The cycle of vibration is completed.

Vocal folds make contact inferiorly.

Decreased pressure and elastic quality of the vocal folds causes folds to move (snap) back toward the midline.

Vocal folds are blown open, flow between the folds increases (i.e., transglottal flow), and pressure drops.

Superior aspect of vocal folds begins to open.

Air pressure causes the vocal folds to separate in the inferior.

Air pressure beneath the vocal folds arises from respiratory flow.

One Cycle of Vocal Fold Vibration as seen through a Frontal Section.
Vocal Fold Closure

FIGURE 3.74
Schematic of vertical phase difference during a cycle of vocal fold vibration.
Single frame excerpts from a high-speed film showing vertical phase differences.
Vocal Fold Closure

A typical cycle of normal vocal fold vibration taken from a high-speed motion picture film of the larynx.
Physiology of phonation

Nonspeech laryngeal function.

Coughing.
Mediated by portion of the X vagus nerve.

- deep inhalation through widely abducted folds followed by tensing and tight adduction of the vocal folds and elevation of the larynx.
- arytenoids are rotated downward as they are adducted
- very high subglottal air pressure then blows the folds apart.
- this expels foreign matter
- problem is that the force of adduction is abusive
- medial compression is quite large--second only to abdominal fixation

Throat clearing

- a near cousin to coughing.
- not as violent as cough, but still stressful
  - build subglottal air pressure
  - vocal folds shut to resist the pressure

Abdominal fixation

- captures air pressure in thorax to strengthen
- take in large breath.
- tight adduction
- most medial compression of any laryngeal act
- you grunt when lifting when air escapes through the valve vibrating vocal folds.

Forced inspiration

- quiet respiration--vocal folds are abducted about 8 mm.
- forced inspiration vocal folds are opened 16 cm.

Swallowing

- when food passes base of tongue
  - larynx elevates
  - epiglottis drops down
  - aryepiglottic folds close
  - vocal folds adduct
- this all happens to protect the airway
Laryngeal functions for speech

- We will talk about Attack, phonation & termination of phonation.

Pre-phonation - Adduct from abducted position. These 2 adjustments combined = a variable air supply account for the versatility of human voice.

- Brings folds together to be in position to begin phonation. Primarily movement is inward rocking. Arytenoids rock down with apexes approaching each other.
- Rotary movement is seen when they are nearly abducted.
- Attacks requires muscular action.
- Attacks occur frequently—for all voiced consonants and vowels. Consider the sentence: "Anatomy is not for the faint of heart." We open and close vocal folds at least 6 times in less than 2 seconds.
- **Three types of attack.** All used frequently. None are "bad" unless over used with excess force.
  - **Simultaneous attack.**
    - Adduction and expiration occur at same time. 
    - Ex: "zipper", if you phonated first you would hear zipper.
  - **Breathy vocal attack.**
    - Start airflow before adducting folds.
    - Occurs frequently in running speech.
    - "Harry is my friend." Air flow starts and continues. Airflow is going before adduction.
  - **Glottal attack.**
    - Adduction occurs before airflow.
    - Heard often in sentences starting with vowels. "OK you can go."
    - Is problematic if hard glottal attack is used excessively.

Termination of phonation

- Abduct occurs for all voiceless consonants and for pauses, rests, end of sentence, etc.
- Achieved through lateral cricoarytenoids.

Sustained Phonation

- Vocal attack and termination require muscle activity to achieve the movement
- Sustained phonation requires muscle activity to POSITION the folds and to hold the folds in position.
- Use the term *tonic contraction* to describe the muscle action of holding folds in position.
- Folds are held in position so they interact with airflow causing vibration—called the Bernoulli effect.
- Folds vibrate a few milliseconds before touching and need not touch at all during vibration.
  e.g.: "haaaaairry."

Typical Vocal Fold Vibratory Cycle

**Cycle**

A *cycle* is from one point in a repetitive action until that place is reached again.

- Typical pattern of vibration
  - Folds are adducted. (We have to begin somewhere.)
  - **Opening phase.**
    - Subglottal air pressure builds from below until it "blows folds apart."
They stay apart until enough air has escaped that the air pressure is no longer strong enough to hold them apart.

- **Closing phase.**
  - The folds approximate one another

- **Closed phase.**
  - The folds are together until enough air pressure has been built up to blow them apart again.
  - More info on closed phase.

  - **Collision** of vocal folds. Consider what happens when the vocal folds collide.
  - If they were made of hard substance they would immediately bounce apart from one another. Remember "clackers?"
  - But they are made of soft tissues--mucus tissues covering muscular tissues.
  - They absorb the impact of the collision.
  - This ability to absorb the impact is termed **compliance**.
  - The more compliant the vocal folds are, the more they are able to absorb the impact and the longer the closed phase.

