The articulatory system
Chapter 6

Speech Science
COMD 6305/ UTD Callier Center
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STRUCTURE/FUNCTION VOCAL TRACT

CLASSIFICATION OF CONSONANTS AND VOWELS

MORE ON RESONANCE

ACOUSTIC ANALYSIS/ SPECTROGRAMS

SUPRSEGMENTALS, COARTICULATION

Midsagittal dissection

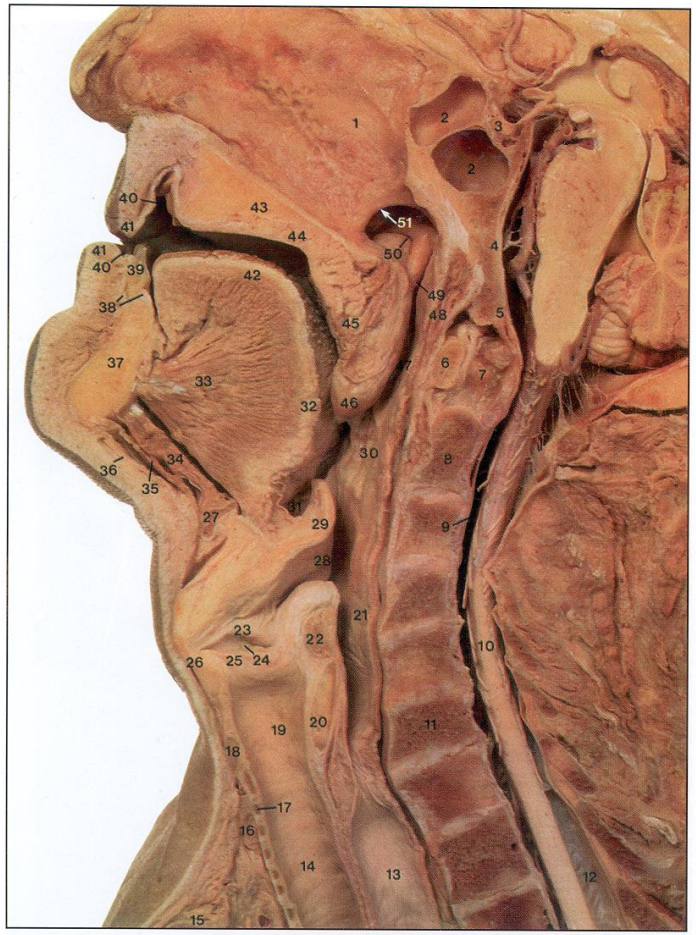
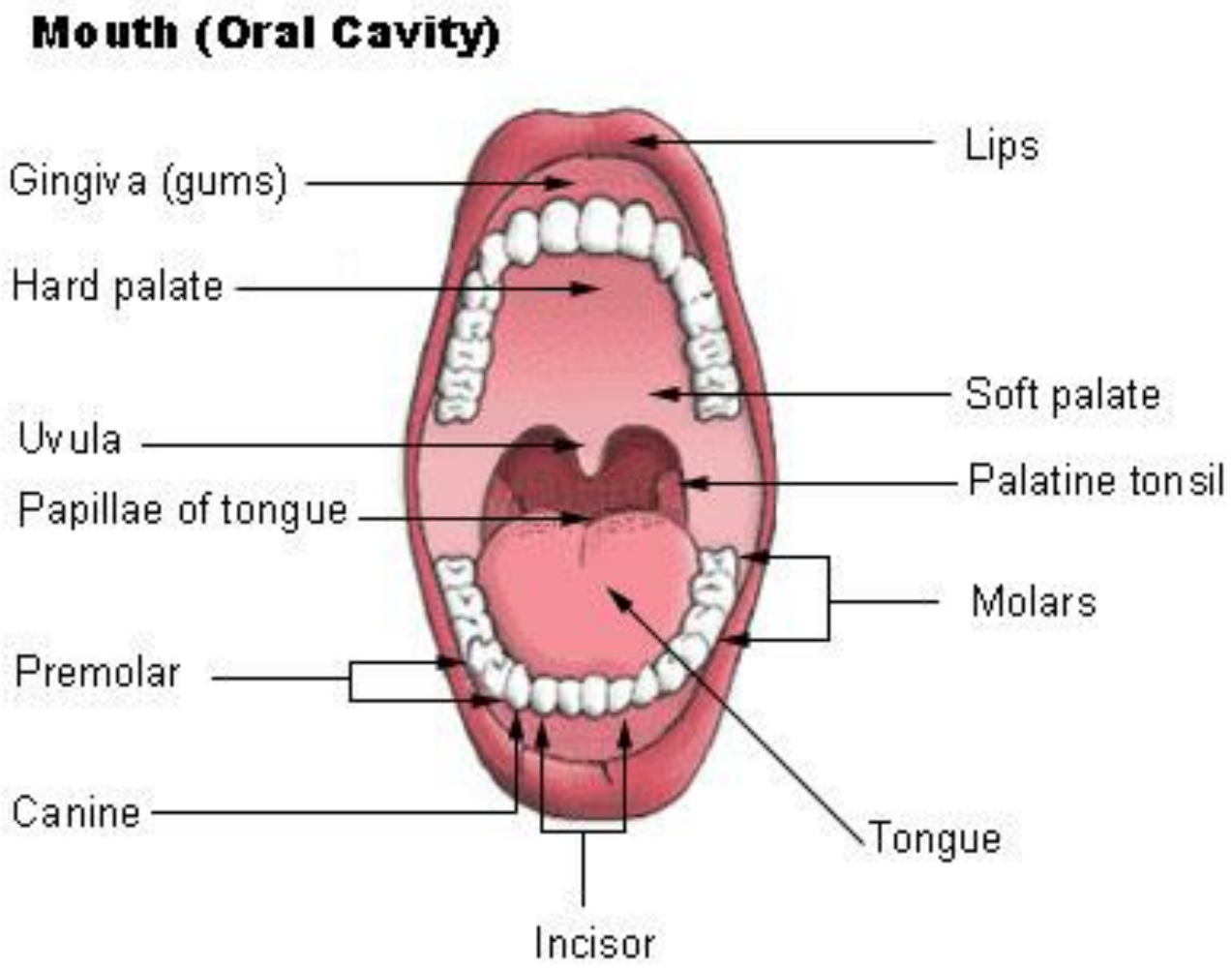


PLATE 9. Upper airway (vocal tract) anatomy, as seen in a dissection of the human head. (From *A Colour Atlas of Head and Neck Anatomy* by R. M. H. McMinn, R. T. Hutchings, & B. M. Logan, 1981, p. 136. London: Wolfe Medical Publications. Reprinted with permission. R. T. Hutchins photo.)

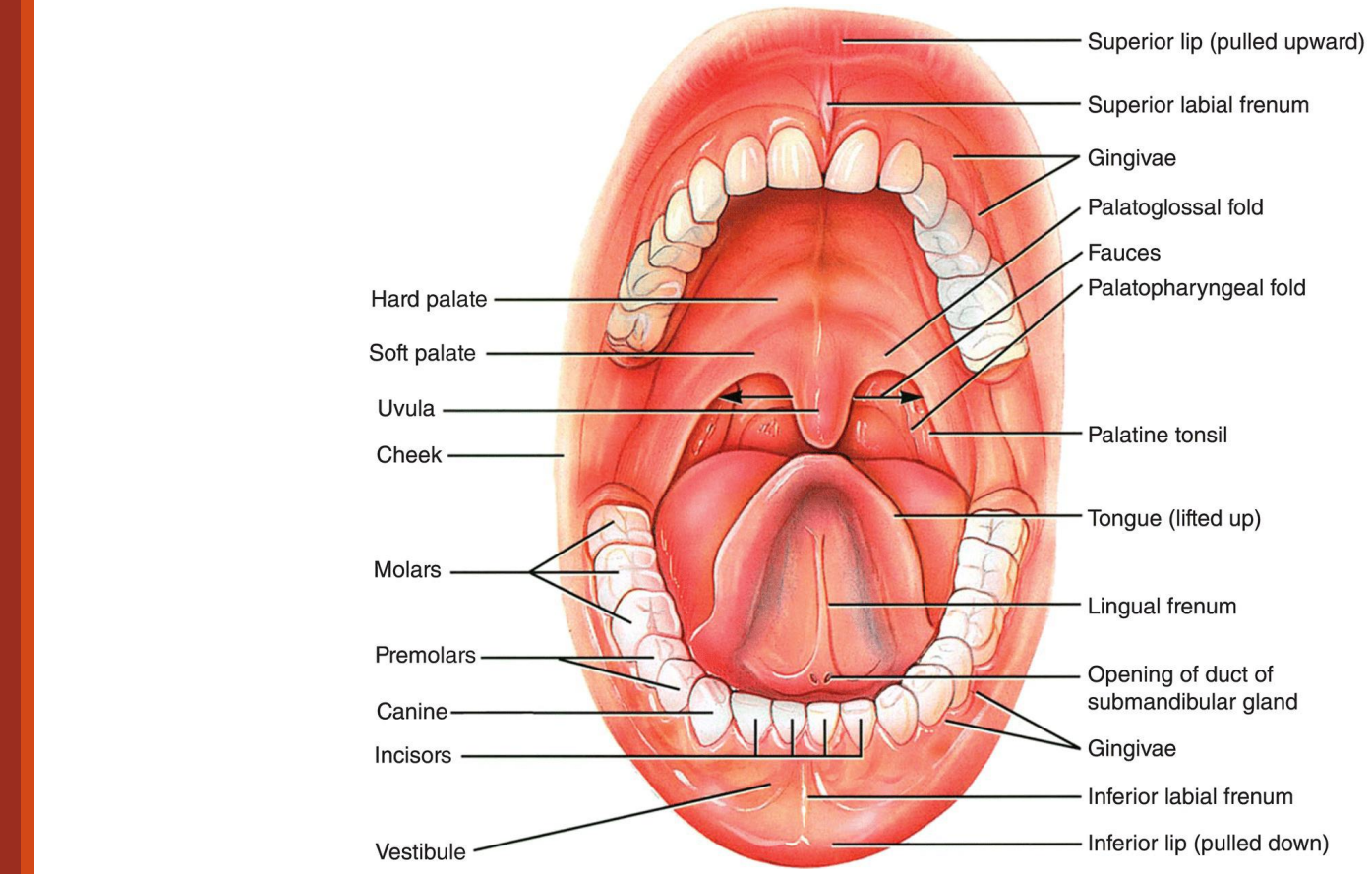
From Kent, 1997


Mouth (Oral Cavity)
Lips
Gingiva (gums)
Hard palate
Soft palate
Uvula
Palatine tonsil
Papillae of tongue
Molars
Premolar
Canine
Tongue
Incisor

Oral Cavity

Oral Structures – continued

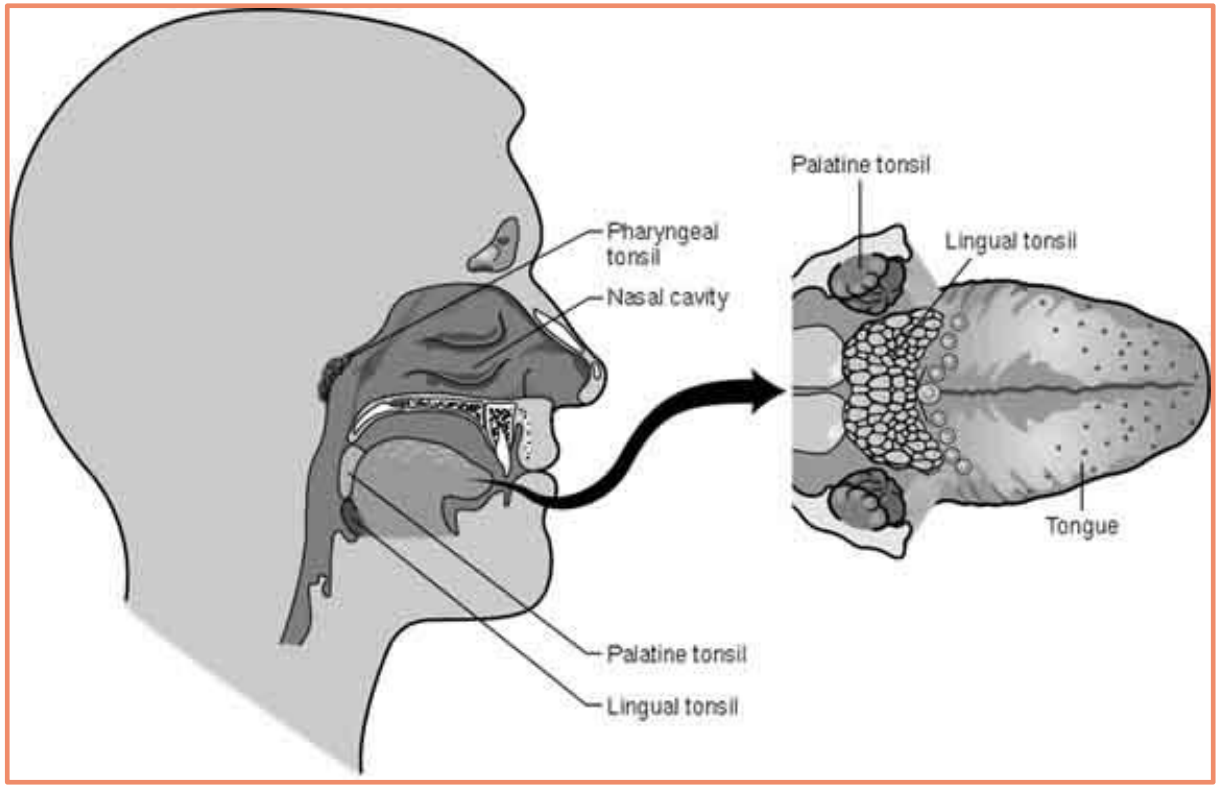
- Moistened by saliva
- Lined by mucosa
- Saliva affected by meds



Tonsils

- PALATINE* (laterally – seen in oral periph
- LINGUAL (inf.- root of tongue)
- ADENOIDS (sup.) [= pharyngeal]
- Palatine, lingual tonsils are larger in children

- *removed in *tonsillectomy*



Adenoid Facies

- Enlargement from infection may cause problems (adenoid facies)
- Can cause problems with nasal sounds or voicing
- Adenoidectomy; also tonsillectomy (for palatine tonsils)

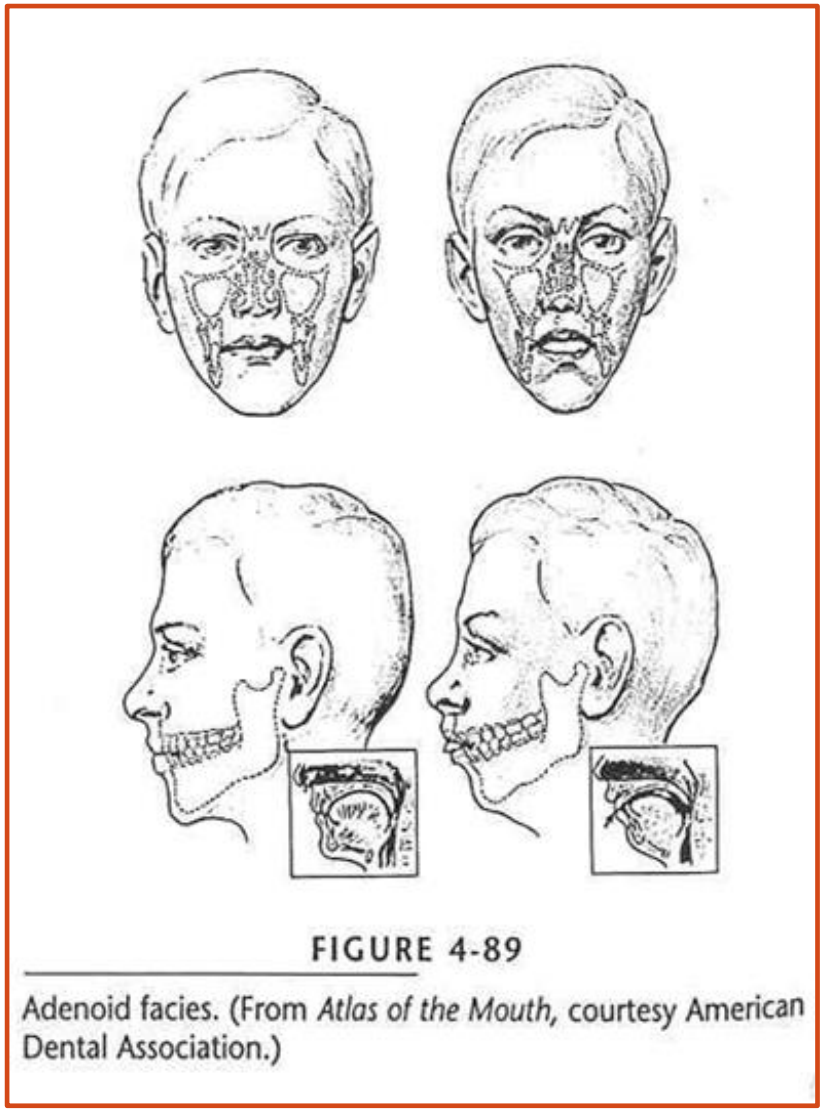


FIGURE 4-89

Adenoid facies. (From *Atlas of the Mouth*, courtesy American Dental Association.)

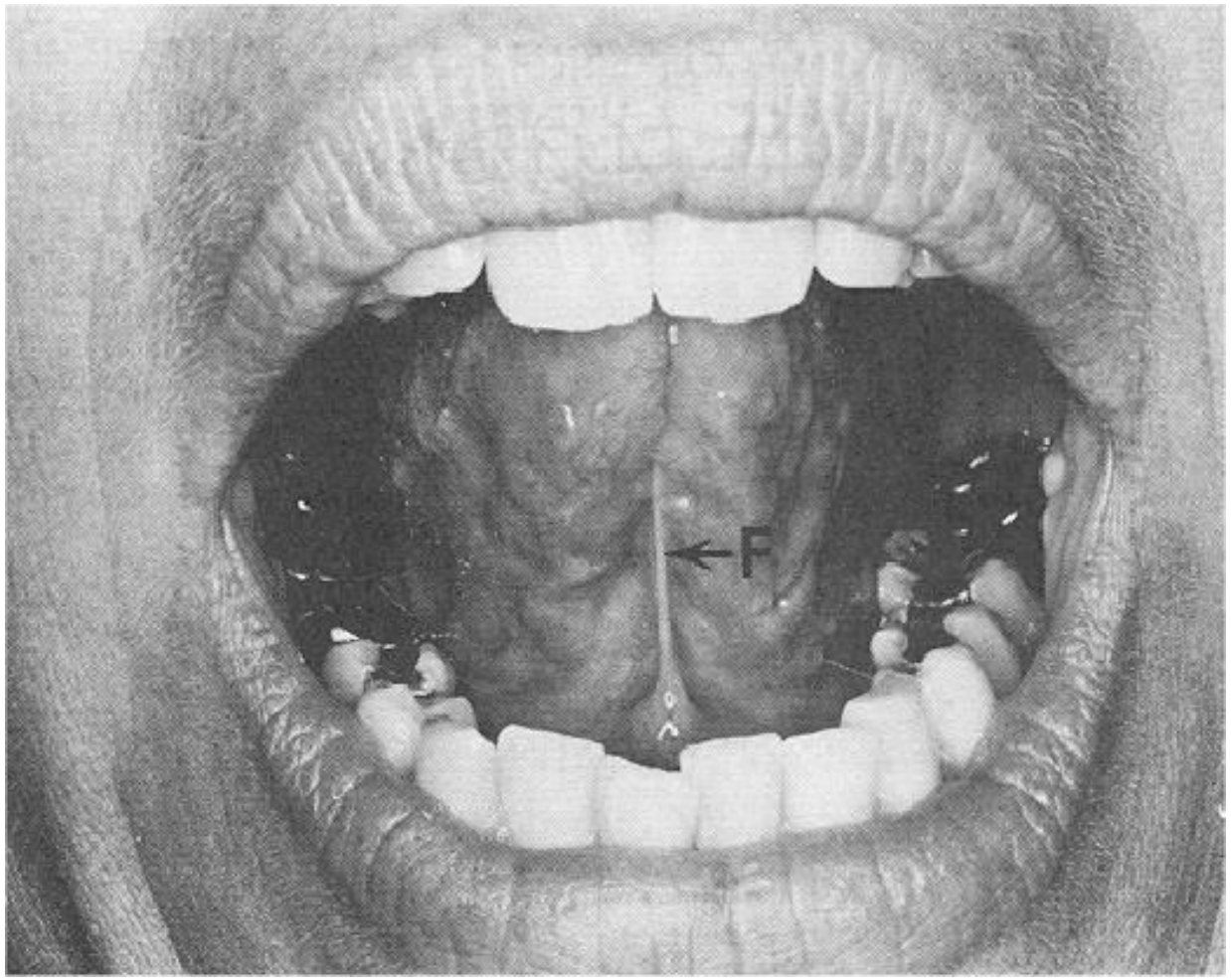
Adenoid faces (example)

Oral structures - frenulum

Important component of oral periphery exam

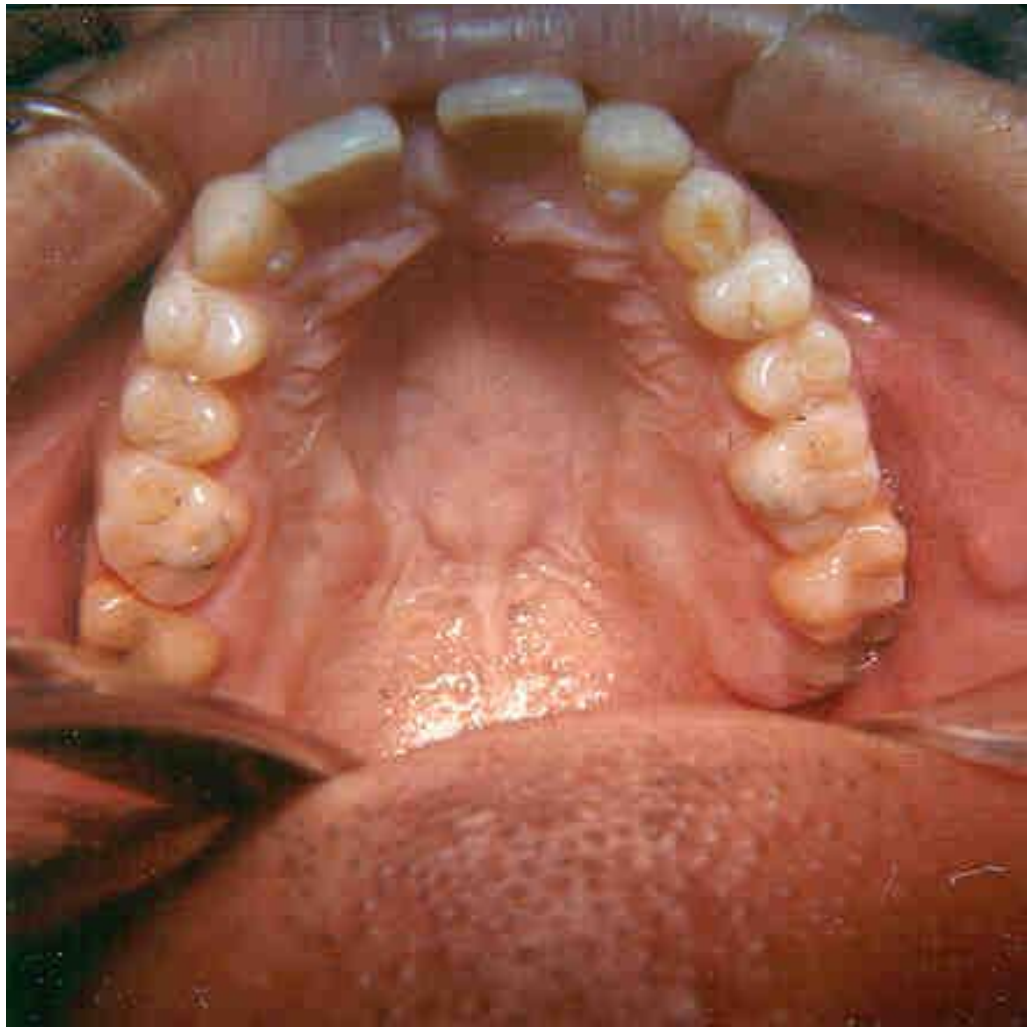
Lingual frenomy – for *ankyloglossia* “tongue-tie”

Some doctors will snip for infants, but often will loosen by itself



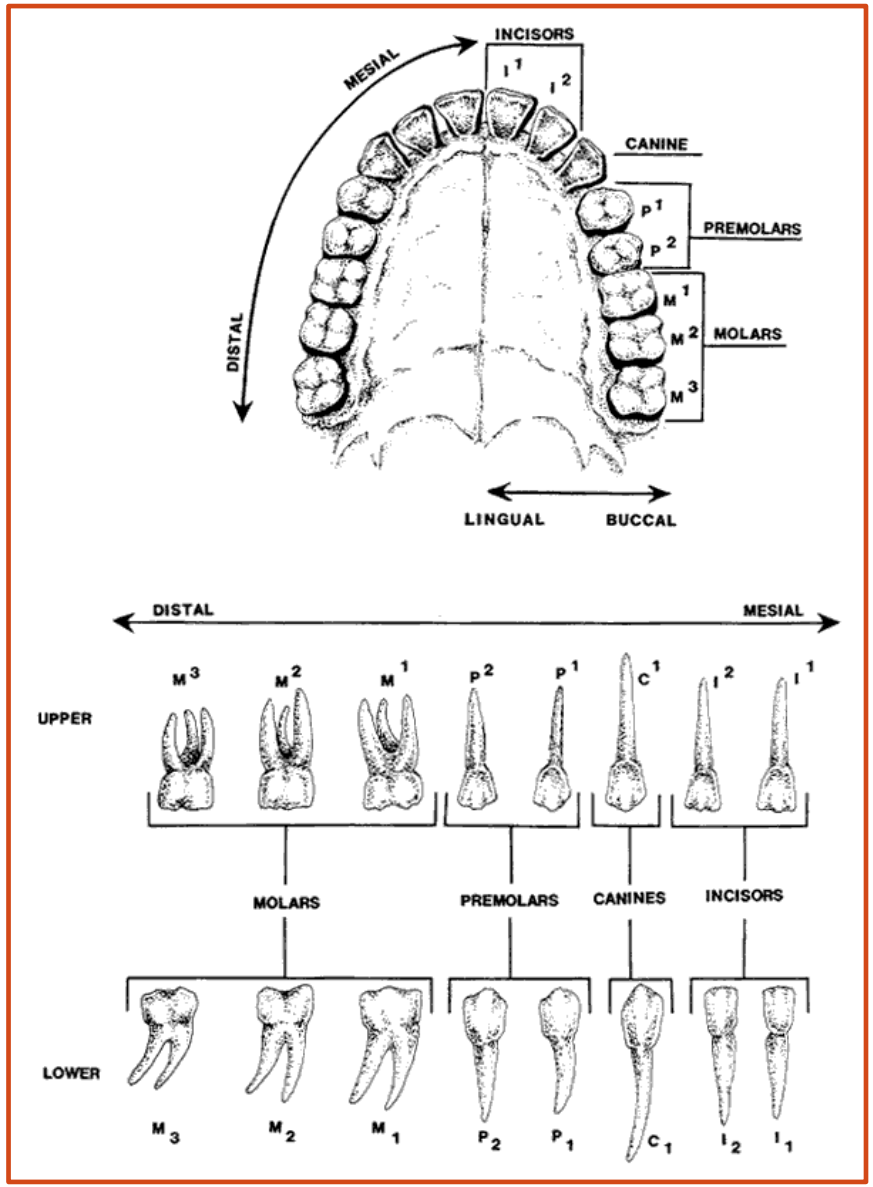
Hard Palate

Much variability in palate shape and height



Very high vault

Teeth


INCISORS
I 1
I 2
CANINE
P 1
P 2
PREMOLARS
M 1
M 2
M 3
MOLARS
MESIAL
DISTAL
LINGUAL
BUCCAL
DISTAL
MESIAL
UPPER
M 3
M 2
M 1
P 2
P 1
C 1
I 2
I 1
MOLARS
PREMOLARS
CANINES
INCISORS
LOWER
M 3
M 2
M 1
P 2
P 1
C 1
I 2
I 1

Dentition - details

Primary (deciduous, milk teeth)

n=20:

- 2 incisor
- 1 canine
- 2 molar

Just for “fun” – baby teeth pushing in!

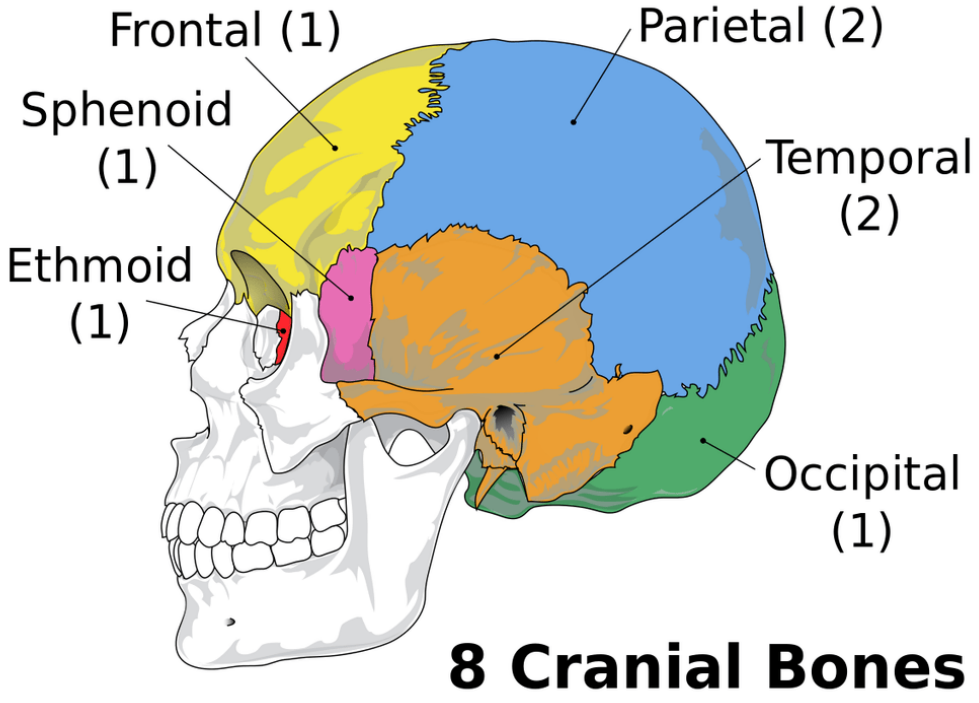
Secondary (permanent)

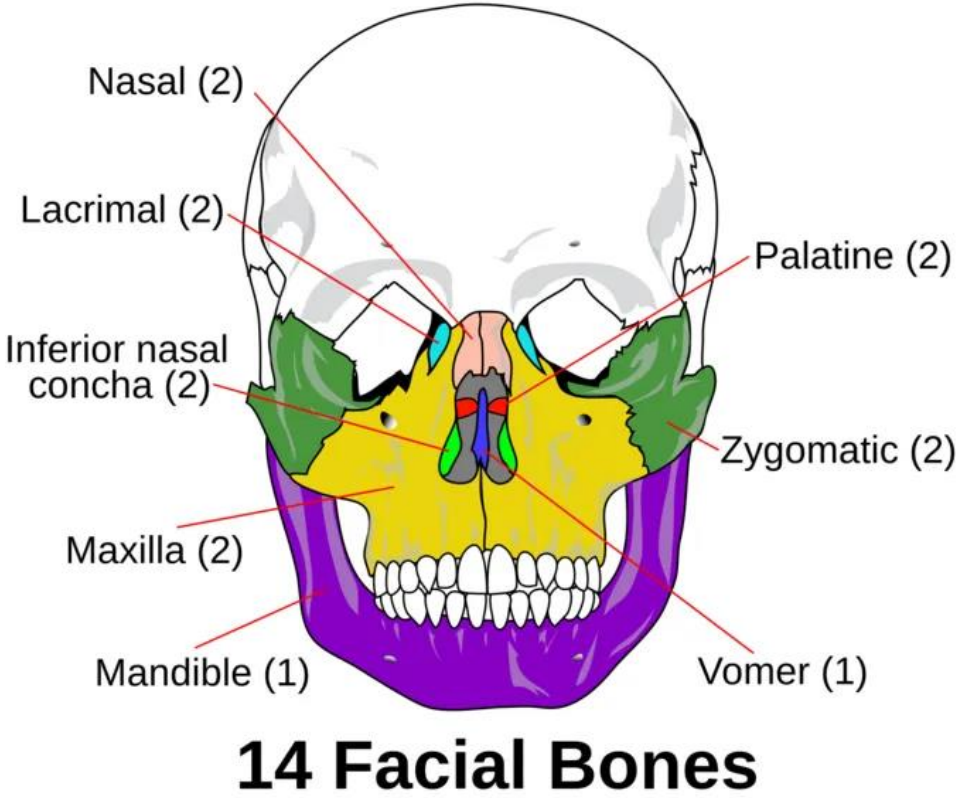
n=32:

- 4 incisor
- 2 canine
- 4 premolar (bicuspid)
- 6 molar

NOTE: x 2 for upper and lower

The skull


Frontal (1)
Parietal (2)
Sphenoid (1)
Temporal (2)
Ethmoid (1)
Occipital (1)
8 Cranial Bones


Nasal (2)
Lacrimal (2)
Palatine (2)
Inferior nasal concha (2)
Zygomatic (2)
Maxilla (2)
Mandible (1)
Vomer (1)
14 Facial Bones

Fun facts about the skull

Forensics:

Male skulls are heavier, larger, and thicker than female skulls.

