Why a lowered larynx is good for human speech production

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Speech

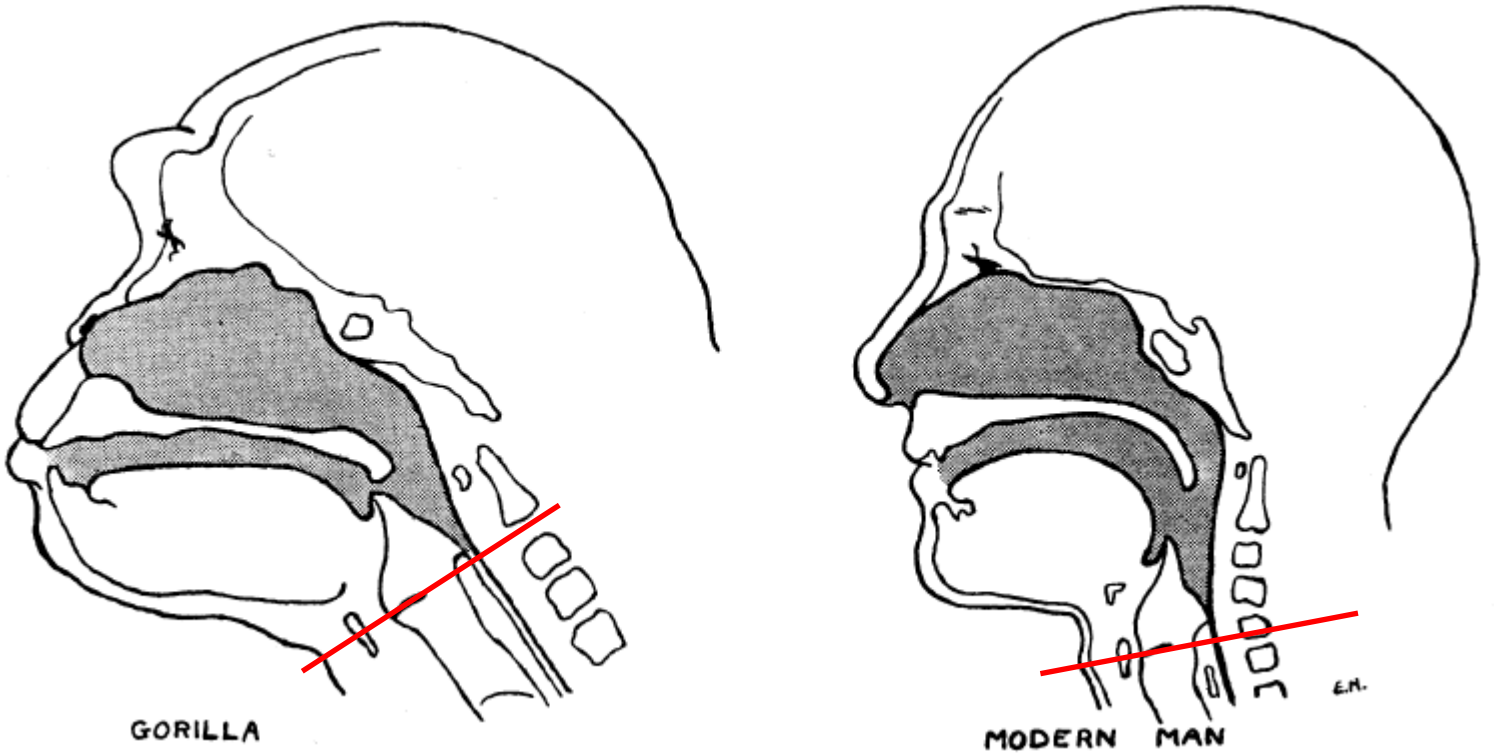
- Concentrate on physical aspects
  - speech as physical behaviour

- Speech organs and vocal tract have an evolutionary history
  - can look at physical traces in the fossil record
  - can look at comparative data from other primates etc.

