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CONTENTS

1

Anatomy of the Esophagus and the Foregut

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TOPOGRAPHIC RELATIONS OF THE ESOPHAGUS

The pharynx ends at the level of the cricoid cartilage and the sixth cervical vertebra (C6) and where the esophagus begins (Figs. 1.1 and 1.2). On average, the esophagus is 40 cm (16 inch) long from the upper incisor teeth to the edge of the cardia of the stomach. The esophagus is divided, with the first part extending 16 cm from the incisors to the lower border of the cricopharyngeus muscle. The remainder is 24 cm long.

The aortic arch crosses behind the esophagus from the left side and is located 23 cm from the incisors and 7 cm below the cricopharyngeus muscle, and 2 cm below this level, the left main bronchus crosses in front of the esophagus. The lower esophageal sphincter (LES) begins 37 to 38 cm from the incisors. The esophageal hiatus is located 1 cm below this point, and the cardia of the stomach is yet lower. In children the dimensions are proportionately smaller. At birth the distance from the incisor teeth to the cardia is approximately 18 cm; at 3 years, 22 cm; and at 10 years, 27 cm.

Like a "good soldier," the esophagus follows a left-right-left path as it marches down the anteroposterior curvature of the vertebral column. It descends anterior to the vertebral column, through the lower portion of the neck and the superior and posterior mediastinum. The esophagus forms two lateral curves that, when viewed anteriorly, appear as a reverse S: the upper esophagus has a convex curve toward the left, and the lower esophagus has a convex curve toward the right. At its origin, the esophagus bends ¼ inch (0.6 cm) to the left of the tracheal margin. It crosses the midline behind the aortic arch at the level of the fourth thoracic vertebra (T4). The esophagus then turns to the right at the seventh thoracic vertebra (T7), after which it turns sharply to the left as it enters the abdomen through the esophageal hiatus of the diaphragm, to join the cardia of the stomach at the gastroesophageal (GE) junction.

The esophagus is composed of three segments: cervical, thoracic, and abdominal. Anterior to the cervical esophagus is the membranous wall of the trachea. Loose areolar tissue and muscular strands connect the esophagus and the trachea, and recurrent laryngeal nerves ascend in the grooves between them. Posterior to the esophagus are the longus colli muscles, the prevertebral fascia, and the vertebral bodies. Although the *cervical esophagus* is positioned between the carotid sheaths, it is closer to the left carotid sheath. The thyroid gland partially overlaps the esophagus on both sides.

The *thoracic esophagus* lies posterior to the trachea. It extends down to the level of the fifth thoracic vertebra (T5), where the trachea bifurcates. The trachea curves to the right as it divides, and thus the left main bronchus crosses in front of the esophagus. Below this, the pericardium separates the esophagus from the left atrium of the heart, which lies anterior and inferior to the esophagus. The lowest portion of the thoracic esophagus passes through the diaphragm into the abdomen.

On the left side of the esophageal wall, in the upper thoracic region, is the ascending portion of the left subclavian artery and the parietal pleura. At approximately the level of T4, the arch of the aorta passes backward and alongside the esophagus. Below this, the descending aorta lies to the left, but when that vessel passes behind the esophagus, the left mediastinal pleura again comes to adjoin the esophageal wall. On the right side, the parietal pleura is intimately applied to the esophagus, except when, at the level of T4, the azygos vein intervenes as it turns forward.

In the upper thorax, the esophagus lies on the longus colli muscle, the prevertebral fascia, and the vertebral bodies. At the eighth thoracic vertebra (T8), the aorta lies behind the esophagus. The azygos vein ascends behind and to the right of the esophagus as far as the level of T4, where it turns forward. The hemiazygos vein and the five upper-right intercostal arteries cross from left to right behind the esophagus. The thoracic duct ascends to the right of the esophagus before turning behind it and to the left at the level of T5. The duct then continues to ascend on the left side of the esophagus.

A small segment of *abdominal esophagus* lies on the crus of the diaphragm and creates an impression in the underside of the liver. Below the tracheal bifurcation, the esophageal nerve plexus and the anterior and posterior vagal trunks adhere to the esophagus.

