

## THE VEINS OF THE OESOPHAGUS

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Among the early anatomists, Vesalius (1543) pictured the oesophageal branches of the left gastric vessels lying close to the vagus nerves. According to Bartholin (1673) the veins of the oesophagus drain into the azygos, intercostal, and jugular veins. Dionis (1703) was probably the first to point out that the veins of the oesophagus drain into the left gastric vein. Portal (1803) described oesophageal veins going to the main veins of the neck and thorax, including the bronchial veins, and to the left gastric vein.

According to Preble (1900), Fauvel reported the first case of rupture of oesophageal varices in cirrhosis of the liver in 1858. This stimulated a considerable amount of interest in the anastomoses between the portal and systemic veins, and a number of French investigators examined the veins of the oesophagus from this point of view (Kundrat, 1886; Dusaussay, 1877; Duret, 1878; and Mariau, 1893). Their accounts are at variance on many points, particularly with regard to the area of the oesophagus draining into the portal vein. Kundrat regarded the lower one-third of the oesophagus as draining into the portal vein; according to Dusaussay and Mariau the lower two-thirds did so. None of these investigators mentioned valves or discussed the possible effect of pressure differences between the portal and systemic veins. They also disagreed as to the relative size, pattern, and drainage routes of the peri-oesophageal and submucous venous plexuses. Mariau alone mentioned longitudinal veins running with the vagus nerves on the outer surface of the oesophagus.

Kegaries (1934) stated that there was no peri-oesophageal plexus but only three to four longitudinal veins on the outer surface of the oesophagus, but he did not mention their relationship to the vagus nerves. Cross anastomoses between these veins were uncommon. The submucosa contained many veins lying both deep and superficial to the muscularis mucosae. Fine longitudinal veins connected the submucous venous plexuses of the stomach and oesophagus. They began at the cardia and ran for 4 to 5 cm. along the oesophagus and were not connected by cross anastomoses. It is not clear from his description whether these veins were deep or superficial to the muscularis mucosae. They drained into the left gastric vein by vessels which passed obliquely through the wall of the oesophagus. The appearance of some specimens suggested that the fine anastomotic channels in the submucosa may occasionally be absent. The left gastric vein received a peri-oesophageal branch which joined it just below the cardia.

Connexions between the pulmonary veins and the veins of the mediastinum, including the veins of the oesophagus, have been described, and the relevant litera-

ture has been well surveyed by Zuckerkandl (1881) and Konaschko (1929). The first-named writer gives good pictures of the veins on the surface of the thoracic oesophagus and their terminations in the left gastric, phrenic, azygos, and bronchial veins.

In 1887 Bimar and Lapeyre described a circumscribed venous plexus on the dorsal wall of the pharynx between the mucous membrane and the inferior constrictor muscle. It formed an oval disc 3 cm. long, 2.5 cm. wide, and 4 to 5 mm. thick. The large extremity of the oval was uppermost. It consisted of many veins lying close to each other and connected by many cross anastomoses. The individual veins were 1 to 3 mm. in diameter and frequently varicose, bearing ampulla-like dilatations. The plexus received tributaries from the pharynx and oesophagus, and drained into the superficial pharyngeal plexus by vessels which passed through "buttonholes" in the inferior constrictor muscles. The plexus was found in individuals from birth to old age and in both sexes.

Luschka (1869 and 1871) gave a more detailed description of this plexus, and noted that it had a ventral part lying on the dorsal aspect of the cricoid cartilage. He named the two parts of this plexus the pharyngo-laryngeal plexus. He confirmed the routes of drainage of the dorsal part of the plexus, and showed that the ventral plexus drained into the lingual and superior laryngeal veins. He noted that these plexuses were at the level of the narrowest part of the pharynx, and suggested that they formed a barrier which could be easily overcome by a bolus of food. In his paper of 1871 he definitely stated that there is no muscular sphincter at the mouth of the oesophagus and that it is closed by distension of these veins.

Elze (1918) and Elze and Beck (1918) gave a still more detailed account of these veins, noting that they had no connexion with the larynx except in so far as the dorsal wall of the larynx formed the ventral wall of the hypopharynx. They used the term "rete mirabile of the hypopharynx."

According to these authors the rectangular ventral rete extended only half-way down the posterior surface of the cricoid cartilage and not to its lower margin as shown by Luschka (1869). They emphasized the dilatation and coiling of the individual veins which are connected by numerous cross anastomoses. They also stressed the fact that the ventral rete occupies the middle part of the posterior surface of the cricoid cartilage and that, laterally, the pyriform sinuses and the sulci pharyngo-laryngei are free from large veins. The blood flow, in both parts of the rete, is directed cranially by means of valves.

The two parts of the rete are not level with each other, but the ventral rete begins at the level of the cranial margin of the dorsal rete. This produces a step-like bend in the lumen of the hypopharynx when seen in sagittal section, as shown in their Fig. 4. Their Fig. 1, however, shows the two parts of the rete to be on the same level as is shown in the figure given by Luschka (1869).

They regard the swelling produced by distension of these veins as producing closure of the middle part of the lumen of the hypopharynx and so acting as a functional continuation of the epiglottis and separating the two lateral food channels. Killian (1908) described the dorsal lip of the mouth of the oesophagus as either a sharp ridge or a blunt pad-like swelling due to the contraction of the caudal fibres of the inferior constrictor muscle, the so-called crico-pharyngeus muscle. According to Elze and Beck (1918) this dorsal lip is due to the distension of the dorsal part

of the rete with blood, and the "tonus" of the ridge is due to the pressure of the contained blood. They regard pulsion diverticula of the pharynx as being herniations through the gaps in the inferior constrictor muscle for the passage of the efferent veins.

#### MATERIAL AND METHODS

The following material was used: 21 human foetuses ranging in age from 11 to 40 weeks; 17 formalin-preserved specimens of pharynx, larynx, and upper oesophagus from dissecting-room subjects; 12 fresh specimens of pharynx, larynx, and upper oesophagus from the post-mortem room. Two fresh specimens of stomach and oesophagus from the post-mortem room.

Thirteen of the foetuses were injected with India ink in reconstituted dried plasma as recommended by Davies and Edwards (1948). These sites of injection were used: femoral vein (4), a main artery (5), umbilical vein (once), and the portal vein (3). The pressure of injection varied from 10 to 130 mm. Hg for 20 to 60 minutes. All the specimens were dissected after preservation in 5% formalin, and in some cases the oesophagus, pharynx, larynx, and stomach were cleared whole in either benzyl benzoate or oil of wintergreen.

Transverse and longitudinal sections were made from specimens of oesophagus, pharynx, and larynx and the junction of stomach and oesophagus. Material from uninjected specimens was cut in wax at 8 to 25  $\mu$ ; injected material was cut in celloidin at 100 to 200  $\mu$ .

The fresh specimens from the post-mortem room were injected with "neoprene" latex 601A at pressures varying from 40 to 100 mm. Hg. The time taken for injection was from 10 to 30 minutes. The latex was coagulated by immersion in weak formalin for one to two hours before dissection. Final preservation was in Kaiserling 3.

#### OBSERVATIONS

The veins of the oesophagus may be conveniently classified as follows:

**INTRINSIC VEINS.**—These veins are found within the walls of the oesophagus and include (a) a sub-epithelial plexus in the lamina propria; (b) a submucous plexus on the outer aspect of the muscularis mucosae; (c) perforating veins which pierce the muscular wall of the oesophagus.

**THE VENAE COMITANTES OF THE VAGUS NERVES.**—These are longitudinal veins in the adventitia of the oesophagus running with the vagus nerves.

**EXTRINSIC VEINS.**—These are formed by the union of groups of perforating veins and terminate in the large veins of the neck and thorax and the left gastric vein.

