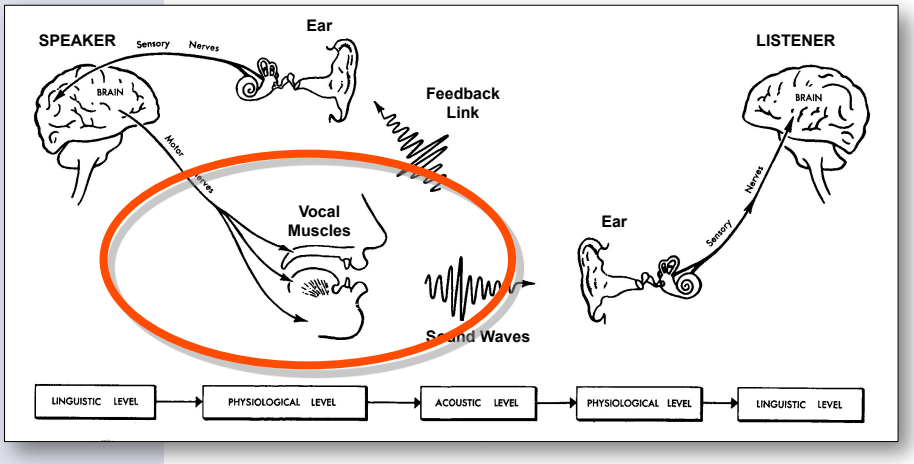
COM3502-4502-6502
SPEECH PROCESSING

Lecture 3
Speaking

The University Of Sheffield.

The Speech Chain



Taken from: Denes, P. B., & Pinson, E. N. (1973). ***The Speech Chain: The Physics and Biology of Spoken Language***: New York: Anchor Press.

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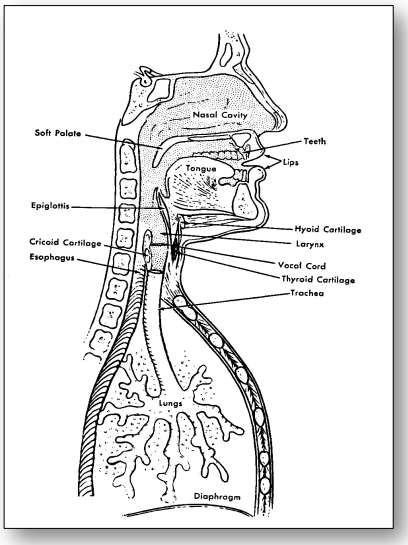
The Human Vocal Organs

The vocal apparatus has evolved for …

- breathing
- eating
- vocalising
- speaking



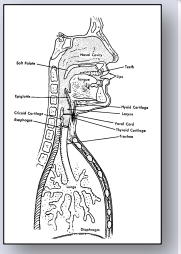
Taken from: Denes, P. B., & Pinson, E. N. (1973). *The Speech Chain: The Physics and Biology of Spoken Language*: New York: Anchor Press.

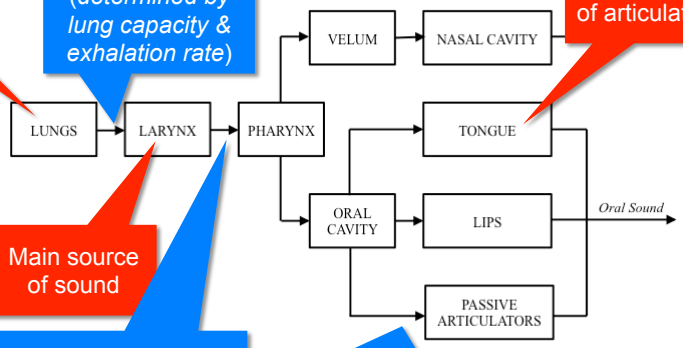
Mammalian Vocalisation

Main source of energy

Airflow (*determined by lung capacity & exhalation rate*)

Main source of articulation



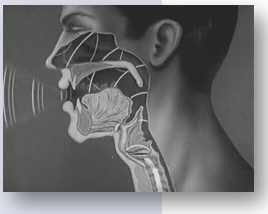


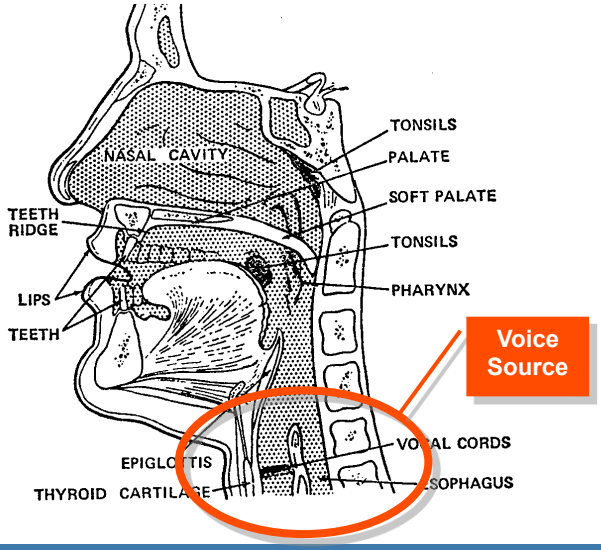
Main source of sound

Harmonic-rich 'buzz' (*fundamental frequency determined by body size*)

