



SOUNDS AND LANGUAGE

Phonology,
phonetics, &
spectrograms

OVERVIEW

- About this class
 - 1. **Phonology:** vowels and consonants
 - 2. How sound works
 - 3. **Spectrograms!** A tool for looking at sounds
 - 4. **Phonetics:** vowels and consonants

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- Note:

- **Phonics**: A method for teaching people how to read
- **Phonology**: The systematic categorization of sounds.
- **Phonetics**: The study of how we make and hear sounds.

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- Note:

- ~~Phonics: A method for teaching people how to read~~
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- Phonetics: The study of how we make and hear sounds.

PHONOLOGY!

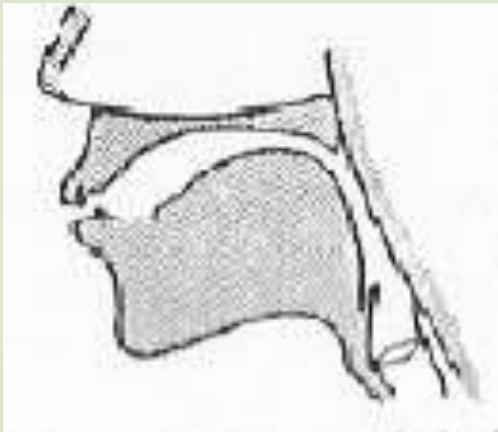
PHONOLOGY

- A phoneme is a sound used by languages in their words.
 - Hawaiian: 10 vowels, 8 consonants
 - (a, e, i, o, u, ā, ē, ī, ō, ū)
 - (h, k, l, m, n, p, w, `)
 - English: 14 vowels, 24 consonants
- The International Phonetic Alphabet (IPA) is what we use to write down phonemes.
- Let's look in more detail at:
 - 1: Vowels
 - 2: Consonants

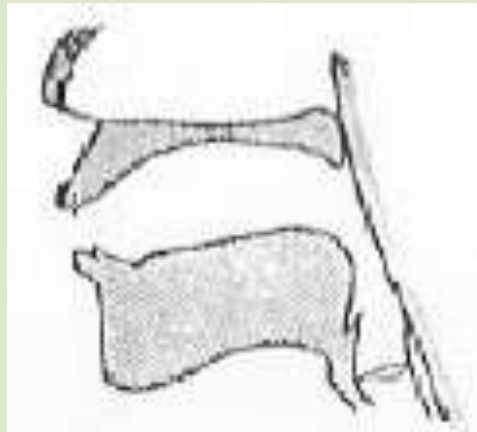
PHONOLOGY: VOWELS

■ Vowels

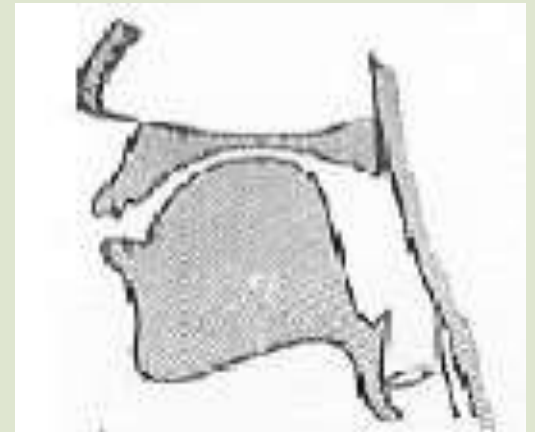
- Vowel sounds produced in *voice box* or *larynx* (try it!)
- Different sounds made by different tongue positions (try it!)



/u/
back
closed



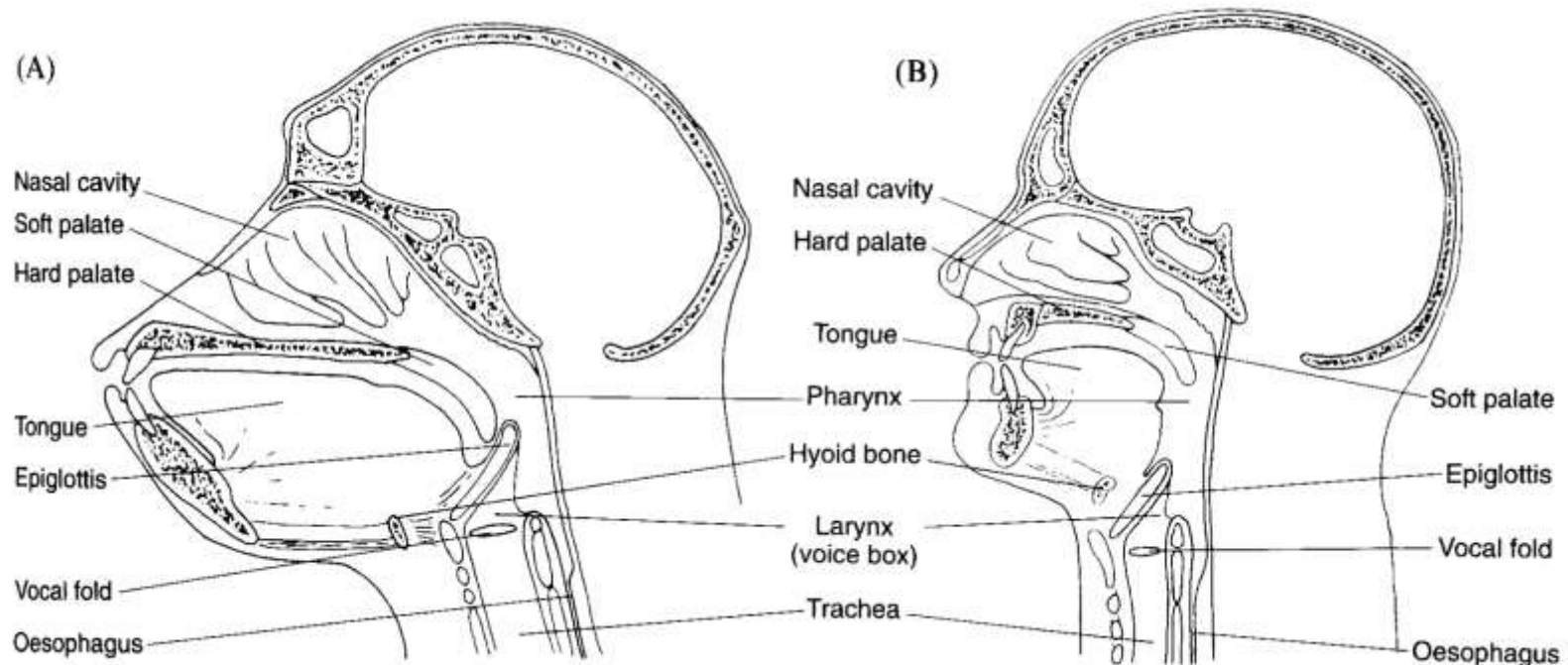
/ɑ/
back
open



/i/
front
closed

PHONOLOGY: VOWELS

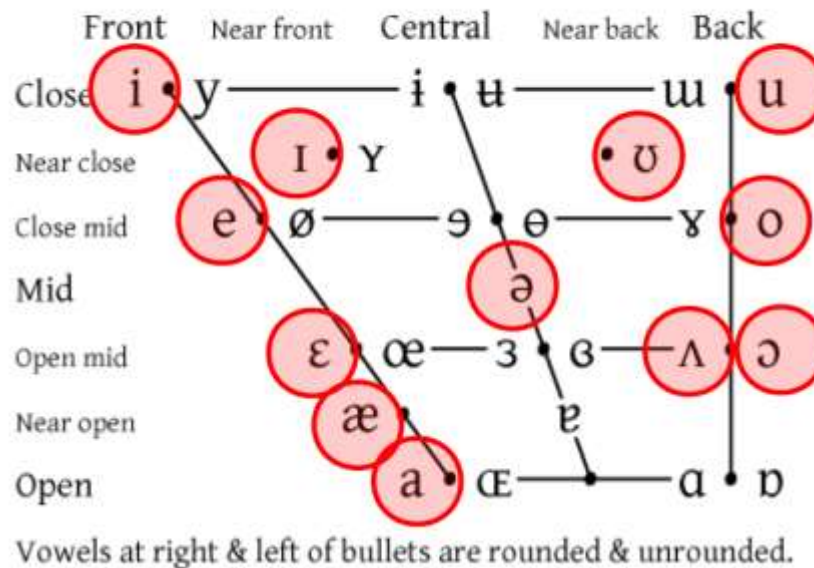
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- Different sounds made by different tongue positions (try it!)
- **Human mouth: specialized for speech?**



PHONOLOGY: VOWELS

- **Vowels**
- Vowel sounds produced in *voice box* or *larynx* (try it!)
- Different sounds made by different tongue positions (try it!)
- Human mouth: specialized for speech?
- **Axes:** front-to-back, open-to-closed, unrounded-to-rounded

VOWELS (of English)



WIKIPEDIA
The Free Encyclopedia

PHONOLOGY: VOWELS

- **Vowels**
- Vowel sounds produced in *voice box* or *larynx* (try it!)
- Different sounds made by different tongue positions (try it!)
- Human mouth: specialized for speech?
- Axes: front-to-back, open-to-closed, unrounded-to-rounded
- **Diphthongs**: when you have two or more vowels combined together into a sound.
 - “oy”
 - “ow”
 - “ey”
 - “ai”

PHONOLOGY: CONSONANTS

- **Consonants**
- **What's the difference between /s/ and /z/?**

PHONOLOGY: CONSONANTS

- **Consonants**
- What's the difference between /s/ and /z/? *Voicing*.
 - /s/ is voiceless. /z/ is voiced. *Try it!*
 - Consider the words: *author, father*. Which /th/ is voiced?

PHONOLOGY: CONSONANTS

■ Consonants

- What's the difference between /s/ and /z/? *Voicing*.
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 - /th/ as in *author* is voiceless. IPA uses /θ/. Old English uses /þ/.
 - /th/ as in *father* is voiced. IPA uses /ð/, and so does Old English.

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Beowulf in Old English

*Hwæt! Wé Gárdena in géardagum
þéodcýninga þrym gefrúnon.
hú ðá æþelingas ellen fremedon.
Oft Scyld Scéþing sceapena þréatum
monegum maégþum meodosetla oftéah
egsode Eorle yððan aérest wearð
féasceaft funden hé þæs frófre gebád
wéox under wolcnum · weorðmyndum þáh
oð þæt him aéghwylc þára ymbsittendra
ofer hronráde hýran scolde,
gomban gylðan · þæt wæs góð cýning!*

PHONOLOGY: CONSONANTS

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 - *Place of articulation*. /s/ is alveolar. /θ/ is dental.
- What's the difference between /s/ and /t/?

