Morphological* information encoded in the voice

From production to perception

*form and structure of the body

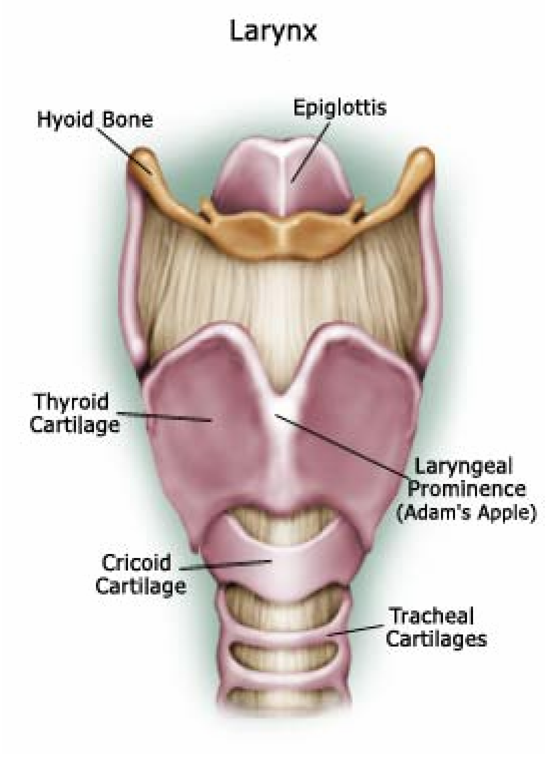
Outline

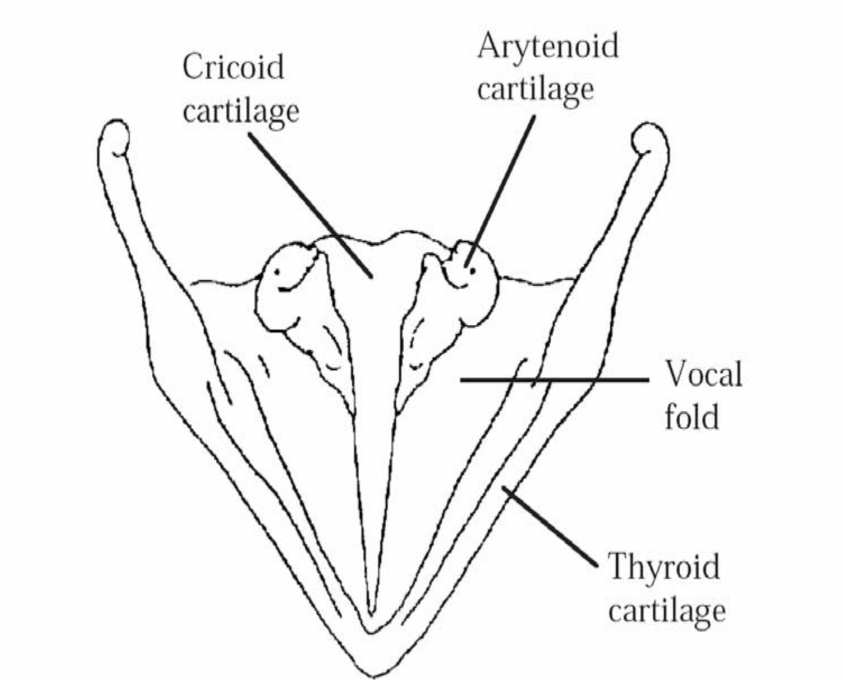
- Production
  - Anatomy
  - Biomechanics
- Voice and body morphology
  - Hormones
  - Body shape
- Perception
  - Attributions to voices

Anatomy

- 2 major components to vocal apparatus
- Larynx
- Supralaryngeal vocal tract
  - Often called vocal tract for brevity

