Speech Science

WiSe 2024

Respiration, Phonation, Voice Quality

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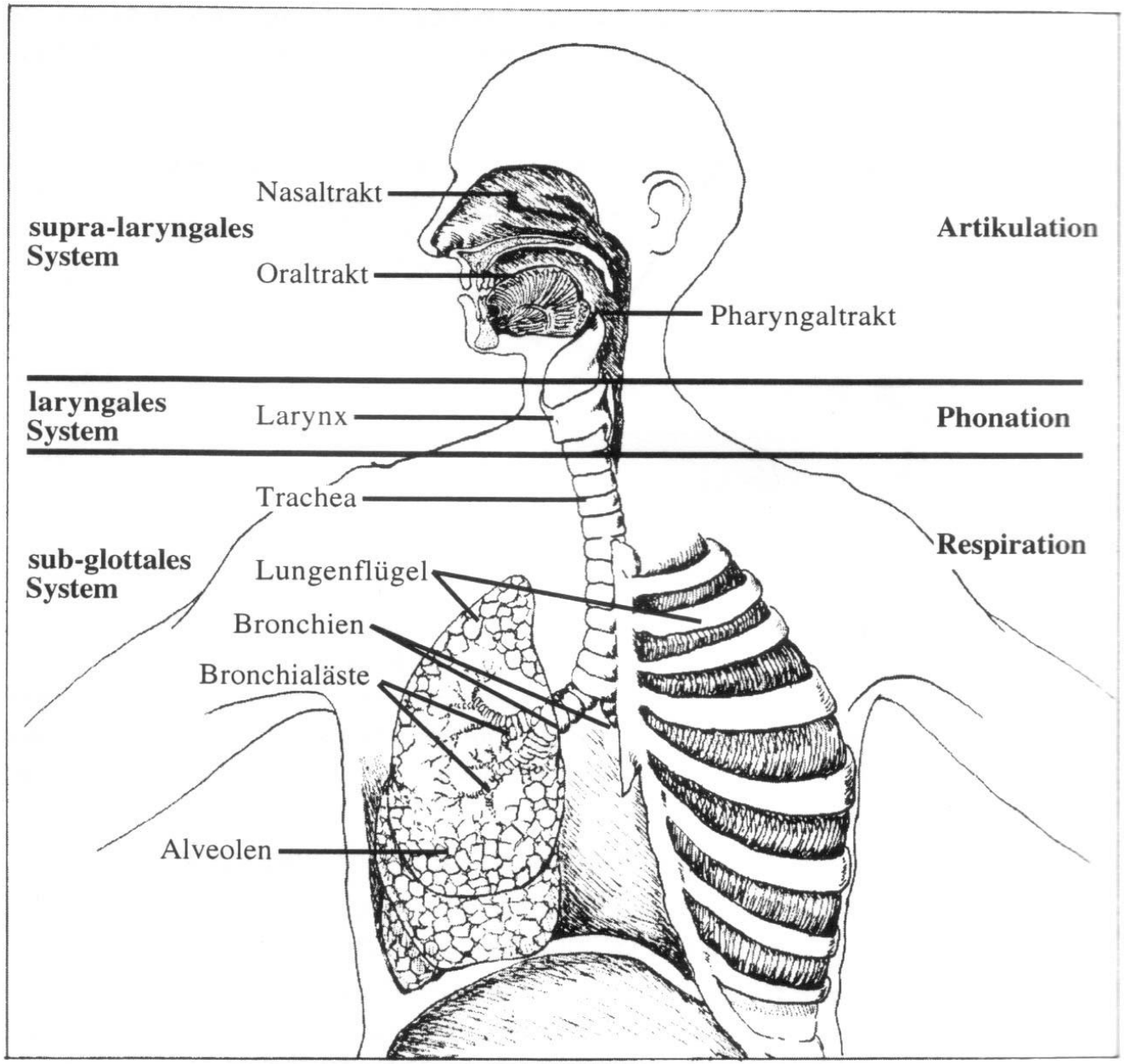
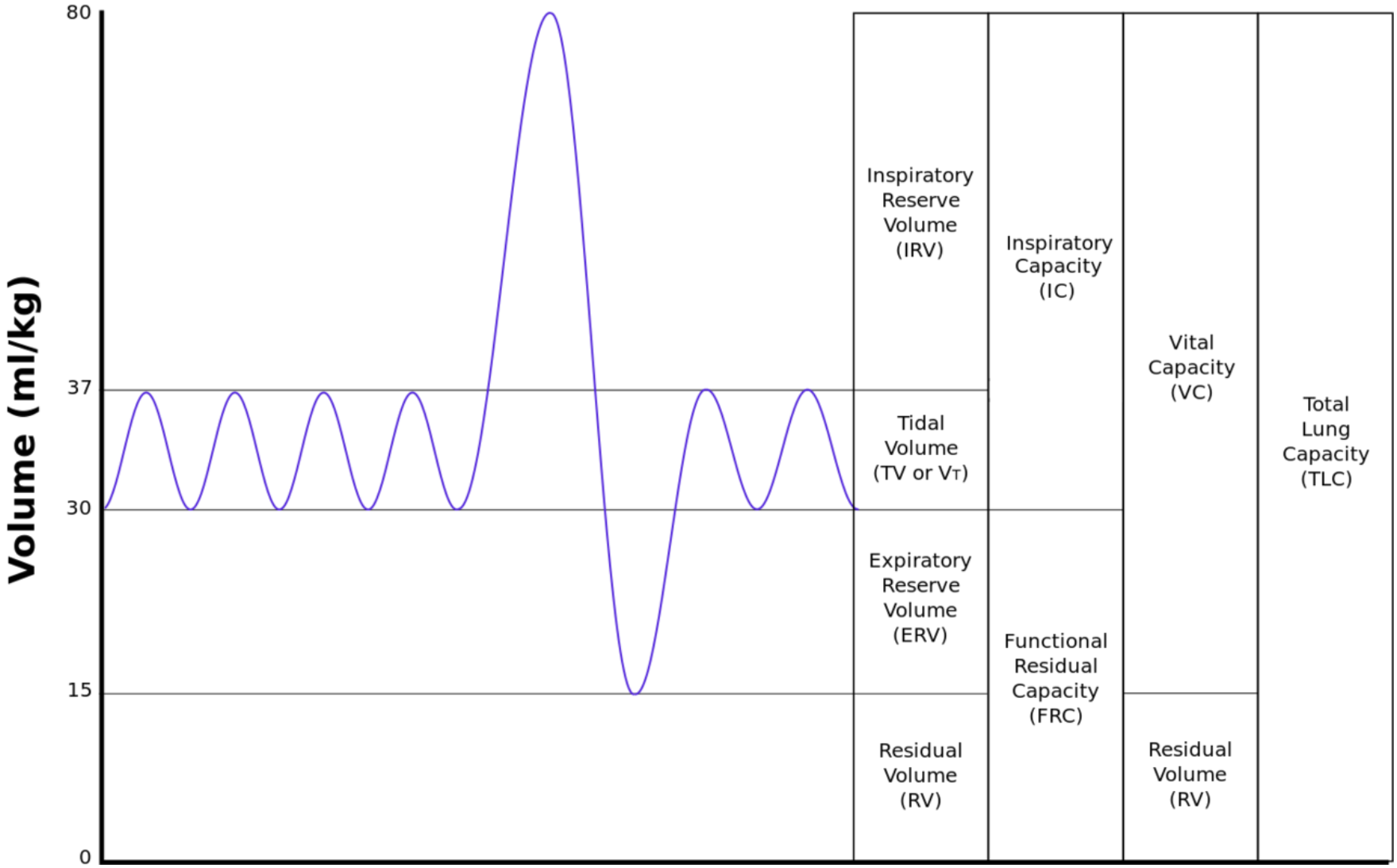
Speech production