(a) *The Sub-epithelial Venous Plexus.*—This plexus lies in the lamina propria close to the epithelium and extends for the whole length of the oesophagus. In the full-term foetus it consists of veins between 10 and 50  $\mu$  in diameter, the average being 30  $\mu$  (Fig. 1). In the adult these veins are up to 170  $\mu$  in diameter. They form a coarse polygonal meshwork with the mesh slightly elongated in the line of the long axis of the oesophagus (Fig. 2A). In the full-term foetus the mesh is approximately 90 to 150  $\mu$  by 30 to 50  $\mu$ . The pattern of this plexus is uniform for the greater part of the oesophagus, but changes at the extreme upper and lower ends. The pattern is more irregular in the adult. It receives its blood supply from the scanty capillary network formed in the lamina propria by the terminal branches

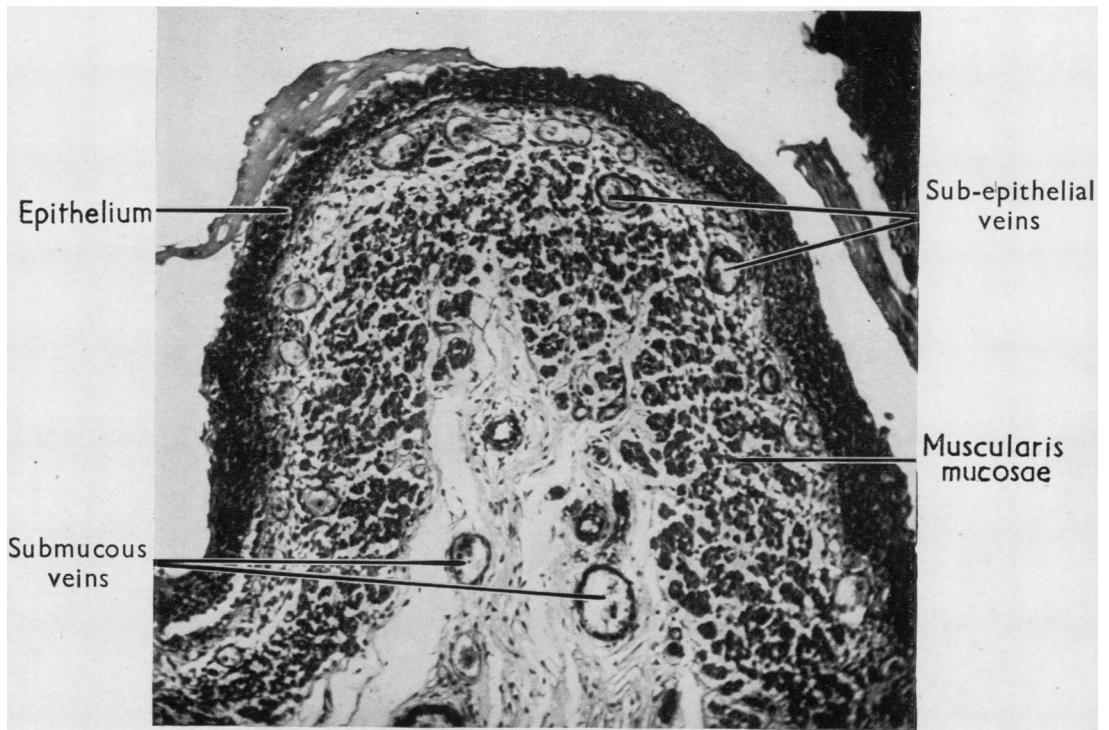


FIG. 1.—Transverse section of the oesophagus of a full-term foetus showing the sub-epithelial veins. H. and E.,  $\times 126$ .

of the oesophageal arteries. Throughout its extent this plexus drains into the larger veins of the submucosa by numerous short veins which pierce the muscularis mucosae. No evidence of the presence of valves was found in this plexus, either in the foetus or the adult.

In the last half-inch of the oesophagus in the full-term foetus the polygonal meshwork was replaced by a more longitudinal arrangement of the veins. These veins are connected by only scanty cross anastomoses (Fig. 2B). This zone is not always clearly seen in the adult. When present this pattern terminates abruptly at the level of the cardia where the veins join the denser subglandular venous plexus of the stomach, thus forming a large number of small connexions between the portal and systemic venous systems (Fig. 2C). The subglandular venous plexus of the stomach was first described in the dog by Mall (1896), and it lies between the muscularis mucosae and the bases of the gastric glands. In the full-term foetus these veins average  $50 \mu$  in diameter.

At the caudal margin of the cricoid cartilage the muscularis mucosae thins out and ends so that the lamina propria merges with the submucosa. The sub-epithelial veins are again more longitudinal in position with scanty cross anastomoses. They join the deeper veins and also the scanty and irregular sub-epithelial plexus of the pharynx.

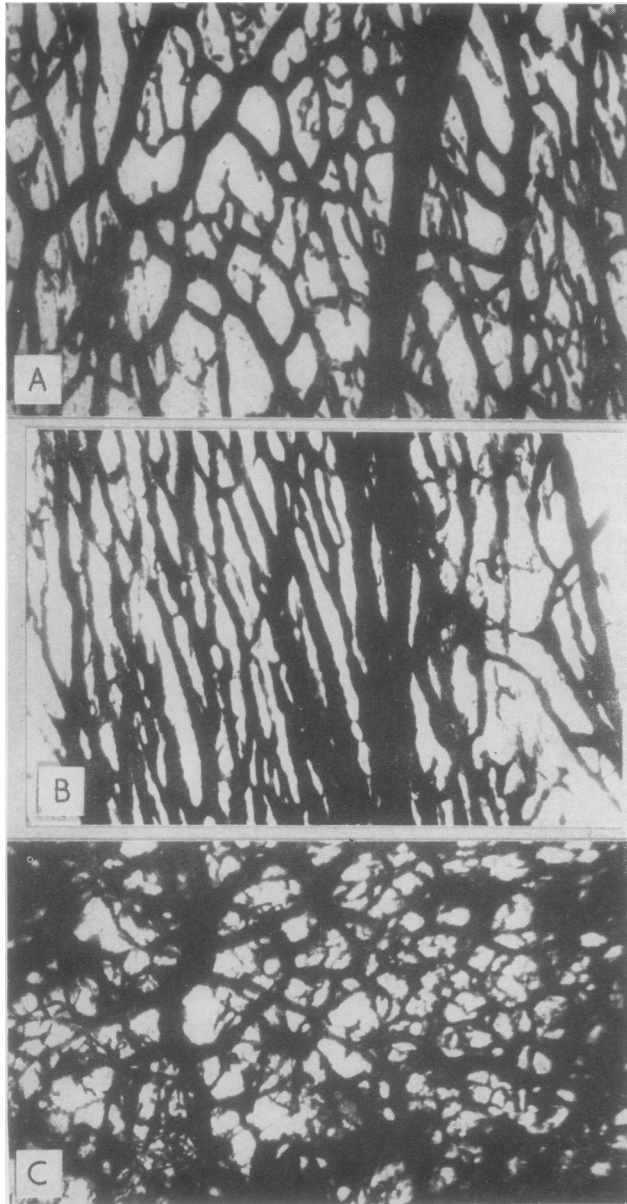


FIG. 2.—Strips of mucous membrane from the oesophagus and stomach injected with India ink and cleared in benzyl benzoate. All  $\times 41$ . (A) Middle third of the oesophagus showing the plexiform sub-epithelial venous plexus. (B) Oesophagus immediately proximal to the cardia showing the longitudinal sub-epithelial veins. (C) Gastric mucosa showing the subglandular venous plexus.

(b) *The Submucous Venous Plexus.*—Numerous small veins pierce the muscularis mucosae where they turn to run longitudinally and unite in groups to form larger vessels. These in turn unite to form 10 to 15 longitudinal veins which lie midway between the muscularis mucosae and the circular muscle coat. They are connected by numerous cross anastomoses. They are 50  $\mu$  in diameter in the full-term foetus and up to 1 mm. in the adult. They are evenly distributed around the circumference of the oesophagus and run for its whole length.

At the lower end of the oesophagus these veins increase in number but decrease in diameter, becoming congregated in the four or five longitudinal folds of the mucosa which begin a short distance above the cardia. In these folds the veins are markedly tortuous, and they connect the submucous veins of the oesophagus to those of the stomach, thus forming another set of anastomoses between the portal and systemic venous systems. At, or just above, the level of the cardia valves may be found in the oesophageal veins, but they are inconstant. If present they are so orientated that they direct the blood flow from the oesophagus to the stomach.

In the upper one-third of the oesophagus the submucous veins increase in diameter and become reduced to about seven or eight veins arranged in dorsal and ventral groups. Each group consists of from one to five veins lying close to the midline, thus leaving two triangular areas of submucosa free from large veins. The apex of each triangle is directed caudally and its base is continuous with the submucosa of the pyriform sinus, which is also bare of large veins.

