LIN228H1F Phonetics
Lecture 5: English Acoustics

Monday, May 17th, 2021

Instructor: Emily Blamire

Today's Plan

1. Clarifications
2. Line Drawings and Narrow Transcription
3. How to read spectrograms
4. Homework 2 answers (time allowing)

Clarifications

Clarifications

Obstruents vs sonorants

- Obstruents = stops, fricatives, and affricates (obstruction to airflow)
- Sonorants = **nasals**, liquids, glides, and vowels (free(ish) airflow)
  - There is glossary in your textbook (pg 299 – 316) with most of the terms used in this class

Stress

- Both secondary stress and primary stress count as “stressed” for the purposes of our narrow transcription rules
- Most narrow transcription processes happen regardless of whether the syllable is stressed or not. 3 are dependent on the syllable being **stressed**
  - Aspiration
  - Liquid devoicing (because it is triggered by aspiration)
  - Vowel lengthening (we only mark in stressed syllables)

Transcription & Line Drawings

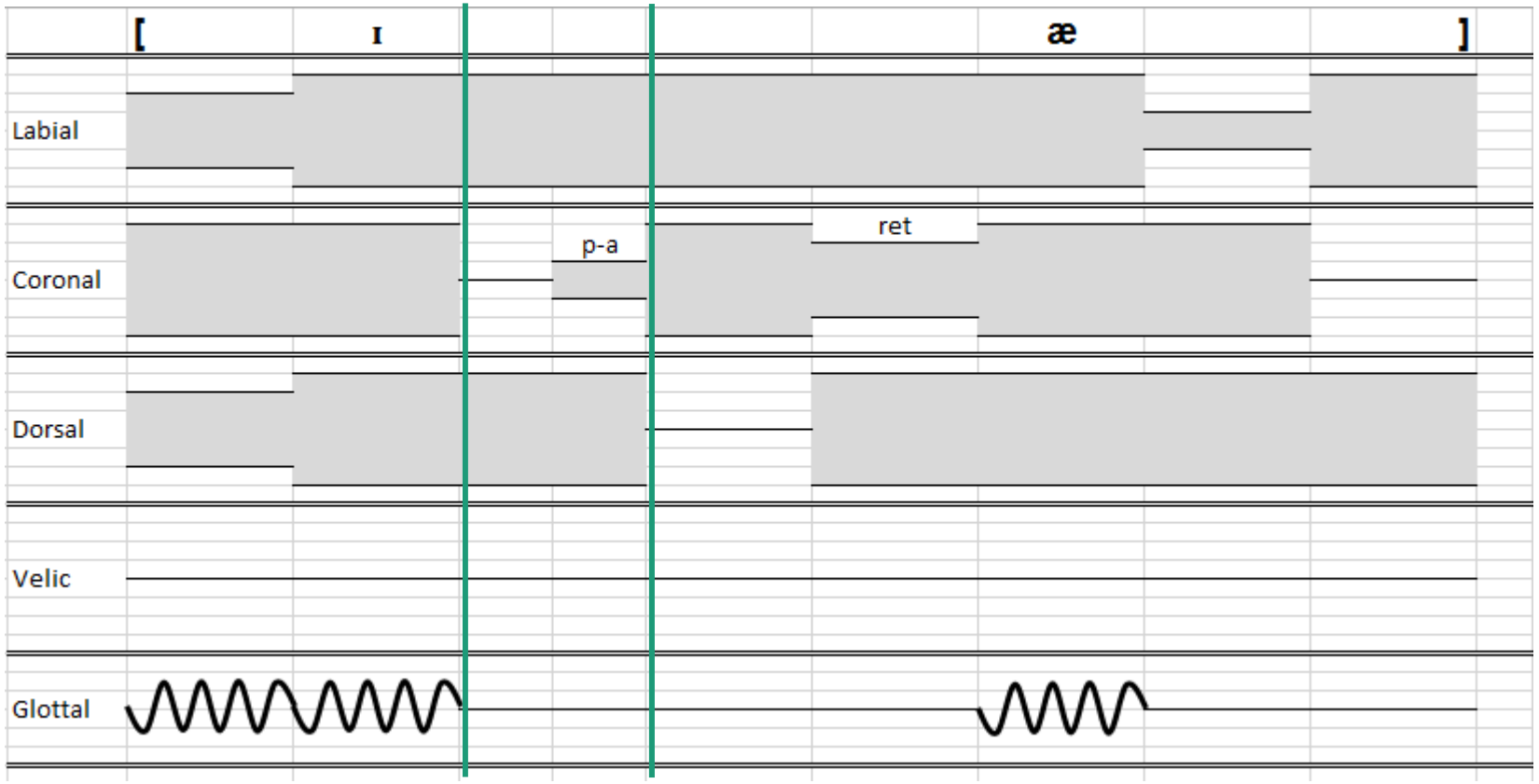
Clarifying Broad vs Narrow Transcription

Narrow Transcription Line Drawings

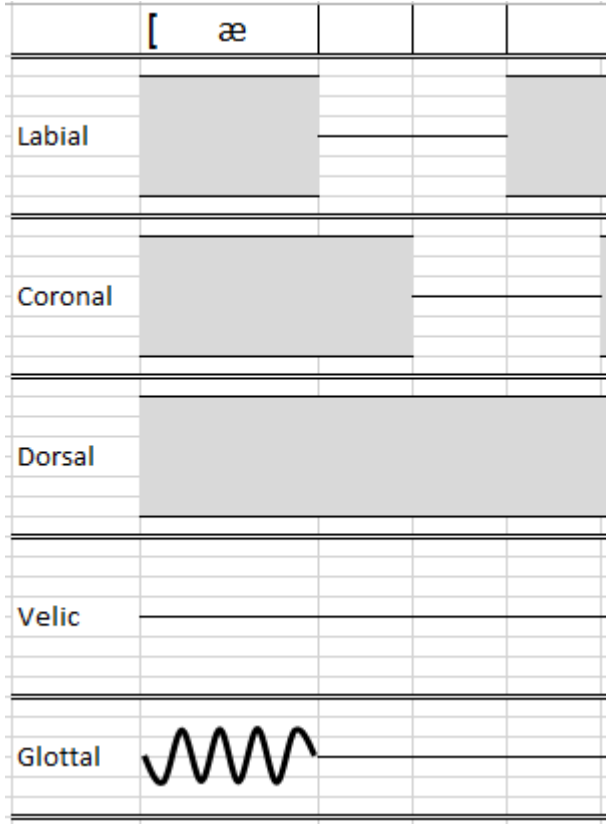
Broad vs Narrow Transcription

- In this course, we will use “Broad Transcription” and “Narrow Transcription” in very specific ways to distinguish between phonetic transcription that includes more or less detail.
  - Broad transcription will include **all regular phonemic contrasts** in Canadian English, plus:
    - Schwa in unstressed syllables
    - Vowel distinctions before /ɹ/
    - Primary stress on words of more than one syllable
    - (Homorganic nasals & Yod-dropping)
  - Narrow transcription will include **everything else**!
- From now on, in order to be clear about which level of transcription we’re using:
    - We will enclose broad transcriptions in slant lines /.../
    - We will enclose narrow transcriptions in square brackets [...]

Narrow Transcription Line Drawings



Narrow Transcription Line Drawings



How to read a spectrogram

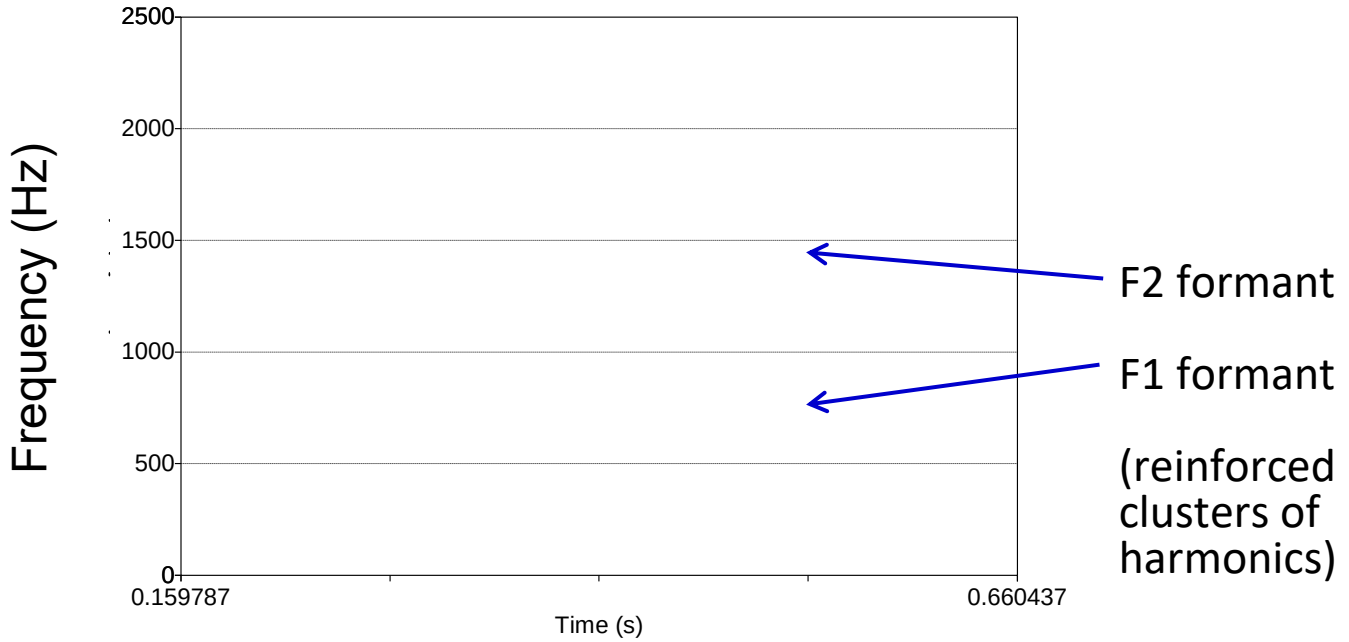
Spectrograms

- A **spectrogram** is a display that is particularly useful when examining speech sounds.

- It has three dimensions:
  1. Time: plotted on the x-axis (horizontal)
  2. Frequency: plotted on the y-axis (vertical)
  3. Intensity: darkness of representation (greater intensity = darker)

Spectrograms

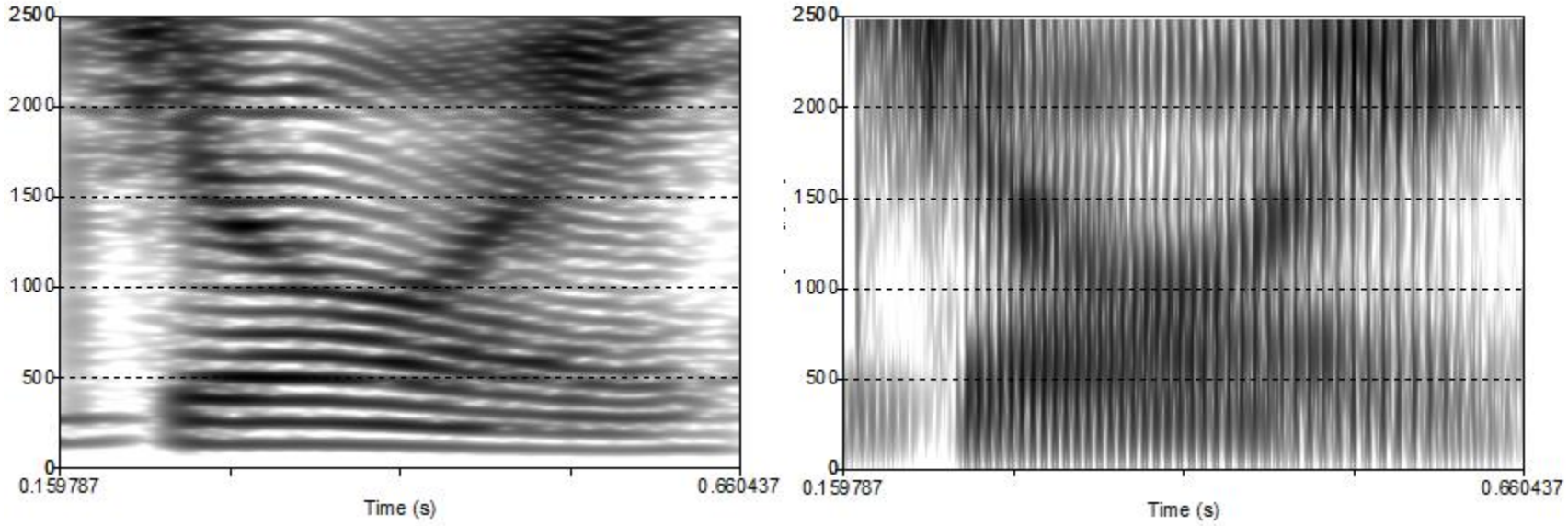
- **Spectrogram**:
  - a display showing time (x-axis), frequency (y-axis), and intensity (darkness).



joy

Spectrograms

- 2 kinds of spectrogram displays:
  - **Narrow-band** spectrograms
    - higher frequency resolution; easy to distinguish individual **harmonics**.
  - **Wide-band** spectrograms
    - higher temporal resolution; easy to see individual wave cycles and formants.



