Language and its Applications LT5903

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Lecture 2: Phonetics

Lecture plan

- Overview, representing speech sounds
- Articulatory phonetics
  - Consonants, Vowels, Suprasegmentals
- Acoustic phonetics
- Auditory phonetics
- Short break (15 mins)
- Group discussion on HW2

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What is phonetics?

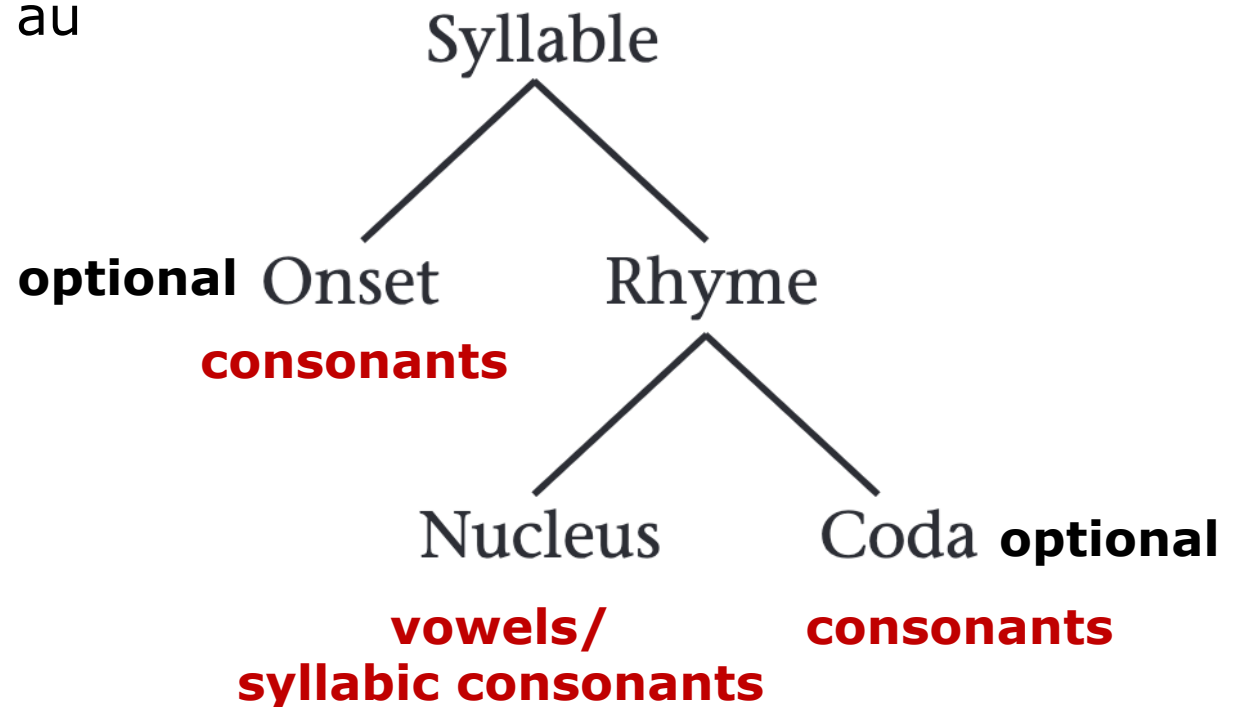The study of the minimal units that make up language.

- **Articulatory phonetics:** The study of the production of speech sounds.
- **Acoustic phonetics:** The study of the transmission and the physical properties of speech sounds.
- **Auditory phonetics:** The study of the perception of speech sounds.

Types of speech sounds

- **Segments:** discrete units of the speech stream
  - **Consonants:** Constriction in the vocal tracts that impedes airflow, e.g., p, t, k, m, n, l, r
  - **Vowels:** Allow air to flow freely through the oral cavity. e.g.,
    - monophthongs: e.g., a, o, e, i, u
    - diphthongs: e.g., ai, oi, ei, au

