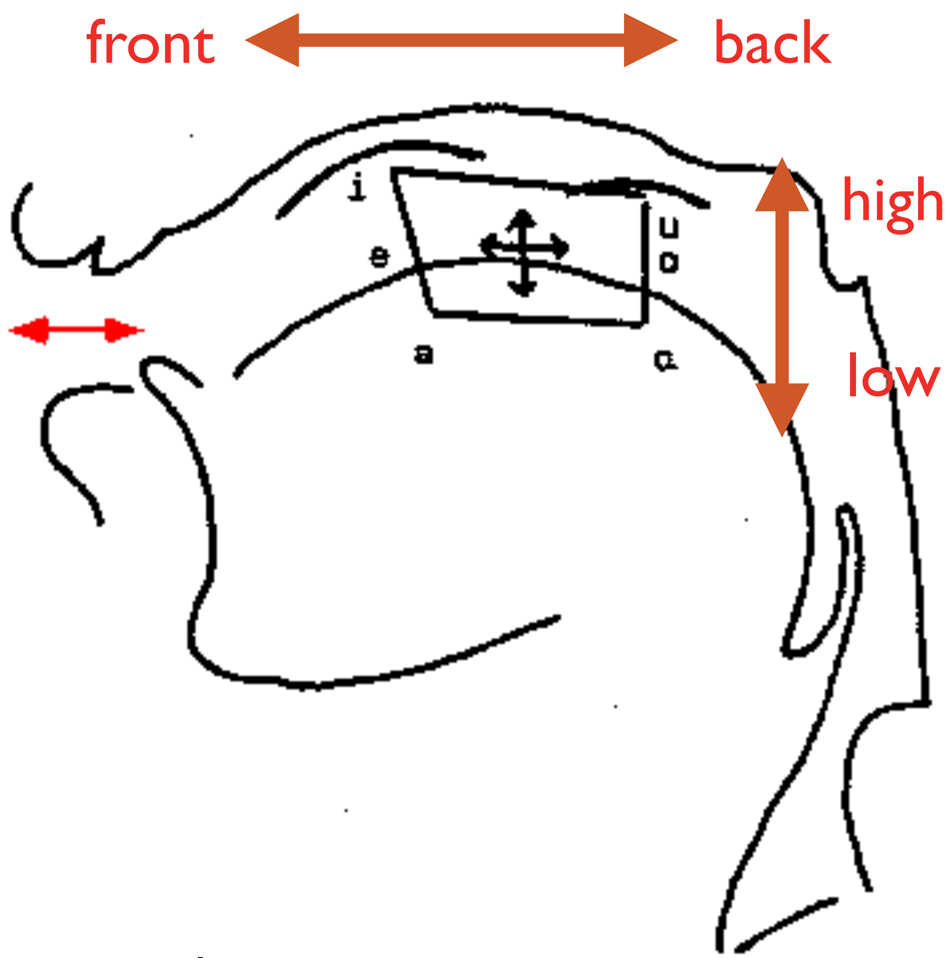
Vowels

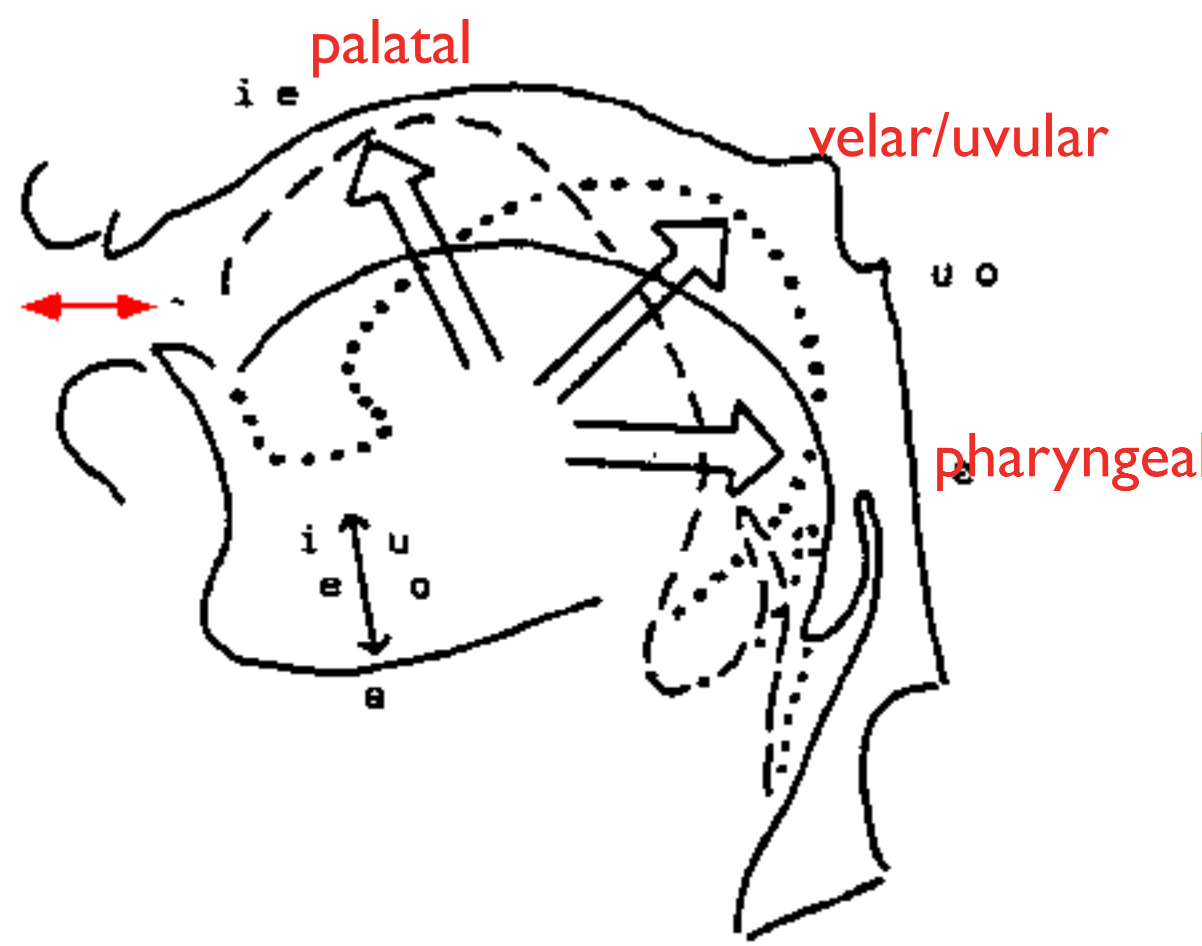
Two approaches to vowels

Continuous 2D Space



- Acoustics
- Auditory properties

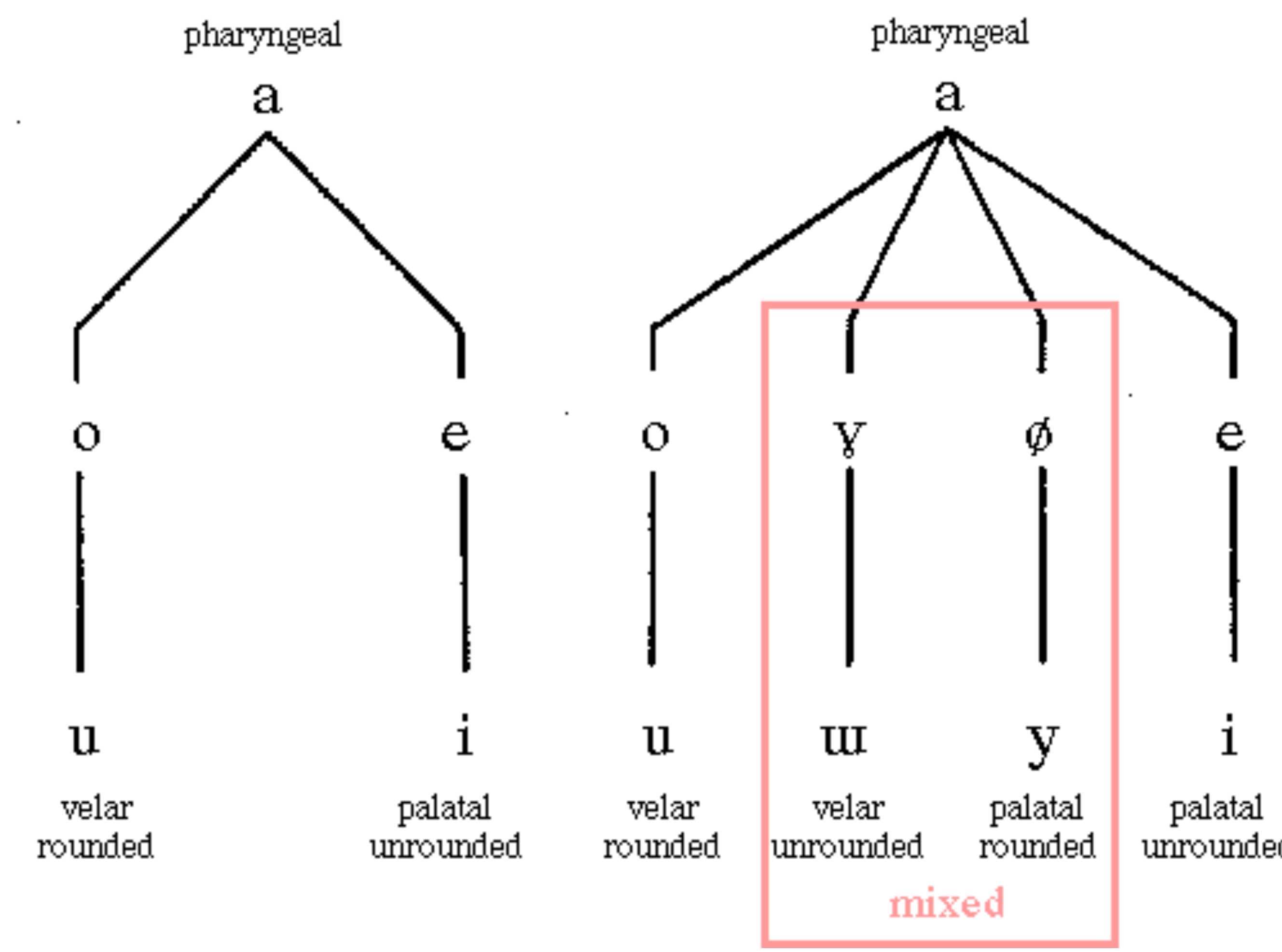
Discrete Constriction Locations



- Articulation
- Contrast

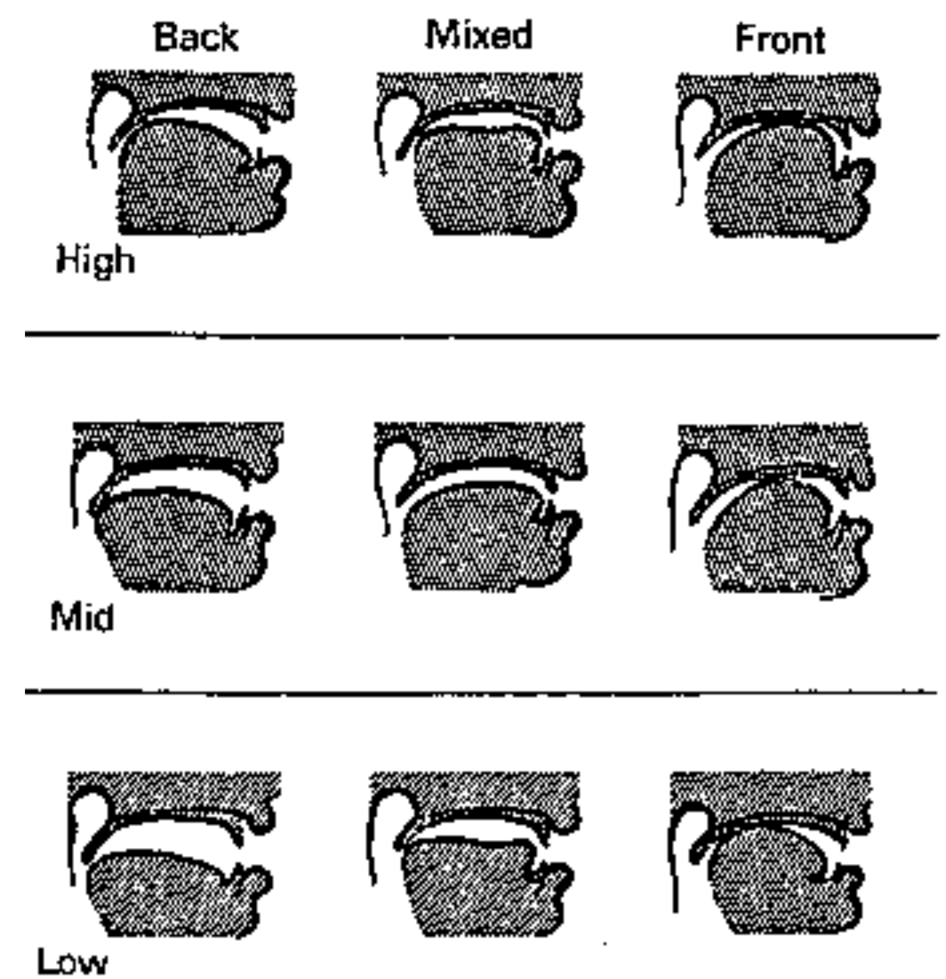
Discrete system

- Historically older, traditional view (at least as old as early Indian grammarians, 7th century).
- Vowels come in three distinct types:
  - palatal ("mouth vowels")
  - labio-velar ("lip vowels")
  - pharyngeal ("throat vowels")
- Each type is categorically distinct.
- Within each type, jaw height may be used to distinguish vowels

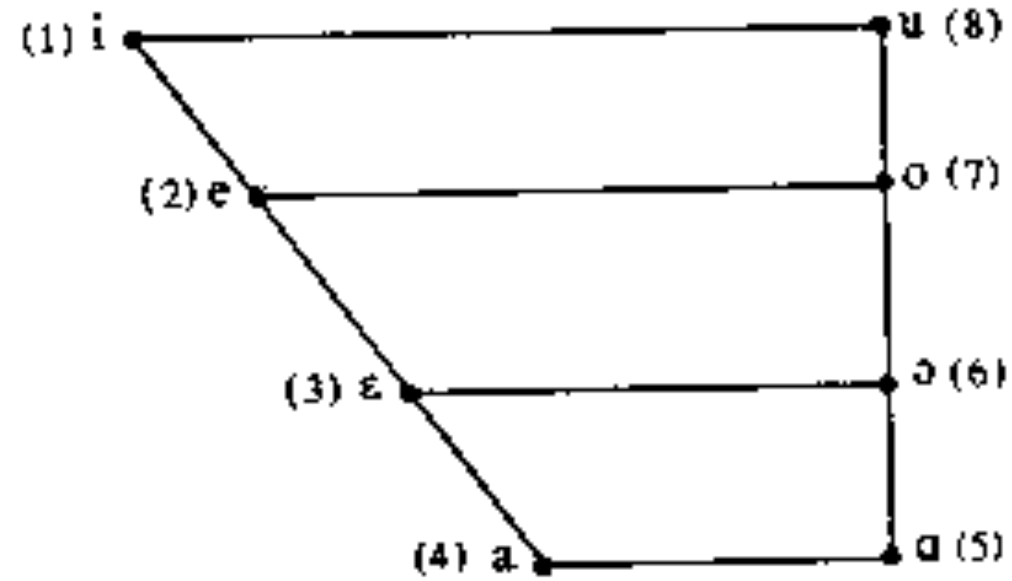


Origin of continuous space theory

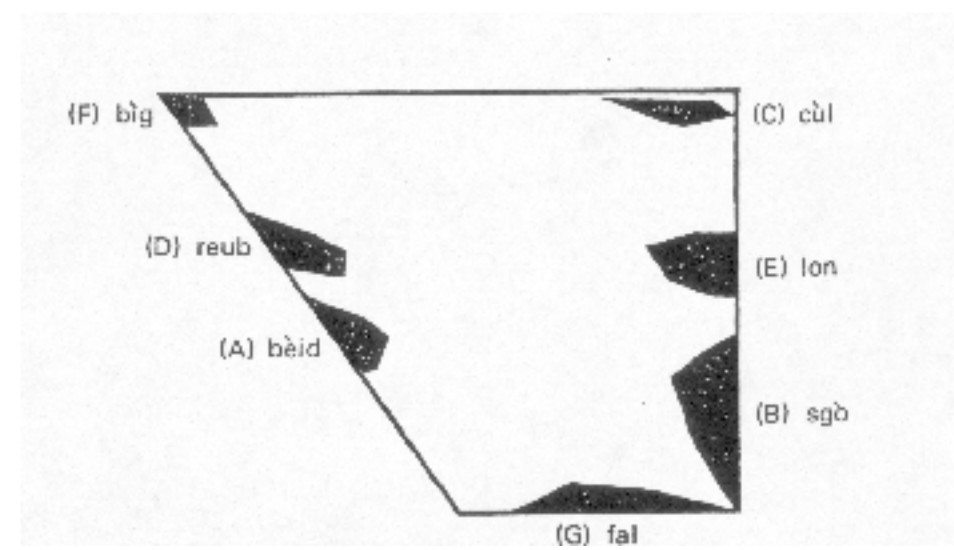
- A.M. Bell
- developed a system for teaching speech to deaf children
- Bell was haunted by inability to categorize the vowel in "Sir" within the tongue constriction theories.
- Bell invented central ("mixed') vowels (around 1867), and characterized vowels as points in a 2-dimensional space (e.g., high vs. low, front vs. back).
- "Mixed" vowels were both front and back. corresponding to his descriptive system