This talk

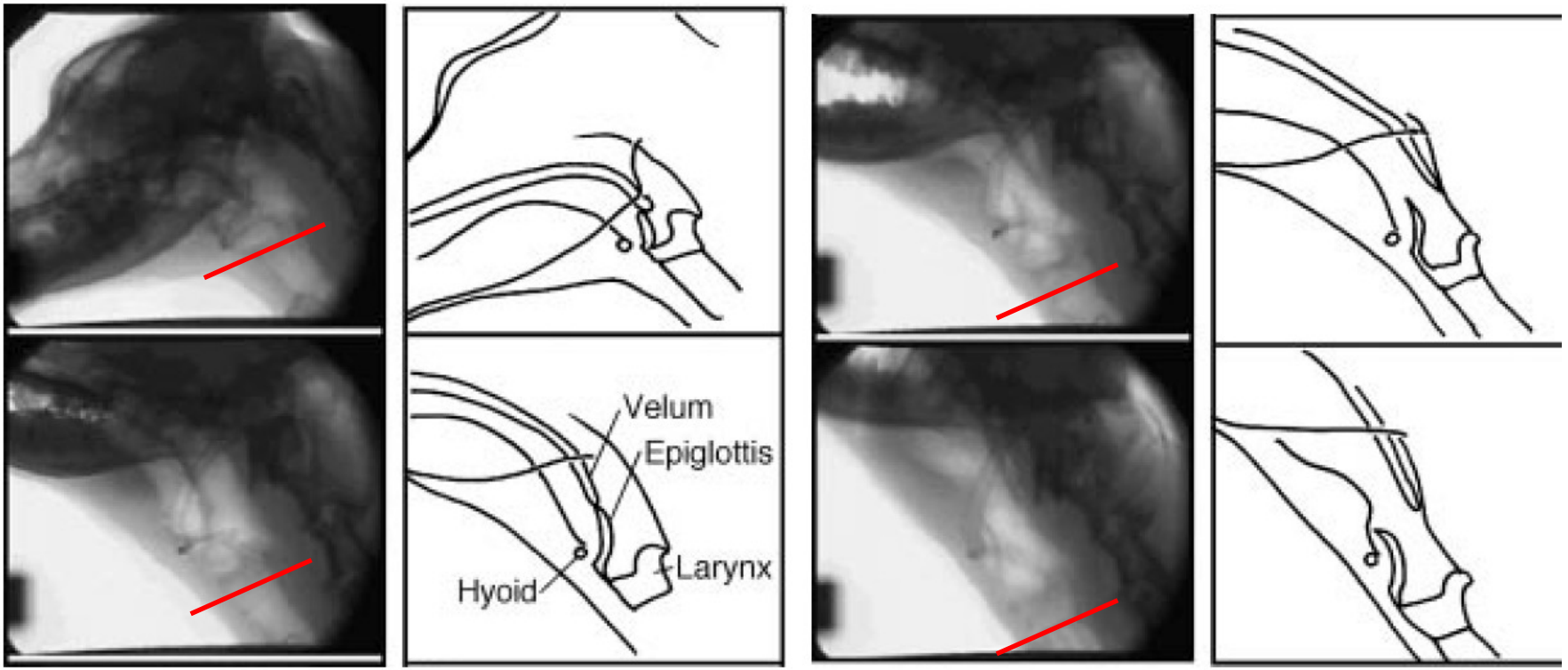
- Focus on lowered larynx
  - found in humans but not (to same extent) in other primates
- Take issue with recent views on motivation for larynx lowering
  - size exaggeration hypothesis (Fitch)
  - point vowels (Lieberman)
- summarise range of possible benefits of low larynx
  - refine some old ideas
  - propose some new ones

Lowered larynx



Negus (1949: 196)

Lowered larynx



Fitch (2000: 209)

Lowered larynx

- Not *uniquely* human
  - Lowered for vocalisation in other animals
    - disengages from nasal cavity
    - louder vocalisations
    - not clear if all primates do (e.g. Owren et al. 1997)

- But humans have ***permanent*** lowering
  - have to raise larynx to swallow
  - we have a ***pharynx***

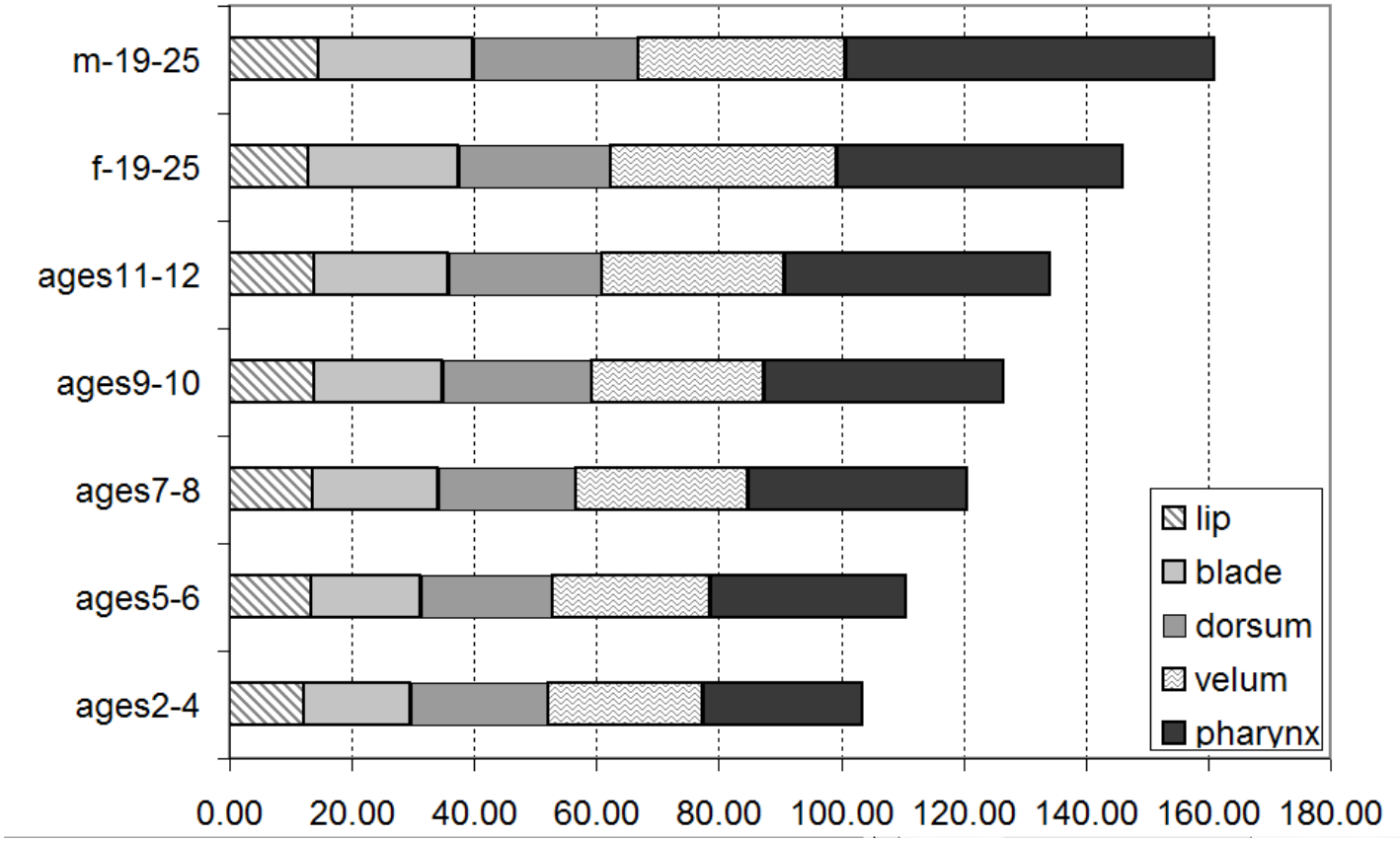
What does this get us?

