

Clinical Anatomy of Swallowing Mechanism

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Swallowing structures

- * The oral cavity, pharynx, larynx, and esophagus are the anatomical areas that are involved in swallowing mechanism.
- * Swallowing involves coordination of the sequence of activation and inhibition for more than 25 pairs of muscles in the mouth, pharynx, larynx, and esophagus [1].

Oral structures

It includes the lips, teeth, cheeks, hard palate, soft palate, uvula, mandible, tongue, and faucial arches.



Figure 1. Surface anatomy of the mouth [9]

Sulci: The oral cavity consists of sulci and cavities where food or liquid remain after swallow. For example,

- The superior and inferior sulci that are formed between alveolus and cheek.
- The anterior and lateral sulci that are formed between the lips and the maxilla and mandible.

Teeth: The teeth are responsible for chewing and biting. Good teeth are essential to good bolus formation.

Cheeks: The muscles contained in the cheeks provide counter force to the tongue to facilitate proper bolus control.

Lips: The muscles in the lips ensure good lip closure which is important to prevent oral contents from leaking out of the mouth. The primary muscle responsible for closing the lips is the Orbicularis Oris.

Faucial pillars: Anterior faucial pillar (or palatoglossal arch) is formed by the Palatoglossus muscle; posterior faucial pillar (or palatopharyngeal arch) is formed by the Palatopharyngeus muscle.

Mucosa: The mucosa covers the entire oral cavity and facilitate bolus transport.

Uvula: The uvula is formed by the Musculus Uvulae; the functional role of this muscle is not clear; it may serve to fill in the region of contact between the velum and posterior pharyngeal wall during contraction and add bulk to the velum when contracted.

Salivary glands:

- In addition to small salivary glands, there are three large salivary glands, including the parotid glands, submandibular glands, and sublingual glands in each side.
- Saliva serves to maintain oral moisture, to reduce tooth decay, and to assist in digestion. Besides, saliva acts as a natural neutralizer of stomach acid when it refluxes into the esophagus.

Tongue: The tongue muscles, both intrinsic and extrinsic, permit bolus manipulation to permit proper chewing and mixing with saliva. The tongue is a muscle structure that can be divided, for swallowing, into an oral portion and a pharyngeal portion.

- The oral portion includes tip, blade, front, center, and back that ends at the circumvallate papillae. It is controlled voluntarily.
- The pharyngeal portion of the tongue (tongue base) begins at the circumvallate papillae and extends to the hyoid bone. It is controlled involuntarily in the brainstem.
- There is a wedge-shaped space called the valleculae that is formed between the base of the tongue and the epiglottis.

Oral bolus containment:

1) Buccinator

Origin: Fibers run horizontally and blend into the fibers of the M. Orbicularis Oris anteriorly; posteriorly they attach to a tendinous structure between the pterygoid bone and the mandible, the pterygomandibular raphe, which is also the attachment for the upper fibers of the upper pharyngeal constrictor.

Action: Contraction tenses the cheek thus maintaining food between the molars; the muscle is also active when sucking and expelling air forcibly.

Nerve supply: Innervation is by the buccal branch of the facial nerve.

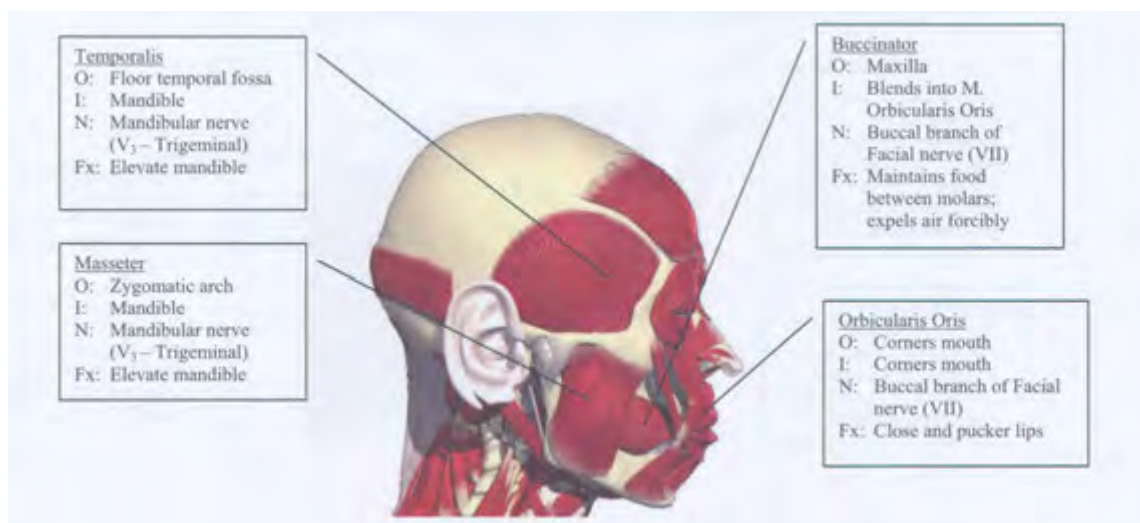


Figure 2. Facial muscles [7]

Note: The fibers of Orbicularis Oris, Buccinator, and Superior Pharyngeal Constrictor are all aligned in a serial fashion and thus create a muscular sling which encircles the oropharyngeal space. This sling is active to create and maintain adequate positive pressure in the oral cavity and in the oropharynx during the propulsion of the bolus towards the hypopharynx.

2) Orbicularis Oris

Origin: Fibers run from one corner to the other corner of the mouth.

Action: Contraction closes and puckers the lips; the muscle is responsible for preventing the bolus from leaking out of the mouth during the oral phase.

Nerve supply: Innervation is by the buccal branch of the facial nerve (CN. VII).

Bolus manipulation:

- Once the food is in the mouth, it needs to be moved around in order to position it under the teeth for chewing, to mix it around with the saliva and to manipulate it into a cohesive bolus before sending it back into the pharynx. The following anatomy is essential to this task.
- The muscles involved in the oral phase of swallowing represent three anatomical regions: the suprahyoid suspensory muscles (which affect the position of the posterior tongue and thus, the hyoid bone), the muscles surrounding the tonsillar pillars, and the muscles involved in the closure of the nasopharynx [1]

Tongue muscles:

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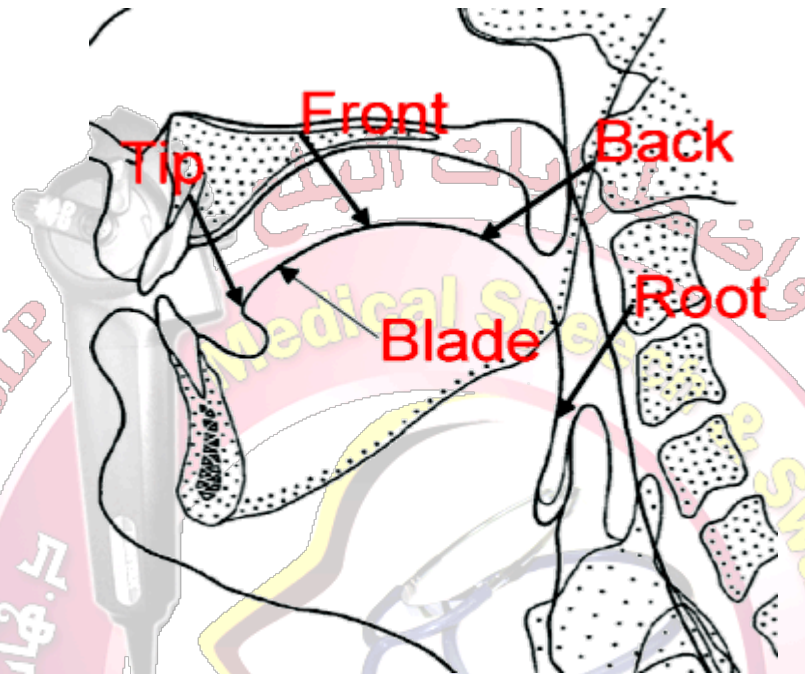


Figure 3. Tongue areas

Intrinsic tongue muscles:

As shown in Figure 4, there are 4 muscles contained within the body of the tongue (intrinsic):

- 1) **Superior longitudinal**, 2) **Verticalis**, 3) **Transversus**, and 4) **Inferior longitudinal**.

1) Superior longitudinal lingual muscle:

Origin: Runs from the tip of the tongue (apex) to the back of the tongue (root).

Action: Bilateral contraction shortens the tongue and curls the tip and the sides of the tongue upward.

Nerve supply: Innervation is by the hypoglossal nerve (CN. XII).

2) Verticalis

Origin: Runs from the dorsal lingual surface to the ventral lingual surface.

Action: Contraction flattens and widens the tongue.

Nerve supply: Innervation is by the hypoglossal nerve (CN. XII).

3) Transversus

Origin: Runs from the median fibrous septum to the lateral lingual margin.

Action: Contraction narrows and elongates the tongue.

Nerve supply: Innervation is by the hypoglossal nerve (CN. XII).

4) Inferior longitudinal lingual muscle

Origin: Runs from the tip of the tongue (apex) to the back of the tongue (root).

Action: Bilateral contraction shortens the tongue and curls the tip and sides of the tongue downward.

Nerve supply: Innervation is by the hypoglossal nerve (CN. XII).

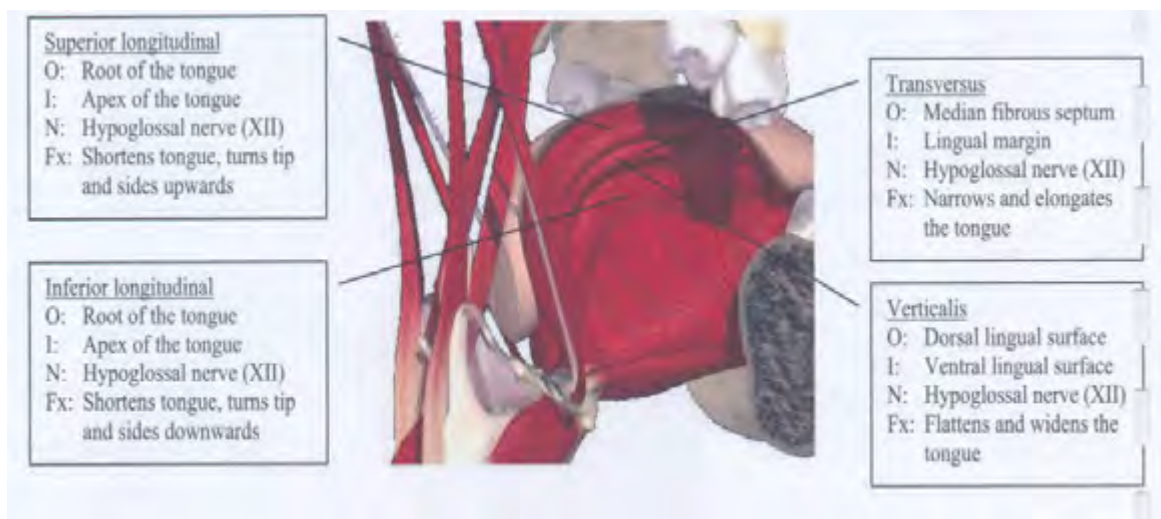


Figure 4. Longitudinal lingual muscles [7]

Extrinsic tongue muscles:

There are 4 muscles that connect the tongue with the skeleton (extrinsic):

1) Genioglossus, 2) Hyoglossus, 3) Styloglossus, and 4) Palatoglossus

1) Genioglossus

Origin: Fibers run from the front of the mandible.

Insertion: it fans into the substance of the tongue.

Action: By means of their posterior fibers, draw the root of the tongue forward, and protrude the apex from the mouth. The anterior fibers draw the tongue back into the mouth. The two muscles acting in entirety draw the tongue downward, so as to make its superior surface concave from side to side, forming a channel along which fluids may pass toward the pharynx, as in sucking.

Nerve supply: Innervation is by the hypoglossal nerve (CN. XII).

2) Hyoglossus

Origin: Runs from the hyoid bone.

Insertion: to the side of the tongue.

Action: Contraction depresses the tongue and pulls it backward toward the hyoid bone

Nerve supply: Innervation is by the hypoglossal nerve (CN. XII).

3) Styloglossus

The **Styloglossus**, the shortest and smallest of the three styloid muscles.

Origin: From the anterior and lateral surfaces of the styloid process, near its apex, and from the stylomandibular ligament. Passing downward and forward between the internal and

external carotid arteries, it divides upon the side of the tongue near its dorsal surface, blending with the fibers of the Longitudinalis inferior in front of the Hyoglossus; the other, oblique, overlaps the Hyoglossus and decussates with its fibers.

Action: It draws the tongue upward and backward.

