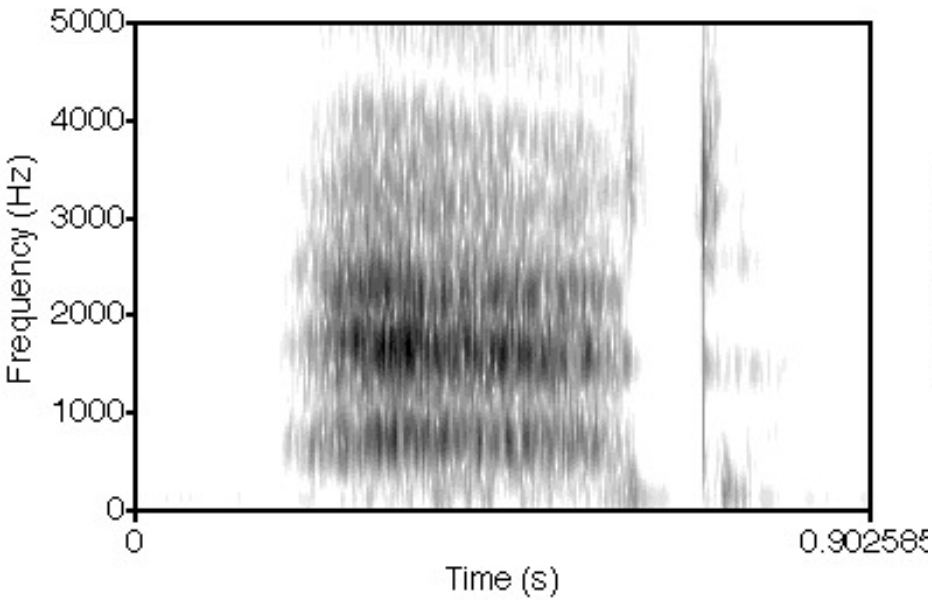


# Fricatives

# Source/Filter (again)

- So far, we've considered the following source/filter configuration:
  - source: voicing at the vocal folds
  - filter: the resonating vocal tract
- Q: What would happen if we changed the source by:
  - Opening the glottis (i.e., not voicing)
  - And increasing airflow so that...
    - there is some audible turbulence as the air passes through the vocal folds?
- A: We'd get something called **whispering** (technical term)

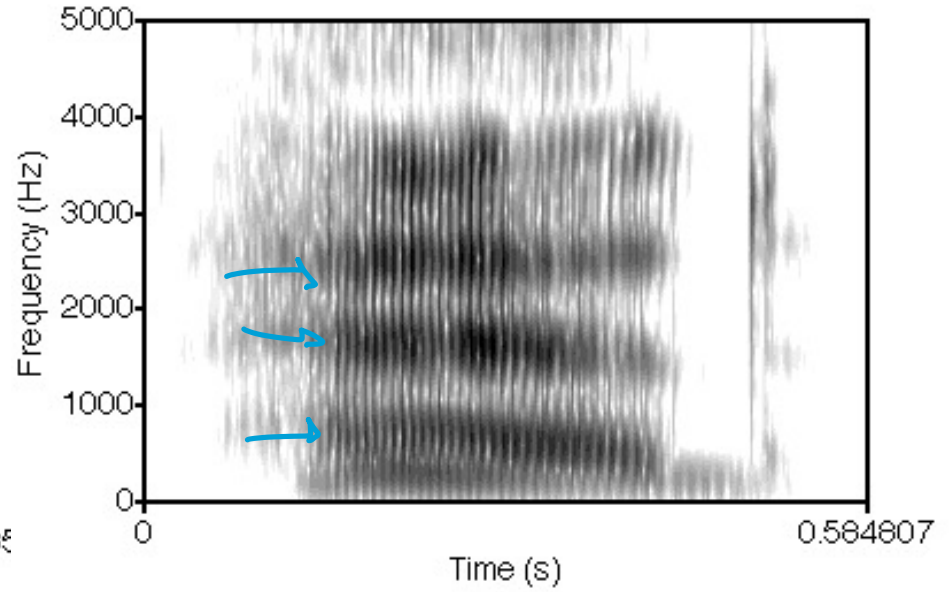
# Whispering Example



whispered



“had”