Vocal tract resonant frequencies (*determined by body size & position of articulators*)

The Human Vocal Tract





Taken from: Denes, P. B., & Pinson, E. N. (1973). *The Speech Chain: The Physics and Biology of Spoken Language*: New York: Anchor Press.

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The Human Larynx

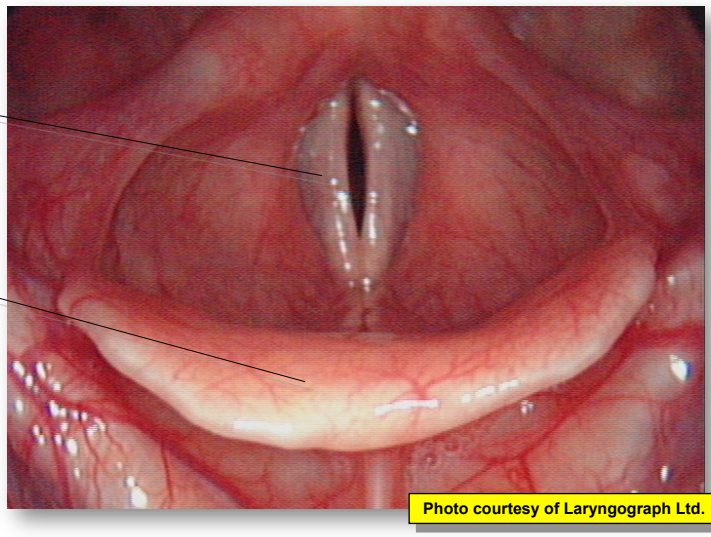

Photo courtesy of Laryngograph Ltd.

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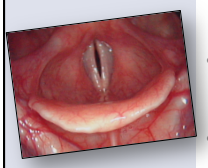
Voice 'Source'



- Air pressure from the lungs builds up behind closed 'vocal folds' (often called 'vocal cords')
- The vocal folds are repeatedly forced apart and pulled together again, producing a series of small pulses of air
- This modulation of the airstream is known as 'phonation'
- The tension in the muscles attached to the vocal folds determines their rate of vibration and hence the 'fundamental frequency' (F_x *or* F_0) of the speech waveform

- The fundamental frequency contributes to the perceived 'pitch' of the voice
- Because the vibration is not a pure sine wave, there is energy at frequencies that are multiples of the fundamental frequency (*known as the 'pitch harmonics'*)

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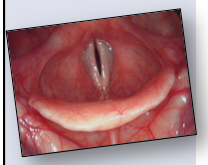
Voice 'Source'



https://youtu.be/-XGds2GAvGQ

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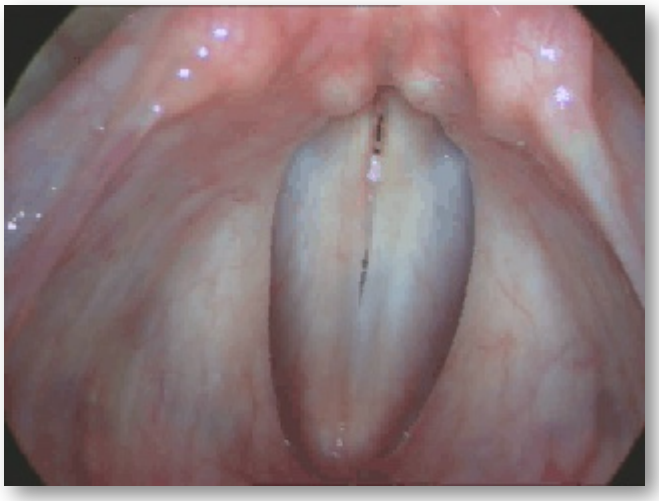
Two Cycles of Vocal Fold Vibration