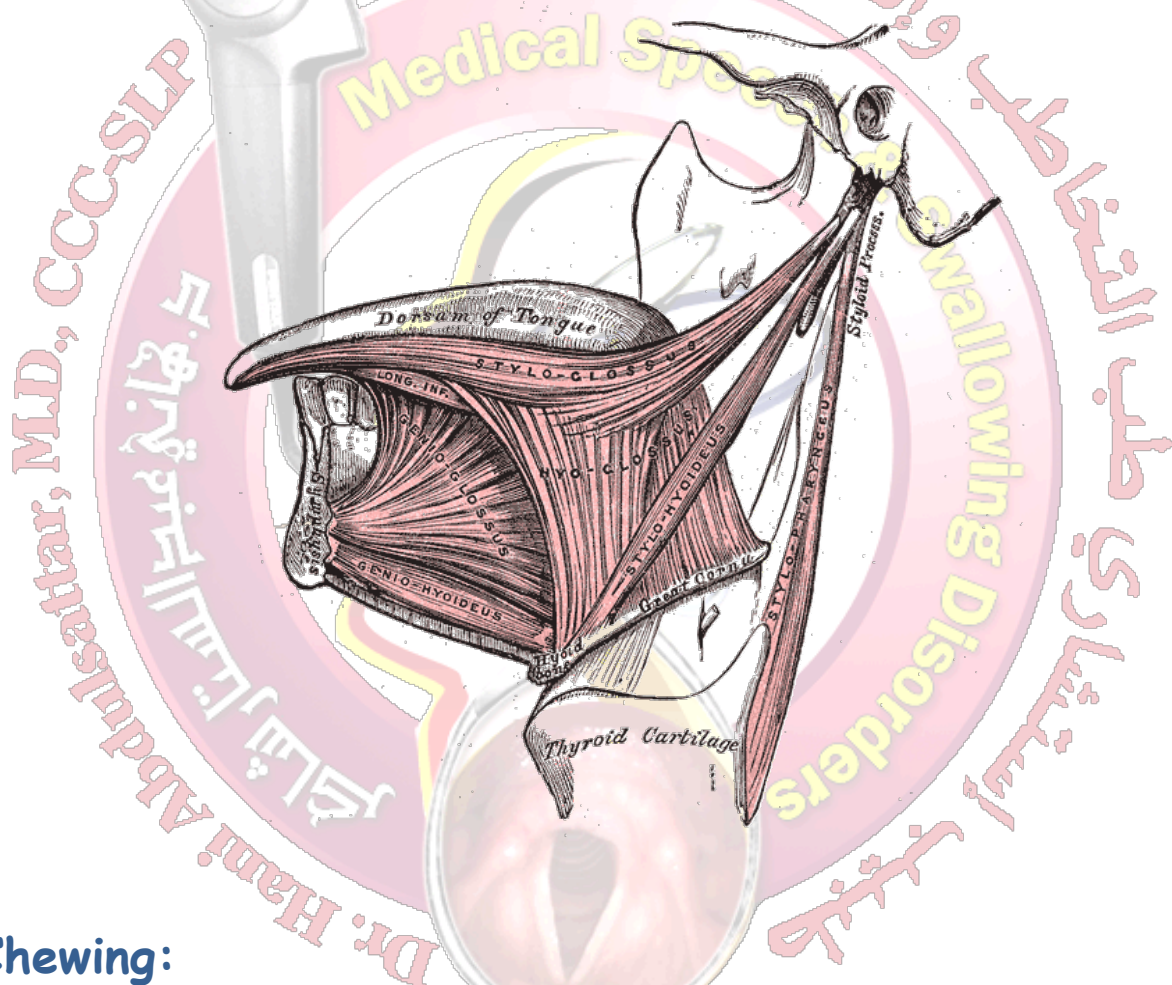
Nerve supply: Innervation is by the hypoglossal nerve (CN. XII).

4) Palatoglossus

Origin: Runs from the soft palate to the side of the tongue.

Action: Contraction elevates the floor of the tongue and approximates the tongue to the palatoglossal arch thus closing off the oral cavity from the oropharynx. It draws the root of the tongue upward.

Nerve supply: Innervation is by the accessory nerve through the pharyngeal plexus.



Chewing:

Many muscles are involved in the act of chewing. Following are some of the more obvious ones that are responsible for closing and opening the jaw and keeping the mouth closed while chewing. The temporomandibular joint is also discussed.

1) Temporalis

Origin: Runs from the floor of the temporal fossa to the mandible.

Action: Contraction elevates and retracts the mandible (closing of the jaw).

Nerve supply: Innervation is by the mandibular nerve (branch of the trigeminal nerve, CN. V).

2) Masseter

Origin: Runs from the zygomatic arch to the mandible.

Action: Contraction elevates the mandible (closing of the jaw).

Nerve supply: Innervation is by the mandibular nerve (branch of the trigeminal nerve, CN. V).

3) Internal (Medial) Pterygoid

Origin: Fibers run from the sphenoid, palatine and maxillary bones to the medial surface of the ramus and angle of the mandible.

Action: Contraction closes the jaw by raising the mandible against the maxilla.

Nerve supply: Innervation is by the mandibular nerve (branch of the trigeminal nerve, CN. V).

4) External (Lateral) Pterygoid

Origin: Fibers run from the sphenoid bone and lateral surface of the lateral pterygoid plate to the condyle of the mandible and the front margin of the articular disk of the temporomandibular joint (TMJ).

Action: Contraction assists in opening the mouth by drawing the condyle and articular disk forward (grinding motion).

Nerve supply: Innervation is by the mandibular nerve (branch of the trigeminal nerve, CN. V).

5) Supra- and Infrahyoid muscles

- The supra- and infrahyoid muscles assist during mastication by opening the jaw
- The suprahyoid muscles run from the mandible to the hyoid bone and pull the mandible inferiorly, thus depressing the mandible and opening the mouth
- The infrahyoid muscles (strap muscles) pull the hyoid bone inferiorly, thus fixing its position; when the suprahyoid muscles contract using the hyoid bone as a fixed position, they pull the mandible inferiorly and open the jaw.

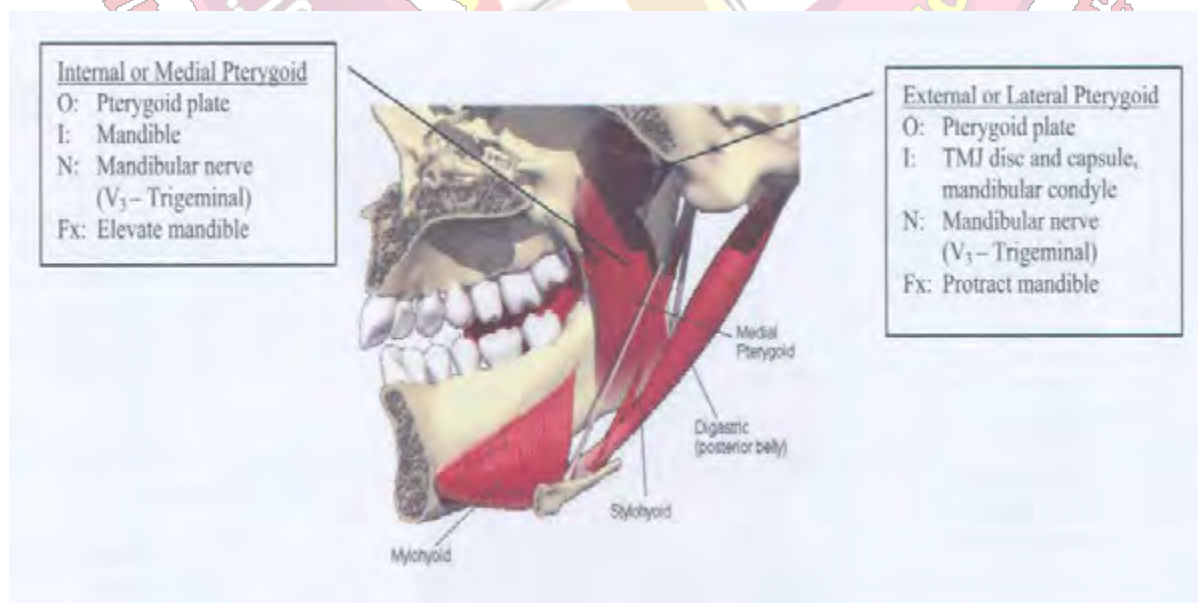


Figure 5. Pterygoid muscles [7]

6) Temporomandibular joint (TMJ)

- Joint between the maxilla and the mandible.
- Joint contains an intra-articular disk which facilitates movement between the two bones.
- Sensory innervation of the joint is by the mandibular nerve (branch of the trigeminal nerve, CN. V).

Pharyngeal structures

- * The pharynx is a funnel shaped that is situated behind the nasal cavities, the mouth, and the larynx.
- * The pharynx is a membranous tube running from the level of the base of the skull to the level approximating the sixth cervical vertebra.
- * Parts of the pharynx:
 - Nasal part of the pharynx: It lies behind the nasal cavities above the soft palate.
 - Oral part of the pharynx: It lies behind the mouth cavity and extends from the soft palate to the upper border of the epiglottis.
 - Laryngeal part of the pharynx: It lies behind the opening into the larynx and the posterior surface of the larynx. It extends between the upper border of the epiglottis and the lower border of the cricoid cartilage.

Velopharyngeal closure

- The Soft Palate is a movable fold, suspended from the posterior border of the hard palate.
- When occupying its usual position, i.e. relaxed and pendent, its anterior surface is concave, continuous with the roof of the mouth, and marked by a median raphé
- Its upper border is attached to the posterior margin of the hard palate, and its sides are blended with the pharynx; its lower border is free.
- Its lower portion, which hangs like a curtain between the mouth and pharynx, is termed the palatine velum.
- Hanging from the middle of its lower border is a small, conical, pendulous process, the palatine uvula; and arching laterally and downward from the base of the uvula on either side are two curved folds of mucous membrane, containing muscular fibers, called the arches or pillars of the fauces.
- Poor velopharyngeal closure will affect speech but is not a matter of great concern in regard to the safety of swallowing. Although the entrance of food into the nasopharynx may be unpleasant, it certainly is not life-threatening. However, poor velopharyngeal closure will prevent or hinder pressure generation by the pharyngeal tongue during the initiation of the pharyngeal phase of the swallow. This may be of considerable consequence to facilitating adequate upper esophageal sphincter opening.
- Velopharyngeal closure is the result of contraction of the **Levator Veli Palatini**, **Superior Pharyngeal constrictor**, and the **Palatopharyngeus** muscles.
- **Tensor Veli Palatini** and **Uvula** do not play role in velopharyngeal closure.

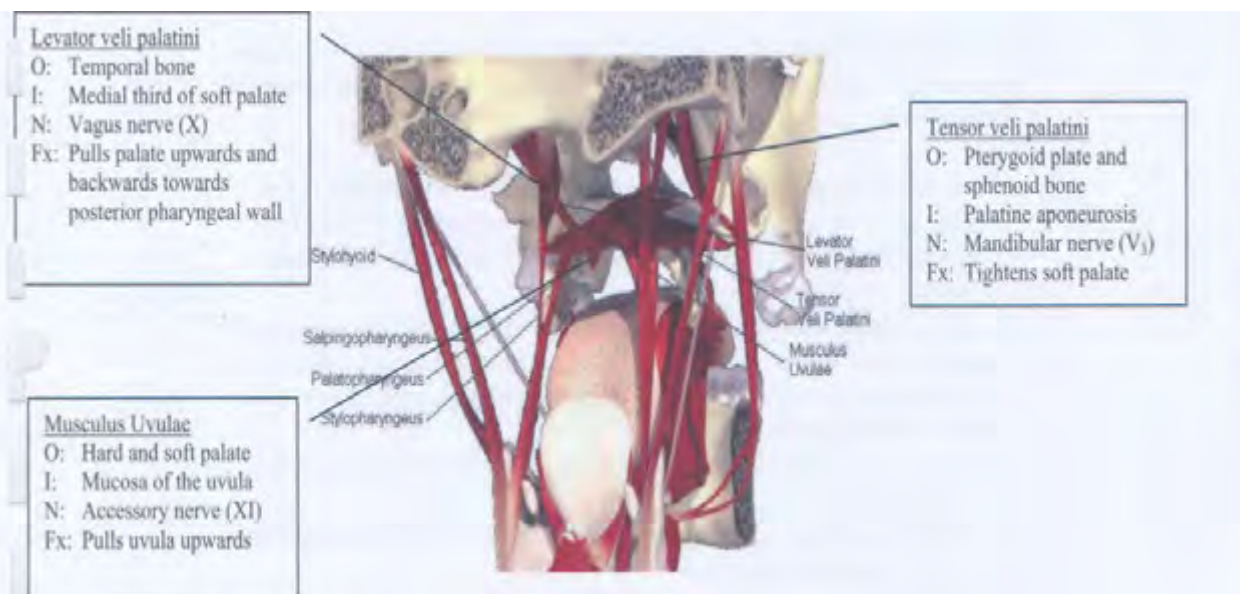


Figure 6. Velopharyngeal closure muscles [7]

7) Levator Veli Palatini

Origin: Fibers run from the temporal bone to the soft palate; the muscles on each side join each other in midline (creating a sling).