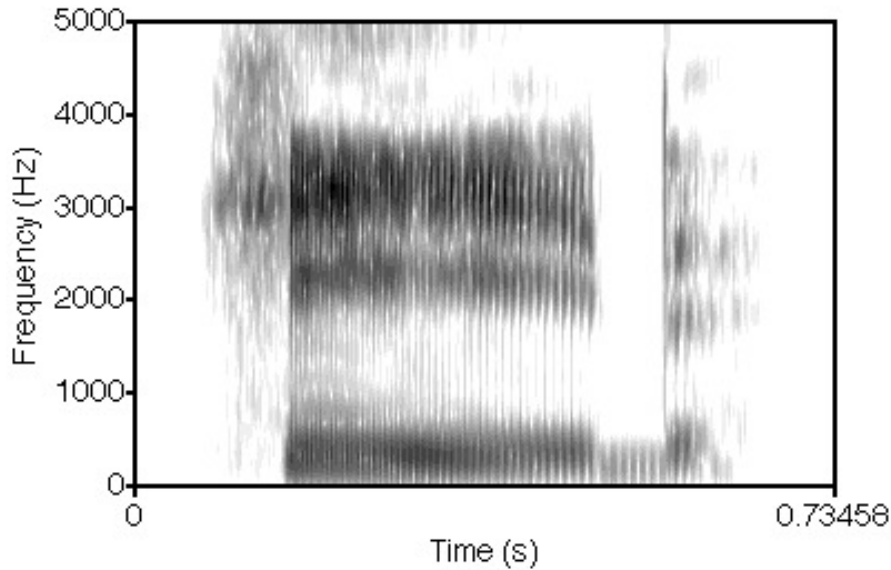
voiced



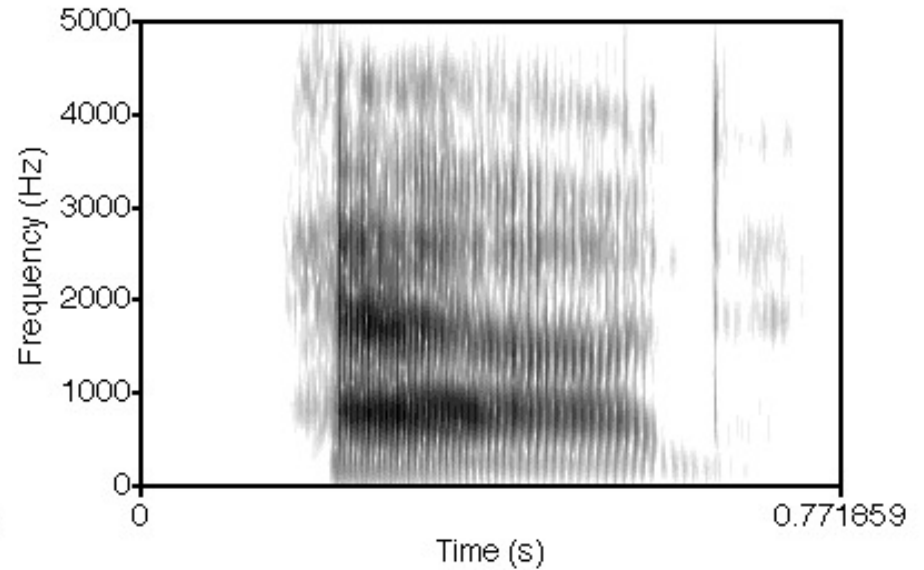
# Glottal Fricatives

- The sound “source” of whispering is the turbulence that airflow creates as it passes through the vocal folds.
  - “Glottal fricatives”
- The IPA lists two sounds as “glottal fricatives”
  - voiceless: [h]
  - voiced: [ɦ]
- The “filter” of both sounds is the same vocal tract shapes that we find in vowels.
  - ⇒ In a sense, [h] is a “voiceless vowel”

# [h] in different vowel contexts



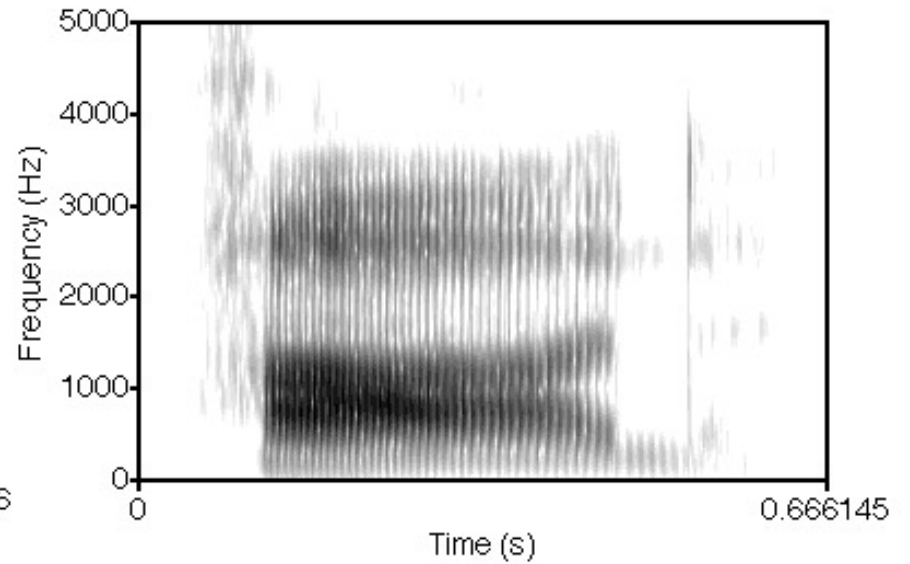
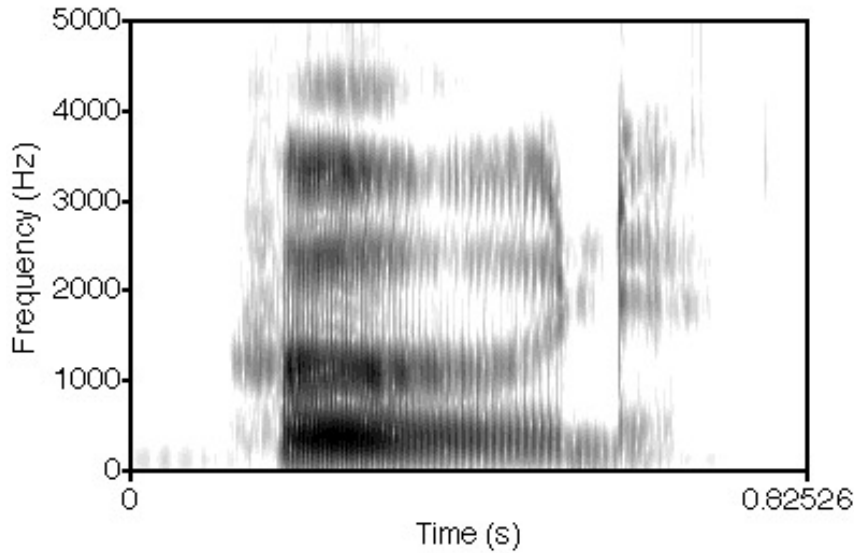
“heed”



“had”

