24.910 Topics in Linguistic Theory: Laboratory Phonology
Spring 2007

24.910
Laboratory Phonology

Readings: Johnson (textbook)

- chapter 1,
- chapter 2, pp.19-33,
- chapter 3

I. Vowel inventories

- Common vowel inventories:

i u a	i u e o a	i u e o ɛ ɔ a
Arabic, Nyangumata, Aleut, etc.	Spanish, Swahili, Cherokee, etc.	Italian, Yoruba, Tunica, etc.

- Unattested vowel inventories:

i e a	i ɯ e ɤ a	i u ɪ ʊ

Why?

II. Perceptual cues and the distribution of phonological contrasts

- Phonological contrasts generally have restricted distributions.
- E.g. Lithuanian voicing contrasts

  a. obstruent voicing is distinctive before vocoids and consonantal sonorants:

áu**k**le	nu**k**niaũti	au**g**lingas	dre**g**na
sil**p**nas	ry**t**metỹs	sko**b**nis	bã**d**metys

  b. obstruent voicing is neutralized (to voiceless) word-finally:

  [dau**k**] [ka**t**]

  c.obstruent voicing is neutralized before any obstruent (assimilating in voicing to following obstruent):

a[**d**-g]al	mè[**z**-d]avau	dìr[**p**-t]i	dè[**k**-t]i

II. Perceptual cues and the distribution of phonological contrasts

Different contrasts have different characteristic patterns of distribution (Steriade 1999):

(i) Obstruent voicing contrasts are permitted only before sonorants
(e.g. German, Lithuanian, Russian, Sanskrit).

(ii) Major place contrasts (labial vs. coronal vs. dorsal) are permitted only before vowels
(e.g. Japanese, Luganda, Selayarese).

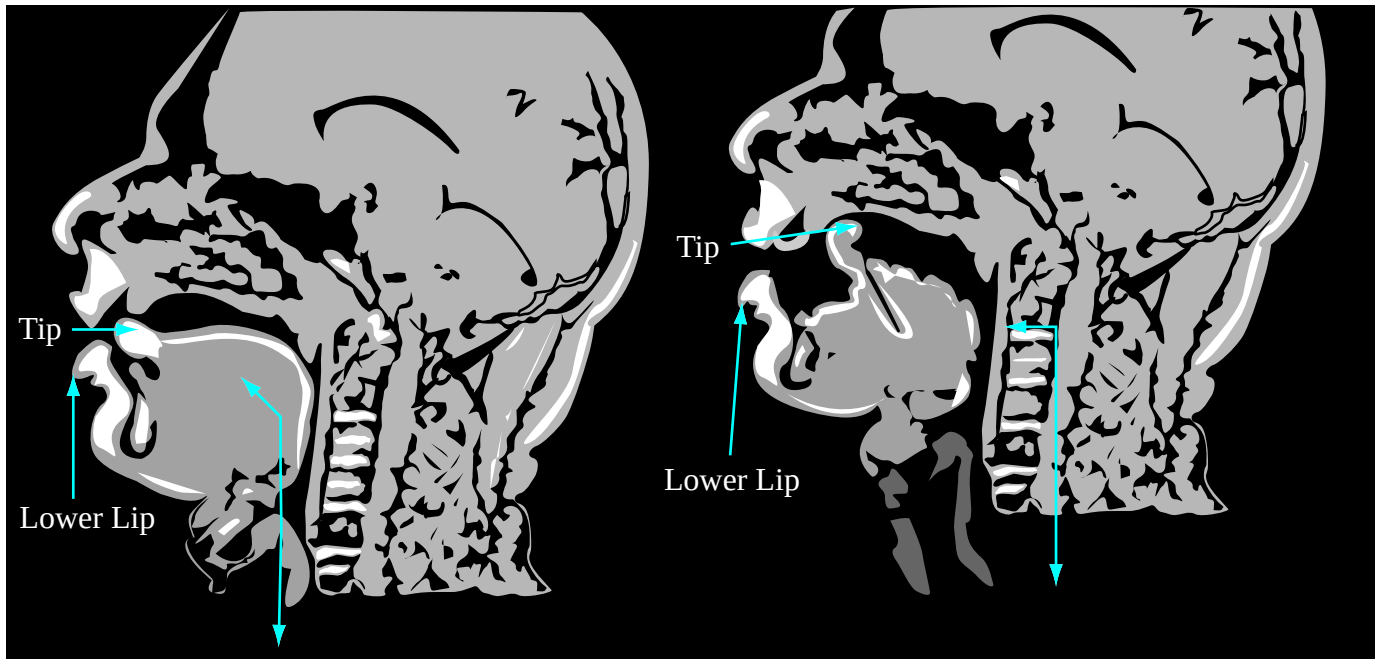
(iii) Retroflexion contrasts (retroflex vs. apical alveolar) are permitted only after vowels
(e.g. Gooniyandi, Miriwung, Walmatjari).

II. Perceptual cues and the distribution of phonological contrasts

Hypothesized explanation: ‘The likelihood that distinctive values of the feature F will occur in a given context is a function of the relative perceptibility of the F-contrast in that context’ (Steriade 1999).

- Contrasts differ in their distribution of cues so they are subject to different patterns of neutralization.
- Obstruent voicing is best cued by Voice Onset Time - only realized with a following sonorant.

The phonetics and phonology of retroflex consonants

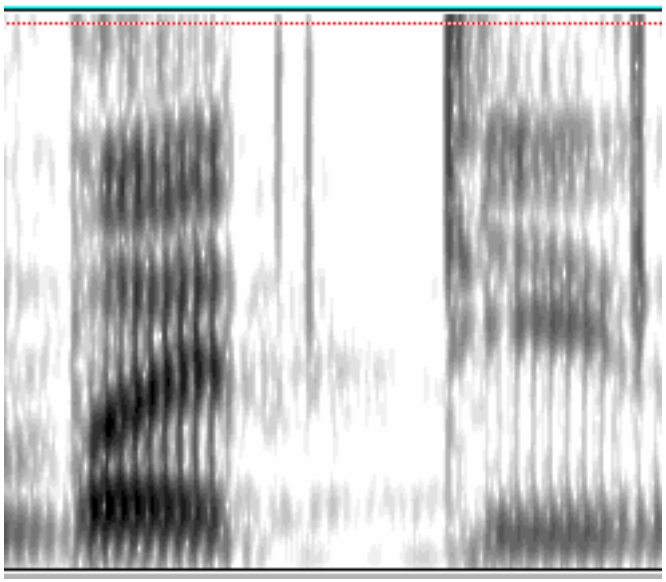


dental [l̪] retroflex [ɭ]

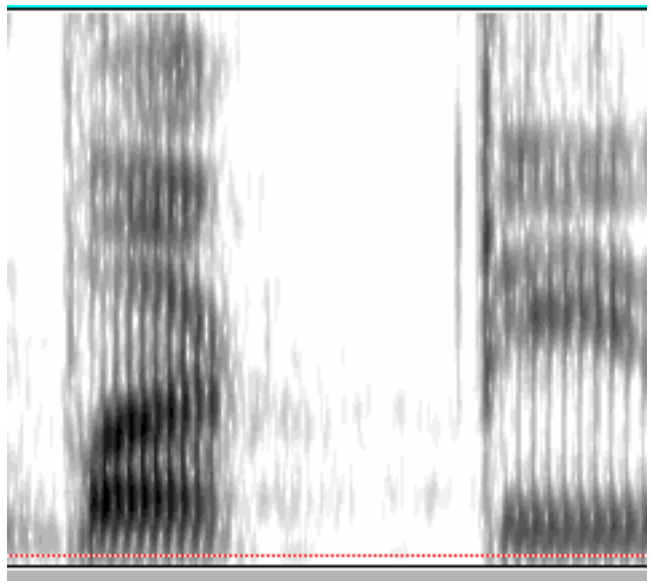
MRI images of Tamil laterals (Narayanan et al 1999)

Figure by MIT OpenCourseWare, adapted from Narayanan, Shrikanth, Dani Byrd, and Abigail Kaun.
"Geometry, Kinematics, and Acoustics of Tamil Liquid Consonants." *The Journal of the Acoustical Society of America* 106, no. 4 (October 1999): 1993-2007.

The phonetics and phonology of retroflex consonants



apical alveolar [t]



retroflex [ʈ]

Malayalam

Distribution of retroflexion contrasts in Gooniyandi (Steriade 1995)

Intervocalic: **contrast**

	apico-alveolar	**retroflex**
oral stops	**ɟutu** 'straight'	**ɟuɖu** 'GLOSS'
nasals	**maniŋa** 'night time'	**maɳiŋga** 'sister'
laterals	**wila** 'ok, finish'	**wiɭa** 'back'
rhotics	**ɟari** 'if'	**ɟaːɽi** 'dry roots'

Word final, post V apicals: **contrast**

apico-alveolar	retroflex
jawan (subsection term)	**jilŋiɳ** 'dew'

Distribution of retroflexion contrasts in Gooniyandi

Preconsonantal, post V apicals: **contrast**

	apico-alveolar	retroflex
oral stops	**dʃ**	**ɖb, ɖg**
nasals	**nʃ, ng, nɲ**	**ɳʃ, ɳg, ɳm, ɳɲ**
laterals	**lb, lʃ, lg, lm, lɲ, lw**	**ɭb, ɭj, ɭg, ɭm, ɭɲ, ɭw**

e.g.: **ɟunɟunanaɟgu** 'pardalote' vs. **gambunɟuwa** (toponym)
balŋaŋa 'outside' vs. **wanbiŋa** 'I'll go'

Word-initial: **no contrast** (free variation):
ʈu:wu: ~ tu:wu 'cave'
ɳɑ:gʌ ~ nɑ:gʌ 'dress'

Postconsonantal: **no contrast**
Apical clusters: **nd, ɳɖ, ld, ɳɭ**
e.g.: **banɖi** 'spider' vs. **jambiyindi** (subsection name)
banɭundi 'I returned'

Distribution of retroflexion contrasts in Gooniyandi

Summary:

- Contrast between retroflex and apical alveolar after vowels V_#, V_V
- No contrast elsewhere #_, V_C

- This pattern of distribution is common in Australian and Dravidian languages.
- An unusual pattern of distribution - major place contrasts, voicing contrasts occur preferentially before vowels.

Distribution of retroflexion contrasts

Explanation (Steriade 1995, etc):

- The primary cues to the contrast between retroflex and apical alveolar are located in the VC transitions (unlike major place contrasts.
  - Most retroflex consonants are retroflexed at closure, but the tongue tip moves forward during closure.
  - At release tongue tip position is similar to an apical alveolar, consequently the release and CV transitions of the two consonant types are similar.
- Contrasts preferentially appear in environments where they are better cued.

Warlpiri [ʈ] from onset of closure to post-release: Butcher 1993

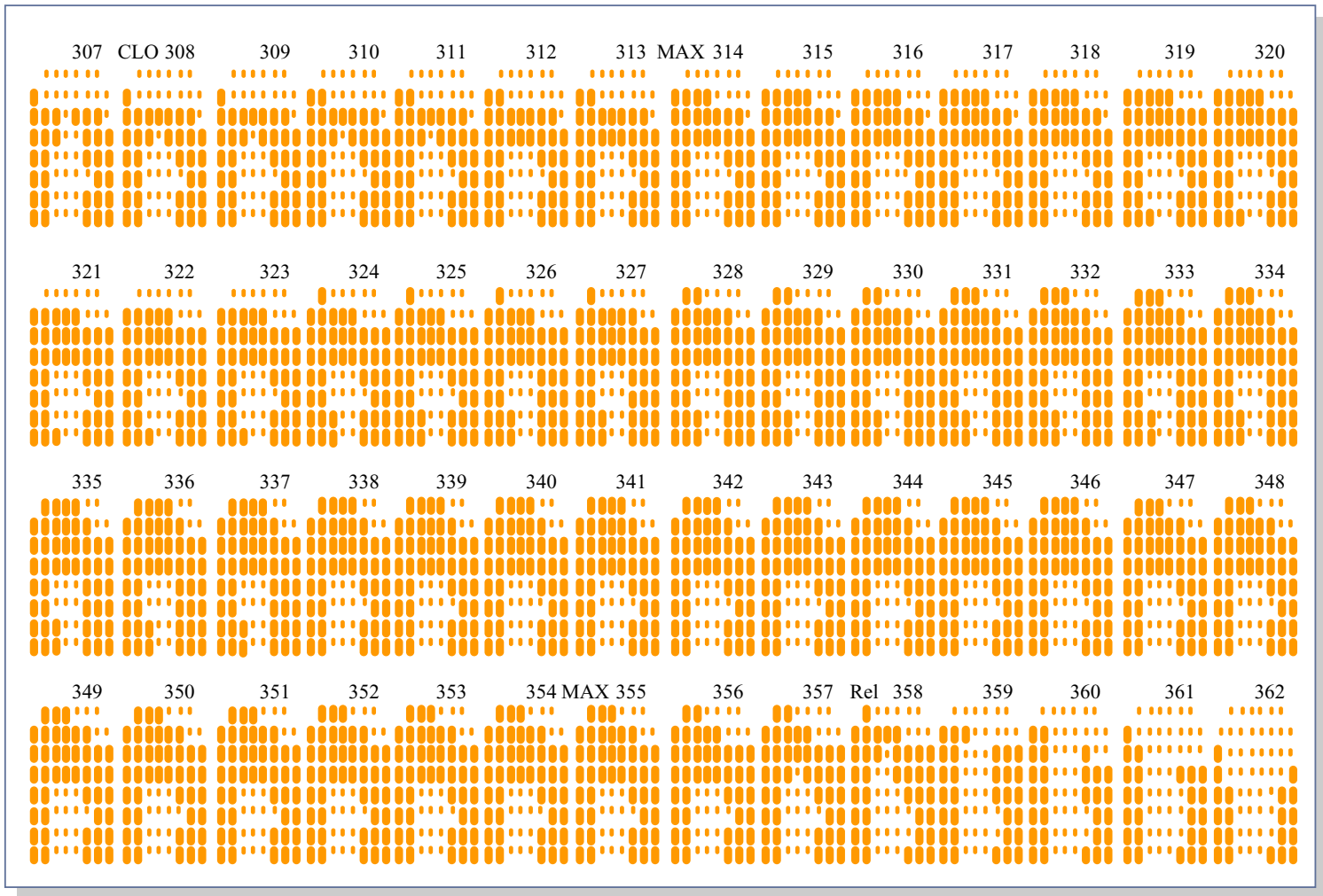


Figure by MIT OpenCourseWare. Adapted from Butcher, Andrew. "The Phonetics of Australian Languages." Flinder University, South Australia, 1993. Unpublished manuscript.