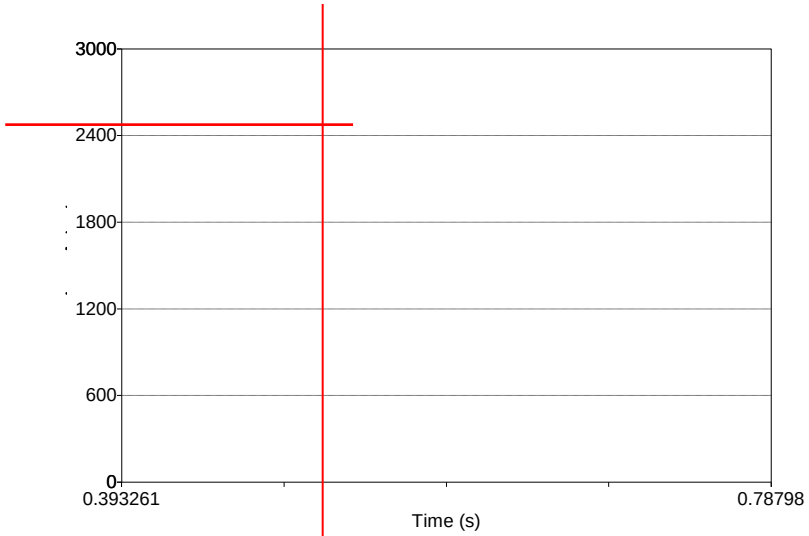
joy

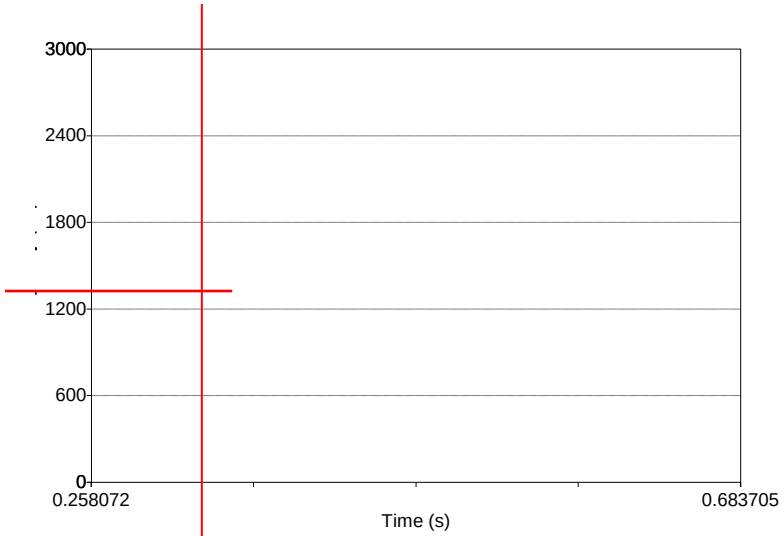
Spectrograms

Why do we count up 10 harmonics instead of just measuring where the first harmonic is?

All harmonics above have frequencies that are multiple of F0.

- Narrow-band spectrograms
  - can easily measure pitch (F0).





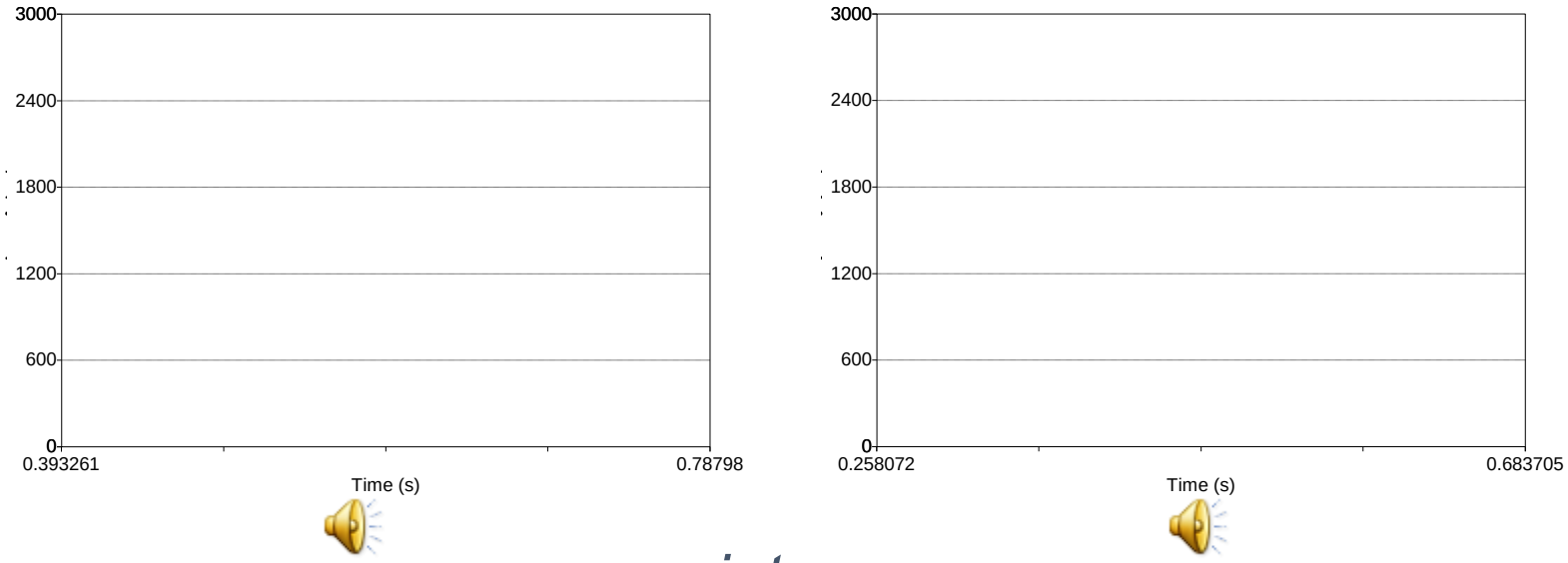
winter

F_0 = ~245 Hz (2450/10)

F_0 = ~130 Hz (1300/10)

Spectrograms

- Wide-band spectrograms
  - most useful for characterizing phonetic segments.



winter

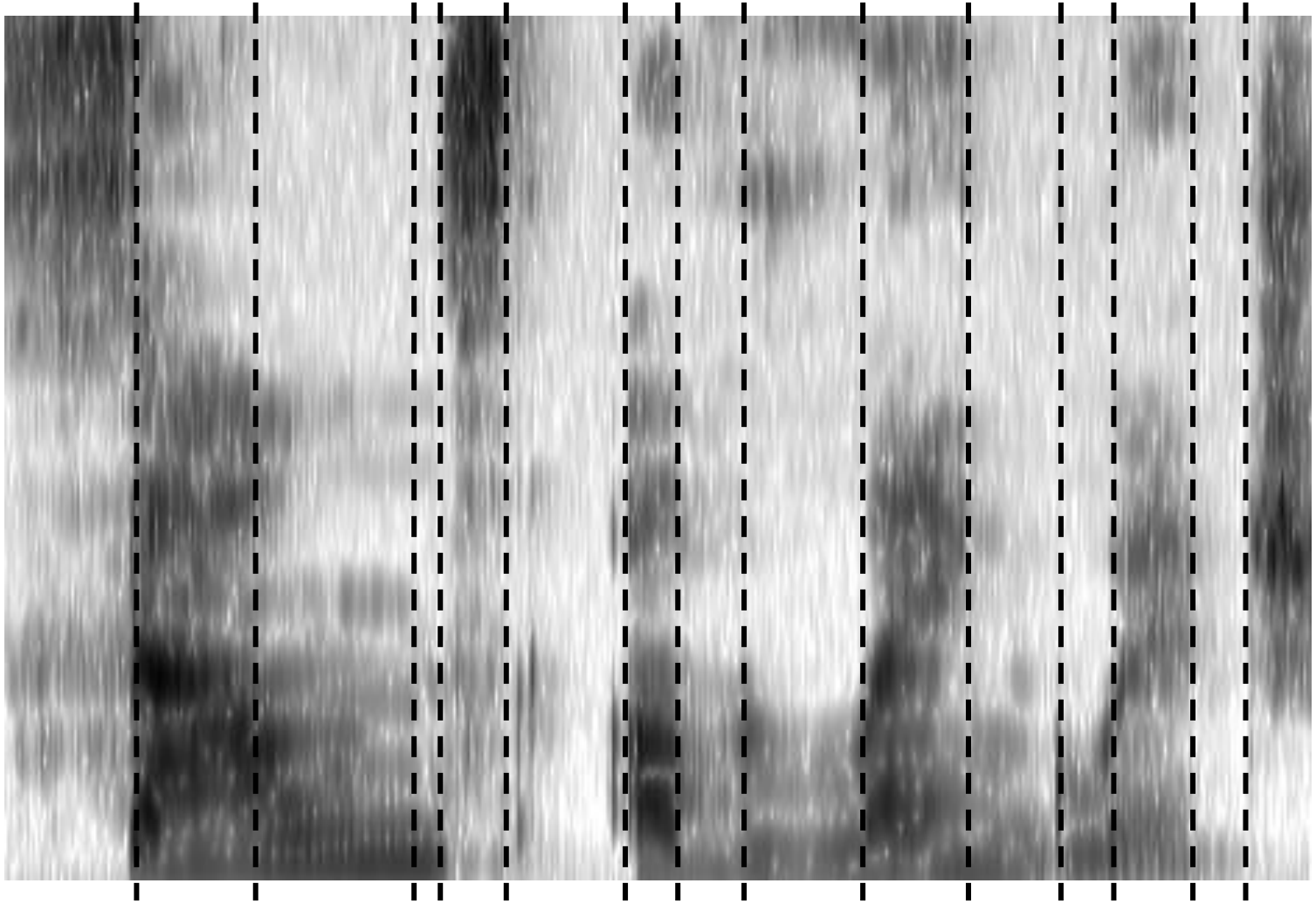
How to read spectrograms:

- Every speech sound has a unique acoustic pattern that can be identified on a spectrogram.

- Manner of articulation is a characteristic of speech sounds that is very easily distinguished.
  - Vowels & Glides
  - Fricatives
  - Stops
  - Affricates
  - Nasals
  - Liquid Approximants

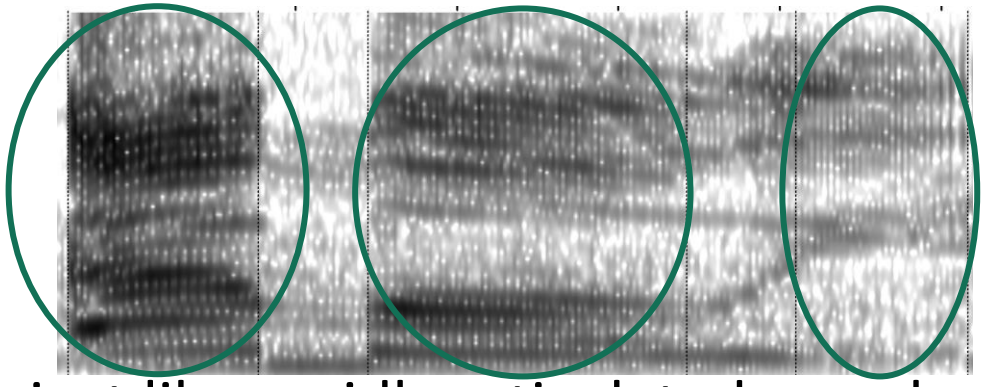
How to read spectrograms:

“Sounds of Language”
/sawndz əv læŋgwɪʤ/



How to read spectrograms:

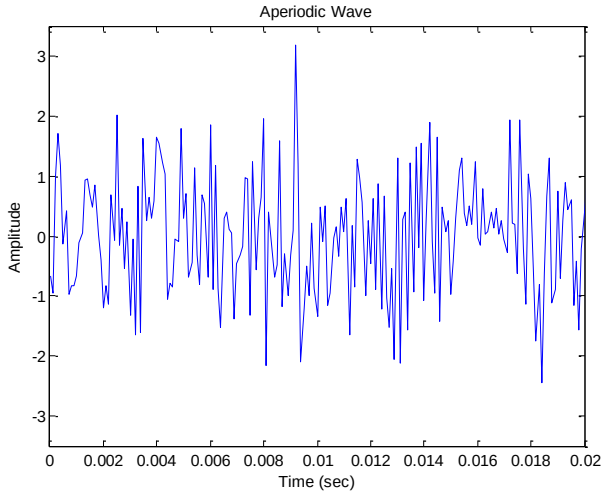
- **Vowels** are characterised by a series of very dark stripes starting at low frequencies.
  - These dark stripes are the formants (the clusters of harmonics that are reinforced by the resonating properties of the vocal tract)