- Functional model of speech production
  - *Respiration*, respiratory system (breathing)
  - *Phonation*, voicing produced by vocal fold vibration
  - *Articulation*, speech sound formation by means of active and passive articulators

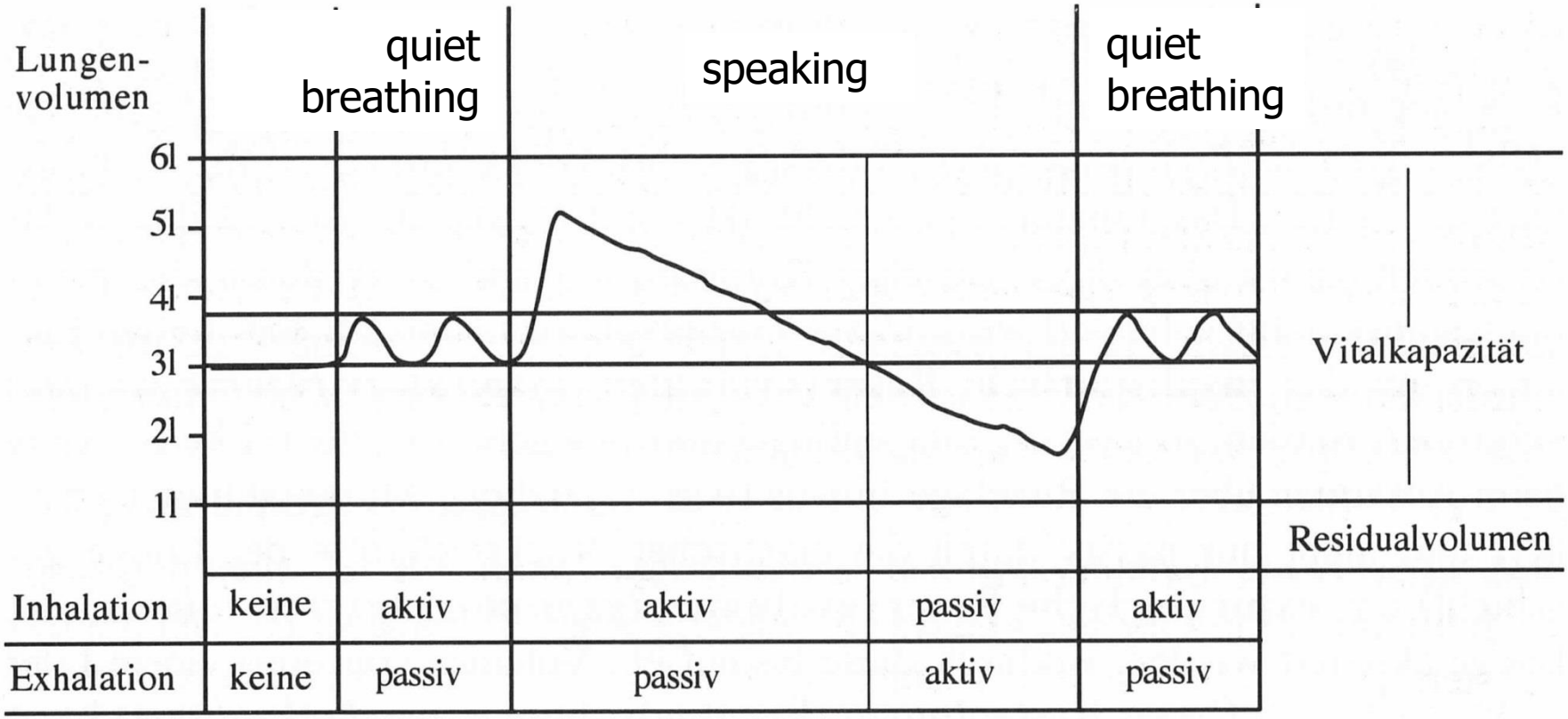
Speech production organs [Reetz 1999, p. 101]



Respiration: no air, no fun(etics)