- Fitch (1994, 2000) Fitch & Hauser (1995):
- larynx lowering increases vocal tract ***length***
  - **reduces** frequency of resonances
  - makes animal sound **bigger**
    - **Size exaggeration hypothesis**

- Larynx lowers from birth
- In human males, **additional** larynx lowering at puberty
  - males have disproportionately large pharynxes
  - supports size exaggeration hypothesis
    - sexual dimorphism

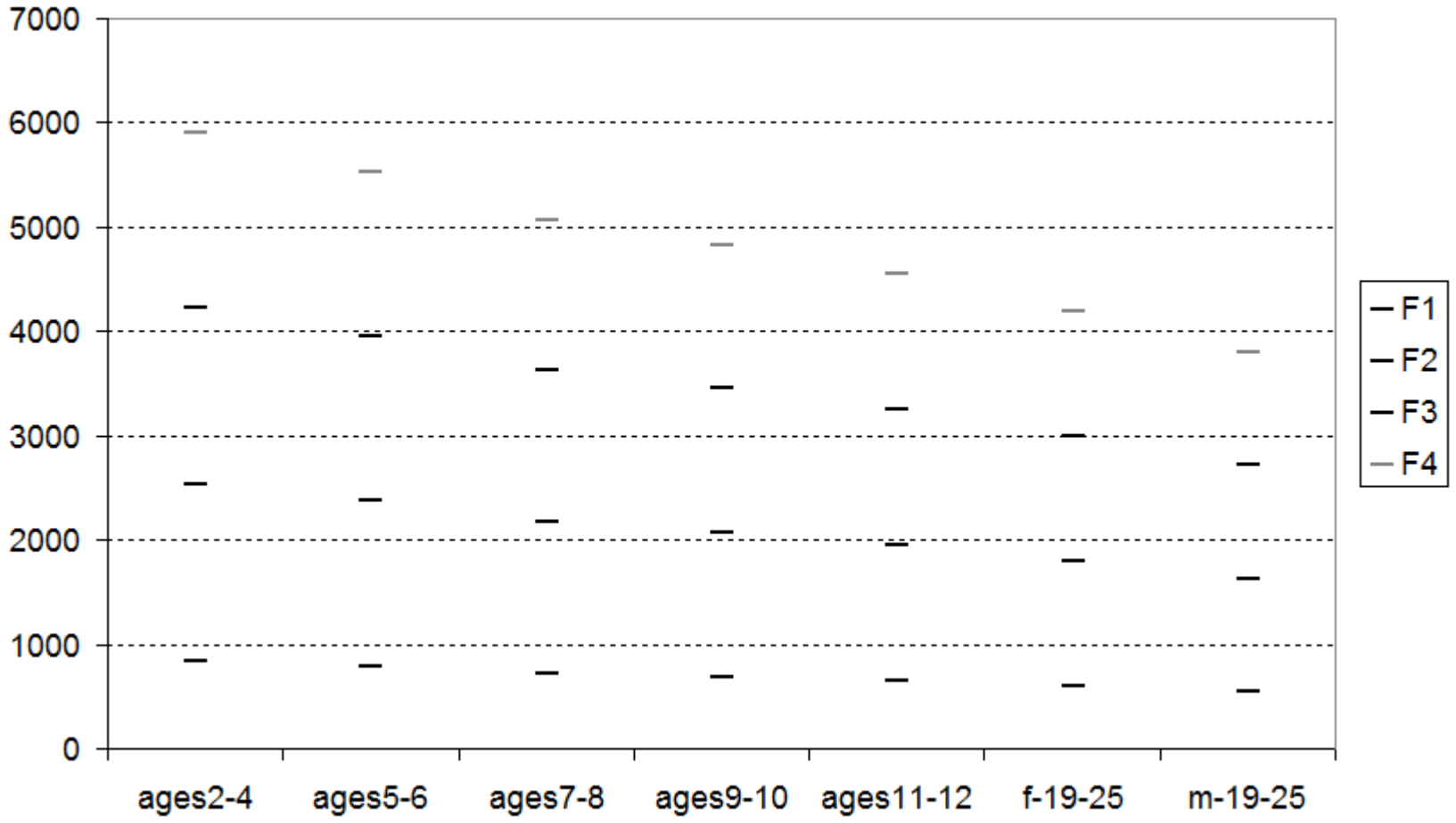
- **No doubt** longer VT means lower resonances