Each group of submucous veins drains into the corresponding dorsal or ventral part of the pharyngo-laryngeal plexus or rete mirabile of the hypopharynx. The smaller ventral part lies in the submucosa covering the dorsal surface of the cricoid cartilage (Fig. 3). It lies upon the medial part of the oblique and transverse arytenoid muscles and the tendon of origin of the longitudinal muscle of the oesophagus. The veins form two longitudinal masses on each side of the midline separated by a gap which varies from 2 to 6 mm. Each half of the plexus is 2 cm. wide and extends the whole length of the cricoid cartilage. Towards the cranial margin of the cricoid cartilage the two halves of the plexus are united by numerous cross anastomoses which are, for the most part, embedded in a mass of mucous glands. They may, if the midline gap is large, reach to the lateral borders of the cricoid cartilage, but in no case did these large veins extend into the pyriform sinuses. The only large veins in the pyriform sinuses are one or two small efferent veins from the plexus which are seen in the cranial end of the sinuses (Fig. 3).

The individual veins are slightly tortuous, but show fusiform and globular dilations which give them a varicose appearance. They are up to 4 mm. in diameter in the adult. Their varicose appearance is normal and is seen in specimens of all ages. From the most cranial cross anastomosis between the two halves of the plexus one or two efferent veins arise on each side, and these have a much smaller calibre than the individual veins of the plexus. They run cranially and laterally on to the cranial end of the floor of the pyriform sinuses to join the superior laryngeal veins just before these veins pierce the thyro-hyoid membrane. Smaller veins continue in a cranial direction, cross the pharyngo-epiglottic folds into the valleculae, and join the lingual veins on the dorsum of the tongue. Valves in the superior laryngeal veins and the afferent veins from the oesophagus direct the blood flow in

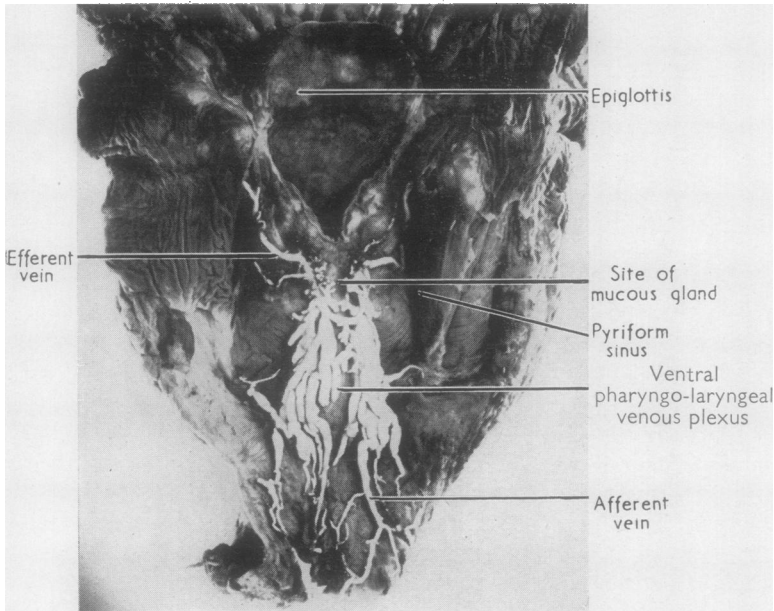


FIG. 3.—The ventral part of the pharyngo-laryngeal venous plexus of an adult. Injected with “neoprene” latex 601A and exposed by removal of the mucous membrane. Natural size.

a cranial direction. A few small veins connect the dorsal and ventral parts of the rete, but, owing to their very small size, it is impossible to inject one part from the other.

As the dorsal group of submucous veins of the oesophagus reaches the level of the caudal margin of the cricoid cartilage it joins a triangular mass of dilated and tortuous veins forming the dorsal part of the rete (Fig. 4). The base of the triangle is concave, with the concavity facing cranially, and it lies on the same horizontal level as the cranial margin of the cricoid cartilage. The height of the triangle is 1.5 to 2.5 cm. and the base is 2.0 cm. in the adult, while it is 1.0 cm. high and 0.5 cm. across the base in the full-term foetus.

The individual veins measure up to 4.0 mm. diameter and are dilated with frequent varicosities. These varicosities are found in both sexes at all ages and must be regarded as a normal feature. The general direction of the veins is longitudinal, but they are joined by many cross anastomoses. In one specimen the veins had become confluent to form a triangular space with fine trabeculae joining the dorsal and ventral surfaces. The plexus lies in the submucosa and is separated from the epithelium by a thick layer of white fibrous tissue. The dorsal surface of the plexus is embedded in the deep surface of the inferior constrictor muscle. When distended this plexus raises a smooth swelling on the dorsal wall of the hypopharynx immediately above the slit-like orifice of the oesophagus.

The main efferent veins of the plexus are as follows:

(1) From each end of the base of the triangle one or two veins run cranially and laterally towards the posterior border of the thyroid cartilage. They pierce the pharyngeal wall obliquely and join either the superficial pharyngeal plexus or the plexus of veins on the surface of the upper pole of the thyroid gland. (2) A median unpaired vein, which arises from the middle of the cranial margin of the plexus, pierces the inferior constrictor muscle very obliquely in a cranial direction, and joins the superficial pharyngeal plexus. By both these routes the blood eventually enters and internal jugular veins (Figs. 4 and 5).

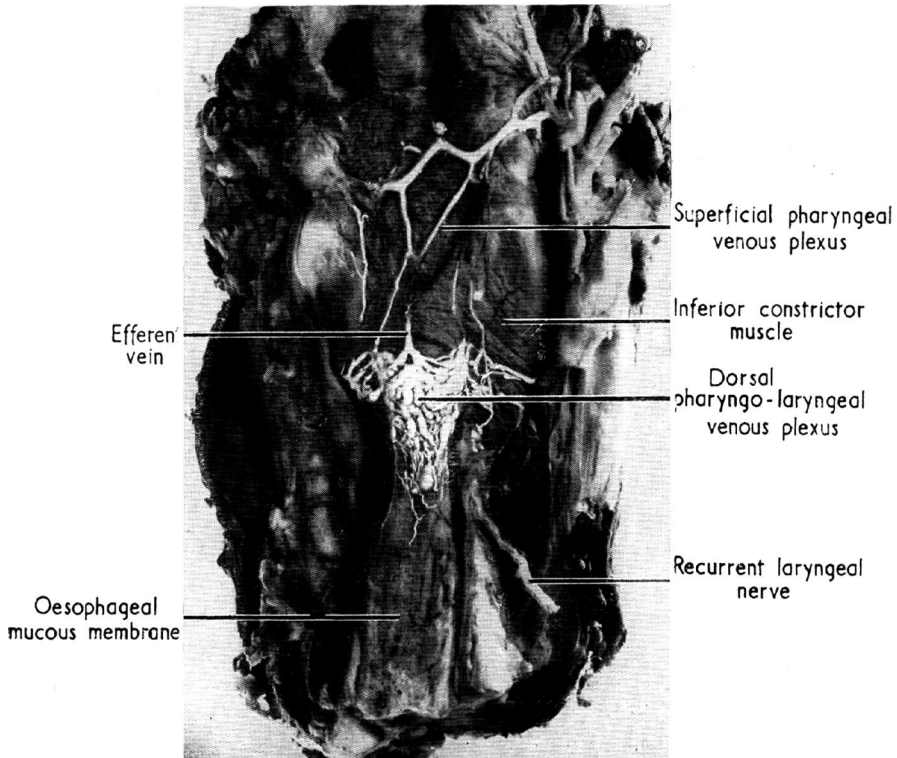


FIG. 4.—The dorsal part of the pharyngo-laryngeal and the superficial pharyngeal venous plexuses injected with "neoprene" latex 601A. The dorsal pharyngo-laryngeal plexus has been exposed from behind by removing the caudal part of the inferior constrictor muscle and the muscle of the dorsal surface of the oesophagus. Natural size.

Either just before, or immediately after, they have pierced the pharyngeal wall, the efferent veins have valves which direct the blood flow into the superficial pharyngeal plexus. This plexus is so valved that the blood flow is into the internal jugular veins. Valves are sometimes found in the afferent veins from the oesophagus, and these, when present, direct the blood from the oesophagus to the dorsal rete. Valves were found in adults of all ages and were first seen in a 10-weeks-old foetus.