Respiration: no air, no fun(etics) [Reetz 1999, p. 108]



quiet breathing: 40% inhale, 60% exhale
speaking: 10% inhale, 90% exhale

Respiration: no air, no fun(etics) [Clark et al. 2007, p. 176]

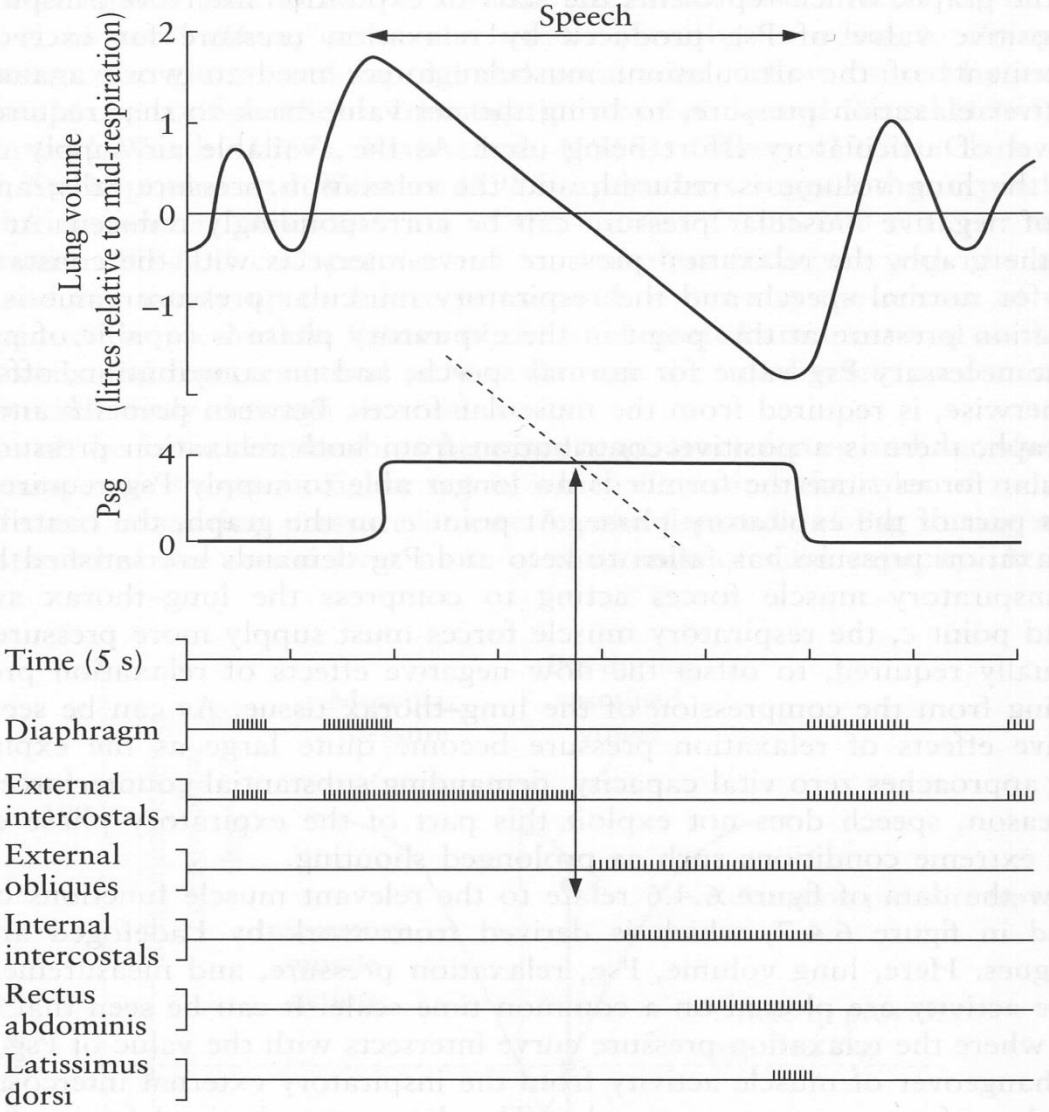


Figure 6.4.7 Respiration and associated muscle activity during speech
Adapted from: Ladefoged 1967, p. 12.

