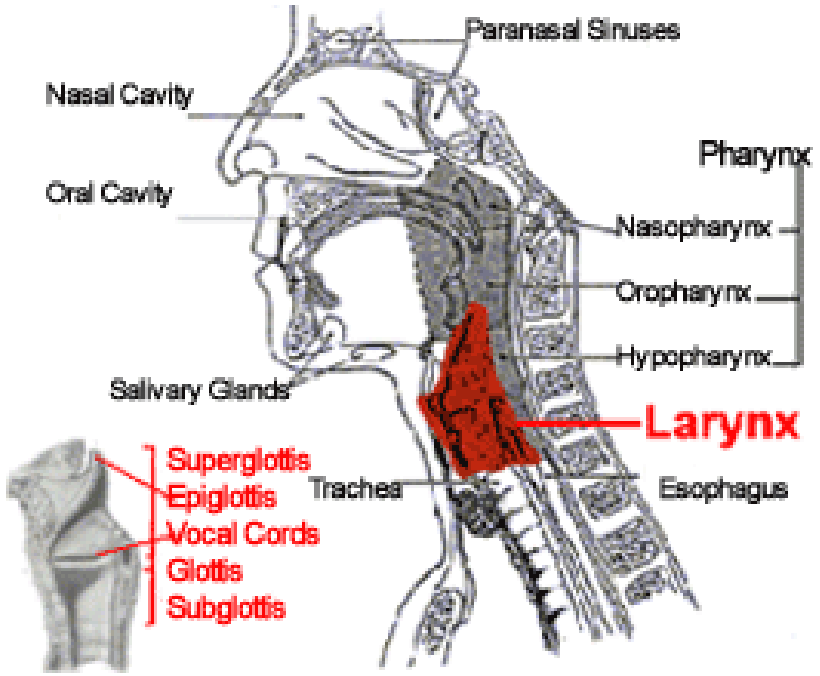
COMD #6305

The Phonatory system
Chapters 4, 5

- LARYNGEAL FUNCTION
- JITTER, SHIMMER
- VOCAL REGISTERS
- NORMAL VS. ABNORMAL VOICE QUALITIES
- MEASUREMENTS OF VOICE QUALITY
- CLINICAL APPLICATIONS
- INSTRUMENTATION

The **larynx-** review

Division between glottal, subglottal, and superglottal regions

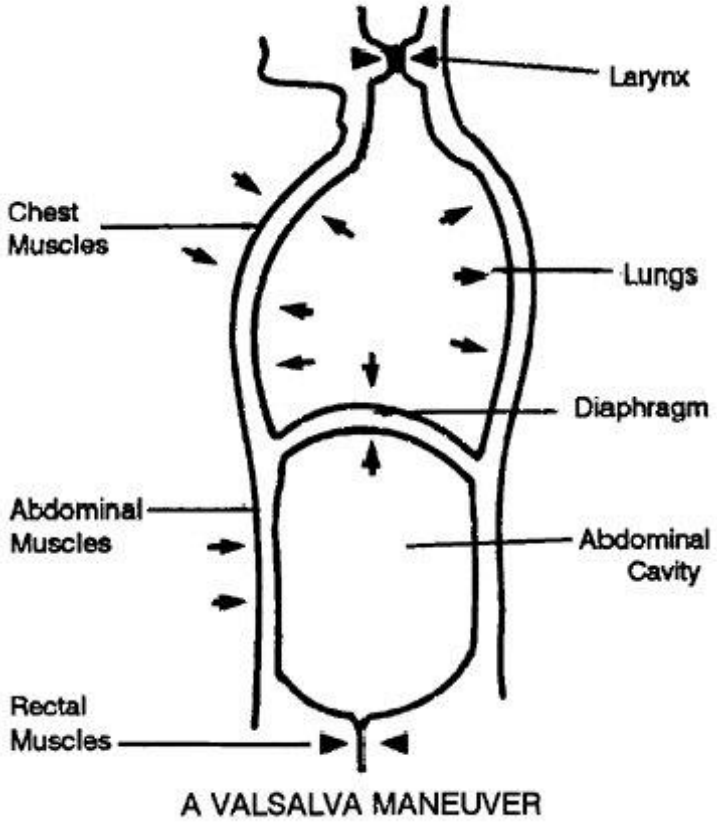


Laryngeal Actions

- Safety (preventing aspiration)
- Valsalva (*see next slide*)
- Phonation

Valsalva mechanism

Antonio Maria Valsalva (1666-1723)



A VALSALVA MANEUVER

- Larynx closes (adducts), diaphragm raises, abdominal and chest muscles constrict
- Lung pressure increases: Assists with physical exertion
- Also clears ears

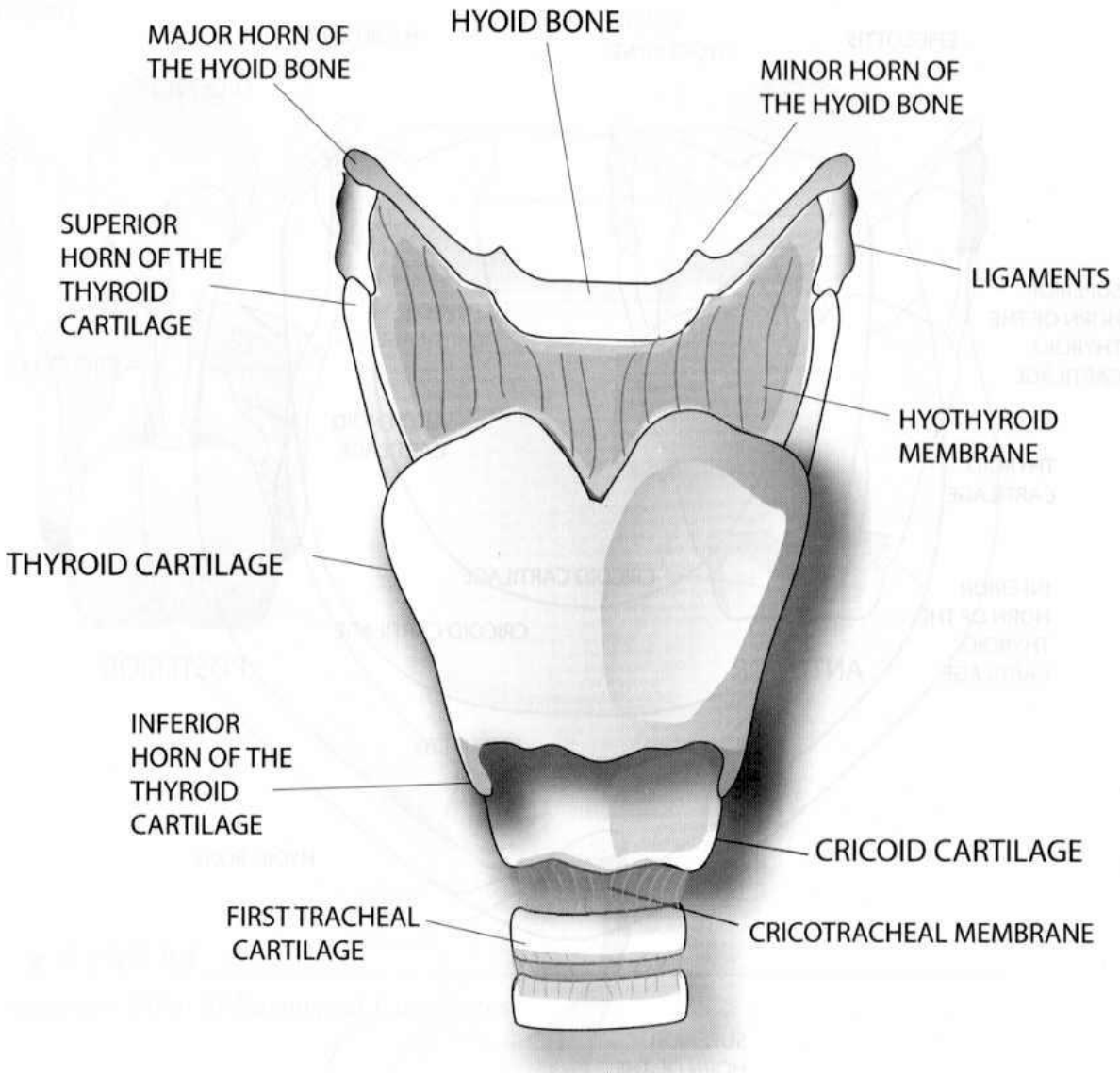


Fig. 6.1. Anterior View - Larynx, Trachea

CARTILAGES

UNPAIRED

- Thyroid Cartilage
- Cricoid cartilage
- Epiglottis

PAIRED

- Arytenoids
- Corniculates
- Cuneiforms

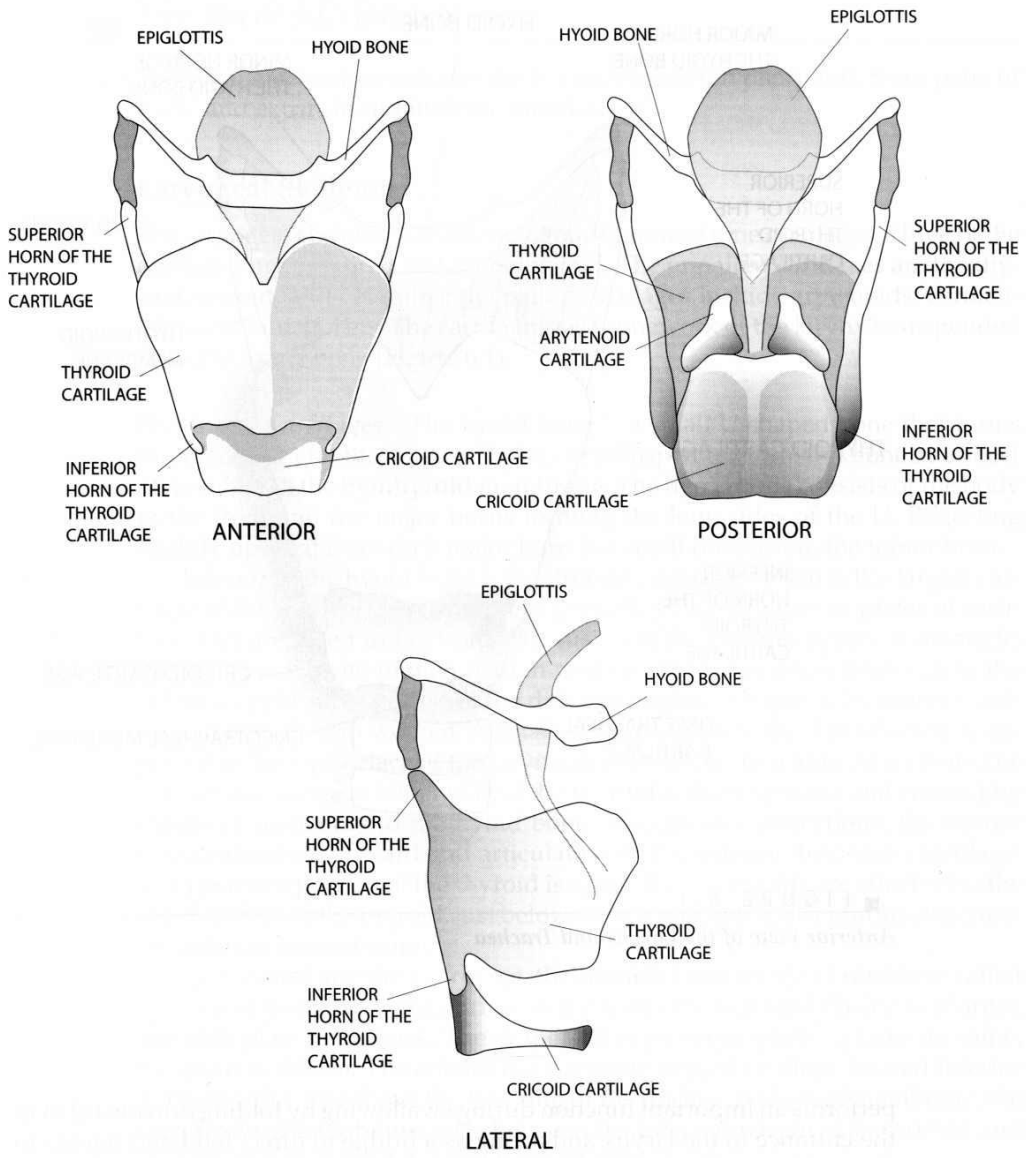


Fig. 6.2 Cartilages

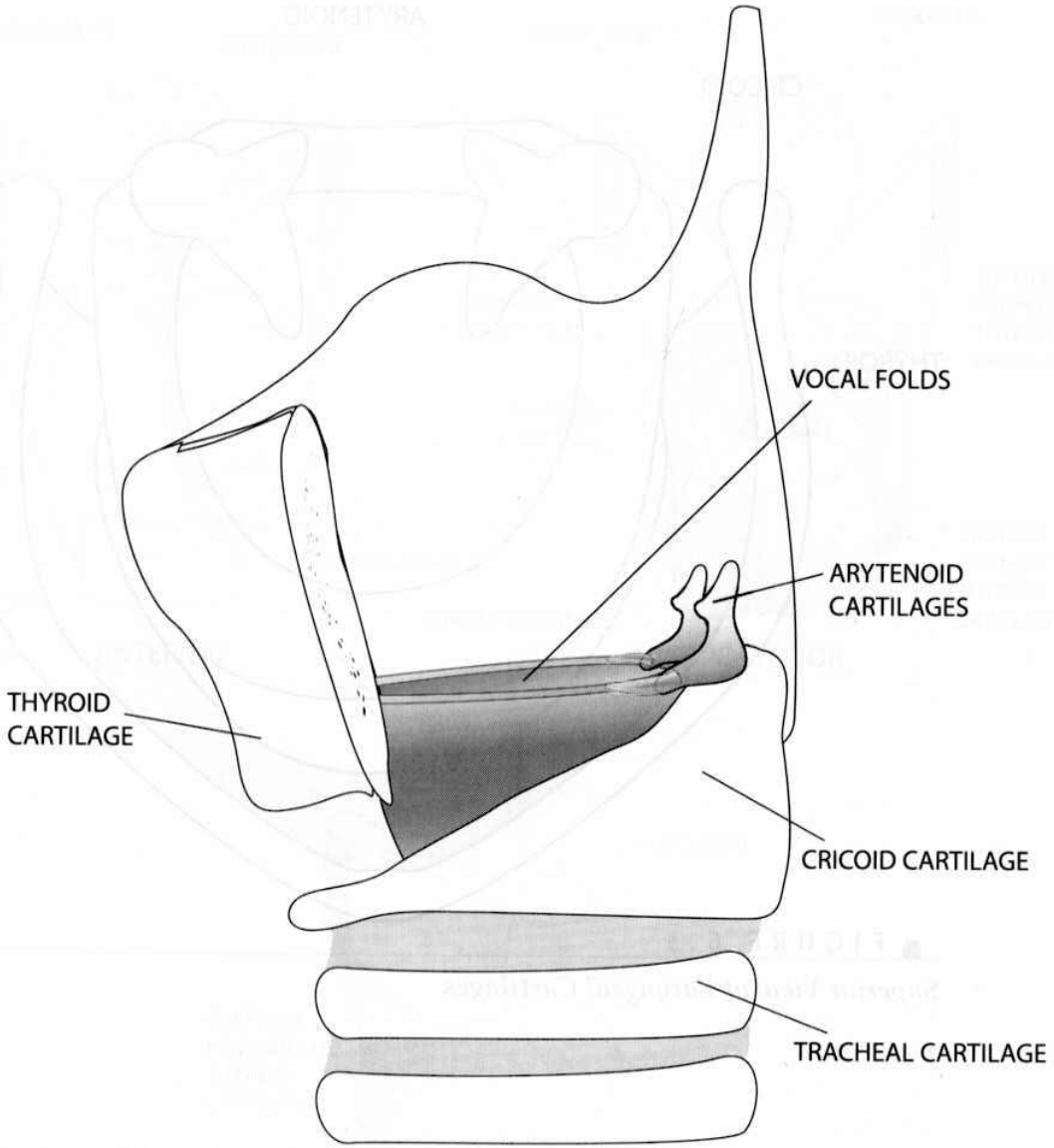
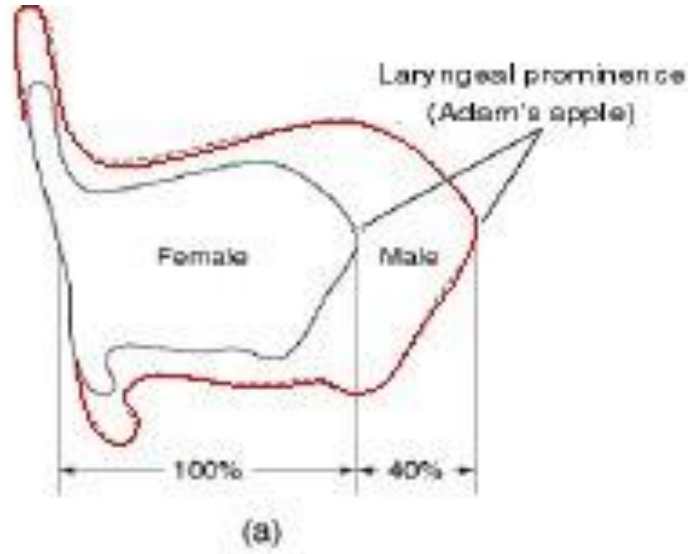
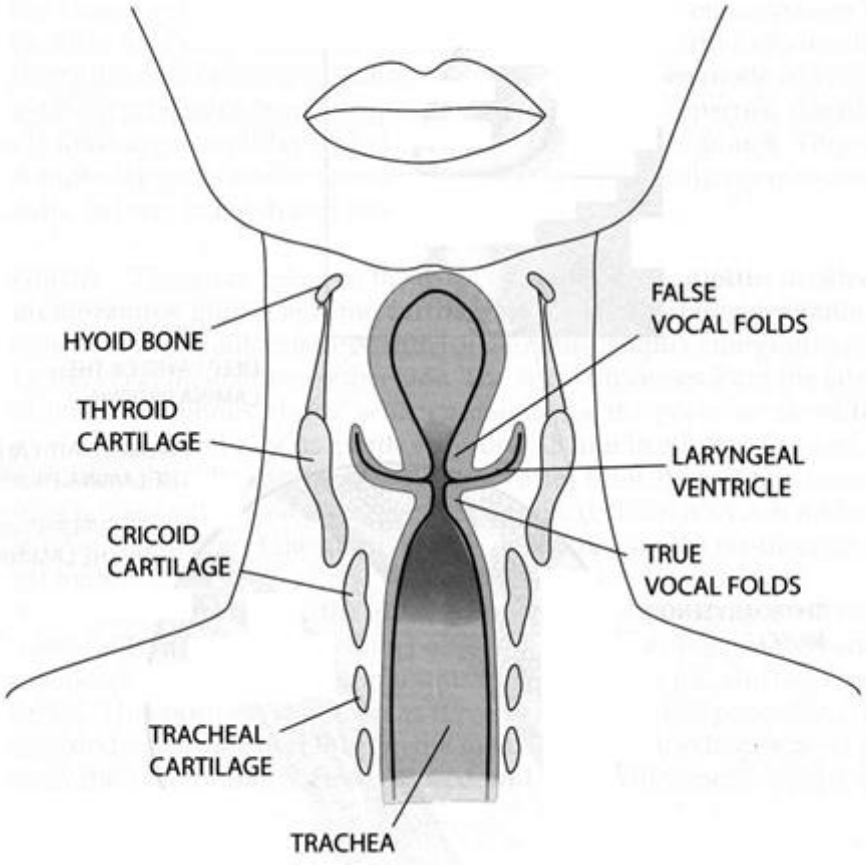


