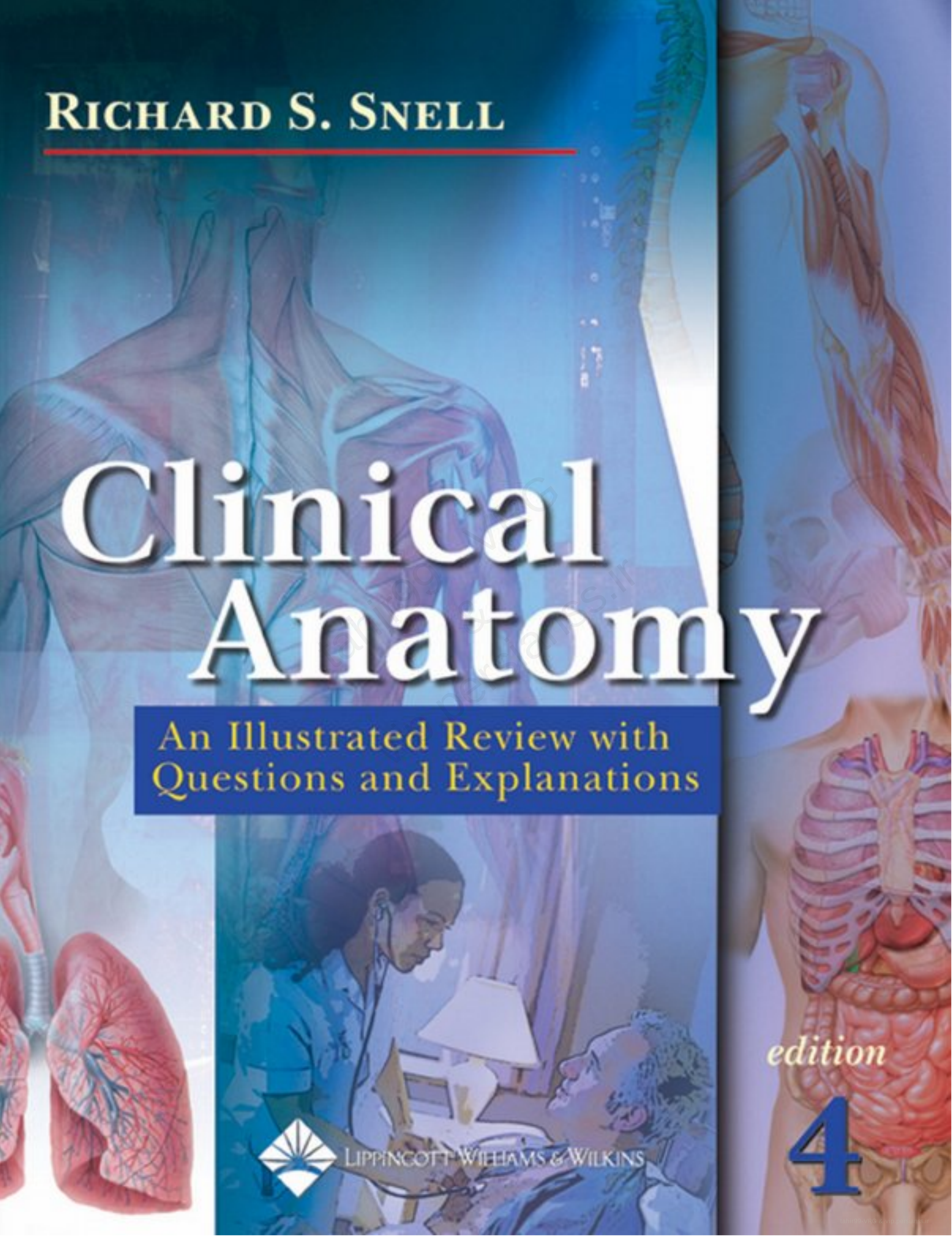
RICHARD S. SNELL
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Clinical anatomy is the study of the macroscopic
structure and function of the body
as it relates to the practice of
medicine and other health sciences.

PREFACE

This book is written for medical, dental, allied health students, and nurses who are preparing for examinations. It is also for students during their clinical clerkships and for interns who require a quick review of basic clinical anatomy.

This edition has been modified to reflect the reduced amount of material required in modern curricula. No longer is anatomic detail described that cannot be used in relation to patients for the purpose of making diagnoses and instituting appropriate treatment. To further emphasize this theme, the review questions at the end of each chapter are increasingly centered around patients in a clinical setting. Again, I thank the many students and instructors for their written comments on how this book could be improved to satisfy their needs.

The clinical anatomy has been presented in a condensed form with numerous simple diagrams, radiographs, CT scans, MRI studies, and sonograms. The extensive use of tables simplifies the learning of muscles and their actions and nerve supplies and assists in the memorization of the distribution of cranial and peripheral nerves. To emphasize clinical relevance, short clinical notes are highlighted by the use of icons, and the notes are enclosed in a gray box. For a more extensive review, this book can be used in conjunction with the 7th edition of Clinical Anatomy, also published by Lippincott Williams & Wilkins.

I wish to express my sincere thanks to Ira Alan Grunther, AMI, for his excellent artwork. To the staff of Lippincott Williams & Wilkins, I wish to express my gratitude for their patience and assistance throughout the preparation of this new revised edition.

R.S.S.

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CHAPTER 1

Thorax

THORACIC WALL

Bones of the Thoracic Wall

The bones of the thoracic wall consist of the sternum, the ribs, and the costal cartilages (Fig. 1-1).

STERNUM

The sternum is a flat bone that is divided into three parts: the manubrium, the body, and the xiphoid process.

Manubrium

The manubrium forms the upper part of the sternum. It articulates with the body of the sternum at the manubriosternal joint, and it also articulates with the clavicles and with the first costal cartilage and the upper part of the second costal cartilage on each side.

The **sternal angle** (**angle of Louis**) is formed by the articulation of the manubrium with the body of the sternum (Fig. 1-1). It is an important surface landmark, and it lies at the level of:

1. The second costal cartilage.
2. The intervertebral disc between the fourth and fifth thoracic vertebrae.
3. The junction of the ascending aorta and the aortic arch and the junction of the aortic arch and the descending thoracic aorta.
4. The bifurcation of the trachea.
5. The junction of the superior mediastinum and the inferior mediastinum (see p. 9).

Body of the Sternum

The body of the sternum articulates above with the manubrium at the **manubriosternal joint** and below with the xiphoid process at the **xiphisternal joint**. On each side, it articulates with the second to the seventh costal cartilages (Fig. 1-1).

Xiphoid Process

The xiphoid process is a thin plate of cartilage that becomes ossified at its proximal end during adult life. No ribs or costal cartilages are attached to it.

> **CLINICAL NOTES**
>
> **STERNUM AND MARROW BIOPSY**
>
> Because the sternum possesses red hemopoietic marrow throughout life, the body of the sternum is a common site for marrow biopsy.

RIBS

There are twelve pairs of ribs, all of which are attached posteriorly to the thoracic vertebrae. Ribs are divided into three categories:

- **True ribs:** The upper seven pairs are attached to the sternum by their costal cartilages.
- **False ribs:** The eighth, ninth, and tenth pairs are attached anteriorly to each other and to the seventh rib by their costal cartilages and small synovial joints.
- **Floating ribs:** The eleventh and twelfth pairs have no anterior attachment.

Typical Rib

The typical rib is a long, twisted flat bone with a rounded superior border and a grooved inferior border (the **costal**

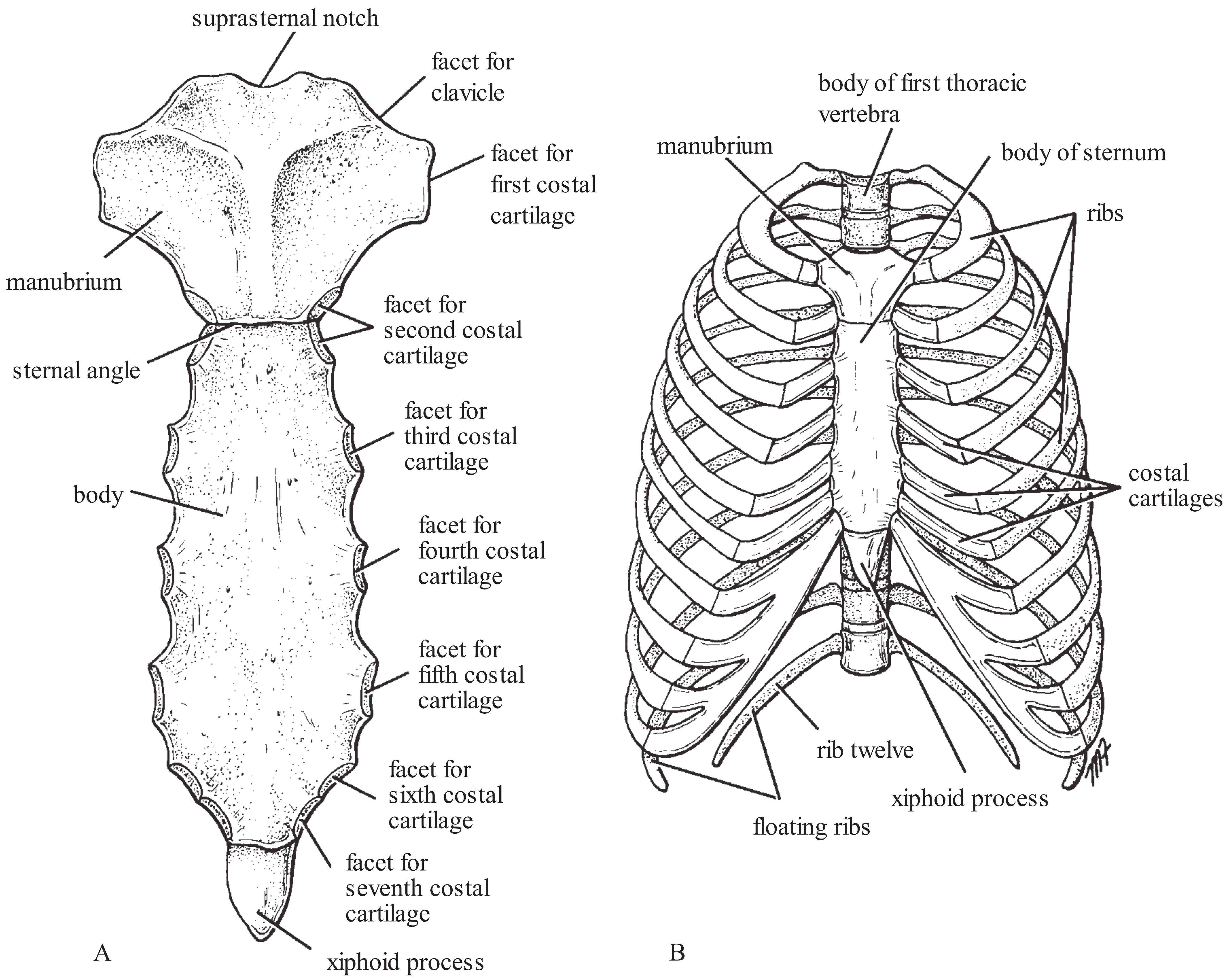


Figure 1-1 A. Anterior view of the sternum. B. The sternum, ribs, and costal cartilages forming the thoracic skeleton.

groove), which accommodates the intercostal vessels and nerve. The anterior end of each rib is attached to the corresponding costal cartilage (Fig. 1-2).

A rib has a **head, neck, tubercle, shaft,** and **angle.** The head has two facets for articulation with the numerically corresponding vertebral body and the vertebra immediately above it. The tubercle has a facet for articulation with the transverse process of the numerically corresponding vertebra. The angle is where the shaft bends forward sharply.

Atypical Rib

The **first rib** is important clinically because of its close relationship to the nerves of the brachial plexus and the subclavian artery and vein. The rib is small and flattened from above downward. The scalenus anterior is attached to its upper surface and inner border. Anterior to the scalenus anterior, the subclavian vein crosses the rib; posterior to the muscle attachment, the subclavian artery and lower trunk of the brachial plexus lie in contact with the bone.

CLINICAL NOTES

CERVICAL RIB

A cervical rib occurs in approximately 0.5% of persons. It arises from the transverse process of the seventh cervical vertebra. It may have a free anterior end, may be connected to the first rib by a fibrous band, or may articulate with the first rib. It also may cause pressure on the lower trunk of the brachial plexus or the subclavian artery, leading to symptoms and signs that are referred to as the **thoracic outlet syndrome**.

COSTAL CARTILAGES

The costal cartilages are bars of cartilage connecting the upper seven ribs to the lateral edge of the sternum and the eighth, ninth, and tenth ribs to the cartilage immediately above them (Fig. 1-1). The cartilages of the eleventh and twelfth ribs end in the abdominal musculature.

Joints of the Thoracic Wall

MANUBRIOSTERNAL JOINT

The manubriosternal joint is a cartilaginous joint. The bony surfaces are covered with hyaline cartilage and joined by a disc of fibrocartilage. A small amount of movement is possible during respiration.

CLINICAL NOTES

Sternal Angle As an Important Clinical Bony Landmark

The position of the sternal angle—that is, the angle between the manubrium sterni and the body of the sternum—can be easily felt and is often seen as a transverse ridge. It lies at the level of the second costal cartilage and second rib. All other ribs and costal cartilages can be counted from this point.

XIPHISTERNAL JOINT

The xiphisternal joint is a cartilaginous joint. The xiphoid process usually fuses with the body of the sternum during middle age.

COSTOVERTEBRAL JOINTS

From the second to the ninth ribs, the head articulates by a synovial joint with the corresponding vertebral body and that of the vertebra above it. There is a strong **intra-articular ligament** that connects the head to the intervertebral disc. The heads of the first and the lowest three ribs have a simple synovial joint with the corresponding vertebral body.

The tubercle of a rib articulates by a synovial joint with the transverse process of the corresponding vertebra. (This joint is absent on the eleventh and twelfth ribs.)

COSTOCHONDRAL JOINTS

Costochondral joints are cartilaginous joints. No movement is possible.

JOINTS OF THE COSTAL CARTILAGES WITH THE STERNUM

The first costal cartilages articulate with the manubrium by cartilaginous joints that permit no movement. The second to the seventh costal cartilages articulate with the lateral border of the sternum by synovial joints. In addition, the sixth, seventh, eighth, ninth, and tenth costal cartilages articulate with one another along their borders by small synovial joints. The cartilages of the eleventh and twelfth ribs are embedded in the abdominal musculature.

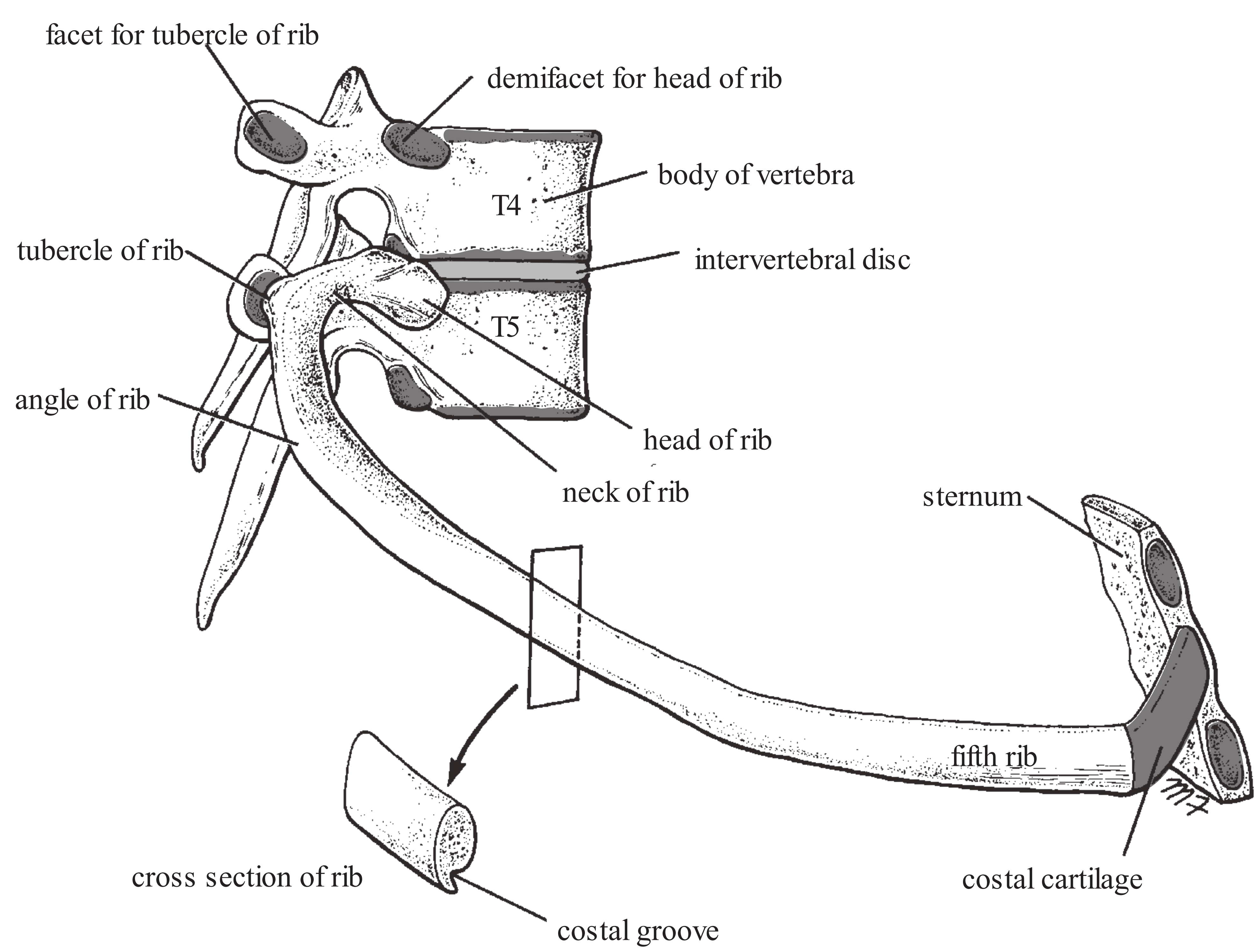


Figure 1-2 The fifth right rib as it articulates with the vertebral column posteriorly and with the sternum anteriorly. Note that the rib head articulates with the vertebral body of its own number and with that of the vertebra immediately above. Note also the costal groove along the inferior border of the rib.

The raising and lowering of the ribs during respiration result in rotation of the neck of each rib around its own axis.

CLINICAL NOTES

THORACIC OUTLET SYNDROMES

The brachial plexus of nerves (C5, 6, 7, 8, and T1) and the subclavian artery and vein are closely related to the upper surface of the first rib and the clavicle as they enter the upper limb. It is here that the nerves or blood vessels may be compressed between the bones.

Muscles of the Thoracic Wall

The muscles of the thoracic wall are summarized in Table 1-1.

INTERCOSTAL SPACES

The spaces between the ribs contain three muscles of respiration: the external intercostal, the internal intercostal, and the innermost intercostal muscle. The innermost intercostal muscle is lined internally by the **endothoracic fascia** and parietal pleura. The intercostal nerves and blood vessels run between the internal and the innermost intercostal muscles (Fig. 1-4). They are arranged in the following order from above downward: intercostal vein, intercostal artery, and intercostal nerve (i.e., VAN).

CLINICAL NOTES

NEEDLE THORACOSTOMY

A needle thoracostomy is necessary for patients with tension pneumothorax or with a large hemothorax. The purpose is to remove the air or blood to allow the lung to reexpand. The needle should be kept close to the upper border of the rib to avoid injuring the intercostal vessels and nerve in the subcostal groove.

DIAPHRAGM

The diaphragm is the most important muscle of respiration (Fig. 1-3). It is dome shaped, and it consists of a peripheral

Table 1-1 Muscles of the Thorax

Name of Muscle	Origin	Insertion	Nerve Supply	Action
Diaphragm	Xiphoid process; lower six costal cartilages; one to three lumbar vertebrae by crura and medial and lateral arcuate ligaments	Central tendon	Phrenic nerve	Most important muscle of inspiration, increases vertical diameter of the thorax by pulling down the central tendon; assists in raising lower ribs
Intercostal muscles External intercostal (fibers pass downward and forward)	Inferior border of the rib above	Superior border of the rib below	Intercostal nerves	With the first rib fixed, they raise ribs during inspiration and thus increase anteroposterior and transverse diameters of the thorax; with the last rib fixed by abdominal muscles, they lower the ribs during expiration
Internal intercostal (fibers pass downward and backward)	Inferior border of the rib above	Superior border of the rib below	Intercostal nerves	Assist the external intercostal muscles
Innermost intercostal (fibers pass transversely, forms incomplete layer of muscle)	Adjacent ribs	Adjacent ribs	Intercostal nerves	Assist external and internal intercostal muscles
Levatores costarum (twelve total)	Transverse processes of the seventh cervical to the eleventh thoracic vertebra	Superior border of the ribs	Posterior rami of the thoracic spinal nerves	Elevate ribs
Serratus posterior superior	Ligamentum nuchae and upper thoracic spines	Upper ribs	Intercostal nerves	Elevates ribs
Serratus posterior inferior	Lower thoracic and upper lumbar spines	Lower ribs	Intercostal nerves	Lowers ribs

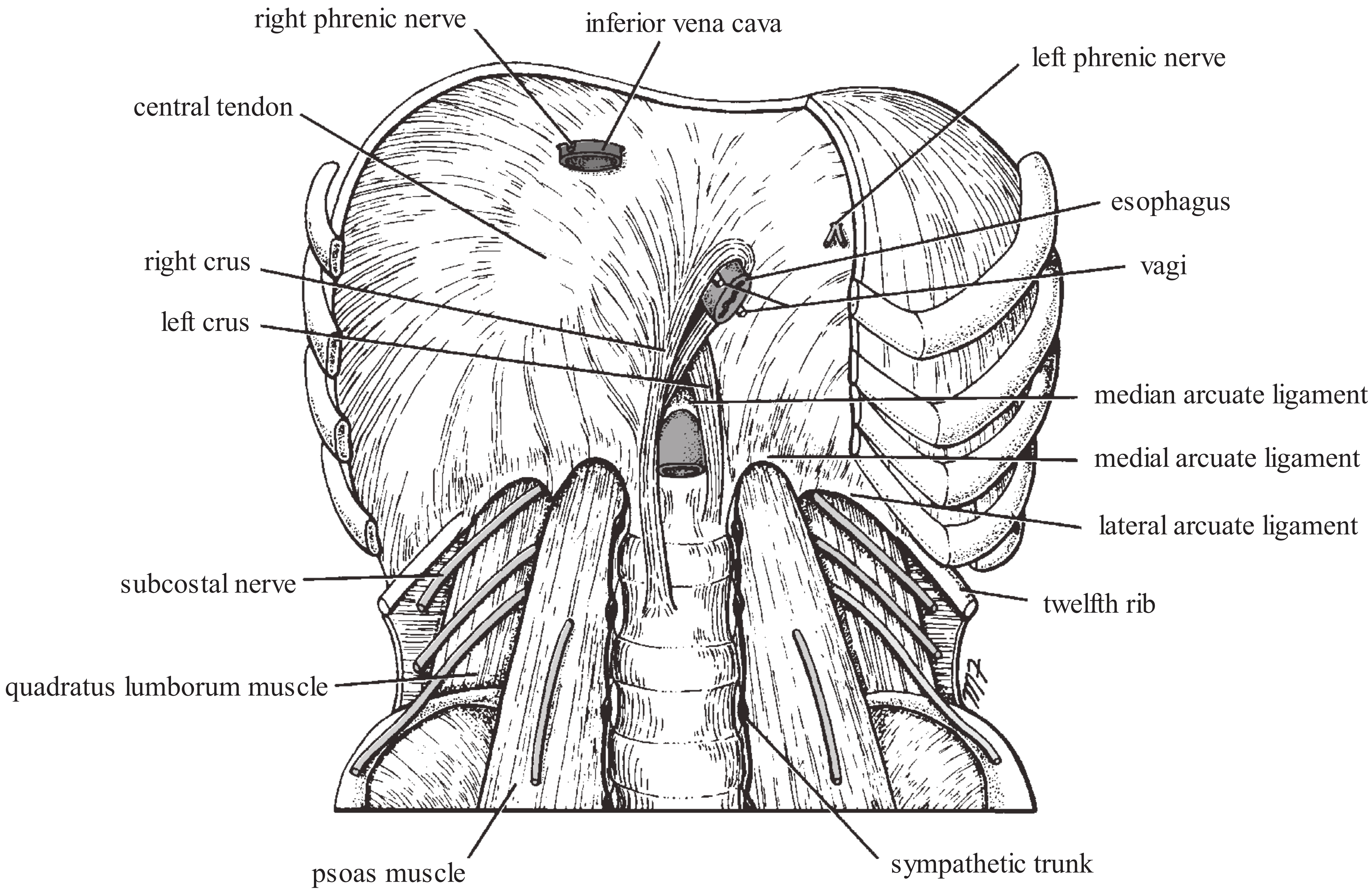


Figure 1-3 The diaphragm as seen from below. The anterior portion of the right side has been removed. Note the sternal, costal, and vertebral origins of the muscle and important structures that pass through it.

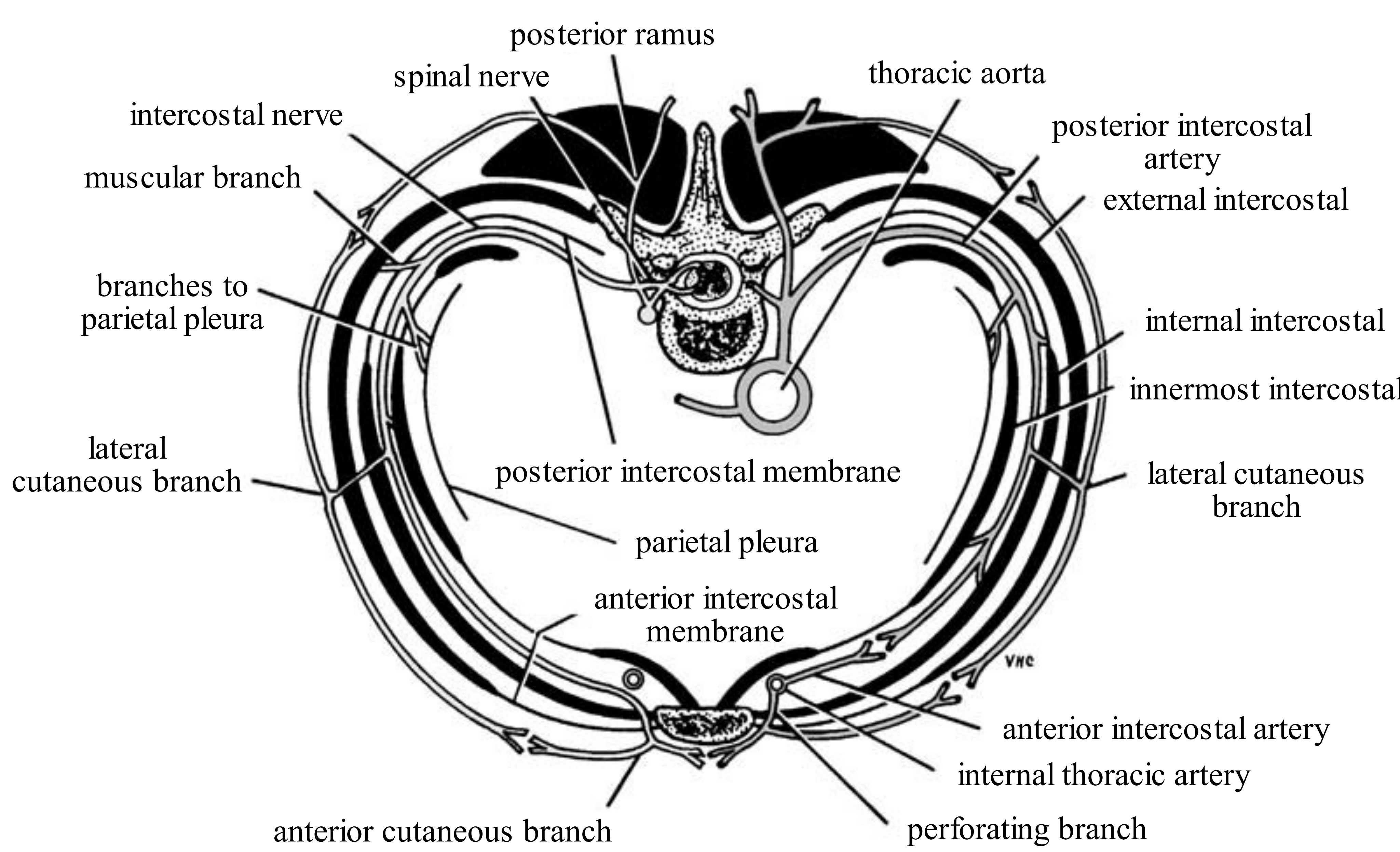


Figure 1-4 Cross section of the thorax showing the distribution of a typical intercostal nerve and of a posterior and an anterior intercostal artery.

muscular part and a centrally placed tendon. The origin of the diaphragm is divided into three parts:

- A **sternal part** arising from the posterior surface of the xiphoid process.
- A **costal part** arising from the deep surfaces of the lower six ribs and their costal cartilages.
- A **vertebral part** arising from vertical columns or crura and from the arcuate ligaments.

The **right crus** arises from the sides of the bodies of the first three lumbar vertebrae and the intervertebral discs, and it splits to enclose the esophagus. The **left crus** arises from the sides of the bodies of the first two lumbar vertebrae and the intervertebral disc. Lateral to the crura, the diaphragm arises from the medial and the lateral arcuate ligaments. The **medial arcuate ligament** extends from the side of the body of the second lumbar vertebra to the transverse process of the first lumbar vertebra, and the **lateral arcuate ligament** extends from the transverse process of the first lumbar vertebra to the twelfth rib. The diaphragm is inserted into a **central tendon**.

As seen from the front, the diaphragm curves up into right and left domes. These domes support the right and left lungs, whereas the central tendon supports the heart.

Nerve Supply

The phrenic nerve (C3–5).

Action

- **Muscle of inspiration:** On contraction, the diaphragm pulls its central tendon down and increases the vertical diameter of the thorax.
- **Muscle of abdominal straining:** The contraction of the diaphragm assists the contraction of the muscles of the anterior abdominal wall in raising the intra-abdominal pressure for micturition, defecation, and parturition.
- **Weight-lifting muscle:** In a person taking a deep breath and holding it (fixing the diaphragm), the diaphragm assists the muscles of the anterior abdominal wall in raising the intra-abdominal pressure to such an extent that it helps support the vertebral column and prevent its flexion.
- **Thoracoabdominal pump:** The descent of the diaphragm decreases the intrathoracic pressure and increases the intra-abdominal pressure. This mechanism assists the return of venous blood in the inferior vena cava to the right atrium and the passage of lymph upward in the thoracic duct.

Openings in the Diaphragm

Aortic Opening

The aortic opening lies anterior to the body of the twelfth thoracic vertebra between the crura and transmits the aorta, the thoracic duct, and the azygos vein.

Esophageal Opening

The esophageal opening lies at the level of the tenth thoracic vertebra in a sling of muscle fibers derived from the right crus. It transmits the esophagus, the right and left vagus nerves, the esophageal branches of the left gastric vessels, and the lymphatic vessels from the lower third of the esophagus.

Caval Opening

The caval opening lies at the level of the eighth thoracic vertebra in the central tendon. It transmits the inferior vena cava and the terminal branches of the right phrenic nerve.

In addition to these structures, the splanchnic nerves pierce the crura, the sympathetic trunk passes posterior to the medial arcuate ligament on each side, and the superior epigastric vessels pass between the sternal and the costal origins of the diaphragm on each side.

CLINICAL NOTES

Penetrating Injuries of the Diaphragm

Any penetrating wound to the chest below the level of the nipples should be suspected of causing damage to the diaphragm until proved otherwise. The arching domes of the diaphragm can reach the level of the fifth rib (the right dome can reach a higher level).

Blood Vessels of the Thoracic Wall

INTERCOSTAL ARTERIES AND VEINS

Each intercostal space possesses a large, single **posterior intercostal artery** and two small **anterior intercostal arteries.**

The corresponding **posterior intercostal veins** drain into the azygos or hemiazygos veins. The corresponding **anterior intercostal veins** drain into the internal thoracic and musculophrenic veins.

Posterior Intercostal Arteries

The posterior intercostal arteries (Fig. 1-4) of the first two spaces are branches of the superior intercostal artery, which in turn is a branch of the costocervical trunk of the subclavian artery. The posterior intercostal arteries of the lower nine spaces are branches of the thoracic aorta.

Anterior Intercostal Arteries

The anterior intercostal arteries (Fig. 1-4) of the first six spaces are branches of the internal thoracic artery. The anterior intercostal arteries of the lower spaces are branches of the musculophrenic artery (one of the terminal branches of the internal thoracic artery).

INTERNAL THORACIC ARTERY AND VEIN

Internal Thoracic Artery

The internal thoracic artery (Fig. 1-4) arises from the first part of the subclavian artery. It descends directly behind the first six costal cartilages and in front of the parietal pleura, and it lies about a fingerbreadth lateral to the sternum. It terminates in the sixth intercostal space by dividing into the superior epigastric artery and the musculophrenic arteries.

Branches

- **Anterior intercostal arteries** supply the upper six intercostal spaces.
- **Perforating arteries** pierce the intercostal muscles and supply the skin and the mammary gland.
- **Pericardiophrenic artery** supplies the pericardium and the diaphragm.
- **Mediastinal arteries** supply the mediastinum, including the thymus.
- **Superior epigastric artery** enters the rectus sheath and supplies the upper part of the rectus muscle.
- **Musculophrenic artery** follows the costal margin on the upper surface of the diaphragm and supplies the diaphragm and the lower intercostal spaces

Internal Thoracic Vein

The internal thoracic vein begins as venae comitantes of the internal thoracic artery. The venae eventually join to form a single vessel that drains into the brachiocephalic vein on each side.

Lymphatic Drainage of the Thoracic Wall

The **skin** of the anterior chest wall drains to the anterior axillary lymph nodes. The skin of the posterior chest wall drains to the posterior axillary nodes. (Lymphatic drainage of the breast is described on p. 113.)

The **intercostal spaces** drain forward to the **internal thoracic nodes,** which are situated along the internal thoracic artery, and posteriorly to the **posterior intercostal nodes,** which is close to the heads of the ribs and the **para-aortic nodes** in the posterior mediastinum.

Nerves of the Thoracic Wall

INTERCOSTAL NERVES

The intercostal nerves are the anterior rami of the first eleven thoracic spinal nerves (Fig. 1-5). Each nerve enters an intercostal space and runs forward inferiorly to the intercostal vessels in the subcostal groove of the corresponding rib, between the innermost and the internal intercostal muscles (Fig. 1-4).

The first six nerves are distributed within their intercostal spaces. The seventh, eighth, and ninth intercostal nerves leave the anterior ends of their intercostal spaces by passing deep to the costal cartilages to enter the abdominal wall. The tenth and eleventh nerves pass forward directly into the abdominal wall.

Branches

- **Collateral branch** runs forward below the main nerve.
- **Lateral cutaneous branch** divides into anterior and posterior branches that supply the skin.
- **Anterior cutaneous branch** forms the terminal part of the main nerve. It divides into a medial and a lateral branch, and it supplies the skin near the midline.
- **Muscular branches** run to the intercostal muscles.
- **Pleural branches** run to the parietal pleura, and **peritoneal branches (seventh to eleventh intercostal nerves only)** run to the parietal peritoneum; these are sensory nerves.

It should be noted that the seventh to eleventh intercostal nerves supply the skin and parietal peritoneum covering the outer and inner surfaces of the anterior abdominal wall, respectively. The seventh to eleventh intercostal nerves also supply the anterior abdominal muscles (external and internal oblique, transversus abdominis, and rectus abdominis muscles).

The **first** and **second intercostal nerves,** however, are exceptions. The **first intercostal nerve** gives rise to a large branch (equivalent to the lateral cutaneous branch of typical intercostal nerves) that joins the anterior ramus of the eighth cervical nerve to form the lower trunk of the brachial plexus (see p. 144). The remainder of the first intercostal nerve is small.

The **second intercostal nerve** is joined to the medial cutaneous nerve of the arm by the **intercostobrachial nerve.** The second intercostal nerve therefore supplies the skin of the armpit and the upper medial side of the arm.

CLINICAL NOTES

Skin Innervation of the Chest Wall and Disease

Above the level of the sternal angle, the nerve supply to the skin of the anterior chest wall and shoulder region is derived from the **supraclavicular nerves** (**C3** and **4**). Referred pain from the gallbladder can be felt on the point of the shoulder by way of these nerves (see p. 56). Below the level of the sternal angle, the anterior and lateral cutaneous branches of the intercostal nerves supply oblique bands of skin (**dermatomes**) in regular sequence. Since the seventh to the eleventh intercostal nerves also supply dermatomes on the anterior abdominal wall, muscles of the anterior abdominal wall, and parietal peritoneum, this fact becomes of great clinical importance. Disease in the thoracic wall may be revealed as pain in a dermatome that extends across the chest wall into the abdominal wall.

CLINICAL NOTES

Coronary Heart Disease and the Intercostobrachial Nerve

In coronary heart disease pain is often referred along the intercostobrachial nerve to the medial side of the arm.

THORACIC CAVITY

The thoracic cavity is divided into a median partition (the mediastinum) and the laterally placed pleurae and lungs.

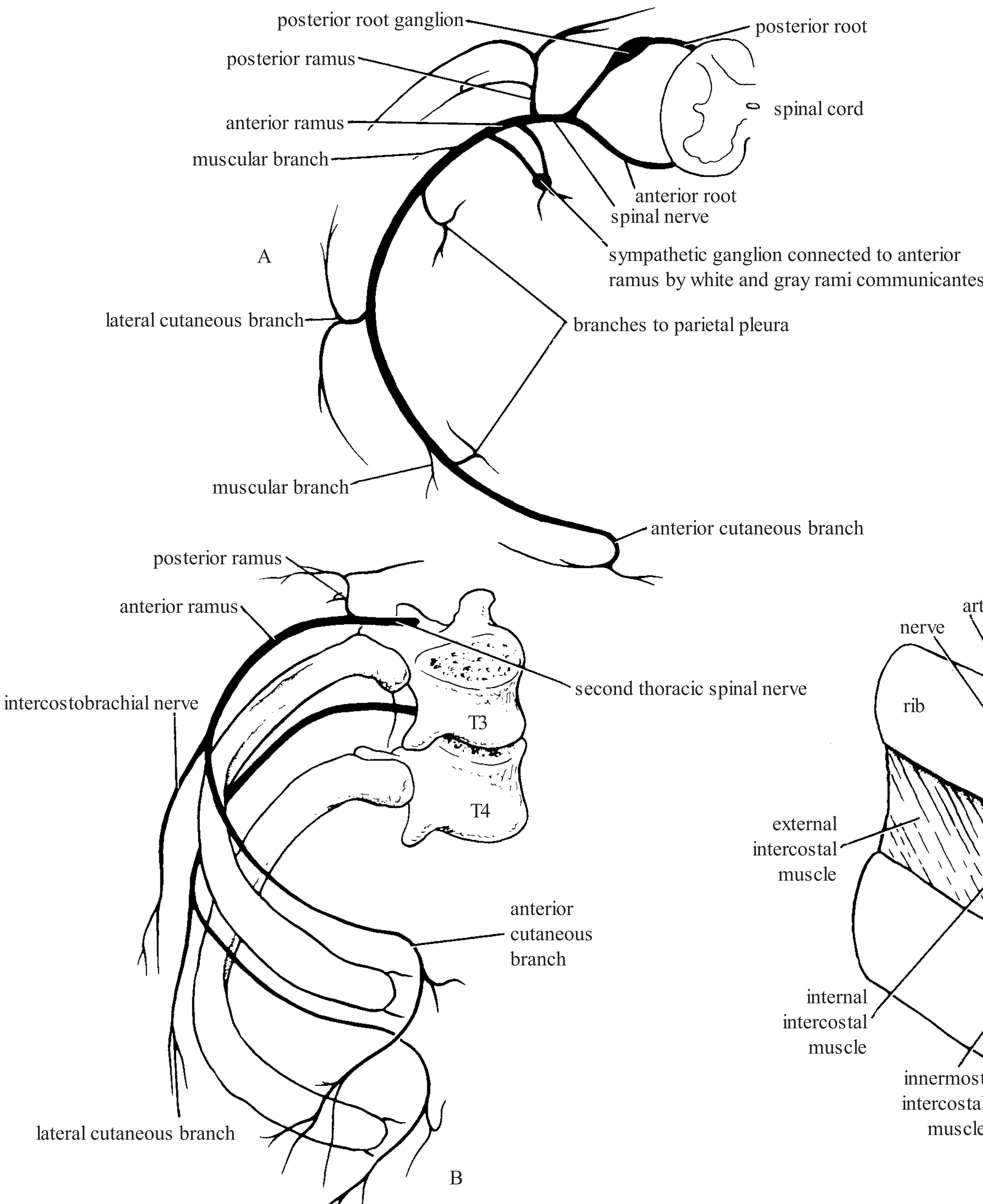


Figure 1-5 A. Origin and distribution of a thoracic spinal nerve. B. Distribution of two intercostal nerves relative to the rib cage. C. Section through an intercostal space that shows the positions of the intercostal nerve, artery, and vein relative to the intercostal muscles.

The thoracic cavity communicates with the root of the neck through an opening that clinicians call the **thoracic outlet.** This opening is bounded posteriorly by the first thoracic vertebra, laterally by the medial borders of the first ribs and costal cartilages, and anteriorly by the superior border of the manubrium sterni. Through this opening pass the esophagus, trachea, and many vessels and nerves. Because of the obliquity of the opening, the apices of the lungs and pleurae project upward into the neck.

Below, the thoracic cavity communicates with the abdomen through a large opening. This opening is bounded posteriorly by the twelfth thoracic vertebra, laterally by the curving costal margin, and anteriorly by the xiphisternal joint. Through this large opening, which is closed by the diaphragm, pass the esophagus as well as many large vessels and nerves, all of which pierce the diaphragm.

Mediastinum

The mediastinum is an interpleural partition that extends superiorly to the thoracic outlet and the root of the neck and inferiorly to the diaphragm. It extends anteriorly to the sternum and posteriorly to the vertebral column. It is divided into the **superior** and **inferior mediastina** by an imaginary plane passing from the sternal angle anteriorly to the lower border of the body of the fourth thoracic vertebra posteriorly (Fig. 1-6). The inferior mediastinum is further subdivided into the **middle mediastinum,** which consists of the pericardium and heart; the **anterior mediastinum,** which is a space between the pericardium and the sternum; and the **posterior mediastinum,** which lies between the pericardium and the vertebral column.

SUPERIOR MEDIASTINUM

The contents of the superior mediastinum, **from anterior to posterior,** include the remains of thymus, brachiocephalic veins, the upper part of superior vena cava, the brachiocephalic artery, the left common carotid artery, the left subclavian artery, the arch of the aorta, both phrenic and vagus nerves, left recurrent laryngeal and cardiac nerves, the trachea and lymph nodes, the esophagus and thoracic duct, and sympathetic trunks.

ANTERIOR MEDIASTINUM

The contents of the anterior mediastinum include the sternopericardial ligaments, lymph nodes, and remains of thymus.

MIDDLE MEDIASTINUM

The contents of the middle mediastinum include the pericardium, the heart and roots of great blood vessels, phrenic nerves, bifurcation of trachea, and lymph nodes.

POSTERIOR MEDIASTINUM

The contents of the posterior mediastinum include the descending thoracic aorta, esophagus, thoracic duct, azygos and hemiazygos veins, vagus nerves, splanchnic nerves, sympathetic trunks, and lymph nodes.

CLINICAL NOTES

DEFLECTION OF THE MEDIASTINUM

In the living, the mediastinum is very mobile. If air should enter the pleural cavity as the result of chest trauma or lung disease, the lung on that side collapses and the mediastinum is displaced to the opposite side. Thus on physical examination the trachea and heart are found to be displaced to the opposite side.

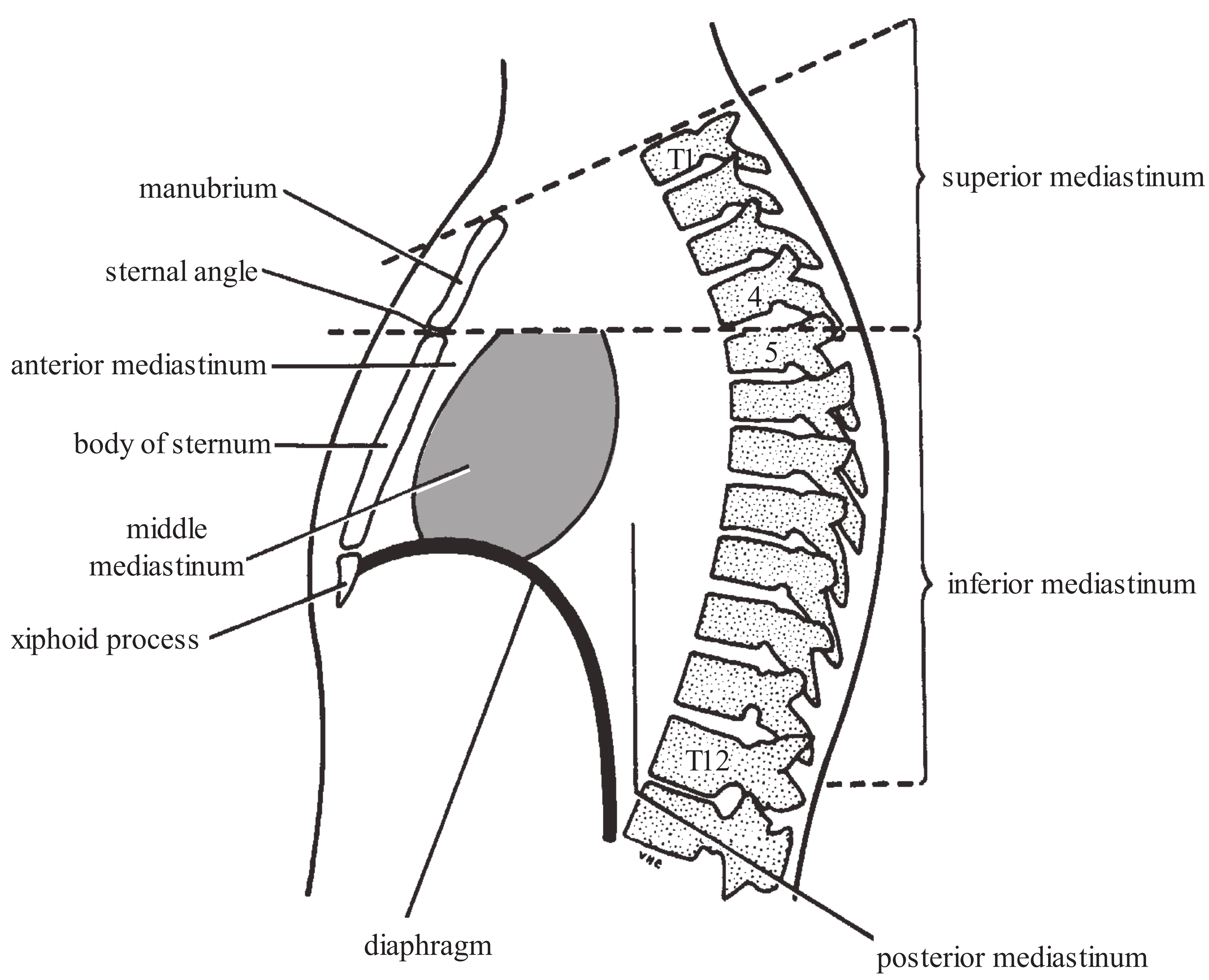


Figure 1-6 Subdivisions of the mediastinum.

Trachea and Bronchi

TRACHEA

The trachea is a mobile cartilaginous and membranous tube (Fig. 1-7). It begins as a continuation of the larynx at the lower border of the cricoid cartilage (level of the sixth cervical vertebra), and it descends in the midline of the neck and ends in the thorax by dividing into right and left principal (main) bronchi at the level of the sternal angle (the disc between the T4–5 vertebrae).

The trachea is approximately 5 in. (13 cm) in length and 1 in. (2.5 cm) in diameter in adults. The fibroelastic tube has U-shaped cartilaginous rings embedded in its wall.

Tracheal Relations in the Superior Mediastinum

- **Anteriorly:** Sternum, thymus, left brachiocephalic vein, origins of brachiocephalic and left common carotid arteries, and arch of the aorta.
- **Posteriorly:** Esophagus and left recurrent laryngeal nerve.

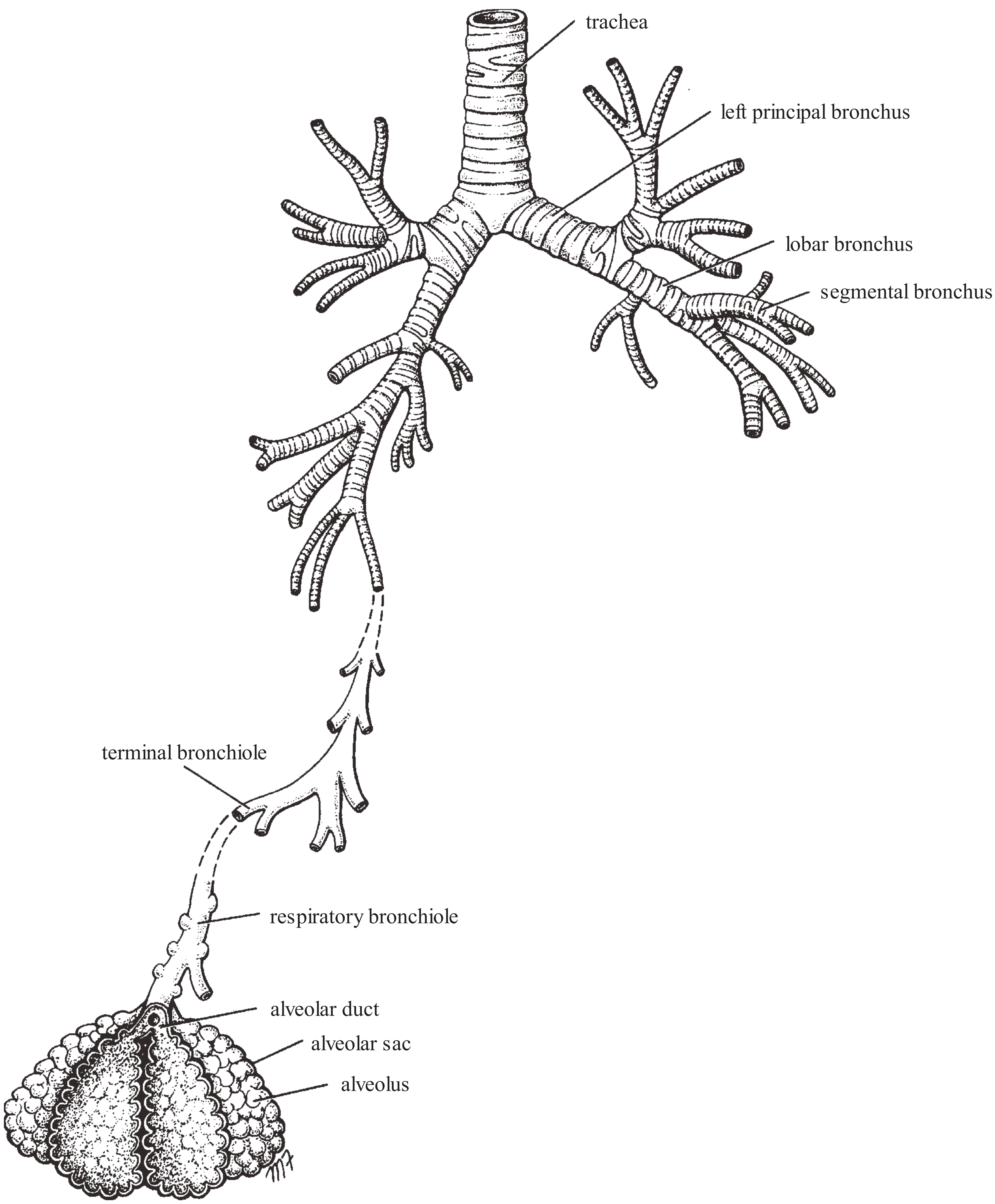


Figure 1-7 The trachea, bronchi, bronchioles, alveolar ducts, alveolar sacs, and alveoli. Note the path taken by inspired air from the trachea to the alveoli.

- **Right side:** Azygos vein, right vagus nerve, and pleura.
- **Left side:** Arch of the aorta, left common carotid, left subclavian arteries, left vagus nerve, left phrenic nerve, and pleura.

BRONCHI

Right Principal

The **right principal (main) bronchus** is wider, shorter, and more vertical than the left principal bronchus. Before entering the hilum of the right lung, it gives off the **superior lobar bronchus.** On entering the hilum, it divides into a **middle** and an **inferior lobar bronchus.**

Left Principal

The **left principal (main) bronchus** is narrower, longer, and more horizontal than the right principal bronchus. It passes to the left below the arch of the aorta and in front of the esophagus. On entering the hilum of the left lung, it divides into a **superior** and an **inferior lobar bronchus.**

CLINICAL NOTES

INHALED FOREIGN BODIES

Because the right bronchus is wider and more direct continuation of the trachea, foreign bodies tend to enter the right instead of the left bronchus. From there they usually pass into the middle or lower lobe bronchi.

Pleurae

The pleurae are two serous sacs surrounding and covering the lungs (Fig. 1-8). Each pleura has two parts: a **parietal pleura,** which lines the thoracic wall and covers the thoracic surface of the diaphragm and the lateral surface of the mediastinum; and a **visceral pleura,** which covers the outer surfaces of the lungs and extends into the interlobar fissures. The parietal pleura becomes continuous with the visceral pleura at the **hilum** of each lung. Here, they form a cuff that surrounds the structures entering and leaving the lung at the **lung root.** The **pulmonary ligament** is a loose extension of this cuff below the lung root that allows movement during respiration.

The **pleural cavity (pleural space)** is a slitlike space that separates the parietal and the visceral pleurae. It normally contains a small amount of **pleural fluid** that lubricates the apposing pleural surfaces. The **costodiaphragmatic recess** is the lowest area of the pleural cavity into which the lungs expand during deep inspiration.

CLINICAL NOTES

PNEUMOTHORAX

As the result of disease or injury, air can enter the pleural cavity from the lungs or through the chest wall; this condition is known as pneumothorax.

NERVE SUPPLY OF THE PLEURA

Parietal Pleura

The parietal pleura is sensitive to pain, temperature, touch, and pressure. The costal pleura is supplied by the intercostal nerves, the mediastinal pleura by the phrenic nerve, and the diaphragmatic pleura over the domes by the phrenic nerve and around the periphery by the lower intercostal nerves.

Visceral Pleura

The visceral pleura receives an autonomic nerve supply from the pulmonary plexus. It is sensitive only to stretching.

ENDOTHORACIC FASCIA

The endothoracic fascia is a thin layer of loose connective tissue that separates the parietal pleura from the thoracic wall.

Lungs

The lungs (right and left) are situated on each side of the mediastinum (Fig. 1-8). Between them, in the mediastinum, lie the heart and great vessels. The lungs are conical in shape and are covered with visceral pleura. The lungs are freely suspended, but they are attached by their roots to the mediastinum.

Each lung has a blunt **apex** that projects upward into the neck (Fig. 1-9) for approximately 1 in. (2.5 cm) above the clavicle, a concave **base** that sits on the diaphragm, a convex **costal surface** that corresponds to the concave chest wall, and a concave **mediastinal surface** that is molded to the pericardium and other mediastinal structures. About the middle of the mediastinal surface is the **hilum,** which is a depression where the bronchi, vessels, and nerves enter the lung to form the **root.**

The **anterior border** is thin and overlaps the heart, and here, on the left lung, is a notch called the **cardiac notch.** The **posterior border** is thick and lies beside the vertebral column.

LOBES AND FISSURES

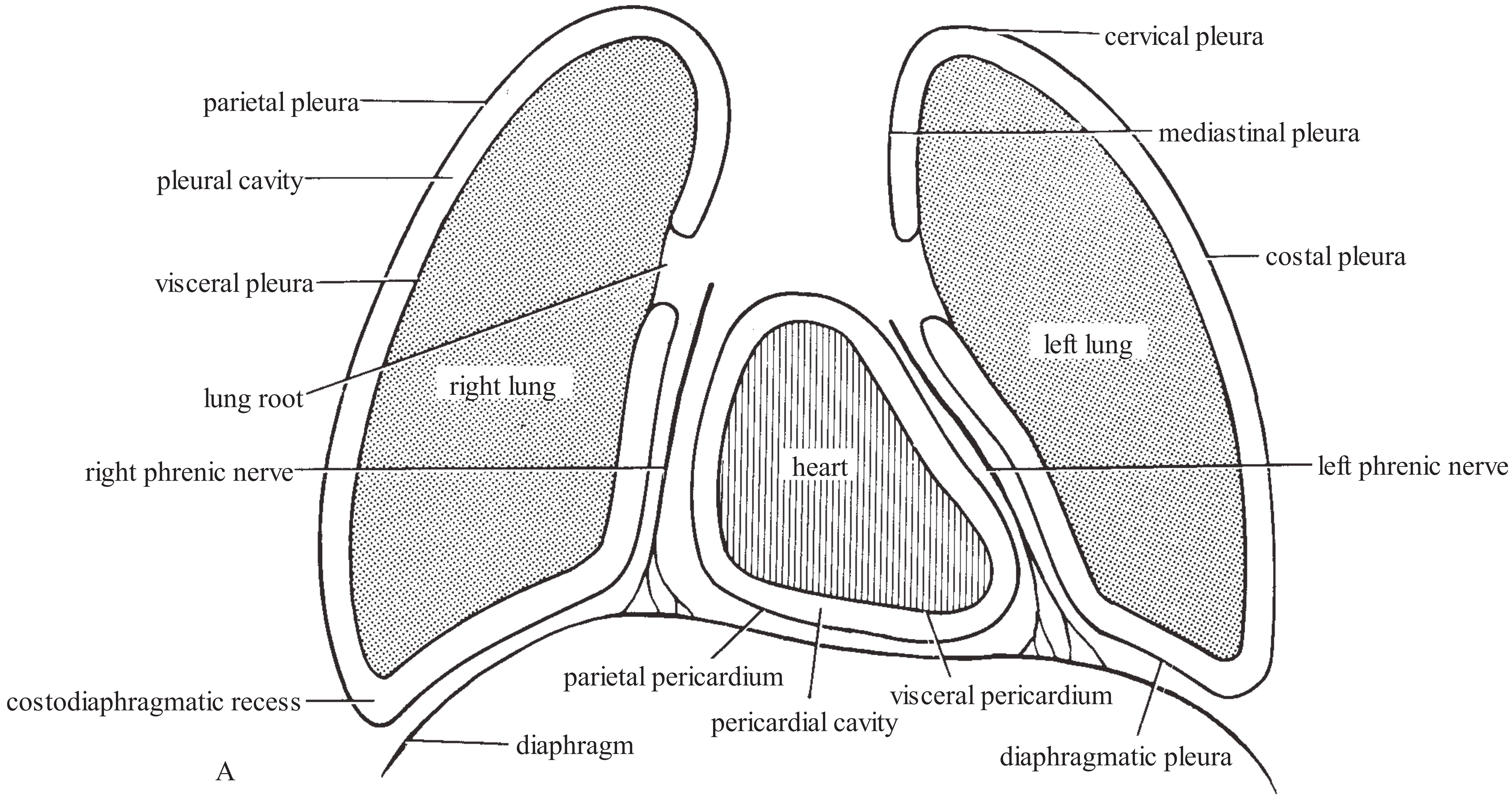
Right Lung

The right lung is slightly larger than the left lung, and it is divided into the **upper, middle,** and **lower lobes** by the oblique and the horizontal fissures (Fig. 1-9).

The **oblique fissure** runs from the inferior border upward and backward across the medial and costal surfaces until it cuts the posterior border. The **horizontal fissure** runs horizontally across the costal surface to meet the oblique fissure. The middle lobe is thus a small, triangular lobe bounded by the horizontal and oblique fissures.

Left Lung

The left lung is divided by only one fissure (the oblique fissure) into two lobes, the **upper** and **lower lobes.**



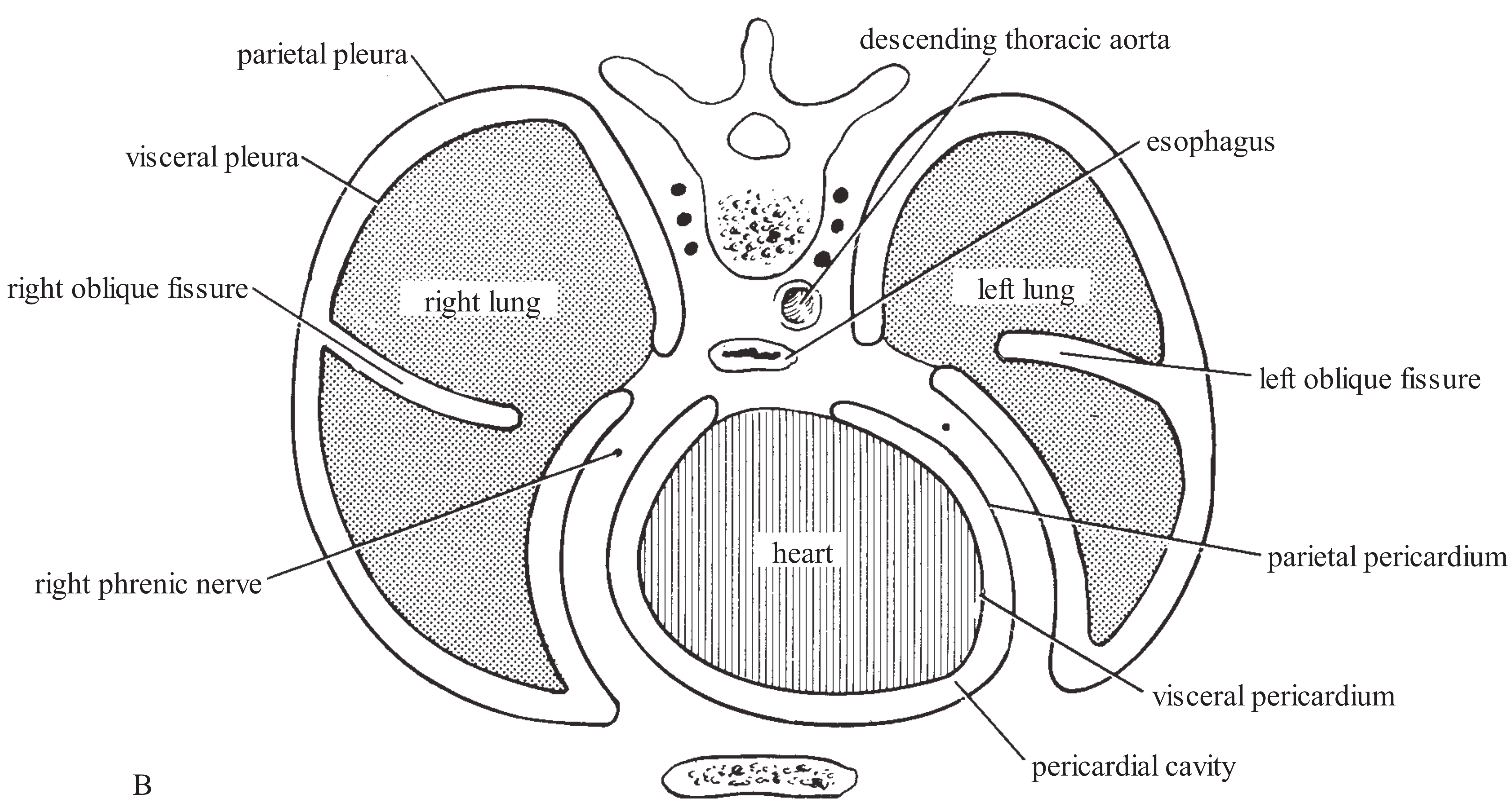


Figure 1-8 A. Coronal section of the thorax showing the arrangements of the visceral and parietal layers of the pleura and of the serous pericardium. B. Horizontal section of the thorax showing the arrangement of the pleura and the pericardium.

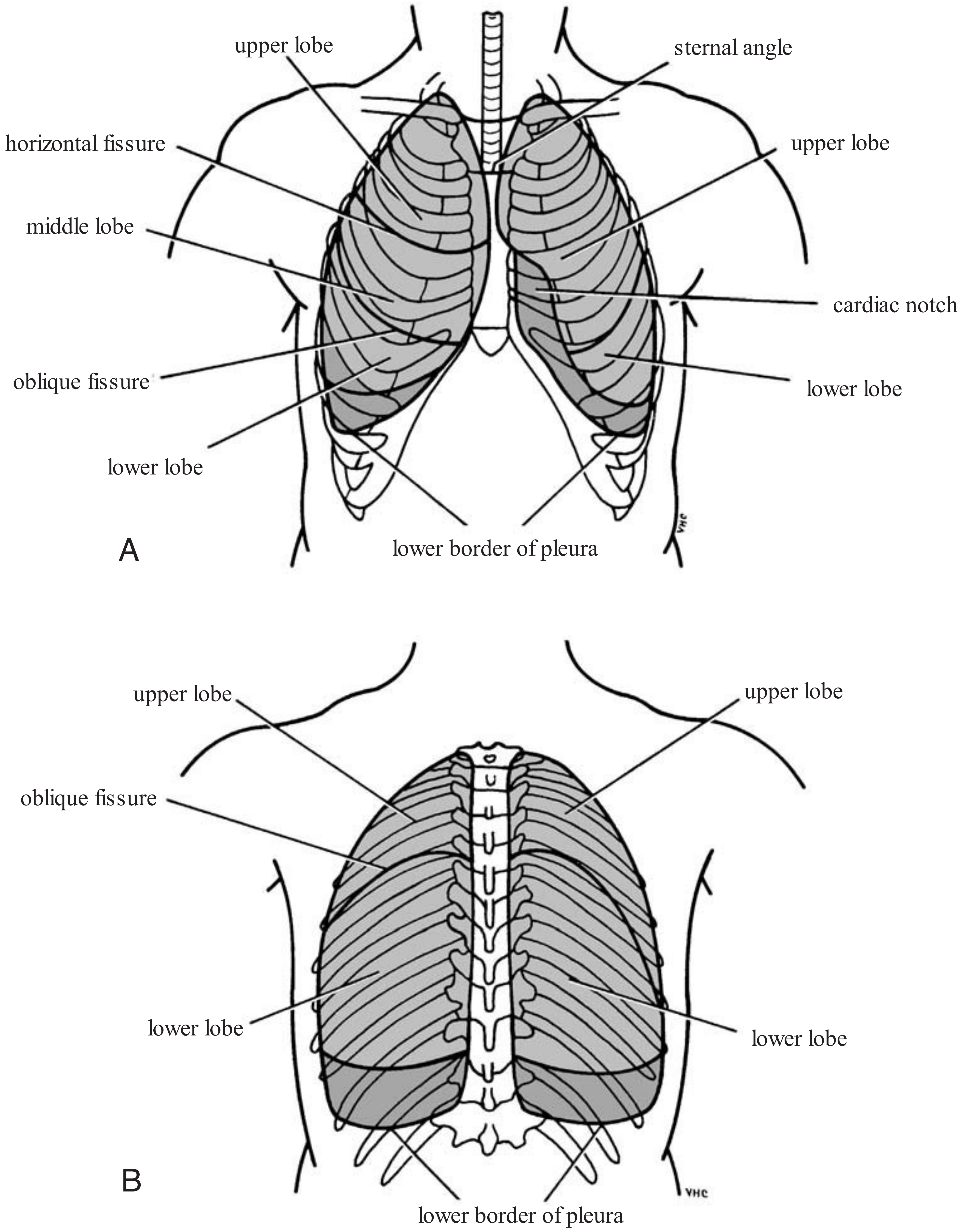


Figure 1-9 A. Surface markings of the lungs and parietal pleura on the anterior thoracic wall. B. Surface markings of the lungs and parietal pleura on the posterior thoracic wall.

BRONCHOPULMONARY SEGMENTS

Bronchopulmonary segments are the anatomic, functional, and surgical units of the lungs. Each lobar (secondary) bronchus, which passes to a lobe of the lung, gives off branches called **segmental (tertiary) bronchi** (Fig. 1-7). Each segmental bronchus then enters a bronchopulmonary segment. A **bronchopulmonary segment** has the following characteristics:

- It is a subdivision of a lung lobe.
- It is pyramidal in shape, with its apex toward the lung root.
- It is surrounded by connective tissue.
- It has a segmental bronchus, a segmental artery, lymph vessels, and autonomic nerves.
- The segmental vein lies in the connective tissue between adjacent bronchopulmonary segments.
- Because it is a structural unit, a diseased segment can be removed surgically.

BLOOD SUPPLY OF THE LUNGS

The bronchi, connective tissue, and visceral pleura are supplied by the bronchial arteries, which are branches of the descending thoracic aorta. The bronchial veins drain into the azygos and the hemiazygos veins.

The alveoli receive deoxygenated blood from the pulmonary arteries. Two pulmonary veins leave each lung root.

LYMPH DRAINAGE OF THE LUNGS

The lymph vessels originate in the superficial plexus and the deep plexus and are not present in the alveolar walls. The **superficial plexus** lies beneath the visceral pleura and drains over the surface of the lung toward the hilum, where the lymph vessels enter the **bronchopulmonary nodes.** The **deep plexus** travels along the bronchi and pulmonary vessels toward the hilum of the lung and passes through **pulmonary nodes** within the lung substance; the lymph then enters the bronchopulmonary nodes in the hilum of the lung. All the lymph from the lung leaves the hilum and drains into the **tracheobronchial nodes** and then into the **bronchomediastinal lymph trunks.**

NERVE SUPPLY OF THE LUNGS

Each lung is supplied by the **pulmonary plexus.** The plexus is formed by branches of the sympathetic trunk and receives parasympathetic fibers from the vagus nerve.

CLINICAL NOTES

Pain and Lung Disease

Lung tissue and the visceral pleura are insensitive to pain (supplied by autonomic nerves and devoid of pain-sensitive nerve endings). Once lung disease crosses the pleural cavity to involve the parietal pleura, pain becomes a prominent feature (supplied by intercostal and phrenic nerves with pain-sensitive nerve endings).

MECHANICS OF RESPIRATION

Inspiration and expiration are accomplished by the alternate increase and decrease in the capacity of the thoracic cavity (16–20 times per minute in normal, resting adults).

Quiet Inspiration

The vertical diameter of the thoracic cavity is increased by the contraction and descent of the diaphragm. The anteroposterior diameter is increased by raising the ribs and thrusting the sternum forward through contraction of the intercostal muscles. The transverse diameter is increased by raising the ribs (like bucket handles) through contraction of the intercostal muscles.

Forced Inspiration

In addition to the muscles used in quiet inspiration, the maximum increase in thoracic capacity is achieved by contraction of the scalenus anterior and medius (raises first rib), sternocleidomastoid (raises the sternum), and serratus anterior and pectoralis minor (raise the ribs) muscles. If the upper limb is fixed, the sternal origin of the pectoralis major may also assist in elevating the sternum and the ribs.

Quiet Expiration

Quiet expiration is a passive process accomplished by the elastic recoil of the lungs and the relaxation of the intercostal muscles and diaphragm.

Forced Expiration

Forced expiration is an active process accomplished by contraction of the muscles of the anterior abdominal wall (forcing the relaxed diaphragm upward by raising intra-abdominal pressure) and contraction of the quadratus lumborum (pulling the twelfth rib downward). The latissimus dorsi muscle may also assist in pulling down the lower ribs.

PERICARDIUM

The pericardium is a fibroserous sac that encloses the heart and the roots of the great blood vessels (Fig. 1-10). It lies within the middle mediastinum (Fig. 1-6).

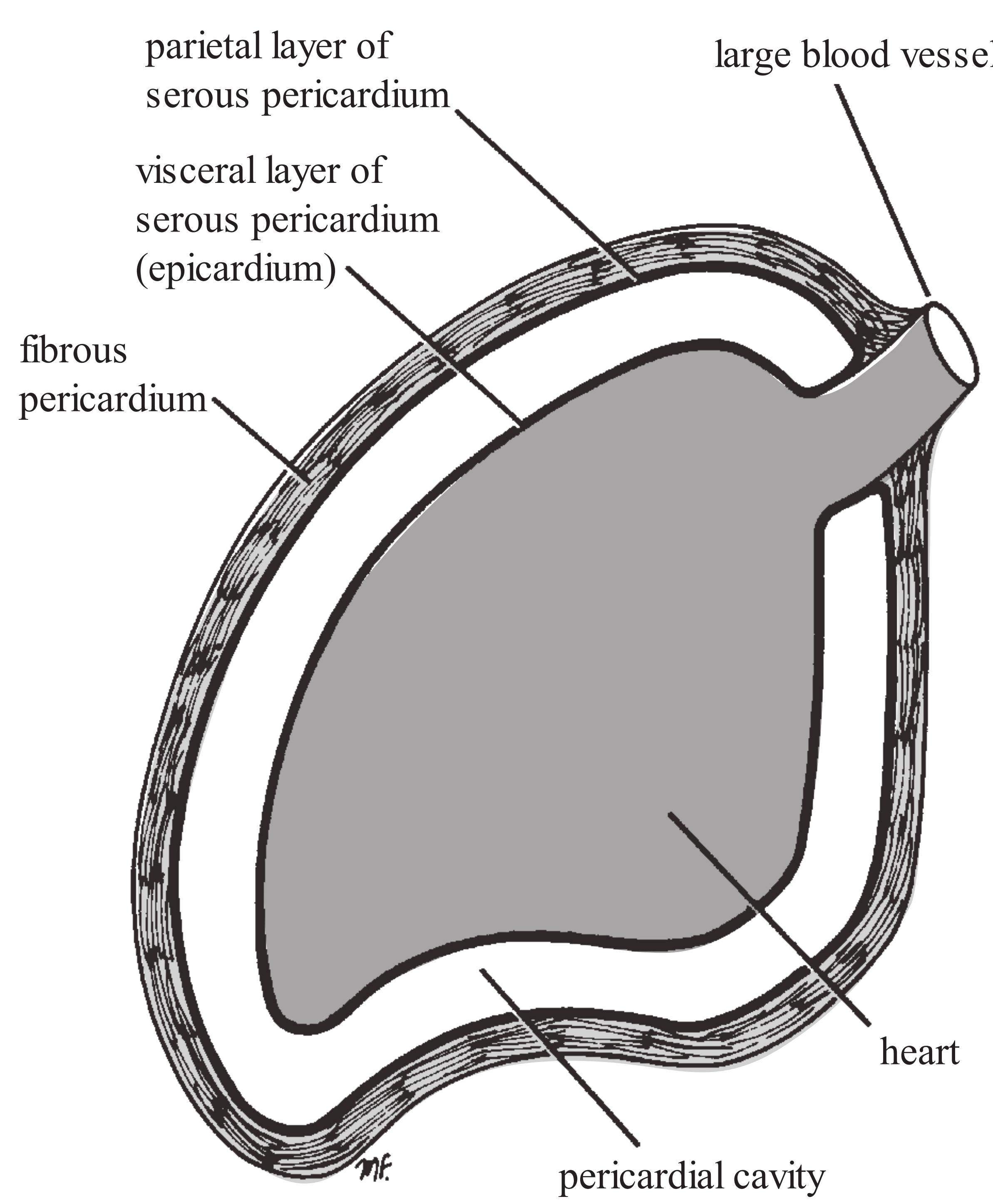


Figure 1-10 Layers of the pericardium.

Fibrous Pericardium

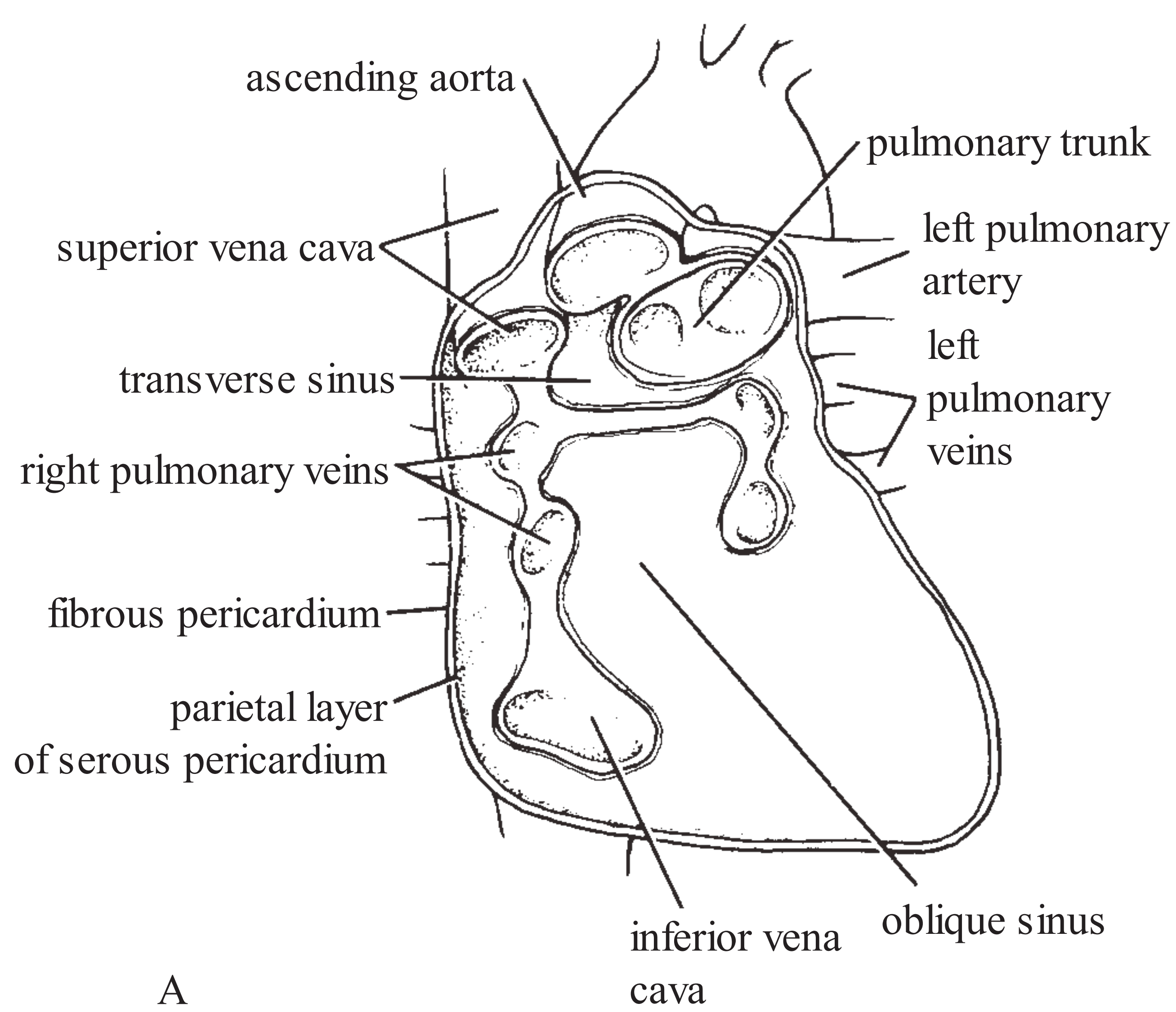
The fibrous pericardium is the fibrous part of the pericardial sac. It is strong and limits unnecessary movements of the heart. It fuses above with the walls of the great blood vessels (ascending aorta, pulmonary trunk, superior and inferior venae cavae, and pulmonary veins), and it is firmly attached below to the central tendon of the diaphragm. It is attached anteriorly to the sternum by the **sternopericardial ligaments.**

Serous Pericardium

The serous pericardium has both a parietal and a visceral layer (Fig. 1-10). The **parietal layer** lines the fibrous pericardium and is reflected around the roots of the great vessels to become continuous with the **visceral layer,** which closely covers the heart (the **epicardium**). The **pericardial cavity** is the slitlike space between the parietal and the visceral layers. The **pericardial fluid** is the small amount of fluid normally present in the pericardial cavity as a lubricant to facilitate cardiac movements.

Pericardial Sinuses

The **transverse sinus** is a passage on the posterior surface of the heart between the reflection of the serous pericardium around the ascending aorta and the pulmonary trunk and the reflection around the great veins (Fig. 1-11). The **oblique sinus** is a recess formed by the reflection of the



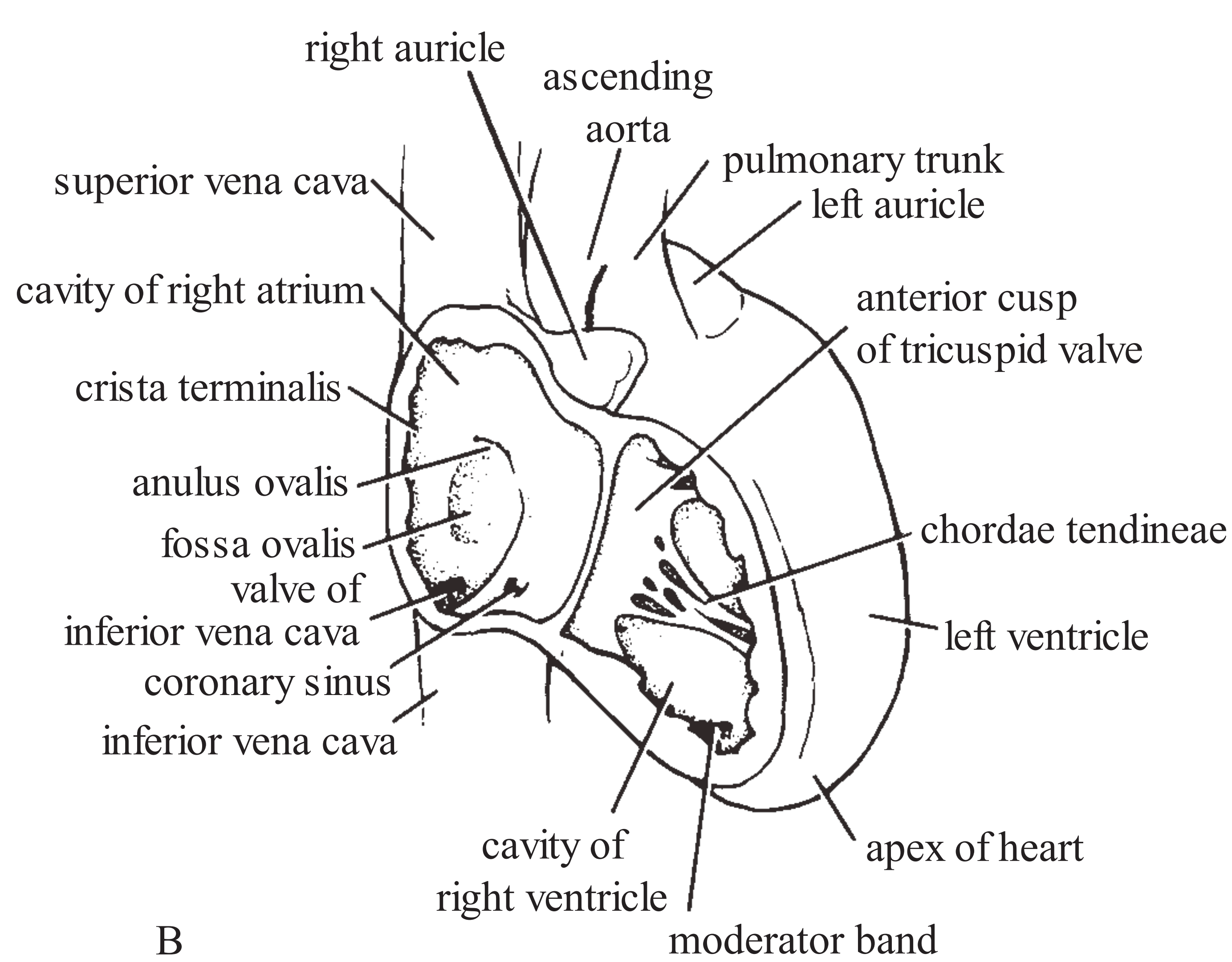


Figure 1-11 A. Great blood vessels and interior of the pericardium. B. Interior of the right atrium and right ventricle.

serous pericardium around the venae cavae and the four pulmonary veins (Fig. 1-11).

Nerve Supply of Pericardium

The phrenic nerves.

HEART

The heart is a hollow, muscular organ within the pericardium in the middle mediastinum. It is somewhat pyramidal in shape, and it has three surfaces: the sternocostal (anterior), the diaphragmatic (inferior), and the base (posterior). It also has an **apex,** which is directed downward, forward, and to the left (Fig. 1-11). The apex of the heart lies at the level of the fifth left intercostal space, approximately 3.5 in. (9 cm) from the midline.

Structure

The heart is divided by vertical septa into four chambers: the right and left atria and the right and left ventricles. The right atrium lies anterior to the left atrium, and the right ventricle lies anterior to the left ventricle (Fig. 1-12). The walls of the heart consist of three layers:

- The outer, visceral layer of serous pericardium (the **epicardium**).
- The middle, thick layer of cardiac muscle (the **myocardium**).
- The inner, thin layer (the **endocardium**).

The **skeleton of the heart** consists of fibrous rings that surround the atrioventricular, pulmonary, and aortic orifices and are continuous with the membranous upper part of the ventricular septum.

Chambers

RIGHT ATRIUM

The right atrium lies anterior to the left atrium and consists of a main cavity and an **auricle** (Fig. 1-11). At the junction of these parts is an external vertical groove, the **sulcus terminalis,** which on the inside forms a ridge, the **crista terminalis** (the junction between the sinus venosus and the right atrium proper). The part of the atrium posterior to the ridge is smooth walled, whereas the interior of the auricle is roughened by bundles of muscle fibers, the **musculi pectinati.**

Openings

The **superior vena cava** opens into the upper part of the right atrium; there is no valve. The **inferior vena cava,** which actually is larger than the superior vena cava, opens into the lower part of the right atrium; here, there is a rudimentary valve.

The **coronary sinus** opens into the right atrium (Fig. 1-11) between the inferior vena cava and the atrioventricular orifice (Fig. 1-12). It is guarded by a rudimentary valve.

The **right atrioventricular orifice** lies anterior to the inferior vena caval opening. It is guarded by the tricuspid valve (Fig. 1-11).

There are also many orifices of small veins that drain the wall of the heart and open directly into the right atrium.

Fetal Remnants

In addition to the rudimentary valve of the inferior vena cava, there are the **fossa ovalis** and the **anulus ovalis** (Fig. 1-11). These structures lie on the atrial septum, which separates the right atrium from the left atrium. The fossa ovalis is a shallow depression that is the site of the **foramen ovale** in the fetus. (Before birth, oxygenated blood passed through this foramen from the right atrium into the left atrium.) The anulus ovalis forms the upper margin of the fossa.

RIGHT VENTRICLE

The right ventricle forms the greater part of the anterior surface of the heart, and it lies anterior to the left ventricle (Fig. 1-11). The right ventricle communicates with the right atrium through the atrioventricular orifice and with the pulmonary trunk through the pulmonary orifice. The approach to the pulmonary orifice is funnel shaped and known as the **infundibulum.**

The walls of the right ventricle are much thicker than those of the right atrium. The internal surface shows projecting ridges called **trabeculae carneae.** There are three types of these ridges:

- **Papillary muscles** are attached by their bases to the ventricular wall. Their apices are connected by fibrous chords (**chordae tendineae**) to the cusps of the tricuspid valve.
- The ridges are attached at their ends to the ventricular wall and are free in the middle. The **moderate band** is a large ridge, and it is attached at its ends to the septal and the anterior ventricular walls. It conveys within it the right branch of the atrioventricular bundle, which is part of the conducting system of the heart.
- Simple, prominent projections.

Tricuspid Valve

The tricuspid valve guards the atrioventricular orifice (Fig. 1-11). It consists of three cusps, the bases of which are attached to the fibrous ring of the skeleton of the heart. To their free edges and ventricular surfaces are attached the chordae tendineae, which connect the cusps to the papillary muscles. The cusps are the **anterior, septal,** and **inferior.** The anterior cusp lies anteriorly; the septal cusp, against the ventricular septum; and the inferior cusp, inferiorly.

Pulmonary Valve

The pulmonary valve guards the pulmonary orifice, and the three semilunar cusps of this valve are attached by their curved, lower margins to the arterial wall. The open mouths of the cusps are directed upward into the pulmonary trunk. There are one posterior and two anterior semilunar cusps. The **pulmonary sinuses** are three dilatations at the root of the pulmonary trunk, with one being situated external to each cusp (see the section on the aortic valve).

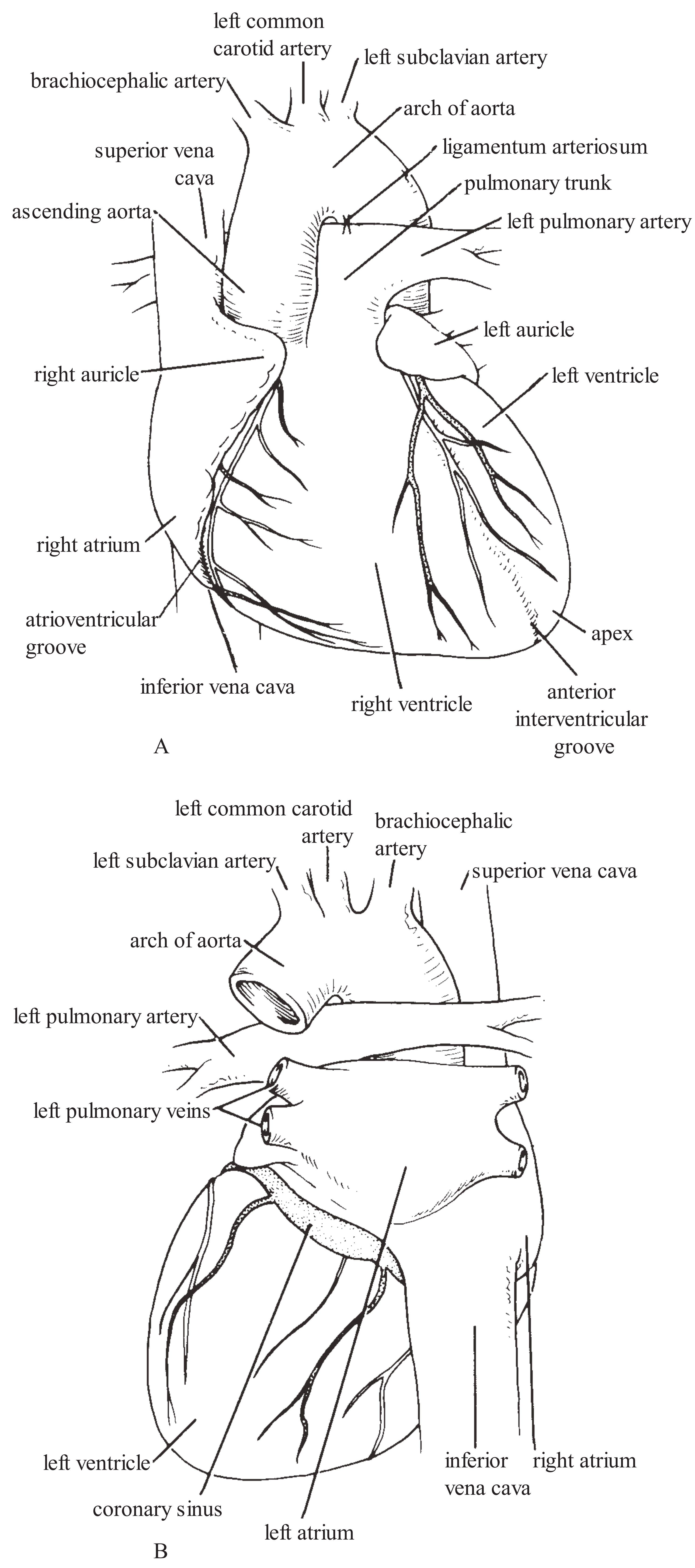


Figure 1-12 A. Anterior surface of the heart and great blood vessels. B. Posterior surface of the heart.

LEFT ATRIUM

The left atrium (Fig. 1-12) lies posterior to the right atrium. It consists of a main cavity and an auricle. The interior of the auricle possesses muscular ridges as in the right auricle.

Openings

The four **pulmonary veins,** two from each lung, open through the posterior wall; there are no valves. The left **atrioventricular orifice** is guarded by the mitral valve.

LEFT VENTRICLE

The left ventricle is situated largely behind the right ventricle (Fig. 1-12). A small portion, however, projects to the left and forms the left margin of the heart and the heart apex. The left ventricle communicates with the left atrium through the atrioventricular orifice and with the aorta through the aortic orifice. The walls of the left ventricle are three times thicker than those of the right ventricle. There are **trabeculae carneae** and two **papillary muscles;** however, there is no moderator band. The **aortic vestibule** is the part of the ventricle below the aortic orifice.

Mitral Valve

The mitral valve guards the atrioventricular orifice and consists of two cusps, one anterior and one posterior. Attached to the cusps are chordae tendineae and papillary muscles similar to those in the tricuspid valve.

Aortic Valve

The aortic valve guards the aortic orifice and, as with the pulmonary valve, consists of three semilunar cusps. One cusp is located on the anterior wall, and two are located on the posterior wall. Behind each cusp, the aortic wall bulges to form an **aortic sinus.** The anterior aortic sinus gives rise to the right coronary artery, and the left posterior sinus gives rise to the left coronary artery.

CLINICAL NOTES

HEART SOUNDS

The heart makes two sounds: lūb, and dŭp. The first sound is produced by the contraction of the ventricles and the closure of the tricuspid and the mitral valves. The second, shorter sound is produced by the sharp closure of the aortic and the pulmonary valves.

The **tricuspid valve** is best heard over the right half of the lower end of the body of the sternum.

The **mitral valve** is best heard over the apex beat (i.e., at the level of the fifth left intercostal space, approximately 3.5 in. [9 cm] from the midline).

The **pulmonary valve** is best heard over the medial end of the second left intercostal space.

The **aortic valve** is best heard over the medial end of the second right intercostal space.

Conducting System

The conducting system of the heart is composed of modified cardiac muscle.

SINUATRIAL NODE (PACEMAKER)

The sinuatrial node initiates the heartbeat. It is situated at the upper part of the sulcus terminalis close to the opening of the superior vena cava (Fig. 1-13). It is usually supplied by the right coronary artery but is sometimes supplied by the left.

ATRIOVENTRICULAR NODE

The atrioventricular node is in the lower part of the atrial septum, just above the attachment of the septal cusp of the tricuspid valve (Fig. 1-13). It receives its blood supply from the right coronary artery.

ATRIOVENTRICULAR BUNDLE

The atrioventricular bundle is continuous with the atrioventricular node above and with the fibers of the Purkinje plexus below. It descends behind the septal cusp of the tricuspid valve on the membranous part of the ventricular septum. On reaching the muscular part of the septum, it divides into two branches (Fig. 1-13). The right bundle branch passes to the right ventricle, and the left bundle branch passes to the left ventricle. The atrioventricular bundle is the only muscular connection between the myocardium of the atria and the myocardium of the ventricles.

The terminal branches of the atrioventricular bundle spread out into the ventricular walls. There, they become continuous with the fibers of the **Purkinje plexus.**

The atrioventricular bundle is supplied by the right coronary artery. The right bundle branch is supplied by the left coronary artery, and the left bundle branch is supplied by the right and the left coronary arteries.

CLINICAL NOTES

FAILURE OF THE CONDUCTING SYSTEM OF THE HEART

The atrioventricular bundle is the only route by which the cardiac impulse can spread from the atria to the ventricles. Failure of the bundle to conduct the normal impulses results in alteration in the rhythmic contraction of the ventricles or, if complete bundle block occurs, complete dissociation between the atria and the ventricular rates of contraction.

Blood Supply of the Heart

ARTERIAL SUPPLY

Right Coronary Artery

The right coronary artery arises from the anterior aortic sinus of the ascending aorta (Fig. 1-14). It descends in the right atrioventricular groove and sends branches to the right

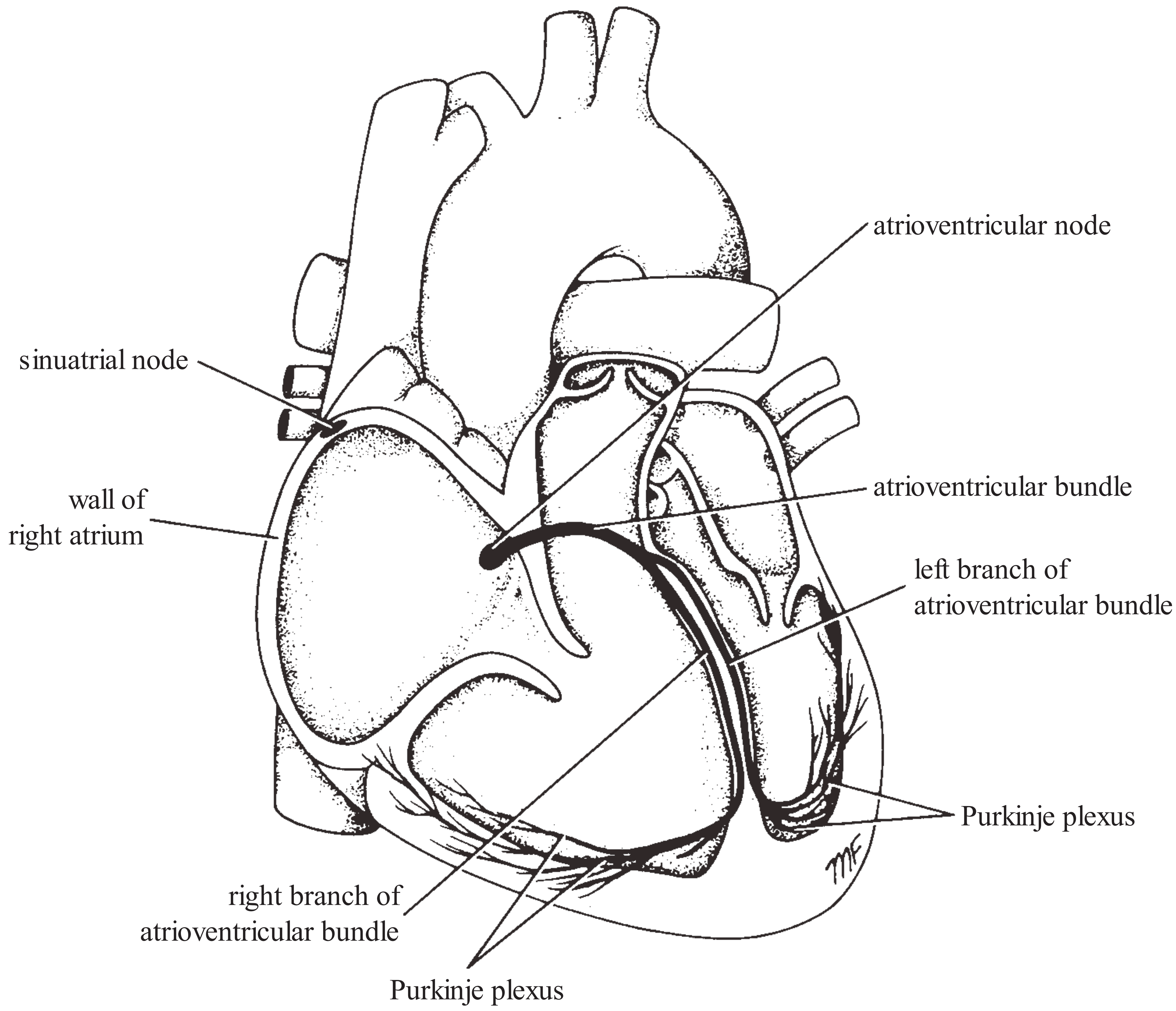


Figure 1-13 The heart. Note the arrangement and positions of the different parts of the conducting system.

atrium and ventricle. It ends by anastomosing with the left coronary artery in the posterior interventricular groove.

Branches

- **The right conus artery** supplies the anterior surface of the infundibulum of the right ventricle and the upper part of the anterior wall of the right ventricle.
- **The anterior ventricular branches** are two or three in number and supply the anterior surface of the right ventricular. The **marginal branch** is the largest, and it follows the lower margin of the costal surface to reach the apex.
- **The posterior ventricular branches** are usually two in number and branches supply the diaphragmatic surface of the right ventricle.
- **The posterior interventricular (descending) artery** runs toward the apex in the posterior interventricular groove and sends branches to the right and the left ventricles.
- **The atrial branches** supply the anterior and the lateral surfaces of the right atrium.

Left Coronary Artery

The left coronary artery arises from the left posterior aortic sinus of the ascending aorta (Fig. 1-14). The left coronary artery is larger than the right coronary artery. In the atrioventricular groove, it divides into an anterior interventricular branch and a circumflex branch.

Branches

- **The anterior interventricular (descending) branch** runs downward in the anterior interventricular groove to the apex of the heart. In most individuals, it then passes around the apex of the heart, enters the posterior interventricular groove, and anastomoses with the terminal branches of the right coronary artery. In one third of individuals, it ends at the apex of the heart. This branch supplies the right and the left ventricles.
- **The circumflex artery** is the same size as the anterior interventricular artery. It winds around the left margin of the heart in the atrioventricular groove. **Left marginal, anterior ventricular,** and **posterior ventricular branches** supply the left ventricle, and **atrial branches** supply the left atrium.

The arrangement just described is subject to variation. In the case of "right dominance," the posterior interventricular artery is a large branch of the right coronary artery. In the case of "left dominance," the posterior interventricular artery is a branch of the left coronary artery.

CLINICAL NOTES

Coronary Artery Disease

Although the coronary arteries have numerous anastomoses at the arteriolar level, they are essentially functional end arteries. A sudden block of one of the large branches of either coronary artery will usually lead to necrosis of the cardiac muscle in the vascular area, and often the patient dies.

VENOUS DRAINAGE

Most venous blood from the heart wall drains into the right atrium through the coronary sinus (Fig. 1-14). The remainder drains directly into the right atrium through the **anterior cardiac vein** and small veins (the **venae cordis minimae**).

Coronary Sinus

The coronary sinus lies in the posterior part of the atrioventricular groove. It is the largest vein draining the heart wall (Fig. 1-14) and is a continuation of the great cardiac vein.

Great Cardiac Vein

The great cardiac vein ascends from the apex of the heart in the anterior interventricular groove (Fig. 1-14). It then enters the atrioventricular groove, curves to the left side and back of the heart, and empties into the coronary sinus.

Middle Cardiac Vein

The middle cardiac vein runs from the apex of the heart in the posterior interventricular groove and empties into the coronary sinus (Fig. 1-14).

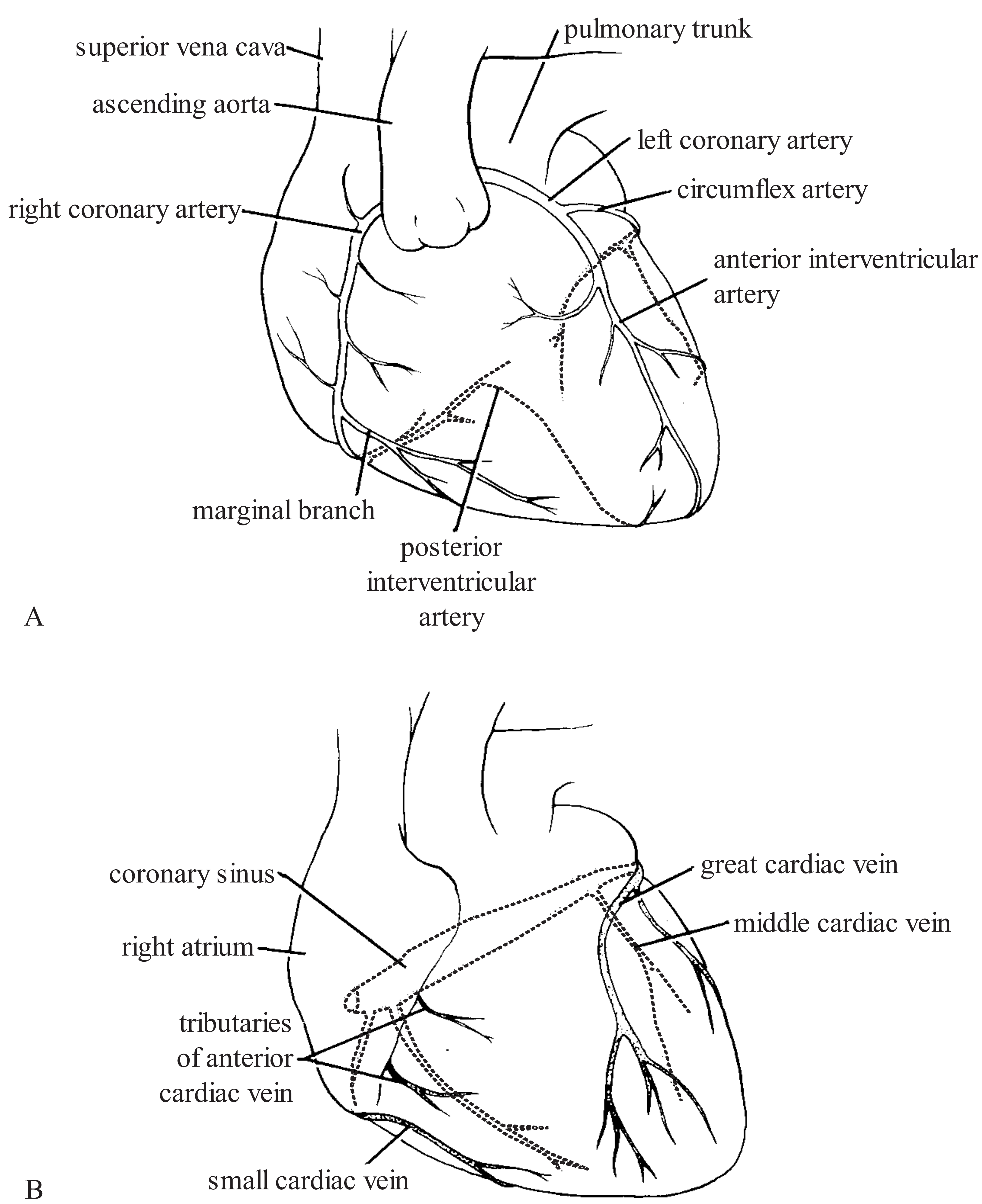


Figure 1-14 A. The coronary arteries. B. The cardiac veins.

Small Cardiac Vein

The small cardiac vein accompanies the marginal artery along the inferior border of the heart and empties into the coronary sinus (Fig. 1-14).

Anterior Cardiac Vein

The anterior cardiac vein drains the anterior surface of the right atrium and the right ventricle. It empties directly into the right atrium (Fig. 1-14).

Nerve Supply of the Heart

The heart is innervated by sympathetic and parasympathetic fibers of the autonomic nervous system via the **cardiac plexuses.** The postganglionic sympathetic fibers terminate on the sinoatrial and the atrioventricular nodes, cardiac muscle fibers, and coronary arteries. Activation of these nerves results in cardiac acceleration, increased force of contraction by the cardiac muscle, and dilatation of the coronary arteries. The parasympathetic fibers reach the cardiac plexuses in the vagus nerves. Postganglionic fibers terminate on the sinuatrial and the atrioventricular nodes and on the coronary arteries. Activation of the parasympathetic nerves results in a reduced rate and force of contraction by the heart and a constriction of the coronary arteries.

CLINICAL NOTES

CARDIAC PAIN

Pain originating in the heart as the result of ischemia results in the stimulation of the sensory nerve endings in the myocardium. The afferent nerve fibers ascend to the central nervous system via the sympathetic trunk and enter the spinal cord through the upper four thoracic nerves. The pain varies considerably, from a severe crushing pain to nothing more than a mild discomfort. The pain is not felt in the heart but is referred to the skin areas supplied by the corresponding spinal nerves. The skin areas supplied by the upper four intercostal nerves and by the intercostobrachial nerve (T2) are therefore mainly affected.

Gross Anatomic Changes in the Fetal Circulation at Birth

When the umbilical cord is tied, the blood pressure in the inferior vena cava immediately falls (Fig. 1-15). Coupled with the increased left atrial pressure from the increased pulmonary blood flow, this causes the **foramen ovale** to close.

The diminished pulmonary vascular resistance associated with inflation of the lungs causes the direction of flow through the ductus arteriosus to change from right to left to the neonatal route of left to right. The ductus arteriosus constricts as a reaction of its muscle to the raised oxygen tension; it later closes and becomes the **ligamentum arteriosum.** In addition, the wall of the ductus venosus contracts, and the lumen closes. Later, the ductus venosus becomes fibrosed to form the **ligamentum venosum.**

CLINICAL NOTES

SOME IMPORTANT CONGENITAL DEFECTS OF THE HEART AND GREAT VESSELS

Atrial Septal Defect

In 25% of individuals, the foramen ovale does not completely close. When the opening is small, it has no clinical significance. Occasionally, however, the opening is large, and this results in oxygenated blood from the left atrium passing into the right atrium (Fig. 1-16).

Ventricular Septal Defects

The ventricular septum is normally formed by fusion of the small, membranous upper part with the larger, lower muscular part. Ventricular septal defects occur in the membranous part of the septum. Oxygenated blood passes through the defect from left to right, causing enlargement of the right ventricle.

Tetralogy of Fallot

The following four defects occur with tetralogy of Fallot (Fig. 1-16):

- Large ventricular septal defeat.
- Stenosis of the pulmonary trunk.
- Exit of the aorta from the heart immediately above the ventricular septal defect.
- Hypertrophy of the right ventricle (because of the resulting high blood pressure in that ventricle).

Patent Ductus Arteriosus

Normally, the ductus arteriosus has closed by the end of the first month after birth. Failure of the ductus arteriosus to close results in aortic blood passing into the pulmonary artery, which then raises the pressure in the pulmonary circulation and causes hypertrophy of the right ventricle (Fig. 1-16).

Coarctation of the Aorta

Coarctation of the aorta is a narrowing of the aorta just proximal, opposite, or distal to the site of attachment of the ligamentum arteriosum (Fig. 1-16). It arises after birth and is thought to result from the contraction of ductus arteriosus muscle tissue that has been incorporated in the wall of the aorta. When the ductus arteriosus contracts normally, the aortic wall also contracts, and the aortic lumen narrows. Later fibrosis causes permanent narrowing.

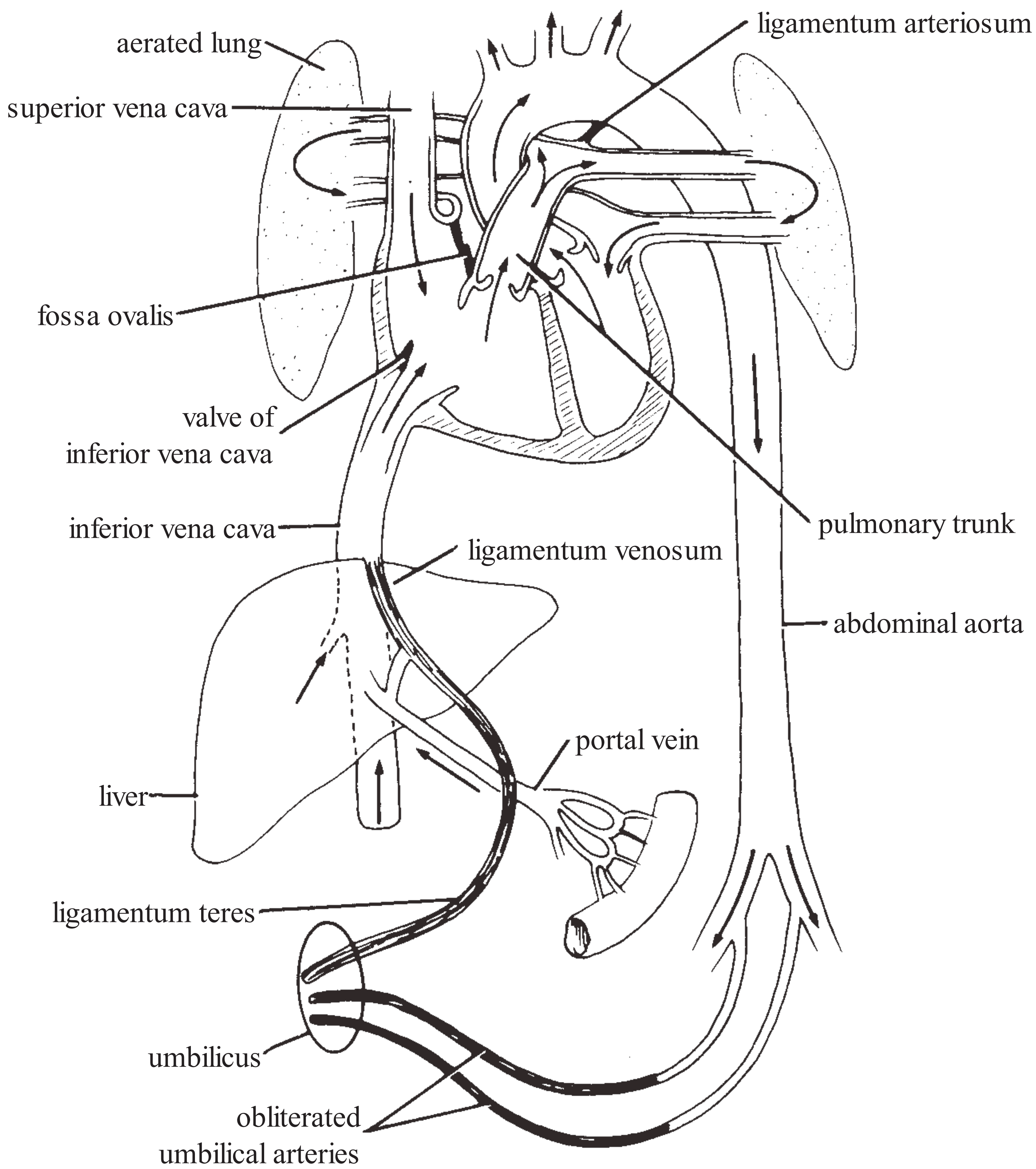


Figure 1-15. The circulatory system after birth.

LARGE VEINS OF THE THORAX

Brachiocephalic Veins

The **right brachiocephalic vein** is formed at the root of the neck by the union of the right subclavian and the right internal jugular veins. The **left brachiocephalic vein** has a similar origin on the left side of the root of the neck. It then passes downward and to the right, where it joins the right brachiocephalic vein to form the superior vena cava.

Superior Vena Cava

The superior vena cava is a large vein formed by the union of the two brachiocephalic veins, and it descends vertically to drain into the right atrium of the heart (Fig. 1-12). The azygos vein joins the posterior aspect of the superior vena cava.

Azygos Vein

The azygos vein has a variable origin, but it is commonly formed by the union of the **right ascending lumbar vein** and the **right subcostal vein.** It ascends through the aortic opening in the diaphragm, and at the level of the fifth thoracic vertebra, it arches forward to join the superior vena cava. The azygos vein has numerous tributaries, including the eight lower right intercostal veins, the right superior intercostal vein, the superior and inferior hemiazygos veins, and numerous mediastinal veins.

Inferior Hemiazygos Vein

The inferior hemiazygos vein is formed by the union of the left ascending lumbar vein and the left subcostal vein. It ascends through the left crus of the diaphragm to join the azygos vein.

Superior Hemiazygos Vein

The superior hemiazygos vein is formed by the union of the fourth with the eighth intercostal vein. It joins the azygos vein.

Inferior Vena Cava

The inferior vena cava is formed in the abdomen (see p. 63). It perforates the central tendon of the diaphragm and the pericardium, and it then opens into the right atrium of the heart.

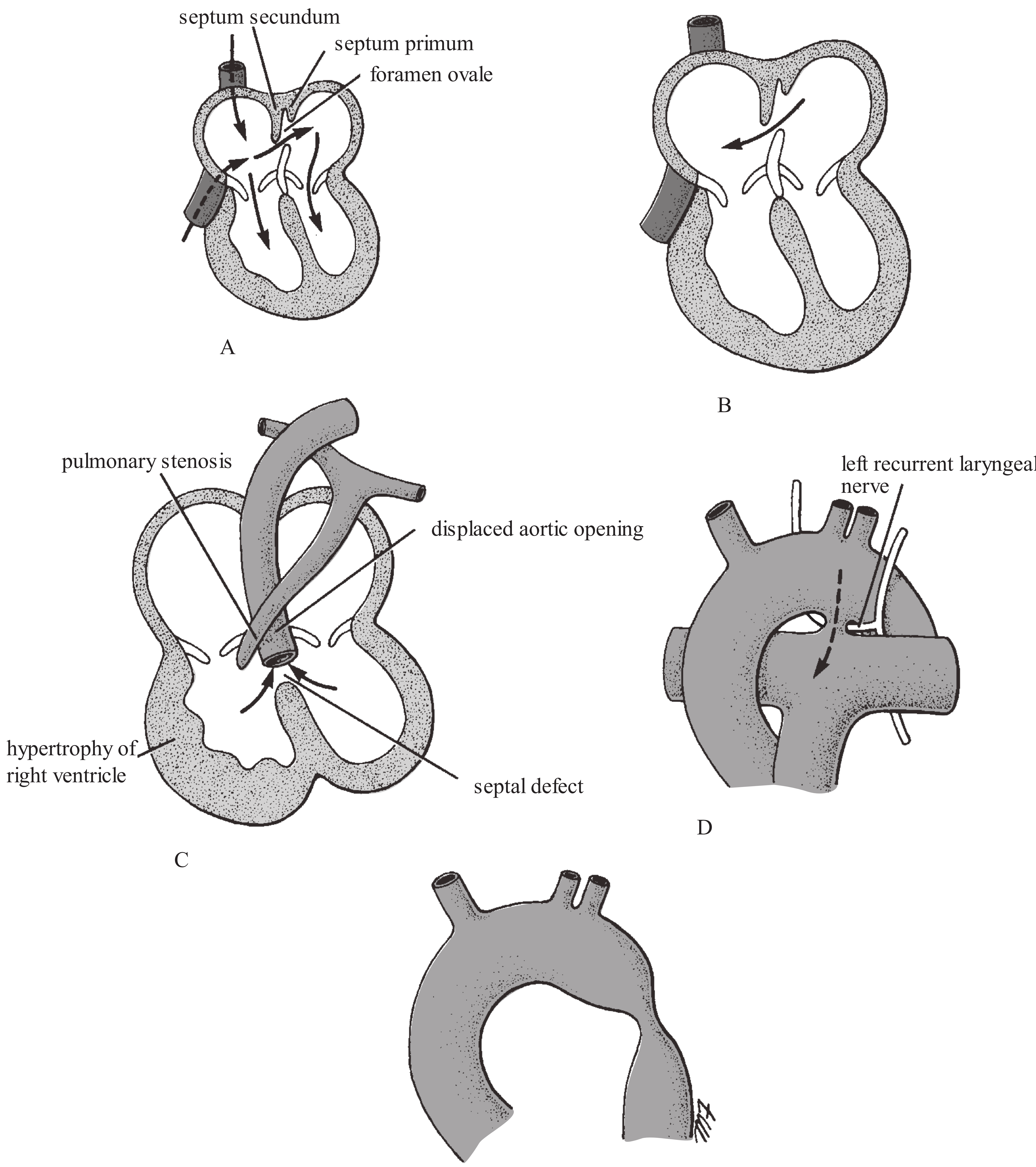


Figure 1-16 A. The normal fetal heart. B. Atrial septal defect. C. Tetralogy of Fallot. D. Patent ductus arteriosus. Note the close relationship with the left recurrent laryngeal nerve. E. Coarctation of the aorta.

CLINICAL NOTES

Azygos Veins and Caval Obstruction

In obstruction of the superior or inferior venae cavae, the azygos veins provide an alternative pathway for the return of venous blood to the right atrium of the heart.

Pulmonary Veins

There are four pulmonary veins, two from each lung (Fig. 1-12). They carry oxygenated blood from the lungs, and they open into the left atrium of the heart.

LARGE ARTERIES OF THE THORAX

Aorta

The aorta may be divided into four parts:

- The ascending aorta.
- The arch of the aorta.
- The descending aorta.
- The abdominal aorta.

The first three parts are in the thorax.

ASCENDING AORTA

The ascending aorta arises from the left ventricle and ascends behind the sternum to the level of the sternal angle, where it becomes continuous with the arch of the aorta (Fig. 1-12). At its root it possesses three bulges (the **sinuses of the aorta**), with one behind each aortic cusp.

Branches

- The **right coronary artery** arises from the anterior aortic sinus.
- The **left coronary artery** arises from the left posterior aortic sinus.

ARCH OF THE AORTA

A continuation of the ascending aorta, the arch of the aorta arches upward, backward, and to the left behind the manubrium sterni and in front of the trachea. At the level of the sternal angle, it becomes continuous with the descending aorta. The arch is related inferiorly to the root of the left lung, the ligamentum arteriosum, the left recurrent laryngeal nerve, and the bifurcation of the pulmonary trunk.

Branches

Three branches arise from the convex surface of the aortic arch (Fig. 1-12):

- The **brachiocephalic artery.**
- The **left common carotid artery.**
- The **left subclavian artery.**

DESCENDING AORTA

The descending thoracic aorta begins as a continuation of the arch of the aorta on the left side of the lower border of the body of the fourth thoracic vertebra (level of sternal angle). It descends through the posterior mediastinum until reaching the anterior surface of the twelfth thoracic vertebra. Here, it enters the abdomen behind the diaphragm (passing through the aortic opening) in the midline and becomes continuous with the abdominal aorta.

Branches

- The **posterior intercostal arteries,** which pass to the lower nine intercostal spaces on each side.
- The **subcostal arteries,** which are given off on each side and run along the lower border of the twelfth rib to enter the abdominal wall.
- The **pericardial arteries.**
- The **esophageal arteries.**
- The **bronchial arteries.**

Pulmonary Trunk

The pulmonary trunk conveys deoxygenated blood from the right ventricle to the lungs. It ascends from the right ventricle, and it terminates in the concavity of the aortic arch by dividing into the right and the left pulmonary arteries (Fig. 1-12).

The **ligamentum arteriosum** is a fibrous band that connects the bifurcation of the pulmonary trunk with the lower surface of the aortic arch (Fig. 1-12). It is the remains of the **ductus arteriosus** (p. 21).

BRANCHES

The **right** and **left pulmonary arteries** enter the root of their respective lungs, where they divide into branches for each lobe.

LYMPH NODES AND VESSELS OF THE THORAX

Lymph Nodes

INTERNAL THORACIC NODES

Five in number, the internal thoracic nodes lie alongside the internal thoracic artery. They drain lymph from the medial quadrants of the breast, the deep structures of the anterior thoracic and abdominal walls (down as far as the umbilicus), and the upper surfaces of the liver.

INTERCOSTAL NODES

The intercostal nodes lie close to the heads of the ribs. They receive lymph from the intercostal spaces and the breast.

DIAPHRAGMATIC NODES

The diaphragmatic nodes lie on the upper surface of the diaphragm. They drain lymph from the diaphragm and the upper surface of the liver.

BRACHIOCEPHALIC NODES

The brachiocephalic nodes lie alongside the brachiocephalic veins. They drain lymph from the thyroid and the pericardium.

POSTERIOR MEDIASTINAL NODES

The posterior mediastinal nodes lie alongside the descending aorta. They drain lymph from the esophagus, the pericardium, and the diaphragmatic nodes.

TRACHEOBRONCHIAL NODES

The tracheobronchial nodes lie alongside the trachea and the bronchi. They drain lymph from the lungs, the trachea, and the heart.

Lymph Vessels

THORACIC DUCT

In the root of the left side of the neck, the thoracic duct conveys lymph to the blood. The lymph originates in the lower limbs; the pelvic cavity; the abdominal cavity; the left side of the thorax; and the left side of the head, neck, and left upper limb (Fig. 1-17).

The thoracic duct begins in the abdomen as a dilated sac, the **cisterna chyli.** It ascends through the aortic opening in the diaphragm on the right side of the descending aorta. It eventually reaches the left border of the esophagus, and it then follows the esophagus to the root of the neck. Here, it turns laterally behind the carotid sheath and enters the beginning of the left brachiocephalic vein.

At its termination, the thoracic duct receives the left jugular, subclavian, and mediastinal lymph trunks, but these trunks may drain independently into neighboring large veins in this region.

RIGHT LYMPHATIC DUCT

In the root of the right side of the neck, the right lymphatic duct conveys lymph to the blood from the right side of the head and neck, the right upper limb, and the right side of the thorax. This duct is approximately 0.05 in. (1.3 cm) in length, and it opens into the beginning of the right brachiocephalic vein (Fig. 1-17).

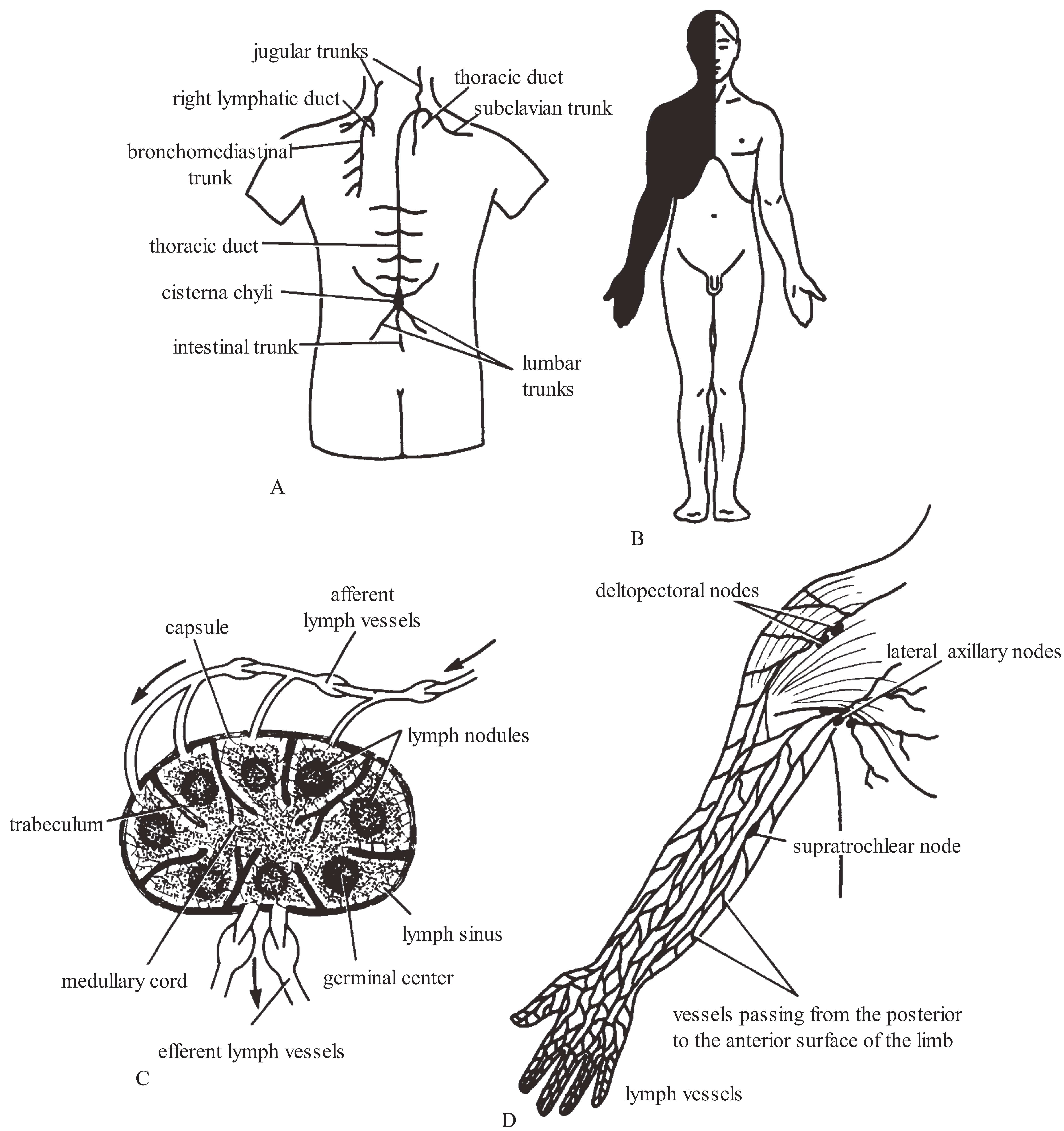


Figure 1-17 A. The thoracic and right lymphatic ducts with their main tributaries. B. Areas of the body drained by the thoracic duct (clear) and the right lymphatic duct (black).

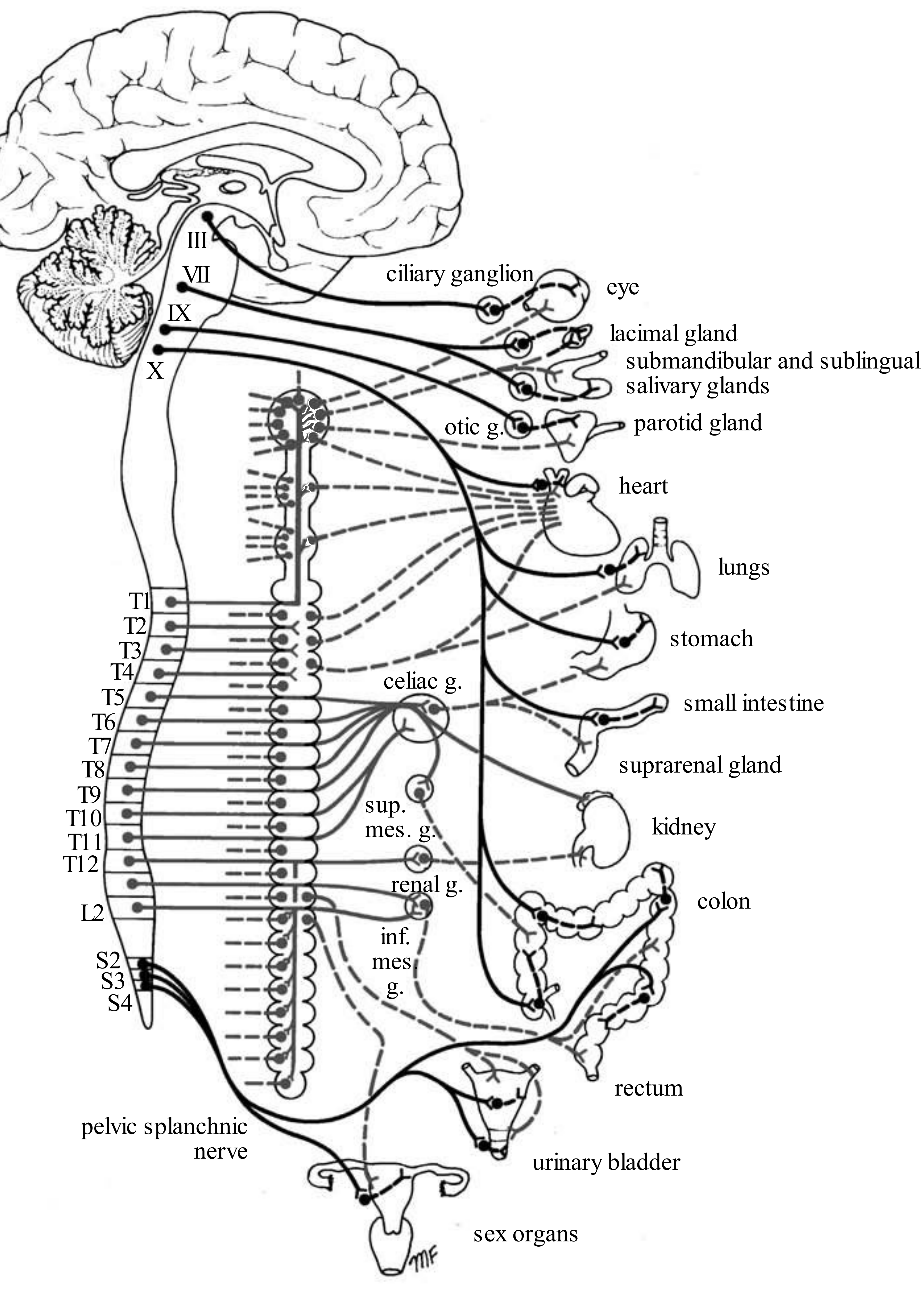


Figure 1-18 The efferent part of the autonomic nervous system. Note the preganglionic parasympathetic fibers (solid black), postganglionic parasympathetic fibers (interrupted black), preganglionic sympathetic fibers (solid black), and postganglionic parasympathetic fibers (interrupted black).

Sometimes, the right lymphatic duct is absent. In these individuals, the right jugular, right subclavian, and right bronchomediastinal trunks open independently into the great veins at the root of the neck.

LARGE NERVES OF THE THORAX

Vagus Nerves

The **right vagus nerve** crosses the anterior surface of the subclavian artery and descends laterally to the trachea and medially to the azygos vein. It runs behind the root of the right lung and contributes to the **pulmonary plexus,** then passes onto the posterior surface of the esophagus and contributes to the **esophageal plexus.** Finally, it leaves the thorax and enters the abdomen behind the esophagus, passing through the esophageal opening of the diaphragm (see Fig. 6-18).

The **left vagus nerve** descends into the thorax between the left common carotid and the left subclavian arteries. It crosses the left side of the aortic arch, descends **behind** the root of the left lung, and contributes to the **pulmonary**

plexus. The left vagus then passes down on the anterior surface of the esophagus and contributes to the **esophageal plexus.** Finally, it enters the abdomen through the esophageal opening of the diaphragm in front of the esophagus. (The abdominal course is shown in Figure 6-18.)

BRANCHES

- **Recurrent laryngeal nerves.** The left recurrent laryngeal nerve arises from the vagus nerve as the latter crosses the arch of the aorta. It hooks beneath the arch behind the ligamentum arteriosum and then ascends into the neck between the trachea and the esophagus. (The right recurrent laryngeal nerve arises from the right vagus nerve in the neck and hooks around the subclavian artery.)
- **Cardiac branches.** Two or three branches arise from the vagus nerve in the neck and descend into the thorax to end in the cardiac plexuses.
- **Pulmonary branches.**
- **Esophageal branches.**

The vagus nerves thus supply the thorax, the heart, the trachea, the bronchi, the lungs, and the esophagus with parasympathetic and sensory nerve fibers.

Phrenic Nerves

The phrenic nerves arise in the neck from the anterior rami of the third, fourth, and fifth cervical nerves.

The **right phrenic nerve** descends in the thorax along the right side of the superior vena cava and **in front of** the root of the right lung. It then passes over the pericardium to the diaphragm.

The **left phrenic nerve** descends along the left side of the left subclavian artery and crosses the left side of the aortic arch and the left vagus nerve. It passes **in front of** the root of the left lung and then descends on the pericardium to the diaphragm.

The phrenic nerve is the **only** motor nerve supply to the diaphragm. It also sends sensory branches to the pericardium, the mediastinal parietal pleura, and the pleura and peritoneum covering the upper and lower surfaces of the central part of the diaphragm.

Thoracic Part of Sympathetic Trunk

The thoracic part of the sympathetic trunk, which is the most lateral structure in the mediastinum, runs downward on the heads of the ribs. It leaves the thorax by passing behind the medial arcuate ligament and then becomes continuous with the lumbar part of the sympathetic trunk. The trunk has 11 or 12 segmentally arranged ganglia (Fig. 1-18). The first ganglion is often fused with the inferior cervical ganglion to form the **stellate ganglion.**

BRANCHES

- The **white rami communicantes** join each ganglion to a corresponding thoracic spinal nerve. A white ramus contains preganglionic nerve fibers and afferent sensory nerve fibers (Fig. 1-19).

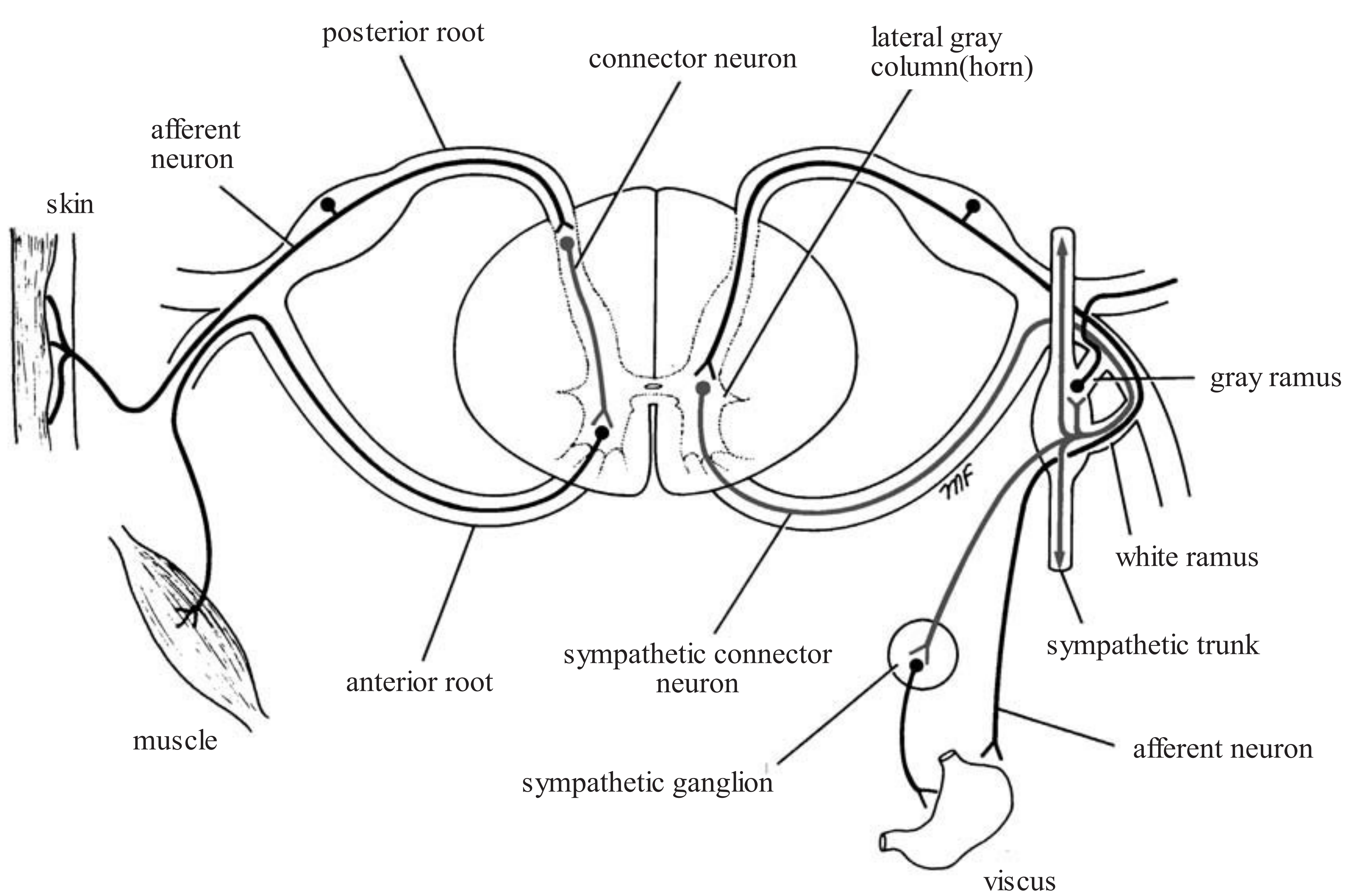


Figure 1-19 General arrangement of the somatic (left) and autonomic (right) parts of the nervous system.

- The **gray rami communicantes** join each ganglion to a corresponding thoracic spinal nerve. A gray ramus contains postganglionic nerve fibers.
- The **cardiac, aortic, pulmonary,** and **esophageal branches** arise from the first five ganglia.
- The **splanchnic nerves** descend and pierce the crura of the diaphragm to supply abdominal viscera. The **greater splanchnic nerve** arises from ganglia 5 to 9, the **lesser splanchnic nerve** from ganglia 10 and 11, and the **lowest splanchnic nerve** from the last thoracic ganglion.

ESOPHAGUS

The esophagus is a muscular tube approximately 10 in. (25 cm) in length that is continuous above with the pharynx opposite the sixth cervical vertebra. It passes through the diaphragm at the level of the tenth thoracic vertebra to join the stomach, and it has three constrictions:

- Where it begins.
- Where it is crossed by the left bronchus.
- Where it pierces the diaphragm.

The esophagus descends through the thorax behind the trachea, the left bronchus, and the left atrium of the heart (Fig. 1-8).

Blood Supply

- **Upper third:** Inferior thyroid artery.
- **Middle third:** Branches from the descending thoracic aorta.
- **Lower third:** Left gastric artery.

The veins from the upper third drain into the inferior thyroid veins, from the middle third into the azygos veins, and from the lower third into the left gastric vein, which is a tributary of the portal vein.

CLINICAL NOTES

LOWER THIRD OF ESOPHAGUS AS SITE OF PORTOSYSTEMIC ANASTOMOSIS

At the lower third of the esophagus, the tributaries of the azygos veins (systemic circulation) anastomose with the left gastric vein, a tributary of the portal vein. Should the portal vein become obstructed, the veins at the site of the portosystemic anastomosis become dilated and varicosed as the result of the increased flow of blood. This pathologic change is an attempt to return the portal blood to the systemic circulation without going through the normal obstructed channel through the liver.

Lymphatic Drainage

- **Upper third:** Deep cervical lymph nodes.
- **Middle third:** Superior and posterior mediastinal lymph nodes.
- **Lower third:** Left gastric nodes and celiac nodes in the abdomen.

Nerve Supply

Parasympathetic and sympathetic nerves, including branches from the recurrent laryngeal nerves, the vagus nerves, the sympathetic trunks, and the greater splanchnic nerves.

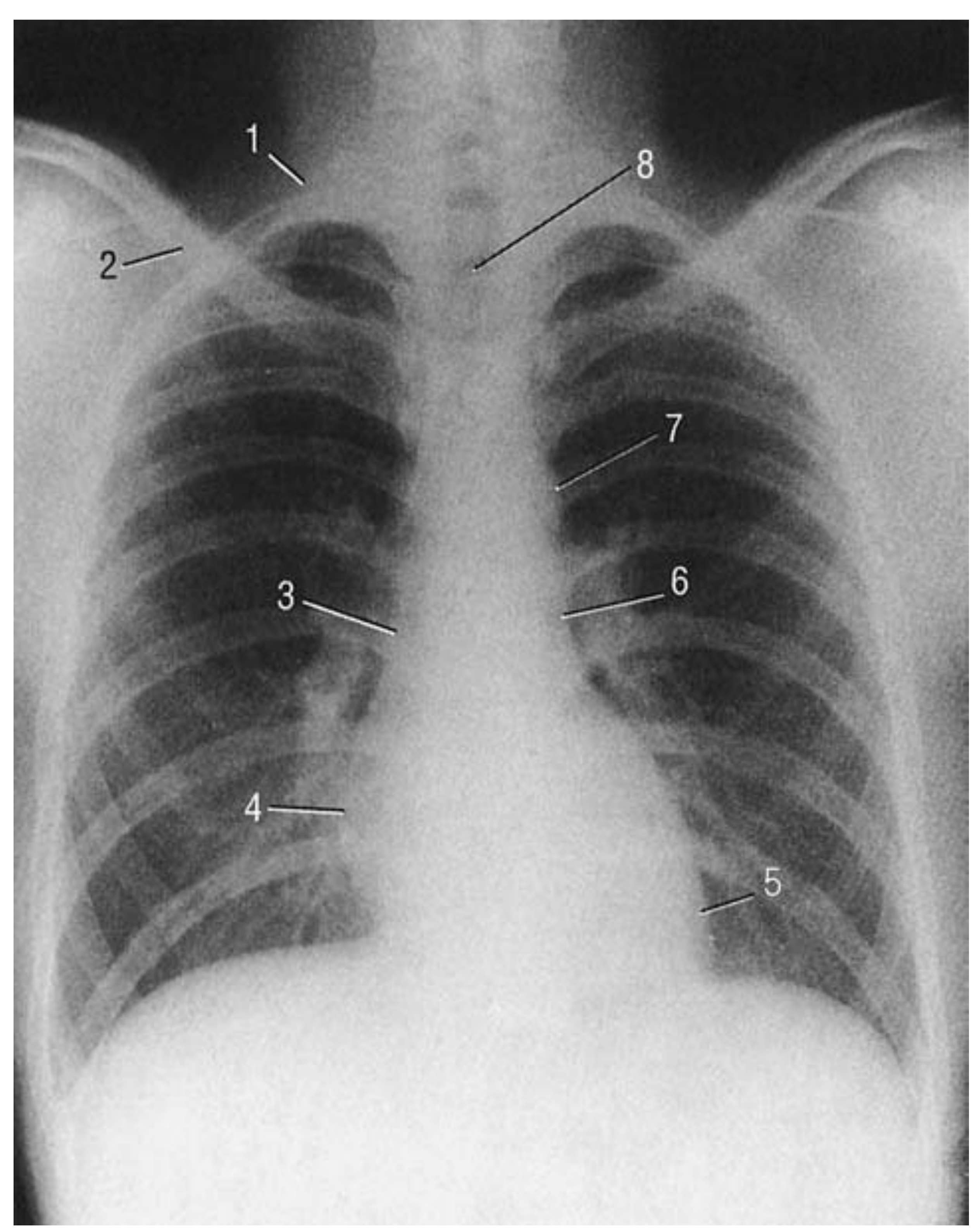
THYMUS

The thymus is a flattened, bilobed structure between the sternum and the pericardium. It continues to grow until puberty and is an important source of T-lymphocytes.

REVIEW

Matching Questions

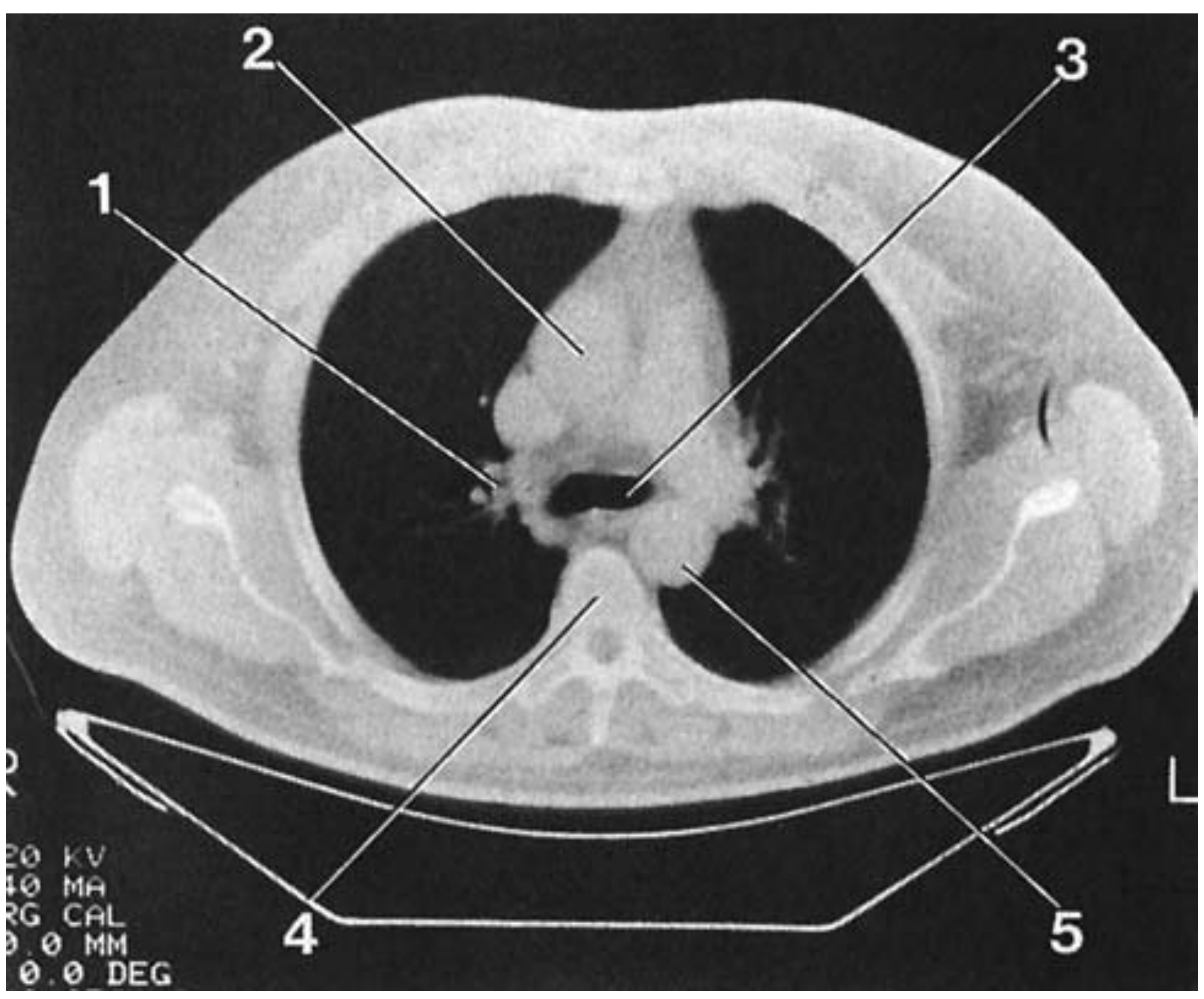
Match the numbered structures shown on the posteroanterior radiograph of the thorax with the appropriate lettered structures.



1. Structure 1
2. Structure 2
3. Structure 3
4. Structure 4
5. Structure 5
6. Structure 6
7. Structure 7
8. Structure 8

A. Trachea
B. Pulmonary trunk
C. Right atrium
D. Clavicle
E. Left ventricle
F. Superior vena cava
G. Aortic arch
H. First rib
I. Right ventricle
J. None of the above

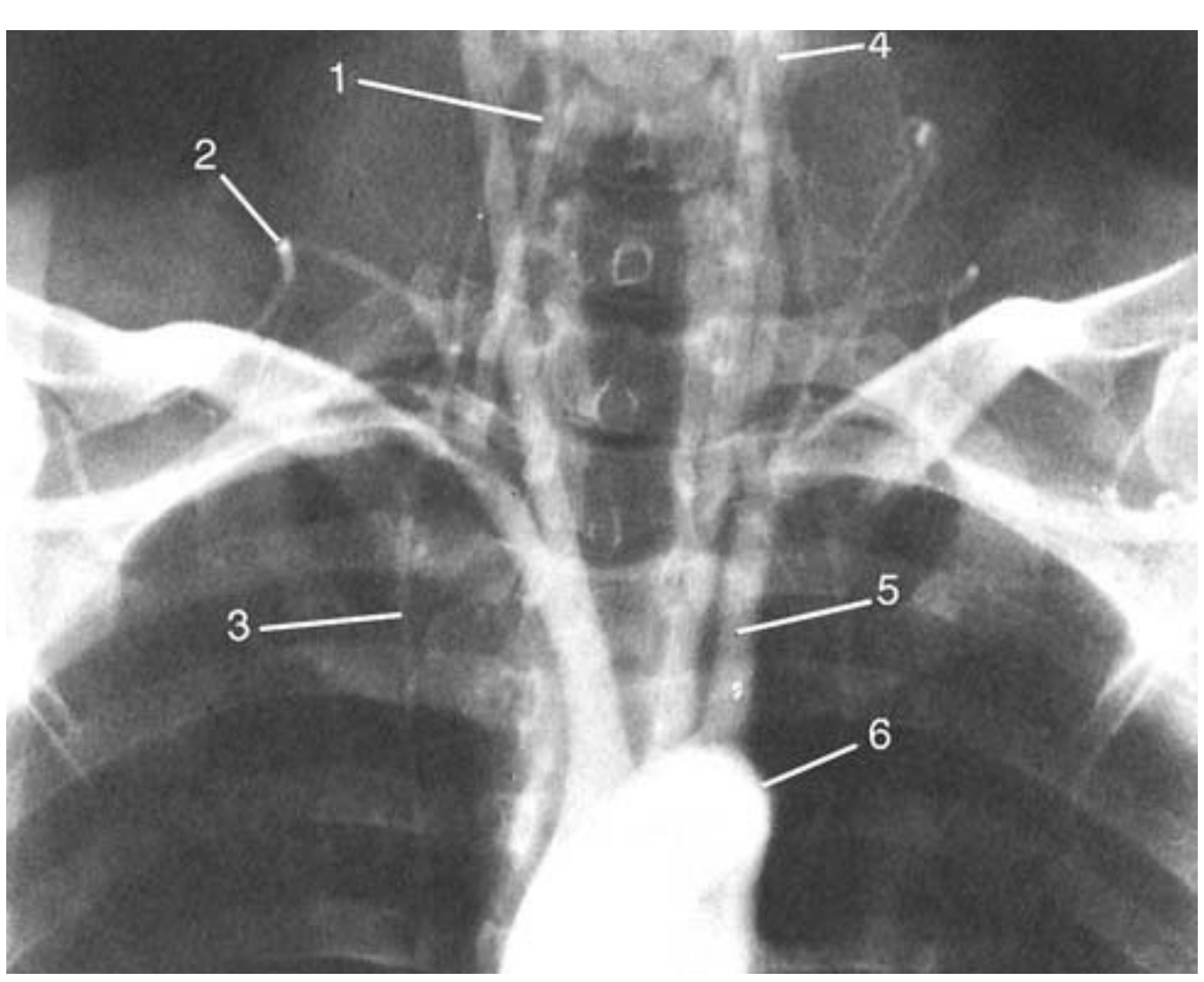
Match the numbered structures shown on the CT scan of the thorax with the appropriate lettered structures.



9. Structure 1
10. Structure 2
11. Structure 3
12. Structure 4
13. Structure 5

A. Body of thoracic vertebra
B. Bifurcation of trachea
C. Descending thoracic aorta
D. Right pulmonary artery
E. Ascending aorta
F. None of the above

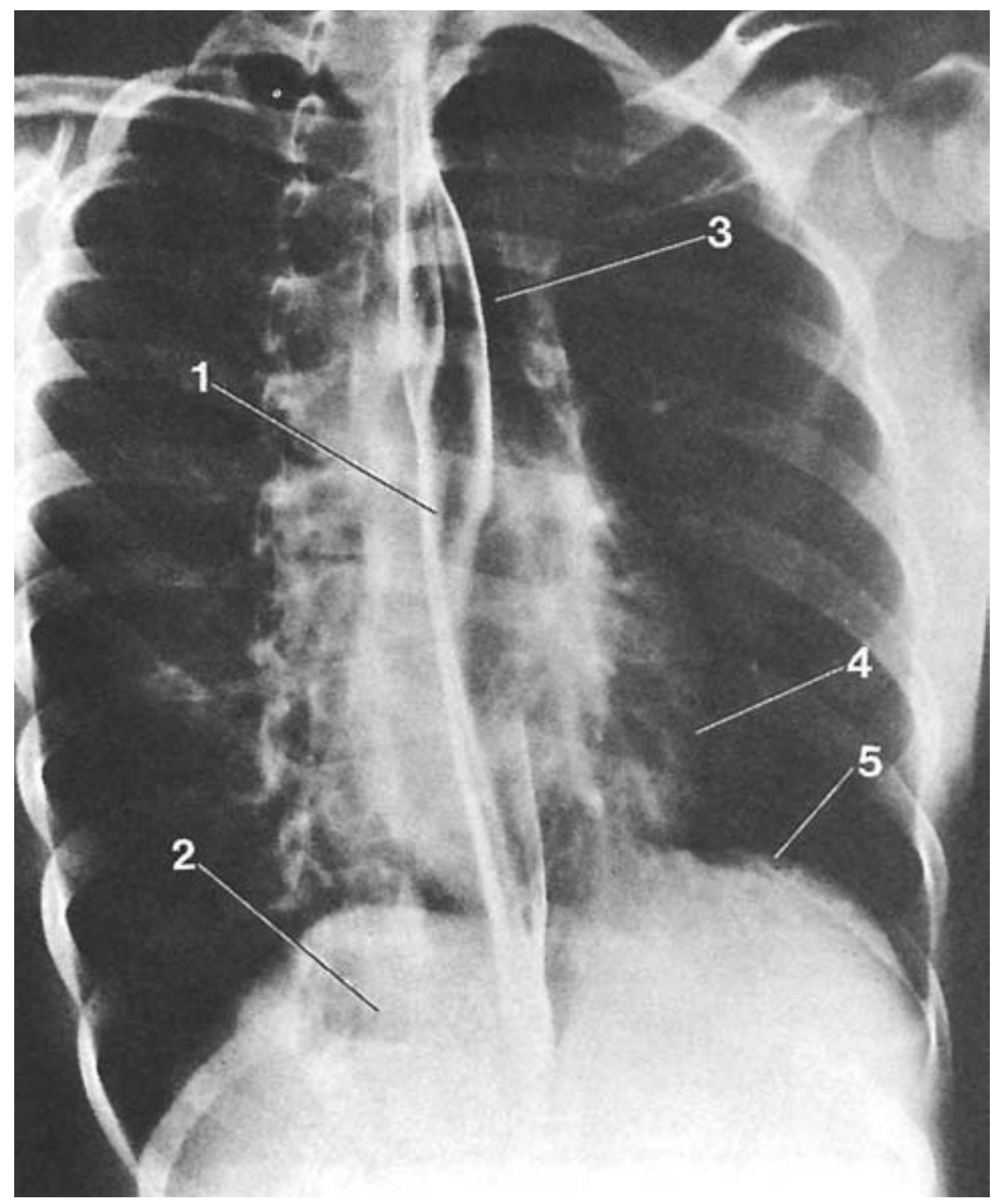
Match the numbered structures shown on the aortic arch angiogram with the appropriate lettered structures.



14. Structure 1
15. Structure 2
16. Structure 3
17. Structure 4
18. Structure 5
19. Structure 6

A. Right internal thoracic artery
B. Left subclavian artery
C. Right vertebral artery
D. Suprascapular artery
E. Left common carotid artery
F. Arch of aorta
G. Brachiocephalic artery

Match the numbered structures shown on the oblique radiograph of the thorax with the appropriate lettered structures. (Note the barium swallow also shown.)



20. Structure 1
21. Structure 2
22. Structure 3
23. Structure 4
24. Structure 5

A. Gas bubble in fundus of stomach
B. Right dome of diaphragm
C. Esophagus
D. Trachea
E. Right ventricle
F. Superior vena cava

Match the valves of the heart on the left with the areas on the chest wall where they are best heard with a stethoscope on the right.

25. Tricuspid valve
26. Mitral valve
27. Pulmonary valve
28. Aortic valve

A. Second right intercostal space
B. Lower end of sternum
C. Fifth left intercostal space valve 3.5 in. (9 cm) from the midline
D. Second left intercostal space
E. Sixth left intercostal space 3.5 in. (9 cm) from the midline

Match the structures on the left with the regions of the heart on the right. (Each lettered region may be used more than once.)

29. Moderator band	A. Left ventricle
30. Sinuatrial node	B. Right ventricle
31. Bicuspid valve	C. Left atrium
32. Aortic vestibule	D. Right atrium
	E. Right side of membranous part of interventricular septum

Match the structures on the left with the appropriate sympathetic ganglia on the right.

33. Lowest splanchnic nerve	A. T1–4
34. Sympathetic innervation to the head and neck	B. T5–9
35. Lesser splanchnic nerve	C. T12
36. Greater splanchnic nerve	D. T10–11
	E. None of the above

Multiple-Choice Questions

Select the best answer for each question.

37. The following statements concerning the right tracheobronchial lymph nodes are correct except which?
    A. They could become enlarged as the result of invasion of malignant tumor cells from the middle lobe of the right lung.
    B. They could become enlarged as the result of invasion of malignant tumor cells from the inferior lobe of the right lung.
    C. They are situated alongside the trachea and the bronchi.
    D. They drain lymph from the lower end of the trachea.
    E. They do not drain lymph from the heart.

