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Anatomy and Physiology

Knowledge of the anatomy and physiology of the laryngeal mechanism is paramount to understanding voice disorders, and is a foundation for examining the larynx, evaluating phonatory function, and recognizing the impact of abnormal changes or adaptations on voice production. A solid understanding of the normal structure and function of the larynx is the basis for interpreting evaluative findings and developing appropriate voice treatment plans.

ANATOMY

The larynx is essentially a cartilaginous tube that connects inferiorly to the respiratory system, (trachea and lungs), and superiorly to the vocal tract and oral cavity. This orientation in the body is important because it exploits the interactive relationship between these three subsystems of speech: the pulmonary power supply, the laryngeal valve, and the supraglottic vocal tract resonator. When considering the "vocal mechanism," it is common to emphasize the complex and intricate structures of the larynx and vocal folds, but this limited perspective is flawed if it fails to include the broader contributions of subglottic breath support and supraglottic vocal tract resonance. Indeed, vocal function of the larynx relies heavily on the integration of this three-part system: respiration, phonation, and vocal tract resonance (Figure 2–1).

The lungs function as the power supply by providing aerodynamic (subglottal) tracheal pressure that blows the vocal folds apart and sets them into vibration. This vocal fold oscillation provides the sound source for phonation. As the tissues open and close in repeated cycles, the vocal folds modulate subglottal pressure and transglottal flow as short pulses of sound energy. The vocal tract serves as the resonating cavity, which shapes and filters the