Laryngograph



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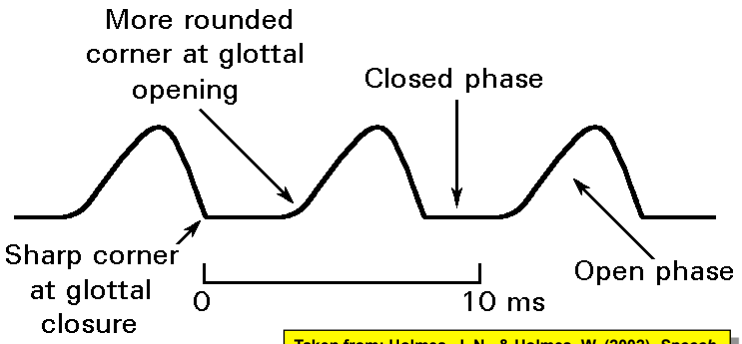
Air-Flow Through Glottis

The acoustic output from the vocal tract is initiated by the closure of the vocal folds



Taken from: Holmes, J. N., & Holmes, W. (2002). *Speech Synthesis and Recognition*: Taylor & Francis.

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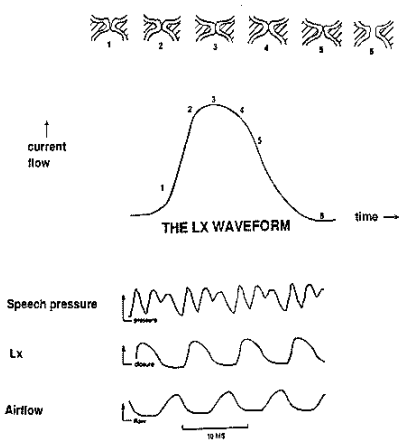
Electroglottograph (EGG) / Laryngograph



Laryngograph

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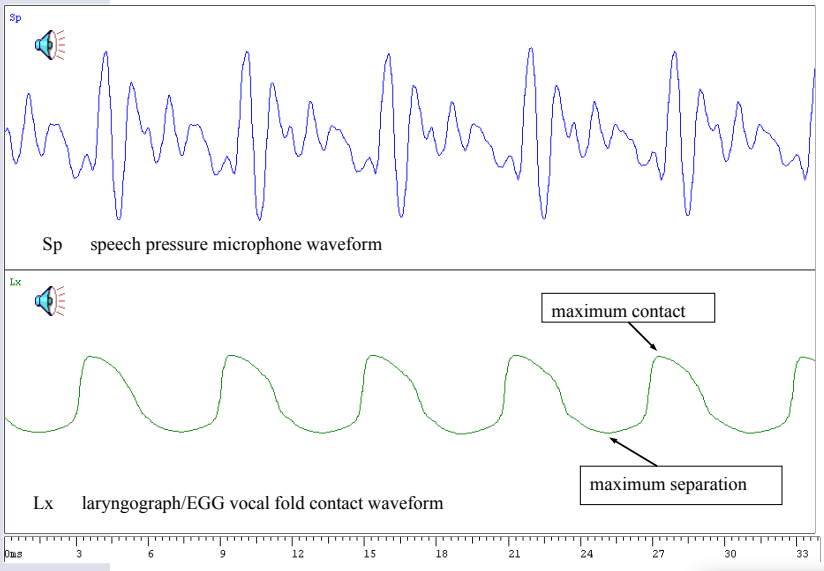

modal voice - adult male

Laryngograph

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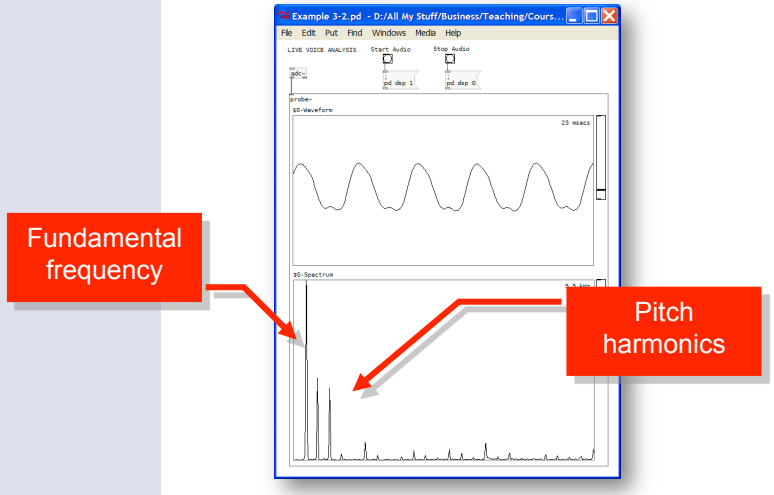
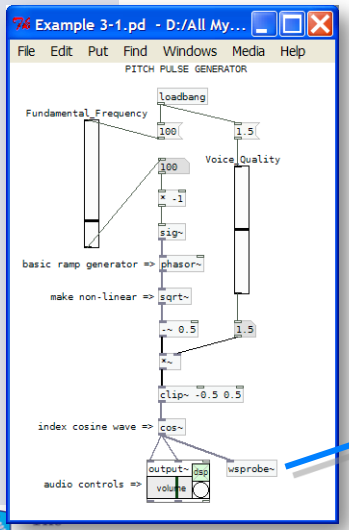
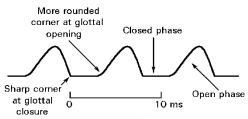
Analysing the Voice Source

