
I has a coffee and a grumpy.
STARBUCKS
COFFEE
Guess which one I will share with you.
ICANHASCHEEZBURGER.COM

Things are a little different today. I'm presenting using LaTeX.

Don't try this at home. Seriously, don't.

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Don't try this at home. Seriously, don't.

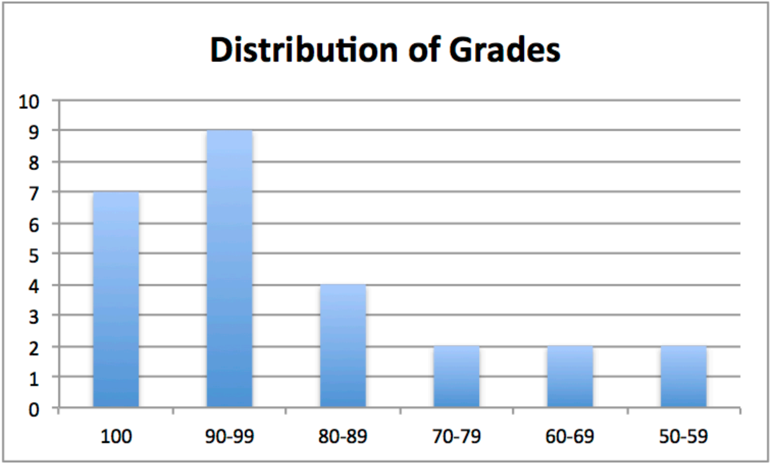
[ˈpʰl̥ɑːɾĩŋ ˈiːvɫ̩]

Exam 1 Statistics

Mean: 88.1%

Median: 95%

Standard Deviation: 14.7%



For those of you who struggled, office hours are open, and

OK... so now what?

We've finished with articulatory phonetics and IPA transcription.

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We’ve been talking about sounds as gestures and as symbols.
Now we get to talk about their true nature.

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- How do speech sounds sound?
- How can we measure speech to learn more about it?

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- How does sound work?
- How does sound work in the mouth?
- How do speech sounds sound?
- How can we measure speech to learn more about it?
- How can we use these measurements to reinforce and bolster our claims about speech, phonetics and phonology?

Introduction to Sound: Continued

Will Styler

LING 5030

October 11th, 2011

Welcome back to Acoustics!

Where we left off...

Acoustics is the study of waves


冨嶽三十六景 神奈川沖浪裏

Where we left off...

Sound is the perceptual consequence of air pressure variations, series of compressions and rarefactions in the air

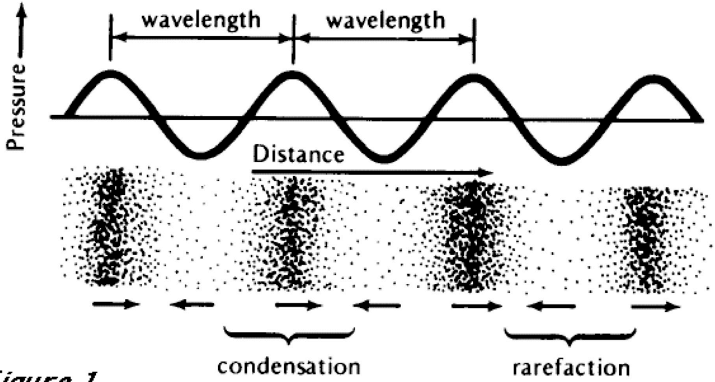

Figure 1

Where we left off...

The characteristics of sounds

Frequency

Amplitude

Wavelength

Period

Duration

Where we left off...

The characteristics of sounds

Frequency - How often does it cycle? (~Pitch)

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Amplitude - How powerful are the waves? (~Loudness)

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Amplitude - How powerful are the waves? (~Loudness)

Wavelength - What's the distance from peak to peak?

The characteristics of sounds

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Amplitude - How powerful are the waves? (~Loudness)

Wavelength - What's the distance from peak to peak?

Period - How long does one cycle take?

Where we left off...

The characteristics of sounds

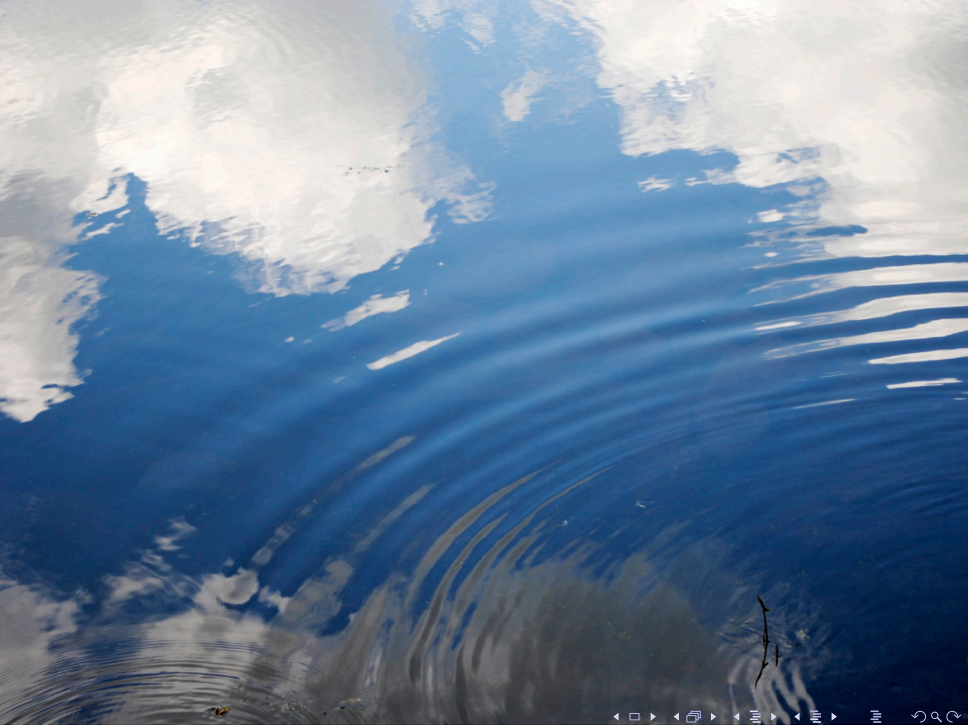
Frequency - How often does it cycle? (~Pitch)

Amplitude - How powerful are the waves? (~Loudness)

Wavelength - What's the distance from peak to peak?

Period - How long does one cycle take?

Duration - How long does the sound last?



Showing sound with Fire

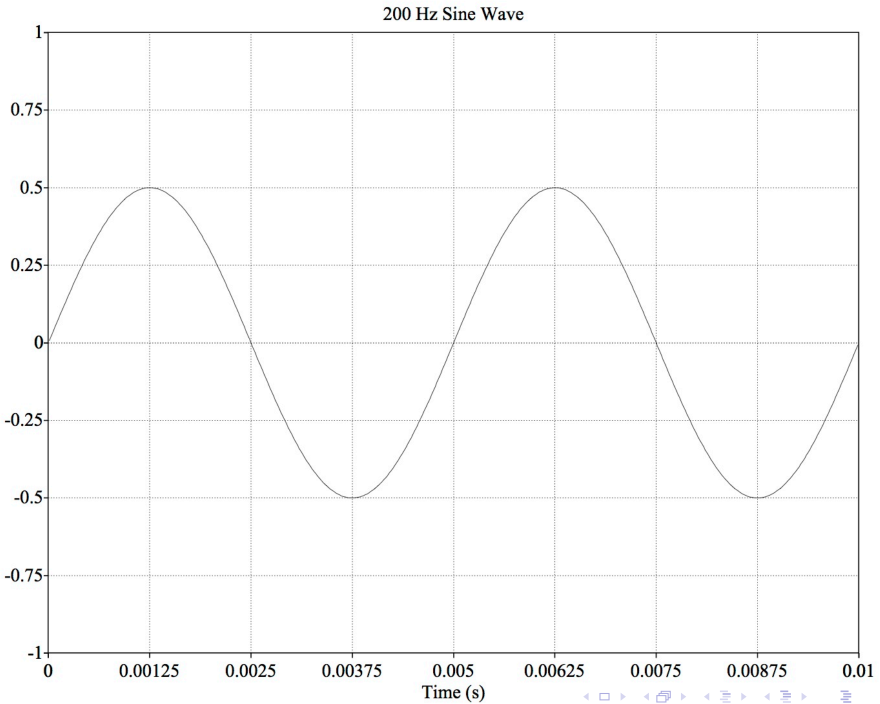
http://www.youtube.com/watch?v=wBydVCF4DrY

