L105/205 – Phonetics
Scarborough

Handout 5
Oct. 11, 2005

reading: Johnson Ch.1.4, Ch.5.1-5.3 (today); Johnson Ch. 5.4, Ch. 6 (Thurs);
optional: Ladefoged Ch. 5, Ch. 7 (today); Ladefoged Ch. 8 (Thurs)

Source-filter Theory

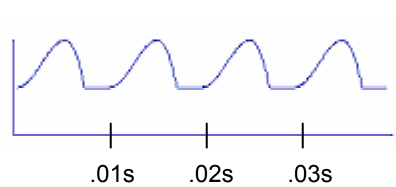
1. Speech sounds are characterized by a number of different articulations or vocal tract configurations. But these articulations by themselves do not produce any sound.

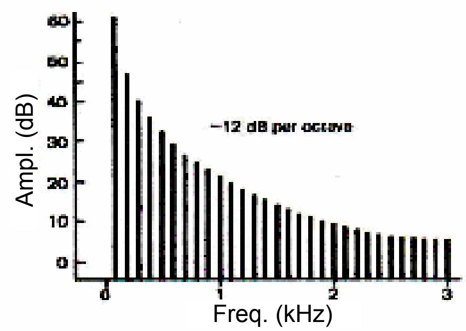
   When the vocal folds vibrate, they produce sound. But they vibrate the same for all voiced sounds (within a phonation type), always yielding the same "buzz".

   So speech, with its variety of sounds, relies on having both a *source* of sound and a means to shape or *filter* that sound.

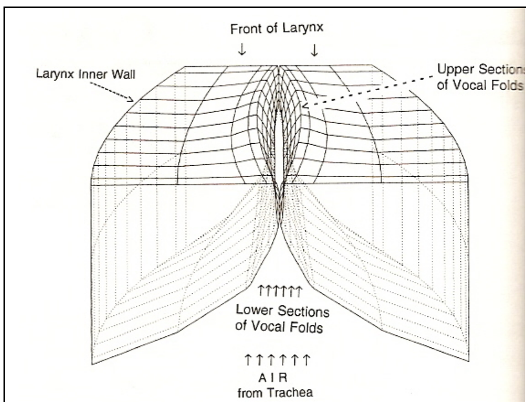
2. Voicing Source
   - Vocal fold vibration produces a complex periodic wave (pressure fluctuation). The spectrum of this wave contains energy at the fundamental frequency of laryngeal vibration and at multiples of the fundamental frequency—harmonics.

waveform of a glottal pulse:





- each harmonic is a multiple of the fundamental frequency (H1)
- amplitude goes down 12 dB for each doubling of the frequency (for each octave)

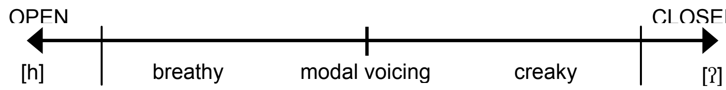


(figure from Pickett, 1999)

- In a cycle of vocal fold vibration, the lower parts of the vocal folds are blown apart first.
- As the lower parts move apart, they pull the upper parts along with them.
- When the upper parts separate, air flows through the glottal opening.
- Pressure between the lower folds drops, causing the lower sections to move towards one another.
- When they get close, the Bernoulli effect sucks them together quickly.
- The upper sections are pulled along.

- Thus, the pressure fluctuations resulting from laryngeal vibration are not perfectly sinusoidal.

  - phonation types
    - breathy, creaky, modal

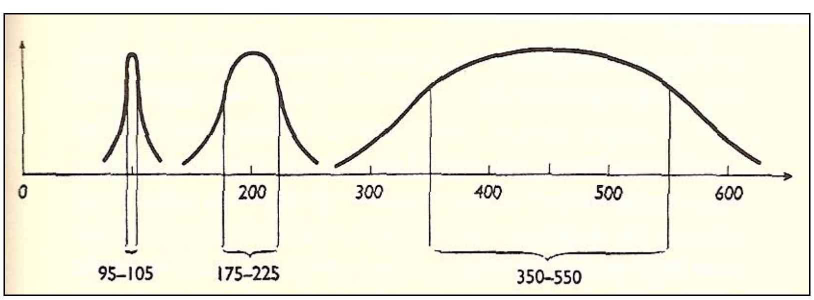


      - phonation type affects the relative amplitudes of the first and second harmonics of the voicing spectrum

- So, the glottal waveform is a harmonically rich signal with energy in the whole frequency range important for speech. It is the source of all the acoustic energy needed for all the different (voiced) speech sounds.

