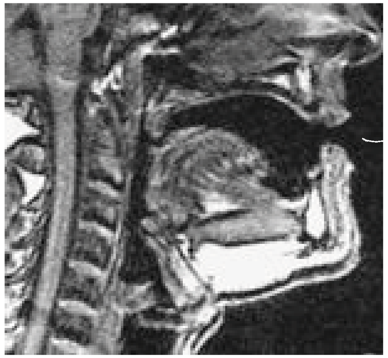
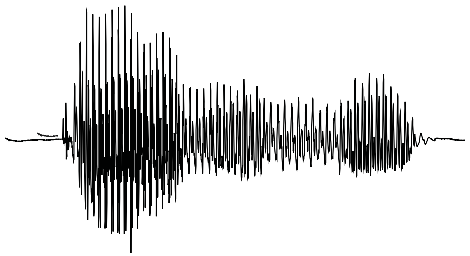
24.915/24.963
Linguistic Phonetics

Introduction: Phonetics and Grammar





Phonetic Grammars

- Phonetics is part of grammar and the study of the linguistic phonetics is in many respects similar to phonology.
- Phonological grammars must account for the distribution of sounds in languages.
- E.g. Russian voiced and voiceless stops

	_V (gen.sg.)	_# (nom.sg.)		
voiceless	bra**t**a	bra**t**		'brother'
voiced	vra**g**a	vra**k**	*vra**g**	'enemy'

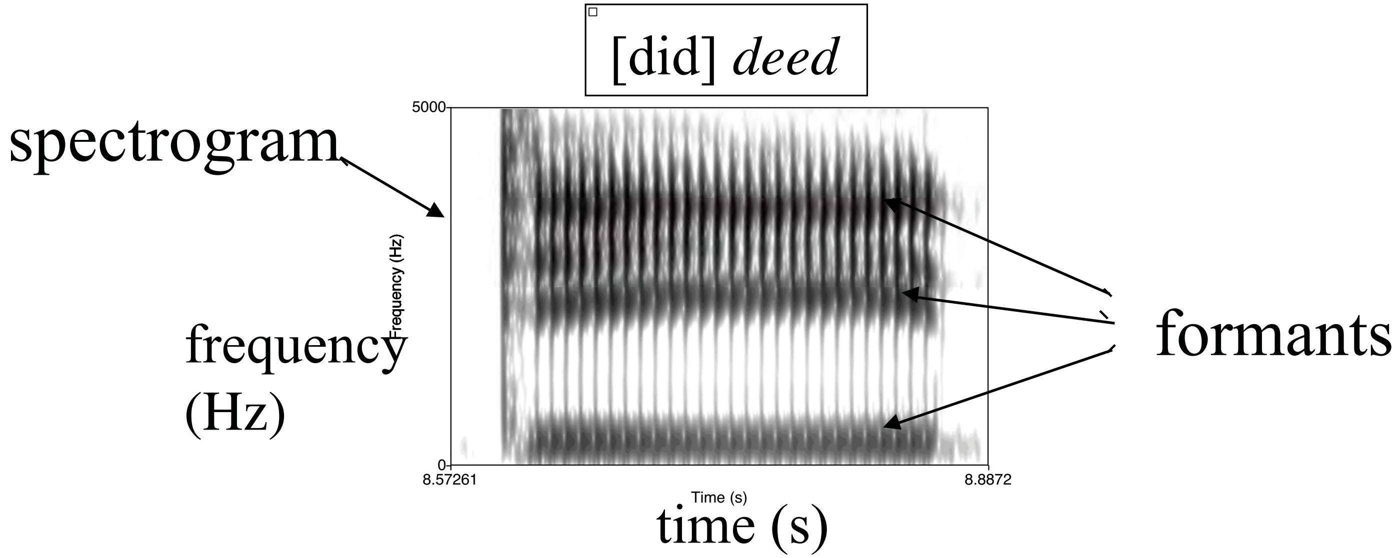
- [+voice, -sonorant] → [-voice]/ _ #
- Ident(voice)/_V >> *[+voice, -sonorant] >> Ident(voice)/_#

Phonetic Grammars

- Phonological grammars must account for the distribution of sounds in languages.
- Allophonic variation, e.g. nasalized vowels in English
  - vowels are nasalized before nasals [hæ̃m] *[hæm]
  - oral elsewhere [hæd] *[hæ̃d]
- Grammar:
  - [vowel] → [+nasal]/ _ [+nasal]
  - *OralV-N >> *NasalV >> Ident(nasal)

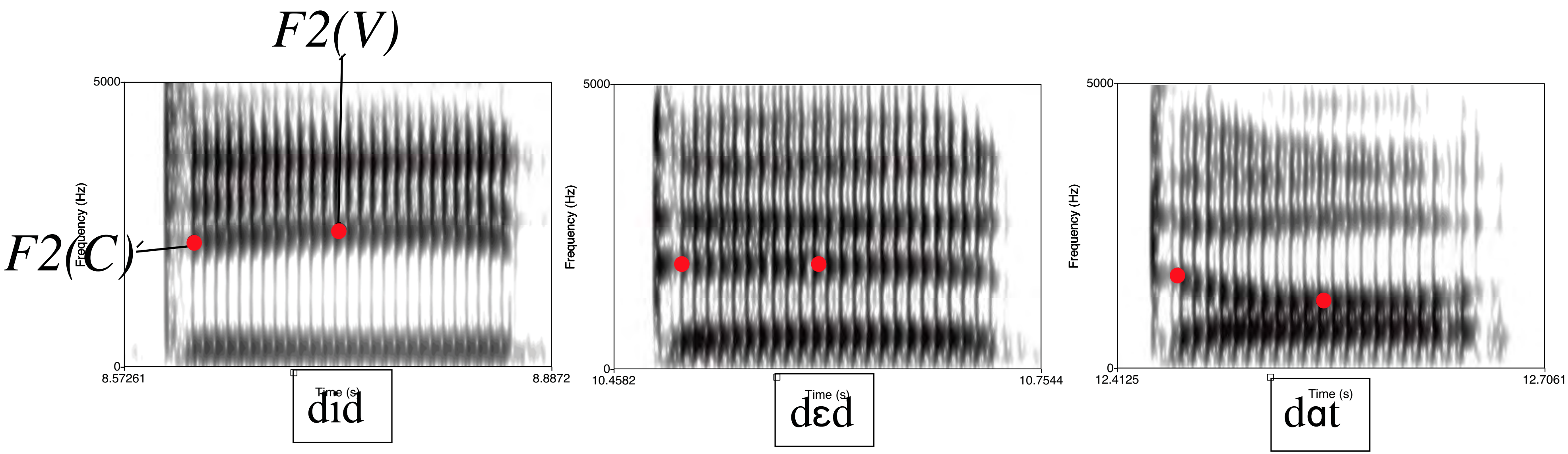
Phonetic grammars

- There is allophonic variation in much finer phonetic details, e.g. formants at the release of a stop, e.g [d].



Phonetic grammars

- The frequency of the second formant (F2) at the release of a [d] varies depending on the following vowel.
    - allophonic variation in the realization of [d]



- We can state a simple rule to describe this pattern of variation quite accurately:

$$F2(C) = 0.52F2(V) + 931$$

Phonetic grammars

- *F2(C)* is a linear function of *F2(V)* (Krull 1987, etc).

Figure removed due to copyright restrictions.
Source: Figure 1, Fowler, Carol A. "Invariants, specifiers, cues: An investigation of locus equations as information for place of articulation." Attention, Perception, & Psychophysics 55, no. 6 (1994): 597-610.

- It is not feasible to transcribe this variation in the pronunciation of [d], but we can measure it.
- It would not be desirable to describe it using a symbolic re-write rule because it involves a multiplicative relationship between two continuous variables *F2(C)* and *F2(V)*.
- But it must be derived in some way in the grammar of English

Phonetic grammars

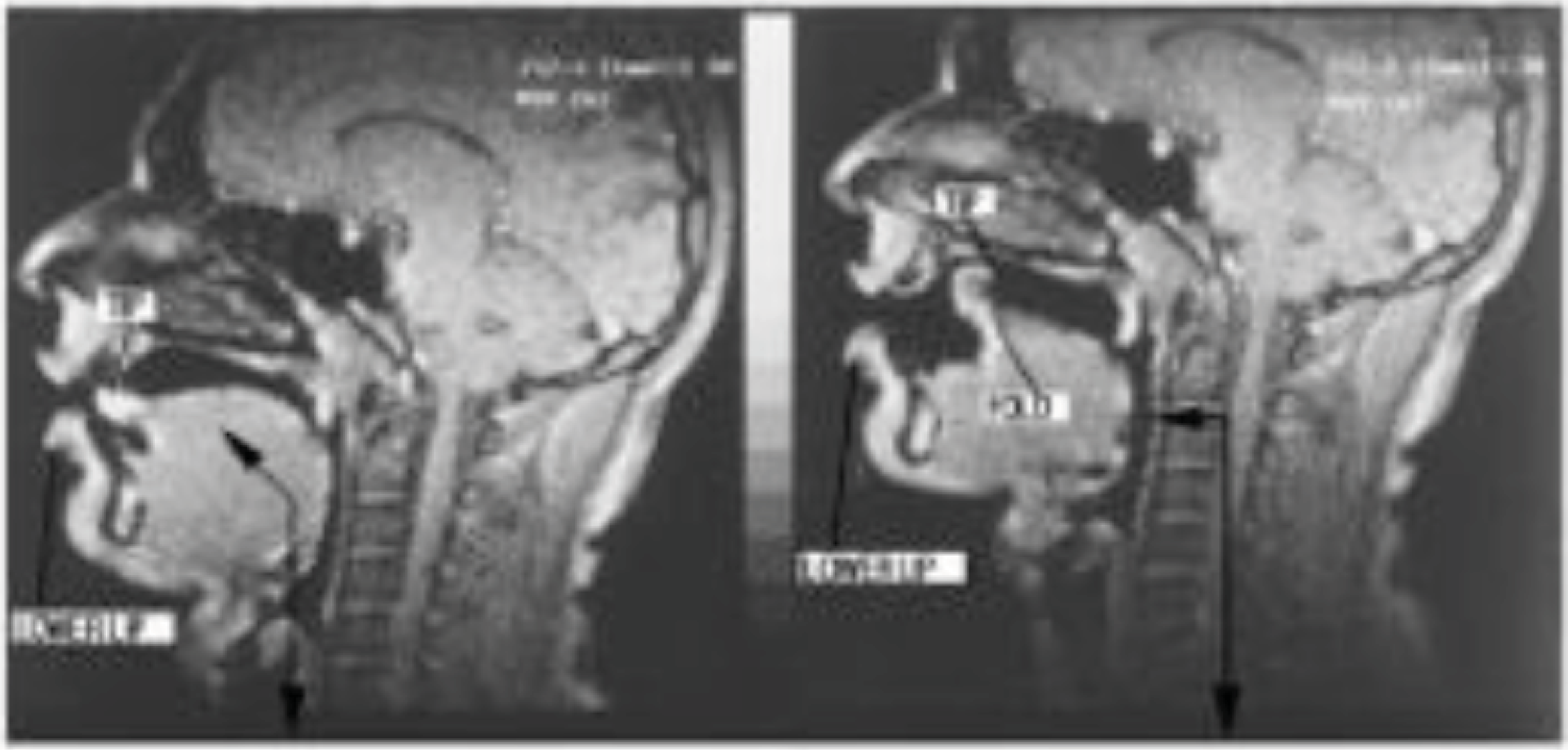
- $F2(C)$ after stops is a linear function of $F2(V)$ in CV sequences in all languages that have been studied, but the slope and intercept of that function differ from language to language.
  - Thai [d̪] $F2(C) = 0.3F2(V) + 1425$ (0.24-0.33)
  - Urdu [d̪] $F2(C) = 0.5F2(V) + 857$ (0.43-0.57)
  - Sussman et al (1993).
  - Averages over 6 and 5 speakers respectively. Both stops are reported to be dental.
- So these different patterns must be derived from differences between the grammars of these languages.
  - What is the form of this phonetic grammar?

Phonetic grammars

- To study phonetic grammar we need to be able to describe speech (quantitatively) - acoustically and articulatorily.
  - E.g. spectrograms, formants.

- Phonetics is also relevant to other areas of linguistics, particularly phonology.

The phonetics and phonology of retroflex consonants

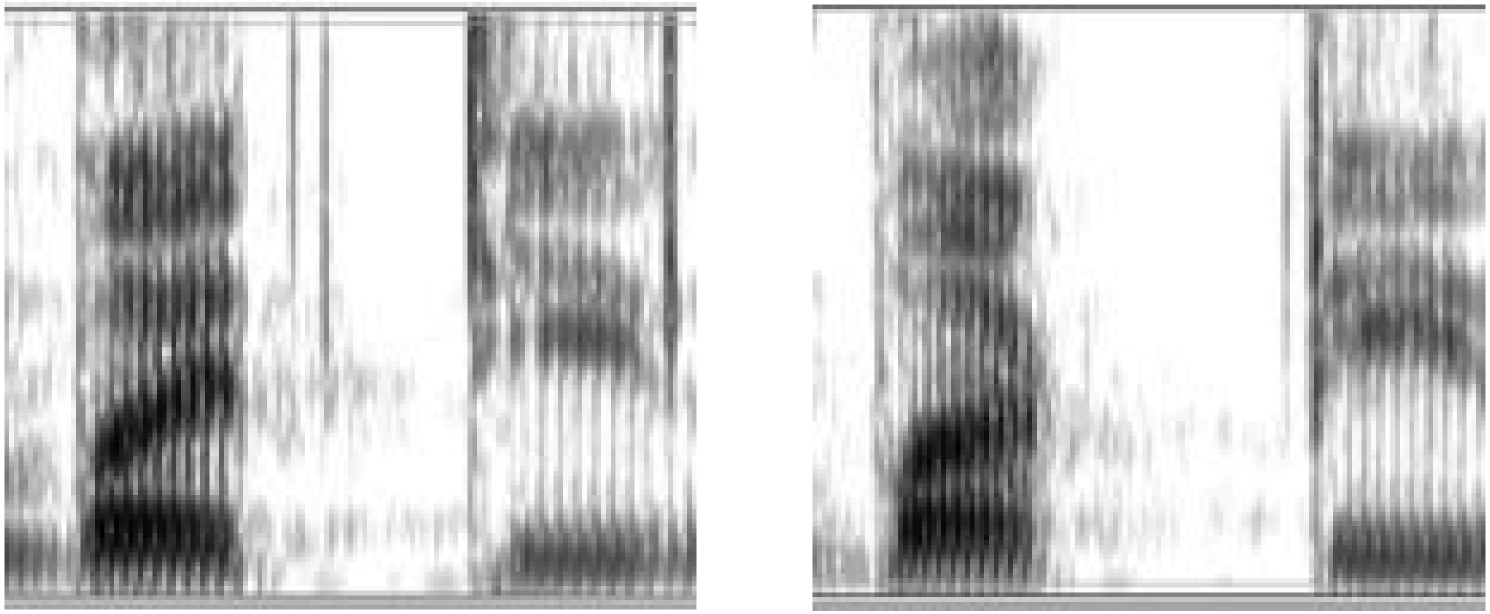


Reproduced from Srikanth, Byrd and Kaun. (1999) "Geometry, kinematics, and acoustics of tamil liquid consonants." The Journal of the Acoustical Society of America, with the permission of the Acoustical Society of America.

dental [l̪] retroflex [ɭ]

MRI images of Tamil laterals (Narayanan et al 1999)

The phonetics and phonology of retroflex consonants



Courtesy of Ashtu Killimangalam. Used with permission.

apical alveolar [t] retroflex [ʈ]

Malayalam

Distribution of retroflexion contrasts in Gooniyandi (Steriade 1995)

- Contrast between retroflex and apical alveolar:
  - V_V ɟu**t**u ‘straight’ ɟu**ɖ**u ‘?’

    wi**l**a ‘finish’ wi**ɭ**a ‘back’
  - V_# jawa**n** (subsection term) jilŋi**ɳ** ‘dew’
  - V_C ɟu**nɟ**unanaɟgu ‘pardalote’ gambu**ɳɟ**uwa (toponym)
- No contrast elsewhere:
  - #_ **ʈ**uːwuː ~ **t**uːwuː ‘cave’

    ɳaːgʌ ~ **n**aːgʌ ‘dress’
  - C_ baɳ**ɖ**i ‘spider’ * baɳ**d**i

    jambijin**d**i * jambijin**ɖ**i

Distribution of retroflexion contrasts in Gooniyandi

Summary:

- Contrast between retroflex and apical alveolar **after vowels** V_#, V_V, V_C
- No contrast elsewhere   #_, C_
- This pattern of distribution is common in Australian and Dravidian languages.
- Probable universal: If a language contrasts retroflexes and apical alveolars in contexts with no preceding vowel, then it also contrasts these sounds following vowels.
    - Why?

