

# Physics of Musical Sound

Class 23

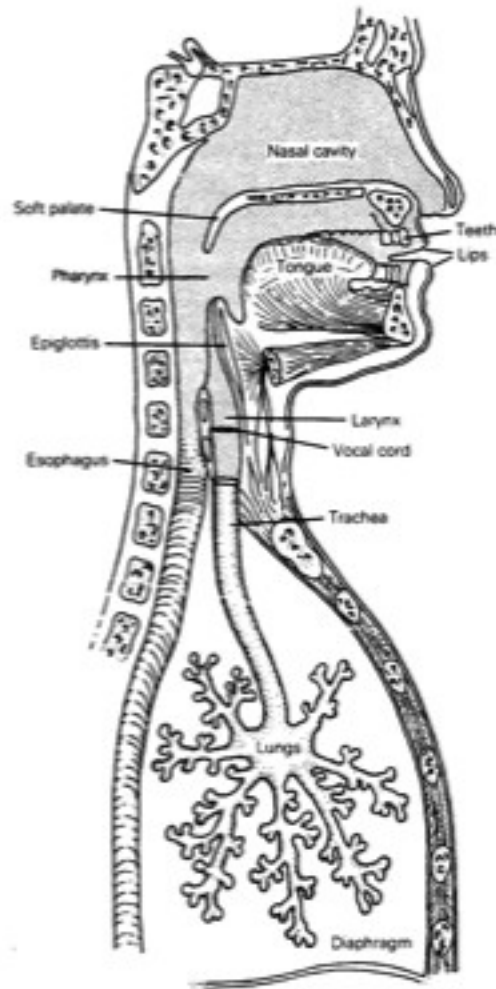
Read Chapters 15, 16, & 17

Quiz

# Vocal Anatomy

- The **Lungs**, serve as air reservoir and pump.
- **Trachea** connects lungs to
- **Larynx**, containing **vocal chords**, serves as valve and produces basic buzzing sound that powers the voice.
- Roughly tubular **pharynx** is first part of resonator tube that ends in
- the **oral cavity**, bounded by **lips** and shaped by **tongue** and separated by **palate** from
- **nasal cavity** and **sinuses**.