Larynx



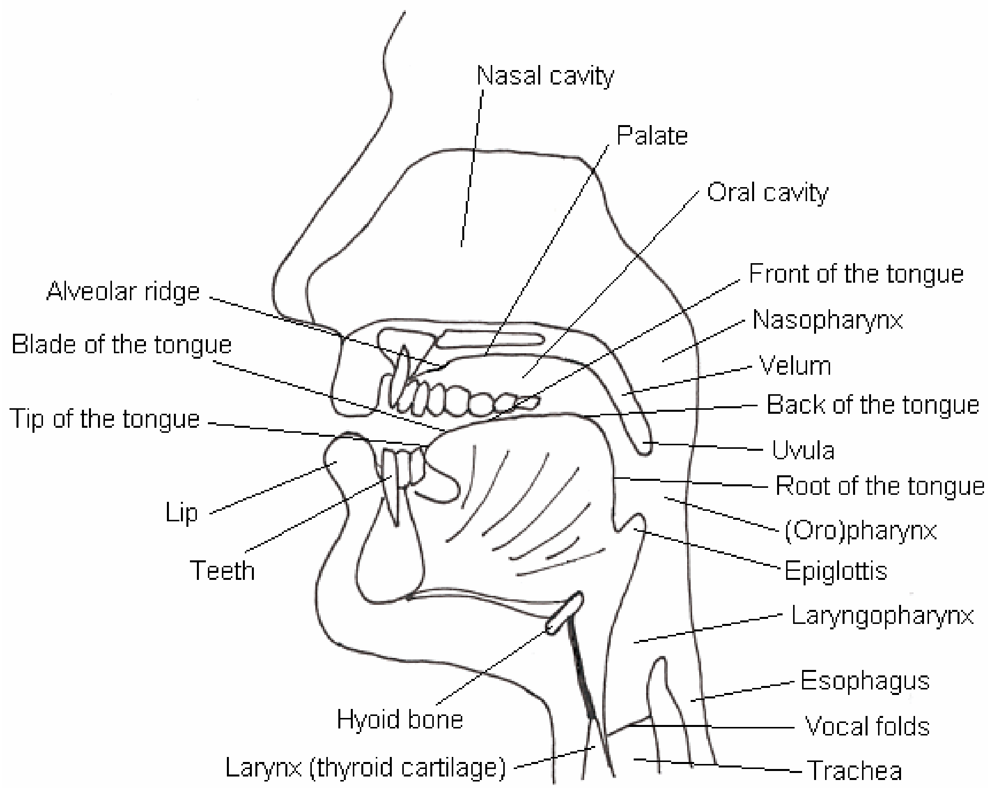


Key things to remember:

•The larynx is made of soft tissue (muscle and cartilage)

•The larynx can grow independently of the rest of the body

Supralaryngeal Vocal Tract



Key thing to remember:

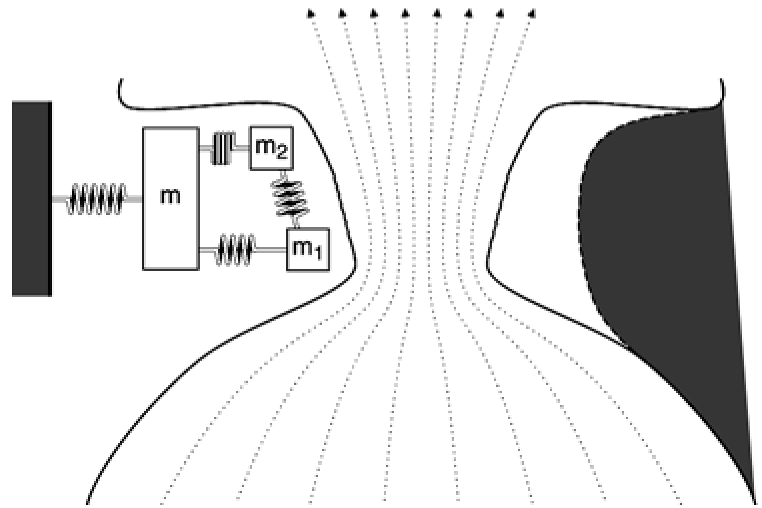
- The vocal tract is like a tube that can change in size and shape

Biomechanics

- Vocal folds
  - Source of sound
- Vocal tract
  - Resonating Chamber
  - “Shapes” sound

Vocal fold mechanics

- Air is expelled from lungs
- Passes through vocal folds
- Asymmetry in pressure between air above and below vocal folds creates sustained oscillation
- Sound caused by vocal folds vibrating



Calculating fundamental frequency from myoelastic properties of vocal folds:

$$F = \frac{1}{L}\sqrt{\frac{\sigma}{\rho}}$$

L=the length of the vocal folds, σ=stress and ρ=density

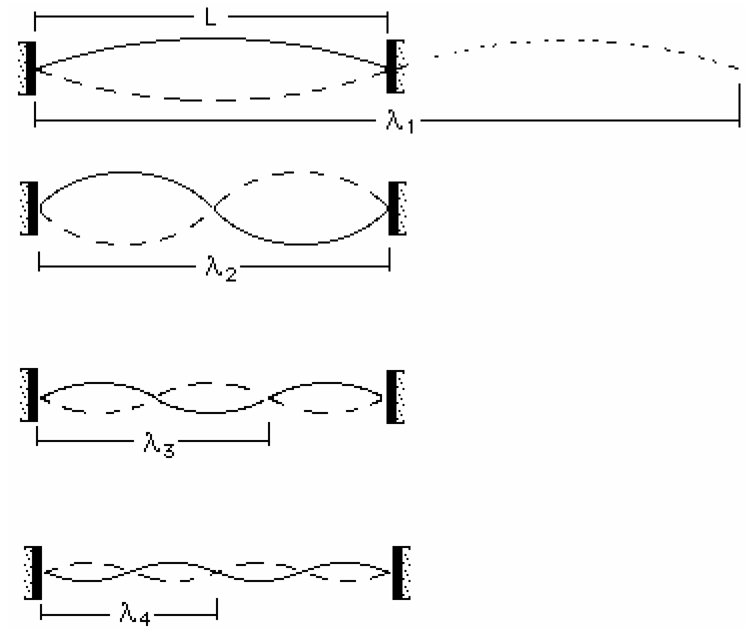
Harmonics

•Degrees of freedom of vocal folds correspond to natural modes (harmonics)