Distribution of retroflexion contrasts

Outline explanation (Steriade 1995, 2001 etc):

- Contrasts preferentially appear in environments where they are easier to distinguish perceptually.
  - i.e. where listener is less likely to be confused about which sound they are hearing.
- Apical alveolars are more distinct from retroflexes when they are preceded by a vowel.
- Therefore some languages only allow the contrast in this context.

Perception of retroflexion contrasts - Anderson 1997

Perception in Arrernte

stimulus place

VCV

perceived place

	p	t̪	t	ʈ	t̠	k
p-R	85	1	1	0	0	0
t̪-R	12	96	10	1	1	3
t-R	3	1	70	24	0	1
ʈ-R	0	1	19	74	0	2
t̠-R	0	1	0	0	99	1
k-R	0	1	0	0	0	94

CV

	p	t̪	t	ʈ	t̠	k
p-R	83	3	1	5	1	1
t̪-R	11	83	27	47	3	2
t-R	1	4	35	18	1	1
ʈ-R	3	4	28	19	1	3
t̠-R	1	1	1	2	94	2
k-R	1	6	8	9	1	92

- Perception of [t, ʈ] as dental vs. apical depends on duration of voiceless closure

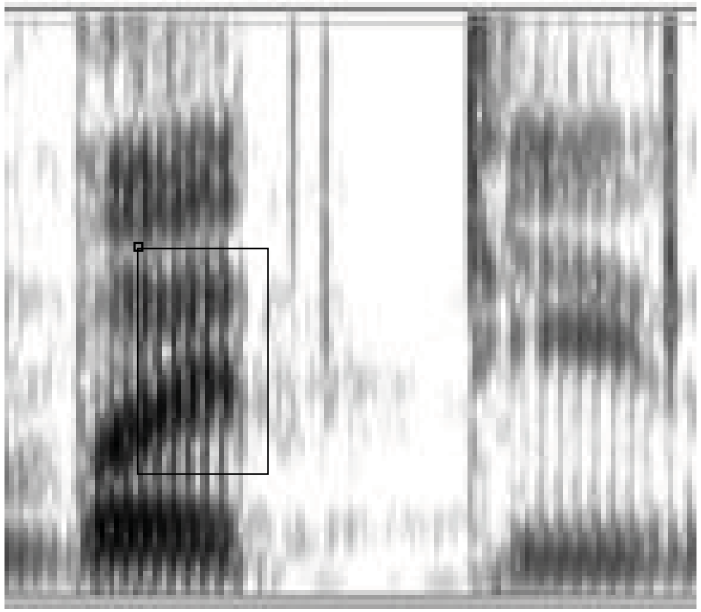
Source: Anderson, Victoria B. "The perception of coronals in Western Arrernte." In EUROSPEECH. 1997.

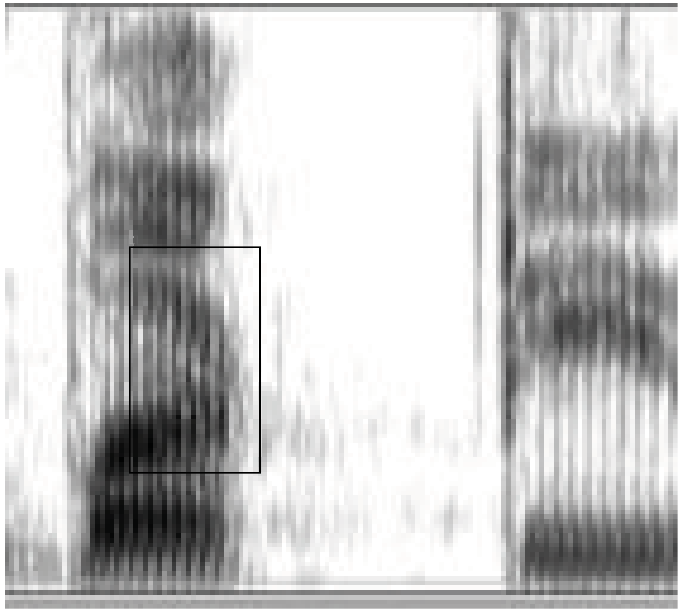
Distribution of retroflexion contrasts

Why are apical alveolars more distinct from retroflexes where they follow a vowel?

- The primary cues to the contrast between retroflex and apical alveolar are located in the VC transitions (unlike major place contrasts.
- This pattern has a basis in the production of these sounds:
    - 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.

The phonetics and phonology of retroflex consonants

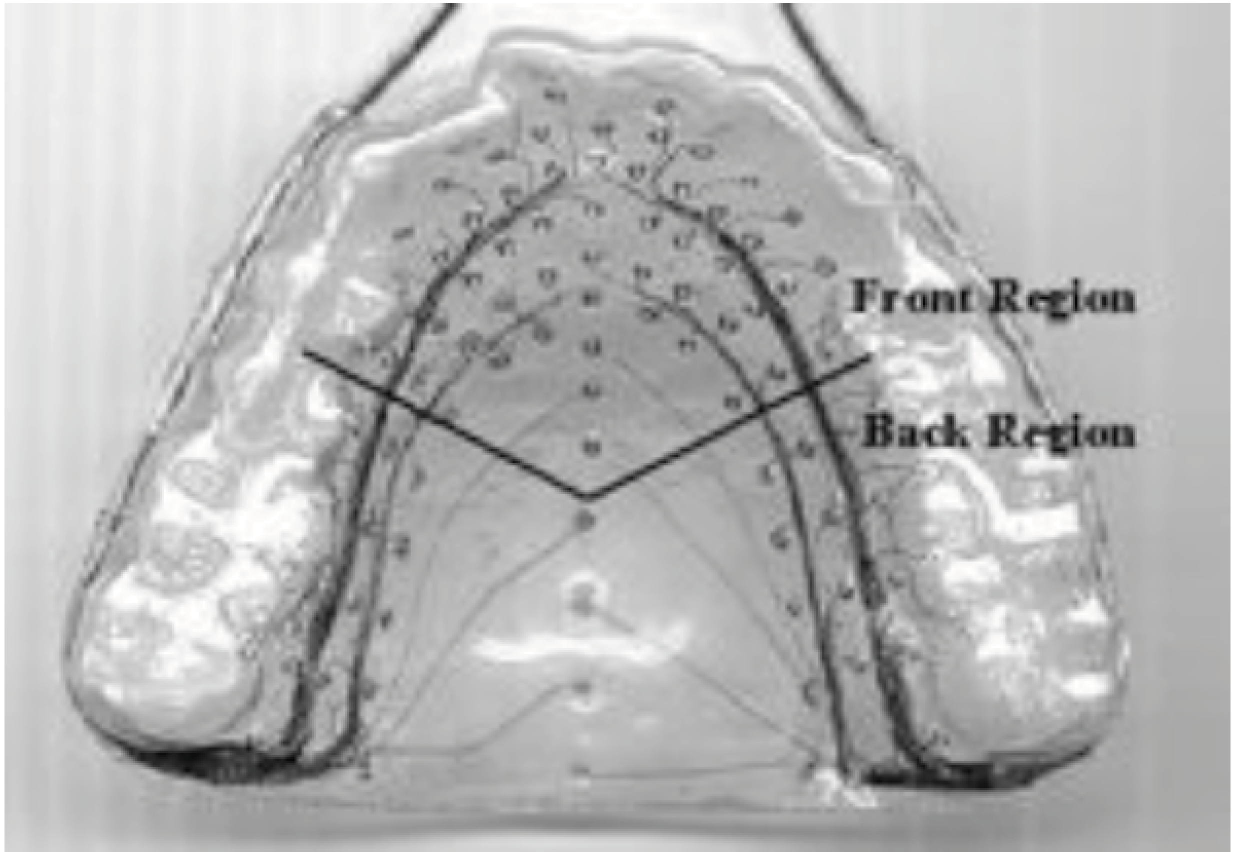




apical alveolar [t] retroflex [ʈ]

Malayalam

Electropalatography



Source: Ladefoged, Peter. Phonetic Data Analysis: An Introduction to Fieldwork and Instrumental Techniques/Peter Ladefoged. Oxford: Blackwell, 2003.

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

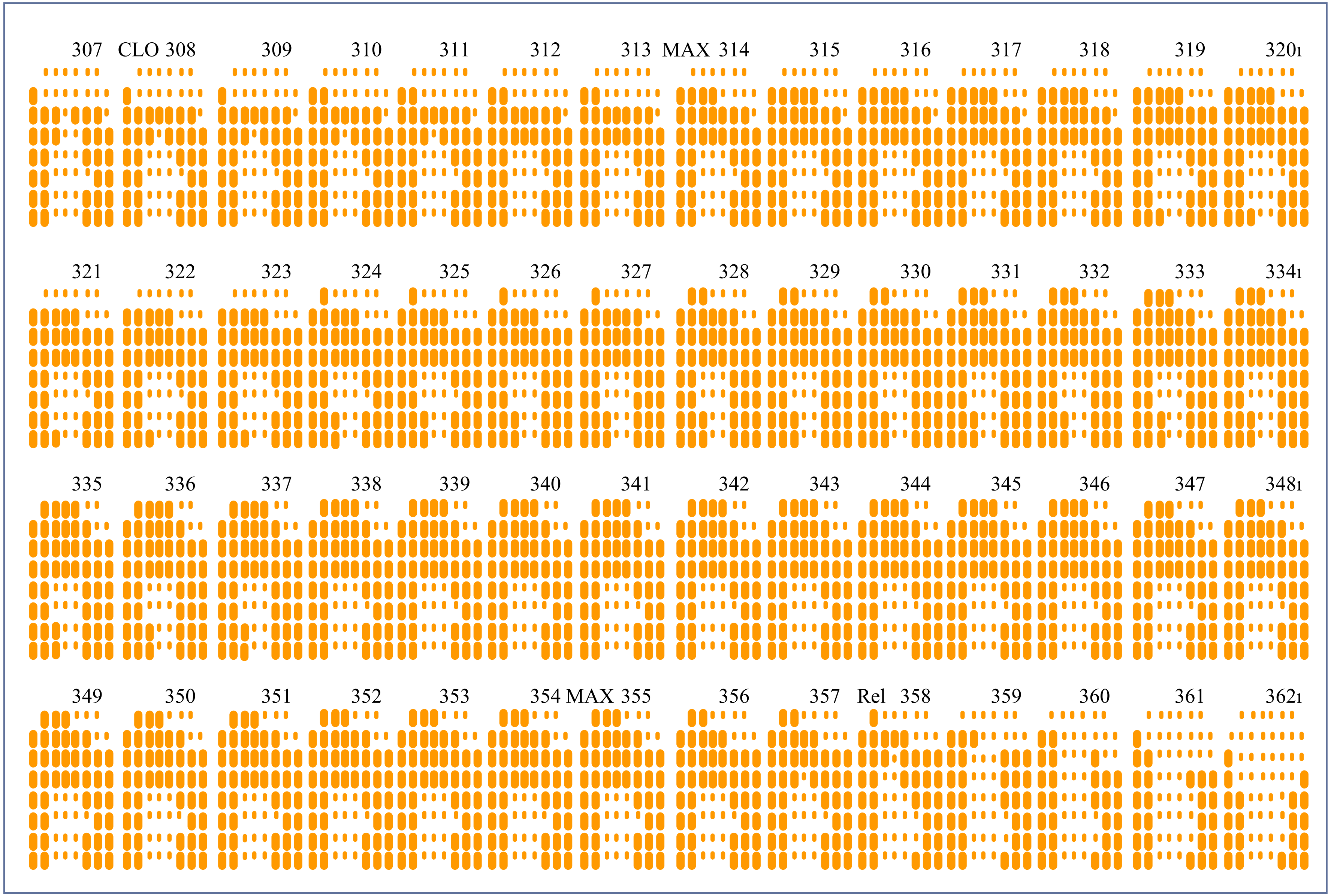


Image by MIT OCW.

Adapted from Butcher, Andrew. "The Phonetics of Australian languages." Unpublished manuscript. Flinders University, South Australia, 1993.

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

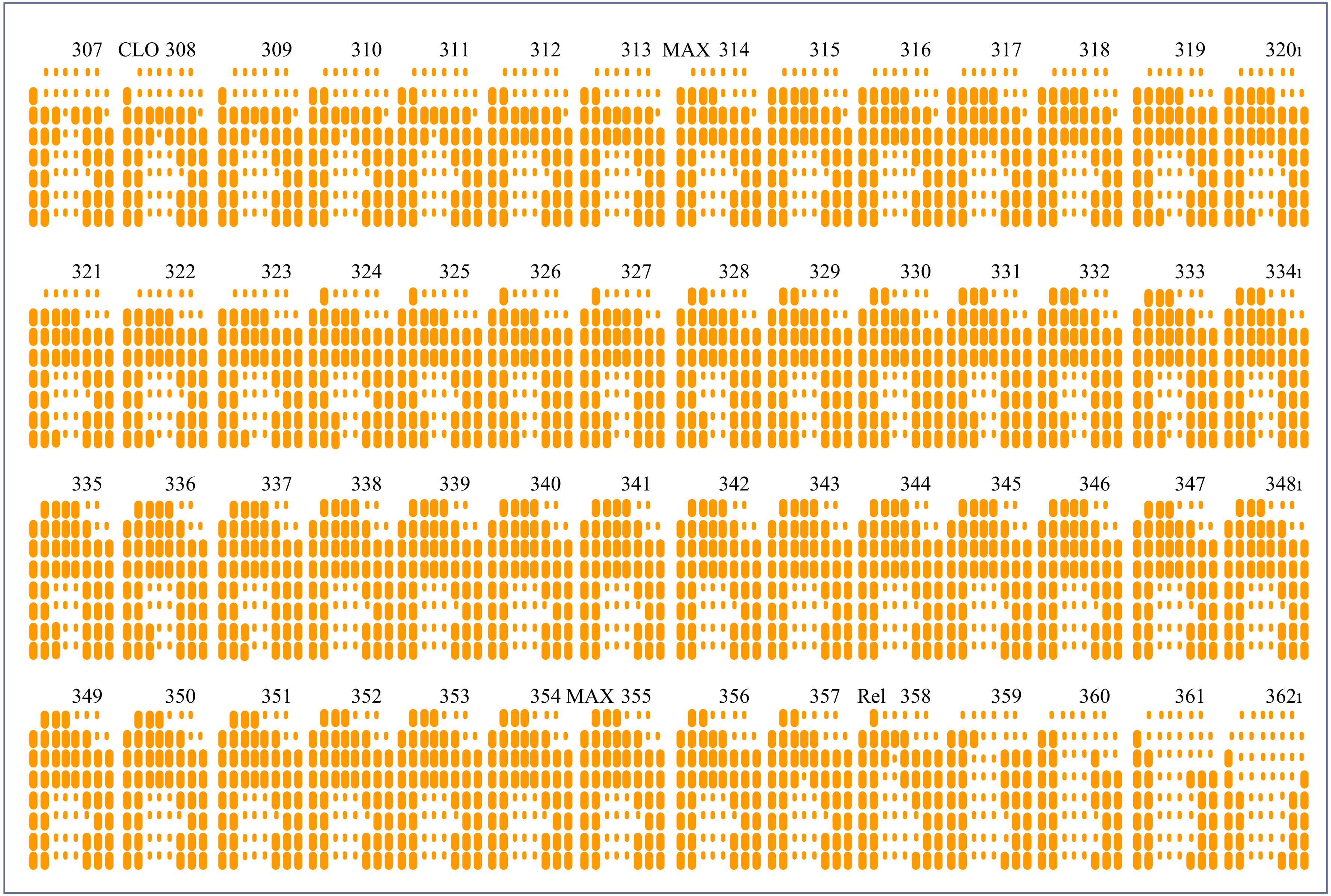


Image by MIT OCW.

