Physiology of the Voice

- Voice is necessary to articulate speech sound.
- Voice helps communicate more than what the words says.
- Voice also is unique so that the baby can recognize his mother's voice.
- Several voice disorders have associated medical problems.

Sex differences:

- By puberty, the larynx descends to the level of C6 or C7.
- Adult males typically have longer and thicker vocal folds than females (differences occur at puberty).
- In males, the rise in testosterone at puberty stimulates the anterior growth of the thyroid notch and wide growth of the pharynx.

Aging voice differences:

- In newborns, the larynx is situated high in the neck, with the cricoid positioned at the approximate level of C3 to C4 in the cervical column.
- Newborns breathe only through nasal passages in the first few months of life, thus allowing them to breathe and swallow simultaneously.
- Infant larynx ~ 1/3 eventual size.
- Infants = 500Hz ➔ they are crying in high pitch with their fathers and in low pitch with their mothers.
- Children = 300Hz
- Among geriatric speakers, there is deterioration in voice quality, pitch, and loudness range.
- The clinical observation of these geriatric changes in voice quality and laryngeal appearance has been termed "Presbylaryngeus," or aging larynx.
- In geriatric there will be anatomical and physiological changes ➔
    - Ossification and calcification in laryngeal cartilages
    - Slight erosion of joint surfaces
    - Atrophy of muscle tissue comprising the vocal folds
    - Breakdown of the collagen and elastin fibers in aging vocal folds ➔ Loss of elasticity
    - The lamina propria decreases in flexibility and elasticity with age, due to increased cross-linking of fibers
    - Slight decrease in vocal intensity due to changes in elasticity of respiratory system
    - The intermediate layer of the geriatric vocal folds was observed to be looser and thinner which could contribute to a loss of tissue bulk,

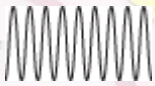
resulting in the characteristic bowed appearance of geriatric glottic closure pattern.

VOCAL PICH, VOLUME, AND QUALITY

- Pitch, volume, and quality are important characteristics of the voice.
- People's personality, intelligence, and competence are often judged by these parameters.
- Voice disorders tend to affect vocal pitch, volumes, and quality.
- Experienced clinicians listen for disturbances in these aspects of voice when evaluating clients with voice disorders.

1) Pitch:

- The perceptual correlate of frequency.
- Pitch is largely based on the frequency with which the vocal folds vibrate.
- The pitch of a voice depends on the frequency of vocal fold vibration.

Voice Feature	Vocal Fold Vibration	Sound Wave Diagram
High-pitched voice	Increase in frequency	
Low-pitched voice	Decrease in frequency	

- Three factors affect the vocal fold vibrations:
  - Mass: The more massive the folds are, the lower rate of vibration ➔ Lower frequency ➔ low pitch. Male has lower pitch than female
  - Tension: Tense vocal folds vibrate faster than relaxed ones ➔ higher frequency ➔ higher pitch.
  - Elasticity:
- This rate is often described as the **fundamental frequency**. Fundamental frequency is generally considered an individual habitual or typical pitch.
- To achieve higher pitch, contraction of the cricothyroid muscle causes the vocal folds to lengthen and the medial edge to thin.
- To lower pitch, contraction of the vocalic shortens vocal fold length, decreasing tension on the cover and rounding the medial edge for greater amplitude of vibration
- Two other factors appear to covary with fundamental frequency in predictable ways.
  - Firsts subglottal pressure increases proportionally with increased fundamental frequency.
  - Second, vocal fold vibratory amplitude motion is inversely proportional to the rate of vocal fold vibration: The higher the pitch, the smaller the amplitude.
- Frequency perturbation or **Jitter** refers to variations in vocal frequency that is often heard in dysphonic patients.
- Jitter can be measured instrumentally as a patient sustains a vowel.

- Patients with voice problems such as tremor or hoarseness might show a large amount of jitter.

- **Fundamental Frequency Across the Life-Span**

Age	Gender	Average Freq.
Infants	Both	413 (crying freq.)
7 years	Both	275 Hz
10 years	Both	250 Hz
11 years	Both	225 Hz
14	Male	185 Hz
15	Female	215 Hz
18	Male	115 Hz
18	Female	200 Hz
30s	Male	112 Hz
30s	Female	196 Hz
60s	Male	112 Hz
60s	Female	189 Hz
80s **	Male	146
80s **	Female	200

2) Volume:

- The perceptual correlate of intensity.
- Volume or loudness is determined by the intensity of the sound signal; the more intense the sound signal, the greater its perceived loudness.
- How loud or how soft a voice is depends on the amplitude of vocal fold vibration.