Cardinal Vowels of Daniel Jones (1917)



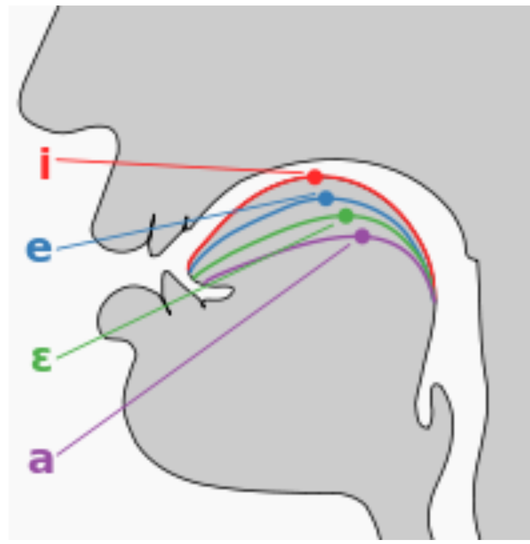
- Arbitrary Reference points in a 2D vowel space
- Auditory qualities learned by rote
- Definitions:
  - highest front possible = (1)
  - lowest back possible = (5)
  - others "auditorily equidistant"
  - (1) has maximal lip spreading
  - (8) has maximal lip rounding
  - gradual increase in rounding from (1) to (8).
- System could be used reliably by people trained

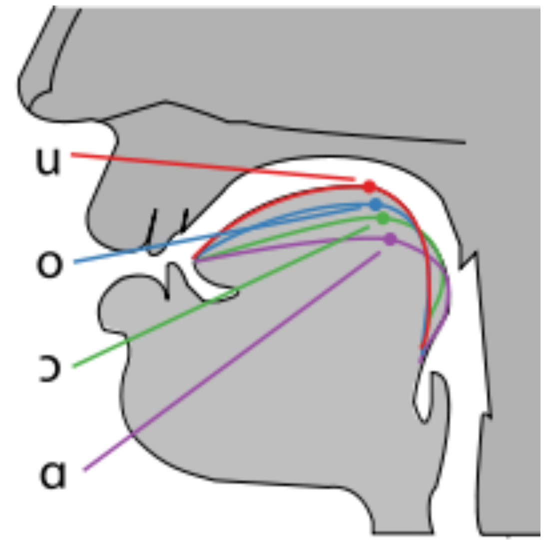


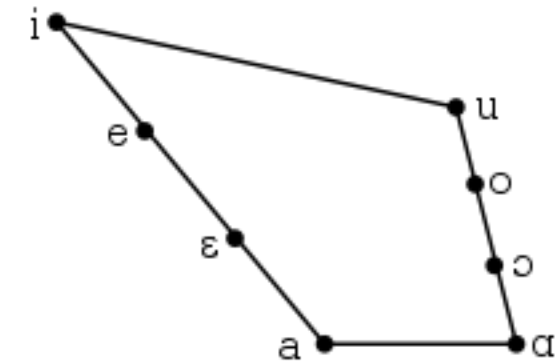
14/15 judgements of phoneticians listening to Gaelic vowels

Dimensions of Cardinal Vowel Space?

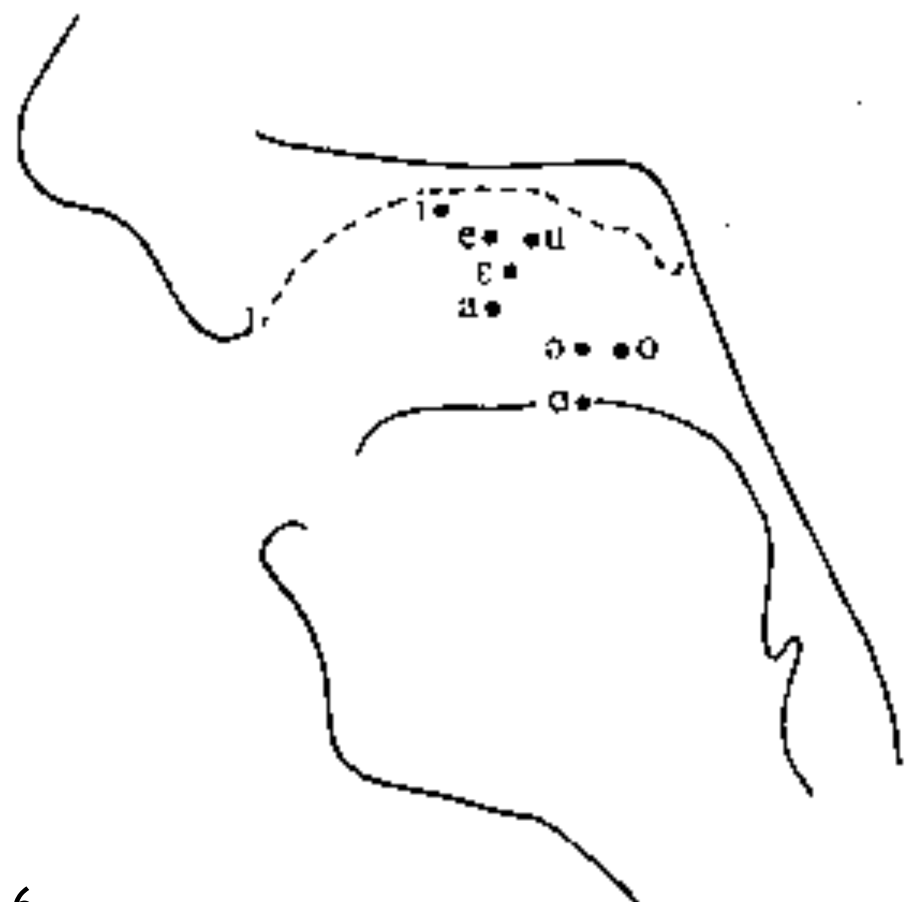
Phoneticians Imagine: position of highest point of tongue







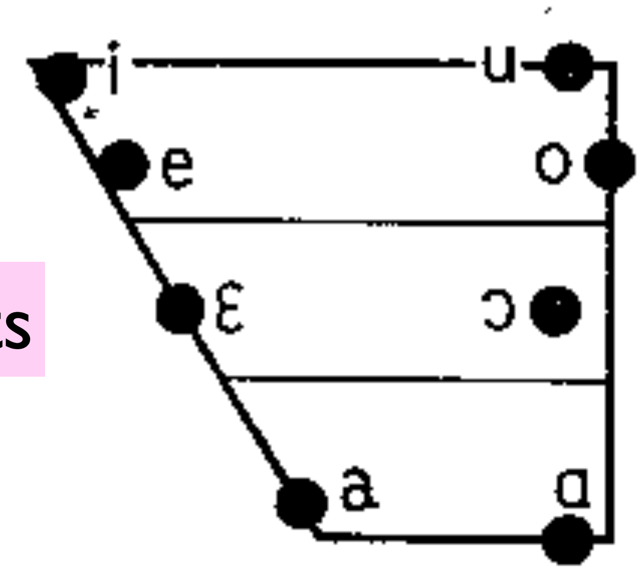
But the truth is a bit different
Cardinal Vowel X-rays of Stephen Jones (1929)



Peter Ladefoged: Formant Frequencies

- Sir Isaac Newton recognized the relation between vowel qualities and resonances.
- He noted that he could hear a progression of different vowels as he poured beer into a flaggon.
- Ladefoged: Very close relation spatial agreement between auditory judgments of trained phoneticians and plot of F2-F1 vs F2

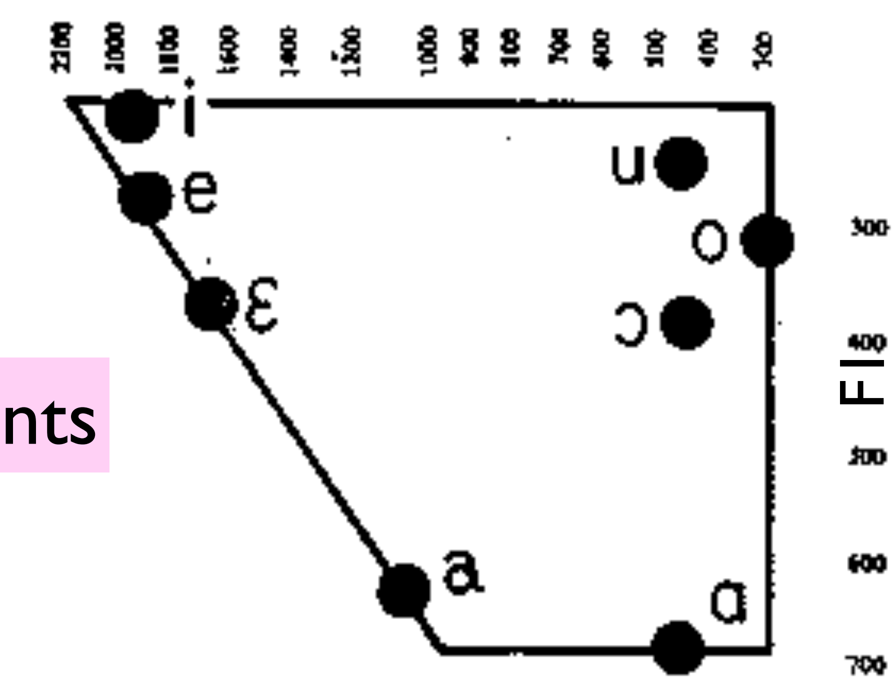
Judgements



Uldall (1933)

Danish Vowels

F2-F1

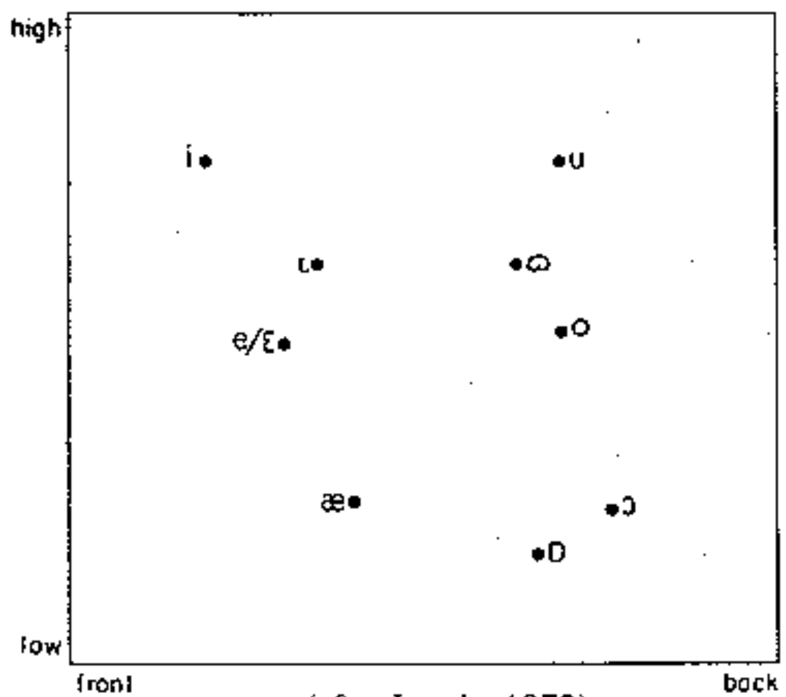


Formants

Fischer-Jorgensen (1972)

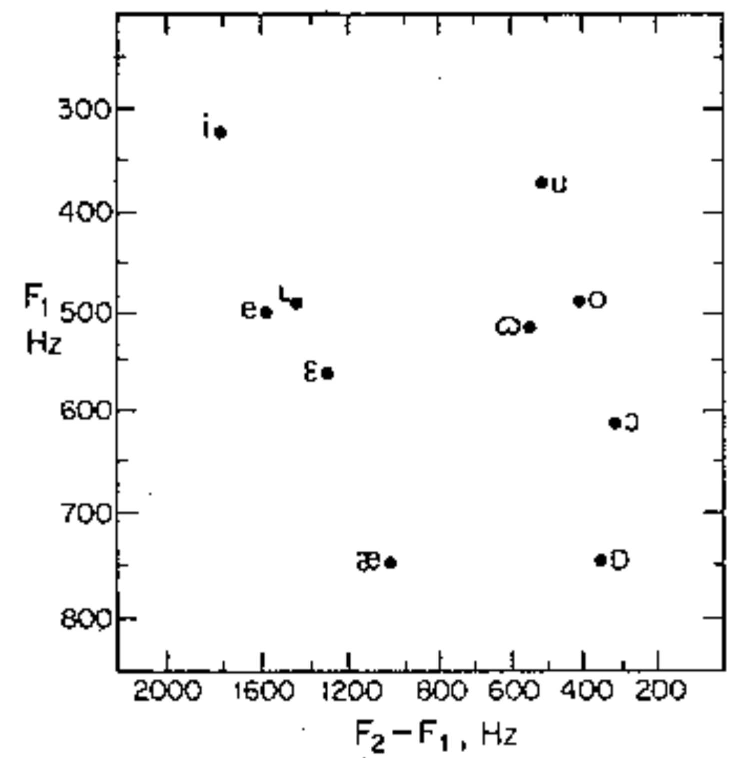
English Vowels

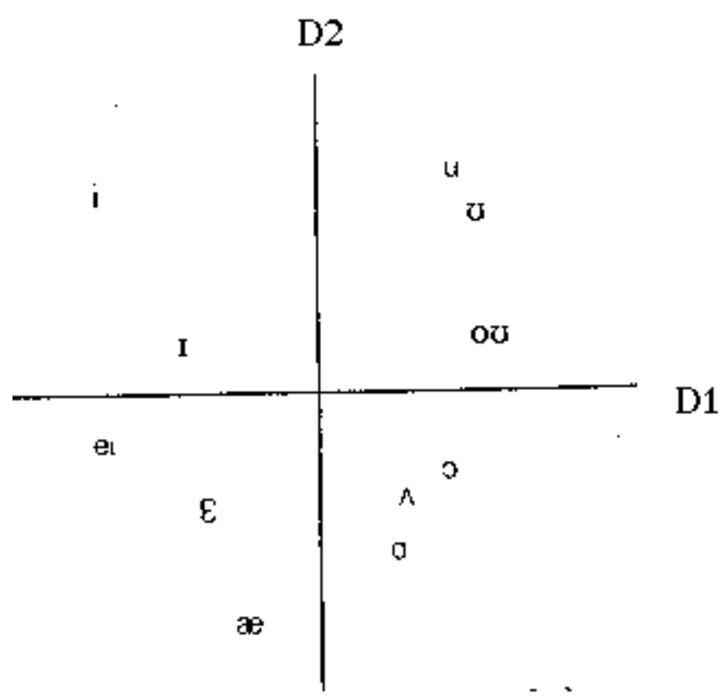
Auditory Judgements



(after Lewis, 1972)

Formants



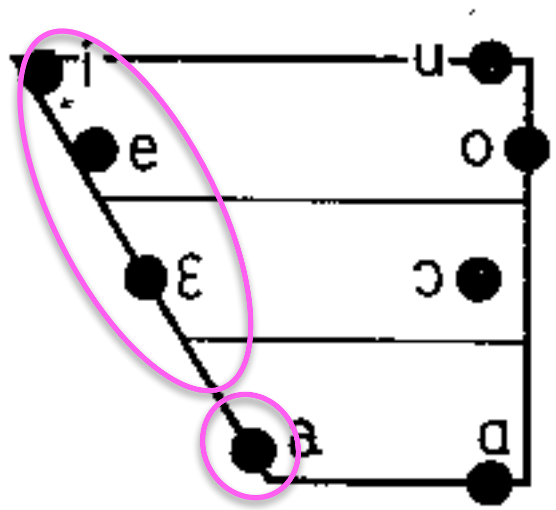


After Fox (1983)