•Harmonics occur at integer multiples of the fundamental frequency

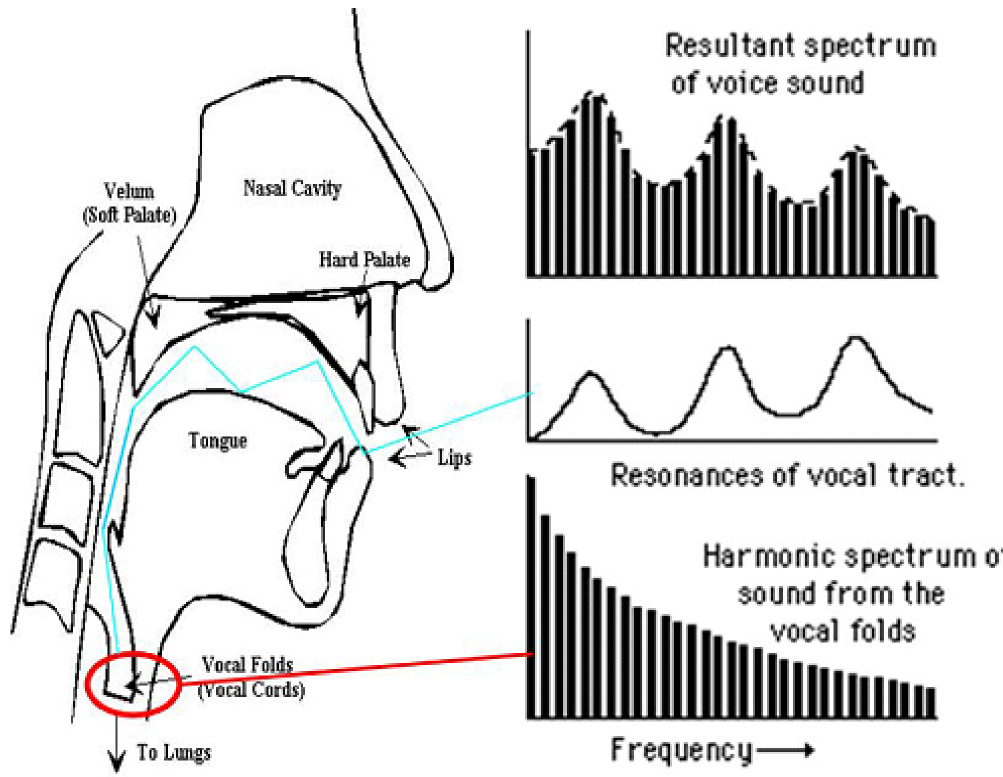
•Can we hear fundamental frequency when it is not present?

- •Yes –telephones
- •Harmonic spacing = fundamental frequency



Formant frequencies

- Formants are caused by air vibrating in vocal tract
- Independent of fundamental frequency
- Selectively attenuate harmonics



Deriving formants from a tube

- L=length of tube
- c=speed of sound (350 m/s)
- F=frequency (Hz)
- t_0=transit time (for wave to propogate from one end of the tube to the other and back again)
- T=period=1/F
- T/2=t_0
- Using formula time=distance/rate:

$$t_0 = \frac{2L}{c}$$

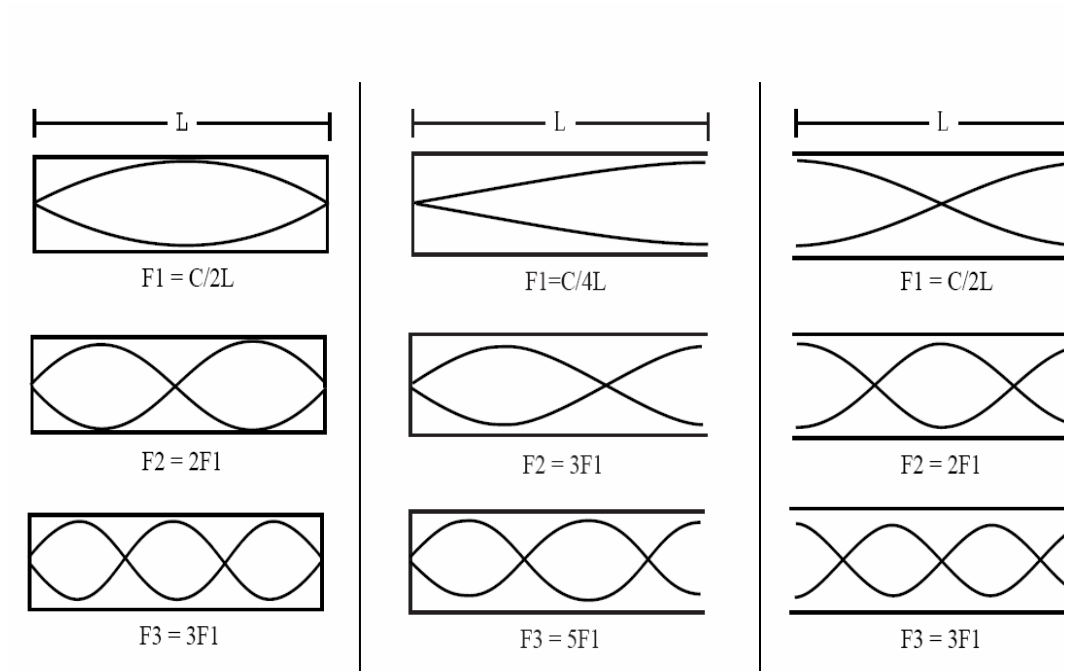
$$\frac{T}{2} = \frac{2L}{c}$$

$$\frac{\frac{1}{F}}{2} = \frac{2L}{c}$$

$$\frac{1}{F} = \frac{4L}{c}$$

$$F = \frac{c}{4L}$$

Formants modified by glottis being open or closed



$$F_n = (n)\left(\frac{c}{4L}\right)$$

$$F_n = (2n-1)\left(\frac{c}{4L}\right)$$

$$F_n = (2n)\left(\frac{c}{4L}\right)$$

Formant dispersion

- Consider a tube 17.5cm
- Open-open:
  - F1=1000 Hz
  - F2=2000 Hz
  - F3=3000 Hz
  - F4=4000 Hz
- Open-closed
  - F1=500 Hz
  - F2=1500 Hz
  - F3=2500 Hz
  - F4=3500 Hz

Vocal tract is same size, but formants differ, so how can we approximate vocal tract length?

Distance between formants = 1000 Hz in both cases

$$\frac{\sum_{i=1}^{N-1} F_{i+1} - F_i}{N-1}$$

Bigger dispersion=smaller tube

Whispered speech

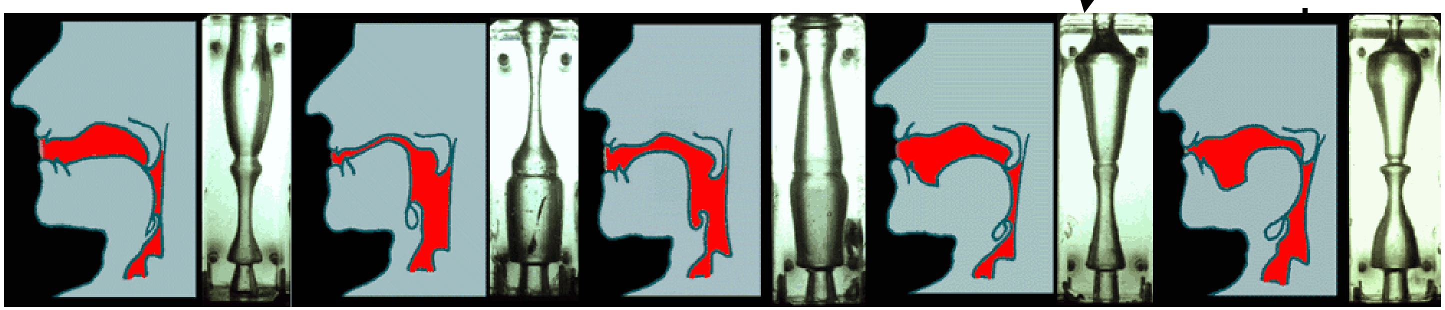
- Vocal cords are too far apart to vibrate
- “white noise” is produced
- But…
  - We can still understand whispered speech
  - Because vocal-tract filters all noise
  - Formants change when mouth moves during speech

Putting fundamental and formant frequencies together

Duck caller (resonator) simulates vocal cord vibration (pitch)