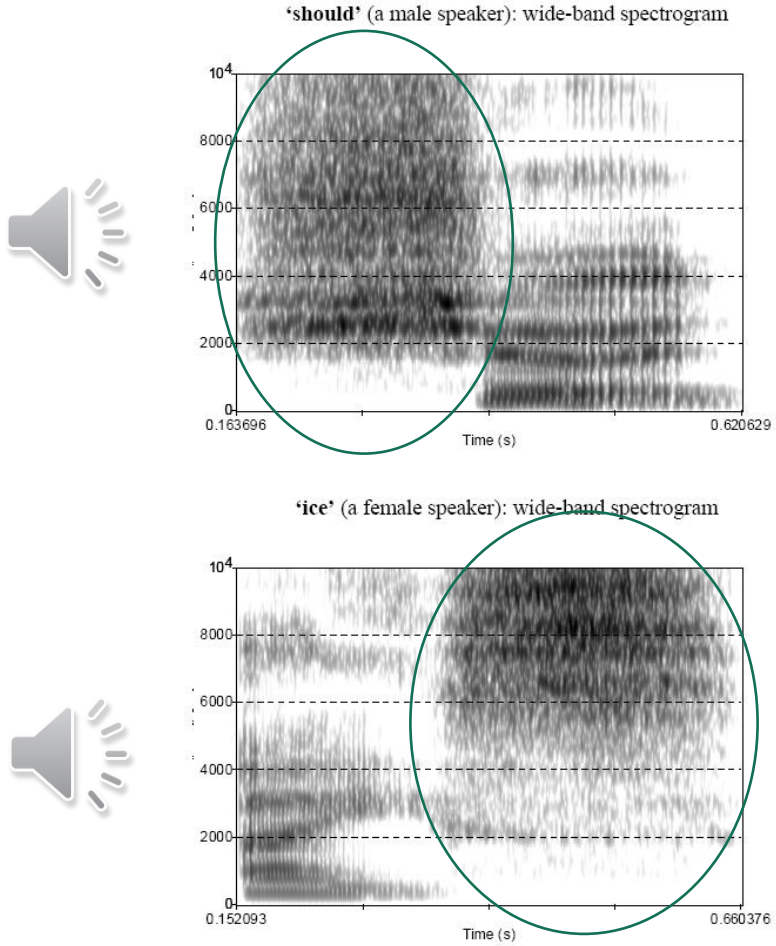


- Note that glides are just like rapidly articulated vowels.
  - On a spectrogram, they will look just like vowels, and it is often difficult to find where on a spectrogram a vowel ends and a glide begins (or vice versa)

How to read spectrograms:

- **Fricatives** are characterized by random noise.
  - Large areas of intensity. No formants.
  - Usually at high frequencies.
- **Note, the sibilant** fricatives (s, z, ʃ, ʒ) tend to be much darker and easier to see than other fricatives (f, v, etc.)

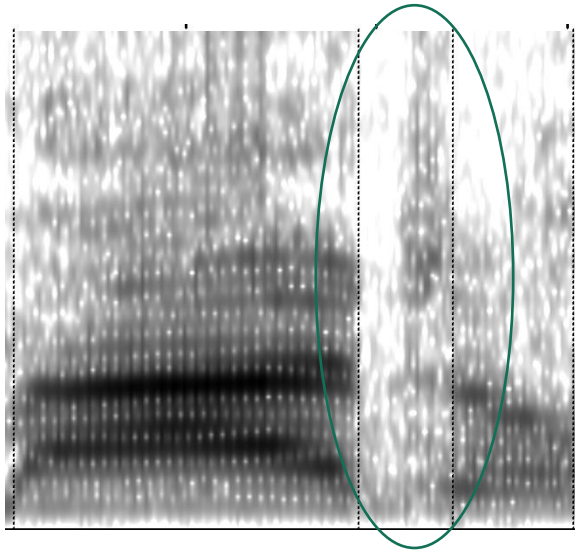


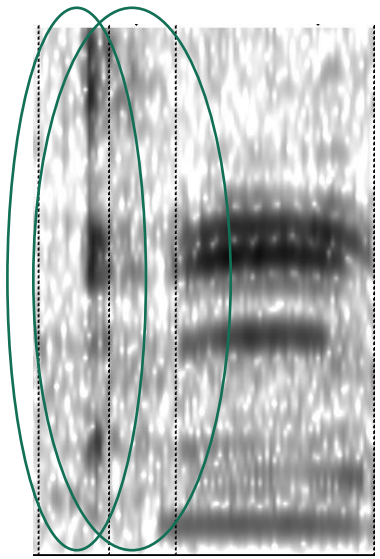


E.g. voiceless fricatives: turbulence caused by narrowing of the vocal tract.

How to read spectrograms:

- **Stops** are characterised by a period of silence, often followed by a short burst of energy (like a sharp vertical line).
  - Aspirated stops will be followed by a longer period of fricative-like noise with light formants that match the formants of the following vowel.

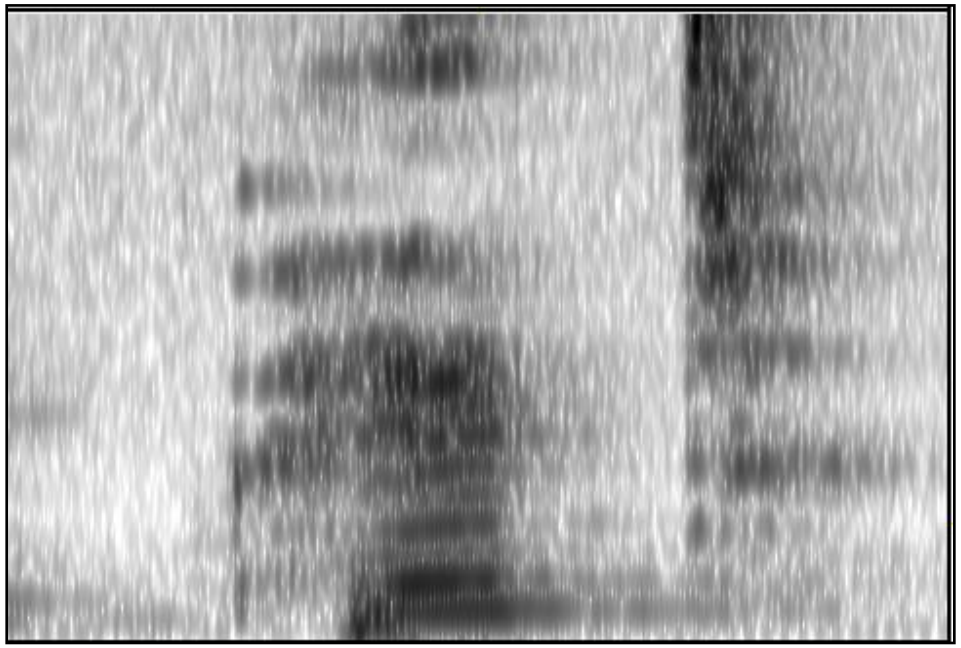


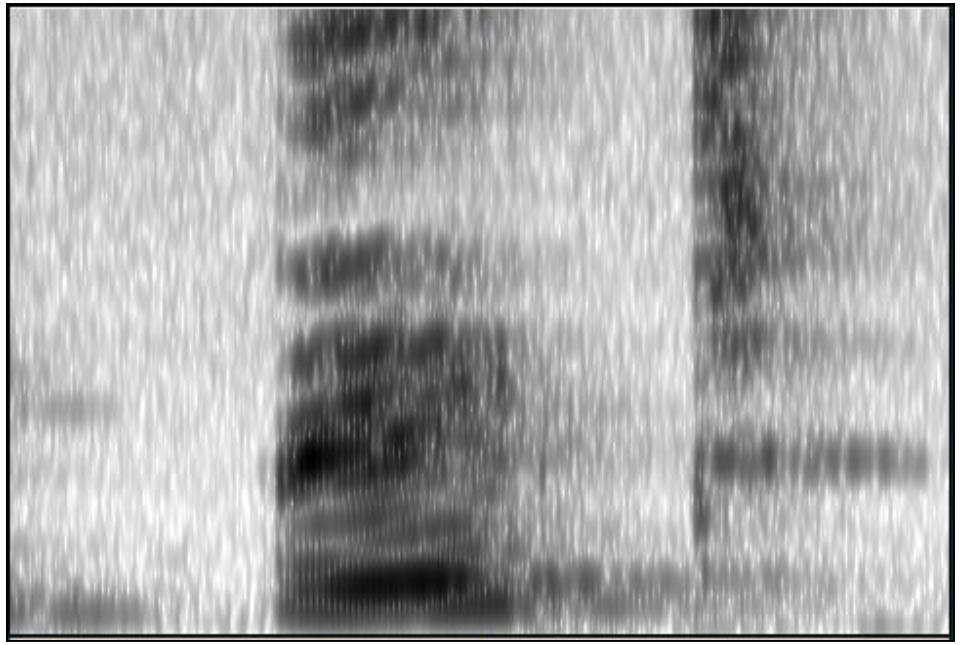


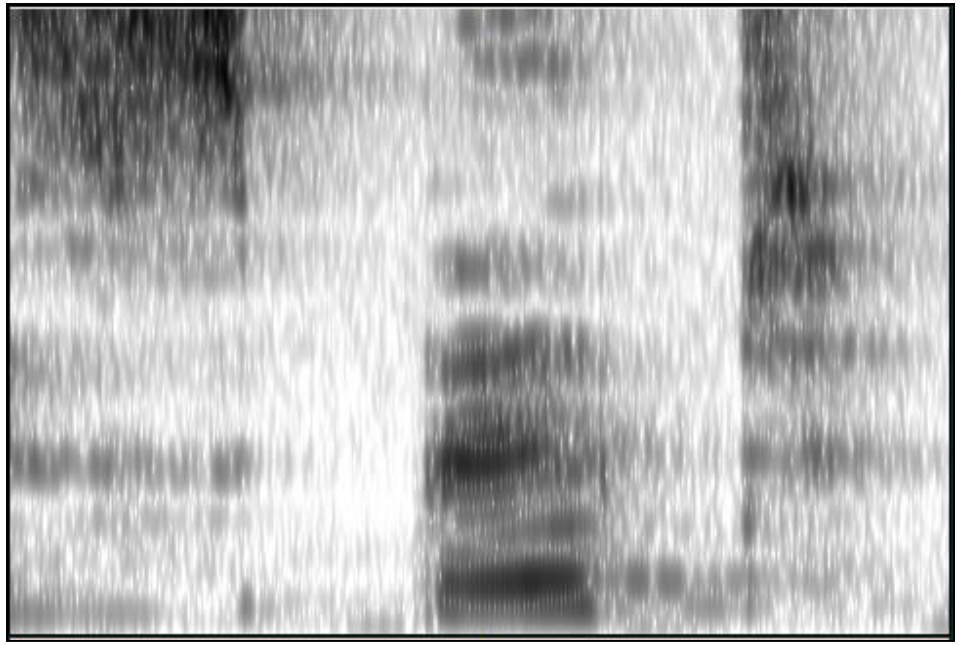
Pit

Bit

Spit





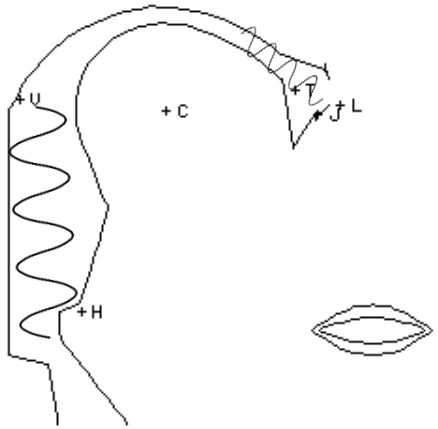


Vowels

- Spectrograms of different vowels are distinguished from one another on the basis of formants.
  - Recall that **formants** are **clusters of harmonics** which are **enhanced** by the **resonating properties** of the **vocal tract**.
  - The configuration of the vocal tract differs for each vowel leading to different formant frequencies for each vowel.
  - The lowest formants, F1 and F2, give us the most information in distinguishing one vowel from another.
    - **F1** is determined by the resonating frequency of the **back cavity**
    - **F2** is determined by the resonating frequency of the **front cavity.**