Fig. 6.4. Larynx – cutaway view



Thyroid cartilage – male/female differences



6.5. Larynx – coronal view

Arytenoids (lit. “ladle-like”)

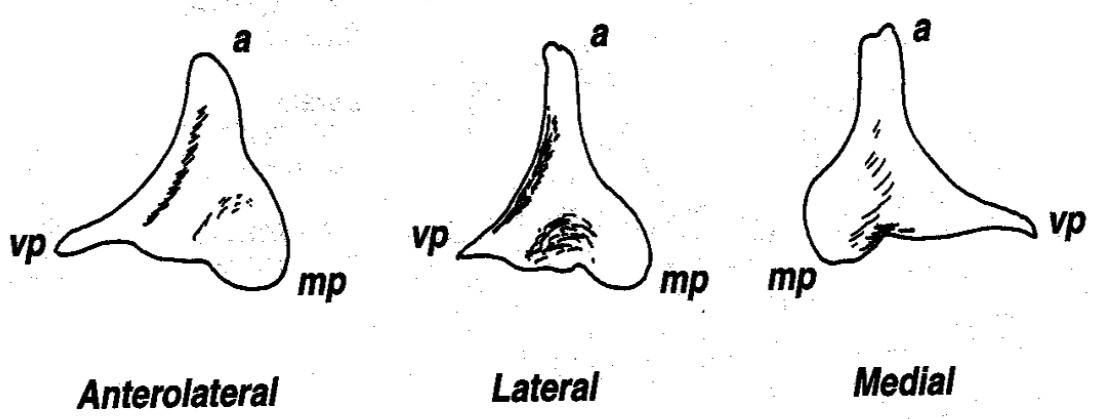


Figure 4–33. The arytenoid cartilages, shown in three perspectives. *Key:* a = apex, vp = vocal process, and mp = muscular process.

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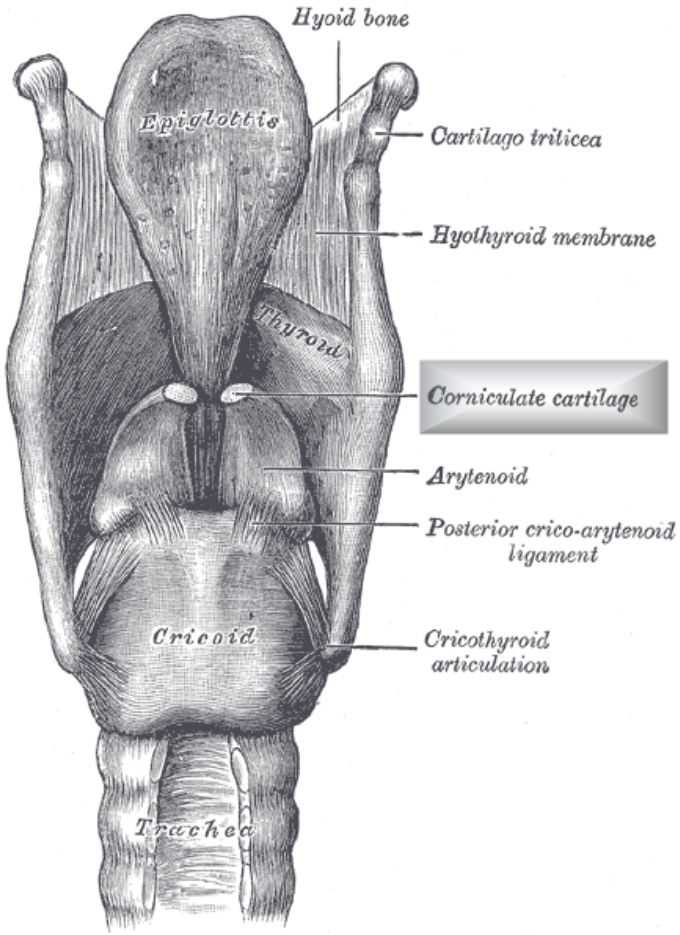


(Gray's Anatomy, 1858)

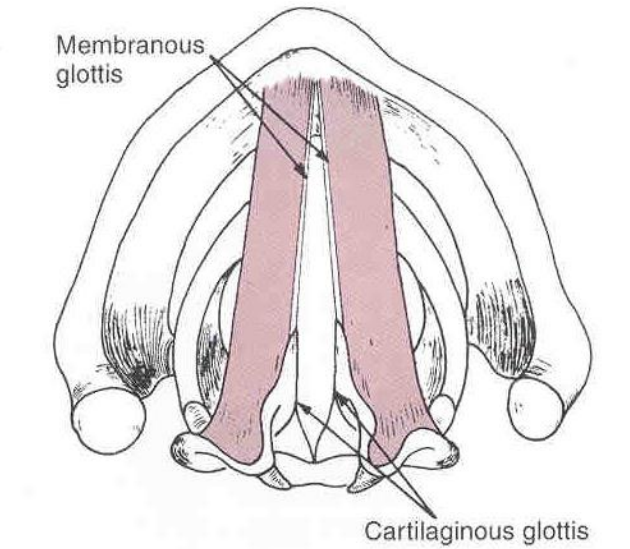
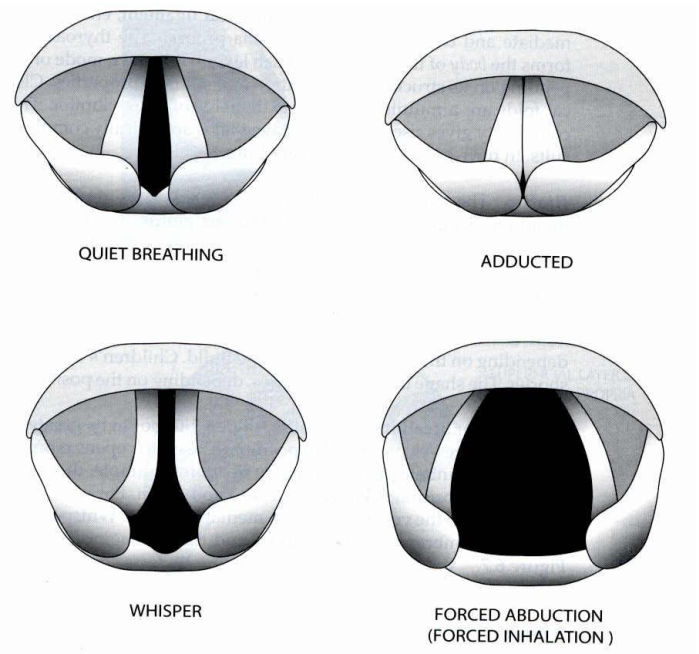


FIGURE 3-29

Schematic of larynx as seen from above, showing membranous or vocal glottis and the cartilaginous glottis.



Vocal Folds

Vocal Folds

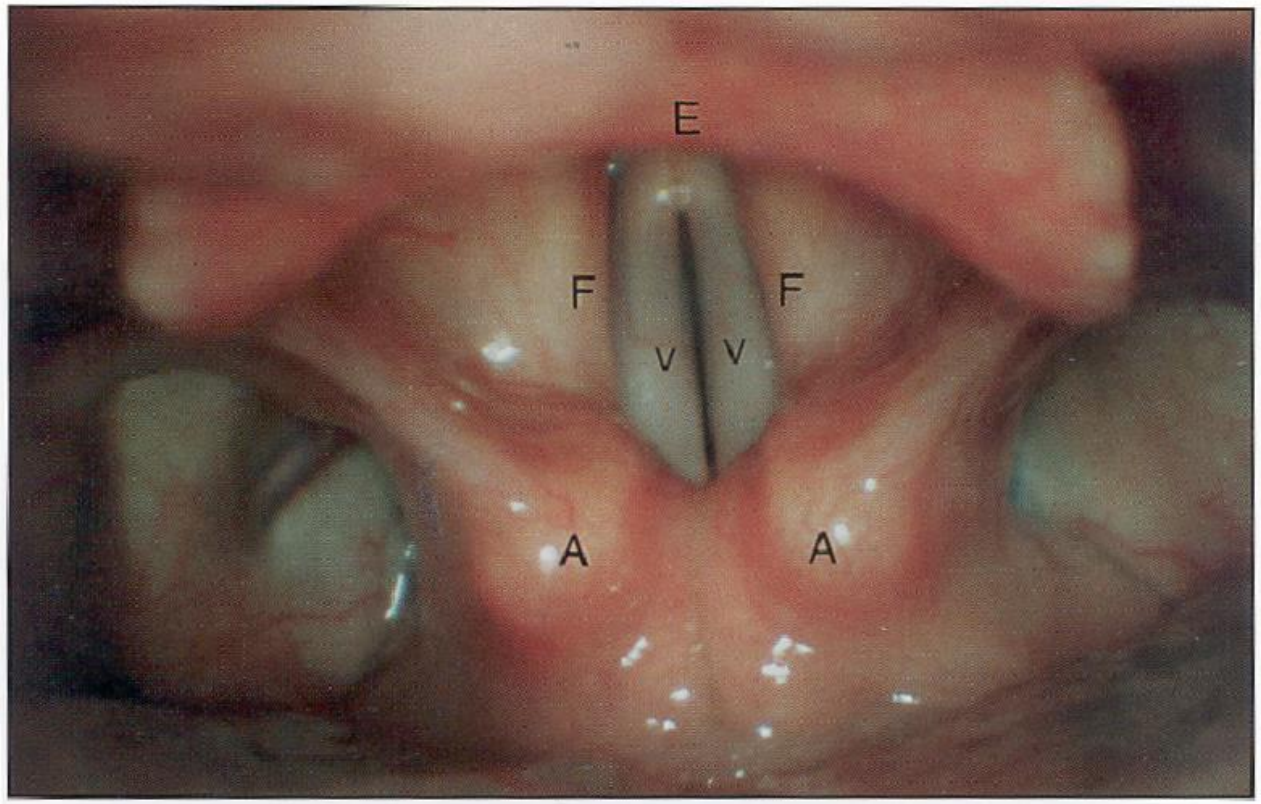


PLATE 1. Photograph of normal larynx showing vocal folds (V), false vocal folds (F), arytenoids (A), and epiglottis (E).

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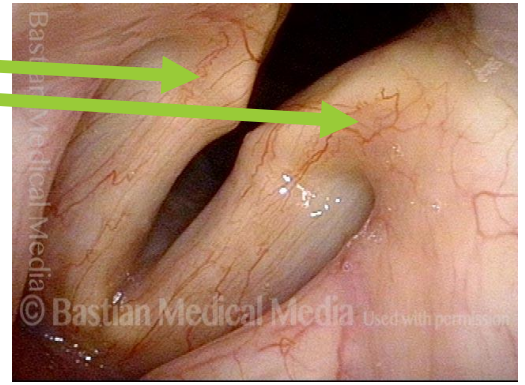
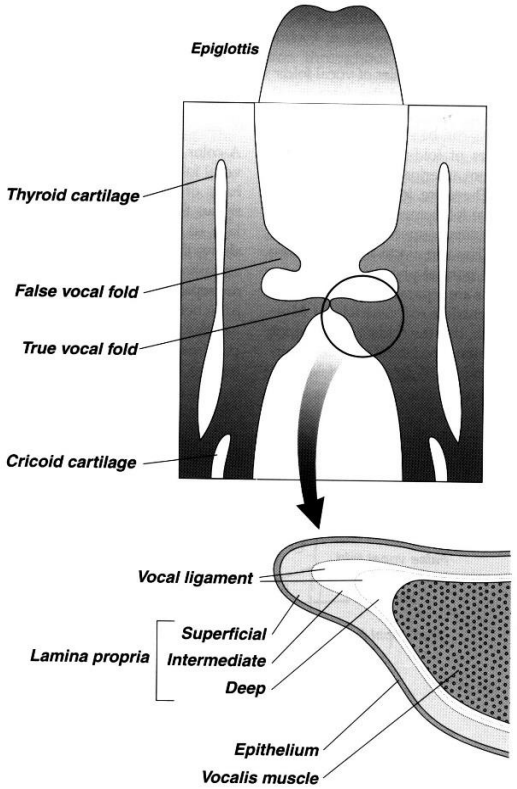
Glottis

- Membranous glottis (vocal folds) = anterior 2/3 (also space between this segment)
- Cartilaginous glottis (post. 2/5 – back towards artytenoids)
- CG must be closed at arytenoids for voiced modal speech to begin



VOCAL FOLDS

- True vocal folds lie inferior to the false folds.
- Separated by a small cleft called the ventricle.
- TRUE FOLDS, FALSE FOLDS and the VENTRICLE divide the subglottic, glottic and supraglottic regions.