PHONOLOGY: CONSONANTS

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 - *Frication*. /s/ is a fricative. /t/ is a stop.
- What in the world does “voiced alveolar fricative” mean?

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- What in the world does “voiced alveolar fricative” mean?
 - /z/.
- **Let's fill out the rest of the chart!**

PHONOLOGY: CONSONANTS

- Consonants
- Some of the consonants of English

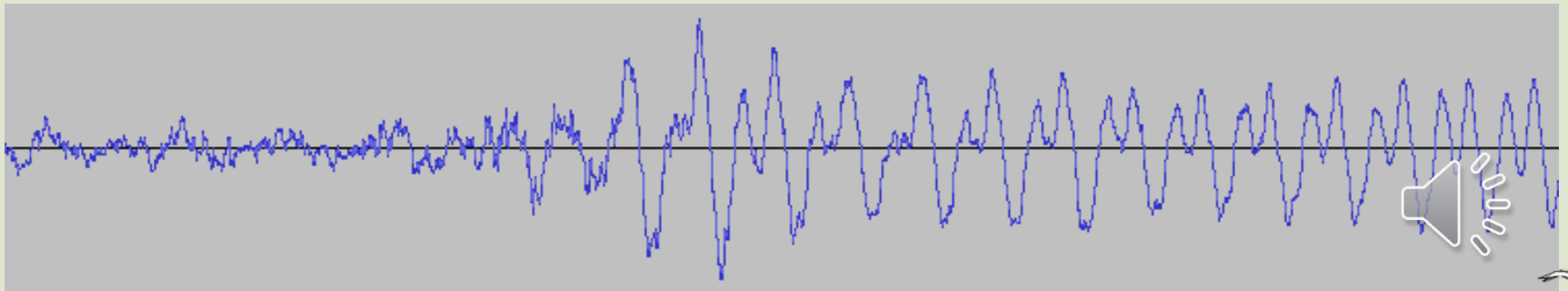
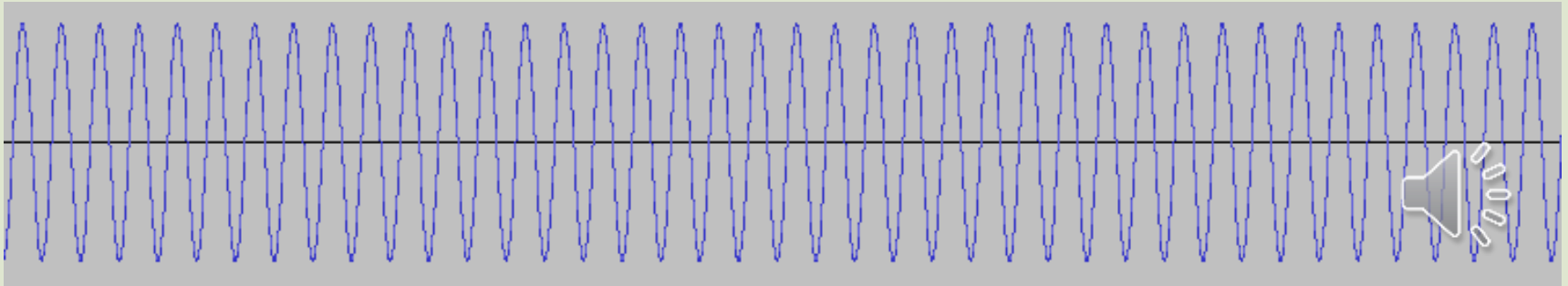
CONSONANTS (PULMONIC)

	Bilabial	Labio-dental	Dental	Alveolar	Post-alveolar	Retroflex	Palatal	Velar	Uvular	Pharyngeal	Epi-glottal	Glottal
Nasal	m	ɱ	n			ɳ	ɲ	ŋ	ɴ			
Plosive	p b	ɸ β	t d			ʈ ɖ	c ɟ	k ɡ	q ɢ	ʔ		ʔ
Fricative	ɸ β	f v	θ ð	s z	ʃ ʒ	ʂ ʐ	ç ʝ	x ɣ	χ ʁ	ħ ʕ	ħ ʕ	h ɦ
Approximant		ʋ	ɹ			ɻ	j	ɰ				ɦ
Trill	ʙ			r					ʀ		ʀ	
Tap, Flap		ⱱ		ɾ		ɽ						
Lateral fricative				ɬ ɮ		ɭ	ɥ	ɮ				
Lateral approximant				l		ɭ	ʎ	ʟ				
Lateral flap				ɭ		ɮ						

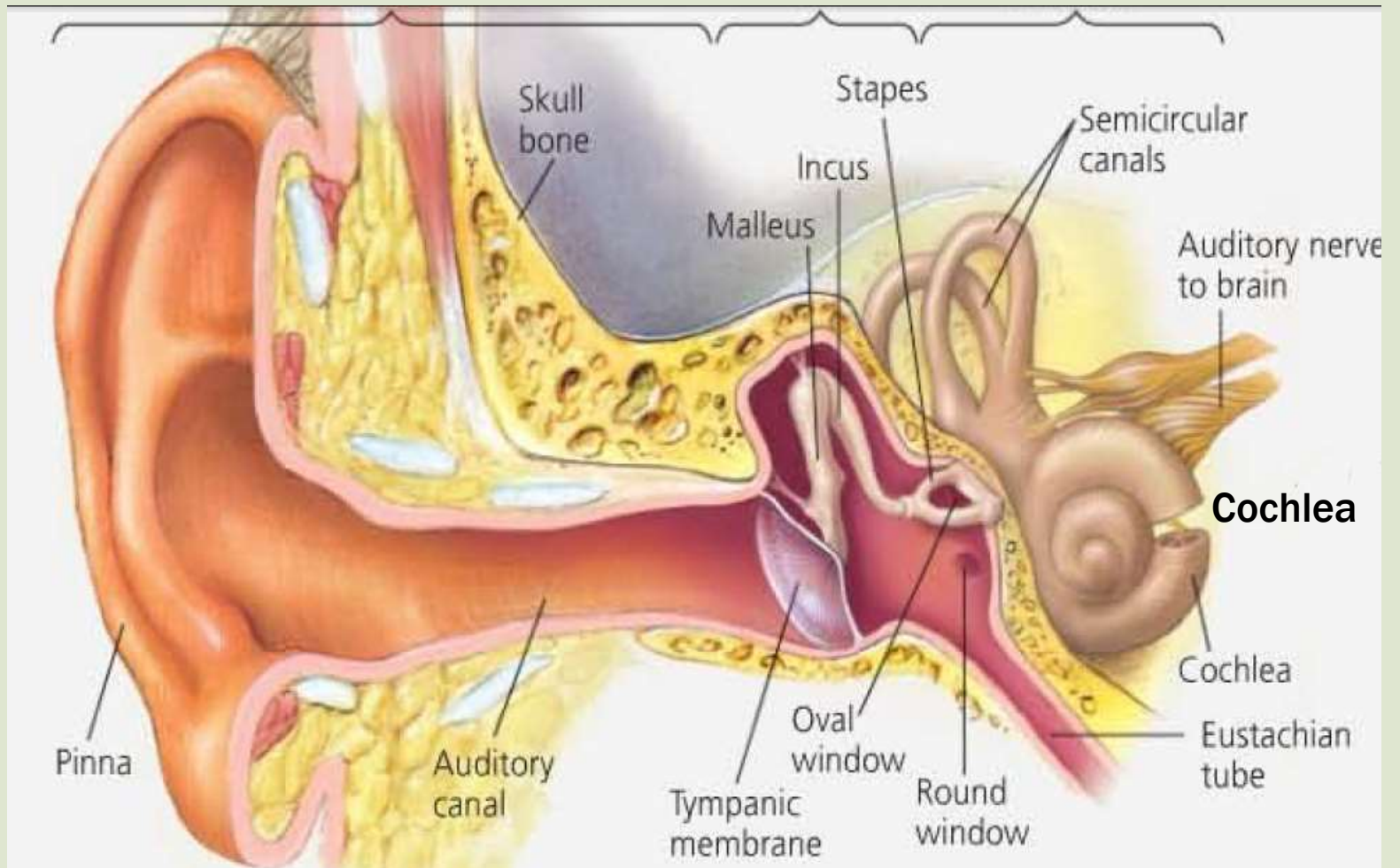
Where symbols appear in pairs, the one to the right represents a modally voiced consonant, except for murmured ɦ. Shaded areas denote articulations judged to be impossible. Light grey letters are unofficial extensions of the IPA.

SOUND!