38. The following structure(s) may press against the esophagus during the passage of a barium meal except which?
    A. Left ventricle
    B. Left principal bronchus and aorta
    C. Margins of the esophageal opening in the diaphragm
    D. Muscular fibers of the lower end of the pharynx
    E. Left atrium

39. The following statements concerning coarctation (narrowing) of the aorta are correct except which?
    A. The third to the eleventh posterior intercostal arteries have a diminished blood flow.
    B. The first and second posterior intercostal arteries will have a diminished blood flow.
    C. The narrowing of the aorta lies just proximal, opposite, or distal to the site of attachment of the ligamentum arteriosum.
    D. The narrowing takes place after birth.
    E. The condition is thought to result from contraction of ductus arteriosus muscle tissue.

40. The following statements concerning an intercostal space are correct except which?
    A. The anterior intercostal arteries of the lower five intercostal spaces are branches of the musculophrenic artery.
    B. The sensory fibers in the lower five intercostal nerves supply the skin of the lateral thoracic and anterior abdominal walls.
    C. The posterior intercostal arteries of the lower nine spaces are branches of the thoracic aorta.
    D. Throughout an intercostal space, the intercostal nerves and blood vessels lie close to the upper border of the lower rib.
    E. The intercostal nerves and blood vessels run between the internal and the innermost intercostal muscles.

41. The following statements concerning the positions of thoracic structures at different phases of respiration are correct except which?
    A. The trachea bifurcates opposite the manubriosternal angle in the midrespiratory position.
    B. On full inspiration, the lower margin of the left lung could extend down the midclavicular line to the eighth costal cartilage.
    C. The lower margin of the right lung in the midclavicular line could cross the sixth rib in the midrespiratory position.
    D. The apex of the heart can usually be felt in the sixth left intercostal space in the midrespiratory position.
    E. On full expiration the right dome of the diaphragm may extend up as far as or beyond the upper border of the fifth rib.

42. The following statements concerning the heart are correct except which?
    A. The first sound of the heart is lūb and is produced by the contraction of the ventricles and the closure of the tricuspid and mitral valves.
    B. The second shorter sound of the heart is dŭp, which is produced by the sharp closure of the aortic and pulmonary valves.
    C. The pulmonary valve has two semilunar cusps.
    D. The left atrium lies posterior to the right atrium.
    E. The apex beat of the heart is best felt by asking the patient to sit up and lean forward.

43. The following statements concerning the structure of the heart are correct except which?
    A. The trabeculae carneae are internal surface structures of both the left and the right ventricles.
    B. The pericardial cavity is the potential space between the fibrous and the serous pericardia.
    C. The coronary arteries are functional end arteries.

D. The sinuatrial node is supplied by the right and sometimes the left coronary artery.
E. The four pulmonary veins open through the posterior wall of the left atrium and there are no valves.

44. The following statements regarding the innervation of thoracic structures are correct except which?
A. The lung and visceral pleura are innervated by the autonomic nerves and are not sensitive to sensations of temperature, touch, and pressure.
B. The motor innervation of the diaphragm is provided by the third, fourth, and fifth cervical spinal nerves and by the lower six intercostal nerves.
C. The sensory nerve supply to the mucous membrane of the lower part of the trachea is from the vagus and the recurrent laryngeal nerves.
D. The nerve supply of the pericardium is the phrenic nerves.
E. The sinuatrial node is supplied by sympathetic and parasympathetic nerves via the cardiac plexuses.

45. The following statements concerning thoracic structures are correct except which?
A. The carina is the name given to the site of bifurcation of the trachea.
B. The ligamentum arteriosum is the remains of the ductus arteriosus.
C. The ductus arteriosus is formed from the sixth left pharyngeal arch.
D. The thymus lies in the middle mediastinum.
E. The thymus receives its arterial supply mainly from the internal thoracic arteries.

46. The following events occur on inhalation except which?
A. The diaphragm descends.
B. The external intercostal muscles contract.
C. The abdominal muscles contract and push the abdominal viscera cranially.
D. The ribs are raised.
E. The vertical dimension of the thoracic cavity increases.

47. When passing a needle through the chest wall and into the pleural cavity in the midaxillary line, the following structures will be pierced except which?
A. The external intercostal muscle
B. The skin
C. The parietal pleura
D. The levator costarum
E. The internal intercostal muscle

48. The following statements concerning the bronchopulmonary segments are correct except which?
A. It is a subdivision of a lung lobe.
B. It is pyramidal in shape, with its apex toward the lung surface.
C. It is surrounded by connective tissue.
D. It has a segmental bronchus, a segmental artery, lymph vessels, and autonomic nerves.
E. When diseased, it can be removed surgically as a structural unit.

49. The following statements concerning the main bronchi are correct except which?
A. The right main bronchus is wider than the left main bronchus.
B. The right main bronchus is shorter than the left main bronchus.
C. The right main bronchus is more vertical in position than the left main bronchus.
D. The left main bronchus passes to the left in front of the esophagus.
E. The left main bronchus gives off the superior lobar bronchus before entering the hilum of the lung.

50. The following statements concerning the diaphragm are correct except which?
A. The diaphragm is a thin musculotendinous sheet that can be ruptured by extreme pressure applied from below.
B. On contraction, the diaphragm increases the intrathoracic pressure.
C. The right crus provides a sphincter-like mechanism for the esophagus.
D. On contraction, the diaphragm assists in the return of venous blood to the right atrium and of lymph to the thoracic duct.
E. When viewed from in front, the central tendon of the diaphragm lies behind the xiphisternal joint.

51. The following statements concerning the lungs are correct except which?
A. Each lung is very elastic, and should the thoracic cavity be opened by a stab wound, the lung shrinks to one third or less in volume.
B. The cardiac notch lies in the lower lobe of the left lung.
C. The visceral pleura covering each lung lines the fissures that are situated between the lobes.
D. The apex of each lung extends up into the root of the neck and lies anterior to the lower roots of the brachial plexus.
E. The bronchi, connective tissue, and visceral pleura of the lungs are supplied by the bronchial arteries.

52. With aging, the following detrimental changes occur in the thorax except which?
A. The ribs and the costal cartilages become more rigid.
B. The elastic tissue in the lungs tends to degenerate.
C. The manubriosternal joint becomes more mobile.
D. The thoracic and the abdominal muscles tend to atrophy.
E. The xiphoid process becomes ossified.

53. The following anatomic events occur at the level of the sternal angle (angle of Louis) except which?
A. The right and the left pulmonary arteries enter the lungs.
B. The right recurrent laryngeal nerve arises from the right vagus nerve.
C. The trachea bifurcates.

D. The ascending aorta becomes continuous with the arch of the aorta.
E. The second costal cartilages articulate with the sternum.

54. The following structures open into the right atrium except which?
A. The superior vena cava
B. The coronary sinus
C. The anterior cardiac vein
D. The inferior vena cava
E. The right pulmonary veins

55. The conducting system of the heart is composed of the following structures except which?
A. The Purkinje plexus
B. The deep cardiac plexus
C. The sinuatrial node
D. The atrioventricular bundle
E. The atrioventricular node

56. The following anatomic facts regarding the right coronary artery are correct except which?
A. It gives rise to a marginal branch.
B. It passes forward between the right auricle and the pulmonary trunk.
C. It gives rise to an anterior interventricular branch.
D. It arises from the anterior aortic sinus.
E. It descends in the right atrioventricular groove.

57. During fetal life, the following facts regarding the circulatory system are correct except which?
A. The blood passing through the foramen ovale is more oxygenated than that passing through the right atrioventricular orifice.
B. The direction of blood flow through the ductus arteriosus is from right to left.
C. The ductus venosus permits blood to bypass the liver.
D. The blood in the abdominal aorta is relatively more oxygenated than that in the internal carotid arteries.
E. The valve of the inferior vena cava deflects blood toward the foramen ovale.

58. Pain arising in the heart is commonly referred to the following skin areas except which?
A. Up into the neck and jaw
B. Down the medial side of the arm
C. The point of the shoulder
D. The epigastric area
E. Over the sternum

Read the case histories and select the best answer to the questions following them.

A patient is examined in the standing position with a left-sided pleurisy.

59. Where would you expect the pleural fluid to gravitate down to?
A. The oblique fissure
B. The cardiac notch
C. The costomediastinal recess
D. The costodiaphragmatic recess
E. The horizontal fissure

A patient was seen in the Emergency Department in cardiac arrest.

60. During cardiopulmonary resuscitation the posterior surface of the heart was compressed by which of the following structures?
A. The body of the sternum
B. The heads of the ribs
C. The tracheal bifurcation
D. The inferior vena cava
E. The bodies of the vertebrae

A patient was admitted into hospital with acute pericarditis. Because the movements of the heart were compromised by the excess of fluid in the pericardial cavity, and the cause of the infection was unknown, it was decided to perform a pericardiocentesis. A specimen of the fluid was kept for bacteriological examination.

61. Pericardiocentesis is best performed by passing a needle through
A. the fourth intercostal space.
B. the sixth intercostal space at the left paravertebral border.
C. the second intercostal space at the midclavicular line.
D. the subcostal angle.
E. the second intercostal space at the right sternal angle.

A patient was seen in the emergency department with a myocardial infarction. After a thorough clinical examination, including an electrocardiogram, it was concluded that the anterior interventricular branch of the left coronary artery was occluded.

62. From the areas of the heart listed below select the one most likely to be involved.
A. The entire diaphragmatic surface of the left ventricle
B. The anterior part of the ventricular septum and the anterior (septal) papillary muscle of the left ventricle
C. The posterior wall of the right atrium
D. The atrioventricular bundle
E. The right auricle

A 4-year-old boy with cyanosis was examined by a pediatrician. The child had apparently become cyanotic during his 1st year of life. Since that time, sudden attacks of breathlessness had occurred on exertion. After a careful workup, a diagnosis of tetralogy of Fallot was made. In this congenital anomaly of the heart there are four cardiac defects.

63. Which of the following is the most characteristic of the condition?
    A. Pulmonary stenosis with hypertrophy of the right ventricle
    B. Large atrial septal defect
    C. Hypertrophy of the left ventricle
    D. Stenosis of the aorta
    E. High blood pressure in the left ventricle

A 22-year-old man was seen in the emergency department after a street shootout. The patient showed signs of severe hemorrhagic shock. A small entrance wound was found in the third left intercostal space approximately 1 in. (2.5 cm) from the lateral margin of the sternum, but there was no exit wound. The left side of his thorax was dull on percussion, and breath sounds were absent on that side of the chest. It was decided to open the chest (thoracotomy) through the fourth left intercostal space, after which it was found that the left atrium had been perforated by the bullet.

64. When the thoracotomy incision was made to enter the pleural cavity, the following structures were incised except for which one?
    A. The skin and subcutaneous tissue
    B. The pectoral muscles and the serratus anterior muscle
    C. The latissimus dorsi muscle
    D. The external intercostal muscle and the anterior intercostal membrane
    E. The internal intercostal and innermost intercostal muscles
    F. The endothoracic fascia and the parietal pleura

65. The following important structures are in the region of the thoracotomy incision except which one?
    A. The internal thoracic artery
    B. The intercostal nerve
    C. The superior epigastric artery
    D. The intercostal artery
    E. The intercostal vein

A 35-year-old woman was seen in the emergency department after an automobile accident. While driving her car, she had been wearing a lap belt but without the shoulder strap; she hit a utility pole head-on. Examination of the thoracic cage revealed a fracture of the body of the sternum and of the third and the fourth left ribs.

66. In this case, the following structure(s) located behind the body of the sternum and the left ribs could have been injured except which one(s)?
    A. The pericardium
    B. The right ventricle of the heart
    C. The right atrium of the heart
    D. The left ventricle of the heart
    E. The phrenic nerves
    F. The esophagus

67. In such an accident, the patient's age may play a large role in the extent of anatomic injury. Which of the following statements accounting for this fact is likely to be correct?
    A. The increased elasticity of fibrous structures in elderly people.
    B. The highly flexible rib cage in children.
    C. The ossification of the xiphoid cartilage that occurs with age.

ANSWERS

1. H	8. A	15. D	22. D
2. D	9. D	16. A	23. E
3. F	10. E	17. E	24. B
4. C	11. B	18. B	25. B
5. E	12. A	19. F	26. C
6. B	13. C	20. C	27. D
7. G	14. C	21. A	28. A

For answers 25 to 28, the sites chosen are those where each valve is most clearly heard with the minimum amount of noise from the other valves.

29. B
30. D
31. A
32. A
33. C This nerve is sometimes absent.
34. A The preganglionic fibers ascend in the sympathetic trunk and synapse in the superior, middle, or inferior cervical ganglia.
35. D
36. B
37. E
38. A
39. B. The first and second posterior intercostal arteries are branches of the superior intercostal artery, which in turn is a branch of the subclavian artery. The subclavian arteries arise proximal to the obstruction and are therefore unaffected.
40. D. The intercostal nerves and blood vessels run forward in the subcostal groove of the upper rib in the intercostal space. They are arranged from above downward as follows: vein, artery, and nerve.
41. D. The apex of the heart can usually be felt in the fifth left intercostal space 3.5 in. (9 cm) from the midline.
42. C. The pulmonary valve guards the pulmonary orifice and has three semilunar cusps attached by their curved lower margins to the arterial wall.
43. B. The pericardial cavity lies between the parietal and visceral layers of the serous pericardium.
44. B. The motor innervation of the diaphragm is supplied only by the phrenic nerve (C3–5).
45. D. The thymus lies in the superior mediastinum and when enlarged may extend into the neck
46. C. On inspiration, the abdominal muscles relax to accommodate the abdominal viscera as the diaphragm descends.

47. D. The levator costarum muscles are small accessory muscles of inspiration found on the back of the chest wall alongside the vertebral column.
48. B. The apex of the pyramidal-shaped bronchopulmonary segment points toward the lung root.
49. E. The right principal (main) bronchus gives off the superior lobar bronchus before entering the hilum of the right lung. The left principal bronchus gives off the superior lobar bronchus after entering the left lung.
50. B. On contraction, the diaphragm descends and thus increases the vertical diameter of the thoracic cavity and reduces the intrathoracic pressure.
51. B. The cardiac notch of the left lung lies in the upper lobe.
52. C. The manubriosternal joint becomes less mobile with age. Eventually, the manubrium becomes joined with the body of the sternum by bone.
53. B. At the level of the sternal angle, the left recurrent laryngeal nerve arises from the left vagus nerve, hooks beneath the arch of the aorta, and ascends to the neck. The right recurrent laryngeal nerve arises from the right vagus nerve in the neck and hooks beneath the right subclavian artery; the right recurrent laryngeal nerve does not enter the thorax.
54. E. By entering the left atrium, the two right pulmonary veins and the two left pulmonary veins return oxygenated blood to the heart.
55. B. The deep cardiac plexus is an autonomic nerve plexus that lies outside the heart and below the arch of the aorta.
56. C. The anterior interventricular artery is a branch of the left coronary artery.
57. D. The most richly oxygenated blood reaches the brain via the internal carotid arteries. The abdominal aorta contains blood from the right ventricle, the pulmonary trunk, and the ductus arteriosus; but this blood is poorly oxygenated.
58. C. Pain arising from the myocardium ascends to the central nervous system through the cardiac branches of the sympathetic trunk and enters the spinal cord through the posterior roots of the upper four thoracic nerves. This pain is not felt in the heart; rather, it is referred to the skin areas supplied by the upper four intercostal nerves and by the intercostobrachial nerve (T2). The intercostobrachial nerve communicates with the medial cutaneous nerve in the upper part of the arm. A certain amount of spread of nervous information occurs within the central nervous system, because the pain is sometimes felt in the neck, the jaw, and the epigastrium, Cardiac pain is not referred to the point of the shoulder.
59. D. The costodiaphragmatic recess is the most dependent part of the pleural cavity.
60. E.
61. D. Pericardial fluid may be aspirated from the pericardial cavity by inserting the needle to the left of the xiphoid process in an upward and backward direction at a 45° angle to the skin. Because of the cardiac notch, the needle misses the pleura and the lungs, and it pierces the pericardium.
62. B. The diaphragmatic surface of the left ventricle receives its blood supply from the posterior interventricular branch of the right coronary artery as well as from the anterior interventricular branch of the left coronary artery. The posterior wall of the right atrium, the right auricle, and the atrioventricular bundle are all supplied by the right coronary artery.
63. A. The tetralogy of Fallot consists of a large ventricular septal defect, stenosis of the pulmonary trunk, the exit of the aorta immediately above the ventricular septal defect, and right ventricular hypertrophy secondary to the ventricular septal defect and the pulmonary stenosis. The pulmonary stenosis results in an impaired pulmonary circulation, with consequent poor oxygenation of the blood. It is not surprising, that the increased oxygen needed on exertion produces excessive breathlessness.
64. C. The latissimus dorsi is a sheet of muscle that covers the back of the thoracic cage and inserts into the floor of the bicipital groove of the humerus. It is located too far posteriorly to be damaged by this exploratory thoracotomy.
65. C. The internal thoracic artery terminates in the sixth intercostal space by dividing into the musculophrenic artery and the superior epigastric artery. The superior epigastric artery quickly enters the anterior abdominal wall.
66. F. The heart can be squeezed between the sternum and the vertebral column when the thorax is subjected to a severe frontal impact. The right atrium, the right ventricle, or part of the left ventricle is commonly injured. The pericardium may be punctured by a fractured rib or, rarely, be ruptured by a sudden blow. If pericardial rupture occurs, it tends to take place along the lateral margins with involvement of the phrenic nerves.
67. B. The highly flexible rib cage in children makes myocardial bruising a common occurrence. In elderly patients, toughness of the pericardium and diminished elasticity may make rupture more common.

CHAPTER 2

Abdomen

ANTERIOR ABDOMINAL WALL

Skin

NERVE SUPPLY

The cutaneous nerve supply to the anterior abdominal wall is derived from the anterior rami of the lower six thoracic and the first lumbar nerves (Figs. 2-1 and 2-2). The thoracic nerves are the lower five intercostal and the subcostal nerves; the first lumbar nerve is represented by the iliohypogastric and the ilioinguinal nerves.

The dermatome of T7 is located in the epigastrium over the xiphoid process. The dermatome of T10 includes the umbilicus, and that of L1 lies just above the inguinal ligament and the symphysis pubis. The dermatomes and distribution of cutaneous nerves are shown in Figures 2-3 and 2-4.

BLOOD SUPPLY

Arteries

The skin near the midline is supplied by branches of the superior and the inferior epigastric arteries. The skin of the flanks is supplied by branches of the intercostal, the lumbar, and the deep circumflex iliac arteries (Fig. 2-1).

Veins

The venous drainage passes above into the axillary vein via the lateral thoracic vein and below into the femoral vein via the superficial epigastric and the great saphenous veins.

CLINICAL NOTES

CAVAL–CAVAL ANASTOMOSIS AND PARAUMBILICAL VEINS

Note the important indirect connection between the superior and inferior venae cavae. This may permit the reversal of blood flow in patients with an obstructed vena cava caused by a large mediastinal or abdominal tumor. Note also the presence of small **paraumbilical veins** that connect the systemic skin veins in the region of the umbilicus along the ligamentum teres to the portal vein. This may provide an important portal–systemic anastomosis in patients with obstruction of the portal vein, as in cirrhosis of the liver.

LYMPH DRAINAGE

The cutaneous lymph vessels above the level of the umbilicus drain upward into the anterior axillary lymph nodes. The vessels below this level drain downward into the superficial inguinal nodes.

Superficial Fascia

The superficial fascia is divided into the superficial **fatty layer (fascia of Camper)** and the deep **membranous layer (Scarpa's fascia).**

The fatty layer is continuous with the superficial fascia over the rest of the body. The membranous layer fades out laterally and above. Inferiorly, the membranous layer passes over the inguinal ligament to fuse with the deep fascia of the

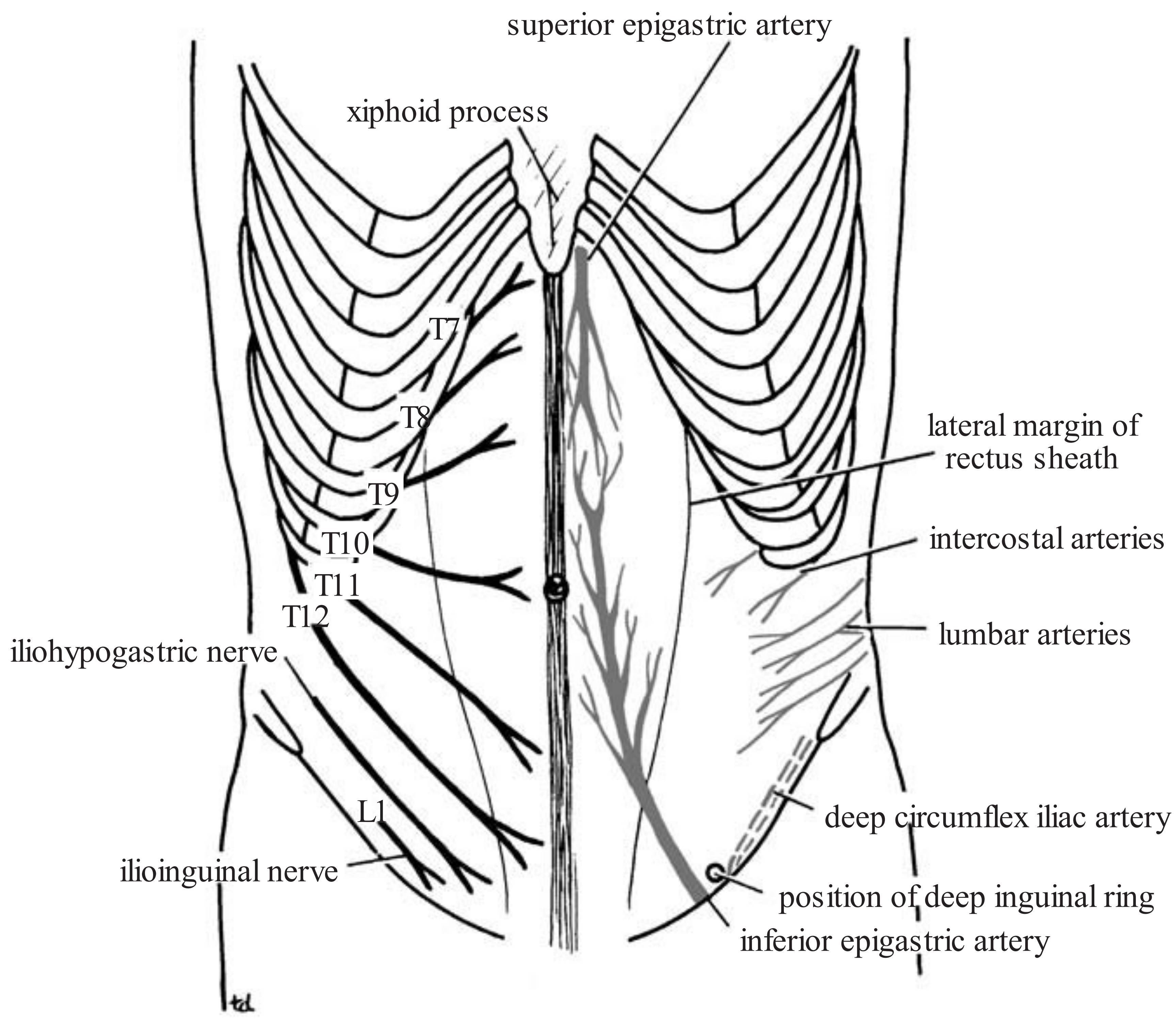


Figure 2-1 Segmental innervation (left) and arterial supply (right) to the abdominal wall.

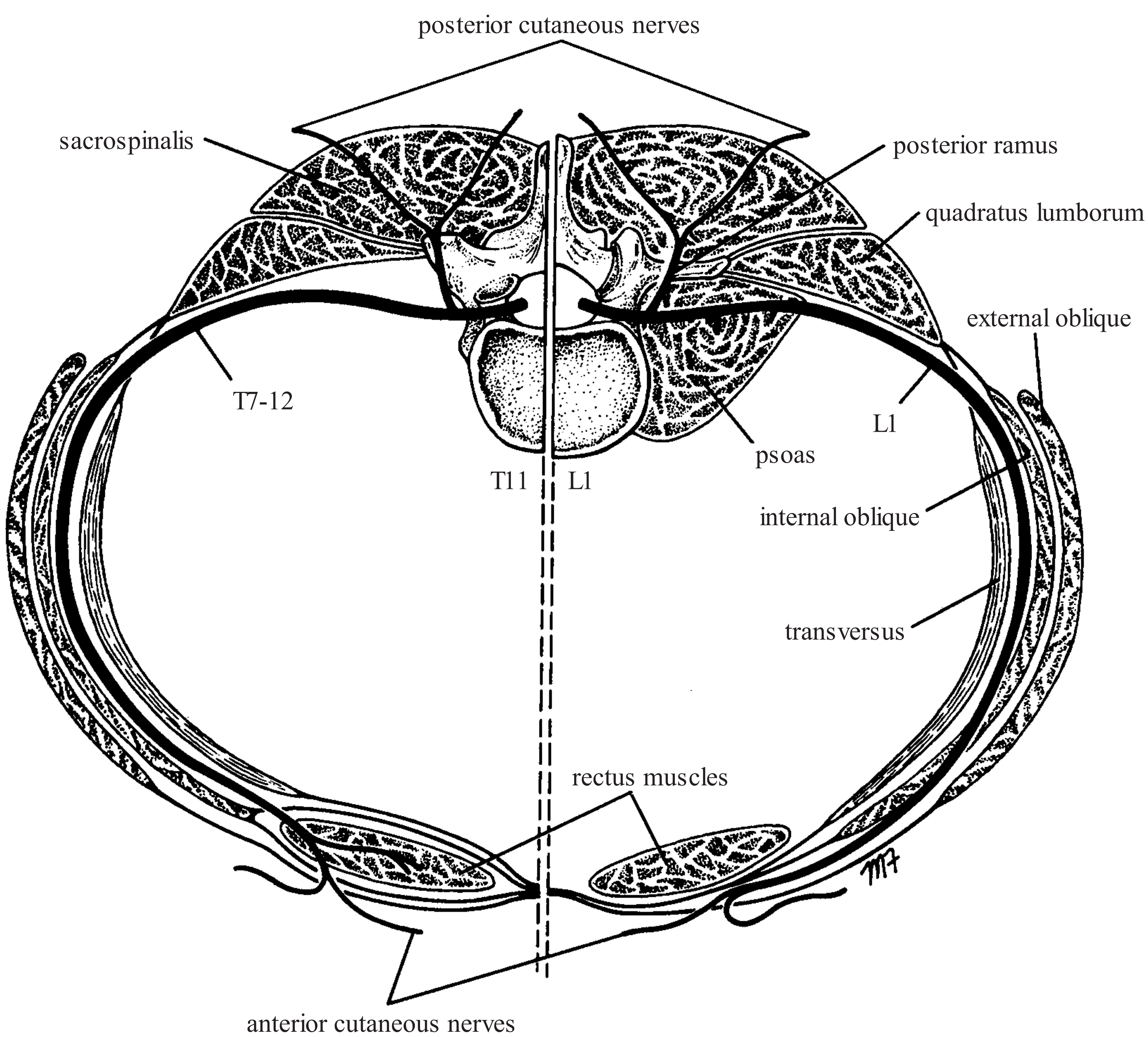


Figure 2-2 Cross section of the abdomen showing the courses of the lower thoracic and the first lumbar nerves.

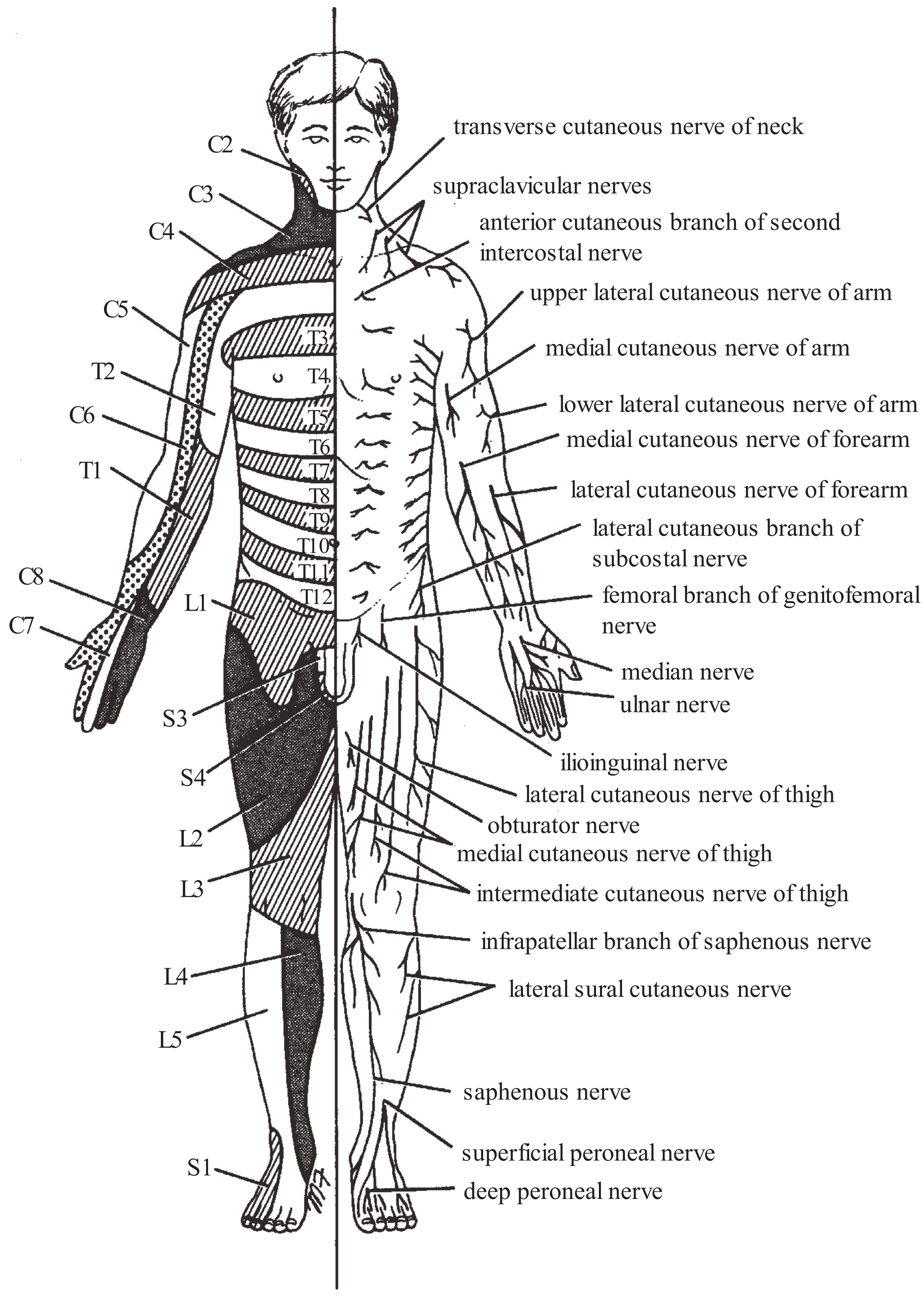


Figure 2-3 Dermatomes and distribution of cutaneous nerves on the anterior aspect of the body.

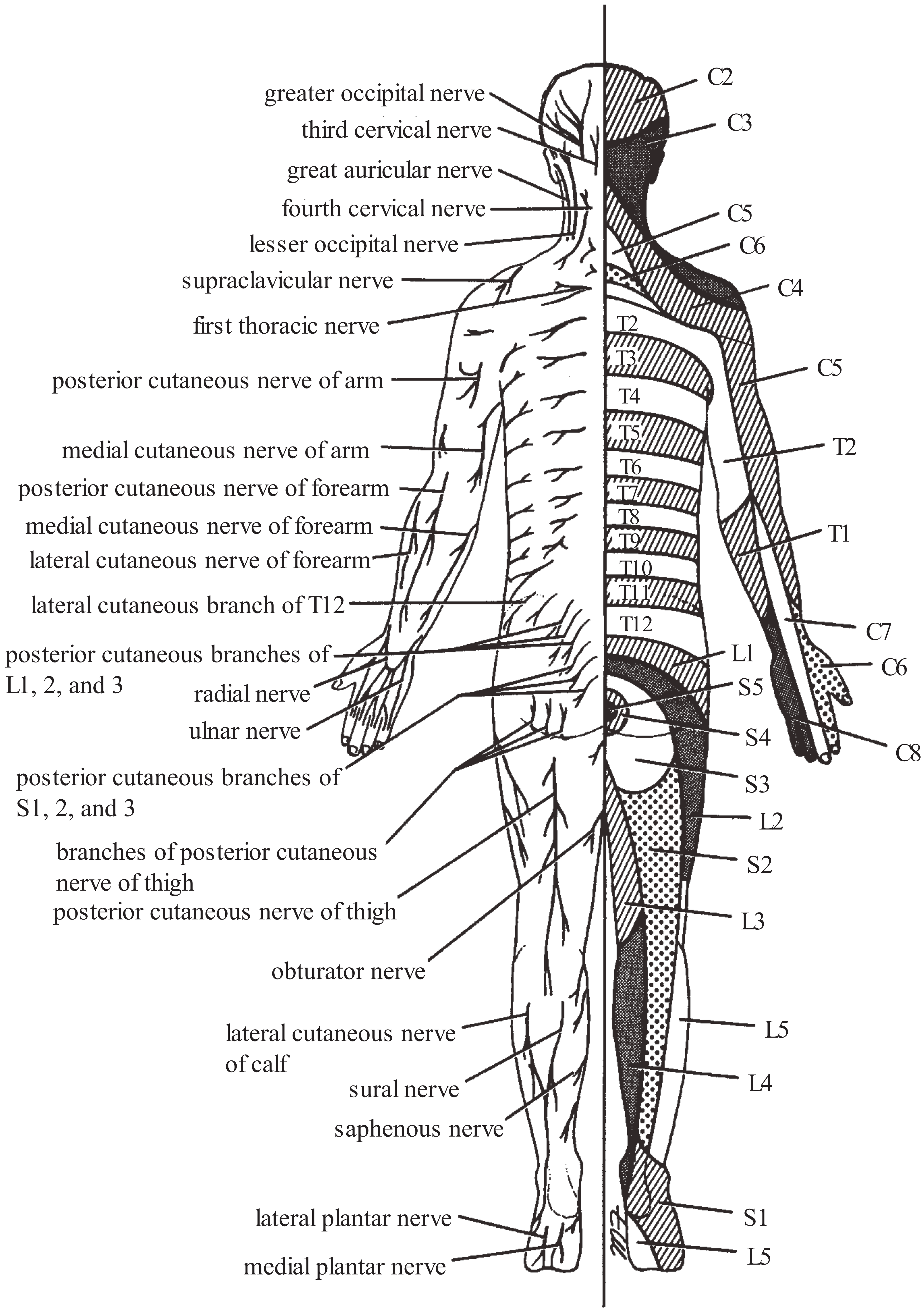


Figure 2-4 Dermatomes and distribution of cutaneous nerves on the posterior aspect of the body.

thigh (fascia lata) approximately one fingerbreadth below the inguinal ligament. In the midline, it is not attached to the pubis but instead forms a tubular sheath for the penis (clitoris). In the perineum, it is attached on each side to the margins of the pubic arch and is known as **Colles' fascia.** Posteriorly, it fuses with the perineal body and the posterior margin of the perineal membrane.

CLINICAL NOTES

SUPERFICIAL FASCIA AND THE EXTRAVASATION OF URINE

The membranous layer of superficial fascia has beneath it a potential closed space that does not open into the thigh but is continuous with the superficial perineal pouch via the penis and scrotum. Rupture of the penile urethra may be followed by extravasation of urine into the scrotum, perineum, and penis and then up into the lower part of the anterior abdominal wall deep to the membranous layer of fascia. The urine is excluded from the thigh because of the attachment of the fascia to the deep fascia of the thigh.

Deep Fascia

In the anterior abdominal wall, the deep fascia is a thin layer of areolar tissue covering the muscles.

Muscles of the Anterior Abdominal Wall

The muscles of the anterior abdominal wall consist mainly of three broad, thin sheets that are aponeurotic in front. From exterior to inferior, these sheets are the **external oblique,** the **internal oblique,** and the **transversus** (Fig. 2-5). In addition, on either side of the midline anteriorly, there is a wide, vertical muscle called the **rectus abdominis** (Fig. 2-6). As the aponeuroses of the three sheets pass forward, they enclose the rectus abdominis to form the **rectus sheath.**

In the lower part of the rectus sheath, there may be a small muscle called the **pyramidalis.**

The **cremaster muscle** is derived from the lower fibers of the internal oblique; it passes inferiorly as a covering of the spermatic cord and enters the scrotum.

The muscles of the anterior abdominal wall are shown in Table 2-1.

RECTUS SHEATH

The rectus sheath (Fig. 2-7) is a long fibrous sheath that encloses the rectus abdominis muscle and pyramidalis muscle (if present) and contains the anterior rami of the lower six thoracic nerves and the superior and inferior epigastric vessels and lymph vessels. It is formed by the aponeuroses of the three lateral abdominal muscles. The internal oblique aponeurosis splits at the lateral edge of the rectus abdominis to form two laminae; one passes anteriorly and one posteriorly to the rectus. The aponeurosis of the external oblique fuses with the anterior lamina, and the transversus aponeurosis fuses with the posterior lamina. At the level of the anterior superior iliac spines, all three aponeuroses pass anteriorly to the rectus muscle, leaving the sheath deficient posteriorly below this level. The lower, crescent-shaped edge of the posterior wall of the sheath is called the **arcuate line.** All three aponeuroses fuse with each other and with their fellows of the opposite side in the midline between the right and the left recti muscles to form a fibrous band called the **linea alba,** which extends from the xiphoid process above to the pubic symphysis below.

The posterior wall of the sheath, however, has no attachment to the muscle. The transverse **tendinous intersections,** which divide the rectus abdominis muscle into segments, are usually three in number: One at the level of the xiphoid process, one at the level of the umbilicus, and one between these two.

CLINICAL NOTES

SURGERY AND TENDINOUS INTERSECTIONS OF THE ABDOMINIS MUSCLE

Note that the anterior wall of the rectus sheath is firmly attached to the tendinous intersections of the rectus abdominis muscle. The posterior wall of the sheath, however, has no attachment to the muscle.

LINEA SEMILUNARIS

The linea semilunaris is the lateral edge of the rectus abdominis muscle. It crosses the costal margin at the tip of the ninth costal cartilage.

CONJOINT TENDON

The internal oblique muscle has a lower, free border that arches over the spermatic cord (or the round ligament of the uterus) and then descends behind and attaches to the pubic crest and the pectineal line. Near their insertion, the lowest tendinous fibers are joined by similar fibers from the transversus abdominis to form the **conjoint tendon,** which strengthens the medial half of the posterior wall of the inguinal canal.

INGUINAL LIGAMENT

The inguinal ligament (Fig. 2-5) connects the anterior superior iliac spine with the pubic tubercle. This ligament is formed by the lower border of the aponeurosis of the external oblique muscle, which is folded back on itself. From the medial end of the ligament, the **lacunar ligament** extends backward and upward to the pectineal line on the superior ramus of the pubis, where it becomes continuous with the **pectineal ligament** (a thickening of the periosteum). The lower border of the inguinal ligament is attached to the deep fascia of the thigh (the **fascia lata**).

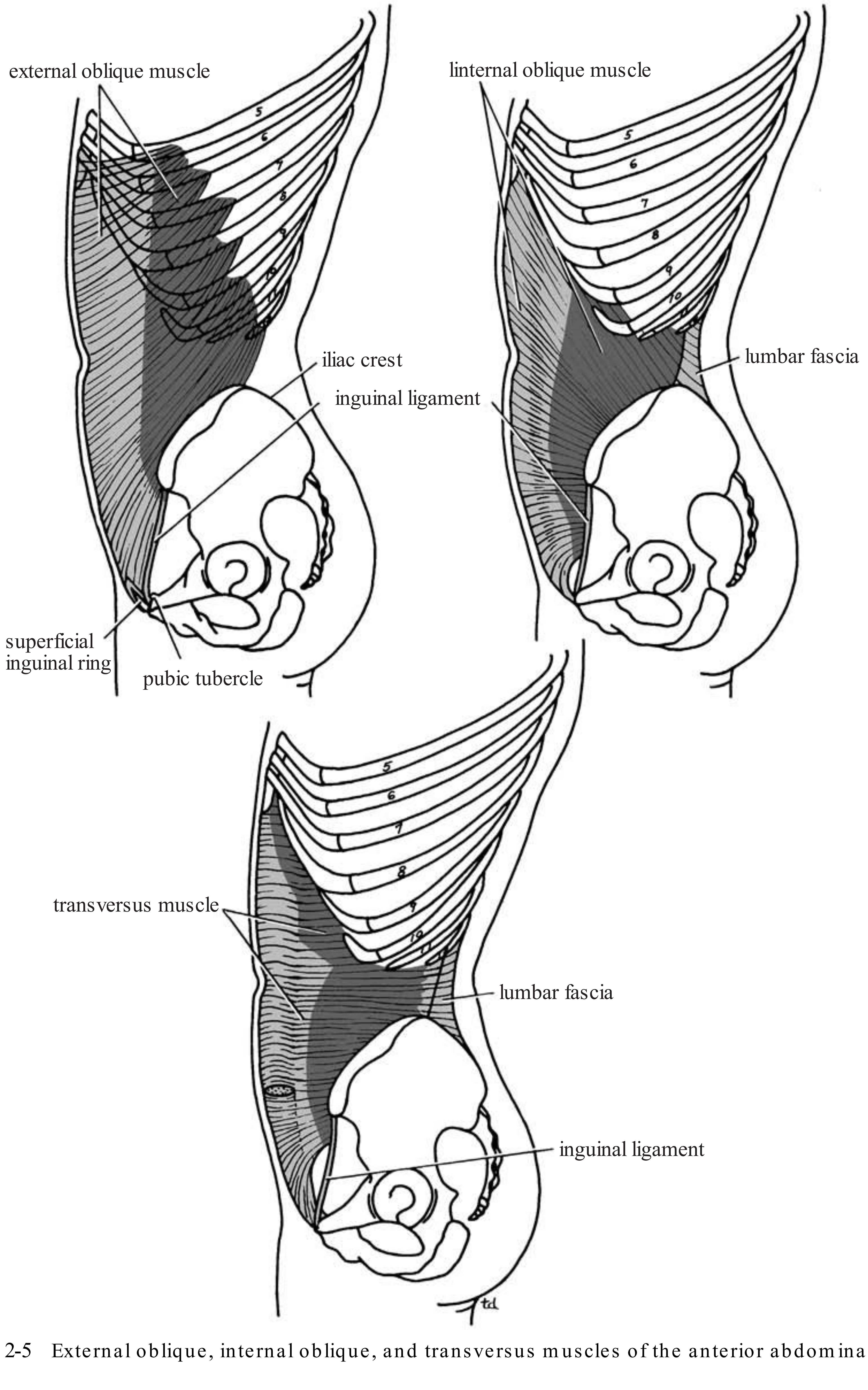


Figure 2-5 External oblique, internal oblique, and transversus muscles of the anterior abdominal wall.

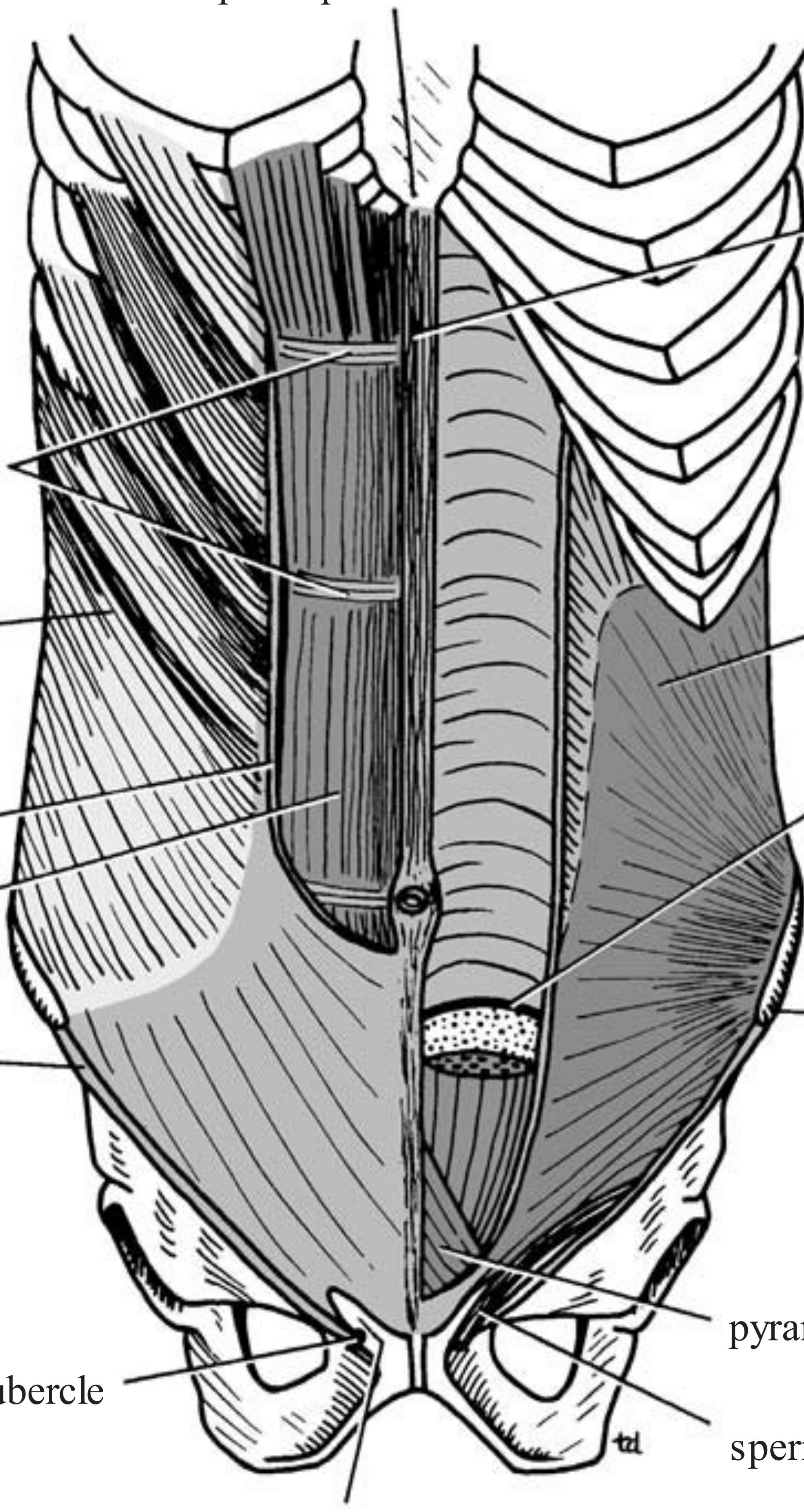


Figure 2-6 Anterior view of the rectus abdominis muscle and the rectus sheath. Left: The anterior wall of sheath has been partly removed revealing the rectus muscle with its tendinous intersections. Right: The posterior wall of the rectus sheath. Note the edge of the arcuate line at the level of the anterior superior iliac spine.

FASCIA TRANSVERSALIS

The fascia transversalis is a thin layer of fascia that lines the transversus muscle and is continuous with a similar layer lining the diaphragm and the iliacus muscle. The **femoral sheath** of the femoral vessels is formed by the fascia transversalis and the fascia iliaca.

INGUINAL CANAL

The inguinal canal (Fig. 2-8) is an oblique passage through the lower part of the anterior abdominal wall. In males, it allows structures to pass to and from the testis to the abdomen. In females, it allows the round ligament of the uterus to pass from the uterus to the labium majus.

The canal is approximately 1.5 in. (4 cm) in length among adults and extends from the deep inguinal ring downward and medially to the superficial inguinal ring. It lies parallel to and immediately above the inguinal ligament.

The **deep inguinal ring** is an oval opening in the fascia transversalis and lies approximately 0.5 in. (1.3 cm) above the inguinal ligament. The margins of this ring give attachment to the **internal spermatic fascia.**

The **superficial inguinal ring** is a triangular-shaped defect in the aponeurosis of the external oblique muscle and lies immediately above and medial to the pubic tubercle. The margins of this ring give attachment to the **external spermatic fascia.**

Walls

- **Anterior wall:** External oblique aponeurosis, reinforced laterally by origin of the internal oblique from the inguinal ligament (Fig. 2-8).
- **Posterior wall:** Conjoint tendon medially, fascia transversalis laterally (Fig. 2-8).
- **Roof or superior wall:** Arching fibers of the internal oblique and transversus muscles (Fig. 2-8).
- **Floor or inferior wall:** Inguinal and lacunar ligaments.

Function of the Inguinal Canal

In males, the inguinal canal allows structures to pass to and from the testis to the abdomen. (Normal spermatogenesis

Table 2-1 Muscles of the Anterior Abdominal Wall

Name of Muscle	Origin	Insertion	Nerve Supply	Action
External oblique	Lower right ribs	Xiphoid process, linea alba, pubic crest, pubic tubercle, iliac crest	Lower six thoracic nerves, iliohypogastric and ilioinguinal nerves (L1)	Compresses abdominal contents; assists in flexing and rotation of trunk; pulls down ribs in forced expiration
Internal oblique	Lumbar fascia, iliac crest, lateral two thirds of inguinal ligament	Lower three ribs and costal cartilages, xiphoid process, linea alba, symphysis pubis; forms conjoint tendon with transversus	Lower six thoracic nerves, iliohypogastric and ilioinguinal nerves (L1)	Compresses abdominal contents; assists in flexing and rotation of trunk; pulls down ribs in forced expiration
Transversus	Lower six costal cartilages, lumbar fascia, iliac crest, lateral third of inguinal ligament	Xiphoid process, linea alba, symphysis pubis; forms conjoint tendon with internal oblique	Lower six thoracic nerves, iliohypogastric and ilioinguinal nerves (L1)	Compresses abdominal contents
Rectus abdominis	Symphysis pubis and pubic crest	Fifth, sixth, and seventh costal cartilages and xiphoid process	Lower six thoracic nerves	Compresses abdominal contents and flexes vertebral column; accessory muscle of expiration
Pyramidalis (often absent)	Anterior surface of pubis	Linea alba	Twelfth thoracic nerve	Tenses the linea alba
Cremaster	Lower margin of internal oblique muscle	Pubic crest	Genital branch of genito-femoral nerve (L1, 2)	Retracts testis

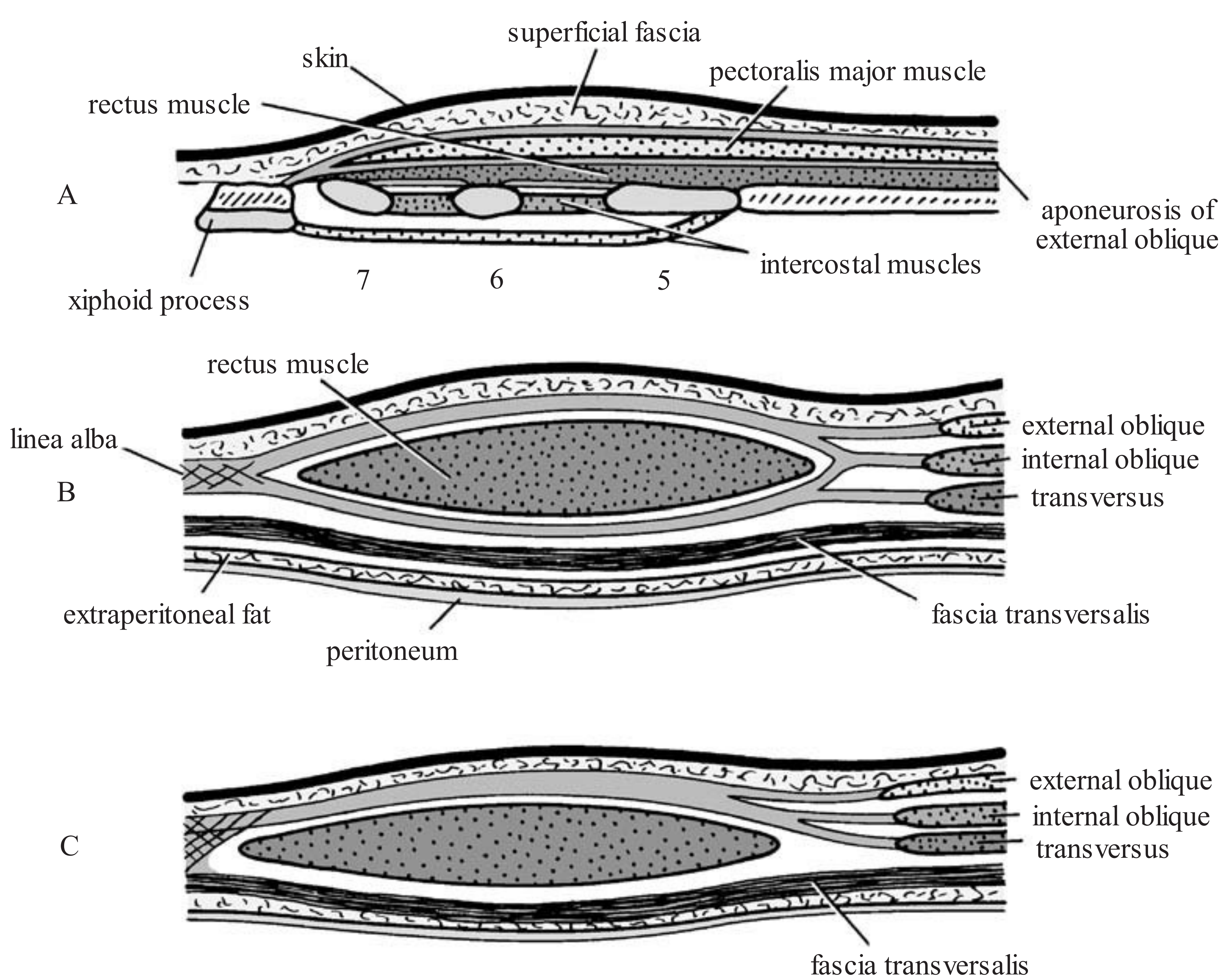


Figure 2-7 Transverse sections of the rectus sheath. A: Above the costal margin. B: Between the costal margin and the level of the anterior superior iliac spine. C: Below the level of the anterior superior iliac spine and above the pubis.

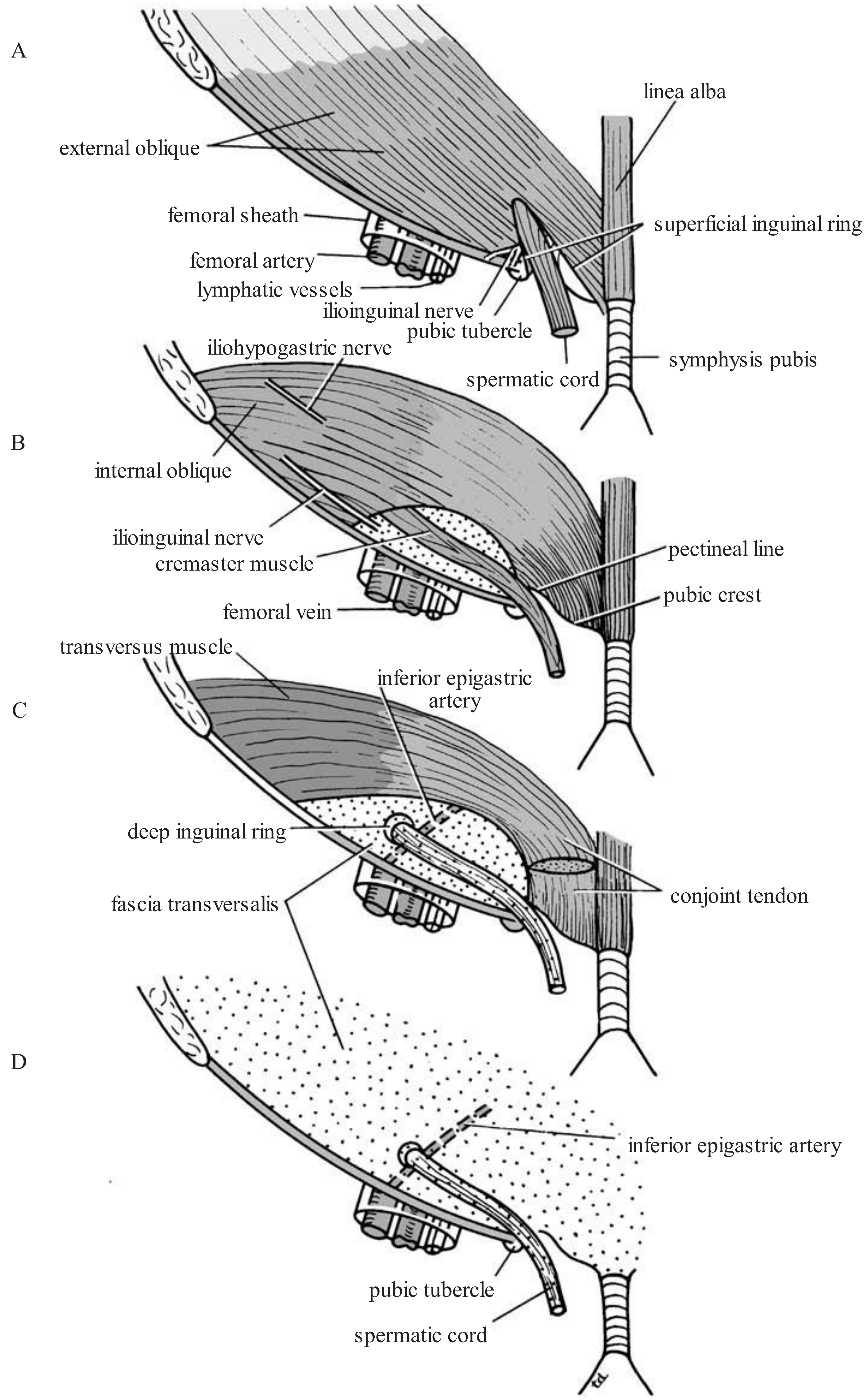


Figure 2-8 The inguinal canal. Note the arrangement of (A) the external oblique muscle, (B) the internal oblique muscle, (C) the transversus muscle, and (D) the fascia transversalis. The anterior wall is formed by the external and the internal oblique muscles, and the posterior wall is formed by the fascia transversalis and the conjoin tendon. The deep inguinal ring lies lateral to the inferior epigastric artery.

occurs only if the testis leaves the abdominal cavity and enters a cooler environment in the scrotum.) In females, the smaller canal allows the round ligament of the uterus to pass from the uterus to the labium majus. In both sexes, the canal also transmits the ilioinguinal nerve.

Mechanics of the Inguinal Canal

The inguinal canal is a site of potential weakness in both sexes. On coughing and straining (as in micturition, defecation, and parturition), the arching lowest fibers of the internal oblique and transversus abdominis muscles contract and flatten the arch. In turn, this lowers the roof of the canal toward the floor and virtually closes the canal.

CLINICAL NOTES

Inguinal Hernia

An inguinal hernia occurs above the inguinal ligament, whereas a femoral hernia occurs below the inguinal ligament. Inguinal hernias are of two types: indirect and direct.

Indirect Inguinal Hernia

- The hernial sac is the remains of the processus vaginalis.
- An indirect inguinal hernia is more common than a direct inguinal hernia.
- It is much more common in males than in females.
- It is more common on the right side.
- It is most common in children and young adults.
- The hernial sac enters the inguinal canal through the deep inguinal ring and **lateral** to the inferior epigastric vessels. The neck of the sac is narrow.
- The hernial sac may extend through the superficial inguinal ring above and medial to the pubic tubercle (femoral hernia below and lateral to the pubic tubercle).
- The hernial sac may extend down into the scrotum or labium majus.

Direct Inguinal Hernia

- It is common among elderly men with weak abdominal muscles but is rare among women.
- The hernial sac bulges forward through the posterior wall of the inguinal canal **medial** to the inferior epigastric vessels.
- The neck of the hernial sac is wide.

Spermatic Cord

The spermatic cord is a collection of structures that pass through the inguinal canal to and from the testis. These structures include the following:

- The vas deferens.
- The testicular artery.
- Testicular veins (pampiniform plexus).
- Testicular lymph vessels.
- Autonomic nerves.
- Remains of the processus vaginalis.
- The cremasteric artery.
- The artery of the vas deferens.
- The genital branch of the genitofemoral nerve, which supplies the cremaster muscle.

Coverings of the Spermatic Cord

There are three concentric layers of fascia derived from the layers of the anterior abdominal wall:

- **External spermatic fascia** derived from the external oblique muscle and attached to the margins of the superficial inguinal ring.
- **Cremasteric fascia** derived from the internal oblique muscle.
- **Internal spermatic fascia** derived from the fascia transversalis and attached to the margins of the deep inguinal ring.

PROCESSUS VAGINALIS

The processus vaginalis is a peritoneal diverticulum formed in the fetus that passes through the lower part of the anterior abdominal wall to form the inguinal canal. The **tunica vaginalis** is the lower, expanded part of the processus vaginalis. Normally, the cavity of the tunica vaginalis becomes shut off from the upper part of the processus and the peritoneal cavity just before birth. The tunica vaginalis is thus a closed sac invaginated from behind by the testis.

CLINICAL NOTES

Clinical Anatomy of the Processus Vaginalis

The processus vaginalis is a peritoneal diverticulum, formed in the fetus, that passes through the layer of the anterior abdominal wall to form the inguinal canal. The tunica vaginalis is the lower expanded part of the processus vaginalis. Normally, just before birth, the cavity of the tunica vaginalis becomes shut off from the upper part of the processus and the peritoneal cavity. The tunica vaginalis is thus a closed sac, invaginated from behind by the testis. The following anomalies may occur:

- **Preformed sac of indirect inguinal hernia:** The processus may persist partially or in its entirety as a hernial sac.
- **Congenital hydrocele:** The processus vaginalis becomes narrowed but not obliterated and remains in communication with the abdominal cavity. Peritoneal fluid accumulates in it, forming a hydrocele.
- **Encysted hydrocele of the cord:** The upper and lower ends of the processus become obliterated, leaving a small intermediate encysted area. This presents as a small fluctuant swelling in the inguinal region, often within the inguinal canal, that moves medially on gentle downward pulling of the testis and the covering of tunica vaginalis.

GUBERNACULUM TESTIS

The gubernaculum testis is a musculoligamentous cord that connects the fetal testis with the floor of the developing scrotum. It plays an important role in the descent of the testis, and it is homologous to the female round ligament of the ovary and the round ligament of the uterus.

SCROTUM

The scrotum is an outpouching of the lower part of the anterior abdominal wall. It contains the testes, the epididymides, and the lower ends of the spermatic cords.

The wall of the scrotum has the following layers:

- Skin.
- Superficial fascia, in which dartos muscle (smooth muscle) replaces the fatty layer.
- External spermatic fascia from the external oblique muscle.
- Cremasteric fascia from the internal oblique muscle; the cremasteric muscle is supplied by the genital branch of the genitofemoral nerve.
- Internal spermatic fascia from the fascia transversalis.
- Tunica vaginalis (a closed sac that covers the anterior, medial, and lateral surfaces of each testis).

TESTES

The testes are paired, ovoid organs responsible for the production of spermatozoa and testosterone. Normal spermatogenesis occurs only at a temperature lower than that of the abdominal cavity, hence the descent of the testes into the scrotum. The **tunica albuginea** is the outer, fibrous capsule of the testis.

EPIDIDYMIDES

The epididymis on each side lies posterior to the testis and has a **head,** a **body,** and a **tail.** It is a coiled tube approximately 20 ft. (6 m) in length. The vas deferens emerges from the tail.

Blood Supply of the Testis and Epididymis

The testicular artery is a branch of the abdominal aorta. The testicular vein emerges from the testis and the epididymis as a venous network (the **pampiniform plexus**), which becomes reduced to a single vein as it ascends through the inguinal canal. The right testicular vein drains into the inferior vena cava, and the left vein joins the left renal vein.

CLINICAL NOTES

VARICOCELE

In varicocele, there is an elongation and dilation of the veins of the pampiniform plexus. It is a common disorder found in adolescents and young adults. The great majority occur on the left side, because the right testicular vein drains into the low-pressure inferior vena cava, whereas the left vein drains into the left renal vein, in which the venus pressure is higher. Very rarely, a malignant tumor of the left kidney with invasion of the left renal vein may block the exit of the testicular vein.

Lymph Drainage of the Testis and Epididymis

Para-aortic lymph nodes on the side of the aorta at the level of the first lumbar vertebra.

CLINICAL NOTES

TESTICULAR TUMOR

A testicular tumor is usually a hard, irregular, nontender mass. Note that if the tumor is malignant it will metastasize to the para-aortic lymph nodes at the level of the first lumbar vertebra.

Nerves of the Anterior Abdominal Wall

The nerves of the anterior abdominal wall are the anterior rami of the lower six thoracic and the first lumbar nerves (Fig. 2-2). These nerves run downward and forward between the internal oblique and the transversus muscles. They supply the skin, the muscles, and the parietal peritoneum of the anterior abdominal wall. The lower six thoracic nerves pierce the posterior wall of the rectus sheath. The first lumbar nerve is represented by the **iliohypogastric** and the **ilioinguinal nerves,** which do not enter the rectus sheath. Instead, the iliohypogastric nerve pierces the external oblique aponeurosis above the superficial inguinal ring, and the ilioinguinal nerve passes through the inguinal canal to emerge through the ring.

Blood Supply of the Anterior Abdominal Wall

ARTERIES

The **superior epigastric artery** arises from the internal thoracic artery and enters the rectus sheath. It descends behind the rectus muscle, supplies the upper central part of the anterior abdominal wall, and anastomoses with the inferior epigastric artery.

The **inferior epigastric artery** arises from the external iliac artery above the inguinal ligament. It runs medial to the deep inguinal ring and enters the rectus sheath, ascends behind the rectus muscle, and supplies the lower central part of the anterior abdominal wall. It anastomoses with the superior epigastric artery.

The **deep circumflex iliac** artery is a branch of the external iliac artery. It runs upward and laterally toward the anterior superior iliac spine, and it supplies the lower lateral part of the abdominal wall.

The **lower two posterior intercostal arteries** from the descending thoracic aorta and the **four lumbar arter-**

ies from the abdominal aorta supply the lateral part of the anterior abdominal wall. The **superficial epigastric artery,** the **superficial circumflex iliac artery,** and the **superficial external pudendal artery** branches of the femoral artery also supply the lower part of the anterior abdominal wall.

VEINS

The **superior** and **inferior epigastric veins** and the **deep circumflex iliac veins** follow the arteries and drain into the internal thoracic and the external iliac veins. The **posterior intercostal veins** drain into the azygos veins, and the **lumbar veins** drain into the inferior vena cava. The **superficial epigastric,** the **superficial circumflex iliac,** and the **superficial external pudendal veins** drain into the great saphenous vein and, from there, into the femoral vein. The **thoracoepigastric vein** is the name given to the anastomoses between the lateral thoracic vein and the superficial epigastric vein, which is a tributary of the great saphenous vein. This vein provides an alternative path for the venous blood should the superior or inferior vena cava become obstructed, as previously noted.

Lymph Drainage of the Anterior Abdominal Wall

The cutaneous lymph vessels above the level of the umbilicus drain upward into the anterior axillary lymph nodes. Cutaneous lymph vessels below this level drain downward into the superficial inguinal nodes. The deep lymph vessels follow the arteries and drain into the internal thoracic, the external iliac, the posterior mediastinal, and the para-aortic (lumbar) nodes.

PERITONEUM

The peritoneum is the serous membrane that lines the abdominal and the pelvic cavities and that clothes the viscera (Fig. 2-9). The peritoneum can be regarded as a balloon against which organs are pressed from the outside. The **parietal layer** lines the walls of the abdominal and the pelvic cavities, and the **visceral layer** covers the organs. The potential space between the parietal and the visceral layers is called the **peritoneal cavity.** In males, this is a closed cavity, but in females, there is communication with the exterior through the uterine tubes, the uterus, and the vagina.

The peritoneal cavity is divided into two parts: the greater sac and the lesser sac (Fig. 2-9). The **greater sac** is the main compartment and extends from the diaphragm down into the pelvis. The **lesser sac** is smaller and lies behind the stomach. The greater and the lesser sacs are in free communication with one another through the **epiploic foramen.** The peritoneum secretes a small amount of serous fluid that lubricates the peritoneal surfaces and facilitates free movement between the viscera.

Peritoneal Ligaments, Omenta, and Mesenteries

The peritoneal ligaments, omenta, and mesenteries permit blood, lymph vessels, and nerves to reach the viscera.

PERITONEAL LIGAMENTS

Peritoneal ligaments are two-layered folds of peritoneum that connect solid viscera with the abdominal walls. The liver, for example, is connected to the diaphragm by the **falciform ligament,** the **coronary ligament,** and the **right** and the **left triangular ligaments** (Fig. 2-10).

OMENTA

Omenta are two-layered folds of peritoneum that connect the stomach with another viscus. The **greater omentum** connects the greater curvature of the stomach with the transverse colon (Fig. 2-9). It hangs down like an apron in front of the coils of the small intestine and is folded back on itself. The **lesser omentum** suspends the lesser curvature of the stomach to the fissure for the ligamentum venosum and the porta hepatis of the liver (Figs. 2-9 and 2-10). The **gastrosplenic omentum** (ligament) connects the stomach to the hilus of the spleen.

MESENTERIES

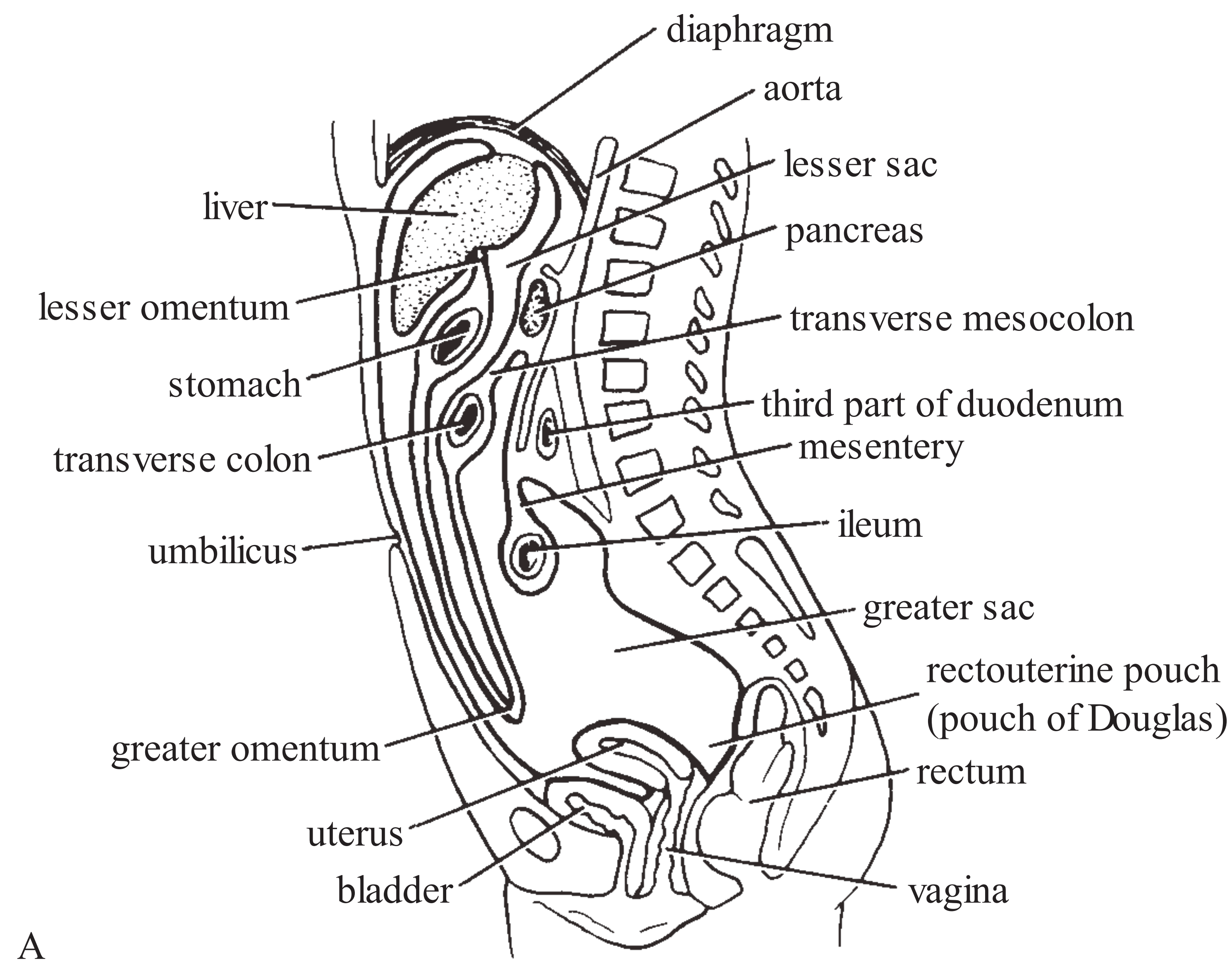
Mesenteries are two-layered folds of peritoneum connecting parts of the intestines with the posterior abdominal wall (e.g., the **mesentery of the small intestine,** the **transverse mesocolon,** the **sigmoid mesocolon**) (Fig. 2-9).

Lesser Sac

The lesser sac lies behind the stomach and the lesser omentum (Fig. 2-9). It extends upward as far as the diaphragm and downward between the layers of the greater omentum. The left margin of the sac is formed by the spleen, the gastrosplenic omentum, and the splenicorenal ligament. The right margin opens into the greater sac (the main part of the peritoneal cavity) through the **epiploic foramen.**

BOUNDARIES OF THE EPIPLOIC FORAMEN

- **Anteriorly:** Free border of the lesser omentum, the bile duct, the hepatic artery, and the portal vein.
- **Posteriorly:** Inferior vena cava.
- **Superiorly:** Caudate process of the caudate lobe of the liver.
- **Inferiorly:** First part of the duodenum.



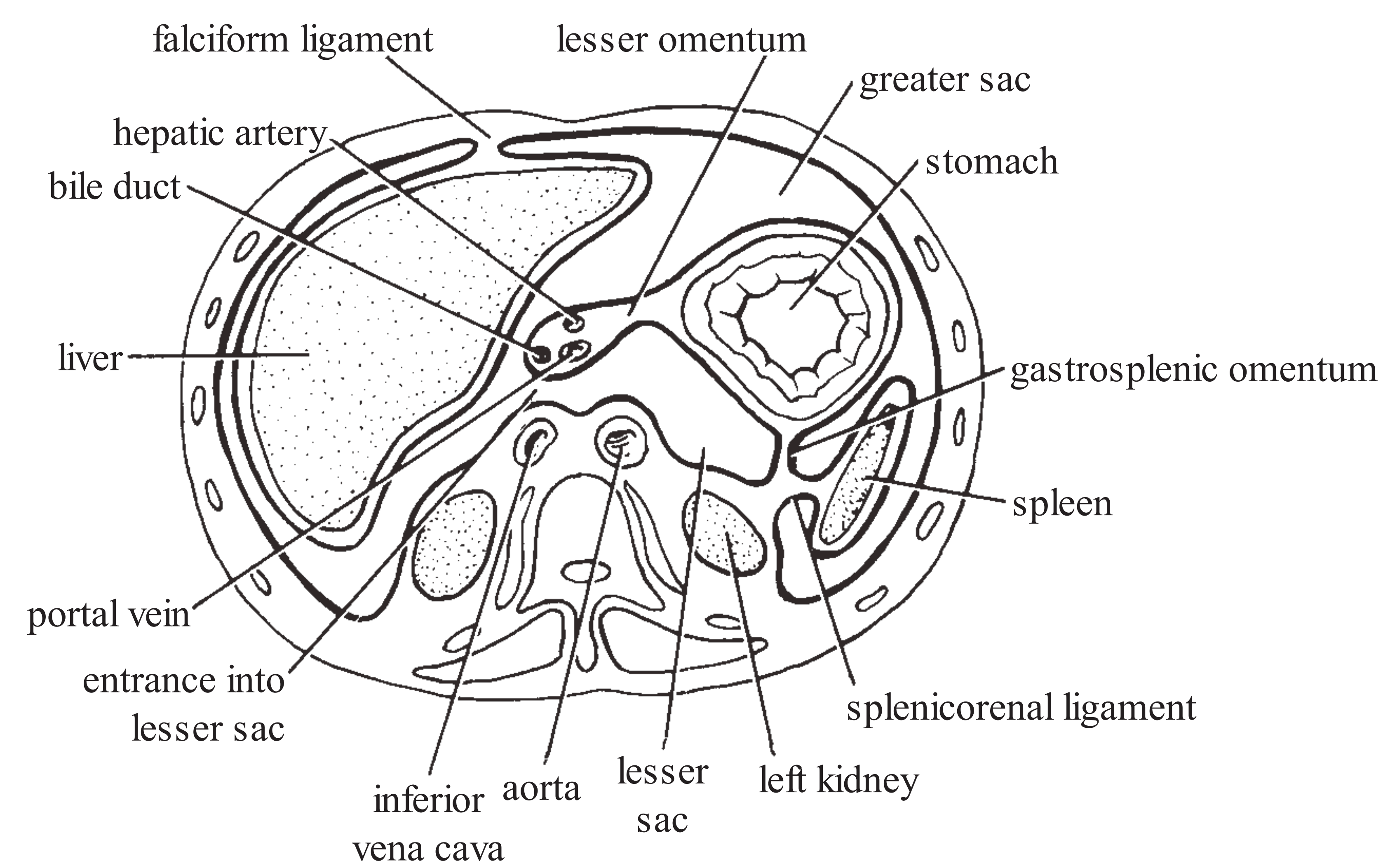


Figure 2-9 A. Sagittal section of a female abdomen showing the arrangement of the peritoneum. B. Transverse section (as viewed from below) of an abdomen showing the arrangement of the peritoneum.

Peritoneal Recesses, Spaces, and Gutters

DUODENAL RECESSES, CECAL RECESSES, SPACES, AND GUTTERS

Duodenal Recesses

Close to the duodenojejunal junction, there may be four small pouches of peritoneum called the **superior duodenal recess,** the **inferior duodenal recess,** the **paraduodenal recess,** and the **retroduodenal recess.**

Cecal Recesses

Folds of peritoneum close to the cecum produce three peritoneal recesses called the **superior ileocecal recess,** the **inferior ileocecal recess,** and the **retrocecal recess.**

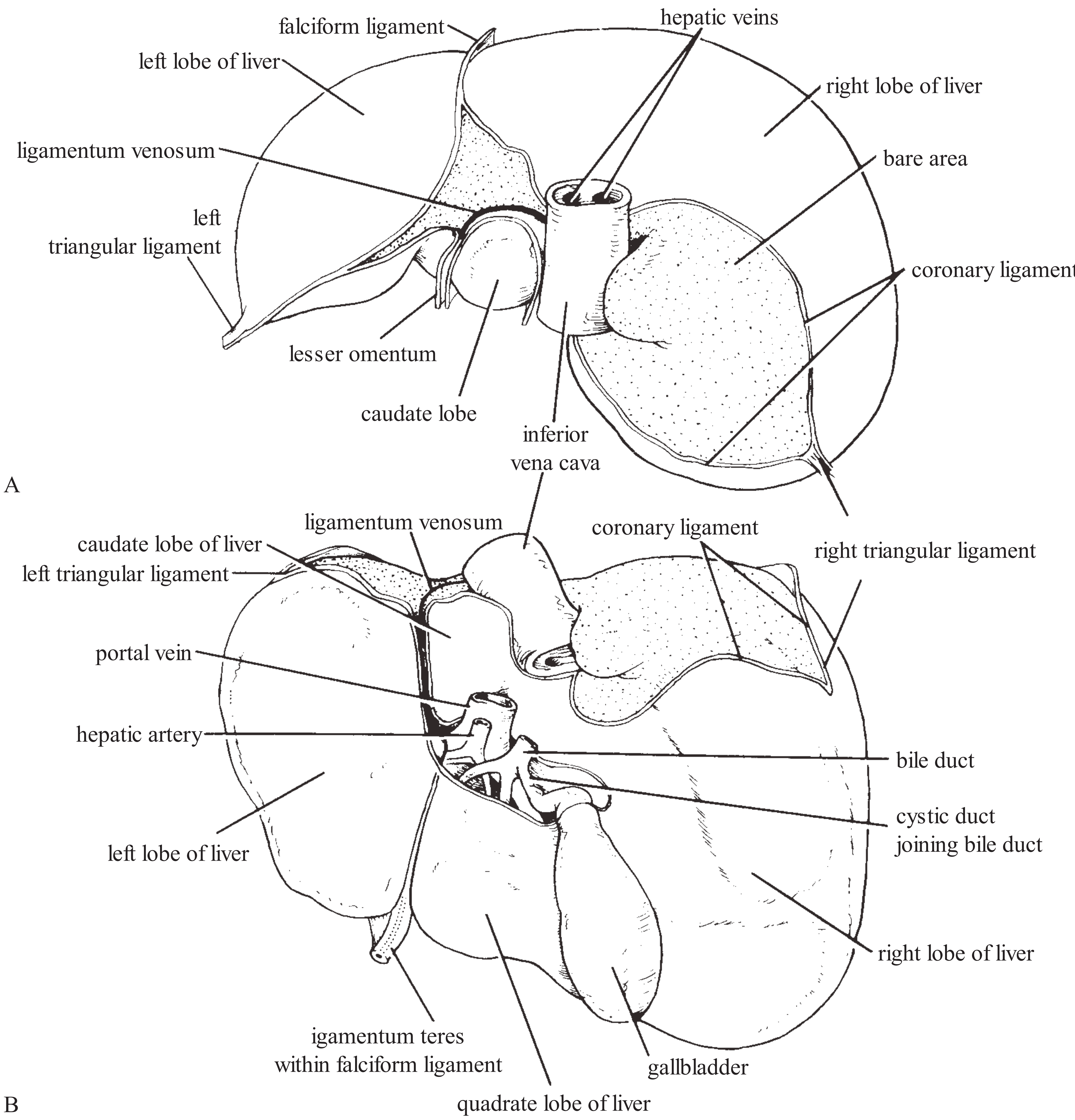


Figure 2-10 A. The liver as viewed from above. B. The liver as viewed from behind. Note the position of the peritoneal reflections, the bare areas, and the peritoneal ligaments.

CLINICAL NOTES

Paracolic Gutters

Paracolic gutters lie on the lateral and the medial sides of the ascending and the descending colons, respectively. They provide channels for the movement of infected fluid in the peritoneal cavity.

Subphrenic Spaces

Subphrenic spaces lie between the diaphragm and the liver, and they are called the **right** and **left anterior** and **posterior subphrenic spaces.** Clinically, these spaces are important because they may provide sites for the accumulation of pus.

Nerve Supply of the Peritoneum

The **parietal peritoneum** is supplied for pain, temperature, touch, and pressure by the lower six thoracic and first lumbar nerves. The parietal peritoneum in the pelvis is mainly supplied by the obturator nerve.

CLINICAL NOTES

Peritoneal Pain

Pain from the Parietal Peritoneum

Because the parietal peritoneum is innervated from somatic nerves, pain involving this area is of the somatic type and can be precisely localized; it is usually severe.

Pain from the Visceral Peritoneum

Because the visceral peritoneum and that of the mesenteries are innervated by autonomic nerves, pain involving these areas is of the visceral type and is dull and poorly localized. Remember that stretch caused by overdistension of a viscus or pulling on a mesentery can give rise to visceral pain.

The **visceral peritoneum** is supplied for stretch only by autonomic nerves that supply the viscera or that are traveling in the mesenteries.

GASTROINTESTINAL VISCERA

Stomach

The stomach is a dilated portion of the alimentary canal situated in the upper part of the abdomen (Fig. 2-11). It is roughly J-shaped, and it has two openings (the **cardiac** and the **pyloric orifices**), two curvatures (the **greater** and the **lesser curvatures**), and two surfaces (an **anterior** and a **posterior surface**).

The stomach may be divided into the following parts:

- **Fundus:** This is dome-shaped and projects upward and to the left of the cardiac orifice. It is usually full of gas.
- **Body:** This extends from the cardiac orifice to the **incisura angularis** (a constant notch in the lower part of the lesser curvature).
- **Pyloric antrum:** This extends from the incisura angularis to the pylorus.
- **Pylorus:** This is the most tubular part of the stomach. The thick, muscular wall is called the **pyloric sphincter,** and the cavity of the pylorus is called the **pyloric canal.**

The **lesser curvature** forms the right border of the stomach and is connected to the liver by the lesser omentum. The **greater curvature** is much longer than the lesser curvature, and it extends from the left of the cardiac orifice over the dome of the fundus and along the left border of the stomach. The gastrosplenic omentum (ligament) extends from the upper part of the greater curvature to the spleen. The greater omentum extends from the lower part of the greater curvature to the transverse colon.

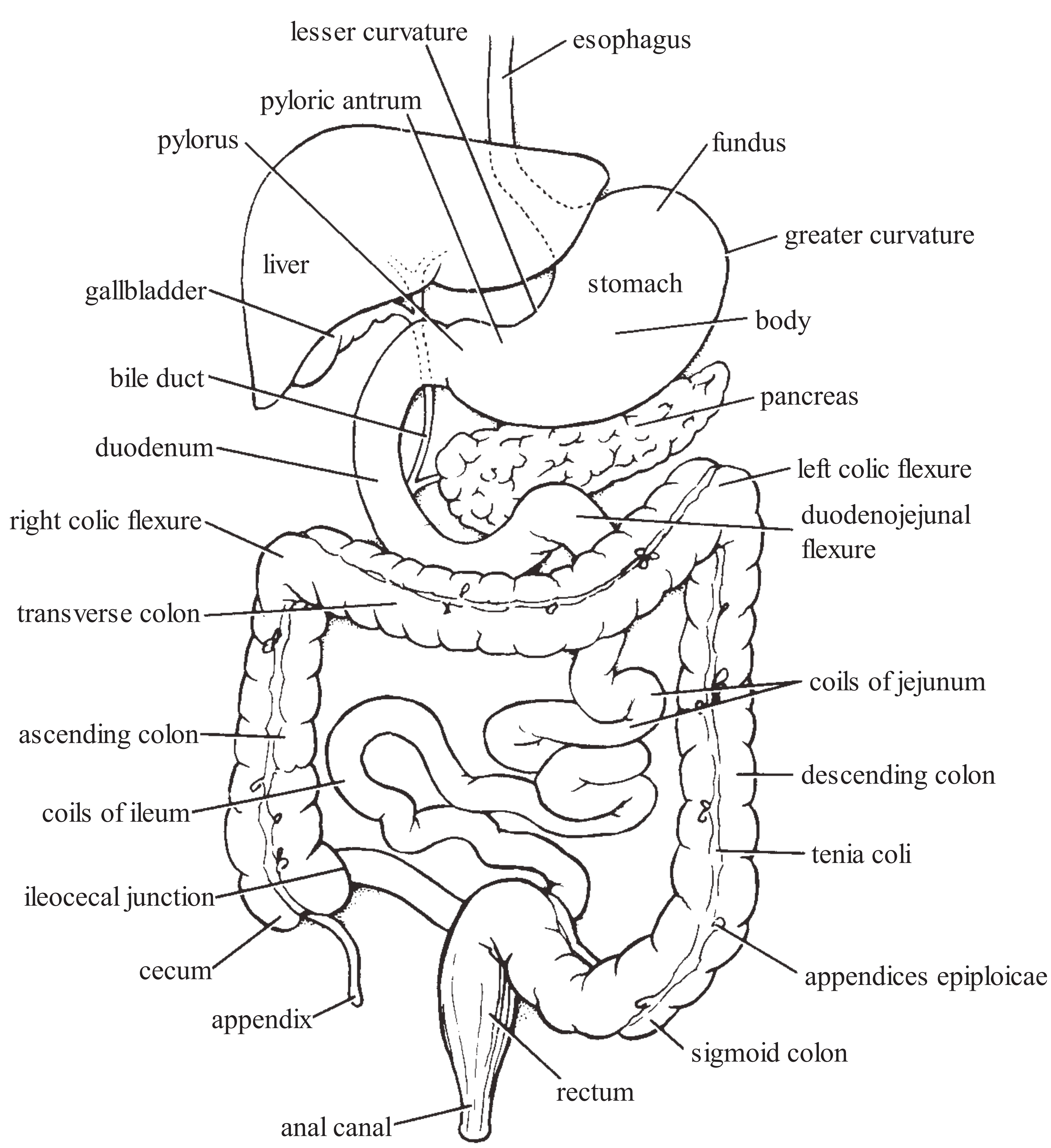


Figure 2-11 General arrangement of the abdominal viscera.

The esophagus enters the stomach at the **cardiac orifice.** No anatomic sphincter can be demonstrated here, but a physiologic mechanism prevents the regurgitation of stomach contents into the esophagus.

The **pyloric orifice** is formed by the pyloric canal. The circular muscle coat of the stomach is much thicker here and forms the anatomic and physiologic **pyloric sphincter.**

BLOOD SUPPLY

Arteries

The right and left gastric arteries supply the lesser curvature. The right and left gastroepiploic arteries supply the greater curvature. Short gastric arteries derived from the splenic artery supply the fundus (Fig. 2-12).

Veins

The veins drain into the portal circulation. The right and left gastric veins drain into the portal vein. The short gastric and the left gastroepiploic veins drain into the splenic vein, and the right gastroepiploic vein drains into the superior mesenteric vein.

LYMPH DRAINAGE

The lymph vessels follow the arteries into the left and right gastric nodes, the left and right gastroepiploic nodes, and the short gastric nodes. All lymph from the stomach eventually passes to the celiac nodes.

NERVE SUPPLY

The sympathetic nerve supply is from the celiac plexus, and parasympathetic is from the vagus nerves.

Small Intestine

The greater part of digestion and food absorption occurs in the small intestine, which extends from the pylorus of the stomach to the ileocecal junction (Fig. 2-11). The small intestine is divided into three parts: the duodenum, the jejunum, and the ileum.

DUODENUM

The duodenum is a C-shaped tube approximately 10 in. (25 cm) in length that curves around the head of the pancreas (Fig. 2-13). The duodenum begins at the pyloric sphincter of the stomach, and it ends by becoming continuous with the jejunum. The first inch of the duodenum has the lesser omentum attached to its upper border and the greater omentum attached to its lower border. The remainder of the duodenum is retroperitoneal.

The duodenum is divided into four parts:

- The **first part** runs upward and backward on the transpyloric plane at the level of the first lumbar vertebra.

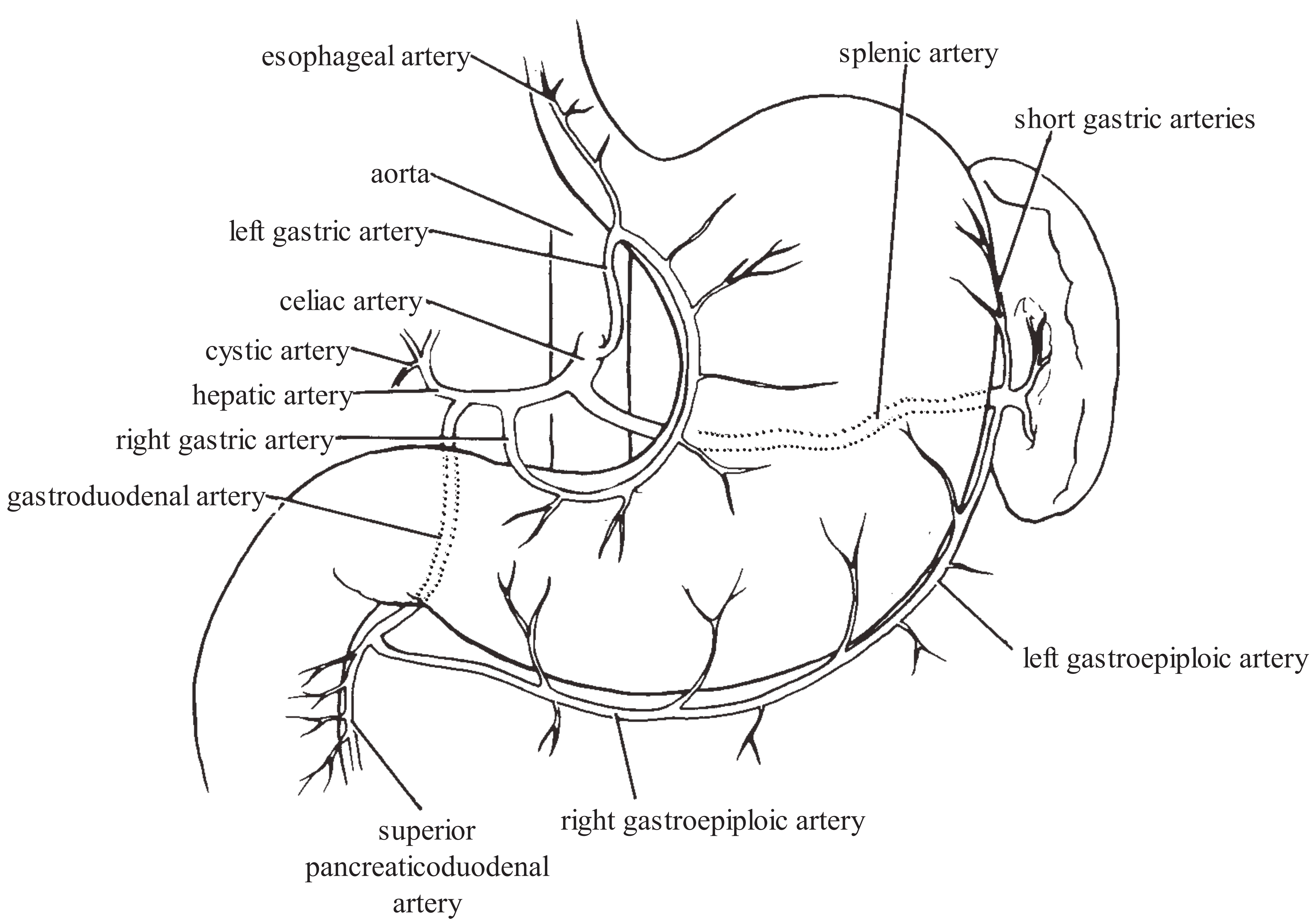


Figure 2-12 Arterial supply to the stomach. Note that all the arteries are branches of the celiac artery.

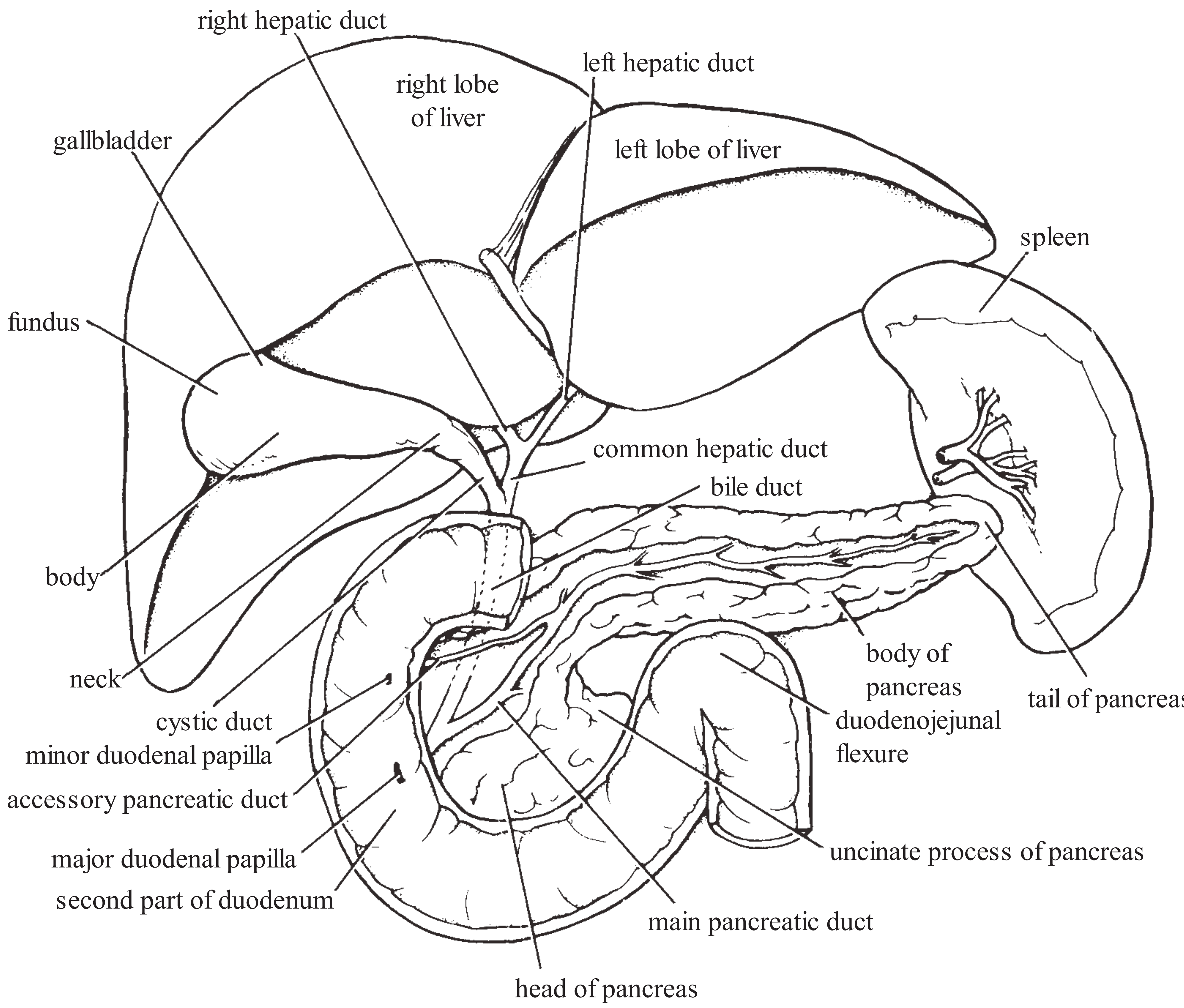


Figure 2-13 The liver, biliary ducts, pancreas, and spleen. Note their relationship to one another and to the duodenum.

- The **second part** runs vertically downward. The bile and the main pancreatic ducts pierce the medial wall approximately halfway down, and they unite to form an ampulla that opens on the summit of a **major duodenal papilla** (Fig. 2-12). The accessory pancreatic duct (if present) opens into the duodenum on a **minor duodenal papilla,** approximately 0.75 in. (1.9 cm) above the major duodenal papilla.
- The **third part** passes horizontally in front of the vertebral column. The root of the mesentery of the small intestine and the superior mesenteric vessels cross this part anteriorly.
- The **fourth part** runs upward and to the left to the **duodenojejunal flexure.** The flexure is held in position by the **ligament of Treitz,** which is attached to the right crus of the diaphragm.

Blood Supply

Arteries

The upper half of the duodenum is supplied by the superior pancreaticoduodenal artery, which is a branch of the gastroduodenal artery. The lower half is supplied by the inferior pancreaticoduodenal artery, which is a branch of the superior mesenteric artery.

Veins

The superior pancreaticoduodenal vein joins the portal vein. The inferior pancreaticoduodenal vein joins the superior mesenteric vein.

Lymph Drainage

The lymph vessels drain upward via the pancreaticoduodenal nodes to the gastroduodenal nodes and the celiac nodes. They drain downward via the pancreaticoduodenal nodes to the superior mesenteric nodes.

Nerve Supply

The duodenum is supplied by the sympathetic and vagus nerves via the celiac and the superior mesenteric plexuses.

JEJUNUM AND ILEUM

The jejunum measures approximately 8 ft. (2.5 m) long and the ileum, approximately 12 ft. (3.6 m) long. The jejunum begins at the duodenojejunal flexure (Fig. 2-11) in the upper part of the abdominal cavity and to the left of the midline. It is wider in diameter, thicker walled, and redder in color than the ileum.

The coils of the ileum occupy the lower right part of the abdominal cavity and tend to hang down into the pelvis. The ileum ends at the ileocecal junction. The coils of the jejunum and the ileum are suspended from the posterior abdominal wall by a fan-shaped fold of peritoneum called the **mesentery of the small intestine.**

Blood Supply

Arteries

Branches of the superior mesenteric artery (Fig. 2-14) anastomose with one another to form arcades.

Veins

The veins drain into the superior mesenteric vein.

Lymph Drainage

The lymph passes to the superior mesenteric nodes via intermediate mesenteric nodes.

Nerve Supply

Sympathetic and vagus nerve fibers arise from the superior mesenteric plexus.

CLINICAL NOTES

MECKEL'S DIVERTICULUM

Meckel's diverticulum is a congenital anomaly representing a persistent portion of the vitellointestinal duct. It is located (if present) on the antimesenteric border of the ileum approximately 2 ft. (60 cm) from the ileocecal junction. It is about 2 in. (5 cm) in length, and it occurs in approximately 2% of individuals. It is important clinically because bleeding may occur from an ulcer in its mucous membrane.

Large Intestine

The large intestine extends from the ileum to the anus (Fig. 2-11). It is divided into the cecum, the appendix, the as-

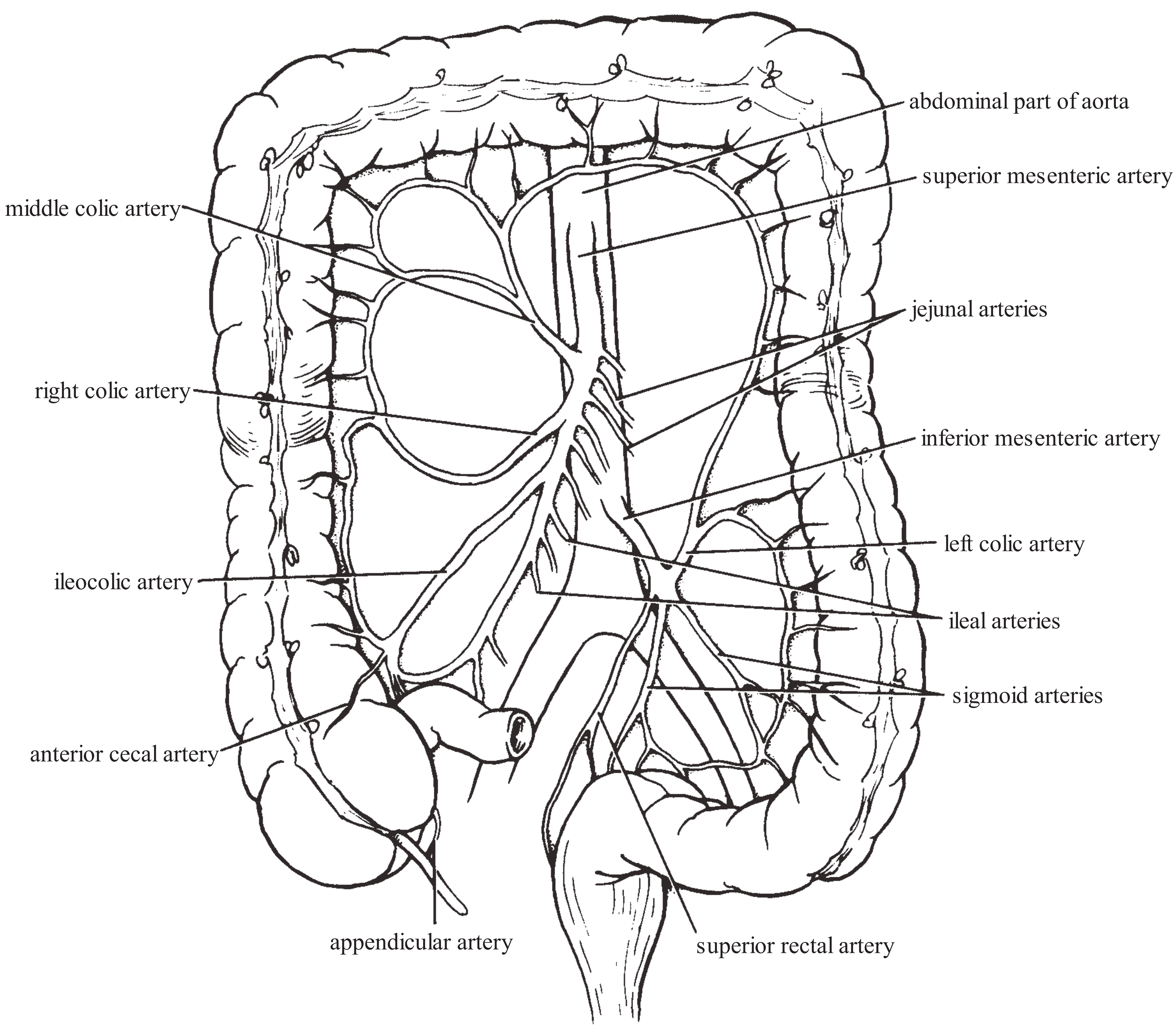


Figure 2-14 The superior and inferior mesenteric arteries and their branches.

cending colon, the transverse colon, the descending colon, the sigmoid colon, the rectum, and the anal canal. (The rectum and the anal canal are discussed in Chapter 3.) The main functions of the large intestine include absorption of water, production of certain vitamins, storage of undigested food materials, and formation and excretion of feces from the body.

CECUM

The cecum is a blind-ended pouch within the right iliac fossa and is completely covered with peritoneum (Fig. 2-11). At the junction of the cecum and the ascending colon, it is joined on the left side by the terminal part of the ileum. The appendix is attached to its posteromedial surface.

Blood Supply

Arteries

Anterior and posterior cecal arteries from the ileocolic artery (Fig. 2-14), which is a branch of the superior mesenteric artery.

Veins

The veins drain into the superior mesenteric vein.

Lymph Drainage

The lymph drains into the mesenteric and superior mesenteric nodes.

Nerve Supply

Sympathetic and vagus nerves, via the superior mesenteric plexus, supply the cecum.

ILEOCECAL VALVE

A rudimentary structure, the ileocecal valve consists of two horizontal folds of mucous membrane that project around the orifice of the ileum. The valve plays little or no part in preventing reflux of cecal contents into the ileum. The circular muscle at the lower end of the ileum (the **ileocecal sphincter**) serves as a sphincter and controls the flow of contents from the ileum into the colon. The smooth muscle tone is reflexively increased when the cecum is distended; the hormone gastrin, which is produced by the stomach, causes relaxation of the muscle tone.

APPENDIX

The appendix (Fig. 2-11) is a narrow, muscular tube with a large amount of lymphoid tissue in its wall. It is attached to the posteromedial surface of the cecum approximately 1 in. (2.5 cm) below the ileocecal junction. It has a complete peritoneal covering, which is attached to the mesentery of the small intestine by a short mesentery of its own called the **mesoappendix.** The mesoappendix contains the appendicular vessels and nerves.

The base of the appendix can be located inside the abdomen by tracing the teniae coli of the cecum and then following them to the appendix, where they converge to form a continuous muscle coat.

CLINICAL NOTES

Variability of Position of Appendix and the Diagnosis of Appendicitis

The inconstancy of the position of the appendix should be borne in mind when attempting to diagnose an appendicitis. A retrocecal appendix, for example, may lie behind the cecum, and it may be difficult to elicit tenderness on palpation in the right iliac region. An appendix hanging down in the pelvis may result in absent abdominal tenderness in the right lower quadrant but deep tenderness may be experienced just above the symphysis pubis. Rectal or vaginal examination may reveal tenderness of the peritoneum in the pelvis on the right side.

Blood Supply

Arteries

Appendicular artery is a branch of the posterior cecal artery (Fig. 2-14).

Veins

The veins drain into the posterior cecal vein.

Lymph Drainage

The lymph drains into nodes in the mesoappendix and eventually into the superior mesenteric lymph nodes.

Nerve Supply

The appendix is supplied by the sympathetic and vagus nerves from the superior mesenteric plexus.

CLINICAL NOTES

Pain of Appendicitis

Visceral pain in the appendix is produced by distention of its lumen or spasm of its muscle. The afferent pain fibers enter the spinal cord at the level of the tenth thoracic segment, and a **vague referred pain** is felt in the region of the umbilicus. Later, the pain shifts to where the inflamed appendix irritates the parietal peritoneum, and then the pain is **precise, severe,** and **localized.**

ASCENDING COLON

The ascending colon is approximately 5 in. (13 cm) in length and extends upward from the cecum to the inferior surface of the right lobe of the liver (Fig. 2-11). Here, it turns to the left (forming the **right colic flexure**) and becomes continuous with the transverse colon. The peritoneum covers the front and the sides of the ascending colon, binding it to the posterior abdominal wall.

Blood Supply

Arteries

The area is supplied by the ileocolic and right colic branches of the superior mesenteric artery (Fig. 2-14).

Veins

The veins drain into the superior mesenteric vein.

Lymph Drainage

The lymph drains into the colic lymph and superior mesenteric nodes.

Nerve Supply

Sympathetic and vagus nerves from the superior mesenteric plexus supply the area.

TRANSVERSE COLON

The transverse colon is approximately 15 in. (38 cm) in length and passes across the abdomen, occupying the umbilical and the hypogastric regions (Fig. 2-11). It begins at the right colic flexure below the right lobe of the liver and hangs downward, suspended by the transverse mesocolon from the pancreas. It then ascends to the left colic flexure below the spleen. The **left colic flexure** is higher than the right colic flexure and is held up by the **phrenicocolic ligament.** The **transverse mesocolon** (or mesentery of the transverse colon) is attached to the superior border of the transverse colon and suspends it from the pancreas; the posterior layers of the greater omentum are attached to the inferior border.

Blood Supply

Arteries

The proximal two thirds of the transverse colon is supplied by the middle colic artery (Fig. 2-14), which is a branch of the superior mesenteric artery. The distal one third is supplied by the left colic artery, which is a branch of the inferior mesenteric artery.

Veins

The veins drain into the superior and the inferior mesenteric veins.

Lymph Drainage

The proximal two thirds drain into the colic nodes and into the superior mesenteric nodes. The distal one third drains into the colic nodes and then the inferior mesenteric nodes.

Nerve Supply

The proximal two thirds is innervated by the sympathetic and the vagal nerves through the superior mesenteric plexus. The distal one third is innervated by the sympathetic and the parasympathetic pelvic splanchnic nerves through the inferior mesenteric plexus.

DESCENDING COLON

The descending colon is approximately 10 in. (25 cm) in length and extends downward from the left colic flexure to the pelvic brim, where it becomes continuous with the sigmoid colon (Fig. 2-11). The peritoneum covers the front and the sides and also binds it to the posterior abdominal wall.

Blood Supply

Arteries

Left colic branch and sigmoid branches of the inferior mesenteric artery (Fig. 2-14) supply the area.

Veins

The veins drain into the inferior mesenteric vein.

Lymph Drainage

The lymph passes to the colic and inferior mesenteric nodes.

Nerve Supply

Sympathetic and parasympathetic pelvic splanchnic nerves through the inferior mesenteric plexus supply the area.

SIGMOID COLON

The sigmoid colon is 10 to 15 in. (25 to 38 cm) in length and begins as a continuation of the descending colon in front of the pelvic brim (Fig. 2-11). Below, it becomes continuous with the rectum in front of the third sacral vertebra. It hangs down into the pelvic cavity in the form of a loop and is attached to the posterior pelvic wall by the fan-shaped **sigmoid mesocolon.**

Blood Supply

Arteries

Sigmoid branches of the inferior mesenteric artery (Fig. 2-14) supply the sigmoid colon.

Veins

The veins drain into the inferior mesenteric vein.

Lymph Drainage

The lymph drains into the colic and inferior mesenteric nodes.

Nerve Supply

Sympathetic and parasympathetic nerves through the inferior hypogastric plexuses supply the area.

Differences between Small and Large Intestines

EXTERNAL DIFFERENCES

- The small intestine is more mobile (except for the duodenum), whereas the ascending and the descending parts of the colon are fixed.
- The small intestine has a mesentery (except for the duodenum), whereas the large intestine is retroperitoneal (except for the transverse colon and sigmoid colon).
- The diameter of the full small intestine is smaller than that of the full large intestine.
- In the small intestine, the longitudinal muscle forms a continuous layer around the gut, whereas in the large intestine (except for the appendix, rectum, and anal canal), the longitudinal muscle forms three bands (the **teniae coli**).
- The small intestine has no fatty tags attached to its wall, whereas the large intestine has the **appendices epiploicae.**
- The wall of the small intestine is smooth, whereas the wall of the large intestine is sacculated.

INTERNAL DIFFERENCES

- The mucous membrane of the small intestine has permanent folds (the **plicae circulares**), whereas the large intestine does not.
- The mucous membrane of the small intestine has **Peyer's patches,** whereas the large intestine has **solitary lymph follicles.**
- The mucous membrane of the small intestine has villi, whereas the large intestine does not.

ACCESSORY ORGANS OF THE GASTROINTESTINAL SYSTEM

Liver

The largest organ in the body, the liver (Fig. 2-10) occupies the upper part of the abdominal cavity just beneath the diaphragm. The liver may be divided into a large **right lobe** and a small **left lobe** by the attachment of the peritoneum of the falciform ligament (Fig. 2-10). The right lobe is further subdivided into a **quadrate lobe** and a **caudate lobe** by the gallbladder, the fissure for the ligamentum teres, the inferior vena cava, and the fissure for the ligamentum venosum.

The liver is completely surrounded by a fibrous capsule but is only partially covered with peritoneum.

PORTA HEPATIS, FISSURES, GROOVES, AND FOSSAE

Porta Hepatis

The porta hepatis (or hilus) of the liver is on the posteroinferior surface of the liver (Fig. 2-10). The upper part of the lesser omentum is attached to its margins. Within the porta hepatis are the right and left hepatic ducts; the right and left branches of the hepatic artery; and the portal vein, nerves, and lymph vessels.

Fissure for the Ligamentum Teres

The fissure that contains the **ligamentum teres** lies between the left lobe and the quadrate lobe (Fig. 2-10). The ligamentum teres is the fibrous remains of the **umbilical vein.**

Fissure for the Ligamentum Venosum

The fissure that contains the **ligamentum venosum** lies between the left lobe and the caudate lobe (Fig. 2-10). The ligamentum venosum is the fibrous remains of the ductus venosus, and the upper part of the lesser omentum is attached to the margins of the fissure.

Groove for the Inferior Vena Cava

The groove for the inferior vena cava lies between the right lobe and the caudate lobe (Fig. 2-10). Here, the hepatic veins join the inferior vena cava.

Fossa for the Gallbladder

The fossa for the gallbladder lies between the right lobe and the quadrate lobe (Fig. 2-10). There is no peritoneum between the gallbladder and the right lobe of the liver.

PERITONEAL LIGAMENTS

Falciform Ligament

The falciform ligament is a two-layered fold of peritoneum that attaches the liver to the diaphragm above and to the anterior abdominal wall below (Fig. 2-10). It has a sickle-shaped free margin that contains the **ligamentum teres** (the remains of the umbilical vein).

Coronary Ligament

The coronary ligament attaches the liver to the diaphragm (Fig. 2-10). The peritoneal layers forming the ligament are widely separated, leaving a "bare area" of liver devoid of a peritoneal covering.

Right Triangular Ligament

The right triangular ligament is a V-shaped fold of peritoneum formed by the right extremity of the coronary ligament (Fig. 2-10). It connects the posterior surface of the right lobe of the liver to the diaphragm.

Left Triangular Ligament

The left triangular ligament is formed by the reflection of the peritoneum from the upper surface of the left lobe of the liver to the diaphragm (Fig. 2-10).

LESSER OMENTUM

The upper end of the lesser omentum is attached to the margins of the porta hepatis and the fissure for the ligamentum venosum. It is attached below to the lesser curvature of the stomach (Fig. 2-9).

BLOOD SUPPLY

The **hepatic artery,** which is a branch of the celiac artery, divides into right and left terminal branches that enter the porta hepatis. The **portal vein** divides into right and left terminal branches that enter the porta hepatis behind the arteries. Three or more **hepatic veins** emerge from the posterior surface of the liver and drain into the inferior vena cava.

LYMPH DRAINAGE

The lymph enters nodes in the porta hepatis and then drains into the celiac nodes. Some lymph passes through the diaphragm to enter the posterior mediastinal nodes.

NERVE SUPPLY

The liver is supplied by sympathetic and parasympathetic (vagal) fibers from the celiac plexus. The left vagus nerve gives rise to a large hepatic branch that travels directly to the liver.

Gallbladder

The gallbladder is a pear-shaped sac lying on the undersurface of the liver (Fig. 2-10). It is divided into a **fundus,** a **body,** and a **neck.** It has a capacity of approximately 30 mL, and it both stores and concentrates bile by absorbing water. The neck is continuous with the cystic duct.

BLOOD SUPPLY

Arteries

The cystic artery, which is a branch of the right hepatic artery, supplies the gallbladder.

Veins

The cystic vein drains into the portal vein.

LYMPH DRAINAGE

The lymph passes to the cystic lymph node near the neck of the gallbladder, then to the hepatic nodes, and finally to the celiac nodes.

NERVE SUPPLY

The gallbladder is supplied by sympathetic and parasympathetic vagal fibers from the celiac plexus. The gallbladder contracts in response to the hormone **cholecystokinin,** which is produced by the mucous membrane of the duodenum on the arrival of food from the stomach.

CLINICAL NOTES

GALLSTONES

Gallstones are usually asymptomatic; however, they can give rise to gallstone colic or produce acute cholecystitis. Biliary colic is usually caused by spasm of the smooth muscle of the wall of the gallbladder. Afferent nerve fibers ascend through the celiac plexus and the greater splanchnic nerves to the thoracic segments of the spinal cord. Referred pain is felt in the right upper quadrant of the epigastrium (T7, 8, and 9 dermatomes).

ACUTE CHOLECYSTITIS

Inflammation of the gallbladder may cause irritation of the subdiaphragmatic parietal peritoneum, which is supplied in part by the phrenic nerve (C3, 4, and 5). This may give rise to referred pain over the shoulder, because the skin in this region is supplied by the supraclavicular nerves (C3 and 4).

Bile Ducts

HEPATIC DUCTS

The **right** and the **left hepatic ducts** emerge from the right and left lobes of the liver in the porta hepatis. Each hepatic duct is formed by the union of small bile ducts (bile canaliculi) within the liver. The **common hepatic duct** is formed by the union of the right and the left hepatic ducts, and it is joined on the right side by the cystic duct from the gallbladder to form the bile duct (Fig. 2-10).

CYSTIC DUCT

The cystic duct is an S-shaped duct that connects the neck of the gallbladder with the common hepatic duct to form the bile duct (Fig. 2-10). The mucous membrane is raised to form a spiral fold (spiral valve) that keeps the lumen constantly open.

BILE DUCT (COMMON BILE DUCT)

The bile duct is formed by the union of the cystic with the common hepatic duct (Fig. 2-13). It runs in the right free margin of the lesser omentum with the portal vein behind and the hepatic artery on the left. It descends in front of the opening into the lesser sac and passes behind the first part of the duodenum and then the head of the pancreas. The bile duct ends below by piercing the medial wall of the duodenum approximately halfway down its length (Fig. 2-13). It is usually joined by the main pancreatic duct, and, together, they open into a small ampulla in the duodenal wall called the **ampulla of Vater.** The ampulla opens into the lumen of the duodenum by means of a small papilla called the **major duodenal papilla** (Fig. 2-13). The terminal parts of both ducts and the ampulla are surrounded by circular smooth muscle called the **sphincter of Oddi.** Occasionally, the bile and the pancreatic ducts open separately into the duodenum.

Pancreas

The pancreas is both an exocrine and an endocrine gland. It is an elongated structure that lies on the posterior abdominal wall behind the stomach and behind the peritoneum. It may be divided into a head, a neck, a body, and a tail (Fig. 2-13). The **head** is disc shaped and lies within the concavity of the C-shaped duodenum. The **uncinate process** is a projection to the left from the lower part of the head behind the superior mesenteric vessels. The **neck** is narrow and connects the head to the body; it lies in front of the beginning of the portal vein. The **body** passes upward and to the left across the midline, and the **tail** extends to the hilus of the spleen in the splenicorenal ligament.

PANCREATIC DUCTS

The **main pancreatic duct** opens into the second part of the duodenum with the bile duct on the major duodenal papilla (Fig. 2-13). The main duct also sometimes drains separately into the duodenum. The **accessory duct** (if present) drains the upper part of the head and opens into the duodenum on the **minor duodenal papilla.**

BLOOD SUPPLY

Arteries

The splenic artery and the superior and inferior pancreaticoduodenal arteries supply the pancreas.

Veins

The pancreatic veins drain into the portal vein.

LYMPH DRAINAGE

The lymph nodes are situated along the arteries and drain into the celiac and the superior mesenteric nodes.

NERVE SUPPLY

Sympathetic and parasympathetic vagal nerve fibers from the celiac plexus supply the pancreas.

Spleen

The spleen is the largest single mass of lymphoid tissue in the body (Fig. 2-13). It lies just beneath the left half of the diaphragm close to the ninth, the tenth, and the eleventh ribs. The spleen is ovoid in shape, with a notched anterior border. It is surrounded by peritoneum that passes from the hilus to the stomach as the **gastrosplenic omentum** (ligament) and to the left kidney as the **splenicorenal ligament** (Fig. 2-9). The gastrosplenic omentum contains the short gastric and the left gastroepiploic vessels, and the splenicorenal ligament contains the splenic vessels and the tail of the pancreas.

BLOOD SUPPLY

Artery

The large splenic artery, which is a branch of the celiac artery (Fig. 2-12), supplies the spleen.

Vein

The splenic vein joins the superior mesenteric vein to form the portal vein.

BLOOD SUPPLY OF THE GASTROINTESTINAL VISCERA

The **celiac artery** is the artery of the foregut, and it supplies the gastrointestinal tract from the lower third of the esophagus down to the middle of the second part of the duodenum (Fig. 2-12). The **superior mesenteric artery** is the artery of the midgut, and it supplies the gastrointestinal tract from the middle of the second part of the duodenum to the distal third of the transverse colon (Fig. 2-14). The **inferior mesenteric artery** is the artery of the hindgut, and it supplies the large intestine from the distal third of the transverse colon to halfway down the anal canal.

Celiac Artery (Trunk)

The celiac artery is a short, large artery that arises from the front of the abdominal aorta as it emerges through the diaphragm (Fig. 2-12). It has three terminal branches: the left gastric, the splenic, and the hepatic arteries.

LEFT GASTRIC ARTERY

The left gastric artery is a small artery that runs to the cardiac end of the stomach, gives off a few esophageal branches, and then turns to the right along the lesser curvature of the stomach. It anastomoses with the right gastric artery.

SPLENIC ARTERY

The splenic artery is the largest branch of the celiac trunk, and it runs to the left in a wavy course along the upper border of the pancreas and behind the stomach. On reaching the left kidney, it enters the splenicorenal ligament and runs to the hilum of the spleen.

Branches

- **Pancreatic branches.**
- **Left gastroepiploic artery:** This arises near the hilum of the spleen and reaches the greater curvature of the stomach in the gastrosplenic omentum. In the greater omentum, it passes to the right along the greater curvature of the

stomach. It anastomoses with the right gastroepiploic artery.
- **Short gastric arteries:** Five or six in number, these pass to the fundus of the stomach in the gastrosplenic omentum. They anastomose with the left gastric artery and the left gastroepiploic artery.

HEPATIC ARTERY

The hepatic artery* runs forward and ascends within the lesser omentum (Fig. 2-12). It lies in front of the opening into the lesser sac, and it is placed to the left of the bile duct and in front of the portal vein. At the porta hepatis, it divides into right and left branches that supply the corresponding lobes of the liver.

Branches

- **Right gastric artery:** This runs to the pylorus and then to the left in the lesser omentum along the lesser curvature of the stomach. It anastomoses with the left gastric artery.
- **Gastroduodenal artery:** This descends behind the first part of the duodenum. It divides into the **right gastroepiploic artery,** which runs along the greater curvature of the stomach in the greater omentum, and the **superior pancreaticoduodenal artery,** which descends between the second part of the duodenum and the head of the pancreas.
- **Right and left hepatic arteries:** These run to the right and the left lobes of the liver. The right hepatic artery usually gives off the **cystic artery,** which runs to the neck of the gallbladder.

Superior Mesenteric Artery

The superior mesenteric artery arises from the front of the abdominal aorta behind the neck of the pancreas (Fig. 2-14). It runs downward in front of the uncinate process of the pancreas and in front of the third part of the duodenum. It then continues downward to the right in the root of the mesentery of the small intestine.

BRANCHES

- **Inferior pancreaticoduodenal artery:** This passes to the right as a single or a double branch along the upper border of the third part of the duodenum and below the head of the pancreas.
- **Middle colic artery:** This runs into the transverse mesocolon to supply the transverse colon (Fig. 2-14). It divides into a right branch, which anastomoses with the right colic artery, and a left branch, which anastomoses with the left colic artery.
- **Right colic artery:** This is often a branch of the ileocolic artery (Fig. 2-14). It passes to the right to supply the ascending colon.
- **Ileocolic artery:** This passes downward and to the right (Fig. 2-14). It gives rise to a **superior branch,** which anastomoses with the right colic artery, and an **inferior branch,** which anastomoses with the end of the superior mesenteric artery. The inferior branch gives rise to the **anterior** and the **posterior cecal arteries;** the **appendicular artery** is a branch of the posterior cecal artery.
- **Jejunal and ileal branches:** There are 12 to 15 of these, which arise from the left side of the superior mesenteric artery (Fig. 2-14). Each artery divides into branches that unite with adjacent branches to form arcades. Small, straight branches supply the intestine.

Inferior Mesenteric Artery

The inferior mesenteric artery arises from the abdominal aorta approximately 1.5 in. (3.8 cm) above its bifurcation (Fig. 2-14). This artery runs downward and to the left, and it crosses the left common iliac artery. Here, its name is changed to the superior rectal artery.

BRANCHES

- **Left colic artery:** This divides into ascending and descending branches that supply the distal third of the transverse colon, the left colic flexure, and the upper part of the descending colon (Fig. 2-14).
- **Sigmoid arteries:** Two or three in number, these supply the descending and the sigmoid colon (Fig. 2-14).
- **Superior rectal artery:** This is a continuation of the inferior mesenteric artery, and it descends into the pelvis behind the rectum (Fig. 2-14). It supplies the rectum and the upper half of the anal canal, and it anastomoses with the middle and the inferior rectal arteries that arise from the internal iliac and the internal pudendal arteries, respectively.

Marginal Artery

The colic arteries anastomose around the concave margin of the large intestine, where they form a single arterial trunk called the **marginal artery.** The marginal artery begins at the ileocolic junction and ends at the junction of the sigmoid colon and the rectum.

Portal Venous System

PORTAL VEIN

The portal vein is approximately 2 in. (5 cm) in length and is formed behind the neck of the pancreas by the union of the superior mesenteric and the splenic veins (Fig. 2-15). It ascends to the porta hepatis behind the first part of the duodenum and in the free margin of the lesser omentum. In the porta hepatis, it then divides into right and left terminal branches.

*The hepatic artery is sometimes divided into the **common hepatic artery,** which extends from its origin to the gastroduodenal branch, and the **hepatic artery proper,** which is the remainder of the artery.

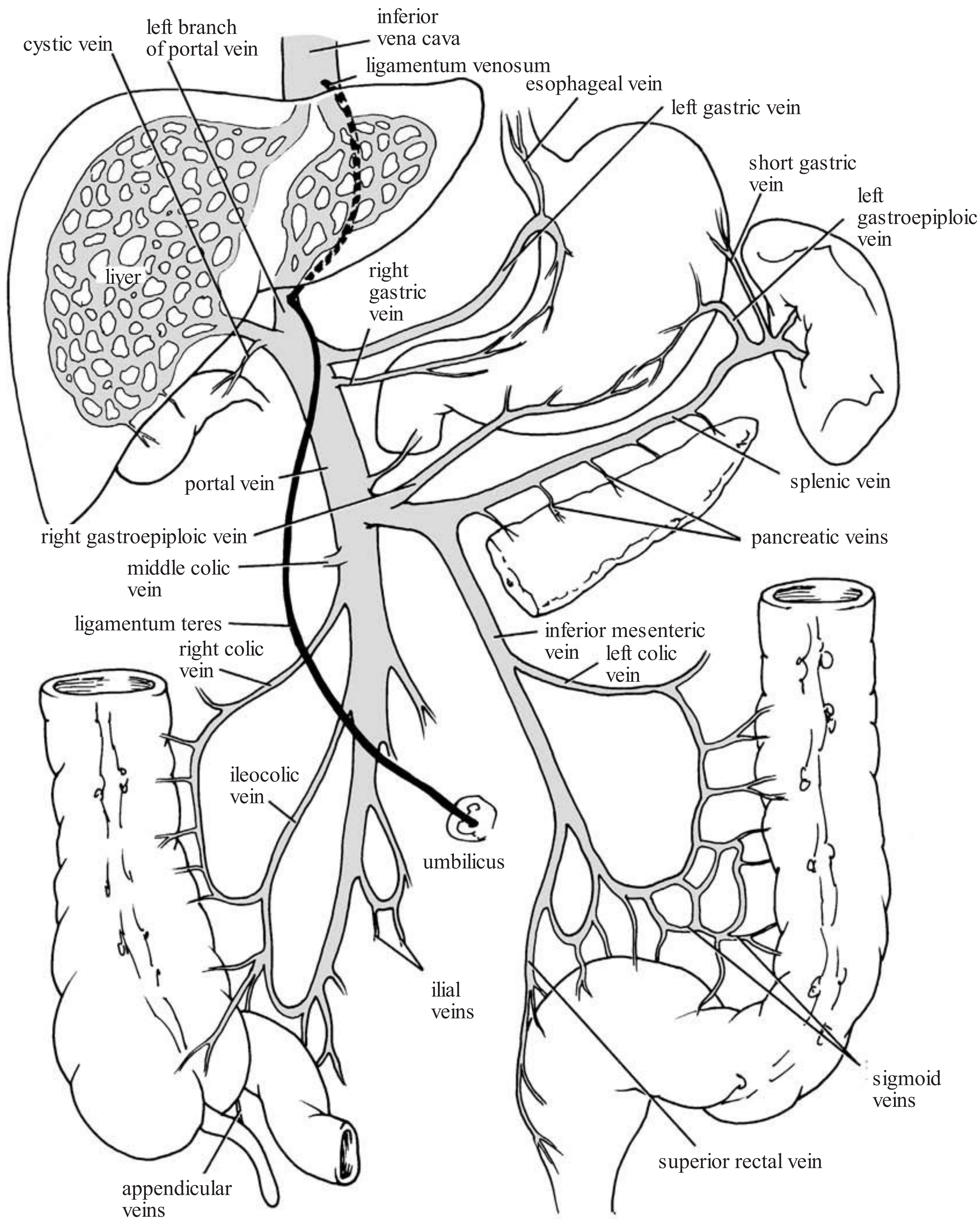


Figure 2-15 Tributaries of the portal vein.

The portal vein drains blood from the gastrointestinal tract (from the lower end of the esophagus to halfway down the anal canal) as well as from the pancreas, the gallbladder, the bile ducts, and the spleen.

TRIBUTARIES

- **Splenic vein:** This leaves the spleen and unites with the superior mesenteric vein behind the neck of the pancreas to form the portal vein (Fig. 2-15). It receives the short gastric, the left gastroepiploic, the inferior mesenteric, and the pancreatic veins.
- **Inferior mesenteric vein:** This ascends on the posterior abdominal wall and joins the splenic vein behind the body of the pancreas (Fig. 2-15). It receives the superior rectal, the sigmoid, and the left colic veins.
- **Superior mesenteric vein:** This ascends in the root of the mesentery of the small intestine on the right side of the

artery. It passes in front of the third part of the duodenum, and it joins the splenic vein behind the neck of the pancreas (Fig. 2-15). It receives the jejunal, the ileal, the ileocolic, the right and middle colic, the inferior pancreaticoduodenal, and the right gastroepiploic veins.
- **Left gastric vein:** This drains the left portion of the lesser curvature of the stomach and the distal part of the esophagus. It opens directly into the portal vein (Fig. 2-15).
- **Right gastric vein:** This drains the right portion of the lesser curvature of the stomach. It drains directly into the portal vein (Fig. 2-15).
- **Cystic veins:** These drain the gallbladder either directly into the liver or join with the portal vein (Fig. 2-15).

CLINICAL NOTES

PORTAL–SYSTEMIC ANASTOMOSES

Portal–systemic anastomoses are important in patients with cirrhosis of the liver and in whom the portal vein may be obstructed.

- At the lower third of the esophagus, the esophageal branches of the left gastric vein (the portal tributary) anastomose with the esophageal veins draining the middle third of the esophagus into the azygos veins (the systemic tributaries).
- Halfway down the anal canal, the superior rectal veins (the portal tributaries) draining the upper half of the anal canal anastomose with the middle and the inferior rectal veins (the systemic tributaries).
- The **paraumbilical veins** connect the left branch of the portal vein with the superficial veins of the anterior abdominal wall (the systemic tributaries). The paraumbilical veins travel in the falciform ligament, and they accompany the ligamentum teres.
- The veins of the ascending and descending colon, the duodenum, the pancreas, and the liver (the portal tributaries) anastomose with the renal, the lumbar, and the phrenic veins (the systemic tributaries).

KIDNEYS AND URETERS

Kidneys

The kidneys are paired organs that lie behind the peritoneum high up on the posterior abdominal wall on either side of the vertebral column (Fig. 2-16). The right kidney is slightly lower than the left kidney because of the large size of the right lobe of the liver. With contraction of the diaphragm during respiration, both kidneys move by as much as 1 in. (2.5 cm) downward in a vertical direction. On the medial concave border of each kidney is the **hilus,** which extends into a large cavity (the **renal sinus**). The hilus transmits the renal pelvis, the renal artery, the renal vein, and the sympathetic nerve fibers. The kidneys have the following coverings:

- **Fibrous capsule:** This is closely applied to its outer surface.
- **Perirenal fat:** This is fat that covers the fibrous capsule.
- **Renal fascia:** This is a condensation of areolar tissue outside the perirenal fat. It encloses the kidneys and the suprarenal glands.
- **Pararenal fat:** This is external to the renal fascia and is often large in amount.

The perirenal fat, the renal fascia, and the pararenal fat support the kidneys and hold them in position on the posterior abdominal wall.

RENAL STRUCTURE

The outer **cortex** is dark brown in color, and the inner **medulla** is light brown. The medulla is composed of approximately 12 **renal pyramids,** each having its base oriented toward the cortex and its apex (the **renal papilla**) projecting medially (Fig. 2-17). The cortex extends into the medulla between adjacent pyramids as the **renal columns**. Extending from the bases of the renal pyramids into the cortex are striations called **medullary rays.**

Within the renal sinus, the upper expanded end of the ureter (the **renal pelvis**) divides into two or three **major calyces,** each of which in turn divides into two or three **minor calyces** (Fig. 2-17). Each minor calyx is indented by the apex of the renal pyramid (the **renal papilla**).

BLOOD SUPPLY

Artery

The renal artery, which is a branch of the aorta, supplies the kidneys.

Vein

The renal vein drains into the inferior vena cava.

LYMPH DRAINAGE

The lymph drains into the lateral aortic lymph nodes around the origin of the renal artery.

NERVE SUPPLY

The renal sympathetic plexus supplies the kidneys.

Ureters

The two ureters are muscular tubes that extend from the kidneys to the posterior surface of the urinary bladder (Fig. 2-16). Each ureter measures approximately 10 in. (25 cm) in length and has an upper expanded end called the **renal pelvis.** The renal pelvis lies within the hilus of the kidney, where it receives the major calyces.

CLINICAL NOTES

URETERIC CONSTRICTIONS AND STONES

Ureteric stones may be arrested at the following sites:

- Where the renal pelvis joins the ureter.
- Where the ureter is kinked as it crosses the pelvic brim to enter the pelvis.
- Where the ureter pierces the bladder wall.

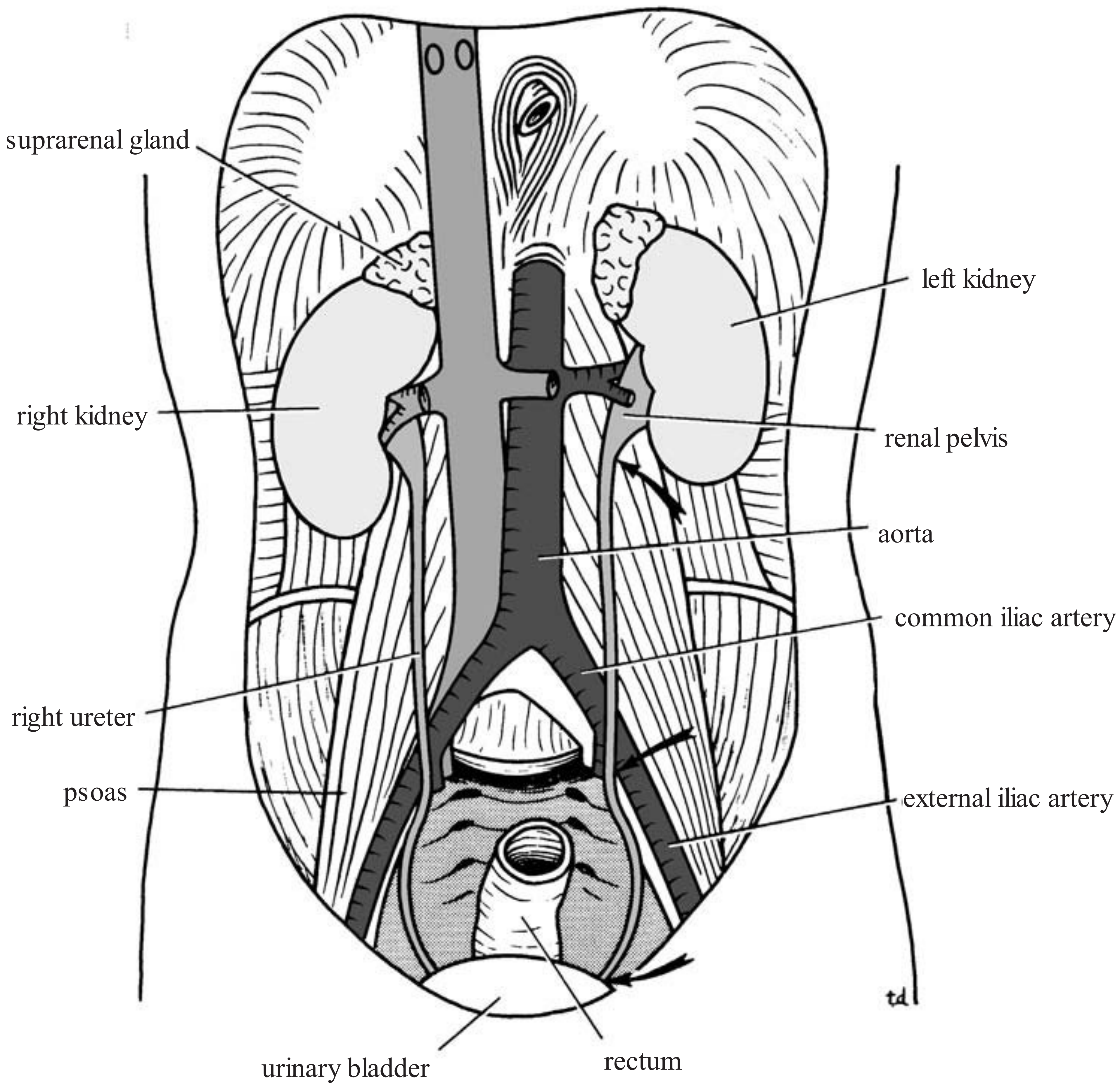


Figure 2-16 Posterior abdominal wall and the kidneys and ureter in situ. Arrows indicate three sites where the ureter is narrowed.

BLOOD SUPPLY

Arteries

- **Upper end:** The renal artery.
- **Middle portion:** The testicular or the ovarian artery.
- **Inferior end:** The superior vesical artery.

Veins

The veins of the kidney correspond to the relevant arteries.

LYMPH DRAINAGE

The lymph drains into the lateral aortic and iliac nodes.

NERVE SUPPLY

The renal, testicular (or ovarian), and hypogastric plexuses supply the kidney.

CLINICAL NOTES

RENAL PAIN

Renal pain varies from a dull ache to a severe pain in the flank that may radiate downward into the lower abdomen. Renal pain can result from stretching of the kidney capsule or spasm of the smooth muscle in the renal pelvis. Afferent nerve fibers ascend through the renal plexus and reach the spinal cord through the lowest splanchnic nerve and the sympathetic trunk. They enter the spinal cord at the level of T12. Pain is commonly referred along the distribution of the subcostal nerve (T12) to the flank and the anterior abdominal wall.

RENAL COLIC

In renal colic, strong peristaltic waves of contraction pass down the ureter in an attempt to pass a stone onward. The afferent nerves from the ureter enter the spinal cord at segments T11 and 12 and L1 and 2. The spasm of the smooth muscle of the ureter causes an agonizing colicky pain, which is referred to the skin areas that are supplied by these segments of the spinal cord—namely, the flank, loin, and groin.

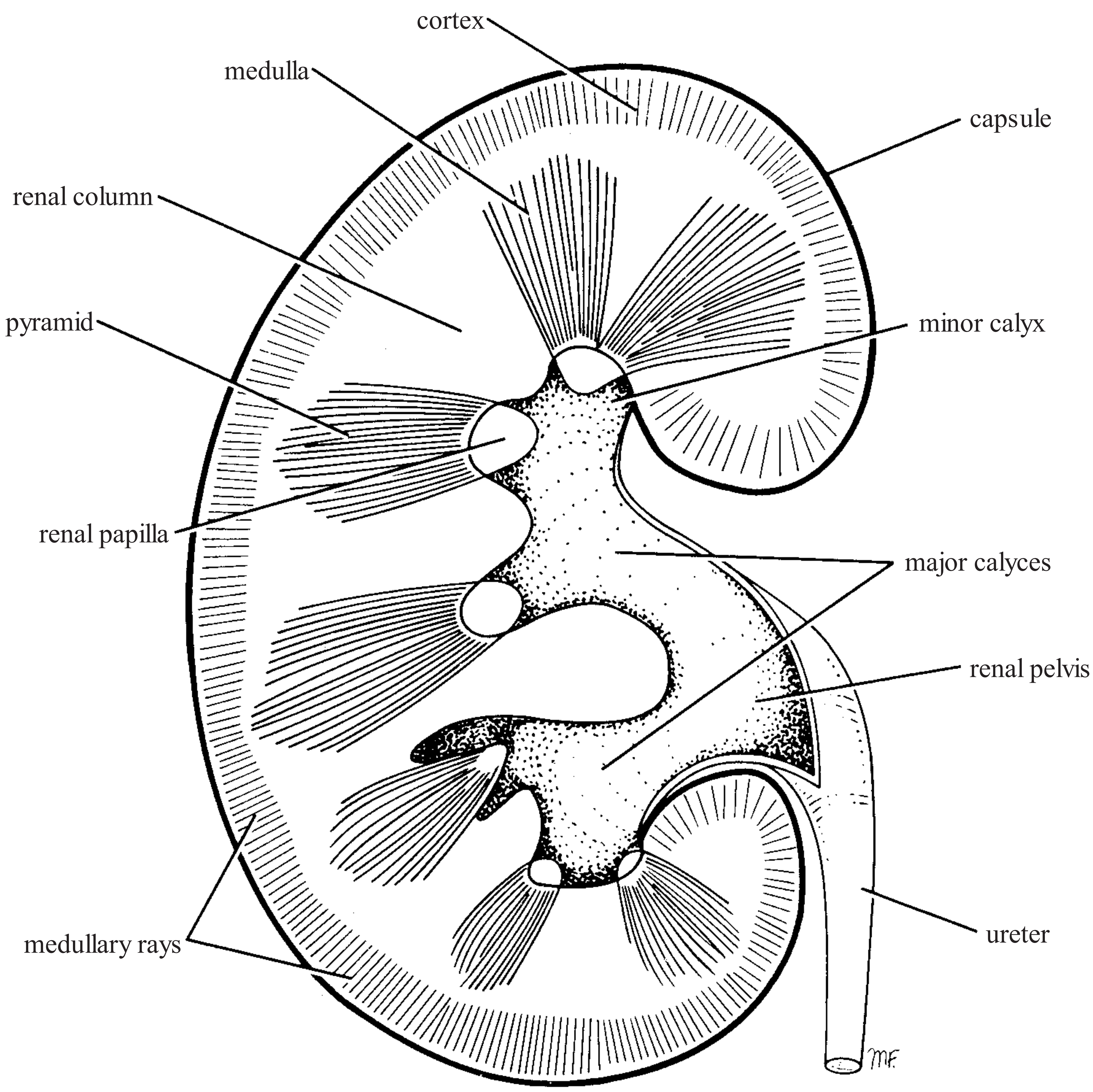


Figure 2-17 Longitudinal section through the kidney showing the cortex, the medulla, the pyramids, the renal papillae, and the calyces.

SUPRARENAL (ADRENAL) GLANDS

The two suprarenal glands are located close to the upper poles of the kidneys on the posterior abdominal wall (Fig. 2-16). They are retroperitoneal and surrounded by renal fascia, but they are separated from the kidneys by the perirenal fat. Each gland has a yellow-colored **cortex** and a dark brown **medulla.**

Blood Supply

ARTERIES

Branches from the inferior phrenic artery, the aorta, and the renal arteries supply these glands.

VEINS

There is a single vein on each side. The right suprarenal vein drains into the inferior vena cava; the left suprarenal vein drains into the left renal vein.

Lymph Drainage

The lymph drains into the lateral aortic nodes.

Nerve Supply

Numerous preganglionic sympathetic nerves from splanchnic nerves supply the suprarenal glands. The majority of these fibers end on cells in the suprarenal medulla.

AORTA AND INFERIOR VENA CAVA

Abdominal Aorta

The aorta enters the abdomen through the aortic opening of the diaphragm in front of the twelfth thoracic vertebra (Fig. 2-18). It descends on the anterior surfaces of the bodies of the lumbar vertebrae, and it divides into the two common iliac arteries in front of the fourth lumbar vertebra.

BRANCHES

- Three anterior visceral branches: the celiac artery, superior mesenteric artery, and inferior mesenteric artery.
- Three lateral visceral branches: the suprarenal artery, renal artery, and testicular or the ovarian artery.
- Five lateral abdominal branches: the inferior phrenic artery and four lumbar arteries.
- Three terminal arteries: two common iliac arteries and the median sacral artery.

Common Iliac Arteries

The right and the left common iliac arteries are the terminal branches of the abdominal aorta (Fig. 2-18). They run downward and laterally to end opposite the sacroiliac joint by dividing into the external and the internal iliac arteries. At the bifurcation, the common iliac artery is crossed anteriorly by the ureter on each side.

Inferior Vena Cava

The inferior vena cava is formed by the union of the common iliac veins at the level of the fifth lumbar vertebra (Fig. 2-18). It ascends on the right side of the aorta, pierces the central tendon of the diaphragm at the level of the eighth thoracic vertebra, and drains into the right atrium of the heart.

TRIBUTARIES

- Two anterior visceral tributaries (the hepatic veins).
- Three lateral visceral tributaries: the right suprarenal vein (the left vein drains into the left renal vein), renal veins, and right testicular or ovarian vein (the left vein drains into the left renal vein).
- Five lateral abdominal wall tributaries: the inferior phrenic vein and four lumbar veins.
- Three veins of origin: two common iliac veins and the median sacral vein.

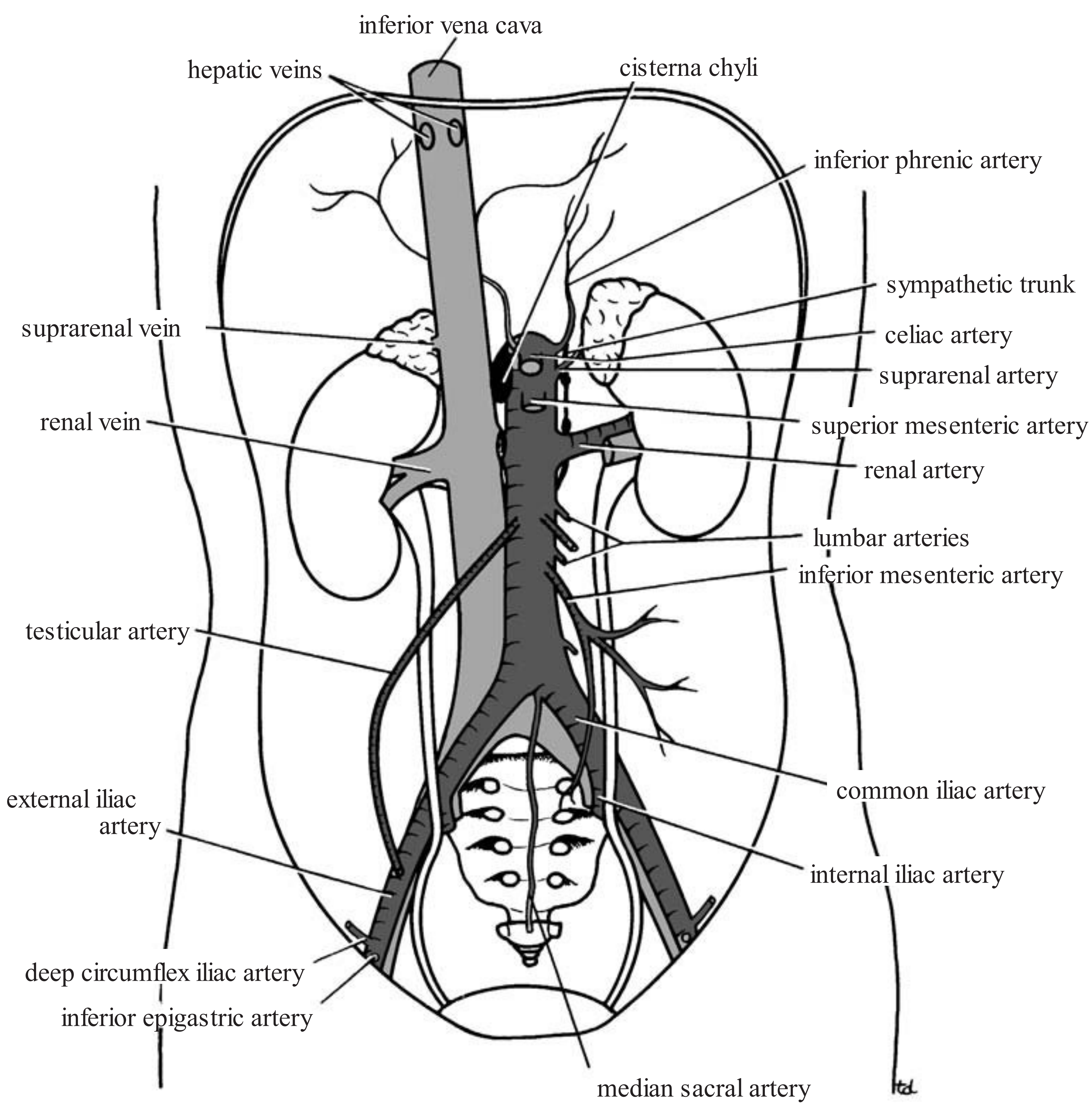
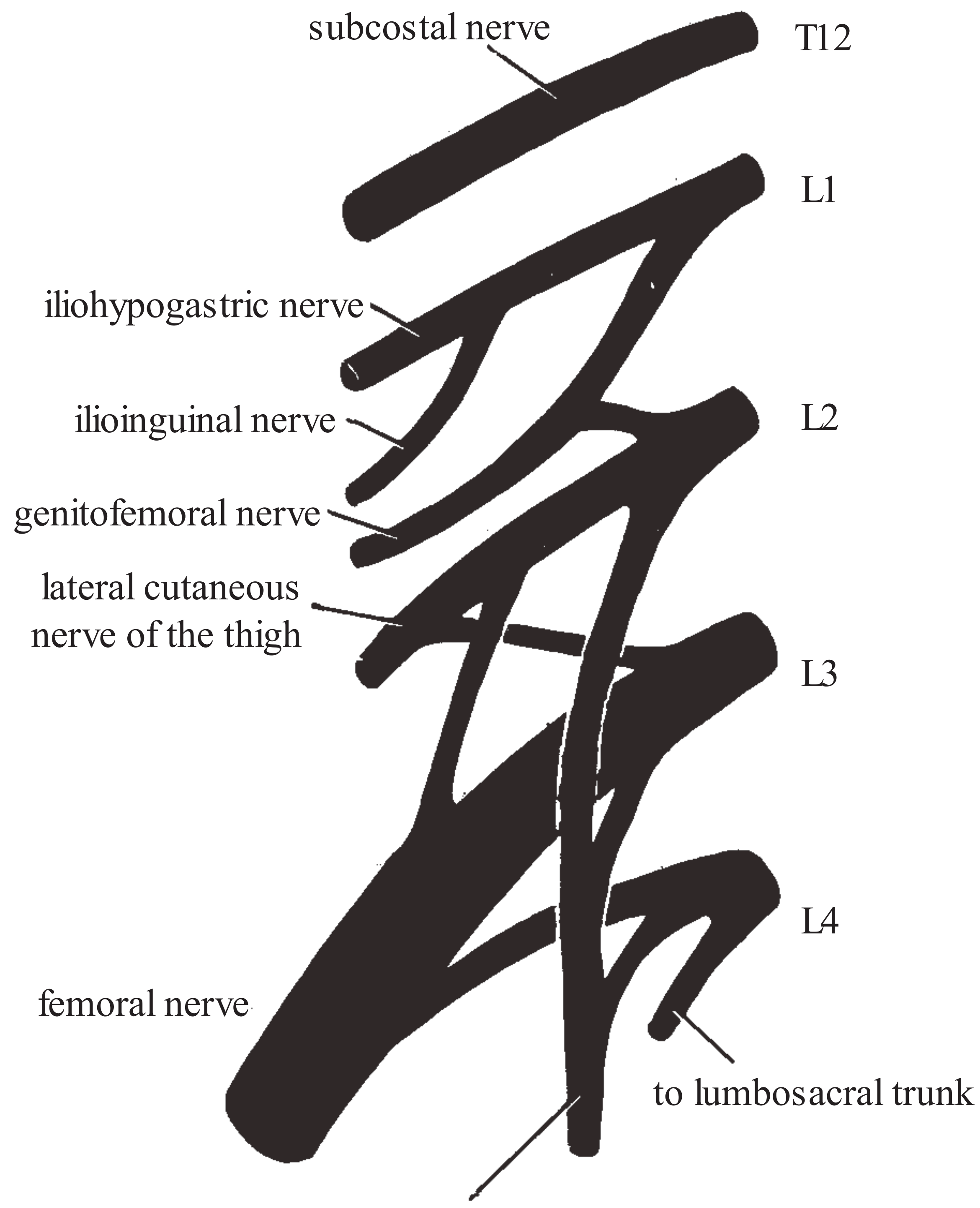


Figure 2-18 The aorta and the inferior vena cava.



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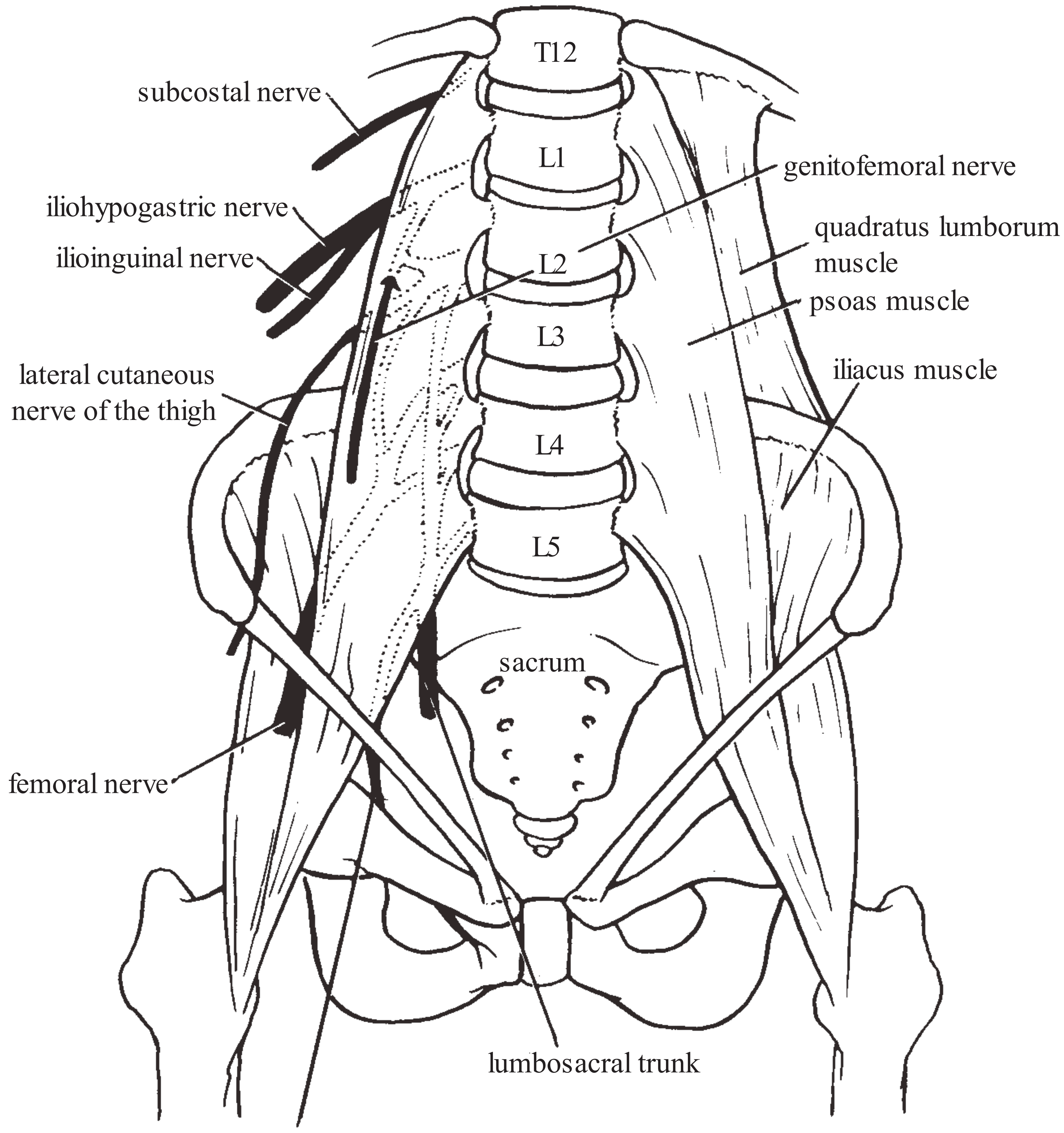


B

Figure 2-19 A. The lumbar plexus and its main branches. B. The lumbar plexus and its branches on the posterior abdominal wall.

CLINICAL NOTES

Compression of the Inferior Vena Cava

During the later stages of pregnancy, the enlarged uterus commonly presses on the inferior vena cava, producing edema of the ankles and feet and temporary varicosed veins.

Malignant retroperitoneal tumors can cause severe compression and eventual blockage of the inferior vena cava. This results in the dilatation of the extensive anastomoses of the communicating veins joining the inferior vena cava to the superior vena cava. The alternative pathway for the blood to return to the right atrium of the heart is referred to as the **caval–caval shunt.** The same pathway comes into effect in patients with a superior mediastinal tumor compressing the superior vena cava. Clinically, the enlarged subcutaneous anastomosis between the lateral thoracic vein, a tributary of the axillary vein, and the superficial epigastric vein, a tributary of the femoral vein, may be seen on the thoracoabdominal wall.

LYMPHATICS ON THE POSTERIOR ABDOMINAL WALL

Lymph Nodes

The lymph nodes form a preaortic and a right and left lateral aortic chain.

PREAORTIC LYMPH NODES

The preaortic lymph nodes are on the anterior surface of the abdominal aorta. Their efferent vessels form the **intestinal trunk,** which drains into the cisterna chyli. These nodes are divided into the **celiac,** the **superior mesenteric,** and the **inferior mesenteric groups,** which lie close to the origins of these arteries.

