SSC 0158: The Science of Talking

The Source-Filter Model of Speech Production

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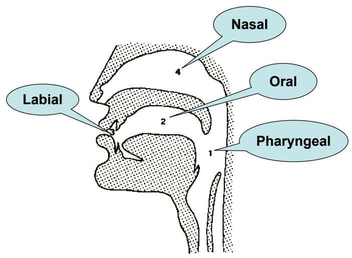
Plan for afternoon

- Lecture: Production of vowels
- Lab: Frequency analysis of vowels used in sentences
- Tutorial: Review & check understanding

What is a vowel?

- **Vowel**: A sound produced without a close obstruction in the vocal tract.

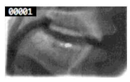


Ashby, M. & Maidment, J. (2005: 200). Introducing phonetic science. Cambridge University Press.

X-ray films of vocal tract

- 'Why did Ken set the soggy net on top of his deck?'

- 'Le boulanger but onze bières.'

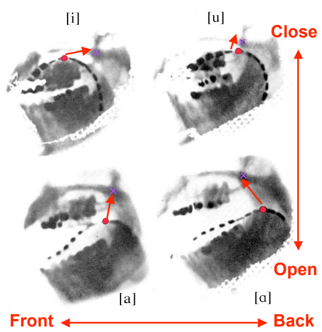


- 'It's ten below outside.'

http://psyc.queensu.ca/~munhallk/05_database.htm

X-rays of cardinal vowels

- X-ray photographs of the tongue positions of **Daniel Jones' cardinal vowels [i, u, a, ɑ]**
  - A chain of small lead plates strung together was placed on **the tongue** to show its outline.
  - The large dot added on each photograph marks **the highest point** of the tongue.
  - The cross is a point of **reference** (near the end of the hard palate)



http://en.wikipedia.org/wiki/File:Cardinal_vowels-Jones_x-ray.jpg

Cardinal vowels

- **Cardinal vowels:**
  - "**a standard set of vowels for reference** — a scale of vowels which can be used in the same sort of way as a scale of degrees which enables us to specify temperatures."
  - "The vowel sounds of such a scale are called **cardinal vowels**."
- "Cardinal Vowels **can only be learnt** from a teacher who knows how to make them or from a gramophone record or tape record."
- **Daniel Jones (1881-1967):**
  - Started phonetics teaching at UCL: 1907
  - Professor of Phonetics: 1921-49
  - Head of Department of Phonetics

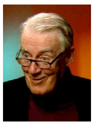

Daniel Jones

Jones, D. (1956: 6). Cardinal vowels (8th ed.). Cambridge: W. Heffer & Sons Ltd.

Henry Sweet, Daniel Jones, Peter Ladefoged, and My Fair Lady


(1845-1912)

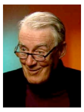

(1881–1967)


(1925–2006)

(1964)
George Bernard Shaw's 'Pygmalion'

Lineage

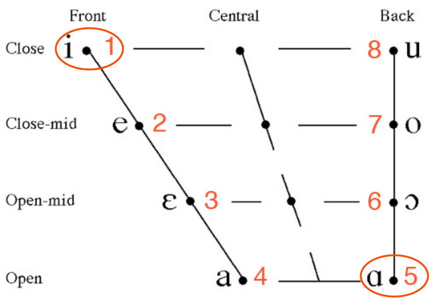


- **Henry Sweet** taught phonetics to **Daniel Jones**.
- Daniel Jones taught **David Abercrombie**.
- David Abercrombie taught **Peter Ladefoged**.
- Peter Ladefoged taught **Sean Fulop**.
- Sean Fulop taught **me**.
- I am teaching **you**.

https://webdisk.ucalgary.ca/~swinters/public_html/ling441/index.html

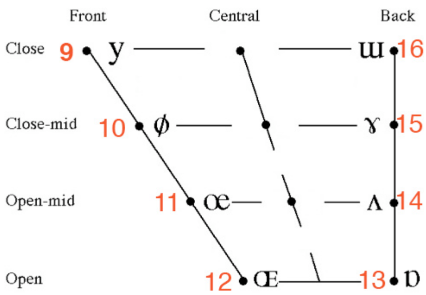
Primary cardinal vowels



Jones (1956): Ladefoged:

http://www.langsci.ucl.ac.uk/ipa/vowels.html

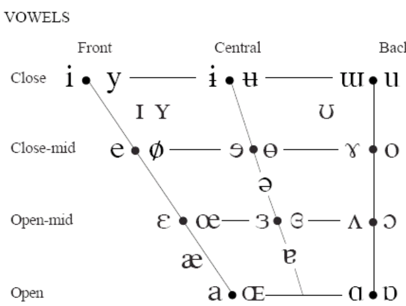
Secondary cardinal vowels



Jones (1956): Ladefoged:

http://www.langsci.ucl.ac.uk/ipa/vowels.html

International Phonetic Alphabet (IPA)



