, the resulting opening in the trachea is called the **tracheostomy**.

What is the bifurcation of the trachea?

The **bifurcation of the trachea** refers to the point where the trachea divides into the right and left main bronchi at the level of the lower border of the 4th thoracic vertebra (T4). From this point, the airway continues as the right and left main bronchi (Figure 8.9).

What are the blood supply and innervation of the trachea?

The trachea receives its blood supply from the inferior thyroid artery in the neck region and the bronchial arteries in the thoracic cavity. Its sympathetic innervation is provided by the sympathetic trunk, while parasympathetic innervation is carried by the vagus nerve.

What are the primary bronchi, and where do they originate?

The primary bronchi originate from the bifurcation of the trachea at the level of the 4th thoracic vertebra and lead to the hilum of the lungs.

What are the differences between the right and left primary bronchi?

The right primary bronchus is <u>short</u> (about 2.5 cm), <u>wide</u>, and <u>more vertical</u>, while the left primary bronchus is <u>long</u> (about 5 cm), thin and <u>more horizontal</u>.

How are the primary bronchi divided?

The right primary bronchus divides into two branches: one for the upper lobe and one for the middle and lower lobes of the right lung. The left primary bronchus divides into two branches: one for the upper lobe and one for the lower lobe of the left lung.

What is the structure of the bronchial tree, starting from the primary bronchi?

The bronchial tree begins with the primary bronchi and branches sequentially into lobar bronchi, segmental bronchi, lobular bronchioles, terminal bronchioles, respiratory bronchioles, alveolar ducts, alveolar sacs, and finally, alveoli.

What is the function of the bronchial tree?

The bronchial tree ensures the efficient distribution of air within the lungs, ending in alveoli where gas exchange occurs.

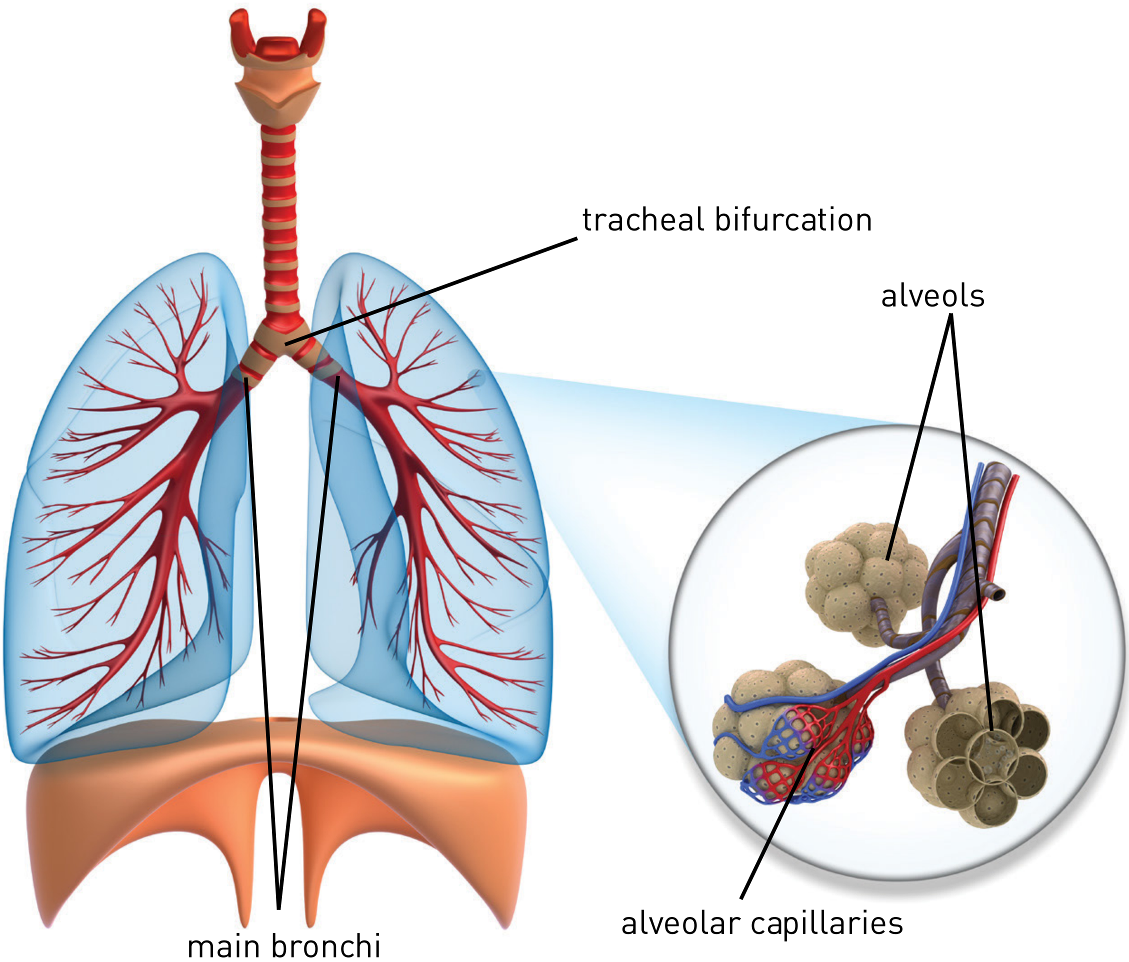


Figure 8.10. Bronchial system and alveolar structure.

CLINICAL RELEVANCE

A **bronchoscopy** is a medical procedure that allows doctors to look inside the lungs and airways using a thin, flexible tube called a **bronchoscope**. The scope is usually inserted through the nose or mouth and down into the lungs. It helps diagnose lung problems, take tissue samples (biopsies), or remove blockages like mucus or foreign objects.

LUNGS

The lungs are soft, spongy, and elastic respiratory organs located in the thoracic cavity (Figure 8.11).

Figure 8.11. Position of the lungs.

What is the shape of the lungs?

The lungs have a triangular pyramid shape, with an apex, a base, three surfaces, and three borders (Figure 8.12).

The surfaces of the lungs are named according to the structures they are adjacent to:

costal surface: faces the ribs

mediastinal surface: faces the mediastinum and the opposite lung

diaphragmatic surface: faces the diaphragm and forms the base of the lung.

The borders (edges) of the lungs include:

anterior border: thin

posterior border: smooth

inferior border: thin

On the left side, the anterior border has a typical notch which is in front of the heart, so it is called as the **cardiac notch**.

How many lobes do the lungs have?

The right lung consists of three lobes: **upper, middle,** and **lower**, while the left lung has two lobes: **upper** and **lower** (Figure 8.12).

What is a fissure?

A **fissure** is a groove that separates the lobes of the lungs (Figure 8.12).Fissures are named **oblique** and **horizontal** fissures. The **oblique fissure** is present in both lungs, while the **horizontal fissure** is found only in the **right lung**, separating the **upper and middle lobes**..

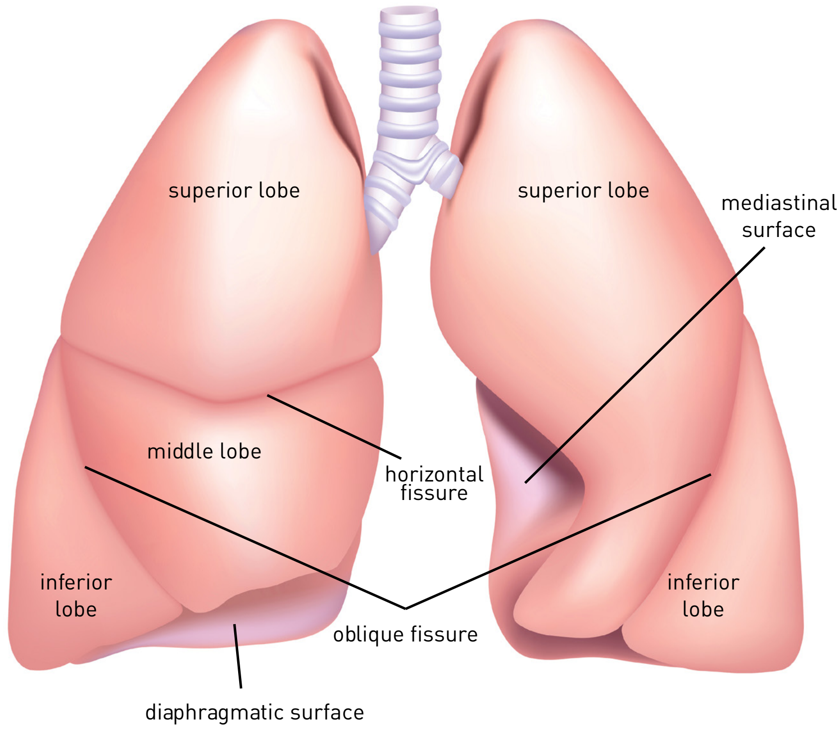


Figure 8.12. Surfaces, borders, and divisions of the lungs.

What is the pulmonary root?

The pulmonary root is a collection of structures enclosed by a reflection of the pleura, located on the mediastinal surface of the lung. This enclosed structure contains blood vessels, bronchi, nerves, lymphatic vessels, and lymph nodes that enter and exit the lungs.

What is the hilum of the lung?

The **hilum of the lung** is the area on the mediastinal surface where the pulmonary root structures enter and exit the lung.

What are the blood vessels of the lungs?

The lungs receive blood supply from two types of circulation:

- **bronchial circulation** (supplies lung tissue itself):
  - **bronchial arteries:** supply oxygenated blood to the lung tissues.
  - **bronchial veins:** drain deoxygenated blood from the lung tissues back to the heart.
- **pulmonary circulation** (for gas exchange):
  - **pulmonary arteries:** carry deoxygenated blood from the heart to the lungs for oxygenation.
  - **pulmonary veins:** return oxygenated blood from the lungs to the heart (left atrium). There are **four pulmonary veins**, two from each lung.

What are the nerves of the lungs?

The lungs are innervated by the **pulmonary plexus**, which is formed by branches coming from the **vagus nerve** and the **sympathetic trunk**.

What is the pleura?

The pleura is a thin membrane that envelops the lungs (Figure 8.13).

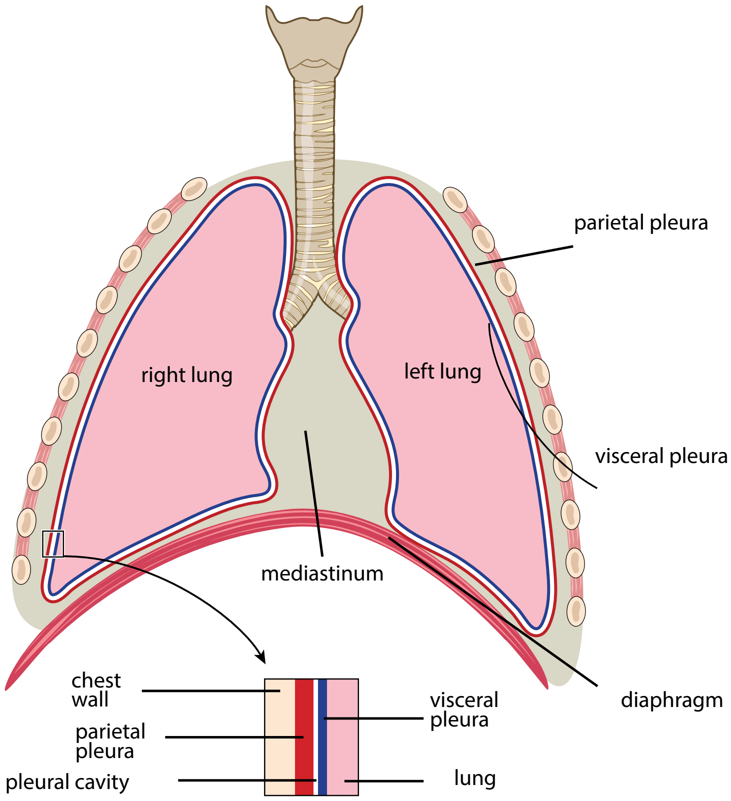


Figure 8.13. Pleura and its parts.

What are the parietal pleura and visceral pleura?

The **parietal pleura** is the portion of the pleura that lines the inner surface of the thoracic cavity and covers the superior surface of the diaphragm. The portion of the pleura that covers the lungs is called **visceral pleura**. Parietal and visceral pleura are histologically identical and they are continuous with each other at the hilum.

The parietal pleura extends over the lungs and continues as the **visceral pleura**, which closely adheres to the lung surface. The **visceral pleura** also dives into the fissures and lines each lobe separately (Figure 8.13).

What is the pleural cavity?

The **pleural cavity** is a potential space located between the **parietal pleura** and **visceral pleura**, containing a small amount of **pleural fluid** (approximately 50cc). This fluid provides lubrication, reducing friction between the lung surfaces and allowing smooth movement of the lungs during respiration (Figure 8.13).

What are pleural recesses?

Pleural recesses are potential spaces created by the parietal pleura as it reflects between different surfaces of the thoracic cavity. These recesses allow for lung expansion during inhalation (Figure 8.13).

Pleural recesses include:

costodiaphragmatic recess: formed where the parietal pleura lining the ribs transitions to the pleura covering the diaphragm.

costomediastinal recess: formed where the pleura lining the ribs transitions to the pleura covering the mediastinum.

cupula (pleural dome): the superior extension of the pleural cavity covering the apex of the lung.

CLINICAL RELEVANCE

Dyspnea is the medical term for **shortness of breath** or **difficulty breathing**. It can feel like you're not getting enough air and may be caused by conditions like asthma, heart failure, lung disease, or anxiety. It can be sudden (acute) or long-term (chronic), and severity can vary from mild to life-threatening.

Pleural effusion is the accumulation of excess fluid in the pleural cavity. This can cause difficulty breathing, chest pain, and coughing. It may result from various conditions, including heart failure, infections, cancer, or liver disease. Treatment typically involves addressing the underlying cause and may include draining the fluid with a procedure called **thoracentesis**, or in some cases, surgery.

Hemothorax is the accumulation of blood in the pleural cavity. It typically occurs due to trauma, such as a rib fracture or injury to the blood vessels, but can also result from conditions like tumors or blood clotting disorders. Symptoms may include chest pain, difficulty breathing, and rapid heart rate. Treatment often involves draining the blood from the pleural space through a chest tube or surgery, depending on the severity.

Pneumothorax is the condition where air enters the pleural cavity, causing the lung to collapse partially or completely. This can happen spontaneously, due to trauma, or as a result of certain medical conditions. Symptoms often include sudden chest pain and difficulty breathing. Treatment may involve removing the trapped air with a needle or chest tube.

Thoracentesis is a medical procedure used to remove fluid or air from the pleural cavity. It is typically performed to diagnose or treat conditions such as pleural effusion, infection, or pneumothorax. During the procedure, a needle or catheter is inserted through the chest wall to drain the fluid or air. Thoracentesis can help relieve symptoms like shortness of breath and chest pain, and the fluid removed is often tested to determine the underlying cause.

THORACIC CAGE (Thorax)

What is thoracic cage?

The thoracic cage is a bony structure that encloses and protects vital organs such as the heart and lungs. It is composed of the vertebral column posteriorly, the ribs laterally, and the sternum anteriorly.

The thoracic cage has two openings:

superior thoracic aperture (thoracic outlet): connects the thorax to the neck region.

inferior thoracic aperture: located at the lower boundary of the thoracic cavity, but unlike the superior aperture, it is closed off by the diaphragm (Figure 8.14a, b).

CLINICAL RELEVANCE

Thoracic outlet syndrome is the compression of the brachial plexus, subclavian artery, or vein in the thoracic outlet, between the clavicle and the first rib. This compression can lead to arm pain, numbness, and weakness in the neck, shoulder, arm, or hand. It is often caused by anatomical abnormalities, injury, or repetitive movements. Treatment may involve physical therapy, pain management, or, in severe cases, surgery to relieve the pressure on the affected nerves or blood vessels.

Which bones form the skeleton of the thoracic cage?

The thoracic cage consists of the following bony structures:

- **thoracic vertebrae** (posteriorly)(explained in the "Spine Anatomy" section)
- **ribs** (both bony and cartilaginous parts, laterally)
- **sternum** (anteriorly)

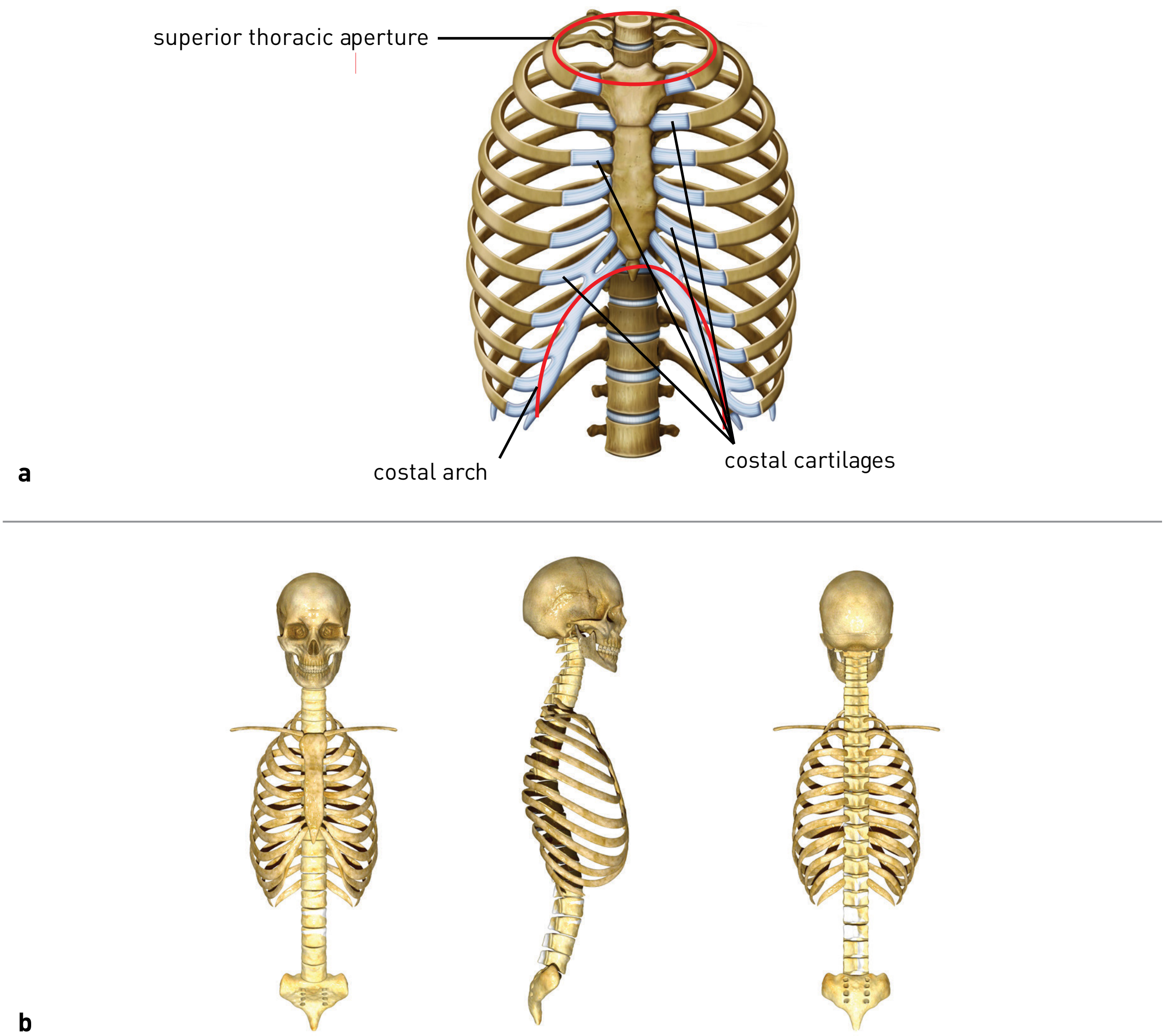


Figure 8.14. Thoracic cage**. a.** cartilaginous ribs are shown in blue. **b.** anterior, lateral, and posterior views of the thoracic cage and rib arrangement.

What are ribs?

The **ribs** form the largest portion of the thoracic wall. There are a total of **12 pairs** of ribs, distributed equally on the right and left sides. They are curved, flat bones, shaped like the letter C. The size of the ribs gradually increases from the 1st rib to the 7th rib (Figure 8.15a, b).

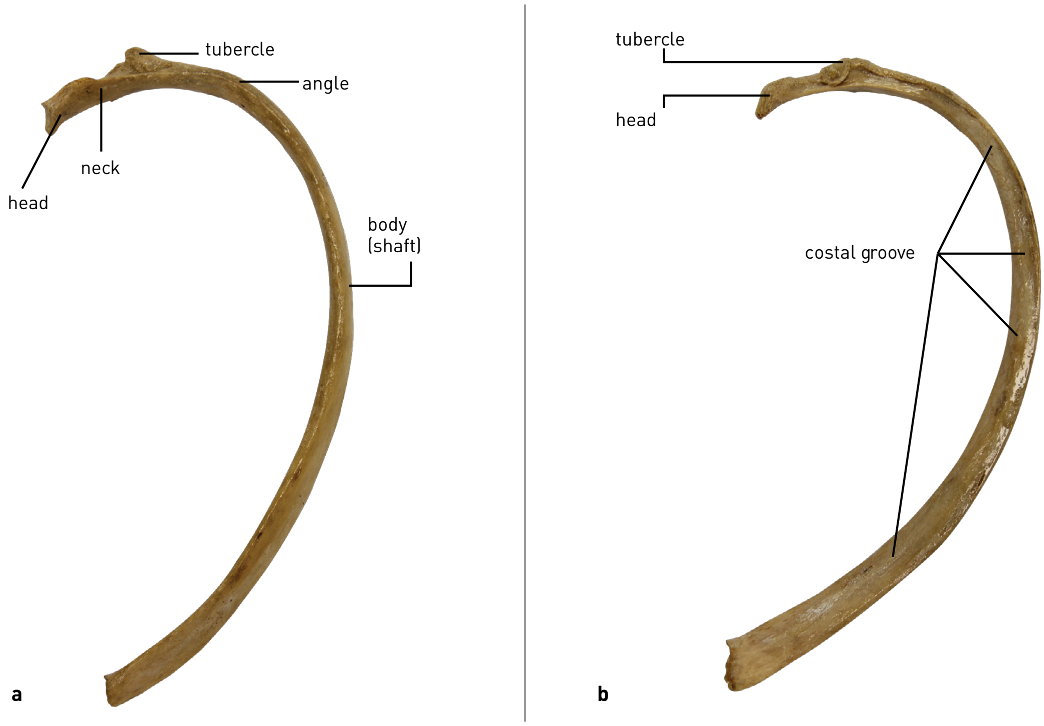


Figure 8.15. Typical rib. **a.** superior view. **b.** inferior view.

What is costal cartilage?

The **costal cartilage** refers to the cartilaginous portion at the anterior ends of the ribs. These cartilages connect the ribs to the sternum, forming the costosternal joints (Figure 8.14a).

Which bones do the ribs articulate with?

posteriorly: all 12 pairs of ribs articulate with the thoracic vertebrae in the thoracic region of the vertebral column.

anteriorly: the **first 7 pairs** of ribs (**true ribs**) connect directly to the **sternum** via **costal cartilage**.

ribs 8-10 (**false ribs**) do not attach directly to the sternum; instead, they connect to the cartilage of the rib above.

ribs 11 and 12 (**floating ribs**) have **free anterior ends** and do not articulate with the sternum or any other structure (Figure 8.14a).

What is the costal arch?

The **costal arch** is formed by the **fusion of the costal cartilages of ribs 8-10**, which do not directly attach to the sternum. Instead, these ribs connect to the cartilage of the rib above, creating the lower margin of the rib cage.

On both sides, the costal arches extend toward the midline and meet at the inferior end of the sternum, forming a curved structure on the anterior lower part of the thoracic cage (Figure 8.14a)

What is the costal groove?

The **costal groove** is a linear depression located on the inner inferior surface of the rib's body. This groove houses the intercostal vein, artery, and nerve in a superior-to-inferior order (Figure 8.15b).

What is a typical rib?

Ribs **3 to 9** are classified as **typical ribs**. These ribs have a consistent structure and share common anatomical features. Each typical rib consists of the following parts:

head: the wedge shaped, posterior end featuring two articular facets divided by a crest that connects to the body of a thoracic vertebrae. The upper facet articulates with the vertebra above, while the lower facet articulates with the vertebra below.

neck: a short, narrow region between the head and the tubercle.

tubercle: a small projection at the junction of the neck and body that articulates with the transverse process of the corresponding vertebra.

angle: the curved portion where the rib changes direction, marking the most prominent bend in its structure.

body: the main elongated portion of the rib extending anteriorly toward the sternum (Figure 8.15a, b).

What is an atypical rib?

Some ribs are defined as atypical due to certain features that are not present in others. These **atypical ribs** include:

Figure 8.16. The first rib, classified as an atypical rib, differs from others by being positioned completely horizontally. Instead of internal and external surfaces, it has superior and inferior surfaces. The head (caput), which articulates with the first thoracic vertebra, is a single, rounded structure.

the first two ribs (1st and 2nd): first rib has a single articular surface on its head, two grooves formed by the subclavian vessels passing over it, and small bony projections formed by scalene muscles attaching to it. The second rib also has bony projection due to the attachment of the posterior scalene muscle. These grooves and projections make these two ribs atypical.

the last three ribs (10th, 11th, and 12th ribs): they have a single facet on their head, and have no neck and tubercle.

These ribs have unique anatomical characteristics that distinguish them from typical ribs (Figure 8.16).

What is the intercostal space?

The **intercostal space** refers to the gap between adjacent ribs. Each side of the thorax consists of **12 ribs** and **11 intercostal spaces**. These spaces are filled with **intercostal muscles**, which connect the ribs, maintain structural integrity, and contribute to respiratory movements.

What is the sternum?

The **sternum** is a vertically oriented bone located in the midline of the anterior thoracic cage. It serves as a central attachment point for the ribs and provides structural support to the thoracic cavity (Figure 8.17). It is formed by the union of three parts.

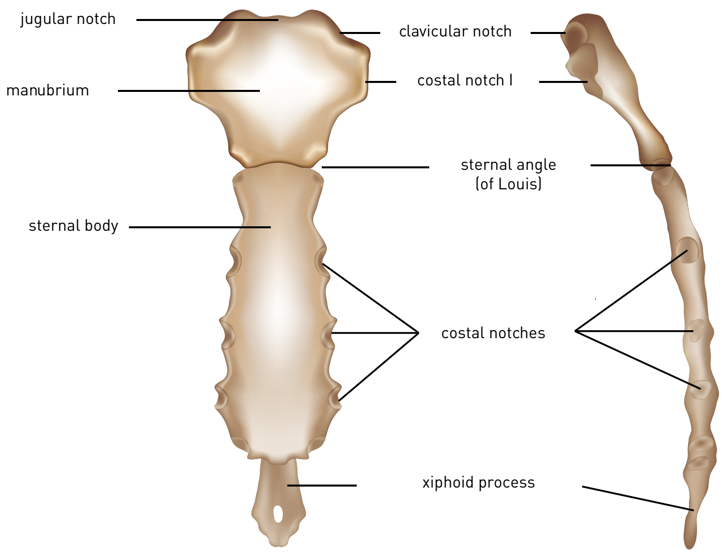


Figure 8.17. Sternum. The areas where the clavicle and ribs articulate are shown. **a.** anterior view **b.** lateral view.

What are the parts of the sternum?

The **sternum** consists of three main parts:

- **manubrium**: the upper portion.
- **body**: the central and largest part.
- **xiphoid process**: the small, inferior extension of the sternum.

Which bones does the sternum articulate with?

The **sternum** articulates with the **clavicle** and the **first seven costal cartilages** on both sides.

What are the other important structures on the sternum?

- **jugular notch:** a visible and palpable depression at the superior border of the manubrium, located at the midline of the body. On its both sides, there are the sternoclavicular joints, which are the only joints connecting the upper extremity to the trunk.
- **sternal angle (angle of Louis):** the articulation between the manubrium and the body of the sternum, forming a distinct angle. This landmark is palpable and important as it corresponds to the level where the **second rib** articulates with the sternum, serving as a reference point in clinical examinations.

MUSCLES OF THE THORACIC REGION

What are the muscles of thoracic wall?

The muscles of the thoracic wall are located in the **intercostal spaces, anterior chest (pectoral region), and lateral thoracic wall**. These muscles play essential roles in respiration and movement of the upper limb.

What are the intercostal muscles?

The **intercostal muscles** are thin muscles filling the space between the ribs. They are arranged from superficial to deep. They are considered accessory respiratory muscles, assisting in breathing.

external intercostal muscles: the most superficial layer, aiding in inspiration.

internal intercostal muscles: located beneath the external intercostal, assisting in forced expiration.

innermost intercostal muscles: the deepest layer, contributing to respiration by stabilizing the rib cage.

Additionally, two other muscles are present in the thoracic wall:

transversus thoracis (sternocostalis m.): extends from the lower sternum to the ribs, contributing to forced expiration.

subcostal muscle: connects vertebrae to the lower ribs and assists in rib depression.

These muscles play a role in respiration by controlling the movement of the ribs (Figure 8.18).

Figure 8.18. External intercostal muscle.

What is the function of intercostal muscles?

The **intercostal muscles** function as **accessory respiratory muscles**, assisting in the movement of the rib cage during breathing. However, the primary muscle responsible for respiration is the diaphragm.

These muscles play a supportive role in respiration, adjusting the volume of the thoracic cavity during inspiration and expiration.

Where is the pectoral region?

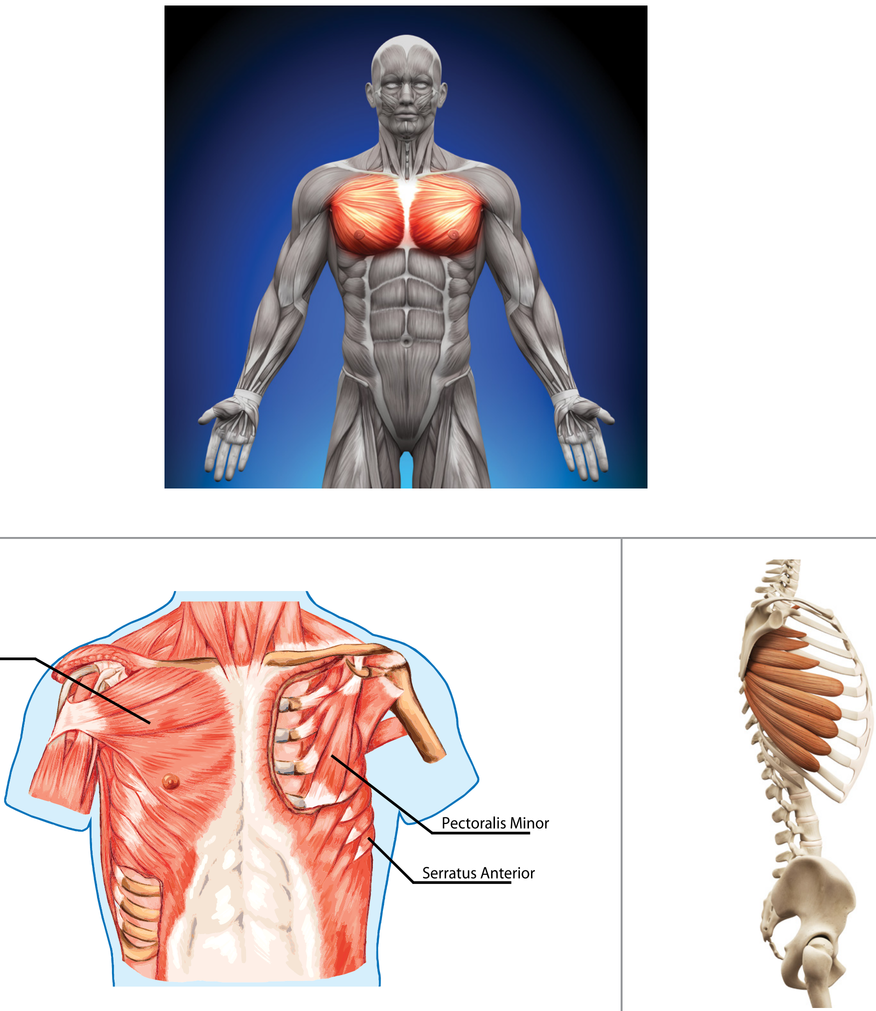
The **pectoral region** refers to the upper and anterior part of the chest wall. It is bounded superiorly by the clavicle. Sternum is located at the midline here. This region contains the pectoralis muscles and plays a key role in the movement of the upper limb, as well as in respiratory functions.

What structures are found in the pectoral region?

The **pectoral region** contains the **pectoralis major** and **pectoralis minor muscles** (Figure 8.19a, b). These muscles contribute to the contour of the chest. The pectoralis major plays a role in adduction of the arm.

On the lateral and inferior part of the pectoral region, there is a serrated-shaped muscle called the **serratus anterior** (Figure 8.19c). This muscle attaches to the medial border of the scapula and, when contracted, rotates the glenoid cavity upward, facilitating arm abduction beyond 90 degrees.

Superficially, the most notable structure in this region is the **breast (mammary gland)**.



a

b

c

Figure 8.19. Pectoral region muscles**. a.** location of pectoralis major muscle. **b.** on the right side of the chest, pectoralis major muscle is shown, while on the left side, pectoralis minor and serratus anterior muscles are displayed. **c.** serratus anterior muscle.

Muscles of the thoracic region, their innervation, and functions

Muscle	Innervation	Function
external intercostal muscle		elevates the ribs (inspiration)
internal intercostal muscle		depresses the ribs (expiration)
innermost intercostal muscle	intercostal nerve	assists in expiration
subcostal muscle		assists in expiration
transversus thoracis muscle		assists in expiration
pectoralis major muscle	medial and lateral pectoral nerves	adduction and internal rotation of the arm
pectoralis minor muscle	medial pectoral nerve	rotates and moves the scapula forward
serratus anterior muscle	long thoracic nerve	enables arm abduction beyond 90° by rotating the scapula

What are the arteries supplying thoracic wall?

The thoracic wall is primarily supplied by the **anterior** and **posterior intercostal arteries**. When they enter the intercostal space, they each give off a collateral branch that runs parallel to them.

The posterior intercostal artery and its collateral branch travel from back to front within the intercostal space.

The anterior intercostal artery and its collateral branch travel from front to back in the same space, eventually anastomosing with the posterior intercostal artery.

How are the origins of the intercostal arteries?

Anterior and posterior intercostal arteries originate from different sources.

posterior intercostal arteries:

the **1st** and **2nd posterior intercostal arteries** originate from the superior intercostal artery, a branch of the costocervical trunk.

the **3rd to 11th posterior intercostal arteries** are branches of the thoracic aorta. The artery located below the 12th rib is not an intercostal artery, but it follows a similar path and is known as the subcostal artery.

anterior intercostal arteries:

the **1st to 6th anterior intercostal arteries** arise from the internal thoracic artery.

the **7th to 9th anterior intercostal arteries** arise from the musculophrenic artery.

the 10th and 11th intercostal spaces do not contain anterior intercostal arteries; they are supplied only by the posterior intercostal arteries.

How is the pathway of the intercostal arteries?

Intercostal arteries travel along the inferior border of each rib in the costal groove. They are accompanied by an intercostal vein and intercostal nerve, forming the neurovascular bundle.

What are the collateral branches of the intercostal arteries?

Collateral branches are the branches of the intercostal arteries which run in the same intercostal space but at a lower position, near the upper border of the rib below.

What are the veins draining the thoracic wall?

The veins of the thoracic wall run parallel to the arteries and are arranged in anterior and posterior groups, forming an interconnected venous network through anastomoses.

The **posterior intercostal veins** drain into the **azygos venous system**, which ultimately empties into the superior vena cava (SVC).

The **anterior intercostal veins** drain into the **internal thoracic vein**. The internal thoracic vein then empties into the brachiocephalic vein, which subsequently drains into the superior vena cava.

What is the azygos venous system?

The **azygos venous system** is a major venous network responsible for draining the posterior thoracic wall and part of the abdominal wall.

How is the formation and course of the azygos vein?

The **azygos vein** originates at the L1 vertebral level in the posterior abdominal wall. It enters the thoracic cavity by passing through the aortic hiatus of the diaphragm. As it ascends in the posterior mediastinum, it runs along the right side of the vertebral column. At the level of the 4th thoracic vertebra (T4), it arches anteriorly over the right main bronchus before draining into the superior vena cava.

How is the venous drainage of the thoracic wall?

Posteriorly right and left side venous drainage system is different for the thoracic wall.

right side: The 1^{st} posterior intercostal vein drains directly into the **brachiocephalic vein**.

The 2^{nd}–4^{th} posterior intercostal veins unite to form the **superior intercostal vein**, which drains into the azygos vein.

The 5^{th}–11^{th} posterior intercostal veins drain directly into the **azygos vein**.

left side: The 1^{st} posterior intercostal vein drains directly into the **brachiocephalic vein**.

The 2^{nd}–4^{th} posterior intercostal veins form the **superior intercostal vein**, which drains into the left brachiocephalic vein.

The 5^{th}–8^{th} posterior intercostal veins unite to form the **accessory hemiazygos vein**.

The 9^{th}–11^{th} posterior intercostal veins merge to form the **hemiazygos vein**.

Both the hemiazygos and accessory hemiazygos veins cross over to the right side and drain into the azygos vein.

Anteriorly**,** venous drainage of the thoracic wall is the same on both sides.

The **first six anterior intercostal veins** drain into the **internal thoracic vein**, which runs vertically along the sternum on both sides. The 7^{th}–9^{th} anterior intercostal veins drain into the **superior epigastric vein**, which continues as the internal thoracic vein.

What are the nerves of the thoracic wall?

The thoracic wall is innervated by 11 pairs of intercostal nerves, which originate from the thoracic segments of the spinal cord. These nerves travel within the intercostal spaces, running between the intercostal muscles from posterior to anterior. As they course along the thoracic wall, the intercostal nerves provide:

motor branches to the intercostal muscles.

sensory branches:

lateral cutaneous branch: provides sensory innervation to the lateral aspect of the thoracic wall.

anterior cutaneous branch: provides sensory innervation to the anterior part of the thoracic wall.

This segmented innervation pattern corresponds to the thoracic spinal nerve levels, forming band-like regions of sensory distribution known as the dermatomes of the thoracic wall.

BREAST

What is the mammary gland (Breast)?

The breast is located on the anterior thoracic wall, embedded within the superficial fascia beneath the skin. It is primarily composed of adipose tissue, with **mammary glands** (lobes of the mammary gland) embedded within this fatty tissue (Figure 8.20a, b). It extends between the 2nd and 6th ribs.

During lactation, milk produced by these glands is transported to the nipple through **lactiferous ducts**. The size and shape of the breast vary among individuals and can change with age. In males, the breast remains as an underdeveloped tissue.

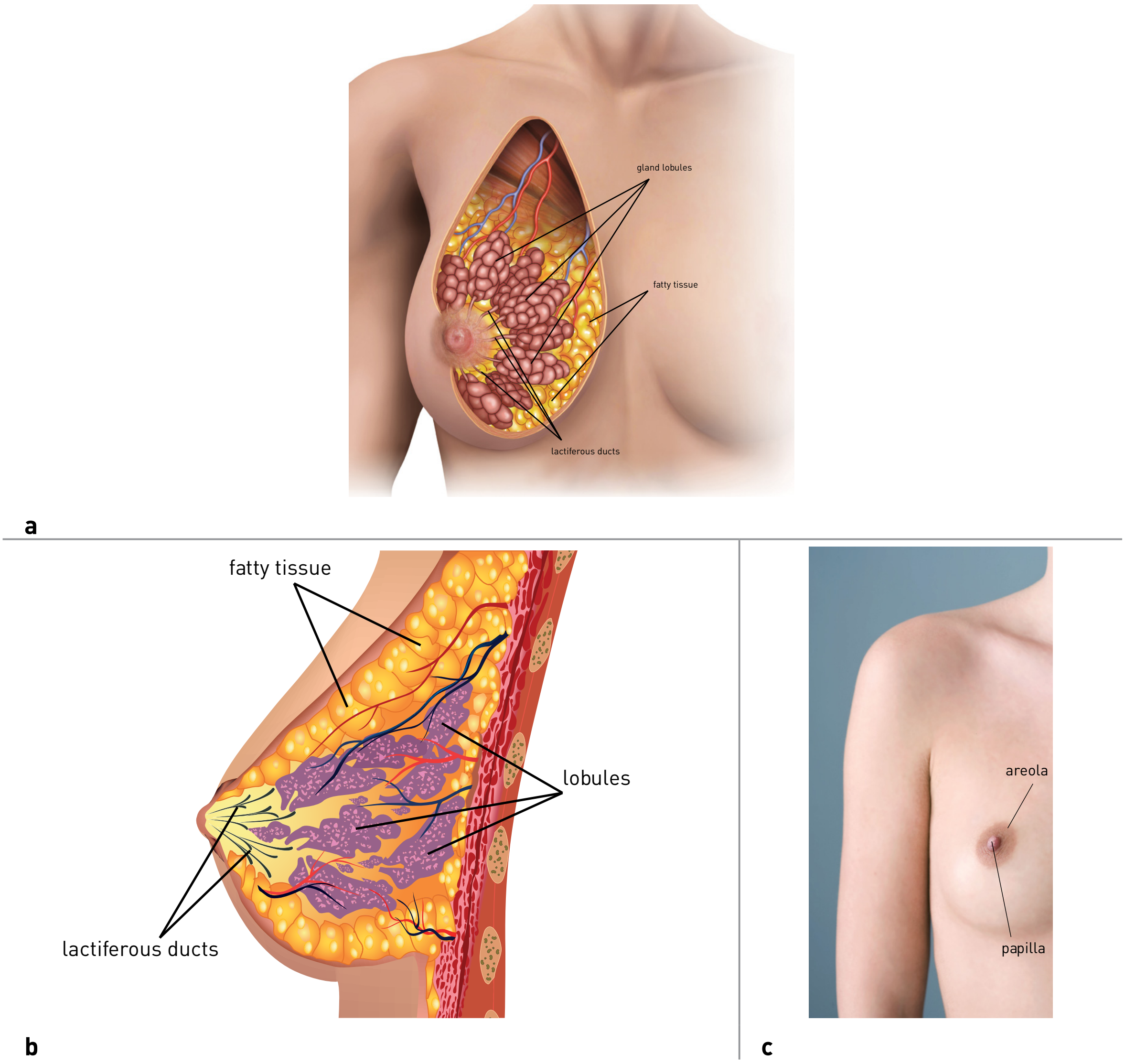


Figure 8.20. a. breast with glandular tissue and milk ducts. **b.** lateral view. **c.** areola and papilla.

What is the areola?

The **areola** is the circular pigmented area on the surface of the breast, which appears darker compared to the surrounding skin (Figure 8.20c). The surface of the areola has a slightly rough texture due to the presence of small glands located beneath the skin.

What is the papilla?

The **papilla (nipple)** is the raised structure located at the center of the areola (Figure 8.20c). It is typically positioned at the intersection of the midclavicular line and the fourth rib.

CLINICAL RELEVANCE

Mastitis is the inflammation of the breast tissue, often caused by bacterial infection, usually in lactating women. Symptoms include pain, redness, swelling, and fever. Treatment typically involves antibiotics to clear the infection, along with pain relief and continuing breastfeeding or pumping to help drain the affected breast. In severe cases, an abscess may form and may require drainage.

Breast Cancer is the malignant tumor originating from glandular tissue (glands or milk ducts) of the breast. Commonly spreads through lymphatic drainage, especially via the axillary lymph nodes. Clinical signs include painless lumps, nipple retraction, skin dimpling and abnormal discharge. It can occur in both women and men, though it is far more common in women, being the most common cancer type in women. The exact cause is not always known, but risk factors include genetics, hormonal changes, and lifestyle factors. Treatment options include surgery, chemotherapy, radiation, hormone therapy, and targeted therapies, depending on the stage and type of cancer.

Gynecomastia is the enlargement of breast tissue in males, often caused by an imbalance of the hormones estrogen and testosterone. It can occur during puberty, with aging, or due to certain medical conditions, medications, or lifestyle factors. Symptoms include swollen or tender breast tissue. In many cases, gynecomastia resolves on its own, but if persistent or causing discomfort, treatment options like medication or surgery may be considered. It is generally not a serious condition, though it can affect a person's self-esteem or body image.

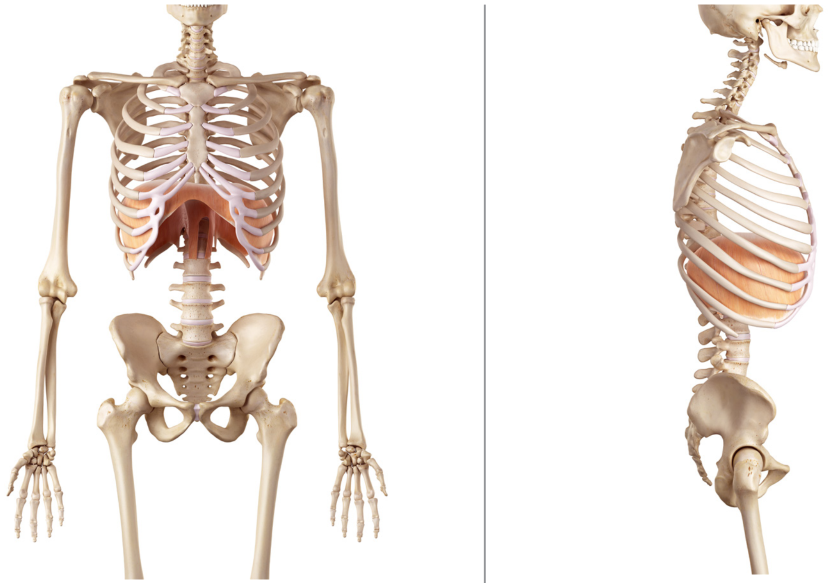
Mammography is an imaging technique used to detect breast cancer in women, typically through low-dose X-rays. It helps identify tumors or abnormalities in the breast tissue, often before they can be felt physically. It is an important tool for routine breast cancer screening, especially for women over 40 or those with a higher risk. The procedure is quick, non-invasive, and can help catch cancer early, improving the chances of successful treatment.

Mastectomy is a surgical procedure in which all or part of the breast tissue is removed, usually as a treatment for breast cancer. There are different types of mastectomy, including total mastectomy, which removes the entire breast, and more targeted approaches like a partial mastectomy or **lumpectomy** (removal of only the tumor and a margin of surrounding tissue, preserving most of the breast). It can also be performed as a preventive measure in women with a high genetic risk of breast cancer.

DIAPHRAGM

What is the diaphragm?

The **diaphragm** is a dome-shaped structure composed of muscle and fibrous tissue that separates the thoracic and abdominal cavities (Figure 8.21a,b). The right dome is positioned higher than the left. The base of the lungs rests on the domes of the diaphragm. Since it is primarily a muscle, the diaphragm has an origin and an insertion like other muscles.



a. b.

Figure 8.21. Diaphragm. **a.** anterior view. **b.** lateral view.

What are the origin and insertion points of the diaphragm?

The diaphragm has three distinct points of origin:

- **sternal part** – the smallest portion, originating from the **xiphoid process**
- **costal part** – arises from the **inner surfaces of the lower six ribs**
- **lumbar part** – originates from the **first three lumbar vertebrae (L1–L3)**

All muscle fibers from these three parts converge toward the center and insert into a common tendinous structure called the **central tendon**.

