LIN228H1F Phonetics
Lecture 7: Vowels and Air Steam Mechanisms

Wednesday, May 26th, 2021

Instructor: Emily Blamire

Today's Plan

1. Acoustic Phonetics Assignment
2. Articulatory and Acoustic properties of vowels
3. Additional vowel qualities
4. Airstream Mechanisms
5. Explaining the Alien question

Articulatory and Acoustic properties of vowels

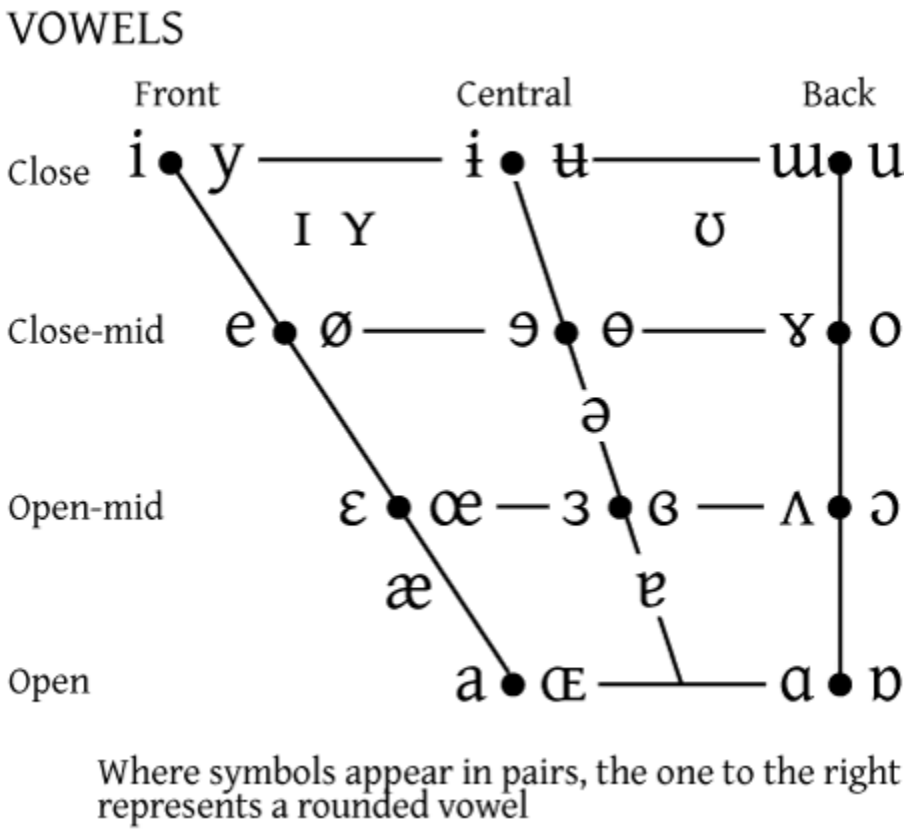
Vowels

- Vowels we already know from English

	front	central	back
high	i ɪ		u ʊ
mid	ej ɛ	ə ʌ	ow ɔj (ɔ)
low	æ	aj aw	ɑ

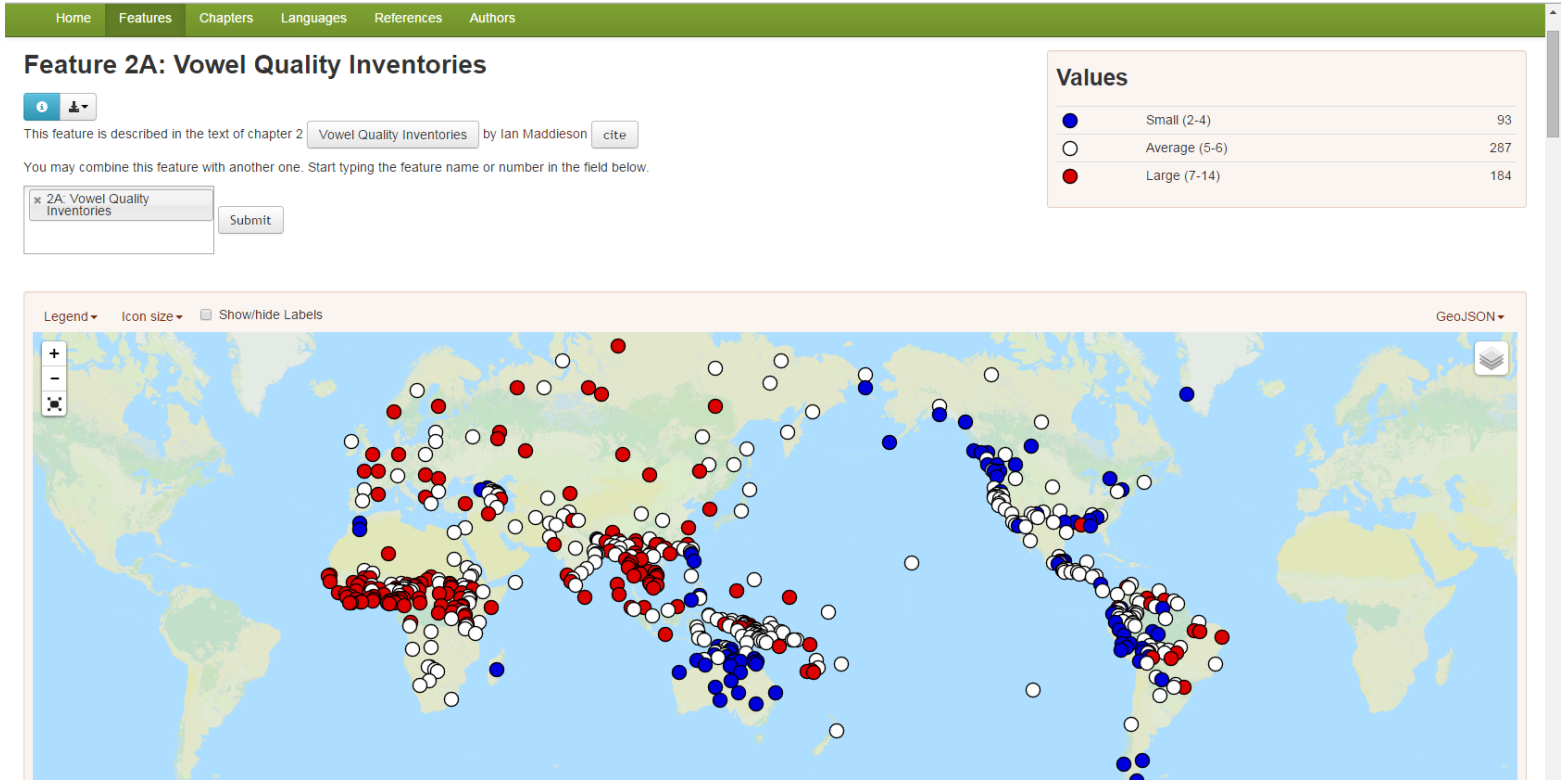
Vowels

- Symbols used to describe vowel sounds in the world's languages:



Vowel quality inventories

- *The World Atlas of Language Structures* (**WALS**) http://wals.info
  - Vowel Quality Inventories, numbers of surveyed languages
    - Small (**2-4** vowels) 93
    - Average (**5-6** vowels) 287
    - Large (**7-14** vowels) 184



Articulatory and Acoustic properties of vowels

- Articulatory descriptions of vowels use the parameters of:
  - **Height; Backness; Rounding**

  - These descriptions are meant to correlate with the highest point of the tongue in the mouth. However, they are based on the intuitions of traditional phoneticians who did not have access to x-ray technology or other methods of accurately investigating tongue placement.

- Acoustic descriptions of vowels are based on the frequencies of the **1st**, **2nd** and **3rd** formants.

Articulatory and Acoustic properties of vowels

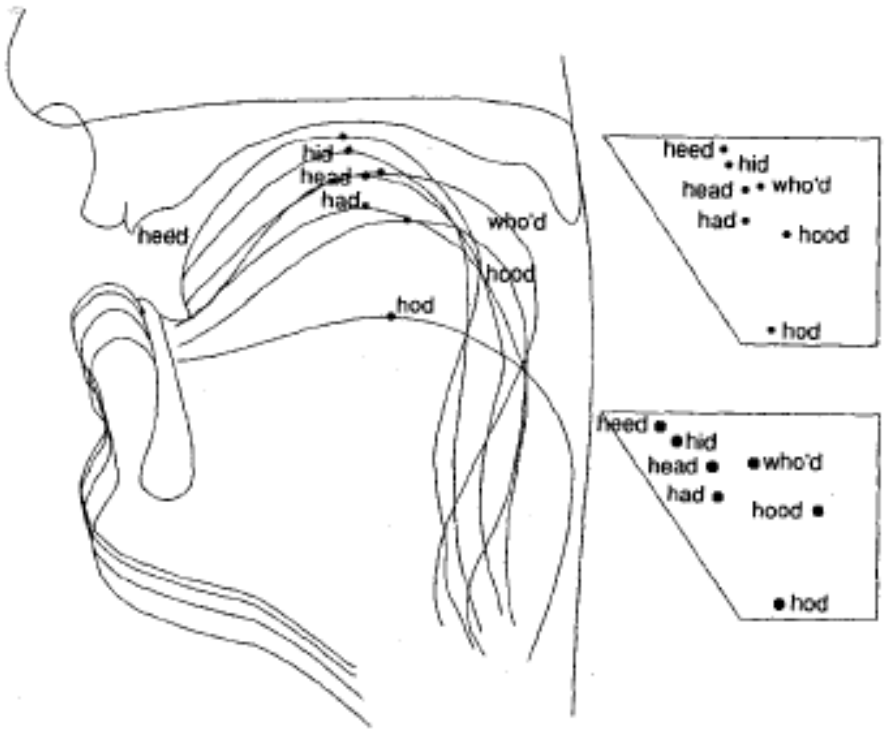


Figure 11.8 The position of the highest point of the tongue in General American English vowels. The lip positions are those for the vowels in figure 11.1. The lower quadrilateral on the right has the horizontal scale expanded.

- The illustrations show the highest point of the tongue in GA vowels.
- The relative position of the vowels does not closely resemble the traditional vowel descriptions.

From: Ladefoged (2001) *Vowels and Consonants*, pages 115-116

Articulatory and Acoustic properties of vowels

Traditional descriptions more accurately reflect acoustic properties of vowels than articulatory properties of vowels.

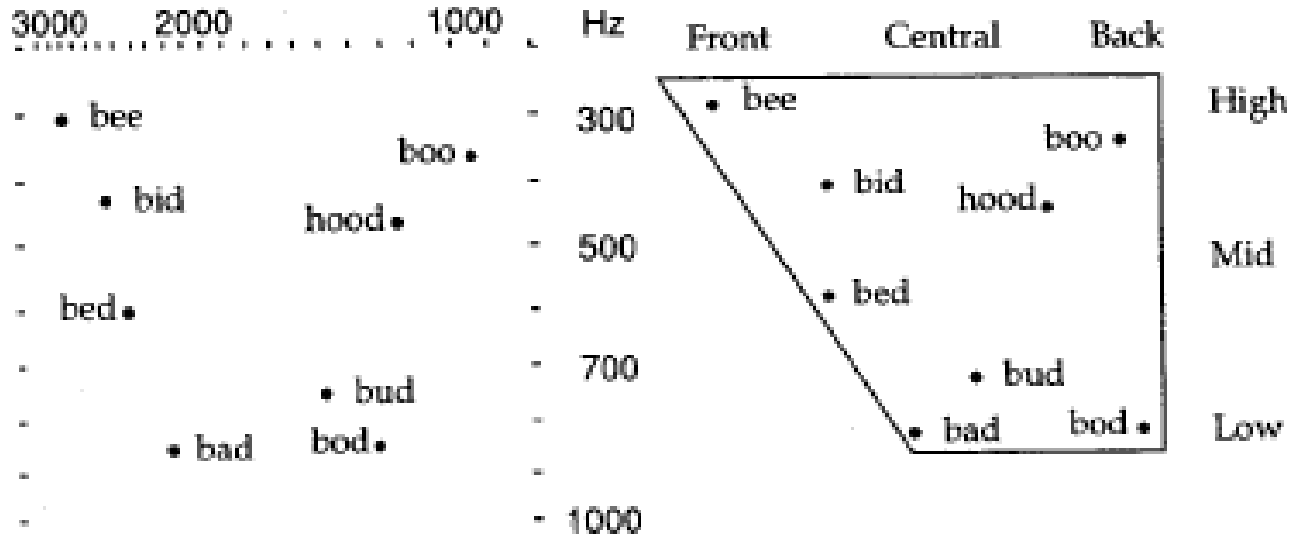


Figure 11.9 The quadrilateral on the right is a traditional representation of what is taken to be the relative position of the highest point of the tongue in some American English vowels. The corresponding acoustic data (taken from figure 6.5) are shown on the left.

