LING 520 Introduction to Phonetics I
Fall 2008

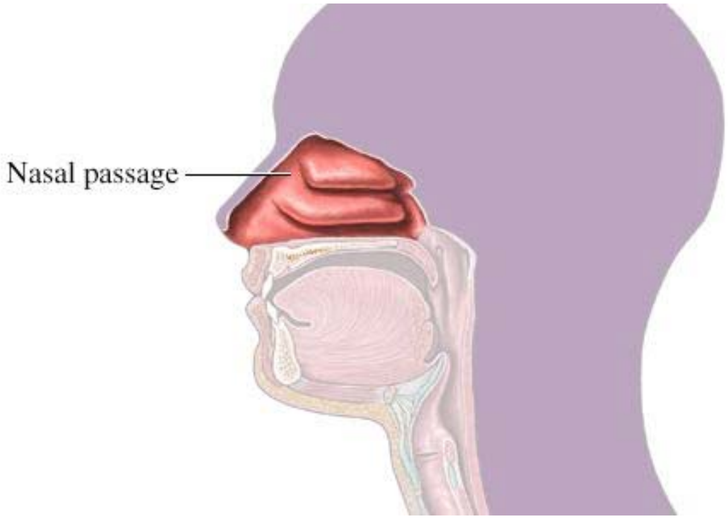
Week 8

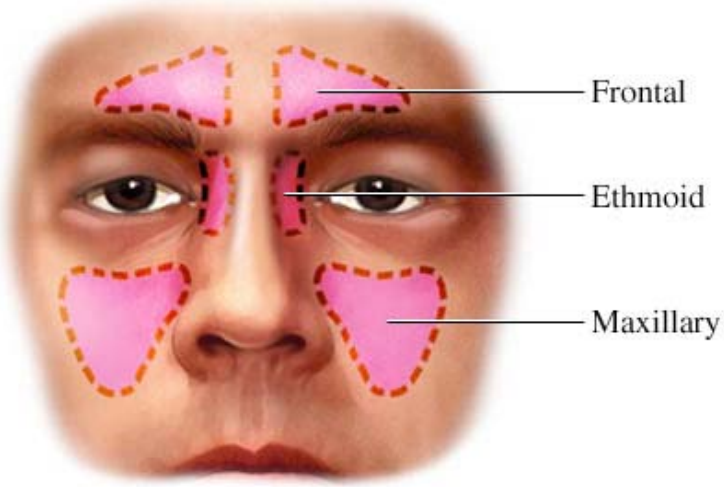
Acoustics of nasals and liquids

Oct. 27, 2008

Nasals

- Nasal cavity anatomy:
  - The nose is composed of two nasal cavities, or spaces, separated by a middle wall, which is called the nasal septum.
  - The sinuses are are air-filled cavities behind the nose in the cheeks and forehead.

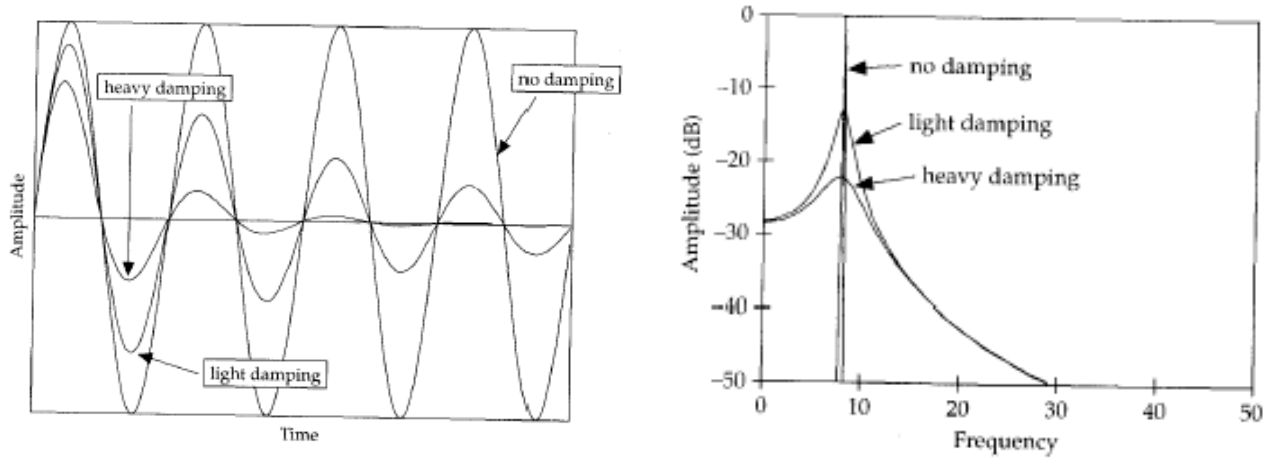




[Figures from: Nucleus Communications website]