What are the openings in the diaphragm?

The diaphragm, which separates the thoracic and abdominal cavities, contains specific openings that allow structures to pass between these regions. These openings include:

- **foramen vena cavae:** located at the **T8** vertebral level, this is the highest opening, through which the inferior vena cava passes into the thoracic cavity to open into the right ventricle.
- **esophageal hiatus:** found at the **T10** vertebral level, this opening allows the esophagus and branches of the vagus nerve to pass into the abdominal cavity.
- **aortic hiatus:** situated at the **T12** vertebral level, this opening permits the aorta and sympathetic trunk to pass into the abdominal cavity, while the thoracic duct ascends into the thoracic cavity.

Which nerve innervates the diaphragm?

The diaphragm is innervated by the **phrenic nerve**.

What is the function of the diaphragm?

The diaphragm is the primary muscle responsible for respiration. During inhalation, the diaphragm contracts and moves downward, increasing the volume of the thoracic cavity, allowing the lungs to expand as they fill with air. During exhalation, the diaphragm relaxes and moves upward, reducing thoracic cavity volume, which helps expel air from the lungs (Figure 8.22).

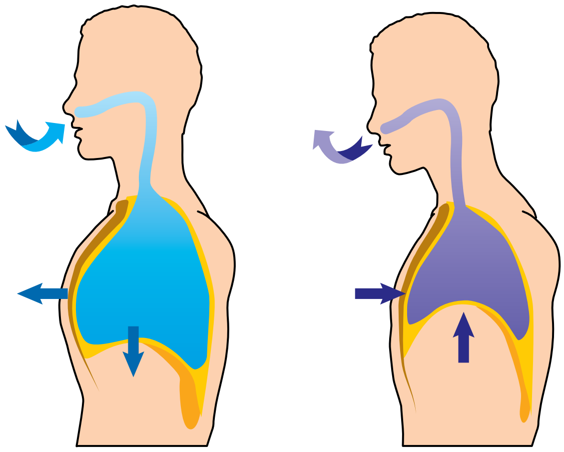


Figure 8.22. Diaphragmatic movements during respiration.

CLINICAL RELEVANCE

Diaphragmatic paralysis is a condition where damage to the phrenic nerve can lead to diaphragmatic dysfunction, affecting breathing. This can be caused by trauma, surgery, or neurological conditions. Symptoms may include difficulty breathing, shortness of breath, or fatigue, especially when lying down. Treatment depends on the underlying cause and may include breathing support or surgery in severe cases.

MEDIASTINUM

What is mediastinum?

The **mediastinum** is the space located between the right and left pleural sacs, which enclose the lungs. It is situated between the medial surfaces of the lungs (Figure 8.23).

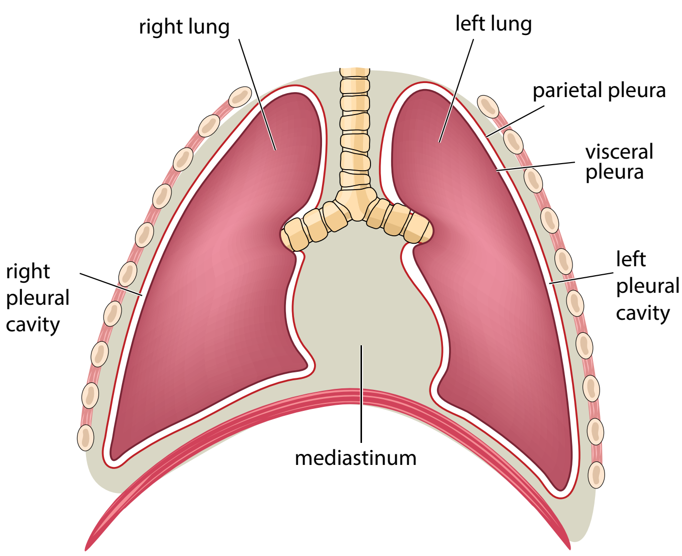


Figure 8.23. Mediastinum.

What are the boundaries of the mediastinum?

superiorly: thoracic inlet (superior thoracic aperture)

inferiorly: diaphragm

anteriorly: sternum

posteriorly: thoracic vertebrae

laterally: the mediastinal surfaces of the lungs

How is the mediastinum divided?

The mediastinum is divided into two parts as the

superior mediastinum and

inferior mediastinum

by a horizontal plane passing through the sternal angle anteriorly and the lower border of the fourth thoracic vertebra posteriorly:

The inferior mediastinum is further subdivided into three regions:

anterior mediastinum

middle mediastinum

posterior mediastinum

What are the structures located in the mediastinum?

Some of the structures located in the mediastinum are listed below.

superior mediastinum: includes the great vessels entering and exiting the heart, the trachea, and the esophagus.

middle mediastinum: contains the pericardium, heart, great vessels associated with the heart, and the phrenic nerve.

anterior mediastinum: primarily occupied by the thymus.

posterior mediastinum: houses the thoracic aorta, vagus nerve, azygos vein, hemiazygos vein, and thoracic duct.

Sample Questions for the Respiratory System Anatomy:

1. Which of the following is one of the two main bones that form the nasal septum?
   a) Maxilla
   b) Vomer
   c) Nasal bone
   d) Palatine bone
   e) Sphenoid bone

2. What is the name of the boundary between the nasal cavity and the nasopharynx at the posterior end?
   a) Nasal meatus
   b) Nasal concha
   c) Choana
   d) Sinus
   e) Ethmoidal air cells

3. Which of the following is not one of the sinuses surrounding the nasal cavity?
   a) Maxillary sinus
   b) Ethmoidal sinus
   c) Frontal sinus
   d) Sphenoidal sinus
   e) Sigmoid sinus

4. Which structure does the larynx attach to superiorly?
   a) Hyoid bone
   b) Sphenoid bone
   c) Mastoid process
   d) Mandible
   e) Trachea

5. Which of the following laryngeal cartilages completely encircles the laryngeal cavity?
   a) Epiglottis
   b) Thyroid cartilage
   c) Cricoid cartilage
   d) Arytenoid cartilage
   e) Corniculate cartilage

6. What is the name of the opening between vocal folds?
   a) Laryngeal ventricle
   b) Laryngeal vestibule
   c) Laryngeal prominence
   d) Rima glottidis
   e) Laryngeal inlet

7. What is the space between the parietal and visceral pleura called?
   a) Pulmonary plexus
   b) Pleural cavity
   c) Cupula
   d) Costodiaphragmatic recess
   e) Costomediastinal recess

8. Which of the following statements about the lungs is correct?
   a) The right lung has 2 lobes
   b) The left lung does not have a horizontal fissure
   c) The surface of the lungs adjacent to the diaphragm is called the mediastinal surface
   d) The costal surface is adjacent to the heart
   e) The lowest part of the lung is called the apex

9. What is the name of the space between the right and left pleural sacs, located between the medial surfaces of the lungs?
   a) Pulmonary root
   b) Pulmonary hilum
   c) Pleural cavity
   d) Mediastinum
   e) Cupula

10. Which of the following nerves innervates the diaphragm?
   a) Vagus
   b) Long thoracic
   c) Medial pectoral
   d) Lateral pectoral
   e) Phrenic

Answers: 1.B, 2. C, 3.E, 4.A, 5.C, 6.D, 7.B, 8.B, 9.D, 10.E

NERVOUS SYSTEM

NERVOUS SYSTEM

DEFINITIONS

The nervous system is the most complexly organized part of the body, responsible for regulating all body functions and the reactions of the body to its environment. It is divided into two parts:

Central nervous system (CNS)
Peripheral nervous system (PNS)

The central nervous system consists of the **brain** and **brainstem** located within the skull and the **spinal cord** located within the spine. The brainstem and spinal cord are continuous with each other just below the skull. On the other hand, the peripheral nervous system comprises **12 pairs of cranial nerves** and **31 pairs of spinal nerves** connected to the central nervous system, along with neuron clusters called **ganglia** located in various regions of the body (Figure 9.1).

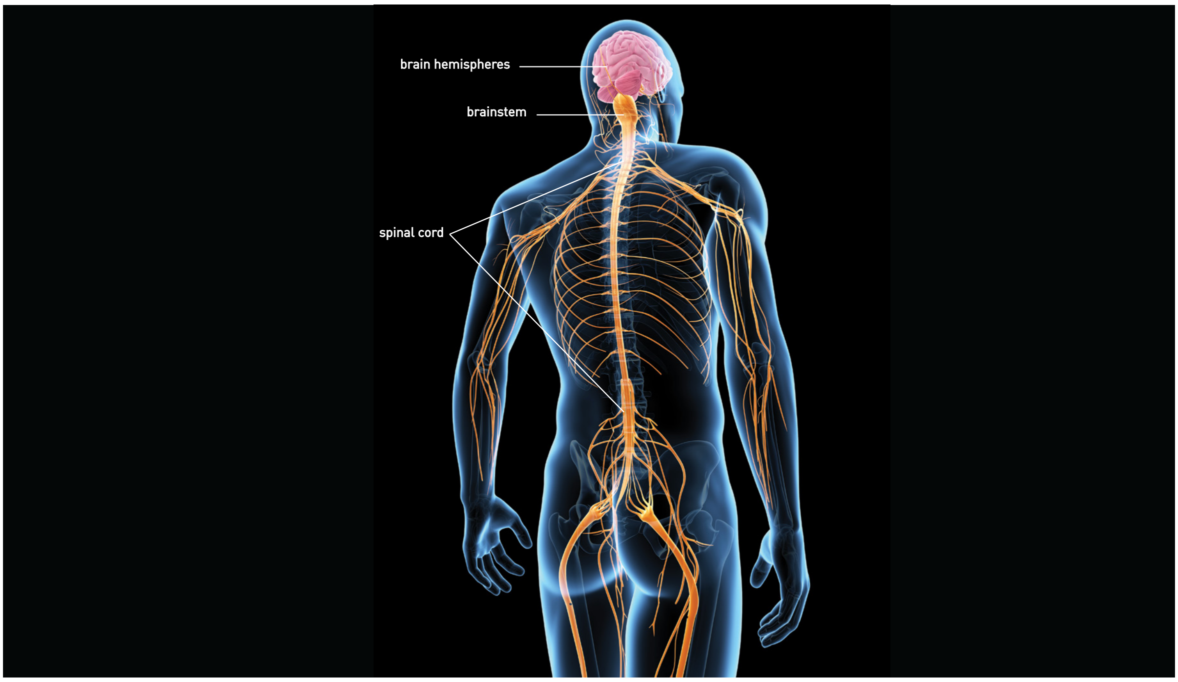


Figure 9.1. General view of the central and peripheral nervous system.

What are the main functions of the nervous system?

The main functions of the nervous system are:

Sensory function

Motor function

Somatic nervous system (motor supply to skeletal muscles)

Autonomic nervous system (nerve supply to smooth muscles and glands)

Regulatory function

What is a neuron?

A neuron is a nerve cell. It is a cell with a **body** and extensions called **axon** and **dendrite**, through which it transmits and receives signals, respectively (Figure 9.2).

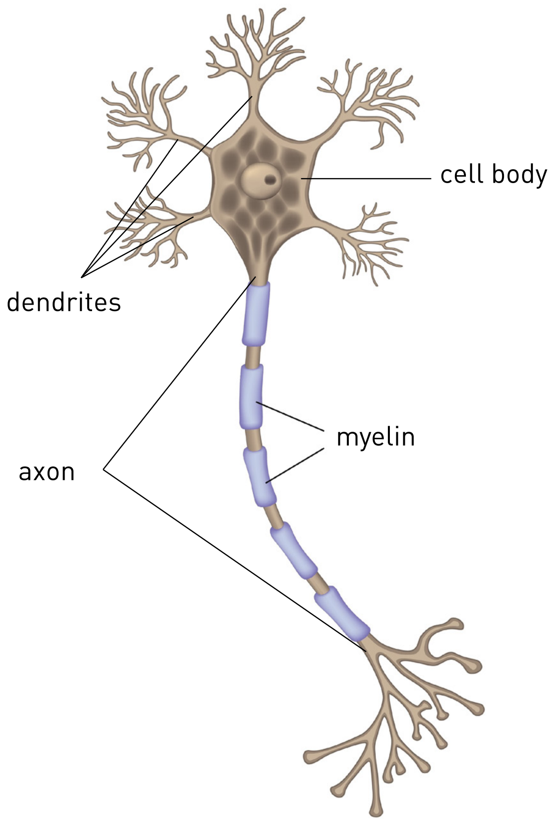


Figure 9.2. Neuron.

What is an interneuron?

Interneurons are nerve cells that provide connections between motor and sensory pathways.

What is a nucleus?

Group of neuron cell bodies gathered together for a specific function in the central nervous system, is called a **nucleus**. Plural of nucleus is the **nuclei**.

What is a ganglion?

Cluster of neuron cell bodies located outside the central nervous system, in another part of the body, is called a **ganglion**.

What do "tract" and "fascicle" mean?

Tract and fascicle refer to collections of axons in the central nervous system that are organized to perform a specific function. These pathways are typically named based on their starting and ending points. For example, the corticospinal tract is the name for a collection of axons extending from the cerebral cortex in the brain to the spinal cord. Tract is abbreviated as "tr." and fascicle as "fasc."

What are the other cells in the nervous system?

Besides neurons, which are the primary nerve cells, the nervous system contains supporting tissue cells. These include:

microglia

oligodendrocytes

astrocytes

ependymal cells

Schwann cells

These cells are involved in functions such as nourishing nerve tissue, phagocytosis of foreign bodies, and covering axons with a myelin sheath.

What is a synapse?

A synapse is the connection point between two nerve cells (Figure 9.3). Signal transmission between nerves does not occur directly. When a signal reaches the axon terminal, it causes the release of substances called **neurotransmitters** into the **synaptic cleft**, which is the gap between two nerve cells. These neurotransmitters bind to corresponding receptors on the surface of the next cell, generating an electrical signal in that cell. Thus, the neural signal is transmitted from one nerve cell to the next.

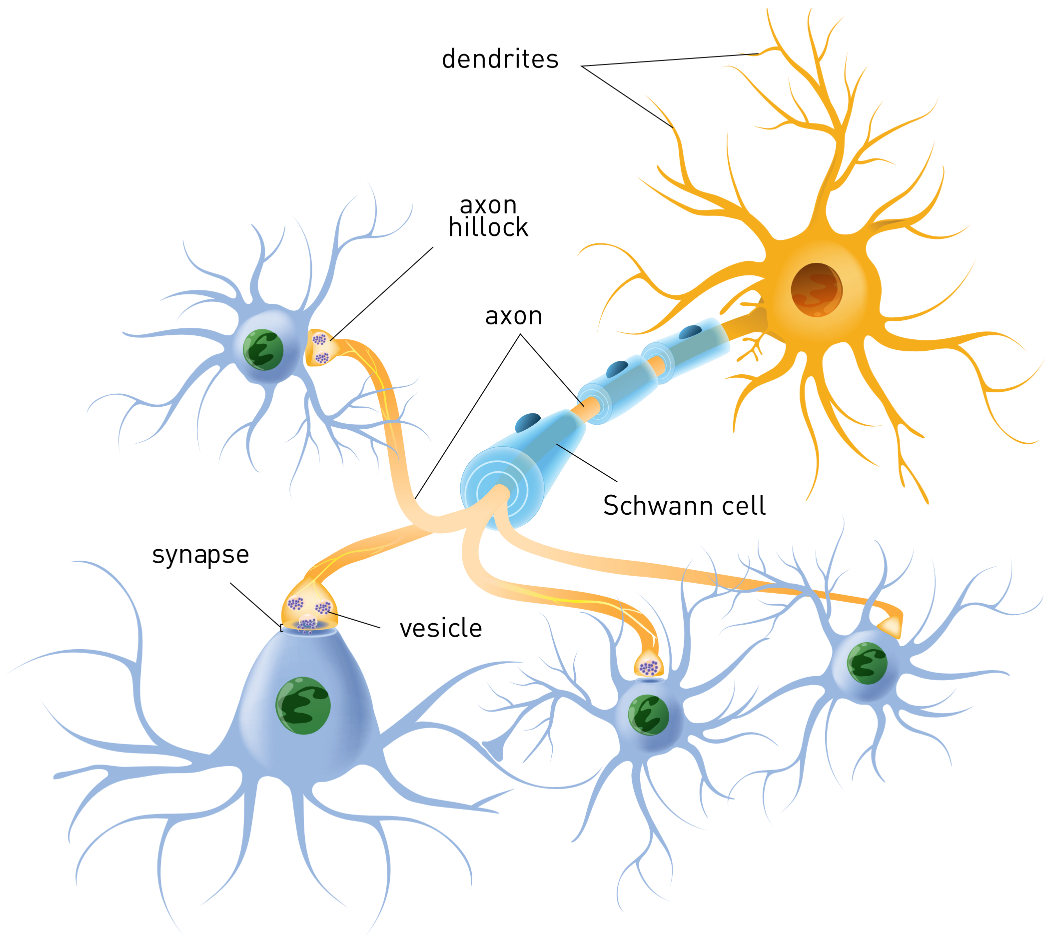


Figure 9.3. Synapses, which are the connection points between nerve cells.

Cerebrum (Brain)

The cerebrum is a large part of the central nervous system located within the skull (Figure 9.4a-c). It consists of two **hemispheres**. These hemispheres are separated by a deep groove in the midline called the **longitudinal cerebral fissure**. The surface of the hemispheres typically appears as folds (**gyrus**) separated by grooves (**sulcus**).

Deep within the hemispheres, they are connected at the midline by a structure called the **corpus callosum** and the **diencephalon**. Below this, the diencephalon connects the cerebrum to the spinal cord through a narrower structure called the **brainstem** (Figure 9.4a-c).

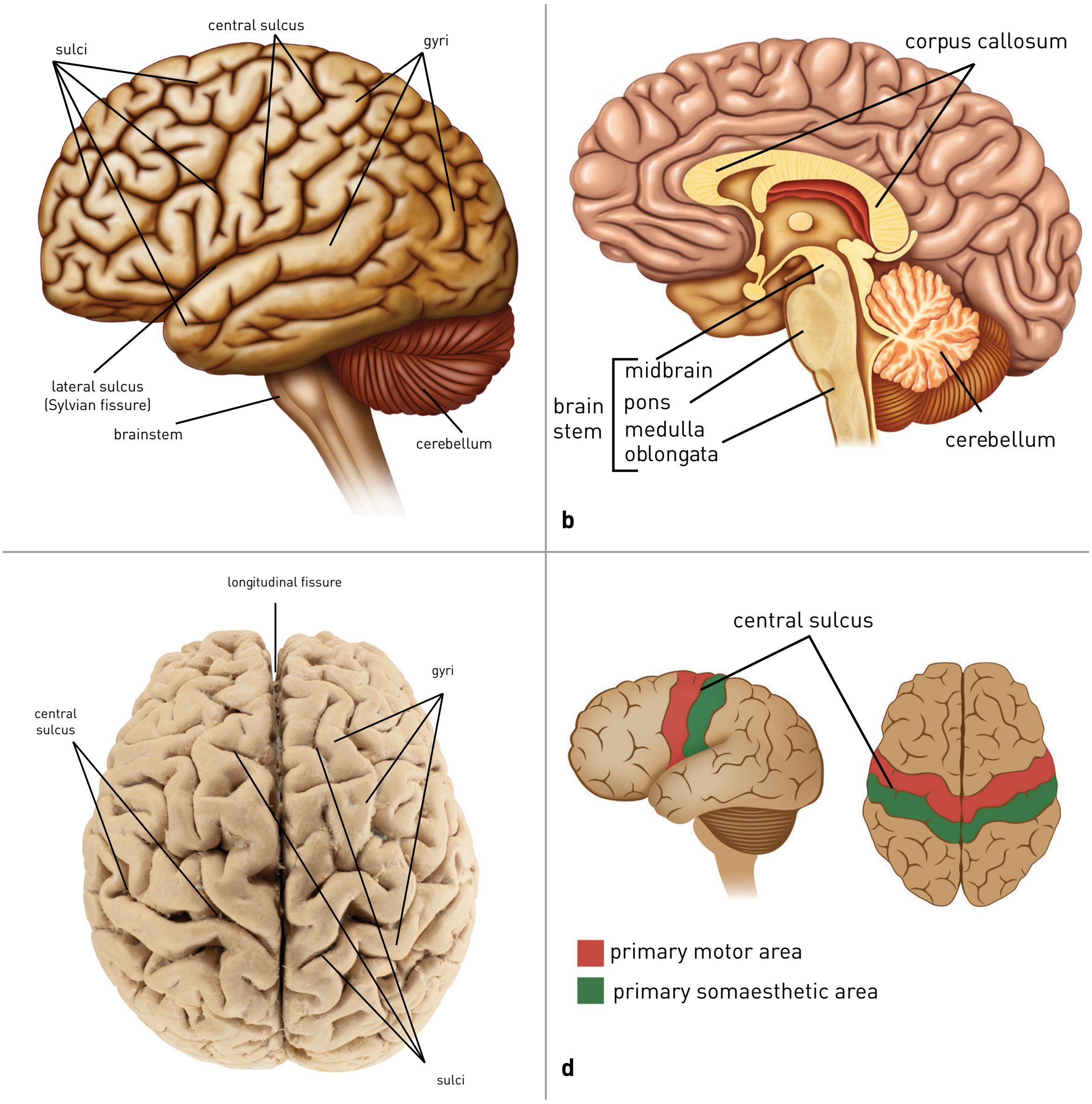


Figure 9.4. Brain (cerebrum). **a.** surface of the cerebral hemisphere and brainstem **b.** inner aspect of the cerebral hemisphere and brainstem in sagittal section **c.** superior view of the cerebral hemisphere **d.** location of the primary motor and somatosensory areas on the cerebral hemisphere.

On the outer surface of the cerebrum lies the **cerebral cortex**, which is a few millimeters thick. It contains the cell bodies of neurons. Areas with neuronal cell bodies appear gray in cross-sections and are referred to as **gray matter**. Below this thin cortical layer, the deeper layers consist of white matter, which appears white due to the myelin sheath, the sheath that covers the nerve cell extensions. Embedded within the white matter are clusters of neuronal cell bodies called **nucleus**, which also appear gray.

What are the lobes of the cerebral hemispheres?

Each cerebral hemisphere is divided into following lobes (Figure 9.5):

- **frontal lobe**
- **parietal lobe**
- **occipital lobe**
- **temporal lobe**

When viewed from the side, the sulcus lateralis separates the temporal lobe from the frontal lobe in the upper front and the parietal lobe in the upper back (Figure 9.4a-c, 9.5).

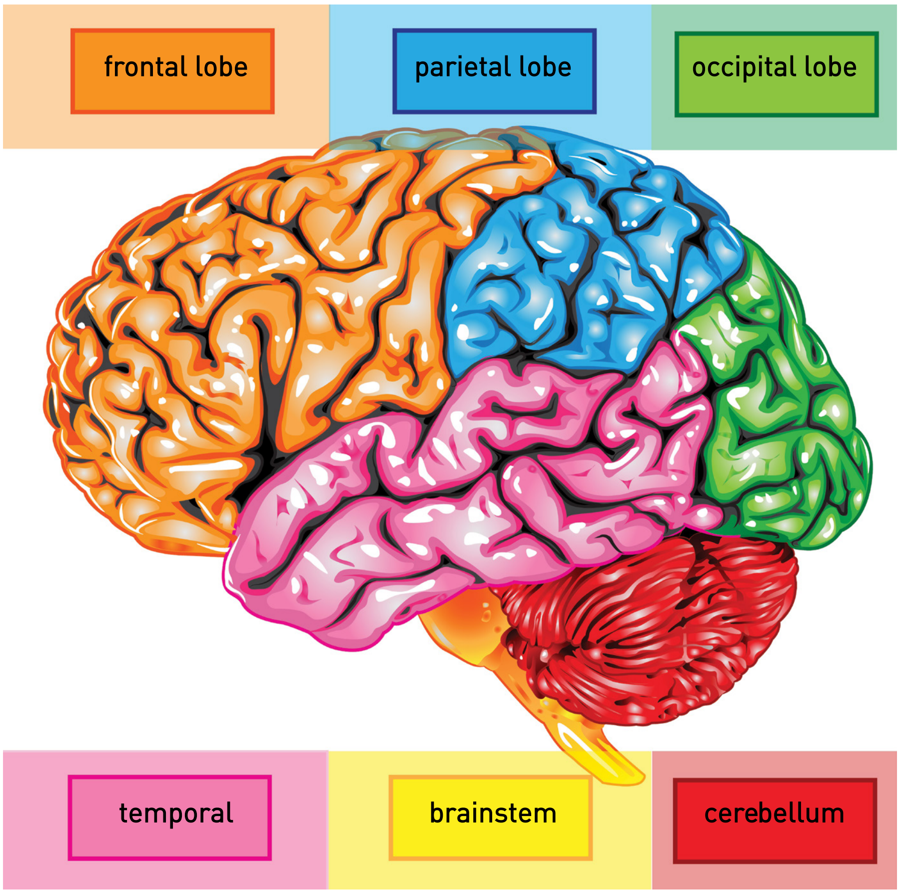


Figure 9.5. Lobes of the cerebral hemisphere.

Certain gyri and sulci on the cerebrum are typically consistent across individuals, allowing the cerebrum to be divided into structural and functional subregions. Each hemisphere has a medial, inferior, and outer (lateral) surface.

On the outer surface of the hemispheres, a prominent groove called the **central sulcus** extends downward, separating the frontal and parietal lobes.

Anterior to this sulcus in the frontal lobe is the **precentral gyrus** (primary motor area), which is responsible for voluntary muscle activity on the opposite side of the body (Figure 9.4a-d). Posterior to this sulcus in the parietal lobe is the **postcentral gyrus** (primary somesthetic area), which receives various sensory inputs processed in the thalamus before being transmitted here.

What are Brodmann Areas?

The cortical layer covering the outer surface of the cerebrum was divided by the neuroanatomist Brodmann into regions known as Brodmann Areas, based on cell size, cell density, and their cortical layers. These areas, totally 52, each have distinct functions.

Below are some examples of Brodmann Areas:

Brodmann Area (BA)	Location	Function
3, 1, 2	Postcentral gyrus	Primary sensory area
4	Precentral gyrus	Primary motor area
6	Dorsomedial frontal cortex, dorsal to area 8 in frontal gyrus	Supplementary motor functions
8	Superior frontal gyrus, in front of precentral sulcus	Frontal eye field
17	Occipital lobe, surrounding the upper and lower areas of calcarine sulcus	Primary visual area (V1, visual cortex)
18	Anterior to the primary visual area	Secondary visual area (V2)
41	Superior surface of superior temporal gyrus, facing lateral sulcus and in its depth	Primary auditory area
42	Area adjacent to the primary auditory area	Secondary auditory area
44, 45	(in the left hemisphere) Inferior frontal gyrus (opercular and triangular parts)	Motor speech area (Broca's area)

What is the corpus callosum?

The corpus callosum is a C-shaped structure of white matter composed of axons that connect the two hemispheres, located deep within the longitudinal cerebral fissure (Figure 9.4b). It is further divided into four parts: **rostrum**, **genu, body,** and **splenium**.

What is corona radiata?

The corona radiata is a fan-shaped structure of white matter formed by fibers that either approach or depart from the cortex, located deep within the hemispheres.

What is internal capsule?

The internal capsule is an L-shaped structure formed by the corona radiata as it passes between the thalamus and basal nuclei. It contains pathways ascending to or descending from the cortex.

What is the function of the cerebral cortex?

Mental activities occur in the cortex, the outer layer of the cerebrum. Each area of the cortex has specific responsibilities, which can be sensory or motor in nature. Neurons in a motor area of the cortex transmit signals via their extensions to neurons in the brainstem and spinal cord, then to spinal nerves, enabling voluntary motor movements. Sensory signals from peripheral receptors travel in the opposite direction, reaching the corresponding sensory area in the cerebrum through the spinal cord and brainstem. These signals form bundles of axons along pathways called **tract** or **fascicle**.

What is the diencephalon?

The diencephalon is a small but highly important region located beneath the cerebrum. It contains many nuclei that regulate essential functions, including hunger, thirst, reproduction, sensory organization, and body temperature. The diencephalon includes the following regions:

thalamus
hypothalamus
epithalamus
subthalamus

The **thalamus**, located on both sides of the third ventricle, serves as a critical relay station for organizing all sensory information traveling to the cerebrum and motor commands traveling from the cerebrum to the periphery.

The **hypothalamus**, located below and in front of the thalamus, is the center of the autonomic nervous system and also has neuroendocrine functions. It is connected to the pituitary gland located just below it.

The **epithalamus** is the dorsal part of the diencephalon which includes the **pineal body**, the **habenula,** the **habenular commissure** and the **stria medullaris**. It is related with the limbic system and basal ganglia. Pineal gland secretes melatonin which is critical for the circadian rhythm. It also contributes the regulation of motor pathways and emotions.

The **subthalamus** is the caudal part of the diencephalon. It is connected to the basal nuclei and important for motor functions.

What are the basal nuclei?

Basal nuclei are a group of subcortical nuclei located in the prosencephalon (forebrain). It consists of five nuclei:

caudate nucleus
putamen
globus pallidus
substantia nigra
subthalamic nucleus

Basal nuclei are connectod to the cerebral cortex; receive signals from the cortex, process the data and transmit it back to the cortex via the thalamus. In this way, the basal nuclei play an important role in planning, modulation and control of movement, decision making, behavior and emotions.

What is the brainstem?

The brainstem, located below the cerebrum and in front of the cerebellum, is a continuation of the diencephalon. It is composed of descending and ascending white matter tracts on the outside and nuclei of gray matter embedded within. Some of these nuclei are associated with cranial nerves, the cerebellum, and various endocrine organs.

What are the divisions of the brainstem?

The brainstem consists of three parts:

midbrain (mesencephalon)
pons
bulbus (medulla oblongata)

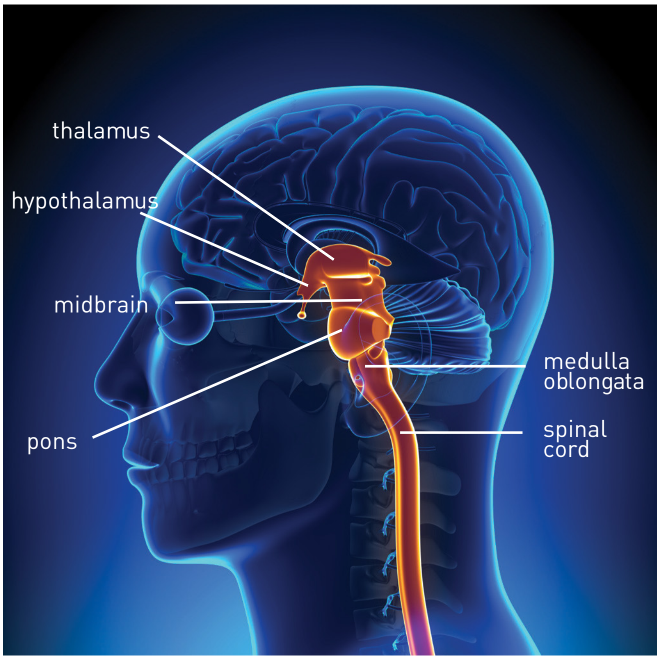


Figure 9.6. Brainstem and the upper part of the spinal cord.

Midbrain (Mesencephalon)

The midbrain connects the brainstem to the diencephalon. Its anterior part is called the **cerebral peduncle**, and its posterior part is the **tectum**. The **cerebral peduncle**, which continues with the **internal capsule** in each hemisphere above, approach each other downwards. Thus, a hollow area called the **interpeduncular fossa** is formed between the two cerebral peduncles. This fossa contains the oculomotor nerve (cranial nerve III), mammillary bodies, and the infundibulum of the pituitary gland. The **tectum** has four bumps: upper two are the **superior colliculus**, associated with visual reflexes, and the lower two are the **inferior colliculus**, associated with auditory reflexes. The **cerebral aqueduct**, connecting the third and fourth ventricles, is located anterior to the tectum.

Pons

The pons is the middle part of the brainstem, located between the midbrain and the medulla oblongata, and in front of the cerebellum. It has a bulging anterior surface separated by grooves from the midbrain above and the medulla below. The groove at the bottom gives rise to cranial nerves VI (abducent n.), VII (facial n.), and VIII (vestibulocochlear n.). Cranial nerve V (trigeminal n.) exits from the upper lateral part of the pons. The anterior surface has a vertical groove called the **basilar sulcus**, which contains the basilar artery. Posterior surface of the pons is hidden by the cerebellum.

Bulbus (Medulla Oblongata)

The medulla oblongata is the lowest part of the brainstem and contains vital centers for respiration and circulation. It connects to the spinal cord through the foramen magnum, the largest opening at the base of the skull. Its anterior surface resembles the spinal cord and features a deep vertical groove, the **anterior median fissure**. Bumps on either side of this groove are the **pyramids**, which contain motor pathways (corticospinal tr.). They extend downward and at the lower part of the medulla, most of these fibers cross to the opposite side, forming the **pyramidal decussation**. Lateral to the pyramid is the **olive**, a small oval prominence containing the inferior olivary nucleus. From the groove medial to the olive emerges the cranial nerve XII (hypoglossal n.), while the cranial nerves IX (glossopharyngeal n.), X (vagus n.), and XI (accessory n.) emerge from the groove lateral to it.

Cerebellum

The cerebellum is located behind the brainstem (pons and medulla oblongata) and is connected to it via three structures called the **superior, middle,** and **inferior cerebellar peduncles** (Figure 9.7). The fourth ventricle lies between the cerebellum and the brainstem. The cerebellum's surface features numerous thin, horizontal folds called **folium**. Cerebellum consists of a midline structure called the **vermis** and two **cerebellar hemispheres**. Like the brain, the cerebellar hemispheres have an outer gray matter layer, an inner white matter layer, and nuclei embedded within the white matter. The cerebellum contains four nuclei:

Dentate nucleus (located in the cerebellar hemisphere)

Emboliform nucleus (also called as the **interposed nucleus** together with the globose nucleus)

Globose nucleus

Fastigial nucleus (located in the midline)

Figure 9.7. Cerebellum.

What is the function of the cerebellum?

The cerebellum is involved in regulating movement and posture, coordinating actions, learning new movements, and maintaining balance.

Spinal Cord

The spinal cord is a cylindrical part of the central nervous system located within the vertebral canal of the spine, extending from the base of the skull (foramen magnum) to the lumbar region (usually L1 vertebral level) (Figure 9.8). It is the continuation of the brainstem.

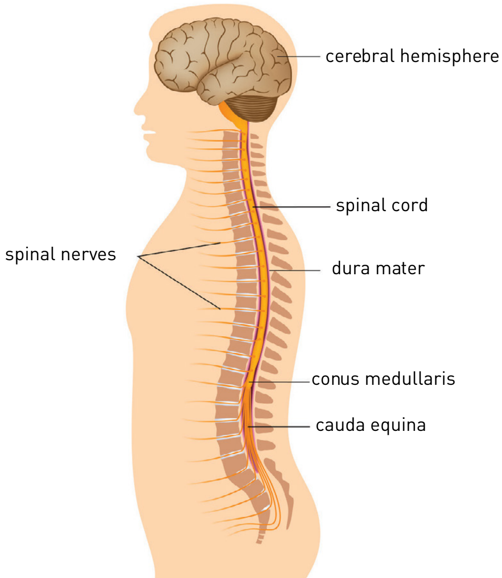


Figure 9.8. Spinal cord.

How is the external appearance of the spinal cord?

On its anterior surface, a deep, vertical fissure called the **anterior median fissure** runs from top to bottom. On the posterior surface, a groove called the **posterior median sulcus** is observed. On both sides, lateral grooves are present, called the **anterolateral sulcus** and **posterolateral sulcus** (Figures 9.9, 9.11a).

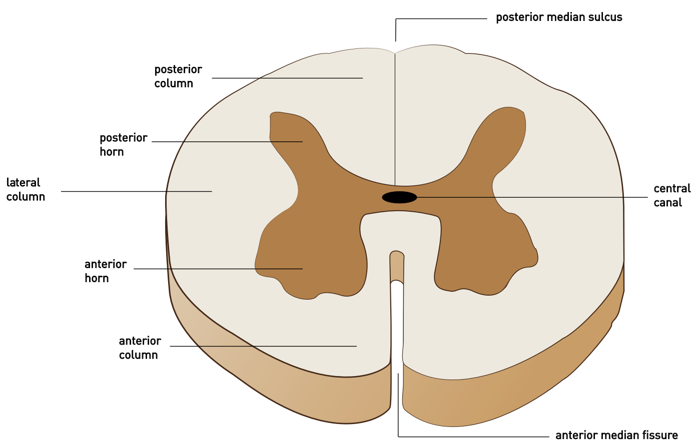


Figure 9.9. Horizontal (transverse) section of the spinal cord.

What is observed in a cross-section of the spinal cord?

Unlike the brain, the white matter is on the outside, and the gray matter is on the inside (Figure 9.9). The white matter contains ascending and descending pathways, while the gray matter contains motor neurons, autonomic neurons, and interneurons associated with these pathways. The gray matter has an H-shaped or butterfly-shaped view in cross-section, with a midline **central canal** filled with cerebrospinal fluid (CSF). The larger anterior extensions of the gray matter are called the **anterior horns**, and the thinner posterior extensions are the **posterior horns**. Anterior horns contain motor neurons. Posterior horns contain sensory neurons. The white matter is divided into three regions:

anterior funiculus: between the midline and anterolateral sulcus.

posterior funiculus: between the midline and posterolateral sulcus.

lateral funiculus: between anterolateral and posterolateral sulcus.

These regions contain axonal bundles forming pathways (tracts, fascicles).

What is the conus medullaris?

The conus medullaris is the tapered end of the spinal cord in the lumbar region (Figure 9.10). In adults, it typically aligns with the lower edge of the first lumbar vertebra.

What is the cauda equina?

The cauda equina refers to the bundle of spinal nerve roots extending downward from the lower segments of the spinal cord within the subarachnoid space, resembling a horse's tail (Figure 9.9).

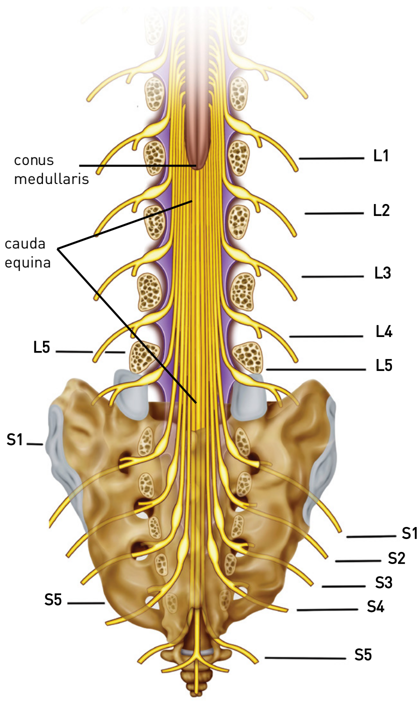


Figure 9.10. Conus medullaris. The posterior part of the vertebrae has been removed and shown from the back. The conus medullaris, which is the terminal part of the spinal cord, and the cauda equina starting immediately below it.

What is a spinal cord segment?

The spinal cord gives rise to 31 pairs of spinal nerves. The part of the spinal cord where each pair emerges is called a **segment**.

There are 31 spinal segments:

- **8** cervical
- **12** thoracic
- **5** lumbar
- **5** sacral
- **1** coccygeal

Each segment supplies motor signals to muscles and receives sensory signals from specific body regions.

What are the anterior root and posterior root?

They are structures that emerge from the anterolateral and posterolateral sulcus of the spinal cord and unite to form a spinal nerve. The anterior root (radix anterior) that emerges from the anterior side contains motor fibers, while the posterior root (radix posterior) that emerges from the posterior side contains sensory fibers (Figure 9.11a-c). The spinal nerves leave the vertebral canal through the intervertebral foramen.

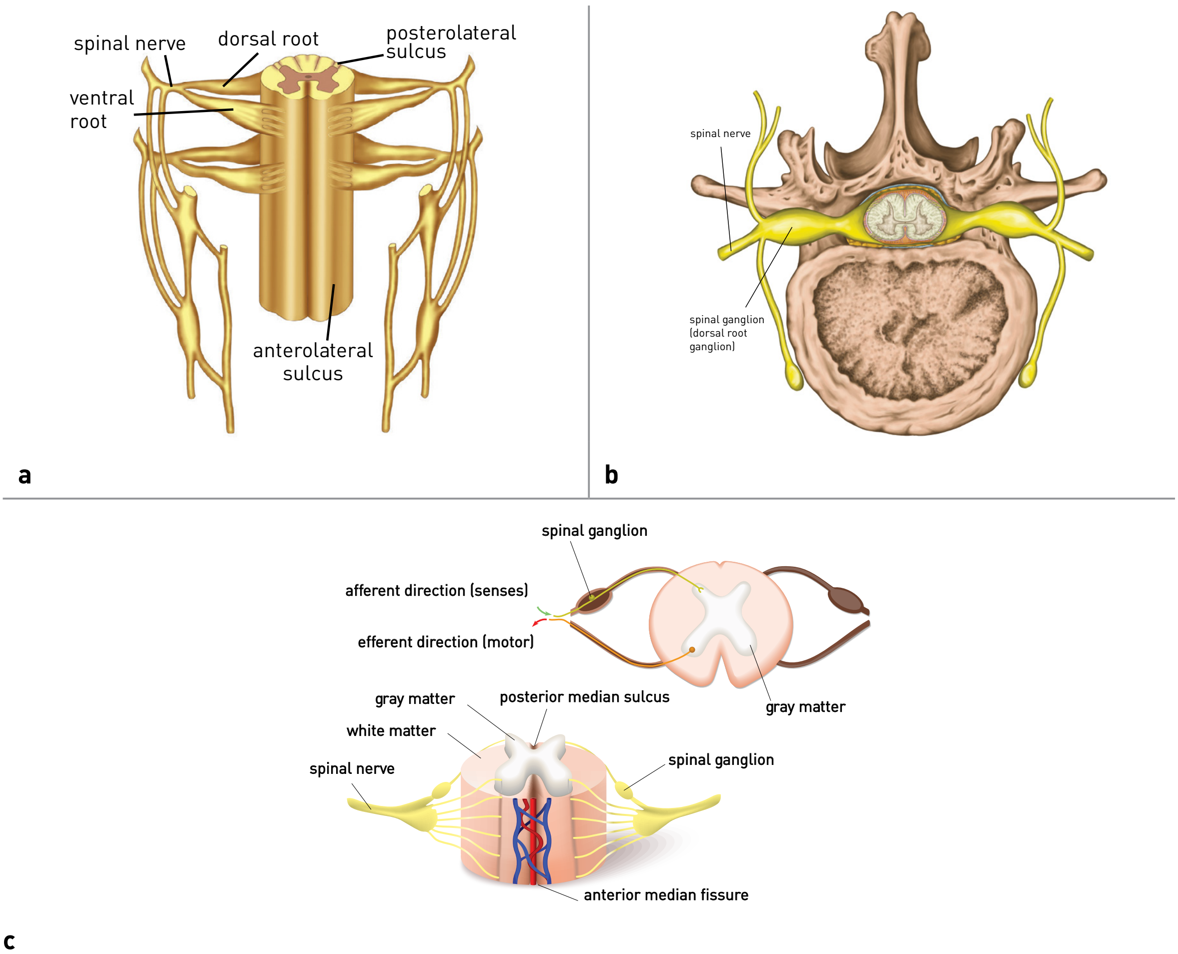


Figure 9.11. Spinal cord sections showing the formation of the spinal nerve with the anterior and posterior roots. **a.** anterior view **b.** horizontal section showing the spinal cord inside the spine and the spinal nerves emerging from it **c.** spinal cord, roots, spinal nerves, and posterior root ganglia.

What is the dorsal root ganglion?

It is a ganglion formed by the neuron bodies located on the dorsal root of the spinal cord (Figure 9.11a-c). It is also called the **dorsal ganglion** or **spinal ganglion**. The peripheral extensions of the neurons located in this ganglion receive sensation from the environment and carry it to the cell body, while the central extension of the same neuron transmits the stimulus related to this sensation to another neuron located in the spinal cord via the dorsal root.

What is the role of ascending tracts of the spinal cord?

The ascending tracts of the spinal cord are essential for transmitting sensory information to the brain, allowing us to perceive the world around us and maintain coordination and balance. These tracts carry various types of sensory data, including touch, pain, temperature, proprioception (awareness of body position), and pressure. Damage to any of these tracts can result in sensory deficits, affecting a person's ability to perceive or respond to stimuli. The integrity of these pathways is crucial for normal sensory processing and motor control.

What are the first-order, second-order, and third-order neurons?

The ascending tracts of the spinal cord involve multiple neurons, each playing a specific role in transmitting sensory information from the body to the brain. These neurons are typically classified as **first-order**, **second-order**, and **third-order** neurons, each of which has a specific role in the relay of sensory signals.

What are the main ascending tracts of the spinal cord?

There are many pathways in the spinal cord carrying sensory impulses coming from the periphery or the internal organs and structures. They are located in one of the three columns of the white matter as tracts or fasciculus. They connect the spinal cord to the brain. The main ascending tracts in the spinal cord, along with the specific sensations they convey, include the following:

1. Gracile & Cuneate Fasciculus

gracile fasciculus: carries sensory information from the lower body and legs.

cuneate fasciculus: carries sensory information from the upper body and arms.

These fascicles are primarily responsible for conveying

fine touch: the ability to distinguish small or light stimuli, such as the feeling of a feather on the skin

vibration: the sensation of oscillations or vibrating sensations felt through the skin.

proprioception: awareness of the position of body parts, allowing for coordinated movement and posture

First-order neurons: are located in the dorsal root ganglion. These neurons have their receptors in the skin, muscles, or joints. The axons of these neurons travel through the dorsal columns of the spinal cord (either the gracile or cuneate fasciculus) to the medulla oblongata.

Second-order neurons: are located in the **gracile nucleus** (for lower body input) and **cuneate nucleus** (for upper body input) in the medulla oblongata. These neurons decussate at the medulla oblongata and ascend to the thalamus as the **medial lemniscus**.

Third-order neurons: are located in the **ventral posterolateral (VPL) nucleus** of the thalamus. These neurons relay sensory information to the somatosensory cortex in the parietal lobe of the brain for conscious perception.

2. Spinothalamic Tract

The **spinothalamic tract** carries information about pain, temperature, and crude touch (a less detailed sense of touch) to the brain.

pain: includes both sharp, localized pain (nociceptive) and dull, aching pain (nociceptive).

temperature: detection of hot and cold sensations.

crude touch: the sensation of general touch, which is not precise enough for detailed localization but allows awareness of contact with the skin.

pressure: the sensation of force applied to the skin, such as the feeling of something pressing against the body.

This tract is divided into two parts:

lateral spinothalamic tract: carries sensations of pain and temperature from the body. This includes sharp, stabbing pain (nociception) and sensations related to heat or cold.

anterior spinothalamic tract: carries sensations of crude touch (light touch that cannot be precisely localized) and pressure.

First-order neurons: are located in the dorsal root ganglion. These neurons have their receptors in the skin, tissues, and organs that detect pain, temperature, and crude touch. Their efferent fibers enter the spinal cord via the dorsal roots and synapse with second-order neurons in the spinal cord.