Naive Listener Judgements

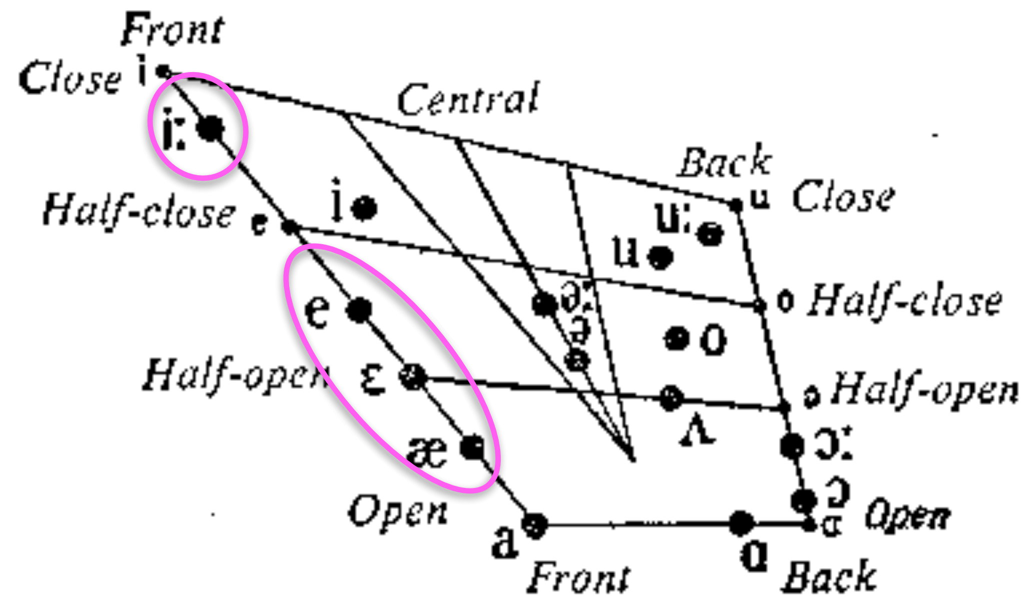
Capturing Language Differences

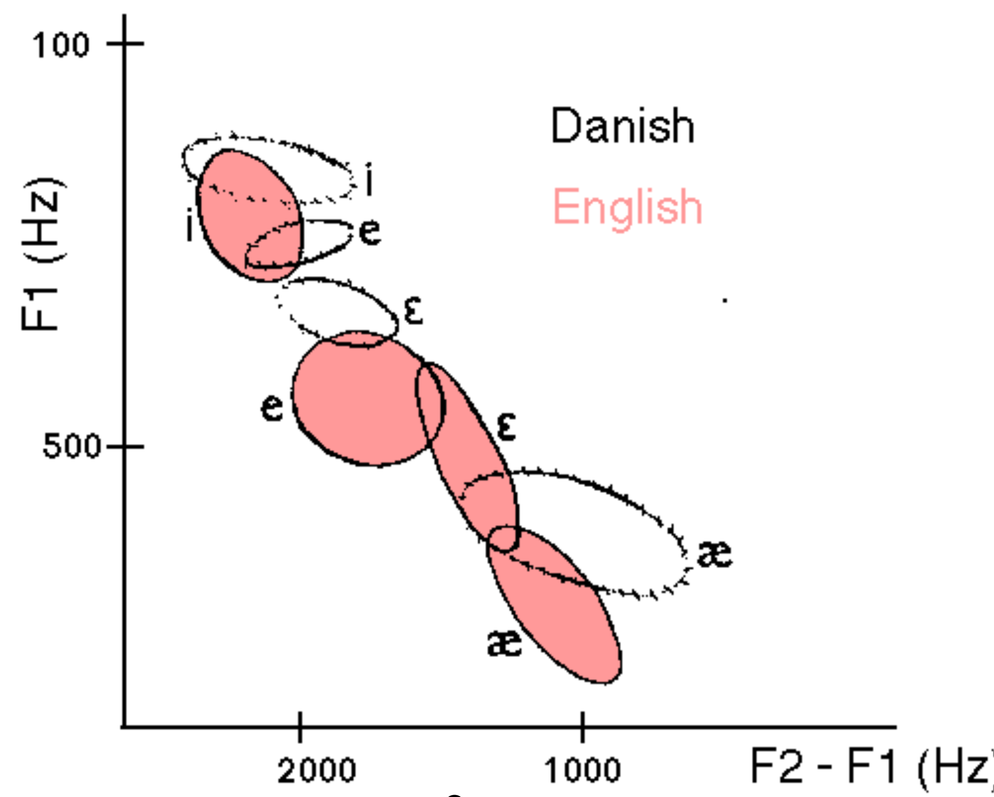
Danish



Uldall (1933)

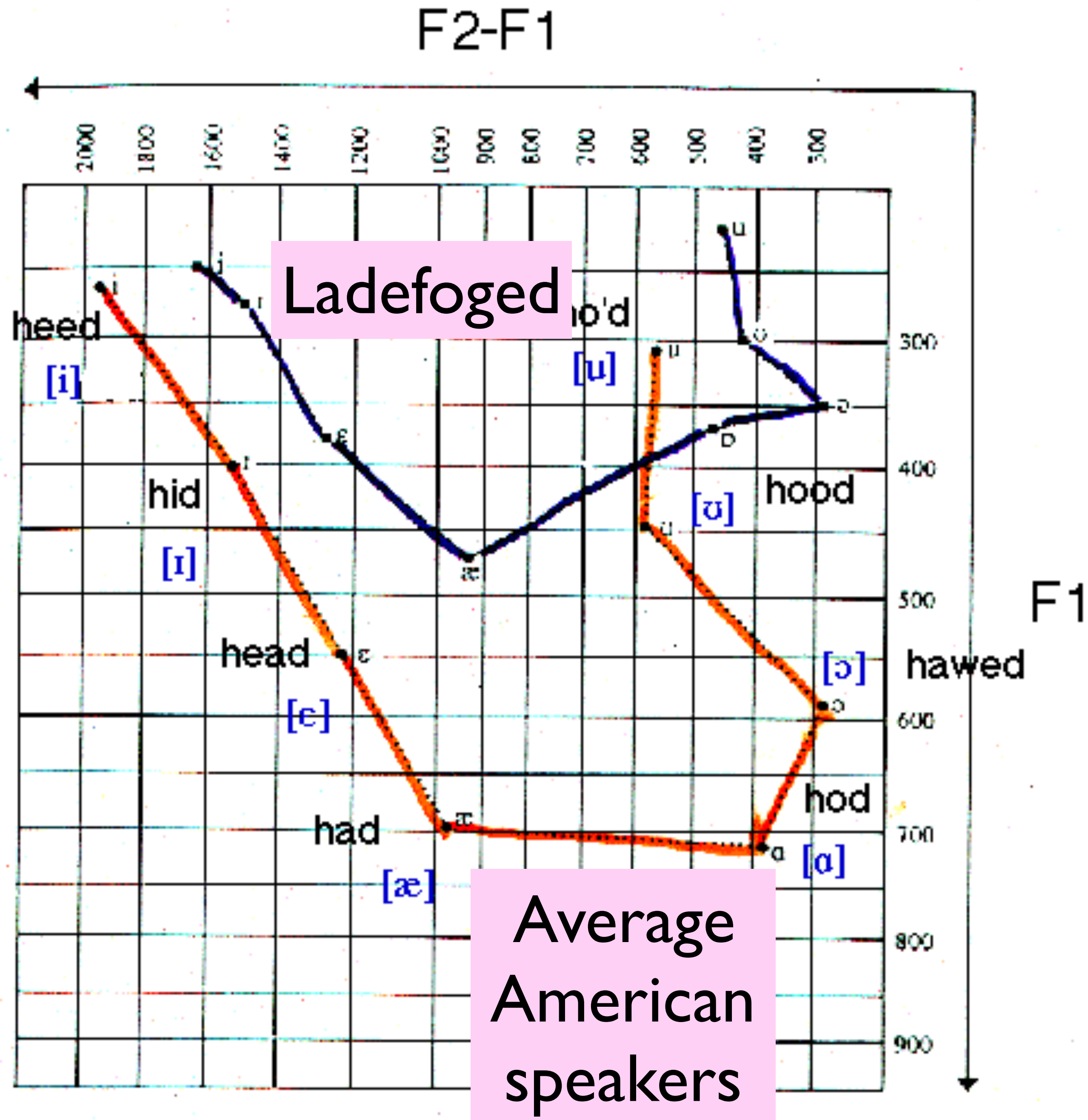
English





after Disner (1982)

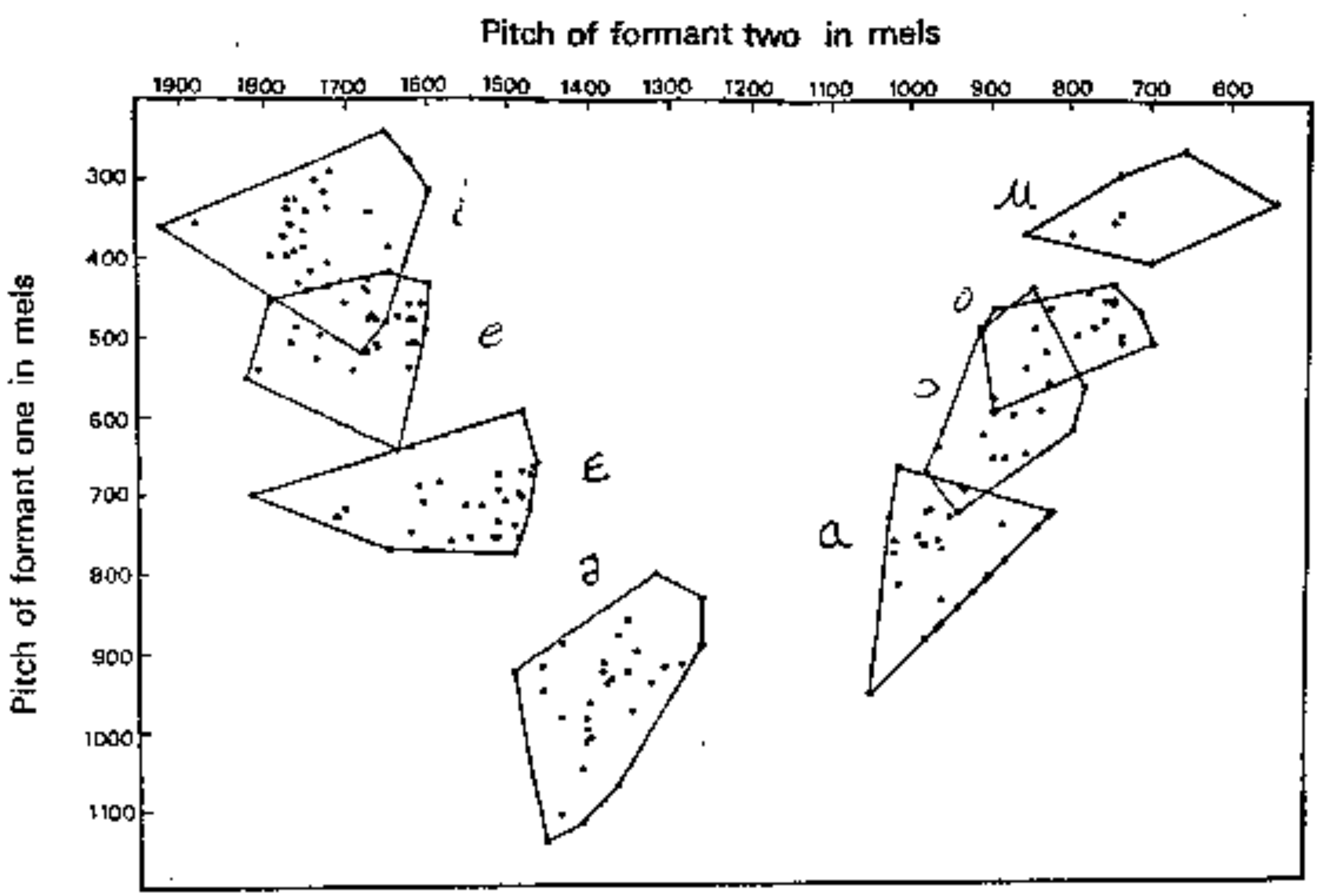
"But wait…"



- Formants are influenced by overall head size of the speaker.
- How can they represent the phonetic qualities of a language??

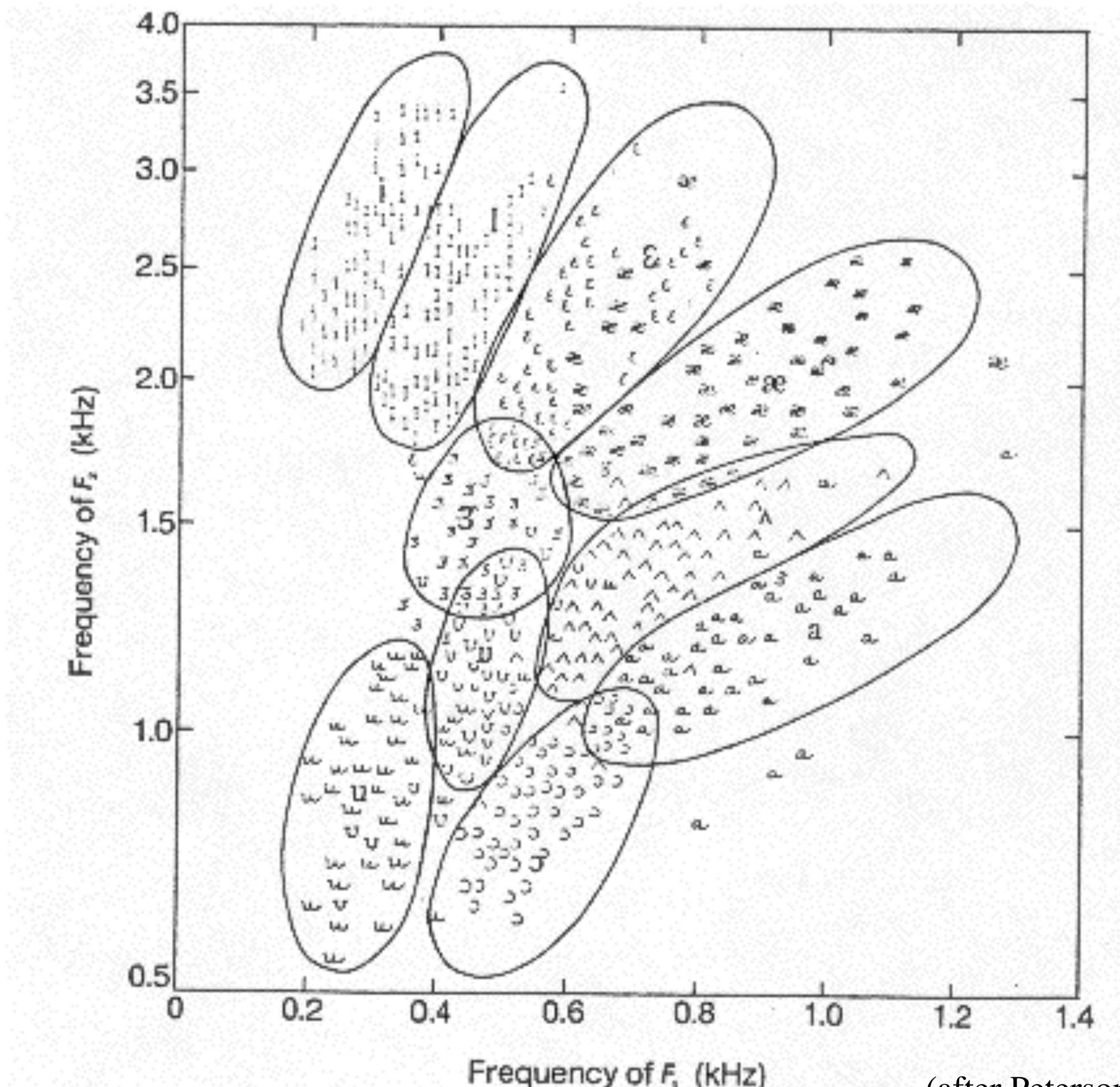
Individual differences in Cardinal Vowels

- Vowels spoken by trained phoneticians
- Different and different vowels overlap!



after Ladefoged (1967)

Formants values of American English speakers



(after Peterson & Barney, 1952

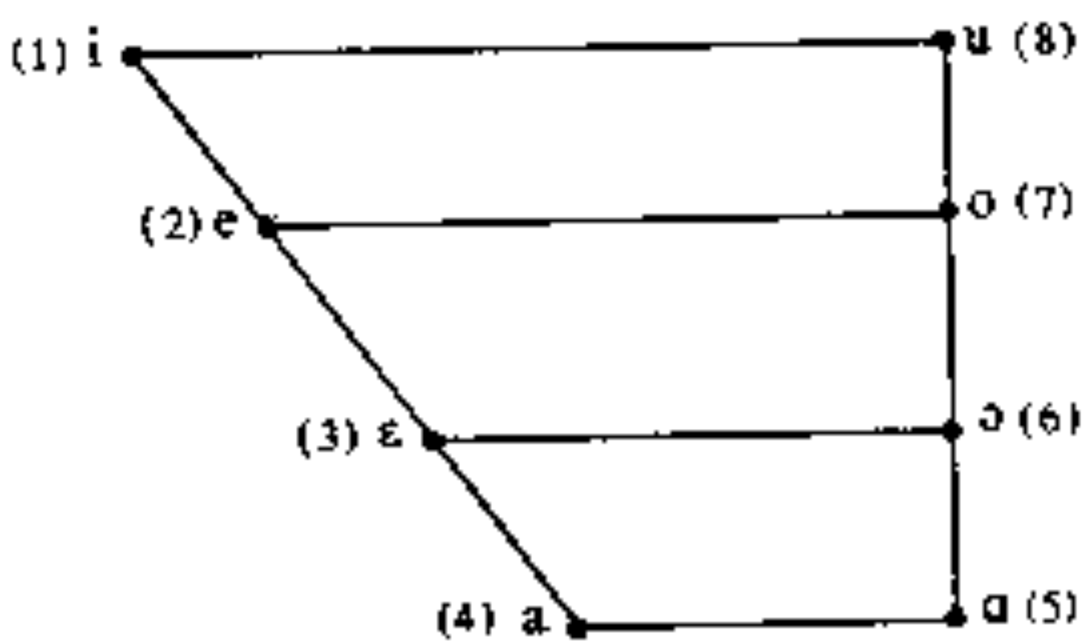
Normalization

- How do we hear the same vowels produced by different speakers as "the same"?
  - Relative normalization
    compared to other vowels produced by that speaker
  - Higher formant normalization
    Values of F5 and higher are determined by vocal tract length alone
    No effect of constrictions
  - Dynamic Normalization
    Changes in formant frequencies from consonants to vowels give information about constrictions