Voice Feature	Vocal Fold Vibration	Sound Wave Diagram
Loud voice	Increase in amplitude	
Soft voice	Decrease in amplitude	

- The sound is a disturbance in air particles; it is in the form of waves that move forward and backward in a medium such as air or water. The extent of such movements is **amplitude**. The greater the amplitude, the louder the voice.
- The psychological correlate of intensity is loudness
- Factor responsible for increasing in intensity is increased airflow from the lungs.
- Increased resistance to flow from the vocal folds that result in increased sub-glottal pressure.
- Human beings on average can produce a tone at between 100-108 dB at a distance of 1 meter (about 3 feet)

- Amplitude perturbation, or **shimmer**, can be measured instrumentally as a patient sustains a vowel. Patients who have difficulties with regularity of vocal fold vibration (e.g., roughness) might show large amounts of shimmer.

3) Relationship between frequency and intensity (pitch and loudness)

- The phase of vocal fold vibration is modified during periods of increased intensity…the closed cycle lasts longer to facilitate the build-up of sub-glottal pressure.
- Thus, pitch and loudness are interactive (clinical implications).

4) Vocal quality:

- Voice quality is the perceptual correlate of complexity. It refers to the physical complexity of the laryngeal tone, which is modified by the resonating cavities
- The determination of voice quality is frequently subjective, it cannot be objectively measured.
- The quality of voice relies on multiple factors, including compliant and symmetric biomechanical properties of the vocal folds, an adequate and consistent subglottic pressure and flow source, and appropriate vocal tract tuning characteristics.
- Types of Vocal Quality: **Hoarseness**, **Harshness**, **Breathiness**, **Strain-Strangle**, **Glottal Fry**, **diplophonia**, and **Stridency**
- Other terms are ➔ Mellow, rich, clear, bright, hollow, smooth, harmonious, pleasing, velvety, sharp, throaty, flat, constricted, strident, shrill, whispery, thin, piercing, twangy
- **Harshness**
  - Voice is described as rough, unpleasant, and 'gravelly' sounding.
  - It is associated with excessive muscular tension and effort.
  - The vocal folds are adducted too tightly, and the air is then released too abruptly.
- **Breathiness**
  - It is the perceptual impression of excessive leakage of air during phonation.
  - The breathy voice results from the vocal folds being slightly open, or not firmly approximated, during phonation. Air escapes through the glottis and adds noise to the sound produced by the vocal folds
  - Breathiness can be due to organic (physical) or non-organic (nonphysical, or functional) causes. For example, bowing of the folds, paralysis, or Additive lesions
  - Patients frequently complain that they feel like they are running out of air.
  - Breathy voices are often soft, with little variation in loudness.

- **Hoarseness**
  - The voice shows a combination of breathiness and harshness, which results from irregular vocal fold vibrations.

- Hoarse voices often sound breathy, low-pitched, and husky.
- There may be pitch breaks and excessive throat clearing.
- it is a sign of laryngeal pathology
- There will be swollen inflammation of the vocal folds ➔ turbulaent air flow.
- Functional disorder (Psychogenic disorder) ➔ structure unchanged but functionally is inappropriate

❋ **Strain-Strangle**
- Phonation is effortful, and the patient sounds like she or he is "squeezing" the voice at the glottal level.
- Talking fatigues patients, and they experience much tension when they speak.

❋ **Glottal Fry (Also called focal fry)**
- Glottal fry is heard when the vocal folds vibrate very slowly.
- The resultant sound occurs in slow but discrete bursts and is of extremely low pitch.
- The voice sounds "crackly."

❋ **Diplophonia**
- This means "double voice."
- It occurs when one can simultaneously perceive two distinct pitches during phonation.
- Diplophonia usually occurs when the vocal folds vibrate at different frequencies due to differing degrees of mass or tension.
- A client with a unilateral polyp, for example, might sound diplophonic.

❋ **Stridency**
- A patient with a strident voice sounds thrill, unpleasant, somewhat high-pitched, and "tinny."
- Physiologically, stridency is often caused by hypertonicity or tension of the pharyngeal constrictors and elevation of the larynx
- Tense patients may sound strident .