Second-order neurons: are located in the dorsal horn of the spinal cord. After the synapse here, axons of the second-order neurons decussate in the spinal cord at the level of entry. After decussation, the axons ascend on the contralateral side of the spinal cord either within the anterior or lateral spinothalamic tract to reach the thalamus. Anterior spinothalamic tract is located in the anterior column while the lateral spinothalamic tract is located in the lateral column.

Third-order neurons: are located in the **ventral posterolateral (VPL) nucleus** of the thalamus. These neurons relay sensory information to the somatosensory cortex in the parietal lobe of the brain for conscious perception.

3. Spinocerebellar Tracts

The **spinocerebellar tracts** transmit **unconscious proprioceptive information** from the muscles and joints to the cerebellum, which plays a crucial role in balance, coordination, and motor control. These tracts provide continuous feedback to the cerebellum about the position and movement of body parts, allowing for fine motor coordination and adjustments in posture.

posterior spinocerebellar tract: transmits unconscious proprioceptive information from the lower body and legs to the cerebellum, helping coordinate movements of the lower limbs. The first-order neurons are located in the dorsal root ganglion. Their efferent fibers enter the spinal cord via the dorsal roots and synapse with second-order neurons in the nucleus dorsalis (Clark's column). Postsynaptic fibers remain on the same side (no decussation), and travel to the ipsilateral cerebellar hemisphere via the inferior cerebellar peduncle.

anterior spinocerebellar tract: transmits unconscious proprioceptive information from the upper body and arms to the cerebellum, helping coordinate upper limb movements and posture. The first-order neurons are located in the dorsal root ganglion. Their efferent fibers enter the spinal cord via the dorsal roots and synapse with second-order neurons in the nucleus dorsalis (Clark's column). Postsynaptic fibers decussate (first decussation) and ascend in the contralateral lateral column till the midbrain level and decussate once more (second decussation) to pass the contralateral cerebellar hemisphere via the superior cerebellar peduncle.

cuneocerebellar tract: specifically transmits proprioceptive information from the arms, neck, and upper trunk (above C8 level) to the cerebellum. The first-order neurons are located in the dorsal root ganglion. Their efferent fibers enter the spinal cord via the dorsal roots and ascend in the cuneate fascicle without any decussation till the accessory cuneate nucleus. After synapsing here fibers enter the cerebellar hemisphere via the inferior cerebellar peduncle.

The spinocerebellar and cuneocerebellar tracts transmit proprioceptive feedback directly to the cerebellum, bypassing the thalamus. These pathways are essential for maintaining balance and smooth, coordinated movement. Additionally, these pathways transmit sensory stimuli from the side of the body where they originate from to the same side of the cerebellar hemisphere. They accomplish this either without decussating at all or by decussating twice, remaining on the same side.

What are the main descending tracts of the spinal cord?

Descending tracts of the spinal cord are pathways that carry motor commands from the brain to the muscles and glands. These tracts are responsible for voluntary movements and the regulation of various autonomic functions. They are located in the white matter of the spinal cord and include important tracts such as the **corticospinal tract**, the **reticulospinal tract**, the **vestibulospinal tract**, **rubrospinal tract**, **tectospinal tract** and the **descending autonomic pathway**.

1. The Corticospinal Tract

The corticospinal tract is one of the most important motor pathways in the central nervous system, responsible for carrying voluntary motor signals from the brain to the spinal cord. It originates in the primary motor cortex (precentral gyrus), which is located in the frontal lobe. This area is responsible for the initiation of voluntary movements, and the neurons here are involved in the control of precise and skilled movements. Fibers arising from the premotor cortex (Brodmann area 6), primary sensory area (Brodmann area 3,1,2), and supplementary sensory area (Brodmann area 5) also contribute the corticospinal tract. The corticospinal fibers descend through the **corona radiata**, which is a fan-shaped structure of white matter in the brain. The fibers then converge into a narrow band called the **internal capsule**, located between the thalamus and the basal nuclei. After passing through the internal capsule, the fibers continue down into the **midbrain**. Here, the corticospinal fibers run through the most anterior portion, **crus cerebri**, which are large bundles of nerve fibers. The corticospinal fibers descend further through the ventral portion of the pons and reach the **medulla oblongata**, where the fibers form distinct ridges known as the **pyramids**. The majority of corticospinal fibers (approximately 90%) cross to the opposite side of the body at the **pyramidal decussation** in the lower medulla. The fibers that cross form the **lateral corticospinal tract**. A smaller portion of the corticospinal fibers (about 10%) do not decussate and continue descending on the same side to form the **anterior corticospinal tract**. The **lateral corticospinal tract** runs in the lateral funiculus of the spinal cord, and the **anterior corticospinal tract** runs in the anterior funiculus. In the spinal cord, the corticospinal tract fibers synapse with **lower motor neurons** in the anterior horn of the spinal cord. The axons of the lower motor neurons then exit the spinal cord and travel to the target muscles.

2.The Reticulospinal Tract

The reticulospinal tract is an important descending pathway that plays a key role in motor control, particularly in regulating posture, muscle tone, and reflexive movements. It originates from the **reticular formation**, in the brainstem, which is involved in a wide range of functions, including motor control, arousal, and autonomic regulation. The reticulospinal tract is divided into two main parts:

- the **medial reticulospinal tract**: originates in the **pontine reticular formation** (in the pons), descends on the same side through the anterior funiculus of the spinal cord. It is involved in the facilitation of **extensor muscle activity**, particularly helping to maintain posture and balance by influencing the muscles of the trunk and limbs.

- the **lateral reticulospinal tract**: originates in the **medullary reticular formation** (in the medulla oblongata), descends primarily ipsilaterally, runs through the lateral funiculus of the spinal cord. This tract helps modulate **flexor muscle activity** and contributes to the coordination of automatic movements, such as those related to walking.

3. The Vestibulospinal Tract

The **vestibulospinal tract** is a descending pathway that plays a critical role in maintaining balance, posture, and head position. It originates in the **vestibular nuclei**, which are located in the pons and medulla. These nuclei receive input from the vestibular system, which is responsible for detecting changes in head position and movement, as well as the body's orientation in space. The vestibulospinal tract is divided into two main components:

- the **medial vestibulospinal tract**: originates from the **vestibular nuclei,** primarily descends bilaterally through the **medial longitudinal fasciculus** and into the cervical and upper thoracic regions of the spinal cord. It plays a crucial role in **head and neck posture** by controlling the muscles of the neck and upper trunk. It helps stabilize the head and coordinates head movements with eye movements, a function known as the **vestibulo-ocular reflex (VOR)**.
- the **lateral vestibulospinal tract**: originates from the **vestibular nuclei**, descends on the same side through the **lateral funiculus** of the spinal cord. It is primarily involved in maintaining postural stability by regulating the muscles of the trunk and limbs, especially those involved in standing and walking. It helps to adjust muscle tone and coordinate balance in response to changes in body position.

4. The Rubrospinal Tract

The **rubrospinal tract** is a descending motor pathway that originates in the **red nucleus** of the midbrain and plays a role in motor control, particularly in the coordination of voluntary movements. The red nucleus regulates muscle tone and facilitates movements of the limbs, especially those of the upper extremities.

5. The Tectospinal Tract

The **tectospinal tract** is a descending motor pathway that plays a crucial role in coordinating head and eye movements in response to visual and auditory stimuli. It originates in the **superior colliculus** of the midbrain, a structure involved in processing sensory information related to vision. The tectospinal tract helps coordinate reflexive movements that align the head and eyes towards stimuli in the environment, facilitating rapid adjustments to sensory input.

6. The Descending Autonomic Fibers

The **descending autonomic fibers** are neural pathways that carry autonomic motor signals from the brain to the spinal cord, influencing the function of various internal organs, smooth muscles, and glands. These fibers are part of the autonomic nervous system, which regulates involuntary physiological functions such as heart rate, digestion, respiratory rate, and blood pressure. The descending autonomic fibers primarily originate from centers in the brainstem and hypothalamus and travel down the spinal cord to influence the sympathetic and parasympathetic divisions of the autonomic nervous system.

What is the upper and lower motor neurons?

An **upper motor neuron** (**UMN**) is a neuron whose cell body is located in the cerebral cortex and terminates within the brainstem or spinal cord. **Lower motor neuron (LMN)** has its cell body in the anterior horn of the spinal cord (ventral horn) and at cranial nerve nuclei and directly innervates skeletal muscles.

In both upper and lower motor neuron lesions, muscle weakness is observed, but there are distinct differences between them. In upper motor neuron damage, muscle weakness, spasticity and increased muscular tonus, increased deep tendon reflexes, and pathological reflexes are typical, whereas in lower motor neuron lesions, muscle weakness, decreased muscular tonus, decreased tendon reflexes, and muscle fasciculation are characteristic.

CLINICAL RELEVANCE

A **spinal cord injury** is damage to the spinal cord that disrupts communication between the brain and the body. It can result from trauma (like car accidents or falls) or diseases (such as tumors or infections). Depending on the severity and location of the injury, it may cause **partial or complete loss of movement, sensation, and autonomic functions** (like bladder control) below the injury site. Spinal cord injuries are classified as **complete** (no function below the injury) or **incomplete** (some function remains). Recovery varies, and treatment often includes emergency care, rehabilitation, and long-term support.

A **stroke** occurs when the blood supply to part of the brain is interrupted or reduced, preventing brain tissue from getting enough oxygen and nutrients. This can cause brain cells to die within minutes. There are two main types: **ischemic stroke** (caused by a blocked artery) and **hemorrhagic stroke** (caused by a burst blood vessel). Common symptoms include sudden weakness or numbness, especially on one side of the body, confusion, trouble speaking, vision problems, and loss of balance. Stroke is a medical emergency, and immediate treatment is crucial to reduce brain damage and improve outcomes.

Paresthesia refers to abnormal sensations on the skin, such as tingling, prickling, burning, or numbness. People often describe it as a "pins and needles" feeling. It can be temporary, like when a limb "falls asleep," or it can be chronic, caused by conditions such as nerve damage, diabetes, multiple sclerosis, or spinal cord injuries. While sensation is altered in paresthesia, muscle movement usually remains unaffected.

Paralysis, is the loss of muscle function in part of the body. It can be partial or complete and is typically caused by spinal cord injuries, strokes, or neurological diseases. Depending on the location and severity of the damage, paralysis can affect just one limb (**monoplegia**), one side of the body (**hemiplegia**), both legs (**paraplegia**), or all four limbs along with the trunk (**quadriplegia**). In paralysis, voluntary movement is lost, and sometimes sensation is also affected.

What are the ventricles?

Ventricles are cavities within the cerebrum filled with cerebrospinal fluid (CSF) (Figure 9.12). There are four ventricles:

- **lateral ventricles** (one in each hemisphere).
- **third ventricle** (between the right and left thalamus).
- **fourth ventricle** (behind the pons and medulla oblongata, in front of the cerebellum).

The lateral ventricles connect to the third ventricle through the **interventricular foramen** (**foramen of Monro**). The third ventricle connects to the fourth ventricle through the **cerebral aqueduct** (**aqueduct of Sylvius**). The fourth ventricle continues into the spinal cord's central canal and opens into the subarachnoid space via three openings: the **foramen of Magendie** (midline) and the **foramina of Luschka** (lateral). Through these openings, the CSF produced in the ventricles passes into the subarachnoid space and spreads around all central nervous system structures.

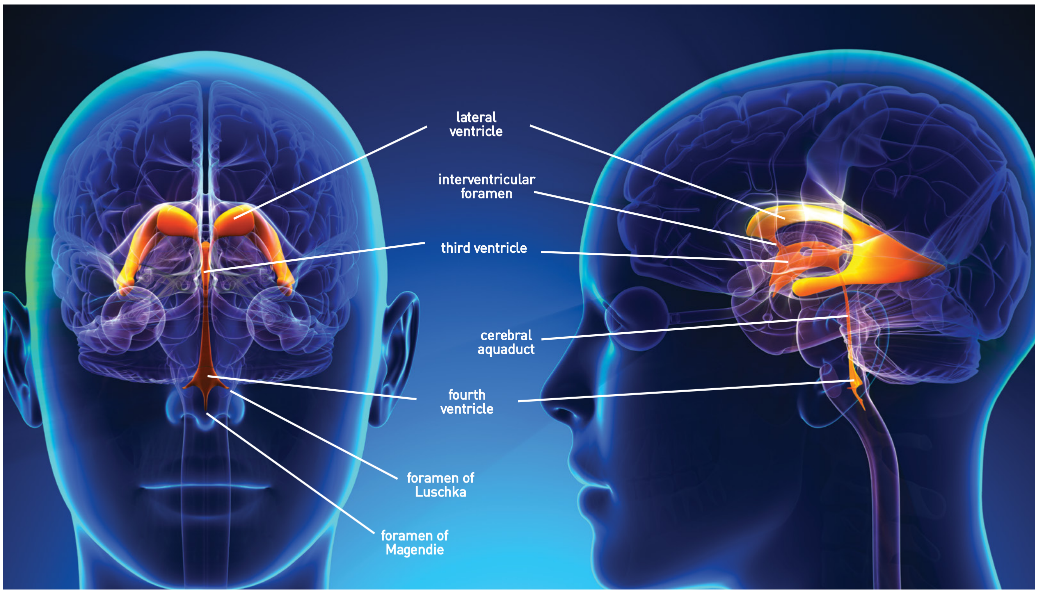


Figure 9.12. Ventricular system.

What is cerebrospinal fluid (CSF)?

CSF is a colorless fluid produced in the ventricles by the **choroid plexus**. It circulates around the brain, brainstem, cerebellum, and spinal cord, eventually returning to general circulation through brain veins. The brain and central nervous system structures literally float in this liquid. CSF provides protection for the brain and removes metabolic waste.

CLINICAL RELEVANCE

Hydrocephalus is a condition in which excess cerebrospinal fluid (CSF) builds up within the ventricles, leading ventricular enlargement and subsequent compression of the surrounding brain tissue. This condition can be either congenital, present at birth, or acquired, developing later in life. In the congenital form of hydrocephalus, symptoms may include an unusually large head size, bulging of the fontanel, and vomiting. In the acquired type, which typically results from factors such as injury, infection, or tumors, symptoms may include headaches, vomiting, and visual disturbances. Early detection and treatment is critical, as unmanaged cases can lead to severe brain damage and neurological deficits. Treatment often involves surgical interventions like ventriculoperitoneal shunting to drain the excess CSF and reduce pressure on the brain.

What are the meninges?

Meninges are the three layers of membranes surrounding the central nervous system structures, including the brain, brainstem, cerebellum, and spinal cord (Figures 9.13a,b). From outermost to innermost:

dura mater

arachnoid mater

pia mater

The outermost membrane, the dura mater, is a very thick membrane that is tightly attached to the inner surface of the skull on the outside. The potential space between the duramater and the inner surface of the cranium is called as the **epidural space**. It has two layers: outer **periosteal layer** and the inner **meningeal layer**. Dural venous sinuses are located between these two layers. Dura mater sends several extensions toward the cranial cavity such as the;

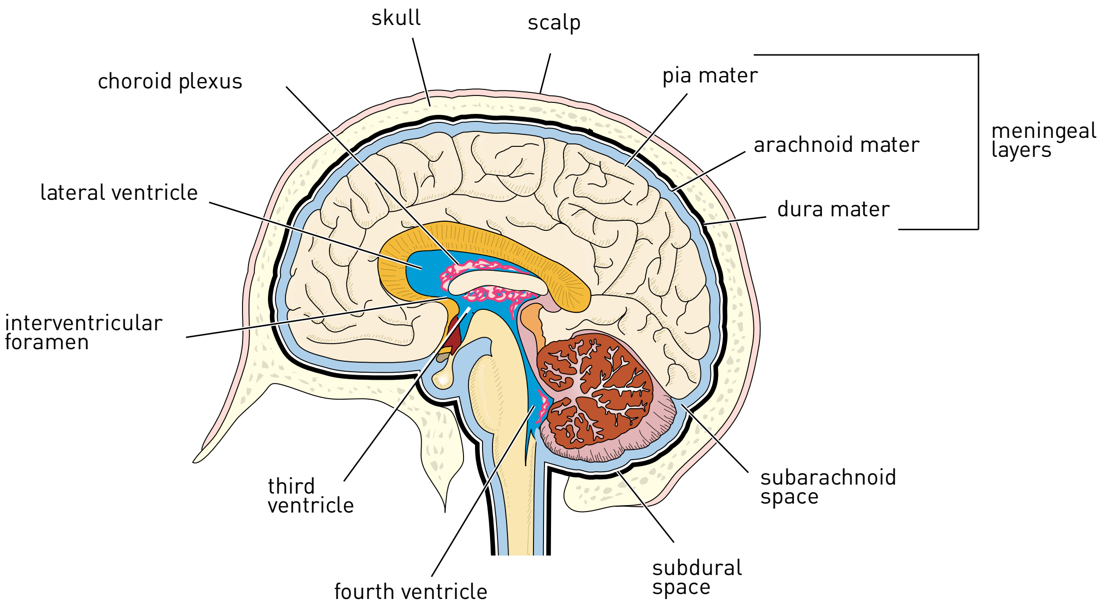
falx cerebri: separates the right and left cerebral hemispheres

tentorium cerebelli: separates the occipital lobes from the cerebellum

falx cerebelli: separates the right and left cerebellar hemispheres

diaphragma sellae: covers the hypophysial fossa.

Dura mater is tightly attached to the inner meningeal layer arachnoid mater. The space between the arachnoid and the pia mater is called the **subarachnoid space**, and the cerebrospinal fluid (CSF) and the vessels of the brain are found in this space. The innermost pia mater has two layers as **epipial layer** and the **pia intima**. It is tightly attached to the brain tissue it covers. It penetrates into all the folds of the brain surface and deep into the sulci.



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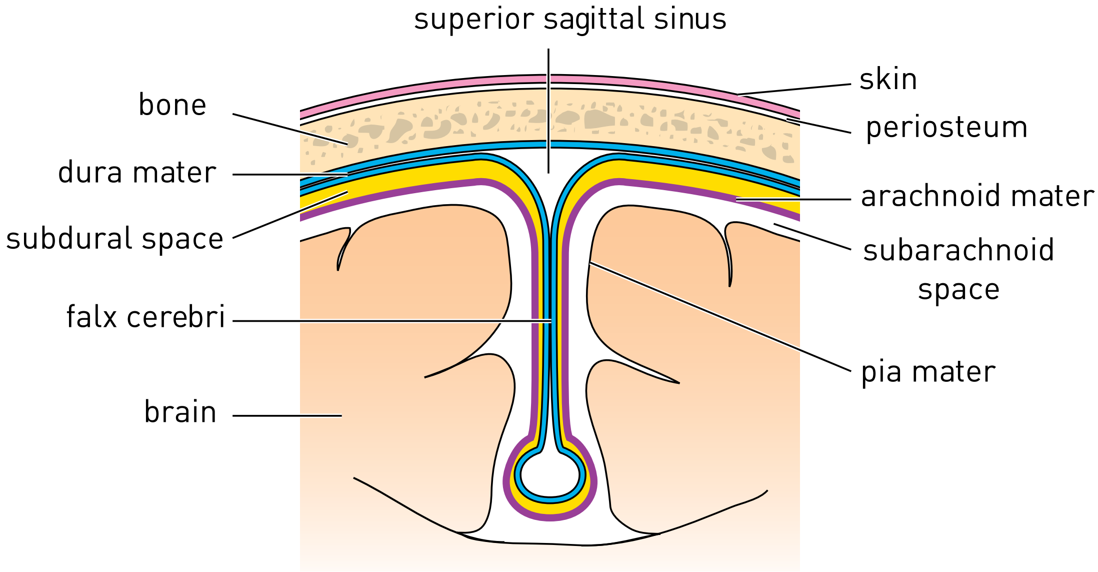

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Figure 9.13. Meninges. **a.** meninges in the sagittal section and the subarachnoid space **b.** meninges in the coronal section.

CLINICAL RELEVANCE

Meningitis is an inflammation of the meninges. It is usually caused by an infection, most commonly viruses**,** bacteria, or, less often, fungi. Symptoms often develop quickly and include fever, headache, stiff neck, sensitivity to light, nausea, and sometimes confusion or seizures. Early diagnosis and treatment are crucial to prevent serious complications.

An **epidural hematoma** is a collection of blood between the skull and the dura mater. It can be a life-threatening condition and usually requires immediate treatment or can cause brain damage or possibly death if left untreated. It typically occurs when a skull fracture tears an underlying blood vessel, most commonly the middle meningeal artery. Typical signs of epidural hematoma include a brief loss of consciousness followed by a period of awareness that may last several hours before brain function deteriorates, sometimes leaving the patient in a coma. Other symptoms may include headache, vomiting and seizure. In most cases, surgery is required to remove the blood clot to reduce pressure on the brain and stop further bleeding to prevent the hematoma from reoccurring.

A **subdural hematoma** occurs when blood accumulates beneath the dura mater, often due to a head injury. It can be either acute, which involves rapid bleeding typically caused by a significant trauma such as a car accident or fall, or chronic, which develops slowly and is more common in older individuals or those taking blood-thinning medications. Symptoms may appear gradually or within hours after the injury and can include: persistent headache, confusion, weakness or numbness on one side of the body, drowsiness, dizziness, nausea or vomiting, seizures. Surgery is required for larger ones while smaller ones are treated with medication to control blood pressure, seizures or headaches.

A **subarachnoid hemorrhage** is bleeding in the space between the arachnoid and pia mater, often resulting from head trauma. The primary symptom of subarachnoid hemorrhage is a sudden, severe headache that is unlike any the person has experienced before. Other symptoms may include nausea, vomiting, and loss of consciousness. As subarachnoid hemorrhage is a life-threatening emergency, it is usually treated in a hospital's intensive care unit. Treatment depends on the underlying cause and may involve medical management or, in some cases, surgery.

Spinal anesthesia is a regional anesthesia technique where a local anesthetic is injected into the subarachnoid space at the L3-L4 or L4-L5 intervertebral space. Commonly used in lower abdominal, pelvic, and lower limb surgeries. Provides rapid and sensory and motor block.

Epidural anesthesia involves injecting anesthetic into the epidural space, typically at the lumbar levels (L3-L4, L4-L5) or thoracic region, without penetrating the dura mater. Commonly used for pain management in labor, postoperative pain control, and certain surgical procedures.

Lumbar puncture (spinal tap) is a diagnostic and therapeutic procedure where a needle is inserted into the subarachnoid space at the L3-L4 or L4-L5 level, below the termination of the spinal cord to avoid spinal cord injury. It is used to collect cerebrospinal fluid (CSF) for diagnosing infections (e.g., meningitis), neurological disorders, and measuring intracranial pressure. Also used for administering medications such as chemotherapy or antibiotics.

Caudal epidural block is a procedure used for regional anesthesia and pain management. It is performed by inserting a needle through the sacral hiatus to reach the epidural space. It is considered a safe and effective method of managing pain, particularly for procedures involving the lower half of the body.

What are the arteries supplying the central nervous system?

The central nervous system (CNS) is supplied by the right and left **internal carotid arteries** and the **vertebral arteries** (Figure 9.14a,b). Internal carotid a. supplies the frontal, parietal, and temporal lobes (anterior portions of the cerebral hemispheres).

Vertebral a. supplies the posterior parts of the hemispheres, brainstem, and cerebellum.

The cerebrum is mainly supplied by three arteries (Figure 9.14a-c):

- **anterior cerebral a.** (a branch of internal carotid a.): supplies the anterior and middle parts of the medial surface of the hemisphere and the external surface near the longitudinal cerebral fissure.
- **middle cerebral a.** (a branch of internal carotid a.): supplies the majority of the lateral surface of the hemisphere and the deep central regions.
- **posterior cerebral a.** (a branch of basilar a.): supplies the posterior and inferior regions of the hemisphere and dorsal medial surface.

The brainstem and cerebellum are supplied by the vertebral a. and the basilar a. The spinal cord is supplied by branches of the vertebral arteries, namely the **spinal arteries**.

At the inferior surface of the hemispheres, near the midbrain, the terminal branches of the internal carotid a. (anterior and middle cerebral arteries) connect with the terminal branch of the basilar a. (posterior cerebral a.), forming the **Circle of Willis**. The anterior and posterior communicating arteries complete this arterial ring (Figure 9.14c,d). Circle of Willis provides collateral blood flow in case of narrowing or blockage in one of the major arteries supplying the brain.

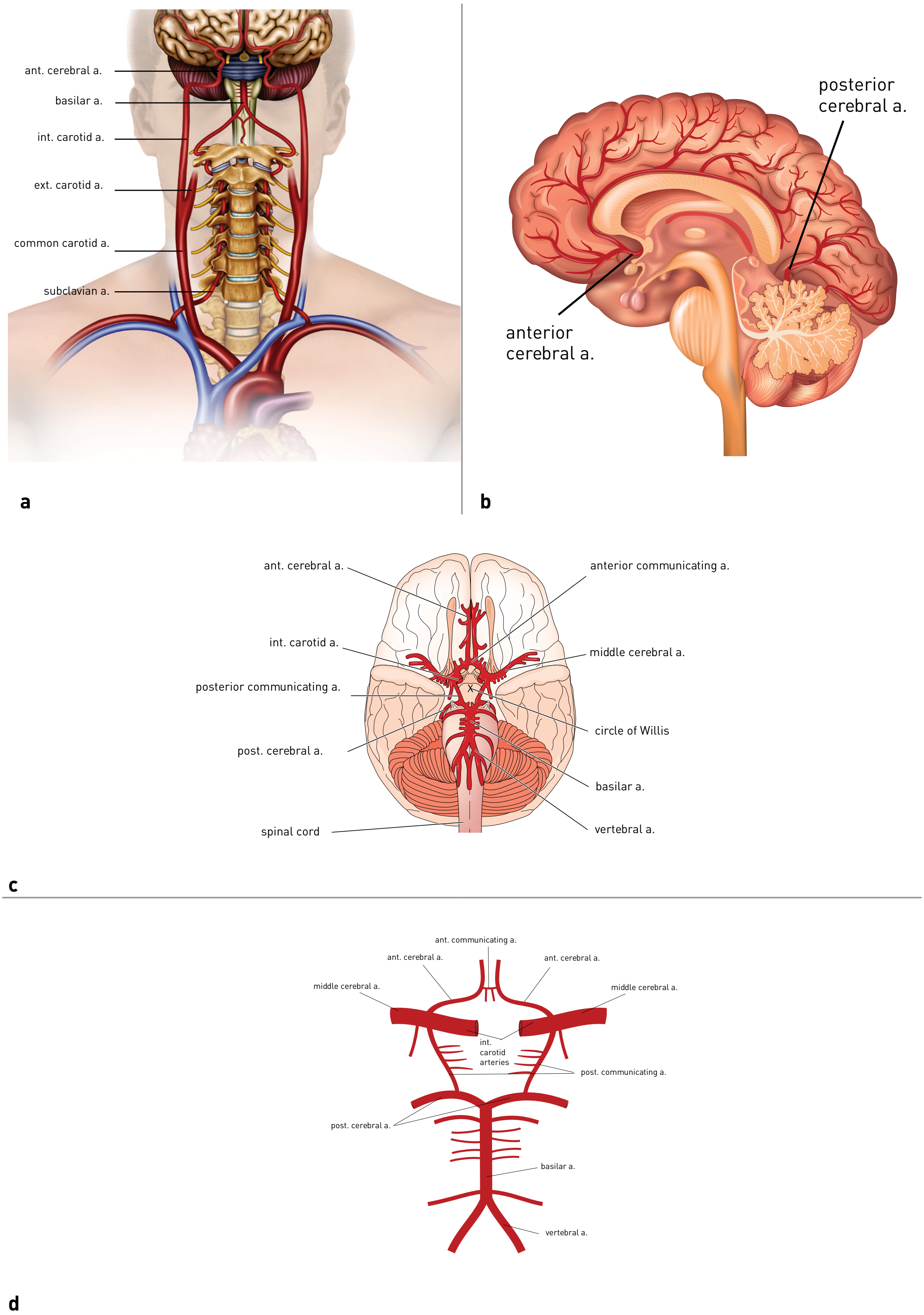


Figure 9.14. Arteries of the brain. **a.** vertebral artery, common carotid artery and the course of its internal carotid branch **b.** distribution of the anterior cerebral and posterior cerebral arteries on the medial aspect of the cerebral hemisphere **c-d.** circle of Willis.

How is the venous drainage of the brain?

The venous blood from the CNS in the skull is drained by **superficial** and **deep veins** and **dural venous sinuses**. After draining all the venous blood from the skull, the sinuses open into the **internal jugular vein**. Thus, the venous blood of the brain is now outside the skull to return into the heart.

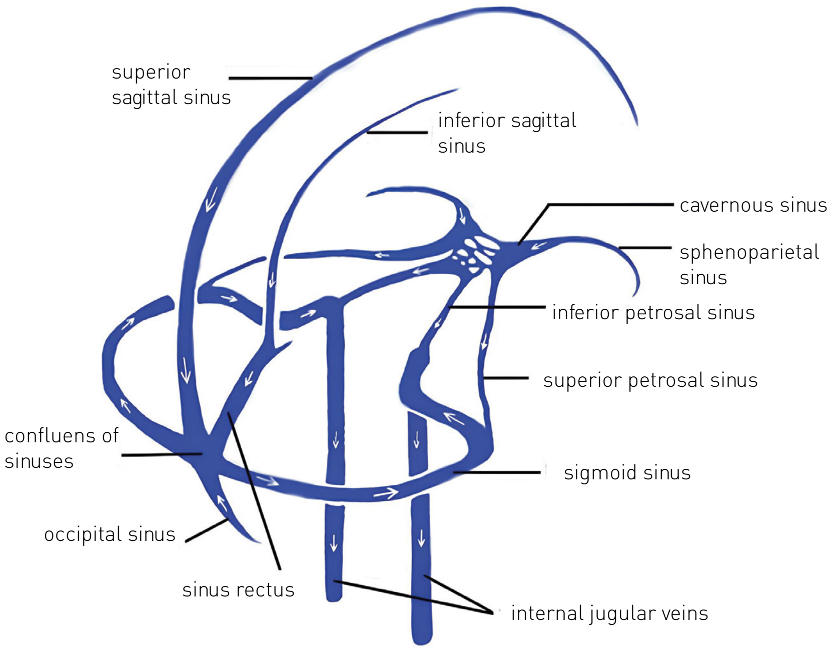


Figure 9.15. Dural venous sinuses.

Superficial Veins

These drain the outer surfaces of the cerebral hemispheres:

superior cerebral veins: drain into the superior sagittal sinus.

superficial middle cerebral veins: drain into the cavernous sinus.

cerebral inferior veins: drain into the transverse sinus.

The superficial middle cerebral vein has also connections with the superior sagittal and transverse sinuses via the superior (Trolard vein) and inferior (Labbe vein) anastomotic veins, respectively.

Deep Veins

basal v. (Rosenthal vein): formed by the union of anterior cerebral v. and deep medial cerebral v.

internal cerebral v.: formed by the union of thalamostriate v. and choroideal v.

great cerebral v. (Galen vein): formed by the union of basal v. and internal cerebral v., drains into the sinus rectus.

After the venous blood of the brain is collected by the superficial and deep veins, it is transferred to the dural venous sinuses formed between the two layers of the dura mater (Figure 9.15). The dural venous sinuses and their locations are as follows:

superior sagittal sinus: lies along the superior edge of the falx cerebri.

inferior sagittal sinus: located along the inferior free edge of the falx cerebri, drains into the straight sinus.

straight sinus: located between the falx cerebri and tentorium cerebelli, drains into the confluence of sinuses.

occipital sinus: the smallest dural sinus, extends between the foramen magnum and the internal occipital protuberance.

confluence of sinuses: receives blood from the superior sagittal, occipital, and transverse sinuses.

cavernous sinus: surrounds the sella turcica and drains via petrosal sinuses. Unique for containing several cranial nerves and the internal carotid artery.

sphenoparietal sinus: located on the ala minor of the sphenoid bone and transfers venous blood from the superficial veins to the cavernous sinus.

superior petrosal sinus: originates from the cavernous sinus, extends over the petrous part of the temporal bone and opens into the sigmoid sinus.

inferior petrosal sinus: originates from the cavernous sinus, extends downward and outward and opens into the sigmoid sinus.

transverse sinus: begins at the internal occipital protuberance, proceeds laterally and joins the sigmoid sinus.

sigmoid sinus: continuation of the transverse sinus, exits the skull through the jugular foramen, and drains into the internal jugular vein.

PERIPHERAL NERVOUS SYSTEM (PNS)

The PNS comprises spinal nerves and cranial nerves:

Spinal Nerves: 31 pairs, formed by the union of anterior (motor) and posterior (sensory) roots. In the cervical and lumbosacral regions, they form plexuses (e.g., cervical, brachial, lumbar, and sacral plexuses).

Cranial Nerves: 12 pairs originating from the brain. They may be motor, sensory, or mixed nerves. These exit from the holes at the skull base and spread throughout the head and neck region. Only the vagus n. (cranial nerve X) extends to the chest and abdominal regions.

Cranial Nerve Classifications Based on Function:

Afferent (sensory):

GSA (General Somatic Afferent): General sensations from skin and mucosa.

GVA (General Visceral Afferent): Sensations from internal organs.

SSA (Special Somatic Afferent): Vision and hearing.

SVA (Special Visceral Afferent): Taste and smell.

Efferent (motor):

GSE (General Somatic Efferent): Stimulate non-branchial muscles (e.g., eye, tongue).

GVE (General Visceral Efferent): Stimulate smooth muscles and glands.

SVE (Special Visceral Efferent): Stimulate branchial arch-derived muscles (e.g., facial expression, mastication, pharyngeal muscles).

There are 12 pairs of cranial nerves in the human body (Figure 9.16). Their formation, central connections, and associated cortical areas are as follows:

I. Cranial Nerve: Olfactory Nerve

The olfactory nerve is responsible for the sense of smell. It consists of numerous fine fibers (**fila olfactoria**) formed by receptor cells located in the upper nasal mucosa. These fibers pass through the upper nasal wall and synapse with cells in the olfactory bulb located on the brain's inferior surface. Axons of these cells continue in the olfactory tract and directly reach the piriform cortex (olfactory cortex) without passing through the thalamus. This area connects with structures such as the amygdala and entorhinal cortex, which are part of the limbic system. The connection to the limbic system links smell to memory and emotions.

II. Cranial Nerve: Optic Nerve

The optic nerve transmits visual information. It is formed by the axons of ganglion cells in the retina. These fibers exit the eye and travel in the orbit posteriorly, pass through the optic canal into the cranial cavity, where they meet fibers from the opposite eye at the optic chiasm. Fibers from the medial retina cross to the opposite side at the chiasm, while fibers from the lateral retina remain on the same side. After the chiasm, fibers continue as the optic tract to the lateral geniculate nucleus (LGN) of the thalamus. Visual signals are then relayed via the optic radiation to the visual cortex in the occipital lobe.

III. Cranial Nerve: Oculomotor Nerve

This nerve innervates some of the extraocular muscles and internal eye muscles. It originates from the midbrain and travels through the cavernous sinus and superior orbital fissure to reach the orbit. It supplies most of the extraocular muscles: superior rectus, inferior rectus, medial rectus, inferior oblique and levator palpebrae superioris. Additionally, sphincter pupillae muscle and ciliary muscle are innervated by the oculomotor nerve.

IV. Cranial Nerve: Trochlear Nerve

The trochlear nerve is unique in emerging from the posterior surface of the brainstem. It loops forward and passes through the cavernous sinus and superior orbital fissure to reach the orbit. It innervates the superior oblique muscle, which controls downward and lateral eye movement.

V. Cranial Nerve: Trigeminal Nerve

The trigeminal nerve is the largest cranial nerve, emerging from the anterolateral surface of the pons. It has both sensory and motor fibers and three main branches:

ophthalmic n.: general sensory input from the forehead and vertex.

maxillary n.: sensory input from the midface.

mandibular n.: sensory input from lower face and lower jaw. Motor fibers supply the muscles of mastication, the anterior belly of the digastric, mylohyoid, and tensor tympani.

VI. Cranial Nerve: Abducens Nerve

Emerging from the groove between the pons and medulla oblongata, this nerve passes through the cavernous sinus and superior orbital fissure to reach the orbit. It innervates the lateral rectus muscle, which abducts the eye.

VII. Cranial Nerve: Facial Nerve

This nerve contains sensory, motor, and autonomic fibers. It emerges between the pons and medulla, passes through the internal acoustic meatus, traverses the temporal bone, and exits at the stylomastoid foramen. It supplies:

motor fibers to facial expression muscles, posterior digastric, and stylohyoid.

sensory input to receive taste from the anterior two-thirds of the tongue via the chorda tympani.

autonomic (parasympathetic) fibers to salivary glands (submandibular, sublingual), lacrimal glands, and nasal/oral mucosa.

VIII. Cranial Nerve: Vestibulocochlear Nerve

This nerve is responsible for hearing and balance. It consists of fibers from the cochlea (hearing) and vestibular apparatus (balance), passing through the internal acoustic meatus to nuclei in the brainstem.

IX. Cranial Nerve: Glossopharyngeal Nerve

Emerging from the upper medulla, this nerve contains sensory, motor, and autonomic fibers. It provides:

sensory fibers to receive taste and general sensation from the posterior third of the tongue.

autonomic (parasympathetic) fibers to the parotid gland.

sensory input from the carotid sinus and body.

X. Cranial Nerve: Vagus Nerve

A mixed nerve emerging from the medulla, it innervates structures in the head, neck, thorax, and abdomen. It provides:

Sensory: From the pharynx, larynx, and abdominal organs.

Motor: To the pharyngeal and laryngeal muscles.

Autonomic: Parasympathetic fibers to thoracic and abdominal viscera.

XI. Cranial Nerve: Accessory Nerve

This nerve has a cranial root (from the medulla) and a spinal root (from the cervical spinal cord). It supplies:

Motor fibers to the sternocleidomastoid and trapezius muscles.

XII. Cranial Nerve: Hypoglossal Nerve

Emerging from the medulla, it innervates all intrinsic and most extrinsic tongue muscles.

CLINICAL RELEVANCE

Papilloedema is the swelling of the optic disc (the area where the optic nerve-CN II connects the eyeball) due to increased pressure inside the skull (intracranial pressure). This pressure can result from conditions such as brain tumors, head injuries, brain infections, or hydrocephalus. It often affects both eyes and may cause blurred or double vision, headaches, nausea, and sometimes temporary vision loss. Papilloedema is a sign of a serious underlying condition and requires prompt medical evaluation and treatment.

Trigeminal neuralgia is a chronic pain condition that affects the **trigeminal nerve**, which carries sensation from the face to the brain. It causes sudden, severe, electric shock-like or stabbing pain in the face, usually on one side. The pain can be triggered by simple activities like chewing, talking, touching the face, or even a light breeze. It is often caused by pressure on the nerve, such as from a blood vessel, or may be related to multiple sclerosis or other nerve disorders. Trigeminal neuralgia can be very painful but is often manageable with medications or surgical treatments.

Bell's palsy is a sudden, temporary weakness or paralysis of the muscles on one side of the face. It occurs when the facial nerve-CN VII becomes inflamed or compressed, often due to a viral infection. Symptoms usually appear suddenly and can include drooping of the mouth, inability to close the eye, loss of facial expression, and drooling on the affected side. Most people begin to recover within a few weeks, and full recovery often occurs within 3 to 6 months. Treatment may include medications like corticosteroids, eye protection, and sometimes physical therapy.

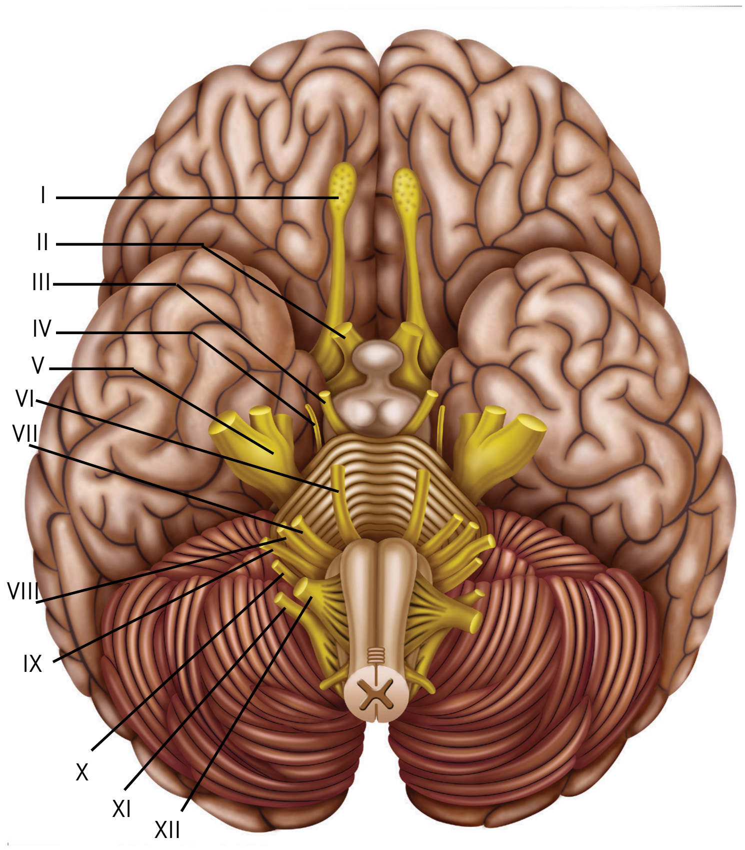


Figure 9.16. Cranial nerves.

AUTONOMIC NERVOUS SYSTEM (ANS)

The autonomic nervous system (ANS) is the involuntary division of the nervous system that regulates the activities of internal organs and glands. It maintains the body's internal balance (homeostasis), supports metabolic functions, and manages stress. The ANS operates hierarchically, starting from the cerebral cortex and extending to lower control centers. The hypothalamus in the brainstem serves as the central coordination hub for the ANS, regulating subordinate centers in the brainstem. These centers send fibers to connect with neurons in ganglia located in various body regions. After synapsing in these ganglia, fibers travel to their target structures through nerves.

Subdivisions of the ANS

The ANS comprises two opposing subsystems:

Sympathetic Nervous System

Prepares the body for stressful situations, often referred to as the "fight or flight" response.

Effects include:

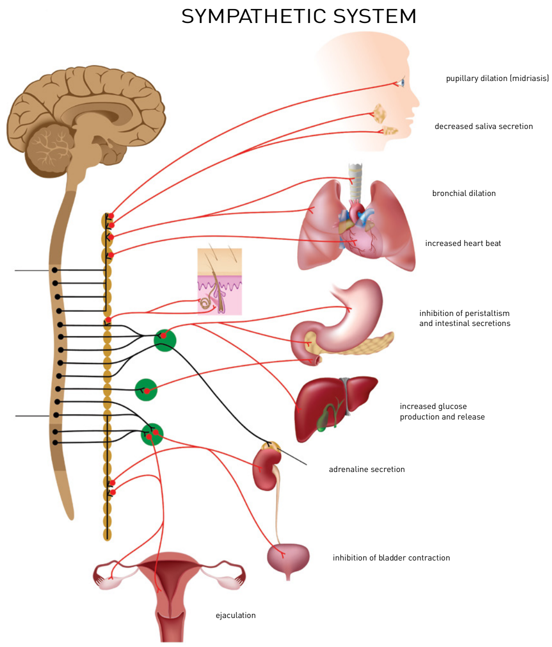
Increasing heart rate and contraction strength.
Enhancing respiratory rate and dilating airways.
Constricting superficial blood vessels to redirect blood to muscles and the brain.
Activating sweat glands.
Dilating pupils.
Raising body hairs.
Suppressing digestive and urinary processes.
This system equips the body to respond effectively to danger or emergencies.

Parasympathetic Nervous System

Dominates during restful and relaxed conditions, supporting the "rest and digest" response.

Effects include:

Reducing heart rate and blood pressure.
Stimulating digestion and nutrient absorption.
Constricting pupils.
Enhancing urinary formation.
Promoting tissue repair and growth.
Unlike the sympathetic system, parasympathetic fibers and related ganglia are found in certain cranial nerves (III, VII, IX, X).



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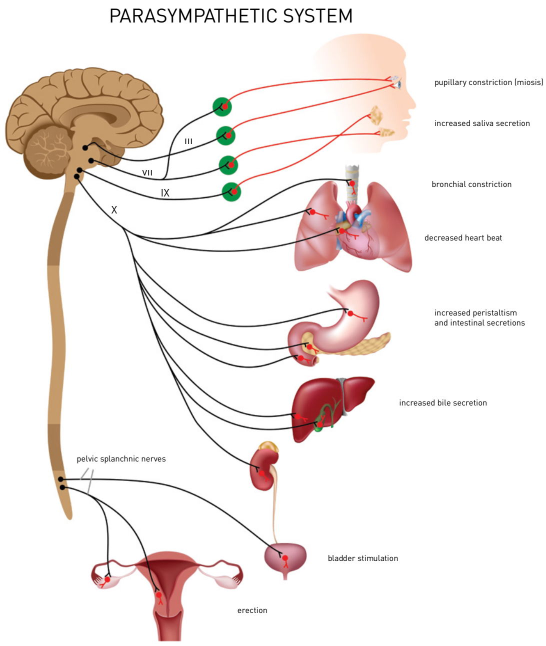

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Figure 9.17. Effects of **a.** sympathetic and **b.** parasympathetic systems on organs. After the spinal cord, the sympathetic system-related stimuli pass through the truncus sympathicus and from there they go to the relevant organ via different nerves. The parasympathetic system-related stimuli are transmitted to the relevant structures either within some cranial nerves or via the pelvic splanchnic nerves.

What is the sympathetic trunk?

The sympathetic trunk) is a chain of ganglia associated with the sympathetic nervous system. It consists of 22–23 paired ganglia extending along both sides of the vertebral column, from the base of the skull to the coccyx. These ganglia are the sites where sympathetic fibers synapse before traveling to target organs.

This chain plays a vital role in coordinating and distributing sympathetic signals throughout the body..

Sample Questions on Nervous System Anatomy

1. What is the term for the connections between nerve cells?
   a) Axon
   b) Dendrite
   c) Soma
   d) Synapse
   e) Nucleus

2. Which of the following statements about the cerebrum is **not** correct?
   a) It is divided into two hemispheres by the longitudinal cerebral fissure.
   b) The central sulcus separates the frontal and temporal lobes.
   c) The folds between sulci are called gyri.
   d) The corpus callosum is the white matter that connects the two hemispheres.
   e) Its outer part, called the cortex, is made of gray matter.

3. Which of the following is **not** observed in the midbrain?
   a) Colliculus superior
   b) Colliculus inferior
   c) Interpeduncular fossa
   d) Cerebral peduncle
   e) Pyramid

4. Which of the following is **not** observed in the medulla oblongata?
   a) Anterior median fissure
   b) Pyramidal decussation
   c) Basilar sulcus
   d) Olive
   e) Pyramid

5. Which of the following is **not** one of the nuclei in the cerebellum?
   a) Vestibular nucleus
   b) Dentate nucleus
   c) Globose nucleus
   d) Emboliform nucleus
   e) Fastigial nucleus

6. At what level does the spinal cord terminate in adults?
   a) Below T10
   b) Below T12
   c) Below L1
   d) Below S1
   e) Below S5

7. What is the name of the point where the spinal cord terminates?
   a) Cauda equina
   b) Sacral Horn
   c) Lateral funiculus
   d) Spinal segment
   e) Conus medullaris

8. Where is the cerebrospinal fluid (CSF) located?
   a) Epidural space
   b) Subdural space
   c) Subarachnoid space
   d) Subpial space
   e) Epipial space

9. What connects the third and fourth ventricles?
   a) Interventricular foramen
   b) Cerebral aqueduct
   c) Foramen of Luschka
   d) Foramen of Magendie
   e) Foramen of Monroe

10. Which artery is located on the anterior surface of the pons?
   a) Basilar
   b) Vertebral
   c) Anterior communicating
   d) Posterior communicating
   e) Posterior inferior cerebral

Answers: 1.D, 2. B, 3.E, 4.C, 5.A, 6.C, 7.E, 8.C, 9.B, 10.A

DIGESTIVE SYSTEM

DIGESTIVE SYSTEM

DEFINITIONS

All living organisms require energy to grow, develop, and maintain daily life. This energy is obtained from nutrients processed by the digestive system.