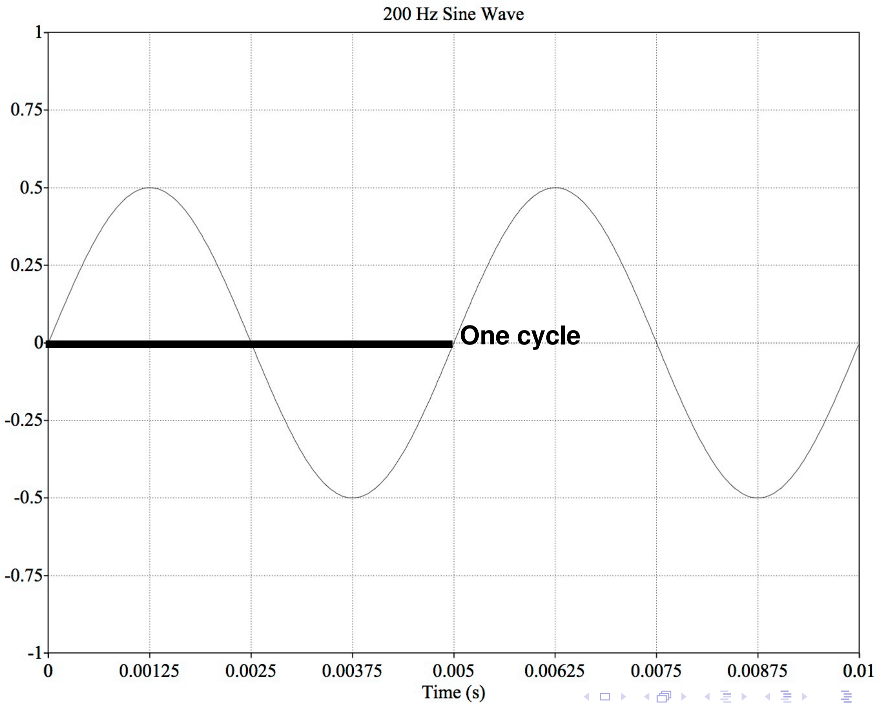
Showing sound with Water

http://www.youtube.com/watch?v=xPW3gihYnZE

What units do we use to measure these properties?

Characteristic	**Unit of Measure**
Frequency	Hertz (Cycles per second)
Amplitude	dB (or dB SPL, dB HL, etc)
Wavelength (λ)	Meters
Period	Seconds (or Milliseconds)
Duration	Some unit of time


200 Hz Sine Wave
1
0.75
0.5
0.25
0
-0.25
-0.5
-0.75
-1
0
0.00125
0.0025
0.00375
0.005
0.00625
0.0075
0.00875
0.01
Time (s)


200 Hz Sine Wave
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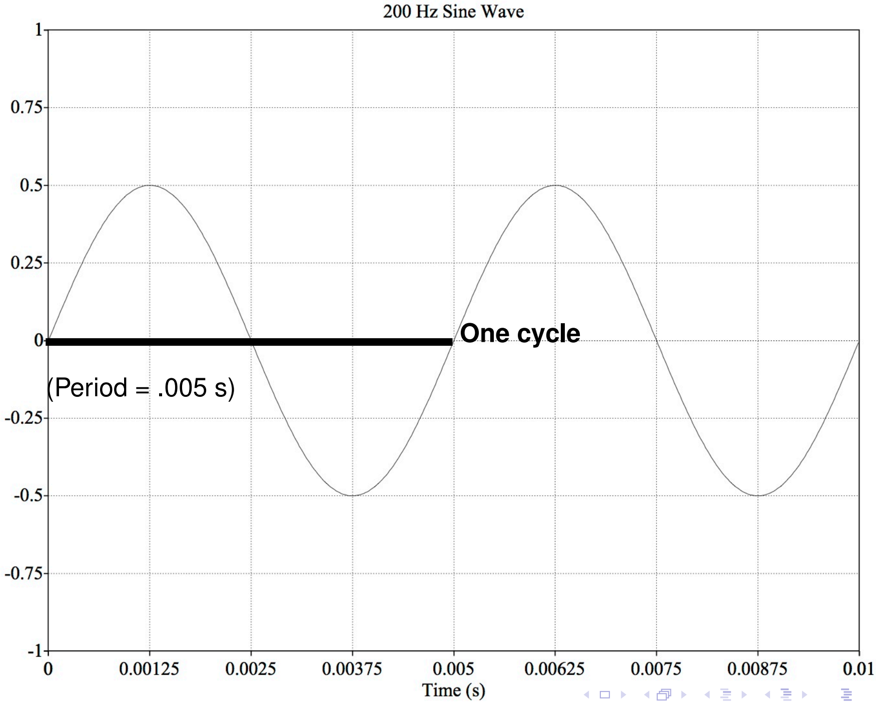
One cycle
0
0.00125
0.0025
0.00375
0.005
0.00625
0.0075
0.00875
0.01
Time (s)


200 Hz Sine Wave
1
0.75
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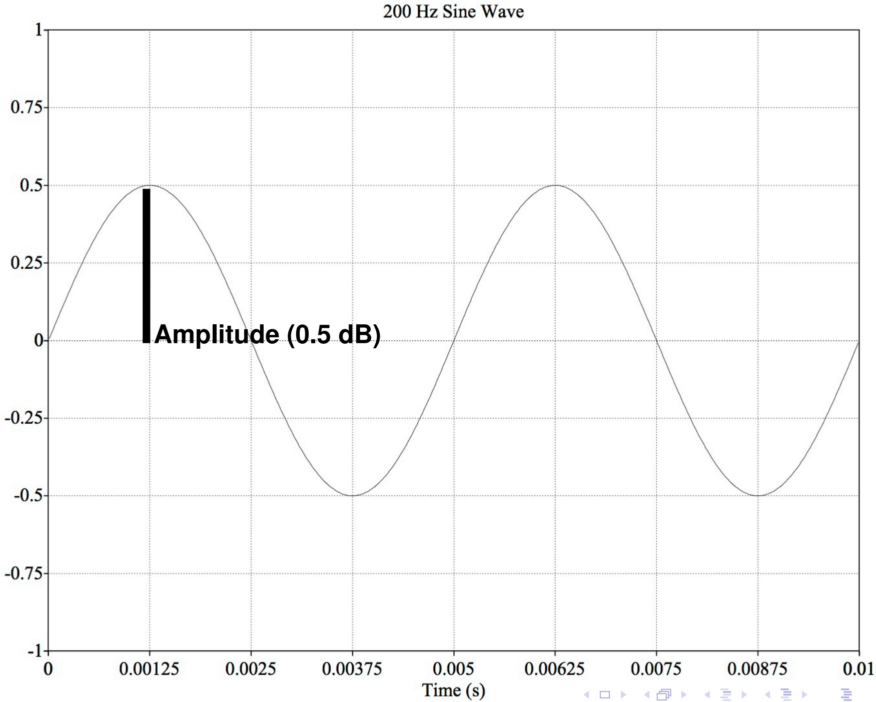
-0.25
-0.5
-0.75
-1
0
0.00125
0.0025
0.00375
0.005
0.00625
0.0075
0.00875
0.01
Time (s)
One cycle
(Period = .005 s)



200 Hz Sine Wave
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0.75
0.5
0.25
0
-0.25
-0.5
-0.75
-1
0
0.00125
0.0025
0.00375
0.005
0.00625
0.0075
0.00875
0.01
Time (s)
Amplitude (0.5 dB)

The Frequency Formula

$$f = \frac{1}{t}$$

f = The Frequency in Hz

t = The Period in Seconds

So for our sound...

$$f = \frac{1}{t}$$

So for our sound...

$$f = \frac{1}{t}$$

$$f = \frac{1}{0.005s}$$

So for our sound...

$$f = \frac{1}{t}$$

$$f = \frac{1}{0.005s}$$

$$\mathbf{200} = \frac{1}{0.005s}$$

So for our sound...

$$f = \frac{1}{t}$$

$$f = \frac{1}{0.005s}$$

$$\mathbf{200} = \frac{1}{0.005s}$$

Frequency = 200 Hz

The Wavelength Formula

$$\lambda = \frac{c}{f}$$

c = Speed of sound in air (343 m/s)

f = The Frequency (in Hz)

So for our sound...

$$\lambda = \frac{c}{f}$$

So for our sound...

$$\lambda = \frac{c}{f}$$

$$\lambda = \frac{343}{200Hz}$$

So for our sound...

$$\lambda = \frac{c}{f}$$

$$\lambda = \frac{343}{200Hz}$$

$$\mathbf{1.715m} = \frac{343}{200Hz}$$

So for our sound...

$$\lambda = \frac{c}{f}$$

$$\lambda = \frac{343}{200Hz}$$

$$\mathbf{1.715m} = \frac{343}{200Hz}$$

Wavelength = 1.715 m

So, now we can measure sounds from their waveforms.