As the esophagus travels from the neck to the abdomen, it encounters several indentations and constrictions. The first narrowing occurs at the cricopharyngeus muscle and the cricoid cartilage. The aortic arch creates an indentation on the left side of the esophagus, and the pulsations of the aorta may be seen during esophagoscopy. Below this point, the left main bronchus creates an impression on the left anterior aspect of the esophagus. The second narrowing occurs at the LES.

Although the esophagus is described as a "tube," it is oval and has a flat axis anterior to posterior with a wider transverse axis. When the esophagus is at rest, its walls are approximated and its width is 2 cm, but it distends and contracts, depending on its state of tonus.

MUSCULATURE OF THE ESOPHAGUS

The esophagus is composed of outer longitudinal and inner circular muscle layers (Figs. 1.3 and 1.4). On the vertical ridge of the dorsal aspect of the cricoid cartilage, two tendons originate as they diverge and descend downward around the sides of the esophagus to the dorsal aspect. These tendons weave in the midline of the ventral area, creating a V-shaped gap between the two muscles, known as the V-shaped area of Laimer. This gap, or bare area, exposes the underlying circular muscle. Located above this area is the cricopharyngeus muscle. Sparse longitudinal muscles cover the area, as do accessory fibers from the lower aspect of the cricopharyngeus muscle.

In the upper esophagus, longitudinal muscles form bundles of fibers that do not evenly distribute over the surface. The thinnest layers of muscle are anterior and adjacent to the posterior wall of the trachea. The longitudinal muscle of the esophagus receives fibers from an accessory muscle on each side that originates from the posterolateral aspect of the cricoid cartilage and the contralateral side of the deep portion