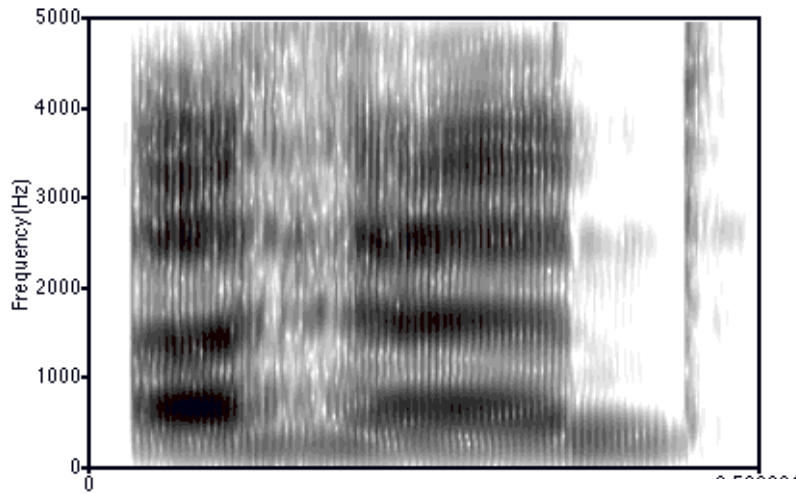


# [h] in different vowel contexts

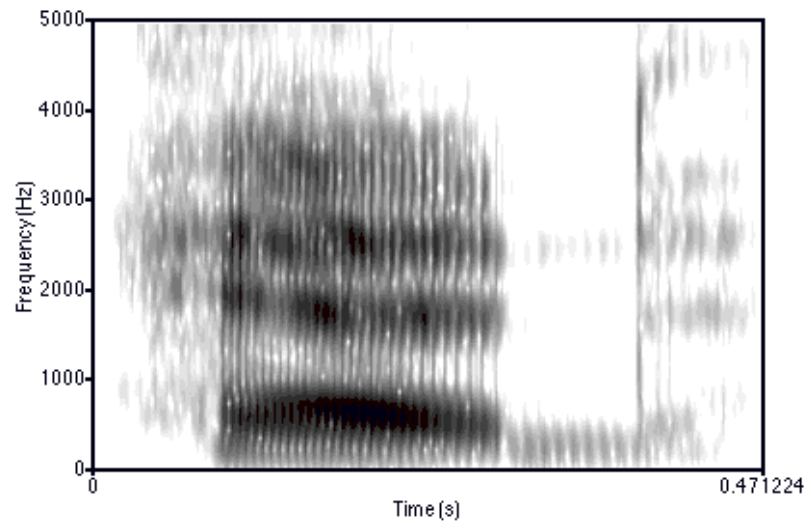


# “Voiced” /h/

- In English, /h/ often surfaces as breathy voiced [h̥] when it appears between two vowels.



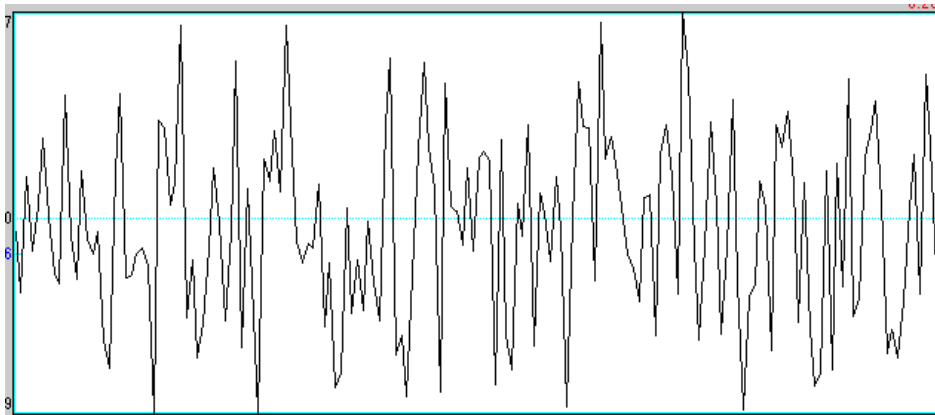
“ahead”



“head”

# Turbulence Acoustics

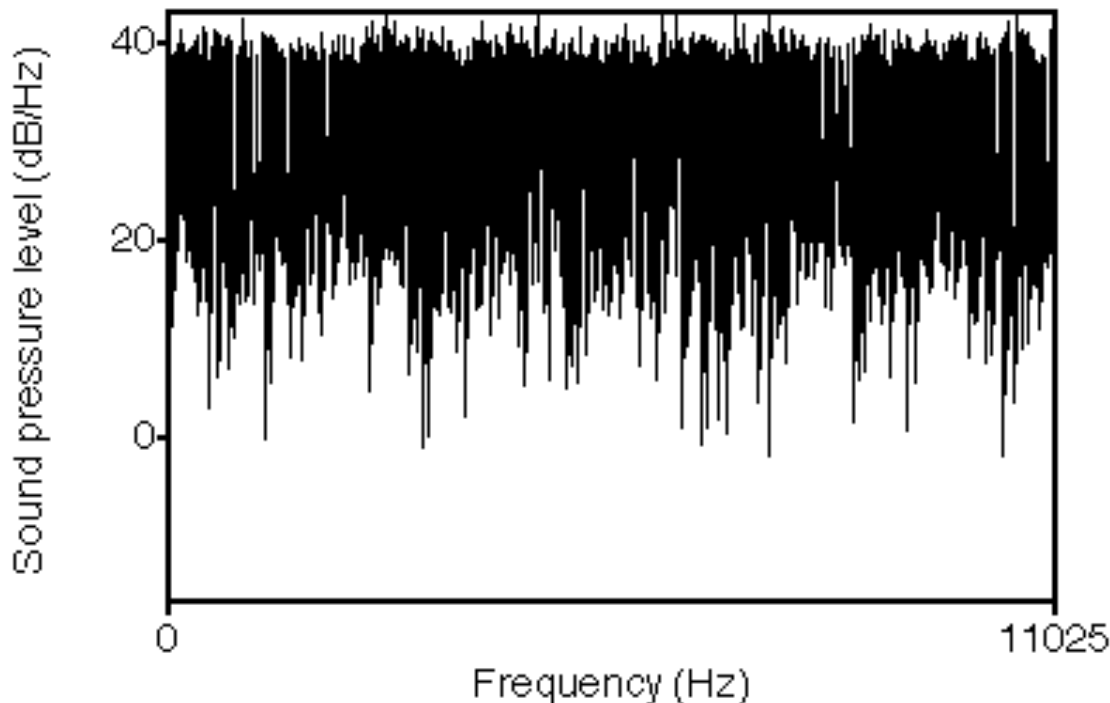
- The “source” of fricative sounds is aerodynamic turbulence
  - aperiodic
  - random
- **Aperiodic** sounds are noisy
  - Their pressure values vary randomly over time
  - waveform snippet of aperiodic “white noise”:



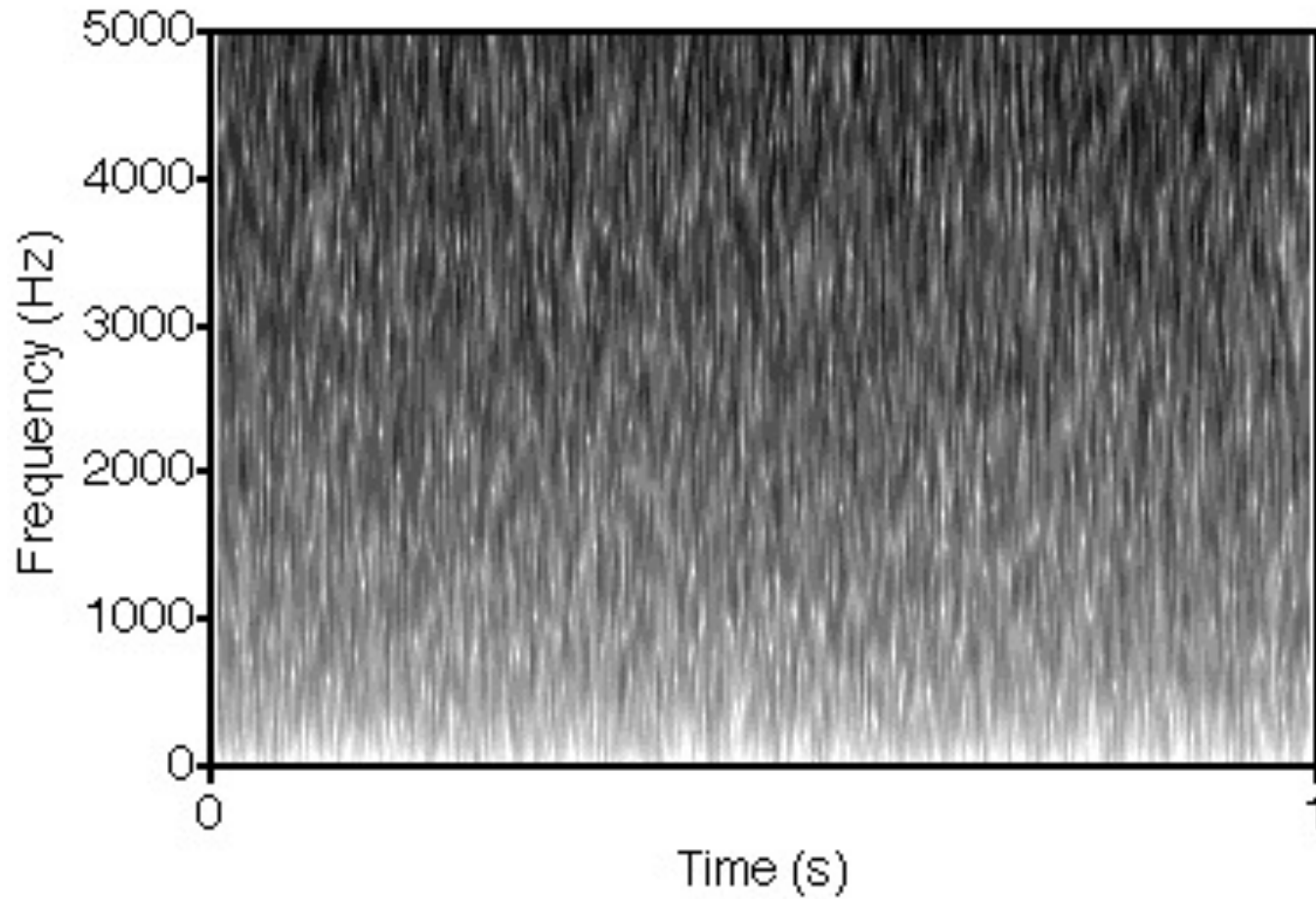


# White Noise Spectrum

- Recall: **white light** is what you get when you combine all visible frequencies of the electromagnetic spectrum
- **White noise** is so called because it has an unlimited range of frequency components



