Chapter 10: Anatomy of the pharynx and esophagus

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Embryological development

During the development of the embryo, a process of cephalocaudal and lateral folding takes place with the result that part of the endoderm-lined cavity of the secondary or definitive yolk sac is incorporated into the embryo to form the primitive gut. In the cephalic part of the embryo, the primitive gut forms a blind ending tube, the foregut, separated from the ectodermally lined stomatodaeum by the buccopharyngeal membrane. Towards the end of the first month (23-25 days, 10-14 somite stage), the foregut comes to lie dorsal to the developing heart tube and to the developing septum transversum (developing diaphragm). Shortly afterwards (26-27 days, 20 somite stage), the buccopharyngeal membrane ruptures and the stomatodaeum becomes continuous with the foregut. The approximate relationship between the age of the embryo and the number of somites is given in Table 10.1.

Table 10.1 Approximate relationship between age of embryo and number of somites

<table>
<thead>
<tr>
<th>Approximate age</th>
<th>No of somites</th>
<th>Approximate age</th>
<th>No of somites</th>
</tr>
</thead>
<tbody>
<tr>
<td>(days)</td>
<td>(days)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>1-4</td>
<td>25</td>
<td>17-20</td>
</tr>
<tr>
<td>21</td>
<td>4-7</td>
<td>26</td>
<td>20-23</td>
</tr>
<tr>
<td>22</td>
<td>7-10</td>
<td>27</td>
<td>23-26</td>
</tr>
<tr>
<td>23</td>
<td>10-13</td>
<td>28</td>
<td>26-29</td>
</tr>
<tr>
<td>24</td>
<td>13-17</td>
<td>30</td>
<td>34-35</td>
</tr>
</tbody>
</table>

The endodermal lining of the foregut differentiates into a number of different structures which can be summarized as follows:

(1) part of the nasal cavities
(2) the endodermally lined part of the buccal cavity
(3) the pharynx, together with the glands and other structures derived from it, namely the anterior lobe of the pituitary gland, the thyroid, thymus and parathyroid glands, the ultimobranchial body, the pharyngotympanic (eustachian) tube, the middle ear and the tonsils
(4) the submandibular and sublingual salivary glands
(5) the larynx, trachea, bronchi and lungs
(6) the oesophagus
(7) the stomach
(8) the duodenum as far as the liver diverticulum.

The development of the cephalic portion of the primitive gut and its derivatives will be discussed in two sections: (1) the pharyngeal gut or pharynx extending from the buccopharyngeal membrane to the tracheobronchial diverticulum; (2) the foregut, lying caudal to the tracheobronchial diverticulum from which the oesophagus develops.
**Pharynx (pharyngeal gut)**

The development of the branchial or pharyngeal arches in the fifth week provides one of the most characteristic external features of the head and neck region of the embryo. They consist initially of bars of mesenchymal tissue separated by deep clefts known as branchial or pharyngeal clefts. At the same time as the arches and clefts develop on the outside, a number of out-pocketings (the pharyngeal pouches) appear within the pharyngeal gut along the lateral wall. The pouches and clefts gradually penetrate the surrounding mesenchyme but, in spite of there being only a small amount of mesenchyme between the ectodermal and endodermal layers, open communication is not established. Therefore, although these developments resemble the formation of gill slits in fishes, in the human embryo real gills, or branchia, are not formed and the term 'pharyngeal arches' rather than branchial arches has been used in this description (Langman, 1981). The pharyngeal arches contribute not only to the formation of the neck and pharynx, but to the development of the head (see Chapters 5 and 8). By the end of the fourth week, the stomatodaeum is surrounded by the first pair of pharyngeal arches in the form of the mandibular swellings caudally, and the maxillary swellings laterally, which are the dorsal portion of the first arch. The development of the pharyngeal arches, pouches and clefts, with their derivatives, are discussed separately.

**Pharyngeal arches**

Each pharyngeal arch is made up of a core of mesodermal tissue covered on the outside by surface ectoderm and on the inside by epithelium derived from endoderm. The core of the arch has, in addition to local mesenchyme, substantial numbers of crest cells which migrate into the arches to contribute to the skeletal components of the face. The original mesoderm of each arch differentiates into a cartilaginous bar and muscular component together with an arterial component. Each arch receives afferent and efferent nerves to supply the skin, musculature and endodermal lining. The muscular components of each arch have their own nerve and, wherever the muscular cells migrate, they carry their own cranial nerve component. In addition, each arch receives a branch from the nerve of the succeeding arch. The arrangement of the nerve supply to each arch is a relic of the pattern found in vertebrates at a time when the nerve to the gill region was distributed cranial and caudal to the corresponding gill cleft. As a result, in man and in mammals generally, each arch receives a branch, called the post-trematic, from the nerve of its own arch; and a second branch, called the pre-trematic, from the succeeding arch. This is illustrated in Table 10.2.

<table>
<thead>
<tr>
<th>Arch</th>
<th>Post-trematic nerve</th>
<th>Pre-trematic nerve</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>Mandibular nerve (V)</td>
<td>Chorda tympani branch of VII</td>
</tr>
<tr>
<td>2nd</td>
<td>Facial nerve (VII)</td>
<td>Tympanic branch of IX (Jacobson's nerve)</td>
</tr>
<tr>
<td>3rd</td>
<td>Glossopharyngeal nerve (IX)</td>
<td>Pre-trematic nerves not well</td>
</tr>
<tr>
<td>4th</td>
<td>Vagus (X) and accessory (XI)</td>
<td>defined in man</td>
</tr>
<tr>
<td>5th</td>
<td>via superior and recurrent</td>
<td></td>
</tr>
<tr>
<td>6th</td>
<td>laryngeal and pharyngeal branches</td>
<td></td>
</tr>
</tbody>
</table>
At the end of the first month (30-32 days, 34-35 somites), the floor of the foregut shows a number of elevations produced by the mesodermal condensations and separated by depressions. The first arch of each side forms an elevation in the side wall of the foregut and the elevations meet in the midline. A small medial elevation, the tuberculum impar, is seen immediately behind the middle part of the mandibular swelling. Behind the tuberculum impar is a small median depression, the foramen caecum, which marks the site of the invagination which will give rise to the median primordium of the thyroid gland. The second arch of each side is continuous across the midline of the foregut floor. Immediately caudal to the second arch, a second and larger medial swelling develops, the hypobranchial eminence. The third and fourth arches fail to reach the midline owing to the presence of this eminence. The fifth arch makes a transitory appearance only. Caudal to the hypobranchial eminence, a tracheobronchial groove develops in the midline, the lateral boundary of which is the rudimentary sixth arch. From this groove, there develops the lining epithelia and associated glands of the larynx, trachea, bronchi and, possibly, the respiratory epithelium of the alveoli. The development of the tongue is described in Chapter 8. In the course of this development, there is a caudal migration of the hypobranchial eminence and a relative reduction in its size. At the same time, it comes to be more transversally placed behind the developing tongue, but still remains attached to the side wall of the pharynx by part of the third arch tissue, which becomes the lateral glosso-epiglottic fold of the adult. The groove between the dorsum of the tongue and the epiglottis, the glosso-epiglottic groove, is divided into the two valleculae by the appearance of a median glosso-epiglottic fold. The poorly developed swellings which lie each side of the tracheobronchial diverticulum become the arytenoid swellings.

First pharyngeal arch

The cartilage of the first pharyngeal arch consists of a dorsal portion known as the maxillary process, and a ventral portion, the mandibular process or Meckel's cartilage. As development proceeds, both the maxillary process and Meckel's cartilage disappear except for small portions at their dorsal ends which form the incus and malleus respectively, together with the sphenomandibular ligament. Membranous ossification subsequently takes place in the mesenchyme of the maxillary process to give rise to the premaxilla, maxilla, zygomatic bone and part of the temporal bone. The mandible is formed in a similar way by membranous ossification in the mesenchymal tissue surrounding Meckel's cartilage.

The musculature of the first pharyngeal arch develops to form the muscles of mastication (temporalis, masseter, medial and lateral pterygoids), as well as the anterior belly of the digastric, the mylohyoid, the tensor tympani and tensor palati. Although the muscles are not always attached to the bony or cartilaginous components of their own arch, because of migration into surrounding regions, the arch of origin can always be traced by way of the nerve supply which comes from the original arch. In the case of the first arch, this nerve supply is provided by the mandibular branch of the trigeminal nerve. The same nerve provides an afferent or sensory supply to the skin and endodermal lining of this arch.

Second pharyngeal arch

The cartilage of the second or hyoid arch (Reichert's cartilage) gives rise to the stapes, the styloid process of the temporal bone, the stylohyoid ligament and, ventrally, the lesser
horn and the upper part of the body of the hyoid bone. The muscles of this arch are the stapedius, the stylohyoid, the posterior belly of the digastric, the auricular muscles and the muscles of facial expression. They are supplied by the facial nerve which is the nerve of this arch.

**Third pharyngeal arch**

The cartilage of the third arch gives rise to the lower part of the body and the greater horn of the hyoid bone. The caudal part of the arch cartilage disappears. The muscle of the arch is the stylopharyngeus supplied by the glossopharyngeal nerve, the nerve of the third arch.

**Fourth and sixth pharyngeal arches**

The remaining anterior parts of the cartilages of the fourth and sixth arches fuse to form the thyroid, cricoid, arytenoid, corniculate and cuneiform cartilages of the larynx. The fifth arch only makes a transitory appearance as indicated previously. The muscles of the fourth arch are the cricothyroid, the levator palati and the constrictors of the pharynx. They are innervated by the vagus nerve, the nerve of the fourth arch, through its superior laryngeal branch and its contribution to the pharyngeal plexus. The recurrent laryngeal branch of the vagus, the nerve of the sixth arch, innervates the intrinsic muscles of the larynx.

**Pharyngeal pouches**

In the human embryo, there are five pairs of pharyngeal pouches, although the last one of these is often considered as part of the fourth. Each pouch has a ventral and dorsal section. The epithelial endodermal lining of the pouches gives rise to a number of derivatives that have functions very different from those of primitive gill slits.

**First pharyngeal pouch**

The dorsal part of the first pouch, with the adjacent pharyngeal wall and part of the dorsal portion of the second pouch, produces a diverticulum, the tubotympanic recess, which comes into contact with the ectodermal epithelial lining of the first pharyngeal cleft, the future external auditory meatus. The distal portion of the tubotympanic recess widens to form the primitive tympanic or middle ear cavity, whereas the proximal, stalk-like part, forms the pharyngotympanic (eustachian) tube. The ventral part of the first pouch is obliterated by the development of the tongue.