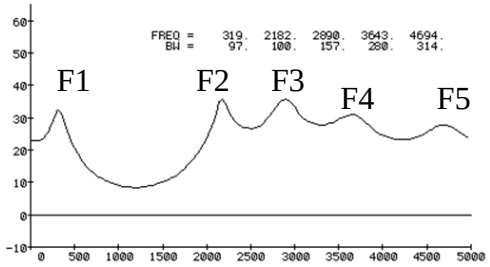
Vowels

/i/



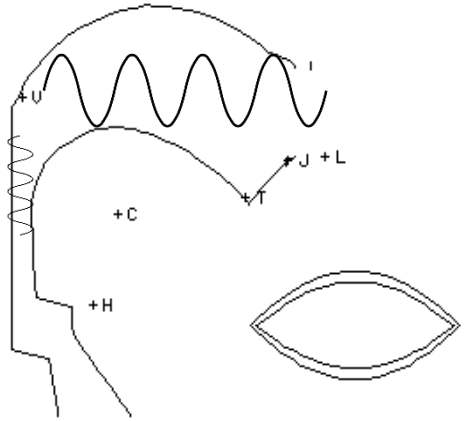
Back cavity: large
Front cavity: small

⇓



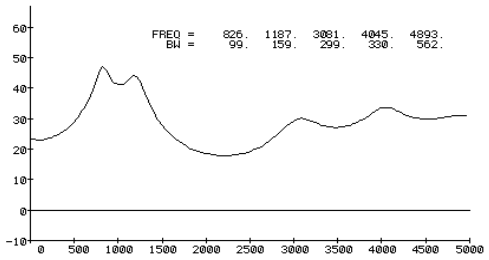
Low F1
High F2

/ɑ/



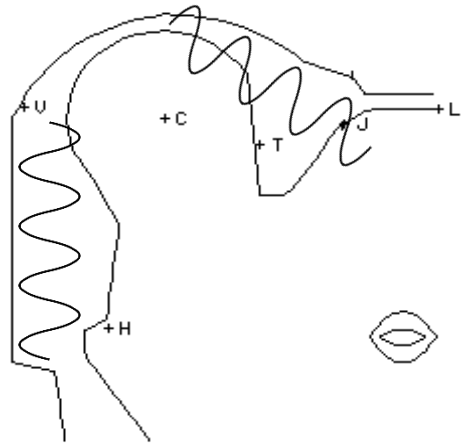
Back cavity: small
Front cavity: large

⇓



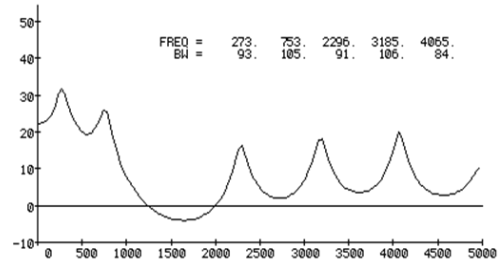
High F1
Low F2

/u/



Back cavity: large
Front cavity: large
(and increased by lip protrusion)

⇓



Low F1
Low F2

Vowels

- The lowest formants F1 and F2 give us the most information in distinguishing one vowel from another.
  - F1 is determined by the resonating frequency of the back cavity
    - It is lower for high vowels (larger back cavity, lower resonating frequency) and higher for low vowels (smaller back cavity, higher resonating frequency).
  - F2 is determined by the resonating frequency of the front cavity
    - It is higher for front vowels (smaller front cavity, higher resonating frequency) and lower for back vowels (larger front cavity, lower resonating frequency).
    - F2 is even lower for rounded vowels because the front cavity is increased by lip protrusion.

Vowels

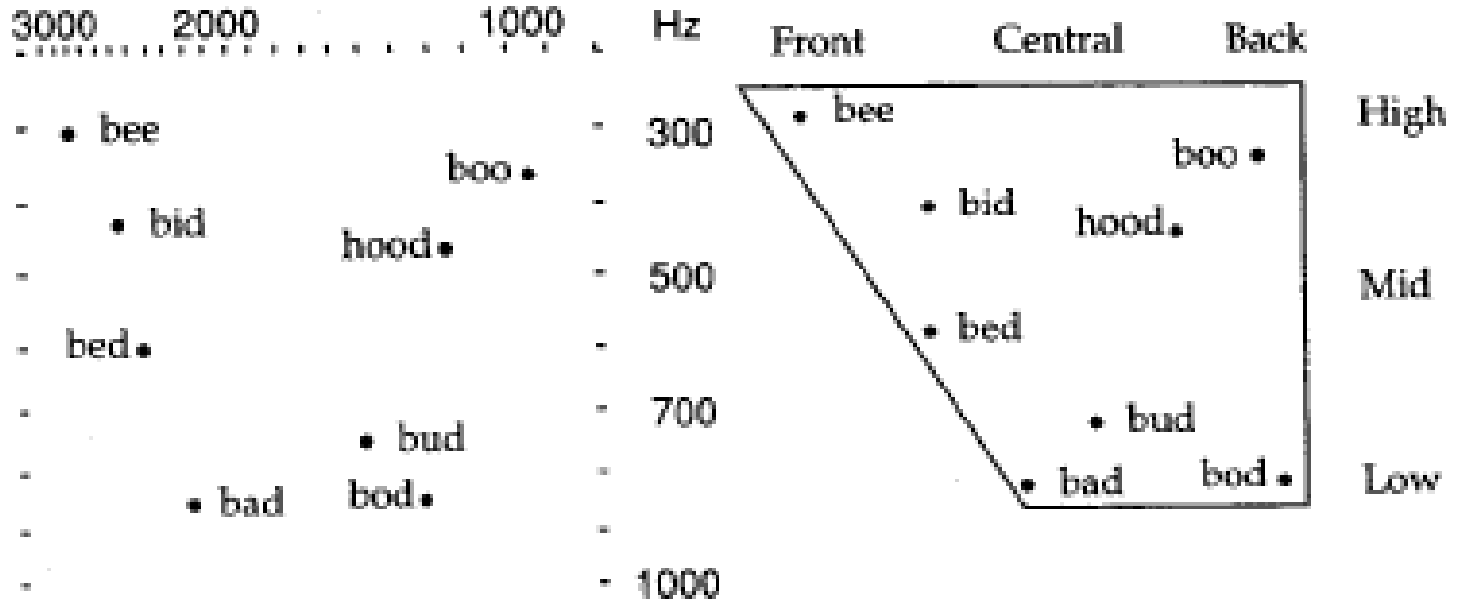
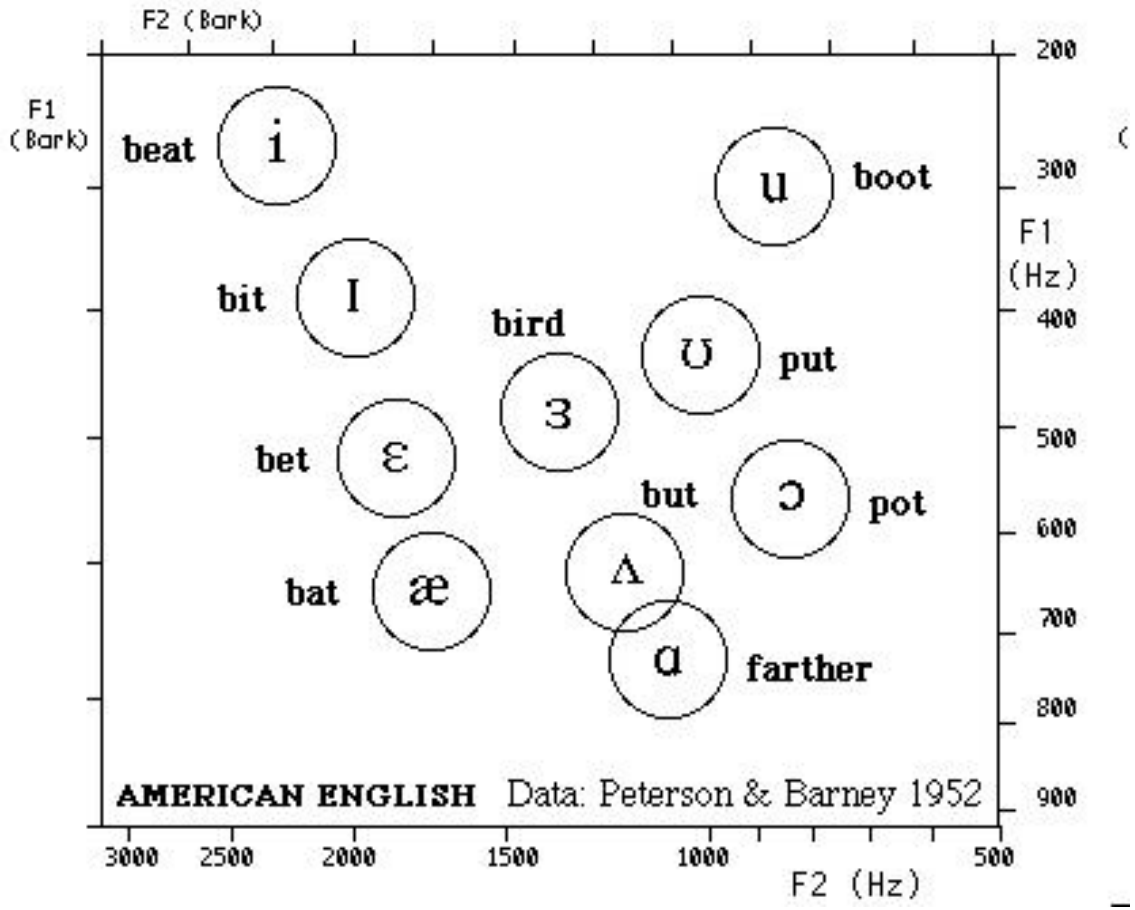
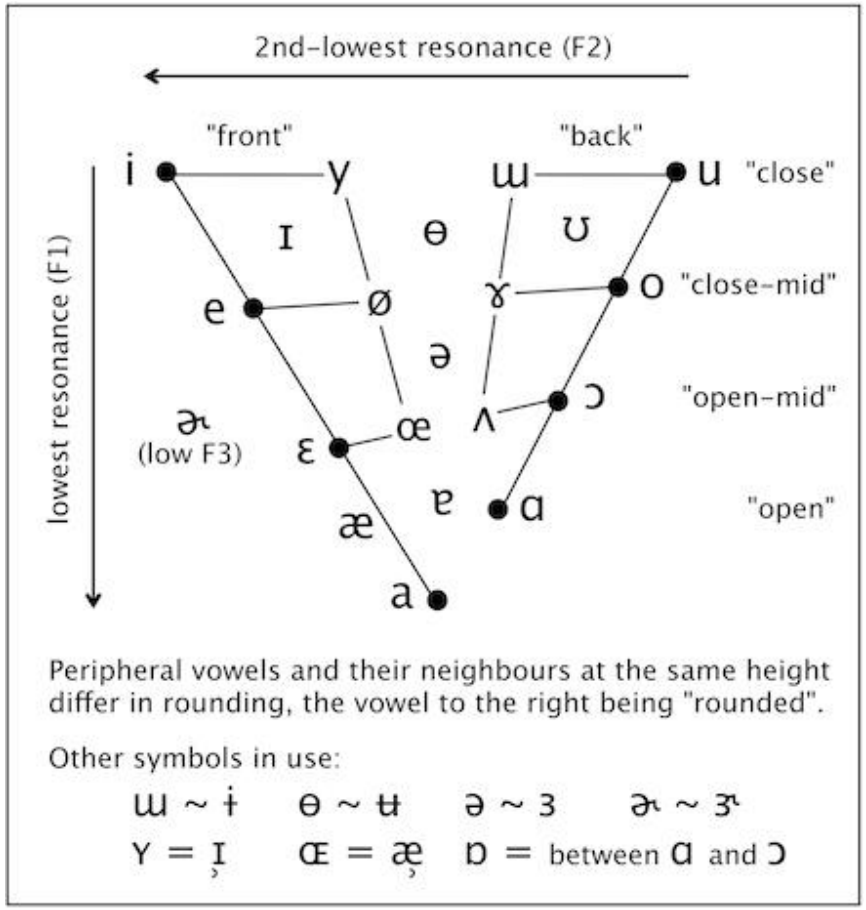


Figure 11.9 The quadrilateral on the right is a traditional representation of what is taken to be the relative position of the highest point of the tongue in some American English vowels. The corresponding acoustic data (taken from figure 6.5) are shown on the left.