TRUE VOCAL FOLDS

VOCAL FOLD

- 1. Mucosa
- 2. Muscle (Thyroarytenoid)

THREE MAJOR LAYERS

- 1. Cover – epithelium and superficial lamina propria
- 2. Transition – intermediate and deep lamina propria
- 3. Body – vocalis muscle

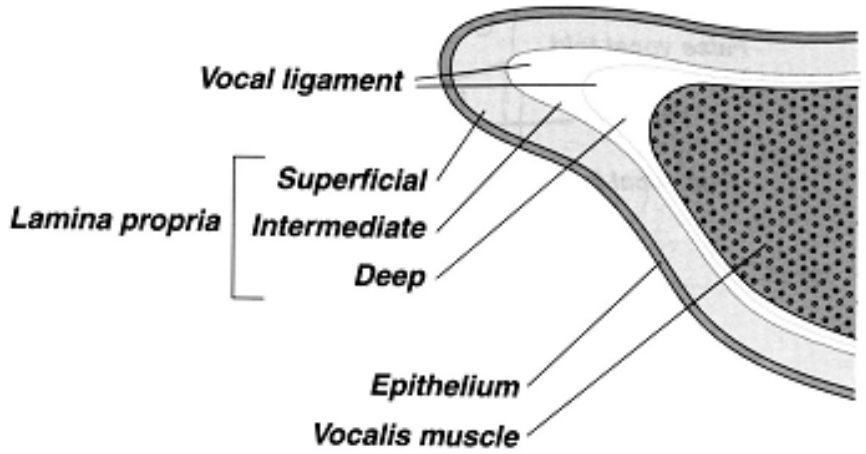
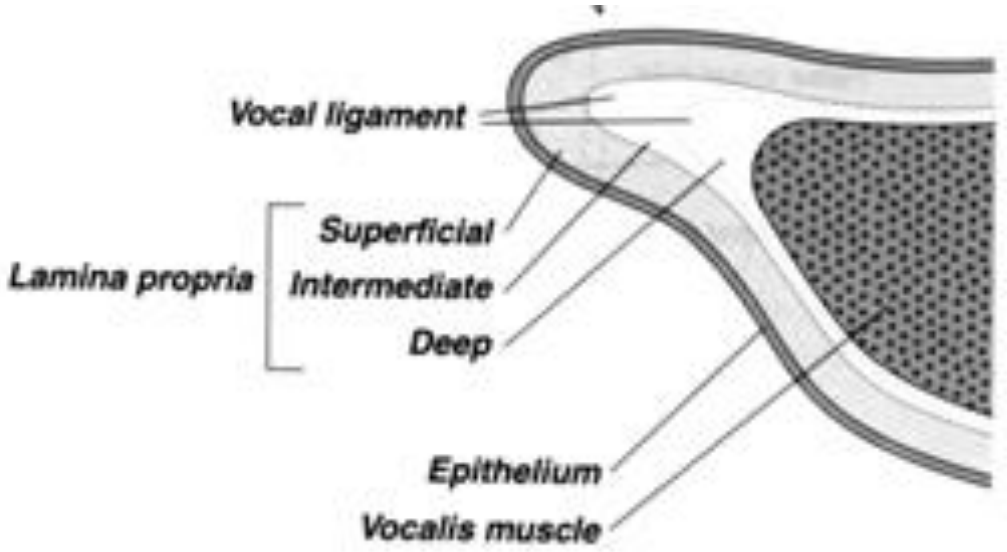


Figure 4–35. The vocal fold, shown in coronal section and an enlargement to represent the layered structure.

Cover-body model (Hirano)

- Cover* is least stiff
- Vocal ligament is more stiff
- Body (muscle) has greatest stiffness



*cover = epithelium & superficial layer

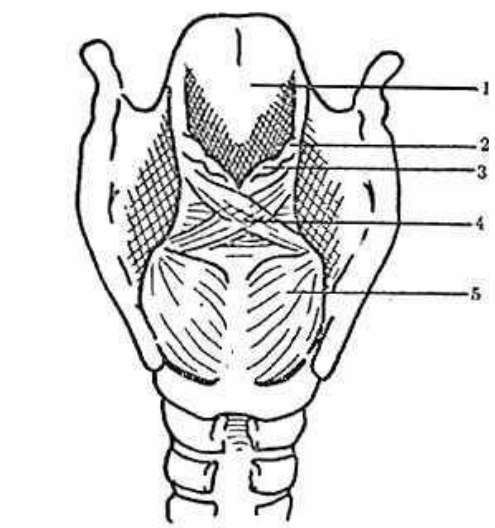
Muscles of Larynx

Intrinsic

- Have origin and insertion within larynx

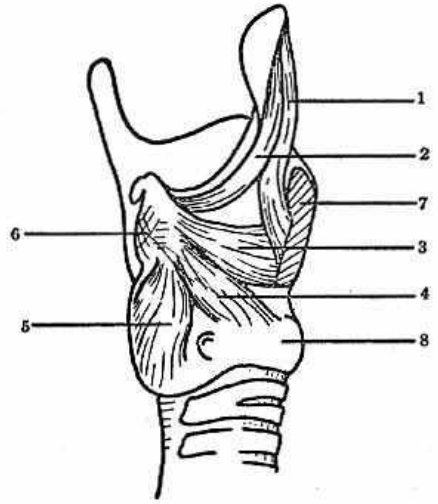
Extrinsic

- Have one point of attachment → larynx and other attachment → other structure



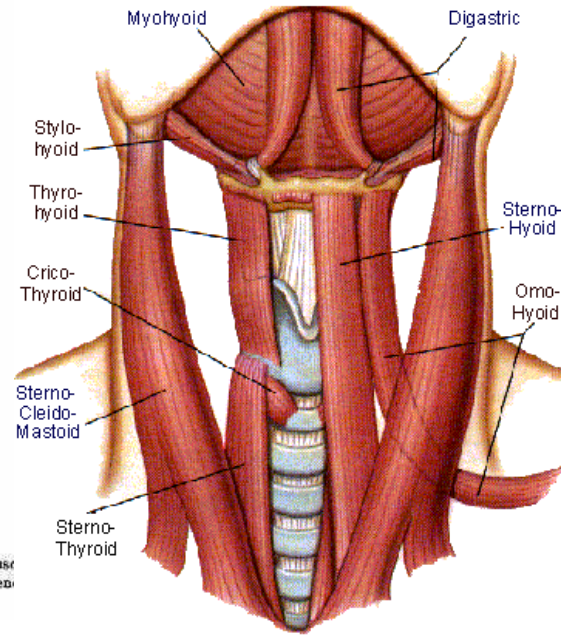
Muscles of the Larynx from behind (Hefner)

1 - Epiglottis 2 - Cuneiform cartilage 3 - Corniculate cartilag
4 - Arytenoid muscle 5 - Cricoarytenoid muscle



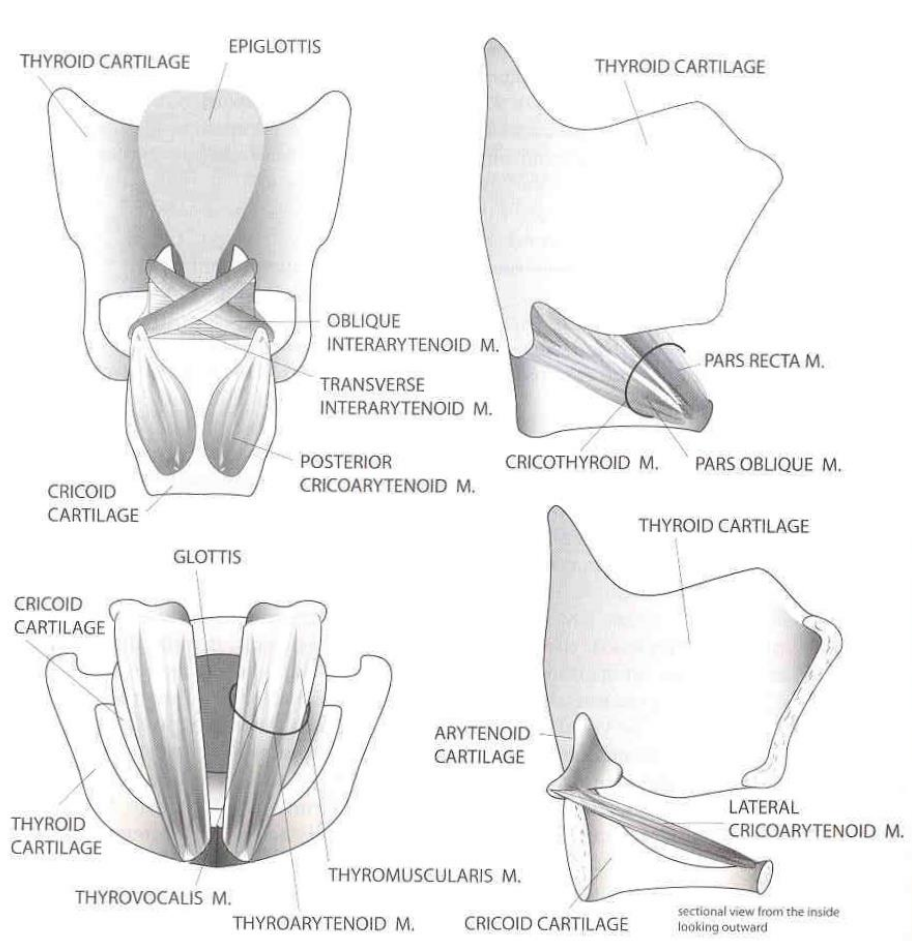
Muscles of the Larynx from the side (Hefner)

1—Thyroepiglottic muscle. 2—Aryepiglottic muscle. 3—Thyroarytenoid musc
4—Lateral ericoarytenoid muscle. 5—Posterior ericoarytenoid muscle. 6—Aryten
muscle. 7—Thyroid cartilage. 8—Cricoid cartilage.



INTRINSIC MUSCLES OF LARYNX

- Abduct (open) or adduct (close) the folds.
- Vocal fold length and tension.
- Attach at origin and insertion of different cartilages
- Roles in respiration, swallowing, and vocalization.



■ FIGURE 6.9

Intrinsic muscles of the larynx.

Post.

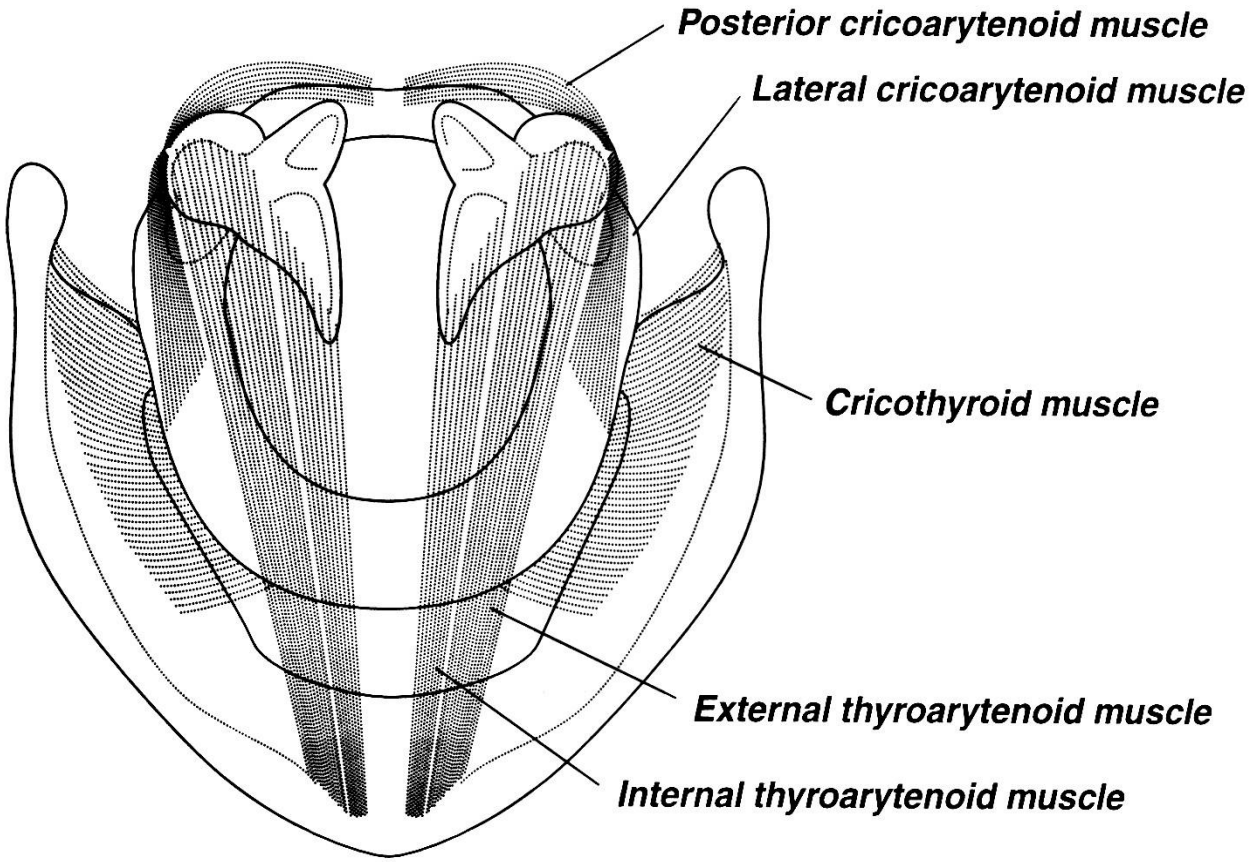


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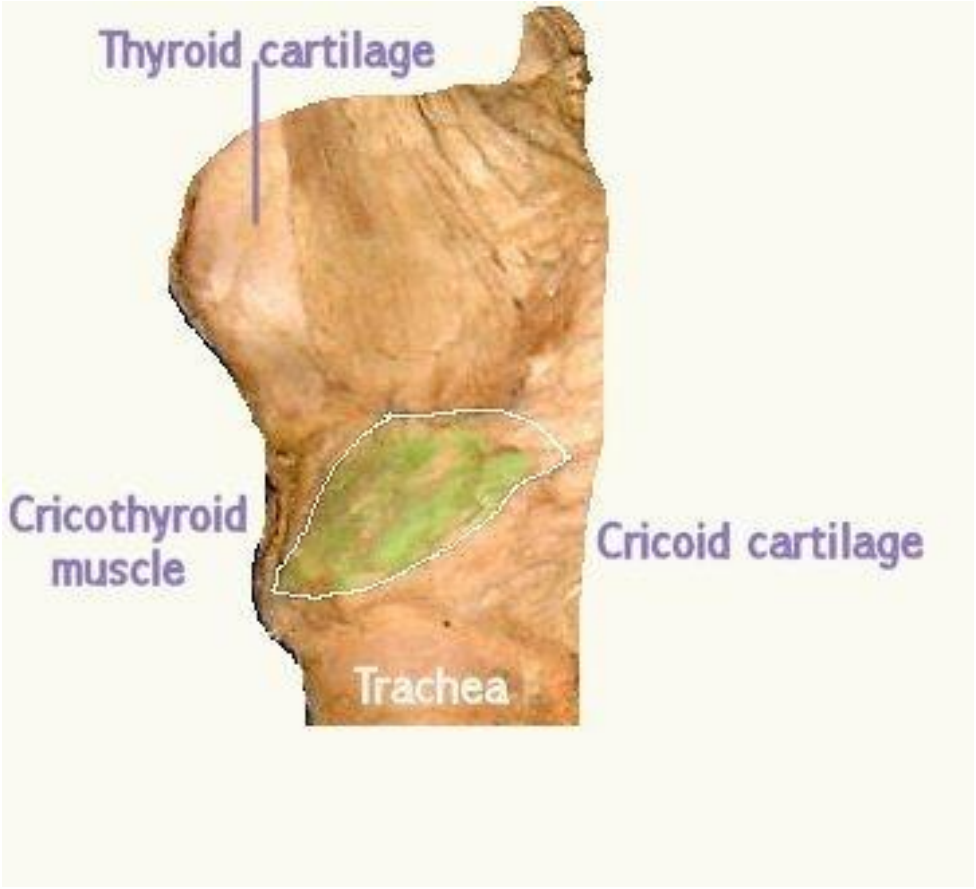
Figure 4–39. Intrinsic muscles of the larynx visible in a superior view.

Cricothyroid Muscle



- Attached to thyroid and cricoid cartilages
- Rocks thyroid forward; stretching and tensing the vocal folds
- Raises pitch –push on this and mechanically raise your pitch!