The rete was found in all the adults examined, and these ranged in age from 43 to 85 years. It is always found in the full-term foetus, in which it is relatively



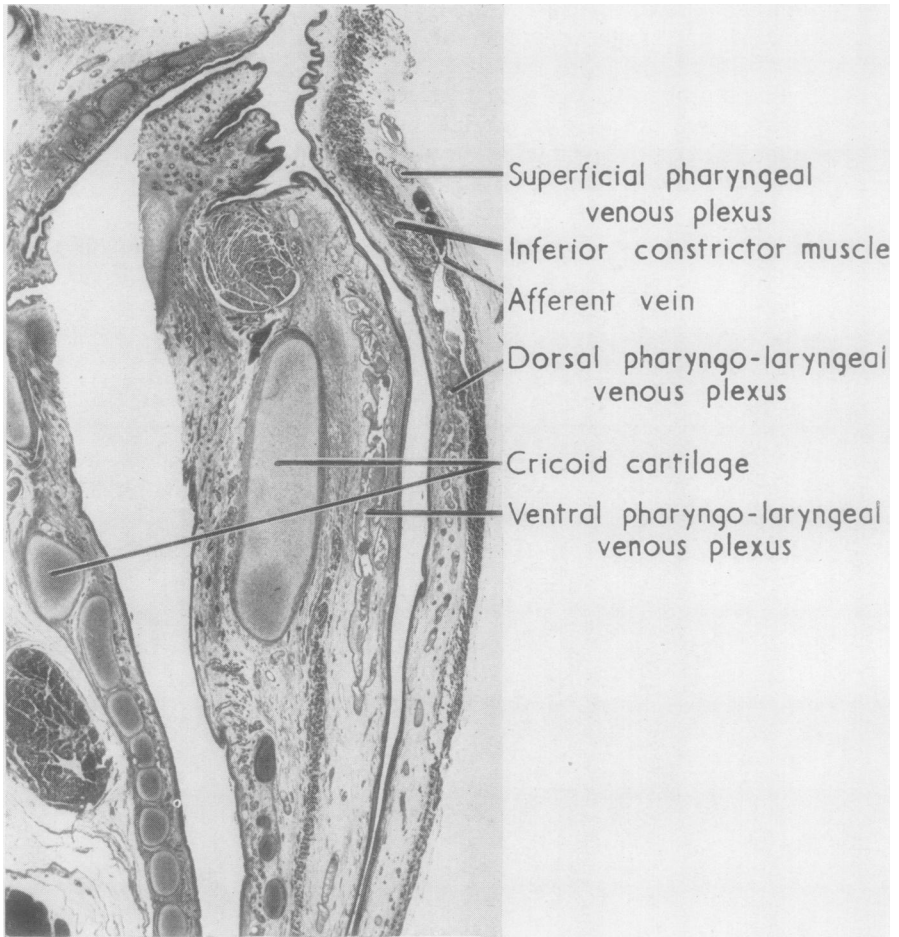


FIG. 5.—Sagittal section of the hypopharynx and larynx of a full-term foetus to show the extent and relations of the dorsal and ventral parts of the pharyngo-laryngeal venous plexuses. H. and E.,  $\times 9.9$ .

larger than in the adult. It begins to develop in the 30-mm. (8- to 10-week) embryo. The features of the rete are alike in both male and female.

(c) *The Perforating Veins.*—At frequent intervals large veins arise from the longitudinal submucous veins and perforate the muscle coats of the oesophagus to reach its outer surface. They receive tributaries from the muscle coats. Most of them reach the outer surface along the right and left borders of the oesophagus in close proximity to the recurrent laryngeal nerves and the oesophageal plexuses of the vagus nerves. They frequently run for short distances on the surface of the oesophagus before uniting in twos and threes to form the extrinsic veins. At their point of exit from the muscle they have valves which direct the blood outwards.

THE VENAE COMITANTES OF THE VAGUS NERVES.—Two longitudinal veins run on the outer surface of the oesophagus in close proximity to the oesophageal plexuses of the vagus nerves and their caudal continuations, the anterior and posterior gastric nerves. Caudal to the bifurcation of the trachea, these veins follow the spiral course

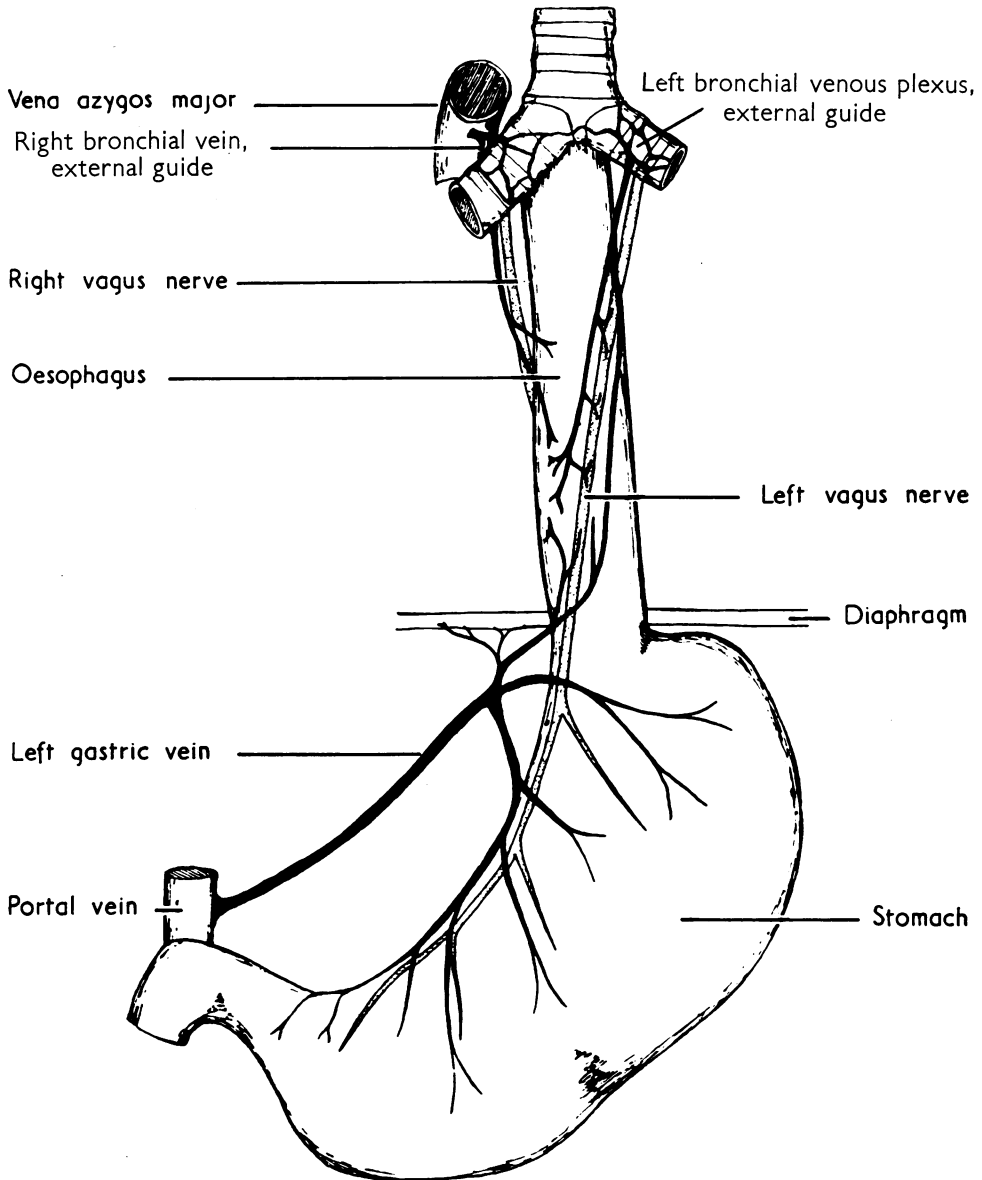


FIG. 6.—Diagram of the venae comitantes of the vagus nerves connecting the left gastric vein to the azygos and bronchial veins.

of the nerves around the oesophagus. They connect the left gastric vein to the azygos veins, either directly or via the posterior bronchial veins. Caudally the right or posterior vein begins as a posterior oesophageal branch of the left gastric vein on the posterior surface of the abdominal oesophagus and it runs with the posterior gastric nerve. It then takes a slightly spiral course across the posterior surface of the oesophagus to reach its right border close to the caudal aspect of the right bronchus. In this part of its course the vein runs with a main branch of the right vagus nerve, or it may divide into two or more branches, each of which is in close proximity to a nerve. It receives tributaries from the venous plexuses of the nerves and the oesophagus. It terminates by joining the vena azygos major, the right posterior bronchial vein, or the venous plexus on the surface of the right bronchus (Fig. 6).