So, now we can measure sounds from their waveforms.

Hooray!

So, now we can measure sounds from their waveforms.

Hooray!

... but not all sounds are so neatly measured

Not all sounds are sine waves

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We talk about two kinds of sounds: Periodic and Aperiodic

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Periodic sounds have a cycle which repeats (a "period")

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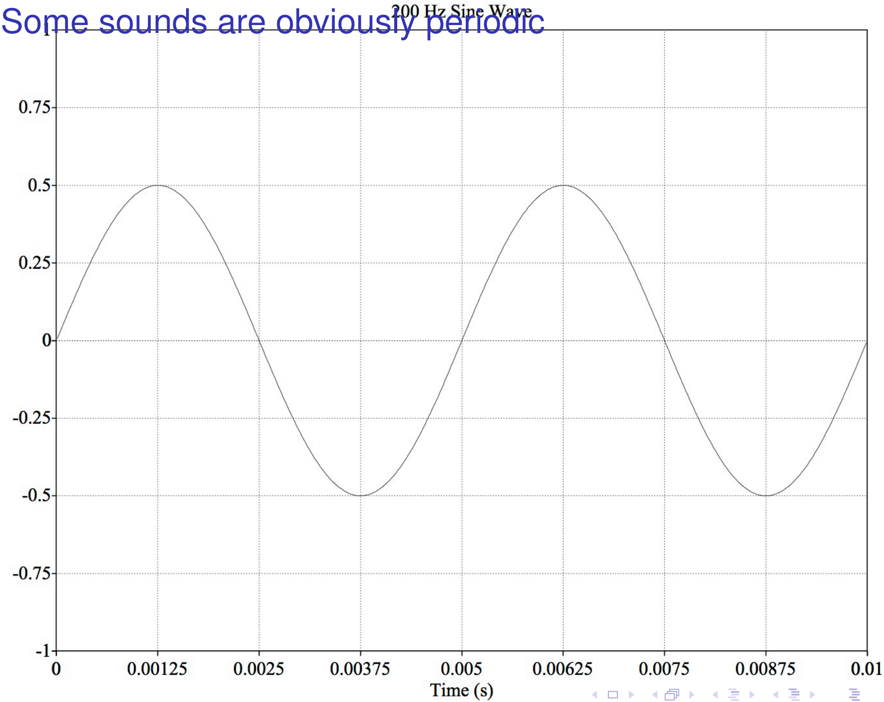
We talk about two kinds of sounds: Periodic and Aperiodic

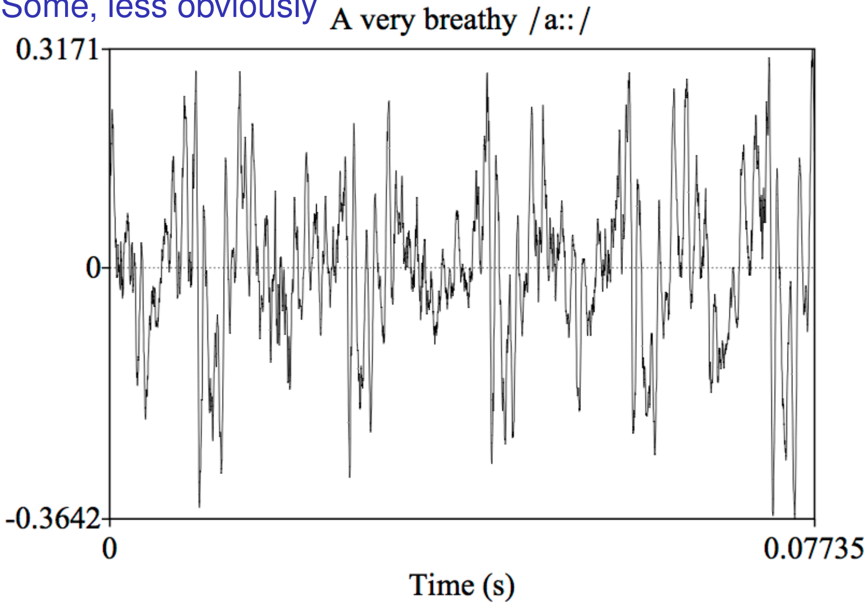
Periodic sounds have a cycle which repeats (a "period")

Aperiodic sounds are just a pressure wave, less of a wave than a splash.

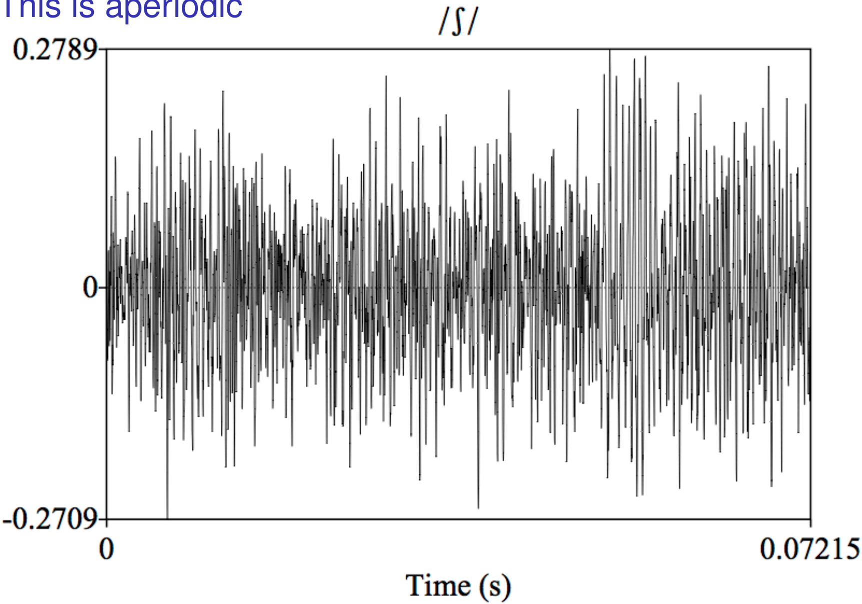
Some sounds are obviously periodic



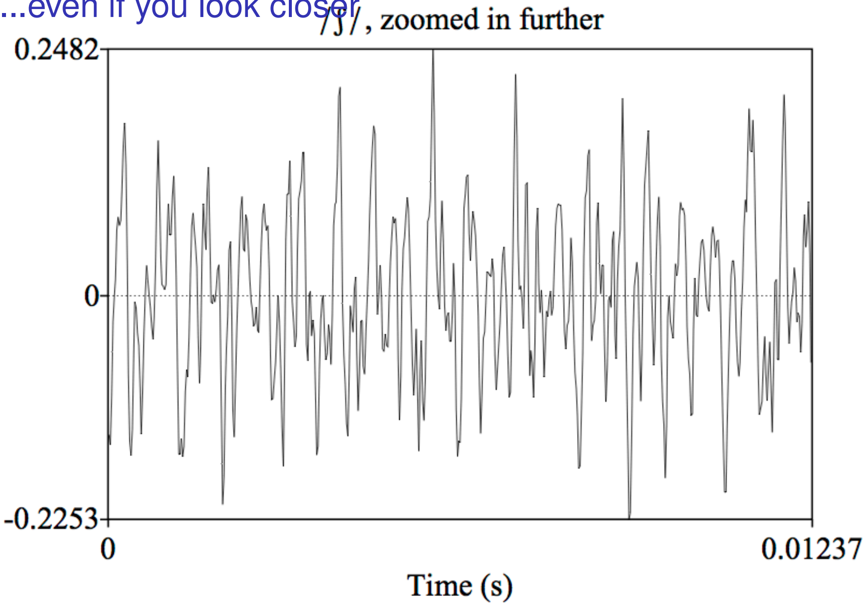
Some, less obviously



This is aperiodic



...even if you look closer



Periodic sounds have a cycle which repeats (a "period")

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- Anything that has a "pitch" is periodic
- All musical instruments except (non-tuned) percussion
- In speech, voicing is THE source of periodicity