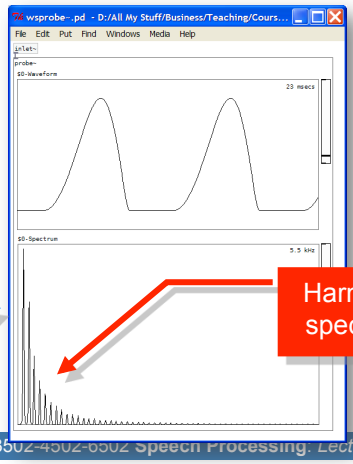


Microphone placed on the larynx

Synthesising the Voice Source



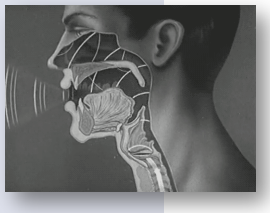




Artificial Larynx / Electrolarynx

SolaTone™

The Human Vocal Tract



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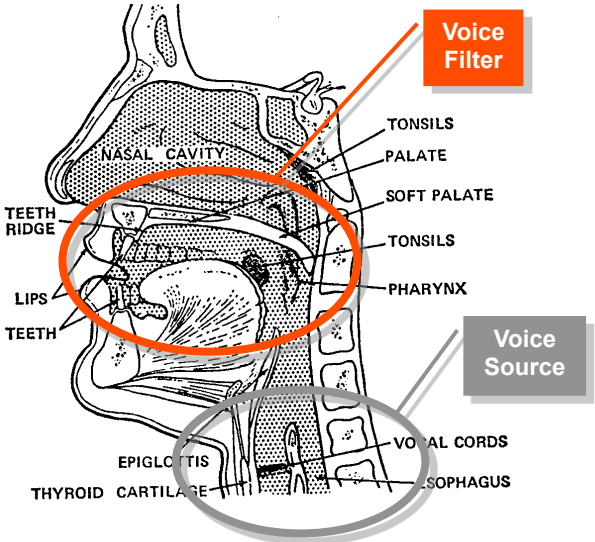
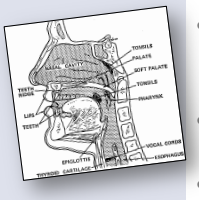
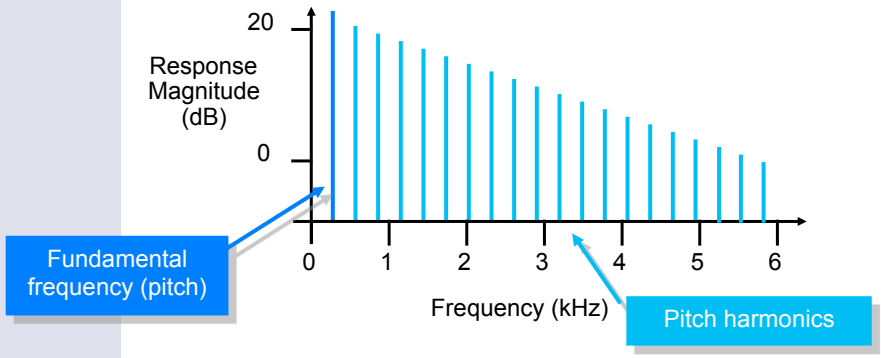


Voice 'Filter'