The skull of a female is rounded with less protruded mandible.

The shape and size of the skull differ in every ethnic group.

Every human skull has fractals or sutures.

An average of 785 pounds is needed to crush a human skull.

Types of malocclusion

- Angle's classification:
- I, II, III
- Also, individual teeth can be misaligned (e.g. labioversion)

Also
"Neutrocclusion/ distocclusion/mesiocclusion"

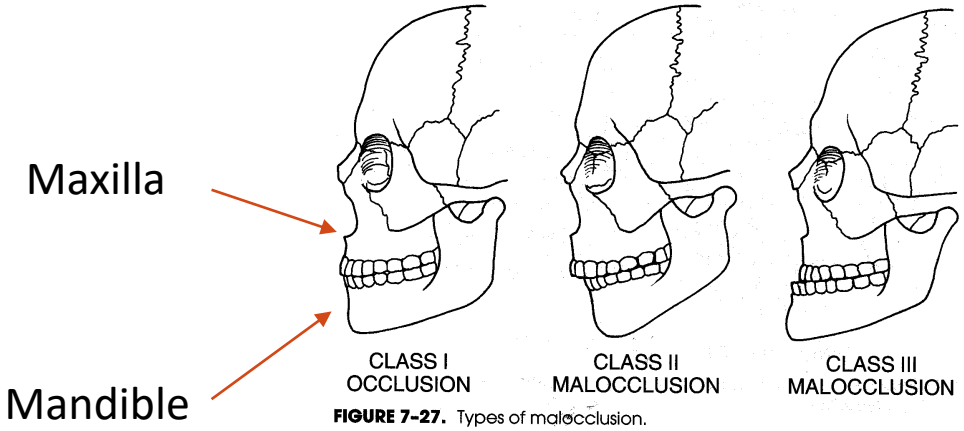
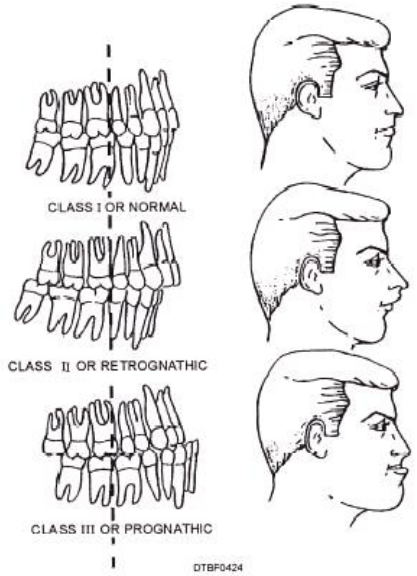


FIGURE 7-27. Types of malocclusion.



Mandible Action

- Primary movements are elevation and depression
- Also…. protrusion/retraction
- Lateral grinding motion

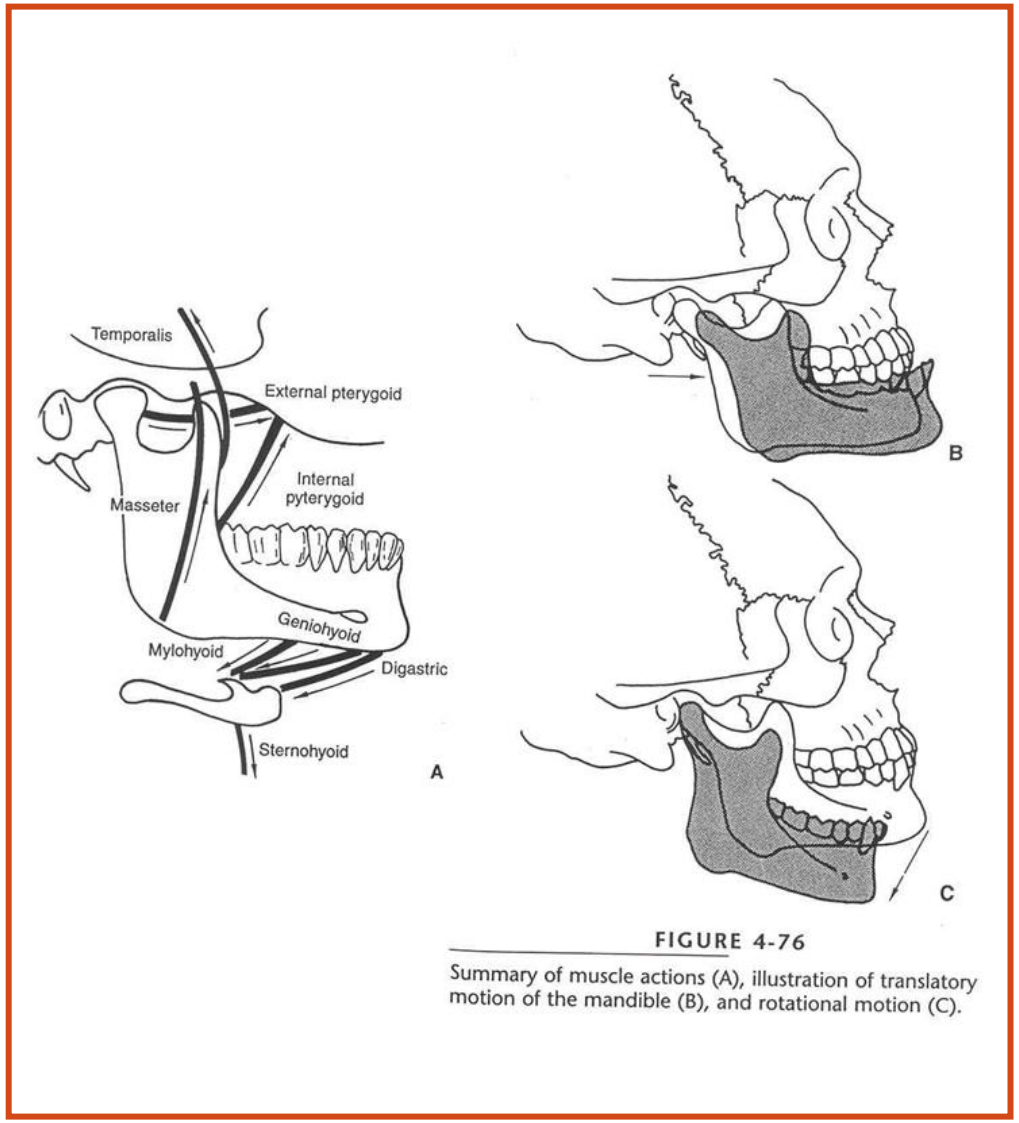
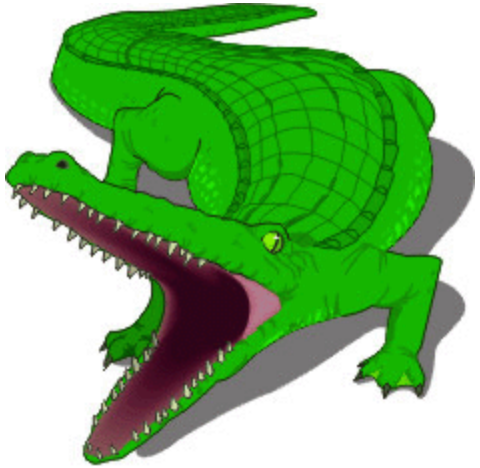


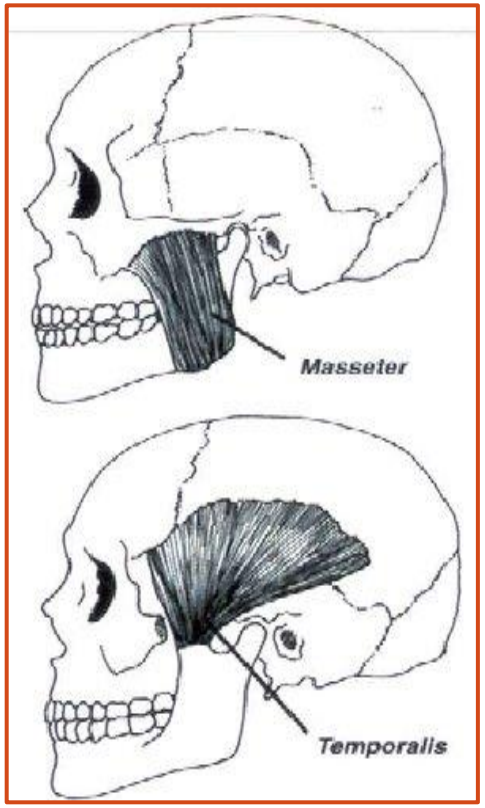
FIGURE 4-76

Summary of muscle actions (A), illustration of translatory motion of the mandible (B), and rotational motion (C).

Muscles of Jaw Elevation

Like alligators, we are much stronger at jaw elevation (closing to head) than depression





Jaw Muscles

ELEVATORS

- Temporalis ✓
- Masseter ✓
- Internal (medial) Pterygoid ✓
- *Masseter and IP part of "mandibular sling"*

DEPRESSORS

- Mylohyoid ✓
- Geniohyoid✓
- Anterior belly of the digastric *(-Kent)*
- External (lateral) pterygoid(?)-- also protrudes and rocks side to side..
- Platysma (plate-like ext. neck muscle)

Muscles of Jaw Elevation - continued

Internal pterygoid (*wing-like*); second component of mandibular sling

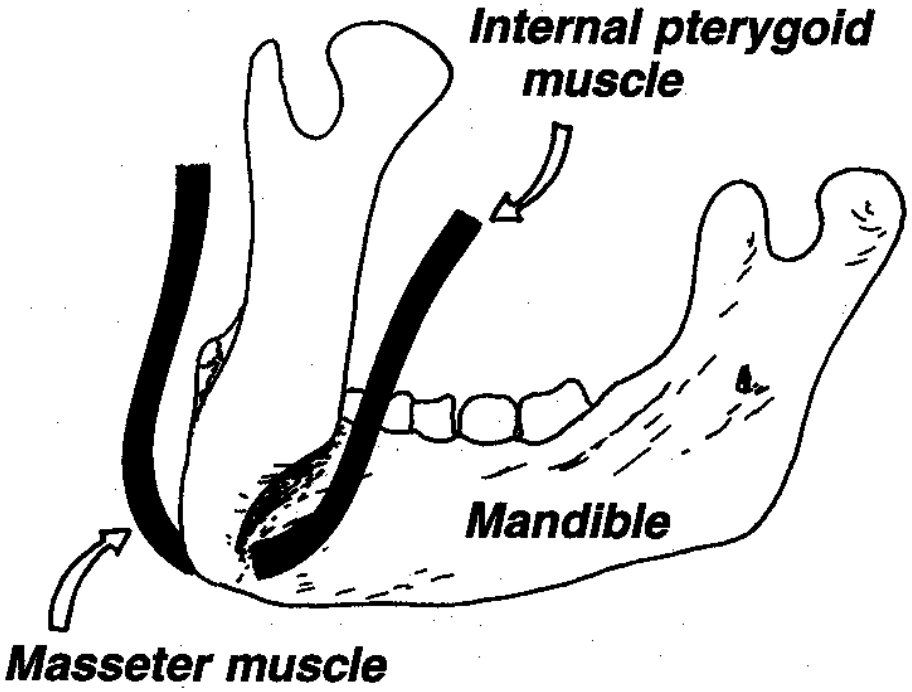


Figure 5–30. Illustration of how the masseter and internal pterygoid muscles form a sling for mandibular elevation.

Muscles of Jaw Depression

- Mylohyoid - forms floor of mouth
- Digastric has two ‘bellies’ -- inserts on a tendon which attaches to the hyoid

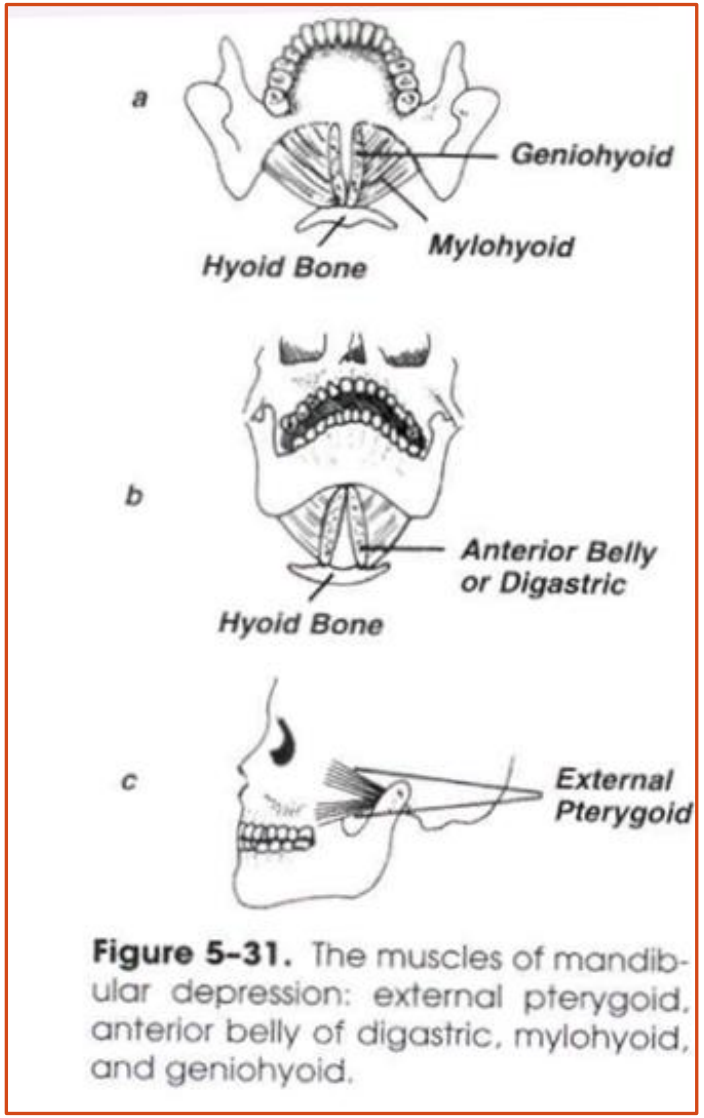


Figure 5–31. The muscles of mandibular depression: external pterygoid, anterior belly of digastric, mylohyoid, and geniohyoid.

The tongue – functional divisions

A muscular ‘hydrostat’

Parts:

- Body
- Root
- Dorsum
- Tip
- Blade

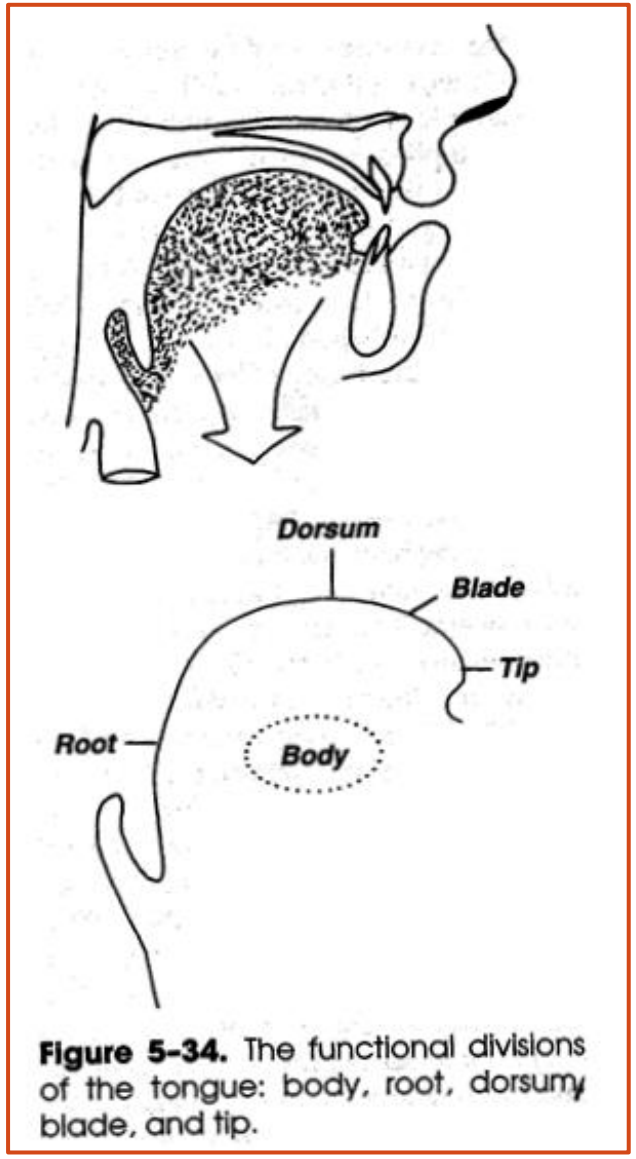
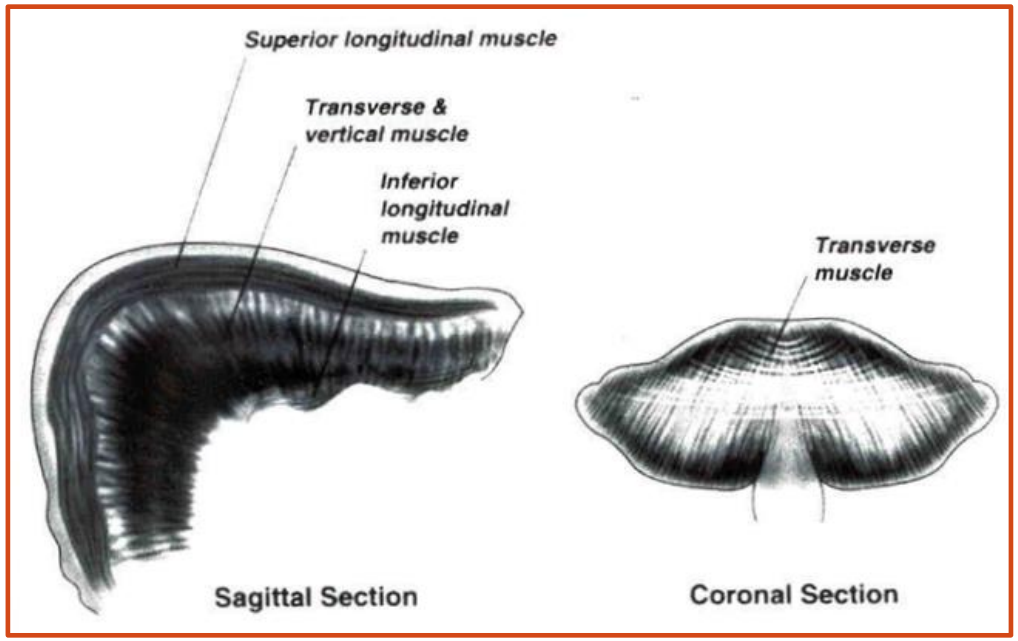
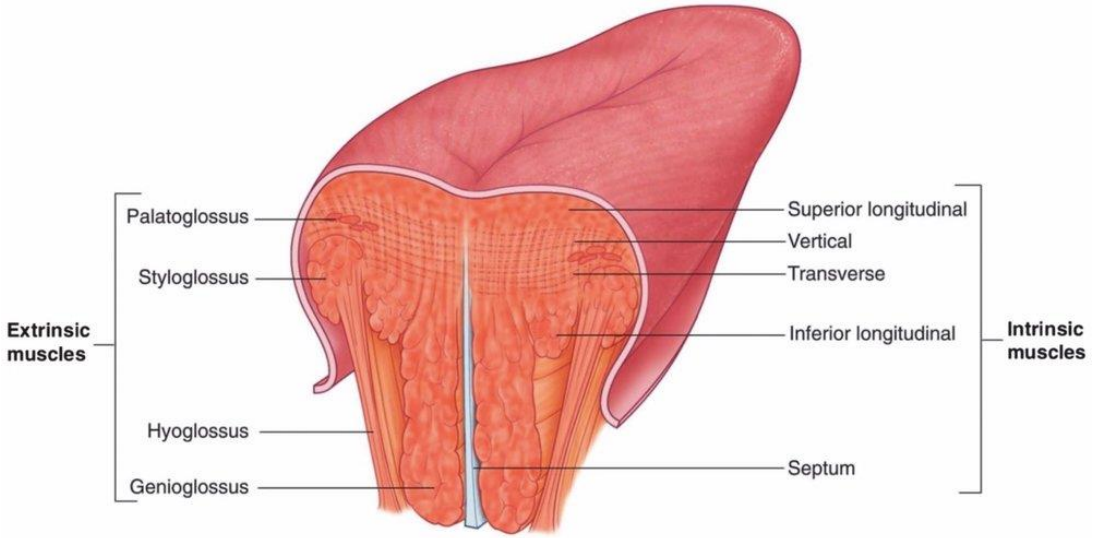


Figure 5-34. The functional divisions of the tongue: body, root, dorsum, blade, and tip.

Intrinsic Muscles of the Tongue

- 4 total
- Involved in fine movements and delicate adjustment of shape and position





- Andreas Astier

Extrinsic muscles of the Tongue

- Genioglossus
- Hyoglossus
- Palatoglossus
- Styloglossus

- *Palatopharyngeal muscle* =
- posterior faucial pillar- later…

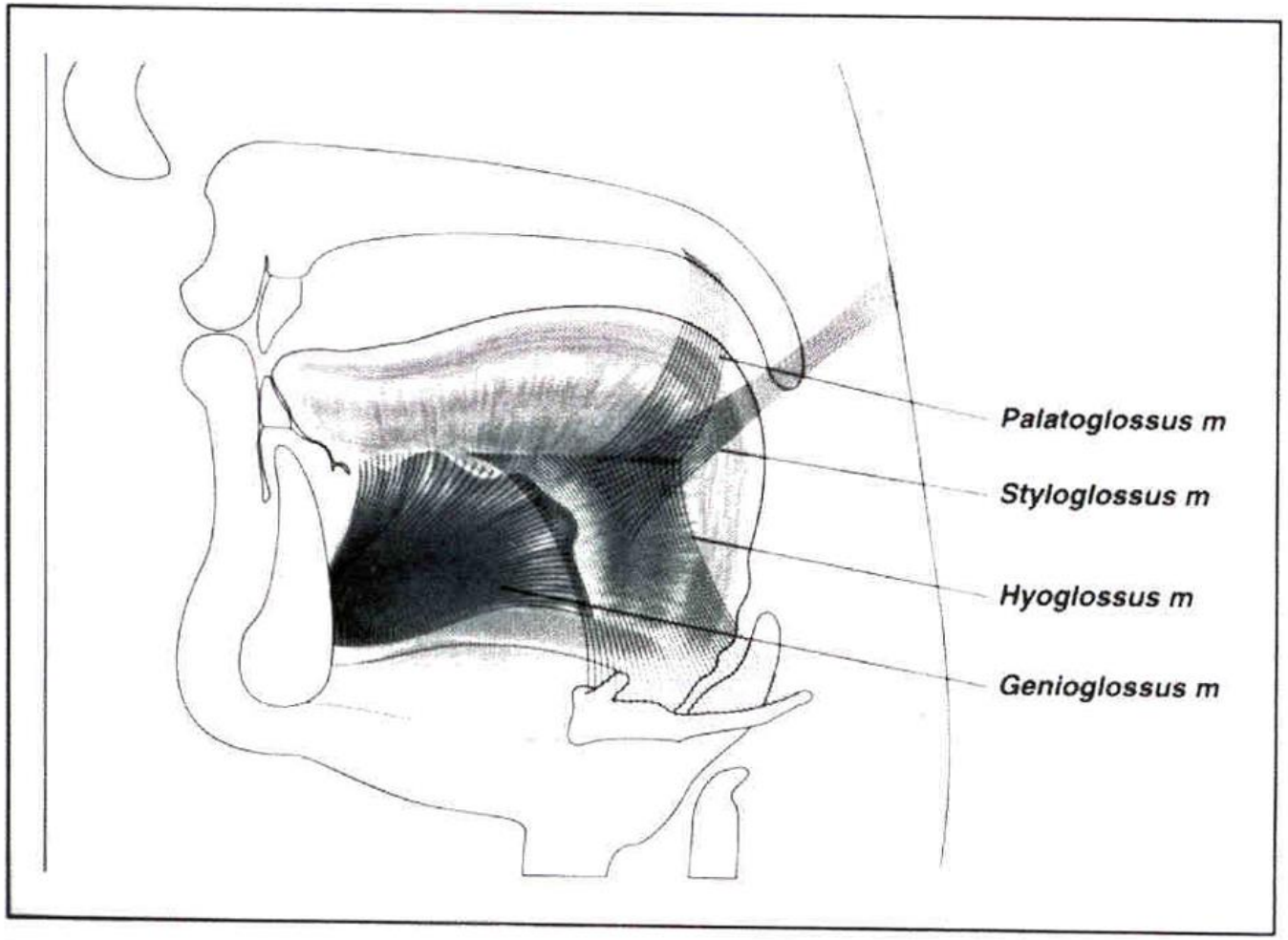


Figure 5–36. The extrinsic muscles of the tongue: palatoglossus, styloglossus, hyoglossus, and genioglossus

Genioglossus

Largest extrinsic lingual muscle

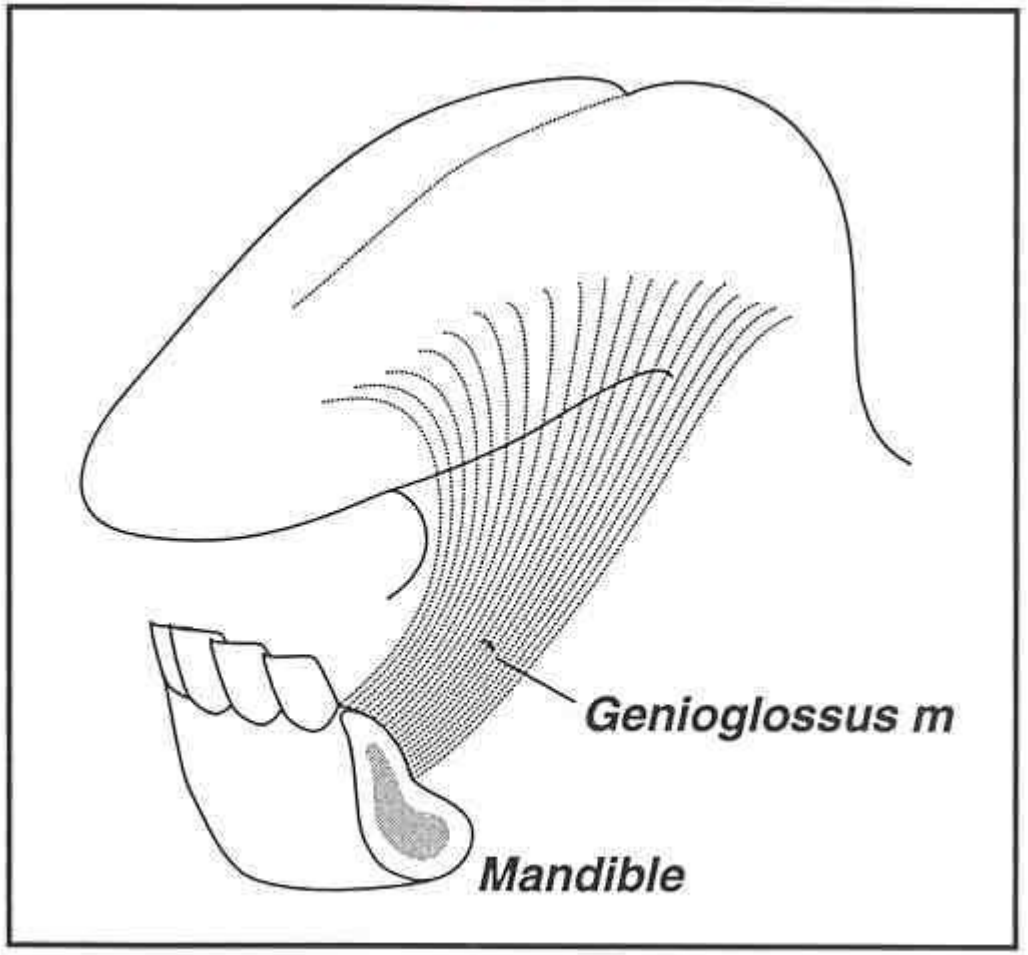


Figure 5–39. The genioglossus muscle.

Hyoglossus

- Origin on hyoid
- Inserts onto body of tongue

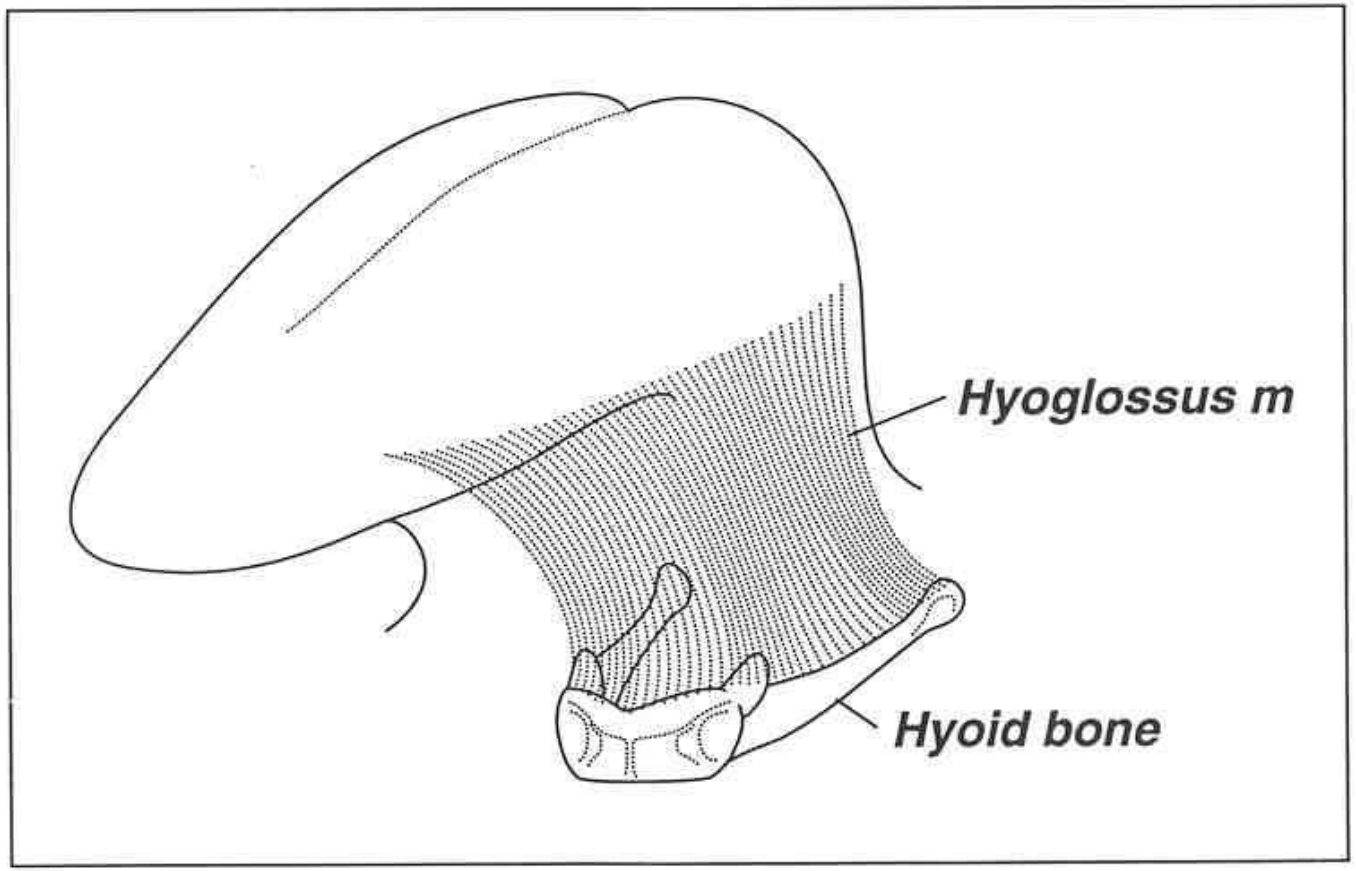


Figure 5–40. The hyoglossus muscle.