LATERAL AORTIC (PARA-AORTIC, LUMBAR) NODES

The lateral aortic nodes are the right and left groups that lie alongside the abdominal aorta. Their efferent vessels form the **right** and **left lumbar trunks** that drain into the cisterna chyli.

Cisterna Chyli

The **thoracic duct** commences in the abdomen as an elongated sac (the cisterna chyli), which lies on the right side of the aorta in front of the first two lumbar vertebrae. The cisterna chyli receives the intestinal trunk, the right and left lumbar trunks, and the lymph vessels that descend from the lower part of the thorax.

NERVES

Lumbar Plexus

The lumbar plexus is formed by the anterior rami of the upper four lumbar nerves (Fig. 2-19). It is situated within the psoas muscle, and its branches emerge from the lateral border, the medial border, and the anterior surface of the muscle.

BRANCHES OF THE LUMBAR PLEXUS ON THE POSTERIOR ABDOMINAL WALL

The branches of the lumbar plexus and their distribution are summarized in Table 2-2.

Table 2-2 Branches of the Lumbar Plexus and Their Distribution

Branches	Distribution
Iliohypogastric nerve (L1)	External oblique, internal oblique, transversus abdominis muscles of anterior abdominal wall; skin over lower anterior abdominal wall and buttock
Ilioinguinal nerve (L1)	External oblique, internal oblique, transversus abdominis muscles of anterior abdominal wall; skin of upper medial aspect of thigh; root of penis and scrotum in males and mons pubis and labia majora in females
Lateral cutaneous nerve of thigh (L2, 3)	Skin of anterior and lateral surfaces of the thigh
Genitofemoral nerve (L1, 2)	Cremaster muscle in scrotum in male; skin over anterior surface of thigh; nervous pathway for cremasteric reflex
Femoral nerve (L2, 3, 4)	Iliacus, pectineus, sartorius, quadriceps femoris muscles; intermediate cutaneous branches to the skin of the anterior surface of the thigh and by saphenous branch to the skin of the medial side of the leg and foot; articular branches to hip and knee joints
Obturator nerve (L2, 3, 4)	Gracilis, adductor brevis, adductor longus, obturator externus, pectineus, adductor magnus (adductor portion); skin on medial surface of thigh; articular branches to hip and knee joints
Segmental branches	Quadratus lumborum and psoas muscles

Iliohypogastric Nerve (L1)

The iliohypogastric nerve emerges from the lateral border of the psoas (Fig. 2-19). It runs forward to supply the transversus abdominis, the internal and external oblique muscles, and the skin above the inguinal ligament.

Ilioinguinal Nerve (L1)

The ilioinguinal nerve emerges from the lateral border of the psoas (Fig. 2-19). It runs forward through the inguinal canal and exits through the superficial inguinal ring. It supplies the transversus abdominis, internal oblique, and external oblique muscles. It also supplies the skin just above the symphysis pubis and the scrotum or labium majus.

Lateral Cutaneous Nerve of the Thigh (L2 and 3)

The lateral cutaneous nerve of the thigh emerges from the lateral border of the psoas, crosses the iliacus muscle, and enters the thigh behind the inguinal ligament (Fig. 2-19).

Femoral Nerve (L2, 3, and 4)

The femoral nerve is the largest branch of the lumbar plexus (Fig. 2-19). It emerges from the lateral border of the psoas and descends between the psoas and the iliacus muscles to enter the thigh lateral to the femoral vessels.

Genitofemoral Nerve (L1 and 2)

The genitofemoral nerve emerges on the anterior surface of the psoas muscle (Fig. 2-19). It divides into a **genital branch,** which supplies the cremaster muscle, and a **femoral branch,** which supplies a small area of skin in the thigh.

Obturator Nerve (L2, 3, and 4)

The obturator nerve emerges from the medial border of the psoas muscle. It runs forward on the lateral wall of the pelvis and enters the thigh through the obturator foramen (Fig. 2-19).

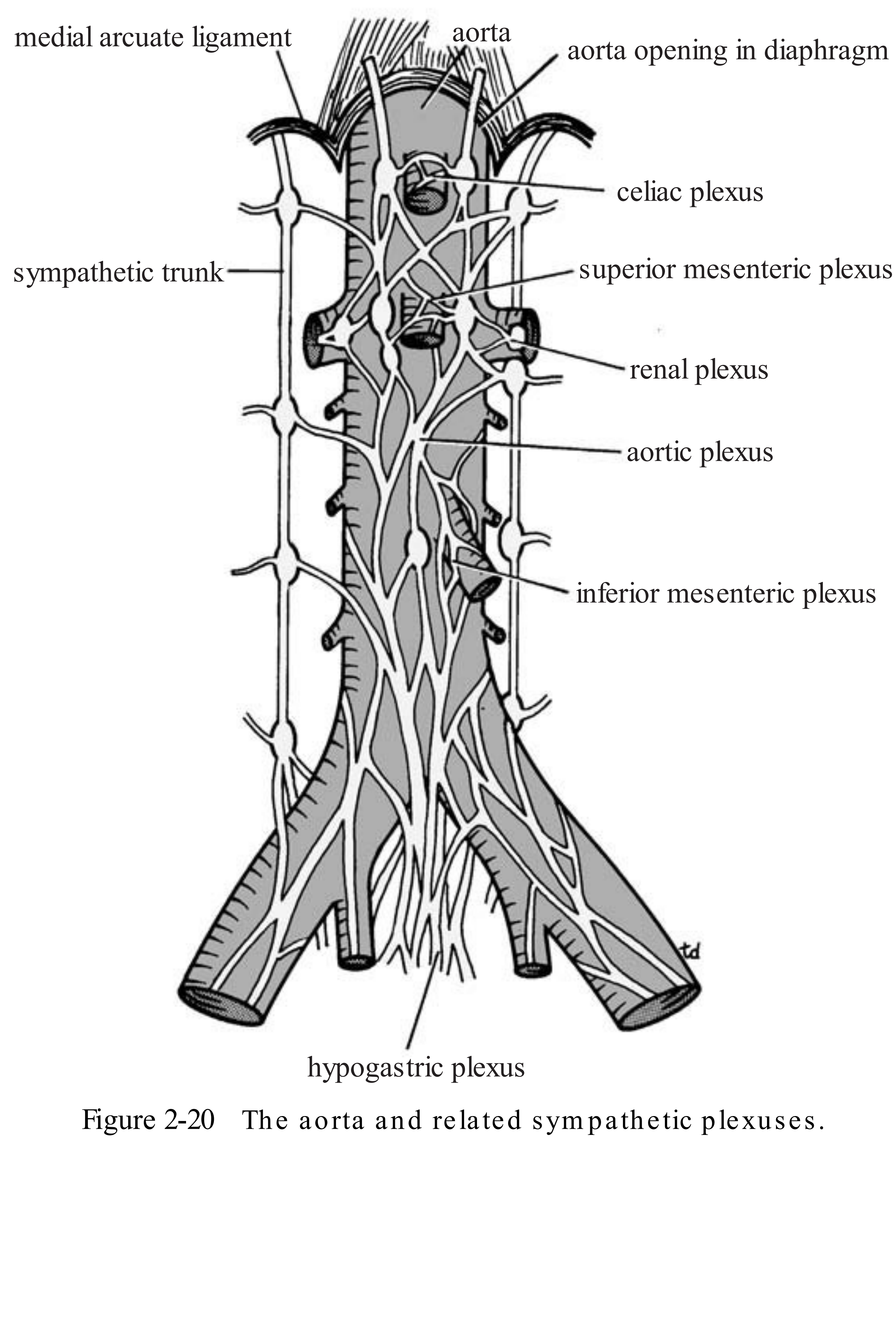


Figure 2-20 The aorta and related sympathetic plexuses.

Abdominal Part of the Sympathetic Trunk and Autonomic Plexuses

SYMPATHETIC TRUNK

The abdominal part of the sympathetic trunk is continuous with the thoracic part above and with the pelvic part of the sympathetic trunk below. It runs downward along the medial border of the psoas muscle on the bodies of the lumbar vertebrae. It enters the abdomen from behind the medial arcuate ligament, and it gains entrance to the pelvis below by passing behind the common iliac vessels. The sympathetic trunk possesses four or five segmentally arranged ganglia (Fig. 2-20)

BRANCHES

- **White rami communicantes** join the first two ganglia with the first two lumbar spinal nerves. A white ramus contains preganglionic and afferent sensory nerve fibers.
- **Gray rami communicantes** join each ganglion to a corresponding lumbar spinal nerve. A gray ramus contains postganglionic nerve fibers.
- Fibers pass medially to the sympathetic plexuses on the abdominal aorta and its branches. (These plexuses also receive fibers from the splanchnic and the vagus nerves.)
- Fibers pass downward and medially to enter the pelvis, where together with branches from the sympathetic nerves in front of the aorta they form a large bundle of nerve fibers called the **superior hypogastric plexus.**

CELIAC PLEXUS

The celiac plexus is situated around the root of the celiac artery (Fig. 2-20). It receives sympathetic fibers from the greater and lesser splanchnic nerves and parasympathetic fibers from the vagus nerve. Branches from the plexus are distributed along branches of the celiac artery.

SUPERIOR MESENTERIC PLEXUS

The superior mesenteric plexus is situated around the root of the superior mesenteric artery (Fig. 2-20). It is continuous above with the celiac plexus, and it receives a branch from the right vagus nerve. Branches from the plexus are distributed along branches of the superior mesenteric artery.

INFERIOR MESENTERIC PLEXUS

The inferior mesenteric plexus is situated around the root of the inferior mesenteric artery (Fig. 2-20). It is continuous with the aortic plexus, and it receives branches from the lumbar part of the sympathetic trunk and parasympathetic fibers from the pelvic splanchnic nerve. Branches from the plexus are distributed along branches of the inferior mesenteric artery.

AORTIC PLEXUS

The aortic plexus is a continuous plexus around the abdominal aorta (Fig. 2-20). Regional concentrations are known as the celiac, the renal, the superior mesenteric, and the inferior mesenteric plexuses.

MUSCLES OF THE POSTERIOR ABDOMINAL WALL

The muscles of the posterior abdominal wall are summarized in Table 2-3.

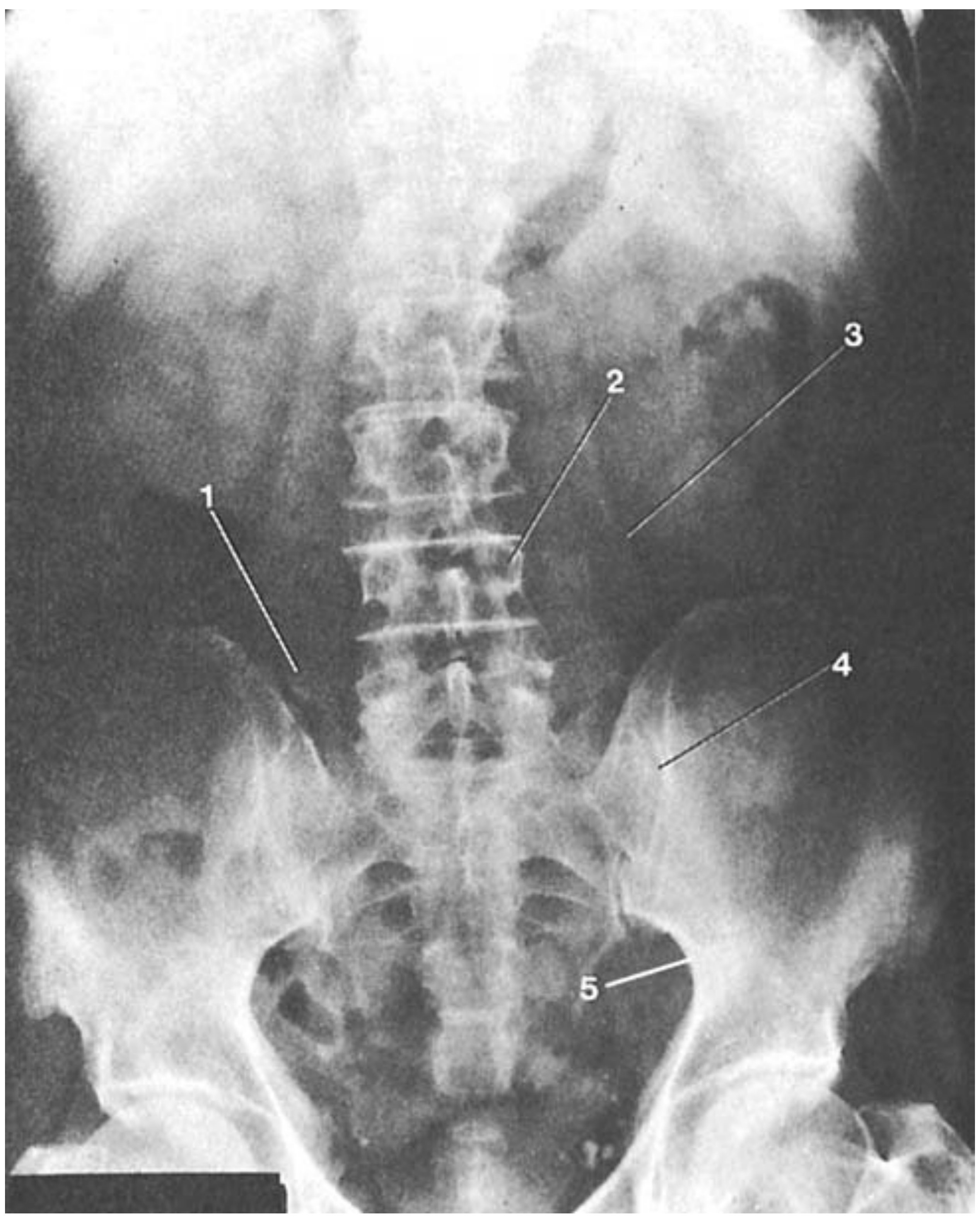
Table 2-3 Muscles of the Posterior Abdominal Wall

Name of Muscle	Origin	Insertion	Nerve Supply	Action
Psoas	Transverse processes, bodies, and intervertebral discs of twelfth thoracic and five lumbar vertebrae	With iliacus into lesser trochanter of femur	Lumbar plexus	Flexes thigh on trunk; if thigh is fixed, flexes the trunk on the thigh (as in sitting up from lying down)
Quadratus lumborum	Iliolumbar ligament, iliac crest, transverse processes of lower lumbar vertebrae	Twelfth rib	Lumbar plexus	Depresses twelfth rib during respiration; laterally flexes vertebral column to same side
Iliacus	Iliac recess	With psoas into lesser trochanter of femur	Femoral nerve	Flexes thigh on trunk; if thigh is fixed, flexes the trunk on the thigh (as in sitting up from lying down)

REVIEW

Matching Questions

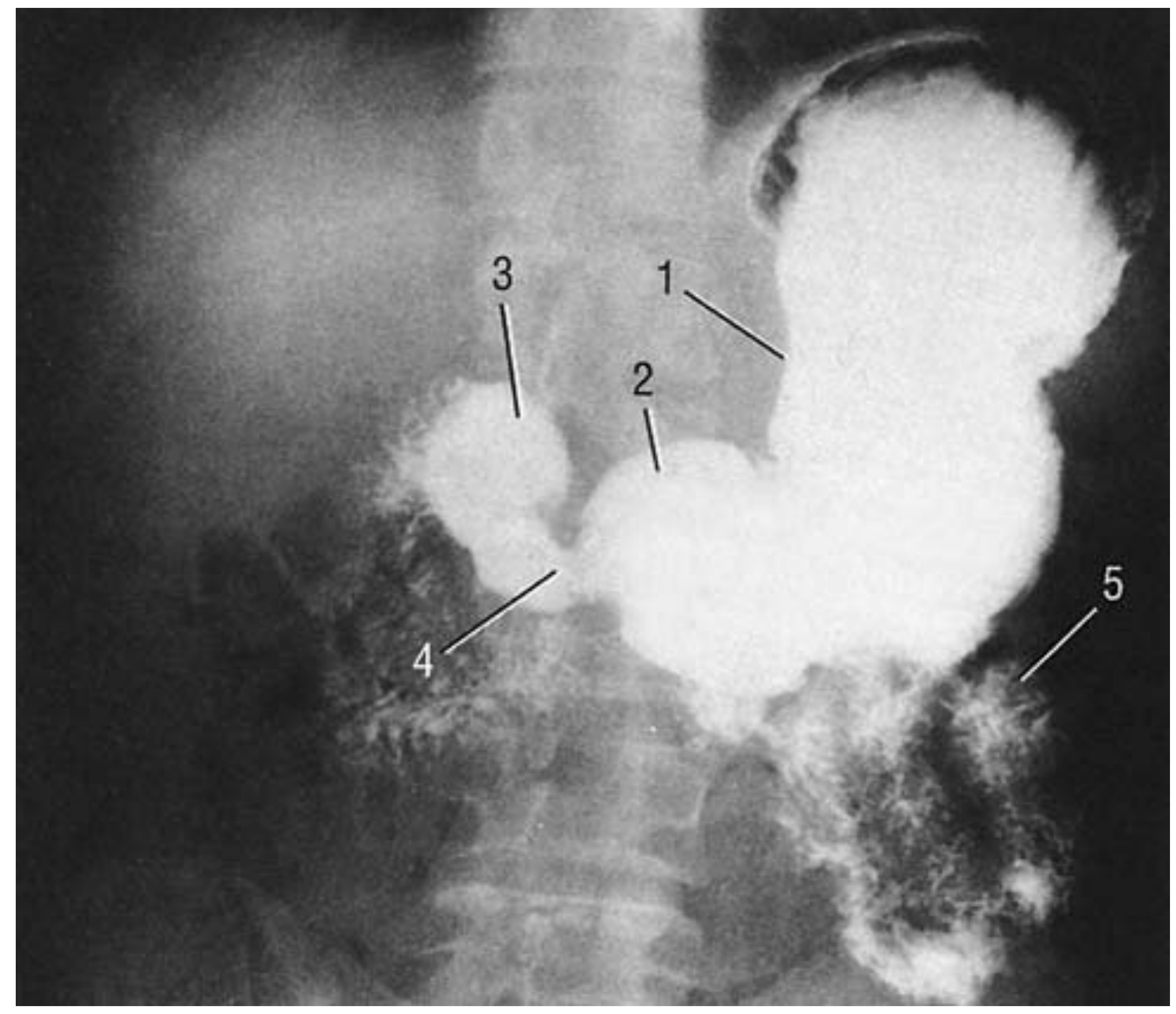
Match the numbered structures shown on the anteroposterior radiograph of the abdomen with the appropriate lettered structures.



1. Structure 1
2. Structure 2
3. Structure 3
4. Structure 4
5. Structure 5

A. Sacroiliac joint
B. Pedicle of the fourth lumbar vertebra
C. Iliopectineal line
D. Transverse process of the fifth lumbar vertebra
E. Psoas muscle
F. None of the above

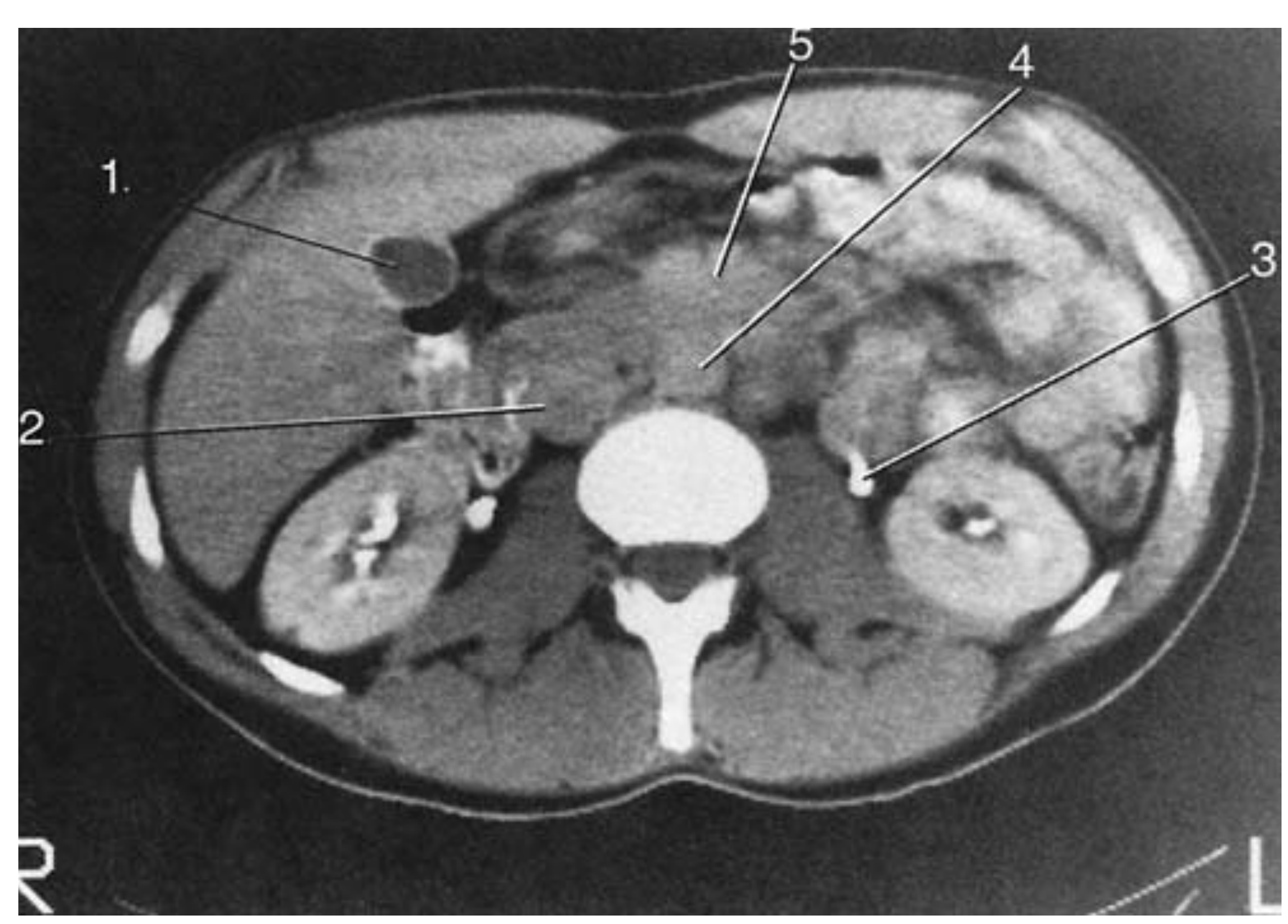
Match the numbered structures shown on the anteroposterior radiograph of the stomach and small intestine after ingestion of a barium meal with the appropriate lettered structures.



6. Structure 1
7. Structure 2
8. Structure 3
9. Structure 4
10. Structure 5

A. Jejunum
B. Pylorus
C. Lesser curvature of the stomach
D. First part of the duodenum
E. Antrum of the stomach
F. None of the above

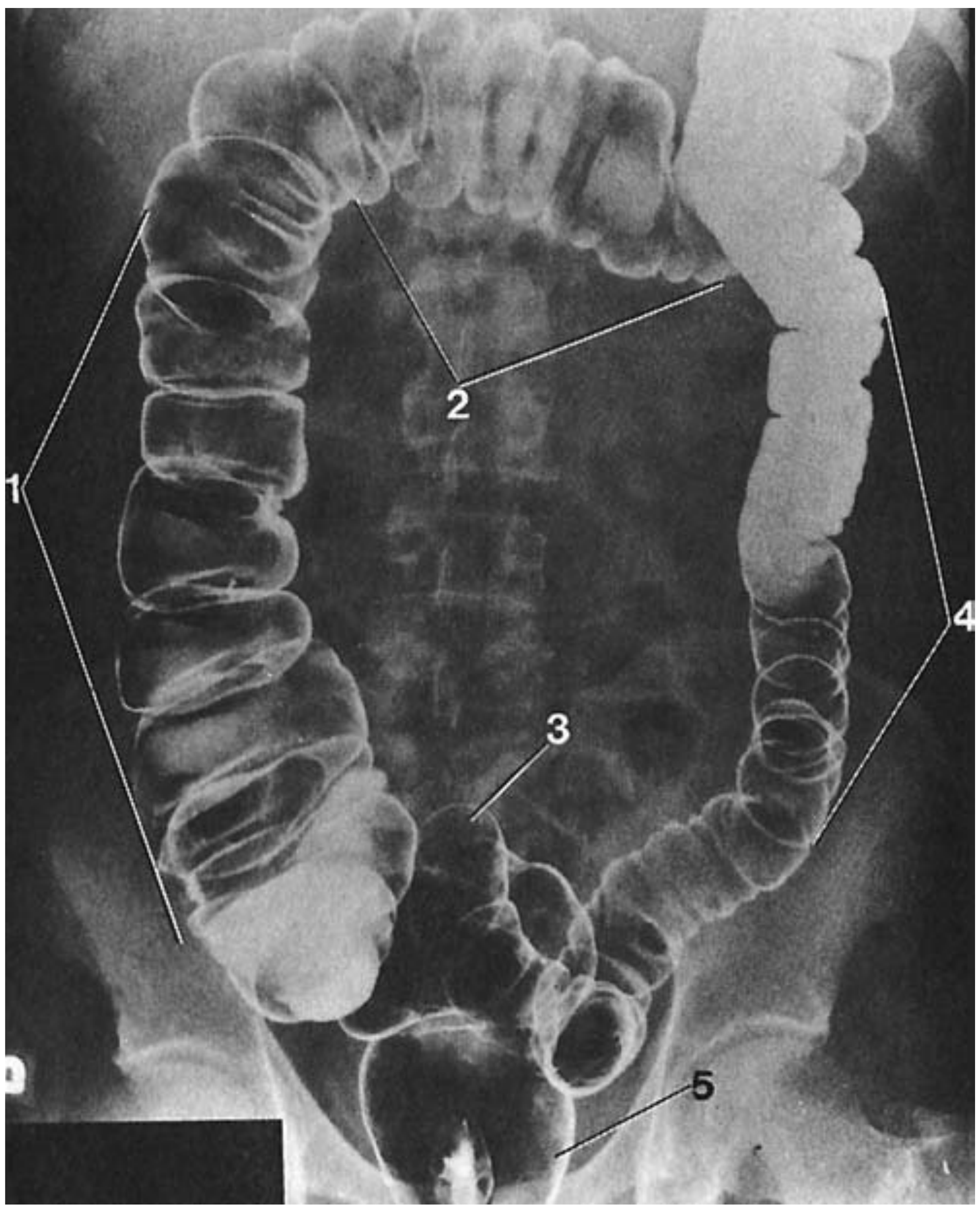
Match the numbered structures shown on the CT scan of the abdomen at the level of the second lumbar vertebra after intravenous pyelography with the appropriate lettered structures.



11. Structure 1
12. Structure 2
13. Structure 3
14. Structure 4
15. Structure 5

A. Aorta
B. Vertebral body
C. Gallbladder
D. Pancreas
E. Left ureter
F. Inferior vena cava
G. None of the above

Match the numbered structures shown on the anteroposterior radiograph of the abdomen after administration of a contrast enema with the appropriate lettered structures.



16. Structure 1
17. Structure 2
18. Structure 3
19. Structure 4
20. Structure 5

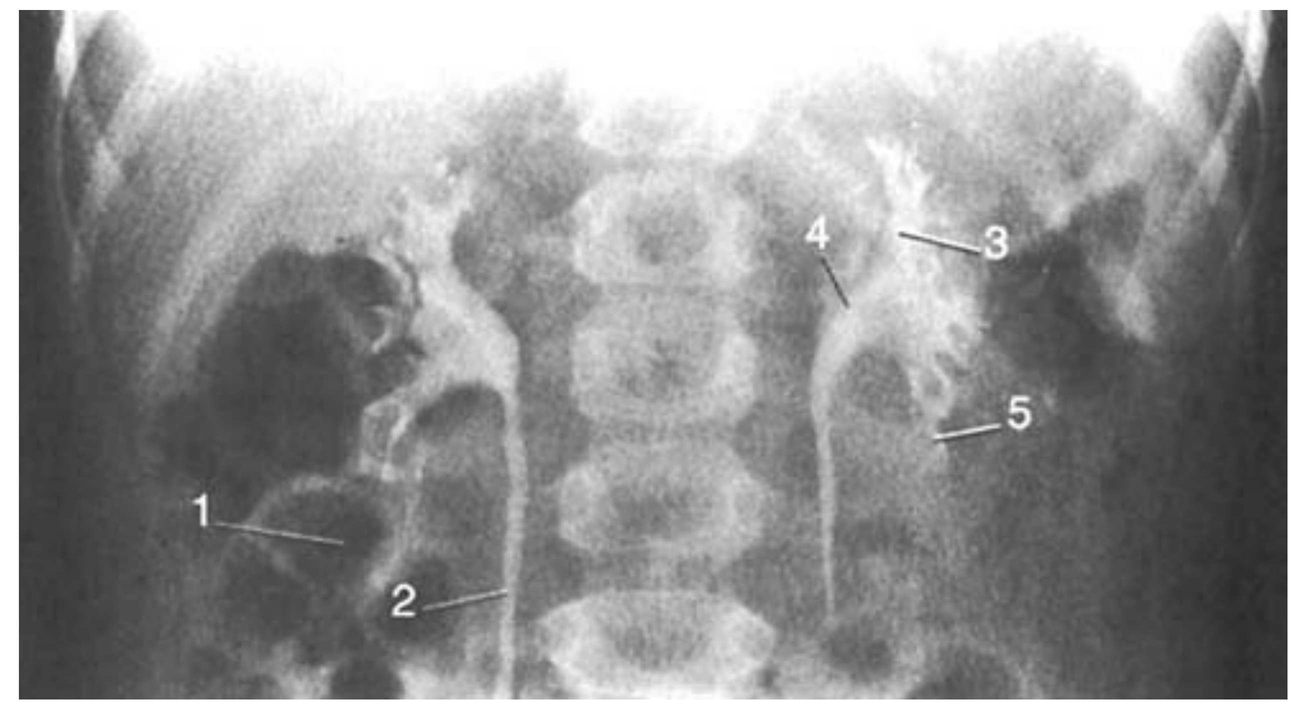
A. Sigmoid colon
B. Ascending colon
C. Rectum
D. Descending colon
E. Transverse colon
F. None of the above

Match the numbered areas shown on the previous radiograph of the abdomen with the appropriate lettered arterial supply.

21. Area 1
22. Area 2
23. Area 3
24. Area 4
25. Area 5

A. Sigmoid arteries from the inferior mesenteric artery
B. Middle colic artery
C. Superior rectal artery
D. Left colic artery
E. Right colic and colic branch of the ileocolic artery
F. None of the above

Match the numbered structures shown on the anteroposterior radiograph of both kidneys after intravenous injection of an iodine-containing compound with the appropriate lettered structure.



26. Structure 1
27. Structure 2
28. Structure 3
29. Structure 4
30. Structure 5

A. Pelvis of the left kidney
B. Pedicle of the lumbar vertebra
C. Minor calyx
D. Gas in the intestine
E. Major calyx
F. Right ureter
G. None of the above

Completion Questions

Select the phrase that best completes each statement.

31. Pain due to a gastric ulcer may be referred to the
    A. umbilical region.
    B. right iliac region.
    C. epigastric region.
    D. penis or clitoris.
    E. None of the above.

32. Pain caused by appendicitis may first be referred to the
    A. right iliac region.
    B. umbilical region.
    C. point of the shoulder.
    D. epigastric region.
    E. below the right shoulder blade.

33. Intermittent pain (colic) in the small intestine may be referred to
    A. the epigastric region.
    B. the left iliac region.
    C. just above the symphysis pubis.
    D. the umbilical region.
    E. None of the above.

34. Pain caused by the passage of a stone down the lower end of the left ureter may be referred to the
    A. umbilical region.
    B. right iliac region.
    C. epigastric region.
    D. penis or clitoris.
    E. None of the above.

35. The short gastric arteries originate from the
    A. superior mesenteric artery.
    B. hepatic artery.
    C. splenic artery.
    D. inferior phrenic artery.
    E. left renal artery.

36. The right gastric artery originates from the
    A. inferior mesenteric artery.
    B. superior mesenteric artery.
    C. hepatic artery.
    D. gastroduodenal artery.
    E. None of the above.

37. The left gastric artery originates from the
    A. superior mesenteric artery.
    B. left renal artery.
    C. splenic artery.
    D. celiac artery.
    E. hepatic artery.

38. The gastroduodenal artery originates from the
    A. splenic artery.
    B. hepatic artery.
    C. superior mesenteric artery.
    D. right renal artery.
    E. celiac artery.

39. The left gastroepiploic artery originates from the
    A. inferior mesenteric artery.
    B. superior mesenteric artery.
    C. splenic artery.
    D. celiac artery.
    E. left renal artery.

40. The descending colon receives parasympathetic nerves from the
    A. pelvic splanchnic nerves.
    B. spinal cord segments L1 and 2.
    C. greater splanchnic nerve.
    D. lesser splanchnic nerve.
    E. vagus nerve.

41. The jejunum receives sympathetic nerves from the
    A. vagus nerves.
    B. pelvic splanchnic nerves.
    C. spinal cord segments L1 and 2.
    D. greater splanchnic nerves and lesser splanchnic nerves.
    E. spinal cord segments S2, 3, and 4.

42. The sigmoid colon receives sympathetic nerves from the
    A. lesser splanchnic nerves.
    B. vagus nerves.
    C. greater splanchnic nerves.
    D. spinal cord segments T5 to 9.
    E. spinal cord segments L1 and 2.

43. The ileum receives parasympathetic nerves from the
    A. vagus nerves.
    B. pelvic splanchnic nerves.
    C. lesser splanchnic nerves.
    D. spinal cord segments T10 and 11.
    E. inferior mesenteric plexus.

44. The azygos vein passes __________ in the diaphragm.
    A. through the aortic hiatus
    B. through the esophageal hiatus
    C. through the vena caval hiatus
    D. through perforations in the crura
    E. between the slips of origin of the diaphragm from the ribs

45. The thoracic duct passes through __________ in the diaphragm.
    A. the esophageal hiatus
    B. the vena caval hiatus
    C. the aortic hiatus
    D. perforations in the crura
    E. None of the above.

46. The vagus nerves pass——- in the diaphragm?
    A. through the vena caval hiatus
    B. through the aortic hiatus
    C. between the slips of origin of the diaphragm from the ribs
    D. through the esophageal hiatus
    E. through the perforation is the crura

47. The iliohypogastric nerve, a branch of the lumbar plexus, emerges from the psoas muscle on its
    A. medial side.
    B. anterior surface.
    C. lateral side.
    D. posterior surface.
    E. None of the above.

48. The obturator nerve, a branch of the lumbar plexus, emerges from the psoas muscle on its
    A. anterior surface.
    B. posterior surface.
    C. medial side.
    D. upper border.
    E. lateral side.

49. The genitofemoral nerve, a branch of the lumbar plexus, emerges from the psoas muscle on its
    A. lateral side.
    B. posterior surface.
    C. medial side.
    D. anterior surface.
    E. None of the above.

50. The femoral nerve, a branch of the lumbar plexus, emerges from the psoas muscle on its
    A. lateral side.
    B. medial side.

C. anterior surface.
D. posterior surface.
E. lower border.

51. The ilioinguinal nerve, a branch of the lumbar plexus, emerges from the psoas muscle on its
A. medial side.
B. inferior border.
C. lateral side.
D. anterior surface.
E. posterior surface.

52. Lymphatic spread of carcinoma of the fundus of the stomach is likely to metastasize to the
A. internal iliac nodes.
B. superior mesenteric nodes.
C. inferior mesenteric nodes.
D. celiac nodes.
E. right gastroepiploic nodes.

53. Infection from an inflamed appendix is likely to spread via the lymphatics to the
A. superior mesenteric nodes.
B. celiac nodes.
C. splenic nodes.
D. inferior mesenteric nodes.
E. right internal iliac nodes.

54. Lymphatic spread of carcinoma of the right side of the greater curvature of the stomach is likely to metastasize to the
A. left renal nodes.
B. celiac nodes.
C. superior mesenteric nodes.
D. right gastroepiploic nodes.
E. splenic nodes.

55. Lymphatic spread of carcinoma of the sigmoid colon is likely to metastasize to the
A. left common iliac nodes.
B. inferior mesenteric nodes.
C. superior mesenteric nodes.
D. celiac nodes.
E. para-aortic nodes.

56. Bacteria from diverticulitis of the proximal two thirds of the transverse colon are likely to spread via lymph vessels to the
A. inferior mesenteric nodes.
B. celiac nodes.
C. para-aortic nodes.
D. superior mesenteric nodes.
E. left renal nodes.

57. The skin of the umbilicus receives its sensory innervation from
A. T7.
B. T10.
C. L1.
D. T12.
E. L2.

58. In both sexes, the inguinal canal is formed by the
A. descent of the gonad.
B. contraction of the gubernaculum.
C. processus vaginalis.
D. growth and descent of the ilioinguinal nerve.
E. contraction of the cremaster muscle.

59. The lacunar ligament is
A. formed from the conjoint tendon.
B. part of the posterior wall of the rectus sheath.
C. not continuous with the inguinal ligament.
D. an important medial relation to the femoral ring of the femoral sheath.
E. attached to the inferior ramus of the pubis.

60. The suprarenal gland receives its arterial supply from the
A. aorta, inferior phrenic, and renal arteries.
B. lumbar arteries.
C. superior phrenic artery.
D. testicular (ovarian) artery.
E. subcostal artery.

Multiple-Choice Questions

Select the best answer for each question.

61. The following statements concerning the abdominal aorta are correct except which?
A. The aorta lies in the midline of the abdomen.
B. The aorta bifurcates into the right and left common iliac arteries.
C. The level of bifurcation of the aorta is the fifth lumbar vertebra.
D. The aorta lies on the left side of the inferior vena cava.
E. The aorta is related to the anterior surface of the bodies of the lumbar vertebrae.

62. The statements concerning the following arteries are correct except which?
A. The superior epigastric artery descends in the rectus sheath posterior to the rectus abdominis muscle.
B. The superior mesenteric artery descends posterior to the third part of the duodenum.
C. The gonadal arteries cross in front of the ureters on both sides.
D. The gastroduodenal artery is directly related to the posterior surface of the first part of the duodenum.
E. The appendicular artery is a branch of the posterior cecal artery.

63. The statements concerning the following veins are correct except which?
A. The inferior mesenteric vein is usually a direct tributary of the splenic vein.
B. The portal vein is formed by the union of the splenic vein and superior mesenteric vein.
C. The hepatic veins emerge from the posterior surface of the liver and drain into the inferior vena cava.

D. The renal vein emerges from the hilum of the kidney in front of the renal artery and drains into the inferior vena cava.
E. The inferior vena cava pierces the central tendon of the diaphragm at the level of the tenth thoracic vertebra.

64. The following statements concerning the lymphatics of the abdomen are correct except which?
A. The intestinal, right, and left lumbar trunks drain into the cisterna chyli.
B. The lymphatic drainage of the kidney is directly to the superior mesenteric nodes.
C. The thoracic duct begins in the abdomen at the cisterna chyli.
D. The cisterna chyli lies in front of the first two lumbar vertebrae.
E. The lymph vessels from the testes drain into the para-aortic nodes at the level of the first lumbar vertebra.

65. The following statements concerning the abdominal peritoneal omenta and ligaments are correct except which?
A. The gastrosplenic omentum contains the short gastric arteries and the left gastroepiploic artery.
B. The splenicorenal ligament contains the tail of the pancreas.
C. The lesser omentum is attached superiorly to the porta hepatis of the liver.
D. The greater omentum is attached to the upper border of the transverse colon.
E. The coronary ligament of the liver is the main support for this organ.

66. The following information concerning the sensory innervation of the abdominal peritoneum is correct except which?
A. The peritoneum on the central part of the inferior surface of the diaphragm is supplied by the phrenic nerves.
B. The peritoneum forming the mesentery of the small intestine is innervated by autonomic nerves.
C. The peritoneum on the peripheral part of the inferior surface of the diaphragm is supplied by the phrenic nerves.
D. The peritoneum lining the anterior abdominal wall in the right lower quadrant is supplied by T12 and L1 spinal nerves.
E. The peritoneum lining the lateral wall of the pelvis is supplied by the obturator nerve.

67. The following statements concerning the right kidney are correct except which?
A. The renal papillae open directly into the major calyces.
B. The kidney lies slightly lower than the left kidney.
C. The right suprarenal gland covers its upper pole.
D. The medulla is composed of approximately twelve renal pyramids.
E. At the junction of the renal pelvis with the ureter, the lumen of the ureter is narrowed.

68. The following statements concerning the wall of the scrotum are correct except which?
A. It is covered by skin.
B. It possesses superficial fascia that contains smooth muscle called the dartos muscle.
C. It has the external spermatic fascia derived from the external oblique aponeurosis.
D. It has cremasteric fascia derived from the internal oblique muscle.
E. It has the internal spermatic fascia derived from the fatty layer of the superficial fascia.

69. The following statements concerning the epididymides are correct except which?
A. Each has a head, a body, and a tail.
B. Each lies anterior to the testis.
C. Each is made up of a coiled tube.
D. The vas deferens emerges from the tail.
E. They provide storage space for the spermatozoa prior to ejaculation.

70. The following statements concerning the spermatic cord are correct except which?
A. It is covered with three layers of fascia derived from the anterior abdominal wall.
B. It contains the vas deferens.
C. The testicular artery and vein lie within it.
D. The inferior epigastric artery passes through it.
E. It contains the genital branch of the genitofemoral nerve.

71. The following statements concerning the sigmoid colon are correct except which?
A. It is a continuation of the descending colon.
B. It begins above in front of the left quadratus lumborum muscle.
C. It receives its arterial supply from the inferior mesenteric artery.
D. It becomes continuous with the rectum in front of the third sacral vertebra.
E. It is attached to the posterior pelvic wall by the sigmoid mesocolon.

72. The following statements concerning the liver are correct except which?
A. Its lymph drainage is to the celiac nodes.
B. The quadrate and the caudate loves are functionally part of the left lobe.
C. Its parasympathetic innervation is from the vagus nerve.
D. It receives highly oxygenated blood from the portal vein.
E. The triangular ligaments connect the liver to the diaphragm.

73. The following differences exist between the ileum and the ascending colon except which?
A. The ascending colon has appendices epiploicae, whereas the ileum does not.
B. The arterial supply to the wall of the ileum is arranged so that it produces areas of weakness through which mucosal herniations may occur.

C. The ascending colon may have a well-developed marginal artery, whereas the ileum does not.
D. The ileum has longitudinal muscle that forms a continuous layer around the wall, whereas the ascending colon has teniae coli.
E. The ascending colon is retroperitoneal, whereas the ileum is intraperitoneal.

74. The following statements concerning the duodenum are correct except which?
A. The lower half of the duodenum receives its arterial supply from the superior mesenteric artery via the inferior pancreaticoduodenal artery.
B. The first part of the duodenum is completely retroperitoneal.
C. The bile duct enters the second (vertical) portion of the duodenum.
D. Lymph from the fourth part of the duodenum drains into the superior mesenteric nodes.
E. The third part of the duodenum passes horizontally to the left in front of the vertebral column and behind the root of the mesentery.

75. The following statements concerning the appendix are correct except which?
A. The appendix is situated in the right iliac region.
B. At the base of the appendix, the teniae coli of the cecum fuse to from a complete longitudinal muscle layer in the wall of the appendix.
C. Afferent pain nerve fibers accompany the sympathetic nerves and enter the spinal cord at the level of the tenth thoracic segment.
D. The appendix receives its blood supply from a branch of the posterior cecal artery.
E. The tip of the appendix cannot reach down into the pelvic cavity.

76. The lesser omentum contains the following important structures except which?
A. The left gastric artery
B. The portal vein
C. The inferior vena cava
D. The bile duct
E. The common hepatic artery

77. The following statements concerning the pyloric sphincter are correct except which?
A. It receives its motor innervation from the sympathetic autonomic nerves.
B. It lies on the level of the third lumbar vertebra.
C. It is inhibited by the impulses passing down the vagus nerves.
D. It is formed by a thickening of the circular layer of smooth muscle in the stomach wall.
E. The cavity of the pylorus is called the pyloric canal.

78. The following structures form the boundaries of the entrance into the lesser sac (epiploic foramen) except which?
A. The inferior vena cava
B. The bile duct
C. The portal vein
D. The quadrate lobe of liver
E. The first part of the duodenum

79. After complete occlusion of the origin of the inferior mesenteric artery with a blood clot, the blood supply of the left portion of the colon is maintained by the following arteries except which?
A. The marginal artery
B. The middle colic artery
C. The left lumbar arteries
D. Anastomoses between the superior, middle, and inferior hemorrhoidal arteries
E. The sigmoid arteries

80. The following statements concerning the gallbladder are correct except which?
A. The arterial supply is from the cystic artery, which is a branch of the right hepatic artery.
B. The fundus of the gallbladder is located just beneath the tip of the right ninth costal cartilage.
C. The peritoneum completely surrounds the fundus, the body, and the neck.
D. The nerves of the gallbladder are derived from the celiac plexus.
E. Pain sensation from gallbladder disease may be referred along the phrenic and the supraclavicular nerves to the skin over the shoulder.

81. In patients with an obstruction of the superior vena cava, blood may return to the right atrium through the following anastomotic channels except which?
A. The lateral thoracic, lumbar, and superficial epigastric veins
B. The superior and inferior epigastric veins
C. The lateral thoracic, paraumbilical, and portal veins
D. The posterior intercostal and lumbar veins
E. The lateral thoracic veins

82. The following structures could be eroded as the result of perforation of an ulcer in the posterior wall of the stomach except which?
A. The splenic artery
B. The right kidney
C. The pancreas
D. The left kidney
E. The spleen

83. The following statements concerning the left ureter are correct except which?
A. It lumen is constricted at the point where it crosses the brim of the pelvis.
B. Its arterial supply is derived from the renal artery above, the gonadal artery halfway down, and the superior vesical artery below.
C. The inferior mesenteric vein lies on its medial side.
D. It lies in direct contact with the tips of the transverse processes of the lumbar vertebrae.
E. It is situated on the posterior abdominal wall behind the peritoneum.

84. The following structures are connected to the liver except which?
   A. The falciform ligament
   B. The coronary ligament
   C. The greater omentum
   D. The ligamentum teres
   E. The ligamentum venosum

85. The following statements concerning the superficial inguinal ring are correct except which?
   A. It is a perforation in the aponeurosis of the external oblique muscle.
   B. Its greatest width lies above and medial to the pubic tubercle.
   C. It is strengthened posteriorly by the conjoint tendon.
   D. The internal spermatic fascia is attached to its margins.
   E. In males, it allows passage of the spermatic cord and ilioinguinal nerve.

86. The following statements concerning the superficial fascia of the anterior abdominal wall are correct except which?
   A. It has a superficial fatty layer and a deep membranous layer.
   B. Scarpa's fascia fuses with the fascia lata just below the inguinal ligament.
   C. Camper's fascia is continuous with the Colles' fascia in the perineum.
   D. It is continuous with the dartos muscle in the wall of the scrotum.
   E. It does not contribute to the femoral sheath.

87. The rectus sheath contains the following structures except which?
   A. The pyramidalis muscle (when present)
   B. The ligamentum teres
   C. The inferior epigastric artery
   D. The T7 to 12 anterior nerve rami
   E. The rectus abdominis muscle

88. The following statements concerning the epididymis are correct except which?
   A. It lies within the scrotum.
   B. It is partially covered by the tunica vaginalis.
   C. It is easily palpated through the scrotal wall.
   D. It is supplied by the testicular artery.
   E. Its lymph drains into the superficial inguinal nodes.

89. The jejunum and ileum can be differentiated on the basis of the following anatomic features except which?
   A. Numerous (four to five) arterial arcades are associated with the jejunum.
   B. The plicae circulares are much more prominent in the jejunum than in the ileum.
   C. Fat depositions are generally present throughout the mesentery associated with the ileum.
   D. The jejunum is generally located in the upper left region of the abdominal cavity.
   E. Peyer's patches are characteristic of the lower ileum and may be visible on the surface.

90. The spermatic cord contains the following structures except which?
   A. The scrotal arteries and veins
   B. The vas deferens
   C. The pampiniform plexus
   D. The testicular artery
   E. Autonomic nerves

91. The following structures pass through the esophageal hiatus in the diaphragm except which?
   A. The left vagus nerve
   B. Branches of the left gastric artery
   C. The left phrenic nerve
   D. The right vagus nerve
   E. A tributary of the portal vein

92. The following statements regarding the peritoneum are correct except which?
   A. The parietal peritoneum is sensitive to pain, temperature, touch, and pressure.
   B. The parietal peritoneum lining the anterior abdominal wall is innervated by the lower six thoracic and the first lumbar spinal nerves.
   C. The visceral peritoneum is innervated by the posterior primary rami of the twelfth thoracic and the lumbar spinal nerves.
   D. The visceral peritoneum is only sensitive to stretch.
   E. The peritoneum lining the lesser sac has a sensory nerve supply.

93. If the portal vein becomes blocked, the following venous anastomoses are important in uniting the portal with the systemic venous systems except which?
   A. Esophageal branches of the left gastric and azygos veins
   B. Veins of the ligamentum teres and paraumbilical veins
   C. The superior and inferior rectal veins
   D. The right colic veins and lumbar veins
   E. The middle and inferior rectal veins

94. In a patient with cancer of the stomach who requires a total gastrectomy, the following arteries must be ligated except which?
   A. The common hepatic artery
   B. The short gastric arteries
   C. The left and the right gastroepiploic arteries
   D. The right gastric artery
   E. The left gastric artery

95. When performing a midline abdominal paracentesis (tapping the abdominal cavity) below the umbilicus, the cannula will pass through the following anatomic structures except which?
   A. The skin and the fascia
   B. The linea alba
   C. The transversalis fascia and extraperitoneal fat
   D. The rectus abdominis muscle
   E. The parietal peritoneum

96. The following statements are correct regarding an inguinal hernia except which?
   A. The inferior epigastric artery lies medial to the neck of an indirect inguinal hernia.
   B. An inguinal hernia is more common than a femoral hernia in females.
   C. A direct inguinal hernia is more common in elderly men than in boys.
   D. The opening of the sac of a direct inguinal hernia is wide.
   E. The contents of an indirect inguinal hernia may be strangulated against the lacunar ligament.

97. The following statements regarding the portal vein are correct except which?
   A. It courses through a portion of the lesser omentum.
   B. It enters the liver at the porta hepatis.
   C. It receives venous blood from both the large and the small intestines.
   D. It originates at the junction of the superior mesenteric and the splenic veins.
   E. It passes in front of the neck of the neck of the pancreas.

98. If the common hepatic artery is unavoidably ligated during surgery, the arterial supply to the liver is maintained by the following anastomotic connections except which?
   A. The superior pancreaticoduodenal artery anastomosing with the inferior pancreaticoduodenal artery
   B. The right gastric artery anastomosing with the left gastric artery
   C. The gastroduodenal artery anastomosing with the splenic artery
   D. The esophageal arteries anastomosing with the inferior phrenic arteries
   E. The right gastroepiploic artery anastomosing with the left gastroepiploic artery

99. The following general statements are correct except which?
   A. The superior and inferior epigastric vessels anastomose on the posterior surface of the rectus abdominis muscle.
   B. The inguinal ligament is attached laterally to the anterior inferior iliac spine.
   C. The abdominal aorta bifurcates below into the two common iliac arteries.
   D. The foregut ends in the second segment of the duodenum.
   E. The umbilicus is inconstant in position but is usually located at the level of L4.

100. The following veins drain directly into the inferior vena cava except which?
   A. The hepatic veins
   B. The renal veins
   C. The lumbar veins
   D. The inferior mesenteric vein
   E. The right testicular (ovarian) vein

101. When tapping a hydrocele (collection of fluid in the tunica vaginalis), the cannula must pierce the following structures except which?
   A. The skin
   B. The fatty subcutaneous tissue
   C. Dartos muscle
   D. The cremasteric fascia
   E. The external and internal spermatic fasciae

102. The following structures are present in the porta hepatis except which?
   A. Lymph nodes
   B. The right and left branches of the portal vein
   C. The right and left hepatic ducts
   D. The right and left hepatic veins
   E. The right and left branches of the hepatic artery

103. The following statements regarding the celiac plexus are correct except which?
   A. The celiac plexus is not a purely sympathetic plexus.
   B. The celiac plexus does not surround the celiac artery.
   C. The celiac ganglia are made of nerve cell bodies and nerve fibers.
   D. Parasympathetic preganglionic fibers pass through the plexus, generally synapsing with postganglionic neurons within the walls of the organs they innervate.
   E. Sympathetic preganglionic fibers to the celiac plexus originate from thoracic spinal segments and travel in thoracic splanchnic nerves.

104. The right kidney has the following important relationships except which?
   A. It is related to the neck of the pancreas.
   B. It is anterior to the right costodiaphragmatic recess.
   C. It is related to the second part of the duodenum.
   D. It is related to the right colic flexure.
   E. It is anterior to the right twelfth rib.

Read the case histories and select the best answer to the questions following them.

A 45-year-old obese woman complaining of indigestion was admitted to hospital for investigation. She had a past history of gallstones and transient attacks of jaundice. Large gallstones have been known to erode through the posterior wall of the gallbladder and enter the intestinal tract.

105. Which part of the intestinal tract is likely to initially contain the stone?
   A. The sigmoid colon
   B. The descending colon
   C. The transverse colon
   D. The ascending colon
   E. The jejunum

A 53-year-old man was admitted to hospital complaining of a chronic gastric ulcer that was not responding to medical treatment. The surgeon decided to perform a vagotomy. The anterior vagal trunk was divided between sutures as it lies on the anterior surface of the abdominal part of the esophagus.

106. Which of the following is likely to result from this procedure?
   A. A loss of secretomotor nerve supply to the mucosal glands of the stomach.
   B. Hoarse voice because of paralysis of the intrinsic muscles of the larynx on the left side.
   C. Increased heart rate because of decreased parasympathetic input to the cardiac plexus.
   D. Incontinence because of an absence of parasympathetic input to the bladder.
   D. Compromised input into the greater splanchnic nerves.

A 54-year-old man with a long history of duodenal ulcer was seen in the emergency department after vomiting blood-stained fluid and exhibiting all the signs and symptoms of severe hypovolemic (loss of blood) shock.

107. Assuming the ulcer had perforated the posterior wall of the first part of the duodenum, name the artery that is most likely to have been eroded.
   A. The splenic artery
   B. The right gastric artery
   C. The gastroduodenal artery
   D. The right gastroepiploic artery
   E. The right renal artery

108. If the duodenal ulcer had perforated the anterior wall of the duodenum, where in the peritoneal cavity would the duodenal contents have entered?
   A. The lesser sac
   B. The right anterior subphrenic space
   C. The left lateral paracolic gutter
   D. The right posterior subphrenic space
   E. The pouch of Douglas

A 10-year-old girl was seen in the emergency department with a temperature of 101°F, a furred tongue, and pain in the right iliac region. On physical examination, the skin in the right lower quadrant was hyperesthetic and tender to touch, and the abdominal muscles showed rigidity and guarding. A diagnosis of acute appendicitis was made.

109. The skin in the right lower quadrant was tender to touch because which of the following nerves was (were) stimulated by the inflamed appendix?
   A. The eighth right intercostal nerve
   B. The tenth right intercostal nerve
   C. The subcostal and first lumbar nerves
   D. The sympathetic autonomic afferent nerves from the appendix
   E. The seventh right thoracic nerve

110. Which of the following muscles was (were) contracted in the right lower quadrant to produce the increased tone and guarding?
   A. The right rectus abdominis muscle
   B. The right pyramidalis muscle
   C. The right psoas muscle
   D. The right external oblique, internal oblique, and transversus abdominis muscles
   E. The right quadratus lumborum muscle

ANSWERS AND EXPLANATIONS

1.	D	9.	B	17.	E	25.	C
2.	B	10.	A	18.	A	26.	D
3.	E	11.	C	19.	D	27.	F
4.	A	12.	F	20.	C	28.	E
5.	C	13.	E	21.	E	29.	A
6.	C	14.	A	22.	B	30.	C
7.	E	15.	D	23.	A	31.	C
8.	D	16.	B	24.	D	32.	B

33. D
34. D. Pain from the upper end of the ureter is referred to the back behind the kidney. Pain from the middle region of the ureter is referred to the inguinal region, and pain from the lower end is referred to the penis or clitoris. This is because the afferent nerves enter the spinal cord at different levels, so the pain is referred along the spinal nerves originating from those spinal cord levels.

35.	C	42.	E	49.	D	56.	D
36.	C	43.	A	50.	A	57.	B
37.	D	44.	A	51.	C	58.	C
38.	B	45.	C	52.	D	59.	D
39.	C	46.	D	53.	A	60.	A
40.	A	47.	C	54.	D		
41.	D	48.	C	55.	B		

61. C. The aorta bifurcates into the two common iliac arteries at the level of the fourth lumbar vertebra.
62. B. The superior mesenteric artery descends anterior to the third part of the duodenum.
63. E. The inferior vena cava pierces the central tendon of the diaphragm at the level of the eighth thoracic vertebra.
64. B. The lymphatic drainage of the kidneys is into the lateral (para-aortic) group of lymph nodes.
65. E. The attachment of the hepatic veins to the inferior vena cava provides the main support for the liver; the various peritoneal ligaments are weak and stretch.
66. C. The peritoneum on the peripheral part of the inferior surface of the diaphragm is supplied by the lower six intercostal nerves.
67. A. The renal papillae open directly into the minor calyces of the kidney.
68. E. The internal spermatic fascia is derived from the fascia transversalis lining the anterior abdominal wall.

69. B. The epididymis lies on the posterior surface of the testis.
70. D. The inferior epigastric artery is a branch of the external iliac artery just above the inguinal ligament. It ascends in the anterior abdominal wall just medial to the deep inguinal ring and eventually reaches the rectus sheath.
71. B. The sigmoid colon begins above the level of the pelvic brim.
72. D. The liver receives highly oxygenated blood via the hepatic artery.
73. B. It is the colon that often develops mucosal herniations along its arterial supply.
74. B. The first inch of the first part of the duodenum is covered by peritoneum on its anterior and posterior surfaces.
75. E. The appendix generally varies in length from 3 to 5 in. (8 to 13 cm), but it can be even longer. (It tends to be longer during childhood and later atrophies.) When long, the tip is often found hanging down into the pelvic cavity.
76. C. The inferior vena cava is retroperitoneal behind the opening into the lesser sac.
77. B. The pylorus lies on the transpyloric plane at the level of the first lumbar vertebra.
78. D. The superior boundary of the entrance into the lesser sac is formed by the caudate process of the caudate lobe of the liver, not by the quadrate lobe.
79. C. The middle colic artery from the superior mesenteric artery, the sigmoid arteries, and the marginal artery as well as the anastomoses of all these arteries with the superior, middle, and inferior hemorrhoidal arteries will maintain the blood supply to the left portion of the colon.
80. C. The fundus is the only part of the gallbladder completely surrounded by peritoneum.
81. E. The lateral thoracic and the superior epigastric veins are directly or indirectly connected with the superior vena cava only.
82. B
83. D. The ureter is separated from the transverse processes of the lumbar vertebrae by the psoas muscle and fascia.
84. C. The greater omentum is attached above to the greater curvature of the stomach and below to the lower border of the transverse colon.
85. D. The external spermatic fascia is attached to the margins of the superficial inguinal ring.
86. C
87. B
88. E. The lymphatic drainage of the epididymis is into the lateral aortic (para-aortic) nodes at the level of the first lumbar vertebra.
89. A. The jejunum usually has only one or two arterial arcades with long branches passing to the intestinal wall.
90. A
91. C. The terminal branches of the left phrenic nerve pierce the diaphragm but do not pass through the esophageal hiatus.
92. C. The visceral peritoneum is sensitive to stretch and is innervated by autonomic afferent nerves.
93. E. The middle and inferior rectal veins are tributaries of the systemic circulation only.
94. A
95. D. The rectus abdominis muscles lie on either side of the midline and are separated by the linea alba.
96. E. The lacunar ligament is related to the sac of a femoral hernia, not an inguinal hernia.
97. E. The portal vein is formed behind the neck of the pancreas by the union of the superior mesenteric vein with the splenic vein.
98. C. The gastroduodenal artery does not directly anastomose with the splenic artery.
99. B. The inguinal ligament is attached laterally to the anterior superior iliac spine.
100. D. The inferior mesenteric vein is a tributary of the splenic vein.
101. B. The dartos muscle takes the place of the fatty subcutaneous tissue in the wall of the scrotum.
102. D. The hepatic veins (three or more in number) leave the posterior surface of the liver and drain directly into the inferior vena cava.
103. B. The celiac plexus completely surrounds the origin of the celiac artery.
104. A. The pancreas is not related to the right kidney.
105. C. The transverse colon is in close posterior relation to the gallbladder.
106. A
107. C. The gastroduodenal artery is a large branch of the hepatic artery. It descends behind the first part of the duodenum and then divides into the superior pancreaticoduodenal artery and the right gastroepiploic artery.
108. D. If the patient is in the erect position when the perforation occurs, the duodenal contents tend to gravitate downward along the right paracolic gutters.
109. C. Once the inflamed appendix comes into contact with the parietal peritoneum in the right iliac region, it stimulates the lower thoracic spinal nerves and first lumbar spinal nerve, which supply the peritoneum. Because these nerves also supply the anterior abdominal wall muscles in this region, they are thus stimulated to contract. This mechanism tends to immobilize this region and assists in localizing the inflammatory process should the appendix rupture.
110. D

CHAPTER 3

Pelvis and Perineum

PELVIS

The term pelvis is loosely used to describe the region where the trunk and the lower limbs meet. The word pelvis means a basin, and it is more correctly applied to the skeleton of the region (the bony pelvis).

BONY PELVIS

The bony pelvis is composed of four bones: the two **hip** bones, the **sacrum,** and the **coccyx** (Fig. 3-1). The two hip bones articulate with each other anteriorly at the **symphysis pubis** and with the sacrum posteriorly at the **sacroiliac joints.**

The pelvis is divided into two parts by the **pelvic brim,** which is formed by the **sacral promontory** behind, the **iliopectineal lines** laterally, and the symphysis pubis anteriorly. Above the brim is the **false pelvis** (greater pelvis), which is the expanded part of the pelvis that forms part of the abdominal cavity. Below the brim is the **true pelvis** (lesser pelvis).

True Pelvis

The true pelvis is a bowl-shaped structure that contains and protects the lower parts of the intestinal and the urinary tracts as well as the internal organs of reproduction. The true pelvis has an inlet, an outlet, and a cavity. The **pelvic inlet** is bounded posteriorly by the sacral promontory, laterally by the iliopectineal lines, and anteriorly by the symphysis pubis. The **pelvic outlet** is bounded posteriorly by the coccyx, laterally by the ischial tuberosities, and anteriorly by the pubic arch. Laterally, in addition to the ischial tuberosities, there are the inflexible sacrotuberous and sacrospinous ligaments (see Figs. 3-1 and 3-2). These ligaments divide the sciatic notches into the greater and the lesser sciatic foramina (Fig. 3-2). The **pelvic cavity** lies between the inlet and the outlet; it is a short, curved canal with a shallow anterior wall and a much deeper posterior wall (Fig. 3-3).

JOINTS OF THE PELVIS

- Sacroiliac joints.
- Symphysis pubis.
- Sacrococcygeal joint.

Sacroiliac Joints

The sacroiliac joints are very strong synovial joints between the sacrum and the iliac bones (Fig. 3-2). The strong **posterior** and **interosseous sacroiliac ligaments** suspend the sacrum between the two iliac bones. The **anterior sacroiliac ligament** is thin and in front of the joint. A small amount of movement is possible at these joints, but their main function is to transmit the weight of the body from the vertebral column to the bony pelvis.

NERVE SUPPLY

Branches of the sacral plexus supply this area.

Symphysis Pubis

The symphysis pubis is a cartilaginous joint between the two pubic bones in the medial plane (Fig. 3-2). The articular surfaces are covered by hyaline cartilage and are connected by a fibrocartilaginous disc. The joint itself is surrounded by ligaments. Almost no movement is possible at this joint.

Sacrococcygeal Joint

The sacrococcygeal joint is a cartilaginous joint between the sacrum and the coccyx. The cornua of the sacrum and the coccyx are joined by ligaments. A great deal of movement is possible at this joint.

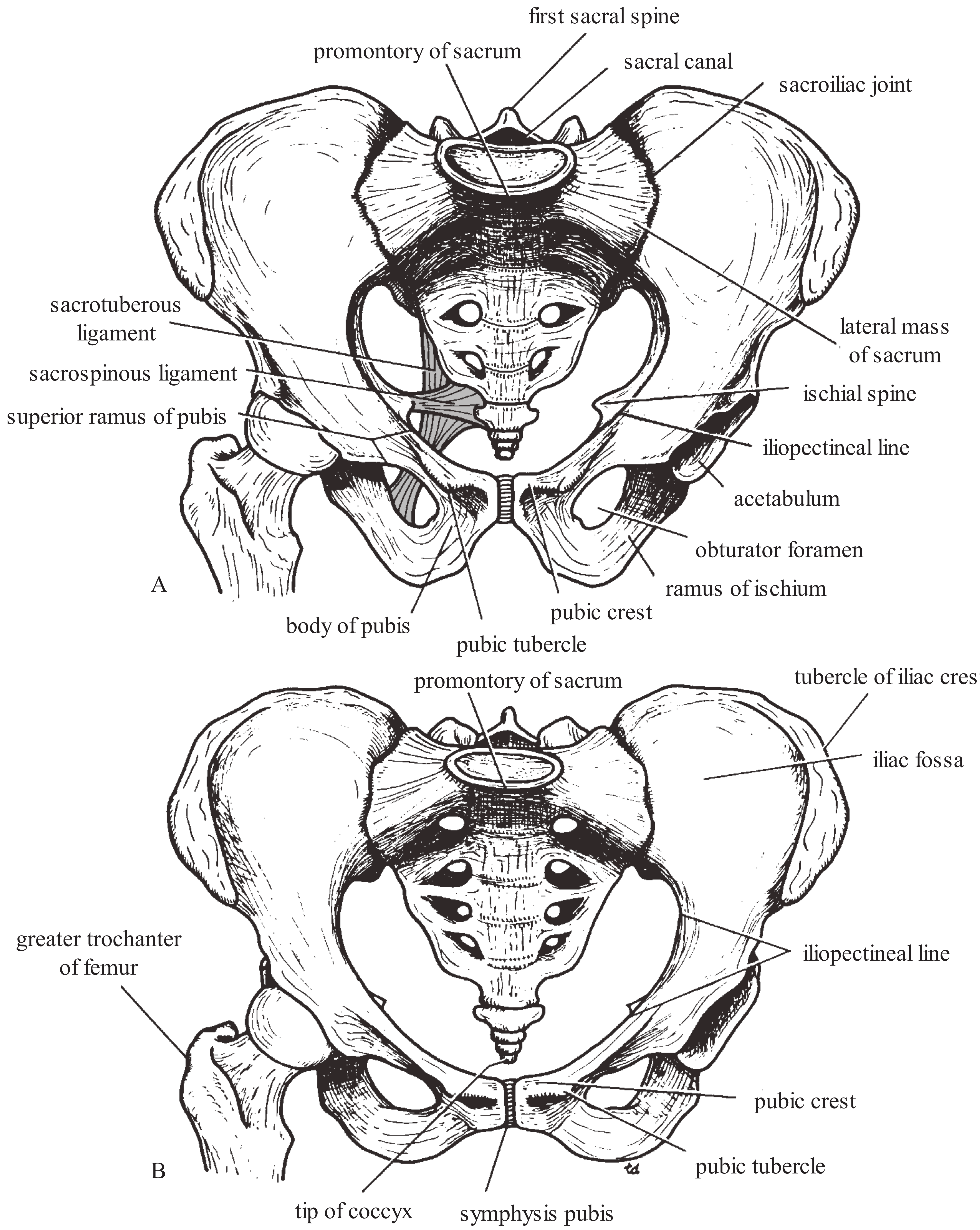


Figure 3-1 A. Anterior view of the male pelvis. B. Anterior view of the female pelvis.

CLINICAL NOTES

Pregnancy and the Pelvic Joints

During pregnancy, the ligaments of the pelvic joints are relaxed by the action of the hormones estrogen, progesterone, and relaxin. This allows the pelvic cavity to enlarge and thus facilitates delivery.

SEX DIFFERENCES OF THE PELVIS

The sex differences of the pelvis (Fig. 3-3) are as follows:

- The false pelvis is shallow in females and deep in males.
- The pelvic inlet is transversely oval in females but heart shaped in males. (This results from the indentation produced by the promontory of the sacrum in males.)
- The pelvic cavity is roomier in females than in males, and the distance between the inlet and the outlet is much shorter in females.
- The pelvic outlet is larger in females than in males. In addition, the ischial tuberosities are everted in females but turned in males.
- The sacrum is shorter, wider, and flatter in females than in males.
- The subpubic angle (pubic arch) is more rounded and wider in females than in males (Fig. 3-1).

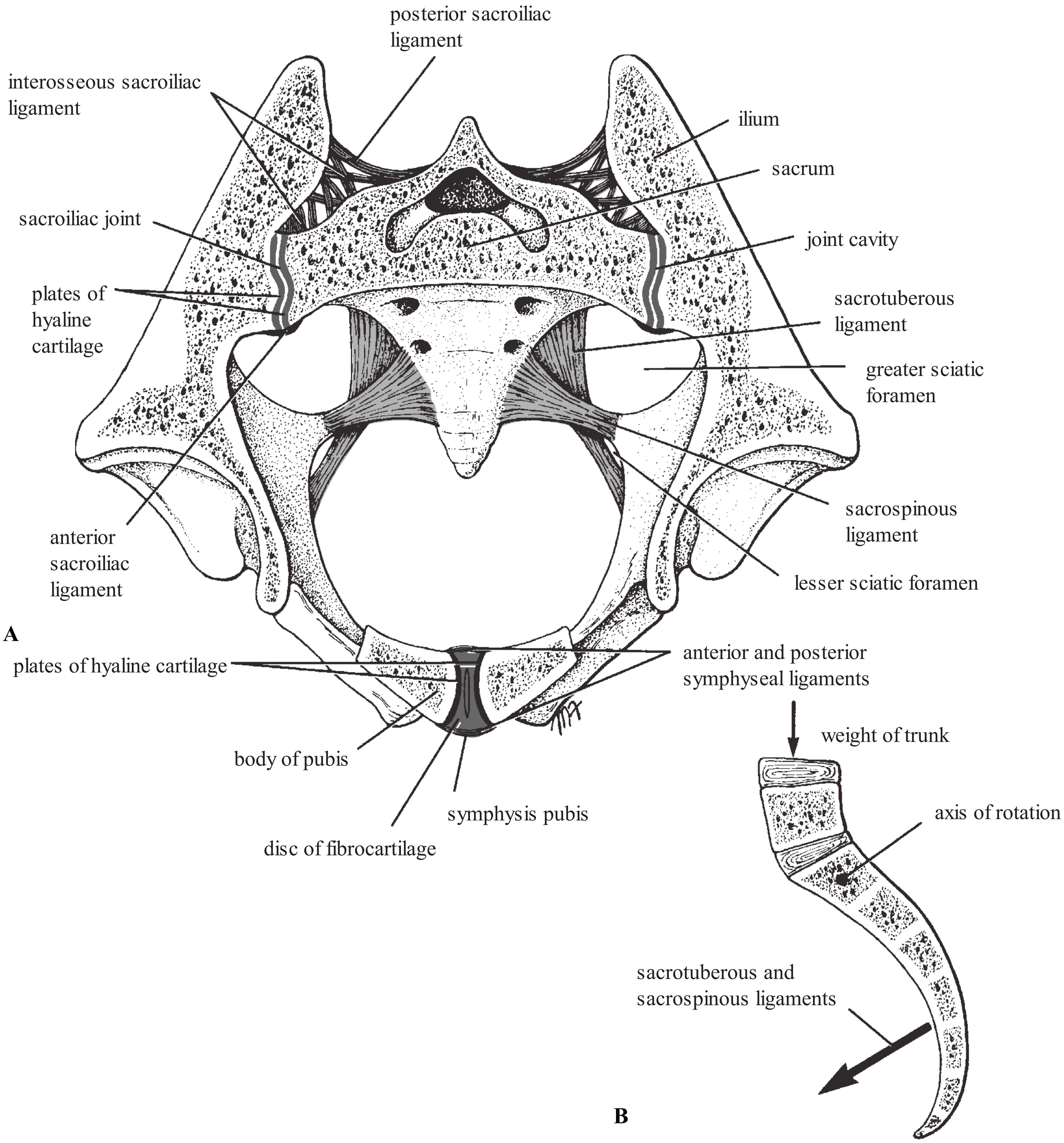


Figure 3-2 **A.** Horizontal section through the pelvis showing the sacroiliac joints and the symphysis pubis. **B.** Function of the sacrotuberous and sacrospinous ligaments in resisting the rotational force exerted on the sacrum by the weight of the trunk.

CLINICAL NOTES

PELVIC MEASUREMENTS IN OBSTETRICS

The capacity and shape of the female pelvis are of fundamental importance in obstetrics. The size of the pelvic inlet is similar in the two sexes; but in the female, the cavity is larger and cylindrical and the pelvic outlet is wider in both the anteroposterior and the transverse diameters. The axis of the pelvis is an imaginary line joining the central points of the anteroposterior diameters from the inlet to the outlet and is the curved course taken by the baby's head as it descends through the pelvis during childbirth.

INTERNAL PELVIC ASSESSMENTS

Internal pelvic assessments are made by a vaginal examination.

- Is the **pubic arch** broad or angular?
- Are the **lateral walls** concave, straight, or converging? Are the ischial spines prominent?
- On the **posterior wall,** is the sacrum straight or excessively curved forward? Can the promontory be felt? The **diagonal conjugate** (i.e., the distance between the lower margin of the symphysis pubis and the promontory of the sacrum) is normally 5 in. (13 cm).
- The distance between the **ischial tuberosities** measures about 4 in. (10 cm).

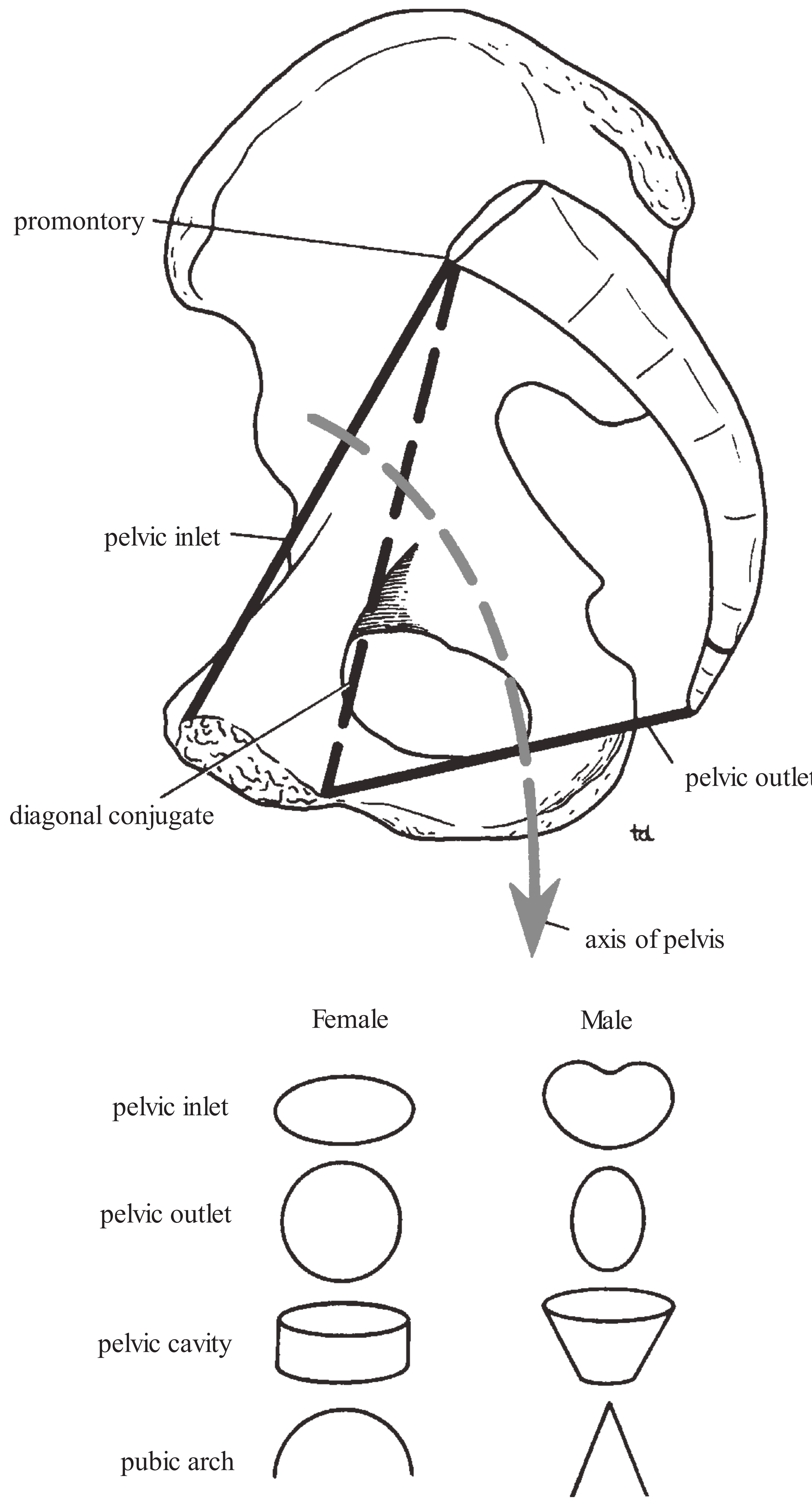


Figure 3-3 The pelvic inlet, pelvic outlet, diagonal conjugate, and axis of the pelvis. Some of the main differences between the female and the male pelvis are also shown.

WALLS OF THE PELVIS

The walls of the pelvis are formed by bones and ligaments that are partly lined with muscles, which in turn are covered with fascia and parietal peritoneum. The pelvis has anterior, posterior, and lateral walls; it also has an inferior wall or floor (Fig. 3-4).

Anterior Pelvic Wall

The anterior pelvic wall is the shallowest wall and is formed by the bodies of the pubic bones, the pubic rami, and the symphysis pubis.

Posterior Pelvic Wall

The posterior pelvic wall is extensive and is formed by the sacrum and the coccyx as well as by the piriformis muscles and their covering fascia.

Lateral Pelvic Wall

The lateral pelvic wall is formed by the hip bone (below the pelvic inlet), the obturator membrane, the sacrotuberous and sacrospinous ligaments, and the obturator internus muscle and its covering fascia.

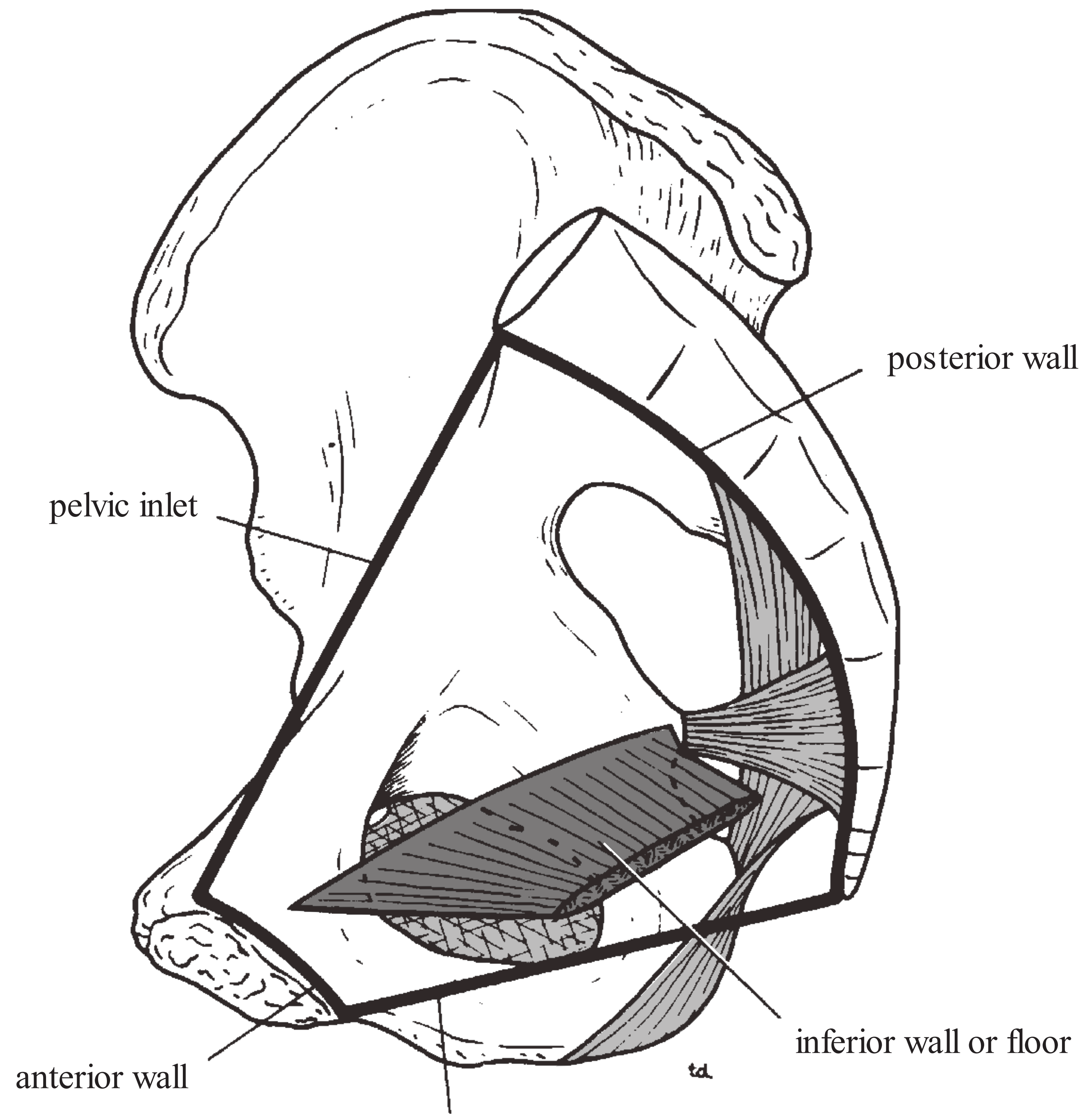


Figure 3-4 The right half of the pelvis showing the pelvic walls.

OBTURATOR MEMBRANE

The obturator membrane is a fibrous sheet that almost completely closes the obturator foramen in the hip bone. A small gap called the **obturator canal** allows passage of the obturator nerve and vessels.

SACROTUBEROUS LIGAMENT

The sacrotuberous ligament is strong and extends from the lateral part of the sacrum and coccyx and the posteroinferior iliac spine to the ischial tuberosity (Fig. 3-2).

SACROSPINOUS LIGAMENT

The sacrospinous ligament is strong and triangular shaped. It is attached by its base to the lateral part of the sacrum and the coccyx and by its apex to the spine of the ischium (Fig. 3-2).

The sacrotuberous and the sacrospinous ligaments prevent the lower end of the sacrum and the coccyx from being rotated at the sacroiliac joint by the weight of the body (Fig. 3-2).

Inferior Pelvic Wall (Pelvic Floor)

The pelvic floor supports the pelvic viscera and is formed by the pelvic diaphragm. Below the pelvic floor is the perineum.

The pelvic diaphragm (Fig. 3-5) is formed by the important levatores ani muscles, the small coccygeal muscles, and the pelvic fascia covering these muscles. The pelvic diaphragm is incomplete anteriorly, which allows passage of the urethra (and also of the vagina in females).

CLINICAL NOTES

THE PELVIC FLOOR AND CHILDBIRTH

At the pelvic inlet, the widest diameter is transverse so that the longest axis of the baby's head (anteroposterior) takes up the transverse position. When the head reaches the pelvic floor, the gutter shape of the floor tends to cause the baby's head to rotate so that its long axis comes to lie in the anteroposterior position. The occipital part of the head now moves downward and forward along the gutter, until it lies under the pubic arch. As the baby's head passes through the lower part of the birth canal, the small gap that exists in the anterior part of the pelvic diaphragm becomes enormously enlarged so that the head may slip through into the perineum. Once the baby has passed through the perineum, the levatores ani muscles recoil and take up their previous position.

Muscles of the Pelvic Walls

The attachments, nerve supplies, and actions of the muscles of the pelvic walls are given in Table 3-1.

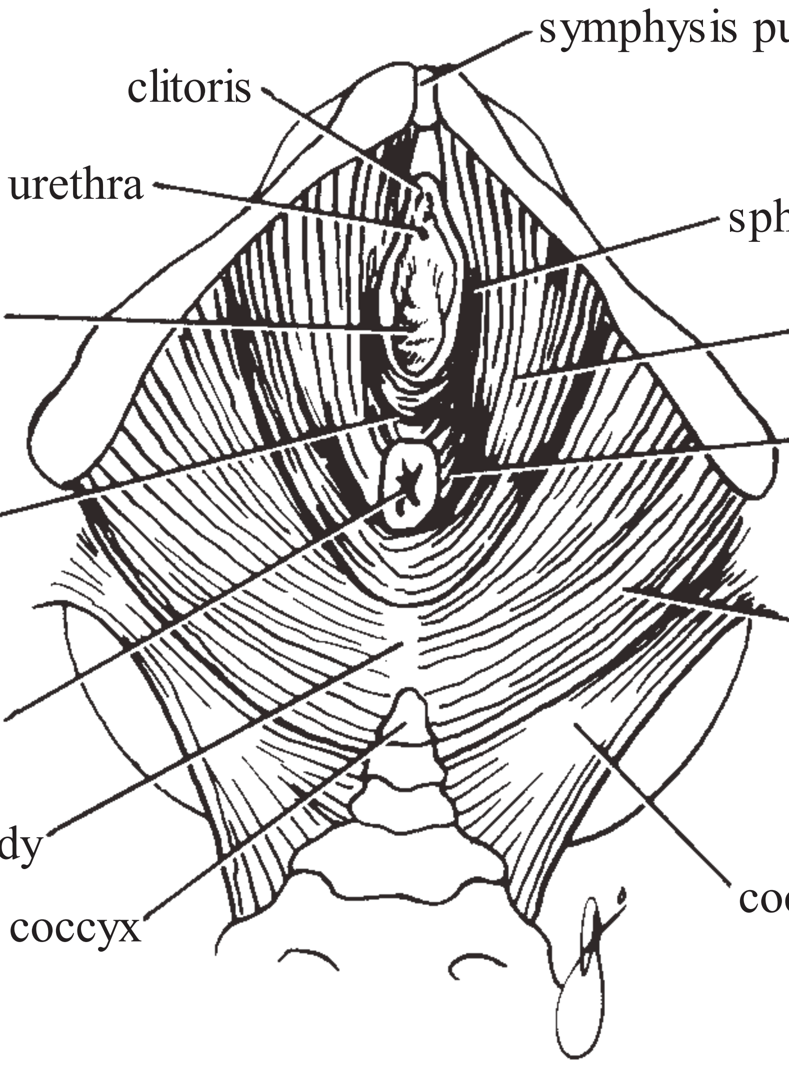


Figure 3-5 The muscles of the pelvic floor. Note that the levator ani muscle is composed of several different muscle groups. The levator ani and the coccygeus muscles with their fascial coverings form a continuous muscle floor to the pelvis known as the pelvic diaphragm.

Pelvic Fasciae

The **parietal pelvic fascia** lines the pelvic walls and is regionally named according to the muscle it overlies. Above the pelvic inlet, it is continuous with the fascia lining the abdominal walls.

The **visceral pelvic fascia** covers all the pelvic viscera. Around the cervix in females, this fascia is called the **parametrium**.

Pelvic Peritoneum

The parietal peritoneum lines the pelvic walls and is reflected onto the pelvic viscera, where it becomes continuous with the visceral peritoneum.

NERVES OF THE PELVIS

Sacral Plexus

The sacral plexus lies on the posterior pelvic wall in front of the piriformis muscle (Fig. 3-6). It is formed by the anterior rami of the fourth and fifth lumbar nerves and the anterior rami of the first, second, third, and fourth sacral nerves (Fig. 3-7). The contribution from the fourth lumbar nerve joins the fifth lumbar nerve to form the **lumbosacral trunk,** which passes down into the pelvis and joins the sacral nerves as they emerge from the anterior sacral foramina.

BRANCHES

Branches to the lower limb that leave the pelvis through the greater sciatic foramen (Fig. 3-6) are the following:

Table 3-1 Muscles of the Pelvic Walls and Floor

Name of Muscle	Origin	Insertion	Nerve Supply	Action
Piriformis	Front of the sacrum	Greater trochanter of the femur	Sacral plexus	Lateral rotator of the femur at the hip joint
Obturator internus	Obturator membrane and adjoining part of the hip bone	Greater trochanter of the femur	Sacral plexus	Lateral rotator of the femur at the hip joint
Levator ani	Body of the pubis, fascia of the obturator internus, spine of the ischium	Perineal body; anococcygeal body; walls of the prostate, vagina, rectum, and anal canal	Pudendal nerve, fourth sacral nerve	Supports the pelvic viscera; sphincter to the anorectal junction and vagina
Coccygeus	Spine of the ischium	Lower end of the sacrum, coccyx	Fourth and fifth sacral nerve	Assists levator ani muscle to support pelvic viscera, flexes coccyx

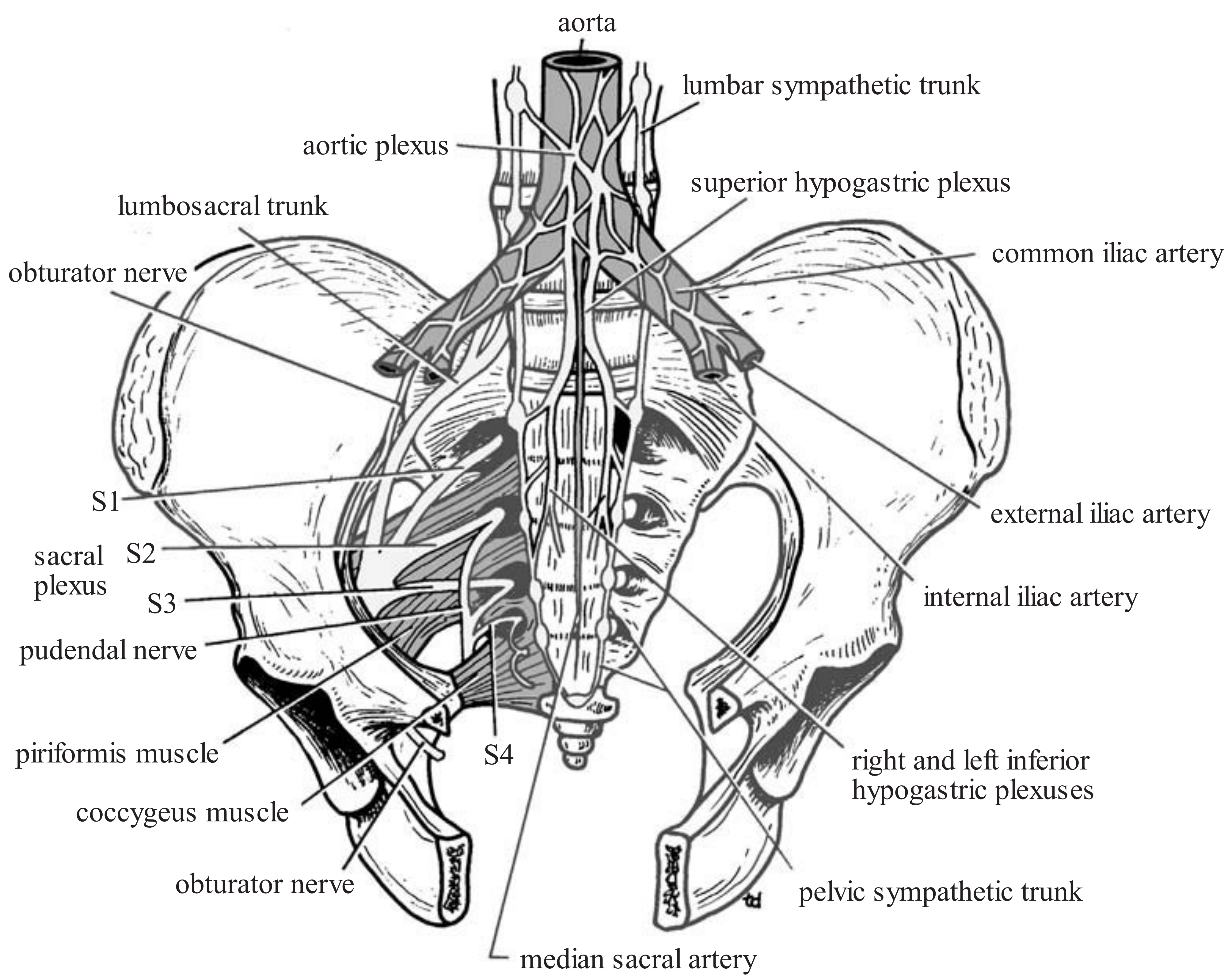


Figure 3-6 The posterior pelvic wall. Note the sacral plexus, superior hypogastric plexus, and right and left inferior hypogastric plexuses. Note also the pelvic parts of the sympathetic trunks.

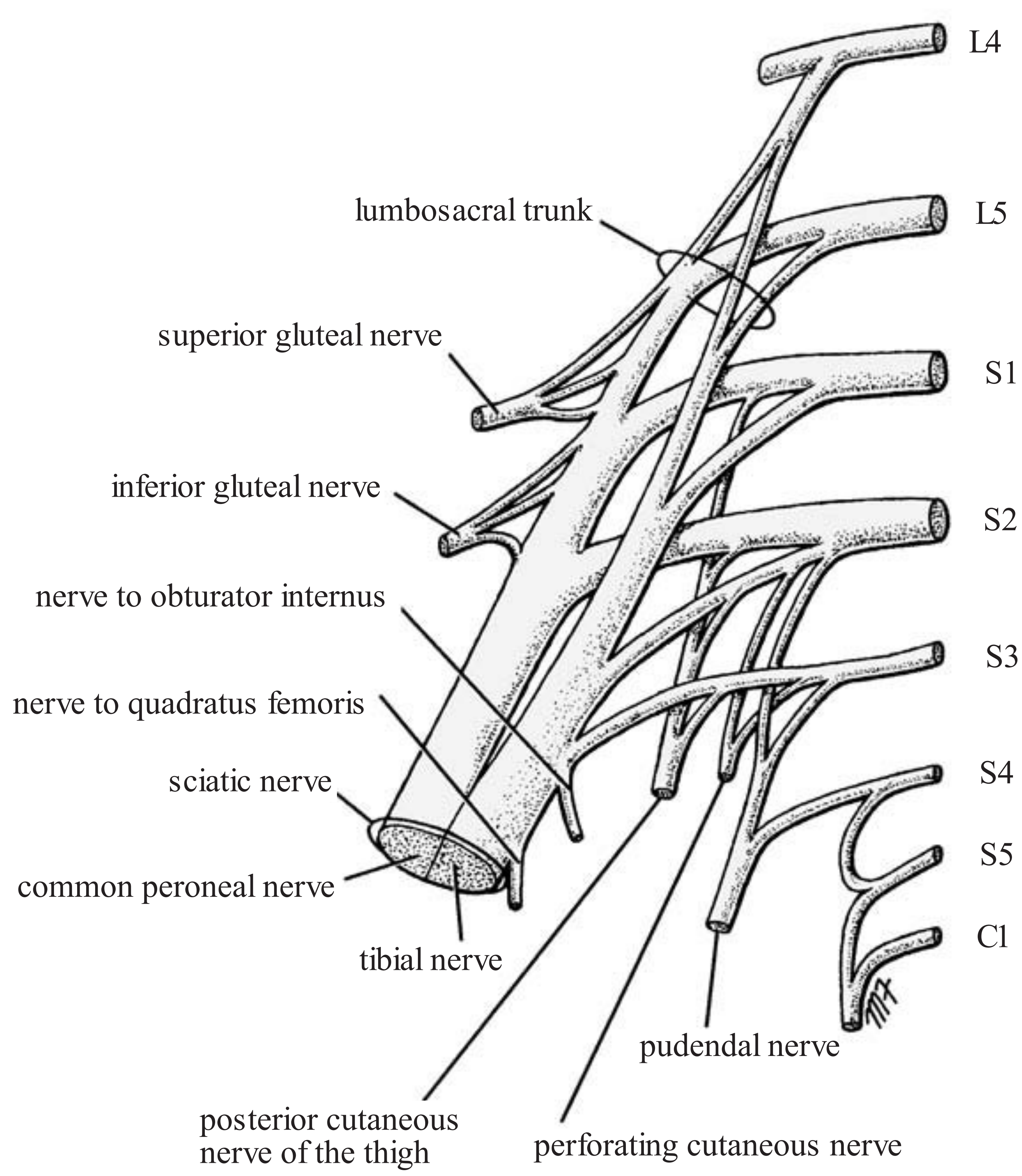


Figure 3-7 The sacral plexus.

Table 3-2 Branches of the Sacral Plexus and Their Distribution

Branches	Distribution
Superior gluteal nerve	Gluteus medius, gluteus minimus, and tensor fasciae latae muscles
Inferior gluteal nerve	Gluteus maximus muscle
Nerve to piriformis	Piriformis muscle
Nerve to obturator internus	Obturator internus and superior gemellus muscles
Nerve to quadratus femoris	Quadratus femoris and inferior gemellus muscles
Perforating cutaneous nerve	Skin over the medial aspect of the buttock
Posterior cutaneous nerve of thigh	Skin over the posterior surface of the thigh and popliteal fossa; also over lower part of the buttock, scrotum, or labium majus
Sciatic nerve (L4 and 5; S1, 2, and 3) Tibial portion	Hamstring muscles (semitendinosus, bicep femoris [long head], adductor magnus [hamstring part]), gastrocnemius, soleus, plantaris, popliteus, tibialis posterior, flexor digitorum longus, flexor hallucis longus, and via the medial and lateral plantar branches to muscles of the sole of the foot; sural branch supplies skin on the lateral side of leg and foot
Common peroneal portion	Biceps femoris muscle (short head) and via deep peroneal branch: tibialis anterior, extensor hallucis longus, extensor digitorum longus, peroneus tertius, and extensor digitorum brevis muscles; skin over the cleft between the first and second toes; the superficial peroneal branch supplies the peroneus longus and brevis muscles and the skin over the lower third of the anterior surface of the leg and dorsum of the foot
Pudendal nerve	Muscles of the perineum, including the external anal sphincter, mucous membrane of the lower half of the anal canal, perianal skin, skin of the penis, scrotum, clitoris, and labia majora and minora

- The **sciatic nerve** (L4 and 5; S1, 2, and 3) is the largest nerve in the body and the largest branch of the sacral plexus.
- The **superior gluteal nerve** supplies the gluteus medius, the gluteus minimus, and the tensor fasciae latae muscles.
- The **inferior gluteal nerve** supplies the gluteus maximus muscle.
- The **nerve to the quadratus femoris muscle** also supplies the inferior gemellus muscle.
- The **nerve to the obturator internus muscle** also supplies the superior gemellus muscle.
- The **posterior cutaneous nerve of the thigh** supplies the skin of the buttock and the back of the thigh.

Branches to the pelvic muscles, the pelvic viscera, and the perineum are the following:

- **The pudendal nerve** (S2, 3, and 4) leaves the pelvis through the greater sciatic foramen and enters the perineum through the lesser sciatic foramen (Fig. 3-6).
- **Nerves to the piriformis muscle.**
- **The pelvic splanchnic nerves** constitute the sacral part of the parasympathetic nervous system. They arise from the second, third, and fourth sacral nerves, and they are distributed to the pelvic viscera.

The branches of the sacral plexus and their distribution are summarized in Table 3-2.

Branches of the Lumbar Plexus

LUMBOSACRAL TRUNK

Part of the anterior ramus of the fourth lumbar nerve emerges from the medial border of the psoas muscle and joins the anterior ramus of the fifth lumbar nerve to form the lumbosacral trunk (Fig. 3-7). This trunk descends into the pelvis and joins the sacral plexus.

OBTURATOR NERVE (L2, 3, AND 4)

The obturator nerve emerges from the medial border of the psoas muscle and accompanies the lumbosacral trunk down into the pelvis. It runs forward on the lateral pelvic wall to reach the obturator foramen (Fig. 3-6). It then splits into anterior and posterior divisions, which pass through the canal to enter the adductor region of the thigh.

BRANCHES

Sensory branches supply the parietal peritoneum on the lateral pelvic wall.

Autonomic Nerves

PELVIC PART OF THE SYMPATHETIC TRUNK

The pelvic part of the sympathetic trunk is continuous above and behind the common iliac vessels with the lumbar part of the trunk. Below, the two trunks come together in front of the coccyx. Each trunk descends behind the rectum in front of the sacrum and medial to the anterior sacral foramina. The sympathetic trunk has four or five segmentally arranged ganglia (Fig. 3-6).

Branches

- Gray rami communicantes to the sacral and the coccygeal spinal nerves.
- Fibers that join the hypogastric plexuses.

PELVIC SPLANCHNIC NERVES

The pelvic splanchnic nerves constitute the parasympathetic part of the autonomic nervous system in the pelvis. They arise from S2, 3, and 4, as described for the sacral plexus. The preganglionic fibers synapse in the ganglia of the hypogastric plexuses.

SUPERIOR HYPOGASTRIC PLEXUS

The superior hypogastric plexus is situated in front of the promontory of the sacrum (Fig. 3-6). It divides inferiorly into the right and the left hypogastric nerves. The plexus is formed as a continuation of the aortic plexus and from branches of the third and the fourth lumbar sympathetic ganglia. It contains sympathetic and sacral parasympathetic nerve fibers as well as visceral afferent nerve fibers.

INFERIOR HYPOGASTRIC PLEXUS

The inferior hypogastric plexus lies on each side of the rectum, the base of the bladder, and the vagina (Fig. 3-6). It is formed from a hypogastric nerve (part of the superior hypogastric plexus) and from the pelvic splanchnic nerve. It contains postganglionic sympathetic nerve fibers, preganglionic and postganglionic parasympathetic nerve fibers, and visceral afferent nerve fibers. Branches pass to the pelvic viscera via small subsidiary plexuses. Parasympathetic fibers from the pelvic splanchnic nerve ascend through the hypogastric nerve to the superior hypogastric plexus and the inferior mesenteric plexus, and they supply the large bowel from the left colic flexure to the upper half of the anal canal.

ARTERIES OF THE PELVIS

Common Iliac Artery

Each common iliac artery ends at the pelvic inlet in front of the sacroiliac joint by dividing into the external and the internal iliac arteries (Figs. 3-6 and 3-8).

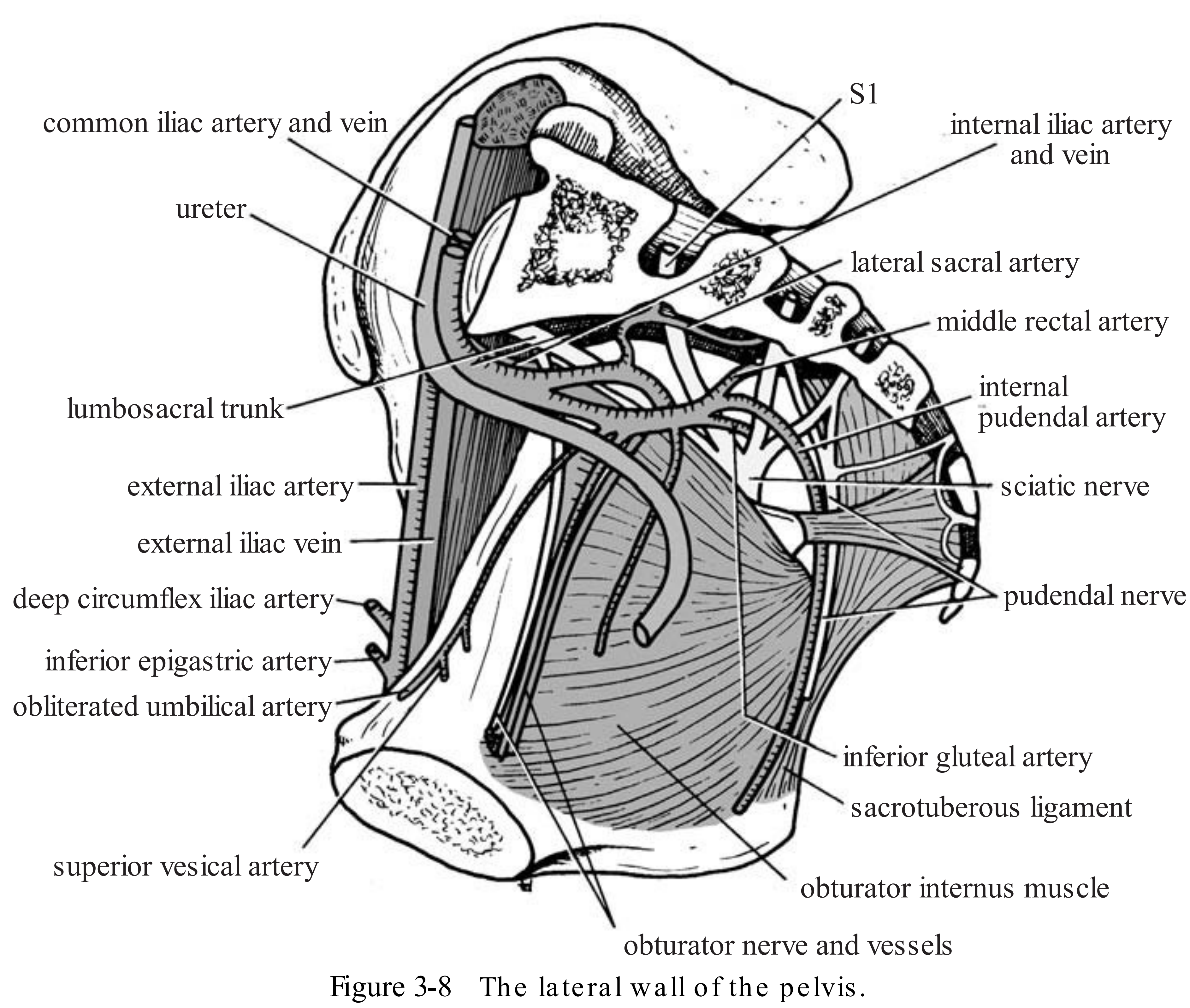


Figure 3-8 The lateral wall of the pelvis.

External Iliac Artery

The external iliac artery runs along the medial border of the psoas muscle and follows the pelvic brim (Fig. 3-8). It gives off the **inferior epigastric** and the **deep circumflex iliac branches.** It leaves the false pelvis by passing under the inguinal ligament to become the **femoral artery.**

The arteries entering the true pelvis are the following:

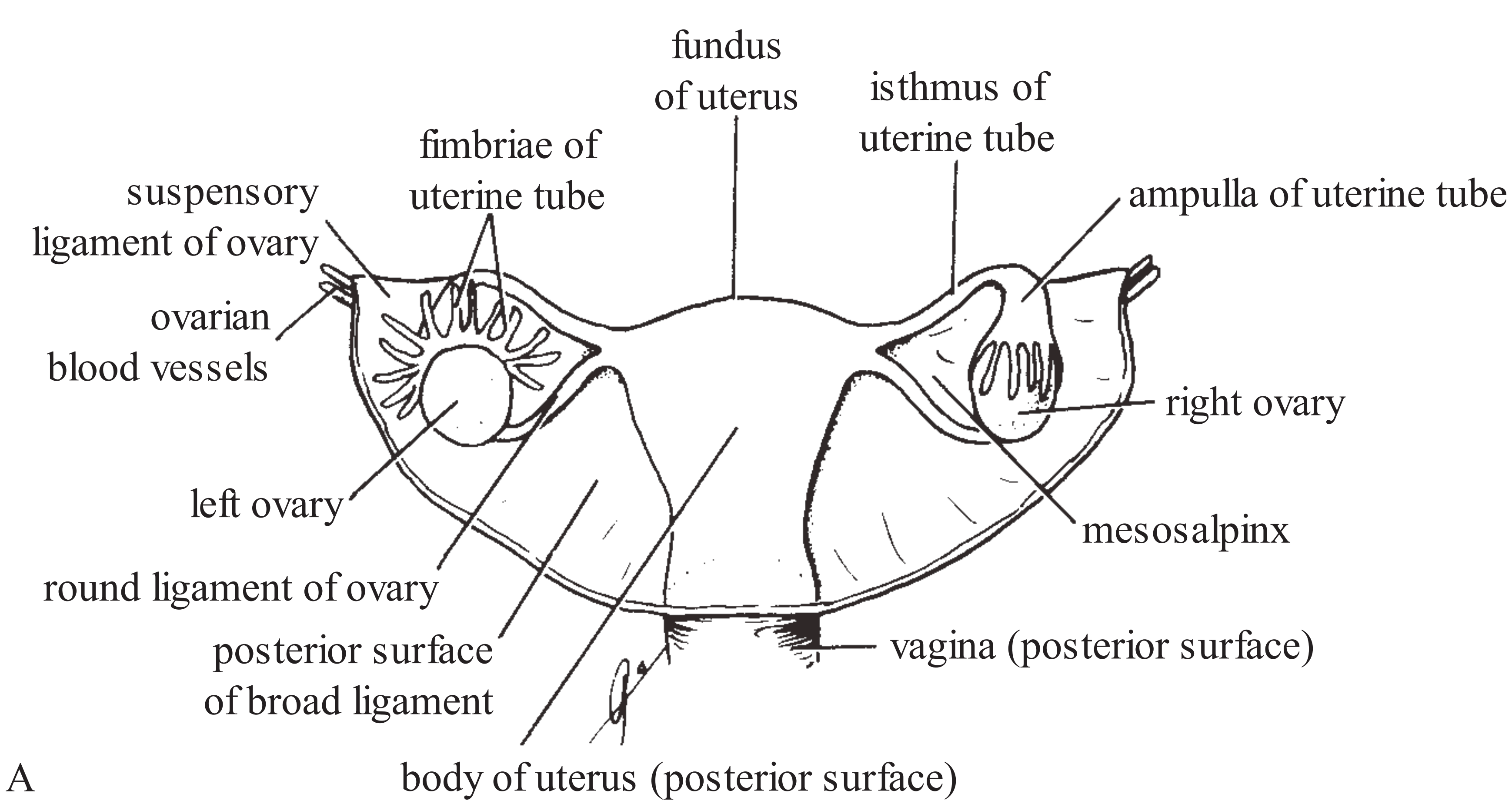
- The internal iliac artery.
- The superior rectal artery.
- The ovarian artery.
- The median sacral artery.

Internal Iliac Artery

The internal iliac artery passes down into the pelvis to the greater sciatic foramen, where it divides into anterior and posterior divisions (Fig. 3-8). The branches of these divisions supply the pelvic viscera, the perineum, the pelvic walls, and the buttocks.

BRANCHES OF THE ANTERIOR DIVISION OF THE INTERNAL ILIAC ARTERY

- **Umbilical artery:** The proximal patent part of this artery gives off the **superior vesical artery,** which supplies the upper portion of the bladder (Fig. 3-8).
- **Inferior vesical artery:** This artery supplies the base of the bladder as well as the prostate and the seminal vesicles in males. It also gives off the **artery to the vas deferens.**
- **Middle rectal artery:** Commonly, this artery arises with the inferior vesical artery (Fig. 3-8). It supplies the muscle of the lower rectum, and it anastomoses with the superior and inferior rectal arteries.
- **Uterine artery:** This artery runs medially on the floor of the pelvis and **crosses the ureter superiorly** (Fig. 3-9). It passes above the lateral fornix of the vagina to reach the uterus, where it ascends between the layers of the broad ligament along the lateral margin of the uterus. It ends by following the uterine tube laterally, where it anastomoses with the ovarian artery. The uterine artery gives off a vaginal branch.



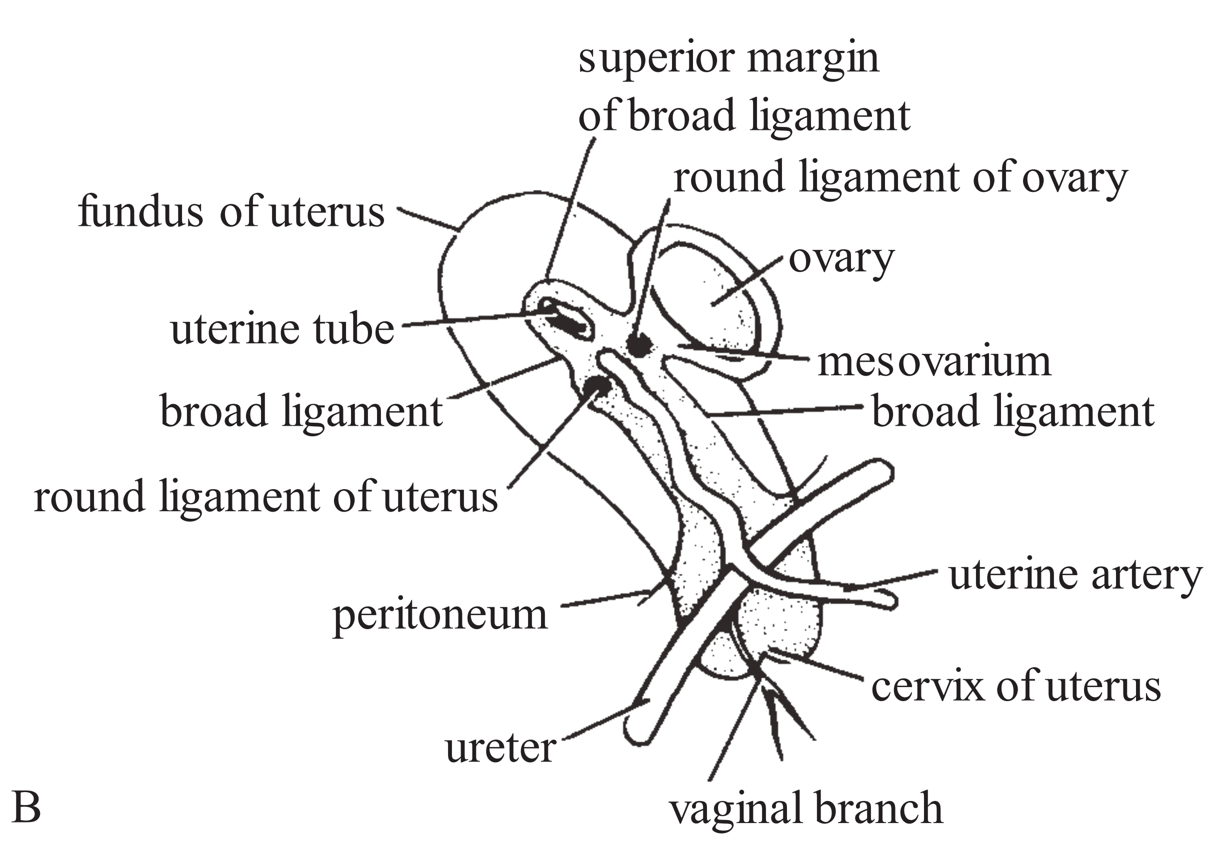


Figure 3-9 A. Posterior surface of the uterus and the broad ligaments. Note the position of the ovaries. B. Lateral view of the uterus. Note the relationship between the left uterine artery and the left ureter.

- **Vaginal artery:** This artery supplies the vagina and the base of the bladder.
- **Inferior gluteal artery:** This artery leaves the pelvis through the greater sciatic foramen (Fig. 3-8). It passes between the first and second or between the second and third sacral nerves.
- **Obturator artery:** This artery runs forward along the lateral wall of the pelvis with the obturator nerve. It leaves the pelvis through the obturator canal.
- **Internal pudendal artery:** This artery leaves the pelvis through the greater sciatic foramen and enters the gluteal region (Fig. 3-8). It enters the perineum through the lesser sciatic foramen and then passes forward in the pudendal canal with the pudendal nerve. By means of its branches, it supplies the musculature of the anal canal as well as the skin and the muscles of the perineum.

BRANCHES OF THE POSTERIOR DIVISION OF THE INTERNAL ILIAC ARTERY

- The **iliolumbar artery** ascends posterior to the external iliac vessels, the psoas muscle, and the iliacus muscles.
- The **lateral sacral arteries** descend in front of the sacral plexus and give off branches to the neighboring structures (Fig. 3-8).
- The **superior gluteal artery** leaves the pelvis through the greater sciatic foramen and supplies the gluteal region.

Superior Rectal Artery

The superior rectal artery is a direct continuation of the inferior mesenteric artery. It supplies the mucous membrane of the rectum and the upper half of the anal canal.

Ovarian Artery

The ovarian artery arises from the abdominal aorta at the level of the first lumbar vertebra. The artery is long and slender and passes downward behind the peritoneum. It crosses the external iliac artery at the pelvic inlet, and it enters the suspensory ligament of the ovary. It then passes into the broad ligament and enters the ovary through the mesovarium. (The testicular artery enters the inguinal canal but does not enter the pelvis.)

Median Sacral Artery

The median sacral artery is small and arises at the bifurcation of the aorta (Fig. 3-6). It descends over the anterior surface of the sacrum and the coccyx.

VEINS OF THE PELVIS

External Iliac Vein

The external iliac vein begins behind the inguinal ligament as a continuation of the femoral vein. It runs along the medial side of the corresponding artery, and it joins the internal iliac vein to form the **common iliac vein** (Fig. 3-8). It receives the **inferior epigastric** and the **deep circumflex iliac veins.**

The veins of the true pelvis are thin-walled vessels. They include the following:

- The internal iliac vein.
- The superior rectal vein.
- The ovarian vein.
- The median sacral vein.

Internal Iliac Vein

The internal iliac vein is formed by the union of tributaries corresponding to the branches of the internal iliac artery (Fig. 3-8). It ascends in front of the sacroiliac joint, and it joins the external iliac vein to form the common iliac vein.

Superior Rectal Vein

The superior rectal vein drains the rectal mucous membrane and mucous membrane of the upper half of the anal canal. It becomes continuous with the inferior mesenteric vein as it crosses the common iliac artery.

CLINICAL NOTES

PORTAL–SYSTEMIC ANASTOMOSIS

The superior rectal vein anastomoses with the middle and the inferior rectal veins and thus forms an important portal–systemic anastomosis.

Ovarian Vein

The right ovarian vein ascends on the posterior abdominal wall, and it drains into the inferior vena cava. The left ovarian vein drains into the left renal vein.

Median Sacral Vein

The median sacral vein is small and drains into the inferior vena cava or the left common iliac vein.

LYMPHATICS OF THE PELVIS

The lymph nodes and vessels are arranged as chains along the main blood vessels. The nodes are named after the blood vessels with which they are associated. Thus there are the **external iliac nodes,** the **internal iliac nodes,** and the **common iliac nodes.**

INTESTINAL VISCERA

Sigmoid Colon

The sigmoid colon is 10 to 15 in. (25 to 38 cm) in length and begins as a continuation of the descending colon in front of the pelvic brim. It becomes continuous below with the rectum in front of the third sacral vertebra (Fig. 3-10), and it

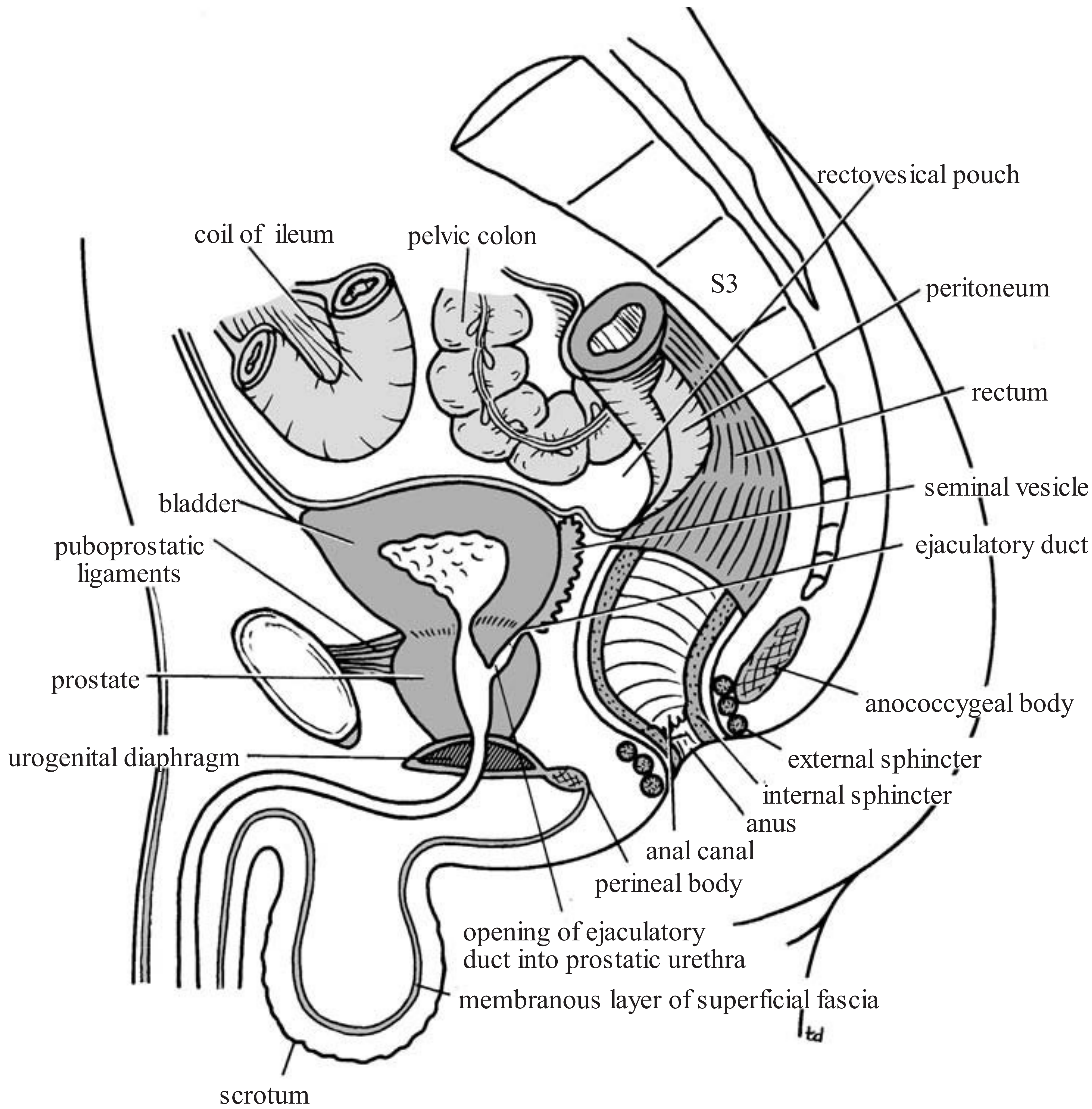


Figure 3-10 Sagittal section of the male pelvis.

hangs down into the pelvic cavity in the form of a loop. The sigmoid colon is attached to the posterior pelvic wall by the **sigmoid mesocolon.**

BLOOD SUPPLY

Arteries

Sigmoid branches of the inferior mesenteric artery supply the sigmoid colon.

Veins

The veins drain to tributaries of the portal venous system.

CLINICAL NOTES

Volvulus of the Sigmoid Colon

Because of its extreme mobility, the sigmoid colon sometimes rotates around its mesentery. Extreme rotation may cut off its arterial supply, a condition known as volvulus.

Colostomy of the Sigmoid Colon

In cases of cancer of the rectum, the surgeon may bring a loop of sigmoid colon with its blood supply intact through a small incision in the left iliac region of the anterior abdominal wall. The bowel is opened and the contents are collected in a container. The colostomy may be temporary or permanent, depending on the severity of the rectal operation.

Sigmoidoscopy

Since the sigmoid colon lies only a short distance from the anus (6.5 in.; 17 cm), it is possible to examine the mucous membrane under direct vision through a sigmoidoscope. Biopsy specimens may be taken for pathologic examination.

Rectum

The rectum is approximately 5 in. (13 cm) in length and begins in front of the third sacral vertebra as a continuation of the sigmoid colon (Figs. 3-10 and 3-11). It passes downward,

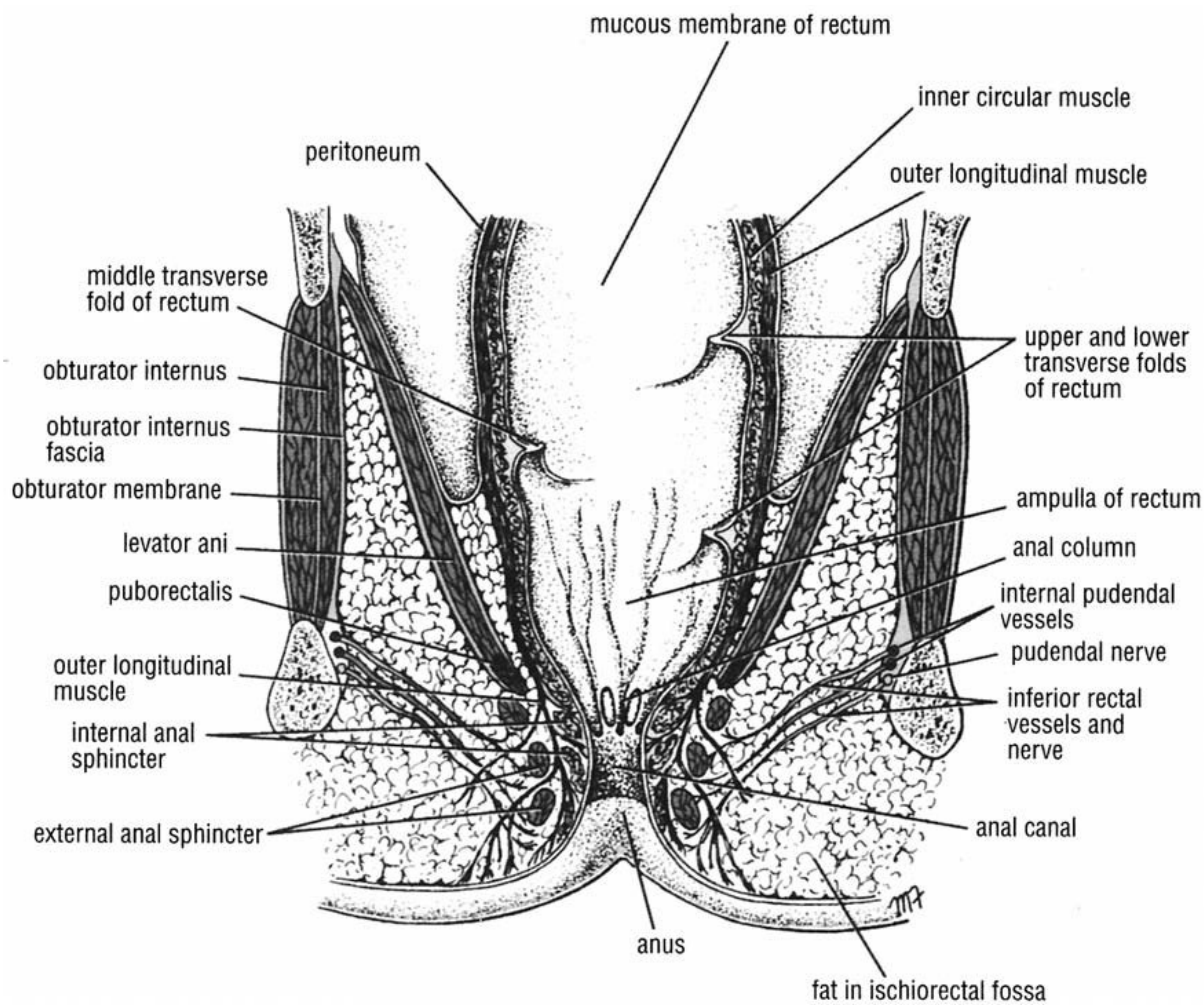


Figure 3-11 Coronal section through the pelvis that shows the rectum and the pelvic floor.

follows the curve of the sacrum and the coccyx, and ends in front of the tip of the coccyx by piercing the pelvic floor and becoming continuous with the anal canal. The lower part of the rectum is dilated to form the **rectal ampulla** (Fig. 3-11). The peritoneum covers only the upper two thirds of the rectum. The circular muscle layer and the mucous membrane of the rectum together form three semicircular folds. They are called the **transverse folds of the rectum.**

BLOOD SUPPLY

Arteries

Superior rectal artery, which is a continuation of the inferior mesenteric artery; middle rectal artery, which is a branch of the internal iliac artery; and inferior rectal artery, which is a branch of the internal pudendal artery, supply the rectum.

Veins

Venous blood drains into the portal vein through the superior rectal vein and into the systemic system through the middle and the inferior rectal veins.

CLINICAL NOTES

Anastomoses of the Rectal Veins

The anastomosis between the rectal veins is an important portal—systemic anastomosis.

LYMPH DRAINAGE

Lymph passes to the **pararectal nodes** and then upward to the **inferior mesenteric nodes.** In addition, some lymph vessels pass to the **internal iliac nodes.**

NERVE SUPPLY

Sympathetic and parasympathetic nerves, through the inferior hypogastric plexuses, supply the rectum.

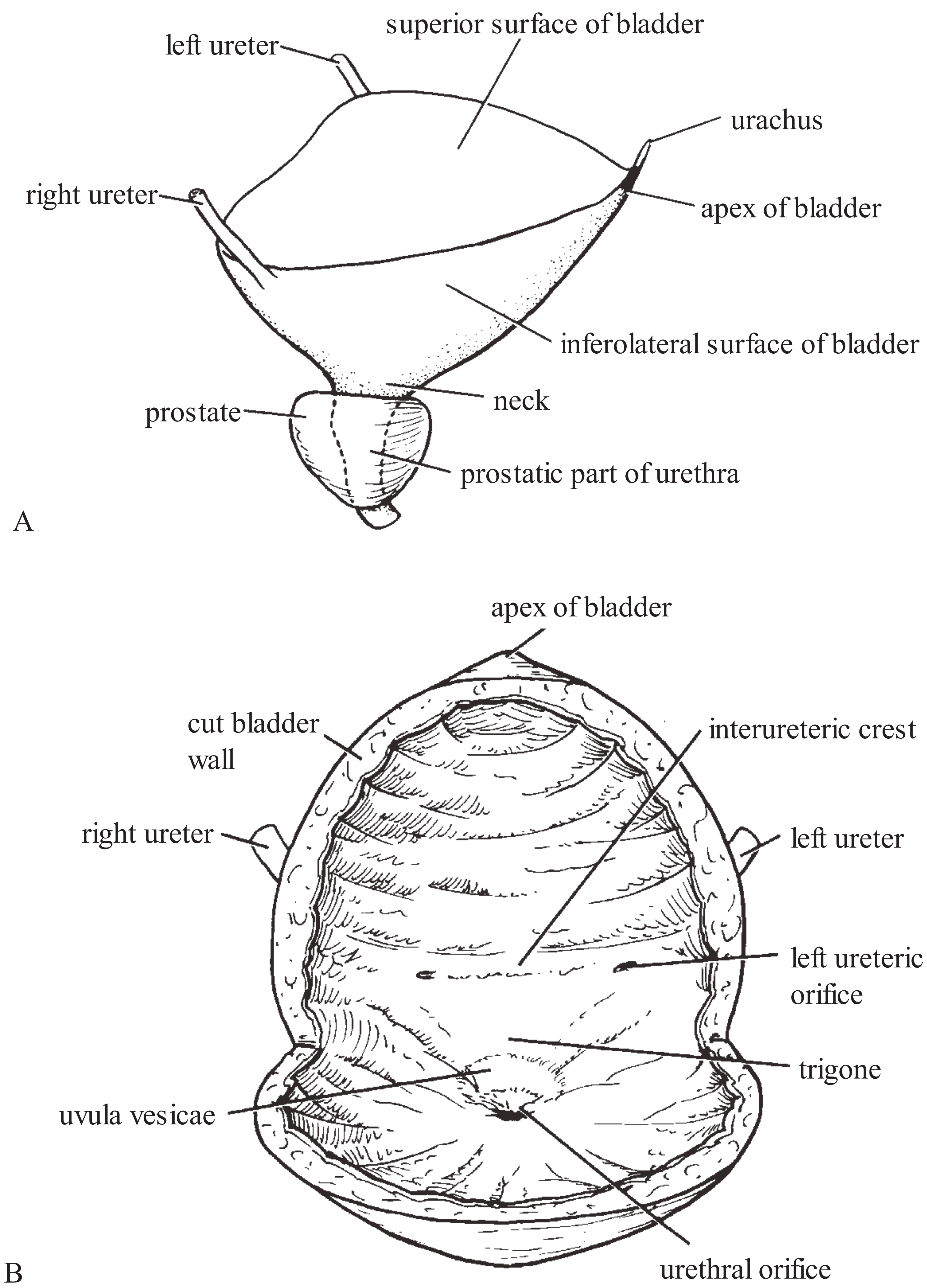


Figure 3-12 A. A partly filled urinary bladder. Note the general shape and surfaces as well as the position of the apex anteriorly and of the neck inferiorly. B. Front view showing the interior of the male urinary bladder.

CLINICAL NOTES

Rectal Curves, Mucosal Folds, and Instrumentation

When passing instruments, remember the anteroposterior flexure of the rectum as it follows the curvature of the sacrum and coccyx, and the lateral flexures. The crescentic transverse mucosal folds must also be borne in mind.

Ureters and Urinary Bladder

URETERS

Each ureter is a muscular tube that extends from the kidney to the posterior surface of the bladder. Its abdominal course is described on page 60.

The ureter enters the pelvis by crossing the bifurcation of the common iliac artery in front of the sacroiliac joint. The ureter then runs down the lateral wall of the pelvis to the region of the ischial spine and turns forward to enter the lateral angle of the bladder (Fig. 3-12).

In males, the ureter is crossed near its termination by the vas deferens. In females, the ureter leaves the region of the ischial spine by turning forward and medially beneath the base of the broad ligament, where it is crossed by the uterine artery (Fig. 3-9).

Ureteric Constrictions

The ureter possesses three constrictions:

- Where the renal pelvis joins the ureter.
- Where it is kinked as it crosses the pelvic brim.
- Where it pierces the bladder wall.

The blood supply, lymphatic drainage, and nerve supply of the ureter are described on page 61.

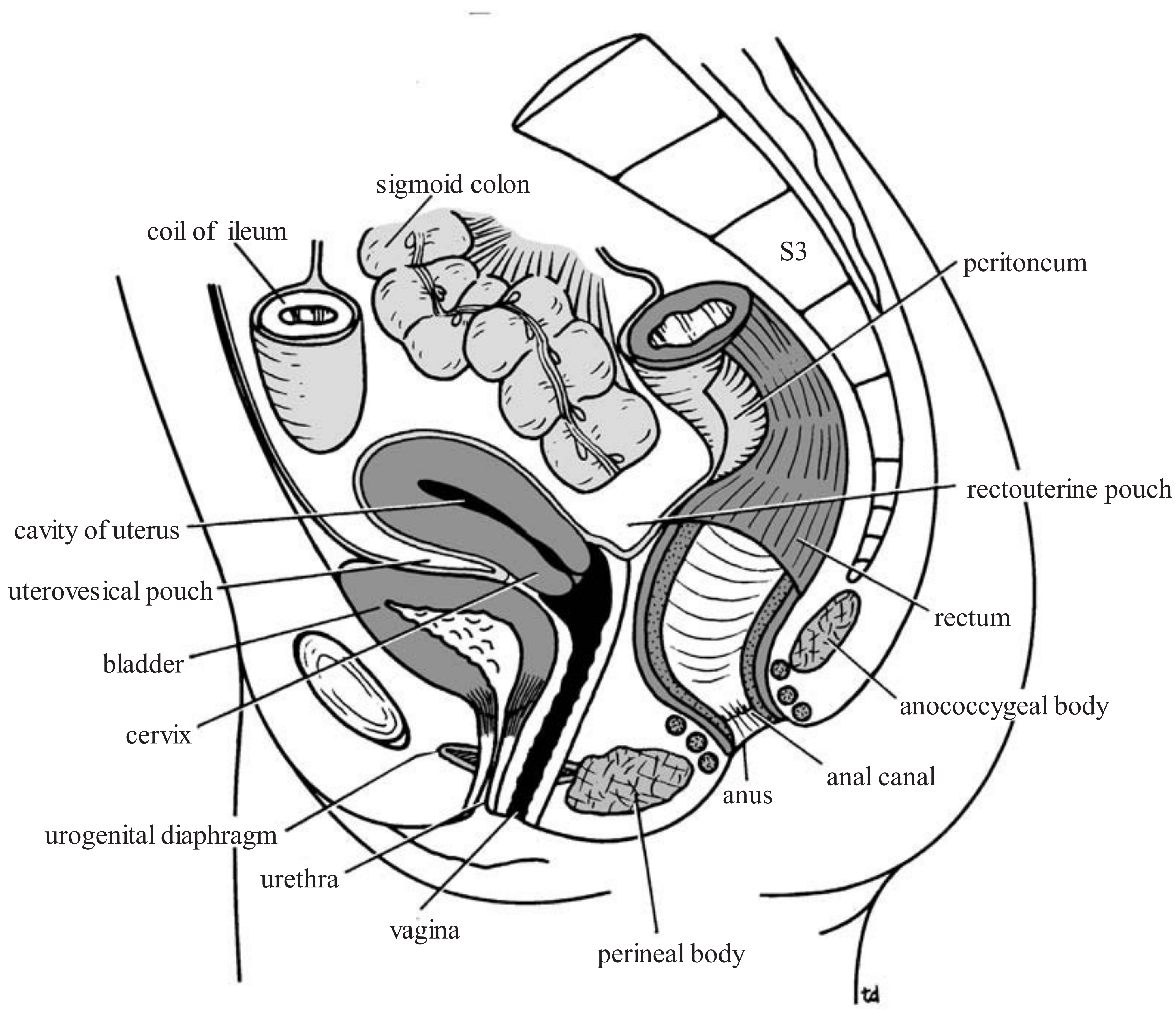


Figure 3-13 Sagittal section of the female pelvis.

Ureteric Stones

The importance of the constrictions of the ureter during the passage of ureteric stones in emphasized on page 60.

URINARY BLADDER

The urinary bladder is located immediately behind the pubic bones within the pelvis (Figs. 3-10 and 3-13). The bladder has a maximum capacity of approximately 500 mL.

The empty bladder is pyramidal in shape and has an apex, a base, and a superior as well as two inferolateral surfaces (Fig. 3-12). It also has a neck. When the bladder fills, it becomes ovoid in shape and the superior surface rises into the abdomen. In young children, the empty bladder projects upward into the abdomen; later, when the pelvis enlarges, the bladder sinks to become a pelvic organ.

The **apex** of the bladder points anteriorly and is connected to the umbilicus by the **median umbilical ligament** (remains of urachus). The **base** of the bladder faces posteriorly and is triangular in shape. The ureters enter the supralateral angles, and the urethra leaves the inferior angle. The **superior surface** of the bladder is covered with peritoneum, which is reflected laterally onto the lateral pelvic walls. As the bladder fills, the superior surface bulges upward into the abdominal cavity and peels the peritoneum off the lower part of the anterior abdominal wall. The **neck** of the bladder points inferiorly.

Interior of Bladder

The internal surface of the base of the bladder is called the **trigone** (Fig. 3-12). Here, the mucous membrane firmly adheres to the underlying muscle and is always smooth. The trigone has small, slitlike openings of the ureters at its lateral angles and below the crescentic opening of the urethra. The **interureteric ridge** runs from one ureteric orifice to the other. It is caused by the underlying muscle, and it forms the upper limit of the trigone. In males, the median lobe of the prostate bulges slightly upward into the bladder, behind the urethral orifice, to form a swelling (the **uvula vesicae**).

Muscular Coat of the Bladder Wall

The muscle coat (the **detrusor muscle**) consists of three interlacing layers of smooth muscle fibers. At the neck of the bladder, the circular muscle forms the **sphincter vesicae**.

Ligaments

The neck of the bladder is held in position by the **puboprostatic ligaments** in males and by the **pubovesical ligaments** in females. These ligaments are formed from pelvic fascia.

Blood Supply

Arteries

Superior and inferior vesical arteries (branches of the internal iliac artery) supply the bladder.

Veins

Vesical veins drain into the internal iliac veins.

Lymph Drainage

The lymph drains into internal and external iliac nodes.

Nerve Supply

Sympathetic and parasympathetic nerve fibers from the inferior hypogastric plexuses supply the bladder.

MICTURITION

When the volume of urine reaches approximately 300 mL in an adult, stretch receptors in the bladder wall transmit impulses to the central nervous system. That individual then has a conscious desire to micturate.

The afferent impulses enter the second, third, and fourth sacral segments of the spinal cord. Efferent impulses leave the cord from the same segments and pass via the parasympathetic preganglionic nerve fibers in the hypogastric plexuses to the bladder wall, where they synapse with postganglionic neurons. The detrusor muscle then contracts, and the sphincter vesicae relaxes. Efferent impulses also pass to the urethral sphincter via the pudendal nerve and this relaxes. Micturition can be assisted by contracting the abdominal muscles to raise the intra-abdominal and the pelvic pressures and to exert external pressure on the bladder.

Voluntary control of micturition is accomplished by contracting the sphincter urethrae. This process is assisted by the sphincter vesicae.

CLINICAL NOTES

PALPATION OF THE BLADDER

The full bladder in the adult projects up into the abdomen and may be palpated through the anterior abdominal wall above the symphysis pubis. In the child, the bladder is in a higher position than in the adult because of the relatively smaller size of the pelvis.

SUPRAPUBIC ASPIRATION

As the bladder fills, the superior wall rises out of the pelvis and peels the peritoneum off the posterior surface of the anterior abdominal wall. In cases of acute retention of urine, when catheterization has failed, it is possible to pass a needle into the bladder through the anterior abdominal wall above the symphysis pubis, without entering the peritoneal cavity.

Male Genital Organs

The **testes** and **epididymides** are described on page 45.

VAS DEFERENS

The vas deferens is a thick-walled tube approximately 18 in. (45 cm) in length. It emerges from the lower end or tail of the epididymis and passes through the inguinal canal into the abdomen. It then descends into the pelvis and crosses the ureter to reach the posterior surface of the bladder, where it expands to form the **ampulla** and then joins the duct of the seminal vesicle to form the **ejaculatory duct.**

EJACULATORY DUCT

There are two ejaculatory ducts. Each is formed by the union of the vas deferens and the duct of the seminal vesicle. Both ejaculatory ducts open into the prostatic part of the urethra (Fig. 3-14).

SEMINAL VESICLES

The seminal vesicles are paired organs that lie on the posterior surface of the bladder (Fig. 3-10) and lateral to the terminal part of the vas deferens. Each seminal vesicle consists of a much-coiled tube embedded in connective tissue. Inferiorly, the seminal vesicle narrows and joins the vas deferens of the same side to form the ejaculatory duct. The seminal vesicles contribute fluid, fructose, ascorbic acid, amino acids, and prostaglandins to the seminal fluid.

PROSTATE

The prostate is a glandular structure that surrounds the prostatic urethra. It lies below the neck of the bladder and above the urogenital diaphragm (Fig. 3-10). The prostate has a fibrous capsule, and outside this capsule is a fibrous sheath that is part of the visceral layer of pelvic fascia (Fig. 3-14). The prostate has a **base,** which lies superiorly against the bladder neck, and an **apex,** which lies inferiorly against the urogenital diaphragm.

The two ejaculatory ducts pierce the upper part of the posterior surface of the prostate and open into the prostatic urethra at the lateral margins of the opening of the **prostatic utricle.**

The numerous glands of the prostate are embedded in a mixture of smooth muscle and connective tissue, and their ducts open into the prostatic urethra. The prostate is divided into a number of lobes. The **anterior lobe** lies in front of the urethra. The **middle** or the **median lobe** lies behind the urethra and above the ejaculatory ducts. The **right** and the **left lateral lobes** lie on either side of the urethra.

Blood Supply

Arteries

Branches of the inferior vesical and the middle rectal arteries supply the prostate.

Veins

A prostatic venous plexus drains into the internal iliac veins.

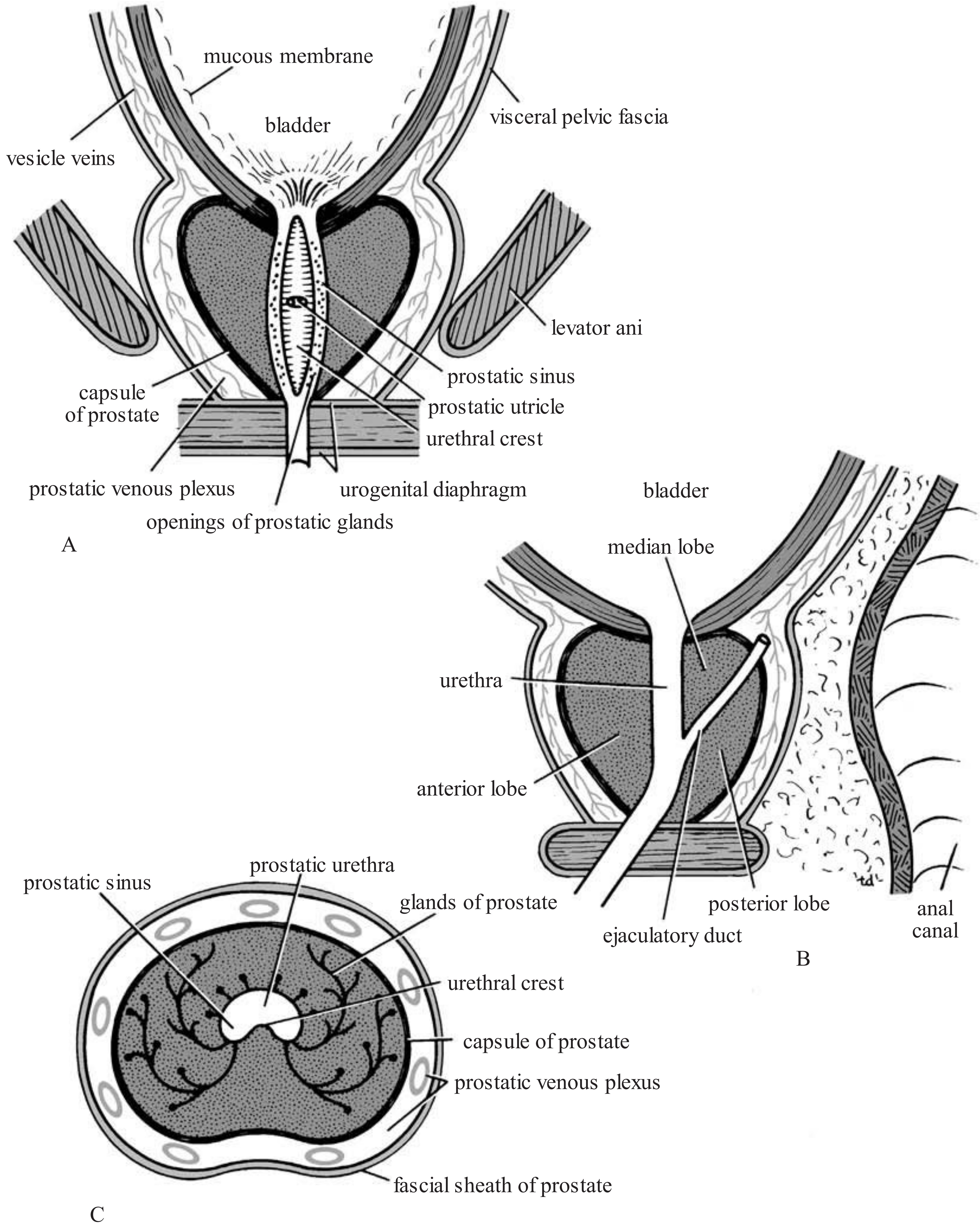


Figure 3-14 The prostate. A. Coronal section. B. Sagittal section. C. Horizontal section.

Lymph Drainage

The lymph drains into the internal iliac nodes.

Nerve Supply

Inferior hypogastric plexuses supply the prostate.

For details regarding the prostatic sinus, the prostatic utricle, and the urethral crest, see the discussion of the prostatic urethra on page 101. For developmental homologs of the male and the female genital systems, see Table 3-3.

CLINICAL NOTES

PROSTATE EXAMINATION

The prostate can be examined clinically via palpation by performing a rectal examination (see p.106). The examiner's gloved finger can feel the posterior surface of the prostate through the anterior rectal wall.

Table 3-3 Developmental Homologs of the Male and Female Genital Systems

Origin	Male	Female
Developing gonad	Testis	Ovary
Mesonephric duct	Duct of the epididymis, vas deferens, seminal vesicle, ejaculatory duct, trigone of the bladder, and part of the prostatic urethra	Ducts of the epoophoron, paroophoron, trigone of the bladder, and part of the urethra
Paramesonephric duct	Prostatic utricle, appendix of the testis	Uterine tubes, uterus
Urogenital sinus	Lower part of the prostatic urethra, membranous urethra, most of the penile urethra, prostate glands, and bulbourethral glands	Vagina and lower part of the urethra, paraurethral glands
Glans of the phallus	Glans of the penis	Glans of the clitoris
Genital (urethral) folds	Floor of the penile urethra	Labia minora
Genital swellings	Scrotum	Labia majora
Gubernaculum	Gubernaculum testis	Round ligament of the ovary, round ligament of the uterus

Female Genital Organs

OVARIES

Each ovary is attached to the back of the broad ligament by the **mesovarium** (Fig. 3-9). The ovarian vessels and nerves enter the ovary at the **hilum.**

The ovary is covered by a modified area of peritoneum called the **germinal epithelium,** beneath which is a thin, fibrous capsule called the **tunica albuginea.** The ovary has an outer **cortex** and an inner **medulla.** Embedded in the connective tissue of the cortex are the **ovarian follicles.**

The ovary usually lies near the lateral wall of the pelvis in a depression called the **ovarian fossa.** The ovarian fossa is bounded by the external and the internal iliac arteries.

Ligaments of the Ovaries

Suspensory Ligament

The suspensory ligament is the lateral part of the broad ligament connecting the mesovarium to the lateral pelvic wall (Fig. 3-9). It contains the blood and the lymphatic vessels as well as the nerves supplying the ovary.

Round Ligament

The round ligament of the ovary is the remains of the upper part of the gubernaculum, and it extends from the medial margin of the ovary to the lateral wall of the uterus (Fig. 3-9). Note that the round ligament of the uterus is the remains of the lower part of the gubernaculum.

Blood Supply

Arteries

The **ovarian artery,** which is a branch of the abdominal aorta, supplies the ovaries.

Veins

The **ovarian vein** drains into the inferior vena cava on the right and the left renal vein on the left.

Lymph Drainage

The lymph drains into the para-aortic nodes at the level of the first lumbar vertebra.

Nerve Supply

The aortic plexus supplies the ovary. (The branches accompany the ovarian artery.)

CLINICAL NOTES

POSITION OF THE OVARY

The ovary is kept in position by the broad ligament and the mesovarium. After pregnancy, the broad ligament is lax, and the ovaries may prolapse into the rectouterine pouch (pouch of Douglas). In these circumstances, the ovary may be tender and cause discomfort on sexual intercourse.

UTERINE TUBES

There are two uterine tubes (Fig. 3-9). Each tube lies in the upper border of the broad ligament and connects the peritoneal cavity in the region of the ovary with the cavity of the uterus. A uterine tube is divided into four parts:

- The **infundibulum** is the funnel-shaped lateral end with fingerlike processes (**fimbrae**) that are draped over the ovary.
- The **ampulla** is the widest part of the tube.
- The **isthmus** is the narrowest part of the tube and lies just lateral to the uterus.
- The **intramural part** is the segment that pierces the uterine wall.

The uterine tube provides a site for fertilization of the ovum (usually in the ampulla). It provides nourishment for the fertilized ovum, and it transports the ovum to the cavity of the uterus. The tube also serves as a conduit along which the spermatozoa travel to reach the ovum.

Blood Supply

Arteries

The uterine and ovarian arteries supply the uterine tubes.

Veins

The veins drain to the uterine and ovarian veins.

Lymph Drainage

The lymph vessels follow the arteries and drain into the internal iliac and the para-aortic nodes.

Nerve Supply

Sympathetic and parasympathetic nerves from the superior and the inferior hypogastric plexuses supply the tubes.

CLINICAL NOTES

PELVIC INFLAMMATORY DISEASE

In pelvic inflammatory disease, pathogenic organisms may ascend from the vagina and uterus and enter the uterine tube, producing **salpingitis.** The infection may spread from the uterine tube into the pelvic part of the peritoneal cavity, producing **peritonitis.**

ECTOPIC PREGNANCY

In ectopic pregnancy, the fertilized ovum becomes implanted in the wall of the uterine tube and not in the uterine cavity. The eroding action of the developing placenta quickly destroys the wall of the tube. Tubal abortion or rupture of the tube, with the effusion of a large quantity of blood into the peritoneal cavity, is the common result.

TUBAL LIGATION

Ligation and division of the uterine tubes is a method of obtaining permanent birth control. It is usually restricted to women who have already had children.

UTERUS

The uterus is divided into the fundus, the body, and the cervix (Fig. 3-9). The **fundus** lies above the entrance of the uterine tubes. The **body** lies beneath the entrance of the uterine tubes, and it narrows below, where it becomes continuous with the **cervix.** The cervix pierces the anterior wall of the vagina (Fig. 3-13). The cavity of the cervix (the **cervical canal**) communicates with the cavity of the body through the **internal os** and with the cavity of the vagina through the **external os.**

Positions of Uterus

Anteversion is the term used to describe the forward bending of the uterus on the long axis of the vagina. **Anteflexion** is the term used to describe the forward bending of the body of the uterus on the cervix.

Supports of the Uterus

The main supports of the uterus are the following:

- The **pelvic diaphragm** (levatores ani and the coccygeus muscles and their fascia).
- The **perineal body** (a fibromuscular structure in the perineum supported by the levatores ani muscles).
- The **transverse cervical (cardinal) ligaments,** which attach the cervix and upper end of the vagina to the lateral pelvic walls.
- The **pubocervical ligaments,** which attach the cervix to the pubic bones.
- The **sacrocervical ligaments,** which attach the cervix and upper end of the vagina to the lower end of the sacrum.

Broad Ligaments

The broad ligaments are two-layered folds of peritoneum that extend across the pelvic cavity from the lateral margins of the uterus to the lateral pelvic walls (Fig. 3-9). Each broad ligament contains the following:

- The uterine tube in its upper free border.
- The round ligaments of the ovary and of the uterus.
- The uterine and the ovarian blood vessels, lymph vessels, and nerves.

The broad ligaments provide little support to the uterus.

Round Ligament of the Uterus

The round ligament extends from the superolateral angle of the uterus through the inguinal canal to the subcutaneous tissue of the labium majus. It assists in keeping the uterus anteverted and anteflexed.

Blood Supply

Arteries

The **uterine artery** from the internal iliac artery and the **ovarian artery** supply the uterus.

Veins

The veins correspond to the uterine and ovarian arteries.

Lymph Drainage

From the fundus, the lymph vessels follow the ovarian artery to the para-aortic nodes at the level of the first lumbar vertebra. From the body and the cervix, the lymph vessels drain into the internal and the external iliac nodes. In addition, a few lymph vessels pass through the inguinal canal to the superficial inguinal nodes.

Nerve Supply

Sympathetic and parasympathetic nerves from the inferior hypogastric plexuses supply the uterus.

CLINICAL NOTES

Bimanual Pelvic Examination of the Uterus

With the bladder empty, the vaginal portion of the cervix is first palpated with the index finger of the right hand. The external os is circular in the nulliparous woman but has anterior and posterior lips in the multiparous woman. The left hand is placed on the anterior abdominal wall above the symphysis pubis, and the fundus and body of the uterus may be palpated between the abdominal and vaginal fingers situated in the anterior fornix. The size and shape, and mobility of the uterus can then be ascertained.

Prolapse of the Uterus

The levatores ani muscles and the transverse cervical, pubocervical, and sacrocervical ligaments are of very great importance in supporting and positioning the uterus. Damage to these structures during childbirth or as a result of general poor body muscular tone may result in downward displacement of the uterus, called uterine prolapse.

VAGINA

The vagina is the female genital canal (Fig. 3-13). It serves as the excretory duct for the menstrual flow from the uterus, and it forms part of the birth canal.

The vagina is a muscular tube that extends between the vulva and the uterus. The cervix of the uterus pierces its anterior wall. The vaginal orifice in the virgin possesses a thin mucosal fold (the **hymen**), which is perforated at its center. The area of the vaginal lumen that surrounds the cervix of the uterus is divided into four regions or **fornices:** the **anterior,** the **posterior,** the **right lateral,** and the **left lateral.** The upper half of the vagina lies within the pelvis between the bladder anteriorly and the rectum posteriorly; the lower half lies within the perineum between the urethra anteriorly and the anal canal posteriorly (Fig. 3-13).

Supports of the Vagina

- **Upper third:** Levatores ani muscles; transcervical, pubocervical, and sacrocervical ligaments.
- **Middle third:** Urogenital diaphragm.
- **Lower third:** Perineal body.

Blood Supply

Arteries

The **vaginal artery** (a branch of the internal iliac artery) and **vaginal branch of uterine artery** supply the area.

Veins

The **vaginal veins** drain into the internal iliac veins.

Lymph Drainage

The upper third of the vagina drains into the internal and the external iliac nodes. The middle third drains into the internal iliac nodes, and the lower third drains into superficial inguinal nodes.

Nerve Supply

The inferior hypogastric plexuses supply the vagina.

For developmental homologs of the male and the female genital systems, see Table 3-3.

CLINICAL NOTES

Prolapse of the Vagina

The vaginal vault is supported by the same structures that support the uterine cervix. Prolapse of the uterus is necessarily associated with some degree of sagging of the vaginal walls. If the supports of the bladder, urethra, or anterior rectal wall are damaged in childbirth, prolapse of the vaginal walls occurs, with the uterus remaining in its correct position.

VISCERAL PELVIC FASCIA IN THE FEMALE PELVIS

As in males, the visceral pelvic fascia covers and supports the pelvic viscera in females. It is condensed to form the pubocervical, the transverse cervical, and the sacrocervical ligaments of the uterus. Clinically, the pelvic fascia in the region of the uterine cervix is often called the **parametrium.**

PERITONEUM IN THE FEMALE PELVIS

The peritoneum passes from the anterior abdominal wall onto the upper surface of the urinary bladder (Fig. 3-13). It then runs onto the anterior surface of the uterus upward and over the fundus of the uterus and then downward on the posterior surface of the uterus. It then continues downward over the upper part of the posterior surface of the vagina, where it forms the anterior wall of the **rectouterine pouch (pouch of Douglas).** The peritoneum is then reflected onto the front of the rectum. The most inferior part of the peritoneal cavity is the rectouterine pouch.

CLINICAL NOTES

The Rectouterine Pouch and Disease

Since the rectouterine pouch (pouch of Douglas) is the most dependent part of the entire peritoneal cavity (when the patient is in the standing position), it frequently becomes the site for the accumulation of blood (from a ruptured ectopic pregnancy) or pus (from a ruptured pelvic appendicitis or in gonococcal peritonitis).

PERINEUM

The perineum lies below the pelvic diaphragm. It is shaped like a diamond and is bounded anteriorly by the **symphysis pubis,** posteriorly by the tip of the **coccyx,** and laterally by the **ischial tuberosities** (Fig. 3-15). The perineum is divided into two triangles by joining the ischial tuberosities with an imaginary line. The anterior triangle, which contains the urogenital orifices, is called the **urogenital triangle;** the posterior triangle, which contains the anus, is called the **anal triangle** (Fig. 3-15).