Adapted from Butcher, Andrew. "The Phonetics of Australian languages." Unpublished manuscript. Flinders University, South Australia, 1993.

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.
- Phonological theory relates these properties to the observed distribution of retroflexion contrasts.

Distribution of retroflexion contrasts

Moral:

- The details of the articulation, acoustics and perception of retroflexes are crucial to understanding their phonological properties.

- We will start with a rapid overview of the 'speech chain', then focus on the acoustics of speech, introducing the spectrogram.

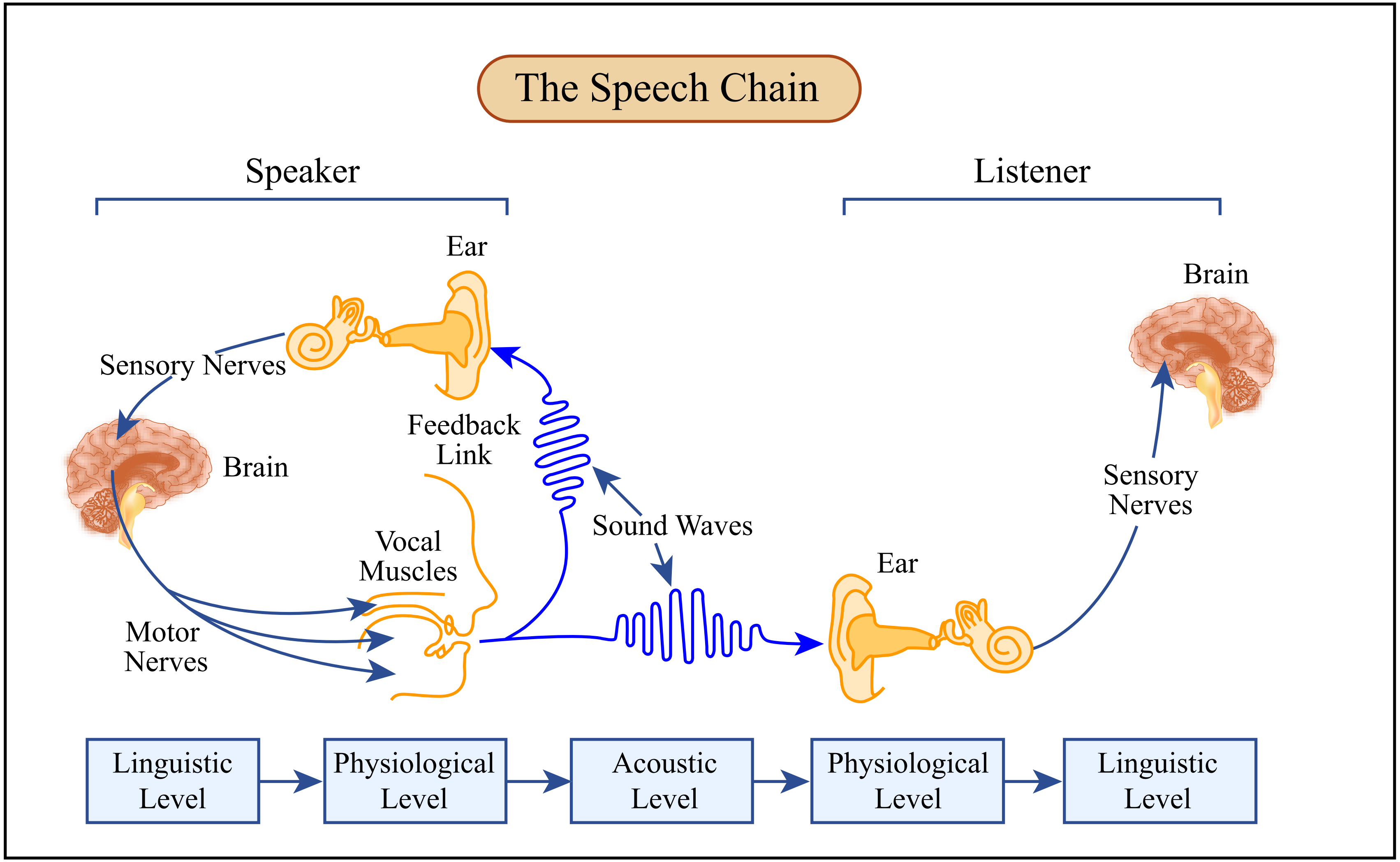


Image by MIT OCW.
Adapted from Denes, Peter B., and Elliot N. Pinson. *The Speech Chain: The physics and biology of spoken speech*. 2nd ed. New York, NY: W. H. Freeman, 1993. ISBN: 9780716723448.

Readings from Johnson for next week:

- Chapter 1
- Chapter 3 pp. 49-68
- Chapter 4

Articulation-
The speech production system

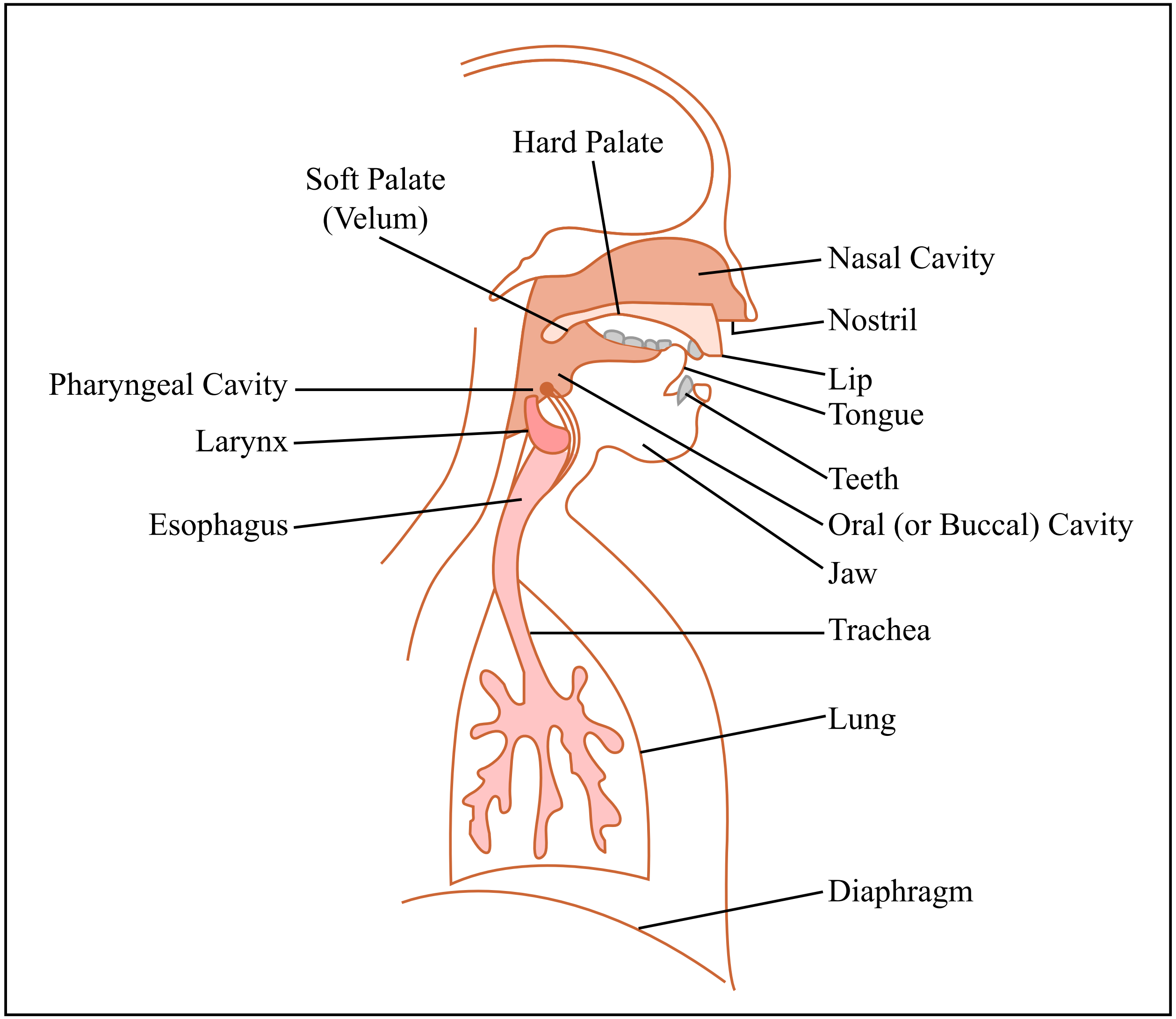
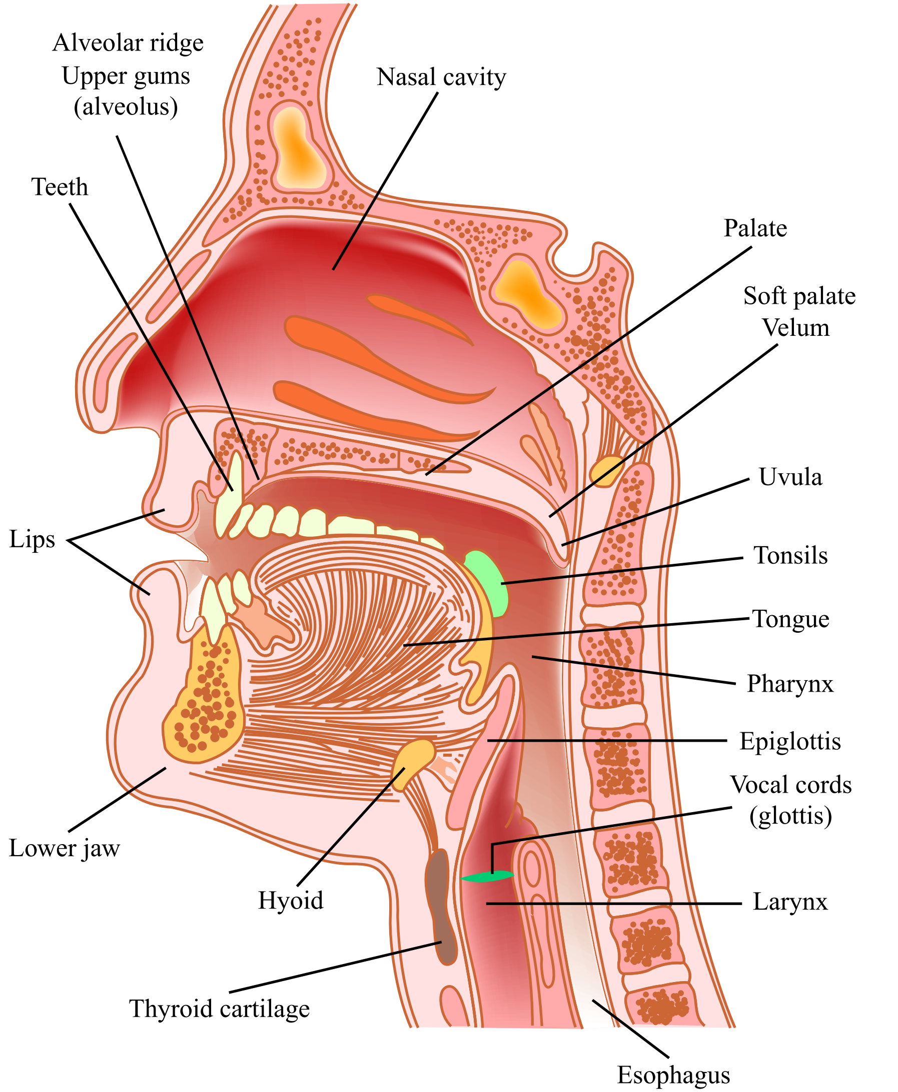


Image by MIT OCW.

The vocal tract



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

Image by MIT OCW.

Articulatory description of speech sounds

Consonants:

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

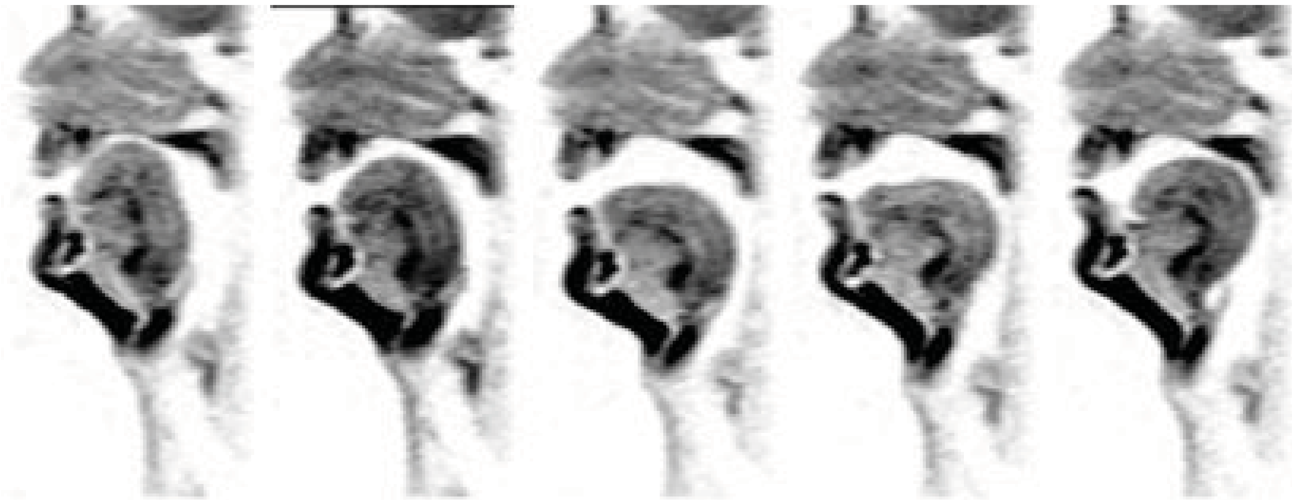
- [s] voiceless alveolar central oral fricative

Articulatory description of speech sounds

Vowels:

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

- [e] mid front unrounded vowel



[i] [e] [a] [o] [u]


i
u
e
o
a

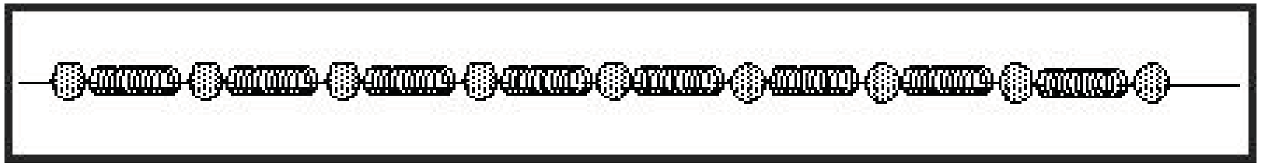
Introduction to acoustics

- Sound consists of pressure fluctuations in a medium (usually air).

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.