3. Filtering
   - The vocal tract (above the larynx) can—and indeed *must*—adjust the relative intensities of the frequency components of the voicing source.
   - Energy originating at the larynx has to pass through the upper vocal tract, which is a sort of chamber or container, in order to eventually reach a listener.
     - Air in a container usually vibrates in a complex manner that is influenced by the shape of the container. The container has particular resonance frequencies at which the contained air naturally tends to vibrate.

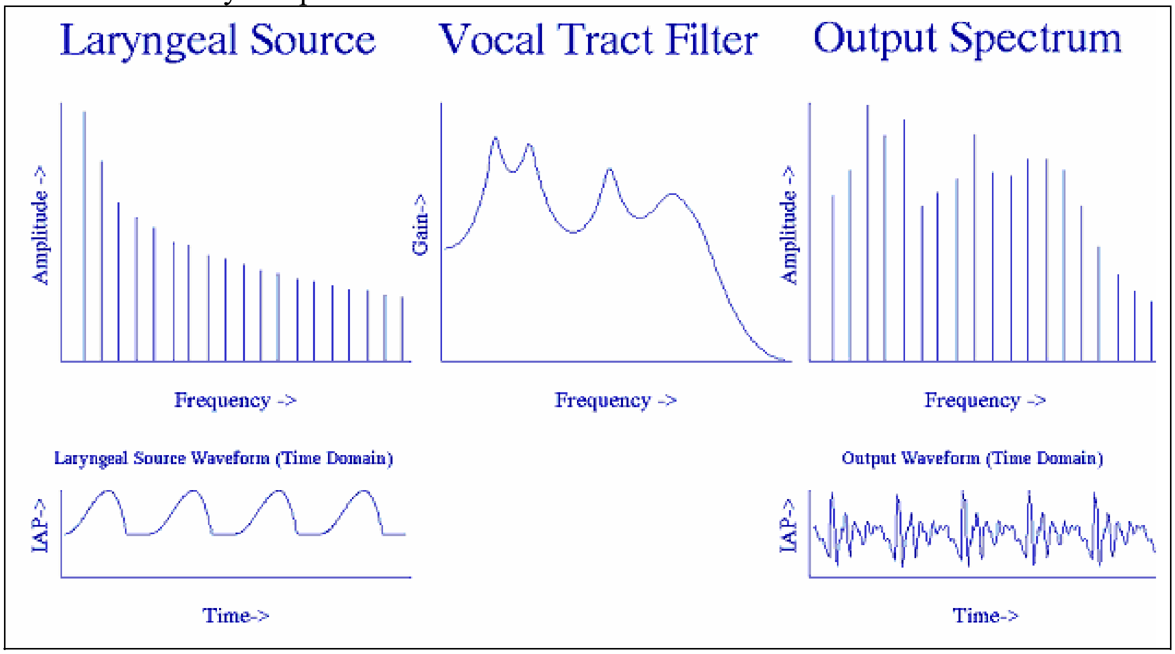
       When B resonates to A, A's vibrations make B vibrate. B will vibrate more if A's frequency of vibration matches B's inherent frequency. If A's frequency is different from B's resonant frequency, it will vibrate with less amplitude.
   - Resonators can function as acoustic filters. Source (input) frequencies close to a resonant frequency are amplified; other frequencies are attenuated.
     - response curve – shows the range of frequencies that will pass through a filter