From: Ladefoged (2001) *Vowels and Consonants*, pages 115-116

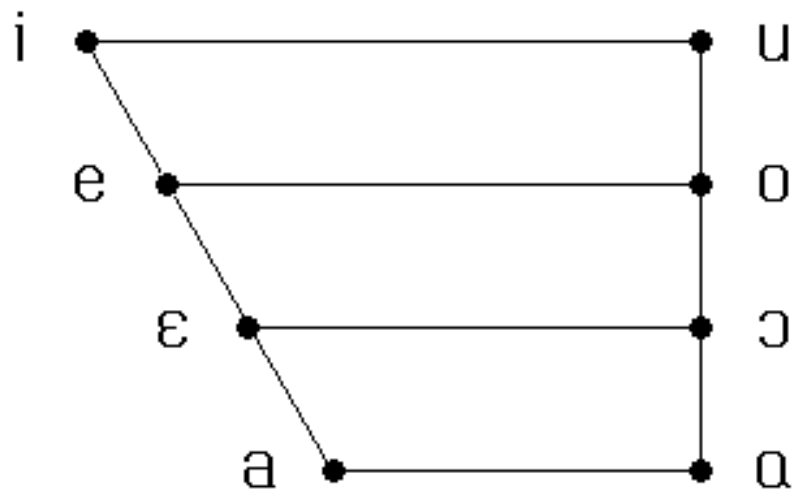
Cardinal vowels

- The cardinal vowel system was designed to provide reference points in the description of vowels.
  - essentially a measuring system
- Vowels in particular languages can be described in reference to the cardinal vowels.
- Cardinal vowels are produced at the extreme periphery of the vowel space and are equidistant from one another.
  - Vertical centre line divides the space in terms of backness
  - Two horizontal line divide the space in terms of height
    - Each of the horizontal lines have cardinal vowels at the front and back extremes.
  - The front and back sets of cardinal vowels are equidistant from one another.
  - The vowel schwa is in the very centre of the vowel space.

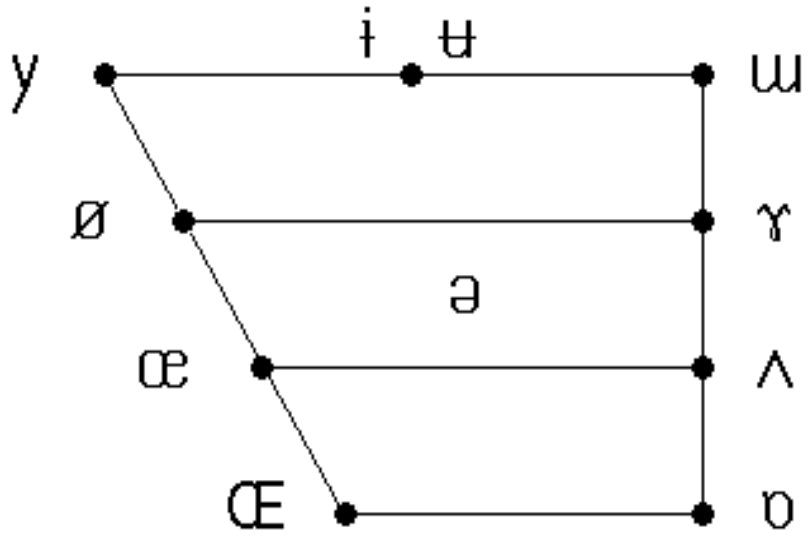
Cardinal vowels

- Cardinal vowels can also be grouped into **primary** and **secondary** sets of vowels.

primary

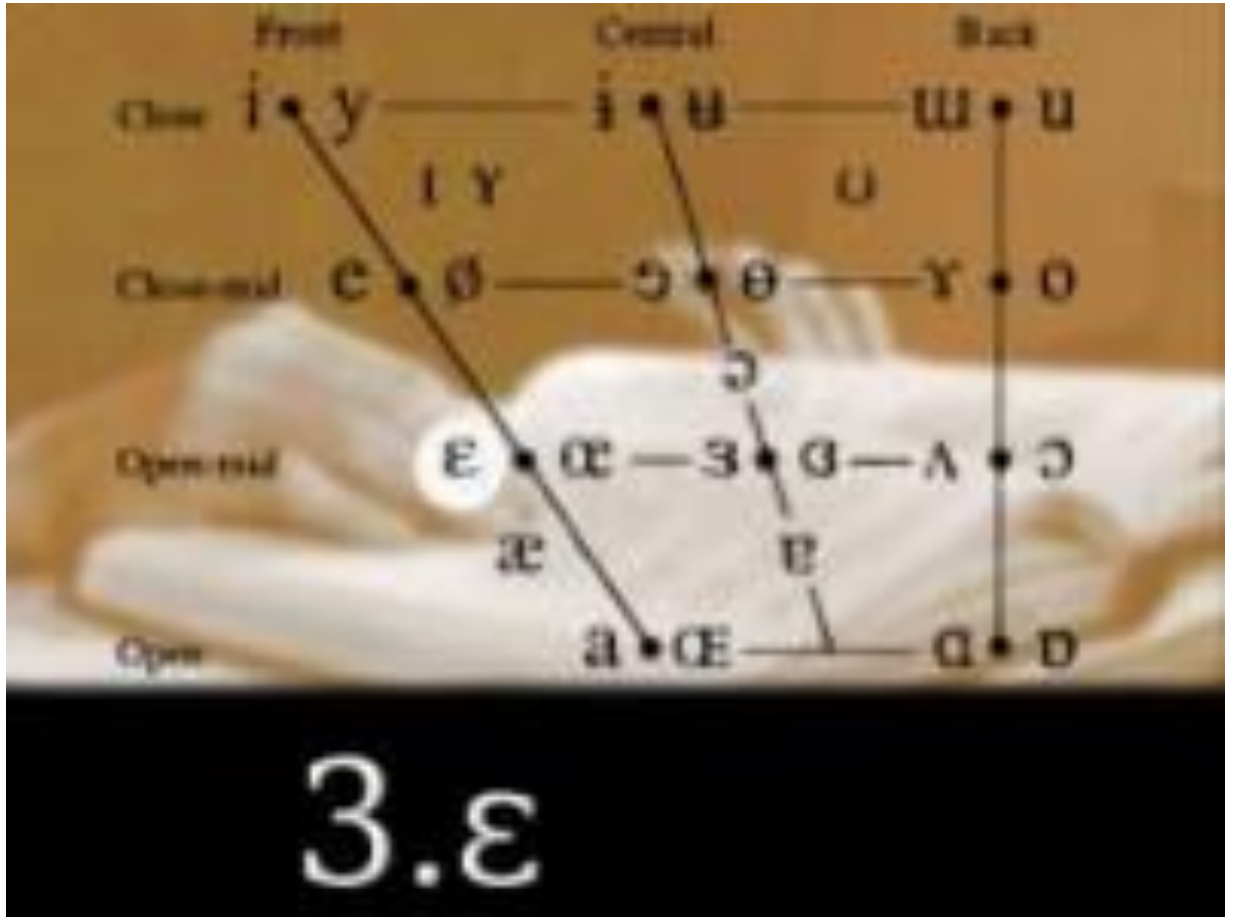


secondary



http://www.phonetics.ucla.edu/course/chapter1/vowels.html

Cardinal Vowels



Cardinal vowels

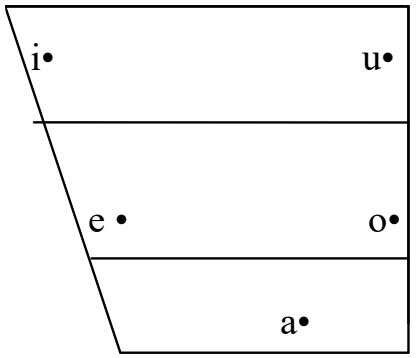
- Primary vowels are more common than secondary vowels across the world's languages.

- Lip rounding for back vowels tends to be made by protruding the lips whereas lip rounding on front vowels tends to be made by narrowing the lips without pushing them forward.
  - Adding lip rounding to front vowels lowers both formants, but particularly F2.
  - Because a high F2 is characteristic of front vowels in general, the effect of rounding gives the impression that a rounded front [y] is somewhere between [i] and [u].

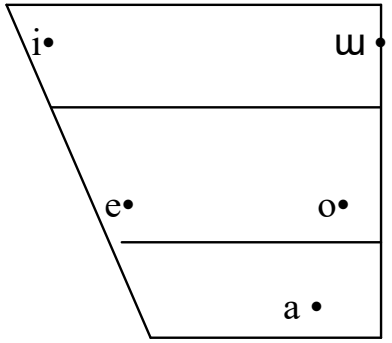
Cardinal vowels

- Vowel systems of particular languages are generally transcribed by using the cardinal vowel symbol that is closest to each vowel in a language.

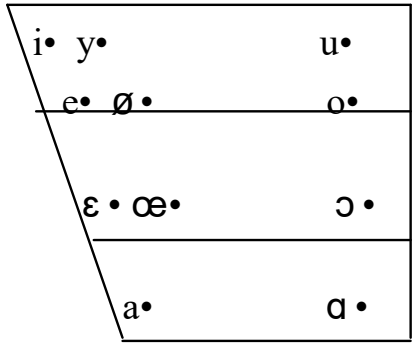
Spanish:



Japanese:



Danish:



E.g., the Spanish /i/ is lower and slightly more back than the cardinal vowel [i].

Cardinal vowels

- Note that, even when the vowel systems of two languages are the same, their average articulation may be slightly different.

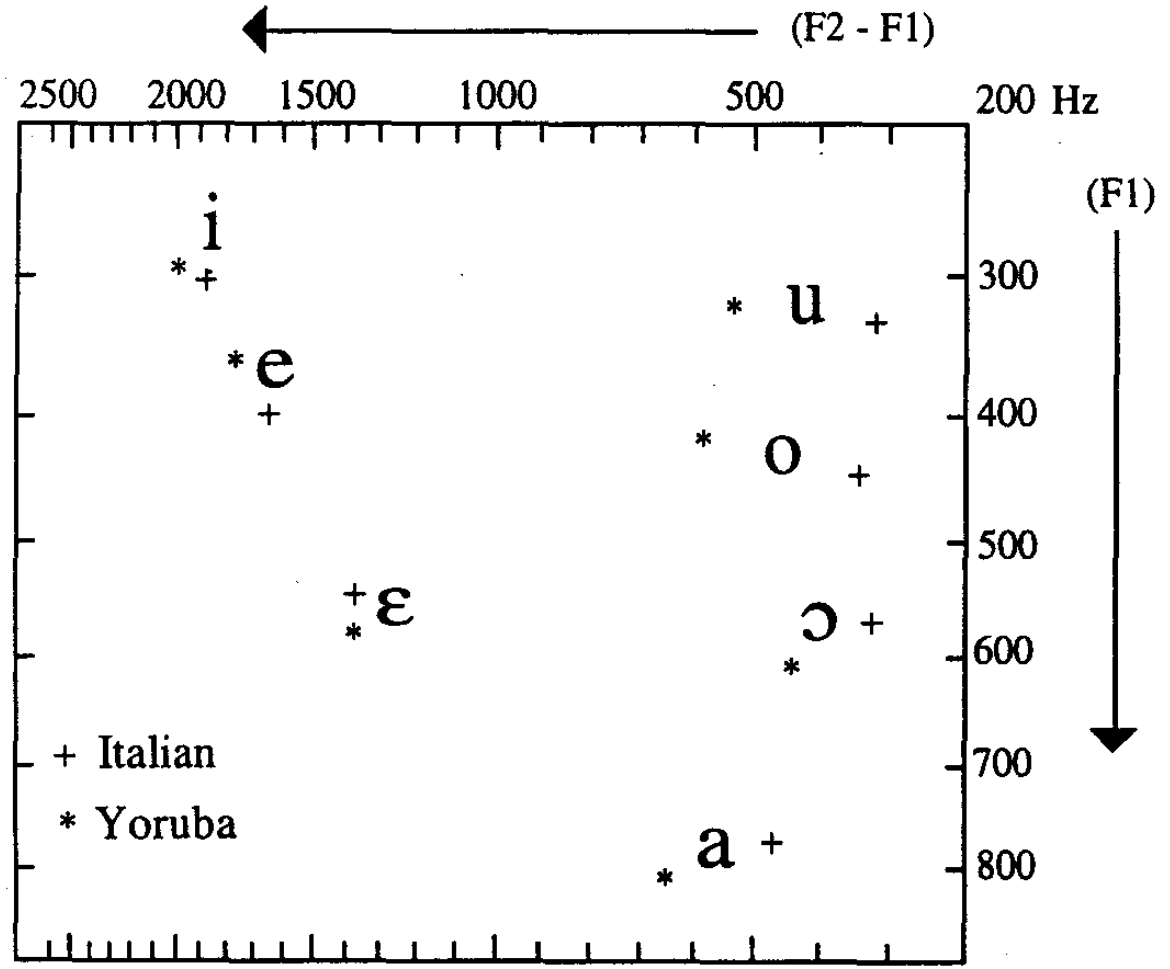


Figure 9.13 Mean formant frequencies of the vowels of Yoruba and Italian (based on data in Disner 1983).