Where symbols appear in pairs, the one to the right represents a rounded vowel.

http://www.langsci.ucl.ac.uk/ipa/vowels.html

Vowels in British English

- Monophthongs
  - bead, bard, bawd, booed, bird - *long*
  - bid, bed, bad, bud, bod(y), budd(hist) - *short*
- Neutral
  - v<u>a</u>nill<u>a</u> - *schwa*
- Diphthongs
  - bayed, bide, Boyd - *fronting*
  - beer, bare, byre, boor - *centering*
  - bode, bowed - *backing*

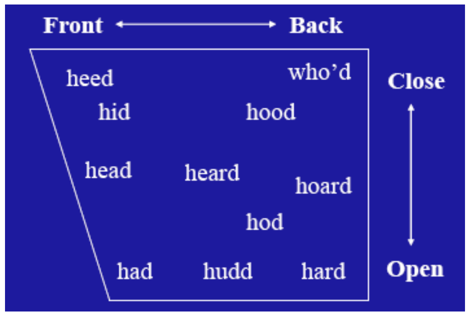
http://www.phonetics.ucla.edu/vowels/chapter3/bbcenglish.html

BBC English Vowels in IPA

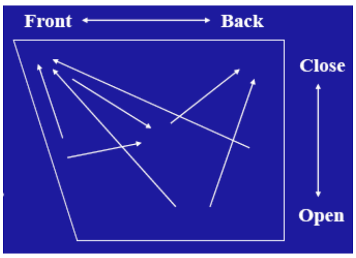
	b__d	IPA		b__d	IPA
1	bead	iː	11	booed	uː
2	bid	ɪ	12	bud	ʌ
3	bayed	eɪ	13	bird	ɜː
4	bed	ɛ	14	bide	aɪ
5	bad	æ	15	bowed	aʊ
6	bard	ɑː	16	Boyd	ɔɪ
7	bod(y)	ɒ	17	beer	ɪə
8	bawd	ɔː	18	bare	ɛə
9	budd(hist)	ʊ	19	byre	aə
10	bode	əʊ	20	boor	ʊə

http://www.phonetics.ucla.edu/vowels/chapter3/bbcenglish.html

English monophthongs on vowel quadrilateral



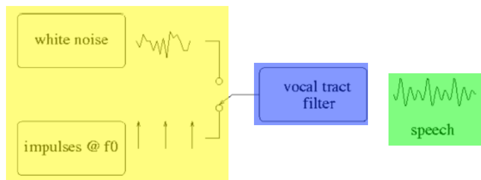
English diphthongs on vowel quadrilateral



- **Find the diphthongs:**
  - **bayed, bide, buoyed (fronting)**
  - **beard, bared (centering)**
  - **bode, bowed (backing)**

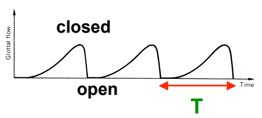
The Source-Filter model

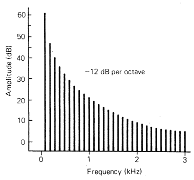
- **Speech** is the result of ***source + filter***
- **Source**: sound produced at the origin
  - **Noise source**: provided by various obstructions of the airflow above or at the larynx
  - **Periodic source**: provided by the vibration of the vocal cords
- **Filter**: the air space(s) in the vocal tract whose resonances modify or shape the source sound.