Intrinsic Muscles

Main | Adductors | |

Only Abductor → Posterior cricoarytenoid

Raises pitch → Cricothyroid

Together make Up vocal folds Thyroarytenoid

TABLE 6.3

Intrinsic Muscles of the Larynx

MUSCLE	ATTACHMENTS	FUNCTION
Lateral cricoarytenoid	Lateral cricoid to muscular process of arytenoid	Adduct vocal folds
Interarytenoid		
Transverse	Lateral margin of one arytenoid to lateral margin of other arytenoid posteriorly	Adduct vocal folds
Oblique	Base of one arytenoid to apex of other arytenoid posteriorly	Adduct vocal folds
Posterior cricoarytenoid	Posterior cricoid to muscular process of arytenoid	Abduct vocal folds
Cricothyroid		
Pars recta	Anterior cricoid to inferior border of thyroid	Elongate and tense vocal folds
Pars oblique	Anterior cricoid to anterior surface of inferior horn of thyroid	Elongate and tense vocal folds
Thyroarytenoid		
Muscularis	Anterior commissure to muscular process	Body of vocal folds; shorten and relax folds
Vocalis	Anterior commissure to vocal process	Body of vocal folds; tenses folds

The Only **AB**DUCTION MUSCLE

- Posterior Cricoarytenoids (PCA)
- Open the glottis
- Move arytenoids away from midline

Abduction

Adduction

Adductor Muscles

- Move arytenoids to midline
- Rock forward
- *Interarytenoids (Transverse and Oblique)*
- *Lateral Cricoarytenoids*

Extrinsic Muscles

"One attachment to a laryngeal and an external structure"

SUPRAHYOID
- Stylohyoid
- Digastric
- Mylohyoid
- Geniohyoid

INFRAHYOID
- Sternohyoid
- Sternothyroid
- Thyrohyoid
- Omohyoid

Infrahyoid muscles

When contracted, pull the entire larynx downward

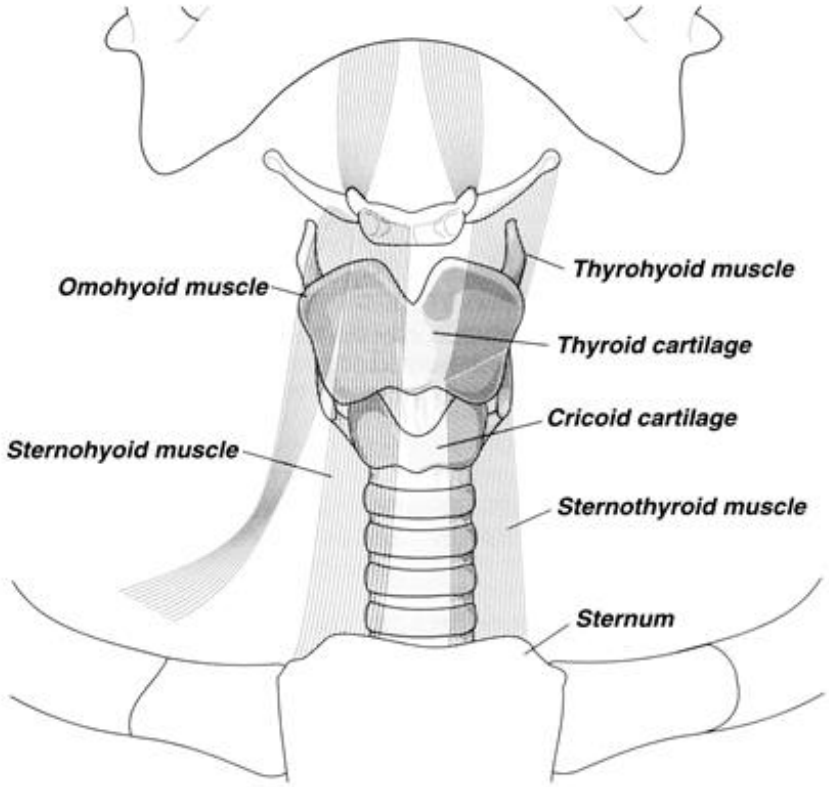
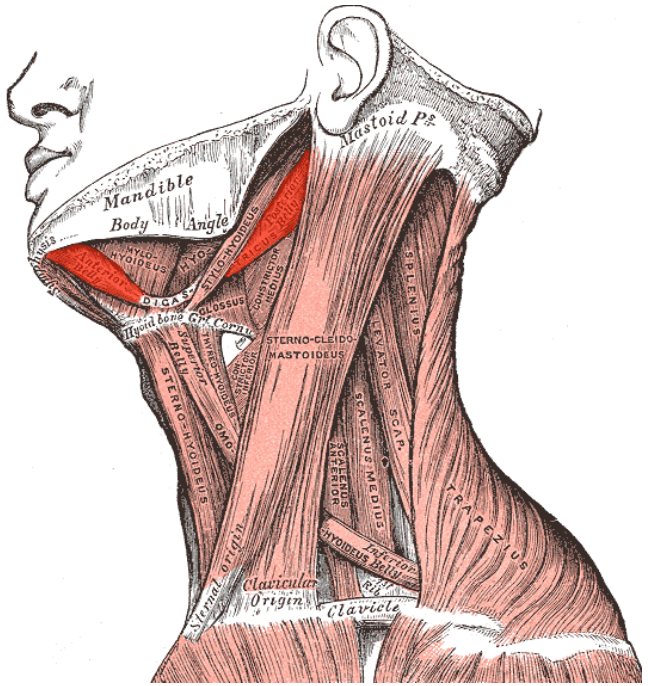
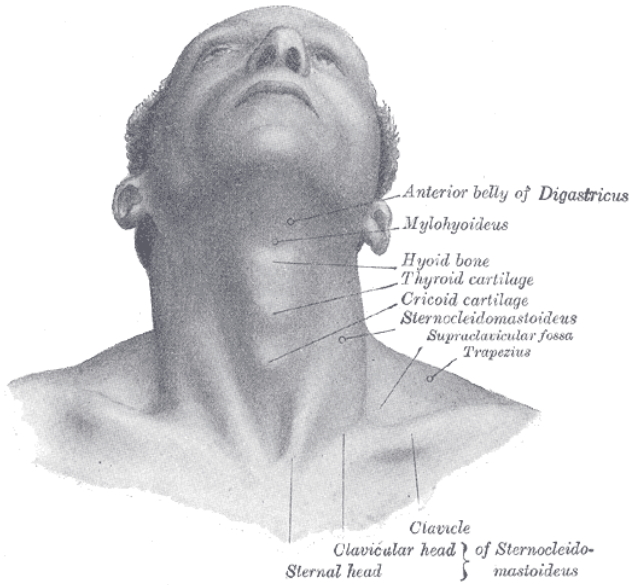


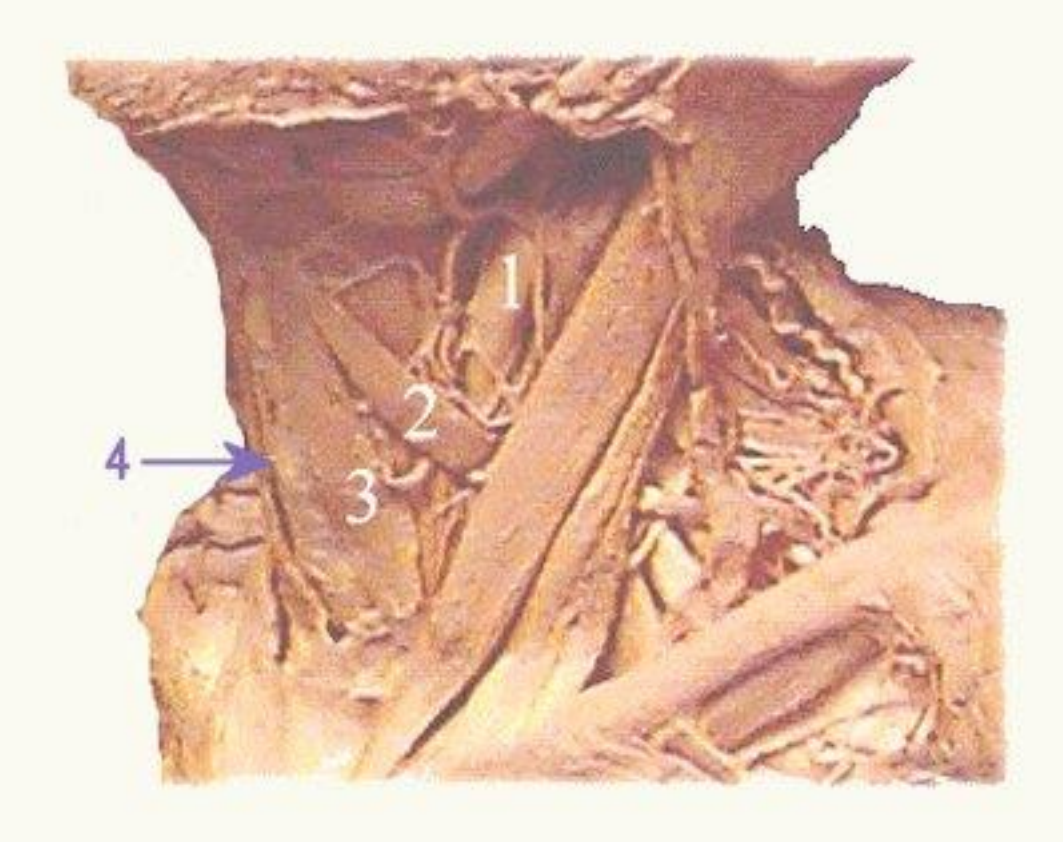
Figure 4–45. The extrinsic (infrahyoid) muscles of the larynx.


Mandible
Body
Angle
Mastoid Pr.
STERNO-CLEIDO-MASTOIDEUS
SPLENIUS
LEVATOR SCAP.
SCALENUS MEDIUS
TRAPEZIUS
Clavicular Origin
Clavicle


Anterior belly of Digastricus
Mylohyoideus
Hyoid bone
Thyroid cartilage
Cricoid cartilage
Sternocleidomastoideus
Supraclavicular fossa
Trapezius
Clavicle
Clavicular head of Sternocleido-
Sternal head mastoideus

Digastric

Suprahyoid muscles



Pulls the entire larynx upwards in the neck.

These large up and down movements occur mainly during swallowing.

3 Branches – Vagus (CN X)

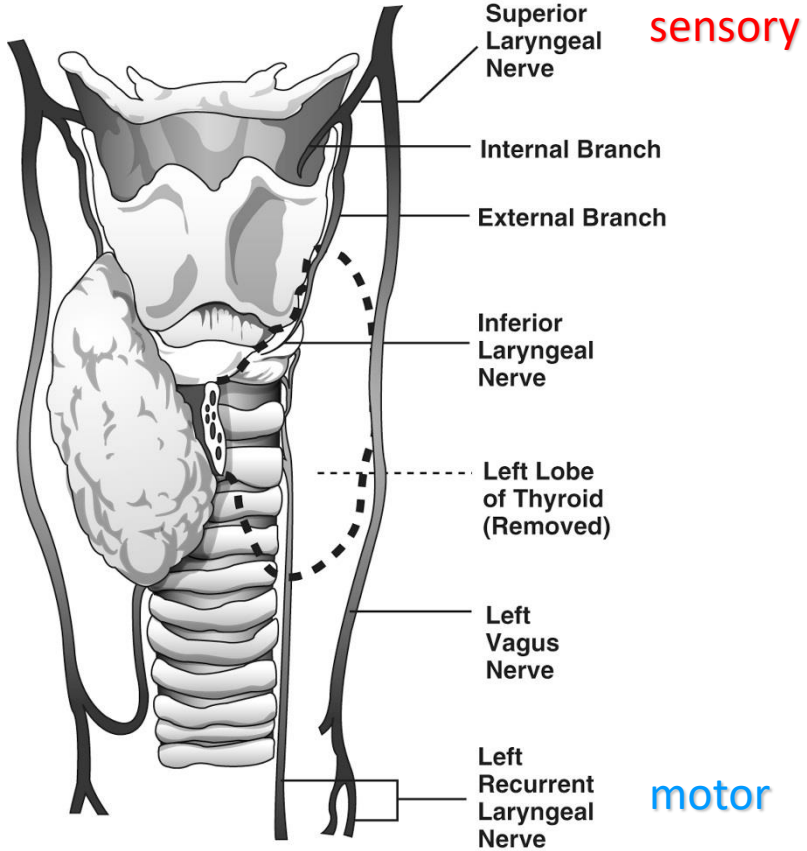
(upper = Pharyngeal Nerve)

Superior Laryngeal Nerve

sensory

Recurrent Laryngeal Nerve

motor



Myoelastic Theory of Phonation

- Orig. by Johannes Muller (1858), then Janwillem van den Berg (1958)
- Basically accurate (but with some RECENT revision)
- *Myo* = muscle, *Elastic* = recoil
- Pulmonic air = active force; vocal folds = passive actors

Johannes Müller

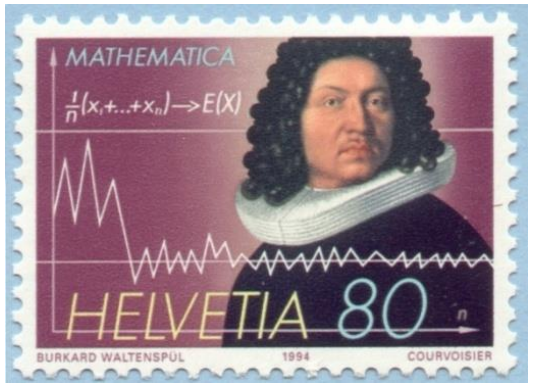
VOCAL FOLD VIBRATION

- Muscle Action
- Subglottal pressure build-up
- > Subglottal than supraglottal pressure
- Creates delta force
- Pressure drop, Bernoulli effect

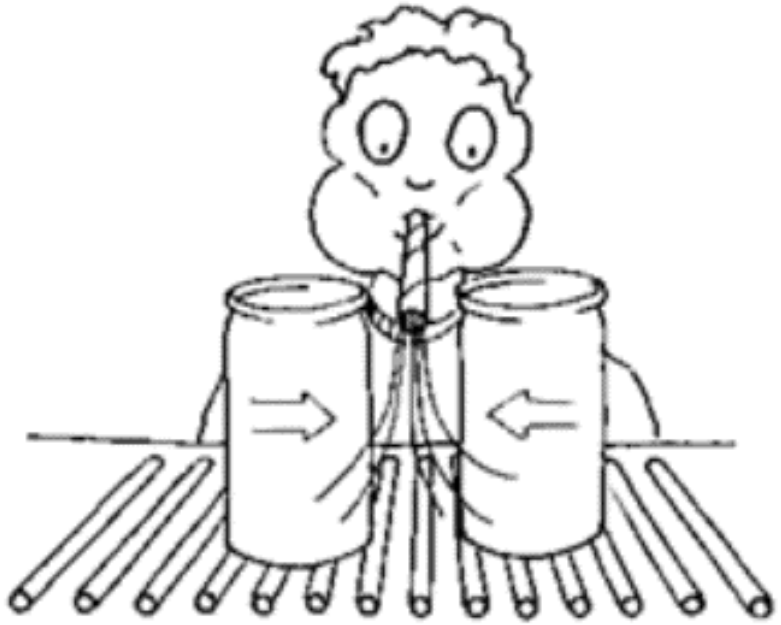
Daniel Bernoulli (1700 – 1782)

←The man

The stamp→



The effect →



Muscosal wave

Vertical phase difference (see next 2 slides)

Longitudinal phase difference (from posterior to anterior, “like a zipper”)

ANT

POST

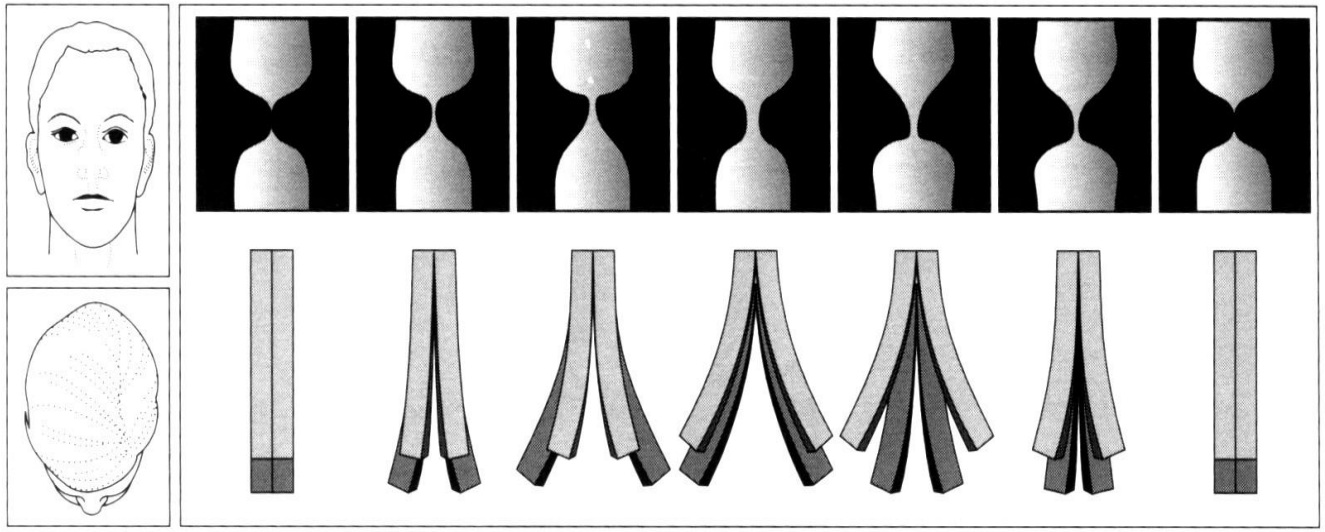
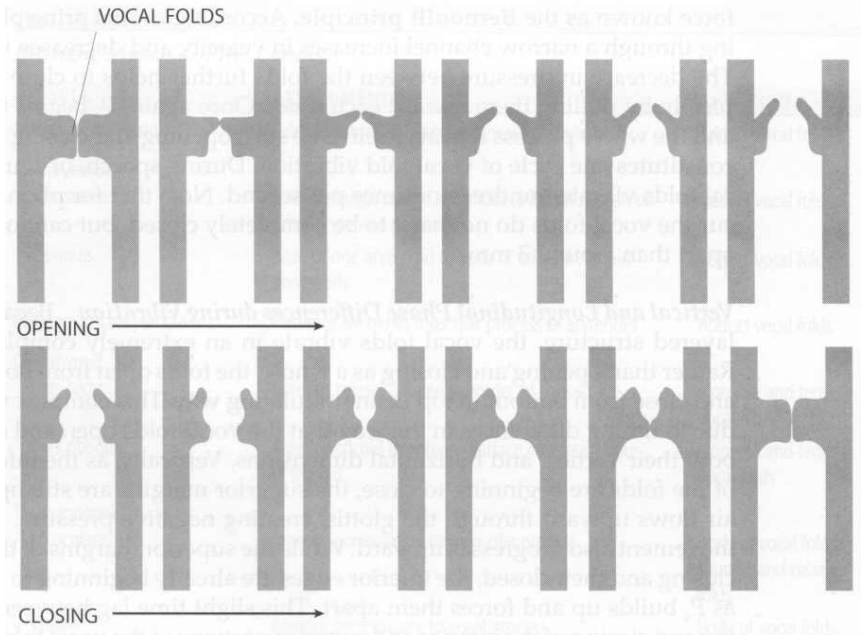


Figure 4–46. A schematic representation of the traveling wave seen during vocal fold motion. The series at the top represents a coronal section through the folds. The series at the bottom shows the relative motions of the upper and lower margins of the folds, from a superior view.