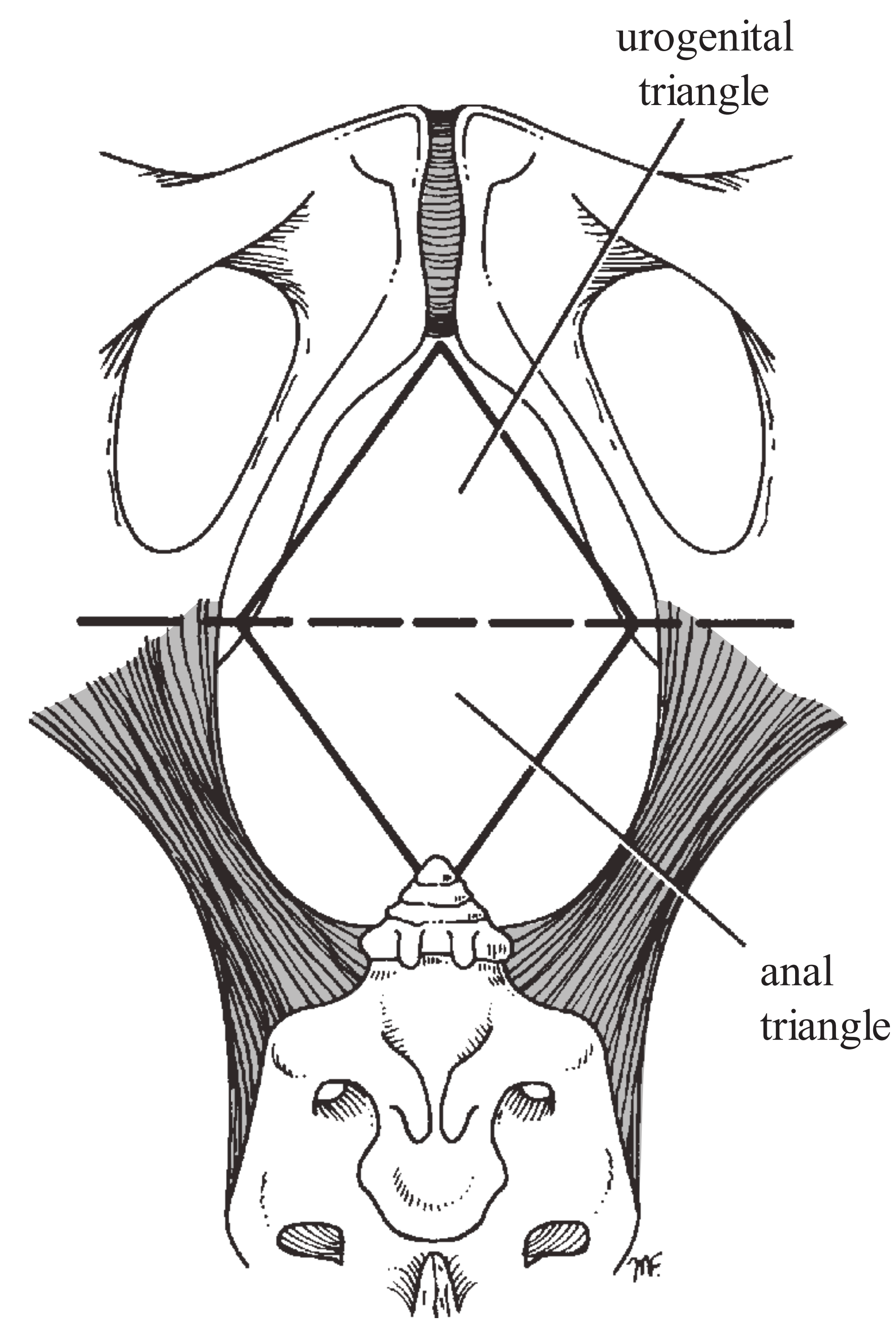


Figure 3-15 The diamond-shaped perineum. The broken line divides the perineum into the urogenital and the anal triangles.

UROGENITAL TRIANGLE

Urogenital Diaphragm

The urogenital diaphragm is a musculofascial diaphragm that fills the gap of the pubic arch (Fig. 3-16). It is formed by the sphincter urethrae and the deep transverse perineal muscles, which are enclosed between a superior and an inferior fascial layer of the urogenital diaphragm. The inferior layer of fascia is called the **perineal membrane.**

PERINEAL BODY

The perineal body is a small mass of fibrous tissue attached to the center of the posterior margin of the urogenital diaphragm. It is a larger structure in females than in males. In females, it supports the posterior vaginal wall; in both sexes, it provides attachment for muscles in the perineum (Fig. 3-16).

PERINEAL POUCHES

Superficial Perineal Pouch

The superficial perineal pouch is a potential space that lies beneath the skin of the perineum. It is bounded below by the membranous layer of the superficial fascia (Colles' fascia) and above by the urogenital diaphragm (Fig. 3-17). Posteriorly, it is closed by the attachment of this membranous layer of fascia to the posterior border of the urogenital diaphragm. Laterally, it is closed by the attachment of the membranous layer of the superficial fascia and the urogenital diaphragm to the pubic arch. Anteriorly, the space communicates freely with the potential space between the superficial fascia of the anterior abdominal wall (Scarpa's fascia) and the anterior abdominal muscles.

CONTENTS OF THE SUPERFICIAL PERINEAL POUCH

In males, the superficial perineal pouch contains the root of the penis and its associated muscles. In females, it contains the root of the clitoris and its associated muscles.

Deep Perineal Pouch

The deep perineal pouch is a closed potential space that lies within the urogenital diaphragm (Fig. 3-17).

CONTENTS OF THE DEEP PERINEAL POUCH

In males, the deep perineal pouch contains the following:

- The membranous part of the urethra.
- The sphincter urethrae.
- The bulbourethral glands.
- The deep transverse perineal muscles.
- The internal pudendal vessels.
- The dorsal nerves of the penis.

In females, the deep perineal pouch contains the following:

- Part of the urethra.
- Part of the vagina.

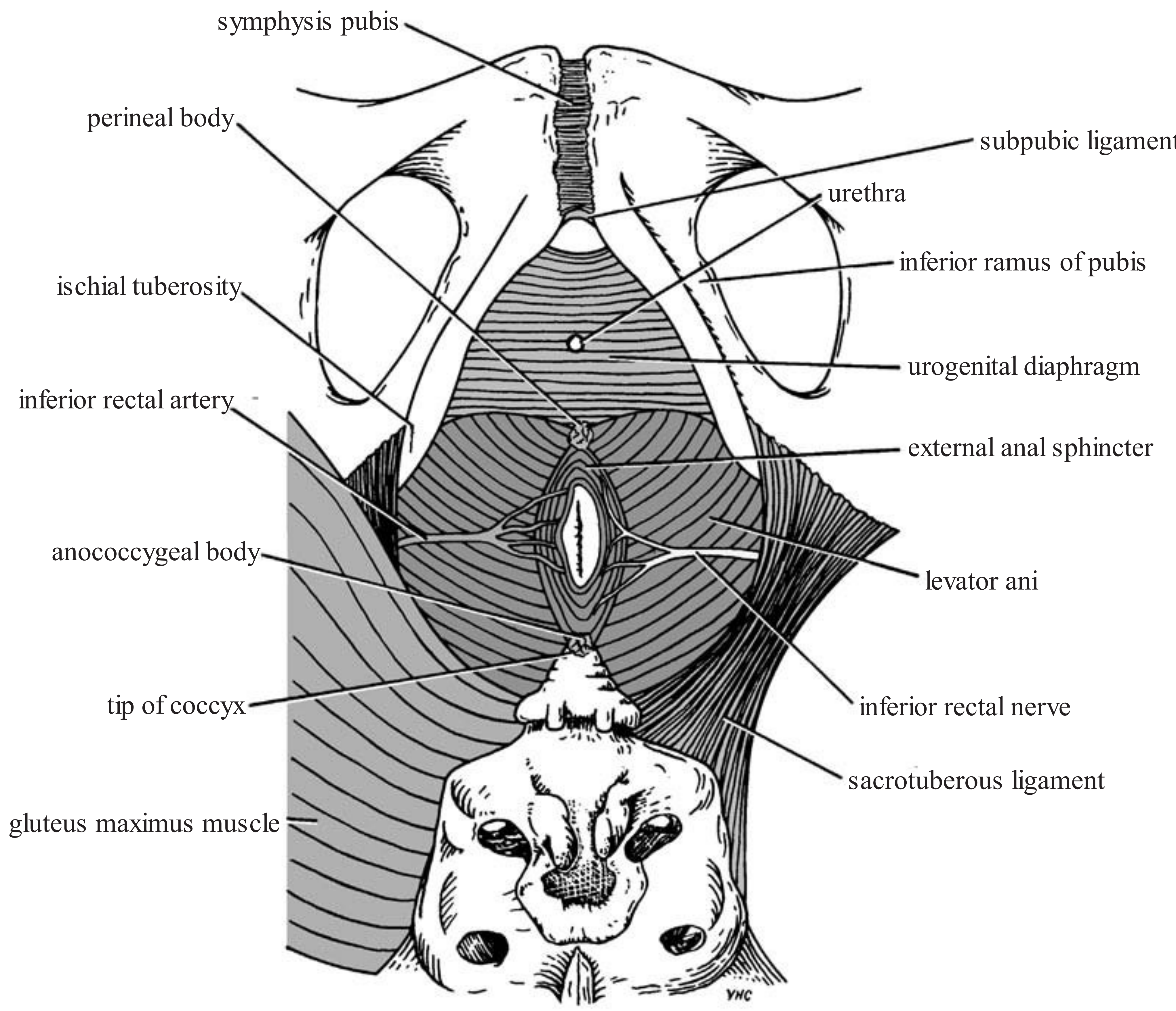


Figure 3-16 The anal and urogenital triangles in the male as seen from below.

- The sphincter urethrae.
- The deep transverse perineal muscles.
- The internal pudendal vessels.
- The dorsal nerves of the clitoris.

MALE EXTERNAL GENITALIA

Penis

The penis has both a cylindrical **body** that hangs free and a fixed **root** (Fig. 3-18). The body of the penis has an expanded distal end called the **glans penis.** The **prepuce** (or **foreskin**) is a hoodlike fold of skin that covers the glans. The interior of the penis body is composed of three cylinders of erectile tissue enclosed in a tubular sheath of fascia. The erectile tissue is composed of two dorsally placed **corpora cavernosa** and a single **corpus spongiosum** applied to their ventral surface (Fig. 3-18). At its distal end, the corpus spongiosum expands to form the glans penis, which covers the distal ends of the corpora cavernosa. The penile part of the urethra runs through the center of the corpus spongiosum and opens onto the surface of the glans at the **external urethral orifice.**

The **root of the penis** is located in the superficial perineal pouch and is composed of three masses of erectile tissue: the **bulb of the penis** and the **right** and the **left crura of the penis** (Fig. 3-18). The bulb is located in the midline, is traversed by the urethra, and is covered on its outer surface by the **bulbospongiosus muscles.** Each crus is attached to the side of the pubic arch and is covered on its outer surface by the **ischiocavernosus muscle.**

The bulb of the penis is continuous anteriorly with the corpus spongiosum. The two crura are continuous anteriorly with the corpora cavernosa in the body of the penis.

BLOOD SUPPLY

Arteries

Deep arteries of the penis and branches of the dorsal arteries of the penis supply the area.

Veins

The veins run into the deep dorsal vein.

LYMPH DRAINAGE

The glans penis drains into the deep inguinal and the external iliac nodes. The skin of the remainder of the organ

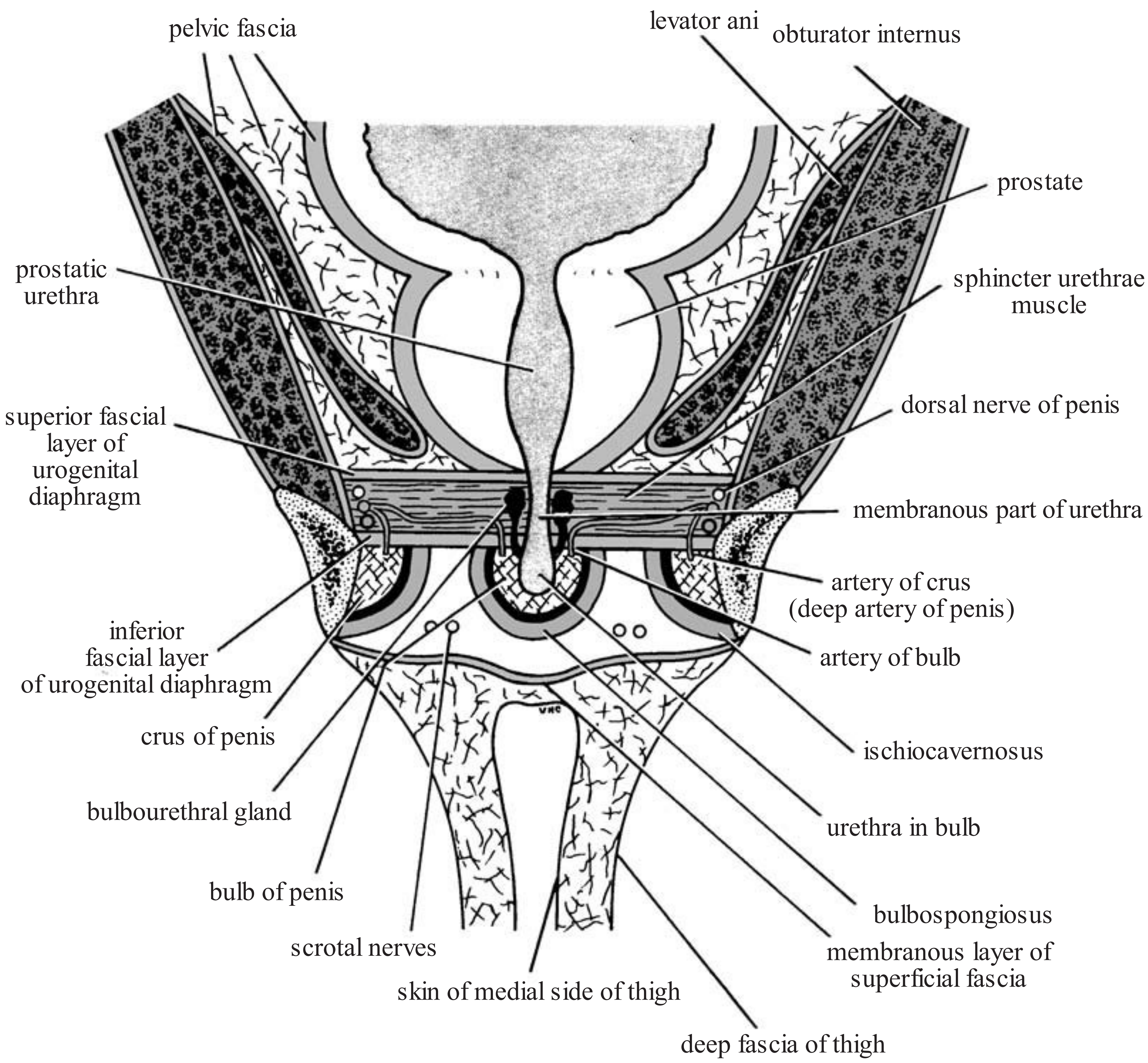


Figure 3-17 Coronal section of the male pelvis showing the prostate, urogenital diaphragm, and contents of the superficial perineal pouch.

drains into the superficial inguinal nodes. The erectile tissue drains into the internal iliac nodes.

NERVE SUPPLY

The pudendal nerve supples the penis.

Scrotum, Testes, and Epididymides

The scrotum, the testes, and the epididymides are described on page 45.

Bulbourethral (Cowper's) Glands

The bulbourethral (Cowper's) glands are two small glands situated in the deep perineal pouch among the fibers of the sphincter urethrae muscle. The ducts of these glands open into the penile urethra.

Male Urethra

The male urethra is divided into three parts: the prostatic, the membranous, and the penile.

PROSTATIC URETHRA

The prostatic urethra passes through the prostate from the base to the apex (Fig. 3-17). It is the widest and most dilatable portion of the entire urethra. On the posterior wall, there is a longitudinal ridge called the **urethral crest** (Fig. 3-14), and on each side of this ridge is a groove called the **prostatic sinus,** into which the prostatic glands open. On the summit of the urethral crest is a depression called the **prostatic utricle,** which is an analog of the uterus and the vagina in females. On the edge of the mouth of the utricle are the openings of the two ejaculatory ducts.

MEMBRANOUS URETHRA

The membranous urethra passes through the urogenital diaphragm and is surrounded by the sphincter urethrae (Fig. 3-17). It is the shortest and least dilatable part of the urethra.

PENILE URETHRA

The penile urethra passes through the bulb and the corpus spongiosum of the penis (Fig. 3-17). The **external meatus** is

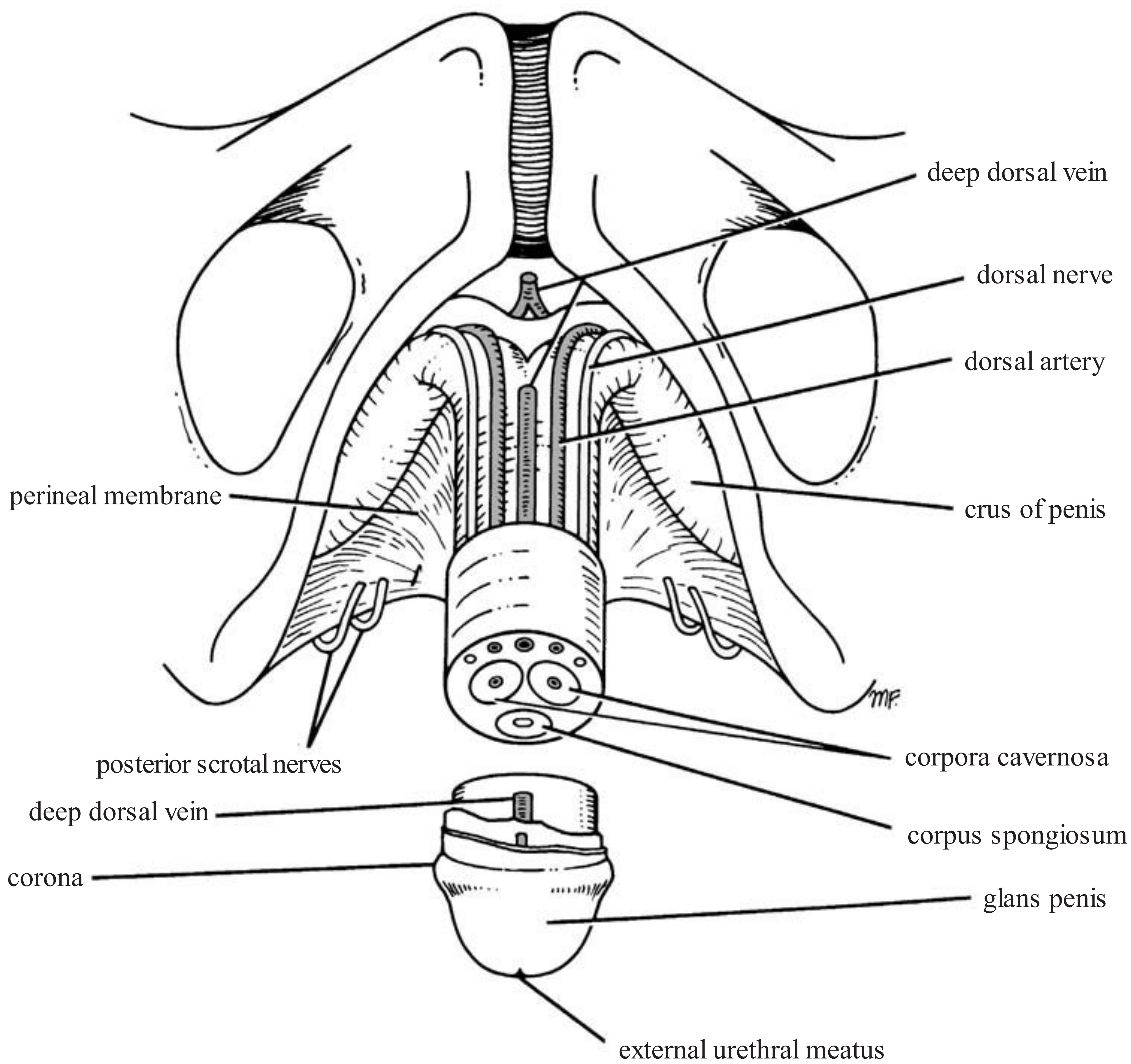


Figure 3-18 The root and body of the penis.

the narrowest part of the entire urethra. The part of the urethra within the glans penis is dilated to form the **fossa terminalis (navicular fossa).** The bulbourethral glands open into the penile urethra below the urogenital diaphragm.

For developmental homologs of the male and the female genital systems, see Table 3-3.

CLINICAL NOTES

Catheterization in the Male

The following anatomic facts should be noted when inserting a catheter.

- The external orifice at the glans penis is the narrowest part of the entire urethra.
- The urethra is dilated within the glans to form the **fossa terminalis.**
- Near the posterior end of the fossa, a fold of mucous membrane projects into the lumen from the roof.
- The membranous part of the urethra is narrow and fixed.
- The prostatic part of the urethra is the widest and most dilatable part of the urethra.
- By holding the penis upward, the S-shaped curve to the urethra is converted into a J-shaped curve.

FEMALE EXTERNAL GENITALIA (VULVA)

The vulva includes the mons pubis (hair-bearing skin in front of the pubis), the labia majora, the labia minora, the clitoris, and the greater vestibular glands.

Labia Majora

The labia major are prominent folds of skin extending from the mons pubis to unite posteriorly in the midline. They contain fat, and hair covers their outer surfaces. (They are equivalent to the scrotum in males.)

Labia Minora

The labia minora are two smaller folds of skin, which are devoid of hair, that lie between the labia majora. Their posterior ends are united to form a sharp fold (the **fourchette**). Anteriorly, they split to enclose the clitoris, thus forming an anterior **prepuce** and a posterior **frenulum.**

Vestibule of the Vagina

The vestibule of the vagina is the space between the labia minora. The vestibule has the clitoris at its apex and the

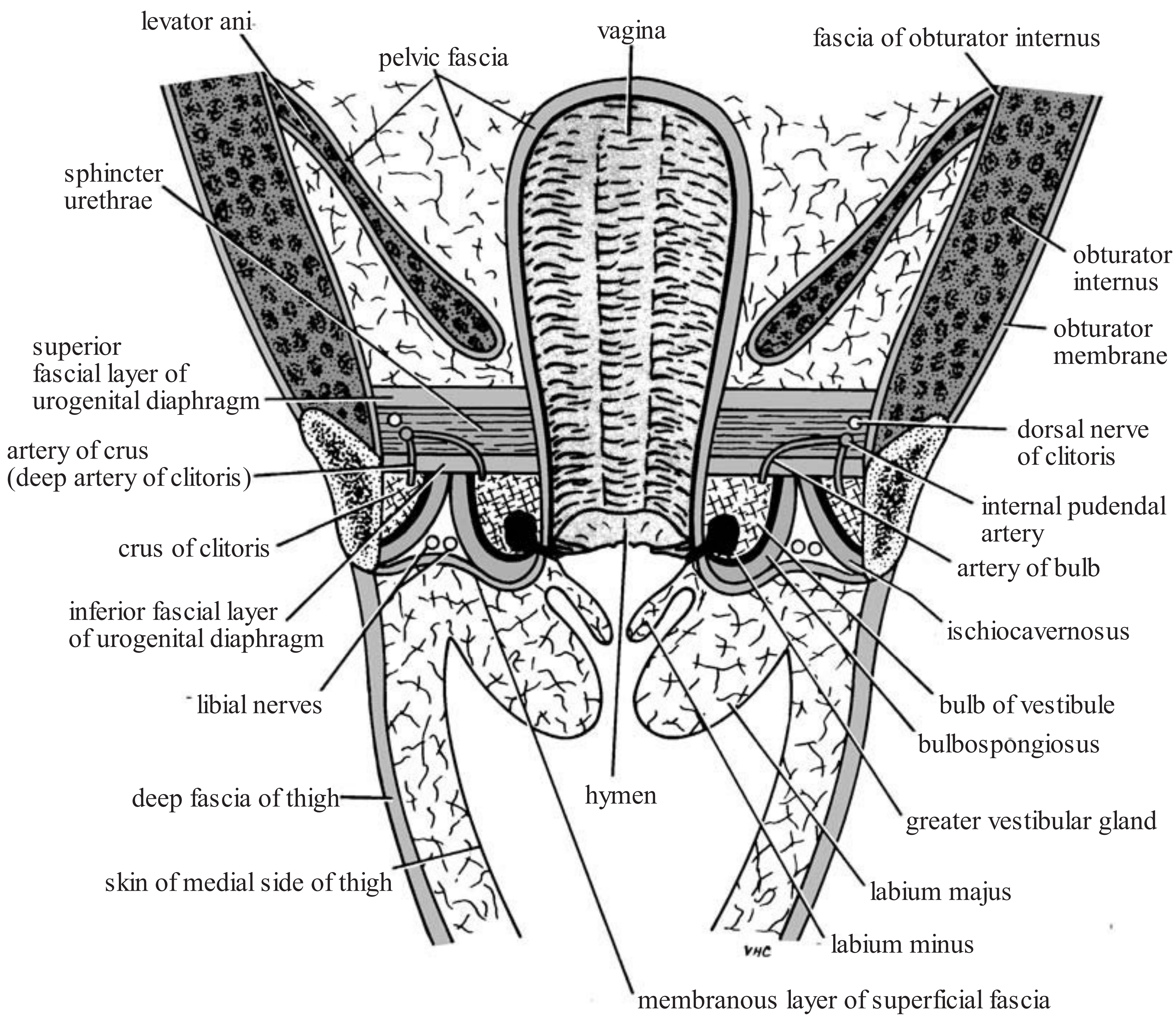


Figure 3-19 Coronal section of the female pelvis that shows the vagina, urogenital diaphragm, and contents of the superficial perineal pouch.

openings of the urethra, the vagina, and the ducts of the greater vestibular glands in its floor.

CLINICAL NOTES

VAGINAL EXAMINATION

The anatomic relations of the vagina are of great clinical importance. The following structures can be palpated through the vaginal walls, from above downward:

- **Anteriorly:** Bladder and urethra.
- **Posteriorly:** Loops of ileum and sigmoid colon in the rectouterine peritoneal pouch (pouch of Douglas), rectal ampulla, and perineal body.
- **Laterally:** Ureters, pelvic fascia and anterior fibers of the levatores ani muscles and urogenital diaphragm.

Clitoris

The clitoris in females corresponds to the penis in males. The **glans** of the clitoris is partly hidden by the **prepuce,** and the **root of the clitoris** is composed of three masses of erectile tissue: the bulb of the vestibule, and the right and the left crura of the clitoris. The **bulb of the vestibule** corresponds to the bulb of the penis, but because of the vagina, it is divided into two halves. It is attached to the undersurface of the urogenital diaphragm and is covered by the **bulbospongiosus muscles.** Anteriorly, the two halves unite to form the glans clitoris. The **crura of the clitoris** correspond to the crura of the penis, and they are covered by the **ischiocavernosus muscles.**

Greater Vestibular Glands

The greater vestibular glands are a pair of mucus-secreting glands that lie under cover of the posterior parts of the bulb of the vestibule and the labia majora (Fig. 3-19). The duct of each gland opens into the groove between the hymen and the posterior part of the labium minus.

Table 3-4 Muscles of the Urogenital Triangle

Muscle	Origin	Insertion	Nerve Supply	Action
Male				
Superficial transverse perineal muscle	Ischial tuberosity	Perineal body	Perineal branch of the pudendal nerve	Fixes the perineal body
Bulbospongiosus	Perineal body and median raphe	Fascia of the bulb of the penis and the corpus spongiosum and cavernosum	Perineal branch of the pudendal nerve	Empties the urethra after micturition and ejaculation, assists in erection
Ischiocavernosus	Ischial tuberosity and ischial ramus	Fascia covering the corpus cavernosum	Perineal branch of the pudendal nerve	Assists in erection
Deep transverse perineal muscle	Ramus of the ischium	Perineal body	Perineal branch of the pudendal nerve	Fixes the perineal body
Sphincter urethrae	Pubic arch	Surrounds the urethra	Perineal branch of the pudendal nerve	Voluntary sphincter of the urethra
Female				
Superficial transverse perineal muscle	Ischial tuberosity	Perineal body	Perineal branch of the pudendal nerve	Fixes the perineal body
Bulbospongiosus	Perineal body	Fascia of the corpus cavernosum	Perineal branch of the pudendal nerve	Sphincter of the vagina, assists in erection of the clitoris
Ischiocavernosus	Ischial tuberosity	Fascia covering corpus cavernosum	Perineal branch of the pudendal nerve	Causes erection of the clitoris
Deep transverse perineal muscle	Ramus of the ischium	Perineal body	Perineal branch of the pudendal nerve	Fixes the perineal body
Sphincter urethrae	Pubic arch	Surrounds the urethra	Perineal branch of the pudendal nerve	Voluntary sphincter of the urethra

Female Urethra

The female urethra is only 1.5 in. (3.8 cm) in length, and it extends from the bladder neck to the external meatus. It passes through the urogenital diaphragm, where it traverses the sphincter urethrae, and opens onto the surface below the clitoris and in front of the vagina.

CLINICAL NOTES

CATHETERIZATION OF THE FEMALE

Because the female urethra is shorter, wider, and more dilatable, catheterization is much easier than in the male. Moreover, the urethra is straight and only minor resistance is felt as the catheter passes through the urethral sphincter.

Muscles of the Urogenital Triangle

The attachments, nerve supplies, and action of the muscles of the urogenital triangle are given in Table 3-4.

For developmental homologs of the male and the female genital systems, see Table 3-3.

ANAL TRIANGLE

Anal Canal

The anal canal is approximately 1.5 in. (4 cm) in length and lies below the pelvic diaphragm (Figs. 3-10 and 3-13). It passes downward and backward from the rectal ampulla to open onto the surface at the **anus.** Its lateral walls are kept in apposition by the levatores ani muscles and the anal sphincters (except during defecation).

The **mucous membrane** of the upper half of the anal canal has vertical folds (**anal columns**). These are con-

Table 3-5 Muscles of the Anal Triangle

Muscle	Origin	Insertion	Nerve Supply	Action
External anal sphincter				
Subcutaneous part	Encircles the anal canal, no bony attachments			
Superficial part	Perineal body	Coccyx	Inferior rectal nerve and perineal branch of the fourth sacral nerve	Voluntary sphincter of the anal canal, closes the anus
Deep part	Encircles the anal canal, no bony attachments			
Puborectalis muscle (part of the levator ani muscle)	Pubic bones	Sling around junction of the rectum and anal canal	Perineal branch of the fourth sacral nerve and from the perineal branch of the pudendal nerve	Together with the external anal sphincter, forms the voluntary sphincter for the anal canal

nected together at their lower ends by small semilunar folds called **anal valves.** The mucous membrane of the lower half of the canal is smooth and merges with the skin at the anus.

The **muscle coat** is divided into outer longitudinal layers and an inner circular layer of smooth muscle. The circular layer is thickened at the upper end of the anal canal and forms the **involuntary internal sphincter.** Surrounding the internal sphincter of smooth muscle is a collar of striped muscle called the **voluntary external sphincter,** which is divided into three parts: the **subcutaneous,** the **superficial,** and the **deep.** The attachments of these parts are given in Table 3-5.

The **puborectalis** fibers of the two levator ani muscles form a sling, which is attached anteriorly to the pubic bones. This sling passes around the junction of the rectum and the anal canal and pulls them forward so that the rectum joins the anal canal at an acute angle.

At the anorectal junction, the internal sphincter, the deep part of the external sphincter, and the puborectalis form a distinct ring called the **anorectal ring.**

BLOOD SUPPLY

Arteries

The superior rectal artery supplies the upper half of the anal canal, and the inferior rectal artery supplies the lower half.

Veins

The upper half of the anal canal is drained by the superior rectal vein into the inferior mesenteric vein, and the lower half is drained by the inferior rectal vein into the internal pudendal vein. The anastomosis between the rectal veins forms an important portal–systemic anastomosis.

CLINICAL NOTES

INTERNAL HEMORRHOIDS

Internal hemorrhoids are varicosities of the tributaries of the superior rectal vein. The tributaries of the vein, which lie in the anal columns at the 3-, 7-, and 11 o'clock positions when the patient is viewed in the lithotomy position (supine position with both hip joints flexed and abducted and the feet held in stirrups). Internal hemorrhoids are covered with mucous membrane and are initially contained within the anal canal (first degree). As they enlarge, they extrude from the canal on defecation but return at the end of the act (second degree). With further elongation, they prolapse on defecation and remain outside the anus (third degree).

EXTERNAL HEMORRHOIDS

External hemorrhoids are varicosities of the tributaries of the inferior rectal vein as they run laterally from the anal margin. They are covered with skin.

LYMPH DRAINAGE

The upper half of the anal canal drains into the pararectal nodes and then into the inferior mesenteric nodes. The lower half drains into the medial group of superficial inguinal nodes.

NERVE SUPPLY

The mucous membrane of the upper half of the anal canal is sensitive to stretch and is innervated by sensory fibers that ascend through the hypogastric plexuses. The lower half is sensitive to pain, temperature, touch, and pressure and is innervated by the inferior rectal nerves.

The internal anal sphincter is supplied by sympathetic nerves from the hypogastric plexuses. The voluntary external anal sphincter is supplied by the inferior rectal nerves.

CLINICAL NOTES

Rectal Examination

The following structures can be palpated by the gloved index finger inserted into the anal canal and rectum.

Anteriorly

In the male:

- **Opposite the terminal phalanx** are the contents of the rectovesical pouch, the posterior surface of the bladder, the seminal vesicles, and the vasa deferentia.
- **Opposite the middle phalanx** are the rectoprostatic fascia and the prostate.
- **Opposite the proximal phalanx** are the perineal body, the urogenital diaphragm, and bulb of the penis.

In the female:

- **Opposite the terminal phalanx** are the rectouterine pouch, the vagina, and the cervix.
- **Opposite the middle phalanx** are the urogenital diaphragm and the vagina.
- **Opposite the proximal phalanx** are the perineal body and the lower part of the vagina.

Posteriorly

The sacrum, coccyx, and anococcygeal body can be felt.

Laterally

The ischiorectal fossa and the ischial spines can be palpated.

Ischiorectal Fossa

The ischiorectal fossa is a wedge-shaped space on each side of the anal canal (Fig. 3-11). The base of the wedge is superficial and is formed by the skin. The edge of the wedge is formed by the junction of the medial and the lateral walls. The medial wall is formed by the sloping levator ani muscle and the anal canal; the lateral wall is formed by the lower part of the obturator internus muscle, which is covered with pelvic fascia.

The fossa is filled with fat that supports the anal canal. The fossa allows the anal canal to distend during the process of defecation. The pudendal nerve and the internal pudendal vessels lie in a fascial canal (the **pudendal canal**) on the medial side of the ischial tuberosity.

CLINICAL NOTES

Ischiorectal Fossa and Infection

The close proximity to the anal canal make the fossae particularly vulnerable to infection.

MUSCLES OF THE ANAL TRIANGLE

The attachments, nerve supplies, and actions of the muscles of the anal triangle are given in Table 3-5.

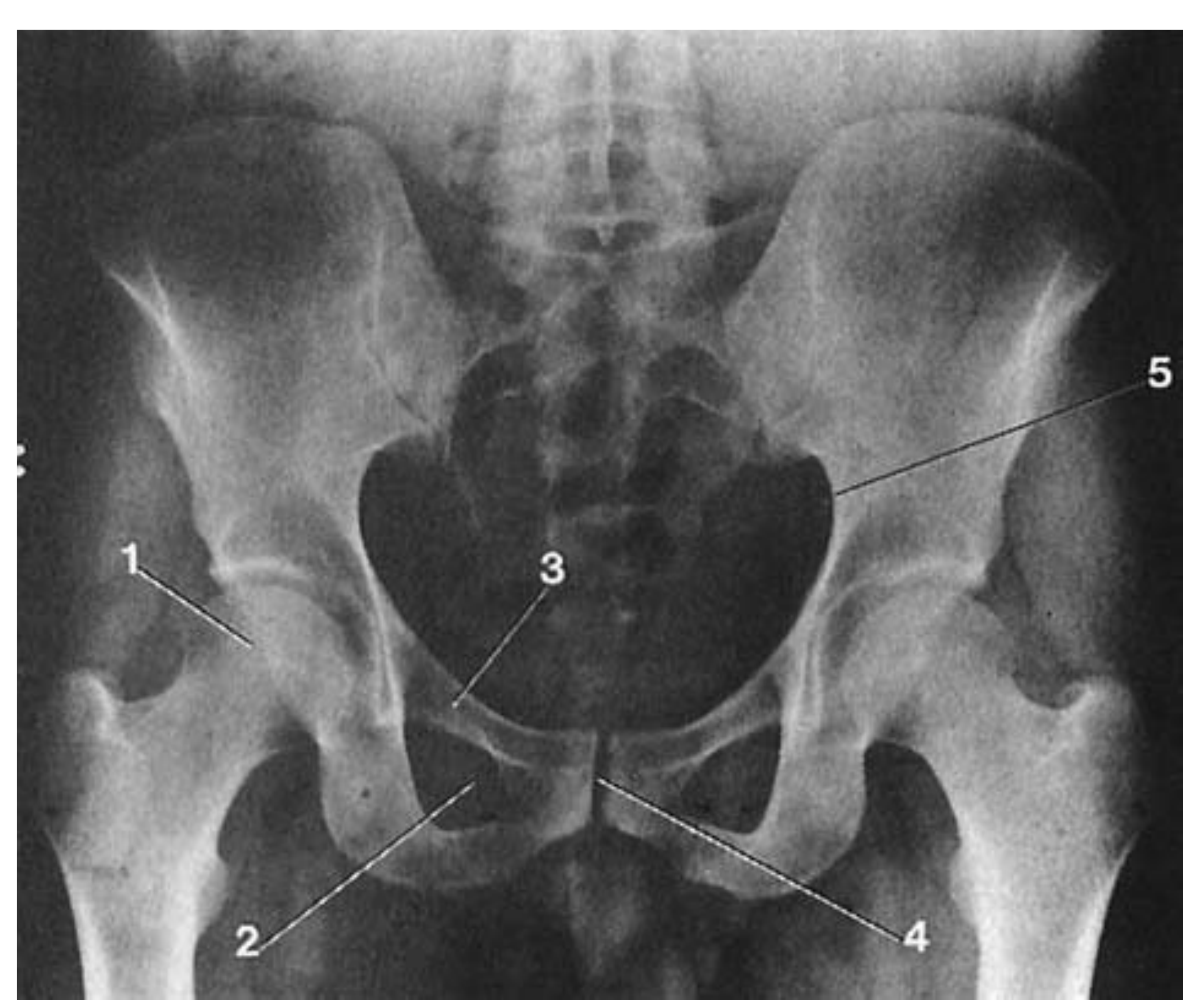
REVIEW

Matching Questions

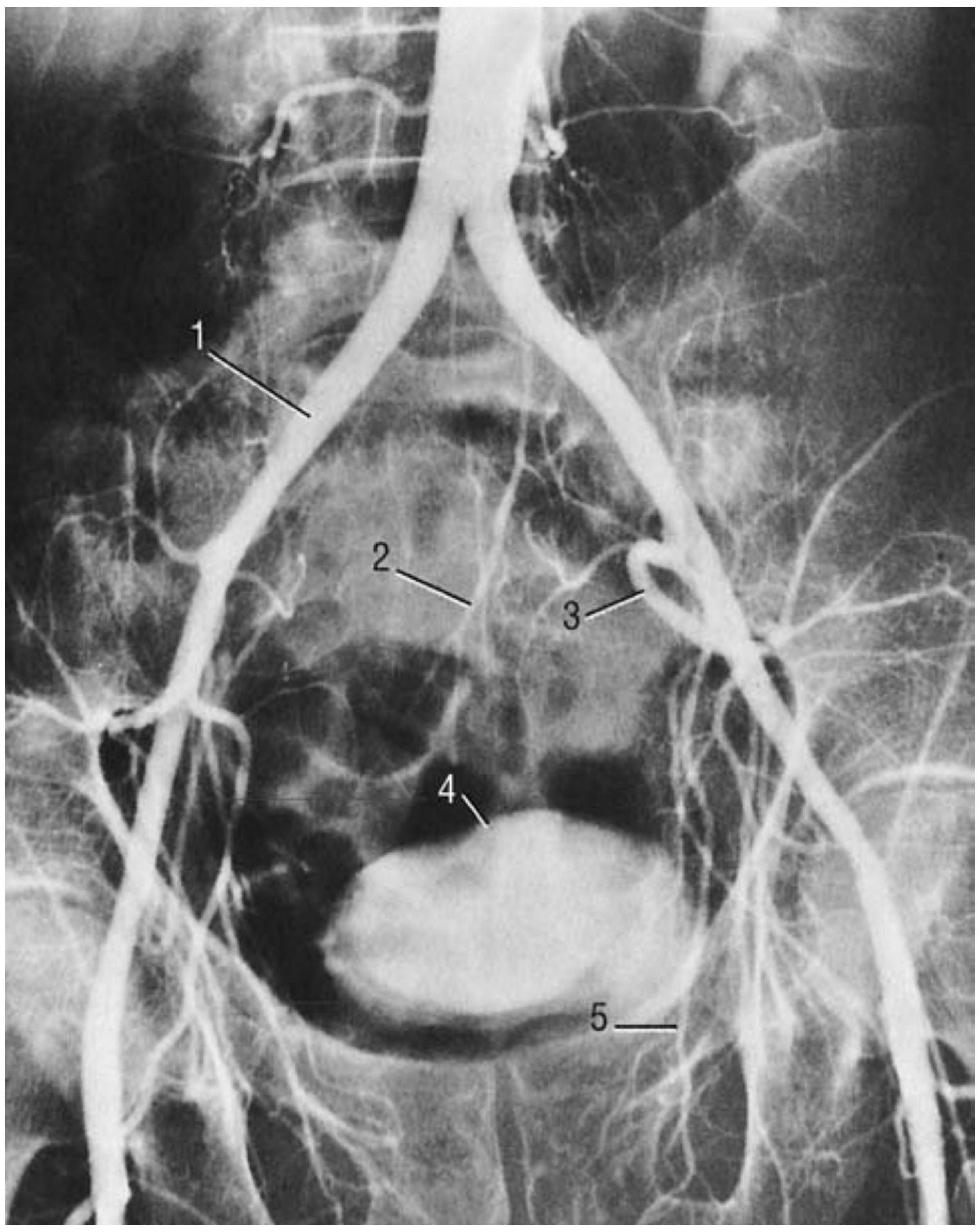
Match the numbered structures shown on the anteroposterior radiograph of the pelvis with the appropriate lettered structures.

1. Structure 1
2. Structure 2
3. Structure 3
4. Structure 4
5. Structure 5

A. Superior ramus of the pubis
B. Symphysis pubis
C. Iliopectineal line
D. Head of the femur
E. Obturator foramen
F. None of the above

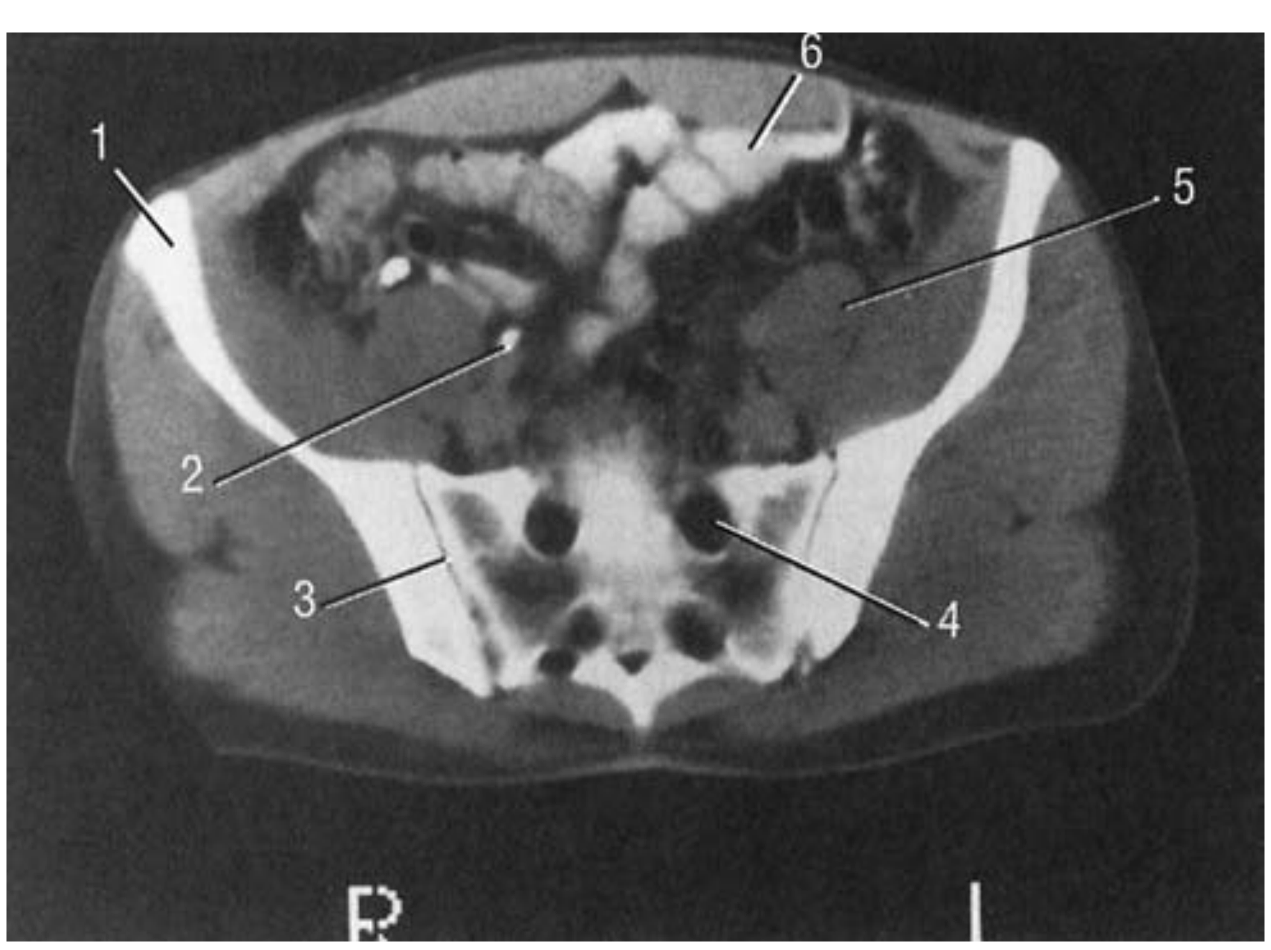


Match the numbered structures shown on the anteroposterior arteriogram of the lower part of the abdominal aorta and the iliac and femoral arteries with the appropriate lettered structures.



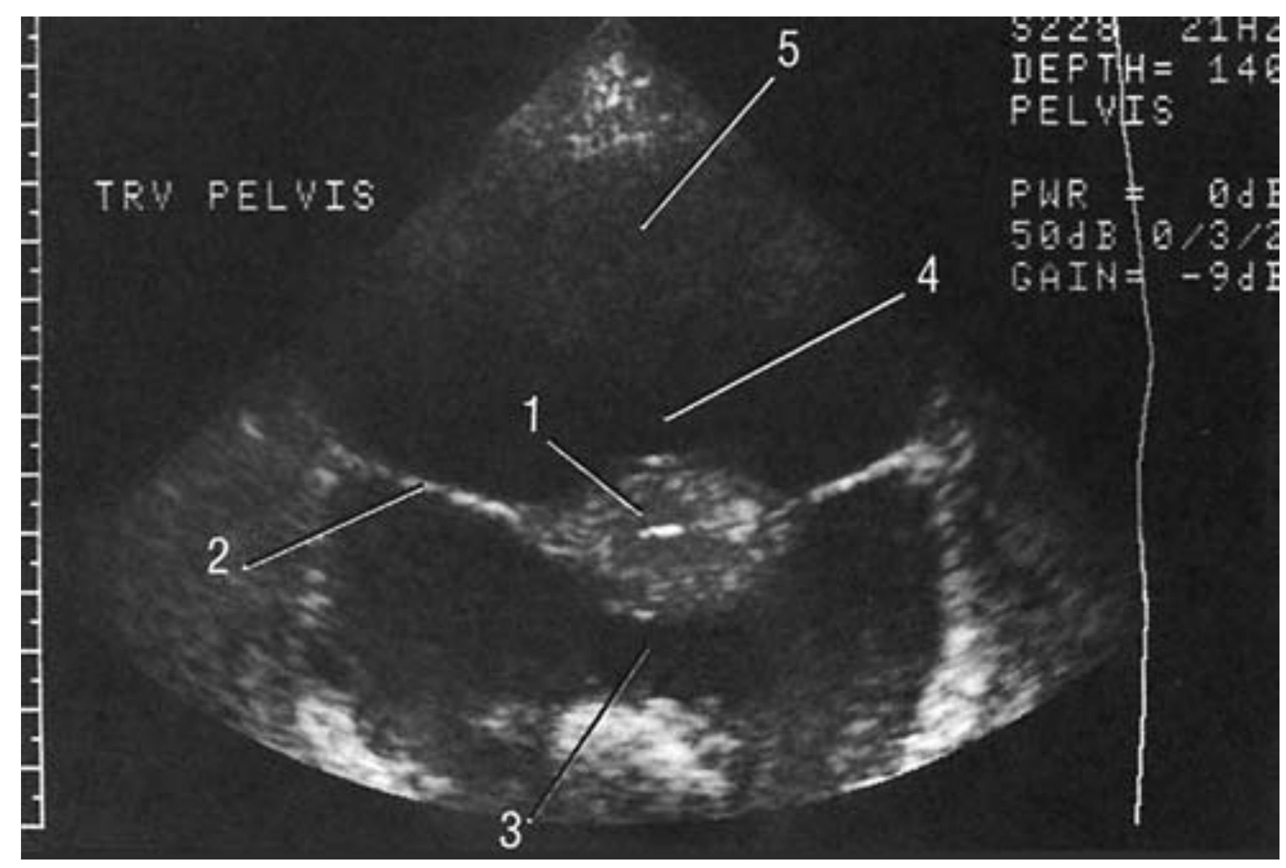
6. Structure 1	A. Internal iliac artery
7. Structure 2	B. Bladder
8. Structure 3	C. Obturator artery
9. Structure 4	D. Superior rectal artery
10. Structure 5	E. Common iliac artery
	F. None of the above

Match the numbered structures shown on the CT scan of the pelvis after a barium meal and intravenous pyelography with the appropriate lettered structures.



11. Structure 1	A. Sacral foramen
12. Structure 2	B. Ilium
13. Structure 3	C. Sacroiliac joint
14. Structure 4	D. Small intestine
15. Structure 5	E. Psoas muscle
16. Structure 6	F. Right ureter
	G. None of the above

Match the numbered structures shown on the transverse sonogram of a female pelvis with the appropriate lettered structure. This patient was involved in a serious automobile accident during which the liver was lacerated and blood escaped into the peritoneal cavity.



17. Structure 1	A. Pouch of Douglas
18. Structure 2	B. Bladder
19. Structure 3	C. Broad ligament
20. Structure 4	D. Body of the uterus
21. Structure 5	E. Uterovesical pouch
	F. None of the above

Select the best answer for each question.

22. The lymphatic drainage of the labia majora is into the
    A. internal iliac nodes.
    B. superficial inguinal nodes.
    C. inferior mesenteric nodes.
    D. internal and external iliac nodes.
    E. para-aortic nodes at the level of the first lumbar vertebra.
23. A carcinoma of the skin of the glans penis is likely to spread via the lymphatics into the
    A. external iliac nodes.
    B. internal iliac nodes.
    C. internal and external iliac nodes.
    D. superficial inguinal nodes.
    E. para-aortic nodes at the level of the first lumbar vertebra.
24. A carcinoma of the cervix of the uterus is likely to spread via the lymphatics into the
    A. external iliac nodes.

B. internal iliac nodes.
C. superficial inguinal nodes.
D. internal and external iliac nodes.
E. presacral lymph nodes.

25. A carcinoma of the prostate is likely to spread via the lymphatics into the
A. internal and external iliac nodes.
B. internal iliac nodes.
C. para-aortic nodes.
D. superficial inguinal nodes.
E. inferior mesenteric nodes.

26. A carcinoma of the vaginal orifice is likely to spread via the lymphatics into the
A. medial group of horizontal superficial inguinal nodes.
B. internal iliac nodes.
C. internal and external iliac nodes.
D. vertical group of superficial inguinal nodes.
E. none of the above.

27. The superior rectal artery originates from the
A. internal pudendal artery.
B. external iliac artery.
C. internal iliac artery.
D. inferior mesenteric artery.
E. none of the above.

28. The left ovarian artery originates from the
A. external iliac artery.
B. internal iliac artery.
C. left renal artery.
D. left common iliac artery.
E. abdominal part of the aorta.

29. The inferior rectal artery originates from the
A. superior mesenteric artery.
B. internal iliac artery.
C. internal pudendal artery.
D. external iliac artery.
E. presacral artery.

30. The middle rectal artery originates from the
A. presacral artery.
B. common iliac artery.
C. internal iliac artery.
D. external iliac artery.
E. inferior mesenteric artery.

31. The obturator internus muscle receives its nerve supply from the
A. obturator nerve.
B. pudendal nerve.
C. pudendal nerve and the perineal branch of S4.
D. hypogastric plexus.
E. none of the above.

32. The internal anal sphincter receives its nerve supply from the
A. hypogastric plexuses.
B. vagus nerve.
C. obturator nerve.
D. pudendal nerve.
E. pudendal nerve and the perineal branch of S4.

33. The sphincter urethrae receives its innervation from the
A. vagus nerve.
B. obturator nerve.
C. pudendal nerve.
D. inferior rectal nerve.
E. hypogastric plexuses.

34. The levator ani muscle receives its innervation from the
A. pudendal nerve.
B. hypogastric plexuses.
C. pudendal nerve and the perineal branch of S4.
D. obturator nerve.
E. inferior rectal nerve.

35. The superior rectal vein drains into the
A. inferior vena cava.
B. internal iliac vein.
C. external iliac vein.
D. inferior mesenteric vein.
E. none of the above.

36. The right ovarian vein drains into the
A. right internal iliac vein.
B. inferior vena cava.
C. inferior mesenteric vein.
D. right external iliac vein.
E. right renal vein.

37. A patient was examined with a left-sided varicocele; the left testicular vein drains into the
A. left renal vein.
B. left internal iliac vein.
C. left external iliac vein.
D. inferior vena cava.
E. left inferior suprarenal vein.

38. The prostatic venous plexus drains into the
A. inferior vena cava.
B. internal iliac veins.
C. external iliac veins.
D. internal and external iliac veins.
E. testicular veins.

39. In most women, the anatomic position of the uterus when the bladder is empty is
A. retroverted.
B. anteverted.
C. anteflexed.
D. anteverted and anteflexed.
E. retroflexed.

40. The uterus receives its blood supply from the
A. superior vesical artery.
B. middle rectal artery.
C. ovarian artery.
D. uterine artery.
E. uterine and ovarian arteries.

41. In a woman with ovarian cancer, it is judicious to examine the
    A. peritoneal cavity for evidence of excessive fluid (ascites).
    B. superficial inguinal lymph nodes.
    C. para-aortic nodes at the level of the first lumbar vertebra.
    D. external iliac lymph nodes.
    E. para-aortic lymph nodes and evidence of excessive peritoneal fluid (ascites).

42. The narrowest part of the male urethra is the
    A. membranous part.
    B. prostatic part.
    C. penile part.
    D. external meatus on the glans penis.
    E. none of the above.

43. Erection of the penis is a response to the activity of the
    A. sympathetic nerves.
    B. parasympathetic nerve.
    C. sympathetic and parasympathetic nerves.
    D. ilioinguinal nerves.
    E. none of the above.

44. Ejaculation is the response to the activity of the
    A. obturator nerves.
    B. perineal branch of S4.
    C. sympathetic nerves.
    D. parasympathetic nerves.
    E. sympathetic and parasympathetic nerves.

45. The posterior wall of the lower third of the vagina is supported by the
    A. coccyx.
    B. perineal body.
    C. anal canal.
    D. anococcygeal body.
    E. none of the above.

46. The rectouterine pouch (pouch of Douglas) can be most efficiently entered by a surgical incision through the
    A. posterior fornix of the vagina.
    B. anterior fornix of the vagina.
    C. anterior rectal wall.
    D. lateral fornix of the vagina.
    E. posterior wall of the cavity of the uterine body.

47. Cancer of the prostate can metastasize to the skull via the
    A. pampiniform plexus.
    B. external iliac veins.
    C. vertebral venous plexus.
    D. portal vein.
    E. inferior vena cava.

48. The middle (median) lobe of the prostate lies
    A. inferior to the ejaculatory ducts.
    B. superior to the ejaculatory ducts.
    C. anterior to the prostatic urethra.
    D. lateral to the lower part of the prostatic urethra.
    E. superior to the ejaculatory ducts and posterior to the upper part of the prostatic urethra.

49. The promontory of the sacrum is formed by the
    A. lower border of the anterior surface of the fifth sacral vertebra.
    B. anterior surface of the second sacral vertebra.
    C. lateral masses of the sacrum.
    D. anterior and upper border of the first sacral vertebra.
    E. lateral edge of the sacrum.

50. The pelvic outlet is bounded posteriorly by the coccyx, laterally by the sacrotuberous ligaments and the ________, and anteriorly by the pubic arch.
    A. ischial spines
    B. piriformis muscle
    C. ischial tuberosities
    D. perineal membrane
    E. obturator foramen

51. The pelvic diaphragm is formed by the ________ and coccygeus muscles and their covering fasciae.
    A. piriformis
    B. levator ani
    C. deep transverse perineal muscles
    D. perineal membrane
    E. sphincter urethrae

52. The urogenital diaphragm is attached laterally to the
    A. tip of the coccyx.
    B. ischial spine.
    C. inferior ramus of the pubis and the ischial ramus.
    D. ischial tuberosities.
    E. obturator internus fascia.

53. During defecation, the levator ani muscles
    A. are completely inactive.
    B. do not support the uterus and vagina.
    C. relax (puborectalis portion) with the anal sphincters.
    D. do not support the sigmoid colon.
    E. do not support the bladder.

54. During the second stage of labor, the gutter shape of the pelvic floor tends to
    A. become flat.
    B. cause the baby's head to rotate so that its fronto-occipital diameter assumes the transverse position.
    C. cause the baby's head to rotate so that its fronto-occipital diameter assumes the anteroposterior position with the occipital bone lying posterior.
    D. cause the baby's head to rotate so that its fronto-occipital diameter assumes the anteroposterior position with the frontal bone lying posterior.
    E. interfere with the normal process of labor.

55. The mucous membrane lining the upper half of the anal canal is
    A. lined with stratified squamous epithelium.
    B. drained by the inferior rectal vein.

C. drained into the superficial inguinal lymph nodes.
D. sensitive to touch and to pain.
E. sensitive to stretch.

56. The anal columns
A. contain tributaries of the superior rectal vein.
B. are connected at their ends by spiral valves.
C. are located in the lower half of the anal canal.
D. are transverse folds of mucous membrane.
E. contain branches of the pudendal nerve.

57. The female urethra
A. is approximately 3 in. (7.62 cm) in length.
B. is difficult to dilate.
C. is insensitive to stretching.
D. opens into the vestibule above the clitoris.
E. is readily accessible to infection.

58. The process of orgasm in the female depends in part on the
A. smooth muscle in the vaginal walls contracting in response to the activity of the parasympathetic innervation.
B. bulbospongiosus muscles contracting in response to the sympathetic nerve fibers.
C. ischiocavernosus muscles contracting in response to the activity of the pudendal nerve.
D. stimulation of the clitoris, which is innervated by the obturator nerve.
E. stimulation of the labia minora, which are innervated by the obturator nerve.

59. The rectouterine pouch (pouch of Douglas)
A. is formed by parietal pelvic fascia.
B. commonly contains coils of jejunum.
C. lies anterior to the vagina.
D. lies behind the posterior fornix of the vagina and the body of the uterus.
E. is not the most dependent part of the female peritoneal cavity when the woman is in the standing position.

60. The following structures are closely related to the rectouterine pouch (pouch of Douglas) except which?
A. Anteriorly is situated the posterior surface of the upper part of the vagina.
B. Posteriorly is situated the upper part of the rectum.
C. The trigone of the bladder is directly related to its anterior wall.
D. Anteriorly is situated the posterior surface of the body of the uterus.
E. Laterally is situated the sacrocervical ligaments passing forward to the cervix.

61. Support for the uterus, either directly or indirectly, is provided by the following structures except which?
A. The perineal body
B. The mesosalpinx
C. The transverse cervical (cardinal) ligaments
D. The levator ani muscles
E. The pubocervical ligaments

62. The following statements regarding the ovary are correct except which?
A. It is attached to the posterior layer of the broad ligament.
B. It ovulates an ovum into the peritoneal cavity.
C. It is attached to the lateral pelvic wall by the round ligament of the ovary.
D. It normally is not related to the posterior fornix of the vagina.
E. The right ovarian vein drains into the inferior vena cava.

63. The following statements regarding the urinary bladder are true except which?
A. It lies in the visceral layer of pelvic fascia beneath the peritoneum.
B. When the bladder is empty, the internal surface is wrinkled except at the trigone, which is smooth.
C. Parasympathetic nerve fibers innervate the detrusor muscle.
D. The trigone is the area between the openings of the urethra and the two ureters.
E. In children, the bladder is located entirely within the pelvis.

64. The broad ligament contains all of the following except which?
A. The round ligament of the ovary
B. The uterine artery
C. The round ligament of the uterus
D. The uterine tubes
E. The ureters

65. Malignant tumors of the trigone of the bladder spread (metastasize) to which of the following lymph nodes?
A. Lumbar
B. Sacral
C. External iliac only
D. External and internal iliac
E. Superficial inguinal

66. In males, traumatic injury to the perineum may rupture the bulb of the penis or the penile urethra. The resulting leakage of blood or urine may be found in all of the following areas except which?
A. The anterior abdominal wall
B. The ischiorectal fossa
C. The scrotum
D. The penis
E. The superficial perineal pouch

Read the case histories and select the best answer to the questions following them.

A 21-year-old woman complaining of severe pain in the right iliac region was seen in the emergency department. Just before admission, she had fainted. On physical examination, her abdominal wall was extremely tender on palpation in the right iliac region, and some rigidity and guarding of the lower abdominal muscles were noticed. A vaginal examination revealed that a tender, "doughlike" mass could be felt through the posterior fornix. The patient had missed her last period. The diagnosis of a ruptured ectopic pregnancy was made. In this ectopic pregnancy, the embryo was implanted in the right uterine tube. Rupture of the tube produced the symptoms and the signs that were noted.

67. Using your knowledge of anatomy, explain the relationship of the uterine tube to the peritoneal cavity.
    A. The tube is retroperitoneal.
    B. The tube lies within the peritoneal cavity.
    C. The tube lies within the broad ligament near its base.
    D. The tube lies in the free margin of the broad ligament.
    E. The tube lies within the parametrium.

68. The tender, doughlike mass felt through the posterior wall of the vagina resulted from what?
    A. A retroverted uterus
    B. Blood in the pouch of Douglas
    C. A full bladder
    D. Blood in the uterovesical pouch
    E. A prolapsed ovary

69. What was responsible for the guarding (partial contraction) of the lower abdominal muscles?
    A. Blood in the peritoneal cavity causing irritation of the parietal peritoneum and reflex contraction of the lower abdominal muscles
    B. Apprehension of the patient
    C. Reflex contraction of the abdominal muscles because of damage to the wall of the uterine tube
    D. Stretching of the peritoneum of the broad ligament
    E. The high level of blood estrogen causing irritability of the abdominal muscles

A 56-year-old man was seen by his physician because the patient had noticed that his “bowel” was protruding from his anus after defecation. On questioning, the patient stated that for the past 2 years he had frequently passed blood-stained stools. Digital rectal examination revealed nothing abnormal. Proctoscopic examination showed that the mucous membrane above the level of the anal valves tended to bulge downward in three areas when the patient strained. The swollen mucous membrane contained large, congested veins beneath the surface.

70. Based on your knowledge of anatomy, make a reasoned diagnosis.
    A. External hemorrhoids
    B. Perianal abscess
    C. Complete rectal prolapse
    D. Internal hemorrhoids
    E. Chronic anal fissures

71. What is the venous drainage of the mucous membrane of the anal canal?
    A. Middle rectal veins only
    B. Inferior rectal veins only
    C. Superior and inferior rectal veins
    D. Middle and inferior rectal veins
    E. Internal pudendal veins

ANSWERS TO REVIEW QUESTIONS

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

31. E. The obturator internus muscle receives its nerve supply from the sacral plexus.

32. A	42. D	52. C
33. C	43. B	53. C
34. C	44. C	54. D
35. D	45. B	55. E
36. B	46. A	56. A
37. A	47. C	57. E
38. B	48. E	58. C
39. D	49. D	59. D
40. E	50. C	
41. E	51. B	

60. C. The pouch of Douglas is separated from the trigone of the bladder by the uterus and the vagina.
61. B. The mesosalpinx is an area of the broad ligament between the uterine tube and the attachment of the mesovarium. It provides no support for the uterus.
62. C. The ovary is attached (suspended) from the lateral wall of the pelvis by the suspensory ligament. It contains the blood and the lymphatic vessels as well as the nerves supplying the ovary. The round ligament of the ovary is the remains of the upper part of the gubernaculum, and it extends from the medial border of the ovary to the lateral wall of the body of the uterus.
63. E. Because the pelvis is small in young children, there is insufficient room for the urinary bladder. Even the empty bladder projects upward into the abdomen. Later, when the pelvis enlarges, the bladder sinks to become a pelvic organ.
64. E. The ureters pass forward inferior to the broad ligaments.

65. D
66. B. The arrangement of the membranous layer of superficial fascia (Colles' fascia) in the perineum prevents fluid from traveling backward into the ischiorectal fossae. The fascia is attached to the posterior border of the urogenital diaphragm.
67. D
68. B. Tubal pregnancies commonly occur where the infundibulum narrows to join the isthmus. Rupture of the tube almost invariably occurs with severe intraperitoneal hemorrhage. The blood gravitates downward into the lowest part of the peritoneal cavity (pouch of Douglas), where it clots and forms a doughlike mass that can usually be felt through the posterior vaginal wall.
69. A. Blood is an irritant to the peritoneum. The parietal peritoneum of the lower part of the abdomen and pelvis receives its sensory nerve supply from the lumbar spinal nerves (iliohypogastric, ilioinguinal, and obturator nerves). The muscles of the lower part of the anterior abdominal wall are innervated by the iliohypogastric and ilioinguinal nerves, and there is a reflex spasm of these abdominal muscles. This spasm is essentially a protective mechanism and an attempt to keep that area of the abdomen at rest so that the irritant will remain localized.
70. D. Internal hemorrhoids are dilatations of the tributaries of the superior rectal vein. They are covered by mucous membrane in the upper half of the anal canal, and they lie within the vertical anal columns. One large tributary occurs on the left of the canal; two large tributaries occur on the right. As these dilatations enlarge, they are pushed down the anal canal during defecation and may be extruded through the anus. At first, they return to the canal at the end of defecation, but with further enlargement and elongation, they remain outside the anus.
71. C. Venous drainage of the mucous membrane of the upper half of the anal canal is from the superior rectal vein and that from the lower half is from the inferior rectal veins. The middle rectal veins are mainly concerned with draining blood from the muscle and connective tissue of the canal. Because the superior rectal vein is a tributary of the portal vein and the inferior and the middle rectal veins are tributaries of the systemic veins, the anal canal is an important site for portal–systemic anastomoses in patients with a blocked portal vein.

CHAPTER 4

Upper Limb

The upper limb is a multijointed lever that is freely movable on the trunk at the shoulder joint. At its distal end is the important organ: the hand.

It is suggested that the upper limb be reviewed in the following order:

1. The **mammary gland.** Situated in the pectoral region, this organ is of great clinical importance.
2. A brief overview of the **bones** and the **major joints,** preferably with the help of an articulated skeleton.
3. A consideration of the more **important muscles,** with special emphasis on their actions and nerve supply.
4. A brief review of the **blood supply** and **lymphatic drainage** of the upper limb.
5. A detailed overview of the **nerves** and their distribution, with special emphasis on the branches of the brachial plexus (which are frequently injured).

To assist students in the review process, tables are used extensively in this chapter.

MAMMARY GLAND

The mammary glands are specialized accessory glands of the skin that secrete milk (Fig. 4-1) and are present in both sexes. In males and immature females, the mammary glands are similar in structure. The **nipples** are small and surrounded by a colored area of skin called the **areola.** The breast tissue consists of a system of ducts embedded in connective tissue that does not extend beyond the margin of the areola.

Under the influence of the ovarian hormones, the mammary glands gradually enlarge and assume their hemispherical shape (Fig. 4-1) in females at puberty. The ducts elongate, but this increased size of the glands mainly results from the deposition of adipose tissue. The base of the breast extends from the second to the sixth rib and from the lateral margin of the sternum to the midaxillary line. The greater part of the gland lies in the superficial fascia, but a small part (the **axillary tail**) pierces the deep fascia at the lower border of the pectoralis major muscle and enters the axilla. The mammary glands are separated from the deep fascia covering the underlying muscle by loose areolar tissue called the **retromammary space.**

Each gland consists of 15 to 20 **lobes** that radiate outward from the nipple. There is no capsule. Each lobe is separated from its neighbor by connective tissue septa that extend from the skin to the deep fascia and that serve as **suspensory ligaments.** The main **lactiferous duct** from each lobe opens separately on the summit of the nipple and possesses a dilated **ampulla** or **lactiferous sinus** just before its termination (Fig. 4-1). The ampulla serves as a small reservoir for the secreted milk.

Blood Supply

ARTERIES

Lateral thoracic and thoracoacromial arteries, branches of the axillary artery, and perforating branches of the internal thoracic and intercostal arteries supply the breast.

VEINS

The veins correspond to the arteries.

Lymphatic Drainage

The lateral quadrants of the breast drain into the anterior axillary or the pectoral nodes (Fig. 4-2). The medial quadrants drain into the internal thoracic nodes. A few lymph vessels also drain posteriorly into the posterior intercostal nodes, and some communicate with the lymphatic vessels of the opposite breast and with those of the anterior abdominal wall.

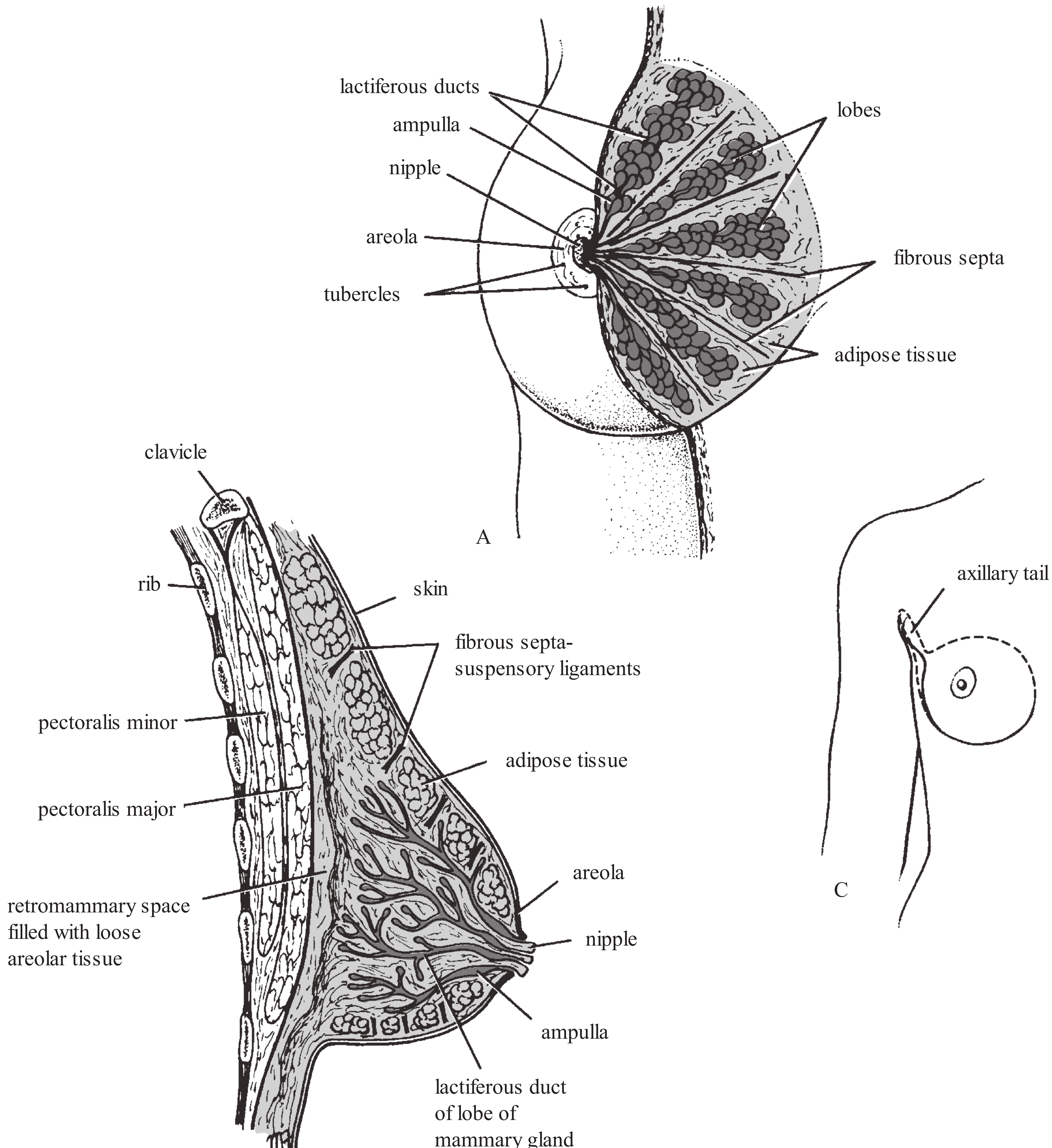


Figure 4-1 Mature mammary gland in the female. A. Anterior view with the skin partially removed to show the internal structure. B. Sagittal section. C. The axillary tail, which pierces the deep fascia and extends into the axilla.

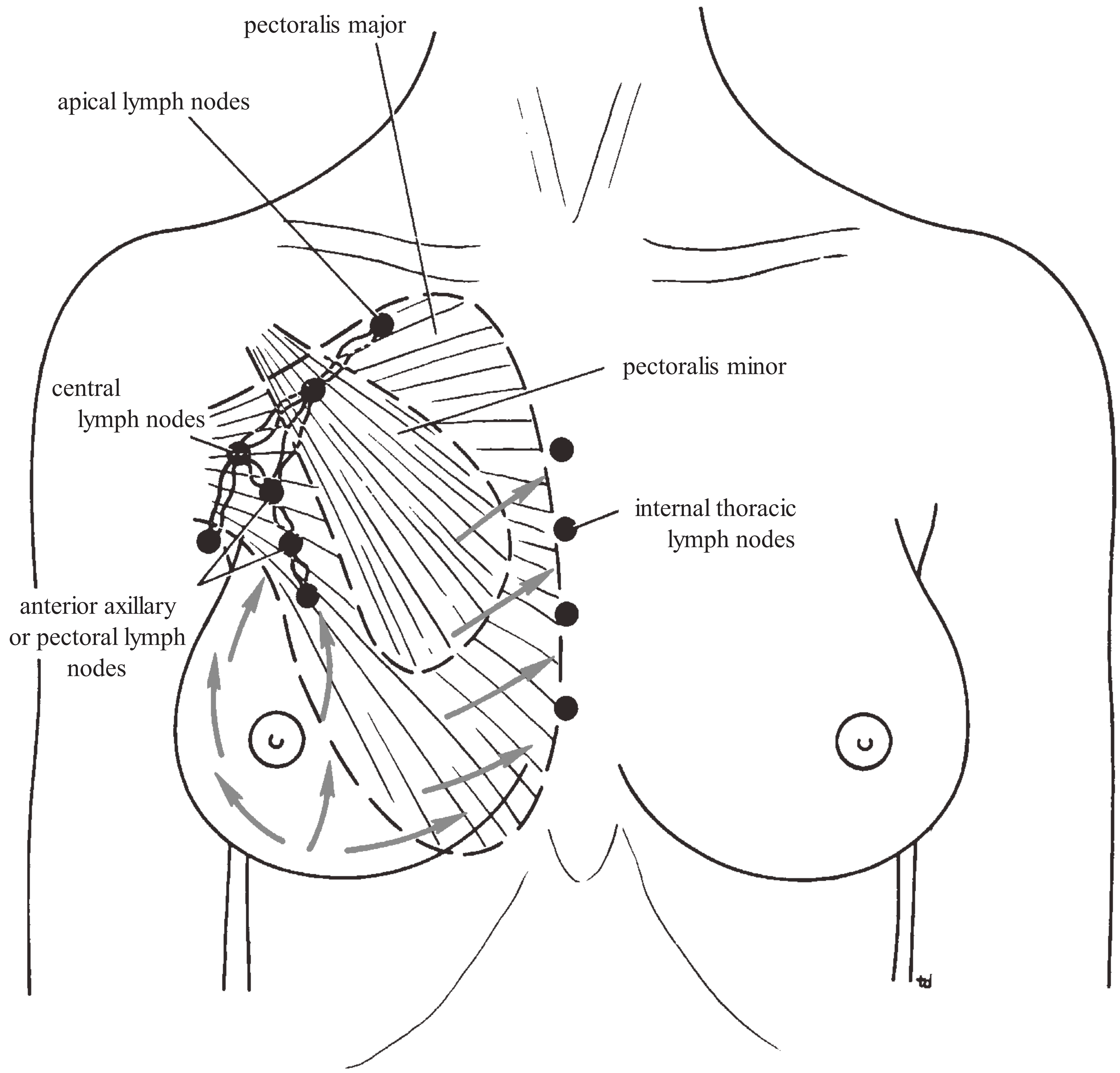


Figure 4-2 Lymph drainage of the mammary gland.

CLINICAL NOTES

Breast Examination

The breast is one of the common sites of cancer in women. It is also subject to different types of benign tumors and may be the site of acute inflammation and abscess formation. On examination, any swelling should be noted and the nipples examined for evidence of retraction. With the patient lying down, the breasts are palpated against the thoracic wall. The patient is then asked to sit up and raise both arms above her head. With this maneuver, a deep-seated carcinoma tethered to the skin, ligaments, or lactiferous ducts, produces dimpling of the skin or retraction of the nipple. The axillary lymph nodes should then be carefully examined for evidence of metastases.

BONES

Bones of the Shoulder Girdle

The clavicle and the scapula form the shoulder girdle.

CLAVICLE

The clavicle articulates medially with the sternum and the first costal cartilage and laterally with the scapula. The medial two thirds is convex forward, and the lateral one third is concave forward.

CLINICAL NOTES

Fractured Clavicle

The clavicle, because of its exposed position, is the most commonly fractured bone in the body. The fracture usually occurs as the result of a fall on the shoulder or outstretched hand.

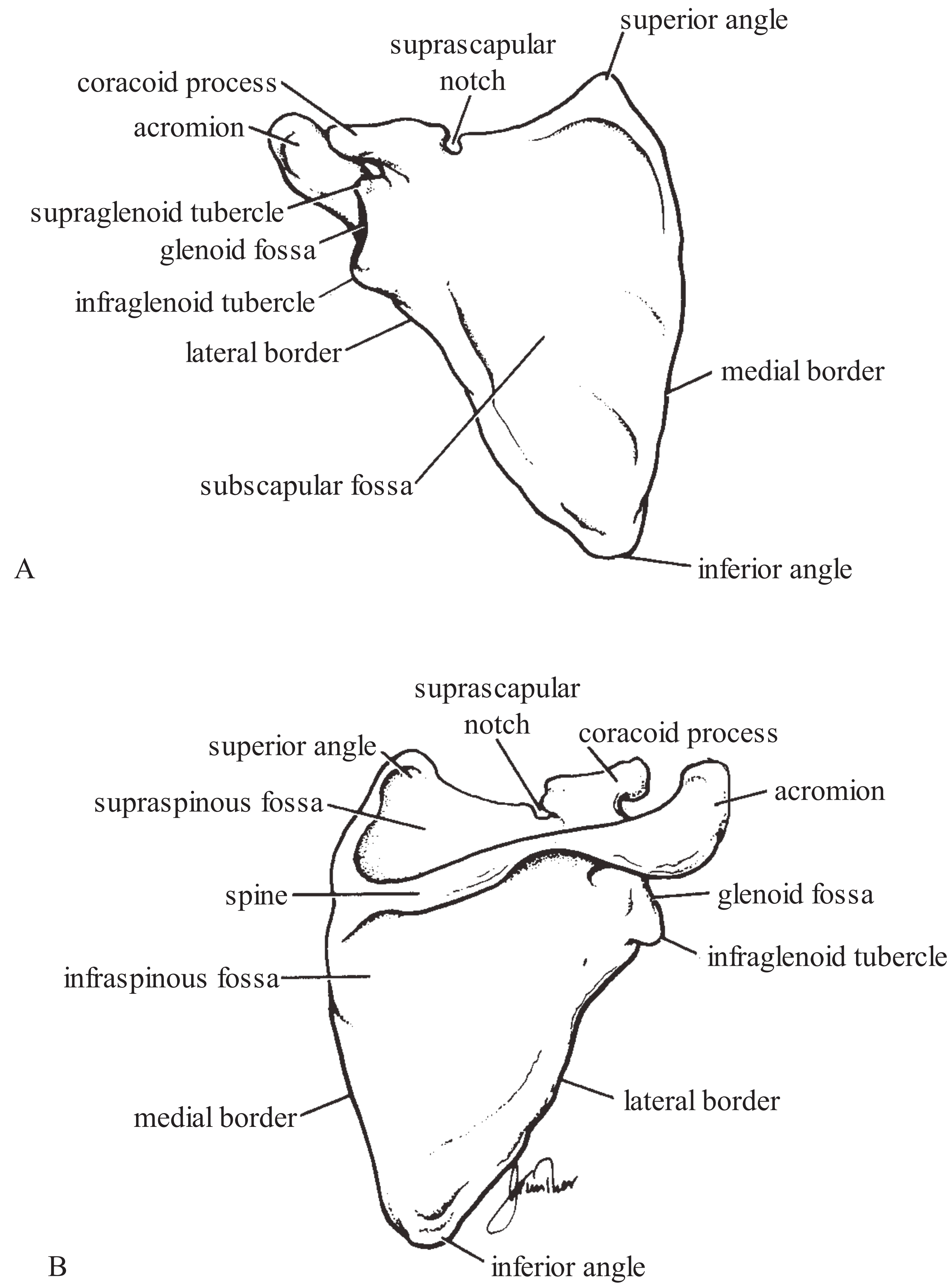


Figure 4-3 The right scapula. A. Anterior surface. B. Posterior surface.

SCAPULA

The scapula is a flat, triangular bone (Fig. 4-3). On its posterior surface, the **spine of the scapula** projects backward. The lateral end of the spine forms the **acromion,** which articulates with the clavicle, and the superolateral angle of the scapula forms the **glenoid cavity,** which articulates with the head of the humerus. The **coracoid process** projects upward and forward, and it provides attachment for muscles and ligaments. Medial to the base of the coracoid process is the **suprascapular notch.** The **subscapular fossa** is the concave anterior surface of the scapula. The **supraspinous fossa** lies above the spine, and the **infraspinous fossa** lies below the spine on the posterior surface of the scapula.

Bones of the Arm

HUMERUS

The **head** of the humerus lies at the upper end and forms approximately a third of a sphere, which articulates with the glenoid cavity of the scapula (Fig. 4-4). Immediately below the head is the **anatomical neck.** Below the anatomic neck are the **greater** and the **lesser tuberosities,** which are separated from each other by the **bicipital groove.** Distal to the tuberosities is this **surgical neck,** which is a narrow region that is frequently fractured. The **deltoid tuberosity** is a roughened area approximately halfway down the lateral aspect of the shaft (Fig. 4-4), and it is for the insertion of the deltoid muscle. Behind and below the deltoid tuberosity is a **spiral groove,** in which the radial nerve lies.

The **medial** and the **lateral epicondyles** lie at the lower end of the humerus and are for the attachment of muscles and ligaments. The rounded **capitulum** articulates with the head of the radius, and the pulley-shaped **trochlea** articulates with the trochlear notch of the ulna. The **radial fossa** lies above the capitulum, and it receives the head of the radius in full flexion of the elbow joint. Above the trochlea anteriorly is the **coronoid fossa,** which receives the coronoid process of the ulna during full flexion of the elbow joint. Above the trochlea posteriorly is the **olecranon fossa,** which receives the olecranon process of the ulna when the elbow joint is extended.

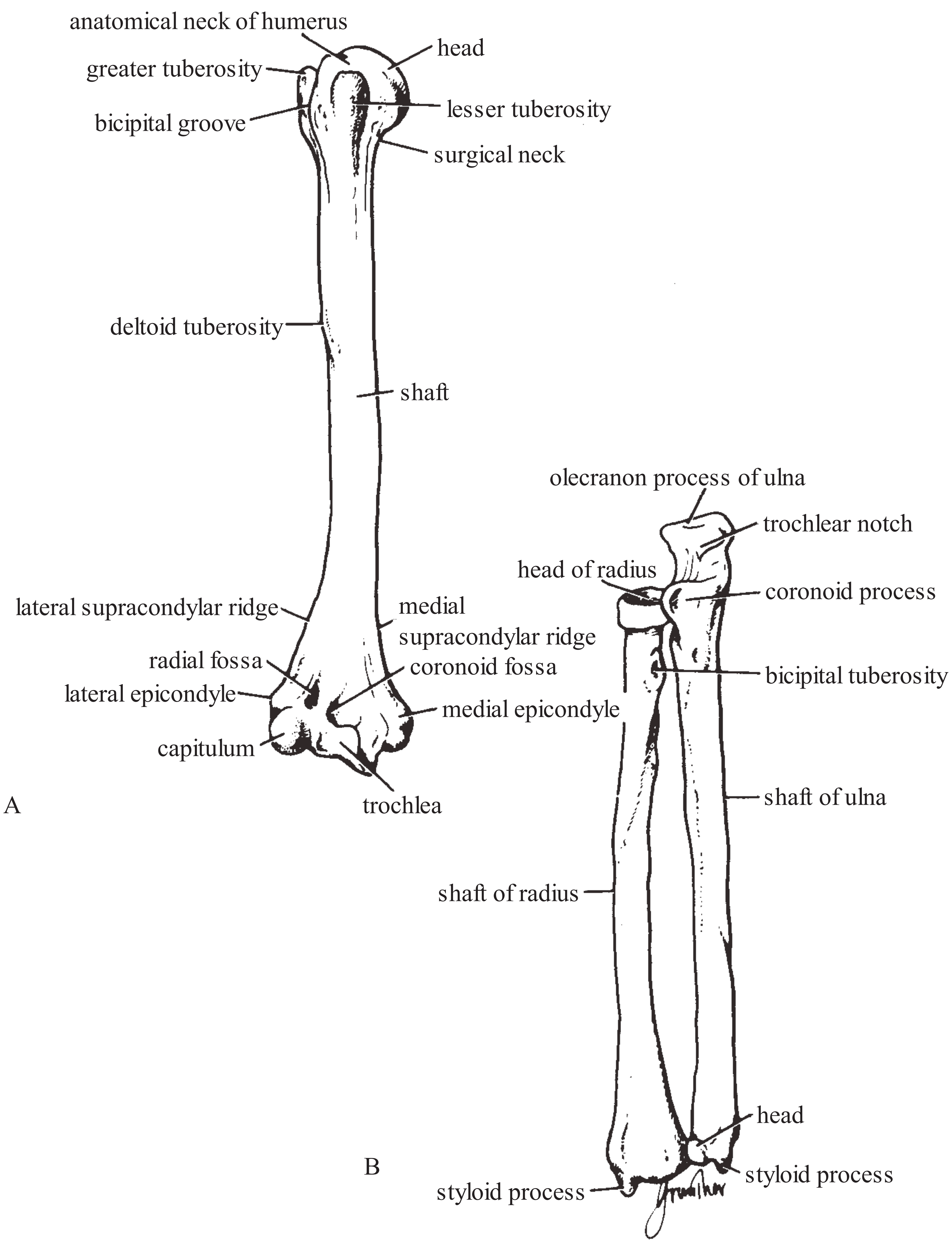


Figure 4-4 The right humerus. A. Anterior surface. B. Posterior surface.

CLINICAL NOTES

FRACTURES OF THE HUMERUS AND INJURY TO THE RADIAL NERVE

The radial nerve can be damaged where it lies in the spiral groove on the posterior surface of the shaft of the humerus under cover of the triceps muscle.

Bones of the Forearm

RADIUS

The radius is the lateral bone of the forearm (Fig. 4-4). The **head,** which is small and circular, lies at the upper end. The upper concave surface articulates with the convex capitulum, and the circumference of the head articulates with the radial notch of the ulna. The bone is constricted below the head to form the **neck,** and below the neck is the **bicipital tuberosity,** which is for the insertion of the biceps brachii muscle.

Medially, the **shaft** has a sharp **interosseous border** for the attachment of the **interosseous membrane,** which binds the radius and the ulna together.

The **styloid process** projects distally from the lateral margin of the lower end of the radius (Fig. 4-4). On the medial surface of the lower end is the **ulnar notch,** which articulates with the head of the ulna. The inferior surface of the lower end articulates with the scaphoid and the lunate bones. On the posterior surface of the lower end is the small **dorsal tubercle,** which is grooved on its medial side by the tendon of extensor pollicis longus.

ULNA

The ulna is the medial bone of the forearm (Fig. 4-4). The **olecranon process** is the large upper end that forms the prominence of the elbow, and the **trochlear notch** lies on the anterior surface of the olecranon process and articulates with the trochlea of the humerus. Below the trochlear notch is the triangular **coronoid process,** which on its lateral surface has the radial notch for articulation with the head of the radius.

Laterally, the **shaft** has a sharp **interosseous border** for the attachment of the interosseous membrane.

The small, rounded **head** lies at the lower end of the ulna. The **styloid process** projects from the medial aspect of the head.

Bones of the Hand

CARPAL BONES

There are eight carpal bones, which are arranged in two rows of four (Fig. 4-5). From lateral to medial, the **proximal row** consists of the **scaphoid** (navicular), the **lunate,** the **triquetral,** and the **pisiform** bones. From lateral to medial, the **distal row** consists of the **trapezium,** the **trapezoid,** the **capitate,** and the **hamate** bones. The carpal bones are united with one another by strong ligaments. Together, the bones form a concavity on their anterior surface, to the lateral and the medial edges of which is attached a strong membranous band (the **flexor retinaculum**) that forms a bridge. This bridge and the carpal bones form the **carpal tunnel** for the passage of the median nerve and the long flexor tendons of the fingers (Fig. 4-6).

CLINICAL NOTES

MEDIAN NERVE AND CARPAL TUNNEL SYNDROME

Clinically, the median nerve may be compressed in the carpal tunnel, thus giving rise to the carpal tunnel syndrome.

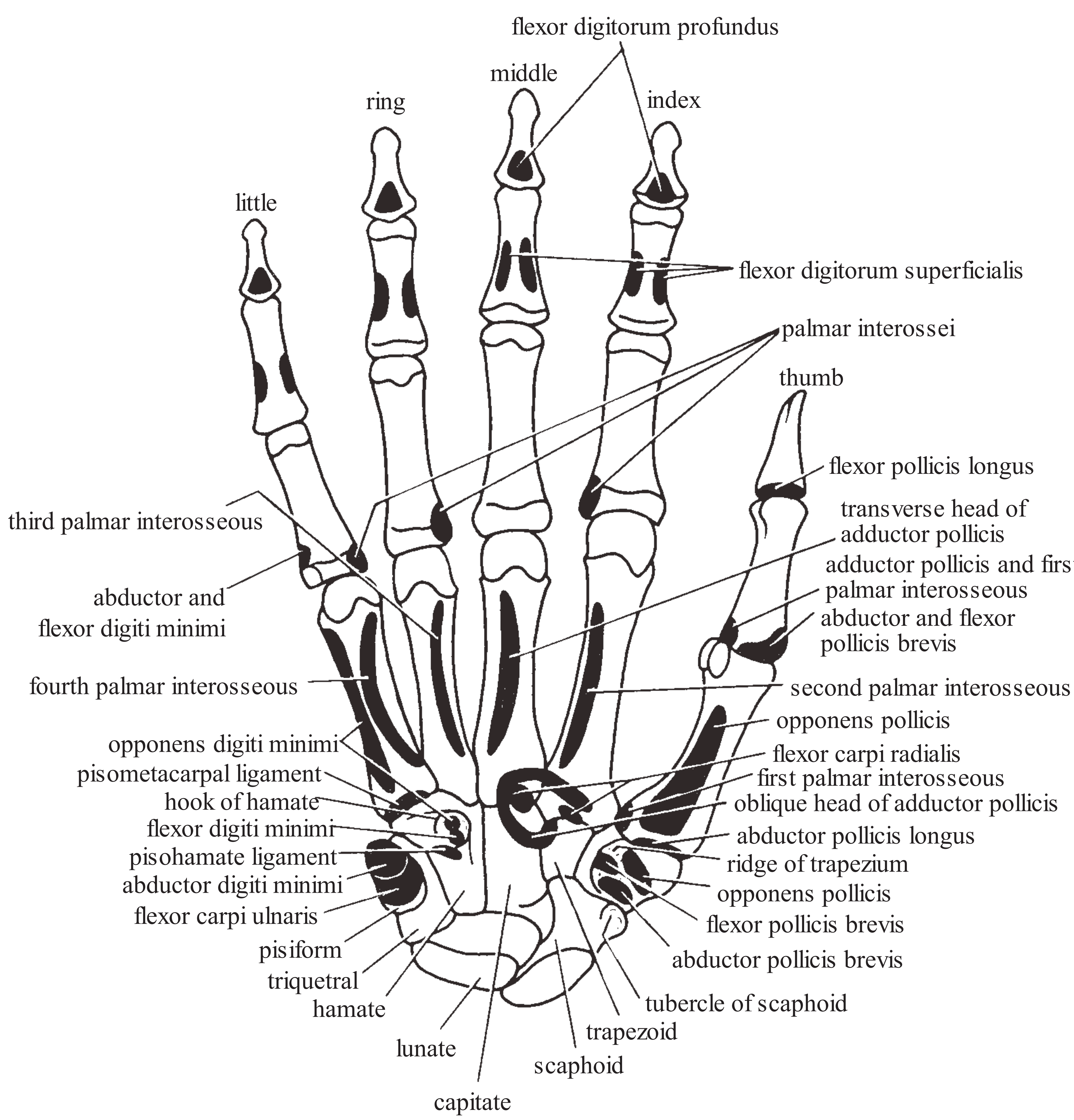


Figure 4-5 Anterior surface of the bones of the right hand showing important muscular attachments.

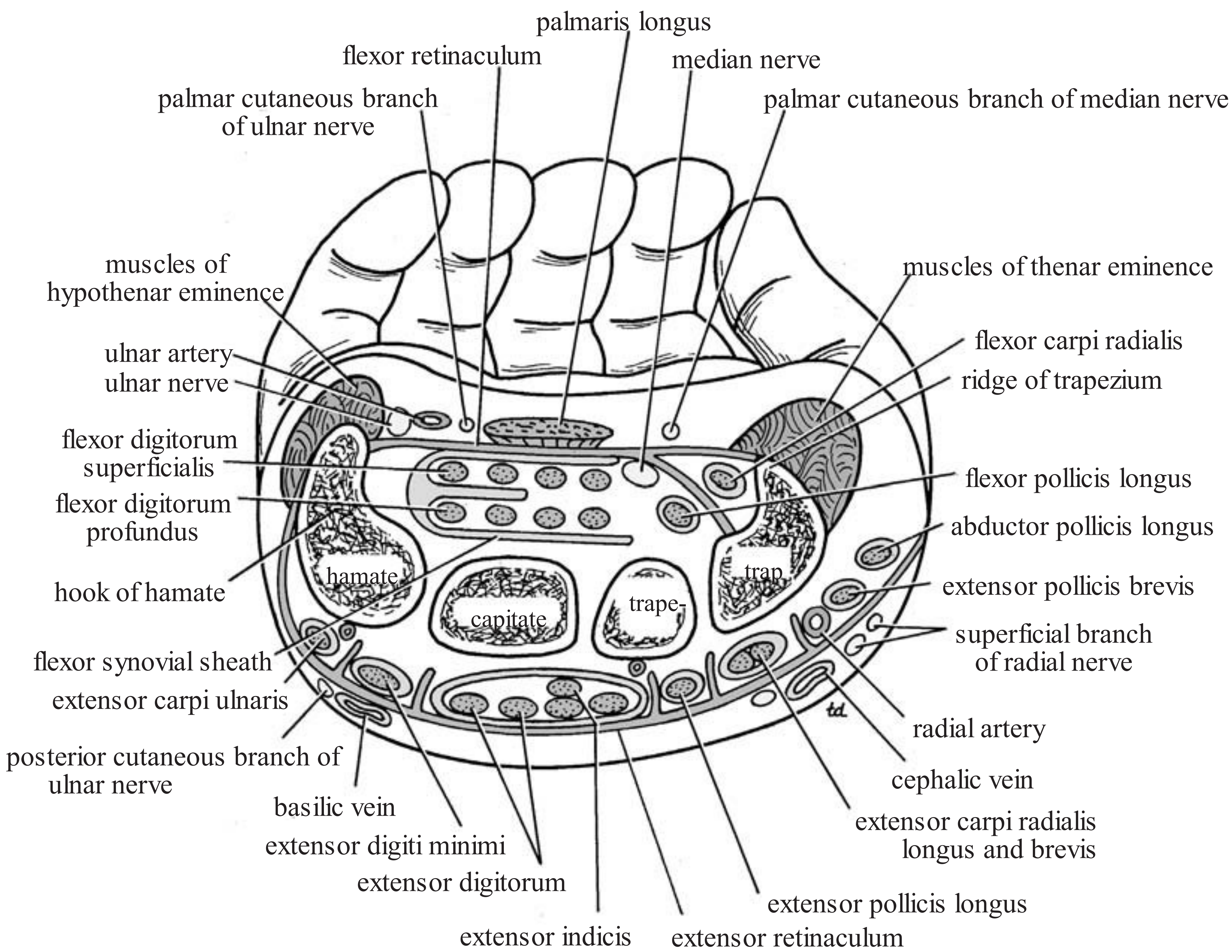


Figure 4-6 Cross section of the hand showing the relationship of the tendons, the nerves, and the arteries to the flexor and the extensor reticula.

METACARPAL BONES

There are five metacarpal bones, each of which has a proximal **base,** a **shaft,** and a distal **head** (Fig. 4-5). The bases of the metacarpal bones articulate with the distal row of the carpal bones. The heads, which form the knuckles, articulate with the proximal phalanges.

PHALANGES

There are three phalanges for each finger, but there are only two for the thumb (Fig. 4-5). Each phalanx has a proximal **base,** a **shaft,** and a distal **head.**

JOINTS

Shoulder Joint

ARTICULATION

The shoulder joint consists of the rounded head of the humerus and the shallow glenoid cavity of the scapula covered with hyaline cartilage (Fig. 4-7). The glenoid cavity is deepened by the fibrocartilaginous rim (the **glenoid labrum**).

TYPE

This joint is a synovial ball-and-socket joint.

CAPSULE

The capsule of the shoulder joint is thin and lax, and it allows for a wide range of movement. It is attached around the outside of the glenoid labrum and to the anatomic neck of the humerus. The capsule is strengthened by the tendons of the short muscles around the joint—namely, the subscapularis muscle anteriorly, the supraspinatus muscle superiorly, and the infraspinatus and teres minor muscles posteriorly. Collectively, these muscle tendons are called the **rotator cuff,** which plays an important role in stabilizing the shoulder joint.

LIGAMENTS

Glenohumeral Ligaments

The glenohumeral ligaments are three bands that strengthen the anterior part of the capsule.

Transverse Humeral Ligament

The transverse humeral ligament bridges the gap between the greater and the lesser tuberosities of the humerus. It holds the tendon of the long head of the biceps muscle in place.

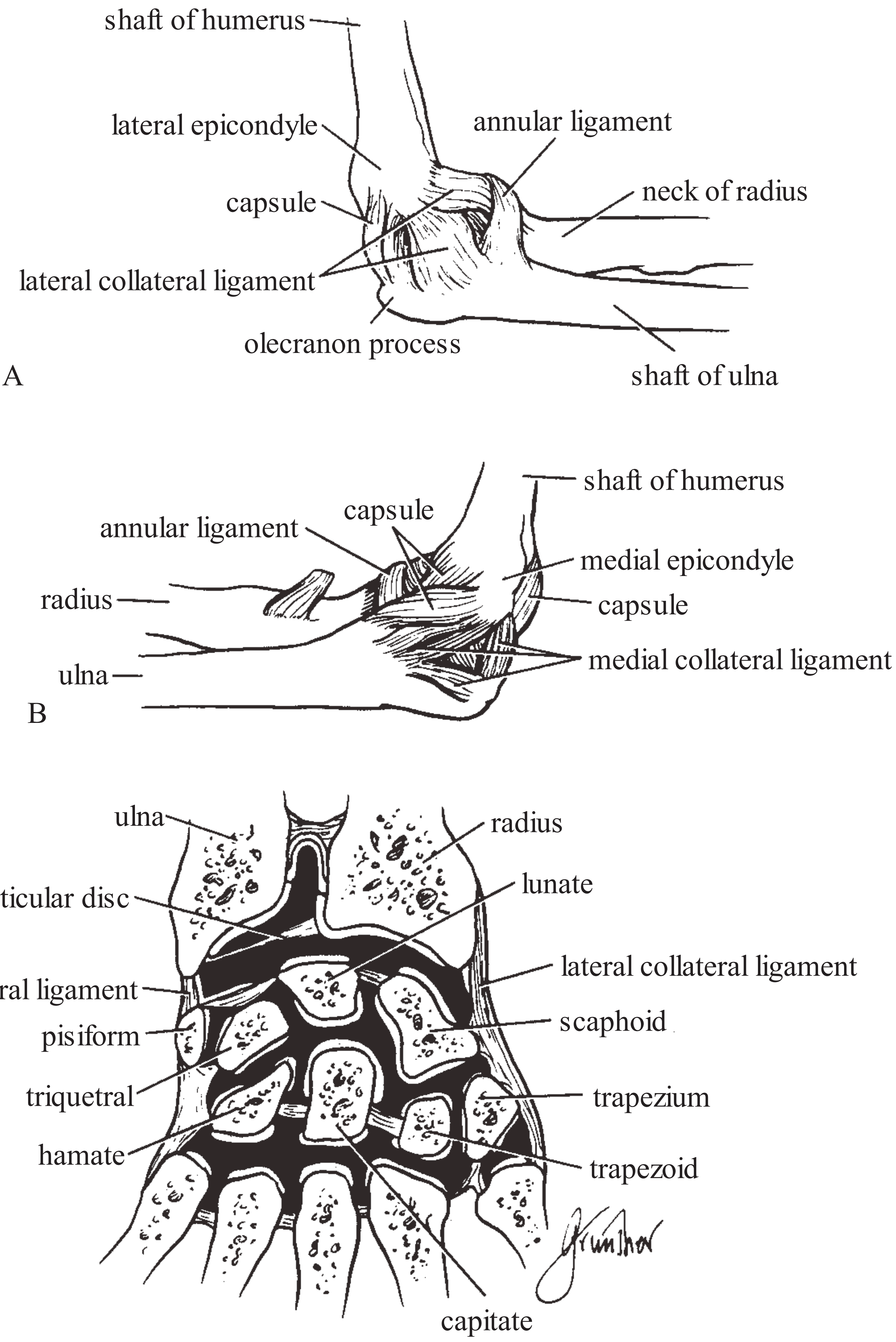


Figure 4-7 A. Lateral aspect of the right elbow joint. B. Medial aspect of the right elbow joint. C. Inferior radioulnar joint, wrist joint, and carpal joints.

Coracohumeral Ligament

The coracohumeral ligament strengthens the capsule above, and it extends from the root of the coracoid process to the greater tuberosity of the humerus.

Accessory Ligament

The **coracoacromial ligament** extends from the coracoid process to the acromion. It protects the superior aspect of the joint.

SYNOVIAL MEMBRANE

The synovial membrane lines the capsule (Fig. 4-8), surrounds the tendon of the biceps, and protrudes forward through the capsule to form a bursa beneath the subscapularis muscle.

NERVE SUPPLY

Axillary and suprascapular nerves supply the joint.

MOVEMENTS AND MUSCLES THAT PRODUCE MOVEMENTS

The shoulder joint has a wide range of movement.

- **Flexion:** Anterior fibers of the deltoid, the pectoralis major, the biceps, and the coracobrachialis muscles.
- **Extension:** Posterior fibers of the deltoid, the latissimus dorsi, and the teres major muscles.
- **Abduction:** Middle fibers of the deltoid muscle, assisted by the supraspinatus muscle.
- **Adduction:** Pectoralis major, latissimus dorsi, teres major, and teres minor muscles.
- **Lateral rotation:** Infraspinatus, teres minor, and posterior fibers of deltoid muscles.
- **Medial rotation:** Subscapularis, latissimus dorsi, teres major, and anterior fibers of deltoid muscles.
- **Circumduction:** A combination of all the described movements.

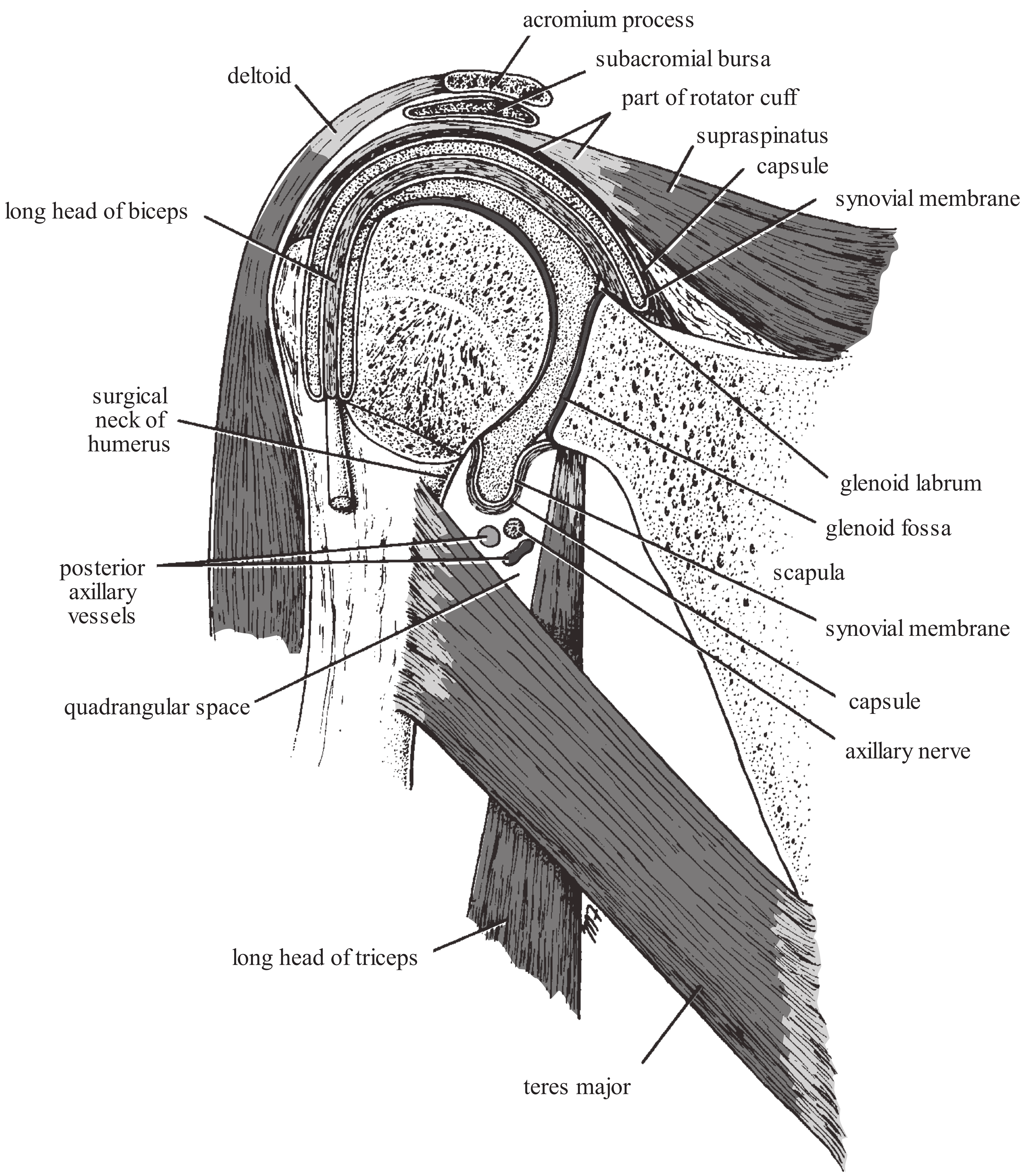


Figure 4-8 Interior of the shoulder joint.

STABILITY

The strength of the joint depends on the tone of the subscapularis, the supraspinatus, the infraspinatus, and the teres minor (tendons from the rotator cuff) muscles. The weakest part of the joint lies inferiorly, because there is little support there and the capsule is weakest in that area.

IMPORTANT RELATIONS

- Anteriorly: Brachial plexus and axillary vessels.
- Inferiorly: Axillary nerve and posterior circumflex humeral vessels (because they lie in the quadrangular space).

CLINICAL NOTES

DISLOCATIONS OF THE SHOULDER JOINT AND AXILLARY NERVE INJURY

A subglenoid displacement of the head of the humerus into the quadrangular space can cause damage to the axillary nerve, as indicated by paralysis of the deltoid muscle and loss of skin sensation over the lower half of the deltoid.

Elbow Joint

ARTICULATION

The elbow joint consists of the trochlea and capitulum of the humerus with the trochlear notch of the ulna and the head of the radius (Fig. 4-7).

TYPE

The elbow is a synovial hinge joint.

CAPSULE

The capsule encloses the joint.

LIGAMENTS

Lateral Collateral Ligament

The lateral collateral ligament is triangular in shape. It is attached by its apex to the lateral epicondyle of the humerus and by its base to the superior margin of the anular ligament and the ulna (Fig. 4-7).

Medial Collateral Ligament

The medial collateral ligament is triangular in shape, and it is attached by its apex to the medial epicondyle of the humerus and by its base to the coronoid process and olecranon process of the ulna (Fig. 4-7). It is closely related to the ulnar nerve.

CLINICAL NOTES

DAMAGE TO THE ULNAR NERVE WITH ELBOW JOINT INJURIES

The close relationship of the ulnar nerve to the medial side of the joint often results in its becoming damaged in dislocations of the joint or in fracture dislocations in this region.

SYNOVIAL MEMBRANE

The synovial membrane lines the capsule and is continuous below with the synovial membrane of the superior radioulnar joint.

NERVE SUPPLY

Median, ulnar, musculocutaneous, and radial nerves supply the joint.

MOVEMENTS AND MUSCLES THAT PRODUCE MOVEMENT

- **Flexion:** Brachialis, biceps, brachioradialis, and pronator teres muscles.
- **Extension:** Triceps and anconeus muscles.

CARRYING ANGLE

The carrying angle, which opens laterally, is seen when the elbow joint is extended and lies between the arm and forearm. The angle is 170° in males and 167° in females. The angle disappears when the elbow joint is flexed.

IMPORTANT RELATIONS

- **Anteriorly:** Median nerve and brachial artery.
- **Medially:** Ulnar nerve as it passes behind the medial epicondyle of the humerus.

Superior Radioulnar Joint

ARTICULATION

The superior radioulnar joint consists of the circumference of the head of the radius and the anular ligament and the radial notch of the ulna. The anular ligament forms a collar around the head of the radius.

SYNOVIAL MEMBRANE

The synovial membrane lines the capsule and is continuous above with that of the elbow joint.

MOVEMENTS AND MUSCLES THAT PRODUCE MOVEMENT

- **Pronation:** Pronator teres and pronator quadratus muscles. This movement rotates the hand medially so that the palm faces posteriorly and the thumb lies on the medial side.
- **Supination:** Biceps and supinator muscles. This movement returns the pronated hand to the anatomic position so that the palm faces anteriorly and the thumb lies on the lateral side. (Supination is more powerful than pronation.)

Inferior Radioulnar Joint

ARTICULATION

The inferior radioulnar joint consists of the head of ulna and the ulnar notch of radius (Fig. 4-7).

TYPE

This is a synovial pivot joint.

CAPSULE AND LIGAMENTS

The capsule encloses the joint and is strengthened by anterior and posterior ligaments.

ARTICULAR DISC

The articular disc is triangular in shape and is composed of fibrocartilage. Its apex is attached to the base of the styloid process of the ulna, and its base is attached to the lower border of the ulnar notch of the radius. It binds the distal ends of the radius and the ulna together and shuts off the inferior radioulnar joint from the wrist joint.

MOVEMENTS AND MUSCLES THAT PRODUCE MOVEMENT

Rotary movements are made around a vertical axis at the superior and the inferior radioulnar joints. (See the movements for the superior radioulnar joint.)

Wrist Joint (Radiocarpal Joint)

ARTICULATION

The wrist joint consists of the distal end of radius and the triangular cartilaginous articular disc above and the scaphoid, the lunate, and the triquetral bones below (Fig. 4-7).

TYPE

The wrist is a synovial condyloid joint.

CAPSULE

The capsule encloses the joint.

LIGAMENTS

- Anterior and posterior ligaments: They strengthen the capsule.
- Medial ligament: It connects the styloid process of the ulna to the triquetral bone.
- Lateral ligament: It connects the styloid process of the radius to the scaphoid bone.

SYNOVIAL MEMBRANE

The synovial membrane lines the capsule.

NERVE SUPPLY

Anterior interosseous nerve from the median and the deep branches of the radial and the ulnar nerves supply the wrist joint.

MOVEMENTS AND MUSCLES THAT PRODUCE MOVEMENT

Rotation is not possible, because the articular surfaces are ovoid in shape. This lack of rotation is compensated for by the movements of pronation and supination of the forearm.

- **Flexion:** Flexor carpi radialis, flexor carpi ulnaris, palmaris longus, flexor digitorum superficialis, flexor digitorum profundus, and flexor pollicis longus muscles.
- **Extension:** Extensor carpi radialis longus, extensor carpi radialis brevis, extensor carpi ulnaris, extensor digitorum, extensor indicis, extensor digiti minimi, and extensor pollicis longus muscles.
- **Abduction:** Flexor carpi radialis, extensor carpi radialis longus and brevis, abductor pollicis longus, and extensor pollicis longus and brevis muscles.
- **Adduction:** Flexor and extensor carpi ulnaris muscles.

IMPORTANT RELATIONS

- Anteriorly: Median and ulnar nerves.
- Laterally: Radial artery.

Carpometacarpal Joints

The carpometacarpal joints are synovial gliding joints with **anterior, posterior,** and **interosseous ligaments** (Fig. 4-7).

CARPOMETACARPAL JOINT OF THE THUMB

Articulation

The carpometacarpal joint of the thumb occurs between the trapezium and the saddle-shaped base of the first metacarpal bone (Fig. 4-7).

Type

This is a synovial saddle joint (biaxial joint).

Movements and Muscles that Produce Movement

- **Flexion:** Flexor pollicis brevis and longus and opponens pollicis muscles.
- **Extension:** Extensor pollicis longus and brevis muscles.
- **Abduction:** Abductor pollicis longus and brevis muscles.
- **Adduction:** Adductor pollicis muscle.
- **Rotation** (as in opposition): Opponens pollicis muscle (which rotates the thumb medially).

Metacarpophalangeal Joints

ARTICULATION

The metacarpophalangeal joint consists of the convex heads of the metacarpal bones and the concave bases of the proximal phalanges (Fig. 4-7).

TYPE

These joints are synovial condyloid joints.

LIGAMENTS

Palmar Ligaments

The palmar ligaments are strong and contain fibrocartilage.

Collateral Ligaments

The collateral ligaments are cordlike bands that join the head of the metacarpal bone to the base of the phalanx. The collateral ligaments are taut when the joint is in flexion, and they are lax when the joint is in extension. (Thus fingers can be abducted and adducted in extension.)

MOVEMENTS AND MUSCLES THAT PRODUCE MOVEMENT

- **Flexion:** Lumbricals and interossei muscles, assisted by flexor digitorum superficialis and profundus muscles.
- **Extension:** Extensor digitorum, extensor indicis, and extensor digiti minimi muscles.
- **Abduction** (movement away from the midline of the third finger): dorsal interossei—that is, **DAB** (dorsal abduct).
- **Adduction** (movement toward the midline of the third finger): palmar interossei—that is, **PAD** (palmar adduct).

In the metacarpophalangeal joint of the thumb, flexion is performed by the flexor pollicis longus and brevis muscles, and extension is performed by the extensor pollicis longus and brevis muscles. Abduction and adduction are performed at the carpometacarpal joint.

Interphalangeal Joints

The interphalangeal joints are synovial hinge joints with a structure similar to that of the metacarpophalangeal joints.

MUSCLES OF THE UPPER LIMB

Shoulder Region

The muscles connecting the upper limb to the vertebral column are shown in Table 4-1. The muscles connecting the upper limb to the thoracic wall are shown in Table 4-2, and the muscles connecting the scapula to the humerus are shown in Table 4-3.

AXILLA

The axilla (or armpit) is a pyramid-shaped space between the upper part of the arm and the side of the chest (Fig. 5-9). The upper end (or **apex**) is directed into the root of the neck, and it is bounded in front by the clavicle, behind by the upper border of the scapula, and medially by the outer border of the first rib. The lower end (or **base**) is bounded in front by the anterior axillary fold (formed by the lower border of the pectoralis major muscle), behind by the posterior axillary fold (formed by the tendon of latissimus dorsi and the teres major muscle), and medially by the chest wall.

The axilla contains the principal vessels (axillary artery and vein) and nerves (brachial plexus and its branches) that supply the upper limb (Fig. 4-9). The axilla also contains many lymph nodes.

Axillary Sheath

The axillary sheath encloses the axillary vessels and the brachial plexus. It is continuous above in the neck with the prevertebral layer of deep cervical fascia.

CLINICAL NOTES

AXILLARY SHEATH AND BRACHIAL PLEXUS NERVE BLOCK

The axillary sheath is important when performing a nerve block of the brachial plexus, because the sheath localizes the anesthetic solution to the nerve plexus.

Table 4-1 Muscles Connecting the Upper Limb to the Vertebral Column

Muscle	Origin	Insertion	Nerve Supply	Action
Trapezius	Occipital bone, ligamentum nuchae, spine of the seventh cervical vertebra, spines of all thoracic vertebrae	Upper fibers into the lateral third of the clavicle, middle and lower fibers into the acromion and the spine of the scapula	Spinal part of the accessory nerve and C3 and 4	Upper fibers elevate the scapula, middle fibers pull the scapula medially, lower fibers pull downward the medial border of the scapula
Latissimus dorsi	Iliac crest, lumbar fascia, spines of the lower six thoracic vertebrae, lower three or four ribs, inferior angle of the scapula	Floor of the bicipital groove of the humerus	Thoracodorsal nerve	Extends, adducts, and medially rotates the arm
Levator scapulae	Transverse process of the first four cervical vertebrae	Medial border of the scapula	C3 and 4 and dorsal scapular nerve	Raises the medial border of the scapula
Rhomboid minor	Ligamentum nuchae and spines of the seventh cervical vertebra and the first thoracic vertebra	Medial border of the scapula	Dorsal scapular nerve	Raises the medial border of the scapula upward and medially
Rhomboid major	Second to fifth thoracic spines	Medial border of the scapula	Dorsal scapular nerve	Raises the medial border of the scapula upward and medially

Table 4-2 Muscles Connecting the Upper Limb to the Thoracic Wall

Muscle	Origin	Insertion	Nerve Supply	Action
Pectoralis major	Clavicle, sternum, and the upper six costal cartilages	Lateral lip of the bicipital groove of the humerus	Medial and lateral pectoral nerves from the brachial plexus	Adducts the arm and rotates it medially; clavicular fibers also flex the arm
Pectoralis minor	Third, fourth, and fifth ribs	Coracoid process of the scapula	Medial pectoral nerve from the brachial plexus	Depresses the point of the shoulder; if the scapula is fixed, it elevates the ribs of origin
Subclavius	First costal cartilage	Clavicle	Nerve to the subclavius from the upper trunk of the brachial plexus	Depresses the clavicle and steadies this bone during movements of the shoulder girdle
Serratus anterior	Upper eight ribs	Medial border and inferior angle of the scapula	Long thoracic nerve	Draws the scapula forward around the chest wall; rotates the scapula

Table 4-3 Muscles Connecting the Scapula to the Humerus

Muscle	Origin	Insertion	Nerve Supply	Action
Deltoid	Lateral third of the clavicle, the acromion and the spine of the scapula	Middle of the lateral surface of the shaft of the humerus	Axillary nerve	Abducts the arm; anterior fibers flex and medially rotate the arm, posterior fibers extend and laterally rotate the arm
Supraspinatus	Supraspinous fossa of the scapula	Greater tuberosity of the humerus; capsule of the shoulder joint	Suprascapular nerve	Abducts the arm and stabilizes the shoulder joint
Infraspinatus	Infraspinous fossa of the scapula	Greater tuberosity of the humerus; capsule of the shoulder joint	Suprascapular nerve	Laterally rotates the arm and stabilizes the shoulder joint
Teres major	Lower third of the lateral border of the scapula	Medial lip of the bicipital groove of the humerus	Lower subscapular nerve	Medially rotates and adducts the arm and stabilizes the shoulder joint
Teres minor	Upper two thirds of the lateral border of the scapula	Greater tuberosity of the humerus; capsule of the shoulder joint	Axillary nerve	Laterally rotates the arm and stabilizes the shoulder joint
Subscapularis	Subscapular fossa	Lesser tuberosity of the humerus	Upper and lower subscapular nerves	Medially rotates the arm and stabilizes the shoulder joint

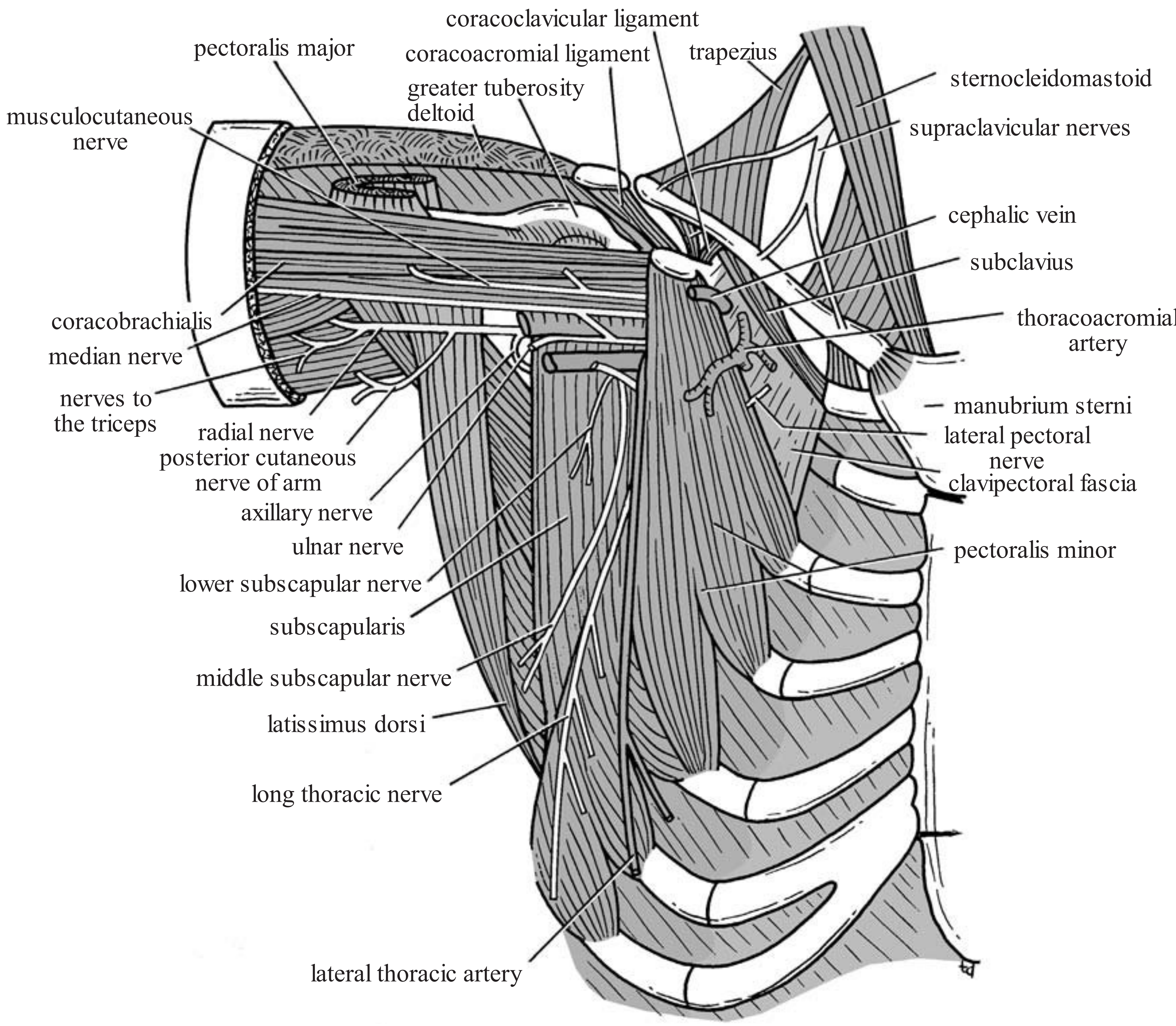


Figure 4-9 Pectoral region and axilla. The pectoralis major muscle has been removed to display the underlying structures.

ROTATOR CUFF

The rotator cuff is the name given to the tendons of the subscapularis, the supraspinatus, the infraspinatus, and the teres minor muscles, which are fused to the underlying capsule of the shoulder joint. The cuff is important in stabilizing the shoulder joint.

> **CLINICAL NOTES**
>
> **ROTATOR CUFF TENDINITIS**
>
> The rotator cuff is a common site of tendinitis and can cause severe pain in the shoulder region.

QUADRANGULAR SPACE

The quadrangular space, located immediately below the shoulder joint, is bounded above by the subscapularis muscle and below by the teres major muscle. It is bounded laterally by the surgical neck of the humerus and medially by the long head of the triceps.

> **CLINICAL NOTES**
>
> **AXILLARY NERVE AND THE QUADRANGULAR SPACE**
>
> The axillary nerve, which passes through the quadrangular space, may be damaged during dislocation of the shoulder joint.

Upper Arm

The muscles of the upper arm (Figs. 4-10 and 4-11) are shown in Table 4-4.

FASCIAL COMPARTMENTS OF THE UPPER ARM

The upper arm is enclosed in a sheath of deep fascia. Two fascial septa (one on the medial and one on the lateral side)

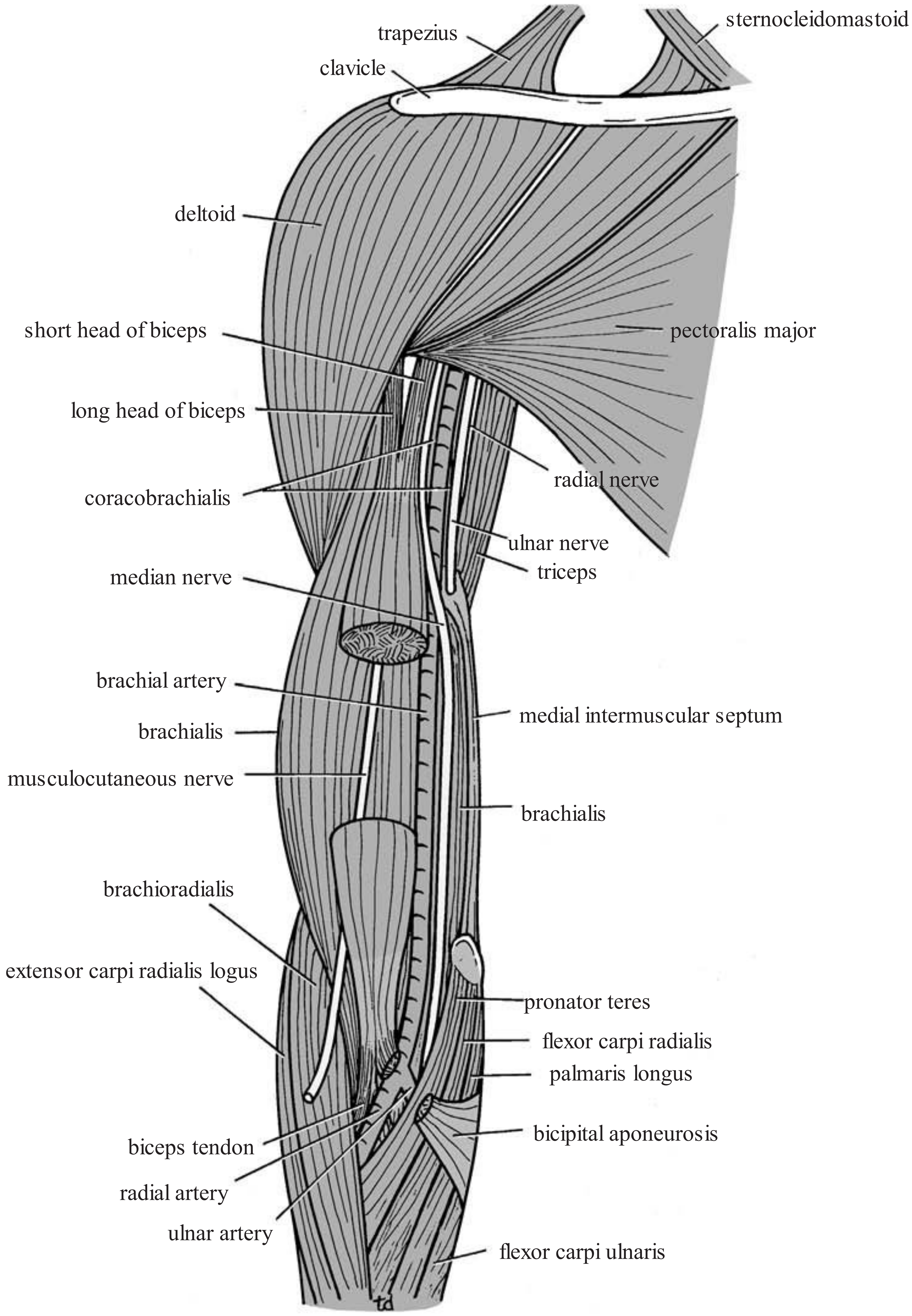


Figure 4-10 Anterior view of the upper arm. The middle portion of the biceps brachii muscle has been removed to show the musculocutaneous nerve lying in front of the brachialis muscle.

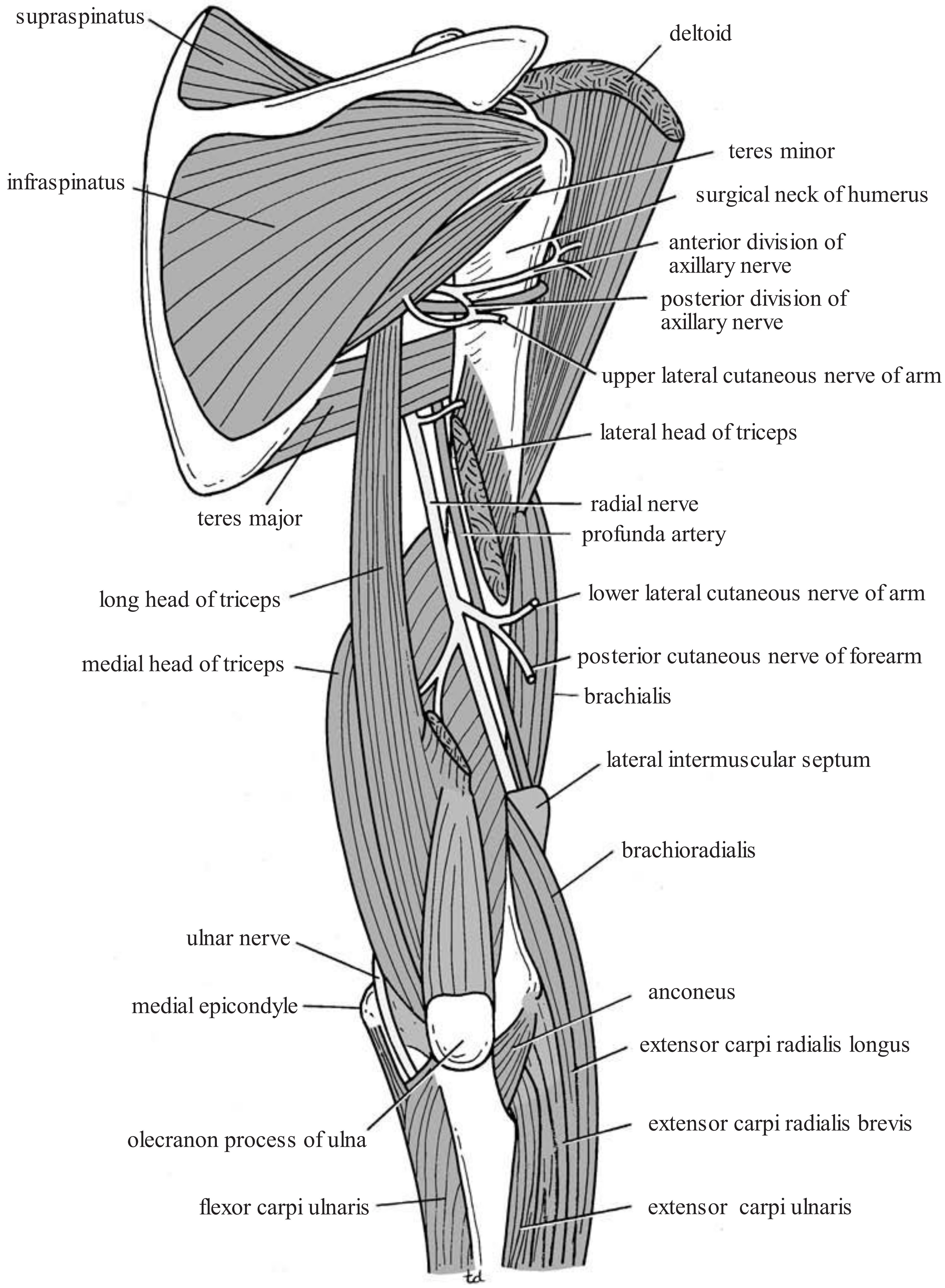


Figure 4-11 Posterior view of the upper arm. The lateral head of the triceps muscle has been divided to display the radial nerve and the profunda artery in the spiral groove of the humerus.

Table 4-4 Muscles of the Upper Arm

Muscle	Origin	Insertion	Nerve Supply	Action
Anterior Fascial Compartment				
Biceps brachii				
Long head	Supraglenoid tubercle of the scapula	Tuberosity of the radius and bicipital aponeurosis into the deep fascia of the forearm	Musculocutaneous nerve	Supinator of the forearm, flexor of the elbow joint, weak flexor of the shoulder joint
Short head	Coracoid process of the scapula			
Coracobrachialis	Coracoid process of the scapula	Medial aspect of the shaft of the humerus	Musculocutaneous nerve	Flexes arm, weak adductor
Brachialis	Front of the lower half of the humerus	Coronoid process of the ulna	Musculocutaneous nerve	Flexor of the elbow joint
Posterior Fascial Compartment				
Triceps				
Long head	Infraglenoid tubercle of the scapula	Olecranon process of the ulna	Radial nerve	Extensor of the elbow joint
Lateral head	Upper half of the posterior surface of the shaft of the humerus			
Medial head	Lower half of the posterior surface of the shaft of the humerus			

extend from this sheath and are attached to the medial and the lateral borders of the humerus, respectively. By this means, the upper arm is divided into an anterior and a posterior fascial compartment, with each compartment having its own muscles, nerves, and arteries.

CUBITAL FOSSA

The cubital fossa is a skin depression that lies in front of the elbow and is triangular in shape (Fig. 4-12). It is bounded **laterally** by the brachioradialis muscle and **medially** by the pronator teres muscle. The **base** of the triangle is formed by an imaginary line drawn between the two epicondyles of the humerus.

From medial to lateral, the cubital fossa contains the median nerve, the bifurcation of the brachial artery into the ulnar and the radial arteries, the tendon of the biceps muscle, and the radial nerve and its deep branch.

Lying in the superficial fascia covering the cubital fossa are the **cephalic** and the **basilic veins** as well as their tributaries.

Forearm

The muscles of the anterior fascial compartment of the forearm (Fig. 4-13) are shown in Table 4-5. The muscles of the lateral fascial compartment (Fig. 4-13) are shown in Table 4-6, and the muscles of the posterior fascial compartment are shown in Table 4-7.

FASCIAL COMPARTMENTS

The forearm is enclosed in a sheath of deep fascia, which is attached to the periosteum of the posterior subcutaneous border of the ulna. Together with the interosseous membrane and fibrous intermuscular septa, this fascial sheath divides the forearm into several compartments, with each compartment having its own muscles, nerves, and blood supply.

INTEROSSEOUS MEMBRANE

The interosseous membrane is a strong membrane that unites the shafts of the radius and the ulna. Because its fibers are taut, the forearm is most stable in the midprone position (position of function). The interosseous membrane provides attachment for the neighboring muscles.

Wrist

FLEXOR AND EXTENSOR RETINACULA

The retinacula are bands of deep fascia that hold the long flexor and extensor tendons in position at the wrist (Fig. 4-6). The flexor retinaculum is attached medially to the pisiform bone and the hook of the hamate and laterally to the tubercle of the scaphoid and the trapezium. The extensor retinaculum is attached medially to the pisiform bone and the hook of the hamate and laterally to the distal end of the radius.

CARPAL TUNNEL

The bones of the hand and the flexor retinaculum form the carpal tunnel (Fig. 4-6).

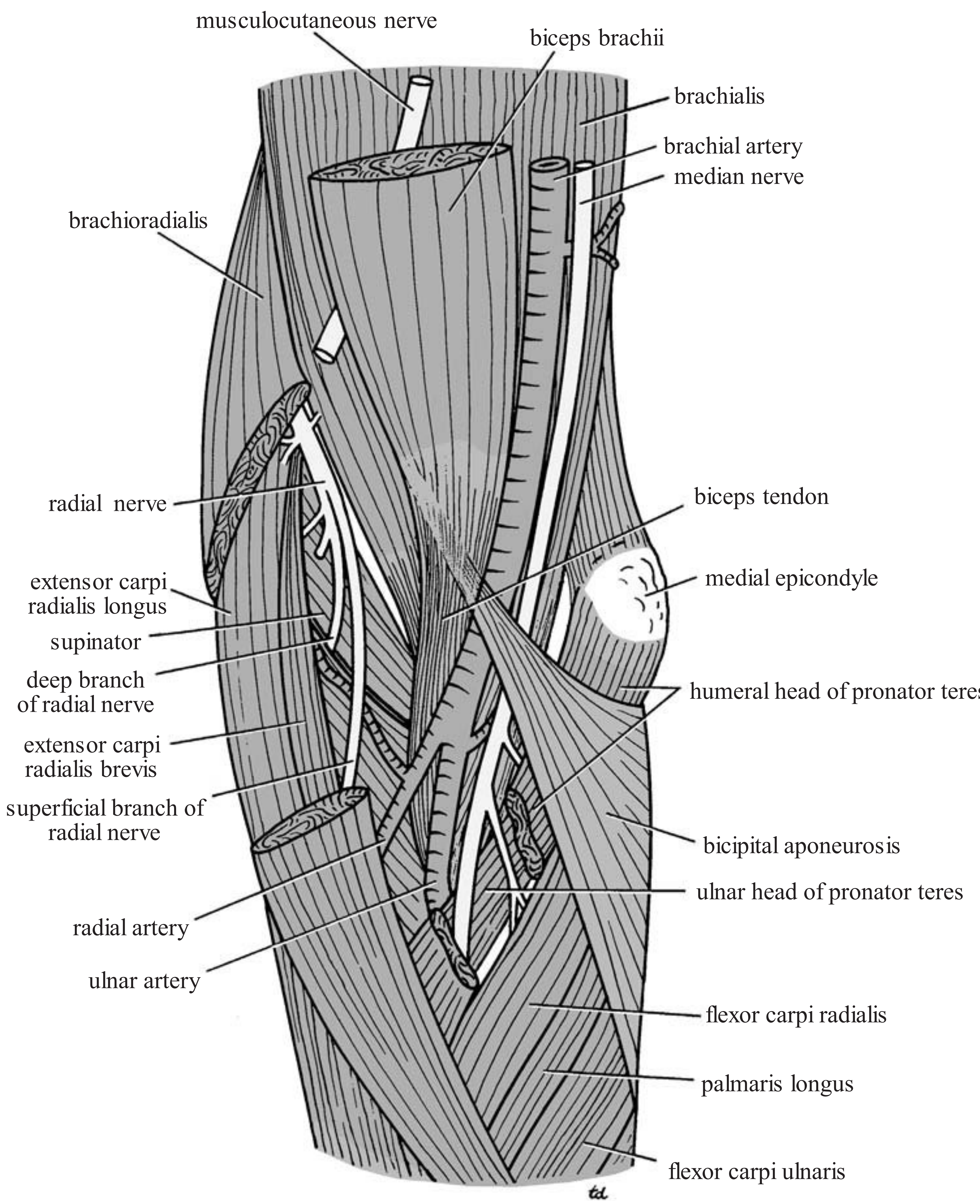


Figure 4-12 Right cubital fossa.

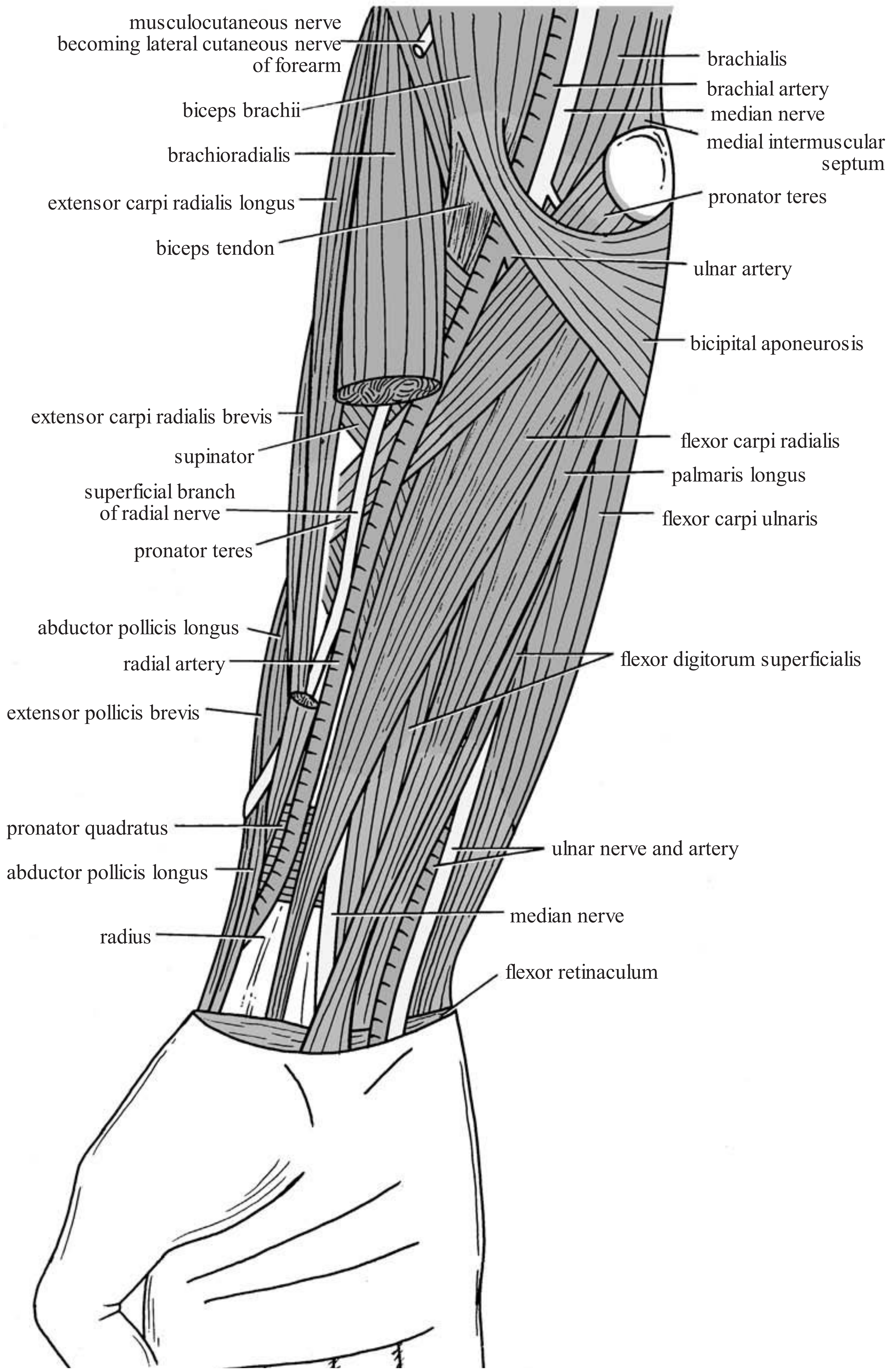


Figure 4-13 Anterior view of the forearm. The middle portion of the brachioradialis muscle has been removed to display the superficial branch of the radial nerve and the radial artery.

Table 4-5 Muscles of the Anterior Fascial Compartment of the Forearm

Muscle	Origin	Insertion	Nerve Supply	Action
Pronator teres				
Humeral head	Medial epicondyle of the humerus	Lateral aspect of the radius	Median nerve	Pronation and flexion of the forearm
Ulnar head	Coronoid process of the ulna			
Flexor carpi radialis	Medial epicondyle of the humerus	Bases of the second and the third metacarpal bones	Median nerve	Flexes and abducts the hand at the wrist joint
Palmaria longus (often absent)	Medial epicondyle of the humerus	Flexor retinaculum and palmar aponeurosis	Median nerve	Flexes the hand
Flexor carpi ulnaris				
Humeral head	Medial epicondyle of the humerus	Pisiform bone, hook of the hamate, base of the fifth metacarpal bone	Ulnar nerve	Flexes and adducts the hand at the wrist joint
Ulnar head	Olecranon process and posterior border of the ulna			
Flexor digitorum superficialis				
Humeroulnar head	Medial epicondyle of the humerus	Middle phalanx of the medial four fingers	Median nerve	Flexes the middle phalanx of the fingers, assists in flexing the proximal phalanx and the hand
Radial head	Oblique line on the anterior surface of the shaft of the radius			
Flexor pollicis longus	Anterior surface of the shaft of the radius	Distal phalanx of the thumb	Anterior interosseous branch of the median nerve	Flexes the distal phalanx of the thumb
Flexor digitorum profundus	Anterior surface of the shaft of the ulna, interosseous membrane	Distal phalanges of the medial four fingers	Ulnar (medial half) and median (lateral half) nerves	Flexes the distal phalanx of the fingers and then assists in flexion of the middle and the proximal phalanges and the wrist
Pronator quadratus	Anterior surface of the shaft of the ulna	Anterior surface of the shaft of the radius	Anterior interosseous branch of the median nerve	Pronates the forearm

Table 4-6 Muscles of the Lateral Fascial Compartment of the Forearm

Muscle	Origin	Insertion	Nerve Supply	Action
Brachioradialis	Lateral supracondylar ridge of the humerus	Styloid process of the radius	Radial nerve	Flexes the forearm at the elbow joint, rotates the forearm to the midprone position
Extensor carpi radialis longus	Lateral supracondylar ridge of the humerus	Base of the second metacarpal bone	Radial nerve	Extends and abducts the hand at the wrist joint

Table 4-7 Muscles of the Posterior Fascial Compartment of the Forearm

Muscle	Origin	Insertion	Nerve Supply	Action
Extensor carpi radialis brevis	Lateral epicondyle of the humerus	Base of the third metacarpal bone	Deep branch of the radial nerve	Extends and abducts the hand at the wrist joint
Extensor digitorum	Lateral epicondyle of the humerus	Middle and distal phalanges of the medial four fingers	Deep branch of the radial nerve	Extends the fingers and the hand
Extensor digiti minimi	Lateral epicondyle of the humerus	Extensor expansion of the little finger	Deep branch of the radial nerve	Extends metacarpophalangeal joint of the little finger
Extensor carpi ulnaris	Lateral epicondyle of the humerus	Base of the fifth metacarpal bone	Deep branch of the radial nerve	Extends and adducts the hand at the wrist joint
Anconeus	Lateral epicondyle of the humerus	Olecranon process of the ulna	Radial nerve	Extends the elbow joint
Supinator	Lateral epicondyle of the humerus, annular ligament of the superior radioulnar joint and the ulna	Neck and shaft of the radius	Deep branch of the radial nerve	Supination of the forearm
Abductor pollicis longus	Shafts of the radius and the ulna	Base of the first metacarpal bone	Deep branch of the radial nerve	Abducts and extends the thumb
Extensor pollicis brevis	Shaft of the radius and the interosseous membrane	Base of the proximal phalanx of the thumb	Deep branch of the radial nerve	Extends the metacarpophalangeal joints of the thumb
Extensor pollics longus	Shaft of the ulna and the interosseous membrane	Base of the distal phalanx of the thumb	Deep branch of the radial nerve	Extends the distal phalanx of the thumb
Extensor indicis	Shaft of the ulna and the interosseous membrane	Extensor expansion of the index finger	Deep branch of the radial nerve	Extends the metacarpophalangeal joint of the index finger

CLINICAL NOTES

MEDIAN NERVE AND RESTRICTED SPACE

In the carpal tunnel the median nerve lies in a restricted space between the flexor digitorum superficialis and the flexor carpi radialis muscles. It may become compressed at this site.

Hand

The small muscles of the hand (Figs. 4-14, 4-15, and 4-16) are shown in Table 4-8.

FIBROUS FLEXOR SHEATHS

The anterior surface of each finger from the metacarpal head to the base of the distal phalanx is provided with a strong, fibrous sheath that is attached to the sides of the phalanges (Fig. 4-14). The sheath and the bones form a blind tunnel in which the long flexor tendons of the finger lie.

SYNOVIAL FLEXOR SHEATHS

In the hand, the tendons of the flexor digitorum superficialis and profundus muscles invaginate a common synovial sheath from the lateral side (Fig. 4-17). The medial part of this common sheath extends distally without interruption on the tendons of the little fingers. The lateral part of the sheath stops abruptly on the middle of the palm, and the distal ends of the long flexor tendons of the index, the middle, and the ring fingers acquire **digital synovial sheaths** as they enter the fingers. The flexor pollicis longus tendon has its own synovial sheath that passes into the thumb. These sheaths allow the long tendons to move smoothly, with a minimum of friction, beneath the flexor retinaculum and the fibrous flexor sheaths.

INSERTION OF THE LONG FLEXOR TENDONS

Each tendon of the flexor digitorum superficialis divides into two halves that pass around the profundus tendon and meet on its posterior surface, where partial decussation of the fibers occurs. The superficialis tendon, having united again, then divides into two further slips, which are attached to the borders of the middle phalanx. Each tendon of the flexor dig-

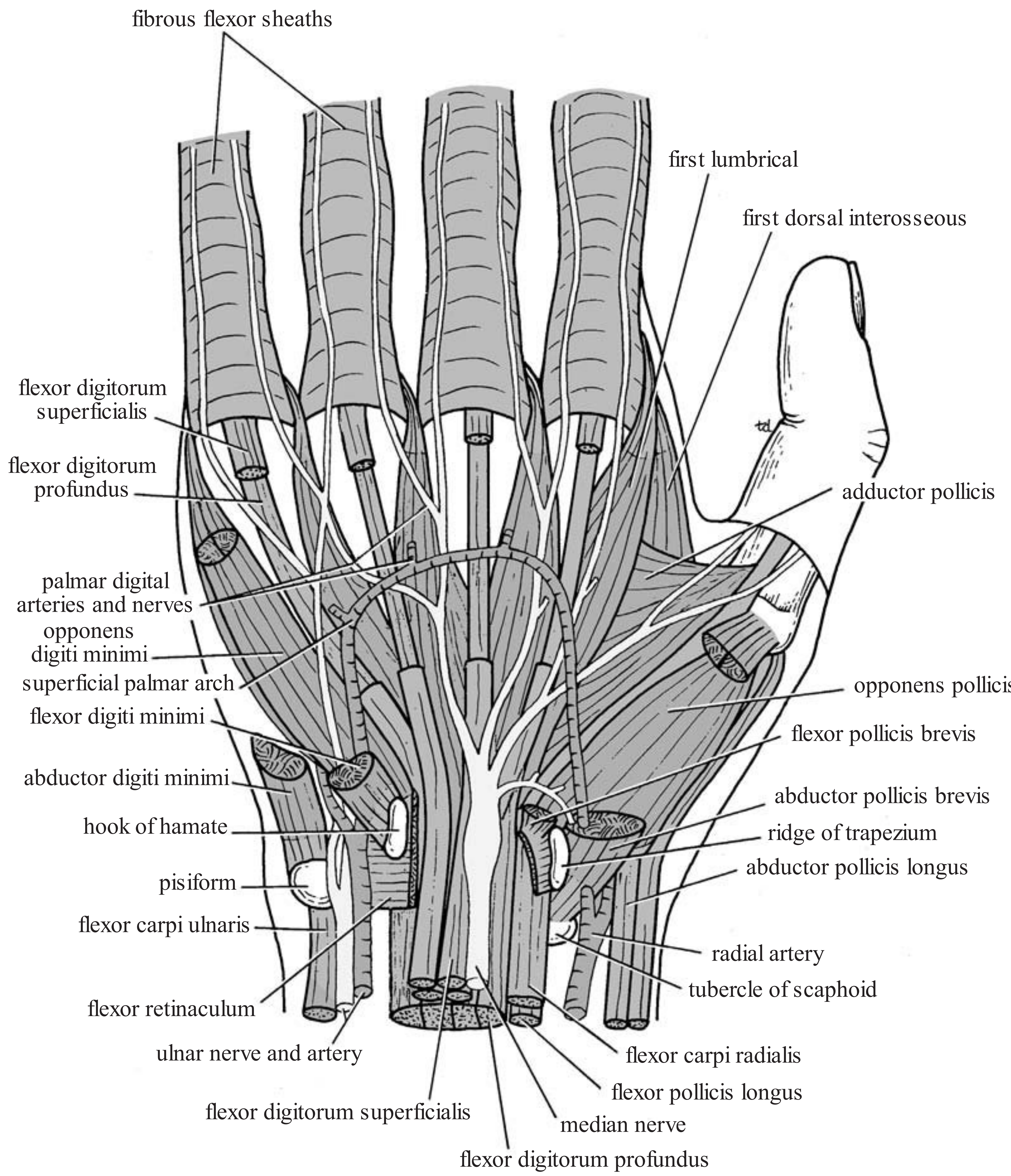


Figure 4-14 Anterior view of the palm of the hand. The palmar aponeurosis and the greater part of the flexor retinaculum have been removed to display the superficial palmar arch, the median nerve, and the long flexor tendons. Note that segments of the tendons of the flexor digitorum superficialis have also been removed to show the underlying tendons of the flexor digitorum profundus.

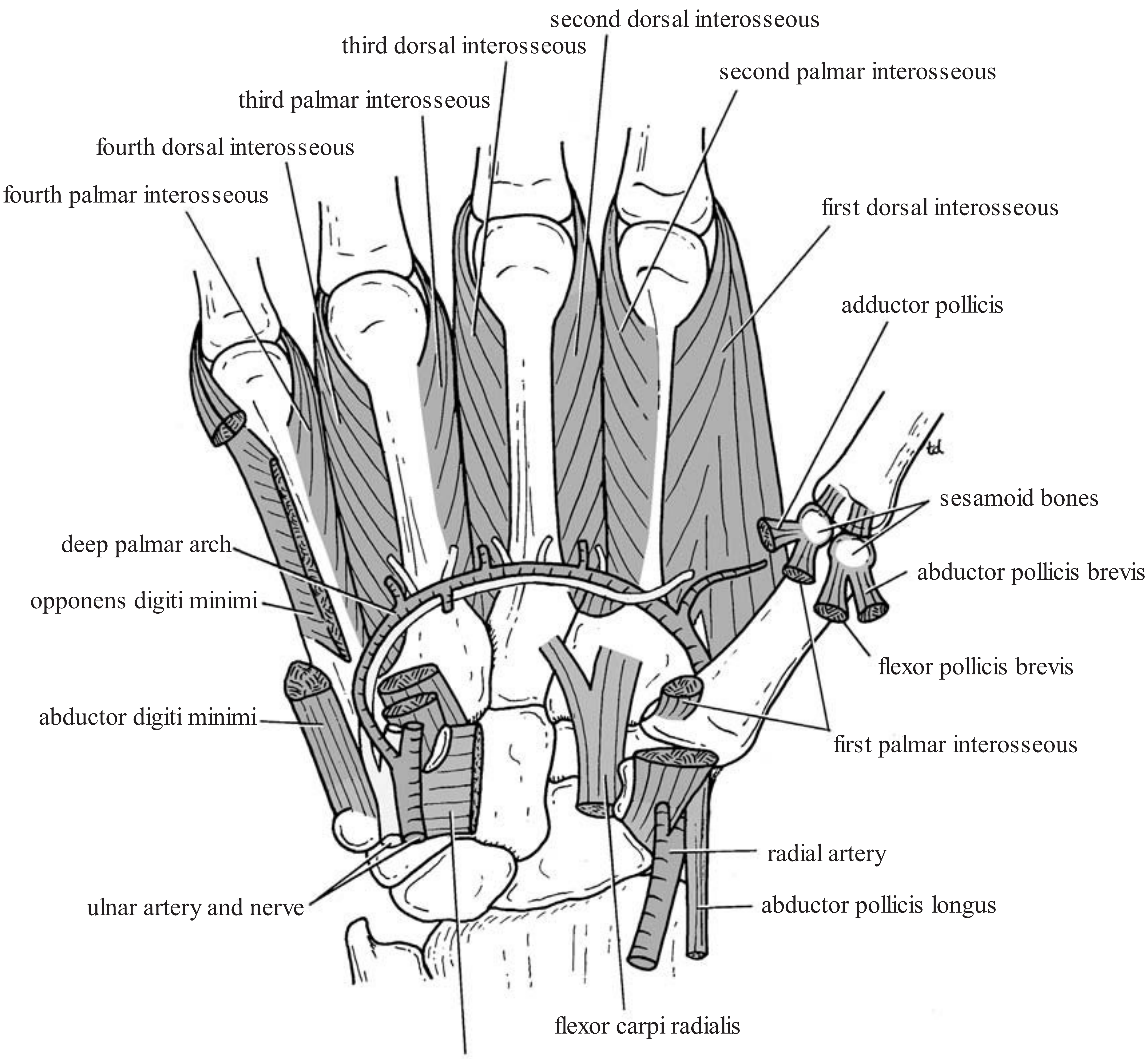


Figure 4-15 Anterior view of the palm of the hand showing the deep palmar arch, the deep terminal branch of the ulnar nerve, and the interossei muscles.

