

Biomechanics of Voice

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Goals:

- To offer medical professionals a review of the function of the vocal mechanism as a complex system of systems
- To present practical applications of this information as it might pertain to the performing artist in a clinical environment
- To inform medical scientists where performers may not be scientifically accurate in the ideas and models that they work with

Topics of Discussion

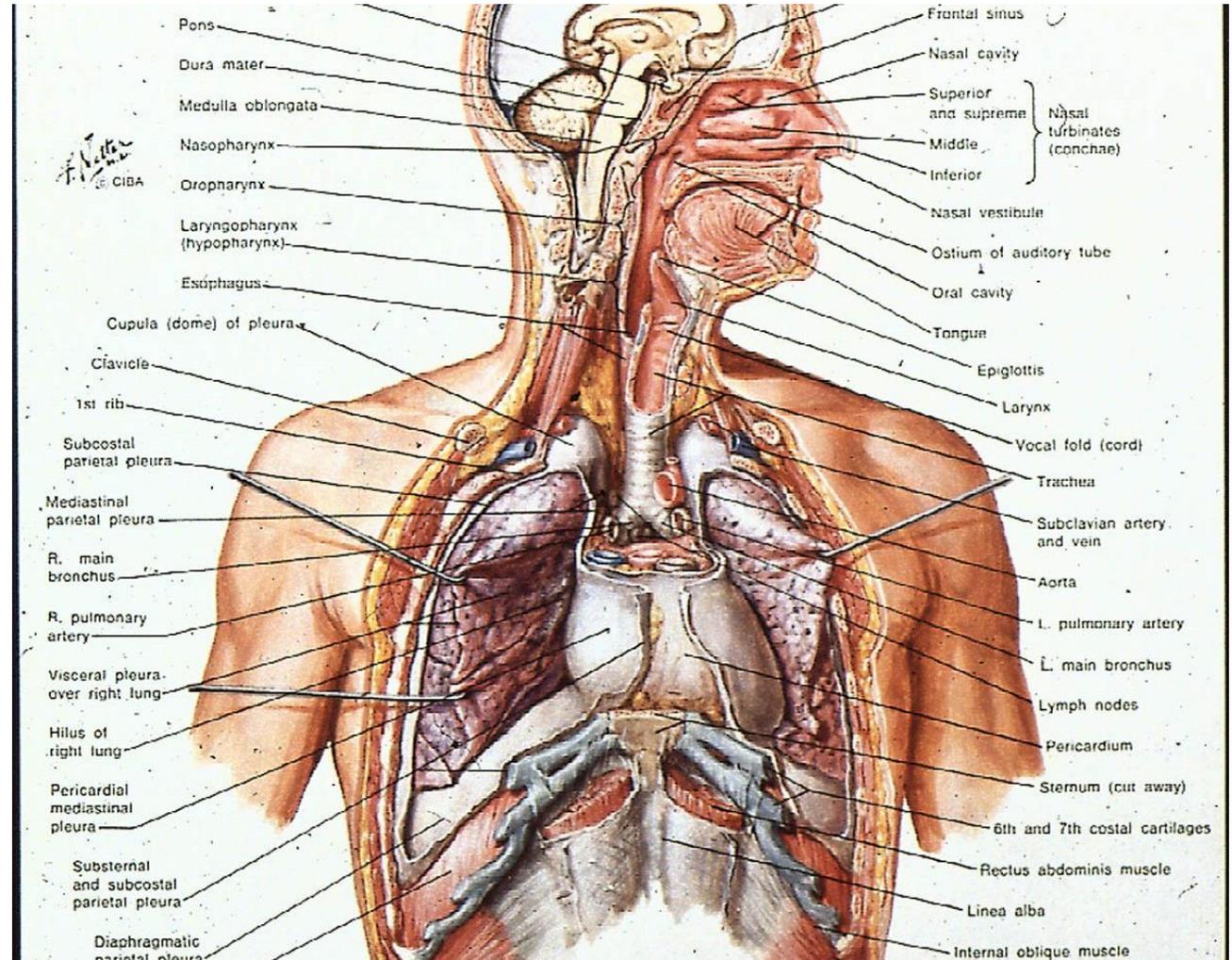
- I. Respiration and ‘support’
- II. Phonation
- III. Vocal tract acoustics

I. Respiration

- A ‘natural’ process that singers must develop into a ‘supernatural’ skill
- Respiration is a key focus in many teaching methods
- Singers rely upon their own sensations and what they have been taught about respiration
- These ideas are often flawed and not based upon even a basic understanding of respiratory physiology

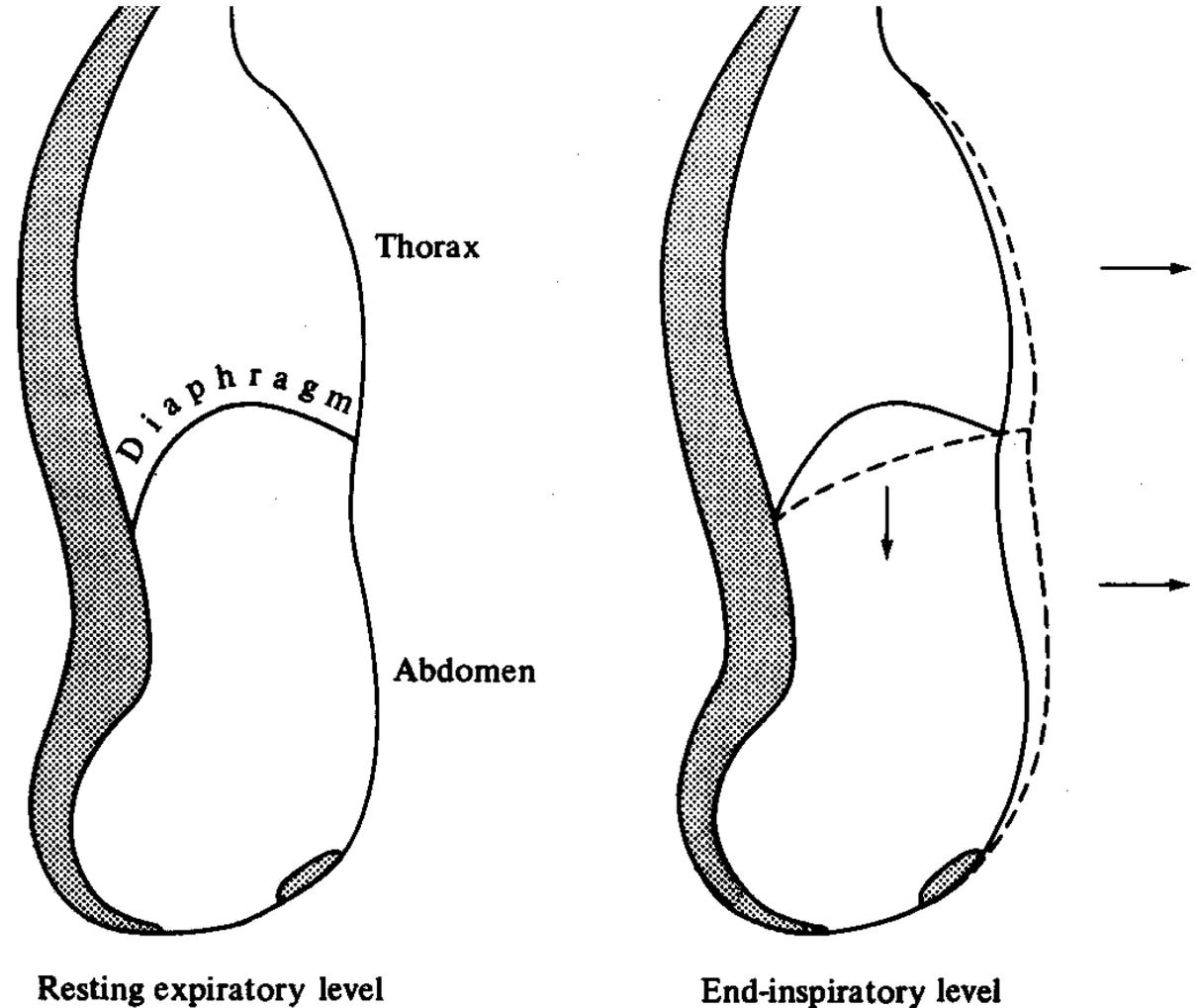
Respiratory Physiology

- Gross anatomy well-understood for many years
- Basic physiology too
- Singers often resist these facts, preferring traditional fantasies



Biomechanics of: Respiration

- Boyle's Law: $PV = \text{constant}$
- Muscles of the thorax/abdominal wall produce a change in volume = change in pressure
- Changes of pressure produce flow in and out of the system
- Chest wall, diaphragm, abdominal wall are 'moveable walls'



Biomechanics of: Respiration

- Respiration depends upon both ‘active’ and ‘passive’ forces
 - Active – requires a muscle to do work
 - Passive – comes from physical properties of tissue and gravity

Inspiration: Active

- Volume of the thorax is increased by the descent of the diaphragm and the lift of the ribs by the external intercostals and other accessory muscles inserting onto the rib cage from the spine
- Pressure in the lungs decreases
- Air flows in through the vocal tract to equalize the pressure

Expiration: Active

- Requires a muscular action
- Primary muscles are of the abdominal wall/internal intercostals with other accessory muscles which depress the thorax
- Abs reposition the diaphragm by increasing pressure in abd. cavity
- Inter. intercostals depress ribs
- Both decrease volume and increase pressure in thorax
- Produces airflow through the larynx

Expiration: Passive

- Gravity
- Elasticity
- Torque
- Not typically used for singing

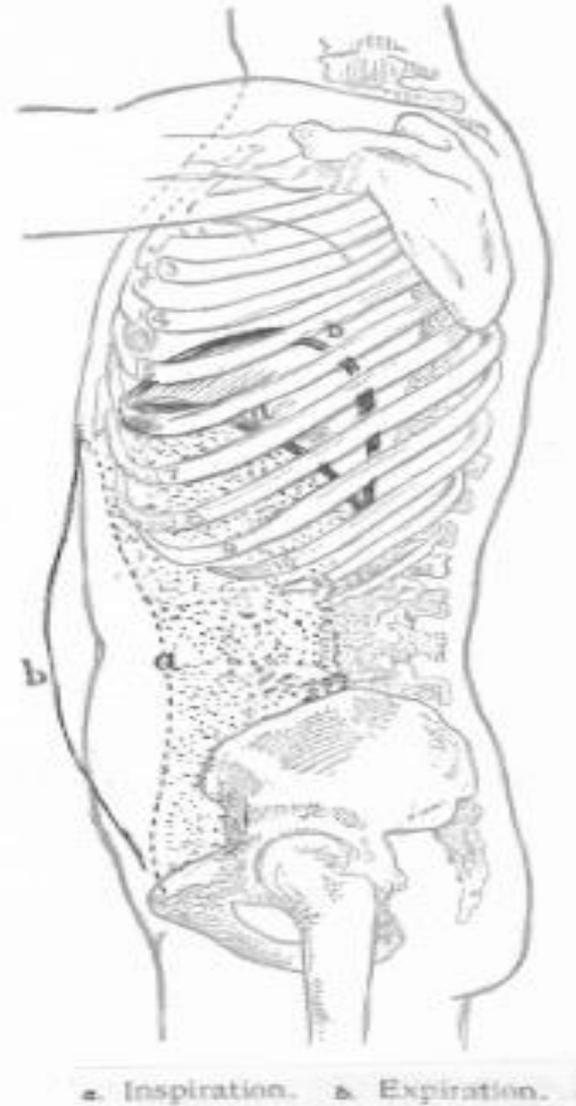
Methods of ‘support’

- ‘In and up’
- ‘Down and out’
- ‘Appoggio’
- ‘Back breathing’
- Lower focus – ‘squeeze the dime’, ‘psoaz’
- ‘Reptilian’ – through the skin!

1. Diagram of the Action of the Diaphragm

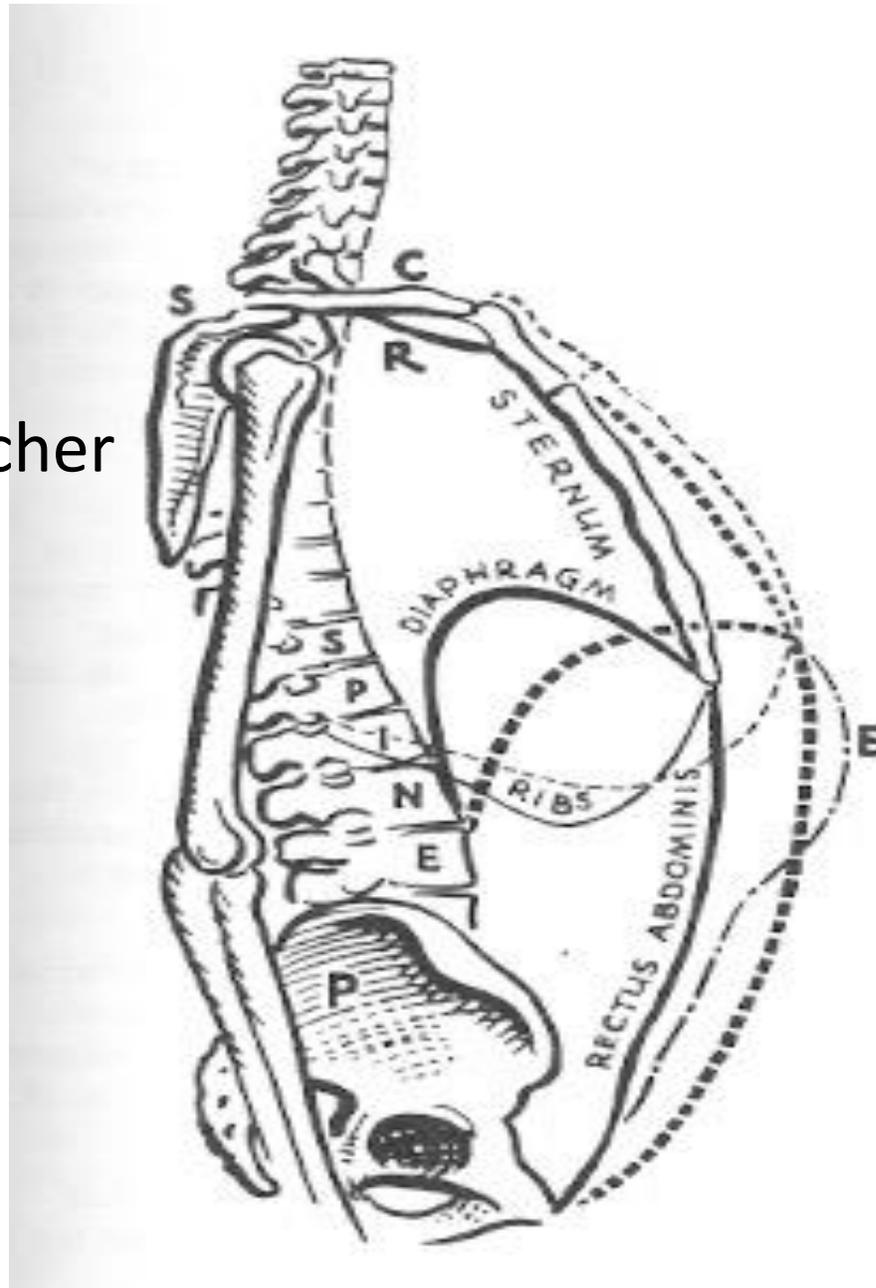
Lamperti: 1908

- Highly regarded teacher
- Inhalation: rib expansion against a rigid abdominal wall – limiting diaphragmatic descent
- Exhalation as presented is paradoxical!