Nasals: damping

- Nasal cavities have greater surface area, hence walls of vocal tract absorb more sound than for non-nasals (sound waves are more damped).
- Damping increases spectral bandwidth. Since the energy in the wave is distributed over a wider range of frequency components, the spectral peak is lower in amplitude.

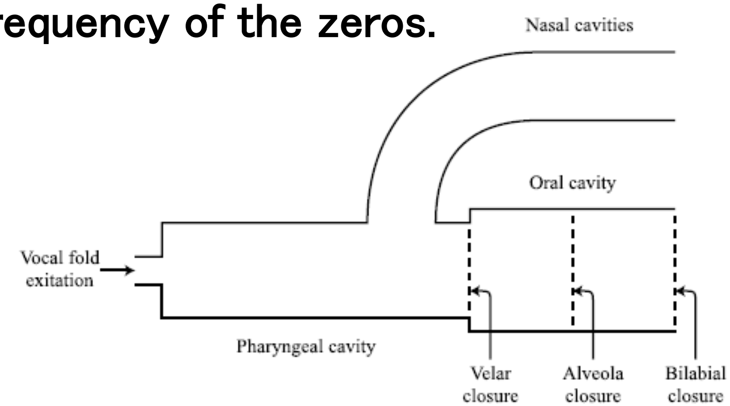


[From: Johnson 2003]

- Bandwidth: a measure of the sharpness of a resonance. It is determined at the half-power ("3dB down") points of the frequency curve. This is. Both the lower and the higher frequencies that define the bandwidth are 3 dB less intense than the peak energy in the band.

Nasals: zeros

- Nasals are produced with closure of the oral cavity and radiation of the sound through the nasal cavity. The obstructed oral cavity acts as a side-branch resonator.
- Side-branch resonators introduce zeros (anti-resonances). Frequency components in the sound source that are near the resonant frequencies of a side cavity resonate in the side branch without making an appearance in the acoustic output of the acoustic tube system. They are "absorbed" ("trapped") in the side branch.
- The frequencies of the trapped energy correspond to resonant frequencies of the oral cavity in a given configuration. Therefore (oversimplifying somewhat…), the longer the oral cavity (e.g., bilabials), the lower the frequency of the zeros.



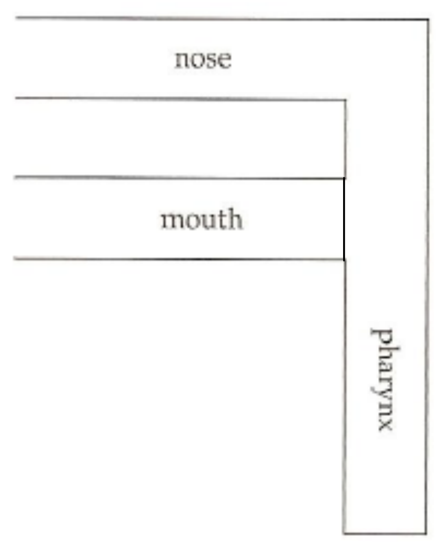
[Figure from: UCL phonetics website]

Nasals: nasal formants

- A uvular nasal [ɴ] can be modeled as a tube closed at the glottis and open at the nostrils. (The oral cavity is blocked off by the closure produced by the velum and the tongue dorsum.)
- Tube length: glottis to uvula: 9cm + uvula to nares: 12.5cm = 21.5cm
- F1 = c/4L = 35,000/(4*21.5) = 407 Hz