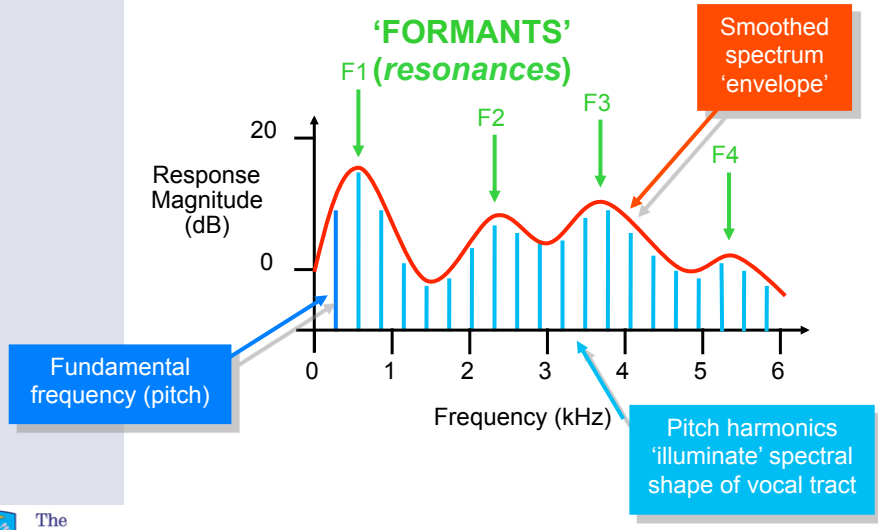


- The vocal tract forms a 'resonator' with a complex shape
- Resonances are known as 'formants'
- Speech is produced by using the 'articulators' to change the shape of the vocal tract, hence modifying its resonant characteristics
- Different configurations of the vocal tract enhance some of the harmonics of the pitch, and suppress (*damp*) others
- The principal articulator is the tongue, but the jaw, lips, soft palate and teeth are also involved

The Excitation Spectrum



The Speech Spectrum



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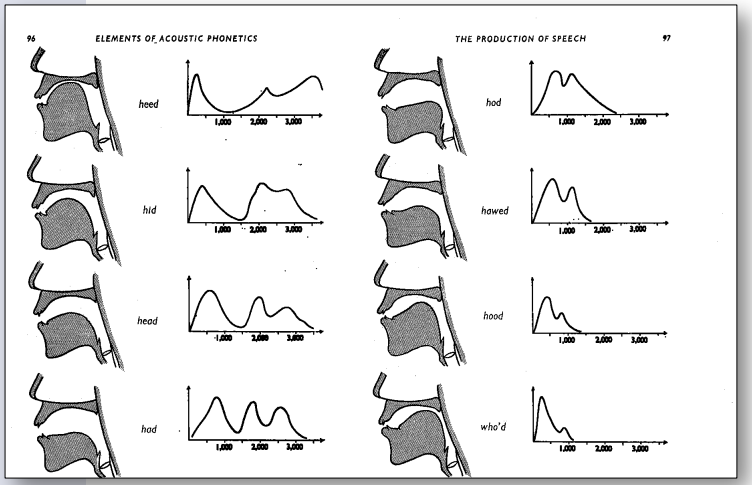
Vocal Tract Shape and Spectra



Taken from: Ladefoged, P. (1962). *Elements of Acoustic Phonetics*: London: University of Chicago Press.

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A Static Vocal Tract

Rhys Prosser

electrolarynx

+

3D-printed tubes

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The Moving Vocal Tract

Magnetic Resonance Imaging (MRI)

University of Southern California

USC

Speech Analysis and Interpretation Laboratory

USC Viterbi School of Engineering

`http://sail.usc.edu/span/index.php`

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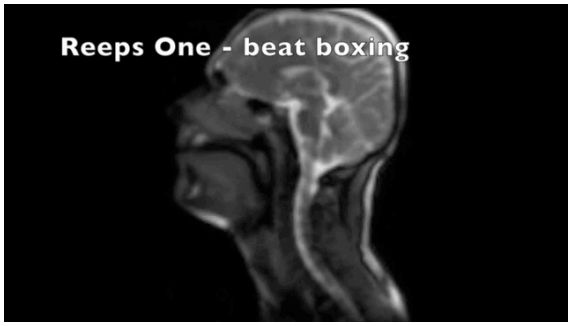
The Moving Vocal Tract



UCL

https://youtu.be/yGV8az8npZU

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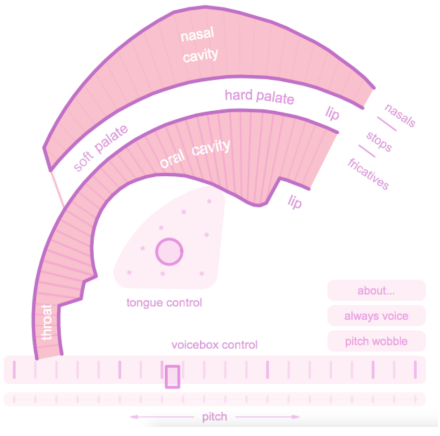
The Moving Vocal Tract