Vennard: 1967

- Voice scientist/teacher
- Dashed line is full inspiration
- Solid line is full exhalation
- Based more on physiology



Summary

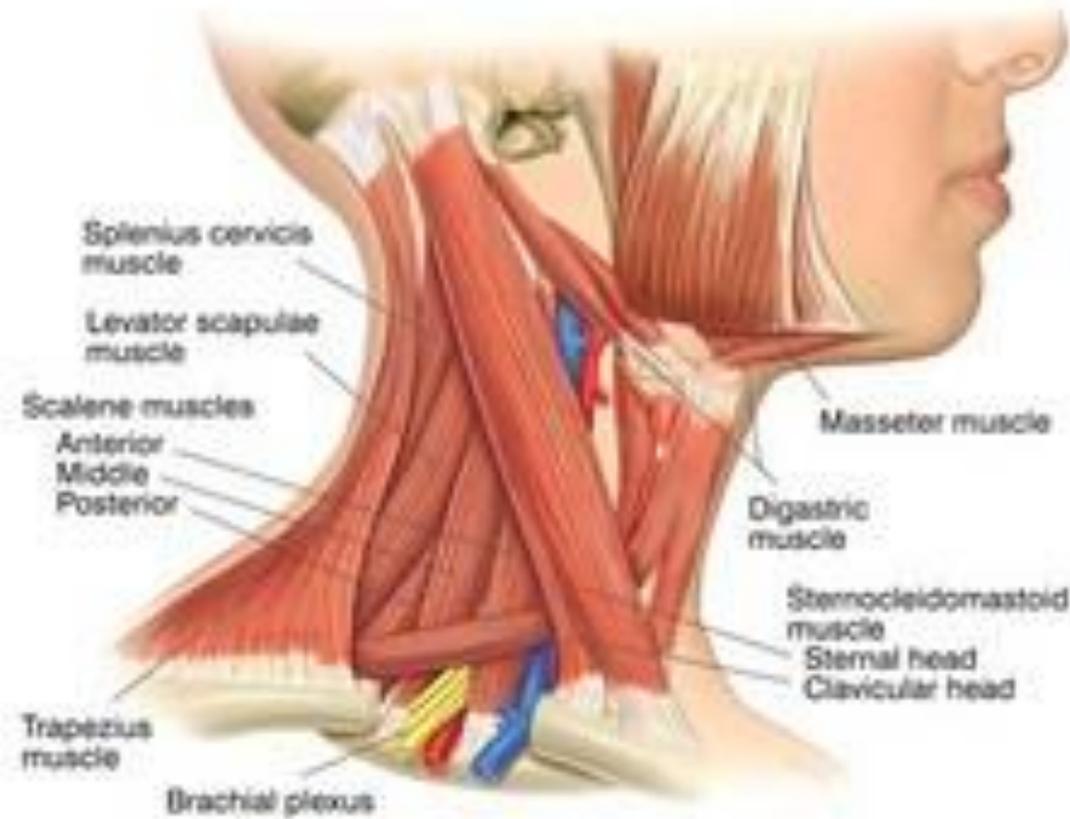
- “I have seen some professional singers with heaving chests, some with protruding bellies, some with raised shoulders, and some with bouncing epigastrums, all of whom sang beautifully... I have also seen awkward postures that have not adversely affected good singing.
- While good posture and good breathing methods are certainly important, especially in a singer’s early training, it is ultimately the way in which the breath is turned into a singing tone that is crucial.”

James Stark, Bel Canto: A History of Vocal Pedagogy.

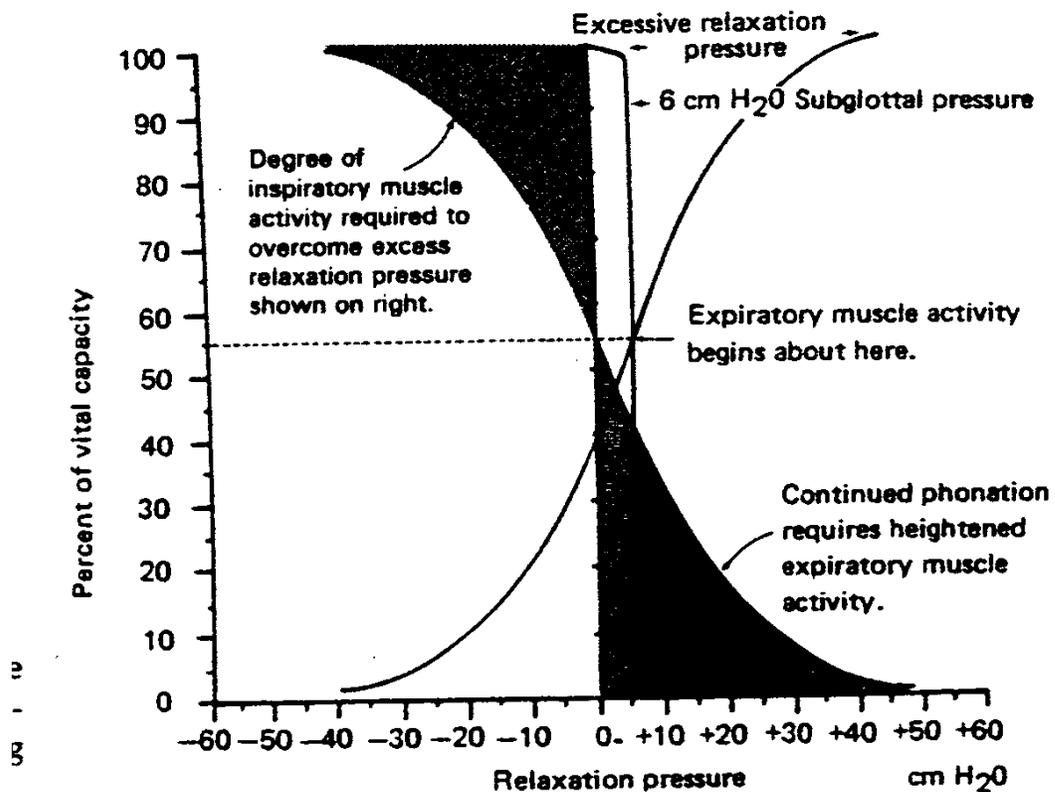
Problem areas for singers:



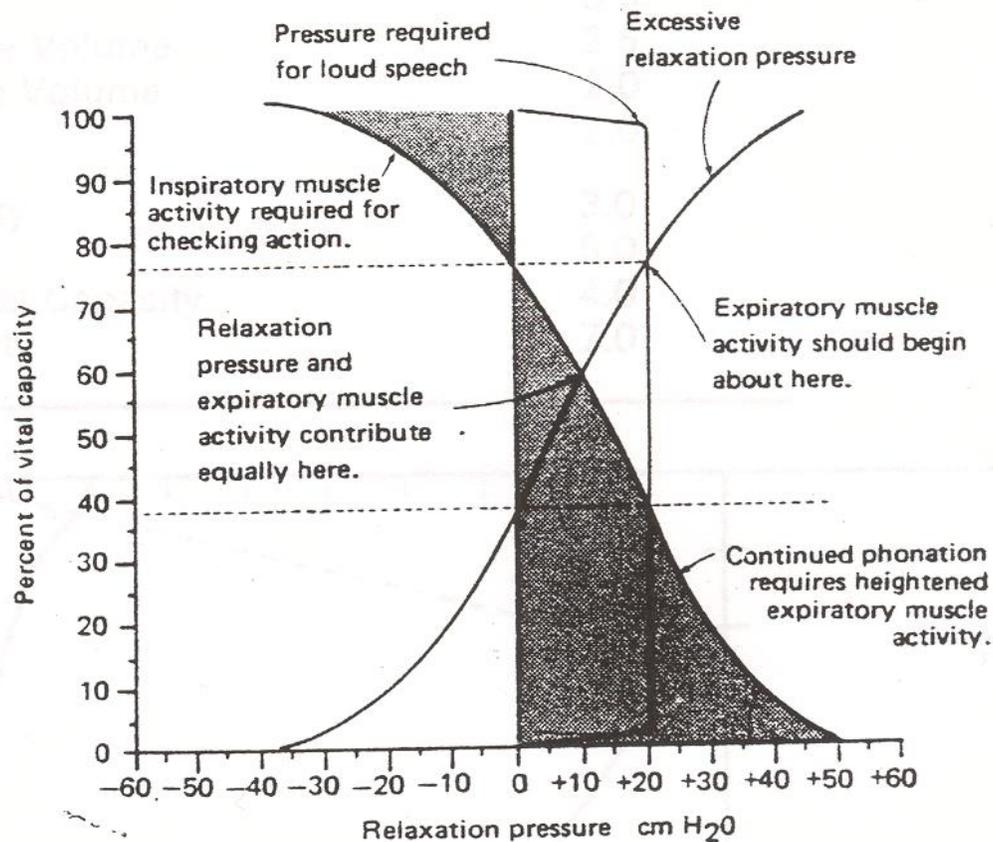
Accessories can be a big problem!



Lutte vocale: The vocal struggle!

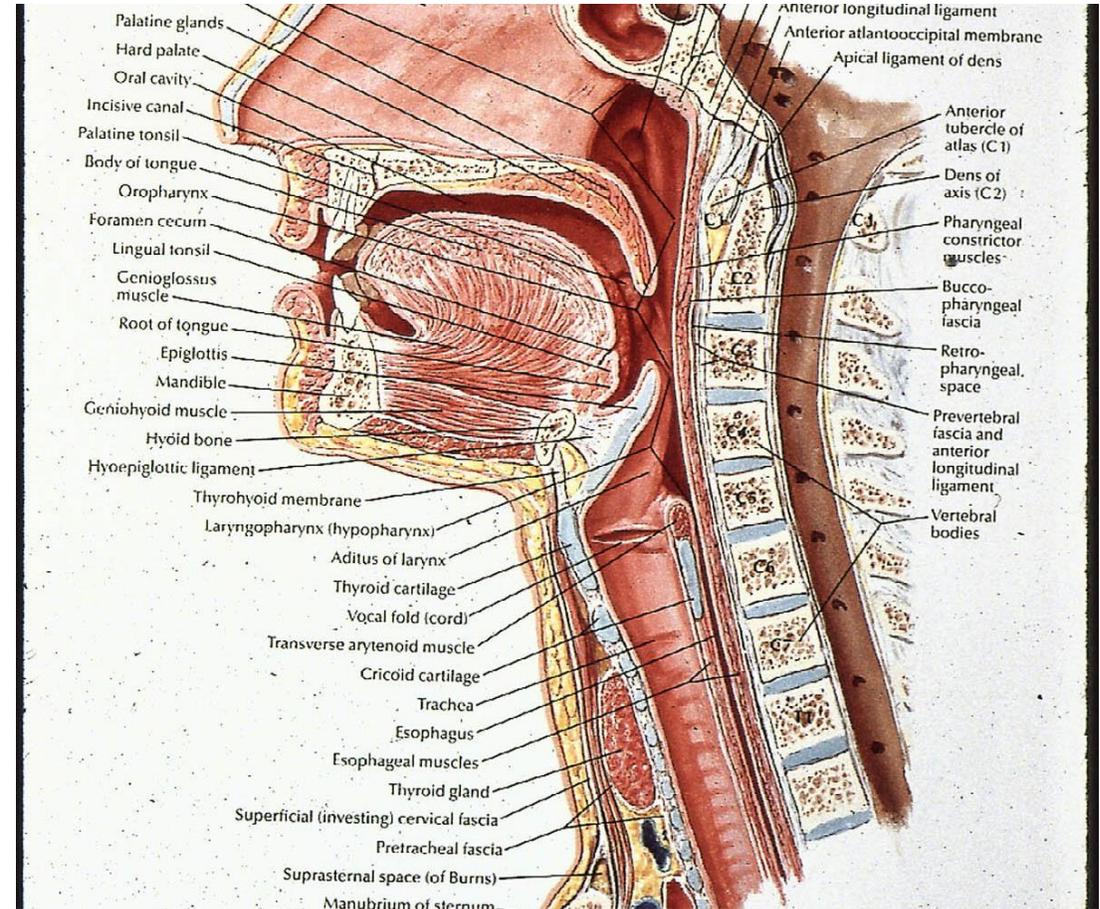


Breathing in while you breathe out

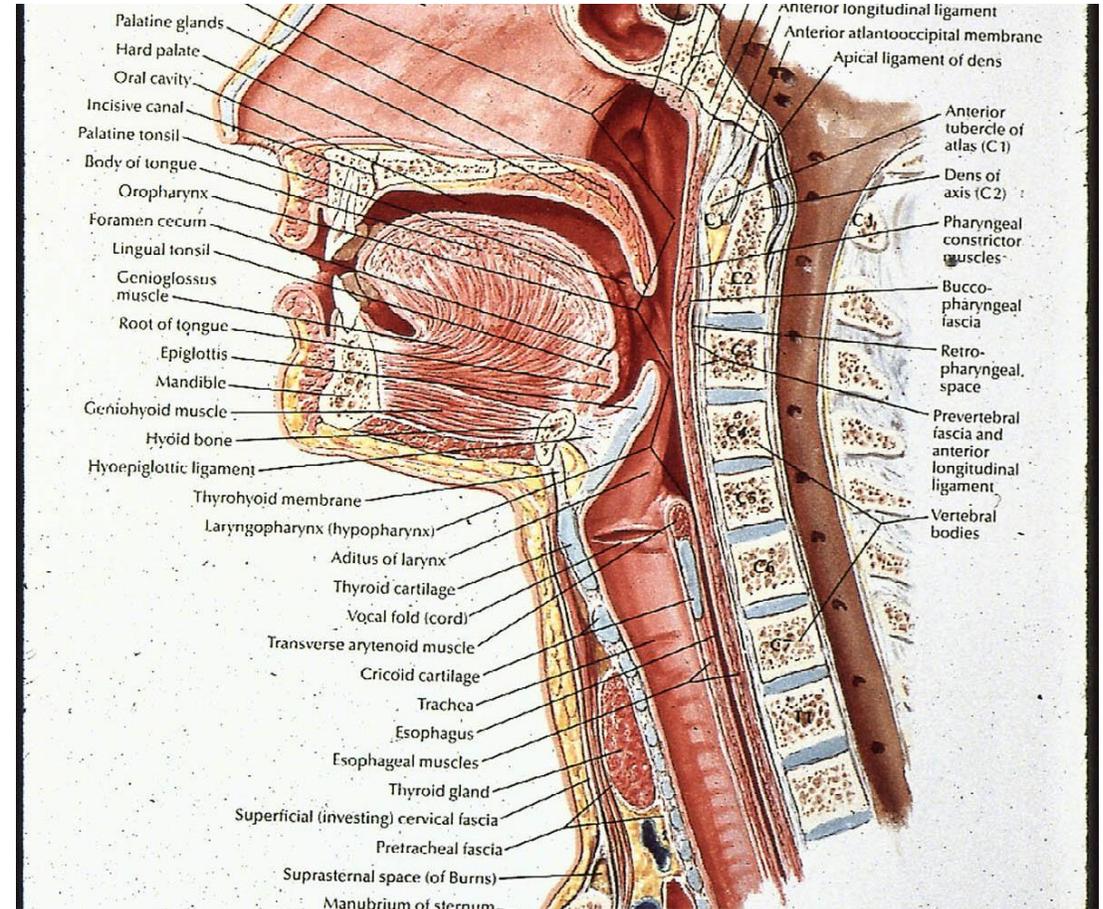


II. Phonation

- The Vocal Tract
 - Trachea/Lungs
 - Larynx
 - Pharynx
 - Laryngopharynx
 - Oropharynx
 - Nasopharynx