- Syllable structure
  - food [fud]
  - awe [ɔ]
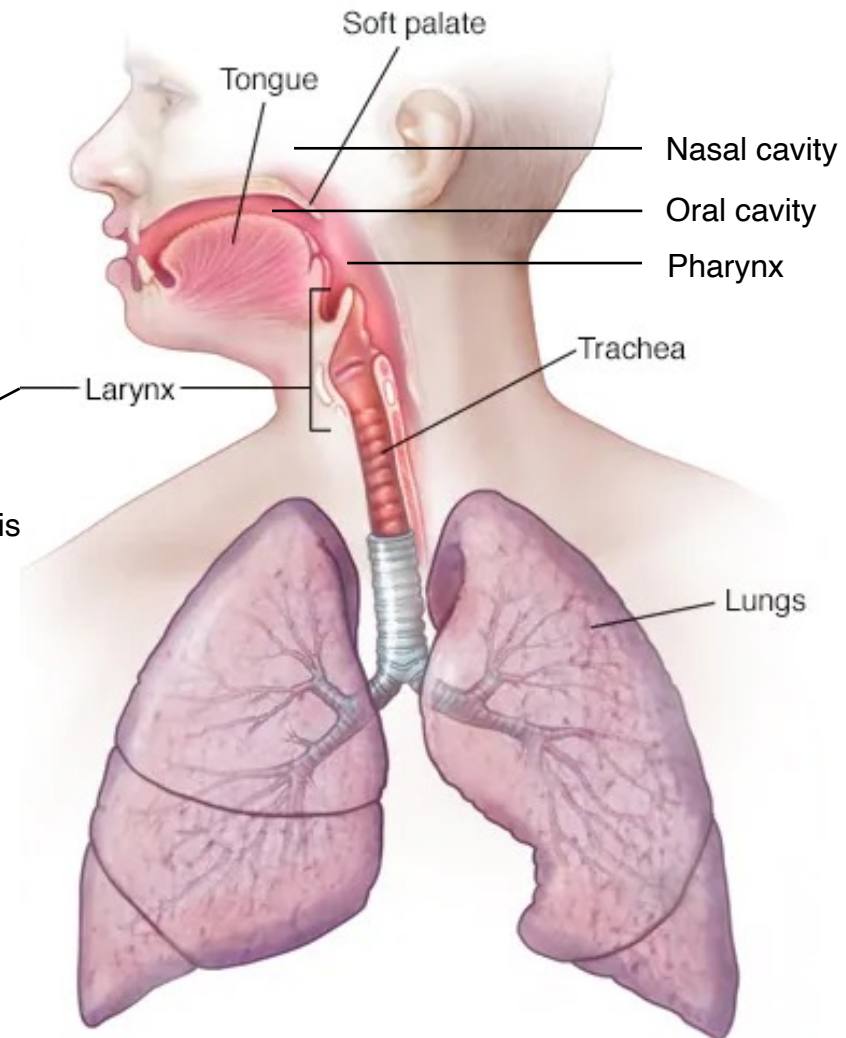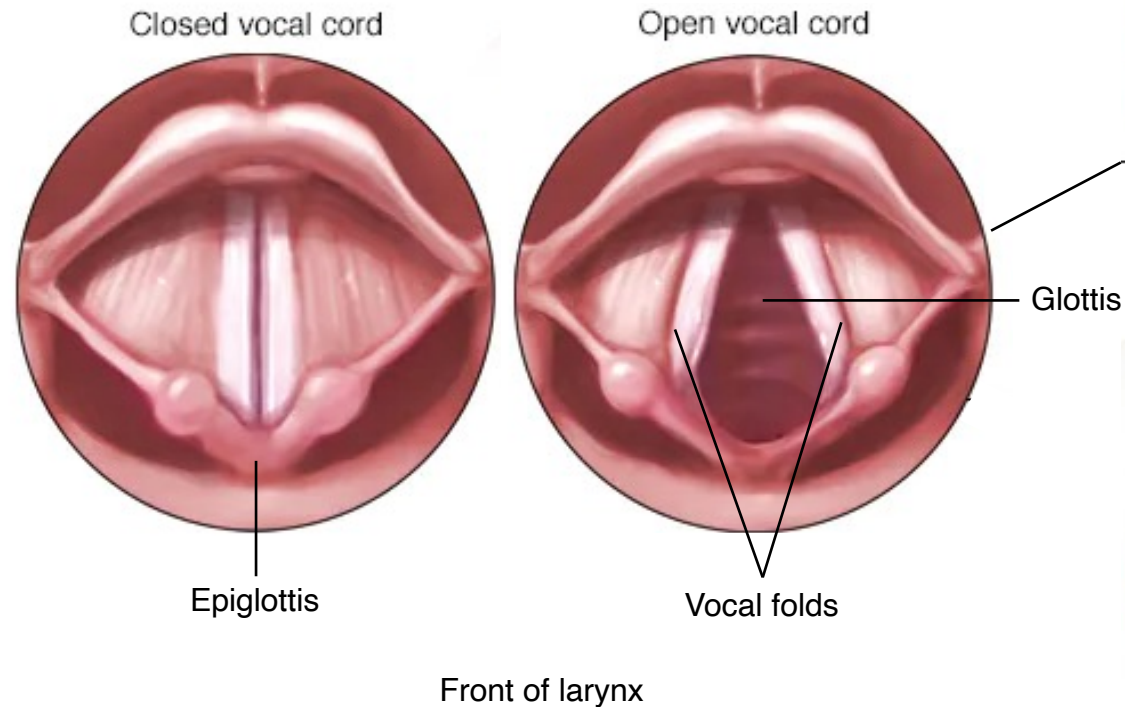 - button [ˈbʌtn]
  - knives [naivz]
  - naive [naˈiv]