Increase vocal tract length



Data from Fitch & Giedd (1999).

Increase vocal tract length



Data from Fitch & Giedd (1999).

Lowered larynx

- Fitch (2000: 39)
  - “the initial impetus for the descent of the larynx in early hominids may have had nothing to do with speech, but instead functioned to exaggerate body size.”
  - permanent lowering – easier for vocalisation
  - pharynx enabled larger range of vowel sounds

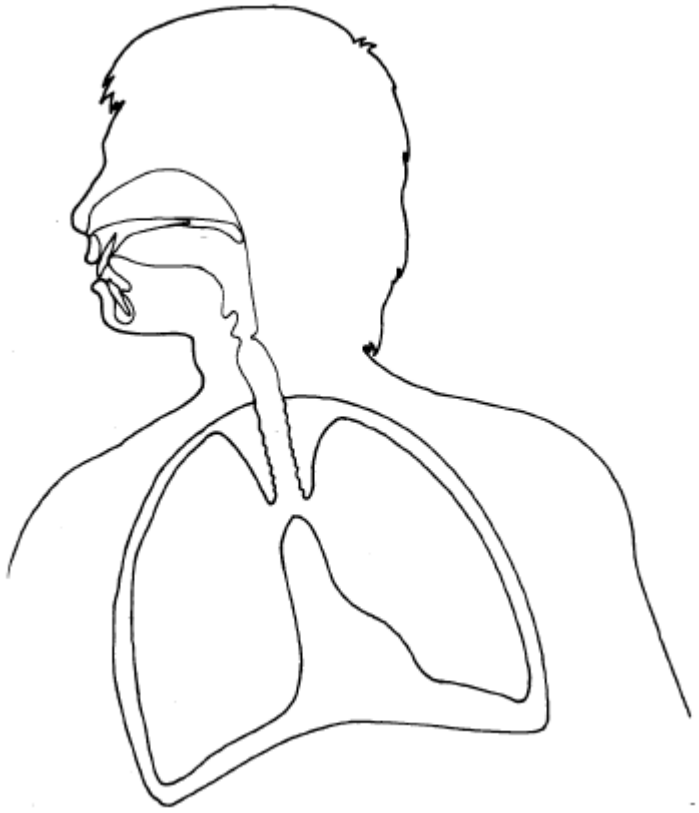
However…

- Fitch often ***confuses*** mechanism of selection (bigger animal survives to reproduce more successfully) with ***motivation*** to lower larynx

- Too teleological:
  - implication that animals know what effect their actions will have
  - same goes for saying ***louder*** voices

- Don't wish to assume lack of understanding of cause and effect but *simpler* not to assume this…