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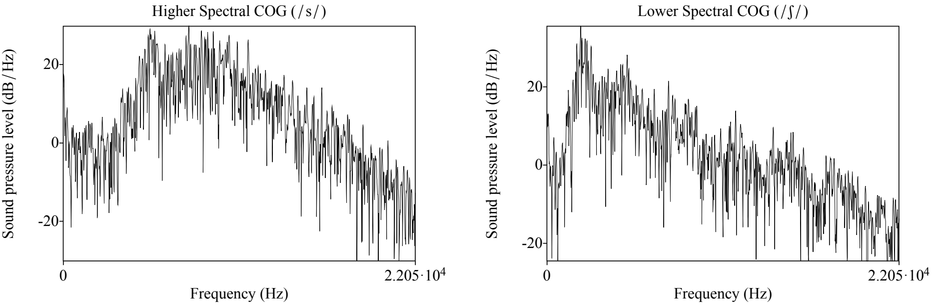
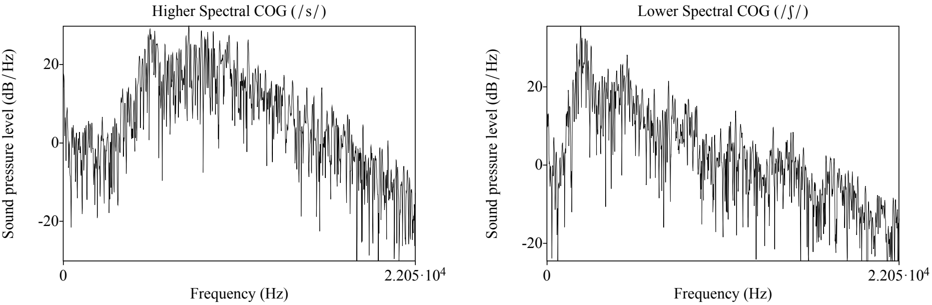
- Anything that has a "pitch" is periodic
- All musical instruments except (non-tuned) percussion
- In speech, voicing is THE source of periodicity

Aperiodic sounds are just a pressure wave, less of a wave than a splash.

- Aperiodic sounds look like black clouds, everywhere
- Frication is aperiodic, as is breathing noise
- Aperiodic sounds have (many) frequencies, but they don’t really have a pitch.



The spread and distribution of the many frequencies in aperiodic sounds are what we measure with "Spectral Center of Gravity" measures



The spread and distribution of the many frequencies in aperiodic sounds are what we measure with "Spectral Center of Gravity" measures

... but we're getting ahead of ourselves.

The moral of this story?

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You can't always find the period, frequency, or wavelength of a sound

So, now we can measure sounds from their waveforms.

Hooray!

... but not all sounds are so neatly measured

So, now we can measure sounds from their waveforms.

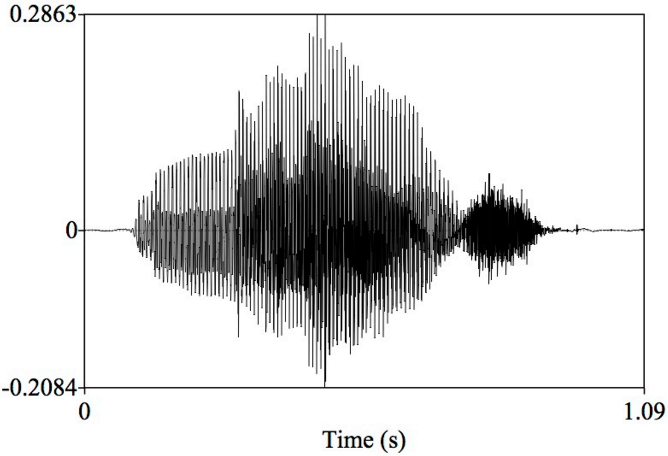
Hooray!

... but not all sounds are so neatly measured

... and waveforms aren't always the best way to visualize sound

Waveforms

Waveforms show us the pressure variations in the air over time.



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Pros:

- They're easy to get
- They're physically real
- They show you the whole sound at once

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Pros:

- They're easy to get
- They're physically real
- They show you the whole sound at once

Cons:

- They don't give much detail about frequencies
- Many sounds and one sound are indistinguishable
- There's not much you can do with them.

We **can** see frequency information in waveforms

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High frequencies show up as jagged edges or feathering on waveforms.

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More ocean-looking waves are usually lower frequencies

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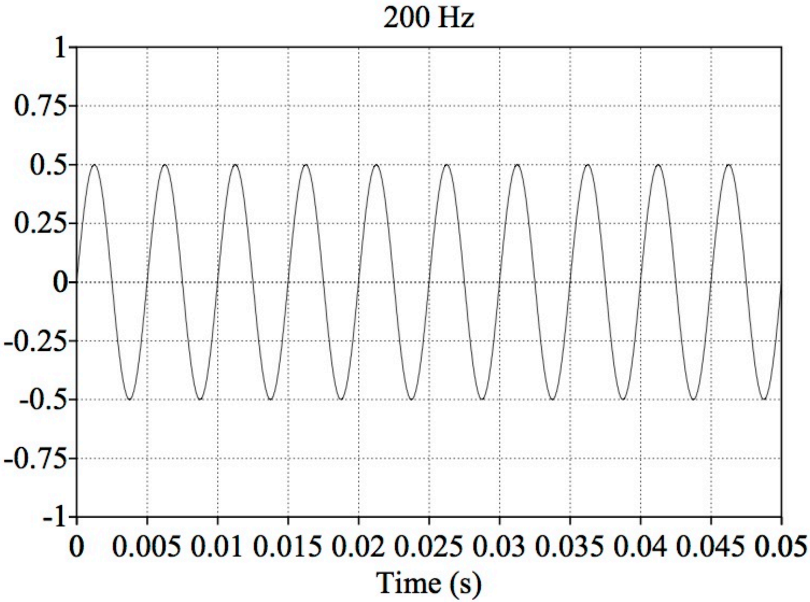
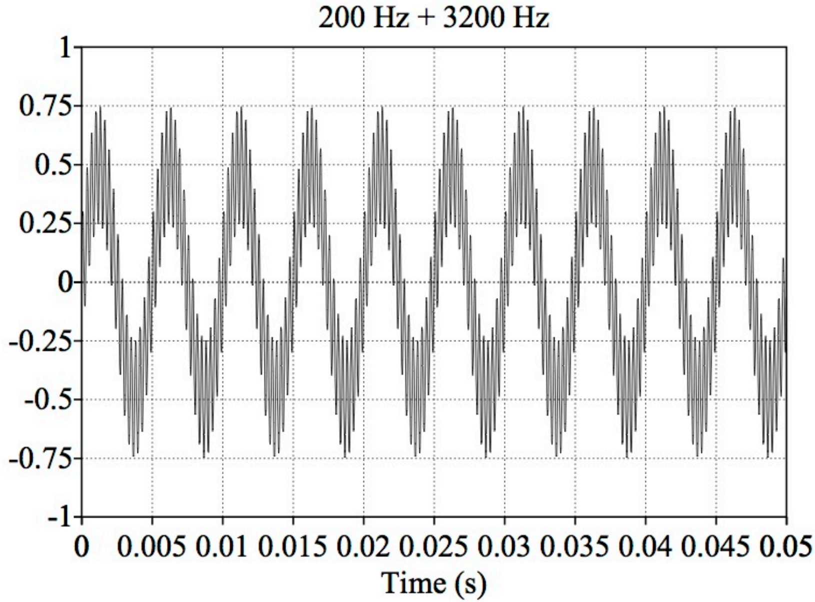
High frequencies show up as jagged edges or feathering on waveforms.