What are some general terms related to the digestive system?

ingestion: Eating; the intake of food via the mouth.

mastication: Chewing; the mechanical breakdown of food in the mouth by teeth, making it small enough to swallow.

deglutition: Swallowing; forming chewed food into a bolus and moving it to the esophagus.

peristalsis: The rhythmic contractions of smooth muscles in the digestive tract that propel food forward.

digestion: The chemical breakdown of large food molecules into smaller molecules.

secretion: The release of fluids produced by epithelial cells and glands into the digestive tract.

absorption: The process of small nutrient molecules being taken up by intestinal cells into the blood or lymphatic system.

defecation: The elimination of undigested food and waste as feces through the anus.

What structures make up the digestive system?

The organs and structures involved in digestion are collectively known as the **digestive** system. Anatomically, it is divided into two main components:

digestive tract

accessory organs and glands

Digestive Tract: is a continuous tube approximately 8-10 meters long extending from the mouth to the anus (Figure 10.1). It includes:

mouth (oral cavity)

pharynx (throat)

esophagus

stomach

small intestines

large intestines

anus

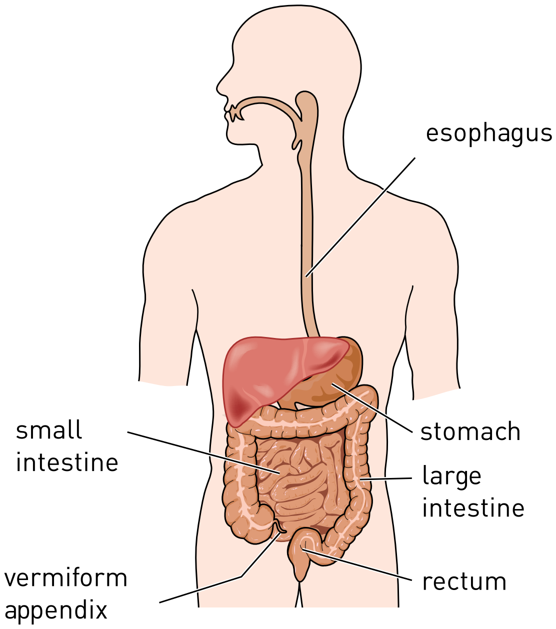


Figure 10.1. Organs of the digestive system.

Accessory Organs of the Digestive System: These are organs that produce various secretions and transmit these secretions into the digestive system through specific ducts. They include:

liver
gallbladder
pancreas
salivary Glands

ORGANS OF THE DIGESTIVE SYSTEM

ORAL CAVITY

The oral cavity is the initial part of the digestive system. It is bounded:

anteriorly by the upper and lower lips,
posteriorly by the isthmus of fauces,
inferiorly by the floor of the mouth,
superiorly by the hard palate,
laterally by the cheeks.

What are the parts of the oral cavity?

The oral cavity has two sections:

Vestibule: The space between the lips/cheeks (externally) and the teeth/gums (internally).

Proper oral cavity: The larger internal space bounded:

anteriorly and laterally by the teeth and gums,
inferiorly by the floor of the mouth,
superiorly by the hard and soft palates, with the tongue occupying the space (Figure 10.2).

What is the rima oris?

The **rima oris** (oral opening; orifice of the mouth) is the opening between the lips and serves as the entry point to the digestive system.

What is the isthmus of fauces?

The **isthmus of fauces** is the posterior boundary of the oral cavity, opening into the pharynx. It is formed by:

superiorly: the **uvula**,

laterally: two folds (the **palatoglossal arch** and **palatopharyngeal arch**),

inferiorly: the tongue.

Between the two lateral folds lies the **palatine tonsil**.

LIPS AND CHEEKS

Lips are flexible structures surrounding the oral opening. At the corners of mouth which is called as the **labial commissure**, the upper and lower lips meet. Lips are composed of skin, fat, muscle and mucous membrane. Skin lines the external surface of the lips and continuous with the mucous membrane at the border called as **vermillion line**. Upper lip has a distinct midline zone which is called as the **philtrum**.

Cheeks are the area bounded superiorly by the zygomatic arch, inferiorly by the lower border of the mandible, posteriorly by the ear, anteriorly by the corners of the lips. Cheeks are covered over by skin externally, and lined with mucosa internally. They contain fat pads and facial expression muscles.

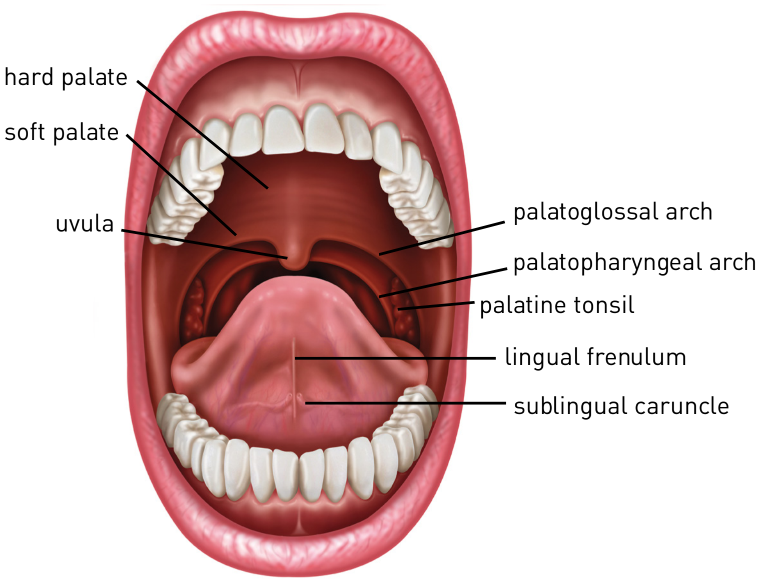


Figure 10.2. Structures in the oral cavity.

TONGUE

The tongue is a muscular organ located on the floor of the mouth, covered with mucosa. It plays roles in speech, swallowing, chewing, and taste perception.

What are the parts of the tongue?

The tongue consists of three parts:

root: attached to the hyoid bone and mandible.

body: the central, movable portion.

tip (apex): the pointed anterior part.

Although the tip and body of the tongue are mobile, the root of the tongue is attached to the hyoid bone and the mandible. The upper surface of the tongue facing the upper palate and pharynx is called the **dorsum of the tongue**, and two grooves can be observed on it: in the midline the **median sulcus of tongue** and the **terminal sulcus** in the shape of an inverted V at the back. The back of the tongue facing the pharynx is the root of the tongue, and the lymph nodes called the **lingual tonsils** are located here (Figure 10.3).

What are the lingual papillae?

The anterior two-thirds of the tongue is covered with **papillae**, which are small projections of the mucosa (Figure 10.3). These include:

filiform papillae: The most numerous, small, and thread-like papillae. They provide a rough surface and involved in mechanical breakdown of food.

fungiform papillae: Mushroom-shaped, reddish papillae located on the sides and tip of the tongue. They contain taste buds sensitive to sweet and salty flavors.

circumvallate papillae: Large, circular papillae arranged in a V-shape in front of the terminal sulcus. They number 7–12 and are sensitive to bitter tastes.

foliate papillae: Leaf-like papillae on the sides and back of the tongue, sensitive to sour flavors.

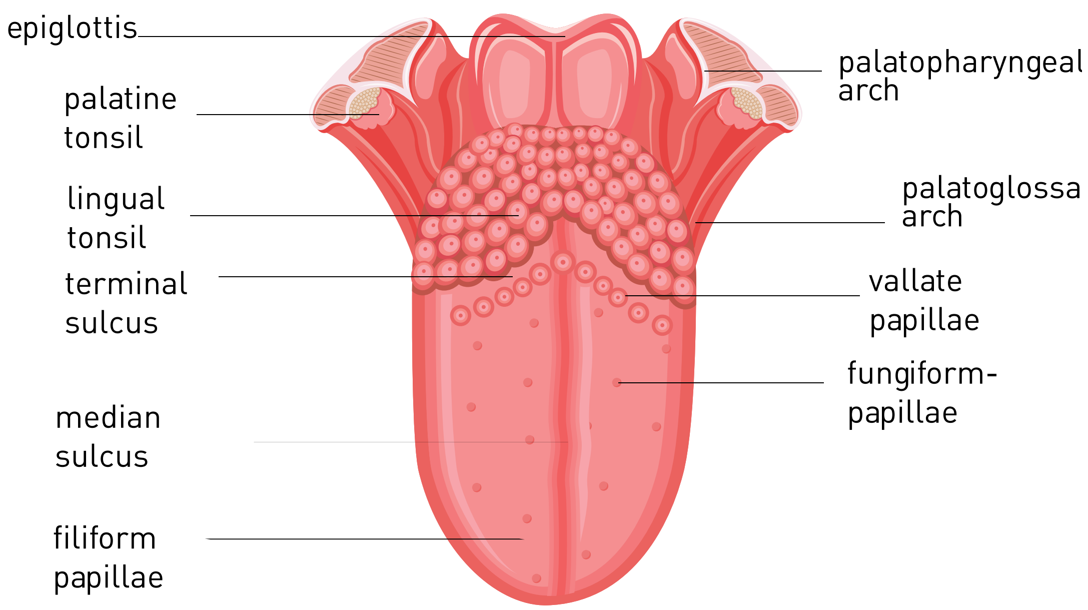


Figure 10.3. Lingual papillae, sulci and several structures of the root of tongue.

What is the lingual frenulum?

The **lingual frenulum** is a midline mucosal fold that connects the underside of the tongue to the floor of the mouth (Figure 10.2). On either side of the frenulum are the **sublingual caruncle**, which are openings of the ducts from the submandibular salivary glands.

What are the muscles of the tongue?

The tongue consists of **intrinsic** and **extrinsic** muscles:

Intrinsic Muscles

These muscles alter the shape of the body of tongue (e.g., flattening or curling the tongue). They are four pairs of:

- **superior** and **inferior longitudinal m.:** runs lengthwise along the tongue.
- **transverse lingual m.:** runs horizontally across the tongue.
- **vertical lingual m.:** runs vertically within the tongue.

Extrinsic Muscles

These four pairs of muscles connect the tongue to surrounding structures and change its position:

- **genioglossus m.:** extends from the mandible to the tongue; protrudes the tongue.
- **hyoglossus m.:** extends from the hyoid bone to the tongue; pulls the tongue downward.
- **styloglossus m.:** extends from the styloid process to the tongue; aids in swallowing.
- **palatoglossus m.:** extends from the posterior palate to the tongue; elevates the back of the tongue.

How is the blood supply and the venous drainage of the tongue?

The tongue is supplied by the branches of:

- **lingual a.**
- **facial a.**
- **ascending pharyngeal a.**

Venous blood drains through the **lingual v.** into the **internal jugular v.**.

How is the lymphatic drainage of the tongue?

- The tip of the tongue drains into the **submental nodes**.
- The anterior two-thirds drains into the **submandibular nodes**.
- The posterior one-third drains into the **deep cervical lymph nodes**.

How is the innervation of the tongue?

Motor Innervation

The intrinsic and extrinsic muscles (except for the **palatoglossus m.**) are innervated by the **hypoglossal nerve** (12th cranial nerve). **Palatoglossus m.** is innervated by the **pharyngeal plexus**.

Sensory Innervation

The tongue also receives nerves for **general sensation** (pain, temperature, touch) and **taste**:

- **general sensation:**
  - Anterior two-thirds: **lingual n.** (branch of the mandibular nerve).
  - Posterior one-third: **glossopharyngeal n.** (9th cranial nerve).

taste sensation:

Anterior two-thirds: **chorda tympani** (branch of the facial nerve).

Posterior one-third: **glossopharyngeal n.** (9th cranial nerve).

TEETH

Teeth are structures which enable the breakdown of nutrients by chewing. They are embedded in the tooth sockets of the maxilla and mandible called **alveolus**.

What are the parts of the tooth?

A tooth consists of the hard tooth tissue called **dentin**, covered with the outermost **enamel** layer (Figure 10.4).

It basically consists of three parts:

Crown (corona dentis): The part that remains outside the tooth socket and is visible when viewed from the outside, covered with enamel.

Neck (collum dentis,): The part between the crown and the root, where the tooth meets the gum.

Root (radix dentis): The part of the tooth covered with **cementum** that enters the tooth socket.

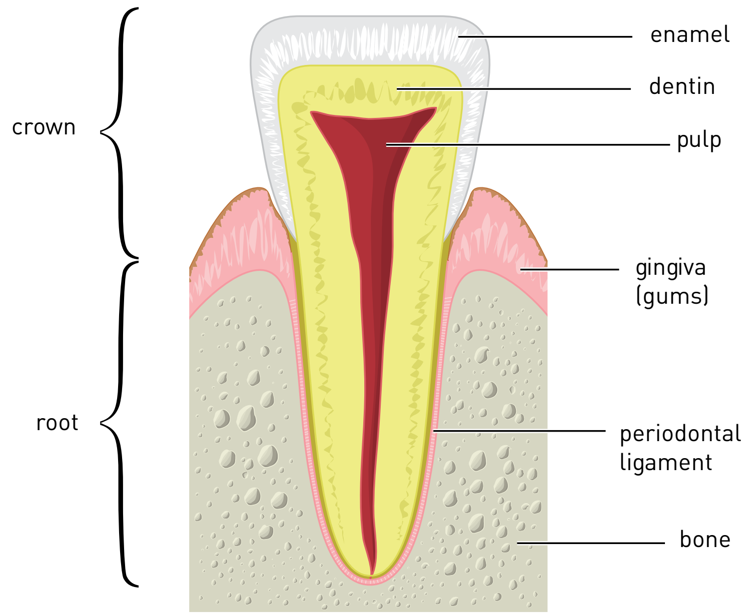


Figure 10.4. Parts of a tooth.

The space inside the tooth is called the **pulp cavity (pulp chamber)**, and the vessels, nerves and loose connective tissue extending inside is called the **tooth pulp**.

What are the types of teeth?

Teeth are classified based on their structure and function (Figure 10.2):

incisors: four in each jaw, totaling eight, located at the front of both jaws, on either side of the midline, designed for cutting and slicing food.

canines: two in each jaw, totaling four, the longest teeth, with larger roots than other teeth, serve to tear food.

premolars: four in each jaw, totaling eight, located behind the canines; shorter than canines, single-rooted and assist in chewing.

molars: six in each jaw, totaling twelve, positioned behind the premolars, play the largest role in chewing.

Classification of Teeth

Teeth are categorized into two groups:

primary teeth (deciduous teeth): also known as milk teeth, these are temporary and consist of 20 teeth; four incisors, two canines, and four molars per jaw. They erupt between **6–8 months** and are completely in place by about 2 years of age. They are shed between **6–12 years**, replaced by permanent teeth.

permanent teeth: Permanent teeth begin to erupt around at the age of 6 and remain throughout life. They are composed of 32 teeth: four incisors, two canines, four premolars, and six molars per jaw.

GUMS (GINGIVA)

Gums are formed by the mucosa and connective tissue that cover the maxilla and mandible bones within the oral cavity. Gums are part of the oral mucosa but is firmly attached to the underlying bones and does not contain glands.

PALATE

The palate is the structure that separates the oral cavity from the nasal cavity, forming the roof of the mouth and the floor of the nasal cavity.

What are the parts of the palate?

The palate is divided into two sections:

hard palate: forms the anterior 2/3 of the palate. Palatine process of the maxilla and the horizontal lamina of the palatine bone constitutes the hard palate. It takes part in speaking and eating. The maxillae of both sides meet in the midline called the **palatine raphe** which forms a ridge. Contains mucous glands known as **palatine glands** in its mucosa.

soft palate: forms the posterior one-third of the palate. It is made of muscles and fibrous tissue located behind the hard palate. It features the **uvula**, a conical projection hanging from the posterior center. The uvula elevates during swallowing to prevent food from entering the nasopharynx. There are two curved arches extending downwards on both sides of the uvula. The one in the front is called the **palatoglossal arch**, and the one at the back is the **palatopharyngeal arch**. There are muscles with the same name inside these folds. Apart from these muscles, there are **tensor veli palatini m., levator veli palatini m.** and **uvula m.** There is a pit between these two arches called the **tonsillary fossa**, which contains the palatine tonsil. With the function of these muscles, the soft palate is stretched, moves upwards and the swallowing is carried out properly.

How is the blood supply of the palate?

Arteries of the palate are:

ascending palatine a.

greater palatine a.

ascending pharyngeal a.

Veins of the palate drain into:

pterygoid plexus

pharyngeal plexus

internal jugular v.

Lymphatics of the palate are:

deep cervical nodes

MASTICATION MUSCLES

There are 4 muscles that attach on to the mandible and move it to perform the chewing. All are innervated by the **mandibular nerve**, a branch of the **trigeminal nerve**.

masseter m.: originates from the zygomatic bone and zygomatic arch and inserts to the mandibular ramus. Elevates the mandible and closes the mouth during chewing, and assists in protraction (moving the jaw forward).

temporalis m.: originates from the temporal bone and its fascia and inserts to coronoid process of the mandible. Elevates the mandible and closes the mouth during chewing, and assists in retraction (pulling the jaw backward).

lateral pterygoid m.: originates from the sphenoid bone, palatine bone, and maxilla and inserts to the pterygoid tuberosity of the mandible. Depresses the mandible (opens the mouth) and assists in protraction. It is the only mastication muscle that helps in opening the mouth.

medial pterygoid m.: originates from the sphenoid bone and inserts to the mandible. Helps close the jaw and assists in protraction.

PHARYNX

The **pharynx** is a shared region of the digestive and respiratory systems, connecting the oral cavity to the esophagus and the nasal cavity to the larynx (Figure 10.5). It extends from the skull base to the level of the 6th cervical vertebra (C6), where it narrows and continues as the **esophagus**. The pharynx is a fibromuscular structure, and its internal cavity is called the **pharyngeal cavity**.

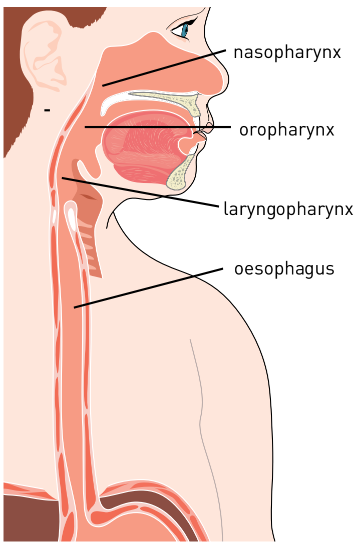


Figure 10.5. Pharynx and esophagus.

What are the parts of the pharynx?

The pharynx is divided into three parts based on its connections:

nasopharynx (nasal part): the upper part of the pharynx connected to the nasal cavity. It extends from the skull base to the level of the soft palate. It communicates with the nasal cavity through passages called the choanae. This part contains the **pharyngeal tonsil** (adenoid) in its posterior roof. On the lateral wall, there is the **pharyngeal opening of auditory tube** which connects to the middle ear. Behind this opening is a lymphoid tissue cluster called **tubal tonsil**.

oropharynx (oral part): the middle part of the pharynx, connecting to the oral cavity. It extends from the soft palate to the level of the hyoid bone (C3). It communicates with the oral cavity via the **isthmus of fauces** and contains the **palatine tonsil**.

laryngopharynx (laryngeal part): the lower part of the pharynx, located behind the larynx and connecting to the esophagus. It extends from the level of C3 to C6 vertebrae. It communicates with the larynx via the **laryngeal inlet**.

What are the muscles of the pharynx?

The pharyngeal muscles are arranged in two layers:

circular muscles (outer layer):

- **superior pharyngeal constrictor m.**
- **middle pharyngeal constrictor m.**
- **inferior pharyngeal constrictor m.**

longitudinal muscles (inner layer):

- **stylopharyngeus m.**
- **salpingopharyngeus m.**
- **palatopharyngeus m.**

All pharyngeal muscles, except **stylopharyngeus m.**, are innervated by the **vagus n.**

Stylopharyngeus m. is innervated by the **glossopharyngeal n.**

What are the blood supply and lymphatics of the pharynx?

The pharynx receives arterial blood from:

- **ascending pharyngeal a.**
- **superior and inferior thyroid a.**
- **ascending palatine a.**
- **lesser palatine aa.**

Venous blood drains into:

pharyngeal plexus, which communicates with:

- **facial v.**
- **internal jugular v.**

Lymphatic drainage occurs via:

- **submandibular nodes**
- **retropharyngeal nodes**
- **deep cervical lymph nodes**

What is Waldeyer's lymphatic ring?

Waldeyer's lymphatic ring refers to the lymphoid structure formed by:

- **lingual tonsil** (at the root of the tongue),
- **palatine tonsil** (on the posterior lateral sides of the oral cavity),
- **tubal tonsil** (in the nasopharynx),
- **pharyngeal tonsil** (on the posterior superior wall of the pharynx).

This ring acts as a protective barrier at the transition point from the mouth and nose to the pharynx.

CLINICAL RELEVANCE

Tonsillitis is the inflammation of the palatine tonsils. It is often caused by viral or bacterial infections, such as the common cold or streptococcus bacteria. Symptoms include a sore throat, difficulty swallowing, fever, and swollen tonsils, which may appear red or have white spots. While viral tonsillitis typically resolves on its own, bacterial tonsillitis may require antibiotics for treatment. In some cases, if tonsillitis becomes chronic or severe, a **tonsillectomy** (surgical removal of the tonsils) may be considered.

ESOPHAGUS

The esophagus is a muscular tube, **18–25 cm long** and approximately **2 cm in diameter**, extending from the pharynx to the stomach. Its primary function is to transport food to the stomach via **peristaltic movements**. It begins at the **C6 level** (behind the cricoid cartilage), enters the thoracic cavity, passing behind the **trachea** and the **heart**, in front of the vertebral column. At the **T10–T11** levels, it passes through the **esophageal hiatus** in the diaphragm and continues into the abdominal cavity to join the stomach.

What are the parts of the esophagus?

The esophagus is divided into three regions based on its location:

- **cervical part:** extends from the **cricoid cartilage** to the **jugular notch**
- **thoracic part:** runs from the **jugular notch** to the **T10–T11 levels** within the thoracic cavity.
- **abdominal part:** extends from the diaphragm to its connection with the stomach.

How is the muscle composition of the esophagus?

- the upper 1/3: **striated muscle** (voluntary).
- the middle 1/3: a mix of **striated** and **smooth muscles**.
- the lower 1/3: **smooth muscle** (involuntary).

This composition affects the speed of food movement, with faster transit in the upper part and slower movement in the lower part.

Where are the constrictions of the esophagus?

The esophagus has three physiological constrictions:

at the pharyngo-esophageal junction where it connects with the pharynx (narrowest part).

where it crosses the aortic arch and left bronchus

where it passes through the esophageal hiatus

How is the blood supply and lymphatic of the esophagus?

Since the esophagus extends from the neck to the abdomen, it receives branches from different arteries in the regions it passes through. The arteries of the esophagus are:

inferior thyroid a.: supplies the cervical portion.

thoracic aorta: supplies the thoracic portion.

left gastric a.: supplies the abdominal portion.

Veins of the esophagus are:

caval system: via **v. azygos**, **v. hemiazygos**, and **v. thyroidea inferior**.

portal system: via **v. gastrica sinistra**.

Lymphatics of the esophagus are:

deep cervical nodes

mediastinal nodes

left gastric nodes

CLINICAL RELEVANCE

Esophageal varices are enlarged or swollen veins in the lower part of the esophagus, usually caused by increased pressure in the liver (**portal hypertension**). This increased pressure can result from liver diseases like cirrhosis. The swollen veins are fragile and can easily rupture, leading to potentially life-threatening bleeding.

How is the nerve supply of the esophagus?

Parasympathetic innervation is provided by the **vagus n.** while the sympathetic innervation is through the **thoracic sympathetic trunk**.

STOMACH

The stomach is the widest part of the digestive tract. Its shape varies from person to person and when it is empty and full in the same person, but it can be likened to the letter "J". It is connected to the to the esophagus via the **cardiac orifice** and to the duodenum via the **pyloric orifice**. It is located in the upper central and left hypochondriac regions of the abdominal cavity, at approximately the **L2 level** (Figure 10.6).

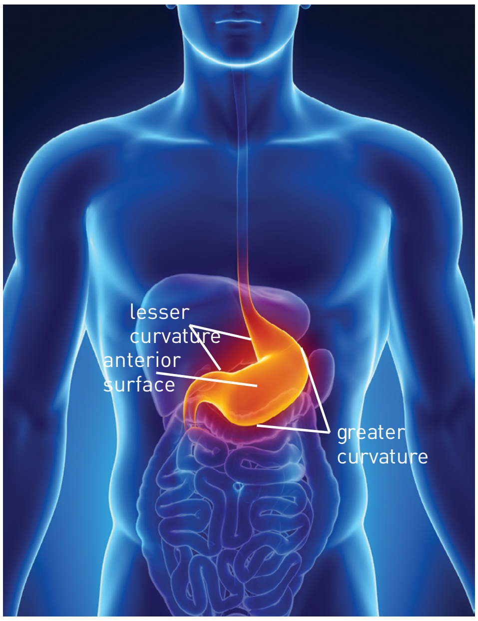


Figure 10.6. Location of the stomach in the body.

What are the structures surrounding the stomach?

The stomach is surrounded by:

superiorly: the inferior surface of the diaphragm.

posteriorly: the left kidney, adrenal gland, spleen, pancreas, and splenic flexure of the transverse colon.

anteriorly: the visceral surface of the liver, diaphragm, anterior abdominal wall, and ribs 7–9.

What are the surfaces and margins of the stomach?

The stomach has **two surfaces:**

anterior surface

posterior surface

and **two margins:**

lesser curvature: shorter upper margin

greater curvature: longer lower margin

What are the parts of the stomach?

The stomach consists of four main parts anatomically (Figure 10.7a):

cardia: where the stomach connects to the esophagus.

fundus: the dome-shaped upper portion above the horizontal line of the cardia, often filled with air.

body: which is the largest part of the stomach.

pylorus: the narrow distal section leading to the duodenum, including:

pyloric antrum

pyloric canal

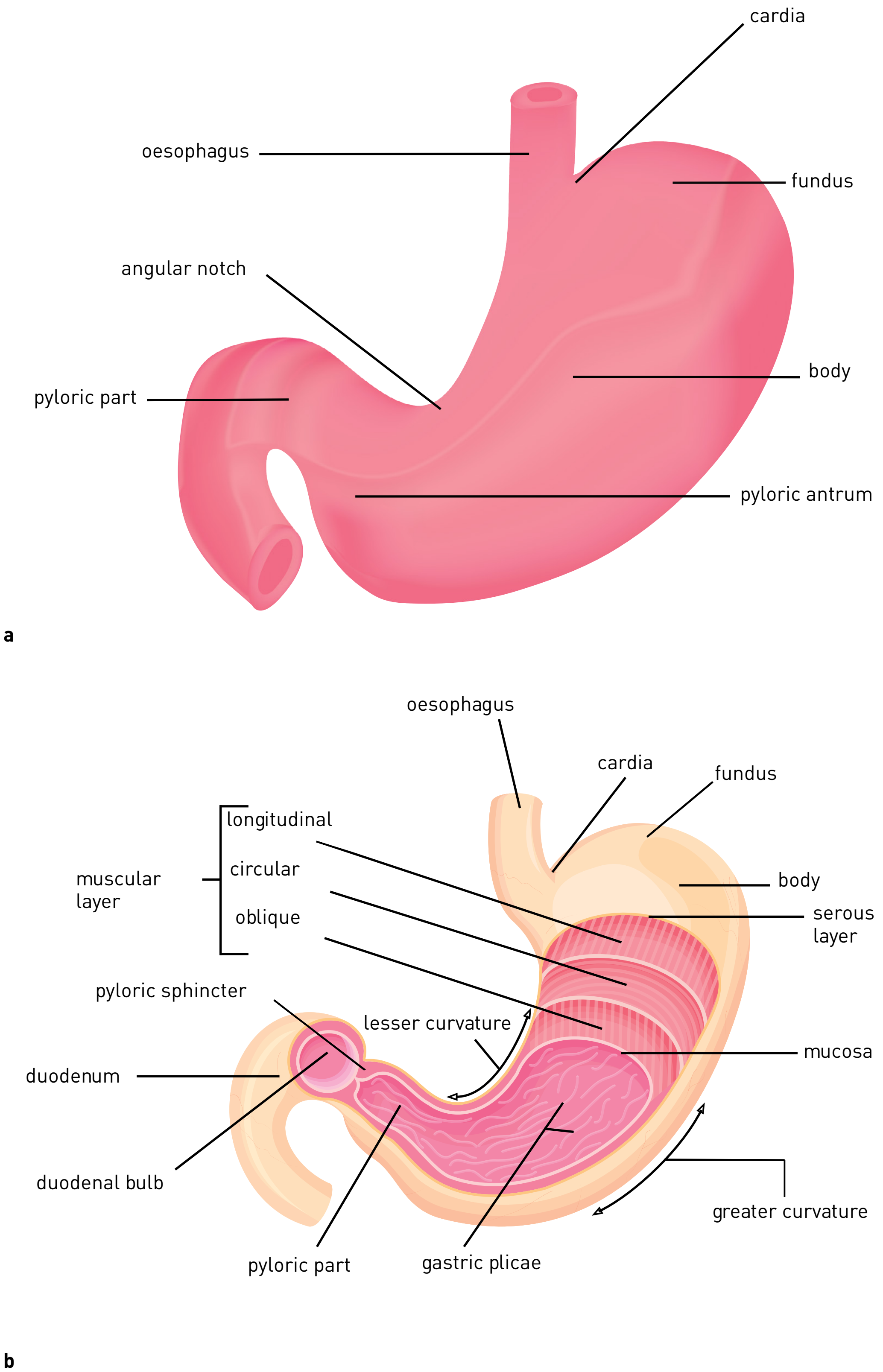


Figure 10.7. Stomach. **a.** its parts **b.** its layers.

What are the layers of the stomach?

From outer to inner, the stomach wall consists of four layers (Figure 10.7b):

- **serous:** a thin layer of peritoneum.
- **muscular:** three distinct muscle layers:
  - **longitudinal (outermost)**
  - **circular (middle)**
  - **oblique (innermost)**
- **submucosal:** a layer containing blood vessels and nerves.
- **mucosal:** contains gastric glands that produce various secretions. The inner surface forms folds called **gastric folds**.

Are there any sphincters in the stomach?

The stomach has one true sphincter: **pyloric sphincter**, which controls the passage of food from the stomach to the duodenum.

The transition from the esophagus to the stomach does not involve a true sphincter but is regulated by other mechanisms.

How is the blood supply and lymphatics of the stomach?

The stomach is supplied by branches of the **coeliac trunk** (Figure 10.8):

- **left gastric a.** (on the left side of the lesser curvature)
- **right gastric a.** (on the right side of the lesser curvature)
- **left gastroomental a.** (on the left side of the greater curvature)
- **right gastroomental a.** (on the right side of the greater curvature)
- **short gastric aa.**

The venous blood of the stomach is drained by veins of the same name as the arteries into the **portal vein**.

Lymphatic vessels drain into the **gastric nodes**, which in turn connect to the **coeliac nodes**.

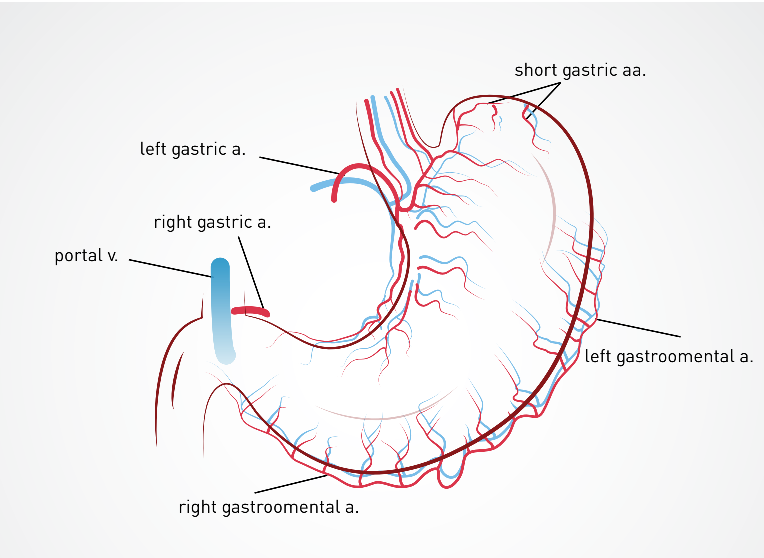


Figure 10.8. Vessels of the stomach.

How is the nerve supply of the stomach?

parasympathetic innervation: provided by the **vagus n**.

sympathetic innervation: derived from branches of the spinal segments **T6–T9**.

CLINICAL RELEVANCE

Reflux, commonly referred to as acid reflux or **gastroesophageal reflux disease** (GERD), occurs when stomach acid or contents flow back into the esophagus. This backflow happens due to a weak or relaxed, physiological lower esophageal sphincter (LES), which normally prevents the acid from moving up. Reflux can cause symptoms like heartburn, chest pain, regurgitation, and difficulty swallowing. In some cases, it can lead to more severe conditions like esophageal damage if left untreated. Lifestyle changes, medication, and sometimes surgery are used to manage reflux.

Peptic ulcers, are open sores on the mucosal layer of the upper digestive tract, usually at stomach and duodenum. These ulcers are often caused by an infection with the bacterium Helicobacter pylori or the prolonged use of nonsteroidal anti-inflammatory drugs (NSAIDs). Ulcers may extend beyond the mucosal layer and may lead to complications such as bleeding, perforation, penetration and in some cases gastric cancer. Symptoms can include stomach pain, bloating, nausea, and indigestion. Treatment typically involves antibiotics (for bacterial infection), acid-reducing medications, and lifestyle changes to promote healing and prevent recurrence.

Hypertrophic pyloric stenosis is a condition that the passage of the gastric content from the stomach to the intestine is blocked due to thickening of the circular muscular layer at the pylorus. It affects the infants from birth to a few months of age. The narrowing of the pylorus causes symptoms like severe vomiting, dehydration, and weight loss. The exact cause is not fully understood, but it can be treated with surgery called **pyloromyotomy**, which relieves the blockage by cutting the thickened muscle. Pyloric stenosis typically develops in the first few weeks of life and is more common in male infants.

SMALL INTESTINE

The small intestine is the longest section of the digestive system; its length varies between 3 to 10 meters (Figure 10.9). It begins at the **pyloric part** of the stomach and ends at the **ileocecal valve**, where it connects to the caecum of the large intestine.

The chemical digestion of nutrients is completed and absorbed here. Unabsorbed substances are transmitted to the large intestine. It is separated from the anterior abdominal wall by the **greater omentum**.

Figure 10.9. Location of the small intestine in the body.

What are the parts of the small intestine?

The small intestine consists of three anatomical parts:

Duodenum

Jejunum

Ileum

Duodenum: The shortest (about 20-25 cm long), widest, and least mobile part of the small intestine (Figure 10.17c). It surrounds the head of the pancreas in the shape of the letter C. It is divided into four parts: **superior**, **descending**, **horizontal**, and **inferior**. It begins after the pylorus of the stomach and ends at the **duodenojejunal flexure**, supported by the **ligament of Treitz**. The descending part receives common bile and pancreatic ducts via the **major duodenal papilla** (ampulla of Vater) which is controlled by the **sphincter of Oddi**. If present, there is another opening here in this part for the **accessory pancreatic duct** (duct of Santorini **minor duodenal papilla**). The inner surface of duodenum has circular folds with the exception for its beginning portion which is smooth (**bulb of duodenum**)

jejunum: It is the part of the small intestine that comes after the duodenum. In a place called **duodenojejunal flexure**, the duodenum makes a sharp bend and continues as the jejunum. The 2/5 proximal part of the small intestine is formed by the jejunum. Since its vascular network is richer, it looks pinker than the ileum. Its wall is thicker and its lumen diameter is wider. **Circular folds** called are prominent in its mucosa and it contains scattered lymphatic tissues and finger-shaped protrusions (intestinal villi) that increase the absorption surface. It is attached to the posterior abdominal wall with the mesentery.

ileum: It is the last part of the small intestines that extends between the jejunum and the caecum. It forms the 3/5th distal part of the small intestine. It is connected to the caecum by the **ileocaecal valve**. Its wall is thinner and its lumen diameter is narrower than the jejunum, thus it appears paler/lighter in color. There is lymphatic tissue arranged in oval and circular plates in its mucosa (**Peyer's patches** - aggregated lymphatic follicles). The plicae and villi in its mucosa are fewer and smaller than the jejunum. Like the jejunum, the ileum is also attached to the posterior abdominal wall by the mesentery.

How is the blood supply of the small intestine?

The initial part of the duodenum receives its blood supply from the **gastroduodenal a.** and **superior pancreaticoduodenal a.** while the rest of the duodenum is supplied by the **inferior pancreaticoduodenal a**.

Jejunum and ileum is supplied by the **superior mesenteric a**. via its **jejunal** and **ileal branches** (around 20 in number) which further unite to form loops called **arterial arcades**. From the arcades, long and straight arteries arise to supply the intestine called the **vasa recta**. Jejunal and ileal branches proceed between the layers of the mesentery to reach the intestine.

Venous blood; drains into the **hepatic portal v**.

Lymphatic vessels open into the **superior mesenteric** and **coeliac** nodes.

How is the nerve supply of the small intestine?

parasympathetic innervation: via the **vagus n**.

sympathetic innervation: via the **intestinal plexus**.

CLINICAL RELEVANCE

Ultrasound (USG), or sonography, is a non-invasive imaging technique that uses high-frequency sound waves to create images of the inside of the body. The sound waves are emitted from a probe, which bounces off tissues and organs, and the returning echoes are used to generate real-time images. Ultrasound is commonly used to visualize soft tissues, monitor pregnancy, guide needle placement for biopsies, and assess conditions such as abdominal pain, kidney stones, and heart issues. It is safe, quick, and does not involve radiation, making it a widely used tool in clinical practice.

Laparoscopy is a minimally invasive surgical procedure that uses a small camera, called a laparoscope, inserted through tiny incisions in the abdomen. It allows surgeons to view and operate on internal organs, such as the stomach, liver, and ovaries, with minimal disruption to surrounding tissues. It's commonly used for diagnostic purposes and to perform surgeries like appendectomies or gallbladder removal.

Endoscopy is a broad term for a variety of procedures that use a flexible tube with a light and camera (an endoscope) to examine the interior of a body cavity or organ. It can be used to inspect the digestive tract, respiratory system, or urinary tract, and it helps in diagnosing conditions like ulcers, cancers, and infections. Endoscopies can be performed through natural body openings like the mouth or nose.

Colonoscopy is a type of endoscopy specifically used to examine the inside of the colon (large intestine) using a long, flexible tube with a camera on the end. It is primarily used to screen for colorectal cancer, identify causes of unexplained gastrointestinal symptoms, and remove polyps or take biopsies. The procedure is typically done under sedation for comfort.

LARGE INTESTINE

It is the part of the digestive system that comes after the small intestines (Figure 10.10). Large intestine is responsible for absorbing water and sodium, as well as temporarily storing unabsorbed materials before they are excreted as feces (defecation). It is located in the abdominopelvic region to form a frame around the small intestines. It extends from the **ileocaecal valve** to the **rectosigmoid junction**. It is approximately 1.5m in length and gradually narrowing in diameter.

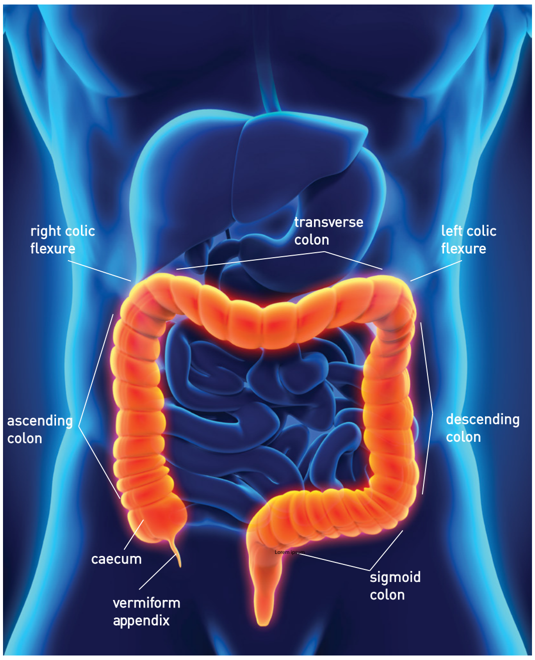


Figure 10.10 Location of the large intestine in the body and its parts.

What are the typical external features of the large intestine?

The formations that give the large intestine its typical appearance are as follows (Figure 10.11):

taenia coli: longitudinal smooth muscle fibers come together to form 3 strips with equal distance between them and extend along the large intestines. They are absent in the rectum. These are:

mesocolic tenia, **omental tenia** and **free tenia**.

haustra coli: small pouches or sacculations between the tenia.

epiploic appendices (fatty appendages): numerous small fat sacs on the outer surface of the large intestine. They are usually absent on caecum and rectum.

What are the parts of the large intestine?

The large intestine is divided into the following parts (Figure 10.10):

caecum: the first and widest part where the large intestine meets the small intestine. It is totally intraperitoneal. It connects to the ileum with the **ileal ostium.** Here, the **ileocaecal valve**, is located, which allows the contents of the small intestine to pass into the large intestine and prevents backflow. **Vermiform appendix**, a worm-like blind diverticulum, arises from the posteromedial aspect of the caecum about 2 cm below this valve. It is variable both in its length (average 7–8 cm) and position, most commonly retrocaecal.

ascending colon: after the caecum, large intestine continues as the ascending colon on the right side of the abdomen, turning sharply at the **right colic (hepatic) flexure** to form the transverse colon. It is retroperitoneal. After lining the abdominal wall, the parietal peritoneum reflects over the ascending colon and forms a vertical groove; the **right paracolic gutter**.

transverse colon: The longest and most mobile part, extending horizontally from right to left, between the right colic (hepatic) and left colic (splenic) flexures. It is intraperitoneal and has a mesentery that suspends it to the posterior abdominal wall: the **transverse mesocolon**.

descending colon: begins at the left colic flexure, descends vertically on the left side of the abdomen, till the sigmoid colon. It is retroperitoneal. Similar to the contralateral side, the parietal peritoneum reflects from the abdominal wall to descending colon to form a vertical groove; the **left paracolic gutter**.

sigmoid colon: S-shaped part after the descending colon and extending into the pelvis to end at the rectum. It is located mostly in the left side of the pelvic cavity. It is intraperitoneal and suspended by the **sigmoid mesocolon**.

rectum: sigmoid colon is continuous with rectum at the **rectosigmoid junction** at the level of S2 vertebra level in front of sacrum (Figure 10.11). Its length is approximately 12-13 cm. It is located in the pelvis in front of the sacrum, in accordance with its concavity. It is adjacent to urinary bladder in front in men and uterus and vagina in women. Below it is continuous with the anal canal at the anorectal junction where it has an anterior convexity; **anorectal flexure**. This flexure is formed by the **puborectalis m**., and contributes to fecal continence. Its upper third is intraperitoneal, while the middle third is retroperitoneal and lower third is extraperitoneal. Unlike other parts of large intestine, it does not have taenia coli, haustra coli, epiploic appendices and mesentery. Its lumen typically has three transverse folds (Houston valves). The widened lower part of rectum is the **ampulla**. (Figure 10.12).

anal canal: it is the last part of the digestive system (Figure 10.12). It is located between the rectum and the **anus**, which is the part where the anal canal opens to the outside. It is approximately 4 cm long. Around the anal canal, the **internal anal** and **external anal sphincter** muscles are located in circular fashion that forms the anal sphincter mechanism. The internal anal sphincter, which consists of smooth muscles, works involuntarily, while the external anal sphincter, which consists of striated muscles, works voluntarily. Continence is provided by this sphincter mechanism. When viewed from the lumen, there are 5-10 longitudinal folds (**anal columns** –Morgagni columns) in its mucosa. These columns are connected to each other below with the **anal valves**. The anal valves together form an irregular circle – known as the **pectinate line** (or **dentate line**).

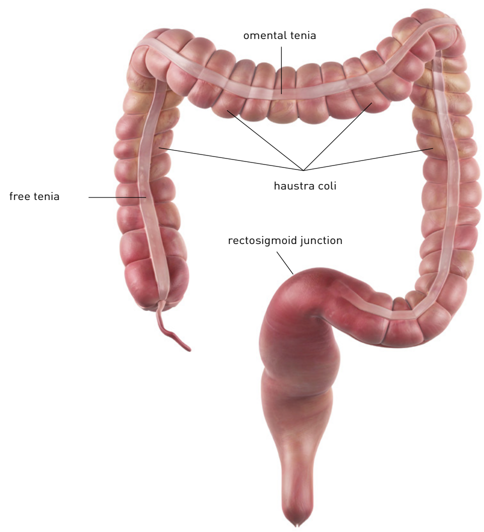
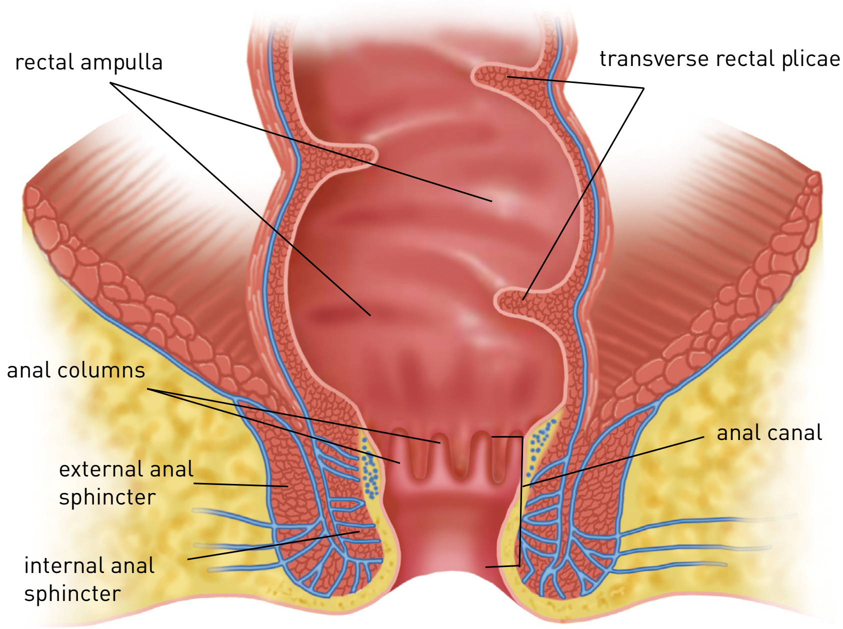


Figure 10.11. Typical external features of the large intestine.