Respiratory function



Speech requires ***airflow***

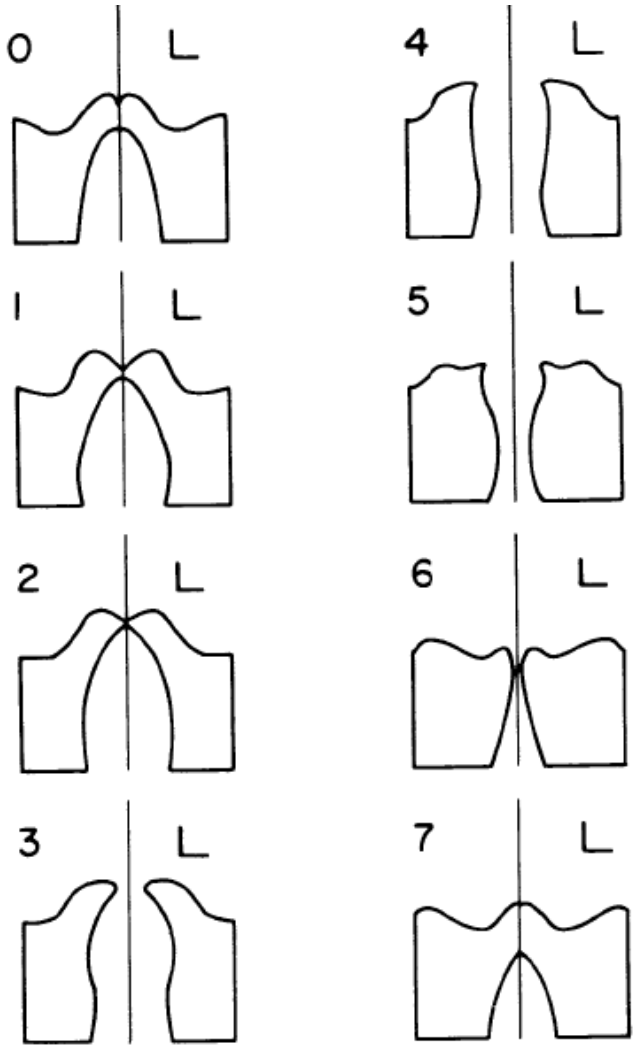
Usually pulmonic egressive

outward from lungs

Lungs inflated and compressed

- elastic return forces
  - external intercostals
  - diaphragm
  - internal intercostals
  - abdominal muscles

Vocal fold vibration



- Subglottal pressure forces vocal folds apart
  - to maintain voicing 3 cm H2O
  - to initiate voicing 8 cm H2O
    - mechanical coupling
    - upper and lower portions
- closure phase
  - elastic return forces within folds
  - Bernoulli effect
- Cycle starts again

Vocal fold vibration

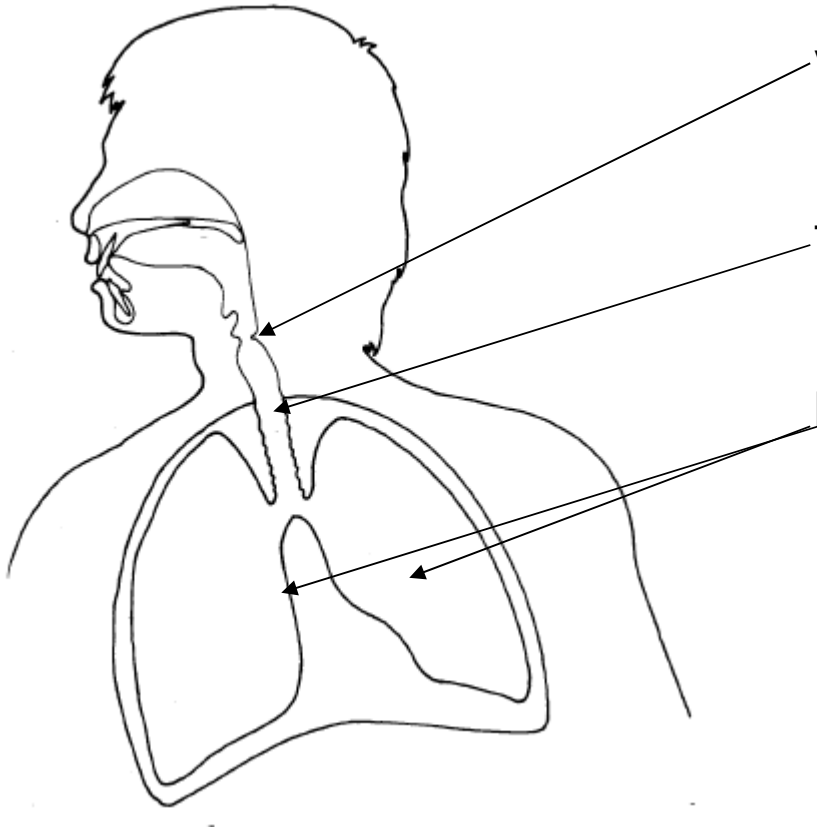
- Vocal folds in larynx
  - require ***trans-glottal pressure drop*** to vibrate
  - subglottal pressure **higher** than supraglottal pressure

  - 3 cm H_2O to ***maintain*** voicing
  - may need 8 cm H_2O to ***initiate*** voicing

    (*figures variable*)