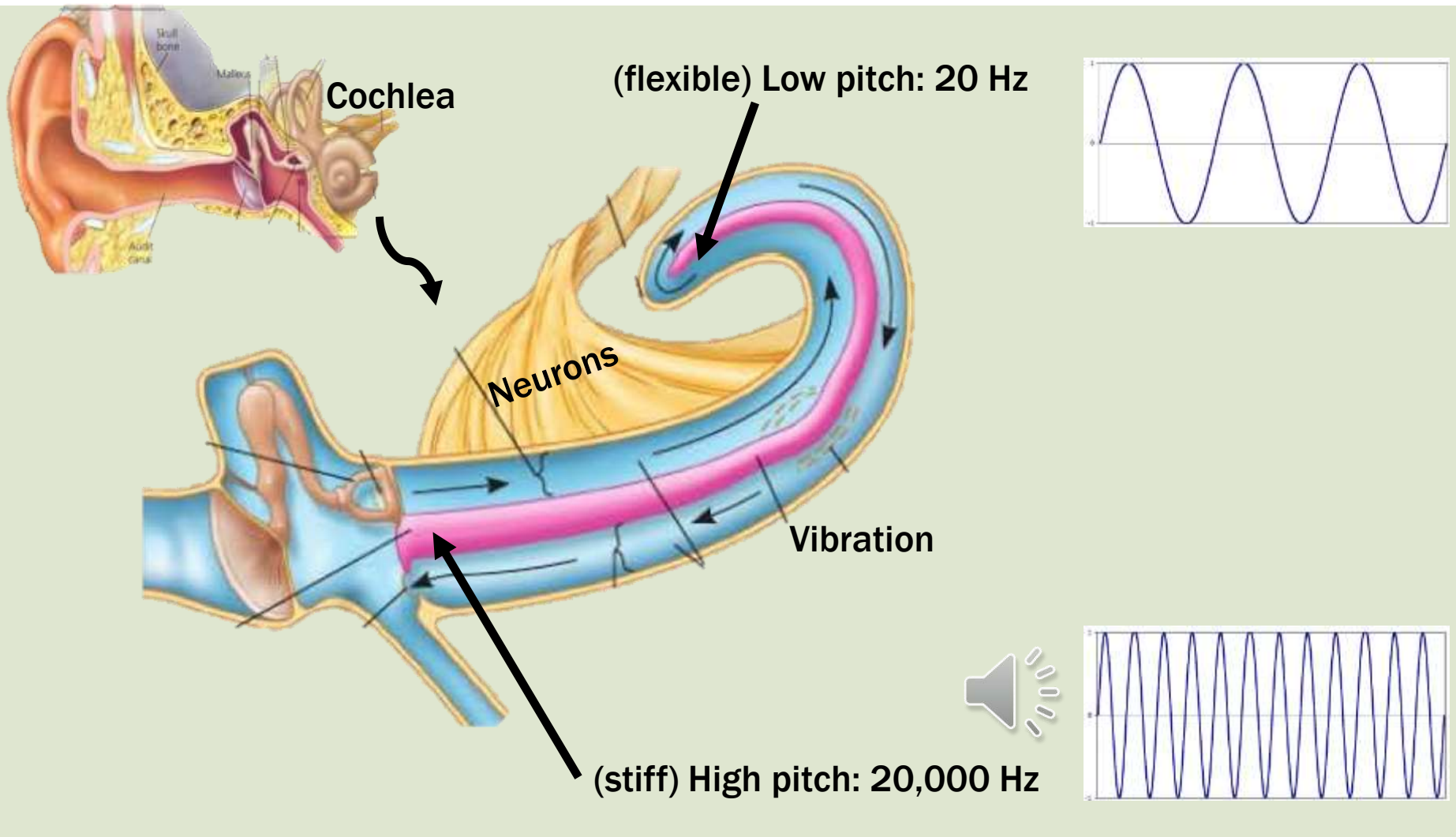
HOW SOUND WORKS



“YOUR EARS CAN DO MATH”



“YOUR EARS CAN DO MATH”



YOUR EARS CAN DO MATH

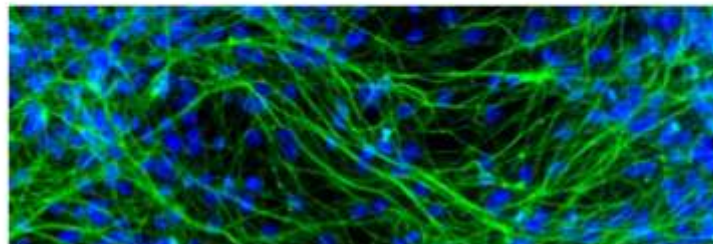
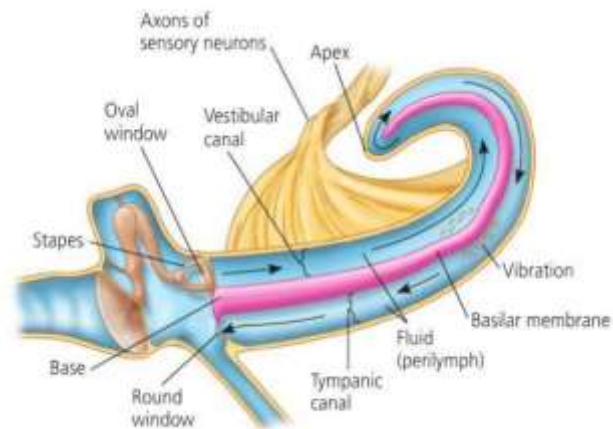
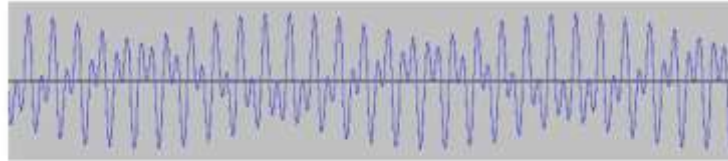
sounds



calculating device



frequencies
(neurons)



YOUR EARS CAN DO MATH

Fourier transform!

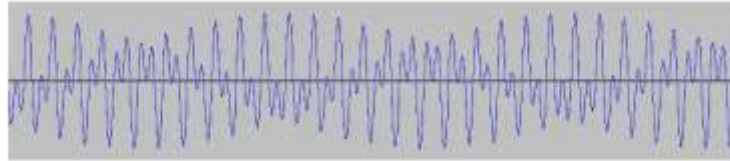
sounds



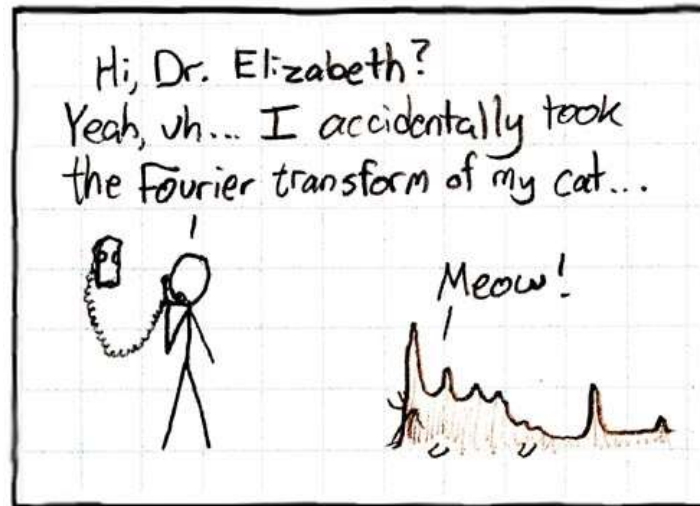
calculating device



frequencies
(graph)



$$\mathcal{F}(\xi) = \int_{-\infty}^{\infty} f(x) e^{-2\pi i x \xi} dx$$

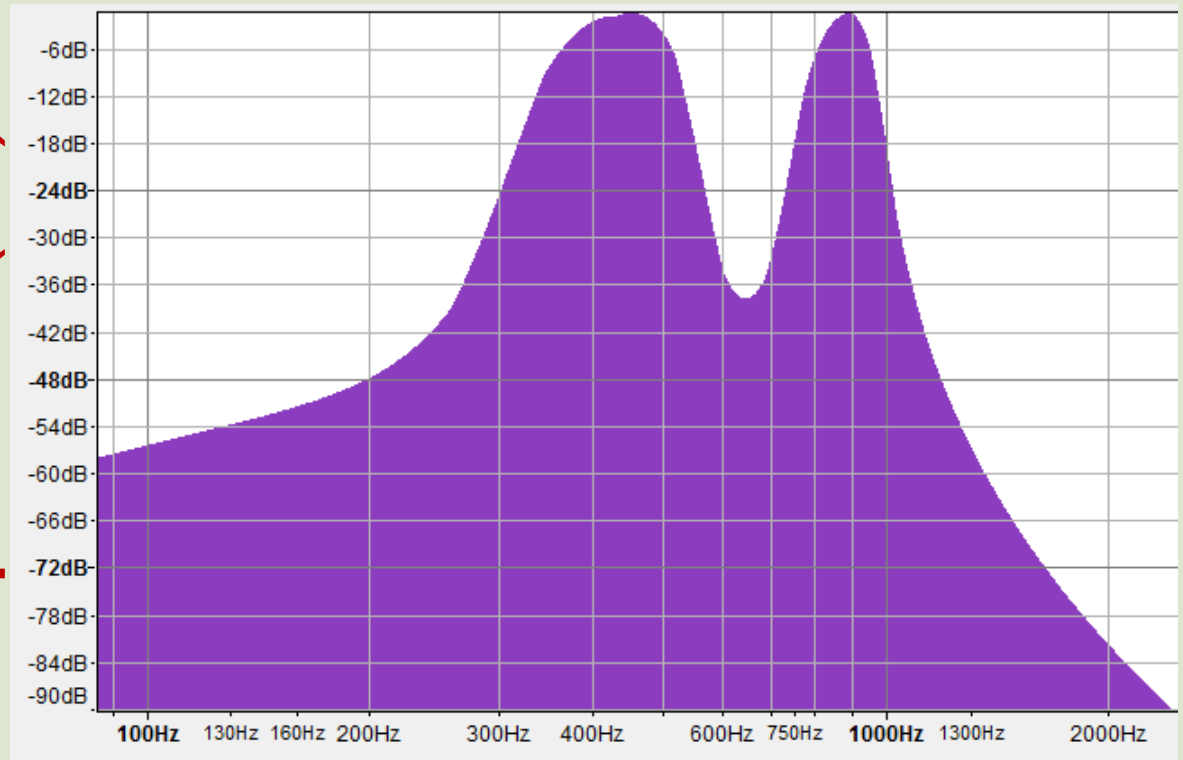


YOUR EARS CAN DO MATH

Fourier transform!

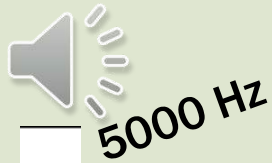


Amplitudes (dB)

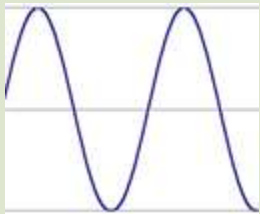


Frequencies (Hz)

SOUND: NOT SO SIMPLE



5000 Hz



frequency

440 Hz

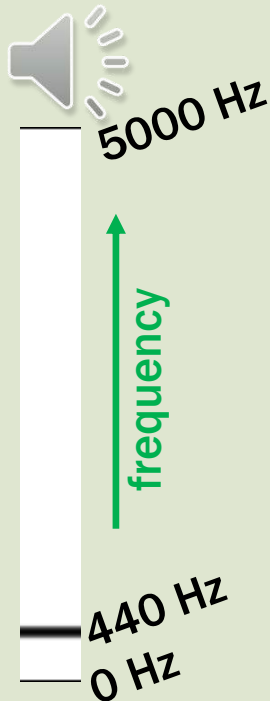
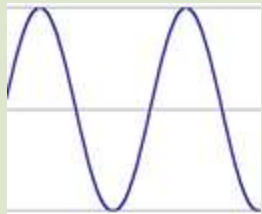
0 Hz

SOUND: NOT SO SIMPLE



(Fourier transform!)

Overtones determine timbre,
which is like texture for sound.