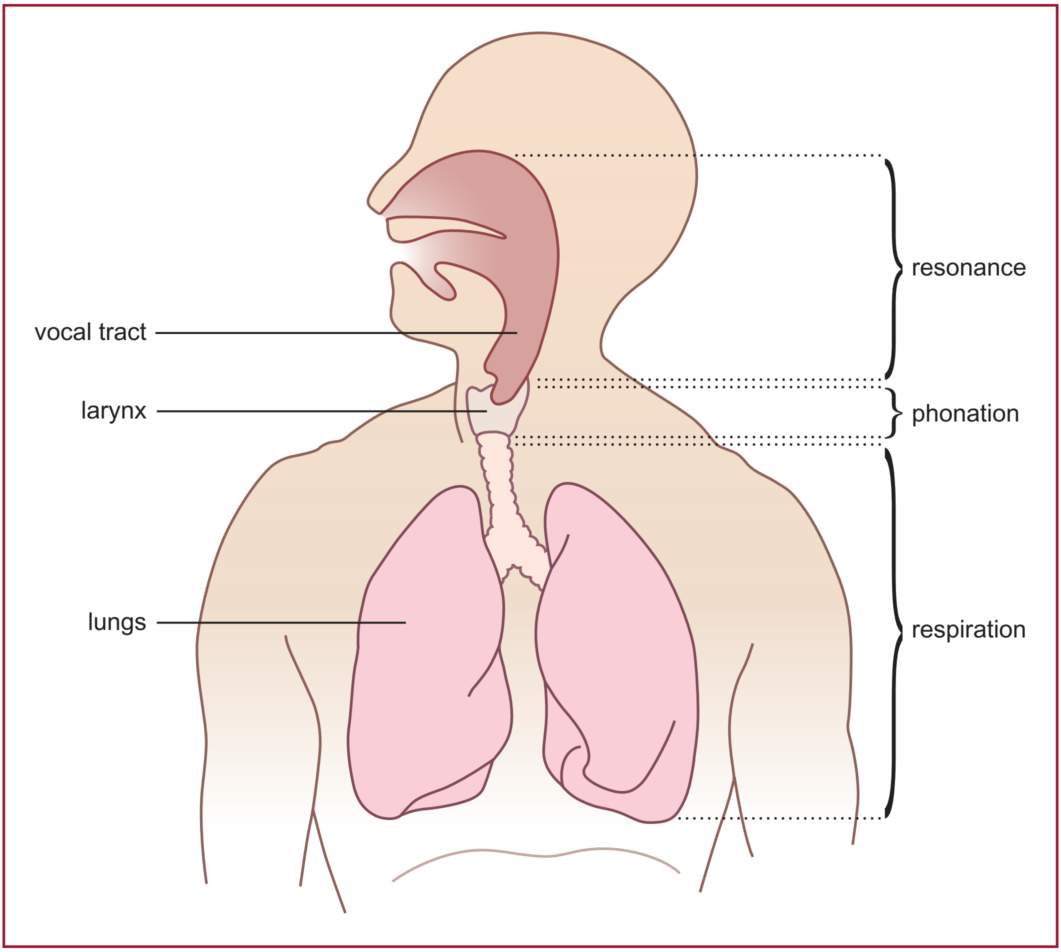


FIGURE 2–1. Orientation of the larynx in the body, at the juncture between the subglottic trachea and lungs and the supraglottic pharyngeal and oral cavities. These structures form the three subsystems of voice: respiration, phonation, and resonance.

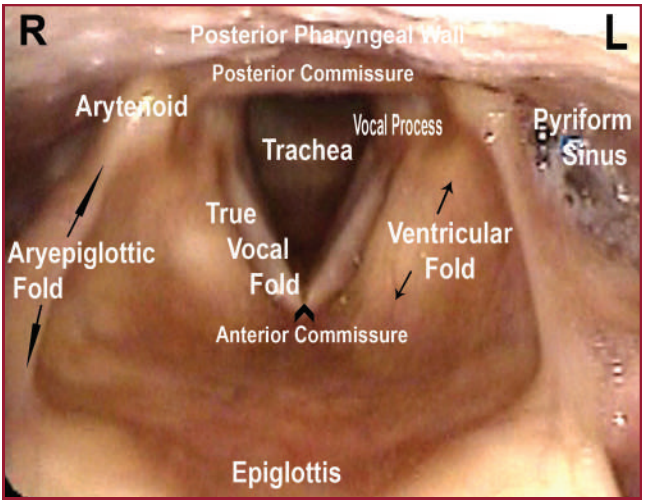
acoustic energy to produce the sound we recognize as human voice.[1–7]

Differential diagnosis of voice disorders requires careful assessment of these three components. Obviously, laryngeal health and vocal function will influence the quality of voice production, but respiratory support and supraglottic resonance will also affect the speech product. For example, adequate or insufficient lung pressure can either maximize or limit vocal fold vibration, respectively. A patient with weak or compromised lung capacity may be unable to generate sufficient subglottal pressure required to produce normal vocal loudness or quality. Similarly, altering the shape and size of the vocal tract can either improve or diminish vocal resonance by enhancing or constricting the phonatory sound source generated by the vocal folds. The loss of either of the subglottal or supraglottal contributions could violate the potential for normal voice quality.[6–7] Indeed, the resulting voice product radiated from the lips is a truly interactive result of these subsystems: respiration, phonation, and resonance.

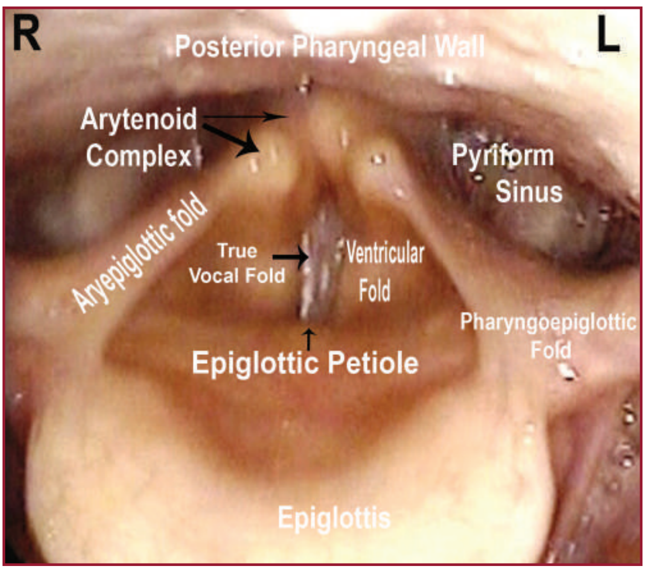
The Laryngeal Valve

The larynx consists of a complex arrangement of cartilages, muscles, connective tissues, and mucosa that allows wide degrees of variation in position, movement, and tension to support three basic functions: airway preservation (opening) for ventilation, airway protection (closing) to block or repel environmental infiltrates, and phonation (vocal fold vibration) for communication and singing. The laryngeal valve achieves these three functions through three levels of "folds" that are best appreciated from an endoscopic view of the larynx (Figure 2–2). Endoscopy permits visualization of internal structures from outside of the body, and it is this view of the larynx that often forms the basis of clinical judgments related to the normalcy of anatomical structure and physiological function. This view of the endolarynx (and surrounding anatomy) shows the vocal folds in their fully open position (A) or closed position (B), and also illustrates the location of each of the three sets of folds (from most superior to most inferior):