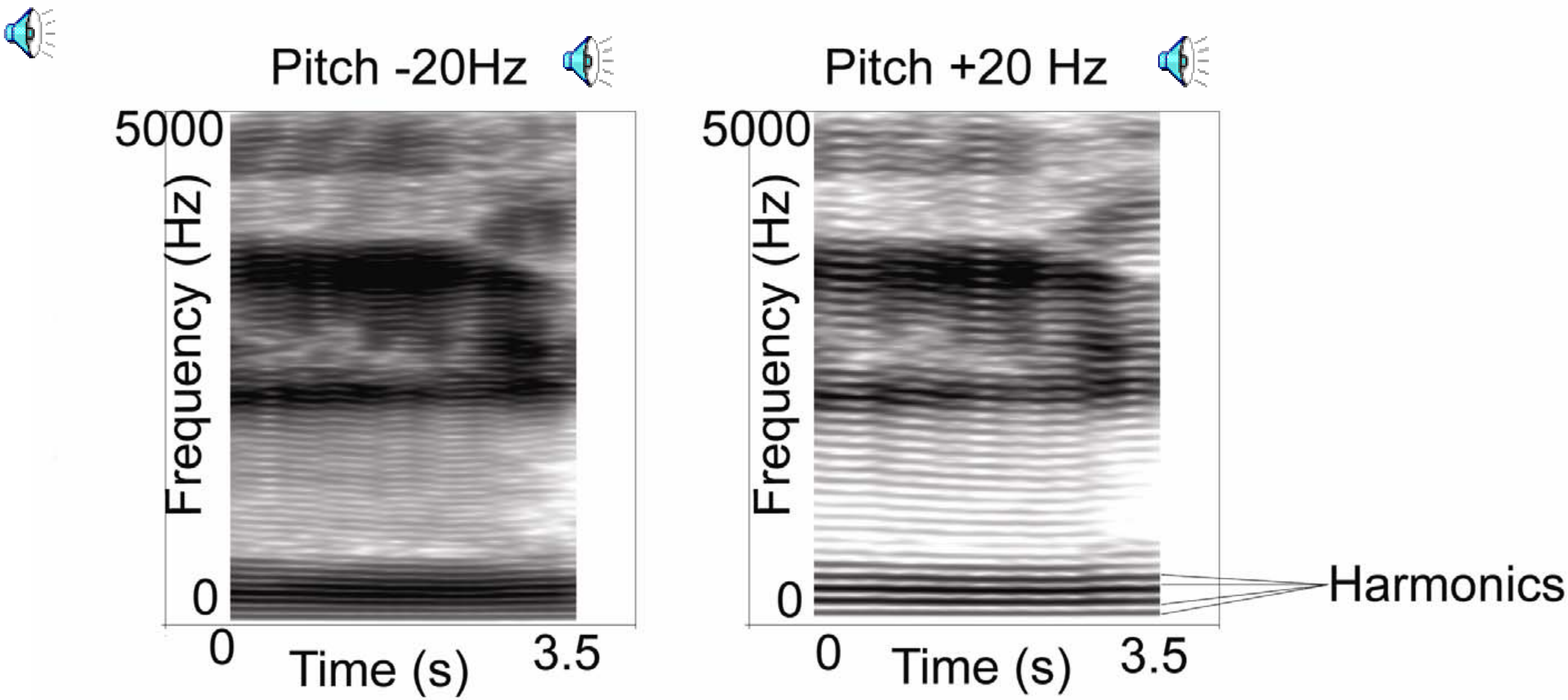
Plastic bottles simulate vocal tract (formants)