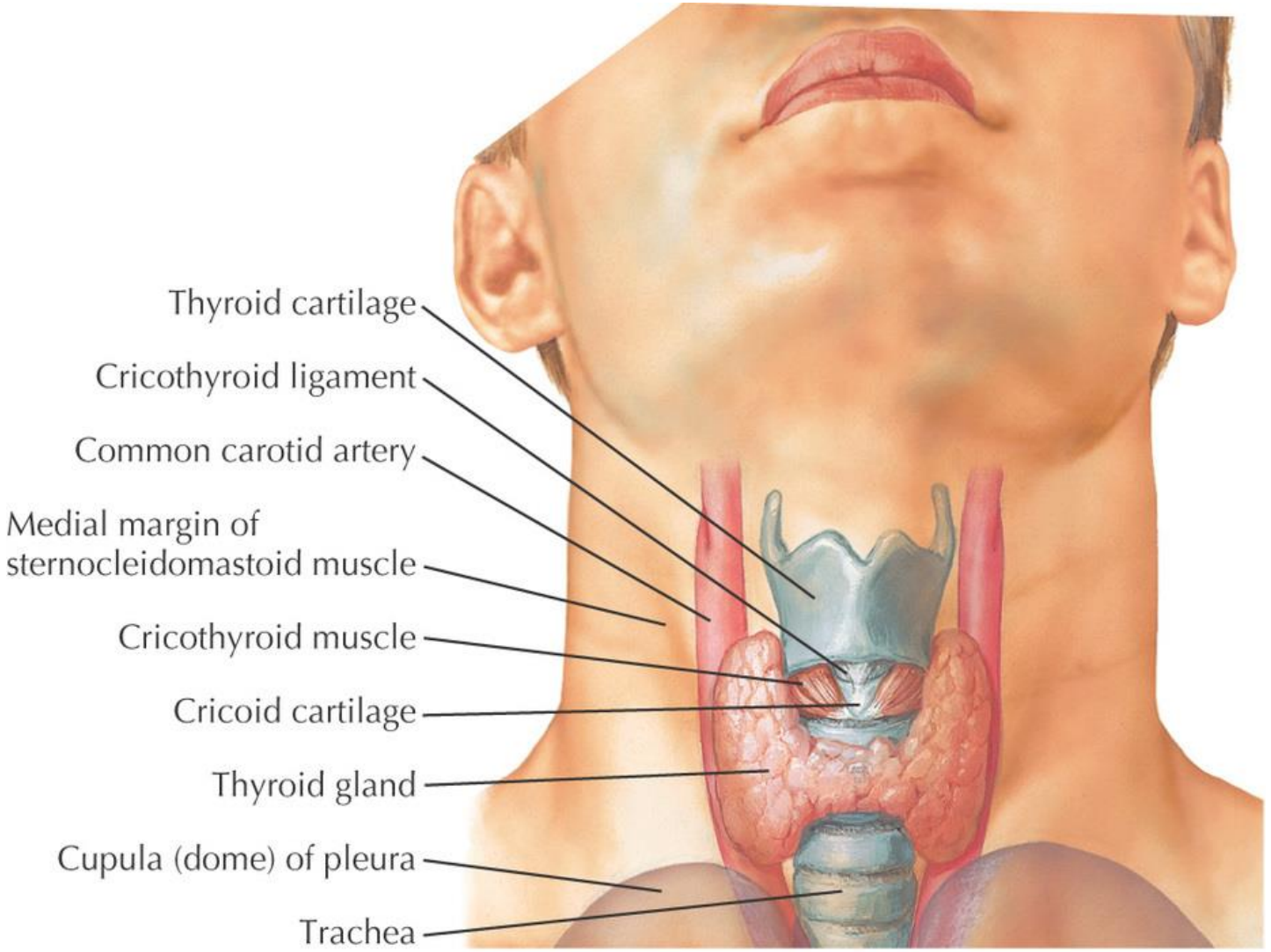
Airstream mechanisms

- Airstream: origin and direction
  - pulmonic airstream, by means of lung activity
    - egressive: most speech sounds
    - ingressive: paralinguistic functions only
  - glottal airstream, by means of laryngeal activity
    - egressive: ejectives; closed glottis, raised larynx
    - ingressive: implosives; closed glottis, lowered larynx
  - velic airstream, by means of velic closure
    - egressive: pops; attested only with paralinguistic function
    - ingressive: clicks; linguistic and paralinguistic functions
  - (what is: egressive-esophageal?)

Phonation

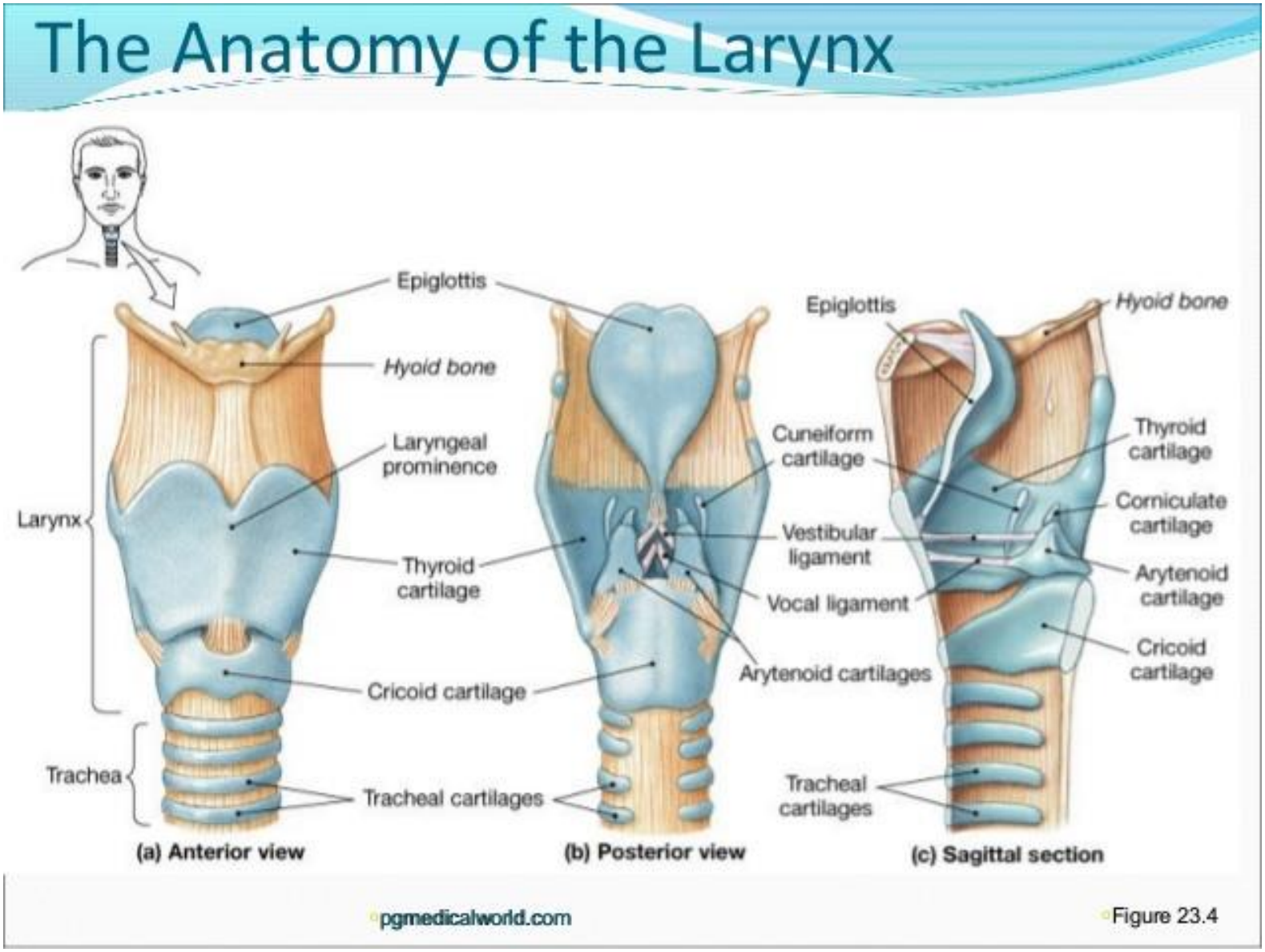
- Phonation
  - production of quasi-periodic excitation signal by means of (regular) vocal fold vibration
  - based on egressive pulmonic airstream
- Voiced vs. voiceless speech sounds
  - speech sounds produced with vs. without vocal fold vibration
- Fundamental frequency (F_0)
  - rate or frequency of vocal fold vibration
    - measured in Hz (number of vibrations per second)
    - perceived as pitch