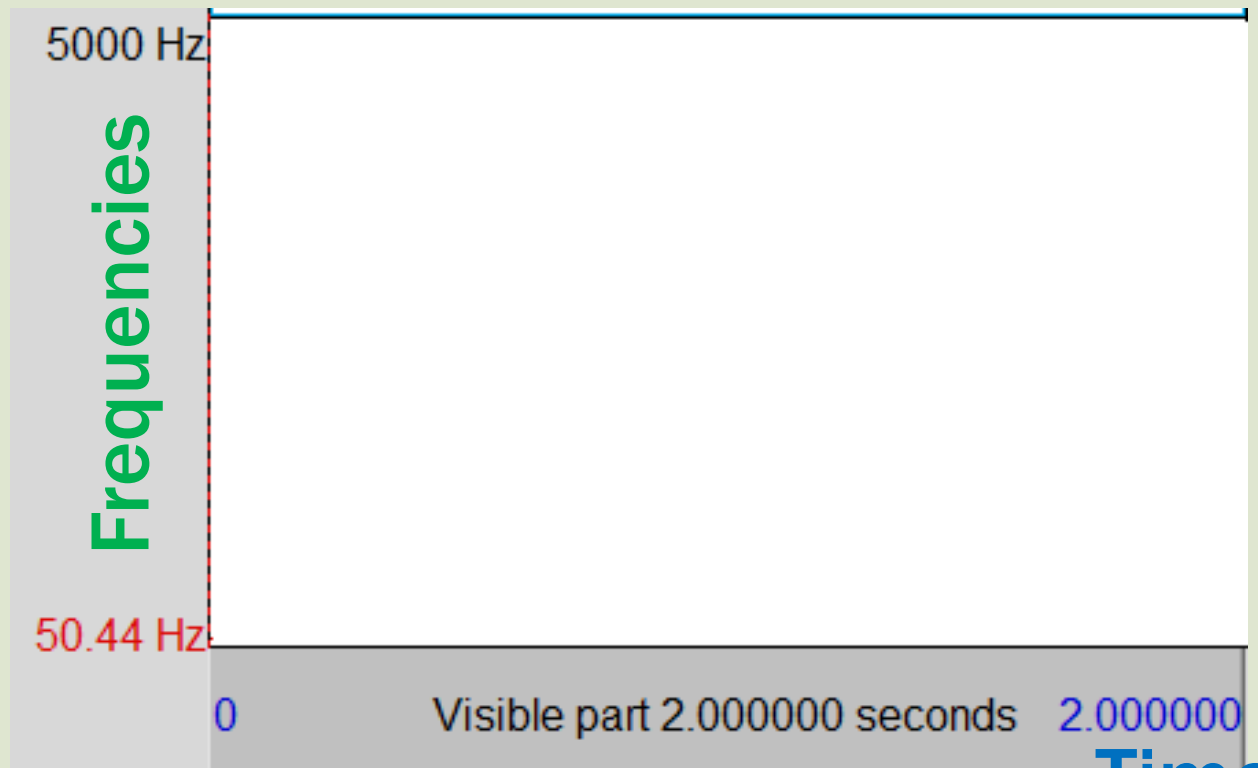


SOUNDS CHANGE OVER TIME



Fourier transform!

Spectrogram!



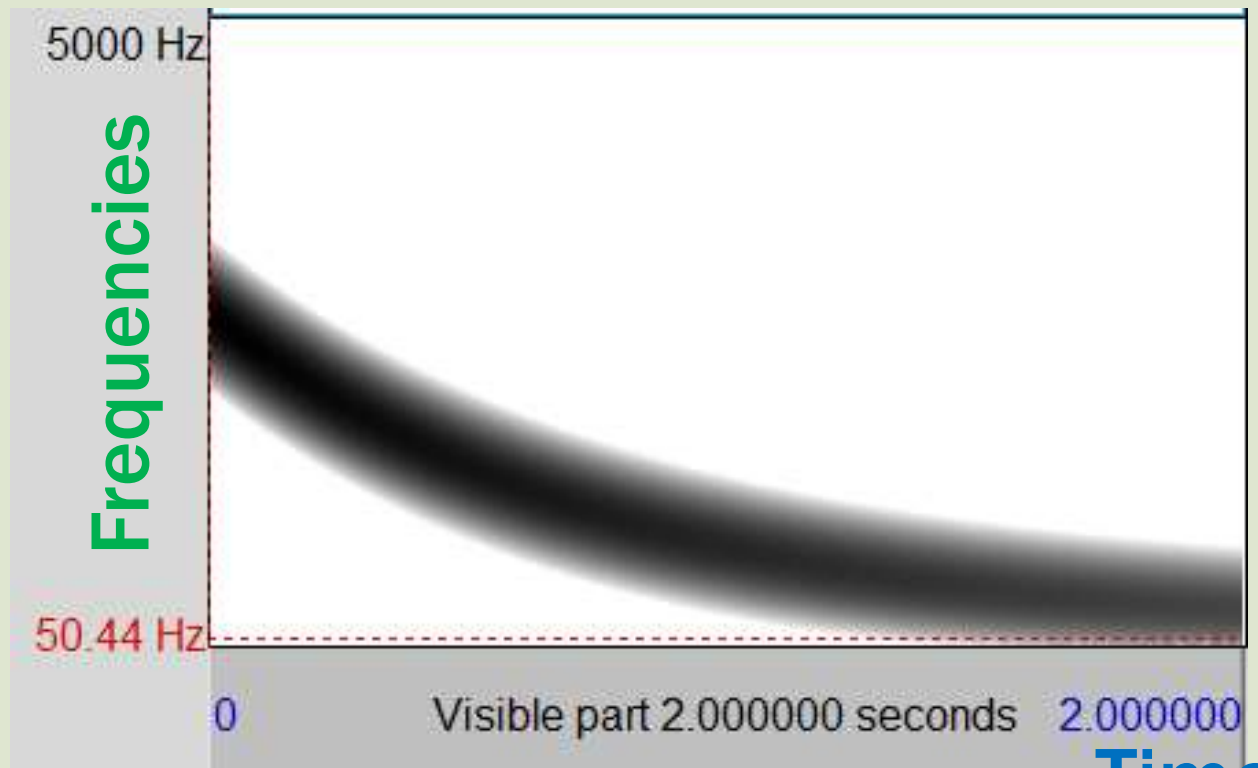
Time

SOUNDS CHANGE OVER TIME



Fourier transform!

Spectrogram!



Time

SOUNDS CHANGE OVER TIME



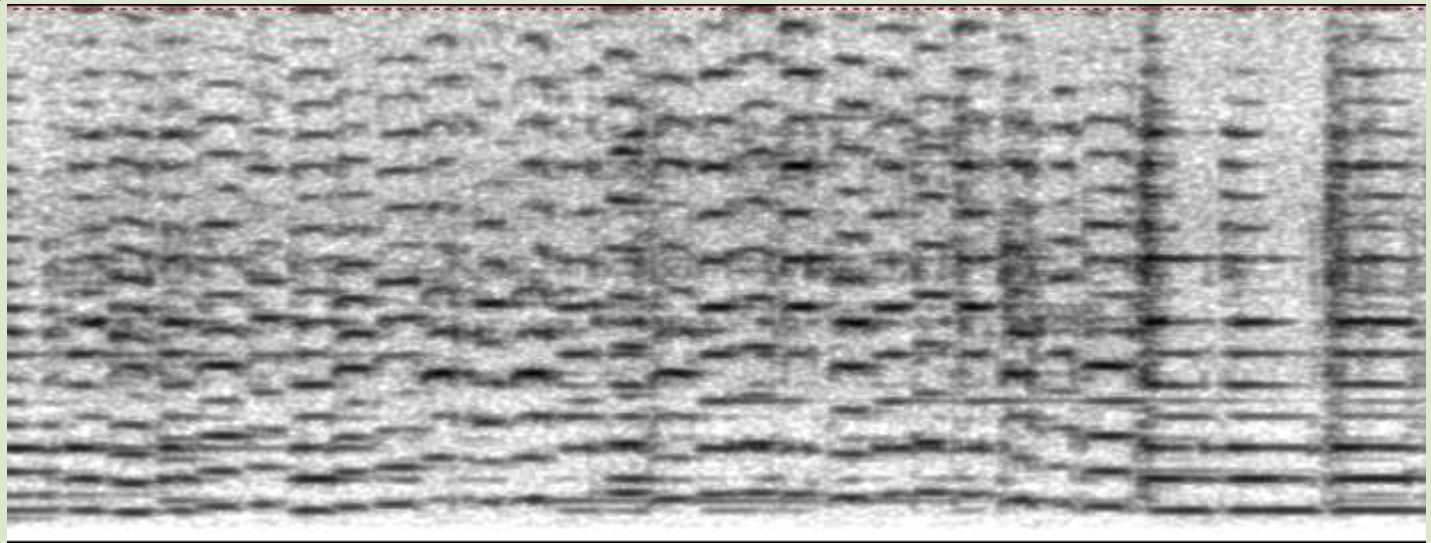
Spectrogram

5000 Hz



frequency

0 Hz



time

SPECTROGRAMS!

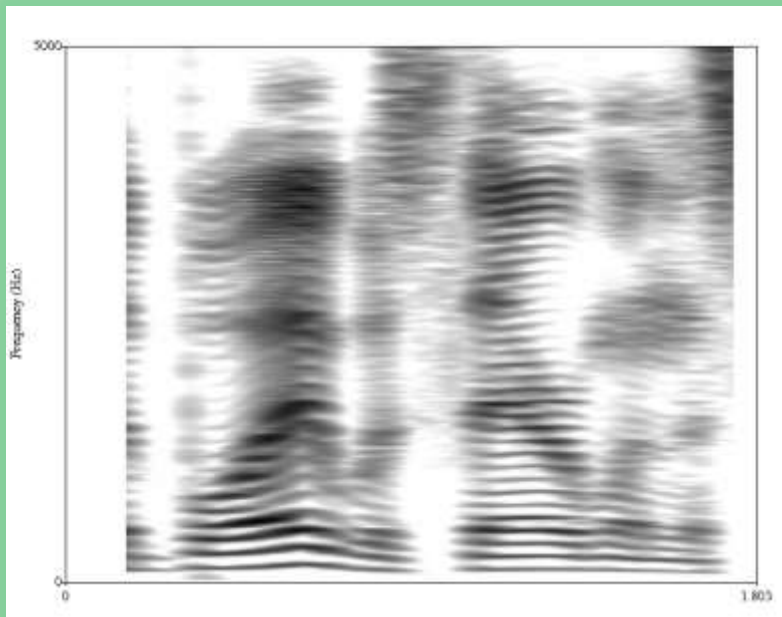
NARROWBAND VERSUS BROADBAND

- Determined by mathematical parameters.