The left or anterior vein begins in a similar manner on the anterior surface of the oesophagus, and runs with the branches of the left oesophageal nerve plexus. It terminates in either the hemi-azygos vein or the left posterior bronchial vein. In a 20-week foetus the right vein was  $150\ \mu$  in diameter at the level of the diaphragm (Fig. 7). An ascending branch of the left gastric artery accompanies each gastric

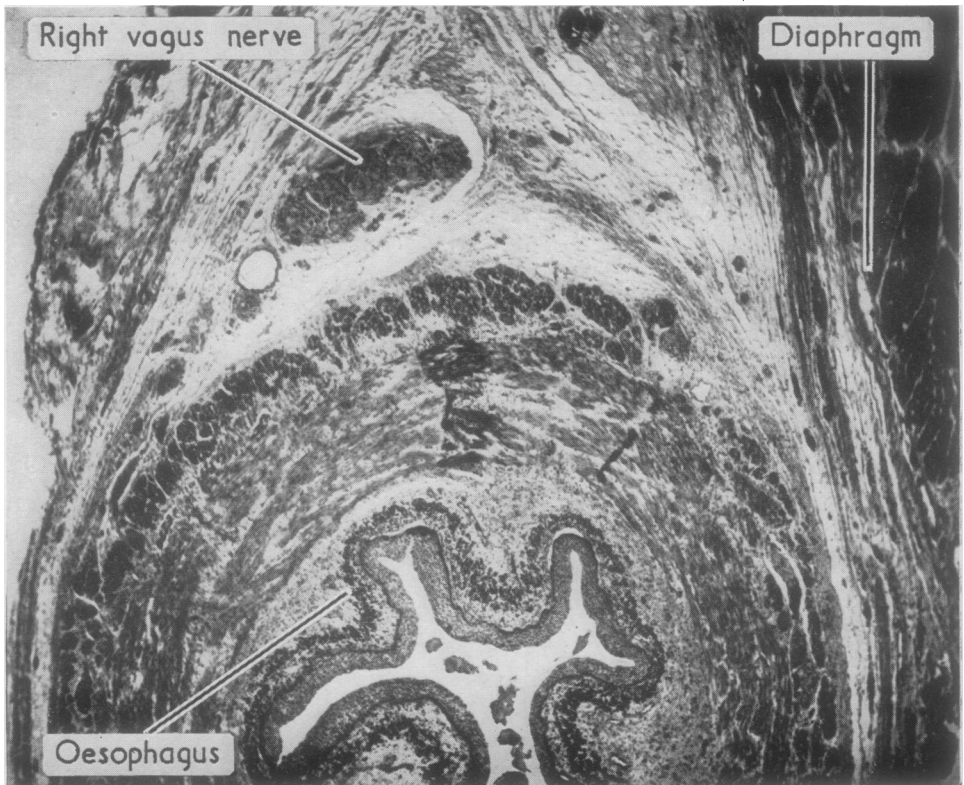


FIG. 7.—Transverse section of the oesophagus of a 20-week foetus at the level of the diaphragm showing the vein and artery running with the right vagus nerve. H. and E.,  $\times 33.75$ .

nerve and anastomoses with a descending branch from the bronchial artery. These arteries supply the nerves and the oesophagus.

**THE EXTRINSIC VEINS.**—These are discussed in three regions.

*In the Neck.*—The extrinsic veins of the cervical (Fig. 8) oesophagus arise mainly along its lateral borders close to the recurrent laryngeal nerves. They run laterally

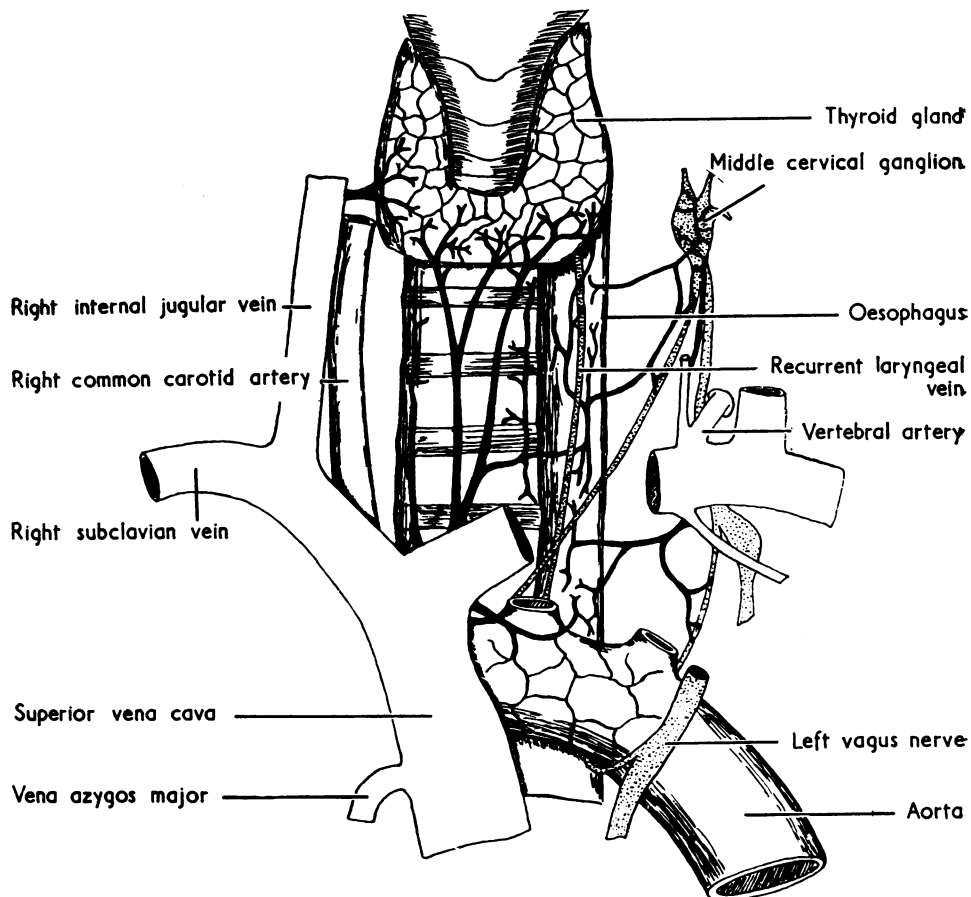


FIG. 8.—Diagram of the extrinsic veins of the oesophagus in the neck. Portions of the left innominate vein and left common carotid and left subclavian arteries have been removed.

and medially to their terminations, passing either deep or superficial to the recurrent nerves. They terminate as follows:

One to three veins cross the anterior surface of the trachea to join the inferior thyroid veins. They receive tributaries from the thymus gland and the venous plexus on the surface of the trachea.

A vein runs cranially in close contact with the recurrent laryngeal nerve to join the venous plexus on the surface of the lower pole of the thyroid gland.

A group of small veins run laterally to join the vertebral and anterior deep cervical veins, either directly or via the venous plexus around the middle cervical ganglion. These veins are situated very close to the cardiac and oesophageal branches of these ganglia.