Note: In middle snapshots we also see “longitudinal” phase difference”

- Kent, Speech Sciences

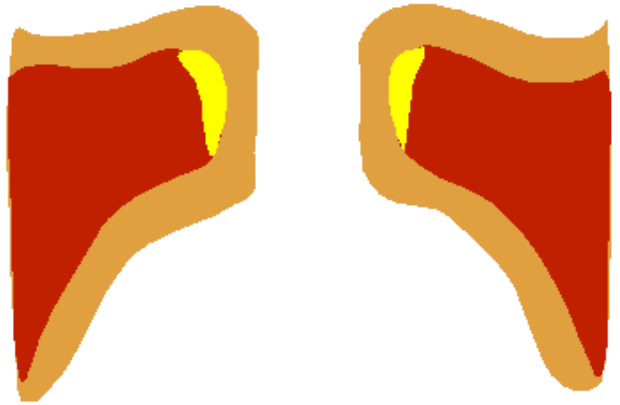


Vocal Fold Phonation

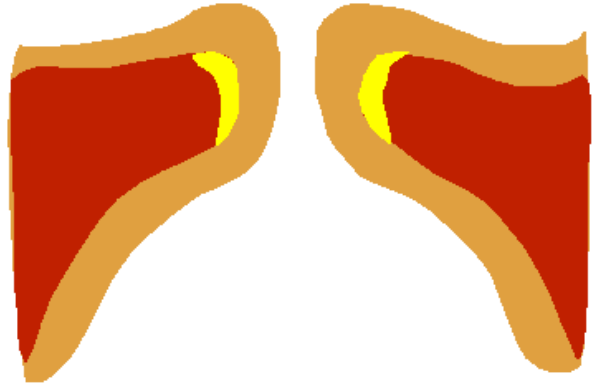
- Determined by mass, length, and tension
- Changes throughout utterance (question vs. statement, etc.)
- Males (F_0: 80-150Hz)
- Females (180-250 Hz)
- Children (250-300 Hz)

Animations

VF modal



VF falsetto



F_0 and Harmonics

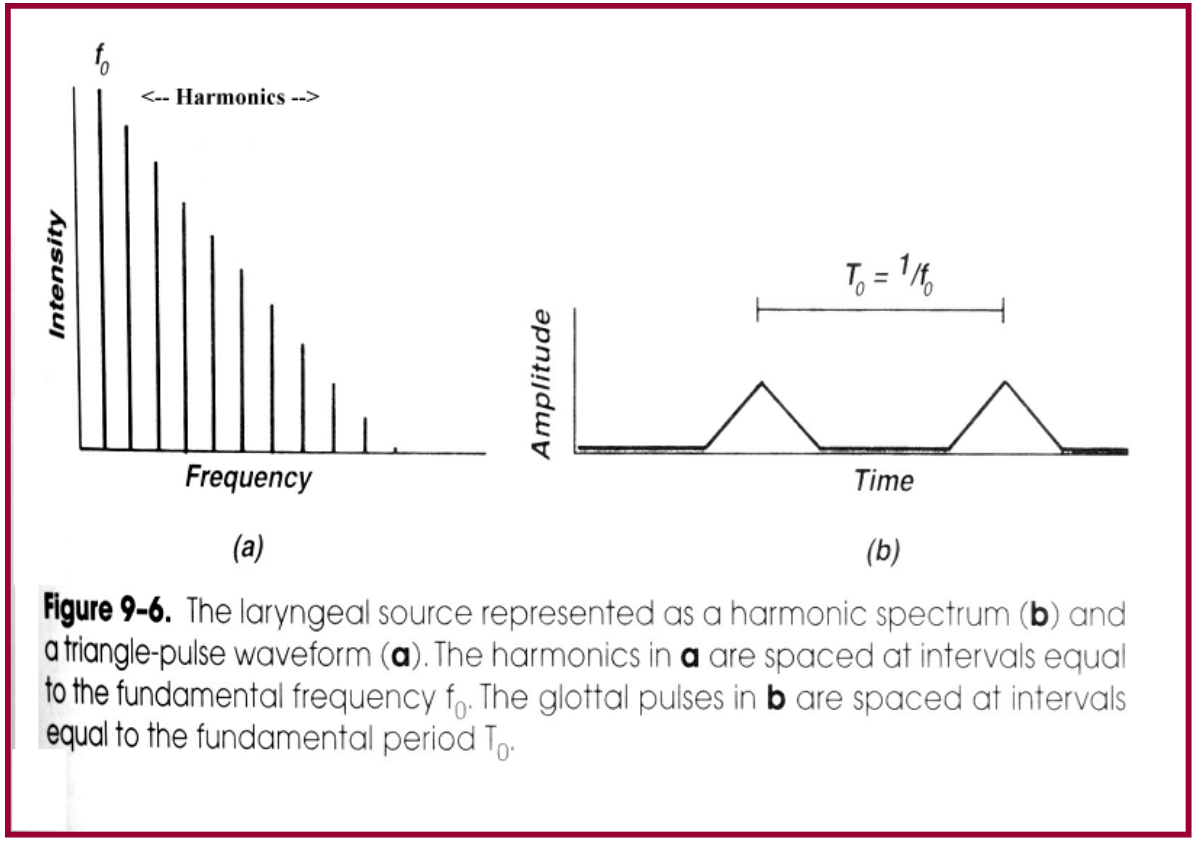
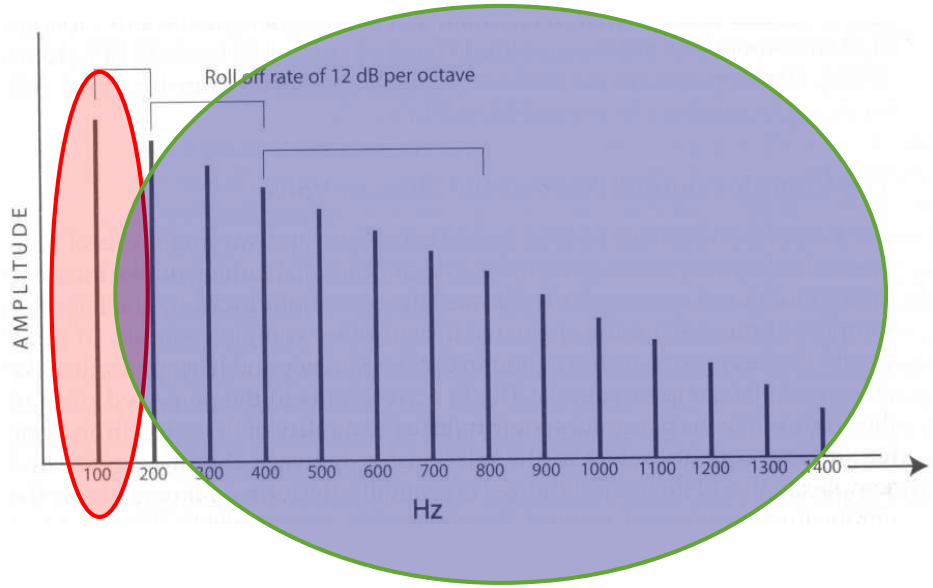


Figure 9-6. The laryngeal source represented as a harmonic spectrum (**b**) and a triangle-pulse waveform (**a**). The harmonics in **a** are spaced at intervals equal to the fundamental frequency f_0. The glottal pulses in **b** are spaced at intervals equal to the fundamental period T_0.

→ The human voice is nearly periodic

Glottal Spectrum

- Glottal F_0 with harmonics
- Does not represent what is heard (due to vocal tract modulation)
- The F_0 corresponds to the perceived pitch of the voice
- The harmonics contribute to the quality of the voice



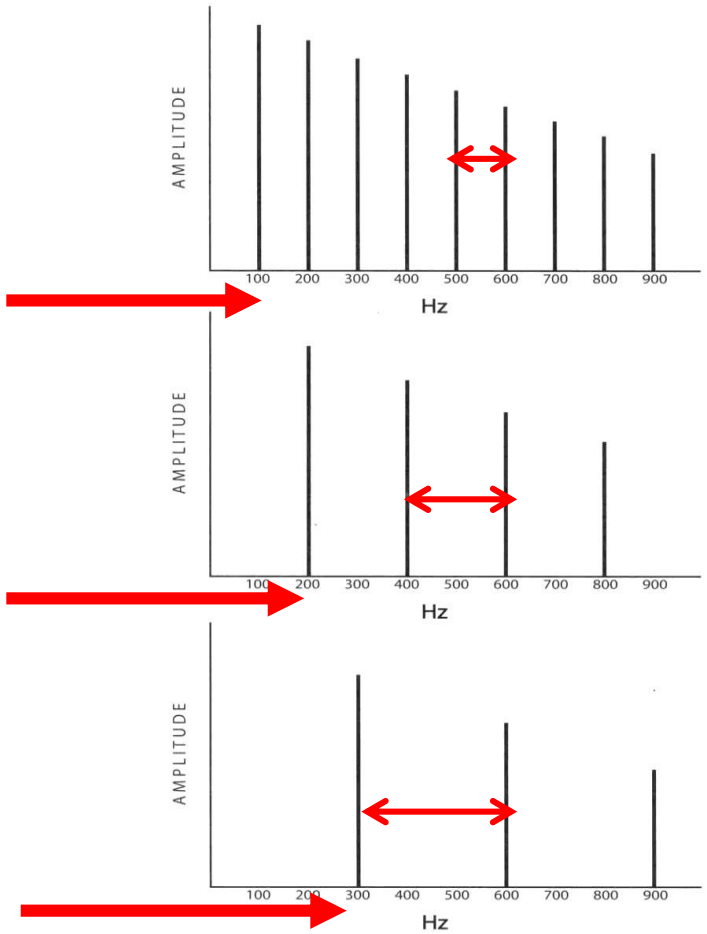
This is what we would see if we lowered a microphone down just over the larynx

F_0 & Harmonic Spacing

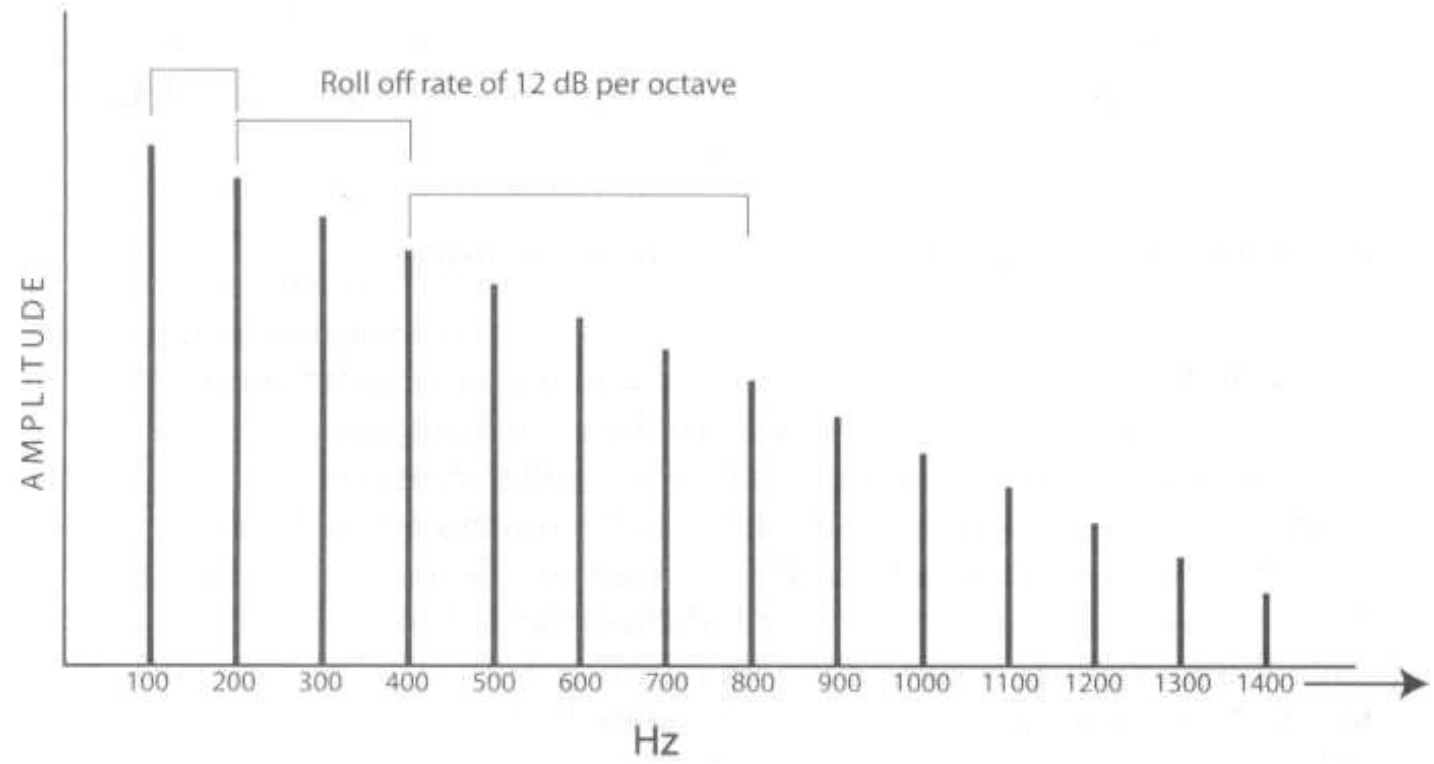
Adult Male

Adult Female

Child



Roll Off—F_0



"About 40 harmonics have at least some acoustic energy in the human voice"

Vocal Registers

- Pulse (= Fry, Creaky)
- Modal
- Falsetto

Average Speaking Ranges for Males and Females at Five Different Registers

	MALES (Hz)	FEMALES (Hz)
Deepest range (pulse)	43–82[a]	87–165[a]
	25–80[b]	25–45[b]
Chest (modal)	98–147[a]	175–294[a]
	75–450[b]	130–520[b]
Midvoice	196–294[a]	349–587[a]
Falsetto	349–494[a]	659–988[a]
	275–620[b]	490–1130[b]
Whistle	523–698[a]	988–2093[a]

(Adapted from Baken, 1996, and Zemlin, 1998.)
Source: [a]Zemlin (1998).
[b]Baken (1996).