Warlpiri [t] from onset of closure to post-release

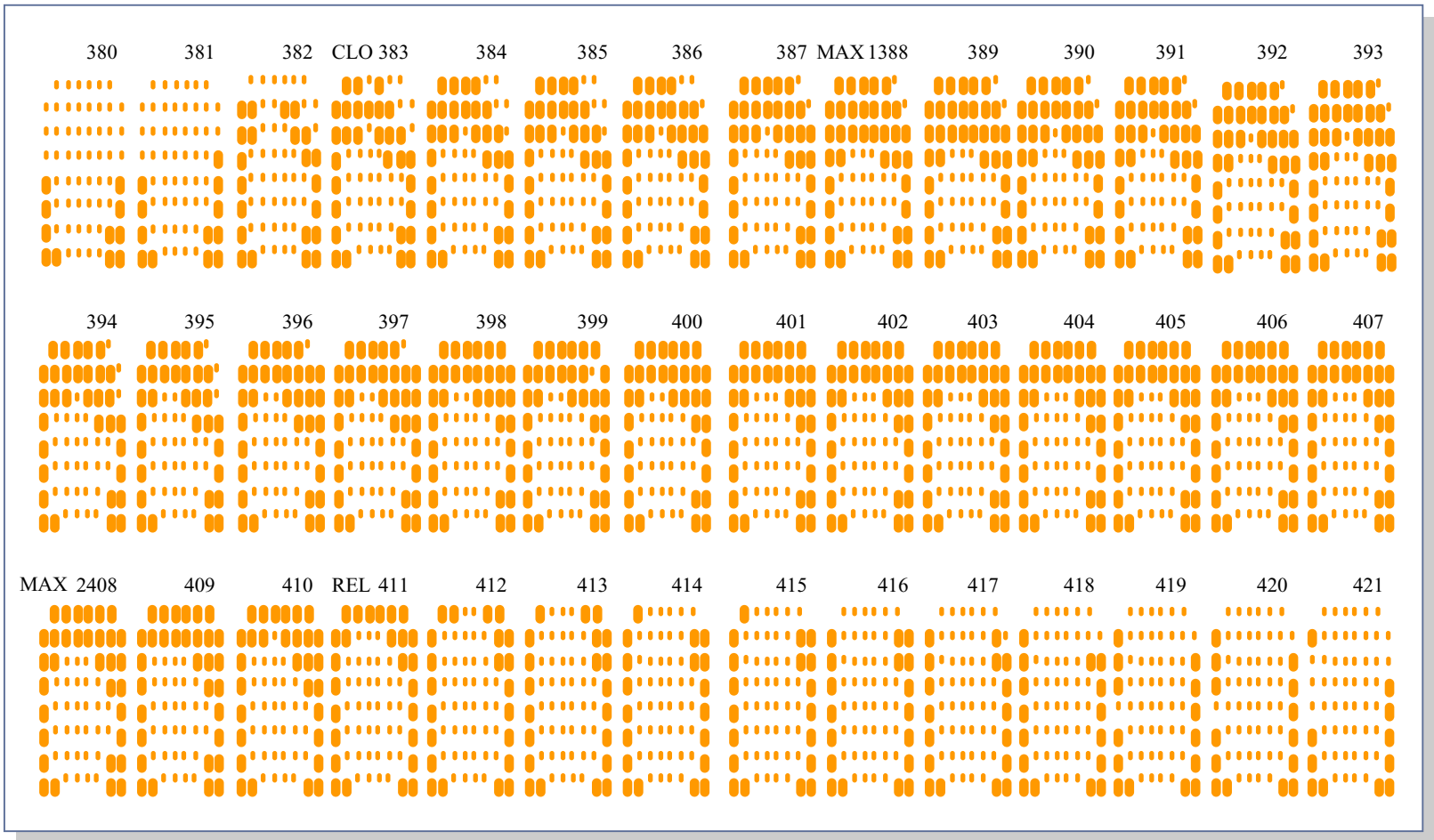


Figure by MIT OpenCourseWare. Adapted from Butcher, Andrew. "The Phonetics of Australian Languages." Flinder University, South Australia, 1993. Unpublished manuscript.

Distribution of retroflexion contrasts

- Acoustic studies provide evidence concerning the differences between apical alveolar and retroflex consonants.
- Articulatory studies help to explain the observed acoustic patterns.
- Perceptual studies confirm that retroflexion contrasts are more difficult to discriminate in the absence of a preceding vowel (Anderson 1997).
- Phonological theory to relate these properties to the observed distribution of retroflexion contrasts.

III. Focus and intonation in English

- Focus - “the informative part of an utterance”.
- ‘the information in the sentence that is assumed by the speaker not to be shared by him and the hearer’ (Jackendoff 1972).
- E.g. Question/answer pairs:

  a. (When did John paint the shed?)

  John painted the shed YESTERDAY.

  #JOHN painted the shed yesterday.

  b. (Who painted the shed yesterday?)

  JOHN painted the shed yesterday.

  #John painted the shed YESTERDAY.

III. Focus and intonation in English

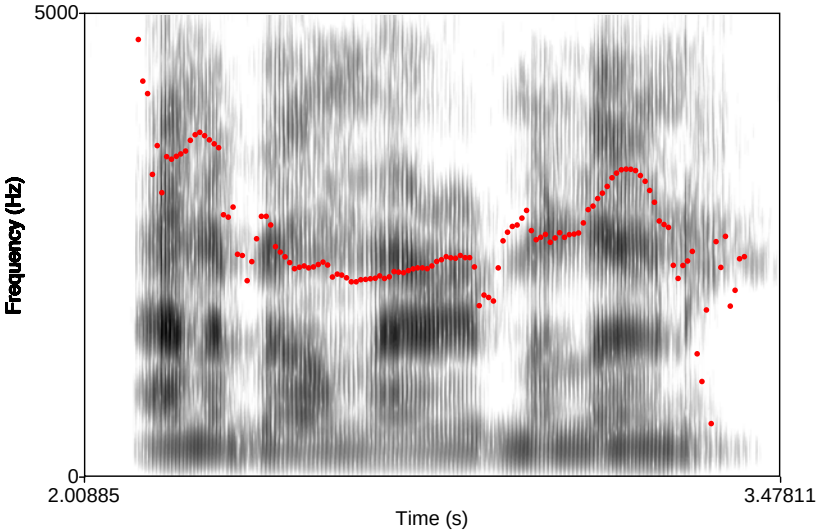
‘Focus sensitive particles’ make the truth conditions of a sentence dependent on the location of focus:

1. Jan only gave BILL money.
2. Jan only gave Bill MONEY.

- Focus is marked by some kind of prominence. What is this exactly?

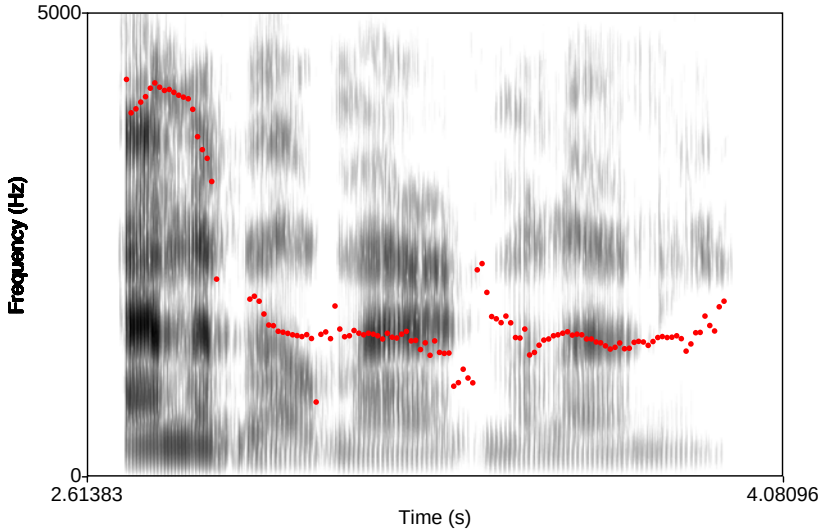
Broad focus:
'what happened'

Audio:
1_broad.wav



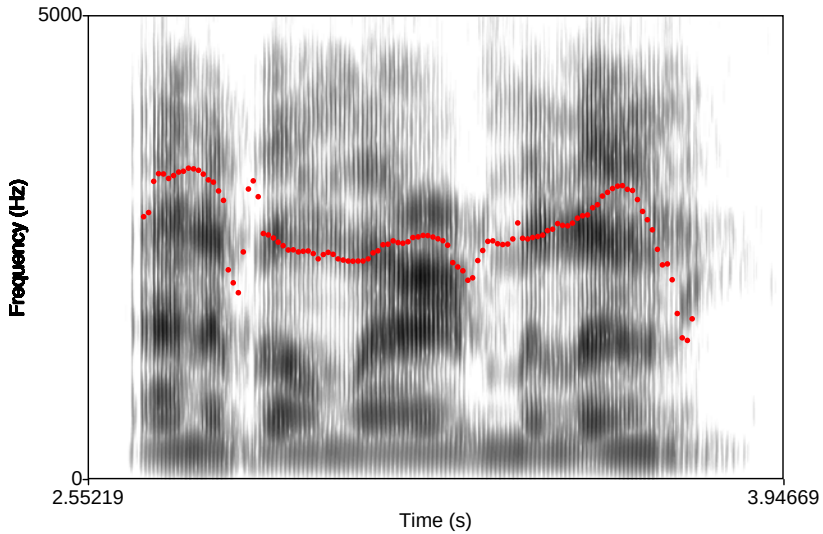
Subject focus:
'who married Maloney?'

Audio:
1_subj.wav



Object focus:
'Who did Annabel marry?'

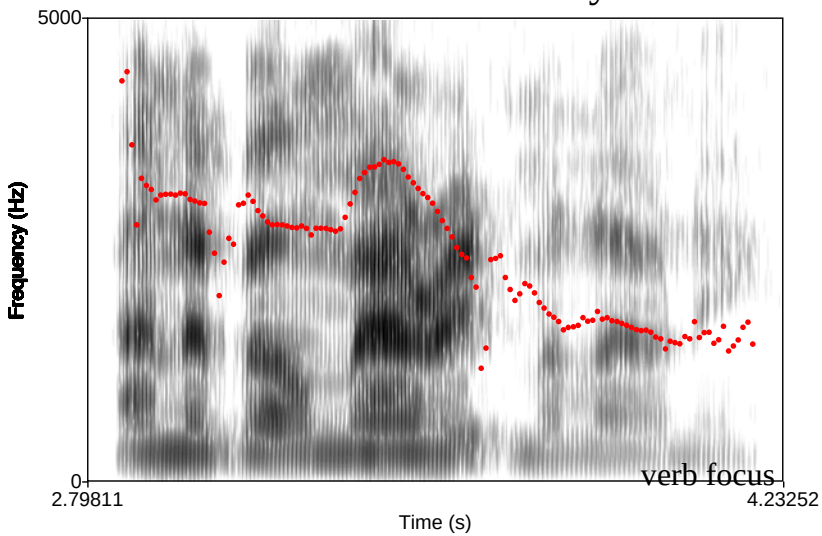
Audio:
1_obj.wav



Annabel married Maloney

Verb focus:
'what did Annabel do to Maloney?'

