Airstream Mechanisms

Back to Aerodynamics

- Remember: sounds are created by the flow of air
- All of the speech sounds that we've looked at so far have a **pulmonic egressive** airstream mechanism.
  - = air pushed out of the lungs
- Aerodynamic method #1: Stops

  A. start air flow

  B. stop air flow

  C. release air flow
- Q: How do we start air flow?

Step 1: Starting Air Flow

- We make air flow by creating differences in air pressure
- Air flows naturally from areas of high pressure to areas of low pressure
    - Popping a balloon
    - Glass experiment

Boyle's Law

- A constant quantity of gas (at a constant temperature) obeys what is called **Boyle's Law**
- The **pressure** of the gas in the chamber is…
  - inversely proportional to the **volume** of gas in the chamber
- Pressure (of gas in a chamber) =

$$\frac{\text{constant value}}{\text{volume of chamber}}$$

  - $P = k / V$

Robert Boyle (1627-1691)

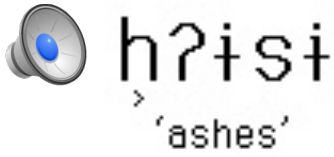
Boyle's Implications

- $\Rightarrow$ Pressure can be increased or decreased by changing the **volume** of the chamber
- Basic airflow strategy:
  - Decreasing volume $\Rightarrow$ increases pressure
  - Increasing volume $\Rightarrow$ decreases pressure
- Pulmonic egressive sounds:

  = air flows out of lungs into the environment
- $\Rightarrow$ Air pressure must be higher in lungs than outside of body
  - $\Rightarrow$ initiated by **decreasing** volume of lungs
- Q: What about pulmonic ingressive sounds?

Pulmonic Ingressive Sounds?

- In the 1980s, a dialect of Tsou was discovered which made use of **pulmonic ingressive** sounds.
  - Tsou is spoken in southern Taiwan.



Pulmonic Ingressive Sounds?

- The existence of pulmonic ingressives in Tsou was disputed by Ladefoged and Zeitoun (1993)
- They tested the claim with the following methods:
  1. Having speakers inhale smoke before making the sounds.
  2. Placing a straw in the speaker's mouth with the other end of the straw in a dark liquid.
- During the production of the sounds:
  - Smoke was exhaled
  - Bubbles appeared in the liquid
- ...for all but one speaker.

Other Airstream Mechanisms

- It is possible to move air in and out of the vocal tract without moving air in and out of the lungs.
- Here's one method:

1. Close the glottis (glottal stop)
2. Make a stop closure above the glottis

- Important: these two closures close off a chamber of air above the glottis.
  - $\Rightarrow$ Boyle's Law applies.

Glottalic Egressives

3. Raise the glottis
    - This compresses the air in the supraglottal cavity
4. Release the stop closure
    - Air rushes out of the vocal tract
    - From high pressure to low pressure
5. Release the glottal closure
    - Air rushes out of the lungs
    - Making a glottal stop

- Sounds which are made in this way use a **glottalic egressive** airstream mechanism.

Ejectives

- Sounds made with a glottalic egressive airstream mechanism are also known as **ejectives**.
- Ejectives are symbolized with a [’] following a symbol for a stop.
-  [ap’a]  [at’a]  [ak’a]
- To make an ejective…
  - Try making stops while holding your breath.
- Alternatively, imitate Elaine from Seinfeld:
  - “yup!”

Quechua, again

• Ejectives are found in about 18% of the world's languages, including Quechua.

	Palato-alveolar	Velar	Uvular
Voiceless	**tʃaka**	**kujui**	**qaʎu**
	'bridge'	'to move'	'tongue'
Aspirated	**tʃʰaka**	**kʰujui**	**qʰaʎu**
	'large ant'	'to whistle'	'shawl'
Ejective	**tʃʼaka**	**kʼujui**	**qʼaʎu**
	'hoarse'	'to twist'	'tomato sauce'

Deep Thought Questions

- Q1: Is it possible to make a voiced ejective?
- No. (They are unattested.)
- Q2: Is it easier to make an ejective at some places of articulation than others?
- Here are the numbers (UPSID data):

Bilabials:	34	[p’]
Alveolar:	50	[t’]
Palatal:	7	[c’]
Velar:	70	[k’]
Uvular:	27	[q’]

Glottalic Ingressives

- It's also possible to make **glottalic ingressive** sounds.
- In fact, you probably already know how.
- Here's how you do it:

1. Make a stop closure above the glottis.
2. Bring together (adduct) the vocal folds.
    - This creates a closed chamber of air above the glottis.
3. Lower the glottis
    - Air rushes through the glottis
    - Voicing occurs

Implosives

- Lowering the larynx also expands the chamber above the glottis
- This reduces air pressure above the glottis.