1. Aryepiglottic folds connect the anterior attachment of the epiglottis cartilage to the arytenoid cartilages to form the superior border of the circular laryngeal column (Figure 2–3). The upper rim of the larynx is formed by the aryepiglottic folds, which are strong fibrous membranes that connect the lateral walls of the epiglottis to the left and right arytenoid cartilage complexes. 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.[1,2,8,9]
2. Ventricular (or false) folds lie superior and parallel to the true vocal folds just above the ventricles. The ventricular folds form the second sphincter. They are not normally active during phonation but may become hyperfunctional or more prominent during effortful speech production, or extreme vegetative closure. The ventricular folds are directly superior to the ventricles, which function as variable pockets of space above the true vocal folds. The ventricular folds form a "double layer" of medial closure, if needed. The principal function of this sphincter is to increase intrathoracic pressure by blocking the outflow of air from the lungs. For example, the ventricular folds compress tightly during rapid contraction of the thoracic muscles (eg, coughing or sneezing) or for longer durations when building up subglottic pressure to stabilize the thorax during certain physical tasks (eg, lifting, emesis, childbirth, or defecation). The ventricular folds also assist in airway protection during swallowing.[1,2,8,9]
3. True vocal folds open for breathing, close for airway protection, and vibrate to produce sound. The third and final layer of this folding mechanism is the true vocal folds. For speech communication, the vocal folds provide a vibrating source for phonation. They also close tightly for nonspeech and vegetative tasks, such as coughing, throat clearing,



A



B

FIGURE 2–2. Endoscopic view of the larynx and surrounding structures as observed from above with the vocal folds in the fully open (**A**), and closed (**B**) positions. R = right, L = left.

and grunting, by functioning as a variable valve, modulating airflow as it passes through the vibrating vocal folds during phonation, closing off the trachea and lungs from foods and liquids during swallowing actions, and providing resistance to increased abdominal pressure during effortful activities. The angles of true vocal fold closure are multidimensional and include the potential for valving in both hori-