Audio:
1_verb.wav



Annabel married Maloney

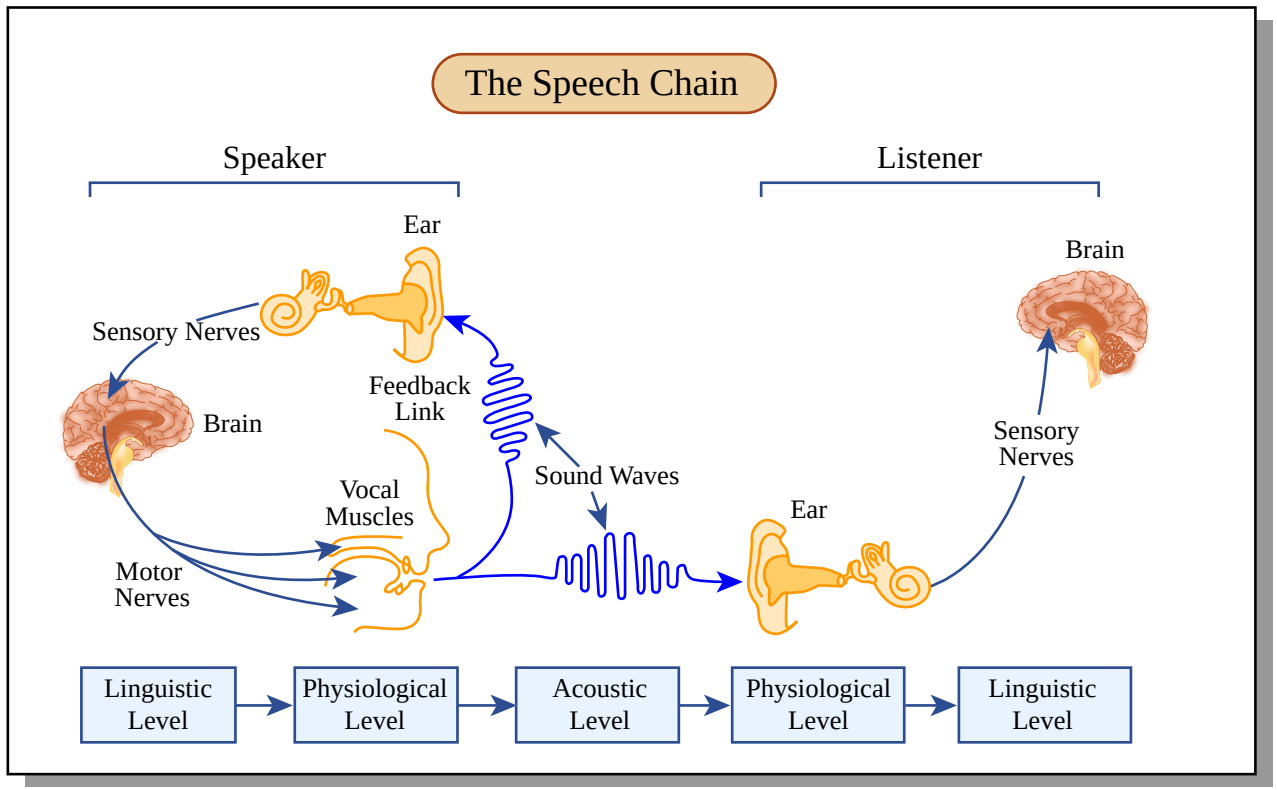


Figure by MIT OpenCourseWare. Adapted from Denes, Peter B., and Elliot N. Pinson.
The Speech Chain: The Physics and Biology of Spoken Speech. 2nd ed. New York, NY: W. H. Freeman, 1993. ISBN: 9780716723448.

Articulation-
The speech production system

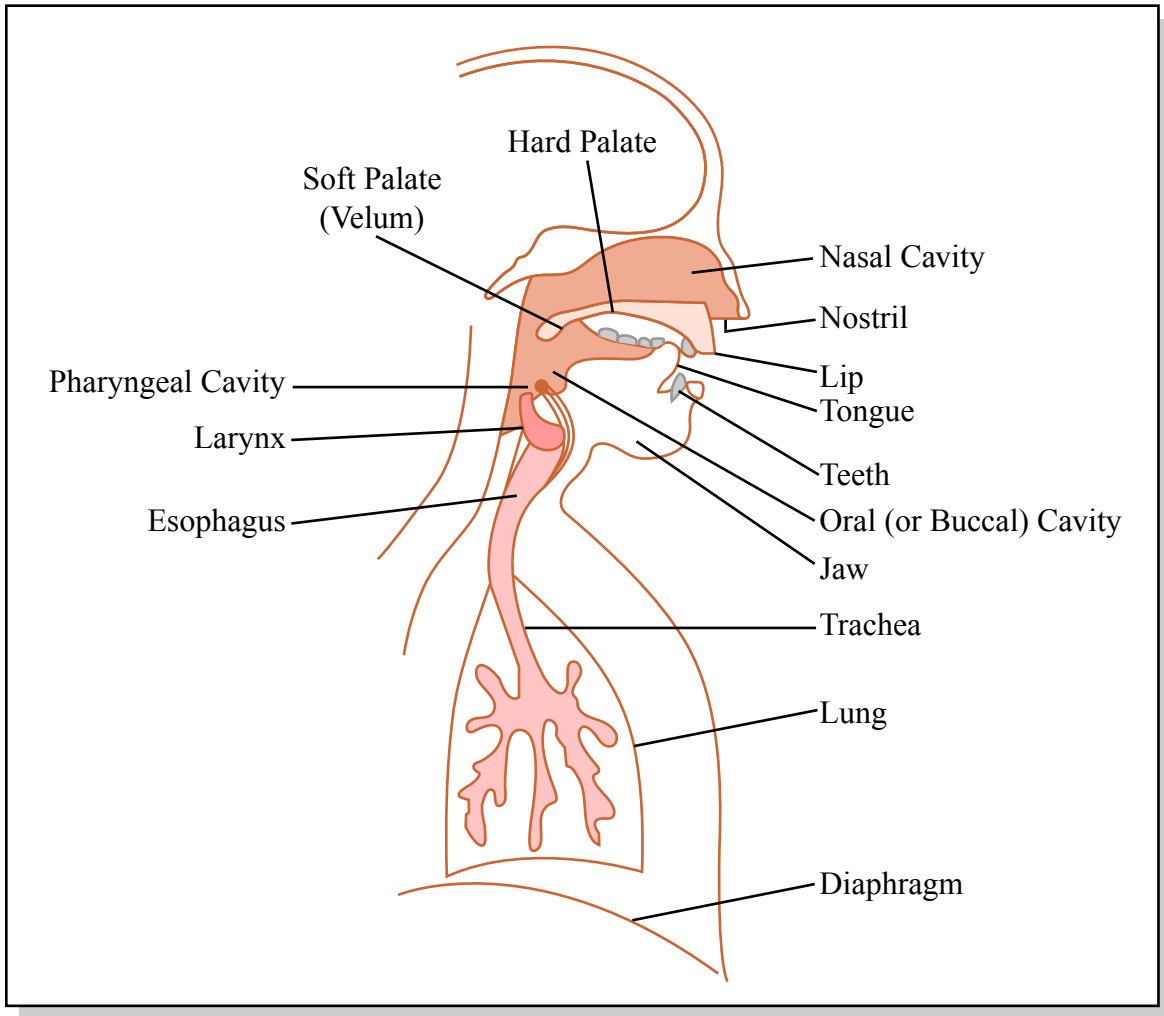
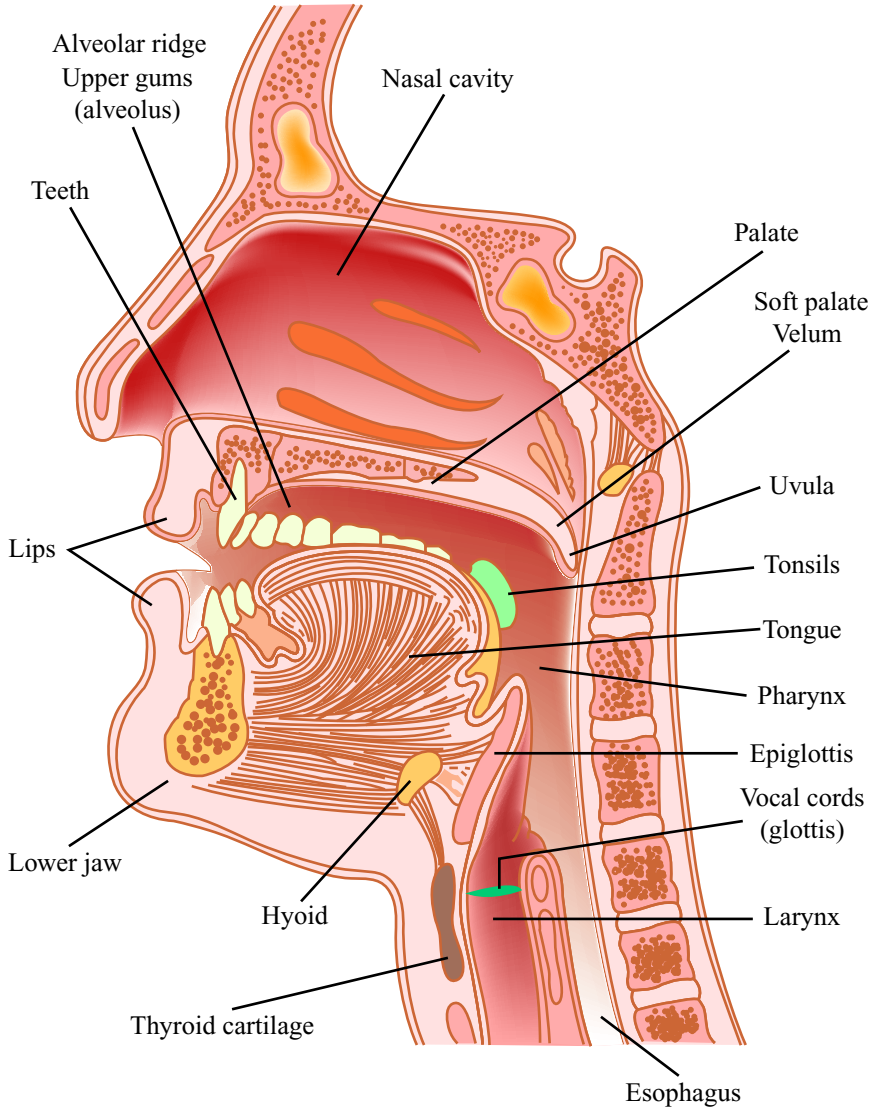


Figure by MIT OpenCourseWare.

The vocal tract



Vocal tract configuration with raised soft palate for articulating non-nasal sounds.

Articulatory description of speech sounds

Consonants:

- Voicing
- Place of articulation
- Manner
- Lateral/Central
- Nasal/Oral

- [s] voiceless alveolar central oral fricative

Articulatory description of speech sounds

Vowels:

- High-low
- Front-back
- Rounded-unrounded

- [e] mid front unrounded vowel

Movie removed due to copyright restrictions.

Please see “Tongue Video” in Peter Ladefoged’s *Vowels and Consonants.*

Introduction to acoustics

- Sound consists of pressure fluctuations in a medium…

  …which displace the ear drum in such a way as to result in stimulation of the auditory nerve.

animation

Speech acoustics

- Movements at a source produce a sound wave in the medium which carries energy to the perceiver.
- Pressure fluctuations move through space, but each air particle moves only a small distance.

Animated image of longitudinal pressure wave removed due to copyright restrictions.

Representing sound waves

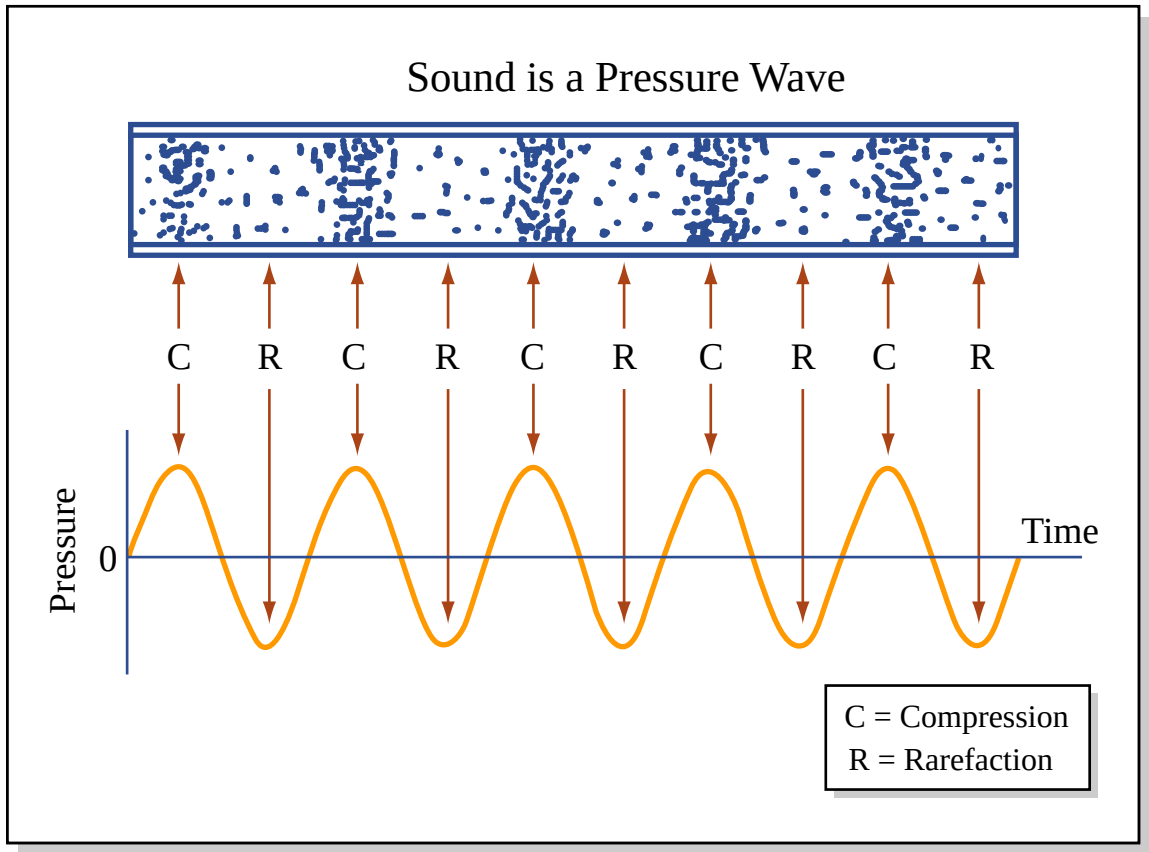
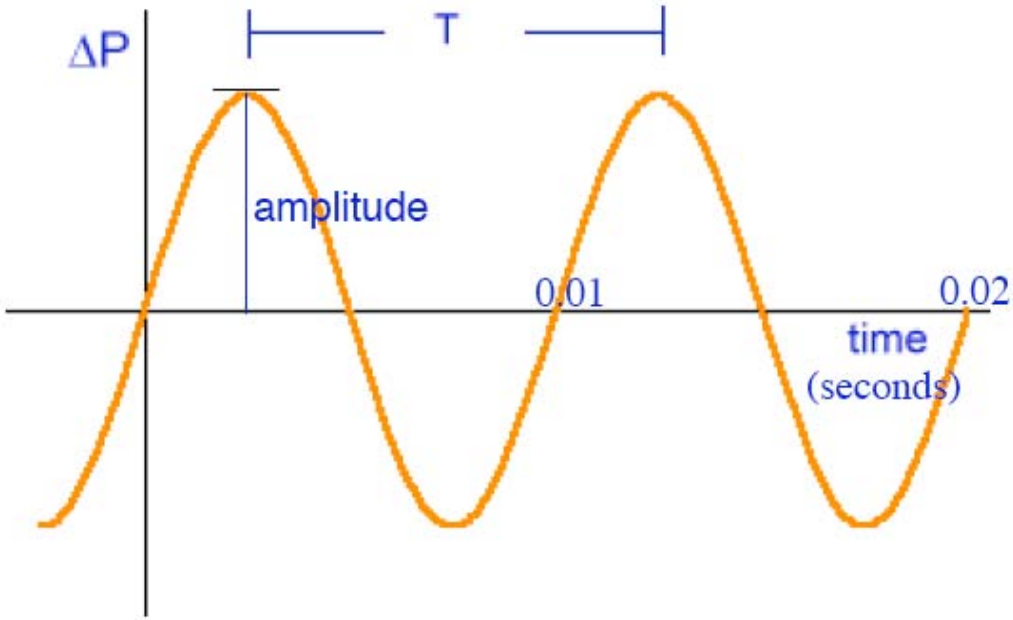


Image by MIT OpenCourseWare. Adapted from The Physics Classroom Tutorial.