Larynx (1)



F. Netter M.D.

Larynx (2)

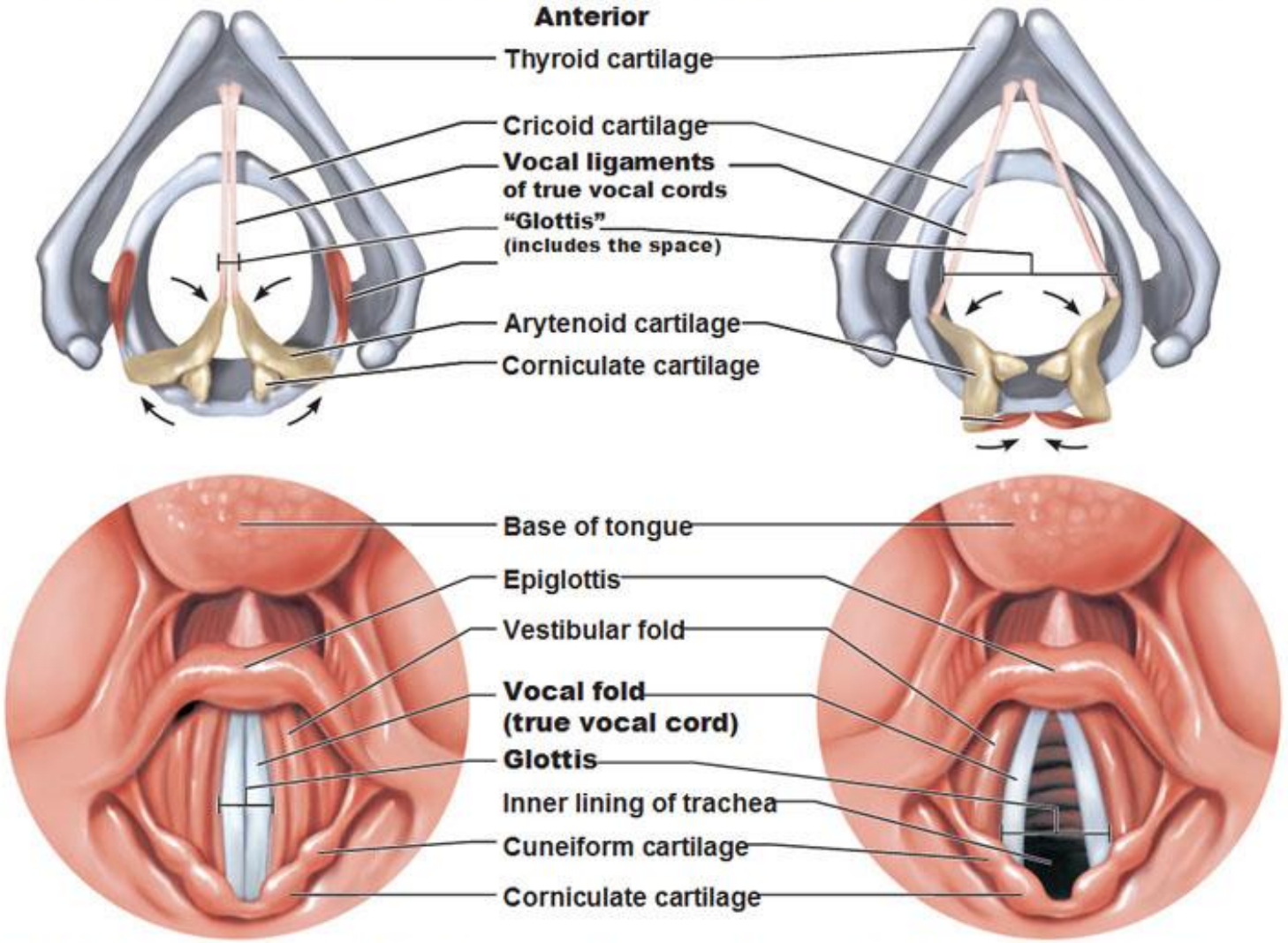


Larynx: structure

- Larynx comprises 5 cartilages
  - flexible position w.r.t. each other
  - held together by membranous tissue
- Cricoid (Ringknorpel)
  - lowest component of larynx
  - cartilaginous part of trachea (windpipe)
- Thyroid (Schildknorpel), pair of cartilages
  - pair of cartilages connecting at the front ("Adam's apple")
  - protects vocal folds from external physical impact from front
  - controls vocal fold tension by tilting w.r.t. cricoid
- Arytenoid (Stellknorpel), pair of cartilages
  - move w.r.t. cricoid by sliding and rotation
  - controls position (adducted vs. abducted) of vocal folds

Variable glottis area

True Vocal Cords (= “Folds” or “Ligaments”)