Representing sound waves

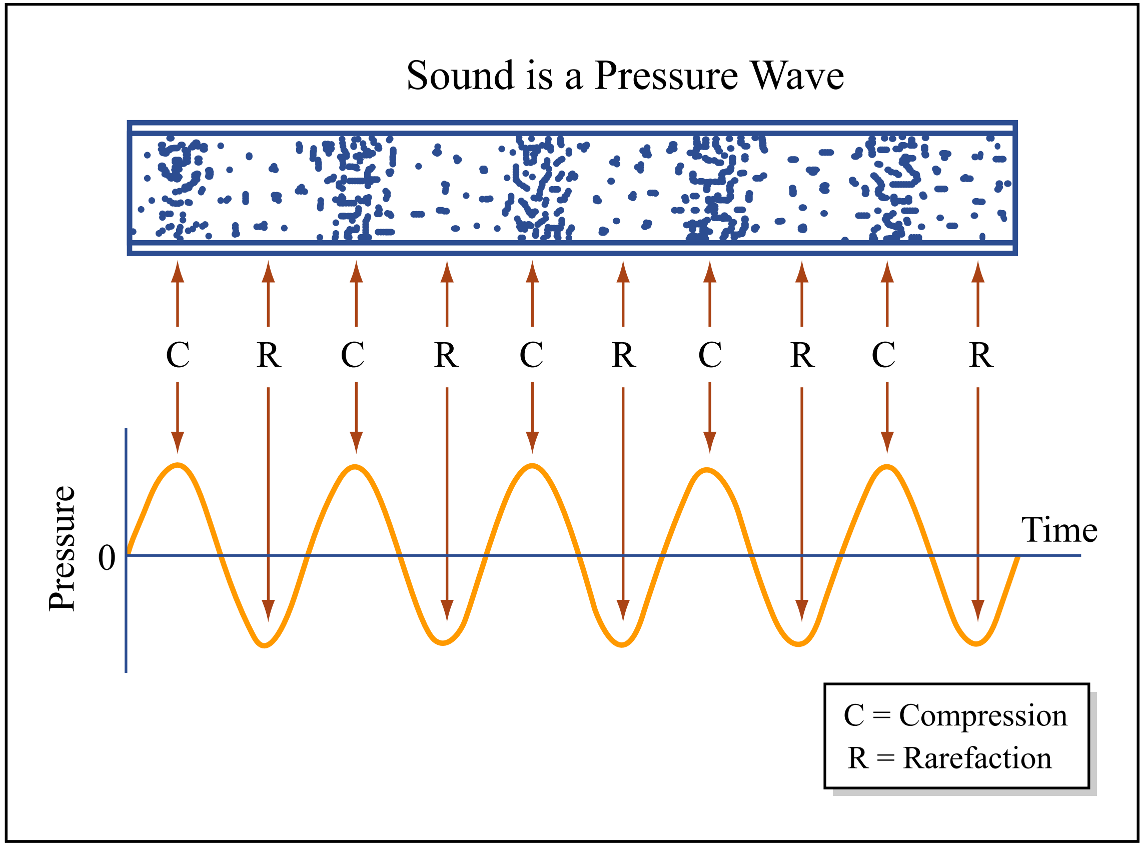


Image by MIT OCW.
Adapted from The Physics Classroom Tutorial.

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

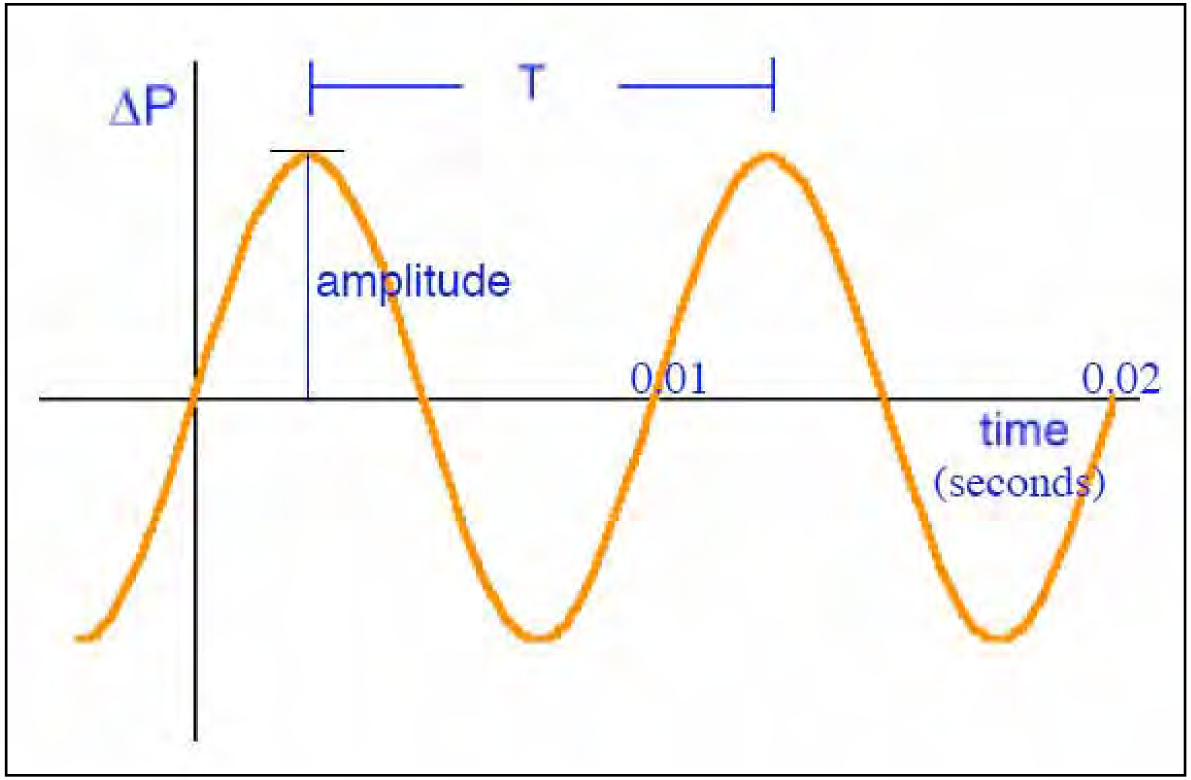


Image by MIT OCW.

Periodic sounds

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

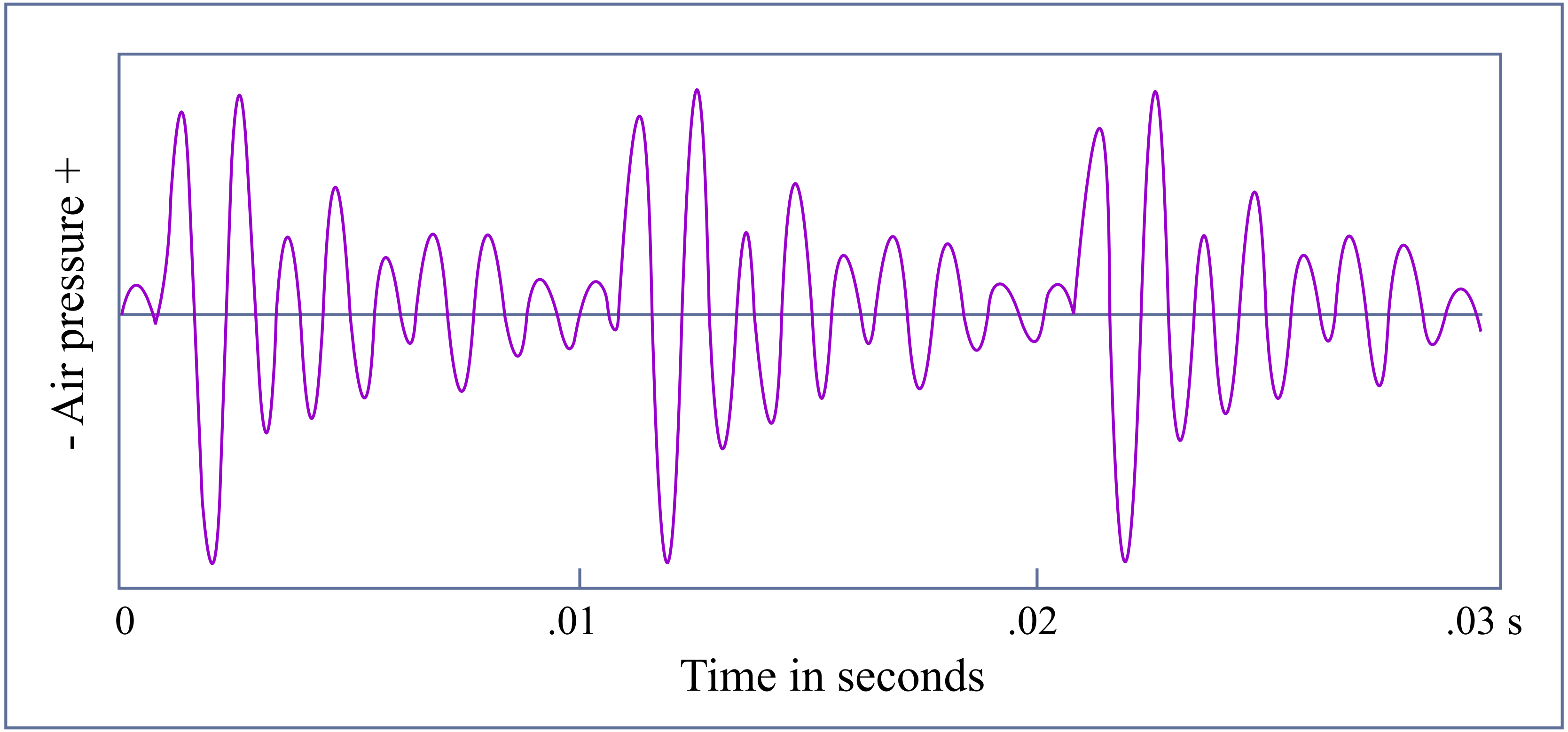
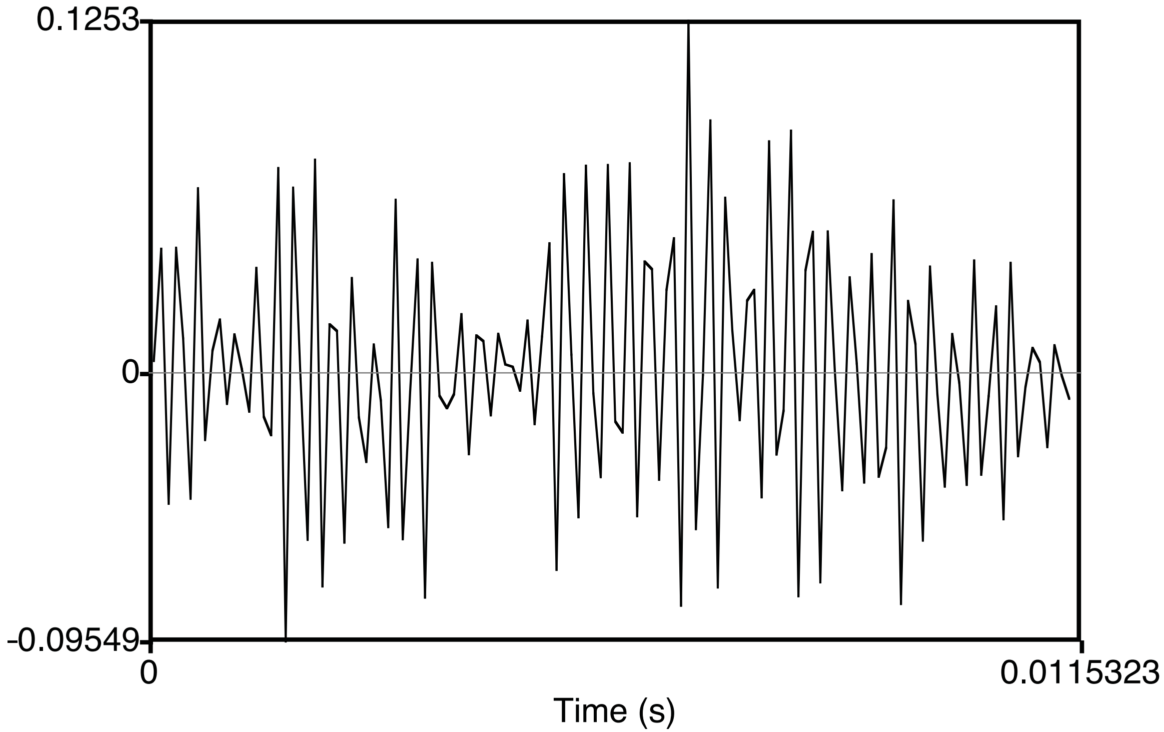


Image by MIT OCW.

Segment of [ɔ]

Aperiodic sounds

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



Segment of [s]

Waveform of a sentence

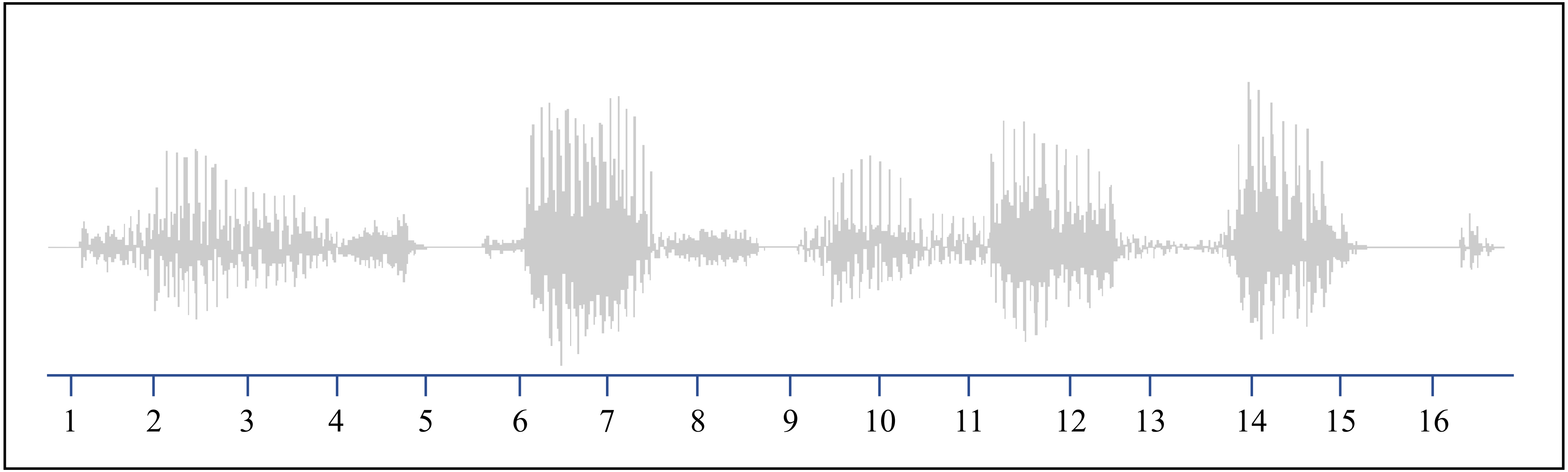


Image by MIT OCW.

