

Thorax

THORACIC WALL

Bones of the Thoracic Wall

The bones of the thoracic wall consist of the sternum, the ribs, and the costal cartilages.

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. 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.

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.

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.

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 groove**), which accommodates the intercostal vessels and nerve.

The anterior end of each rib is attached to the corresponding costal cartilage. 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.

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. 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.

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.

XIPHISTERNAL JOINT

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

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.

Muscles of the Thoracic Wall

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

DIAPHRAGM

The diaphragm is the most important muscle of respiration. It is dome shaped, and it consists of a peripheral 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.

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 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 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 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. The **intercostal spaces** drain forward to the **internal thoracic nodes**, which are situated along the internal thoracic artery, and posteriorly to the **posterior intercostals nodes**, which is close to the heads of the ribs and the **paraaortic 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. 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. The first six nerves are distributed within their intercostals 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 intercostals nerves only**) run to the parietal peritoneum; these are sensory nerves.

It should be noted that the seventh to eleventh intercostals 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. The remainder of the first intercostals 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.

THORACIC CAVITY

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

Trachea and Bronchi

TRACHEA

The trachea is a mobile cartilaginous and membranous tube. 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.
- **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**.

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. 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 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. 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**.

Pleurae

The pleurae are two serous sacs surrounding and covering the lungs. 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.

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**. 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. 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.

PERICARDIUM

The pericardium is a fibroserous sac that encloses the heart and the roots of the great blood vessels. It lies within the middle mediastinum.

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. 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.

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. 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. 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**.

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 between the inferior vena cava and the atrioventricular orifice. 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. 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**. 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. 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. 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).

LEFT ATRIUM

The left atrium 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. 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.

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. 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. 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. 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.

Blood Supply of the Heart

ARTERIAL SUPPLY

Right Coronary Artery

The right coronary artery arises from the anterior aortic sinus of the ascending aorta. It descends in the right atrioventricular groove and sends branches to the right 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 ventricle. 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 .

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.

VENOUS DRAINAGE

Most venous blood from the heart wall drains into the right atrium through the coronary sinus. 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 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. 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.

Small Cardiac Vein

The small cardiac vein accompanies the marginal artery along the inferior border of the heart and empties into the coronary sinus.

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.

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 sinoatrial 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.

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. 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. It perforates the central tendon of the diaphragm and the pericardium, and it then opens into the right atrium of the heart.

Pulmonary Veins

There are four pulmonary veins, two from each lung. 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. 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:

- 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. The **ligamentum arteriosum** is a fibrous band that connects the bifurcation of the pulmonary trunk with the lower surface of the aortic arch. It is the remains of the **ductus arteriosus**.

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. 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. 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. 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.

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. 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.
- 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.

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.

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.