Palatoglossus Muscle

- (or *Glossopalatine*)
- Slinglike
- Forms anterior faucial pillar

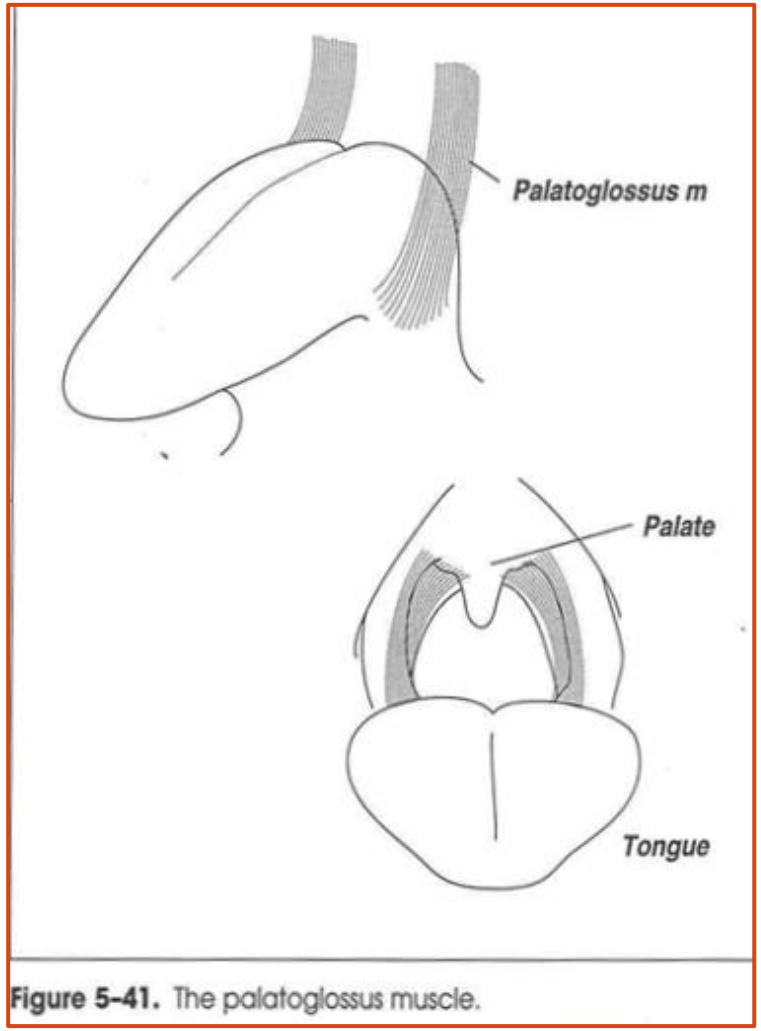


Figure 5-41. The palatoglossus muscle.

Styloglossus

- Origin: Styloid process of temporal bone
- Sling-like movement upwards and backwards

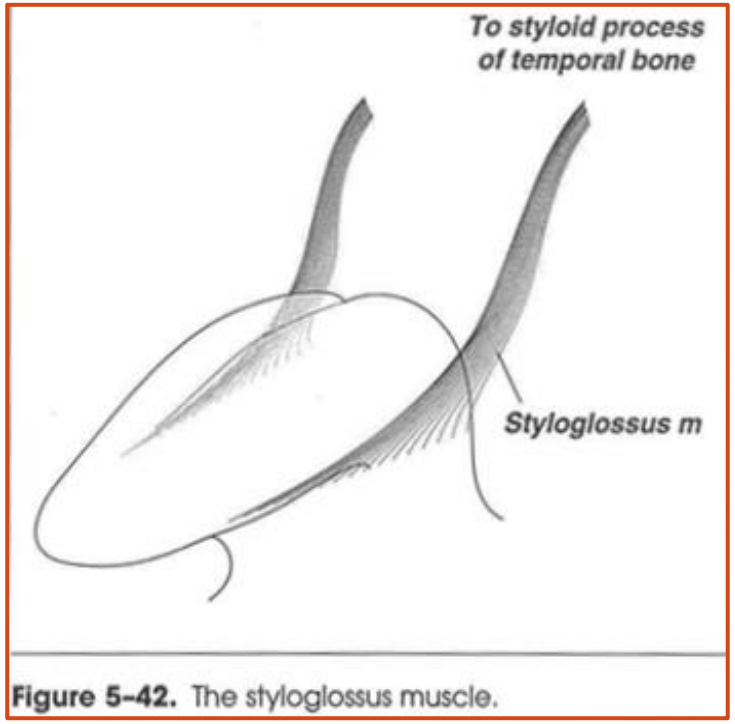


Figure 5–42. The styloglossus muscle.

Lips and Face

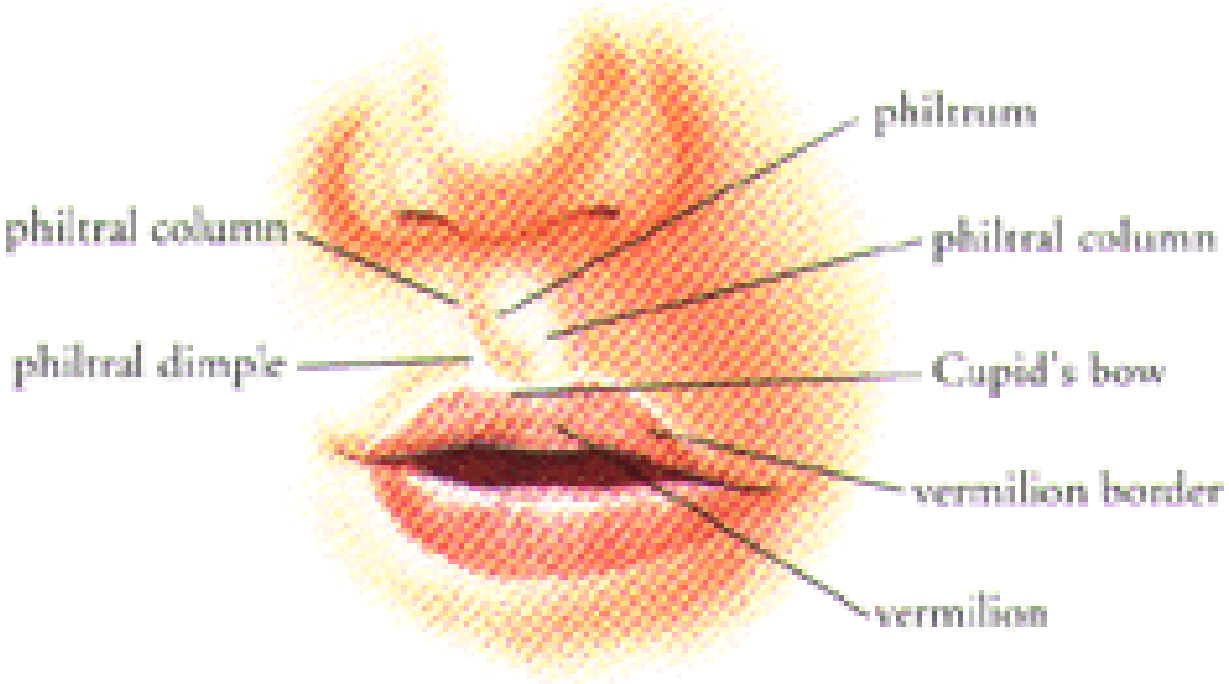
Lips

- Very involved in speech
- Sphincteric muscle (with variable opening)
- *Orbicularis oris* (no definite origin or insertion)

Face

- "Muscles of facial expression"
- Generally not involved in speech, except those that comprise or involve the lips

Lips


philtrum
philtral column
philtral column
philtral dimple
Cupid's bow
vermilion border
vermilion

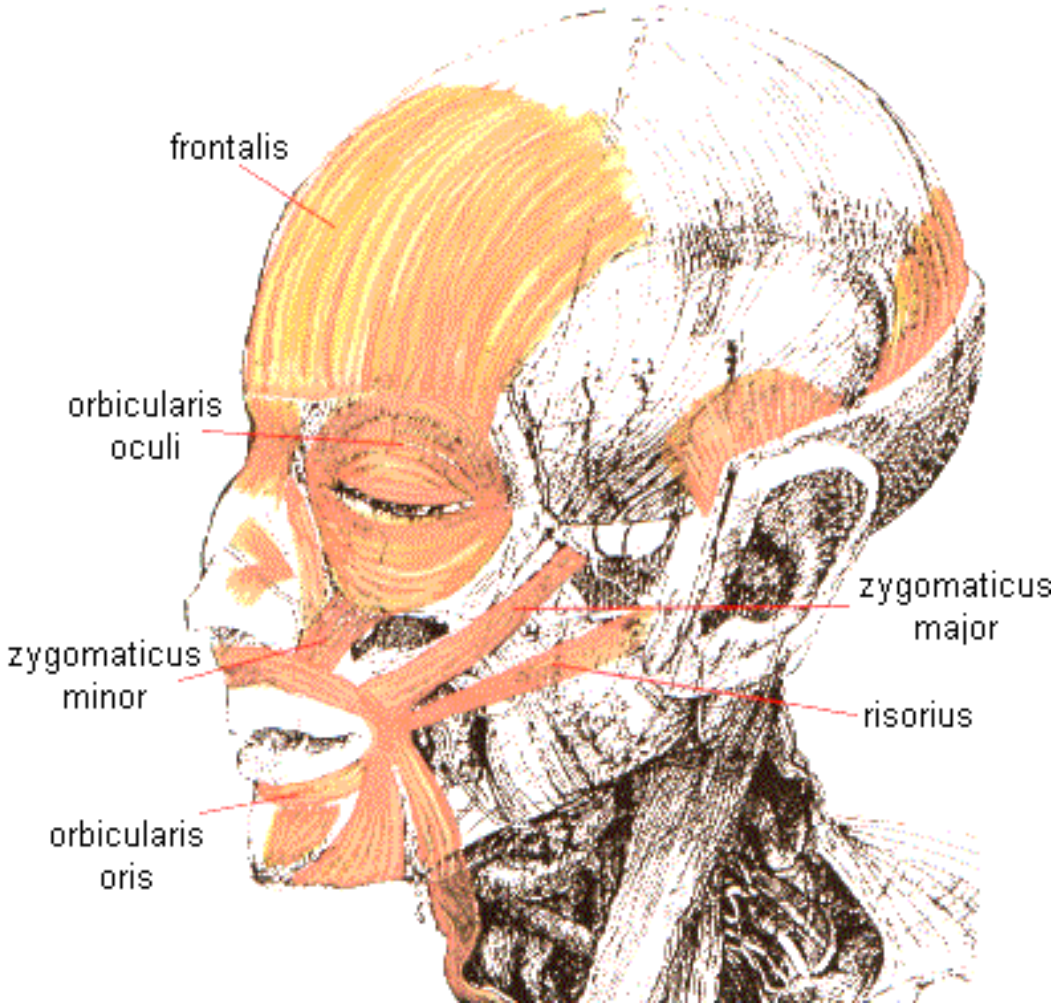
Lip Rounding

- The *orbicularis oris* can extend vocal tract by approx. 1.5 cm

- Drives down all formant frequencies; changes sound quality

Facial Muscles

Overview – details follow for your convenience, but we will not be tested on them



Extrinsic Facial Muscles

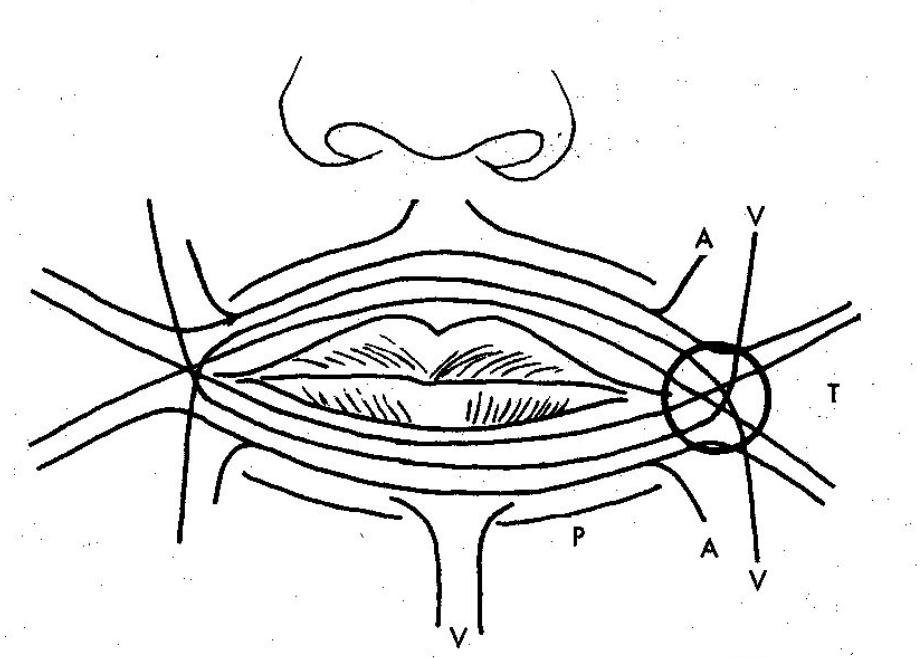
Four main sets:

1.**Transverse** (horizontal)

2. **Angular** (slanting to the corners of the mouth)

3. **Labial** (vertical)

4. **Parallel** (..to lips)



1. Transverse facial Muscles

- Buccinator (*Bugler's muscle*); pulls corners laterally
- Risorius (*muscle of laughing*); draws mouth angle laterally

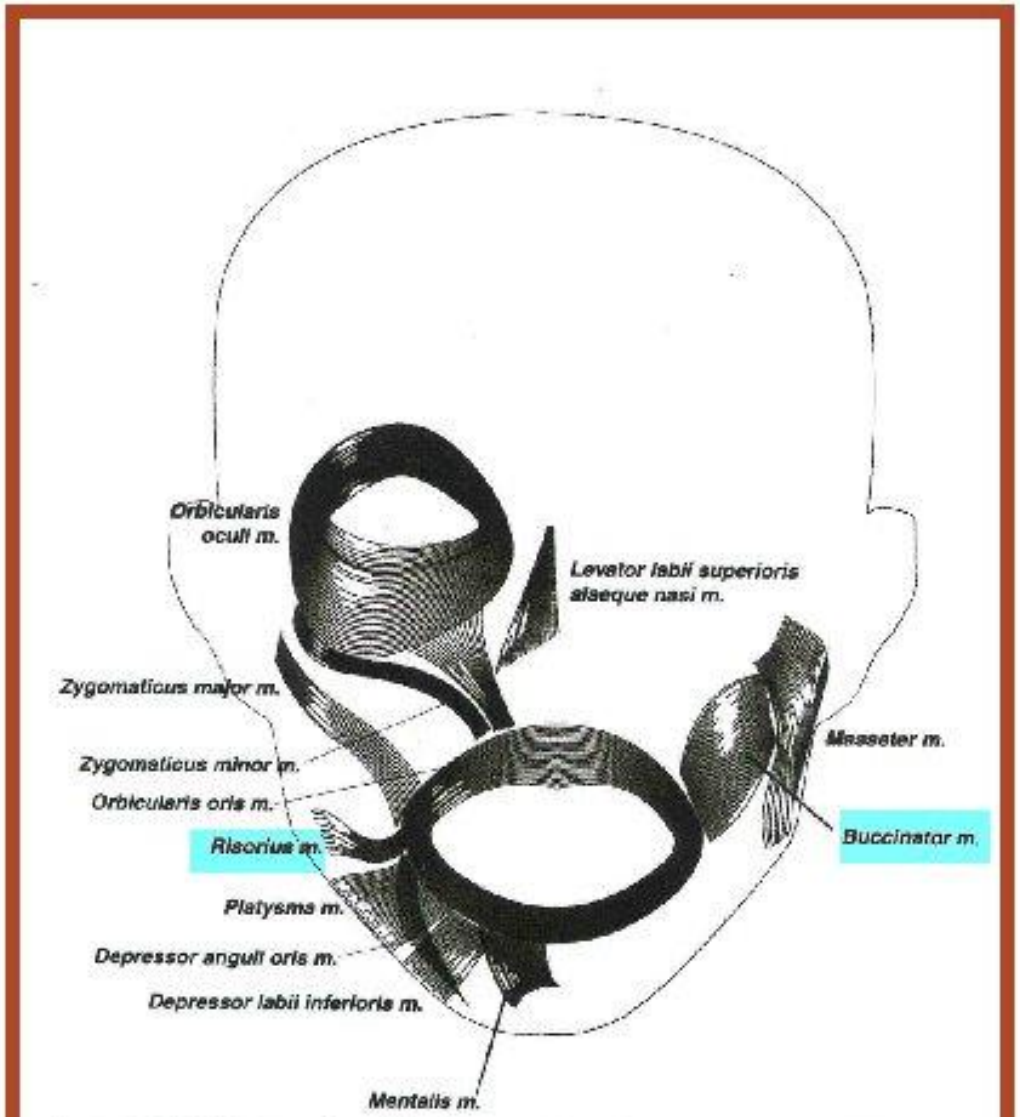


Figure 5–44. The muscles of the lips and face shown in a schematic anterior view.

2. Angular facial Muscles

Levator labii sup. Alaeque nasi (dilates nostrils or elevates upper lip)

Zygomatic - assoc. with broad smile *(shown in next slide)*

Depressor labii inf. - pulls LL down and lateral

Levator labii sup.* (turning lip inside out) shown in next slide..

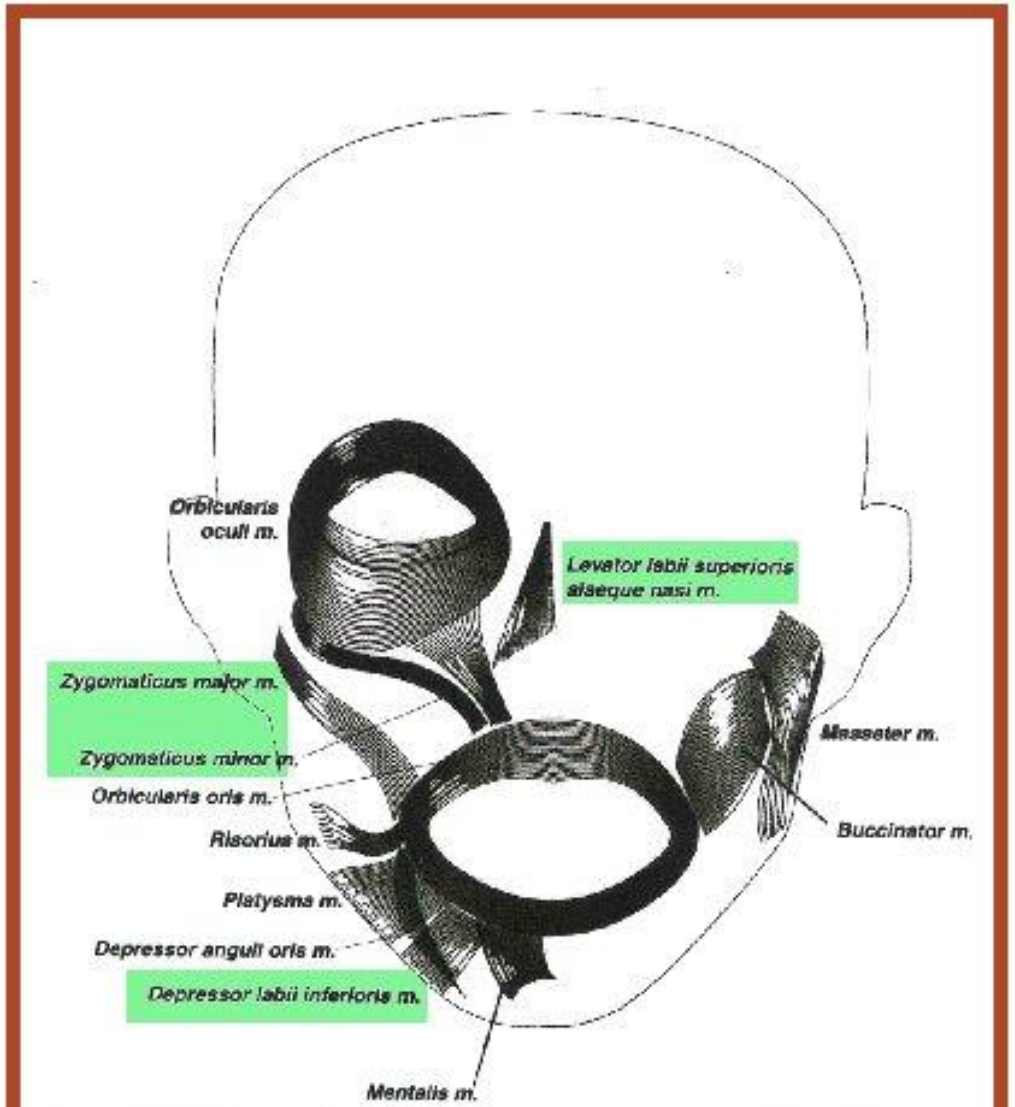


Figure 5–44. The muscles of the lips and face shown in a schematic anterior view.

3. Vertical facial Muscles

- Mentalis - everts LL or wrinkles the chin
- Depressor anguli oris - helps compress lips by pulling UL towards LL
- Levator anguli oris* -pulls LL towards UL

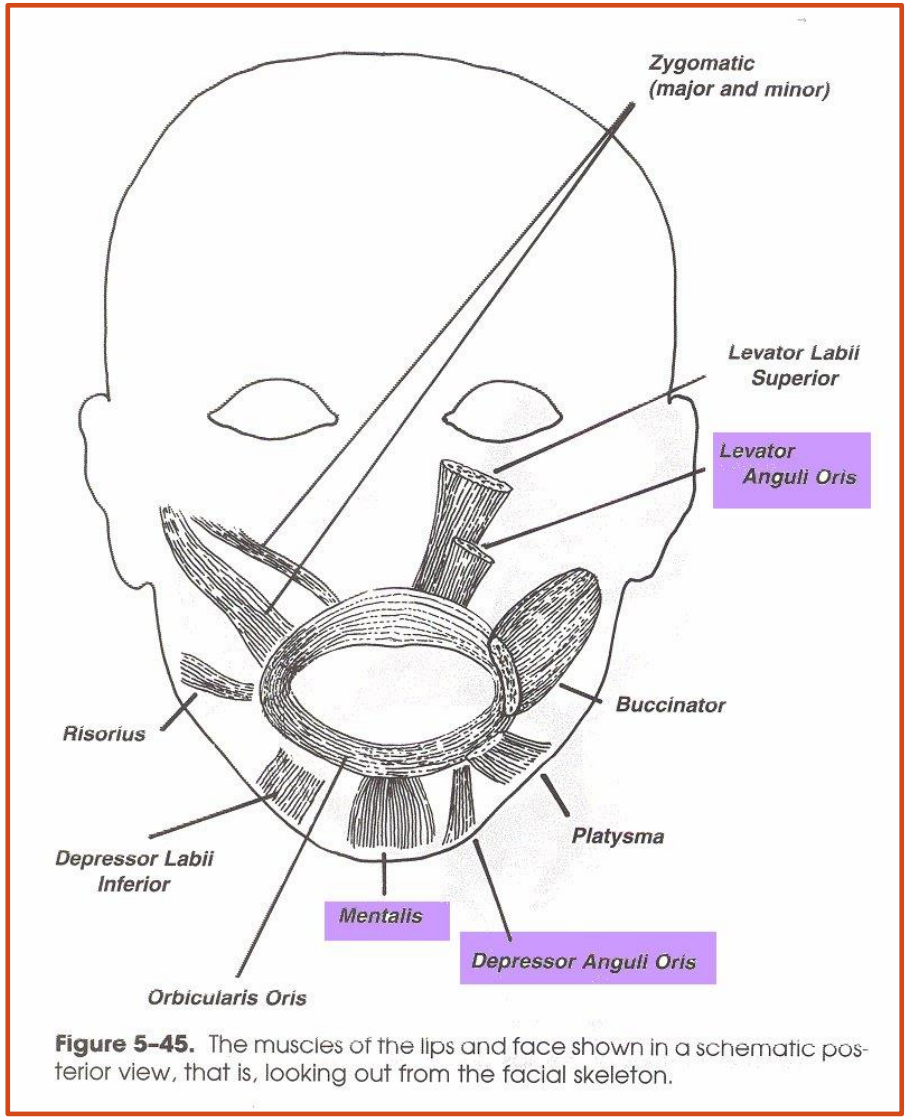
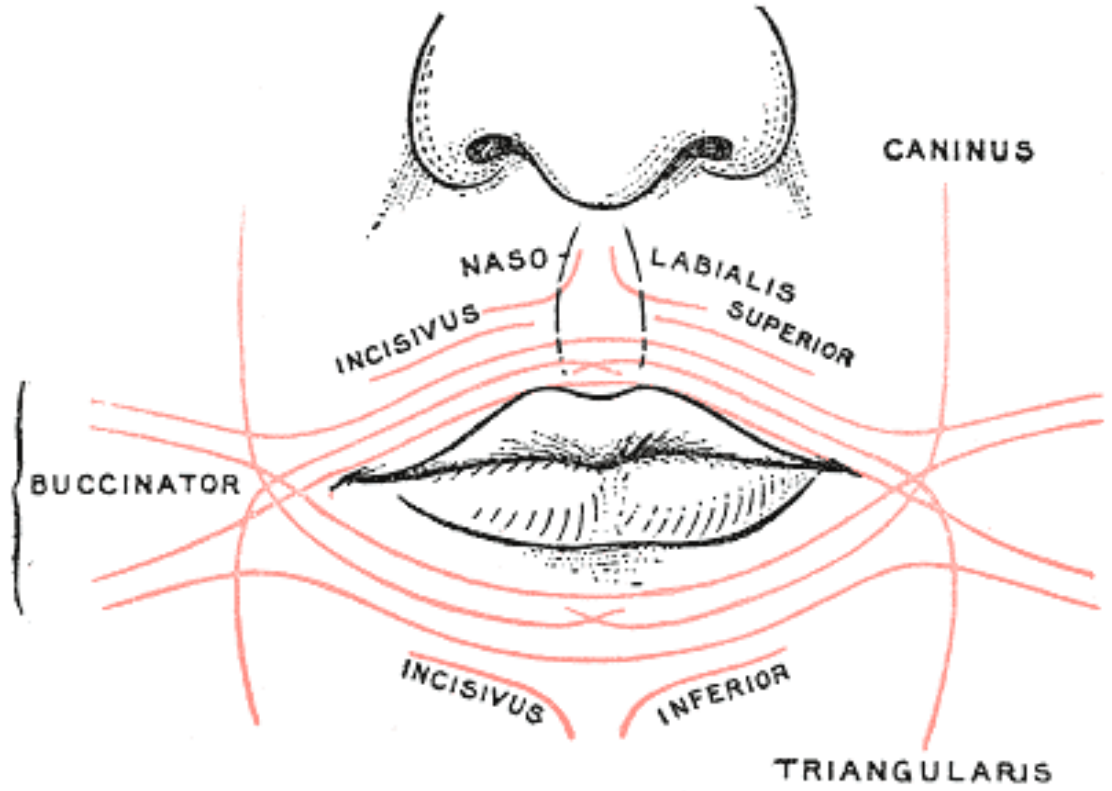


Figure 5–45. The muscles of the lips and face shown in a schematic posterior view, that is, looking out from the facial skeleton.

4. Parallel facial Muscles

- Incisivus labii sup.- helps pucker lips
- Incisivus labii inf. - draws corner of mouth medially and downwards
- Hard to find pictures of these small muscles!!