Please pass me my book

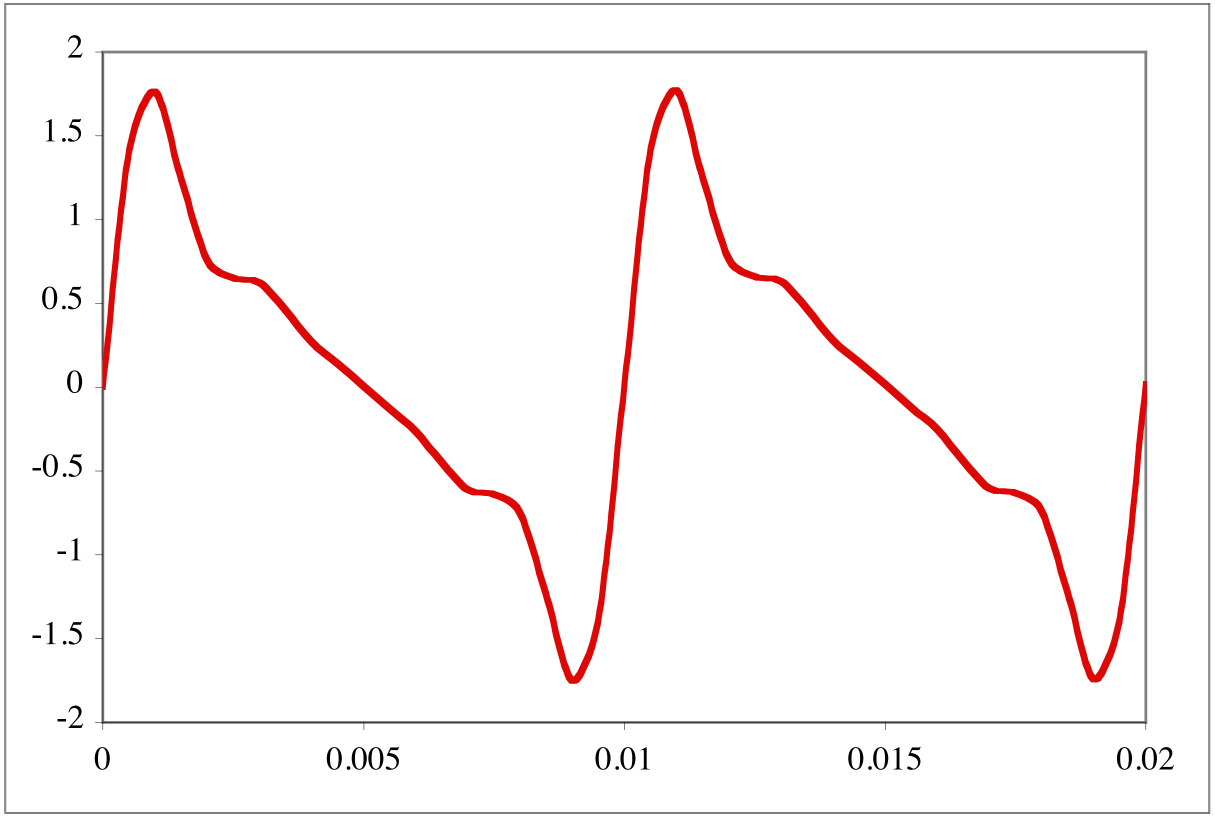
Spectrums and spectrograms

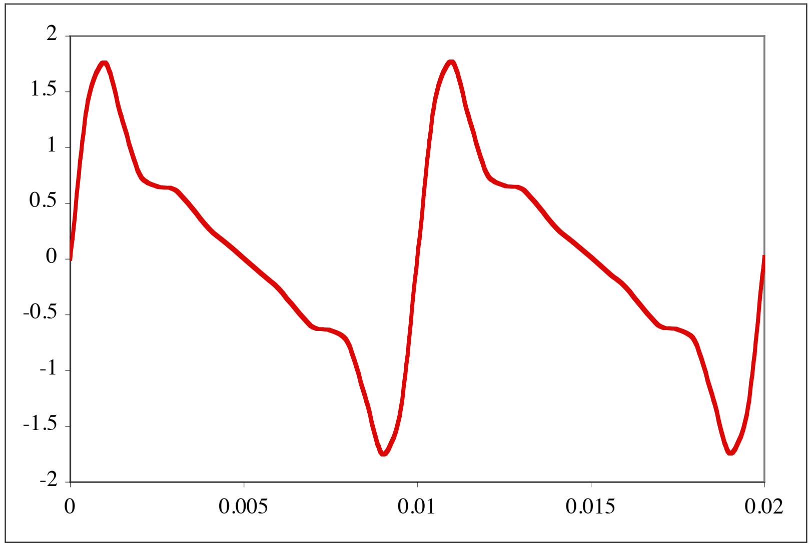
- The spectrum of a sound plays a central role in determining its quality or timbre.

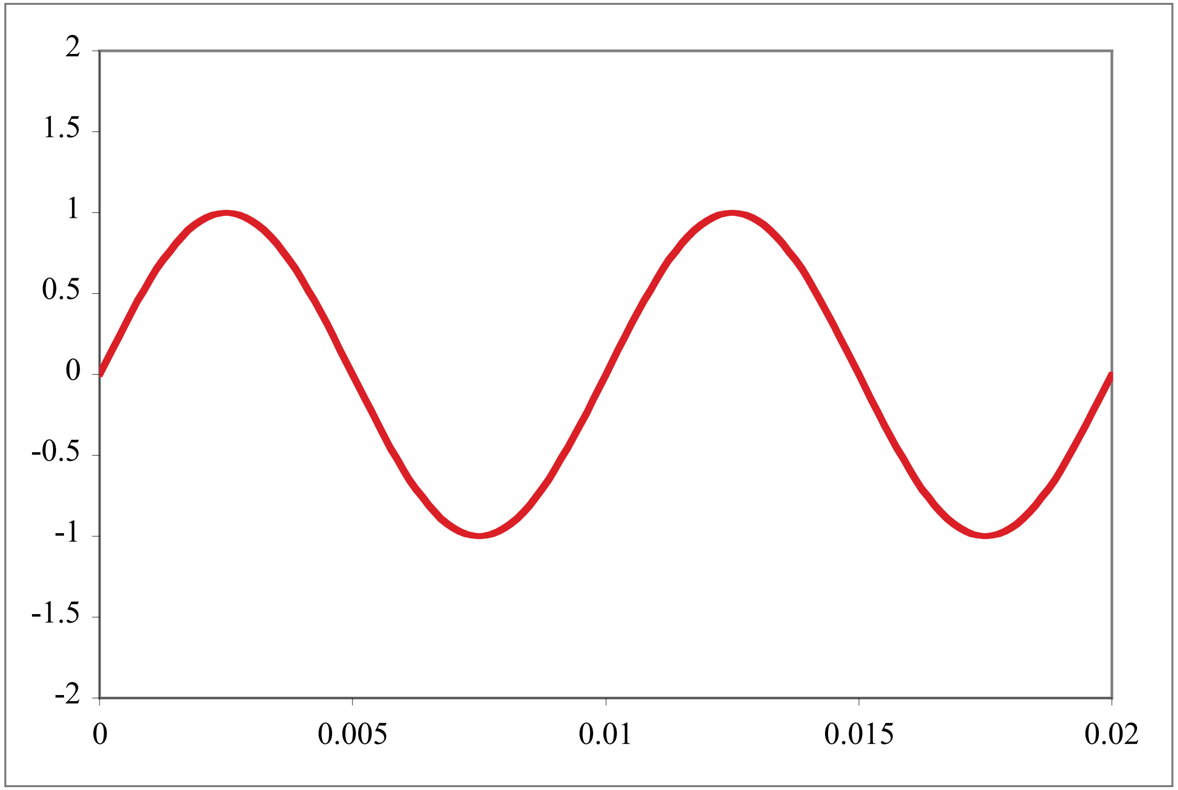
Spectral representation

- 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.