# Vocal Anatomy



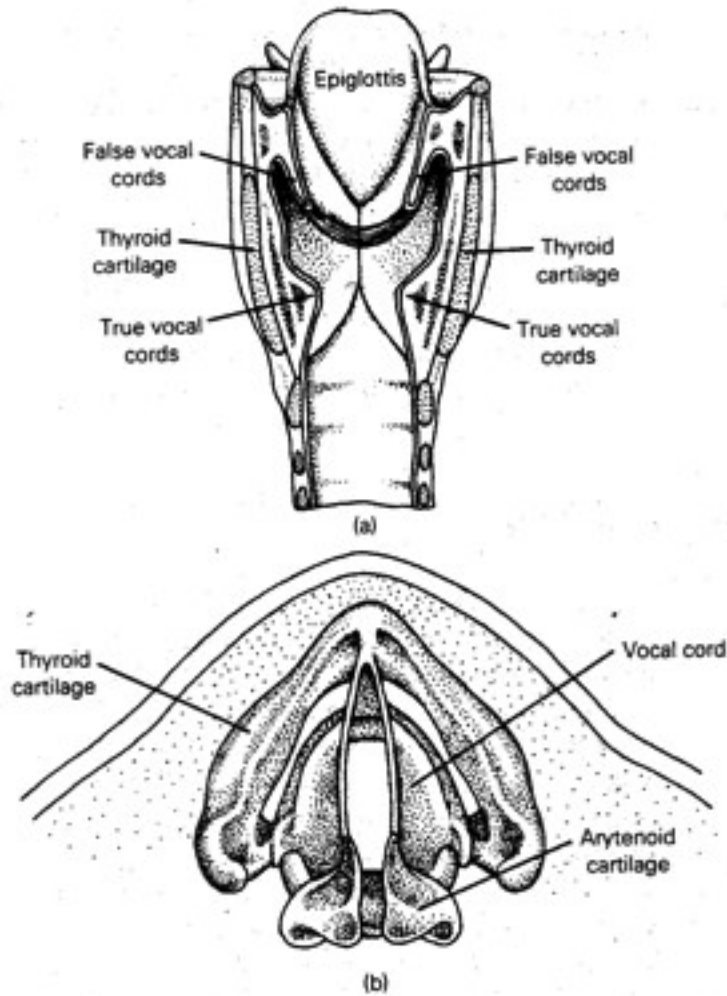
# The Lungs

- Serve as air reservoir and pump.
- Floppy bags sit inside sealed cavity made by ribcage and diaphragm. Can increase the volume of the cavity by expanding rib cage and by lowering diaphragm and decrease it by the reverse process.
  - Increase volume of cavity and pressure in the lungs drops.
  - Air flows in from outside to bring pressure back up.
  - Extra air inflates lungs so they still fill cavity.
  - Decrease cavity and force air out of lungs.
- Total volume 5-6 litres (typ.)
- Tidal volume 1-2 or a little more in singing (typ.)
- Capable of creating significant pressure differences.
  - Sucking  $>3/4$  atmosphere pressure.
  - Blowing  $\sim 1/2$  atmosphere (lips give up!)

# Larynx

- Hard cartilaginous box that protects the vocal chords and separates the reinforced trachea from the soft pharyngeal tissue above.
- Epiglottis is a little flap that closes to prevent food getting into lungs.
- Vocal chords are little flaps of tissue with an array of muscles that can close across the trachea at the lower end of the larynx.
- Raising pressure in lungs and closing vocal chords forces air through gap and produces a buzzing sound, the basic source of most vocal sound.

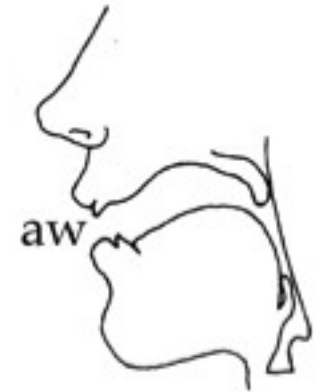
# Larynx



# The Oral/Nasal Cavities

- Separated by palate and soft palate can close nasal cavity off from oral cavity.
- Oral cavity ends in the lips that can be shaped in a wide variety of ways to alter the resonant modes of the cavity.
- Tongue is extremely flexible and can alter the shape of the oral cavity in a wide variety of ways.
- Altering shape of oral cavity and of lip opening can radically alter the resonant modes of the cavity.