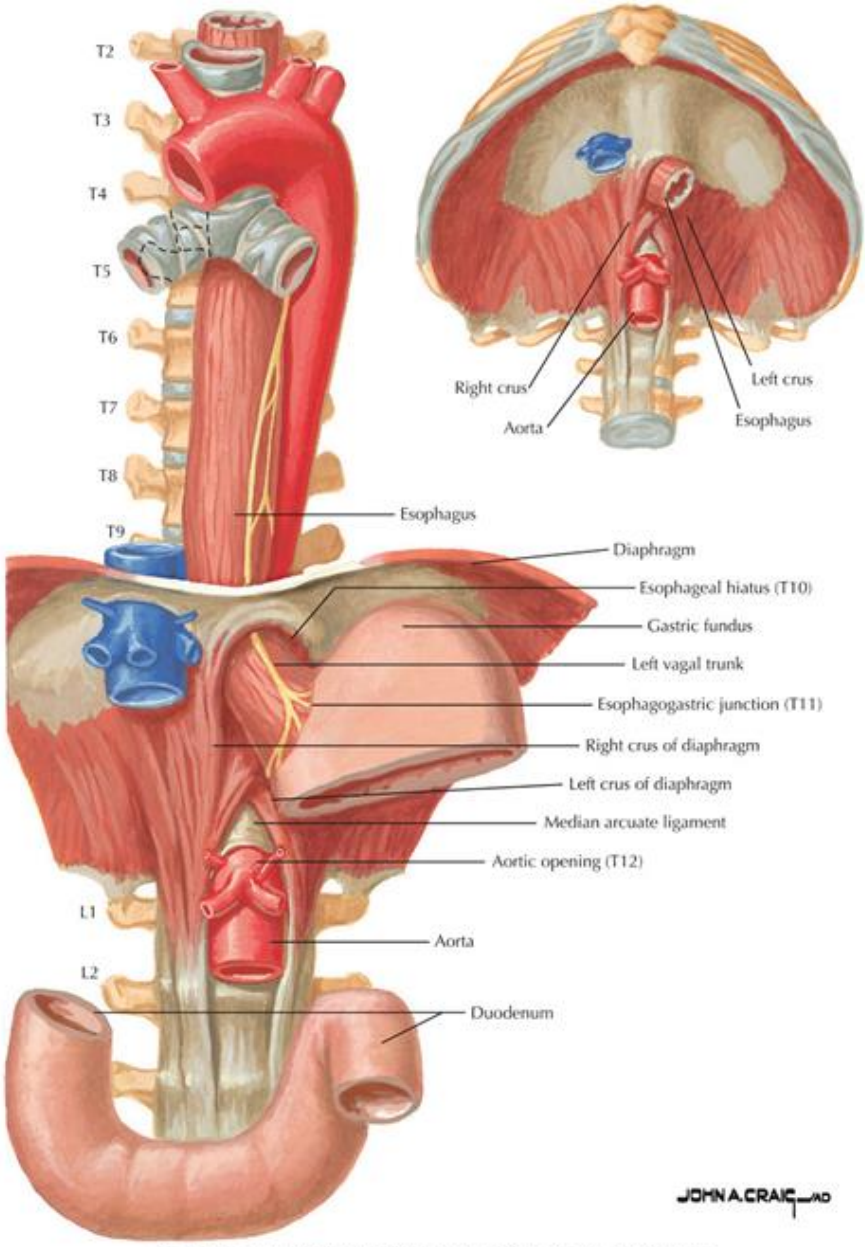

Fig. 1.1 Regional Anatomy of Diaphragm, Stomach, and Esophagus.

of the cricopharyngeus muscle. As the longitudinal muscle descends, its fibers become equally distributed and completely cover the surface of the esophagus.

The inner, circular, muscle layer is thinner than the outer longitudinal layer. This relationship is reversed in all other parts of the gastrointestinal (GI) tract. In the upper esophagus, the circular muscle closely approximates the encircling lower fibers of the cricopharyngeus muscle. The upper esophageal fibers are not circular but elliptical, with the anterior part of the ellipse at a lower level of the posterior part. The ellipses become more circular as the esophagus descends, until the start of its middle third, where the fibers run in a horizontal plane. In one 1-cm segment, the fibers are truly circular. Below this point, the fibers