From: Ladefoged & Maddieson 1996

Cardinal vowels

Want to hear some examples?

- http://www.phonetics.ucla.edu/vowels/chapter3/table3.html
- http://www.phonetics.ucla.edu/vowels/chapter14/french.html

Spanish		Hawaiian	
masa	'dough'	**kaka**	'to rinse'
mesa	'table'	**keke**	'turnstone'
misa	'mass'	**kiki**	'to sting' (bee)
mosca	'fly'	**koko**	'blood'
musa	'muse'	**kuku**	'to beat' (tapa)

Swahili		Japanese	
pata	'hinge'	**ma**	'interval'
peta	'bend'	**me**	'eye'
pita	'pass'	**mi**	'fruit, nut'
pota	'twist	**mo**	'algae'
puta	'thrash'	**mu**	'nothing'

French

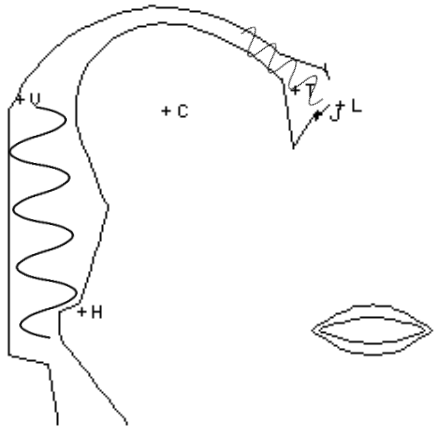
Front		Back
Unrounded	Rounded	
lit **li** 'bed'	lu **ly** 'read' (p.p.)	loup **lu** 'wolf'
les **le** 'the' (pl.)	le **lø** 'the' (m. sg.)	lot **lo** 'prize'
laid **lɛ** 'ugly'	leur **lœʀ** 'their'	lors **lɔʀ** 'during'
la **la** 'there'		las **lɑ** 'tired'

Review: Vocal tract configuration and vowel acoustics

- The configuration of the vocal tract differs for each vowel leading to different formant frequencies for each vowel.
    - The lowest formants, F1 and F2, give us the most information in distinguishing one vowel from another.
        - **F1** is determined by the resonating frequency of the **back cavity**
        - **F2** is determined by the resonating frequency of the **front cavity.**

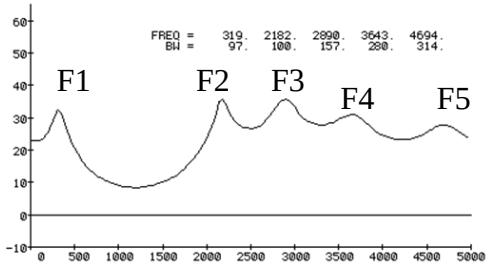
Review: Vocal tract configuration and vowel acoustics

/i/



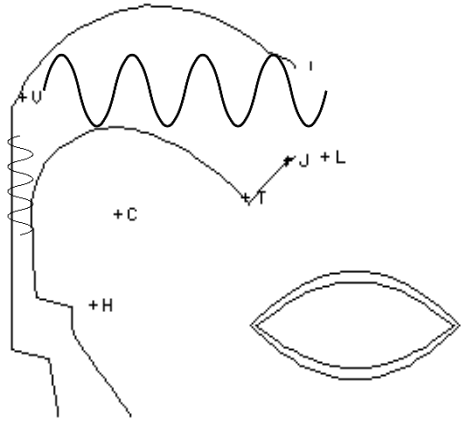
Back cavity: large
Front cavity: small

⇓



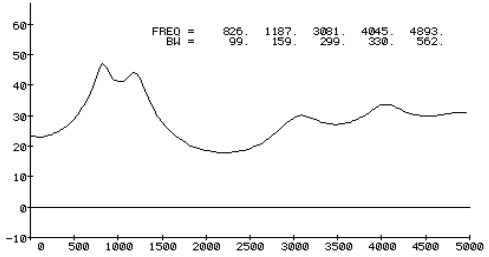
Low F1
High F2

/ɑ/



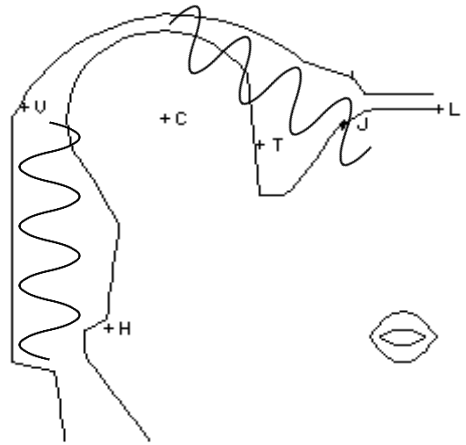
Back cavity: small
Front cavity: large

⇓



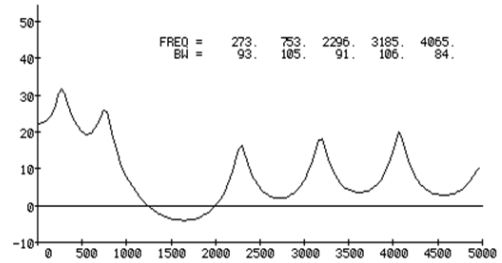
High F1
Low F2

/u/



Back cavity: large
Front cavity: large
(and increased by lip protrusion)

⇓

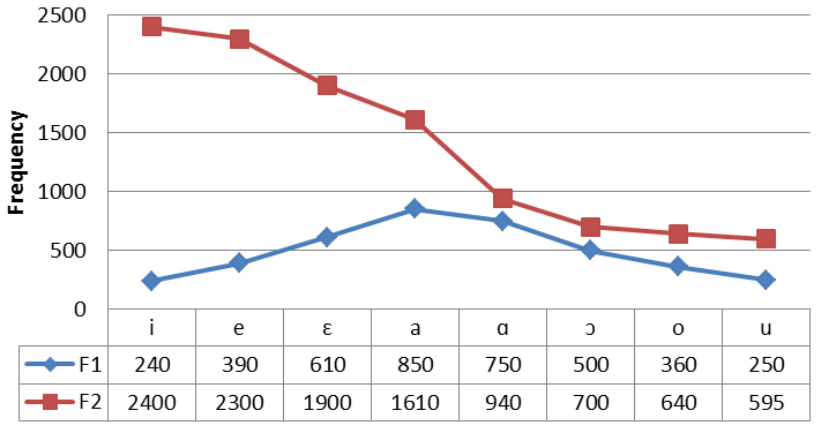


Low F1
Low F2

Acoustics of cardinal vowels

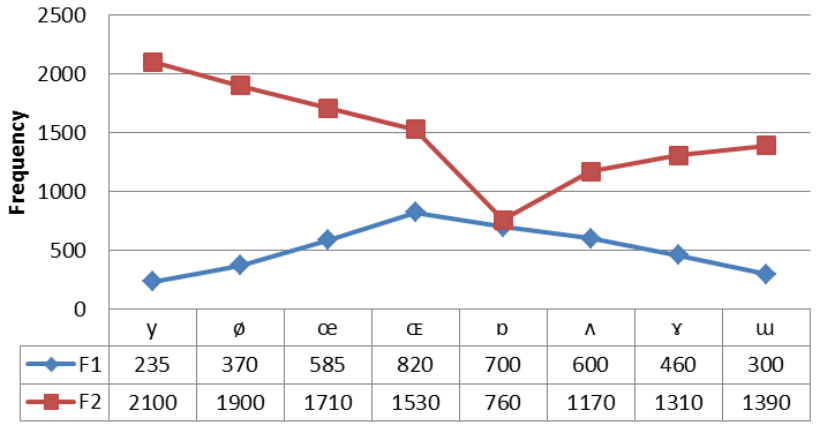
- Average frequencies of F1 and F2 formants of the cardinal vowels (in Hz):

Primary cardinal vowels



	i	e	ɛ	a	ɑ	ɔ	o	u
F1	240	390	610	850	750	500	360	250
F2	2400	2300	1900	1610	940	700	640	595

Secondary cardinal vowels



	y	ø	œ	œ	ɒ	ʌ	ɤ	ɯ
F1	235	370	585	820	700	600	460	300
F2	2100	1900	1710	1530	760	1170	1310	1390

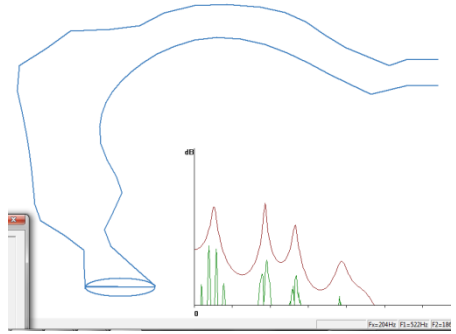
Back cavity is large → **low F1**

Back cavity is small → **high F1**

Front cavity is large → **low F2**

Front cavity is small → **high F2**

Adding lip rounding lowers **F2**. Why?



An increased front cavity

Additional Vowel Symbols

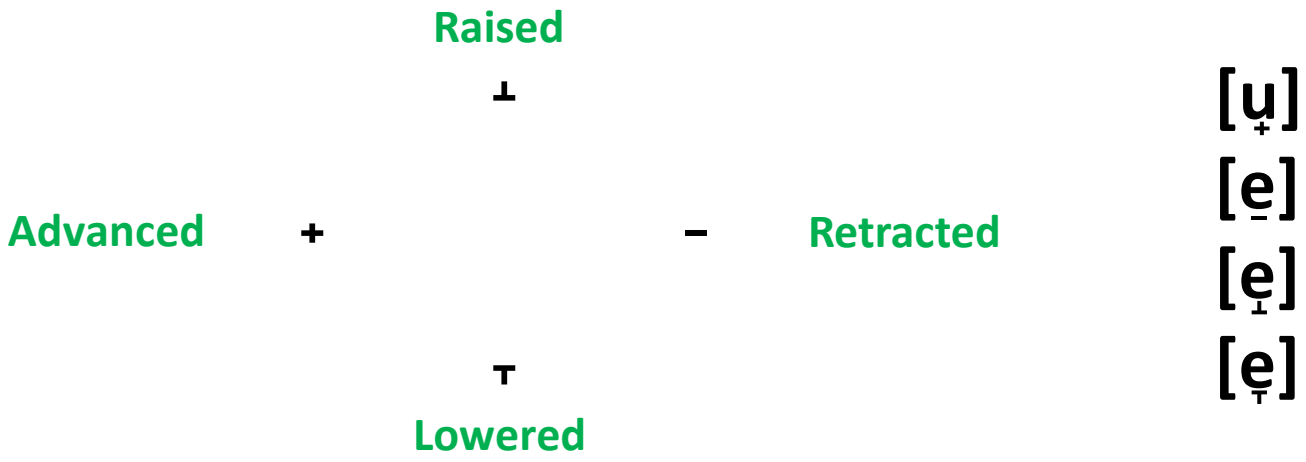
- Language specific transcription traditions also develop and differ from the cardinal vowel usage.
  - Additional symbols are needed for some languages.
  - If a language has five, unrounded front vowels there will not be enough cardinal vowel symbols to represent every vowel in the language.
- The following additional symbols are needed for languages with larger vowel inventories:

  - [ɪ] – between [i] and [e]
  - [ʏ] – between [y] and [ø]
  - [ʊ] – between [u] and [o]
  - [æ] – between [ɛ] and [a]
  - [ɐ] – higher low central unrounded

  - In English, for example, the low front vowel is transcribed with [æ] and not with the low, front cardinal vowel symbol [a], since there can be said to be 3 distinct low unrounded vowels.