Narrowband: This is what we've seen so far.

Better frequency resolution.

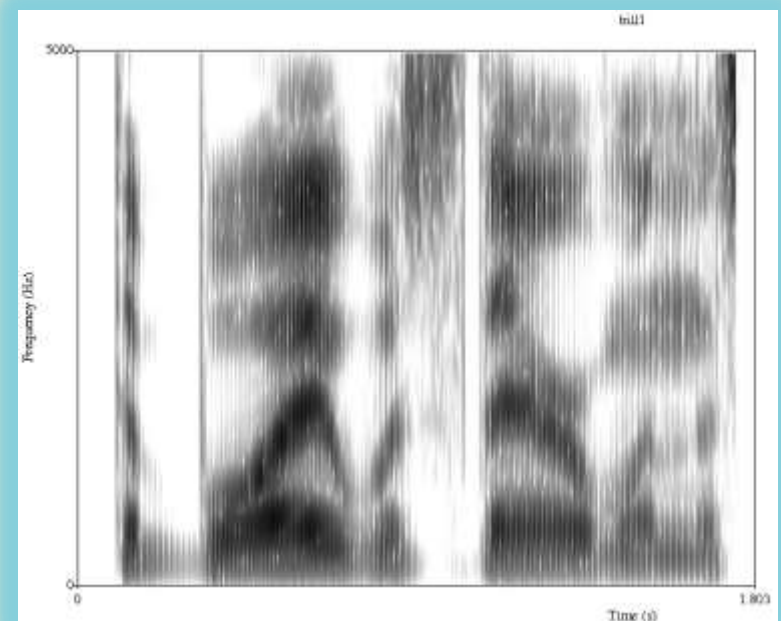
Worse time resolution.



Broadband: Almost everything else for the rest of the class.

Better time resolution.

Worse frequency resolution.

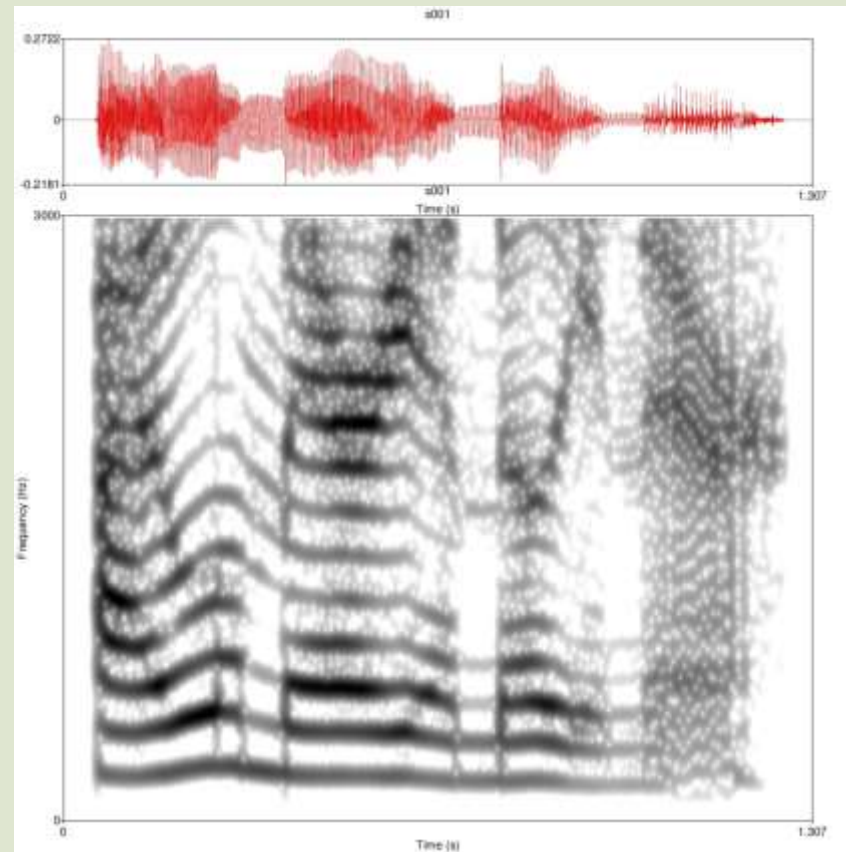
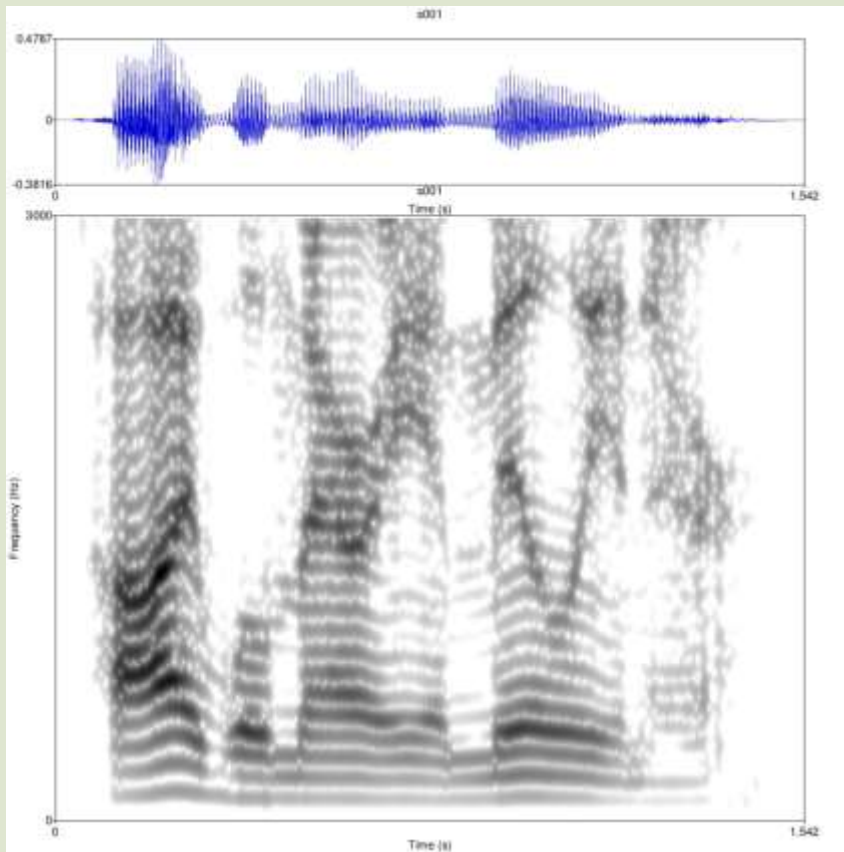


A SMALL PUZZLE

- Two _____band spectrograms.
Which is from a male talker, which is from a female talker?