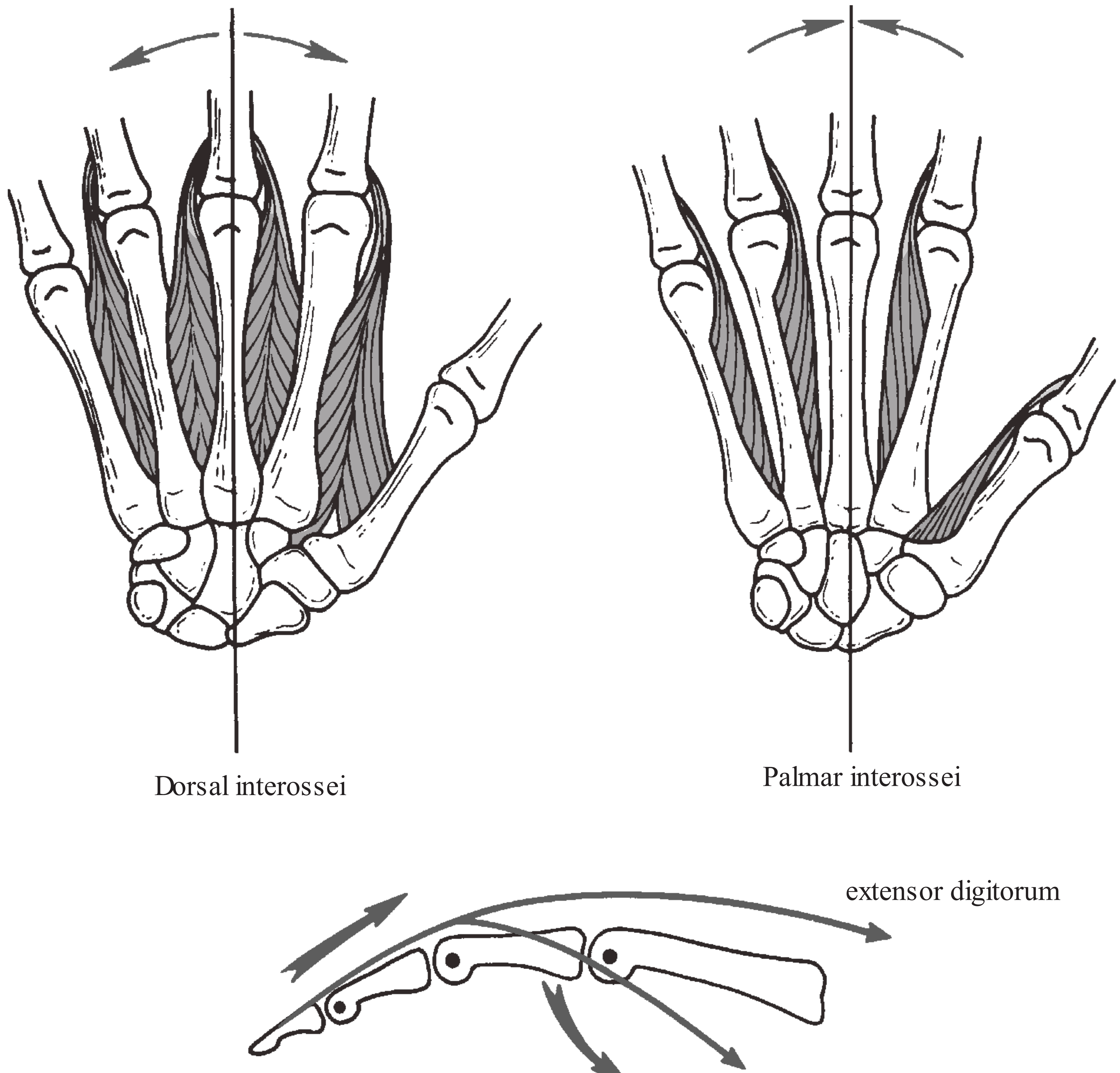


Figure 4-16 Origins and insertions of the palmar and the dorsal interossei muscles and their actions.

itorum profundus, having passed through the superficialis tendon, is inserted into the base of the distal phalanx.

INSERTION OF THE LONG EXTENSOR TENDONS

The four tendons of the extensor digitorum fan out over the dorsum of the hand. The tendon to the index finger is joined on its **medial side** (Fig. 4-18) by the tendon of the extensor indicis. The tendon of the little finger is joined on its **medial side** by the two tendons of the extensor digiti minimi.

On the posterior surface of each finger, the extensor tendon widens to form the **extensor expansion.** Near the proximal interphalangeal joint, the extensor expansion then splits into three parts: a **central part,** which is inserted into the base of the middle phalanx, and **two lateral parts,** which converge to be inserted into the base of the distal phalanx.

In addition, the extensor expansion receives the tendon of insertion of the corresponding interosseous muscle on each side. Farther distally, the extensor expansion also receives the tendon of the lumbrical muscle on the lateral side.

PALMAR APONEUROSIS

In the palm, the deep fascia is greatly thickened to protect the underlying tendons, nerves, and blood vessels and is called the **palmar aponeurosis.** It is continuous proximally with the palmaris longus tendon, and it is attached to the flexor retinaculum. It is also continuous with the fasciae covering the thenar and the hypothenar eminences.

FASCIAL SPACES OF THE PALM

The **thenar space** and the **midpalmar space** are potential spaces lying deep to the palmar aponeurosis that are filled with loose connective tissue. They are separated by an oblique fascial septum. The thenar space lies lateral to the third metacarpal bone, posterior to the long flexor tendons to the index finger, and in front of the adductor pollicis muscle. The midpalmar space lies medial to the third metacarpal bone and posterior to the long flexor tendons to the middle, the ring, and the little fingers.

Table 4-8 Small Muscles of the Hand

Muscle	Origin	Insertion	Nerve Supply	Action
Lumbricals (4)	Tendons of the flexor digitorum profundus	Extensor expansion of the medial four fingers	First and second (lateral two) median nerve, third and fourth ulnar nerve	Flex the metacarpophalangeal joints, extend the interphalangeal joints of the fingers (except the thumb)
Interossei (8)				Adduct the fingers toward the center of the third finger
Palmar (4)	First, second, fourth, and fifth metacarpal bones	Base of the proximal phalanges of the fingers, extensor expansion	Deep branch of the ulnar nerve	Abduct the fingers from the center of the third finger
Dorsal (4)	Contiguous sides of five metacarpal bones	Base of the proximal phalanges of the fingers, extensor expansion	Deep branch of the ulnar nerve	Both the palmar and the dorsal interossei flex the metacarpophalangeal joints and extend the interphalangeal joints
Palmaris brevis	Flexor retinaculum and palmar aponeurosis	Skin of the palm	Superficial branch of the ulnar nerve	Corrugates the skin to improve the grip of the palm
Short Muscles of the Thumb				
Abductor pollicis brevis	Scaphoid, trapezium, and flexor retinaculum	Base of the proximal phalanx of the thumb	Median nerve	Abduction of the thumb
Flexor pollicis brevis	Flexor retinaculum	Base of the proximal phalanx of the thumb	Median nerve	Flexes the metacarpophalangeal joint of the thumb
Opponens pollicis	Flexor retinaculum	Shaft of the metacarpal bone of the thumb	Median nerve	Pulls the thumb medially and forward across the palm
Adductor pollicis				
Oblique head	Second and third metacarpal bones	Base of the proximal phalanx of the thumb	Deep branch of the ulnar nerve	Adducts thumb
Transverse head	Third metacarpal bone			
Short Muscles of the Little Finger				
Abductor digiti minimi	Pisiform bone	Base of the proximal phalanx of the little finger	Deep branch of the ulnar nerve	Flexes the little finger
Flexor digiti minimi	Flexor retinaculum	Base of the proximal phalanx of the little finger	Deep branch of the ulnar nerve	Flexes the little finger
Opponens digiti minimi	Flexor retinaculum	Shaft of the metacarpal bone of the little finger	Deep branch of the ulnar nerve	Pulls the fifth metacarpal bone forward (as in cupping the palm)

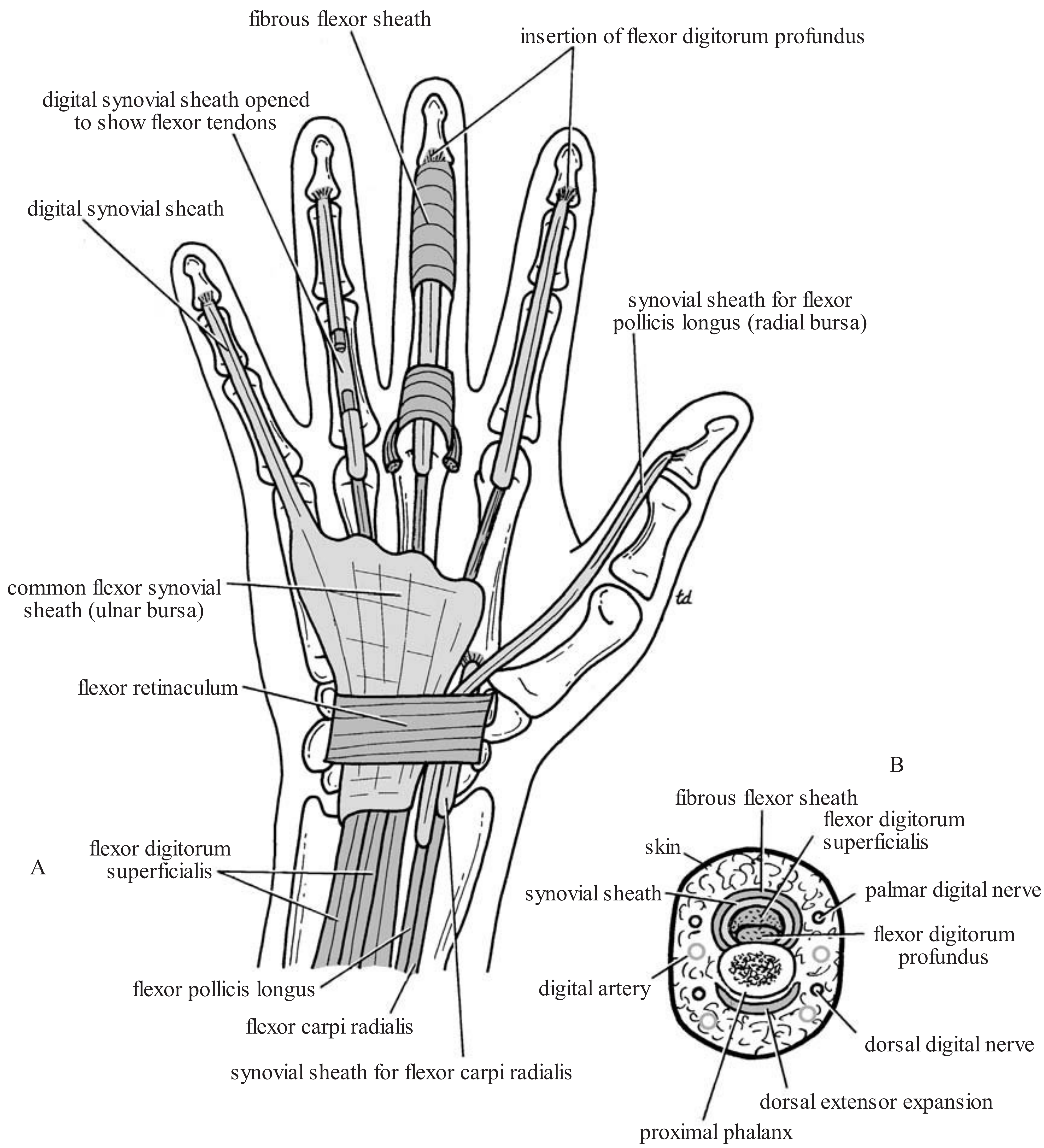


Figure 4-17 A. Anterior view of the palm of the hand showing the flexor synovial sheaths. B. Cross section of a finger.

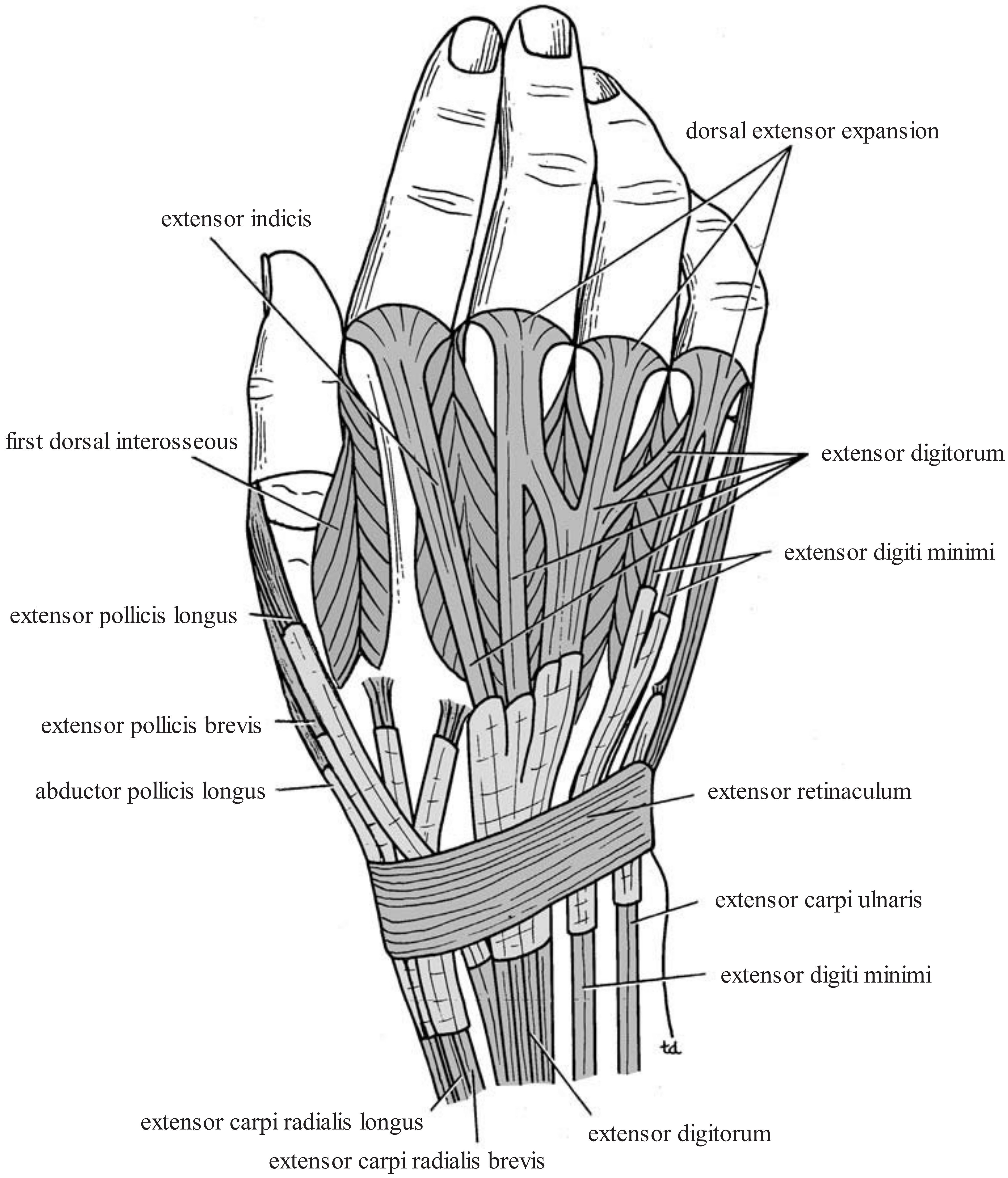


Figure 4-18 Dorsal surface of the hand. Note the long extensor tendons and their synovial sheaths.

CLINICAL NOTES

FASCIAL SPACES OF THE PALM AND INFECTION

The fascial spaces can become infected and distended with pus as a result of the spread of infection from the synovial sheaths of the long flexor tendons (tenosynovitis). Rarely, they can become infected after penetrating wounds, such as falling on a dirty nail.

ARTERIES OF THE UPPER LIMB

Axillary Artery

The axillary artery begins at the lateral border of the first rib as a continuation of the subclavian artery, and at the lower border of the teres major muscle, it becomes the brachial artery (Fig. 4-19). Throughout its course, the artery is related to the cords of the brachial plexus and their branches, and it is enclosed with them in the **axillary sheath**.

The pectoralis minor muscle crosses in front of the artery and thus divides it (for purposes of description) into three parts:

- The lateral border of the first rib to the upper border of the pectoralis minor muscle.
- The portion that lies posterior to the pectoralis minor.
- The portion from the lower border of the pectoralis minor muscle to the lower border of the teres major muscle.

BRANCHES

The first part of the axillary artery gives off one branch. The second part gives off two branches, and the third part gives off three branches.

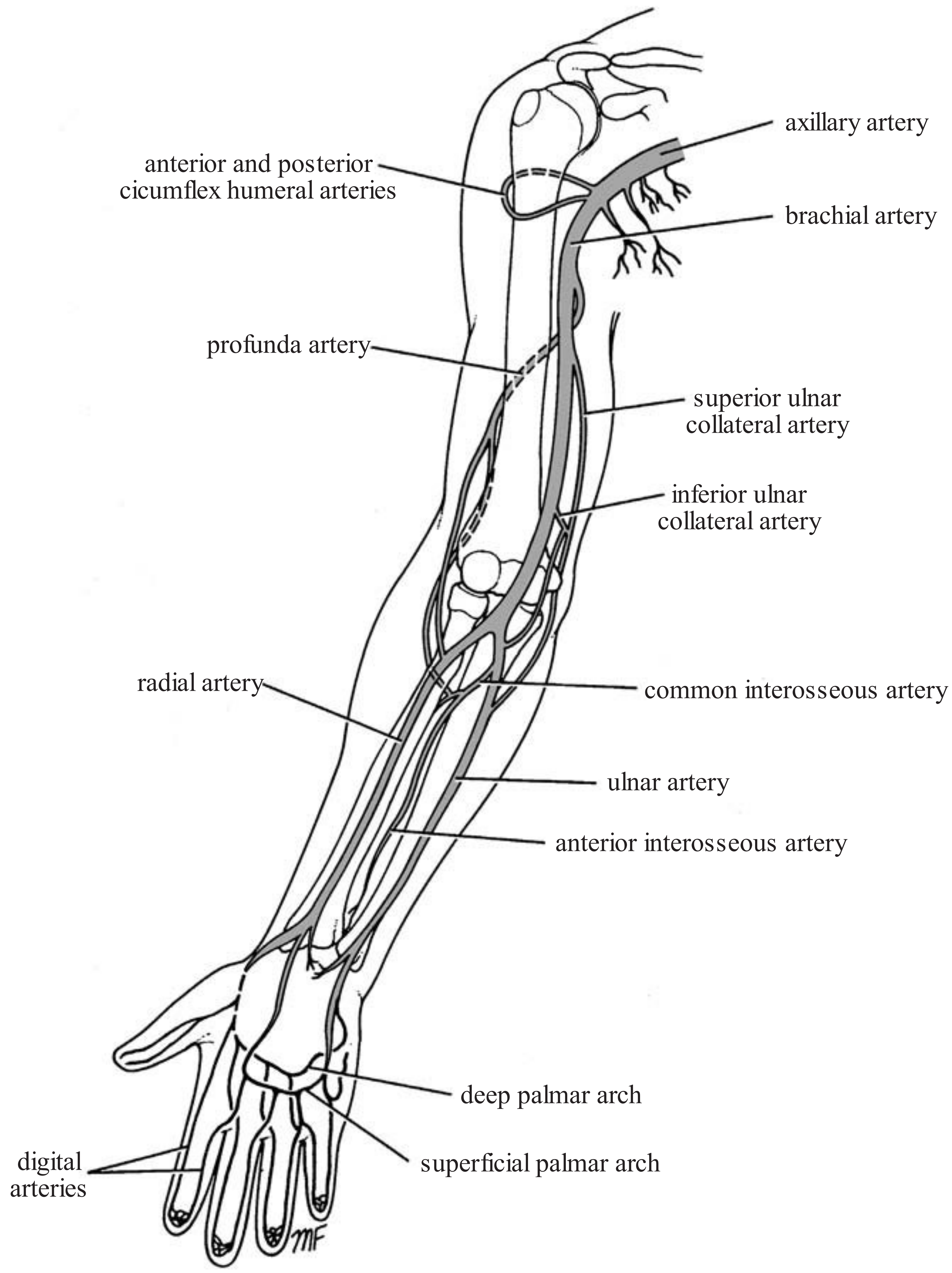


Figure 4-19 Main arteries of the upper limb.

Branch of the First Part

The **highest thoracic artery** is small and runs to the chest wall.

Branches of the Second Part

The **thoracoacromial artery** immediately divides into four terminal branches. The **lateral thoracic artery** runs to the chest wall and, in females, supplies the mammary gland.

Branches of the Third Part

The **subscapular artery** runs along the lower border of the subscapularis muscle. The **anterior** and the **posterior circumflex humeral arteries** wind around the front and the back of the surgical neck of the humerus, respectively.

ARTERIAL ANASTOMOSIS AROUND THE SHOULDER JOINT

The suprascapular and the superficial cervical arteries, which are branches of the thyrocervical trunk from the first part of the subclavian artery, anastomose with the subscapular and the anterior and posterior circumflex humeral arteries, which are branches of the third part of the axillary artery.

Brachial Artery

The brachial artery begins at the lower border of the teres major muscle as a direct continuation of the axillary artery (Fig.

4-19). It descends through the anterior compartment of the arm on the brachialis muscle (Fig. 4-10), enters the cubital fossa, and then ends at the level of the neck of the radius by dividing into the radial and the ulnar arteries (Fig. 4-12).

The brachial artery is superficial and is overlapped from the lateral side by the coracobrachialis and the biceps. The median nerve crosses its middle part, and the bicipital aponeurosis crosses its lower part, which has the tendon of the biceps on its lateral side.

BRANCHES

- **Muscular branches.**
- **Nutrient artery** to the humerus.
- **Profunda artery,** which is a large branch that follows the radial nerve into the posterior compartment of the arm (in the spiral groove).
- **Superior ulnar collateral artery,** which follows the ulnar nerve.
- **Inferior ulnar collateral artery,** which takes part in the anastomosis around the elbow joint.

Radial Artery

The radial artery is the smaller of the two terminal branches of the brachial artery (Fig. 4-19). It begins in the cubital fossa at the level of the neck of the radius, and it descends through the anterior and the lateral compartments of the forearm and lies superficially throughout most of its course (Fig. 4-13). In the middle third of its course, the radial nerve lies on its lateral side. At the wrist, the artery winds backward around the lateral side of the carpus to the proximal end of the space between the first and second metacarpal bones, where it passes anteriorly into the palm between the two heads of the first dorsal interosseous muscle and joins the deep branch of the ulnar artery, thus forming the **deep palmar arch** (Fig. 4-15).

In the lower part of the forearm, the radial artery lies on the anterior surface of the radius and is covered only by skin and fascia. Here, the artery has the tendon of the brachioradialis on its lateral side and the tendon of the flexor carpi radialis on its medial side **(the site for taking a radial pulse).**

BRANCHES

- **Muscular branches.**
- **Recurrent branch,** which takes part in the arterial anastomosis around the elbow joint.
- **Superficial palmar branch,** which arises just above the wrist, enters the palm, and frequently joins the ulnar artery to form the **superficial palmar arch.**
- **First dorsal metacarpal artery,** which supplies the adjacent sides of the thumb and the index finger.
- **Arteria princeps pollicis,** which divides into two branches that supply the sides of the thumb.
- **Arteria radialis indicis,** which supplies the lateral side of the index finger.

DEEP PALMAR ARCH

The deep palmar arch is deeply placed in the palm, and it extends from the proximal end of the space between the first and second metacarpal bones to the base of the fifth metacarpal bone (Fig. 4-15). It is formed as a continuation of the radial artery, and it terminates by anastomosing with the deep branch of the ulnar artery.

Branches

- **Palmar.**
- **Metacarpal.**
- **Perforating.**
- **Recurrent.**

Ulnar Artery

The ulnar artery is the larger of the two terminal branches of the brachial artery (Fig. 4-19). It begins in the cubital fossa at the level of the neck of the radius (Fig. 4-12), and it descends through the anterior compartment of the forearm and enters the palm **in front of** the flexor retinaculum in company with the ulnar nerve (Fig. 4-6). It ends by forming the superficial palmar arch, often anastomosing with the superficial palmar branch of the radial artery (Fig. 4-14).

In the upper part of its course, the ulnar artery lies deep to the flexor muscles (Fig. 4-13). Below, it becomes superficial and lies between the tendons of the flexor carpi ulnaris and the tendons of the flexor digitorum superficialis. In front of the flexor retinaculum, it lies just lateral to the pisiform bone and is covered only by skin and fascia **(the site for taking an ulnar pulse).**

BRANCHES

- **Muscular branches.**
- **Recurrent branches,** which take part in the arterial anastomosis around the elbow joint.
- **Common interosseous artery,** which arises from the upper part of the ulnar artery and divides into the **anterior** and the **posterior interosseous arteries.** These arteries descend on the anterior and the posterior surfaces of the interosseous membrane, respectively.
- **Deep palmar branch,** which arises in front of the flexor retinaculum and joins the radial artery to complete the deep palmar arch.

SUPERFICIAL PALMAR ARCH

The superficial palmar arch lies just beneath the palmar aponeurosis on the long flexor tendons (Fig. 4-14). It is a continuation of the ulnar artery, and it is often completed on the lateral side by the superficial palmar branch of the radial artery.

Branches

Digital arteries supply the four medial fingers.

CLINICAL NOTES

LIGATION OF ARTERIES OF THE UPPER LIMB

Because of the existence of an adequate collateral circulation around the shoulder, elbow, and wrist joints, ligation of the main arteries of the upper limb is not followed by gangrene, provided of course that the arteries forming the collateral circulation are not diseased and the patient's general circulation is satisfactory.

COMPRESSION OF ARTERIES OF THE UPPER LIMB

The third part of the axillary artery can be palpated and compressed as it lies in front of the teres major muscle in the lower part of the axilla. The brachial artery can be palpated and compressed in the arm as it lies on the brachialis muscle and is overlapped on the lateral side by the biceps brachii muscle. The radial artery can be palpated and compressed as it lies superficially in front of the distal end of the radius between the tendons of brachioradialis and flexor carpi radialis. The ulnar artery can be palpated and compressed as it crosses anterior to the flexor retinaculum on the lateral side of the pisiform bone, separated from it by the ulnar nerve.

VEINS OF THE UPPER LIMB

The superficial veins of the upper limb lie in the superficial fascia and are of great clinical importance. The deep veins accompany the main arteries.

Superficial Veins

DORSAL VENOUS NETWORK

The dorsal venous network lies on the dorsum of the hand. It is drained on the lateral side by the cephalic vein and on the medial side by the basilic vein.

CEPHALIC VEIN

The cephalic vein arises from the lateral side of the dorsal venous network and ascends around the lateral border of the forearm (Fig. 4-20). It ascends on the anterior aspect of the forearm and runs along the lateral border of the biceps in the arm. On reaching the interval between the deltoid and the pectoralis major muscles, the cephalic vein pierces the deep fascia and joins the axillary vein.

BASILIC VEIN

The basilic vein arises from the medial side of the dorsal venous network and ascends on the posterior surface of the forearm. Just below the elbow, it inclines forward to reach the cubital fossa (Fig. 4-20). The vein then ascends medial to the biceps and pierces the deep fascia at approximately the middle of the arm, after which it joins the venae comitantes of the brachial artery to form the axillary vein.

MEDIAN CUBITAL VEIN

The median cubital vein connects the cephalic vein to the basilic vein (Fig. 4-20). It lies superficial to the bicipital aponeurosis, which separates it from the brachial artery.

MEDIAN VEIN OF THE FOREARM

The median vein is a small vein that arises in the palm and ascends on the front of the forearm (Fig. 4-20). It drains into the basilic or the median cubital vein or divides into two branches, one of which joins the basilic **(median basilic vein)** and one of which joins the cephalic **(median cephalic vein).**

CLINICAL NOTES

VENIPUNCTURE AND BLOOD TRANSFUSION

The superficial veins of the upper limb are clinically important for venipuncture, transfusion, and cardiac catheterization. The cephalic vein lies fairly constantly in the superficial fascia, immediately posterior to the styloid process of the radius. In the cubital fossa, the median cubital vein is usually visible and is separated from the underlying brachial artery by the bicipital aponeurosis. The basilica vein ascends from the cubital fossa to the axillary vein and is commonly used in central venous catheterization.

Deep Veins

VENAE COMITANTES

The deep veins accompany the respective arteries as venae comitantes. The two venae comitantes of the brachial artery join the basilic vein to form the axillary vein.

AXILLARY VEIN

The axillary vein is formed by the union of the venae comitantes of the brachial artery with the basilic vein. It then ascends along the medial border of the axillary artery and becomes the subclavian vein at the outer border of the first rib. It receives tributaries that correspond to the branches of the axillary artery. It also receives the cephalic vein.

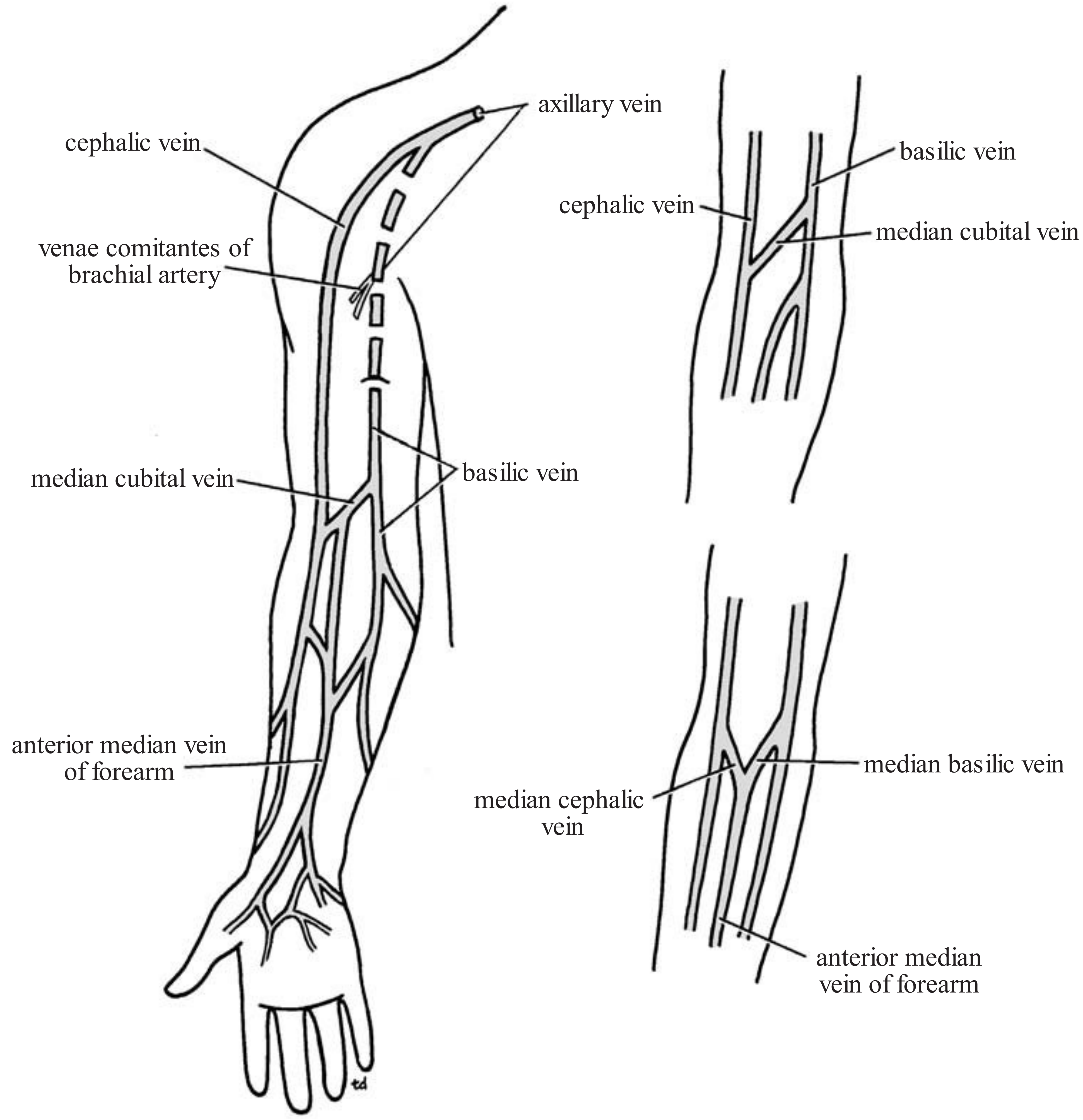


Figure 4-20 Superficial veins of the upper limb. Note the common variations seen in the region of the elbow.

LYMPHATIC DRAINAGE OF THE UPPER LIMB

The **superficial lymph vessels** ascend the limb in the superficial fascia and accompany the superficial veins. The **deep lymph vessels** lie deep to the deep fascia and follow the deep arteries and veins. All lymph vessels of the upper limb ultimately drain into lymph nodes in the axilla.

Axillary Lymph Nodes

The axillary lymph nodes drain lymph vessels from the entire upper limb. In addition, they drain lymph vessels from the **lateral part of the breast** and superficial lymph vessels from the thoracoabdominal walls above the level of the umbilicus.

There are 20 to 30 of these lymph nodes, which are located as follows:

- **Anterior (pectoral) nodes** lie along the lower border of pectoralis minor and behind pectoralis major muscles. They receive lymph from the lateral part of the breast and the superficial vessels from the thoracoabdominal wall above the level of the umbilicus.
- **Posterior (subscapular) nodes** lie in front of the subscapularis muscle. They receive superficial lymph vessels from the back down as far as the level of the iliac crests.
- **Lateral nodes** lie along the axillary vein. They receive most of the lymph vessels from the upper limb (except the superficial lymph vessels draining the lateral side, described below in infraclavicular nodes).
- **Central nodes** lie in the center of the axilla. They receive lymph from the three previously described groups.
- **Infraclavicular (deltopectoral) nodes** are not strictly axillary nodes, because they are located outside the axilla. They lie in the interval between the deltoid and the pectoralis major muscles. They receive lymph from the superficial vessels of the lateral side of the hand, the forearm, and the arm; the lymph vessels accompany the cephalic vein.
- **Apical group nodes** lie at the apex of the axilla. They receive lymph from all other axillary nodes and drain into the subclavian trunk in the neck.

Supratrochlear (Cubital) Lymph Node

The supratrochlear lymph node lies in the superficial fascia in the cubital fossa close to the trochlea of the humerus. It receives lymph from the medial fingers, the medial part of the hand, and the medial side of the forearm. The efferent lymph vessels ascend to the lateral axillary lymph nodes.

CLINICAL NOTES

CLINICAL SIGNIFICANCE OF LYMPH NODES OF THE UPPER LIMB

Medical personal should be familiar with the position of the lymph nodes in the axilla and the cubital fossa so that they may be palpated for enlargement or tenderness. The areas of the body that drain their lymph into the nodes must be known.

NERVES OF THE UPPER LIMB

Brachial Plexus

The brachial plexus is formed by the union of the anterior rami of the fifth, sixth, seventh, and eighth cervical spinal nerves and the first thoracic spinal nerve (Fig. 4-21). This plexus is divided into **roots, trunks, divisions,** and **cords.**

The roots of the brachial plexus enter the base of the neck between the scalenus anterior and the scalenus medius muscles. The trunks and the divisions cross the posterior triangle of the neck, and the cords become arranged around the axillary artery in the axilla. Here, the brachial plexus and the axillary artery and vein are enclosed in the axillary sheath.

The branches of the brachial plexus and their distribution are summarized in Table 4-9. For dermatomal charts for the anterior and the posterior surfaces of the body, see Figures 2-3 and 2-4.

MUSCULOCUTANEOUS NERVE

The musculocutaneous nerve (Fig. 4-21) arises from the lateral cord of the brachial plexus (C5, 6, and 7). It pierces the

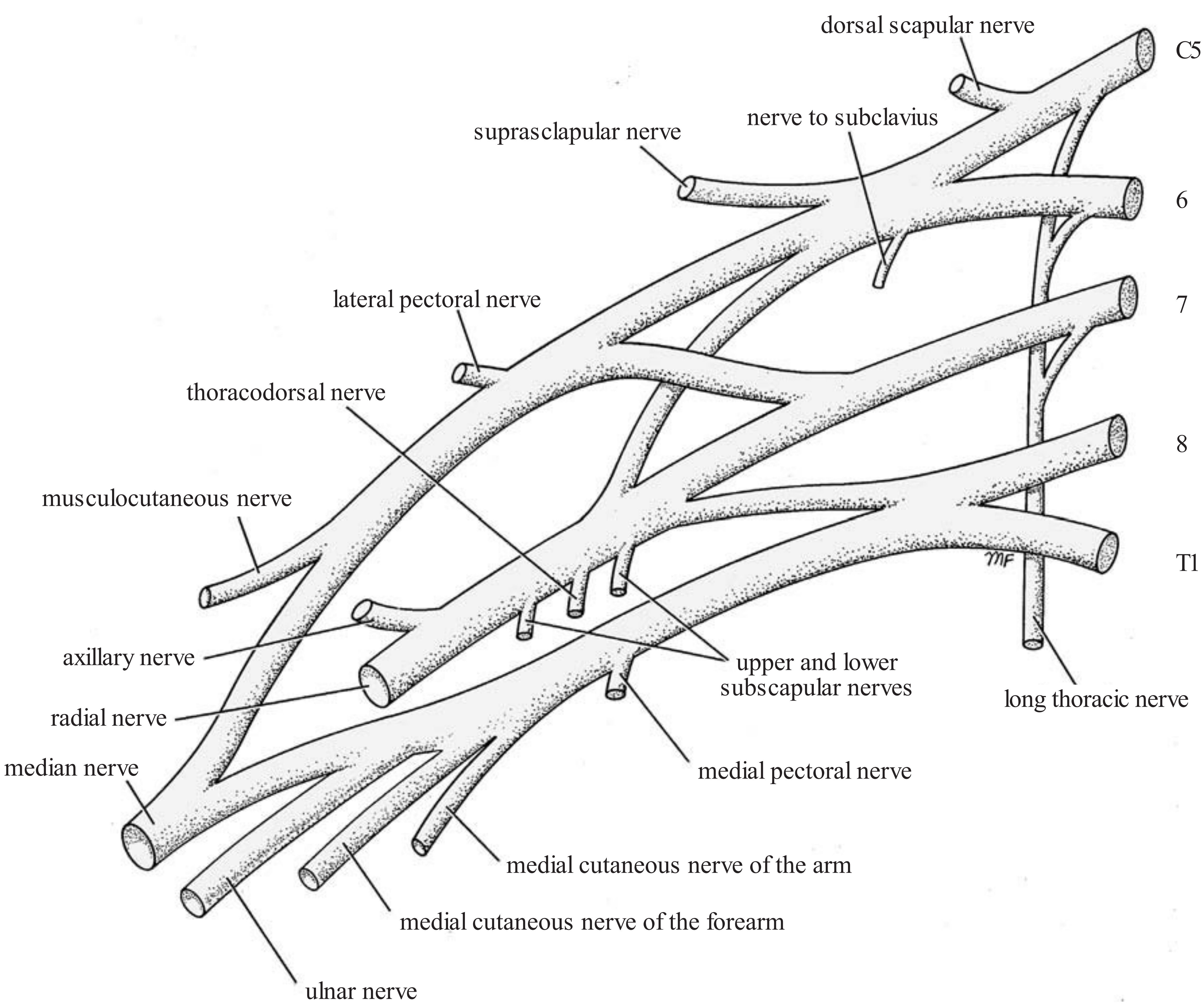


Figure 4-21 Roots, trunks, divisions, cords, and terminal branches of the brachial plexus.

Table 4-9 Branches of the Brachial Plexus and Their Distribution

Branches	Distribution
Roots	
Dorsal scapular nerve (C5)	Rhomboid minor, rhomboid major, levator scapulae muscles
Long thoracic nerve (C5, 6, 7)	Serratus anterior muscle
Upper trunk	
Suprascapular nerve	Supraspinatus and infraspinatus muscles
Nerve to the subclavius	Subclavius muscle
Lateral cord	
Lateral pectoral nerve	Pectoralis major muscle
Musculocutaneous nerve (C5, 6, 7)	Coracobrachialis, biceps brachii, and brachialis muscles; supplies the skin along the lateral border of forearm when it becomes the lateral cutaneous nerve of the forearm
Lateral root of median nerve	See Medial root of median nerve
Posterior cord	
Upper subscapular nerve	Subscapularis muscle
Thoracodorsal nerve	Latissimus dorsi muscle
Lower subscapular nerve	Subscapularis and teres major muscles
Axillary nerve (C5, 6)	Deltoid and teres minor muscles; upper lateral cutaneous nerve of the arm supplies the skin over the lower half of the deltoid muscle
Radial nerve (C5, 6, 7, 8; T1)	Triceps, anconeus, part of the brachialis, and the extensor carpi radialis longus muscles; via the deep radial nerve branch, it supplies the extensor muscles of forearm: the supinator, the extensor carpi radialis brevis, the extensor carpi ulnaris, the extensor digitorum, the extensor digiti minimi, the extensor indicis, the abductor pollicis longus, the extensor pollicis longus, and the extensor pollicis brevis; the skin, lower lateral cutaneous nerve of the arm, and posterior cutaneous nerve of the arm and posterior cutaneous nerve of the forearm; skin on the lateral side of the dorsum of the hand and the dorsal surface of the lateral three and a half fingers; articular branches to the elbow, wrist, and hand
Medial cord	
Medial pectoral nerve	Pectoralis major and minor muscles
Medial cutaneous nerve of arm joined by the intercostal brachial nerve from the second intercostal nerve	Skin of the medial side of the arm
Medial cutaneous nerve of the forearm	Skin of the medial side of the forearm
Ulnar nerve (C8; T1)	Flexor carpi ulnaris and medial half of the flexor digitorum profundus, flexor digiti minimi, opponens digiti minimi, abductor digiti minimi, adductor pollicis, third and fourth lumbricals, interossei, palmaris brevis, skin of the medial half of the dorsum of the hand and the palm, skin of the palmar and the dorsal surfaces of the medial one and a half fingers
Medial root of the median nerve (with the lateral root) forms the median nerve (C5, 6, 7, 8; T1)	Pronator teres, flexor carpi radialis, palmaris longus, flexor digitorum superficialis, abductor pollicis brevis, flexor pollicis brevis, opponens pollicis, first two lumbricals (by way of the anterior interosseous branch), flexor pollicis longus, flexor digitorum profundus (lateral half), pronator quadratus; palmar cutaneous branch to the lateral half of the palm and digital branches to the palmar surface of the lateral three and a half fingers; articular branches to the elbow, wrist, and carpal joints

coracobrachialis muscle and then descends between the biceps and the brachialis muscles. In the region of the elbow, it pierces the deep fascia and is distributed to the skin as the **lateral cutaneous nerve of the forearm.** The musculocutaneous nerve supplies the coracobrachialis, both heads of the biceps, and the greater part of the brachialis muscles. The main branches of the musculocutaneous nerve are summarized in Figure 4-22.

MEDIAN NERVE

The median nerve (Fig. 4-21) arises from the medial and the lateral cords of the brachial plexus (C5, 6, 7, 8, and T1). It descends on the lateral side of the axillary and the brachial arteries. Halfway down the arm, it crosses the brachial artery to reach its medial side. The nerve then descends through the forearm between the two heads of the pronator teres and runs on the posterior surface of the flexor digitorum superficalis. At the wrist, it lies behind the tendon of the palmaris longus. The median nerve enters the palm by passing **behind** the flexor retinaculum and through the carpal tunnel.

Branches of the Median Nerve in the Forearm

- **Muscular branches:** Pronator teres, flexor carpi radialis, palmaris longus, and flexor digitorum superficialis muscles.
- **Articular branches:** Elbow joint.
- **Anterior interosseous nerve: Muscular branches** to flexor pollicis longus, pronator quadratus, and lateral half of the flexor digitorum profundus muscles. **Articular branches** to wrist and carpal joints.
- **Palmar branch:** Skin over the lateral part of the palm.

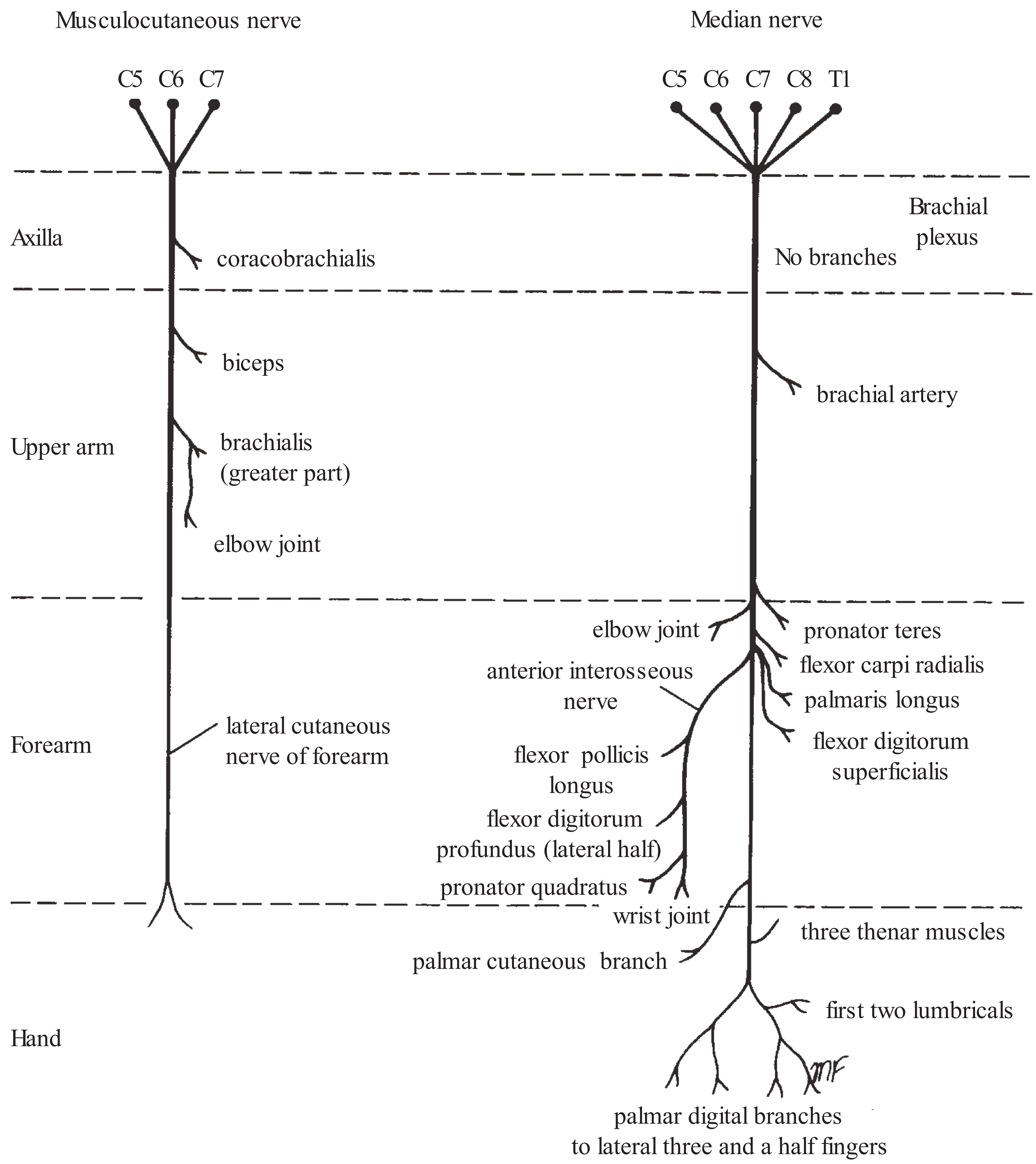


Figure 4-22 Summary of the main branches of the musculocutaneous and the median nerves.

Branches of the Median Nerve in the Palm

- **Muscular branches:** Abductor pollicis brevis, flexor pollicis brevis, opponens pollicis, and the first and the second lumbrical muscles.
- **Cutaneous branches**: Palmar aspect of the lateral three and a half fingers and the distal half of the dorsal aspect of each finger as well.

For a summary of the main branches of the median nerve, see Figure 4-22.

ULNAR NERVE

The ulnar nerve (Fig. 4-21) arises from the medial cord of the brachial plexus (C8, T1). It descends along the medial side of the axillary and the brachial arteries in the anterior compartment of the arm. At the middle of the arm, it pierces the medial intermuscular septum and passes down **behind** the medial epicondyle of the humerus. It then enters the anterior compartment of the forearm and descends behind the flexor carpi ulnaris medial to the ulnar artery. At the wrist, it passes **anterior** to the flexor retinaculum and **lateral** to the **pisiform bone.** It then divides into the **superficial** and the **deep terminal branches.**

Branches of the Ulnar Nerve in the Forearm

- **Muscular branches:** Flexor carpi ulnaris and medial half of the flexor digitorum profundus muscles.
- **Articular branches:** Elbow joint.
- **Dorsal cutaneous branch:** Supplies the skin over the medial side of the back of the hand and back of the medial one and a half fingers over the proximal phalanges.

Branches of the Ulnar Nerve in the Hand

The **superficial terminal branch** descends into the palm and gives off the following branches:

- **Muscular branch:** Palmaris brevis muscle.
- **Cutaneous branches:** Supply the skin over the palmar aspect of the medial one and a half fingers (including their nail beds).

The **deep terminal branch** runs backward between the abductor digiti minimi and the flexor digiti minimi muscles, pierces the opponens digiti minimi muscle, and gives off the following branches:

- **Muscular branches:** Abductor digiti minimi, flexor digiti minimi, opponens digiti minimi, all palmar and all dorsal interossei, third and fourth lumbricals, and adductor pollicis muscles.
- **Articular branches:** Carpal joints.

The main branches of the ulnar nerve are summarized in Figure 4-23.

RADIAL NERVE

The radial nerve (Fig. 4-21) arises from the posterior cord of the brachial plexus (C5, 6, 7, 8, and T1). It descends behind the axillary and the brachial arteries, and it enters the posterior compartment of the arm. The radial nerve winds around the back of the humerus in the spiral groove with the profunda artery. Piercing the lateral intermuscular septum just above the elbow, it descends in front of the lateral epicondyle and divides into the superficial and the deep terminal branches.

Branches of the Radial Nerve in the Axilla

- **Muscular branches:** Long and medial heads of the triceps muscle.
- **Cutaneous branch:** Posterior cutaneous nerve of the arm.

Branches of the Radial Nerve in the Spiral Groove Behind the Humerus

- **Muscular branches:** Lateral and medial heads of the triceps muscle and the anconeus muscle.
- **Cutaneous branches:** Lower lateral cutaneous nerve of the arm, posterior cutaneous nerve of the forearm.

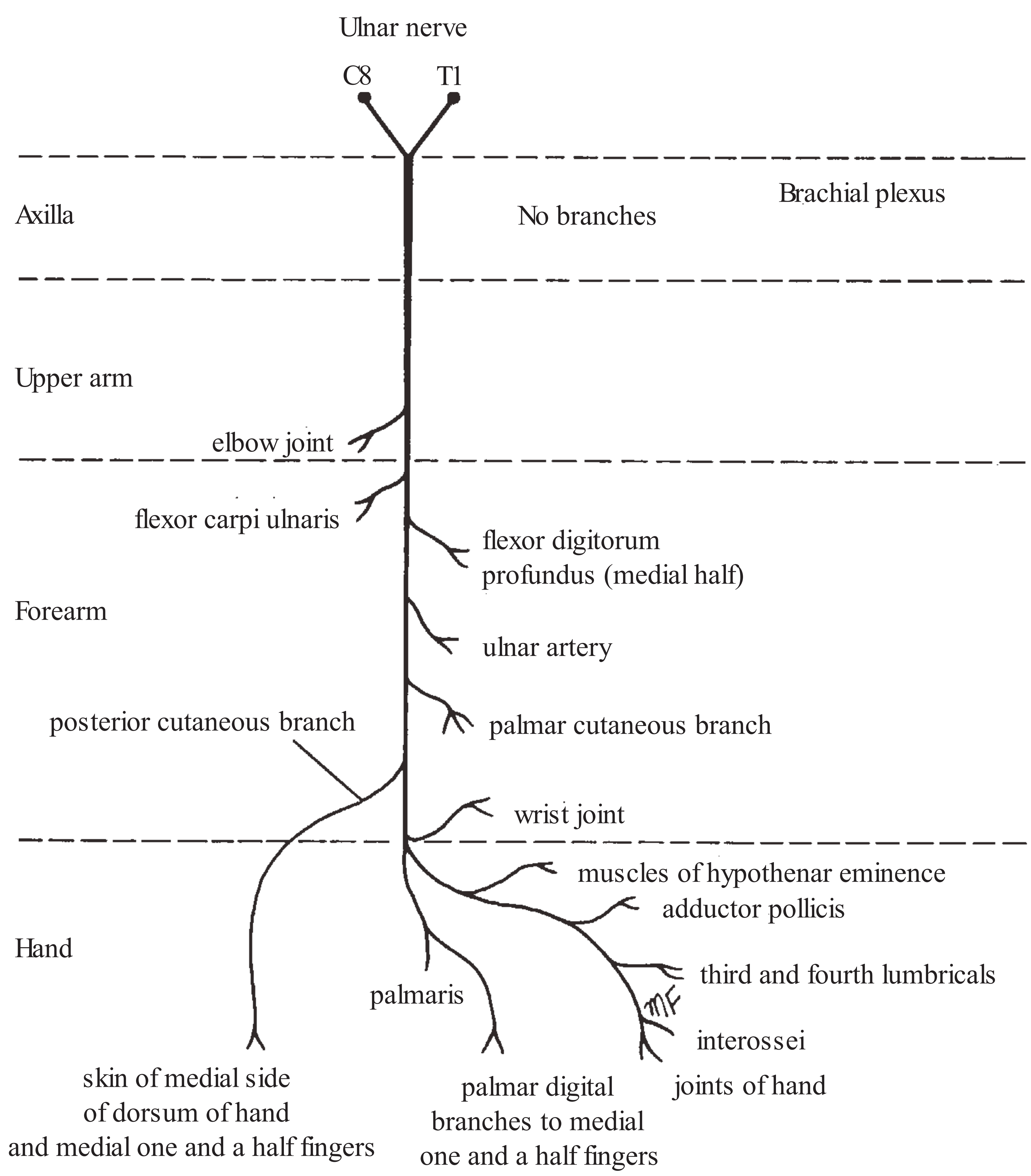


Figure 4-23 Summary of the main branches of the ulnar nerve.

Branches of the Radial Nerve in the Anterior Compartment of the Arm Close to the Lateral Epicondyle

- **Muscular branches:** Brachialis, brachioradialis, and extensor carpi radialis longus muscles.
- **Articular branches:** Elbow joint.

Superficial Branch of Radial Nerve

The superficial branch of the radial nerve descends under cover of the brachioradialis muscle on the lateral side of the radial artery. It emerges from beneath the brachioradialis tendon and then descends on the back of the hand.

Cutaneous Branches

Cutaneous branches run to the lateral two thirds of the dorsal surface of the hand (variable). These branches also run to the posterior surface of the lateral three and a half fingers over the proximal phalanges.

Deep Branch of the Radial Nerve

The deep branch of the radial nerve winds around the lateral side of the neck of the radius within the supinator muscle. It enters the posterior compartment of the forearm, and it descends between the muscles. It gives off the following branches:

- **Muscular branches:** Extensor carpi radialis brevis, supinator, extensor carpi ulnaris, abductor pollicis longus, extensor pollicis brevis, extensor pollicis longus, and extensor indicis muscles.
- **Articular branches:** Wrist and carpal joints.

The main branches of the radial nerve are summarized in Figure 4-24.

AXILLARY NERVE

The axillary nerve (Fig. 4-21) arises from the posterior cord of the brachial plexus (C5 and 6). It passes backward through the quadrangular space below the shoulder joint with the posterior circumflex humeral vessels.

Branches

- **Articular branch,** which supplies the shoulder joint.
- **Anterior terminal branch,** which winds around the surgical neck of the humerus and supplies the deltoid muscle

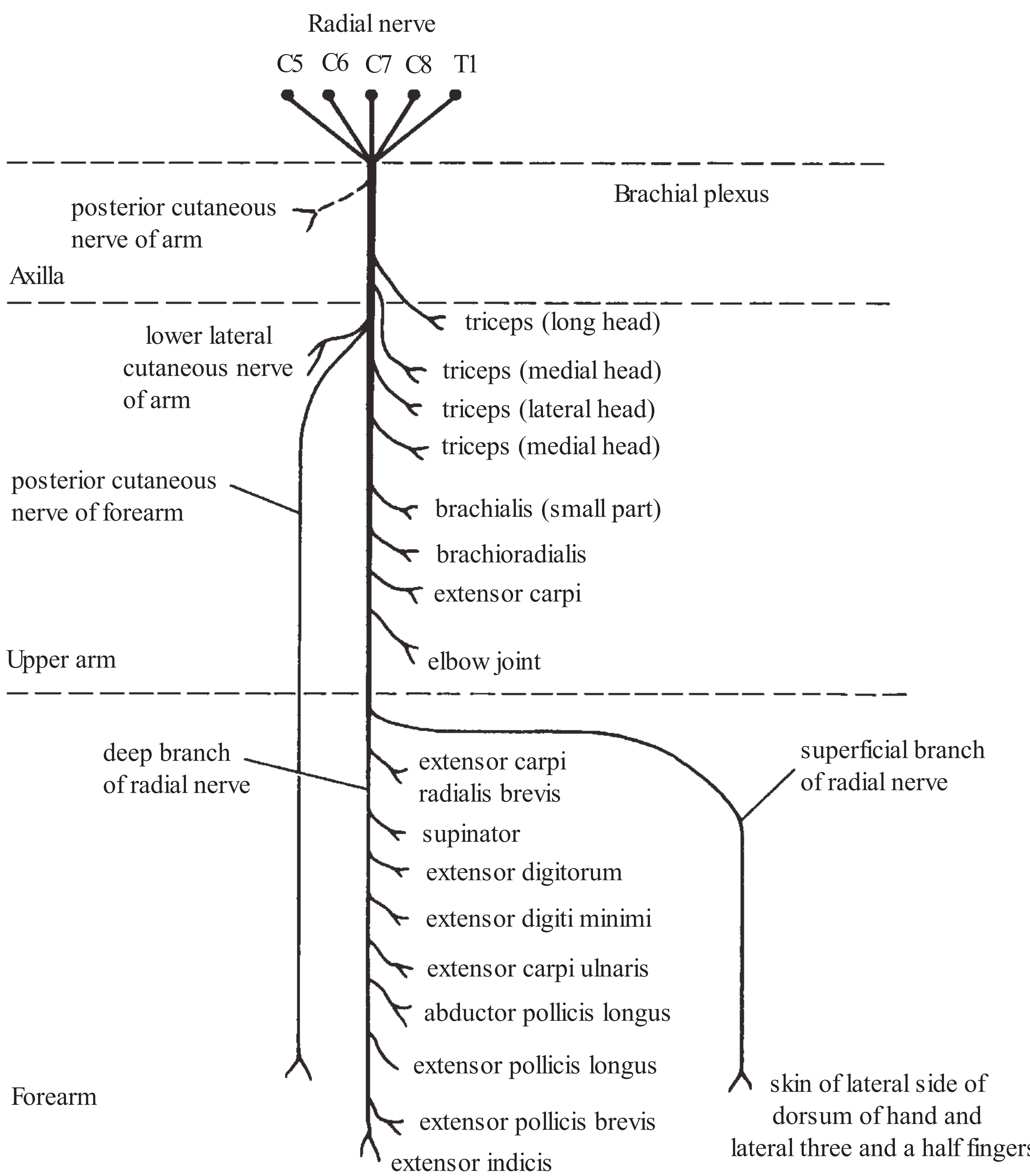


Figure 4-24 Summary diagram of main branches of the radial nerve.

and the skin that covers its lower half. (Supraclavicular nerves supply the skin over the upper half of the deltoid muscle.)

- **Posterior terminal branch,** which supplies the teres minor and the deltoid muscles and then becomes the **upper lateral cutaneous nerve of the arm,** which also supplies the skin over the lower part of the deltoid muscle.

CLINICAL NOTES

Upper Trunk Lesions of the Brachial Plexus (Erb-Duchenne Palsy)

Upper trunk lesions of the brachial plexus result from displacement of the head to the opposite side and depression of the shoulder on the same side, as during falls on the shoulder or in infants during a difficult delivery. The limb hangs limply by the side and is medially rotated, and the forearm is pronated (**waiter's tip hand**).

Lower Trunk Lesions of the Brachial Plexus (Klumpke Palsy)

Lower trunk lesions of the brachial plexus result from traction injury, as in excessive abduction of the arm. The first thoracic nerve is usually torn, all the small muscles of the hand are paralyzed, and the patient develops a **claw hand.**

Long Thoracic Nerve (C5, 6, and 7) Lesions

Long thoracic nerve lesions result from blows or surgical injury to the nerve in the axilla. Paralysis of the serratus anterior muscle allows the inferior angle of the scapula to protrude **(winged scapula).** The patient also has difficulty in raising the arm above the head.

Axillary Nerve (C5 and 6) Lesions

Axillary nerve lesions result from inferior dislocations of the shoulder joint or fracture of the surgical neck of the humerus. Nerve damage occurs in the quadrangular space. The deltoid muscle is paralyzed and rapidly atrophies, and cutaneous sensation is lost over the lower half of the deltoid muscle.

Radial Nerve (C5, 6, 7, 8, and T1) Lesions

Radial nerve lesions commonly result from fracture of the midshaft of the humerus, which injures the nerve in the spiral groove. The patient is unable to extend the wrist and the fingers, and there is **wrist drop.**

Median Nerve (C5, 6, 7, 8, and T1) Lesions

Median nerve lesions commonly result from supracondylar fractures of the humerus and from wounds just proximal to the flexor retinaculum. Among the clinical signs, the muscles of the thenar eminence are paralyzed and wasted so that the eminence is flattened and the thumb is laterally rotated and adducted. The hand looks **apelike.**

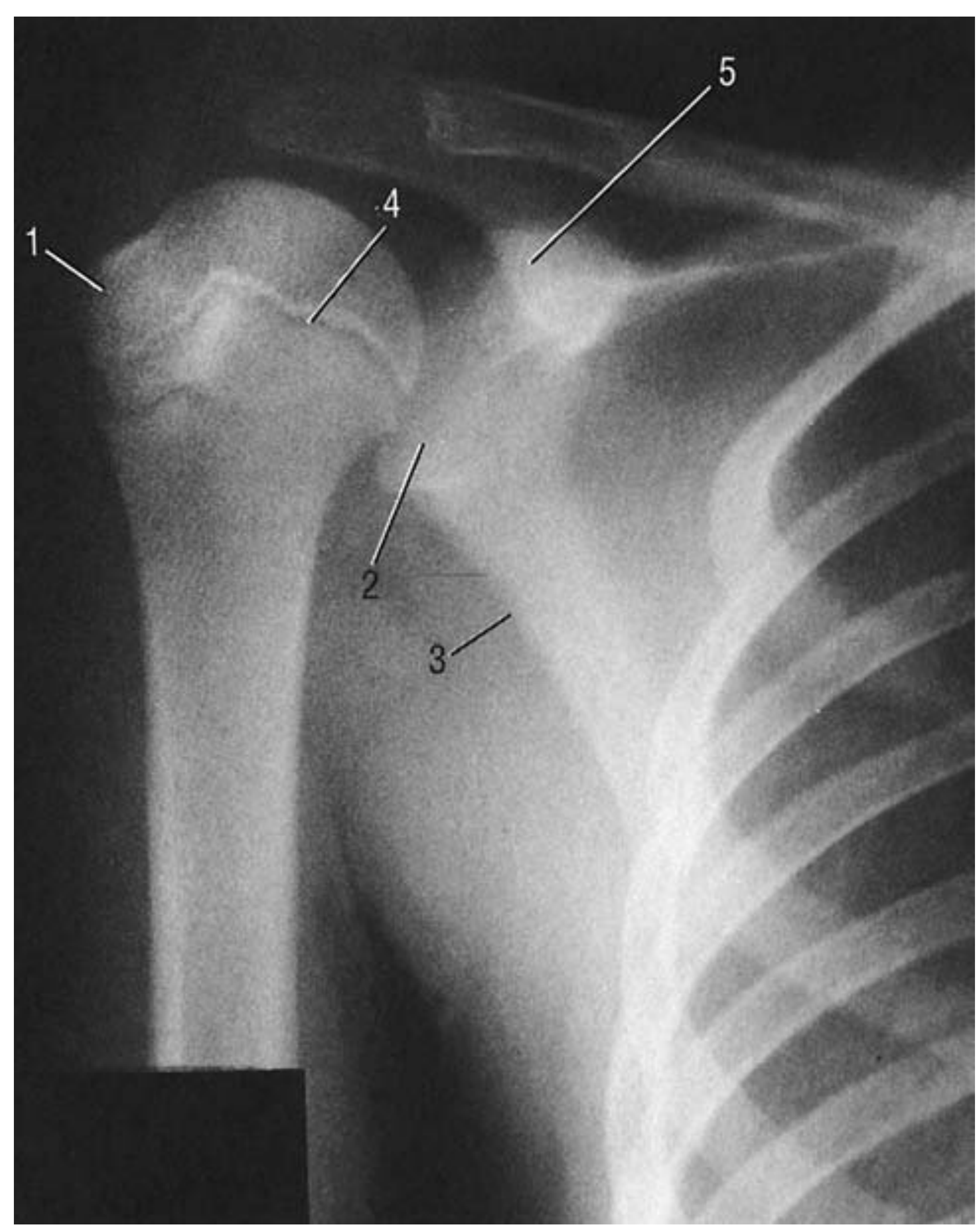
Ulnar Nerve (C8 and T1) Lesions

Ulnar nerve lesions result from injuries where the nerve lies behind the medial epicondyle of the humerus and where it lies in front of the flexor retinaculum at the wrist. The small muscles of the hand will be paralyzed except for the muscles of the thenar eminence and the first two lumbricals (median nerve). The patient is unable to adduct and abduct the fingers. In addition, the thumb cannot be adducted, because the adductor pollicis is paralyzed. The metacarpophalangeal joints become hyperextended from paralysis of the lumbrical and the interosseous muscles, and this is most prominent in the joints of the fourth and the fifth fingers. The interphalangeal joints are flexed (also from paralysis of the lumbrical and the interosseous muscles). In longstanding cases, the hand assumes the characteristic **claw deformity.**

REVIEW

Completion Questions

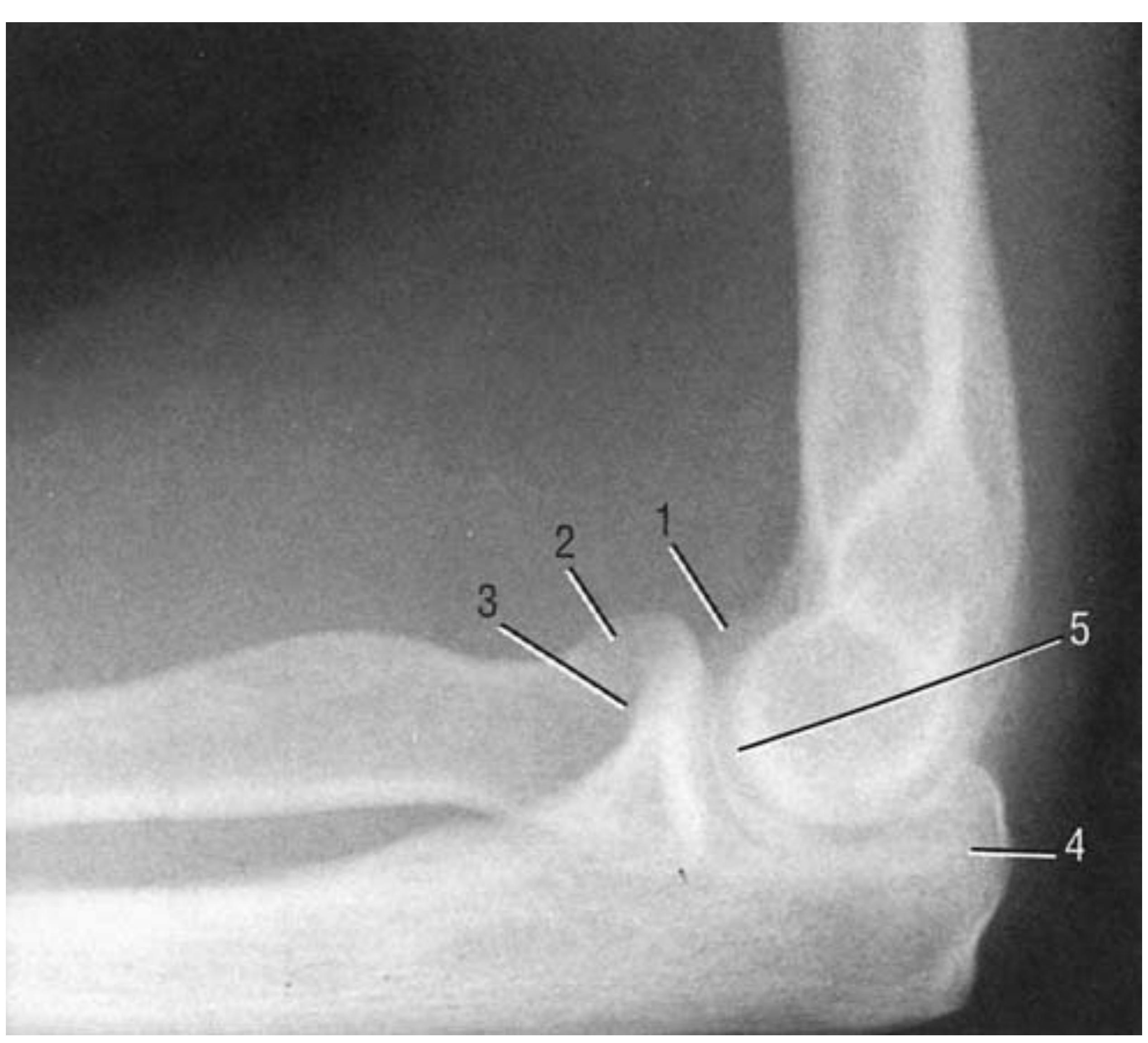
Based on the anteroposterior radiograph of the shoulder region, select the phrase that best completes each statement.



1. Structure 1 is the
   A. acromion process.
   B. lesser tuberosity.
   C. glenoid fossa.
   D. lateral border of the scapula.
   E. greater tuberosity.
   F. None of the above.

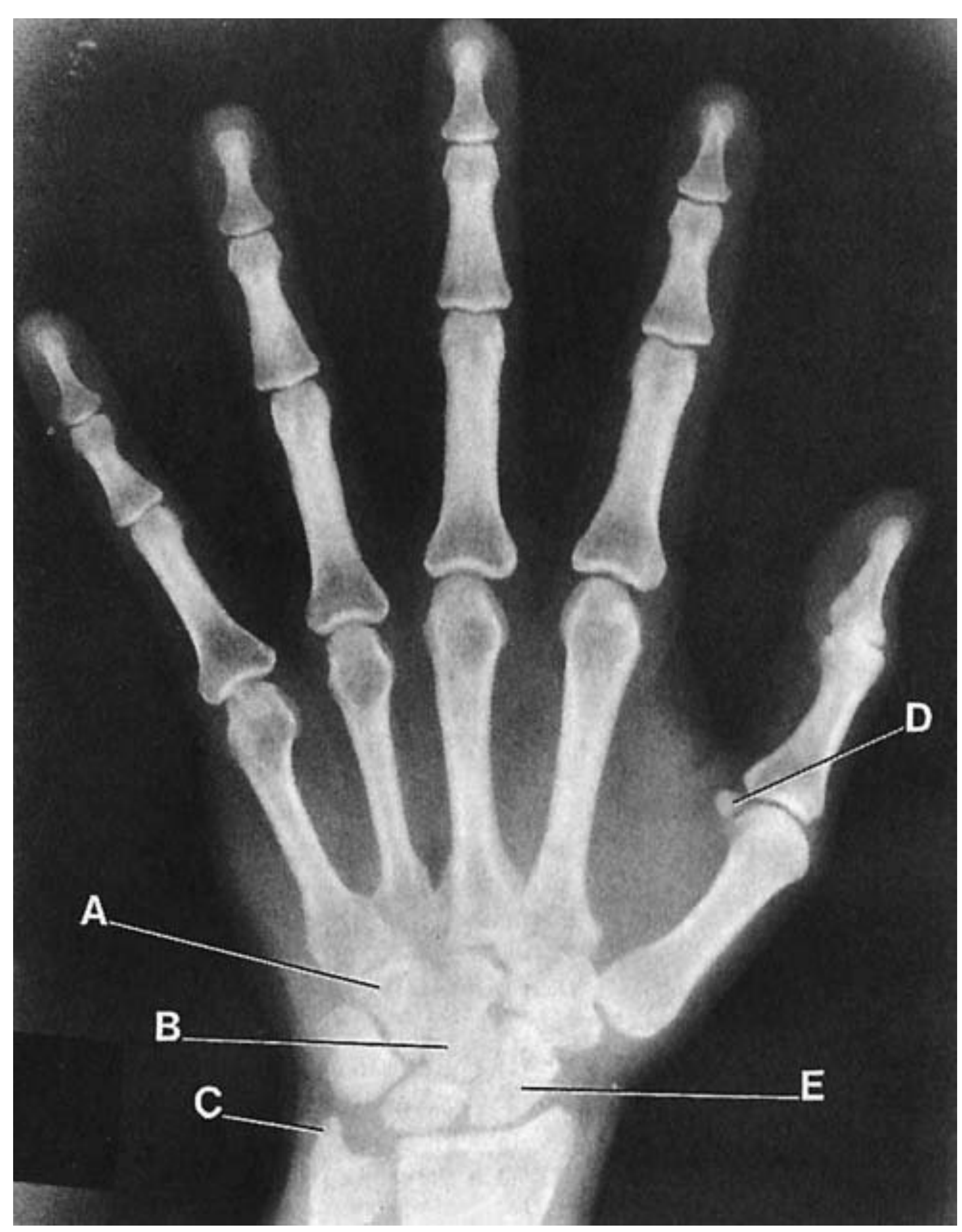
2. Structure 2 is the
   A. supraglenoid tubercle.
   B. glenoid fossa.
   C. coracoid process.
   D. infraglenoid tubercle.
   E. spine of scapula.
   F. None of the above.
3. Structure 3 is the
   A. spine of the scapula.
   B. medial border of the scapula.
   C. ridge on the posterior surface of the scapula.
   D. lateral border of the scapula.
   E. tendon of the latissimus dorsi muscle.
   F. None of the above.
4. Structure 4 is
   A. a calcified supraspinatus tendon.
   B. the epiphyseal line.
   C. the greater tuberosity.
   D. a fracture line.
   E. the subscapularis tendon.
   F. a torn rotator cuff.
5. Structure 5 is the
   A. acromion process.
   B. acromial end of the clavicle.
   C. coracoid process.
   D. glenoid fossa.
   E. spine of the scapula.
   F. None of the above.

Based on the lateral radiograph of the elbow region, select the phrase that best completes each statement.



6. Structure 1 is the
   A. olecranon process.
   B. capitulum.
   C. head of the radius.
   D. coronoid process.
   E. trochlea.
   F. None of the above.
7. Structure 2 is the
   A. head of the radius.
   B. capitulum.
   C. coronoid process.
   D. bicipital tuberosity of the radius.
   E. trochlea.
   F. None of the above.
8. Structure 3 is the
   A. oblique ligament.
   B. coronoid process.
   C. capitulum.
   D. neck of the radius.
   E. head of the radius.
   F. trochlea.
9. Structure 4 is the
   A. insertion of the triceps tendon.
   B. coronoid process.
   C. trochlea.
   D. olecranon process.
   E. head of the radius.
   F. None of the above.
10. Structure 5 is the
   A. joint space.
   B. capitulum.
   C. trochlea.
   D. coronoid process.
   E. head of radius.
   F. coronoid fossa.

Based on the anteroposterior radiograph of the hand, select the phrase that best completes each statement.



11. Structure A is the
    A. capitate.
    B. trapezoid.
    C. capitate.
    D. hook of the hamate
    E. sesamoid bone.
    F. styloid process of the ulna.
12. Structure B is the
    A. capitate.
    B. lunate.
    C. triquetral.
    D. trapezium.
    E. scaphoid.
    F. pisiform.
13. Structure C is the
    A. styloid process of the radius.
    B. pisiform.
    C. lunate.
    D. styloid process of the ulna.
    E. hook of the hamate.
    F. sesamoid bone.
14. Structure D is
    A. the head of the first metacarpal bone.
    B. the pisiform.
    C. the sesamoid bone.
    D. a calcified insertion of the abductor pollicis.
    E. the radial artery in cross section.
    F. the base of the proximal phalanx of the thumb.
15. Structure E is the
    A. pisiform.
    B. lunate.
    C. capitate.
    D. triquetral.
    E. scaphoid.
    F. hook of the hamate.

Multiple-Choice Questions

Select the best answer for each question.

16. The following part or branch of the brachial plexus receives contributions from the C8 spinal nerve.
    A. Lateral cord
    B. Lateral pectoral nerve
    C. Posterior cord
    D. Nerve to the rhomboid muscles
    E. Suprascapular nerve
    F. Nerve to subclavius muscle
17. The following part or branch of the brachial plexus has a terminal branch that supplies the skin on the medial side of the arm.
    A. Musculocutaneous nerve
    B. Lateral cord
    C. Thoracodorsal nerve
    D. Medial cord
    E. Upper subscapular nerve
    F. Ulnar nerve
18. The following part of the brachial plexus is formed from the anterior divisions of two trunks.
    A. Lateral cord
    B. Posterior cord
    C. Median nerve
    D. Medial cord
    E. Lower trunk
    F. None of the above
19. The following part of the brachial plexus has branches that supply the extensor muscles of the arm.
    A. Lateral cord
    B. Medial cord
    C. Posterior cord
    D. Thoracodorsal nerve
    E. Lateral and medial cords
    F. None of the above

Completion Questions

Select the phrase that best completes each statement.

20. During its course in the upper limb, the axillary nerve lies
    A. in front of the lateral epicondyle of the humerus.
    B. against the spiral groove of the humerus.
    C. medial to the brachial artery in the cubital fossa.
    D. against the surgical neck of the humerus.
    E. behind the medial epicondyle of the humerus.
    F. in front of the medial epicondyle of the humerus.
21. During its course in the upper limb, the ulnar nerve lies
    A. in front of the lateral epicondyle of the humerus.
    B. behind the flexor retinaculum of the wrist.
    C. against the spiral groove of the humerus.
    D. medial to the brachial artery in the cubital fossa.
    E. against the surgical neck of the humerus.
    F. behind the medial epicondyle of the humerus.
22. During its course in the upper limb, the median nerve lies
    A. anterior to the flexor retinaculum of the wrist.
    B. in front of the lateral epicondyle of the humerus.
    C. against the spiral groove of the humerus.
    D. against the surgical neck of the humerus.
    E. within the quadrangular muscle space.
    F. medial to the brachial artery in the cubital fossa.
23. During its course in the upper limb the radial nerve lies
    A. against the spiral groove of the humerus.
    B. in front of the medial epicondyle of the humerus.
    C. behind the flexor retinaculum of the wrist.
    D. medial to the brachial artery in the cubital fossa.
    E. against the surgical neck of the humerus.
    F. behind the medial epicondyle of the humerus.
24. The extensor carpi radialis brevis muscle is innervated by the
    A. radial nerve.
    B. ulnar nerve.
    C. superficial radial nerve.
    D. deep branch of the radial nerve.

E. deep branch of the ulnar nerve.
F. None of the above.

25. The dorsal interossei muscles are innervated by the
A. deep branch of the radial nerve.
B. deep branch of the ulnar nerve.
C. musculocutaneous nerve.
D. superficial branch of the ulnar nerve.
E. median nerve.
F. recurrent branch of the median nerve.

26. The extensor indicis muscle is innervated by the
A. radial nerve.
B. ulnar nerve.
C. median nerve.
D. deep branch of the radial nerve.
E. deep branch of the ulnar nerve.
F. musculocutaneous nerve.

27. The extensor carpi ulnaris muscle is innervated by the
A. median nerve.
B. deep branch of the ulnar nerve.
C. ulnar nerve.
D. radial nerve.
E. deep branch of the radial nerve.
F. superficial branch of the ulnar nerve.

28. The extensor carpi radialis longus muscle is innervated by the
A. deep branch of the ulnar nerve.
B. ulnar nerve.
C. radial nerve.
D. median nerve.
E. anterior interosseous nerve.
F. musculocutaneous nerve.

29. A shoulder separation that involves the lateral end of the clavicle sliding onto the superior aspect of the acromion would most likely result from damage to the
A. costoclavicular ligament.
B. sternoclavicular ligament.
C. coracoclavicular ligament.
D. glenohumeral ligament.
E. coracoacromial ligament.

30. The muscle that will compensate in part for the paralysis of the supinator muscle is the
A. extensor carpi ulnaris muscle.
B. brachialis muscle.
C. triceps brachii muscle.
D. biceps brachii muscle.
E. anconeus muscle.

31. The synovial sheath of the flexor pollicis longus muscle forms the
A. thenar space.
B. radial bursa of the wrist.
C. midpalmar space.
D. ulnar bursa of the wrist.
E. digital synovial sheath for the index finger.

32. To test for trapezius muscle paralysis, you would ask the patient to
A. flex the arm fully.
B. adduct the arm against resistance.
C. push against the wall with both hands.
D. shrug the shoulder.
E. abduct the arm fully.

33. The lymph from the medial quadrants of the breast drain mainly into the
A. posterior axillary (subscapular) nodes.
B. internal thoracic nodes.
C. anterior axillary (pectoral) nodes.
D. lateral axillary (brachial) nodes.
E. infraclavicular (deltopectoral) nodes.

34. Cutting the dorsal scapular nerve would most likely result in paralysis of the
A. supraspinatus muscle.
B. deltoid muscle.
C. rhomboid major muscle.
D. trapezius muscle.
E. infraspinatus muscle.

35. After injury to a nerve at the wrist, the thumb is laterally rotated and adducted. The hand looks flattened and apelike. The nerve that has been damaged is the
A. anterior interosseous nerve.
B. ulnar nerve.
C. deep branch of the radial nerve.
D. median nerve.
E. superficial branch of the radial nerve.

36. The dermatome present over the lateral side of the wrist is
A. C8.
B. C6.
C. T1.
D. T2.
E. C5.

Multiple-Choice Questions

Select the best answer for each question.

37. The following statements concerning the blood vessels of the upper limb are correct except which?
A. The pulsation of the radial artery are felt anterior to the distal third of the radius between the tendons of the brachioradialis and the flexor carpi radialis.
B. The axillary vein is formed by the union of the venae comitantes of the brachial artery and the basilic vein.
C. The cephalic vein arises on the palm of the hand.
D. The axillary sheath surrounds the axillary vessels and the brachial plexus.
E. The cephalic vein drains into the axillary vein.

38. At the wrist, the flexor retinaculum is attached to the following bones except which?
A. The hook of the hamate
B. The ridge on the trapezium
C. The pisiform bone
D. The tubercle of the scaphoid
E. The triquetral bone

39. The following statements concerning the shoulder joint are correct except which?
    A. The inferior part of the capsule is the weakest.
    B. The subacromial bursa communicates with the joint cavity.
    C. The strength of the joint depends largely on the tone of the surrounding muscles.
    D. Dislocation of the shoulder joint is common.
    E. The axillary artery lies in front of the shoulder joint.
40. The following statements concerning the lymphatic drainage of the upper limb are correct except which?
    A. Lymph from an infected nail bed of the little finger drains into the supratrochlear lymph node.
    B. Lymph from infected cut of the index finger drains into the infraclavicular nodes.
    C. Lymph from an infected graze over the medial side of the elbow joint drains into the anterior (pectoral) group of axillary nodes.
    D. Lymph from the upper lateral quadrant of the breast drains into the anterior (pectoral) group of axillary nodes.
    E. Lymph from a boil on the back over the inferior angle of the scapula drains into the posterior (subscapular) nodes.
41. The following structures pass superficial to the flexor retinaculum at the wrist except which?
    A. Palmar cutaneous branch of the median nerve
    B. Ulnar nerve
    C. Flexor pollicis longus tendon
    D. Ulnar artery
    E. Palmar cutaneous branch of the ulnar nerve
42. Collateral circulation around the shoulder joint would involve the following except which?
    A. The subscapular artery
    B. The superficial cervical artery
    C. The suprascapular artery
    D. The anterior circumflex humeral artery
    E. The lateral thoracic artery
43. The proximal row of carpal bones includes all the following carpal bones except which?
    A. The pisiform
    B. The capitate
    C. The lunate
    D. The triquetral
    E. The scaphoid
44. Regarding a "winged scapula," the following facts are correct except which?
    A. The spinal part of the accessory nerve is damaged.
    B. The inferior angle of the scapula projects backward.
    C. The serratus anterior muscle may be wasted.
    D. The long thoracic nerve is damaged.
    E. The scapula can no longer be pulled anteriorly around the chest wall (as in thrusting the upper limb anteriorly when reaching).
45. The following statements concerning the rotator cuff are correct except which?
    A. It adds stability to the shoulder joint.
    B. It is formed by the tendons of the short muscles around the shoulder joint.
    C. The muscle tendons are fused to the capsule of the shoulder joint.
    D. Degeneration or tearing of the cuff will cause severe pain in the shoulder region.
    E. All the muscle tendons associated with the cuff are innervated by the suprascapular nerve.
46. The quadrangular space in the region of the shoulder transmits the following structures except which?
    A. The axillary nerve
    B. The posterior circumflex humeral artery
    C. The lymphatic vessels
    D. The radial nerve
    E. The posterior circumflex humeral vein
47. The following statements concerning the lateral cord of the brachial plexus are true except which?
    A. It contains sympathetic nerve fibers
    B. It has a branch that supplies the pectoralis major muscle
    C. It has a branch that supplies the skin on the lateral side of the forearm
    D. It has a branch that supplies the skin on the lateral side of the upper arm
    E. It lies lateral to the second part of the axillary artery
48. An examination of a patient with carpal tunnel syndrome may reveal all the following symptoms and signs except which?
    A. Atrophy of the muscles of the thenar eminence
    B. Weakness in opposition of the thumb
    C. Loss of skin sensation on the medial part of the palm
    D. Loss of skin sensation on the anterior surface of the index finger
    E. Normal skin sensation on the anterior surface of the little finger
49. The following movements are expected to be normal after a complete section of the medial cord of the brachial plexus except which?
    A. Extension of the wrist
    B. Flexion of the elbow
    C. Abduction of the shoulder joint
    D. Metacarpophalangeal flexion and interphalangeal extension of the medial four fingers
    E. Metacarpophalangeal flexion and interphalangeal extension of the thumb
50. The following statements regarding the sympathetic innervation of the upper limb are correct except which?
    A. There are preganglionic nerve fibers originating in spinal cord segments T2 to 8.
    B. It causes vasoconstriction of the arteries and veins of the skin.
    C. There are preganglionic nerve fibers synapsing in the middle cervical, the inferior cervical, and the first thoracic ganglia.

D. Many of the postganglionic fibers are distributed within the branches of the brachial plexus.
E. The sympathetic nerves do not innervate the sweat glands.

51. During an automobile accident, a patient fractured the neck of her right radius and damaged a closely related nerve. At physical examination, the patient exhibited the following except which?
A. Weakness in extending the terminal phalanx of the thumb.
B. A loss of skin sensation on the lateral part of the dorsum of the hand.
C. An inability to extend the metacarpophalangeal joint of the index finger.
D. A normal ability to adduct the thumb at the carpometacarpal joint.
E. Normal skin sensation down the medial border of the hand.

52. Diminished sweating and increased warmth and vasodilation of the skin vessels over the hypothenar eminence as well as the ring and the little fingers could result from the following except which?
A. A lesion of the posterior cord of the brachial plexus.
B. Ulnar nerve damage behind the medial epicondyle of the humerus.
C. A lesion of the medial cord of the brachial plexus.
D. A lesion of the eighth cervical nerve.
E. Ulnar nerve damage over the front of the wrist.

Read the case histories and select the best answer to the question following them.

A 14-year-old boy fell off a wall and fractured his right humerus at midshaft. The wrist joint immediately assumed a flexed position that the patient was unable to correct. Extension and supination of the forearm was weakened but not abolished, and skin sensation over the lateral side of the dorsum of the hand was diminished.

53. Which damaged peripheral nerve could account for these symptoms and signs?
A. The ulnar nerve
B. The median nerve
C. The radial nerve
D. The axillary nerve
E. The musculocutaneous nerve

On examination of a 53-year-old woman, it was found that she could abduct her left shoulder to only a 15° position. She told her physician that 10 years ago she had fallen on ice outside her front door and had dislocated her left shoulder joint. It was noted that the head of the humerus was in its normal position relative to the scapula on the left side. Her left shoulder when compared with the right shoulder, however, showed flattening and had lost most of the normal curvature.

54. Which of the following muscles was likely to have been paralyzed by the dislocation of the shoulder joint 10 years ago?
A. The rhomboid minor
B. The deltoid
C. The supraspinatus
D. The teres minor
E. The subscapularis

An 19-year-old girl was seen in the emergency department and found to have a knife wound to the front of her left wrist. A careful examination revealed that two superficial tendons on either side of the median nerve had been severed.

55. Which of the following tendons were likely to have been cut?
A. The flexor pollicis longus and the pronator quadratus tendons
B. The flexor carpi ulnaris and the flexor digitorum profundus tendons
C. The flexor digitorum superficialis and the flexor carpi radialis tendons
D. The brachioradialis and the pronator teres tendons
E. The abductor pollicis longus and the extensor pollicis brevis tendons

A 17-year-old girl was thrown from her horse while attempting a difficult jump. She landed on her right shoulder and the right side of her head. It was noticed after a week of hospitalization that she kept her right arm medially rotated and close to her side with the forearm pronated. At physical examination, an area of anesthesia was found along the lateral side of the upper part of the arm.

56. Which of the following was damaged during the accident?
A. The lower trunk of the brachial plexus
B. The axillary nerve
C. The radial nerve
D. The middle trunk of the brachial plexus
E. The C5 and C6 roots of the brachial plexus

57. The position adopted by the right arm in this patient can be explained by paralysis of which of the following groups of muscles?
A. Supraspinatus, deltoid, biceps brachii, greater part of brachialis, infraspinatus, and teres minor
B. Latissimus dorsi, triceps, anconeus, brachioradialis, and supinator
C. Flexor digitorum superficialis, flexor pollicis longus, flexor carpi radialis longus, and flexor carpi ulnaris
D. Extensor carpi ulnaris, supinator, extensor indicis, and extensor digiti minimi
E. Pectoralis major, abductor pollicis longus, extensor pollicis brevis, and extensor pollicis longus

A 30-year-old plasterer was finishing a difficult ceiling in a remodeled kitchen. He was standing on top of a stepladder with his right arm above his head. As he used his right hand to move the trowel, loaded with plaster, across the ceiling, he suddenly felt an acute spasm of pain over the tip of the right shoulder. At physical examination of the patient in the emergency department, it was found that the pain in the right shoulder recurred in the middle range of abduction and that there was extreme tenderness over the greater tuberosity of the humerus.

58. What is the most likely structural damage in this patient?
    A. Fracture of the upper end of the humerus
    B. Tearing of the deltoid muscle
    C. Fracture of the acromion
    D. Lesion of the rotator cuff
    E. Tearing of the trapezius muscle

Answers to Review Questions

1. E
2. B
3. D
4. B
5. C
6. B
7. A
8. B
9. D
10. C
11. D
12. A
13. D
14. C
15. E
16. C
17. D. The medial cord of the brachial plexus gives origin to the medial cutaneous nerve of the arm.
18. A
19. C. The posterior cord gives origin to the radial nerve.
20. D
21. F
22. F
23. A
24. D
25. B
26. D
27. E
28. C
29. C
30. D. The biceps brachii is a powerful supinator of the superior and inferior radioulnar joints.
31. B
32. D. The upper fibers of the trapezius muscle elevate the scapula and the shoulder, as in shrugging the shoulder.
33. B. The internal thoracic nodes lie within the thoracic cavity along the internal thoracic artery.
34. C
35. D. The muscles of the thenar eminence are innervated by the recurrent branch of the median nerve. A lesion of the median nerve causes these muscles to atrophy and the eminence to flatten. The adductor pollicis muscle is supplied by the deep branch of the ulnar nerve, and adduction of the thumb is unopposed.
36. B. A dermatome is an area of skin supplied by a single segment of the spinal cord.
37. C. The cephalic vein arises on the dorsum of the hand.
38. E
39. B. The subacromial bursa never communicates with the shoulder joint. The bursa that commonly communicates with the joint is the subscapularis bursa.
40. C. The lymphatic drainage of the skin on the medial side of the elbow ascends the upper limb in lymph vessels that accompany the basilic vein and drain into the medial group of axillary lymph nodes.
41. C. The flexor pollicis longus tendon passes into the palm beneath the lateral part of the flexor retinaculum.
42. E
43. B
44. A. The spinal part of the accessory nerve supplies the sternocleidomastoid and the trapezius muscles.
45. E. The rotator cuff is formed by the tendons of the short muscles that cover the anterior, the superior, and the posterior surfaces of the shoulder joint. These muscles are the subscapularis muscle, supplied by the upper and lower subscapular nerves; the supraspinatus muscle, supplied by the suprascapular nerve; the infraspinatus muscle, supplied by the suprascapular nerve; and the teres minor muscle supplied by the axillary nerve.
46. D
47. D. The skin on the lateral side of the upper arm covering the upper half of the deltoid muscle is innervated by the supraclavicular nerves (C3 and 4), and the skin covering the lower half of the deltoid muscle is innervated by the upper lateral cutaneous nerve of the arm (C5 and 6) from the axillary nerve.
48. C. Carpal tunnel syndrome results from compression of the median nerve as it passes beneath the flexor retinaculum. The median nerve innervates the opponens pollicis muscle, and it gives off digital nerves to the lateral three and a half fingers on the palmar aspect. The muscles of the hypothenar eminence are supplied by the deep branch of the ulnar nerve. The skin of the medial part of the palm is supplied by the palmar cutaneous branch of the ulnar nerve.
49. D. Flexion of the metacarpophalangeal joints is produced by the flexor digitorum superficialis, the flexor digitorum profundus, and the lumbricals and interossei muscles, all of which receive nerve fibers from the medial cord via the median and the ulnar nerves. The interphalangeal joints are extended by the lumbricals and the interossei muscles, which are assisted by the extensor digitorum. The lumbricals and the interossei are innervated by the median and the ulnar nerves, which have many nerve fibers that originate in the medial cord of the brachial plexus.
50. E. The sweat glands of the upper limb are innervated by sympathetic postganglionic nerve fibers.
51. B. The deep branch of the radial nerve lies within the supinator muscle and is closely related to the neck

of the radius. The extensor pollicis longus and extensor digitorum muscles are innervated by the deep branch of the radial nerve. The sensory nerve supply of the skin on the lateral side of the dorsum of the hand is the superficial branch of the radial nerve.

52. A. The sweat glands and the blood vessels of the skin over the hypothenar eminence and the palmar surface of the medial one and a half fingers are innervated by sympathetic postganglionic nerve fibers. These fibers travel in the eighth cervical and first thoracic spinal nerves, the medial cord of the brachial plexus, and the ulnar nerve and its palmar cutaneous and digital branches.
53. C. The radial nerve was damaged in the spiral groove on the posterior surface of the shaft of the humerus.
54. B. The supraspinatus muscle is mainly responsible for approximately the first 15° of abduction by the shoulder joint. From approximately 15° to 90°, the deltoid muscle is largely responsible. Remember that for someone to raise an arm above 90°, the scapula needs to rotate, thus involving contraction of the trapezius and the serratus anterior muscles.
55. C
56. E
57. A. This patient has a right-sided Erb-Duchenne palsy—that is, a lesion of the fifth and the sixth roots of the brachial plexus. The suprascapular nerve, the nerve to subclavius, and the musculocutaneous and axillary nerves all possess nerve fibers derived from C5 and C6 roots and therefore will be functionless. Consequently, the following muscles are paralyzed: The supraspinatus (abductor of shoulder), the subclavius, the biceps brachii (flexor of elbow and strong supinator of forearm), the greater part of the brachialis and coracobrachialis, and the deltoid (abductor of shoulder), and the teres minor (lateral rotator of shoulder). The right upper limb will hang limply by the side (adducted) and be rotated medially by the unopposed sternocostal part of the pectoralis major; the forearm will be pronated through loss of the action of the biceps. The position of the upper limb in this condition has been likened to that of a waiter hinting for a tip. In addition, there will be loss of sensation down the lateral side of the right arm.
58. D. This patient has supraspinatus tendinitis. During the middle range of abduction, the tendon of the supraspinatus impinges against the outer border of the acromion. Normally, the large subacromial bursa intervenes and ensures that the movement is painless and relatively free of friction. In this condition, however, the bursa has degenerated, and the supraspinatus tendon exhibits a localized area of degeneration.

CHAPTER 5

Lower Limb

The primary function of the lower limb is to support the weight of the body and to provide a stable foundation when standing, walking, or running. Each lower limb may be divided into the gluteal region, the thigh, the knee, the leg, the ankle, and the foot.

It is suggested that the lower limb be reviewed in the following order:

1. A brief overview of the bones and the major joints, preferably with use of an articulated skeleton.
2. A consideration of the more important muscles, concentrating on their actions and their nerve supply.
3. A brief review of the blood supply and the lymphatic drainage.
4. A detailed overview of the nerves and their distribution.

To assist students, tables are used extensively in this chapter.

BONES

Bones of the Pelvic Girdle

The pelvic girdle consists of four bones: the two hip bones, the sacrum, and the coccyx (see Fig. 3-1). The pelvic girdle provides a strong connection between the trunk and the lower limbs.

HIP BONE

In children, each hip bone consists of the ilium, the ischium, and the pubis (Fig. 5-1). At puberty, these three bones fuse together to form one large, irregular bone. The **acetabulum** is a cup-shaped depression on the outer surface of the hip bone, and it articulates with the head of the femur. The articular surface of the acetabulum is limited to a horseshoe-shaped area and is covered with hyaline cartilage. The **acetabular fossa** is the floor of the acetabulum, which is nonarticular. The **acetabular notch** is situated on the inferior margin of the acetabulum.

The **iliac crest** runs between the **anterior** and **posterior superior iliac spines.** Below these spines are the corresponding **inferior iliac spines.**

The **ischium** possesses an **ischial spine** and an **ischial tuberosity** (Fig. 5-1).

The **pubis** has a **body** and a **superior** and an **inferior pubic rami.** The body of the pubis has the **pubic crest** and the **pubic tubercle,** and it articulates with the pubic bone of the opposite side at the **symphysis pubis.**

The **obturator foramen** is a large opening that is bounded by the parts of the ischium and pubis (Fig. 5-1).

Bones of the Thigh

The bones of the thigh consist of the femur and the patella (Fig. 5-2).

FEMUR

The **head** of the femur is hemispheric in shape and fits into the acetabulum to form the hip joint. The **fovea capitis** is a small depression in the center of the head for the attachment of the **ligament of the head.** Part of the blood supply to the head of the femur from the obturator artery is conveyed along this ligament and enters the bone at the fovea.

The **neck** connects the head to the shaft (Fig. 5-2). The **greater** and the **lesser trochanters** are large eminences at the junction of the neck and the shaft. Connecting the two trochanters are the **intertrochanteric line** anteriorly (where the iliofemoral ligament is attached) and a promi-

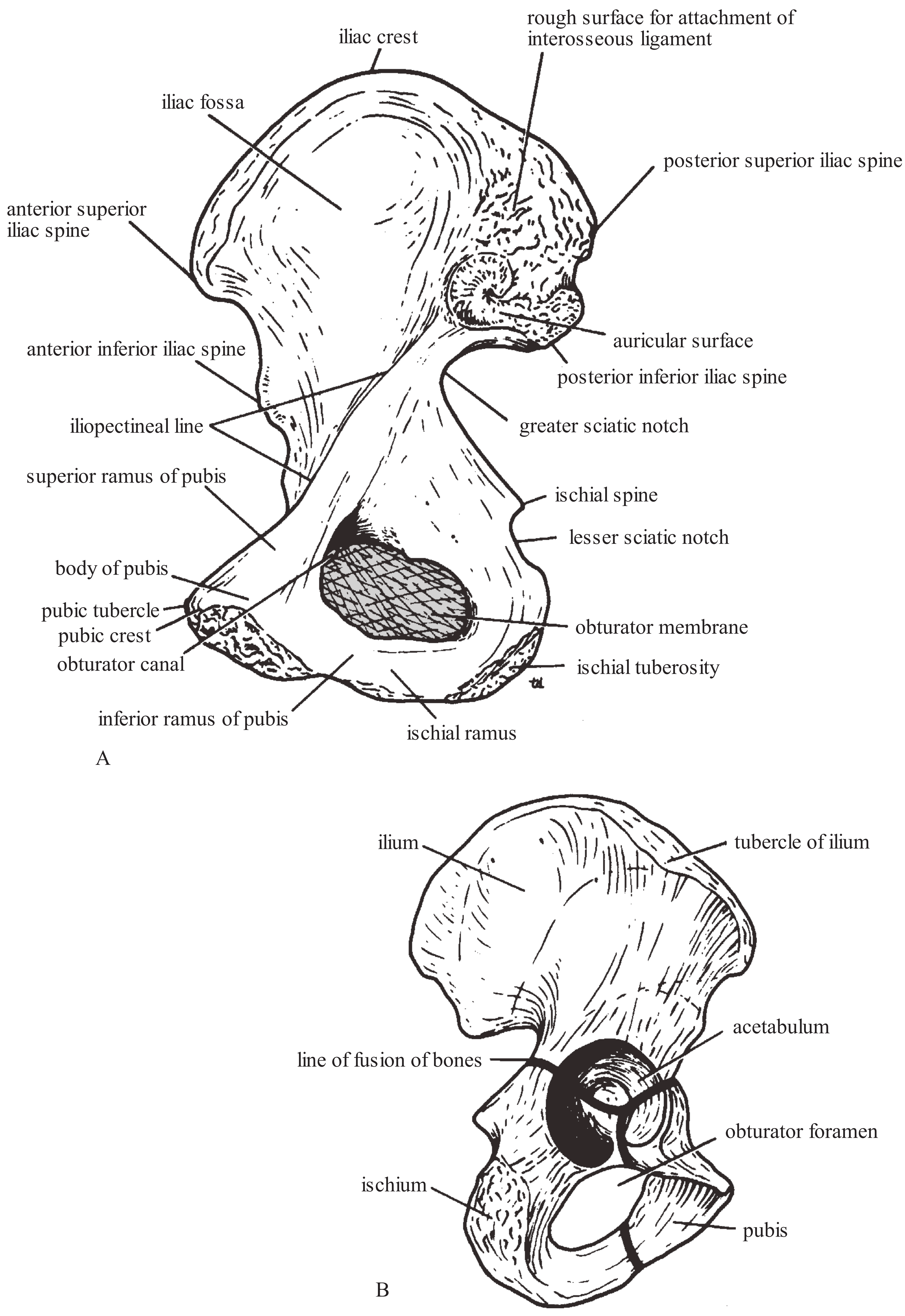


Figure 5-1 Right hip bone. **A.** Medial surface. **B.** Lateral surface. Note the lines of fusion between the ilium, the ischium, and the pubis.

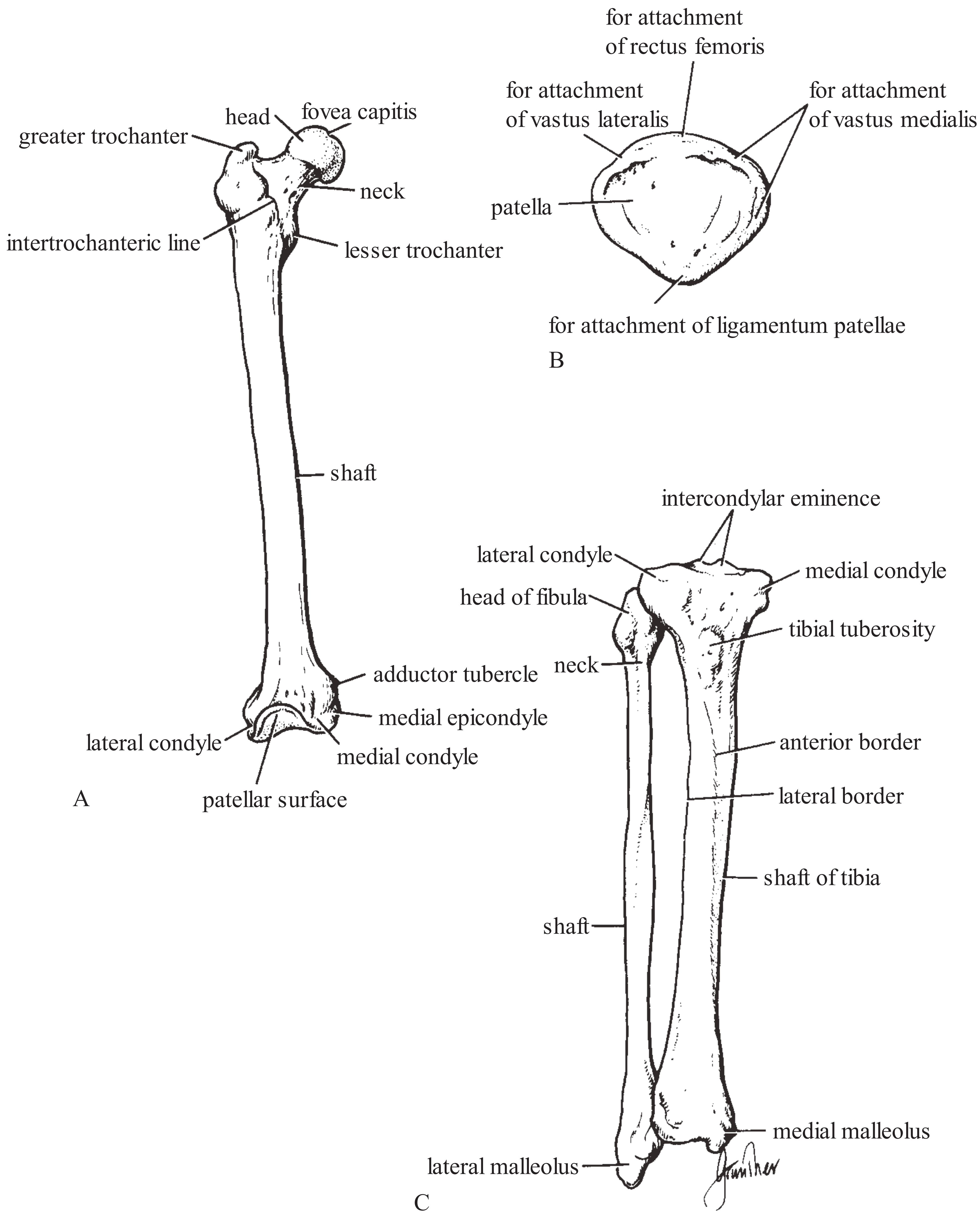


Figure 5-2 **A.** Anterior surface of the right femur. **B.** Anterior surface of the right patella. **C.** Anterior surface of the right tibia and fibula.

nent **intertrochanteric crest** posteriorly (on which is the **quadrate tubercle**).

The **shaft** is smooth on its anterior surface but has a ridge posteriorly (the **linea aspera**) to which are attached muscles and intermuscular septa. The medial margin of the linea aspera continues below (as the **medial supracondylar ridge**) to the **adductor tubercle** (Fig. 5-2) on the medial condyle. The lateral margin becomes continuous below with the **lateral supracondylar ridge.** On the posterior surface of the shaft below the greater trochanter is the **gluteal tuberosity** for the insertion of the gluteus maximus muscle. A flat, triangular area on the posterior surface of the lower end of the shaft is called the **popliteal surface.**

The lower end of the femur has a **lateral** and a **medial condyle,** which are separated posteriorly by the **intercondylar notch.** The anterior surfaces of the condyles are joined by an articular surface for the patella. The two condyles take part in the formation of the knee joint. Above the condyles are the **medial** and the **lateral epicondyles.** The adductor tubercle is continuous with the medial epicondyle.

CLINICAL NOTES

Blood Supply to the Femoral Head and Fractures of the Femoral Neck

In the young, the epiphysis of the head is supplied by a small branch of the obturator artery, which passes to the head along the ligament to the femoral head. The upper part of the neck of the femur receives a profuse blood supply from the medial femoral circumflex artery. In the adult, after the epiphyseal cartilage disappears, an anastomosis between the two sources of blood supply is established. Fractures of the femoral neck interfere with or completely interrupt the main blood supply from the root of the femoral neck to the femoral head. Avascular necrosis of the femoral head is a common complication of femoral neck fractures.

PATELLA

The patella is the largest sesamoid bone (a bone that develops within a tendon), and it lies within the tendon of the quadriceps femoris muscle in front of the knee joint. It is triangular in shape. Its apex lies inferiorly and is connected to the tuberosity of the tibia by the ligamentum patellae. The posterior surface articulates with the condyles of the femur.

Bones of the Leg

The bones of the leg are the tibia and the fibula (Fig. 5-2).

TIBIA

The tibia is the large, weight-bearing, medial bone of the leg. At the upper end are the **lateral** and **medial condyles,** which articulate with the lateral and medial condyles of the femur with the **lateral** and **medial menisci** intervening. Separating the upper articular surfaces of the tibial condyles is the **intercondylar eminence.** The lateral condyle possesses an oval **articular facet for the head of the fibula** on its lateral aspect.

At the upper end of the anterior border of the shaft of the tibia is the **tuberosity** (Fig. 5-2), which receives the attachment of the ligamentum patellae. The anterior border is prolonged downward and medially to form the **medial malleolus** below. The lateral border of the tibia provides attachment to the interosseous membrane, which binds together the tibia and the fibula. The lower end of the tibia shows a wide, rough depression on its lateral surface for articulation with the fibula.

FIBULA

The fibula provides attachment for muscles. It takes no part in articulation at the knee joint, but below, it forms part of the ankle joint.

The **head** forms the upper end of the fibula (Fig. 5-2). It has a **styloid process,** and it possesses an **articular surface** for articulation with the lateral condyle of the tibia. The **shaft** is attached to the tibia by the interosseous membrane. The lower end of the fibula forms the **lateral malleolus.**

CLINICAL NOTES

Fractures of the Neck of the Fibula and Injury to the Common Peroneal Nerve

The common peroneal nerve is in an exposed position as it winds around the neck of the fibula. The nerve can be injured in fractures of the neck of the fibula and by pressure from casts or splints.

Bones of the Foot

The bones of the foot are the tarsal bones, the metatarsal bones, and the phalanges (Fig. 5-3).

TARSAL BONES

The tarsal bones are the calcaneum, the talus, the navicular, the cuboid, and the three cuneiform bones.

Calcaneum

The calcaneum is the largest bone of the foot. It articulates above with the talus and in front with the cuboid bone. The posterior surface forms the prominence of the heel, and the medial surface possesses a large, shelflike ridge (the **sustentaculum tali**) that assists in supporting of the talus.

Talus

The talus articulates above at the ankle joint with the tibia and the fibula, below with the calcaneum, and in front with the navicular bone (Fig. 5-3). It possesses a **head, neck,** and **body.** Numerous important ligaments are attached to the talus, but no muscles are attached to this bone.

Navicular

The navicular lies between the head of the talus and the three cuneiform bones (Fig. 5-3). The **tuberosity** lies in front of and below the medial malleolus, and it attaches to the main part of the tibialis posterior tendon.

Cuboid

The cuboid articulates with the anterior end of the calcaneum (Fig. 5-3). It has a deep groove on its inferior aspect for the tendon of the peroneus longus muscle.

Cuneiform Bones

The three cuneiform bones are small, wedge-shaped bones that articulate proximally with the navicular bone and distally with the first three metatarsal bones. Their wedge shape contributes to the formation and maintenance of the transverse arch of the foot.

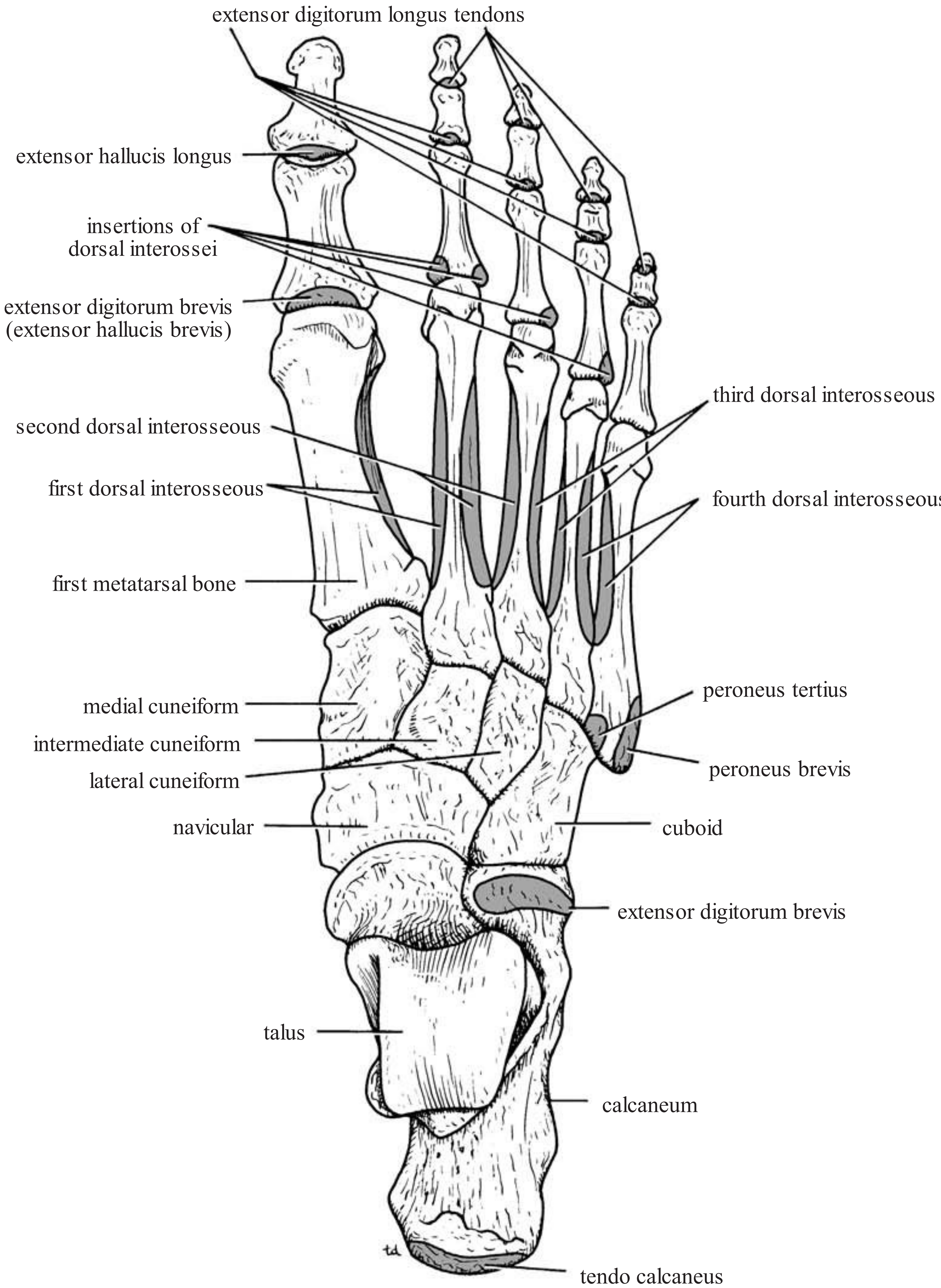


Figure 5-3 Dorsal view of the bones of the right foot. Note the muscle attachments.

METATARSAL BONES AND PHALANGES

The metatarsal bones and the phalanges resemble the metacarpal bones and the phalanges of the hand; each possesses a distal **head, shaft,** and proximal **base** (Fig. 5-3). There are five metatarsal bones, and they are numbered from the medial to the lateral side. The **fifth metatarsal** has a prominent **tubercle** on its base, which can be easily palpated along the lateral border of the foot. The tubercle provides attachment to the peroneus brevis tendon.

Except for the big toe, each toe has three phalanges. The big toe possesses only two.

JOINTS

Hip Joint

ARTICULATION

Articulation is between the head of the femur and the acetabulum of the hip bone (Fig. 5-4). The articular surface of

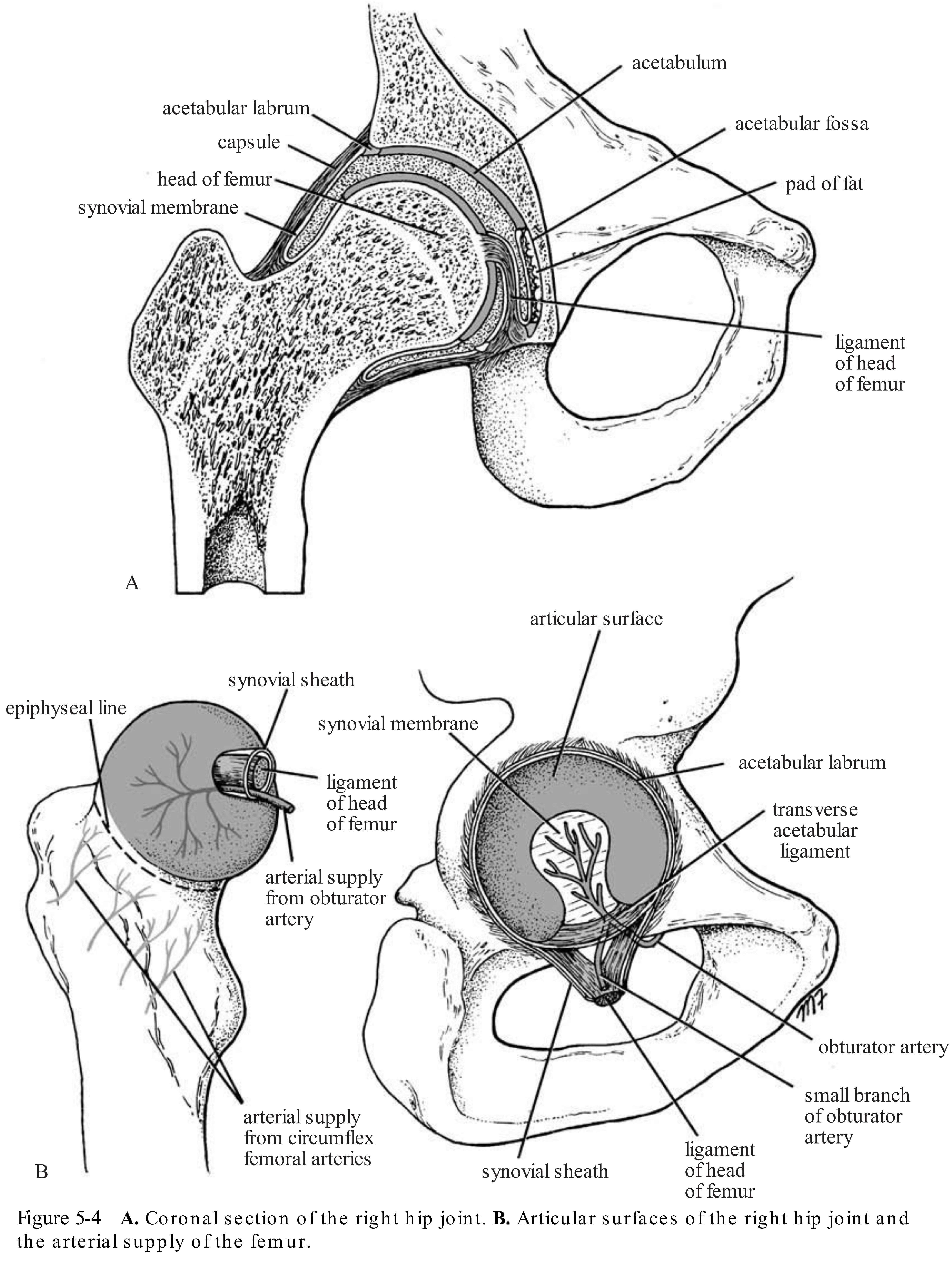


Figure 5-4 **A.** Coronal section of the right hip joint. **B.** Articular surfaces of the right hip joint and the arterial supply of the femur.

the acetabulum is horseshoe shaped and is deficient inferiorly at the **acetabular notch.** The cavity of the acetabulum is deepened by the fibrocartilaginous rim called the **acetabular labrum.** The labrum bridges the acetabular notch and is called the **transverse acetabular ligament.**

TYPE

The hip is a synovial ball-and-socket joint.

CAPSULE

The capsule encloses the joint and is attached medially to the acetabular labrum (Fig. 5-4). It is attached laterally to the intertrochanteric line of the femur in front of and halfway along the posterior aspect of the neck of the bone behind. It is reinforced by the iliofemoral, the pubofemoral, and the ischiofemoral ligaments.

LIGAMENTS

Iliofemoral Ligament

The iliofemoral ligament is the strongest and most important ligament of the hip joint (Fig. 5-5). It is shaped like an inverted Y. Its base is attached to the anteroinferior iliac spine above, and the two limbs of the Y are attached to the upper and the lower parts of the intertrochanteric line of the femur

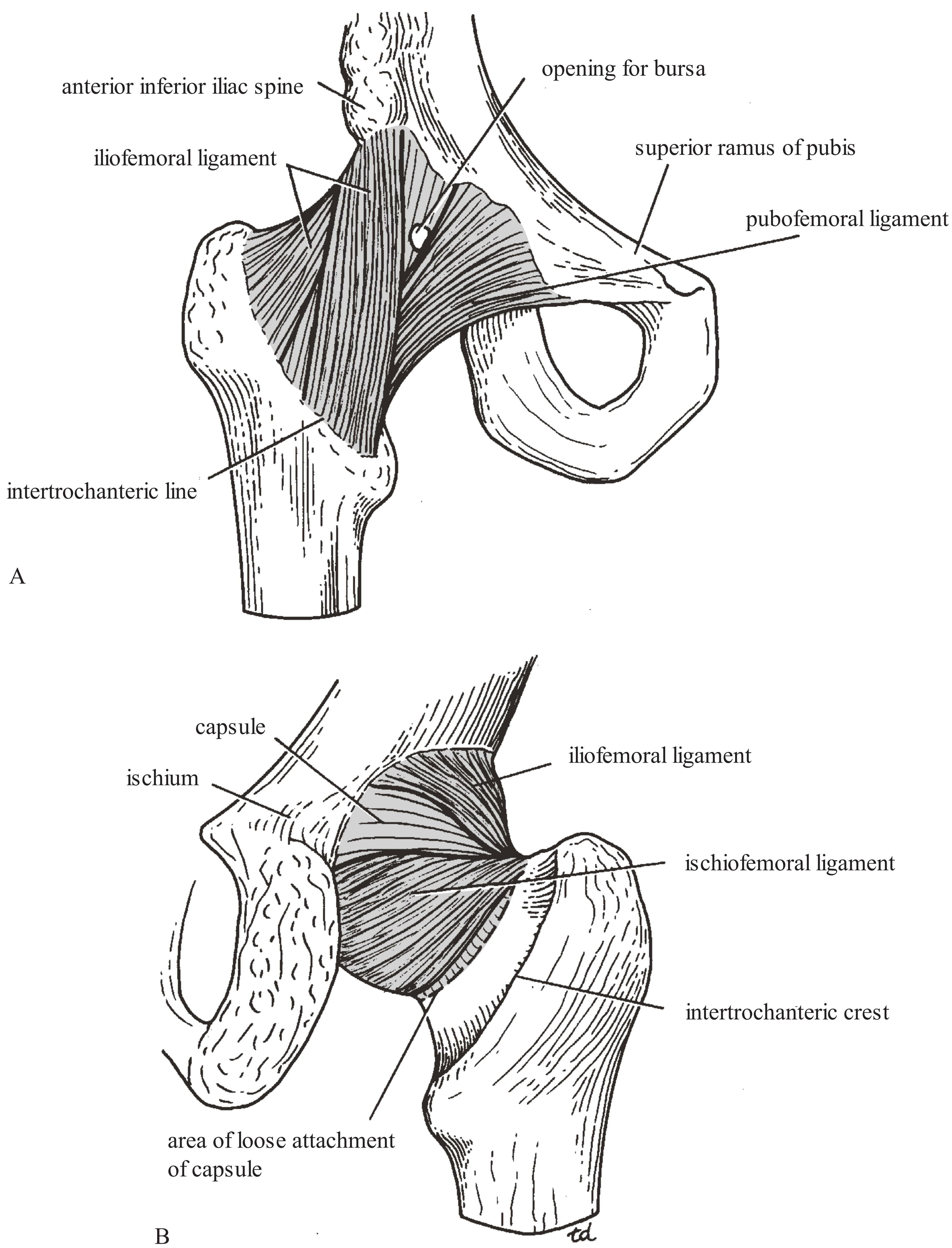


Figure 5-5 Anterior (**A**) and posterior (**B**) views of the right hip joint.

below. This ligament resists hyperextension and lateral rotation of the hip joint.

Pubofemoral Ligament

The pubofemoral ligament is triangular in shape (Fig. 5-5). The base is attached above to the superior ramus of the pubis, and the apex is attached below to the lower end of the intertrochanteric line. This ligament limits abduction and lateral rotation of the hip joint.

Ischiofemoral Ligament

The ischiofemoral ligament is spiral in shape and is attached to the body of the ischium and laterally to the greater trochanter of the femur (Fig. 5-5). This ligament limits medial rotation of the hip joint.

Ligament of the Head of the Femur

The ligament of the head of the femur is flat and triangular in shape (Fig. 5-4). It is attached by its apex to the fovea capitis of the femur and by its base to the transverse acetabular ligament and to the margins of the acetabular notch. This ligament lies within the joint and is ensheathed by synovial membrane. It has a slight limiting action on adduction of the hip joint.

SYNOVIAL MEMBRANE

The synovial membrane lines the capsule (Fig. 5-4) and covers the portion of the femoral neck that lies within the joint capsule. It ensheathes the ligament of the head of the femur and covers the floor of the acetabular fossa. It frequently communicates with the psoas bursa.

NERVE SUPPLY

The femoral, the obturator, and the sciatic nerves and the nerve to the quadratus femoris supply the joint.

MOVEMENTS AND THE MUSCLES THAT PRODUCE MOVEMENT

The hip joint has a wide range of movement.

- **Flexion:** Iliopsoas, rectus femoris, sartorius, and adductor muscles.
- **Extension** (posterior movement of the flexed thigh): Gluteus maximus and hamstring muscles.
- **Abduction:** Gluteus medius and minimus, sartorius, tensor fasciae latae, and piriformis muscles.
- **Adduction:** Adductor longus and brevis, adductor fibers of adductor magnus, pectineus, and gracilis muscles.
- **Lateral rotation:** Piriformis, obturator internus and externus, superior and inferior gemelli, quadratus femoris, and gluteus maximus muscles.
- **Medial rotation:** Anterior fibers of the gluteus medius and minimus and the tensor fasciae latae muscles.
- **Circumduction:** A combination of all the previously described movements.

IMPORTANT RELATIONS

- **Anteriorly:** Femoral vessels and nerve.
- **Posteriorly:** Sciatic nerve.

CLINICAL NOTES

HIP JOINT STABILITY AND TRENDELENBURG'S SIGN

The stability of the hip joint when a person stands on one leg with the foot of the opposite leg raised above the ground depends on three factors:

- The gluteus medius and minimus must be functioning normally.
- The head of the femur must be located normally within the acetabulum.
- The neck of the femur must be intact and must have a normal angle with the shaft of the femur.

If one of these factors is defective, then the pelvis will sink downward on the opposite, unsupported side. The patient is then said to exhibit a positive Trendelenburg's sign.

Knee Joint

ARTICULATION

Above are the condyles of the femur; below are the condyles of the tibia and their menisci (Fig. 5-6). In front is the articulation between the lower end of the femur and the patella.

TYPE

Between the femur and the tibia is a synovial joint of the hinge variety. Between the patella and the femur is a synovial gliding joint.

CAPSULE

The capsule encloses the knee joint, except anteriorly, where the capsule is deficient. Here, the synovial membrane pouches upward beneath the quadriceps tendon and forms the suprapatellar bursa.

LIGAMENTS

Extracapsular

Ligamentum Patellae

The ligamentum patellae is a continuation of the tendon of the quadriceps femoris muscle. It is attached above to the lower border of the patella and below to the tubercle of the tibia.

Lateral Collateral Ligament

The lateral collateral ligament is cordlike; it is attached above to the lateral condyle of the femur and below to the head of the fibula (Fig. 5-6). It is separated from the lateral meniscus by the tendon of the popliteus muscle.

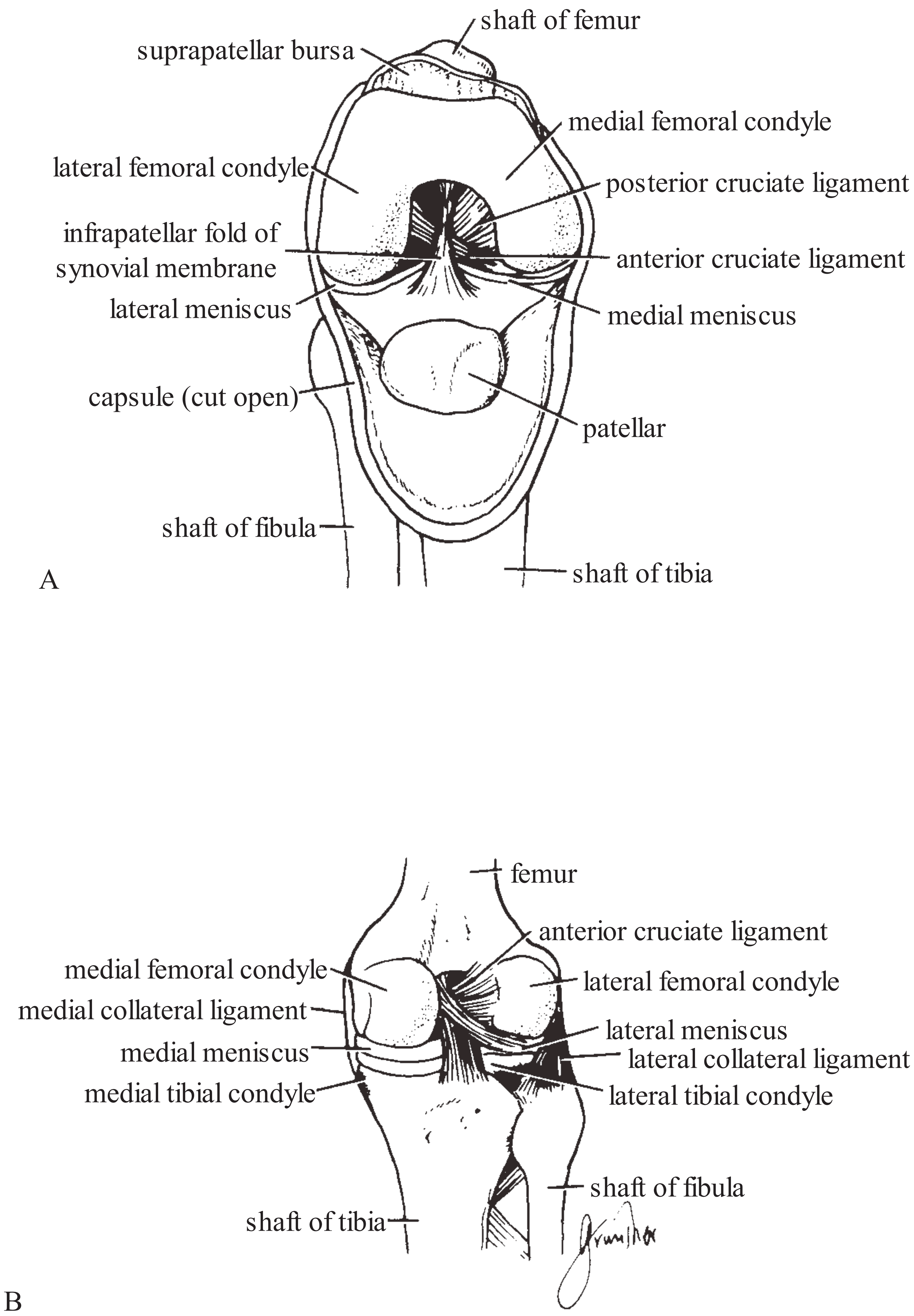


Figure 5-6 **A.** Anterior view of the internal aspect of the right knee joint. Note that the capsule has been cut and the patella turned downward. **B.** Posterior view of the internal aspect of the right knee joint. Note that the capsule and the synovial membrane have been removed.

Medial Collateral Ligament

The medial collateral ligament is a flat band that is attached above to the medial condyle of the femur and below to the medial surface of the shaft of the tibia (Fig. 5-6). It is **strongly attached to the medial meniscus.**

Oblique Popliteal Ligament

The oblique popliteal ligament is a tendinous expansion of the semimembranosus muscle. It strengthens the back of the capsule.

Intracapsular

Cruciate Ligaments

The cruciate ligaments are two very strong ligaments that cross each other within the knee joint (Fig. 5-6). They are termed anterior and posterior, according to their tibial attachments.

The **anterior cruciate ligament** is attached below to the anterior intercondylar area of the tibia (Fig. 5-7), and it passes upward, backward, and laterally to be attached to the lateral femoral condyle.

The **posterior cruciate ligament** is attached below to the posterior intercondylar area of the tibia (Fig. 5-7), and it passes upward, forward, and medially to be attached to the medial femoral condyle.

MENISCI

The menisci are C-shaped sheets of fibrocartilage (Fig. 5-7). The peripheral convex border of each meniscus is thick and attached to the capsule, and the inner concave border is thin and forms a free edge. The upper surfaces are in

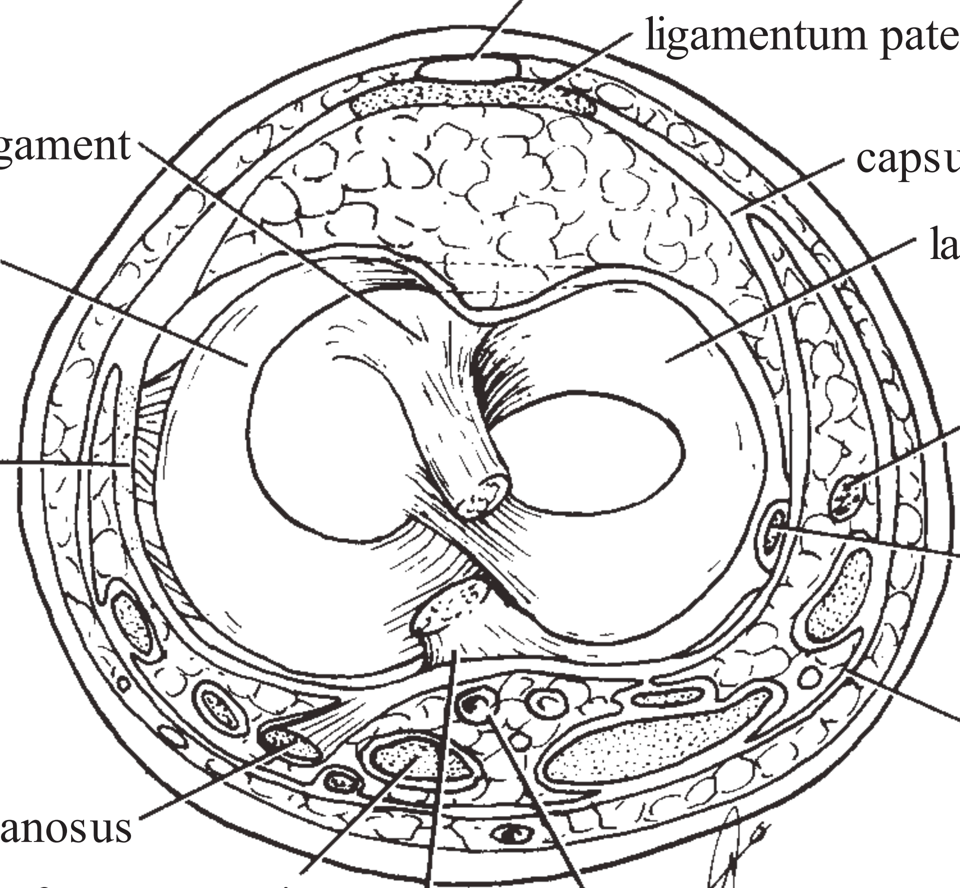


Figure 5-7 Cross-section of the right knee joint as seen from above. Note the positions of the ligaments and the menisci.

contact with the femoral condyles and the lower surfaces with the tibial condyles. Each meniscus is attached to the upper surface of the tibia by the anterior and the posterior **horns.** Because the medial meniscus is also attached to the medial collateral ligament, it is relatively immobile and is very susceptible to injury. The function of these menisci is to deepen the articular surfaces of the tibial condyles to receive the convex femoral condyles.

CLINICAL NOTES

INJURIES TO THE LIGAMENTS AND MENISCI

The ligaments and menisci are commonly injured in active sports. The medial meniscus is damaged much more frequently than the lateral, probably because of its strong attachment to the medial collateral ligament, which restricts its mobility.

SYNOVIAL MEMBRANE

The synovial membrane lines the capsule. Anteriorly, it forms a pouch that extends up beneath the quadriceps femoris muscle to form the **suprapatellar bursa.** Posteriorly, it is prolonged downward on the tendon of the popliteus muscle to form the **popliteal bursa.** The synovial membrane is also reflected forward and around the front of the cruciate ligaments; as a result, the cruciate ligaments lie behind the synovial cavity.

In the anterior part of the lower region of the joint, the synovial membrane is reflected backward from the ligamentum patellae to form the **infrapatellar fold.** The edges of this fold are called the **alar folds.**

BURSAE RELATED TO THE KNEE JOINT

Suprapatellar Bursa

The suprapatellar bursa lies beneath the quadriceps muscle. It is the largest bursa, and it **always communicates** with the knee joint.

Prepatellar Bursa

The prepatellar bursa lies between the patella and the skin.

Infrapatellar Bursae

The **superficial infrapatellar bursa** lies between the ligamentum patellae and the skin. The **deep infrapatellar bursa** lies between the ligamentum patellae and the tibia.

Popliteal Bursa

The popliteal bursa surrounds the tendon of the popliteus. It **always communicates** with the joint cavity.

Semimembranosus Bursa

The semimembranosus bursa lies between the tendon of the semimembranosus muscle and the medial condyle of the tibia. It may communicate with the joint cavity.

NERVE SUPPLY

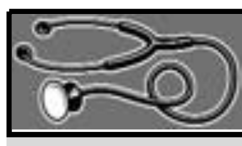
Femoral, obturator, common peroneal, and tibial nerves supply the joint.

MOVEMENTS AND THE MUSCLES THAT PRODUCE MOVEMENT

- **Flexion:** Biceps femoris, semitendinosus, and semimembranosus muscles.

- **Extension:** Quadriceps femoris muscle.
- **Medial rotation:** Sartorius, gracilis, and semitendinosus muscles.
- **Lateral rotation:** Biceps femoris muscle.

The knee joint is most stable when in full extension. As the knee joint assumes this position, medial rotation of the femur results in a twisting and tightening of all the major ligaments of the joint. During flexion, the ligaments are untwisted by contraction of the **popliteus muscle,** which laterally rotates the femur on the tibia.



CLINICAL NOTES

STRENGTH OF THE KNEE JOINT

The strength of the knee joint depends on the strength of the ligaments that bind the femur to the tibia and on the tone of the muscles acting on the joint. The most important muscle group is the quadriceps femoris; provided that this is well developed, it is capable of stabilizing the knee in the presence of torn ligaments.

Ankle Joint

ARTICULATION

The articulation is between the lower end of the tibia, the malleoli above, and the body of the talus below (Fig. 5-8). The **inferior transverse tibiofibular ligament** deepens the socket into which the body of the talus fits snugly.

TYPE

The ankle is a synovial hinge joint.

CAPSULE

The capsule encloses the joint.

LIGAMENTS

Medial (Deltoid) Ligament

The medial ligament is very strong and is attached by its apex to the tip of the medial malleolus (Fig. 5-8). Below, the deep fibers are attached to the medial surface of the body of the talus. The superficial fibers are attached to the medial side of the talus, the sustentaculum tali, the plantar calcaneonavicular ligament, and the tuberosity of the navicular bone.

Lateral Ligament

The lateral ligament is weaker than the medial ligament (Fig. 5-8) and has three bands.

Anterior Talofibular Ligament

The anterior talofibular ligament runs from the lateral malleolus to the lateral surface of the talus.

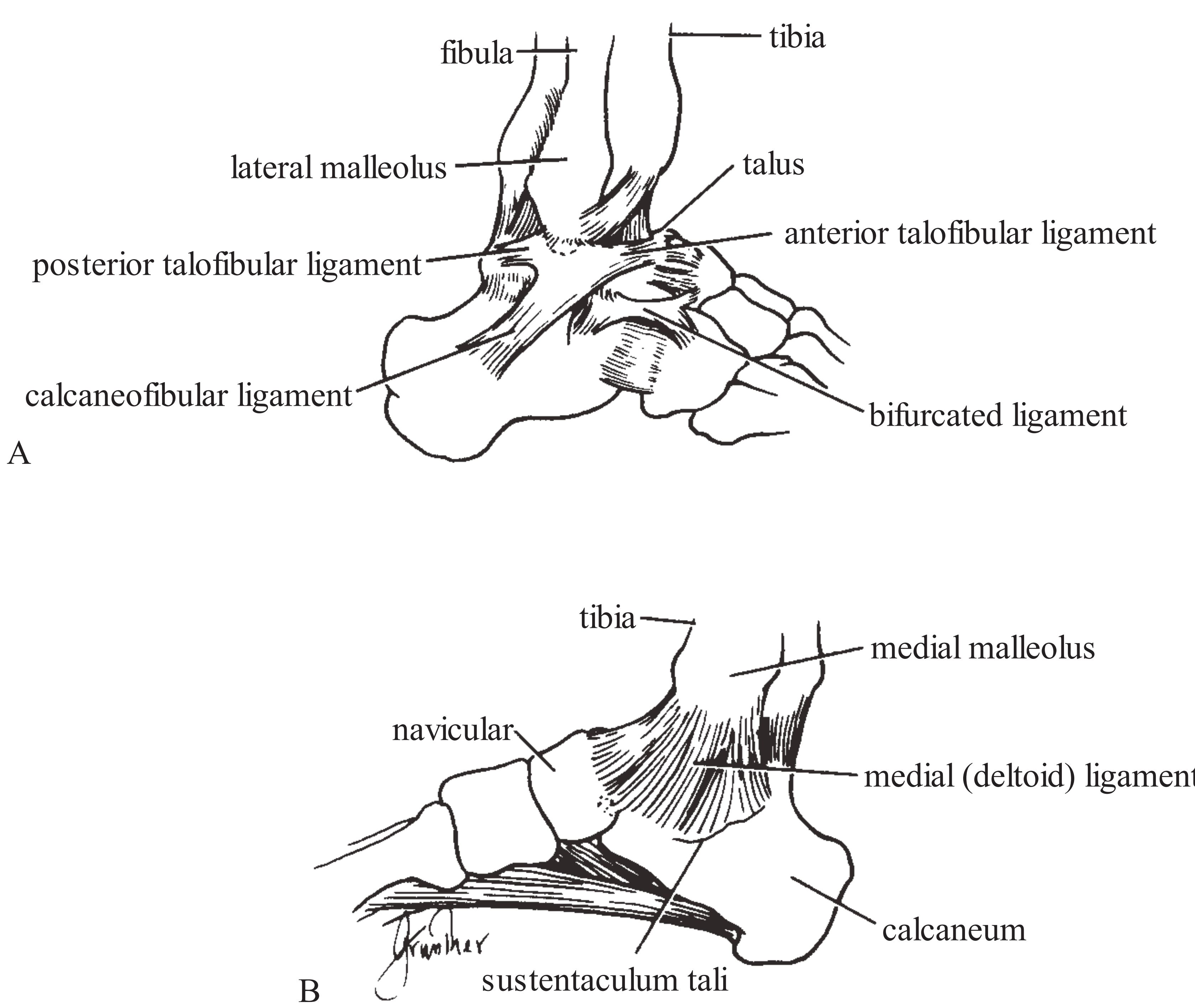


Figure 5-8 Right ankle joint. **A.** Lateral view. **B.** Medial view.

Calcaneofibular Ligament

The calcaneofibular ligament runs from the lateral malleolus to the lateral surface of the calcaneum.

Posterior Talofibular Ligament

The posterior talofibular ligament runs from the lateral malleolus to the posterior tubercle of the talus.

SYNOVIAL MEMBRANE

The synovial membrane lines the capsule.

NERVE SUPPLY

Deep peroneal and tibial nerves supply the joint.

MOVEMENTS AND THE MUSCLES THAT PRODUCE MOVEMENT

- **Dorsiflexion** (toes pointing upward): Tibialis anterior, extensor hallucis longus, extensor digitorum longus, and peroneus tertius muscles.
- **Plantar flexion** (toes pointing downward): Gastrocnemius, soleus, plantaris, peroneus longus, peroneus brevis, tibialis posterior, flexor digitorum longus, and flexor hallucis longus muscles.

IMPORTANT RELATIONS

- **Anteriorly:** Anterior tibial vessels and the deep peroneal nerve (Fig. 5-9).
- **Posteriorly:** Tendo calcaneus (Fig. 5-10).
- **Behind the lateral malleolus:** Tendons of peroneus longus and brevis (Fig. 5-10).
- **Behind the medial malleolus:** Posterior tibial vessels, tibial nerve, and the long flexor tendons of the foot (Fig. 5-10).

Intertarsal Joints

SUBTALAR JOINT

Articulation

The articulation is between the concave inferior surface of the body of the talus and the convex facet on the upper surface of the calcaneum.

Type

The subtalar joint is a synovial gliding joint.

TALOCALCANEONAVICULAR JOINT

Articulation

Articulation is between the rounded head of the talus, upper surface of the sustentaculum tali of the calcaneum, and posterior concave surface of the navicular bone.

Type

The talocalcaneonavicular joint is a synovial joint.

Ligaments

Plantar Calcaneonavicular (Spring) Ligament

The plantar calcaneonavicular ligament runs from the anterior border of the sustentaculum tali to the inferior surface and the tuberosity of the navicular bone. It supports the head of the talus.

CALCANEOCUBOID JOINT

Articulation

Articulation is between the anterior end of the calcaneum and posterior surface of the cuboid.

Type

The calcaneocuboid joint is a synovial gliding joint.

Ligaments

Long Plantar Ligament

The long plantar ligament is strong and connects the undersurface of the calcaneum to the cuboid and the bases of the third, the fourth, and the fifth metatarsal bones.

Short Plantar Ligament

The short plantar ligament is wide and strong and connects the undersurface of the calcaneum to the adjoining part of the cuboid.

MOVEMENTS AND THE MUSCLES THAT PRODUCE MOVEMENT

The movements of the subtalar, the talocalcaneonavicular, and the calcaneocuboid joints are inversion and eversion. Inversion is more extensive than eversion.

- **Inversion** (movement of the foot so that the sole faces medially): Tibialis anterior, extensor hallucis longus, medial tendons of extensor digitorum longus, and tibialis posterior muscles.
- **Eversion** (opposite movement of the foot so that the sole faces laterally): Peroneus longus, peroneus brevis, peroneus tertius, and lateral tendons of extensor digitorum longus muscles.

CUNEONAVICULAR JOINT

Articulation

Articulation is between the three cuneiform bones and the navicular bone.

Type

This is a synovial gliding joint.

CUBOIDEONAVICULAR JOINT

The cuboideonavicular joint is a fibrous joint. The bones are connected by dorsal, plantar, and interosseous ligaments, and a small amount of movement is possible.

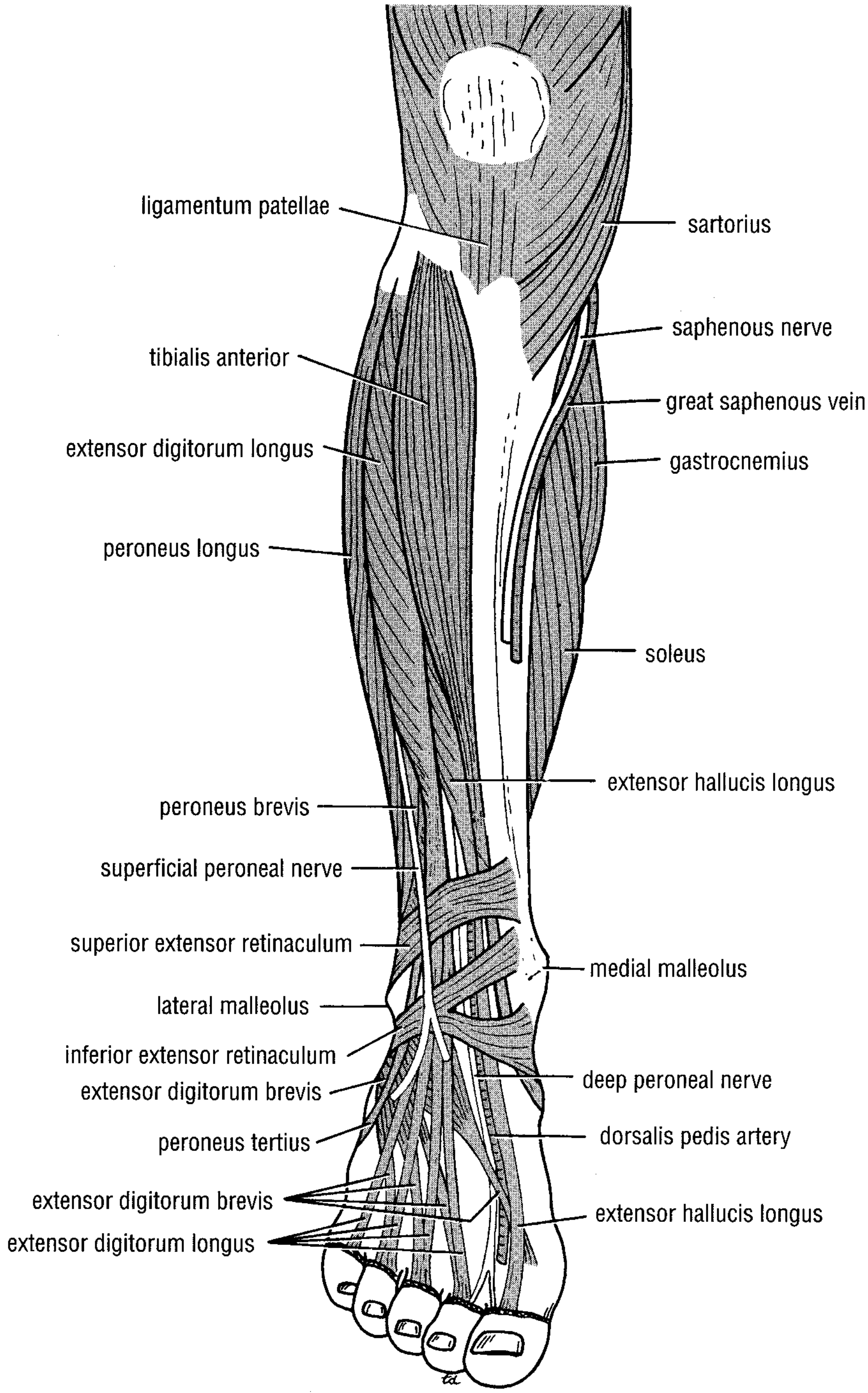


Figure 5-9 Structures of the anterior and lateral right leg and of the dorsum of the foot.

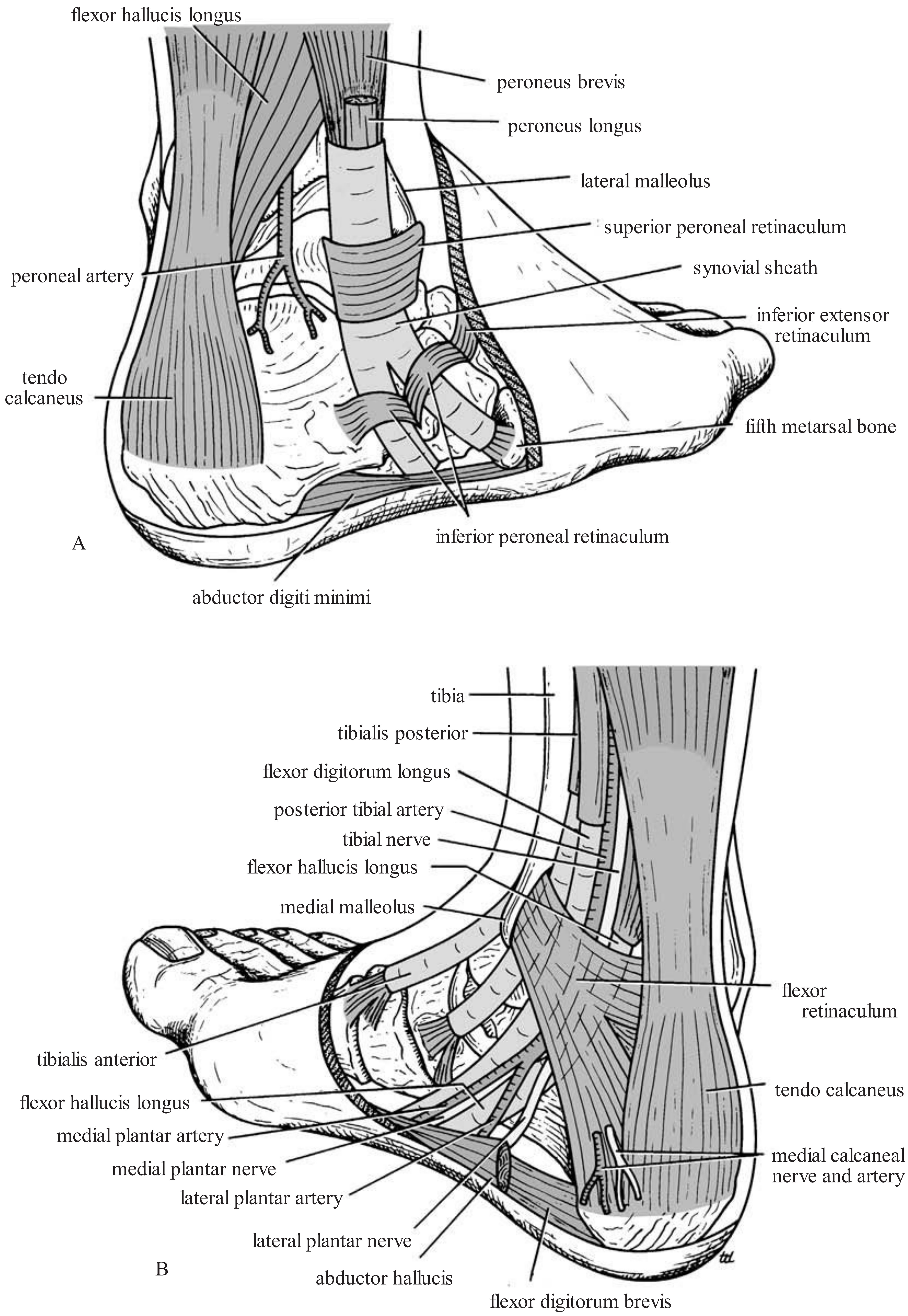


Figure 5-10 Structures passing behind the lateral malleolus (**A**) and the medial malleolus (**B**). Note the position of the retinacula.

INTERCUNEIFORM AND CUNEOCUBOID JOINTS

Intercuneiform and cuneocuboid joints are synovial gliding joints. The bones are connected by dorsal, plantar, and interosseous ligaments.

TARSOMETATARSAL AND INTERMETATARSAL JOINTS

Tarsometatarsal and intermetatarsal joints are synovial gliding joints. The bones are connected by dorsal, plantar, and interosseous ligaments.

METATARSOPHALANGEAL AND INTERPHALANGEAL JOINTS

Metatarsophalangeal and interphalangeal joints are similar to those of the hand (see p. 123 and 124). Abduction and adduction of the toes, which are performed by the interossei muscles, are small in amount and occur from the **midline of the second digit** (and not the third digit, as in the hand).

MUSCLES OF THE LOWER LIMB

Gluteal Region

The gluteal region is bounded superiorly by the iliac crest and inferiorly by the fold of the buttock (Fig. 5-11). This region consists largely of the gluteal muscles and a thick layer of superficial fascia.

The muscles of the gluteal region are described in Table 5-1.

CLINICAL NOTES

GLUTEUS MAXIMUS AND INTRAMUSCULAR INJECTIONS

The great thickness of the gluteus maximus muscle makes it ideal for intramuscular injections. To avoid injury to the underlying sciatic nerve, the injection should be given **well forward on the upper outer quadrant of the buttock.**

FASCIA

Superficial Fascia

The superficial fascia is thick (especially in women) and is impregnated with large quantities of fat.

Deep Fascia

The deep fascia is continuous below with the fascia lata of the thigh, and it splits to enclose the gluteus maximus muscle.

IMPORTANT LIGAMENTS

The sacrotuberous and the sacrospinous ligaments stabilize the sacrum and prevent its rotation by the weight of the vertebral column.

Sacrotuberous Ligament

The sacrotuberous ligament connects the posteroinferior iliac spine, the lateral part of the sacrum, and the coccyx to the ischial tuberosity (Fig. 5-11).

Sacrospinous Ligament

The sacrospinous ligament connects the lateral part of the sacrum and the coccyx to the spine of the ischium (Fig. 5-11).

IMPORTANT FORAMINA

Greater Sciatic Foramen

The greater sciatic foramen is formed by the conversion of the greater sciatic notch of the hip bone into a foramen by the presence of the sacrotuberous and the sacrospinous ligaments.

The following structures pass through the foramen:

- Piriformis muscle.
- Sciatic nerve.
- Posterior cutaneous nerve of the thigh.
- Superior and inferior gluteal nerves.
- Nerves to obturator internus and quadratus femoris muscles.
- Pudendal nerve.
- Superior and inferior gluteal arteries and veins.
- Internal pudendal artery and vein.

Lesser Sciatic Foramen

The lesser sciatic foramen is formed by the conversion of the lesser sciatic notch of the hip bone into a foramen by the presence of the sacrotuberous and the sacrospinous ligaments.

The following structures pass through the foramen:

- Tendon of the obturator internus muscle.
- Nerve to the obturator internus muscle.
- Pudendal nerve.
- Internal pudendal artery and vein.

Thigh

The muscles of the anterior fascial compartment (Fig. 5-12) are described in Table 5-2. The muscles of the medial fascial compartment are described in Table 5-3, and the muscles of the posterior fascial compartment (Fig. 5-13) are described in Table 5-4.

DEEP FASCIA OF THE THIGH (FASCIA LATA)

The deep fascia encloses the thigh as a trouser leg would. The upper end is attached to the pelvis and its associated ligaments.