(a) Vocal folds in closed position; closed glottis

(b) Vocal folds in open position; open glottis

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Vocal folds

- Vocal folds
  - pair of ligaments, attached at inferior edge of thyroid angle and at anterior part of arytenoid cartilages
- Glottis
  - opening between vocal folds
  - length of glottis edges: males 17-22 mm, females 11-16 mm
- Intrinsic larynx muscles
  - between laryngeal cartilages
  - control abduction (opening), adduction (closing), and tension of vocal folds
- Extrinsic larynx muscles
  - control overall (mainly vertical) movement of larynx

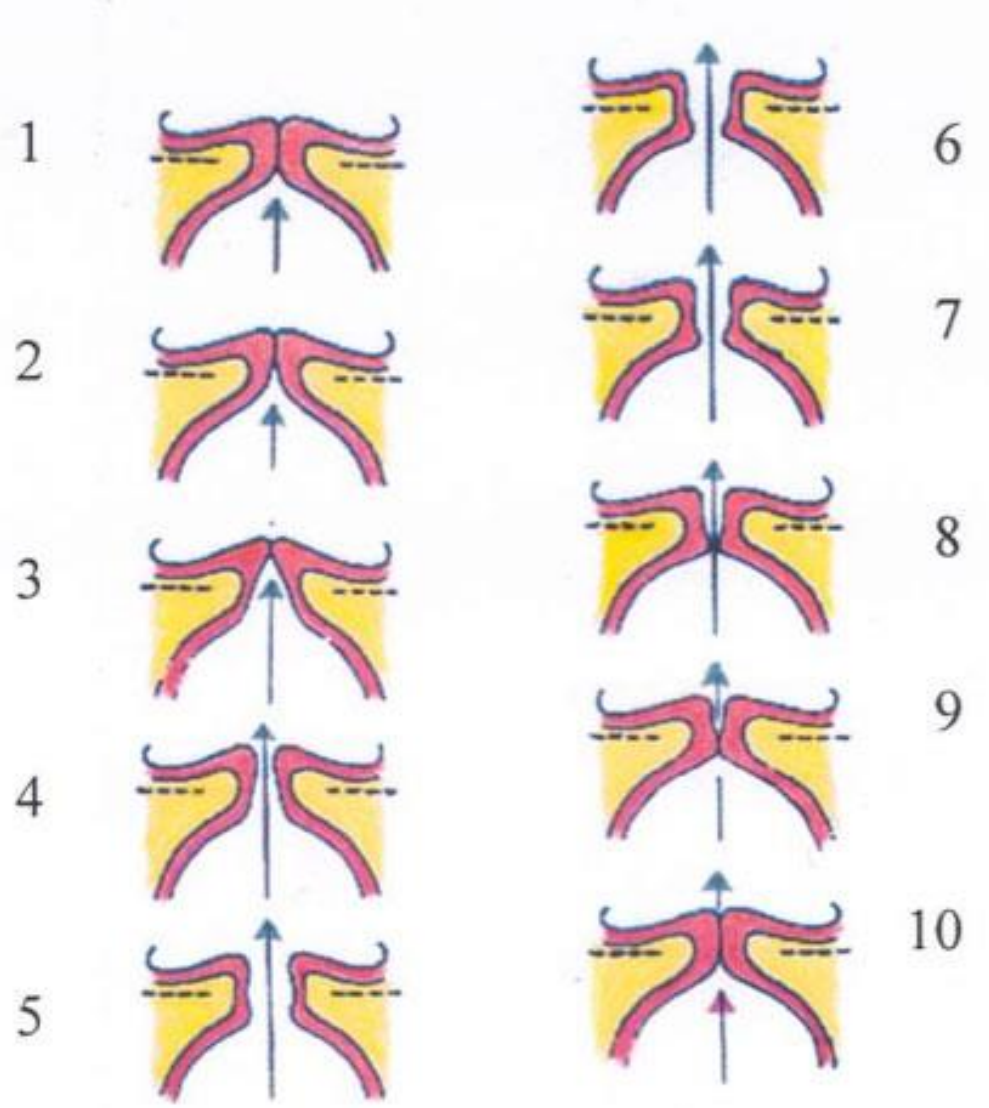
Video demos

- Structure of the larynx
  - https://www.youtube.com/watch?v=b89RSYCaUBo
- Phonation
  - https://www.youtube.com/watch?v=Aoa_N1vQS4M
- Video stroboscopy of vocal fold vibration
  - https://www.youtube.com/watch?v=mJedwz_r2Pc

Aerodynamic-myoelastic theory

- Aerodynamic-myoelastic theory of phonation [van den Berg 1958]
  - glottis closed, expiration airstream builds up subglottal pressure
  - vocal folds opening, speeded airflow through glottis
  - pressure drop (Bernoulli effect)
  - pressure reduction sucks vocal folds together
  - process assisted by elasticity of vocal folds
  - production of voicing by (quasi-)periodic train of air pulses