  - so to achieve this we compress the lungs

Respiratory function



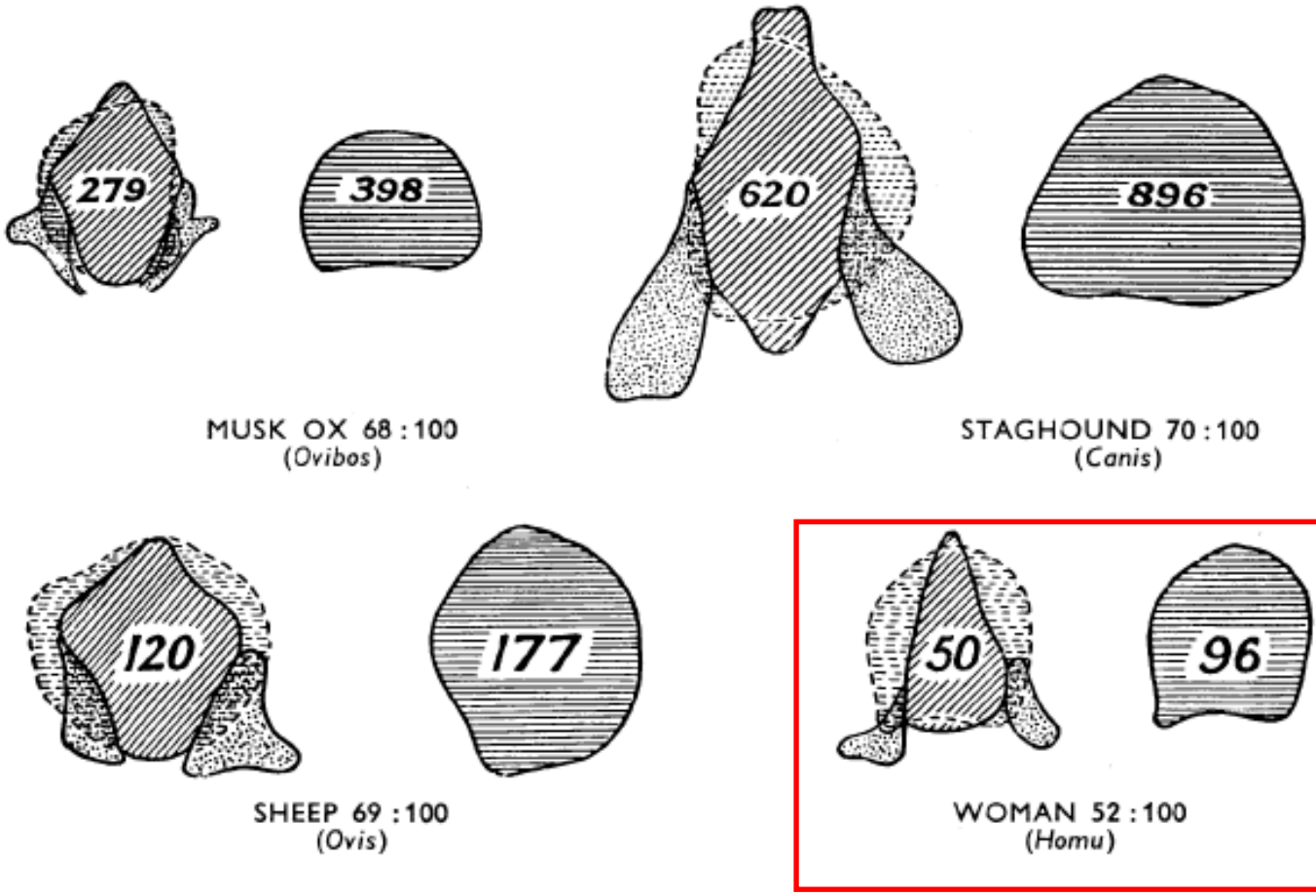
- trachea – c. 16 cm long (males)
- as long as vocal tract
- dead space…

Lower larynx – shorter trachea

- More direct reason to lower larynx
  - shortens ***trachea*** by 3-4 cm
  - ***reduce*** lung compression needed to achieve phonation pressure
    - cf. giraffes don't vocalise

- result:
  - easier phonation but also…
    - louder calls
    - longer vocal tract > lower resonances
      - size exaggeration > selection