Action: Bilateral contraction pulls the palate upward and backward toward the posterior pharyngeal wall, closing off the nasopharynx from the oropharynx.

Nerve supply: Innervation is by the accessory nerve (CN. XI) via the pharyngeal plexus.

8) Superior Pharyngeal constrictor

Origin: Fibers run from the pterygomandibular raphe (a tendinous structure running from the pterygoid bone to the mandible; the buccinator also inserts on this structure) and from the side of the tongue, posteriorly to the pharyngeal raphe (a tendinous structure running along the midline of the posterior pharyngeal wall) and the pharyngeal tubercle on the occipital bone.

Action: Bilateral contraction pulls the superior part of the posterior wall of the pharynx toward the palate, creating a sphincter-like action when working together with the palatine muscles.

Nerve supply: Innervation is by the accessory nerve (CN. XI).

9) The palatopharyngeus muscles

Palatopharyngeus is part of the inner longitudinal muscle layer of the pharynx. It forms the posterior pillar of the fauces or tonsillar fossa.

Origin: Posterior margin of the bony palate and the palatine aponeurosis.

Insertion: Posterior border of thyroid cartilage and aponeurosis of pharynx as it becomes part of the inner longitudinal muscle layer of the pharynx.

Action: Contraction elevates the pharynx and the larynx, narrows fauces, and depresses soft palate. In addition, this muscle together with the superior pharyngeal constrictor muscles is responsible for the anterior excursion of the posterior and lateral pharyngeal walls for velopharyngeal closure.

Nerve supply: Innervation is by the pharyngeal branch of the vagus nerve (CN X) with motor fibres originating in the cranial accessory nerve (CN XI).

Blood supply: Ascending pharyngeal artery.

10) The uvula

- It contains very few muscle fibers and does not contribute to velopharyngeal closure.

11) Tensor Veli Palatini

The tensor Veli palatini is not thought to play a role in velopharyngeal closure.

Origin: Fibers run from the sphenoid and pterygoid bones, wind their way around a bony hook (the pterygoid hamulus) and insert into the palatine aponeurosis.

Action: Bilateral contraction pulls the palate taut and horizontal, creating a platform from which the other palatine muscles can change its position.

Nerve supply: Innervation is by the mandibular nerve (branch of the trigeminal nerve, CN. V).

Tongue base retraction is the result of a co-contraction of the following muscles:

- 1) Palatoglossus
- 2) Styloglossus
- 3) Hyoglossus
- 4) Transversus (Intrinsic tongue muscle)
- 5) Upper pharyngeal constrictor

The Pharyngeal wall muscles:

* The wall of the pharynx has three layers:

- 1) Mucous membrane:
 - Mucous membrane is continuous with that of the nasal cavities, the mouth, and the larynx.
 - The upper part is lined by ciliated columnar epithelium.
 - The lower part is lined by stratified squamous epithelium.
- 2) Fibrous layer:
 - It lies between the mucous membrane and the muscular layer.
 - It is thicker above.
- 3) Muscular layer: It consists of →

Superior, middle, and inferior constrictor muscles:

Origin: Their fibers run in circular direction.

Action: The action of these constrictor muscles: During the process of swallowing, the posterior pharyngeal wall is pulled forward by the action of upper fibers of the superior constrictor muscle, which aid the soft palate in closing off the upper part of the pharynx. The bolus of food is propelled down into the esophagus by the successive contraction of the superior, middle, and inferior constrictors muscles. The cricopharyngeus muscle that is the

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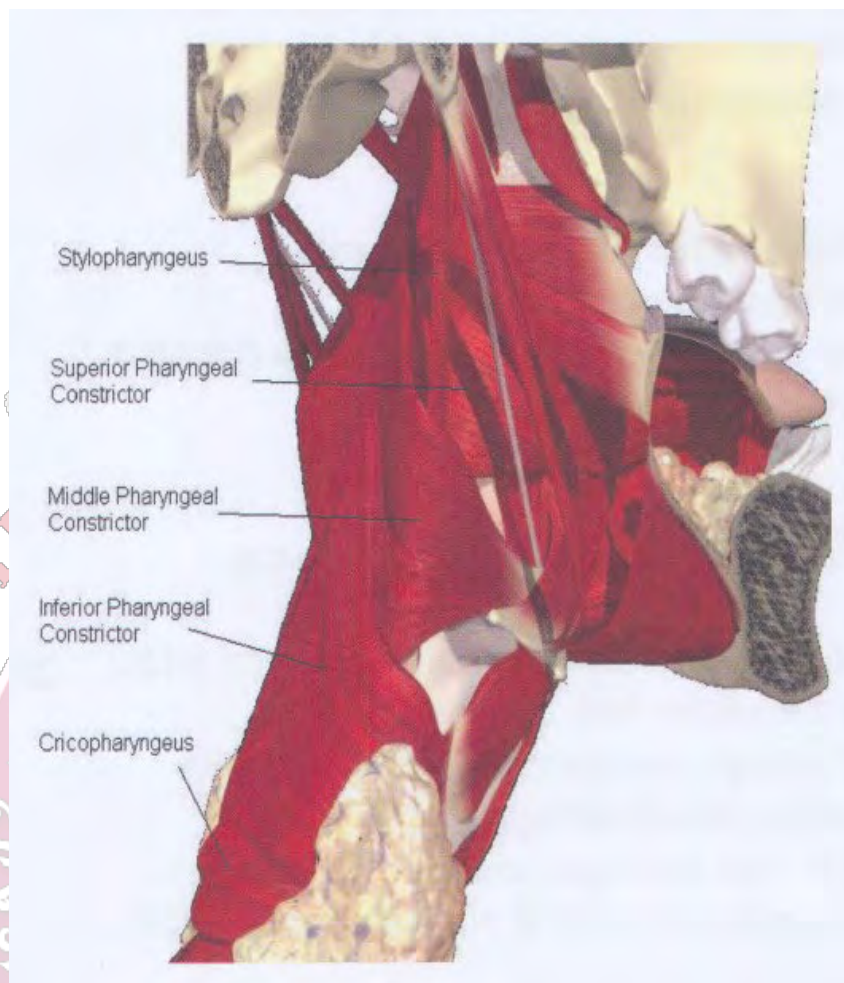


Figure 7. Pharyngeal constrictors muscles [7]

lowest fibers of the inferior constrictor muscle act as upper esophageal sphincter to prevent the entry of air into the esophagus between the acts of swallowing.

Nerve supply: These muscles are innervated by pharyngeal plexus.

Pharyngeal constriction (squeeze) and shortening:

Once the bolus has entered the pharynx, with the base of the tongue sealing off the oral cavity and the velum closing off the nasopharynx, the pharynx now starts pushing the bolus down by squeezing its walls together in a ripple-like effect and by shortening in length. The following muscles contribute to this action →

Inferior Constrictor: It is strongest and thickest of the pharyngeal muscles.

Middle Constrictor: It fans shaped and striated. This muscle is overlapped by the inferior and superior constrictor muscles.

Superior Constrictor: It is the weakest of the pharyngeal muscles.

Stylopharyngeus Muscle: It runs along the sides of the constrictor muscles. This muscle not only aids in the pharyngeal contraction but also aids in elevating the pharynx and larynx.

1) Superior Pharyngeal Constrictor

2) Middle Pharyngeal Constrictor

Origin: Fibers run from the hyoid bone and from the stylohyoid ligament and fan out posteriorly in both a superior and inferior direction to the pharyngeal raphe (a tendinous structure running along the midline of the posterior pharyngeal wall).

Action: Bilateral contraction pulls the posterior wall of the pharynx toward the anterior structures (hyoid bone, thyroid cartilage, epiglottis), assisting in a peristaltic motion together with the other constrictors.

Nerve supply: Innervation is by the pharyngeal plexus (network supplied with sensory and motor nerves by the Trigeminal (CN. V), Glossopharyngeal (CN. IX), Vagus (CN. X) and Accessory (CN. XI) nerves.

3) Lower Pharyngeal Constrictor

Origin: Fibers run from the cricoid and thyroid cartilages and fan out posteriorly and superiorly to insert into the pharyngeal raphe (a tendinous structure running along the midline of the posterior pharyngeal wall).

Action: Bilateral contraction provides a propelling force to the bolus by assisting in a peristaltic motion together with the other constrictors.

Nerve supply: Innervation is by the pharyngeal plexus (network supplied with sensory and motor nerves by the Trigeminal (CN. V), Glossopharyngeal (CN. IX), Vagus (CN. X) and Accessory (CN. XI) nerves.

4) Salpingopharyngeus

Origin: Fibers arise from the cartilage of the auditory tube and runs to the internal surface of the pharynx and then merges with the palatopharyngeus.

Action: Contraction elevates the pharynx and the larynx.

Nerve supply: Innervation is by branches from pharyngeal plexus.

5) Palatopharyngeus

Palatopharyngeus is part of the inner longitudinal muscle layer of the pharynx. It forms the posterior pillar of the fauces or tonsillar fossa.

Origin: Posterior margin of the bony palate and the palatine aponeurosis.

Insertion: Posterior border of thyroid cartilage and aponeurosis of pharynx as it becomes part of the inner longitudinal muscle layer of the pharynx.

Action: Contraction elevates the pharynx and the larynx, narrows fauces, and depresses soft palate.

Nerve supply: Innervation is by the pharyngeal branch of the vagus nerve (CN X) with motor fibres originating in the cranial accessory nerve (CN XI).

Blood supply: Ascending pharyngeal artery.

6) Stylopharyngeus

Origin: It runs from medial side of the styloid process of the temporal bone to pharynx in inferior and medial direction; middle pharyngeal constrictor wraps around the belly of the stylopharyngeus. Its fibers run in a more or less longitudinal direction. It runs along the sides of the constrictor muscles. It runs from the cartilage of the auditory tube down to pharynx.

Insertion: Superior border of the thyroid cartilage and also into the pharyngeal wall.

Action: This muscle not only aids in the pharyngeal contraction but also aids in elevating the pharynx and larynx.

Nerve supply: It is innervated by the glossopharyngeal nerve. Stylopharyngeus, the only muscle innervated by IX, is the only muscle of the pharyngeal wall NOT innervated by the vagus (X) nerve; it is a derivative of the third pharyngeal arch.

Blood supply: Ascending pharyngeal artery.

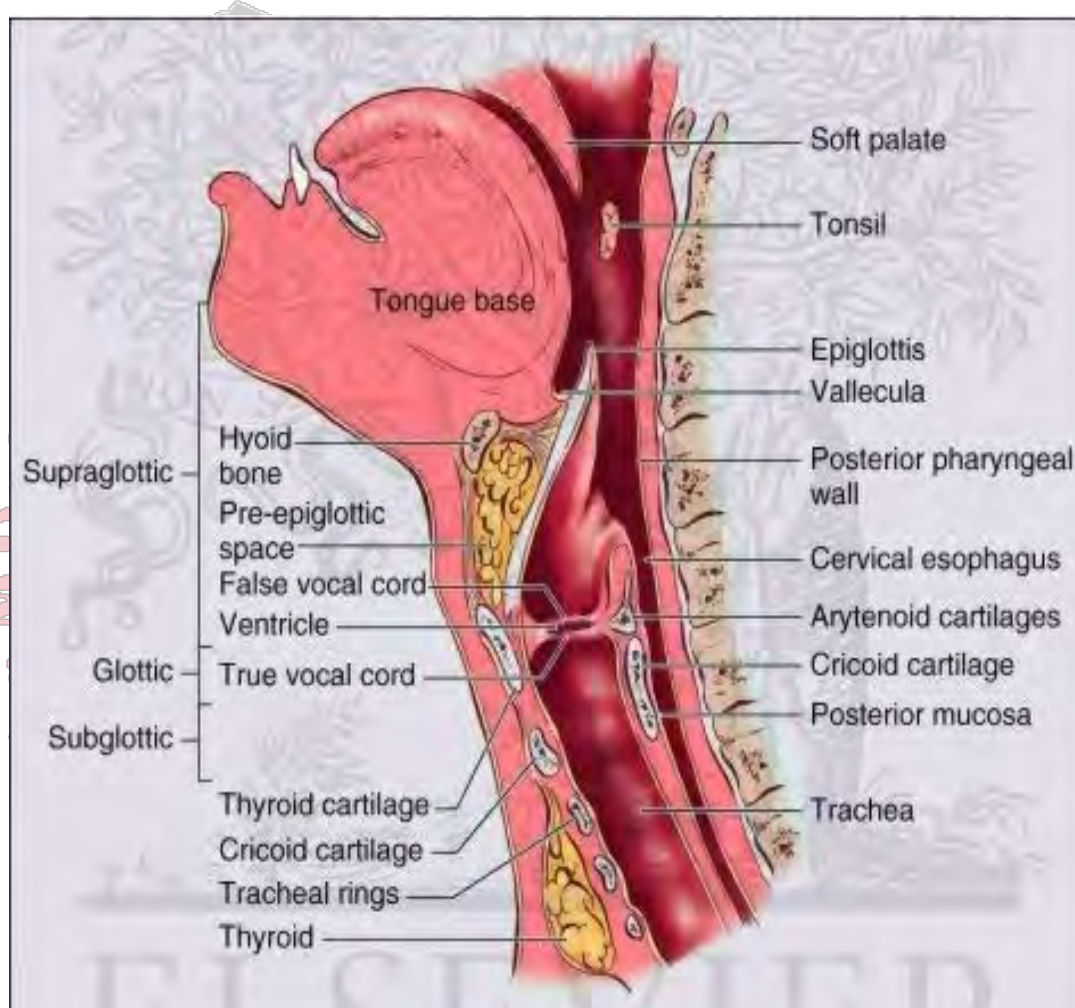


Figure 8. Anatomy of larynx and hypopharynx: Sagittal view. (From Grégoire V, Coche E, Cosnard G, et al: Selection and delineation of lymph node target volumes in head and neck

Hypopharynx

- * The hypopharynx forms the lower third of the pharynx, and it is also known as the laryngopharynx as it connects the throat to the oesophagus [2].
- * Portion of the pharynx that lies inferior to the tip of epiglottis.
- * Posterior and lateral walls are formed by middle and inferior pharyngeal constrictors.
- * Extends inferiorly to the cricopharyngeus, where the pharynx empties into the cervical esophagus. The cricopharyngeus muscle serves as the valve at the top of the esophagus and is also referred to as the cricopharyngeal sphincter.
- * Interiorly, it extends from the valleculae and contains the epiglottis and the larynx.