Additional Vowel Symbols

- If additional precision is needed, the following diacritics can be used to show that a vowel is slightly more front, more back, higher or lower than the cardinal symbol being used:



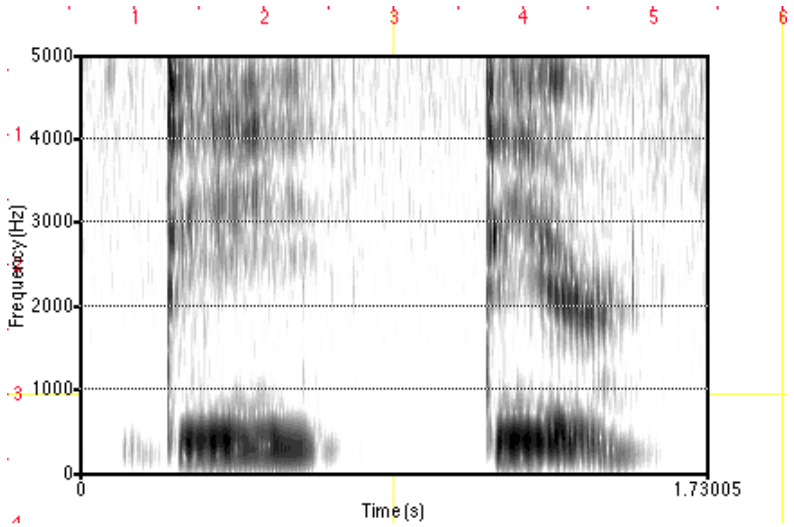
Additional vowel qualities

Additional vowel qualities

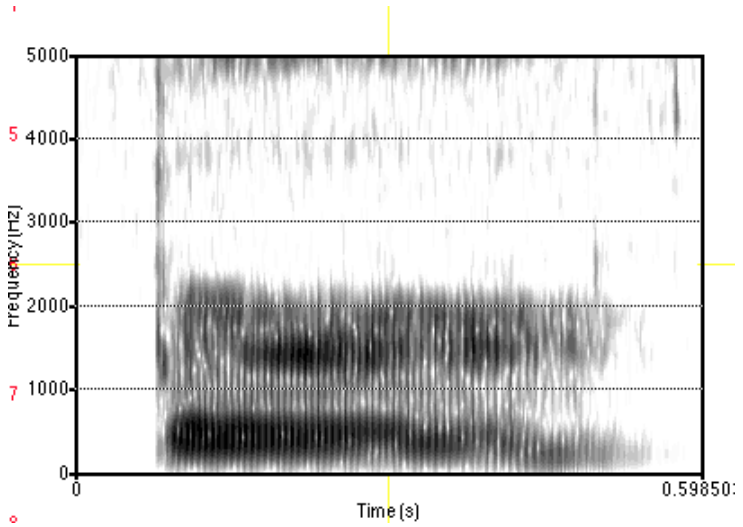
- Rhoticization
- Nasalization
- Expansion
- Length
- Tense-lax
- Glides

Rhoticization

- Vowels are rhoticized by curling back the tongue tip or by retracting the tongue tip into the body of the tongue.
- Rhoticized vowels generally have a hollowing of the tongue body.
- Rhoticization causes lowering of F3.



d i d i ɹ



b ɚ

Rhoticization

- Badaga (Dravidian):

  plain, half-rhotacized, and fully-rhotacized vowels

  - beː ‘mouth’
  - beɾː ‘bangle’
  - beɾɾː ‘banana plant, crop’

Nasalization

- Nasal vowels are produced with a lowered velum and air passing out through both the mouth and the nose.
  - English vowels are nasalized allophonically when they are adjacent to nasal consonants.
  - Some languages use nasalization of vowels contrastively.
  - Nasalization is indicated with a tilde above the vowel symbol. [ẽ]

- French is a language with contrastive nasalization of vowels

[lo] *lot* ‘prize’ [lõ] *long* ‘long’


http://www.phonetics.ucla.edu/vowels/chapter14/french2.html

Expansion

- Some languages make a contrast between vowels made with an expanded pharynx and vowels made without an expanded pharynx.
  - In the expanded set, the tongue root is pulled forward and the larynx is lowered.
  - The non-expanded set is produced with the tongue root back and without any lowering of the larynx.
- The terms *advanced tongue root* (ATR) and *retracted tongue root* (RTR) are also used for expanded and non-expanded vowels respectively.

- *Expanded/ATR* = [e̙]
- *Non-expanded/RTR* = [e̘]

Expansion

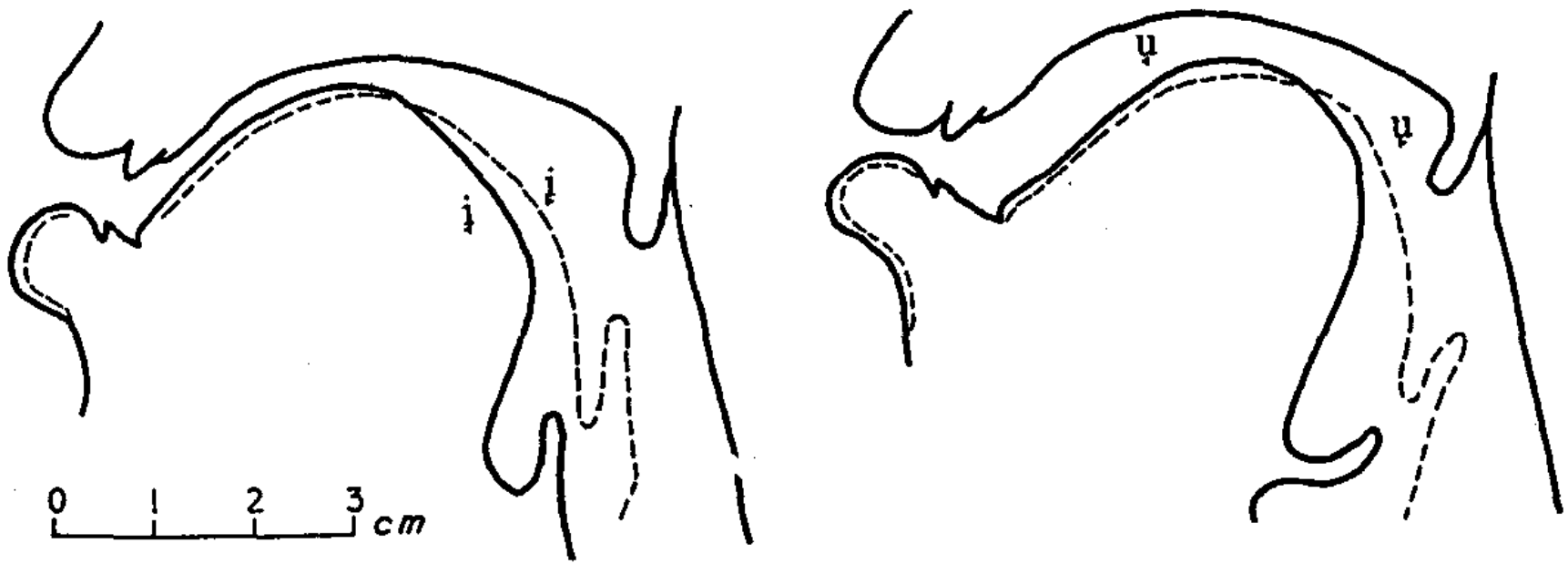


Figure 9.16 Tracings from x-ray cinematography films of Igbo vowels ị as in **ọ́bị̀** (*óbì* in the standard Igbo orthography) 'heart'; ị as in **ụ̀bị̀** (*ụ̀bì*)poverty of ability'; ụ as in **ị́bú** (*íbú*) 'weight'; and ụ as in **ọbụ̀** (*ọbụ*) 'it is'. In accordance with current IPA usage ˖ and ˗ are used to indicate Advanced and Retracted Tongue Root, respectively.

From: Ladefoged & Maddieson 1996

Expansion

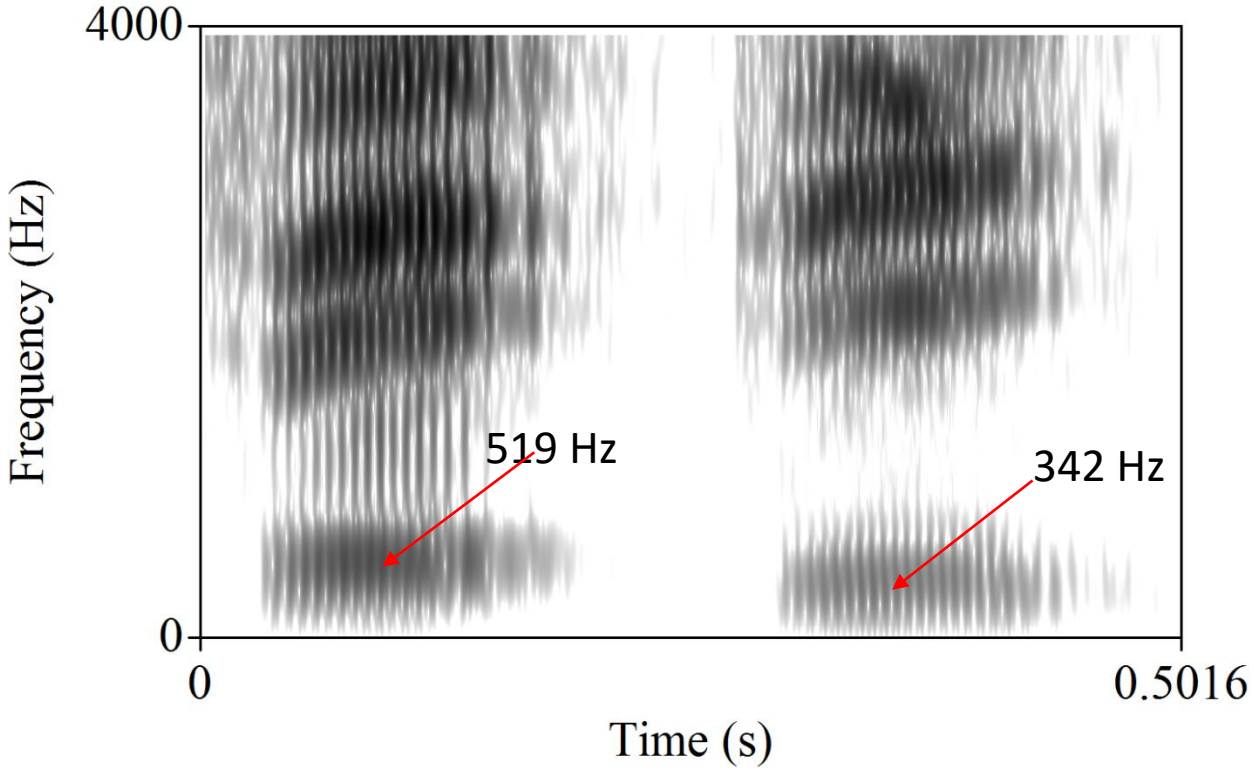
- Expanded vowels have a l cavity.