**Second pharyngeal pouch**

As indicated previously, only a portion of the dorsal part of the second pouch takes part in the development of the pharyngotympanic tube. The remainder of this portion is absorbed into the dorsal pharyngeal wall. The ventral portion of the second pouch is almost completely obliterated by the proliferation of its endodermal epithelial lining which forms buds that penetrate into the surrounding mesenchyme. These buds are secondarily invaded by mesodermal tissue forming the primordium of the palatine tonsil. Part of the pouch persists as the intratonsillar cleft or fossa. During the third to fifth months, the tonsil is gradually
invaded by lymphocytes which have either arisen in situ or have been derived from the blood stream. A similar invasion of the endoderm of the dorsal pharyngeal wall by lymphatic tissue forms the nasopharyngeal tonsil (adenoid). The lingual tonsil is formed by aggregations of lymphatic tissue in the dorsum of the tongue (second and third arch) and the tubal tonsil by aggregations of mesenchymal cells that are later invaded by lymphocytes.

**Third pharyngeal pouch**

In the fifth week, the endodermal epithelium of the dorsal section of the third pouch differentiates into parathyroid tissue which will form the inferior parathyroid gland. The ventral section of the pouch gives rise to the thymus gland. The primordia of both these glands lose their connection with the pharyngeal wall when the thymus migrates in a caudal and medial direction, taking the parathyroid with it. The main portion of the thymus gland fuses with its counterpart from the opposite side when it takes up its final position in the thorax. The tail portion becomes thin and eventually disappears, although sometimes parts of it persist either within the thyroid gland or as isolated thymic cysts.

The parathyroid tissue of this pouch takes up its final position on the posterior surface of the thyroid gland as the inferior parathyroid gland.

**Fourth pharyngeal pouch**

The endodermal epithelium of the dorsal section of this pouch gives rise to the superior parathyroid gland. When this gland loses its contact with the wall of the pharynx, it attaches itself, while migrating caudally, to the thyroid gland, and reaches its final position on the posterior surface of the thyroid as the superior parathyroid gland. The fate of the ventral section of this pouch is uncertain, although it is believed to give rise to a small amount of thymus tissue which disappears soon after its formation.

**Fifth pharyngeal pouch**

This is the last pharyngeal pouch to develop and is usually considered to be the ventral section of the fourth pouch. It produces the ultimobranchial body which is later incorporated into the thyroid gland (Moseley et al, 1968). The cells of the ultimobranchial body give rise to the parafollicular or C cells of the thyroid gland which secrete calcitonin in the adult, a hormone involved in the regulation of the calcium level in the blood. Occasionally, the ultimobranchial body may persist and give rise to cysts.

**Pharyngeal clefts**

At about 5 weeks, four pharyngeal clefts can be seen on the external surface of the embryo. The dorsal section of the first cleft penetrates the underlying mesoderm and gives rise to the external auditory meatus. The ectodermal epithelial lining of this cleft makes contact with the endodermal lining of the first pharyngeal pouch and participates in the formation of the tympanic membrane. The mesoderm of the second arch actively proliferates and moves caudally to overlap the third and fourth arches and intervening clefts before finally fusing with the epicardial ridge in the lower part of the neck. The second, third and fourth
clefts then lose contact with the outside and form a temporary cavity lined with ectodermal epithelium, the cervical sinus.

**Lateral cysts and fistulae of the neck (branchial cysts and fistulae)**

The cervical sinus usually disappears completely, but if it does not do so, a cervical or branchial cyst persists. If the second arch fails to fuse completely with the epicardial ridge, the cervical sinus will remain in the contact with the surface and be seen as a branchial fistula. These fistulae are found on the lateral aspect of the neck anteriorly to the sternomastoid muscle. It is rare for the cervical sinus to be in communication with the pharynx internally as an internal branchial fistula. The opening of this fistula is in the tonsillar region and normally indicates that there has been a rupture of the membrane between the second pharyngeal pouch and cleft.

**Foregut and oesophagus**

At about 4 weeks, a small diverticulum appears on the ventral wall of the foregut at its junction with the pharyngeal gut. This is the respiratory or tracheobronchial diverticulum. It is gradually separated from the dorsal part of the foregut, the developing oesophagus, by the formation of a partition known as the oesophago-tracheal septum. The developing oesophagus comes to lie dorsal to both the developing heart and the septum transversum (diaphragm), as a result of the folding of the anterior part of the embryo. It is embedded in visceral mesoderm without any true mesentery.

The oesophagus is at first a short tube extending from the tracheobronchial diverticulum to the fusiform dilatation of the foregut, which is to become the stomach. As the heart and lungs descend caudally, the oesophagus rapidly lengthens. The muscular coat of the oesophagus is formed from the surrounding mesenchyme and in its upper two-thirds is striated and innervated by the vagus. In the lower third, the muscle coat is smooth and innervated by the splanchnic plexus. The oesophageal endodermal lining is initially of the columnar type, but this is gradually replaced by stratified squamous epithelium.

Atresia of the oesophagus and oesophago-tracheal fistula are thought to occur either from a spontaneous deviation of the oesophagotracheal septum in a posterior direction, or from some other mechanical factor pushing the dorsal wall of the foregut anteriorly. The most common variety is for the proximal oesophagus to end in a blind sac and for the distal part to be connected to the trachea by a narrow canal which joins it just above the bifurcation. Occasionally, the fistulous canal is replaced by a ligamentous cord. It is very unusual for both portions of the oesophagus to open into the trachea. If the oesophageal lumen is obstructed, amniotic fluid cannot pass into the intestinal tract and thus it accumulates in the amniotic sac. This is called polyhydramnios and causes enlargement of the uterus. Once the fetus is born, atresia of the oesophagus becomes evident when drinking, resulting in overflowing into the trachea and lungs.
The pharynx

General description

The pharynx forms the crossroads of the air and food passages. Each major road from the pharynx can be closed by a muscular sphincter.

Table 10.3. Muscles controlling the muscular sphincters in the pharynx

<table>
<thead>
<tr>
<th>Sphincter</th>
<th>Muscles directly involved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nasopharyngeal</td>
<td>Levator palati</td>
</tr>
<tr>
<td></td>
<td>Superior constrictor</td>
</tr>
<tr>
<td>Oropharyngeal</td>
<td>Palatoglossus</td>
</tr>
<tr>
<td></td>
<td>Horizontal intrinsic muscle of tongue</td>
</tr>
<tr>
<td>Cricopharyngeal</td>
<td>Cricopharyngeus</td>
</tr>
<tr>
<td>(upper oesophageal)</td>
<td>(normally closed)</td>
</tr>
<tr>
<td>Laryngeal</td>
<td>Oblique portion of interarytenoid and aryepiglottic muscles</td>
</tr>
</tbody>
</table>

There is a smaller turning each side from the nasal airway, above the nasopharyngeal sphincter, leading to the middle ear; it is the pharyngotympanic or eustachian tube. This tube is normally closed, as is the cricopharyngeal or upper oesophageal sphincter.

The cavity of the pharynx is perhaps best considered as a tube flattened from front to back and with varying widths. Changes in its capacity at different levels in the resting state are best demonstrated by cross-sectional anatomy, which can now be shown by means of computerized tomographic (CT) scanning (see Chapter 17). The pharynx extends from the base of the skull to the level of the sixth cervical vertebra, a distance of about 12 cm, where it joins the oesophagus at the lower level of the cricoid cartilage. The junction is marked by the cricopharyngeus muscle which normally holds the upper oesophageal sphincter closed. The lateral and posterior walls of the pharynx are made up of muscular and fibrous tissue attached to the base of the skull superiorly. The pharynx can be in communication with the air and food passages both anteriorly and inferiorly, as indicated previously. From above downwards, these routes of communication are: the nasal cavities through the posterior nasal apertures; the middle ears through the pharyngotympanic tubes; the mouth through the oropharyngeal isthmus; the larynx through the glottis; and the oesophagus through its upper sphincter.

The interior of the pharynx and its subdivisions

The subdivisions of the pharynx described below are based on those set out in the TNM system for classification of malignant tumours published by the International Union Against Cancer (UICC) (Harmer, 1978). Where the division differs from the purely anatomical one, this has been noted.
Nasopharynx (postnasal space)

The nasopharynx or postnasal space lies behind the nasal cavities and above the soft palate. The anterior wall is formed by the openings into the nasal cavities which allow free communication between the nose and nasopharynx each side of the posterior edge of the nasal septum. Just within these openings lie the posterior ends of the inferior and middle turbinates.

The posterosuperior wall of the nasopharynx extends from the base of the skull, at the superior end of the posterior free edge of the nasal septum, down to the level of the junction of hard and soft palates. Anatomically, this lower level is often considered as being at the free edge of the soft palate. This posterosuperior wall is formed by the anteroinferior surface of the body of the sphenoid bone and basilar part of the occipital bone. These two together are termed the 'basisphenoid'. The bony wall extends as far as the pharyngeal tubercle, but below this the wall is formed by the pharyngobasilar fascia lying in front of the anterior arch of the atlas. A collection of lymphoid tissue, the nasopharyngeal tonsil, is found in the mucous membrane overlying the basisphenoid. When the nasopharyngeal tonsil is enlarged, it is commonly referred to as 'the adenoids'. The nasopharyngeal tonsil has an oblong, rectangular shape, similar to a truncated pyramid, dependent from the roof of the nasopharynx. The anterior edge of this block of tissue is vertical and in the same plane as the posterior nasal aperture. The posterior edge gradually merges into the posterior pharyngeal wall: the lateral edges incline toward the midline.

On each lateral wall of the nasopharynx is the pharyngeal opening of the pharyngotympanic tube. It lies about 1 cm behind the posterior end of the inferior turbinate just above the level of the hard palate. The medial end of the cartilage of the tube forms an elevation shaped like a comma, with a shorter anterior limb and a longer posterior one. Behind and above the tubal cartilage lies the pharyngeal recess (fossa of Rosenmüller). This recess passes laterally above the upper edge of the superior constrictor muscle and corresponds to the position of the sinus of Morgagni. From the posterior edge of the tubal opening the salpingopharyngeal fold, produced by the underlying salpingopharyngeal muscle, passes downwards and fades out on the lateral pharyngeal wall. A less well-defined fold passes from the anterior edge of the tubal opening on to the upper surface of the soft palate, and is caused by the underlying levator palati muscle.

The inferior wall of the nasopharynx is formed by the superior surface of the soft palate. In the midline of this wall, there is an elevation caused by the two uvula muscles on the dorsum of the palate.

Oropharynx

The TNM system, noted previously, describes the oropharynx as extending from the junction of the hard and soft palates to the level of the floor of the valleculae. Anatomical texts describe it as extending from the lower edge of the soft palate to tip of the epiglottis or to the laryngeal inlet. In terms of physiology, it is easier to describe the oropharynx as extending from the oropharyngeal isthmus to the level of the floor of the valleculae which is also the level of the hyoid bone. The oropharyngeal isthmus is the boundary between the buccal cavity and the oropharynx and is marked on each side by the palatoglossal fold formed by the underlying palatoglossus muscle passing from the undersurface of the palate to the side
of the tongue. The paired palatoglossal muscles together with the horizontal intrinsic tongue musculature form the oropharyngeal sphincter.