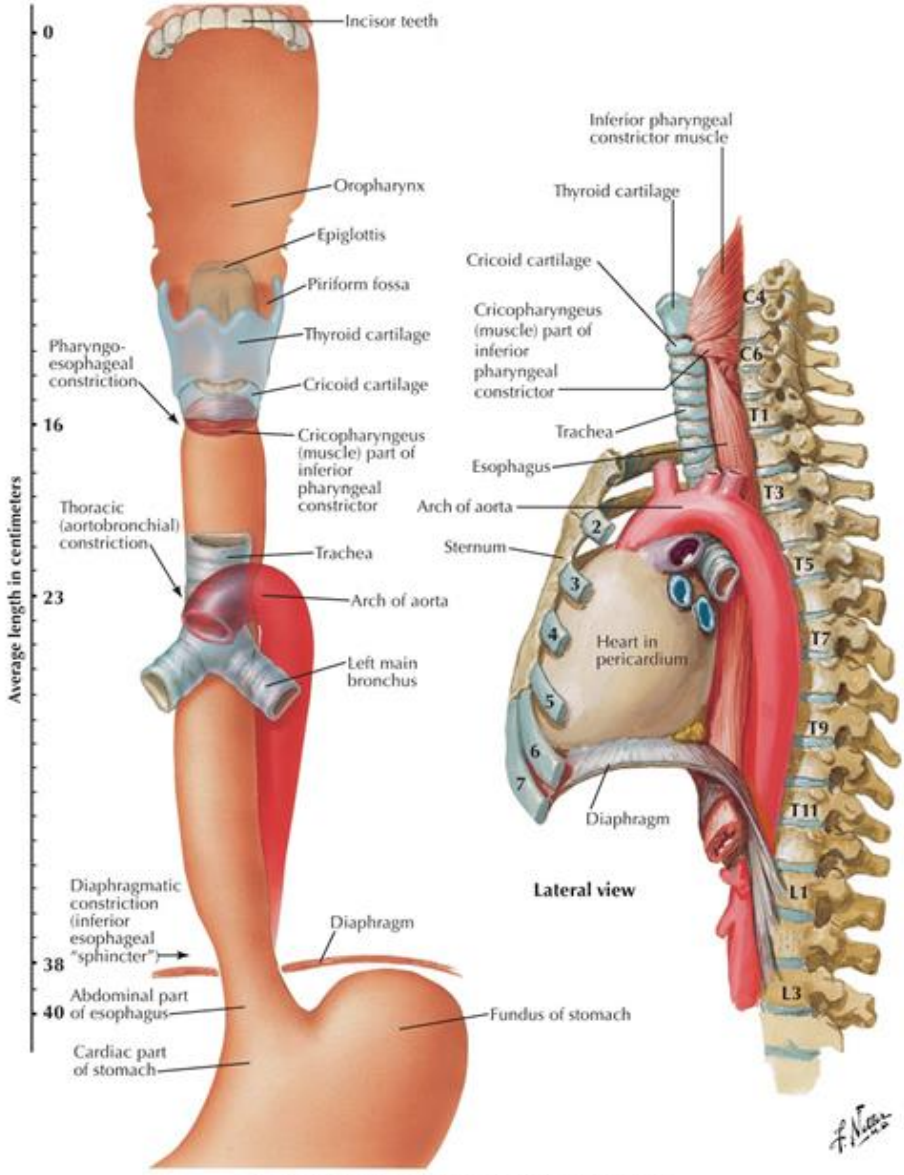

Fig. 1.2 Topography and Constrictions of Esophagus.

become elliptical once again, but they now have a reverse inclination—that is, the posterior part of the ellipse is located at a lower level than the anterior part. In the lower third of the esophagus, the fibers follow a spiral course down the esophagus. The elliptical, circular, and spiral fibers of this layer are not truly uniform and parallel but may overlap and cross, or they may even have clefts between them. Some fibers in the lower two thirds of the esophagus pass diagonally or perpendicularly, up or down, joining fibers at other levels. These branched fibers are 2 to 3 mm wide and 1 to 5 cm long and are not continuous.

The cricopharyngeus muscle marks the transition from pharynx to esophagus. It is the lowest portion of the inferior constrictor of the pharynx and consists of a narrow band of muscle fibers that originate on each side of the posterolateral margin of the cricoid cartilage. The cricopharyngeus then passes slinglike around the dorsal aspect of the pharyngoesophageal (PE) junction. Upper fibers ascend and join the median raphe of the inferior constrictor muscle posteriorly. Lower fibers do not have a median raphe; they pass to the dorsal aspect of the PE junction. A few of these fibers pass down to the esophagus. The

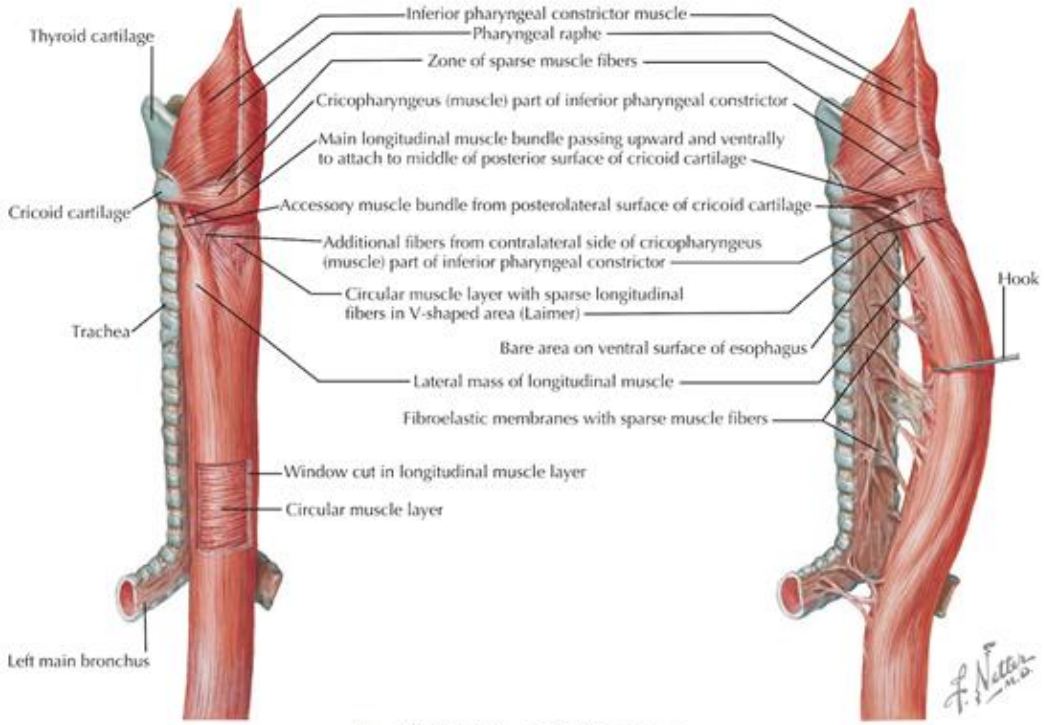

Fig. 1.3 Musculature of the Esophagus.

cricopharyngeus functions as a sphincter of the upper esophagus. Muscle tone of the esophageal lumen is greatest at the level of the cricopharyngeus, and relaxation of this muscle is an integral part of the act of swallowing. There is a weak area between the cricopharyngeus and the main part of the inferior constrictor where Zenker diverticula are thought to develop.