Different shapes resonate different vowel

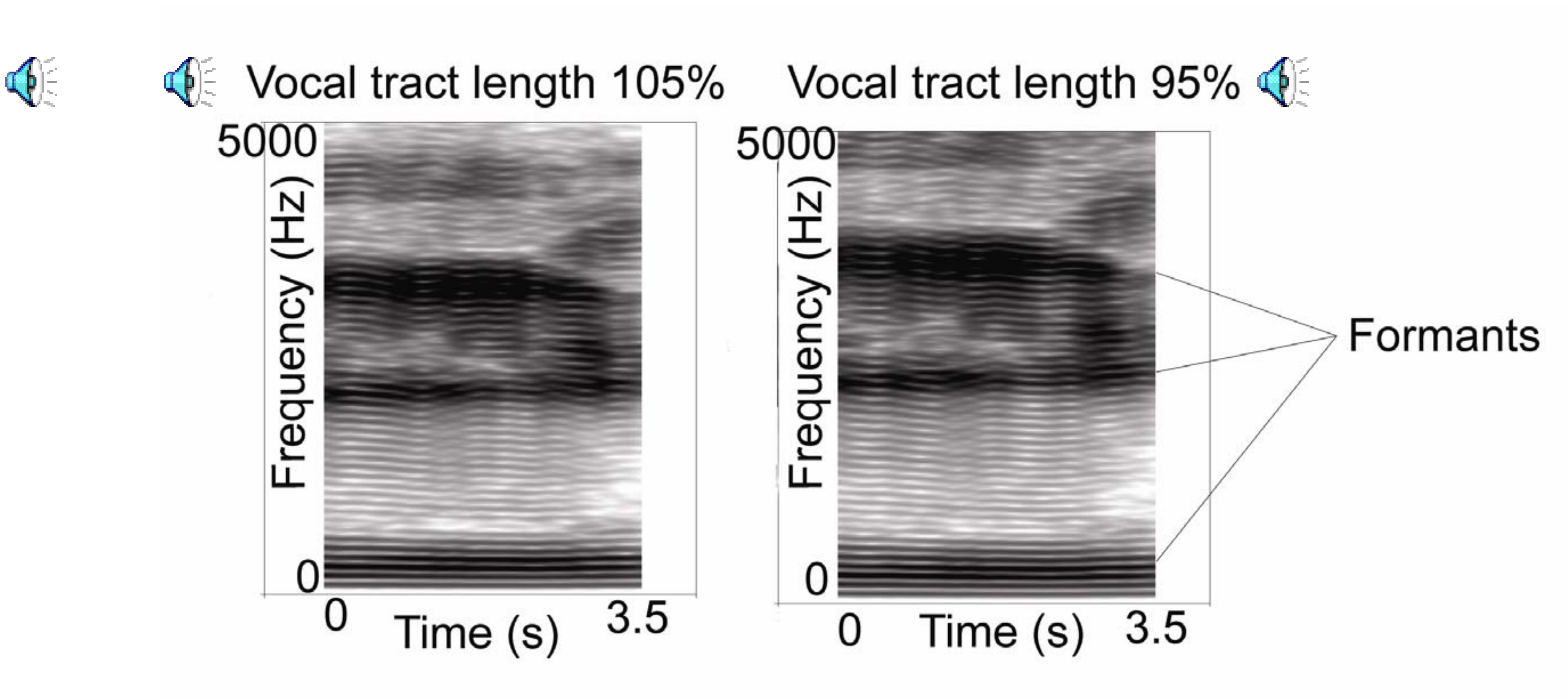


ah ee e o o
h h o

Change in voice pitch (F0)



Change in vocal-tract length (formant dispersion)



Voice and body morphology

- Changes in the voice through development
  - Hormones
    - Testosterone and estrogen
  - Body size
    - Height and weight

volunteers

Voice and hormones

- Testosterone
  - Puberty
    - Voice pitch (F0) drops
    - Larynx descends further down
    - Most markedly in males
- Estrogen
  - Stops testosterone from lowering voice pitch
  - At menopause
    - Estrogen levels drop/Testosterone levels raise
    - Voice pitch drops

- Men’s voices
  - Testosterone is negatively related to F0 and formant dispersion
- Women’s voices
  - Estrogen is positively related to F0 and formant dispersion

Testosterone’s effect on the voice

Body size and the voice

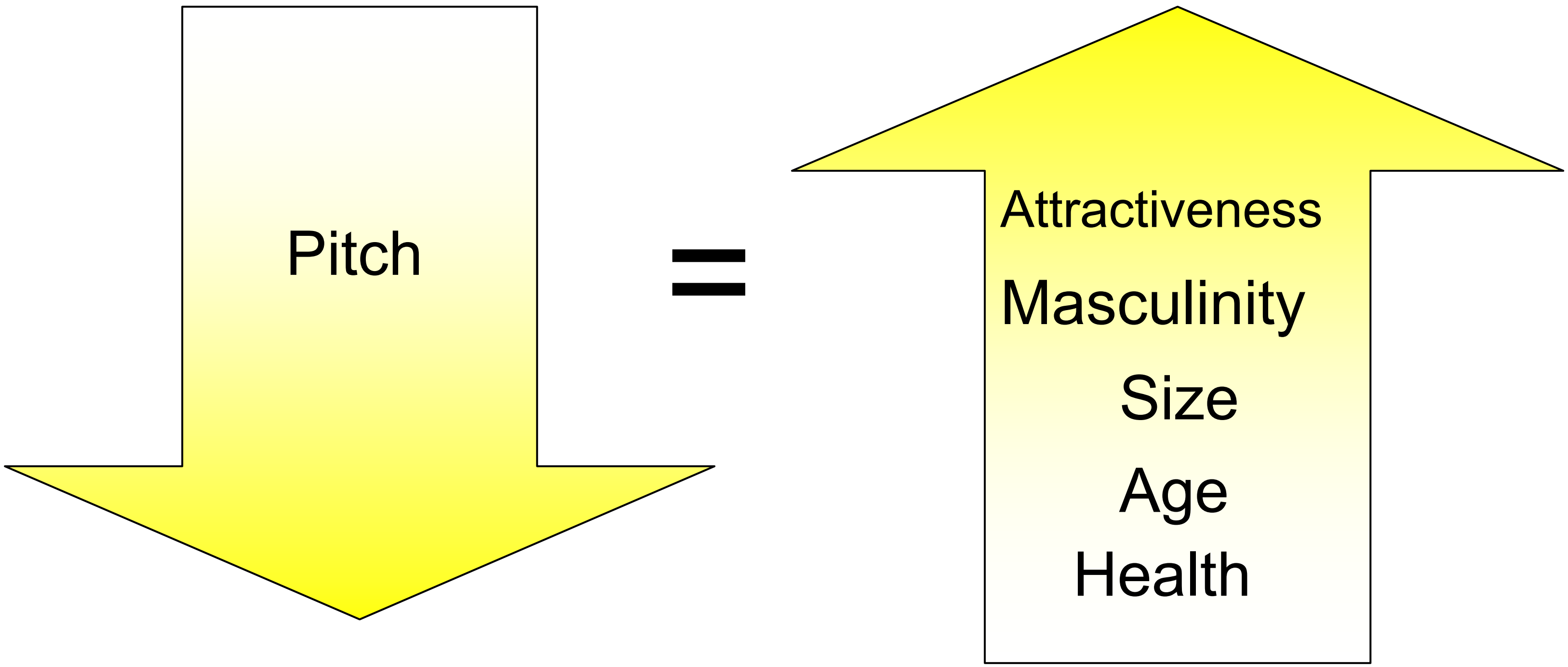
- As we grow our vocal tracts get larger
  - Negative relationship between formant dispersion and body size
- In children, and between men and women voice pitch relates negatively to body size
  - Not in adults of the same gender
  - Because larynx is soft tissue
    - Grows independently of rest of body