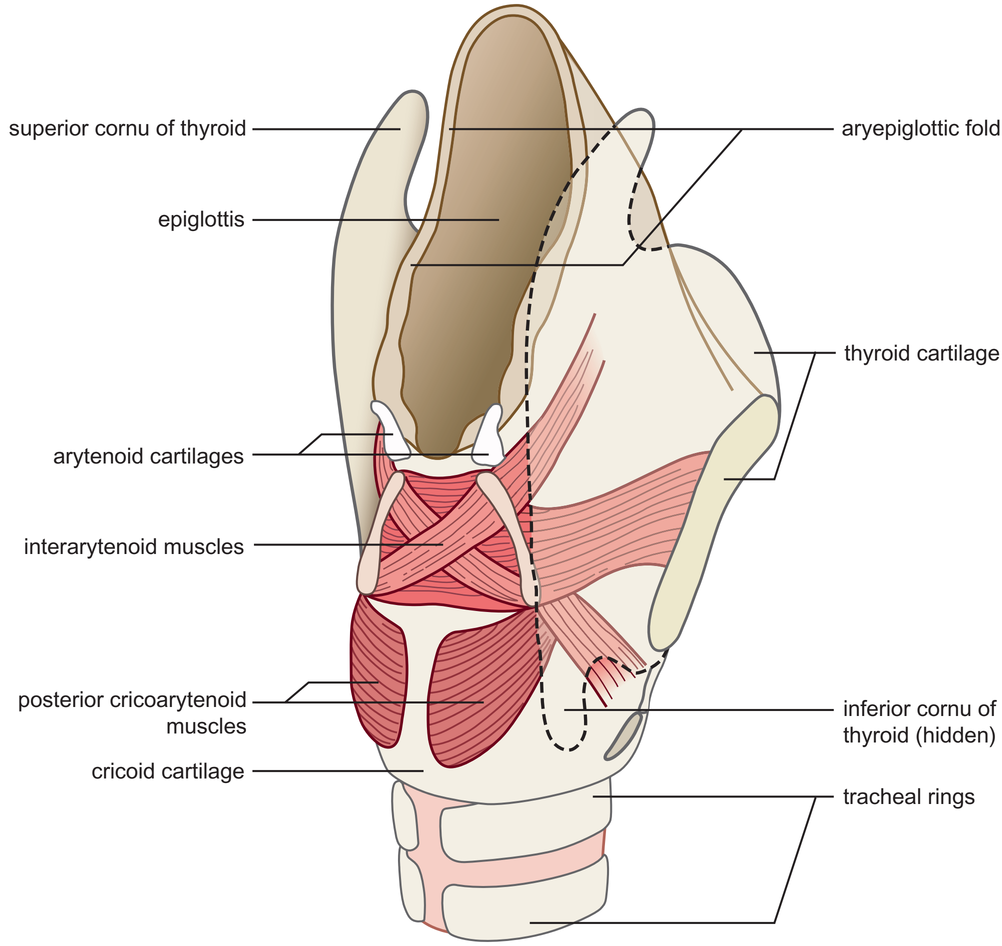


FIGURE 2–3. Oblique view of the larynx.

zontal and vertical planes, depending on the variable shape, tension, and compression of the medial edge. Communicative maneuvers include narrow and rapid opening and closing gestures to produce momentary phonetic contrasts for voiced and voiceless speech sounds, as well as sustained vocal fold closing to produce vibration for phonation.[1,2,8,9]

All three of these folding structures—the epiglottis, ventricular folds, and true vocal folds—exhibit variable shape, tension, and position to accomplish these communicative and vegetative functions in the body. Together, these three levels of airway preservation and protection perform constant adjustments in the airway aperture (Figure 2–4).

Respiration for Phonation

Vocal fold vibration is the sound source that produces phonation and provides the speech signal. Phonation relies on the pulmonary respiratory power, sup-