# The Oral Cavity & Tongue

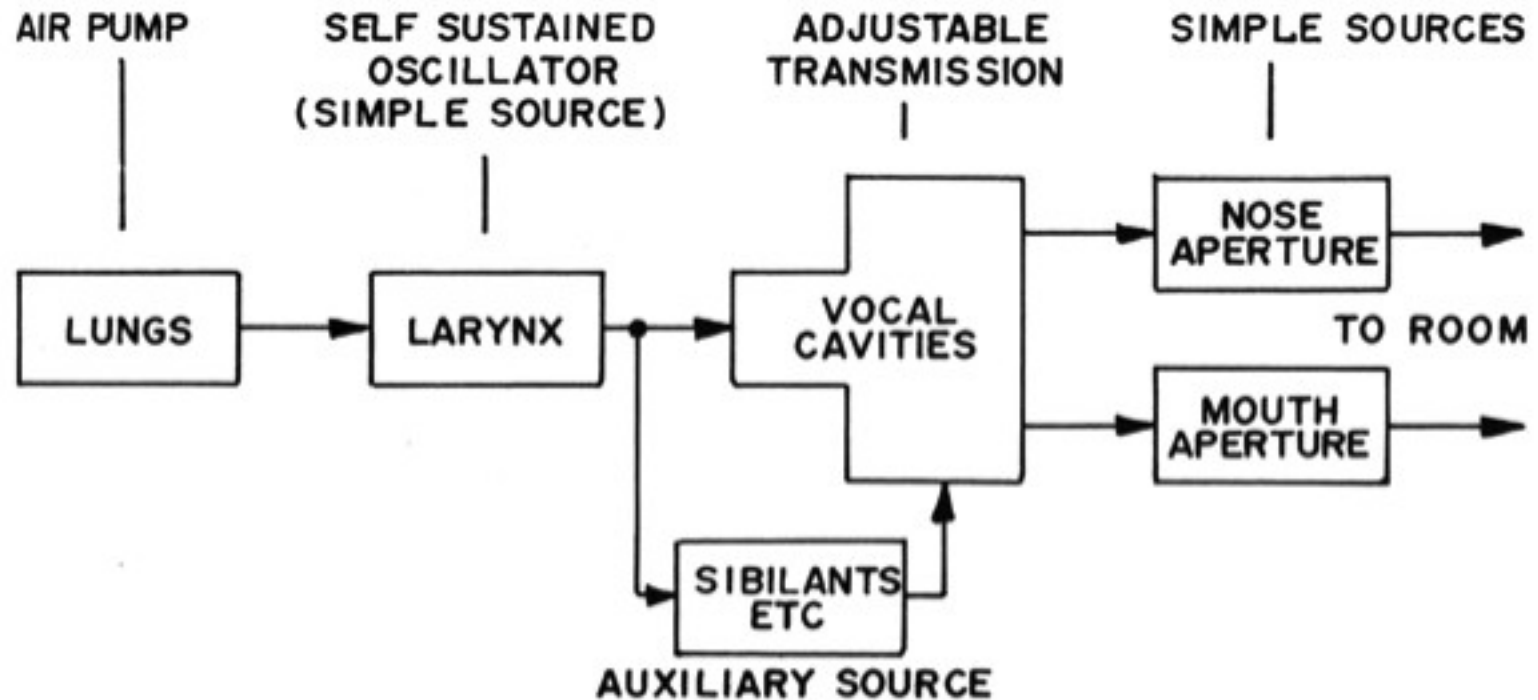




# Vocal System as Synthesizer

- The human vocal system is capable of a very wide range of frequencies and timbres.
- Larynx can produce sounds from extremely low to extremely high.
  - Lowest sung sound recorded is 18Hz (off bottom of piano)
  - Lowest note written in classical music  $B_1^b$  (58Hz, R. Strauss)
  - Highest note written in classical music  $F_6$  (Queen of the Night II)
  - Highest I know of Ima Sumac
  - I can sing at least 43Hz to 700Hz in 3 ranges, profundo, bass/baritone, counter tenor (male alto).