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- * Lateral to the larynx are the pyriform sinuses, two mucosal pouches whose medial borders are the lateral walls of the larynx. The pyriform sinuses end inferiorly at the cricopharyngeus muscle, which is the most inferior structure of the pharynx.
- * Posterior aspect of the hypopharynx contains the posterior pharyngeal wall and posterior cricoid mucosa.

Nerve supply of the pharynx:

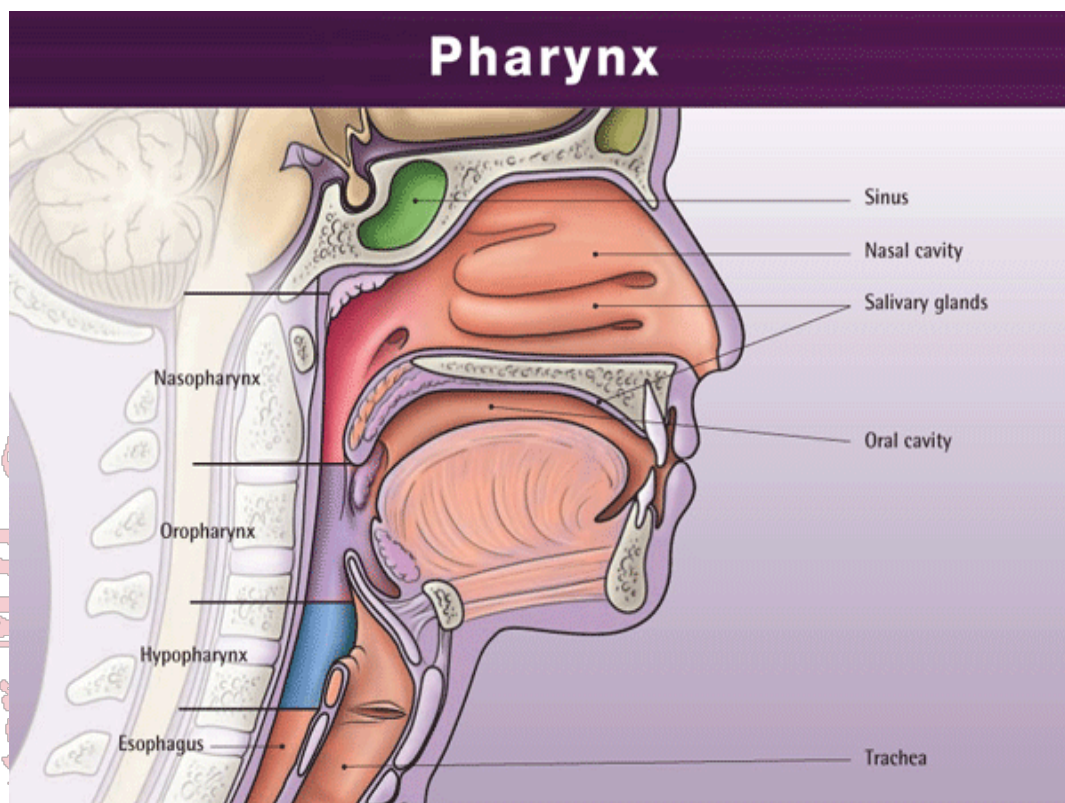


Figure 9. Parts of Pharynx[2]

- * The pharynx is innervated by the pharyngeal plexus, which is formed from branches of the glossopharyngeal, vagus, and sympathetic nerves.
- * The motor nerve supply is derived from the cranial part of the accessory nerve, which, via the branch of the vagus of the pharyngeal plexus, supplies all the muscles of the pharynx except the stylopharyngeus, which is supplied by the glossopharyngeal nerve.
- * The sensory nerve supply of the mucous membrane of →
 - The nasal part is from the maxillary nerve,
 - The oral part is from the glossopharyngeal nerve, and
 - The laryngeal part is from the internal laryngeal branch of the vagus nerve.

Blood supply of the pharynx:

- * The arterial supply of the pharynx is derived from branches of the →
 - Ascending pharyngeal,
 - The ascending palatine,
 - The facial,

- The maxillary, and
- The lingual arteris
- * The veins drain into the pharyngeal venous plexus, which in turn drains into the internal jugular vein.

Lymph drainage of the pharynx:

- * They drain into the deep cervical lymph nodes.

Laryngeal structures

The Larynx

- * The larynx ("organ of voice") is a valve separating the trachea from the upper aerodigestive tract. It is placed at the upper part of the air passage. It is situated between the trachea and the root of the tongue, at the upper and forepart of the neck, where it presents a considerable projection in the middle line.
- * It forms the lower part of the anterior wall of the pharynx, and is covered behind by the mucous lining of that cavity; on either side of it lie the great vessels of the neck.
- * Its vertical extent corresponds to the fourth, fifth, and sixth cervical vertebrae, but it is placed somewhat higher in the female and also during childhood.
- * The framework of the larynx is made up of cartilages, which are connected by membranes and ligaments and moved by muscles. It is lined by mucous membrane.

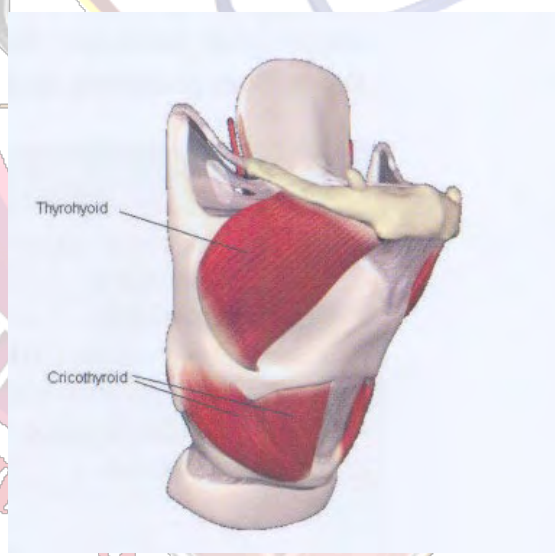


Figure 10. The Larynx [7]

- * The larynx provides a protective sphincter at the inlet of the air passages and is responsible for voice production. Above, it opens into the laryngeal part of the pharynx, and below, it is continuous with the trachea.
- * Purpose: →
 - Organ of communication (the "voice box")
 - Important regulator of respiration
 - Necessary for an effective cough or valsalva maneuver
 - Prevents aspiration during swallowing

- ✳ Together, the muscles and cartilages create three levels of "folds," which serve as sphincters that provide both communicative and vegetative functions in the body [3]:

1) The aryepiglottic folds forms the upper rim of the larynx: [3]

- ✳ It is a strong fibrous membrane that connects the lateral walls of the epiglottis to the arytenoids cartilage complex.
- ✳ When the epiglottis cartilage folds posteriorly and inferiorly over the laryngeal vestibule, it separates the pharynx from the larynx and offers the first line of defense for preserving the airway.
- ✳ The sphincter at the inlet is used only during swallowing. As the bolus of food is passed backward between the tongue and the hard palate, the larynx is pulled up beneath the back of the tongue.
- ✳ The inlet of the larynx is narrowed by the action of the oblique arytenoid and aryepiglottic muscles.

2) The second sphincter is formed by the ventricular fold: [3]

- ✳ It is called superior or false vocal cords
- ✳ It is attached in front to thyroid cartilage, behind to the arytenoid cartilage.
- ✳ It is not normally active during phonation but may become hyperfunctional during effortful speech production or extreme vegetative closure.
- ✳ The ventricular folds are directly superior to the ventricle and the true vocal folds, forming a "double layer" of medial closure, if needed.
- ✳ The principle function of the ventricular sphincter is to increase intrathoracic pressure by blocking the outflow of air from the lungs.
- ✳ The ventricular folds compress tightly during rapid contraction of the thoracic muscles (e.g., coughing or sneezing) or for longer durations when building up subglottic pressure to stabilize the thorax during certain physical tasks (e.g. siftings emesis, childbirth, or defecation).
- ✳ The ventricular folds also add airway protection.

3) The third and final layer of this "folding mechanism" is the true vocal folds [3].

- ✳ It is called inferior or true vocal cords.
- ✳ It is attached in front to the thyroid cartilage, behind to the vocal process of the arytenoids.
- ✳ For speech communication, the vocal folds provide a vibrating source for phonation.

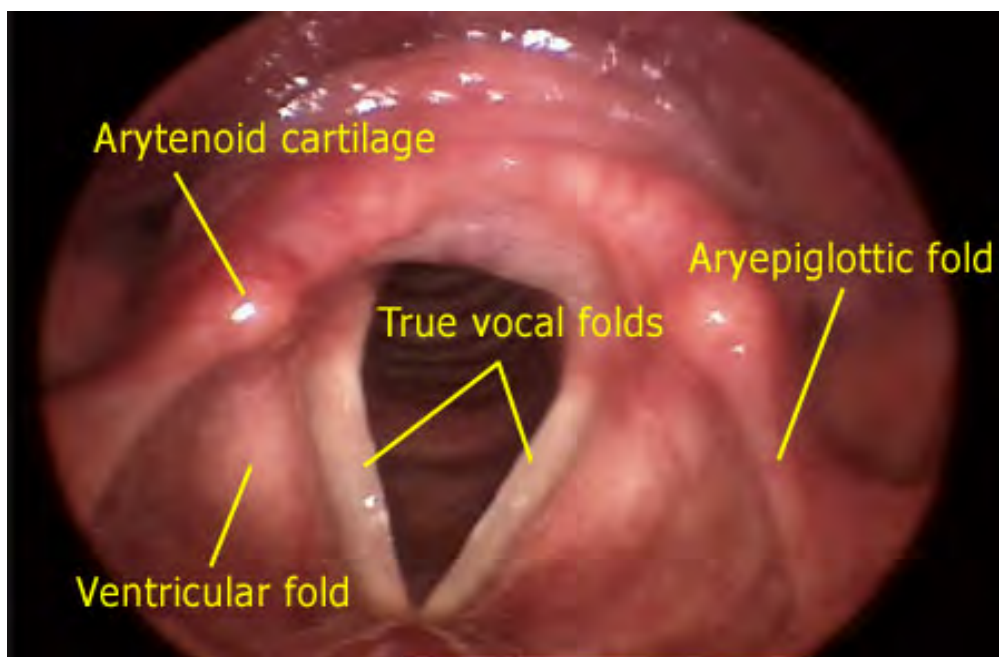


Figure 11. Laryngeal folds & sphincters

- * They also close tightly for non-speech and vegetative tasks, such as coughing, throat clearing, and grunting.
- * In coughing or sneezing, the rima glottidis serves as a sphincter. After inspiration, the vocal folds are adducted, and the muscles of expiration are made to contract strongly.
- * As a result, the intrathoracic pressure rises, whereon the vocal folds are suddenly abducted. The sudden release of the compressed air often dislodges foreign particles or mucus from the respiratory tract and carries the material up into the pharynx. Here, they are either swallowed or expectorated.
- * In abdominal straining associated with micturition, defecation, and parturition, the air is often held temporarily in the respiratory tract by closing the rima glottidis. The muscles of the anterior abdominal wall now contract, and the upward movement of the diaphragm is prevented by the presence of compressed air within the respiratory tract. After a prolonged effort the person often releases some of the air 'by momentarily opening the rima glottidis, producing a grunting sound.

Thus, in a mechanical sense, the larynx and vocal folds function as a variable valve, modulating airflow as it passes through the vibrating vocal folds during phonations closing off the trachea and lungs from foods and liquids during swallowing actions, and providing resistance to increased abdominal pressure during effortful activities.