The Pharynx

- A muscular tube that gradually narrows at the bottom
- Vital to moving air and food
- Note, substantial detail is given in next few slides – *not all this detail needed for exams*

3 Pharyngeal Constrictors

- Inferior (largest)
- Middle (extends from horns of Hyoid to encircle pharynx)
- Superior (weakest, most complex)

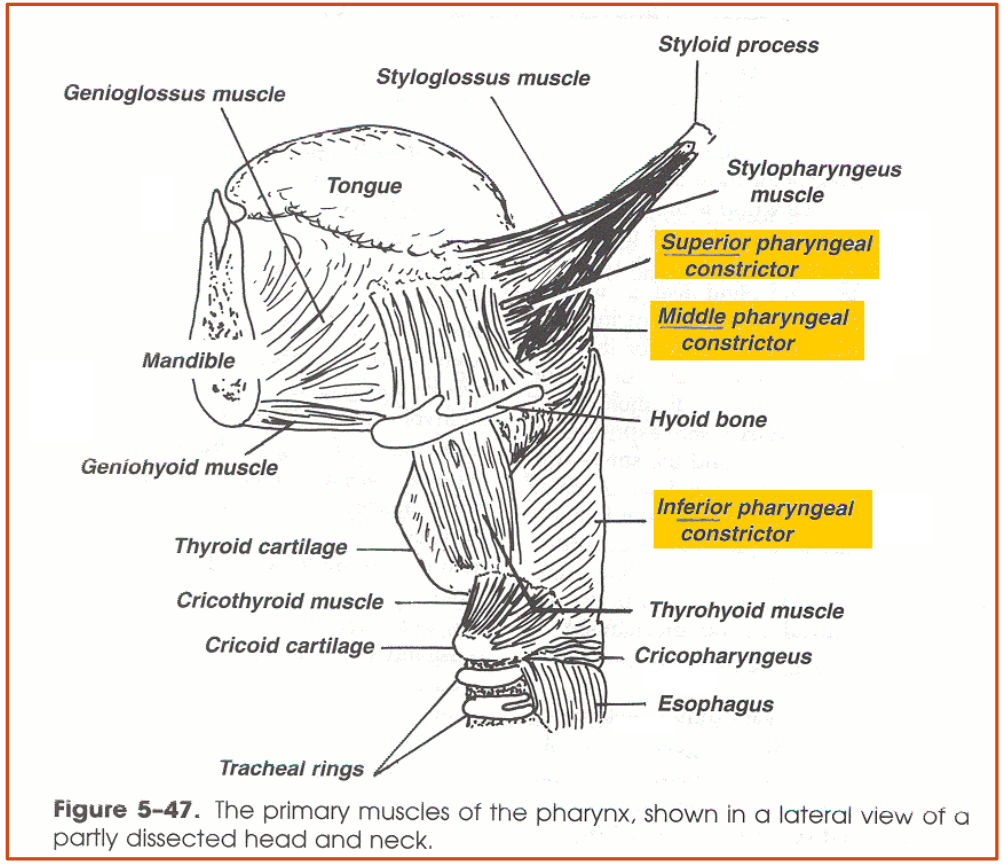
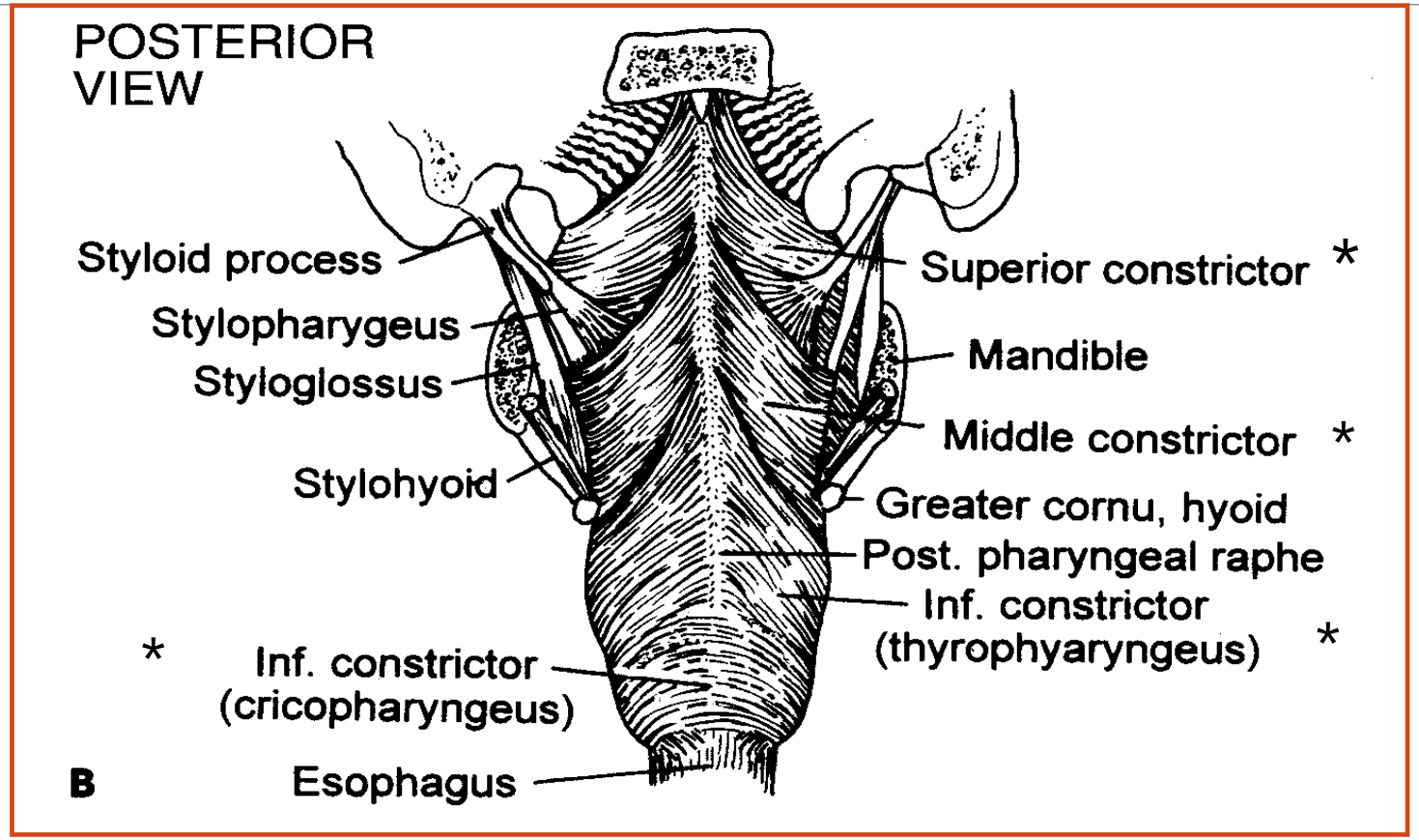


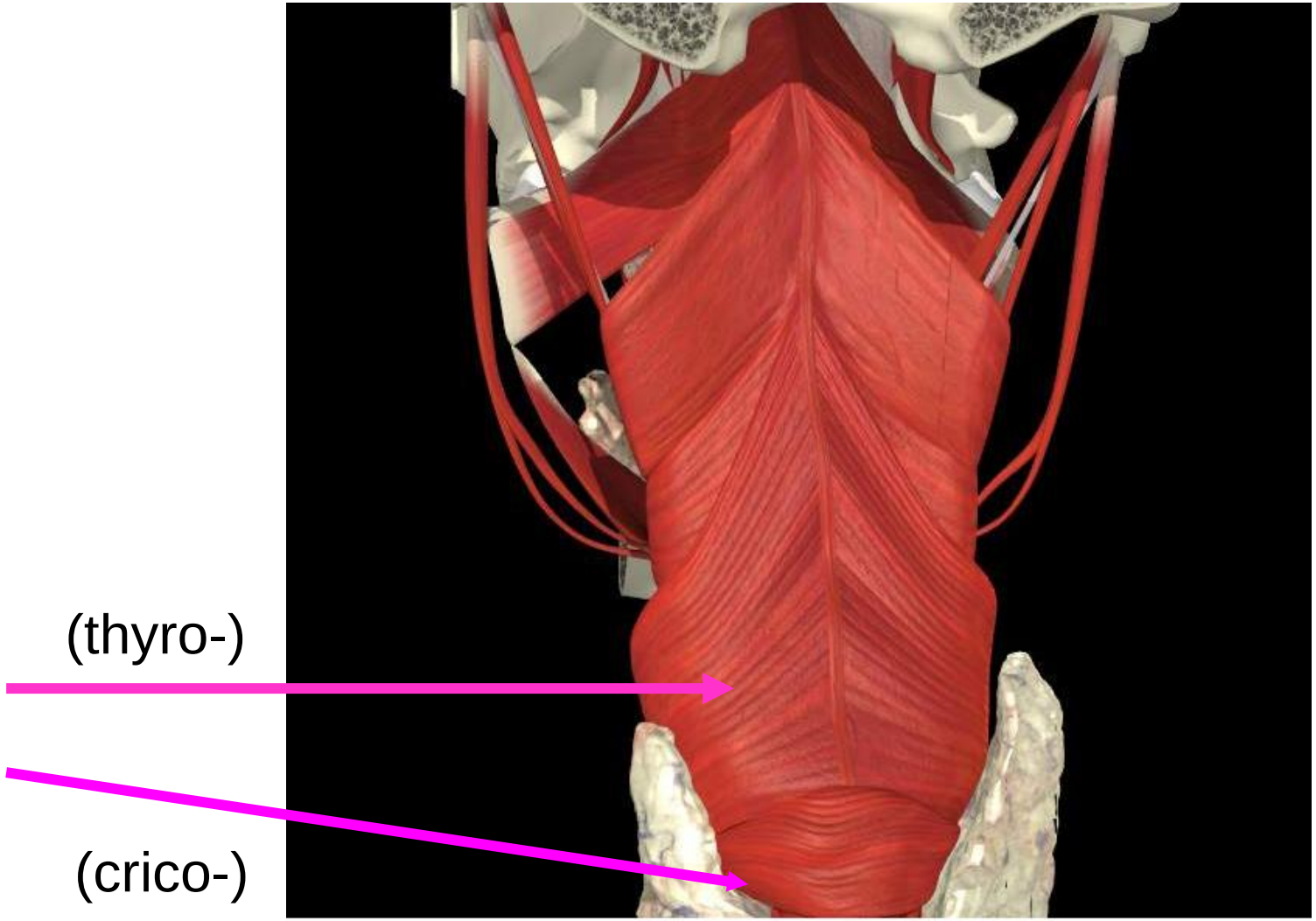
Figure 5–47. The primary muscles of the pharynx, shown in a lateral view of a partly dissected head and neck.

Pharyngeal constrictors

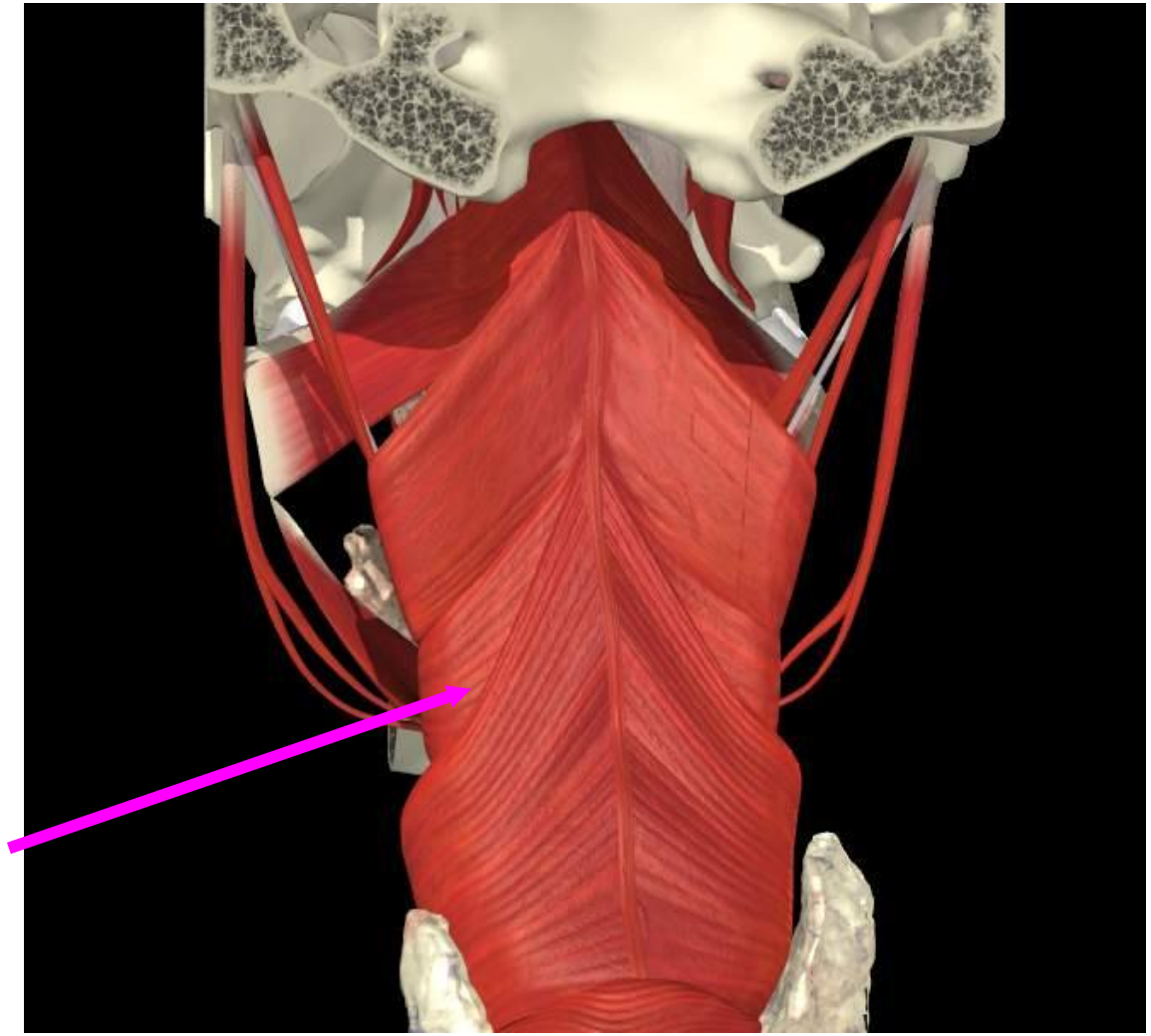


Orientation for next three images…

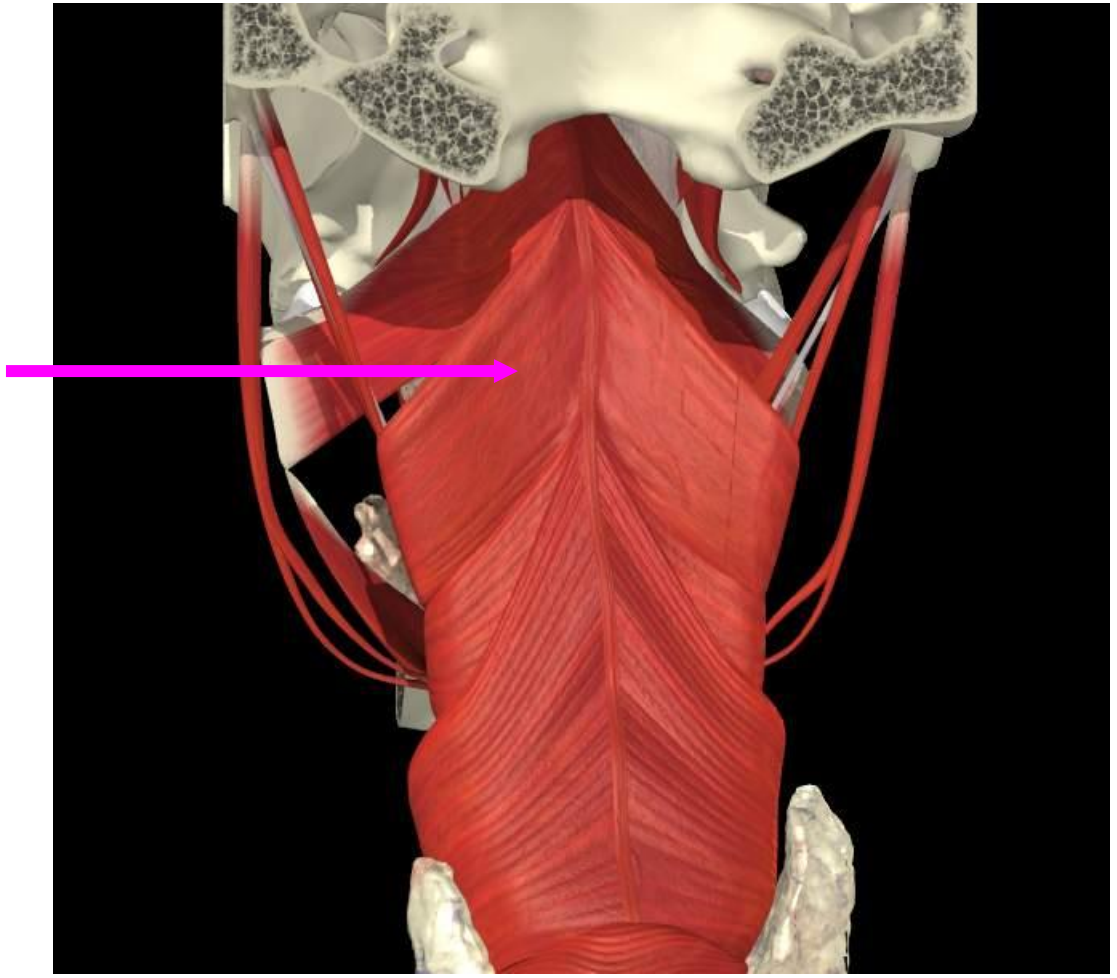
Inferior Pharyngeal Constrictor



Middle Pharyngeal Constrictor



Superior Pharyngeal Constrictor



Other Pharyngeal Muscle Details

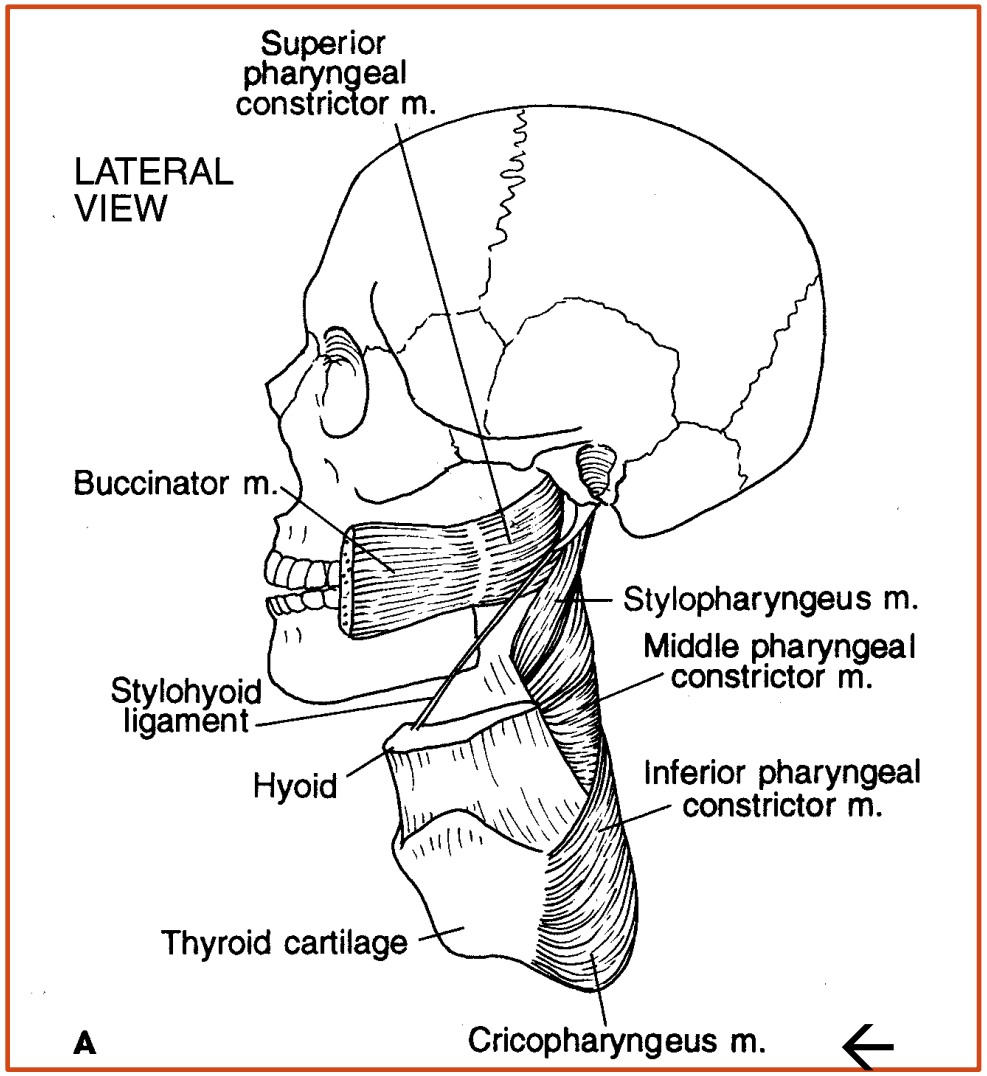
✓ **TWO PARTS OF INFERIOR PHARYNGEAL CONSTRICTOR:**

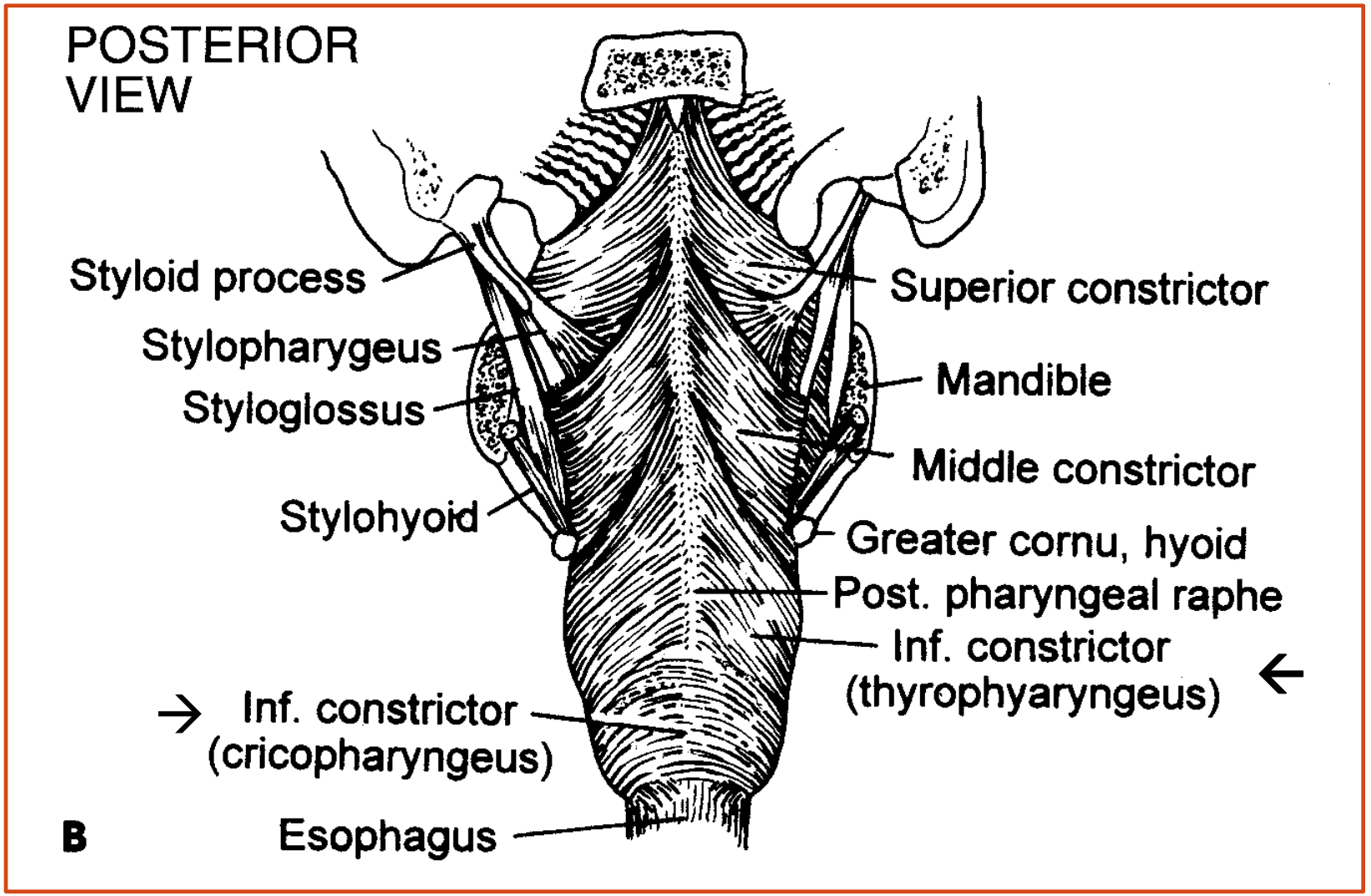
(1) <u>Criopharyngeal Muscle</u> (*esophageal speech, generating low-pitched sound*)
(2) <u>Thyropharyngeus Muscle</u> *(involved in propelling food through the pharynx)*

✓ **TWO OTHER MUSCLES:**

- **Salpingopharyngeus Muscle**
- **Stylopharyngeus Muscle**

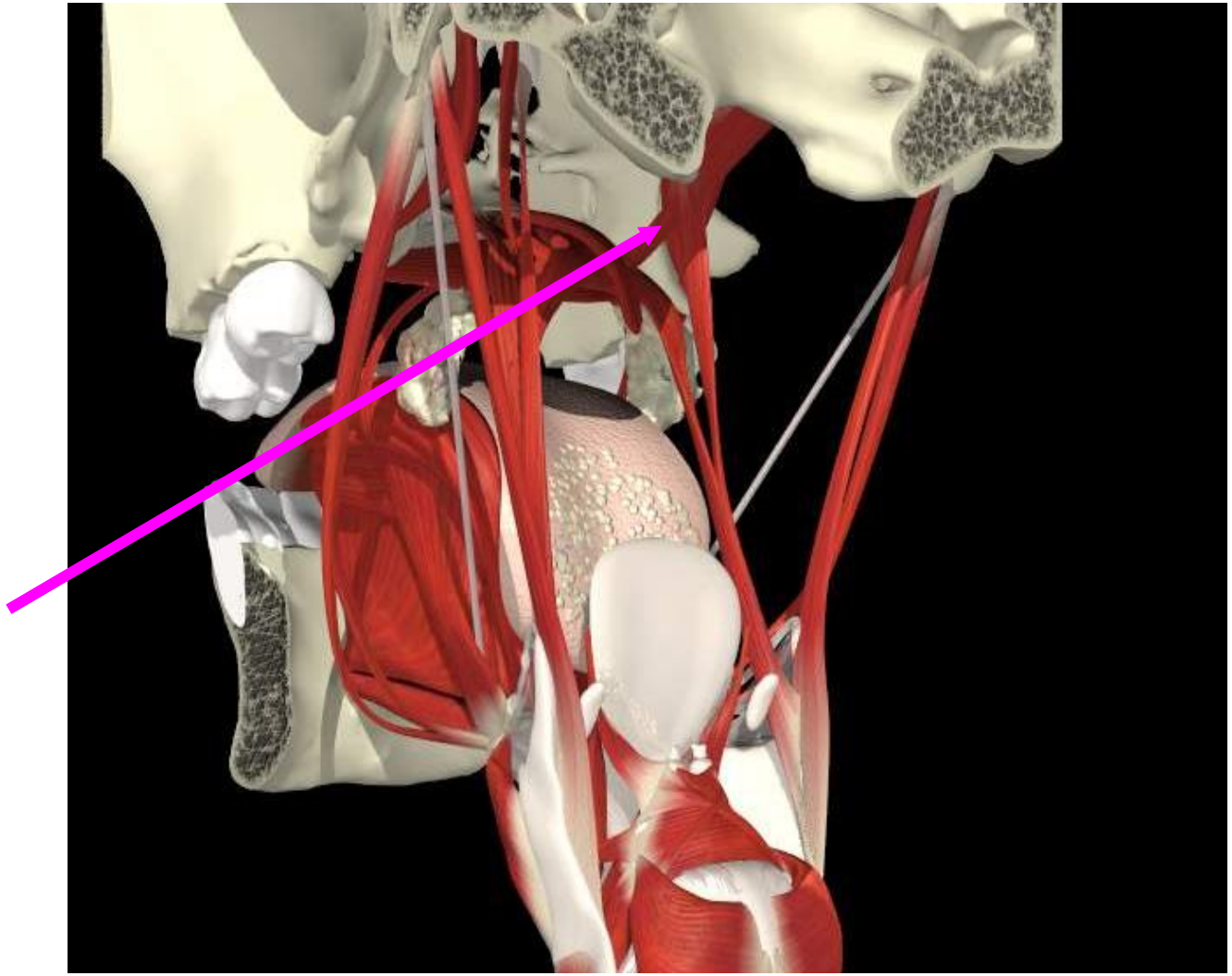
(*these help elevate and open the pharynx*)


Superior pharyngeal constrictor m.
LATERAL VIEW
Buccinator m.
Stylopharyngeus m.
Middle pharyngeal constrictor m.
Stylohyoid ligament
Hyoid
Inferior pharyngeal constrictor m.
Thyroid cartilage
A
Cricopharyngeus m.


POSTERIOR VIEW
Styloid process
Stylopharygeus
Styloglossus
Stylohyoid
Superior constrictor
Mandible
Middle constrictor
Greater cornu, hyoid
Post. pharyngeal raphe
Inf. constrictor (thyrophyaryngeus)
Inf. constrictor (cricopharyngeus)
Esophagus
B

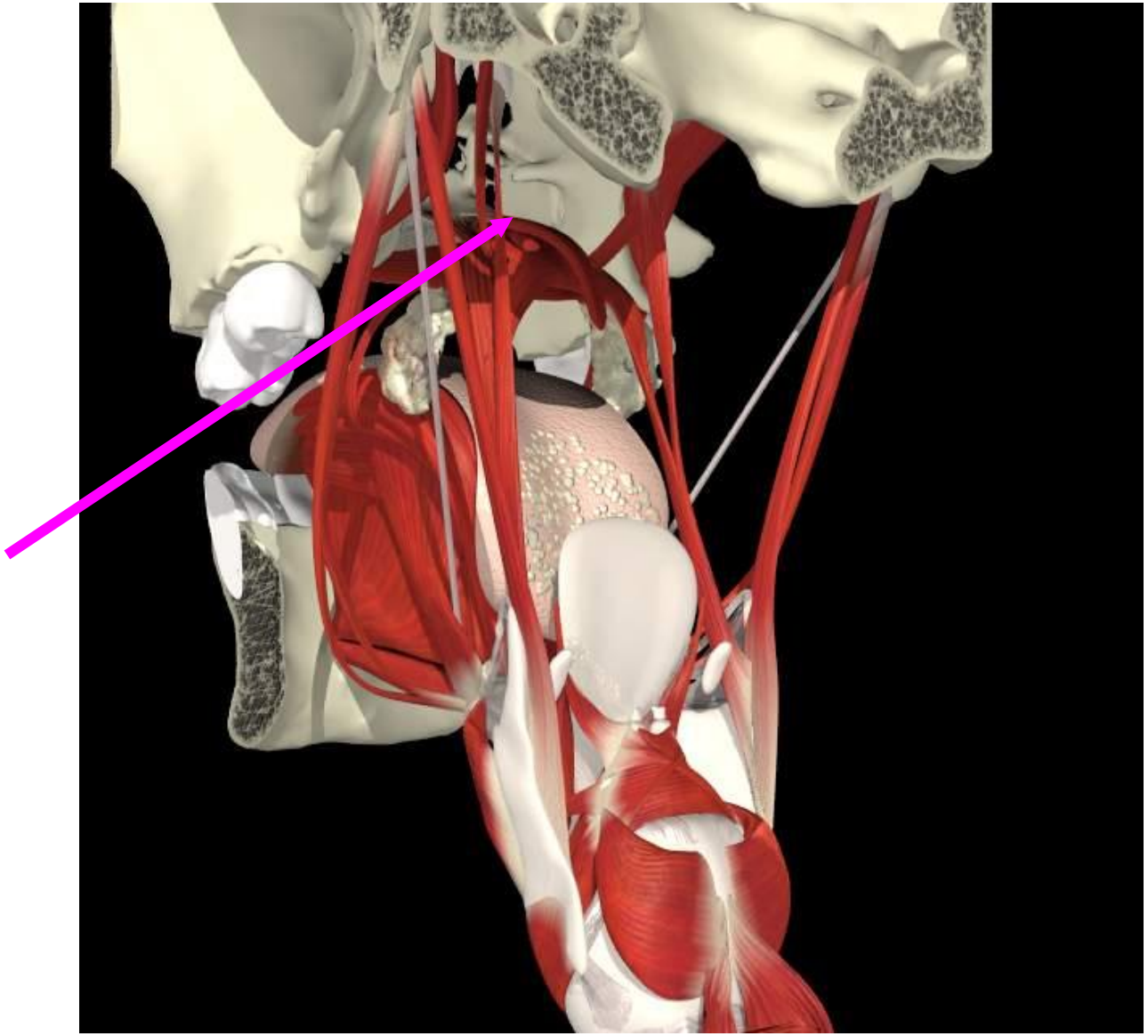
Salpingopharyngeus

Elevation of lateral pharyngeal walls



Stylopharyngeus

Elevates and opens pharynx during swallowing



The soft palate (velopharynx) and speech

- Backing and raising closes nasal cavity for ORAL sounds
- Lowering and fronting opens nasal cavity for NASAL sound

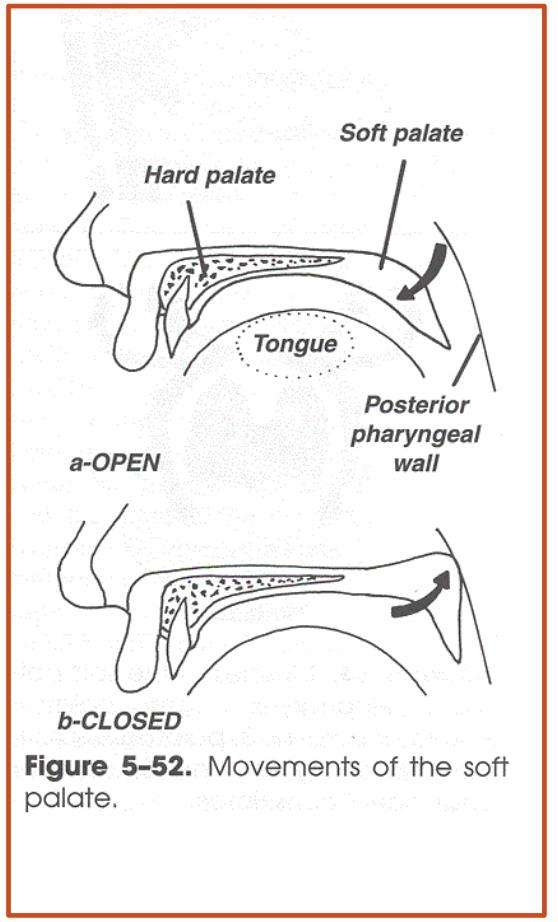


Figure 5–52. Movements of the soft palate.