Other evidence

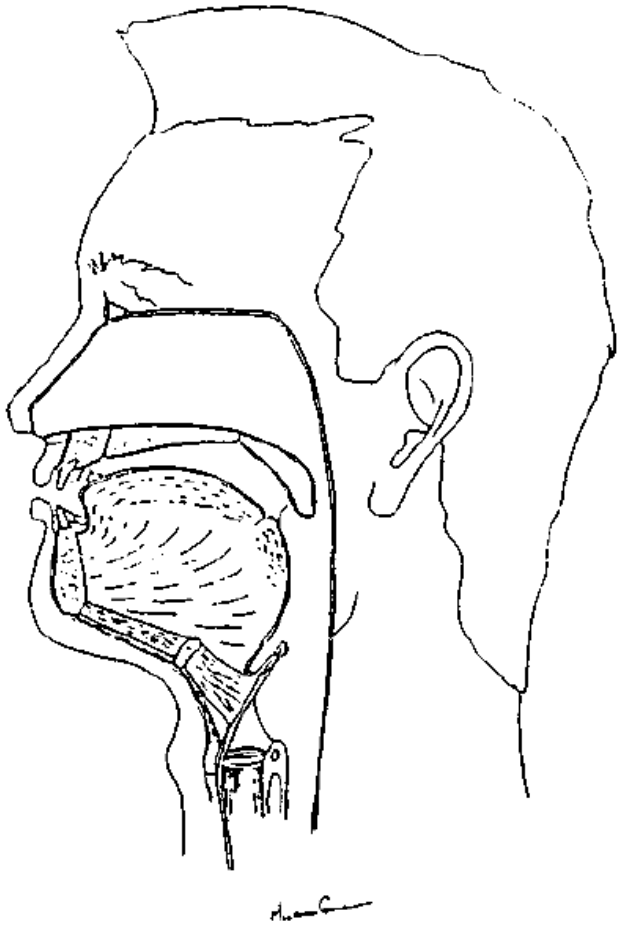


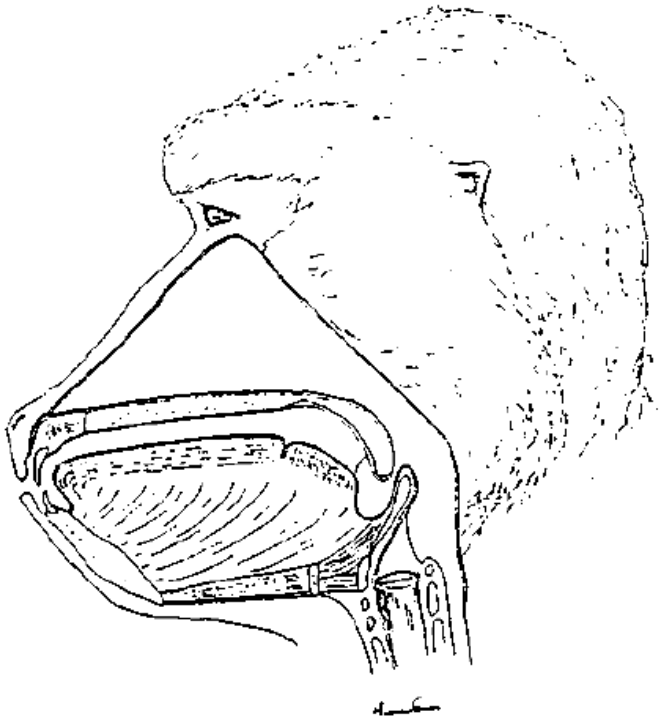
Negus (1949)

Other evidence

- Small glottis relative to trachea
  - vocal folds provide resistance to airflow
  - increases airflow volume velocity (Catford 1977)
    - increases Bernoulli effect
      - ***reduces*** pressure between vocal folds
      - promotes closure & continued vibration
        - » (also vocal fold shape?)
- Respiratory factors crucial

Furthermore…





Owren et al. (1997)

Snout shortening

- Humans have a short snout
  - mandible ***reduced*** in length
  - dentition – ***smaller*** teeth
  - but vocal tract is about ***same length*** in adult *male humans* and *adult female baboons*

- Baboon grunts (Owren et al. 1997)
  - female baboon (VT length c. 16.3 cm)
    - F1: 448 Hz, F2: 1430 Hz, F3: 2677 Hz
  - adult male human (based on 16.1 cm in Fitch & Giedd 1999)
    - F1: 543 Hz, F2: 1628 Hz, F3: 2714 Hz

Snout shortening

- How does this fit in with size exaggeration hypothesis?
  - If VT length so important, why shorten snout?

- Also suggests larynx did not ***fall***, it was ***pushed*** (Negus 1949)

- Possibly…
  - snout shortening (use of fire?) acted with tracheal shortening
  - tongue length maintained for mastication ***or*** vocalisation
    - speech already crucial?

Summary

- Larynx lowering not to make *vocal tract* ***longer***
  - it isn't (cf. female baboons)

- make *trachea* ***shorter***
  - improve respiratory function
  - small glottis also suggests role for respiratory function

- results in louder speech and lower resonances
  - sexual dimorphism in males (also F0)

The role of the pharynx

- Pharynx supposedly gets us more vowels
  - lowered larynx crucial for point/Quantal vowels **i**, **a**, **u**
    - point vowels crucial for speech (e.g. Lieberman & Crelin 1971)

- Not so…
  1) some languages have 2 vowel or vertical vowel system
     - Kabardian, Marshallese
  2) some languages lack a point vowel (usually u – 84.5% UPSID)
     - Navaho, English
  3) u requires lips as well as tongue
     - more complex than just based on larynx position
       - low larynx could also be used for [u] production

Low vowels – the low down

- Confusion reigns about which low vowel
- Boë et al. (2007) in single paragraph (albeit including quotations):
  - [a], [æ], [ɑ]

- These are not the same vowels
- UPSID frequencies are important too:
    - [a] – 5.7%
    - [æ] – 13.6%
    - [ɑ] – 7.9%

  - Best candidate for low point vowel is [ɐ] – 90.5% (cf. 90.9% [i])
    - central vowel – needs no constriction!
    - only [ɑ] might need pharynx (7.9%)