ILIOTIBIAL TRACT

The iliotibial tract is a thickening of the fascia lata on its lateral side. It is attached above to the iliac tubercle and below

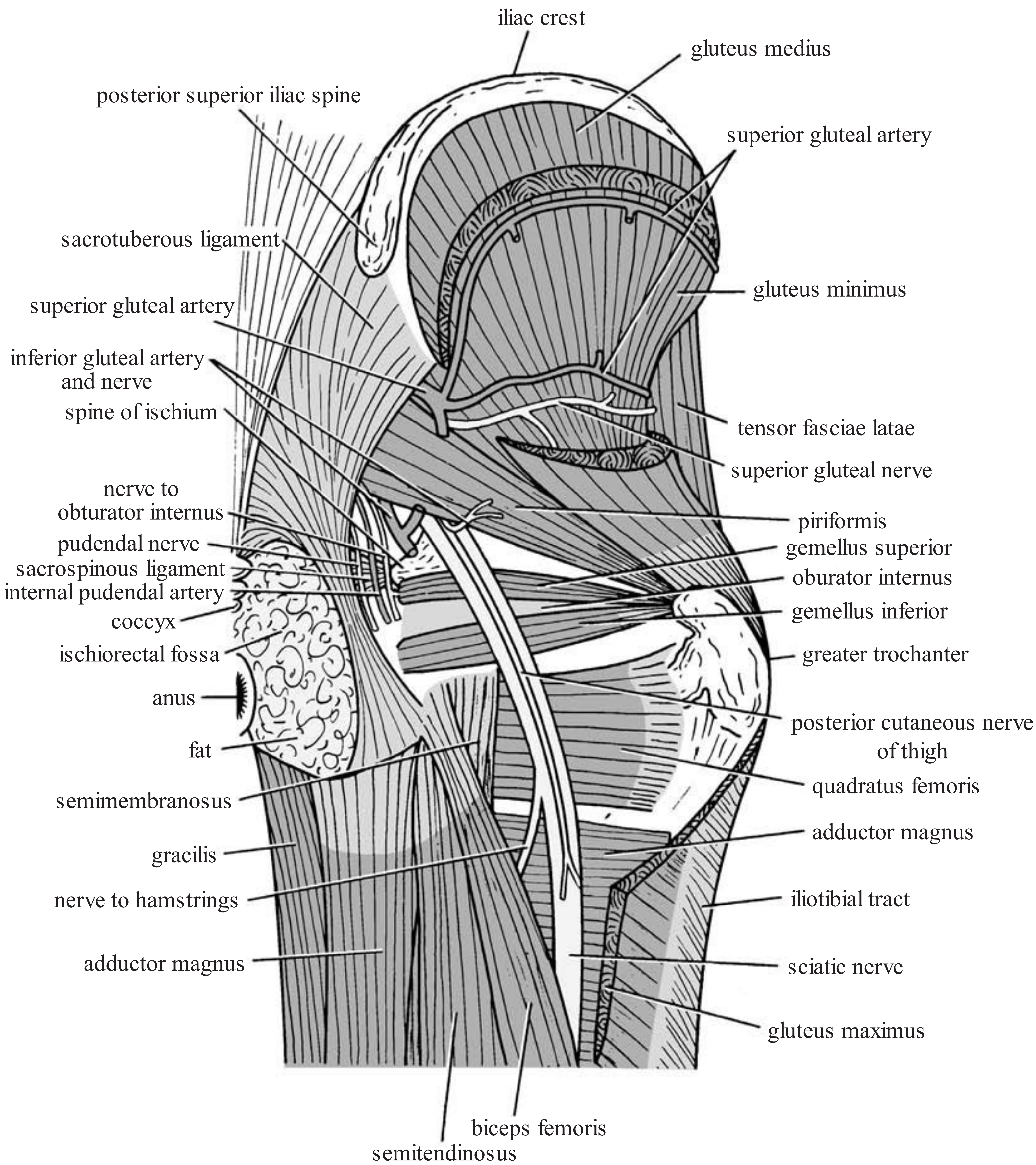


Figure 5-11 Structures of the right gluteal region. Note that the greater part of the gluteus maximus and part of the gluteus medius muscles have been removed.

Table 5-1 Muscles of the Gluteal Region of the Lower Limb

Muscle	Origin	Insertion	Nerve Supply	Action
Gluteus maximus	Outer surface of the ilium, sacrum, coccyx, and sacrotuberous ligament	Iliotibial tract and gluteal tuberosity of the femur	Inferior gluteal nerve	Extends and laterally rotates the thigh at the hip joint; it extends knee joint through the iliotibial tract
Gluteus medius	Outer surface of the ilium	Greater trochanter of the femur	Superior gluteal nerve	Abducts the thigh at the hip joint; tilts the pelvis when walking
Gluteus minimus	Outer surface of the ilium	Greater trochanter of the femur	Superior gluteal nerve	Abducts the thigh at the hip joint; tilts the pelvis when walking; anterior fibers medially rotate the thigh
Tensor fasciae latae	Iliac crest	Iliotibial tract	Superior gluteal nerve	Assists the gluteus maximus in extending the knee joint
Piriformis	Anterior surface of the sacrum	Greater trochanter of the femur	First and second sacral nerves	Laterally rotates the thigh at the hip joint
Obturator internus	Inner surface of the obturator membrane	Greater trochanter of the femur	Sacral plexus	Laterally rotates the thigh at the hip joint
Gemellus superior	Spine of the ischium	Greater trochanter of the femur	Sacral plexus	Laterally rotates the thigh at the hip joint
Gemellus inferior	Ischial tuberosity	Greater trochanter of the femur	Sacral plexus	Laterally rotates the thigh at the hip joint
Quadratus femoris	Ischial tuberosity	Quadrate tubercle on the upper end of the femur	Sacral plexus	Laterally rotates the thigh at the hip joint

to the lateral condyle of the tibia. It receives the insertion of the greater part of the gluteus maximus and the tensor fasciae latae muscles.

SAPHENOUS OPENING

The saphenous opening is a gap in the deep fascia in the front of the thigh and just below the inguinal ligament. It allows passage of the great saphenous vein, some small branches of the femoral artery, and lymph vessels. The opening is filled with loose connective tissue called the **cribriform fascia.**

FASCIAL COMPARTMENTS OF THE THIGH

Three fascial septa pass from the inner aspect of the deep fascial sheath of the thigh to the linea aspera of the femur. By this means, the thigh is divided into three compartments, with each having muscles, nerves, and arteries. The compartments are as follows:

- Anterior with the femoral nerve.
- Medial (adductor) with the obturator nerve.
- Posterior with the sciatic nerve.

FEMORAL TRIANGLE

The femoral triangle is situated in the upper part of the front of the thigh. Its boundaries are as follows:

- **Superiorly:** The inguinal ligament.
- **Laterally:** The sartorius muscle.
- **Medially:** The adductor longus muscle.

The femoral triangle contains the terminal part of the femoral nerve and its branches, the femoral sheath, the femoral artery and its branches, the femoral vein and its tributaries, and the inguinal lymph nodes.

FEMORAL SHEATH

The femoral sheath is a downward protrusion from the abdomen into the thigh of the fascia transversalis and the fascia iliaca. The sheath surrounds the femoral blood vessels and lymph vessels for approximately 1 in. (2.5 cm) below the inguinal ligament. As the **femoral artery** enters the thigh beneath the inguinal ligament, it occupies the **lateral compartment** of the sheath. The **femoral vein** occupies the **intermediate compartment,** and the **lymph vessels** (and usually one lymph node) occupy the most **medial compartment.**

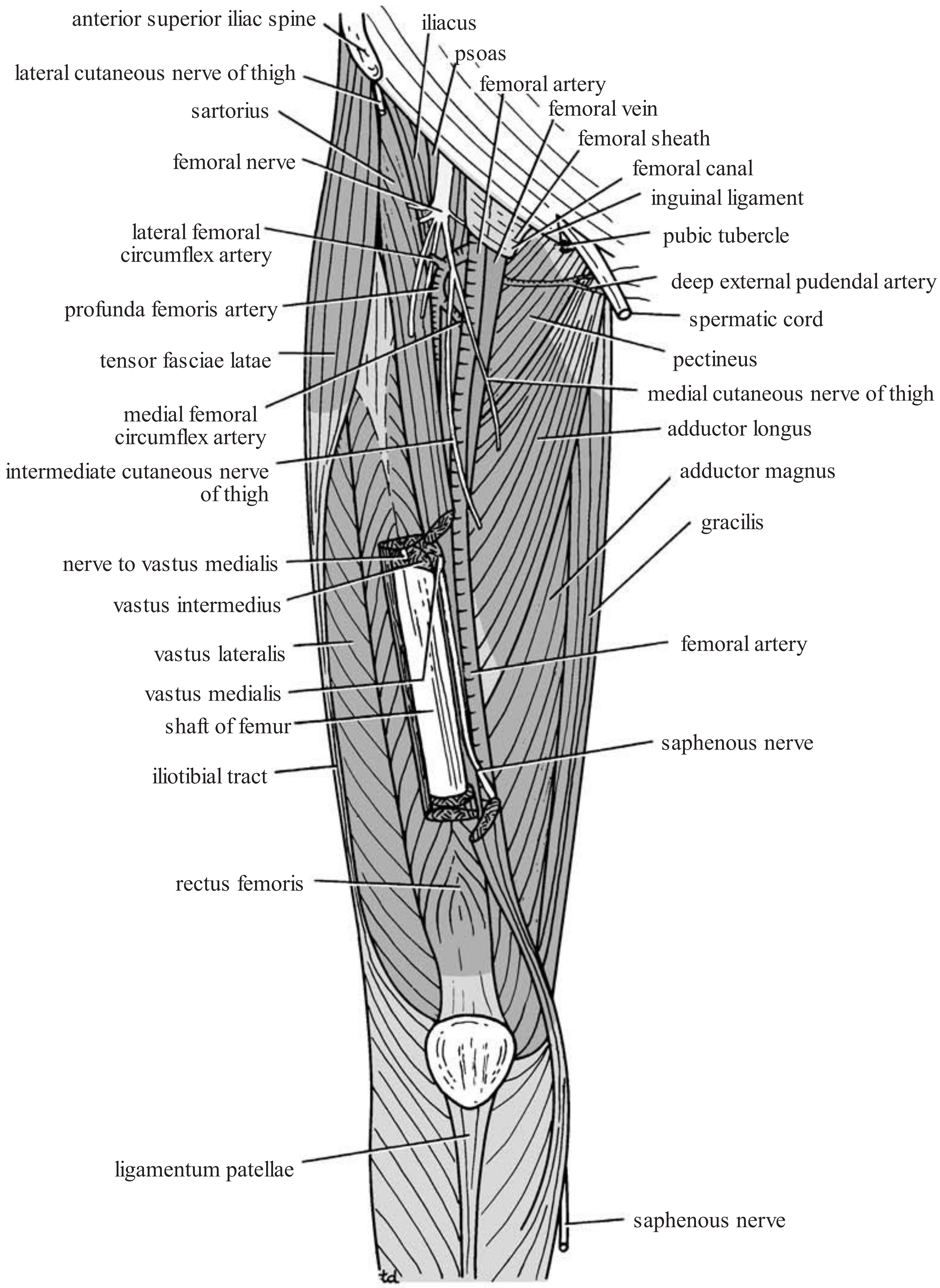


Figure 5-12 Femoral triangle and the adductor (subsartorial) canal in the right lower limb.

Table 5-2 Muscles of the Anterior Fascial Compartment of the Thigh

Muscle	Origin	Insertion	Nerve Supply	Action
Sartorius	Anterior superior iliac spine	Upper medial surface of the shaft of the tibia	Femoral nerve	Flexes, abducts, and laterally rotates the thigh at the hip joint; flexes and medially rotates the leg at the knee joint
Iliacus	Iliac fossa of the hip bone	With psoas into the lesser trochanter of the femur	Femoral nerve	Flexes the thigh on the trunk; if the thigh is fixed, it flexes the trunk on the thigh (as in sitting up from lying down)
Psoas	Twelfth thoracic vertebral body; transverse processes, bodies, and intervertebral discs of the five lumbar vertebae	With the iliacus into the lesser trochanter of the femur	Lumbar plexus	Flexes the thigh on the trunk; if the thigh is fixed, it flexes the trunk on the thigh (as in sitting up from lying down)
Pectineus	Superior ramus of the pubis	Upper end of the shaft of the femur	Femoral nerve	Flexes and adducts the thigh at the hip joint
Quadratus femoris				
Rectus femoris	Straight head; anterior inferior iliac spine; reflected head: ilium above the acetabulum	Quadriceps tendon into the patella	Femoral nerve	Extends the leg at the knee joint; flexes the thigh at the hip joint
Vastus lateralis	Upper end and shaft of the femur	Quadriceps tendon into the patella	Femoral nerve	Extends the leg at the knee joint
Vastus medialis	Upper end and shaft of the femur	Quadriceps tendon into the patella	Femoral nerve	Extends the leg at the knee joint
Vastus intermedius	Shaft of femur	Quadriceps tendon into the patella	Femoral nerve	Extends the leg at the knee joint

Table 5-3 Muscles of the Medial Fascial Compartment of the Thigh

Muscle	Origin	Insertion	Nerve Supply	Action
Gracilis	Inferior ramus of the pubis and ramus of the ischium	Upper part of the shaft of the tibia	Obturator nerve	Adducts the thigh at the hip joint; flexes the leg at the knee joint
Adductor longus	Body of the pubis	Posterior surface of the shaft of the femur	Obturator nerve	Adducts the thigh at the hip joint, assists in lateral rotation
Adductor brevis	Inferior ramus of the pubis	Posterior surface of the shaft of the femur	Obturator nerve	Adducts the thigh at the hip joint, assists in lateral rotation
Adductor magnus	Inferior ramus of the pubis, ramus of the ischium, and ischial tuberosity	Posterior surface of the shaft of the femur, adductor tubercle of the femur	Obturator nerve adductor part; sciatic nerve: hamstring part	Adducts the thigh at the hip joint, assists in lateral rotation, hamstring part extends the thigh at the hip joint
Obturator externus	Outer surface of the obturator membrane	Greater trochanter of the femur	Obturator nerve	Laterally rotates the thigh at the hip joint

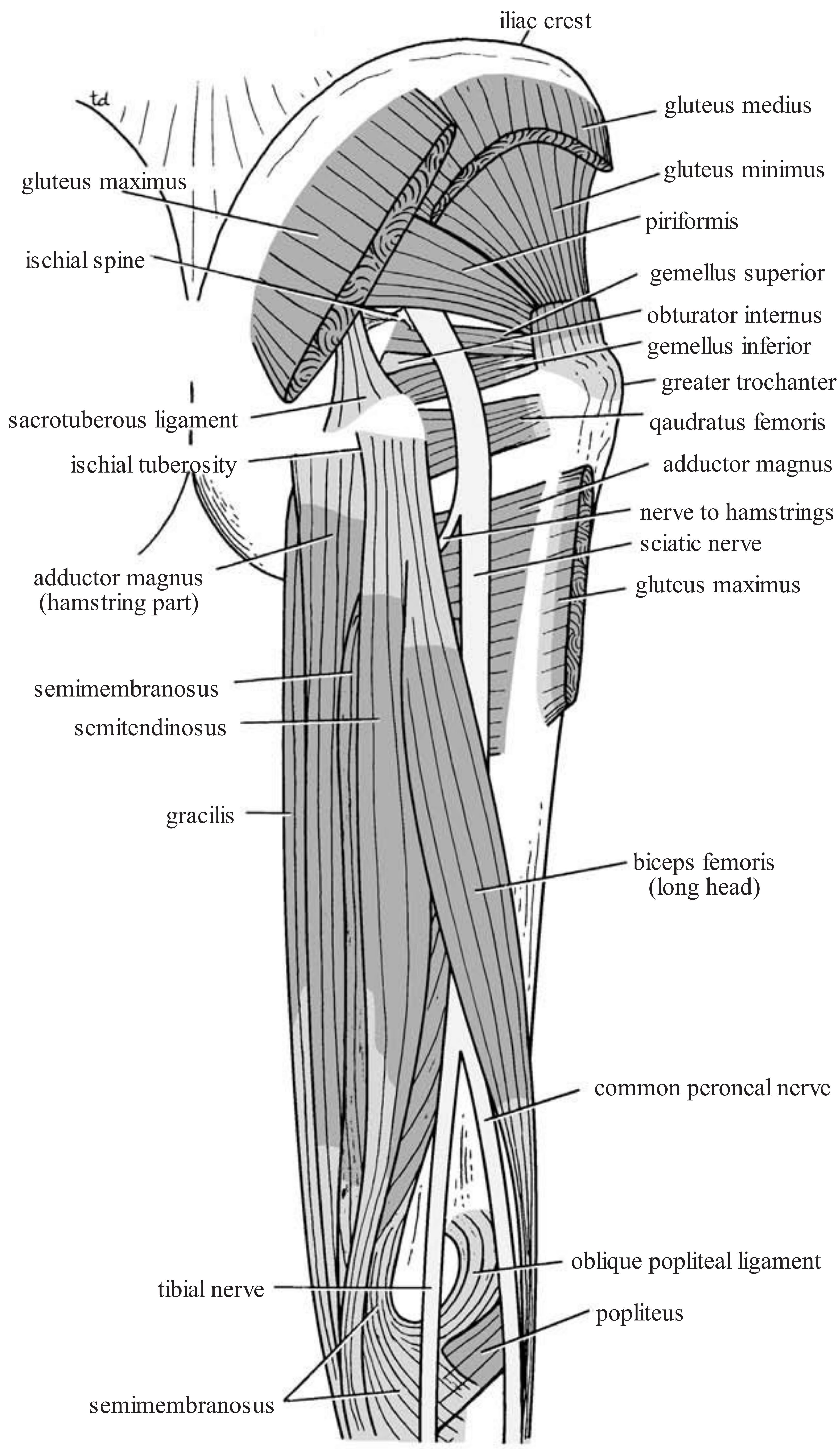


Figure 5-13 Structures of the posterior aspect of the right thigh.

Table 5-4 Muscles of the Posterior Fascial Compartment of the Thigh

Muscle	Origin	Insertion	Nerve Supply	Action
Biceps femoris	Long head: ischial tuberosity; short head: shaft of the femur	Head of the fibula	Sciatic nerve (long head: tibial nerve; short head: common peroneal nerve)	Flexes and laterally rotates the leg at the knee joint; the long head also extends the thigh at the hip joint
Semitendinosus	Ischial tuberosity	Upper part of the medial surface of the shaft of the tibial	Sciatic nerve (tibial portion)	Flexes and medially rotates the leg at the knee joint and extends the thigh at the hip joint
Semimembranosus	Ischial tuberosity	Medial condyle of the tibia, forms the oblique popliteal ligament	Sciatic nerve (tibial portion)	Flexes and medially rotates the leg at the knee joint and extends the thigh at the hip joint
Adductor magnus (hamstring portion)	Ischial tuberosity	Adductor tubercle of the femur	Sciatic nerve (tibial portion)	Extends the thigh at the hip joint

FEMORAL CANAL

The femoral canal is the small, medial compartment of the femoral sheath occupied by the lymphatics. It is approximately 0.5 in. (1.3 cm) in length. It is also a potentially weak area in the wall of the abdomen; a protrusion of peritoneum could be forced down the femoral canal to form a femoral hernia.

FEMORAL RING

The femoral ring is the upper opening of the femoral canal. It is filled by a plug of extra peritoneal fat called the **femoral septum.**

Important Relations

- **Anteriorly:** Inguinal ligament.
- **Posteriorly:** Superior ramus of the pubis and the pectineal ligament.
- **Laterally:** Femoral vein.
- **Medially:** Lacunar ligament (an extension of the inguinal ligament; see page 39).

CLINICAL NOTES

FEMORAL HERNIA

- A protrusion of the abdominal parietal peritoneum down through the femoral canal to form the hernial sac.
- More common in women than in men.
- The neck of the hernial sac lies below and lateral to the pubic tubercle.
- The neck of the hernial sac lies at the femoral ring and is related anteriorly to the inguinal ligament, posteriorly to the pectineal ligament, laterally to the femoral vein, and medially to the sharp, free edge of the lacunar ligament.

ADDUCTOR (SUBSARTORIAL) CANAL

The adductor canal is an intermuscular cleft on the medial aspect of the middle third of the thigh beneath the sartorius muscle. The posterior wall is formed by the adductor magnus muscle, the lateral wall by the vastus medialis, and the anteromedial wall by the sartorius muscle and fascia. The canal contains the femoral artery and vein, the deep lymph vessels, the saphenous nerve, and the nerve to the vastus medialis muscle.

Knee Region

POPLITEAL FOSSA

The popliteal fossa is a diamond-shaped, intermuscular space at the back of the knee (Fig. 5-14). It contains the popliteal vessels, the small saphenous vein, the common peroneal and tibial nerves, the posterior cutaneous nerve of the thigh, connective tissue, and lymph nodes.

BOUNDARIES

- Laterally: The biceps femoris muscle above and the lateral head of the gastrocnemius and plantaris muscles below.
- Medially: The semimembranosus and semitendinosus muscles above and the medial head of the gastrocnemius muscle below.

Leg

The muscles of the anterior fascial compartment (Fig. 5-9) are described in Table 5-5. The muscles of the lateral fascial compartment (Fig. 5-9) are described in Table 5-6, and the muscles of the posterior fascial compartment (Fig. 5-15) are described in Table 5-7. The muscle on the dorsum of the foot is described in Table 5-8.

FASCIAL COMPARTMENTS OF THE LEG

The deep fascia surrounds the leg and is continuous above with the deep fascia of the thigh. It is attached to the anterior and the medial borders of the tibia, and two intermuscular septa pass from its deep aspect to be attached to the fibula. Together with the interosseous membrane, the septa divide

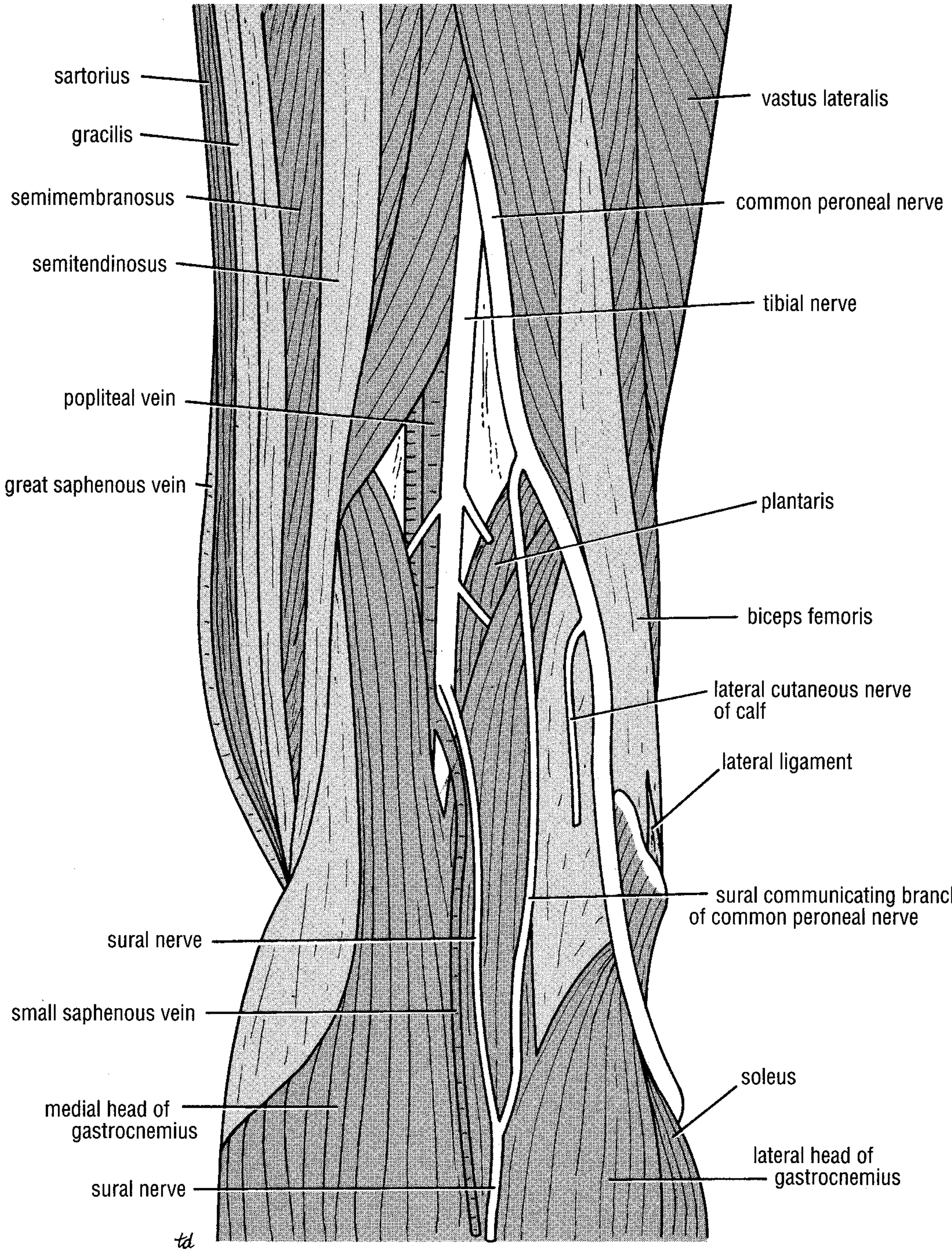


Figure 5-14 Boundaries and contents of the right popliteal fossa.

Table 5-5 Muscles of the Anterior Fascial Compartment of the Leg

Muscle	Origin	Insertion	Nerve Supply	Action[a]
Tibialis anterior	Shaft of the tibia and the interosseous membrane	Medial cuneiform and base of the first metatarsal bone	Deep peroneal nerve	Extends the foot at the ankle joint, inverts the foot at the subtalar and the transverse tarsal joints, and holds up the medial longitudinal arch of the foot
Extensor digitorum longus	Shaft of the fibula and the interosseous membrane	Extensor expansion of the lateral four toes	Deep peroneal nerve	Extends the toes and dorsiflexes the foot at the ankle joint
Peroneus tertius	Shaft of the fibula and the interosseous membrane	Base of the fifth metatarsal bone	Deep peroneal nerve	Dorsiflexes the foot at the ankle joint and everts foot at the subtalar and the transverse tarsal joints
Extensor hallucis longus	Shaft of the fibula and the interosseous membrane	Base of the distal phalanx of the great toe	Deep peroneal nerve	Extends the big toe, dorsiflexes the foot at the ankle joint, and inverts the foot at the subtalar and the transverse tarsal joints

[a]Extension (or dorsiflexion) of the ankle is the movement of the foot away from the ground.

Table 5-6 Muscles of the Lateral Fascial Compartment of the Leg

Muscle	Origin	Insertion	Nerve Supply	Action
Peroneus longus	Shaft of fibula	Base of first metatarsal bone and the medial cuneiform	Superficial peroneal nerve	Plantar flexes the foot at the ankle joint, everts the foot at the subtalar and the transverse tarsal joints, holds up the lateral longitudinal arch of the foot, and supports the transverse arch
Peroneus brevis	Shaft of the fibula	Base of the fifth metatarsal bone	Superficial peroneal nerve	Plantar flexes the foot at the ankle joint, everts the foot at the subtalar and the transverse tarsal joints, and holds up the lateral longitudinal arch of the foot

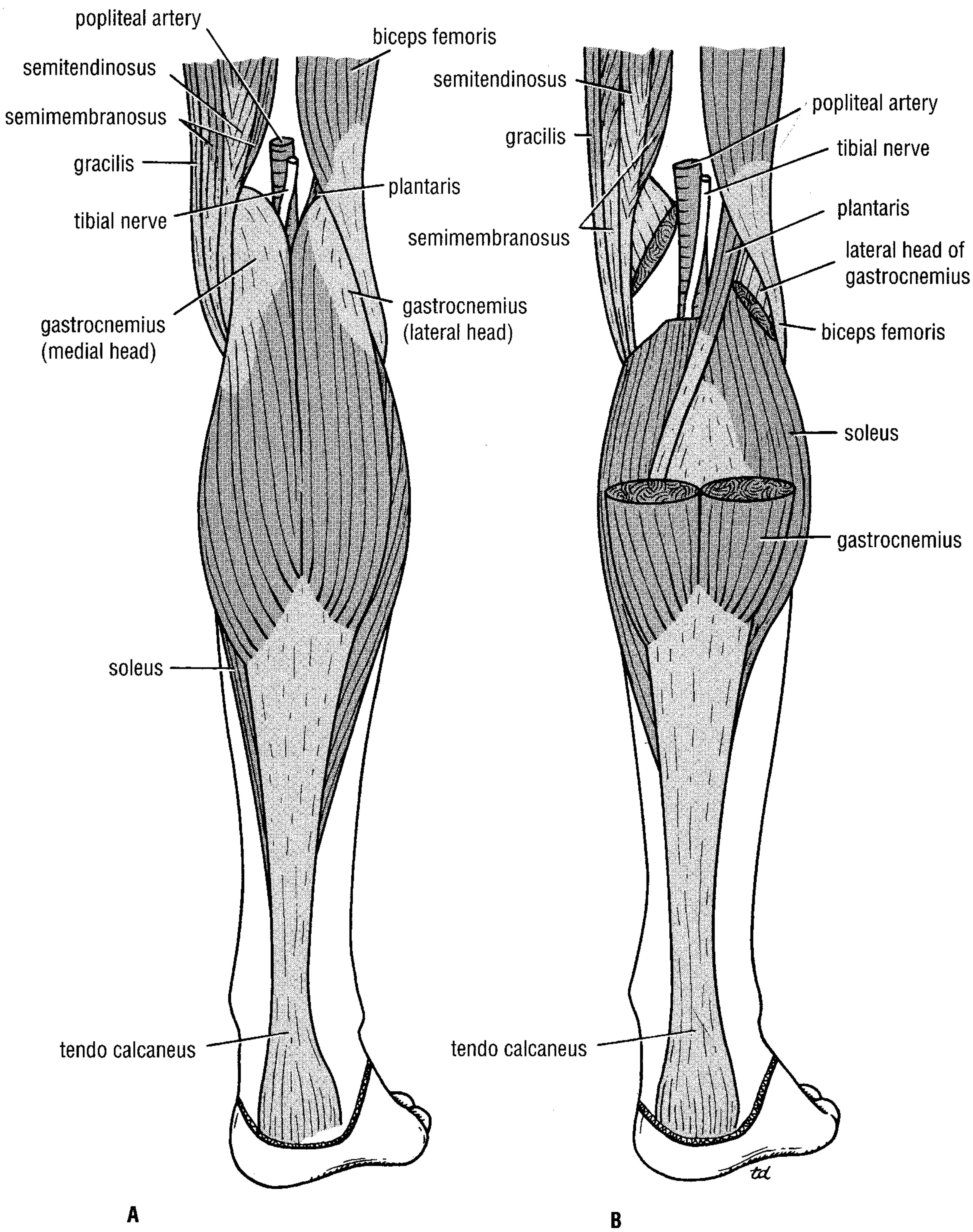


Figure 5-15 Structures of the posterior aspect of the right leg. **A.** The gastrocnemius muscle is shown in full. **B.** Part of the gastrocnemius muscle has been removed.

Table 5-7 Muscles of the Posterior Fascial Compartment of the Leg

Muscle	Origin	Insertion	Nerve Supply	Action
Superficial Group				
Gastrocnemius	Medial and lateral condyles of the femur	Via tendo calcaneus (Achilles tendon) into the calcaneum	Tibial nerve	Plantar flexes the foot at the ankle joint, flexes the knee joint
Plantaris	Lateral supracondylar ridge of the femur	Calcaneum	Tibial nerve	Plantar flexes the foot at the ankle joint, flexes the knee joint
Soleus	Shafts of the tibia and the fibula	Via tendo calcaneus (Achilles tendon) into the calcaneum	Tibial nerve	Together with the gastrocnemius and the plantaris, it is a powerful flexor of the ankle joint; provides the main propulsive force in walking and running
Deep Group				
Popliteus	Lateral condyle of the femur	Shaft of the tibia	Tibial nerve	Flexes the leg at the knee joint; unlocks the knee joint by laterally rotating the femur on the tibia, thus slackening the ligaments of the joint
Flexor digitorum longus	Shaft of the tibia	Bases of the distal phalanges of the lateral four toes	Tibial nerve	Flexes the distal phalanges of the lateral four toes, plantar flexes the foot, and supports the medial and the lateral longitudinal arches of the foot
Flexor hallucis longus	Shaft of the fibula	Base of the distal phalanx of the big toe	Tibial nerve	Flexes the distal phalanx of the big toe, plantar flexes the foot at the ankle joint, and supports the medial longitudinal arch of the foot
Tibialis posterior	Shafts of the tibia and the fibula and the interosseous membrane	Tuberosity of the navicular and other neighboring bones	Tibial nerve	Plantar flexes the foot at the ankle joint, inverts the foot at the subtalar and the transverse tarsal joints, and supports the medial longitudinal arch of the foot

Table 5-8 Muscle on the Dorsum of the Foot

Muscle	Origin	Insertion	Nerve Supply	Action
Extensor digitorum brevis	Calcaneum	By four tendons into the proximal phalanx of the big toe (sometimes called the extensor hallucis brevis) and long extensor tendons to the second, third, and fourth toes	Deep peroneal nerve	Extends the first, second, third, and fourth toes

the leg into three compartments, with each having its own muscles, blood supply, and nerve supply. The compartments are as follows:

- Anterior with the deep peroneal nerve.
- Lateral (peroneal) with the superficial peroneal nerve.
- Posterior with the tibial nerve.

INTEROSSEOUS MEMBRANE

The interosseous membrane binds the tibia and the fibula together and provides attachment for the muscles.

Ankle

RETINACULA

The retinacula are thickenings of the deep fascia that keep the long tendons around the ankle joint in position and act as pulleys (Fig. 5-10).

Superior Extensor Retinaculum

The superior extensor retinaculum is attached to the distal ends of the anterior borders of the fibula and the tibia (Fig. 5-9).

Inferior Extensor Retinaculum

The inferior extensor retinaculum is a Y-shaped band located in front of the ankle joint (Fig. 5-9).

Flexor Retinaculum

The flexor retinaculum extends from the medial malleolus to the medial surface of the calcaneum (Fig. 5-10). It binds the deep muscles of the back of the leg to the back of the medial malleolus as they pass forward to enter the sole.

Superior Peroneal Retinaculum

The superior peroneal retinaculum connects the lateral malleolus to the lateral surface of the calcaneum (Fig. 5-10). It binds the tendons of the peroneus longus and brevis muscles to the back of the lateral malleolus.

Inferior Peroneal Retinaculum

The inferior peroneal retinaculum binds the tendons of the peroneus longus and brevis muscles to the lateral side of the calcaneum (Fig. 5-10).

Sole of Foot

The muscles of the sole (Figs. 5-16 and 5-17) are usually described in four layers (from inferior to superior). These muscles are listed in Table 5-9.

DEEP FASCIA

Plantar Aponeurosis

The plantar aponeurosis is a triangular thickening of the deep fascia that protects the underlying nerves, blood vessels, and muscles. Its apex is attached to the medial and the lateral tubercles of the calcaneum. The base of the aponeurosis divides into five slips that pass into the toes.

ARCHES OF THE FOOT

There are three bony arches in the sole.

Medial Longitudinal Arch

The medial longitudinal arch is formed by the calcaneum, the talus, the navicular bone, three cuneiform bones, and the first (medial) three metatarsal bones.

- **Muscular support:** Medial part of the flexor digitorum brevis, abductor hallucis, flexor hallucis longus, medial part of the flexor digitorum longus, flexor hallucis brevis, tibialis anterior, and tendinous extensions of the insertion of the tibialis posterior.
- **Ligamentous support:** Plantar and dorsal ligaments, including the important calcaneonavicular (spring) ligament, the medial ligament of the ankle joint, and the plantar aponeurosis.

Lateral Longitudinal Arch

The lateral longitudinal arch is formed by the calcaneum, the cuboid, and the fourth and the fifth metatarsal bones.

- **Muscular support:** Abductor digiti minimi, lateral part of the flexor digitorum longus and brevis, and peroneus longus and brevis.
- **Ligamentous support:** Long and short plantar ligaments and plantar aponeurosis.

Transverse Arch

The transverse arch is formed by the bases of the metatarsal bones, the cuboid, and the three cuneiform bones. The wedge shape of the cuneiform bones and the bases of the metatarsal bones play a large role in the support of the transverse arch.

- **Muscular support:** Dorsal interossei, transverse head of the adductor hallucis, and peroneus longus and brevis.
- **Ligamentous support:** Deep transverse ligaments and very strong plantar ligaments.

ARTERIES OF THE LOWER LIMB

Femoral Artery

The femoral artery is a continuation of the external iliac artery (Fig. 5-18). It begins behind the inguinal ligament, where it lies midway between the anterior superior iliac spine and the symphysis pubis (the site for taking a femoral pulse). The artery descends through the femoral triangle (Fig. 5-12) and the adductor canal, and it leaves the front of the thigh by passing through the opening in the adductor magnus and then entering the popliteal space as the popliteal artery (Fig. 5-14).

In the femoral triangle, the artery is related laterally to the femoral nerve and medially, in the upper part of its course, to the femoral vein and the femoral canal.

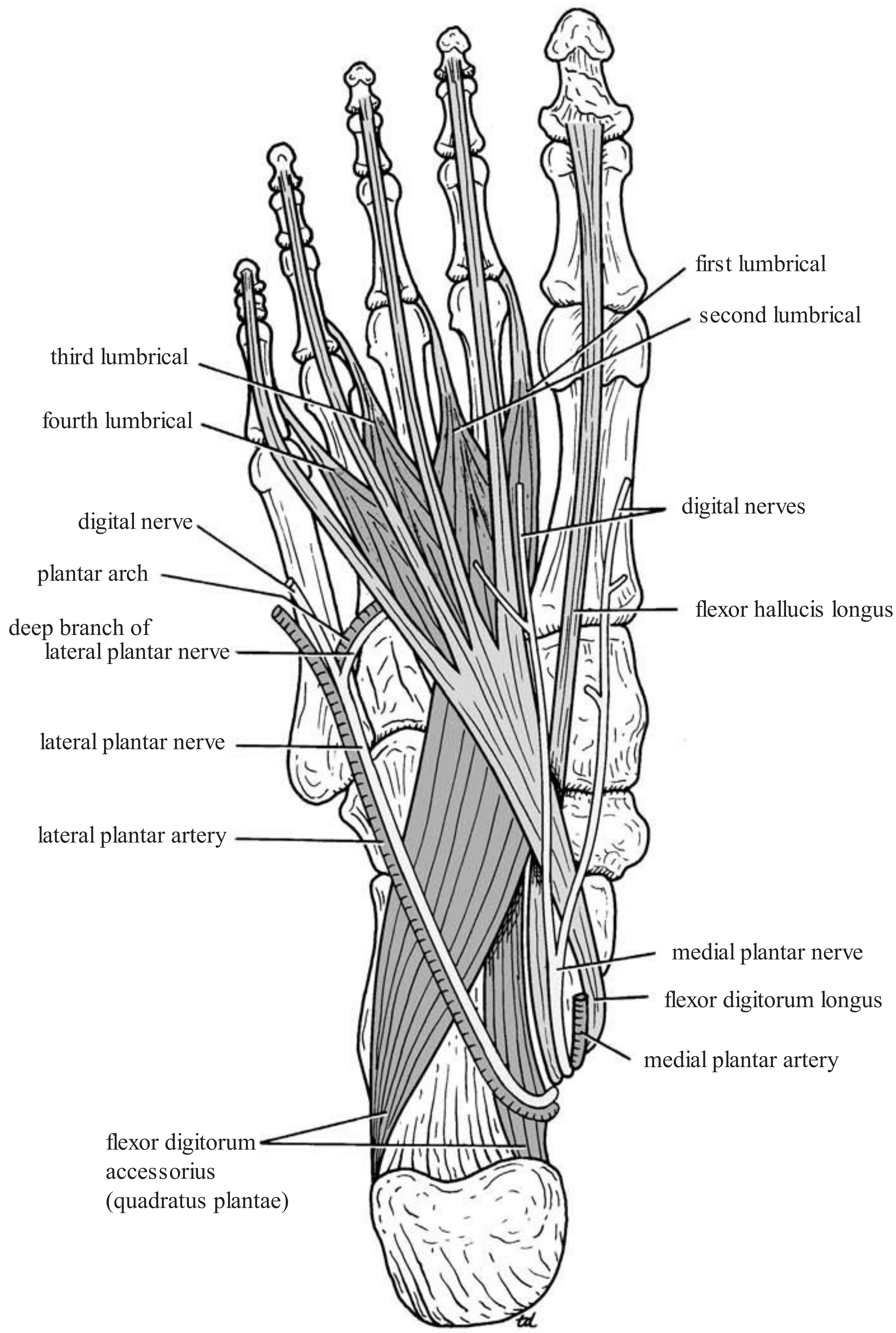


Figure 5-16 Second layer of the plantar muscles of the right foot. Note the medial and the lateral plantar arteries and nerves.

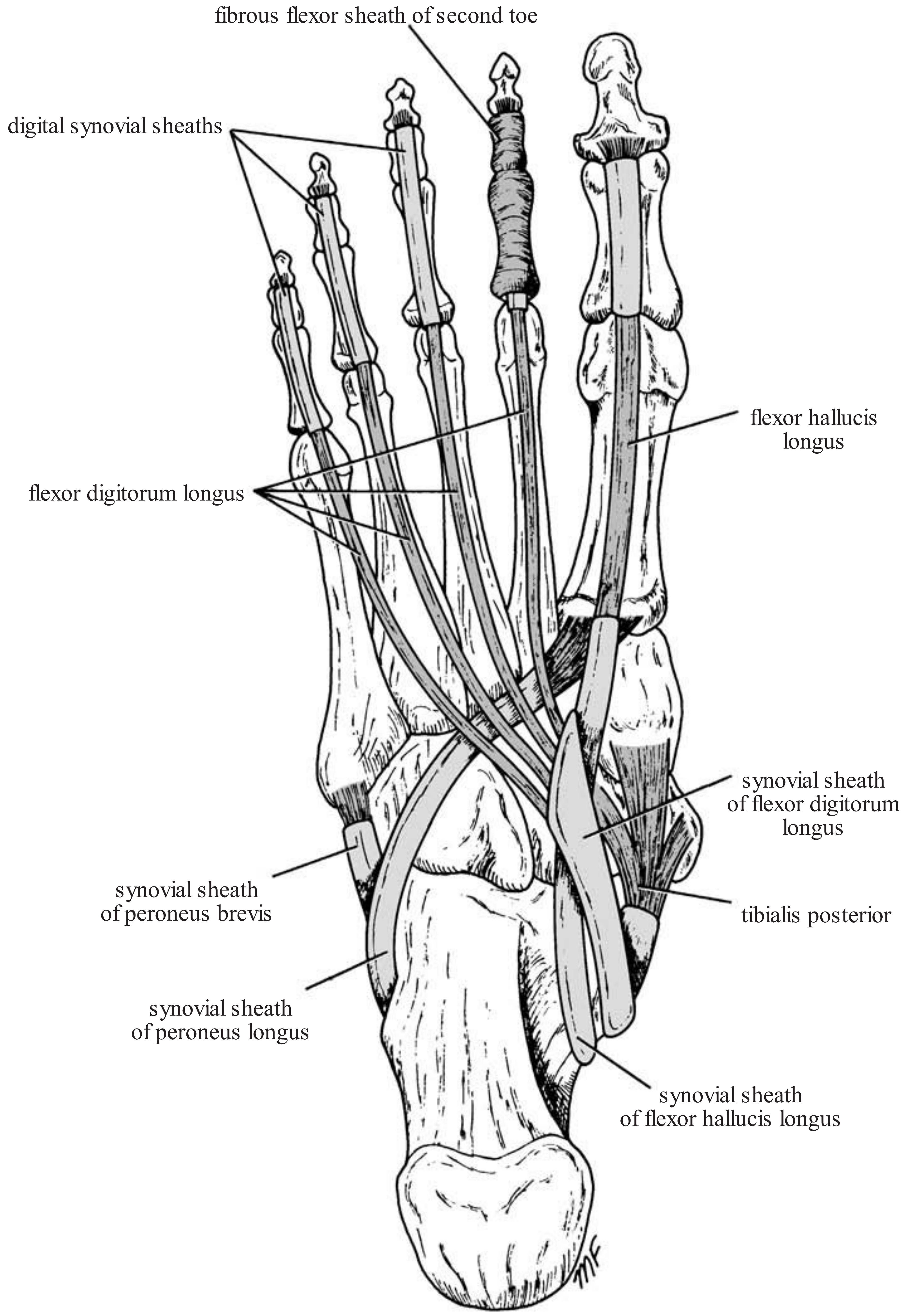


Figure 5-17 Synovial sheaths of tendons on the sole of the right foot.

Table 5-9 Muscles of the Sole

Muscle	Origin	Insertion	Nerve Supply	Action
First Layer				
Abductor hallucis	Medial tubercle of the calcaneum, flexor retinaculum	Medial side of the base of the proximal phalanx of the big toe	Medial plantar nerve	Flexes and abducts the big toe, supports the medial longitudinal arch
Flexor digitorum brevis	Medial tubercle of the calcaneum	Medial phalanx of the four lateral toes	Medial plantar nerve	Flexes the lateral four toes, supports the medial and the lateral longitudinal arches
Abductor digiti minimi	Medial and lateral tubercles of the calcaneum	Lateral side of the base of the proximal phalanx of the fifth toe	Lateral plantar nerve	Flexes and abducts the fifth toe, supports the lateral longitudinal arch
Second Layer				
Flexor digitorum accessorius	Medial and lateral sides of the calcaneum	Tendon of the flexor digitorum longus	Lateral plantar nerve	Assists the long flexor tendons to flex the lateral four toes
Flexor digitorum longus	Shaft of the tibia	Base of the distal phalanx of the lateral four toes	Tibial nerve	Flexes the distal phalanges of the lateral four toes, plantar flexes the foot, and supports the longitudinal arches
Lumbricals (4)	Tendons of the flexor digitorum longus	Dorsal extensor expansion of the lateral four toes	First lumbrical: medial plantar nerve; remainder: deep branch of the lateral plantar nerve	Extends the toes at the interphalangeal joints
Flexor hallucis longus	Shaft of the fibula	Base of the distal phalanx of the big toe	Tibial nerve	Flexes the distal phalanx of the big toe, plantar flexes the foot, and supports the medial longitudinal arch
Third Layer				
Flexor hallucis brevis	Cuboid and lateral cuneiform bones; tibialis posterior insertion	Medial and lateral sides of the base of the proximal phalanx of the big toe	Medial plantar nerve	Flexes the metatarsophalangeal joint of the big toe, supports the medial longitudinal arch
Adductor hallucis				
Oblique head	Bases of the second, third, and fourth metatarsal bones	Lateral side of the base of the proximal phalanx of the big toe	Deep branch of the lateral plantar nerve	Flexes the big toe, supports the transverse arch
Transverse head	Plantar ligaments	Lateral side of the base of the proximal phalanx of the big toe	Deep branch of the lateral plantar nerve	Flexes the big toe, supports the transverse arch
Flexor digiti minimi brevis	Base of the fifth metatarsal bone	Lateral side of the base of the proximal phalanx of the little toe	Lateral plantar nerve	Flexes the little toe
Fourth Layer				
Interossei				
Dorsal (4)	Adjacent sides of the metatarsal bones	Bases of the phalanges and the dorsal expansion of the corresponding toes	Lateral plantar nerve	Abduct the toes from the second toe, flex the metatarsophalangeal joints, and extend the interphalangeal joints
Plantar (3)	Inferior surfaces of the third, fourth, and fifth metatarsal bones	Bases of the phalanges and the dorsal expansion of the corresponding toes	Lateral plantar nerve	Adduct the toes to the second toe, flex the metatarsophalangeal joints, and extend the interphalangeal joints
Peroneus longus	Shaft of the fibula	Base of the first metatarsal bone and the medial cuneiform	Superficial peroneal nerve	Plantar flexes the foot at the ankle joint, everts the foot at the subtalar and the transverse tarsal joints, and holds up the lateral longitudinal and the transverse arches of the foot
Tibialis posterior	Shafts of the tibia and the fibula and the interosseous membrane	Tuberosity of the navicular and other neighboring bones	Tibial nerve	Plantar flexes the foot at the ankle joint, inverts the foot at the subtalar and the transverse tarsal joints, and supports the medial longitudinal arch of the foot

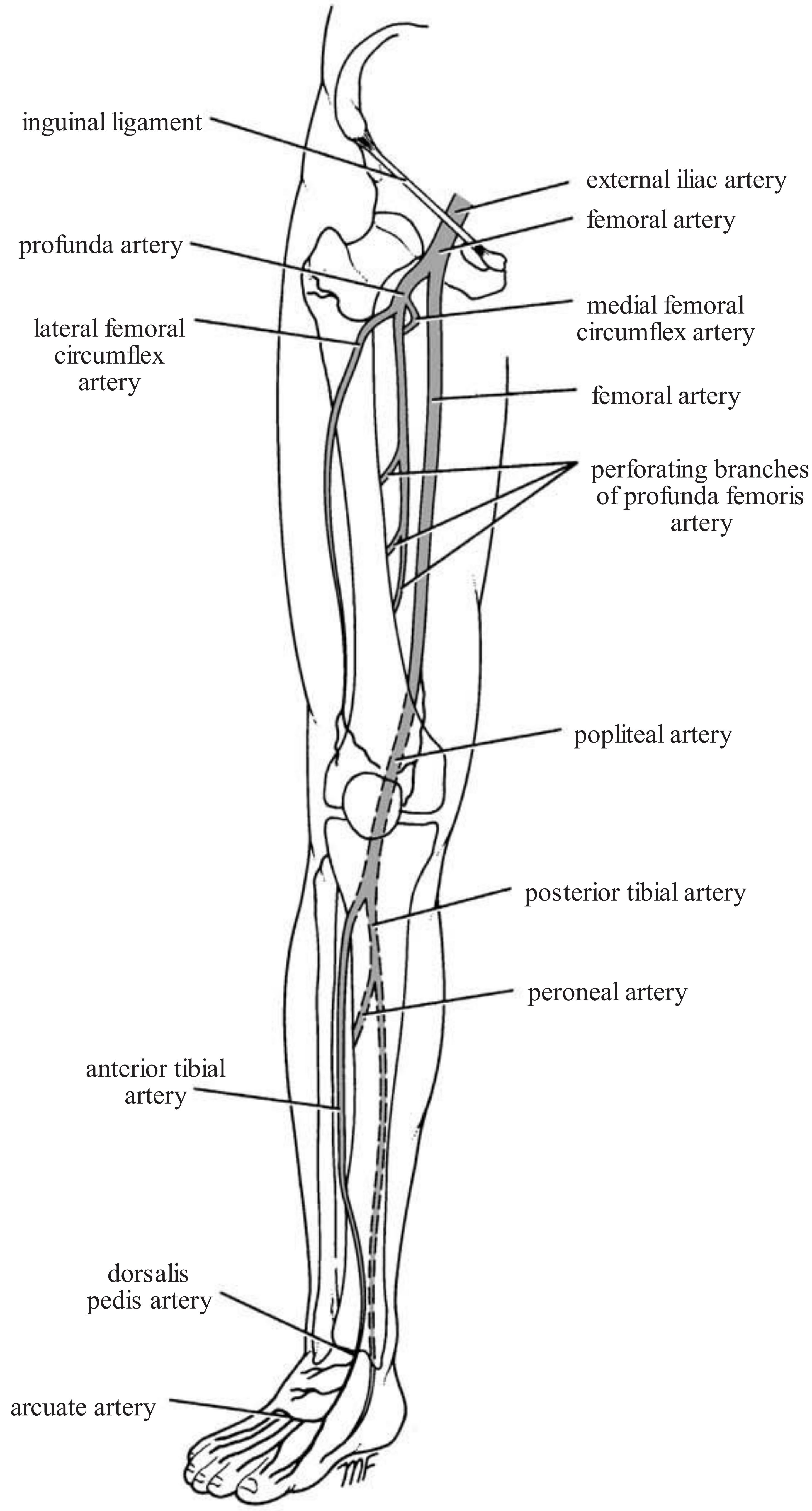


Figure 5-18 Major arteries of the lower limb.

BRANCHES

- **Superficial circumflex iliac artery,** which arises just below the inguinal ligament and runs laterally toward the anterior superior iliac spine.
- **Superficial epigastric artery,** which arises just below the inguinal ligament and runs upward to the abdominal wall.
- **Superficial external pudendal artery.**
- **Deep external pudendal artery** and the superficial external pudendal artery arise just below the inguinal ligament and run medially to supply the skin of the scrotum (or labium majus).
- **Profunda femoris artery,** which is a large branch that arises from the femoral artery approximately 1.5 in. (4 cm) below the inguinal ligament (Fig. 5-12). It supplies structures in the anterior, medial, and posterior fascial compartments of the thigh via the following branches: **medial and lateral femoral circumflex arteries** and **four perforating arteries.**
- **Descending genicular artery.**

TROCHANTERIC ANASTOMOSIS

The trochanteric anastomosis provides the main blood supply to the head of the femur (in adults) via the following arteries:

- Superior gluteal artery.
- Inferior gluteal artery.
- Medial femoral circumflex artery.
- Lateral femoral circumflex artery.

CRUCIATE ANASTOMOSIS

Together with the trochanteric anastomosis, the cruciate anastomosis provides the important connection between the internal iliac and the femoral arteries. The following arteries are involved:

- Inferior gluteal artery.
- Medial femoral circumflex artery.
- Lateral femoral circumflex artery.
- First perforating artery, which is a branch of the profunda artery.

Popliteal Artery

The popliteal artery (Fig. 5-18) is a continuation of the femoral artery. It extends from the opening in the adductor magnus to the lower border of the popliteus muscle, where it divides into the anterior and the posterior tibial arteries. It is deeply placed in the popliteal fossa and lies close to the posterior surface of the femur and the knee joint.

BRANCHES

- **Muscular branches.**
- **Articular branches** to the knee joint.
- **Terminal branches:** Anterior and posterior tibial arteries.

ANASTOMOSIS AROUND THE KNEE JOINT

The arteries involved in anastomosis around the knee joint are as follows:

- The descending genicular artery from the femoral artery.
- The lateral femoral circumflex artery from the profunda femoris.
- The articular branches from the popliteal artery.
- The branches from the anterior and the posterior tibial arteries.

Anterior Tibial Artery

The anterior tibial artery arises at the bifurcation of the popliteal artery in the popliteal fossa (Fig. 5-18). It passes forward between the tibia and the fibula through the upper part of the interosseus membrane and enters the anterior compartment of the leg. It then descends with the deep peroneal nerve to the front of the ankle joint, where it becomes the dorsalis pedis artery (Fig. 5-9).

At the ankle, the anterior tibial artery lies midway between the malleoli and has the tendon of the extensor hallucis longus muscle on its medial side and the tendons of extensor digitorum longus muscle on its lateral side **(the site for taking an anterior tibial pulse).**

BRANCHES

- **Muscular branches.**
- **Anastomotic branches,** which anastomose with branches of other arteries around the knee and ankle joints.

Dorsalis Pedis Artery

The dorsalis pedis artery begins in front of the ankle joint midway between the malleoli and is a continuation of the anterior tibial artery (Figs. 5-9 and 5-18). The dorsalis pedis artery ends by entering the sole through the proximal part of the space between the first and second metatarsal bones. Having passed between the two heads of the first dorsal interosseous muscle, it joins the lateral plantar artery and completes the plantar arch (Fig. 5-16).

At first, the artery is superficial, having the tendons of the extensor digitorum longus muscle on its lateral side and the tendon of the extensor hallucis longus muscle on its medial side **(the site for taking a dorsalis pedis pulse).**

BRANCHES

- **Lateral tarsal artery,** which supplies the dorsum of the foot.
- **Arcuate artery,** which runs laterally across the bases of the metatarsal bones and gives off branches to the toes.
- **First dorsal metatarsal artery,** which supplies both sides of the big toe.

Posterior Tibial Artery

The posterior tibial artery arises at the bifurcation of the popliteal artery in the popliteal fossa (Fig. 5-18). It descends in the posterior compartment of the leg and is accompanied by the tibial nerve. The artery terminates behind the medial malleolus by dividing into the medial and the lateral plantar arteries. The pulse may be felt midway between the medial malleolus and the heel.

BRANCHES

- **Peroneal artery,** which is a large artery that arises close to the origin of the posterior tibial artery. It descends in close association with the flexor hallucis longus muscle to the region of the ankle, and it gives off **muscular branches,** a **nutrient artery** to the fibula, and **anastomotic branches** around the ankle joint.
- **Muscular branches.**
- **Nutrient artery** to the tibia.
- **Anastomotic branches** around the ankle joint.
- **Medial** and **lateral plantar arteries.**

Medial Plantar Artery

The medial plantar artery is the smaller of the terminal branches of the posterior tibial artery (Fig. 5-16). It runs forward along the medial border of the foot with the medial plantar nerve, and it gives off many muscular and cutaneous branches.

Lateral Plantar Artery

The lateral plantar artery is the larger of the terminal branches of the posterior tibial artery (Fig. 5-16). It runs forward deep to the abductor hallucis and the flexor digitorum brevis muscles with the lateral plantar nerve, and it ends by curving medially to form the **plantar arch** through anastomosis with the dorsalis pedis artery. The plantar arch gives off perforating and metatarsal arteries; the metatarsal arteries give rise to digital arteries.

CLINICAL NOTES

Compression of Arteries of the Lower Limb

Medical personal should know the precise position of the main arteries within the lower limb.

- **Femoral artery:** This enters the thigh behind the inguinal ligament at a point midway between the anterior superior iliac spine and the symphysis pubis.
- **Popliteal artery:** This artery can be felt by gentle palpation in the depths of the popliteal space, provided that the deep fascia is fully relaxed by passively flexing the knee joint.
- **Dorsalis pedis artery:** This artery lies between the tendons of the extensor hallucis longus and the extensor digitorum longus, midway between the medial and lateral malleoli on the front of the ankle.
- **Posterior tibial artery:** This artery passes behind the medial malleolus, beneath the flexor retinaculum, and lies between the tendons of flexor digitorum longus and the flexor hallucis longus. The pulsations of the artery can be felt midway between the medial malleolus and the heel.

CLINICAL NOTES

Ligation of Arteries of the Lower Limb

Sudden occlusion of the femoral artery by ligature is usually followed by gangrene. However, gradual occlusion, such as occurs in atherosclerosis, is less likely to be followed by necrosis because the collateral blood vessels have time to dilate fully. The collateral circulation for the proximal part of the femoral artery is through the cruciate and trochanteric anastomoses; for the femoral artery in the adductor canal, it is through the perforating branches of the profunda femoris artery and the articular and muscular branches of the femoral and popliteal arteries.

VEINS OF THE LOWER LIMB

The superficial veins lie in the superficial fascia and are of great clinical importance. The deep veins accompany the main arteries.

Superficial Veins

DORSAL VENOUS NETWORK

The dorsal venous network lies on the dorsum of the foot (Fig. 5-19). It is drained on the medial side by the great saphenous vein and on the lateral side by the small saphenous vein.

GREAT SAPHENOUS VEIN

The great saphenous vein arises from the medial side of the dorsal venous network of the foot (Fig. 5-19), and it ascends directly **in front of** the medial malleolus. Accompanied by the saphenous nerve, it ascends the leg in the superficial fascia, passes behind the knee, and curves forward around the medial side of the thigh. It then passes through the saphenous opening in the deep fascia and joins the femoral vein approximately 1.5 in. (4 cm) below and lateral to the pubic tubercle. The great saphenous vein possess numerous valves, and it is connected to the small saphenous vein by branches that pass behind the knee. Several **perforating veins** connect the great saphenous vein with the deep veins along the medial side of the calf.

The great saphenous vein receives the following small tributaries near its termination:

- The **superficial circumflex iliac vein.**
- The **superficial epigastric vein.**
- The **superficial external pudendal vein.**

CLINICAL NOTES

The Clinical Importance of the Great Saphenous Vein

- **Blood transfusions:** The constant position of the great saphenous vein in front of the medial malleolus should be remembered for patients requiring emergency blood transfusion.
- **Bypass operations:** The insertion of a graft of a portion of the great saphenous vein can be used in occlusive coronary artery disease and also to bypass obstructions of the brachial or femoral arteries.

SMALL SAPHENOUS VEIN

The small saphenous vein arises from the lateral side of the dorsal venous network of the foot (Fig. 5-19). It ascends **behind** the lateral malleolus in company with the sural nerve, passes up the back of the leg, and pierces the deep

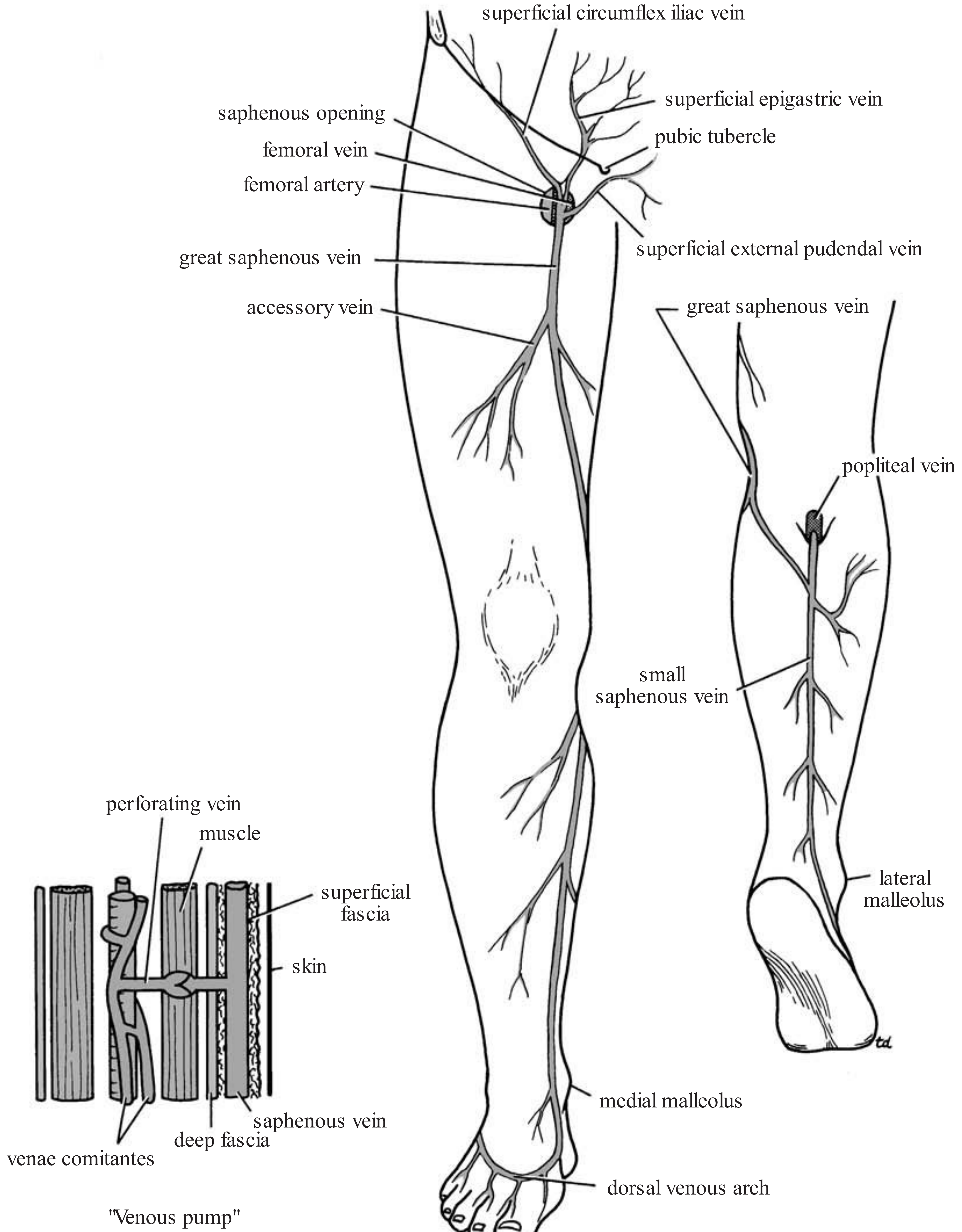


Figure 5-19 Superficial veins of the right lower limb. Note the importance of the valved perforating veins in the "venous pump."

fascia to enter the popliteal fossa. It drains into the popliteal vein. The small saphenous vein communicates with the deep veins and with the great saphenous vein.

The superficial veins of the lower limbs are common sites for varicosities.

Deep Veins

VENAE COMITANTES

The deep veins accompany the respective arteries as venae comitantes. The venae comitantes of the anterior and the posterior tibial arteries unite in the popliteal fossa to form the popliteal vein.

POPLITEAL VEIN

The popliteal vein is formed by the union of the venae comitantes of the anterior and the posterior tibial arteries (Fig. 5-14). It ends by passing through the opening in the adductor magnus muscle to become the femoral vein. The popliteal vein receives numerous tributaries, including the small saphenous vein.

FEMORAL VEIN

The femoral vein is a continuation of the popliteal vein at the opening in the adductor magnus muscle. It ascends through the adductor canal and the femoral triangle and is accompanied by the femoral artery. In the femoral sheath, it lies on the medial side of the femoral artery and on the lateral side to the femoral canal. As it ascends behind the inguinal ligament, it becomes continuous with the external iliac vein. The femoral vein receives the great saphenous vein and the veins that correspond to branches of the femoral artery.

LYMPHATIC DRAINAGE OF THE LOWER LIMB

The **superficial lymph vessels** ascend the limb in the superficial fascia with the superficial veins. The **deep lymph vessels** lie deep to the deep fascia and follow the deep arteries and veins. All the lymph vessels of the lower limb ultimately drain into the deep inguinal group of nodes that are situated in the groin.

Superficial Inguinal Nodes

The superficial inguinal nodes lie in the superficial fascia just below the inguinal ligament and drain into the deep inguinal nodes. The superficial inguinal nodes may be divided into a horizontal and a vertical group.

HORIZONTAL GROUP

The horizontal group receives lymph from the superficial lymph vessels of the anterior abdominal wall below the level of the umbilicus, the perineum, the external genitalia in both sexes (but not the testes), and the lower half of the anal canal. It also receives lymph from the skin of the buttocks.

VERTICAL GROUP

The vertical group lies alongside the terminal part of the great saphenous vein and receives most of the superficial lymph vessels of the lower limb (except from the back and lateral side of the calf and the lateral side of the foot, which drain into the popliteal nodes).

Deep Inguinal Nodes

The deep inguinal nodes are usually three in number and lie along the medial side of the femoral vein and in the femoral canal. They receive all the lymph from the superficial inguinal nodes and the deep structures of the lower limb. The efferent lymph vessels pass upward through the femoral canal into the abdominal cavity, and they drain into the external iliac nodes.

Popliteal Lymph Nodes

Situated in the popliteal fossa, the popliteal lymph nodes receive the superficial lymph vessels that accompany the small saphenous vein from the lateral side of the foot and from the back and the lateral side of the calf. They also receive lymph from the deep structures of the leg below the knee. The efferent vessels from these nodes drain upward to the deep inguinal nodes.

NERVES OF THE LOWER LIMB

Femoral Nerve

The femoral nerve arises from the lumbar plexus (L2, 3, and 4). It enters the thigh behind the inguinal ligament, and it lies lateral to the femoral vessels and the femoral sheath in the femoral triangle (Fig. 5-12). It quickly terminates by dividing into the anterior and the posterior divisions.

BRANCHES OF THE FEMORAL NERVE IN THE THIGH

- **Cutaneous branches: Medial cutaneous nerve of the thigh,** which supplies the skin on the medial side of the thigh. **Intermediate cutaneous nerve of the thigh,** which supplies the skin on the anterior surface of the thigh. **Saphenous nerve,** which descends through the femoral triangle and the adductor canal and crosses the femoral artery. The nerve emerges on the medial side of the knee joint between the tendons of the sartorius and the gracilis muscles, and it accompanies the great saphenous vein down the medial side of the leg and in front of the medial malleolus. It passes along the medial border of the foot as far as the ball of the big toe.
- **Muscular branches** to the sartorius, the pectineus, and the quadriceps femoris muscles.
- **Articular branches** to the hip and knee joints.

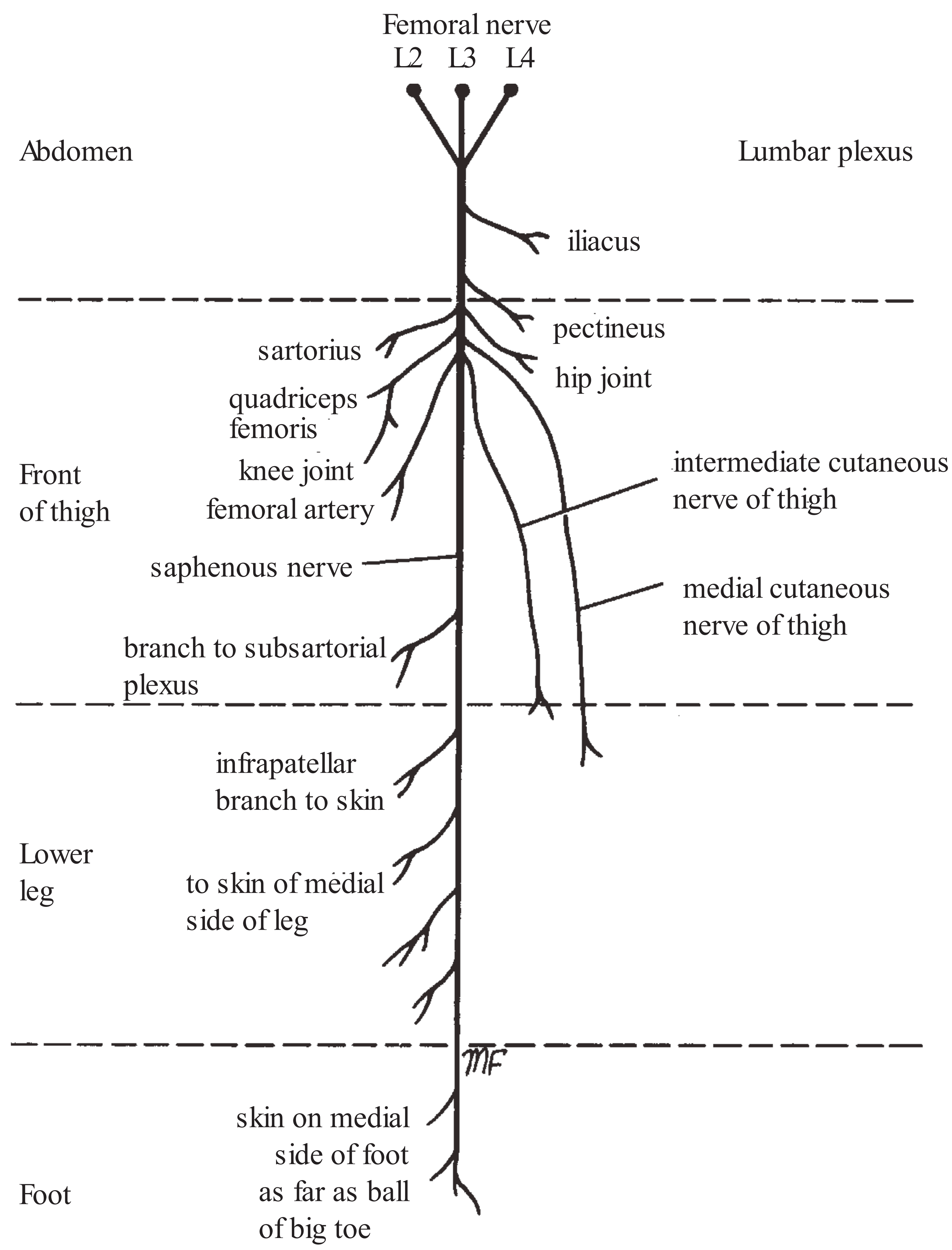


Figure 5-20 Summary of the main branches of the femoral nerve.

The branches of the femoral nerve are summarized in Figure 5-20. Dermatomal charts for the anterior and posterior surfaces of the body are shown in Figures 2-3 and 2-4.

Obturator Nerve

The obturator nerve arises from the lumbar plexus (L2, 3, and 4) and runs forward on the lateral wall of the pelvis to reach the obturator canal (the upper part of the obturator foramen). The obturator nerve divides into the anterior and the posterior divisions.

BRANCHES OF THE OBTURATOR NERVE IN THE THIGH

The **anterior division** descends into the thigh anterior to the obturator externus and the adductor brevis muscles.

- **Muscular branches:** Gracilis, adductor brevis, adductor longus, and sometimes the pectineus muscles.
- **Cutaneous branch:** Skin on the medial side of the thigh.
- **Articular branch:** Hip joint.

The **posterior division** descends through the obturator externus muscle and passes behind the adductor brevis and in front of the adductor magnus muscles.

- **Muscular branches:** Obturator externus, adductor magnus (adductor part), and sometimes the adductor brevis muscles.
- **Articular branch:** Knee joint.

The branches of the obturator nerve are summarized in Figure 5-21. Dermatomal charts for the anterior and the posterior surfaces of the body are shown in Figures 2-3 and 2-4.

Sciatic Nerve

The sciatic nerve arises from the sacral plexus (L4 and 5 and S1, 2, and 3). It passes out of the pelvis and into the gluteal region through the greater sciatic foramen (Fig. 5-11). The nerve appears below the piriformis muscle and is covered by the gluteus maximus muscle. It descends through the gluteal region, and it enters the posterior compartment of

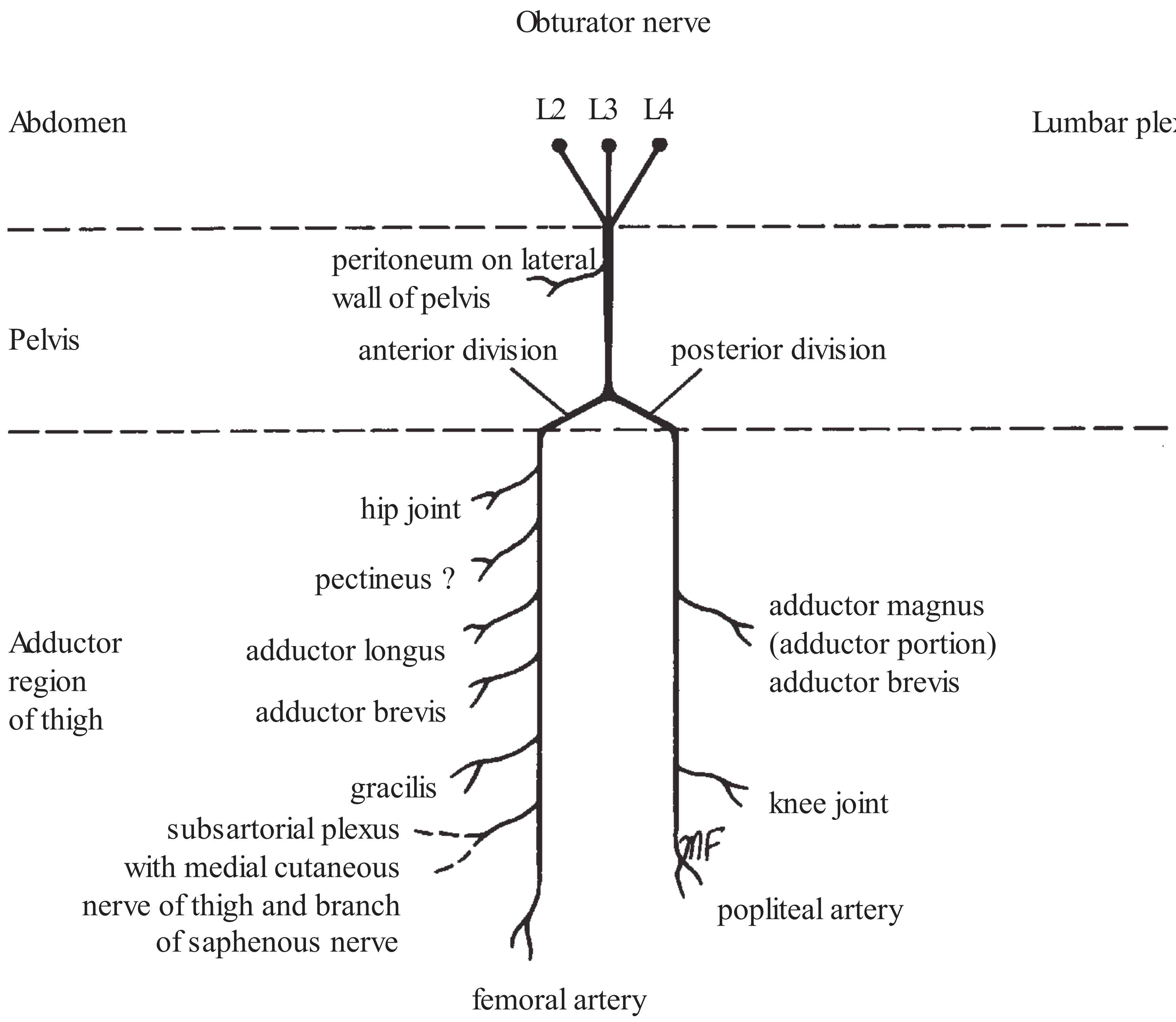


Figure 5-21 Summary of the main branches of the obturator nerve.

the thigh. In the lower third of the thigh (and occasionally at a higher level), it ends by dividing into the tibial and the common peroneal nerves (Fig. 5-13).

BRANCHES OF THE SCIATIC NERVE

- **Muscular branches:** Biceps femoris (long head), semitendinosus, semimembranosus, and hamstring part of the adductor magnus muscles.
- **Articular branches:** Hip joint.
- **Terminal branches:** Tibial and common peroneal nerves.

Tibial Nerve

The tibial nerve descends through the popliteal fossa and the posterior compartment of the leg. It lies deep to the gastrocnemius and soleus muscles, and it reaches the interval between the medial malleolus and the heel. It is covered by the flexor retinaculum and divides into the medial and the lateral plantar nerves.

BRANCHES OF THE TIBIAL NERVE

- **Cutaneous Branches: Sural nerve** (joined by communicating branch of the common peroneal nerve), which supplies the skin of the calf, the back of the leg, the lateral border of the foot, and the lateral side of the little toe (Fig. 5-14). **Medial calcaneal nerve,** which supplies the skin over the medial surface of the heel.
- **Muscular branches:** Gastrocnemius, plantaris, soleus, popliteus, flexor digitorum longus, flexor hallucis longus, and tibialis posterior muscles.
- **Articular branches:** Knee and ankle joints.
- **Medial plantar nerve:** Runs forward deep to the abductor hallucis muscle with the medial plantar artery (Fig. 5-16). **Cutaneous branch,** which supplies the medial part of the sole and the medial three and a half toes and nail beds. **Muscular branch,** which supplies the abductor hallucis, flexor digitorum brevis, flexor hallucis brevis, and first lumbrical muscles.
- **Lateral plantar nerve:** Runs forward deep to the abductor hallucis and flexor digitorum brevis muscles in company with the lateral plantar artery (Fig. 5-16). **Cutaneous branch,** which supplies the lateral part of the sole and the lateral one and a half toes and nail beds. **Muscular branch,** which supplies the flexor digitorum accessorius, abductor digiti minimi, flexor digiti minimi brevis, adductor hallucis, interosseous muscles, second lumbrical, third lumbrical, and fourth lumbrical muscles.

Common Peroneal Nerve

The common peroneal nerve descends through the popliteal fossa (Fig. 5-14). It then passes laterally around the neck of the fibula, pierces the peroneus longus muscle, and divides into the superficial and the deep peroneal nerves.

BRANCHES OF THE COMMON PERONEAL NERVE

- **Cutaneous branches: Sural communicating branch** (Fig. 5-9), which joins the sural nerve (see Branches of the Tibial Nerve). **Lateral cutaneous nerve of the calf,** which supplies the skin on the lateral side of the back of the leg.
- **Muscular branch:** Short head of the biceps femoris muscle.
- **Articular branch:** Knee joint.
- **Superficial peroneal nerve:** Descends between the peroneus longus and brevis muscles in the lateral fascial compartment and becomes subcutaneous (Fig. 5-9). **Cutaneous branch** to the skin on the front of the lower leg and dorsum of the foot (except for the cleft between the big and the second toes, which is innervated by the deep peroneal nerve). **Muscular branch,** which supplies the peroneus longus and brevis muscles.
- **Deep peroneal nerve:** Descends in the anterior fascial compartment deep to the extensor digitorum longus muscle and on the interosseous membrane (Fig. 5-9). It is accompanied by the anterior tibial vessels, and on the dorsum of the foot, it divides into the medial and the lateral terminal branches. **Cutaneous branch,** which suppies the adjacent sides of the big and the second toes. **Muscular branch,** which supplies the tibialis anterior, extensor digitorum longus, peroneus tertius, extensor hallucis longus, and extensor digitorum brevis muscles. **Articular branch,** which supplies the ankle and tarsal joints.

The branches of the sciatic nerve are summarized in Figures 5-22 and 5-23. Dermatomal charts for the anterior and the posterior surfaces of the body are shown in Figures 2-3 and 2-4.

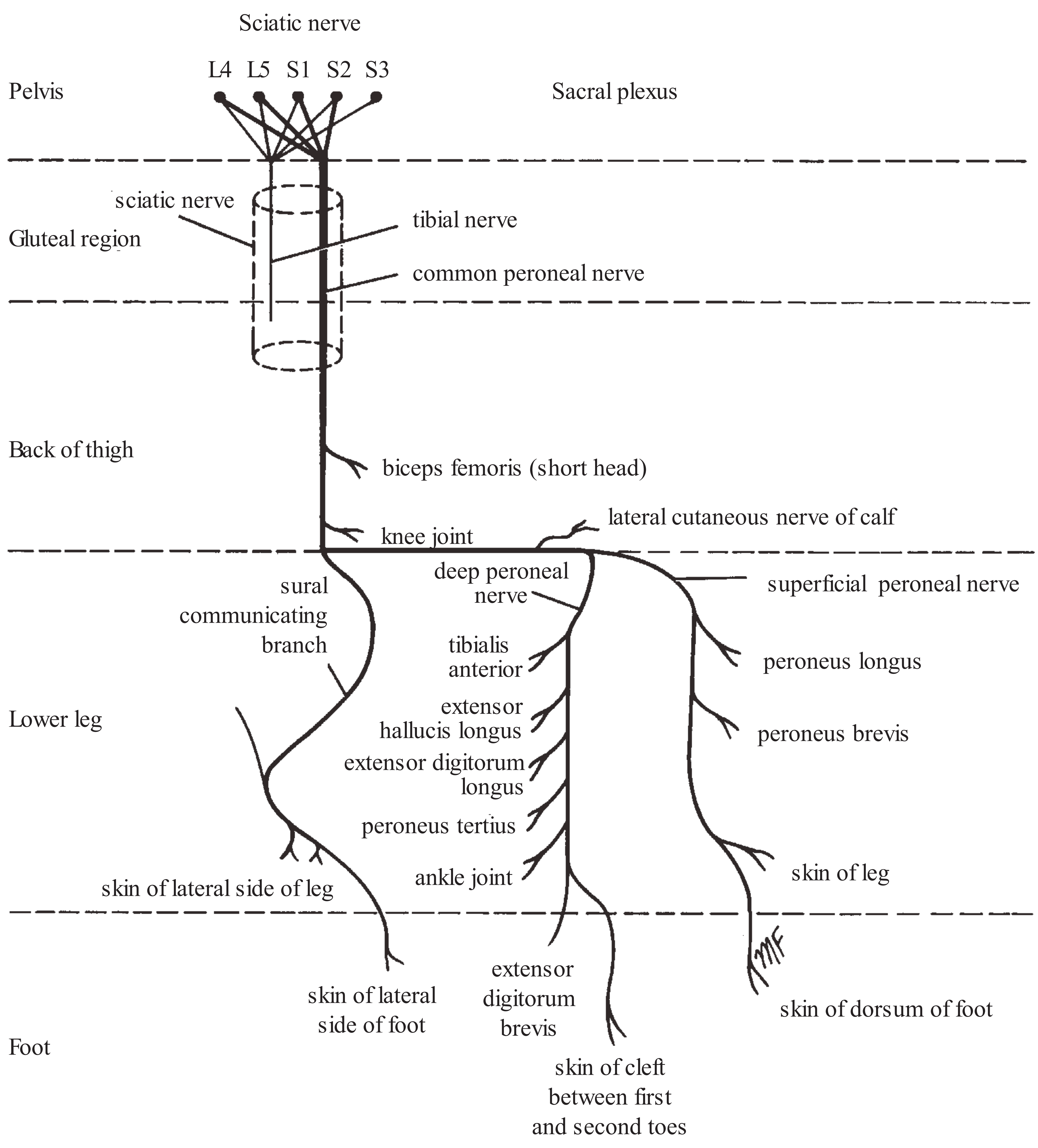


Figure 5-22 Summary of the main branches of the common peroneal nerve and origin of the sciatic nerve.

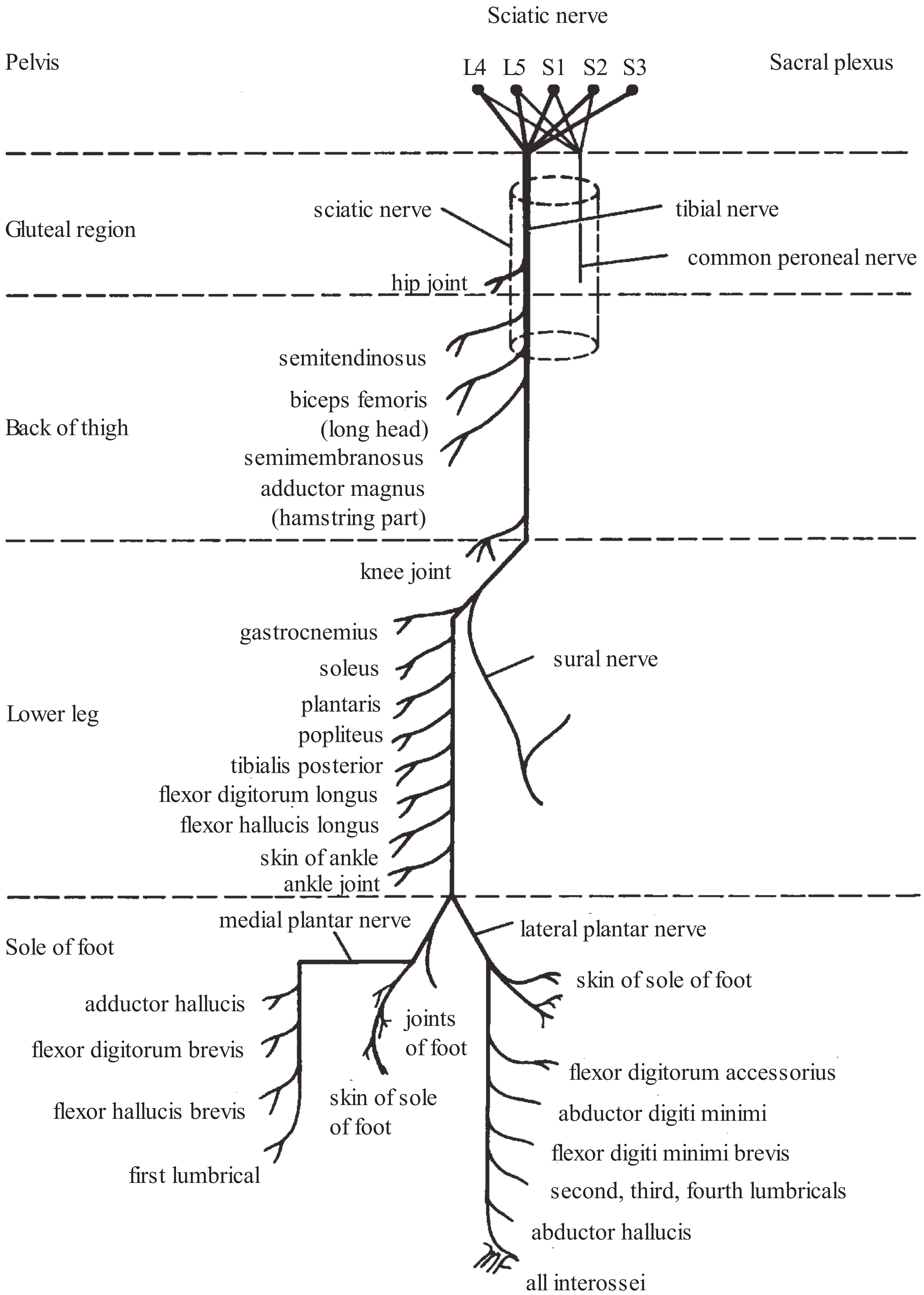


Figure 5-23 Summary of the main branches of the tibial nerve and origin of the sciatic nerve.

CLINICAL NOTES

Femoral Nerve Lesions

Stab or gunshot wounds in the thigh are common causes of femoral nerve lesions, but the nerve is rarely completely divided. In those with such lesions, the quadriceps femoris muscle is paralyzed, and the knee cannot be extended. There is also sensory loss over the medial side of the lower part of the leg and along the medial border of the foot as far as the ball of the big toe.

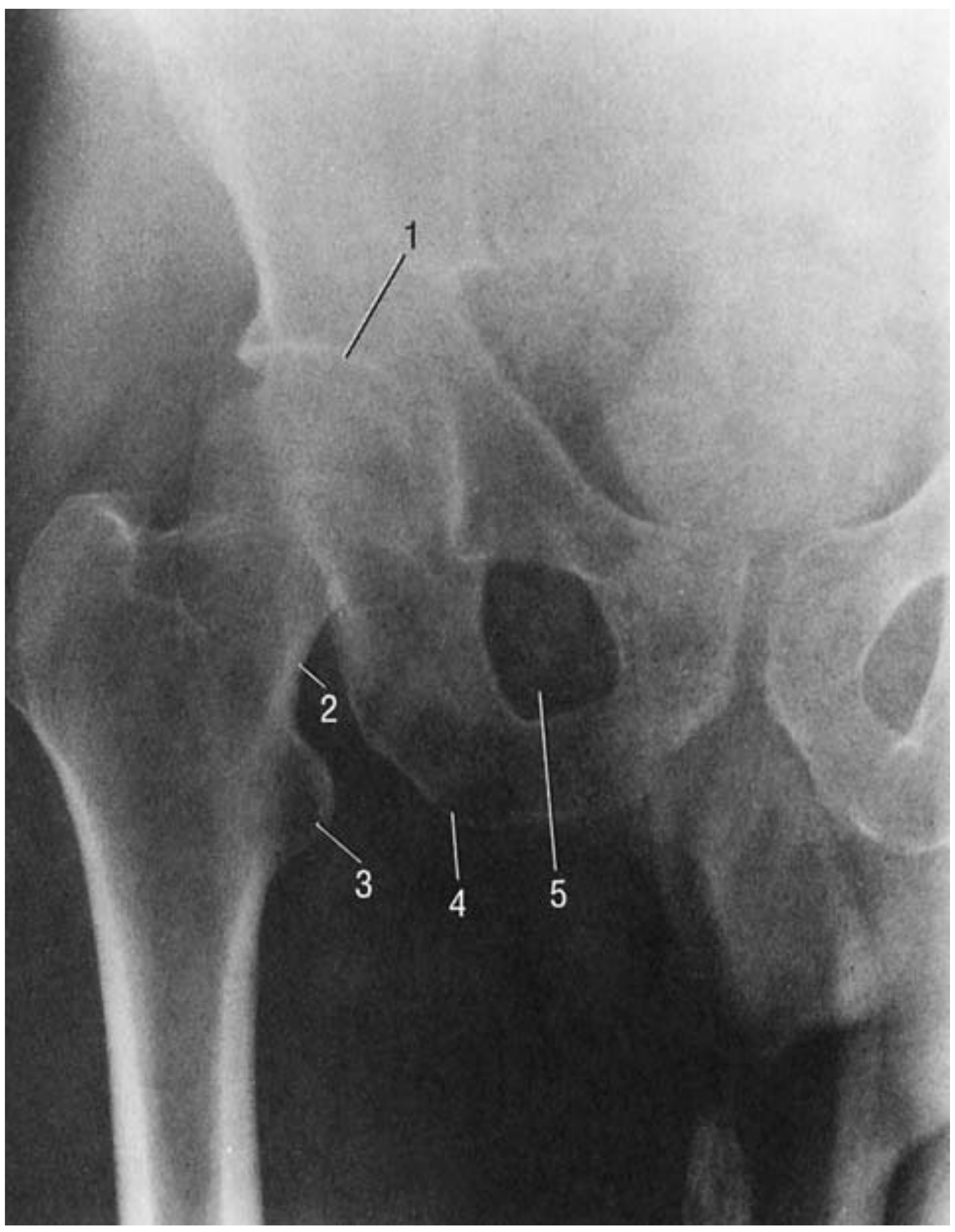
Sciatic Nerve Lesions

Badly placed intramuscular injections in the gluteal region, fracture dislocations of the hip joint, and penetrating wounds may damage the sciatic nerve. In those with such lesions, the hamstring muscles are paralyzed so that flexion of the knee is greatly weakened. All the muscles below the knee are also paralyzed, and the weight of the foot causes it to assume the plantar-flexed position **(foot drop).** There is loss of skin sensation below the knee (except for a narrow part of the leg and the medial border of the foot as far as the ball of the big toe).

REVIEW

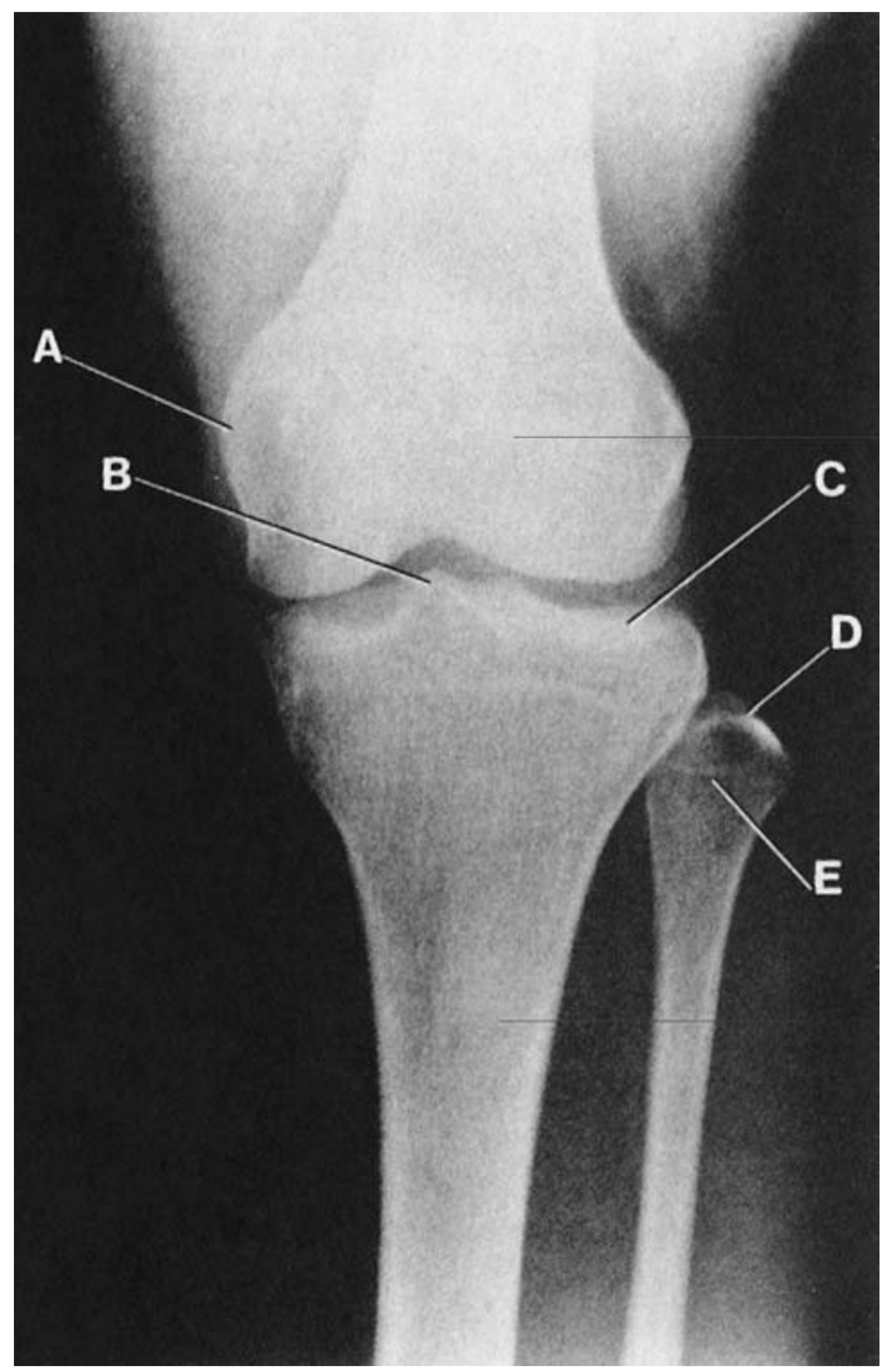
Completion Questions

Based on the anteroposterior radiograph of the hip region, select the phrase that best completes each statement.



1. Structure 1 is the
   A. neck of the femur.
   B. margin of obturator foramen.
   C. acetabulum.
   D. iliopectineal line.
   E. lesser trochanter.
   F. None of the above.
2. Structure 2 is the
   A. head of femur.
   B. iliopectineal line.
   C. ischiotuberosity.
   D. lesser trochanter.
   E. neck of the femur.
   F. None of the above.
3. Structure 3 is the
   A. greater trochanter.
   B. lesser trochanter.
   C. ischial tuberosity.
   D. acetabulum.
   E. ischial ramus.
   F. None of the above.
4. Structure 4 is the
   A. superior ramus of pubis.
   B. body of pubis.
   C. lesser trochanter.
   D. ischial tuberosity.
   E. ischial ramus.
   F. None of the above.
5. Structure 5 is the
   A. lesser sciatic foramen.
   B. greater sciatic foramen.
   C. subpubic angle.
   D. obturator foramen.
   E. fovea capitis.
   F. None of the above.

Based on the anteroposterior radiograph of the knee joint, select the phrase that best completes each statement.



6. Structure A is the
   A. head of the fibula.
   B. medial condyle of the femur.
   C. site of the epiphyseal line.
   D. lateral condyle of the tibia.
   E. intercondylar eminence.
   F. None of the above.

7. Structure B is the
   A. intercondylar eminence.
   B. medial condyle of tibia.
   C. tibial tuberosity.
   D. lateral meniscus.
   E. anterior cruciate ligament.
   F. None of the above.
8. Structure C is the
   A. medial meniscus.
   B. lateral condyle of tibia.
   C. lateral condyle of femur.
   D. intercondylar eminence.
   E. site of epiphyseal line.
   F. None of the above.
9. Structure D is the
   A. lateral condyle of tibia.
   B. neck of the fibula.
   C. superior tibiofibular joint.
   D. common peroneal nerve.
   E. head of the fibula.
   F. None of the above.
10. Structure E is the
   A. site of epiphyseal line.
   B. styloid process of head of fibula.
   C. lateral condyle of tibia.
   D. attachment of medial collateral ligament.
   E. articular surface of head of fibula.
   F. None of the above.

Based on the lateral radiograph of the ankle region, select the phrase that best completes each statement.

11. Structure 1 is the
   A. calcaneum.
   B. lateral malleolus.
   C. body of talus.
   D. navicular.
   E. medial malleolus.
   F. None of the above.
12. Structure 2 is the
   A. cuboid.
   B. medial cuneiform.
   C. navicular.
   D. head of talus.
   E. intermediate cuneiform.
   F. None of the above.
13. Structure 3 is the
   A. sustentaculum tali.
   B. neck of the talus.
   C. navicular.
   D. calcaneum.
   E. lateral malleolus
   F. medial malleolus.
14. Structure 4 is the
   A. medial malleolus.
   B. body of talus.
   C. lateral malleolus.
   D. neck of the talus.
   E. cuboid.
   F. None of the above.
15. Structure 5 is the
   A. navicular.
   B. medial cuneiform.
   C. tuberosity of the navicular.
   D. calcaneum.
   E. insertion of the tendo calcaneus.
   F. None of the above.

Select the phrase that best completes each statement.

16. Flexion of the hip joint (with the knee extended) is limited by the
   A. iliofemoral ligament.
   B. anterior abdominal wall.
   C. ischiofemoral ligament.
   D. pubofemoral ligament.
   E. anterior superior iliac spine.
   F. None of the above.
17. Abduction of the hip joint is limited by the
   A. pectineus muscle.
   B. iliofemoral ligament.
   C. ischiofemoral ligament.
   D. pubofemoral ligament.
   E. ligament of the head of the femur.
   F. None of the above.
18. Extension of the hip joint is limited by the
   A. iliofemoral ligament.
   B. pubofemoral ligament.
   C. ischiofemoral ligament.
   D. quadriceps muscle.
   E. adductor magnus muscle.

19. Flexion of the hip joint (with the knee flexed) is limited by the
    A. hamstring muscles.
    B. iliofemoral ligament.
    C. adductor magnus muscle.
    D. pubofemoral ligament.
    E. anterior abdominal wall.
    F. ischiofemoral ligament.
20. The long head of the biceps femoris muscle is innervated by the
    A. obturator nerve.
    B. tibial portion of the sciatic nerve.
    C. femoral nerve.
    D. common peroneal nerve.
    E. sural nerve.
21. The gracilis muscle is innervated by the
    A. femoral nerve.
    B. common peroneal nerve.
    C. sural nerve.
    D. obturator nerve.
    E. tibial portion of the sciatic nerve.
22. The gluteus maximus muscle is innervated by the
    A. inferior gluteal nerve.
    B. nerve to quadratus femoris.
    C. obturator nerve.
    D. superior gluteal nerve.
    E. nerve to obturator internus.
23. The sartorius muscle is innervated by the
    A. obturator nerve.
    B. femoral nerve.
    C. nerve to vastus medialis.
    D. superior gluteal nerve.
    E. lateral cutaneous nerve of the thigh.
24. The hamstring portion of the adductor magnus muscle is innervated by the
    A. common peroneal nerve.
    B. tibial portion of the sciatic nerve.
    C. obturator nerve.
    D. femoral nerve.
    E. nerve to the pectineus muscle.
25. The adductor longus muscle is innervated by the
    A. femoral nerve.
    B. common peroneal nerve.
    C. tibial portion of the sciatic nerve.
    D. anterior division of the obturator nerve.
    E. posterior division of the obturator nerve.
26. A malignant melanoma (cancer) of the skin covering the buttock is likely to spread via lymphatics to the
    A. horizontal group of superficial inguinal nodes.
    B. vertical group of superficial inguinal nodes.
    C. posterior axillary nodes.
    D. popliteal nodes.
    E. internal iliac nodes.
27. Lymph from the nail bed of the big toe drains into the
    A. horizontal group of superficial inguinal nodes.
    B. presacral nodes.
    C. popliteal nodes.
    D. internal iliac nodes
    E. vertical group of superficial inguinal nodes.
28. The lateral meniscus of the knee joint
    A. has a thick inner border.
    B. is strongly attached around its circumference to the tibia.
    C. is more frequently torn than the medial meniscus.
    D. is strongly attached to the lateral collateral ligament.
    E. is attached by its anterior horn to the tibia in front of the intercondylar eminence.
29. Lymph from the skin of the lateral side of the foot drains into the
    A. popliteal nodes.
    B. internal iliac nodes.
    C. vertical group of superficial inguinal nodes.
    D. horizontal group of superficial inguinal nodes.
    E. subsartorial nodes.
30. Lymph from the skin of the medial side of the knee drains into the
    A. popliteal nodes.
    B. vertical group of superficial inguinal nodes.
    C. medial group of the horizontal superficial inguinal nodes
    D. internal iliac nodes.
    E. lateral group of horizontal inguinal nodes.
31. Lymph from the skin around the anus drains into the
    A. internal iliac nodes.
    B. inferior mesenteric nodes.
    C. lateral group of horizontal superficial inguinal nodes.
    D. medial group of horizontal superficial inguinal nodes.
    E. vertical group of inguinal nodes.

Multiple-Choice Questions

Select the best answer for each question.

32. The sciatic nerve enters the gluteal region through which foramen?
    A. Posterior sacral
    B. Greater sciatic
    C. Anterior sacral
    D. Lesser sciatic
    E. Obturator
33. The common peroneal nerve can be palpated in which region of the knee?
    A. As it winds around the medial side of the neck of the fibula.
    B. As it passes around the medial condyle of the tibia.
    C. As it winds around the lateral side of the neck of the fibula.
    D. As it passes forward between the tibia and the fibula.
    E. As it crosses the lateral side of the head of the fibula.

34. If the dorsalis pedis artery is severed just proximal to its medial and lateral tarsal branches, blood can still reach the dorsum of the foot through which vessel(s)?
    A. The peroneal artery.
    B. The posterior tibial artery.
    C. The medial plantar artery.
    D. The lateral plantar artery.
    E. All of the above.

35. In children, the chief arterial supply to the head of the femur is derived from which artery or arteries?
    A. The obturator artery.
    B. The internal pudendal artery.
    C. Branches from the medial and lateral circumflex femoral arteries.
    D. The deep circumflex iliac artery.
    E. The superficial circumflex iliac artery.

36. Which statement is correct concerning the femoral ring?
    A. It is the opening in the deep fascia of the thigh for the great saphenous vein.
    B. It is the opening in the adductor magnus muscle for the femoral artery.
    C. It is the proximal opening in the femoral canal.
    D. It is the compartment in the femoral sheath for the femoral artery.
    E. It is the compartment in the femoral sheath for the femoral nerve.

37. To lift the left foot off the ground while walking, which of the following muscles plays an important role?
    A. The left gluteus medius muscle
    B. The left gluteus maximus muscle
    C. The right adductor longus muscle
    D. The right gluteus medius muscle
    E. None of the above.

38. Rupture of the tendo calcaneus results in an inability to do what?
    A. Dorsiflex the foot
    B. Evert the foot
    C. Invert the foot
    D. Plantar flex the foot
    E. None of the above.

39. A sprained ankle resulting from excessive eversion most likely demonstrates that which structure is torn?
    A. The talofibular ligament
    B. The tendo calcaneus
    C. The deltoid ligament
    D. The interosseous ligament
    E. The peroneal retinaculum

40. If the foot is permanently dorsiflexed and everted, which nerve might be injured?
    A. The deep peroneal nerve
    B. The superficial peroneal nerve
    C. The common peroneal nerve
    D. The tibial nerve
    E. The obturator nerve

41. The femoral nerve arises from which of the following segments of the spinal cord?
    A. L2 and 3
    B. L4 and 5 and S1, 2, and 3
    C. L2, 3, and 4
    D. L1 and 2
    E. L5 and S1, 2, and 3

42. The dermatome present over the lateral side of the foot is which of the following?
    A. S5
    B. L3
    C. S1
    D. L4
    E. L5

43. The femoral sheath is formed by which of the following layer(s) of fascia?
    A. The pectineus fascia
    B. The fascia iliaca and the fascia transversalis
    C. The fascia lata and the membranous layer of the superficial fascia
    D. The psoas fascia and the fatty layer of superficial fascia
    E. The processus vaginalis

44. Which of the following muscles everts the foot?
    A. The tibialis posterior muscle
    B. The flexor hallucis longus muscle
    C. The peroneus longus muscle
    D. The tibialis anterior muscle
    E. The flexor digitorum longus muscle

45. Injury to the common peroneal nerve results in which condition?
    A. Inability to invert the foot
    B. Inability to plantar flex the ankle
    C. Inability to feel skin sensation on the medial side of the leg
    D. Inability to plantar flex the big toe
    E. Inability to evert the foot

46. After a lesion of the tibial part of the sciatic nerve, some active flexion may still be possible at the knee joint; the muscles responsible for this remaining flexion include which?
    A. The short head of the biceps femoris muscle
    B. The gastrocnemius muscle
    C. The plantaris muscle
    D. The popliteus muscle
    E. The long head of the biceps femoris muscle

47. A patient in the supine position with the hip and knee joints extended is asked to abduct the lower limb against resistance provided by the physician; this exercise tests which of the following muscles?
    A. The semitendinosus muscle
    B. The gluteus medius muscle
    C. The pectineus muscle
    D. The gracilis muscle
    E. The semimembranosus muscle

48. A femoral hernia has the following characteristics except which?
    A. It is more common in women than in men.
    B. The swelling occurs below and lateral to the pubic tubercle.
    C. It descends through the femoral canal.
    D. Its neck is related immediately laterally to the femoral artery.
    E. Its neck is related medially to the sharp edge of the lacunar ligament.

49. The gastrocnemius and the soleus muscles have all the following features in common except which?
    A. They are supplied by the tibial nerve.
    B. They are found in the posterior compartment of the leg.
    C. They arise from the femoral condyles and flex the knee joint.
    D. They insert via the tendo calcaneus.
    E. They plantar flex the ankle joint.

50. All the following statements about the sartorius muscle are correct except which?
    A. It flexes the leg at the knee joint.
    B. It flexes the thigh at the hip joint.
    C. It laterally rotates the thigh at the hip joint.
    D. It adducts the thigh at the hip joint.
    E. It attaches to the anterior superior iliac spine.

51. The following structures are transmitted through the lesser sciatic foramen except which?
    A. The tendon of the obturator internus muscle
    B. The internal pudendal vessels
    C. The nerve to the obturator internus muscle
    D. The pudendal nerve
    E. The inferior gluteal artery

52. The following statements regarding the great saphenous vein are correct except which?
    A. It arises on the dorsum of the foot.
    B. It enters the leg by passing anterior to the medial malleolus.
    C. It drains into the femoral vein approximately 1.5 in. (3.8 cm) below and lateral to the pubic tubercle.
    D. It is accompanied by the saphenous nerve.
    E. It has no communication with the deep veins of the leg.

53. The following statements regarding the obturator nerve are correct except which?
    A. It originates from the lumbar plexus.
    B. It enters the thigh immediately beneath the inguinal ligament.
    C. It innervates the adductor muscles of the thigh.
    D. It divides into an anterior and a posterior division.
    E. It supplies the skin on the medial side of the thigh.

Read the case histories and select the best answer to the question following them.

After a football injury, an orthopedic surgeon noted that the right tibia of the patient could be moved anteriorly with excessive freedom when the knee was flexed.

54. In this patient, which ligament is most likely to be torn?
    A. The lateral collateral ligament
    B. The posterior cruciate ligament
    C. The anterior cruciate ligament
    D. The medial collateral ligament
    E. The patellar ligament

A 69-year-old man was walking down a flight of steps when he slipped and fell. On impact, his left foot hit the ground and was forcibly inverted and medially rotated. He stated that he felt something give on the lateral side of the dorsum of the foot. Though shocked by the fall and the resulting foot pain, he was able to walk home. Within 2 h, the left foot and ankle had swollen considerably, which made examination by his physician difficult. Movements of the ankle were clearly possible, but inversion was extremely painful. On standing, the patient could bear his body weight without too much discomfort. The physician ordered an anteroposterior and a lateral radiograph of the ankle region, both of which showed nothing abnormal. This patient was diagnosed as having an acute sprain of the lateral ankle.

55. Which ligament is most likely to have been damaged?
    A. The deltoid ligament
    B. The anterior talofibular ligament
    C. The plantar calcaneonavicular ligament
    D. The anterior ligament of the inferior tibiofibular joint
    E. The posterior talofibular ligament

A 29-year-old woman was involved in an automobile accident. Her car skidded into a tree, and she was thrown forward, striking her right knee on the dashboard. At examination in the emergency department, she was found to have a posterior fracture dislocation of her right hip joint.

56. What bone or bones are likely to have been fractured?
    A. The greater tuberosity of the femur
    B. The floor of the acetabulum
    C. The posterior rim of the acetabulum and fracture of the femoral head
    D. The lesser trochanter of the femur
    E. The anterior inferior iliac spine

57. What anatomic structure is likely to be compromised in a hip dislocation of this type?
    A. The tendon of obturator internus

B. The sciatic nerve
C. The quadratus femoris muscle
D. The gluteus maximus muscle
E. The superior gluteal nerve

ANSWERS TO REVIEW QUESTIONS

1. C	6. B	11. C
2. E	7. A	12. C
3. B	8. B	13. F
4. D	9. E	14. C
5. D	10. A	15. D

16. F. With the knee joint extended, the hamstring muscles are stretched and limit the degree of flexion of the hip joint.

17. D	20. B	23. B
18. A	21. D	24. B
19. E	22. A	25. D

26. A. Remember that the skin of the back below the level of the iliac crests drains into the horizontal group of superficial inguinal lymph nodes

27. E	28. E	29. A

30. B
31. D. Remember that the mucous membrane of the lower half of the anal canal has the same lymphatic drainage as the skin around the anus—namely, into the medial group of horizontal superficial inguinal nodes.

32. B	33. C	34. E

35. A. The nutrient artery, which is a branch of the obturator artery, reaches the femoral head in children along the ligament of the head and enters the bone at the fovea capitis. The femoral head is separated from the arteries supplying the neck of the femur by the epiphyseal cartilage.
36. C
37. D. The right gluteus medius and the right gluteus minimus tilt the pelvis so that the left lower limb is raised, thus permitting the left foot to be advanced forward clear of the ground.
38. D. The soleus and the gastrocnemius muscles are attached to the calcaneum via the tendo calcaneus. These muscles plantar flex the ankle joint. The plantaris is only a weak plantar flexor muscle.

39. C	41. C	43. B
40. D	42. C	44. C

45. E. The plantar flexors of the ankle joint and the invertors of the foot are mainly supplied by the tibial nerve. The skin on the medial side of the leg is supplied by the saphenous nerve, which is a branch of the femoral nerve.
46. A. The short head of the biceps femoris muscle is supplied by the common peroneal nerve.
47. B. The gluteus medius muscle is a strong abductor of the hip joint.
48. D. The neck of the femoral hernia is related immediately laterally to the femoral vein.
49. C. The soleus does not arise from the femoral condyles.
50. D. The sartorius muscle is an abductor of the hip joint.
51. E. The inferior gluteal artery emerges from the greater sciatic foramen.
52. E. The great saphenous vein has numerous communications with the deep veins of the leg through the valved perforating veins.
53. B. The obturator nerve enters the thigh through the obturator canal.
54. C
55. B. The anterior talofibular ligament is very commonly damaged, more so than those ligaments on the medial side of the joint. Excessive inversion of the foot with plantar flexion of the ankle or attempted medial rotation of the ankle is the common cause.
56. C. The head of the femur is driven backward by the force of the accident through the posterior rim of the acetabulum that is fractured. The head of the femur may also be fractured.
57. B. The sciatic nerve is commonly damaged in this type of fracture dislocation.

CHAPTER 6

Head and Neck

The head and neck are the most complicated areas of gross anatomy to understand and to learn. From a practical viewpoint and for examination purposes, however, only certain areas need to be committed to memory. For example, the distribution of the cranial nerves is most important, whereas the precise relationships of different structures in the neck can be briefly reviewed.

It is suggested that the head and neck be reviewed in the following order:

1. A brief overview of the skull, including the mandible and the temporomandibular joint. (The availability of a dry skull would be helpful.)
2. The important muscles of the neck, including the boundaries of the triangles and their associated fasciae.
3. A brief overview of the muscles of the scalp and the face, which are all supplied by the seventh cranial nerve.
4. A brief review of the blood vessels and the lymphatic drainage.
5. A detailed overview of the cranial nerves and their distribution.
6. The important branches of the cervical plexus of nerves.
7. The distribution of the autonomic nervous system.
8. The parts of the digestive and the respiratory systems in the head and neck.
9. The pituitary, the thyroid, and the parathyroid glands.
10. The gross parts of the eye and the ear.

To assist students in the review process, tables are used extensively in this chapter.

SKULL

Newborn Skull

FONTANELLES

The **anterior fontanelle** is diamond in shape and lies between the two halves of the frontal bone and the two parietal bones. The fibrous membrane forming the floor of the anterior fontanelle is replaced by bone and closed by 18 months of age. The **posterior fontanelle** is triangular in shape, lies between the two parietal bones and occipital bone, and is usually closed by the end of the 1st year of life.

CLINICAL NOTES

Clinical Significance of the Anterior Fontanelle

The heart rate, the intracranial pressure, and the degree of hydration can be examined by palpating the anterior fontanelle.

MASTOID PROCESS

Not present at birth, the mastoid process develops during the first 2 years of life.

Adult Skull

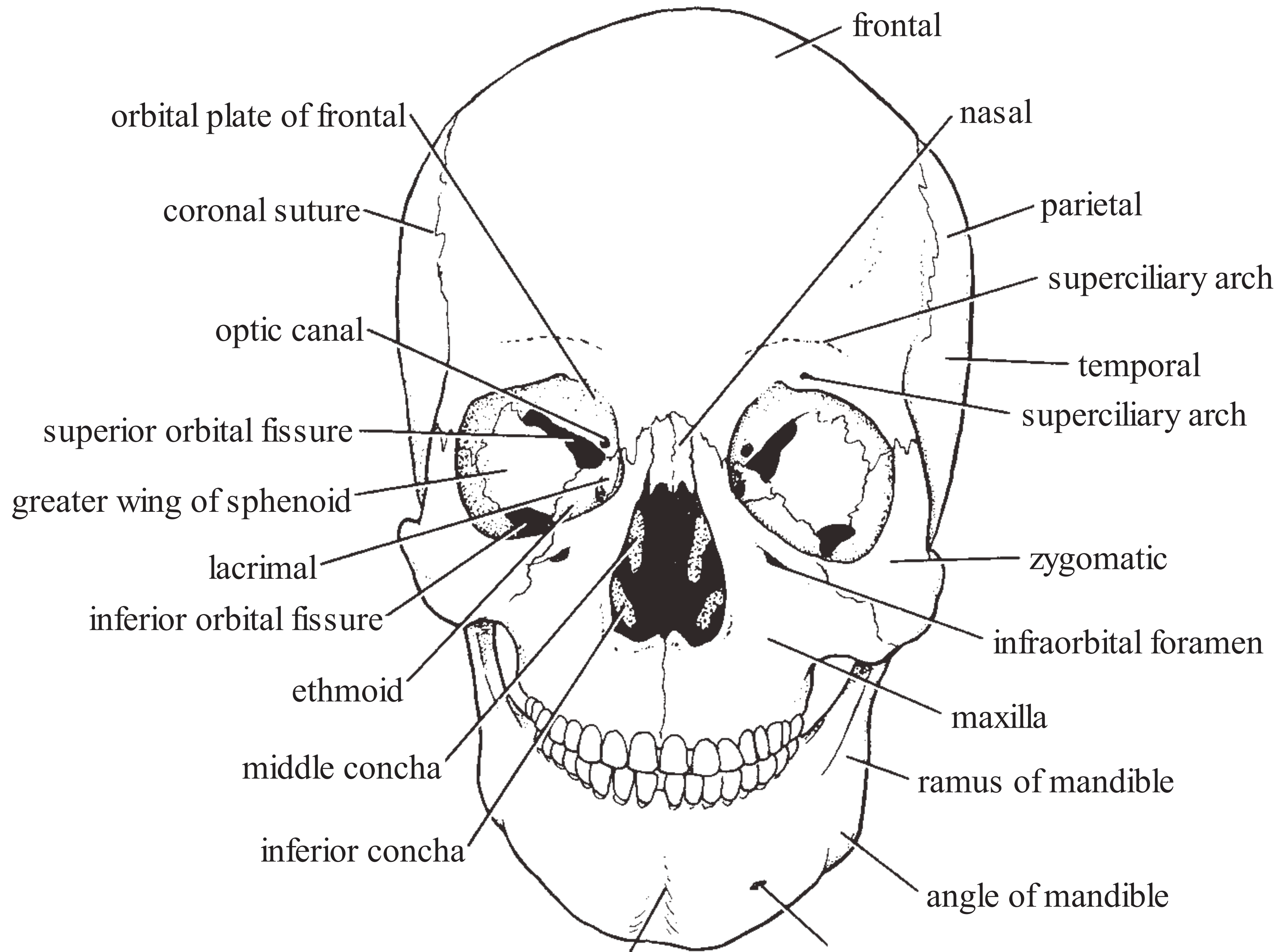
ANTERIOR VIEW

The frontal bone (or forehead bone) curves downward to make the upper margin of the orbits (Fig. 6-1). The **superciliary arches** can be seen on either side.

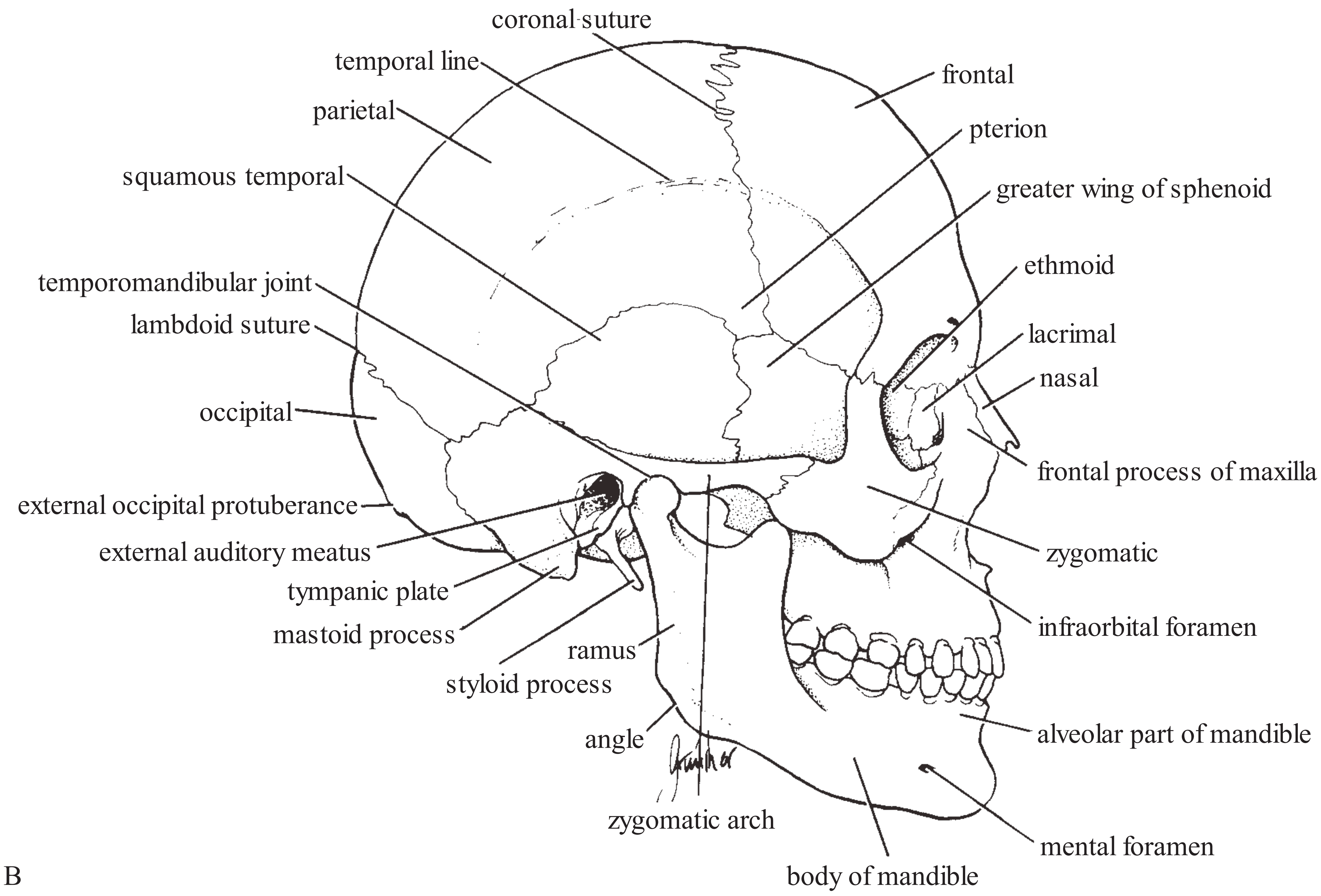
The **orbital margins** are bounded by the frontal bone superiorly, the zygomatic bone laterally, the maxilla inferiorly, and the processes of the maxilla and the frontal bone medially.

Within the **frontal bone**, just above the orbital margins, are two hollow spaces lined with mucous membrane called the **frontal air sinuses**. These communicate with the nasal cavity, and they serve as voice resonators.

The two **nasal bones** form the bridge of the nose, and with the maxillae, their lower borders make the **anterior nasal**



A



B

Figure 6-1 The skull. A. Anterior aspect. B. Lateral aspect.

aperture. The nasal cavity is divided into two parts by the bony nasal septum, which is largely formed by the **vomer** bone. The **superior** and **middle conchae** are shelves of bone that project into the nasal cavity from the **ethmoid** on each side; the **inferior conchae** are separate bones.

The two **maxillae** form the upper jaw (Fig. 6-1), the anterior part of the hard palate, part of the lateral walls of the nasal cavities, and part of the floors of the orbital cavities. These two bones meet in the midline at the **intermaxillary suture,** and they also form the lower margin of the nasal aperture. Below the orbit, the maxilla is perforated by the **infraorbital foramen.** The alveolar process projects downward and, together with the opposite side, forms the **alveolar arch,** which carries the upper teeth. Within each maxilla is a large, pyramid-shaped cavity lined with mucous membrane called the **maxillary sinus.** This sinus communicates with the nasal cavity and serves as a voice resonator.

The **zygomatic bone** forms the prominence of the cheek and part of the lateral wall and floor of the orbital cavity. Medially, it articulates with the maxilla; laterally, it articulates with the zygomatic process of the temporal bone to form the **zygomatic arch.**

CLINICAL NOTES

Fractures of the Facial Bones

Nasal fractures, because of the prominence of the nose are the most common facial fractures. **Fractures of the maxilla** are common and usually result from a direct anteroposterior blow to the face. A severe blow to the orbit (as from a baseball) may cause the contents of the orbital cavity to explode downward through the floor of the orbit into the maxillary sinus. Damage to the infraorbital nerve may occur. **Fractures of the zygoma,** or **zygomatic arch,** result from a blow to the side of the face and may be associated with many other fractures of the face, as often seen in automobile accidents.

LATERAL VIEW

The **frontal bone** forms the anterior part of the side of the skull. It articulates with the parietal bone at the **coronal suture** (Fig. 6-1).

The **parietal bones** form the sides and the roof of the cranium, and they articulate with each other in the midline at the **sagittal suture**. Behind, they articulate with the occipital bone at the **lambdoid suture.**

The skull is completed at the side by the squamous part of the **occipital bone;** parts of the **temporal bone**—namely, the **squamous, tympanic, mastoid process, styloid process,** and **zygomatic process;** and the **greater wing of the sphenoid.** Note the position of the **external auditory meatus.** The ramus and body of the mandible lie inferiorly.

Note also that the thinnest part of the lateral wall of the skull is where the anteroinferior corner of the parietal bone articulates with the greater wing of the sphenoid. This point is referred to as the **pterion.**

CLINICAL NOTES

Clinical Significance of the Pterion

The pterion is important clinically, because it overlies the anterior division of the **middle meningeal artery** and **vein.**

INFERIOR VIEW

If the mandible is discarded, the anterior part of the inferior aspect of the skull can be seen to be formed by the **hard palate.** The **palatal processes of the maxillae** and the **horizontal plates of the palatine bones** can also be identified.

Above the posterior edge of the hard palate are the **choanae** (the posterior nasal apertures). These are separated from each other by the posterior margin of the **vomer**, and they are bounded laterally by the **medial pterygoid plates** of the sphenoid bone. The inferior end of the medial pterygoid plate is prolonged as a curved spike of bone the **pterygoid hamulus.**

The following bony structures should be identified: the **lateral pterygoid plate,** the **infratemporal fossa,** the **petrous part of the temporal bone,** the **styloid process,** the **mastoid process,** the **occipital condyles,** the **external occipital protuberance,** and the **superior nuchal line.** The **mandibular fossa of the temporal bone** and the **articular tubercle,** which form the upper articular surfaces for the temporomandibular joint, should be identified as well.

The following fissures or foramina should also be identified: because they allow passage of the cranial nerves and other important structures from the skull: the **foramen ovale,** the **foramen spinosum,** the **carotid canal,** the **jugular foramen,** the **foramen lacerum,** the **stylomastoid foramen,** and the **hypoglossal canal.** The important **foramen magnum** and the opening of the bony part of the **auditory tube** should be identified as well.

SUPERIOR VIEW OF THE BASE OF THE SKULL

The base of the skull is divided into three cranial fossae: the anterior, the middle, and the posterior (Fig. 6-2). The anterior cranial fossa is separated from the middle cranial fossa by the lesser wing of the sphenoid. The middle cranial fossa is separated from the posterior cranial fossa by the petrous part of the temporal bone.

Anterior Cranial Fossa

The anterior cranial fossa lodges the frontal lobes of the cerebral hemispheres. The perforations of the **cribriform plate of the ethmoid** transmit the olfactory nerves.

Middle Cranial Fossa

The lateral parts of the middle cranial fossa lodge the temporal lobes of the cerebral hemispheres; the middle part is

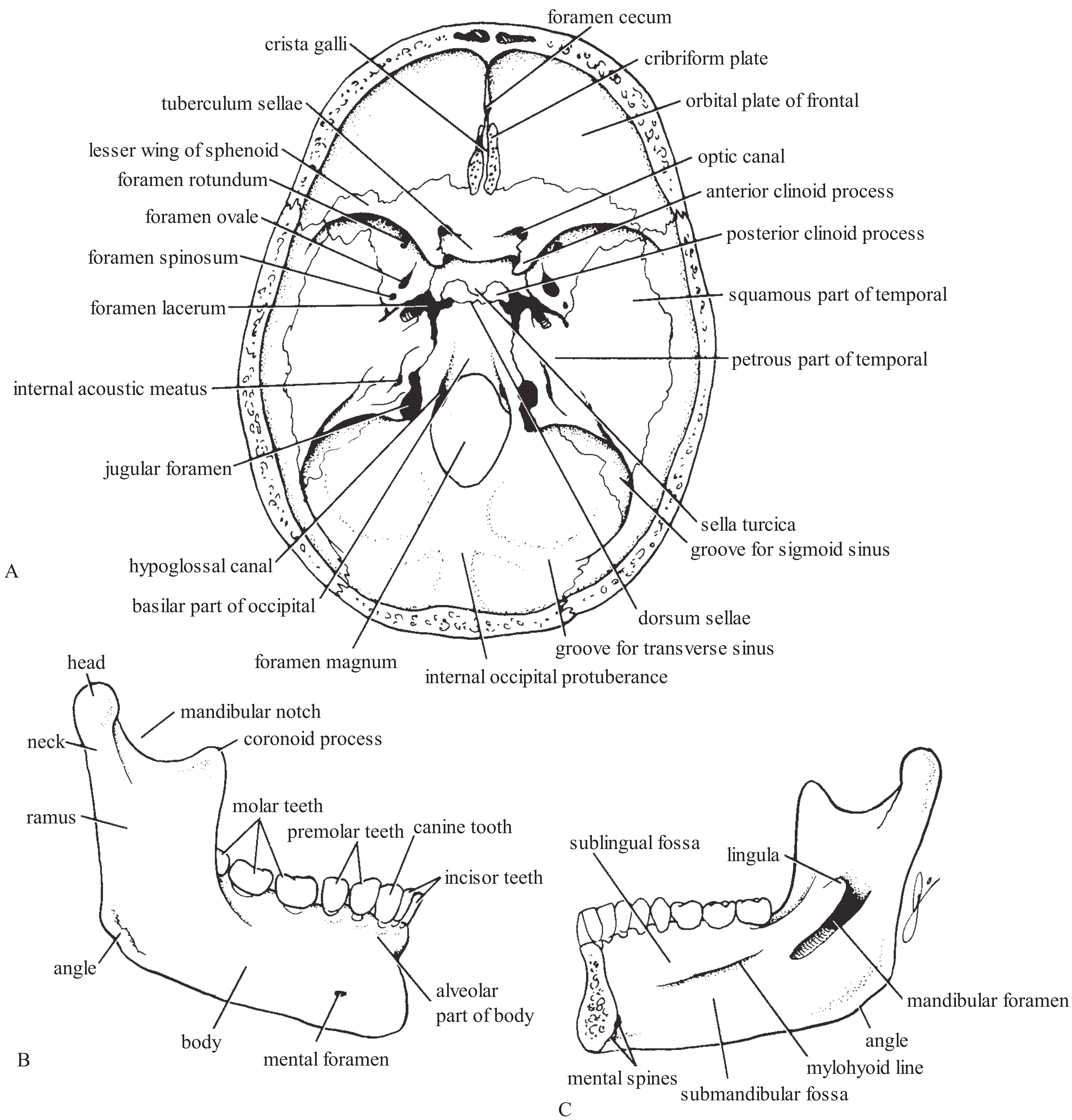


Figure 6-2 A. Internal surface of the base of the skull. B. Lateral aspect of the mandible. C. Medial aspect of the mandible.

raised and formed by the **body of the sphenoid bone** (Fig. 6-2). In front is the **sulcus chiasmatis,** which is related to the optic chiasma and leads laterally to the optic canal on each side. The **optic canal** transmits the optic nerve and the ophthalmic artery. Posterior to the sulcus is an elevation called the **tuberculum sellae.** Behind the elevation is a deep depression called the **sella turcica,** which lodges the **hypophysis cerebri.** The sella turcica is bounded posteriorly by a square plate of bone called the **dorsum sellae,** the superior angles of the which have two tubercles (the **posterior clinoid processes**) that give attachment to the tentorium cerebelli. The cavernous sinus is directly related to the side of the body of the sphenoid.

The sphenoid bone resembles a bat. It has a centrally placed **body** with **greater** and **lesser wings** that are outstretched on each side. The body of the sphenoid contains the **sphenoid air sinuses,** which are lined with mucous membrane, communicate with the nasal cavity, and serve as voice resonators.

The **superior orbital fissure** is a slitlike opening between the lesser and the greater wings of the sphenoid. It transmits the lacrimal, the frontal, the trochlear, the oculo-

Table 6-1 Summary of the More Important Openings in the Base of the Skull and the Structures Passing through Them

Opening in Skull	Bone of Skull	Structures Transmitted
Anterior Cranial Fossa		
Perforations in the cribriform plate	Ethmoid	Olfactory nerves
Middle Cranial Fossa		
Optic canal	Lesser wing of the sphenoid	Optic nerve, ophthalmic artery
Superior orbital fissure	Between lesser and greater wings of the sphenoid	Lacrimal, frontal, trochlear, oculomotor, nasociliary, and abducent nerves; superior ophthalmic vein
Formen rotundum	Greater wing of the sphenoid	Maxillary division of the trigeminal nerve
Foramen ovale	Greater wing of the sphenoid	Mandibular division of the trigeminal nerve, lesser petrosal nerve
Foramen spinosum	Greater wing of the sphenoid	Middle meningeal artery
Foramen lacerum	Between the petrous part of the temporal and the sphenoid	Internal carotid artery
Posterior Cranial Fossa		
Foramen magnum	Occipital	Medulla oblongata, spinal part of the accessory nerve, and the right and left vertebral arteries
Hypoglossal canal	Occipital	Hypoglossal nerve
Jugular foramen	Between the petrous part of the temporal and the condylar part of the occipital	Glossopharyngeal, vagus, and accessory nerves; sigmoid sinus becomes the internal jugular vein
Internal acoustic meatus	Petrous part of the temporal	Vestibulocochlear and facial nerves

motor, the nasociliary, and the abducent nerves. It also transmits the superior ophthalmic vein.

The **foramen rotundum,** which is situated behind the medial end of the superior orbital fissure, perforates the greater wing of the sphenoid (Fig. 6-2). It transmits the maxillary division of the trigeminal nerve.

The **foramen ovale** lies posterolateral to the foramen rotundum (Fig. 6-2). It perforates the greater wing of the sphenoid, and it transmits the sensory and the motor roots of the mandibular division of the trigeminal nerve. It also transmits the lesser petrosal nerve (p. 232).

The **foramen spinosum** is small and lies posterolateral to the foramen ovale (Fig. 6-2). It perforates the greater wing of the sphenoid and transmits the middle meningeal artery.

The **foramen lacerum** is large and irregular in shape; it lies between the apex of the petrous part of the temporal bone and the sphenoid bone (Fig. 6-2). Largely filled by cartilage and fibrous tissue, it allows passage of the internal carotid artery from the carotid canal into the cranial cavity.

CLINICAL NOTES

FRACTURES OF THE MIDDLE CRANIAL FOSSA

Fractures of the middle cranial fossa are common, because this is the weakest part of the base of the skull. This weakness is caused by the presence of numerous foramina and canals in this region. The cavities of the middle ear and the sphenoidal air sinuses are particularly vulnerable.

Posterior Cranial Fossa

The posterior cranial fossa is very deep and lodges parts of the hindbrain, namely, the cerebellum, the pons, and the medulla oblongata. The **foramen magnum** (Fig. 6-2) occupies the central area of the floor and transmits the medulla oblongata and its meninges, the ascending spinal parts of the accessory nerves, and the two vertebral arteries.

The **hypoglossal canal** is situated close to the anterolateral boundary of the foramen magnum. It transmits the hypoglossal nerve.

The **jugular foramen** lies between the petrous part of the temporal bone and the condylar part of the occipital bone. It transmits the glossopharyngeal, the vagus, and the accessory nerves. Here, the sigmoid sinus leaves the skull to become the internal jugular vein.

The **internal acoustic meatus** pierces the posterior surface of the petrous part of the temporal bone. It transmits the vestibulocochlear and the facial nerves (Fig. 6-2).

Table 6-1 summarizes the more important openings in the base of the skull and the structures passing through them.

Mandible

The mandible (or lower jaw) is the largest and strongest bone of the face (Fig. 6-2), and it articulates with the skull at the **temporomandibular joint.** The mandible consists of a horseshoe-shaped **body** and a pair of **rami.** The body of the mandible meets the ramus on each side at the **angle.**

On its external surface in the midline, the **body of the mandible** has a faint ridge called the **symphysis menti.** The **mental foramen** can be seen below the second premolar tooth (Fig. 6-2), and it transmits one of the terminal branches of the inferior alveolar nerve.

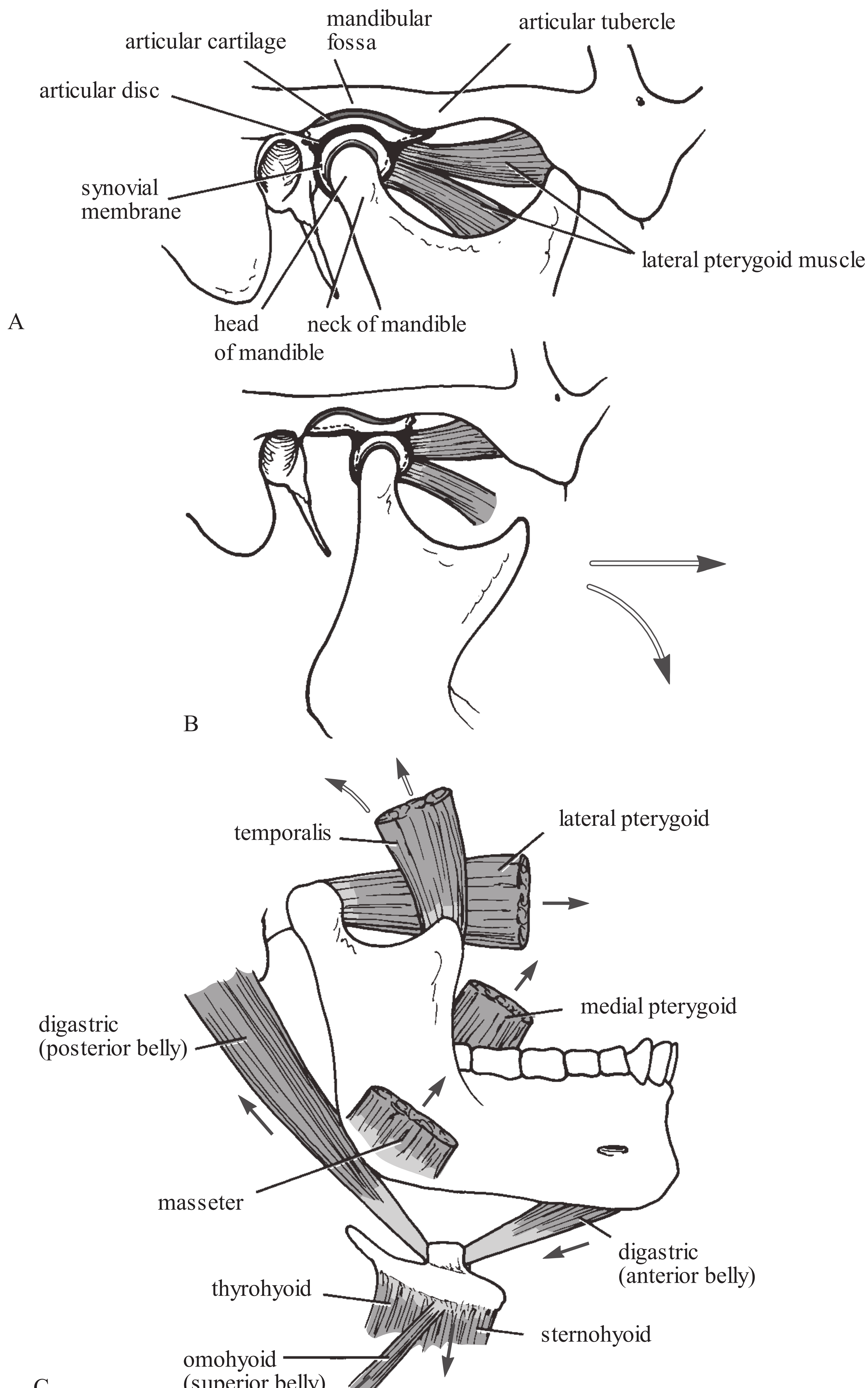


Figure 6-3 The temporomandibular joint (A) with the mouth closed and (B) with the mouth open. Note the position of the head of the mandible and the articular disc in relation to the articular tubercle in each case. C. Also note the attachment of the muscles of mastication to the mandible. Arrows indicate the direction of action for these muscles.

On the medial surface of the body of the mandible is the **submandibular fossa** for the submandibular salivary gland. In front of this fossa is the **sublingual fossa** for the sublingual salivary gland. Between these two fossae runs an oblique ridge called the **mylohyoid line** (Fig. 6-2), which gives attachment to the mylohyoid muscle.

The upper part of the body is called the **alveolar part.** In adults, it contains 16 sockets for the roots of the lower teeth.

The **ramus of the mandible** is vertical and has an anterior **coronoid process** and a posterior **condyloid process** (Fig. 6-2), or **head.** The two processes are separated by the **mandibular notch.** Below the condyloid process is a short **neck.** The **mandibular foramen** lies on the medial surface of the ramus, and it transmits the inferior alveolar nerve. This foramen leads into the **mandibular canal** and then opens onto the lateral surface at the **mental foramen.**

The condyloid process (or head) of the mandible articulates with the temporal bone at the temporomandibular joint.

CLINICAL NOTES

FRACTURES OF THE MANDIBLE

The mandible is horseshoe shaped and forms part of a bony ring with the skull. Traumatic impact is transmitted around the ring, causing a single fracture or multiple fractures of the mandible, often far removed from the point of impact.

Temporomandibular Joint

ARTICULATION

The temporomandibular joint articulates above with the mandibular fossa and the articular tubercle of the temporal bone. It articulates below with the head of the mandible (Fig. 6-3).

TYPE

The temporomandibular joint is a synovial joint. The fibrocartilaginous disc divides the joint into upper and lower cavities.

CAPSULE

The capsule encloses the joint.

LIGAMENTS

Lateral Temporomandibular Ligament

The lateral temporomandibular ligament is attached above to the articular tubercle at the root of the zygomatic arch and below to the neck of the mandible. The fibers extend downward and backward. This ligament limits the posterior movement of the mandible.

Sphenomandibular Ligament

The sphenomandibular ligament is attached above to the spine of the sphenoid and below to the bony projection (lingula) of the mandibular foramen. Its function is unknown.

Stylomandibular Ligament

The stylomandibular ligament is attached to the styloid process above and to the angle of the mandible below. Its function is unknown.

Articular Disc

The articular disc is an oval disc of fibrocartilage (Fig. 6-3). It is attached in front to the tendon of the lateral pterygoid muscle and posteriorly by fibrous tissue to the head of the mandible. The circumference of the disc is attached to the capsule. The disc permits gliding movement in the upper part of the joint and hinge movement in the lower part of the joint.

SYNOVIAL MEMBRANE

The synovial membrane lines the capsule in the upper and the lower cavities.

NERVE SUPPLY

Auriculotemporal and masseteric nerves, branches of the mandibular division of the trigeminal nerve.

MOVEMENTS AND THE MUSCLES THAT PRODUCE MOVEMENT

- **Protrusion:** The head of the mandible (Fig. 6-3) and the articular disc move forward in the upper part of the joint. Lateral pterygoid muscle.
- **Retraction:** The head of the mandible and the articular disc move backward in the upper part of the joint. Posterior fibers of the temporalis muscle.
- **Depression of mandible** (mouth is opened): The head of the mandible rotates on the undersurface of the articular disc around a horizontal axis. Digastrics, geniohyoids, and mylohyoid muscles.
- **Elevation of mandible** (mouth is closed): The head of the mandible rotates on the undersurface of the articular disc. At the same time, the posterior fibers of the temporalis muscle pull back the head of the mandible, and the articular disc is pulled backward by fibroelastic tissue, which connects the disc to the temporal bone posteriorly. Temporalis, masseter, and medial pterygoid muscles.
- **Lateral chewing movements:** Alternate protruding and retracting of the mandible on each side.

CLINICAL NOTES

DISLOCATIONS OF THE TEMPOROMANDIBULAR JOINT

Dislocations of the temporomandibular joint sometimes occur when the mandible is depressed. The head of the mandible and the articular disc move forward until they reach the summit of the articular tubercle. In this position, the joint is unstable, and a minor blow on the chin or a sudden contraction of the lateral pterygoid muscles, as in yawning, may be sufficient to pull the disc forward beyond the summit and dislocation occurs.

Table 6-2 Muscles of Mastication

Muscle	Origin	Insertion	Nerve Supply	Action
Masseter	Zygomatic arch	Lateral surface of the ramus of the mandible	Mandibular division of the trigeminal nerve	Raises the mandible to occlude teeth in mastication
Temporalis	Floor of the temporal fossa and covering fascia	Coronoid process of the mandible	Mandibular division of the trigeminal nerve	Anterior and superior fibers elevate the mandible, posterior fibers retract the mandible
Lateral pterygoid	Greater wing of the sphenoid and the lateral pterygoid plate	Neck of the mandible and articular disc of the temporomandibular joint	Mandibular division of the trigeminal nerve	Pulls the neck of the mandible and disc forward
Medial pterygoid	Tuberosity of the maxilla and the lateral pterygoid plate	Medial surface of the angle of the mandible	Mandibular division of the trigeminal nerve	Raises mandible

Table 6-2 describes the muscles of mastication. These muscles are developed from the first pharyngeal arch and, therefore, are innervated by the mandibular division of the trigeminal nerve (fifth cranial nerve).

MUSCLES OF THE NECK

Table 6-3 describes the superficial muscles of the side of the neck (Fig. 6-4). Table 6-4 describes the suprahyoid and infrahyoid muscles. Table 6-5 describes the anterior and lateral vertebral muscles. Table 6-6 describes the suboccipital muscles.

Key Neck Muscles

STERNOCLEIDOMASTOID MUSCLE

When the sternocleidomastoid muscle (Fig. 6-4) contracts, it appears as an oblique band crossing the side of the neck from the sternoclavicular joint to the mastoid process of the skull. It divides the neck into anterior and posterior triangles. The anterior border covers the carotid arteries, the internal jugular vein, and the deep cervical lymph nodes; it also overlaps the thyroid gland. The muscle is covered superficially by skin, fascia, the platysma muscle, and the external jugular vein. The deep surface of the posterior border is related to the cervical plexus, the phrenic nerve, and the upper part of the brachial plexus. The origin, insertion, nerve supply, and action of the sternocleidomastoid muscle are summarized in Table 6-3.

CLINICAL NOTES

CONGENITAL TORTICOLLIS

Congenital torticollis is caused by the excessive stretching of this muscle during a difficult labor. The muscle is damaged, and the consequent repair with fibrous tissue causes the muscle to be shortened.

SCALENUS ANTERIOR MUSCLE

The scalenus anterior muscle is a key muscle in understanding the root of the neck (Fig. 6-5). It is deeply placed, and it descends almost vertically from the vertebral column to the first rib.

Important Relations

- **Anteriorly:** Related to the carotid arteries, the vagus nerve, the internal jugular vein, and the deep cervical lymph nodes. The transverse cervical and suprascapular arteries and the prevertebral layer of deep cervical fascia bind the phrenic nerve to the muscle.
- **Posteriorly:** Related to the pleura, the origin of the brachial plexus, and the second part of the subclavian artery. The scalenus medius muscle lies behind the scalenus anterior muscle.
- **Medially:** Related to the vertebral artery and vein and the sympathetic trunk. On the left side, the medial border is related to the thoracic duct.
- **Laterally:** Related to the emerging branches of the cervical plexus, the roots of the brachial plexus, and the third part of the subclavian artery.

The origin, insertion, nerve supply, and action of the scalenus anterior muscle are summarized in Table 6-5.

Cervical Fascia

SUPERFICIAL CERVICAL FASCIA

The superficial cervical fascia is a thin layer of connective tissue that encloses the platysma muscle. Also embedded within it are cutaneous nerves, superficial veins, and the superficial lymph nodes.

DEEP CERVICAL FASCIA

The deep cervical fascia supports the muscles, the vessels, and the viscera of the neck (Fig. 6-6). In certain areas, it is condensed to form well-defined, fibrous sheets called the **investing layer,** the **pretracheal layer,** and the **preverte-**

Table 6-3 Superficial Muscles of the Side of the Neck

Muscle	Origin	Insertion	Nerve Supply	Action
Platysma	Deep fascia of the upper part of the chest	Lower margin of the body of the mandible and the angle of the mouth	Facial nerve	Depresses the mandible and angle of the mouth
Trapezius	Occipital bone, ligamentum nuchae, spines of all thoracic vertebrae	Upper fibers into the lateral third of the clavicle, middle and lower fibers into the spine of the scapula	Spinal part of the accessory nerve and C3 and 4 spinal nerves	Upper fibers elevate the scapula, middle fibers pull the scapula medially, lower fibers pull the medial border of the scapula downward
Sternocleidomastoid	Manubrium sterni and medial third of the clavicle	Mastoid process of the temporal bone and the occipital bone	Spinal part of the accessory nerve and C2 and 3 spinal nerves	Muscles of the two sides acting together extend the head and flex the neck, one muscle acting alone rotates the head to the opposite side

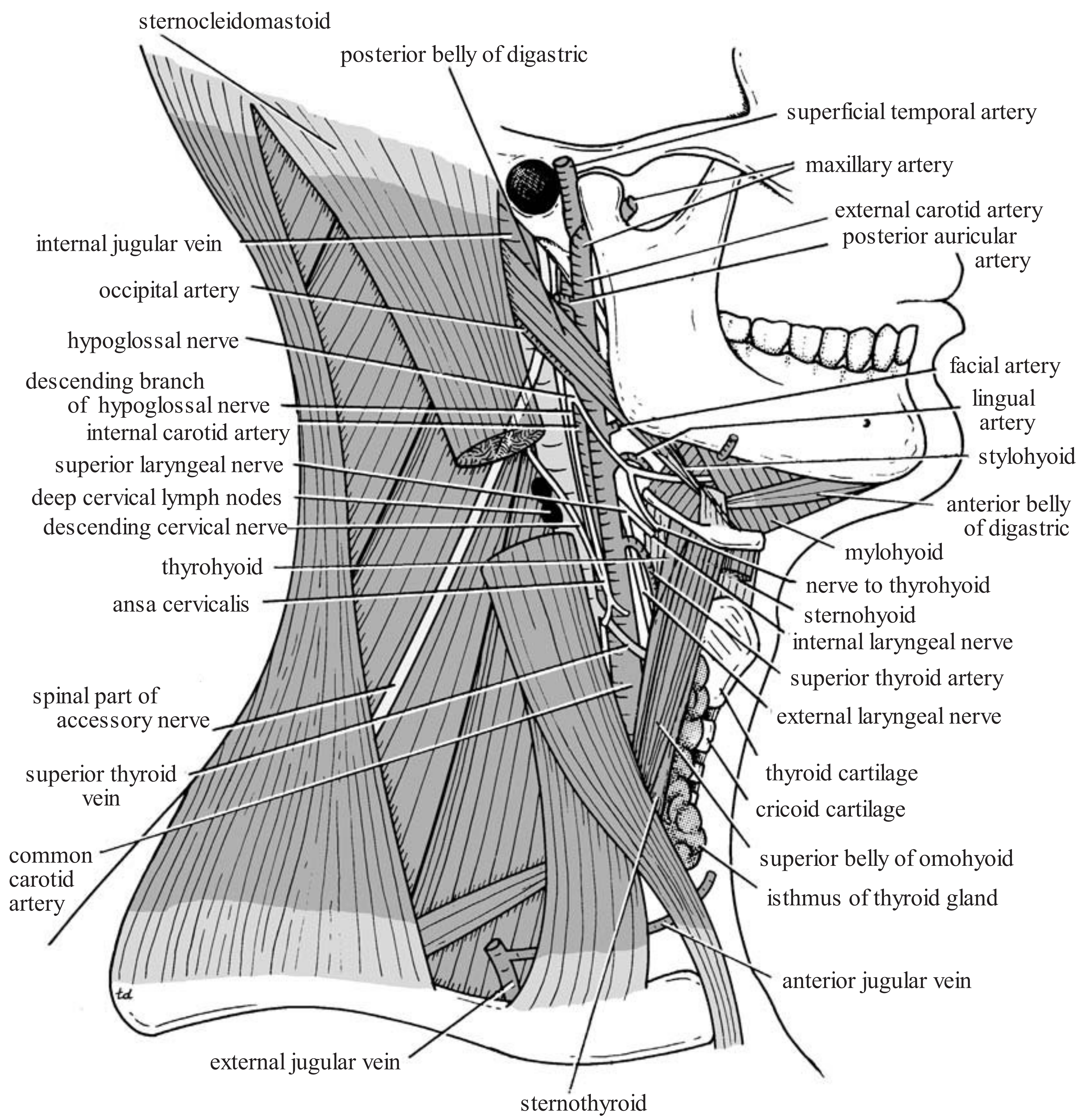


Figure 6-4 Anterior triangle of the neck.

Table 6-4 Suprahyoid and Infrahyoid Muscles

Muscle	Origin	Insertion	Nerve Supply	Action
Suprahyoid Muscles				
Digastric				
Posterior belly	Mastoid process of the temporal bone	Intermediate tendon bound to hyoid bone	Facial nerve	Depresses the mandible or elevates the hyoid bone
Anterior belly	Lower border of the mandible near the midline	Intermediate tendon bound to hyoid bone	Mylohyoid nerve, mandibular division of the trigeminal nerve	Depresses the mandible or elevates the hyoid bone
Stylohyoid	Styloid process of the temporal bone	Body of the hyoid bone	Facial nerve	Elevates the hyoid bone
Mylohyoid	Mylohyoid line on the inner surface of the body of the mandible	Body of the hyoid bone and raphe that extends from the mandible to the hyoid bone	Mandibular division of the trigeminal nerve (inferior alveolar nerve)	Elevates the floor of the mouth and the hyoid bone or depresses the mandible
Geniohyoid	Inferior mental spine on the back of the symphysis menti of the mandible	Body of the hyoid bone	C1 through the hypoglossal nerve	Elevates the hyoid bone or depresses the mandible
Infrahyoid Muscles				
Sternohyoid	Manubrium sterni and medial end of the clavicle	Body of the hyoid bone	Ansa cervicalis (C1, 2, and 3)	Depresses the hyoid bone
Sternothyroid	Manubrium sterni	Oblique line on the lamina of the thyroid cartilage	Ansa cervicalis (C1, 2, and 3)	Depresses larynx
Thyrohyoid	Oblique line on the lamina of the thyroid cartilage	Body of the hyoid bone	C1 through the hypoglossal nerve	Depresses the hyoid bone or elevates the larynx
Omohyoid				
Inferior belly	Upper margin of the scapula and the suprascapular ligament	Intermediate tendon bound to the clavicle and first rib	Ansa cervicalis (C1, 2, and 3)	Depresses the hyoid bone
Superior belly	Body of the hyoid bone	Intermediate tendon bound too the clavicle and first rib	Ansa cervicalis (C1, 2, and 3)	Depresses the hyoid bone

Table 6-5 Anterior and Lateral Vertebral Muscles

Muscle	Origin	Insertion	Nerve Supply	Action
Longus colli	Anterior surface of the vertebrae between the atlas and the third thoracic vertebra	Same as origin	Anterior rami of the cervical nerves	Flexes the cervical part of the vertebral column
Longus capitis	Transverse processes of the lower cervical vertebrae	Occipital bone	Anterior rami of the cervical nerves	Flexes the head
Recturs capitis anterior	Front of the lateral mass of the atlas	Occipital bone	Cervical plexus	Flexes the head
Rectusl capitis lateralis	Transverse process of the atlas	Occipital bone	Cervical plexus	Lateral flexion of the head
Scalenus anterior	Transverse process of the third, fourth, fifth, and sixth cervical vertebrae	First rib	Cervical spinal nerves	Elevates the first rib, laterally flexes and rotates the cervical part of the vertebral column
Scalenus medius	Transverse processes of the upper six cervical vertebrae	First rib	Cervical spinal nerves	Elevates the first rib, laterally flexes and rotates the cervical part of the vertebral column

Table 6-6 Suboccipital Muscles

Muscle	Origin	Insertion	Nerve Supply	Action
Rectus capitis posterior major	Spine of the axis	Occipital bone	Posterior ramus of the first cervical nerve	Extension of the head
Rectus capitis posterior minor	Posterior arch of the atlas	Occipital bone	Posterior ramus of the first cervical nerve	Extension of the head
Obliquus capitis inferior	Spine of the axis	Transverse process of the atlas	Posterior ramus of the first cervical nerve	Rotates face to the same side
Obliquus capitis superior	Transverse process of the atlas	Occipital bone	Posterior ramus of the first cervical nerve	Extends the head to the same side

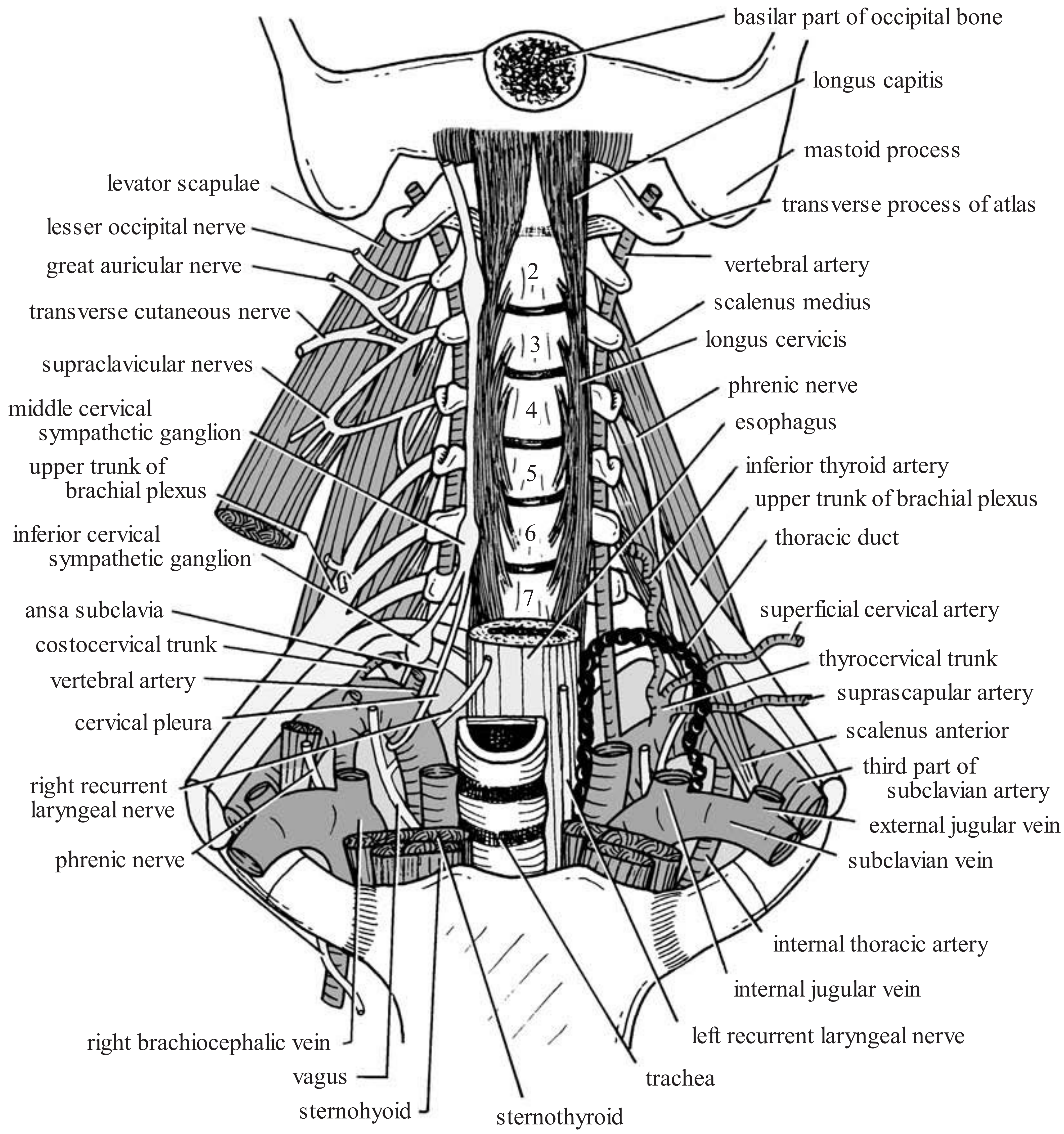
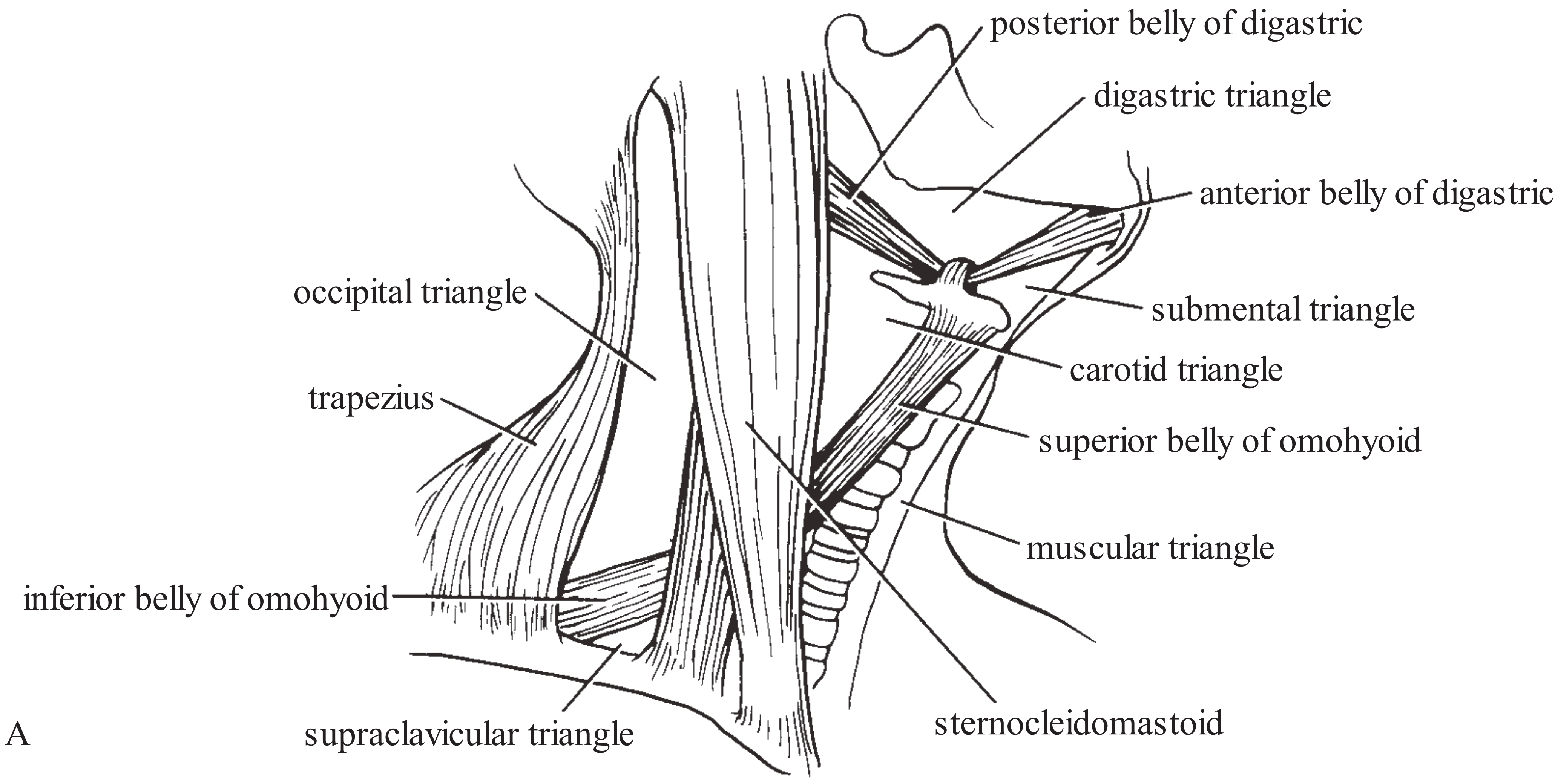


Figure 6-5 Prevertebral region and root of the neck.