https://dood.al/pinktrombone/

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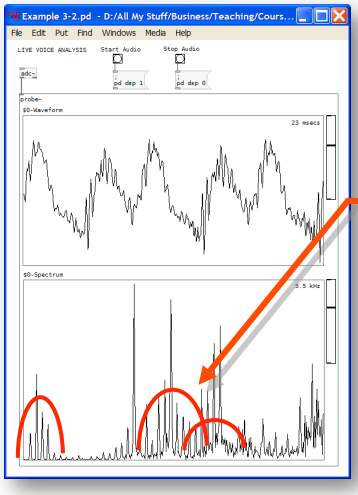
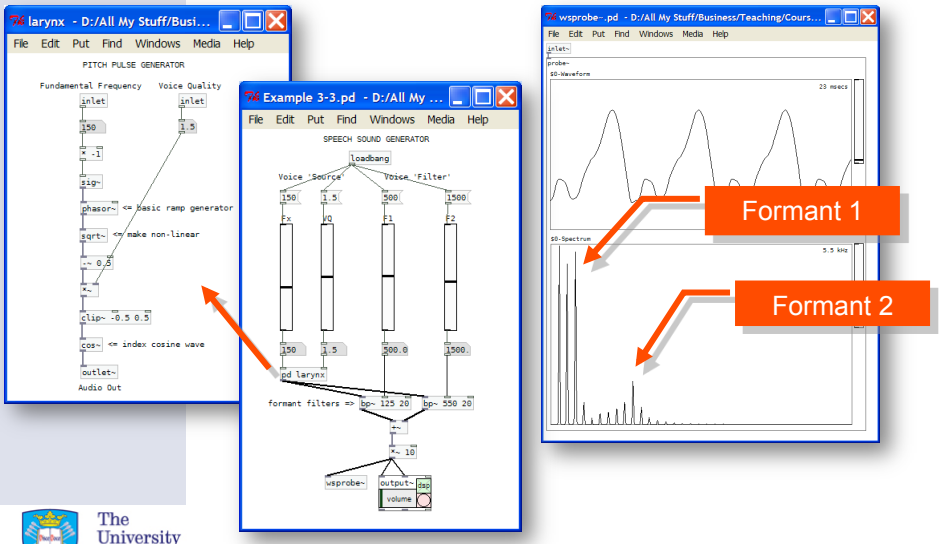
Analysing the Voice Filter



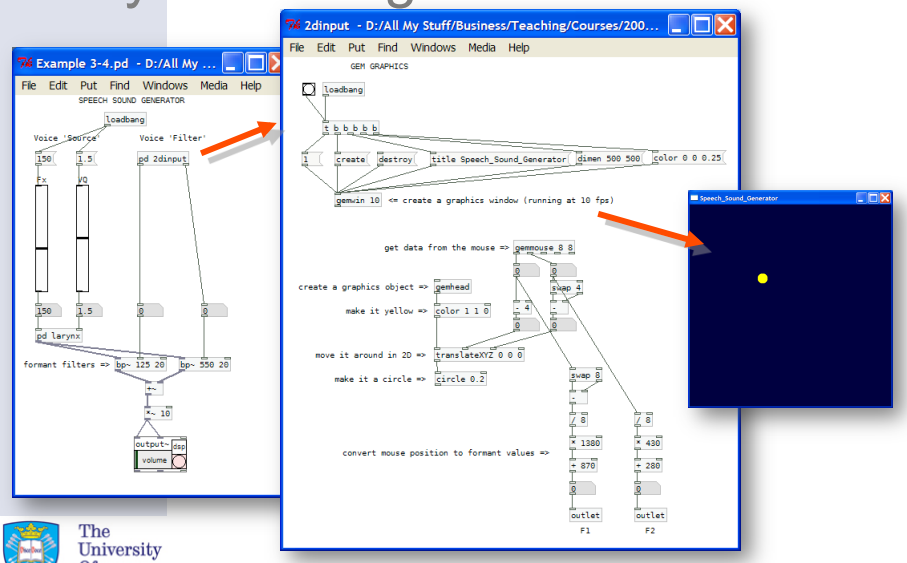
Vocal tract resonances ('formants')

Microphone at the lips

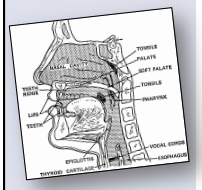
Synthesising the Voice Filter



Synthesising the Voice Filter

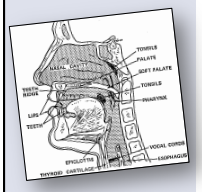


Sound Source



- Question …
  - is the larynx the only source of sound in the human vocal tract ?
- Answer, no …
  - sound can be generated anywhere where there is a partial constriction *(e.g. "sh")*
  - or by exciting a resonance *(e.g. a whistle)*
  - or by vibrating an articulator *(e.g. the tongue)*
  - or by releasing a blockage *(e.g. the lips)*

Types of Speech Sound



- A '**voiced**' sound is one in which the vocal cords are vibrating
- An '**unvoiced**' sound is one in which the vocal cords are not vibrating
- A '**fricative**' sound results from a turbulent air flow at a constriction
- A '**plosive**' sound occurs after a blockage is released

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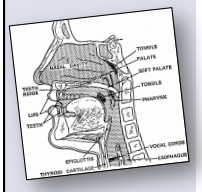
Sound Exercise



Which of the following English words end in a '**voiced**' sound ?