Step 4: Release stop closure above glottis.

  - Air rushes into the mouth.
  - ...because air pressure was higher outside the mouth than inside the mouth.

- Sounds which are made with a glottalic ingressive airstream mechanism are known as **implosives**.
- Implosives are symbolized with an upper hook on a stop symbol:  [aɓa]  [aɗa]  [aɠa]

Sindhi Implosives

ɓani 'field'		ɗiɲu 'festival'	ƒatu 'illiterate'	gˀanu 'handle'
banu 'forest'	daru 'door'	ɗoːru 'you run'	ƭatu 'illiterate' [variant]	gunu 'quality'
panu 'leaf'	taru 'bottom'	ʈanu 'ton'	caʈu 'to destroy'	kanu 'ear'

- Sindhi is spoken in India.

Familiar (?) Implosives

- Implosives are found in some dialects of American English
  - In the South
  - Some portions of the Midwest/Midlands region
- Consider:
- ‘Bama [ˈɓæmə]
- duh! [ɗʌə]
- Swallowing caricature: [ɠəɠəɠə]
- A former student: 

Implosive Stats

- Implosives occur in about 10% of the world's languages
    - Not quite as common as ejectives
- Q: Should some places of articulation be more conducive to making implosives than others?
- Implosives are more frequently found at fronter places of articulation

Bilabial:	39	Palatal:	7
Alveolar:	36	Velar:	5
Retroflex:	1	Uvular:	1

- The reason why is historical, as well as physical.

Another Thought Question

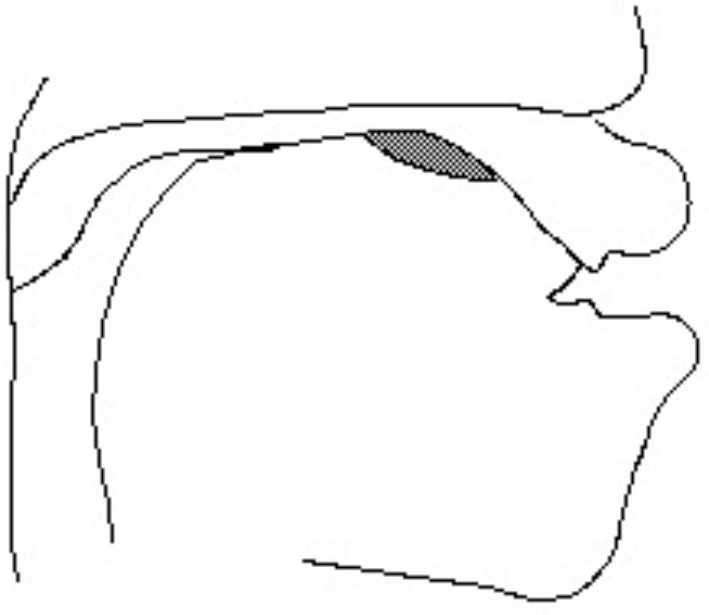
- Is it possible to make a voiceless implosive?
- Yes, but they are exceedingly rare.
    - They are only found in about three languages.
- Vocal folds must remain tightly closed as the larynx is pushed down.
    - Vocal fold closure prevents voicing from occurring.