How the voice changes as we age

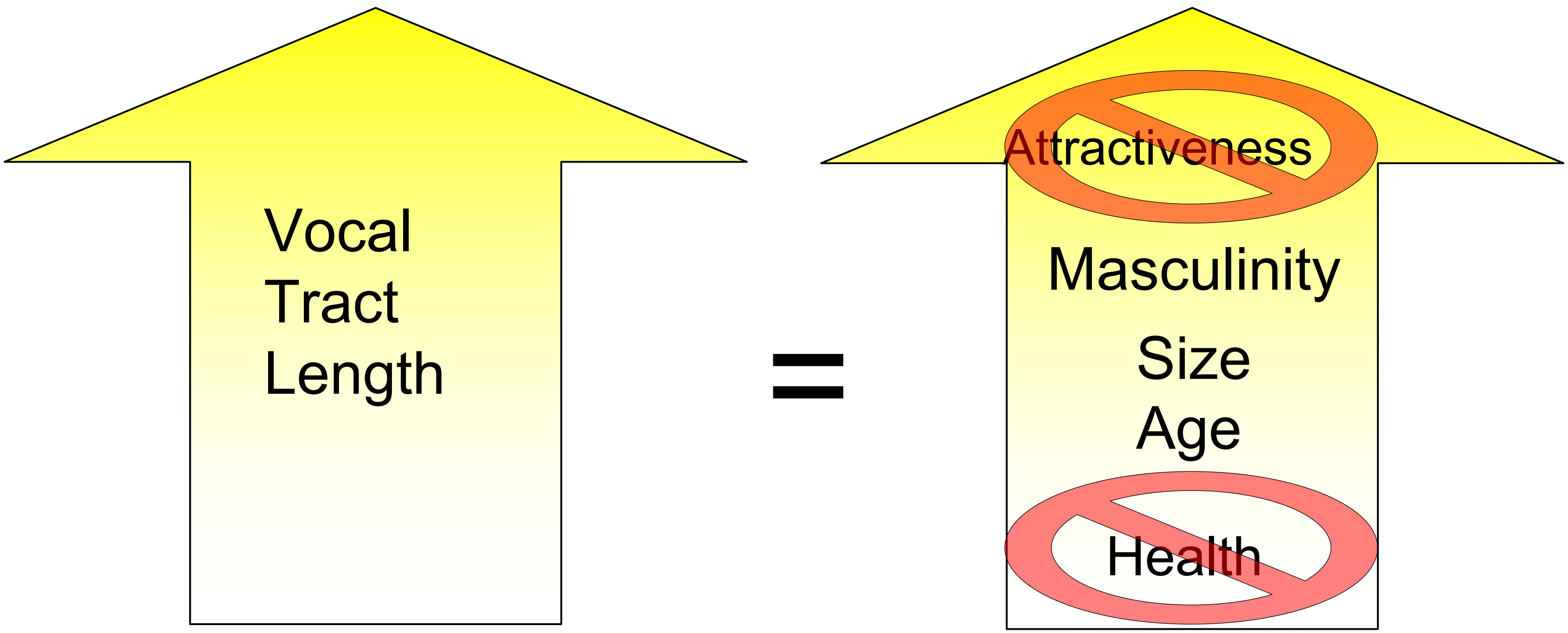
Voice perception

- Pitch and formant dispersion reflect size (developmental status), and age
- Do people use these acoustic features when evaluating voices?