More ocean-looking waves are usually lower frequencies

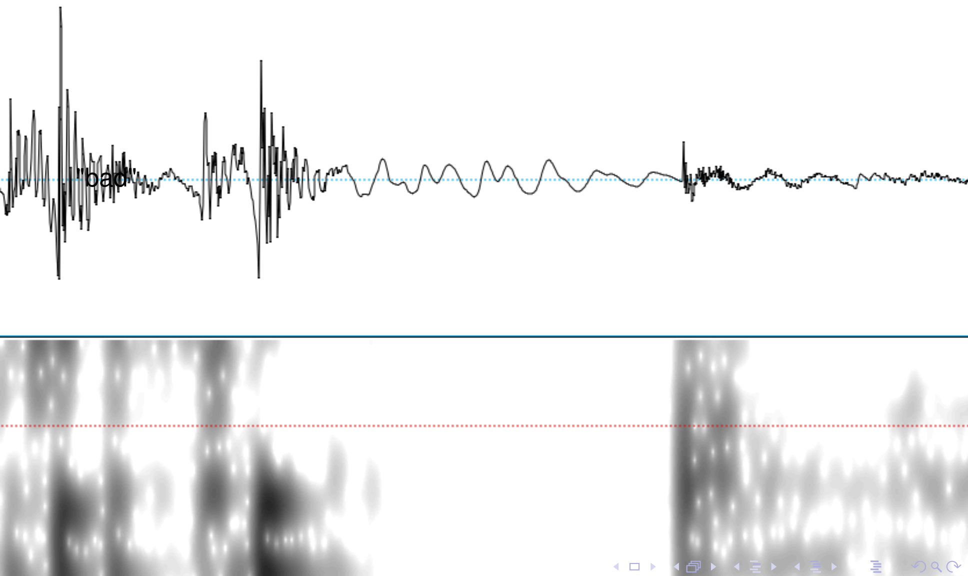
This is crazy-useful for segmenting sounds

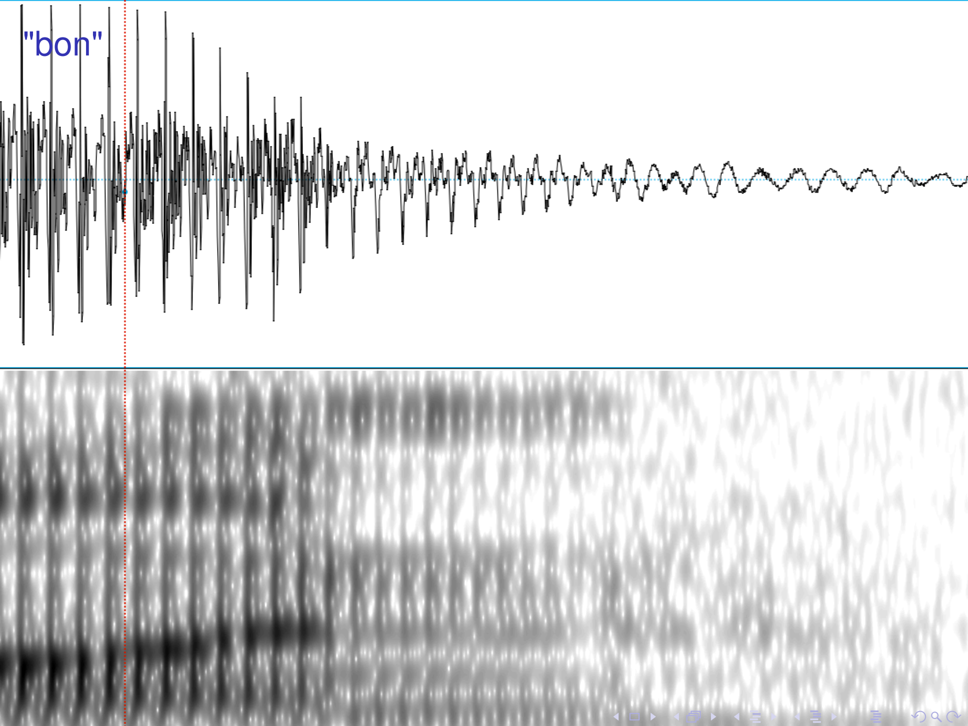

200 Hz
1
0.75
0.5
0.25
0
-0.25
-0.5
-0.75
-1
0
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04
0.045
0.05
Time (s)

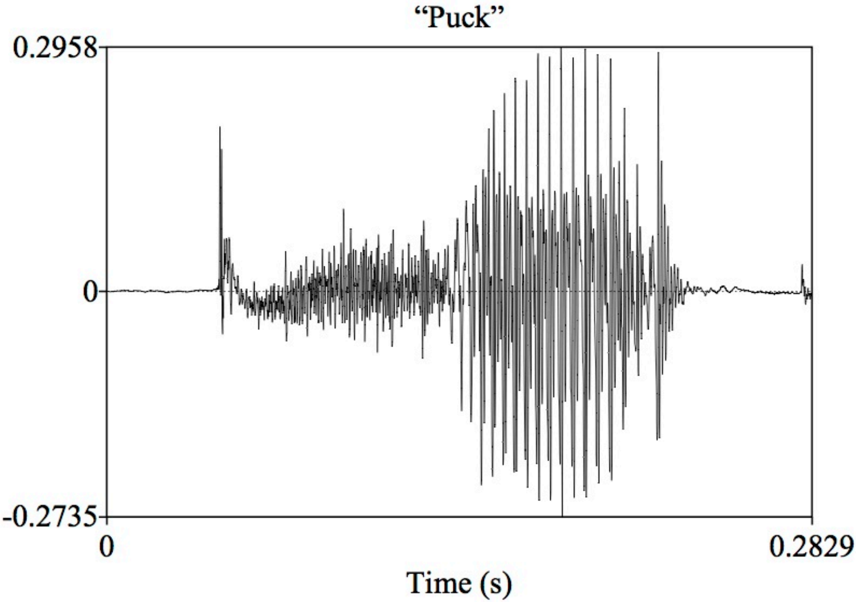


200 Hz + 3200 Hz
1
0.75
0.5
0.25
0
-0.25
-0.5
-0.75
-1
0
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04
0.045
0.05
Time (s)

"bad"




"bon"


"Puck"
0.2958
0
-0.2735
0
0.2829
Time (s)

Amplitude is useful too!

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Vowels are usually louder than onsets, codas

Amplitude is useful too!

Vowels are usually louder than onsets, codas

Nasals are usually quieter than vowels

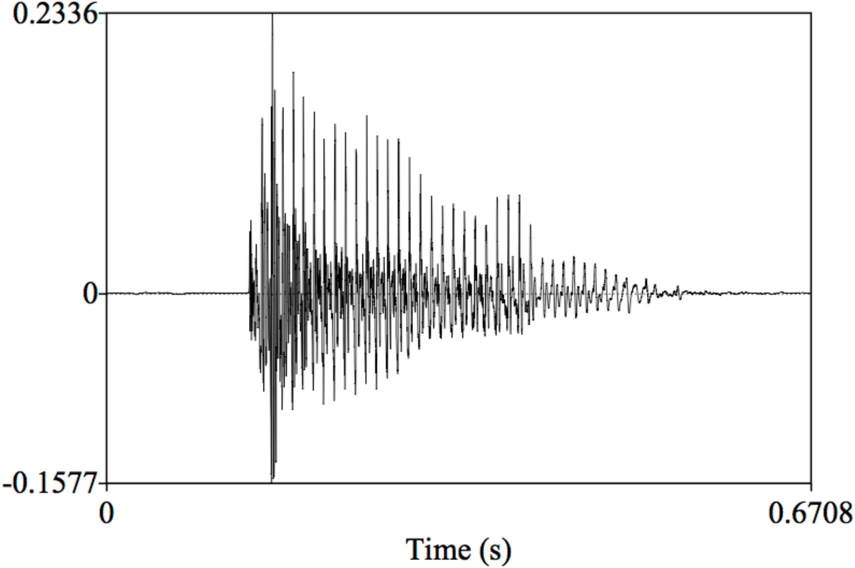
Amplitude is useful too!

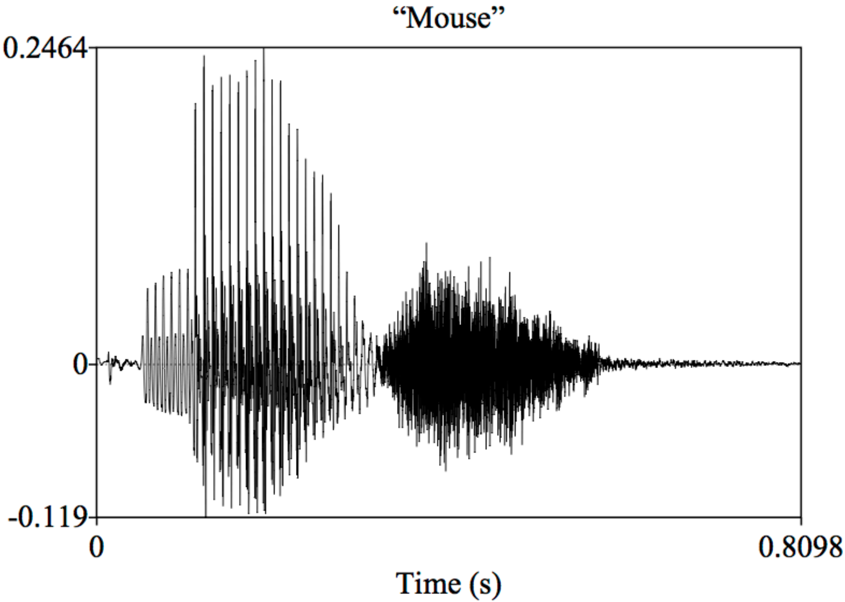
Vowels are usually louder than onsets, codas