The anterior wall of the oropharynx is, at its upper end, in free communication with the buccal cavity. Below this, the glossopiglottic area is formed by the posterior one-third of the tongue posterior to the vallate papillae (base of tongue). At the lower part of this anterior wall are found the paired valleculae. The valleculae are separated from each other in the midline by the median glossopiglottic fold passing from the base of the tongue to the anterior or lingual surface of the epiglottis. Laterally, each is bounded by the lateral glossopiglottic fold. The TNM system incorporates the anterior or lingual surface of the epiglottis into the oropharynx. The anterior boundary of the lateral wall of the oropharynx is drawn by the palatoglossal fold and underlying palatoglossus muscle described previously. Behind this, from the lower edge of the soft palate, the palatopharyngeal fold passes downwards and a little backwards to the side wall of the pharynx, where it fades away. Like the palatoglossal fold, this is caused by an underlying muscle, the palatopharyngeus. In the triangular space between these two folds lies the palatine or faucial tonsil. The pharyngeal surface of the tonsil is oval in shape and demonstrates a variable number of pits or crypts. Towards the upper pole of the tonsil, but within its substance, is found the intratonsillar cleft which is much deeper than the other pits and may extend well down the deep surface of the tonsil within its capsule. A more detailed description of the structure of the tonsil and its anatomical relationships is given later.

Two folds of mucous membrane are usually described in connection with the tonsil. A thin triangular fold of mucous membrane passes backwards from the palatoglossal fold to the base of the tongue covering the lower border of the tonsil to a variable extent. A further semilunar fold of mucous membrane passes from the upper part of the palatopharyngeal fold towards the palatoglossal fold. There is wide variation in the extent to which the tonsil is set back between the palatoglossal and palatopharyngeal folds. In some cases, the tonsil seems to be very much on the surface of the lateral wall of the oropharynx giving the false impression that it is large; in other instances, it is set deeply between the folds and appears very much smaller even though its volume may be the same in both cases. Tonsils that stand out into the oropharynx are better described as prominent rather than large. The palatoglossal and palatopharyngeal folds are often called the anterior and posterior faucial pillars. Between the tonsil and the base of the tongue lies the glossotonsillar sulcus.

The posterior wall of the oropharynx is formed by the constrictor muscles and overlying mucous membrane. The superior wall of the oropharynx is formed by the inferior surface of the soft palate and uvula. The soft palate is described in detail later.

**Hypopharynx (laryngopharynx)**

The hypopharynx is that part of the pharynx which lies behind the larynx and partly to each side, where it forms the pyriform fossae or sinuses. It is continuous above with the oropharynx and below with the oesophagus, at the lower border of the cricoid cartilage, through the cricopharyngeal sphincter.

In the anterior wall of the hypopharynx lies the larynx itself with its oblique inlet. The inlet is bounded anteriorly and superiorly by the upper part of the epiglottis, posteriorly by
the elevations of the arytenoid cartilage, and laterally by the aryepiglottic folds. Below the laryngeal inlet, the anterior wall is formed by the posterior surfaces of the paired arytenoid cartilages and the posterior plate of the cricoid cartilage. To each side of the larynx lie the pyriform fossae. They are bounded laterally by the thyroid cartilage and medially by the surface of the aryepiglottic fold, the arytenoid and cricoid cartilages. They extend from the lateral glosso-epiglottic fold (pharyngo-epiglottic fold) to the upper end of the oesophagus. Deep to the mucous membrane of the lateral wall of the pyriform fossa lies the superior laryngeal nerve, where it is accessible for local anaesthesia.

The TNM system describes the posterior wall of this section of the pharynx as extending from the level of the floor of the valleculae to the level of the cricoarytenoid joint. This wall is formed by the constrictor muscles and overlying mucous membrane. The region below this, down to the inferior border of the cricoid cartilage, is called the pharyngo-oesophageal junction and is bounded anteriorly by the posterior plate of the cricoid cartilage and encircled by the cricopharyngeus muscle which forms the upper oesophageal sphincter.

The soft palate

The soft palate is a mobile, flexible partition between the nasopharyngeal airway and the oropharyngeal food passage, and it can be likened to a set of points on a railway track, movement of which opens one line and closes another. It extends posteriorly from the edge of the hard palate, and laterally it blends with the lateral walls of the oropharynx. The soft palate forms the roof of the oropharynx and the floor of the nasopharynx. It lies between two sphincters: the nasopharyngeal which pulls the palate up and back to close the nasopharyngeal airway, and the oropharyngeal which pulls it down and forwards to close the oropharyngeal isthmus.

Structure of the soft palate

The basis of the soft palate is the palatine aponeurosis formed by the expanded tendons of the tensor palati muscles which join in a median raphe. The aponeurosis is attached to the posterior edge of the hard palate and to its inferior surface behind the palatine crest. It is thicker in the anterior two-thirds of the palate but very thin further back. Near the midline, it splits to enclose the uvular muscle; all the other muscles of the soft palate are attached to it. The anterior part of the soft palate is less mobile and more horizontal than the posterior part and it is principally on this part that the tensor palati acts. From the posterior edge of the soft palate hangs the uvula in the midline. From the base of the uvula on each side, a fold of mucous membrane containing muscle fibres sweeps down to the lateral wall of the oropharynx; this is the palatopharyngeal fold, and the two folds together form the palatopharyngeal arch. More anteriorly, a smaller fold, also containing muscle fibres, passes from the soft palate to the side of the tongue. This is the palatoglossal fold, and with its opposite number, it forms the palatoglossal arch which marks the junction of the buccal cavity and the oropharynx, the oropharyngeal isthmus. The term 'isthmus of the fauces' is sometimes used to describe both the palatal arches together.

The soft palate contains numerous mucous glands and lymphoid tissue, chiefly on the inferior aspect of the palatal aponeurosis and toward its posterior edge. The palate also contains the fibres of those muscles acting on it which will be described in detail later.
The mucous membrane on the superior or nasopharyngeal aspect of the palate is pseudostratified ciliated columnar in type, often known as ‘respiratory epithelium’. On the inferior or oropharyngeal aspect, the epithelium is of the non-keratinized stratified squamous variety. The lamina propria is very vascular and contains many elastic fibres.

**Muscles of the soft palate**

The muscles of the soft palate are activated by swallowing, breathing and phonation (Fritzell, 1976). Deglutition is described in detail in Chapter 11.

**Tensor palati**

The tensor palati muscle is a thin triangular muscle which arises from the scaphoid fossa of the pterygoid process of the sphenoid bone, the lateral lamina of the cartilage of the pharyngotympanic tube and the medial aspect of the spine of the sphenoid bone. As it descends on the lateral surface of the medial pterygoid plate, its fibres converge to form a small tendon which passes round the pterygoid hamulus of the medial plate before piercing the attachment of the buccinator to the pterygomandibular raphe and spreading out to form the palatine aponeurosis described previously. There is a small bursa between the tendon and the pterygoid hamulus. The two tensor palati muscles, acting together, tighten the soft palate, primarily in its anterior part and depress it by flattening its arch. Acting alone, one tensor palati muscle will pull the principal opener of the pharyngotympanic tube, assisted by the levator palati, through its attachment to the lateral lamina of the tubal cartilage.

All the muscles of the soft palate, except the tensor palati, belong to the same group as the superior constrictor and have the same nerve supply by way of the pharyngeal plexus. The tensor palati, however, is an immigrant muscle which at one time played a part in mastication. Its nerve supply comes from the mandibular division of the trigeminal nerve.

**Levator palati**

The levator palati is a cylindrical muscle arising by a small tendon from a rough area on the inferior surface of the petrous temporal bone immediately in front of the lower opening of the carotid canal. It also arises by a few fibres from the inferior surface of the cartilaginous part of the pharyngotympanic tube. At its origin, the muscle lies inferior rather than medial to the pharyngotympanic tube and crosses to the medial side of the tube only at the level of the medial pterygoid plate. The muscle passes downwards, forwards and inwards over the upper edge of the superior constrictor muscle where it pierces the pharyngobasilar fascia, and descends in front of the salpingopharyngeus muscle to be inserted into the upper surface of the palatine aponeurosis between the two bundles of the palatopharyngeus muscle. The muscle fibres blend with those of the levator palati from the opposite side. The action of the muscle is to raise the soft palate upwards and backwards. Its action, coupled with that of some of the upper fibres of the superior constrictor, described later, plays an important role in the closure of the nasopharyngeal isthmus during deglutition. It also assists in opening the pharyngotympanic tube by elevating the medial lamina of the tubal cartilage, but not until after the age of 7 years or so (Holborow, 1970, 1975).
Palatoglossus

The palatoglossus is a small fleshy bundle of muscle fibres arising from the oral surface of the palatine aponeurosis where it is continuous with the muscle of the opposite side. It passes anteroinferiorly and laterally in front of the tonsil where it forms the palatoglossal arch. It is inserted into the side of the tongue where some of its fibres spread over the dorsum of the tongue while others pass more deeply into its substance to intermingle with the transverse intrinsic muscle fibres. The action of the two muscles, together with the horizontal intrinsic fibres of the tongue, is to close the oropharyngeal isthmus by approximation of the palatoglossal arches and elevation of the tongue against the oral surface of the soft palate.

Palatopharyngeus

The palatopharyngeus arises in the palate as two bundles separated by the levator palati. The anterior bundle, which is the thicker of the two, arises from the posterior border of the hard palate and from the palatine aponeurosis. It passes back between the levator and tensor palati. The posterior bundle is thinner and arises from beneath the mucous membrane of the palate and passes medial to the levator palati. The two bundles unite at the posterolateral aspect of the palate to descend in the palatopharyngeal fold before spreading out to form the inner vertical muscle layer of the pharynx and to be inserted into the posterior edge of the lamina of the thyroid cartilage. The action of the muscle is to pull the walls of the pharynx upwards, forwards and medially, so shortening the pharynx and elevating the larynx during deglutition. Acting together, the two muscles approximate the palatopharyngeal arches to the midline and direct food and fluid down into the lower part of the oropharynx.

Uvular muscle

This is a small paired muscle arising from the palatine aponeurosis just behind the hard palate. Its fibres lie adjacent to the midline between the two laminae of the aponeurosis. It passes backwards and downwards to be inserted into the mucous membrane of the uvula. Its action is to pull up and shorten the uvula and to add bulk to the dorsal surface of the soft palate which assists in closure of the nasopharyngeal opening (velopharyngeal closure) in speech and deglutition (Pigott, 1969; Azzam and Kuehn, 1977).