- bus ✗
- breathe ✓
- has ✓
- off ✗
- buzz ✓
- breath ✗
- rule ✓
- of ✓

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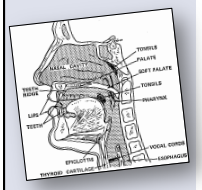
Sound Exercise



Which of the following English words end in a 'fricative' sound ?

- bus ✓
- breathe ✓
- hat ✗
- off ✓
- bun ✗
- teeth ✓
- rule ✗
- of ✓

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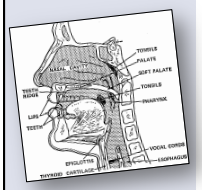
Sound Exercise



Which of the following English words start with a 'plosive' sound ?

- bus ✓
- give ✓
- has ✗
- sat ✗
- pull ✓
- teeth ✓
- rule ✗
- cough ✓

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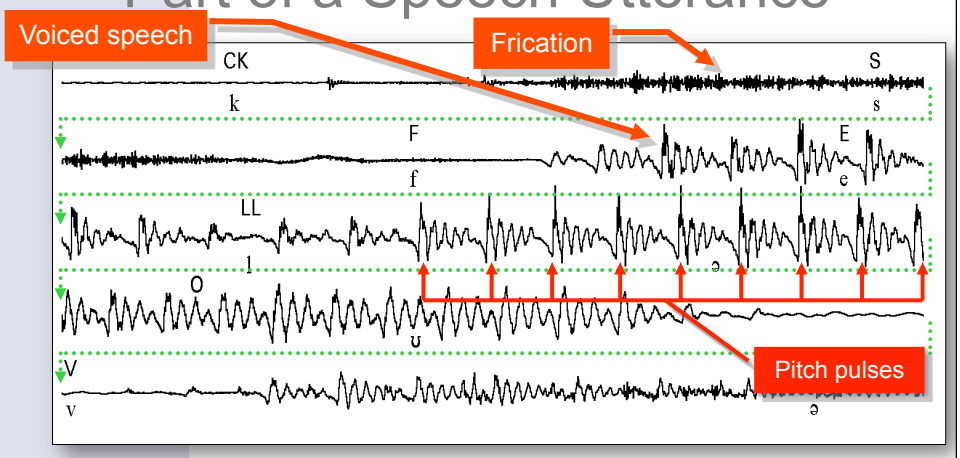
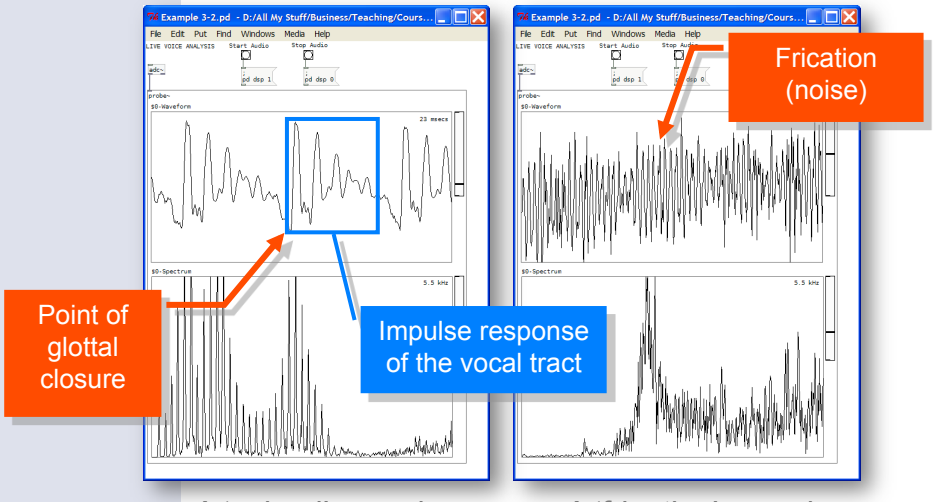
Part of a Speech Utterance



"briCKS FELL OVER"

Taken from: Holmes, J. N., & Holmes, W. (2002). *Speech Synthesis and Recognition*: Taylor & Francis.