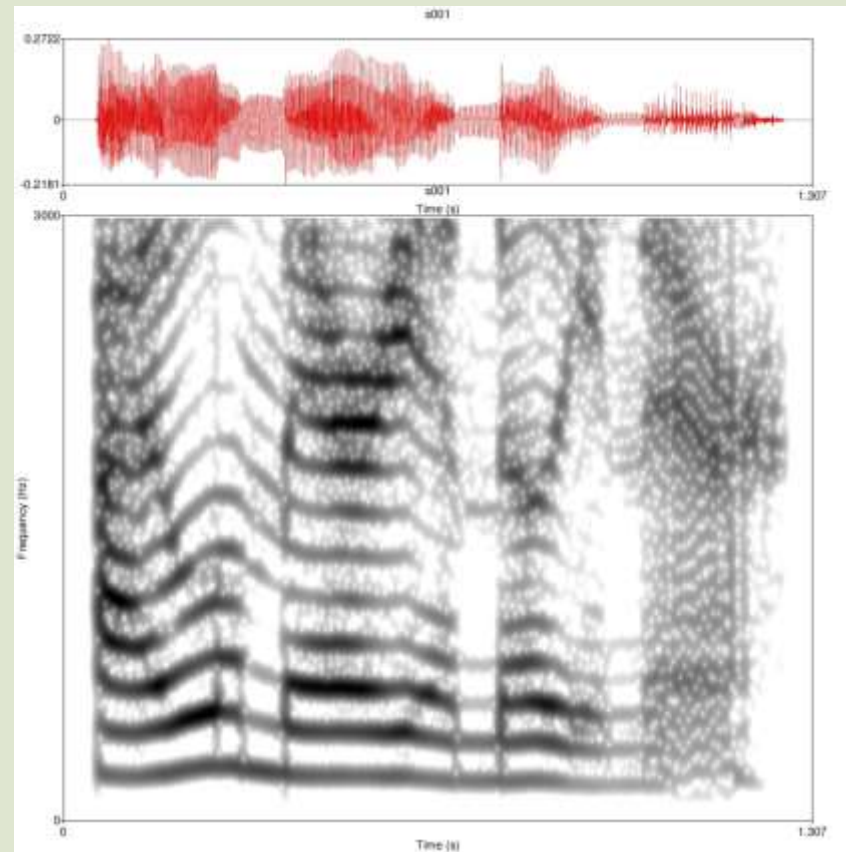
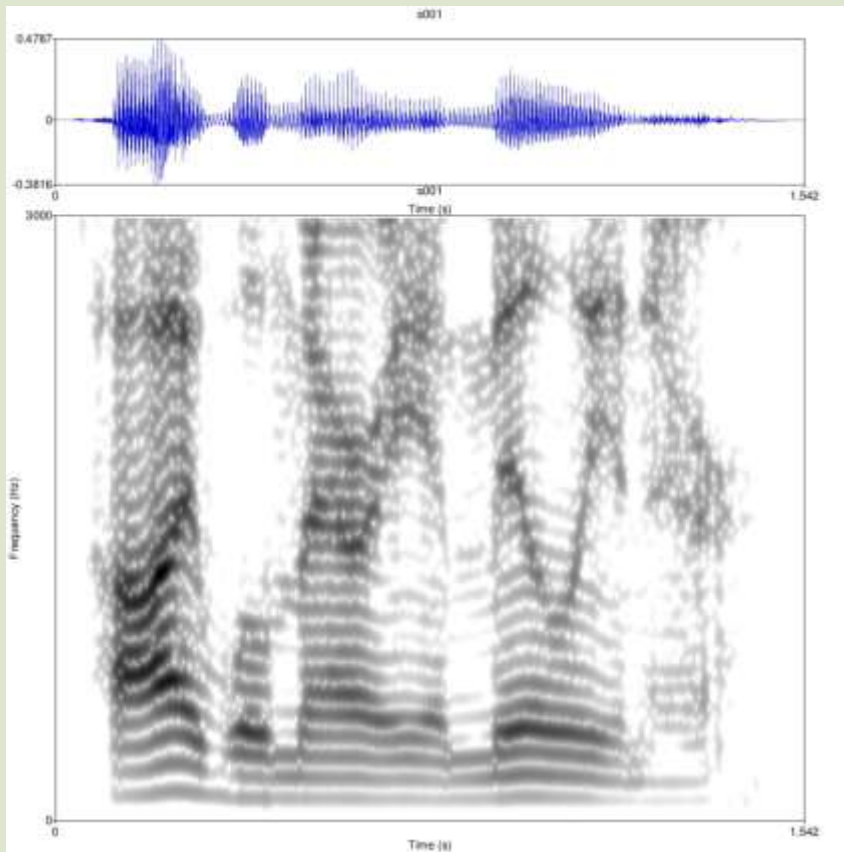
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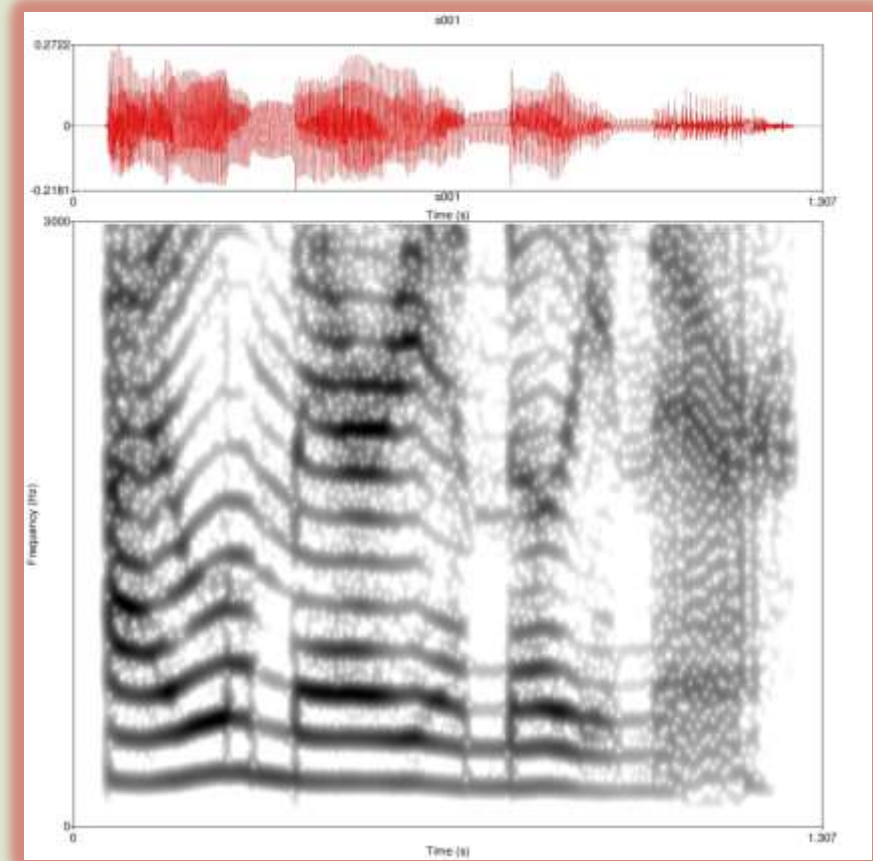
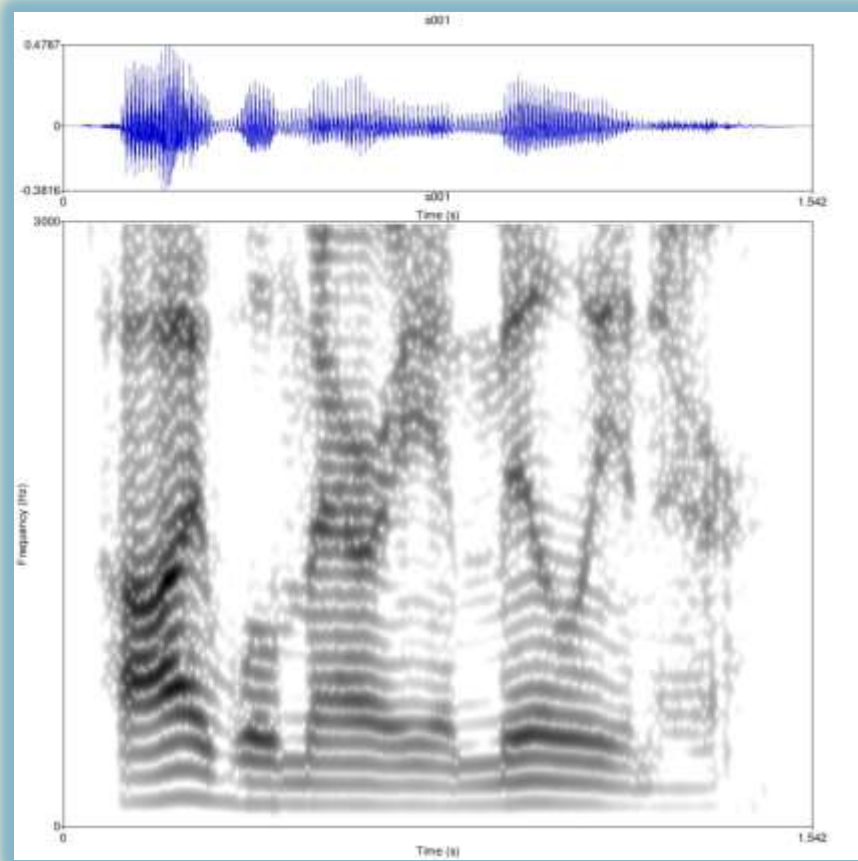
A SMALL PUZZLE

- Two narrowband spectrograms. Which is from a male talker, which is from a female talker?



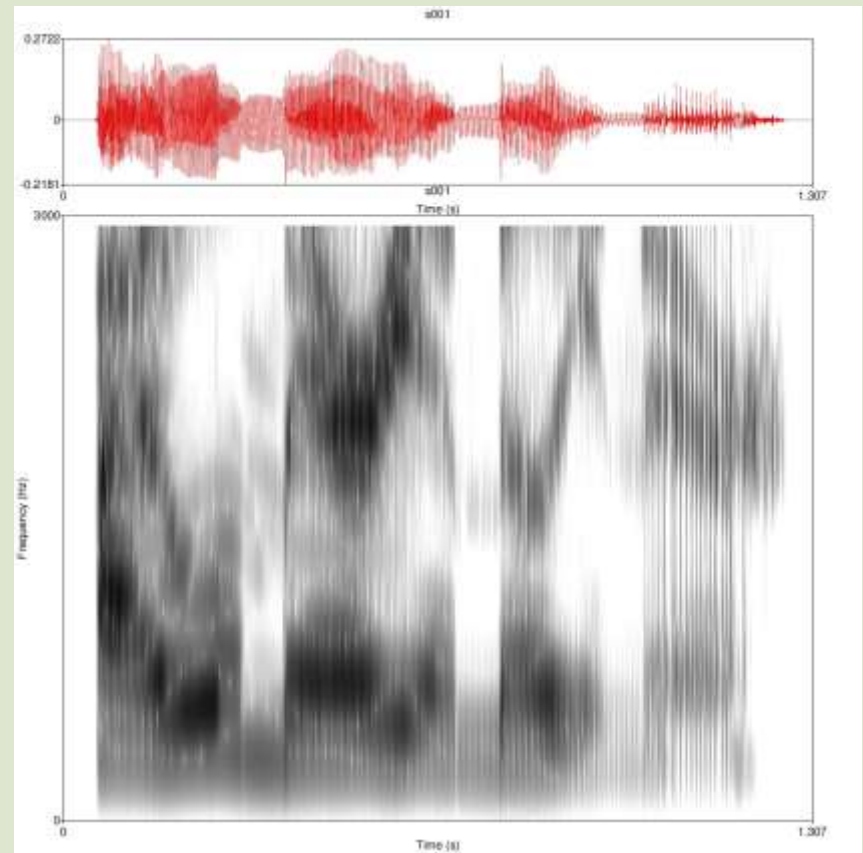
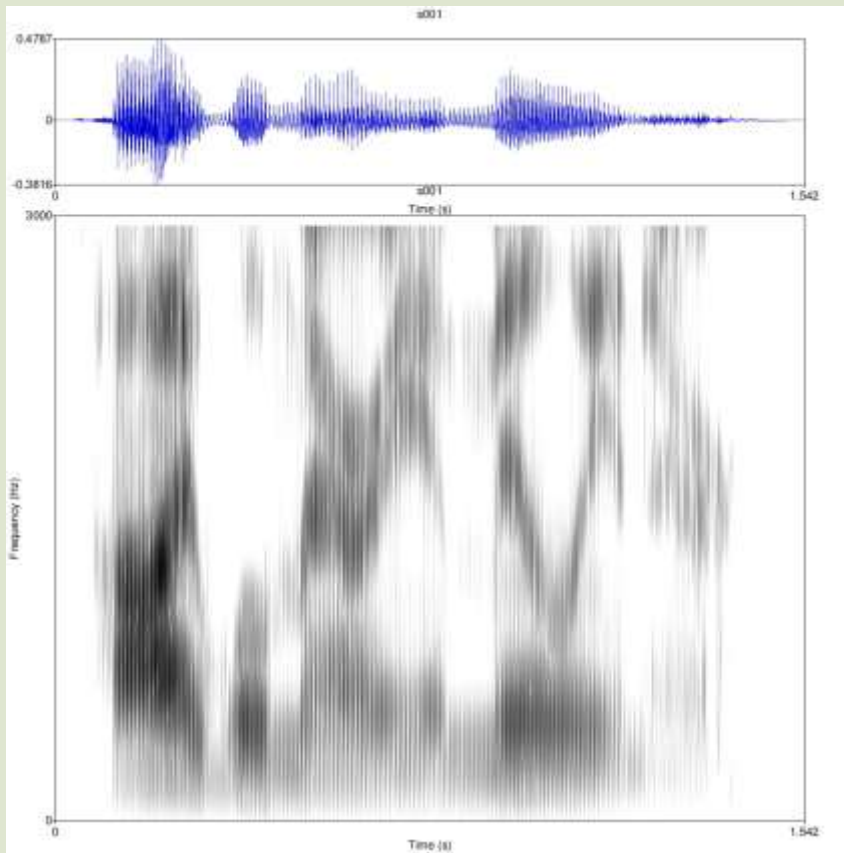
A SMALL PUZZLE

- Two narrowband spectrograms. Which is from a **male** talker, which is from a **female** talker?