Nerve supply of the soft palate

All the muscles of the soft palate, except the tensor palati, are supplied by way of the pharyngeal plexus (Broomhead, 1951) with an additional supply from the facial nerve (Nishio et al, 1976a, b; Ibuki et al, 1978). The cell bodies of these motor nerves are found in the nucleus ambiguus and leave the brainstem in the cranial root of the accessory to join the vagus nerve and pass by its pharyngeal branch to the pharyngeal plexus. The cell bodies of the facial nerve innervation arise in the facial nucleus and pass through the geniculate ganglion, greater petrosal nerve and pterygopalatine ganglion before reaching the palatal muscles. The tensor palati is supplied by the trigeminal nerve through the nerve to the medial pterygoid, a branch of the mandibular nerve. The fibres pass through, but do not synapse, in the otic ganglion.
The sensory supply to the palate is derived from the greater and lesser palatine branches of the maxillary division of the trigeminal nerve which pass on to the surface of the palate through the greater and lesser palatine foramina. These nerves appear to be branches of the pterygopalatine ganglion but have no synaptic connection in the ganglion, the cell bodies of the sensory fibres being in the trigeminal ganglion. A sensory supply is also provided by pharyngeal branches of the glossopharyngeal nerve. The small number of taste buds on the palate are supplied by the same palatine branches, and the fibres pass up through the pterygopalatine ganglion, without synapsing, into the nerve of the pterygoid canal and the greater petrosal nerve to reach the geniculate ganglion of the facial nerve where the cell bodies are situated. The central processes enter the brainstem by way of the nervus intermedius portion of the facial nerve and end in the nucleus of the tractus solitarius. Sympathetic fibres reach the palate on the blood vessels supplying it and are derived from the superior cervical ganglion.

**Blood supply of the soft palate**

The blood supply of the soft palate is provided by the palatine branch of the ascending pharyngeal artery which curls over the upper edge of the superior constrictor muscle before being distributed to the palate. The ascending palatine branch of the facial artery provides an additional supply, as do the lesser palatine branches of the descending palatine branch of the maxillary artery; it runs upwards on the side wall of the pharynx and may, together with the ascending pharyngeal artery, send a branch over the upper edge of the superior constrictor muscle to the palate.

The venous drainage of the palate is to the pterygoid plexus and thence through the deep facial vein to the anterior facial vein and internal jugular vein.

**Lymphatic drainage of the soft palate**

The lymphatic drainage of the soft palate is partly by way of the retropharyngeal nodes, but chiefly direct to the upper deep cervical group of nodes.

**The pharyngeal wall**

The pharyngeal wall consists of four layers which, from the inner layer outwards, are as follows:

1. mucous membrane
2. pharyngobasilar facia
3. muscle layer
4. buccopharyngeal fascia.

**Mucous membrane**

The epithelial lining of the pharynx varies in accordance with differing physiological function. The nasopharynx is part of the respiratory pathway and normally only traversed by air. It is lined by a pseudostratified columnar ciliated epithelium as far as the level of the lower border of the soft palate. The oropharynx and hypopharynx are part of the alimentary
tract and subject to the abrasion caused by the passage of food. These two areas have an epithelial lining of non-keratinizing stratified squamous epithelium. In the border zone between the nasopharynx and oropharynx, there may be a narrow zone of stratified columnar epithelium. Immediately beneath the epithelium, there is a connective tissue lamina propria that contains a large amount of elastic tissue and which takes the place of the muscularis mucosae found in the oesophagus.

The respiratory type of epithelium in the nasopharynx contains goblet cells. Elsewhere, the mucous membrane is pierced by ducts from glands that lie deep to it in the submucosa. These may be mucous, serous, or mixed.

The pharynx has a large amount of subepithelial or gut-associated lymphoid tissue encircling both its alimentary and respiratory openings forming Waldeyer's ring. There are three large aggregations of this tissue and three smaller ones. The larger are the two palatine tonsils in the oropharynx, and the nasopharyngeal tonsil on the roof of the nasopharynx. The three smaller aggregations are the tubal tonsil, above and behind the pharyngeal opening of the pharyngotympanic tube, the lingual tonsil, and the two lateral bands which run down posterior to the palatopharyngeal fold. The pharyngeal lymphoid tissue is described in more detail later.

**Pharyngobasilar fascia**

A fibrous intermediate layer lies between the mucous membrane and the muscular layers in place of the submucosa. It is thick above, where the muscle fibres are absent, and is firmly connected to the basilar region of the occipital bone and petrous part of the temporal bone medial to the carotid canal, bridging below the pharyngotympanic tube, and extending forwards to be attached to the posterior border of the medial pterygoid plate and the pterygomandibular raphe. The pharyngobasilar fascia bridges the gap between the superior border of the superior constrictor and the base of the skull. In this region it is firmly united to the buccopharyngeal fascia, forming a single layer. This fibrous layer diminishes in thickness as it descends. It is strengthened posteriorly by a strong fibrous band which is attached above to the pharyngeal tubercle on the undersurface of the basilar portion of the occipital bone, and passes downwards as a median raphe (the pharyngeal raphe), which gives attachment to the constrictors. Although the pharyngeal muscles are usually described as lying external to the fibrous layer, it is formed, in reality, from the thickened, deep epimysial covering of these muscles, and the thinner external layer of the epimysium constitutes the buccopharyngeal fascia.

**Muscle layer**

The muscles of the pharyngeal wall are arranged into an inner longitudinal layer and an outer circular layer. The inner layer is formed by three paired muscles, namely:

1. stylopharyngeus
2. palatopharyngeus
3. salpingopharyngeus.
The outer layer also has three paired muscles, named:

(1) superior constrictor
(2) middle constrictor
(3) inferior constrictor.

Each of the constrictor muscles is a fan-shaped sheet arising on the lateral wall of the pharynx and sweeping round to be inserted into the median raphe posteriorly. The muscles overlap each other from below upwards. Although together they form an almost complete coat for the side and posterior walls of the pharynx, their attachments anteriorly separate the edges, and it is through these intervals that structures can pass from the exterior of the pharynx towards its lumen. The interval between the upper border of the superior constrictor and the base of the skull is sometimes called the sinus of Morgagni. During deglutition, the constrictor muscles contract in a coordinated way to propel the bolus through the oropharynx into the oesophagus. The longitudinal muscles elevate the larynx and shorten the pharynx during this movement.

**The superior constrictor muscle**

This muscle arises from above downwards from the posterior border of the lower part of the medial pterygoid plate, the pterygoid hamulus, the pterygomandibular raphe, the posterior end of the mylohyoid line on the inner surface of the mandible, and by a few fibres from the side of the tongue. The fibres pass backwards in a largely quadrilateral sheet to be inserted into the median pharyngeal raphe and, by an aponeurosis, to the pharyngeal tubercle on the basilar part of the occipital bone. A band of muscle fibres arises from the anterior and lateral part of the upper surface of the palatine aponeurosis and sweeps backwards, lateral to the levator palati, to blend with the internal surface of the superior constrictor near its upper border (Whillis, 19300. This band is termed the 'palatopharyngeal sphincter'. It produces a rounded ridge on the pharyngeal wall, known as Passavant's ridge, which is seen when the nasopharyngeal sphincter contracts (Calnan, 1958).

**The middle constrictor muscle**

This muscle arises from the posterior edge of the lower part of the stylohyoid ligament and lesser horn of the hyoid bone, as well as from the whole length of the upper border of the greater horn. The fibres spread in a wide fan-shape upwards and downwards as they pass backwards to be inserted into the whole length of the median pharyngeal raphe. As the upper fibres ascend, they overlap the superior constrictor, the middle fibres pass horizontally backwards, and the lower fibres descend, deep to the inferior constrictor, as far as the lower end of the pharynx.

**The inferior constrictor muscle**

This is the thickest of the constrictors and consists of two parts: thyropharyngeus and cricopharyngeus. The thyropharyngeus part arises from the oblique line on the lateral surface of the lamina of the thyroid cartilage, from a fine tendinous band across the cricothyroid muscle, and from a small area on the lateral surface of the cricoid cartilage at the lower edge of the above band. There is also a small slip from the inferior horn of the thyroid cartilage.
These fibres pass backwards to be inserted into the median pharyngeal raphe, the upper ones ascending obliquely to overlap the middle constrictor. The cricopharyngeus part of the inferior constrictor arises form the side of the cricoid cartilage in the interval between the origin of the cricothyroid in front and the articular facet for the inferior horn of the thyroid cartilage behind. These fibres pass horizontally backwards and encircle the pharyngo-oesophageal junction to be inserted at the same site on the opposite side of the cricoid cartilage. They are continuous with the circular fibres of the oesophagus. Posteriorly, there is a small triangular interval between the upper edge of the cricopharyngeus and the lower fibres of the thyropharyngeus. This interval is sometimes referred to as Killian's dehiscence. It is occasionally described as a point of 'weakness' in the pharyngeal wall, but this is incorrect as it is a feature of the normal anatomy of this region. However, when there is incoordination of the pharyngeal peristaltic wave, and the cricopharyngeus does not relax at the appropriate time, pressure may temporarily build up in the lower part of the pharynx, in which case the most likely place for a diverticulum to form is at Killian's dehiscence, where the additional support of the constrictor muscles is deficient.

The stylopharyngeus muscle

This muscle arises from the medial side of the base of the styloid process of the temporal bone and descends along the side of the pharynx, passing between the superior and middle constrictors, after which its fibres spread out beneath the mucous membrane, some of them merging into the constrictors and the lateral glossoepiglottic fold while others are inserted, with the palatopharyngeus, into the posterior border of the thyroid cartilage. The muscle is long and slender with a cylindrical shape above, flattening out below within the pharynx. It is supplied by a branch of the glossopharyngeal nerve, which winds around its posterior border before entering the pharynx alongside it to reach the tongue.

The palatopharyngeus muscle

This muscle, with its covering of mucous membrane, forms the palatopharyngeal fold or posterior faucial pillar. It arises as two bundles within the soft palate. The anterior bundle, the thicker of the two, arises from the posterior border of the hard palate and from the palatine aponeurosis. It passes backwards, first anterior and then lateral to the levator palati, between the levator and the tensor palati, before descending into the pharynx. The smaller posterior and inferior bundle arises in contact with the mucous membrane covering the surface of the palate, together with the corresponding bundle of the opposite side in the median plane. At the posterolateral border of the palate, the two bundles of muscle unite and are joined by the fibres of salpingopharyngeus. Passing laterally and downwards behind the tonsil, the palatopharyngeus descends posteromedial to, and in close contact with, the stylopharyngeus muscle and is inserted with it into the posterior border of the thyroid cartilage. Some of its fibres end in the side wall of the pharynx attached to the fibrous coat, and others pass across the median plane to decussate with those of the opposite side.

Salpingopharyngeus

This muscle arises from the posteroinferior corner of the cartilage of the pharyngotympanic tube near its pharyngeal opening. The fibres pass downwards and blend with the palatopharyngeus muscle.
Structures entering the pharynx

Above the superior constrictor

The cartilaginous part of the pharyngotympanic tube and the tensor and levator palati muscles pass through the pharyngobasilar fascia to reach the lateral wall of the pharynx and palate respectively. The palatine branch of the ascending pharyngeal artery curls over the upper edge of the superior constrictor.

Between the middle and superior constrictor muscles

The stylopharyngeus muscle enters the pharynx at this level, as described previously, before it blends with fibres form the palatopharyngeus. It is accompanied by the glossopharyngeal nerve which supplies it before passing forward to the tongue.