# White Noise Spectrogram



# Fricative Filtering

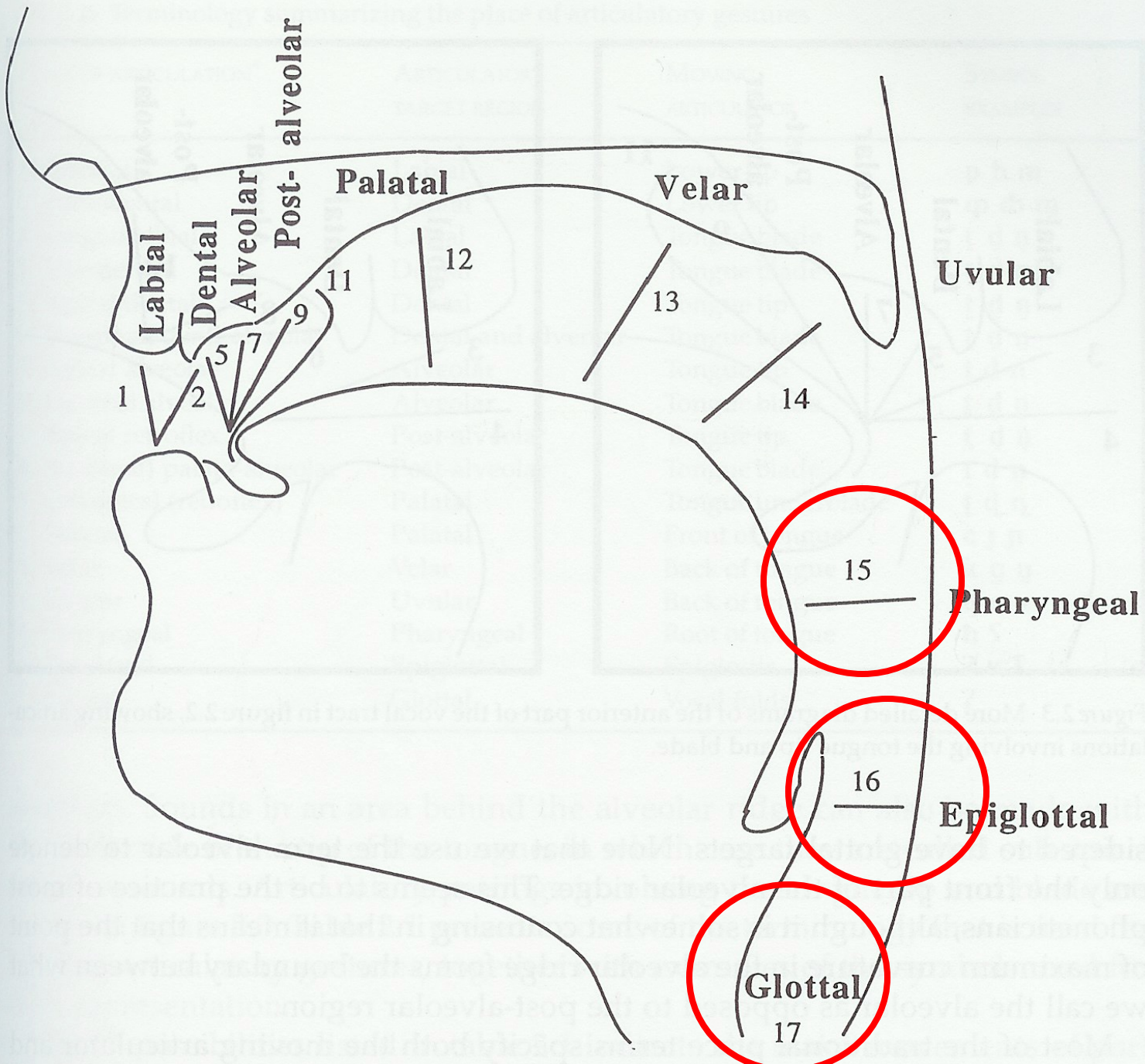
- The sound source of fricatives resembles white noise.
  - ...but this aperiodic noise may be filtered by the vocal tract in the same way that voiced vowels are.
- Ex: [h] tends to take on the spectral characteristics of its surrounding vowels
  - $\Rightarrow$  [h] just replaces the voicing source with an aperiodic sound source.
  - = coarticulation

# Fricative Place of Articulation

- A fricative's place of articulation is where, in the vocal tract, its turbulence noise is made.
- Fricatives may be produced at essentially any place of articulation.

	Bilabial	Labiodental	Dental	Alveolar	Postalveolar	Retroflex	Palatal	Velar	Uvular	Pharyngeal	Glottal
Fricative	ɸ β	f v	θ ð	s z	ʃ ʒ	ʂ ʐ	ç ʝ	x ɣ	χ ʁ	ħ ʕ	h ɦ

- At different places of articulation, fricatives will have:
  - Different filters
    - based on the area and shape of the vocal tract in front of the obstruction of the airflow
  - Different sound sources
    - based on the flow of air through the obstruction



# Glottals, Epiglottals, and Pharyngeals

- Glottal fricatives: [h] [ħ]



- Epiglottal fricatives: [ʕ] [ʕ̰]



- Pharyngeal fricatives: [ħ] [ʕ̰]



- Note: try not to confuse the symbols for the:

- voiced epiglottal fricative [ʕ]

- voiceless epiglottal stop [ʕ̰]











- And also note the symbols for the:

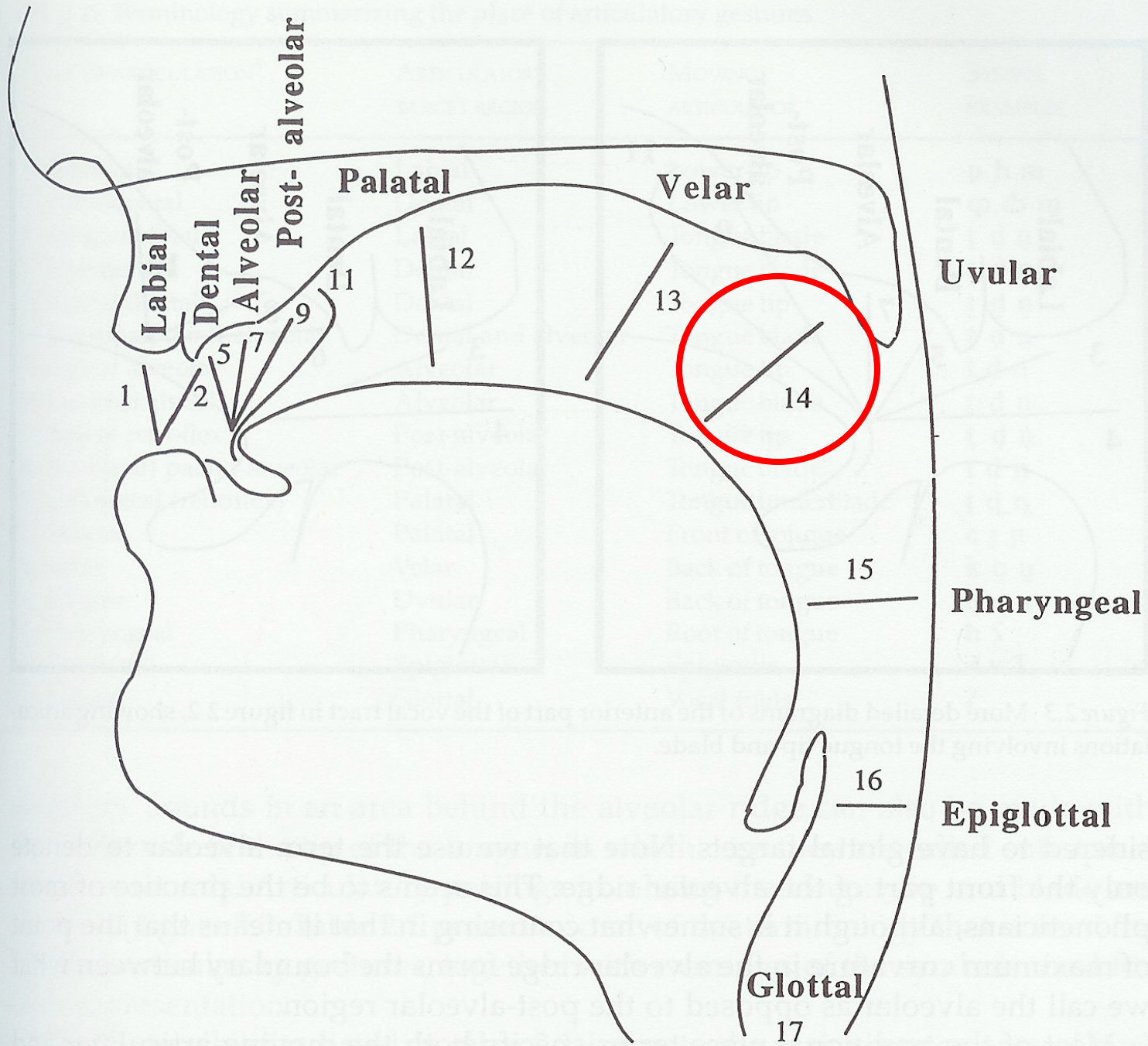
- voiced pharyngeal fricative [ħ]

- glottal stop [ʔ]

# Agul

- Glottals, epiglottals and pharyngeals contrast in the Caucasian language Agul.

Agul (Burkixan Dialect)			
<b>Voiced pharyngeal fricative</b>		muʕ <sup>ə</sup> 'bridge'	 muʕar 'bridges'
<b>Voiceless pharyngeal fricative</b>		muħ 'barn'	 muħar 'barns'
<b>Voiceless epiglottal fricative</b>		mɛH 'whey'	 mɛHɛr 'wheys'
<b>Voiceless epiglottal stop</b>		jaʔ 'center'	 jaʔar 'centers'
		sɛʔ 'measure'	 sɛʔɛr 'measures'