Glottal vibration cycle



closed phase: 1–3, 8–10

open phase: 4–7

Phonation – acoustics - perception

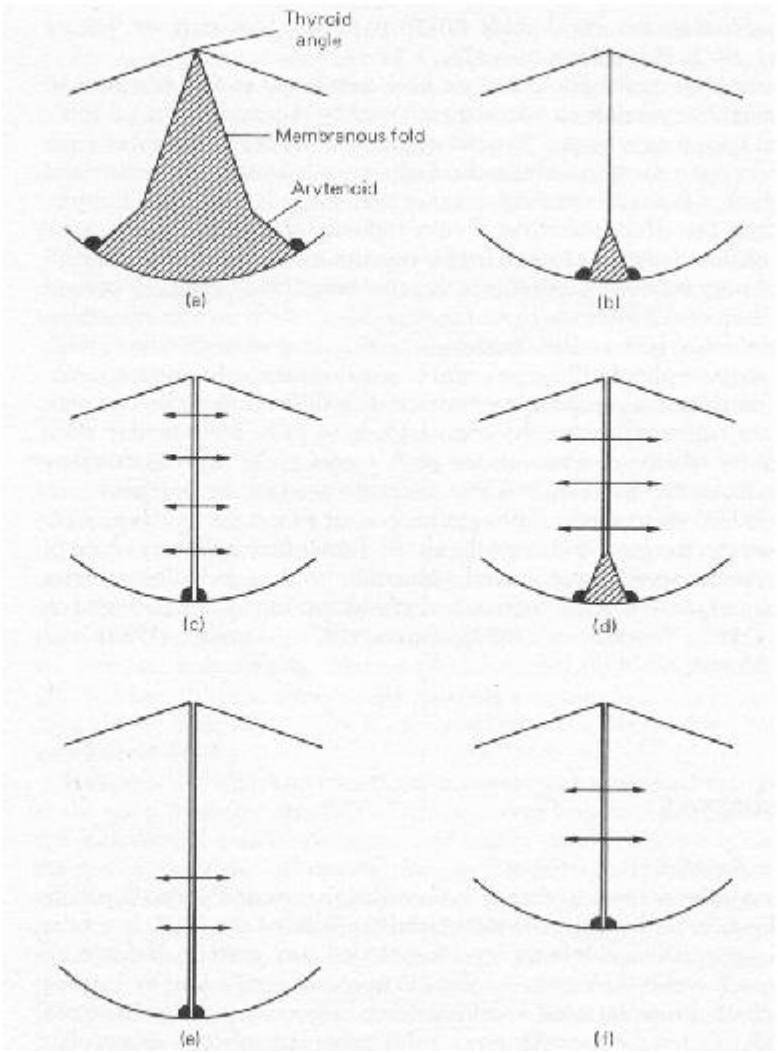
- Phonation → acoustics
  - F0 = lowest frequency component of a complex periodic signal
  - speech signal results from shaping, or filtering, the excitation signal by varying the geometry of the vocal tract
- Phonation → perception
  - rate of vocal fold vibration → perceived pitch
  - subglottal pressure → perceived loudness
  - phonation type → perceived voice quality

Phonation types and voice qualities

- **Modal voice (modal)**: normal speaking voice without noisy components, regular vocal fold vibrations along entire length of folds
- **Breathy voice (behaucht)**: voice with soft noise components, moderate vocal fold tension, glottis never completely closed
- **Creaky voice (knarrend)**: low voice without noise components, small front opening of vocal folds, irregular vocal fold vibration
- **Rough voice (rau)**: high vocal fold tension
- **Falsetto voice (falsetto)**: high adductive vocal fold tension, narrowing of vocal folds, reduced vibrating mass, high frequency
- **Whisper (flüsternd)**: strong frication without phonation, moderate vocal fold tension, open "whisper triangle" between arytenoids
- **Voicelessness (stimmlos)**: no glottal voice source, glottis wide open along entire length of vocal folds