Glottal source

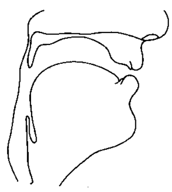
- Vocal fold vibrations produce a sound source - **a glottal wave**
- **Periodic wave** with **fundamental frequency** plus a range of **harmonics.**
  - **Cycle:** one complete unit of the wave
  - **Period T:** the time it takes for the wave to complete one cycle
  - **Fundamental frequency F0 = 1/T**, how often the wave (cycle) repeats itself in 1 second, in cycles/second or Hz
- The spectrum of the glottal source decreases in amplitude with increasing frequency at a rate of around **-12 dB per octave**

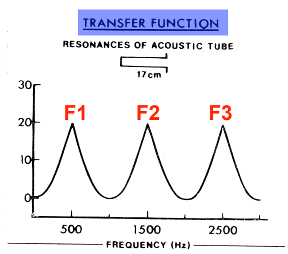




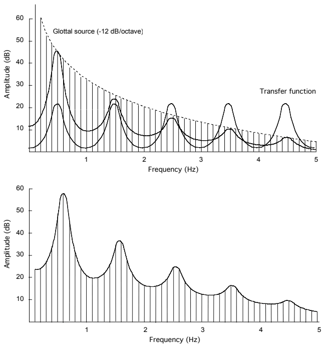
The Filter

- **Vocal tract** is a **resonator (filter)** that will dampen certain harmonics and emphasise others – those that are closest to its resonant frequencies - **formants**
- For a relatively unconstricted vocal tract (**the vowel schwa**), the resonances of a 17 cm vocal tract occur at **500 Hz** (**F1**), **1500 Hz** (**F2**), **2500 Hz** (**F3**)…

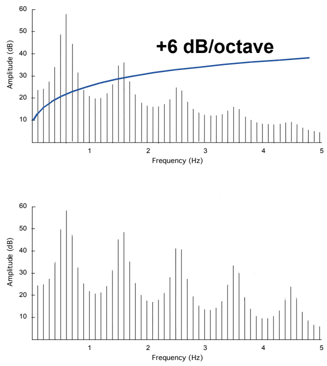




Applying transfer function to glottal source spectrum



Effects of Radiation at the lips



Source-Filter Model in a nutshell

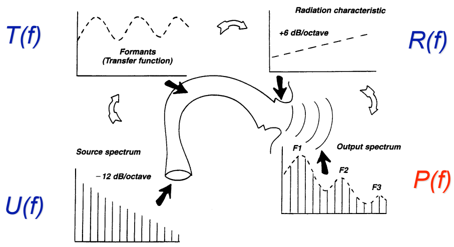


Figure 9–7. Diagrammatic summary of the source-filter theory of speech production.

P(f)* = *U(f)* • *T(f)* • *R(f)

P(f) **— Output sound pressure spectrum**

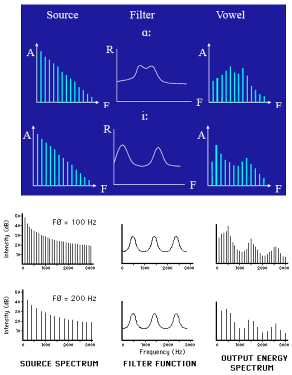
U(f) **— Laryngeal source spectrum**

T(f) **— Transfer function of the vocal tract —** ***formants***

R(f) **— Radiation characteristic**

Independence of source and filter

- **The characteristics of the source and filter can vary independently without affecting the characteristics of the other:**
  - **Different vowels can have the same pitch**
  - **The same vowel can have different pitches**



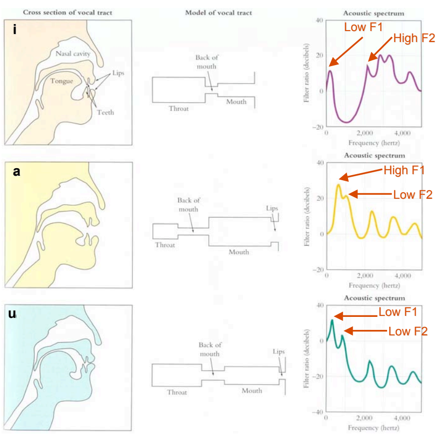
http://www.haskins.yale.edu/featured/heads/mmsp/acoustic.html

Different vowels…

/i/ constriction in the front half of the tube

/a/ constriction in the rear half of the tube

/u/ constrictions both in the middle of the tube and at the front end of the tube

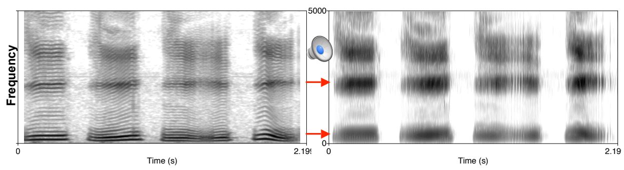


Measuring formants from the spectrogram

- Spectrogram shows how composition of sound varies with *frequency* and *time*: **Wideband** vs. **narrowband**, with different sizes of band-pass filter (e.g., **330 Hz** vs. **45 Hz**)