Muscles of the soft palate - summary

- (#1) tensor veli palatini - tenses and shortens
- (#2) levator veli palatini - elevates
- (#3) palatoglossus and (#4) palatopharyngeus – depress
- uvula - bunches

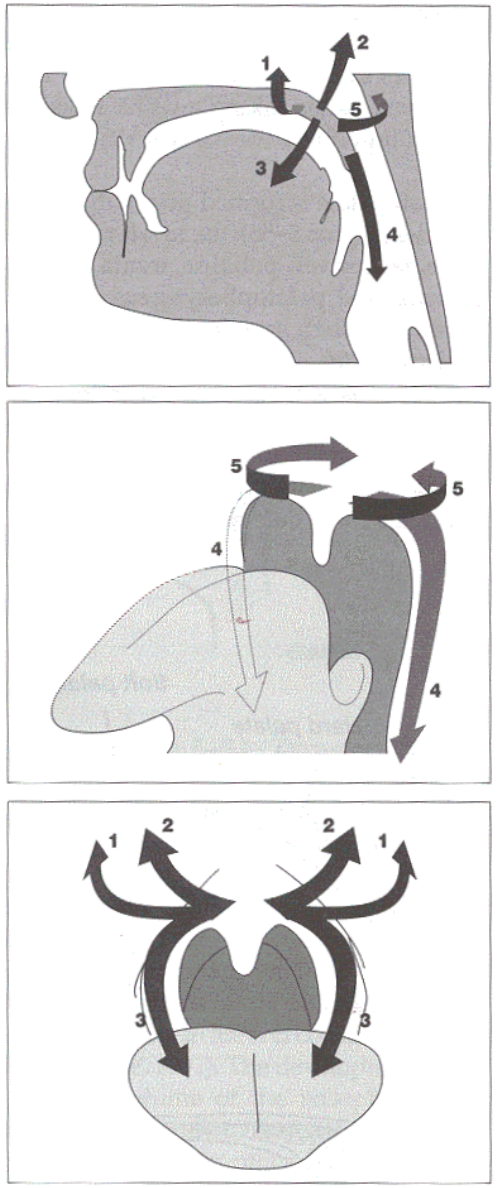


Figure 5–53. Muscles of the soft palate or velopharynx: 1, tensor palatini; 2, levator palatini; 3, palatoglossus; 4, palatopharyngeus, and 5, superior pharyngeal constrictor.

Velopharyngeal Valving

- Differences between men, women and children (women have greater seal; children more adenoidal)
- Problems can lead to hyper- or hypo-nasality

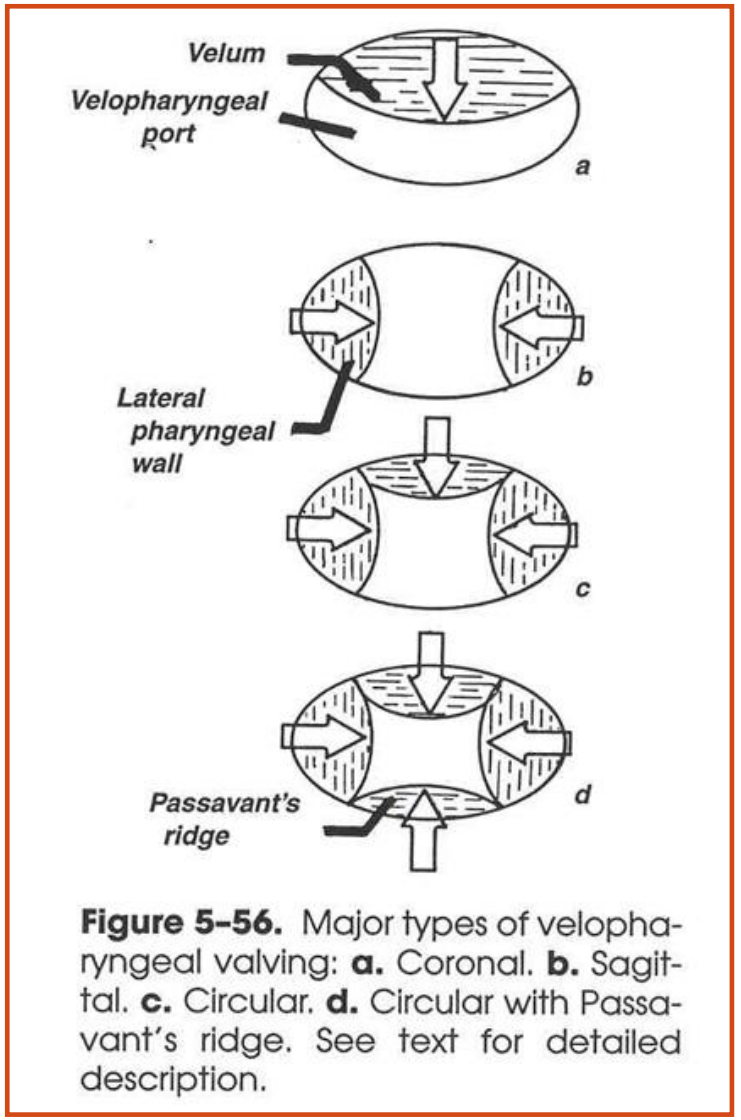
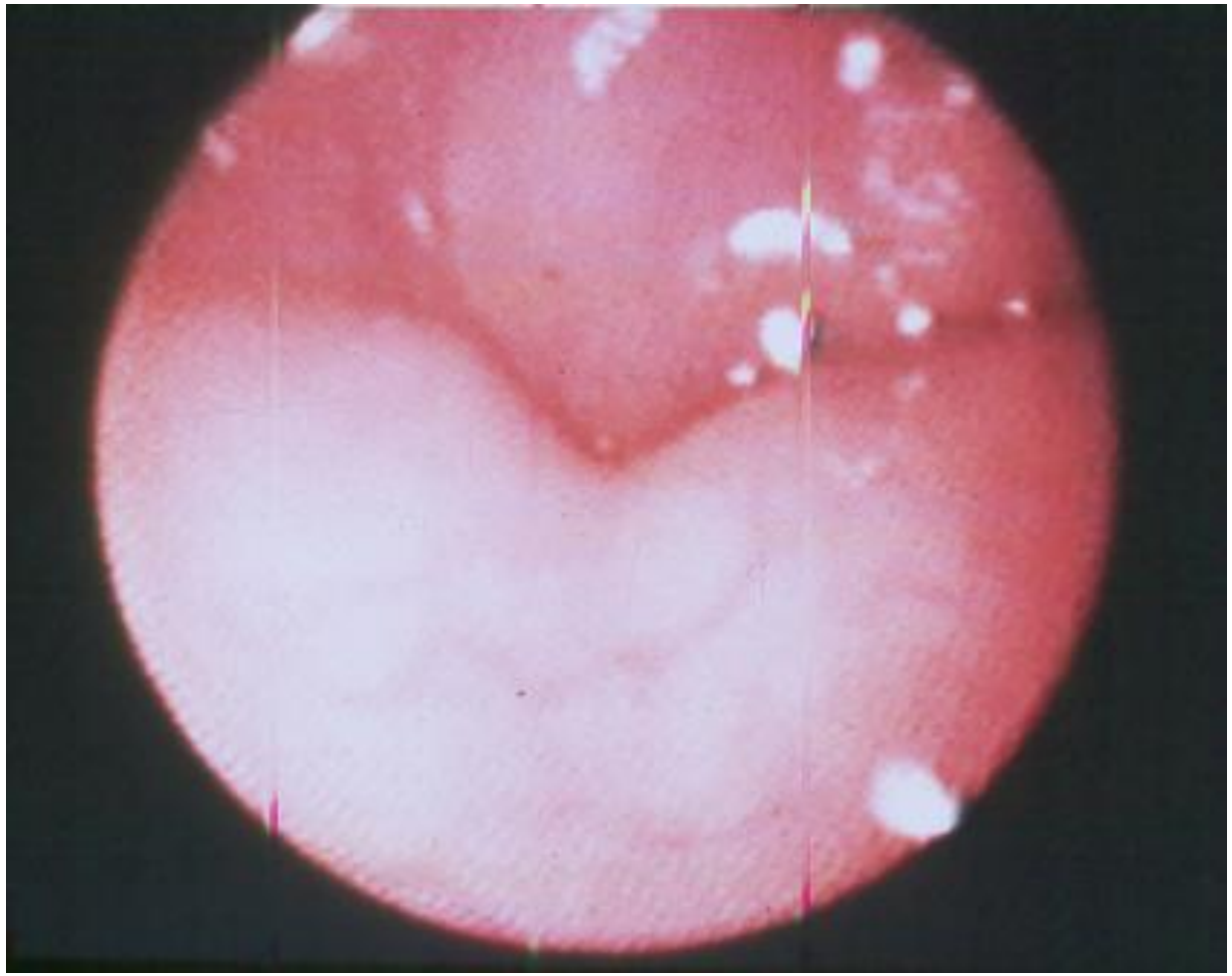
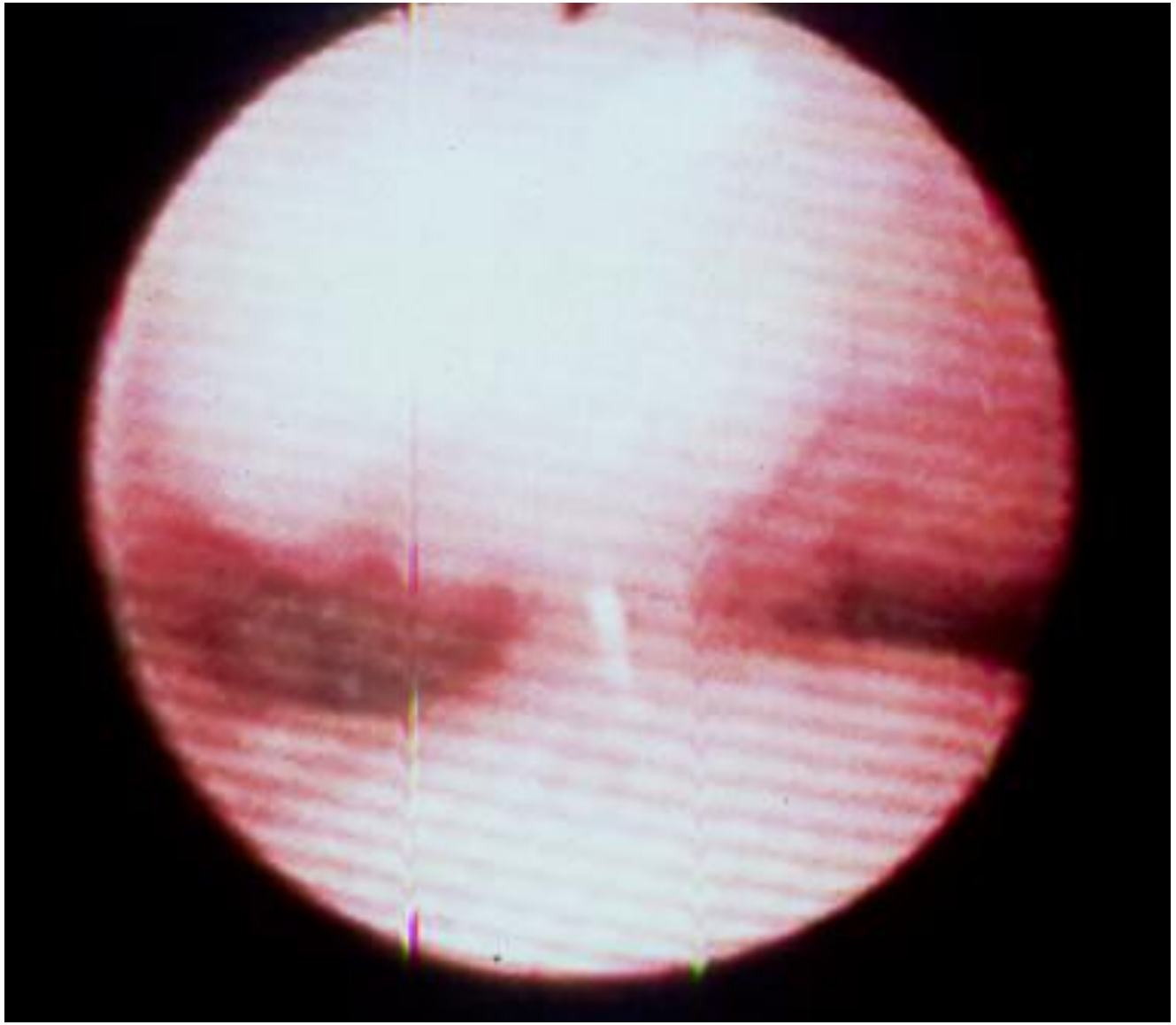


Figure 5–56. Major types of velopharyngeal valving: **a.** Coronal. **b.** Sagittal. **c.** Circular. **d.** Circular with Passavant's ridge. See text for detailed description.

Endoscopy view

Full velic closure, but submucous cleft palate

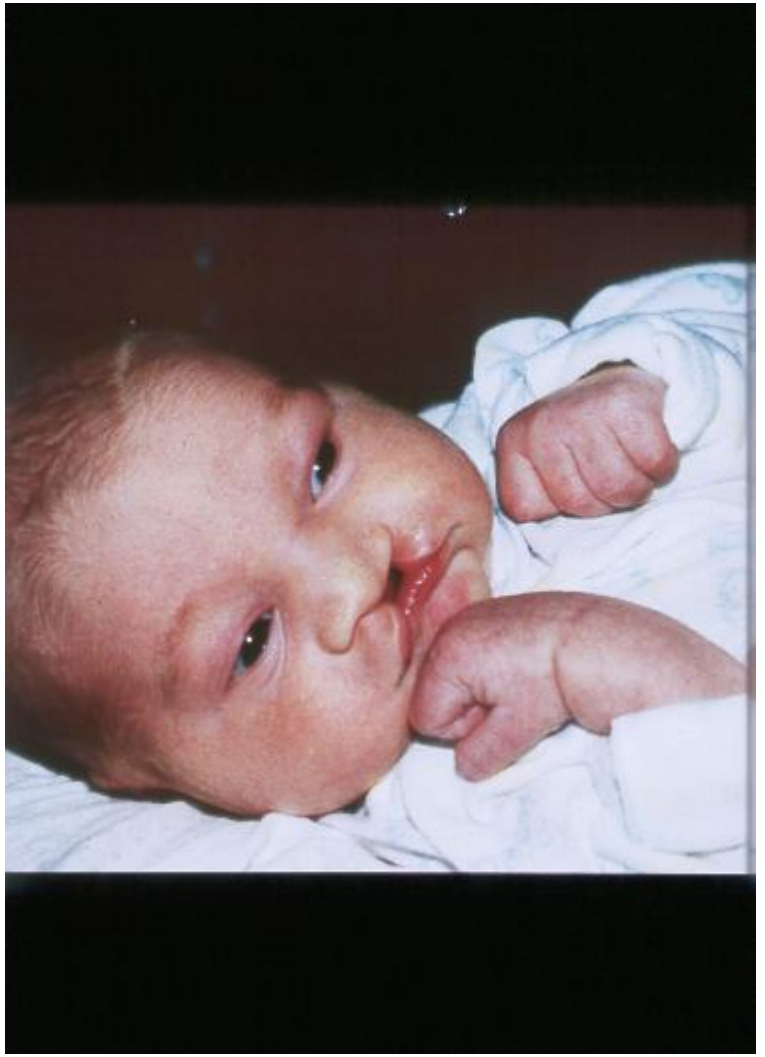




Incompetent velic closure

Cleft lip and palate

Photo thanks to Diane Altuna



Speech Production

I. Segmental: Phonemes
- Consonants
  - Voiced
  - Unvoiced
- Vowels / Diphthongs

II. Suprasegmental – Prosody, sentence-level intonation

Production of Consonants

Place of articulation

- Where major constriction occurs in vocal tract

Manner

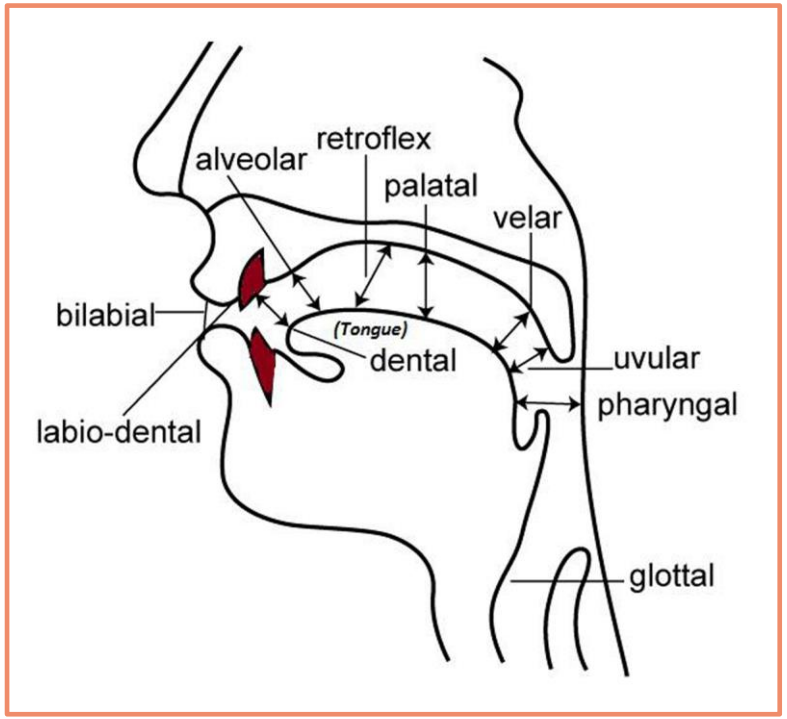
- How consonant is produced

Voicing

- Voiced or unvoiced

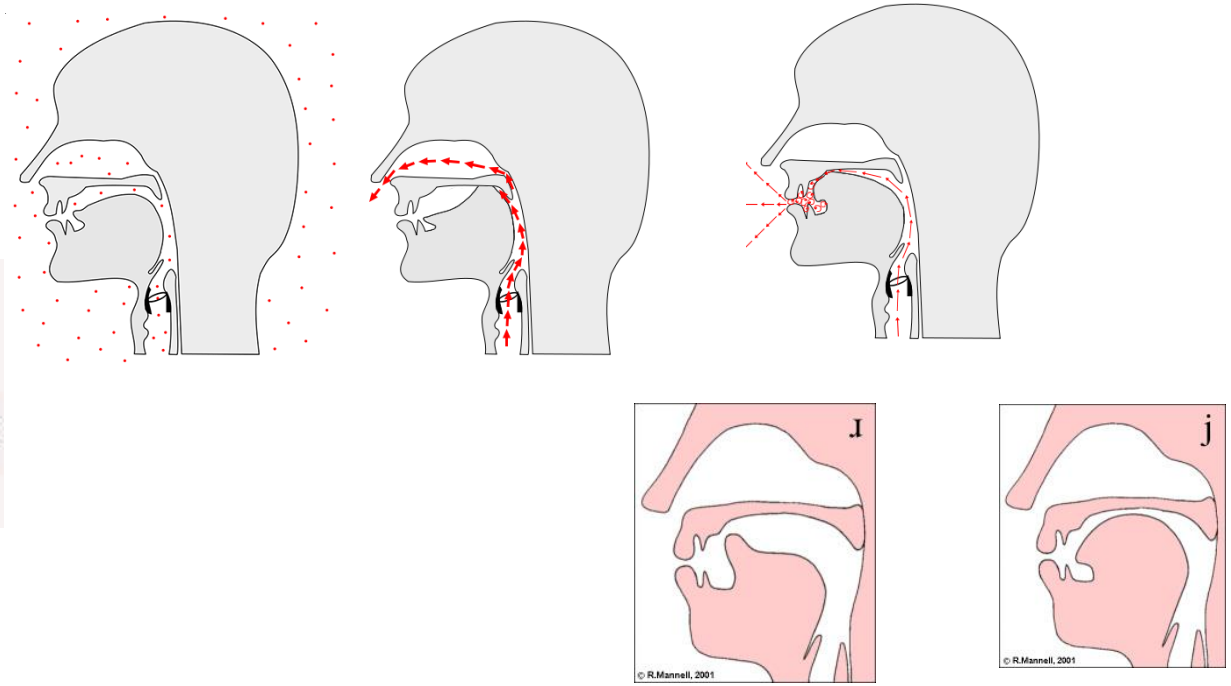
Places of articulation - GAE

- Bilabial
- Labiodental
- Dental
- Alveolar
- Palatoalveolar
- Palatal
- Velar
- Glottal



Manner of Articulation

- Stops
- Nasals
- Fricatives
- Affricates
- Approximates (glides, liquids)
- Taps/flaps https://youtu.be/Do_cYPnbv8M



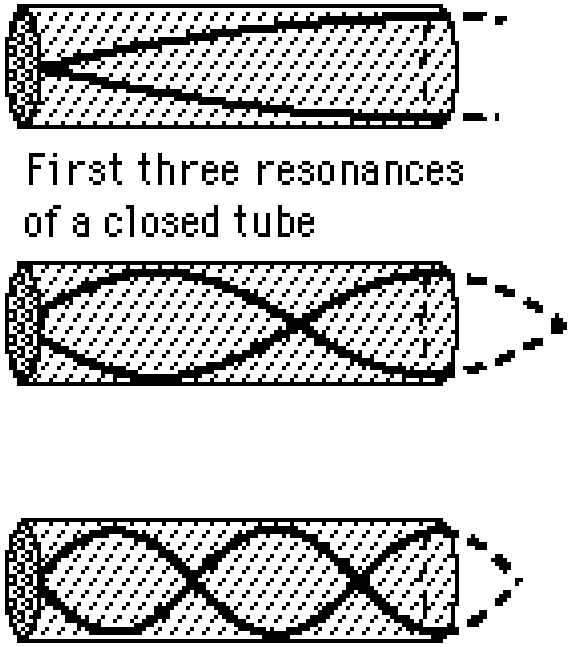
Hat tip: http://www.learnlanguagesonyourown.com/manners-of-articulation.html

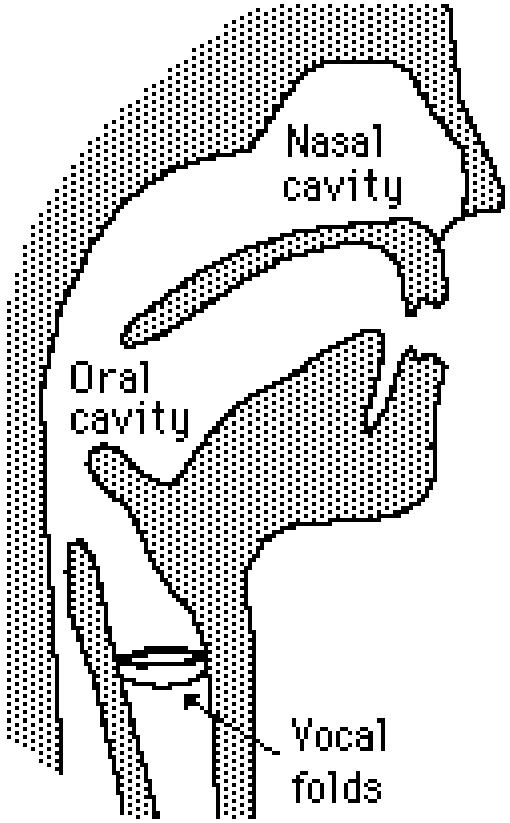
Vocal Tract

Approx. 17 cm for males

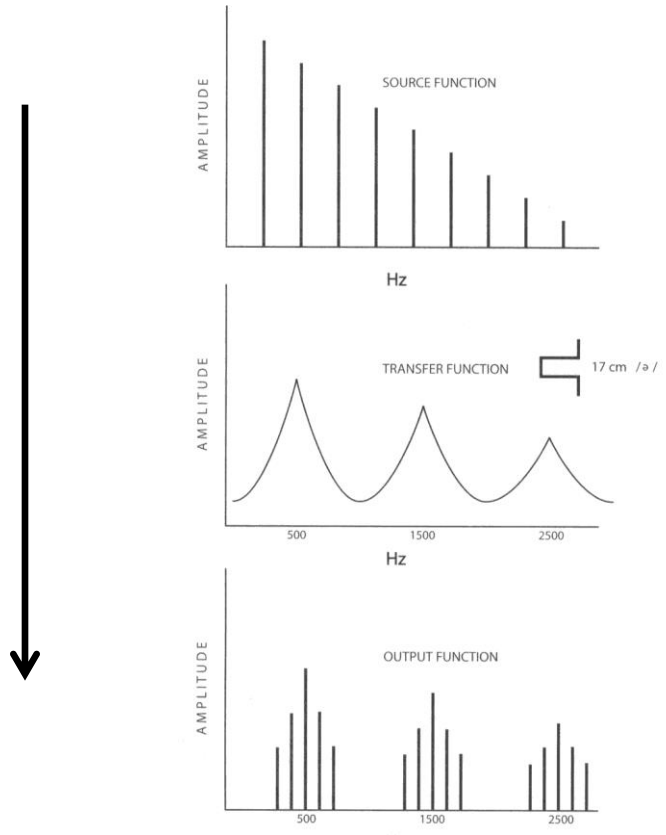
5/6 the length for females

Children roughly half the length of adult male





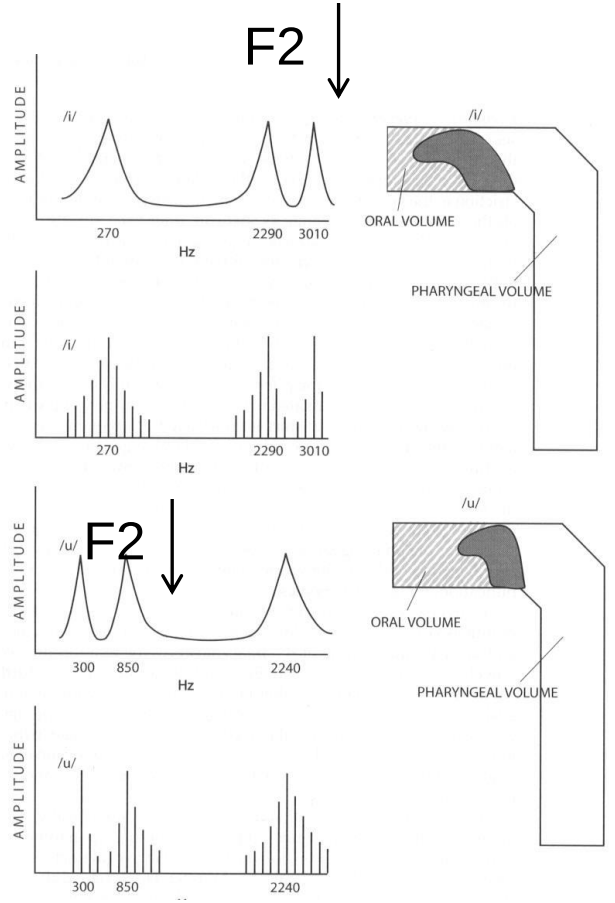
Source Filter Model



F_0 (source produced at vocal folds)

Formants (F1, F2, F3, …) created by vocal tract resonance

Formants with Tongue Position



Vowel formant frequencies

	FRONT VOWELS											
	/i/			/ɪ/			/ɛ/			/æ/		
	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
M	270	2290	3010	390	1990	2550	530	1840	2480	660	1720	2410
W	310	2790	3310	430	2480	3070	610	2330	2990	860	2050	2850
C	370	3200	3730	530	2730	3600	690	2610	3570	1010	2320	3320

	BACK VOWELS											
	/u/			/ʊ/			/ɔ/			/a/		
	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3	F_1	F_2	F_3
M	300	870	2240	440	1020	2240	570	840	2410	730	1090	2440
W	370	950	2670	470	1160	2680	590	920	2710	850	1220	2810
C	430	1170	3260	560	1410	3310	680	1060	3180	1030	1370	3170

	CENTRAL VOWELS					
	/ə/			/ɚ/		
	F_1	F_2	F_3	F_1	F_2	F_3
M	640	1190	2390	490	1350	1690
W	760	1400	2780	500	1640	1960
C	850	1590	3360	560	1820	2160

Resonance – four basic rules

- **F1 rule** – inversely related to jaw height. *As the jaw goes down, F1 goes up,* etc.
- **F2 rule** – directly related to tongue fronting. *As the tongue moves forward, F2 increases*.
- **F3 rule** – F3 decreases during r-coloring
- **Lip rounding rule** – All formants are lowered by lip rounding (because lip protrusion lengthens the vocal tract 'tube')

Examples of resonance for /i,a,u/

- /i/ is made with the tongue high (thus, low F1) and fronted (high F2)
- /ɑ/ is made with the tongue low (high F1) and back (low F2)

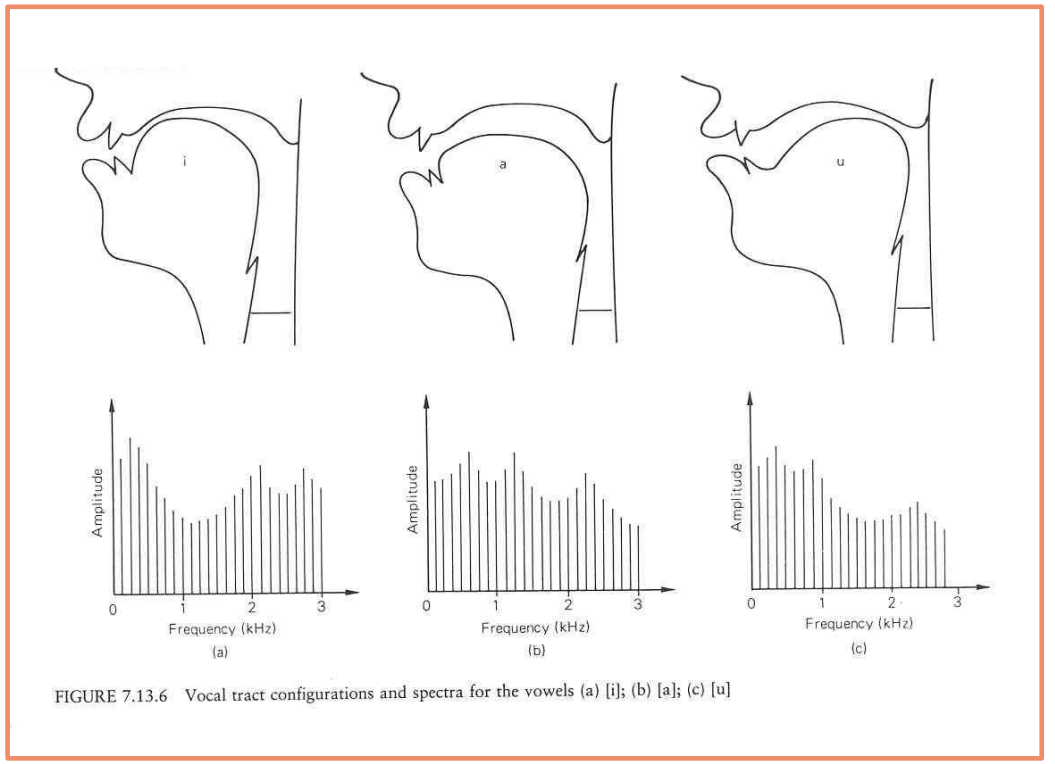


FIGURE 7.13.6 Vocal tract configurations and spectra for the vowels (a) [i]; (b) [a]; (c) [u]

Resonance – advanced

Although it is easy to think of the three resonance rules in terms of vocal tract chamber size, in fact it is more complicated – velocity nodes and antinodes must be considered

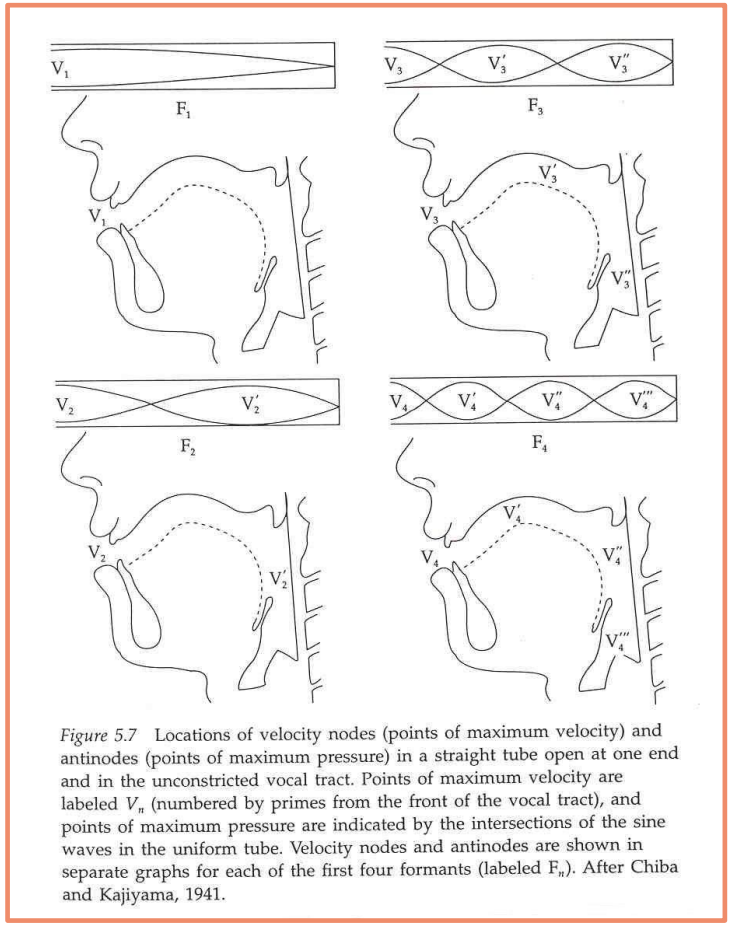
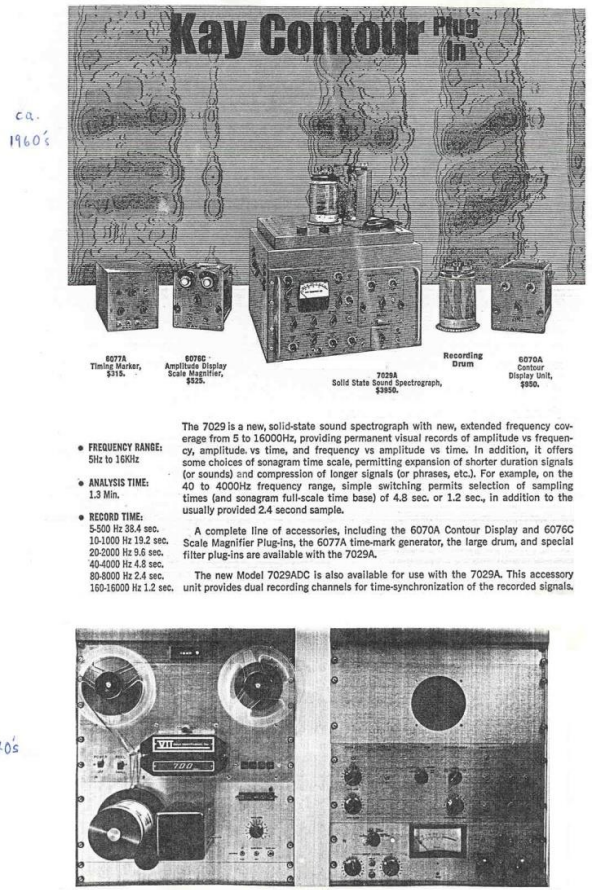


Figure 5.7 Locations of velocity nodes (points of maximum velocity) and antinodes (points of maximum pressure) in a straight tube open at one end and in the unconstricted vocal tract. Points of maximum velocity are labeled V_n (numbered by primes from the front of the vocal tract), and points of maximum pressure are indicated by the intersections of the sine waves in the uniform tube. Velocity nodes and antinodes are shown in separate graphs for each of the first four formants (labeled F_n). After Chiba and Kajiyama, 1941.