Periodic sounds

- A waveform is periodic if it repeats at regular intervals.
- Frequency of a wave is the number of cycles occurring per unit of time.
  - Units: 1 Hertz (Hz) is 1 cycle/second



Periodic sounds

- Voiced sounds have complex (quasi-)periodic wave forms.
- The perceived pitch of a sound depends on its frequency.

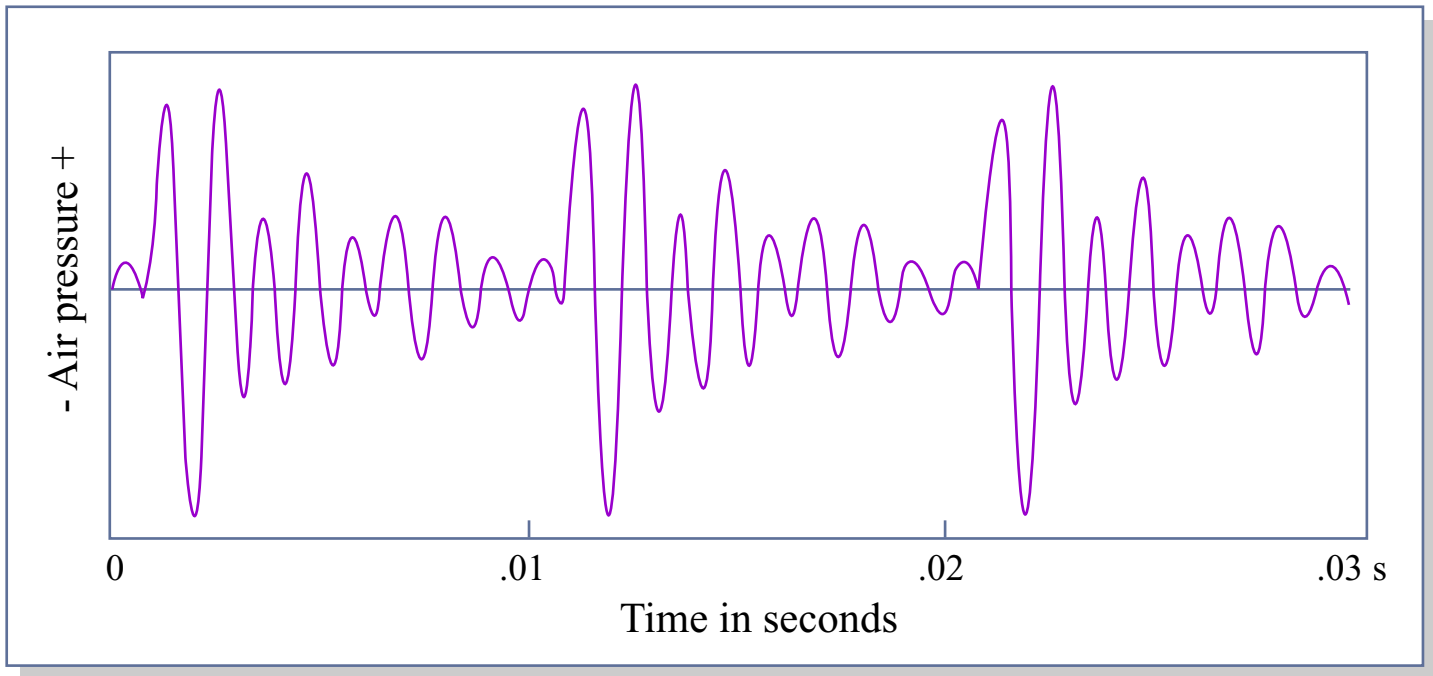
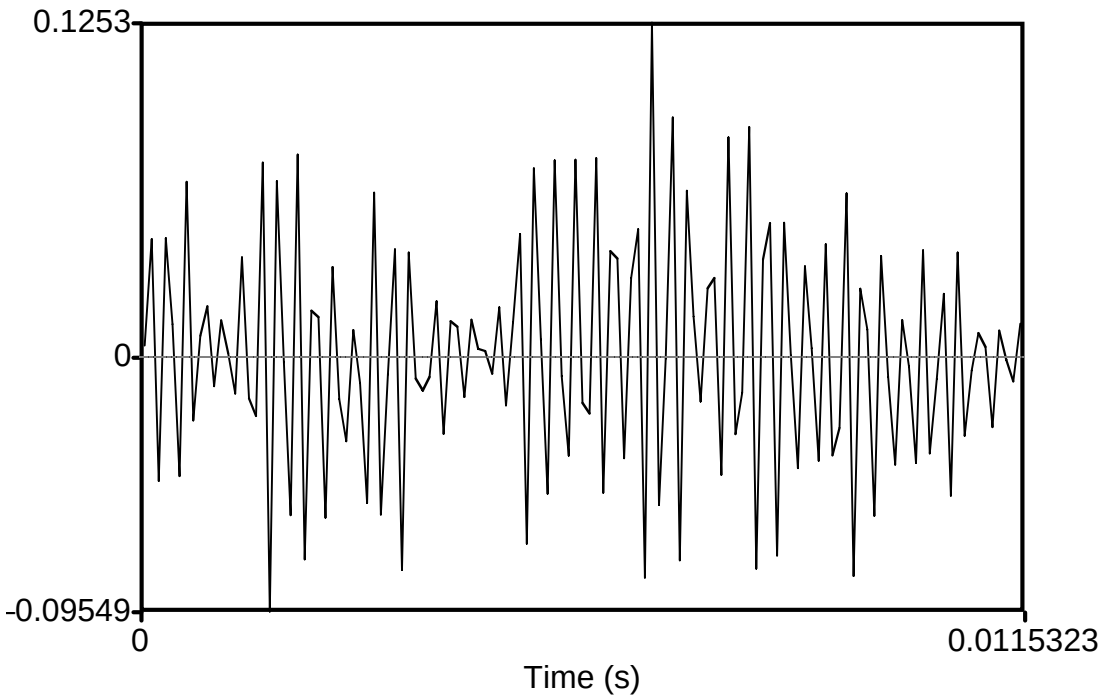


Figure by MIT OpenCourseWare.

Aperiodic sounds

- Aperiodic sounds have waveforms that do not repeat.
- Fricative noise is aperiodic.



Segment of [s]

Waveform of a sentence

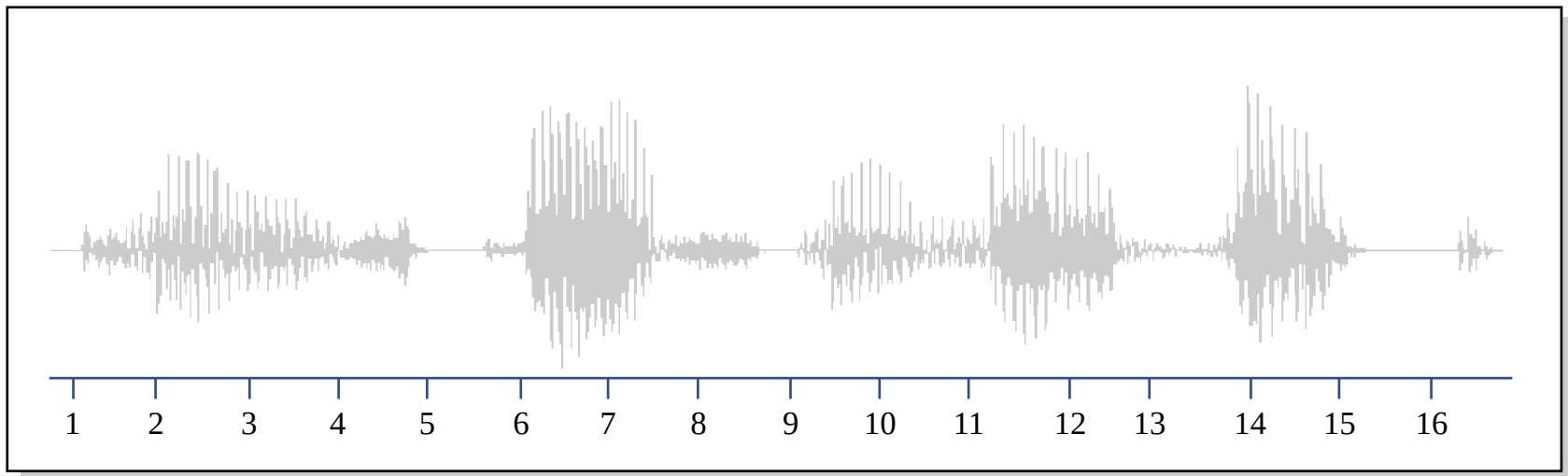


Figure by MIT OpenCourseWare.

Please pass me my book

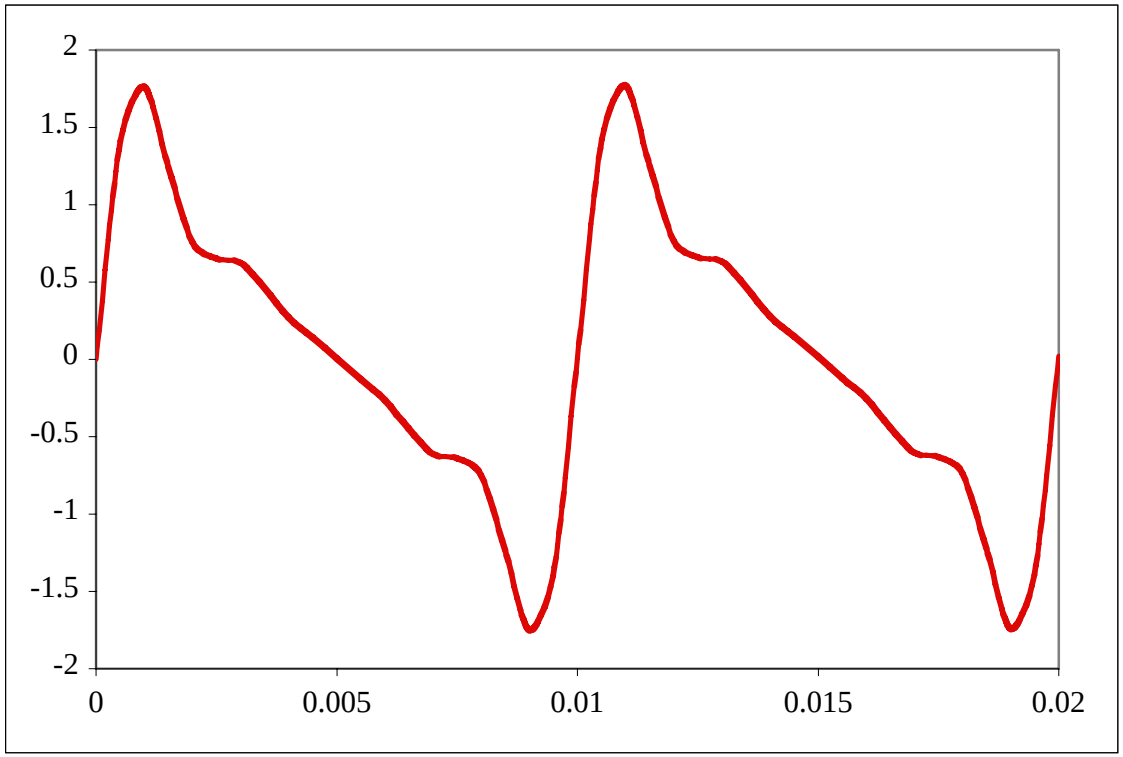
Spectrums and spectrograms

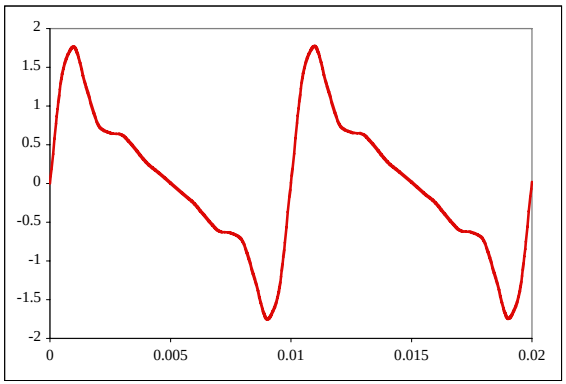
- The spectrum of a sound plays a central role in determining its quality or timbre.