Between the middle and inferior constrictor muscles

The internal laryngeal nerve and superior laryngeal vessels pierce the thyrohyoid membrane and come to lie submucosally on the lateral wall of the pyriform fossa, where the nerve is accessible for local anesthesia.

Below the inferior constrictor

The recurrent laryngeal nerve and inferior laryngeal artery pass between the cricopharyngeal part of the inferior constrictor and the oesophagus behind the articulation of the inferior horn of the thyroid cartilage with the cricoid cartilage.

Buccopharyngeal fascia

This thin fibrous layer forms the outer coat of the pharynx and, as already indicated, probably represents the thinner external epimysial covering of the constrictor muscles. It is a coat of areolar tissue and contains the pharyngeal plexus of nerves and veins. Posteriorly, it is loosely attached to the prevertebral fascia covering the prevertebral muscles and, at the sides, is loosely connected to the styloid process and its muscles, and to the carotid sheath.

Nerve supply of the pharynx

The motor, sensory and autonomic nerve supply of the pharynx is provided through the pharyngeal plexus, which is situated in the buccopharyngeal fascia surrounding the pharynx. The plexus is formed by the pharyngeal branches of the glossopharyngeal and vagus nerves together with sympathetic fibres from the superior cervical ganglion. The cells of origin of the glossopharyngeal and vagal motor branches that supply the muscles are in the rostral part of the nucleus ambiguus. The fibres leave the brainstem with the glossopharyngeal nerve and with the cranial root of the accessory nerve which joins the vagus at the level of its superior ganglion. The pharyngeal branch of the vagus carries the main motor supply to the pharyngeal plexus. All the muscles of the pharynx, with the exception of stylopharyngeus, are supplied by the pharyngeal plexus. The stylopharyngeus is supplied by a muscular branch of the glossopharyngeal nerve as it passes round the muscle to enter the pharynx with it. It
is the only muscle supplied by the glossopharyngeal which is otherwise a sensory nerve. The cricopharyngeus part of the inferior constrictor has an additional supply from the external laryngeal nerve and receives parasympathetic vagal fibres from the recurrent laryngeal nerve.

The sensory nerve supply to the pharynx is also provided by branches of the glossopharyngeal and vagus nerves, chiefly through the pharyngeal plexus. The glossopharyngeal nerve provides the supply to the upper part of the pharynx, including the surface of the tonsil, which is also supplied by the lesser palatine branch of the maxillary nerve. The posterior third of the tongue, including the vallate papillae, is supplied for both ordinary sensation and taste by the glossopharyngeal nerve. The tongue in front of the valleculae and the valleculae themselves are supplied by the internal laryngeal nerve, a branch of the superior laryngeal nerve of the vagus. A small part of the nasopharynx behind the opening of pharyngotympanic tube receives a sensory supply from the pharyngeal branch of the maxillary nerve. These fibres pass through the pterygopalatine ganglion without synapsing and their cell bodies are in the trigeminal ganglion.

The afferent sensory fibres of the glossopharyngeal nerve have their cell bodies in the superior and inferior ganglia of the nerve. The central processes of the unipolar nerve cells in these ganglia are received in the nucleus of the tractus solitarius for taste, and probably in the nucleus of the spinal tract of the trigeminal nerve for common sensation. In the case of the vagus nerve, the sensory fibres synapse in the inferior vagal ganglion before being received in the above brainstem nuclei.

The parasympathetic secretomotor supply to the glands of the pharyngeal mucosa, which are mainly in the nasopharynx, come by way of the pterygopalatine ganglion. The cell bodies are in the superior salivary nucleus, and the fibres leave the brainstem in the nervus intermedius. They pass through the geniculate ganglion of the facial nerve without synapsing and leave it by the greater petrosal nerve, passing by way of the nerve of the pterygoid canal to reach the pterygopalatine ganglion. Here they synapse with the postganglionic cell bodies whose axons reach the pharyngeal mucosa by the nasal, palatine, and pharyngeal branches from the ganglion.

Sympathetic fibres are derived from the superior cervical ganglion of the cervical sympathetic trunk. The preganglionic cell bodies are in the lateral grey column of spinal cord segments T1-T3. Their axons pass up in the sympathetic trunk to synapse in the cervical ganglia from which postganglionic fibres leave and reach the pharynx by running with its blood vessels.

The cricopharyngeal sphincter has a double autonomic innervation. Parasympathetic vagal fibres reach the muscle in the recurrent laryngeal nerve and postganglionic sympathetic fibres come from the superior cervical ganglion. Stimulation of the vagus causes relaxation and sympathetic excitation causes contraction of the sphincter.

**Blood supply of the pharynx**

The ascending pharyngeal artery arises from the medial side of the external carotid artery just above its origin. It passes upwards behind the carotid sheath and immediately against the pharyngeal wall. Branches are distributed to the wall of the pharynx and the
tonsils. Its palatine branch passes over the upper free edge of the superior constrictor muscle to supply the inner aspect of the pharynx and the soft palate. A small branch supplies the pharyngotympanic tube. The pharynx receives a further supply of blood from the ascending palatine and tonsillar branches of the facial artery and the greater palatine and pterygoid branches of the maxillary artery. The dorsal lingual branches of the lingual artery provide an additional small contribution.

The veins of the pharynx are arranged in an internal submucous and an external pharyngeal plexus with numerous communicating branches, not only between the two plexuses but with the veins of the dorsum of the tongue, the superior laryngeal veins, and the oesophageal veins. The pharyngeal plexus drains to the internal jugular and anterior facial veins. It also communicates with the pterygoid plexus.

**Lymphatic drainage of the pharynx**

All the lymph vessels of the pharynx drain into the deep cervical group of lymph nodes, either directly from the tissues themselves, or indirectly after passing through one of the outlying groups of nodes. The efferents from the deep cervical group form the jugular trunk which, on the right side, may end in the junction of the internal jugular and subclavian veins or may join the right lymphatic duct. On the left side, the jugular trunk usually enters the thoracic duct although it may join either the internal jugular or the subclavian vein.

The deep cervical group of nodes lies along the carotid sheath by the internal jugular vein and is divided into superior and inferior groups. The superior group is adjacent to the upper part of the internal jugular vein, mostly deep to the sternocleidomastoid. Within this superior group, a smaller group consisting of one large and several small nodes is particularly to be noted. It lies in the triangular region bounded by the posterior belly of the digastric above, the facial vein, and the internal jugular vein. It is termed the 'jugulo-digastric group'.

The inferior group of deep cervical lymph nodes is also partly deep to sternocleidomastoid and extends into the subclavian triangle. It is closely related to the brachial plexus and the subclavian vessels. Within this group, one lies on, or just above, the intermediate tendon of omohyoid. It is called the jugulo-omohyoid node. The superior group of nodes drains into the inferior group. In addition to the pharynx, all of the lymph vessels of the head and neck drain into this group. The upper part of the pharynx, including the nasopharynx and the pharyngotympanic tube, drains first into the retropharyngeal lymph nodes which comprise a median and two lateral groups lying between the buccopharyngeal fascia covering the pharynx and the prevertebral fascia. These nodes are said to atrophy in childhood. Efferent vessels from them pass to the upper deep cervical nodes.

The lymphatic vessels of the oropharynx pass to the upper deep cervical group of nodes and, in particular, to the jugulodigastric group described previously. Vessels from the tonsil pierce the buccopharyngeal fascia and the superior constrictor and pass between the stylohyoid and internal jugular vein to the jugulodigastric node.

The hypopharynx drains chiefly to the inferior deep cervical group of nodes, but may also drain to paratracheal nodes which lie alongside the trachea and oesophagus beside the recurrent laryngeal nerves. Efferents from these nodes pass to the deep cervical group.
The lymphoid tissue of the pharynx

A full account of basic immunology appears in Chapter 18. This section discusses some anatomical and histological aspects of the lymphoid tissue in the pharynx.

The walls of the alimentary and respiratory tracts contain large amounts of unencapsulated lymphoid tissue, the lymphoid nodules, and these are collectively termed the 'epitheliolymphoid' or 'gut-associated lymphoid' tissue. They form part of the peripheral lymphoid organs, the other parts being the lymph nodes and similar tissues in the bone marrow and spleen. Lymphoid nodules are particularly prominent in the pharynx and include the nasopharyngeal, tubal, palatine and lingual tonsils. Further down the alimentary tract, nodules occur in the wall of the oesophagus and large groups in the small intestine (Peyer's patches) and the vermiform appendix. There are also nodules in the trachea and bronchial tree. The prominent nodules just described, together with some less easily seen, form a ring of gut-associated lymphoid tissue around the entrance to the respiratory and alimentary tracts, known as Waldeyer's ring.

In general, lymphoid nodules are situated in the lamina propria just beneath the epithelium, although when active they may extend more deeply into the submucosa and be diffused through neighbouring tissue. Although the precise form of the nodules depends on their location, there are certain features common to all sites. It is possible to distinguish within them numerous rounded follicles, similar to those seen in lymph nodes, which have germinal centres. The latter are particularly noticeable when the follicles are actively stimulated with antigens. Between the follicles lie less closely packed parafollicular lymphocytes. The follicles and intervening tissue, together with many macrophages, are supported by a fine mesh of reticulin fibres and associated fibroblasts. In some of the larger nodules, such as the palatine tonsil, there are coarser connective tissue trabeculae. In the case of the tonsil, these arise from the capsule. The surface facing the lumen is covered with epithelium pierced by glandular or other diverticula which penetrate deeply into the aggregations of lymphocytes.

The nodules have an extensive vascular network of blood vessels branching from the surrounding connective tissue to supply the follicles with a capillary plexus, which drains into postcapillary venules. This network allows free movement of lymphocytes to and from the blood stream. The lymphatic vessels associated with the lymph nodules are exclusively efferent and drain into the general network of lymphatic channels serving the area in which they are found.

Immunofluorescent studies have demonstrated that the rounded follicles contain the B lymphocytes, and the parafollicular areas contain the T lymphocytes. These cells can move either into the lymphatic system and rejoin the blood stream, or they may move out into adjacent tissues; in the case of non-stratified epithelia, they may eventually pass into the lumen of the alimentary or respiratory tracts.

The B lymphocytes are concerned with the synthesis of secretory antibodies of the IgA class, whereas T lymphocytes are concerned with cell-mediated immunity, that is they are able to kill cells infected by viruses and fungi, or neoplastic cells.
There continues to be much discussion about the exact role of the lymphoid nodules in the total lymphoid system of the body. It seems likely that these regions provide areas in which B and T lymphocytes can proliferate and act as reservoirs of defensive cells that can infiltrate the surrounding tissue to provide local defences. As already indicated, the B lymphocytes are important in the synthesis of antibodies of the IgA class which are present in the secretions of the alimentary tract. In the lamina propria, migrating B lymphocytes are often seen to have become transformed into plasma cells, and it is these cells that secrete the antibodies in the intercellular spaces of the unicellular epithelia and into subepithelial glands. Where the epithelial lining is of the stratified squamous type, the subepithelial glands are of particular importance in enabling the antibodies to reach the lumen. In this case, certain varieties of glandular cell appear to take up the antibodies which are then modified to form the final secretory form of IgA. The role of these antibodies is of great importance in dealing with pathogenic organisms within the various tracts in which they are found.