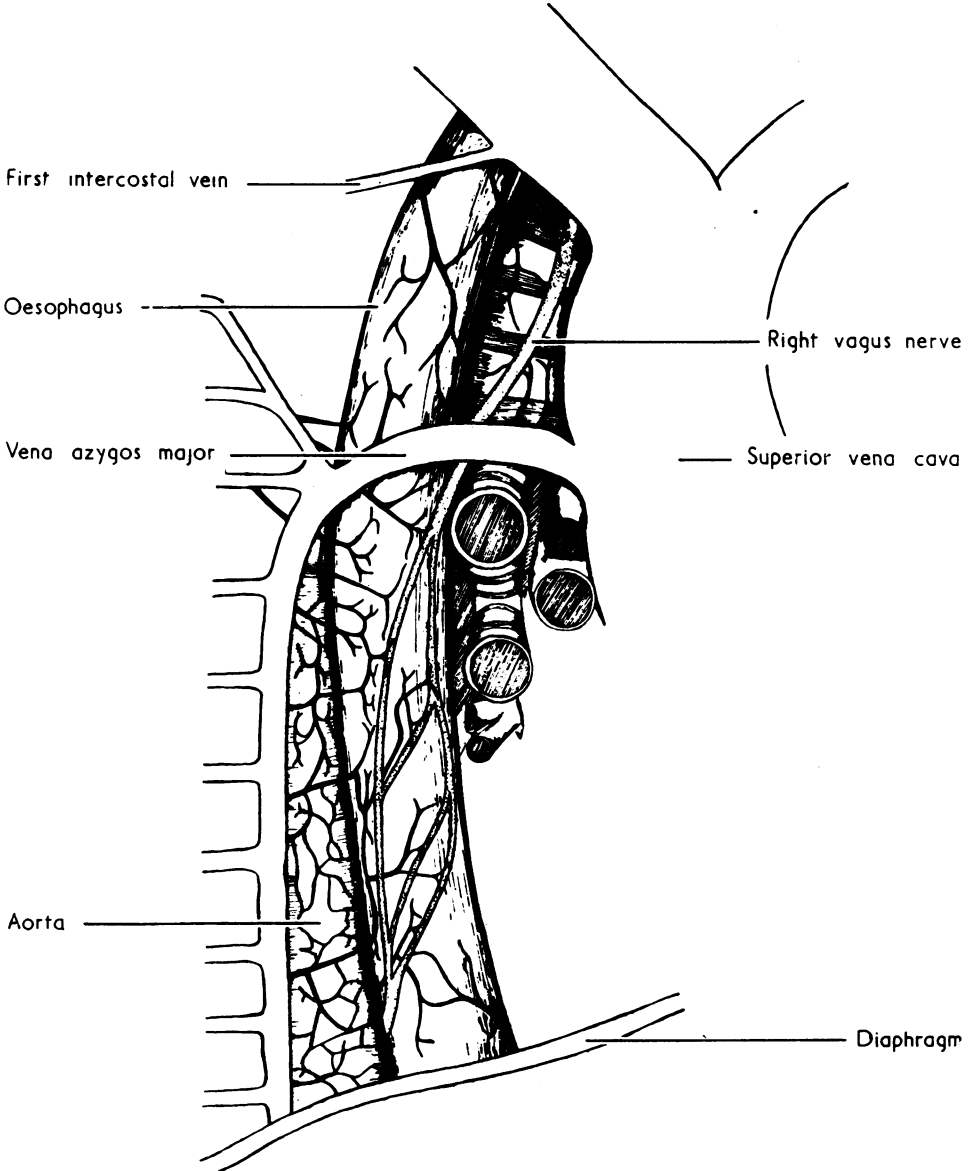


FIG. 9.—Diagram of the extrinsic veins of the right side of the thoracic oesophagus. The venae comitantes of the vagus nerve have been omitted.

Several small veins pass directly from the anterior surface of the oesophagus to the peri-tracheal venous plexus.

The exact number and disposition of these veins vary from side to side and from specimen to specimen. Valves, when present, direct the blood flow away from the oesophagus.

*In the Thorax.*—Most of the veins draining the thoracic oesophagus join the azygos veins and their tributaries. The following veins may be found on the right side (Fig. 9):

Just below the level of the first rib a vein runs cranially and laterally to join the first intercostal vein before this vein joins the right innominate or vertebral vein. This vein also drains the lowest part of the cervical oesophagus. It lies close to the cardiac branch of the inferior cervical ganglion.

The remainder of the oesophagus above the level of the arch of the vena azygos major is drained by two veins running in a caudal and posterior direction. They join the right superior intercostal vein and the arch of the vena azygos major.

Caudal to the arch of the vena azygos major the oesophagus is drained by eight to ten veins which arise along its right border. They mainly join the medial aspect of the vena azygos major, but occasionally pass dorso-medial to this vein to join an intercostal vein. They do not have a strictly segmental arrangement. Sometimes they form venous rings around the intercostal arteries. Between the aorta and the vena azygos major they pass dorsal to the thoracic duct. The most cranially situated of these veins join the caudal side of the arch of the vena azygos major close to the right posterior bronchial vein and the venae comitantes of the right vagus nerve. The remainder cross the right surface of the aorta, and as they lie upon this vessel they receive many tributaries from the rich peri-aortic venous plexus. Some of the oesophageal veins terminate in this plexus.

As the oesophagus pierces the diaphragm several small oesophageal veins join the superior and inferior phrenic veins.

The general arrangement is similar on the left side of the mediastinum except that the veins drain into the hemi-azygos veins. Where these veins are absent the oesophageal veins join the intercostal veins. The number of oesophageal veins is always fewer on the left side than on the right, especially if the hemi-azygos system is poorly developed. The maximum number found was eight, and this was in a foetus with an exceptionally well-developed hemi-azygos system (Fig. 10).

*In the Abdomen.*—Three or four oesophageal veins join the left gastric vein where it turns to the right to leave the lesser omentum and gain the posterior abdominal wall. These veins drain the abdominal oesophagus, the caudal part of the thoracic oesophagus, and the vagus nerves. The main anterior and posterior branches join the left gastric veins to the bronchial veins. A few small oesophageal veins join the inferior phrenic veins.

An attempt was made to demonstrate the anastomoses between the portal and systemic venous systems at the lower end of the oesophagus in three full-term foetuses. A ligature was placed on the portal vein as close as possible to where it divides into right and left branches, thus ensuring that the left gastric vein was intact and still in communication with the trunk of the portal vein. A cannula, pointing in the direction of normal blood flow, was inserted into the superior mesenteric

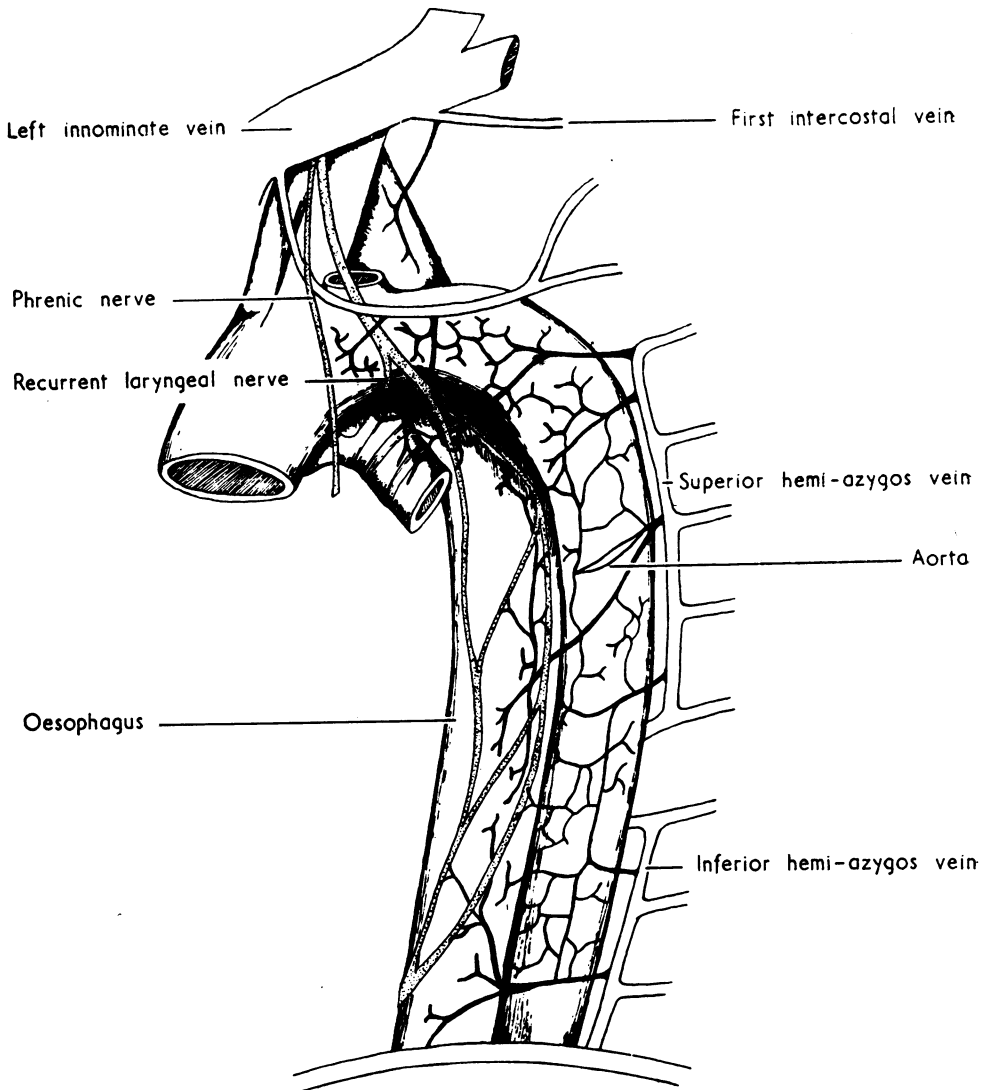


FIG. 10.—Diagram of the extrinsic veins of the left side of the oesophagus. The venae comitantes of the vagus nerve have been omitted.

vein, and India ink in reconstituted plasma was injected at a pressure of 30 to 40 mm. Hg. The normal portal pressure, measured when the abdomen is opened at operation, varies from 4 to 8 mm. Hg, and values over 11 mm. Hg are regarded as pathological (Walker, 1949). Thus the conditions of injection resembled acute portal venous obstruction.