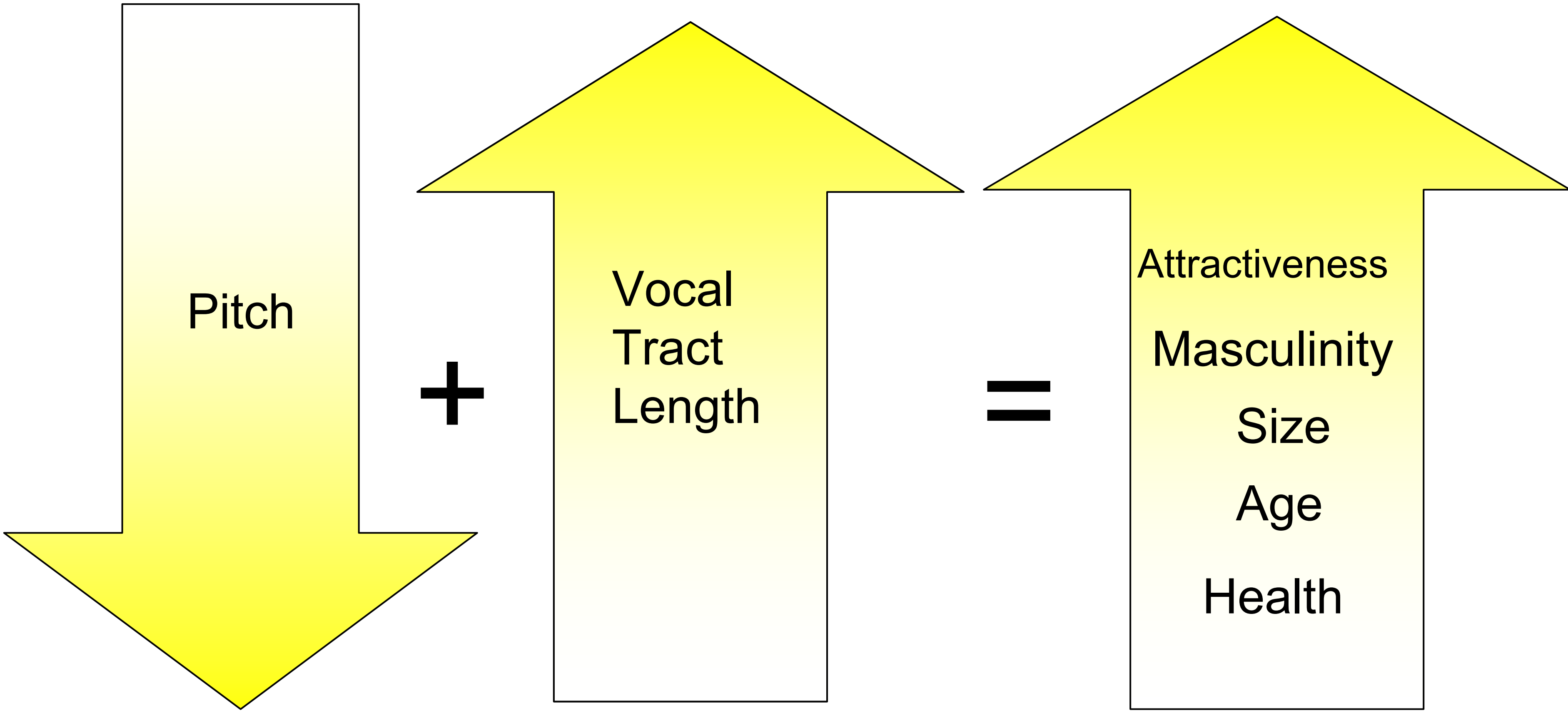
Perceptions of Pitch Only Manipulation



Vocal Tract Length Only Manipulation



Pitch and Vocal Tract Length Manipulated Together



Individual Differences

Female height & weight

=

Preference for male vocal tract length

Perceptions of pitch and VTL in Red Deer

- Pitch (F0)
  - No effect on female preferences for males
  - No effect on male-male competition
- Vocal-tract length (formant dispersion)
  - Females prefer large vocal tracts
  - Males with large vocal tracts win agonistic interactions
  - Males with large vocal tracts have highest reproductive success

Summary

- Fundamental and formant frequencies differ in:
  - Modes of production
  - Relation to body morphology
  - Perceptions

Recommended reading

- Feinberg, D. R., Jones, B. C., Little, A. C., Burt, D. M., and Perrett, D. I. (2005). Manipulations of fundamental and formant frequencies influence the attractiveness of human male voices. *Animal Behaviour* **69**(3)**,** 561-568

- Smith, D.R.R. and Patterson, R.D. (2005) The interaction of glottal-pulse rate and vocal-tract length in judgements of speaker size, sex, and age. *The Journal of the Acoustical Society of America* **118** (5), 3177-3186

- Fitch, W.T. and Hauser, M.D. (1995) Vocal production in nonhuman primates: acoustics, physiology and functional constraints on "Honest" advertising. *American Journal of Primatology* **37**, 191-219

- Titze, I.R. (1994) *Principles of Voice Production*, Prentice Hall