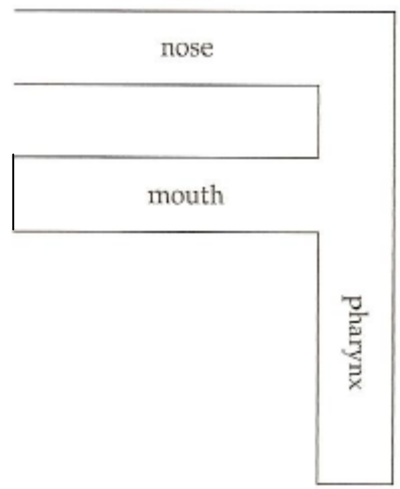
  F2 = 3c/4L = 1221 Hz

  F3 = 5c/4L = 2035 Hz



Nasals: anti-formants

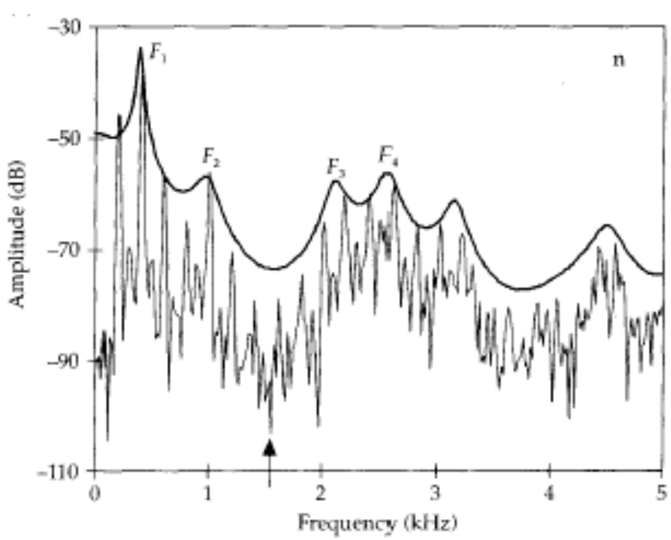
- The vocal tract for a bilabial nasal [m] can be seen as that of an uvular nasal [ɴ] plus a side branch formed by the mouth cavity.
- The mouth cavity is opened at one end (the uvular) and closed at the other (the lips), with a length of about 8 cm.
- F1 = c/4L = 35,000/(4*8) = 1094 Hz
  F2 = 3c/4L = 3281 Hz

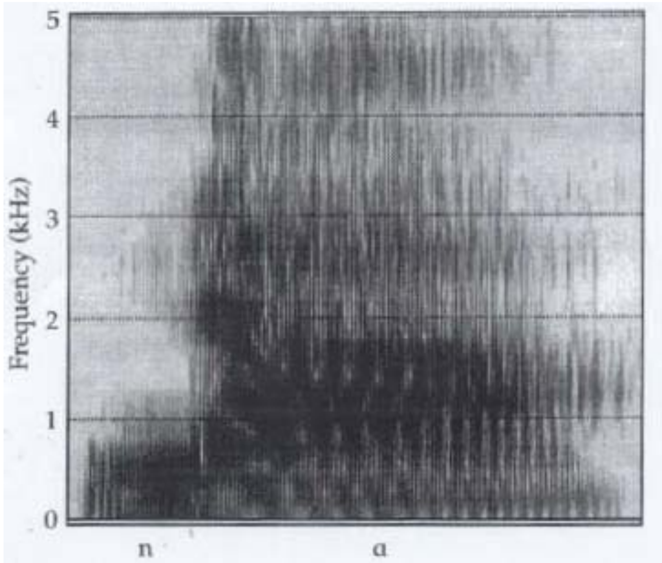


- The mouth cavity in [n] is about 5.5 cm long. Its anti-formants are at 1591 Hz and 4773 Hz.
- The frequencies of the anti-formants are cues to the place of articulation in the nasals.

Nasals: the acoustics of the nasal murmur

- A high-intensity low-frequency F1, called “nasal formant”;
- Low-amplitude, wide bandwidth higher-frequency formants;
- Zeros or anti-formants whose frequencies are determined by the place of articulation of the stop;
- Close spacing between formants.