- Here are some examples

  Akan:

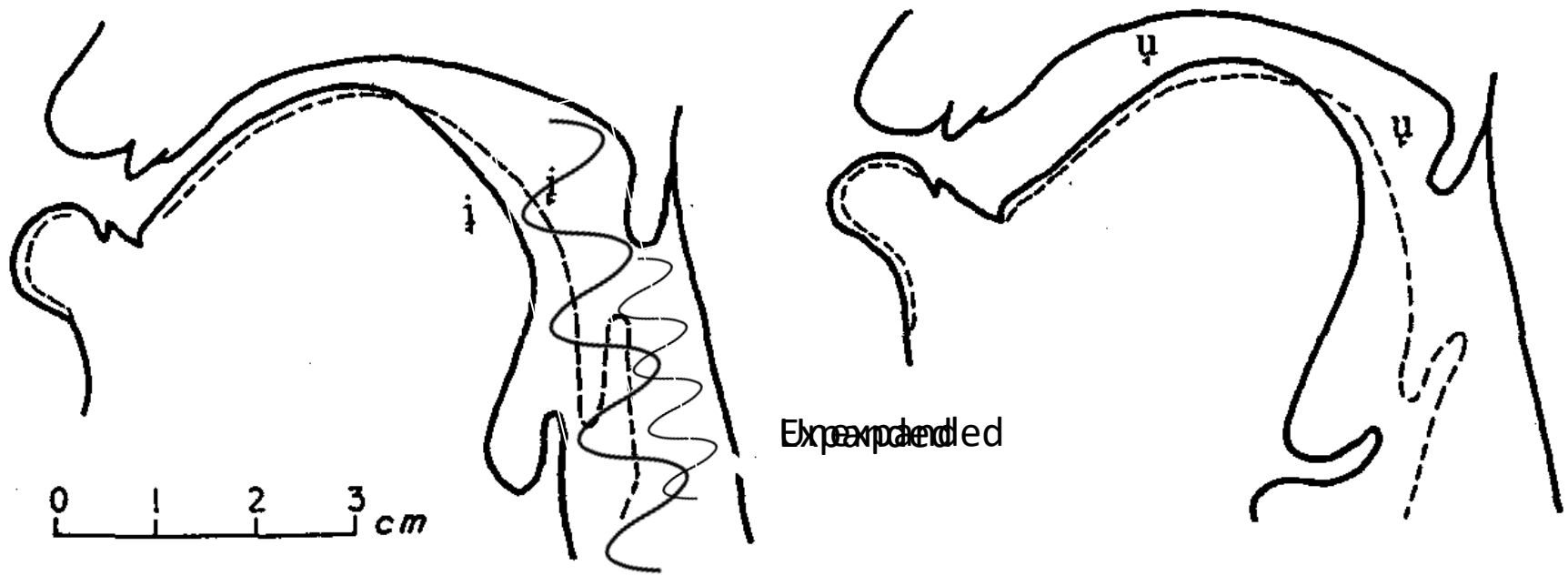
  [sɻi] - say (RTR)

  [sɪ̟i] - wash (ATR)



http://www.phonetics.ucla.edu/course/chapter9/akan/akan.html

Expansion



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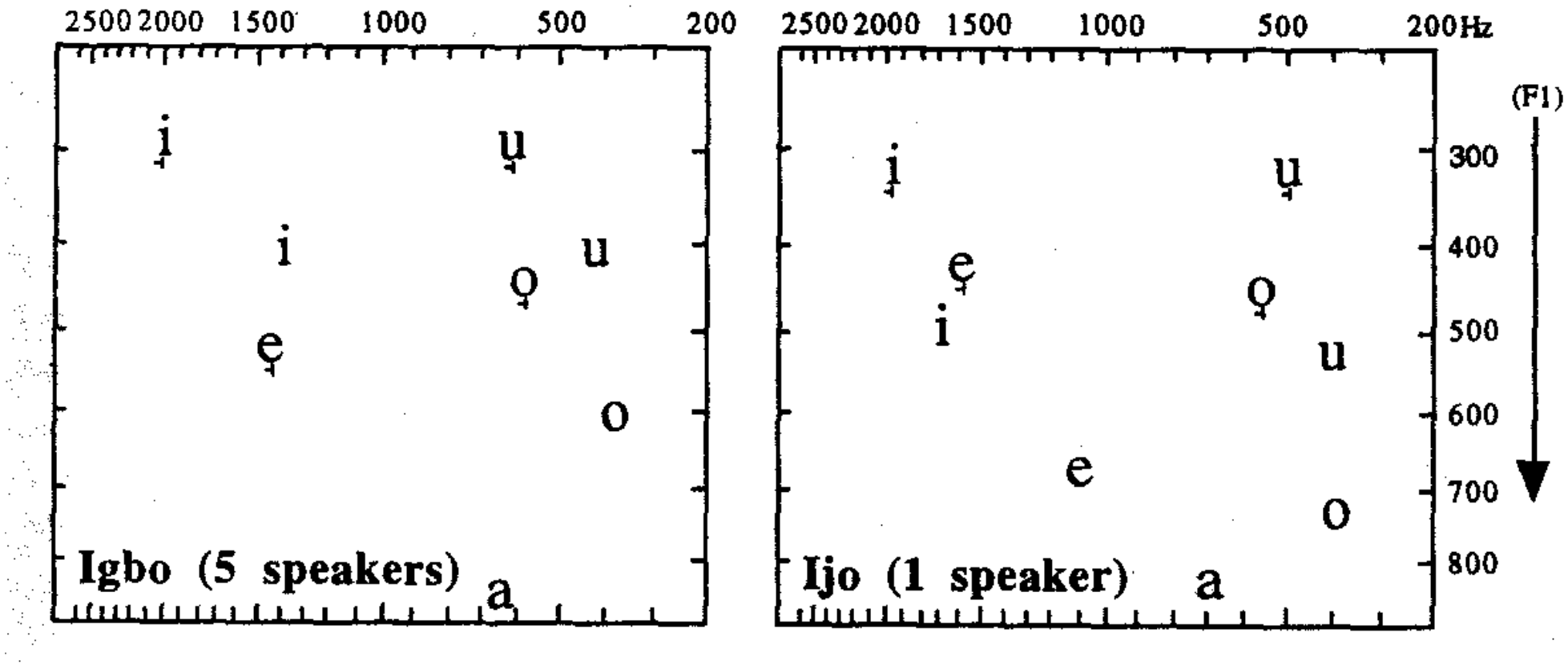


From: Ladefoged & Maddieson 1996

Tense-lax

- The tense-lax distinction is useful in describing phonological classes of English vowels and may be relevant for other languages as well.
- Phonetically, however, there is no articulatory or acoustic trait which consistently distinguishes tense from lax vowels.

- Sometimes the terms or symbols are conventionally used interchangeably, but this is not the same as [ATR] or [RTR].

Tense-lax

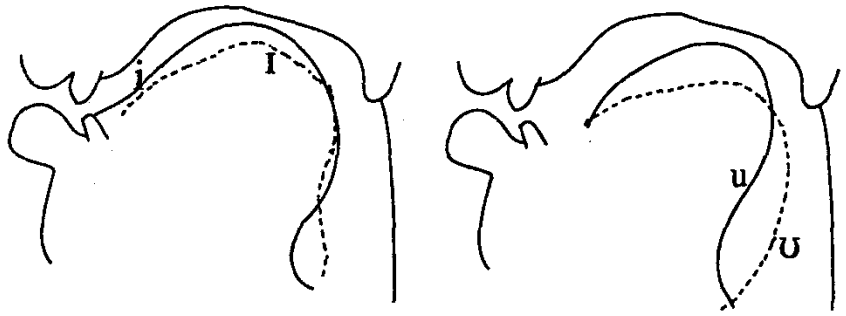


Figure 9.19 X-ray tracings of the articulatory positions in some so-called Tense/Lax pairs of vowels in English (redrawn from data in Perkell 1969).

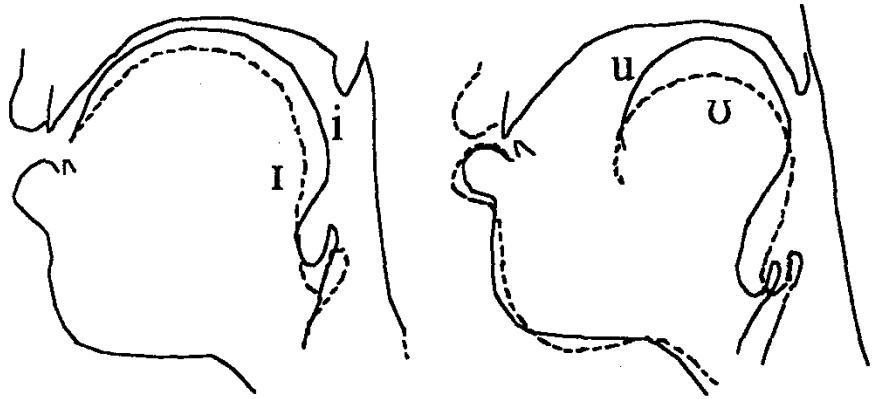
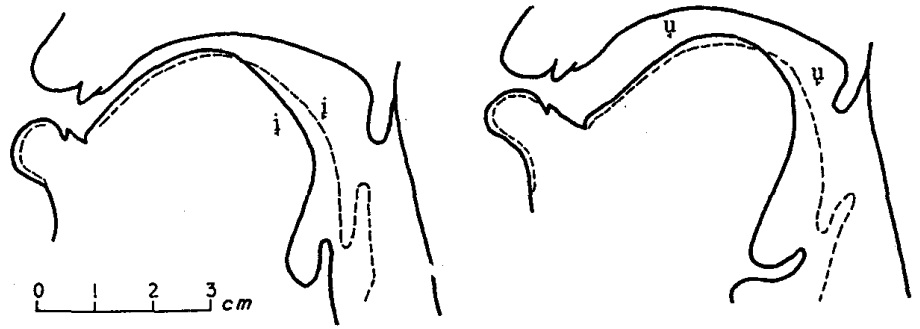


Figure 9.20 X-ray tracings of the articulatory positions in some so-called Tense/Lax pairs of vowels in German (after Bolla and Valaczkai 1986).

- Note that, for the most part, you don't get a larger pharyngeal cavity when articulating the English lax vowels.



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Length

- A length distinction is present in some languages.

Scots Gaelic:

[ˈsapaʤ]	‘fight’
[ˈsaːpaʤ]	‘Sabbath’
[ənˈtul]	‘the flood’
[ənˈtuːl]	‘the eye’

German

[vʏːtən]	‘to rage’
[bʏtən]	‘tubs’

http://www.phonetics.ucla.edu/vowels/chapter14/gaelic.html

http://www.phonetics.ucla.edu/vowels/chapter14/germ.html

Glides

- Glides are non-syllabic counterparts of vowels.
- Any vowel symbol can be made to represent a glide by using a subscript arch [̯], e.g. [e̯].

Vowel	Glide
i	j
u	w
ɯ	ɯ̯
y	ɥ

French has three glides:

mjɛt	mɥɛt	mwɛt
'crumb'	'mute'	'gull'
ljɛ	lɥi	lwi
'tied'	'him'	(name)
	ɥit	wi
	'eight'	'yes'



http://www.phonetics.ucla.edu/course/chapter11/frvowel/frenchvowel.html

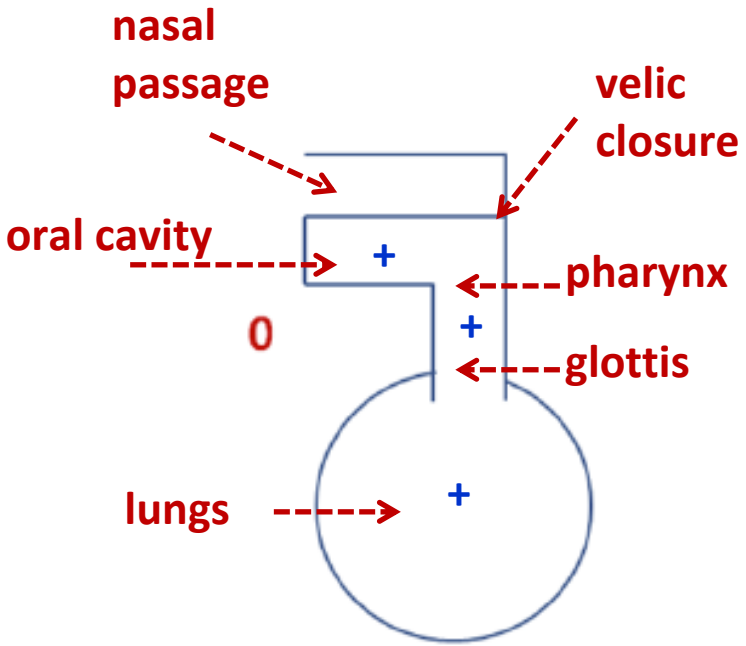
Air stream mechanisms

Airstream mechanisms

- All articulation depends on manipulating a flow of air across the articulators in the vocal tract.
- The flow of air is initiated by the creation of a difference of air pressure between the air pressure in the body and the air pressure outside of the body.
- Air will flow from an area of high pressure to an area of low pressure.