CLINICAL RELEVANCE

Appendicitis is the inflammation of the appendix. It occurs when the appendix becomes blocked, often by stool, a foreign object, or infection, leading to swelling and infection. Common symptoms include sharp pain in the lower right abdomen, nausea, vomiting, and fever. Appendicitis is a medical emergency and typically requires surgical removal of the appendix (**appendectomy**) to prevent it from rupturing, which can lead to serious complications like infection in the abdominal cavity.



Şekil 10.12. Rectum and anal canal

How is the blood supply of the colon, rectum, and anal canal?

The large intestine is supplied by the branches of the **superior mesenteric** and the **inferior mesenteric arteries**.

Parts of the large intestine those are supplied by the superior mesenteric artery are:

caecum

ascending colon

initial (proximal 1/3) part of transverse colon

Parts of the large intestine those are supplied by the inferior mesenteric artery are:

the rest (distal 2/3) of transverse colon

descending colon

sigmoid colon

proximal 2/3 of rectum

The distal 1/3 of rectum and the anal canal are supplied by **branches originating from the internal iliac artery** and the **pudendal a.**.

Veins accompanying the arteries drain

the colon and upper rectum into the **superior mesenteric v.** and **inferior mesenteric v.** and the lower rectum and anal canal into the **internal iliac v.** and **pudendal v.**.

What is portosystemic (portocaval) anastomosis?

Portosystemic (portocaval) anastomoses are naturally existing connections between the portal vein and the systemic venous circulation. These anastomoses occur at four main sites:

1. **esophageal veins**: between the left gastric vein (portal circulation) and the azygos vein (systemic circulation).
2. **rectal veins**: between the superior rectal vein (portal circulation) and the middle and inferior rectal veins (systemic circulation).
3. **paraumbilical veins**: between the paraumbilical veins (portal circulation) and veins around the anterior abdominal wall (systemic circulation).
4. **retroperitoneal veins**: between the veins of the retroperitoneum (portal circulation) and the renal or lumbar veins (systemic circulation).

CLINICAL RELEVANCE

Portal hypertension is a condition where there is increased blood pressure within the portal vein, which carries blood from the digestive organs to the liver. It usually occurs due to liver diseases like cirrhosis, which obstruct normal blood flow through the liver. As a result, blood is redirected to smaller veins, leading to their enlargement (such as esophageal varices), which are fragile and prone to bleeding.

Hemorrhoids (piles) are swollen submucosal veins in the lower part of the rectum or anus, similar to varicose veins. They can be caused by factors like chronic constipation, straining during bowel movements, prolonged sitting on the toilet, pregnancy, being overweight. Symptoms include pain, itching, bleeding during bowel movements, and prolapse. There are two types of hemorrhoids; internal (in the rectum, painless) and external (under the skin around anus, painful). Treatment typically involves lifestyle changes, over-the-counter creams containing a local anesthetic, and in some cases, medical procedures to remove or shrink the hemorrhoids.

How is the lymphatic drainage of the colon, rectum, and anal canal?

caecum, ascending colon, and proximal 1/3 transverse colon: drain into **superior mesenteric nodes**

distal 2/3 transverse colon till rectum: drain into **inferior mesenteric nodes**

upper half of the rectum: drains into **pararectal nodes**

lower half of the rectum: drains into **internal iliac nodes**.

anal canal above the pectinate line: drains into **internal iliac nodes**

anal canal below the pectinate line: drains into **superficial inguinal nodes**

How is the nerve supply of the large intestine?

colon:

peristaltic movements:

stimulated by **parasympathetic nerves**

inhibited by **sympathetic nerves**

sympathetic innervation:

up to the proximal 1/3 of the transverse colon: **T6 spinal segment**, via **coeliac ganglion** and **superior mesenteric ganglion**.

remaining parts: via the first three lumbar spinal nerves, **superior hypogastric plexus**, and **inferior mesenteric ganglion**.

parasympathetic innervation:

Up to the proximal 1/3 of the transverse colon: **vagus n.**

Beyond this: **pelvic splanchnic nn (nn. erigentes)**.

rectum and anal canal:

sympathetic innervation:

via the lumbar part of the **sympathetic trunk**, **superior hypogastric plexus**, and **inferior hypogastric plexus**.

parasympathetic innervation:

Via **pelvic splanchnic nn.**

ACCESSORY ORGANS OF THE DIGESTIVE SYSTEM

Accessory organs assist digestion by producing and secreting substances into the digestive tract via specific ducts.

Salivary Glands

Salivary glands are located around and deep within the oral mucosa.

What are the types of salivary glands?

The salivary glands are basically divided into two parts: **minor** and **major salivary glands**. Minor salivary glands are the salivary glands found in the lips, cheeks, tongue and palate. The major salivary glands are three in number, namely the **parotid gland**, **submandibular gland** and **sublingual gland** (Figure 10.13).

parotid gland: it is the largest salivary gland, located on the lower front side of the auricle. It discharges the saliva it secretes into the oral cavity at the level of the second upper molar through a channel called the **parotid duct (Stenon's canal)**.

submandibular gland: it is located under the inner surface of the mandible, above the digastric m. It discharges the saliva it produces into the oral cavity through a canal called **submandibular duct (Wharton's canal)**.

sublingual gland: it is the smallest of the major salivary glands. It is located under the tongue at the floor of the mouth. It discharges the saliva into the oral cavity through numerous small canals.

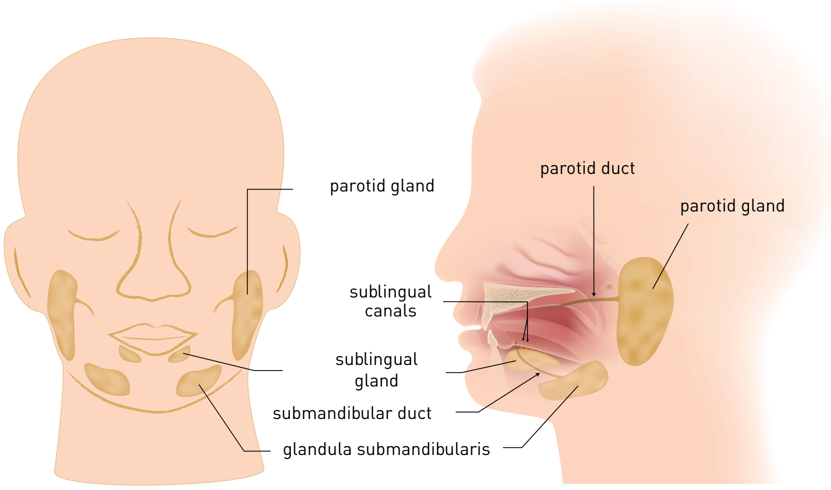


Figure 10.13. Main salivary glands.

How is the nerve supply of salivary glands?

The salivary glands are innervated by the **autonomic nervous system**.

Nerve supply of the parotid gland:

- **parasympathetic** fibers originating from the **glossopharyngeal n.** synapse in the **otic ganglion**, and postganglionic fibers reach the gland via the **auriculotemporal n**.
- **sympathetic** fibers originating from the nerve plexus around the **external carotid artery** reach the gland with the arteries.

Nerve supply of the submandibular and sublingual glands:

- **parasympathetic** fibers originating from the **facial n.** via the **chorda tympani** synapse in the **submandibular ganglion** and postganglionic fibers innervate both glands.
- **sympathetic** fibers originate from the nerve plexus around the **external carotid artery** reach the gland with the arteries.

CLINICAL RELEVANCE

Mumps is an infectious, acute viral disease characterized by inflammation of the salivary glands, commonly occurring in school-aged children. It spreads through coughing and respiratory droplets. Symptoms include severe swelling near the ear, pain while chewing or swallowing, fever, and headache. While it typically resolves without any other health issues, it can, in rare cases, lead to complications such as hearing loss or meningitis and encephalitis, which are inflammations of the meninges and brain. The mumps vaccine given during childhood has significantly prevented the disease worldwide.

Liver

It is the largest organ in the digestive system and abdominal cavity. It is an intraperitoneal organ except the bare area where it is attached to the lower surface of the diaphragm. Weighing approximately 1.5 kg, the majority of this organ is located in the upper right part of the abdominal cavity, under the right dome of the diaphragm, while the remainder extends to the middle and left side. While almost all of it is located under the ribs, a small part is directly adjacent to the anterior abdominal wall (Figure 10.14).

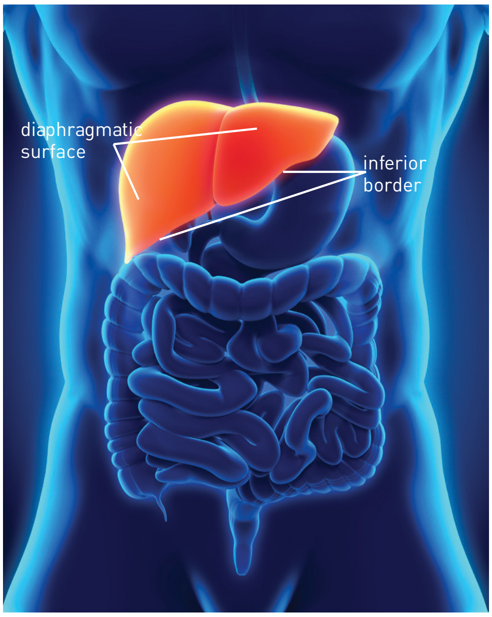


Figure 10.14. Location of the liver in the body.

What is the function of the liver?

The functions of the liver include **exocrine activities** such as bile synthesis and secretion and bilirubin conjugation, and **endocrine activities** such as insulin and glucagon synthesis, proteins synthesis such as albumin and fibrinogen, and synthesis of amino acids and some hormones.

What are the surfaces and margins of the liver?

It has two surfaces and two edges. The upper and front flat surface in contact with the diaphragm is called the **diaphragmatic surface.** This surface is mostly lined by the peritoneum till the **subphrenic recess** where the peritoneum skips to the diaphragm. The rest of this surface is not covered by the peritoneum and contributes the bare area. The irregular surface on the underside, molded by the abdominal organs is called the **visceral surface**. This surface of liver is directly in contact with several organs such as the duodenum, stomach, right kidney and suprarenal gland, hepatic flexure of colon, and gallbladder.

These two surfaces are separated by a sharp edge at the front called the **inferior margin** and a blunted edge at the back called the **superior margin** (Figure 10.15).

What are the ligaments of the liver?

There are various ligaments that originate from the peritoneum and connect the liver to the surrounding structures (Figure 10.15):

falciform lig.: is formed by the reflected peritoneum that attaches the superior and posterior portions of the liver to the concave inferior portion of the diaphragm.

coronary lig.: the peritoneum covering the diaphragmatic surface of the liver skips to the diaphragm at the top and forms this ligament. The peritoneum-free area between the two leaves of the coronary lig. is called the **bare area**.

triangular lig.: is the continuation of the coronary lig. on both sides over the upper surface of the liver and connects it the to the diaphragm. It encircles the bare area and provides structural support to help hold the liver in place.

round lig.: is the fibrous remnant of the umbilical vein, which is active in the fetal period. It extends in the inferior border of the falciform ligament and lies in the fissure of the lig. venosum at the visceral surface of the liver.

lig. venosum: is the remnant of the ductus venosus, connection between the umbilical v. and the inferior v. cava that was active in the fetal period.

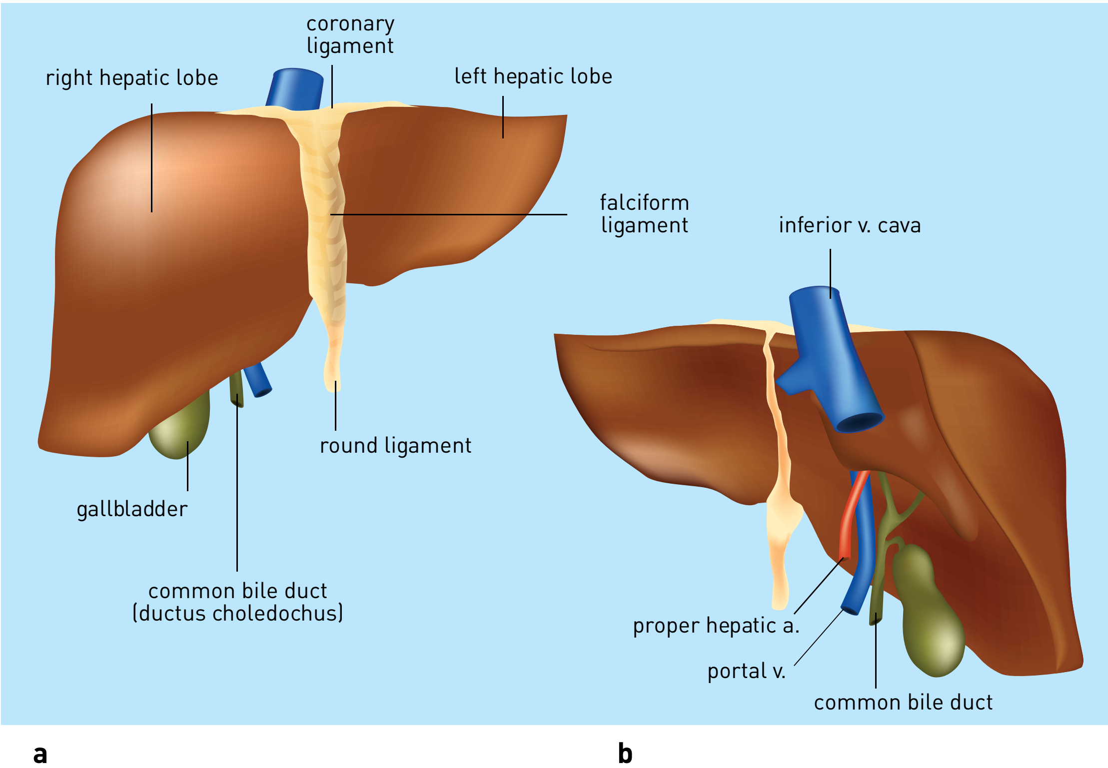


Figure 10.15. Surfaces of the liver and its ligaments. **a.** view of the upper anterior part of the liver **b.** view of the lower posterior part of the liver.

What are the lobes of the liver?

The liver consists of **four lobes** (Figure 10.15):

right lobe
left lobe
caudate lobe
quadrate lobe

There is a region consisting of grooves in the shape of the letter H on the visceral surface of the liver. Parallel grooves extend from front to back on the right and left. The horizontal groove forming the middle of the letter H is formed by the **porta hepatis**.

Right vertical groove contains:

anteriorly: **gallbladder**

posteriorly: **inferior v. cava**

Left vertical groove contains:

anteriorly: **round lig.**

posteriorly: **lig. venosum**

Horizontal groove (porta hepatis) is the "gateway to the liver" and contains the structures entering and leaving the liver:

portal v.

proper hepatic a.

common hepatic duct

How is the internal structure of the liver?

The liver is made up of **lobules**. The lobules are also made up of clusters of **hepatocytes**, which are hexagonal liver cells supported by connective tissue cells. In the center of the lobules is a vein called the **central v**. The portal canals, **interlobular spaces** are located between the lobules and contains **a branch of the hepatic artery, a branch of the portal vein**, and **a bile duct** which forms the **portal triad**. The blood transferred by the portal v. passes through the sinusoids, received by the hepatocytes here. Hepatocytes extract nutrients and detoxify the blood. It is then drained into the central v. which ultimately flows into the hepatic v. and then the inferior v. cava. cava.

What is the liver segment?

A liver **segment** is an independent functional unit which has its own hepatic arterial branch, portal vein branch and bile duct. The liver is divided into **8** segments, 4 in right and 4 in left lobes.

How are the vessels of the liver?

The artery that supplies the liver tissue is the **proper hepatic a.** The venous blood is drained into the inferior vena cava through the **hepatic veins**. Regarding its function, apart from these veins that drain the liver tissue, venous blood from the digestive system is also carried to the liver through the **portal v.** It brings venous blood rich in nutrients from the digestive system. 80% of all the blood coming to the liver is made up of blood coming through the portal v. The portal v. enters the liver through the porta hepatis, divides into two as right and left branches, and then ramifies like a tree that gradually become smaller and enter the liver cells on a microscopic scale (Figure 10.16).

Which veins form the portal vein?

The **superior mesenteric v.** and the **splenic (lineal) v.** unite to form the portal vein (Figure 10.16).

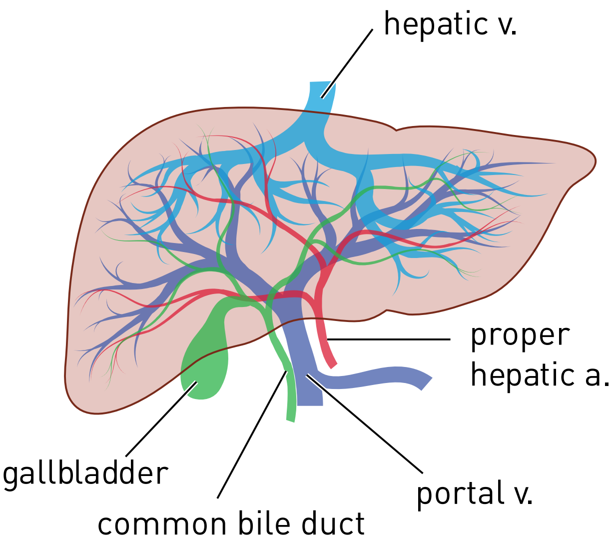


Figure 10.16. Vessels of the liver and the bile ducts.

How are the lymphatics of the liver?

The liver drains into lymph nodes located around its associated blood vessels.

How is the nerve supply of the liver?

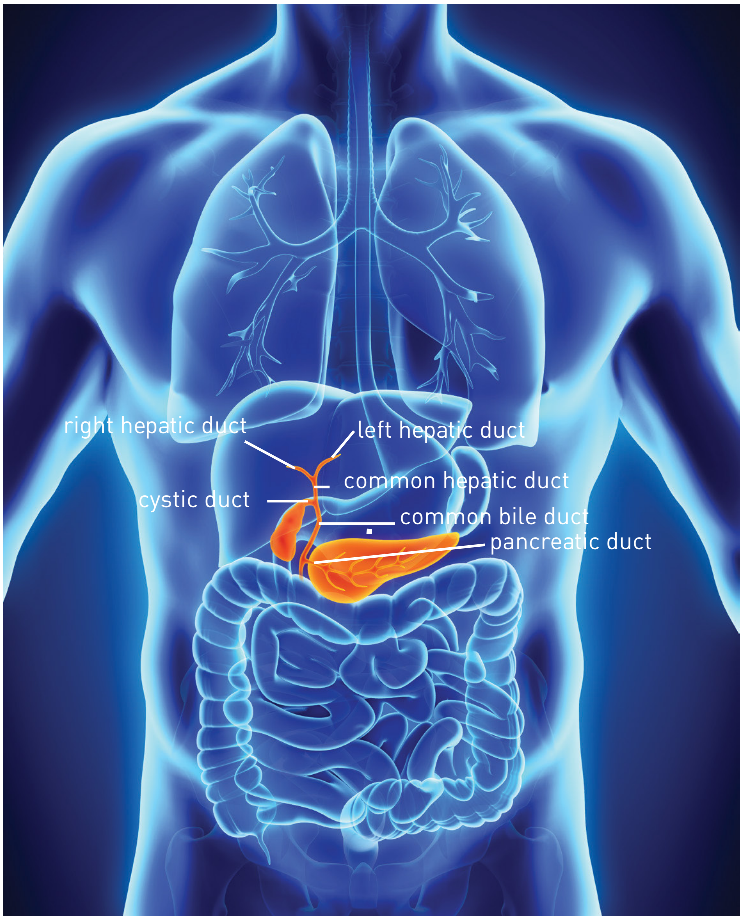
The sympathetic nerves are derived from the **greater splanchnic n.**, and the parasympathetic nerves are derived from the **vagus n**.

CLINICAL RELEVANCE

Hepatitis is an inflammation of the liver, commonly caused by viral infections, but can also be triggered by excessive alcohol consumption, certain medications, toxins, or autoimmune diseases. The most common types are Hepatitis A, B, C, D, and E, with Hepatitis B and C being the most serious because they can lead to chronic liver disease, cirrhosis, or liver cancer. Symptoms may include fatigue, nausea, abdominal pain, jaundice, and dark urine. While some forms of hepatitis resolve on their own (such as Hepatitis A), others, particularly Hepatitis B and C, may require antiviral treatment to prevent long-term liver damage. Vaccines are available for Hepatitis A and B.

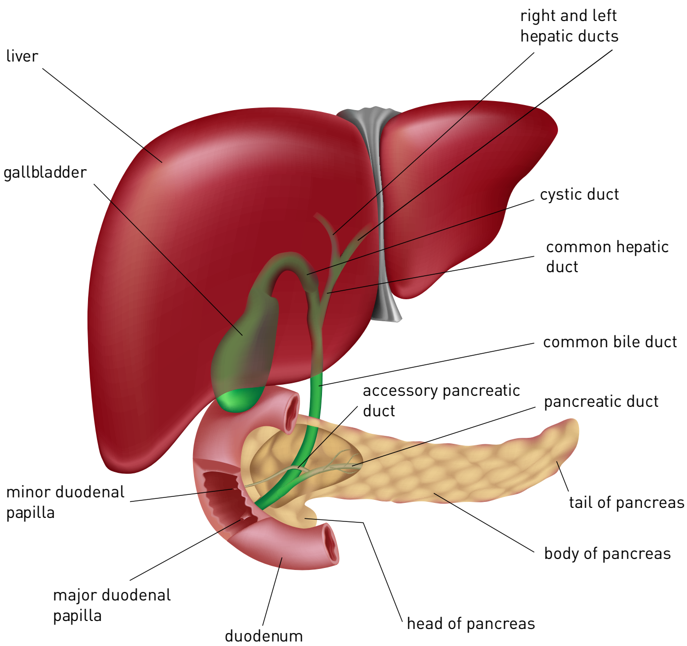
What are the bile ducts?

Bile produced in the liver cells is discharged into larger bile ducts via small bile ducts. These bile ducts then unite to form the **right** and **left hepatic ducts**. These two ducts unite at the porta hepatis to form the 4-6 cm long **common hepatic duct** which exits the liver. Common hepatic duct then unites with the **cystic duct**, which is the excretory duct of the gallbladder, to form the **common bile duct (Choledoch's duct)**. The common bile duct opens into the second part of the duodenum. In this region, the pancreatic duct, which carries pancreatic secretion, joins the common bile duct. The **sphincter of Oddi**, a sphincter formed by smooth muscles that controls the flow of bile into the duodenum, is located in the part of the common bile duct (Figure 10.17a-c).



a

Liver, Gallbladder, Pancreas and Bile Passage



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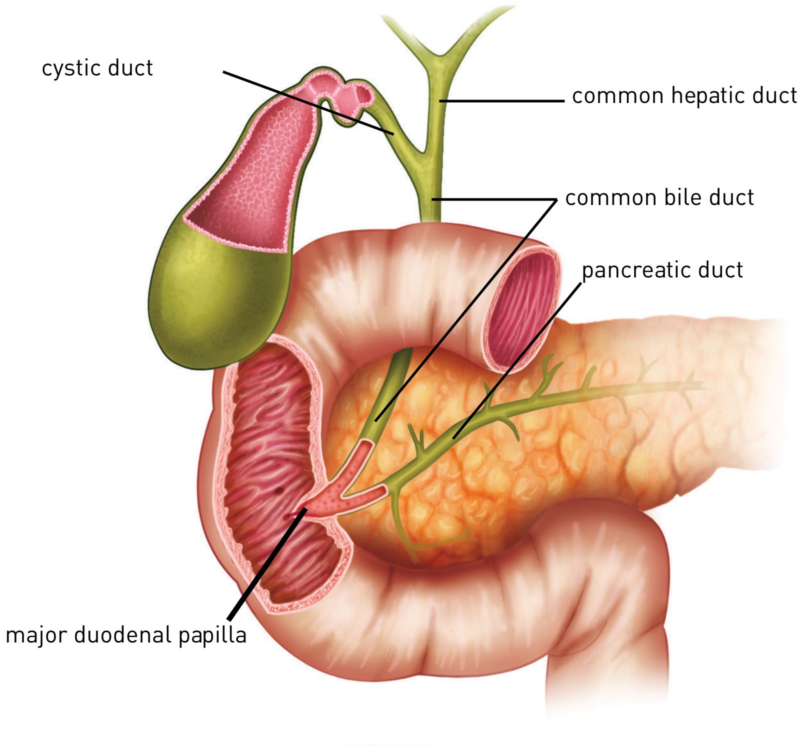


c

Figure 10.17. Bile ducts. **a.** location of the gallbladder in the body **b.** relationship of the bile ducts with surrounding structures **c.** opening of the bile and pancreatic ducts into duodenum.

Gallbladder

The gallbladder is a **pear-shaped, thin-walled organ** located beneath the liver in the **gallbladder fossa** (Figure 10.17a-c). It stores approximately **400–450 mL** of concentrated bile, which is transported from the liver through bile ducts.

What are the parts of the gallbladder?

It consists of three parts (Figure 10.17c):

fundus
body
neck

The fundus projects slightly from the anterior edge of the liver. The surface projection of this point on the anterior abdominal wall is called **Murphy's point**. Murphy's point is defined as the point where the midclavicular line (an imaginary line passing perpendicular to the ground from the middle of the collarbone) intersects the costal arch.

After the passage of nutrients into the duodenum, the gallbladder, stimulated by various hormonal mechanisms, contracts and discharges the concentrated bile it has stored into the duodenum through the bile duct.

How is the blood supply of the gallbladder?

The gallbladder is supplied by the **cystic a.** Its veins open into the veins of the liver. Its lymphatics open into the lymphatics of the liver.

How is the nerve supply of the of the gallbladder?

The sympathetic nerves are derived from the **coeliac plexus**, and the parasympathetic nerves are derived from the **vagus n.**

CLINICAL RELEVANCE

Gallbladder stones, also known as **gallstones**, are hardened deposits that form inside the gallbladder. They can be made up of cholesterol, bile pigments, or a combination of both. Gallstones can vary in size, from tiny grains to large stones. Many people with gallstones don't experience symptoms, a condition known as **"silent" gallstones**. However, when a stone blocks a bile duct, it can cause severe pain (called a **biliary colic**), nausea, vomiting, and even inflammation or infection of the gallbladder (cholecystitis). In some cases, gallstones can lead to complications like pancreatitis or jaundice. Treatment may involve medications to dissolve the stones or surgical removal of the gallbladder (cholecystectomy).

Pancreas

The pancreas is a retroperitoneal organ located horizontally behind the stomach, at the level of the first and second lumbar vertebrae on the posterior abdominal wall, between the duodenum on the right and the spleen on the left. It is a gland that produces both endocrine and exocrine secretions. While endocrine secretions (insulin and glucagon) are released into the blood, exocrine secretions (amylase, lipase and trypsin) are discharged to the second part of the duodenum through a duct (Figures 10.17a-c, 10.18a,b).

What are the parts of the pancreas?

The pancreas consists of the following parts:

- **head**: it is located in the C-shaped curve of the duodenum. The protrusion that starts from the bottom of the head of the pancreas and extends towards the midline is called **uncinate proc**.
- **neck**: the shortest part that runs between the head and the body. On its back, the superior mesenteric vein and the splenic v. unite to form the portal v.
- **body**: it is the longest part that runs between the neck and the tail. On its front, there is a small peritoneal cavity called the **omental bursa** between the stomach and the cauda.
- **tail**: it is the narrow end that extends towards the spleen.

What are the pancreatic ducts?

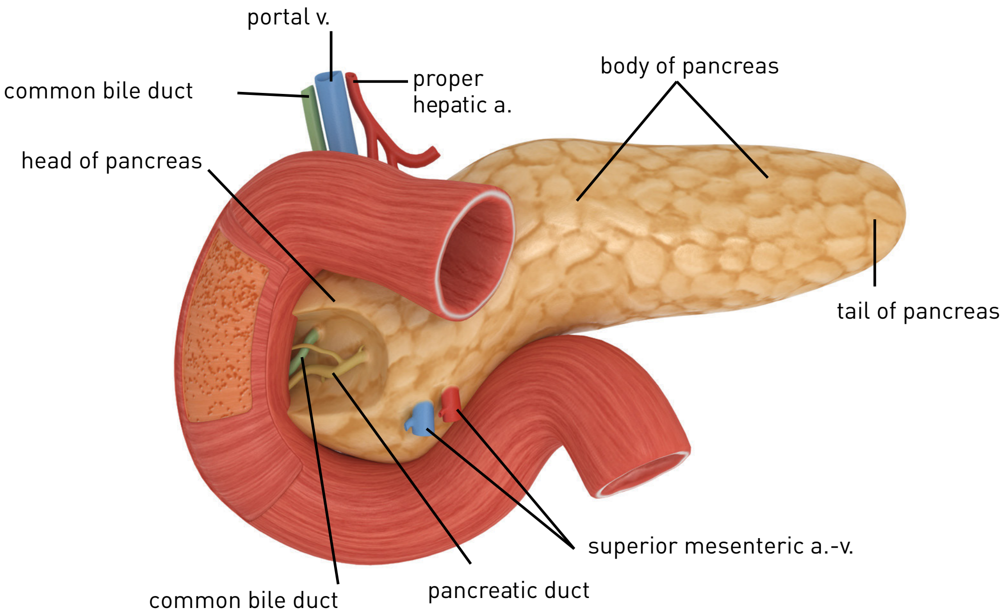
The pancreas contains two main ducts (Figures 10.17c, 10.18a,b):

pancreatic duct (duct of Wirsung):

the main excretory duct, it runs through the pancreas and merges with the common bile duct in the head to form the **hepatopancreatic ampulla**.
This ampulla opens into the second part of the duodenum at the **major duodenal papilla**.

accessory pancreatic duct (duct of Santorini):

a secondary duct that opens into the duodenum at the **minor duodenal papilla**, located about 2 cm above the major duodenal papilla.



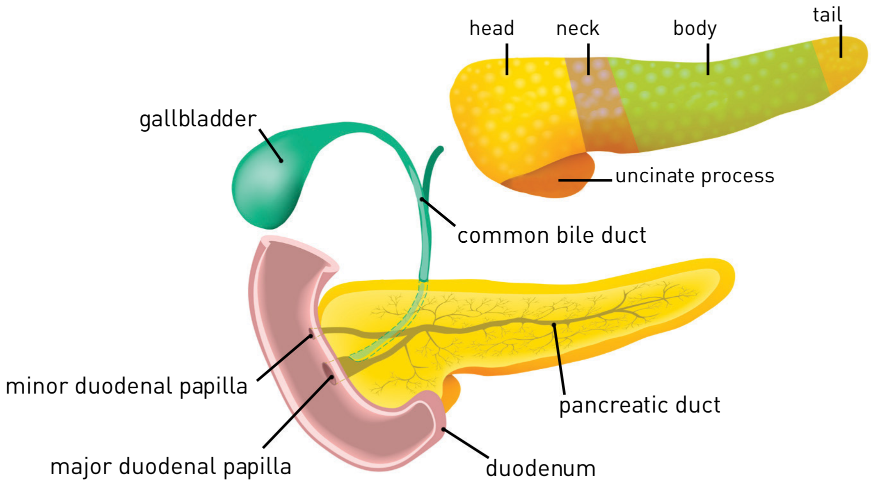


Figure 10.18. Pancreas. **a.** relationship of the pancreas with duodenum and neighboring vascular structures **b.** parts of the pancreas and its ducts.

How is the blood supply of the pancreas?

The pancreas is supplied by arteries from multiple sources:

lienal a. (splenic a.): a branch of the **coeliac trunk**
superior pancreaticoduodenal a.: a branch of the **gastroduodenal a.**
inferior pancreaticoduodenal a.: a branch of the **superior mesenteric a.**

Venous drainage follows the same pattern with veins draining into the **portal v.** Lymph from the pancreas drains into lymph nodes surrounding the pancreas.

How is the nerve supply of the of the pancreas?

The sympathetic nerves are derived from **major** and **minor splanchnic n.**, and the parasympathetic nerves are derived from the **vagus n.**

What is the coeliac trunk?

The **coeliac trunk** is the largest branch of the abdominal aorta. It supplies blood to several major abdominal organs, including the:

- **liver**
- **gallbladder**
- **stomach**
- **spleen (lien)**
- **pancreas**
- **duodenum**

The coeliac trunk branches into three main arteries:

- **common hepatic a.**: supplies the liver, gallbladder, and part of the stomach and duodenum
- **lienal a. (splenic a.)**: supplies the spleen and part of the pancreas and stomach
- **left gastric a.**: supplies part of the stomach and esophagus

These branches ensure an extensive and interconnected blood supply to these organs.

PERITONEUM

What is the peritoneum?

The **peritoneum** is a serous membrane that lines the abdominal and partially the pelvic cavity, as well as the organs within these cavities. It consists of two layers:

- **parietal peritoneum**: lines the walls of the abdominal and pelvic cavities
- **visceral peritoneum**: covers the organs within these cavities

Where is the peritoneal cavity?

The **peritoneal cavity** is the space between the parietal and visceral peritoneum. It is divided into two parts:

- **greater peritoneal cavity (greater sac)**: the larger portion of the peritoneal cavity
- **lesser peritoneal cavity (lesser sac, omental bursa)**: is located between the stomach and pancreas.

It contains a thin film of peritoneal fluid, which acts as a lubricant, enabling free movement of the abdominal organs. The greater and lesser peritoneal sacs are connected by a small opening called the **epiploic foramen** (Winslow's foramen). The four borders of this opening consists of critical structures; namely the <u>inferior v. cava</u> behind, <u>caudate lobe of liver</u> above, <u>hepatoduodenal lig</u>. in front and the <u>upper part of duodenum</u> below.

What are the subdivisions of the greater sac?

The greater sac is further divided into 2 as the **supracolic** and **infracolic** compartments, by the transverse mesocolon. However, they are connected to each other by the paracolic gutters. The supracolic compartment is above the transverse mesocolon and comprises the liver, stomach and the spleen. The infracolic compartment is below the transverse mesocolon and comprises the small intestine, and the ascending and descending colon.

What are the formations derived from the peritoneum?

Peritoneum has several extensions within the abdominopelvic cavity such as:

mesentery: is the double layer of peritoneum that suspends the organs to the posterior abdominal wall. Neurovascular structures pass through the mesentery and extend from the posterior abdominal wall to the organ.

greater omentum: is an extension of the peritoneum between the stomach and the transverse colon. It begins at the greater curvature of the stomach and the first part of the duodenum, descends in front of the intestine, and ascends back to the transverse colon, where it connects. The left border of the greater omentum is the **gastrosplenic ligament (gastrolienal ligament)**. It is very mobile and moves around in the abdominal cavity, preventing organs from sticking together. In case of inflammation, it covers the inflamed organ to protect healthy organs.

lesser omentum: is the double layer of peritoneum that extends from the lesser curvature of the stomach and the proximal duodenum to the liver. It consists of two ligaments: **hepatogastric lig.** and **hepatoduodenal lig.**. Hepatogastric lig. is formed by two layers of peritoneum while the hepatoduodenal lig. comprises the **portal triad** (portal vein, proper hepatic artery and bile duct).

ligaments: the two layers of peritoneum become tighter in some places to form ligaments which attach the organs to the abdominal wall and keep their position. Some examples of peritoneal lig.s are as follows: **hepatoduodenal lig**, **gastrolienal lig.**, **lienorenal lig.**, **gastrophrenic lig.**, **falciform lig**.

What are the peritoneal pouches or recesses?

As the peritoneum lines the abdominal and pelvic cavities and proceeds to cover the organs, it forms dead ends called **recess** or **pouch** in certain locations. These may be around several parts of the intestinal system such as liver (**subphrenic recess** or **hepatorenal recess**), around duodenum (**duodenal recesses**), or caecum (**caecal recesses**).

The clinical significance of the peritoneal recesses is being a potential site for <u>hernia</u>. Movable abdominal organs such as the small intestine may enter and trapped in these recesses.

Within the pelvic cavity, peritoneum lines the upper wall of the urinary bladder and passes to the rectum in males and forms the **rectovesical pouch**. In females, the peritoneum lines the upper wall of the uterus and then passes to the rectum and forms the **rectouterine pouch** (**Douglas pouch**). This is the most caudal site of the abdominal cavity. Also in females, a shallower **vesicouterine pouch** exists in front, between uterus and the urinary bladder.

The clinical significance of the pelvic peritoneal pouches is being the site for collection of any sort of fluid in the abdominal cavity, such as blood, pus, or ascites in various pathological conditions, such as intra-abdominal bleeding, infection, and tumor.

How is the classification of organs based on their relationship with the peritoneum?

Organs are classified into three groups based on their relationship with the peritoneum:

intraperitoneal organs: are fully enclosed by the peritoneum and suspended by mesentery from the posterior abdominal wall such as; stomach, jejunum, caecum, transverse colon, sigmoid colon, liver, and spleen.

retroperitoneal organs: are located behind the peritoneum and covered only on their anterior surface such as; kidneys and adrenal glands.

secondary retroperitoneal organs: are initially intraperitoneal during fetal development, but later adhere to the posterior abdominal wall, leaving only their anterior surface covered by the peritoneum such as; duodenum, pancreas, ascending colon, and descending colon.

This classification reflects the development and anatomical positioning of abdominal organs in relation to the peritoneum.

What are the regions of the anterior abdominal wall?

The anterior abdominal wall is divided into 9 regions by two horizontal and two vertical lines parallel to each other. The horizontal lines pass through the L1 vertebra above and the L5 vertebra below. Vertical lines are two lines that pass vertically through the midpoint of both clavicles. The 9 regions formed on the abdominal wall divided by these 4 lines are as follows:

umbilical region: around the navel

right and left lumbar regions: on either side of the umbilical region

epigastric region: above the umbilical region

right and left hypochondriac regions: on either side of the epigastric region

hypogastric region: below the umbilical region

right and left inguinal regions: on either side of the hypogastric region

What are the layers of the anterior abdominal wall?

The anterior abdominal wall consists of the following layers, starting from the most superficial skin to the deepest muscular layer:

skin

subcutaneous layer

- **Camper's fascia:** superficial fatty layer
- **Scarpa's fascia:** deeper membranous layer

muscles

Deep to the muscular layer, there is the transversalis fascia and then the parietal peritoneum.

MUSCLES OF THE ABDOMINAL WALL

What are the abdominal wall muscles?

These are the muscles surrounding the abdominal cavity. They provide support to the organs in the abdominal cavity, protection against external effects and increase intra-abdominal pressure in situations such as micturition (urination), defecation, coughing, sneezing, straining, and childbirth. Abdominal muscles are classified as anterolateral and posterior group (back) muscles.

Anterolateral abdominal wall muscles

First 3 muscles are quite thin, sheet like muscles which are organized bilaterally as three layers from superficial to deep. They begin as muscle fibers and as they proceed they turn into aponeurotic form and unite in the midline, at the linea alba. These 3 muscles are:

external oblique abdominal m.: forms the outermost muscular layer, with fibers running downward and inward.

origin: from the external surface of the last 8 ribs

insertion: linea alba via its aponeurosis

function: its unilateral contraction laterally flexes and rotates the trunk (same shoulder forward), while its bilateral contraction flexes the trunk.

innervation: intercostal nn.

internal oblique abdominal m.: forms the middle layer, with fibers running upward and inward at right angle to the external oblique.

origin: iliac crest and anterior superior iliac spine

insertion: linea alba via its aponeurosis

function: its unilateral contraction lateral flexes and rotates (opposite shoulder forward), while its bilateral contraction flexes the trunk.

innervation: intercostal nn.

transversus abdominis m.: forms the innermost layer, with fibers running horizontally.

origin: inner surfaces of the last 6 ribs, iliac crest, and anterior superior iliac spine

insertion: linea alba via its aponeurosis

function: its unilateral contraction rotates the trunk to the same side.

innervation: intercostal nn.

Following 2 muscles are found on the anterior part of the abdominal wall.

rectus abdominis m.: is the vertical muscle located on either side of the linea alba. It has typical horizontal tendinous bands, **tendinous intersections**, usually 3 in number which make it unique.

origin: from the pubic symphysis and pubic crest

insertion: cartilages of the 5th–7th ribs and the xiphoid process of the sternum.

function: it flexes the trunk.

innervation: intercostal nn.

pyramidalis m.: is a small triangular muscular slip located between the linea alba and the pubis which tenses the linea alba.

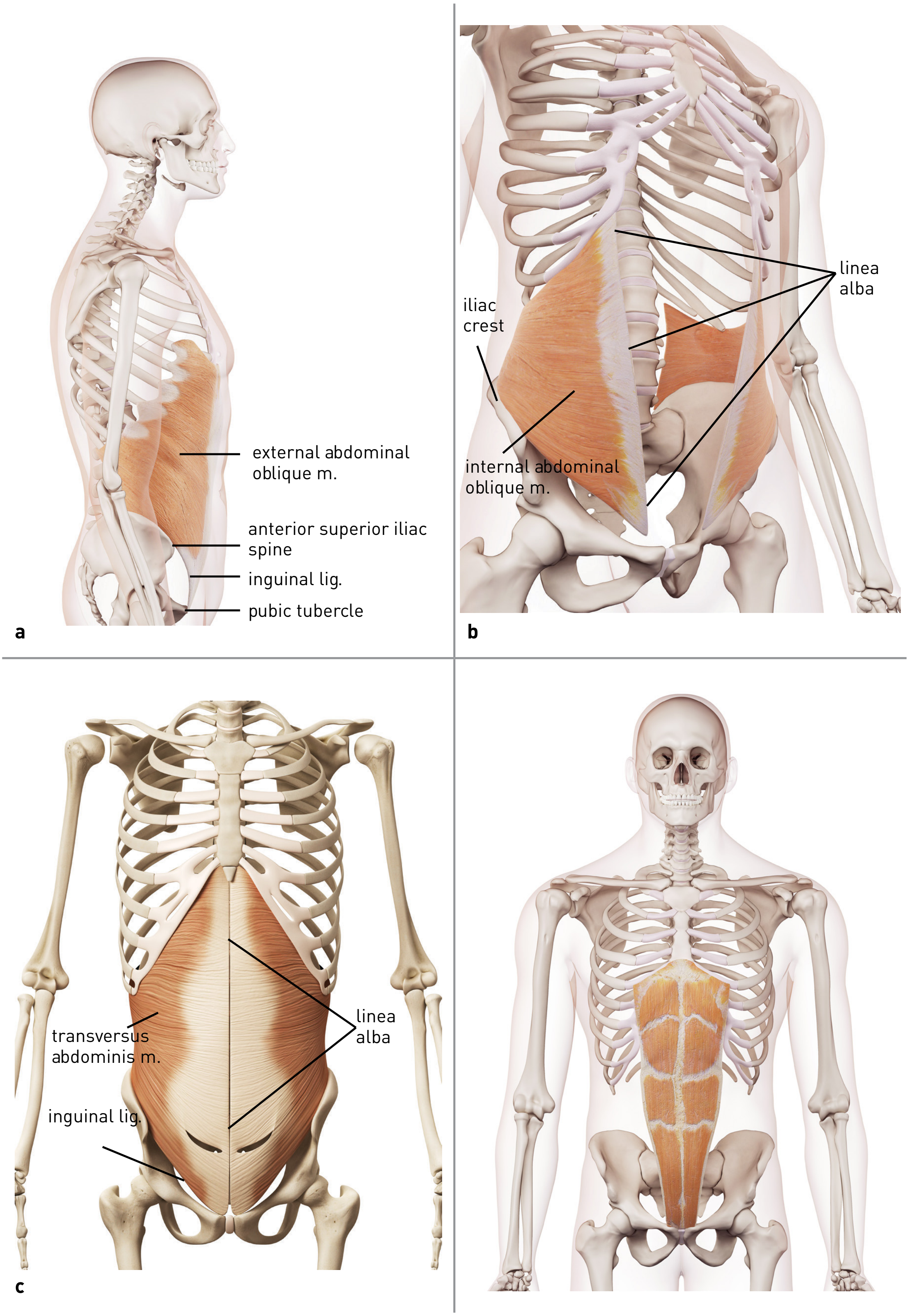


Figure 10.19. Antero-lateral abdominal wall muscles. **a.** external abdominal oblique m. **b.** internal abdominal oblique m. **c.** transversus abdominis m. **d.** rectus abdominis m.

What are the posterior abdominal wall muscles?

This group includes **psoas major m., psoas minor m., iliacus m.** and **quadratus lumborum m.** The first three muscles are described in the thigh region.

quadratus lumborum m.: is a deeply located muscle.

origin: from the iliac crest and iliolumbar lig.
insertion: inferior border of 12^{th} rib, transverse proc. of L1-L4 vertebrae
function: it laterally flexes the trunk.
innervation: subcostal n.

What is the inguinal ligament?

It is a ligament formed from the aponeurosis of the obliquus externus abdominis m. It extends between the **anterior superior iliac spine (ASIS)** and the **pubic tubercle** (Figure 10.20).

What is the inguinal canal?

It is a canal located in the groin or inguinal region. It is formed between the muscles of the anterior abdominal wall and is a potential passage between the abdominal cavity and the scrotum in men and the mons pubis in women. It is located between two openings called the **superficial** and **deep inguinal rings**. The deep inguinal ring is the opening in the transversalis fascia on the inner surface of the abdominal wall. The superficial inguinal ring is the opening in the aponeurosis of the external oblique abdominal m. The canal has four walls:

anterior wall: is formed by the **external oblique abdominal m**. and partially by the **internal oblique abdominal** m.

posterior wall: is formed by the **transversalis fascia** and partially by the **conjoint tendon**

superior wall (roof): is formed by the **internal oblique abdominal** m. and **transversus abdominis m.**

inferior wall (floor): is formed by the **inguinal lig.** and partially by the **lacunar lig.**

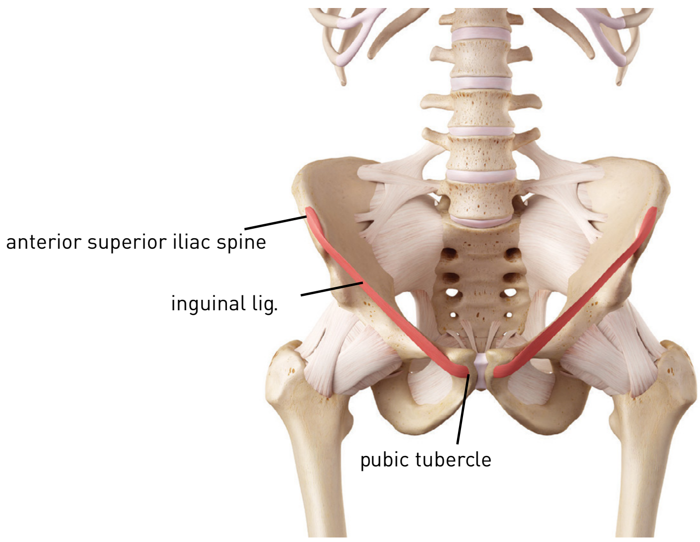


Figure 10.20. Inguinal ligament.

What is the Hesselbach's (inguinal) triangle?

This is a triangular area at the lower anterior abdominal wall which is important as being the area of potential weakness, that may lead to direct inguinal hernia. The boundaries of Hesselbach's triangle are inferior epigastric artery (laterally), inguinal ligament (inferiorly) and inferolateral border of rectus abdominis (medially).