	Bilabial	Alveolar
Voiced	 íba	 ída
	'to get rich'	'to cut'
Voiceless unaspirated	 ípa	 ńtà
	'to carry'	[name]
Aspirated	 íp^{h}à	 ít^{h}a
	'to squeeze'	'to blame'
Breathy voiced	 íb^{ɦ}a	 íd^{ɦ}a
	'to peel'	'to fall'
Voiceless implosive	 íɓ̥a	 íɗ̥a
	'to gather'	'to chew'
Voiced implosive	 íɓa	
	'to dance'	

- Voiceless implosives are found in Igbo, a language spoken in Nigeria

Velaric Ingressive Sounds

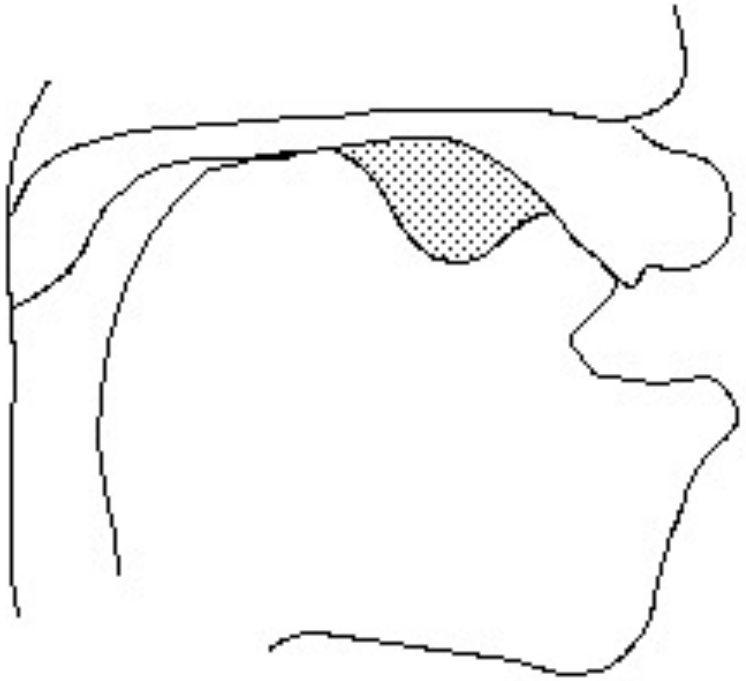
- It's possible to make **velaric ingressive** sounds.
- First make a stop closure at the velum, along with another stop closure in front of the velum.



- This creates a closed chamber of air between the velum and the forward stop closure.

Velaric Ingressives

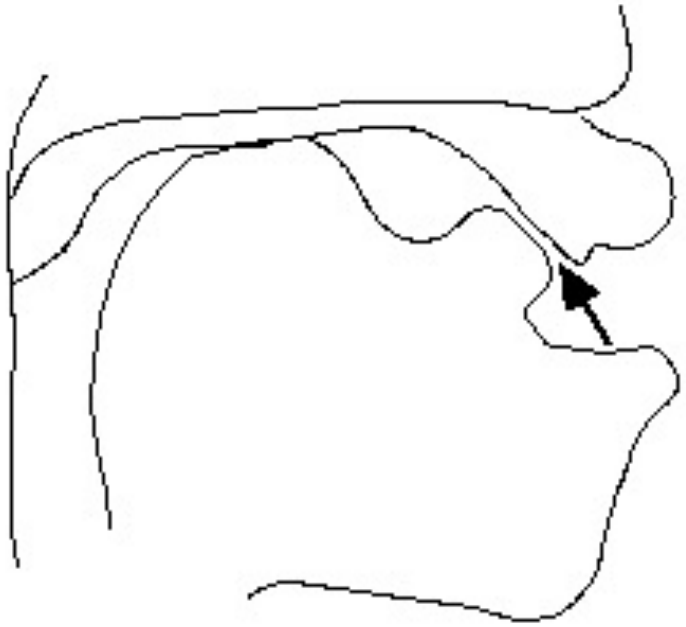
• Step 2: Expand the closed chamber of air by lowering the tongue.



• The air pressure in the closed chamber decreases.