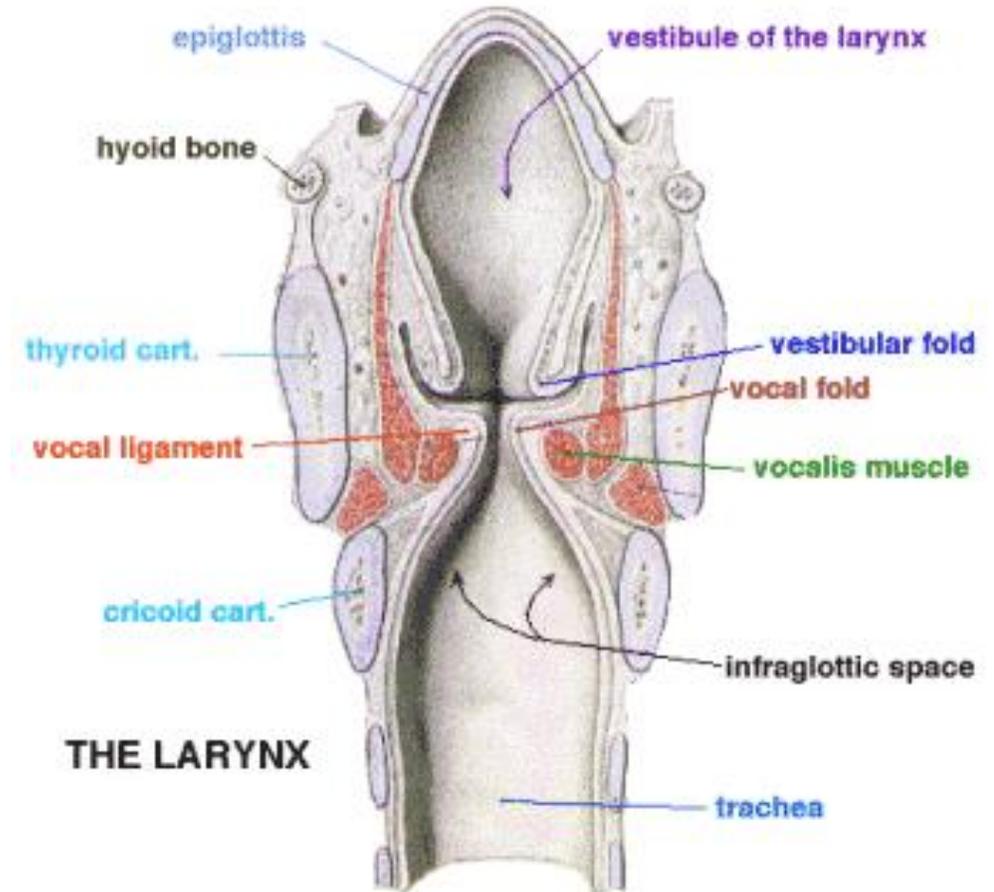


- The Vocal Tract
 - Oral cavity
 - Nasal cavity



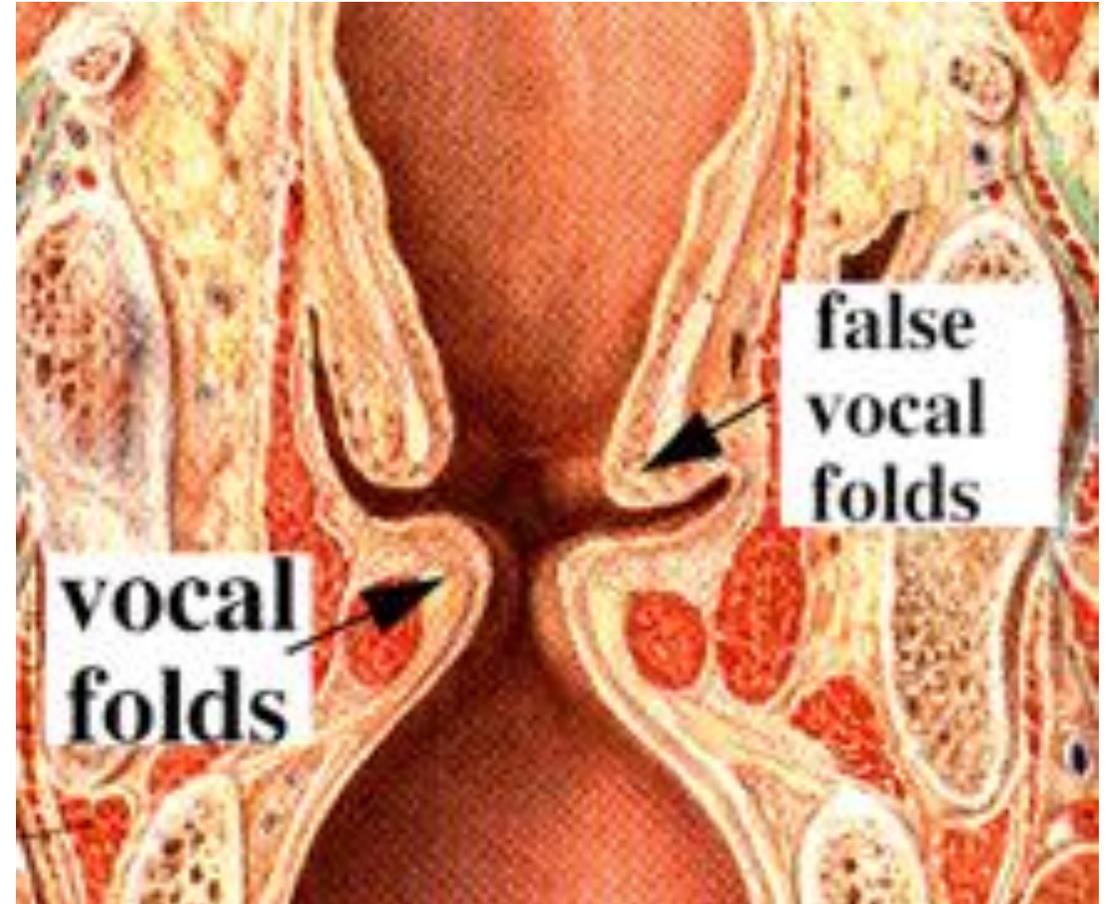
The Larynx

- Biological Function
 - Protects the airway
 - Swallowing
 - Coughing



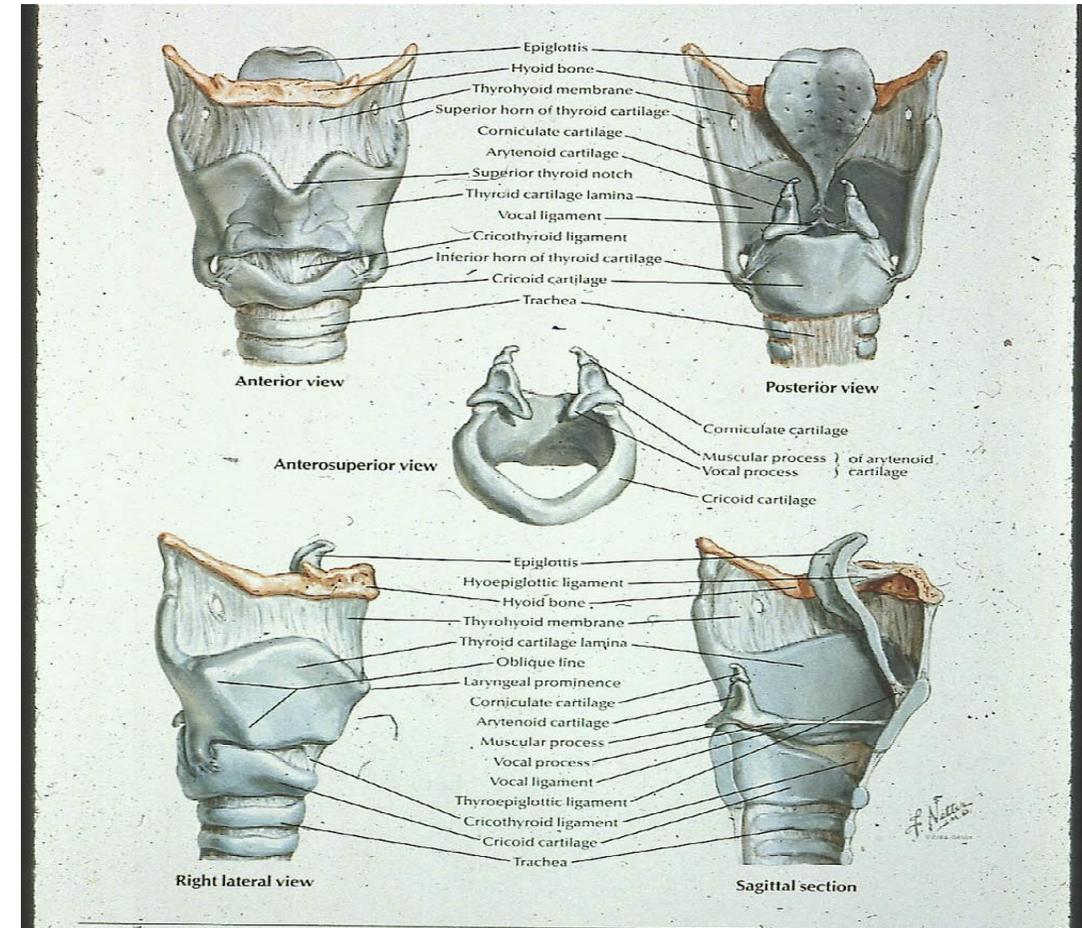
The Larynx

- Vocal Folds provide acoustic excitation for voice
 - Source is like a siren, not a string
 - vocal folds, not cords
 - An aerodynamic/myoelastic oscillator
 - Like a lip buzz!

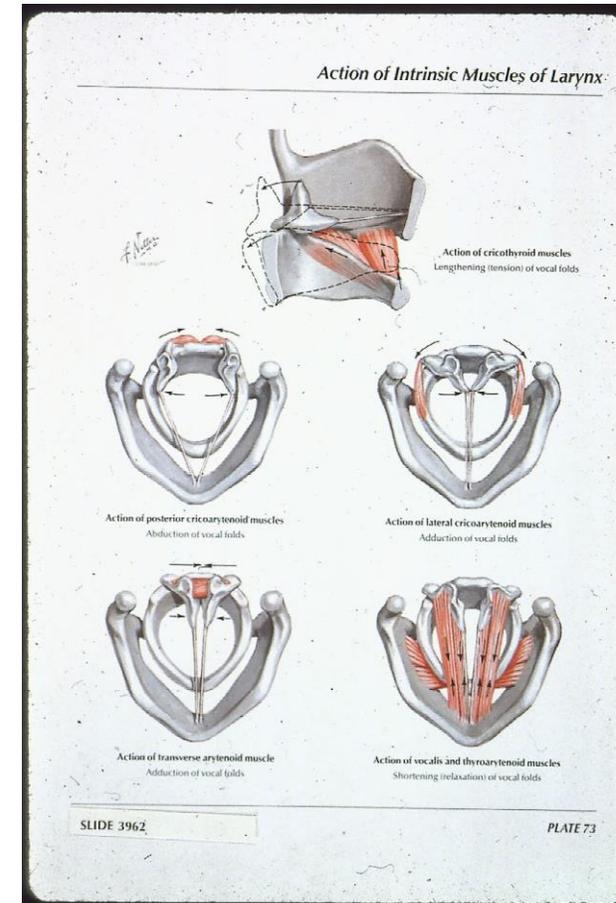


Laryngeal Framework

- Cricoid Cartilage
- Thyroid Cartilage
- Arytenoid Cartilages (2)
- Epiglottis
- Hyoid Bone

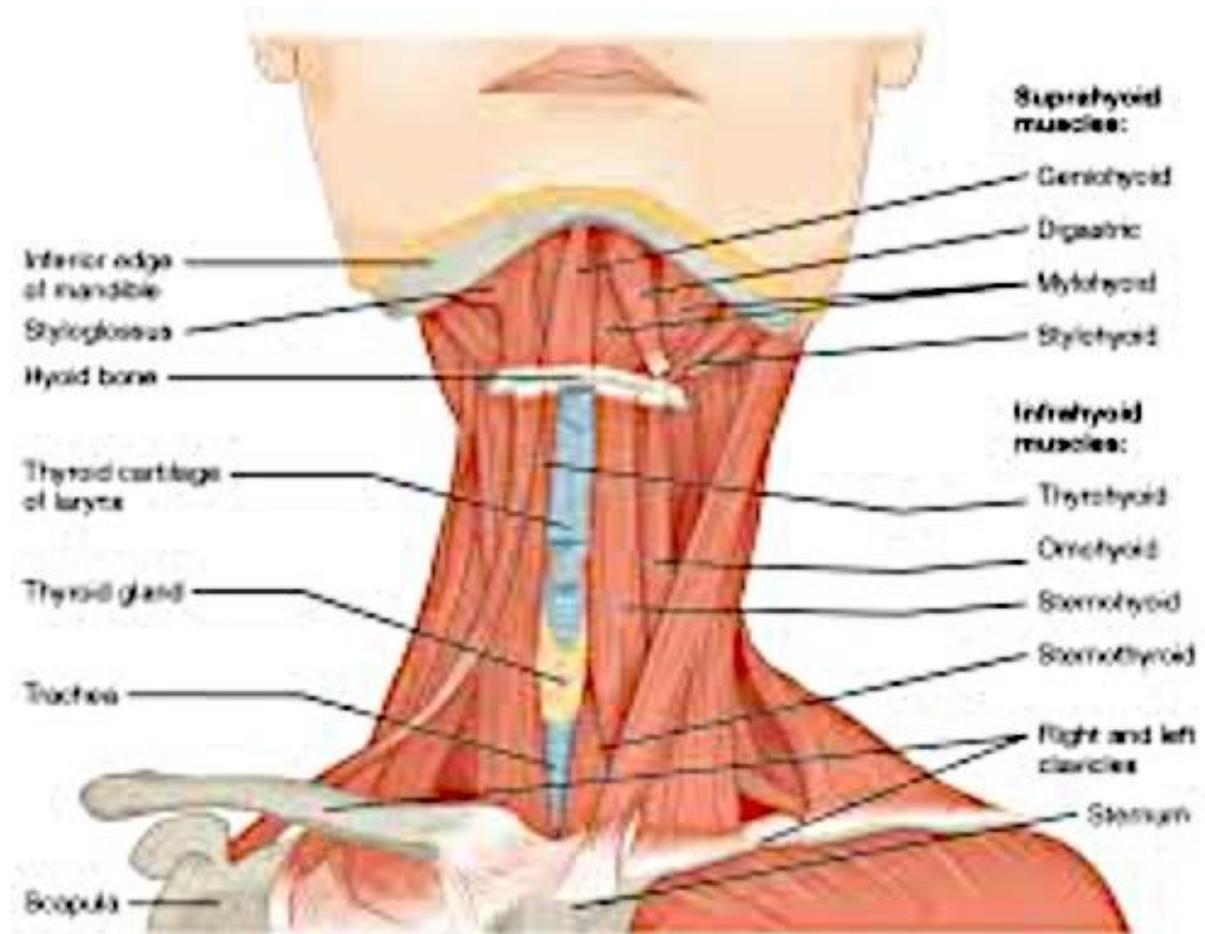


- **Intrinsics:**
 - Control the length, tension or position of the vocal folds (vf)
 - All but 1 are paired
 - Tensors/Relaxers – elongate or shorten the vf
 - Abductors – opening the glottis
 - Adductors – closing the glottis