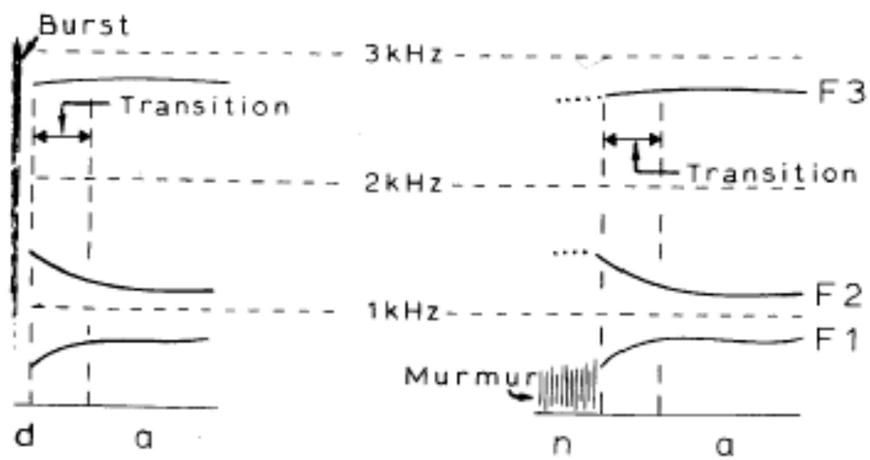




[From: Johnson 2003]

Nasals: formant transitions

- Nasals are also associated with formant transitions when they are produced in sequence with other sounds.
- The similar patterns of formant transitions are observed for the stop-nasal pairs, [b]-[m], [d]-[n], and [g]-[ŋ]. (/ba/, /ma/, /da/, /na/)
- Perceptual experiments (Kurowski and Blumstein 1984) showed that the nasal murmur and the transitions are roughly equal in providing information on place of articulation. Their results also indicated that neither the murmur nor the transition is sufficient for perception of place of articulation.



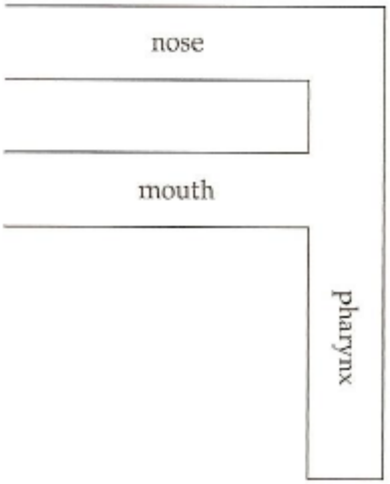
[From: *The acoustic Analysis of Speech*, Kent and Read, 1992]

Nasalized vowels

- Nasalized vowels are the most complicated configuration of the vocal tract found in speech. In nasalized vowels there are two resonant systems operating at once, one composed of the pharynx cavity plus the mouth cavity, the other of the pharynx cavity plus the nasal cavity.
- The tube models predict that the spectrum of a nasalized vowel will have a lot of formants: oral formats plus nasal formants.
- In nasalized vowels, the resonances of the nasal cavity become anti-formants, because the mouth is more open than the nose, so the acoustic coupling between the mouth and the air is greater than the coupling between the nasal cavity and the air.
- For a nasalized schwa:

Table 9.1 Predicted frequencies of oral and nasal formants and nasal anti-formants in nasalized vowels (assuming uniform tubes and disregarding the effects of acoustic coupling).

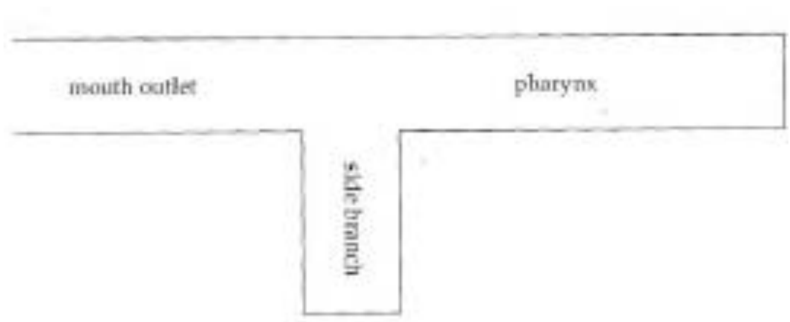
	Nasal formants	*Oral formants*	*Anti-formants*
	(l = 21.5 cm)	(l = 17.5 cm)	(l = 12.5 cm)
F_1	407	500	680
F_2	1,221	1,500	2,040
F_3	2,035	2,500	-