Velaric Ingressives

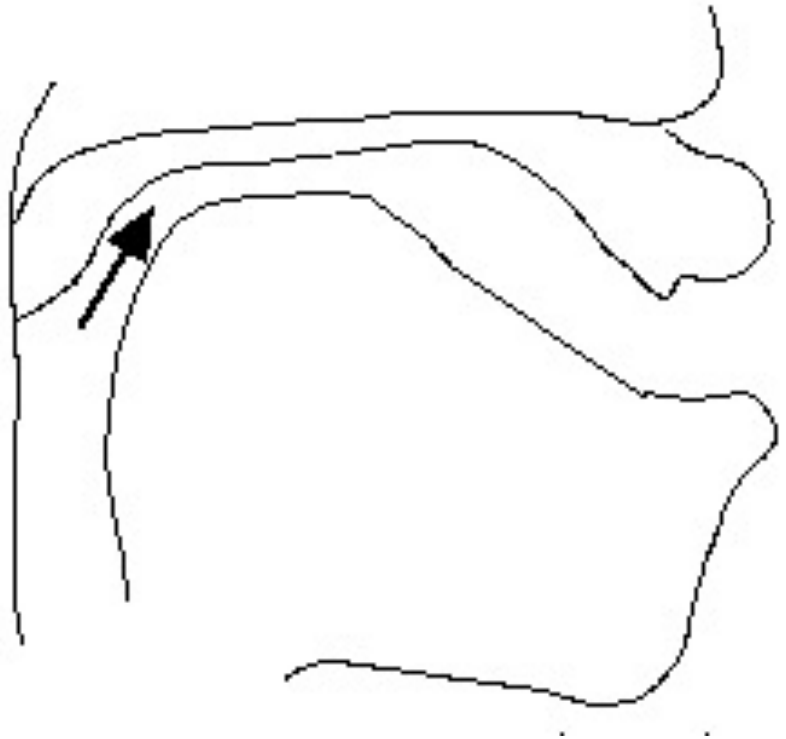
- Step 3: Release the forward stop closure.



- Air rushes into the mouth
    - From high pressure (outside) to low pressure (inside)
- The rush of air creates a loud “clicking” sound

Velaric Ingressives

- Step 4: Release the velar stop closure.



- This may or may not result in a velar stop release burst.

Click Examples

- Clicks can be made at five different places of articulation.

ʘ	Bilabial
ǀ	Dental
ǃ	(Post)alveolar
ǂ	Palatoalveolar
ǁ	Alveolar lateral

- Languages which use clicks as contrastive sounds are exclusively found in southern and central Africa.
    - Particularly in the Khoisan languages

!Xoo Examples

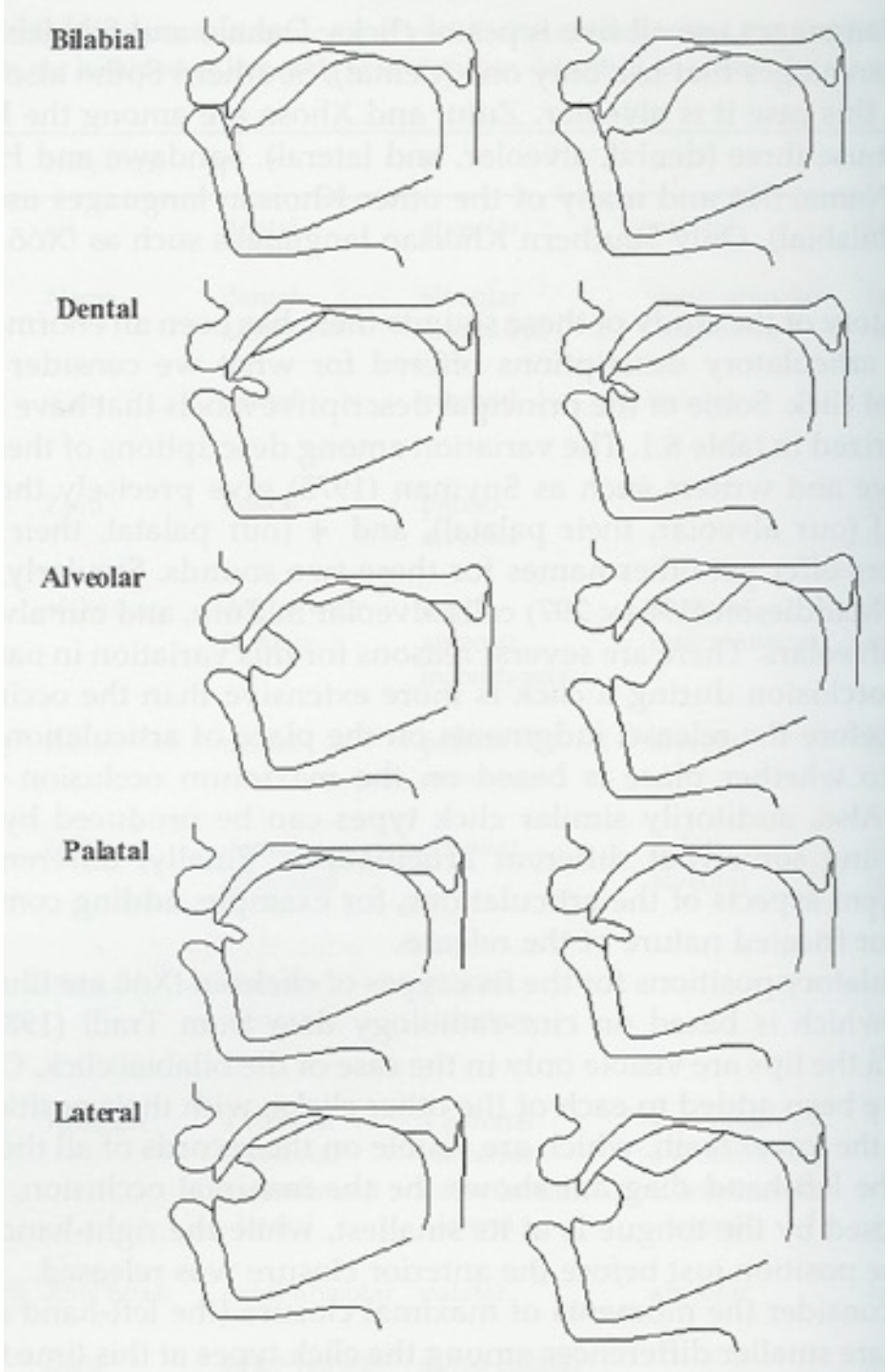
- !Xoo (spoken in Botswana) contrasts clicks at all five places of articulation
- Note that !Xoo is also a tone language.