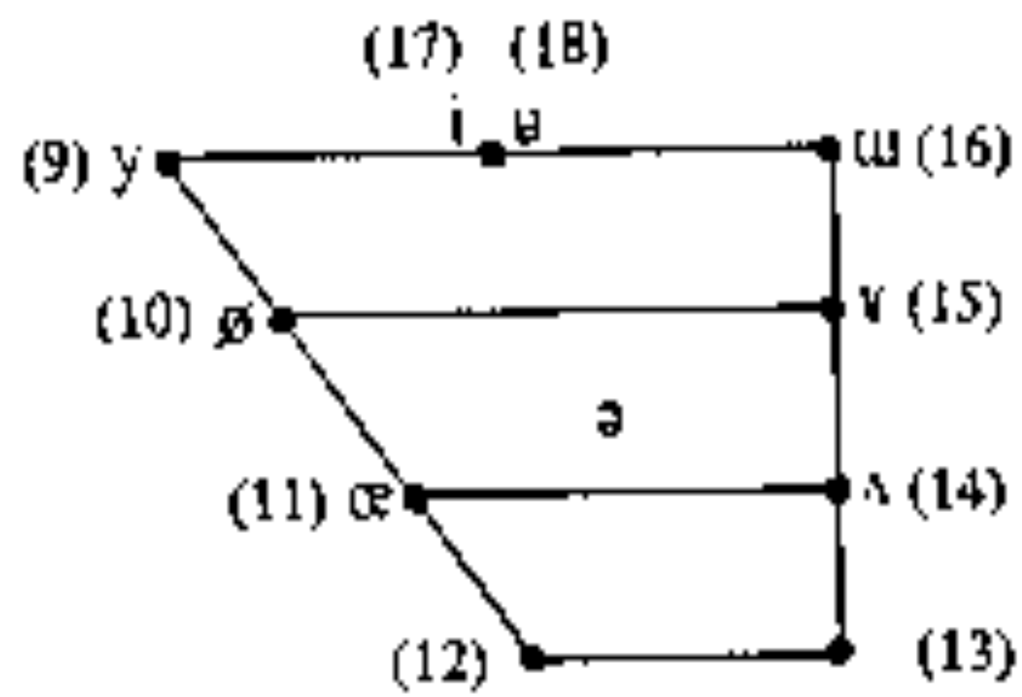
Other problems with formants: rounding

- Vowels that differ only in lips: [i] vs. [y]
- "Opposite" lip positions in Secondary Chart
  - e.g., (1) and (9) have same tongue, but opposite lips
  - but they have different values of F1, F2 (rounding always lowers formants, so position in the formant space is not independent of rounding.

Primary CVs

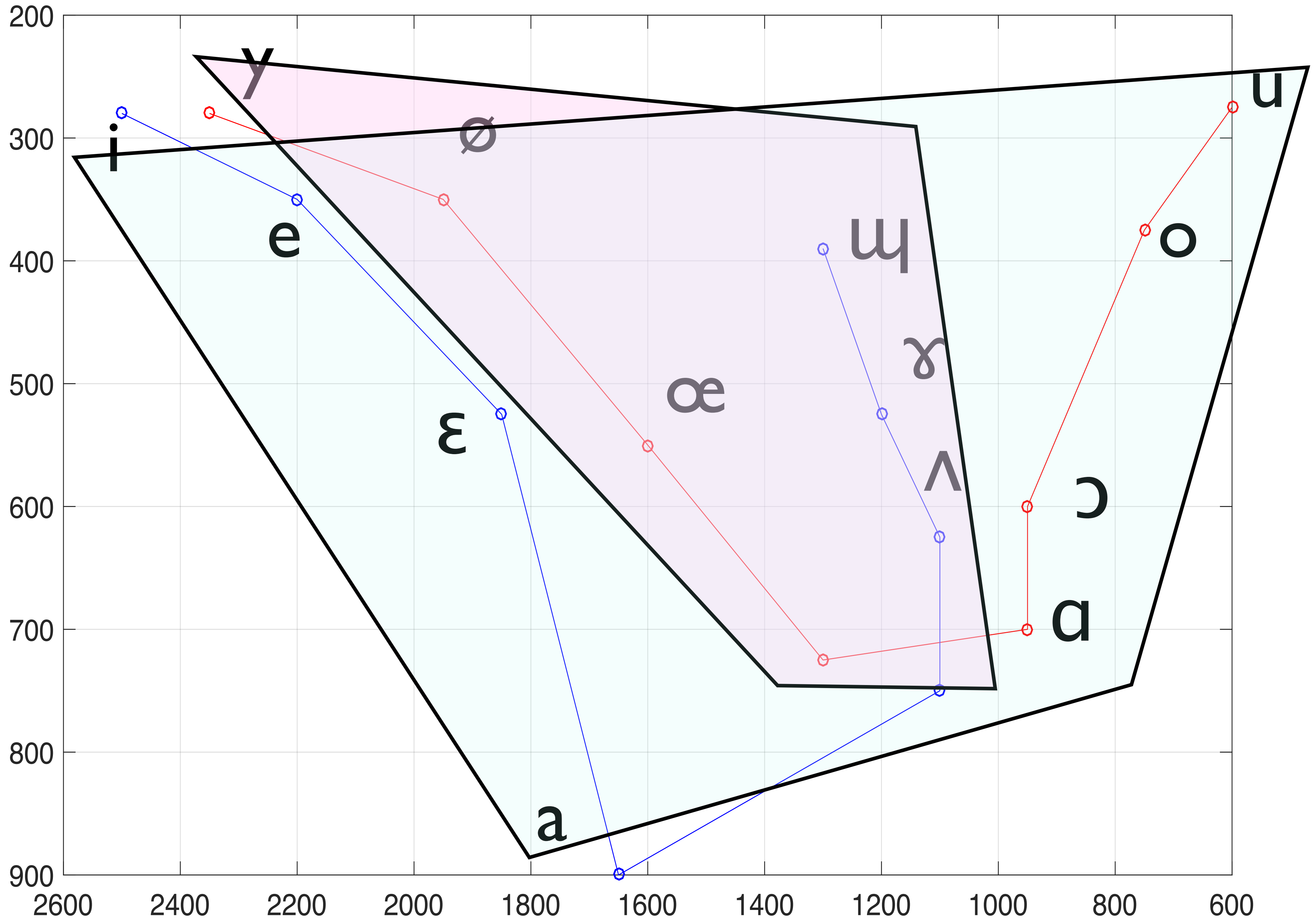


Secondary CVs

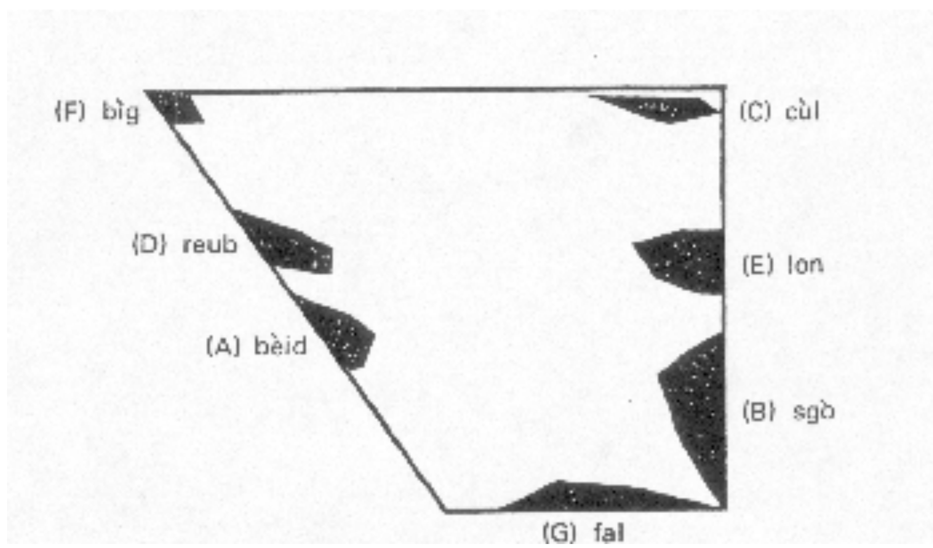
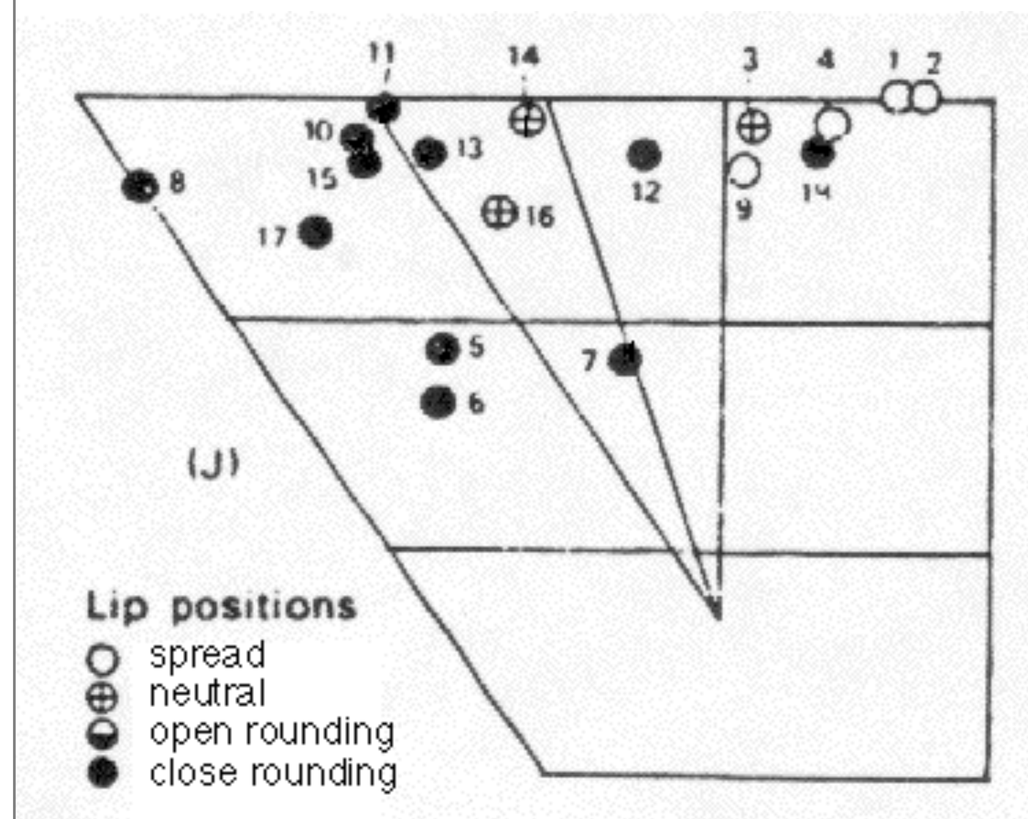


Formants of Daniel Jones' CVs

Formant space of secondary vowels is shrunken compared to primary



Phoneticians' judgments of Gaelic vowels

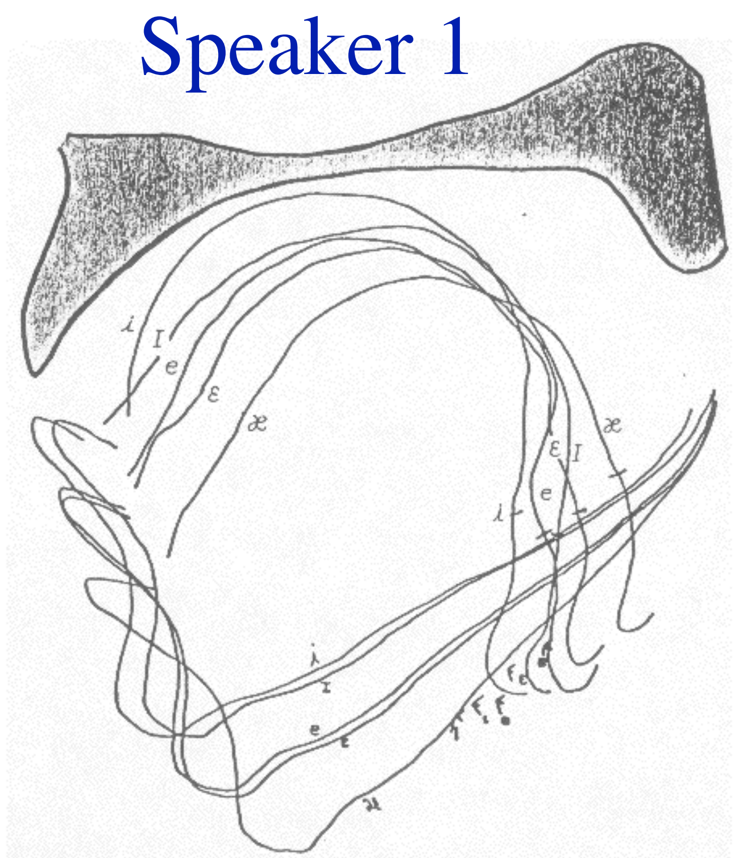
vowels on primary plane (14/15 judgments)	high vowel not on primary plane
	

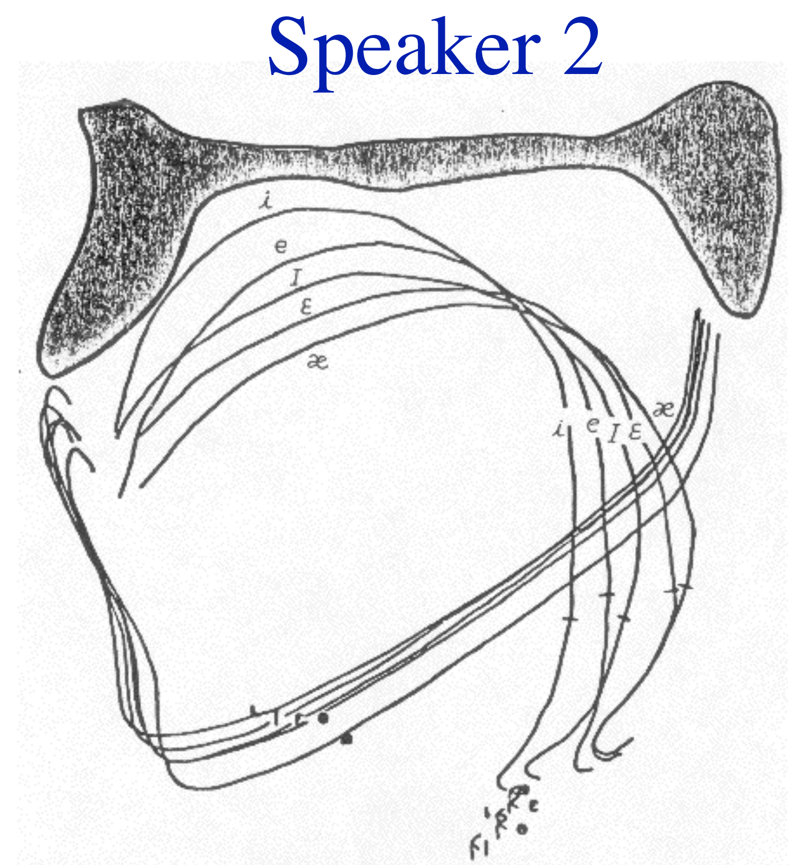
- When phoneticians listen to a audio recording of a vowel in an unknown language that is not found on the primary cardinal vowel "slice", they may not be able to tell whether the the vowel is a front rounded or a back unrounded vowel--they cannot separate position in the space from rounding.