The sound spectrograph

- Invented in the 1940s
- First called ‘visible speech’
- Originally thought to produce a ‘speech fingerprint’
- We now know speech perception is far more complicated and ambiguous than fingerprint identification



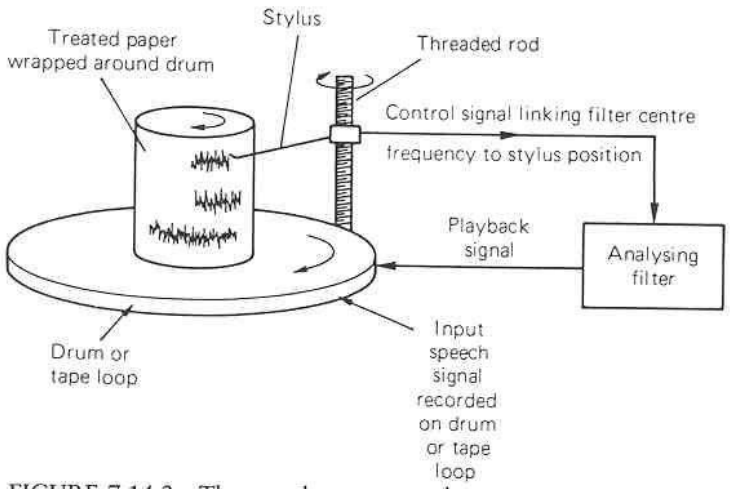


FIGURE 7.14.2 The speech spectrograph

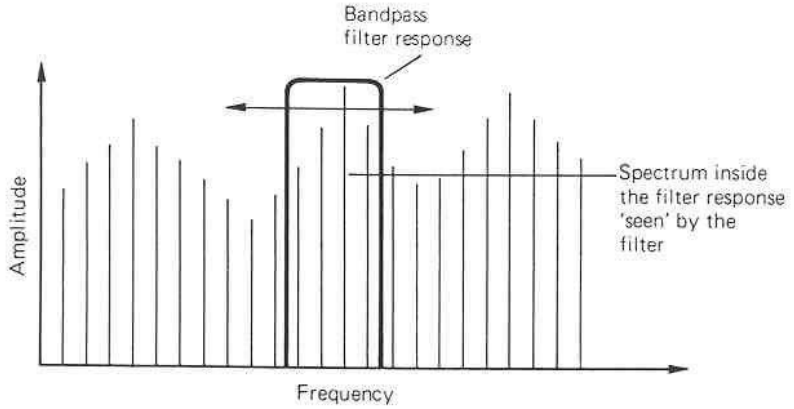


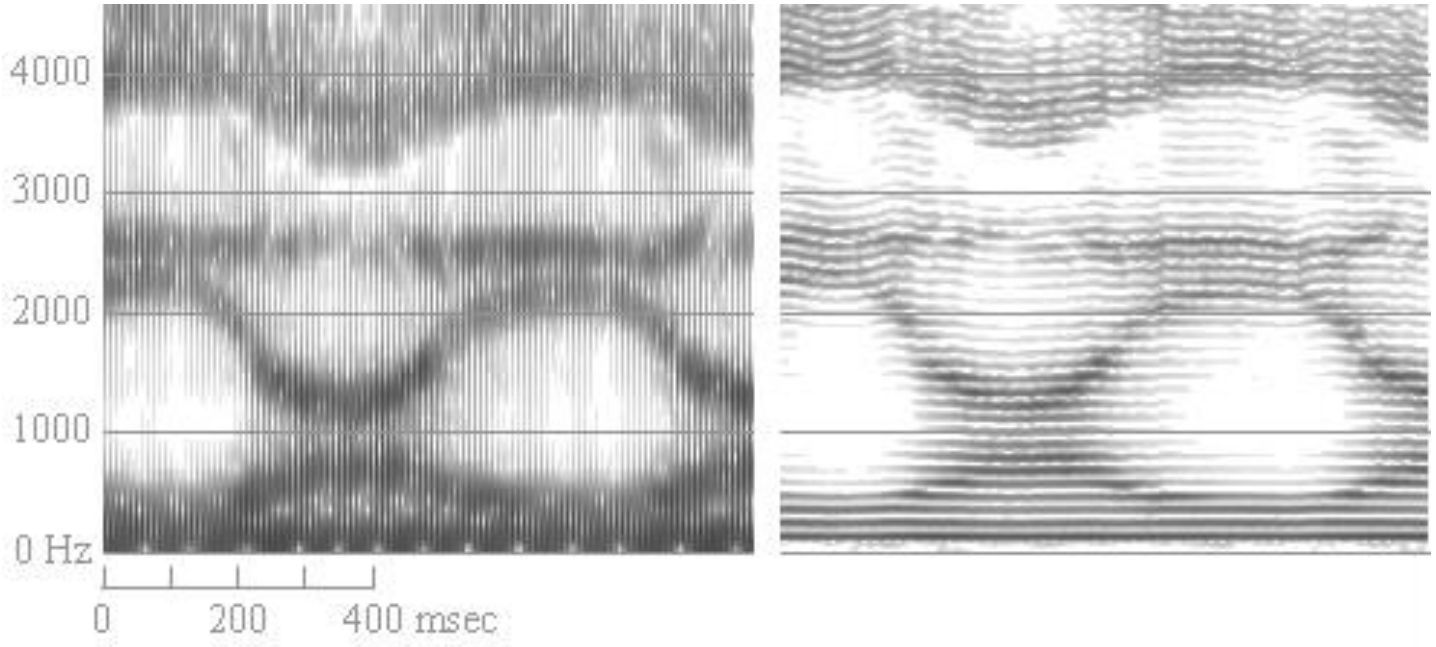
FIGURE 7.14.3 Bandpass filtering

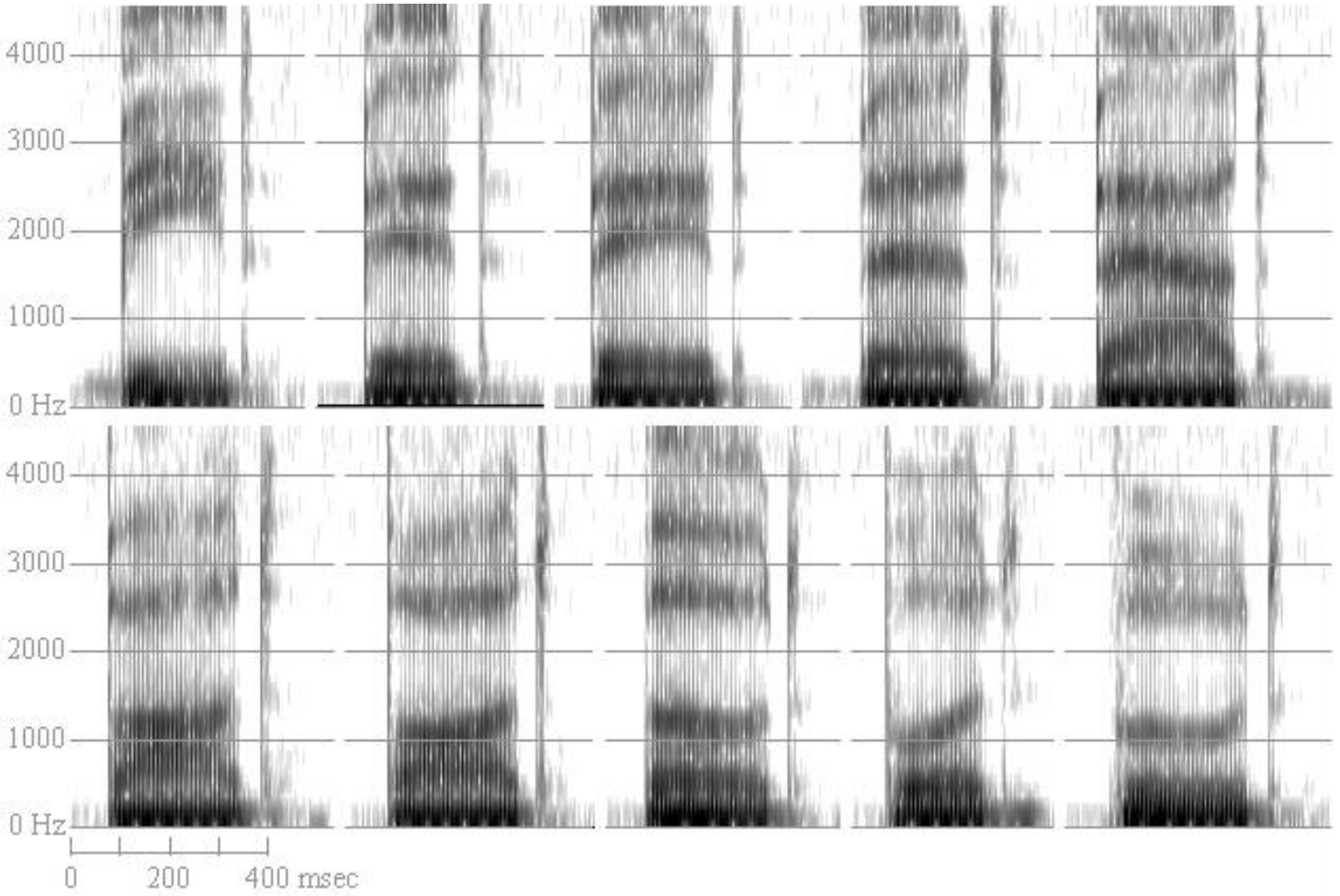
Basics of spectrograph operation

- Original systems used bandpass filters
- Accumulated energy was represented by a dark image burned onto specially-treated paper
- Nowadays, performed digitally using variety of algorithms (e.g., DFT, LPC)

Some B&W examples: Vowels

- /i a i a / -- produced with level pitch
- Wideband spectrogram (left); narrow band (right)

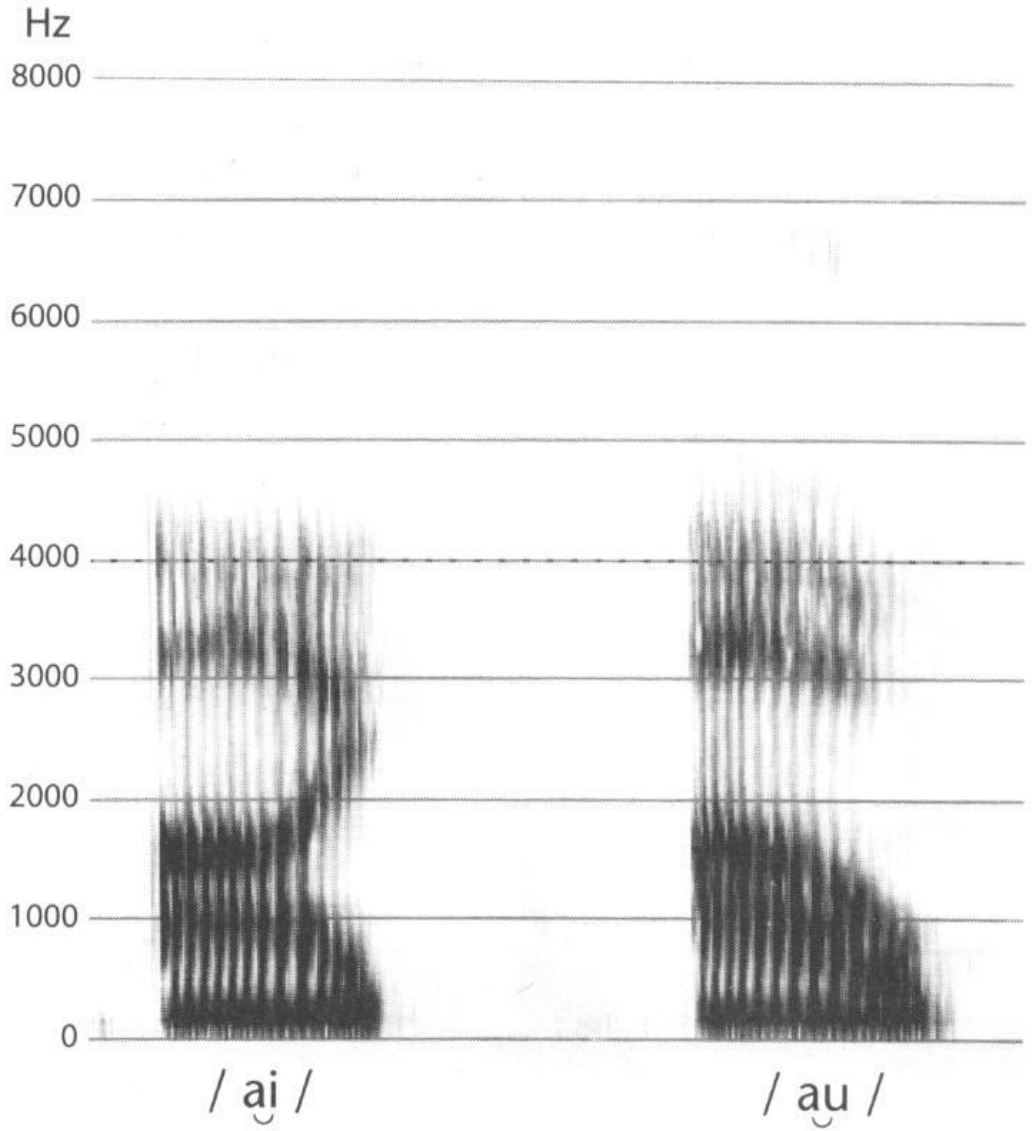




American English vowels (in /b_d/ context)

- TOP ROW (front vowels):
- “bead bid bade bed bad”

- BOTTOM ROW (back vowels)
- “bod bawd bode buhd booed”



Diphthongs

Consonants – formant transitions

Example of an F1 transition for the syllable /da/

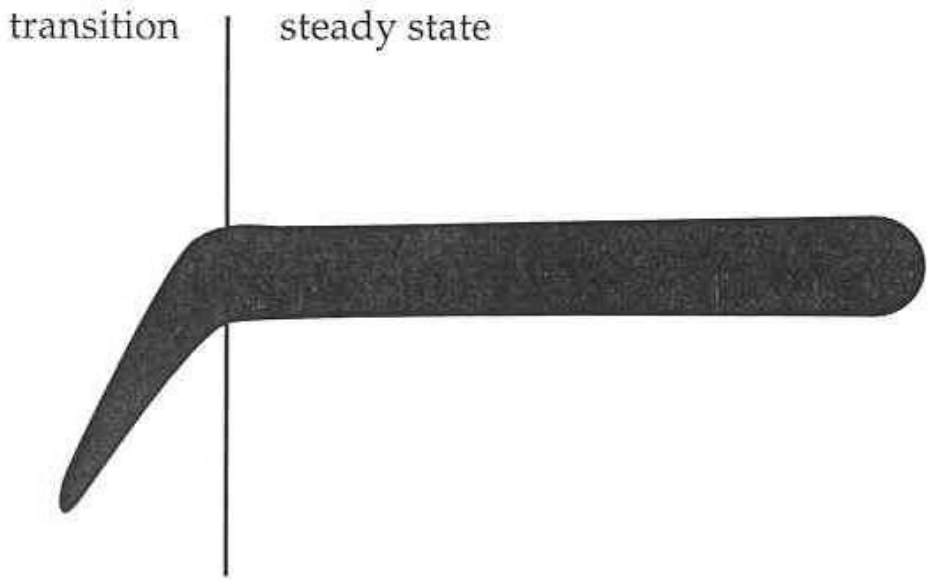
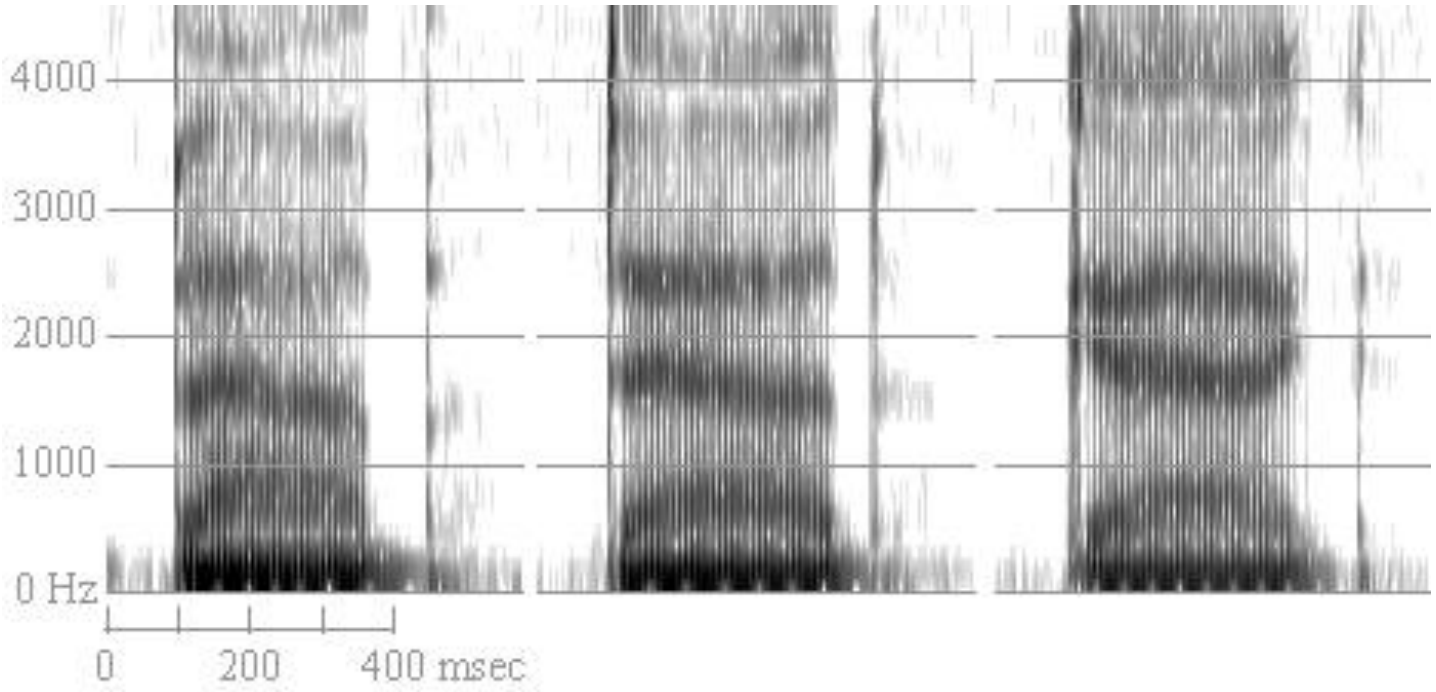


FIGURE 6.3 Schematic diagram of a formant frequency with the transition and steady- state portions labeled. (Reprinted with permission by Singular Publishing Group, Inc. from J. Ryalls, *A Basic Introduction to Speech Perception*, 1996)

Stops/ formant transitions

- Spectrograms of “bab” “dad” and “gag”
- Labials - point down
- Alveolars point to ~1700-1800 Hz
- Velars “pinch” F2 and F3 together
- Note: bottom-most fuzzy is the voice bar!

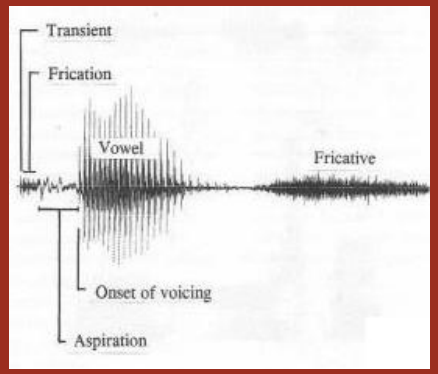


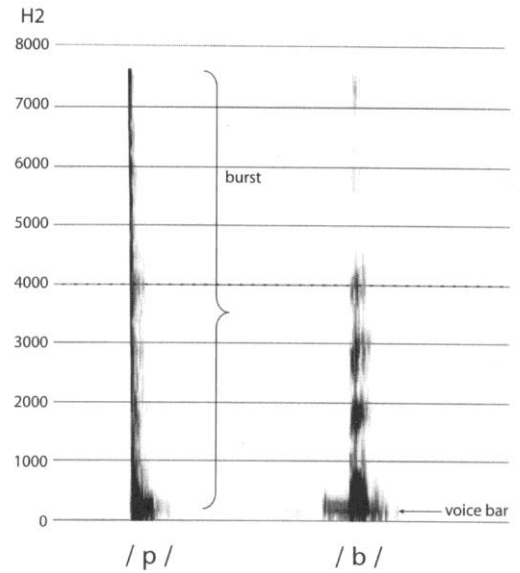
Stops – continued

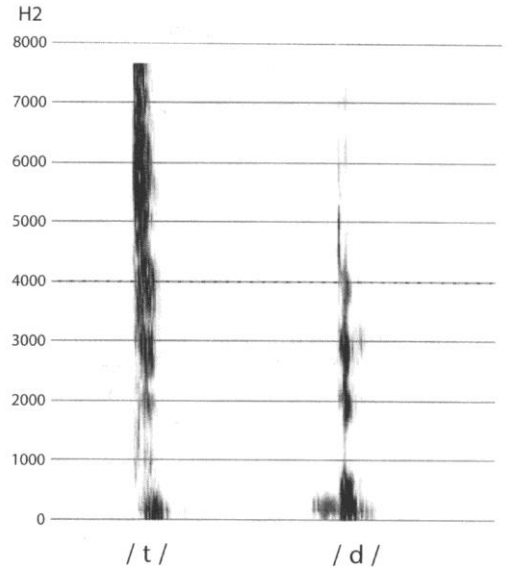
Produced with a closure within the oral cavity, a build up of pressure behind this closure and a release of the closure allowing the air to be rapidly expelled.

Acoustically these events can be divided into five components:

1. Occlusion
2. Transient (“Burst”)
3. Frication
4. Aspiration (Glottal turbulence/airflow)
5. Transition

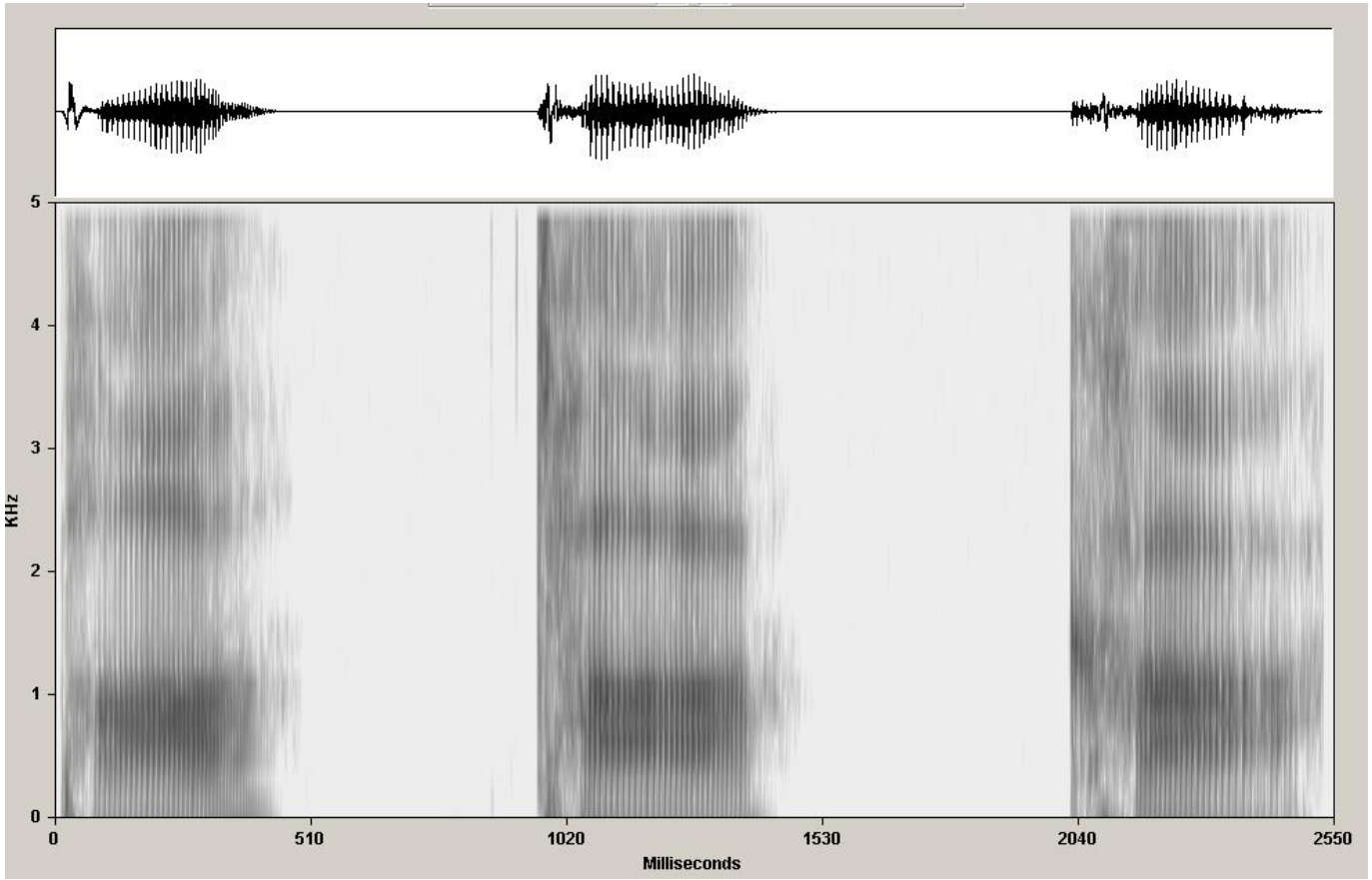






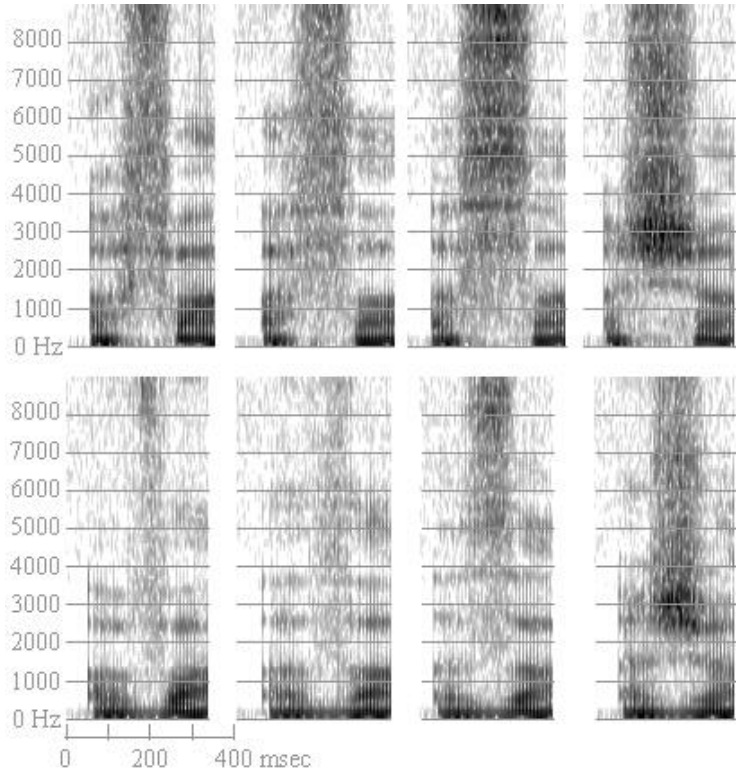
/pa/ /ta/ /ka/

(voice of WK)



Fricatives

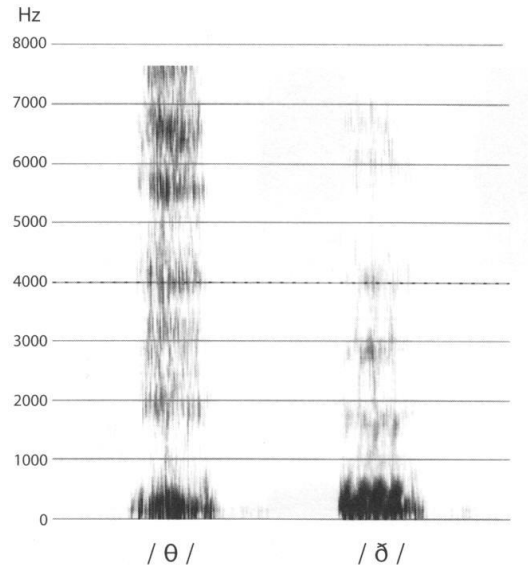
- Top row: /f/, /θ/, /s/, /ʃ/,
- Bottom row: /v/, /ð/, /z/, /ʒ/
- Distribution of the spectral noise is the key here!