A SMALL PUZZLE

- Two narrowband spectrograms.
- What do these look like in **broadband** instead? **This:**



SPECTROGRAMS!

- Let's look at some spectrograms.



VOWELS!

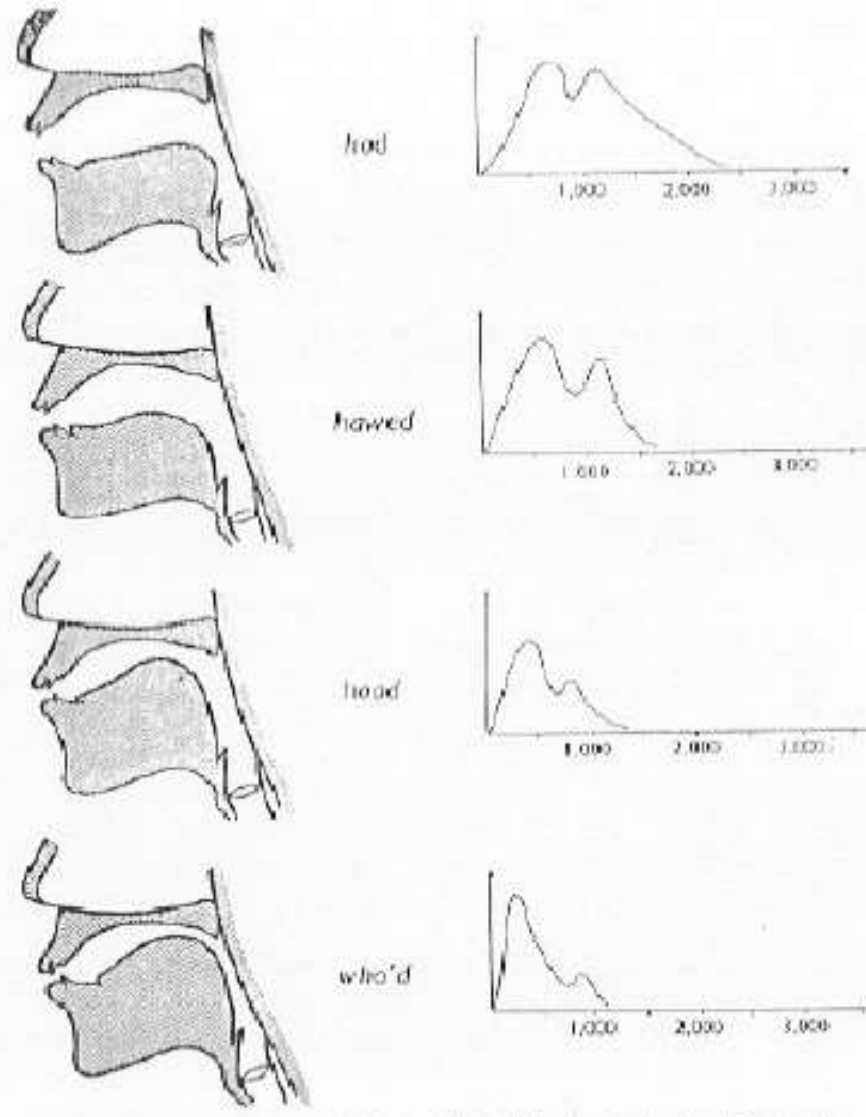
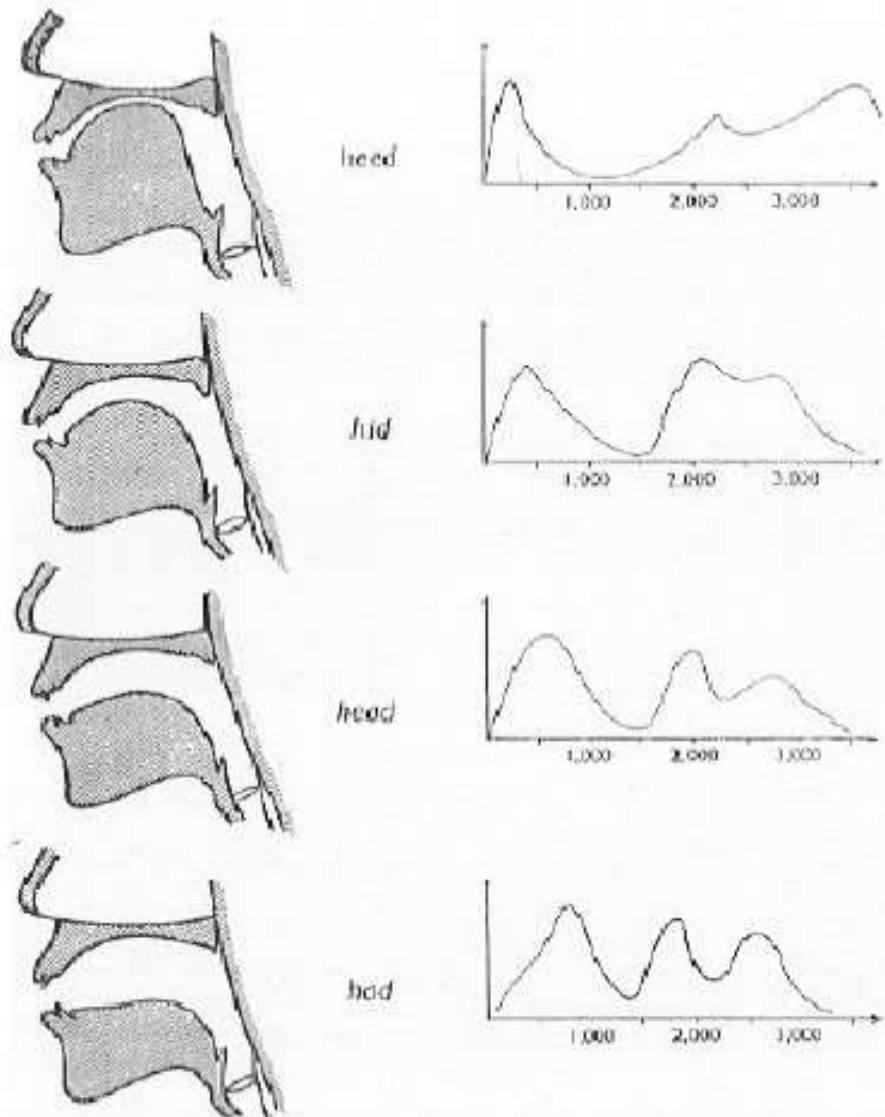
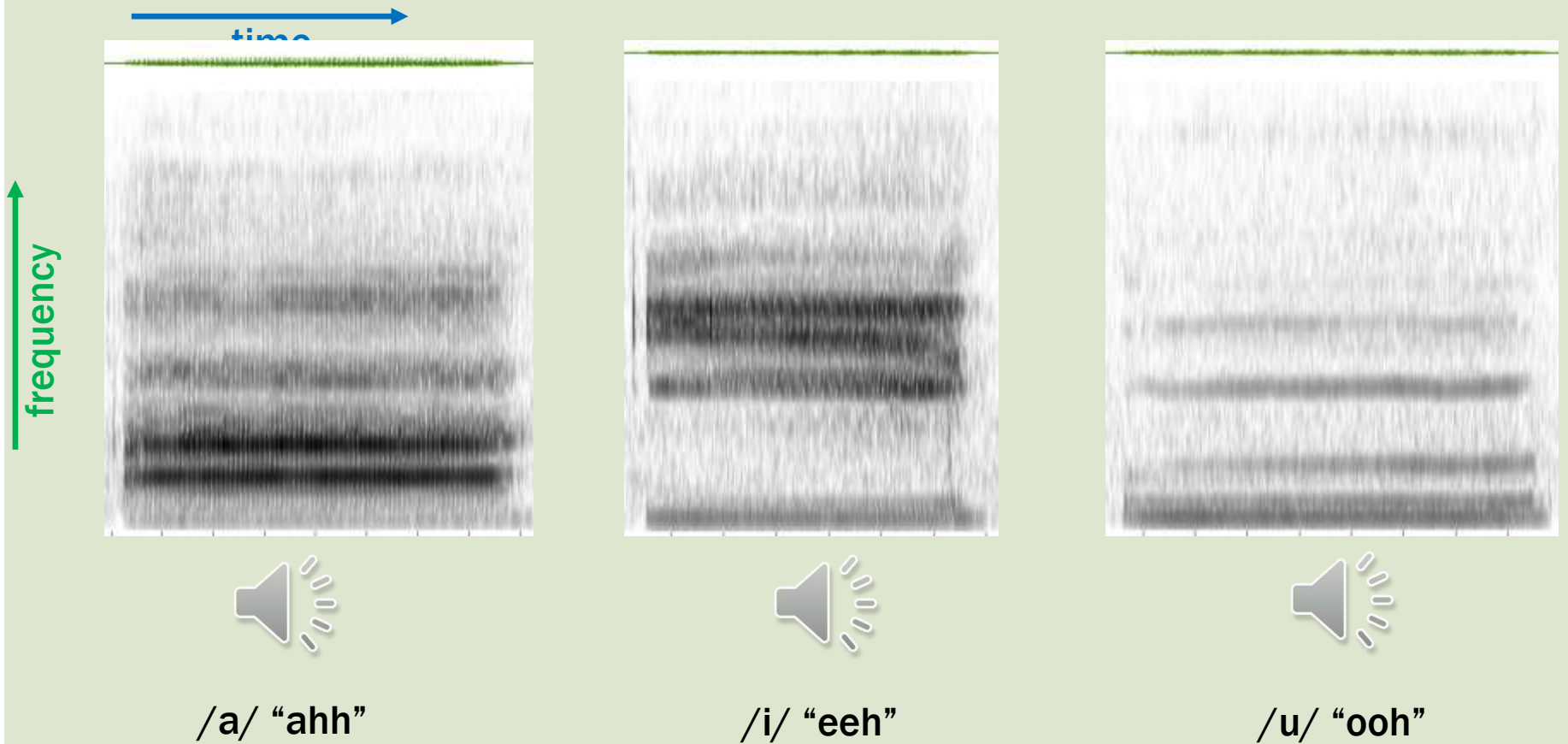


Fig. 7.5. The position of the vocal organs (based on data from X-ray phonographs) of the author and the spectra of the vowel sounds in the middle

of the words *heed*, *hid*, *hood*, *had*, *hoved*, *hood*, *who'd*, in the author's speech.

FORMANTS: YOU TRY!



FORMANTS: YOU TRY!