- Vocal tract has several resonant frequencies (formants) adjustable over a wide range.

# Vocal System as Synthesizer



# Vocal Styles

- Extraordinary range of different vocal styles used around world.
  - Modern pop/rock
  - Classical operatic/lieder singing
  - Renaissance/Baroque pure styles
  - Edgier western European folk styles
  - Vivid eastern European folk styles
  - Amazing Throat Singing from Central Asia
  - Extremely fluid Eastern styles
- Almost any sound the voice is capable of making has been fashionable somewhere!

# Larynx Waveforms

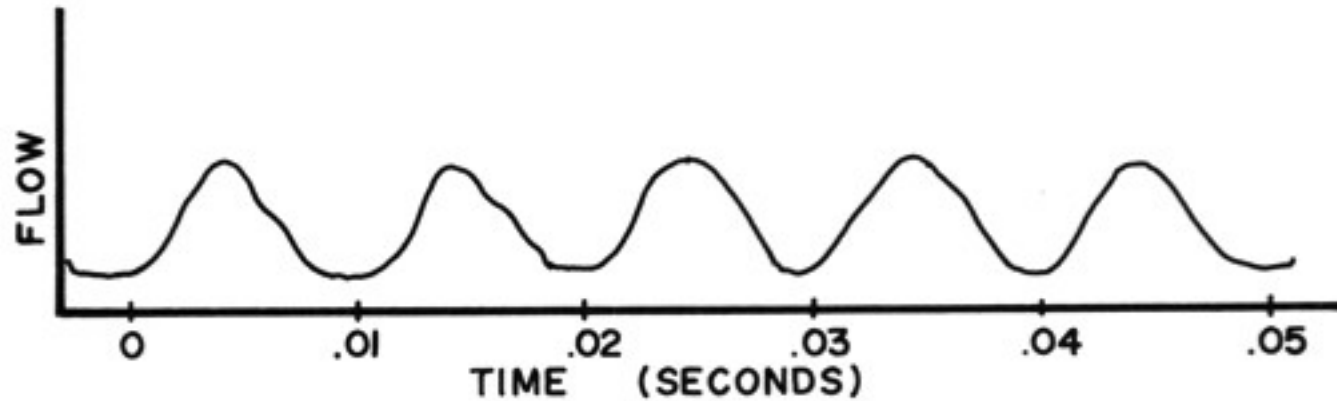
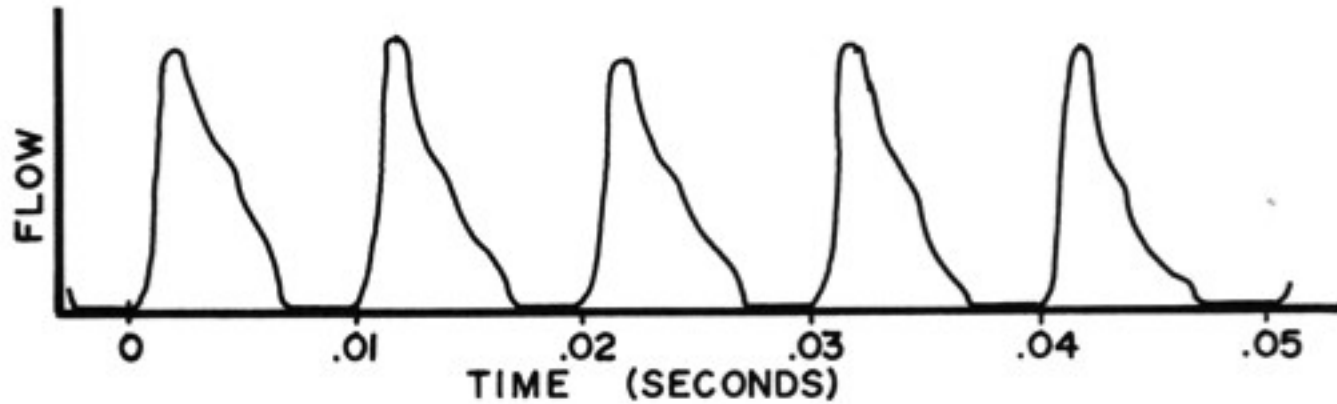