In two foetuses, India ink passed from the veins of the stomach into those of the lowest half-inch of the oesophagus. The longitudinal veins which connect the sub-

epithelial venous plexus of the stomach and oesophagus were well injected, and beyond them the meshes of the sub-epithelial plexus had begun to fill. There appears to be no reason why the whole length of the sub-epithelial plexus of the oesophagus could not be injected in this manner. The injection faded out about half an inch above the cardia. Injection mass had also passed into the submucous veins of the oesophagus, but only for about a quarter of an inch above the cardia.

The oesophageal branches of the left gastric vein were well injected, and India ink had reached the azygos veins and the posterior bronchial veins via the *venae comitantes* of the vagus nerves. The resistance to the passage of the injection mass appears to be inversely proportional to the diameter of the vessels. The smaller distance of injection in the submucous veins as compared with the narrower sub-epithelial veins may be due to their tortuosity above the cardia.

In the third foetus no India ink passed beyond the level of the diaphragm, despite an excellent injection of the portal venous system. At first sight this seemed to be due to the presence of valves, but further examination suggested that it was due to agonal contraction of the diaphragm. Similar appearances were seen in uninjected stillborn infants.

#### DISCUSSION

The findings with regard to the arrangement of the veins in the wall of the oesophagus are in agreement with those of Kundrat (1886) and Kegaries (1934). As both these investigators showed, the submucous veins of the oesophagus and stomach are continuous at the cardia. The sub-epithelial veins of the oesophagus are continuous with the subglandular veins of the stomach by the zone of fine longitudinal sub-epithelial veins. These vessels form a series of anastomoses between the portal and systemic veins which lie in the inner wall of the oesophagus. They are of a much smaller diameter than the anastomoses on the outer surface of the oesophagus formed by the *venae comitantes* of the vagus nerves. The tortuosity of the submucous veins immediately above the cardia also impedes the passage of injection mass. Thus the anastomoses in the submucosa and the lamina propria offer more resistance than the *venae comitantes* of the vagus nerves, and, according to Walker (1949), the submucous veins become varicose before those upon the outer surface of the oesophagus. In portal venous obstruction it is common to find large varices of the submucous veins in the cardiac end of the stomach (Preble, 1900; McIndoe, 1928). Kegaries (1934) thought that this was due to the damming back of the blood by the fine submucous connexions at the cardia. This was borne out by the findings in two cases of portal venous obstruction in which the varices were injected. In both cases the sub-epithelial and the submucous veins of both stomach and oesophagus were dilated to form varices, but in one case the longitudinal sub-epithelial veins at the cardia were not conspicuous. This case showed very large varices in the cardiac end of the stomach, but in the other case the longitudinal sub-epithelial veins were conspicuously dilated and the gastric varices were much smaller. The varices produced in portal venous obstruction are very close to the lumen of the oesophagus, particularly the sub-epithelial ones, and in both the cases examined the bleeding had come from a ruptured sub-epithelial varix.

The peri-oesophageal or superficial venous plexus of the oesophagus is well developed and does not consist solely of three to four longitudinal channels as



described by Kegaries (1934). Compared to the peri-aortic plexus it is poorly developed. The numerous extrinsic veins lie on the surface of the oesophagus as they run to their terminations in the main veins of the neck and thorax. They are joined by longitudinal anastomoses which, in close proximity to the vagus nerves, form two or more main longitudinal channels, the *venae comitantes* of the vagus nerves. These veins form direct communicating channels between the left gastric vein and the azygos veins, joining them directly or via the bronchial veins. These veins also play a part in establishing alternative routes for the portal blood in portal venous obstruction. The injection experiments and the observations of Walker (1949) suggest that they provide an easier route than the submucous and sub-epithelial veins. Furthermore, they are not exposed to the risk of rupture as are those separated from the oesophageal lumen by epithelium alone.

Kundrat (1886) and Dussausay (1877) rather arbitrarily partitioned the venous drainage of the oesophagus between the portal and systemic venous systems, but gave no convincing reasons for doing so. They do not mention valves or the differences between the pressure of the portal and systemic blood. There do not appear to be any observations on the direction of blood flow in the veins of the lower oesophagus in the intact living animal, and it is possible to discuss some only of the factors involved.

**VALVES.**—There do not appear to be any valves in the veins of the sub-epithelial plexus or at the caudal end of the *venae comitantes* of the vagus nerves. These latter have valves where they enter the azygos veins which direct the blood into the azygos veins. There are inconstant valves in the submucous veins above the cardia which direct the blood from the oesophagus to the stomach.

**PORTAL VENOUS PRESSURE.**—Both in man and animals the portal venous pressure is higher than the pressure in the systemic veins. The most complete set of figures is that recorded for the dog by Burton-Opitz (1903). A selection of his figures is given below:

Mesenteric vein	..	..	..	..	..	14.7 mm. Hg
Gastro-splenic vein	..	..	..	..	..	10.1 " "
Portal vein	..	..	..	..	..	8.9 " "
External jugular vein	..	..	..	..	..	0.45 to -0.11 " "
Inferior vena cava	..	..	..	..	..	-1.38 to -2.85 " "

The pressure increases towards the periphery of the portal venous system, and so the values for the submucous veins of the stomach would be higher than the figure of 10.1 mm. Hg recorded in the gastro-splenic vein.

Bellis (1942) compared the portal venous pressure with the pressure in a vein at the ankle in man. He showed that the range of portal venous pressure in 16 subjects with no evidence of portal venous obstruction was from 14 to 22 cm. of saline. The venous pressure at the ankle in the same subjects ranged from 5 to 12 cm. of saline. These figures suggest that the pressure differences between the portal and systemic veins, in the absence of valves, would lead to blood flowing from stomach to oesophagus.

**RESPIRATION.**—Inspiration draws blood into the thorax, and Buckstein (1948) showed that oesophageal varices become more prominent during inspiration. Various authors have suggested that respiration plays an important part in the production of oesophageal varices (Preble, 1900; McIndoe, 1928; Lichtman, 1949). McMichael

(1932) showed that in the cat the portal venous pressure rises with inspiration. It is possible that the contraction of the diaphragm during inspiration may so compress the veins of the oesophagus that blood flow may be suspended during this phase of respiration.

The factors controlling the direction of blood flow in the lower oesophagus are complex, and it is impossible to dogmatize as to how much of the organ drains into the portal venous system. Only direct observation in the living subject could answer the question, and it is difficult to envisage how this could be accomplished without opening either the abdomen or the thorax.

The investigation of the veins of the rete mirabile of the hyopharynx confirmed most of the observations of Elze and Beck (1918), but there was disagreement on certain points. The shape and situation of the ventral part of the rete were not accurately described by these workers. The ventral rete is not as abundant as shown in their Fig. 1, and it does not cover the whole of the posterior aspect of the cricoid cartilage. It forms two "streams" of vessels, one on each side of the midline, separated by an interval. In a longitudinal direction it extends the whole length of the cricoid cartilage and does not end half-way down the cartilage. Between the upper margin of the rete and the notch between the arytenoid cartilages is a large, pad-like mass of mucous glands in which are embedded the main cross anastomoses between the two lateral parts of the plexus.

The main disagreement is with regard to the level of the cranial margin of the triangular dorsal rete. It is on the same level as the cranial margin of the ventral rete, i.e., the level of the cranial border of the cricoid cartilage. It does not begin at the level of the caudal margin of the anterior plexus as shown by Elze and Beck, i.e., half-way up the dorsal surface of the cricoid cartilage. Consequently there is no "step" in the lumen of the pharynx when seen in sagittal section as shown in their Fig. 4. In neither part of the plexus are the veins as coiled as shown in their figures.