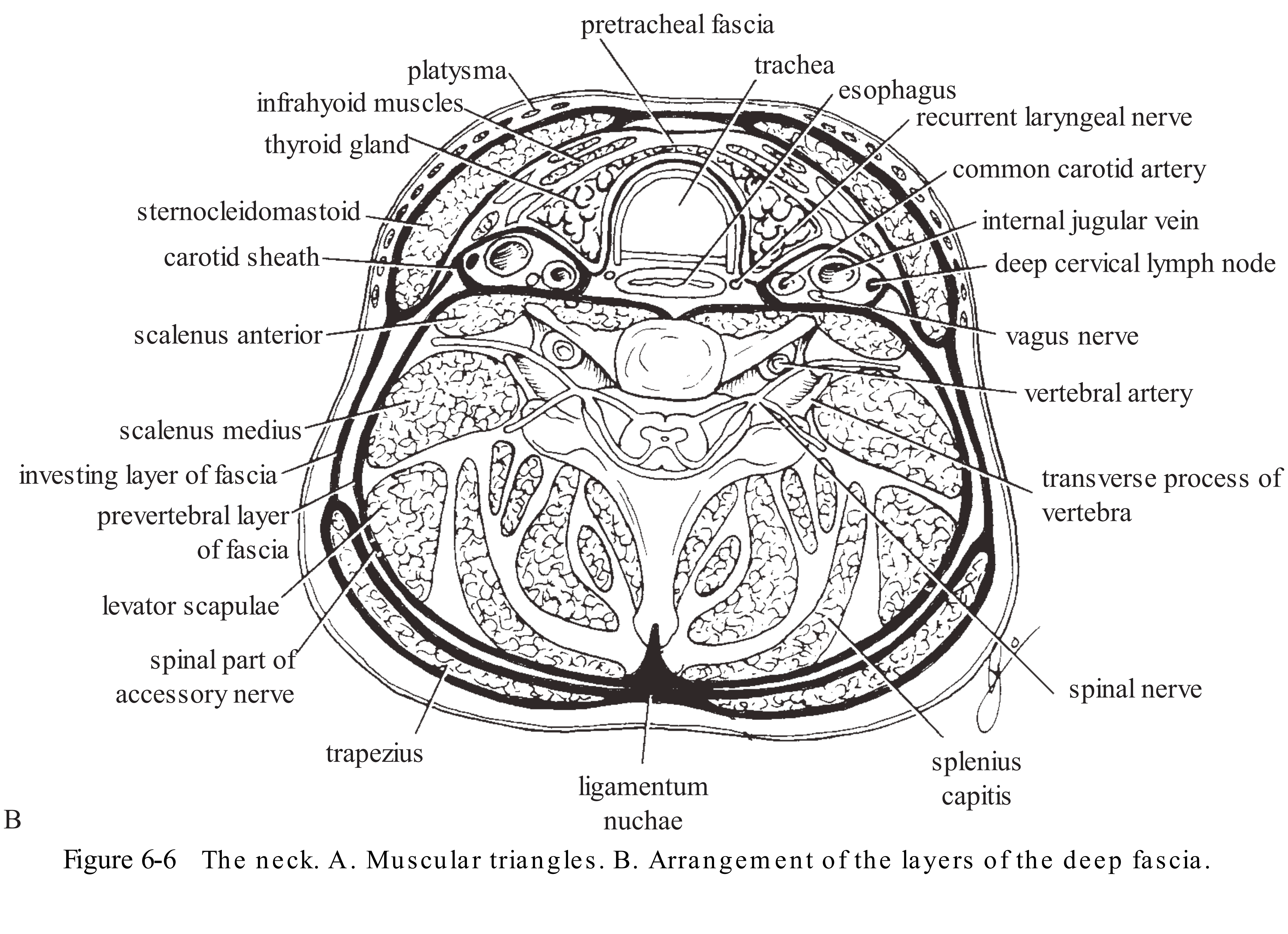


Figure 6-6 The neck. A. Muscular triangles. B. Arrangement of the layers of the deep fascia.

bral layer. It is also condensed to form the **carotid sheath** (Fig. 6-6).

Investing Layer

The investing layer is a thick layer that encircles the neck. It splits to enclose the trapezius and the sternocleidomastoid muscles (Fig. 6-6).

Pretracheal Layer

The pretracheal layer is a thin layer that is attached above to the laryngeal cartilages (Fig. 6-6). It surrounds the thyroid and the parathyroid glands, forming a sheath for them, and encloses the infrahyoid muscles.

Prevertebral Layer

The prevertebral layer is a thick layer that passes like a septum across the neck behind the pharynx and the esophagus and in front of the prevertebral muscles and the vertebral column (Fig. 6-6). It forms the fascial floor of the posterior triangle, and it extends laterally over the first rib into the axilla to form the important **axillary sheath** (see p. 124).

Carotid Sheath

The carotid sheath is a local condensation of the prevertebral, the pretracheal, and the investing layers of the deep fascia that surround the **common** and **internal carotid arteries,** the **internal jugular vein,** the **vagus nerve,** and the **deep cervical lymph nodes** (Fig. 6-6).

CLINICAL NOTES

DEEP FASCIA AND FASCIAL SPACES

The deep fascia and fascial spaces are important because infections in the mouth, teeth, pharynx, and esophagus can spread among the fascial planes and spaces. The tough fascia can determine the direction and extent of the spread.

Cervical Ligaments

- **Stylohyoid Ligament:** Connects the styloid process to the lesser cornu of the hyoid bone.
- **Stylomandibular Ligament:** Connects the styloid process to the angle of the mandible.
- **Sphenomandibular Ligament:** Connects the spine of the sphenoid bone to the lingula of the mandible.
- **Pterygomandibular Ligament:** Connects the hamular process of the medial pterygoid plate to the posterior end of the mylohyoid line of the mandible. It also gives attachment to the superior constrictor and the buccinator muscles.

Triangles of the Neck

The sternocleidomastoid muscle divides the neck into the anterior and the posterior triangles (Fig. 6-6).

ANTERIOR TRIANGLE

The anterior triangle is bounded above by the body of the mandible, posteriorly by the sternocleidomastoid muscle, and anteriorly by the midline (Fig. 6-6). It is further subdivided into the **carotid triangle,** the **digastric triangle,** the **submental triangle,** and the **muscular triangle** (Fig. 6-6).

POSTERIOR TRIANGLE

The posterior triangle is bounded posteriorly by the trapezius muscle, anteriorly by the sternocleidomastoid muscle, and inferiorly by the clavicle (Fig. 6-6).

CLINICAL NOTES

THE CLINICAL SIGNIFICANCE OF THE TRIANGLES OF THE NECK

The triangles of the neck assist the medical examiner in accurately localizing a wound, tumor, or a swelling. Commit to memory the boundaries and make a list of the important contents of each triangle.

MUSCLES OF THE SCALP AND FACE

The muscles of the scalp and face are all derived from the second pharyngeal arch. Therefore, they are all supplied by the facial nerve (seventh cranial nerve).

Muscles of the Scalp

The scalp consists of five layers, the first three of which are bound together and move as a whole on the skull. These layers are:

- Skin.
- Connective tissue of the superficial fascia.
- Aponeurosis of the occipitofrontalis muscle.
- Loose connective tissue, which permits the first three layers to move on the fifth layer.
- Periosteum of the skull bones.

Note that the first letter of each layer combines to spell the acronym **SCALP.** The origin, insertion, nerve supply, and action of the scalp muscles are summarized in Table 6-7.

Muscles of Facial Expression

Situated in the superficial fascia, the muscles of facial expression arise from the skull and are inserted into the skin (Fig. 6-7). These muscles serve as sphincters and dilators to the orbit, the nose, and the mouth. They also modify the expression of the face.

The origin, insertion, nerve supply, and action of the muscles of facial expression are summarized in Table 6-8. (Try using the various muscles while looking in the mirror. For examination purposes, it is unnecessary to know the precise attachments of these muscles.)

CLINICAL NOTES

THE INNERVATION OF THE MUSCLES OF FACIAL EXPRESSION

The muscles of facial expression are supplied by the facial nerve. This nerve may be damaged (e.g., in surgery or by forceps deliveries), subject to viral infection (Bell's palsy), or be involved in cancer of the parotid salivary gland. The resulting paralysis may have profound psychological effects on the patient and may seriously affect his or her ability to work in the marketplace.

ARTERIES OF THE HEAD AND NECK

Common Carotid Artery

The right common carotid artery arises from the brachiocephalic artery behind the right sternoclavicular joint (Fig. 6-8). The left artery arises from the arch of the aorta. The common carotid artery runs upward in the carotid sheath through the neck under cover of the anterior border of the

Table 6-7 Muscles of the Scalp and the External Ear

Muscle	Origin	Insertion	Nerve Supply	Action
Muscle of the Scalp				
Occipitofrontalis				
Occipital bellies	Occipital bone	Epicranial aponeurosis	Facial nerve	Moves scalp on the skull and raises the eyebrows
Frontal bellies	Skin and fascia of the eyebrow	Epicranial aponeurosis	Facial nerve	Moves scalp on the skull and raises the eyebrows
Muscles of the External Ear				
Auricularis anterior	Epicranial aponeurosis	Auricle	Facial nerve	Small amount of auricular movement in some individuals
Auricularis superior	Epicranial aponeurosis	Auricle	Facial nerve	Small amount of auricular movement in some individuals
Auricularis posterior	Epicranial aponeurosis	Auricle	Facial nerve	Small amount of auricular movement in some individuals

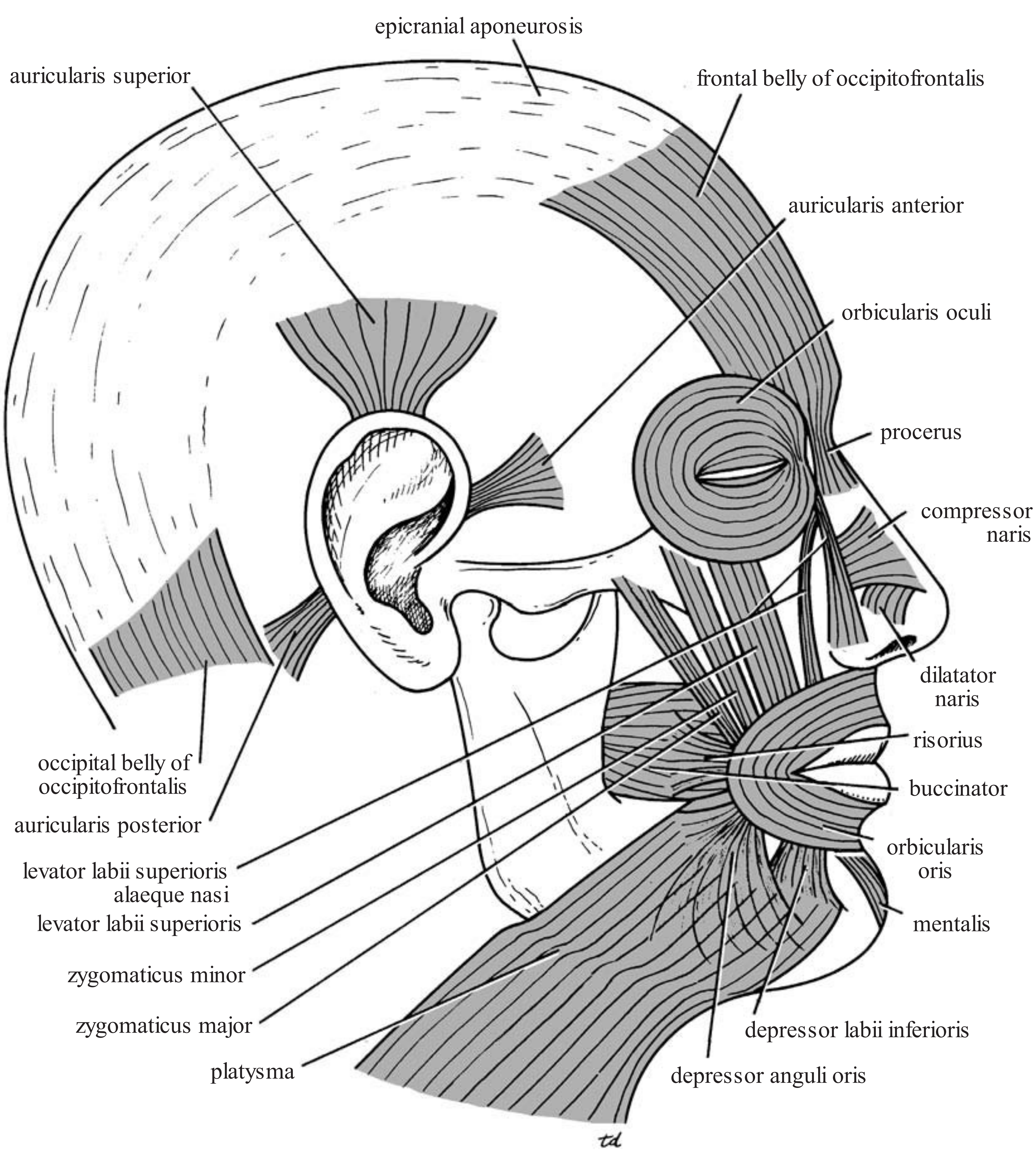


Figure 6-7 The muscles of facial expression.

Table 6-8 Muscles of Facial Expression

Muscle	Origin	Insertion	Nerve Supply	Action
Muscles of the Eyelids				
Orbicularis oculi				
Orbital part	Frontal bone, maxillary bone, medial palpebral ligament	No interruption, forms concentric loops	Facial nerve	Pulls skin of the forehead, temple, and cheek like a purse string ("screws up the eye")
Palpebral part	Medial palpebral ligament	Lateral palpebral ligament	Facial nerve	Closes eyelids
Lacrimal part	Lacrimal bone	Both eyelids	Facial nerve	Empties tears from the lacrimal sac
Corrugator supercilii	Medial part of the superciliary arch of the frontal bone	Skin of the eyebrow	Facial nerve	Pulls the eyebrows medially
Muscles of the Nostrils				
Compressor nairs	Frontal process of the maxilla	Via aponeurosis into muscle of the opposite side	Facial nerve	Compresses the nasal aperture
Dilator naris	Maxilla	Ala of the nose	Facial nerve	Widens the nasal aperture
Procerus	Nasal bone and lateral nasal cartilage	Skin between the eyebrows	Facial nerve	Wrinkles the skin at the root of the nose
Muscles of the Lips and Cheeks				
Sphincter muscle of the lips				
Orbicularis oris	Maxilla and mandible, skin of the lips, some fibers from the buccinator muscle	Surrounds the orifice at the mouth	Facial nerve	Compresses the lips together
Dilator Muscles of the lips (levator labii superioris alaeque nasi, levator labii superioris, zygomaticus minor, zygomaticus major, levator anguli oris, risorius, depressor anguli oris, depressor labii inferioris, entalis)	Bones and fascia around the oral aperture	Substance of the lips	Facial nerve	Separates the lips
Buccinator	Alveolar margins of maxilla and mandible; pterygomandibular ligament	Fibers decussate and enter the upper and lower lips	Facial nerve	Compresses the cheeks and lips against the teeth
Platysma	Deep fascia of the upper chest	Lower margin of the body of the mandible and angle of the mouth	Facial nerve	Depresses the mandible and draws down the angle of the mouth

sternocleidomastoid muscle. At the upper border of the thyroid cartilage, it divides into the external and internal carotid arteries. In the carotid sheath, the artery is related laterally to the internal jugular vein; the vagus nerve lies between these two structures.

CAROTID SINUS

The carotid sinus is a localized dilatation of the common carotid artery at its point of division into the external and internal carotid arteries (Fig. 6-8). It is supplied by the glossopharyngeal nerve and is a pressoreceptor that assists in regulation of the blood pressure.

CAROTID BODY

The carotid body is a small structure that lies posterior to the point of division of the common carotid artery. It is supplied by the glossopharyngeal nerve. The carotid body is a chemoreceptor, being sensitive to excess carbon dioxide and reduced oxygen tensions in the blood, and it assists in regulating the heart and the respiratory rates.

Branches

- External carotid artery.
- Internal carotid artery.

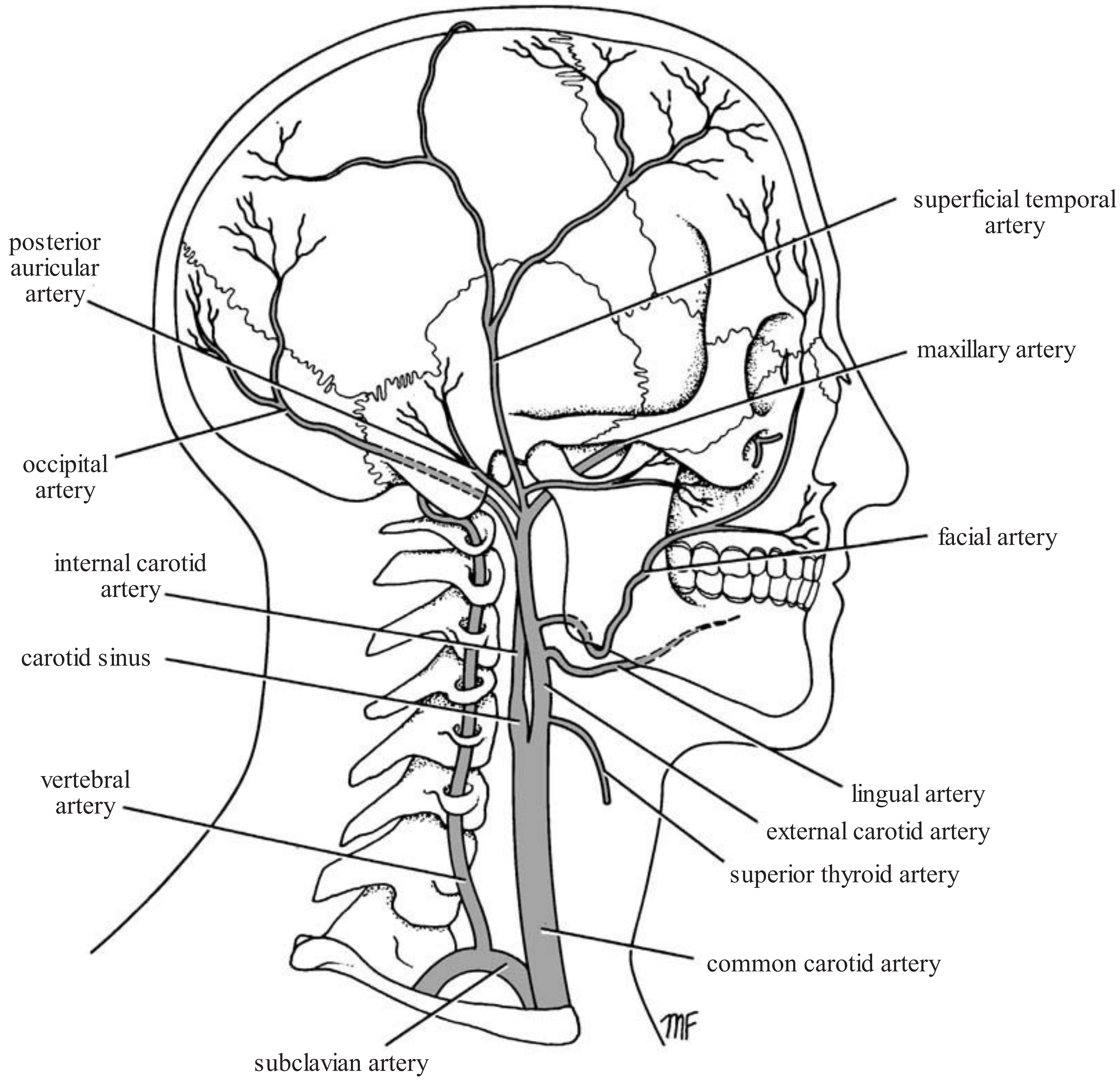


Figure 6-8 The main arteries of the head and neck. For clarity, the thyrocervical trunk, the costoverical trunk, the internal thoracic artery—branches of the subclavian artery—are not shown.

External Carotid Artery

The external carotid artery begins at the level of the upper border of the thyroid cartilage as one of the terminal branches of the common carotid artery (Fig. 6-8). It ascends to terminate in the parotid salivary gland behind the neck of the mandible, where it divides into the superficial temporal and the maxillary arteries.

CLINICAL NOTES

THE CAROTID PULSE

As it emerges from under cover of the anterior border of the sternocleidomastoid muscle, the external carotid artery lies within the carotid triangle, **where its pulsations can easily be felt.**

BRANCHES

- Superior thyroid artery.
- Ascending pharyngeal artery.
- Lingual artery.
- Facial artery.
- Occipital artery.
- Posterior auricular artery.
- Superficial temporal artery.
- Maxillary artery.

Superior Thyroid Artery

The superior thyroid artery curves downward to the upper pole of the thyroid gland (Fig. 6-8). It is accompanied by the **external laryngeal nerve,** which supplies the cricothyroid muscle.

Ascending Pharyngeal Artery

The ascending pharyngeal artery both ascends along and supplies the pharyngeal wall.

Lingual Artery

The lingual artery loops upward and forward. It supplies the tongue (Fig. 6-8). It is crossed superficially by the **hypoglossal nerve.**

Facial Artery

The facial artery loops upward on the lateral surface of the pharynx close to the tonsil (Fig. 6-8). It grooves (or tunnels) the submandibular salivary gland, bends around the lower border of the mandible, and ascends over the face close to the anterior border of the masseter muscle. The artery ascends lateral to the mouth and terminates at the medial angle of the orbit. Its pulsations can be felt against the mandible.

Branches of the facial artery supply the tonsil, the submandibular salivary gland, and the muscles and the skin of the face.

Occipital Artery

The occipital artery supplies the back of the scalp (Fig. 6-8).

Posterior Auricular Artery

The posterior auricular artery supplies the auricle and the scalp.

Superficial Temporal Artery

The superficial temporal artery ascends over the zygomatic arch, where it may be palpated just in front of the auricle (Fig. 6-8). It is accompanied by the auriculotemporal nerve, and it supplies the scalp.

CLINICAL NOTES

THE TEMPORAL ARTERY PULSE

The arterial pulse may be taken by palpating the artery just in front of the auricle.

Maxillary Artery

The maxillary artery runs forward medial to the neck of the mandible (Fig. 6-8). It leaves the infratemporal fossa through the pterygomaxillary fissure to enter the pterygopalatine fossa, where it splits up into branches that follow the branches of the maxillary division of the trigeminal nerve.

Branches

Branches supply the upper and the lower jaws, the muscles of mastication, the nose, the palate, and the meninges.

The **middle meningeal artery** ascends between the roots of the auriculotemporal nerve to enter the skull through the foramen spinosum. It runs laterally within the skull and divides into anterior and posterior branches. The **anterior branch** is particularly important, because it lies close to the motor area of the cerebral cortex. Accompanied by its vein, it grooves (or tunnels) through the upper part of the greater wing of the sphenoid bone and the thin anteroinferior angle of the parietal bone, where it is prone to damage after a blow to the lateral side of the head. Because the blood vessels lie between the meningeal layer of dura (the dura proper) and the periosteal layer of dura (the periosteum of skull), the resulting hemorrhage would be extradural.

Internal Carotid Artery

The internal carotid artery begins at the level of the upper border of the thyroid cartilage (Fig. 6-8). It ascends through the neck in the carotid sheath with the internal jugular vein and the vagus nerve, and it passes deep to the parotid salivary gland.

The internal carotid artery enters the cranial cavity by passing forward through the carotid canal in the petrous part of the temporal bone. It passes upward and then forward in the cavernous sinus. At the anterior end of the sinus, the artery bends upward through the roof and medial to the anterior clinoid process. The artery then inclines backward, lateral to the optic chiasma, and terminates by dividing into the anterior and the middle cerebral arteries.

BRANCHES

There are no branches in the neck. Many important branches, however, are given off in the skull.

The **ophthalmic artery** arises from the internal carotid artery as it emerges from the cavernous sinus. It passes forward into the orbital cavity through the optic canal, and it gives off the **central artery of the retina,** which enters the optic nerve and runs forward to enter the eyeball. The central artery is an end artery and the only blood supply to the retina.

The **posterior communicating artery** runs backward to join the posterior cerebral artery.

The **anterior cerebral artery** is a terminal branch of the internal carotid artery (Fig. 6-9). It passes forward between the cerebral hemispheres and then winds around the corpus callosum to supply the medial and the superolateral surfaces of the cerebral hemisphere. It is joined to the artery of the opposite side by the **anterior communicating artery.**

The **middle cerebral artery** is the largest terminal branch of the internal carotid artery (Fig. 6-9), and it runs laterally in the lateral cerebral sulcus. It supplies the entire lateral surface of the cerebral hemisphere except the narrow strip along the superolateral margin (which is supplied by the anterior cerebral artery) and the occipital pole and inferolateral surface of the hemisphere (both of which are supplied by the posterior cerebral artery). The middle cerebral artery thus supplies all the motor area of the cerebral cortex except the leg area. It also gives off central branches that supply central masses of gray matter and the internal capsule.

Circle of Willis

The circle of Willis lies in the subarachnoid space at the base of the brain. It is formed by the anastomosis between the branches of the two internal carotid arteries and the two

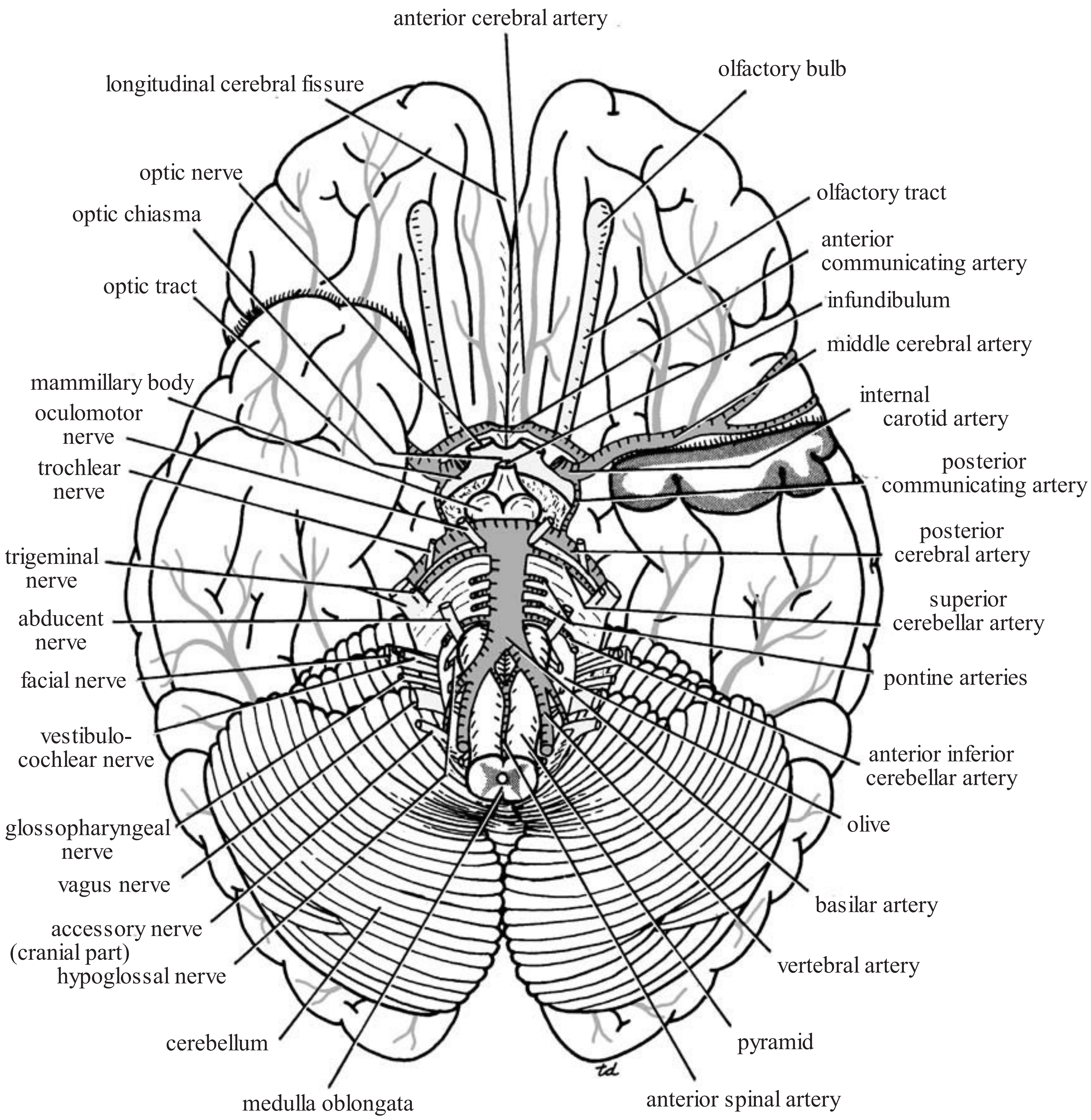


Figure 6-9 Arteries and cranial nerves on the inferior surface of the brain. To show the course of the middle cerebral artery, the anterior pole of the left temporal lobe has been removed.

vertebral arteries (Fig. 6-9). The anterior communicating, anterior cerebral, internal carotid, posterior communicating, posterior cerebral, and basilar (formed by the junction of the two vertebral arteries) are all arteries that contribute to the circle. Cortical and central branches arise from the circle and supply the brain.

Subclavian Arteries

RIGHT SUBCLAVIAN ARTERY

The right subclavian artery arises from the brachiocephalic artery, behind the right sternoclavicular joint (Fig. 6-8). It arches upward and laterally over the pleura and between the scalenus anterior and medius muscles. At the outer border of the first rib, it becomes the axillary artery.

LEFT SUBCLAVIAN ARTERY

The left subclavian artery arises from the arch of the aorta in the thorax. It ascends to the root of the neck and then arches laterally in a manner similar to that of the right subclavian artery.

The scalenus anterior muscle is used to divide the subclavian artery into three parts.

FIRST PART OF THE SUBCLAVIAN ARTERY

The first part of the subclavian artery extends from the origin of the subclavian artery to the medial border of the scalenus anterior muscle. This part gives off the vertebral artery, the thyrocervical trunk, and the internal thoracic artery.

Branches

The **vertebral artery** ascends in the neck through the foramina in the transverse processes of the **upper** six cervical vertebrae (Fig. 6-8). It passes medially above the posterior arch of the atlas and then ascends through the foramen magnum into the skull. On reaching the anterior surface of the medulla oblongata at the level of the lower border of the pons, it joins the vessel of the opposite side to form the basilar artery.

The **basilar artery** (Fig. 6-9) ascends in a groove on the anterior surface of the pons. It gives off branches to the pons, the cerebellum, and the internal ear. It finally divides into the two posterior cerebral arteries.

On each side, the **posterior cerebral artery** (Fig. 6-9) curves laterally and backward around the midbrain. Cortical branches supply the inferolateral surfaces of the temporal lobe and the visual cortex on the lateral and the medial surfaces of the occipital lobe.

- **Branches in the neck:** Spinal and muscular arteries.
- **Branches in the skull:** Meningeal, anterior and posterior spinal, posterior inferior cerebellar, medullary arteries.

The **thyrocervical trunk** is a short trunk that gives off three terminal branches (Fig. 6-5):

- The **inferior thyroid artery** ascends to reach the posterior surface of the thyroid gland, where it is closely related to the **recurrent laryngeal nerve.** The inferior thyroid artery supplies the thyroid and the inferior parathyroid glands.
- The **superficial cervical artery** runs laterally over the phrenic nerve and crosses the brachial plexus.
- The **suprascapular artery** runs laterally over the phrenic nerve and crosses the brachial plexus. It follows the suprascapular nerve into the supraspinous fossa of the scapula, and it takes part in the anastomosis around the scapula.

The **internal thoracic artery** enters the thorax behind the first costal cartilage and in front of the pleura (Fig. 6-5). It descends vertically one fingerbreadth lateral to the sternum; in the sixth intercostal space, it divides into the superior epigastric and the musculophrenic arteries (p. 6).

SECOND PART OF THE SUBCLAVIAN ARTERY

The second part of the subclavian artery lies behind the scalenus anterior muscle.

Branches

The **costocervical trunk** runs backward over the dome of the pleura and divides into the **superior intercostal artery,** which supplies the first and the second intercostal spaces, and the **deep cervical artery,** which supplies the deep muscles of the neck.

THIRD PART OF THE SUBCLAVIAN ARTERY

The third part of the subclavian artery extends from the lateral border of the scalenus anterior muscle (Fig. 6-5) across the posterior triangle of the neck to the lateral border of the first rib. With the nerves of the brachial plexus, it is surrounded by the **axillary sheath** of fascia.

Branches

The third part of the subclavian artery usually has no branches. Occasionally, however, the superficial cervical arteries, the suprascapular arteries, or both arise from this part.

VEINS OF THE HEAD AND NECK

The veins of the head and neck may be divided into (1) the veins of the brain, venous sinuses, diploic veins, and emissary veins and (2) the veins of the scalp, face, and neck.

Veins of the Brain

The veins of the brain are thin walled and have no valves. They consist of the **cerebral veins,** the **cerebellar veins,** and the **veins of the brain stem,** all of which drain into the neighboring venous sinuses.

Venous Sinuses

The venous sinuses are situated between the periosteal and the meningeal layers of the dura mater (Fig. 6-10). They have thick, fibrous walls, but they possess no valves. They receive tributaries from the brain, the skull bones, the orbit, and the internal ear.

SUPERIOR SAGITTAL SINUS

The superior sagittal sinus lies in the upper fixed border of the falx cerebri (Fig. 6-10). It runs backward and becomes continuous with the right transverse sinus, and it communicates on each side with the **venous lacunae.** Numerous arachnoid villi and granulations project into the lacunae.

INFERIOR SAGITTAL SINUS

The inferior sagittal sinus lies in the lower free margin of the falx cerebri (Fig. 6-10). It runs backward and joins the **great cerebral vein** to form the straight sinus.

STRAIGHT SINUS

The straight sinus lies at the junction of the falx cerebri and the tentorium cerebelli. Formed by the union of the inferior sagittal sinus with the great cerebral vein, it drains into the left transverse sinus.

TRANSVERSE SINUSES

The right transverse sinus begins as a continuation of the superior sagittal sinus; the left transverse sinus is usually a continuation of the straight sinus (Fig. 6-10). Each sinus lies in the lateral attached margin of the tentorium cerebelli, and they end on each side by becoming the sigmoid sinus.

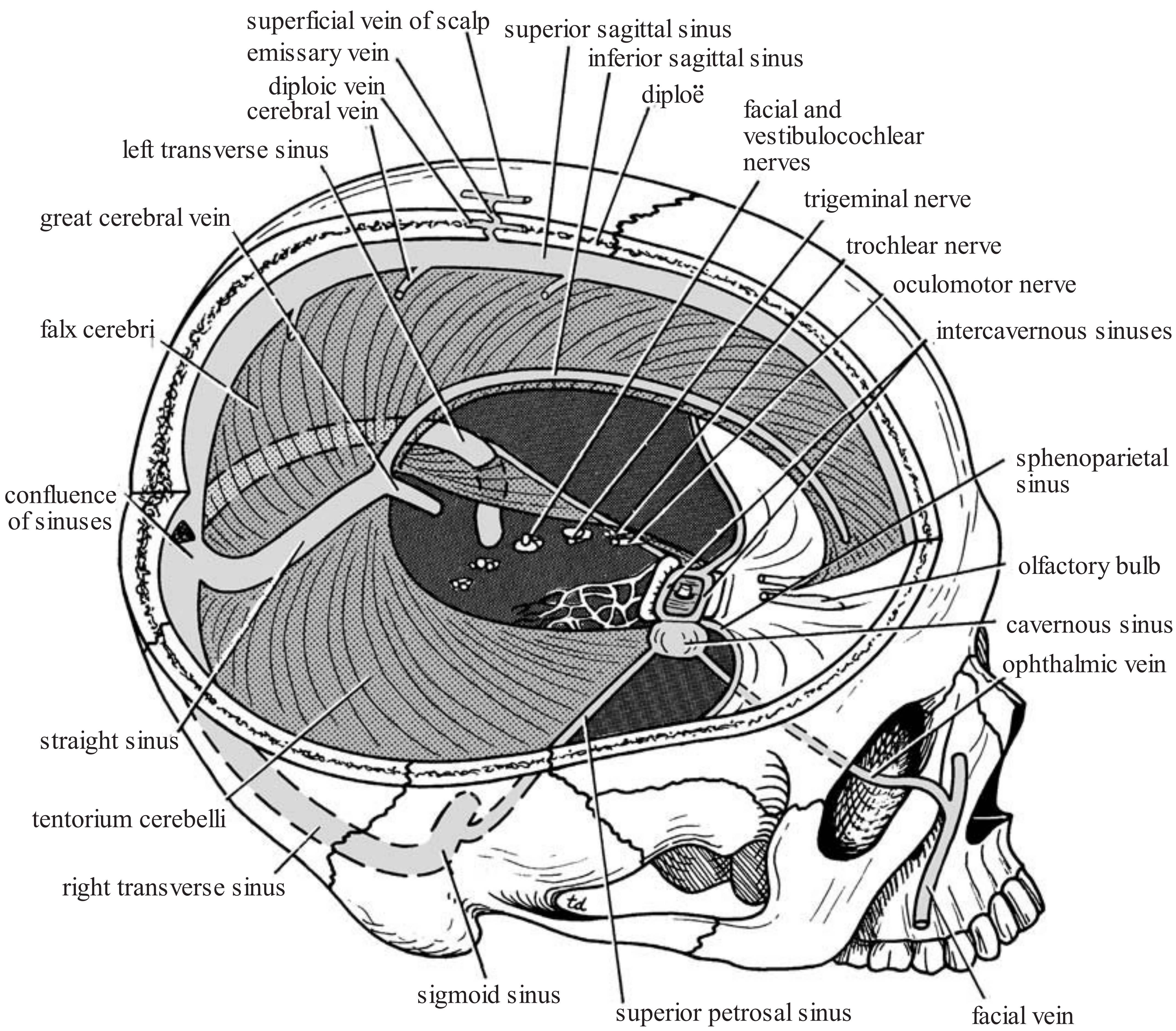


Figure 6-10 Interior view of the skull showing the dura mater and its venous sinuses. Note the connections of the veins of the scalp and the face with the venous sinuses.

SIGMOID SINUSES

The sigmoid sinuses are a direct continuation of the transverse sinuses. Each sinus curves downward behind the mastoid antrum and then leaves the skull through the jugular foramen to become the internal jugular vein.

CLINICAL NOTES

THE SIGMOID SINUS AND INFECTION FROM THE MASTOID ANTRUM

Infection of the antrum may spread to the sigmoid sinus, causing thrombosis and septicemia..

OCCIPITAL SINUS

The occipital sinus lies in the attached margin of the falx cerebelli. It communicates with the vertebral veins through the foramen magnum and with the transverse sinuses.

CAVERNOUS SINUSES

Each cavernous sinus lies on the lateral side of the body of the sphenoid bone (Fig. 6-28). Anteriorly, the sinus receives the inferior ophthalmic vein and the central vein of the retina. The sinus drains posteriorly into the transverse sinus through the superior petrosal sinus. Intercavernous sinuses connect the two cavernous sinuses through the sella turcica.

Important Structures Associated with the Cavernous Sinuses

- The internal carotid artery and the sixth cranial nerve, which travel through it (Fig. 6-28).
- In the lateral wall, the third and the fourth cranial nerves and the ophthalmic and the maxillary divisions of the fifth cranial nerve (Fig. 6-28).
- The hypophysis cerebri, which lies medially in the sella turcica (Fig. 6-28).
- The veins of the face, which are connected with the cavernous sinus via the facial vein and inferior ophthalmic vein (and are an important route for the spread of infection from the face).

SUPERIOR AND INFERIOR PETROSAL SINUSES

The petrosal sinuses run along the upper and the lower borders of the petrous part of the temporal bone.

Diploic Veins

The diploic veins occupy channels within the bones of the vault of the skull.

Emissary Veins

The emissary veins are valveless veins that pass through the skull bones. They connect the veins of the scalp to the venous sinuses (and are an important route for the spread of infection).

Veins of the Face and the Neck

FACIAL VEIN

The facial vein is formed at the medial angle of the eye by the union of the **supraorbital** and the **supratrochlear veins** (Fig. 6-11). It is connected through the ophthalmic veins with the cavernous sinus. The facial vein descends down the face with the facial artery and passes lateral to the mouth. It then crosses the mandible, is joined by the anterior division of the retromandibular vein, and drains into the internal jugular vein.

SUPERFICIAL TEMPORAL VEIN

The superficial temporal vein is formed on the side of the scalp (Fig. 6-11). It follows the superficial temporal artery and the auriculotemporal nerve and then enters the parotid salivary gland, where it joins the maxillary vein to form the retromandibular vein.

MAXILLARY VEIN

The maxillary vein is formed in the infratemporal fossa from the pterygoid venous plexus (Fig. 6-11). The maxillary vein joins the superficial temporal vein to form the retromandibular vein.

RETROMANDIBULAR VEIN

The retromandibular vein is formed by the union of the superficial temporal and the maxillary veins (Fig. 6-11). On

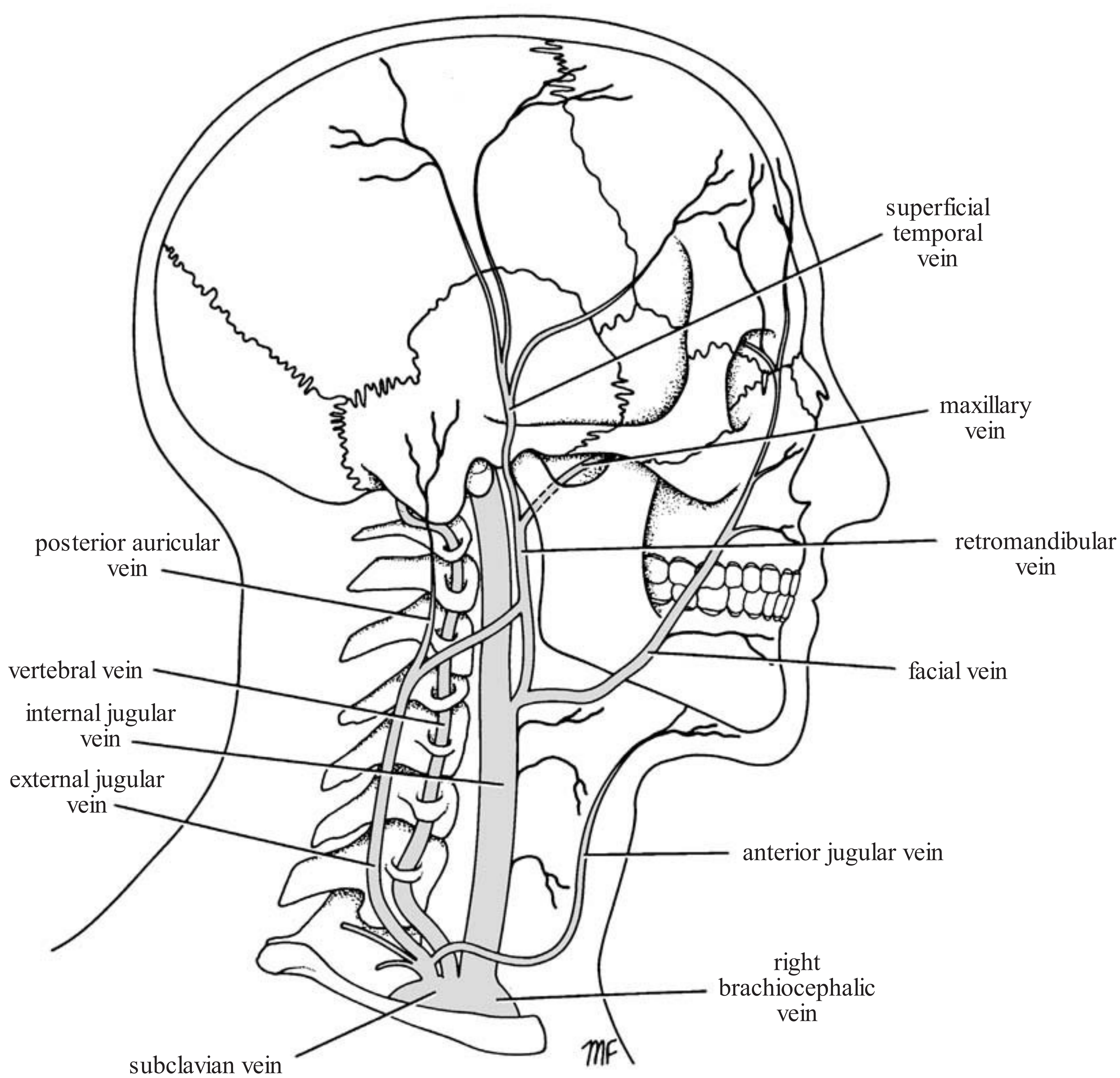


Figure 6-11 The main veins of the head and neck.

leaving the parotid salivary gland, it divides into an anterior branch, which joins the facial vein, and a posterior branch, which joins the **posterior auricular vein** to form the external jugular vein.

EXTERNAL JUGULAR VEIN

The external jugular vein is formed behind the angle of the jaw by the union of the posterior auricular vein with the posterior division of the retromandibular vein (Fig. 6-11). It descends across the sternocleidomastoid muscle and beneath the platysma muscle, and it drains into the subclavian vein behind the middle of the clavicle.

Tributaries

- **Posterior external jugular vein** from the back of the scalp.
- **Superficial cervical vein** from the skin and the fascia over the posterior triangle.
- **Suprascapular vein** from the suprascapular fossa.
- **Anterior jugular vein.**

CLINICAL NOTES

CLINICAL SIGNIFICANCE OF THE EXTERNAL JUGULAR VEIN

The external jugular vein, since it is usually visible in most patients, may serve as a useful venous manometer in cardiac cases. It can also be used for catheterization.

ANTERIOR JUGULAR VEIN

The anterior jugular vein descends in the neck close to the midline (Fig. 6-11). Just above the sternum, it is joined to the opposite vein by the jugular arch. The anterior jugular vein joins the external jugular vein deep to the sternocleidomastoid muscle.

INTERNAL JUGULAR VEIN

The internal jugular vein is a large vein that drains blood from the brain, face, scalp, and neck (Fig. 6-11). It starts as a continuation of the sigmoid venous sinus and leaves the skull through the jugular foramen. It then descends through the neck in the carotid sheath lateral to the vagus nerve and the internal and the common carotid arteries. It ends by joining the subclavian vein to form the brachiocephalic vein behind the medial end of the clavicle. Throughout its course, it is closely related to the **deep cervical lymph nodes.**

Tributaries

- **Inferior petrosal sinus.**
- **Facial vein.**
- **Pharyngeal veins.**
- **Lingual vein.**
- **Superior thyroid vein.**
- **Middle thyroid vein.**

SUBCLAVIAN VEIN

The subclavian vein is a continuation of the axillary vein at the outer border of the first rib (Fig. 6-11). It joins the internal jugular vein to form the brachiocephalic vein, and it receives the external jugular vein. In addition, it often receives the **thoracic duct** on the left side and the **right lymphatic duct** on the right.

CLINICAL NOTES

SUBCLAVIAN VEIN CATHETERIZATION

The subclavian vein, where it lies in the root of the posterior triangle of the neck, may be used for cardiac catheterization.

LYMPHATIC DRAINAGE OF THE HEAD AND NECK

The lymph nodes are arranged in two groups (Fig. 6-12): the **regional group**, which surrounds the neck below the chin like a collar, and the **deep vertical group**, which is embedded in the carotid sheath.

Regional Lymph Nodes

- **Occipital nodes:** Situated at the apex of the posterior triangle. They receive lymph from the back of the scalp.
- **Mastoid nodes:** Lie over the mastoid process. They receive lymph from the scalp above the ear, the auricle, and the external auditory meatus.
- **Parotid nodes:** Situated on or within the parotid salivary gland. They receive lymph from the scalp above the parotid gland, the eyelids, the auricle, and the external auditory meatus.
- **Buccal nodes:** One or two in number, they lie on the buccinator muscle. They drain lymph from the face and the anterior part of the scalp, and they pass this lymph to the submandibular nodes.
- **Submandibular nodes:** Lie superficial to the submandibular salivary gland just below the body of the mandible. They receive lymph from the front of the scalp; the nose; the cheek; the upper and lower lip (except the central part of the lower lip); the frontal, the maxillary, and the ethmoid sinuses; the upper and the lower teeth (except the lower incisors); the anterior two thirds of the tongue (except the tip); the floor of the mouth; and the vestibule and the gums.
- **Submental nodes:** Lie in the submental triangle just below the chin. They receive lymph from the tip of the tongue, the floor of the anterior part of the mouth, the incisor teeth, the central part of the lower lip, and the skin over the chin.

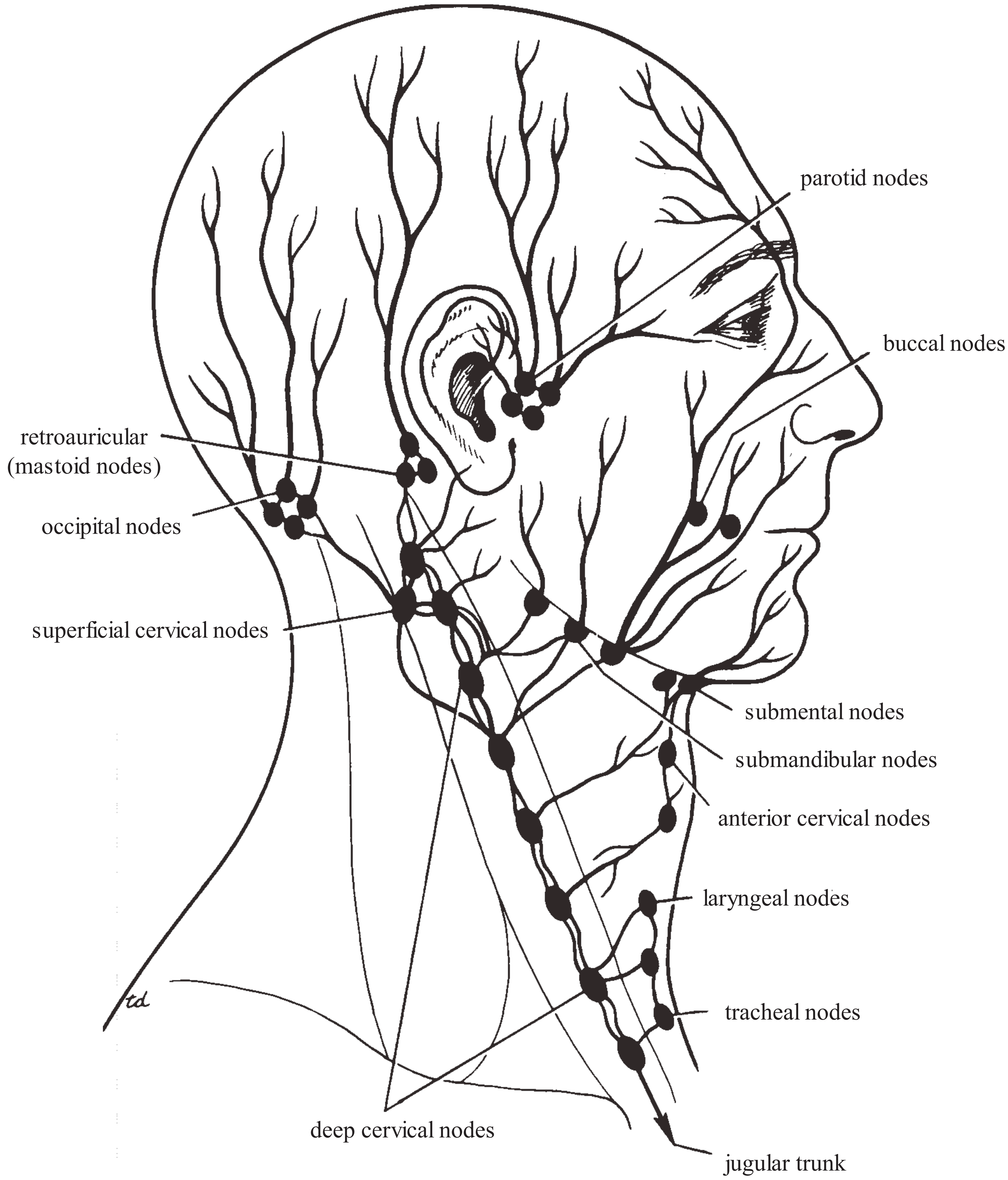


Figure 6-12 Lymphatic drainage of the head and neck.

- **Anterior cervical nodes:** Lie along the course of the anterior jugular veins. They receive lymph from the skin of the front of the neck.
- **Superficial cervical nodes**: Lie along the external jugular vein. They receive lymph from the skin over the angle of the jaw and the lower part of the parotid gland and from the lobe of the ear.
- **Retropharyngeal nodes:** Lie between the pharynx and the vertebral column. They receive lymph from the nasopharynx, the auditory tube, and the vertebral column.
- **Laryngeal nodes:** Lie in front of and receive lymph from the larynx.
- **Tracheal (paratracheal) nodes**: Lie alongside the trachea and receive lymph from the trachea and the thyroid gland.

Deep Cervical Lymph Nodes

The deep cervical lymph nodes are arranged in a vertical chain along the course of the internal jugular vein within the carotid sheath (Fig. 6-12). They receive lymph from all the regional nodes previously discussed.

The efferent lymph vessels from all the deep cervical lymph nodes join to form the **jugular trunk,** which drains into the thoracic duct or the right lymphatic duct.

- **Jugulodigastric node:** Located behind the angle of the jaw and drains the tonsil.
- **Jugulo-omohyoid node:** Located approximately halfway down the neck, it is mainly associated with drainage of the tongue.

CLINICAL NOTES

Clinical Importance of the Cervical Lymph Nodes

A knowledge of the lymph drainage of an organ or region is of great clinical importance. For a pathologically enlarged node, a physician has to search systematically the various areas known to drain into a particular node to discover the cause.

CRANIAL NERVES

There are twelve pairs of cranial nerves:

I. The olfactory (sensory).
II. The optic (sensory).
III. The oculomotor (motor).
IV. The trochlear (motor).
V. The trigeminal (mixed).
VI. The abducent (motor).
VII. The facial (mixed).
VIII. The vestibulocochlear (sensory).
IX. The glossopharyngeal (mixed).
X. The vagus (mixed).
XI. The accessory (motor).
XII. The hypoglossal (motor).

Olfactory Nerves

The olfactory nerves arise from olfactory nerve cells in the upper part of the nasal mucous membrane above the superior concha (Fig. 6-13). Bundles of these nerves pass through the openings in the cribriform plate of the ethmoid bone to enter the **olfactory bulb** inside the skull. The olfactory bulb is connected to the **olfactory area of the cerebral cortex** by the olfactory tract.

Optic Nerve

The optic nerve axons arise from the cells of the **ganglionic layer of the retina** (Fig. 6-13). The optic nerve leaves the eyeball in the orbital cavity, and it passes through the optic canal to enter the middle cranial fossa. It unites with the optic nerve of the opposite side to form the **optic chiasma.**

In the optic chiasma, the fibers from the medial (nasal) half of each retina cross the midline and enter the **optic tract** of the opposite side, whereas the fibers from the lateral (temporal) half of each retina pass posteriorly in the optic tract of the same side (Fig. 6-13). Most fibers of the optic tract terminate by synapsing with nerve cells in the **lateral geniculate body,** which is a small projection from the posterior thalamus. A few fibers pass to the pretectal nucleus and superior colliculus of the midbrain, however, and are concerned with light reflexes.

The axons of the nerve cells of the lateral geniculate body pass posteriorly as the **optic radiation** and terminate in the **visual cortex** of the cerebral hemisphere.

Oculomotor Nerve

The oculomotor nerve emerges on the anterior surface of the midbrain (Fig. 6-14). It passes forward in the lateral wall of the cavernous sinus, and it divides into superior and inferior rami, both of which enter the orbital cavity through the superior orbital fissure.

The oculomotor nerve supplies the following:

- The levator palpebrae superioris, the superior rectus, the medial rectus, the inferior rectus, and the inferior oblique muscles (the extrinsic muscles of the eye).
- The parasympathetic nerve fibers to the constrictor pupillae of the iris and the ciliary muscles (the intrinsic muscles of the eye). These fibers synapse in the **ciliary ganglion** and reach the eyeball in the **short ciliary nerves.**

The oculomotor nerve, therefore, is entirely motor. It is responsible for lifting the upper eyelid; turning the eye upward, downward, and medially; constricting the pupil; and accommodating the eye.

Trochlear Nerve

The trochlear nerve is the most slender of the cranial nerves. Having decussated (crossed) the nerve of the opposite side, it leaves the posterior surface of the midbrain (Fig. 6-14). It then runs forward in the lateral wall of the cavernous sinus and enters the orbit through the superior orbital fissure.

The trochlear nerve supplies the superior oblique muscle of the eyeball (an extrinsic muscle). It is entirely motor and assists in turning the eye downward and laterally.

Trigeminal Nerve

The trigeminal nerve is the largest cranial nerve (Fig. 6-15). It leaves the anterior aspect of the pons as a small motor root and a large sensory root, and it passes forward, out of the posterior cranial fossa, to reach the middle cranial fossa, where the sensory root then expands to form the **trigeminal ganglion.** The trigeminal ganglion lies within a pouch of dura mater called the **trigeminal cave.** The ophthalmic, maxillary, and mandibular nerves arise from the anterior border of the ganglion.

Ophthalmic Nerve

The ophthalmic nerve (Fig. 6-15) is entirely sensory. It runs forward in the lateral wall of the cavernous sinus, and it divides into three branches (the lacrimal, the frontal, and the nasociliary nerves) that enter the orbital cavity through the superior orbital fissure.

Branches

The **lacrimal nerve** runs forward on the upper border of the lateral rectus muscle. It is joined by the zygomaticotemporal branch of the maxillary nerve, which contains the parasympathetic secretomotor fibers to the lacrimal gland. The lacrimal nerve then enters the lacrimal gland and gives branches to the conjunctiva and the skin of the upper eyelid.

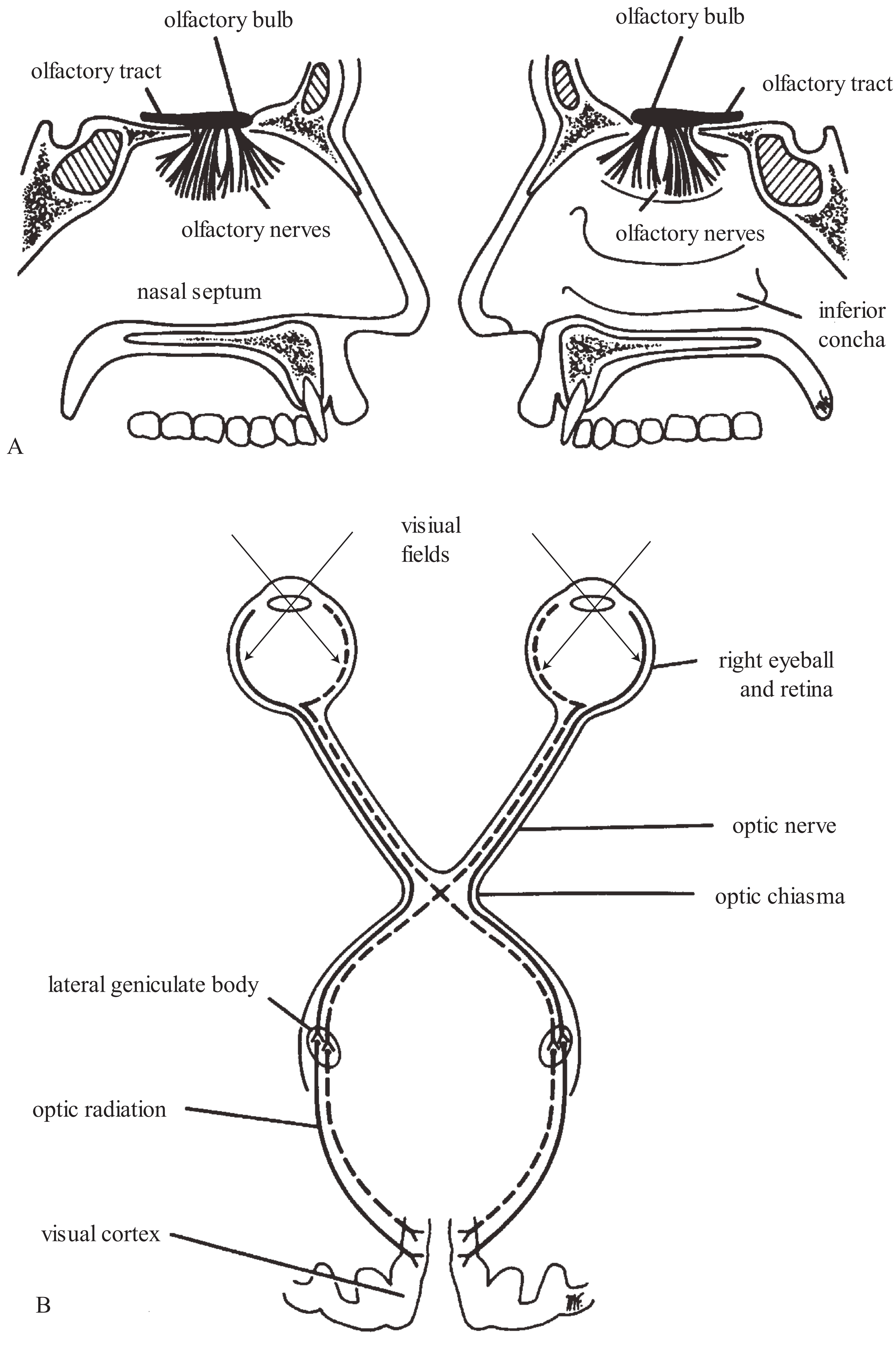


Figure 6-13 A. Distribution of the olfactory nerves on the nasal septum and the lateral wall of the nose. B. The optic nerve and its connections.

The **frontal nerve** runs forward on the upper surface of the levator palpebrae superioris muscle and divides into the **supraorbital** and the **supratrochlear nerves.** These nerves leave the orbital cavity and supply the frontal air sinus and the skin of the forehead and the scalp.

The **nasociliary nerve** crosses the optic nerve, runs forward on the upper border of the medial rectus muscle, and continues as the **anterior ethmoid nerve** through the anterior ethmoidal foramen to enter the cranial cavity. It then descends through a slit at the side of the crista galli to enter the nasal cavity. It gives off two **internal nasal branches,** and it then supplies the skin of the tip of the nose with the **external nasal nerve.** Its branches include the following:

- **Sensory fibers** to the ciliary ganglion.
- **Long ciliary nerves** that contain sympathetic fibers to the dilator pupillae muscle and sensory fibers to the cornea.

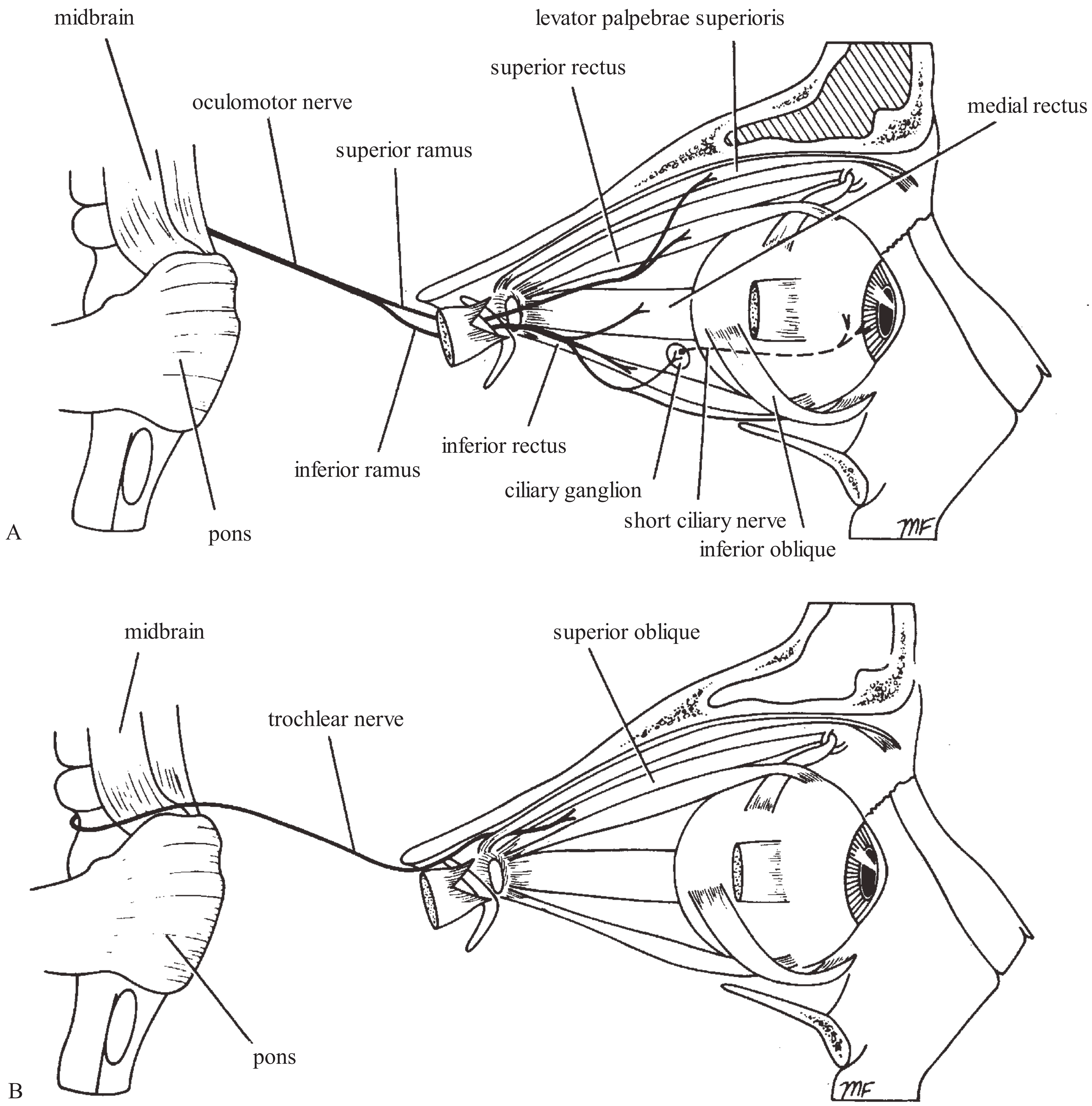


Figure 6-14 A. Origin and distribution of the oculomotor nerve. B. Origin and distribution of the trochlear nerve.

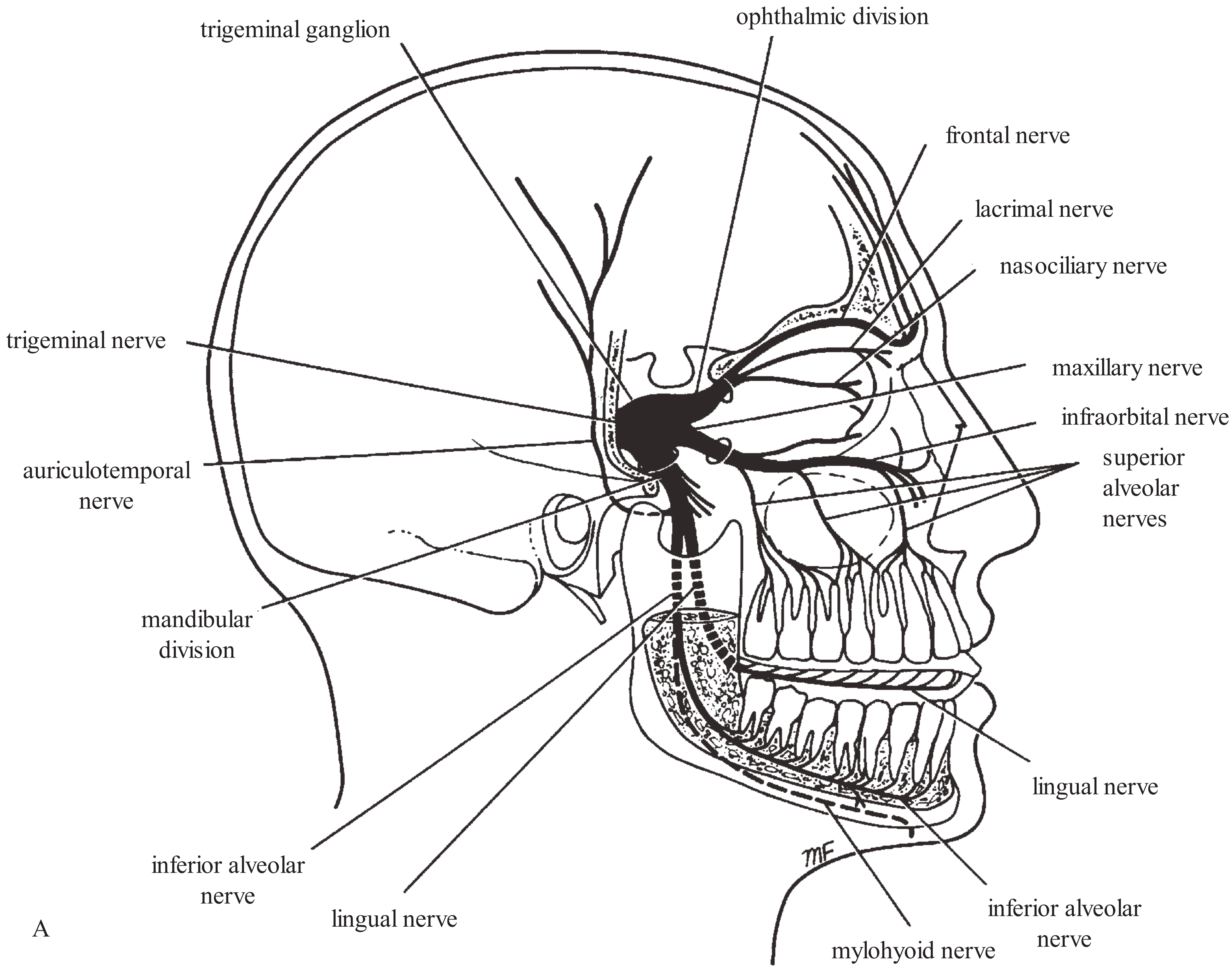
- The **infratrochlear nerve** that supplies the skin of the eyelids.
- The **posterior ethmoidal nerve** that is sensory to the ethmoid and the sphenoid sinuses.

MAXILLARY NERVE

The maxillary nerve (Fig. 6-15) is purely sensory. It leaves the skull through the foramen rotundum and crosses the pterygopalatine fossa to enter the orbit through the inferior orbital fissure. It then continues as the **infraorbital nerve** in the infraorbital groove, and it emerges on the face through the infraorbital foramen. It gives sensory fibers to the skin of the face and the side of the nose.

Branches

- The **meningeal branches.**
- The **zygomatic** branch, which divides into the **zygomaticotemporal** and the **zygomaticofacial nerves** that supply the skin of the face. The zygomaticotemporal branch gives parasympathetic secretomotor fibers to the lacrimal gland via the lacrimal nerve.
- The **ganglionic branches,** which are two short nerves that suspend the pterygopalatine ganglion in the pterygopalatine fossa. They contain sensory fibers that have passed through the ganglion from the nose, the palate, and the pharynx. They also contain postganglionic parasympathetic fibers that are going to the lacrimal gland.



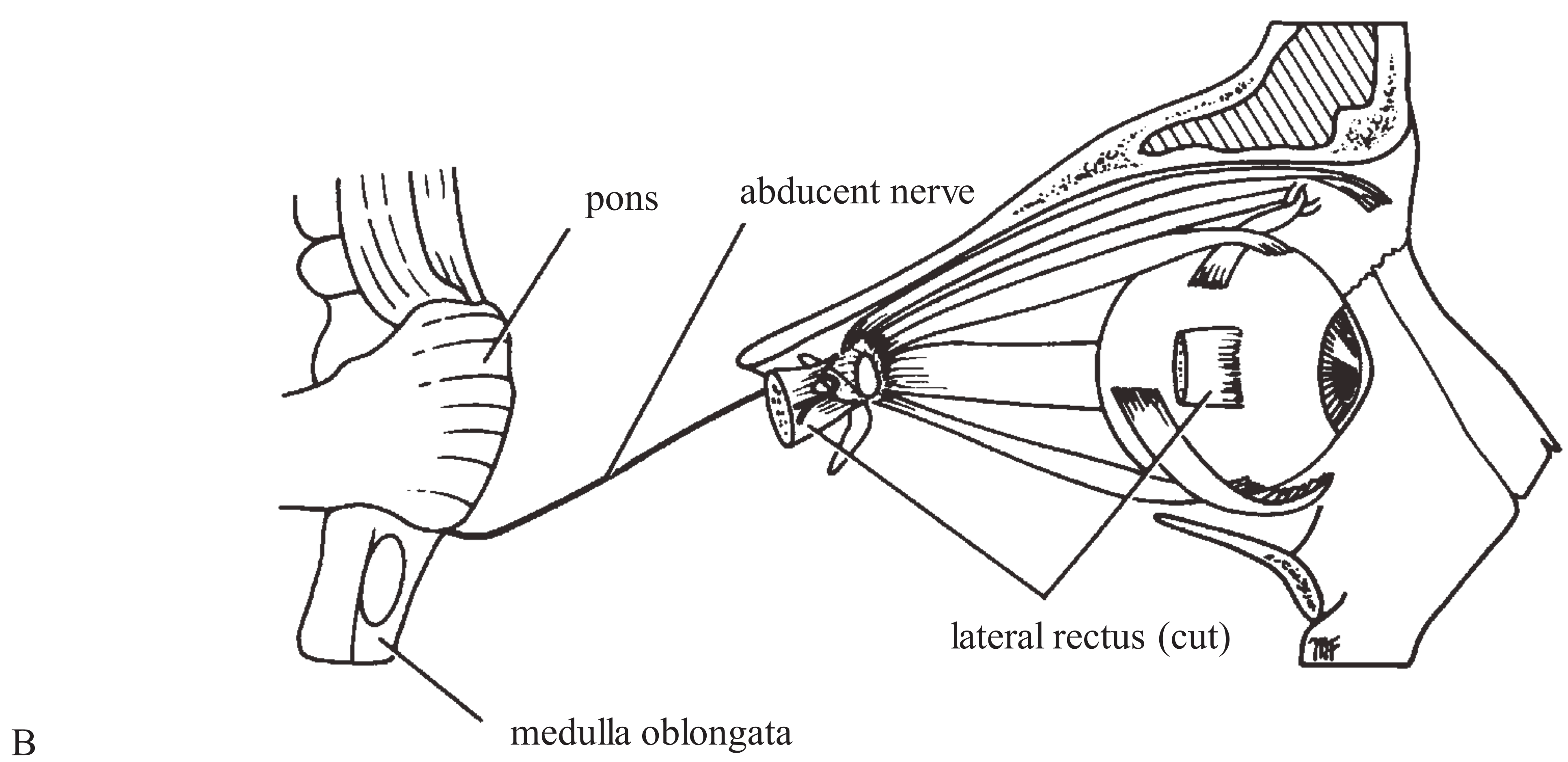


Figure 6-15 A. Distribution of the trigeminal nerve. B. Distribution of the abducent nerve.

- The **posterior superior alveolar nerve,** which supplies the maxillary sinus as well as the upper molar teeth and adjoining parts of the gum and the cheek.
- The **middle superior alveolar nerve,** which supplies the maxillary sinus, the upper premolar teeth, the gums, and the cheek.
- The **anterior superior alveolar nerve,** which supplies the maxillary sinus as well as the upper canine and the incisor teeth.

Pterygopalatine Ganglion

The pterygopalatine ganglion is a parasympathetic ganglion, which is suspended from the maxillary nerve in the pterygopalatine fossa. It is secretomotor to the lacrimal and the nasal glands (see p. 230).

Branches

- The **orbital branches,** which enter the orbit through the inferior orbital fissure.
- The **greater** and the **lesser palatine nerves,** which supply the palate, the tonsil, and the nasal cavity.
- The **nasal branches.**
- The **pharyngeal branch,** which supplies the roof of the nasopharynx.

MANDIBULAR NERVE

The mandibular nerve (Fig. 6-15) is both motor and sensory. The sensory root leaves the trigeminal ganglion and passes through the foramen ovale to enter the infratemporal fossa. The motor root also passes through the foramen ovale, joins the sensory root to form the trunk of the mandibular nerve, and then divides into a small anterior and a large posterior division.

Branches from the Main Trunk of the Mandibular Nerve

- The **meningeal branch**.
- The **nerve to the medial pterygoid muscle**, which supplies not only the medial pterygoid but the tensor veli palatini muscle as well.

Branches from the Anterior Division of the Mandibular Nerve

- The **masseteric nerve** to the masseter muscle.
- The **deep temporal nerves** to the temporalis muscle.
- The **nerve to the lateral pterygoid muscle.**
- The **buccal nerve** to the skin and the mucous membrane of the cheek. The buccal nerve **does not** supply the buccinator muscle (which is supplied by the facial nerve), and it is the only sensory branch of the anterior division of the mandibular nerve.

Branches from the Posterior Division of the Mandibular Nerve

- The **auriculotemporal nerve,** which supplies the skin of the auricle, the external auditory meatus, the temporomandibular joint, and the scalp. This nerve also conveys postganglionic parasympathetic secretomotor fibers from the otic ganglion to the parotid salivary gland.
- The **lingual nerve,** which descends in front of the inferior alveolar nerve and enters the mouth. It then runs forward on the side of the tongue and crosses the submandibular duct. In its course, it is joined by the **chorda tympani nerve,** and it supplies the mucous membrane of the anterior two thirds of the tongue and the floor of the mouth. It also gives off **preganglionic parasympathetic secretomotor fibers** to the submandibular ganglion.
- The **inferior alveolar nerve,** which enters the mandibular canal to supply the teeth of the lower jaw and emerges through the mental foramen (the mental nerve) to supply the skin of the chin. Before entering the canal, it gives off the **mylohyoid nerve,** which supplies the mylohyoid muscle and the anterior belly of the digastric muscle.
- The **communicating branch,** which frequently runs from the inferior alveolar nerve to the lingual nerve.

The branches of the posterior division of the mandibular nerve are sensory (except the nerve to the mylohyoid muscle).

Otic Ganglion

The otic ganglion is a parasympathetic ganglion that is located medial to the mandibular nerve just below the skull, and it is adherent to the nerve to the medial pterygoid muscle. The preganglionic fibers originate in the glossopharyngeal nerve, and they reach the ganglion via the lesser petrosal nerve (see p. 230). The postganglionic secretomotor fibers reach the parotid salivary gland via the auriculotemporal nerve.

Submandibular Ganglion

The submandibular ganglion is a parasympathetic ganglion that lies deep to the submandibular salivary gland and is attached to the lingual nerve by small nerves. Preganglionic parasympathetic fibers reach the ganglion from the facial nerve via the chorda tympani and the lingual nerves. Postganglionic secretomotor fibers pass to the submandibular and the sublingual salivary glands.

Abducent Nerve

The abducent nerve is a small nerve that leaves the anterior surface of the brain between the pons and the medulla oblongata (Fig. 6-15). It passes forward through the cavernous sinus with the internal carotid artery, enters the orbit through the superior orbital fissure, and supplies the lateral rectus muscle. The abducent nerve is therefore responsible for turning the eye laterally.

Facial Nerve

The facial nerve has a motor root and a sensory root (**nervus intermedius**) (Fig. 6-16). The nerve emerges on the anterior surface of the brain between the pons and the medulla oblongata, and it enters the internal acoustic meatus with the vestibulocochlear nerve. At the bottom of the

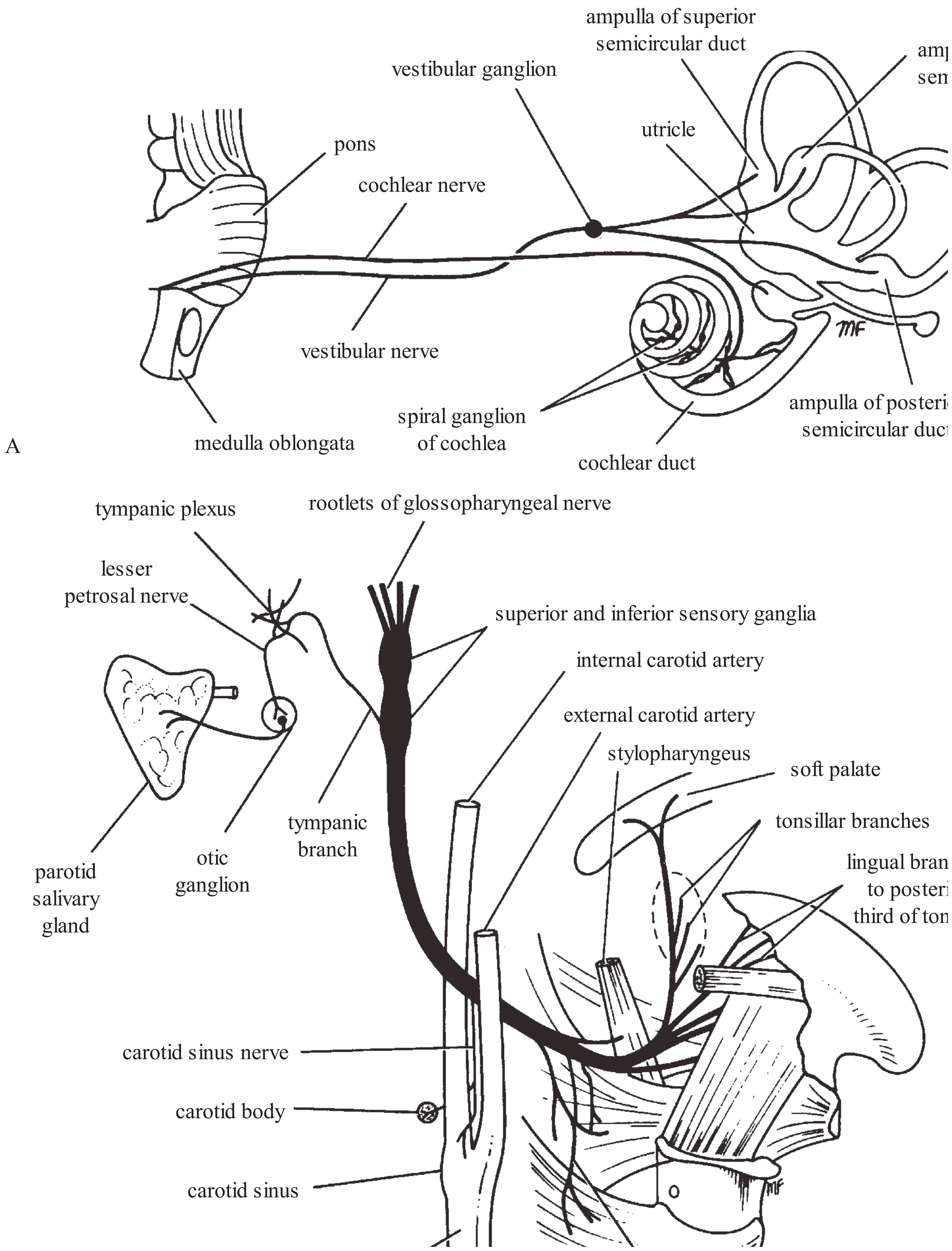


Figure 6-16 The facial nerve. A. Distribution. B. Branches within the petrous part of the temporal bone. The taste fibers are shown in white; the glossopharyngeal nerve is also shown.

meatus, the facial nerve enters the facial canal and then passes laterally through the inner ear. On reaching the medial wall of the middle ear (tympanic cavity), the nerve swells to form the sensory **geniculate ganglion** (Fig. 6-16). The nerve then bends sharply backward above the promontory and, at the posterior wall of the middle ear, bends down on the medial side of the aditus of the mastoid antrum. The nerve descends behind the pyramid, and it emerges from the temporal bone through the stylomastoid foramen.

IMPORTANT BRANCHES OF THE FACIAL NERVE

The **greater petrosal nerve** arises from the nerve at the geniculate ganglion (Fig. 6-16). It contains preganglionic parasympathetic fibers that synapse in the pterygopalatine ganglion. The postganglionic fibers are secretomotor to the lacrimal gland and the glands of the nose and the palate. The greater petrosal nerve also contains taste fibers from the palate.

The **nerve to stapedius** supplies the stapedius muscle within the pyramid (Fig. 6-16).

The **chorda tympani** arises from the facial nerve in the facial canal in the posterior wall of the middle ear (Fig. 6-16). It runs forward over the medial surface of the upper part of the tympanic membrane and leaves the middle ear through the **petrotympanic fissure,** thus entering the infratemporal fossa and joining the lingual nerve. The chorda tympani contains preganglionic parasympathetic secretomotor fibers to the submandibular and the sublingual salivary glands. It also contains taste fibers from the anterior two thirds of the tongue and the floor of the mouth.

The **posterior auricular,** the **posterior belly of the digastric,** and the **stylohyoid nerves** (Fig. 6-16) are muscular branches given off as the facial nerve emerges from the stylomastoid foramen.

The **five terminal branches to the muscles of facial expression** are the **temporal,** the **zygomatic,** the **buccal,** the **mandibular,** and the **cervical branches** (Fig. 6-16). The facial nerve lies within the parotid salivary gland after leaving the stylomastoid foramen, and it is located between the superficial and the deep parts of the gland. Here, it gives off the terminal branches that emerge from the anterior border of the gland and pass to the muscles of the face and the scalp. The buccal branch supplies the buccinator muscle, and the cervical branch supplies the platysma and the depressor anguli oris muscles.

Vestibulocochlear Nerve

The vestibulocochlear nerve is a sensory nerve that consists of two sets of fibers: the **vestibular**, and the **cochlear** (Fig. 6-16). These fibers emerge from the anterior surface of the brain between the pons and the medulla oblongata and enter the internal acoustic meatus.

VESTIBULAR FIBERS

The vestibular fibers are the central processes of the nerve cells of the **vestibular ganglion** situated in the internal acoustic meatus (Fig. 6-17). The vestibular fibers originate from the vestibule and the semicircular canals; therefore, they are concerned with the sense of position and with movement of the head.

COCHLEAR FIBERS

The **cochlear fibers** are the central processes of the nerve cells of the **spiral ganglion of the cochlea** (Fig. 6-17). The cochlear fibers originate in the **spiral organ of Corti** and are, therefore, concerned with the sense of hearing.

Glossopharyngeal Nerve

The glossopharyngeal nerve is a motor and sensory nerve (Fig. 6-17). It emerges from the anterior surface of the medulla oblongata between the olive and the inferior cerebellar peduncle, and it leaves the skull through the jugular foramen. The **superior** and the **inferior sensory ganglia** are located on the nerve as it passes through the foramen. The nerve descends in the neck and winds around the posterior border of the stylopharyngeus muscle to be distributed to the pharynx and the tongue.

IMPORTANT BRANCHES OF THE GLOSSOPHARYNGEAL NERVE

The **tympanic branch** passes to the tympanic plexus in the **middle ear**. Preganglionic parasympathetic fibers for the parotid salivary gland now leave the plexus as the **lesser petrosal nerve,** and they synapse in the otic ganglion (Fig. 6-17).

The **carotid branch** contains sensory fibers from the carotid sinus (pressoreceptor mechanism for the regulation of blood pressure) and the carotid body (chemoreceptor mechanism for the regulation of heart rate and respiration) (Fig. 6-17).

The **nerve to the stylopharyngeus muscle** is another important branch.

The **pharyngeal branches** (Fig. 6-17) run to the **pharyngeal plexus,** which in turn gives sensory fibers to the pharynx and also receives branches from the vagus nerve and the sympathetic trunk.

The **lingual branch** (Fig. 6-17) passes to the mucous membrane of the posterior third of the tongue (including the vallate papillae).

Vagus Nerve

The vagus nerve is both a motor and a sensory nerve (Fig. 6-18). It emerges from the anterior surface of the medulla oblongata between the olive and the inferior cerebellar peduncle. It leaves the skull through the jugular foramen, and it has **superior** and **inferior sensory ganglia.** Below the inferior ganglion, the cranial root of the accessory nerve joins the vagus nerve and is distributed mainly in its pharyngeal and recurrent laryngeal branches.

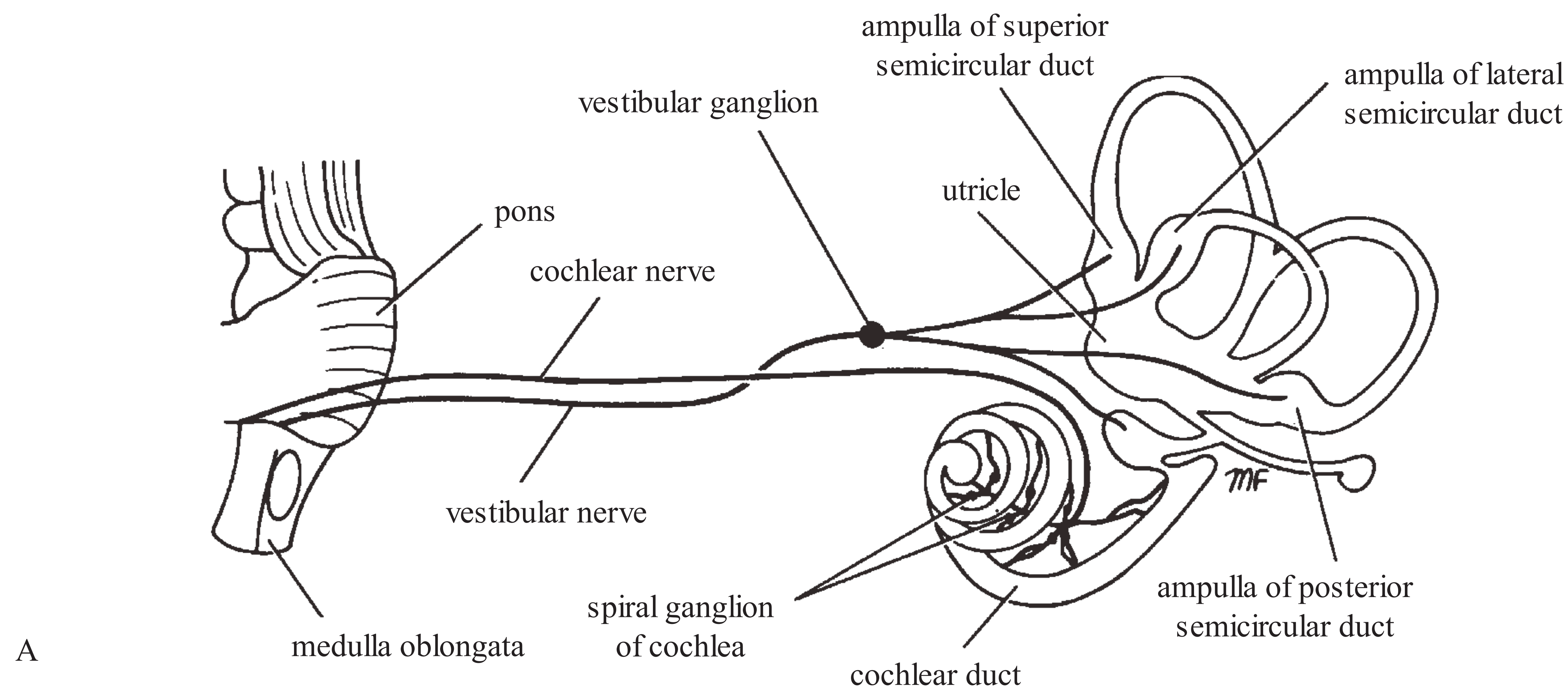
The vagus nerve descends vertically in the neck, within the carotid sheath, with the internal jugular vein and the internal and the common carotid arteries. It descends through the thorax in the mediastinum, passing behind the root of the lung, and enters the abdomen through the esophageal opening in the diaphragm.

IMPORTANT BRANCHES OF THE VAGUS NERVE IN THE NECK

The **meningeal** and the **auricular branches** arise from the vagus nerve.

The **pharyngeal branch** contains nerve fibers from the cranial root of the accessory nerve. This branch joins the **pharyngeal plexus** and supplies all the muscles of the pharynx (except the stylopharyngeus) and of the soft palate (except the tensor veli palatini).

The **superior laryngeal nerve** (Fig. 6-18) divides into the internal and the external laryngeal nerves. The **internal**



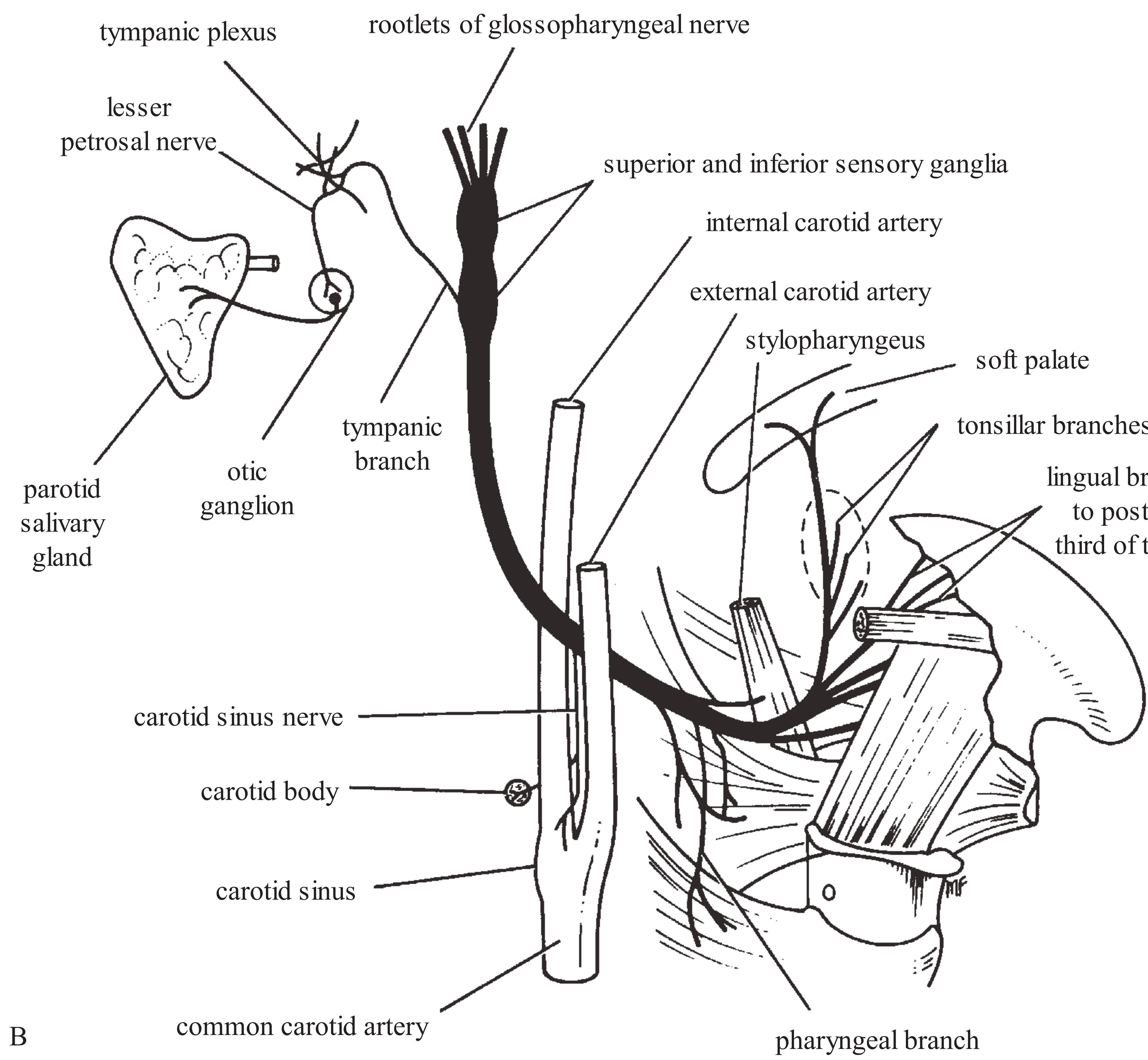


Figure 6-17 A. Origin and distribution of the vestibulocochlear nerve. B. Distribution of the glossopharyngeal nerve.

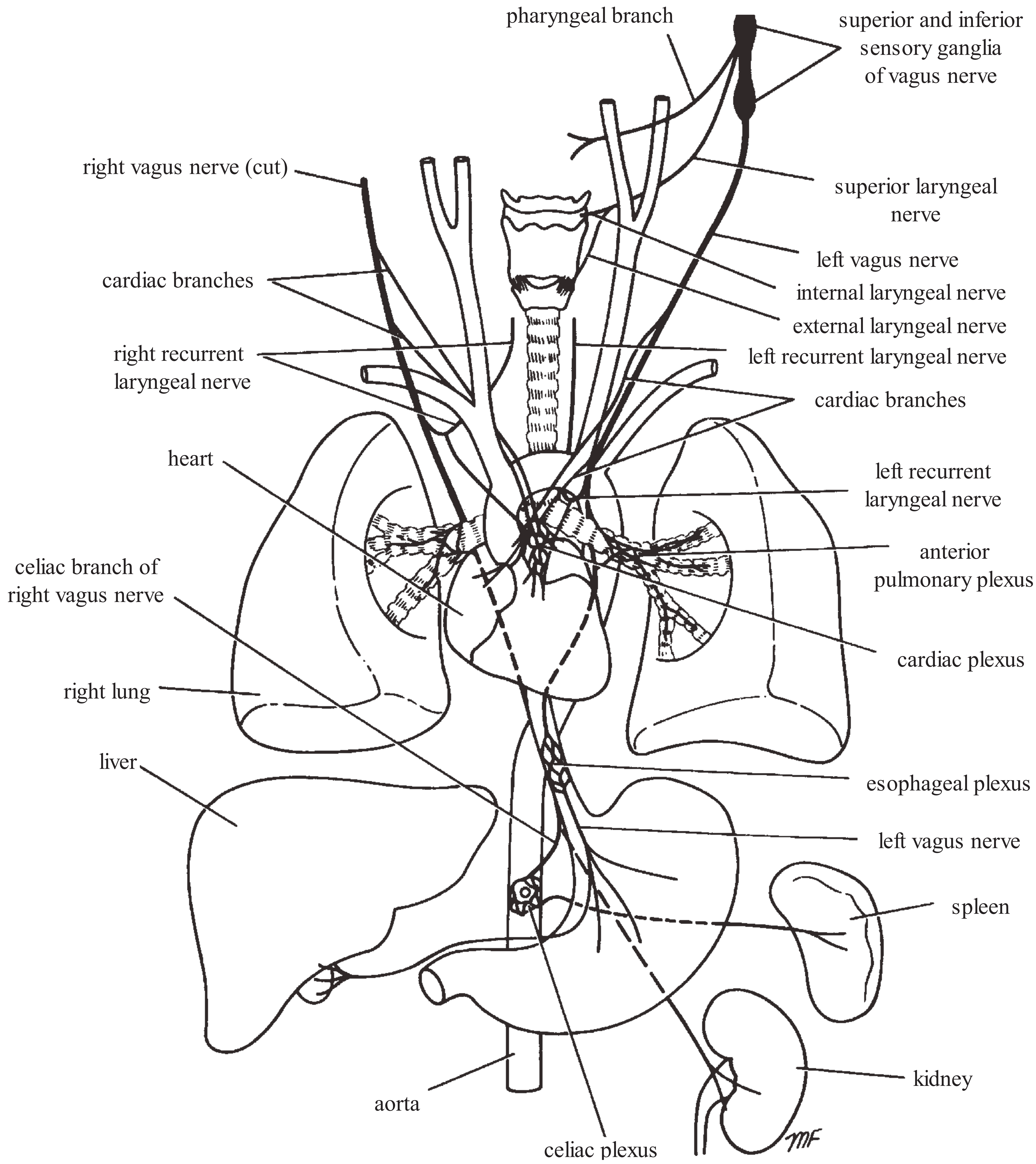


Figure 6-18 Distribution of the vagus nerve.

laryngeal nerve is sensory to the mucous membrane of the piriform fossa and the larynx down as far as the vocal folds. The **external laryngeal nerve** is motor; it is located close to the superior thyroid artery and supplies the cricothyroid muscle.

On the **recurrent laryngeal nerve** (Fig. 6-18), on the right side of the body, the nerve hooks around the **first part of the subclavian artery** and then ascends in the groove between the trachea and the esophagus. On the left side, the nerve hooks around the **arch of the aorta** and then ascends into the neck between the trachea and the esophagus. The nerve is closely related to the inferior thyroid artery, and it supplies all the muscles of the larynx, except the cricothyroid muscle, the mucous membrane of the larynx below the vocal folds, and the mucous membrane of the upper part of the trachea.

Two or three of the **cardiac branches** of the vagus nerve arise in the neck, descend into the thorax, and end in the cardiac plexus (Fig. 6-18).

The vagus nerve has the most extensive distribution of all the cranial nerves. Its distribution in the thorax is described on page 26; its distribution in the abdomen is shown in Figure 6-18.

Accessory Nerve

The accessory nerve is a motor nerve with cranial and spinal roots (Fig. 6-19).

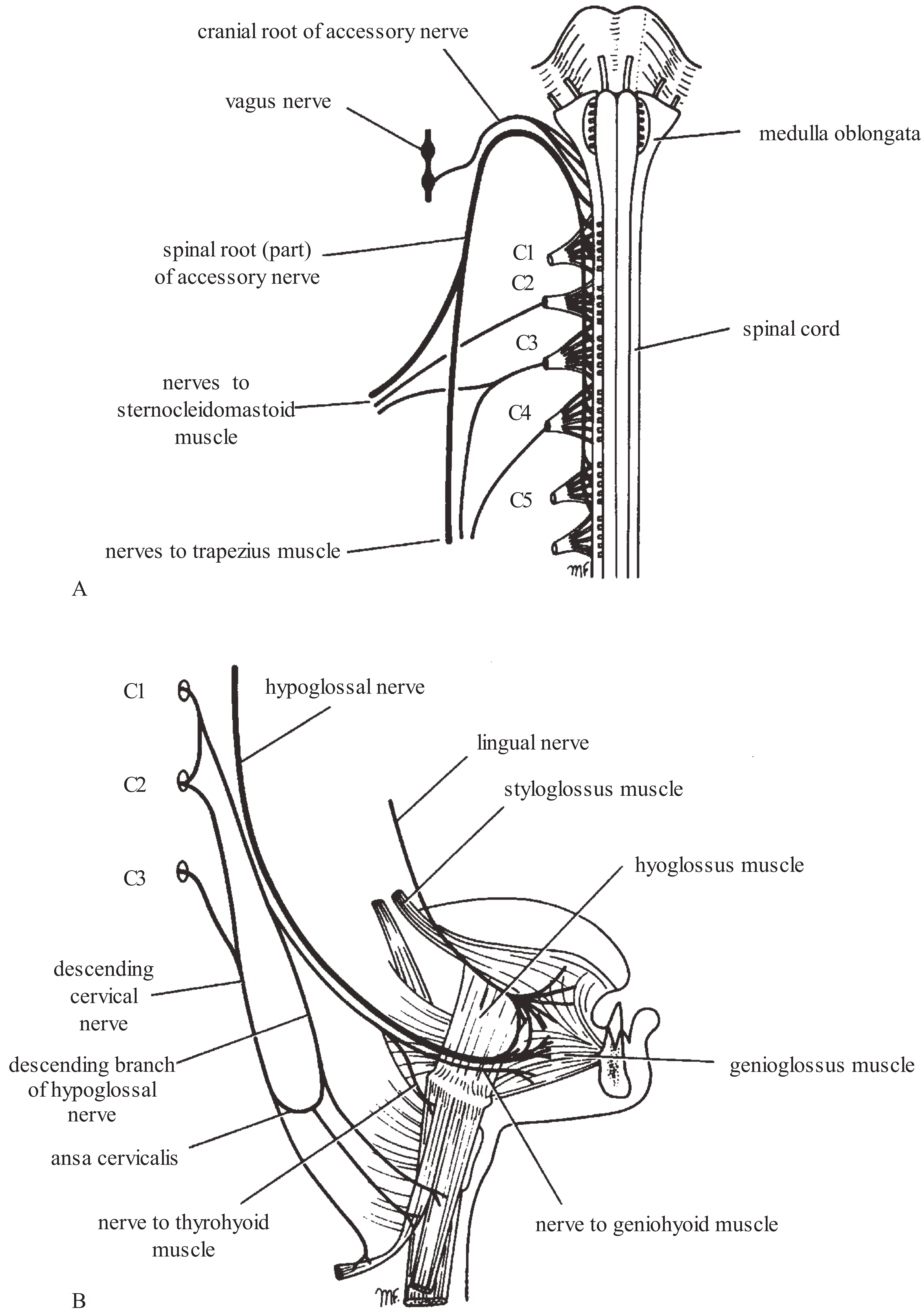


Figure 6-19 A. Origin and distribution of the accessory nerve. B. Distribution of the hypoglossal nerve.

CRANIAL ROOT

The cranial root of the accessory nerve emerges from the anterior surface of the medulla oblongata between the olive and the inferior cerebellar peduncle (Fig. 6-19).

SPINAL ROOT

The spinal root of the accessory nerve arises from the nerve cells in the anterior gray column of the upper five segments of the cervical part of the spinal cord (Fig. 6-19). The nerve ascends beside the spinal cord, and it enters the skull through the foramen magnum.

The two roots unite and leave the skull via the jugular foramen. The roots then separate. The cranial root joins the vagus nerve and is distributed in its pharyngeal and recurrent laryngeal branches to the muscles of the soft palate, the pharynx, and the larynx. The spinal root runs downward and laterally, and it enters the deep surface of the sternocleidomastoid muscle, which it supplies, and then crosses the posterior triangle of the neck to supply the trapezius muscle.

The accessory nerve thus brings about movements of the soft palate, the pharynx, and the larynx, and it controls the movements of two large muscles of the neck.

Hypoglossal Nerve

The hypoglossal nerve is a motor nerve that emerges on the anterior surface of the medulla oblongata between the pyramid and the olive (Fig. 6-19). It leaves the skull through the hypoglossal canal, descends in the neck, and then turns forward and crosses the internal and external carotid arteries. The nerve passes forward on the side of the tongue. In the upper part of its course, it is joined by C1 fibers from the cervical plexus.

IMPORTANT BRANCHES OF THE HYPOGLOSSAL NERVE

- The **meningeal branch.**
- The **descending branch** (C1 fibers), which passes downward and joins the **descending cervical nerve** (C2 and 3) to form a loop called the **ansa cervicalis.** Branches from this loop supply the omohyoid, the sternohyoid, and the sternothyroid muscles.
- The **nerve to the thyrohyoid muscle** (C1).
- The **muscular branches** to all the muscles of the tongue except the palatoglossus (the pharyngeal plexus).
- The **nerve to the geniohyoid** (C1).

The hypoglossal nerve proper thus supplies most muscles of the tongue, and it controls the shape and the movements of the tongue.

The openings in the skull through which the cranial nerves leave the cranial cavity are listed in Table 6-1.

CLINICAL NOTES

TESTING THE INTEGRITY OF THE CRANIAL NERVES

Systematic examination of the twelve cranial nerves is an important part of the examination of every neurologic patient. It may reveal a lesion of a cranial nerve nucleus or its central connections, or it may show an interruption of the lower motor neurons.

CERVICAL PLEXUS

The cervical plexus is formed by the anterior rami of the first four cervical spinal nerves (Fig. 6-5). The rami join to form loops that lie in front of the origins of the levator scapulae and the scalenus medius muscles. The cervical plexus supplies the skin and the muscles of the head, the neck, and the shoulders.

Branches

- The **lesser occipital nerve** (C2), which supplies the back of the scalp and the auricle.
- The **greater occipital nerve** (C2 and 3), which supplies the scalp as far forward as the vertex of the skull.
- The **transverse cervical nerve** (C2 and 3), which supplies the skin over the front of the neck.
- The **supraclavicular nerves** (C3 and 4). The medial, and intermediate, and lateral branches supply the skin over the shoulder region. These nerves are important clinically, because pain may be referred along them from the phrenic nerve (gallbladder disease).

Important Branch

PHRENIC NERVE

The phrenic nerve is the **only** motor nerve supply to the diaphragm (Fig. 6-5). It runs down the neck on the anterior surface of the scalenus anterior muscle and enters the thorax by passing anterior to the subclavian artery. The further distribution of the phrenic nerve in the thorax and the abdomen is described on page 27.

BRACHIAL PLEXUS

The roots and the trunks of the important brachial plexus are in the posterior triangle of the neck. The plexus itself is described on page 144.

AUTONOMIC NERVOUS SYSTEM IN THE HEAD AND NECK

Sympathetic Part

SYMPATHETIC TRUNKS

In the neck, the sympathetic trunk on each side extends upward to the skull and downward to the first rib, where it becomes continuous with the thoracic part of the trunk. The trunk lies behind the carotid sheath and possesses three ganglia: superior, middle, and inferior cervical (Fig. 6-5).

Superior Cervical Ganglion

The superior cervical ganglion lies immediately below the skull.

Branches

- The **internal carotid nerve,** which accompanies the internal carotid artery and forms the **internal carotid plexus.**
- The **gray rami communicantes,** which pass to the upper four cervical spinal nerves.
- The **arterial branches** to the common and the external carotid arteries.
- The **cranial nerve branches** to the ninth, tenth, and twelfth cranial nerves.
- The **pharyngeal branches**, which join the pharyngeal branches of the ninth and tenth cranial nerves to form the **pharyngeal plexus**.
- The **superior cardiac branch**, which descends into the thorax and joins the cardiac plexus.

Middle Cervical Ganglion

The middle cervical ganglion lies at level of cricoid cartilage.

Branches

- The **gray rami communicantes** to the fifth and sixth cervical spinal nerves.
- The **thyroid branches.**
- The **middle cardiac branch,** which descends into the thorax and joins the cardiac plexus.

Inferior Cervical Ganglion

In most people, the inferior cervical ganglion is fused to the first thoracic ganglion to form the **stellate ganglion.** It is located between the transverse process of the seventh cervical vertebra and the neck of the first rib.

Branches

- The **gray rami communicantes** to the seventh and eighth cervical spinal nerves.
- The **arterial branches** to the subclavian and the vertebral arteries.
- The **inferior cardiac branch**, which descends into the thorax and joins the cardiac plexus.

Ansa Subclavia

The portion of the sympathetic trunk that connects the middle to the inferior cervical ganglia is in the form of two or more bundles (Fig. 6-5). The anterior bundle crosses anterior to the first part of the subclavian artery and is called the **ansa subclavia.**

Parasympathetic Part

The cranial portion of the craniosacral outflow of the parasympathetic part of the autonomic nervous system is located in the nuclei of the **oculomotor (third), facial (seventh), glossopharyngeal (ninth),** and **vagus (tenth) cranial nerves.**

The parasympathetic nucleus of the oculomotor nerve is called the **Edinger-Westphal nucleus** and includes those of the facial nerve the **lacrimatory** and the **superior salivary nuclei,** that of the glossopharyngeal nerve the **inferior salivary nucleus,** and that of the vagus nerve the **dorsal nucleus of the vagus.** The axons of these connector nerve cells are myelinated preganglionic fibers that emerge from the brain within the cranial nerves.

These preganglionic fibers synapse in peripheral ganglia located close to the viscera they innervate. The cranial parasympathetic ganglia are the **ciliary,** the **pterygopalatine,** the **submandibular,** and the **otic.** In certain locations, the ganglion cells are placed in nerve plexuses, such as the **cardiac plexus,** the **pulmonary plexus,** the **myenteric plexus (Auerbach's plexus),** and the **mucosal plexus (Meissner's plexus).** The last two plexuses are found in the gastrointestinal tract. The postganglionic fibers are nonmyelinated, and they are short in length.

THE DIGESTIVE SYSTEM IN THE HEAD AND NECK

Mouth

The mouth is divided into the **vestibule,** which lies between the lips and the cheeks externally and the gums and the teeth internally, and the **mouth cavity,** which lies within the gums and the teeth (Figs. 6-20 and 6-21).

The **cheek** is formed by the buccinator muscle, is covered on the outside by skin, and is lined by mucous membrane. Opposite the upper second molar, the **duct of the parotid gland** opens into the vestibule on a small papilla.

ROOF OF MOUTH

The roof of the mouth is formed by the hard palate anteriorly and the soft palate posteriorly.

FLOOR OF MOUTH

The floor of the mouth is formed largely by the anterior two thirds of the tongue and by the mucous membrane extending from the tongue to the gums. The **frenulum of the tongue** connects the undersurface of the tongue to the floor of the mouth (Fig. 6-21). On each side of the frenulum is the **papilla** and **orifice** of the **duct of the submandibular salivary gland** (Fig. 6-21). Lateral to this is the **sublingual fold**, which is produced by the underlying sublingual salivary gland. There are 18 to 20 ducts for this gland, and they open onto the summit of the fold.

SENSORY INNERVATION OF THE MOUTH

- **Roof:** The greater palatine and nasopalatine nerves (maxillary nerve).
- **Floor:** The lingual nerve (common sensation) and chorda tympani (taste).
- **Cheek:** The buccal nerve (mandibular nerve).

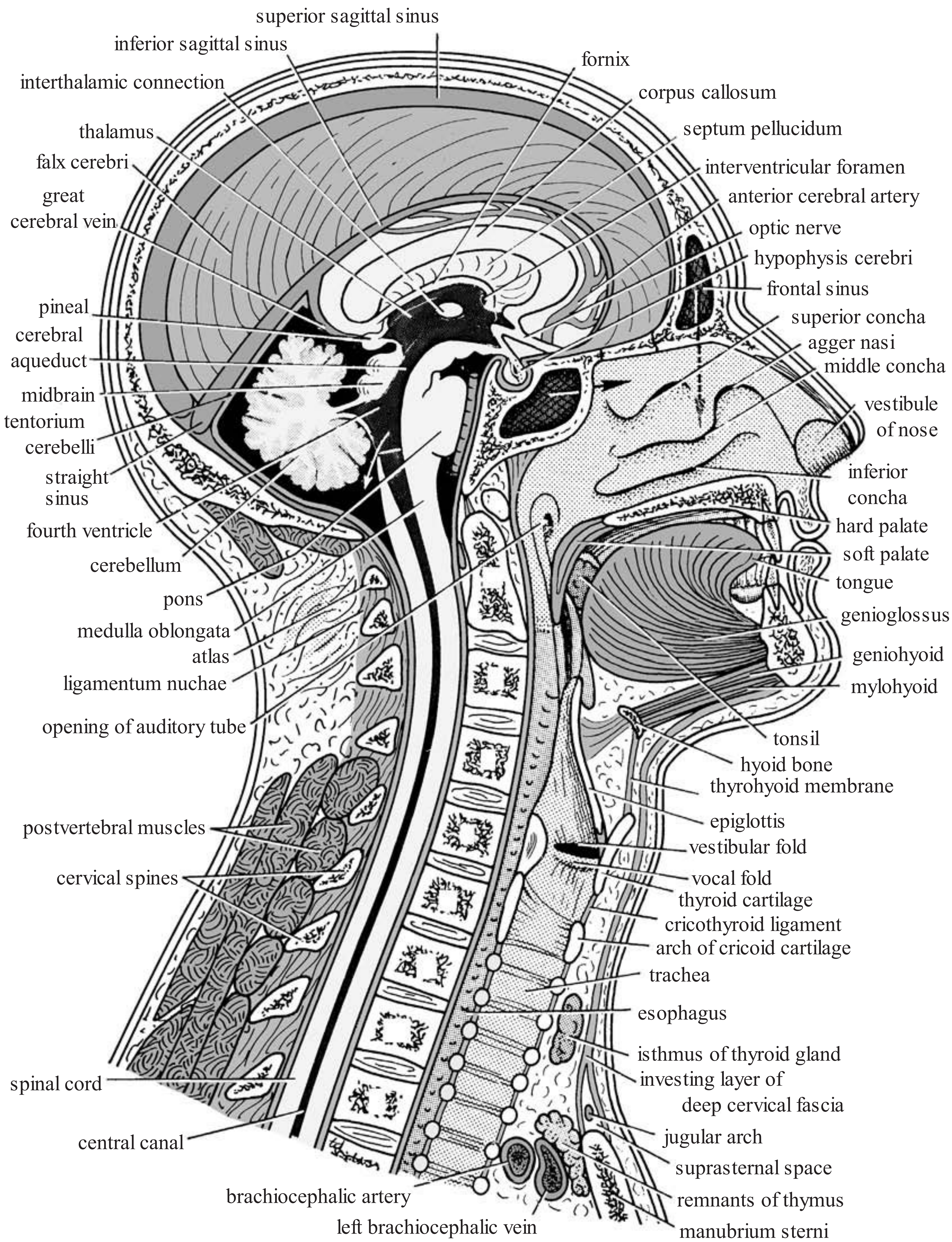


Figure 6-20 Sagittal section of the head and neck.

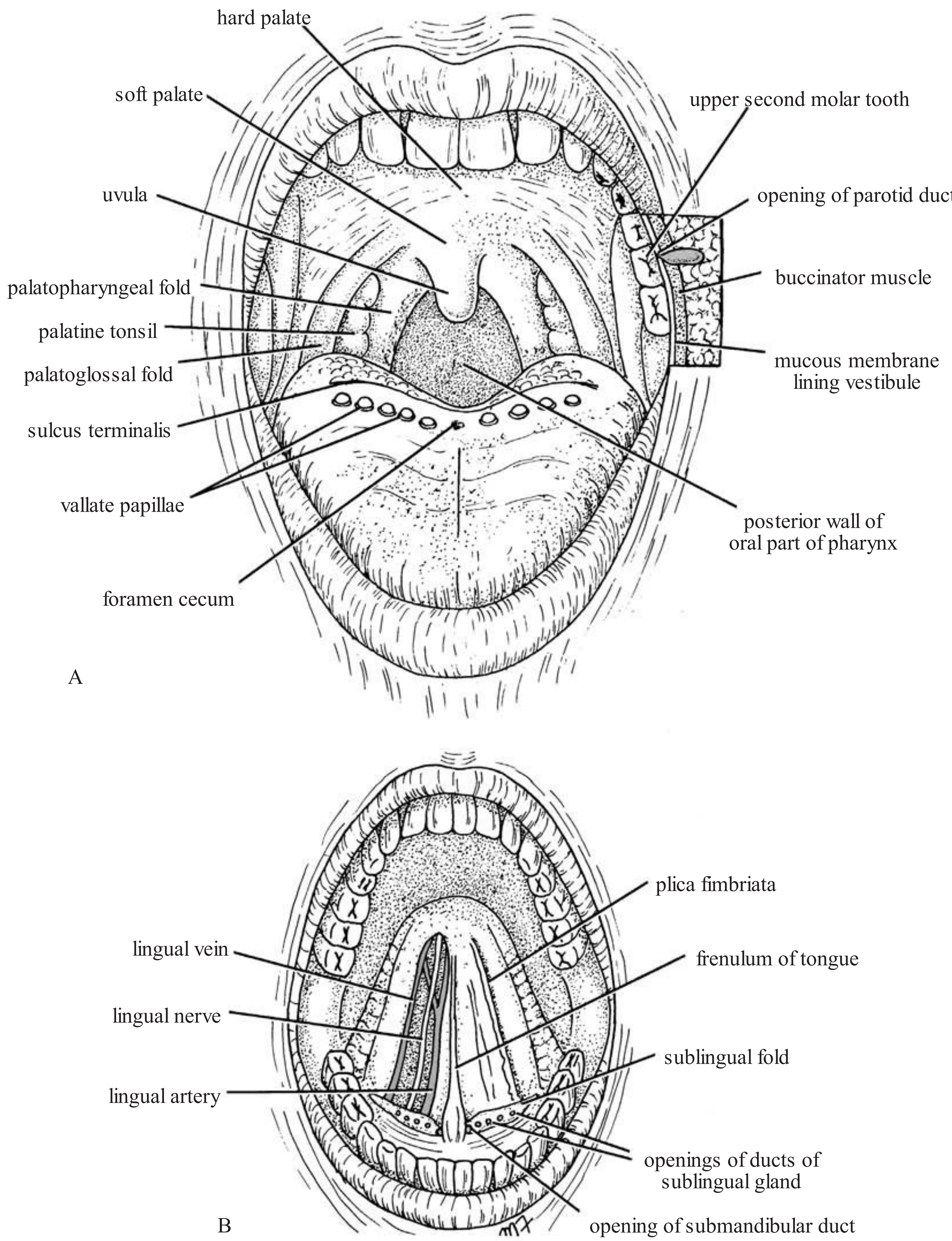


Figure 6-21 A. Cavity of the mouth. The cheek on the left side has been cut away to show the buccinator muscle and the parotid duct. B. Undersuface of the tongue.

Teeth

There are two sets of teeth: the deciduous, which are 20 in number, and the permanent, which are 32 in number.

CLINICAL NOTES

Clinical Examination of the Mouth

The mouth is one of the important areas of the body that the physician or allied health provider is called to examine. Needless to say, the examiner must be able to recognize all the structures visible in the mouth and be familiar with the normal variations in the color of the mucous membrane covering the underlying structures. The sensory nerve supply and the lymph drainage of the mouth cavity must be known.

Tongue

The tongue is a mass of striated muscle covered with mucous membrane and divided by a **median fibrous septum.**

MUSCLES

- **Intrinsic:** The longitudinal, transverse, and vertical muscles.
- **Extrinsic:** The genioglossus, hyoglossus, styloglossus, and palatoglossus muscles.

The origin, insertion, nerve supply, and action of the tongue muscles are summarized in Table 6-9.

MUCOUS MEMBRANE

On the upper surface of the tongue, between the anterior two thirds and the posterior third, is a V-shaped groove called the **sulcus terminalis.** Three types of papillae are present on the upper surface of the anterior two thirds: the **filiform,** the **fungiform,** and the **vallate.** The vallate papillae are 10 to 12 in number, and they are situated in a row in front of the sulcus terminalis.

BLOOD SUPPLY

The lingual artery, the tonsillar branch of facial artery, and the ascending pharyngeal artery supply the tongue.

LYMPH DRAINAGE

- **Tip:** Submental lymph nodes.
- **Sides of anterior two thirds:** Submandibular lymph nodes.
- **Posterior third:** Deep cervical lymph nodes.

SENSORY INNERVATION

- **Anterior two thirds:** The lingual nerve (general sensation) and chorda tympani (taste).
- **Posterior third:** The glossopharyngeal nerve (general sensation and taste).

MOVEMENTS OF THE TONGUE

- **Protrusion:** The genioglossus muscles on both sides.
- **Retraction:** The styloglossus and hyoglossus muscles on both sides.
- **Depression:** The hyoglossus muscles on both sides.
- **Retraction and elevation of posterior third:** The styloglossus and palatoglossus muscles on both sides.
- **Shape changes:** The intrinsic muscles.

CLINICAL NOTES

Laceration of the Tongue

Bleeding is halted by grasping the tongue between the finger and thumb posterior to the laceration, thus occluding the branches of the lingual artery.

Table 6-9 Muscles of the Tongue

Muscle	Origin	Insertion	Nerve Supply	Action
Intrinsic Muscles				
Longitudinal	Medial septum and submucosa	Mucous membrane	Hypoglossal nerve	Alters shape of the tongue
Transverse				
Vertical				
Extrinsic Muscles				
Genioglossus	Superior genial spine of the mandible	Blends with other muscles of the tongue	Hypoglossal nerve	Protrudes the apex of the tongue through the mouth
Hyoglossus	Body and greater cornu of the hyoid bone	Blends with other muscles of the tongue	Hypoglossal nerve	Depresses the tongue
Styloglossus	Styloid process of the temporal bone	Blends with other muscles of the tongue	Hypoglossal nerve	Draws the tongue upward and backward
Palatoglossus	Palatine aponeurosis	Side of the tongue	Hypoglossal nerve	Pulls the root of the tongue upward and backward, narrows the oropharyngeal isthmus

Palate

The palate may be divided into two parts: the hard palate in front, and the soft palate behind.

HARD PALATE

The hard palate is formed by the palatine process of the maxillae and the horizontal plates of the palatine bones (Fig. 6-21).

SOFT PALATE

The soft palate is a mobile fold attached to the posterior border of the hard palate (Fig. 6-21). Its free border has a conical projection (the **uvula**) in the midline.

PALATOGLOSSAL ARCH

The palatoglossal arch is a muscular fold (Fig. 6-21) containing the **palatoglossus muscle,** which extends from the soft palate to the side of the tongue (Fig. 6-22). **The**

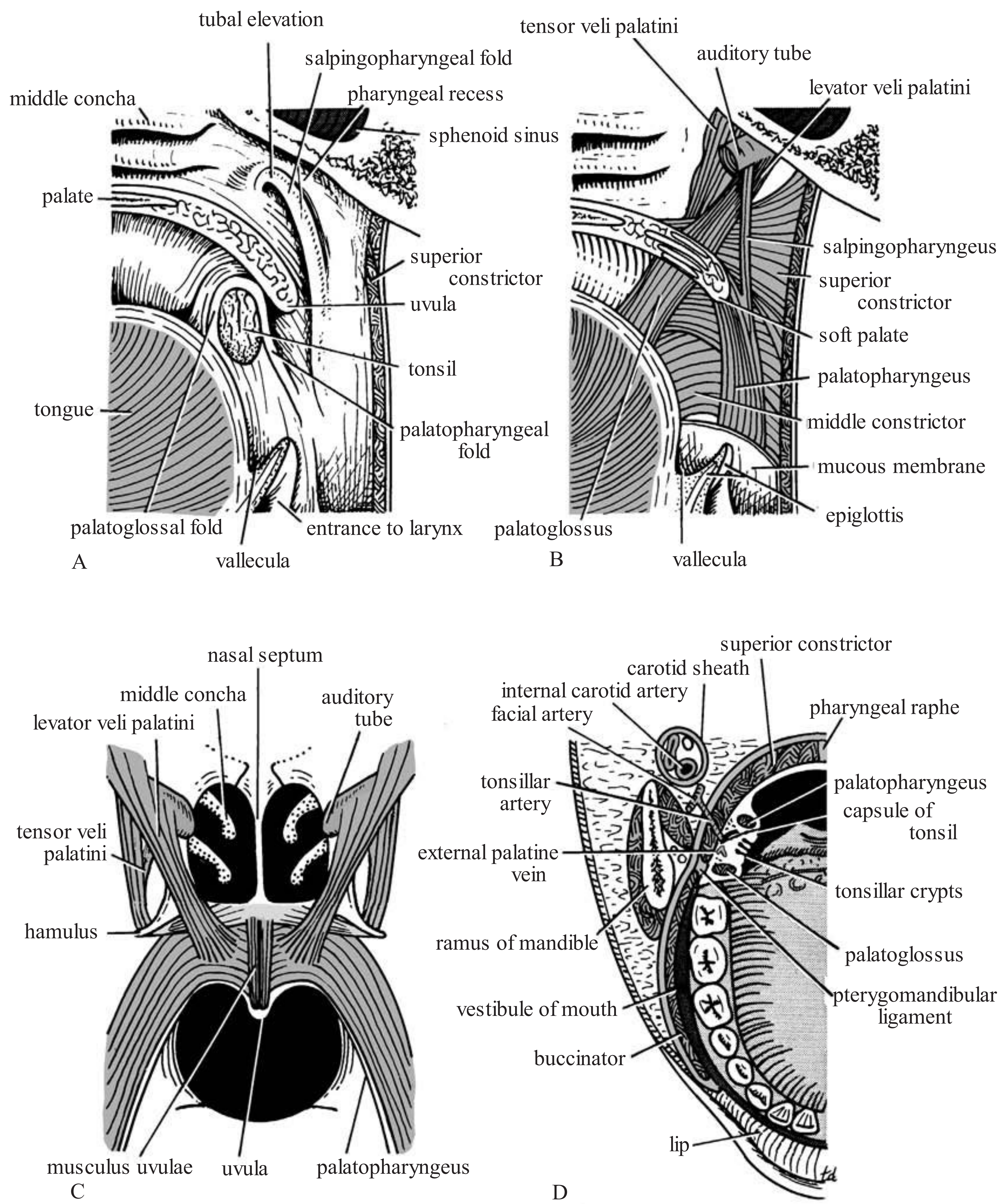


Figure 6-22 A. Junction of the nose with the nasal part of the pharynx and the mouth with the oral part of the pharynx. Note the position of the tonsil and the opening of the auditory tube. B. Muscles of the soft palate and the upper part of the pharynx. **C.** Muscles of the soft palate as seen from behind. **D.** Horizontal section through the mouth and the oral part of the pharynx showing the relations of the tonsil.

palatoglossal arch marks where the mouth becomes the pharynx.

PALATOPHARYNGEAL ARCH

The palatopharyngeal arch is a muscular fold (Fig. 6-21) behind the palatoglossal arch (Fig. 6-22) that runs downward and laterally to join the pharyngeal wall. The muscle contained within the fold is the **palatopharyngeus muscle.** The **palatine tonsils,** which are masses of lymphoid tissue, are located between the palatoglossal and the palatopharyngeal arches.

The muscles of the soft palate are the **tensor veli palatini,** the **levator veli palatini,** the **palatoglossus,** the **palatopharyngeus,** and the **musculus uvulae.** The origins, insertions, nerve supply, and actions of these muscles are summarized in Table 6-10.

BLOOD SUPPLY

The greater palatine branch of maxillary artery, the ascending palatine branch of facial artery, and the ascending pharyngeal artery.

LYMPH DRAINAGE

The lymph drains into the deep cervical lymph nodes.

SENSORY INNERVATION

The greater and lesser palatine nerves and the nasopalatine and glossopharyngeal nerves supply the area.

MOVEMENTS OF THE SOFT PALATE

- **Raise palate:** The levator veli palatini muscle closes off the channel between the oral pharynx and the nasal pharynx. At the same time, the upper fibers of the superior constrictor muscle contract and pull the posterior wall of the pharynx forward. The palatopharyngeus muscles also contract on both sides, pulling in the palatopharyngeal folds like side curtains.
- **Lower palate:** The palatoglossus and the palatopharyngeus muscles lower the soft palate.

The soft palate is stretched by the contraction of the tensor veli palatini muscle during the process of raising and lowering the palate.

CLINICAL NOTES

MOVEMENTS OF THE SOFT PALATE AND UVULA

When the patient says "Ah," the soft palate should rise symmetrically on the right and left sides, and the uvula should move backward in the midline. Failure of such movements has one of two explanations. First, the soft palate is anchored down on one side as a result of inflammation or the presence of a neoplasm. Second, the cranial part of the eleventh cranial nerve is not functioning normally. Remember that the cranial part of the eleventh cranial nerve joins the vagus nerve and is distributed to the levator palati muscle in its pharyngeal branch to the pharyngeal plexus.

Salivary Glands

PAROTID GLAND

The parotid gland is the largest salivary gland and is composed mostly of serous acini. It lies in a deep hollow below the external auditory meatus, behind the ramus of the mandible, and in front of the sternocleidomastoid muscle. The facial nerve divides the gland into **superficial** and **deep lobes.** The **duct** passes forward over the masseter muscle and then turns medially and pierces the buccinator muscle to open into the mouth opposite the upper second molar tooth.

Table 6-10 Muscles of the Soft Palate

Muscle	Origin	Insertion	Nerve Supply	Action
Tensor veli palatini	Spine of the sphenoid, auditory tube	Forms the palatine aponeurosis with the muscle of the other side	Nerve to medial pterygoid from the mandibular nerve	Tenses the soft palate
Levator veli palatini	Petrous part of the temporal bone, auditory tube	Palatine aponeurosis	Pharyngeal plexus	Raises the soft palate
Palatoglossus	Palatine aponeurosis	Side of the tongue	Pharyngeal plexus	Pulls the root of the tongue upward and backward, narrows the oropharyngeal isthmus
Palatopharyngeus	Palatine aponeurosis	Posterior border of the thyroid cartilage	Pharyngeal plexus	Elevates the wall of the pharynx, pulls the palatopharyngeal folds medially
Musculus uvulae	Posterior border of the hard palate	Mucous membrane of the uvula	Pharyngeal plexus	Elevates the uvula

Structures within the Parotid Gland

From lateral to medial, the structures within the parotid gland are the facial nerve, the retromandibular vein, and the external carotid artery. Some lymph nodes are also present.

Nerve Supply

Parasympathetic secretomotor supply arises from the glossopharyngeal nerve. The axons pass to the gland via the tympanic branch, the lesser petrosal nerve, and the otic ganglion. Postganglionic fibers pass to the gland via the auriculotemporal nerve. Postganglionic sympathetic fibers reach the gland from the superior cervical sympathetic ganglion.

SUBMANDIBULAR GLAND

The submandibular gland consists of a mixture of serous and mucous acini. It lies beneath the lower border of the body of the mandible and is divided into superficial and deep parts by the mylohyoid muscle. The deep part of the gland lies below the mucous membrane of the mouth on the side of the tongue. The **duct** leaves the anterior end of the deep part of the gland and runs forward beneath the mucous membrane of the mouth. The duct is crossed by the lingual nerve and opens into the mouth on a small papilla at the side of the frenulum of the tongue (Fig. 6-21).

Nerve Supply

Parasympathetic secretomotor supply is from the facial nerve via the chorda tympani. The nerves pass to the submandibular ganglion, and postganglionic fibers pass to the gland. Postganglionic sympathetic fibers run from the superior cervical sympathetic ganglion.

SUBLINGUAL GLAND

The sublingual gland lies beneath the mucous membrane of the floor of the mouth (the sublingual fold). It has both serous and mucous acini, with the latter predominating. There are 8 to 10 **ducts,** and they open into the mouth on the sublingual fold (Fig. 6-21).

Nerve Supply

The nerve supply is the same as that for the submandibular gland.

Pharynx

The pharynx is funnel in shape and can be divided into the **nasal,** the **oral,** and the **laryngeal** parts (Fig. 6-20). It is continuous with the esophagus opposite the sixth cervical vertebra. The anterior wall is deficient, however, and is replaced by the posterior opening of the nose, the opening into the mouth, and the inlet of the larynx.

The muscles of the pharyngeal wall consist of the superior, middle, and inferior constrictor muscles, whose fibers run in a more or less circular direction; and the stylopharyngeus and salpingopharyngeus muscles, whose fibers run in a more or less longitudinal direction. The origin, insertion, nerve supply, and action of these muscles are summarized in Table 6-11.

Table 6-11 Muscles of the Pharynx

Muscle	Origin	Insertion	Nerve Supply	Action
Superior constrictor	Medial pterygoid plate, pterygoid hamulus, pterygomandibular ligament, mylohyoid line of the mandible	Pharyngeal tubercle of the occipital bone raphe in the midline posteriorly	Pharyngeal plexus	Aids the soft palate in closing off the nasal pharynx, propels the bolus downward
Middle constrictor	Lower part of the stylohyoid ligament, lesser and greater cornu of the hyoid bone	Pharyngeal raphe	Pharyngeal plexus	Propels the bolus downward
Inferior constrictor	Lamina of the thyroid cartilage, cricoid cartilage	Pharyngeal raphe	Pharyngeal plexus	Propels the bolus downward
Cricopharyngeus	Lowest fibers of the inferior constrictor muscle	Pharyngeal raphe	Pharyngeal plexus	Sphincter at the lower end of the pharynx
Stylopharyngeus	Styloid process of the temporal bone	Posterior border of the thyroid cartilage	Glossopharyngeal nerve	Elevates larynx during swallowing
Salpingopharyngeus	Auditory tube	Blends with the palatopharyngeus	Pharyngeal plexus	Elevates the pharynx
Palatopharyngeus	Palatine aponeurosis	Posterior border of the thyroid cartilage	Pharyngeal plexus	Elevates the wall of the pharynx, pulls the palatopharyngeal folds medially

INTERIOR OF THE PHARYNX

Nasal Pharynx

The nasal pharynx lies above the soft palate and behind the nasal cavities (Fig. 6-20). In the roof is the collection of lymphoid tissue called the **pharyngeal tonsil.** The **pharyngeal isthmus** is the opening in the floor between the soft palate and the posterior pharyngeal wall. The **auditory tube** opens on the lateral wall (Fig. 6-23), and the elevated edge of the tube is called the **tubal elevation.** The **pharyngeal recess** is a depression in the pharyngeal wall behind the tubal elevation. The **salpingopharyngeal fold** is a vertical fold of mucous membrane covering the salpingopharyngeus muscle (Fig. 6-22).

Oral Pharynx

The oral pharynx lies behind the oral cavity. In the floor in the midline between the tongue and the epiglottis is the **median glossoepiglottic fold,** and on each side is the **lateral glossoepiglottic fold.** The **vallecula** is the depression on each side of the median glossoepiglottic fold.

The **palatine tonsils** are located on the lateral wall on each side between the palatoglossal and the palatopharyngeal folds (Fig. 6-22). The **tonsillar sinus** is a recess between these folds and is occupied by the tonsil. The **oropharyngeal isthmus** is the interval between the two palatoglossal folds that marks the boundary between the mouth and the pharynx.

Laryngeal Pharynx

The laryngeal pharynx lies behind the opening into the larynx. The lateral wall is formed by the thyroid cartilage and the thyrohyoid membrane. The **piriform fossa** is a depression in the mucous membrane on each side of the laryngeal inlet (Fig. 6-23) and is a common site for the lodging of fish bones.

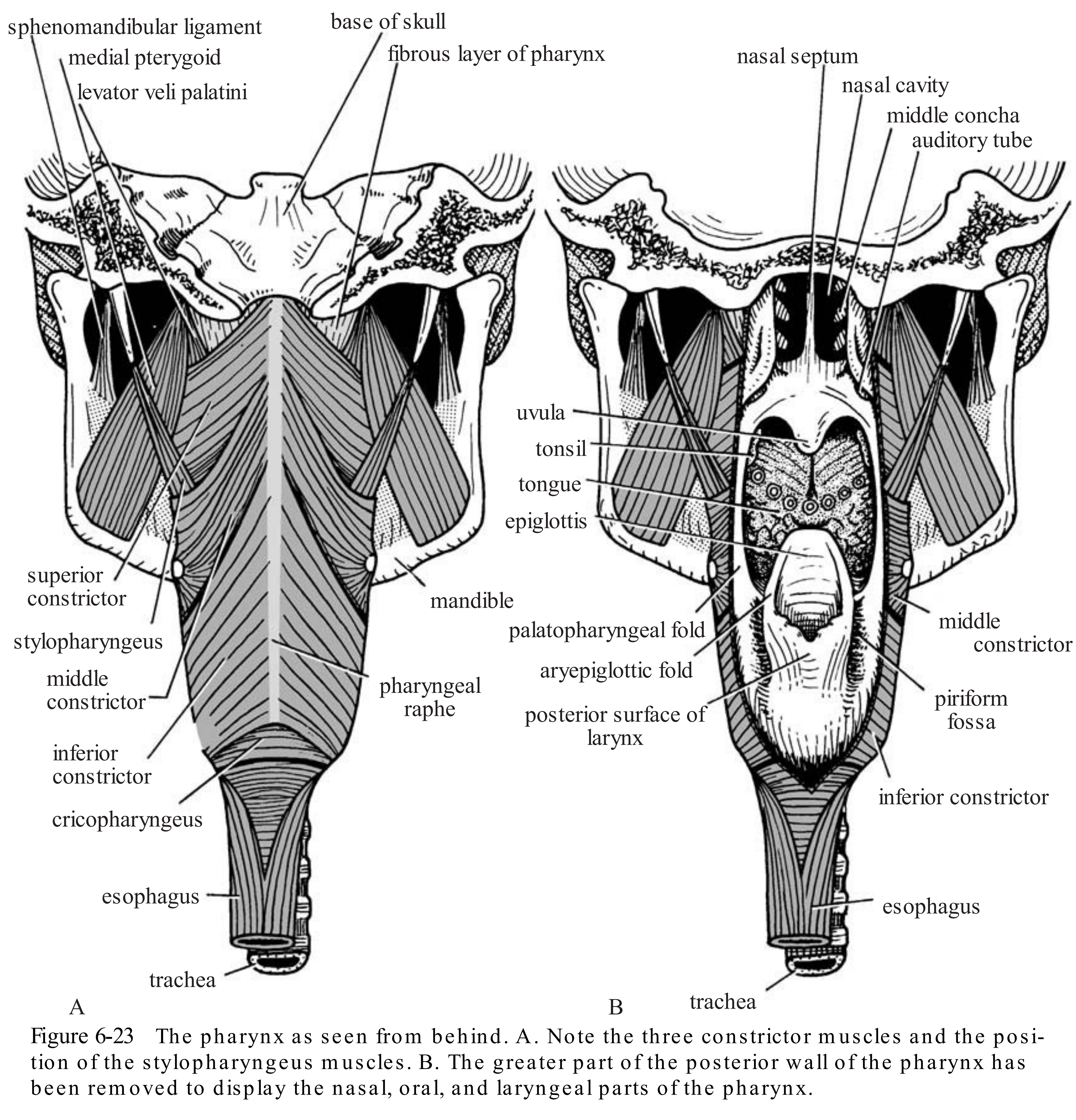


Figure 6-23 The pharynx as seen from behind. A. Note the three constrictor muscles and the position of the stylopharyngeus muscles. B. The greater part of the posterior wall of the pharynx has been removed to display the nasal, oral, and laryngeal parts of the pharynx.

SENSORY NERVE SUPPLY OF THE PHARYNGEAL MUCOUS MEMBRANE

- **Nasal pharynx:** The maxillary nerve.
- **Oral pharynx:** The glossopharyngeal nerve.
- **Laryngeal pharynx** (around entrance into larynx): The internal laryngeal nerve, branch of the superior laryngeal branch of the vagus.

Palatine Tonsil

The palatine tonsil is a mass of lymphoid tissue on each side of the oral pharynx. The medial surface is pitted by numerous small openings that lead into the **tonsillar crypts** (Fig. 6-22), and the lateral surface is covered by a capsule.

CLINICAL NOTES

Examination of the Tonsil

Note that the tonsillar crypts lie on the tonsil's medial surface. Note also that the tonsils reach their maximum size during childhood, but they become smaller after puberty. The lymph drainage is into the upper deep cervical lymph nodes, just below and behind the angle of the mandible.

Swallowing

Masticated food is formed into a ball (or bolus) on the dorsum of the tongue and then voluntarily pushed upward and backward against the undersurface of the hard palate. This is accomplished as follows: The styloglossus muscles on both sides contract, which pulls the root of the tongue upward and backward, and the palatoglossus muscles squeeze the bolus backward into the pharynx. From this point onward, the process of swallowing becomes an involuntary act.

The nasal part of the pharynx is shut off from the oral part by the elevation of the soft palate, the pulling forward of the posterior wall of the pharynx, and the pulling medially of the palatopharyngeal folds. This prevents the passage of food and drink into the nasal cavities.

The larynx and the laryngeal part of the pharynx are then pulled upward by the contraction of the stylopharyngeus, the salpingopharyngeus, the thyrohyoid, and the palatopharyngeus muscles. The main part of the larynx is thus elevated to the posterior surface of the epiglottis, and the entrance into the larynx is now closed.

The bolus moves downward over the epiglottis, the closed entrance into the larynx, and reaches the lower part of the pharynx because of the successive contraction of the superior, the middle, and the inferior constrictor muscles. Some of the food slides down the piriform fossa on either side of the entrance into the larynx. Finally, the lower part of the pharyngeal wall relaxes, and the bolus enters the esophagus.

Esophagus

The esophagus begins in the neck at the level of the cricoid cartilage as a continuation of the pharynx (Fig. 6-23). The esophagus descends in the midline behind the trachea (Fig. 6-5).

IMPORTANT RELATIONS

- **Anteriorly:** The trachea and the recurrent laryngeal nerves.
- **Posteriorly:** The prevertebral muscles and the vertebral column.
- **Laterally:** The thyroid gland, the carotid sheath, and the thoracic duct on the left side.

BLOOD SUPPLY

The inferior thyroid arteries supply the area.

LYMPH DRAINAGE

The lymph drains into the deep cervical lymph nodes.

NERVE SUPPLY

The recurrent laryngeal nerves and branches from the sympathetic trunk supply the esophagus.

RESPIRATORY SYSTEM IN THE HEAD AND NECK

Nose

EXTERNAL NOSE

The external nose is formed above by the nasal bones, the frontal processes of the maxillae, and the nasal part of the frontal bone. Below, the framework is formed by plates of hyaline cartilage.

NASAL CAVITY

The nasal cavity is divided into right and left halves by the **nasal septum** (Fig. 6-24). The septum is made up of the **septal cartilage,** the **vertical plate of the ethmoid,** and the **vomer.** Each nasal cavity extends from the **nostril** in front to the **choanae** behind. The nasal cavity has a floor, a roof, and both lateral and medial walls.

Floor

The palatine process of the maxilla and the horizontal plate of the palatine bone make up the floor.

Roof

The roof consists of the body of the sphenoid, the cribriform plate of the ethmoid, the frontal bone, and the nasal bone.

Lateral Wall

The lateral wall has three projections called the **superior, middle,** and **inferior nasal conchae** (Fig. 6-24). The space below each concha is called a **meatus.**

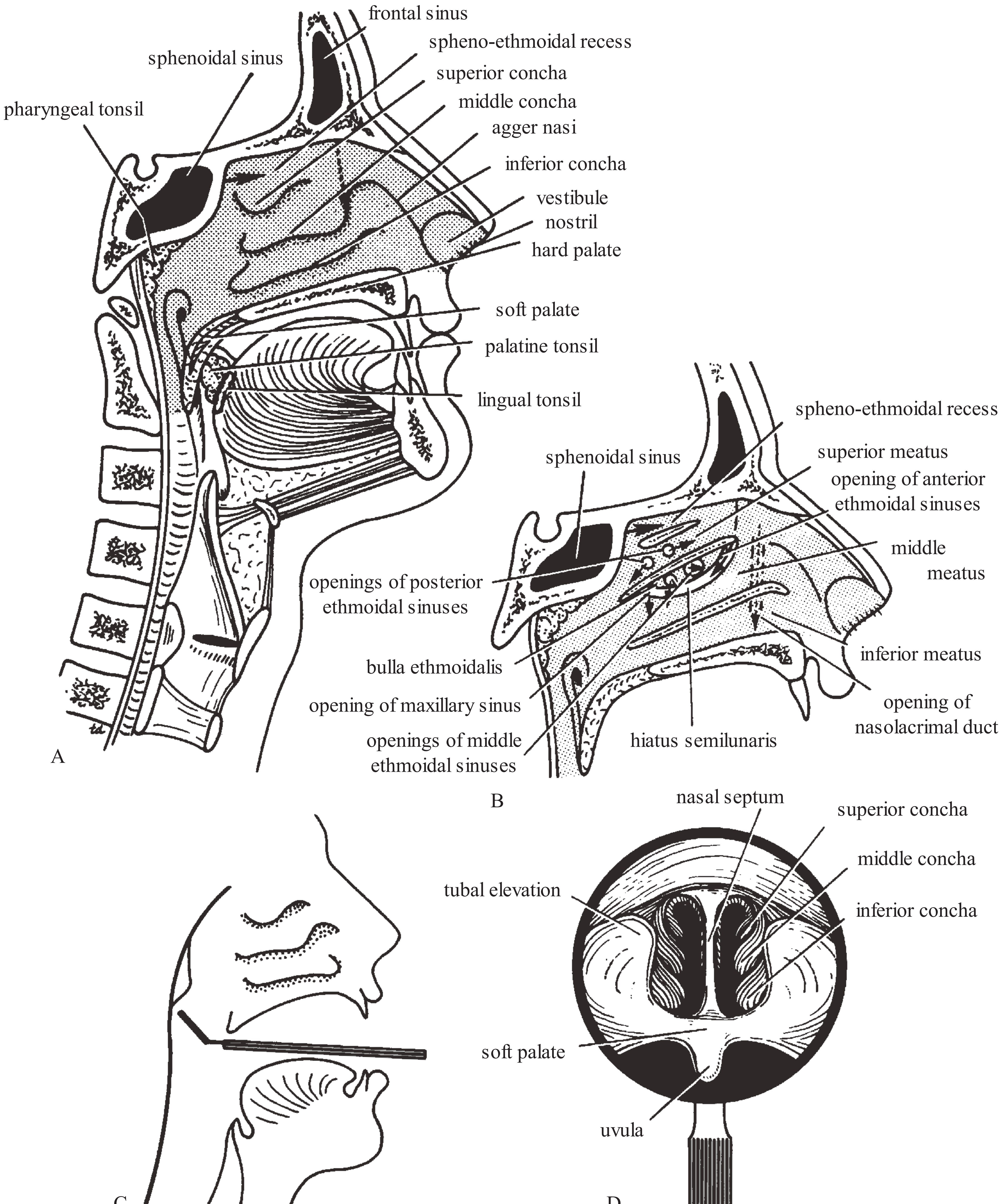


Figure 6-24 A. Sagittal section through the nose, the mouth, the larynx, and the pharynx. B. The lateral wall of the nose and the nasal part of the pharynx. C. Position of the mirror during a posterior rhinoscopy. D. The structures seen in the mirror during a posterior rhinoscopy.

Sphenoethmoidal Recess

The sphenoethmoidal recess is a small area above the superior concha. It receives the opening of the **sphenoidal air sinus.**

Superior Meatus

The superior meatus lies below the superior concha. It receives the openings of the **posterior ethmoidal sinuses.**

Middle Meatus

The middle meatus lies below the middle concha. It has a rounded swelling called the **bulla ethmoidalis** that is formed by the underlying **middle ethmoidal sinuses,** which open on its upper border. A curved opening called the **hiatus semilunaris** lies just below the bulla (Fig. 6-24). The anterior end of the hiatus leads into a funnel-shaped channel called the **infundibulum.** The **maxillary sinus** opens into the middle meatus through the hiatus semilunaris, and the **frontal sinus** opens into and is continuous with the infundibulum. The middle meatus is continuous in front with the **vestibule** via the **atrium;** the vestibule is lined by modified skin-bearing **hairs.**

Inferior Meatus

The inferior meatus lies below the inferior concha and receives the opening of the **nasolacrimal duct.** The opening is guarded by a fold of mucous membrane.

Medial Wall

The medial wall is formed by the nasal septum.

Mucous Membrane of Nasal Cavity

The vestibule is lined by modified skin. The area above the superior concha is lined with olfactory mucous membrane. The lower part of the nasal cavity is lined with respiratory mucous membrane.

NERVE SUPPLY

Olfactory nerves innervate the olfactory mucous membrane. The remainder is supplied by branches of the ophthalmic and the maxillary divisions of the trigeminal nerve.

BLOOD SUPPLY

Branches of the maxillary artery supply the nasal cavity. The sphenopalatine branch anastomoses with the septal branch of the facial artery in the vestibule (a common site for nose bleeds).

CLINICAL NOTES

NOSE BLEEDING

Epistaxis is a frequent condition. The bleeding may be arterial or venous. Most episodes occur on the anteroinferior portion of the septum and involve the septal branches of the sphenopalatine and facial vessels.

Paranasal Sinuses

MAXILLARY SINUS

The maxillary sinus is pyramidal in shape and lies within the maxilla on each side (Fig. 6-25). The roof is formed by the floor of the orbit, and the floor is related to the roots of the premolar and the molar teeth. The maxillary sinus opens into the middle meatus of the nose through the hiatus semilunaris.

FRONTAL SINUSES

The two frontal sinuses are contained within the frontal bone (Fig. 6-24). Each sinus opens into the middle meatus of the nose through the infundibulum.

SPHENOIDAL SINUSES

The two sphenoidal sinuses lie within the body of the sphenoid bone (Fig. 6-24). Each sinus opens into the sphenoethmoidal recess above the superior concha.

ETHMOIDAL SINUSES

The ethmoidal sinuses are anterior, middle, and posterior, and they are contained within the ethmoid bone on each side (Fig. 6-25). The anterior sinus opens into the infundibulum of the middle meatus. The middle sinus opens into the middle meatus, either above or on the bulla ethmoidalis, and the posterior sinus opens into the superior meatus.

The various sinuses and their openings into the nose are summarized in Table 6-12.

CLINICAL NOTES

SINUSITIS

Infection of the paranasal sinuses is a common complication of nasal infections.

Larynx

The larynx is a sphincter that is responsible for voice production (Figs. 6-26 and 6-27). It opens above into the laryngeal part of the pharynx, and it is continuous with the trachea below.

CARTILAGES OF THE LARYNX

Thyroid Cartilage

The thyroid cartilage (Fig. 6-26) is the largest cartilage of the larynx, and it consists of two laminae, each of which has a superior and an inferior cornu. On the outer surface is an oblique line for the attachment of muscles.

Cricoid Cartilage

The cricoid cartilage (Fig. 6-27) has a shallow arch in front and a broad lamina behind. It lies below the thyroid carti-

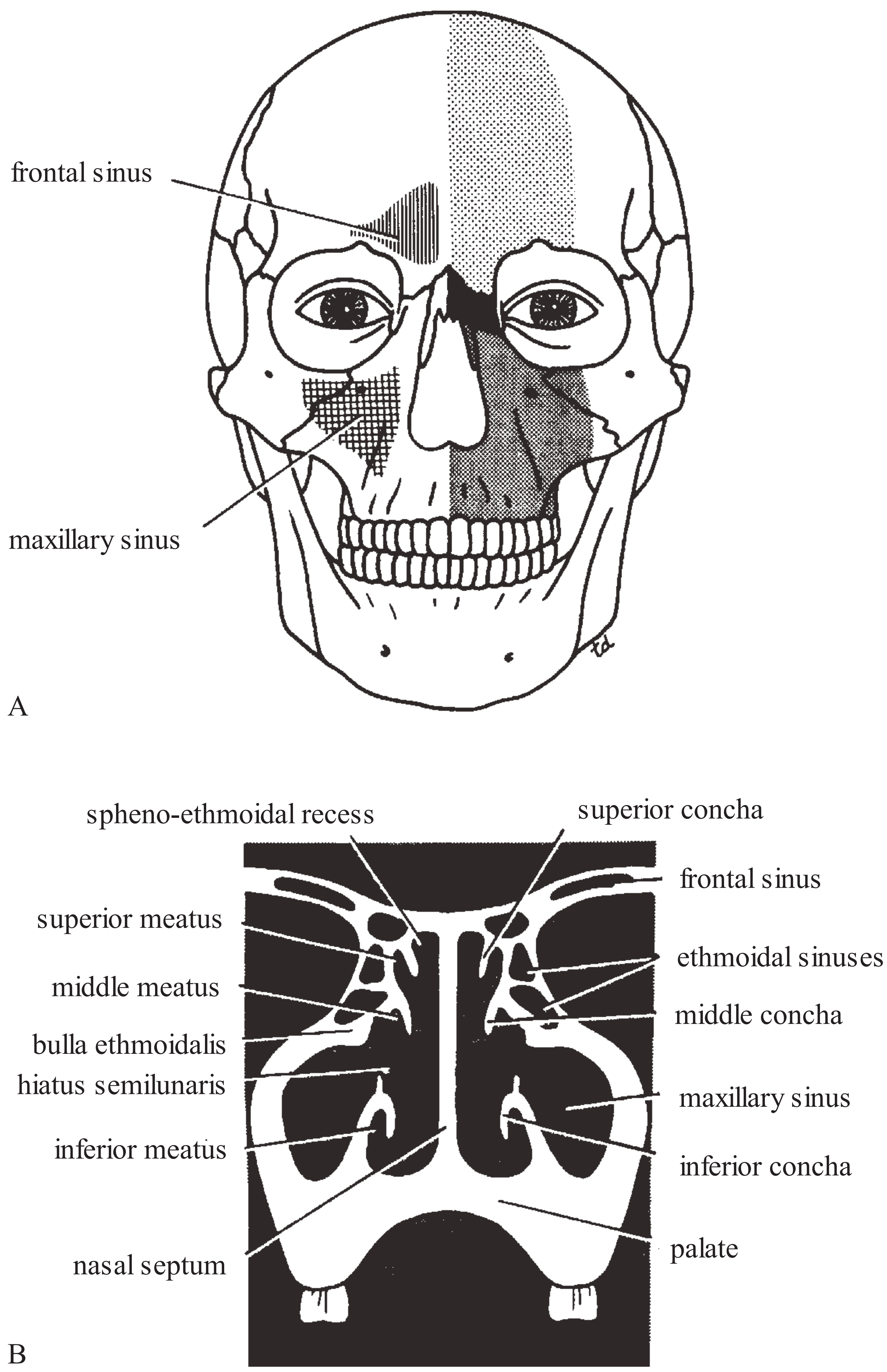


Figure 6-25 A. The bones of the face. Note the positions of the frontal and the maxillary sinuses. Pain is experienced during frontal sinusitis in the lightly dotted area, during sphenoethmoidal sinusitis in the solid area, and during maxillary sinusitis in the heavily dotted area. B. Coronal section through the nasal cavity showing the frontal, ethmoidal, and maxillary sinuses.