Pathogens which have already penetrated the epithelium are dealt with by other types of antibody, IgM and IgG, secreted by plasma cells of the lamina propria. In order that this system can work efficiently, there must be a mechanism in which the lymphocytes within the lymphoid nodules can detect antigens present on the outer luminal side of the epithelium. Recently, specialized phagocytic cells have been demonstrated in the epithelium overlying lymphoid follicles, and these appear to be capable of passing particulate material to the lymphoid tissue beneath, thus providing a route for antigens to reach the immune system (Bockman and Cooper, 1973; Owen and Jones, 1974). The longitudinal clefts of the nasopharyngeal tonsil seem to be a way of presenting a bigger surface area to the incoming air in the same way as the crypts of the palatine tonsil increase the surface area presented to food and fluid passing through the pharynx. In the case of the palatine tonsil, an additional mechanism exists which may have some significance in enabling it to undertake 'sampling'. As deglutition takes place, contraction of the pharyngeal musculature, in particular that of the two palatopharyngeus muscles, draws the tonsils towards the midline and turns them forward so that the bolus travels across the surface.

**The palatine tonsil**

The palatine tonsil has already been briefly described, but is dealt with in more detail here because of the importance of its surgical applied anatomy.

The tonsil is an oval mass of specialized subepithelial lymphoid tissue situated in the triangular tonsillar fossa between the diverging palatopharyngeal and palatoglossal folds. The medial surface of the tonsil is free and projects to a variable extent into the oropharynx, depending partly on its size but, probably more importantly, on the degree to which it is embedded into the tonsillar fossa. In late fetal life, a triangular fold of mucous membrane extends back from the lower part of the palatoglossal fold to cover the anteroinferior part of the tonsil. In childhood, however, this fold is usually invaded by lymphoid tissue and becomes incorporated into the tonsil. It is not usually possible to distinguish it clearly. A semilunar fold of mucous membranes passes from the upper part of the palatopharyngeal arch towards the upper pole of the tonsil and separates it from the base of the uvula. The extent to which this fold is visible depends upon the prominence of the tonsil.
The appearance of the tonsil, on examination of the throat, may give a misleading estimate of its size, as indicated previously. Some tonsils appear to lie very much on the surface of the throat with only a shallow tonsillar fossa; others are much more deeply buried in a deep tonsillar fossa. The upper pole of the tonsil may extend up into the soft palate and the lower pole may extend downwards beside the base of the tongue. At this point, the lymphoid tissue of the tonsil is continuous with the subepithelial lymphoid tissue on the base of the tongue, the lingual tonsil. A sulcus usually separates the tonsil from the base of the tongue, the tonsillolingual sulcus. The tonsil is larger in childhood, when it is more active, and gradually becomes smaller during puberty.

Structure of the tonsil

The tonsil consists of a mass of lymphoid follicles supported in a fine connective tissue framework. The lymphocytes are less closely packed in the centre of each nodule, which is described as a germinal centre, because multiplication of the lymphocytes takes place in this situation. The medial surface of the tonsil, facing the lumen, is characterized by 15-20 openings, irregularly spaced over the surface, leading into deep, narrow, blind-ended recesses termed the ‘tonsillar crypts’. These may penetrate nearly the whole thickness of the tonsil and distinguish it histologically from other lymphoid organs. The mucous membrane covering the luminal surface is of the non-keratinizing stratified squamous type and is continuous with that of the remainder of the oropharynx. It also dips down to line the crypts. The crypts may contain desquamated epithelial debris and cells. These plugs of debris are usually cleared from the crypts, but may occasionally remain and become hardened and yellow in appearance.

In the upper part of the tonsil, there is a deep intratonsillar cleft, much larger than the tonsillar crypts, extending laterally and inferiorly toward the lower pole of the tonsil within its capsule. This cleft lies within the substance of the tonsil. It is thought to represent a persistent part of the ventral portion of the second pharyngeal pouch. Some authorities, however, believe that the site of this part of the pouch is represented by the supratonsillar fossa, which is the area of mucous membrane above the tonsil between the palatoglossal and palatopharyngeal folds.

The deep surface of the tonsil, that is all that part not covered by mucous membrane, is covered by a fibrous capsule which is separated from the wall of the oropharynx by loose areolar tissue. This separation makes dissection of the tonsil relatively easy provided that inflammatory disease has not obliterated this space. Suppuration in this space leads to the formation of a peritonsillar abscess.

Relationships of the tonsil

The medial surface of the tonsil is free and faces towards the cavity of the oropharynx. In the act of swallowing, contraction of the musculature in this region, particularly that of the palatopharyngeus, moves the tonsil medially and turns it towards the buccal cavity.

Anteriorly and posteriorly, the tonsil is related to the palatoglossus and palatopharyngeus muscles lying within their respective folds. The muscles have already been described in connection with the soft palate. Some muscular fibres of the palatopharyngeus are found in the tonsil bed and are attached to the lower part of the capsule, as are fibres of
the palatoglossus. Inferiorly, the capsule is firmly connected to the side of the tongue. Superiorly, the tonsil extends to a variable degree into the edge of the soft palate.

Laterally, the floor of the tonsillar fossa is formed by the pharyngobasilar fascia deep to which, in the upper part of the fossa, is the superior constrictor muscle, and below it the styloglossus muscle passing forward into the tongue. Lateral to the superior constrictor is the buccopharyngeal fascia. The glossopharyngeal nerve and stylohyoid ligament pass obliquely downwards and forwards beneath the lower edge of the superior constrictor in the lower part of the tonsillar fossa. A large palatine vein, the external palatine or paratonsillar vein, descends from the soft palate across the lateral aspect of the capsule of the tonsil before piercing the pharyngeal wall to join the pharyngeal plexus. The tonsillar artery, a branch of the facial artery, pierces the superior constrictor and immediately enters the tonsil accompanied by two small veins. It is at this point of vascular supply that, in the course of a dissection tonsillectomy, a fibrous band will be noted between the tonsil capsule and the tonsil bed.

More distant, lateral relations of the lower part of the tonsil, outside the pharyngeal wall, are the posterior belly of the digastric muscle and the submandibular salivary gland, with the facial artery arching over them. Further laterally still are the medial pterygoid muscle and the angle of the mandible.

**Nerve supply of the tonsil**

The sensory nerve supply to the tonsillar region is mainly by the tonsillar branch of the glossopharyngeal nerve. The cell bodies of these fibres are in the glossopharyngeal ganglia. The upper part of the tonsil nearest to the soft palate is supplied by the lesser palatine nerves, branches of the maxillary division of the trigeminal nerve received by way of the pterygopalatine ganglia. The cell bodies of these fibres are in the trigeminal ganglion. There is no synapse in the pterygopalatine ganglia. Sympathetic fibres reach the tonsil on the arteries supplying it and are derived from the superior cervical ganglion.

**Blood supply of the tonsil**

The main artery of the tonsil is the tonsillar branch of the facial artery which enters the tonsil near its lower pole by piercing the superior constrictor just above the styloglossus muscle. A further arterial supply reaches the tonsil from the lingual artery, by way of the dorsal lingual branches, from the ascending palatine branch of the facial artery, and ascending pharyngeal vessels. The upper pole receives an additional supply from greater palatine vessels of the descending palatine branch of the maxillary artery.

Venous drainage of the tonsil is to the paratonsillar vein, and vessels also pass to the pharyngeal plexus or facial vein after piercing the superior constrictor. There is communication with the pterygoid plexus and drainage is eventually into the common facial and internal jugular veins.
Lymphatic drainage of the tonsil

Lymphatic vessels from the tonsil pierce the buccopharyngeal fascia and pass to the upper deep cervical group of nodes, in particular to the jugulodigastric group situated just below the posterior belly of the digastric muscle. The tonsil has no afferent lymphatic vessels.

Relationships of the pharynx

There are two important potential spaces in relation to the posterior and lateral aspects of the pharynx, and a description of these will precede an account of the other structures related to the pharynx. These spaces provide possible pathways for the spread of infection once it has entered them.

Retropharyngeal space

The potential space, known as the retropharyngeal space, lies between the prevertebral fascia posteriorly and the buccopharyngeal fascia, covering the constrictor muscles, anteriorly. (The prevertebral fascia is also known as the prevertebral lamina of the cervical fascia.) The space is filled with loose areolar tissue and may contain the retropharyngeal group of lymph nodes which are present in infancy but disappear as the child grows older. The space is closed above by the base of the skull and on each side by the carotid sheath, which is a condensation of the cervical fascia in which the common and internal carotid arteries, the internal jugular vein, the vagus nerve and constituents of the ansa cervicalis are embedded. It is thicker around the arteries than the vein. Inferiorly, it is possible to pass into the superior mediastinum. A median partition has been described connecting the prevertebral fascia with the buccopharyngeal fascia and dividing the retropharyngeal space into two lateral spaces. However, during deglutition and movement of the head, the pharynx must be free to move and the areolar tissue that fills the space does not tether it.

Posteriorly, the prevertebral fascia covers the prevertebral muscles, longus capitis and longus cervicis, which separate it from the body and transverse processes of the cervical vertebrae. In the midline, the anterior longitudinal ligament of the vertebral column is just beneath the fascia.

Suppuration in a retropharyngeal lymph node, with the formation of pus, may push the posterior pharyngeal wall forward and present as a retropharyngeal abscess. As indicated previously, this normally occurs only in infants. It is possible, however, for such infection to spread downwards into the superior mediastinum. Infection with suppuration behind the prevertebral fascial presents laterally in the posterior triangle of the neck.

Parapharyngeal space

The potential space, filled with areolar tissue and fat, known as the parapharyngeal space and also as the lateral pharyngeal space, lies lateral to the pharynx on each side. It extends from the base of the skull above, where it is widest, downwards towards the superior mediastinum. Its medial wall is formed by the buccopharyngeal fascia overlying the constrictor muscles. Its posterior wall is the prevertebral fascia. The lateral wall is formed posteriorly by the parotid gland and anteriorly by the medial pterygoid muscle overlying the
angle of the mandible. The styloid process and its muscles separate, to some extent, this space from the carotid sheath, which is more posteriorly situated. In the lower part of the neck, the lateral wall is formed by the sternomastoid muscle and the infrahyoid muscles of the neck within their fascial envelope. The space contains the deep cervical group of lymph nodes. Infection may enter the space through lymphatic vessels coming to these nodes and may extend downwards toward the superior mediastinum or by way of veins to the internal jugular vein. Infection is prevented from spreading into the retropharyngeal space by the condensation of fascia around the carotid sheath.