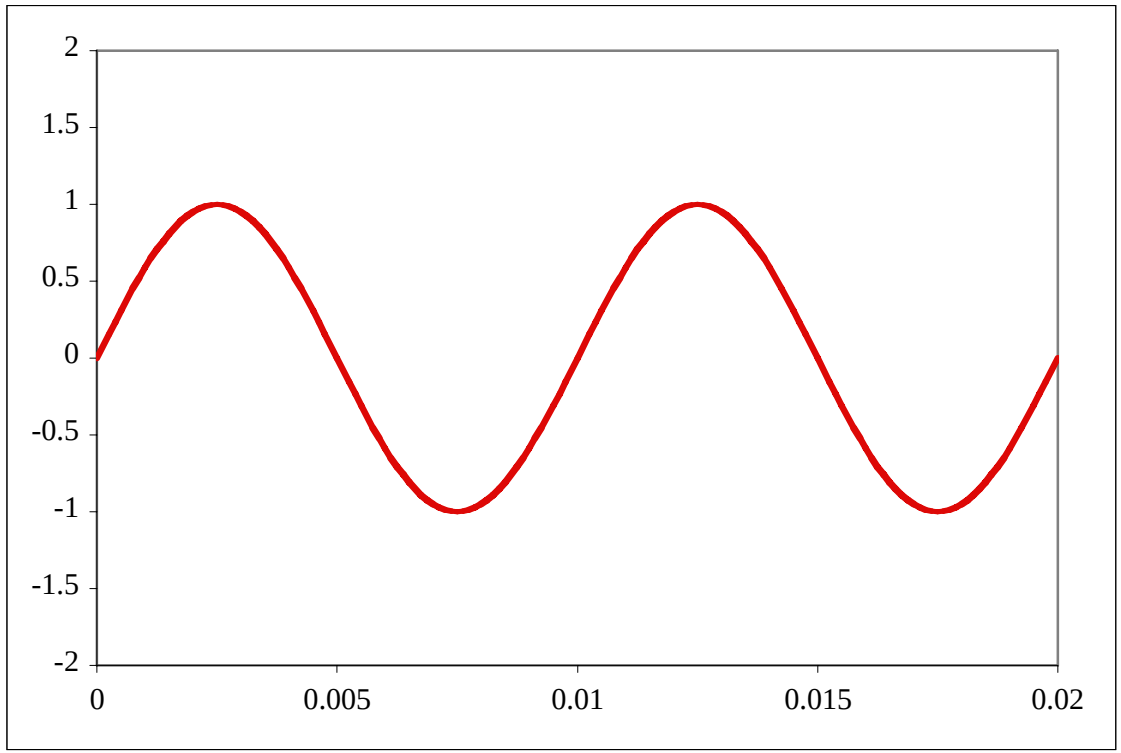
Spectral representation

- Any complex wave can be analyzed as the combination of a number of sinusoidal waves of different frequencies and intensities (Fourier's theorem).
- In the case of a periodic sound like a vowel these will be
  - the fundamental frequency
  - multiples of the fundamental frequency (harmonics)
- The quality of a periodic sound depends on the relative amplitude of its harmonics.