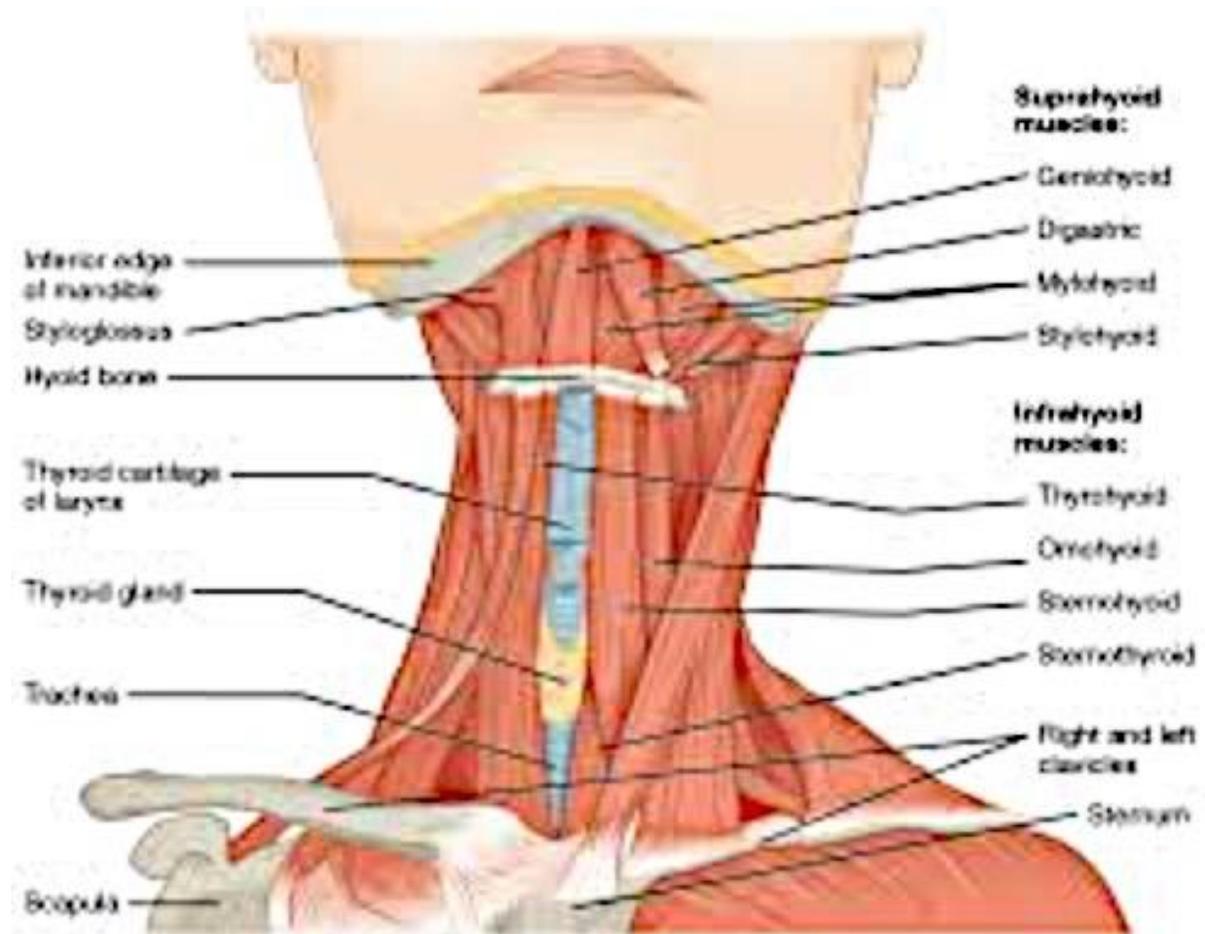
Extrinsics:

- Vertical position of the larynx establishes timbre and function of the voice.
- Below resting level is associated with *bel canto* singing.
- This does not usually happen without specific training.



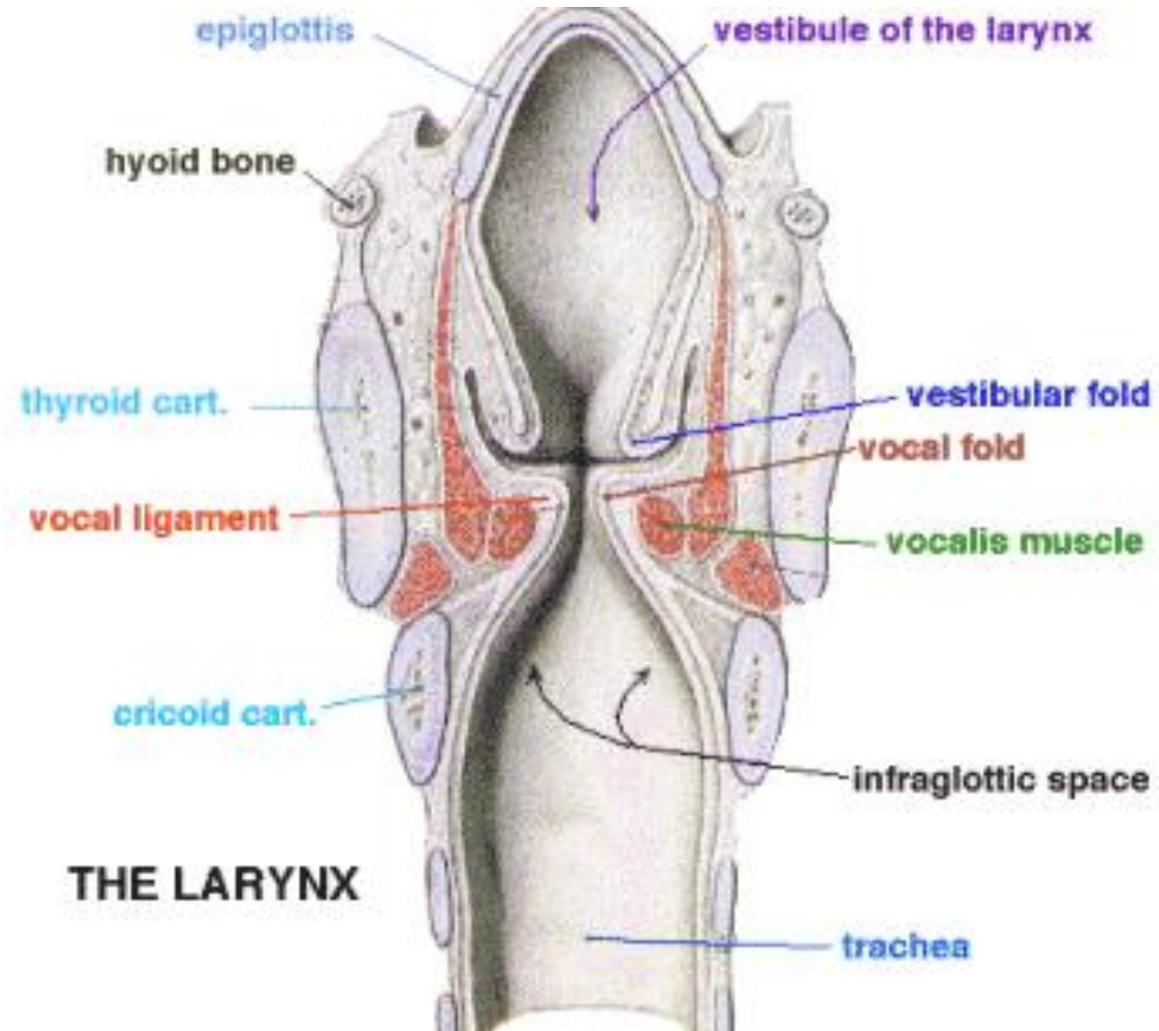
Extrinsics:

- Improper position can wreak havoc!
- High: Kermit the Frog
- Low: Eeyore
- Asymmetric laryngeal position can cause dysphonia



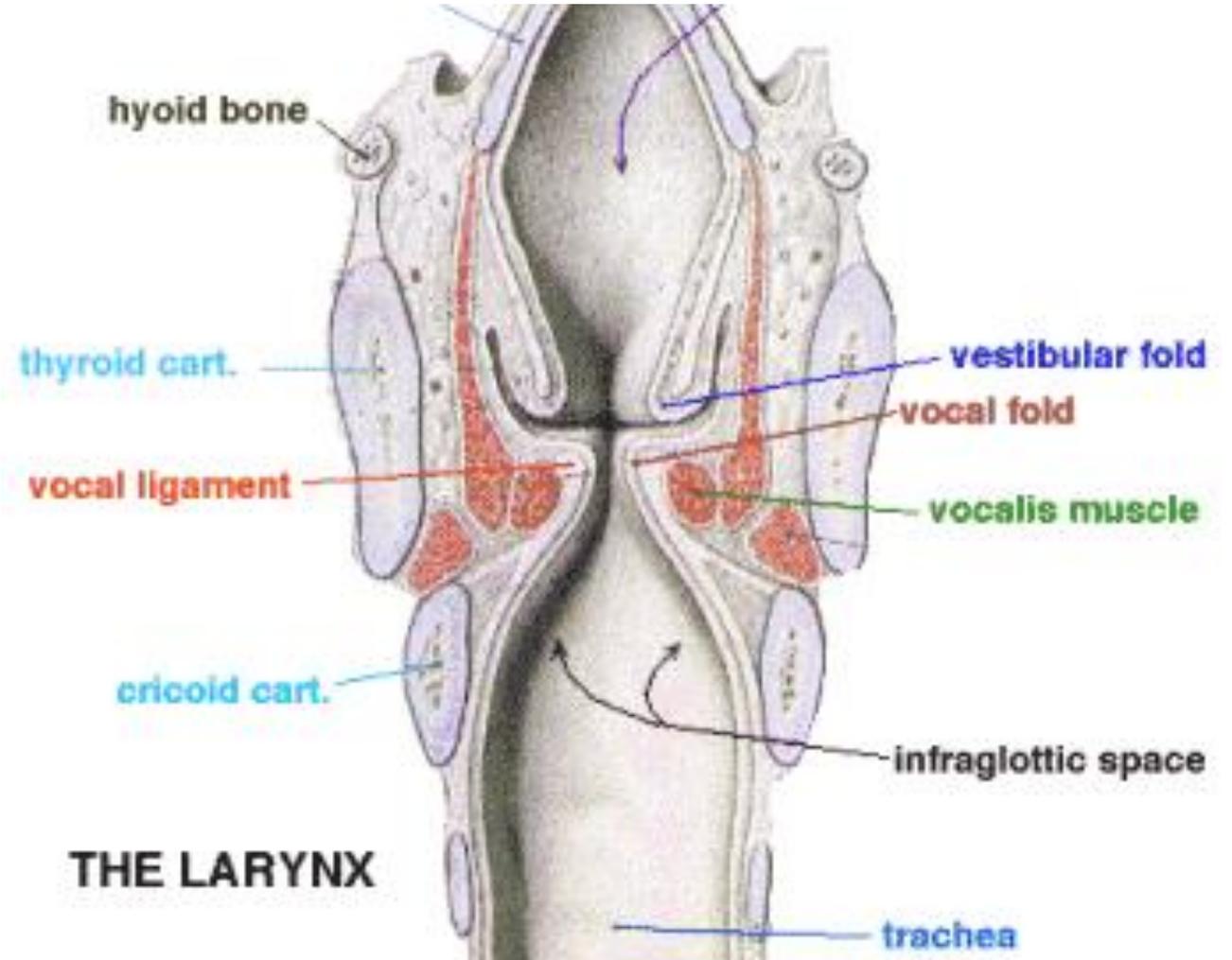
Vocal Folds

- A complex, multi-layered structure
- Muscle with a loose, pliable cover called the *lamina propria*



Lamina Propria

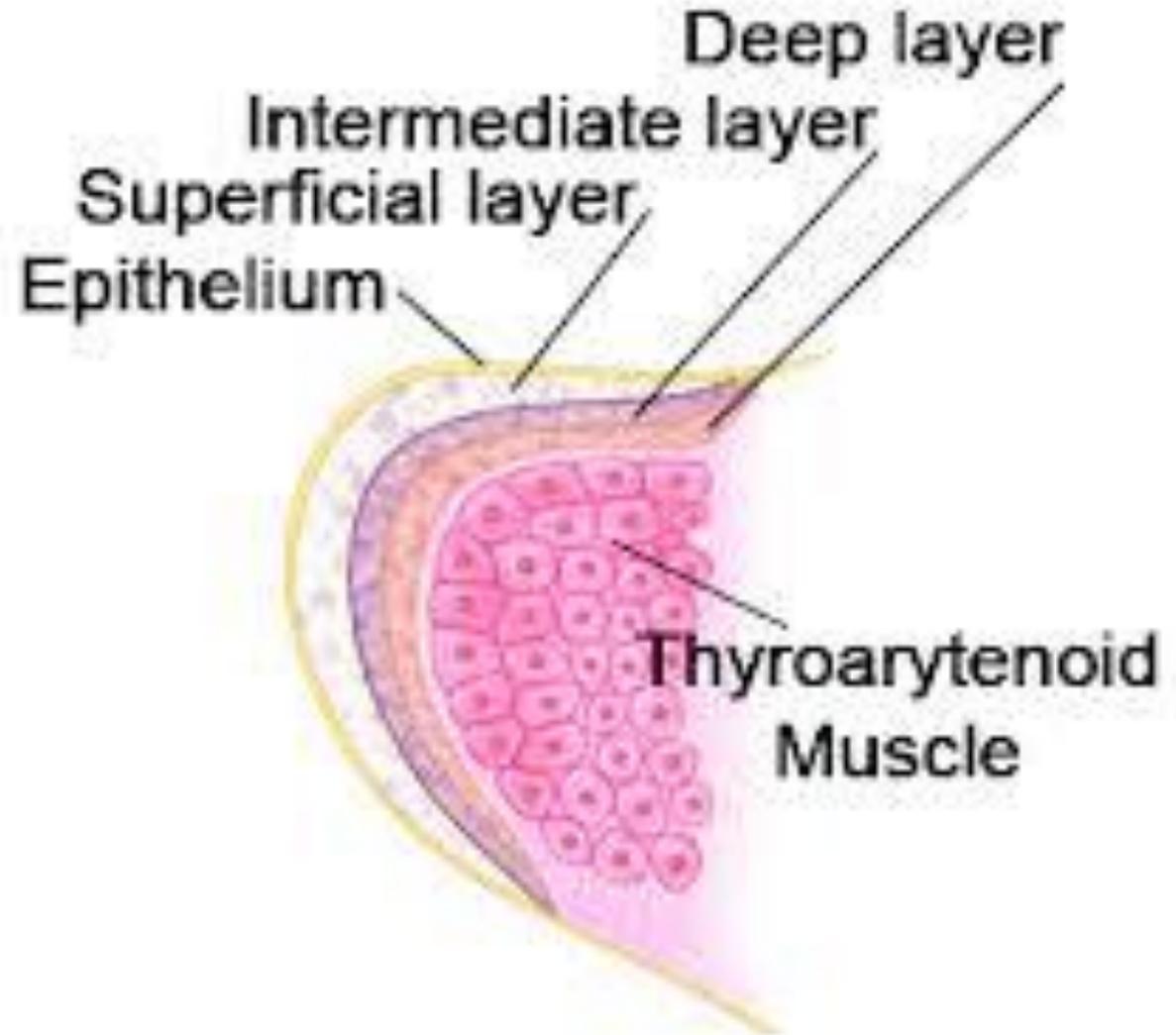
- Described by Hirano (1970s)
- Revolutionized voice care
- Completed theory on vf vibration