From: Ladefoged (2001) *Vowels and Consonants*, pages 115-116

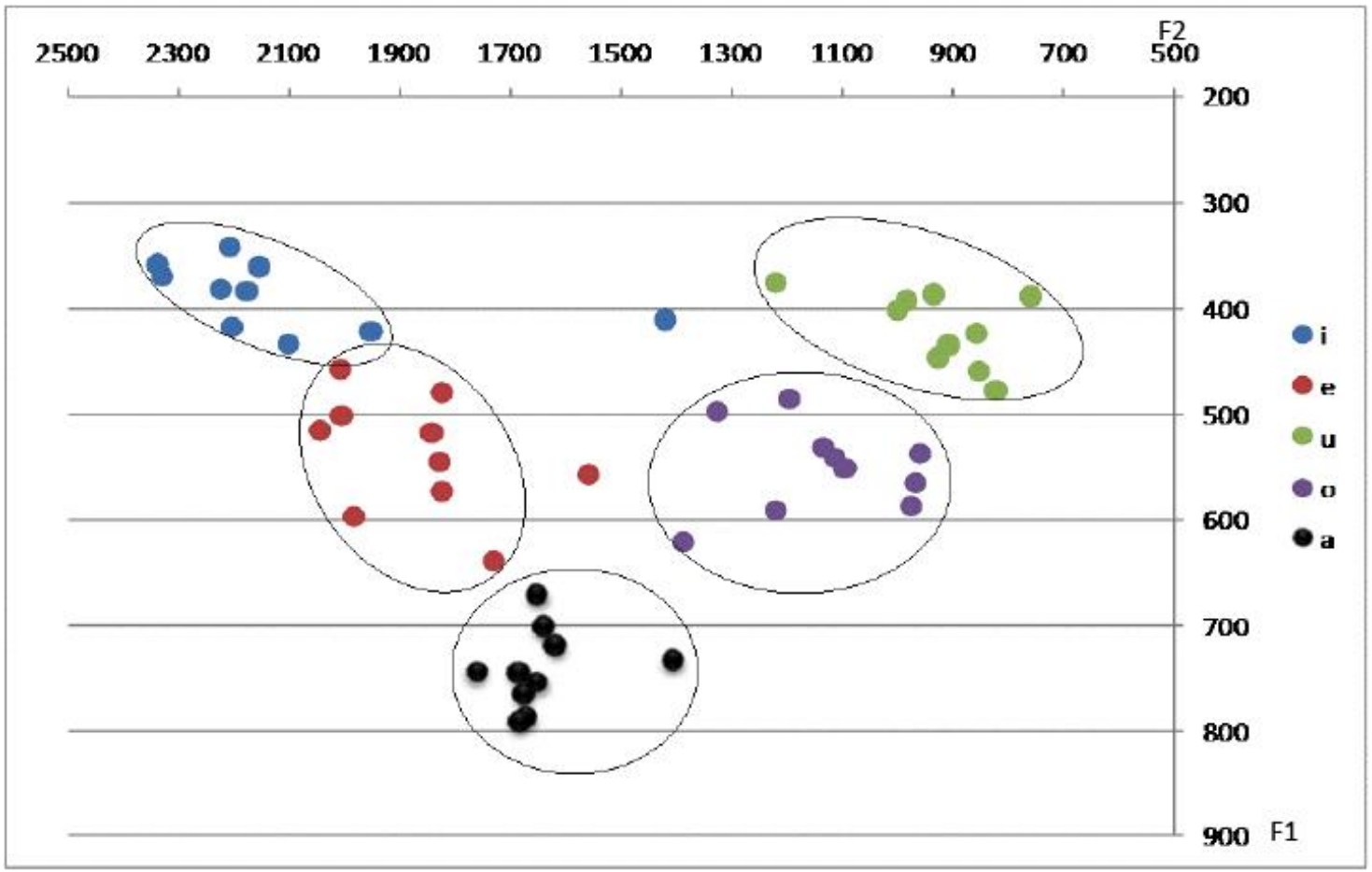
Vowels





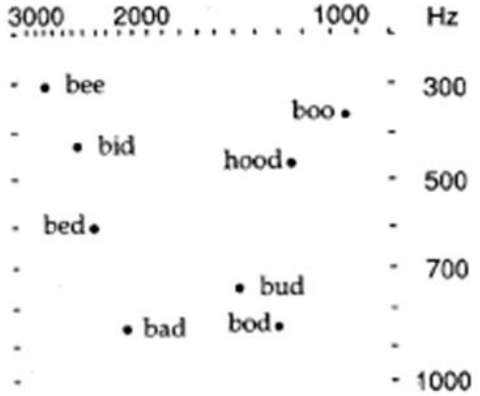
From: http://englishspeechservices.com/blog/the-vowel-space/

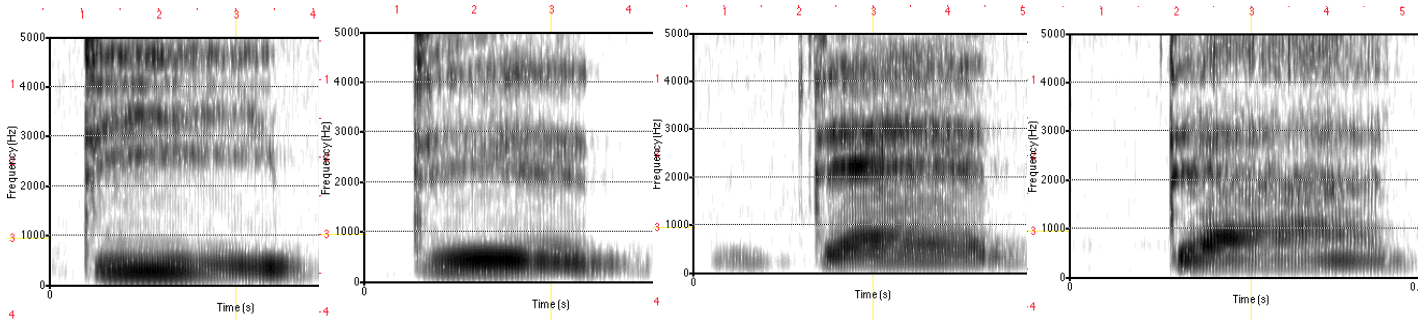
Vowels


F2
2500
2300
2100
1900
1700
1500
1300
1100
900
700
500
200
300
400
500
600
700
800
900
F1
i
e
u
o
a

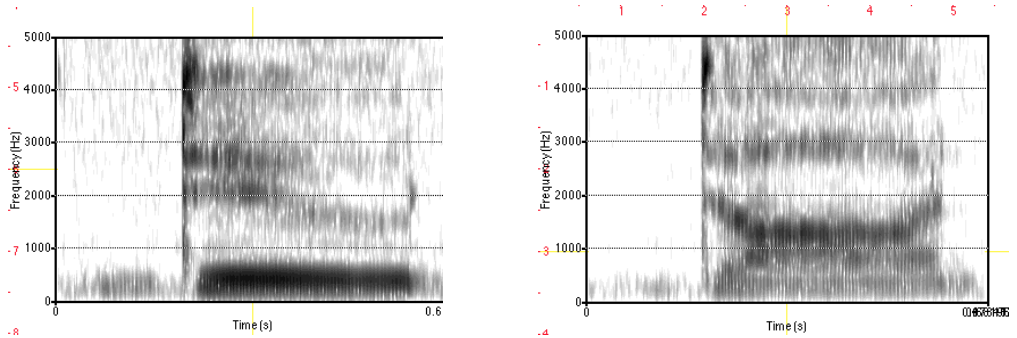
Vowels

- F1 is lower for high vowels and higher for low vowels.
- F2 is higher for front vowels and lower for back vowels.
- F3 is similar to F2 but higher.



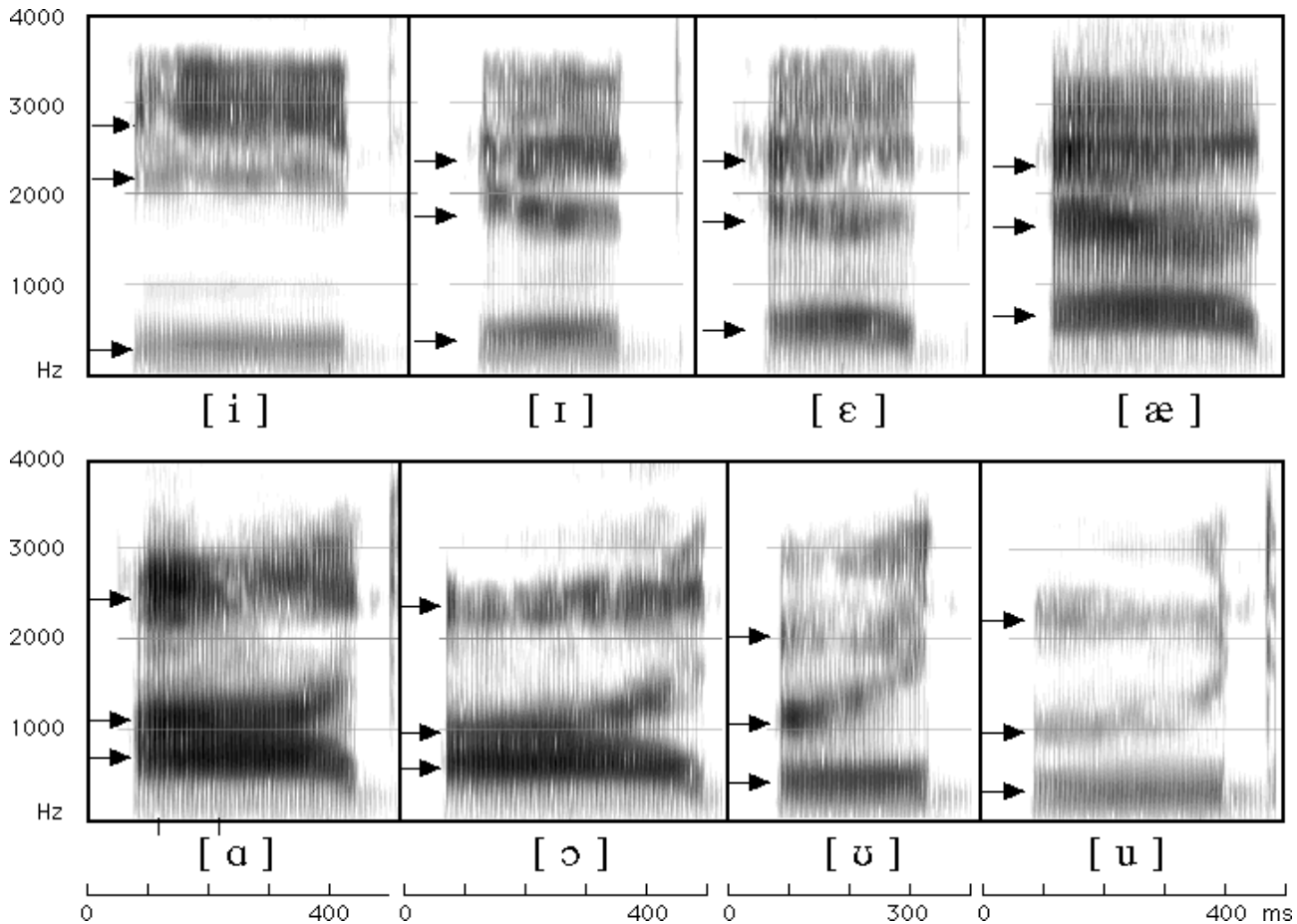


deed [i] *did* [ɪ] *dead* [ɛ] *dad* [æ]



dude [u] [dɑd]

Vowels


4000
3000
2000
1000
Hz
[i]
[ɪ]
[ɛ]
[æ]
4000
3000
2000
1000
Hz
[ɑ]
[ɔ]
[ʊ]
[u]
0
400
0
400
0
300
0
400 ms

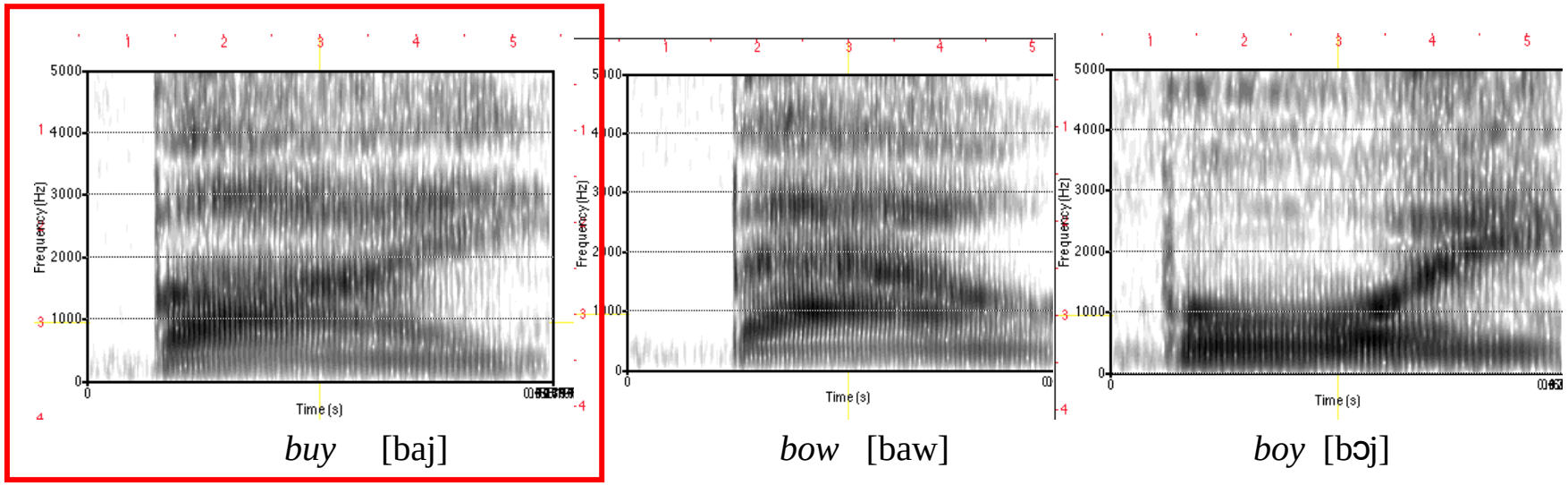
Diphthongs

- Diphthongs are vowels that involve a change in vowel quality during their articulation.