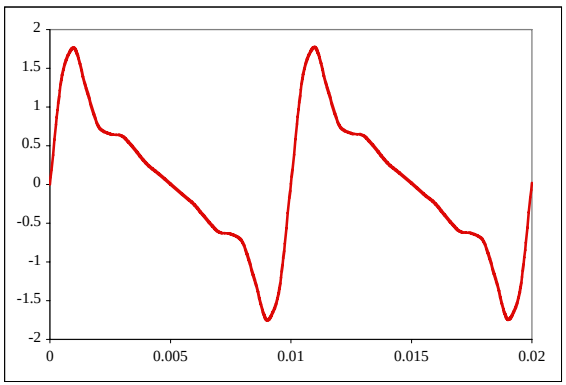
Spectral representation

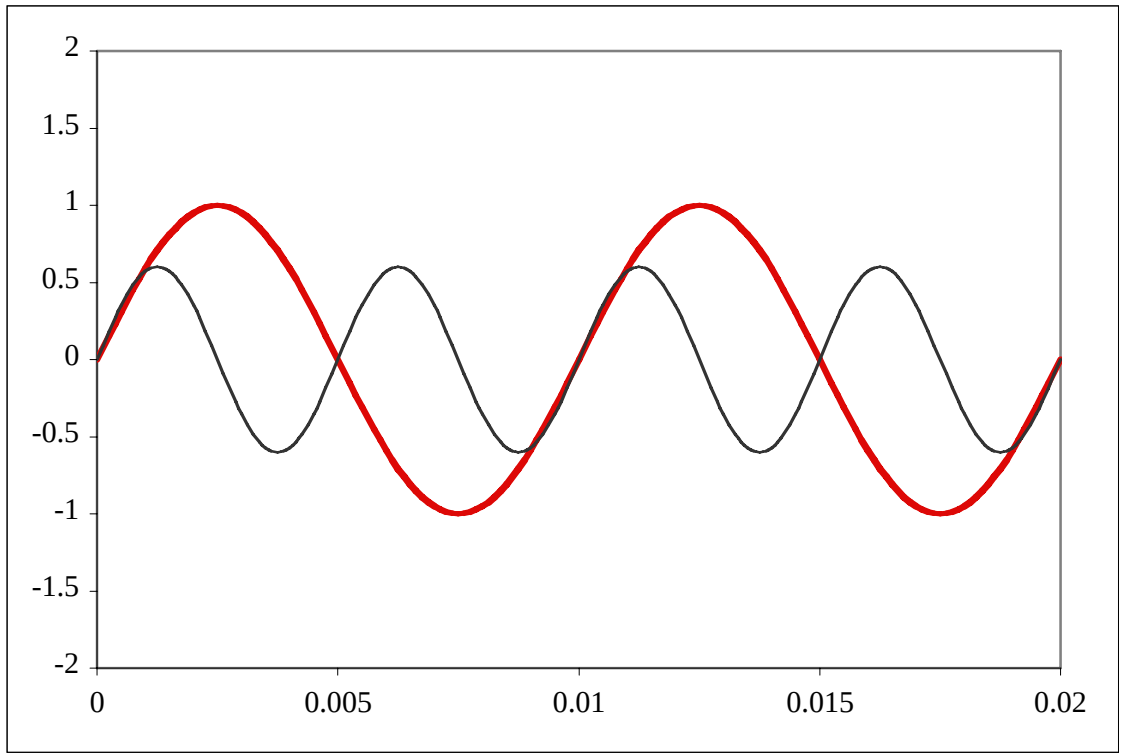




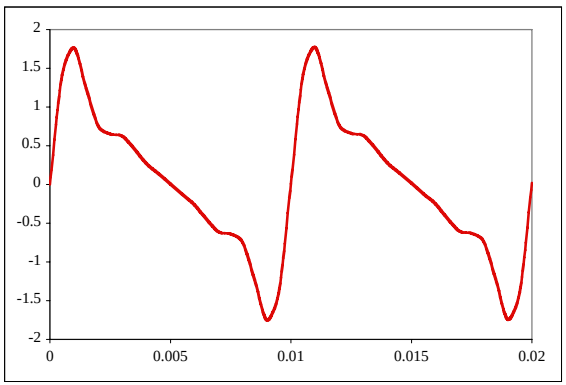


Fundamental frequency





2nd harmonic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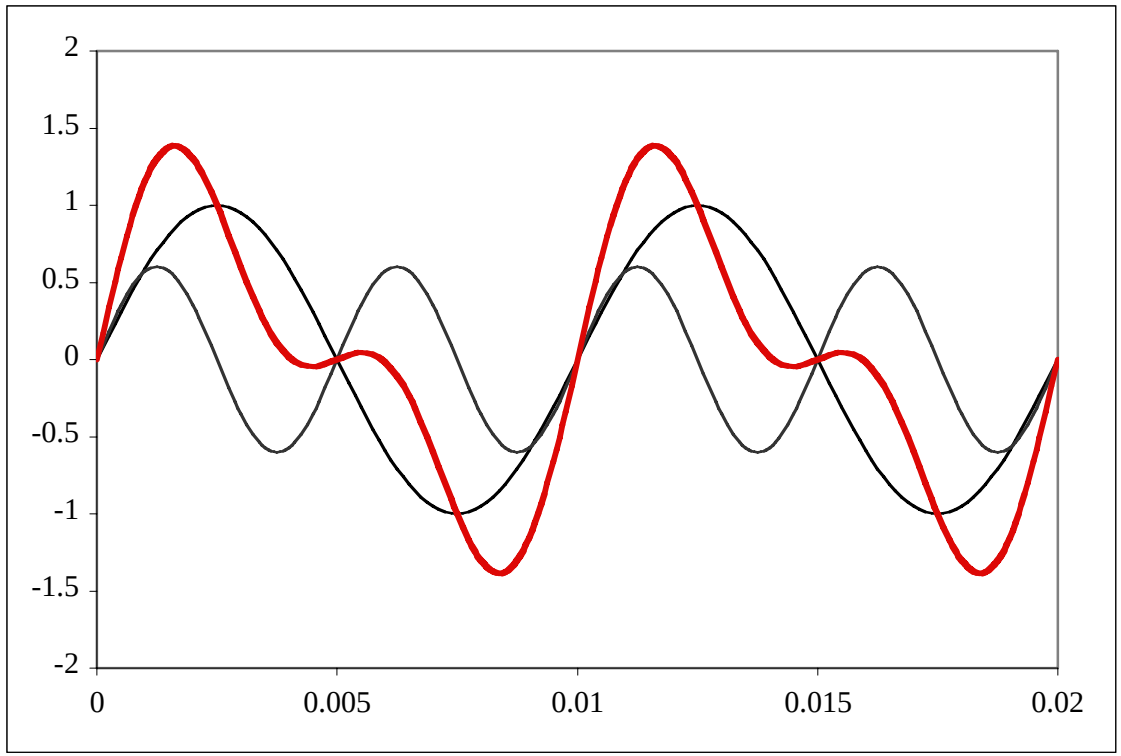
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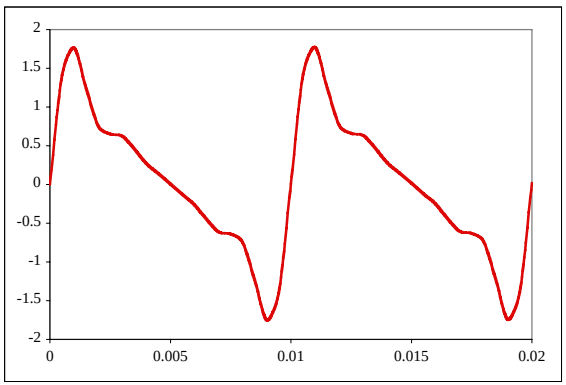
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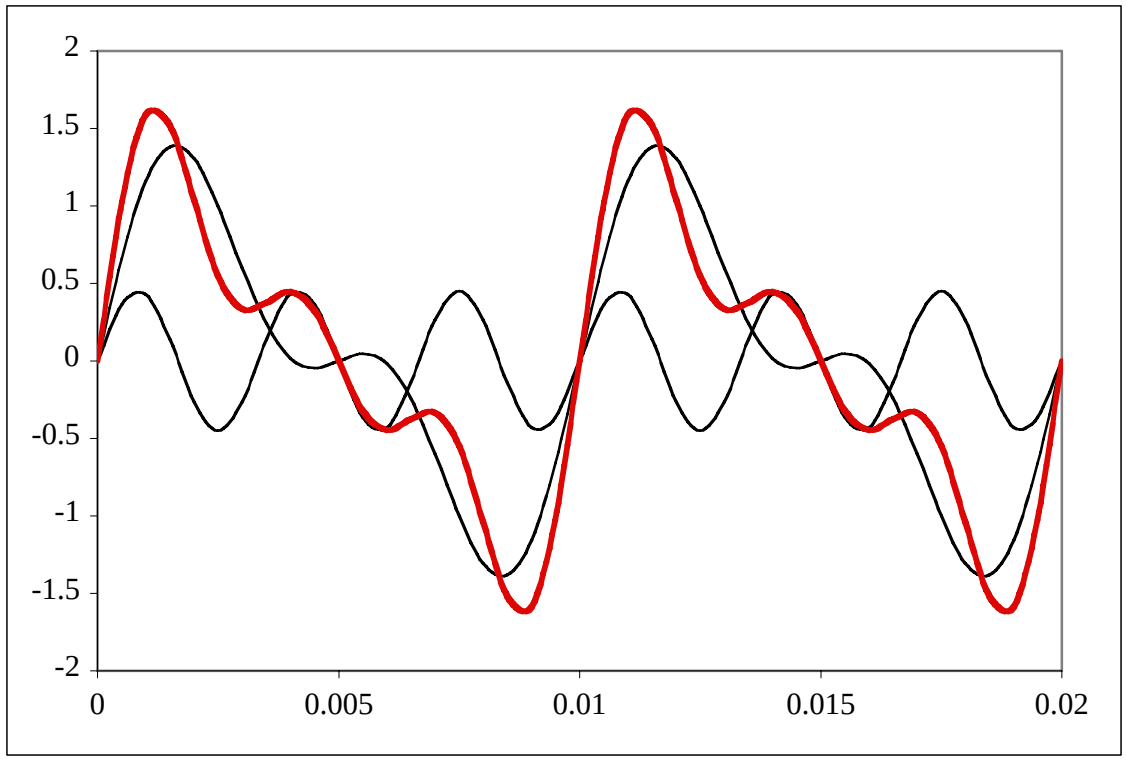
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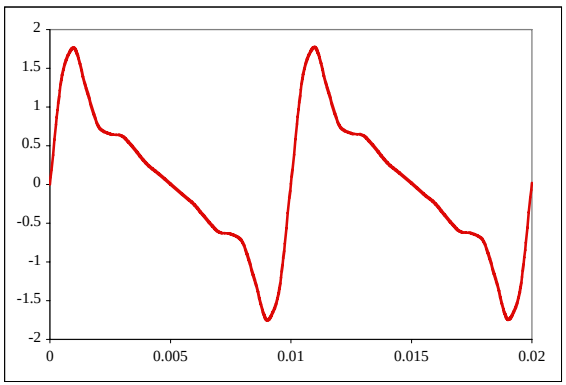
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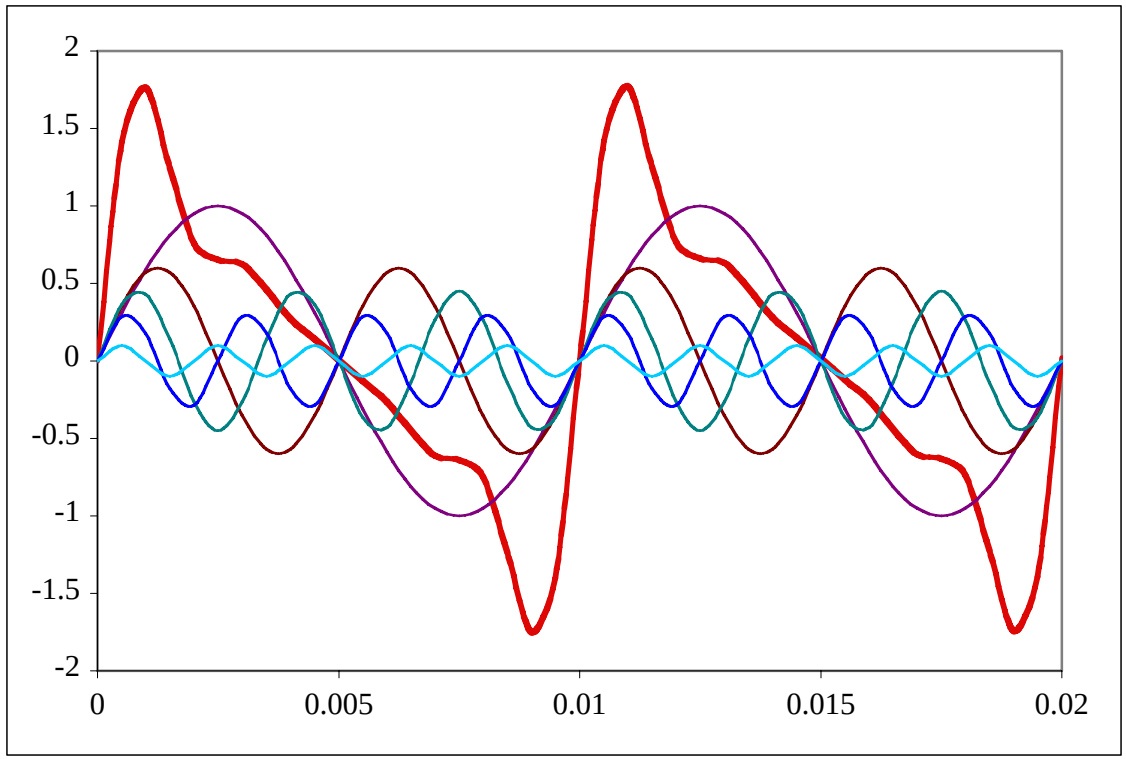
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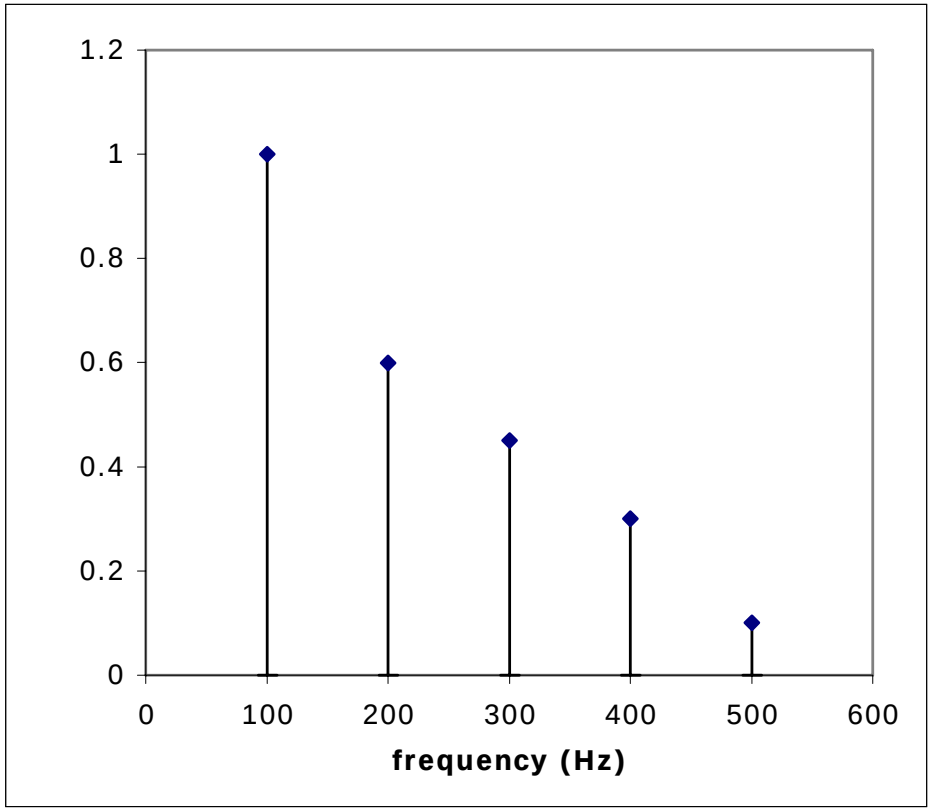
Spectral representation

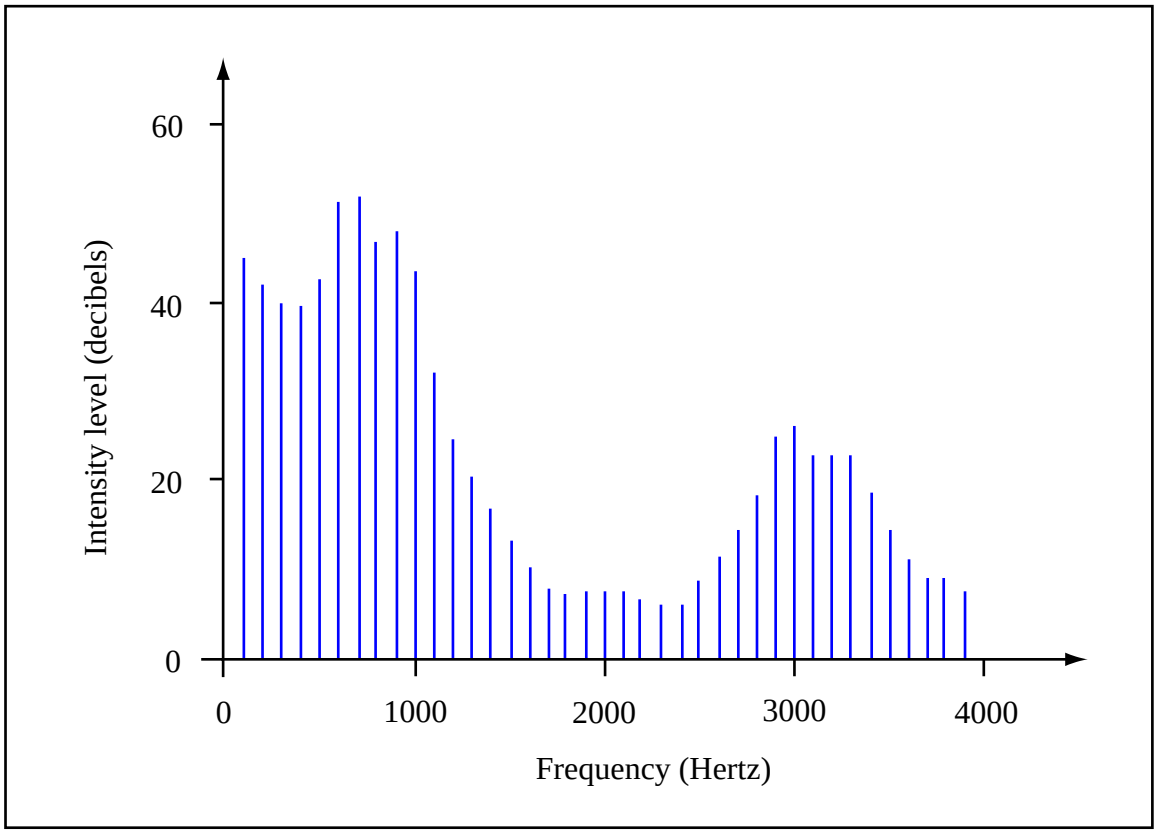
- Phase differences are relatively unimportant to sound quality, so key properties of a complex wave can be specified in terms of the frequencies and amplitudes of its sinusoidal components.

Frequency (Hz)	Amplitude
100	1
200	0.6
300	0.45
400	0.3
500	0.1



Power spectrum

Idealized vowel spectrum



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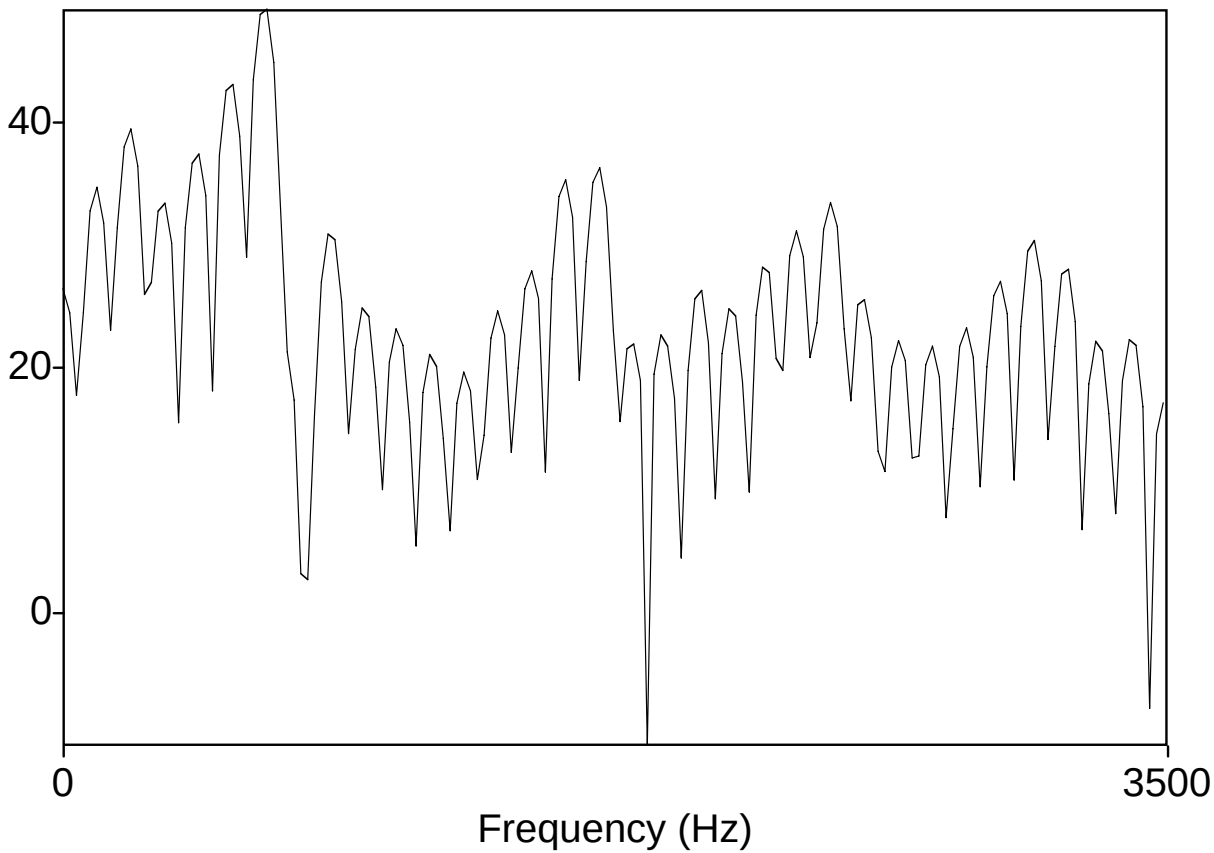
vowel spectrum

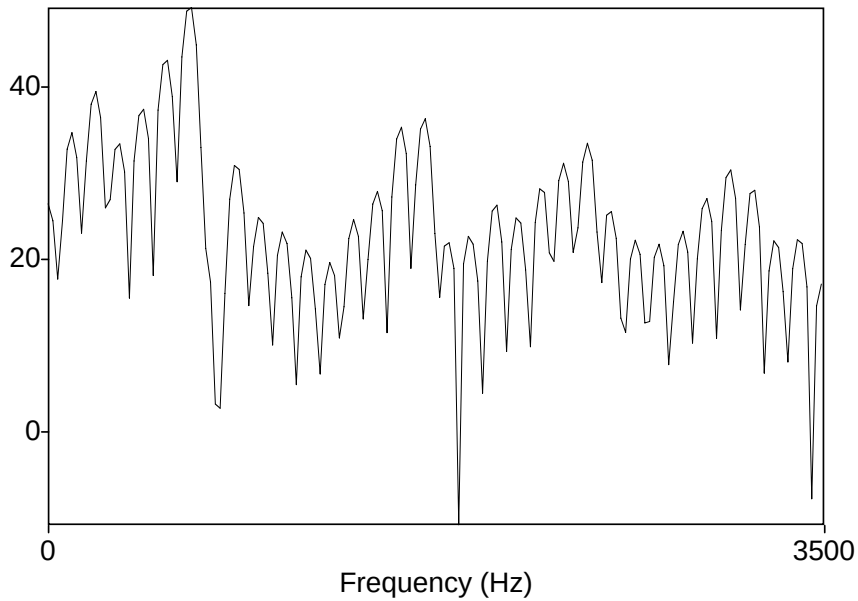


[æ]

Vowel quality

- The quality of a vowel depends on the shape of its spectrum.
- The shape of the spectrum depends on the shape of the vocal tract.