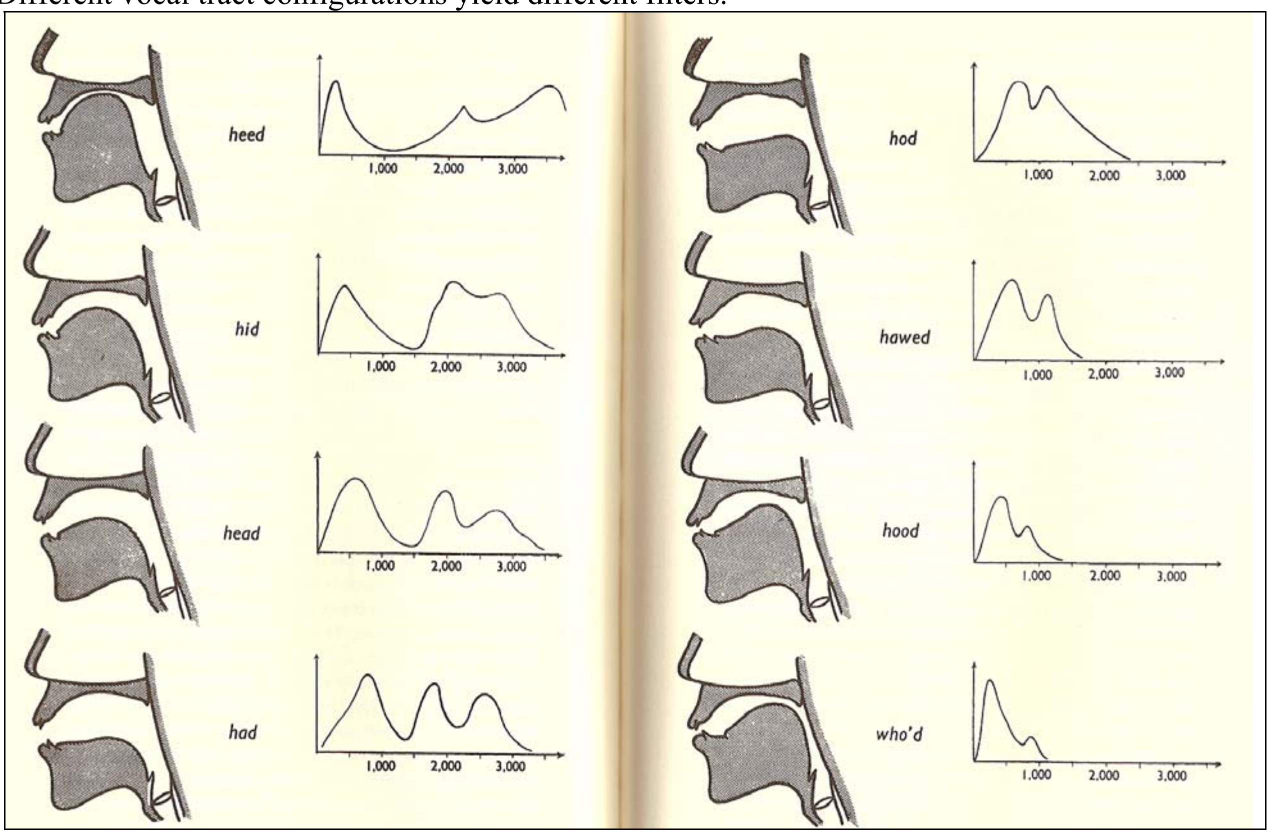
(from Ladefoged, 1996)

4. The vocal tract (or actually, air in the vocal tract) has certain resonances. We call these formants. Thus the vocal tract is a complex filter, and the formants are peaks in the vocal tract's filter function.
   - The filter function depends on the particular configuration of the vocal tract.

5. *Source Filter Theory of Speech*



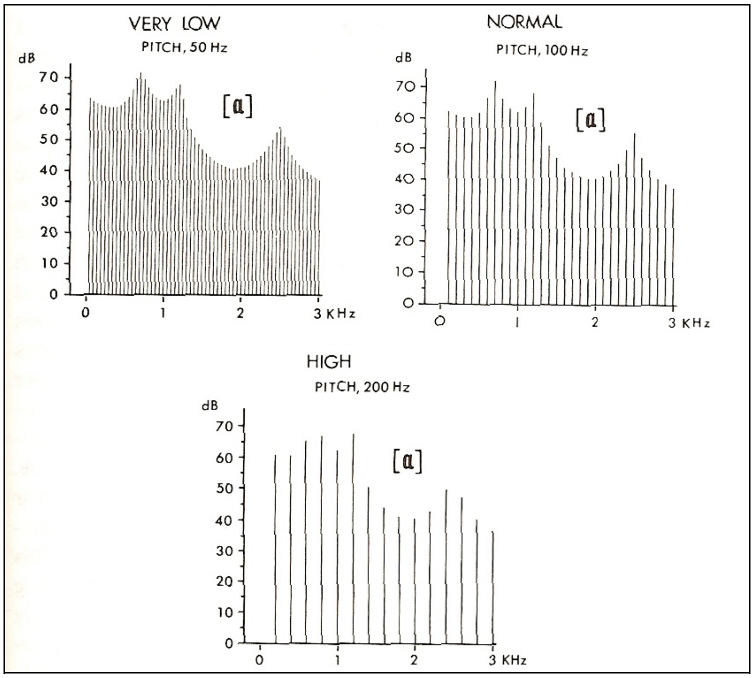
- Different vocal tract configurations yield different filters.



(from Ladefoged, 1996)

  - Note that the filter determines what component frequencies characterize a particular complex sound.

- Different fundamental frequencies (pitches) change the harmonic spacing (and thus the resolution of the spectrum), but the shape of the spectrum is constant.
    - The frequencies of the source and the frequencies of the filter are independent.



(from Pickett, 1999)

    - This is why it is sometimes difficult to understand the vowels of a soprano singing at the top of her range.
    - This is also why the formants of male voices may be easier to measure than those of female voices.