Vocal Folds

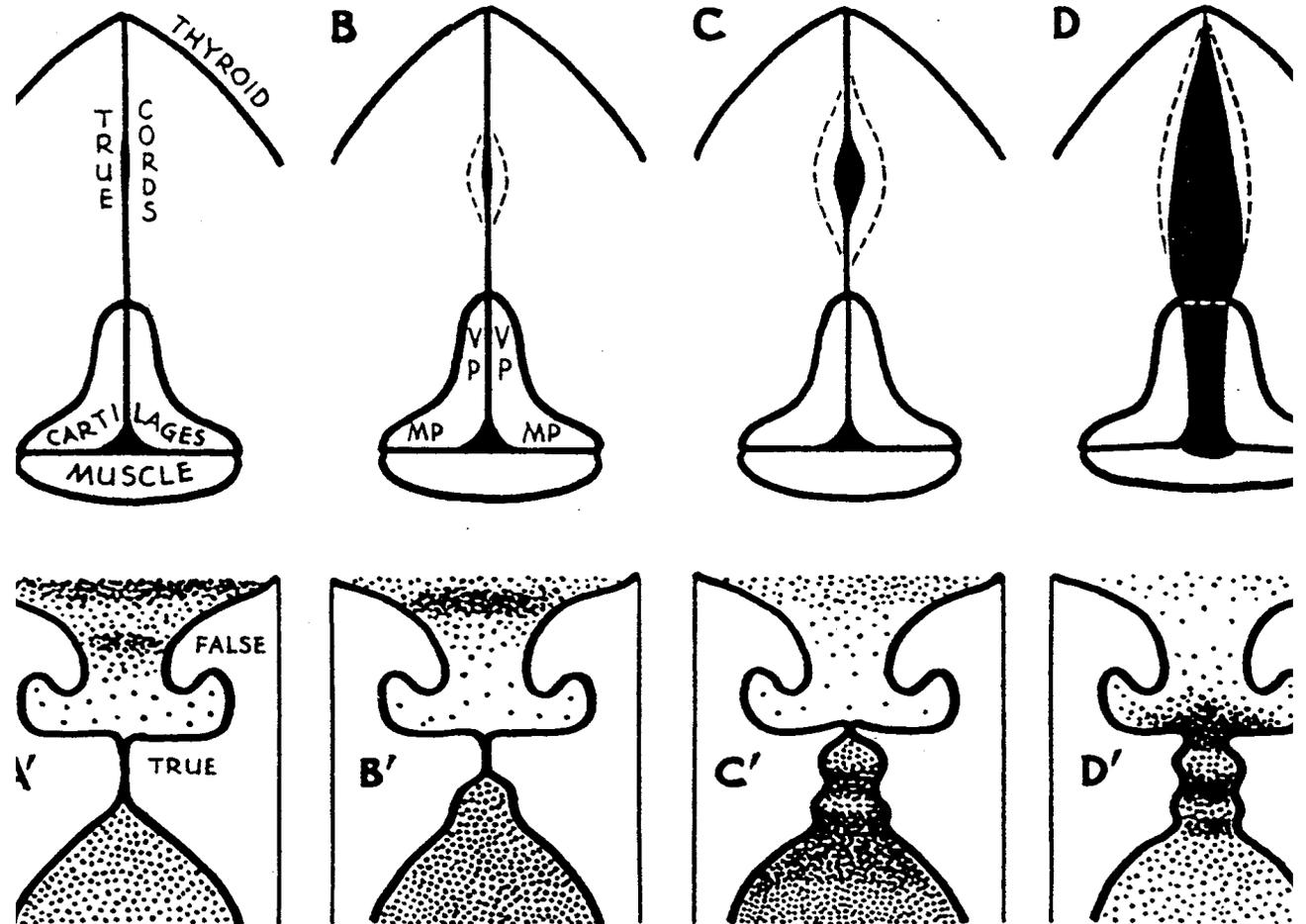
5 layer structure:

- Mucosa – outer skin of squamous epithelium
- Lamina Propria
 - Superficial layer – Reinke's space
 - Intermediate layer
 - Deep layer
- Body – Vocalis muscle



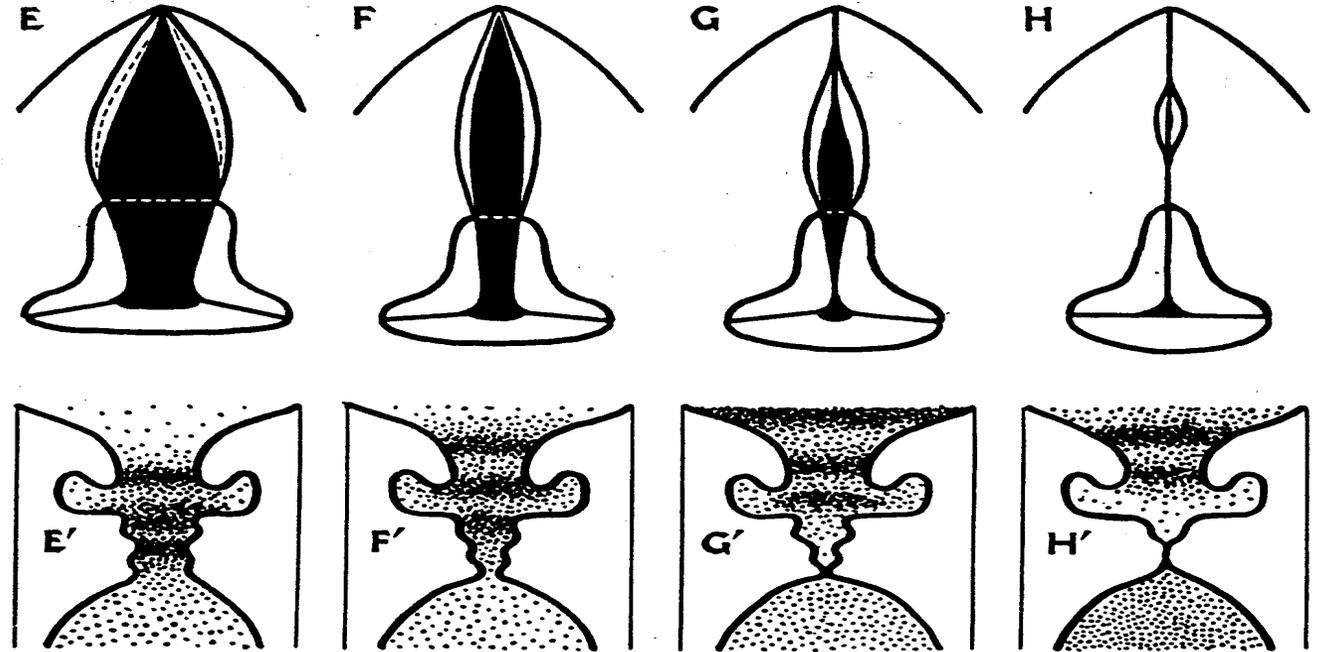
Vertical Phase difference

- The loose cover allows quasi-independent movement of the top and bottom sections
- Changing air pressures and elasticity of the tissue



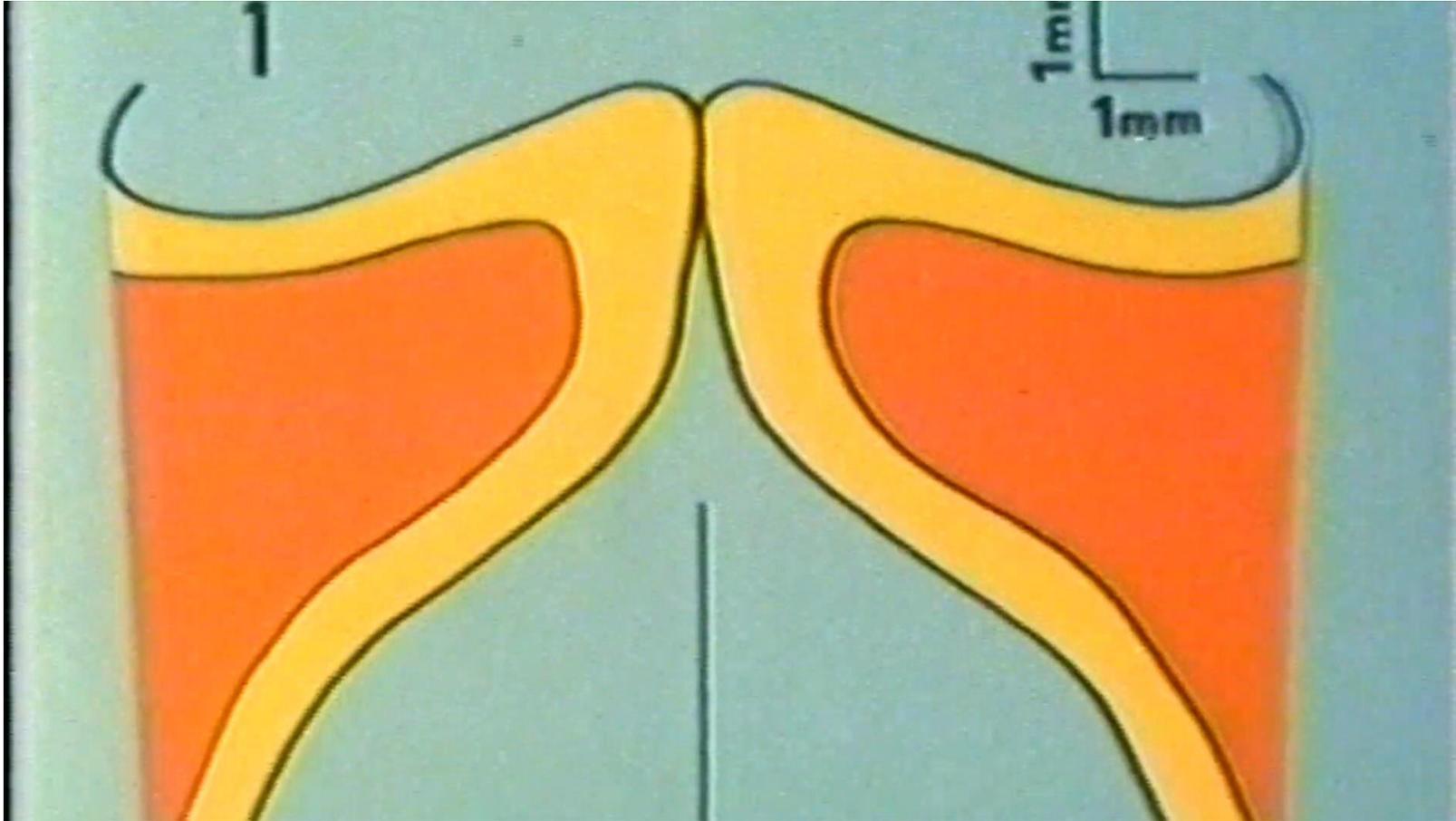
Vertical Phase difference

- P_{sg} separates the folds at bottom
- VF blown open
- Elasticity brings them back to midline
- Bottom of the VF closes first
- Top of the VF follows



Vennard, W.V. (1967). Singing: The Mechanism and the Technique.

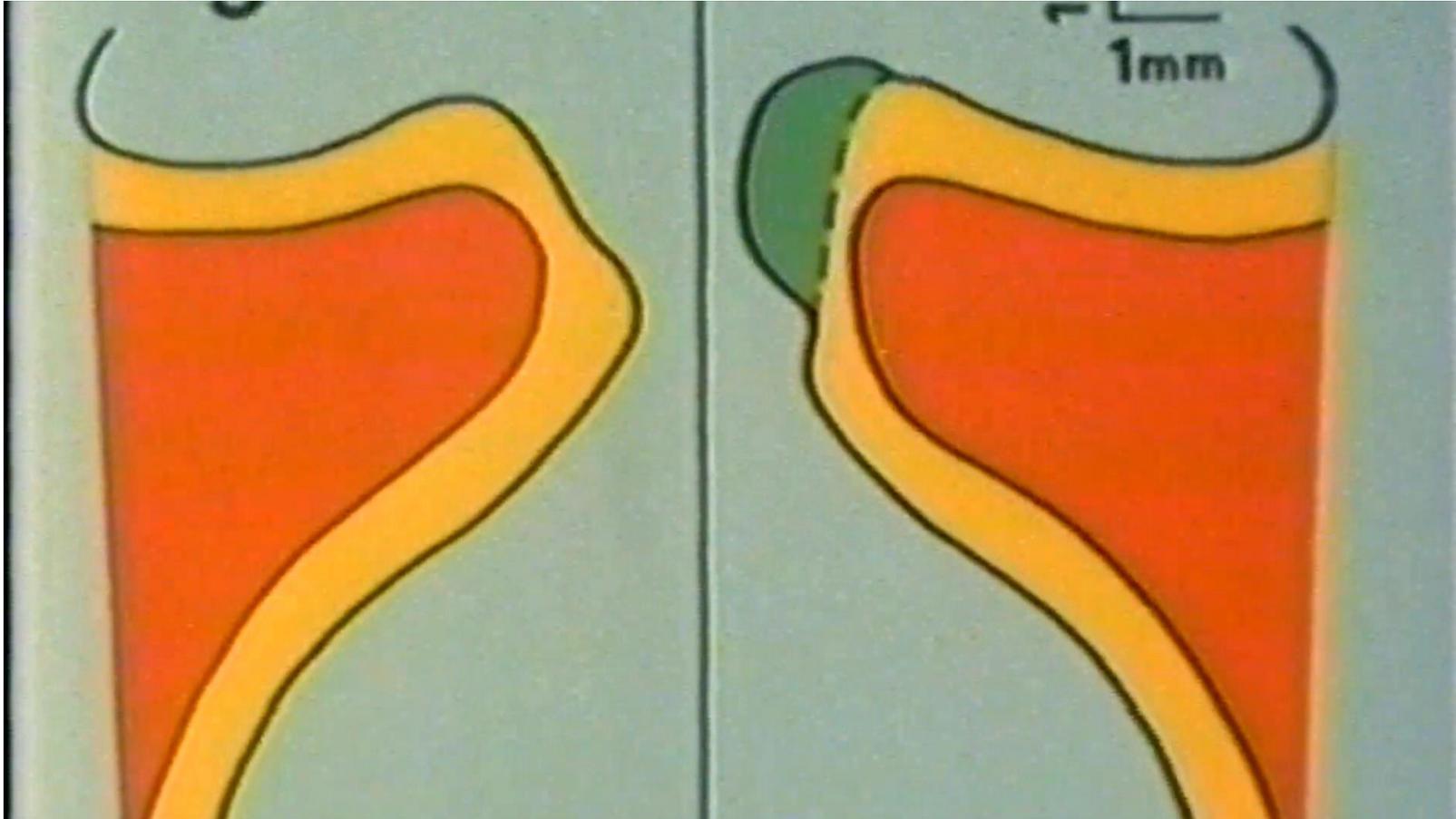
Hirano, 1976



Space occupying lesion:



Breathy, hoarse, rough... Fatigue!



Sounds...

High Larynx:

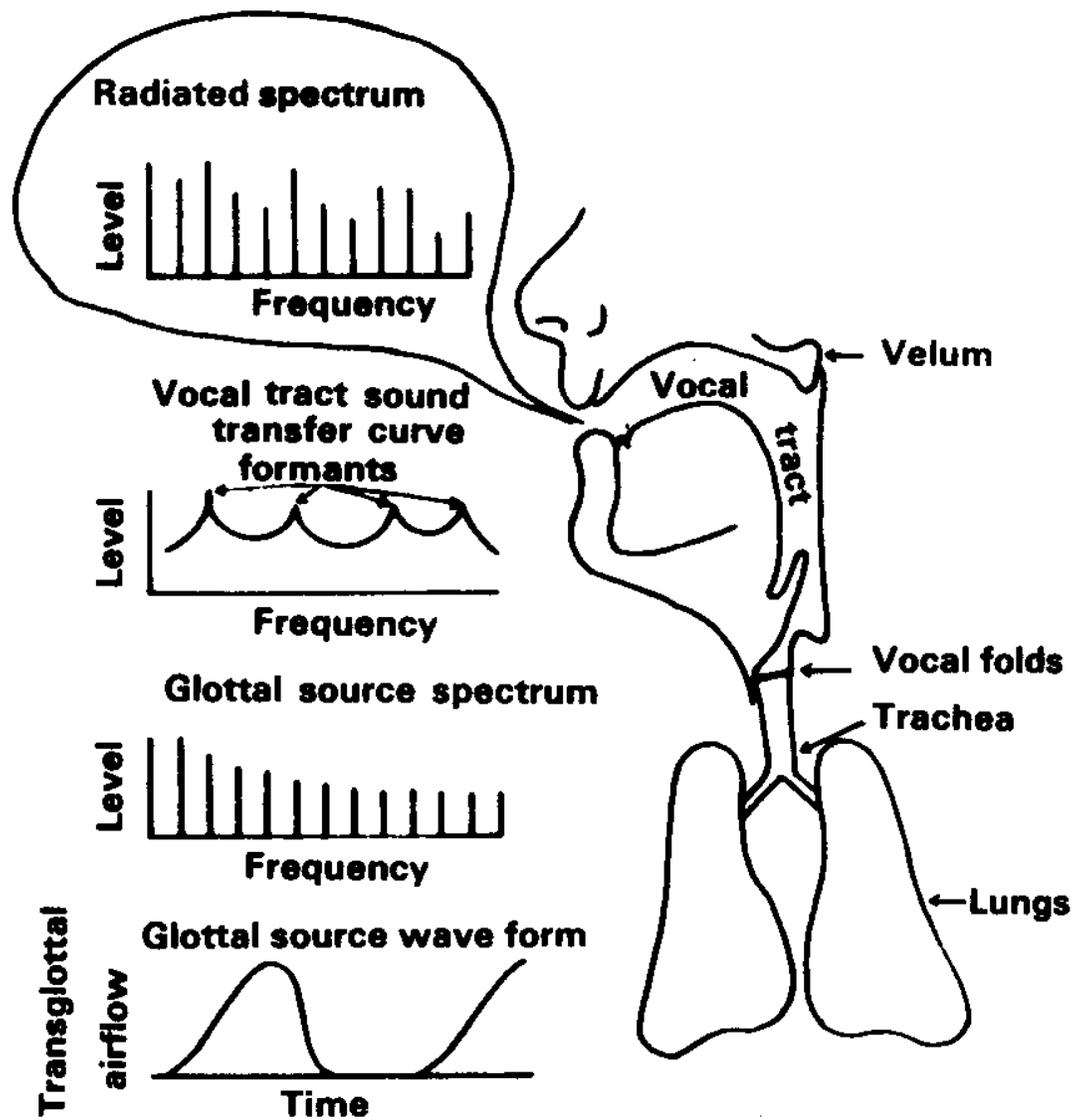


Low Larynx:



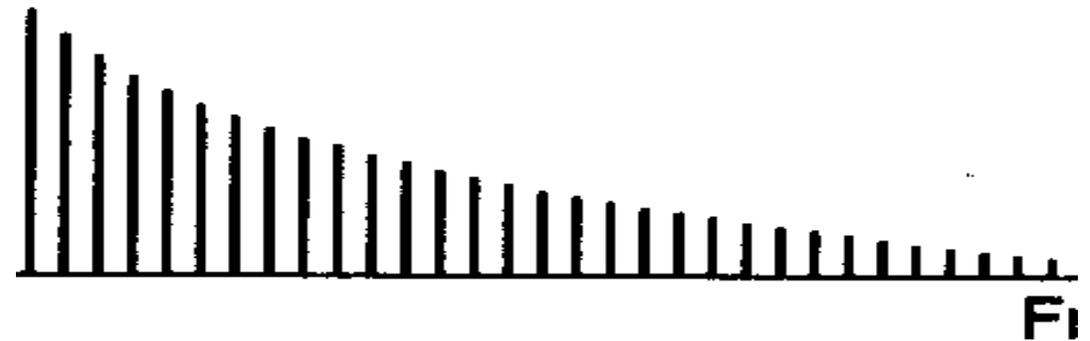
MTD:





Complex wave

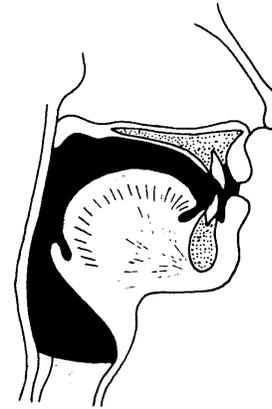
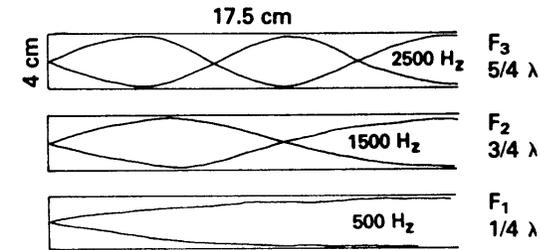
- Larynx produces a complex tone.
- Passes through vocal tract
- Air space ‘selects’ certain partials to amplify - to ‘resonate’



(a)

Formant: Resonance
of the vocal tract.

- Closed/open tube
- Schwa vowel
- Neutral vocal tract shape

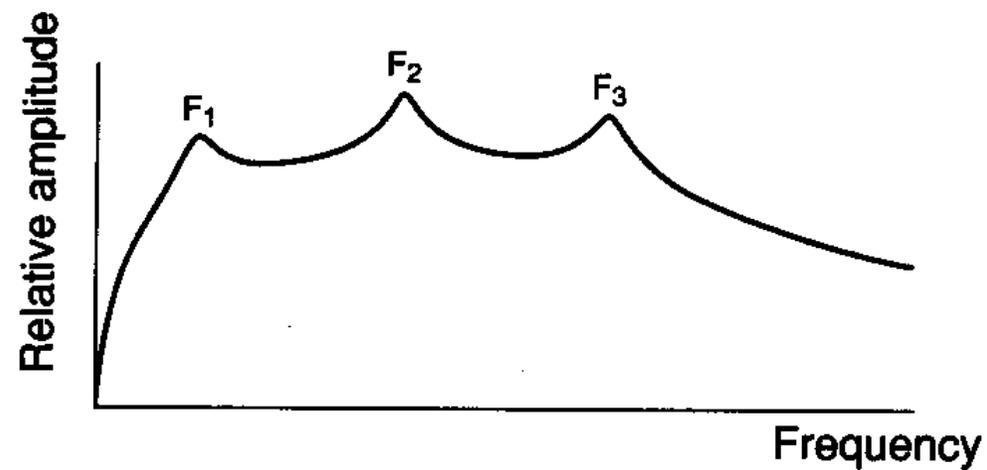


$$F_n = (2n-1) c/4L$$

where c = speed of sound
 L = length of the tube

Formant

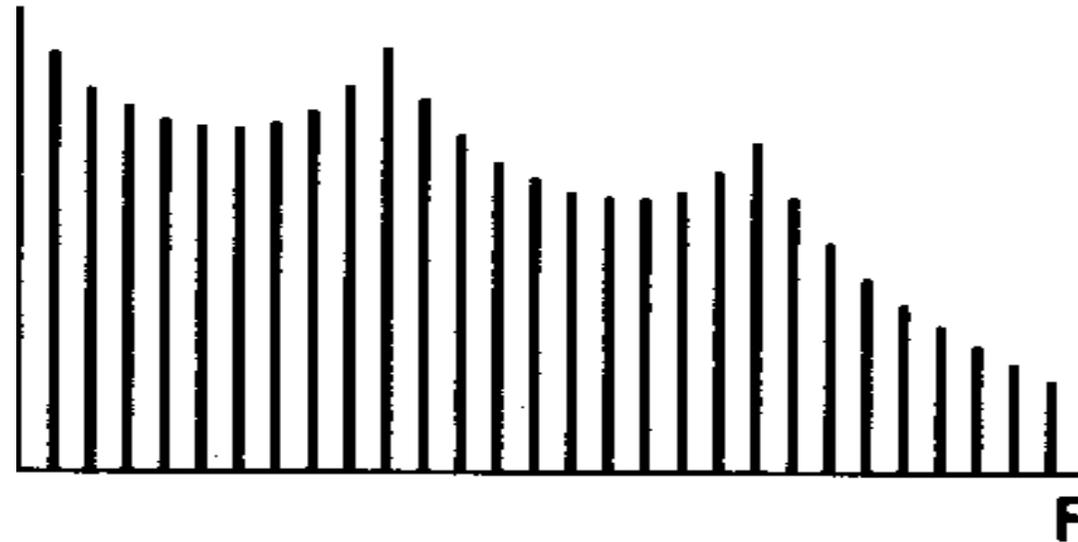
- Formants have ‘pitch’ determined by the shape of the vocal tract



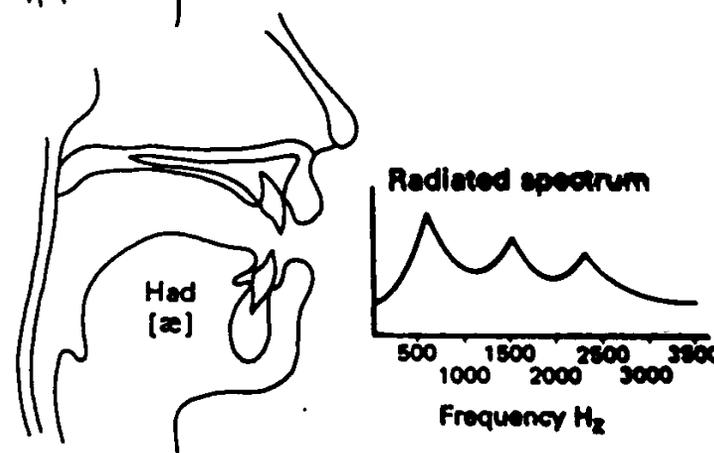
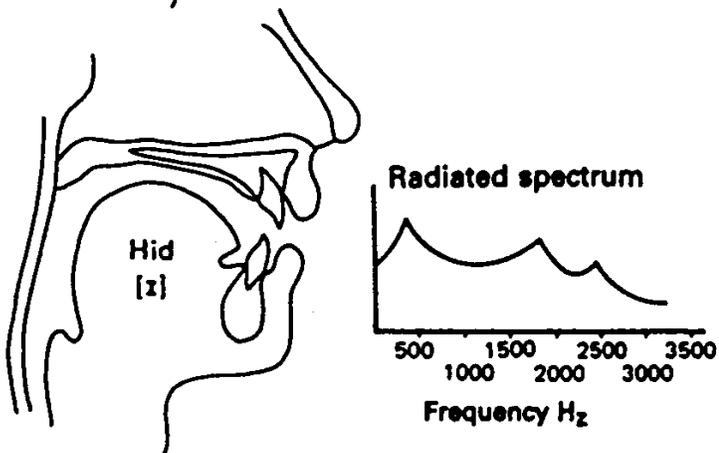
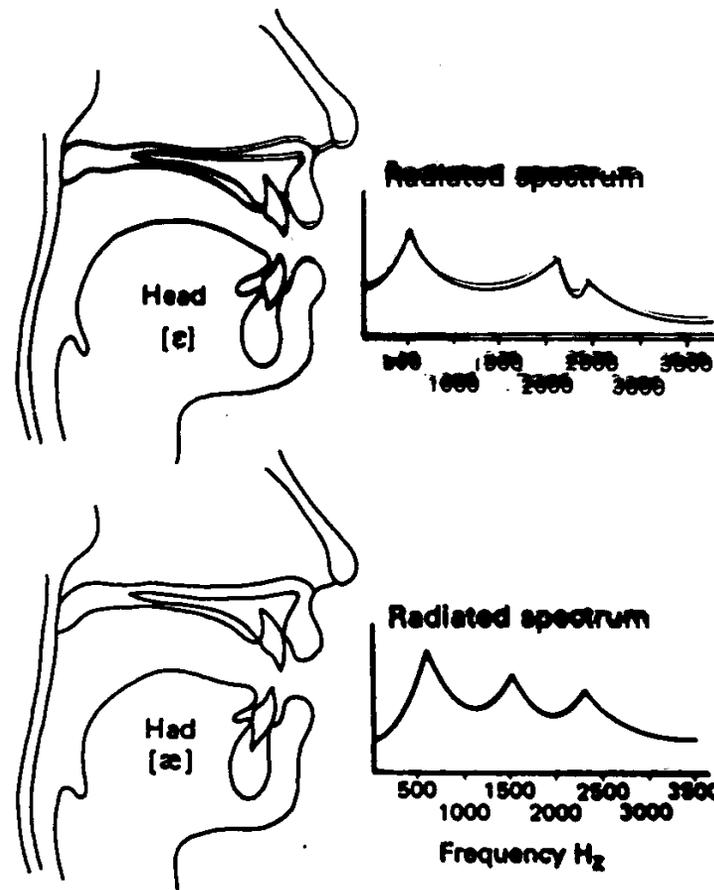
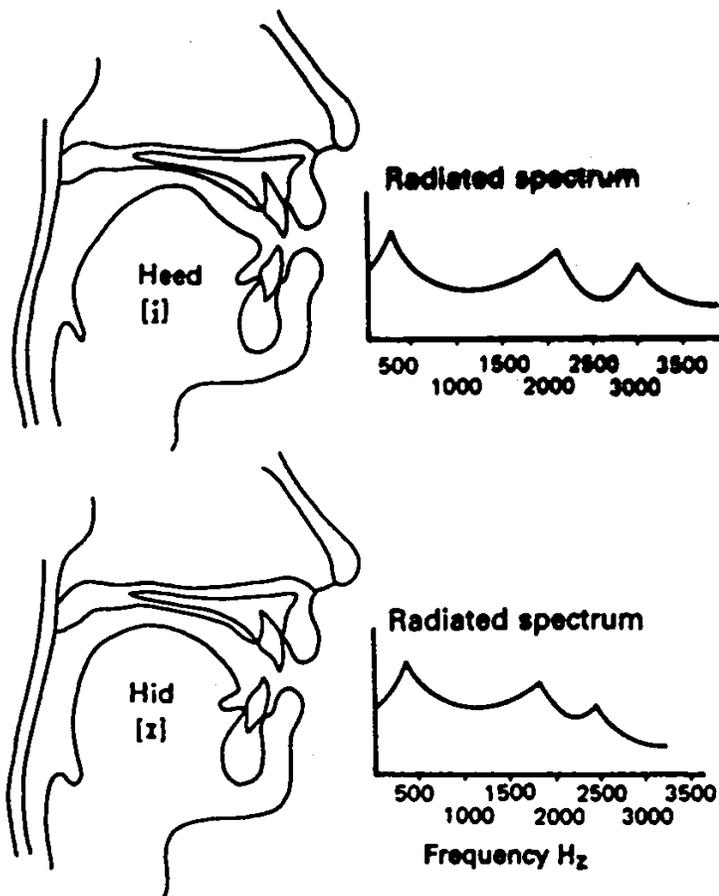
(b)

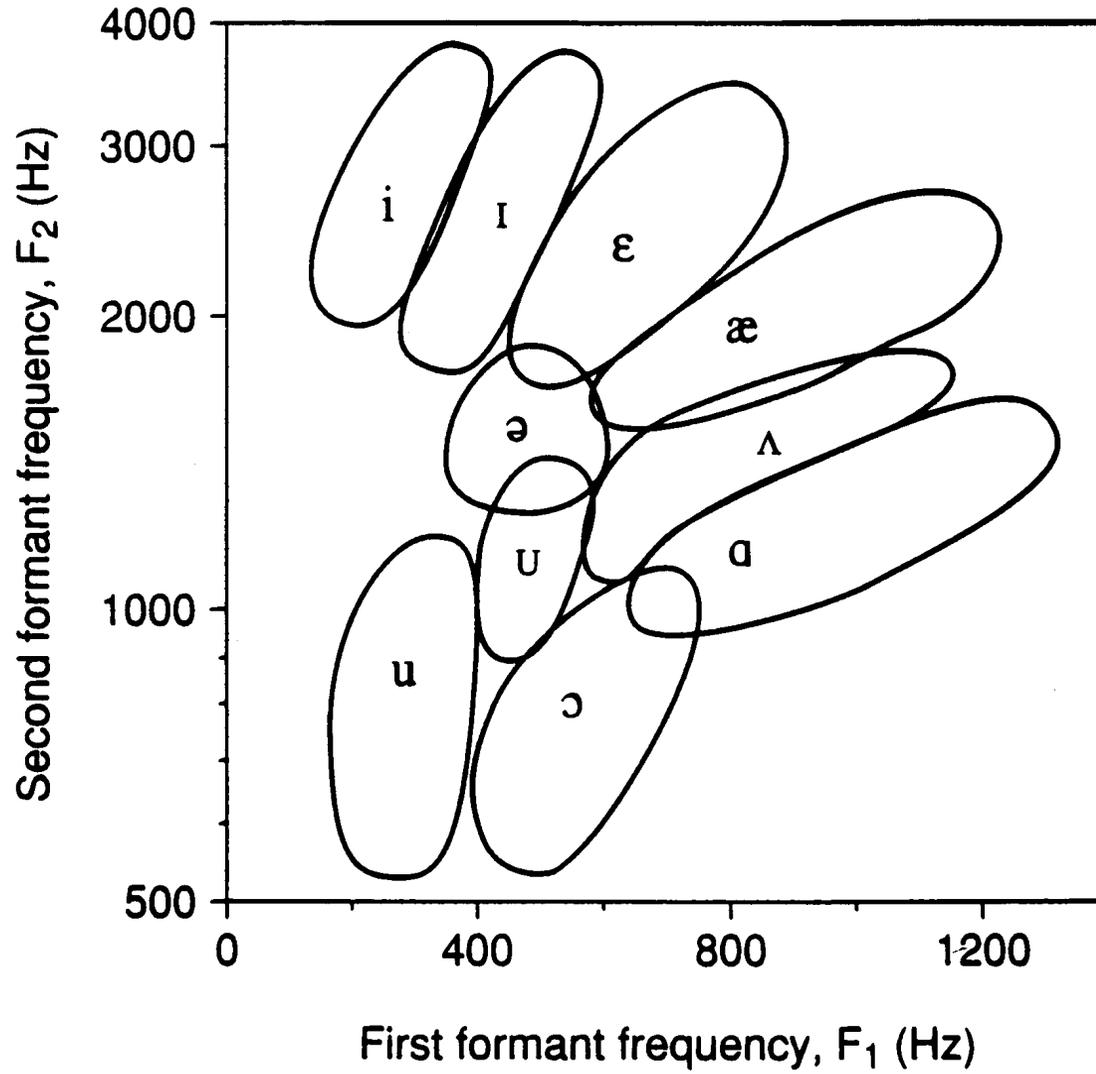
Vowel

- F1 and F2: relative frequencies determine vowel
- Changed by position:
 - Tongue, jaw, lips, larynx, soft palate