Laryngeal cavities: [4]

- * The mucous membrane of the larynx lines the cavity and is covered with ciliated columnar epithelium.
- * There are many mucous glands contained within the mucous membrane, and they are especially numerous in the saccules. Here, the secretion pours down onto the upper surface of the vocal folds and lubricates them during phonation.
- * **The cavity of the larynx extends from the inlet to the lower border of the cricoid cartilage. It can be divided into three parts: (1) the upper part, or vestibule; (2) the middle part; and (3) the lower part.**

1) Entrance is aditus larynges (The upper part): →

- * The vestibule of the larynx extends from the inlet to the vestibular folds. The latter are two thick folds of mucous membrane that cover the vestibular ligaments.
- * The vestibule has an anterior, posterior, and lateral wall. The anterior wall is formed by the posterior surface of the epiglottis, which is covered by mucous membrane. The posterior wall is formed by the arytenoid cartilages and the interarytenoid fold of mucous membrane, containing the transverse arytenoid muscle. The lateral walls are formed by the aryepiglottic folds, which contain the **aryepiglottic muscle**.
- * Below, the vestibule is narrowed by the pink vestibular folds, which project medially.
- * The rima vestibuli is the gap between the vestibular folds.
- * The vestibular ligament, which lies within each vestibular fold, is the thickened lower edge of the quadrangular membrane.
- * The ligament stretches from the thyroid cartilage to the side of the arytenoid cartilage.

2) The middle part of the larynx: →

- * It extends from the level of the vestibular folds to the level of the vocal folds. The vocal folds are white in color and contain the vocal ligaments. Each vocal ligament is the thickened upper edge of the **cricothyroid ligament**. It stretches from the thyroid cartilage in front to the vocal process of the arytenoid cartilage behind.
- * The rima glottidis is the gap between the vocal folds in front and the vocal processes of the arytenoid cartilages behind.
- * Between the vestibular and vocal folds on each side is a small recess, called the sinus of the larynx. It is lined with mucous membrane, and from it, a small diverticulum, called the saccule of the larynx, passes upward between the vestibular fold and the thyroid cartilage.

3) The lower part of the larynx: →

- * It extends from the level of the vocal folds to the lower border of the cricoid cartilage.
- * Its walls are formed by the inner surface of the cricothyroid ligament and the cricoid cartilage.

Vocal Fold Structure:

- * It consists of vocalis muscle, lamina propria, and epithelial layer.

Vocalis muscle

- * It is the medial layer of **thyroarytenoid muscle**, which is considered the “body” of the vocal fold.

Lamina Propria

- * It covers the vocalis muscle; there are three layers of the Lamina Propria.
 - Deep → Intermediate
 - Medial → Intermediate
 - Superficial → Cover

Stratified Squamous epithelial cells → Cover

- * Squamous epithelial cells and superficial lamina propria forms the cover of the vocal fold.
- * The superficial layer of the Lamina propria is covered by a surface of mucosal epithelium.
- * The zone between the superficial layer and the mucosal epithelium is an area where phonotrauma occurs. It is very sensitive to vocal abuse and misuse and will be the site of Reinke’s edema which may be the precursor to nodules and polyps.

The cartilages of the larynx:

The Thyroid cartilage:

- * The **thyroid cartilage** consists of two laminae of hyaline cartilage meeting in the midline in the prominent V angle of the Adam's apple.
- * The posterior border of each lamina is drawn upward into a **superior cornu** and downward into an **inferior cornu**.
- * On the outer surface of each lamina is an **oblique line** for the attachment of the sternothyroid, the thyrohyoid, and the inferior constrictor muscles.
- * The deep surface of the thyroid cartilage gives an attachment to the anterior end of vocal ligaments.
- * The lower border of the lamina of the thyroid cartilage gives an insertion to the upper fibers of cricothyroid muscle.
- * The anterior border of the inferior cornu of the thyroid cartilage gives an insertion to the lower fibers of cricothyroid muscle.

The Cricoid cartilage:

- * The **cricoid cartilage** is formed from a complete ring of hyaline cartilage.
- * It is shaped like a signet ring and lies below the thyroid cartilage.
- * It has a narrow anterior **arch** and a broad posterior **lamina**.
- * On each side of the lateral surface there is a circular facet for articulation with the inferior cornu of the thyroid cartilage.

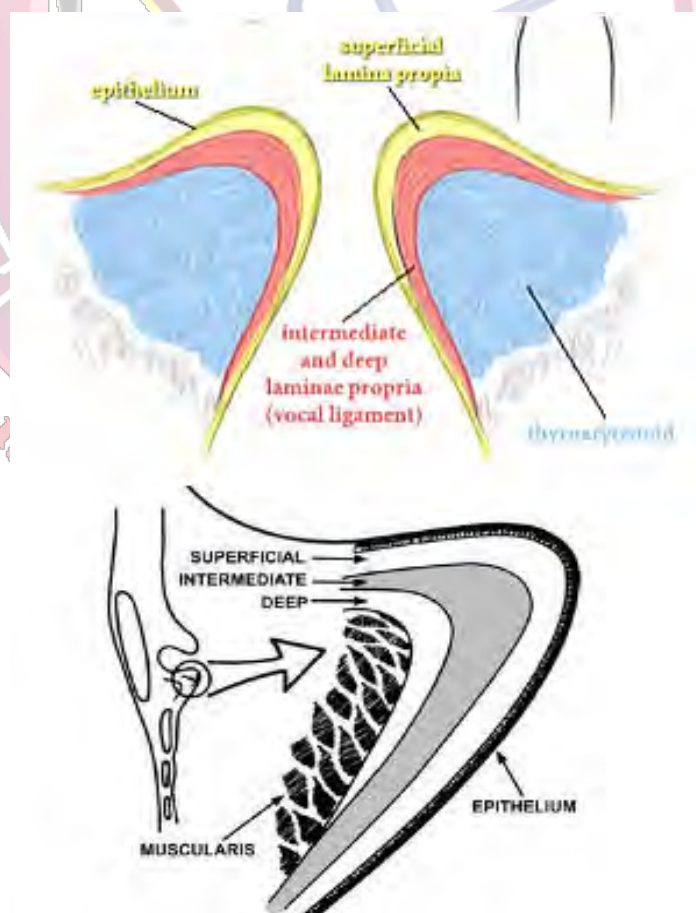


Figure 12. Vocal folds' layers

- * On each side of the upper border there is an articular facet for articulation with the base of the arytenoid cartilage.
- * All these joints are synovial joints.
- * From the side of the cricoid cartilage is the origin of **cricothyroid muscle**.
- * From the upper border of the arch of the cricoid cartilage is the origin of the lateral cricoarytenoid muscle.
- * From the back of the lamina of the cricoid cartilage is the origin of posterior cricoarytenoid muscle.

The Arytenoid cartilages:

- * The **arytenoid cartilages** are small, two in number, and pyramidal in shape.
- * The two small arytenoids cartilages are attached by the vocal folds and are attached to the cricoid cartilages through the cricoarytenoid joint. This joint permits circular and sliding movements.
- * They are situated at the back of the larynx, on the lateral part of the upper border of the lamina of the cricoid cartilage.
- * Each cartilage has an **apex** above and a **base** below. The apex supports the corniculate cartilage. The base articulates with the cricoid cartilage.
- * Two processes project from the base. The **vocal process** projects horizontally forward and gives attachment to the vocal ligament. The **muscular process** projects laterally and gives attachment to the posterior and lateral cricoarytenoid muscles, and gives an origin to the oblique interarytenoid muscle.
- * The back and medial surfaces of the arytenoids cartilage gives and origin and attachment of the transverse interarytenoid muscles.

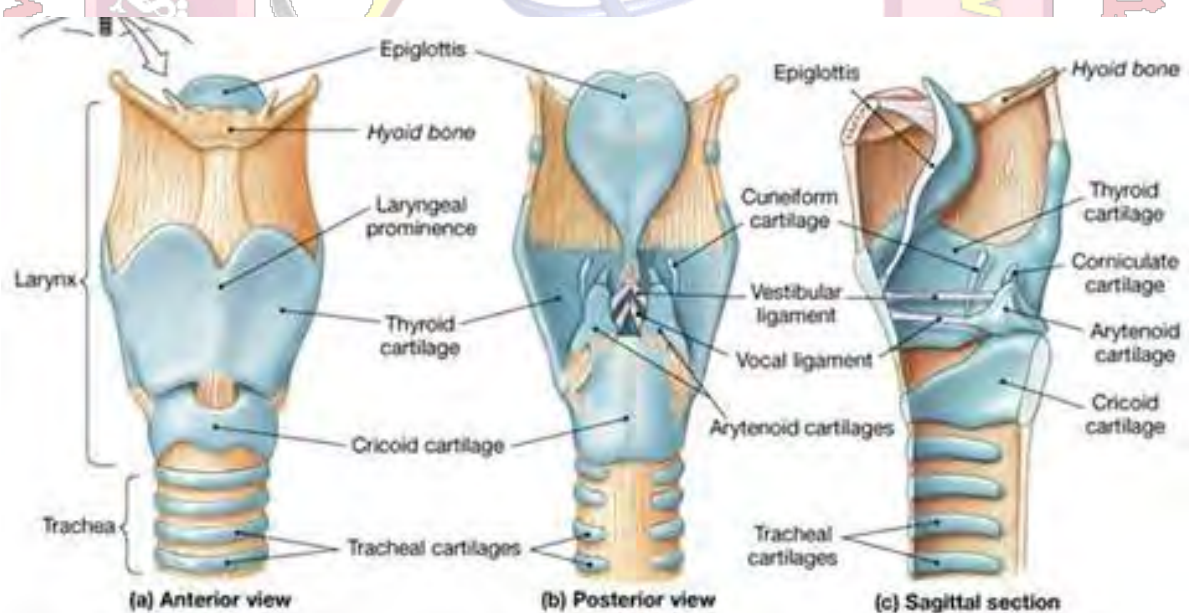


Figure 13. Laryngeal Cartilages

The Corniculate cartilages:

- * It is also called the cartilages of **Santorini**².
- * The **corniculate cartilages** are two small nodules that articulate with the apices of the arytenoid cartilages and give attachment to the aryepiglottic folds.

The Cuneiform cartilages:

- * It is also known as the cartilages of Wrisberg².
- * The **cuneiform cartilages** are two small, rod-shaped pieces of cartilage placed so that one is in each aryepiglottic fold.
- * They serve as supports for the folds.

Laryngeal membranes and ligaments:

- * There are extrinsic and intrinsic membranes.
- * They connect cartilages with adjacent structures.

The Thyrohyoid membrane:

- * The **thyrohyoid membrane** connects the upper margin of the thyroid cartilage below to the upper margin of the posterior surface of the body and greater cornu of the hyoid bone above.
- * In the midline the membrane is thickened to form the **median thyrohyoid ligament**; the posterior borders are thickened to form the **lateral thyrohyoid ligaments**. On each side the membrane is pierced by the superior laryngeal vessels and the internal laryngeal nerve.

The Cricothyroid ligament:

- * The lower part of the fibroelastic membrane is called the cricothyroid ligament.
- * The anterior part of the cricothyroid ligament is thick and connects the cricoid cartilage to the lower margin of the thyroid cartilage.
- * The lateral part of the ligament is thin and is attached below to the upper margin of the cricoid cartilage.

The Vocal ligaments:

- * The superior margin of the cricothyroid ligament is thickened and forms the vocal ligament on each side.
- * The anterior end of each vocal ligament is attached to the deep surface of the thyroid cartilage.
- * The posterior end is attached to the vocal process of the arytenoids cartilage.
- * The glottis is the variable opening. Anterior portion is membranous glottis; posterior cartilaginous. The glottis is varied by adduction and abduction, rotation and tilt of arytenoids, airstream against the vocal folds, and contraction of laryngeal muscles. They are covered with epithelial on outer surface. Between the epithelial and the muscle bundles is the lamina propria with three layers, the most superficial of which is **Reinke's space**. Mucosal wave travels across vocal folds from medial to lateral edge in vibration. Scars would interfere with wave motion.

The Vestibular ligament:

It is the the lower margin of fibroelastic membrane of the larynx, which lies beneath the mucous membrane lining the larynx. The upper portion of fibroelastic membrane is called the **quadrangular membrane**.

The Cricotracheal ligament:

The cricotracheal ligament connects the lower margin of the cricoid cartilage to the first ring of the trachea.