Narrowband spectrograms reveal **harmonic** structure -- **Source**

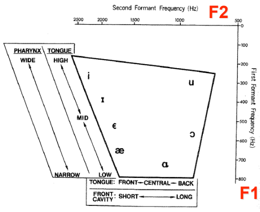
Wideband spectrograms show **formant** structure -- **Filter**

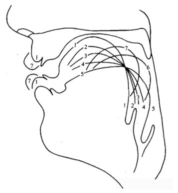


/i/ with Chinese four tones: High, Rising, Falling-rising, Falling

- **Vertical striation = glottal pulses**
- **Darkness = intensity (dB)**
- **Dark horizontal bands = formant frequencies (Hz)**

Vowels: Articulation vs. acoustics





Vocal tract shape for vowels in words:

(1) heed
(2) hid
(3) head
(4) had
(5) father
(6) good
(7) food

F1 correlates with **size of pharyngeal cavity** and **degree of lip opening** (when **the tongue high, the pharyngeal cavity is larger**, as in [i], resulting in **lower F1**) -- **Vowel openness or height**

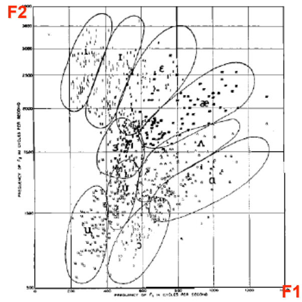
F2 correlates with **the length of the oral cavity** -- **frontness/backness** (**the longer the oral cavity** - due to the more retracted tongue - **the lower F2**)

Lip rounding protracts the oral cavity and thus will **decrease F2**

Ladefoged, P. (2001). A course in phonetics (4th ed.). Harcourt College Publishers.

Acoustics vs. Vocal tract size

- **Actual formant frequencies differ across speakers due to differences in their vocal tract size**
- **In general, larger vocal tracts (adult males) result in lower resonant frequencies than the smaller ones (adult females and children)**
- **However, the formant patterns (F1, F2, F3) are consistent speaker to speaker**

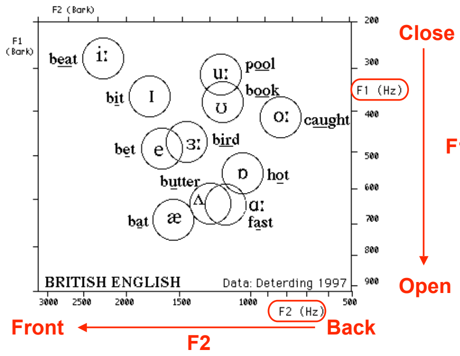


Peterson & Barney (1952): F1 x F2 plot for 10 American English vowels, by 33 men, 28 women, and 15 children, 1520 tokens

Summary: Vowel classification

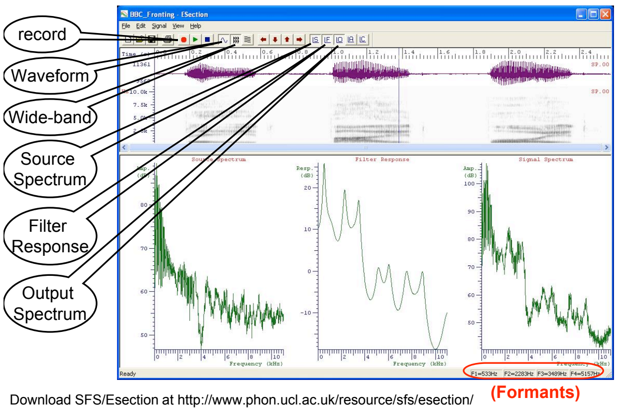
- **Frontness (on vowel quadrilateral)**
  - **Front – Central – Back**
  - **The more front the vowel, the higher the F2**
- **Openness (on vowel quadrilateral)**
  - **Close – Close-mid – Open-mid – Open**
  - **The more open the mouth (the lower the vowel), the higher the F1**
- **Length**
  - **Long – short**
- **Direction of any quality change**
  - **Fronting – Centering – Backing**

Formants of English Monophthongs



Deterding, David (1997) The formants of monophthong vowels in Standard Southern British English pronunciation. Journal of the International Phonetic Association 27, 47-55.

Lab: Measuring formants using SFS/ESection



Download SFS/Esection at http://www.phon.ucl.ac.uk/resource/sfs/esection/