Lindblom’s dispersion theory`

- Languages choose vowel qualities to maximize the size of the acoustic space,
  - Front unrounded, back rounded

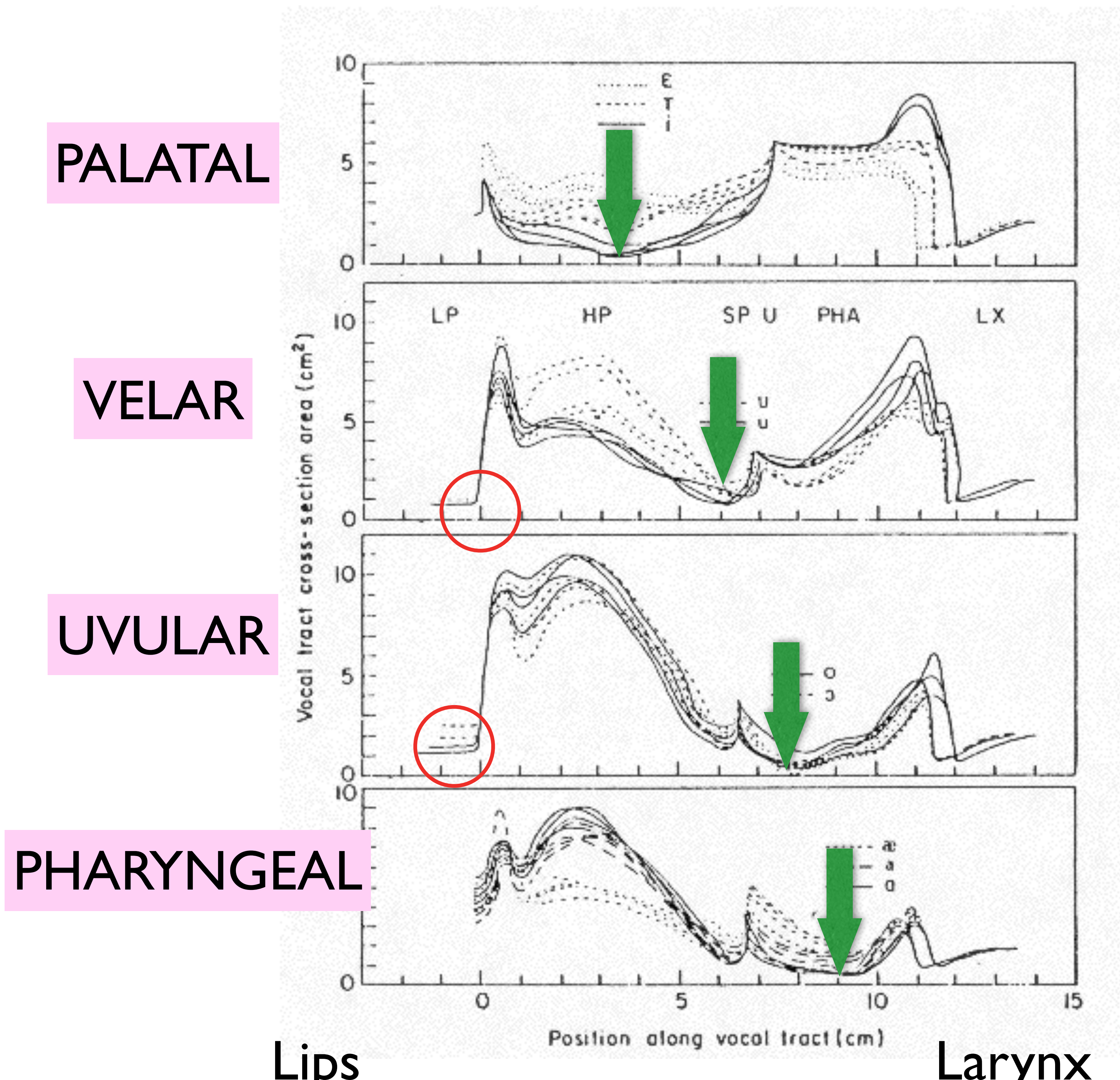
Problem with continuous space: vowel height





- If vowel height is the relevant parameter on which vowel gestures contrast, how can different speakers order the same two vowels differently along this parameter?
- The speakers are mutually intelligible; they do not confuse the vowels.

Discrete Constriction Approach

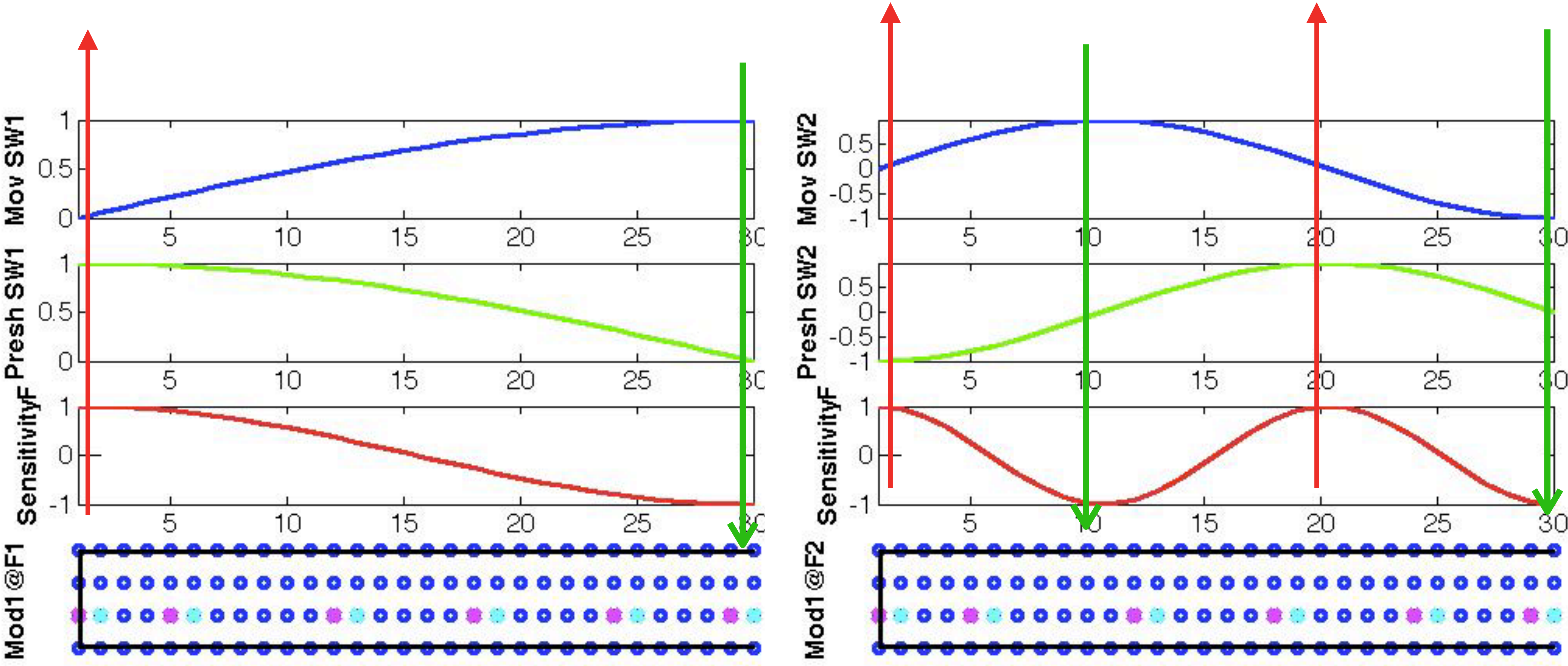


- Wood (1984) measured area functions from a variety of languages show constrictions limited to these four locations.
- Velar and Uvular usually accompanied by lip constrictions.

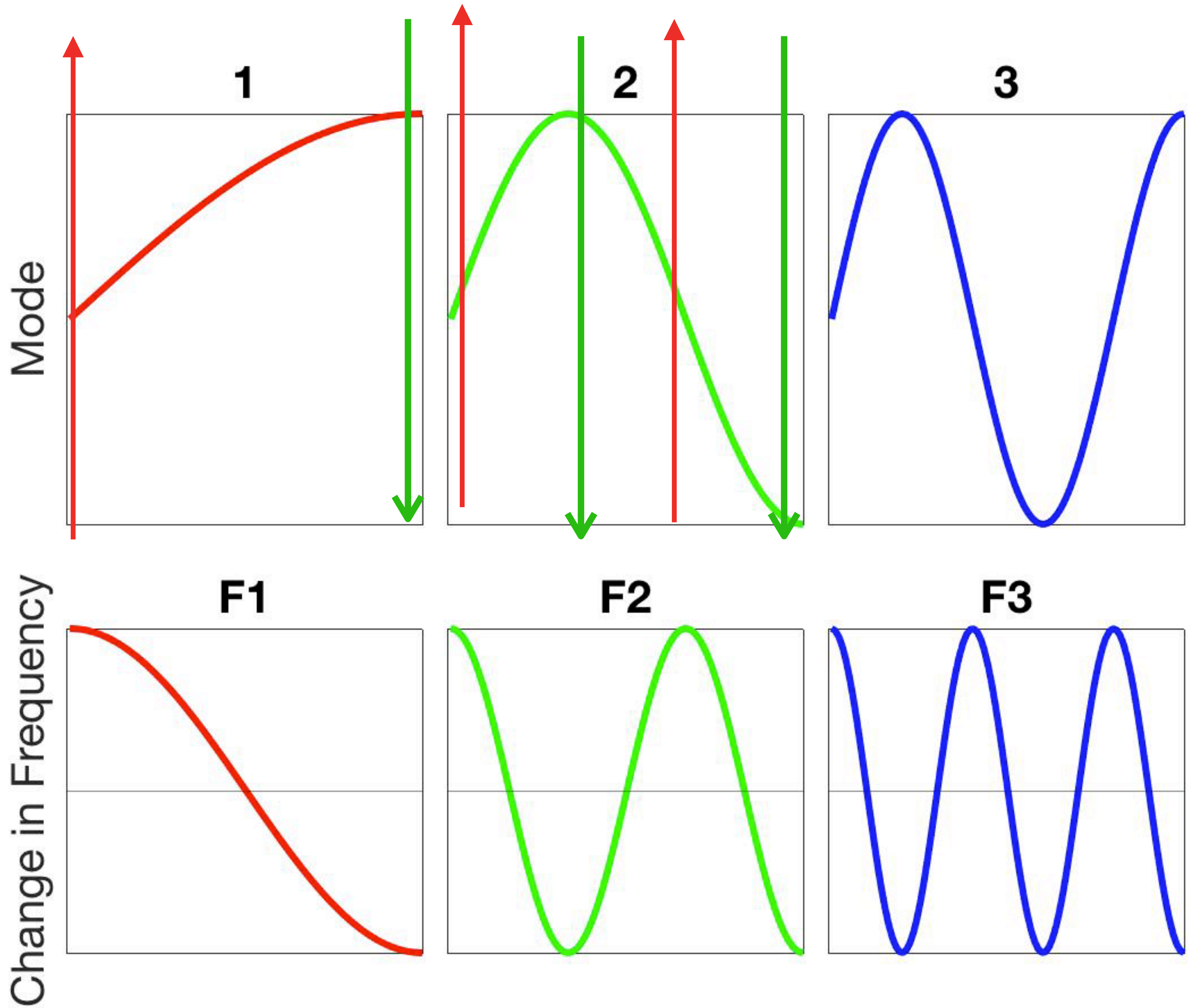
How do distinct constrictions produce distinct formant patterns?

- palatal (e.g. /i/)
  - F1 down, F2 up
- Pharyngeal (e.g. /a/)
  - F1 up, F2 down
- Velar (e.g. /u/)
  - F1 down, F2 down

Modes of air vibration in tube with one open end



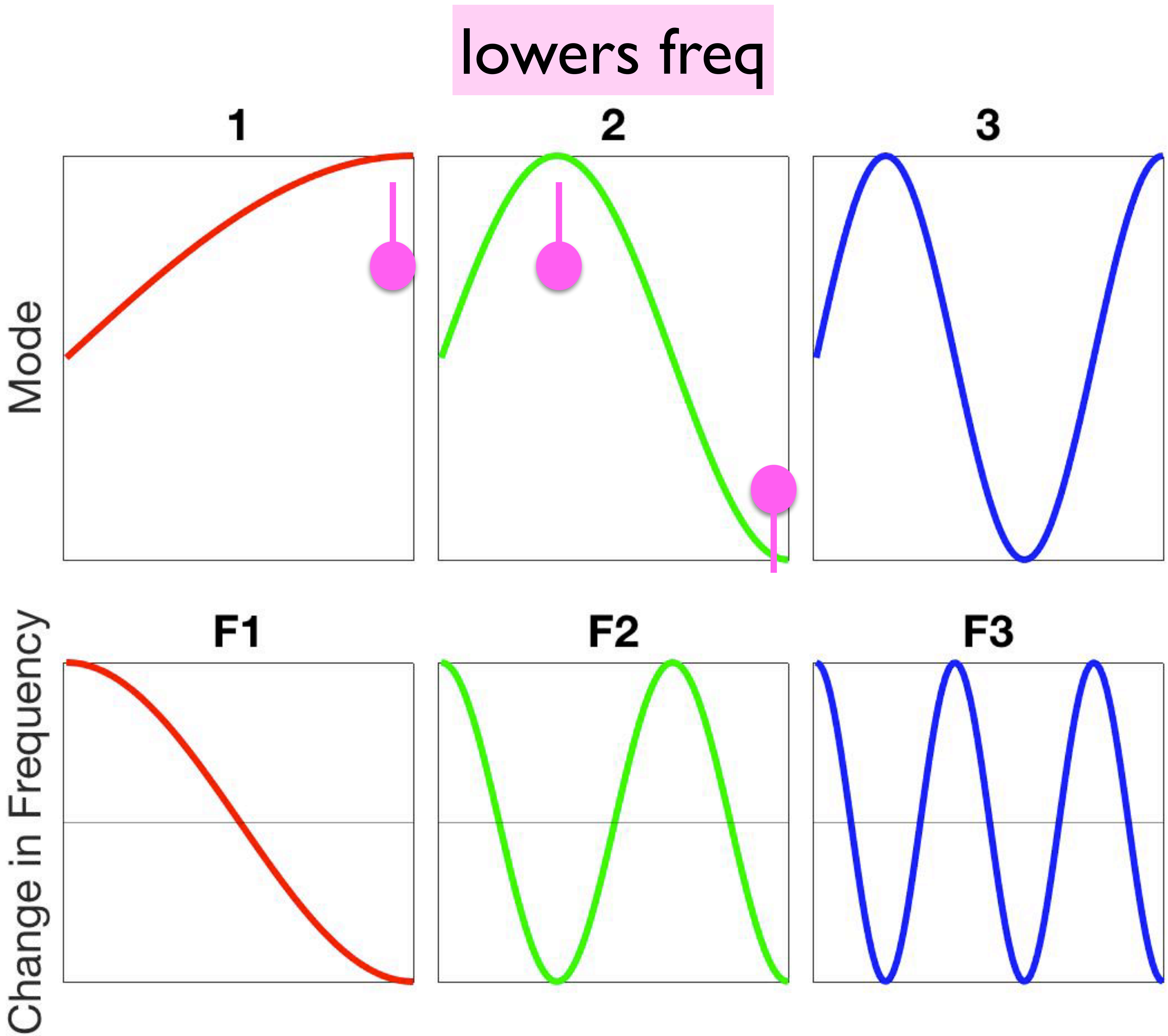
Another view of modes: strings



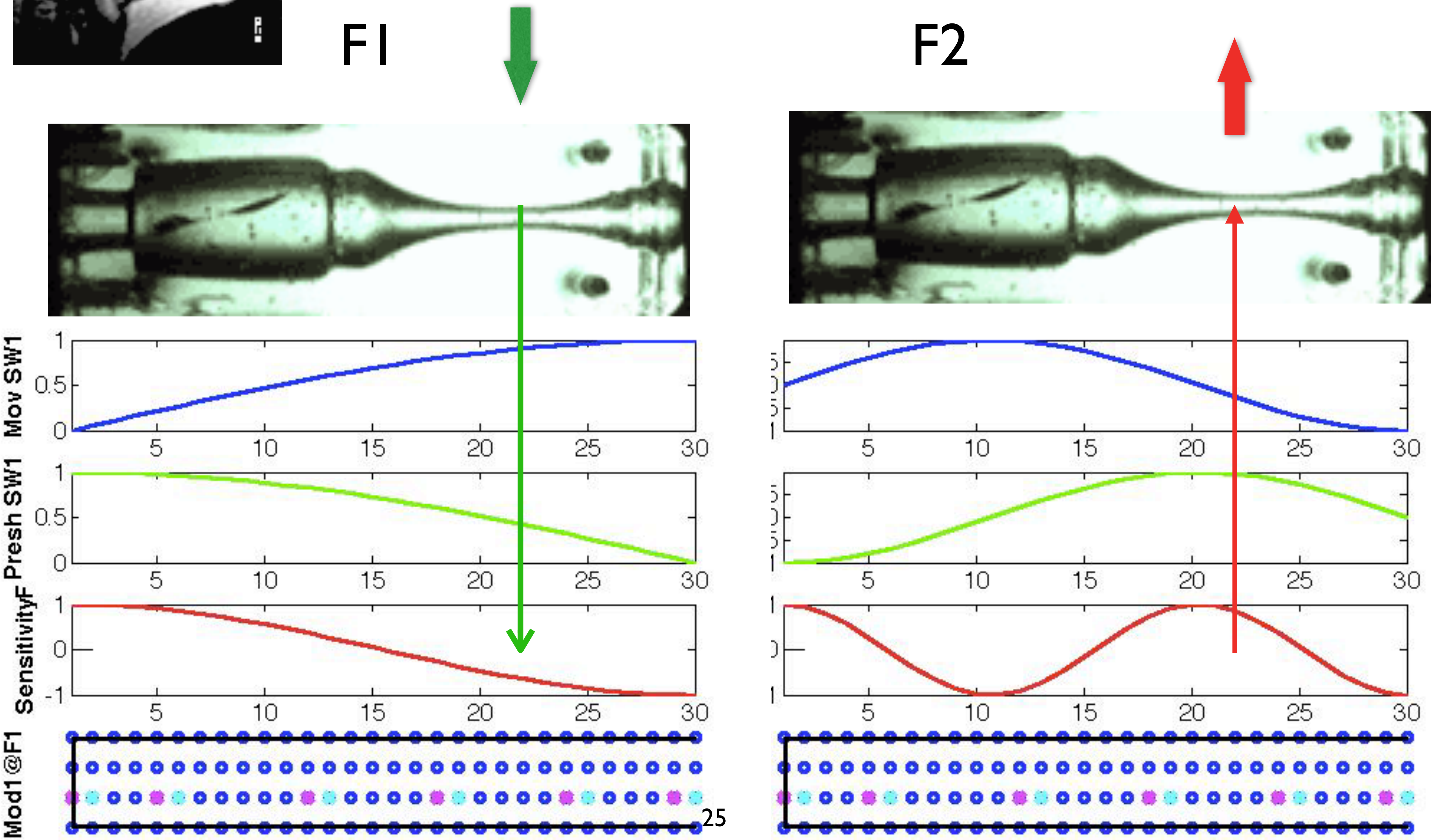
Constriction is like adding mass

- Adding mass where air (or string) is moving a lot frequency of mode goes down.
- Adding mass where air (or string) is NOT moving a lot frequency of mode goes up.