Airstream mechanisms

- In speaking, we take air into the body and then change the size of the space in which it is contained.
  - If the space is contracted, the air pressure inside the body will increase and air will be forced out. This is an ***egressive*** **airstream**.
  - If the space expands, then the inside air pressure decreases and air will flow inwards. This is an ***ingressive*** **airstream**.

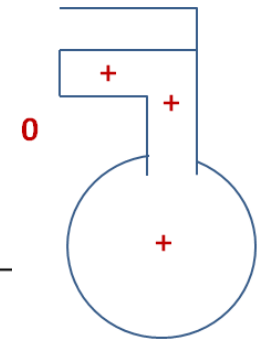
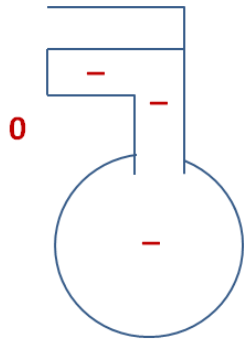


Airstream mechanisms

- Direction of airflow:
  - **egressive** - made with air flowing outwards
  - **ingressive** - made with air flowing inwards

- Body part controlling the air pressure
  - **pulmonic** - made with the lungs
  - **glottalic** - made by raising or lowering the glottis
  - **velaric** - made with air trapped in front of a dorsovelar closure

Airstream mechanisms - Pulmonic

Mechanism Direction	Pulmonic	Glottalic	Velaric
Egressive	 in all languages [p t k], etc.		
Ingressive	 rarely used		

Pulmonic egressive

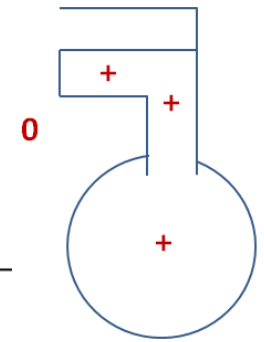
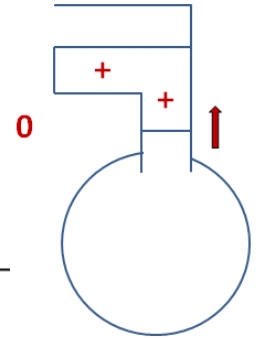
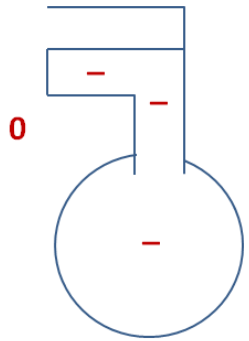
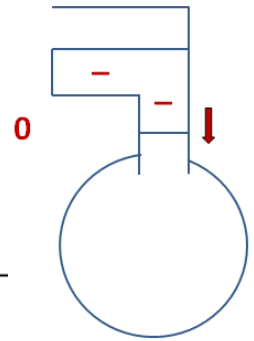
- The lungs compress, increasing air pressure in the body; air goes out.

Pulmonic ingressive

- The lungs expand, decreasing air pressure in the body; air goes in.

Airstream mechanisms - Pulmonic

Airstream mechanisms - Glottalic

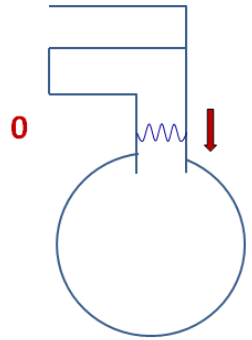
Mechanism / Direction	Pulmonic	Glottalic	Velaric
Egressive	 in all languages [p t k], etc.	 ejectives, [p’ t’ k’]	
Ingressive	 rarely used	 implosives [ɓ, ɗ, ʄ, ɠ]	

Glottalic egressive

- The larynx raises, increasing air pressure in the oral cavity.

Glottalic ingressive

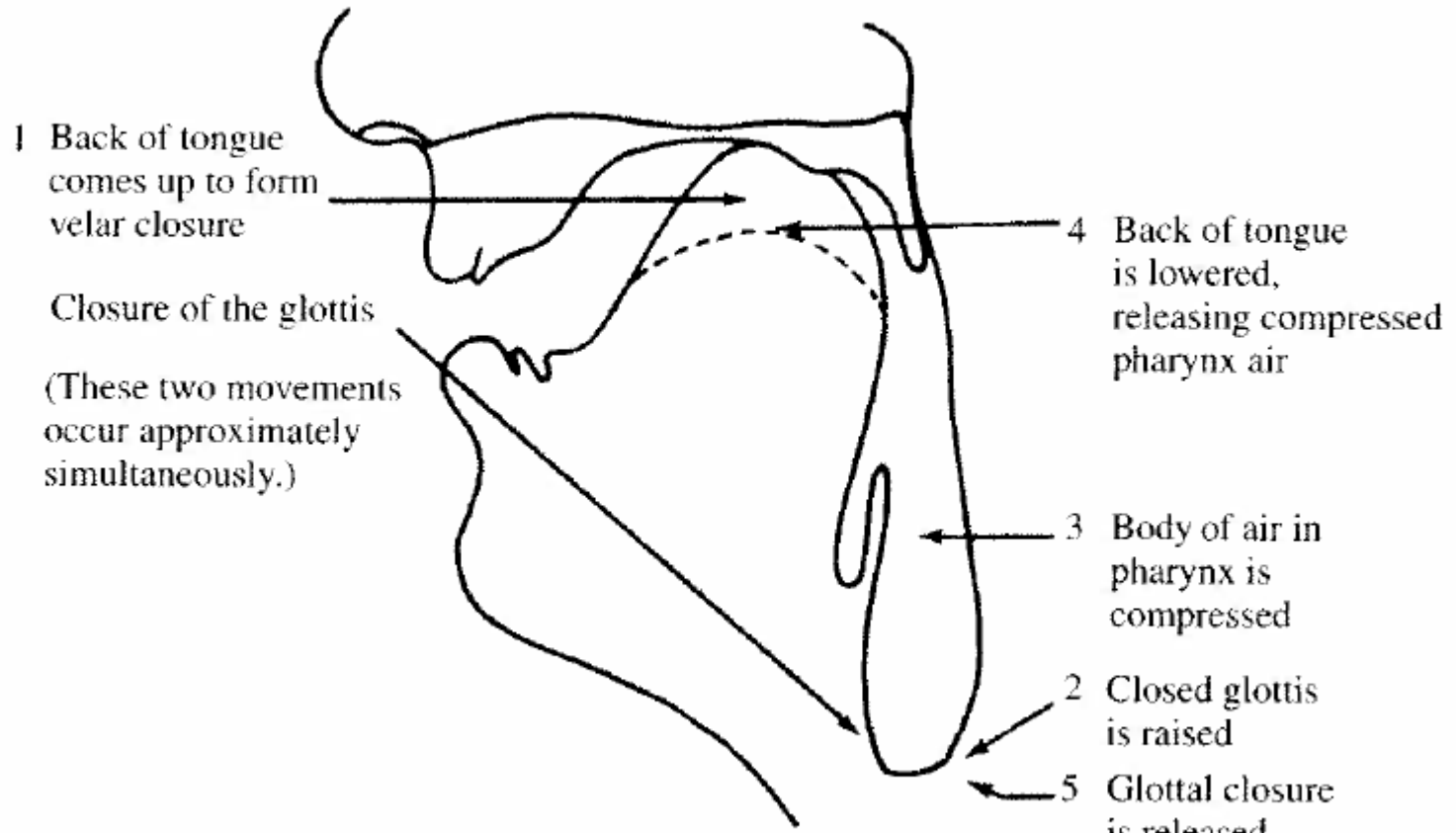
- The larynx lowers, decreasing air pressure in the oral cavity.



implosives are usually voiced

Airstream mechanisms - Ejectives

Figure 6.1 The sequence of events that occurs in a glottalic egressive velar stop [k'].



Airstream mechanisms - Ejectives

- Lakhota

Glottalic egressive

[pʼo] *foggy*  [t̪ʼuʃɛ] *at all costs* [kʼu] *to give* 

Pulmonic egressive

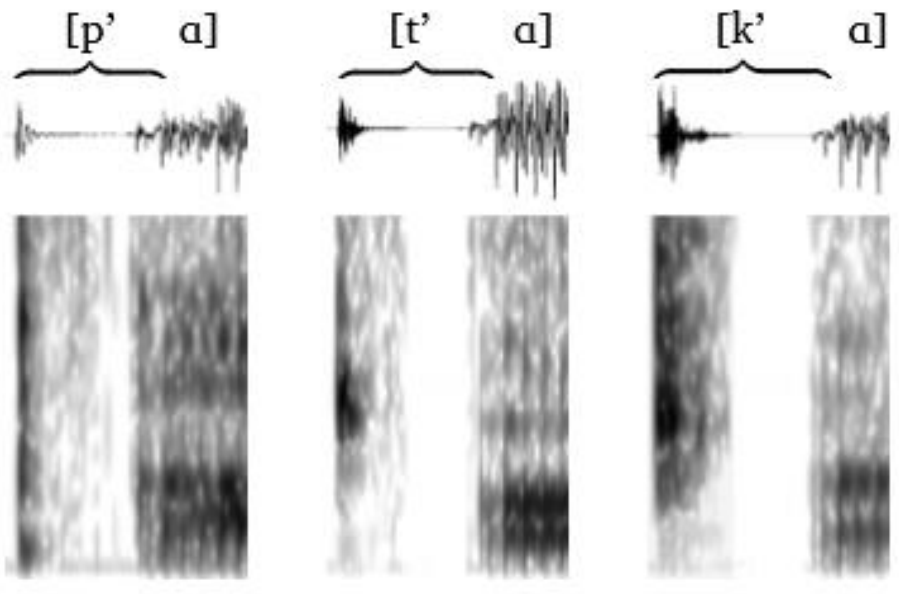
[paɣot̪a] *mallard*  [t̪uwa] *who* [kah] *that* 

http://www.phonetics.ucla.edu/course/chapter6/lakhota/lakhota.html

- Ejectives in English:
  - *https://youtu.be/lHn4ncUg_m8?t=1m52s*
  - Use of velar ejectives for **k** when before a pause. Notice *think* at about 2:00 and 3:09, and *back* at 2:50 and at 3:20.

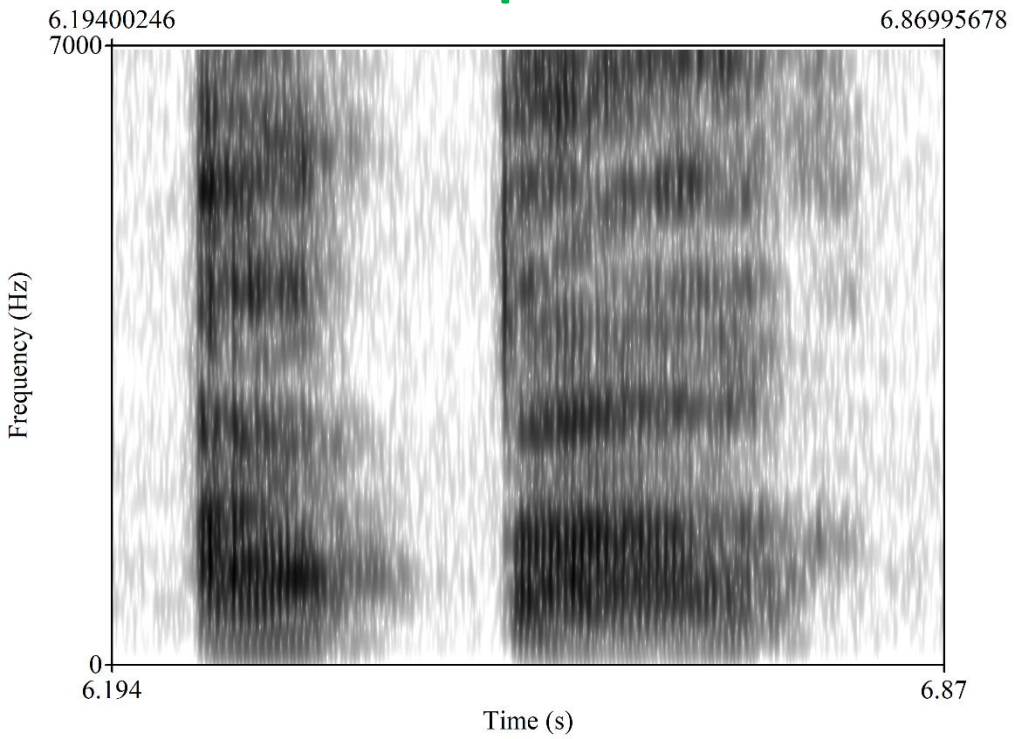
Acoustics of Ejectives

- Ejectives have two releases
  - There is a period of silence between the first and second release
  - The first release looks similar to a plosive release of the same place of articulation, but a bit louder
  - The second release is often difficult to see, making the period of silence the most salient clue
  - The silence is generally around .05 seconds long