The upper 25% to 33% of the esophagus is composed of striated muscle, whereas the lower or remaining portion is smooth muscle. Within the second fourth of the esophagus is a transitional zone where striated muscle and smooth muscle are present. The lower half contains purely smooth muscle. Between the two muscular coats of the esophagus, a narrow layer of connective tissue is inserted that accommodates the myenteric plexus of Auerbach.

ARTERIAL BLOOD SUPPLY OF THE ESOPHAGUS

The blood supply of the esophagus is variable (Fig. 1.5). The inferior thyroid artery is the primary supplier of the cervical esophagus; esophageal vessels emanate from both side branches of the artery and from the ends of the vessels. Anterior cervical esophageal arteries supply small branches to the esophagus and trachea. Accessory arteries to the cervical esophagus originate in the subclavian, common carotid, vertebral, ascending pharyngeal, superficial cervical, and costocervical trunk.

Arterial branches from the bronchial arteries, the aorta, and the right intercostal vessels supply the thoracic esophagus. Bronchial arteries, especially the left inferior artery, distribute branches at or below the tracheal bifurcation. Bronchial artery branches are variable. The standard—two left and one right—occurs in only about 50% of patients. Aberrant vessel patterns include one left and one right in 25% of patients, two right and two left in 15%, and one left and two right in 8%. Rarely do three right or three left arteries occur.

At the tracheal bifurcation, the esophagus receives branches from the aorta, aortic arch, uppermost intercostal arteries, internal mammary artery, and carotid artery. Aortic branches to the thoracic esophagus usually consist of two unpaired vessels. The cranial vessel is 3 to 4 cm long and usually arises at the level of the sixth to seventh thoracic vertebrae (T6-T7). The caudal vessel is longer, 6 to 7 cm, and arises at the level of T7 to T8. Both arteries pass behind the esophagus and divide into ascending and descending branches. These branches anastomose along the esophageal border with descending branches from the inferior thyroid and bronchial arteries, as well as with ascending branches from the left gastric and left inferior phrenic arteries. Right intercostal arteries, mainly the fifth, give rise to esophageal branches in approximately 20% of the population.

The abdominal esophagus receives its blood supply from branches of the left gastric artery, the short gastric artery, and a recurrent branch of the left inferior phrenic artery. The left gastric artery supplies cardioesophageal branches either through a single vessel that subdivides or through two to five branches before they divide into anterior and posterior gastric branches. Other arterial sources to the abdominal esophagus are (1) branches from an aberrant left hepatic artery, derived from the left gastric, an accessory left gastric from the left hepatic, or a persistent primitive gastrohepatic arterial arc; (2) cardioesophageal branches from the splenic trunk, its superior polar, terminal divisions (short gastrics), and its occasional large posterior gastric artery; and (3) a direct, slender, cardioesophageal branch from the aorta, celiac, or first part of the splenic artery.