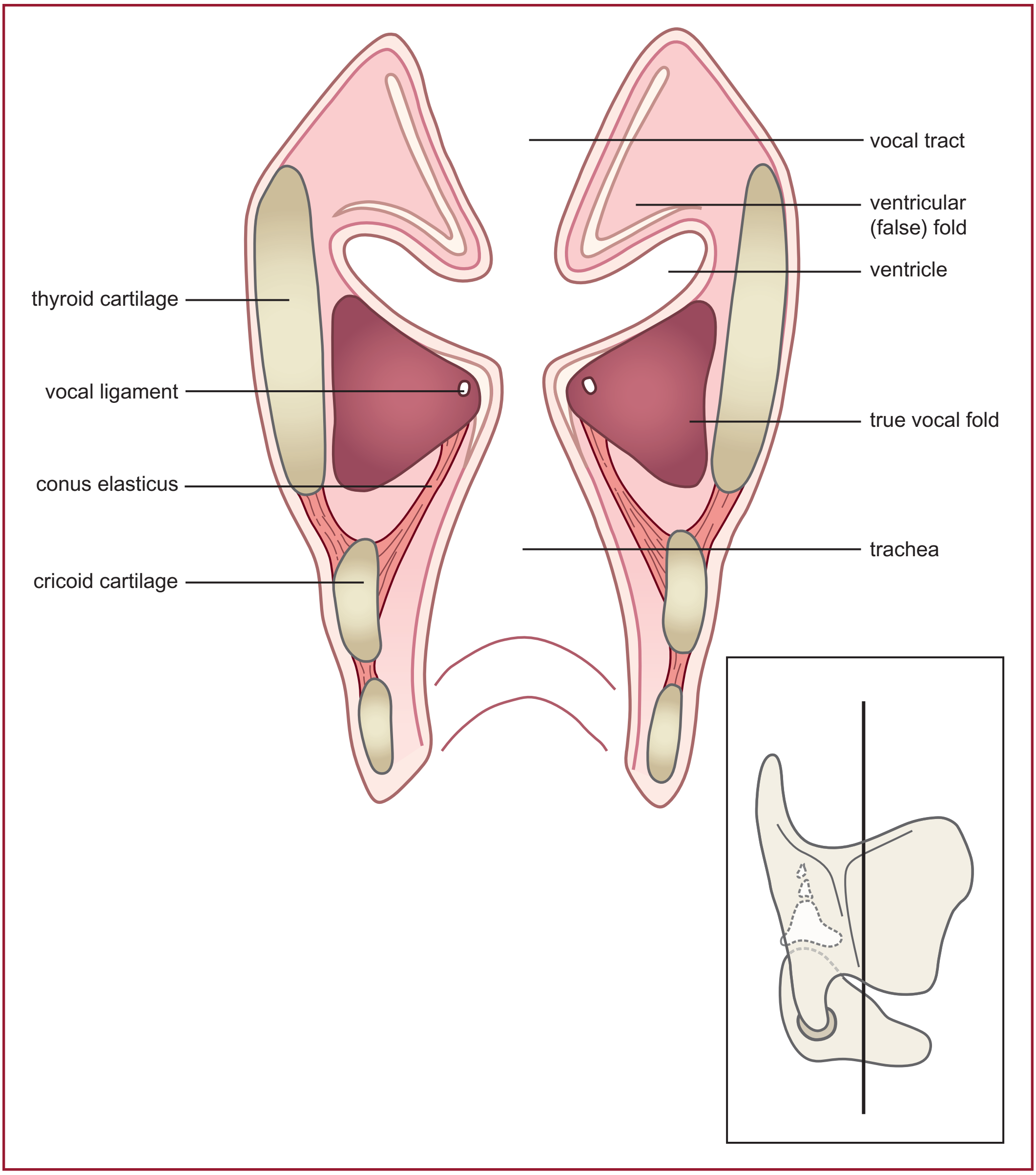


FIGURE 2–4. Coronal view of the ventricular and true vocal folds. (insert: Coronal plane of Figure 2–5).

ported by the abdominal and thoracic musculature. The lungs are housed within the rib cage in the thorax and separated from the viscera (digestive organs in the abdomen) by a large, dome-shaped muscle called the diaphragm. The bottoms of the lungs are attached to the top of the diaphragm by a double-walled pleural lining. During inhalation, the diaphragm contracts (flattening downward in the body), compressing the viscera, and simultaneously pulling the lungs downward, thereby expanding the lung volume. As this lung volume expands, air is drawn passively into the lungs. During exhalation, the diaphragm relaxes and rises back up to its resting position, as passive elastic recoil pushes air out of the lungs and upward through the vocal folds and vocal tract. During quiet exhalation, the vocal folds are abducted (opened) in the paramedian position (approximately 60% of the full glottal aperture), so no sound is generated. To exhale for speech, however, the vocal folds adduct (close) at midline, constricting the airflow stream as it exits the lungs. This aerodynamic breath stream builds up pressure below the adducted vocal folds until they are blown apart and set into oscillation, creating the vibratory sound source of phonation.[10–12] Without this airflow, no sustained phonatory sound source can be achieved. The interactive relationship between the subglottal air pressure buildup and transglottal airflow rate passing through the vibrating vocal fold valve influences the overall pitch, loudness, and quality of phonation.[4,5,10–14]

VOCAL TRACT RESONANCE

As sound waves generated by the vocal folds travel through the supraglottic air column into the pharynx, oral and nasal cavities, and across articulatory structures such as the velum, hard palate, tongue, and teeth, the excitation of air molecules within this space creates a phenomenon called resonance. Resonance occurs when sound is reinforced or prolonged as acoustic waveforms reflect off another structure. The model of acoustic energy (phonation) traveling through a filter (vocal tract) modified in variable shape, size, and constriction characteristics (articulatory gestures) is the basis for Fant's *Acoustic Theory of Speech Production*.[15] This theory underlies our understanding of the three components of the acoustic speech product: *glottal sound source* provided by the vibrating vocal folds, coupled with the supraglottic contributions of *vocal tract filtering*, and *resonant characteristics*.[15,16]