Adding mass where string is moving…

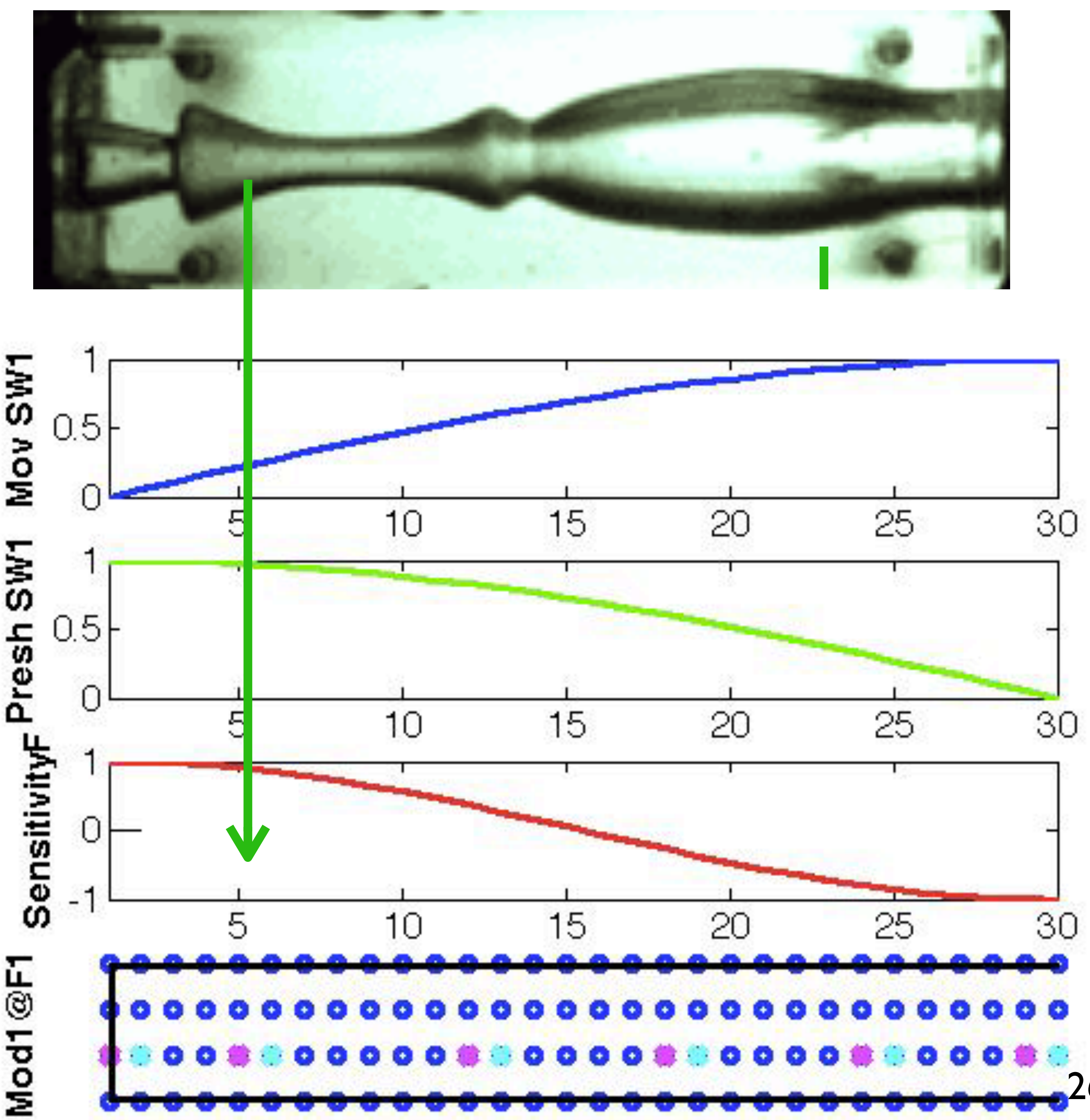


Palatal Constrictions

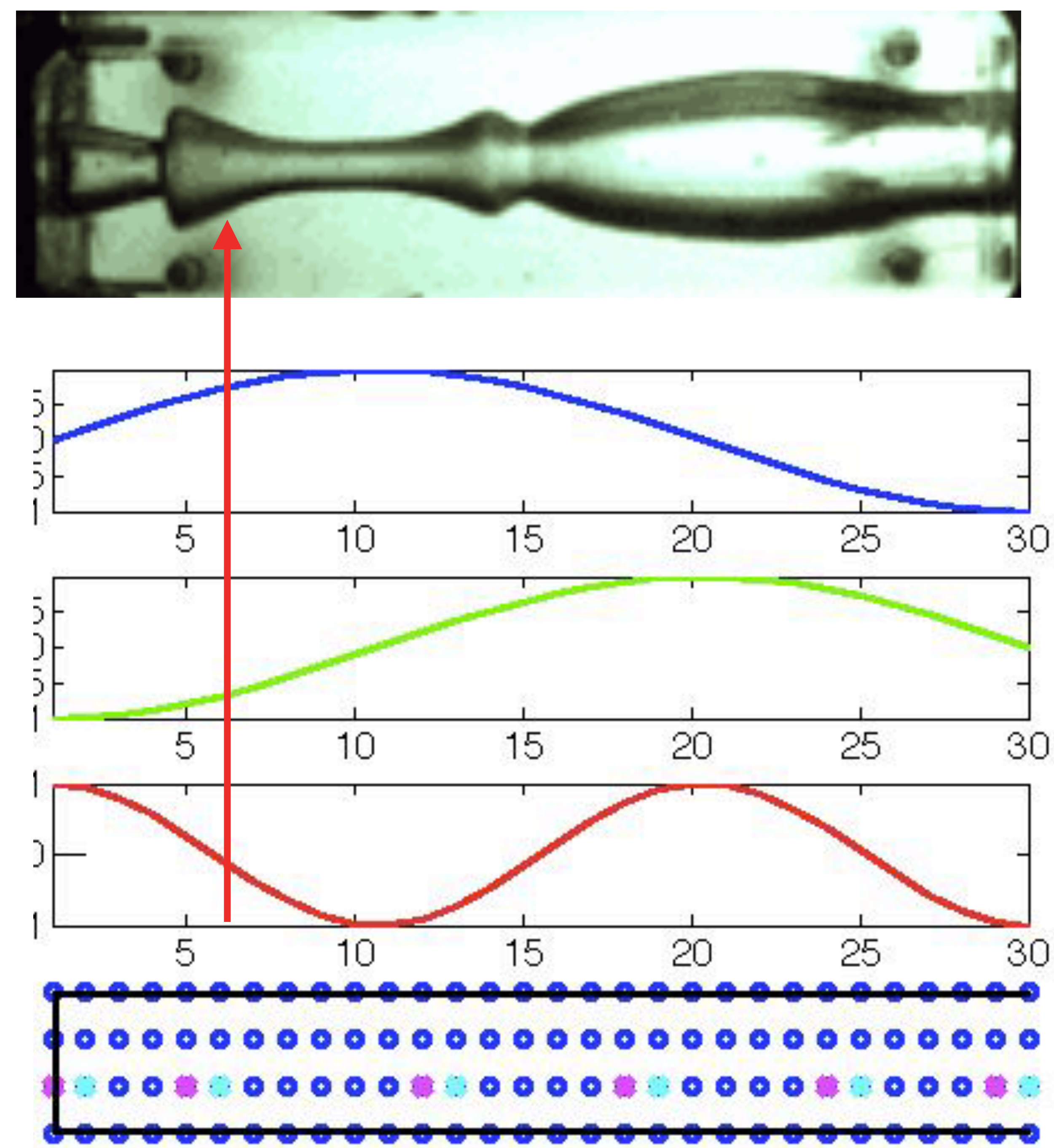


Pharyngeal Constrictions

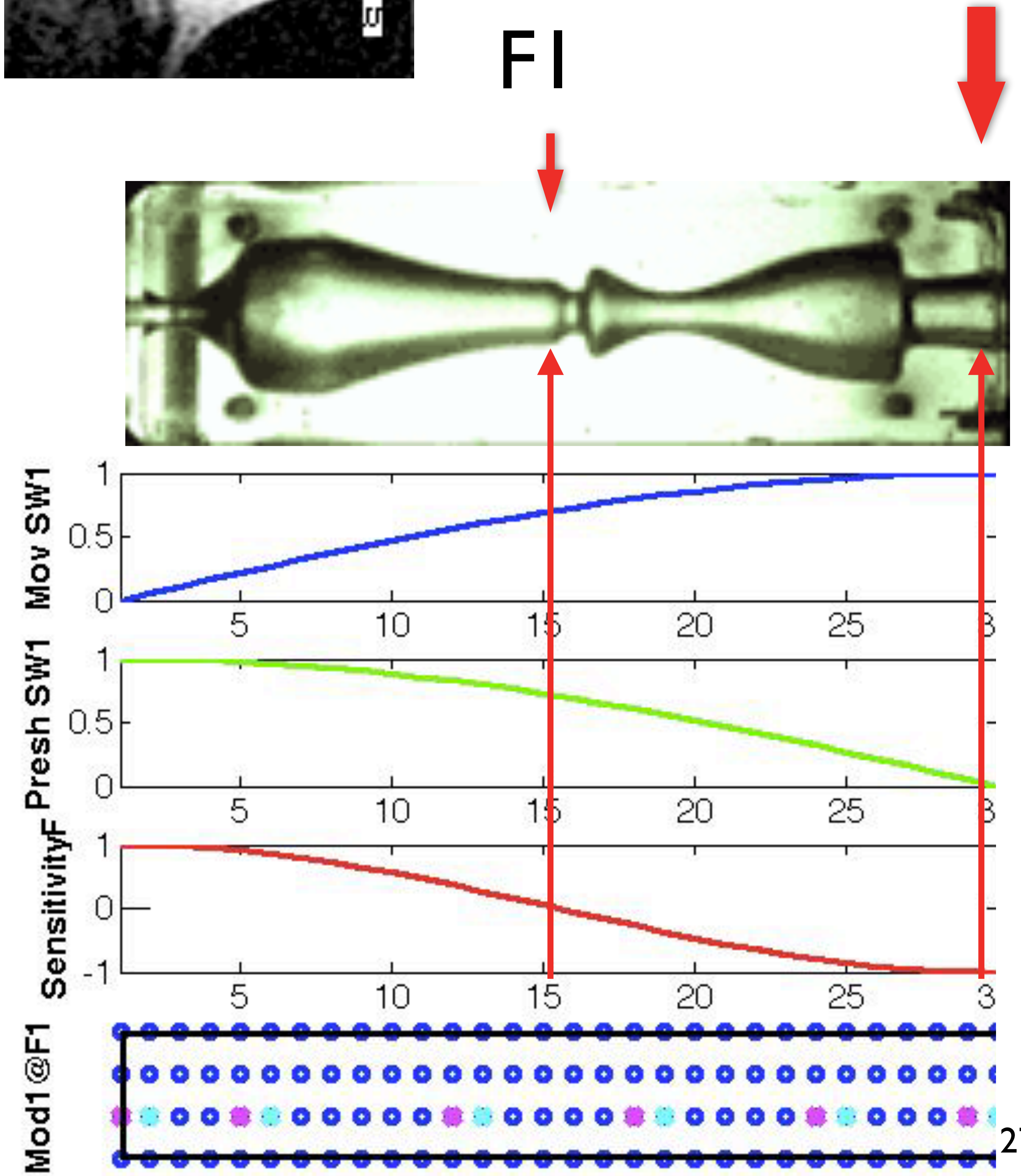
F1

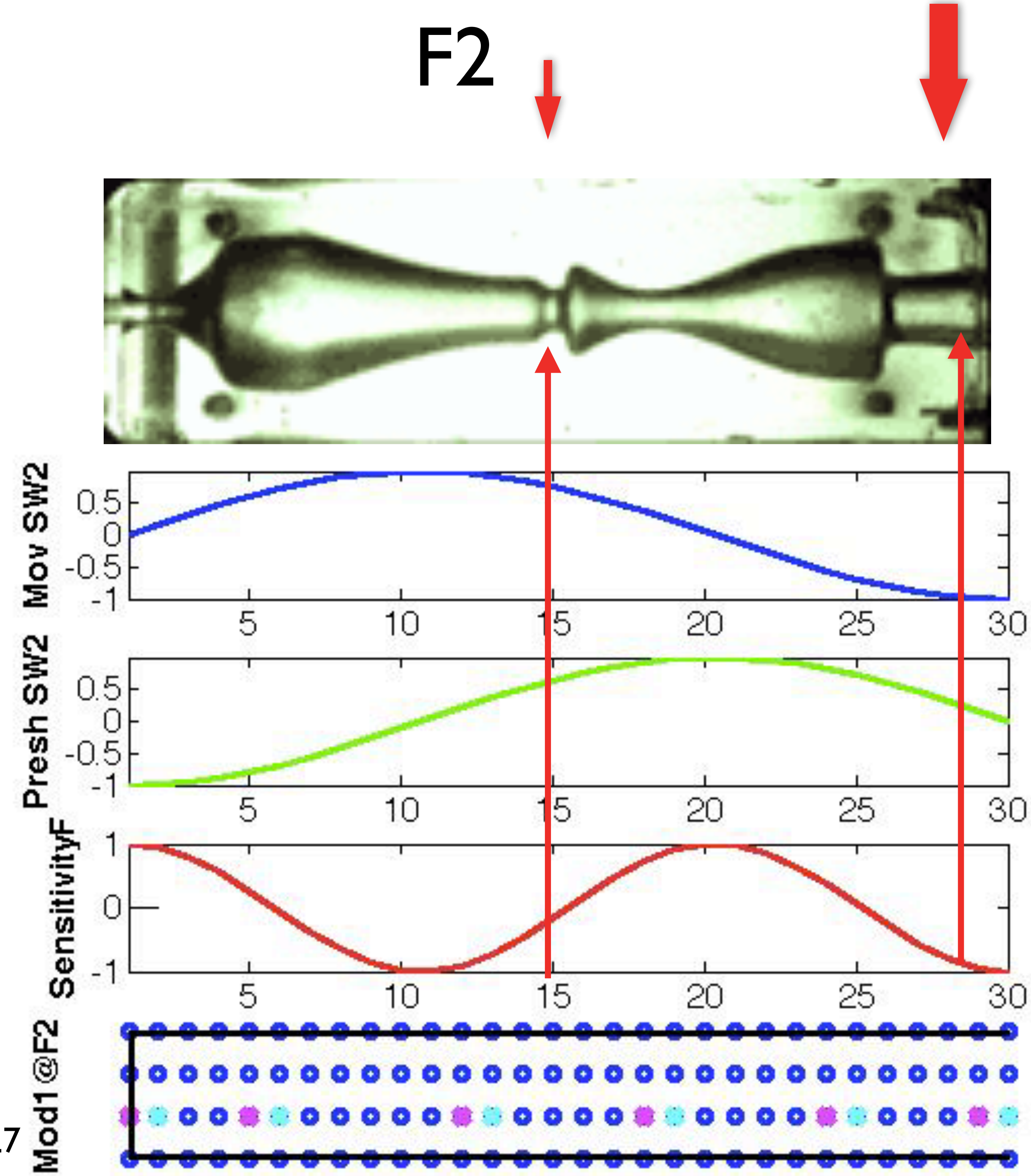


F2

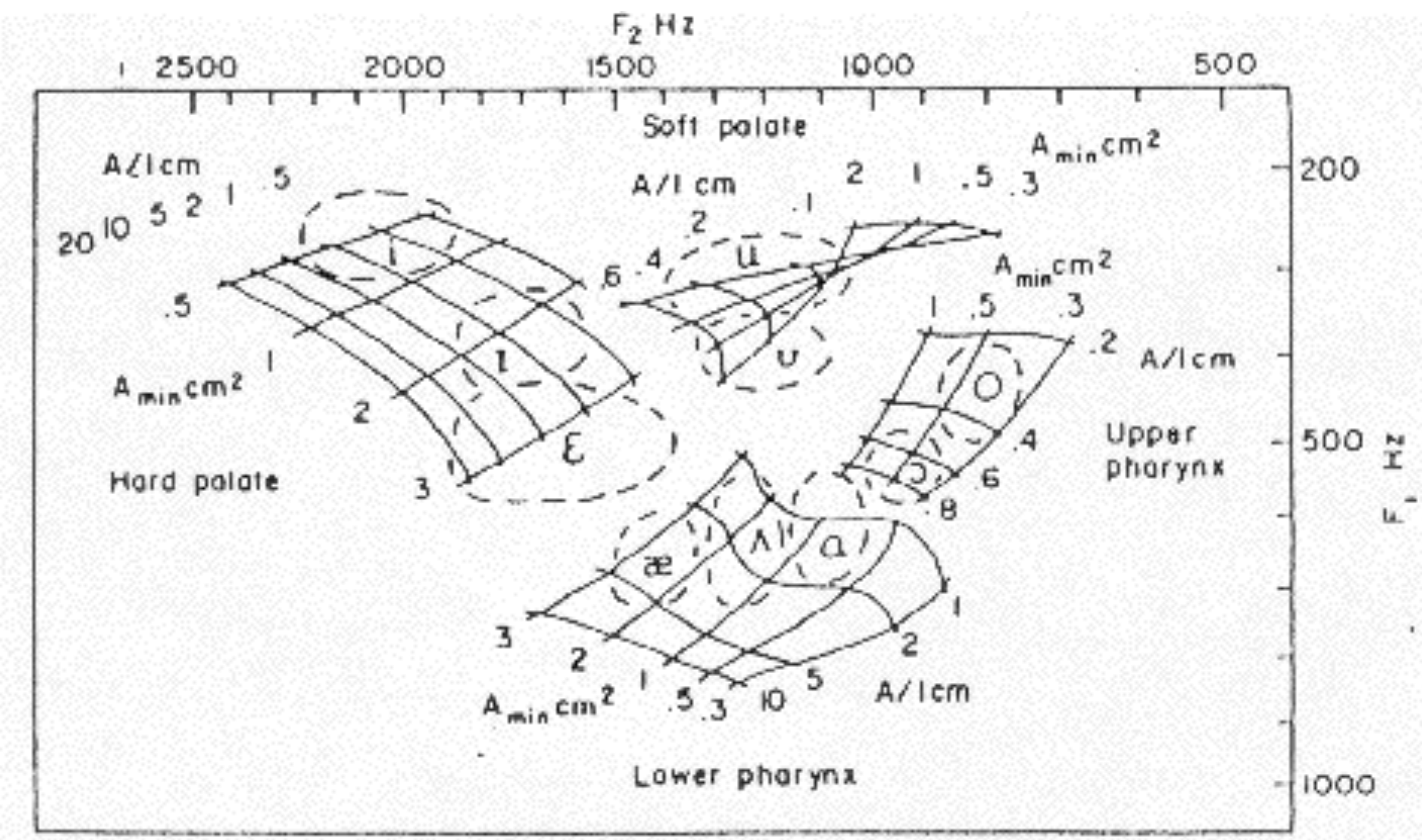


Velar/Uvular + Labial constrictions





Formant variation within constrictions



