Mechanisms of Voice Production

The mechanisms of voice production can be divided into 3 systems: the air pressure (breathing mechanism), vibratory (the vocal folds), and the resonating systems (the supraglottic airway and vocal tract).

Anatomy

- The breathing mechanism or power source includes the lungs, diaphragm and chest wall muscles
- The vibratory system or sound source includes the vocal folds
    - the intrinsic laryngeal muscles control the shape of the glottis and the length and tension of the vocal folds; all of these muscles are innervated by the terminal branch of the recurrent laryngeal nerve (RLN), except for the cricothyroid muscle which is innervated by the external branch of the superior laryngeal nerve (SLN).
    - the intrinsic laryngeal muscles include 3 adductors, 1 abductor and 1 tensor:
        - **adductors**: thyroarytenoid (TA), lateral cricoarytenoid (LCA), and interarytenoid (IA), which also consists of transverse and oblique arytenoid fibers.
        - **abductor**: posterior cricoarytenoid (PCA)
        - **tensor**: cricothyroid (CT)
    - the vocal folds are composed of three layers: mucosa, vocal ligament and muscle
        - the **mucosa** includes the squamous epithelium, basement membrane, and the superficial lamina propria (Reinke's space)
        - the **vocal ligament** includes the intermediate and deep layers of the lamina propria (LP) layer
        - the **muscle** includes the thyroarytenoid/vocalis muscle
    - the anterior 2/3 of the vocal fold in adults is typically the membranous or phonatory portion, while the posterior 1/3 is the cartilaginous or respiratory portion
    - the vascular supply to the larynx comes from the superior and inferior laryngeal arteries and veins

- The resonating system or vocal tract include the supraglottic larynx, pharynx, oral cavity, and nasal cavities

References

Flint Paul W. Cummings Otolaryngology-Head & Neck Surgery, 6th Edition. Philadelphia: Elsevier/Saunders, 2015. (This textbook provides an overview of laryngeal anatomy.)

Physiology and Function

- The process of voice production is outlined below:
    - Glottic closure → during exhalation facilitates increase in subglottic pressure → once subglottic pressure exceeds glottic closure force → air passes through the vocal folds → mucosal wave begins infraglottically and is propagated superolaterally → glottic pressure drops due to open phase + elastic recoil of tissues → leads to glottal closure → which facilitates increase in subglottic pressure & glottal cycle repeats
- The primary motor neurons controlling the intrinsic laryngeal muscles are located in the nucleus ambiguus, which receives both excitatory and inhibitory input from the brainstem, controlling respiration, cough, and swallowing. For phonation (volitional movement), there is direct innervation from the cerebral cortex. For emotional vocalizations, there are additional connections from the limbic system.
- The microanatomy of the vocal folds is specialized such that the pliable cover layer can vibrate freely over the stiffer body underlayer, creating a mucosal wave
- The vocal tract individualizes the human voice by acting as both a resonator and filter of the sound created by the vocal folds
    - Vocal fold vibration results in a *fundamental frequency* (F0) of vibration, as well as many other frequencies or *Harmonics*, whose frequencies are integer multiples of the fundamental frequency
    - *Formants* are a result of vocal tract shape and refer to how the vocal tract changes the relative amplitude of the harmonic spectrum. The vocal tract can actively change shape (e.g. different shapes for different vowels), which leads to unique shaping of the amplitudes of harmonics into unique format structures.

- Resonance is achieved when the harmonics and formants are the same, resulting in an increased intensity of the sound created; a resonant singing tone is desirable in classical music and allows a singer to be easily heard over an orchestra without amplification

References

- Rosen C. and Simpson C. *Operative Techniques in Laryngology*. Leipzig: Springer, 2008. (Drs. Rosen and Simpson include a description of the process of sound production as well as an overview of laryngeal anatomy.)
- Vahabzadeh-Hagh A. et al. Dynamics of Intrinsic Laryngeal Muscle Contraction. *Laryngoscope*: October 2018. (In this basic science study, Drs. Chhetri and colleagues present a summary of both the central control of intrinsic laryngeal musculature as well as the differences in muscle activation time.)
- Titze Ingo R. *Fascinations with the Human Voice*. Salt Lake City: National Center for Voice and Speech, 2010. (Dr. Titze provides a description of both resonance and vocal function.)