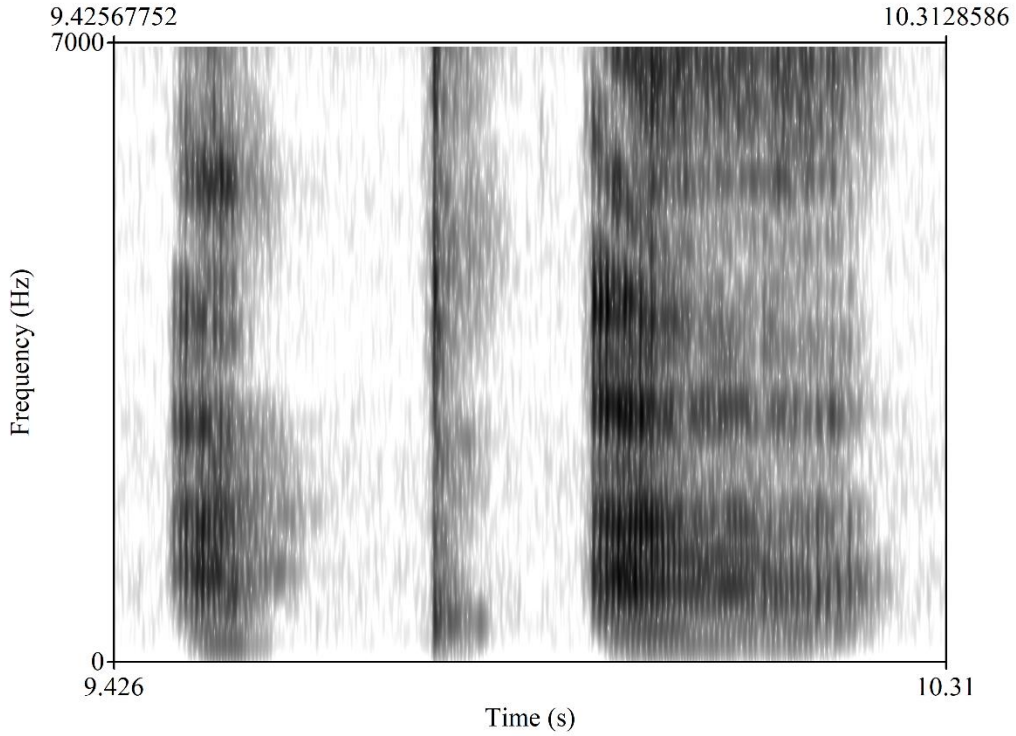


Acoustics of Ejectives

apa

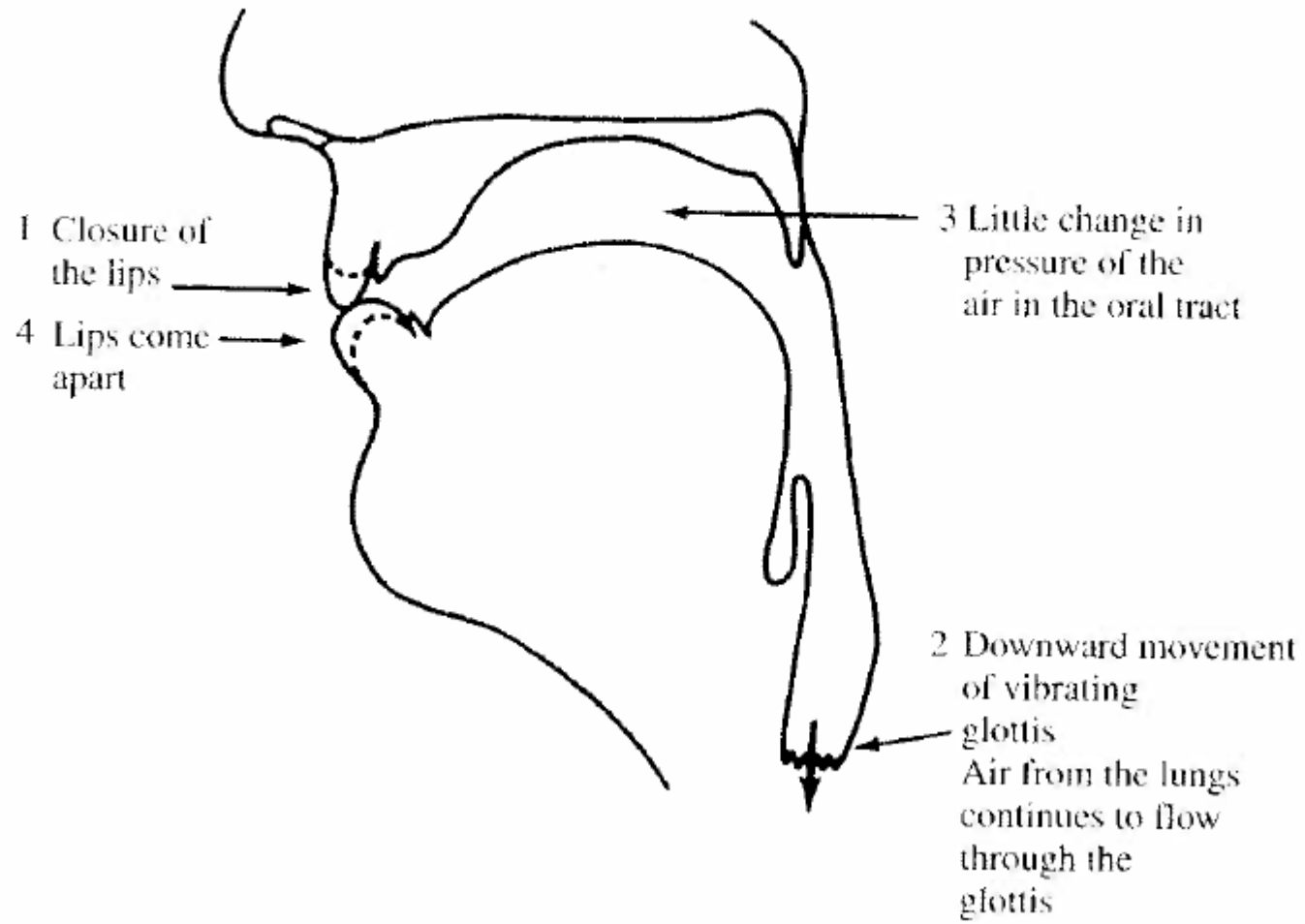


ap’a



Airstream mechanisms - Implosives

Figure 6.3 Estimated sequence of events in a Sindhi bilabial implosive [6].



Airstream mechanisms - Implosives

- Implosives are transcribed with symbols similar to those used for pulmonic egressive voiced stops, but with an additional rightward-pointing hook at the top:
  - [ɓ, ɗ, ʄ, ɠ, ɠ] etc.

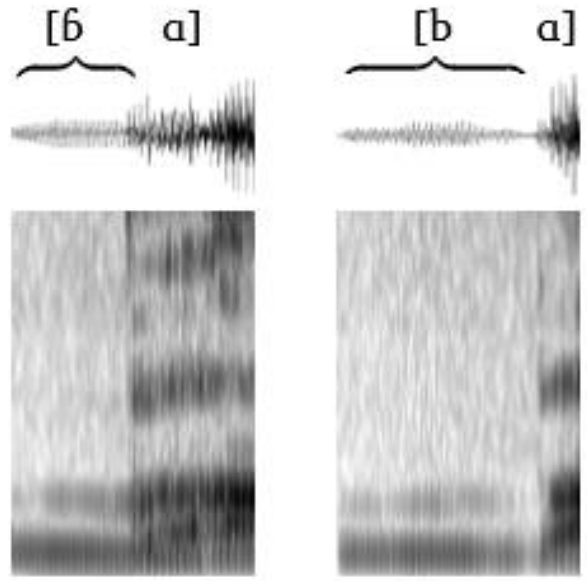
Sindhi

- *Pulmonic egressives*
  - [banu] *forest*  [gunu] *quality*
- *Implosives*
  - [ɓani] *field*  [ɠanu] *handle*

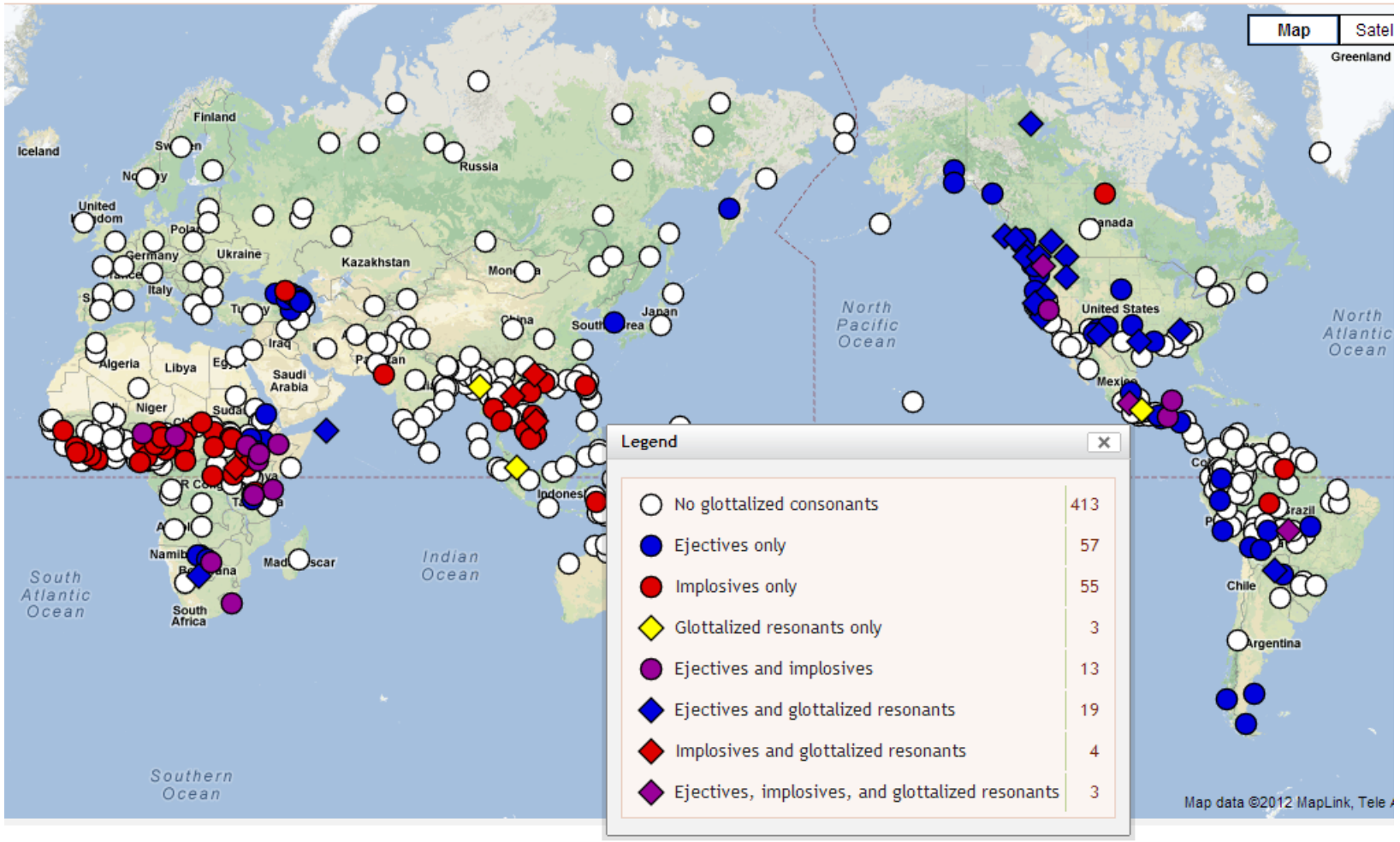
- http://www.phonetics.ucla.edu/course/chapter6/sindhi/sinhi.html