**Lateral relationships of the pharynx**

The chief lateral relation running alongside the pharynx is the carotid sheath with its associated arteries, veins and nerves, together with their branches. Closely associated with the sheath are the muscles and ligament arising from the styloid process. More laterally, the angles of the mandible and pterygoid muscles are related to the upper part of the pharynx anteriorly, and with the parotid gland and posterior belly of the digastric muscle more posteriorly. At a lower level, the sternocleidomastoid muscle covers the carotid sheath, with the infrahyoid muscles more anteriorly and the lateral lobes of the thyroid gland interposed.

In particular, the superior constrictor has on its lateral surface the lingual and inferior alveolar branches of the mandibular nerve, the ascending pharyngeal artery, the ascending palatine branch of the facial artery, the stylohyoid ligament, the styloglossus and stylopharyngeus muscles and, more laterally, the medial pterygoid muscle deep to the angle of the mandible. The maxillary artery runs anteriorly to enter the pterygopalatine fossa.

The middle constrictor has on its outer surface the lingual artery, the hyoglossus muscle and the hypoglossal nerve with the tendon of the posterior belly of the digastric muscle.

The inferior constrictor has on its lateral surface the external laryngeal nerve, the thyroid gland and the sternothyroid and sternohyoid muscles together with the omohyoid.

**The oesophagus**

**General description**

The oesophagus is a muscular tube, about 25 cm in length, connecting the pharynx to the stomach. It extends from the lower border of the cricoid cartilage at the level of the sixth cervical vertebra, where it is continuous with the pharynx, to the cardiac orifice of the stomach at the side of the body of the eleventh thoracic vertebra. In passing from the pharynx to the stomach, it traverses the neck and then the superior and posterior parts of the mediastinum before piercing the diaphragm, after which it has a short abdominal course before joining the stomach.

In the new-born infant, the upper limit of the oesophagus is found at the level of the fourth or fifth cervical vertebra and it ends higher, at the level of the ninth thoracic vertebra. At birth, the length of the oesophagus varies between 8 and 10 cm, but by the end of the first
year it has increased to 12 cm. Between the first and fifth years, it reaches a length of 16 cm, but growth after this is slow as it measures only 19 cm by the fifteenth year.

The diameter of the oesophagus varies according to whether or not a bolus of food or fluid is passing through it. At rest, in the adult, the diameter is about 20 mm, but this may increase to as much as 30 mm. At birth, the diameter is about 5 mm, but this dimension almost doubles in the first year, and by the age of 5 years it has attained a diameter of 15 mm. In its course from the pharynx to the stomach, the oesophagus presents an anteroposterior flexure, corresponding to the curvature of the cervical and thoracic parts of the vertebral column. It also presents two gentle curves in the coronal plane. The first begins a little below the commencement of the oesophagus and continues with a deviation to the left through the cervical and upper thoracic parts of its course, until it returns to the midline at the level of the fifth thoracic vertebra. The second coronal curve is formed as the oesophagus bends to the left to cross the descending thoracic aorta, to pierce the diaphragm and then to join the stomach.

The oesophagus is the narrowest region of the alimentary tract, except for the vermiform appendix, and it has three constrictions or indentations in its course. These are found:

1. at 15 cm from the upper incisor teeth where the oesophagus commences at the cricopharyngeal sphincter, which is normally closed
2. at 23 cm from the upper incisor teeth where it is crossed by the aortic arch and left main bronchus
3. at 40 cm from the upper incisor teeth where it pierces the diaphragm and where the lower 'physiological' oesophageal sphincter is sited.

The oesophageal wall

The wall of the oesophagus has four layers which are, from within outwards, the mucous membrane, the submucosa, the muscle coat and an outer fibrous layer.

Mucous membrane of the oesophagus

The oesophagus is lined by a non-keratinizing stratified squamous epithelium which is continuous with that of the pharynx. At the junction with the stomach, however, there is an abrupt change to the columnar epithelium of that organ.

The epithelium of the oesophagus has the typical basement membrane beneath which is a loose connective tissue lamina propria containing a very fine network of elastic fibres and lymphoid nodules. At rest the mucous membrane is thrown into longitudinal folds which disappear when the organ is distended by the passage of a bolus. They can be clearly seen on a normal barium swallow (Chapter 17). Although the pharynx contains no muscularis mucosae, this layer of visceral muscle cells makes its appearance soon after the oesophagus begins. Towards the lower end of the oesophagus, this layer becomes thicker than in any other
part of the alimentary tract and, because of this thickening, it is sometimes mistakenly identified in histological preparation as part of the muscular wall.

In early embryonic life, the epithelium of the oesophagus is composed of columnar epithelium, many of the cells of which are ciliated. At the time of birth, the ciliated cells are isolated in small groups and eventually disappear. The oesophagus is now lined with stratified squamous epithelium five to six cell layers in thickness. Soon after birth, the epithelium thickens rapidly to assume its adult appearance.

**The submucosa of the oesophagus**

The submucosa loosely connects the mucous membrane and the muscular coat. It contains the larger blood vessels and Meissner's nerve plexus of postganglionic parasympathetic fibres, as well as the oesophageal glands which are small, compound racemose glands of the mucous type. Each gland opens into the lumen by a long duct which pierces the muscularis mucosae. These glands secrete the mucus that lubricates the passage of food through the oesophagus. The glands are distributed irregularly throughout the oesophagus. In the abdominal part of the oesophagus, near to its junction with the stomach, other glands are found which do not penetrate the muscularis mucosae and which, because structurally they resemble the cardiac glands of the stomach, are called oesophageal 'cardiac' glands. They are also found at the upper end of the oesophagus where they continue to be called 'cardiac' glands. The distal part of the duct of the oesophageal glands is lined with three or four layers of stratified squamous epithelium. Proximally, at the junction of the duct with the gland, there is a gradual transition from this stratified epithelium to a low cuboidal epithelium.

**The muscular coat of the oesophagus**

The muscular layer of the oesophagus is composed of an outer longitudinal and an inner circular coat. The longitudinal fibres form a complete covering for nearly the whole of the oesophagus, but at the upper end, at a point between 3 and 4 cm below the cricoid cartilage, the fibres diverge from the median plane posteriorly and form two longitudinal fasciculae which incline upwards and forwards to the front of the oesophagus where they are attached to the posterior surface of the lamina of the cricoid cartilage through a small tendon. In general, the longitudinal muscular coat of the oesophagus is thicker than the circular muscular coat.

The fibres of the circular coat are continuous superiorly with the fibres of the cricopharyngeus part of the inferior constrictor. Anteriorly, these fibres are inserted into the lateral margins of the tendon, already described, of the longitudinal fibres. Inferiorly, the circular muscle fibres are continuous with the oblique fibres of the stomach. At the lower end of the oesophagus, the circular fibres form one component of a 'physiological' sphincter which will be described later.

In the upper third of the oesophagus, the muscle fibres of both coats are striated. In the middle third, there is a gradual transition to non-striated muscle, and the lower third contains non-striated muscle only.
Fibrous layer of the oesophagus

The fibrous layer consists of an external adventitia of irregular, dense connective tissue containing many elastin fibres. The arrangement of this tissue allows expansion during swallowing and maintains the position of the oesophagus in relation to adjacent structures. In the abdominal segment of the oesophagus there is an additional covering of peritoneum. At the diaphragmatic opening, the fibrous layer attaches the oesophagus to the margins of the opening and this attachment is known as the phreno-oesophageal ligament.

The presence of this adventitial layer makes it possible for the oesophagus to be mobilized by blunt finger dissection during operations from above and below without the chest being opened. It can then be withdrawn from the thorax as, for example, in the operation of pharyngolaryngo-oesophagectomy.

Nerve supply of the oesophagus

The striated muscle in the upper third of the oesophagus is supplied by the recurrent laryngeal branches of the vagus. The cell bodies for these fibres are in the rostral part of the nucleus ambiguus. However, the chief motor supply to the non-striated muscle is parasympathetic, and the cell bodies for these fibres are in the dorsal nucleus of the vagus. They reach the oesophagus by way of the oesophageal branches of the vagus itself and through its recurrent laryngeal branches, and synapse in the oesophageal wall in the ganglia of the submucosal plexus (Meissner's) and myenteric plexus (Auerbach's), which is between the outer longitudinal and inner circular muscle layers. From these cell bodies, short postganglionic fibres emerge to innervate the muscle fibres.

The cell bodies of the preganglionic sympathetic motor fibres are found in the lateral grey column of the spinal cord in thoracic segments 2 to 6 (chiefly 5 and 6). The fibres pass out in the anterior nerve roots and reach the sympathetic trunk by way of white rami communicantes. They then run upwards to the cervical ganglia where they synapse. From these ganglia, postganglionic fibres pass down into the thorax by the superior, middle, and inferior cardiac nerves to join the cardiac plexus, which they traverse without synapsing to reach the oesophagus. Some sympathetic fibres take a more direct route to the oesophagus by way of the thoracic ganglia 2 to 6, where the synapses are situated. The cervical oesophagus receives its sympathetic supply by means of a plexus around the inferior thyroid artery. The thoracic oesophagus has branches from the sympathetic trunks which form plexuses around the blood vessels supplying this section. In the abdominal oesophagus, the plexuses form around the left gastric and inferior phrenic arteries.

Afferent fibres from the oesophagus run with the branches of the vagus and have their cell bodies in the inferior vagal ganglion from where impulses reach the dorsal vagal nucleus and nucleus of the tractus solitarius. Some of the afferent fibres that run with the sympathetic nerves convey pain sensation.

Oesophageal pain

From cervical cardiac nerves and sympathetic trunk ganglia, fibres enter the thoracic spinal nerves by way of grey rami communicantes. Although any one of the thoracic nerves
may be involved, most of the pain fibres have their cell bodies in the dorsal root ganglia of thoracic spinal nerves 5 and 6. After entering the spinal cord, the fibres synapse with cell bodies in the gelatinous substance and posterior horn. The impulses are then conveyed by the lateral spinothalamic tract to the thalamus. The stimulus which seems to initiate oesophageal pain is tension in the muscular wall, resulting from either distension or muscular spasm. The mucosa is sensitive to heat and cold but not to touch. Chemical stimulation by reflux of gastric acid may, under certain conditions, cause pain.

Oesophageal pain is poorly localized and is referred to other areas. It can be severe and, if retrosternal, resembles cardiac pain. Pain produced by experimental oesophageal distension is localized anteriorly in the midline of the body in the region of the sternum. The area of reference to which the pain is projected corresponds roughly with the level of the part of the oesophagus being distended. Pain from the upper oesophagus is referred to the suprasternal region; that from the middle of the oesophagus to the retrosternal region; and that from the lower end of the oesophagus to the epigastrium.

Another variety of oesophageal pain, commonly called heartburn, is a burning, hot sensation felt under the lower part of the sternum and radiating up into the neck and jaw. The sensation may be accompanied by regurgitation of acid fluid into the throat. This pain is often ascribed to irritation of the oesophageal mucosa by acid regurgitation from the stomach. However, heartburn has been reported in patients with achlorhydria, and instillation of acid into normal oesophagus may not cause this sensation. On the other hand, a burning sensation similar to heartburn has been produced by inflation of a balloon introduced into the lower oesophagus in normal subjects. Furthermore, radiological studies have shown that during an attack of heartburn, the whole oesophagus is often in spasm. This suggests that the cause of heartburn sensation is not primarily acid reflux, but a prolonged spastic contraction of muscle comparable to that causing the pain of intestinal colic. In some patients, where there is inflammation of the oesophageal mucosa, the pain threshold may be lowered and reflux of gastric acid may well precipitate heartburn. It is still possible, however, that the mechanism of the pain production is that the acid irritates the lower oesophageal mucosa causing muscle spasm.