[æ]



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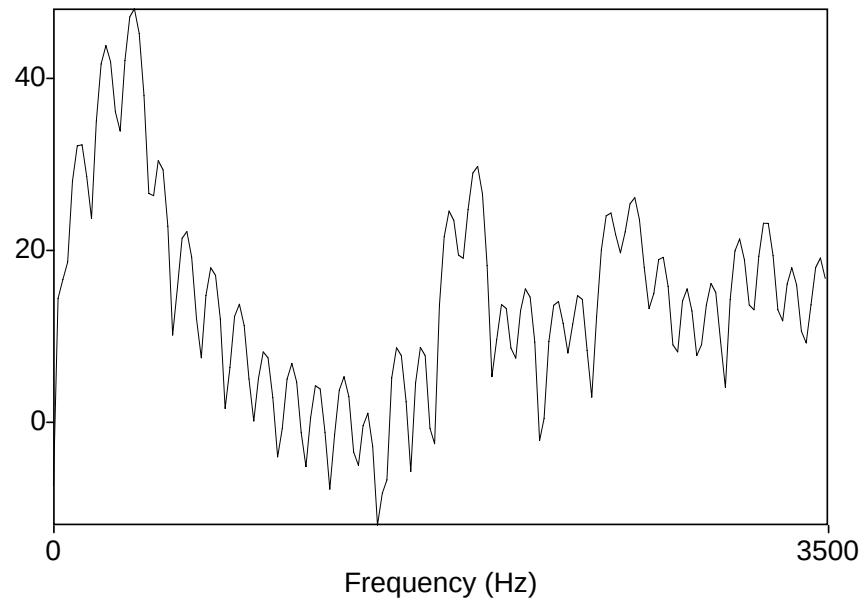
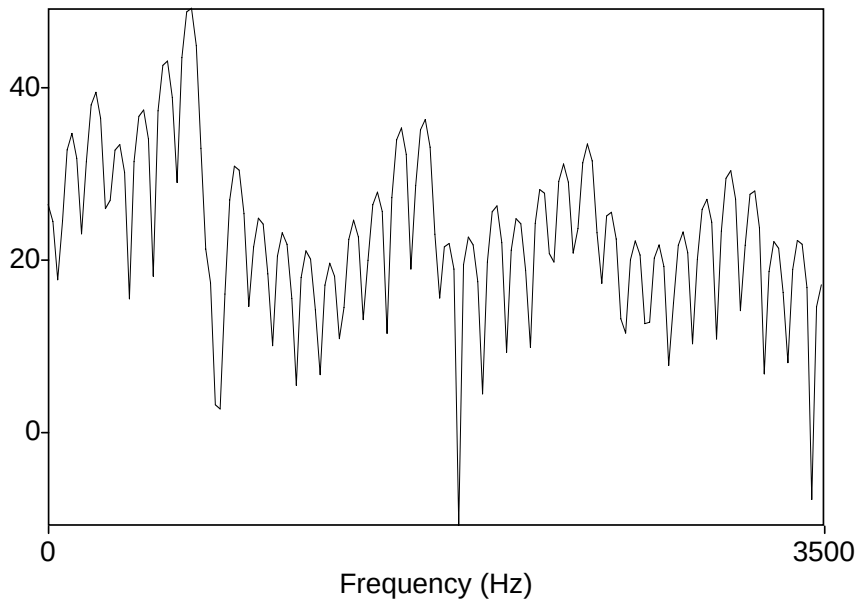


Vowel quality

- The peaks in the spectrum of a vowel are called **formants**.
- Perceived vowel quality depends primarily on the frequencies of the first three formants.

[æ]



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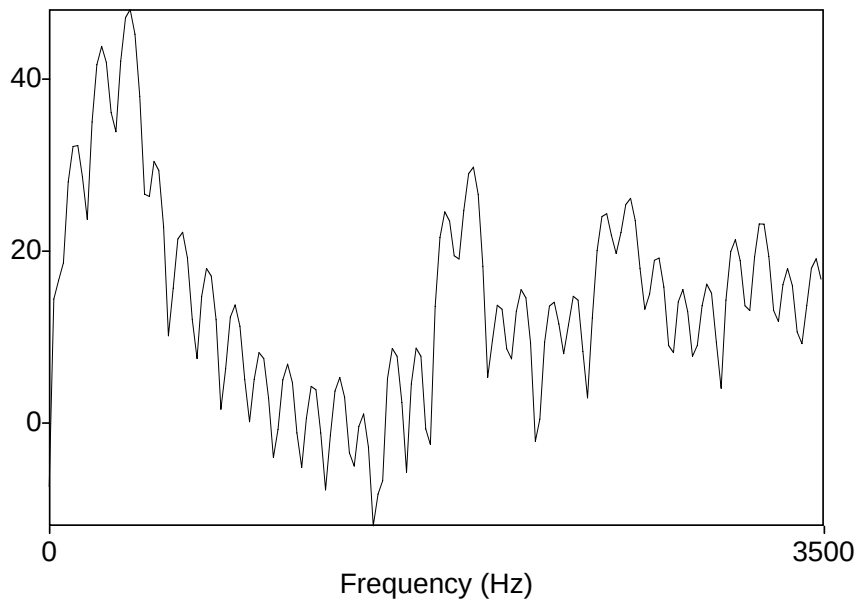
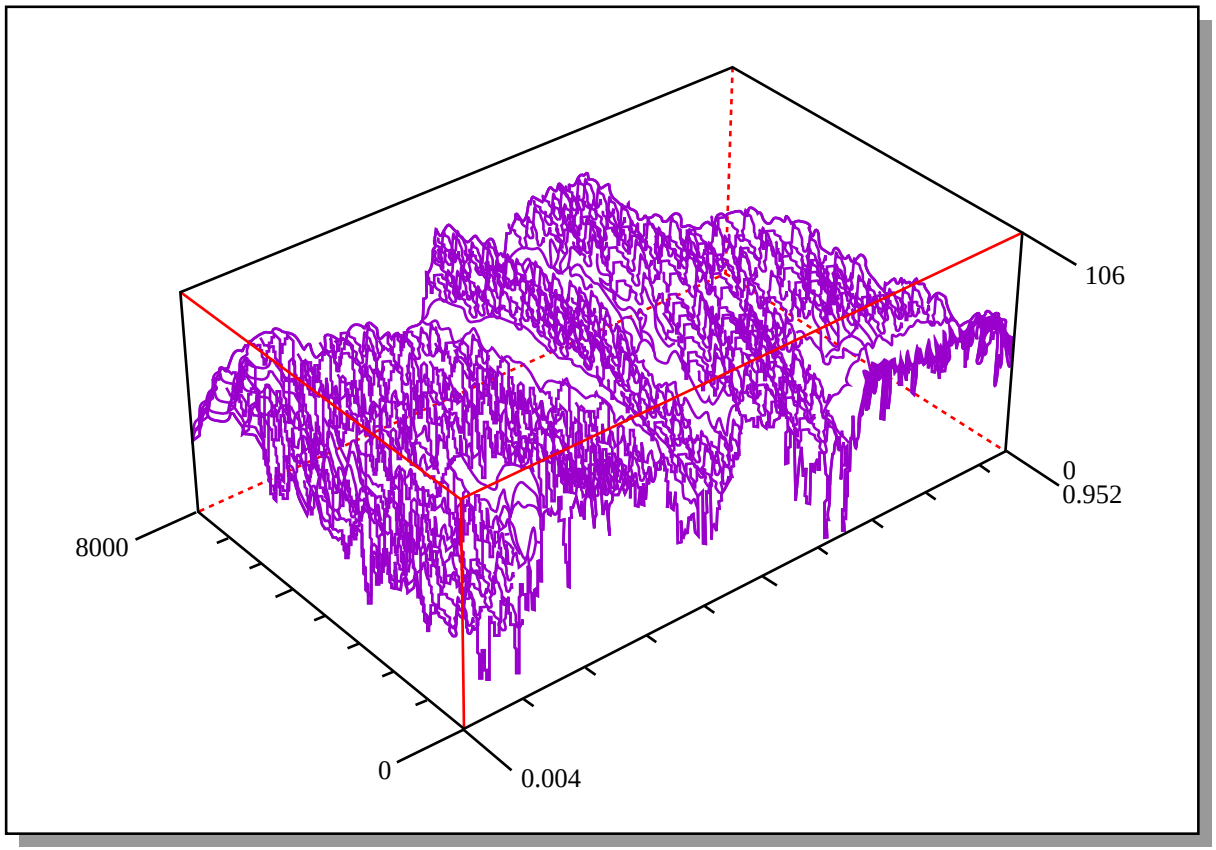