Table 6-12 Paranasal Sinuses and Their Sites of Drainage into the Nose

Sinus	Site of Drainage
Maxillary sinus	Middle meatus through the hiatus semilunaris
Frontal sinus	Middle meatus via the infundibulum
Sphenoid sinuses	Sphenoethmoidal recess
Ethmoidal sinuses	
Anterior group	Infundibulum and into the middle meatus
Middle group	Middle meatus on or above the bulla ethmoidalis
Posterior group	Superior meatus

lage, and it articulates with the inferior cornu. Posteriorly, the lamina articulates on its upper edge with the arytenoid cartilages.

Arytenoid Cartilages

There are two arytenoid cartilages (Fig. 6-26). They are pyramidal in shape, and they articulate with the upper border of the lamina of the cricoid cartilage. Each cartilage has an **apex,** a **base,** a **vocal process,** and a **muscular process.**

Corniculate Cartilages

There are corniculate cartilages (Fig. 6-26). They are conical in shape, and they articulate with the arytenoid cartilages.

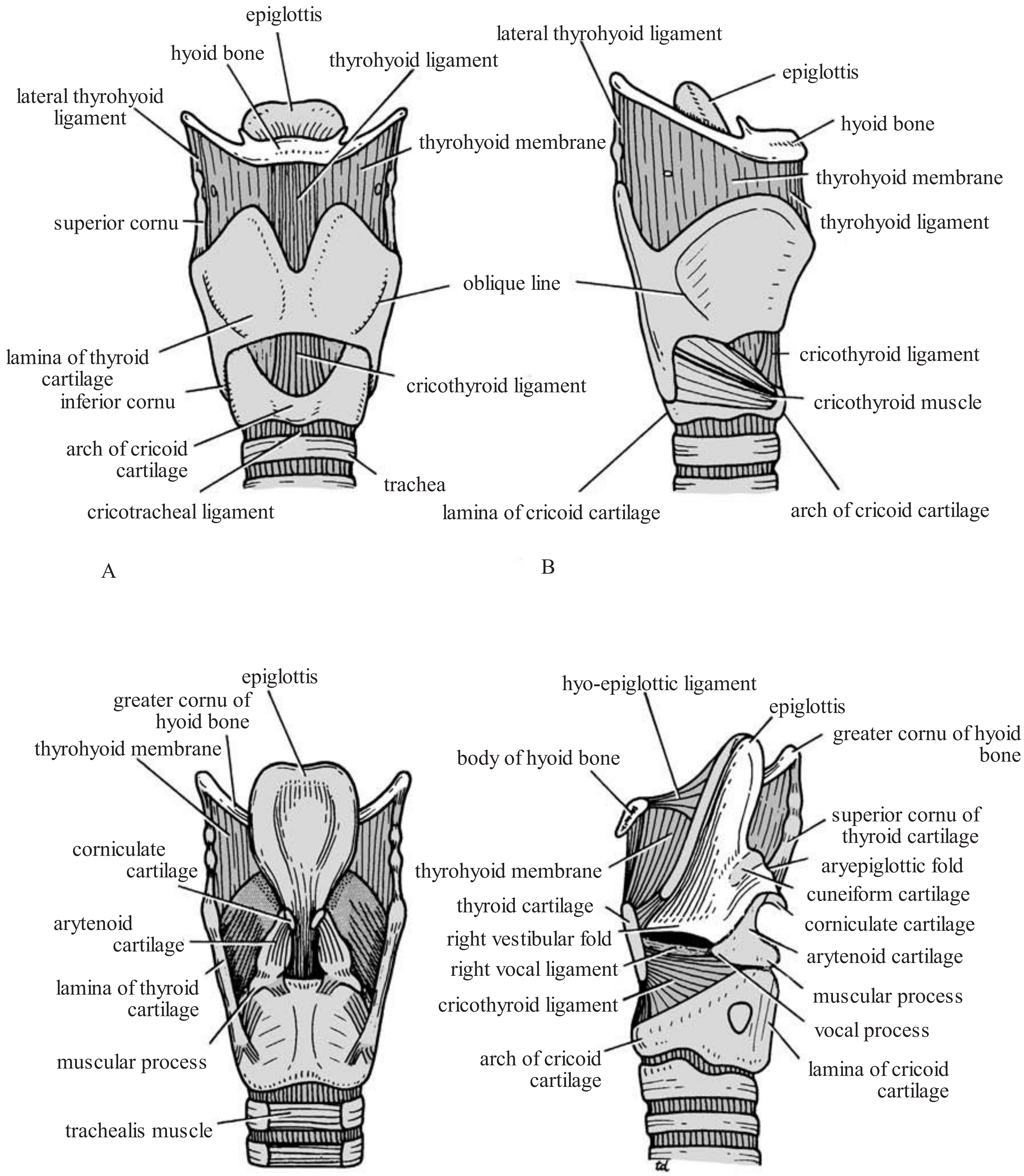


Figure 6-26 The larynx and its ligaments. A. Frontal view. B. Lateral view. C. Rear view. D. View with the left lamina of the thyroid cartilage removed to display the interior of the larynx.

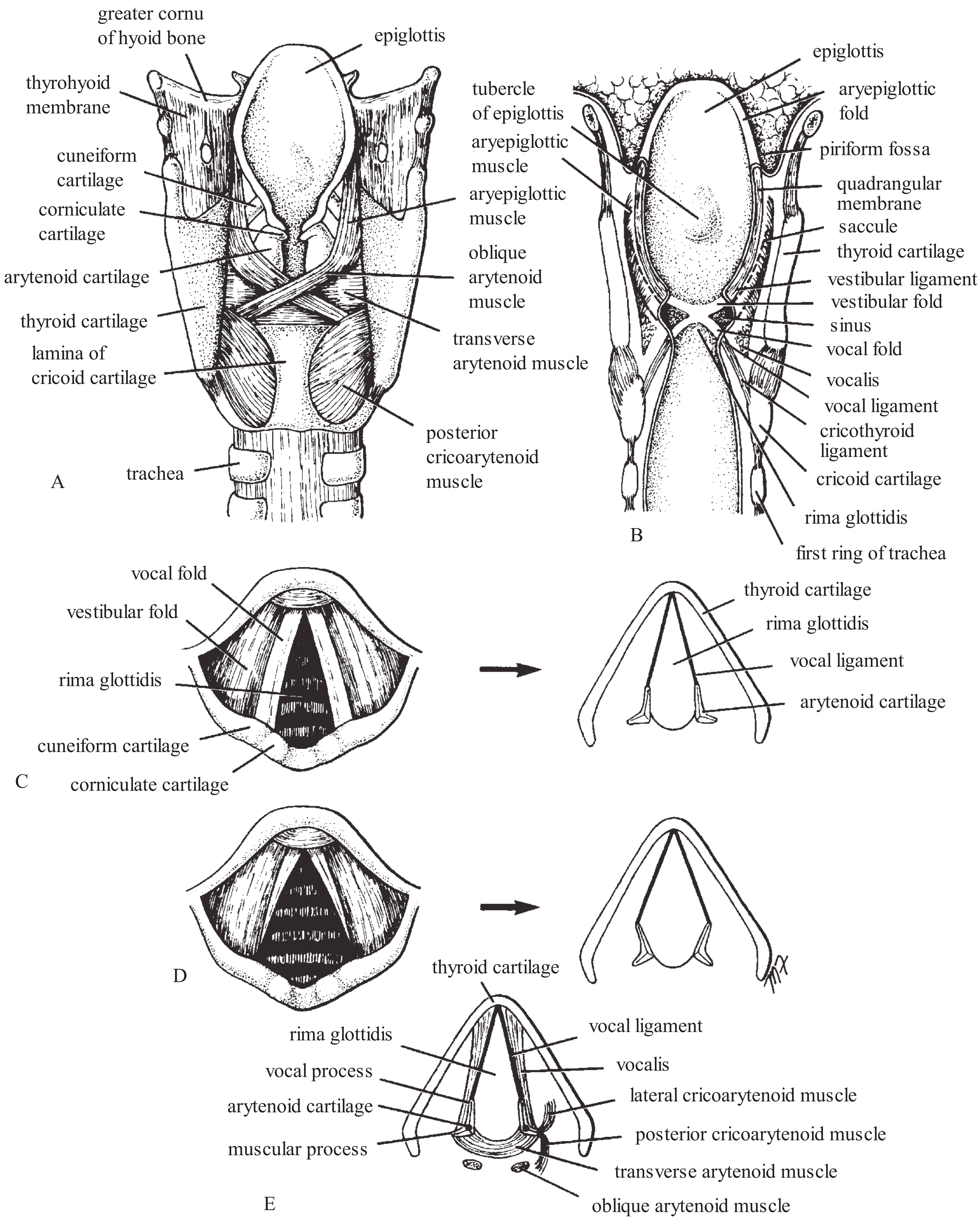


Figure 6-27 A. The muscles of the larynx as seen from behind. B. Coronal section through the larynx. C. The rima glottidis when partially open (as during quiet breathing). D. The rima glottidis when wide open (as during deep breathing). E. The muscles that move the vocal cords.

Cuneiform Cartilages

The rod-shaped cuneiform cartilages (Fig. 6-26) strengthen the aryepiglottic folds.

EPIGLOTTIS

The leaf-shaped epiglottis lies behind the root of the tongue (Figs. 6-26 and 6-27). It is attached by its stalk to the thyroid cartilage.

MEMBRANES AND LIGAMENTS

Thyrohyoid Membrane

The thyrohyoid membrane connects the upper margin of the thyroid cartilage to the hyoid bone (Fig. 6-27). It is pierced by the superior laryngeal vessels and the internal laryngeal nerve.

Quadrangular Membrane

The quadrangular membrane extends between the epiglottis and the arytenoid cartilages. Its inferior margin forms the **vestibular ligaments,** and the vestibular ligaments form the interior of the vestibular folds.

Cricothyroid Ligament

The cricothyroid ligament is attached below to the upper margin of the cricoid cartilage (Fig. 6-27). Above, however, it ascends on the medial surface of the thyroid cartilage instead of being attached to the lower margin of the cartilage. The upper margin forms the important **vocal ligament** on each side (Fig. 6-27). The vocal ligaments form the interior of the **vocal folds** (vocal cords). The anterior end of each vocal ligament is attached to the thyroid cartilage; the posterior end is attached to the vocal process of the arytenoid cartilage.

CAVITY OF THE LARYNX

The cavity of the larynx has three regions:

- The **vestibule**, which is situated between the inlet and the vestibular folds.
- The middle region, which is situated between the vestibular folds above and the vocal folds below.
- The lower region, which is situated between the vocal folds above and the lower border of the cricoid cartilage below.

LARYNGEAL FOLDS

Vestibular Fold

The vestibular fold is a **fixed** fold on each side of the larynx (Fig. 6-27). It is formed by mucous membrane covering the vestibular ligament and is **pink** in color.

Vocal Fold (Vocal Cord)

The vocal fold is a **mobile** fold on each side of the larynx. It is formed by mucous membrane covering the vocal ligament and is **white** in color.

Sinus of the Larynx

The sinus of the larynx is a small recess on each side of the larynx between the vestibular and the vocal folds (Fig. 6-27). It is lined with mucous membrane.

SACCULE OF THE LARYNX

The saccule of the larynx is a diverticulum that ascends from the sinus (Fig. 6-27). The secretion lubricates the vocal cords.

MUSCLES OF THE LARYNX

Extrinsic Muscles

- **Elevation:** The digastric, stylohyoid, mylohyoid, geniohyoid, stylopharyngeus, salpingopharyngeus, and palatopharyngeus muscles.
- **Depression:** The sternothyroid, sternohyoid, and omohyoid muscles.

Intrinsic Muscles

Two muscles modify the laryngeal inlet (Fig. 6-27):

- **Narrowing the inlet:** The oblique arytenoid muscle.
- **Widening the inlet:** The thyroepiglottic muscle.

Five muscles move the vocal folds (Fig. 6-27) are:

- **Tensing the vocal folds:** The cricothyroid muscle.
- **Relaxing the vocal folds:** The thyroarytenoid (vocalis) muscle.
- **Adducting the vocal folds:** The lateral cricoarytenoid muscle.
- **Abducting the vocal folds:** The posterior cricoarytenoid muscle.
- **Approximates arytenoids:** The transverse arytenoid muscle.

The muscles of the larynx are summarized in Table 6-13.

NERVE SUPPLY

Sensory Nerves

- **Above the vocal folds:** The internal laryngeal nerve.
- **Below the vocal folds:** The recurrent laryngeal nerve.

Motor Nerves

All the intrinsic muscles except the cricothyroid muscle are supplied by the recurrent laryngeal nerve. The cricothyroid muscle is supplied by the external laryngeal nerve.

Trachea

The trachea begins at the lower border of the larynx, and it descends in the midline of the neck to enter the thorax (Figs. 6-5 and 6-20).

IMPORTANT RELATIONS IN THE NECK

- **Anteriorly:** The skin, fascia, **isthmus of the thyroid gland** (in front of the second, third, and fourth rings), inferior thyroid veins, jugular arch, thyroidea ima artery (if

Table 6-13 Muscles of the Larynx

Muscle	Origin	Insertion	Nerve Supply	Action
Extrinsic Muscles				
Elevator muscles	These include the digastric, stylohyoid, mylohyoid, geniohyoid, stylopharyngeus, salpingopharyngeus, and palatopharyngeus muscles (Tables 6-4 and 6-11)			
Depressor muscles	These include sternothyroid, sternohyoid, and omohyoid muscles (Table 6-4)			
Intrinsic Muscles				
Muscles Controlling the Laryngeal Inlet				
Oblique arytenoid	Muscular process of the arytenoid cartilage	Apex of the opposite arytenoid cartilage	Recurrent laryngeal nerve	Narrows the inlet by bringing the aryepiglottic folds together
Thyroepiglottic	Medial surface of the thyroid cartilage	Lateral margin of the epiglottis and the aryepiglottic fold	Recurrent laryngeal nerve	Widens the inlet by pulling the aryepiglottic folds apart
Muscles Controlling Movements of the Vocal Cords				
Cricothyroid	Side of the cricoid cartilage	Lower border and inferior cornu of the thyroid cartilage	External laryngeal nerve	Tenses the vocal cords
Thyroarytenoid (vocalis is part of the muscle)	Inner surface of the thyroid cartilage at the angle between the laminae	Anterior surface of the arytenoid cartilage	Recurrent laryngeal nerve	Relaxes the vocal cords
Lateral cricoarytenoid	Upper border of the cricoid cartilage	Muscular process of the arytenoid cartilage	Recurrent laryngeal nerve	Adducts the vocal cords by rotating the arytenoid cartilage
Posterior cricoarytenoid	Back of the cricoid cartilage	Muscular process of the arytenoid cartilage	Recurrent laryngeal nerve	Abducts the vocal cords by rotating the arytenoid cartilage
Transverse arytenoid	Back and medial surface of the arytenoid cartilage	Back and medial surface of the opposite arytenoid cartilage	Recurrent laryngeal nerve	Closes the posterior part of the rima glottidis by approximating the arytenoid cartilages

present), and left brachiocephalic vein in children, overlapped by the sternothyroid and sternohyoid muscles.
- **Posteriorly:** The right and left recurrent laryngeal nerves and the esophagus.
- **Laterally:** The lobes of the thyroid gland and the carotid sheath and its contents.

ENDOCRINE GLANDS IN THE HEAD AND NECK

Pituitary Gland (Hypophysis Cerebri)

The pituitary gland is situated in the hypophyseal fossa in the sella turcica of the sphenoid bone (Fig. 6-28), and it is connected to the undersurface of the brain by the **stalk (infundibulum).** The pituitary gland can be divided into an **anterior lobe (adenohypophysis)** and a **posterior lobe (neurohypophysis).** The anterior lobe can be subdivided into the **pars anterior** and the **pars intermedia** by a cleft that is a remnant of an embryonic pouch. A projection from the pars anterior, the **pars tuberalis,** extends up along the anterior and the lateral surfaces of the pituitary stalk.

IMPORTANT RELATIONS

- **Anteriorly:** The sphenoid sinus.
- **Posteriorly:** The dorsum sellae, basilar artery, and pons.
- **Superiorly:** The diaphragma sellae and the optic chiasma.
- **Inferiorly:** The body of the sphenoid and the sphenoid sinus.
- **Laterally:** The cavernous sinus and its contents (the internal carotid artery and the abducent nerve).

BLOOD SUPPLY

The superior and inferior hypophyseal arteries and branches of the internal carotid artery supply the gland.

CLINICAL NOTES

THE PITUITARY GLAND AND THE OPTIC CHIASMA

Enlargement of the pituitary because of a tumor usually results in the gland initially expanding superiorly and pressing on the optic chiasma through the diaphragma sellae. Pressure on the chiasma produces bitemporal hemianopia. Further enlargement results in erosion of the bone of the sella turcica, which can be recognized on a lateral radiograph of the skull.

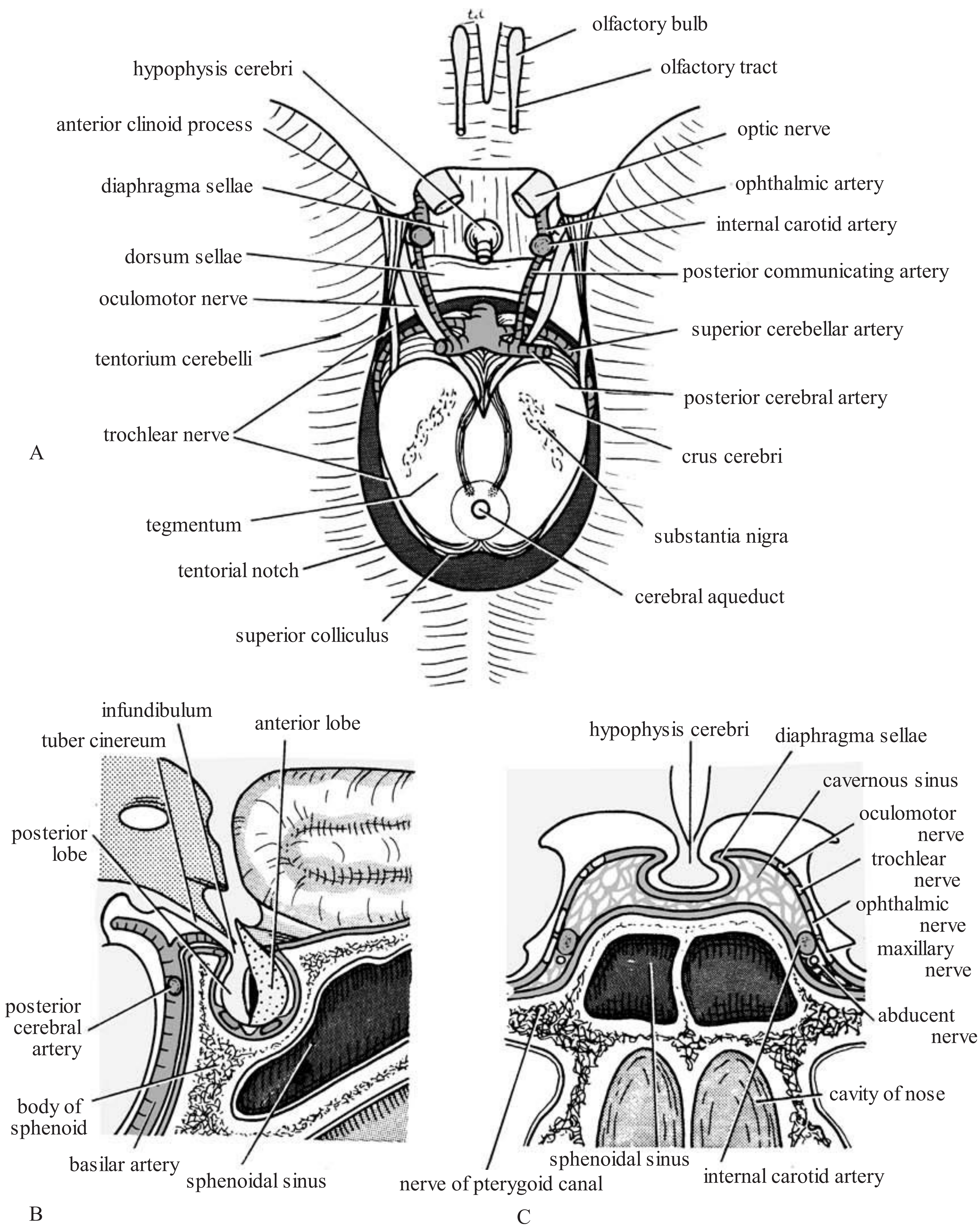


Figure 6-28 A. Interior of the skull as seen from above. For clarity, the forebrain has been removed, leaving the midbrain, the hypophysis cerebri, and the internal carotid and basilar arteries in position. B. Sagittal section through the sella turcica showing the hypophysis cerebri. C. Coronal section through the body of the sphenoid showing the hypophysis cerebri and the cavernous sinuses. Note the position of the cranial nerves.

Thyroid Gland

The thyroid gland consists of right and left lobes connected by a narrow isthmus (Fig. 6-4). It is surrounded by a sheath formed of pretracheal fascia, and this sheath attaches the gland to the larynx and the trachea.

Each **lobe** of the gland is pear shaped, with its apex directed upward along the lateral side of the thyroid cartilage and its base below alongside the trachea. The **isthmus** crosses the midline in front of the **second,** the **third,** and the **fourth rings of the trachea.** A **pyramidal lobe** is often present and projects upward from the isthmus. A muscular band called the **levator glandulae thyroideae** often connects the pyramidal lobe to the hyoid bone.

IMPORTANT RELATIONS OF THE THYROID GLAND

- **Anterolaterally:** The infrahyoid group of muscles and the anterior border of sternocleidomastoid muscle.
- **Posterolaterally:** The carotid sheath and its contents.
- **Medially:** The larynx, trachea, pharynx, esophagus, external laryngeal nerve, and recurrent laryngeal nerve.
- **Posteriorly:** The parathyroid glands.

BLOOD SUPPLY

Arteries

The superior thyroid artery (related to the external laryngeal nerve) from the external carotid, the inferior thyroid artery (related to the recurrent laryngeal nerve) from the thyrocervical trunk, and the thyroidea ima artery (if present) from the brachiocephalic or the aortic arch supply the gland.

Veins

The superior and the middle thyroid veins drain into the internal jugular vein. The inferior thyroid vein drains into the left brachiocephalic vein.

CLINICAL NOTES

THYROID ARTERIES AND LARYNGEAL NERVES

The relationship of the superior and inferior thyroid arteries to the external laryngeal and recurrent laryngeal nerves, respectively, is of great clinical importance during thyroid surgery. Unless the nerves are carefully identified, they may be included in the ligatures of the arteries with disastrous consequences.

Parathyroid Glands

SUPERIOR PARATHYROID GLANDS

The two superior parathyroid glands lie behind the middle of the posterior surface of the thyroid gland.

INFERIOR PARATHYROID GLANDS

The two inferior parathyroid glands lie close to the inferior poles of the thyroid gland (sometimes found some distance below in the superior mediastinum).

CLINICAL NOTES

CLINICAL SIGNIFICANCE OF THE PARATHYROID GLANDS

The parathyroid glands lie within the fascial capsule of the thyroid gland and are at risk during thyroidectomy operations.

BLOOD SUPPLY

The superior and the inferior thyroid arteries.

ORBIT

Orbital Margin

The orbital margin is formed by the frontal, maxilla, and zygomatic bones.

Orbital Walls

The orbital walls are shown in Figure 6-29.

- **Superior wall (or roof):** Formed by the orbital plate of the frontal bone and the lesser wing of the sphenoid bone.
- **Inferior wall (or floor):** Formed by the orbital plate of the maxilla, which separates the orbital cavity from the maxillary sinus.
- **Lateral wall**: Formed by the zygomatic bone and the greater wing of the sphenoid.
- **Medial wall**: Formed from before backward by the frontal process of the maxilla, the lacrimal bone, the orbital plate of the ethmoid (which separates the orbital cavity from the ethmoid sinuses), and the body of the sphenoid.

Openings into the Orbital Cavity

The openings into the orbital cavity are shown in Figure 6-29.

- **Orbital opening:** Lies anteriorly. Approximately one sixth of the eye is exposed; the remainder is protected by the walls of the orbit.
- **Supraorbital groove (foramen):** Situated on the superior orbital margin; it transmits the supraorbital nerve and blood vessels.
- **Infraorbital groove and canal:** Situated on the floor of the orbit in the orbital plate of the maxilla. They transmit the infraorbital nerve and blood vessels.
- **Nasolacrimal canal:** Located anteriorly on the medial wall. It communicates with the inferior meatus of the nose and transmits the nasolacrimal duct.
- **Inferior orbital fissure:** Located posteriorly between the maxilla and the greater wing of the sphenoid. It communicates with the pterygopalatine fossa and transmits the maxillary nerve and its zygomatic branch, the inferior ophthalmic vein, and sympathetic nerves.

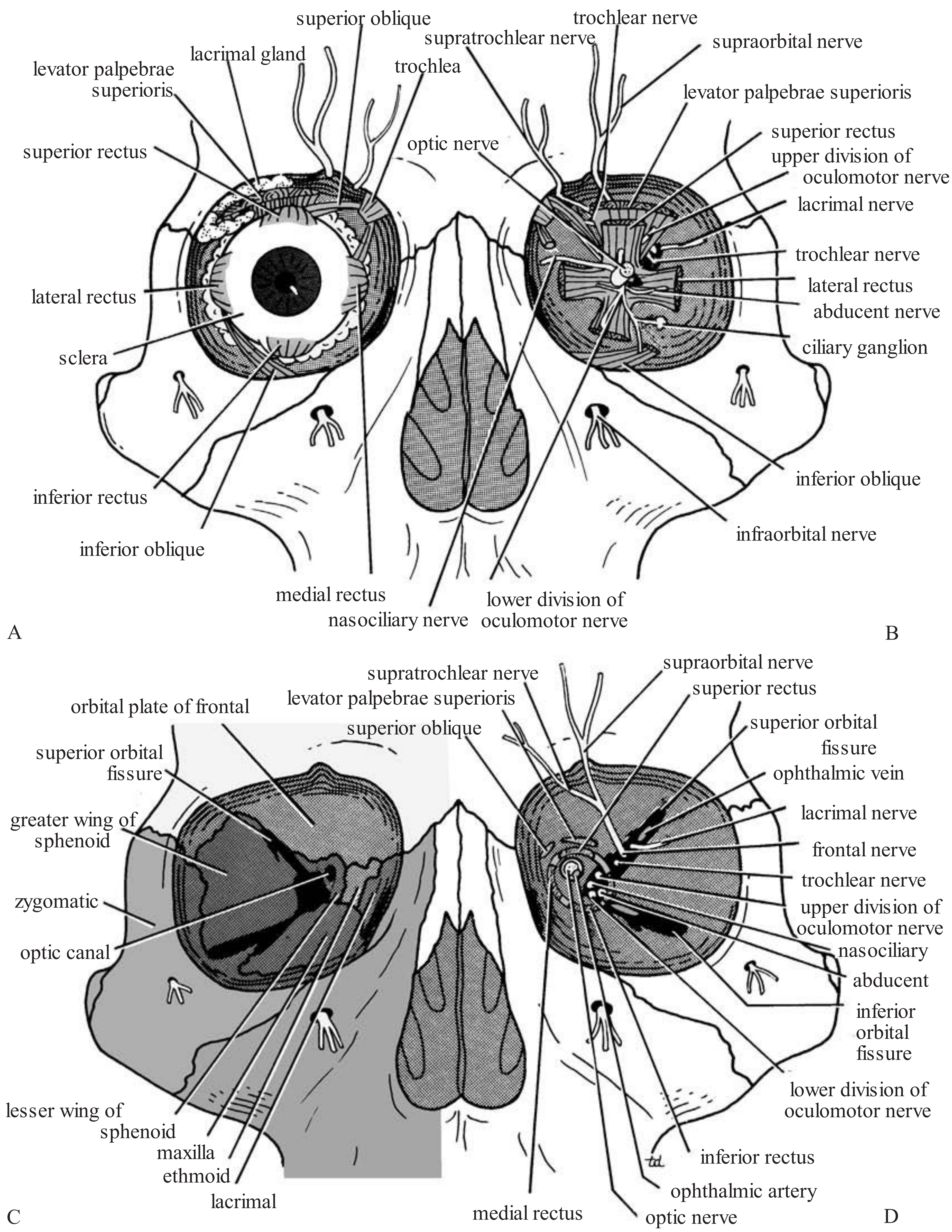


Figure 6-29 A. The right eyeball as exposed from in front. B. The muscles and nerves of the left orbit as exposed from in front. C. The bones forming the walls of the right orbit. D. The optic canal and the superior and inferior orbital fissures on the left side.

- **Superior orbital fissure:** Located posteriorly between the greater and the lesser wings of the sphenoid. It communicates with the middle cranial fossa and transmits the lacrimal nerve, the frontal nerve, the trochlear nerve, the oculomotor nerve (upper and lower divisions), the abducent nerve, the nasociliary nerve, and the superior ophthalmic vein.
- **Optic canal:** Located posteriorly in the lesser wing of the sphenoid (Fig. 6-29). It communicates with the middle cranial fossa and transmits the optic nerve and the ophthalmic artery.

EYE

Eye Muscles

There are extrinsic and intrinsic eye muscles.

EXTRINSIC MUSCLES

There are six extrinsic muscles that run from the posterior wall of the orbital cavity to the eyeball (Figs. 6-30 and Fig. 6-29). These are the **superior rectus,** the **inferior rectus,** the **medial rectus,** the **lateral rectus,** and the **superior** and the **inferior oblique muscles.**

INTRINSIC MUSCLES

The intrinsic muscles are the **ciliary muscle** and the **constrictor** and the **dilator pupillae of the iris** (discussed later).

Because the superior and the inferior recti are inserted on the medial side of the vertical axis of the eyeball, they not only raise and depress the cornea, respectively, but also **rotate it medially**. For the superior rectus muscle to raise the cornea directly upward, the inferior oblique muscle must assist; for the inferior rectus to depress the cornea directly downward, the superior oblique muscle must assist. Note that the tendon of the superior oblique muscle passes through a fibrocartilaginous pulley (trochlea) attached to the frontal bone. The tendon now turns backward and laterally and is inserted into the sclera beneath the superior rectus muscle.

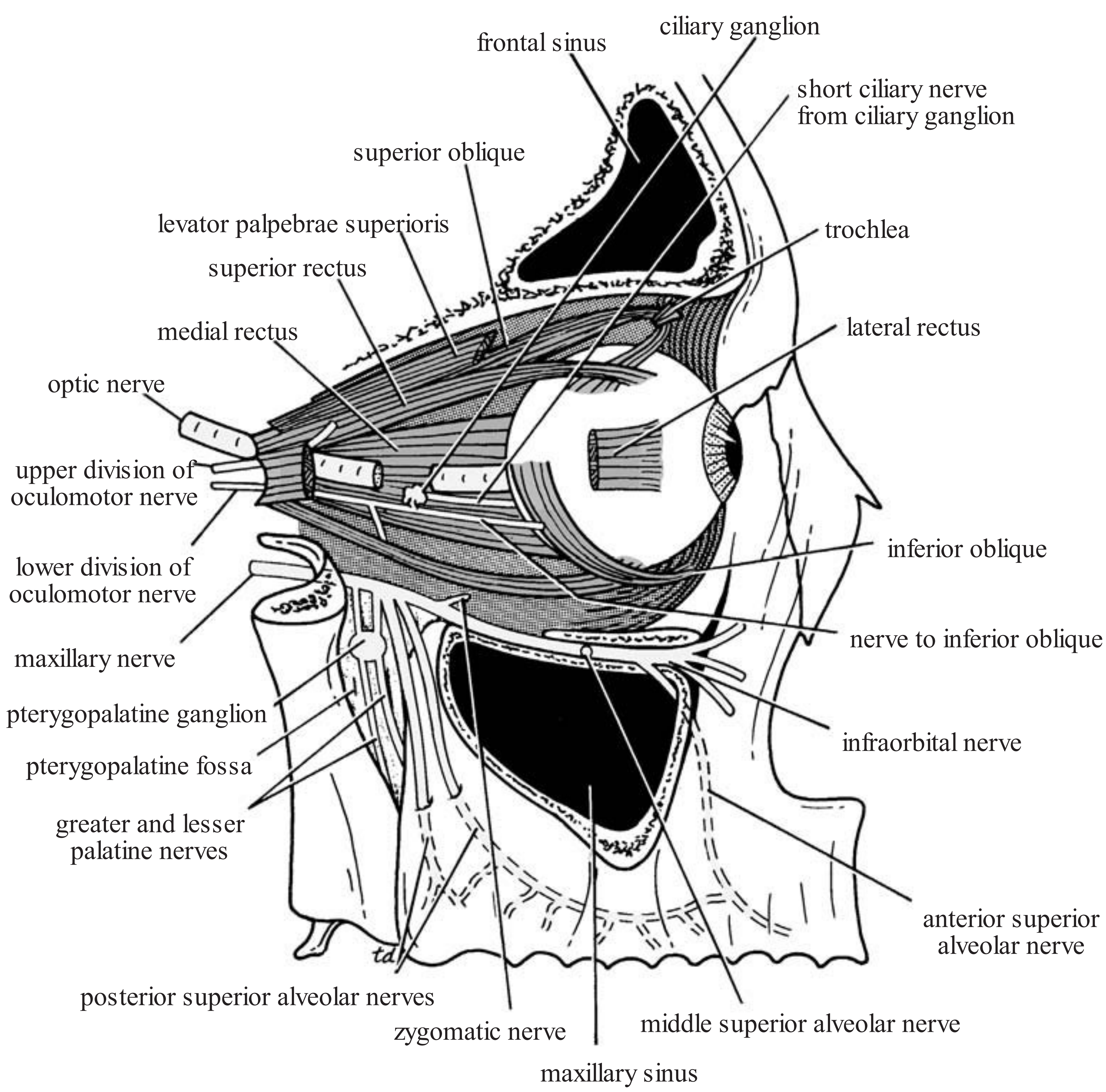


Figure 6-30 Lateral view of the muscles and nerves of the right orbit. The maxillary nerve and the pterygopalatine ganglion are also shown.

Table 6-14 Muscles of the Eyeball and Eyelids

Muscle	Origin	Insertion	Nerve Supply	Action
Extrinsic Muscles of the Eyeball (Striated Skeletal Muscle)				
Superior rectus	Tendinous ring on the posterior wall of the orbital cavity	Superior surface of the eyeball just posterior to the corneoscleral junction	Oculomotor nerve (third cranial nerve)	Raises the cornea upward and medially
Inferior rectus	Tendinous ring on the posterior wall of the orbital cavity	Inferior surface of the eyeball just posterior to the corneoscleral junction	Oculomotor nerve (third cranial nerve)	Depresses the cornea downward and medially
Medial rectus	Tendinous ring on the posterior wall of the orbital cavity	Medial surface of the eyeball just posterior to the corneoscleral junction	Oculomotor nerve (third cranial nerve)	Rotates the eyeball so that the cornea looks medially
Lateral rectus	Tendinous ring on the posterior wall of the orbital cavity	Lateral surface of the eyeball just posterior to the corneoscleral junction	Abducent nerve (sixth cranial nerve)	Rotates the eyeball so that the cornea looks laterally
Superior oblique	Posterior wall of the orbital cavity	Passes through pulley and is attached to the superior surface of the eyeball beneath the superior rectus	Trochlear nerve (fourth cranial nerve)	Rotates the eyeball so that the corneal looks downward and laterally
Inferior oblique	Floor of the orbital cavity	Lateral surface of the eyeball deep to the lateral rectus	Oculomotor nerve (third cranial nerve)	Rotates the eyeball so that the cornea looks upward and laterally
Intrinsic Muscles of the Eyeball (Smooth Muscle)				
Sphincter pupillae of the iris			Parasympathetic via the oculomotor nerve	Constricts the pupil
Dilator pupillae of the iris			Sympathetic	Dilates the pupil
Ciliary muscle			Parasympathetic via the oculomotor nerve	Controls the shape of the lens; in accommodation, makes the lens more globular
Muscles of the Eyelids				
Orbicularis oculi (Table 6-8)				
Levator palpebrae superioris	Back of the orbital cavity	Anterior surface of the upper margin of the superior tarsal plate	Striated muscle: oculomotor nerve; smooth muscle; sympathetic	Raises the upper lid

The origins, insertions, nerve supply, and actions of the muscles of the eyeball are summarized in Table 6-14.

Main Parts of the Eyeball

The main parts of the eyeball are shown in Figure 6-31. There are three **coats:** the fibrous, the vascular pigmented, and the nervous.

FIBROUS COAT

The fibrous coat consists of a posterior, white, opaque part called the **sclera** and an anterior, transparent part called the **cornea** (Fig. 6-31). The **lamina cribrosa** is the area of the sclera that is pierced by the nerve fibers of the optic nerve. The sclera is directly continuous with the cornea at the **corneoscleral junction (limbus).**

VASCULAR PIGMENTED COAT

From back to front, the vascular pigmented coat consists of the choroid, the ciliary body, and the iris (Fig. 6-31).

Choroid

The choroid consists of an outer, pigmented layer and an inner, vascular layer.

Ciliary Body

The ciliary body is a complete ring that runs around the inside of the sclera (Fig. 6-31). It is composed of the ciliary

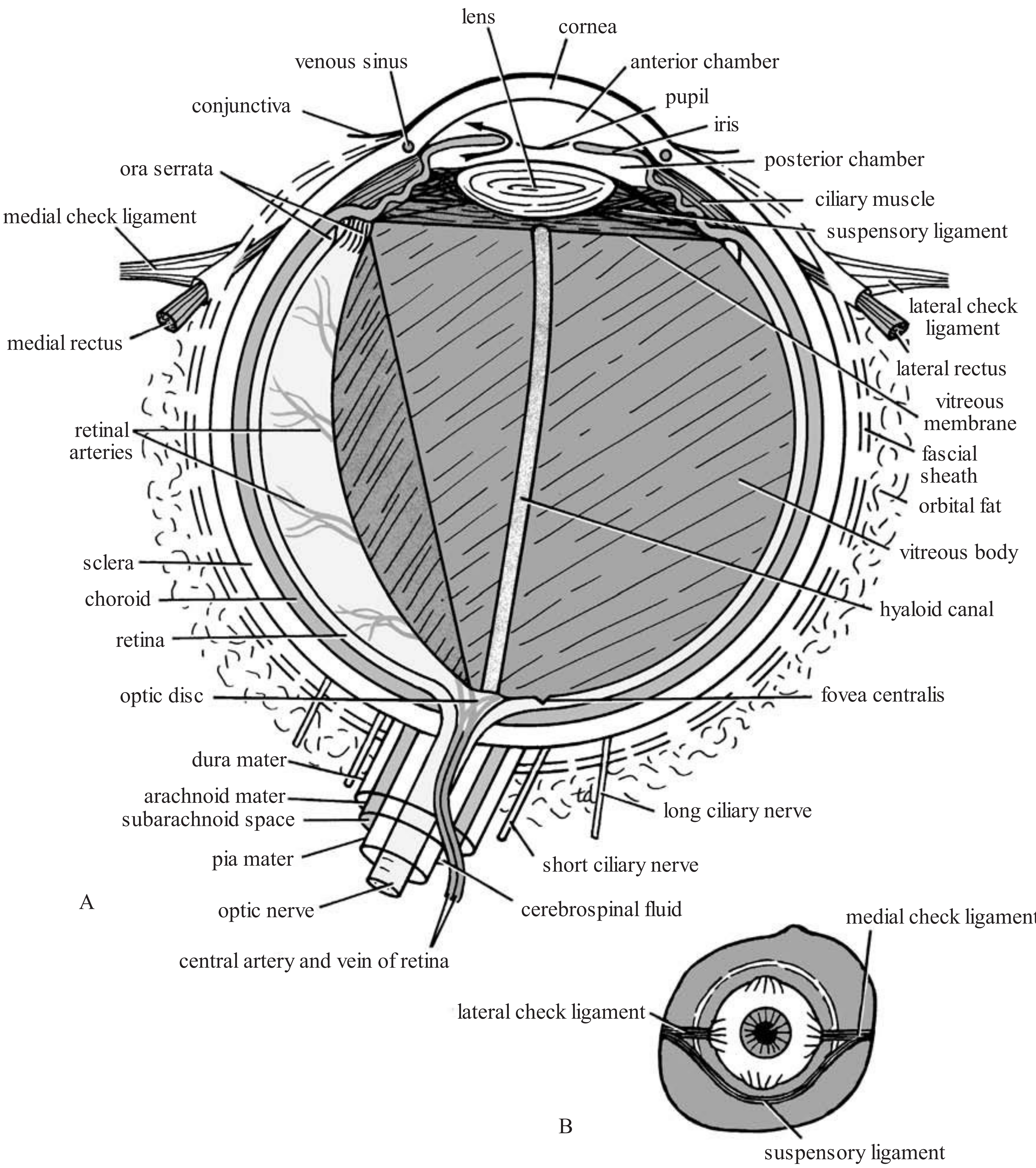


Figure 6-31 A. Horizontal section through the eyeball and the optic nerve. Note that the central artery and vein of the retina cross the subarachnoid space to reach the optic nerve. B. The check ligaments and suspensory ligaments of the eyeball.

processes and the ciliary muscle. The **ciliary processes** are radially arranged folds that are connected to the **suspensory ligaments of the lens.** The **ciliary muscle,** which is responsible for changing the shape of the lens, is composed of meridional and circular fibers of smooth muscle. The meridional fibers run backward from the region of the corneoscleral junction to the ciliary processes, and the circular fibers run around the eyeball within the ciliary body.

Nerve Supply of the Ciliary Muscle

Parasympathetic fibers within the oculomotor nerve synapse in the ciliary ganglion. Postganglionic fibers reach the eyeball in the short ciliary nerves.

Action of the Ciliary Muscle

By pulling the suspensory ligaments forward, the ciliary muscle slackens the ligaments. The elastic lens thus becomes more convex, and the refractive power is increased.

Iris

The iris is a thin, contractile, pigmented sheet with a central hole (the **pupil**). The iris is suspended in the aqueous humor between the cornea and the lens (Fig. 6-31), and it divides the space between the cornea and the lens into **anterior** and **posterior chambers**. The function of the iris is to control the amount of light that enters the eye. **Sphincter pupillae** are a collection of smooth muscle fibers arranged around the pupil; **dilator pupillae** consist of radial fibers.

Nerve Supply of the Muscle of Iris

The sphincter pupillae are supplied by parasympathetic fibers from the oculomotor nerve. The parasympathetic fibers synapse in the ciliary ganglion, and the postganglionic fibers reach the eyeball in the short ciliary nerves. The dilator pupillae are supplied by sympathetic fibers that reach the eye in the long ciliary nerves.

Action of the Iris

The sphincter pupillae constrict the pupil in the presence of bright light and during accommodation. The dilator pupillae dilate the pupil in the presence of low-intensity light or excessive sympathetic activity.

NERVOUS COAT (RETINA)

The nervous coat is the innermost layer of the eyeball (Fig. 6-31). It consists of an outer, **pigmented layer** and an inner, **nervous layer.**

The **optic nerve** leaves the retina at the optic disc. The **optic disc** is depressed at its center and is pierced by the **central artery of the retina** (Fig. 6-31).

Contents of the Eyeball

AQUEOUS HUMOR

The aqueous humor is a clear fluid that fills the anterior and the posterior chambers.

VITREOUS BODY

The vitreous body is a transparent gel and fills the eyeball behind the lens.

LENS

The lens is a transparent, biconvex disc that lies behind the iris and in front of the vitreous body (Fig. 6-31). The circumference of the lens is attached to the ciliary processes of the ciliary body by the suspensory ligament. The pull of the radiating fibers of the suspensory ligament tends to keep the elastic lens flattened, so that the eye may be focused on distant objects.

PERIORBITAL STRUCTURES

Eyelids

The eyelids are thin, movable folds with a fibrous framework called the **orbital septum.** The orbital septum is thickened at the lid margins to form the **tarsal plates,** and the ends of the tarsal plates are attached to the orbital margins by the **lateral** and the **medial palpebral ligaments.**

The eyelids are closed by contraction of the orbicularis oculi muscle. The eye is opened by the levator palpebrae superioris muscle, which raises the upper lid.

Lacrimal Apparatus

The lacrimal apparatus consists of the lacrimal gland and the ducts that drain the conjunctival sac.

LACRIMAL GLAND

The lacrimal gland secretes tears and is situated above the eyeball in the anterior and upper part of the orbit (Fig. 6-29). Several ducts open from the gland into the superior part of the conjunctival sac.

Nerve Supply

Parasympathetic secretomotor nerves from the facial nerve (seventh cranial nerve) supply the gland.

LACRIMAL SAC

Tears circulate across the cornea and enter the canaliculi, which open into the lacrimal sac. The sac is the upper blind end of the nasolacrimal duct.

NASOLACRIMAL DUCT

The nasolacrimal duct emerges from the lower end of the sac and descends downward and laterally in a bony canal to enter the inferior meatus of the nose (Fig. 6-24).

EAR

The ear consists of the external, middle, and internal ears.

External Ear

The external ear has an **auricle** and an **external auditory meatus** (Fig. 6-32). The meatus is a curved tube approximately 1 in. (2.5 cm) in length that leads from the auricle to the tympanic membrane. The outer third has a framework of elastic cartilage; the inner two thirds have a framework of bone.

Middle Ear

The middle ear has four walls: lateral, medial, anterior, and posterior.

- **Lateral wall:** The tympanic membrane (Fig. 6-32).
- **Medial wall:** The lateral wall of the inner ear. The **promontory** is a rounded projection resulting from the underlying first turn of the cochlea (Fig. 6-33). The **fenestra vestibuli (oval window),** which is oval in shape and closed by the footpiece of the stapes, lies above and be-

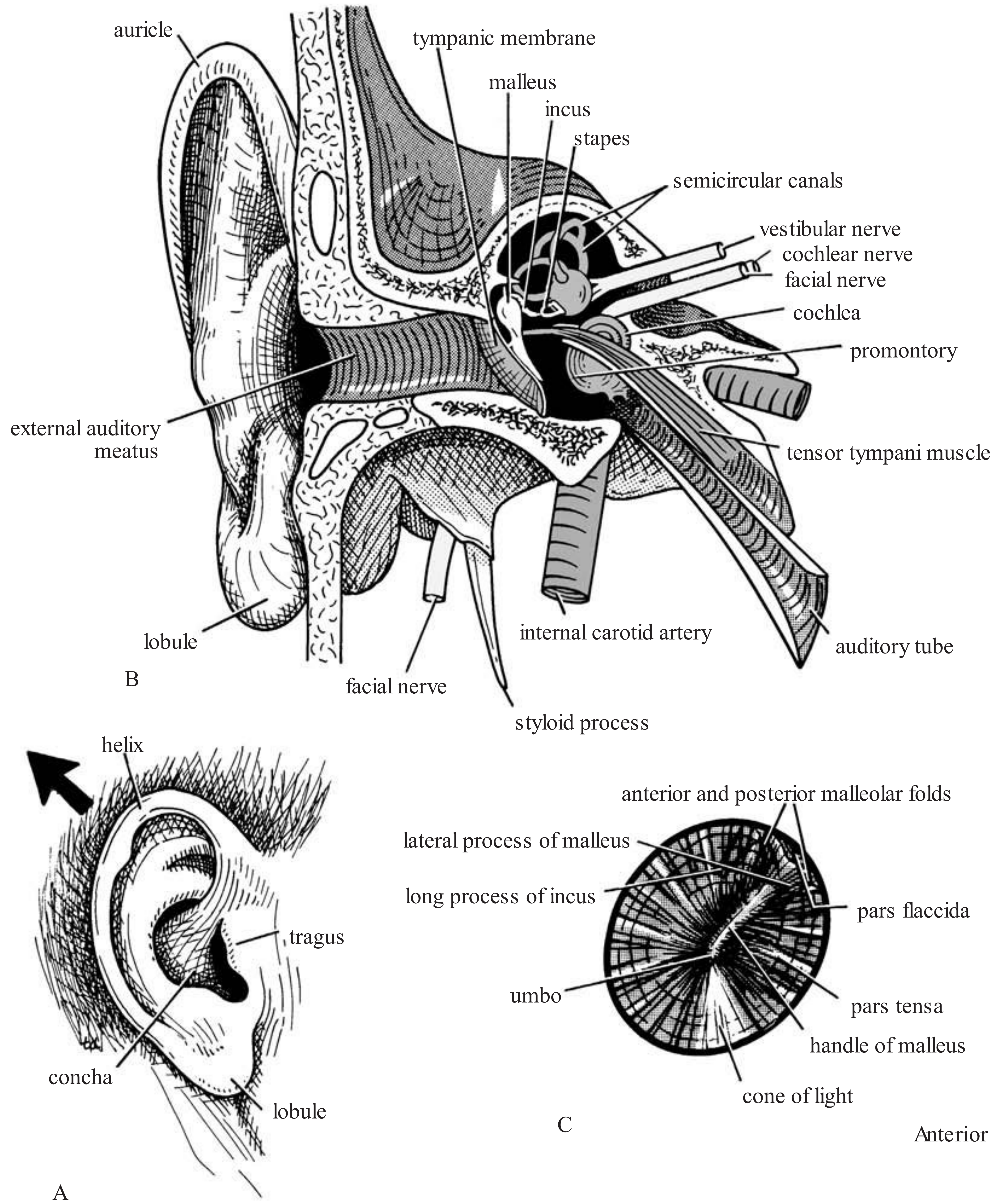


Figure 6-32 A. The auricle of the external ear. The arrow indicates the direction that the auricle should be pulled to straighten the external auditory meatus before insertion of an otoscope in adults. B. The external and middle portions of the right ear as viewed from in front. C. The right tympanic membrane as seen through an otoscope.

hind the promontory. The **fenestra cochlea,** which is round in shape and closed by the **secondary tympanic membrane,** lies below the posterior end of the promontory. The **prominence of the facial canal,** for the facial nerve, runs backward above the promontory to reach the posterior wall, where it turns downward behind the pyramid.

- **Anterior wall:** The canal for the **tensor tympani muscle** and the opening for the **auditory tube.**
- **Posterior wall:** The **aditus to the mastoid antrum**. Below this is a hollow, conical projection from whose apex emerges the tendon of the **stapedius muscle.**

AUDITORY OSSICLES

The auditory ossicles are the malleus, the incus, and the stapes (Fig. 6-32). The **malleus** (hammer) is the largest ossicle and possesses a head, a neck, a long process or handle,

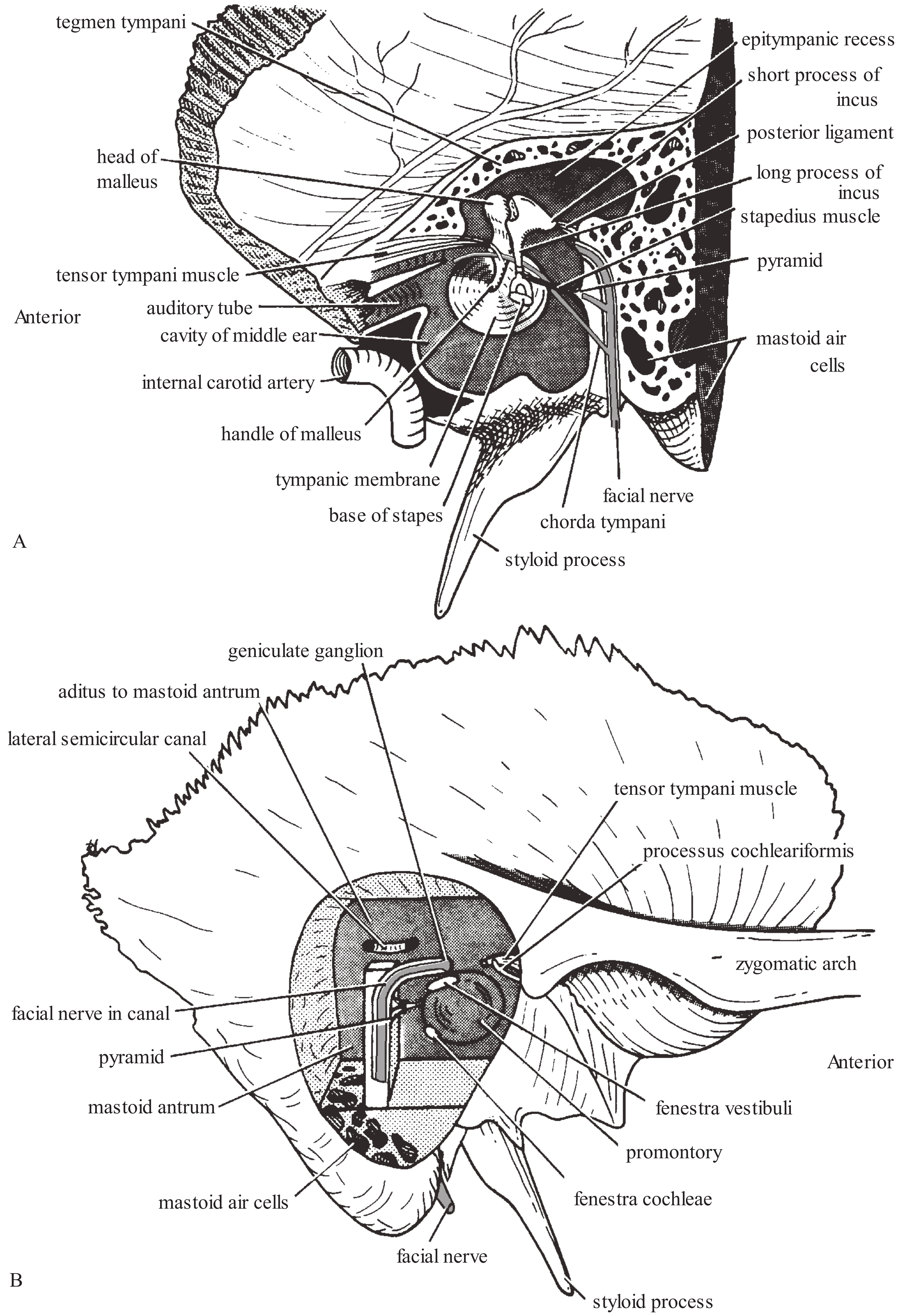


Figure 6-33 A. Lateral wall of the right middle ear as viewed from the medial side. Note the position of the ossicles and the mastoid antrum. B. Medial wall of the right middle ear as viewed from the lateral side. Note the position of the facial nerve in its bony canal.

Table 6-15 Muscles of the Middle Ear

Muscle	Origin	Insertion	Nerve Supply	Action
Tensor tympani	Wall of auditory tube and wall of its own canal	Handle of the malleus	Mandibular division of the trigeminal nerve (fifth cranial nerve)	Dampens down vibrations of the tympanic membrane
Stapedius	Pyramid (bone projection on the posterior wall of the middle ear)	Neck of the stapes	Facial nerve (seventh cranial nerve)	Dampens down vibration of the stapes

an anterior process, and a lateral process. The **incus** (anvil) possesses a large body and two processes. The **stapes** (stirrup) has a head, a neck, two limbs, and a base. The edge of the base is attached to the margin of the fenestra vestibuli by a ring of fibrous tissue called the **anular ligament.**

Muscles of the Ossicles

The muscles of the middle ear (ossicles) are summarized in Table 6-15.

TYMPANIC MEMBRANE

The tympanic membrane is concave laterally. At the depth of the concavity is a small depression called the **umbo** (Fig. 6-32). The membrane is composed of fibrous tissue and is covered on the outer surface with stratified squamous epithelium. The outer surface is innervated by the trigeminal and the vagus nerves. The inner surface of the membrane is covered with mucous membrane and is innervated by the glossopharyngeal nerve.

CLINICAL NOTES

TYMPANIC MEMBRANE EXAMINATION

Otoscopic examination of the tympanic membrane is facilitated by first straightening the external auditory meatus by gently pulling the auricle upward and backward in the adult, and straight backward or backward and downward in the infant. Normally, the tympanic membrane is pearly gray and concave..

AUDITORY TUBE

The auditory tube extends from the anterior wall of the middle ear to the nasal pharynx (Fig. 6-33). The posterior one-third is bony; the anterior two-thirds are cartilaginous.

MASTOID ANTRUM

The mastoid antrum lies behind the middle ear in the petrous part of the temporal bone (Fig. 6-33). It communicates with the middle ear through the posterior wall.

MASTOID AIR CELLS

The mastoid air cells are a series of communicating cavities within the mastoid process (Fig. 6-33). The cells are continuous above with the antrum and the middle ear.

Facial Nerve

The facial nerve enters the internal acoustic meatus and then the facial canal (Fig. 6-33). It emerges through the stylomastoid foramen, and it enters the parotid salivary gland. The branches of this important nerve are described on page 229.

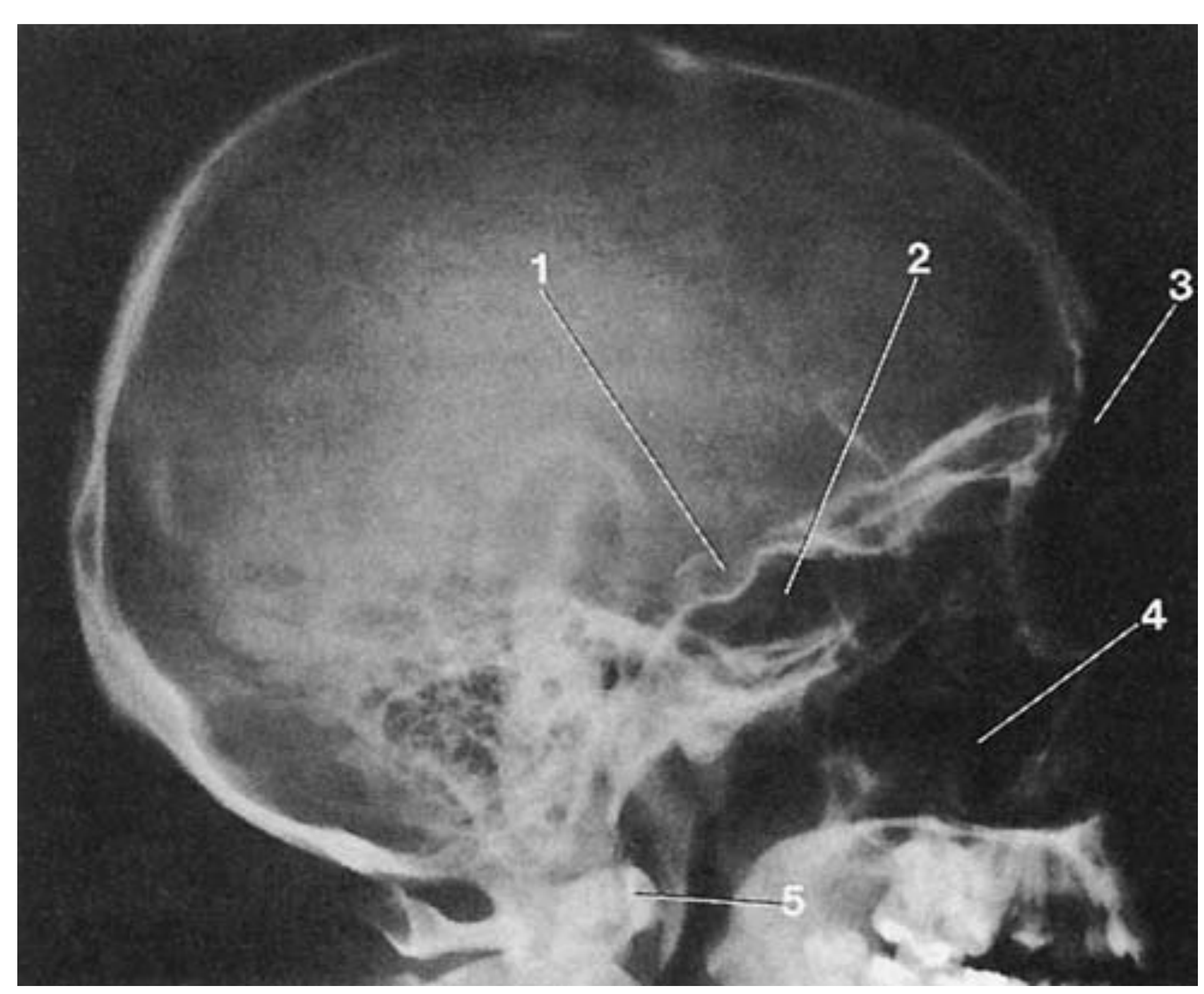
Tympanic Plexus

The tympanic plexus lies on the promontory of the medial wall of the middle ear. It is formed from the tympanic branch of the glossopharyngeal nerve, sympathetic nerves, and a communicating branch from the facial nerve. The plexus supplies the mucous membrane of the middle ear, and it gives origin to the lesser petrosal nerve, which passes to the otic ganglion (see p. 230).

REVIEW

Completion Questions

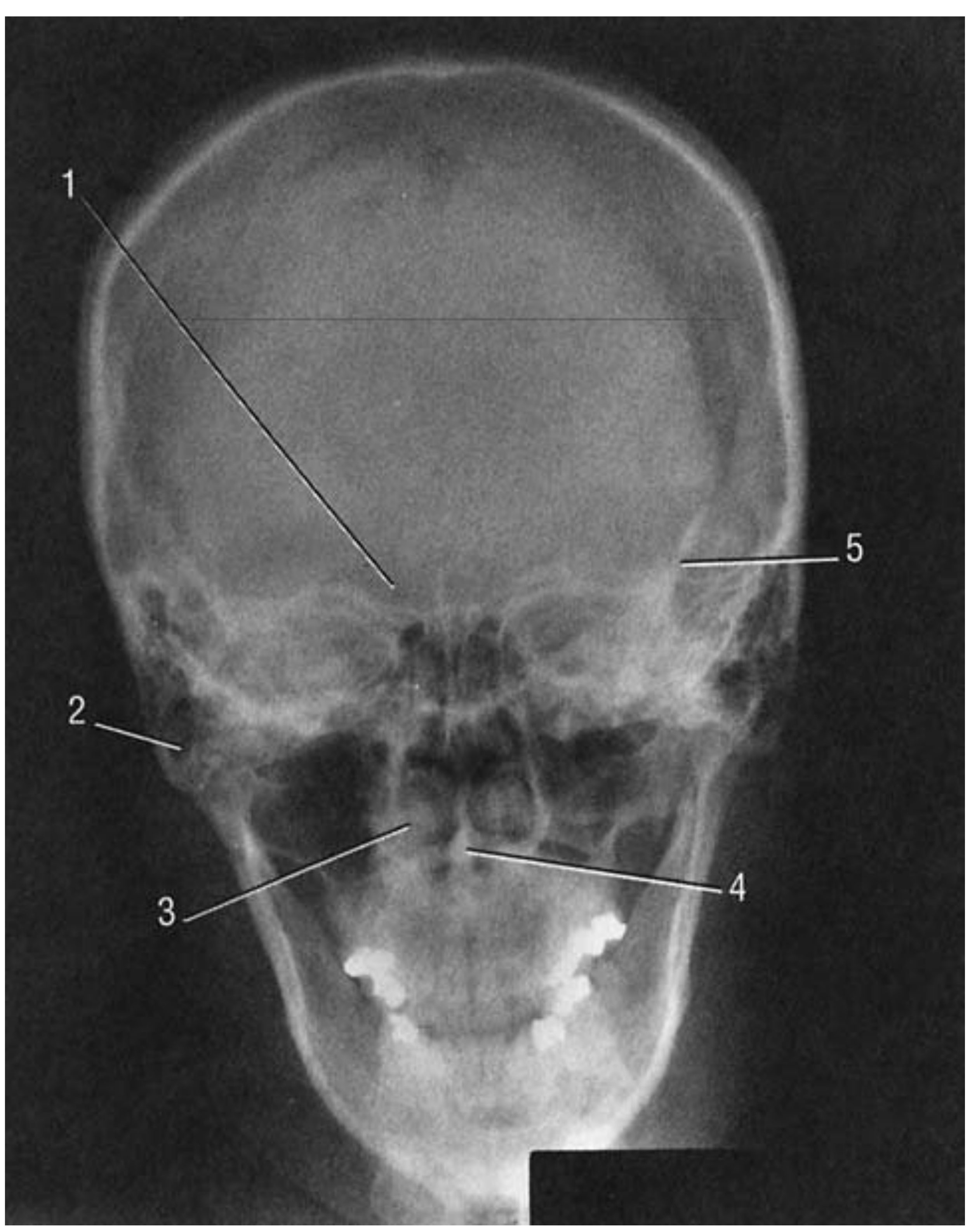
Based on the lateral radiograph of the skull, select the phrase that best completes each statement.



1. Structure 1 is the
   A. maxillary sinus.
   B. frontal sinus.
   C. anterior arch of the atlas.
   D. sella turcica.
   E. temporomandibular joint.
   F. none of the above.

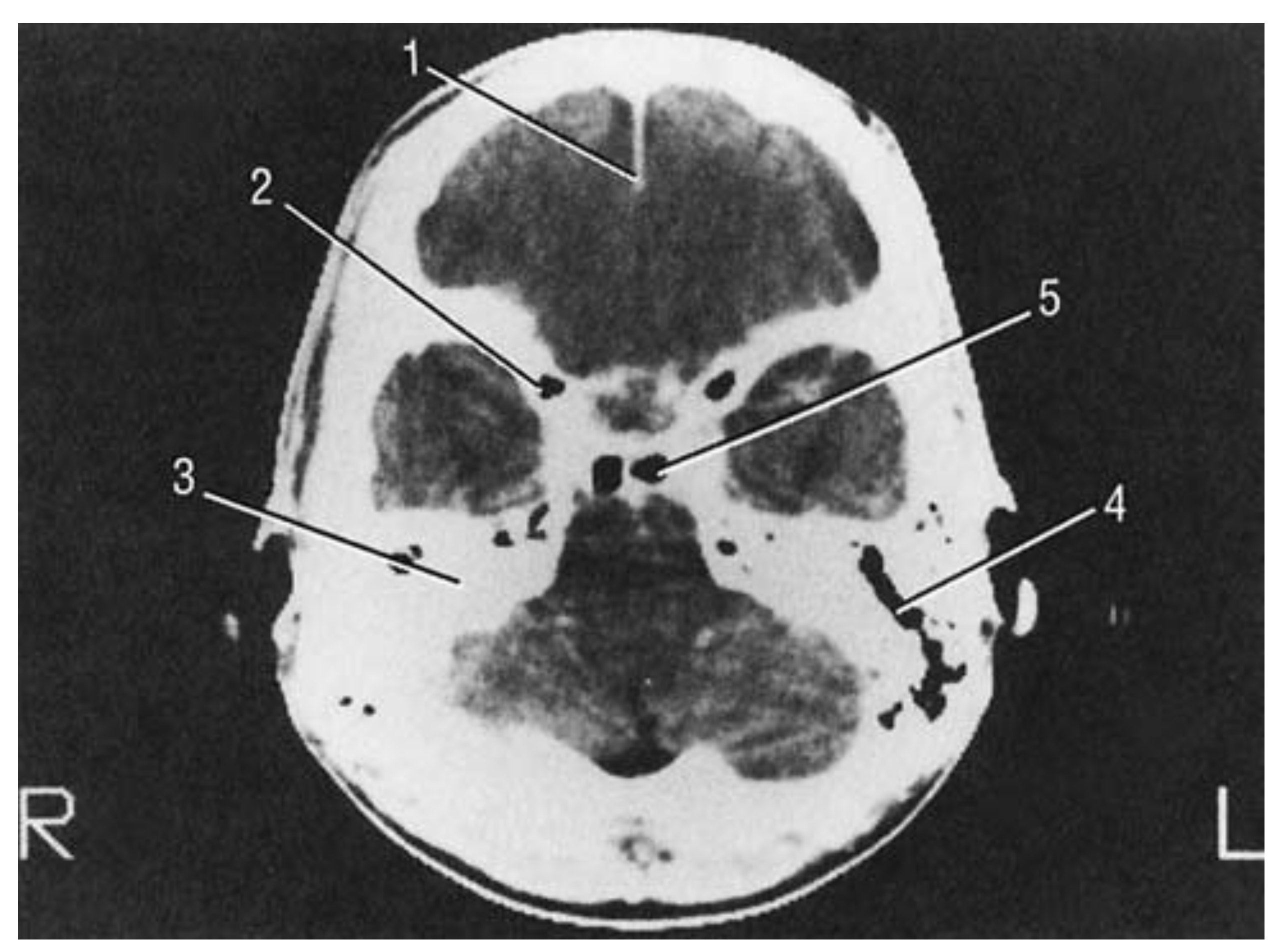
2. Structure 2 is the
   A. orbital cavity.
   B. maxillary sinus.
   C. sphenoid sinus.
   D. tympanic cavity.
   E. frontal sinus.
3. Structure 3 is the
   A. orbital cavity.
   B. nasal cavity.
   C. frontal sinus.
   D. maxillary sinus.
   E. sphenoid sinus.
4. Structure 4 is the
   A. mouth cavity.
   B. frontal sinus.
   C. nasal cavity.
   D. sphenoid sinus.
   E. maxillary sinus.
5. Structure 5 is the
   A. posterior arch of the atlas.
   B. body of the axis.
   C. anterior arch of the atlas.
   D. odontoid process of axis.
   E. anterior longitudinal ligament.

Based on the anteroposterior radiograph of the skull, select the phrase that best completes each statement.



6. Structure 1 is the
   A. nasal septum.
   B. mastoid air cells.
   C. greater wing of the sphenoid.
   D. frontal sinus.
   E. maxillary sinus.
7. Structure 2 is the
   A. greater wing of the sphenoid.
   B. temporomandibular joint.
   C. petrous part of the temporal bone.
   D. mastoid air cells.
   E. styloid process.
8. Structure 3 is the
   A. maxillary sinus.
   B. inferior concha.
   C. nasal septum.
   D. hard palate.
   E. root of molar tooth.
9. Structure 4 is the
   A. nasal septum.
   B. incisor tooth.
   C. crista galli.
   D. septum in sphenoid air sinus.
   E. odontoid process.
10. Structure 5 is the
   A. lesser wing of sphenoid.
   B. orbital plate of frontal bone.
   C. petrous part of the temporal bone.
   D. anterior inferior end of parietal bone.
   E. greater wing of the sphenoid.

Based on the axial (horizontal) CT scan of the skull, select the phrase that best completes each statement.



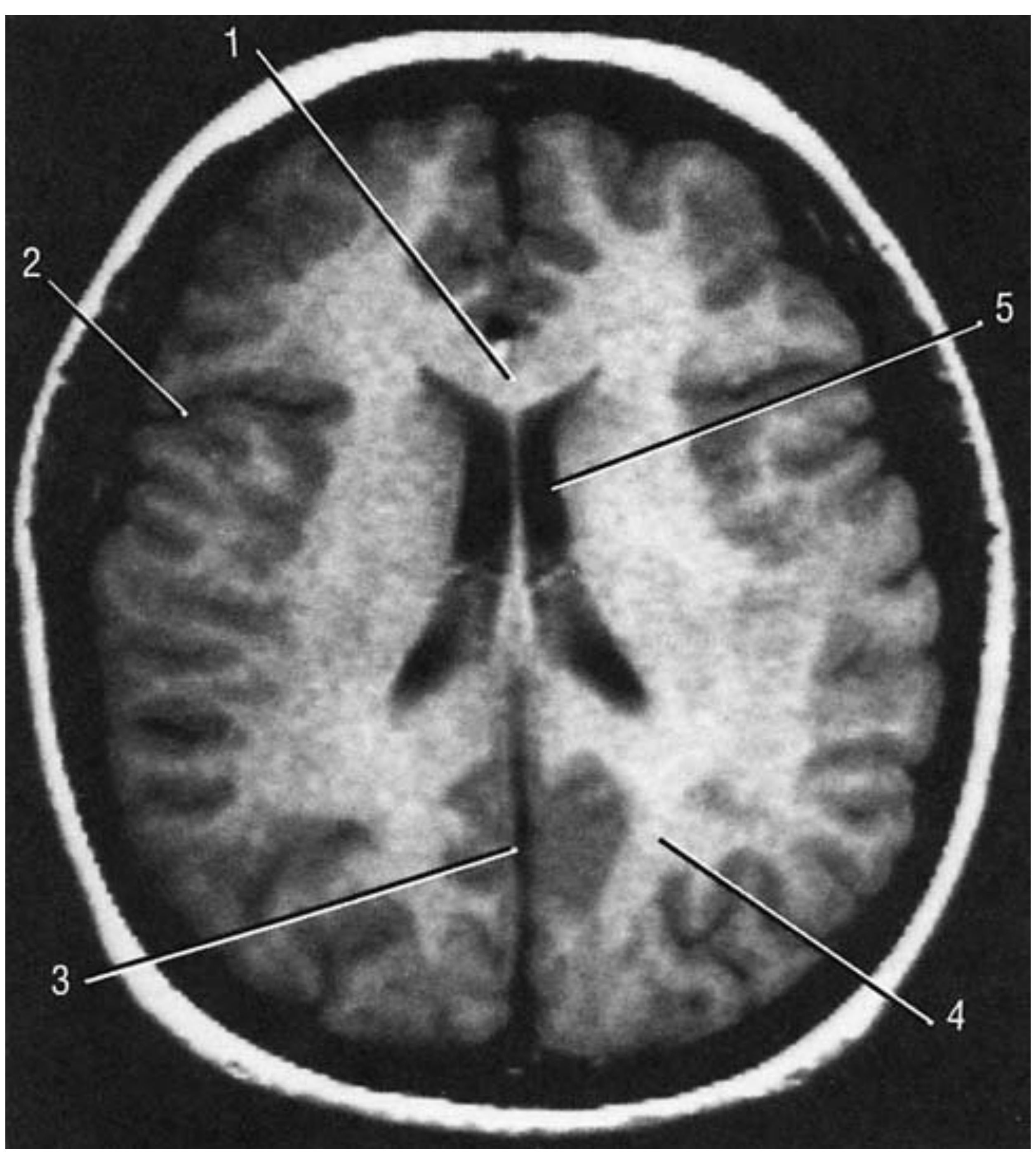
11. Structure 1 is the
   A. crista galli.
   B. nasal septum.
   C. superior sagittal sinus.
   D. falx cerebri.
   E. frontal bone.
12. Structure 2 is the
   A. internal carotid artery.
   B. middle cerebral artery.
   C. foramen rotundum.
   D. optic canal.
   E. sphenoid sinus.
13. Structure 3 is the
   A. greater wing of the sphenoid.
   B. petrous part of the temporal bone.

C. mastoid process.
D. malleus.
E. head of the mandible.

14. Structure 4 is the
A. mastoid antrum.
B. internal carotid artery.
C. tympanic cavity.
D. pharyngotympanic tube.
E. external auditory meatus.

15. Structure 5 is the
A. sella turcica.
B. sphenoid air sinus.
C. third ventricle.
D. pineal gland.
E. foramen magnum.

Based on the axial (horizontal) MRI study of the skull, select the phrase that best completes each statement.



16. Structure 1 is the
A. white matter of the occipital lobe.
B. falx cerebri.
C. septum pellucidum.
D. genu of the corpus callosum.
E. optic chiasma.

17. Structure 2 is the
A. posterior edge of the lesser wing of the sphenoid bone.
B. lateral sulcus.
C. middle cerebral artery.
D. middle meningeal artery.
E. anterior inferior end of the parietal bone.

18. Structure 3 is the
A. falx cerebri.
B. septum pellucidum.
C. basilar artery.
D. foramen magnum.
E. fourth ventricle.

19. Structure 4 is the
A. gray matter.
B. white matter of the occipital lobe.
C. genu of the corpus callosum.
D. tentorium cerebelli.
E. cerebellum.

20. Structure 5 is the
A. third ventricle.
B. fourth ventricle.
C. body of the lateral ventricle.
D. inferior horn of the lateral ventricle.
E. thalamus.

Select the phrase that best completes each statement.

21. The foramen ovale in the skull
A. allows entrance of the spinal part of the accessory nerve into the cranial cavity.
B. is located in the petrous part of the temporal bone.
C. allows entrance of the middle meningeal artery into the cranial cavity.
D. allows exit of the mandibular division of the trigeminal nerve.
E. allows exit of the glossopharyngeal nerve.

22. The foramen spinosum in the skull
A. allows exit of the facial nerve.
B. is located in the lesser wing of the sphenoid.
C. allows entrance of the middle meningeal artery into the cranial cavity.
D. allows exit of the maxillary division of the trigeminal nerve.
E. allows passage only of emissary veins.

23. The internal acoustic meatus in the skull
A. is located in the body of the sphenoid bone.
B. is located in the mastoid bone.
C. allows passage of the glossopharyngeal nerve.
D. allows passage of the facial nerve only.
E. allows passage of the vestibulocochlear nerve and the facial nerve.

24. The foramen magnum in the skull
A. allows entrance of the spinal part of the accessory nerve into the cranial cavity.
B. allows exit of the spinal part of the accessory nerve out of the cranial cavity.
C. is located in the sphenoid bone.
D. is located in the temporal bone.
E. allows entrance of the cranial part of the accessory nerve.

25. The jugular foramen in the skull
A. is located in the petrous part of the temporal bone.
B. allows exit of the hypoglossal nerve.
C. is located in the middle cranial fossa.
D. allows exit of the vagus nerve.
E. allows entrance of the external jugular vein.

26. The middle ethmoid sinuses drain into the
A. middle meatus of the nose.
B. superior meatus of the nose.

C. sphenoethmoidal recess.
D. inferior meatus of the nose.
E. nasolacrimal duct.

27. The sphenoid sinus drains into the
A. superior meatus of the nose.
B. inferior meatus of the nose.
C. sphenoethmoidal recess.
D. nasolacrimal duct.
E. middle meatus of the nose.

28. The frontal sinus drains into the
A. middle meatus of the nose.
B. lacrimal sac.
C. inferior meatus of the nose.
D. sphenoethmoidal recess.
E. superior meatus of the nose.

29. The anterior ethmoidal sinuses drain into the
A. lacrimal sac.
B. superior meatus of the nose.
C. middle meatus of the nose.
D. sphenoid sinus.
E. inferior meatus of the nose.

30. The nasolacrimal duct drains into the
A. lacrimal sac.
B. inferior meatus of the nose.
C. superior meatus of the nose.
D. middle meatus of the nose.
E. sphenoethmoidal recess.

Multiple-Choice Questions

Select the best answer for each question.

31. All the following statements concerning the palatine tonsil are correct except which?
A. It is related laterally to the superior constrictor muscle and the external palatine vein.
B. The main blood supply is from the facial artery.
C. The lymphatic drainage is into the submandibular lymph nodes.
D. It is covered on its medial surface by mucous membrane and on its lateral surface by a fibrous capsule.
E. The tonsil reaches its maximum size during early childhood.

32. The muscles or nerves that are responsible for adducting the eyeball (rotating the cornea medially) include the following except which?
A. The superior rectus muscle
B. The medial rectus muscle
C. The oculomotor nerve
D. The inferior oblique muscle
E. The inferior rectus muscle

33. The following statements regarding Horner's syndrome are correct except which?
A. Ptosis may be present because of loss of innervation to the smooth muscle portion of the levator palpebrae superioris.
B. Excessive sweating may occur on one side of the face.
C. It can be caused by injury to the superior cervical sympathetic ganglion.
D. Pupillary constriction may occur because of loss of innervation to the dilator pupillae muscle.
E. It can be caused by injury to the sympathetic chain (trunk) in the neck.

34. Infection of the middle ear can spread along all the following pathways except which?
A. Through the tegmen tympani to the middle cranial fossa
B. Through the medial wall into the labyrinth
C. Through the canal for the tensor tympani muscle into the internal carotid artery
D. Through the floor into the internal jugular vein
E. Through the aditus to the mastoid antrum into the mastoid air cells

35. Compression of the facial nerve in the facial canal in the posterior wall of the middle ear could result in all the following except which?
A. A cessation of lacrimal secretion
B. Paralysis of the posterior belly of the digastric muscle
C. Inability to whistle
D. Decreased saliva in the mouth
E. Loss of taste sensation to the anterior two-thirds of the tongue

36. The following statements concerning the structures in the neck are correct except which?
A. The parotid salivary gland contains within its substance the facial nerve and the external carotid artery.
B. The parotid duct opens into the mouth opposite the upper second molar tooth.
C. As the trachea descends through the neck it rests posteriorly on the vertebral column.
D. The nerve to the mylohyoid muscle innervates the anterior belly of the digastric muscle.
E. The hypoglossal nerve innervates the muscles of the tongue.

37. The following general statements concerning structures in the head and neck are correct except which?
A. The sensory nerve supply to the mucous membrane lining the upper part of the trachea is from the recurrent laryngeal nerve.
B. The spinal part of the accessory nerve can be injured easily as it crosses the posterior triangle of the neck.
C. The afferent sensory nerve fibers for the gag reflex are contained in the glossopharyngeal nerve.
D. The afferent sensory nerve fibers for the cough reflex are contained in the vagus nerve.
E. The sternocleidomastoid and the trapezius muscles receive their innervation from the cranial part of the accessory nerve.

38. The following statements concerning the middle cranial fossa are correct except which?
A. The pituitary gland (hypophysis cerebri) is related anterosuperiorly to the optic chiasma.
B. The pituitary gland receives its blood supply from the middle meningeal arteries.

C. The oculomotor nerve passes forward in the lateral wall of the cavernous sinus.
D. The internal carotid artery passes forward through the cavernosa sinus.
E. The abducent nerve passes forward through the cavernous sinus.

39. The following general statements concerning the tympanic membrane are correct except which?
A. It is pearly gray in color.
B. It is concave laterally.
C. It is crossed by the chorda tympani over the medial surface of the inferior part of the membrane.
D. It is best visualized in the adult by pulling the auricle upward and backward.
E. The inner surface is covered with mucous membrane.

40. Impaired function of which of the following muscles produce difficulty in protruding the jaw?
A. The anterior belly of the digastric muscle
B. The lateral pterygoid
C. The medial pterygoid
D. The masseter
E. The temporalis

41. Which process is responsible for closing off the nasal cavity from the oropharynx during swallowing?
A. Elevation of the tongue to the roof of the mouth
B. Contraction of the aryepiglottic muscles
C. Bending of the epiglottis
D. Relaxation of the pharyngeal constrictor muscles
E. Contraction of the tensor and the levator veli palatini muscles

42. Sustained tension of the vocal cords (folds) is best achieved through the action of which of the following muscles?
A. The cricopharyngeus
B. The cricothyroid
C. The aryepiglottic
D. The salpingopharyngeus
E. The posterior cricoarytenoid

43. Which of the following muscles is responsible for protruding the tongue?
A. The styloglossus
B. The hyoglossus
C. The genioglossus
D. The palatoglossus
E. The mylohyoid

44. Which of the following nerves might be injured when tying the inferior thyroid artery during operations on the thyroid gland?
A. The sympathetic trunk
B. The internal laryngeal nerve
C. The descendens cervicalis
D. The recurrent laryngeal nerve
E. The superior laryngeal nerve

45. A patient has lost cutaneous sensation over the tip of the nose. Which nerve is most likely to be damaged?
A. The facial nerve
B. The ophthalmic division of the trigeminal nerve
C. The greater auricular nerve
D. The mandibular division of the trigeminal nerve
E. The maxillary division of the trigeminal nerve

46. A patient has a boil on the tip of her nose. To which lymph nodes does the lymph from the skin of the infected area drain?
A. Submandibular nodes
B. Submental nodes
C. Parotid nodes
D. Superficial cervical nodes
E. Tracheobronchial nodes

47. A patient having lunch accidentally bit the inside of her left cheek. To which lymph nodes are infecting bacteria likely to spread?
A. Mastoid nodes
B. Parotid nodes
C. Submental nodes
D. Superficial cervical nodes
E. Submandibular nodes

48. A 64-year-old man was seen by his physician for a hard-based ulcer on the right lateral edge of the anterior two thirds of the tongue. Which group of nodes should be examined by the physician for possible evidence of metastases?
A. Superficial cervical nodes
B. Submental nodes
C. Submandibular nodes
D. Parotid nodes
E. Buccal nodes

49. A 24-year-old woman was seen by her ophthalmologist because of a red infected skin abrasion involving the lateral ends of both right eyelids. Which lymph nodes should be examined for evidence of spread of infection from the skin abrasion?
A. Mastoid nodes
B. Superficial cervical nodes
C. Submandibular nodes
D. Parotid nodes
E. Submental nodes

Read the case histories and select the best answer to the questions following them.

A 45-year-old man was riding his bicycle when he swerved to avoid a pothole and lost his balance. He then crashed and hit his head against a rock. When he regained consciousness in the emergency department of a neighboring hospital, it was immediately noted that he had medial strabismus (squint) of his right eye. At questioning, the cyclist admitted that he had not been wearing a crash helmet.

50. Which eye muscle was paralyzed in this injury?
A. The medial rectus muscle
B. The inferior rectus muscle
C. The superior rectus muscle
D. The lateral rectus muscle
E. The superior oblique muscle

51. Which nerve was damaged by the crash?
    A. The facial nerve
    B. The oculomotor nerve
    C. The abducent nerve
    D. The trochlear nerve
    E. The ophthalmic division of the trigeminal nerve
52. Which anatomic structure is most likely to have damaged the nerve?
    A. The petrous part of the temporal bone
    B. The greater wing of the sphenoid bone
    C. The lesser wing of the sphenoid bone
    D. The tentorium cerebelli
    E. The falx cerebelli

A 59-year-old woman with a small swelling below the chin was seen by her physician. At physical examination, a single, hard swelling could be palpated in the submental triangle. It was mobile on the deep tissues and not tethered to the skin. A diagnosis of a malignant secondary deposit in a submental lymph node was considered.

53. Using your knowledge of anatomy, where would you look for the primary carcinoma?
    A. The posterior third of the tongue
    B. The maxillary sinus
    C. The angle of the mouth
    D. The center of the lower lip
    E. The lining of the cheek
54. To where do the submental lymph nodes drain?
    A. The superficial cervical lymph nodes
    B. The deep cervical lymph nodes
    C. The submandibular lymph nodes
    D. The tracheobronchial lymph nodes
    E. The anterior cervical lymph nodes

ANSWERS AND EXPLANATIONS

1. D	6. D	11. D	16. D	21. D
2. C	7. D	12. D	17. B	22. C
3. C	8. B	13. B	18. A	23. E
4. E	9. A	14. C	19. B	24. A
5. C	10. E	15. B	20. C	25. D

26. A. On the bulla ethmoidalis.
27. C
28. A. Via the infundibulum.
29. C. Via the infundibulum.
30. B. Guarded by a valve.
31. C. The lymphatic drainage of the tonsil is into the jugulodigastric node, a member of the deep cervical group of lymph nodes.
32. D. The oblique muscles turn the eyeball laterally. (In addition, the superior oblique muscle turns the eye downward, and the inferior oblique muscle turns the eye upward.) The superior rectus muscle turns the eye medially as well as upward, and the inferior rectus turns the eye medially as well as downward (because these muscles take origin from the back of the orbit medial to the vertical axis of the eyeball). The oculomotor nerve supplies the medial, superior, and inferior recti and the inferior oblique muscles.
33. B. In Horner's syndrome, sweating is reduced because of the loss of sympathetic innervation to the sweat glands of the facial skin.
34. C. The canal for the tensor tympani muscle is closed at its deep end and is filled by the origin of the tensor tympani muscle.
35. A. Lacrimal secretion is controlled by the lacrimal nucleus of the facial nerve. The fibers leave the facial nerve as the greater petrosal nerve on the medial wall of the middle ear before the facial nerve reaches the posterior wall of the middle ear.
36. C. The esophagus, the prevertebral layer of the deep cervical fascia, and the prevertebral muscles separate the trachea from the vertebral column.
37. E. The sternocleidomastoid and the trapezius muscles receive their motor nerve supply from the spinal part of the accessory nerve and their sensory innervation from C2 and 3, and C3 and 4, respectively.
38. B. The blood supply of the pituitary gland is from the superior and inferior hypophyseal branches of the internal carotid artery.
39. C. The chorda tympani crosses the medial surface of the superior part of the tympanic membrane. The sensory innervation of the membrane is from the tympanic branch of the glossopharyngeal nerve, the auriculotemporal branch of the mandibular division of the trigeminal nerve, and the auricular branch of the vagus.
40. B. The anterior belly of the digastric muscle depresses the jaw. The medial pterygoid muscle elevates the jaw, the masseter muscle elevates the jaw, and the temporalis muscle (anterior fibers) elevates the jaw. The posterior fibers retract the jaw.
41. E. The tensor and levator veli palatini muscles raise the soft palate, which closes off the nasal from the oral part of the pharynx. The tensor veli palatini stretches the soft palate (like a sheet), thus allowing it to be elevated.
42. B. The cricothyroid muscle, which tilts the cricoid cartilage and the arytenoid cartilages backward and thus tenses the vocal cords.
43. C. Both genioglossus muscles pull the tongue forward. Remember that if only one of the muscles functions, the tip of the tongue points to the side of the resting or paralyzed muscle.
44. D. Note that the superior thyroid artery is closely related to the external laryngeal nerve.
45. B. The skin of the tip of the nose is innervated by external nasal branch of the nasociliary branch of the ophthalmic division of the trigeminal nerve.
46. A. Note that for the patients described in questions 46 to 49, the deep cervical nodes are also palpated to ascertain if the disease has spread beyond the local lymph nodes.

47. E
48. C
49. D
50. D
51. C
52. A. The long, slender abducent nerve (the sixth cranial nerve) is commonly damaged in severe head injuries. Sudden movement of the head may result in injury to the nerve as it leaves the posterior cranial fossa by passing over the superior border of the petrous part of the temporal bone to enter the cavernous sinus.
53. D. The lymph from the posterior third of the tongue drains into the deep cervical nodes. The lymph from the lining of the cheek, the angle of the mouth, and maxillary sinus drains into the submandibular nodes.
54. B

CHAPTER 7

Back

The back extends from the skull to the tip of the coccyx. Superimposed on the upper part are the scapulae and the muscles connecting the scapulae to the trunk.

It is suggested that the back be reviewed with the help of an articulated skeleton and in the following order:

1. A review of the vertebral column, and a brief study of the regional differences between the vertebrae.
2. A brief overview of the joints of the vertebral column, including the atlanto-occipital and atlantoaxial joints.
3. A review of the structure and the function of the intervertebral disc.
4. A brief review of the muscles of the back (detailed attachments of the muscles are not required).
5. A brief review of the arteries, the veins, and the lymphatic drainage of the back.
6. A review of the nerves of the back.
7. An overview of the gross anatomy of the spinal cord and its meninges, including the anatomy of the lumbar puncture.

VERTEBRAL COLUMN

The vertebral column is the central pillar of the body (Fig. 7-1). The head is balanced on the upper end of the pillar and the ribs, and the thoracic and the abdominal viscera are suspended from the front. The vertebral column protects the spinal cord and also supports the weight of the head and the trunk, which it transmits to the hip bones and the lower limbs. The vertebral column is flexible because it is segmented and made of **vertebrae**, their joints, and pads of fibrocartilage called **intervertebral discs.** The intervertebral discs alone form one-fourth of the length of the column.

The vertebrae are grouped as follows:

- Cervical (7).
- Thoracic (12).
- Lumbar (5).
- Sacral (5 fused to form the sacrum).
- Coccygeal (4; the lower 3 are commonly fused).

Intervertebral Foramina

Intervertebral foramina are present between the vertebrae. They allow the spinal nerves, which leave the spinal cord, to be distributed to the different parts of the body.

Curves of the Vertebral Column

As seen from the side, there are four curves of the vertebral column (Fig. 7-2):

- **Cervical region:** The posterior concavity.
- **Thoracic region:** The posterior convexity.
- **Lumbar region:** The posterior concavity.
- **Sacral region:** The posterior convexity.

Pregnant women, because of the weight of the fetus, have an increased posterior lumbar concavity (**lordosis**). **Old age,** because of the accompanying atrophy of the intervertebral discs, tends to produce a continuous posterior convexity of the vertebral column, so these individuals have a bent-forward appearance (**kyphosis**).

General Characteristics of a Vertebra

A typical vertebra has a rounded body anteriorly and a **vertebral arch** posteriorly (Fig. 7-2). The **vertebral foramen** is the space enclosed by the body and the arch. The vertebral arch consists of a pair of **cylindrical pedicles,** which form the sides of the arch, and a pair of flattened **laminae,** which complete the arch posteriorly. The vertebral arch gives rise to seven processes: one spinous, two transverse, and four articular (Fig. 7-2).

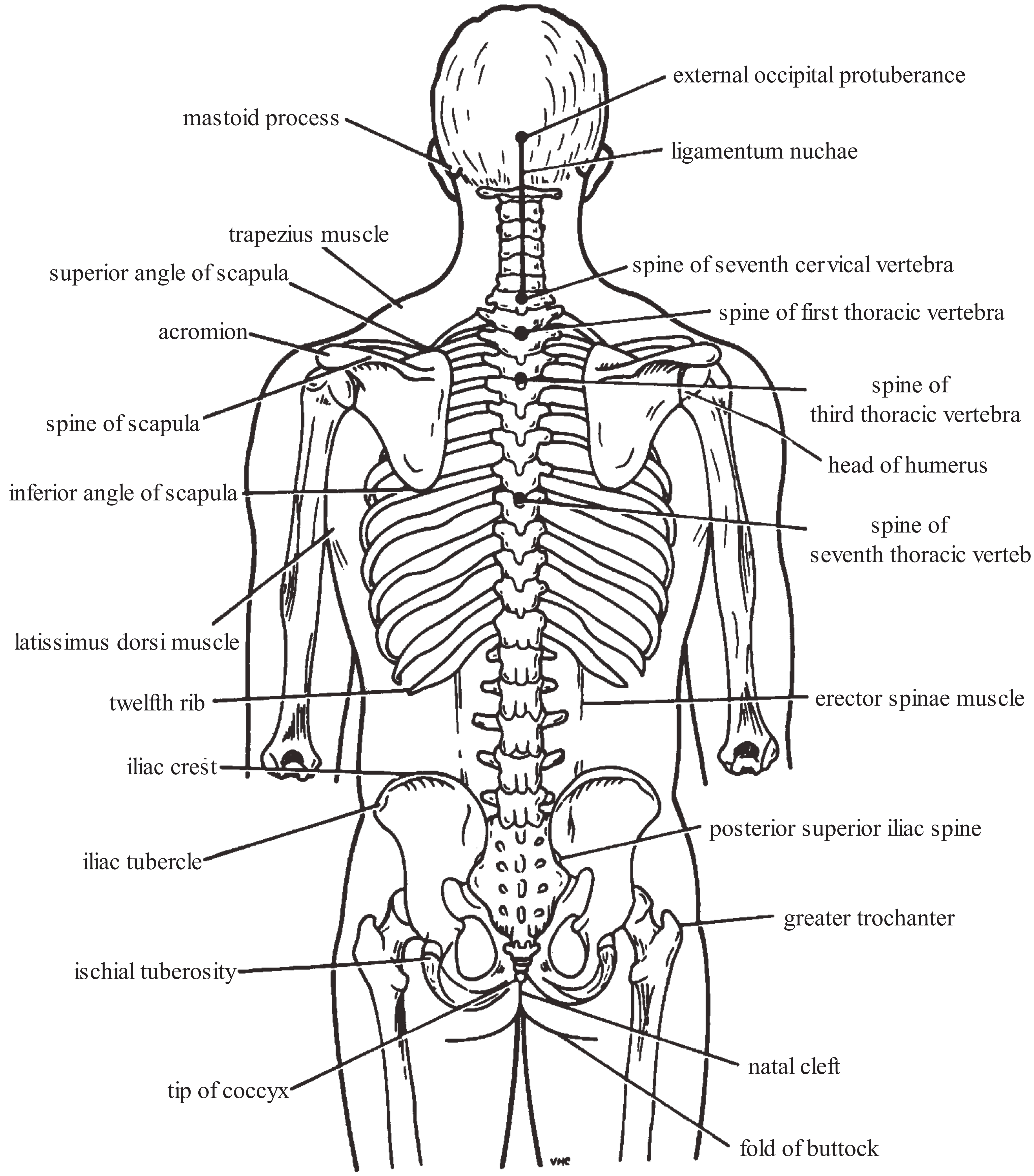


Figure 7-1 Posterior view of the skeleton that shows surface markings on the back.

Spinous Process (Spine)

The spinous process is directed posteriorly from the junction of the two laminae. **Transverse processes** are directed laterally from the junction of the laminae and the pedicles. Both processes serve as levers, and both receive attachments of muscles and ligaments.

Articular Processes

Articular processes are arranged vertically and consist of two superior and two inferior processes. They arise from the junction of the laminae and the pedicles. The two superior articular processes of one vertebra articulate with the two inferior articular processes of the vertebra above it.

The pedicles are notched on their upper and their lower borders, thus forming the **superior** and the **inferior vertebral notches.** The superior notch of one vertebra and the inferior notch of an adjacent vertebra together form an **intervertebral foramen** (Fig. 7-3). These foramina transmit the spinal nerves and blood vessels.

Cervical Vertebra

A typical cervical vertebra has the following characteristics (Fig. 7-2):

- **Foramen transversarium** in the transverse process, which allows passage of the vertebral artery and veins.
- **Spines,** which are small and bifid.
- **Body,** which is small and broad and has two small synovial joints on each side.

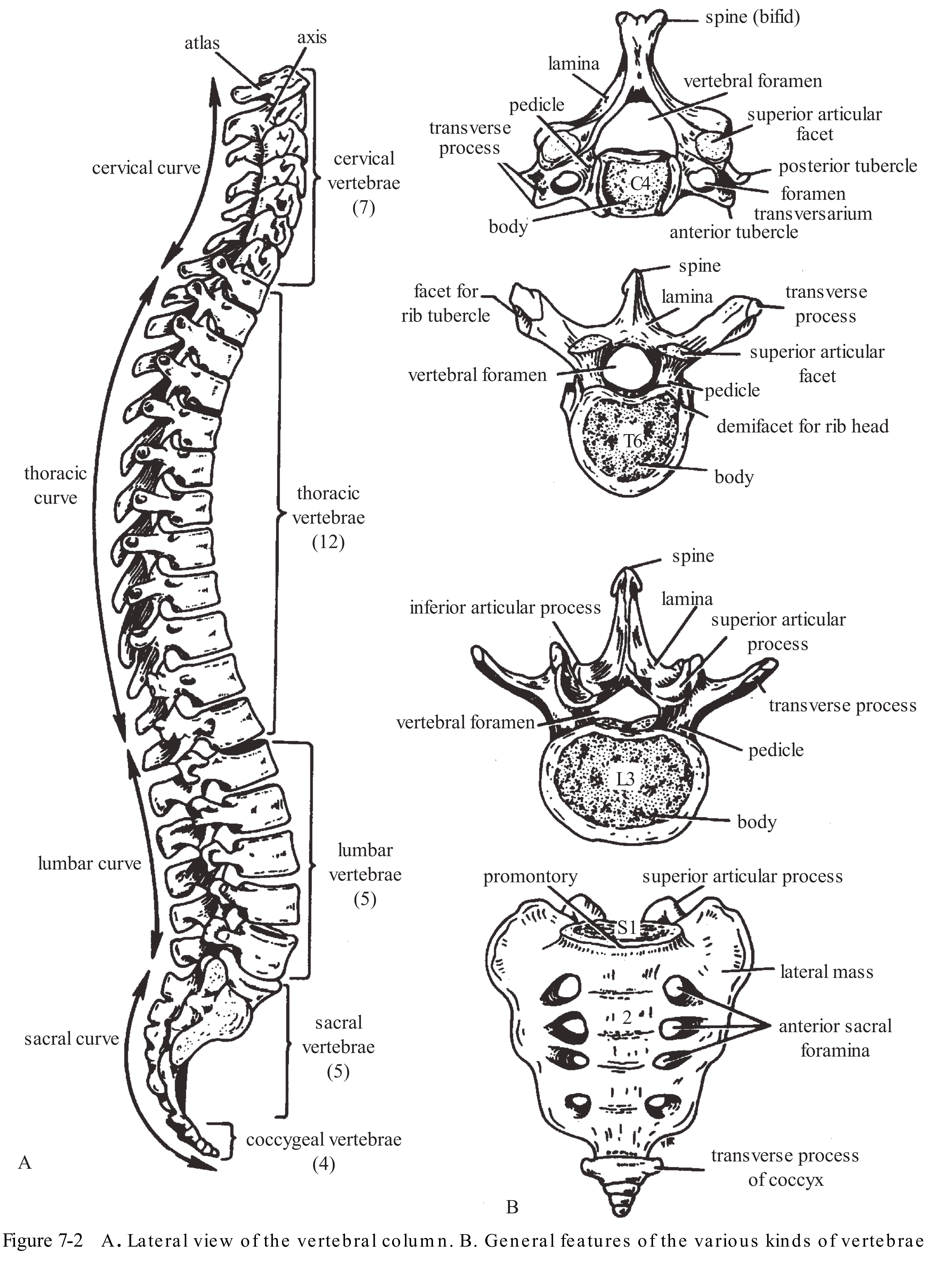


Figure 7-2 A. Lateral view of the vertebral column. B. General features of the various kinds of vertebrae.

- **Vertebral foramen,** which is large and triangular in shape.
- **Superior articular processes,** which have small, flat articular facets that face backward and upward.
- **Inferior articular processes,** which have facets that face downward and forward.

Atypical Cervical Vertebrae

The **first cervical vertebra (atlas)** has no body and no spinous process, but it has an **anterior arch,** a **posterior arch,** and a **lateral mass** on each side. Each lateral mass has **articular surfaces** on its upper and its lower aspects.

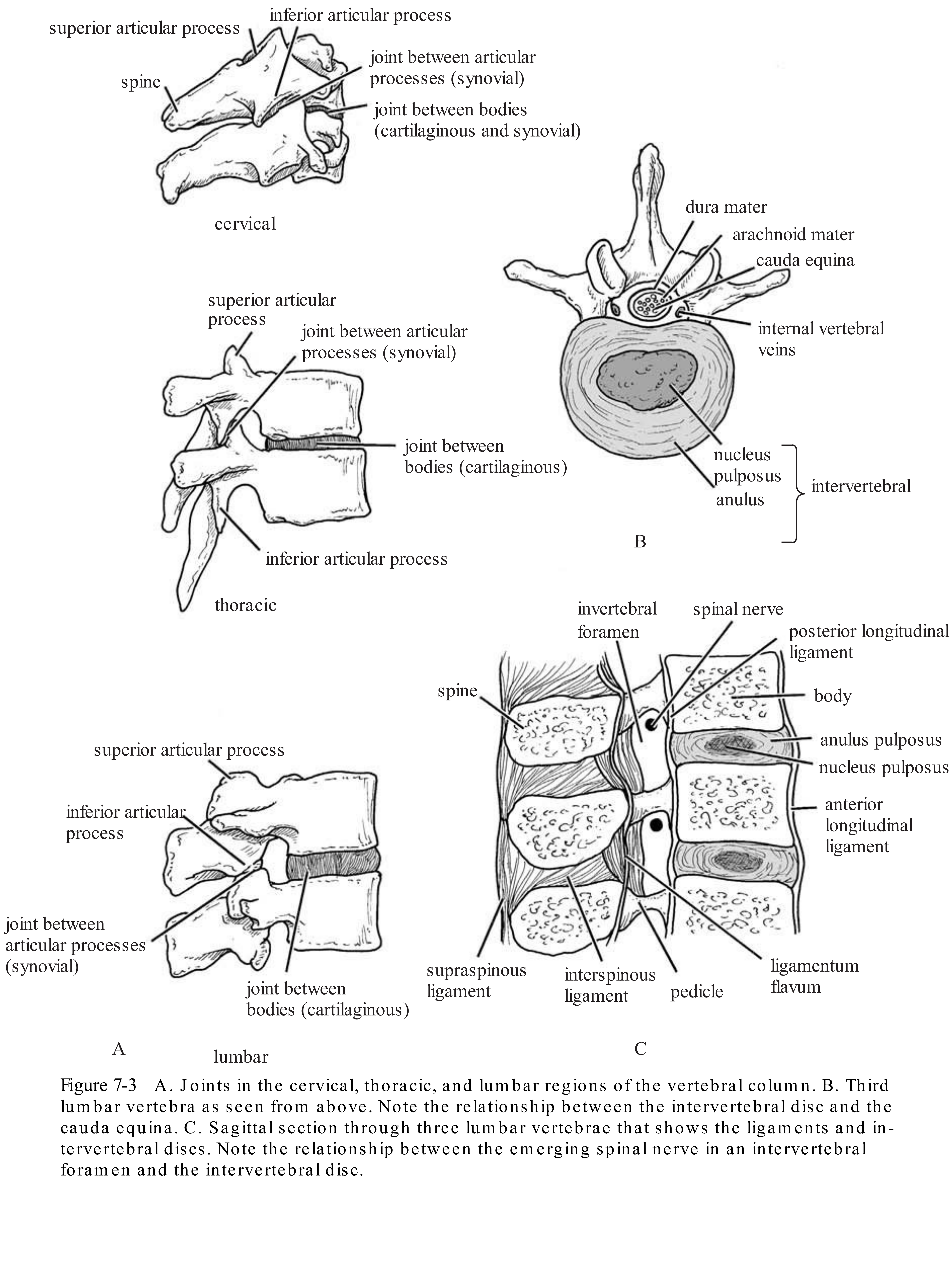


Figure 7-3 A. Joints in the cervical, thoracic, and lumbar regions of the vertebral column. B. Third lumbar vertebra as seen from above. Note the relationship between the intervertebral disc and the cauda equina. C. Sagittal section through three lumbar vertebrae that shows the ligaments and intervertebral discs. Note the relationship between the emerging spinal nerve in an intervertebral foramen and the intervertebral disc.

The atlas articulates above with the occipital condyles of the skull and below with the axis.

The **second cervical vertebra (axis)** has a peglike **odontoid process,** which projects upward from the superior surface of the body and represents the body of the atlas that has fused with the axis.

The **seventh cervical vertebra** has the longest spinous process, but this spinous process is not bifid. The **transverse process** is large, but the foramen transversarium is small and does **not transmit** the vertebral artery.

Thoracic Vertebra

A typical thoracic vertebra has the following characteristics (Fig. 7-2):

- **Body,** which is medium in size and heart-shaped.
- **Vertebral foramen,** which is small and circular.
- **Spines,** which are long and inclined downward.
- **Costal facets,** which are present on the sides of the bodies and on the transverse processes. (T11 and 12 have no facets on the transverse processes.)
- **Superior articular processes,** which have facets that face backward and laterally, whereas the facets on the inferior articular processes face forward and medially.

Lumbar Vertebrae

A typical lumbar vertebra has the following characteristics (Fig. 7-2):

- **Body,** which is massive and kidney-shaped.
- **Pedicles,** which are strong.
- **Laminae,** which are thick.
- **Vertebral foramina,** which are triangular in shape.
- **Transverse processes,** which are long and slender. They do not have rib facets or foramina.
- **Spinous processes,** which are short, flat, and quadrangular in shape and project directly backward.
- **Superior articular processes,** which have facets that face medially, whereas the facets for the inferior articular processes face laterally.

Sacral Vertebrae

Sacral vertebrae consist of five rudimentary vertebrae that are fused together to form a single wedge-shaped bone called the **sacrum**. The sacrum has the following characteristics (Fig. 7-2):

- **Sacral promontory,** which is the anterior and the upper margin of the first sacral vertebra that bulges forward into the pelvic cavity; **it is an important obstetric landmark.**
- **Sacral canal,** which is formed from the sacral foramina. It contains part of the **cauda equina,** the **filum** terminale, and the **meninges** down as far as the lower border of the second sacral vertebra. The lower part of the canal contains the lower sacral and the coccygeal nerve roots as well as the filum terminale.
- **Sacral hiatus,** which is formed by the failure of the laminae of the fifth and, sometimes, the fourth sacral vertebra to meet in the midline.
- **Anterior** and **posterior sacral foramina** on the anterior and posterior surfaces of the sacrum, which allow passage of the anterior and the posterior rami of the upper four sacral spinal nerves.

The upper border (or base) of the sacrum articulates with the fifth lumbar vertebra (Fig. 7-2), and the narrow inferior end articulates with the coccyx. Laterally, the sacrum articulates with the two hip bones to form the sacroiliac joints (Fig. 7-1).

Coccygeal Vertebrae

There are four coccygeal vertebrae that are fused together to form a single, small, triangular bone called the **coccyx** (Fig. 7-2). The first coccygeal vertebra commonly is not fused with the second vertebra.

CLINICAL NOTES

DISEASE AND THE INTERVERTEBRAL FORAMINA

The intervertebral foramina transmit the spinal nerves and small blood vessels. Each foramen is bounded above and below by the pedicles of adjacent vertebrae, in front by part of the vertebral body and the intervertebral disc, and behind by the articular processes and the joint between them. Here, the spinal nerve is vulnerable and may be pressed on by surrounding structures. Herniation of the intervertebral disc, fractures of the vertebral bodies, and osteoarthritis of neighboring joints can result in pressure on the spinal nerves, giving rise to pain and muscle weakness.

JOINTS OF THE VERTEBRAL COLUMN

Atlanto-Occipital Joints

Atlanto-occipital joints are synovial joints that are formed between the occipital condyles, which are found on either side of the foramen magnum of the skull, and the facets on the superior surfaces of the lateral masses of the atlas below (Fig. 7-4). They are enclosed by a capsule.

LIGAMENTS

Anterior Atlanto-Occipital Membrane

The anterior atlanto-occipital membrane connects the anterior arch of the atlas to the anterior margin of the foramen magnum (Fig. 7-4).

Posterior Atlanto-Occipital Membrane

The posterior atlanto-occipital membrane connects the posterior arch of the atlas to the posterior margin of the foramen magnum (Fig. 7-4).

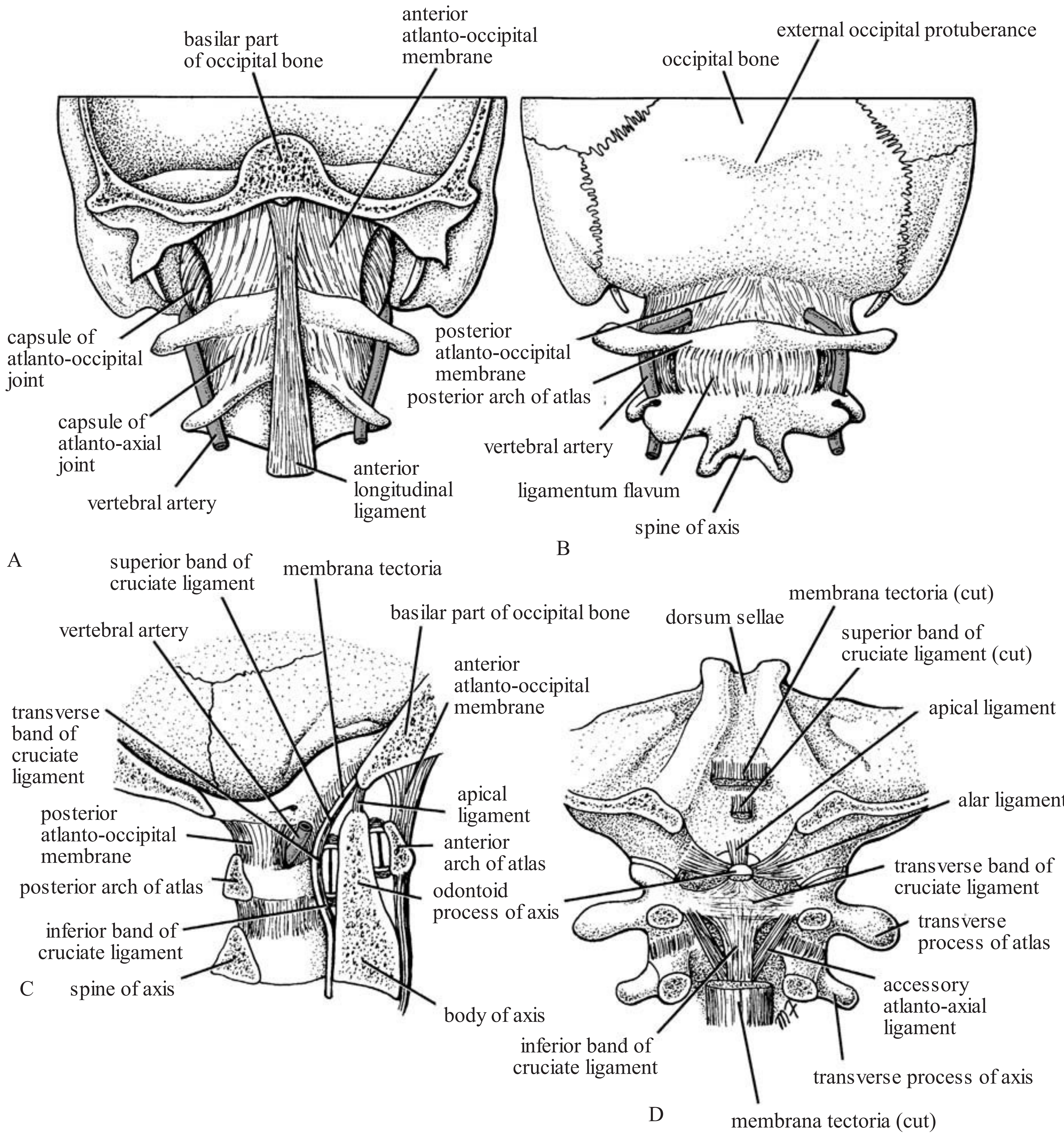


Figure 7-4 A. Anterior view of the atlanto-occipital joints. B. Posterior view of the atlanto-occipital joints. C. Sagittal section of the atlantoaxial joints. D. Posterior view of the atlantoaxial joints. Note that the posterior arch of the atlas and the laminae and spine of the axis have been removed.

MOVEMENTS

Flexion, extension, and lateral flexion are possible. No rotation is possible.

Atlantoaxial Joints

Atlantoaxial joints are synovial joints. One is between the odontoid process and the anterior arch of the atlas; the other two are between the lateral masses of the bones (Fig. 7-4). The joints are enclosed by capsules.

LIGAMENTS

- Apical ligament: Connects the apex of the odontoid process to the anterior margin of the foramen magnum (Fig. 7-4).
- Alar ligaments: Lie on each side of the apical ligament and connect the odontoid process to the medial sides of the occipital condyles (Fig. 7-4).
- Cruciate ligament: Consists of the transverse and the vertical parts (Fig. 7-4). The **transverse part** is attached on each side to the lateral mass of the atlas and binds the

odontoid process to the anterior arch of the atlas. The **vertical part** connects the body of the axis to the anterior margin of the foramen magnum.
- Membrana tectoria: An upward continuation of the posterior longitudinal ligament that is attached above to the occipital bone (Fig. 7-4).

MOVEMENTS

Rotation of the atlas with the head on the axis is possible.

Joints of the Vertebral Column below the Axis

- **Cartilaginous joints:** Between the vertebral bodies.
- **Synovial joints:** Between the articular processes.

Joints between Two Vertebral Bodies

The bodies of adjacent vertebrae are covered by a thin plate of hyaline cartilage, and sandwiched between these plates of cartilage is an intervertebral disc of fibrocartilage (Fig. 7-3). This disc strongly unites the bodies of the two vertebrae.

LIGAMENTS

The **anterior** and **posterior longitudinal ligaments** run as continuous bands down the anterior and the posterior surfaces of the vertebral column from the skull to the sacrum (Fig. 7-3).

Intervertebral Discs

The intervertebral discs have the following important characteristics:

- They are **responsible** for one fourth of the length of the vertebral column. They are thicker in the cervical and the lumbar regions.
- The **anulus fibrosus** forms the periphery of the disc (Fig. 7-3). It is composed of fibrocartilage, in which the collagen fibers are arranged in concentric layers or sheets. The fibers pass obliquely between adjacent vertebral bodies, and their inclination is reversed in alternate sheets. The anulus is strongly attached to the anterior and the posterior longitudinal ligaments.
- The **nucleus pulposus** forms the central part of the disc (Fig. 7-3). It is an ovoid mass of gelatinous material and is normally under pressure. With advancing age, the water content of the nucleus diminishes and is replaced by fibrocartilage.
- **No discs** are present between the first two cervical vertebrae or in the sacrum or the coccyx.

CLINICAL NOTES

HERNIATION OF THE NUCLEUS PULPOSUS

Herniation of the nucleus pulposus may result from a sudden increase in the compression load on the vertebral column. The anulus fibrosus ruptures, and the nucleus herniates posteriorly into the vertebral canal, where it may press on the spinal nerve roots, a spinal nerve, or even the spinal cord. Herniation frequently occurs in the lower lumbar (most common) and the lower cervical regions.

Joints between Two Vertebral Arches

The joints between two vertebral arches are the synovial joints between the superior and the inferior articular processes of adjacent vertebrae (Fig. 7-3). These joints are surrounded by a capsule.

LIGAMENTS

- **Supraspinous ligament:** Connects adjacent spines.
- **Interspinous ligament:** Connects adjacent spines.
- **Ligamentum flavum:** Connects adjacent laminae.

In the cervical region, the supraspinous and the interspinous ligaments are greatly thickened to form the **ligamentum nuchae.**

NERVE SUPPLY

Branches of the corresponding spinal nerves supply the joints.

MOVEMENTS OF THE VERTEBRAL COLUMN

The type and range of movements possible in each region of the column depend on the thickness of the intervertebral discs and the shape and direction of the articular processes.

- **Flexion:** A forward movement.
- **Extension:** A backward movement.

Both flexion and extension are extensive in the cervical and the lumbar regions, but they are restricted in the thoracic region by the presence of the ribs.

- **Lateral flexion:** The bending of the body to one or the other side. It is extensive in the cervical and the lumbar regions, but it is restricted in the thoracic region by the presence of the ribs.
- **Rotation:** A twisting of the vertebral column. It is least extensive in the lumbar region.
- **Circumduction:** A combination of all the previously described movements.

CLINICAL NOTES

DISLOCATIONS OF THE VERTEBRAL COLUMN

Dislocations without fracture occur only in the cervical region, because the inclination of the articular processes of the cervical vertebrae permits dislocation to take place without fracture of the processes. In the thoracic and lumbar regions, dislocations can occur only if the vertically placed articular processes are fractured. Bilateral cervical dislocations are almost always associated with severe injury to the spinal cord.

FRACTURES OF THE VERTEBRAL COLUMN

Fractures of the **spinous processes, transverse processes,** or **laminae** are caused by direct injury or, in rare cases, by severe muscular activity.

Anterior and **lateral compression fractures** of the **vertebral bodies** are usually caused by an excessive flexion–compression injury.

Fracture dislocations are usually caused by a combination of flexion and rotation injuries; the upper vertebra is excessively flexed and twisted on the lower vertebra.

MUSCLES OF THE BACK

The muscles of the back may be divided into three groups:

- The **superficial muscles** connected with the shoulder girdle.
- The **intermediate muscles** involved with movements of the thoracic cage.
- The **deep** or **postvertebral muscles** belonging to the vertebral column.

Postvertebral Muscles

The postvertebral muscles are very well developed in humans and form a broad, thick column of muscle tissue that occupies the hollow on each side of the spinous processes (Fig. 7-5). The spines and the transverse processes of the vertebrae serve as levers that assist with actions of the muscles. The muscles of longest length lie superficially and run from the sacrum to the rib angles, the transverse processes, and the upper vertebral spines. The muscles of intermediate length run obliquely from the transverse processes to the spines. The shortest and deepest muscle fibers run between the spines and between the transverse processes of adjacent vertebrae.

The postvertebral muscles may be classified as follows:

- **Superficial vertically running muscles.**
- **Erector spinae:** Iliocostalis, longissimus, and spinalis.
- **Intermediate oblique running muscles.**
- **Transversospinalis:** Semispinalis, multifidus, and rotatores.
- **Deepest muscles:** Interspinales and intertransversarii.

Students are not required to learn the detailed attachments of these muscles. Figure 7-5 shows the arrangement of the deep muscles of the back.

Muscular Triangles

AUSCULTATORY TRIANGLE

The auscultatory triangle is the site on the back where breath sounds may be most easily heard with a stethoscope. The boundaries are the latissimus dorsi, the trapezius, and the medial border of the scapula. The rhomboid major forms the floor.

LUMBAR TRIANGLE

The lumbar triangle is the site where pus may emerge from the abdominal wall. The boundaries are the latissimus dorsi, the posterior border of the external oblique muscle of the abdomen, and the iliac crest.

ARTERIAL SUPPLY OF THE BACK

- **Cervical region:** The occipital artery, vertebral artery, deep cervical artery, and ascending cervical artery.
- **Thoracic region:** The posterior intercostal arteries.
- **Lumbar region:** The subcostal and lumbar arteries.
- **Sacral region:** The iliolumbar and lateral sacral arteries.

VENOUS DRAINAGE OF THE BACK

The veins form complicated plexuses that extend along the vertebral column from the skull to the coccyx. The **external vertebral venous plexus** lies external to the vertebral column, and the **internal vertebral venous plexus** lies within the vertebral canal (Fig. 7-6).

There is free communication between the plexuses and the veins in the neck, the thorax, the abdomen, and the pelvis. They communicate above through the foramen magnum with the venous sinuses in the cranial cavity.

The internal plexus also communicates with the veins draining the vertebral bodies (the **basivertebral veins**) and the veins of the meninges and the spinal cord.

The vertebral plexuses are drained into the vertebral, the intercostal, the lumbar, and the lateral sacral veins.

CLINICAL NOTES

CLINICAL IMPORTANCE OF THE VERTEBRAL VENOUS PLEXUSES

The plexuses provide a pathway for the spread of malignant disease from the pelvis to the skull..

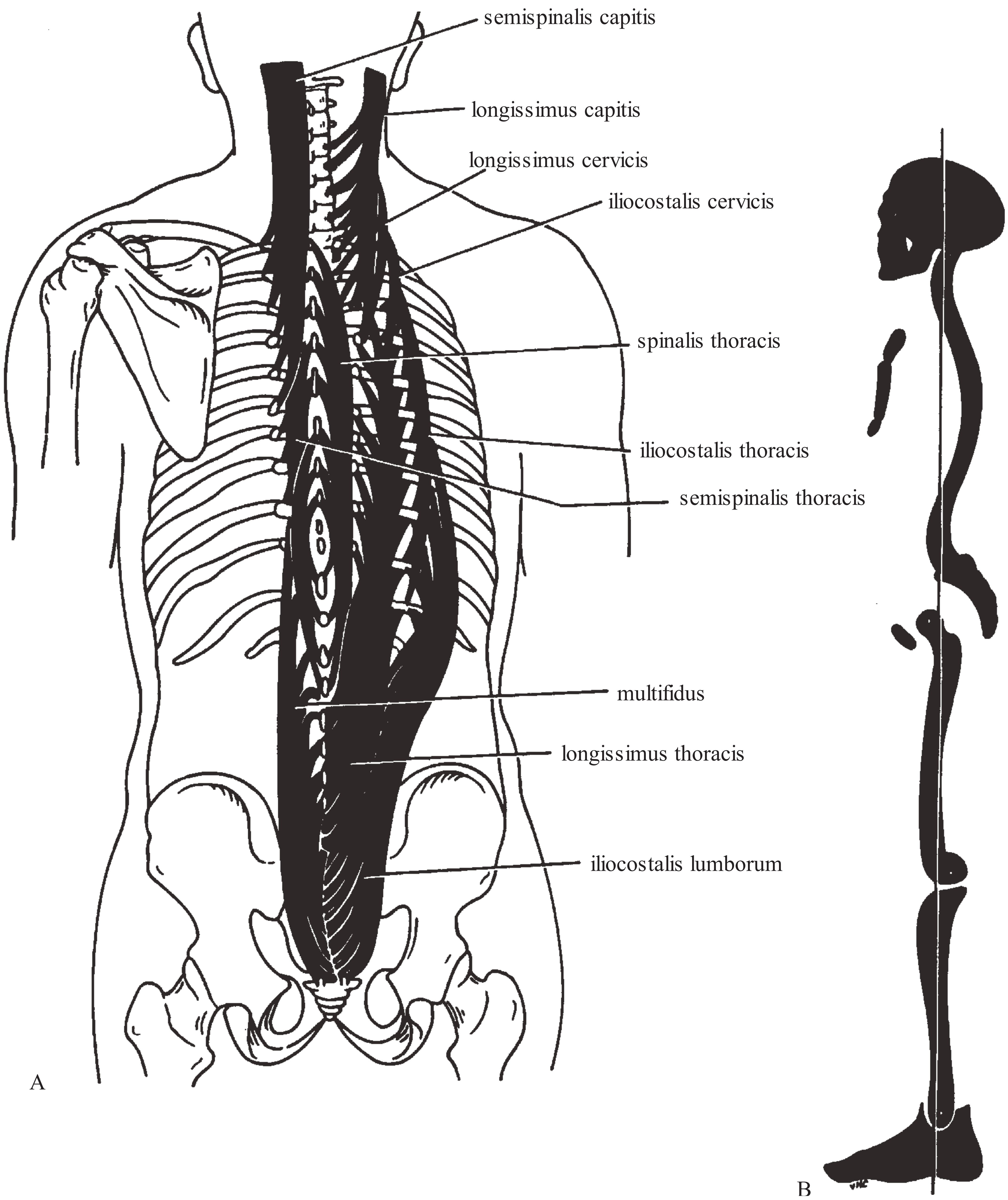


Figure 7-5 A. Deep muscles of the back showing their arrangement. B. Lateral view of the skeleton showing the line of gravity. Because the greater part of the body weight lies anteriorly to the vertebral column, the deep muscles of the back are important in maintaining the normal postural curves of the vertebral column in the standing position.

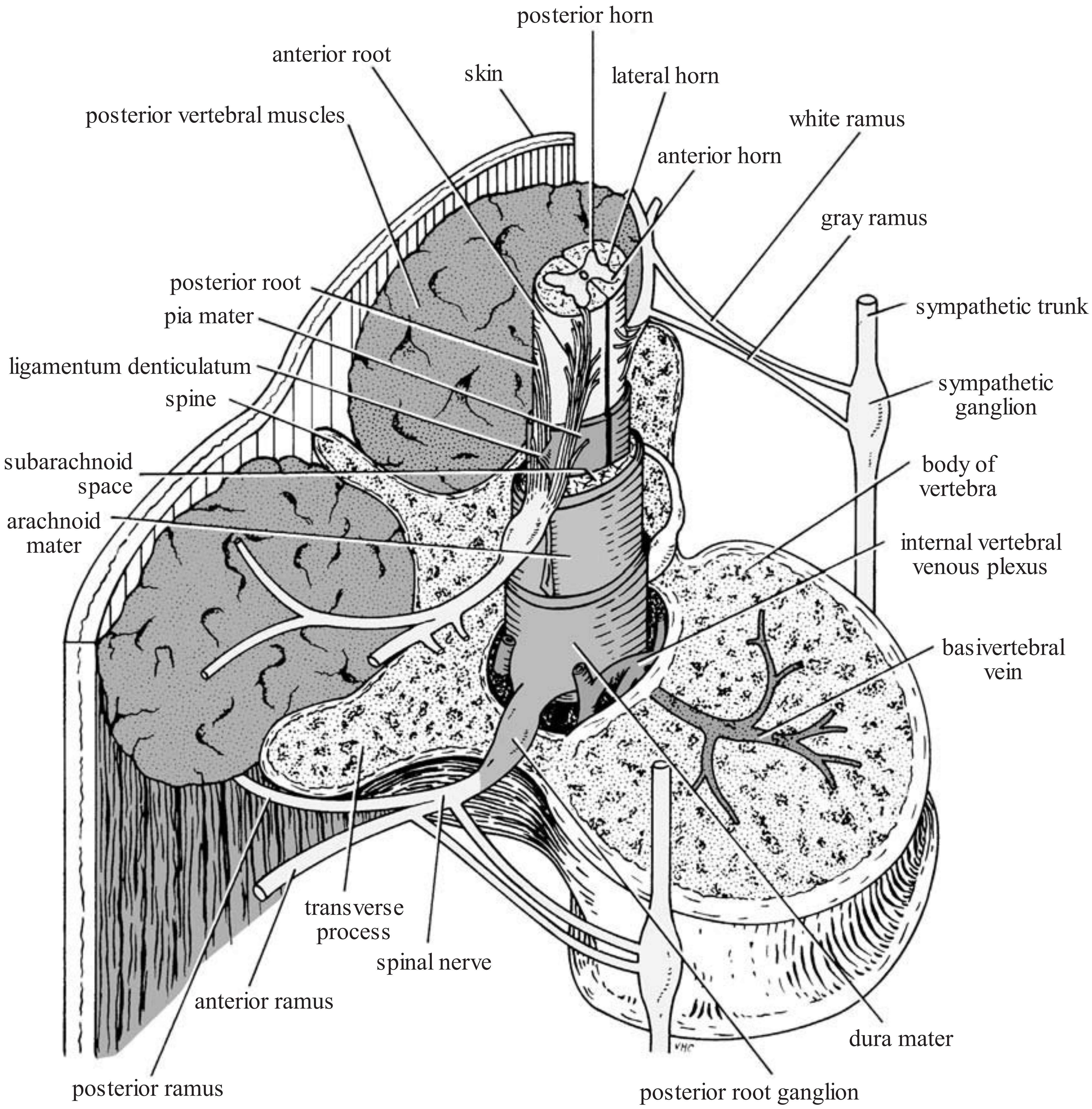


Figure 7-6 Oblique section through the first lumbar vertebra showing the spinal cord and its covering membranes. Note the relationship between the spinal nerve and the sympathetic trunk on each side. Note also the important internal vertebral venous plexus.

LYMPHATIC DRAINAGE OF THE BACK

- **Superficial lymph:** Above, the iliac crest drains into the axillary nodes. Below, the iliac crest drains into the superficial inguinal nodes.
- **Deep lymph:** The deep lymph drains into the deep cervical, the posterior mediastinal, the lateral aortic, and the sacral nodes.

NERVES OF THE BACK

Segmental supply to the skin and muscles arises from the posterior rami of the 31 pairs of spinal nerves. Note that the posterior rami of the C1, 6, 7, and 8, and L4 and 5 spinal nerves supply the deep muscles of the back but **do not supply the skin.**

A dermatomal chart for the posterior surface of the body is shown in Figure 2-4.

SPINAL CORD

The spinal cord is cylindrical in shape and begins superiorly at the foramen magnum, where it is continuous with the medulla oblongata of the brain. **In adults, it terminates below at the level of the lower border of the first lumbar vertebra.** The spinal cord thus occupies the upper two thirds of the vertebral canal and is surrounded by the three meninges: the **dura mater,** the **arachnoid mater,** and the **pia mater** (Figs. 7-6 and 7-7). Additional protection is provided by the **cerebrospinal fluid** in the **subarachnoid space.** The spinal cord has both **cervical** and **lumbar enlargements,** where it gives origin to the brachial and

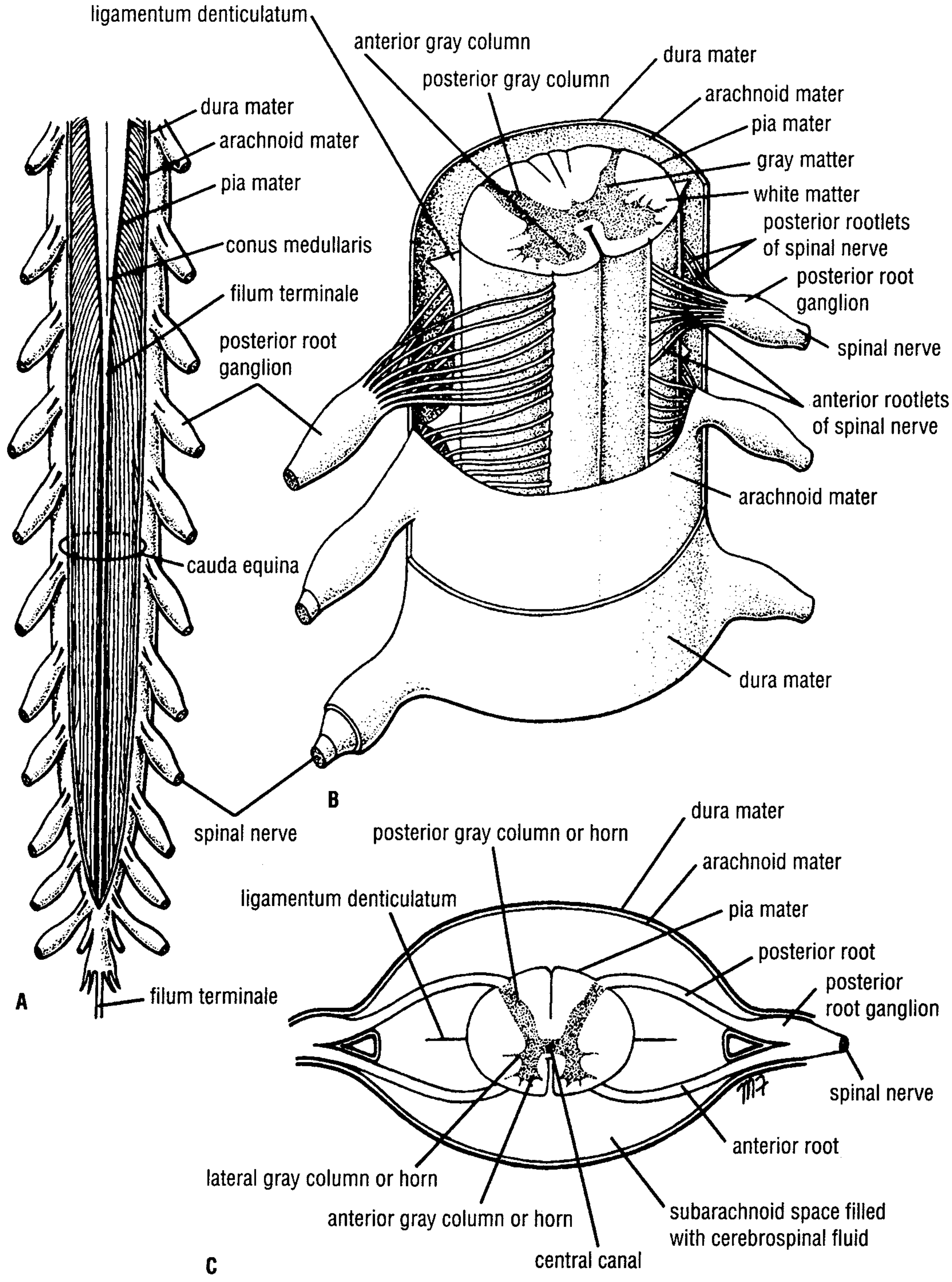


Figure 7-7 A. Lower end of the spinal cord and the cauda equina. B. Section through the thoracic part of the spinal cord that shows the anterior and posterior roots of the spinal nerves and meninges. C. Transverse section through the spinal cord showing the meninges and position of the cerebrospinal fluid.

lumbar plexuses. The spinal cord is tapered below to form the **conus medullaris** (Fig. 7-7). The **filum terminale** is a prolongation of the pia mater that extends from the conus to the back of the coccyx (Fig. 7-7).

CLINICAL NOTES

RELATIONSHIPS OF SPINAL CORD SEGMENTS TO VERTEBRAL NUMBERS

Because the spinal cord is shorter than the vertebral column, the spinal cord segments do not correspond numerically with the vertebrae that lie at the same level. The following list helps determine which spinal segment is contiguous with a given vertebral body. This information can be extremely helpful when viewing radiographic, CT, and MRI studies of the vertebral column.

Vertebrae	Spinal Segment
Cervical	Add 1
Upper thoracic	Add 2
Lower thoracic (T7–9)	Add 3
Tenth thoracic	L1 and 2 cord segments
Eleventh thoracic	L3 and 4 cord segments
Twelfth thoracic	L5 cord segment
First lumbar	Sacral and coccygeal cord segments

Fissures of the Spinal Cord

- Anterior median fissure: Located in the midline on the anterior surface of the cord.
- Posterior median fissure: Located in the midline on the posterior surface of the cord.

Roots of the Spinal Nerves

The 31 pairs of spinal nerves are attached to the spinal cord by **anterior** and **posterior roots** (Fig. 7-7). The anterior roots are motor, and the posterior roots are sensory. In addition, each posterior root possesses a **posterior root ganglion** (Fig. 7-7).

In the upper cervical region, the spinal nerve roots are short and run almost horizontally. The roots of the lumbar and the sacral nerves below the level of termination of the cord (in adults, the lower border of the first lumbar vertebra), however, form a vertical leash of nerves around the filum terminale called the **cauda equina.**

As the spinal nerve roots pass through the intervertebral foramina, they unite to form the **spinal nerves** (Fig. 7-6). After emerging from the intervertebral foramen, each spinal nerve then divides into a large **anterior ramus** and a smaller, **posterior ramus**, with each ramus containing both motor and sensory fibers (Fig. 7-6).

Blood Supply of the Spinal Cord

ARTERIES

- **Posterior spinal arteries:** Arise directly or indirectly from the vertebral arteries. They supply the posterior third of the spinal cord.
- **Anterior spinal arteries:** Arise from the vertebral arteries and unite to form a single artery, which descends in the anterior median fissure. They supply the anterior two thirds of the spinal cord.
- **Radicular arteries:** Branches of regional arteries that reinforce the anterior and the posterior spinal arteries.

CLINICAL NOTES

SPINAL CORD ISCHEMIA

The blood supply to the spinal cord is meager. The anterior and posterior spinal arteries have small and variable diameters, and the reinforcing segmental arteries vary in number and in size. Ischemia of the spinal cord can easily follow minor damage to the arterial supply as a result of regional anesthesia, pain block procedures, or aortic surgery.

VEINS

The veins drain into the internal vertebral venous plexus.

Meninges of the Spinal Cord

DURA MATER

An external membrane of dense fibrous tissue, the dura mater encloses the spinal cord and the cauda equina (Fig. 7-7). Above, the dura is continuous with the meningeal layer of dura covering the brain. Below, the dura ends on the filum terminale at the level of the lower border of the second sacral vertebra. The dura gives sheaths to all the spinal nerve roots.

ARACHNOID MATER

The arachnoid mater is a delicate, impermeable membrane that lies within the dura and outside the pia (Fig. 7-7). It is separated from the pia mater by a wide space (the **subarachnoid space**) that is filled with **cerebrospinal fluid.** The arachnoid is continuous above through the foramen magnum with the arachnoid covering the brain. Inferiorly, it ends on the filum terminale at the level of the **lower border of the second sacral vertebra.** The arachnoid continues along the spinal nerve roots, forming small, lateral extensions of the subarachnoid space.

PIA MATER

The pia mater is a vascular membrane that closely covers the spinal cord. It is thickened on either side between the nerve roots to form the **ligamentum denticulatum**, which passes laterally to adhere to the arachnoid and the dura (Fig. 7-7). The pia mater extends along each nerve root as far as the spinal nerve. Inferiorly, it is prolonged off the lower end of the spinal cord as the **filum terminale.**

CLINICAL NOTES

Lumbar Puncture (Spinal Tap)

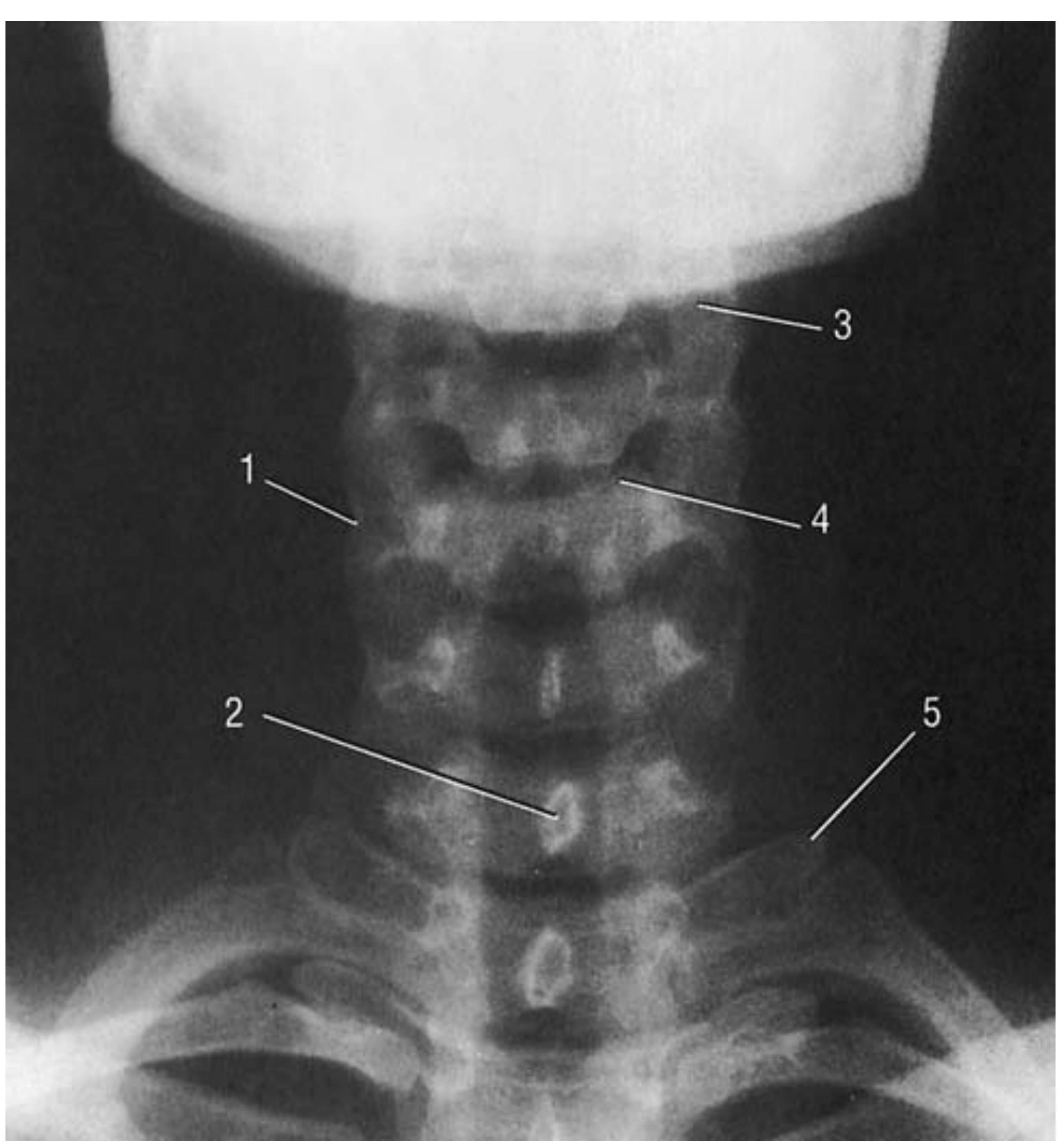
The fourth lumbar spine is identified by passing an imaginary line between the highest points on the iliac crests; the spine lies on that imaginary line. As the patient lies on his or her side with the vertebral column well flexed, a lumbar puncture needle is passed into the vertebral canal either above or below the fourth lumbar spine. The needle passes through the following anatomic structures before entering the subarachnoid space:

- The **skin.**
- The **fascia.**
- The **supraspinous ligament.**
- The **interspinous ligament.**
- The **ligamentum flavum.**
- The **fatty tissue** and the **internal vertebral venous plexus.**
- The **dura mater.**
- The **arachnoid mater.**

REVIEW

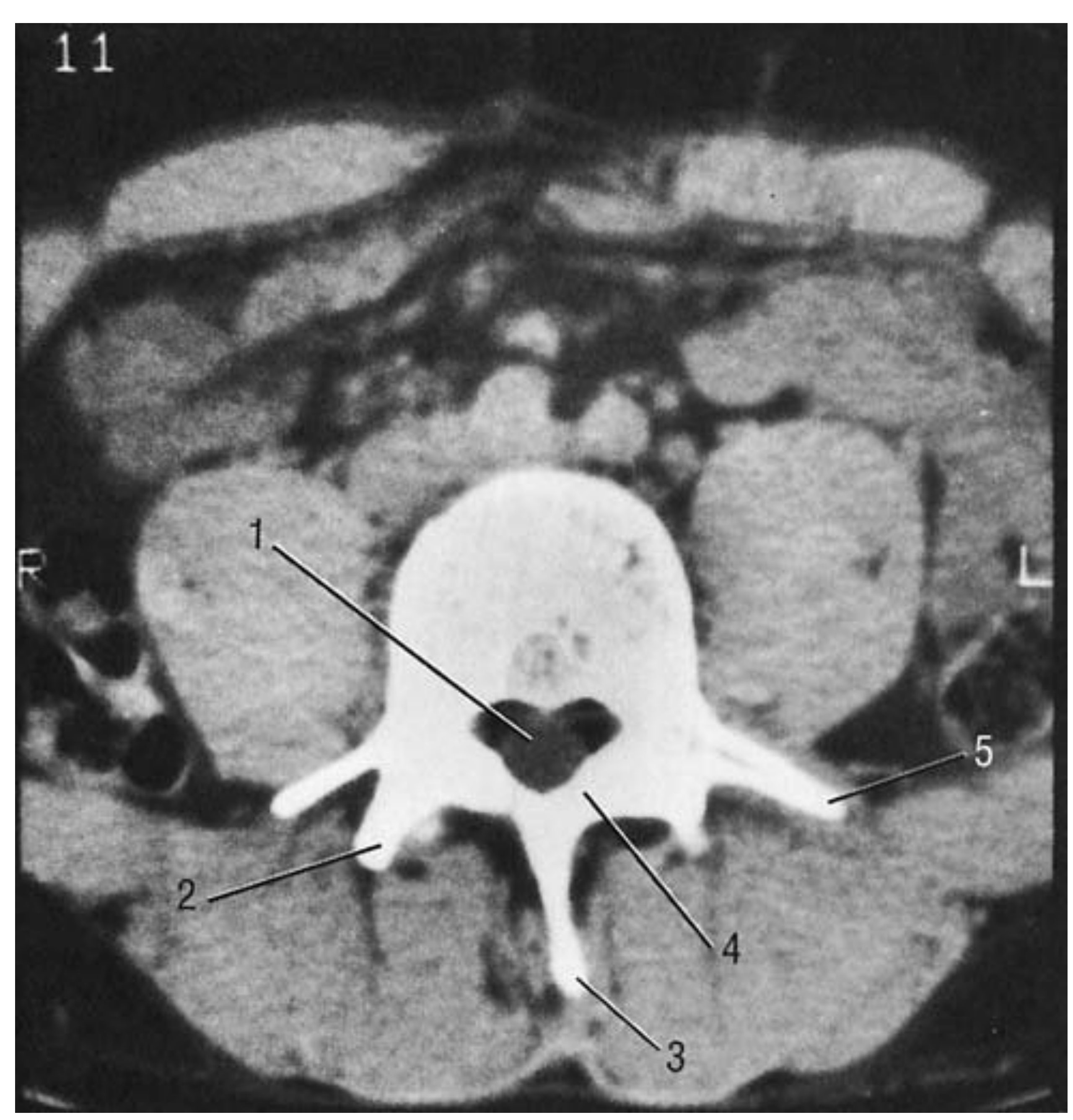
Completion Questions

Based on the anteroposterior radiograph of the cervical part of the vertebral column, select the phrase that best completes each statement.



1. Structure 1 is the
   A. transverse process of the first thoracic vertebra.
   B. joint between the articular processes of the third and fourth cervical vertebrae.
   C. transverse process of the fifth cervical vertebra.
   D. spinous process of the seventh cervical vertebra.
   E. lateral synovial joint between the adjacent vertebral bodies.
2. Structure 2 is
   A. a foreign body in the esophagus.
   B. the cricoid cartilage.
   C. part of a necklace.
   D. the spinous process of the seventh cervical vertebra.
   E. the body of the seventh cervical vertebra.
3. Structure 3 is the
   A. vertebral artery.
   B. joint between the articular processes of the third and fourth cervical vertebrae.
   C. lateral synovial joint between adjacent vertebral bodies.
   D. mastoid process of the temporal bone.
   E. internal carotid artery.
4. Structure 4 is the
   A. lateral synovial joint between adjacent vertebral bodies.
   B. vertebral artery.
   C. pedicle of vertebra.
   D. transverse process of second cervical vertebra.
   E. lamina of vertebra.
5. Structure 5 is the
   A. transverse process of the first thoracic vertebra.
   B. first rib.
   C. transverse process of the seventh cervical vertebra.
   D. clavicle.
   E. coracoid process of scapula.

Based on the axial (transverse) CT scan through the lumbar part of the vertebral column, select the phrase that best completes each statement.



6. Structure 1 is the
   A. lamina.
   B. articular process.
   C. spinous process.
   D. cauda equina.
   E. transverse process.
7. Structure 2 is the
   A. transverse process.
   B. articular process.
   C. spinous process.
   D. lamina.
   E. posterior superior iliac spine.
8. Structure 3 is the
   A. first sacral spine.
   B. lamina.
   C. spinous process.
   D. articular process.
   E. transverse process.
9. Structure 4 is the
   A. pedicle of vertebra.
   B. spinous process.
   C. lamina.
   D. transverse process.
   E. superior articular process of sacrum.
10. Structure 5 is
   A. transverse process.
   B. spinous process.
   C. iliac crest.
   D. articular process.
   E. lamina.

Select the phrase that best completes each statement.

11. The subarachnoid space ends inferiorly at the level of the
   A. L5 vertebra.
   B. L3 vertebra.
   C. S2–3 vertebrae.
   D. T12 vertebra.
   E. L1 vertebra.
12. In adults, the spinal cord usually ends inferiorly at the
   A. lower border of S2.
   B. upper border of S1.
   C. lower border of S4.
   D. upper border of the coccyx.
   E. lower border of L1.
13. The least serious congenital abnormality involving the neural arch and the neural tube is
   A. rachischisis.
   B. meningohydroencephalocele.
   C. meningomyelocele.
   D. spina bifida occulta.
   E. meningoencephalocele.
14. To perform a lumbar puncture (spinal tap) in an adult, the needle is introduced between the spinous processes of
   A. L4 and 5.
   B. L2 and 3.
   C. S1 and L2.
   D. T12 and L1.
   E. S3 and L4.
15. Lymph from the skin of the back in the region of the spinous process of the tenth thoracic vertebra drains into the
   A. posterior mediastinal lymph nodes.
   B. superficial inguinal lymph nodes.
   C. axillary lymph nodes.
   D. sacral lymph nodes.
16. The ________ passes between the sixth and seventh cervical vertebrae.
   A. vertebral artery
   B. seventh cervical spinal nerve
   C. sixth cervical spinal nerve
   D. vertebral vein
   E. eighth cervical spinal nerve
17. The cauda equina is made up of the
   A. spinal nerves of S1–3.
   B. anterior rami of spinal nerves L2 and 3.
   C. posterior rami of spinal nerves L1 to cocc 1.
   D. anterior and the posterior nerve roots of the spinal nerves below the first lumbar segment of the spinal cord.
   E. spinal nerves of L1–5.
18. The strength of the flexor muscles of the vertebral column can be assessed by asking the patient to
   A. sit up from the supine position while keeping the hips and the knees extended.
   B. lift the shoulders from the examining table while in the prone position.
   C. extend the head while lying in the prone position.
   D. sit up from the supine position while keeping the hips and the knees flexed.
   E. perform the movement of forced expiration.
19. A herniated disc that causes sensory changes in a specific dermatome is pressing on
   A. an anterior primary ramus.
   B. an anterior gray horn of the spinal cord.
   C. an anterior root.
   D. a posterior primary ramus.
   E. a spinal nerve or a posterior root.

Multiple-Choice Questions

Select the best answer for each question.

20. Which of the following statements regarding the blood supply to the spinal cord is true?
   A. The anterior spinal arteries are two in number and run down the anterior surface of the spinal cord close to the anterior nerve roots.
   B. The posterior spinal arteries supply the posterior third of the spinal cord.
   C. The veins of the spinal cord drain into the external vertebral venous plexus.
   D. The anterior and the posterior spinal arteries do not anastomose with the radicular arteries.
   E. The spinal cord has a profuse blood supply.

21. The following statements concerning the vertebral column are correct except which?
    A. The intervertebral discs make up approximately one fourth the length of the vertebral column.
    B. In old age, atrophy of the intervertebral discs tends to produce a continuous posterior convexity of the vertebral column.
    C. During pregnancy, the weight of the developing fetus increases the posterior lumbar concavity of the vertebral column.
    D. The odontoid process of the axis represents developmentally the body of the atlas.
    E. There are seven cervical spinal nerves and eight cervical vertebrae.
22. The following statements concerning the vertebral column are correct except which?
    A. The posterior ramus of the first cervical spinal nerve and its continuation, the great occipital nerve, supplies the skin over the back of the scalp.
    B. When an individual is in the standing position, the line of gravity passes anterior to the cervical part of the vertebral column and posterior to the thoracic and lumbar regions of the column.
    C. The tip of the spine of a thoracic vertebra lies directly behind the vertebral body of the vertebra below.
    D. The intervertebral disc is innervated by a recurrent branch of spinal nerve that enters the vertebral canal through the intervertebral foramen.
    E. The atlantoaxial joints permit rotation of the atlas with the head on the axis.
23. When performing a lumbar puncture (spinal tap), the following structures are pierced by the needle except which?
    A. The posterior longitudinal ligament
    B. The supraspinous ligament
    C. The arachnoid mater
    D. The ligamentum flavum
    E. The dura mater
24. All the following characteristics are present in a lumbar vertebra except which?
    A. There is a massive kidney-shaped body.
    B. The transverse processes are short and thick.
    C. The spinous processes are short, flat, and quadrangular in shape.
    D. The transverse processes have no foramen.
    E. The articular surfaces of the superior articular processes face medially.
25. The following statements regarding the internal vertebral venous plexus are correct except which?
    A. It drains blood from the vertebral bodies.
    B. It permits malignant cells from the prostate to metastasize to the skull.
    C. It does not possess competent valves.
    D. The venous flow is indirectly influenced by changes in the intra-abdominal pressure.
    E. It does not communicate with veins within the thorax.
26. The following statements regarding herniation of an intervertebral disc are correct except which?
    A. It generally herniates posteriorly.
    B. In the lumbar region, it usually affects the spinal nerve whose number corresponds to the vertebra below.
    C. It is a portion of the nucleus pulposus that actually herniates.
    D. A contributing factor to the herniation may be excessive compression of the posterior region of the disc.
    E. It may press on the spinal cord.
27. The following statements regarding an intervertebral disc are correct except which?
    A. During aging, the fluid within the nucleus pulposus is diminished and the amount of fibrocartilage is increased.
    B. The atlantoaxial joint possesses a small disc.
    C. The discs play a major role in development of the curvatures of the vertebral column.
    D. The discs are thickest in the lumbar region.
    E. The discs are innervated by adjacent spinal nerves.

Read the case history and select the best answer to the questions following it.

A 69-year-old woman complaining of a burning pain over the left shoulder and upper part of the left arm was seen by her physician. The pain had started approximately 2 weeks previously and had progressively worsened. The pain was made worse by moving the neck. At physical examination, the patient showed hyperesthesia of the skin over the lower part of the left deltoid muscle and down the lateral side of the arm. In addition, her left deltoid and biceps brachii muscles were weaker than those on the right side. At radiologic examination, extensive osteoarthritic changes of the vertebrae with spur formation on the bodies of the fourth, fifth, and sixth cervical vertebrae were seen.

28. Assuming that the osteoarthritic changes caused narrowing of the cervical intervertebral foramina, which spinal nerve roots were most likely to have been pressed on to cause the burning pain and the hyperesthesia?
    A. C3 and 4
    B. C6
    C. C5 and 6
    D. C7
    E. C8 and T1
29. The weakness of the left deltoid and biceps brachii muscles could have resulted from pressure on which nerve roots?
    A. the posterior nerve roots of C5 and 6
    B. the anterior nerve roots of C5 and 6
    C. the anterior nerve roots of C7 and 8
    D. the anterior nerve roots of C8 and T1
    E. None of the above.
30. The sensory and motor changes in this patient resulted from pressure on the cervical spinal nerves or their roots as they passed through the intervertebral

foramina. The following structures form the boundaries of each foramen except which?
A. intervertebral discs
B. bodies of the cervical vertebrae
C. the posterior longitudinal ligament
D. articular processes of the vertebrae
E. pedicles of the vertebrae

ANSWERS AND EXPLANATIONS

1. C
2. D
3. B
4. A
5. A
6. D
7. B
8. C
9. C
10. A
11. C
12. E
13. D
14. A
15. C. The subscapular group of axillary nodes.
16. B
17. D. The cauda equina is not made up of the spinal nerves or the rami of the spinal nerves.
18. D. Sitting up from the supine position while keeping the hip and the knee joints extended results in use of the iliacus and psoas muscles in addition to the main flexor muscles the vertebral column.
19. E. Anterior and posterior primary rami arise from a spinal nerve outside the vertebral canal. An anterior root does not contain sensory nerve fibers. The anterior gray horn of the spinal cord contains motor neurons.
20. B. There is only one anterior spinal artery formed by the union of branches from each vertebral artery. The anterior spinal artery is small, and it runs downward in the anterior median sulcus of the spinal cord. The veins of the spinal cord drain into the internal vertebral venous plexus. The spinal cord has a relatively poor blood supply.
21. E. It is important to remember that there are eight cervical spinal nerves but only seven cervical vertebrae.
22. B. In the standing position, the line of gravity passes through the odontoid process of the axis, in front of the thoracic vertebrae, and through the lumbar vertebrae but anterior to the sacrum (Fig.7-5).
23. A
24. B. The transverse processes are long and slender.
25. E. The internal vertebral venous plexus communicates with the veins of the neck, the thorax, the abdomen, and the pelvis via the radicular veins.
26. D. Excessive compression of the anterior part of the disc, as in excessive forced flexion, may contribute to herniation.
27. B. The atlantoaxial joint has no intervertebral disc.
28. C. The burning pain and hyperesthesia occurred in the fifth and sixth cervical dermatomes on the left side.
29. B. The deltoid muscle is innervated by the axillary nerve (C5 and 6), and the biceps brachii muscle is innervated by the musculocutaneous nerve (C5, 6, and 7). Most of the motor fibers emerge from the spinal cord in the anterior nerve roots of the C5 and 6 spinal nerves.
30. C

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