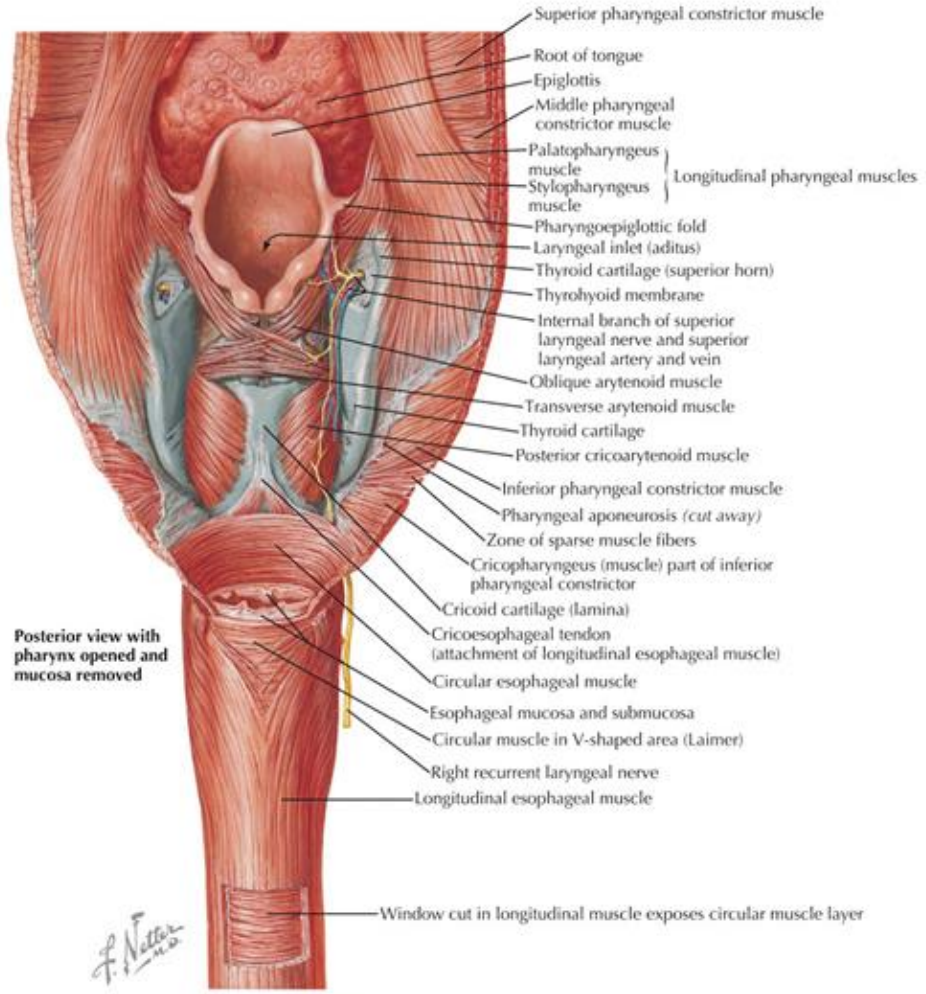

Fig. 1.4 Pharyngoesophageal Junction.

With every resection surgery, areas of devascularization may be induced by (1) excessively low resection of the cervical segment, which always has a supply from the inferior thyroid; (2) excessive mobilization of the esophagus at the tracheal bifurcation and laceration of the bronchial artery; and (3) excessive sacrifice of the left gastric artery and the recurrent branch of the inferior phrenic artery to facilitate gastric mobilization. Anastomosis around the abdominal portion of the esophagus is usually copious, but sometimes it is limited.

VENOUS DRAINAGE OF THE ESOPHAGUS

Venous drainage of the esophagus begins in small tributaries that eventually empty into the azygos and hemiazygos veins (Fig. 1.6). Drainage begins in a submucosal venous plexus that exits externally to the surface of the esophagus. Tributaries from the cervical periesophageal venous plexus drain into the inferior thyroid vein, which empties into the right or left brachiocephalic (innominate) vein, or both. Tributaries from the thoracic periesophageal plexus on the right side join the azygos, the right brachiocephalic, and occasionally the vertebral vein; on the left side, they join the hemiazygos, the accessory hemiazygos, the left brachiocephalic, and occasionally the vertebral vein. Tributaries from the short abdominal esophagus drain into the left gastric (coronary) vein of the stomach. Other tributaries are in continuity with the short gastric, splenic, and left gastroepiploic veins. They may also drain to branches of the left inferior phrenic vein and join the inferior vena cava (IVC) directly or the suprarenal vein before it enters the renal vein.

The composition of the azygos system of veins varies. The *azygos vein* arises in the abdomen from the ascending right lumbar vein, which receives the first and second lumbar and the subcostal veins. The azygos may arise directly from the IVC or may have connections with the right common iliac or renal vein. In the thorax, the azygos vein receives the right posterior intercostal veins from the fourth to eleventh spaces and terminates in the superior vena cava (SVC). The highest intercostal vein drains into the right brachiocephalic vein or into the