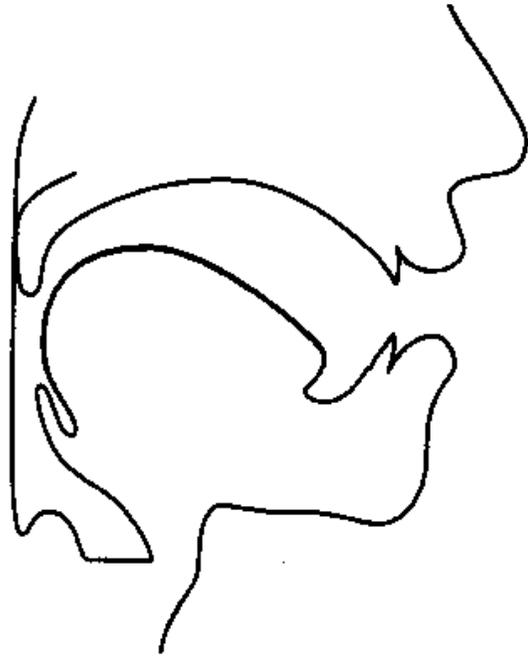
(c)





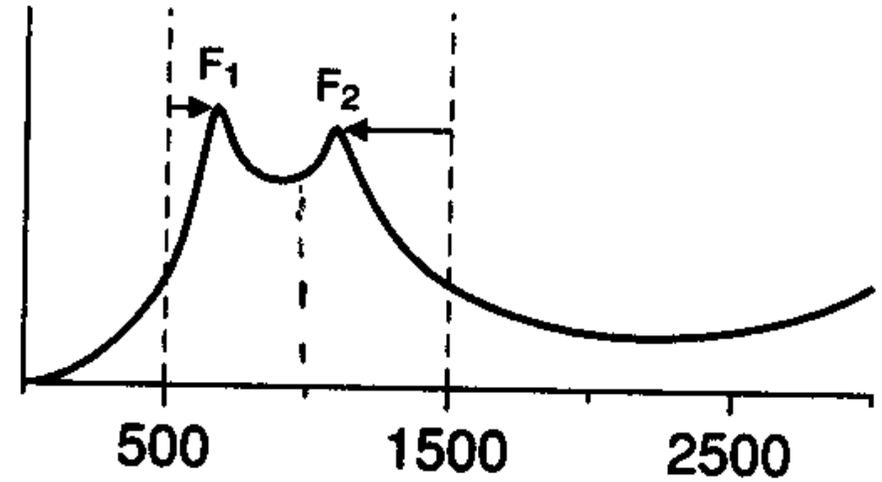
Rules for Vowel Tuning

- Dropping the jaw raises F1
- Lowering the larynx and extending lips lowers all formants
- A ‘back constriction’ raises F1 and lowers F2
- A ‘front’ constriction’ lowers F1 and raises F2



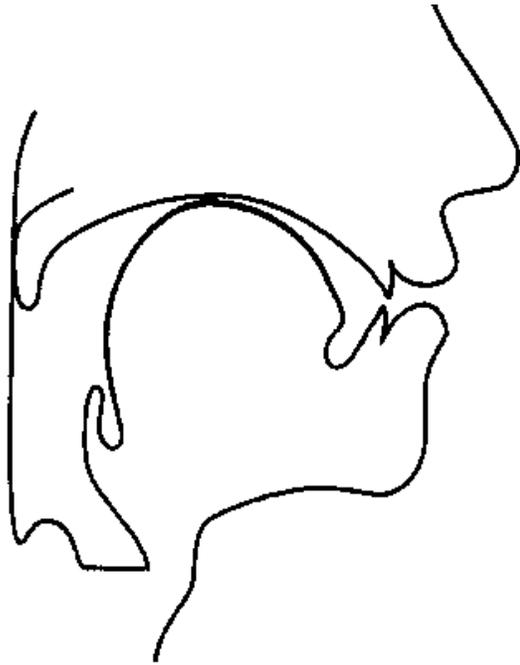
[a] vowel

Relative amplitude



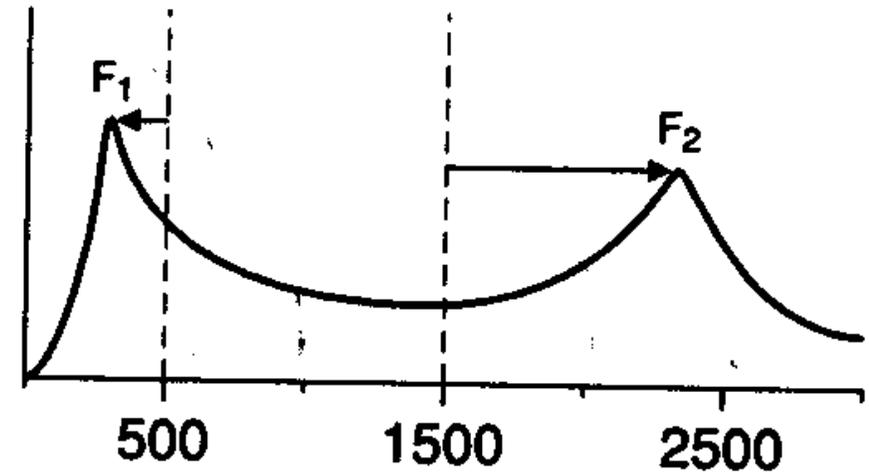
Frequency (Hz)

(a)



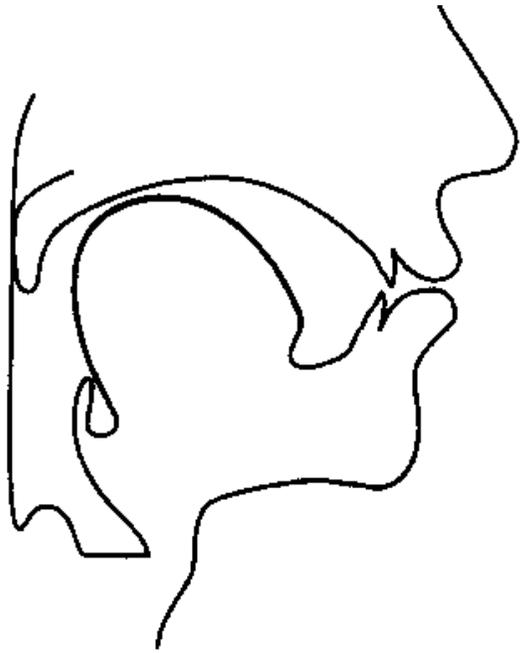
[i] vowel

Relative amplitude



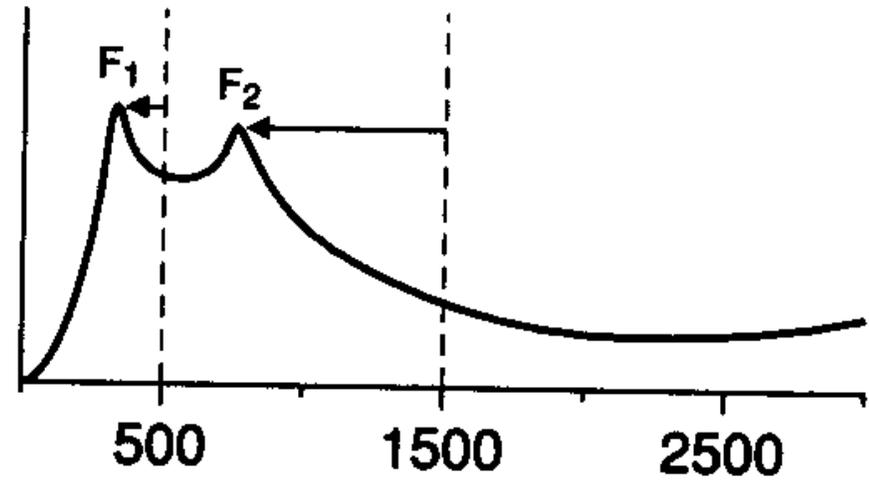
Frequency (Hz)

(b)



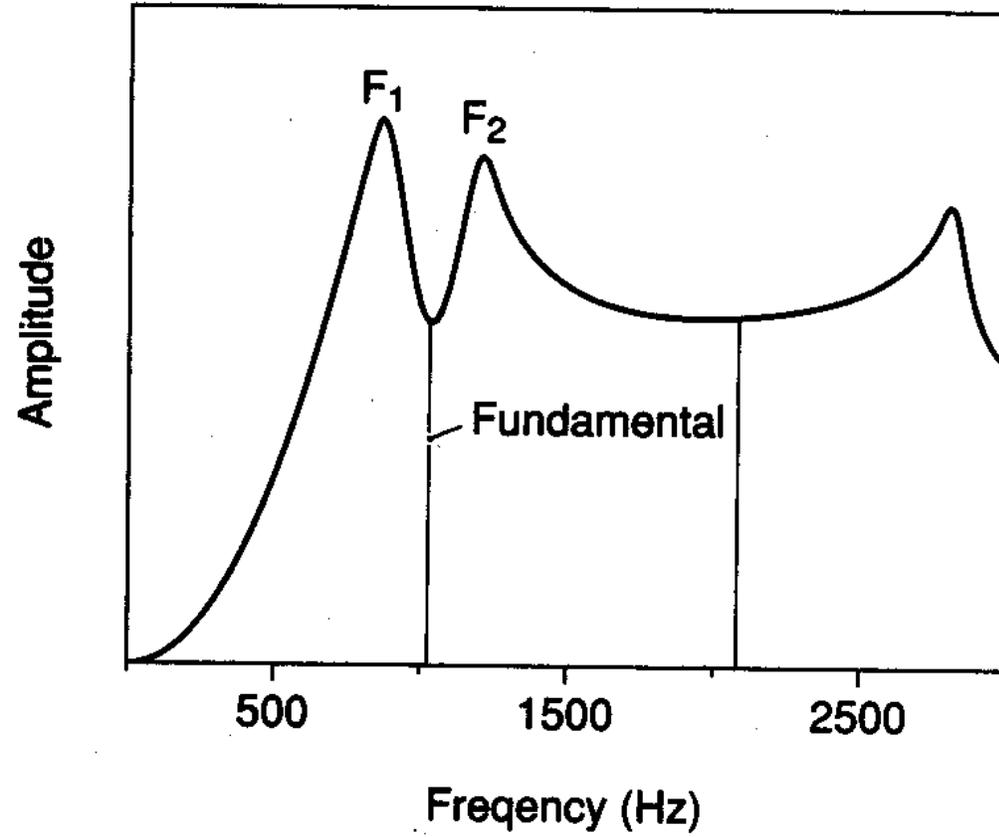
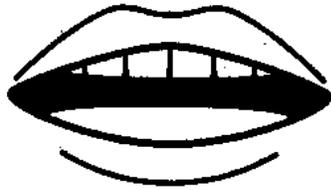
[u] vowel

Relative amplitude

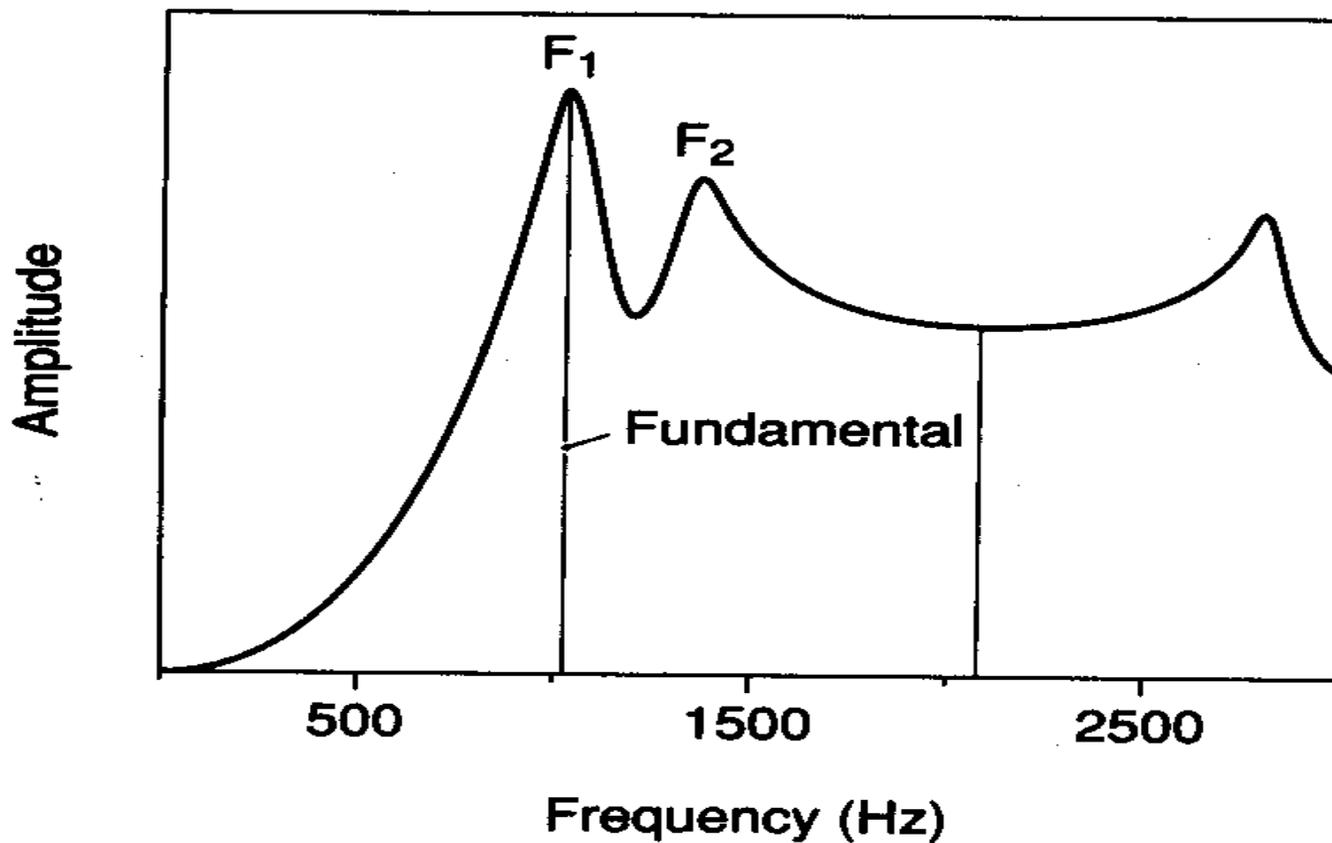
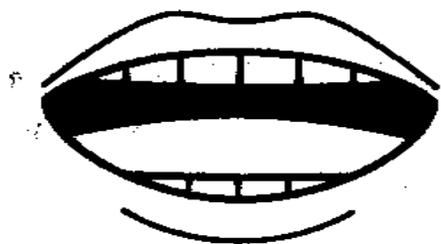