- Spectrograms for five words are given in scrambled order here. Match them!
- **spooky**
- **maki**
- **kiwi**
- **pie**

CONSONANTS



CONSONANTS

- Consonants
- Some of the consonants of English

CONSONANTS (PULMONIC)

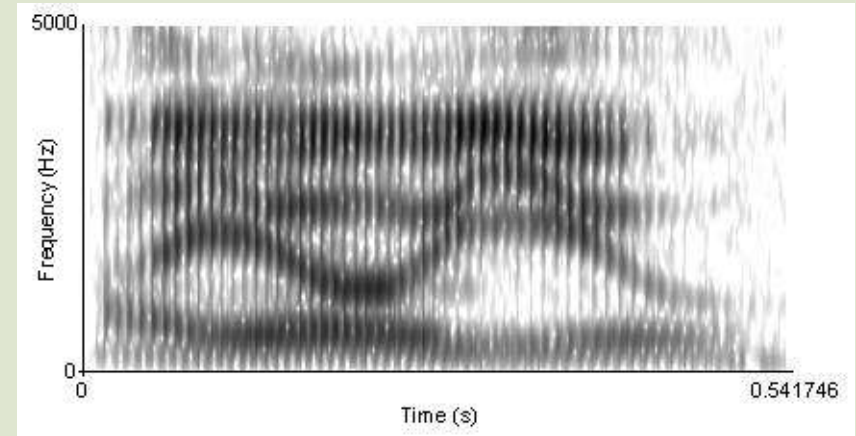
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Plosive	p b	ɸ β	t d			ʈ ɖ	c ɟ	k ɡ	q ɢ	ʔ		ʔ
Fricative	ɸ β	f v	θ ð	s z	ʃ ʒ	ʂ ʐ	ç ʝ	x ɣ	χ ʁ	ħ ʕ	ħ ʕ	h ɦ
Approximant		ʋ	ɹ			ɻ	j	ɰ				ɦ
Trill	ʙ			r					ʀ		ʀ	
Tap, Flap		ⱱ		ɾ		ɽ						
Lateral fricative				ɬ ɮ		ɭ	ʎ	ɮ				
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SPEECH SYNTHESIS

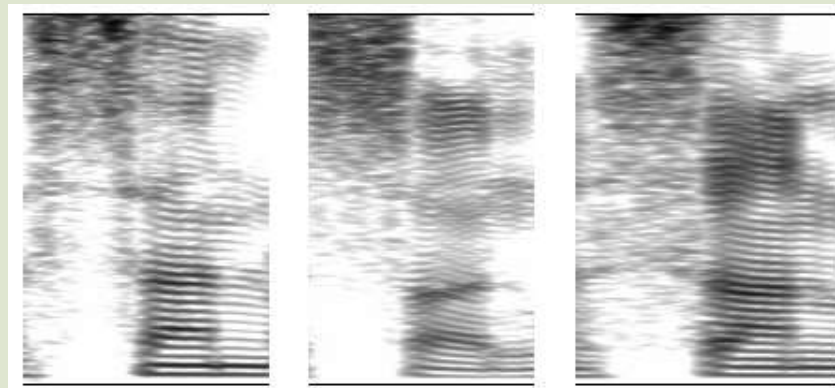
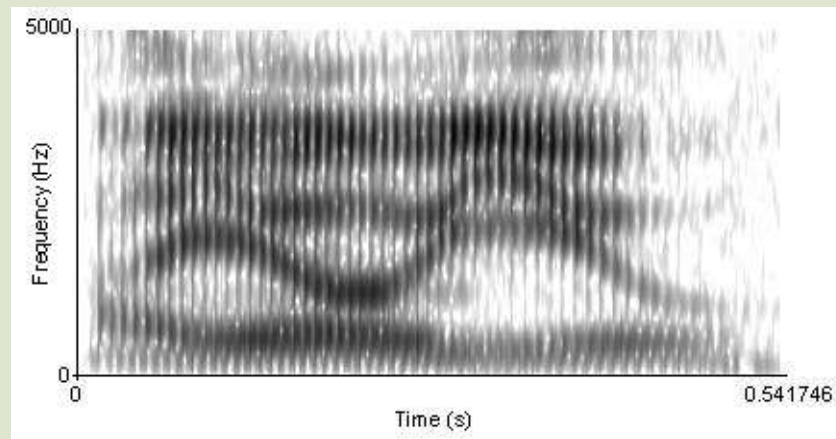
SPEECH RECOGNITION

- Speech recognition is *hard!*
- **Segmentation problem**
 - How many words are in that → spectrogram?
 - Where does one word end and the other begin?



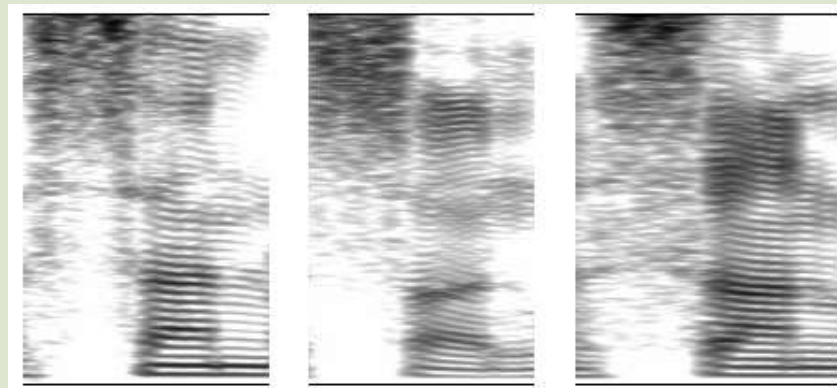
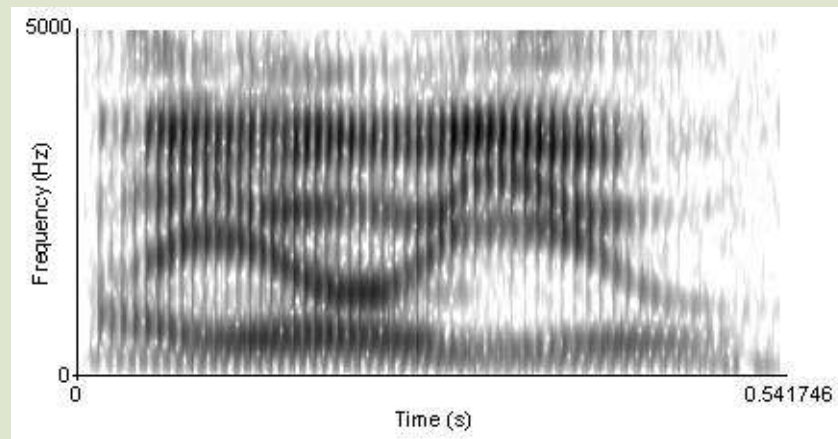
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 - Different speech from different people varies!
 - We're good at normalizing for what one person's voice sounds like, but computers aren't.



SPEECH RECOGNITION

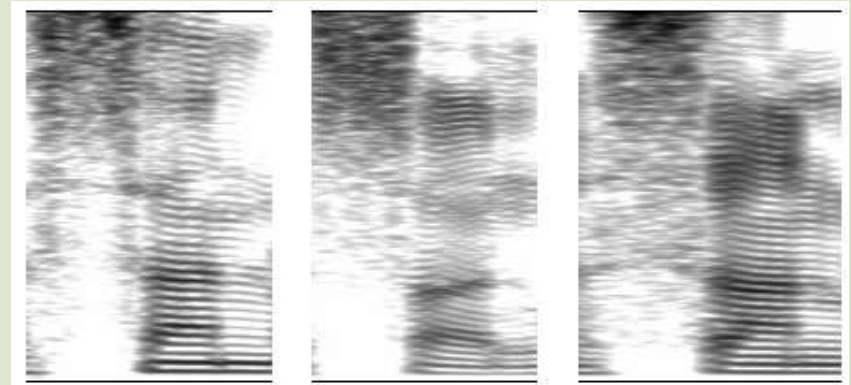
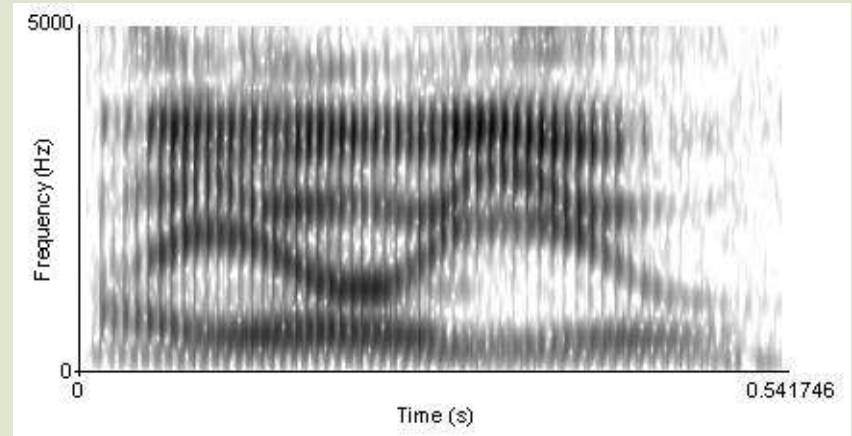
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诗 shī 石 shí 始 shǐ 室 shì

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 - Different speech from different people varies!
 - We're good at normalizing for what one person's voice sounds like, but computers aren't.
- Syllable stress and tones
- **But we're working on it!**
 - (Siri, anyone?)



诗 shī 石 shí 始 shǐ 室 shì

DO IT YOURSELF!

- If you think that this is all really cool:
 - **Download Praat** to your computer at home and have fun using it to experiment! (It's *really fun*.) <http://www.fon.hum.uva.nl/praat/>
 - **Download RTgram**, which can make spectrograms in real-time: <http://www.phon.ucl.ac.uk/resource/sfs/rtgram/>
 - **Come to my Linguistics Problem Solving walk-in activity!** Tomorrow (Sunday), 1:30pm-3:30pm, in Lobby 13.
 - **Consider trying the North American Computational Linguistics Olympiad (NACLO)! <http://naclo.cs.cmu.edu/>**
 - The first round is **January 30, 2014**.
 - You can sign up to take it at MIT or at many other universities, or ask a high school teacher to proctor the exam.
 - **Browse Wikipedia** to learn more about phonology!
http://en.wikipedia.org/wiki/International_Phonetic_Alphabet
http://en.wikipedia.org/wiki/IPA_vowel_chart_with_audio
http://en.wikipedia.org/wiki/IPA_pulmonic_consonant_chart_with_audio