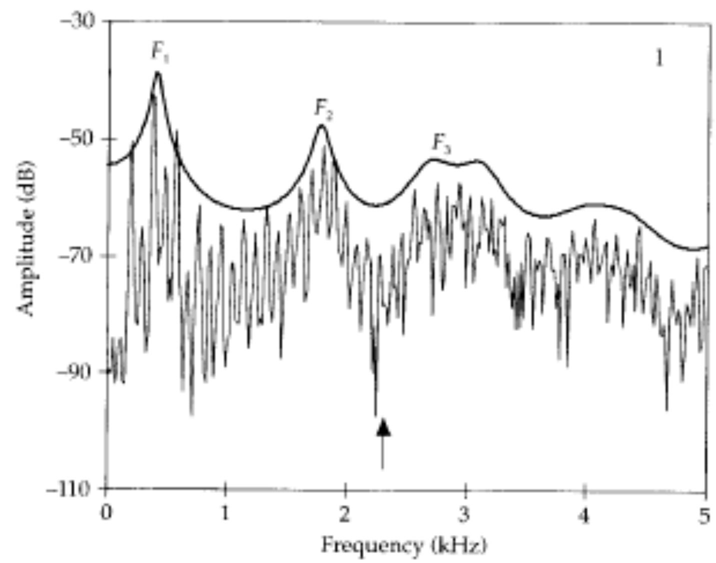
[From: Johnson 2003]

Laterals

- Like nasals, laterals have a side cavity that introduces anti–formants in the output spectrum.
- The side cavity is the pocket of air on top of the tongue. The main cavity curves around one or both sides of the tongue.



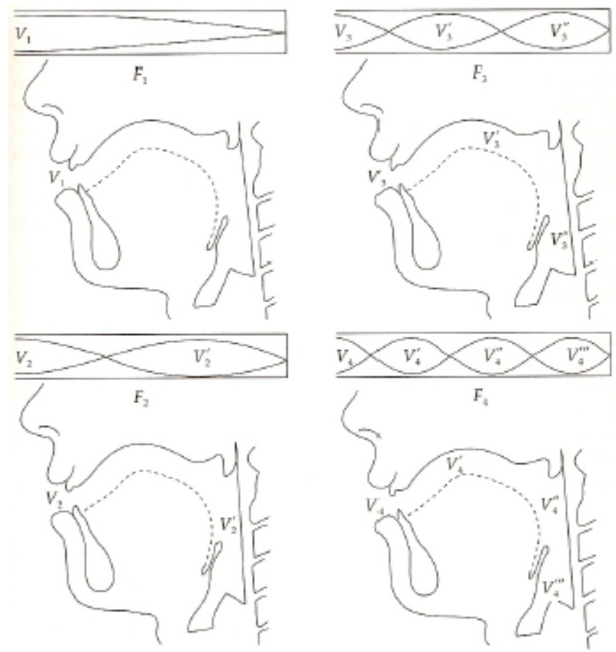
- The pocket (side branch) is about 4 cm. This gives an anti-formant around 2100Hz (so between F2 and F3).



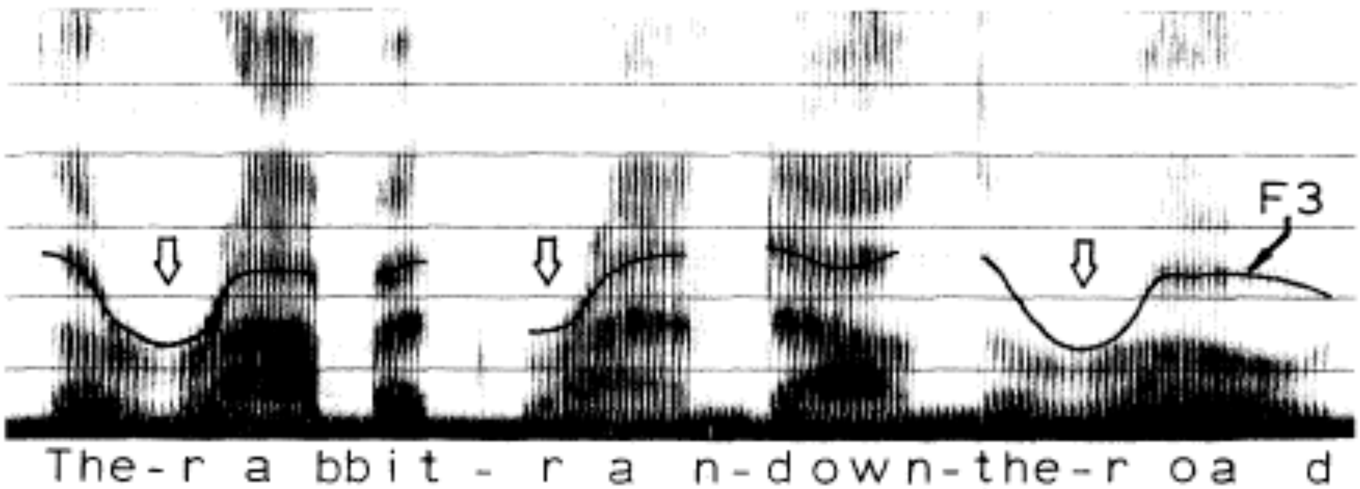
[From: Johnson 2003]