(cf. Table 5.5)

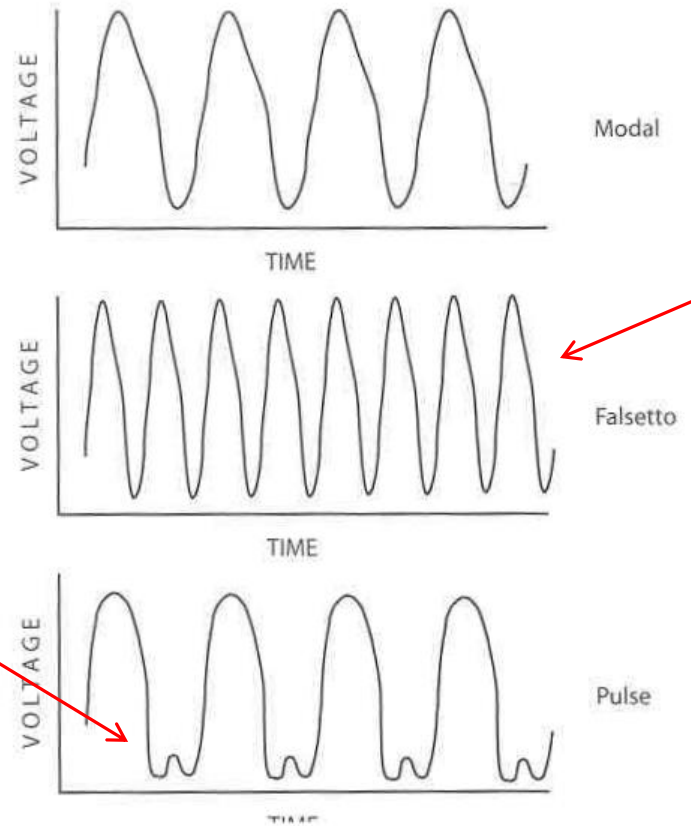
Registers – continued

Pulse –

Folds closed 90% of time

biphasic or multiphasic

Leaves an acoustic temporal gap

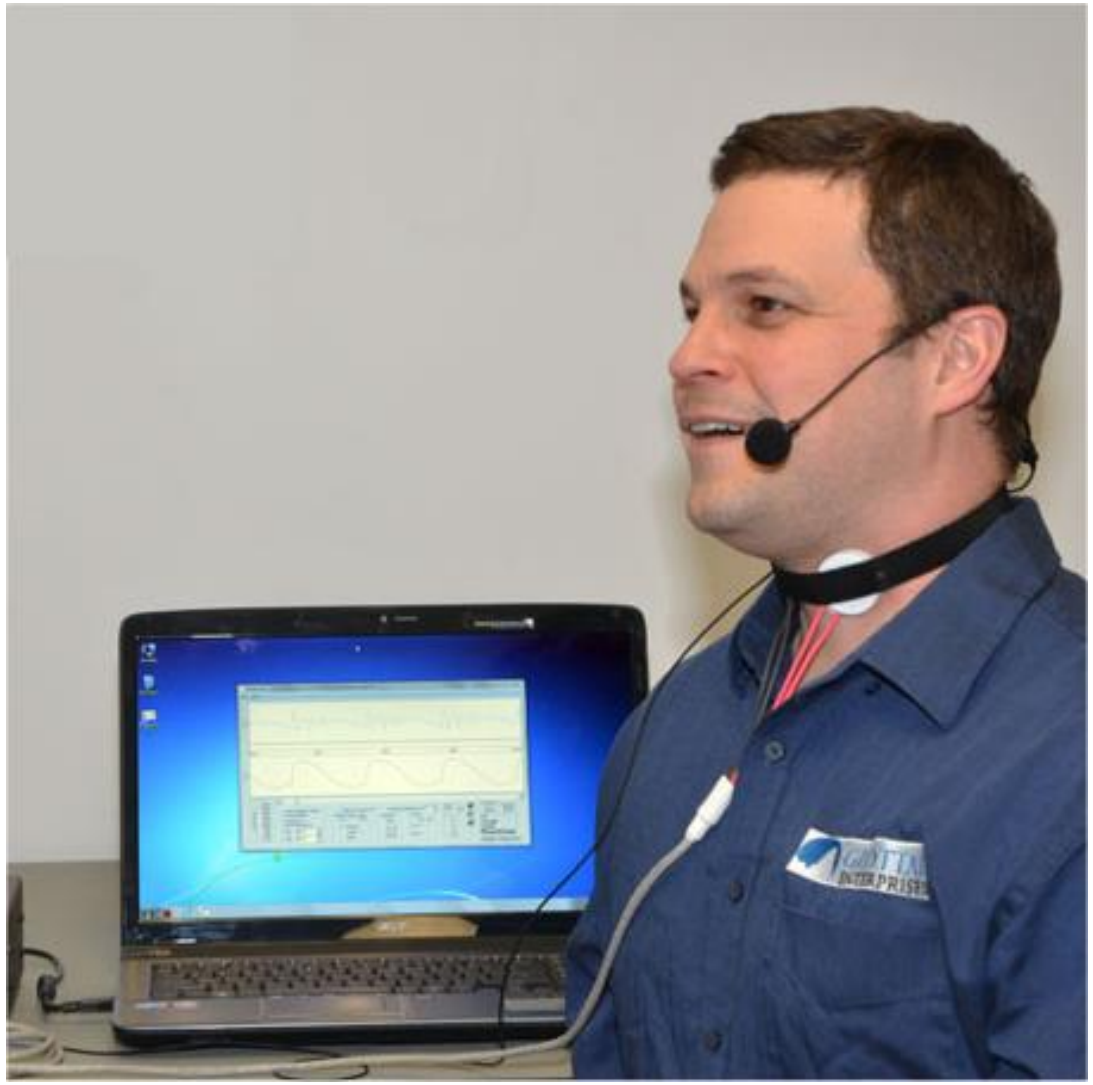


Falsetto – Folds long and stiff, Thinner quality sound

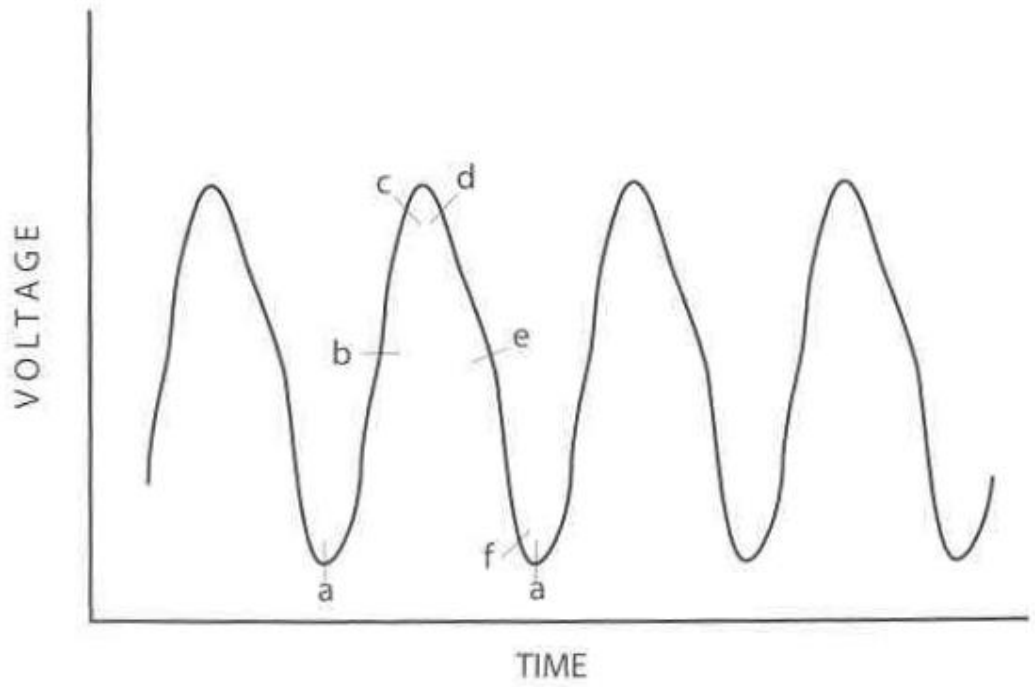
Electroglottography (EGG)

- More contact between vocal folds → greater conductivity between electrodes
- Works better on men than women

Best at detecting closing phase



EGG Readout



EGG – Lx wave

Reflects surface area of contact of the vocal folds

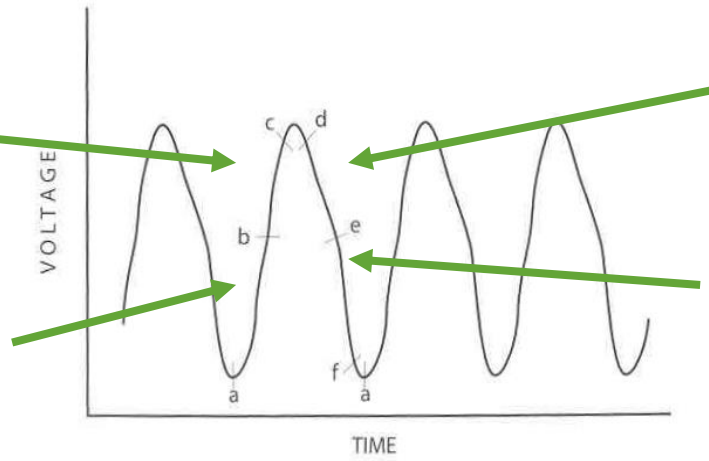
“Duty cycle” of vocal fold vibration

Lx wave – continued

CLOSING

2. Btwn *b* - c, superior margins closing

1. Btwn *a* - *b*, lower margins closing

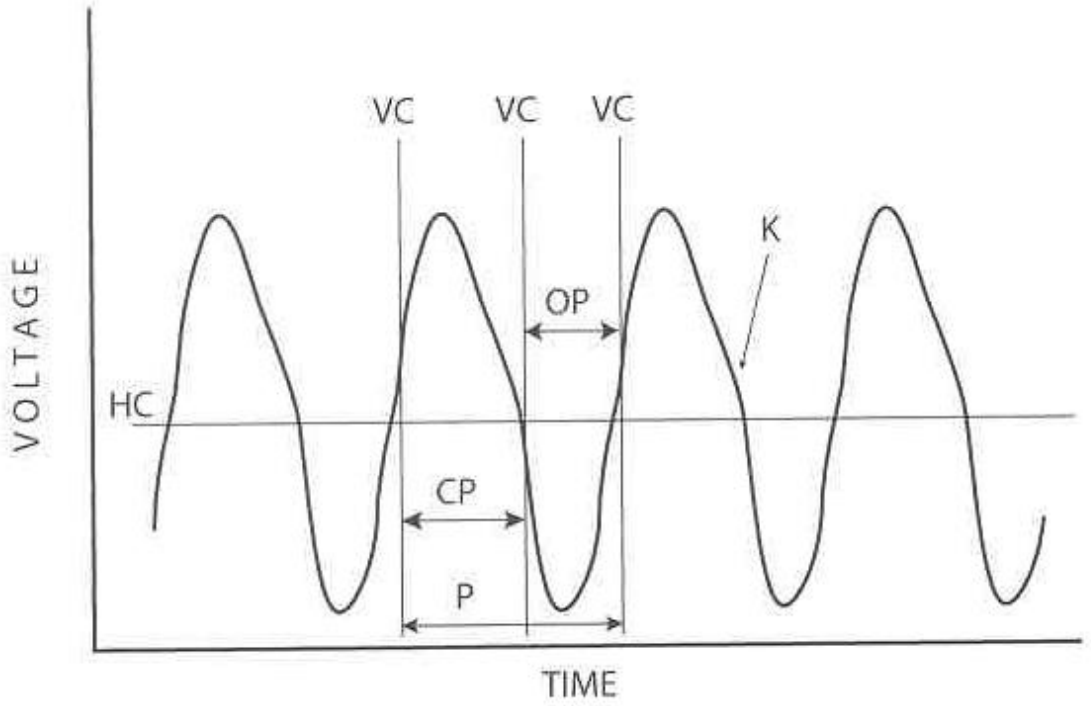


OPENING

3. Btwn *d*-*e* inferior margins separate

4. At *e* (“knee”) – superior begins to open

5. By *f*, width of glottis is widest



P = period of cycle
HC = horizontal cursor
VC = vertical cursor
K = knee
OP = open phase
CP = closed phase

$$\text{Closed quotient (CQ)} = \frac{CP}{P}$$

$$\text{Closed to open ratio} = \frac{CP}{OP}$$

$$\text{Contact index (CI)} = \frac{CP\text{-}OP}{CP}$$

EGG quotients

OP – open phase

CP closed phase

CQ closed quotient = CP/P

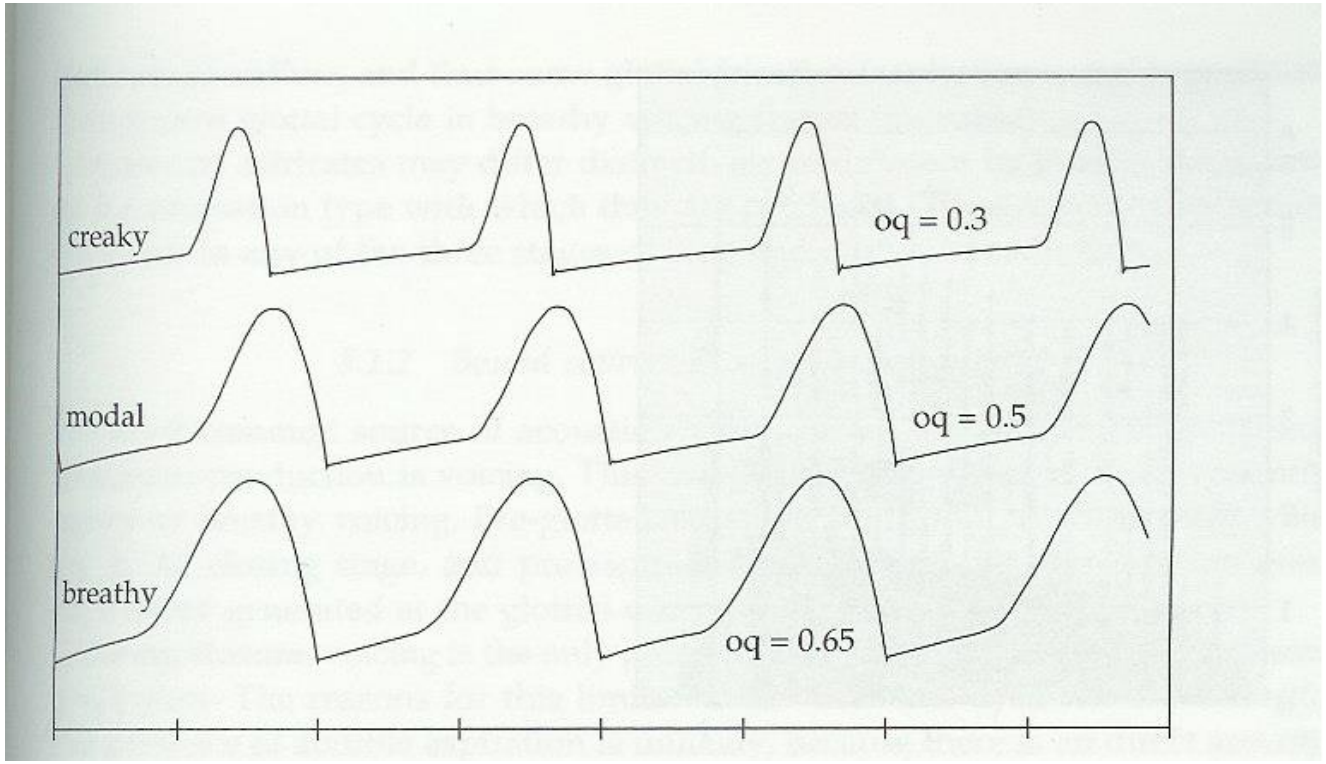
Closed to open ratio = CP/OP

Etc.