CLINICAL RELEVANCE

An **inguinal hernia** occurs when a part of the intestine, covered by the peritoneum (peritoneal sac), enters in the inguinal canal. This causes a noticeable bulge, which may become more prominent when coughing, bending over, or lifting heavy objects. It is more common in men. There are two types of inguinal hernia:

indirect inguinal hernia: occurs when the peritoneal sac enters through the deep inguinal ring and traverses the inguinal canal. This is the more common type. It is more common in males.

direct inguinal hernia: occurs when the peritoneal sac enters the inguinal canal though an area at the posterior wall of the inguinal canal, the Hesselbach's triangle. This type is not congenital and more common in older adults due to the weakening of the abdominal muscles due to ageing.

Both types can cause similar symptoms, including a bulge in the groin, pain, or discomfort, especially when bending, lifting, or coughing. Treatment often involves surgery.

What is the conjoint tendon?

Conjoint tendon is derived from the common aponeurosis of the internal oblique abdominal m. and the transversus abdominis m. It inserts to the pubic crest and supports the posterior wall of the inguinal canal.

Which structures pass through the inguinal canal?

The structures passing through the inguinal canal differ between males and females:

<u>in females:</u>

- **ilioinguinal n.**
- **genital branch of genitofemoral n.**
- **round lig. of uterus**

<u>in males:</u>

- **ilioinguinal n.**
- **genital branch of genitofemoral n.**
- **spermatic cord**

What are the blood vessels of the posterior abdominal wall?

The posterior abdominal wall contains two of the body's largest blood vessels running parallel to each other: **abdominal aorta** and **inferior vena cava**

Abdominal aorta is the continuation of the thoracic aorta and enters the abdominal cavity by passing through the aortic hiatus of the diaphragm at the level of the T12 vertebra. It descends to the level of the L4 vertebra on the anterior and slightly left side of the spine and ends by dividing into two called **aortic bifurcation**. It has anterior, lateral and posterior branches.

anterior aortic branches: are the **coeliac trunk**, **superior mesenteric a.**, and the **inferior mesenteric a.** and all are unpaired.

coeliac trunk: it arises from the abdominal aorta at the level of Th12 vertebra immediately after it passes through the diaphragm. It further divides into three main branches: **lienal (splenic) a**., **left gastric a**., and **common hepatic a**. Through these branches, it supplies the liver, stomach, duodenum, spleen, pancreas, gall bladder, and the lower end of the esophagus.

superior mesenteric a.: it arises from the abdominal aorta below the coeliac trunk, at the level of the L1 vertebra, and supplies the pancreas, duodenum, jejunum, ileum, vermiform appendix, caecum, ascending colon, and the proximal half of transverse colon.

inferior mesenteric a.: it arises from the abdominal aorta below at the level of the L3 vertebra and supplies the distal half of transverse colon, descending colon, sigmoid colon, and the proximal part of the rectum.

lateral aortic branches: are paired (one on each side).

middle suprarenal a.: supplies the adrenal glands.

renal a.: one of the largest branches, supplying the kidneys.

gonadal aa.: known as **testicular a.** in males and **ovarian a.** in females.

posterior aortic branches:

inferior phrenic a.: is the first branch of the abdominal aorta and it supplies the inferior surface of the diaphragm.

lumbar aa.: usually 4 pairs of arteries which supply the posterior abdominal wall structures and the lower part of the spinal cord.

median sacral a.: is the unpaired and the last branch of the aorta; runs anterior to the sacrum, and supplies the surrounding structures.

Inferior v. cava is the thickest vein in the body. It is formed by the union of the two common iliac veins at the level of the L5 vertebra, just below the bifurcation of the aorta, and runs upwards on the right side of the abdominal aorta. It passes through the diaphragm at the level of the T8 vertebra and enters the thorax, and after a short course, opens into the right atrium of the heart. The veins that join the inferior vena cava bilaterally along its course are: lumbar, renal, suprarenal, hepatic and inferior phrenic. In addition, only the right side gonadal veins (testicular v. in males, ovarian v. in females) join the inferior v. cava.

Digestive System Anatomy Sample Questions:

1. What is the name given to the opening between the lips?

    a) Isthmus of fauces
    b) Rima oris
    c) Vestibule
    d) Oral cavity
    e) Soft palate

2. Which of the following can be observed on the dorsal surface of the tongue?

    a) Terminal sulcus
    b) Palatine tonsil
    c) Lingual frenulum
    d) Palatoglossal arch
    e) Uvula

3. Which of the following is **not** a mastication muscle?

    a) Masseter
    b) Temporal
    c) Buccinator
    d) Medial pterygoid
    e) Lateral pterygoid

4. What is the correct anatomical level of the esophagus in the body?

    a) C1-C6
    b) C6-T5
    c) C6-T11
    d) T1-T12
    e) C1-T10

5. Which of the following is **not** a part of the stomach?

    a) Cardia
    b) Body
    c) Fundus
    d) Antrum
    e) Ampulla

6. Which artery supplies the fundus of the stomach?
   a) Right gastric
   b) Left gastric
   c) Right gastroepiploic
   d) Left gastroepiploic
   e) Short gastric

7. Into which intestinal segment does the pancreatic duct open?
   a) Duodenum
   b) Jejunum
   c) Ileum
   d) Caecum
   e) Rectum

8. Which is the widest part of the large intestine?
   a) Caecum
   b) Ascending colon
   c) Transverse colon
   d) Descending colon
   e) Rectum

9. Which ligament extends vertically on the anterior surface of the liver?
   a) Triangular lig.
   b) Coronary lig.
   c) Round lig.
   d) Falciform lig.
   e) Lig. venosum

10. Which is the duct that exits the gallbladder?
   a) Right hepatic duct
   b) Common hepatic duct
   c) Duct cystic
   d) Common bile duct
   e) Pancreatic duct

Answers: 1.B, 2. A, 3.C, 4.C, 5.E, 6.E, 7.A, 8.A, 9.D, 10.C

URINARY SYSTEM

URINARY SYSTEM

What is the urinary system?

It is the system responsible for regulating the ion balance of the blood and filtering it to remove harmful substances from the body through urine. Additionally, it plays a role in the regulation of blood pressure.

ORGANS

Which organs constitute the urinary system?

The urinary system is composed of the following organs (Figure 11.1):

Kidneys
Ureters
Urinary bladder
Urethra

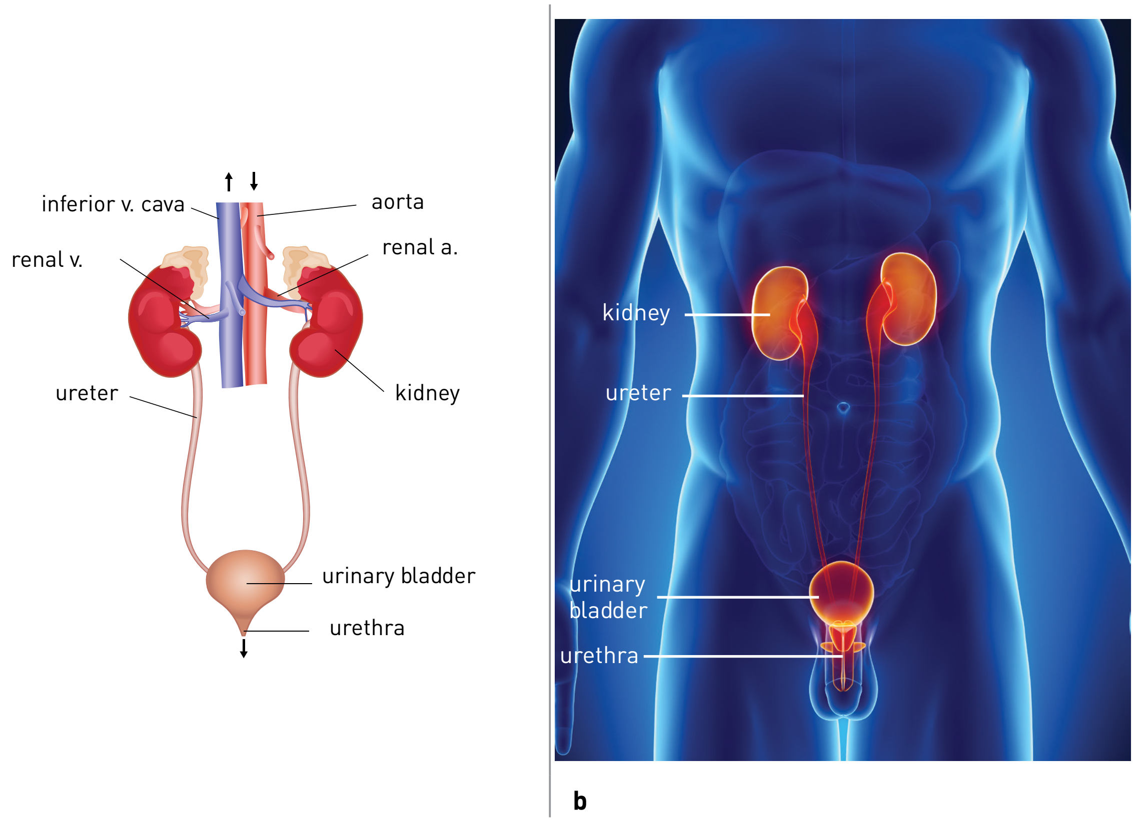


Figure 11.1. Organs of the urinary system and their anatomical positions within the body.

Kidneys

What are the kidneys?

The kidneys are a pair of retroperitoneal organs which regulate the body's ion balance and produce urine by filtering the blood.

Where are the kidneys located?

The kidneys are located on either side of the vertebral column, along the posterior abdominal wall. The right kidney lies just below the liver, while the left kidney is situated postero-medial to the spleen. The right kidney is located slightly lower than the left. The right kidney is typically found between the T12 and L3 vertebrae, and the left kidney lies between T11 and L2 (Figure 11.1).

What is the shape and appearance of the kidneys?

The kidneys are bean-shaped, reddish-brown organs. Each kidney has an anterior and a posterior surface, a convex lateral border and a concave medial border, and a superior and an inferior pole. They measure approximately 12 cm in length, 6 cm in width, and 3 cm in thickness. The medial border curves inward to form a depression called the **renal sinus**. This space contains the renal blood vessels, nerves, and the **renal pelvis**.

What are the surrounding structures of the kidneys?

The kidneys are retroperitoneal organs, meaning they are located behind the peritoneum, which only covers their anterior surface. Each kidney is embedded in fatty tissue. Posterior surface of the right kidney is related to the 12th rib, while the left kidney is related to 11th and 12th ribs. The posterior surface is also related to the diaphragm, psoas major muscle, quadratus lumborum muscle, subcostal vessels and nerve, and the iliohypogastric and ilioinguinal nerves.

The anterior surfaces of both kidneys are related to the adrenal glands at their superior poles. The right kidney is anteriorly related to the liver, duodenum, right colic flexure, and small intestine. The left kidney is anteriorly related to the stomach, spleen, pancreas, left colic flexure, and small intestine.

The medial border of each kidney faces the vertebral column and contains a vertical indentation called the **renal hilum**. At the hilum, from anterior to posterior, the following structures are arranged: **renal vein**, **renal artery**, and **renal pelvis** (abbreviated as V-A-P).

What are the surrounding layers of the kidneys?

The kidneys are covered by three layers from innermost to outermost:

fibrous capsule: a thin connective tissue layer that directly surrounds the kidney.

adipose capsule: a layer of fat that cushions and protects the kidney.

renal fascia: a fibrous connective tissue that encloses both the kidney and the adrenal gland, anchoring them to surrounding structures.

How is the internal structure of the kidney?

The kidney consists of the following main parts (Figure 11.2):

renal cortex: the outer, lighter-colored region of the kidney. It extends inward between the medullary pyramids (darker region) as **renal columns**. Nephrons, the functional units of the kidney, are located here.

renal medulla: the inner, darker region composed of **renal pyramids**. These contain the collecting ducts for urine. Each kidney typically has 15–20 pyramids. The base of each pyramid faces the renal cortex, while its apex, known as the **renal papilla**, projects into a minor calyx. Small openings called **papillary foramina** papillaria are located on the papilla, through which urine from the collecting ducts drains into the calyces.

What is the renal calyx?

Renal papillae open into small, cup-shaped structures called **minor calyces** (Figure 11.2). Several minor calyces merge to form larger structures called **major calyces**. The major calyces unite to form the **renal pelvis**, which is the largest collecting structure of the kidney. The renal pelvis narrows at the hilum and continues as the ureter.

What is the renal corpuscle (Malpighian corpuscle)?

The **renal corpuscle** is the initial part of the nephron, located in the renal cortex. It consists of the **glomerulus** and the surrounding **Bowman's capsule**, where the process of blood filtration begins.

What is a nephron?

The nephron is the functional unit of the kidney, with approximately 1 million nephrons in each kidney. It consists of a **renal corpuscle** and its associated **tubules**, which are responsible for urine formation. Tubules from multiple nephrons drain into **collecting ducts**, which then open into the **papillary foramina** located at the apex of the renal pyramids.

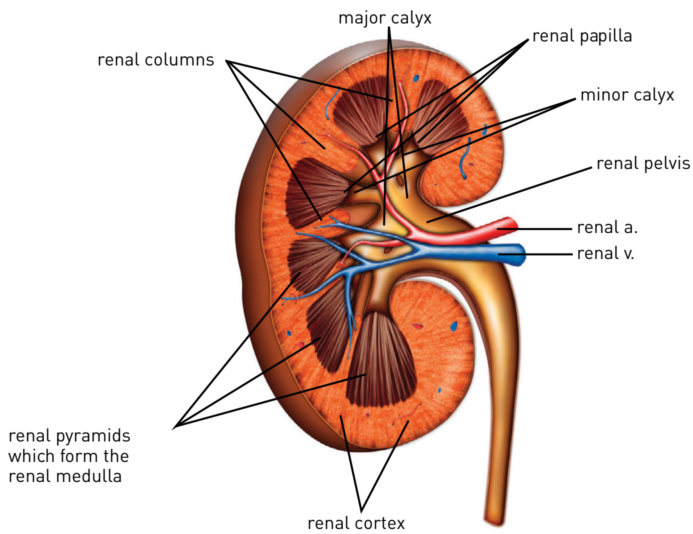


Figure 11.2. Section of the kidney.

How is urine formed?

Capillary branches from the interlobular arteries enter the Bowman's capsule located in the renal cortex and form a tuft called the glomerulus. Blood is filtered through this structure, and the resulting filtrate passes through the tubules and collecting ducts to reach the calyces.

What are the vessels of the kidneys?

The kidneys receive their blood supply from the **renal arteries**, which are major branches of the **abdominal aorta** (Figure 11.3). Each renal artery enters the renal hilum and divides into **segmental arteries**. These further branch into **interlobar arteries**, **arcuate arteries** and **interlobular arteries**.

Venous drainage occurs through the **renal veins**, which drain into the **inferior vena cava**. It is worth noting that the left renal vein also receives blood from the left suprarenal and left testicular (ovarian) veins, whereas on the right side, these veins drain directly into the inferior vena cava.

Lymph from the kidneys drains into the **lateral aortic lymph nodes**.

How is urine formed?

Capillary branches from the interlobular arteries enter the Bowman's capsule located in the renal cortex and form a tuft called the **glomerulus**. Blood is filtered through this structure, and the resulting filtrate passes through the tubules and collecting ducts to reach the calyces.

What are the nerves of the kidney?

The kidneys are innervated by nerves arising from the **renal plexus.** The parasympathetic fibers in this plexus are provided by the **vagus nerve**, while the sympathetic fibers are supplied by the **lesser splanchnic nerve**, the **least splanchnic nerve**, and lumbar sympathetic nerves.

CLINICAL RELEVANCE

Kidney biopsy is a procedure in which a small sample of kidney tissue is taken with a needle to examine under a microscope. The needle is inserted under local anesthesia through the back, guided by ultrasound or CT. It is usually done to diagnose kidney disease, assess the severity of damage or monitor a treatment.

Nephrostomy is a procedure in which a tube is inserted directly into the renal pelvis through the skin to drain urine when the ureter is blocked (e.g., by a stone or tumor). Often used as a temporary solution to relieve pressure in the kidney.

Pyelonephritis is the kidney infection, often starts as a urinary tract infection and spreads to one or both kidneys. It is caused by bacteria, most often E. coli, and can lead to symptoms like fever, back pain, nausea, vomiting, and painful urination. It can be acute (sudden and severe) or chronic (recurring or long-lasting). Prompt treatment with antibiotics is important to prevent complications like kidney damage or sepsis.

Urinary stones are hard mineral deposits that can form anywhere in the urinary tract, including the kidneys, ureters, bladder, or urethra. They develop when minerals in the urine become too concentrated and crystallize. Symptoms can include pain, blood in the urine, difficulty urinating, or frequent urination. Causes include dehydration, diet, infections, or underlying medical conditions. Treatment varies depending on the size and location of the stone and may involve increased fluid intake, medications, or procedures to break up or remove the stones.

Ureters

What is the ureter?

The ureter is a 25–30 cm long, fibromuscular tube that transports urine collected in the renal pelvis to the urinary bladder (Figures 11.1, 11.3). It is positioned retroperitoneally and descends along the posterior abdominal wall, anterior to the psoas major muscle. Posteriorly, it is crossed by the genitofemoral nerve, and anteriorly by the testicular artery (in males) or ovarian artery (in females). It crosses the iliac vessels to enter the pelvic cavity, and approaches the bladder from the posterior side, entering it through openings called **ureteric orifice**. Before entering the bladder, it crosses the following anatomical structures: the ductus deferens in males, uterine artery in females, which are surgically important.

What are the parts of the ureter?

The ureter is composed of three parts:

abdominal part: the portion between the renal pelvis and the pelvic brim
pelvic part: the segment between the pelvic brim and the urinary bladder
intramural part: the part that runs within the wall of the urinary bladder

What are the constrictions of the ureter?

There are three natural constrictions along the course of the ureter:

at the junction with the renal pelvis (ureteropelvic junction)
where it crosses the iliac vessels
at the entry point into the urinary bladder (ureterovesical junction), which is the narrowest part

What are the vessels of the ureter?

Considering its arterial supply, the ureter does not receive blood from a single dedicated artery. Branches from multiple arteries contribute to its vascularization along the course. These include:

abdominal aorta
renal artery
testicular (or ovarian) artery
common iliac artery
internal iliac artery
superior vesical artery
inferior vesical artery (in males)
uterine artery (in females)

Venous drainage is through the renal vein, inferior vena cava, and the endopelvic venous plexus. Lymph from the ureter drains into lateral aortic nodes, common iliac nodes, external iliac nodes, and internal iliac nodes.

What is the nerve supply of the ureter?

The sympathetic innervation of the ureter arises from the T10–T12 spinal cord segments. The parasympathetic innervation is provided by the vagus nerve (cranial parasympathetic) and pelvic splanchnic nerves (nervi erigentes) from the sacral region (S2–S4).

CLINICAL RELEVANCE

Urinary stones are most likely to get stuck at three points (**Ureteric narrowings**) where the ureter has natural constrictions: at the ureteropelvic junction, where the ureter crosses the iliac vessels and at the entry into the bladder (ureterovesical junction). Since the latter is the most narrowest part, so even smaller stones can get stuck here.

The **ureter** and the **uterine artery** are anatomically close to each other in the female pelvis. The uterine artery runs along the lateral side of the uterus, while the ureter travels nearby, passing beneath the uterine artery at the level of the cervix. This close proximity is important during surgeries involving the uterus, as the ureter is at risk of injury when the uterine artery is ligated or manipulated. It's crucial for surgeons to be aware of this relationship to avoid damage to the ureter during pelvic or gynecological procedures.

Ureteric colic is the pain from a stone traveling through the ureter. The pain often radiates from the flank to the groin.

Urinary Bladder

What is the urinary bladder?

The urinary bladder is a muscular organ that stores the urine transmitted by the ureters for a certain period (Figure 11.3). When empty, it is located in the lesser pelvis behind the pubic symphysis. When filled to capacity, it can extend above the level of the pubic symphysis. It can store approximately 500 mL of urine. The superior and lateral surfaces are covered by peritoneum.

The bladder wall contains a smooth muscle layer called the **detrusor muscle**. When the bladder is full, contraction of this muscle initiates the act of urination (micturition). The distal end of the ureter enters the urinary bladder from its posterior aspect, traversing the smooth muscle layers, and opens into the bladder through the ureteric orifice. A triangular region called the **trigone of the bladder** is formed between the two ureteric orifices and the internal urethral orifice.

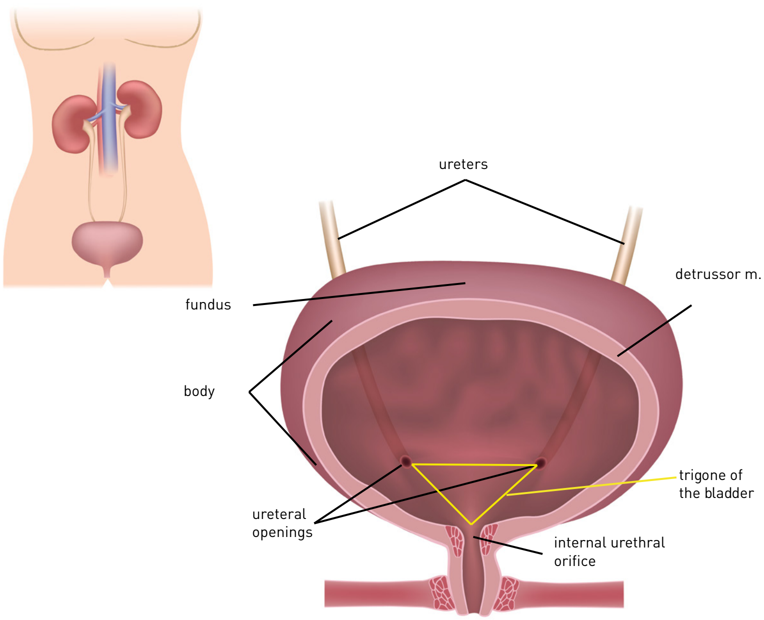


Figure 11.3. Anterior view of the bladder in coronal section.

What are the parts of the urinary bladder?

The urinary bladder consists of the following parts:

apex
fundus
body
neck

What are the anatomical relations of the urinary bladder?

In males, the urinary bladder is located anterior to the rectum and superior to the prostate. The peritoneal recess between the rectum and the bladder is called the **rectovesical pouch**. Additionally, the ductus deferens and seminal vesicles are located between the bladder and the rectum.

In females, the bladder is positioned anterior to the uterus and vagina. The peritoneal recess between the uterus and bladder is called the **vesicouterine pouch**, while the recess between the uterus and rectum is referred to as the **rectouterine pouch (Douglas pouch)**.

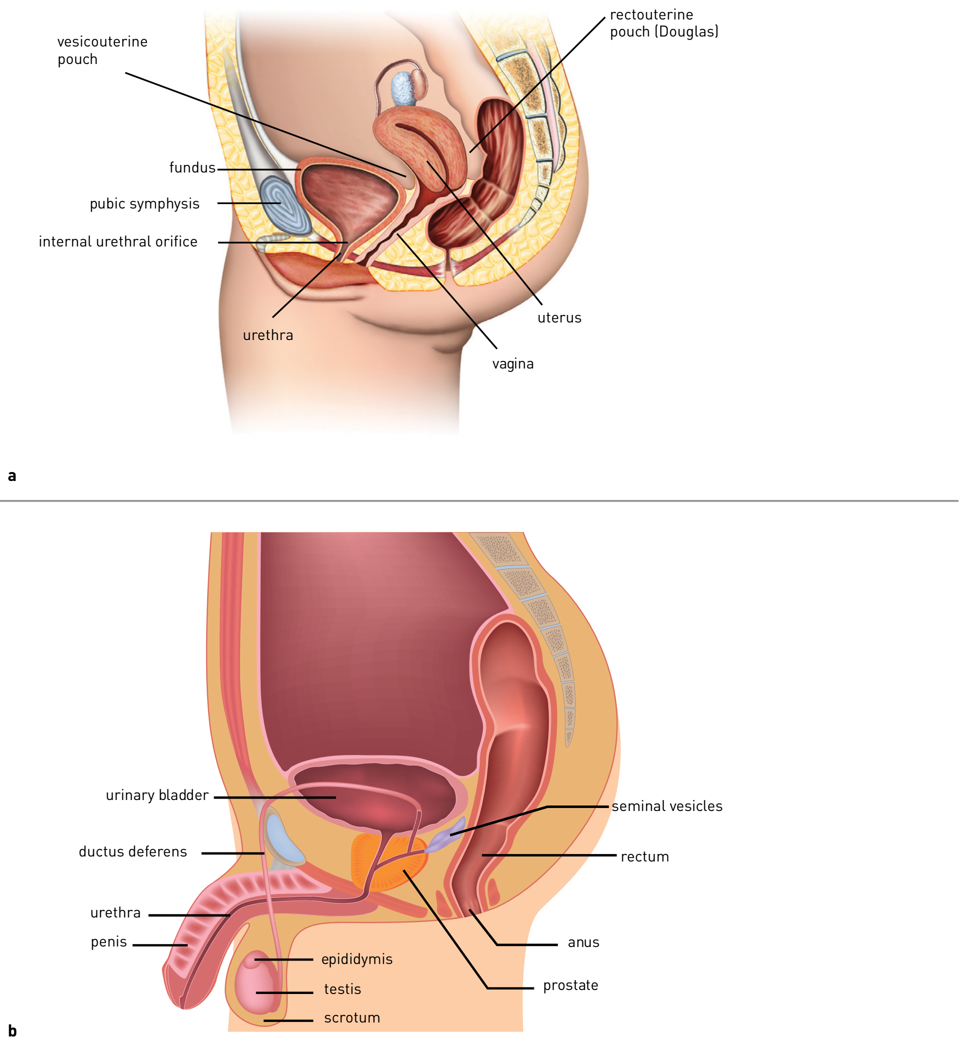


Figure 11.4. Surrounding structures of the bladder in sagittal sections. Relationship of the bladder with adjacent structures **a.** in females, and **b.** in males.

What are the blood vessels of the urinary bladder?

The bladder receives its arterial supply from the **superior** and **inferior vesical arteries**, which are branches of the internal iliac artery.

Venous drainage occurs via veins that drain into the **internal iliac vein**.

Lymphatic drainage is directed to the **external and internal iliac lymph nodes**.

What is the innervation of the urinary bladder?

The bladder receives parasympathetic innervation from the pelvic splanchnic nerves (S2–S4 segments of the spinal cord), and sympathetic innervation from the T11–T12 and L1–L2 spinal segments.

Parasympathetic stimulation causes contraction of the detrusor muscle and relaxation of the internal urethral sphincter, facilitating urination.

CLINICAL RELEVANCE

Cystitis is an inflammation of the bladder, often caused by a urinary tract infection (UTI). It typically leads to symptoms such as frequent, painful urination, lower abdominal discomfort, and cloudy or bloody urine. The condition is more common in women and can result from bacterial infections or irritation from medications. Treatment usually involves antibiotics if it's caused by a bacterial infection, along with pain relief and increased fluid intake.

Cystoscopy is an endoscopic diagnostic procedure used to examine the inner lining of the bladder and urethra. An instrument called a cystoscope is inserted through the urethra into the bladder, allowing direct visualization of the internal structures. It is commonly performed to investigate the cause of urinary symptoms, such as bleeding, recurrent infections, or to evaluate conditions like bladder tumors.

What is urethra (Urinary canal)?

The urethra is a muscular tube responsible for conveying urine stored in the bladder to the outside of the body (Figure 11.4a,b). It has two openings:

- the **internal urethral orifice**, is the opening where urine flows from the bladder into the urethra.
- the **external urethral orifice**, located at the distal end, where it opens to the exterior (in males on the tip of the penis, in females in front of vaginal orifice)

The urethra differs between males and females not only anatomically but also functionally.

What is the brief description of male urethra?

It is approximately 18–20 cm long. The external urethral orifice is located on the tip of the glans penis. It serves as a common passage for both urine and semen to be expelled from the body.

What are the parts of the male urethra?

The male urethra consists of four parts:

preprostatic part: a short segment (1–1.5 cm) located between the bladder and the prostate.

prostatic part: a 4–5 cm long portion passing through the prostate. It is the region where the ejaculatory ducts from the male reproductive system open, allowing the passage of semen into the urethra.

membranous part: the shortest segment of the urethra, located where the urethra passes through the pelvic floor. It is surrounded by the **external urethral sphincter**, composed of striated muscle under voluntary control and innervated by the pudendal nerve.

spongy part: the longest and terminal portion of the urethra, running within the spongious body of penis. It opens to the external environment through the **external urethral orifice.**

Where are the narrow parts of the male urethra?

The narrow regions of the male urethra are:

internal urethral orifice

membranous part

external urethral orifice (narrowest)

What are the blood vessels of the male urethra?

The urethra is supplied by the **urethral artery** and the **artery of the bulb of the penis**

Venous blood drains into veins that accompany these arteries.

Lymphatic drainage flows into the **external and internal iliac nodes**, as well as the **deep and superficial inguinal nodes**.

What is the nerve supply of the male urethra?

The urethra receives innervation from fibers originating in the **prostatic plexus** and the **pudendal nerve.**

What is the brief description of female urethra?

The female urethra is approximately 3–4 cm long. It begins at the exit of the bladder and ends in the vestibule of the vagina. The external urethral is located between the clitoris and the vaginal opening. It serves solely as a passage for urine excretion.

What is the arterial supply of the female urethra?

It is supplied by the internal pudendal artery and inferior vesical artery. Venous drainage follows similarly named veins. Lymphatic drainage is toward the internal iliac nodes, superficial inguinal nodes, and sacral nodes.

What is the innervation of the female urethra?

It receives nerve fibers from the pelvic plexus and the pudendal nerve.

CLINICAL RELEVANCE

Urinary tract infections (UTIs) are common in females due to their shorter urethra, which makes it easier for bacteria to reach the bladder. UTIs can cause symptoms like frequent, painful urination, cloudy or foul-smelling urine, and lower abdominal discomfort. They are often caused by E. coli bacteria, but other factors like sexual activity or poor hygiene can increase the risk. UTIs are typically treated with antibiotics, and drinking plenty of fluids can help prevent future infections.

Urethral stricture is a narrowing of the urethra. This condition can be caused by injury, infection, or inflammation, and it can lead to symptoms like difficulty urinating, a weak urine stream, or frequent urinary tract infections (UTIs). It is much more common in males than in females. This is because the male urethra is longer and more prone to injury or scarring. Factors such as trauma, infections, or certain medical procedures can lead to strictures in men. In females, the urethra is shorter and less likely to develop strictures, though they can still occur, typically due to infections or surgery. Treatment may involve procedures to dilate or surgically repair the narrowed area, depending on the severity of the stricture.

Urinary catheterization is a medical procedure where a tube, called a catheter, is inserted into the bladder through the urethra (or through the abdomen in some cases) to drain urine. It is used when a person is unable to urinate on their own due to obstruction, surgery, injury, or certain medical conditions. The catheter can be temporary or long-term, depending on the patient's needs, and is typically monitored to prevent infection or other complications.

Sample Questions on the Anatomy of the Urinary System

1. Which of the following is located anterior to the right kidney?
   a) Spleen
   b) Pancreas
   c) Gallbladder
   d) Liver
   e) Stomach

2. Into which structure does the renal papilla open?
   a) Minor calyx
   b) Major calyx
   c) Renal pelvis
   d) Renal sinus
   e) Renal hilum

3. What is the name of the triangular, dark-colored structure observed in a cross-section of the kidney?
   a) Renal cortex
   b) Renal column
   c) Renal papilla
   d) Renal pelvis
   e) Renal pyramid

4. The renal artery is a branch of which of the following?
   a) Internal iliac artery
   b) External iliac artery
   c) Abdominal aorta
   d) Hepatic artery
   e) Splenic artery

5. Which of the following is not a part of the urinary bladder?
   a) Body
   b) Tail
   c) Fundus
   d) Neck
   e) Apex

6. Which structure is located posterior to the urinary bladder in males?

a) Prostate
b) Urethra
c) Seminal vesicle
d) Rectum
e) Transverse colon

7. Which structure is located posterior to the urinary bladder in females?

a) Ovary
b) Urethra
c) Vagina
d) Rectum
e) Pubic bone

8. Which of the following is not a part of the male urethra?

a) Preprostatic part
b) Prostatic part
c) Membranous part
d) Spongy part
e) Abdominal part

9. Which of the following is correct regarding the male urethra?

a) It is shorter than the female urethra
b) Its narrowest part is the internal urethral orifice
c) Its shortest part is the prostatic part
d) The internal urethral orifice is located in the glans penis
e) It extends between the internal and external urethral orifices

10. The arteries supplying the urinary bladder are branches of which artery?

a) Internal iliac artery
b) External iliac artery
c) Abdominal aorta
d) Renal artery
e) Umbilical artery

Answers: 1.D, 2. A, 3.E, 4.C, 5.B, 6.D, 7.C, 8.E, 9.E, 10.A

GENITAL SYSTEM (REPRODUCTIVE SYSTEM)

GENITAL SYSTEM (REPRODUCTIVE SYSTEM)

The genital system is composed of organs responsible for reproduction. It is divided into two groups:

female genital organs
male genital organs

FEMALE GENITAL ORGANS

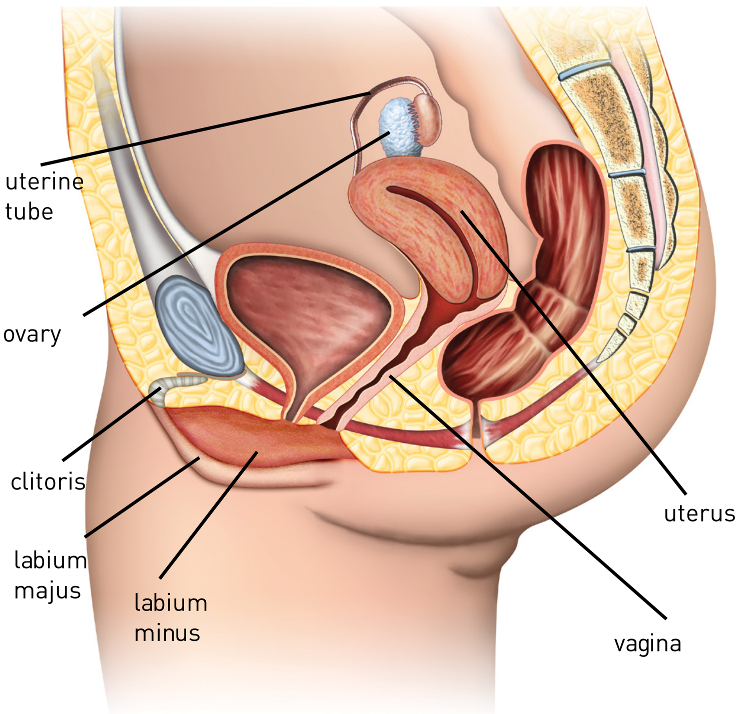
Female Genital System

The female genital system is divided into two parts: **internal** and **external genital organs**.
It is responsible for the production of sex hormones and reproductive cells (oocytes), as well as for supporting the formation of the zygote, pregnancy, childbirth, and postpartum processes.

What are the internal genital organs in females?

The internal genital organs in females include the following structures (Figure 12.1a,b):

ovary
uterine tube (also called **Fallopian tube** or **salpinx**)
uterus
vagina



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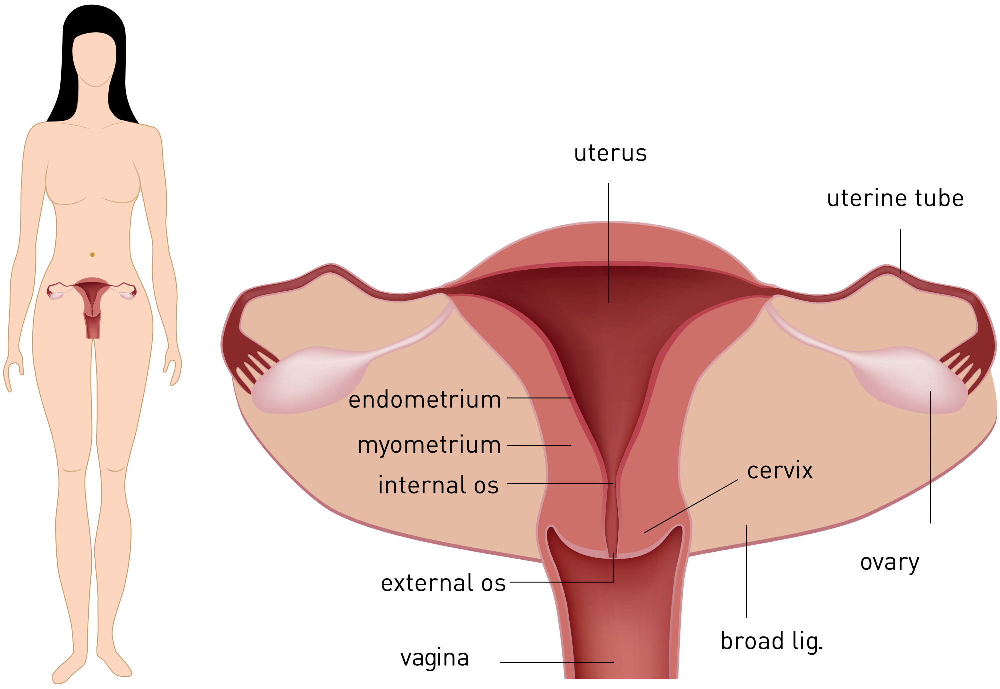


b

Figure 12.1. Female genital organs. **a.** sagittal section showing the position of the female genital system organs within the pelvis. **b.** relationship between the uterus, vagina, uterine tubes (tuba uterina), and ovaries.

Ovary

There are two ovaries, one on each side. They function as both endocrine and exocrine glands.

They are the female equivalent of the testes in males. The ovaries produce ova (egg cells) and secrete hormones such as estrogen and progesterone.

What is the shape and appearance of the ovary?

The ovary is almond-shaped and gray-pink in color. It has two surfaces (medial and lateral), two poles (superior and inferior), and two borders (anterior and posterior).

The point where blood vessels and nerves enter or leave the ovary is called the **hilum of the ovary**.

Where is the ovary located, and what are its surrounding structures?

The ovary is located in the **ovarian fossa** on the lateral wall of the pelvis. It is separated from the fossa by the parietal peritoneum. Behind the peritoneum lie the ureter, internal iliac artery and vein, and the obturator artery.

What are the ligaments of the ovary?

The ovary is supported by the following ligaments:

- **suspensory ligament of the ovary**: a fold of peritoneum that contains the ovarian artery and vein.
- **proper ovarian ligament**: connects the ovary to the uterus.
- **mesovarium**: a short fold of peritoneum through which blood vessels and nerves reach the ovary.

How many parts does the ovary have?

The ovary consists of two main regions:

- **cortex**: the outer region that contains follicles.
- **medulla**: the inner region.

What are the vessels of the ovary?

Arterial supply: **ovarian artery**.

Venous drainage: pampiniform plexus forms the **ovarian vein**.

Lymphatic drainage: drains into preaortic and lateral aortic lymph nodes.

What are the nerves of the ovary?

Sympathetic innervation: from spinal segments **T10–T11**.

Parasympathetic innervation: from the **vagus nerve** and **pelvic splanchnic nerves (nn. erigentes)**.

Nerve fibers reach the ovary through the **ovarian plexus**.

What is the ovarian cycle?

The ovarian cycle refers to the sequence of events that occur in the ovary, including follicular development, the hormonal regulation of this process, ovulation, and the formation of the "corpus luteum". This cycle typically lasts about 28 days.

During the first half of the cycle, a follicle in the ovary begins to mature and produce estrogen. Near the middle of the cycle, an increase in GnRH (gonadotropin-releasing hormone) secretion from the hypothalamus stimulates the pituitary gland to release FSH (follicle-stimulating hormone) and LH (luteinizing hormone). These hormones complete the maturation of the follicle, which then releases the ovum—a process called ovulation.

After ovulation, the ruptured follicle transforms into a temporary endocrine structure called the corpus luteum, which secretes estrogen and progesterone for the remaining ~14 days of the cycle. These hormones prepare the uterus for a possible pregnancy and inhibit further FSH and LH secretion to prevent the development of additional follicles.

If fertilization does not occur, the corpus luteum degenerates, leading to a drop in estrogen and progesterone levels. As a result, the cycle ends and a new one begins. (Figure 12.2)

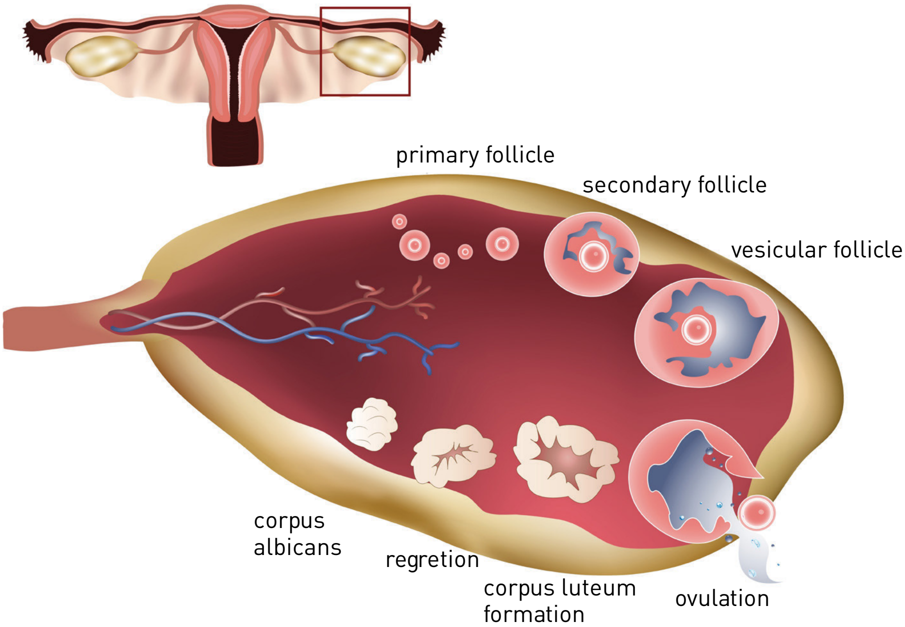


Figure 12.2. Ovarian cycle.

What is the menstrual cycle?

The menstrual cycle refers to the approximately 28-day series of periodic changes that occur in the uterus to prepare for implantation of a fertilized ovum. During the first half of the cycle, the endometrial lining of the uterus thickens in response to hormonal stimulation, creating a suitable environment for potential pregnancy.

Midway through the ovarian cycle (around 14th day), a mature follicle ruptures and the ovum is released. Then it is captured by the uterine (Fallopian) tube. If fertilization occurs within the tube, the resulting zygote (fertilized ovum with a sperm) travels to the uterus and implants in the thickened endometrium, marking the beginning of pregnancy.

If fertilization does not occur, the ovum degenerates. The thickened endometrial mucosa, no longer needed, begins to shed. As this tissue breaks down, it leaks into the uterine cavity and is expelled through the vagina as menstrual bleeding (menses).

Uterine Tube (Fallopian Tube, Salpinx, Tubes)

The uterine tube is a muscular passage approximately 10 cm long and 1–3 mm in diameter that connects the ovary to the uterus, facilitating the transport of the ovum (egg cell) from the ovary to the uterine cavity (Figure 12.1a,b). The tube has two ends, each opening into a different cavity:

abdominal ostium: the lateral opening of the tube, facing the peritoneal cavity and directed toward the ovary.

uterine ostium: the medial opening through which the tube communicates with the uterine cavity.

What are the parts of the uterine tube?

The uterine tube is divided into four parts:

infundibulum: the funnel-shaped part that extends toward the ovary, with finger-like projections called **fimbriae tubae uterinae**.

ampulla: the widest segment, where fertilization usually occurs.
isthmus: the narrow portion located close to the uterus.
uterine part: the narrowest section, which passes through the wall of the uterus.

What are the vessels of the uterine tube?

The part near the ovary is supplied by branches of the **ovarian artery**, while the part closer to the uterus is supplied by branches of the **uterine artery**.

Venous drainage is into the **ovarian vein** and **uterine vein**.

Lymphatic drainage goes to the **lateral aortic** and **preaortic lymph nodes**.

What are the nerves of the uterine tube?

Sympathetic innervation arises from **T10 to L2 segments**, and parasympathetic innervation comes from the **vagus nerve** and **pelvic splanchnic nerves**.

Uterus

The uterus is a thick-walled, muscular organ located in the pelvic cavity between the rectum and the urinary bladder. It contains a central cavity called the **uterine cavity**.

The uterus is connected to the **uterine tubes** at its upper lateral angles and to the **vagina** inferiorly (Figures 12.1 and 12.3).

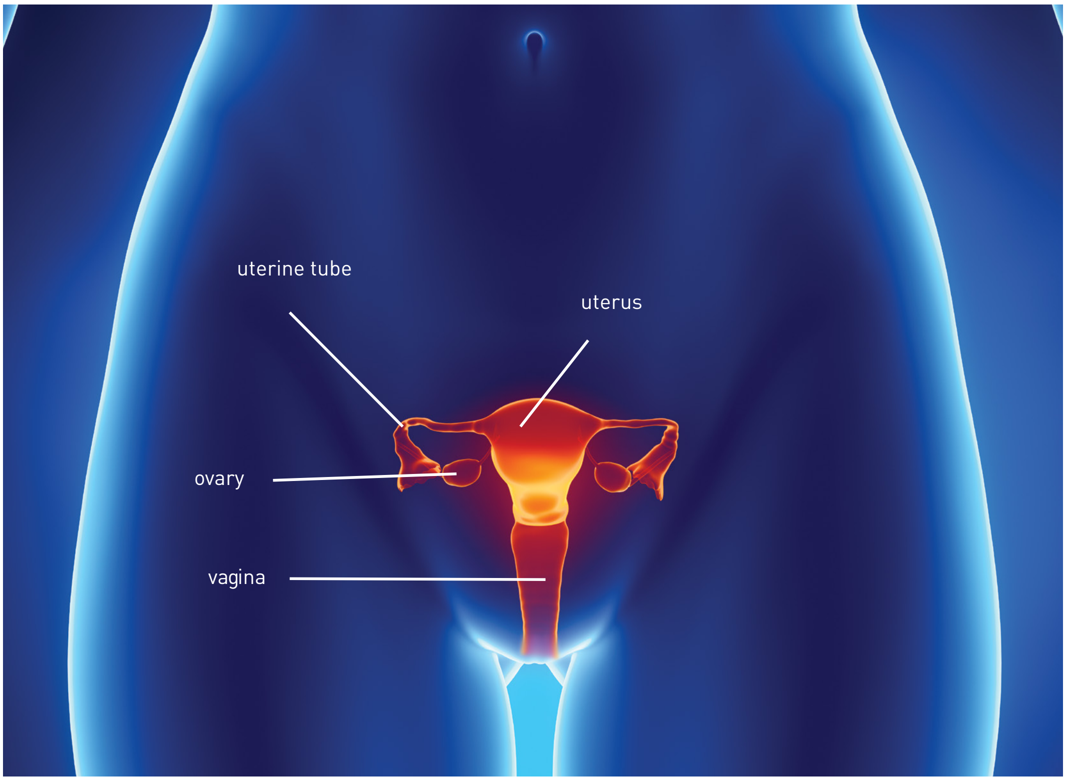


Figure 12.3. Anatomical position of the uterus within the body.

What are the parts of the uterus?