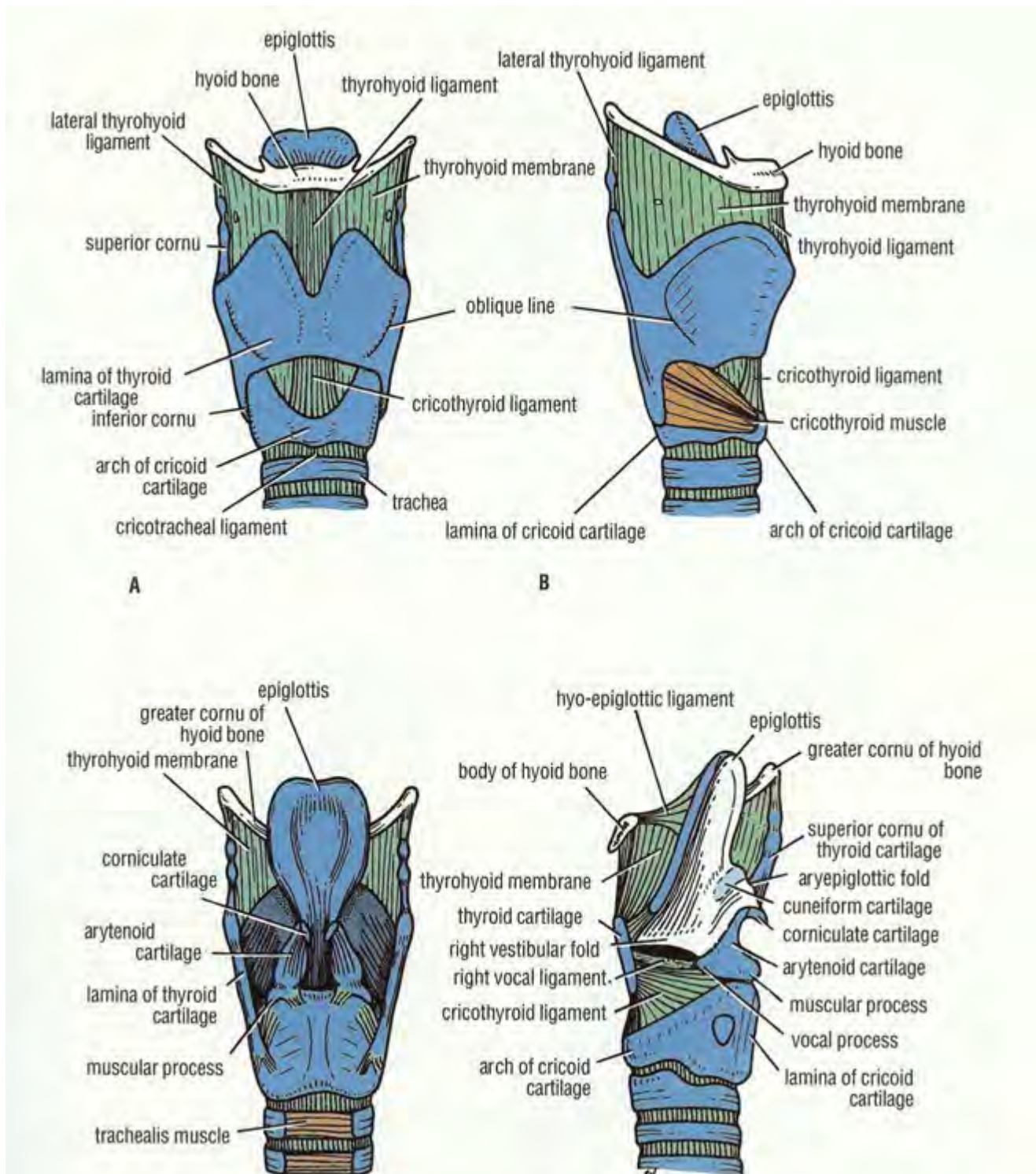


Figure 14. Laryngeal membranes and ligaments [9]

Muscles of the Larynx:

- * The muscles can be divided into two groups: (1) extrinsic and (2) intrinsic.

The extrinsic muscles:

- * The extrinsic muscles of the larynx aid in hyoid and laryngeal excursion (elevation and depression).
- * They are commonly referred to as the strap muscles of the larynx.
- * These muscles include: →

1) Digastrics, anterior belly → elevates, protracts the hyoid bone

2) Digastrics, posterior belly → elevates, retracts the hyoid bone

3) Stylohyoid → elevates, retracts the hyoid bone

4) Mylohyoid → elevates and protracts hyoid

5) Geniohyoid → depresses jaw, elevates and protracts hyoid

6) Sternohyoid → depresses the hyoid

7) Sternothyroid → depresses the thyroid

8) Omohyoid → depresses the hyoid

9) Thyrohyoid → shortens distance between thyroid and hyoid bone

- * Since the hyoid bone is attached to the thyroid cartilage by the thyrohyoid membrane, it follows that movements of the hyoid bone are accompanied by movements of the larynx.
- * The larynx moves up during the act of swallowing and down following the act.
- * This action is particularly important during a swallow, when laryngeal elevation can help protect the airway from aspiration.
- * Clinically, laryngeal elevation during phonation may be a sign of excessive extrinsic laryngeal muscle tension and is often an accurate indicator of hyperfunctional voice use.²
- * They can be divided into two opposing groups, the elevators of the larynx and the depressors of the larynx.

Elevators of the Larynx (Supra-Hyoid muscles):

- * In addition to the external laryngeal muscles, the **stylopharyngeus**, the **salpingopharyngeus**, and the **palatopharyngeus**, which are inserted into the posterior border of the lamina of the thyroid cartilage, also elevate the larynx.
- * The external laryngeal muscles that elevate the larynx are:
 - Digastric, anterior and posterior bellies
 - Mylohyoid
 - Stylohyoid
 - Geniohyoid

- * These muscles perform two very important actions. During the act of deglutition they raise the hyoid bone, and with it the base of the tongue; when the hyoid bone is fixed by its depressors and those of the larynx, they depress the mandible. During the first act of deglutition, when the mass of food is being driven from the mouth into the pharynx, the hyoid bone and with it the tongue, is carried upward and forward by the anterior bellies of the Digastrici, the Mylohyoidei, and Geniohyoidei. In the second act, when the mass is passing through the pharynx, the direct elevation of the hyoid bone takes place by the combined action of all the muscles; and after the food has passed, the hyoid bone is carried upward and backward by the posterior bellies of the Digastrici and the Stylohyoidei, which assist in preventing the return of the food into the mouth.

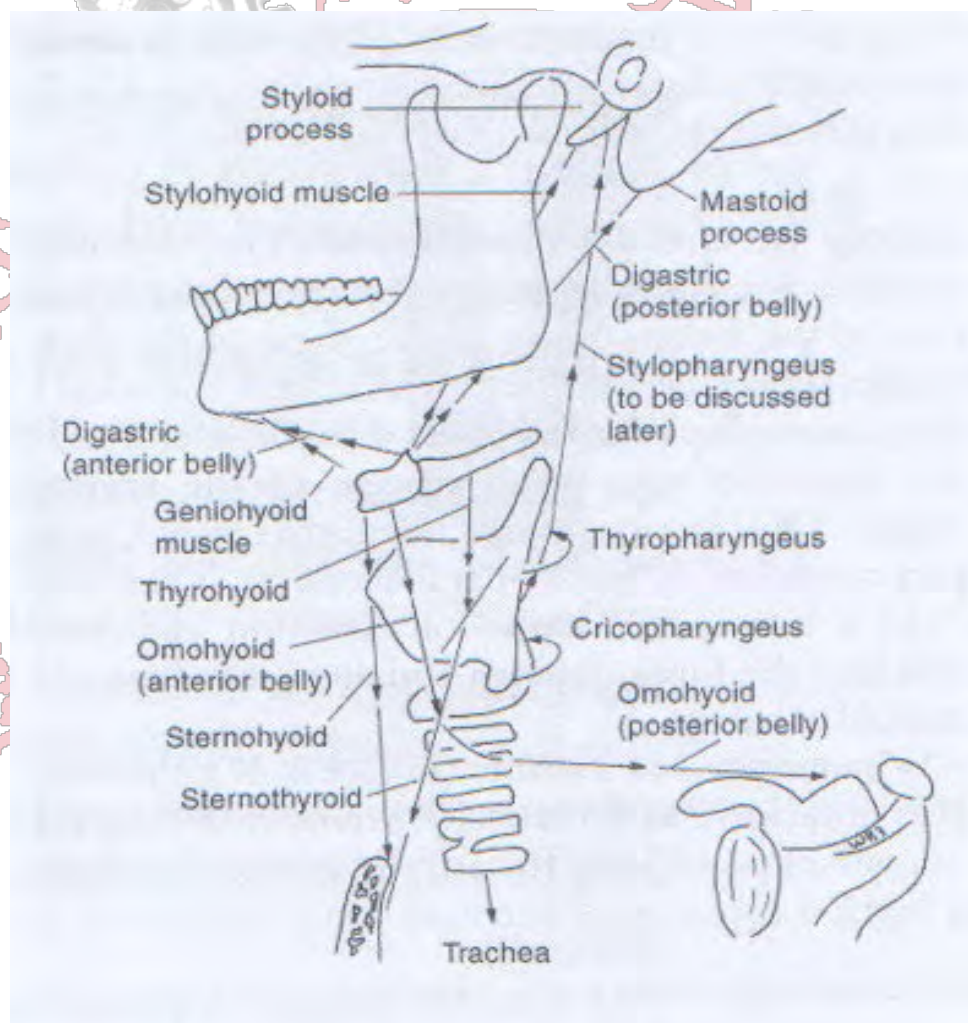


Figure 15. Elevator and Depressor muscles of the Larynx

1) Digastric, anterior and posterior bellies

Origin: The anterior belly is attached to the belly and runs backward toward the hyoid bone where it becomes the digastric tendon. Fibers of the posterior belly run from the digastric notch just posterior to the mastoid process downward and insert in the same digastric tendon which is attached to the hyoid bone.

Action: Contraction of the anterior belly pulls the hyoid toward the chin while the posterior belly elevates the hyoid bone and thereby the larynx; the whole muscle contracting in union will pull the hyoid up and forward but its main action is to open the mandible (during chewing).

Nerve supply: Innervation of the posterior belly is by the facial nerve (CN. VII), innervation of the anterior belly is by the mylohyoid branch nerve from the mandibular division of the facial (VII) nerve.

2) Mylohyoid

It is flat and triangular; is situated immediately above the anterior belly of the Digastricus.

Origin: It *arises* from the whole length of the mylohyoid line of the mandible, extending from the symphysis in front to the last molar tooth behind. The posterior fibers pass medialward and slightly downward, to be *inserted* into the body of the hyoid bone.

Action: Contraction raises the floor of the mouth and aids in elevating the hyoid forward and in depressing the mandible.

Nerve supply: It is innervated by the mylohyoid nerve from the mandibular division of the facial (VII) nerve.

3) Stylohyoid

Origin: The muscle attaches to the base of the styloid process and inserts into the hyoid bone

Action: Contraction pulls the hyoid (and with it the floor of the mouth and the base of the tongue) upward and backward.

Nerve supply: As for the posterior belly of the digastric, the stylohyoid is innervated by the facial nerve (CN. VII).

4) Geniohyoid

Origin: It *arises* from the inferior mental spine on the back of the symphysis menti, and runs backward and slightly downward, to be *inserted* into the anterior surface of the body of the hyoid bone; it lies in contact with its fellow of the opposite side.

Action: Contraction pulls the hyoid forward and is a weak depressor of the mandible.

Nerve supply: Innervation is by cervical nerves C1 and C2, traveling with the hypoglossal nerve (CN. XII).

Depressors of the Larynx (Infra-Hyoid muscles):

* The infrahyoid muscles are:

- **Sternohyoideus.**
- **Thyreohyoideus.**
- **Sternothyreoideus.**
- **Omohyoideus.**

Action → These muscles depress the larynx and hyoid bone, after they have been drawn up with the pharynx in the act of deglutition. The Omohyoidei not only depress the hyoid bone, but carry it backward and to one or the other side. They are concerned especially in prolonged inspiratory efforts; for by rendering the lower part of the cervical fascia tense they lessen the inward suction of the soft parts, which would otherwise compress the great vessels and the apices of the lungs. The Thyreohyoideus may act as an elevator of the thyroid cartilage, when the hyoid bone ascends, drawing the thyroid cartilage up behind the hyoid bone. The Sternothyreoideus acts as a depressor of the thyroid cartilage.

Nerve supply → The Infrahyoid muscles are supplied by branches from the first three cervical nerves. From the first two nerves the branch joins the hypoglossal trunk, runs with it some distance, and sends off a branch to the Thyreohyoideus; it then leaves the hypoglossal to form the descendens hypoglossi and unites with the communicantes cervicalis from the second and third cervical nerves to form the ansa hypoglossi from which nerves pass to the other Infrahyoid muscles.

1) Sternohyoid muscle

Origin: It is a thin, narrow muscle, which *arises* from the posterior surface of the medial end of the clavicle, the posterior sternoclavicular ligament, and the upper and posterior part of the manubrium sterni. Passing upward and medialward.

Insertion: It is *inserted*, by short, tendinous fibers, into the lower border of the body of the hyoid bone.

- Below, this muscle is separated from its fellow by a considerable interval; but the two muscles come into contact with one another in the middle of their course, and from this upward, lie side by side.
- It sometimes presents, immediately above its origin, a transverse tendinous inscription.

2) Thyrohyoid

Origin: It *arises* from the oblique line on the lamina of the thyroid cartilage.

Insertion: It is *inserted* into the lower border of the greater cornu of the hyoid bone.