❋ Singing a note requires a more prolonged release of the expired air between the adducted vocal folds.

❋ In **whispering**, the vocal folds are adducted, but the arytenoid cartilages are separated; the vibrations are given to a constant stream of expired air that passes through the posterior part of the rima glottidis.

❋ In silent breathing, the folds are abducted and inhalation and exhalation smoothly alternate with each other.

5) Vocal Register

❋ A way to describe the laryngeal and resonance focus of a vocal tone.
- **Pulse register (vocal fry)** ➔ 3-50 Hz can be produced under extreme glottal tension or relaxation.
- **Modal register** ➔ Typical register of most speakers and singers

- **Falsetto (loft register)** ➔ Only the margins of the vocal folds are vibrating.

6) Vibrato

- A periodic or regular modulation in pitch and loudness above and below modal level.
- A desired effect in the singing voice.
- If you hear vibrato in the speaking voice it is called **vocal tremor**

The Process of Voice Production:

- Speaking and singing involve a voice mechanism that is composed of three subsystems. Each subsystem is composed of different parts of the body and has specific roles in voice production.
- Sound is produced when aerodynamic phenomena cause vocal folds to vibrate rapidly in a sequence of vibratory cycles with a speed of about:
  - 110 cycles per second (men) = lower pitch
  - 180 to 220 cycles per second (women) = medium pitch
  - 300 cycles per second (children) = higher pitch
  - ***Higher voice:*** increase in frequency of vocal fold vibration
  - ***Louder voice:*** increase in amplitude of vocal fold vibration
- Speech involves the intermittent release of expired air between the adducted vocal folds.
- The theory holds that at the onset of phonation, subglottal pressure rises as expiratory forces are met by resistance from the adducted vocal folds.

Three Voice Subsystems

Subsystem	Voice Organs	Role in Sound Production
Air pressure system	Diaphragm, chest muscles, ribs, abdominal muscles Lungs	Provides and regulates air pressure to cause vocal folds to vibrate
Vibratory system	Voice box (larynx) Vocal folds	Vocal folds vibrate, changing air pressure to sound waves producing "voiced sound," frequently described as a "buzzy sound" Varies pitch of sound
Resonating system	Vocal tract: throat (pharynx), oral cavity, nasal cavities	Changes the "buzzy sound" into a person's recognizable voice

Voice production involves a three-step process:

1) Air pressure system ➔ A column of air pressure is moved towards the vocal folds:

- Air is moved out of the lungs and towards the vocal folds by coordinated action of the diaphragm, abdominal muscles, chest muscles, and rib cage
- Van den Berg's classical description of the aerodynamic-myoelastic theory shows that both airflow (aerodynamic) and muscular (myoelastic) properties account for the passive convergent and divergent motions of the vocal folds during phonation.

2) Vibratory system ➔ Vocal fold vibration – sequence of vibratory cycles:

- Vocal folds are moved to midline by voice box muscles, nerves, and cartilages
- The vibratory cycle occurs repeatedly; one vibratory cycle is as follows:

1) Column of air pressure opens the bottom of vocal folds
2) Column of air continues to move upwards and towards the top of vocal folds, and opens the top of vocal folds
3) The low pressure created behind the fast-moving air column produces a **"Bernoulli effect"** which causes the bottom to close, followed by the top
4) Closure of the vocal folds cuts off the air column and releases a pulse of air
5) New cycle repeats. There is a repeated cycle of opening and closing of the folds that is repeated more than 100 times each sound.

- The rapid pulses of air created by repeated vibratory cycles produce "voiced sound" which is really just a buzzy sound, which is then amplified and modified by the vocal tract resonators, producing voice "as we know it."
- *Loudness:* Increase in air flow "blows" vocal folds wider apart, which stay apart longer during a vibratory cycle – thus increasing amplitude of the sound pressure wave
- *Pitch:* Increase in frequency of vocal fold vibration raises pitch
- The frequency, or pitch, of the voice is determined by changes in the length and tension of the vocal ligaments.