Phonation types and voice qualities

(a) voicelessness



(b) whisper

(c) modal voice

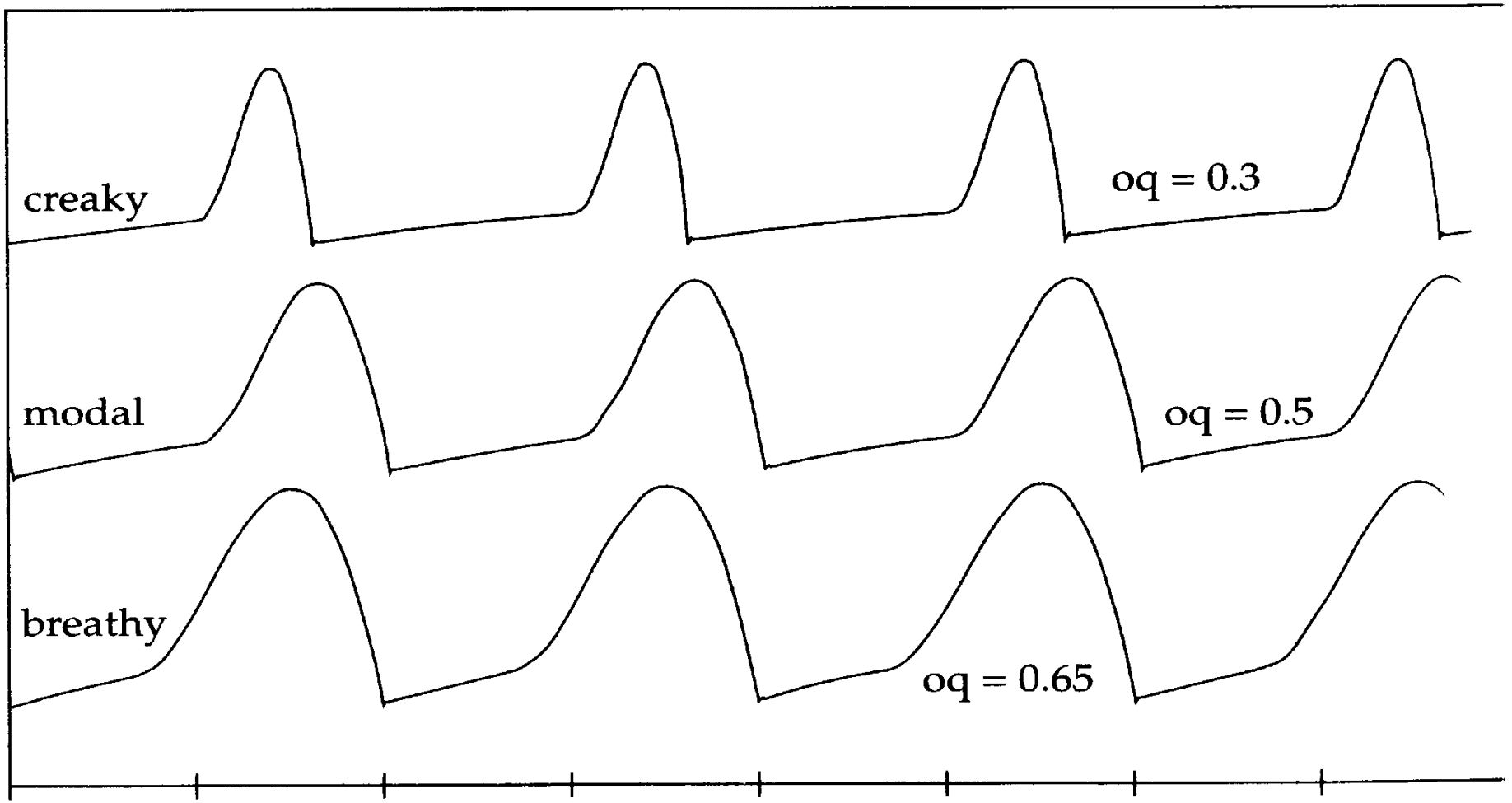
(d) murmur

(e) falsetto

(f) creak

Glottal excitation signal

- Lx signal, recorded by electroglottography (EGG, laryngograph)



Laryngograph (Electroglottograph)

Laryngealization

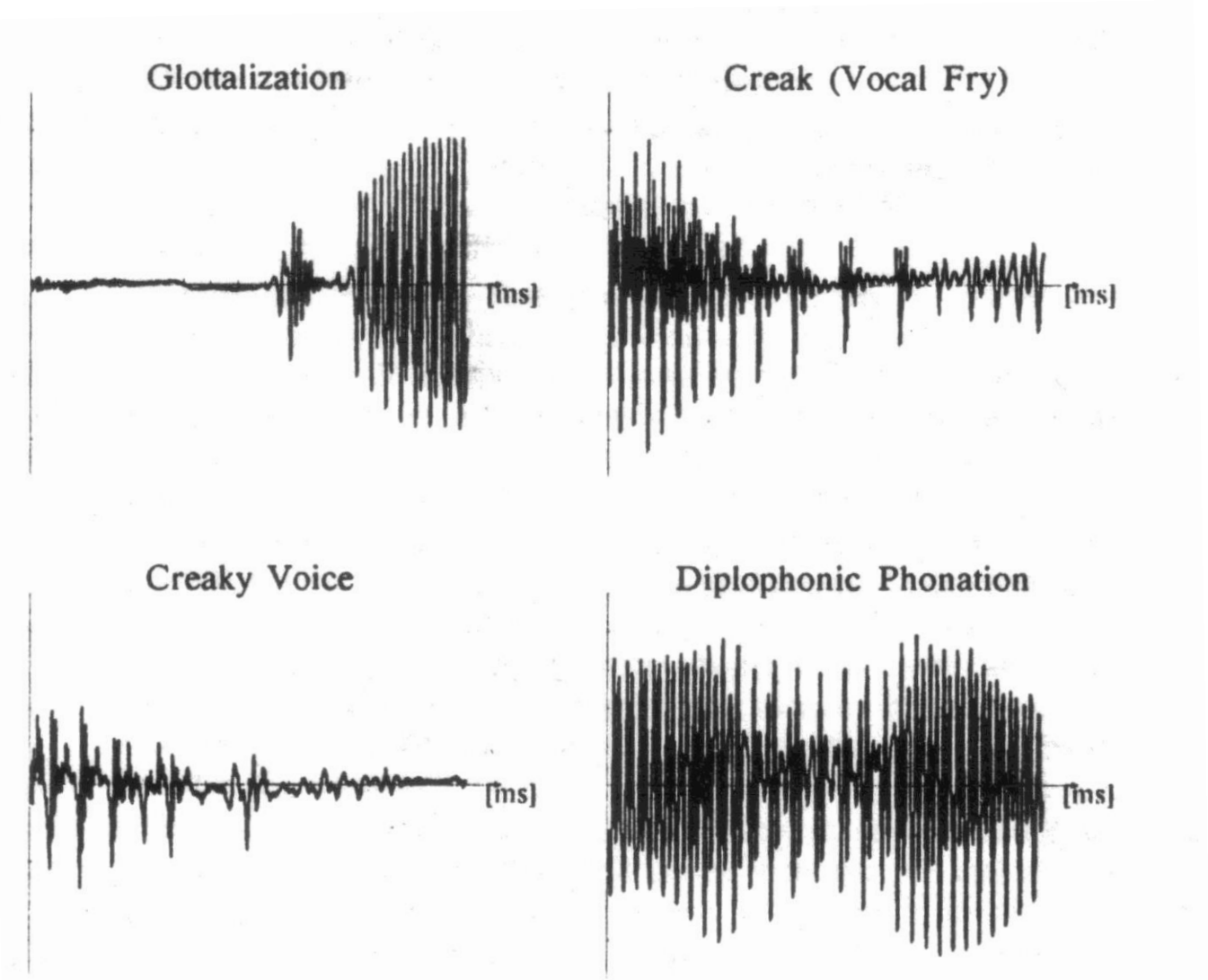


Figure 1 Patterns of aperiodic glottal vibration

References

- John Clark, Colin Yallop, Janet Fletcher (2007): An Introduction to Phonetics and Phonology. Blackwell.
- Peter Ladefoged (1967): Three Areas of Experimental Phonetics. Oxford University Press.
- Henning Reetz (1999): Artikulatorische und akustische Phonetik. Wissenschaftlicher Verlag, Trier.
- Janwillem van den Berg (1958): "Myoelastic-aerodynamic theory of voice production". Journal of Speech and Hearing Research 1, 227-244.
- Hartwig Eckert, John Laver (1994): Menschen und ihre Stimmen. Beltz PVU. [demos on accompanying Audio CD]
- John Laver (2009): The Phonetic Description of Voice Qualities. Cambridge University Press.

Thanks!