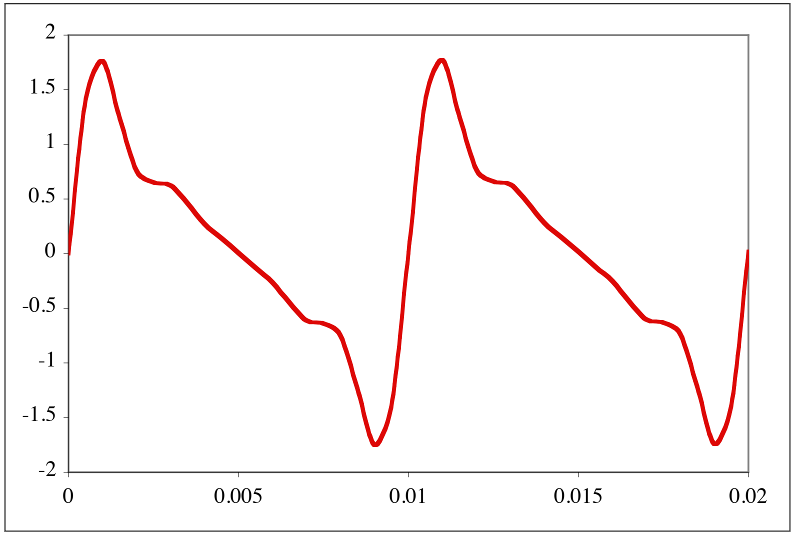
Spectral representation

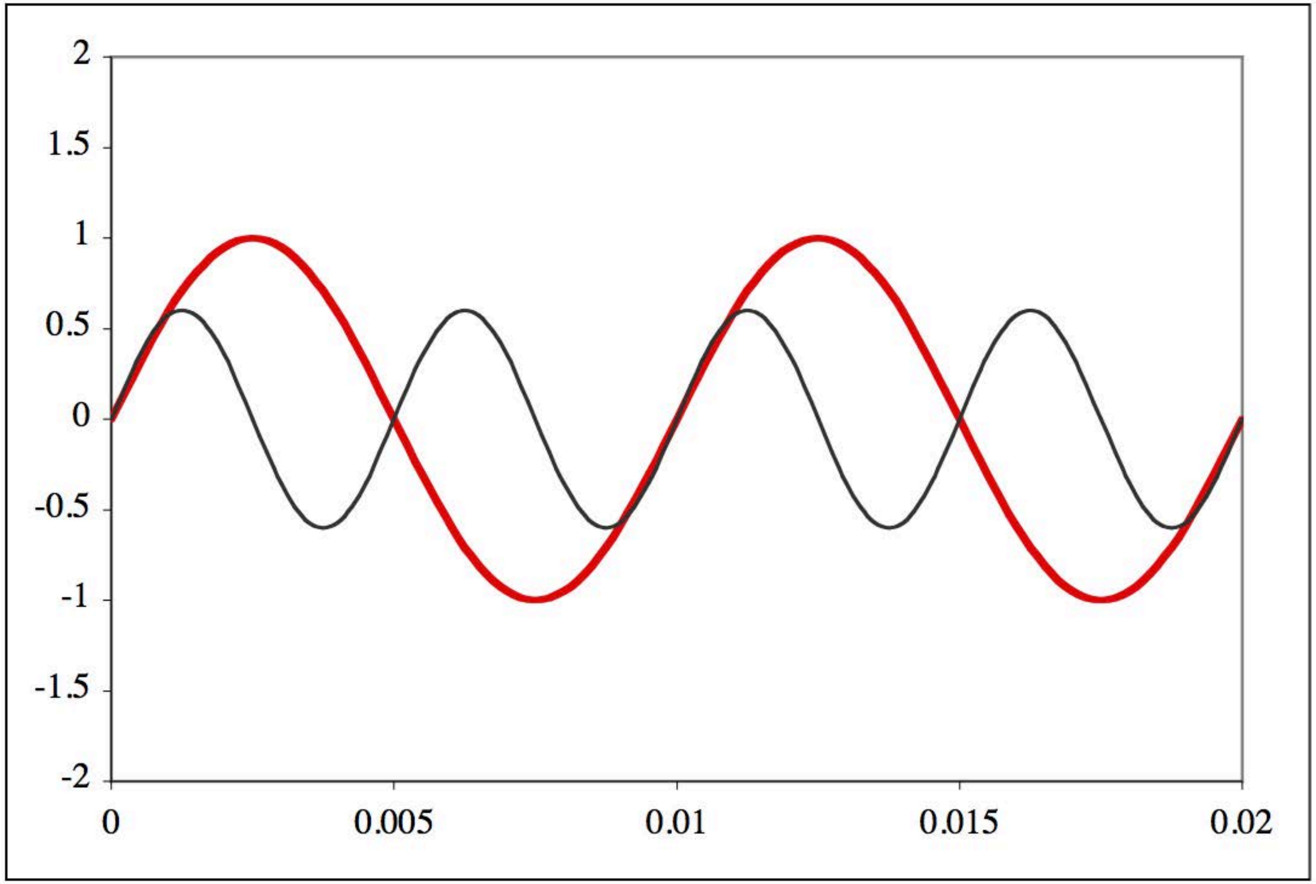




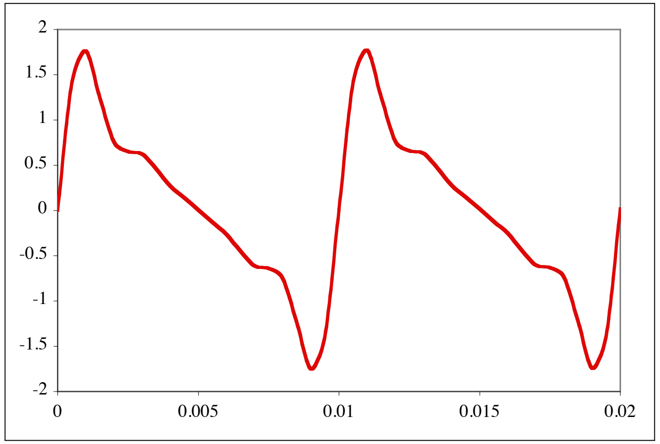


Fundamental frequency





2nd harmonic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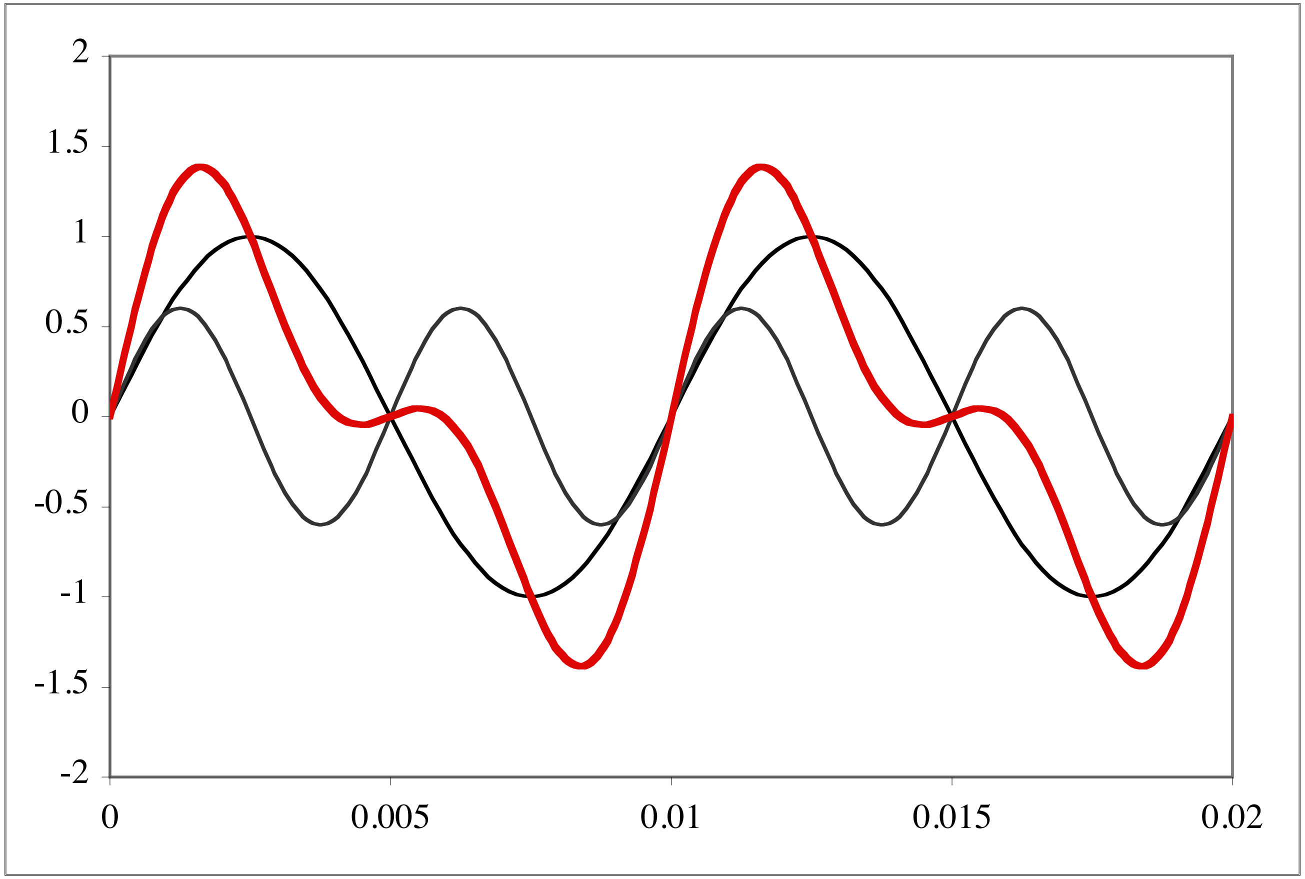
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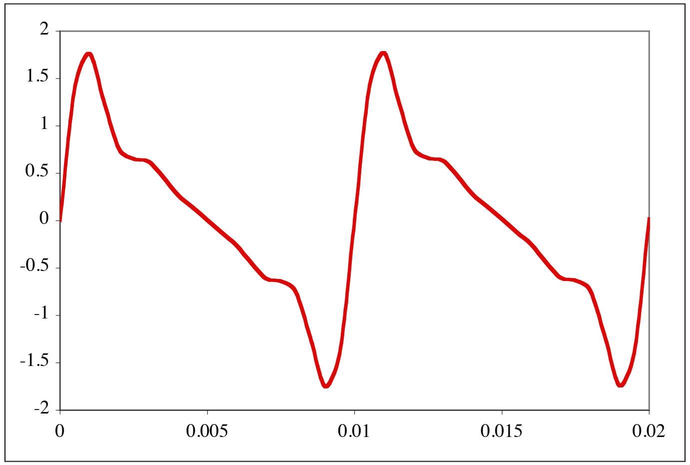
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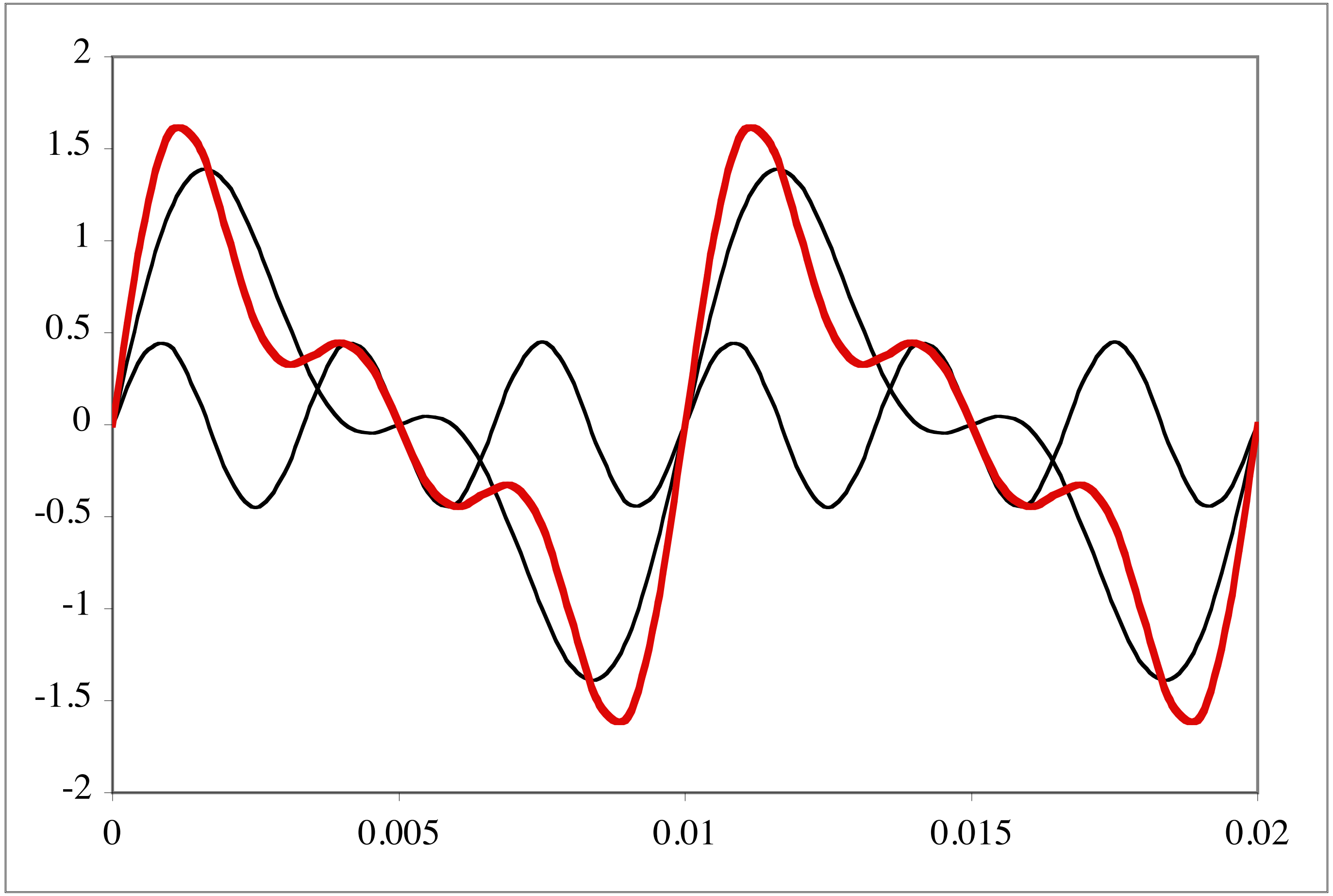
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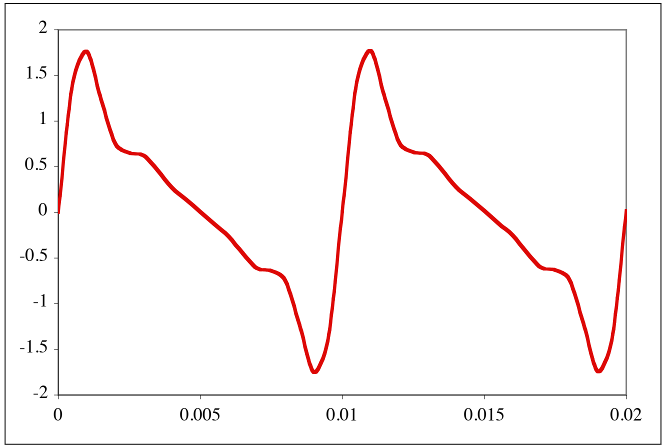
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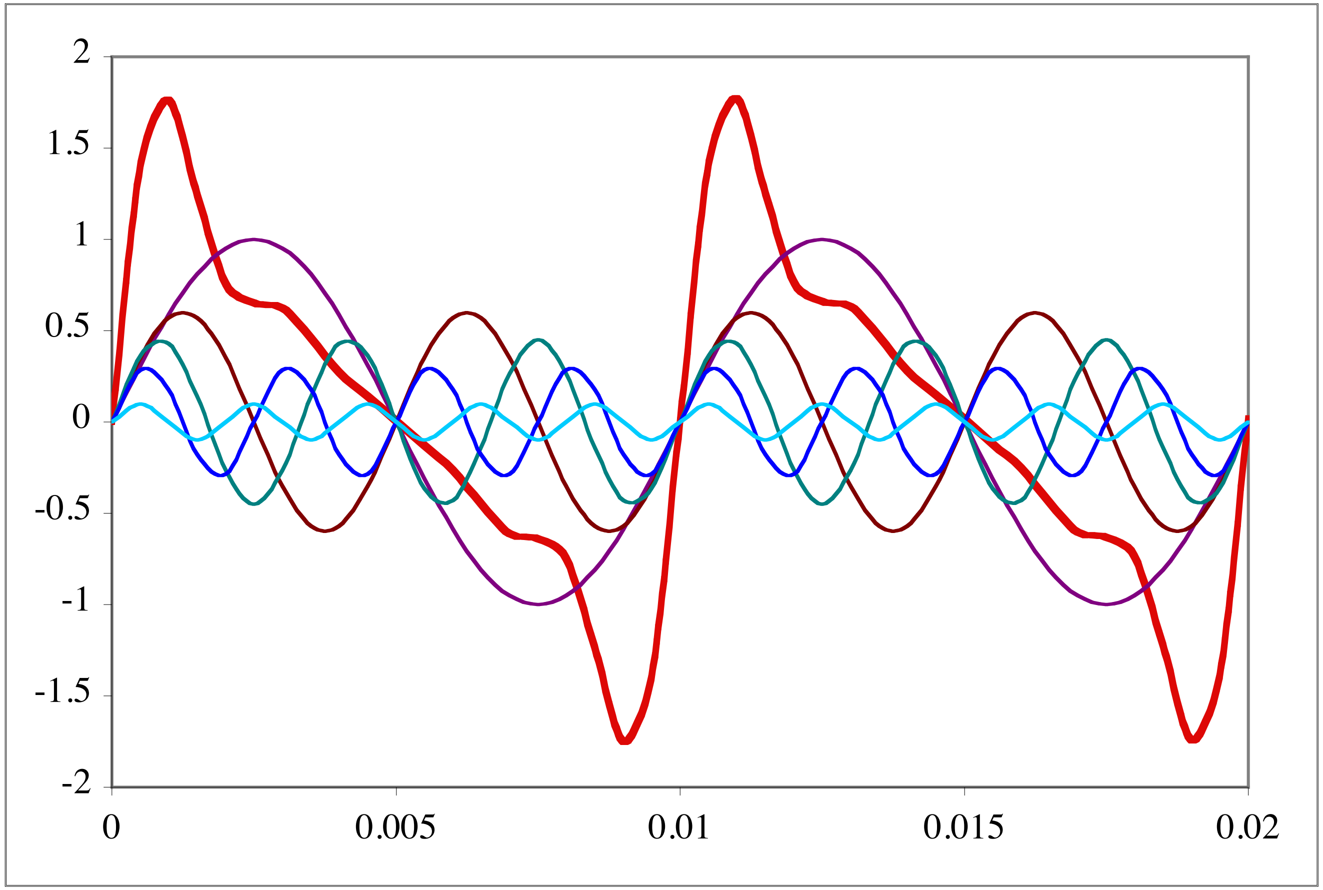
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-1
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-2
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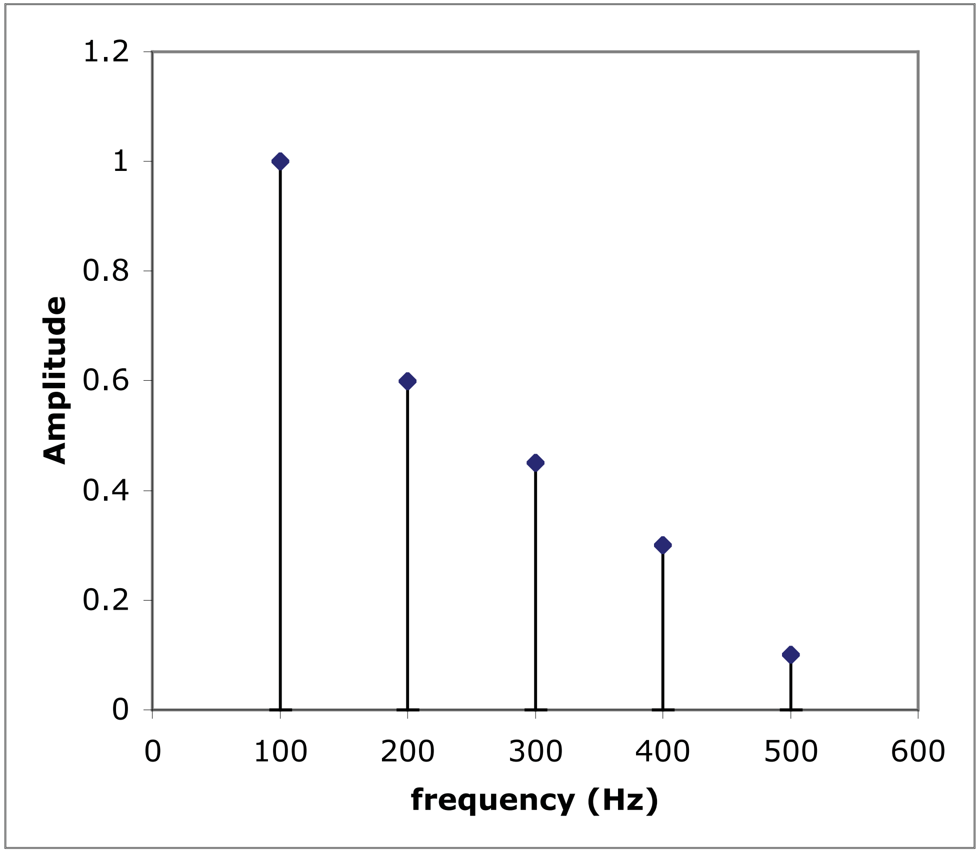
0.005
0.01
0.015
0.02

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

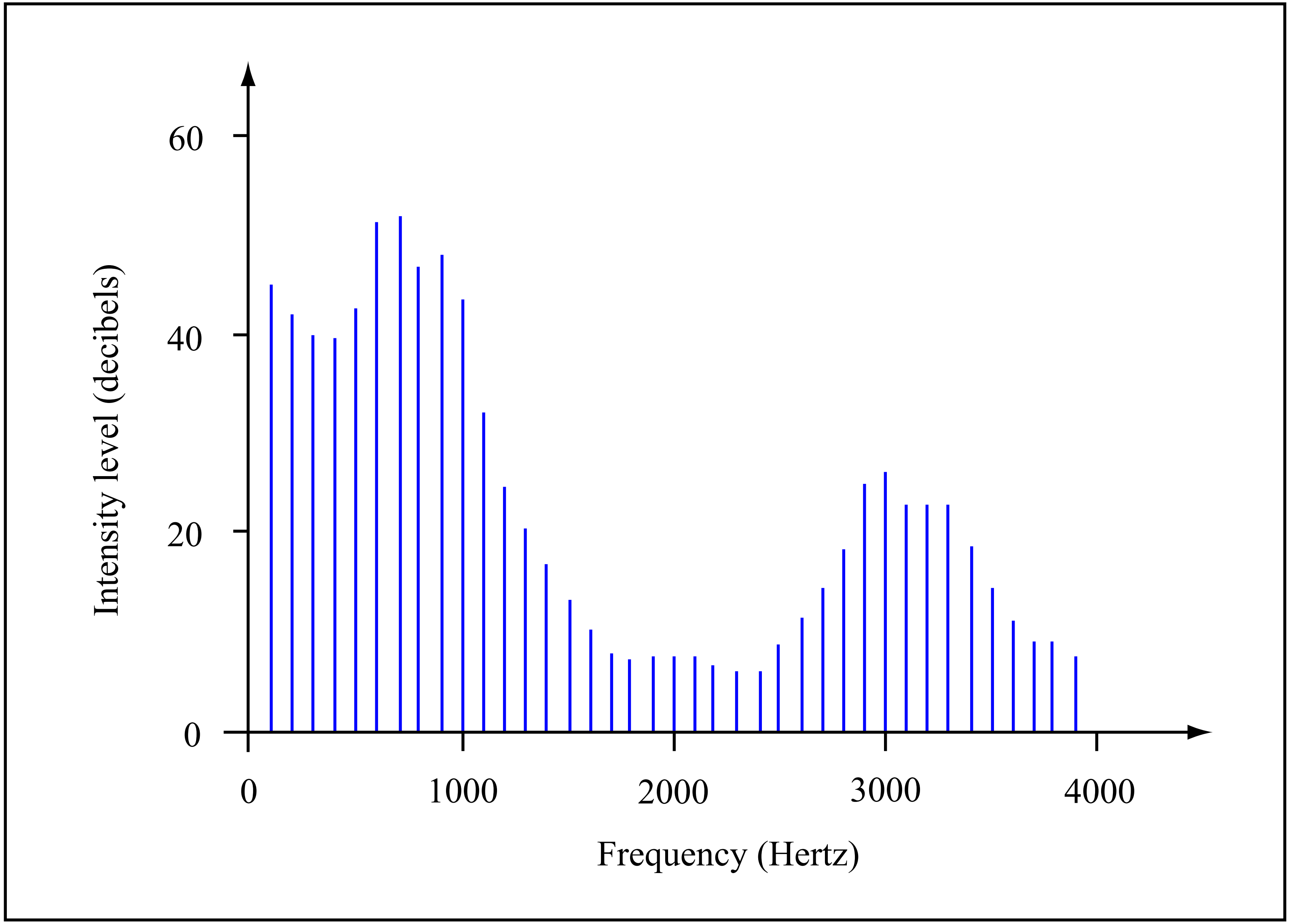
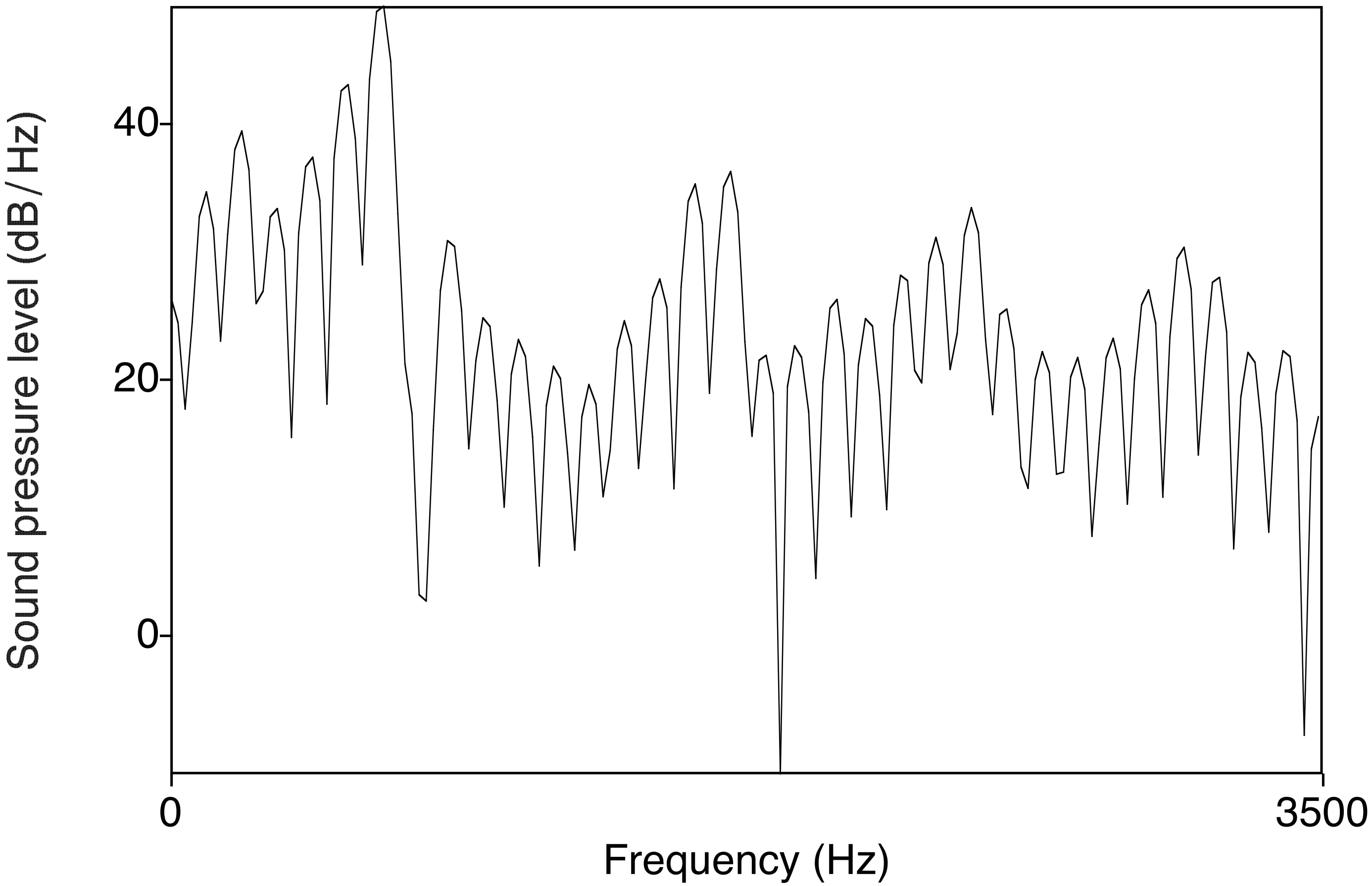