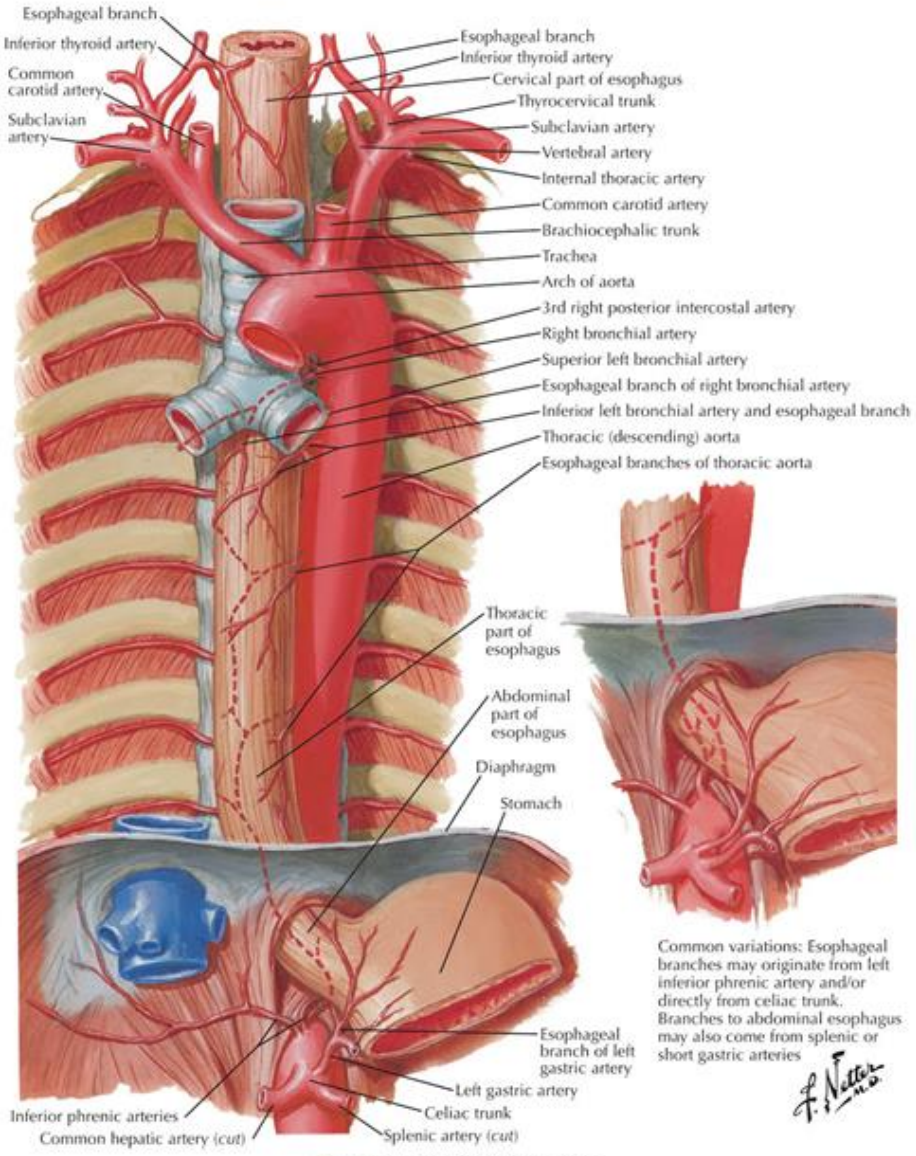

Fig. 1.5 Arteries of the Esophagus.

vertebral vein. Veins from the second and third spaces unite in a common trunk, the right superior intercostal, which ends in the terminal arch of the azygos.

The *hemiazygos vein* arises as a continuation of the left ascending lumbar or from the left renal vein. The hemiazygos receives the left subcostal vein and the intercostal veins from the eighth to the eleventh spaces, and then it crosses the vertebral column posterior to the esophagus to join the azygos vein.

The accessory hemiazygos vein receives intercostal branches from the fourth to the eighth intercostal veins, and it crosses over the spine and under the esophagus to join the hemiazygos or the azygos vein. Superiorly, the accessory hemiazygos communicates with the left superior intercostal that drains the second and third spaces, and ends in the left brachiocephalic vein. The first space drains into the left brachiocephalic or vertebral vein. Often the hemiazygos, the accessory hemiazygos, and the superior intercostal trunk form a continuous longitudinal channel with no connections to the azygos. There may be three to five connections between the left azygos, in which case a hemiazygos or an accessory hemiazygos is not formed. If the left azygos system is very small, the left venous drainage of the esophagus occurs through its