### Vocal Registers

- We use this term to describe how the folds are vibrating and the resulting pitch (and to a minimum extent, tone quality.)
- During sustained vibration, the folds may vibrate in a number of patterns producing very different sounding voices. We call these **vocal register**. Will talk about 3 registers and two variations of the most common or modal register.

#### Modal Register

- **Mode** means that which occurs most often
- Used in daily conversation
- Most efficient and healthy use of voice
- Unique vibratory pattern is seen in vertical view and also in anterior posterior view.
- Avg. pitch women = 230, avg. men = 120
- Review info on table at end.
- What the vibratory cycle looks like. Must consider the view vertically and horizontally--or looking down on it.

### Layers of the vocal folds

- Vocalis muscle
- Deep layer of mucosal tissue
- Intermediate layer
- Superficial layer

- The mucosal tissue vibrates
- Medial edge of thyroarytenoid vibrates
**Vertical phase difference**

- Folds open from the bottom, top is then drawn along to open
- Folds close from the bottom, top is then drawn along to close

**Anterior-posterior vibration**

- Folds open from posterior to anterior
- Close from anterior to posterior
- When viewed from top there is normal variation between different speakers as to what portion of the vocal fold opens first and in which direction the vibratory wave travels.
- Remember the discussion about the different layers covering the vocalis muscle. The intermediate layer (lamina propria) connects the epithelium to the core or deep layers of the vocal fold. This allowed the mucosal layer to vibrate separately from the muscular fibers.

**Minimum driving pressure**

- Need 3-5 cm H₂O pressure for folds to vibrate
- A test of vocal integrity is ability to sustain 3-5 cm H₂O pressure for 5 seconds. If they cannot do this, it's unlikely the patient can use speech.
<table>
<thead>
<tr>
<th></th>
<th>Modal or &quot;Chest&quot;</th>
<th>Falsetto</th>
<th>Glottal Fry</th>
</tr>
</thead>
<tbody>
<tr>
<td>subglottal pressure</td>
<td>&gt; 3 cm H2O</td>
<td>increased</td>
<td>&lt; 2 cm H2O</td>
</tr>
<tr>
<td>pitch</td>
<td>male avg = 120 Hz</td>
<td>300-600 Hz</td>
<td>30 - 80 Hz</td>
</tr>
<tr>
<td></td>
<td>female avg = 230 Hz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(longitudinal tension)</td>
<td>medium</td>
<td>high</td>
<td>very low</td>
</tr>
<tr>
<td>medial compression</td>
<td>medium</td>
<td>very thin</td>
<td>very strong</td>
</tr>
<tr>
<td>vocal fold diameter</td>
<td>medium</td>
<td>long</td>
<td>short</td>
</tr>
<tr>
<td>vocal fold length</td>
<td>medium</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% time in closed phase</td>
<td>approx 13 % of time</td>
<td>closed very briefly</td>
<td>closed a very long time, up to 90% of the time.</td>
</tr>
<tr>
<td>excursion or amplitude of vibration</td>
<td>medium</td>
<td>reduced</td>
<td></td>
</tr>
<tr>
<td>portion of folds vibrating</td>
<td>most of &quot;vibratory portion&quot;</td>
<td>folds bowed to create narrow opening of anterior section.</td>
<td>only edge vibrates</td>
</tr>
<tr>
<td>quality &amp; other comments</td>
<td>Easiest to produce</td>
<td>syncopation</td>
<td></td>
</tr>
</tbody>
</table>

**Pitch**

- Pitch is the psychological correlate of frequency of vibration.
- Typical pitch is...
  - Men -- 80 to 240 Hz with a mean of 124
  - Women -- 225-250
  - Infants -- avg of 400 but range up to 1,200
- **Optimum pitch** describes the frequency of vibrations which is most efficient and healthy for an individual. Varies as to age and gender.
- **Habitual pitch** describes the frequency of vibrations which the individual uses most often or habitually.
- **Average Fundamental Frequency** represents habitual pitch over a longer averaging period.
- Pitch Range -- most of us have a two octave range. Reduced by pathology. Increased by training.
- **Things which influence pitch** -- will consider the muscular forces are adjusted to interact with aerodynamic forces to produce different pitches.
  - Pitch is very related to size of vocal mechanism, & size of folds.
  - **Maturation.** As children grow, pitch decreases. Decrease in pitch is correlated with increasing length and mass of folds.
  - **Mass.** As the mass of a vibrating body decreases, frequency of vibration increases. We talk about mass per unit length, to accommodate changes in length and thickness.
  - Pitch is not changed by length of vocal folds alone. Becomes clear when we realize that to increase pitch we lengthen folds.
  - Exactly how it works that lengthening folds increases pitch is not well understood. It appears to be influenced by the thickness and stiffness of the folds.
    - **Thickness.** Folds are not only longer in men but thicker. Stretching folds thins them.
    - **Stiffness.** Achieved through contraction of vocalis and lengthening by CT. The folds are pulled in two directions and become stiff.
• When folds are elongated, tensing vocalis stiffens muscle a bit more than when the
folds are shortened.
  o **Subglottal air flow.** Increasing pitch involves increasing the tension of the mechanism.
    If the mechanism is more tense, it will take more air pressure to drive the mechanism.
    Increases in subglottal air flow appear as a RESPONSE to increased tension (the effort
to increase pitch) and not as a cause.
  o The shorter the glottal cycle the more times the cycle can be repeated per second. Thus
    **adjustments which shorten the cycle increase the pitch.**
  • Increase contraction in the vocalis—results in increased stiffness.
    Folds are more resistant to being pushed so far apart by subglottal air pressure. This
    produces shorter opening phase. When the folds collide at closure they will be
    more resistive to the impact and consequently bounce back open more quickly.
    The net effect shortened the entire glottal cycle.
  • Shortening the glottal cycle increases the number times per second it can be
    repeated which increases the pitch.