Image by MIT OCW.

vowel spectrum

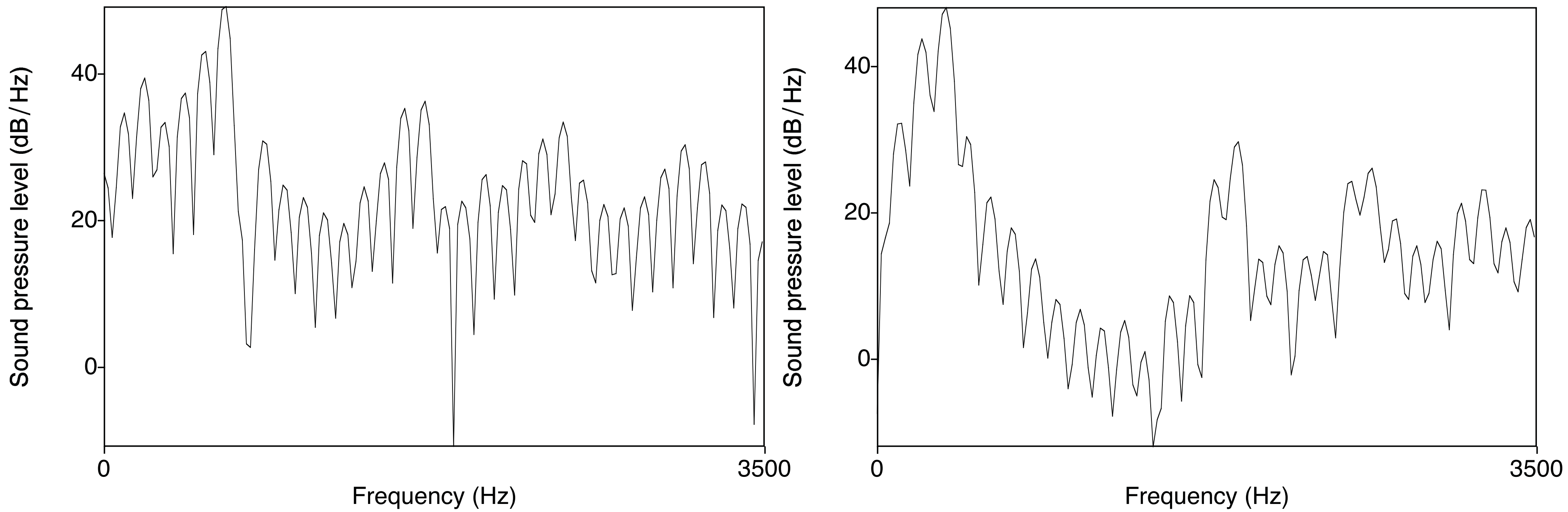


[æ]

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.

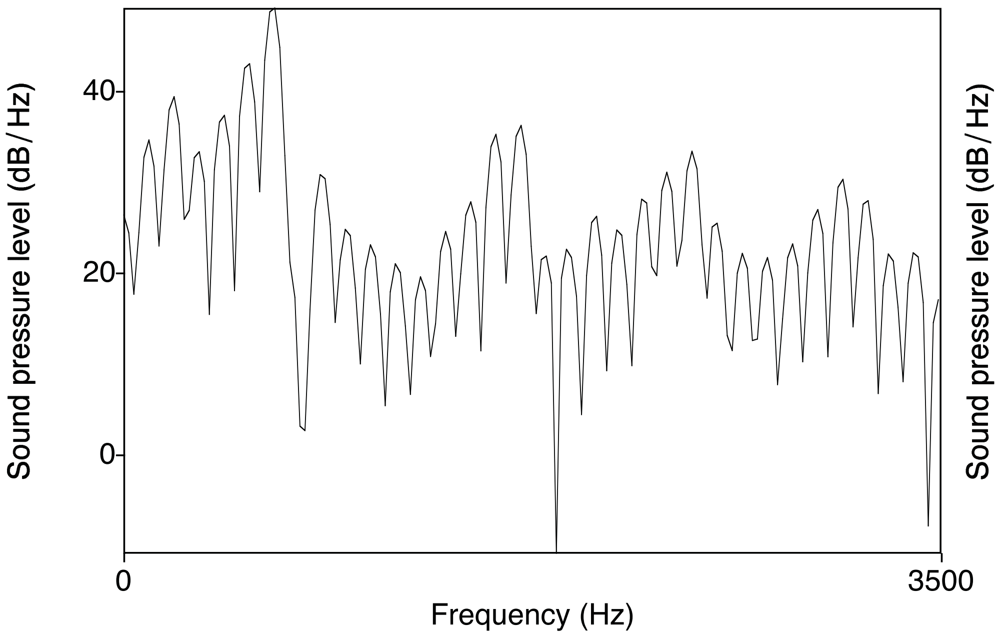
[æ] [ɪ]



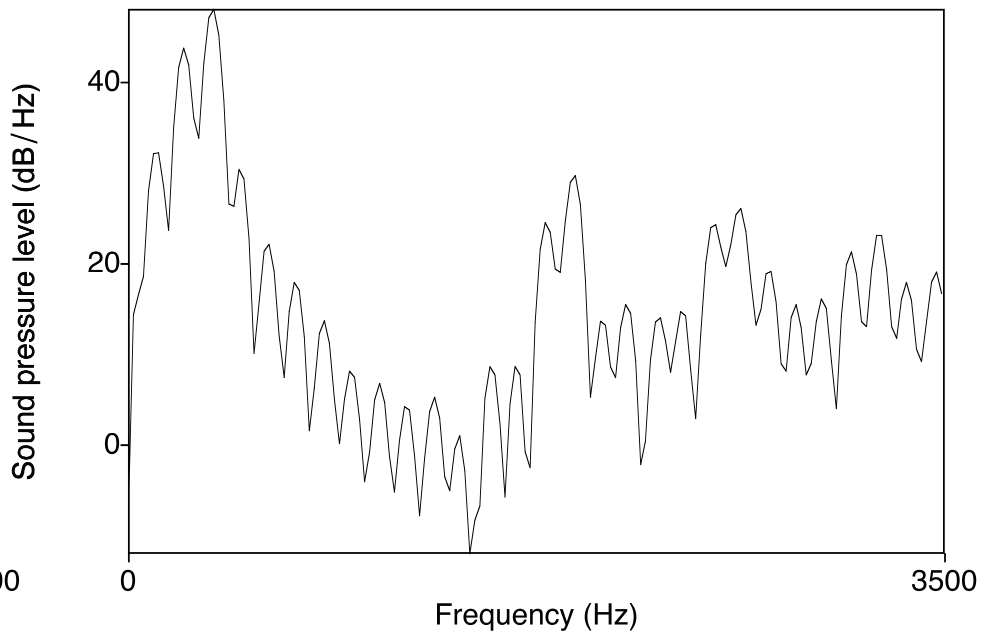
Vowel quality

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

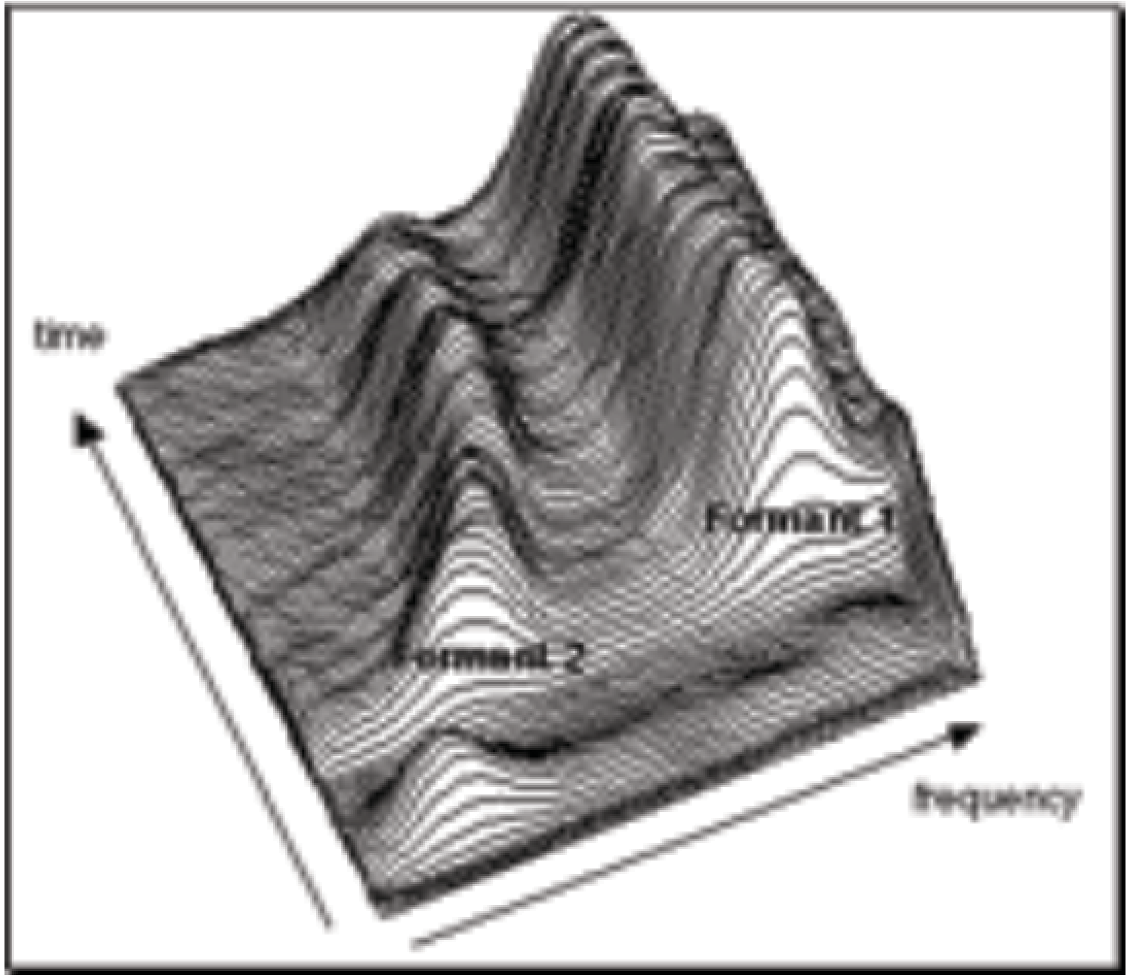
[æ]



[ɪ]