/r/ [ɹ]

- There are three simultaneous constrictions in production of American [ɹ]: labial (rounding), palatal (bunching or retroflexion) and pharyngeal. All three are near velocity maxima for F3.
- By perturbation theory, this results in extreme lowering of F3. Among English sounds, [ɹ] has the lowest F3 frequency, and this feature alone can often be used to identify the occurrence of this liquid.

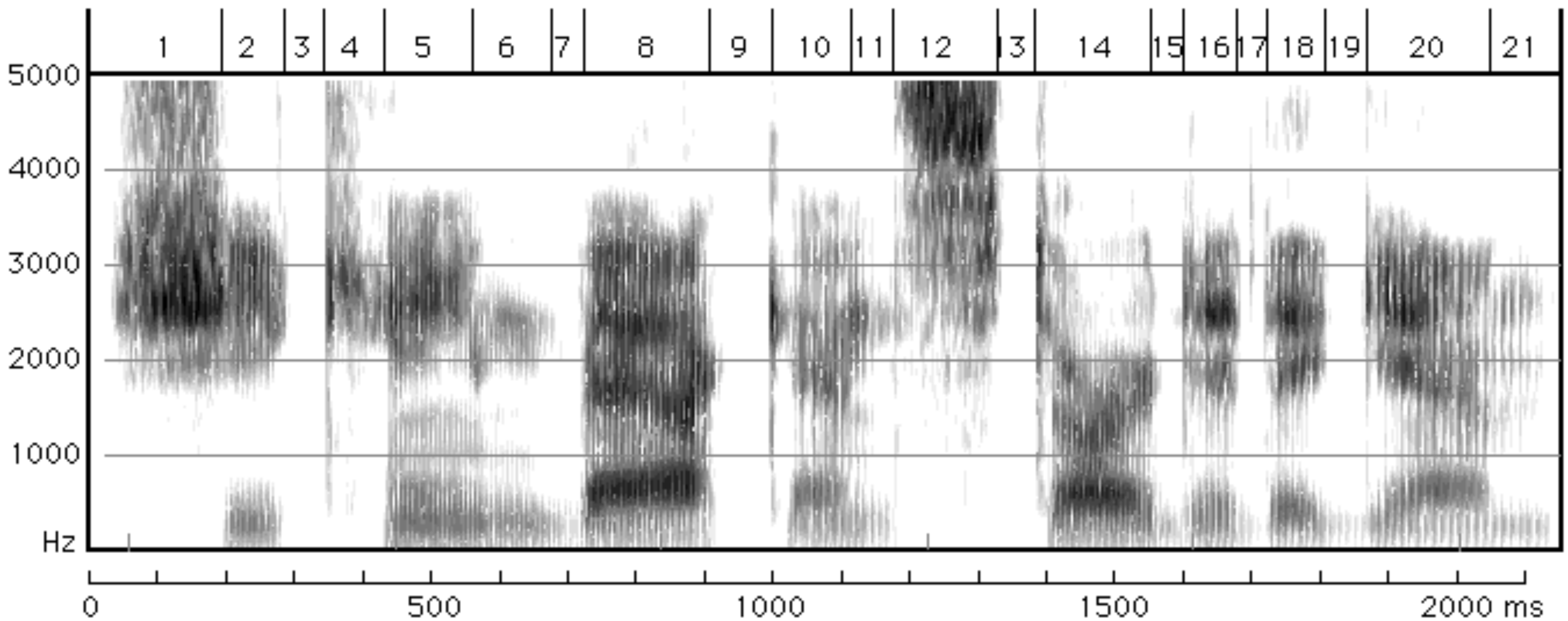


/r/ [ɹ]



[From: *The acoustic Analysis of Speech*, Kent and Read, 1992]

Spectrogram reading



5. [eɪ];	7. [b];	8. [æ];	10. [ə];	11.[n];
14. (nasalized or r-colored) [ɑ];		16. [ɪ];	20.[æ].	