# Uvular Fricative Symbols





UVULAR	PHARYNGEAL	GLOTTAL
χ ʁ	ħ ʕ	h ɦ

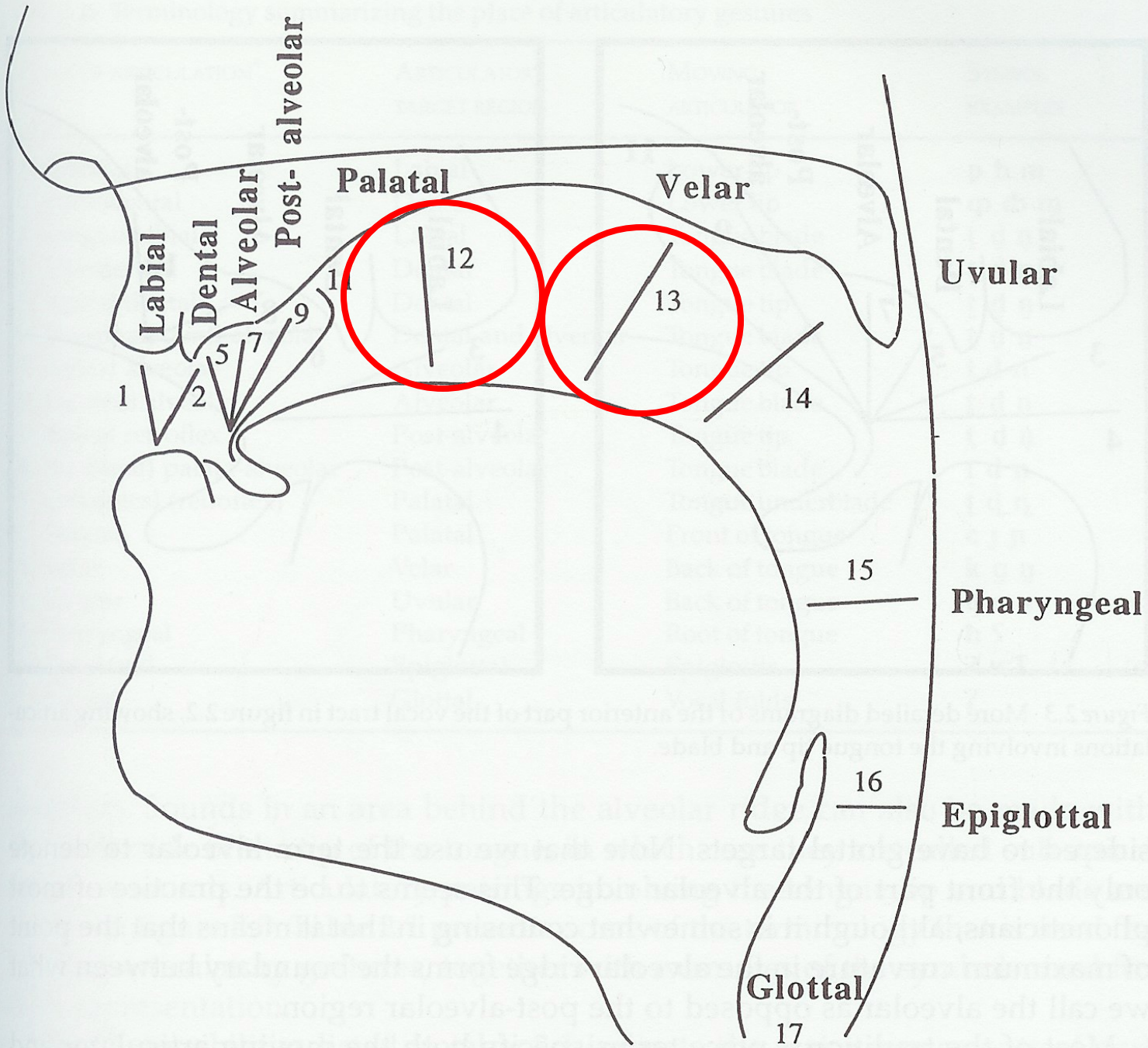
- Peter says:



- Uvular fricatives contrast with pharyngeals and glottals in one dialect of Hebrew.

# Hebrew (Oriental dialect)

	Uvular	Pharyngeal	Glottal
<b>Initial</b>	 $\chi$ imia 'chemistry'	 ḥor 'hole'  ʕor 'skin'	 hem 'them'  ʔor 'light'
	<b>Medial</b>	 ma $\chi$ ar 'he sold'	 naḥar 'snored'  naʕar 'made a donkey noise'
<b>Final</b>		 la $\chi$ 'for you' [fem.]	 laḥ 'humid'  naʕ 'moved'



# Palatal and Velar Symbols

PALATAL	VELAR	UVULAR	PHARYNGEAL	GLOTTAL
ç j	x ɣ	χ ʁ	ħ ʕ	h ɦ



<-- Peter says

- Possible confusion #1:
  - voiceless palatal fricative [ç]
  - voiceless palatal stop [c]
- Possible confusion #2:
  - voiced palatal fricative [j]
  - voiced palatal stop [t]
- Possible confusion #3: [ɣ] [ʁ]

# Greek

Dental



θiki

'box'



ðiki

'trial'

Palatal



çeri

'hand'



jeri

'old men'

Velar



xɔma

'soil'



ɣɔma

'eraser'

# Coronal Fricatives







DENTAL	ALVEOLAR	POST-ALVEOLAR	RETROFLEX
θ ð	s z	ʃ ʒ	ʂ ʐ

Peter says:



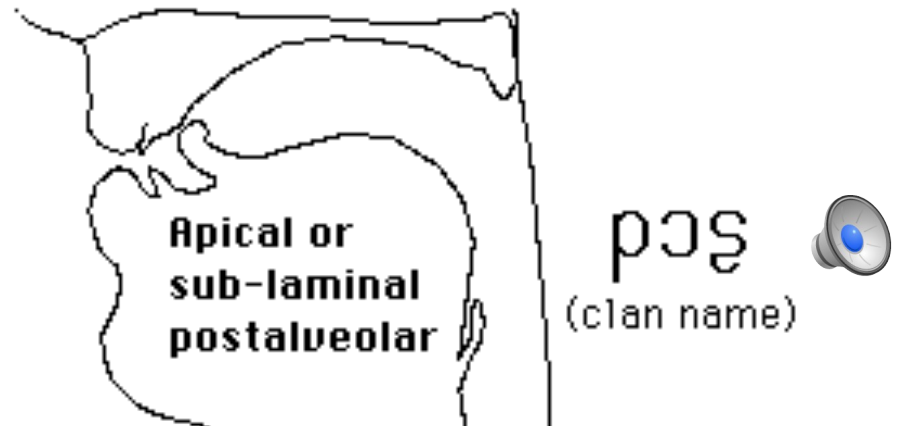
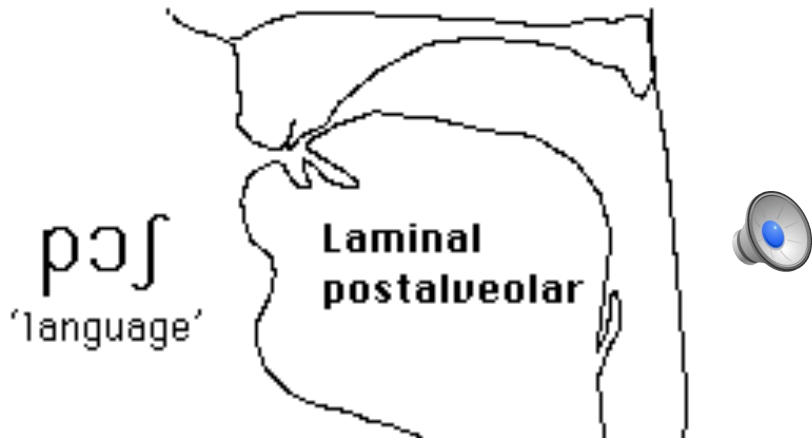
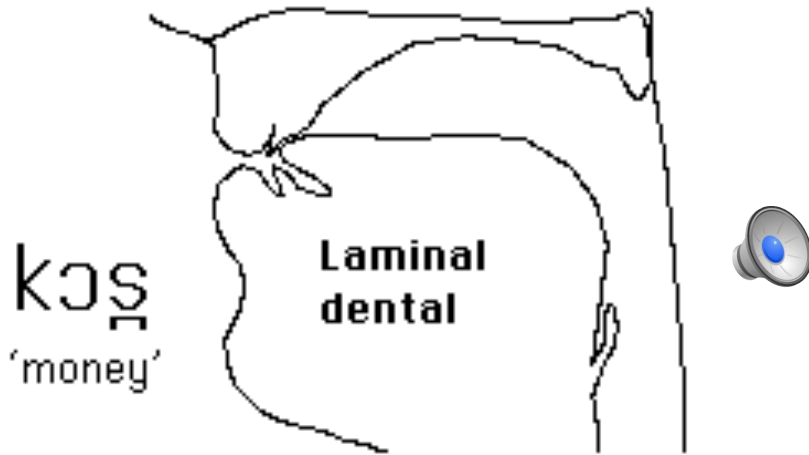
- The coronal fricative landscape is very complex.
- Next time we'll look in detail at how coronal fricatives are produced in:
  - English
  - Chinese
  - Polish

# Toda

<b>Labiodental</b>		pɔf	'swelling'
<b>Dental</b>		pɔθ	'roof beam'
<b>Dental sibilant</b>		kɔʂ	'money'
<b>Postalveolar sibilant</b>		pɔʃ	'language'
<b>Retroflex sibilant</b>		pɔʂ	(clan name)
<b>Velar</b>		pɔx	'blood'





Toda is spoken in southern India.

# Toda Mid-Sagittal Diagrams





# Bilabial Fricatives

BILABIAL	LABIO-DENTAL
$\phi$ $\beta$	$f$ $v$
 	 

- Bilabial fricatives exist allophonically in some languages (e.g., Spanish)
- They were not recognized as a potentially contrastive sound until relatively recently ('70s or '80s)
  - it was discovered that they contrasted with labio-dental fricatives in Ewe, a language spoken in Ghana.

# Ewe



éḻá

'he polished'



éḻle

'he bought'



éḻá

'he was cold'



éḻlě

'he split off'



èḻè

'Ewe' (the language)



èḻló

'mushroom'



èḻè

'two'

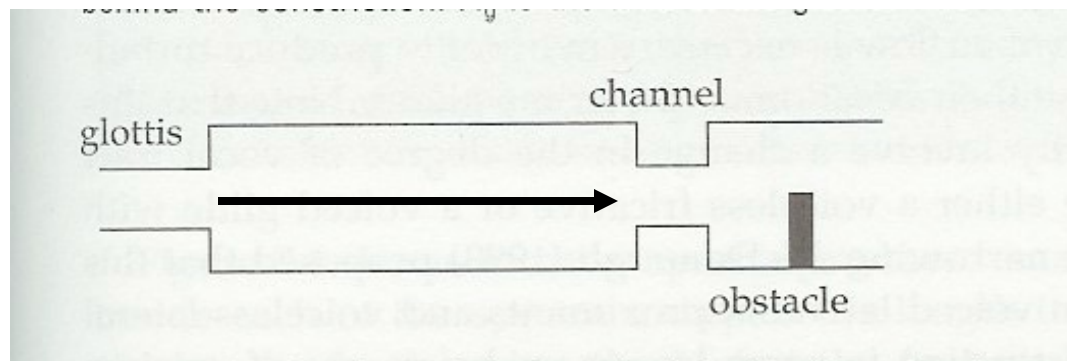


éḻló




'he is evil'

# Turbulence Sources

- For fricatives, turbulence is generated by forcing a stream of air at high velocity through either a narrow **channel** in the vocal tract or against an **obstacle** in the vocal tract.
- Channel turbulence
  - produced when airflow escapes from a narrow channel and hits inert outside air
- Obstacle turbulence
  - produced when airflow hits an obstacle in its path



# Obstacles, Channels, Walls

- General rule of thumb: obstacle turbulence is much noisier than channel turbulence
  - [f] vs. [ϕ]  
- Also: obstacle turbulence is louder, the more perpendicular the obstacle is to the airflow
  - [s] vs. [x]
  - [x] is a “wall fricative” 
- Rule of thumb: voiced fricatives are hard to make.
- In fact, fricatives are kind of hard to make in general.

# Fricatives = difficult

- Fricatives require great articulatory precision.
  - it's necessary to create a narrow channel through which air can flow.
    - (and hold it)
    - ballistic vs. controlled articulations
- Some data for [s]: (Subtelny et al., 1972)
  - alveolar constriction  $\approx$  1 mm
  - incisor constriction  $\approx$  2-3 mm
- Larger constriction sizes result in [ʃ]-like sounds
- Also: **voiced** fricatives are even more difficult
- Why?