Fig. 19.4. Limiting Forms of the Airflow Patterns from a Larynx

# Vowel Formants

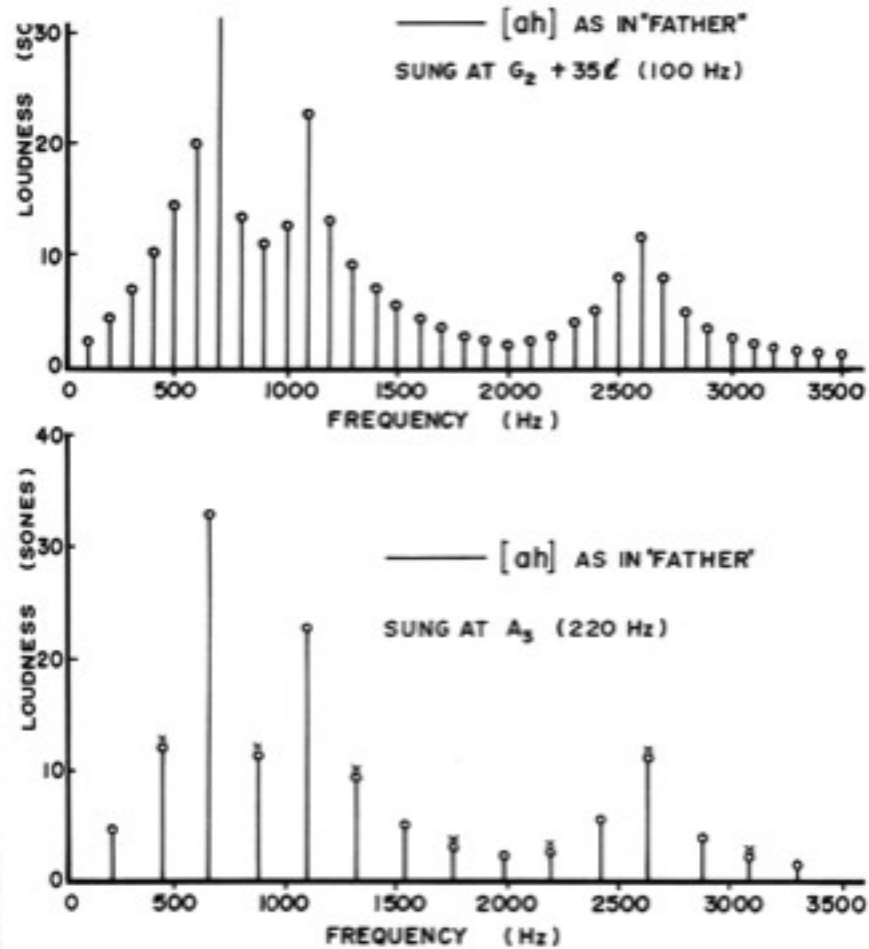
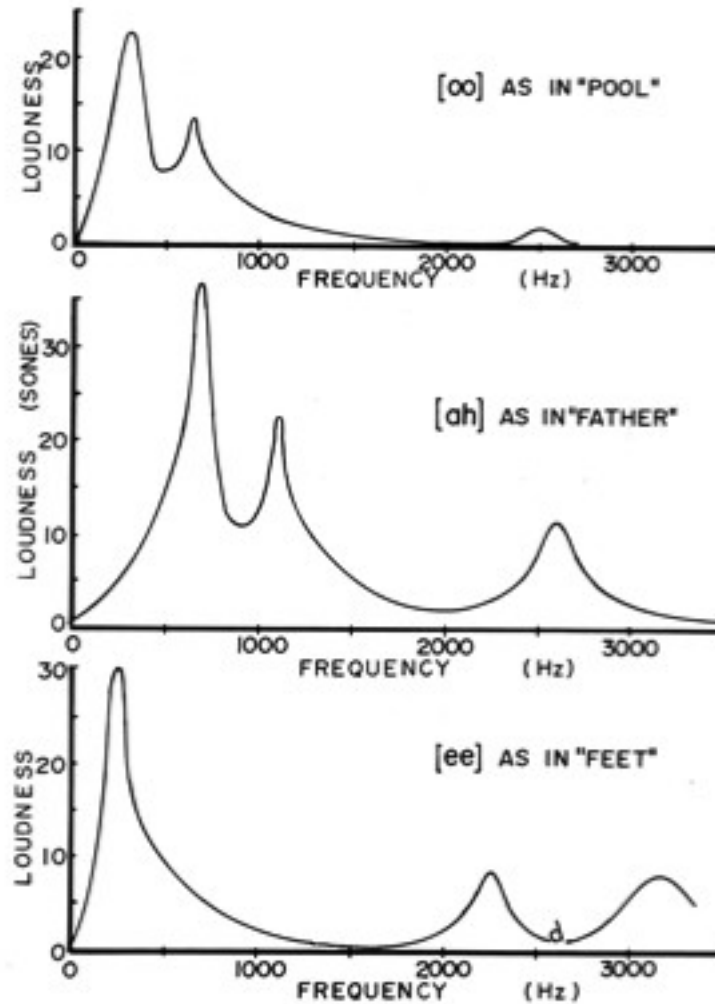
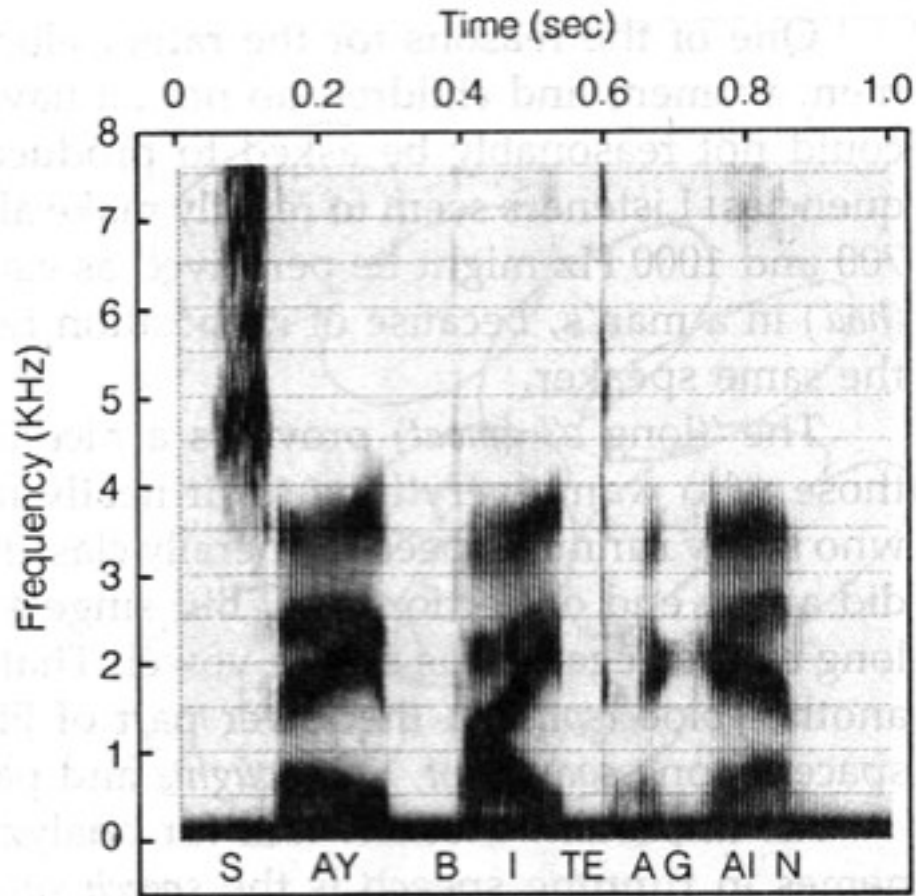


Fig. 19.5. Loudness Recipes for a Vowel Sung at Two Different Pitches

# Vowel Formants



# A Vocal Spectrogram



(a)