- They can be recognized on spectrograms due to the change in their formants.

Diphthongs

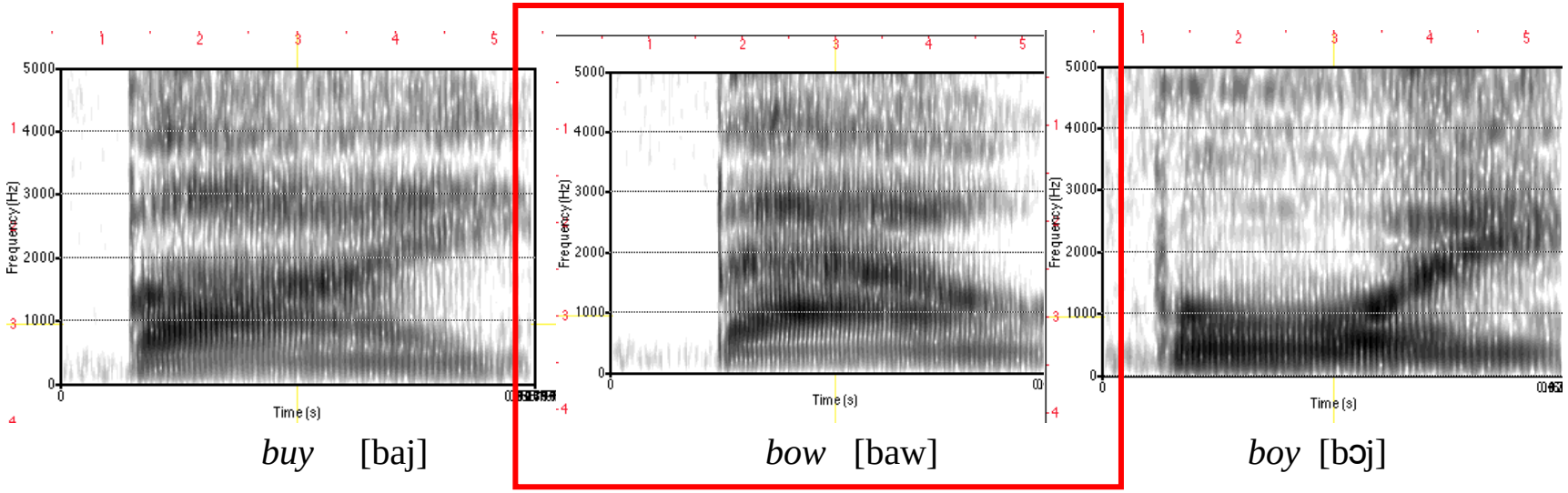
- /aj/ begins with a relatively high F1 on account of the initial low vowel articulation and a relatively low F2 on account of it being a central vowel.
- Then the formants move to the low F1 and high F2 of the high front vowel /i/.



buy [baj] *bow* [baw] *boy* [bɔj]

Diphthongs

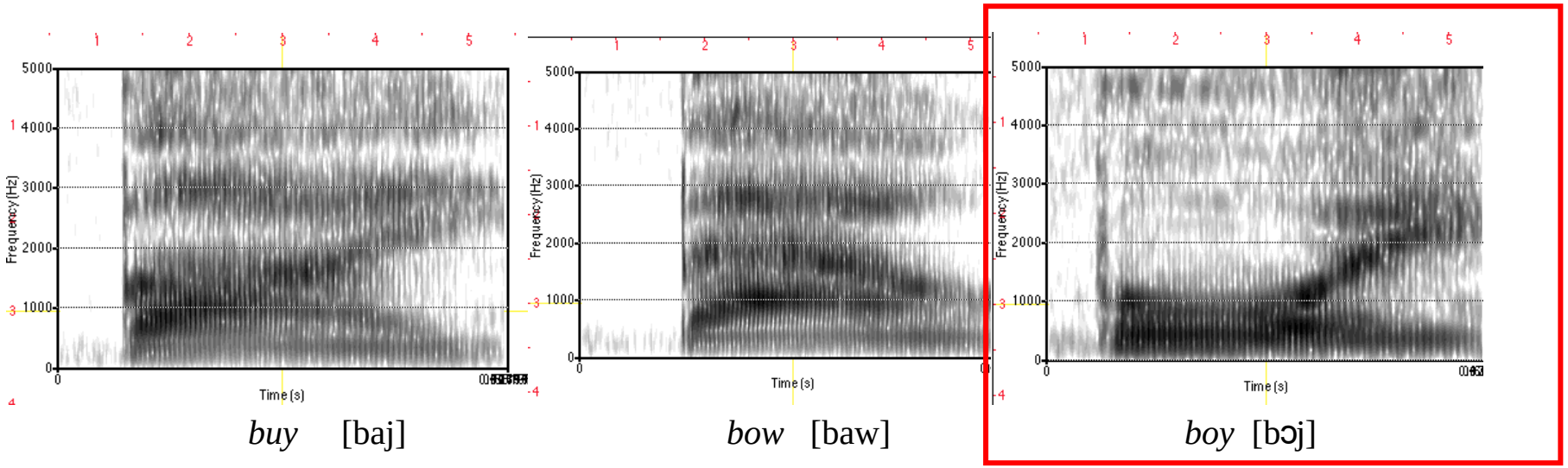
- /aw/ begins similarly to /aj/ as it also begins with a low vowel articulation
  - (high F1, low F2)
- The formants then change with F1 lowering in accordance with the vowel height of the /u/ portion of the diphthong and the F2 lowering as well on account of the /u/ being farther back in articulation than the central /a/.



buy [baj] *bow* [baw] *boy* [bɔj]

Diphthongs

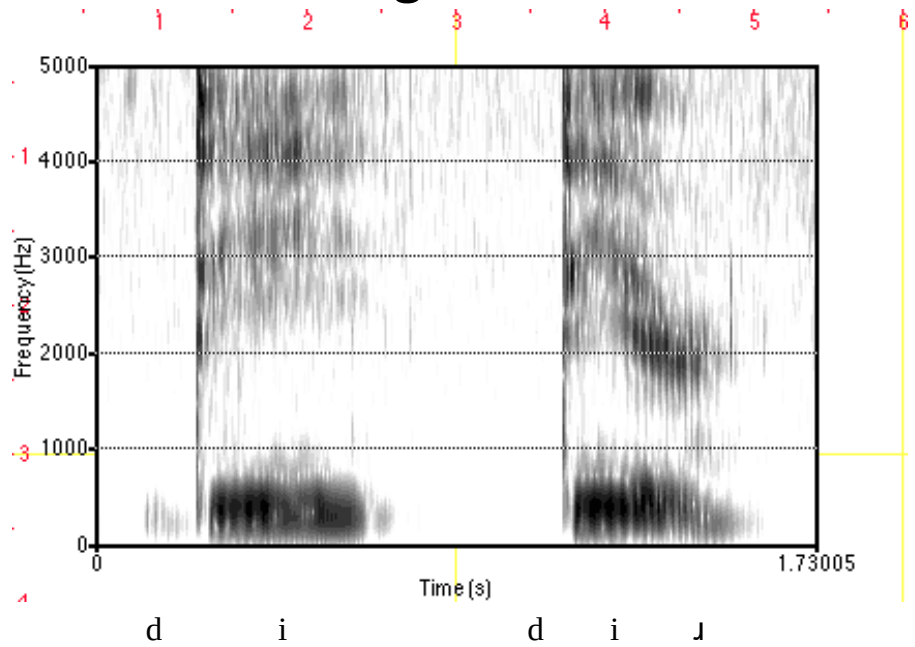
- /ɔj/ begins with the two formants relatively low and close together
- Then they spread apart into the typical low F1 and high F2 of the high front vowel articulation.



buy [baj] *bow* [baw] *boy* [bɔj]

Rhoticization

- Vowels are rhoticized by curling back the tongue tip or by retracting the tongue tip into the body of the tongue.
- Rhoticized vowels generally have a hollowing of the tongue body.
- Rhoticization causes lowering of F3.



The words *dee* and *deer*. Note the lowering of F3 in the articulation of the [ɹ]

Rhoticization

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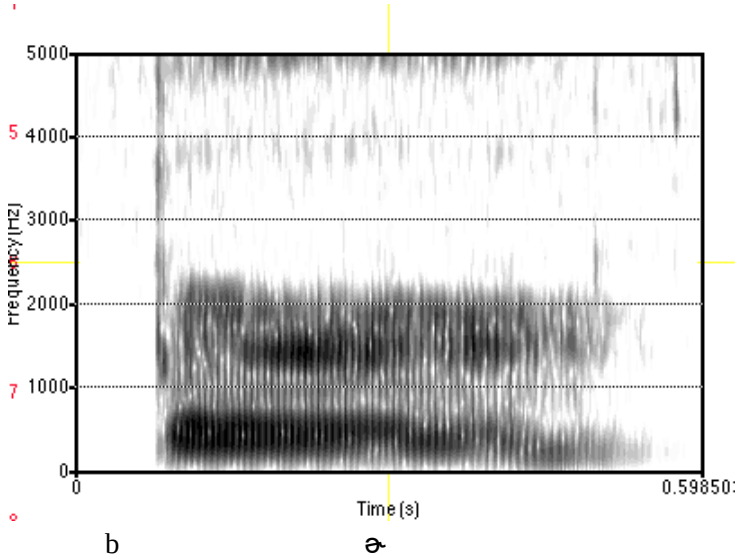
- Rhoticized vowels generally have a hollowing of the tongue body.
- Rhoticization causes lowering of F3.

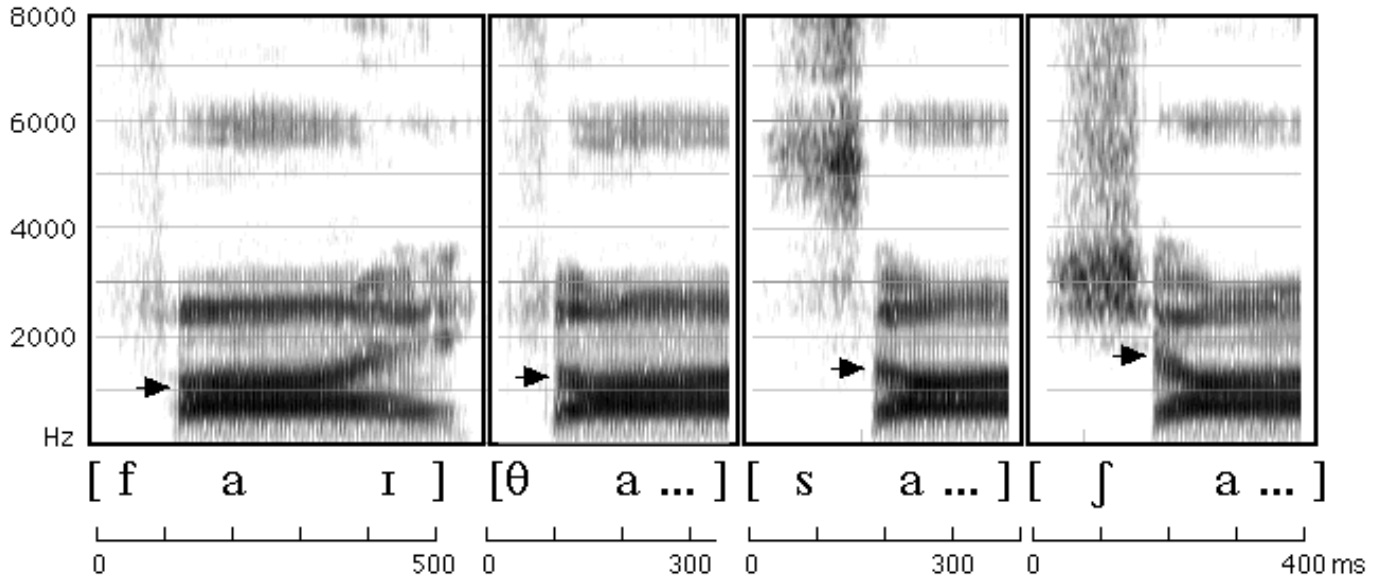


In this spectrogram of *burr*, F3 is low throughout the articulation of the rhoticized vowel.

Fricatives

A random noise pattern
- Generally at high frequency
- No formants

Greater intensity for sibilants (/s, z, ʃ, ʒ/)



Frequency:
alveolars = higher (above 4000 Hz);
postalveolars = lower (2000-6000 Hz).

- A spectrogram of *fie, thigh, sigh, sh*y. The scale is 0 - 8000 Hz. The arrows mark the onsets of the second formant transitions.