The uterus consists of three main parts (Figure 12.4):

body: this is the main part of the uterus, extending from the dome-shaped top called the **fundus** of uterus to the cervix. The uterine tubes opens into the upper corners of the body which are called the **uterine horns**

isthmus: a narrow and short segment between the corpus and the cervix.

cervix: a cylindrical portion about 2.5 cm in length. Its internal opening, **internal os**, leads into the uterine cavity, while its external opening, **external os**, opens into the vagina. The **cervical canal** runs between these two openings and contains mucosal folds that interlock, almost closing the canal. The lower part of the cervix projects into the vagina, forming recesses around it called the **fornices of the vagina**.

Where is the uterus located and what are its anatomical relations?

The uterus is located in the pelvic cavity, anterior to the rectum and posterior to the urinary bladder. Its superior surface is covered by peritoneum.

The peritoneal recess between the uterus and the bladder is called the **vesicouterine pouch**, and the recess between the uterus and the rectum is referred to as the **rectouterine pouch** or **Douglas pouch**. Loops of intestines may occupy this posterior recess.

On both sides, the peritoneum extends from the uterus to the lateral walls of the pelvis, forming the **broad ligament**. The position of the uterus may vary depending on the filling status of the bladder and rectum.

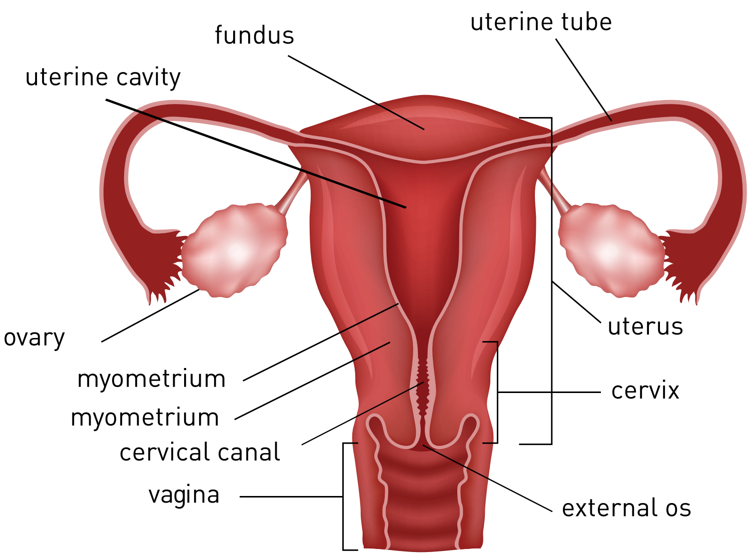


Figure 12.4. Parts and layers of the uterus.

What are anteversion and anteflexion angles?

The angle between the axis of the vagina and the axis of the cervical canal, approximately 90°, is called the **anteversion angle**, and a uterus in this position is referred to as **anteverted**.

The angle between the axis of the body of uterus and the cervix, approximately 170°, is called the **anteflexion angle**, and a uterus in this position is called **anteflexed**.

In most women who have not given birth, the uterus is in an anteverted position. When the bladder is empty, the uterus typically assumes an **anteflexed** position.

What are the layers of the uterus?

The uterus consists of three layers (Figure 12.4):

endometrium: the innermost layer, which undergoes cyclic changes during the menstrual cycle and is the site where a fertilized ovum implants.
myometrium: the thick muscular middle layer responsible for uterine contractions.
perimetrium: the thin outer layer formed by the peritoneum.

What are the ligaments of the uterus?

The ligaments of the uterus are either peritoneal folds or true ligaments. (Figure 12.5)

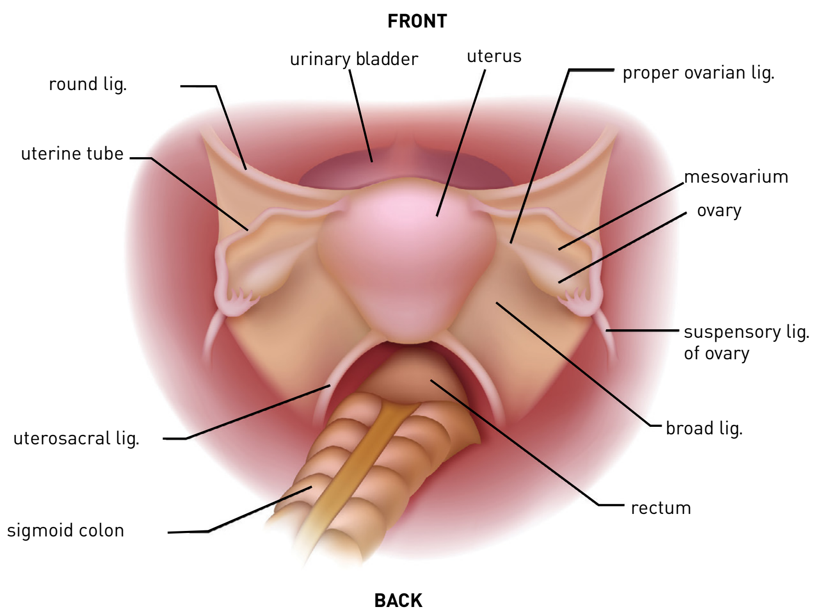


Figure 12.5. Ligaments of the uterus.

Peritoneal folds:

uterovesical fold: a peritoneal fold extending from the anterior aspect of the uterus to the urinary bladder.
rectovaginal fold: a peritoneal fold stretching from the posterior fornix of the vagina to the anterior surface of the rectum.
broad ligament of the uterus: a double layer of peritoneum extending from the sides of the uterus to the lateral pelvic walls. It divides the pelvic cavity into anterior and posterior parts and contains important reproductive structures.
The broad ligament is divided into three parts:

mesosalpinx: the portion adjacent to the uterine tube.

mesovarium: the portion associated with the ovary.

mesometrium: the portion closest to the uterus.

The **broad ligament** contains/covers the **uterine tubes, ovaries, uterine artery, round ligament of the uterus**, and **ureter**.

True ligaments:

uterosacral ligament: a pair of fibrous bands extending from the lower posterior uterus to the sacrum. They help to support the uterus posteriorly.

round ligament of the uterus: arises from the uterine horn and passes anteriorly and inferiorly into the inguinal canal, terminating in the connective tissue of the major labia.

cardinal ligament (transverse cervical ligament): anchors the cervix and lateral fornix of the vagina to the lateral pelvic walls, providing strong support to the uterus.

What are the vessels of the uterus?

The uterus is supplied by the **uterine artery**, which is a branch of the **internal iliac artery**. The **uterine artery** forms anastomoses with the **ovarian artery** and the **vaginal artery**.

Venous drainage is through the **uterine vein**, which drains into the **internal iliac vein**.

Lymphatic drainage flows to the **lateral aortic**, **preaortic**, **external iliac**, **internal iliac**, and **sacral lymph nodes**.

What are the nerves of the uterus?

Sympathetic fibers supplying the uterus arise from the **T12–L1 spinal segments**, while parasympathetic fibers originate from the **S2–S4 spinal segments** via the **pelvic splanchnic nerves (nn. erigentes)**.

These autonomic fibers reach the uterus through the **uterovaginal plexus**.

Vagina

The vagina is a fibromuscular canal, approximately 8–10 cm long, extending between the uterus and the vulva (see Figure 12.1a). It serves as the birth canal during delivery and provides the outlet for menstrual flow.

Anteriorly, it is related to the urinary bladder and urethra, posteriorly to the rectum and anal canal, and laterally to the levator ani muscles. The upper part of the vagina surrounds a portion of the uterine cervix, forming the **fornix**, a recess that helps support the uterus.

The internal surface of the vaginal wall contains transverse folds called **vaginal rugae**, which allow the vagina to stretch and elongate during childbirth. The lower end opens into the **vestibulum of vagina** through the **ostium of vagina**. In individuals who have not engaged in sexual intercourse, a thin mucosal fold called the **hymen** may partially cover the vaginal opening.

What are the vessels of the vagina?

The arterial supply of the vagina comes from the **vaginal arteries**.

Venous drainage is provided by the **vaginal venous plexus**, which drains into the **internal iliac vein**.

Lymphatic drainage is directed to the **external iliac**, **internal iliac**, and **superficial inguinal lymph nodes**.

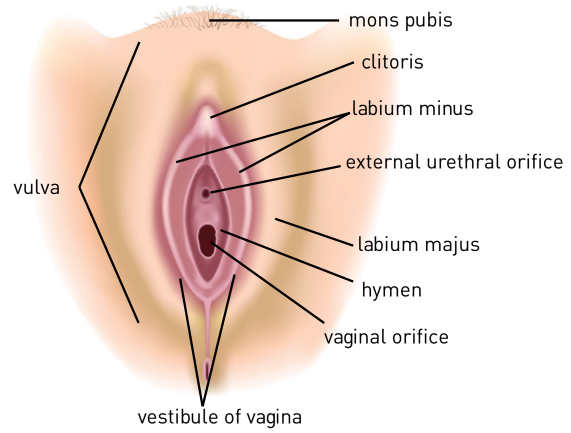
What are the nerves of the vagina?

The vagina receives sympathetic and parasympathetic innervation via the **uterovaginal** and **pelvic plexuses**.

The **distal portion** of the vagina is innervated by the **pudendal nerve**.

What are the external genital organs in females?

All the female external genital organs are collectively referred to as the **vulva**.



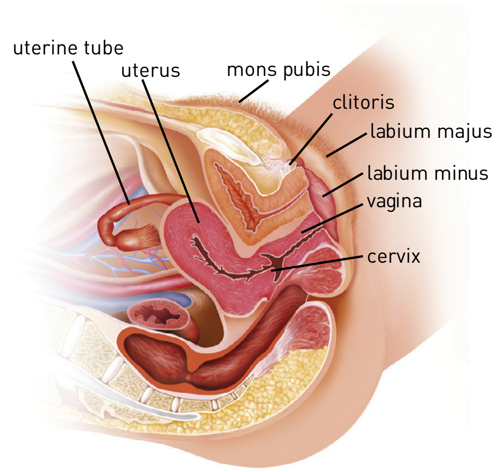


Figure 12.6. Female genital organs. **a.** vulva, anterior view of the external genital organs. **b.** sagittal section showing the position of the genital organs.

The components of the female external genitalia include (see Figure 12.6a,b):

mons pubis
major labia
minor labia
vestibule of vagina
clitoris
vestibular bulbs
greater vestibular gland (Bartholin's glands)

Mons pubis A fatty elevation located anterior to the pubic symphysis. It is covered with pubic hair after puberty.

Major labia Homologous to the male scrotum. These are longitudinal folds of skin extending from the mons pubis posteriorly. The outer surface is pigmented and sparsely hairy, while the inner surface is lighter and hairless. The space between the two major labia is called the **rima pudendi (pudendal cleft)**. The round ligament of the uterus terminates in the major labia.

Minor labia Located within the major labia, these folds are homologous to the skin of the penis in males. They surround the **clitoris** from both anteriorly and posteriorly and extend backward.

Vestibule of vagina The space between the minor labia. It contains the **external urethral orifice** (anteriorly) and the **vaginal orifice** (posteriorly).

Clitoris The female homologous to the penis. It is partially surrounded by the minor labia and is an **erectile structure**. The small, rounded portion at the anterior end is called the **glans of clitoris**.

Vestibular bulbs The female homologous to the **bulb of the penis** and **spongious body of penis**. It lies deep to the major labia and is surrounded by the **bulbospongiosus muscle**.

Greater vestibular gland (Bartholin's gland):Responsible for lubricating the vaginal orifice during intercourse. It secretes mucus into the space between the minor labia. It is the homologous to the **bulbourethral gland (Cowper's gland)**.

CLINICAL RELEVANCE

Uterine Position & Fertility. The position of the uterus can play a role in fertility, although it is not usually a primary cause of infertility. A normally positioned uterus (anteverted) facilitates sperm movement toward the Fallopian tubes. However, variations like a retroverted uterus (tilted backward) are generally considered normal and rarely cause infertility on their own. In some cases, abnormal positioning may be linked to underlying conditions such as endometriosis, fibroids, or pelvic adhesions, which can impair fertility. Proper assessment of uterine position is important during fertility evaluations to guide diagnosis and treatment. Alterations in position may sometimes be associated with dyspareunia (painful intercourse), pelvic pain, or difficulty in conception.

Ectopic pregnancy is a condition where a fertilized ovum implants and grows outside the main cavity of the uterus, most commonly in the Fallopian tube. This type of pregnancy is not viable and can pose serious health risks if left untreated, including tube rupture and internal bleeding. Symptoms may include sharp abdominal pain, vaginal bleeding, and dizziness. Early diagnosis through ultrasound and blood tests is critical, and treatment often involves medication or surgery. Prompt medical intervention is essential to prevent complications and preserve future fertility.

Cervical cancer is a type of cancer that occurs in the cells of the cervix. It is most commonly caused by persistent infection with high-risk types of human papillomavirus (HPV). Early stages may not show symptoms, but advanced cases can cause abnormal vaginal bleeding, pelvic pain, or pain during intercourse. Regular screening through Pap smears and HPV testing can detect precancerous changes early. These tests can identify abnormal cervical cells before they turn cancerous, allowing for timely treatment. Screening significantly reduces the risk of developing or dying from cervical cancer and is recommended for women starting in their early 20s. Cervical cancer is highly preventable with vaccination against HPV and routine gynecological care.

Hysterectomy is a surgical procedure in which a woman's uterus is removed. It may be performed for various medical reasons, including conditions such as uterine cancer, fibroids, endometriosis, chronic pelvic pain, abnormal bleeding, or uterine prolapse. While this surgery resolves certain health issues, it ends a woman's ability to become pregnant. The surgical procedure in which the tubes and ovaries are removed bilaterally along with the uterus is called **hysterosalpingo-oophorectomy**.

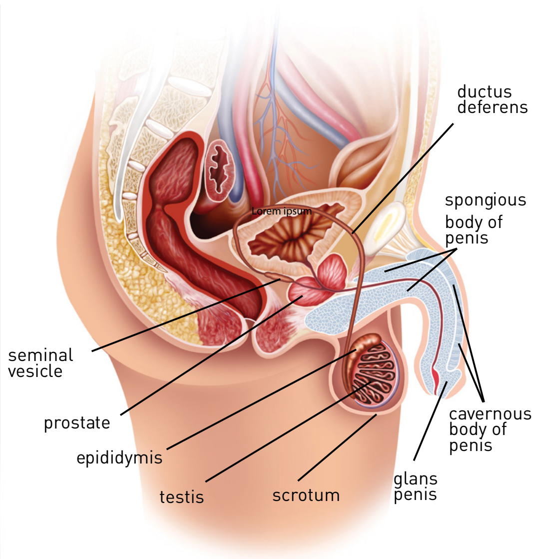
MALE GENITAL ORGANS

They are classified into two groups: **internal genital organs** and **external genital organs**.

What are the internal genital organs in males?

The internal genital organs in males include the following (Figure 12.7a, b):

testis
epididymis
ductus (vas) deferens
ejaculatory duct
seminal vesicles
prostate
bulbourethral gland



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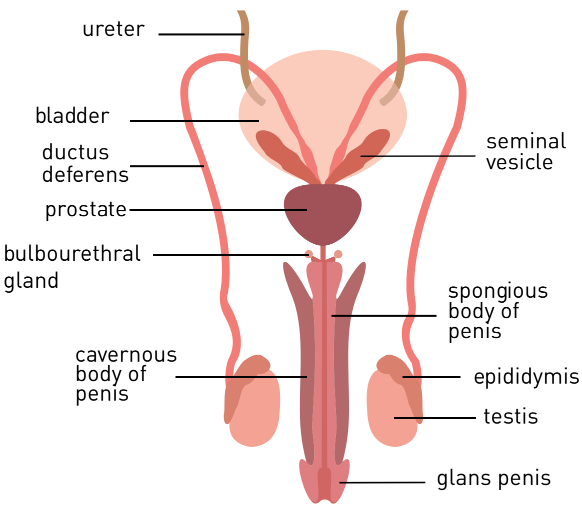


b

Figure 12.7. Male genital organs. **a.** sagittal section showing the anatomical position of the organs. **b.** the pathway of sperms from the testes to the urethra and the structures they pass through.

Testis (gonad, testicle)

Each testis is approximately 5 cm long and 3 cm wide. These paired sex organs are responsible for the production of sperm and the secretion of testosterone. Because sperm production is temperature-sensitive, the testes are located outside the body cavity within a sac called the **scrotum**. During fetal development, the testes initially develop inside the abdominal cavity and gradually descend into the pelvis, eventually reaching the scrotum near birth. Each testis is surrounded by a fibrous capsule called the **tunica albuginea**, which extends inward to divide the testis into **lobules**. Externally, the testes are also covered by the **tunica vaginalis**, a peritoneal extension that forms a protective outer covering within the scrotum.

What are the vessels of the testis?

The **testicular artery**, a direct branch of the abdominal aorta, supplies arterial blood to the testis.

Venous blood is first collected by a network of veins called the **pampiniform plexus**, which then converges into the **testicular vein**. The **right testicular vein** drains directly into the **inferior vena cava**, while the **left testicular vein** drains into the **left renal vein**.

Lymphatic drainage of the testis is directed to the **preaortic** and **lateral aortic lymph nodes**.

What are the nerves of the testis?

The testis is innervated by **sympathetic fibers** originating from the **T7 spinal segment**, which travel through the **aortic plexus**, and by **parasympathetic fibers** from the **vagus nerve**. These autonomic fibers regulate vascular tone and contribute to testicular function.

Epididymis

Located on the superior-posterior surface of the testis, the **epididymis** consists of three parts: **head**, **body**, and **tail**. It is actually a highly coiled duct where sperm is **stored** and **matures**. During ejaculation, smooth muscle in its wall contracts, propelling sperm into the ductus deferens.

Ductus (Vas) Deferens

The **ductus deferens** is a muscular tube approximately <u>45 cm long</u> that begins at the tail of the epididymis and serves to transport sperm. It ascends within the **spermatic cord**, accompanied by blood vessels, lymphatics, and nerves, and passes through the inguinal canal to enter the pelvic cavity. In the pelvis, it travels posterior to the bladder, crosses anterior to the ureter, and approaches the superior aspect of the seminal vesicle. Before joining the duct of the seminal vesicle (ductus excretorius) to form the ejaculatory duct, it dilates into a widened segment known as the **ampulla**.

Ejaculatory duct

The ductus deferens joins with the duct of the seminal vesicle to form the **ejaculatory duct**. This duct then opens into the prostatic part of the urethra.

Seminal vesicles

Located posterior to the bladder and anterior to the rectum, above the prostate gland, the seminal vesicles are a pair of glands that contribute about 60% of the volume of the ejaculate. This fluid is rich in fructose, providing an energy source for sperm. Their duct is called the

ductus excretorius, one on each side, which joins with the **ductus deferens** to form the **ejaculatory ducts**. These ducts then open into the **prostatic part of the urethra** through two small openings.

Prostate

The prostate is a chestnut-sized gland located just below the bladder, surrounding the initial part of the urethra (prostatic urethra). It secretes its fluid through 15–20 small ducts directly into the prostatic part of the urethra. The secretion is alkaline, which helps neutralize the acidic environment of the vagina, thereby enhancing sperm survival. The prostate contributes approximately 20% of the ejaculate volume.

Bulbourethral gland (Cowper's gland)

These are a pair of pea-sized glands (2–4 cm) located within the deep transverse perineal muscle. Each gland opens into the spongy part of the urethra. Their secretion, released before ejaculation, helps lubricate the urethra and facilitates the smooth passage of semen.

What are the external genital organs in males?

The external genital organs in males include:

penis
scrotum

Penis

Penis serves as a common organ for both the urinary and reproductive systems. During sexual intercourse, it enlarges (erection) and is inserted into the vagina to deliver ejaculate. During urination, it transports urine from the bladder to the exterior through the urethra, which runs within its spongy part.

What are the parts of the penis?

The penis is divided into two main parts:

free part
fixed part /root (Figure 12.7a)

Free part is the movable part of the penis that is visible externally in the midline of the groin region. It consists of two components:

body of penis (shaft)
glans penis (head)

The shaft contains:

one **spongious body of penis**, located on the underside
two **cavernous body of penis**, lying dorsally.

These erectile tissues are enclosed by a tough fibrous sheath called **tunica albuginea**. The spongious body expands at its distal end to form the **glans penis**, which is covered by the **prepuce (foreskin)**. The urethra runs through the spongious body and opens at the tip of the glans through the **external urethral orifice**.

Fixed part (root of the penis) is immobile and attaches to the pubic bone. It includes:

two **crura penis**, covered by **ischiocavernosus muscle**
one **bulb of penis**, located between the crura and covered by **bulbospongiosus muscle.**

The crura of the penis unite beneath the **pubic symphysis** and continue forward as the **cavernous body**, while the bulb of penis continues as the **spongious body of penis**.

What are the vessels of the penis?

The arterial supply of the penis includes the

artery of bulb of penis
urethral artery
dorsal artery of penis
deep artery of penis

Venous drainage is mainly through the **deep dorsal veins**, which drain into the **prostatic venous plexus**.

The lymphatic vessels of the penile skin primarily drain into the **deep inguinal lymph nodes** and **internal iliac lymph nodes**.

What are the nerves of the penis?

The sensory innervation of the penis is primarily provided by the **dorsal nerve of the penis**, which is a branch of the **pudendal nerve**.

Scrotum

The scrotum is a pouch-like structure located in the perineum, containing the **testes**, **epididymis**, and the lower part of the **spermatic cord**. It is the male counterpart of the **major labia** in females. Positioned behind and below the penis, it lies between the thighs. The scrotal skin is thin, darker than the rest of the body, and sparsely hairy. A midline ridge known as the **raphe of scrotum** is visible, which continues anteriorly as the **penil raphe** and posteriorly in the perineum as the **perineal raphe**, indicating the midline of these structures.

The scrotal temperature is approximately 2–4°C lower than core body temperature, which is essential for optimal sperm production. Internally, the **scrotal septum** divides the scrotum into right and left compartments, each housing a testis.

What are the layers of the scrotum?

The scrotum is composed of **five layers**, listed from superficial to deep:

skin
tunica dartos (dartos muscle)
external spermatic fascia
cremasteric fascia and cremaster muscle
internal spermatic fascia

Just beneath the skin lies the tunica dartos, which contains smooth muscle fibers known as **dartos muscle**. When these muscles contract (e.g. in cold environments), the scrotum becomes wrinkled, reducing heat loss. Conversely, in warm environments, the muscle relaxes, the scrotal wall smoothens, and heat dissipation increases. This temperature regulation is crucial for optimal sperm production, as sperm development requires a temperature slightly lower than the body's core.

What are erection and ejaculation?

Erection is the process in which the cavernous body of penis fill with blood, causing the penis to enlarge, become firm, and stand erect. This physiological response is controlled by the central nervous system and primarily mediated by the **parasympathetic nervous system**. While the spongious body of penis also becomes engorged, it remains less rigid to allow for the passage of semen through the urethra.

Ejaculation refers to the expulsion of **ejaculate (semen)** from the penis during sexual intercourse, and it is primarily under **sympathetic nervous system** control.

What is semen (ejaculate)?

Semen, also known as **ejaculate**, is the fluid composed of sperm cells and the secretions of the male accessory sex glands. It typically contains 20 to 150 million sperm cells per milliliter.

A sperm concentration below 20 million/ml is called **oligospermia**, and the absence of sperm cells in the ejaculate is referred to as **azoospermia**.

CLINICAL RELEVANCE

Digital Rectal Examination (DRE) is a physical examination technique in which a healthcare provider inserts a lubricated, gloved finger into the rectum to check for abnormalities in the prostate, rectum, and surrounding tissues. As the prostate gland lies anterior to the rectum and can be palpated through the rectal wall during DRE, it is commonly used to screen for prostate problems, such as enlargement or cancer, and to assess rectal issues like tumors, bleeding, or hemorrhoids. The procedure is quick, generally painless, and can help detect issues that may not be visible or detectable through other methods. Regular DREs are often recommended for men over 50 or those with a family history of prostate cancer.

Benign Prostatic Hyperplasia (BPH) is a non-cancerous enlargement of the prostate gland, commonly seen in older men. As the prostate grows, it can press against the urethra and block the flow of urine, leading to symptoms like frequent urination, difficulty starting urination, weak urine stream, and the feeling of incomplete bladder emptying. BPH is not cancer and does not increase the risk of prostate cancer, but it can affect quality of life. Treatment options include lifestyle changes, medications, and in more severe cases, surgical procedures to relieve the blockage.

Hydrocele is a condition in which fluid accumulates in the sac surrounding a man's testicle, leading to swelling in the scrotum. It is typically painless and can occur on one or both sides. Hydrocele is common in newborns and often resolves on its own. In adults, it may result from injury, infection, or inflammation, and in some cases, it can be associated with underlying conditions such as tumors or hernias. While hydroceles are generally not harmful, they may cause discomfort or cosmetic concerns. Treatment options, such as surgery, may be considered if the hydrocele is large, persistent, or symptomatic.

Varicocele is a condition where the pampiniform venous plexus within the scrotum become enlarged, similar to varicose veins that occur in the legs. It is often painless but can cause discomfort, swelling, or a feeling of heaviness in the scrotum. Varicoceles are most commonly found on the left side, due to drainage into the left renal vein at a right angle, and may be associated with infertility, as the increased temperature in the affected area can impair sperm production and function. In some cases, varicoceles may require treatment, such as surgery or embolization, especially if they cause pain or fertility issues. Regular monitoring is recommended for those who experience symptoms or are concerned about fertility.

Testicular torsion is a medical emergency in which the spermatic cord twists, cutting off the blood supply to the testicle. This condition causes sudden, severe scrotal pain and swelling, often accompanied by nausea and vomiting. It most commonly occurs in adolescent males but can happen at any age. Prompt diagnosis and surgical intervention are critical—ideally within 6 hours—to save the testicle and prevent permanent damage or loss. If treated quickly, the testicle can often be preserved; delayed treatment may lead to its removal.

Vasectomy is a minor surgical procedure used as a permanent method of male contraception. It involves cutting or sealing the ductus (vas) deferens thereby preventing sperm from being included in the ejaculate. The procedure is usually performed under local anesthesia, is quick, and has a short recovery time. Vasectomy does not affect sexual function, hormone levels, or ejaculation volume. While it is highly effective in preventing pregnancy, it should be considered permanent, though reversal is sometimes possible but not guaranteed.

PELVIS AND PERINEUM

Pelvis (hip bone) is formed by the union of the **coxa, sacrum**, and **coccyx** bones (Figure 12.8). These bones are connected by the following joints:

sacroiliac joint, between the **sacrum** and the **ilium** part of the coxa
pubic symphysis, between the two **pubic bones**
sacrococcygeal joint, between the **sacrum** and the **coccyx**

Together, these structures form a bony ring known as the **pelvic girdle**.

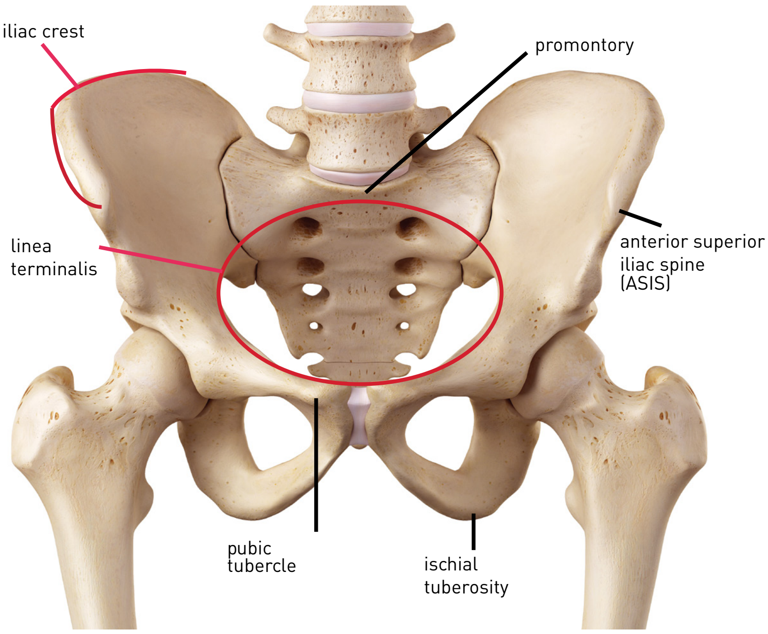


Figure 12.8. Pelvis

What are the important bony landmarks on the pelvis?

Some of the important bony landmarks on the pelvis are as follows (Figure 12.8):

iliac crest: the thick free upper border of the ilium. It serves as the superficial attachment site for abdominal wall muscles.

sacral promontory: the prominent anterior upper edge of the sacrum that projects into the pelvic cavity (see Figure 5.11a, c).

linea terminalis: a boundary that separates the **greater pelvis** from the **lesser (true) pelvis**. It begins on both sides from the promontory, runs forward on the ilium and pubis, and ends at the pubic symphysis.

anterior superior iliac spine (ASIS): the prominent anterior projection of the iliac crest.

pubic tubercle: a forward-projecting bony prominence on the superior ramus of the pubic bone, serving as the attachment site for the inguinal ligament.

ischial tuberosity: the thickened, lowest part of the ischium. It is the part of the pelvis that bears weight when sitting.

What are the parts of the pelvis?

The pelvis is divided into two parts:

greater pelvis: located above the **linea terminalis**, it is mostly surrounded by muscles and partially by bones.

lesser pelvis (true pelvis): located below the **linea terminalis**, this region is narrower and almost entirely surrounded by bones.

linea terminalis, separating the greater and lesser pelvis is composed of

posteriorly: the **promontory** of the sacrum

paterally: the **arcuate line**

anteriorly: the **pecten pubis** and the **pubic symphysis**

The posterior and lateral walls of the greater pelvis are formed by the ilium of the coxa, while the anterior and remaining portions are made up of muscles and fascia. The lesser pelvis is bordered posteriorly by the **sacrum** and **coccyx**, laterally by the **ilium** and **ischium**, and anteroinferiorly by the **pubis**.

What are the pelvic inlet (superior pelvic aperture) and pelvic outlet (inferior pelvic aperture)?

The boundary between the greater and lesser pelvis, or the entrance to the lesser pelvis is called the **pelvic inlet (superior pelvic aperture).** The exit opening of the lesser pelvis inferiorly is called the **pelvic outlet (inferior pelvic aperture).** The space located between these two openings is referred to as the **pelvic cavity**.

Are there differences between the male and female pelvis?

The pelvis is one of the anatomical site that shows distinct differences between males and females. These differences include:

the **pelvic inlet** is usually **oval in females** and **heart-shaped in males**.

the **pelvic outlet** is **wider in females**, **narrower in males**.

the **pelvic cavity** is **wide and shallow in females**, but **narrow and deep in males**.

- the **bones** are **lighter and more delicate in females**, **thicker and heavier in males**.

All these structural differences support the female's ability to give birth.

What is the pelvic diaphragm?

The **pelvic diaphragm** is a group of muscles which form the floor of the pelvis, closes the inferior pelvic aperture and supports the pelvic organs by holding them in place. Pelvic diaphragm helps resist increased intra-abdominal pressure during defecation, urination, and childbirth (see Figure 12.1a).

Which structures form the pelvic diaphragm?

The **pelvic diaphragm** is composed of the **levator ani** and **coccygeus muscles**.

Levator ani muscle is subdivided into three parts as **puborectalis, pubococcygeus, iliococcygeus muscles** which are all innervated by the **pudendal nerve**. Coccygeus muscle is located posterior to the levator ani, and innervated by the **ventral rami of the lower sacral spinal nerves**.

PERINEUM

The **perineum** is a diamond-shaped region located between the **pubic symphysis** anteriorly, the **ischial tuberosities** laterally, and the **coccyx** posteriorly.

What are the subdivisions of the perineum?

The diamond-shaped perineal region is divided into two triangles by an imaginary horizontal line drawn between the ischial tuberosities:

- **urogenital triangle:** it is the anterior triangle. The urethra passes through it in both sexes, and in women, the vagina also passes through it. It has superficial and deep layers. The superficial layer contains external genital organs and the transversus perinei superficialis, ischiocavernosus and bulbospongiosus muscles. The deep layer contains the sphincter urethrae externus and transversus perinei profundus muscles, and in males, the bulboutrehral glands.
- **anal triangle:** it is the posterior triangle which contains the anal canal, the external anal sphincter muscle, and the ischioanal fossa.

The urogenital triangle has several fascial layers and in between perineal pouches. The layers of the urogenital triangle from deep to superficial are

- **endopelvic fascia**
- **perineal membrane**
- **Colles fascia**

Between the endopelvic fascia and the perineal membrane is the **deep perineal pouch** and between the perineal membrane and the Colles fascia is the **superficial perineal pouch**.

The **urethra** and, in females, also the **vagina** passes through the urogenital diaphragm and these two pouches. Deep and superficial perineal pouches contain muscles around the urethra controling urination, neurovascular structures, glands and some genital organs.

The **superficial perineal pouch** includes:

superficial transverse perineal muscle
ischiocavernosus muscle
bulbospongiousus muscle
external genital organs

The **deep perineal pouch** includes:

external urethral sphincter muscle
deep transverse perineal muscle
In males: bulbourethral glands (Cowper's glands)

The posterior triangle that contains the **anal canal**, **external anal sphincter**, and the **ischioanal fossa**. The **ischioanal fossa** is a space located on either side of the anus, between the ischium and the anal canal. Its medial boundary is formed by the anal canal and the external anal sphincter while the lateral boundary is formed by the ischium and the obturator internus muscle. The obturator fascia covers the obturator internus muscle and contributes to the fossa's lateral wall. Above is the levator ani muscle (part of the pelvic diaphragm), which separates the ischioanal fossa from the pelvic cavity. Below is the perineal skin, which forms the floor of the fossa. Anteriorly, it extends toward the pouch between the urogenital membrane and the pelvic diaphragm. The posterior boundary is formed by the gluteus maximus muscle, which also provides some posterior support to the space. It is filled with fat and contains important structures such as the pudendal nerve and its branches, inferior rectal vessels and nerves. This area helps support the lower rectum and anus.

CLINICAL RELEVANCE

Due to its bony ring structure, high-impact trauma (e.g., motor vehicle accidents or falls) may lead to **pelvic fractures** at multiple pelvic sites and can damage pelvic organs and neurovascular bundles. They can range from mild, stable fractures to severe, life-threatening injuries involving internal bleeding and damage to organs. Symptoms may include pelvic pain, difficulty walking, bruising, and swelling. Diagnosis is typically made through physical examination and imaging studies like X-rays or CT scans. Treatment depends on the severity; minor fractures may heal with rest and pain management, while severe cases may require surgery and intensive care.

Perineal tears occur during childbirth when the skin and tissue between the vagina and the perineum tear as the baby passes through the birth canal. These tears range from minor tears to severe ones, which involve the anal sphincter and rectal tissue. Treatment typically involves stitches, and recovery time depends on the severity of the tear.

An **episiotomy** is a surgical incision made in the perineum during labor to widen the vaginal opening and facilitate delivery, particularly when there are concerns about the baby's health or in cases of a difficult birth. While once routine, episiotomies are now performed less frequently and are recommended only when necessary, as perineal tears tend to heal well and naturally in most cases. Both perineal tears and episiotomies require proper care and follow-up to prevent infection and ensure proper healing.

An **anal abscess** is a localized collection of pus that forms due to infection in the anal glands, often as a result of blocked glands or bacterial infections. It can occur in the anal triangle, causing pain, swelling, redness, and sometimes fever. If left untreated, an anal abscess may progress into an **anal fistula**, a small tunnel that forms between the anal canal and the skin. Treatment usually involves drainage of the abscess and antibiotics, and surgery may be necessary if the abscess is recurrent or complicated.

Pudendal nerve block is a medical procedure used to block the sensation of pain in the pelvic region, particularly during childbirth, surgery, or certain diagnostic procedures. It involves the injection of a local anesthetic near the pudendal nerve, which supplies sensation to the genital and perineal areas. The procedure is commonly used during labor to provide pain relief during vaginal deliveries or episiotomies and can also be used in the management of chronic pelvic pain or before pelvic surgeries. The block effectively numbs the perineum, vulva, and lower vagina, allowing for pain relief without affecting consciousness.

Incontinence refers to the inability to control bodily functions, particularly urination (urinary incontinence) or bowel movements (fecal incontinence). The pelvic diaphragm helps to control these functions by providing support and control over the bladder, rectum, and urethra. When the pelvic floor muscles weaken or become damaged—due to factors like childbirth, aging, or trauma—this can lead to incontinence.

In women, **pelvic floor weakness or dysfunction** is a common cause of **stress urinary incontinence** (leaking urine when coughing, sneezing, or laughing) or **urge incontinence** (the sudden, intense urge to urinate). Strengthening the pelvic diaphragm through exercises can help manage or prevent incontinence by improving muscle tone and support. In more severe cases, physical therapy, medications, or surgery may be required to address the issue.

Sample Questions – Genital System Anatomy

1. Which of the following is not one of the female internal genital organs?

   a) Ovary
   b) Uterine tube
   c) Uterus
   d) Vagina
   e) Clitoris

2. Which of the following structures is located on the lateral wall of the pelvis?
   a) Ovary
   b) Uterine tube
   c) Uterus
   d) Vagina
   e) Clitoris

3. Which of the following is not a part of the uterine tube?
   a) Infundibulum
   b) Ampulla
   c) Cervix
   d) Isthmus
   e) Intramural part

4. Between which two structures does the uterine tube extend?
   a) Ovary – Vagina
   b) Ovary – Uterus
   c) Uterus – Vagina
   d) Uterus – Clitoris
   e) Ovary – Clitoris

5. Which ligament extends between the ovary and the uterus?

   a) Broad ligament of the uterus
   b) Round ligament of the uterus
   c) Suspensory ligament of the ovary
   d) Proper ovarian ligament
   e) Cardinal ligament

6. Which of the following structures extends between the epididymis and the prostate?
   a) Ductus excretorius
   b) Ejaculatory duct
   c) Ductus deferens
   d) Spongious part of urethra
   e) Membranous urethra

7. Which of the following layers directly surrounds the testis (innermost layer)?
   a) Tunica albuginea
   b) Tunica dartos
   c) External spermatic fascia
   d) Internal spermatic fascia
   e) Cremasteric fascia

8. Which of the following is not one of the male internal genital organs?
   a) Epididymis
   b) Seminal vesicle
   c) Prostate
   d) Ductus deferens
   e) Scrotum

9. What is the name of the expanded distal part of the corpus spongiosum penis?
   a) Root of the penis
   b) Prepuce of the penis
   c) Crus of the penis
   d) Glans penis
   e) Bulb of the penis

10. Which of the following muscles is a component of the pelvic diaphragm?
   a) Superficial transverse perineal muscle
   b) Deep transverse perineal muscle
   c) Levator ani
   d) Piriformis
   e) Obturator internus

Answers: 1.E, 2. A, 3.C, 4.B, 5.D, 6.C, 7.A, 8.E, 9.D, 10.C

ENDOCRINE SYSTEM

ENDOCRINE SYSTEM

The endocrine system consists of glands that produce and secrete hormones, which regulate the activity of cells and organs (Figure 13.1). Hormones are released into the bloodstream and travel through it to reach the structures and organs they affect. Thus, cells in different parts of the body, their functions, and their effects on other cells and structures are regulated under the control of the nervous system.

The endocrine system operates through a feedback system. The releasing hormone secreted from the hypothalamus affects the pineal gland. In response to this effect, the pineal gland releases a stimulating hormone into the bloodstream. The stimulating hormone acts on the target organ or structure, triggering it to release its own secretion. As the level of the target organ's secretion in the bloodstream, the hypothalamus detects this and sends an inhibitory hormone to the pineal gland to slow down the production of this secretion. As a result, a balance in the blood levels of all endocrine secretions is maintained, ensuring bodily regulation. This balance is achieved for all endocrine system organs through different releasing, stimulating, and inhibitory hormones.

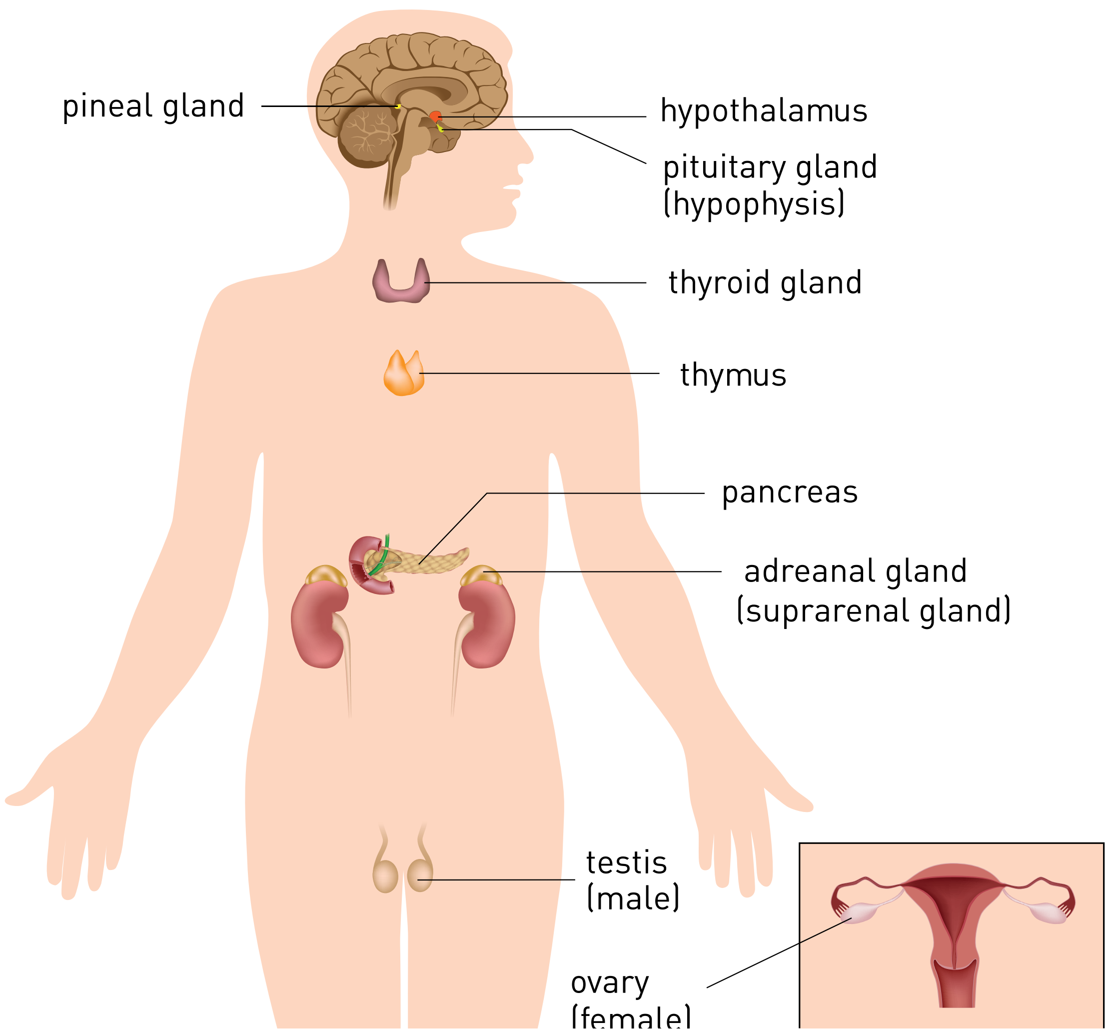


Figure 13.1. Endocrine system organs.

What structures are involved in the endocrine system?

The structures and organs included in the endocrine system are as follows:

hypothalamus
pituitary gland
pineal gland
thyroid gland
parathyroid gland
adrenal glands
pancreas

Hypothalamus: is located in the diencephalon, it is the center of the autonomic nervous system. It influences the pituitary gland through the factors it secretes.

Pituitary gland (hypophysis)**:** is located within the hypophyseal fossa of the sphenoid bone. It is connected to the hypothalamus by a stalk called the **infundibulum**. It consists of two lobes: the anterior lobe, called the **adenohypophysis**, and the posterior lobe, called the **neurohypophysis**. The adenohypophysis secretes **growth hormone** (**GH**), **melanocyte-stimulating hormone** (**MSH**), **follicle-stimulating hormone** (**FSH**), **luteinizing hormone** (**LH**), **prolactin (PRL)**, **adrenocorticotropic hormone** (**ACTH**), and **thyroid-stimulating hormone** (**TSH**). The neurohypophysis releases **oxytocin**, which controls the contraction of uterine muscles during childbirth and the secretion of milk from the mammary ducts, and **vasopressin** (**ADH**), which regulates blood pressure (Figure 13.2).

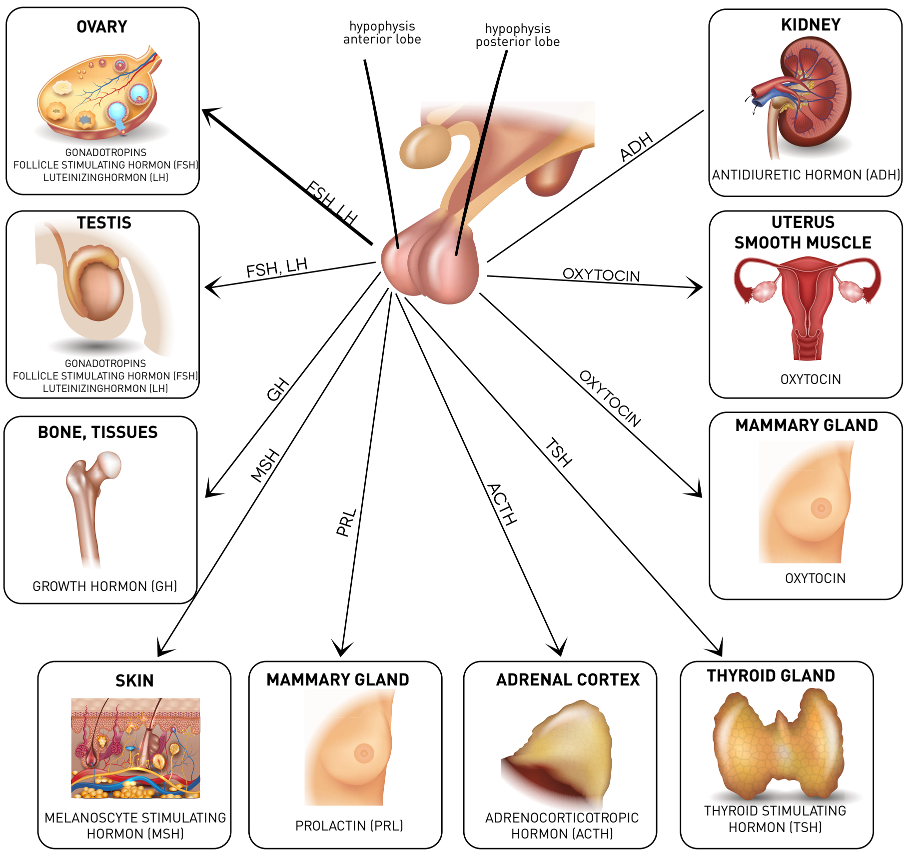


Figure 13.2. The hormones secreted by the pituitary gland and the organs it affects.

What are the arteries of the pituitary gland?

The pituitary gland is supplied by the **superior** and **inferior hypophyseal a**.