Acoustics of Implosives

- Implosives look similar to voiced plosives of the same place of articulation
- Implosives are typically shorter than their plosive counterparts
- There are no easy, consistent ways to tell voiced plosives and implosives apart acoustically
  - Thus, many languages only have one or the other of these sounds



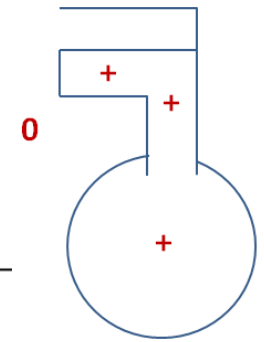
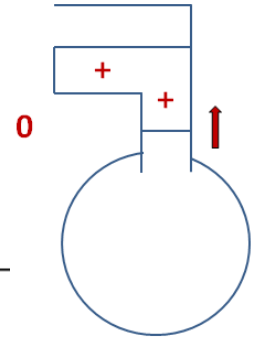
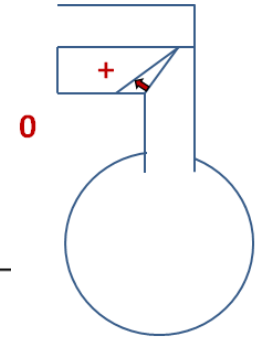
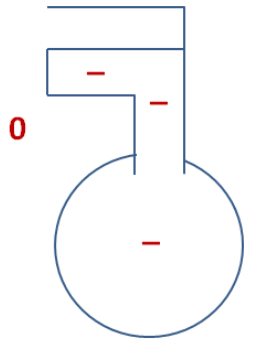
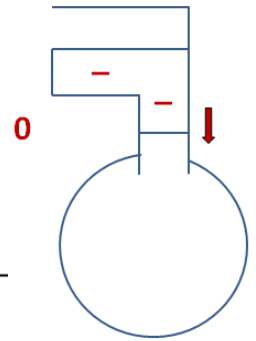
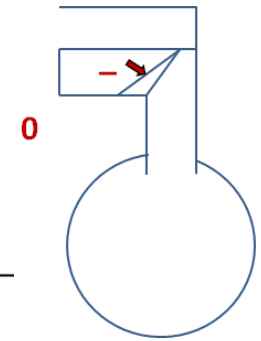
Airstream mechanisms – Glottalic



The World Atlas of Language Structures (*WALS*)

http://wals.info/

Airstream mechanisms - Velaric

Mechanism / Direction	Pulmonic	Glottalic	Velaric
Egressive	 in all languages [p t k], etc.	 ejectives, [p’ t’ k’]	 not used
Ingressive	 rarely used	 implosives [ɓ, ɗ, ʄ, ɠ]	 clicks

Velaric egressive

- The same as ingressive, but the tongue moves forward/up, increasing air pressure.

Velaric ingressive

- The tongue makes a dorso-velar closure, with a simultaneous more anterior closure;
- The tongue is pulled back/low, decreasing air-pressure at the front.

Symbols for clicks:

ʘ bilabial ǁ lateral

ǀ dental ǂ palatoalveolar

ǃ alveolar

Clicks

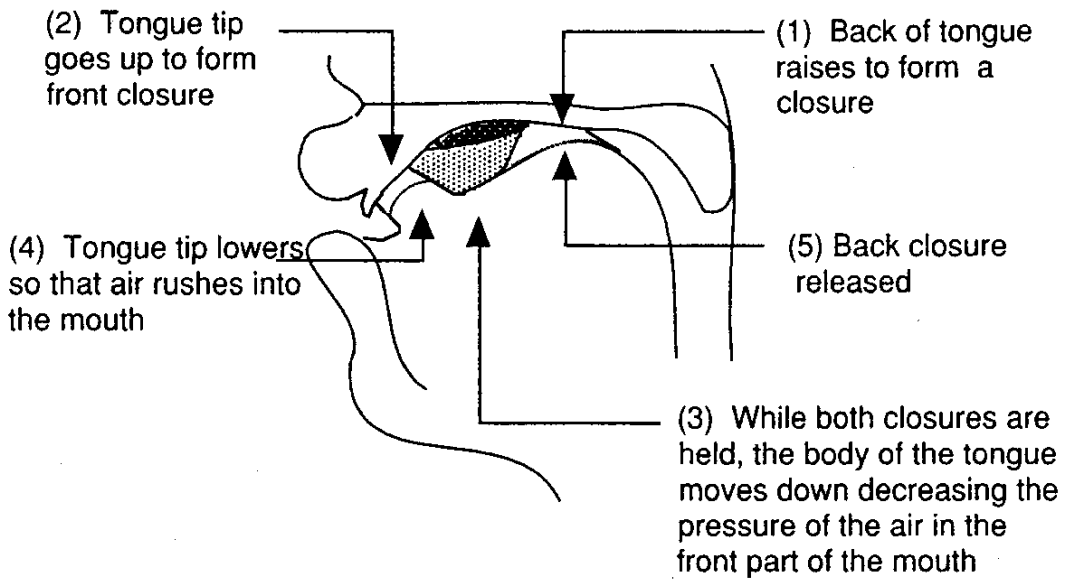
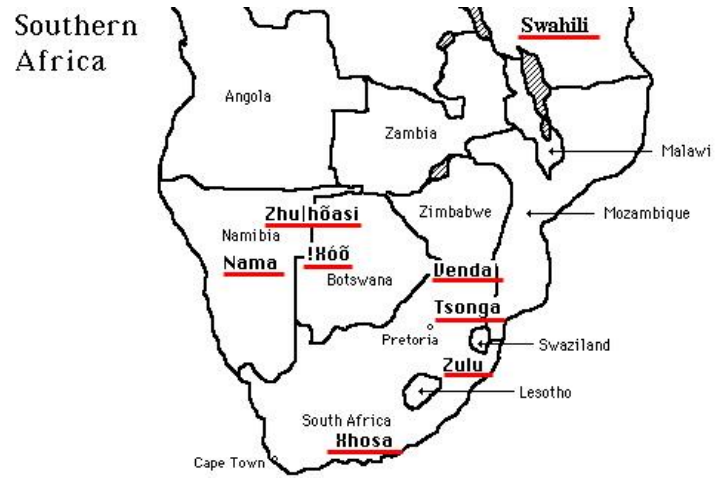


Figure 13.11 The movements involved in making a click. The dark shaded area shows the cavity enclosed when the closures are formed. The light shaded area shows the cavity just before the release of the front closure. The dashed lines show the lowered tongue positions corresponding to steps 4 and 5.

From: Ladefoged's 'Vowels and Consonants'

Airstream mechanisms - Clicks

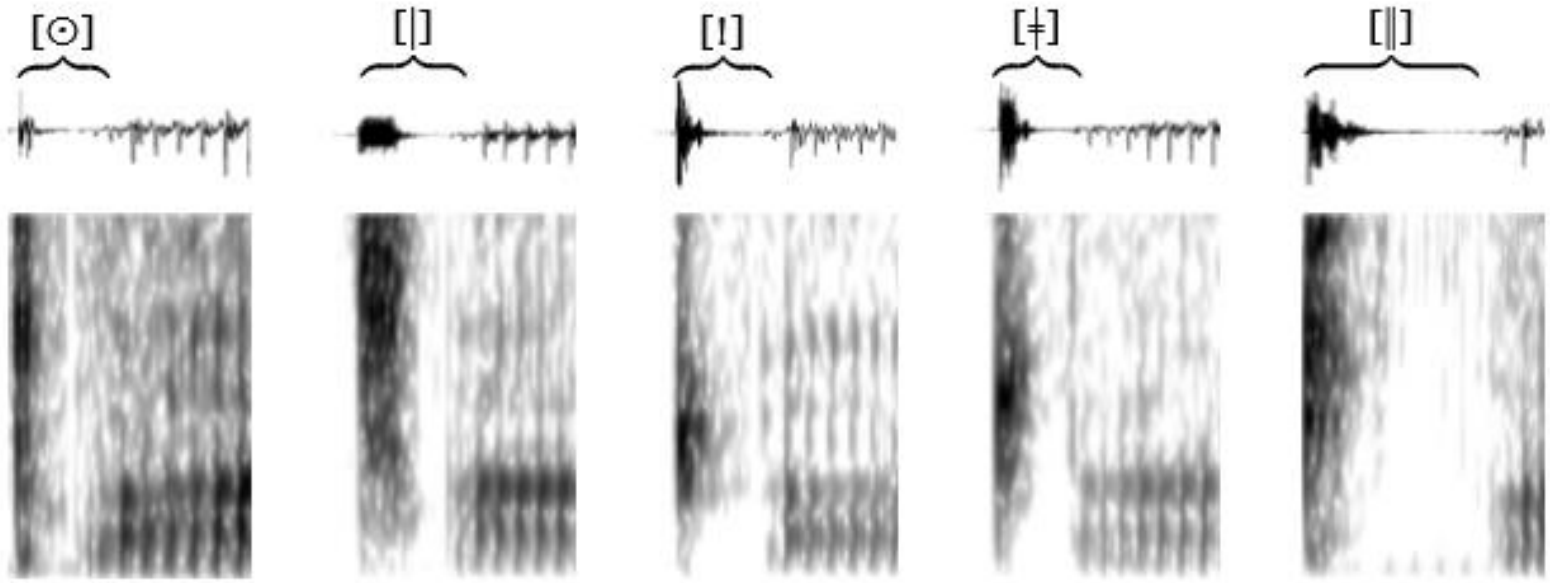
	DENTAL	ALVEOLAR	PALATAL	ALVEOLAR LATERAL
VOICELESS UNASPIRATED	**kǀoa** 'put into'	**k!oas** 'hollow'	**kǂais** 'calling'	**kǁaros** 'writing'
VOICELESS ASPIRATED	**kǀʰo** 'play music'	**k!ʰoas** 'belt'	**kǂʰaris** 'small one'	**kǁʰaos** 'strike'
VOICELESS NASAL	**ŋ̊ǀʰo** 'push into'	**ŋ̊ !ʰoas** 'narrating'	**ŋ̊ ǂʰais** 'baboon's arse'	**ŋ̊ǁʰaos** 'cooking place'
VOICED NASAL	**ŋǀo** 'measure'	**ŋ!oras** 'pluck maize'	**ŋǂais** 'turtle dove'	**ŋǁaes** 'pointing'
GLOTTAL CLOSURE	**kǀˀoa** 'sound'	**k!ˀoas** 'meeting'	**kǂˀais** 'gold'	**kǁˀaos** 'reject a present'



http://www.phonetics.ucla.edu/vowels/chapter13/nama.html

Acoustics of Clicks

	bilabial [⊙]	dental [ǀ]	alveolar [ǃ]	palatal [ǂ]	lateral [ǁ]
release intensity	soft		loud		
release duration	≈ 0.01 s	≥ 0.02 s	≈ 0.01 s		≥ 0.02 s
release frequencies	variable	> 2000 Hz	< 2000 Hz	> 2000 Hz	
silence duration	≤ 0.02 s				≥ 0.05 s



Soft cheeks

Variable sized oral cavity

Airflow around the teeth

Scattered airflow

Large oral cavity

Airflow around the tongue

Airflow around the tongue

Airflow at tongue release

Airstream mechanisms

Time for YouTube videos!

From: Ladefoged's *A Course in Phonetics*

TABLE 6.4 The principal airstream processes.

Airstream	Direction	Brief Description	Specific Name for Stop Consonant	Examples	Vocal Folds
Pulmonic	egressive	lung air pushed out under the control of the respiratory muscles	plosive	p t k b d g	voiceless or voiced
Glottalic	egressive	pharynx air compressed by the upward movement of the closed glottis	ejective	p' t' k'	voiceless
Glottalic	ingressive	downward movement of the vibrating glottis; pulmonic egressive airstream may also be involved	implosive	ɓ ɗ ɠ	usually voiced by the pulmonic airstream
Velaric	ingressive	mouth air rarefied by the backward and downward movement of the tongue	click	ǀ ǃ ǁ ʘ	combine with the pulmonic airstream for voiced or voiceless velar nasals

Announcements and Reminders

- Your Homework 4 is due Saturday, May 29th at 11:59 PM.
- I am holding office hours on Friday, May 28th at 12-1 PM