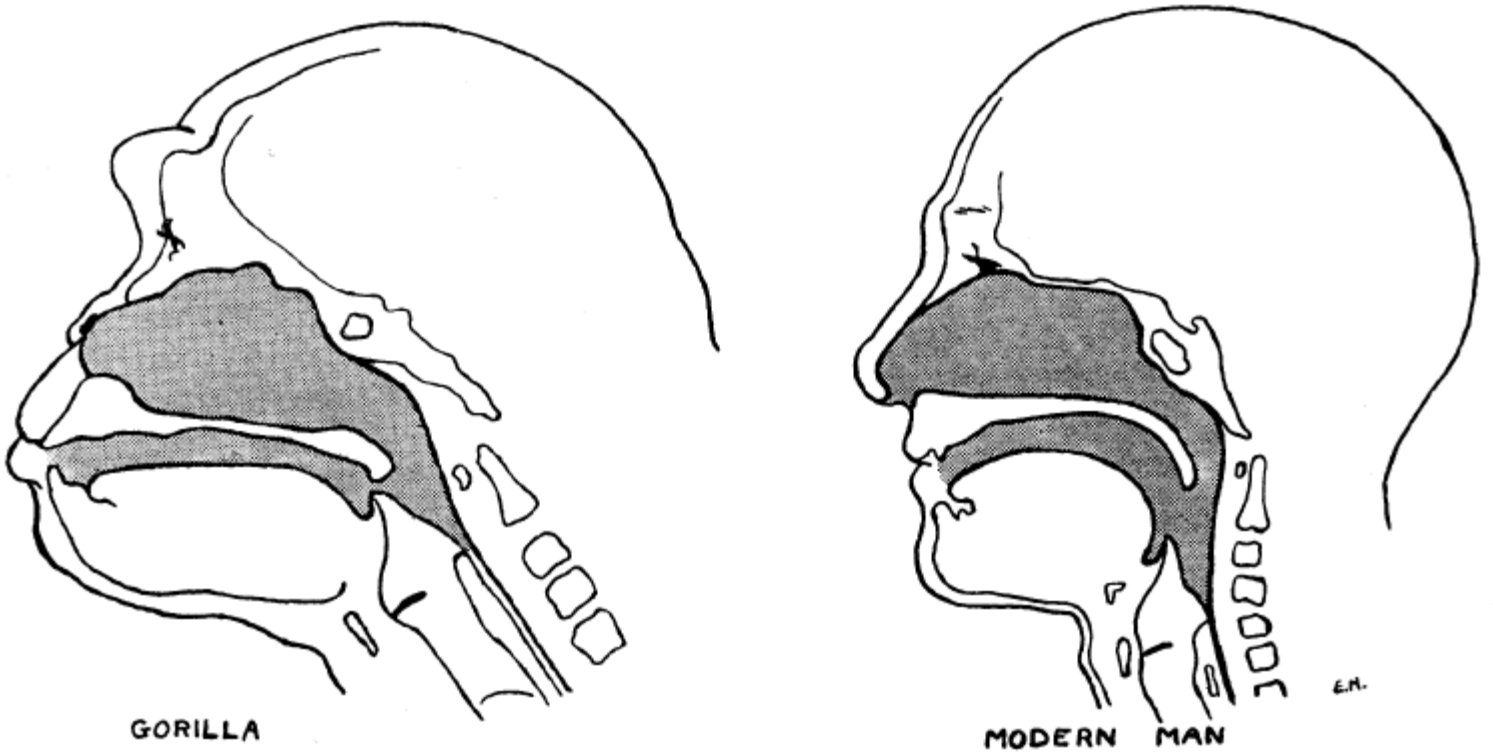
Vowels and the pharynx

- Granat et al. (2007)
  - bend in vocal tract unimportant
- Not so important acoustically
  - sound goes round corners

    but cf. Sondhi (1986)
- But what about ***mechanically***?

- Don't know much about human tongue
  - know even less about primates (especially extrinsic musculature)

The bent vocal tract



Vowels and the pharynx

- Lowered larynx gives the tongue a ***pivot point***
  - rock ***forward*** for [i]
    - does exert pull on larynx via hyoid (in some subjects)
  - rock ***backwards*** for [ɑ] and other back vowels
    - gravity assisted
  - heave up and back for [u]
    - plus control of lips – is this more effort/variable?
- But arguably what we really need to know about are consonants
  - vowels are ***relics*** of prehuman vocalisation

The pharynx

- Useful for whole range of lingual consonants
  - tongue
    - muscular hydrostat

      (Kier & Smith 1985, Baker 2008)
    - bag filled with water (blood)
    - incompressible volume

- lingual volume must be accommodated somewhere
  - maybe it shifts into the pharynx
  - Hamann on retroflexes (2003)
    - cf. acquisition of English /r/ by age 3 or so

Conclusions

- Larynx lowering has its origins in respiratory control
  - as widely seen in vocalisation
- Lower larynx and shorten trachea
  - shorten by as much as 4 cm
  - ‘delete’ dead space
  - makes lung compression more efficient
    - habitual lowering
  - other evidence for role of respiratory factors
    - glottal opening

Conclusions

- humans keep larynx low
  - importance of continuous vocalisation (Fitch 2000)
- may have been pushed back by snout shortening
  - not motivated by size exaggeration!

  - female baboons have ***same size*** vocal tracts as human males
  - if size matters, why not keep the snout?
  - teleology…

Conclusions

- vowel evidence shaky
  - point vowels not crucial
    - typological patterns
    - phonetic details of articulation
      - acoustic studies suggest pharynx not needed

(Boë et al. 2002, 2007)

- pharynx may play a role though
  - indirectly: bent tongue ***facilitates*** the production of vowels
    - not making possible, but ***easier/more efficient***
  - production of lingual consonants
    - accommodate displacements in lingual volume

Final word(s)

- Human speech production unique
  - harnessed existing structures
    - but changed them in the course of evolution…
- More data
  - on humans & other primates
- Gradual process
  - 2 million years (homo ergaster/erectus)
    - male-female cooperation?
- Wider view of speech production needed
  - look beyond vowel contrasts, consider mechanics