CLINICAL RELEVANCE

Hypophyseal tumors, also known as **pituitary tumors**, are abnormal growths that occur in the pituitary gland, which is located at the base of the brain. These tumors can be classified as either functional or non-functional. Functional tumors secrete hormones, leading to various hormonal imbalances, such as Cushing's disease (excess cortisol), acromegaly (excess growth hormone), or hyperprolactinemia (excess prolactin). Non-functional tumors do not secrete hormones but may cause symptoms due to their size and pressure on surrounding structures, like the optic chiasm, leading to vision problems. Common symptoms include headaches, vision disturbances, and hormonal imbalances, depending on the type of tumor. Diagnosis is usually made through MRI or CT scans, alongside blood tests to check hormone levels. Treatment options depend on the type and size of the tumor and may include medication, surgery, or radiotherapy. Early detection and treatment are essential to prevent complications such as vision loss or severe hormonal disorders.

Hyperthyroidism is a condition where the thyroid gland produces excessive thyroid hormones, leading to an overactive metabolism. Common causes include Graves' disease, thyroid nodules, and thyroiditis. Symptoms may include rapid heartbeat, weight loss, heat intolerance, anxiety, tremors, and fatigue. Treatment options are medication, radioactive iodine therapy and surgery.

Hypothyroidism is a condition where the thyroid gland produces insufficient thyroid hormones, leading to a slowed metabolism. Common causes include Hashimoto's thyroiditis (an autoimmune disease), iodine deficiency, and certain medications or treatments. Symptoms may include fatigue, weight gain, cold intolerance, dry skin, constipation, depression, and slow heart rate. It is diagnosed through blood tests that measure TSH and thyroid hormone levels. Treatment typically involves daily hormone replacement therapy to normalize hormone levels and alleviate symptoms.

It is diagnosed through blood tests measuring thyroid hormones and TSH levels. Treatment options include antithyroid medications, radioactive iodine therapy, surgery, and beta-blockers to manage symptoms. Proper treatment is essential to prevent complications like heart problems and bone loss.

Pineal gland: is located in the upper posterior part of the diencephalon, just above the superior colliculi. It has a regulatory effect on the body's biological rhythm. Its secretions include serotonin, melatonin, and norepinephrine. It ensures that puberty begins after a certain age due to its inhibitory effect on the gonads. Its effect increases in the dark and decreases with daylight. Calcifications form inside after the age of 17.

Thyroid gland: is located at the front of the neck, below the larynx, and on the front and lateral surfaces of the trachea (Figure 13.3a, b). It weighs approximately 30-40 grams. It has two lobes, right and left, and a middle part called the **isthmus**. It secretes thyroxine, which is responsible for regulating metabolism, and calcitonin, which reduces blood calcium levels.

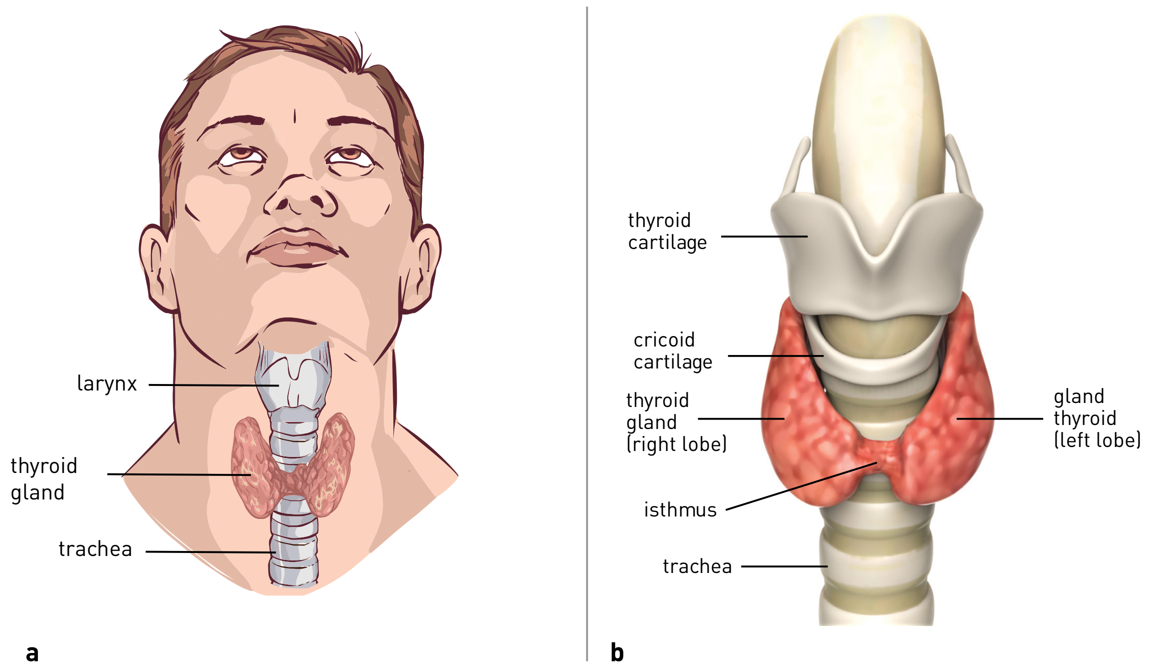


Figure 13.3. Thyroid gland. **a.** its location **b.** parts.

What are the blood vessels and nerves of the thyroid gland?

The thyroid gland is supplied by the **superior thyroid a.**, **inferior thyroid a.**, and occasionally **thyroid ima a**. The veins draining the thyroid gland include the **superior**, **middle**, and **inferior thyroid veins**. The veins of the thyroid gland form a venous plexus around the gland. The lymphatic drainage of the thyroid gland is through the **paratracheal** and **deep cervical nodes** towards the **thoracic duct**.

What are the nerves of the thyroid gland?

Sympathetic nerve fibers come from the **superior**, **middle**, and **inferior cervical ganglia**. Parasympathetic fibers are carried by the **vagus n**.

Parathyroid glands: are embedded in the posterior surface of the thyroid gland, at its upper and lower poles, two glands on each side, totaling four, each about the size of a lentil (Figure 13.4). When the calcium level in the blood falls, these glands are activated and they release parathormone (PTH), which promotes the release of calcium from bone tissue into the bloodstream.

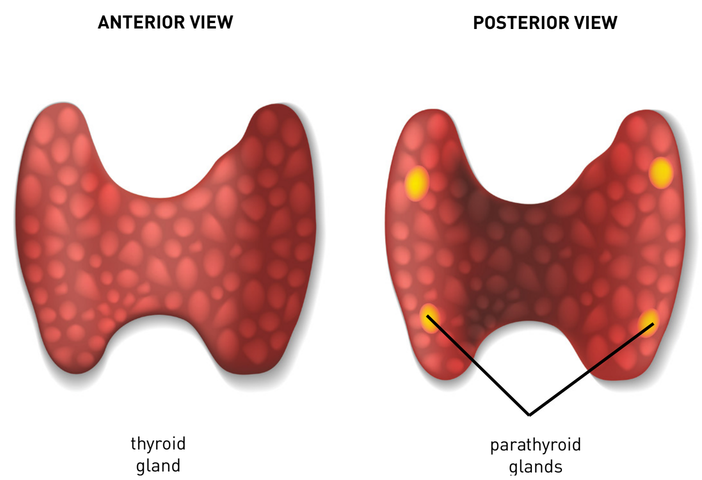


Figure 13.4. Parathyroid gland. Posterior view.

What are the vessels and nerves of the parathyroid gland?

Arteries: the parathyroid gland is supplied by the **superior** and **inferior thyroid a.** Veins: the venous drainage is through the **venous plexus of the thyroid gland**. lymphatics: the lymphatic drainage is directed towards the **deep cervical** and **paratracheal** lymph nodes.

What are the nerves of the parathyroid gland?

Sympathetic nerve fibers come from **superior** and **middle cervical ggl**.; parasympathetic fibers come from **vagus n**.

Adrenal glands: are a pair of glands located at the upper ends of the kidneys, surrounded by the sheets that cover the kidneys. They weigh 5-10 g, are 4 cm long and 3 cm thick. They are retroperitoneal organs.

How is the internal structure of the adrenal glands?

The adrenal glands consist of two main parts, both anatomically and physiologically:

- **cortex:** is the outer layer. It is histologically divided into three zones:
  - **zona glomerulosa:** secretes mineralocorticoids, such as aldosterone, which regulate the body's fluid and electrolyte balance.
  - **zona fasciculata:** secretes glucocorticoids, which regulate the metabolism of fats, proteins, and carbohydrates in the body.
  - **zona reticularis:** secretes androgens, which affect the testes, and estrogens, which affect the ovaries.
- **medulla:** is the inner layer. Under the influence of the sympathetic nervous system, it synthesizes, stores, and releases adrenaline, noradrenaline, and dopamine. Adrenaline and noradrenaline play a key role in maintaining the body's balance during states of excitement and fear.

What are the blood vessels and nerves of the adrenal gland?

Arteries: the adrenal glands are supplied by the **superior**, **middle**, and **inferior suprarenal aa.** veins: the left adrenal gland drains into the **left suprarenal v.**, which then drains into the **renal v**. The right adrenal gland drains into the **right suprarenal v.**, which in turn drains into the **inferior v. cava**. lymphatics: the lymphatic drainage of the adrenal glands leads to the **lateral aortic** lymph nodes.

What are the nerves of the adrenal gland?

The nerve fibers from the **greater splanchnic n.** form the **suprarenal plexus**, which controls the secretion of adrenaline and noradrenaline in the medulla.

Thymus: is an organ of the immune system located in the upper part of the thoracic cavity, in the anterior and superior mediastinum. It is located in front of the sternum and behind the pericardium. It is most developed in newborns but begins to shrink after puberty.

What are the secretions of the thymus?

The thymus secretes hormones such as **thymosin alpha**, **thymosin beta 1, 2...5**, **thymopoietin I-II**, **thymic humoral factor (THF)**, **thymostimulin**, and **thymic serum factor (TSF)**, which play roles in the development of T and B lymphocytes. Additionally, thymus hormones stimulate the secretion of reproductive hormones from the pituitary gland.

What are the blood vessels and nerves of the thymus?

arteries: the blood supply to the thymus comes from the **internal thoracic a.**, **superior** and **inferior thyroid a**. veins: the veins drain into the right and left **brachiocephalic v.**, **internal thoracic v.**, **superior** and **inferior thyroid v**.lymphatics: the lymphatic drainage leads to the **tracheobronchial** and **parasternal nodes**.

What are the nerves of the thymus?

The sympathetic fibers originate from the **superior** and **middle cervical ganglia** while the parasympathetic nerve fibers come from the **vagus n**.

Pancreas: (is given in detail in the digestive system section) is both an exocrine and endocrine gland. It is located in the posterior abdominal wall, extending horizontally between the duodenum and the spleen. Its endocrine secretions include **insulin**, which lowers blood glucose levels, and **glucagon**, which raises blood glucose levels.

Gonads (Testes/Testicles and Ovaries): are the organs that produce sex-specific hormones (estrogen, progesterone, testosterone).

Testes/Testicles: the male reproductive cells, **sperms**, are produced in testes/testicles, while **Leydig cells** secrete androgen hormones (testosterone) that play a role in the development of secondary sexual characteristics. **Sertoli cells** secrete **inhibin**, which suppresses FSH production, and a small amount of estrogen.

Ovaries: (are given in detail in the genital/reproductive system section) are responsible for the production of follicles and the development of primary and secondary sexual characteristics. They also prepare the body for pregnancy and, if pregnancy occurs, secrete **progesterone** to maintain a healthy pregnancy.

Sample Questions on Endocrine System Anatomy:

1. Which of the following is the center of the autonomic nervous system?
   a) Hypothalamus
   b) Hypophyisis
   c) Medulla oblongata
   d) Pons
   e)Midbrain

2. Which of the following is **not** one of the organs classified within the endocrine system?
   a) Thyroid gl.
   b) Parathyroid gl.
   c) Submandibular gl.
   d) Suprarenalis gl.
   e) Pancreas

3. The thyroid gl. is located on the anterior and lateral surfaces of which structure?
   a) Esophagus
   b) Larynx
   c) Ascending aorta
   d) Trachea
   e) Vertebral column

4. Secretion of the which endocrine gland increases in darkness and causes the onset of puberty after a certain age due to its inhibitory effect on the gonads?
   a) Pancreas
   b) Thyroid gl.
   c) Parathyroid gl.
   d) Suprarenal gl.
   e) Pineal gl.

5. The zona glomerulosa, zona fasciculata, and zona reticularis are layers of which endocrine organ?
   a) Pancreas
   b) Thyroid gl.
   c) Parathyroid gl.
   d) Suprarenal gl.
   e) Pineal gl.

6. Which of the following is an endocrine secretion of the pancreas?
   a) Parathormone
   b) Insulin
   c) Progesterone
   d) Testosterone
   e) Calcitonin

7. The isthmus is part of which endocrine organ?
   a) Hypothalamus
   b) Hypophysis
   c) Thyroid gl.
   d) Suprarenal gl.
   e) Pineal gl.

8. Which hormone secreted by the thyroid gl. reduces blood calcium levels?
   a) Thyroxine
   b) Calcitonin
   c) Parathormone
   d) TSH
   e) TRH

9. From which endocrine organ is aldosterone secreted?
   a) Suprarenalis gl.
   b) Thyroidea gl.
   c) Pineal gl.
   d) Hypothalamus
   e) Hypophysis

10. From which endocrine organ are glucocorticoids secreted?
    a) Suprarenalis gl.
    b) Thyroidea gl.
    c) Pineal gl.
    d) Hypothalamus
    e) Hypophysis

Answers: 1.A, 2. C, 3.D, 4.E, 5.D, 6.B, 7.C, 8.B, 9.A, 10.A

SENSORY ORGANS

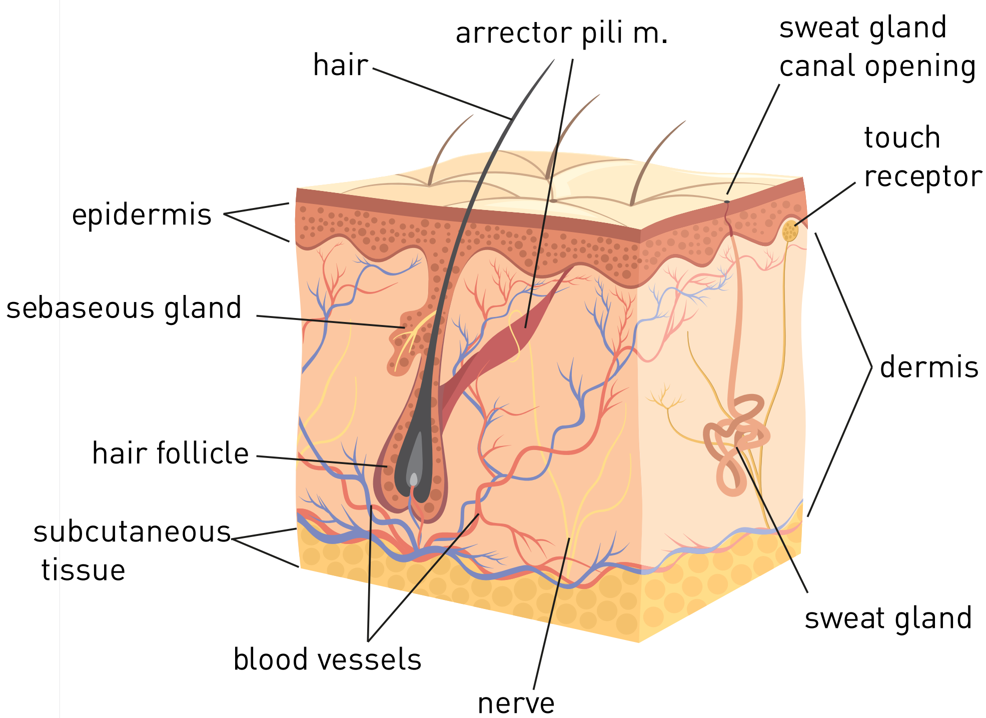
SENSORY ORGANS

Sense organs are those that receive stimuli such as touch, temperature, hearing, vision, taste, balance, etc., from the environment through specialized cells.

DEFINITIONS

What is a receptor?

A receptor is a group of specialized cells that detect stimuli and the changes in the internal and external environment, converting them into electrical signals, allowing the individual to understand the world around them. They are located in organs such as the skin, eyes, and ears, and are structures sensitive to specific types of stimuli (Figure 14.1).



Şekil 14.1. Elements related to the skin and touch-sensitive receptors.

How many types of receptors are there?

Receptors located in the skin, muscles, tendons, and internal organs are classified into three groups: external receptors (exteroreceptors), internal receptors (interoreceptors), and sensory receptors (proprioreceptors).

How many types of senses are there?

There are two types of senses in our body: **general senses** (pressure, touch, temperature, and pain) and **special senses** (vision, hearing, smell, and taste).

SKIN

The skin is the largest organ that covers the outside of the body. It contains receptors that detect touch, pressure, pain, temperature, and vibration. The skin protects the body from harmful external effects.

How many layers does the skin consist of?

The skin consists of three layers: epidermis, dermis, and hypodermis, from the outside to the inside.

epidermis: the outermost layer of the skin. It is surrounded by a layer of keratinized cells, forming a barrier on the body surface. It does not contain blood vessels; the blood vessels in the dermis provide nourishment to the epidermis. The pigment melanin, which gives the skin its color, is found in the epidermis.

dermis: this layer lies beneath the epidermis and contains nerve endings, hair follicles, and receptors. Its thickness varies throughout the body, being thickest on the palms and soles of the feet. The eyelids, penis, scrotum, and labia majora and minora have particularly thin skin.

hypodermis (subcutaneous): the deepest layer is made up of adipose tissue and loose connective tissue. It is also known as the **superficial fascia**. It is thicker than the dermis. This layer contains subcutaneous sensory nerves, superficial veins, and lymph vessels. Due to the loose connective tissue, the skin above it can move easily. In women, more fat accumulates in the hypodermis compared to men. Factors that determine skin color include melanin, carotene, and the amount of blood vessels in the dermis, as well as the color of the blood flowing through these vessels.

What are the appendages of the skin?

The following structures are considered appendages of the skin:

sweat glands: these are located in the deepest part of the dermis or in the hypodermis. Under the influence of the sympathetic system, they cause localized sweating, while the parasympathetic system triggers general sweating.

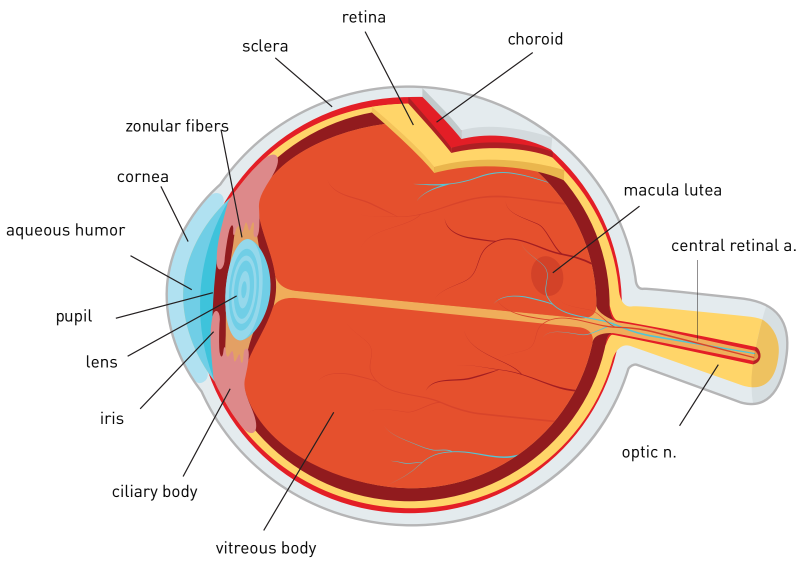
sebaceous glands: these are found with hair follicles and release their secretion into the hair follicle. They are absent in hairless areas, such as the soles of the feet and palms. The secretion is called sebum, and it helps form a barrier against bacteria and fungi on the skin surface.

nails: these are keratinized and elastic structures that form from the modification of the epidermis and are located on the dorsal part of the distal phalanges. They are transparent and appear pink due to the blood vessels in the dermis layer beneath them, which allows light to pass through. The nail grows approximately 0.1 mm per day. It consists of two parts: **nail matrix** (nail bed) and **nail plate**. Nail matrix is located deep to the plate and responsible for nail growth. This part appears as a white crescent shape on the nail and is called the **lunula**. Plate is the outer keratinized part of the nail. **Eponychium**, is the proximal part of the nail where it connects with the skin while hyponychium is the distal part of the nail bed where it is continuous with the free edge of the nail.

hair tissue: hair is found all over the body, except for the palms of the hands, soles of the feet, lips, glans penis, nipple, and greater labia. It is responsible for protection and thermoregulation functions. The part of the hair located within the skin is called the **hair root**, while the visible part of the hair on the skin is called the **hair shaft**. The lowest, widest part of the hair root is called the **hair bulb**. Hair growth occurs through the bulb, where blood vessels and nerves enter. The m. arrector pili muscle attaches to the hair root and is innervated by sympathetic nerves. It makes the hair erect due to emotional reasons or temperature changes. The color of the hair is determined by the melanin pigment released from melanocyte cells in the skin. Hair is also named according to its location: hirci (armpit hair), pubes (pubic hair), capilli (head hair), barba (beard), mystax (mustache), tragi (outer ear canal hair), cilia (eyelashes), supercilium (eyebrows), vibrissae (nose, shoulder, back, chest, abdomen, and arm hair).

THE ORGAN OF VISION

The eye is the organ that allows us to perceive the outer world and the color, shape, and structure of objects around us. It is embedded within a fatty layer that fills the eye socket (orbit) in the skull. The front of the eye is covered by the eyelids, called palpebrae. It remains moist continuously through the secretion of the lacrimal gland.



Şekil 14.2. The layers of the eyeball in a sagittal section.

How many parts does the eye consist of?

The eye consists of two main parts: the eyeball and the accessory organs (Figure 14.2).

eyeball: the eyeball has three layers: from outer to inner, they are the fibrous layer, vascular layer, and nervous layer.

fibrous layer: this is the outermost layer. It is composed of the **cornea**, which forms the front 1/6th, and the **sclera**, which forms the remaining 5/6th. The cornea is the transparent, convex part of the eye and lacks blood vessels. It helps refract the light entering the eye. The sclera maintains the shape of the eyeball. At the back of the sclera, there is a region called the **lamina cribrosa**, through which the optic nerve fibers pass.

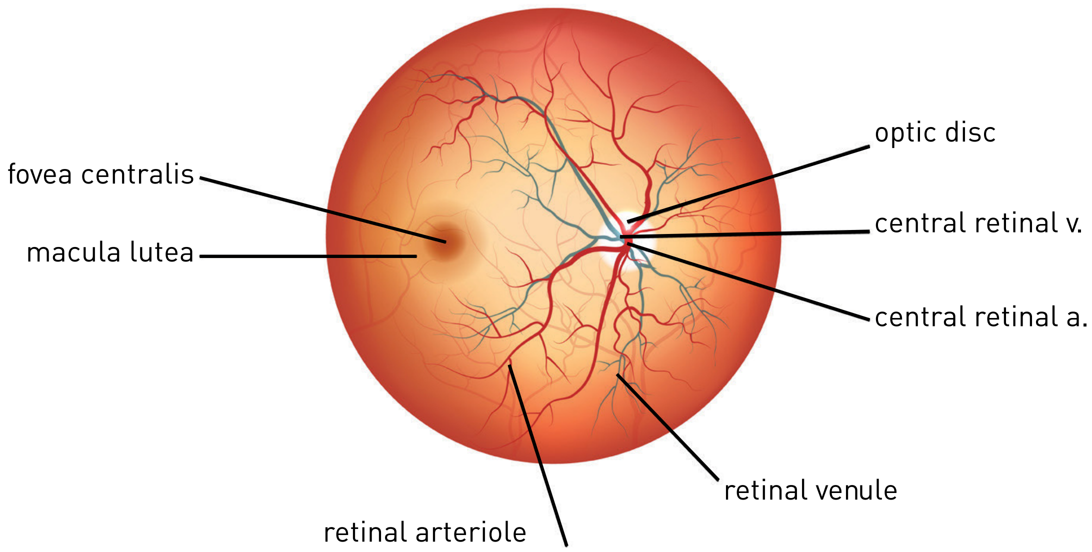
vascular layer (uvea): this is the middle layer, rich in blood vessels and pigments. It is divided into three parts from back to front: the **choroid**, **ciliary body**, and **iris**.

choroid: it forms the largest part of the vascular layer and lines the inner surface of the sclera. It provides nourishment to the retina located deep to it. At the front, it connects with the ciliary body at a serrated-looking region called the **ora serrata**.

ciliary body: it is located between the iris and the choroid. The protrusions called **ciliary process**es secrete the **aqueous humor**. The aqueous humor is first emptied into the **posterior chamber**, then passes into the **anterior chamber** and drains into the **sinus venosus of sclera**. The **zonular fibers**, which are extending from the ciliary body, attach to the lens. The majority of the ciliary body is composed of the ciliary mm., which, under the influence of the parasympathetic system, adjust the thickness of the lens, enabling **accommodation** (adjusting for near vision).

iris: the iris is the anterior part of theis layer, and it gives the eye its color due to the pigment cells it contains. It is located behind the cornea and in front of the lens. It lies between the anterior and posterior chambers of the eyeball. The iris consists of smooth muscles; dilator and sphincter. The opening in the center of the iris is called the **pupil**. The smooth muscles control the constriction (**myosis**) and dilation (**mydriasis**) of the pupil.

nervous layer (retina): this is the innermost layer. It lies between the choroid on the outside and the **vitreous body** on the inside. This layer contains **cone** and **rod cells**. In the posterior part of the retina, there is an oval area that appears lighter in color which is called the **macula lutea**. At the center of the macula lutea, there is a small pit called the **fovea centralis**. This is the area of sharpest vision, where only cone cells are located. About 2-3 mm medially from the macula lutea, there is the **optic disc**, where the optic nerve exits by piercing the retina. This area is called the **blind spot**, and it contains no receptors (Figure 14.3).



Şekil 14.3. The appearance of the retina, the innermost layer of the eye.

What are the structures that refract light?

In the eyeball, there is a series of refractive media through which light passes and is refracted as it moves toward the deeper layers. These media ensure that light, as it enters the eye from the external environment, is refracted at the appropriate angle to reach the retina and stimulate the receptor cells located there. These refractive media are listed from outer to inner as follows: **cornea**, **aqueous humor**, **lens**, and **vitreous humor**. The most powerful refractive medium is the cornea. This means that light is refracted the most as it passes through the cornea.

What is the lens?

The lens is located along the light transmission pathway, behind the pupil and iris, and in front of the vitreous humor. It is attached to the suspensory fibers that extend from the ciliary body. It adjusts its thickness to focus and sharpen the image.

What are aqueous humor and vitreous humor?

The aqueous humor is the fluid found in the anterior and posterior chambers of the eyeball. The gelatinous fluid that fills the interior of the eyeball, located behind the lens, is called **vitreous humor**.

What are the chambers of eye?

The eye consist of two parts: the **anterior** and **posterior chambers**. The anterior chamber is the area between the iris and the cornea, while the posterior chamber is the space between the iris and the lens. Both chambers are filled with the aqueous humor.

What are the accessory organs related with the eyeball?

The accessory organs related with the eyeball are as follows:

eyelids: upper and lower eyelid are made of muscle and connective tissue. They are located in front of the eyeball to protect it from external factors. The outer surface is covered by skin, and the inner surface is lined with the **conjunctiva**. Between the skin and the conjunctiva are the orbicularis oculi m., tarsus, tarsal glands, blood vessels, and nerves.

tarsus: the tarsus is the fibrous tissue that forms the skeleton of the upper and lower eyelids. The space between the orbital wall and the tarsus is closed by a connective tissue called the **orbital septum**.

tarsal glands (Meibomian glands): these are glands located between the conjunctiva and the tarsus.

eyelashes: eyelashes are thick, free, long hairs arranged in two or three rows at the edge of the eyelids.

What are the extraocular muscles?

These are the muscles that move the eyeball (Figure 14.4). Four of them are arranged straight, while two are arranged diagonally. The straight muscles are as follows:

superior rectus m.: primarily moves the eyeball upward, and also slightly inward.

inferior rectus m.: primarily moves the eyeball downward, and also slightly inward.

lateral rectus m.: moves the eyeball outward.

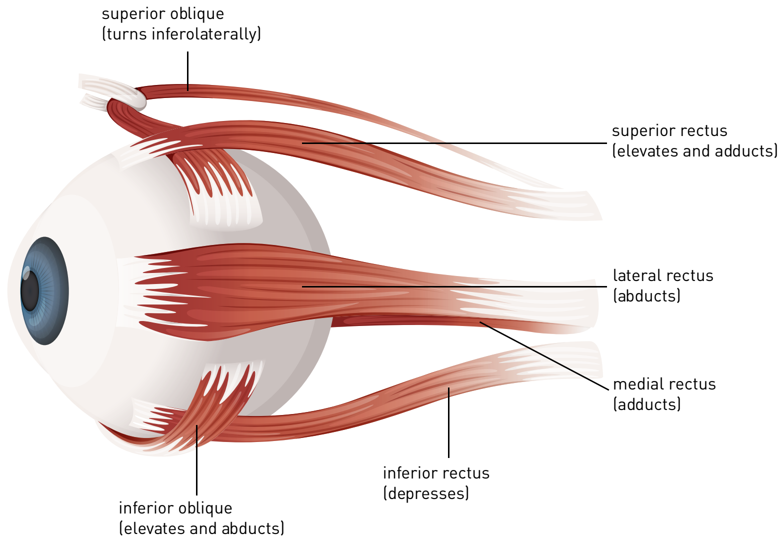
medial rectus m.: moves the eyeball inward.

The diagonally arranged muscles are:

superior oblique m.: moves the eyeball downward and inward.

inferior oblique m.: moves the eyeball upward and inward.

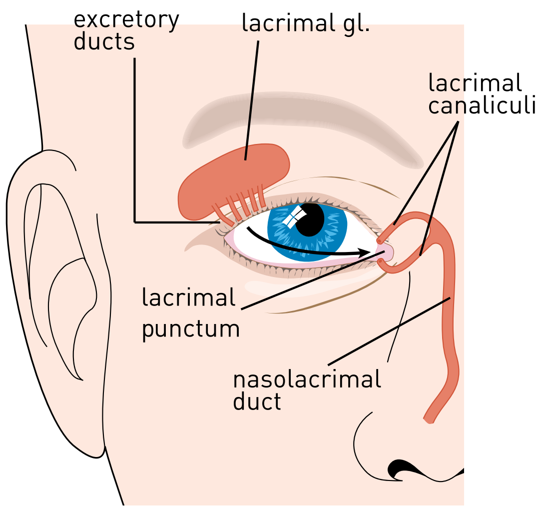
In addition to these, the **levator palpebrae superioris m.**, which lifts the upper eyelid, is also considered part of the extraocular muscles. The lateral rectus m. is innervated by the abducens n. (6th cranial nerve), the superior oblique m. by the trochlear n. (4th cranial nerve), and all other extraocular muscles and the levator palpebrae superioris m. by the oculomotor n. (3rd cranial nerve).



Şekil 14.4. The extraocular muscles that move the eyeball and their functions.

What is the lacrimal gland?

Lacrimal gland is located in the upper outer part of the orbit, releases tears and drains them onto the cornea through channels that open into the superior conjunctiva. Tears help to moisten and clean the cornea. With its antibacterial enzymes, it protects the conjunctiva from bacteria. Excess tears accumulate in the **lacus lacrimalis** (lacrimal lake) in the medial corner of the eye and pass through small holes called **lacrimal punctum** at the outer ends of the both eyelids, moving into the **superior and inferior lacrimal canaliculi**. The tears then flow into the lacrimal sac and from there into the nasolacrimal duct, which drains into the nasal cavity (Figure 14.5).



Şekil 14.5. The lacrimal gland and the lacrimal ducts.

What is conjunctiva?

Conjunctiva is the mucous membrane which lines the front of the cornea and the back of the eyelids.

What are the blood vessels of the visual organ?

Eye is supplied by the branches of the **ophthalmic a.**, and the venous blood of the eye is drained through the **superior** and **inferior ophthalmic veins** into the **cavernous sinus**. The lymphatics drain into the parotid and submandibular nodes.

CLINICAL RELEVANCE

Visual impairments occur when the eye cannot properly focus light, resulting in blurred vision. The most common types of visual impairments are:

myopia (nearsightedness): distant objects appear blurry, while close objects are clear.

hyperopia (farsightedness): close objects appear blurry, while distant ones are clear.

astigmatism: vision is blurry or distorted at all distances due to an irregularly shaped cornea or lens.

presbyopia: an age-related condition causing difficulty seeing up close.

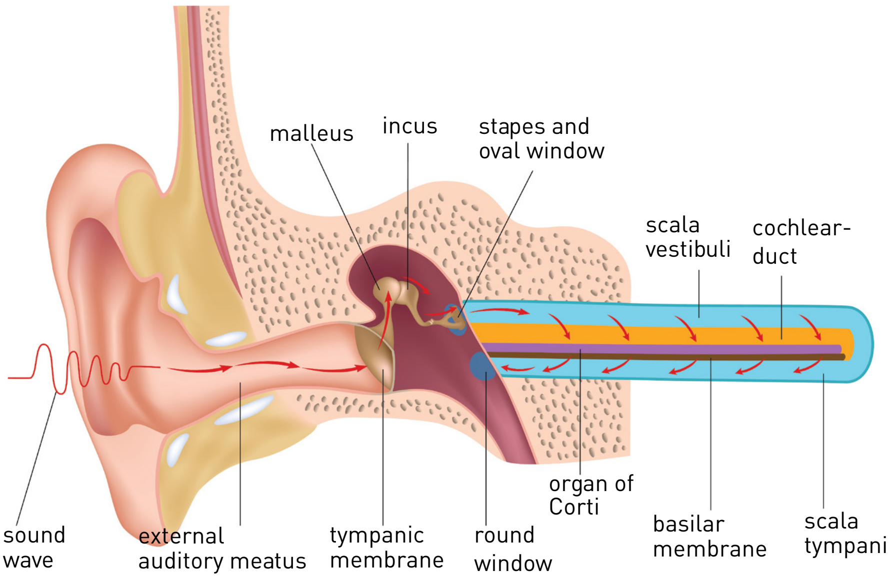
These vision problems can usually be corrected with glasses, contact lenses, or laser surgery.

Glaucoma is an eye disease that usually occurs as a result of increased intraocular pressure, which damages the optic nerve and can lead to vision loss over time. It typically progresses slowly and does not show symptoms in the early stages. Symptoms may include narrowing of the visual field, eye pain (especially in acute glaucoma), headache and bBlurred vision. Glaucoma can be controlled with early diagnosis. Treatment options include eye drops, medications, laser therapy, or surgical intervention. Regular eye exams are very important for detecting glaucoma at an early stage.

THE ORGAN OF HEARING AND BALANCE (Vestibulocochlear Organ, The Ear)

The ear is divided into three parts: the **outer ear**, **middle ear**, and **inner ear** (Figure 14.6). It is the organ responsible for hearing and balance.

Outer ear: It collects sound and transmits it to the middle ear.



Şekil 14.6. Parts of the ear.

What are the parts of the outer ear?

The parts of the outer ear are as follows: **auricle (pinna)**, **external acoustic meatus** (**external auditory canal**), and **tympanic membrane (eardrum)**.

auricle (pinna): the auricle is made of cartilage called **auricular cartilage**. The lower part of the ear, which lacks cartilage, is called the **earlobe**. The auricle contains rudimentary muscles.

external acoustic meatus (**external auditory canal**)**:** is a wide, S-shaped passage that transmits the collected sound from the outer ear to the eardrum. The external one-third part is made of cartilage, while the inner two-thirds is bony. Its skin is continuous with the skin of the outer ear. It contains glands that secrete earwax. The wax secreted by these glands helps prevent foreign objects from entering the ear. The cartilage section is covered by hair called tragi.

tympanic membrane (eardrum): is a semi-transparent membrane that separates the outer ear from the middle ear. Its outer surface is covered with skin, and its inner surface is lined with mucosa.

Middle ear: is located within the temporal bone. The middle ear is an air-filled cavity connected to the nasopharynx at the front via the auditory tube and to the mastoid antrum and mastoid cells at the back. It contains the auditory ossicles and muscles that control them.

What are the auditory ossicles in the middle ear?

The auditory ossicles, which transmit vibrations from the eardrum to the oval window in the inner wall, are three small bones: **malleus (hammer)**, **incus (anvil)**, and **stapes (stirrup)** (Figure 14.7).

What are the muscles of the middle ear?

The muscles located in the middle ear are as follows:

tensor tympani m.: this muscle attaches to the malleus and tenses the eardrum, thus slowing down sound vibrations.

stapedius m.: this muscle attaches to the stapes and moves it away from the oval window, preventing excessive sound vibrations from reflecting onto the oval window.

Inner ear: is located in the petrous part of the temporal bone and functions as both an organ of hearing and balance.

What are the parts of the inner ear?

The inner ear consists of two parts (Figure 14.8):

bony labyrinth

membranous labyrinth

Bony labyrinth: this is a capsule-like structure that surrounds the membranous labyrinth. Between the inner surface of the bony labyrinth and the outer surface of the membranous labyrinth, there is a fluid called **perilymph**.

What are the parts of the bony labyrinth?

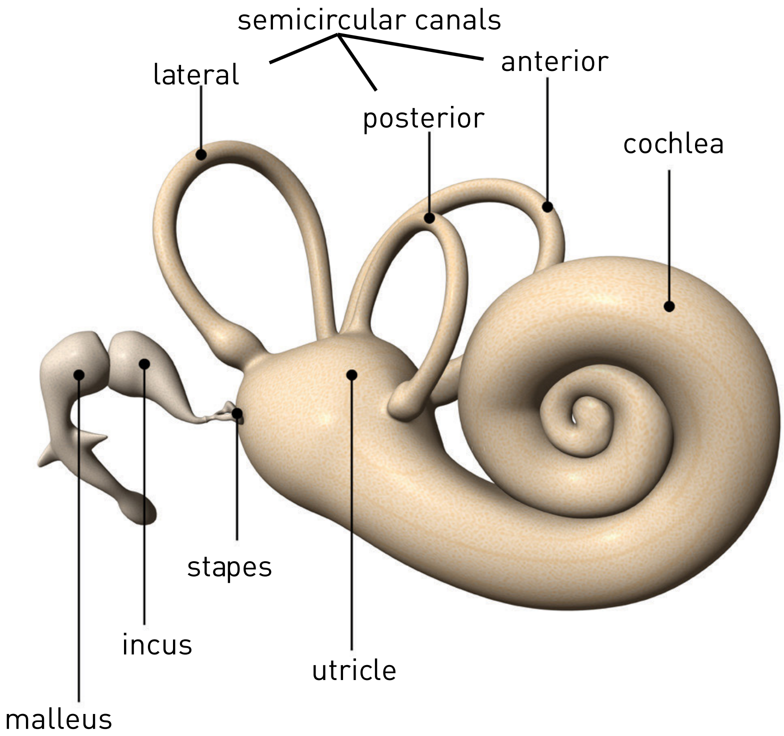
It consists of three sections (Figures 14.7, 14.8):

vestibule: is located at the center of the middle ear, behind the cochlea, and in front of the semicircular canals. The oval window is located in its inner wall and separates it from the middle ear. The **utricle** and **saccule**, which are involved in balance, are also found in this part.

semicircular canals: there are three semicircular canals: **anterior** (superior), **posterior**, and **lateral**. These are part of the inner ear responsible for balance. The dilated ends that open into the vestibule are called **ampulla**.

cochlea: this is the part of the inner ear responsible for hearing. It has the appearance of a spiral shell, coiled around a central bone (**modiolus**) 2.5 times. The part that spirals around the modiolus is called the **spiral canal**. This canal is divided into two as **scala vestibuli** and **scala tympani** by a thin bone **osseous spiral lamina**. This lamina does not completely divide the canal, and its free edge is covered by a soft tissue layer called the **basilar membrane**. The organ of hearing, known as the **organ of Corti** is located on the basilar membrane.

Membranous labyrinth: this is a canal system located inside the bony labyrinth and filled with endolymph fluid.



Şekil 14.7. The middle ear ossicles and the parts of the inner ear.

How many parts does it consist of?

It consists of two parts:

vestibular labyrinth: is the part that comprises of the structures related to balance, including the utricle, saccule, and semicircular ducts.

cochlear labyrinth: is responsible for hearing and is formed by the **cochlear duct** inside the cochlea. The organ of Corti, which converts mechanical stimuli into electrical stimuli, is located here.

Hearing: vibrations from the environment are transmitted through the external auditory canal to the eardrum. From there, the vibrations are transferred to the ossicles in the middle ear, which facilitate the transfer of vibrations to the fluid in the inner ear. The vibration of the fluid stimulates the **organ of Corti** in the inner ear. The stimuli are transmitted by the cochlear nerve through the internal acoustic meatus to the brainstem and then sent to the relevant upper centers of the nervous system.

Balance pathways: balance-related stimuli received via the vestibular nerve are transmitted through the internal acoustic meatus and enter the brainstem, where they are sent to the centers of the nervous system related to balance.

CLINICAL RELEVANCE

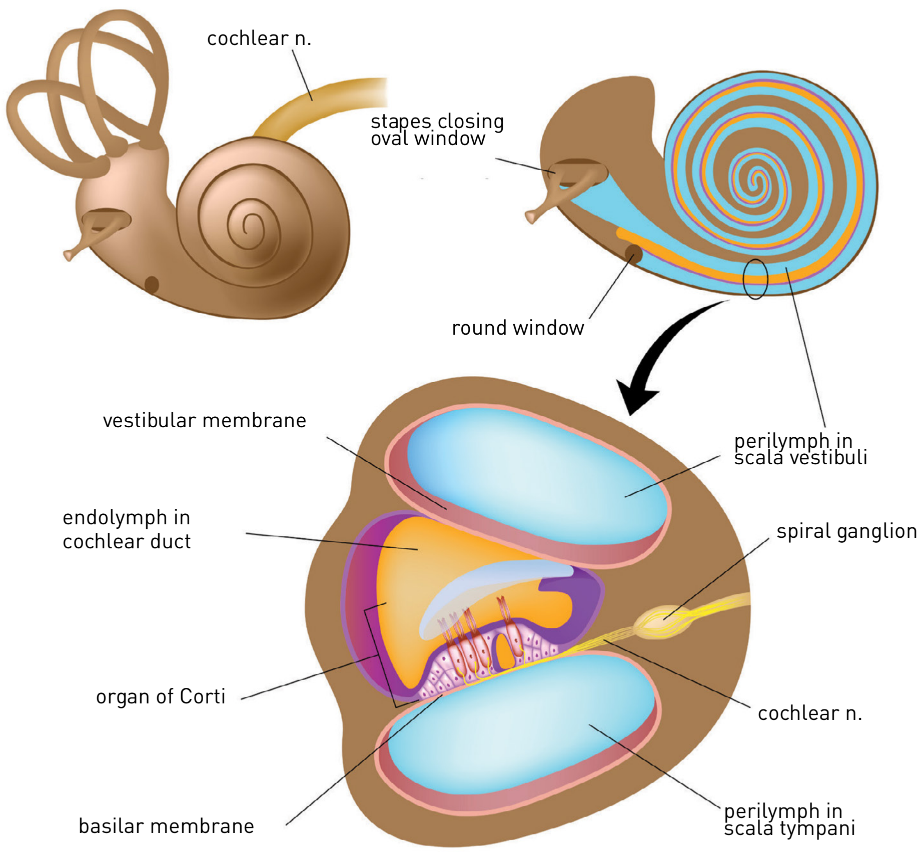
Otitis is the medical term for ear inflammation. It refers to an infection or inflammation occurring in the ear and is classified into different types based on the affected part of the ear:

otitis externa: inflammation of the outer ear canal (also known as swimmer's ear)

otitis media: inflammation of the middle ear, commonly seen in children

otitis interna (labyrinthitis): inflammation of the inner ear, which may cause dizziness and balance problems

Symptoms may include ear pain, hearing loss, ear discharge, fever, and dizziness. Treatment depends on the type of infection and may involve antibiotics, pain relievers, or ear drops.



Şekil 14.8. Cochlea.

Kemik labirent (labyrinthus osseus): Zar labirinti saran kapsül benzeri bir yapıdır. Kemik labirintin iç yüzü ile zar labirintin dış yüzü arasında **perilenfa** adı verilen bir sıvı bulunur.

THE ORGAN OF SMELLING (The Nose)

The nose is the organ of smell. The sense of smell is perceived by the olfactory receptor cells located in the mucosa of the **olfactory region** above the superior nasal concha within the nasal cavity. The odor particles in the inhaled air dissolve in the mucus and are detected by the olfactory receptor cells. These olfactory receptor cells convert the detected smell into nerve impulses. Axons of these receptor cells form the **fila olfactoria** (small nerve bundles) which convey the impulses by passing through the holes in the cribriform plate of the ethmoid bone and terminate at the olfactory bulb. The fibers starting from the olfactory bulb form the olfactory tract and terminate in the brain's olfactory region.

THE ORGAN OF TASTE (The Tongue)

The tongue, which is the taste organ, is a fundamental organ for nutrition and speech in humans. It contains taste receptors (taste buds) made up of neuro-epithelial cells. These receptors are located on the dorsal surface of the tongue, soft palate, palatoglossal arch, the posterior wall of the pharynx, and the epiglottis. Water-soluble particles enter the taste buds. The neuro-epithelial cells in these buds detect the taste sensation and transmit it to the central nervous system through nerves.

Sample Questions for the Anatomy of Sensory Organs:

1. Which of the following is part of the fibrous layer of the eye?
   a) Sclera
   b) Choroid
   c) Iris
   d) Ciliary process
   e) Retina

2. Which of the following is part of the nervous layer of the eye?
   a) Sclera
   b) Choroid
   c) Iris
   d) Ciliary process
   e) Retina

3. Which of the following structures secretes the intraocular fluid (aqueous humor)?
   a) Sclera
   b) Choroid
   c) Iris
   d) Ciliary process
   e) Retina

4. Which of the following structures determines the color of the eye?
   a) Sclera
   b) Choroid
   c) Iris
   d) Ciliary process
   e) Retina

5. Where are the cone and rod cells located in the eye?
   a) Sclera
   b) Choroid
   c) Iris
   d) Ciliary process
   e) Retina

6. Where is the area for the sharpest vision?

   a) Sclera
   b) Anterior chamber
   c) Macula lutea
   d) Optic disc
   e) Fovea centralis

7. Which of the following is one of the muscles of the middle ear?

   a) Temporalis
   b) Tensor tympani
   c) Tensor veli palatini
   d) Auricularis ant.
   e) Auricularis post.

8. Which structure forms the upper wall of the middle ear cavity?

   a) Tympanic membrane
   b) Promontory
   c) Mastoid antrum
   d) Tegmen tympani
   e) Auditory tube opening

9. Which of the following is part of the bony labyrinth in the inner ear?

   a) Tympanic membrane
   b) Mastoid air cells
   c) Semicircular canals
   d) Tegmen tympani
   e) Mastoid antrum

10. Which nerve is related to balance?

   a) Vestibular
   b) Cochlear
   c) Olfactory
   d) Ophthalmic
   e) Glossopharyngeal

Answers: 1.A, 2. E, 3.D, 4.C, 5.E, 6.E, 7.B, 8.D, 9.C, 10.A

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9 786254 449079

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