Action: Contraction pulls the hyoid bone and the thyroid cartilage together. The Thyreohyoideus may act as an elevator of the thyroid cartilage, when the hyoid bone ascends, drawing the thyroid cartilage up behind the hyoid bone. So, it elevates the larynx; depresses/stabilizes the hyoid bone.

Nerve supply: Innervation is by ansa cervicalis (via fibers running with the hypoglossal nerve that leave XII distal to the superior limb of ansa).

Blood supply: Superior thyroid artery.

3) Omohyoid

Origin: It *arises* from the upper border of the scapula, and occasionally from the superior transverse ligament which crosses the scapular notch, its extent of attachment to the scapula varying from a few millimetres to 2.5 cm. From this origin, the inferior belly forms a flat, narrow fasciculus, which inclines forward and slightly upward across the lower part of the neck, being bound down to the clavicle by a fibrous expansion; it then passes behind the Sternocleidomastoideus, becomes tendinous and changes its direction, forming an obtuse angle. It ends in the superior belly, which passes almost vertically upward, close to the lateral border of the Sternohyoideus, to be inserted into the lower border of the body of the hyoid bone, lateral to the insertion of the Sternohyoideus.

Action: The Omohyoid not only depress the hyoid bone, but carry it backward and to one or the other side. They are concerned especially in prolonged inspiratory efforts; for by rendering the lower part of the cervical fascia tense they lessen the inward suction of the soft parts, which would otherwise compress the great vessels and the apices of the lungs.

4) The Sternohyoid

- Acts as a depressor of the thyroid cartilage.

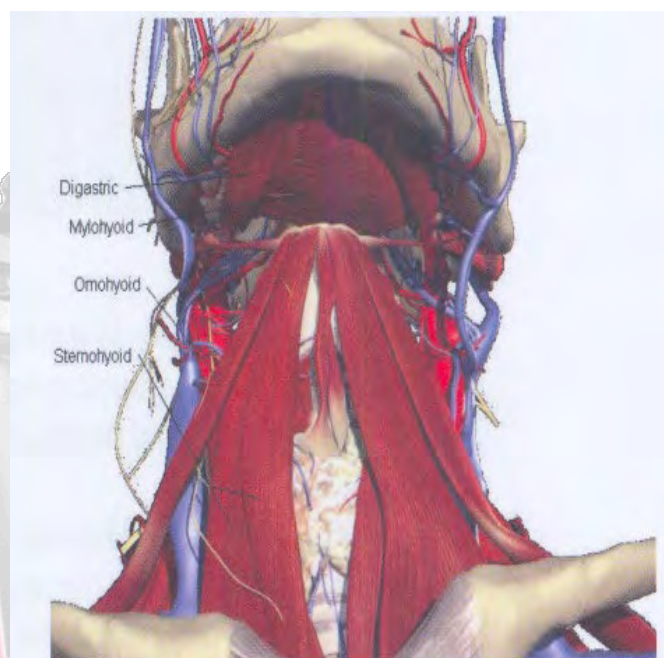


Figure 16. Infra-Hyoid muscles [7]

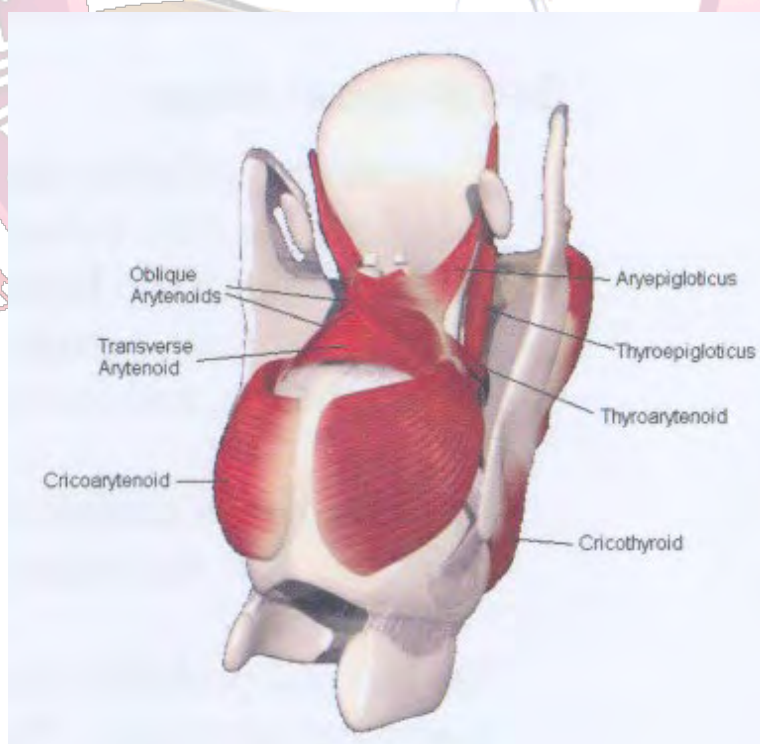


Figure 17. Laryngeal intrinsic muscles [7]

The intrinsic muscles can be divided into two groups:

- * Those that control the inlet into the larynx and those that move the vocal folds.
- * The intrinsic muscles are:

1) Cricothyroid

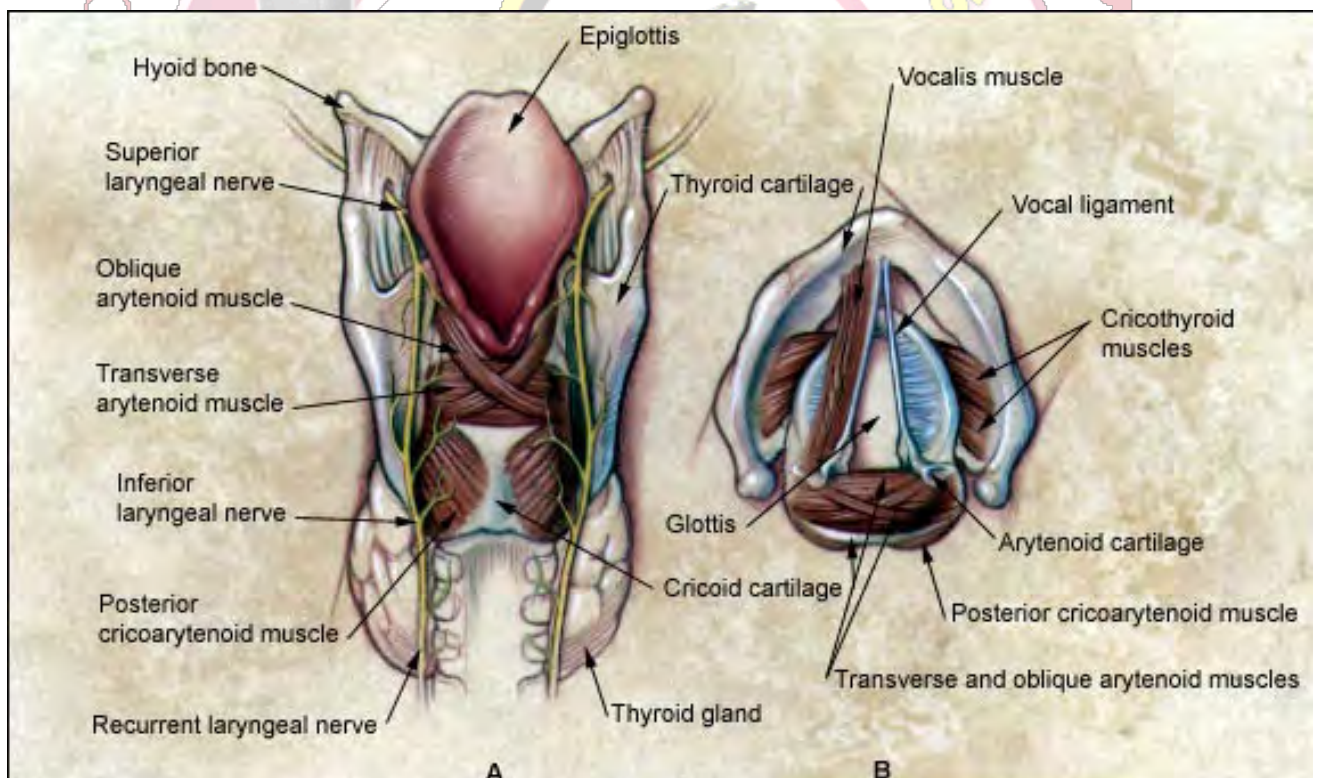
2) Posterior Cricoarytenoid

3) Lateral Cricoarytenoid

4) Interarytenoid: Transverse and Oblique arytenoids

5) Thyroarytenoid

6) Aryepiglotticus



Muscles Controlling the Movements of the Vocal Folds:

- * The vocal folds can be tightened or they can be relaxed.
- * They can be adducted or they can be abducted. The following muscles perform these actions.

1) Cricothyroid (Tensor):

Origin: From the side of the cricoid cartilage.

Insertion: The muscle is triangular in shape. The upper fibers (Pars recta) pass upward and backward and are inserted onto the lower border of the lamina of the thyroid cartilage. The lower fibers (Pars oblique) run backward and are inserted onto the anterior border of the inferior cornu of the thyroid cartilage.

Nerve supply: External laryngeal nerve and SLN that only innervates the cricothyroid muscle (serves to raise pitch) [5].

Action: The vocal ligaments are tensed and elongated by increasing the distance between the angle of the thyroid cartilage and the vocal processes of the arytenoid cartilages. This is brought about by the muscle (1) pulling the thyroid cartilage forward and (2) tilting the lamina of the cricoid cartilage backward with the attached arytenoid cartilages.

2) Thyroarytenoid (Relaxor):

Origin: From the inner surface of the angle of the thyroid cartilage.

Insertion: The fibers lie lateral to the vocal ligament and are inserted onto the anterolateral surface of the arytenoid cartilage. Medial portion of the thyroarytenoid run alongside the vocal ligament and are attached to the vocal process of the arytenoid cartilage, and it called the **vocalis muscle**. The lateral portion of the thyroarytenoid muscle is called **thyromuscularis**.

Nerve supply: Recurrent laryngeal nerve.

Action: Pulls the arytenoid cartilage forward toward the thyroid cartilage and thus shortens and relaxes the vocal ligament.

3) Lateral Cricoarytenoid (Adductor):

Origin: From the upper border of the arch of the cricoid cartilage.

Insertion: Into the muscular process of the arytenoids cartilage.

Nerve supply: Recurrent laryngeal nerve.

Action: Pulls the muscular process of the arytenoids cartilage forward, causing rotation of the arytenoid, so that the vocal process moves medially, and the vocal folds are adducted.

4) Posterior Cricoarytenoid (Abductor):

Origin: From the back of the lamina of the cricoid cartilage.

Insertion: The fibers pass upward and laterally, to be inserted into the muscular process of the arytenoids cartilage.

Nerve supply: Recurrent laryngeal nerve.

Action: Pulls the muscular process of the arytenoids cartilage backward, causing rotation of the arytenoid, so that the vocal process moves laterally, and the vocal fold is abducted.

Muscle Controlling the Laryngeal Inlet:

- * The Interarytenoid muscles are composed of two separate bellies, the **transverse** and the **oblique** portions.
- * When these muscles contract, they shorten the distance between the arytenoids cartilages, thus serving as adductors and contributing to forceful closure of the posterior glottis.

1) Oblique Interarytenoid:

Origin: From the muscular process of the arytenoids cartilage.

Insertion: Into the apex of the opposite arytenoid cartilage. Some of the fibers continue beyond the apex of the arytenoid cartilage and reach the epiglottis via the aryepiglottic fold. The latter fibers form the aryepiglottic muscles.

Nerve supply: Recurrent laryngeal nerve.

Action: The two muscles contracting together serve as a sphincter to the laryngeal inlet. They approximate the arytenoid cartilages to one another and draw them forward to the epiglottis. The laryngeal inlet opens as the result of a relaxation of the oblique arytenoid muscle and the elastic recoil of the ligaments of the joints of the arytenoids cartilages and the cricoid cartilage.

2) Transverse Interarytenoid:

Origin: From the back and medial surface of the arytenoid cartilage.

Insertion: The muscle fibers bridge the interval between the arytenoid cartilages. The fibers are attached to the back and medial surface of the opposite arytenoid cartilage.

Nerve supply: Recurrent laryngeal nerve.

Action: Approximates the arytenoid cartilages and closes the posterior part of the rima glottides (adduct the glottis).

3) Aryepiglottic muscle

Origin: An inconstant fascicle of the oblique arytenoid muscle, originating from the apex (superior part) of the arytenoid cartilage. The mucosa is raised by the underlying aryepiglottic muscle to form the aryepiglottic fold.

Insertion: Inserting on the lateral margin of the epiglottis.

Action: Draws the epiglottis posteriorly and downward during swallowing.

Nerve supply: Inferior laryngeal nerve, from recurrent laryngeal nerve, a branch of the of Vagus (X).

Blood supply: Laryngeal branch of the superior thyroid artery.