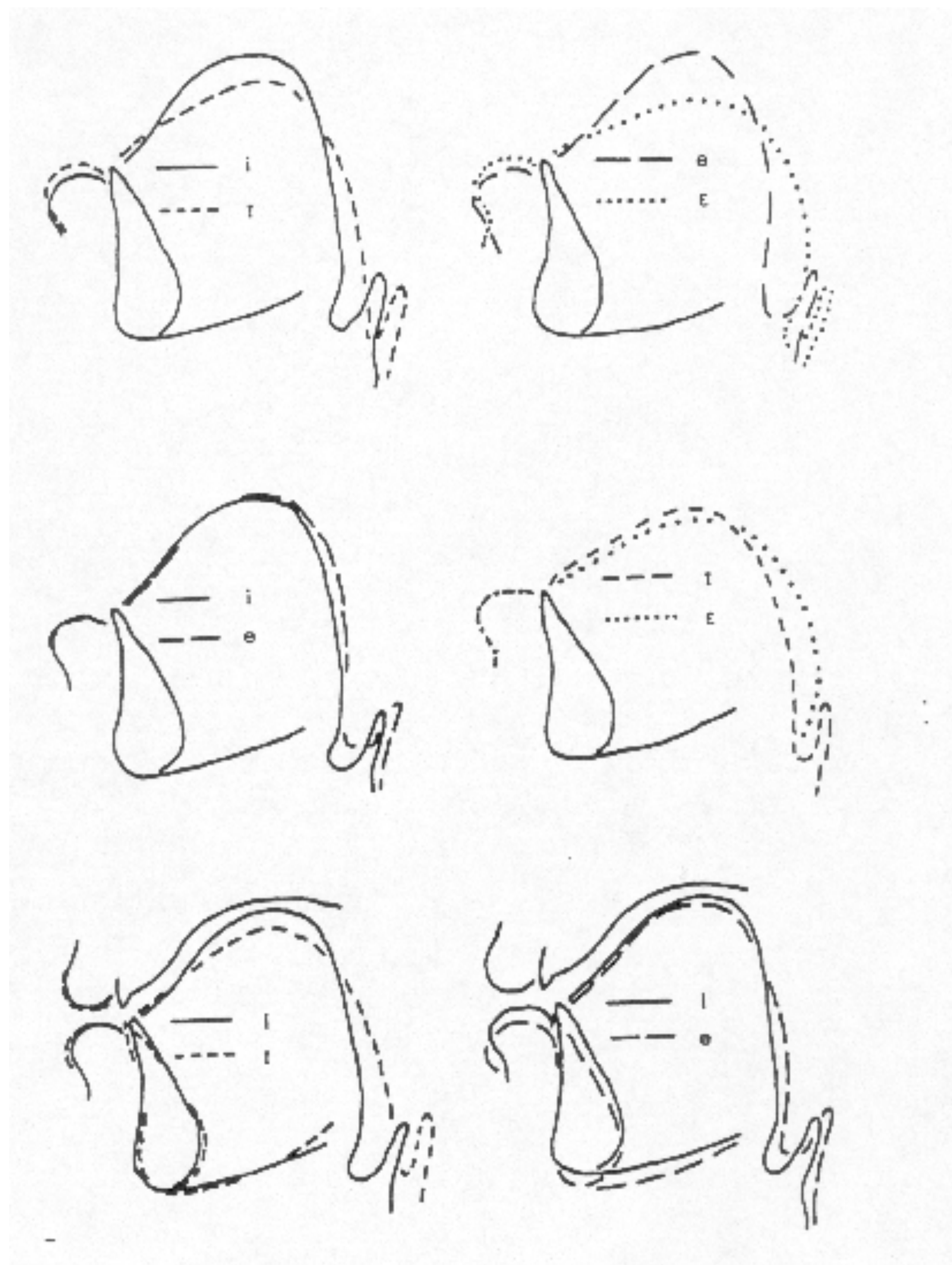
- Jaw height
  - High vs. Low
- Tense vs. Lax shape
  - bunching of tongue root forward to raise front of tongue
- Rounding

Palatal Vowels

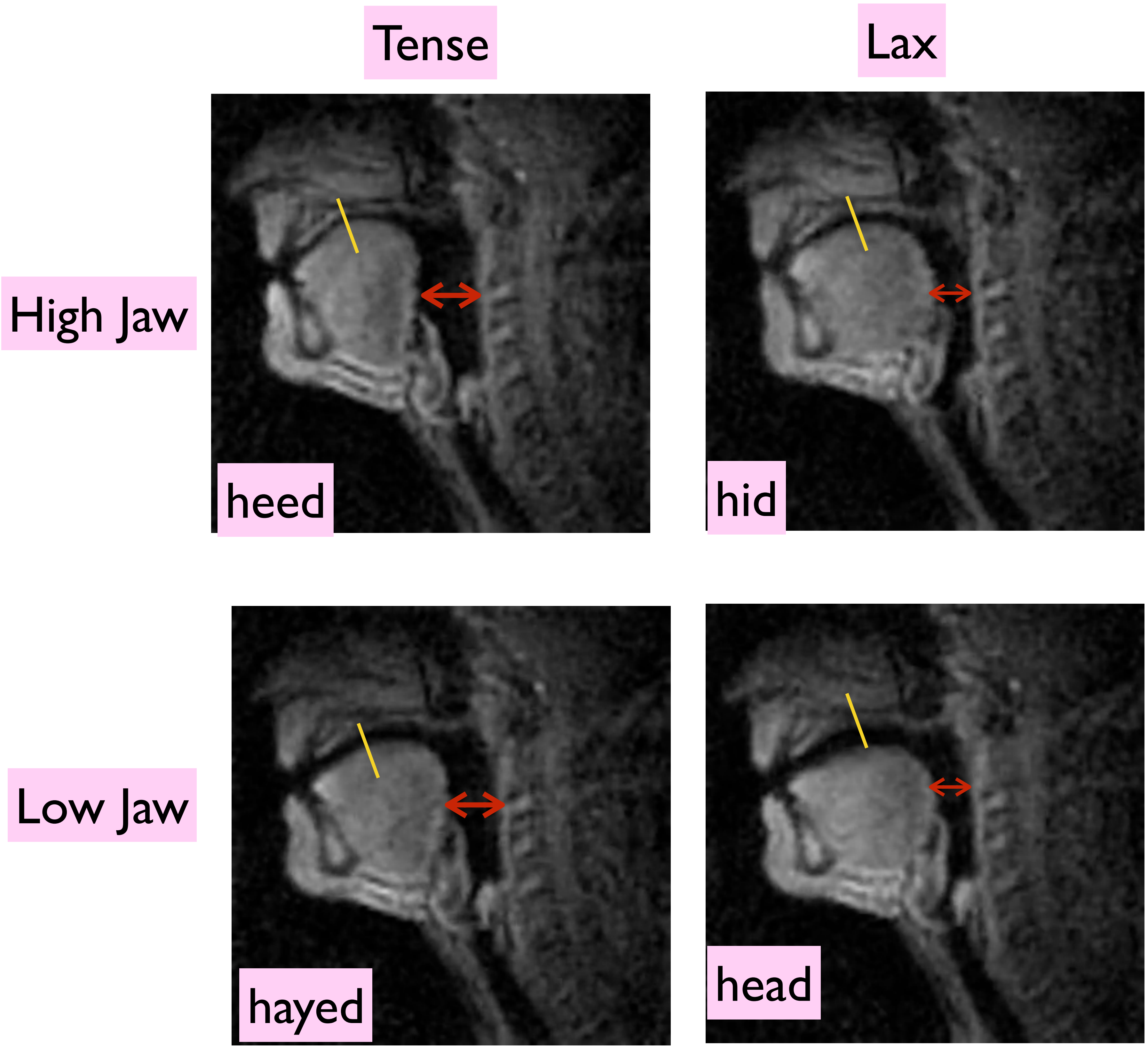
	tense tongue shape	lax tongue shape
Jaw hi	i	ɪ
Jaw lo	e	ɛ

Position of tongue with respect to palate, and therefore F1 will be similar for [e] and [I].