Spectrograms



Spectrograms

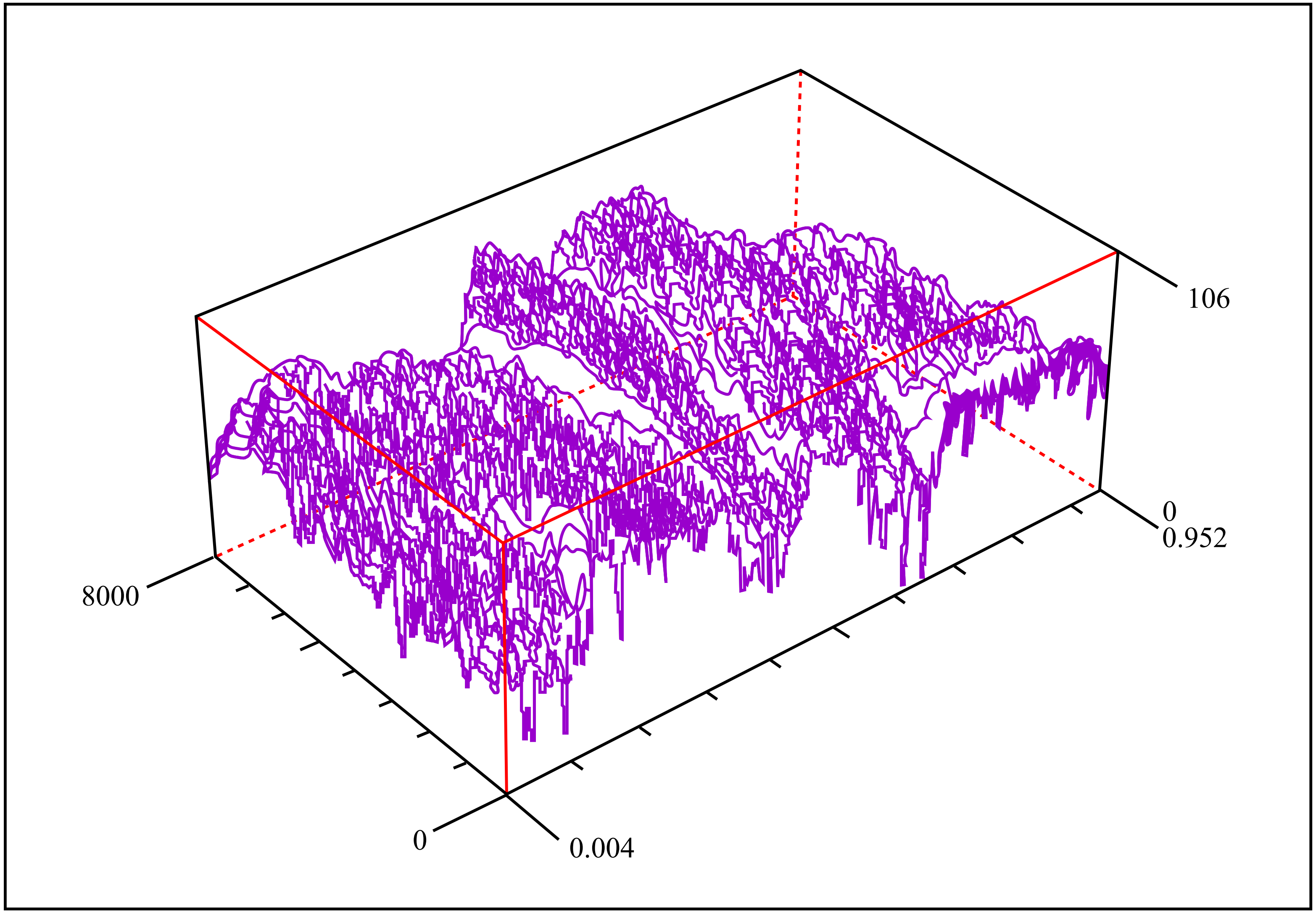
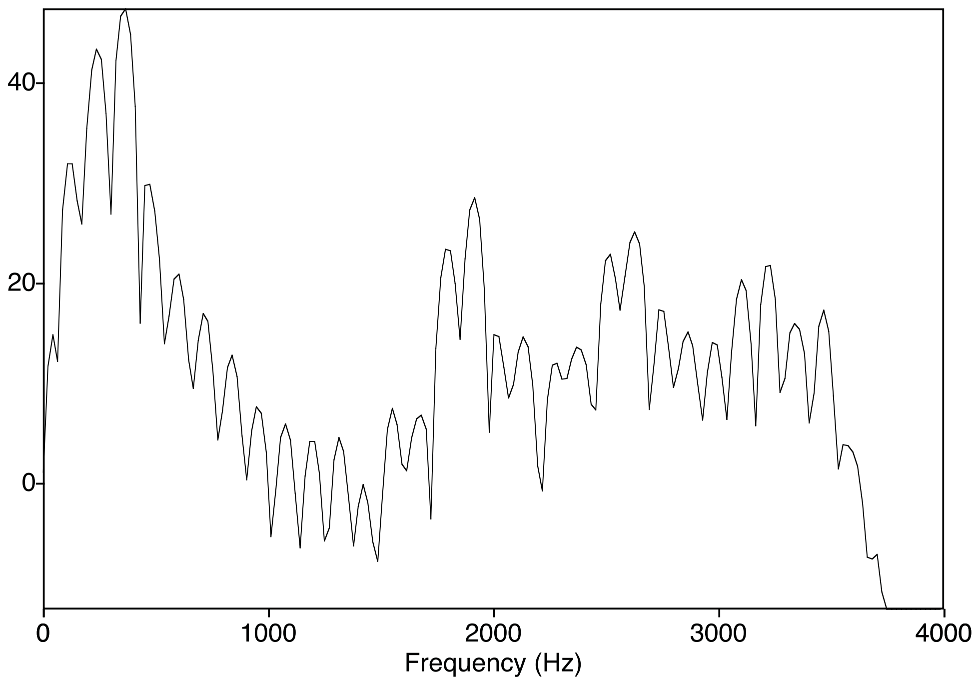
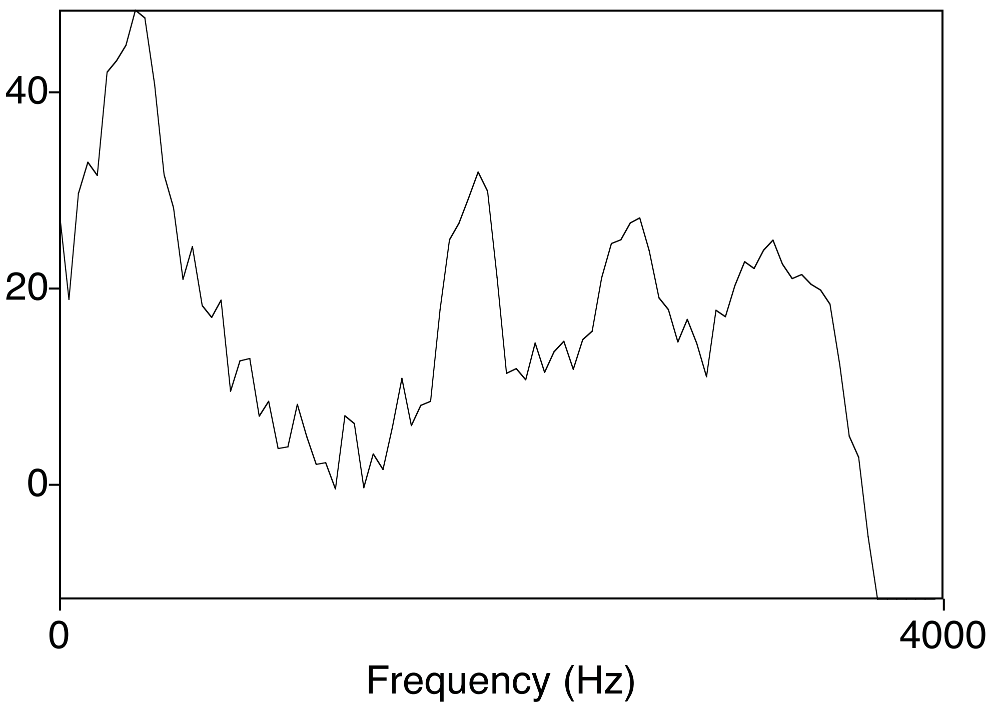


Image by MIT OCW.

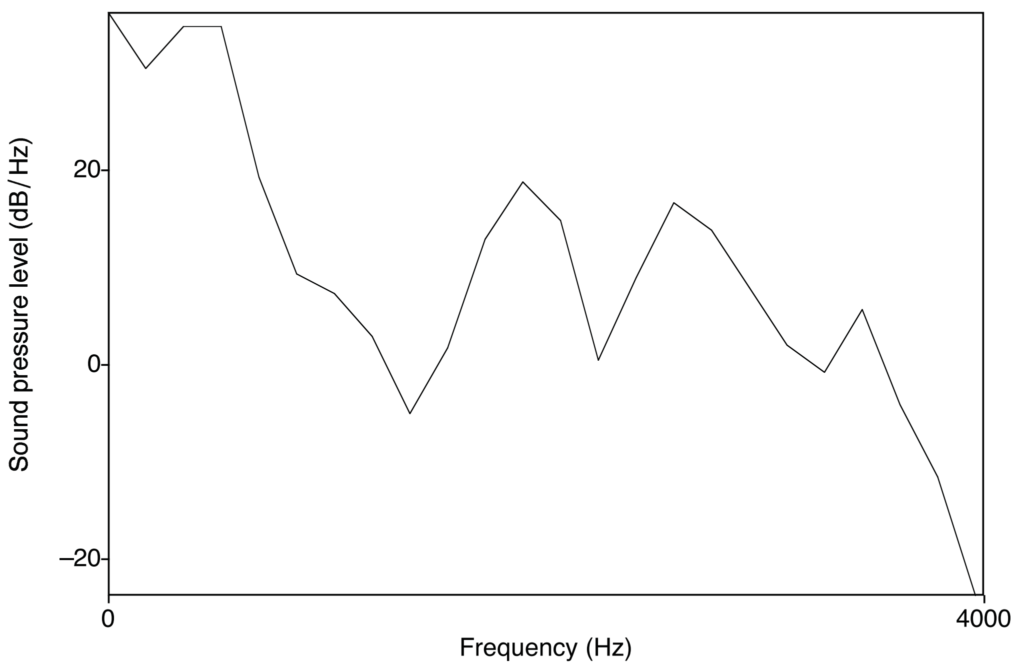
Figure removed due to copyright restrictions.
Source: Figure 8.16, Ladefoged, Peter, and Keith Johnson.
A course in phonetics. Nelson Education, 2014.



narrow band
(long window)



broad band
(short window)



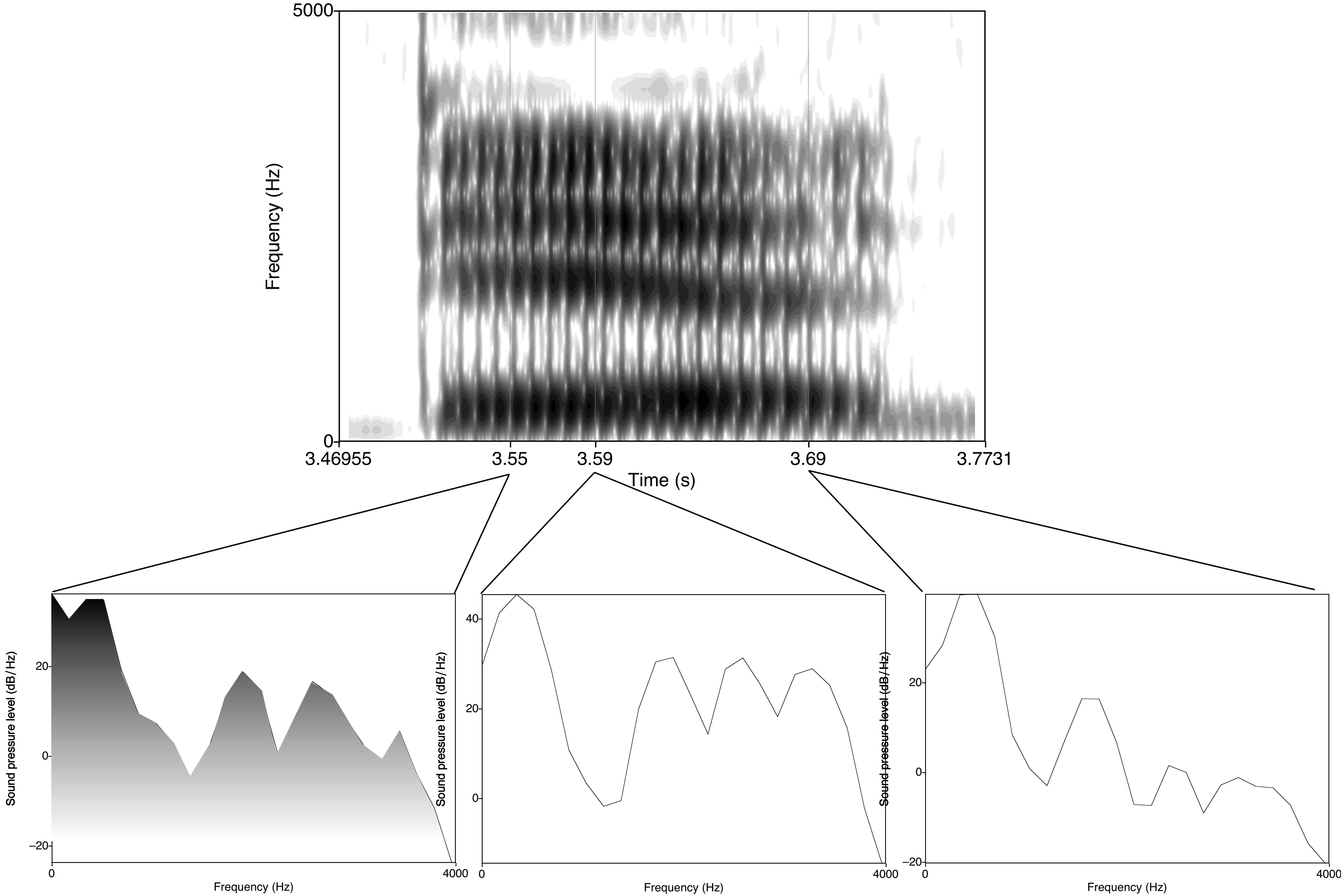

5000
0
Frequency (Hz)
3.46955
3.55
3.59
3.69
3.7731
Time (s)
Sound pressure level (dB/Hz)
20
0
–20
0
4000
Frequency (Hz)
Sound pressure level (dB/Hz)
40
20
0
0
4000
Frequency (Hz)
Sound pressure level (dB/Hz)
20
0
–20
0
4000
Frequency (Hz)

Figure removed due to copyright restrictions.
Source: Figure 8.4, Ladefoged, P., and K. Johnson.
"A Course in Phonetics (Cengage Learning)." (2010).

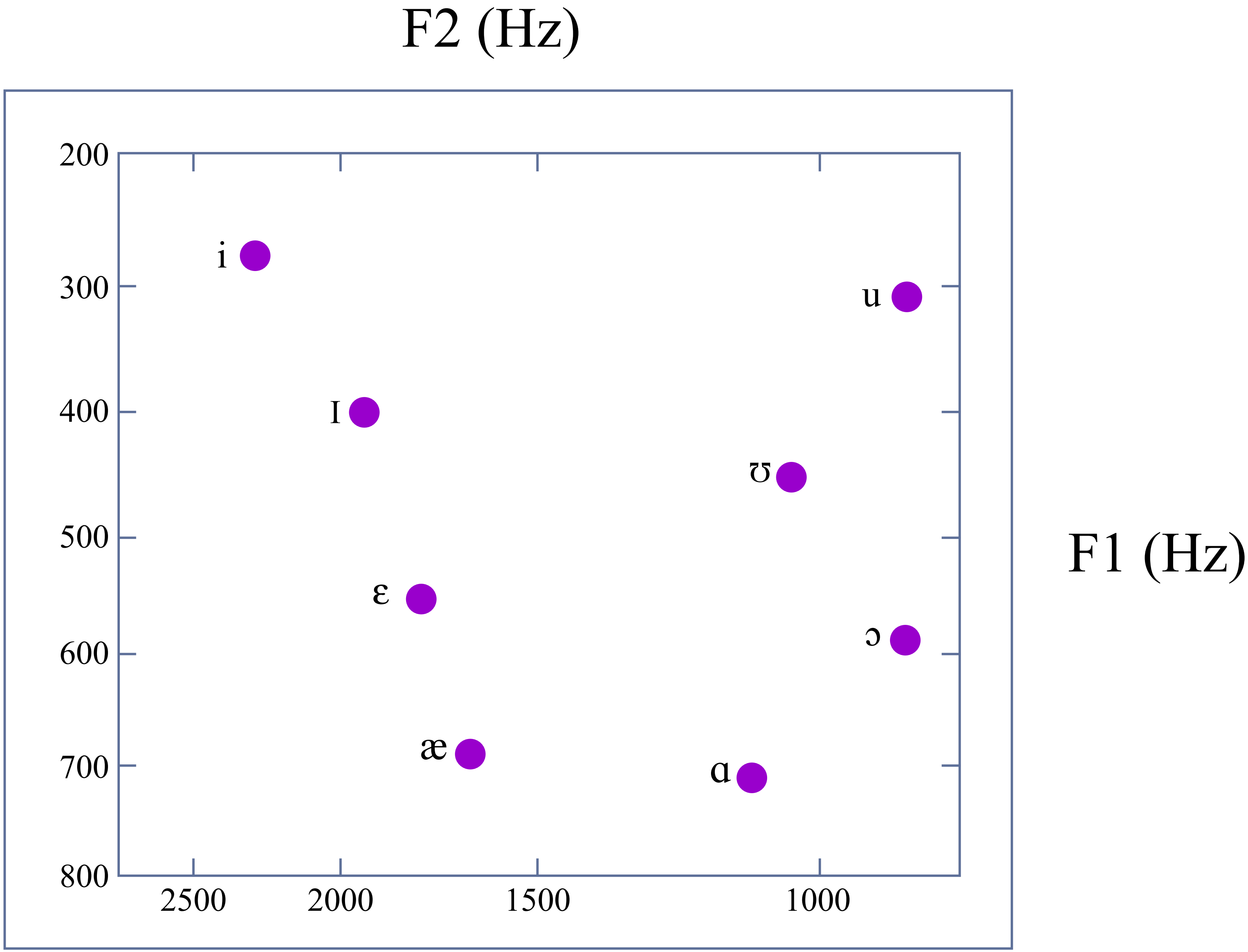


Image by MIT OCW.
Adapted from Peter Ladefoged. A Course in Phonetics. 5th ed. Berlin, Germany: Heinle, 2005.
ISBN: 9781413006889. Available at: http://www.phonetics.ucla.edu/course/contents.html.