The fluctuating dimensions of the vocal tract cross-sectional area, cavity shape, and points of articulatory contact (eg, tongue, teeth, and lips), each have a direct influence on the quality and strength of the acoustic product radiated from the lips, and perceived by listeners. The sound of vocal fold vibration without the supraglottic resonating cavity (for example, in intraoperative conditions or in excised larynx studies) reveals a flat, atonal buzz, devoid of any "ring" and completely unrecognizable as human voice. The contribution of this resonating filter is essential to creating the perceptual attributes of voice, including pitch, loudness, nasality, and quality. Manipulating resonance characteristics by changing the vocal tract shape and oral posturing has been the study of vocal pedagogues, actors, and singers for several centuries.[5,7,11,13–16] Modifying resonance has also been applied directly to voice treatment methods for disordered speakers and professional voice users.[17–20]

STRUCTURAL SUPPORT FOR THE LARYNX

Hyoid Bone

The larynx is composed of a complex system of mucosa, connective tissues, muscles, and cartilages, all suspended from a single semicircular bone, the hyoid. The hyoid bone marks the superior border of the laryngeal complex of muscles and cartilage. It articulates with the superior cornu of the thyroid cartilage and attaches to the thyroid through the thyrohyoid membrane. Although the hyoid serves as the muscular attachment for many extrinsic muscles of the larynx, it is notable as the sole bone in the body that does not articulate with any other bone. This has an important benefit clinically because chronic elevation of the hyoid can reflect excessive tension of the muscular sling that supports the larynx. Speech-language pathologists and vocal pedagogues may palpate the neck to assess hyoid positioning and monitor vocal tension in patients or performers (Figure 2–5).[1,2,9,10]

Laryngeal Cartilages

There are nine laryngeal cartilages that extend from just below the hyoid bone superiorly to the first tracheal ring inferiorly. Together, these cartilages attach to muscles and connective tissues to form the surrounding columnar housing for the vocal folds. The three largest cartilages are (from most superior to inferior) the epiglottis, thyroid, and cricoid. Additionally, there are three smaller pairs of cartilages that form the posterior wall of the laryngeal column; they are (from most inferior to superior)

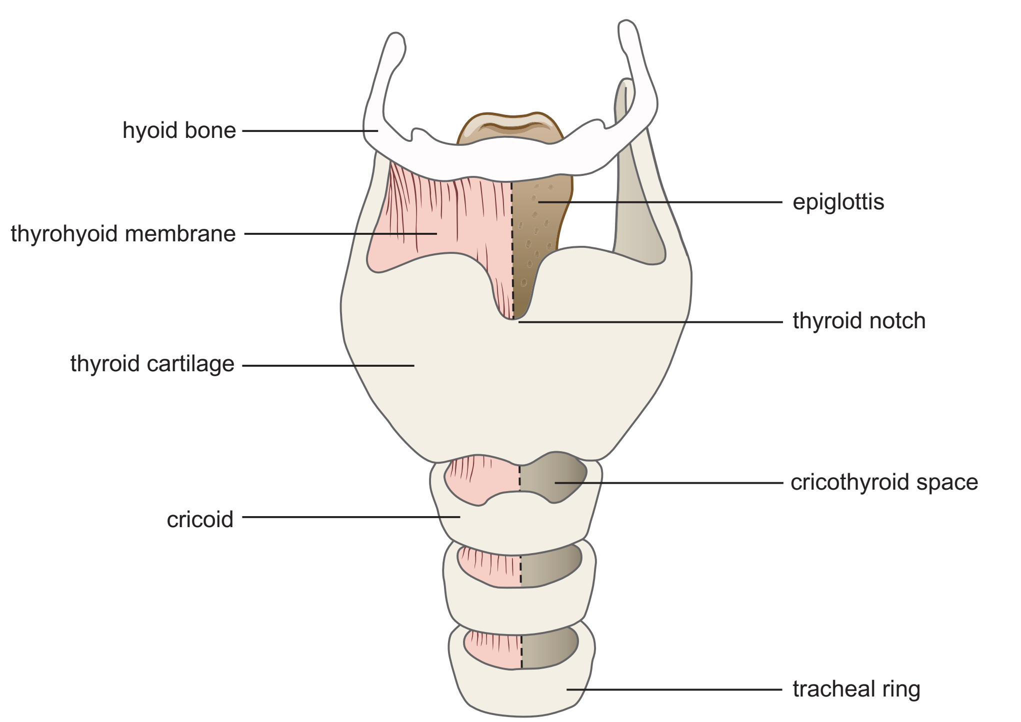


FIGURE 2–5. Anterior view of the hyoid bone and laryngeal cartilages.