Airway closure muscles:

- The larynx closes anatomically from below upward: first, the vocal folds, then the vestibular folds, Then the lower vestibule (approximation and forward movement of the arytenoids), and then the upper vestibule (horizontal position of the epiglottis that contacts the closed arytenoids) [1].

1) Lateral cricoarytenoid

- This muscle originates from the lateral side of the superior border of the arch of the cricoid cartilage; its fibers run posteriorly to attach to the muscular process of the arytenoid cartilage.
- Contraction rotates the arytenoid cartilages, thereby closing the airway.
- Innervation is by the recurrent laryngeal nerve (branch of Vagus, CN. X)

2) Transverse (or inter-) arytenoids

- This is a single, unpaired muscle running between the two arytenoid cartilages.
- Contraction adducts the arytenoid cartilages, thereby closing the airway.
- Innervation is by the recurrent laryngeal nerve (branch of Vagus, CN. X).

Nerve supply of the Larynx:

- * The sensory nerve supply to the mucous membrane of the larynx above the vocal folds is from the **internal laryngeal branch** of the **superior laryngeal branch** of the vagus nerve.
- * Below the level of the vocal folds, the mucous membrane is supplied by the **recurrent laryngeal nerve**.
- * The motor nerve supply to the intrinsic muscles of the larynx is the recurrent laryngeal nerve, except for the cricothyroid muscle, which is supplied by the external laryngeal branch of the superior laryngeal branch of the vagus.
- * Two characteristics of the SLN and RLN ensure the ability of the intrinsic laryngeal muscles to move quickly and with great fine motor control.²
 - First, the laryngeal nerves have a high conduction velocity (second only to the eye) which allows rapid contractions.
 - Second, the innervation ratio is low, meaning that many cells (estimated at 100 to 200) are innervating a single motor unit, allowing very fine motor control.
- * Evidence suggests that afferent information sent from sensory receptors in the larynx to the C.N.S are transmitted by the internal branch of the superior laryngeal nerve, through the vagus to terminate in a region of the medulla called the **Nucleus Tractus Solitarius (NTS)**. This region contains areas that are involved in the control of respiration, laryngeal maneuvers, and swallowing.²

Laryngeal Reflexes

- * Sensory receptors in the larynx are located in mucosal tissue, articular joints, and muscle.
- * The sensory receptors in mucosal tissue respond to touch, vibration, changes in air pressure, and liquid stimuli. These receptors have the ability to elicit tight sphincteric closure to close off the trachea and lungs from foreign material in the upper airway.
- * Muscle receptors are located most predominantly in the **vocalic muscle** and are also present in other intrinsic laryngeal muscles.
- * The laryngeal reflex contracts rapidly to protect the airway from foreign materials or aspiration. Accordingly, these reflexes are triggered by receptors described above in the mucosal tissue, articular joints, and muscles.
- * An extreme glottic closure reflex, called **laryngospasm**, can be triggered by stimuli reaching sites closer to the glottic level, and prolongation of this vocal fold adduction can pose a threat to ventilation.
- * A respiratory reflex that opens the vocal folds in rhythmic coordination with the diaphragm contraction has also been identified. In long-term tracheotomized patients, this rhythmic respiratory reflex appears to be suppressed.

Blood supply and lymph drainage of the larynx:

- * The arterial supply to the upper half of the larynx is from the superior laryngeal branch of the superior thyroid artery.
- * The lower half of the larynx is supplied by the inferior laryngeal branch of the inferior thyroid artery.
- * These arteries branch from the external carotid artery in the neck.
- * Venous return is transmitted through the jugular vein.

Cranial nerves responsible for swallowing and voice:

Olfactory nerve (CN. I)

- Sensory function: innervates sense of smell.
- Lesion: decreased willingness to eat due to absent smell.

Trigeminal nerve (CN. V)

- Motor function: innervates masticatory muscles: Temporalis, Masseter, Pterygoids, anterior belly of Digastric and Mylohyoid; these last two muscles pull the hyoid bone anteriorly.
- Sensory function: innervates TMJ, skin of the face and anterior 2/3 of the tongue (sensation, not taste).
- Lesion: Impairment of the Trigeminal nerve can cause problems in the preparatory oral and oral phase of swallowing due to poor mastication and poor stabilization of the mouth floor [6]
 - Weakness or loss of ability to masticate.
 - Decreased willingness to eat due to facial anesthesia (decreased lip sensation).
 - Decreased sensation of tongue (anterior 2/3).
 - Decreased control of laryngeal elevation and depression.
 - Decreased hyolaryngeal excursion during the pharyngeal phase of swallowing due to mylohyoid and anterior belly digastric muscle impairment [6].

Facial nerve (CN. VII)

- Motor function: innervates many facial muscles of which the Buccinator and Orbicularis Oris, Stylohyoid and posterior belly of the Digastric; these last two muscles elevate and retract the hyoid bone
- Sensory function: innervates anterior 2/3 of the tongue for taste
- Excretory function: innervates salivary and lacrimary glands
- Lesion: Impairment of the Facial nerve (FN) can result in [6]
 - Decreased taste perception (anterior 2/3 tongue)
 - Poor bolus formation during the preparatory oral phase that leads to pocketing of food (Buccinator)
 - Anterior bolus spilling due to loss of labial seal
 - Postswallow oral residue
 - Decreased control of laryngeal elevation and depression.

Glossopharyngeal nerve (CN. IX)

- Motor: Stylopharyngeus (elevation pharynx). It contributes to the innervation of the upper esophageal sphincter, particularly the lower pharyngeal constrictor and to a lesser degree the cricopharyngeus
- Sensory function: innervates posterior 1/3 of the tongue for taste and sensation of the mucous membranes of the palate and the fauces. It innervates sensation of the mucous membranes of the pharynx.
- Excretory function: innervation of salivary glands (Parotid)
- Lesion: Glossopharyngeal nerve (GN) dysfunction can result in

- Decreased elevation of the pharynx
- Decreased or loss of gag reflex (sensory innervation pharynx)
- Decreased willingness to eat due to loss of taste (posterior 1/3 tongue)
- Decrease in salivation leading to dry mouth.
- Decreased compliance of the UES because of decreased sensory innervation pharynx and decreased contractility of the pharyngeal musculature resulting in postswallow pharyngeal pooling.

Vagus nerve (CN. X)

- Motor: palatal muscles (velopharyngeal closure by raising the soft palate), pharyngeal constrictors, intrinsic laryngeal muscles (voice, closure airway), and cricopharyngeus. Main innervation of the cricopharyngeus and both smooth and striated esophageal musculature.
- Sensory function: innervates hard palate for taste and sensation of the epiglottis.
- Lesion: Impairment of the Vagus nerve (VN) can cause
 - Decreased willingness to eat due to some loss of taste (hard palate)
 - Poor velopharyngeal seal and nasal reflux
 - Decreased pharyngeal 'squeeze' (pharyngeal constrictors weak)
 - Reduced vocal fold adduction resulting in dysphonia and poor cough effectiveness.
 - Loss of cough reflex.
 - Decreased airway protection (decreased tone vocal cords)
 - Impaired UES opening—postswallow pharyngeal pooling, and silent aspiration.
 - Decreased esophageal peristalsis.

Hypoglossal nerve (CN. XII)

- Motor function: innervates intrinsic and extrinsic tongue muscles to control tongue movement.
- Lesion: Hypoglossal nerve (HN) in addition to the dysarthria, it can cause problems with [6]
 - Oral control of the bolus
 - Bolus propulsion due to poor lingual pressure and driving forces resulting in premature posterior spill of the bolus to the pharynx
 - Postswallow oral residue.

Ansa Cervicalis (C1, 2, 3)

- Motor: Infrahyoid muscles: Sternohyoid, Sternothyroid, Omohyoid, Thyrohyoid. The ansa cervicalis (AC), the connection between the cervical plexus (C1, C2) and the Hypoglossal nerve, is a loop of nerves, which innervates the omohyoid muscle's superior belly as well as the superior part of the sternothyroid and the sternohyoid muscles. Activation of these muscles initiates hyolaryngeal elevation. Furthermore, the AC also seems to assist in airway protection by compression of the quadrangular membrane thereby assisting in closure of the laryngeal inlet in collaboration with the Trigeminal nerve and Vagus nerve.
- Lesion: Function loss of the AC can cause
 - An impaired UES opening, resulting in postswallow pharyngeal pooling.
 - Decreased airway protection (approximation of hyoid to thyroid weak).
 - Decreased control of laryngeal elevation and depression.

Hyolaryngeal excursion

- * Hyolaryngeal excursion is a movement that occurs during the normal swallowing process.
- * The hyoid and thyroid are pulled together while both are pulled upwards and forwards as well as contraction of the paired thyrohyoid muscles
- * Hyolaryngeal excursion is comprised of 3 components:
 - 1) Thyrohyoid approximation,
 - 2) Hyoid protraction and
 - 3) Hyolaryngeal elevation.
- * These movements allow the epiglottis to invert over the entrance of the airway – the laryngeal vestibule – and also contribute to opening the upper esophageal sphincter to allow the bolus to enter the esophagus.
- * The muscles responsible for shortening the pharynx mentioned above (**Salpingopharyngeus**, **Palatopharyngeus** and **Stylopharyngeus**) partly contribute to hyolaryngeal excursion, but the primary movers for this movement are the suprahyoid muscles together with the **thyrohyoid**.

***Normal movement:** the hyoid moves up $\frac{1}{2}$ to 1 cervical vertebra, moves forward to about halfway between anterior mandible and posterior mandibular ramus. The thyroid cartilage moves toward the hyoid so that the total vertical excursion is approximately 1-2 x the height of a cervical vertebra.*

The esophageal structure

- * It is a muscular tube approximately 23-25 cm long, continuous with the pharynx superiorly and the stomach inferiorly.
- * It has two sphincters: the upper esophageal sphincter (UES) and lower esophageal sphincter.
- * Upper esophageal sphincter – this area is really a group of 3 muscles: the lower fibers of the lower pharyngeal constrictor, the cricopharyngeus and the upper fibers (striated) of the esophageal musculature; this muscle group controls the access of the bolus to the esophagus.
- * It has two layers of muscles, the outer longitudinal and the inner circular muscles. The upper third is made up of striated muscle; the middle third is made up of combination of striated and smooth muscles; and the lower third is made up of smooth muscle.
- * The upper esophageal sphincter, also known as the PE segment, is the third and final sphincter involved in the oropharyngeal phase of deglutition.
- * At rest, the sphincter is closed by the tonic contraction of the cricopharyngeus muscle. Inhibition of the tonic contraction, which results in relaxation and allows for opening of the sphincter, starts at the onset of the oropharyngeal phase of swallowing and lasts until the cricopharyngeus muscle becomes active and propels the bolus into the esophagus [1]

Anatomical landmarks

- * The thoracic esophagus is the top half of the esophagus
- * The distal esophagus is the bottom half of the esophagus
- * The proximal 1/3 of the esophagus is comprised of striated muscle, the bottom 2/3 is comprised of smooth muscle.

Functional aspects

- * Access to the esophagus is controlled by the upper esophageal sphincter (UES).
- * Once the bolus has passed the UES it is transported down to the stomach by a series of peristaltic contractions of the esophageal muscular wall.
- * The UES is not one single muscle but a combination of three muscles: the lower fibers of the inferior pharyngeal constrictor, the cricopharyngeus and the upper fibers of the esophageal muscular wall. This muscular ring separates the pharynx from the esophagus and has the following characteristics.
 - It prevents air from entering the gastrointestinal tract during respiration
 - Protects the airway by preventing the reflux of material from the esophagus into the pharynx
 - Appears to be comprised of at least three groups of striated muscles:
 - 1) Distal portion of the inferior pharyngeal constrictor muscle
 - 2) Cricopharyngeus muscle
 - 3) Muscle of the proximal esophagus.
- * The cricopharyngeus has traditionally been considered as the major muscle of the UES
- * The cricopharyngeus muscle inserts bilaterally at the inferior-lateral margins of the cricoid lamina
- * Only insertion of the cricopharyngeus is to cartilage of the larynx. The sphincter and larynx are therefore obliged to move in unison. This axial mobility is facilitated by a posterior tissue fissure lined with adipose tissue.
- * UES maintains continuing tonic contraction
- * Intraluminal UES pressure is comprised of both an active component related to cricopharyngeal contraction and a passive component (in the order of 10 mm Hg) attributable to elasticity
- * Relaxes at the end of the pharyngeal phase to allow ingested material to enter the esophagus
- * Completely relaxes during belching and vomiting to permit the egress of air and other material from the esophagus into the mouth (this is part of normal physiological function for this muscle)
- * Relaxation precedes opening of the sphincter by about 0.1 second
- * Sphincter opening possibly results from a combination of factors:
 - 1) Traction on the anterior sphincter wall caused by contraction of the suprahyoid and infrahyoid musculature
 - 2) Size of the bolus
 - 3) Positive pressure generated by pharyngeal tongue and upper pharyngeal constrictor
 - 4) Possibly traction force on posterior UES by upper esophageal musculature

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