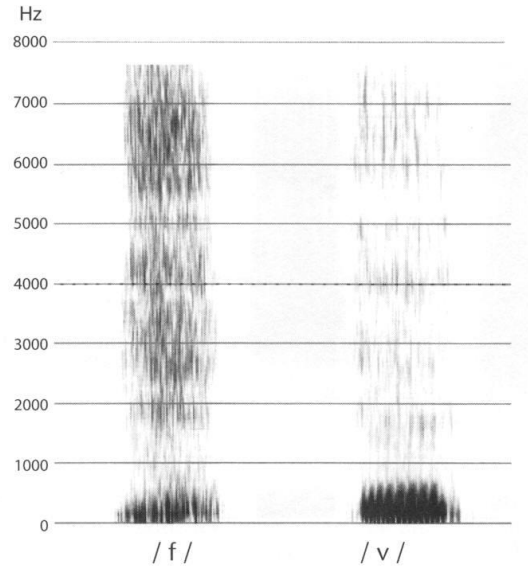


Fricatives – continued

Acoustic characteristics include:

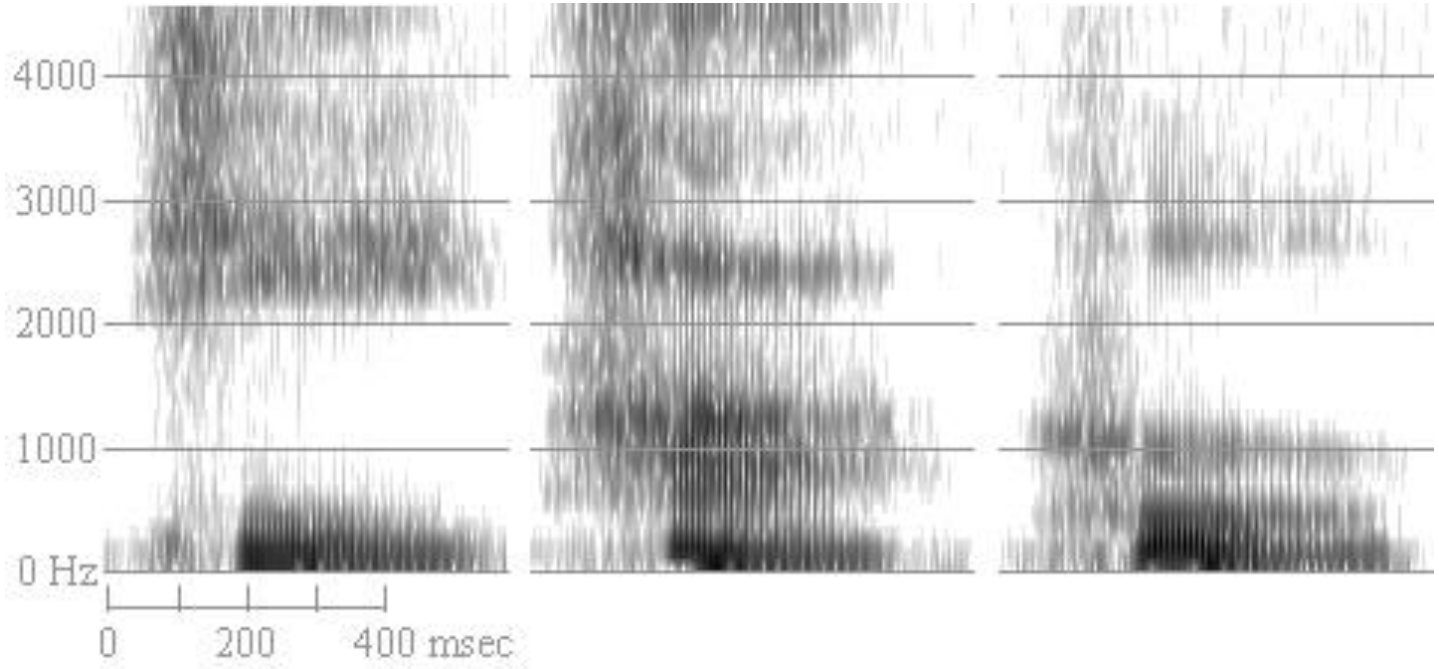
- High frequency hiss
- Long duration
- Weak-to-moderate intensity





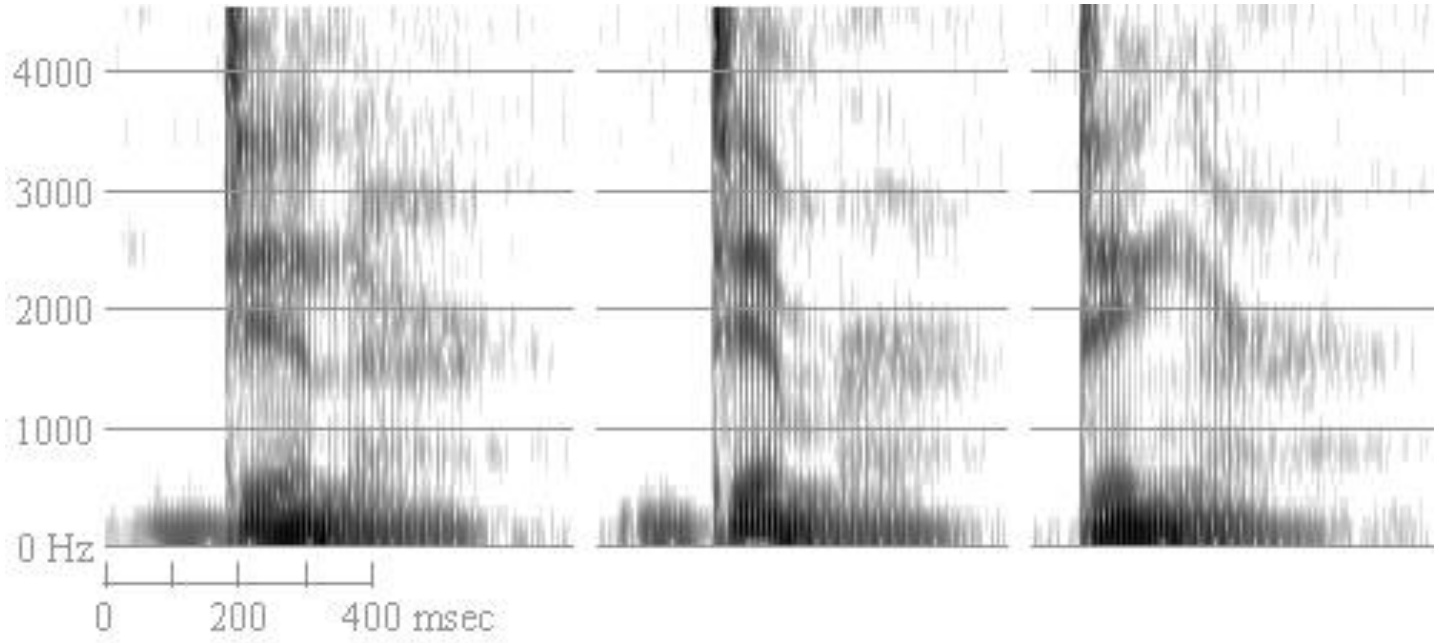
The fricative /h/

- Commonly excites all the formant cavities
- May look slightly different in varying vowel contexts



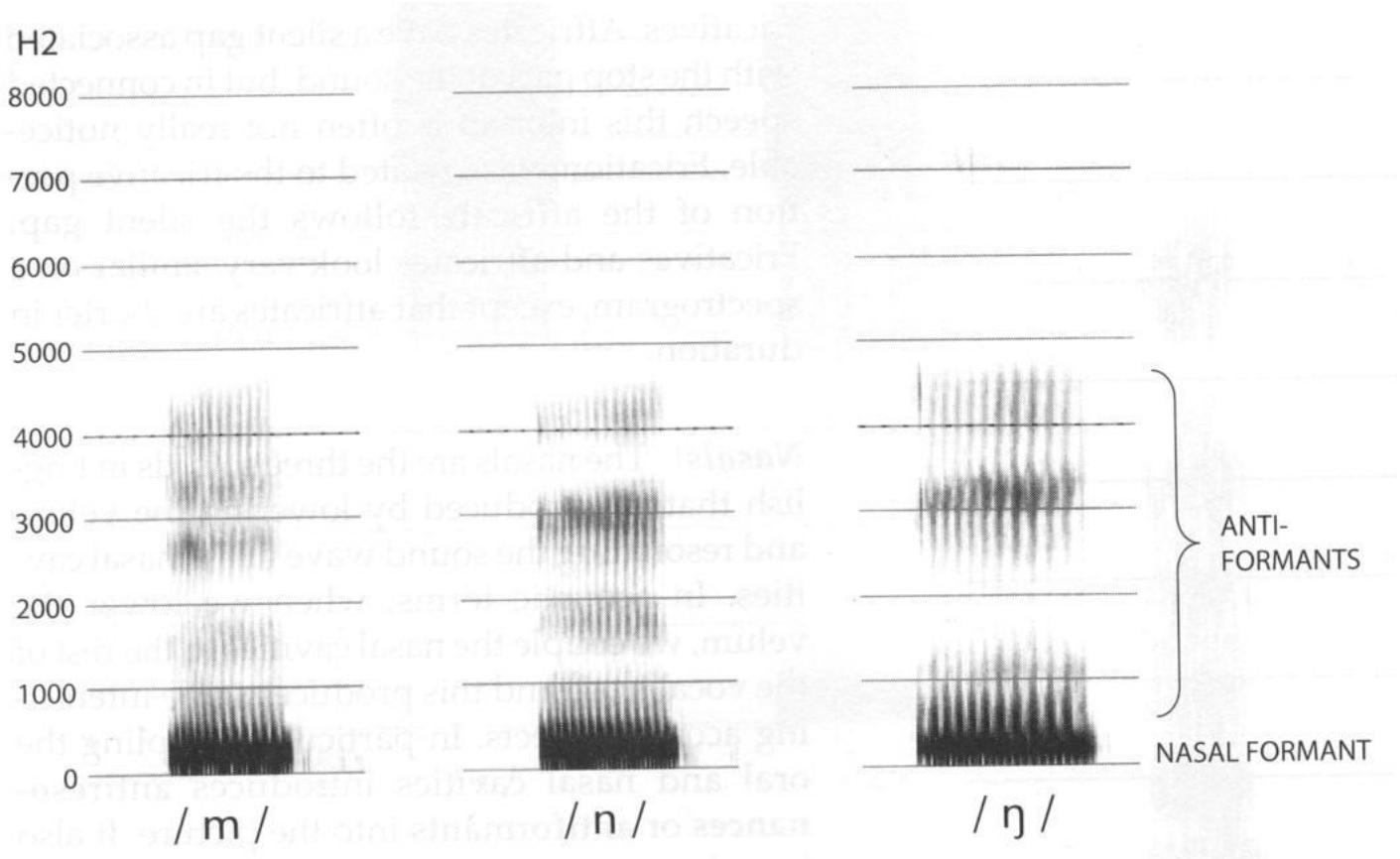
Nasal stops

- Spectrograms of *“dinner dimmer dinger”*
- Marked by “ zeroes” or formant regions with little energy
- Can also result in broadening of formant bandwidths (fuzzying the edges)



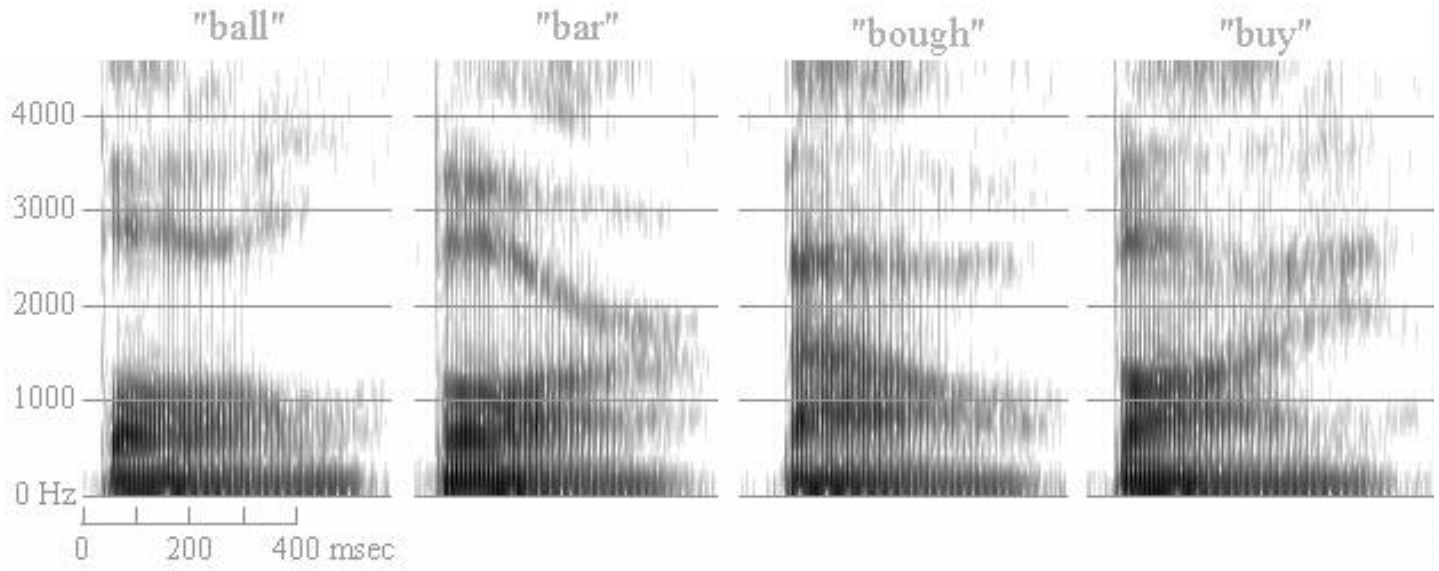
Nasals – continued

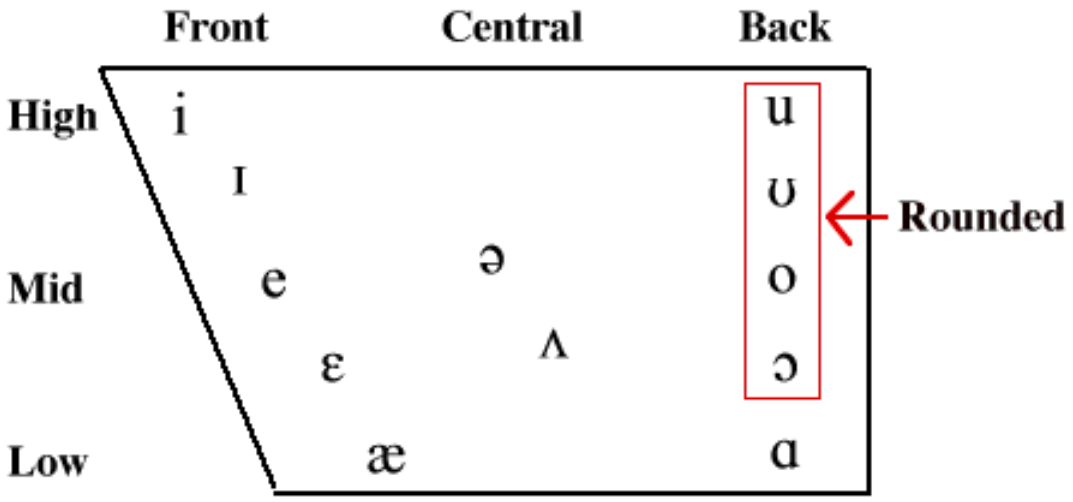
- The nasal tract has its own resonant frequencies or formants.
- ~ 300Hz, 1kHz, 2.2 kHz, 2.9kHz, 4kHz.
- *Anti-resonance*s enter whenever there is a side branch in the main acoustic pathway.
- An *anti-resonance* (or zero) absorbs the sound near the anti-resonant frequencies.
- Reduces the total amplitude of the sound.

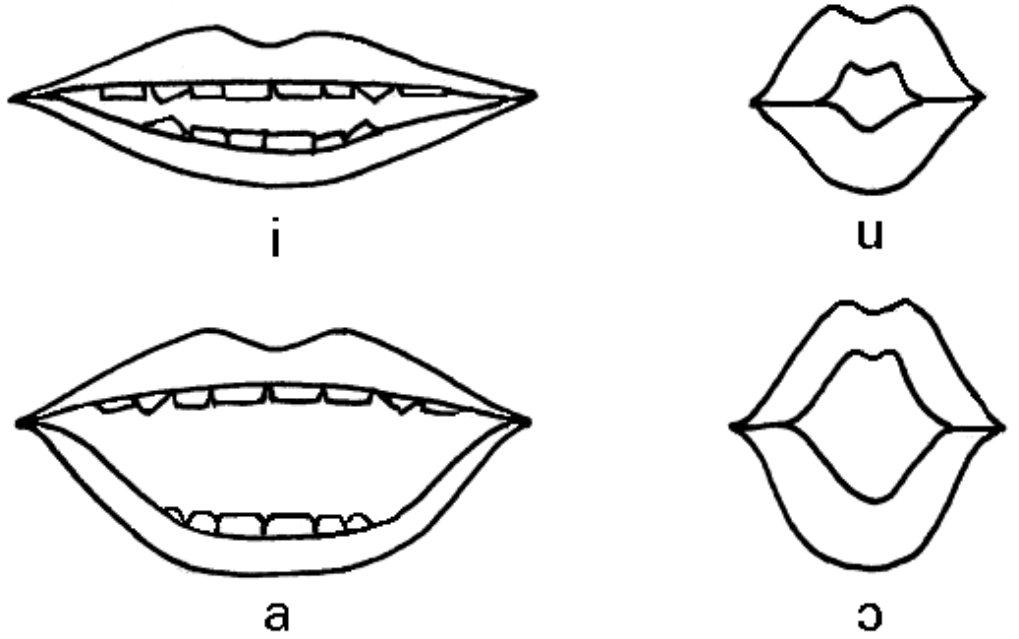


Approximants (semivowels)

- /ɹ/ - very low third formant, just above F2
- /l/ - formants in the neighborhood of 250, 1200, and 2400 Hz
- Less apparent in final position
- Higher formants very reduced in intensity







Lip Rounding

Coarticulation

- Anticipatory ("look ahead" or "Right to Left" -- a measure of speech planning)

  Example: amount of lip rounding in the /s/ of /si/ vs. /su/

- Perseverative ("carryover" – or "Left to Right" --due to mechanico-elastic properties of articulators)

- Coarticulation has both language-specific and universal attributes

Suprasegmentals

- Stress: Lexical, focus (emphasis)
- Sentence– level intonation:
  - ✓Simple declarative
  - ✓Y/N-Q
  - ✓Wh-Q
- Duration – can also signal the end of a sentence or phrase

Chapter 7
Evaluation and treatment of disorders related to articulation

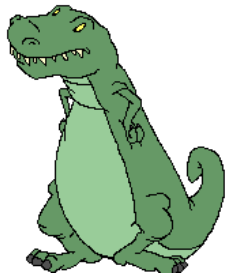
- KINEMATIC MEASURES
- POPULATIONS CONSIDERED:
  - Dysarthria, apraxia, hearing impairment (HI) phonological/articulation disorders, cleft palate, stuttering
- BIOFEEDBACK IN CLINICAL INTERVENTION

Kinematic measures

- Cineradiography
- Strain gauge
- X-ray microbeam

- Ultrasound
- EPG and glossometry
- MRI
- EMA

..the first three are "dinosaurs"



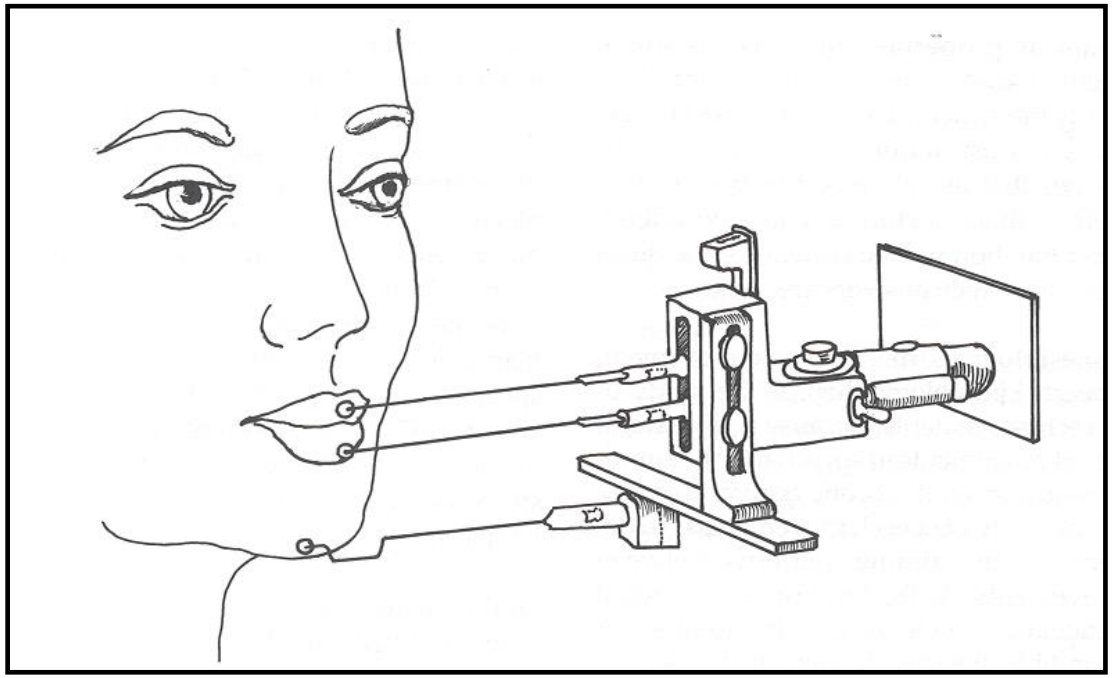
Cineradiography

- Early evidence of hard and soft tissue movement in real time

- Dangerous levels of ionizing radiation exposure

https://www.youtube.com/watch?v=K3aWyZhvACs

Strain Gauge



X-ray microbeam / U. Wisconsin

- Tracked small pellets glued to articulators
- Used a thin beam of x-rays
- Huge machine, cost millions
- No longer in operation

Ultrasound

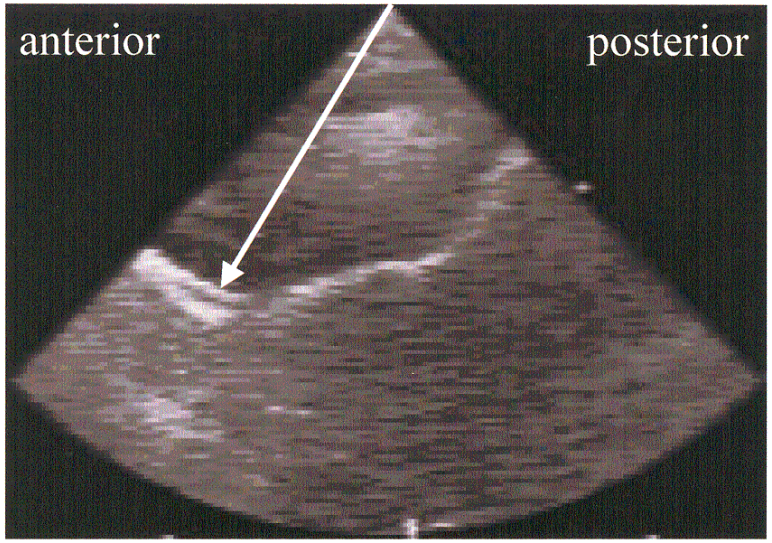
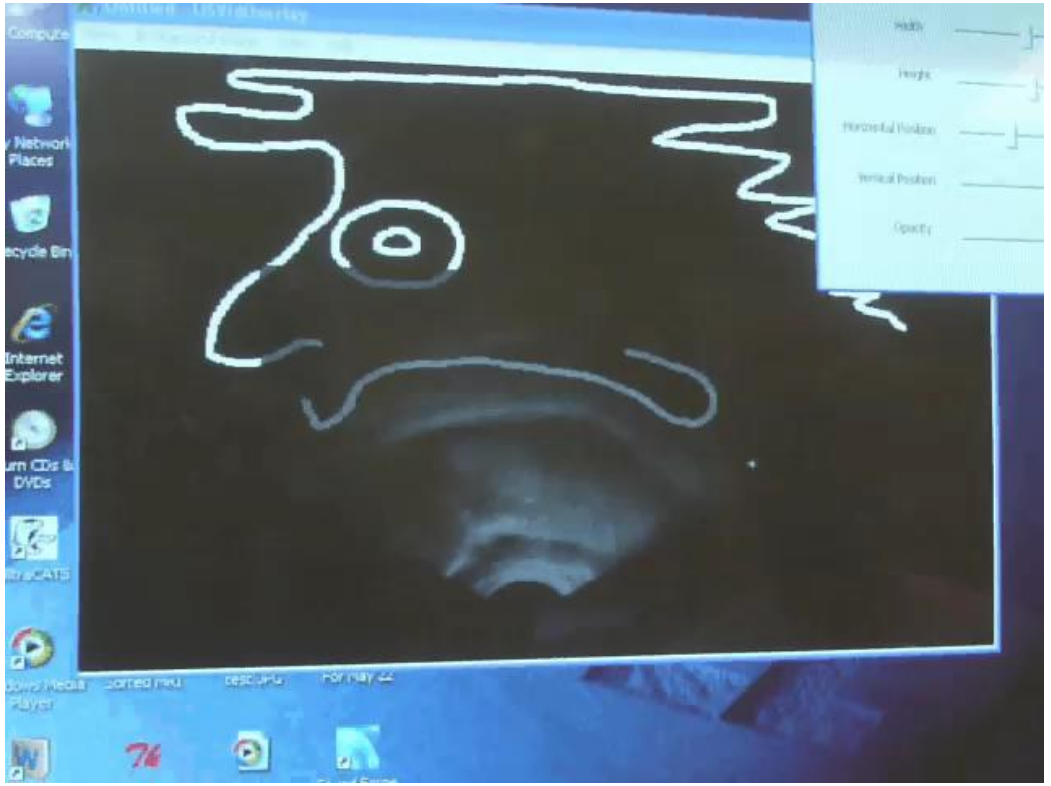


Figure 8. B-mode ultrasonic imaging of the sagittal configuration of the tongue.

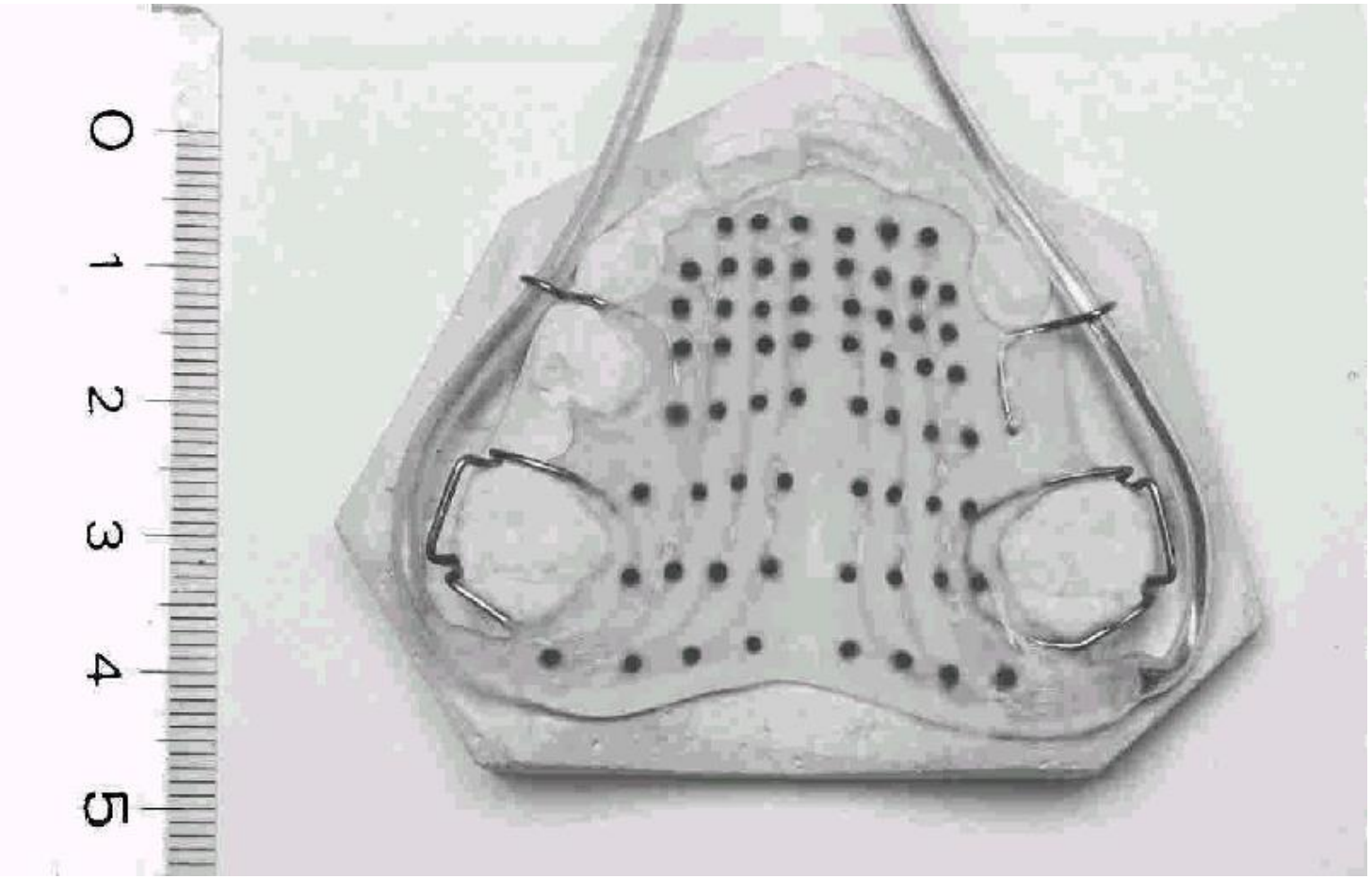
The distances from the top of the fan-shaped ultrasonic beam to the tongue blade were measured every 1/30 second during repetitive production of /ta/ .