  *How to increase pitch*
  o Lengthen folds thru CT. This thins the mass of the vocal folds—reducing mass per unit
    length.
  o Stiffen folds through the vocalis.
  o Reduce the amplitude of vibration through the vocalis.
  o As pitch is raised and raised the round thick folds become thinner and stiffer, moving
    less and less until it is much like a slit with just the edges vibrating.

  *to lower the pitch*
  o Need to shorten, thinken and relax folds.
  o Will be shortened by contraction of TA--lateral or muscularis portion.

**Loudness**
  • loudness is the psychological correlate of intensity or amplitude. The more amplitude of a
    vibration, the louder it is.
  • to increase loudness must increase the vigor of vibrations
    o to cause folds to vibrate more vigorously we **increase subglottal pressure**
    o we also **increase medial compression** which produces a more vigorous vibration. This
      works because as they are held together tighter, they are blown apart with more force,
      resulting in a longer excursion or amplitude of vibration.
  • Loudness and pitch can be manipulated separately, but they are influenced by the same
    mechanisms. It is hard to increase loudness without increasing pitch. Trained speakers/singers
    do this well. Others tend to inc pitch along with loudness.

**Clinical Applications of Phonatory Physiology**

Vocal qualities which are problematic include breathy, hoarse, or harsh voices.

• **breathy** quality.
  o In a breathy voice the folds offer enough resistance to be set into motion, but not
    enough to set up the usual air pressure for the released air. Less pressure
  o Achieved thru 2 laryngeal formations
    ■ Front of folds are close enough together to vibrate and generate a tone while the
      back of the folds are open and excessive air escapes—without being vibrated
    ■ Fold resistance is so low that the folds are blown apart by little subglottal pressure.
      This leaves a large glottal area in each cycle. Much air escapes under very low
      pressure.
- Either way, resulting voice is weak and uses up excessive quantities of air.
  - **harshness.**
    - Also called roughness
    - Gravely voice
    - Heard in weak or loud voices
    - Caused by irregularity of fold vibration.
      - Caused by glottal cycles that are irregular in terms of duration or intensity.
  - **hoarsness.** combines breathiness and harshness.
    - Air leakage is excessive and vibratory patterns are irregular

A few "tools" for examining voices, particularly harsh voices include:

- **Perturbation.**
  - This is the measure of variability from cycle to cycle. A smooth steady voice has little change in the pitch or frequency of vibrations. A hoarse voice has considerable variation in pitch. That's the hoarsness. Perturbation is measured by a computer which compares each cycle to the next. A score telling the percent of variability is produced. Variations in excess of 1-2% will be perceived as hoarse.
- **Maximum phonation time.** Ask the person to sustain a vowel. Time it. Also consider the steadiness of the tone.
- **DDK rate.** Tells of articulatory skills but also ability to phonate/not phonate for vowels and voiceless consonants.
- **Vocal range.**

Generally caused by a pathology. Example a tumor on one fold changes its mass and density. Its response to muscular adjustment will differ slightly from its partner. Therefore it will vibrate differently. The different vibratory pattern of the one fold will result in a pattern of closure that is not even.
LARYNGEAL POSTURES FOR VARIOUS FUNCTIONS

Adducted for phonation

Abducted for quiet respiration

Dilated for forced respiration

Adducted for whisper
Glottal fry

Amplitude (Volts)

Modal phonation

Time (ms)

0 55
Figure 5-2  Asymmetric pathways of the left and right recurrent laryngeal nerves.
Figure 5-1 Pathway of the vagus nerve from brainstem to larynx. R-I-L-M: remaining intrinsic laryngeal muscles.