Spectrograms



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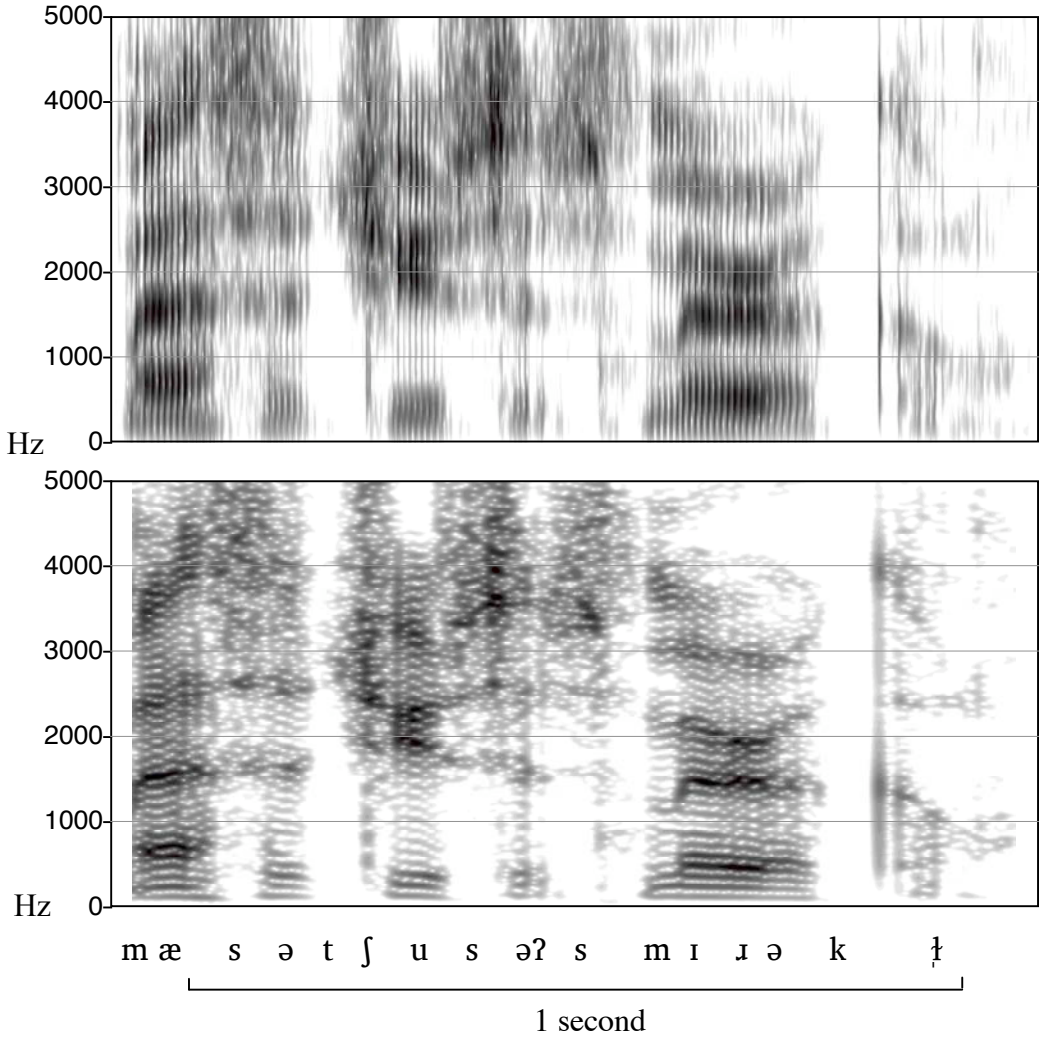
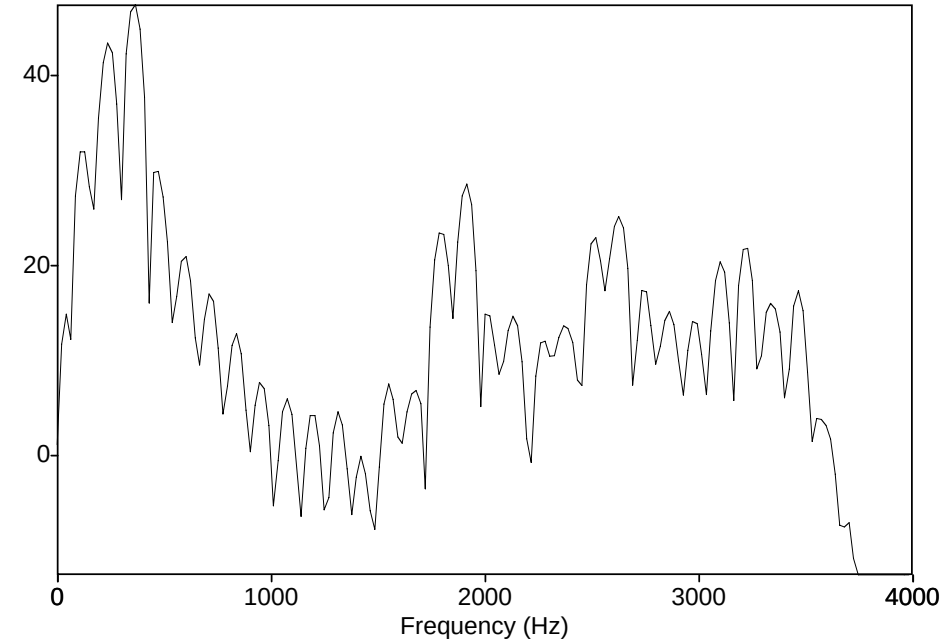
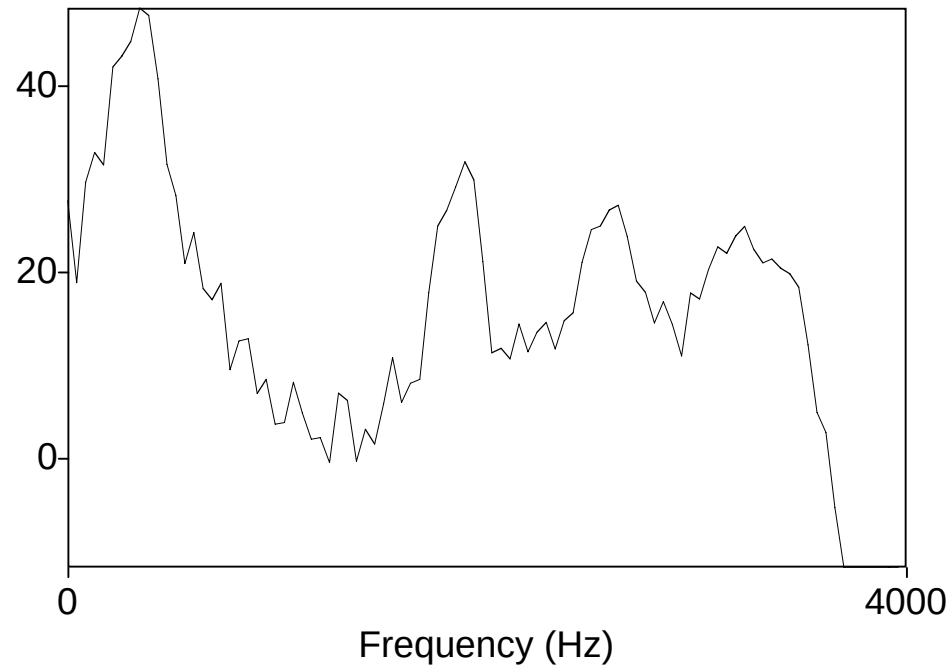
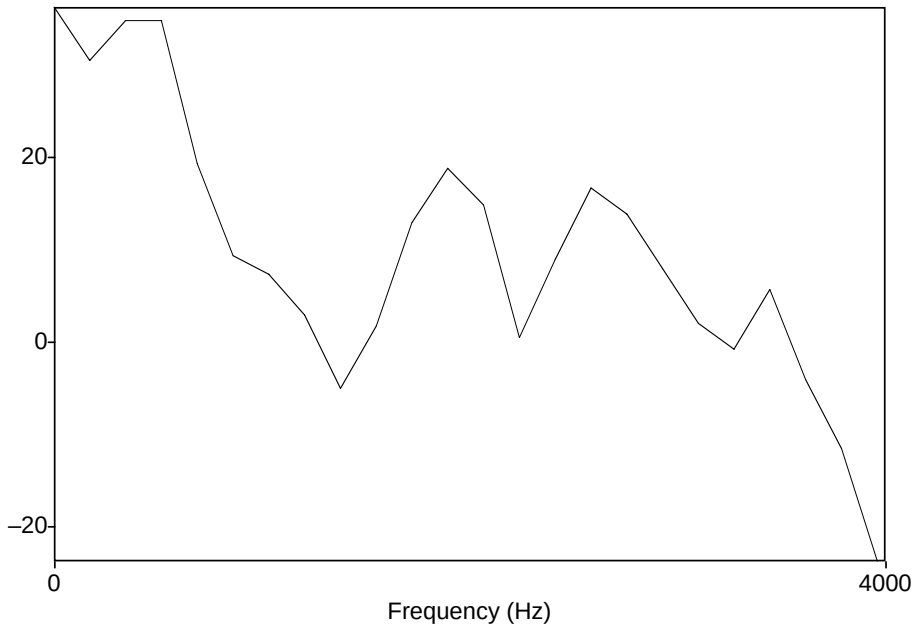

5000
4000
3000
2000
1000
Hz
0
5000
4000
3000
2000
1000
Hz
0
m æ s ə t ʃ u s əʔ s m ɪ ɹ ə k ɬ̰
1 second

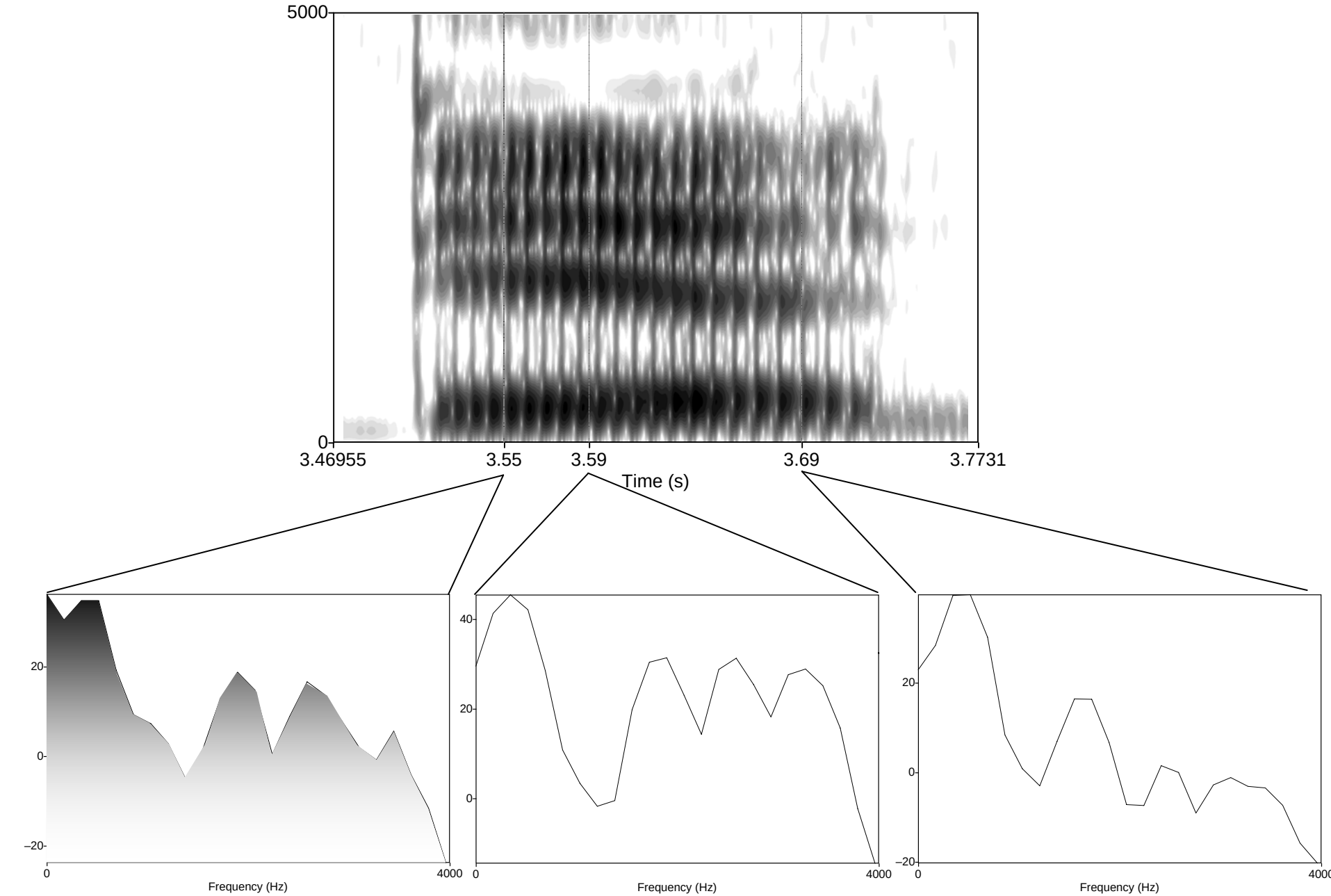


narrow band
(long window)

broad band
(short window)



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3.55
3.59
3.69
3.7731
Time (s)
20
0
–20
0
4000
Frequency (Hz)
40
20
0
0
4000
Frequency (Hz)
20
0
–20
0
4000
Frequency (Hz)

Spectrogram image removed due to copyright restrictions.
See: http://hctv.humnet.ucla.edu/departments/linguistics/VowelsandConsonants/course/chapter8/8.3.htm

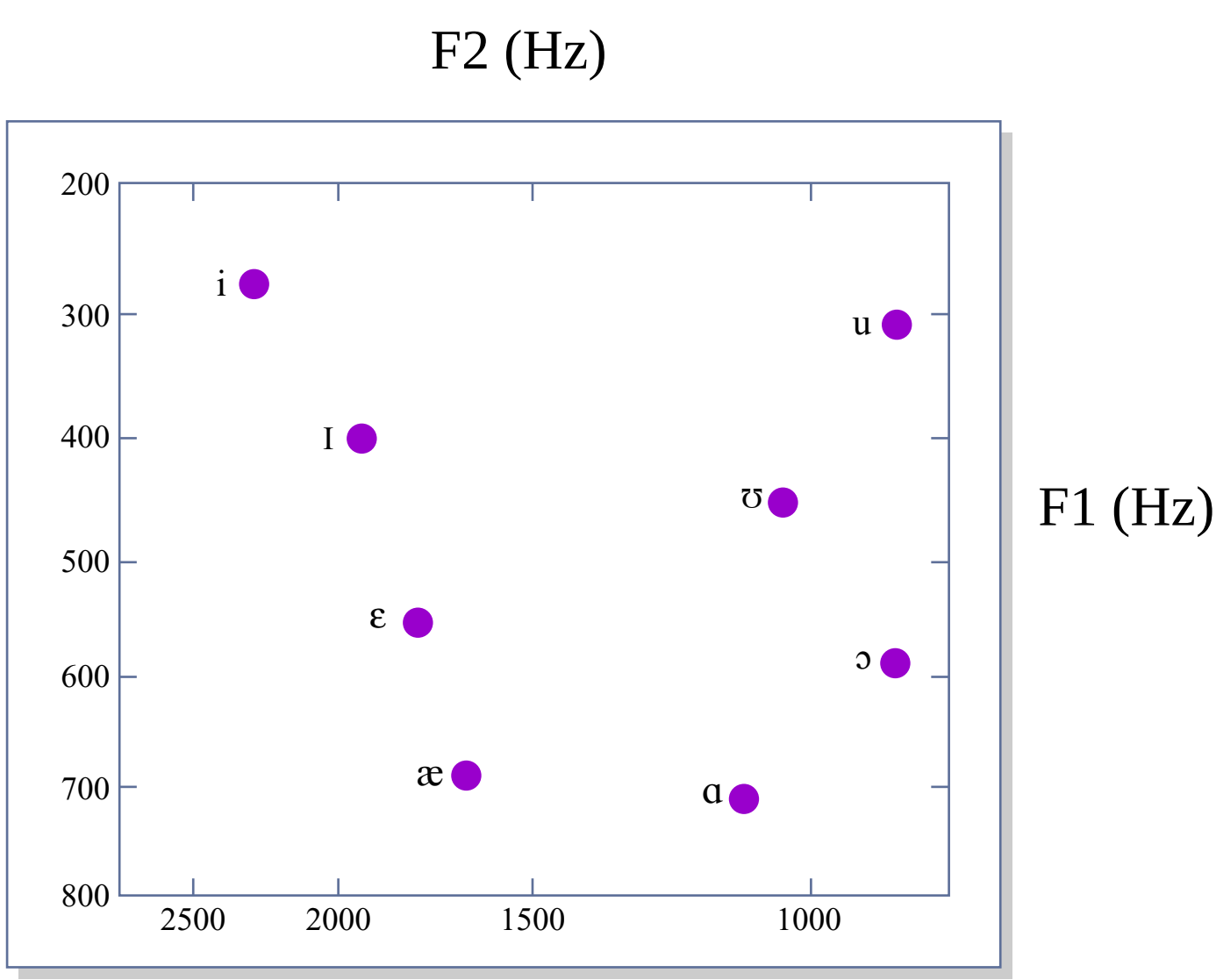

Figure by MIT OpenCourseWare. Adapted from Peter Ladefoged. *A Course in Phonetics.* 5th ed. Berlin, Germany: Heinle, 2005. ISBN: 9781413006889. Available at: http://www.phonetics.ucla.edu/course/contents.html