Open Quotient

$$= \frac{\text{time glottis is open}}{\text{period of voicing cycle}}$$

- Reliable differences between the three voicing types:
  - Breathy → high open quotient
  - Creaky → low open quotient
  - Modal → in-between



Open Quotient Samples

Hyper- hypo- adduction

- Hyper - Vocal abuse, spastic dysphonia; takes more Ps to overcome resistance of folds

- Hypo – inappropriate usage, VF paralysis; VFs do not offer enough resistance

Abnormal voice (dysphonia)

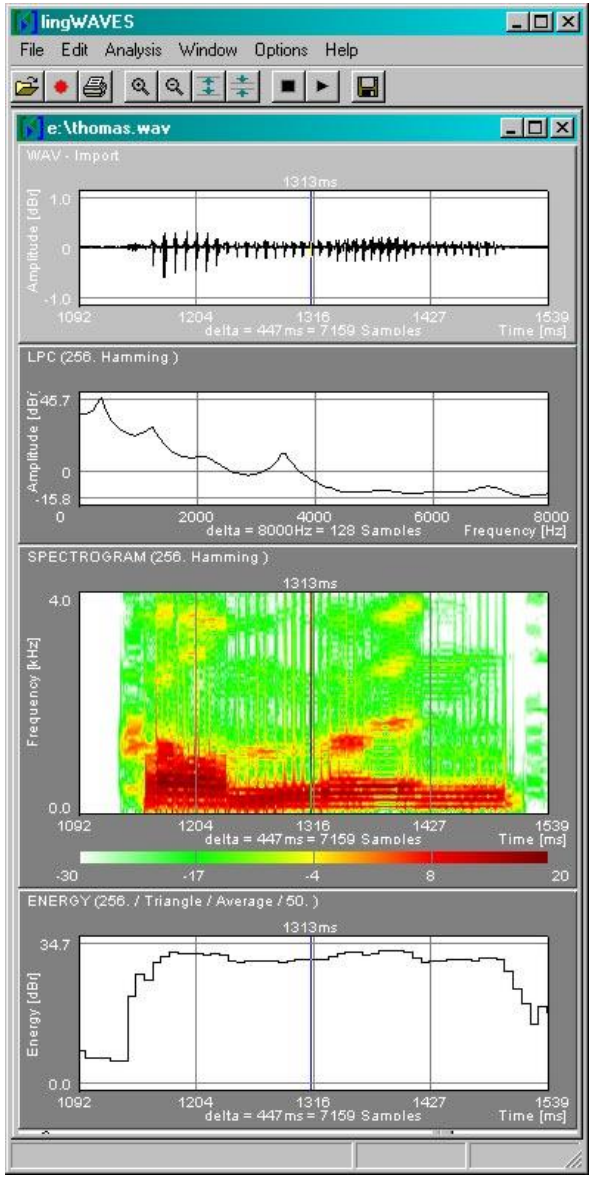
- Breathiness (aspirated)
- Roughness (raspiness /low pitch)
- Hoarseness (combination)

(Clinical) Vocal Quality

- No clear acoustic correlates
- However, clinical terms suggest distinct categories

Some common Terms

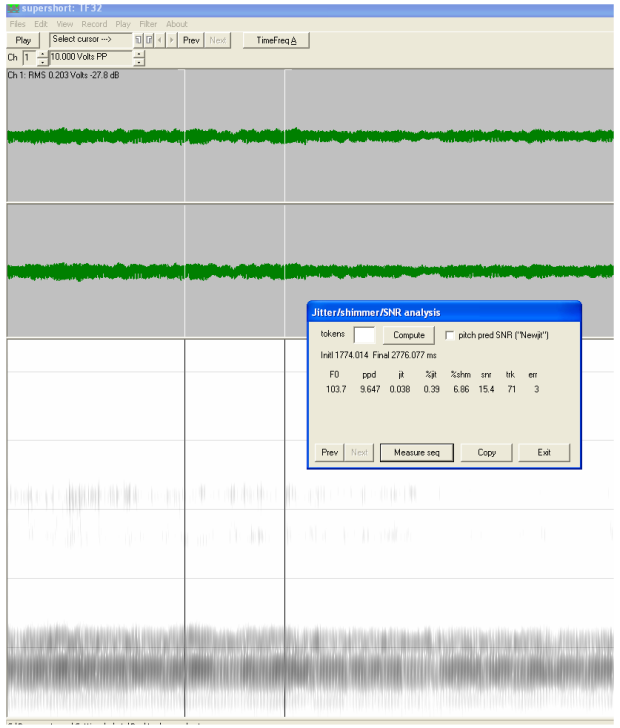
- Breathy
- Tense/strained
- Rough
- Hoarse

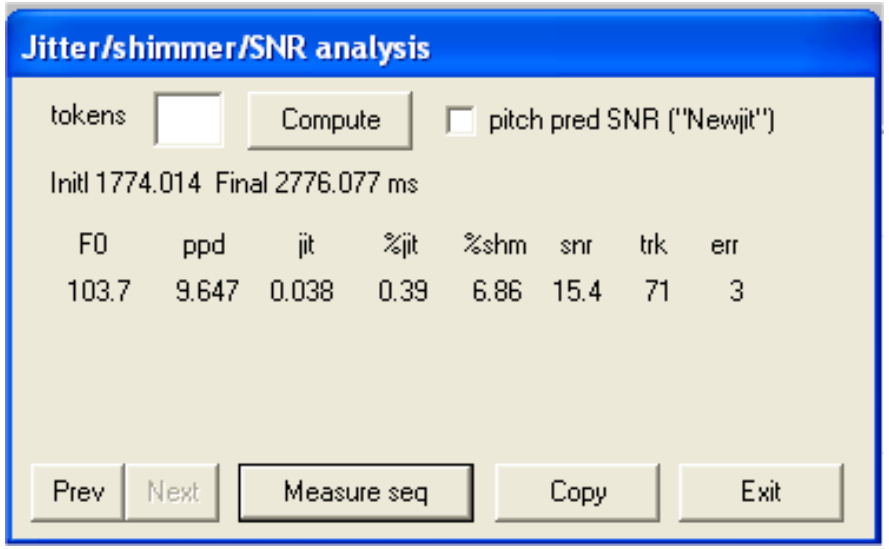


Tools for acoustic analysis

Praat, TF32, Wavesurfer
etc.

Jitter, Shimmer - Sample computing in *TF32* program

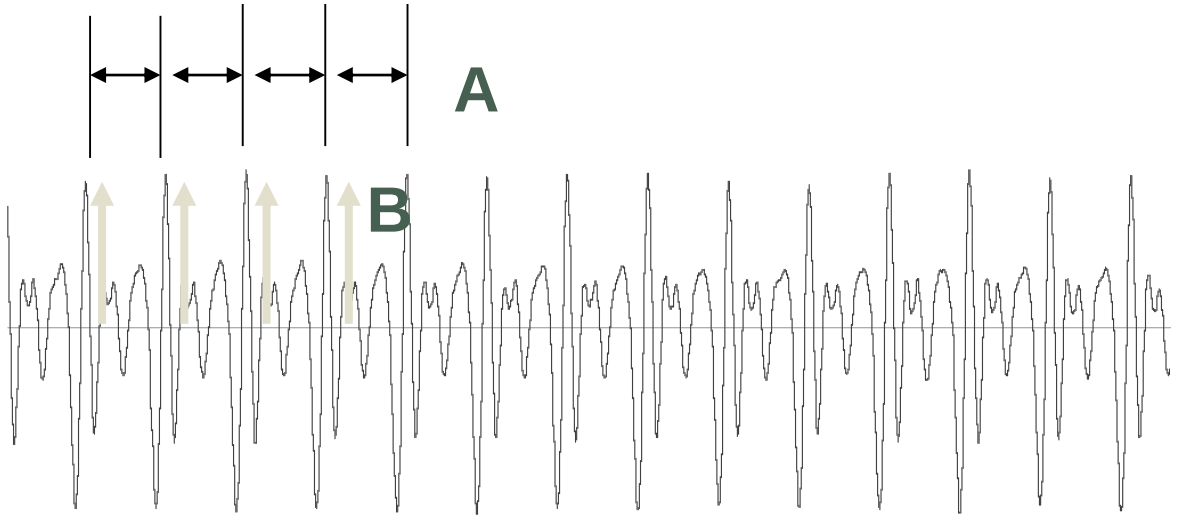




Period/frequency & amplitude variability

A. **Jitter** -: variability in the period of each successive cycle of vibration (A)

B. **Shimmer**: - variability in the amplitude of each successive cycle of vibration (B)



Jitter and Shimmer

Sources

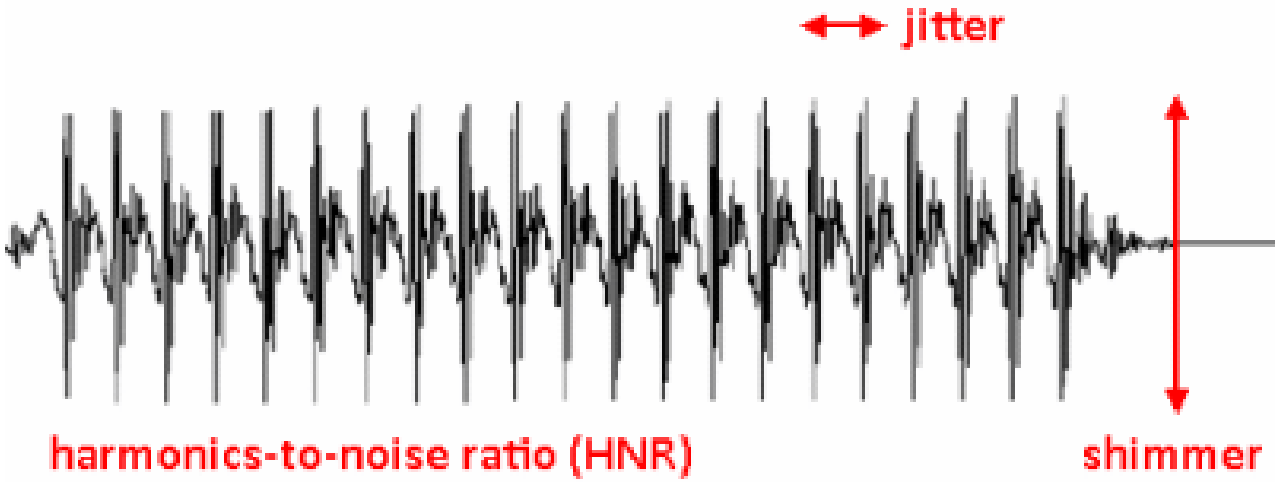
- Small structural asymmetries of vocal folds
- "Material" on the vocal folds (e.g. mucus)
- Biomechanical events, such as raising/lowering the larynx in the neck
- Small variations in tracheal pressures
- "Bodily" events – system noise

Measuring

- Variability in measurement approaches
- …and how measures are reported
- Jitter
  - Typically reported as % or msec
  - Normal ~ 0.2 - 1%
- Shimmer
  - Can be % or dB
  - Norms not well established

Harmonic to Noise Ratio (HNR)

- Noise is introduced into the vocal signal via irregular or asymmetric adduction of the vocal folds.
- Too much noise is perceived as hoarseness (= lower HNR)
- Laryngeal pathology may lead to poor adduction of the vocal folds and, therefore, increase the amount of random noise in the vocal note.



Tense/Pressed/Effortful/Strained Voice

- Sounds “effortful”

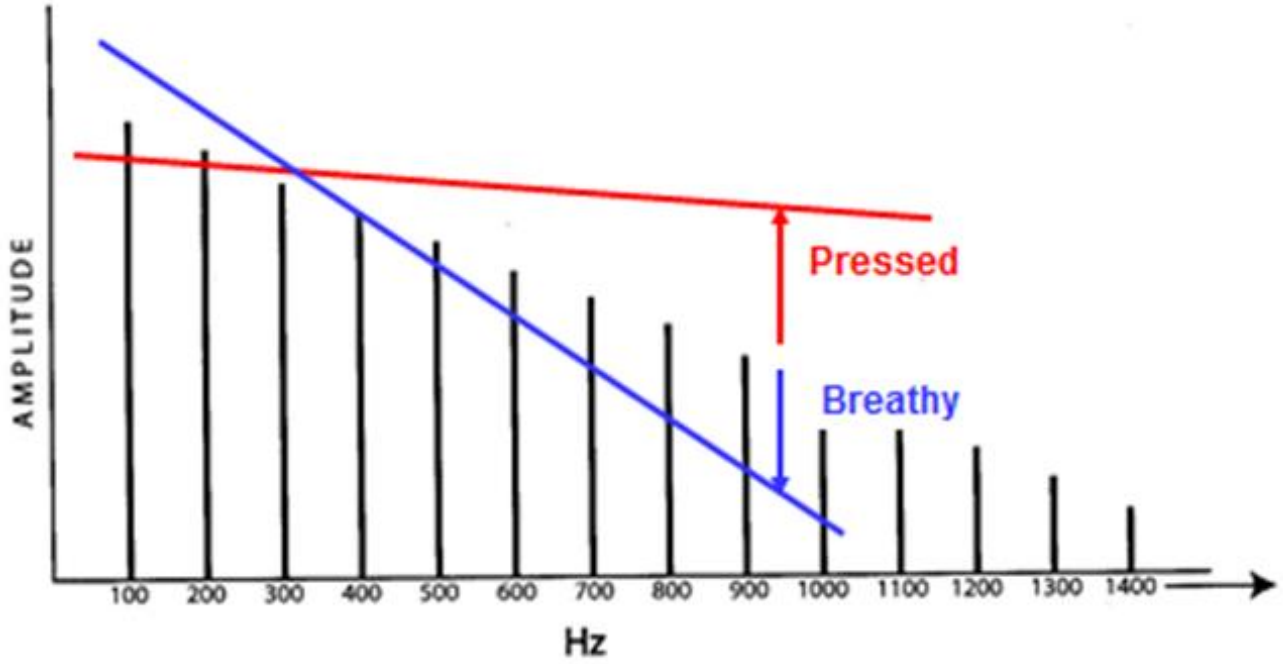
Physiologic

- Longer closed phase
- Reduced airflow

Potential Acoustics

- Change in harmonic (periodic) energy
  - Flatter harmonic roll off

Spectral Tilt



Roughness

Perceptual Description

- Perceived cycle-to-cycle variability in voice

Physiologic Factors

- Vocal folds vibrate, but in an irregular way

Potential Acoustic Consequences

- Cycle-to-cycle variations F0 and amplitude
- Elevated **jitter**
- Elevated **shimmer**

Harmonics (signal)-to-noise-ratio (SNR/HNR)

Index of BREATHINESS

↑ HNR
- Relatively more signal
- Indicative of normality

↓ HNR
- Relatively more noise (thus, disorder)

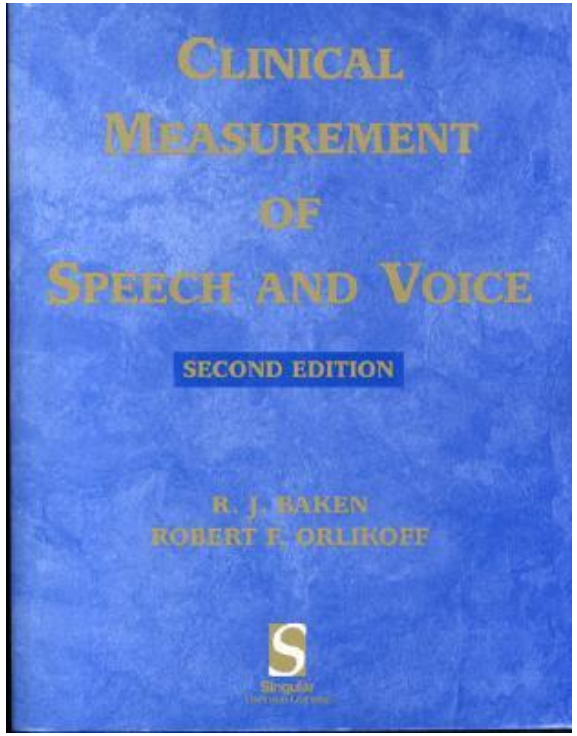
Normative values depend on method of calculation

“normal” HNR ~ 15

What are norms?

Good source:

Baken & Orlikoff (2000)



jitter:	<= 1.040 %	
shimmer:	<= 3.810 %	
HNR:	< 20	
	adult males	**adult females**
mean pitch:	128 Hz	225 Hz
minimum pitch:	85 Hz	155 Hz
maximum pitch:	196 Hz	334 Hz

Suggested Norms for *Praat*

HABITUAL PITCH (SPEAKING F_0)

- Depends on sex and age
- Affected by type of communication type, emotional state, background noise, reading aloud, talking on telephone, any intoxication (alcohol)

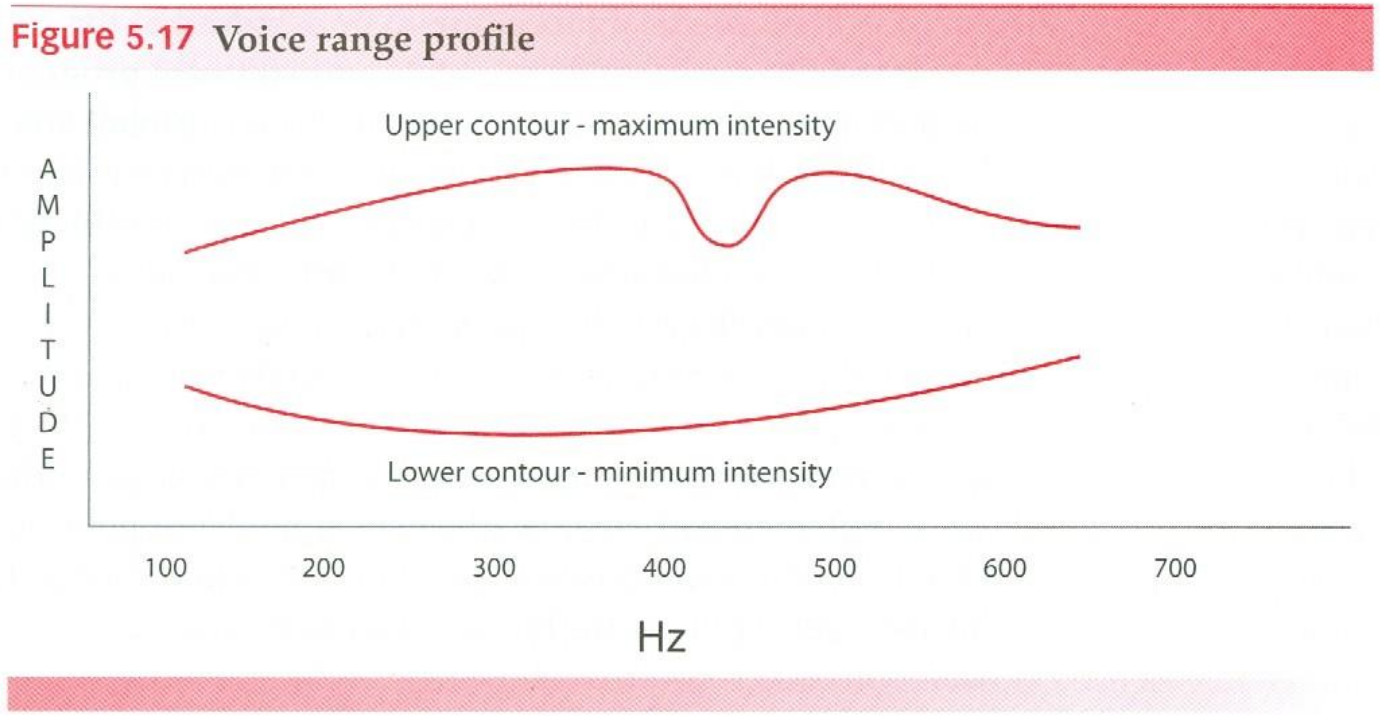
	children	women	men
Mean SF_0 (Hz)	**265**	**225**	**128**
Frequency range (Hz)	**208-440**	**155-334**	**85-196**