German Palatal Vowels

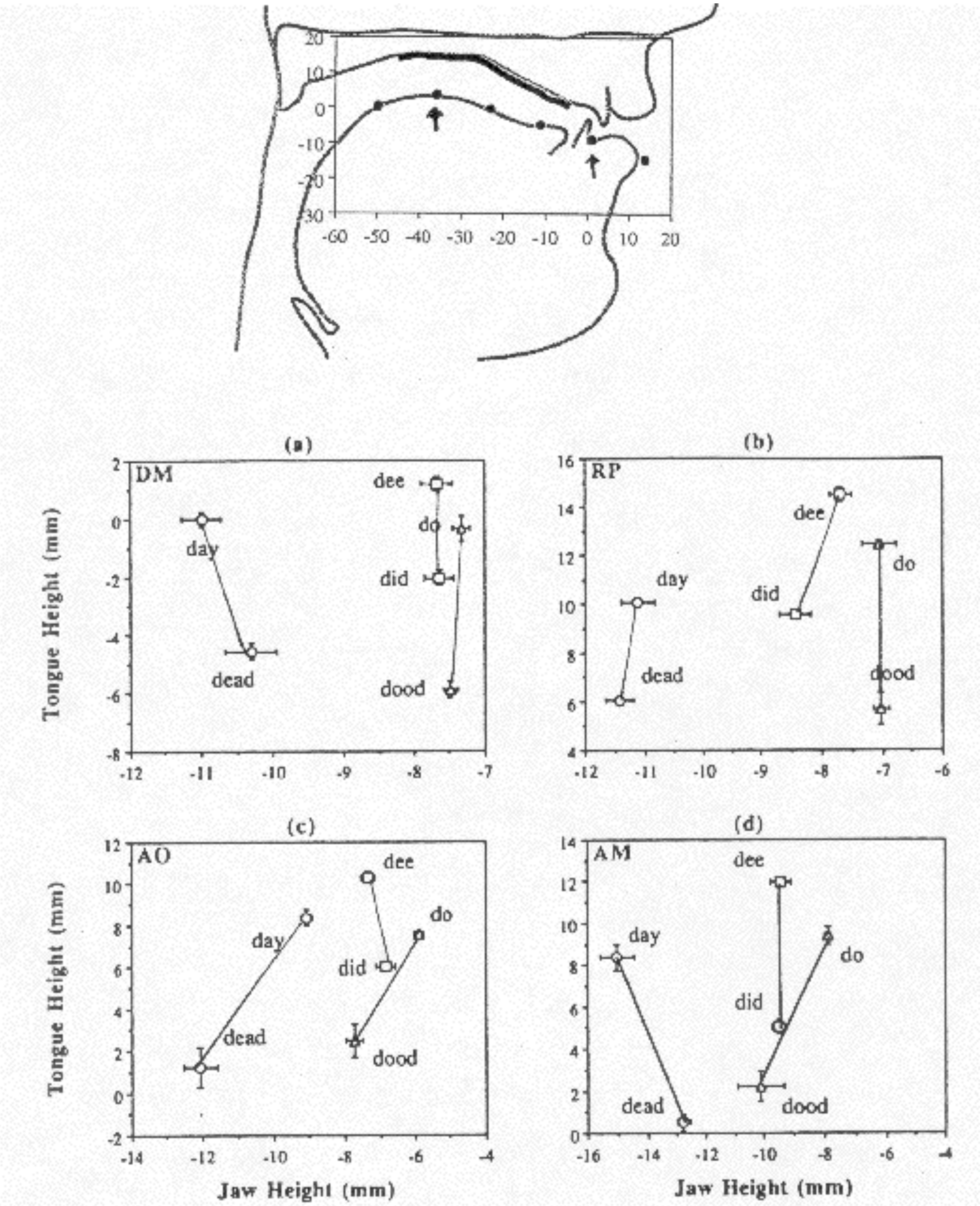


English Palatal Vowels



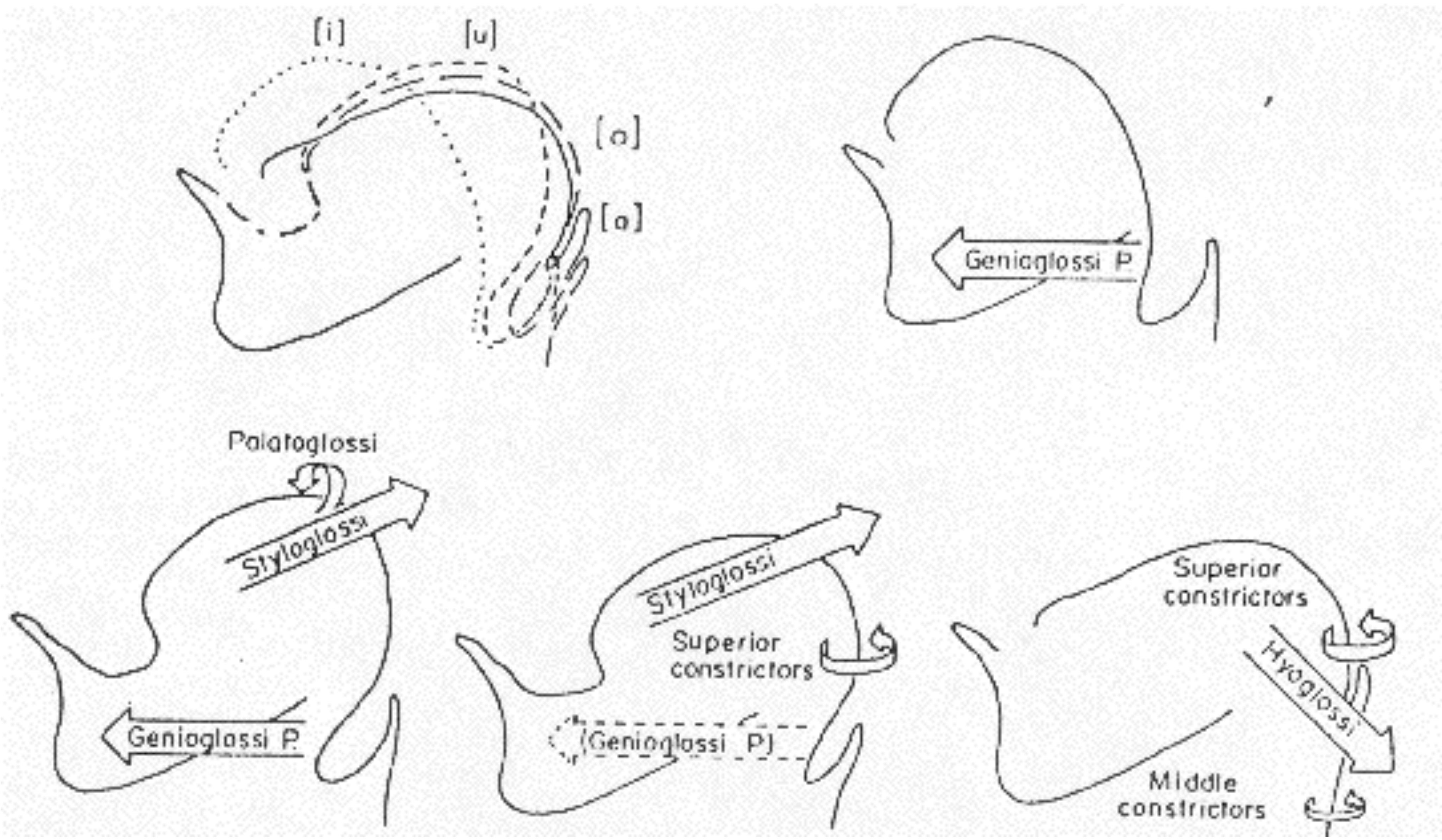
- Jaw height
    - lowering jaw, decreases CD and raises F1
- Tense vs. Lax shape
    - lax tongue root decreases CD and raises F1
- So [ɪ] and [eɪ] have similar F1 but different shapes.

English Palatal Vowels



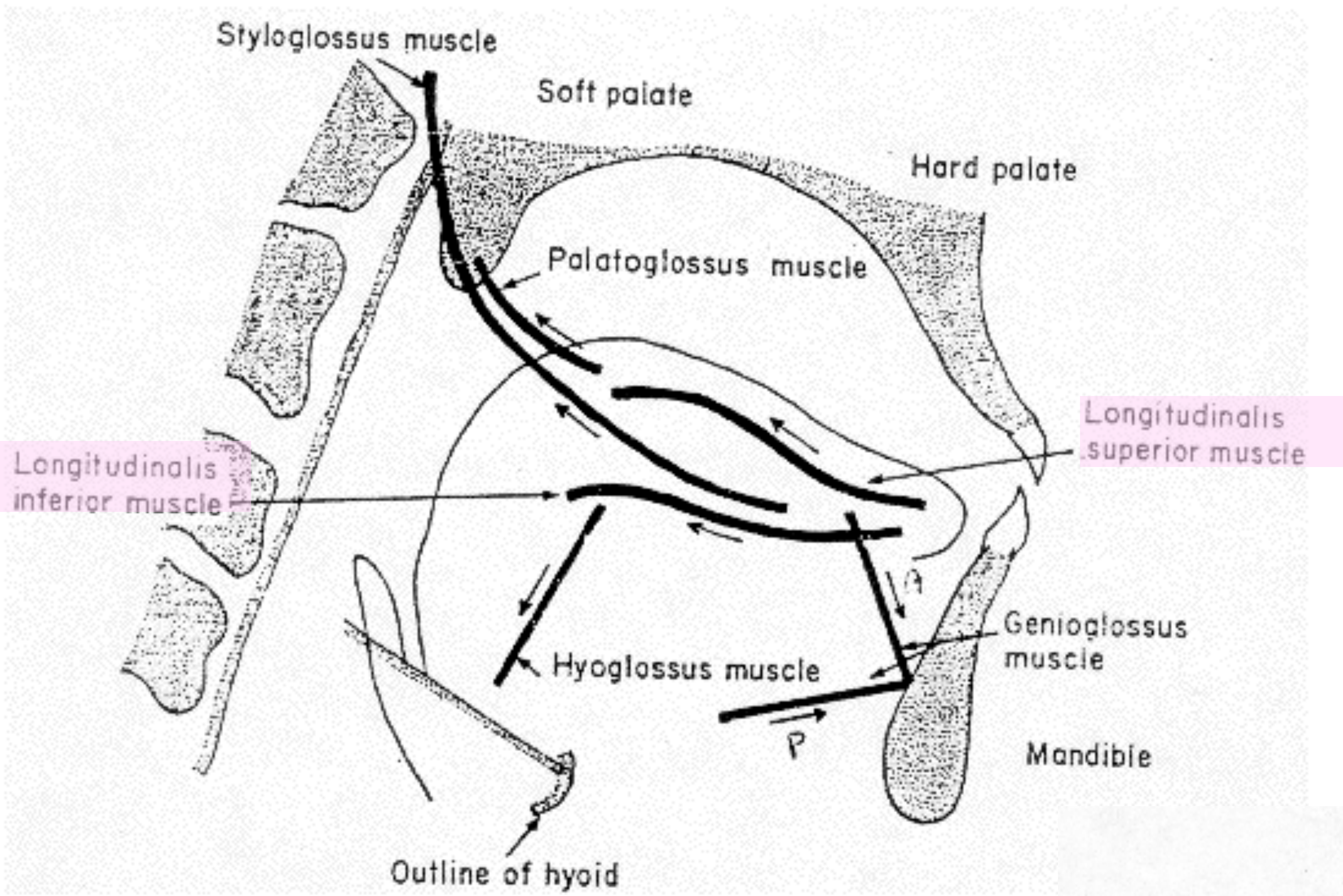
After: Johnson, K., Ladefoged, P., and Lindau, M. (1993). Individual differences in vowel production. *Journal of the Acoustical Society of America, 94*, 701-714.

Distinct Muscles for 4 vowel types

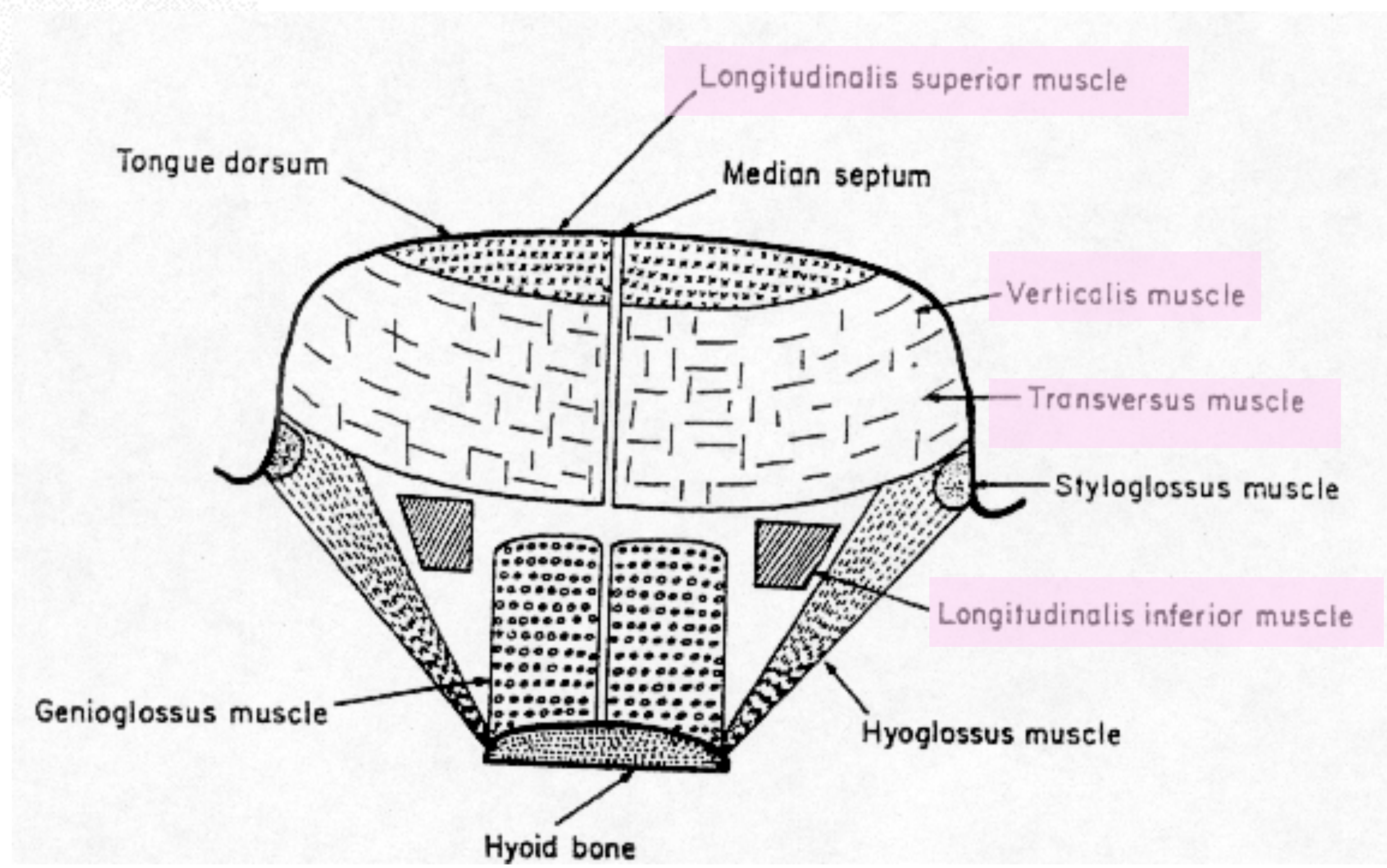


Tongue as complex structure

- Hydrostat
  - like a bag of jelly (e.g. trunk of elephant; octopus arm)
  - no bones or joints
  - Muscles shape bag and position it with respect to fixed surfaces.
- Two types of muscles
  - intrinsic (shaping)
    muscles arise and insert within tongue itself
  - extrinsic (positioning)
    muscles attach at one end to tongue, at one end to external bones or cartilages.



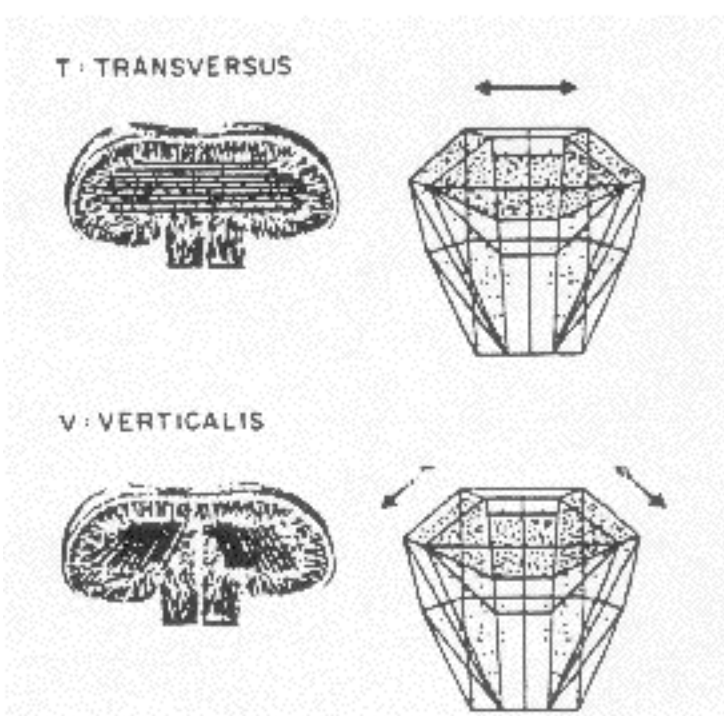
Styloglossus muscle
Soft palate
Hard palate
Palatoglossus muscle
Longitudinalis superior muscle
Longitudinalis inferior muscle
A
Genioglossus muscle
Hyoglossus muscle
P
Mandible
Outline of hyoid

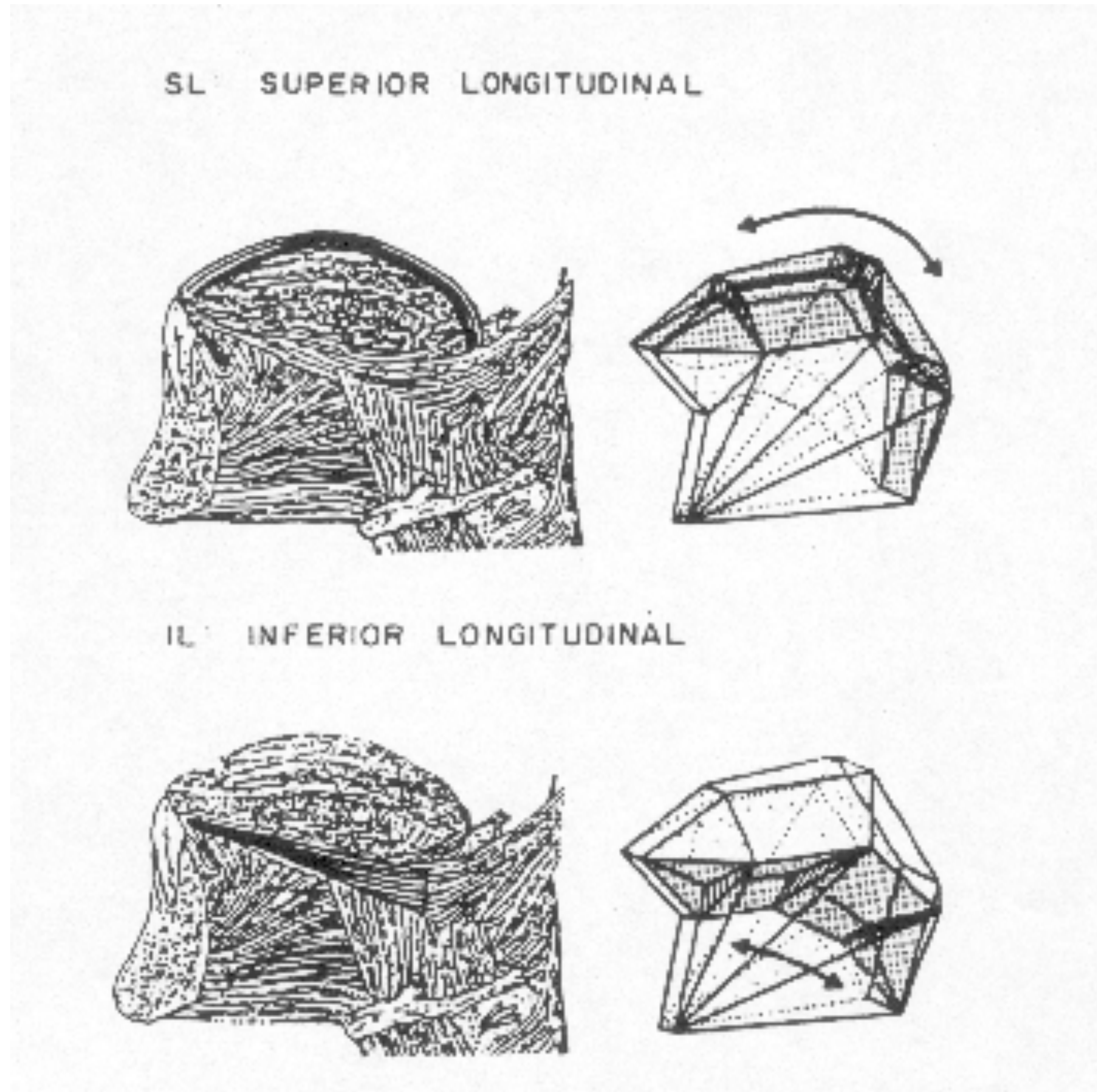


Longitudinalis superior muscle
Tongue dorsum
Median septum
Verticalis muscle
Transversus muscle
Styloglossus muscle
Longitudinalis inferior muscle
Genioglossus muscle
Hyoglossus muscle
Hyoid bone

Intrinsic muscles

- Intrinsic muscles (primary for consonants)
  - longitudinals (primary for coronal consonants)
  - transversus (involved in narrowing tongue during laterals)





Extrinsic Muscles (primarily vowels)