Nasals are usually quieter than vowels

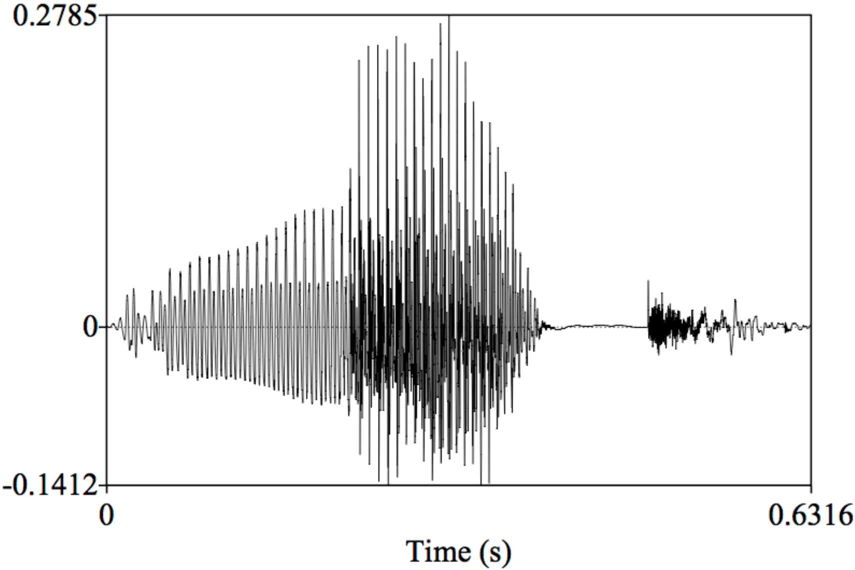
There's often a change in amplitude at the boundary between the vowel and /l/ or /ɹ/

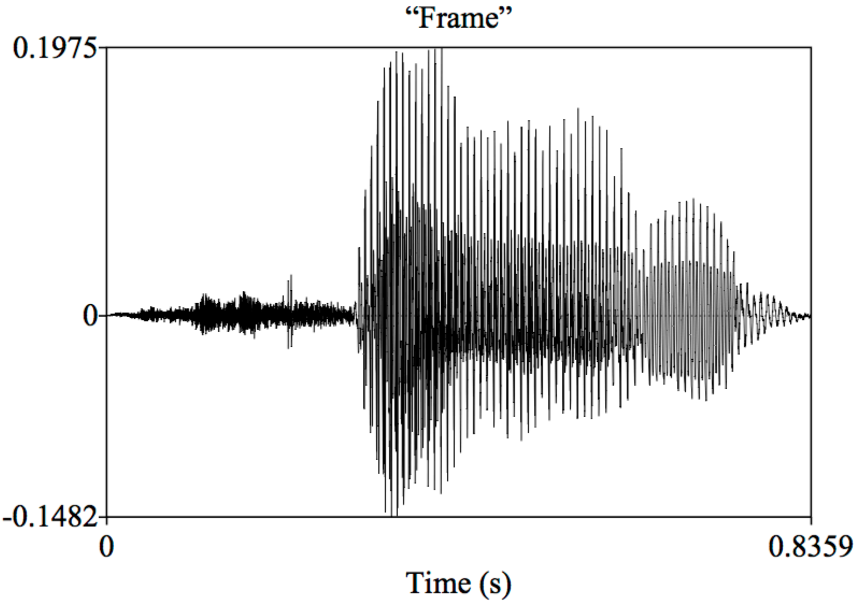
“Dam”




"Mouse"
0.2464
0
-0.119
0
0.8098
Time (s)

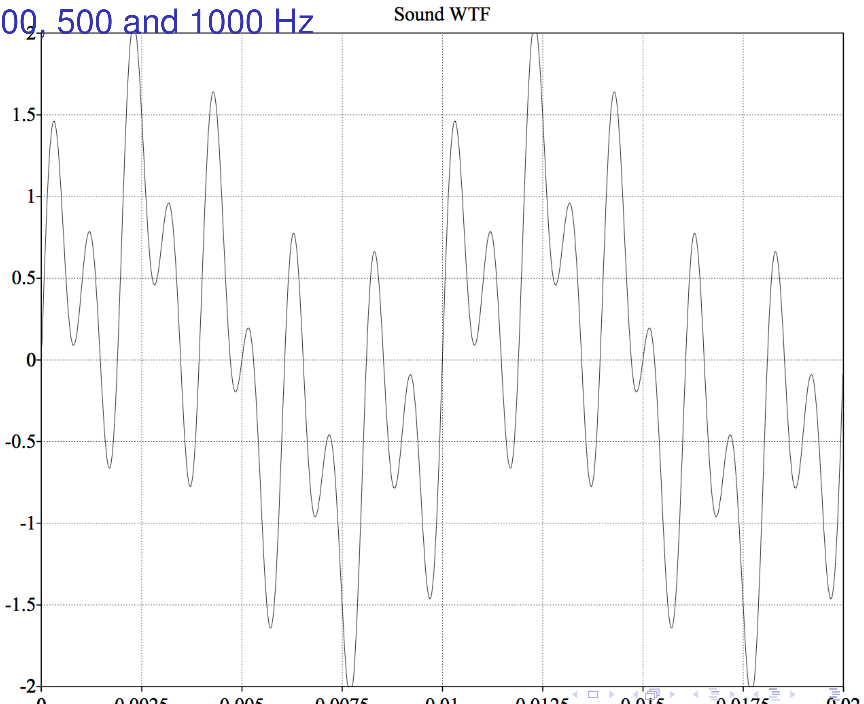
“Melt”



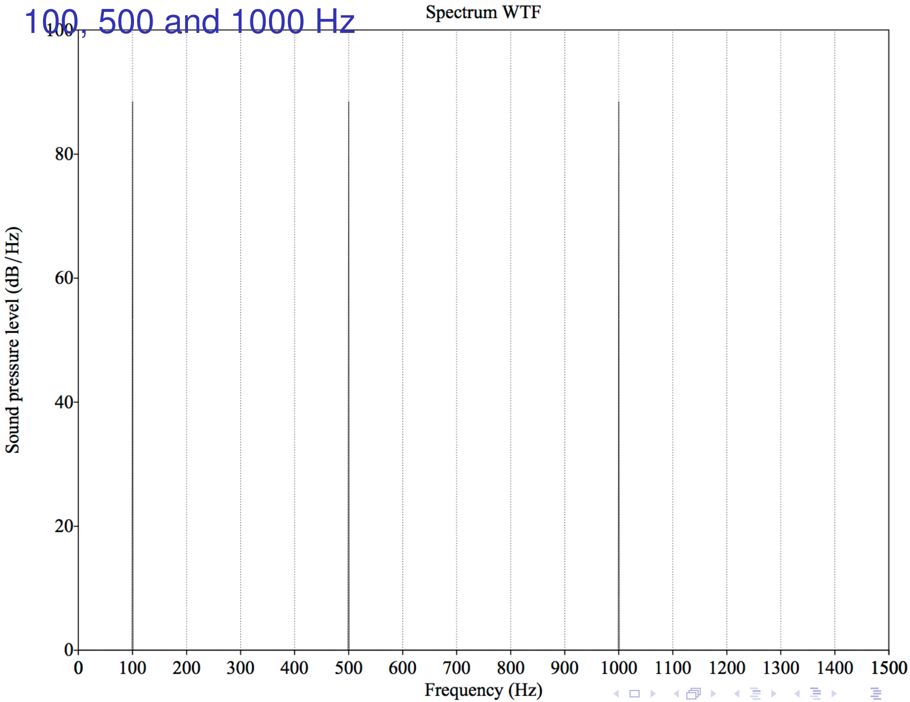

"Frame"
0.1975
0
-0.1482
0
0.8359
Time (s)

... but waveforms can only take you so far.