Bilabial	Dental	Alveolar	Palatal	Lateral
kʘʔôo	k|ʔâa	k!ʔáã	kǂʔāa	k‖ʔàa
'get stuck'	'die'	'be seated'	'shoot you'	'not to be'





- By convention, a [k] appears before all click sounds, to represent the velar closure.



Click Places

Click Cues

- All clicks are very high in acoustic intensity
  - i.e., **loud**
- Alveolar and palatal clicks have a transient (short) release


- Dental and bilabial clicks have an affricated release


- Lateral clicks are somewhere in between

Clicks in connected speech

• If you listen to clicks as they are produced in a long sequence of connected speech, you may experience a phenomenon known as **perceptual streaming**.

Sound file source: http://www.rdg.ac.uk/%7Ellsroach/fue/

Deep Thought Questions

#1: Is it possible to make a voiced click?

- Yes.

#2: Is it possible to make an aspirated click?

- Sort of.

#3: Is it possible to make a nasal click?

- Yes.

#4: Is it possible to make an ejective click?

- Sort of.

Zulu Clicks

	Dental	Alveolopalatal	Alveolar lateral
Voiceless unaspirated velar plosive	k|á:gà 'to whitewash'	k!à:k!á 'to undo'	k‖á:gà 'put into a fix'
Voiceless aspirated velar plosive	k|ʰà:gá 'to identify'	k!ʰà:k!ʰà 'to rip open'	k‖ʰá:gà 'to link horses'
Voiced velar plosive	g|ò:bá 'to grease'	g!ò:bá 'to milk'	g‖ò:bá 'to beat'
Voiced velar nasal	ìsì:ŋ|é (kind of spear)	ìsì:ŋ!é 'rump'	ìsì:ŋ‖é:lè 'left hand'

- Zulu is spoken in South Africa.

Zhu|hoasi Clicks

Alveolar click with		
Voiced velar stop	g!à	‘rain’
Voiceless unaspirated velar stop	k!ábí	‘roll up a blanket’
Aspirated velar stop	k!ʰání	‘palm tree’
Voiced velar nasal	ŋ!àmà	‘road’
Voiceless affricated velar stop	k!ˣárá	‘cough up from throat’
Affricated velar ejective	k!ˣ’àm	‘tighten a bowstring’

- Zhu|hoasi is spoken in Namibia and Botswana.

Airstream Summary

Airflow	Pulmonic	Glottalic	Velaric
OUT (egressive)	fricatives, vowels, stops, etc.	ejectives	*unattested*
IN (ingressive)	*(Tsou)*	implosives	clicks