Formant Tuning

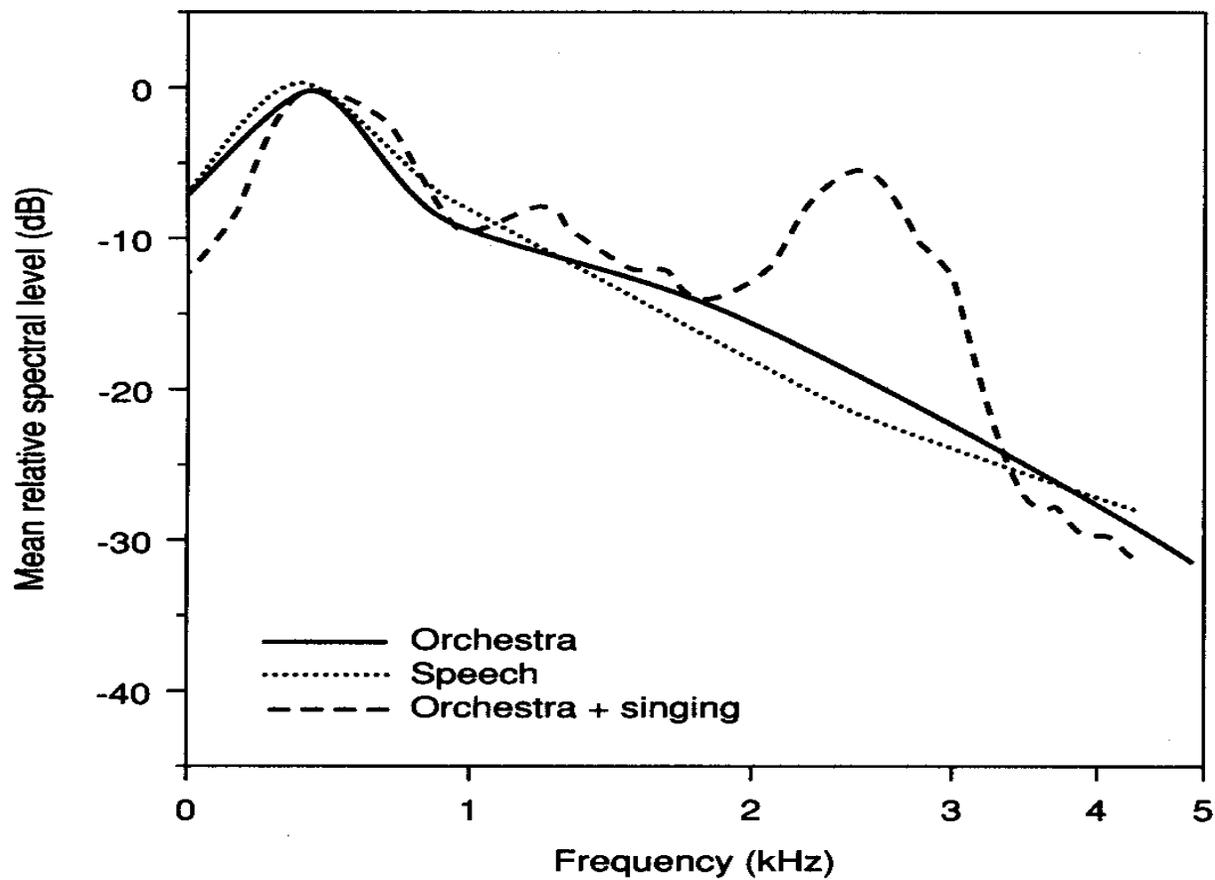
- Lining up formants to partials
 - Enhances intelligibility
 - Maximizes intensity
 - Provides support for vf vibration



30 dB gain:

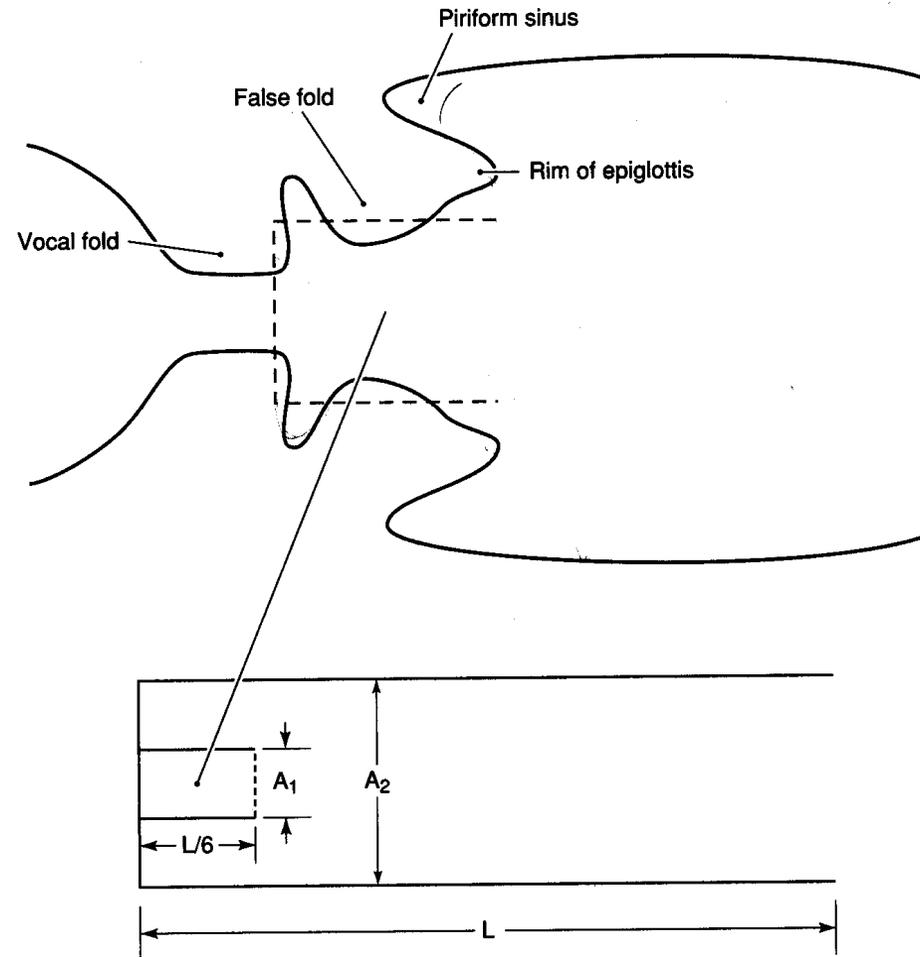


- For male singers, F1 is too high to tune with the F0
- Male solution lies in the ‘Singer’ s Formant’



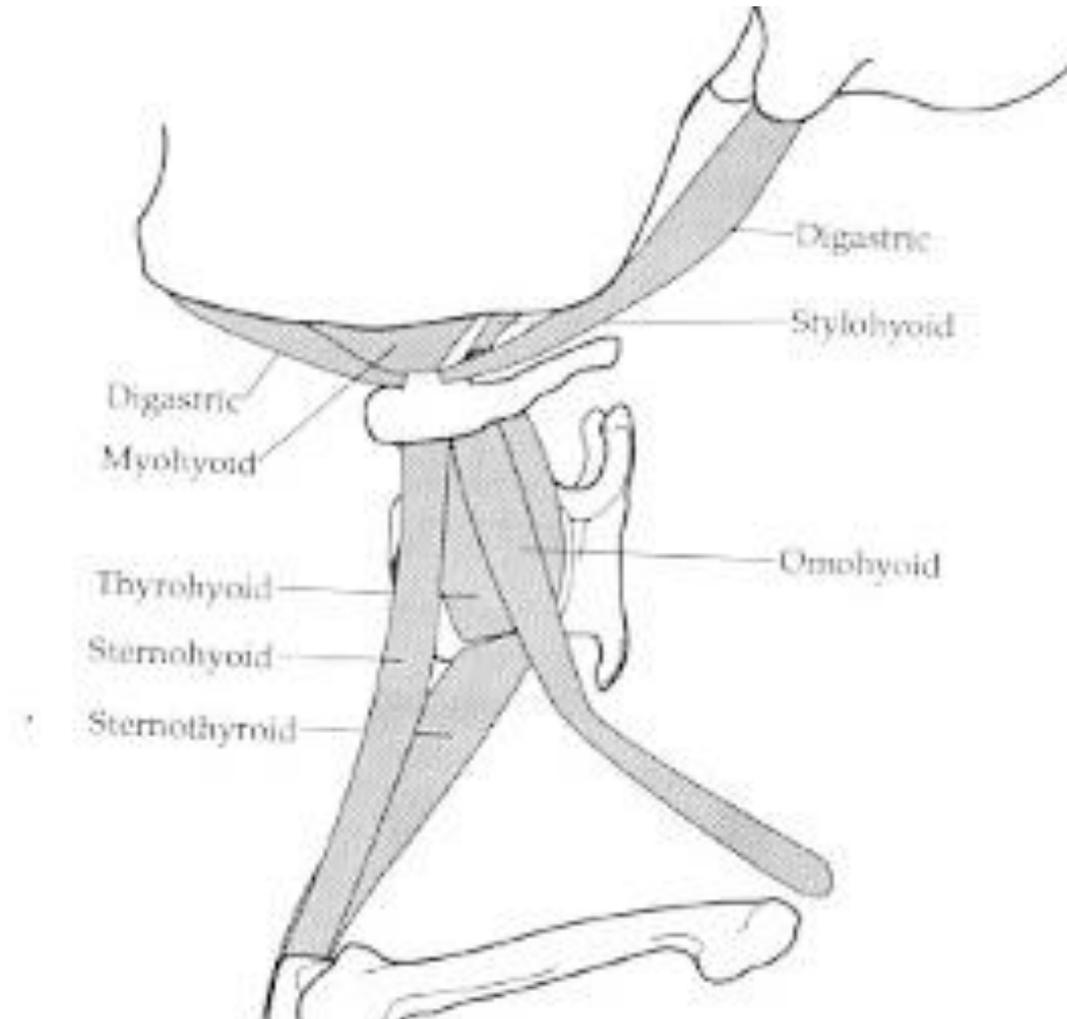
Singer's Formant

- Lowering larynx creates a 1-6 ratio from additus to pharynx
- Clusters F3, F4, and F5



Singer's Formant

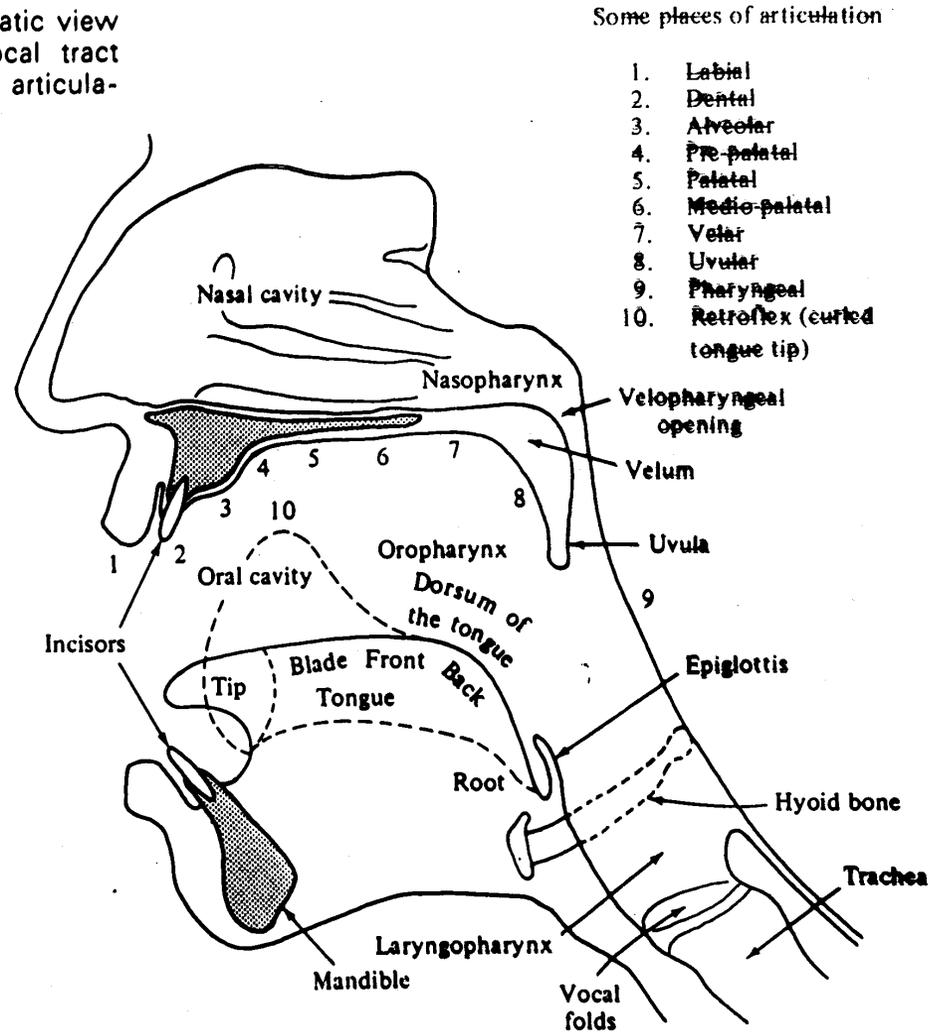
- Created by lowered larynx
- Infrahyoids
- Suprahyoids are dominant in the suspensory system



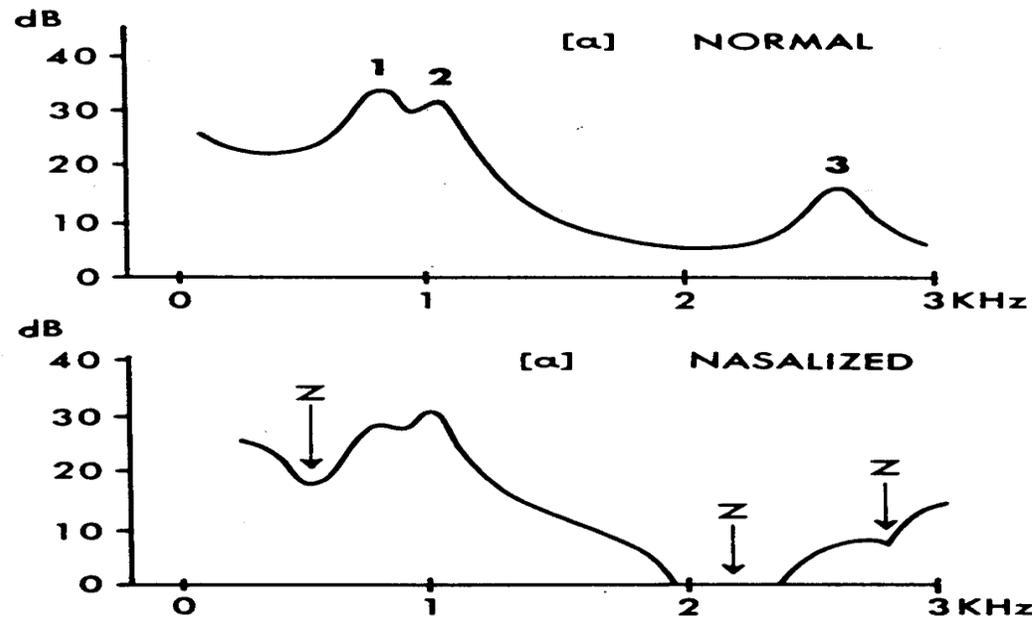
Nasal/Sinus Resonance

- High level of misunderstanding
- *Bel Canto* singing is NEVER nasal
- Some CCM styles use it
- Nasal/Sinus cavities are not ideal resonators.

Figure 5-3 A schematic view of the articulators, vocal tract cavities, and places of articulation.



Nasality: Acoustic 'black holes'



Wooldrige, 1956

- Filled nasal cavity with cotton
- No difference in acoustic signal
- Replicated by Vennard, 1964
- Filled max sinus