100, 500 and 1000 Hz

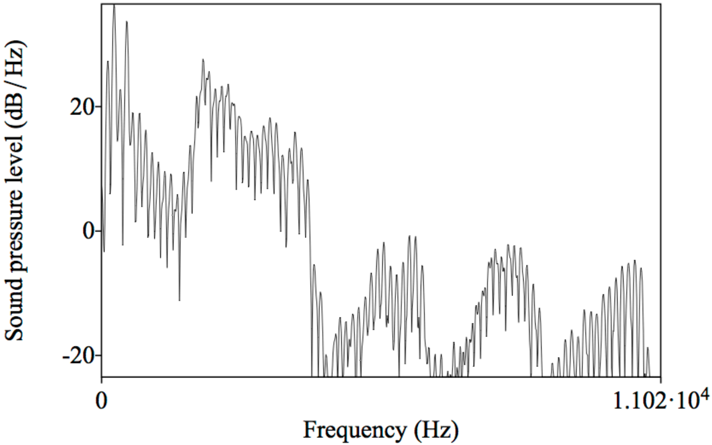


100, 500 and 1000 Hz



Spectra

Spectra show the frequencies which make up complex sounds



Spectra

Spectra (FFTs, Spectral Slices) show the frequencies which make up complex sounds

Pros:

- They show you the component frequencies of sounds
- They show you much more detail about the sound
- They give you much more accessible frequency information

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Spectra (FFTs, Spectral Slices) show the frequencies which make up complex sounds

Pros:

- They show you the component frequencies of sounds
- They show you much more detail about the sound
- They give you much more accessible frequency information

Cons:

- They only show you a small part (a "slice") of the sound

Spectra are most useful for detailed phonetic measurements **at a single point in the word**

Spectra are most useful for detailed phonetic measurements **at a single point in the word**

Spectra are used to measure...

- Nasality

Spectra are most useful for detailed phonetic measurements **at a single point in the word**

Spectra are used to measure...

- Nasality
- Fricative production

Spectra are most useful for detailed phonetic measurements **at a single point in the word**

Spectra are used to measure...

- Nasality
- Fricative production
- Creak

Spectra are most useful for detailed phonetic measurements **at a single point in the word**

Spectra are used to measure...

- Nasality
- Fricative production
- Creak
- Pitch/F0

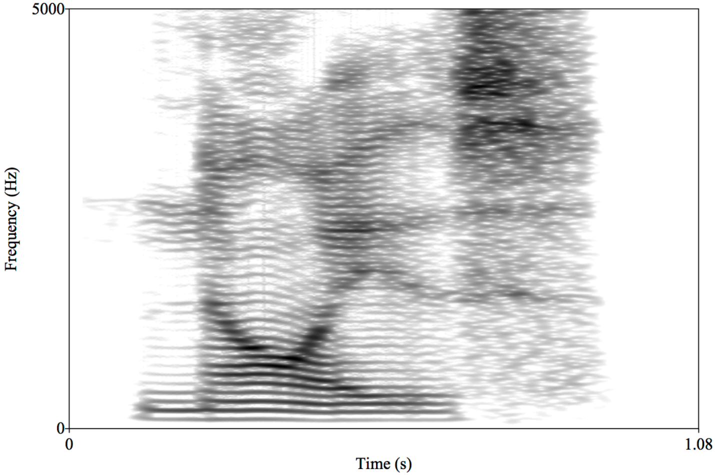
Spectra are most useful for detailed phonetic measurements **at a single point in the word**

Spectra are used to measure...

- Nasality
- Fricative production
- Creak
- Pitch/F0
- ... and much, much more

Spectrograms

Spectrograms show the frequencies present in a sound over time



Spectrograms

Spectrograms show the frequencies present in a sound over time (by lining up a series of spectra next to each other and showing the elevations)

Pros:

- All the time display of waveforms, but with frequency information!
- They show us how the signal changes over time
- Much more easily read and interpreted

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Pros:

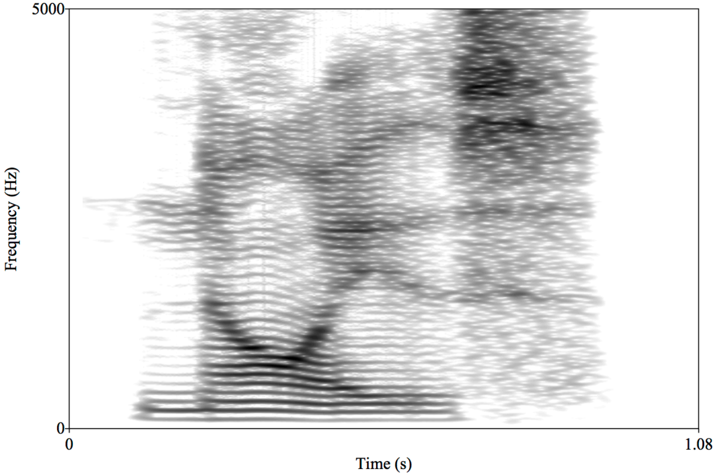
- All the time display of waveforms, but with frequency information!
- They show us how the signal changes over time
- Much more easily read and interpreted

Cons:

- You have to choose between narrowband and broadband spectrograms, depending on your purpose

Narrowband Spectrograms

Narrowband spectrograms look at a broader window (0.05 s), giving better frequency information (at the expense of time)



Narrowband spectrograms are most useful for examining the frequency content of words.

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Narrowband spectrograms are used to examine...

- Pitch/F0

Narrowband spectrograms are most useful for examining the frequency content of words.

Narrowband spectrograms are used to examine...

- Pitch/F0
- Fricative production

Narrowband spectrograms are most useful for examining the frequency content of words.

Narrowband spectrograms are used to examine...

- Pitch/F0
- Fricative production
- Intonation

Narrowband spectrograms are most useful for examining the frequency content of words.

Narrowband spectrograms are used to examine...

- Pitch/F0
- Fricative production
- Intonation
- Tone

Narrowband spectrograms are most useful for examining the frequency content of words.

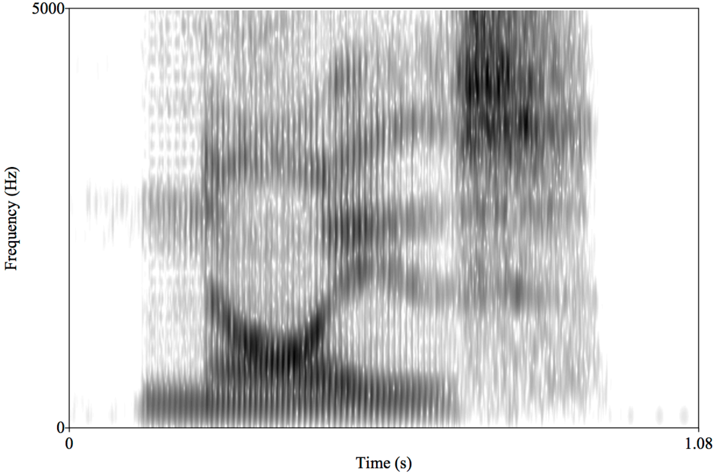
Narrowband spectrograms are used to examine...

- Pitch/F0
- Fricative production
- Intonation
- Tone
- Music

Let's Take Five

Broadband Spectrograms

Broadband spectrograms look at a smaller window (0.005 s), giving better time information (at the expense of frequency)



Broadband spectrograms are most useful for examining the timing of the various sounds of words, as well as vowels.

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Broadband spectrograms are used to examine...

- Vowels!!

Broadband spectrograms are most useful for examining the timing of the various sounds of words, as well as vowels.

Broadband spectrograms are used to examine...

- Vowels!!
- Liquids/Glides

Broadband spectrograms are most useful for examining the timing of the various sounds of words, as well as vowels.

Broadband spectrograms are used to examine...

- Vowels!!
- Liquids/Glides
- Place of articulation cues

Broadband spectrograms are most useful for examining the timing of the various sounds of words, as well as vowels.

Broadband spectrograms are used to examine...