Table 1. Average Speaking Fundamental Frequencies [Source: (Williamson, 2006, p. 177)]

Frequency variability

- Table 5.7 (pg. 182)
- Highest for infants, generally decrease with age
- Men lower than women

Voice range profile



- Fig. 5.17 (pg. 185)
- Max phon range *(x-axis, F_0)* X dynamic range *(y-axis, dB SPL)*
- "dip" = change from modal to falsetto

CLINICAL APPLICATIONS CHAP 5

INSTRUMENTATION: EGG, REGISTER, QUOTIENTS

PATHOLOGY, INJURY, SPECIAL SURGERIES

BOTOX INJECTIONS FOR SD

Laryngeal aging

- *Presbylaryngis* starts by 3rd or 4th decade
- Can lead to *presbyphonia* (breathiness and hoarseness)
- Increased F_0 in males, decreased in females
- See table 6.5 (pg. 206) for more detail

Neurological disorders

- Amyotrophic lateral sclerosis (ALS)
- Parkinson’s disease (PD)
- Unilateral VF paresis/paralysis
- Spastic Dysphonia (SD)
- Nodules/ Muscle Tension Dysphonia (MTD)/or Gastroesophageal Reflux Disease (GERD)

Amyotrophic lateral sclerosis (ALS)

- Degenerative disease of upper & lower motor neurons
- Changes in laryngeal musculature or difficulties eliminating mucous secretions(?)
- Jitter and shimmer tend to be greater
- Perhaps diagnostic of perceptually subclinical cases

66% intelligibility
"say kite again"

Parkinson's Disease (PD)

Dopamine deficiency (excessive muscle contraction)

Voice symptoms visible

- Hoarseness
- Reduced loudness (lower intensity)
- Limited pitch range

 Male, Healthy

 Age-matched, PD

VF paralysis

http://www.youtube.com/watch?v=pcTPOmNStPI

This 15 min. video shows a range of cases

VF paresis

- Paresis
- A partially immobile vocal fold. Similar to a paralysis, except there has been some neurologic recovery.
- Note the limited motion of the right arytenoid (left side of the screen) compared with the left (right side of the screen), and the asymmetry of the mucosal wave. This has been referred to as "chasing asymmetry.“
- http://www.youtube.com/watch?v=gouMMiH6HI0

Spasmodic Dysphonia (SD)

- VF paralysis yields inability to initiate or maintain phonation; strangled voice quality
- Adductor and Abductor varieties (and subtypes)
- BOTOX injections are a new avenue of treatment (see video)

SD speech samples can be browsed here:

http://www.fauquierent.net/voicesd.htm

Botox injection video

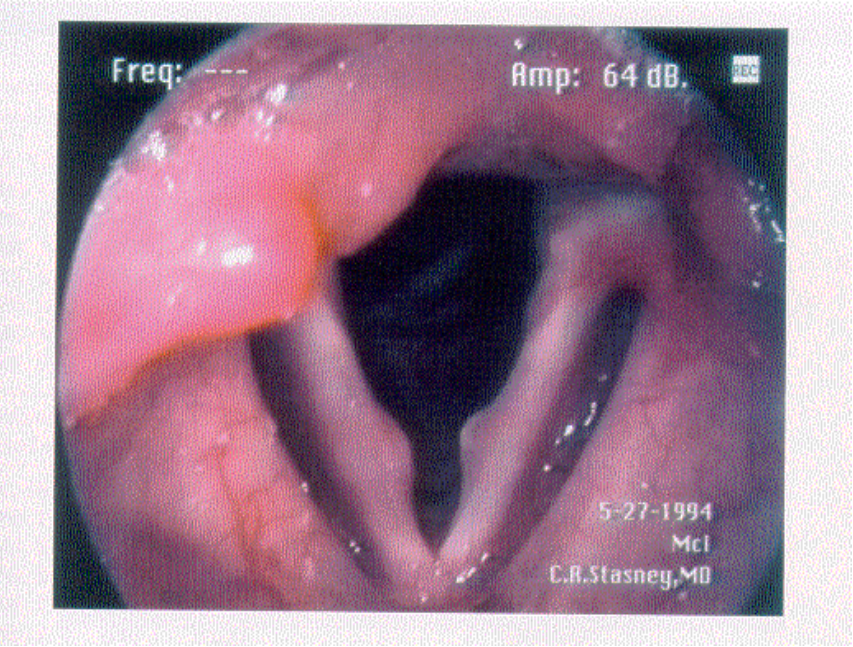
http://www.fauquierent.net/voice/misc/botoxinj.mov

MTD: Muscle Tension Dysphonia

- Compensatory or “squeeze” to make up for e.g. infection or obstruction in larynx
- Tx often consists of relaxation or anaesthesia
- http://www.fauquierent.net/voice/29aphonia/29aphonia.mov

Vocal Fold Nodules

- Typically appear on the anterior 1/3 of the vocal fold, where contact is most forceful
- Found primarily in women and preadolescent boys

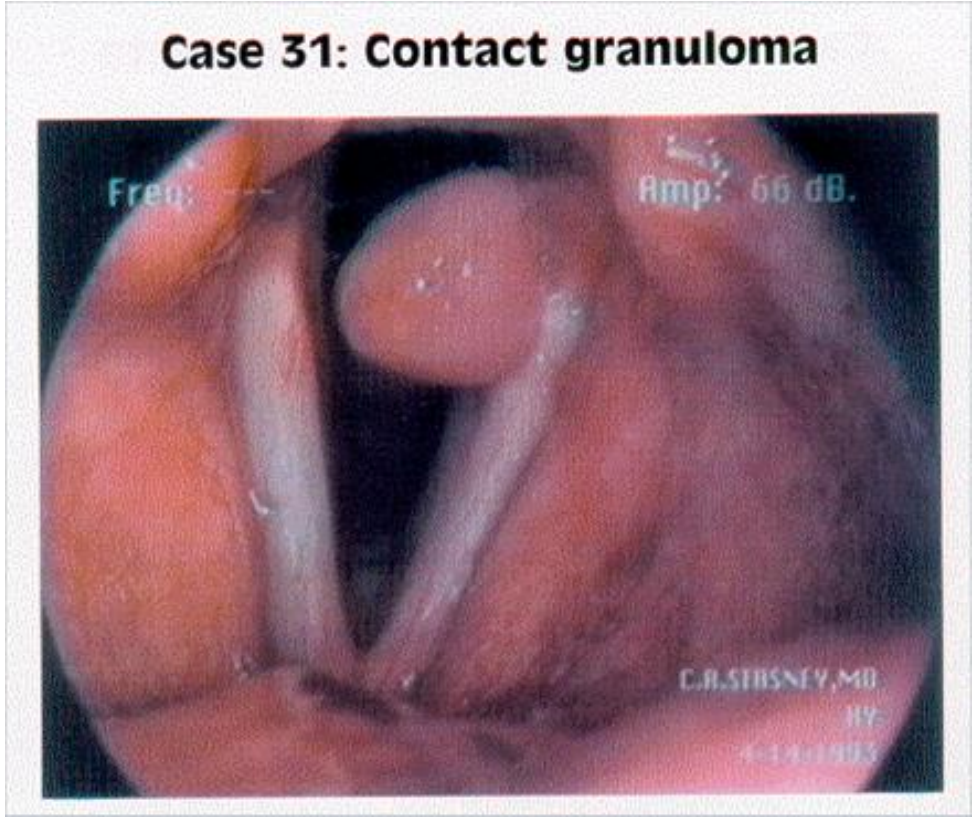


Vocal Fold Polyps

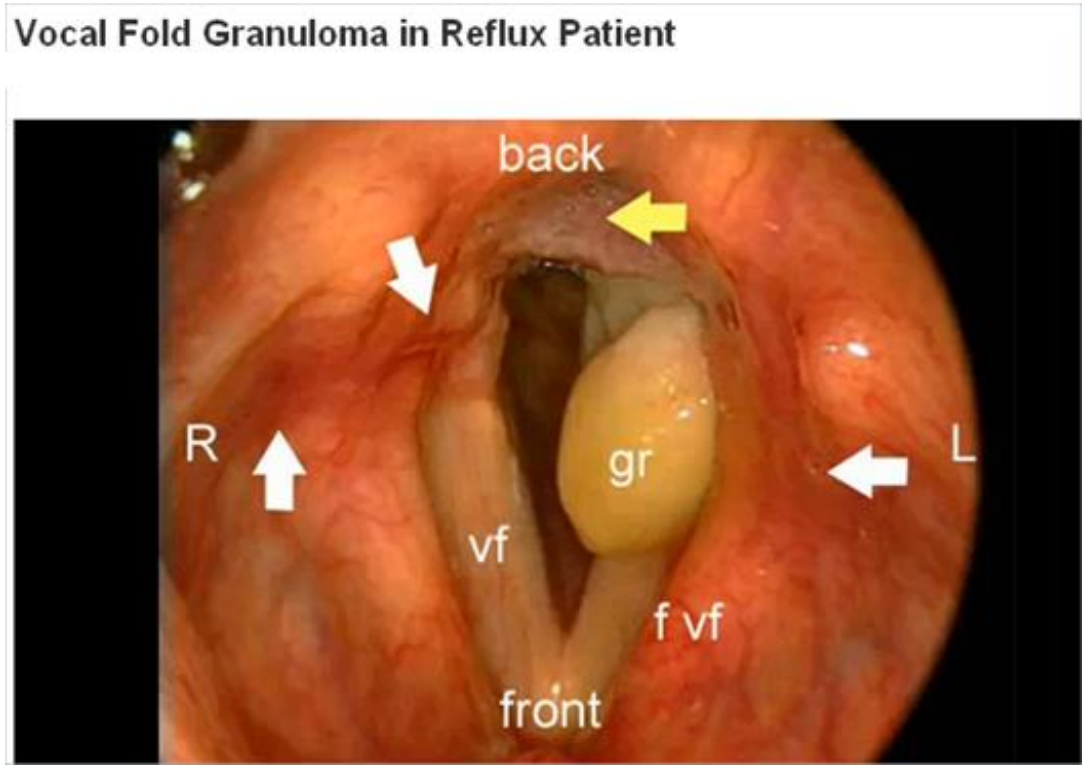
- Mass usually found at the midpoint the vocal cord.
- Result of heavy trauma ("screamer's nodule")
- Treatment: rest, steroids, or surgery

Contact Granuloma

- Result of injury
- Heaped up tissue near arytenoids
- Pinkish-white



Granuloma

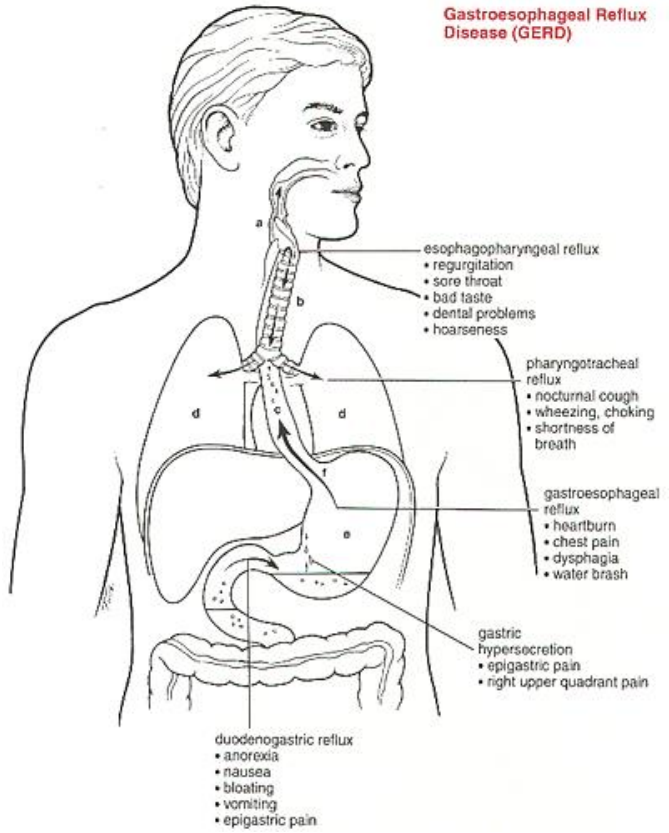


Video

Gastroesophageal Reflux Disease (GERD)

Extraordinary degree of edema following 80 episodes of LPR

(laryngopharyngeal reflux)



Laryngeal Trauma

- (Video)
- Right vocal fold detachment from the vocal process of the arytenoid cartilage.
- It appears shortened, rounded, and sited at higher level than the left on phonation.
- There is accompanying stridor.
- http://www.youtube.com/watch?v=DZFAJgB3d-Y

Stuttering

Jitter/shimmer may help identify children at risk(?)

We will cover stuttering in our *speech perception/production* unit.

→ A teaser: Choral speech

Lie Detection – via voice?

- Deceptive stress
- Detected above chance with F_0 changes, not jitter
- Many problems with this concept

Laryngeal Cancer

- Most common type of laryngeal cancer is squamous cell carcinoma
- Prominent symptom: hoarseness – changes in vibration
- Radiation, chemotherapy, surgery are treatment options

- Jitter can in some cases document chemotherapy effectiveness

Laryngeal Cancer

1) Chronic laryngitis in pt following radiation therapy for glottic carcinoma

2) A nonsmoker with severe documented LPR and squamous cell carcinoma on both true vocal folds

Scar tissue (post op)

Affects

- Aerodynamics
- Acoustics
- Vibratory patterns

In-dwelling voice prosthesis after laryngeal cancer (TEP)

Electrolarynx, Esophogeal, Tracheoesophageal voice prosthesis (TEP) - Samples

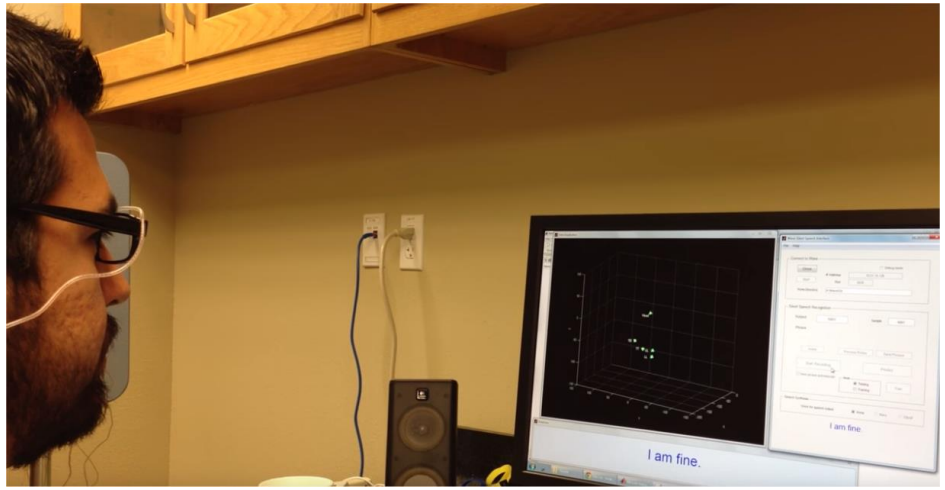
https://www.atosmedical.com/support/speaking-with-a-voice-prosthesis/

Insertion video

HME = heat/moisture exchange

Under current development: Silent speech interface (SSI)

- Jun Wang, Ph.D. (UTD)
- Subject silently articulates
- System displays text on screen
- Synthesizer ‘speaks’ in female voice



https://www.youtube.com/watch?v=23RxvetISac

Transgender issues

Counseling – speaking styles

Surgery?

Laryngoplasty

(audio samples/ before-after)