**Blood supply of the oesophagus**

The oesophagus obtains its blood supply from adjacent vessels. In the cervical part, this is from the inferior thyroid arteries which arise from the thyrocervical trunks of the subclavian artery. In addition, a supply is obtained from the left subclavian artery. In its thoracic part, the oesophagus is supplied segmentally, either directly from the descending thoracic aorta, or by way of branches of the bronchial or upper posterior intercostal arteries. In its abdominal part, the oesophagus is supplied by the left gastric branch of the coeliac trunk and the left inferior phrenic artery direct from the abdominal aorta.

An extensive venous plexus is formed on the exterior of the oesophagus and drains in a segmental way similar to the arterial supply. In the neck, the veins drain into the inferior thyroid veins; in the thorax they drain to the azygos and hemi-azygos system; and in the abdomen into the left gastric vein. This vein is a tributary of the portal system, whereas the other veins are part of the systemic system. The lower end of the oesophagus is a site of major importance for portal-systemic anastomoses and there is free communication between
the two systems. When there is portal obstruction, the multiple, small thin-walled subepithelial veins in this region become varicose and may break down and bleed heavily into the lumen.

At the upper end of the oesophagus, longitudinal submucosal oesophageal veins enter the pharyngeal / laryngeal plexus situated on the posterior and anterior walls of the pharynx at the level of the cricoid cartilage.

**Lymphatic drainage of the oesophagus**

Two network of lymphatic vessels are found in the oesophagus. There is a plexus of fairly large vessels in the mucous membrane which is continuous above with those of the pharynx and below with those of the gastric mucosa. The second plexus of finer vessels is present within the muscular coat and, although this may be independent of the mucosal plexus, it drains by the same collecting vessels. The latter leave the oesophagus in two ways, either piercing the muscular coat immediately and draining into neighbouring nodes, or ascending and descending beneath the mucosa. The efferent vessels from the cervical part of the oesophagus drain into the lower group of deep cervical nodes and into the paratracheal nodes. Vessels from the thoracic part drain into the posterior mediastinal nodes and the tracheobronchial nodes. Vessels from the abdominal part pass to the left gastric nodes. Some vessels may pass directly to the thoracic duct.

**The esophageal sphincters**

A full account of the working of the oesophageal sphincters in the course of deglutition is given in Chapter 11. This section deals with some anatomical aspects of the sphincters.

**The upper oesophageal sphincter**

The upper oesophageal sphincter is provided by the cricopharyngeus part of the inferior constrictor which encircles the oesophageal entrance, being attached to each side of the cricoid cartilage. This muscle has no posterior median raphe. Its fibres are continuous with the circular muscle coat of the oesophagus below. It is described in more detail above, where its nerve supply is also detailed.

This sphincter is always closed, and manometric studies demonstrate a region of raised pressure over about 3 cm in length. The pressure profile in this region shows a 1-cm zone of rising pressure proximally followed by 1 cm of peak pressure reaching about 35 mmHg. This region of peak pressure corresponds to the position of the cricopharyngeus. Beyond this is a distal 1 cm in which the pressure decreases to atmospheric pressure. These recordings demonstrate the existence of a tonic sphincter that is very competent.

**The lower oesophageal sphincter**

It is not possible to demonstrate a lower oesophageal sphincter histologically, on account of there being no thickening of the circular muscle coat. Manometric studies demonstrate a zone of raised pressure about 3 cm in length at the oesophagogastric junction extending above and below the diaphragm. The mean pressure here is approximately 8 mmHg.
higher than the intragastric pressure. Although this pressure is only slightly in excess of that in the stomach, regurgitation of gastric contents does not normally occur. This 'sphincter' region of the oesophagus, with an intraluminal pressure higher than the rest of the oesophagus or stomach, is regarded as one component of a 'physiological' sphincter at the oesophagogastric zone. Radiological studies show that swallowed food is momentarily held up at the lower end of the oesophagus, before entry into the stomach. The possible components of this sphincter mechanism are as follows:

(1) An intrinsic sphincter. Present in the circular muscle fibres of the oesophagus, described previously.

(2) Pinch-cock effect of the diaphragm. The fibres of the right crus of the diaphragm split to encircle the oesophageal opening and may play an auxiliary role in achieving an effective lower oesophageal sphincter.

(3) Mucosal folds. These have been described at the lower end of the oesophagus and have been thought to exert a valvular effect. They may be thrown into prominence by contraction of the muscularis mucosae.

(4) Oblique muscle fibres of the stomach. The portion of the stomach adjacent to the oesophageal opening has a definite collar of muscle which is part of the innermost oblique muscle layer of the stomach. The fibres sweep up from the lesser curvature to encircle the terminal oesophagus. They may help to preserve the angle between the left edge of the oesophageal opening and the fundus of the stomach, the cardiac notch.

(5) Thoracoabdominal pressure gradient. The thoracic part of the oesophagus is subject to a negative pressure as opposed to the abdominal oesophagus which has a positive pressure applied to it. It is felt that this pressure differential may collapse the lower end of the oesophagus like a mechanical flutter valve, preventing reflux. Food and fluid passing down the oesophagus would open this valve, but it would otherwise remain closed.

(6) Oesophagogastric junction angle. It has been suggested that the sharp angle at which the left edge of the oesophagus meets the fundus of the stomach forms a fold that can act as a mechanical flap valve. A rise of intragastric pressure will compress the adjacent part of the terminal oesophagus and prevent a reflux. The higher the pressure in the stomach, the more securely will this flap valve be closed. The angle of entry of the oesophagus into the stomach is, however, very variable in humans, and patients appear to suffer reflux despite a normal oesophagogastric angle.

The way in which a competent lower oesophageal sphincter is achieved remains uncertain, but it seems that a number of mechanisms may act in concert to accomplish this.

Relationships of the oesophagus

The relationships of the cervical, thoracic and abdominal parts of the oesophagus will be dealt with separately.
The cervical part of the oesophagus

In the neck, the trachea lies anterior to the oesophagus attached by loose connective tissue. The recurrent laryngeal nerves ascend on each side in the groove between the trachea and oesophagus. Posteriorly, the oesophagus rests on the prevertebral fascia covering the C6-C8 vertebral bodies and the prevertebral muscles. The thoracic duct passes upwards behind the left border of the oesophagus and, at the level of C6, the duct arches laterally between the carotid and vertebral systems before opening into the junction of the left internal jugular and left subclavian veins. Laterally, on each side, lie the corresponding parts of the carotid sheath together with its contents, with the lower poles of the lateral lobes of the thyroid gland between.

Thoracic part of the oesophagus

In the superior mediastinum, the oesophagus lies between the trachea and the vertebral column, slightly to the left of the median plane. It passes behind and to the right of the aortic arch and enters the posterior mediastinum at the level of the fourth thoracic vertebra. It is related anteriorly to the trachea and posteriorly to the third to fourth thoracic vertebrae. The left recurrent laryngeal nerve is in the groove between the oesophagus and trachea on the left. The thoracic duct is behind the left oesophageal border.

Laterally, adjacent to the left border of the oesophagus, is the arch of the aorta passing from before backwards and slightly to the left, with the vagus nerve crossing the arch on its outer side and giving rise to the left recurrent laryngeal branch, which hooks beneath the ligamentum arteriosum to reach the groove between the oesophagus and the trachea. The left subclavian artery is immediately to the left of the oesophagus as the vessel arises from the aortic arch. On the right side, adjacent to the right margin of the oesophagus, is the azygos vein arching from posterior to anterior over the lung root to enter the superior vena cava. The mediastinal pleura of both sides is in contact with the oesophagus, separated on the right by the azygos vein and on the left by the aortic arch and left subclavian artery.

In the posterior mediastinum, anterior to the oesophagus, the trachea bifurcates at the level of the fifth thoracic vertebra and below this the fibrous pericardium comes into contact with the anterior surface of the oesophagus. At the bifurcation of the trachea, the oesophagus is crossed anteriorly by the left principal bronchus passing into the left lung root beneath the aortic arch. It may indent the oesophagus anteriorly on the left. The right pulmonary artery crosses the oesophagus immediately below the tracheal bifurcation. The inferior tracheobronchial lymph nodes are interposed between the bifurcation of the trachea and the oesophagus. Below this, it is the left atrium of the heart that lies in front of the oesophagus, separated only by the pericardium and its oblique sinus. Lower still, the diaphragm is in front until the oesophagus enters the abdomen.

Posteriorly, in the posterior mediastinum, are the vertebral column and the long cervical muscles. The right posterior intercostal arteries arising from the descending thoracic aorta pass toward the right across the vertebral column. The thoracic duct enters the thorax through the right side of the aortic opening in the diaphragm and runs up behind the right margin of the oesophagus until, at the level of the fifth thoracic vertebra, it crosses obliquely to come to lie behind the left margin as described previously. The two hemi-azygos veins
intervene between the oesophagus and the vertebral column, at the level of the seventh and eighth thoracic vertebrae, as they pass across to join the azygos vein on the right. Inferiorly, near the diaphragm, the aorta passes behind the oesophagus as the latter curves toward the left and turns forward to pass through the diaphragm to the stomach.

On the left side, in the posterior mediastinum, the oesophagus is related to the descending thoracic aorta and left mediastinal pleura. On the right side, the oesophagus is related to the right pleura separated only by the azygos vein. The left and right vagus nerves, having branched to form the cardiac and pulmonary plexuses, come together again as the oesophageal plexus on the oesophageal wall and then form single or multiple nerve trunks that descend with the oesophagus through the same opening in the diaphragm. The left vagal fibres usually lie on the anterior surface of the oesophagus and those on the right posteriorly.

**Abdominal part of the oesophagus**

After the oesophagus emerges from the right crus of the diaphragm, slightly to the left of the median plane at the level of the tenth thoracic vertebra, it comes to lie in the oesophageal groove on the posterior surface of the left lobe of the liver. It curves sharply to the left to join the stomach at the cardia. The right border of the oesophagus continues evenly into the lesser curvature of the stomach, while the left border is separated from the fundus of the stomach by the cardiac notch. This short abdominal section of the oesophagus is covered with the peritoneum of the greater sac anteriorly and on its left side, and with the lesser sac on the right. It is contained in the upper left portion of the lesser omentum and the peritoneum, reflected from its posterior surface to the diaphragm, is part of the gastrophrenic ligament in which the oesophageal branches of the left gastric vessels pass to the oesophagus. Behind the oesophagus at this level are the left crus of the diaphragm and the left inferior phrenic artery.