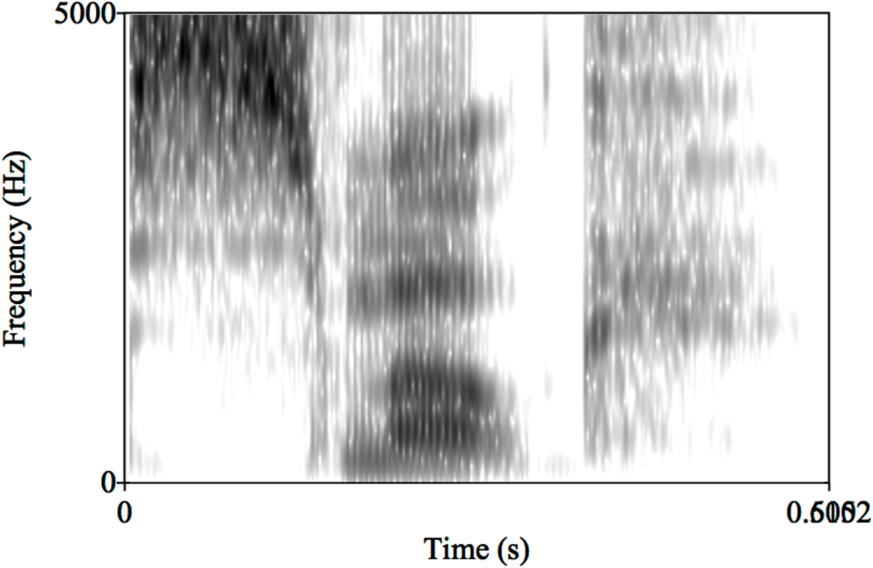
- Vowels!!
- Liquids/Glides
- Place of articulation cues
- VOT

Broadband spectrograms are most useful for examining the timing of the various sounds of words, as well as vowels.

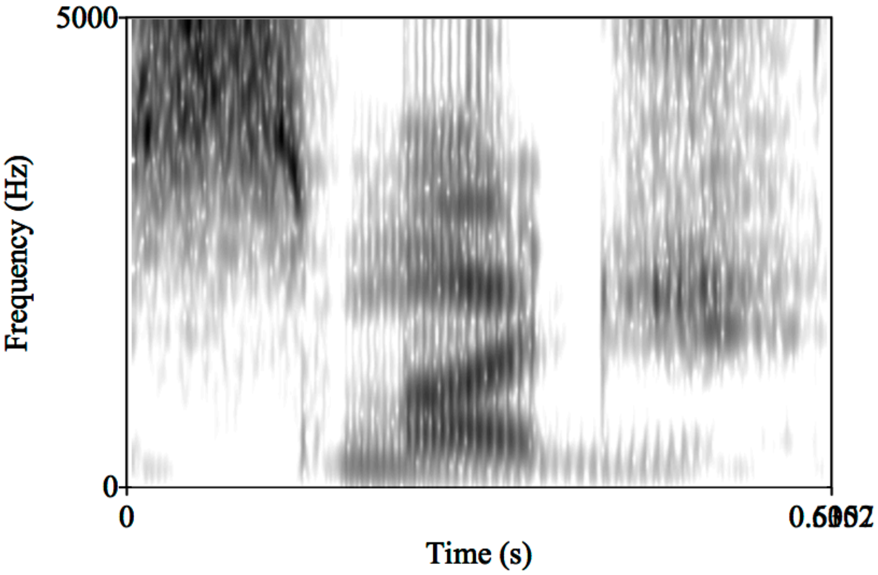
Broadband spectrograms are used to examine...

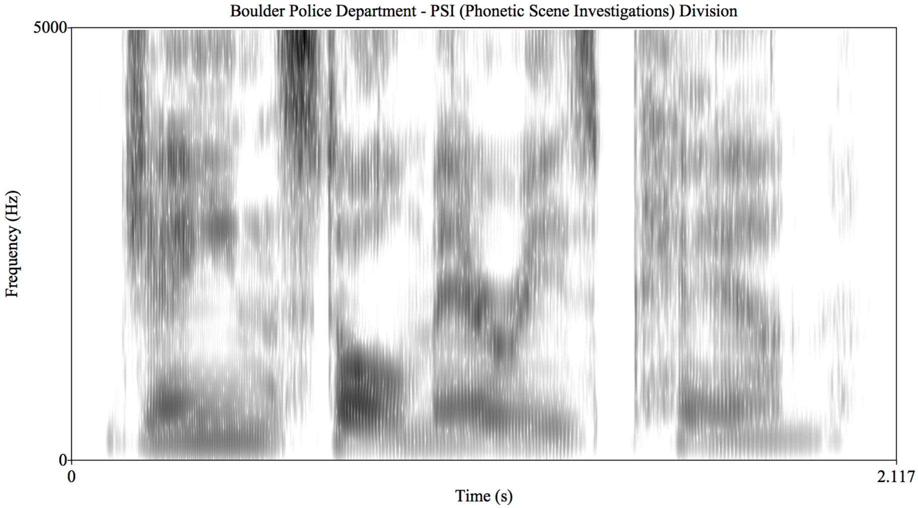
- Vowels!!
- Liquids/Glides
- Place of articulation cues
- VOT
- Duration

"Smoke"

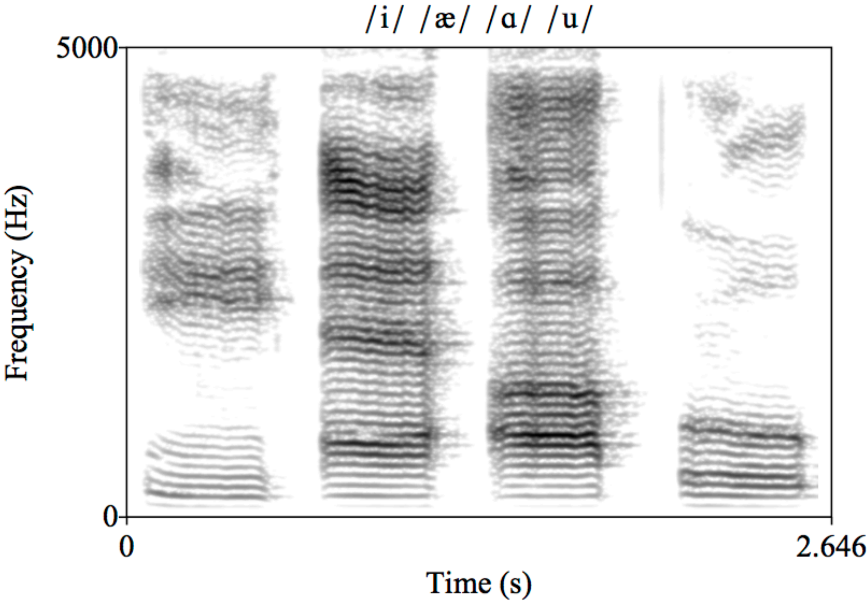


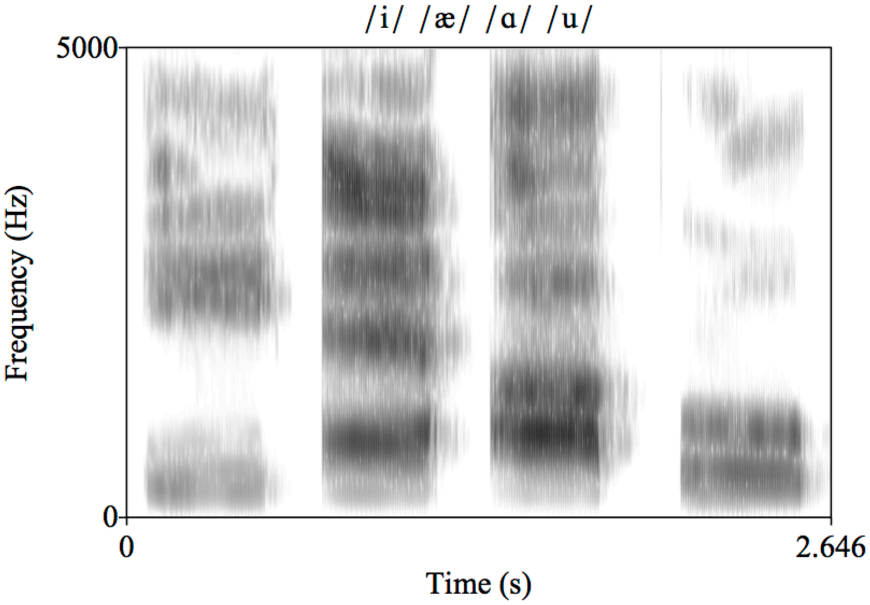
"Smudge"





"Jane Stole Mary's Pan"


/i/ /æ/ /ɑ/ /u/
5000
0
Frequency (Hz)
0
2.646
Time (s)


/i/ /æ/ /ɑ/ /u/
5000
0
Frequency (Hz)
0
2.646
Time (s)

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... and there are many ways to visualize those waves.

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Every visualization method has strengths and weaknesses.

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Every visualization method has strengths and weaknesses.

You need to pick the best tool for the job.

... but how are we capturing the waves?

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and how are we saving them with machines which only understand 0 and 1?

To be continued!