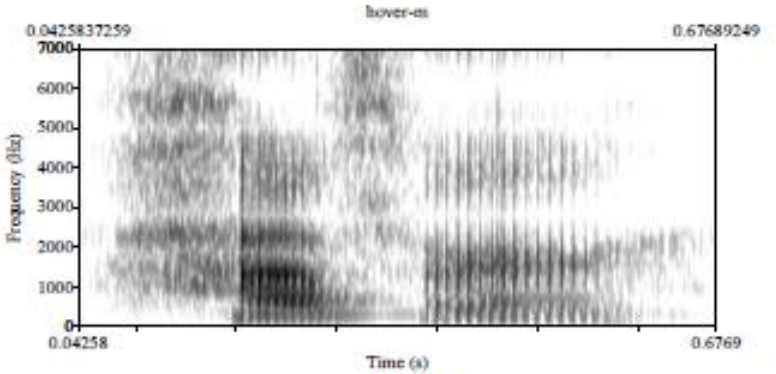
From P. Ladefoged's 'Course in Phonetics'

Fricatives

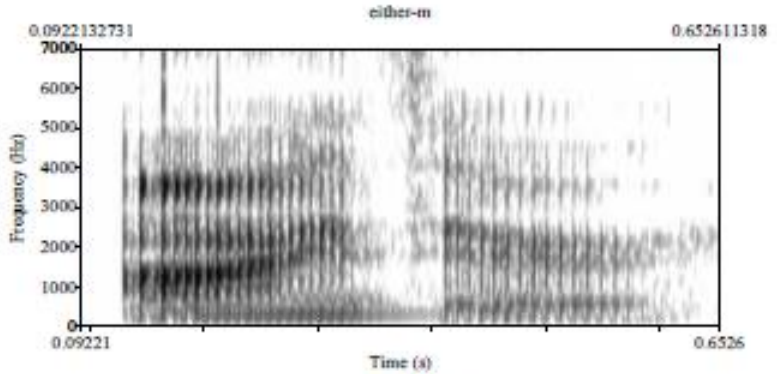
How are voiced fricatives realized in *hover, either*, and *plaza*, compared to their voiceless counterparts? Is there a missing voiced fricative?

How is /h/ realized in *hover* and *hurt*?

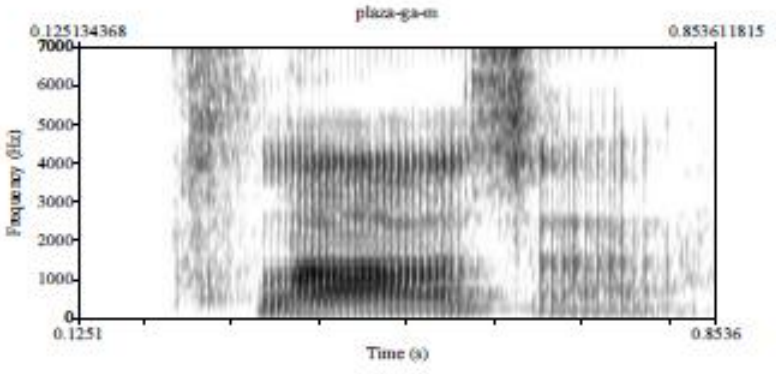
Voiced fricatives: a voice bar (at lower freq.) + random noise; shorter duration.



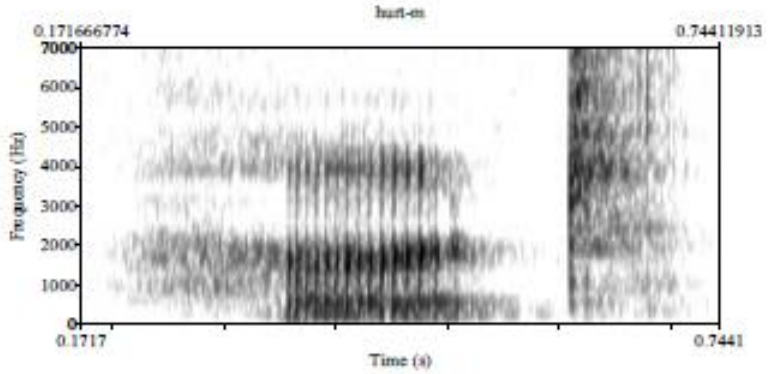
hover



either



plaza



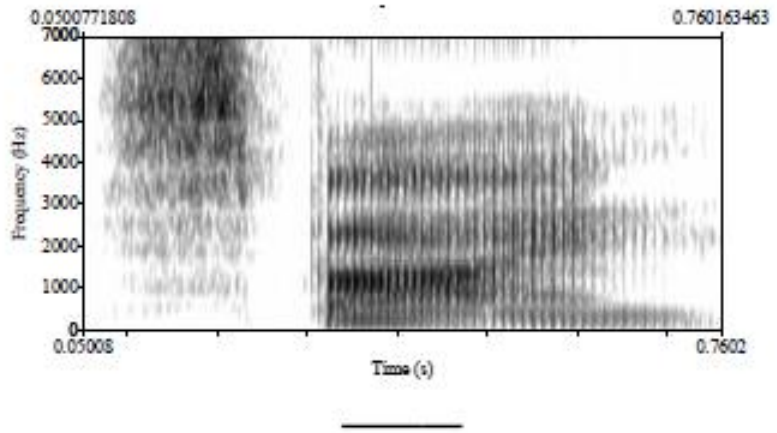
hurt

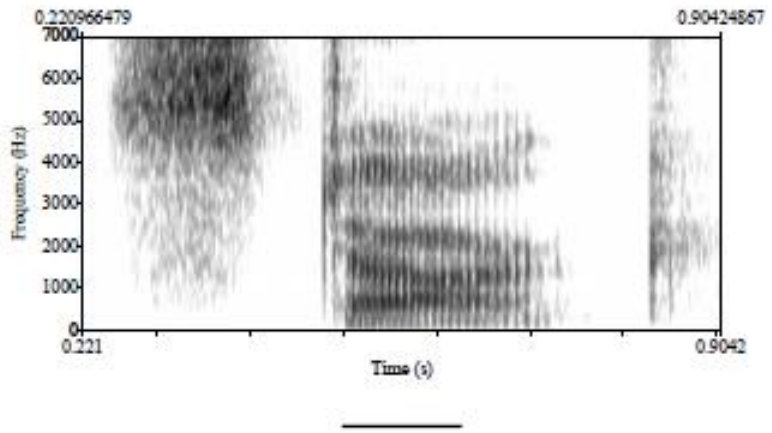
/h/ is a **voiceless** vowel: a weak formant pattern with overlaid noise.

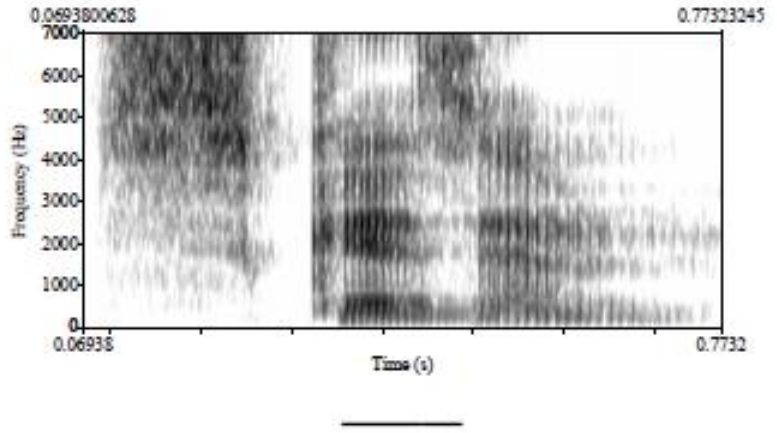
Stops

Give it a try! Answers are on the next slide.

Let's figure out what the acoustic properties of different stops are. Use the characteristics you already know to identify the words *schism, spine,* and *stark*:







A gap, silence (← no airflow) followed by an abrupt onset of noise – burst (← articulator release).
- Voiceless: [h]-like aspiration noise (in appropriate contexts)
- Voiced: a voice bar

Stops

Bilabials have a low frequency locus

Alveolars have a middle frequency locus

Velars have a high(er) frequency locus

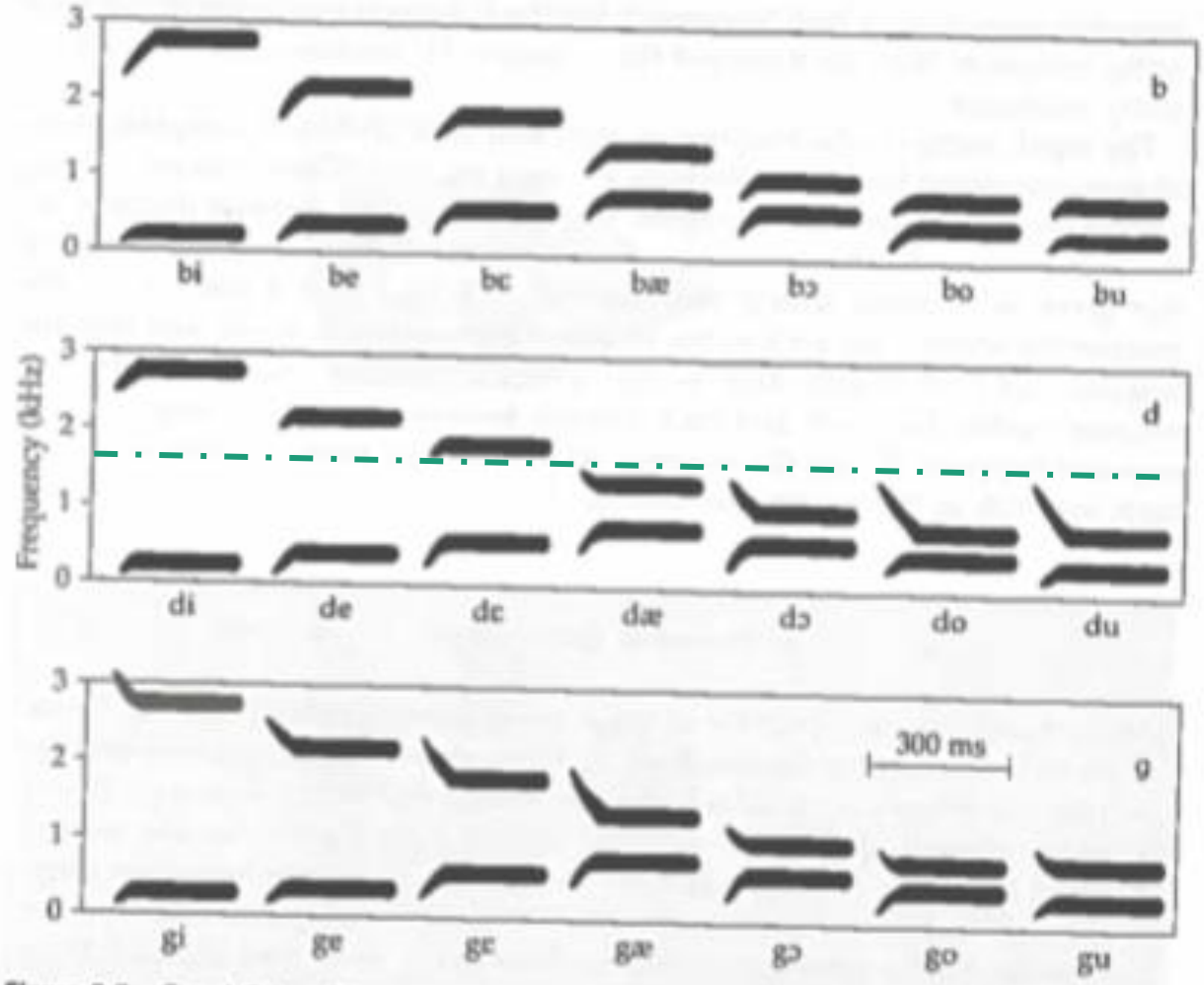


Figure 8.7 F_1 and F_2 transition patterns in stop release used to synthesize [b], [d], and [g] followed by various vowels. Adapted from Delattre et al., 1955, p. 770, and published with permission.