Ultrasound as feedback

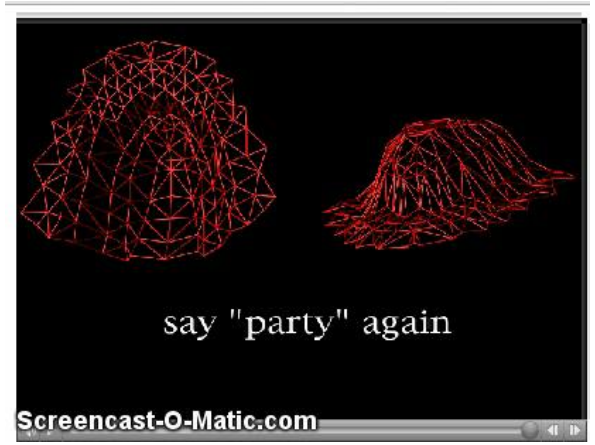
Tim Bressman, U. Toronto

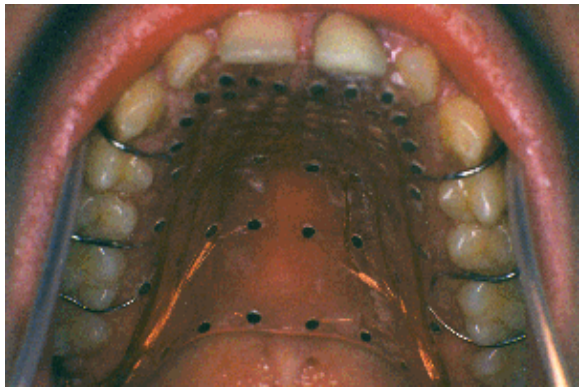


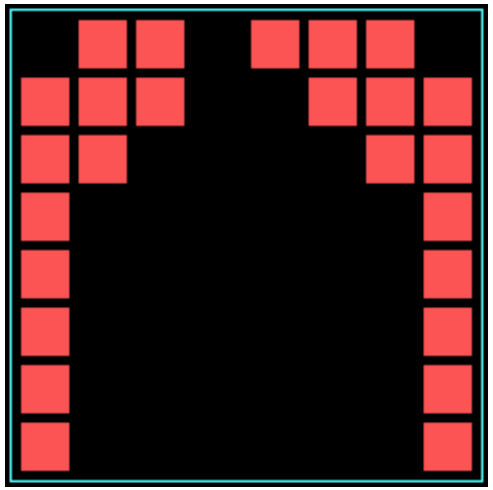
https://youtu.be/eUhlAg-HEM0



Electropalatography (EPG)







EPG – detail

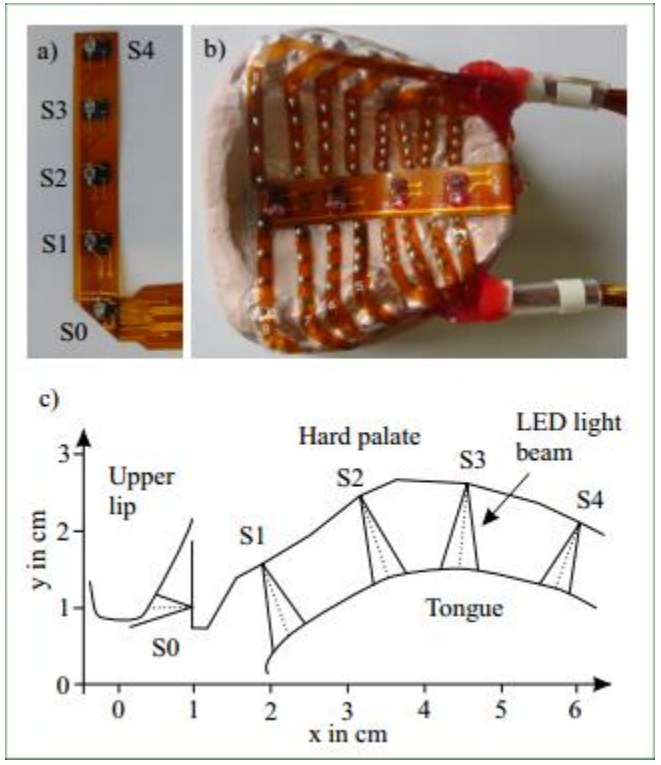
https://youtu.be/O_IRgP-iUuE

EPG in the clinic

https://www.youtube.com/watch?v=UXM3gNxGO2M

Palatometry training demo

TWO-CHANNEL DISPLAY

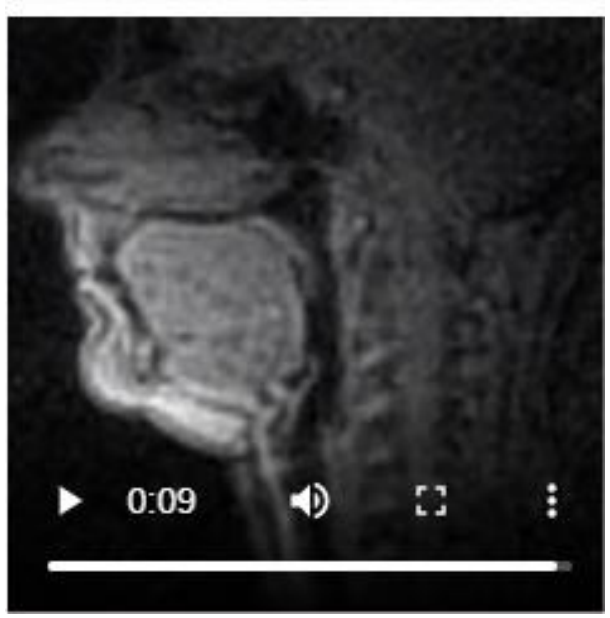


Electro-optical palatography

(BIRKHOLZ ET AL., 2012)

Real-time MRI

NARAYANAN ET AL. *USC 'SAIL' LAB*

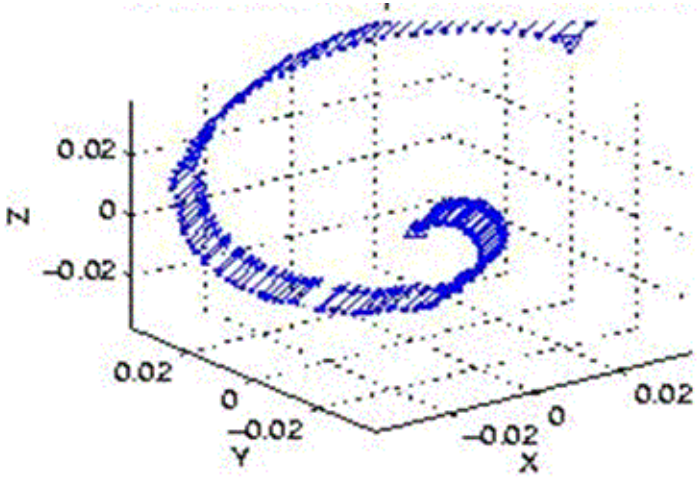


Female talker

https://sail.usc.edu/span/videos/span_welcome.mp4

Female singer

https://youtu.be/TplGVY5mv5Q

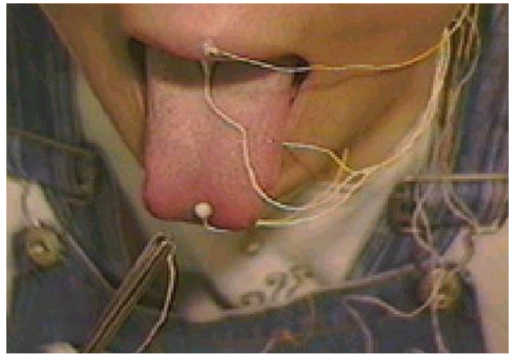


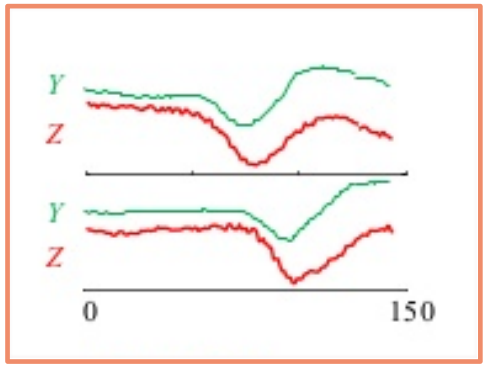
Electromagnetic articulography (EMA)

Magnetic tracking of small sensors attached to lips, jaw, tongue

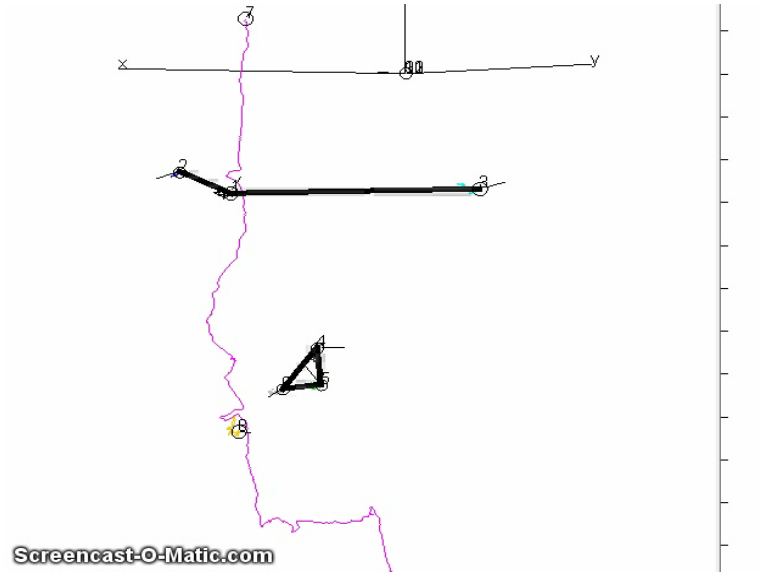
3D

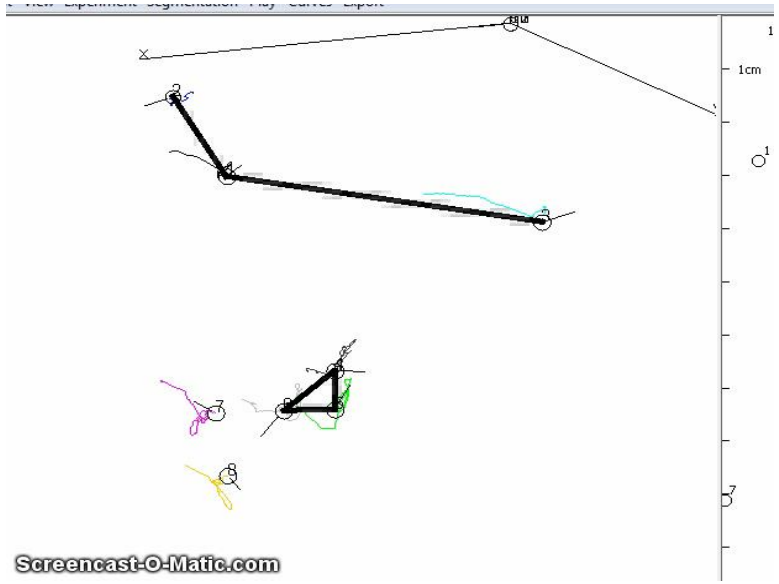
“Fleshpoint” tracking





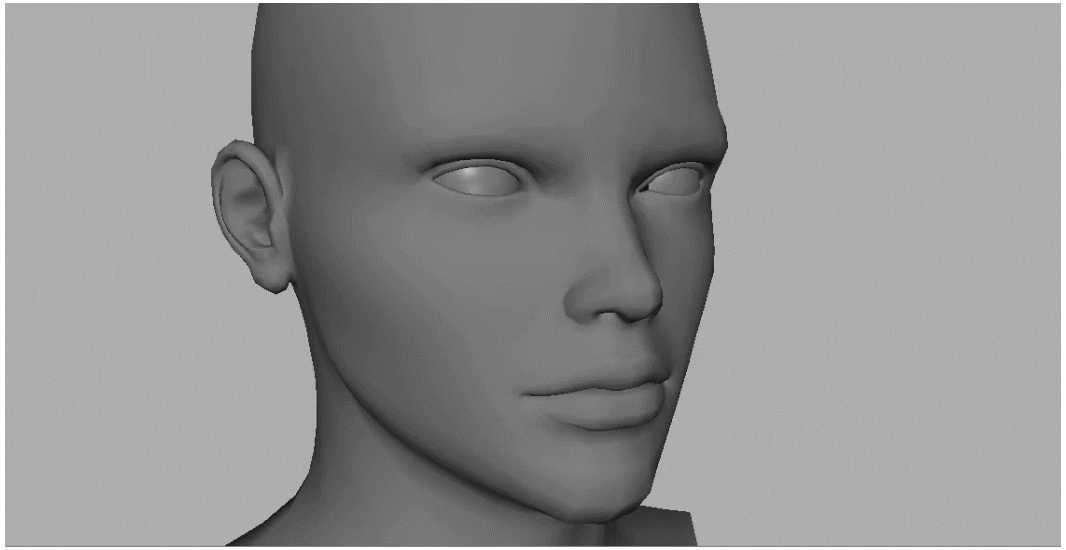
Recent demos - EMA





Recent video from Toronto Lab (van Lieschout)

UTD Visible Speech Project

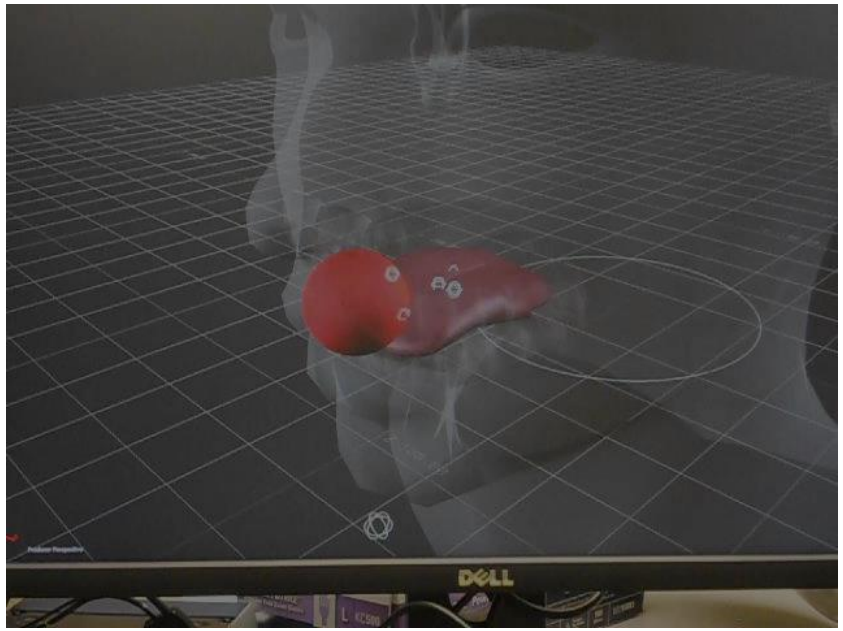


https://youtu.be/4qFxCx7gcXE

Tom Campbell/ Eric Farrar/ William Katz/ Balakrishnan Prabhakaran/Robert Rennaker (2010)

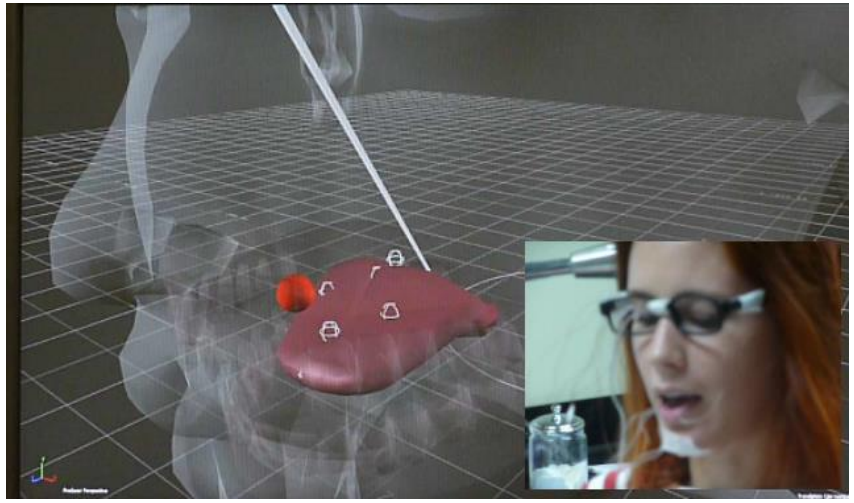
Optispeech – An interactive EMA system

#1 (8-13)



https://youtu.be/OohNe7r3M7M

#2 (9-13)



https://youtu.be/QxKL3Z_Ig-g

Articulation and intelligibility

Dysarthria, Apraxia of speech

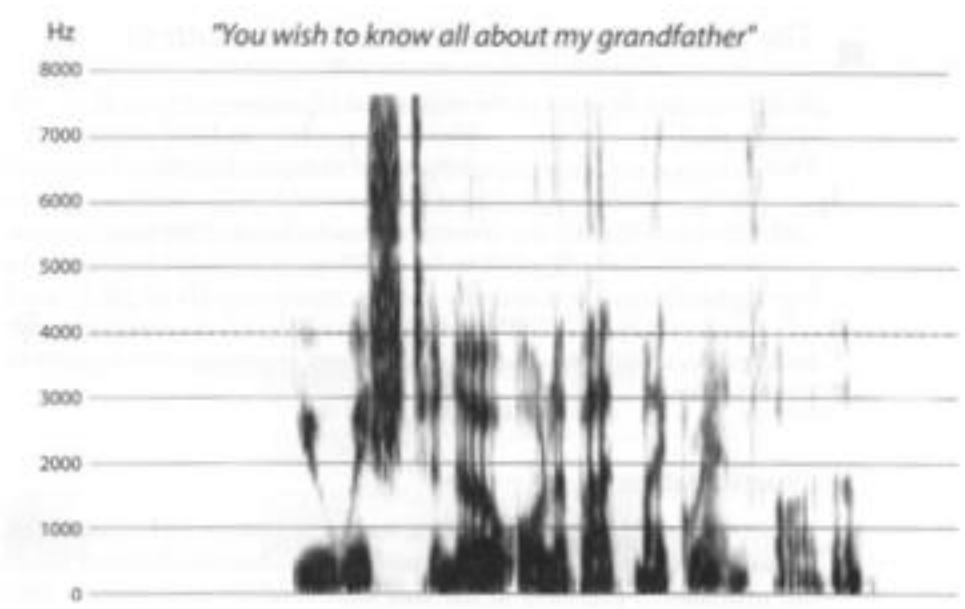
Hearing Impairment (HI), Cochlear implantation

Children with Speech Sound Disorders

Cleft lip/palate

Stuttering

Healthy adult vs. dysarthric speech



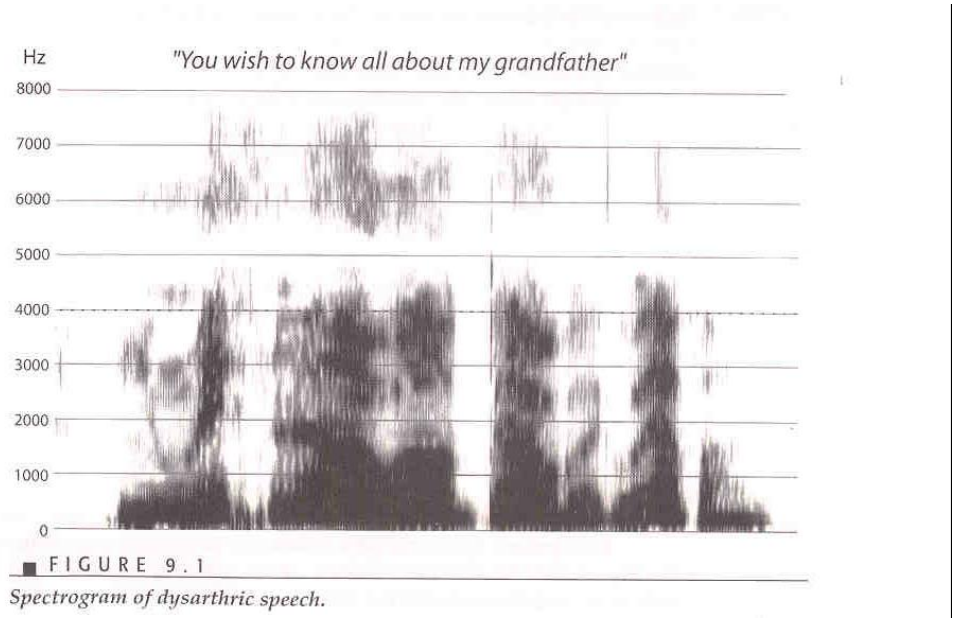


FIGURE 9.1
Spectrogram of dysarthric speech.

Longer durations

Dysarthria - vowels

Widening of vowel F1/F2 values with recovery

- Ziegler and von Cramon (1983)

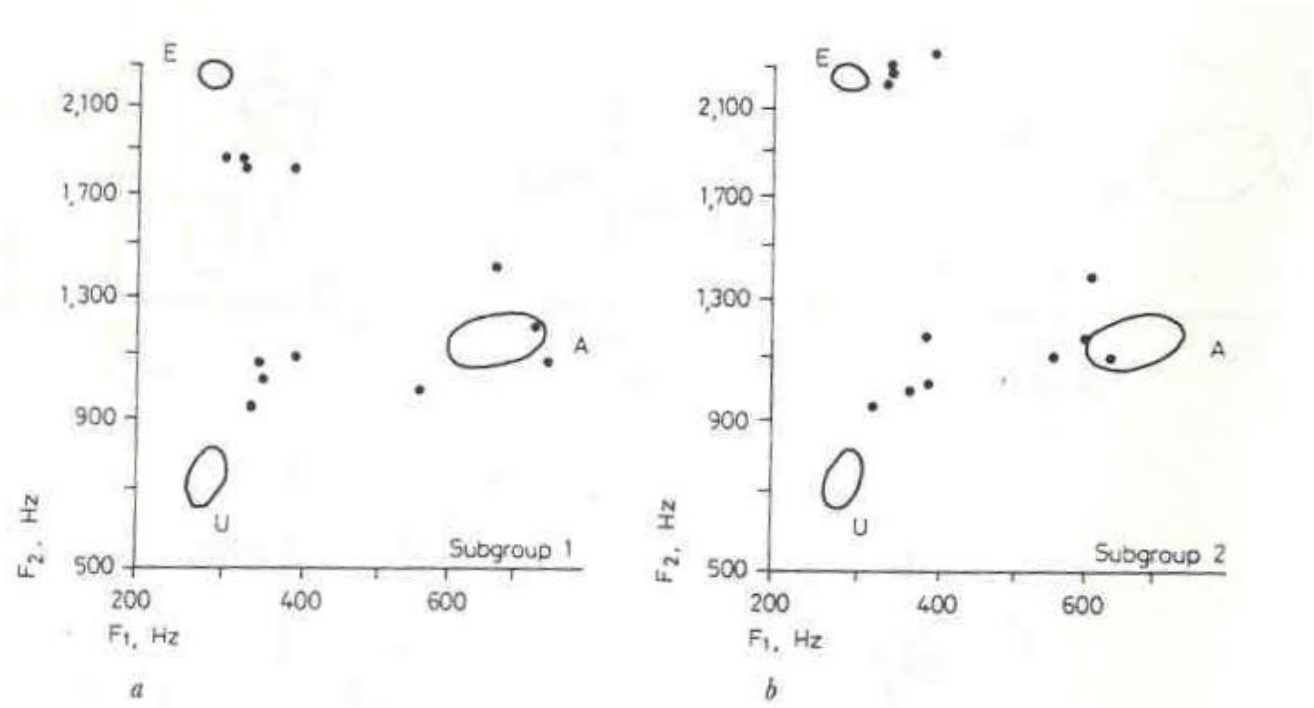


Fig. 3. Formant positions of subgroup $\mathcal{P}_1$ (*a*) and $\mathcal{P}_2$ (*b*) within the initial stage of recovery; the formant positions of the control group are described by 1 σ-radius ellipses.

Dysarthria – consonant measures

- Distortion (e.g., /s/~/ʃ/)
- May interact with speech rate
- Accelerated speech for PD – linked to articulatory undershoot
- Others argue that slowed rate in PD may be a form of compensatory mechanism to ‘make up’ for undershoot

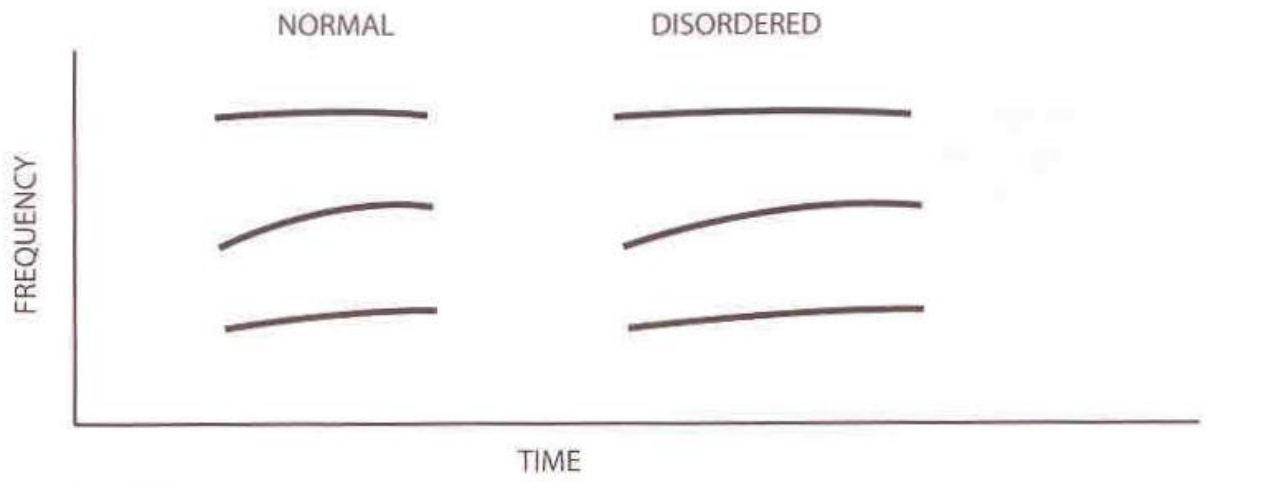


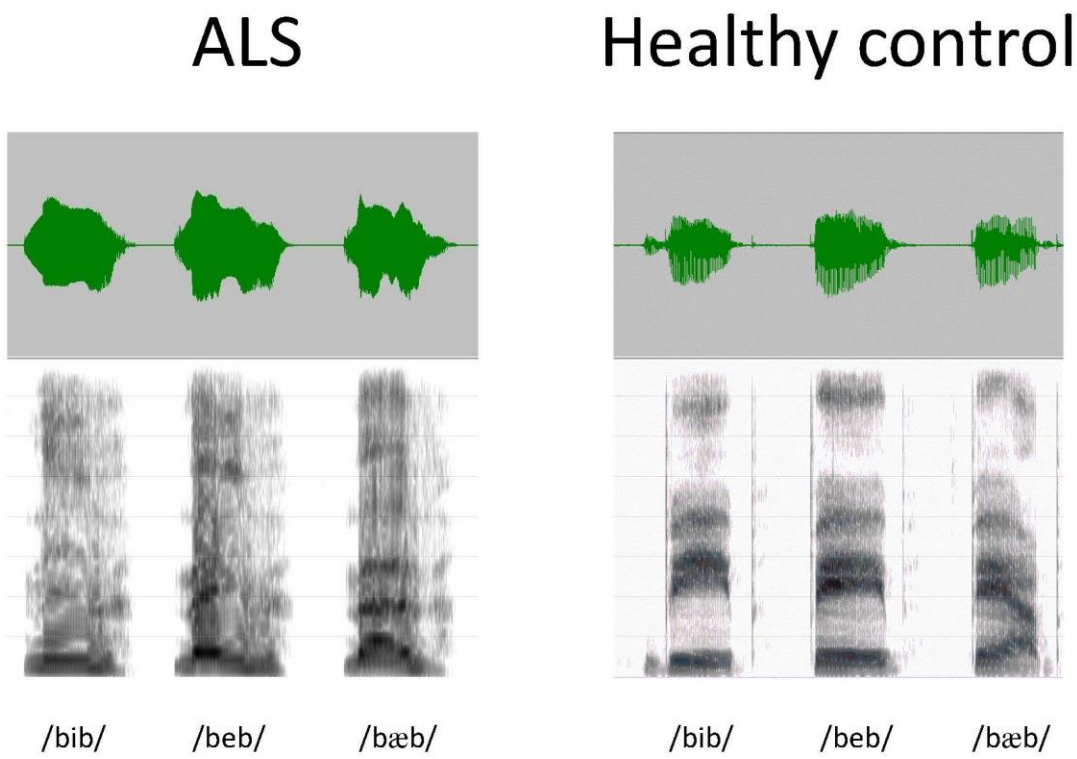
FIGURE 9.2

Formant trajectories.

ALS - consonants

- Formant trajectories
- Slope index (Hz/ms)
- Flatter slope = movement made over a greater period of time

Healthy vs. ALS speech



Apraxia of speech (AOS) Acoustic characteristics

Rate	Increased duration
	Syllable segregation
Vowels	Overall FFs *wnl*
	Increased variability
Consonants	Poorly formed stop bursts
	Imprecise VOT
	Distorted palatal contact for fricatives
Prosody	Highly variable coarticulation

Hearing impairment (HI)

- Congenital (or pre-lingual) loss vs. post-lingual loss
- Loss of speech intelligibility
- Difficulty in segmental aspects of speech
- Difficulty in control of suprasegmental aspects of speech
- Difficulty with coarticulation

HI – continued

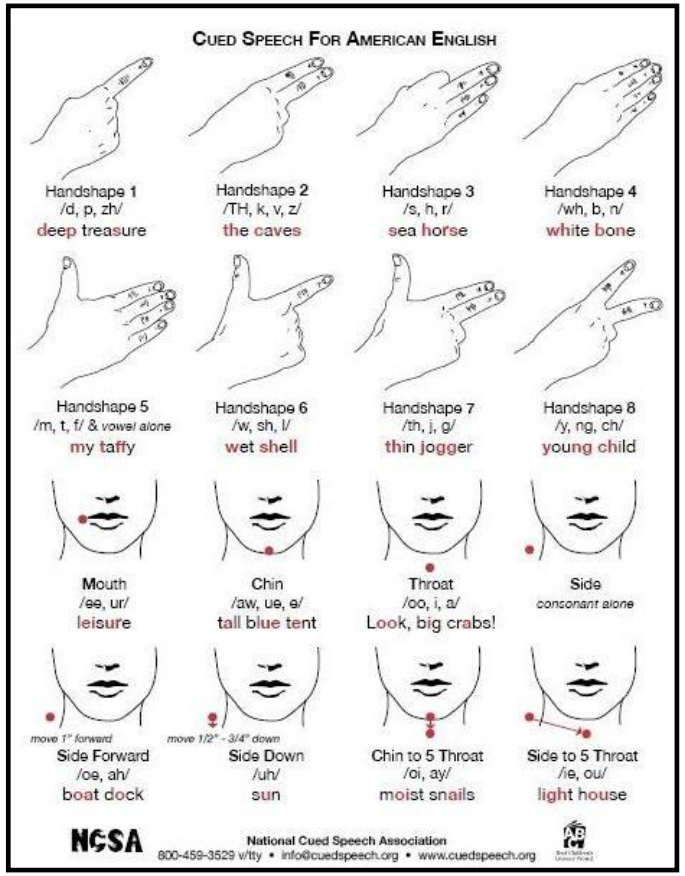
Most frequent errors in spoken language:

- Tend to neutralize vowels
- Marked limitations in both horizontal and vertical degree of tongue movements for vowels
- Consonant errors common—omissions and substitutions involving voicing and manner
- Place errors also common because of imprecise tongue position and reduced articulatory movement

Some HI speech samples….

http://www.youtube.com/watch?v=U8lebyetQkc (SON AND DAUGHTER)

http://www.youtube.com/watch?v=yJLJtWGVjRw&list=PLA19A37A706CA8FA8 (FORMER MISS AMERICA)



Cued speech (1966)

Phonemically based

Adopted for > 60 languages

Note: not covered in text

Acoustic Analysis of Deaf Speech

At segmental level of analysis:

Alveolar and velar stops → produced further back in the vocal tract than normal

- Provides clues for speech therapy

HI - Suprasegmental aspects

- Incorrect F_0 in word and sentence production
- Not enough variation in F_0 to differentiate between declarative and interrogative utterances

HI - Speech therapy

- Many programs focus on improving speech intelligibility
- Maasen & Povel (1985) took speech samples of deaf talkers, resynthesized them, and played back to normal listeners
- Results: improving segmental production caused 50% improvement in intelligibility - with major increase resulting from correcting vowel production
- Feedback therapy (visual, tactile) reports recent gains

HI - Instrumentation in treatment

- Residual hearing
- Visual cues
- Spectrographic displays
- Palatometry
- Glossometry

Children with speech sound disorders (SSD)

- Caused by neurological, structural, syndrome, or sensory problems
- Acoustic data helpful in sorting out error patterns
- Some children can tell between place (e.g. /k/ vs. /t/) or voice (VOT) distinctions – these kids have better prognosis
- Children who do not differentiate may benefit from activities designed to promote awareness of sound differences

  (We will revisit this later in speech perception unit)

Speech sound disorders – cont'd

- Big issue: "Delay vs. deviance"
- Early phonological process in production = fronting

  (e.g., "candy" → /ˈtændi/)
- Questions – What happens with maturation? What if one observes, e.g. backing?

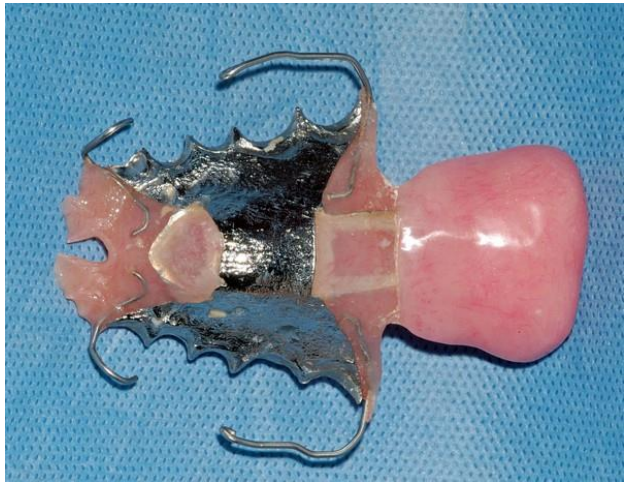
Cleft palate

- Unique compensatory pattern of speech, including glottal stops and pharyngeal fricatives – can be maladaptive
- Michi et al. (1993) used EPG as feedback during fricative production – reported substantial advantages

Girl with velopharyngeal insufficiency (VPI)

Cleft palate - velocardiofacial /22q11.2 deletion

Cleft palate - obturators, prostheses, surgeries



Resonance/Nasalance

3:40 VPI – Velopharyngeal insufficiency – Mayo Clinic

Stuttering – articulatory factors

Longer VOTs

Longer vowel durations

Extended F2 formant transition rates(?)

Subtle differences in jaw, lip, and tongue movements

“Hard contacts” = strong articulatory forces

Recommended: Resources Related To Stuttering (Univ. Washington Speech Motor Control Lab)