Through the courtesy of Mr. A. S. H. Walford I was permitted to examine the hypopharynx in several living persons, but was not able to see the bluish, "bolster-like" swelling which they said was caused by the distended veins of the dorsal rete. There was a small inconspicuous swelling in this region in the fresh specimens when injected with latex, but here the veins were distended at pressures of 30 to 40 mm. Hg. No such swelling is described by writers on oesophagoscopy (Guisez, 1923 ; Chevalier Jackson, 1945).

In respect of the normal varicose condition of these veins, their drainage routes, the situation of the valves, the freedom of the pyriform sinuses from large veins, and the inability to inject one part of the plexus from the other, the observations made by the present writer are in complete agreement with those of Elze and Beck (1918).

It is necessary to consider the precise position of these retia to the upper opening of the oesophagus. By definition the laryngeal part of the pharynx or the hypopharynx ends and the oesophagus begins at the level of the caudal margin of the cricoid cartilage (Gray, 1946). Examination of a true lateral radiograph of the neck shows that the air shadow in the pharynx ends sharply at the level of the cranial margin of the cricoid cartilage. Visualization of the pyriform sinuses and hypopharynx by allowing barium cream to trickle off the dorsum of the tongue as in peroral endoscopy by passive deglutition (Vickers, 1949) shows that the opaque fluid is arrested at this level. Thus the portion of the hypopharynx posterior to the

cricoid cartilage is normally closed. The open part of the hypopharynx ends at about the middle of the body of the fifth cervical vertebra.

At the cranial end of the oesophagus the longitudinal muscle is attached to the mid-portion of the posterior surface of the cricoid cartilage by a pointed tendon (Gillette, 1872 ; Abel, 1913). This tendon reaches up to the cranial margin of the cricoid cartilage and in many mammals reaches to the corniculate cartilages (Negus, 1949).

For these reasons it is suggested that the oesophagus begins at the level of the cranial margin of the cricoid cartilage and not at its caudal margin. If this is accepted then the rete mirabile of the hypopharynx is a venous plexus of the upper end of the oesophagus and is embedded in the upper oesophageal sphincter. Luschka (1871) and Elze and Beck (1918) regarded the rete as forming the sphincter at the mouth of the oesophagus. The veins are in the position of the sphincter, but there is little evidence to support the view that they constitute the sphincter. The evidence in favour of the sphincteric action of the caudal fibres of the inferior constrictor muscle, the so-called cricopharyngeus muscle (Killian, 1908), is very convincing and has been widely accepted. The degree of tone of this sphincter is greatly stressed by all who have written on the technique of oesophagoscopy, and it is for this reason called "the pinchcock of the oesophagus" by Jackson (1945). It is difficult to believe that a plexus of thin-walled veins could produce so much resistance.

A valuable clue to another possible function of these veins is found in the following passage from the paper by Elze and Beck (1918):

"One may say, when the veins are distended to form the pad of mucosa, they form a functional continuation of the epiglottis, by bringing the middle parts of the pharynx together but holding apart the pyriform sinuses and their continuations. The union of the pharyngo-laryngeal sulci and the food pathways would occur at the mouth of the oesophagus."

The lateral food channels are well described by Hasse (1905) and Negus (1949). The former author called them "cavum salivale pharyngo-laryngeum" and regarded them as being concerned with the draining off of excess saliva from the mouth. Neither writer described the point at which these channels meet, but Hasse's text and text-figure 1 give the impression that he placed the meeting-point well below the posterior margin of the glottis. The anterior margin of the glottis is well protected by the epiglottis, which serves to split the stream of fluid into two, as may be easily seen when a barium swallow of fluid consistence is watched on the *x*-ray screen. The fluid streams pass down the pyriform sinuses, and if they pass slowly, as in passive deglutition, they can be seen to follow the anterior walls of the sinuses. The lateral aspect of the glottis is well protected by the ary-epiglottic folds which slope posteriorly to the notch between arytenoid cartilages. Here the wall surrounding the opening of the glottis is very low and this is the least protected part of the glottis. There is therefore reason to look for a means of ensuring that the two streams of fluid do not meet until they are well below the level of the posterior margin of the glottis. The situation of the retia at the mouth of the oesophagus is such that they could, when distended with blood, perform this function (Fig. 11). The contracted fibres of the inferior constrictor muscle may well be a factor in causing damming up of blood in the dorsal rete during this phase of swallowing.

This view is favoured by the fact that the rete is relatively much larger in the newborn than in the adult. Little is known about the mechanism of suckling, but

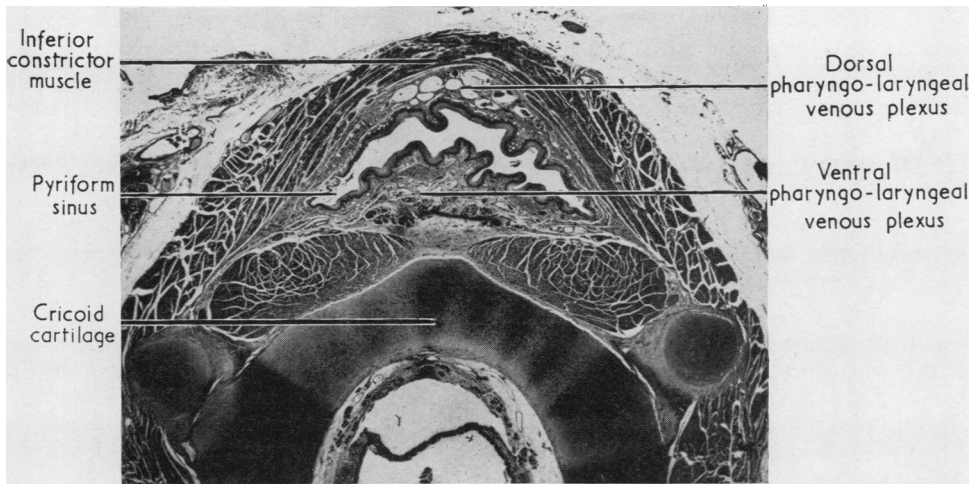


FIG. 11.—Transverse section of the hypopharynx of a full-term foetus through the cricoid cartilage showing the relation of the dorsal and ventral pharyngo-laryngeal plexuses to the pyriform sinuses. H. and E.,  $\times 11.8$ .

it is reasonable to expect that any device for preventing the spilling of fluid into the laryngeal vestibule would be at its maximum development in the newborn. The lumen of the hypopharynx is narrowed in its middle part by the posterior projection of the cricoid cartilage, and this would also assist in keeping the two lateral streams of fluid apart. Attempts have been made to visualize the level of the meeting-point of the streams of swallowed barium, but, owing to technical difficulties and the extreme rapidity of this phase of swallowing, they have been unsuccessful as yet.

The extrinsic veins of the oesophagus and the longitudinal veins upon its outer surface follow closely the course of the nerves. Those with the recurrent laryngeal nerves are a potential source of danger in the operation of thyroidectomy.

#### SUMMARY

The veins of the oesophagus are described under the headings: (a) the intrinsic veins; (b) the venae comitantes of the vagus nerves; and (c) the extrinsic veins.

The sub-epithelial plexus is found for the whole length of the oesophagus, and these thin-walled superficial veins are enlarged in portal venous obstruction to form varices which endanger the life of the patient.

The longitudinal submucous veins of the oesophagus terminate in two circumscribed varicose venous plexuses opposite the level of the cricoid cartilage. It is suggested that the oesophagus begins at the level of the cranial margin of the cricoid cartilage, and these plexuses then form the "rete mirabile of the mouth of the oesophagus" and not the "rete mirabile of the hypopharynx."

The possible function of these plexuses, which are found at all ages and in both sexes, is discussed. There is not sufficient evidence to uphold the earlier view that they formed the sphincter of the mouth of the oesophagus. It is suggested that they serve as a functional continuation of the epiglottis and serve to separate the lateral food channels.

The partition of the venous drainage of the oesophagus between the systemic and portal veins is discussed, and it is shown that it is not possible to say how much of the oesophagus drains into either system. The available evidence suggests that the direction of blood flow in the lower part of the oesophagus may vary during the respiratory cycle.

The anastomoses between the portal and systemic venous systems, at the lower end of the oesophagus, are in the lamina propria, the submucosa, and upon the outer surface of the oesophagus. Those in the lamina propria and the submucosa are smaller in diameter than those upon the outer surface of the oesophagus. All these anastomoses become varicose in portal venous obstruction.

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