Analysing the Human Voice

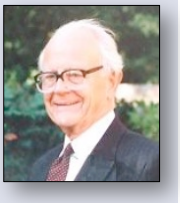


A 'voiced' sound

A 'fricative' sound

Synthesising the Human Voice

John Holmes



- The 'Holmes Parallel Formant Synthesiser'
- Capable of producing speech that is indistinguishable from the real thing (*if properly controlled*)
- 12 parameters (*updated every 10 msecs*):
  - FN low-frequency formant (*fixed at 250 Hz*)
  - ALF amplitude of low-frequency region
  - F1 frequency of 1st formant
  - A1 amplitude of 1st formant
  - F2 frequency of 2nd formant
  - A2 amplitude of 2nd formant
  - F3 frequency of 3rd formant
  - A3 amplitude of 3rd formant
  - AHF amplitude of 4th formant (*fixed at 3500 Hz*)
  - V degree of voicing
  - F0 fundamental frequency
  - MS glottal pulse mark/space ratio (fixed)

Holmes, J. N. (1983). Formant synthesizers: cascade or parallel? *Speech Communication*, 2, 251-273.

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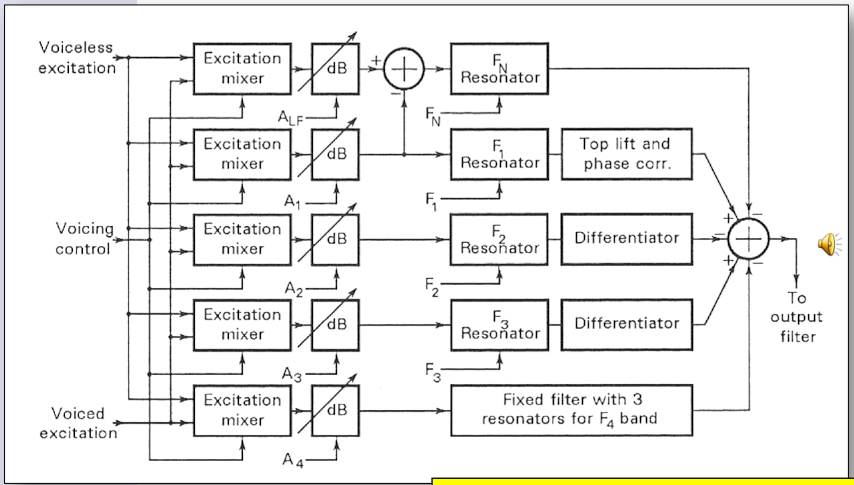
The 'Holmes' Speech Synthesiser



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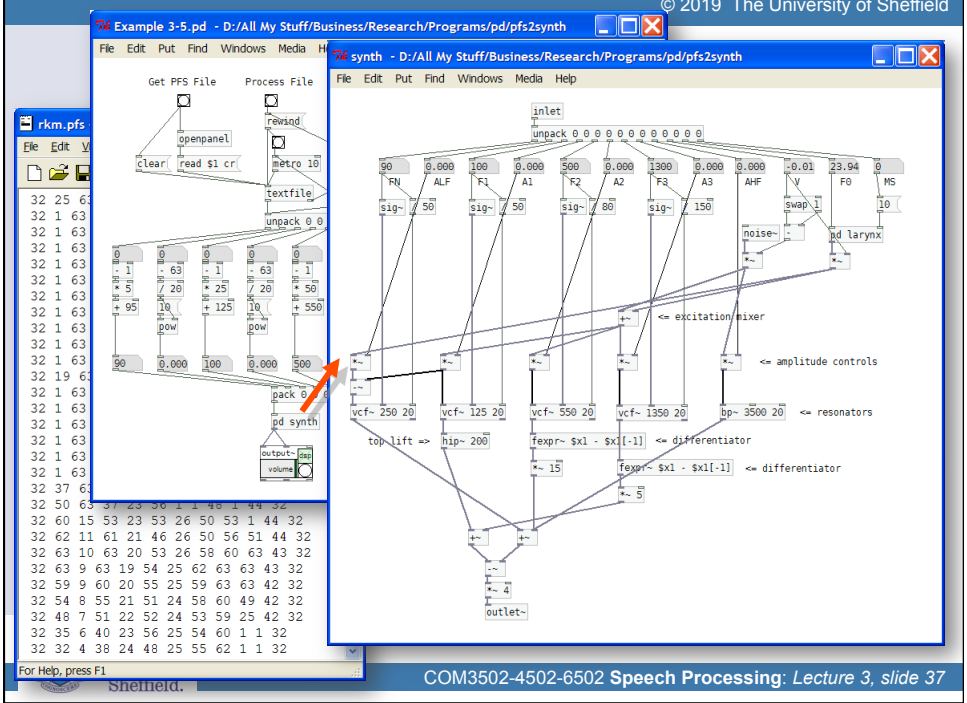

This lecture has covered …

- The human vocal tract
- The larynx
- Generating pitch pulses
- Voice ‘source’ and voice ‘filter’
- The speech spectrum
- Resonances/formants
- Generating speech sounds
- Types of speech sound
- The ‘Holmes’ parallel formant synthesiser

Any Questions ?

Next time …

Hearing