1- Column of air pressure moves upward towards vocal folds in "closed" position

2, 3 Column of air pressure opens bottom of vibrating layers of vocal folds; body of vocal folds stays in place

4, 5 Column of air pressure continues to move upward, now towards the top of vocal folds, and opens the top

6–10 The low pressure created behind the fast-moving air column produces **a Bernoulli effect** which causes the bottom to close, followed by the top

10 Closure of the vocal folds cuts off the air column and releases a pulse of air

New vibratory cycle – repeat 1-10

Any change that affects this mucosal wave – stiffness of vocal fold layers, weakness or failure of closure, imbalance between R and L vocal folds from a lesion on one vocal fold – causes voice problems

3) Resonating system ➔ Vocal tract – resonators and articulators:

- The quality of the voice depends on the resonators above the larynx, namely, the pharynx, mouth, and paranasal sinuses. The quality is controlled by the muscles of the soft palate, tongue, floor of the mouth, cheeks, lips, and jaws.
- Normal speech depends on the modification of the sound into recognizable consonants and vowels by use of the tongue, teeth, and lips.

Respiration

- Phonation requires an outgoing air stream of sufficient force to activate vocal fold vibration
- During passive/quiet breathing there is an approximate 1:1 ratio of inspiration to expiration
- During phonation, on average, the expiratory phase lasts about 10 times longer (factors such as phrase length etc. will change this figure)
- Respiration at rest is controlled by active and passive forces.
    - Active forces are related to the muscular activity necessary to enlarge the thoracic cavity creating the pressure differential that forces air into the lungs.
    - Passive forces are a function of the natural elasticity of the lung tissue and natural recoil forces of contracted muscles

- Passive forces include:
    - Lung tissue elasticity
    - Gravity
    - Visceral recoil
    - Rib antiquing

Respiration for Speech

- Most of the respiratory power needed for speech is provided by passive forces of exhalation.
- However, if as noted previously the expiratory phase is extended then something is balancing out the passive recoil in order to prolong the release of air.
- One of the components of the balancing force is the valving mechanism of the larynx itself. The phonatory cycle prevents the air from rushing out completely.
- During a production of a long phrase or during singing some of the respiratory (expiratory) muscles may be employed to push some of the reserve air from the lungs at sufficient pressure to maintain phonation.
- Because passive force that is needed for speech is beyond our control, we teach patients to practice some techniques in order to replenish their lung during speech.

Respiratory Volume

- Tidal Volume (Vt) ➔
  - Volume inspired and expired with each normal breath
  - Minimum volume: 3 ml/kg
  - Normal volume: 6-7 ml/kg
  - Male= 750cc at rest
  - Female= 340cc
- Inspiratory Reserve Volume (IRV) ➔
  - Maximal inspired volume from end-tidal inspiration (1500-2000cc)
- Expiratory Reserve Volume (ERV) ➔
  - Maximal expired volume from end-tidal inspiration (1500-2000 cc)
  - Normal: 25% of Vital Capacity
- Residual Volume (RV) ➔
  - Volume remaining in lungs after maximal expiration
  - Normal adult: 1.0 to 2.4 Liters
  - This cannot be forced out of the lungs.
  - **We do not speak on "residual air"** we may sometimes speak at the end of our expiratory reserve volume.
- Vital Capacity (VC) ➔
  - Maximal volume expelled after maximal inspiration
  - Represents the total amount of air that can be expired from the lungs and air passages following maximum inhalation (except for residual volume).

Factors influencing respiratory control

- Length of utterance
- Type of utterance (stress and intonation)
- Speaking vs. singing
- Environment (small room requires less voice production to communicating).

Respiratory Considerations

- Most of us adjust respiration automatically and somewhat unconsciously to the speaking/singing demands of the situation.
- Many voice disordered clients fail to take catch-up breaths or may utilize excessive respiratory and laryngeal muscular forces to control airflow.

Key Function of the Voice Box

The key function of the voice box is to open and close the glottis (the space between the two vocal folds).

- **Role in breathing:** open glottis
  - Voice box brings both vocal folds apart during breathing.
- **Role in cough reflex:** close, then open glottis
  - Voice box closes the glottis to build up pressure, then opens it for the forceful expelling of air during cough.
- **Role in swallowing:** close glottis
  - Voice box coordinates closing the glottis by bringing both vocal folds to the midline to prevent choking during swallowing.
- **Role in voice:** close glottis and adjust vocal fold tension
  - Voice box brings both vocal folds to the midline to allow vocal fold vibration during speaking and singing.
  - Voice box adjusts vocal fold tension to vary pitch (how high or low the voice is) and changes in volume (such as loud voice production).