As the vowel gets further back it has a lower frequency F2, so the transition lowers into the vowel

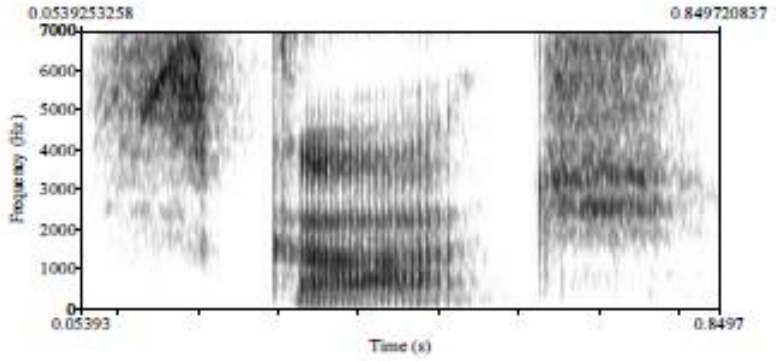
Image from: Johnson, Keith. (2011). Acoustic and Auditory Phonetics

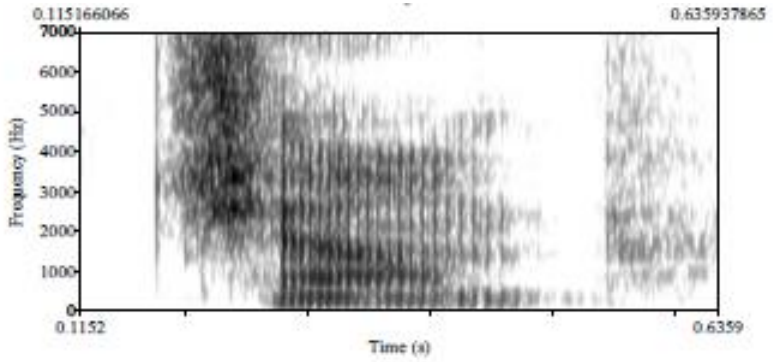
Affricates

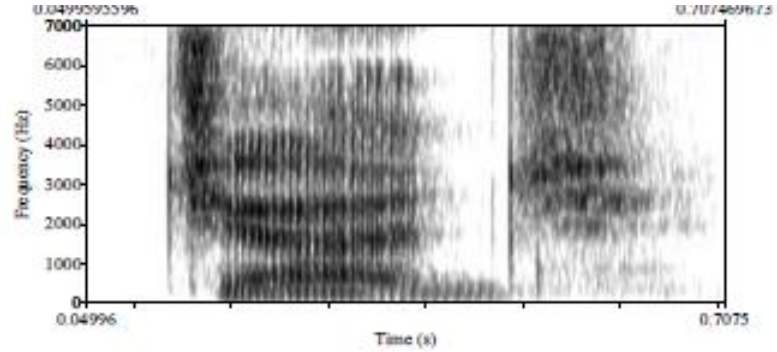
Give it a try! Answers are on the next slide.

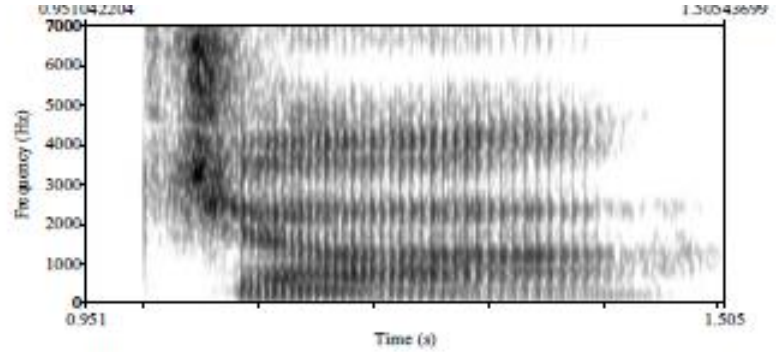
Fricative-like high frequency random noise preceded by a silence gap

- What are acoustic characteristics of affricates? Identify the words *chump, job, judge,* and *Scotch* on the following spectrograms:



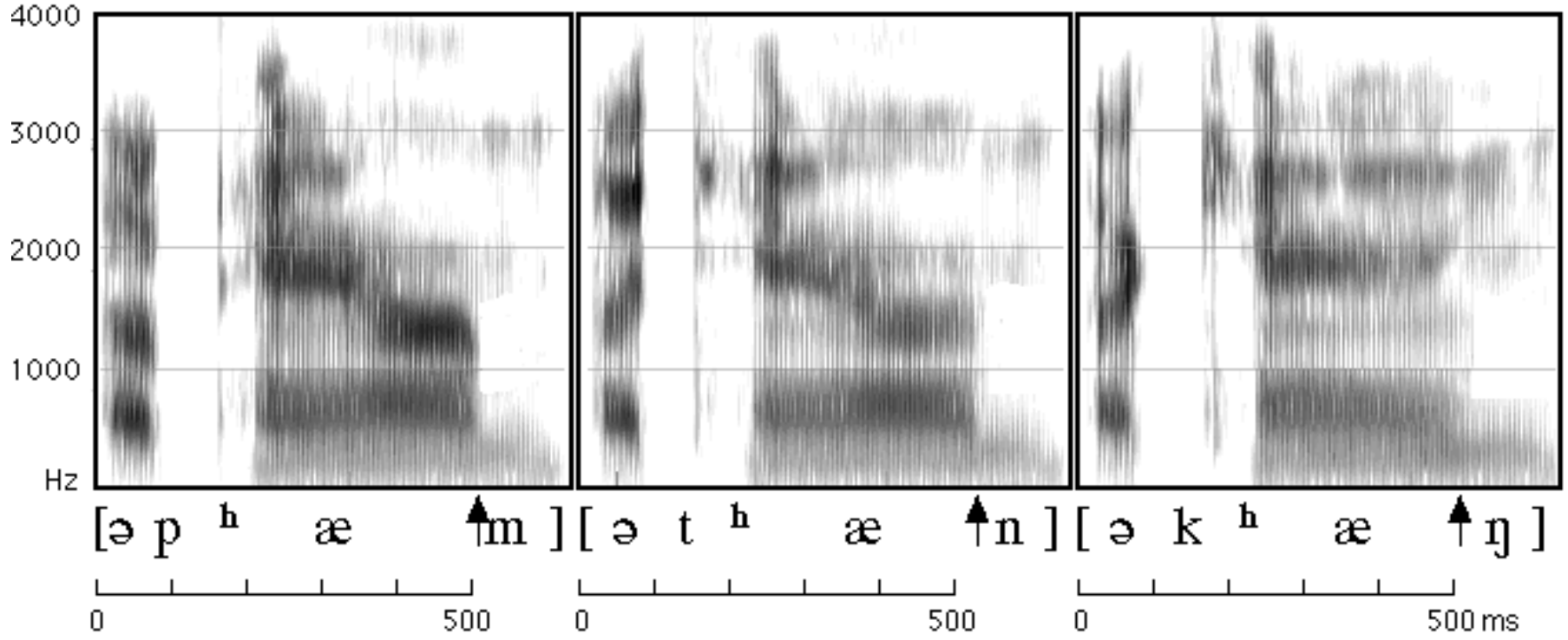






Nasals

A weak formant pattern (airflow through the nose only); a voice bar (voiced).



- A spectrogram of *a Pam, a tan, a kang*. The arrows indicate the oral closures forming the nasal consonants.

From P. Ladefoged's 'Course in Phonetics'

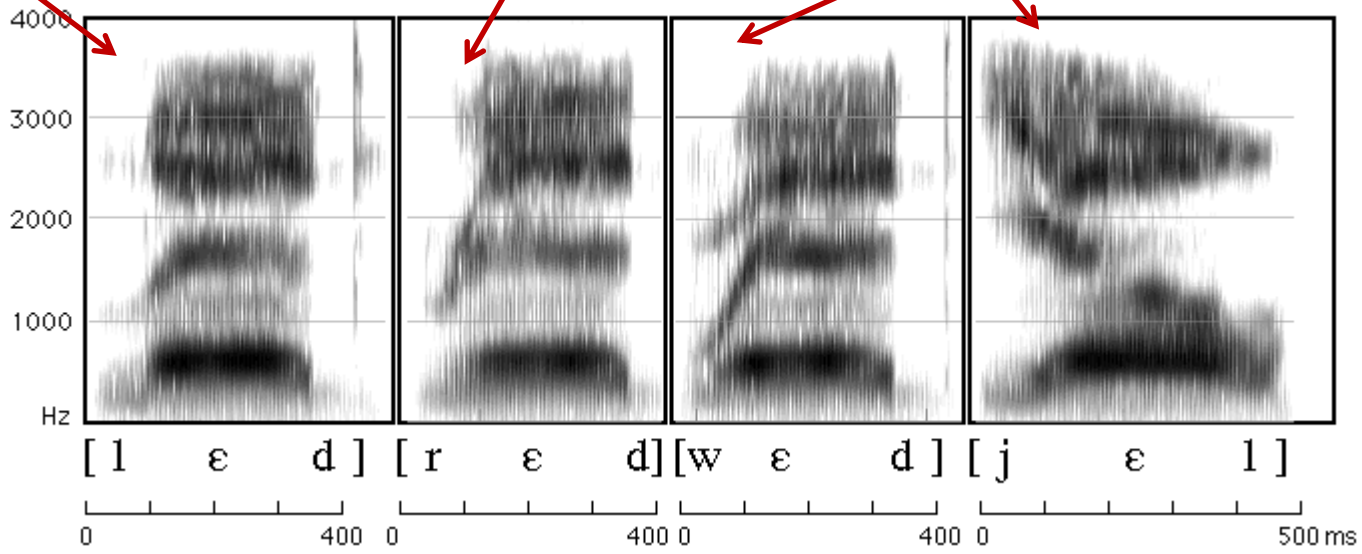
Liquids and Glides

A weaker formant patterns; more vowel-like in coda.

A lowering F2 and esp. F3 effect on surrounding vowels

[u]- or [i]-like articulations respectively; rapid formant changes towards vowels

All: clear formant patterns, often weaker than for vowels, but stronger than for nasals



- A spectrogram of *led, red, wed, yell.*

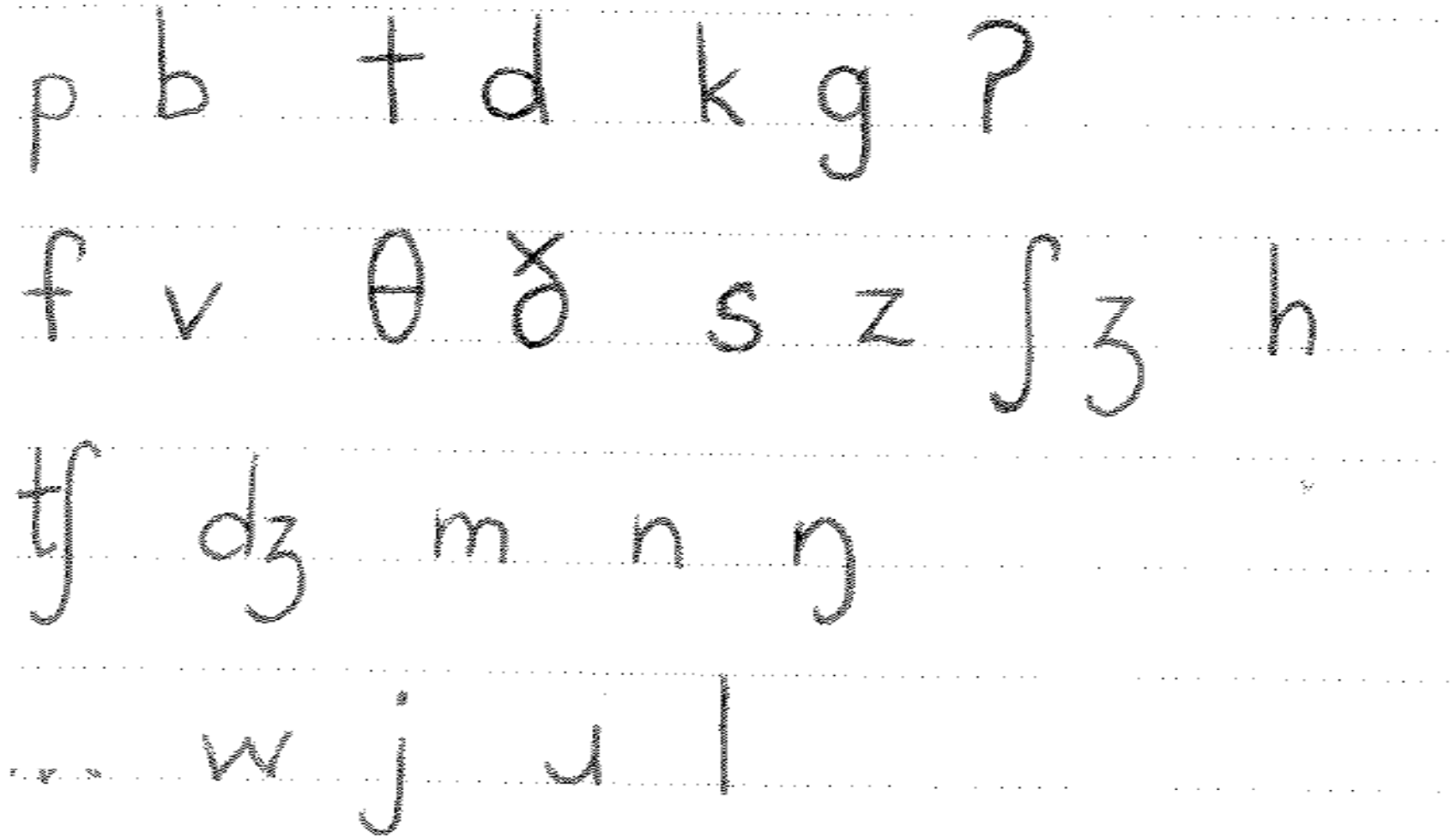
From P. Ladefoged's 'Course in Phonetics'

Reminders

- I will hold office hours tomorrow, **Tuesday 1-2 PM**.

- On Wednesday we will have more of a lab style class than lecture. To prepare you should:
  - Read the handout on Praat that I will be posting
  - Download Praat on to your computer
    - http://www.fon.hum.uva.nl/praat/

Handwriting IPA - Consonants



Handwriting IPA - Vowels