Syllable

optional Onset   Rhyme
          consonants

                    Nucleus   Coda **optional**

                vowels/   **consonants**
            syllabic consonants

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Types of speech sounds

- **Suprasegmentals**: larger properties of speech, often apply to entire strings of consonants and vowels
  - **Length:** beat vs bead
  - **Stress:** perfect / record / subject
  - **Tone:** mā, má, mǎ, mà
    - tone languages: Mandarin Chinese, Cantonese, Vietnamese, Thai, Bantu languages, many North and South American Indian Languages, etc.
  - **Intonation**
    - **pitch accent:** change in pitch in the middle of an utterance
      MARY kissed Peter. / Mary kissed PETER. / Mary KISSED Peter.
    - **phrase tone:** occur at the end of a phrase; affect the overall meaning, group words into phrases:
      - sentence-final intonation: You got an A on the test.
      - question intonation: You got an A on the test?
      - What's that in the road ahead? vs What's that in the road? A head?

Representing speech sounds

- The English spelling system (**orthography**) is not a good phonetic alphabet:
    - s*ee*, s*ea*, sc*e*ne
    - *ch*ater, character
    - spe*c*ial, a*pp*le
    - e*x*it,
    - *k*now, dou*b*t

- The **International Phonetic Alphabet** (**IPA**)
    - Applicable to all spoken languages
    - one-to-one correspondence between sounds and symbols
    - Organized by place and manner of articulation
    - Shading indicates voicing

    Full chart is on the back cover of your textbook

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Articulation: Consonants

Voicing:

Whether the vocal folds are vibrating?

Closed vocal cord

Open vocal cord

Glottis

Epiglottis

Vocal folds

Front of larynx

Soft palate

Tongue

Nasal cavity

Oral cavity

Pharynx

Larynx

Trachea

Lungs

Supralaryngeal vocal tract

Subglottal system

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Voiceless vs voiced consonants

a. [f] fat
   [v] vat

b. [tʃ] rich
   [dʒ] ridge

c. [θ] thigh
   [ð] thy

d. [p] pat
   [b] bat

e. [s] sip
   [z] zip

f. [t] tab
   [d] dab

g. [ʃ] dilution
   [ʒ] delusion

h. [k] kill
   [g] gill

	Bilabial	Labiodental	Dental	Alveolar	Postalveolar	Retroflex	Palatal	Velar	Uvular	Pharyngeal	Glottal
Plosive	p b			t d		ʈ ɖ	c ɟ	k g	q ɢ		ʔ
Nasal	m	ɱ		n		ɳ	ɲ	ŋ	N		
Trill	ʙ			r					R		
Tap or Flap		ⱱ		ɾ		ɽ					
Fricative	ɸ β	f v	θ ð	s z	ʃ ʒ	ʂ ʐ	ç ʝ	x ɣ	χ ʁ	ħ ʕ	h ɦ
Lateral fricative				ɬ ɮ							
Approximant		ʋ		ɹ		ɻ	j	ɰ			
Lateral approximant				l		ɭ	ʎ	L			

Symbols to the right in a cell are voiced, to the left are voiceless. Shaded areas denote articulations judged impossible.

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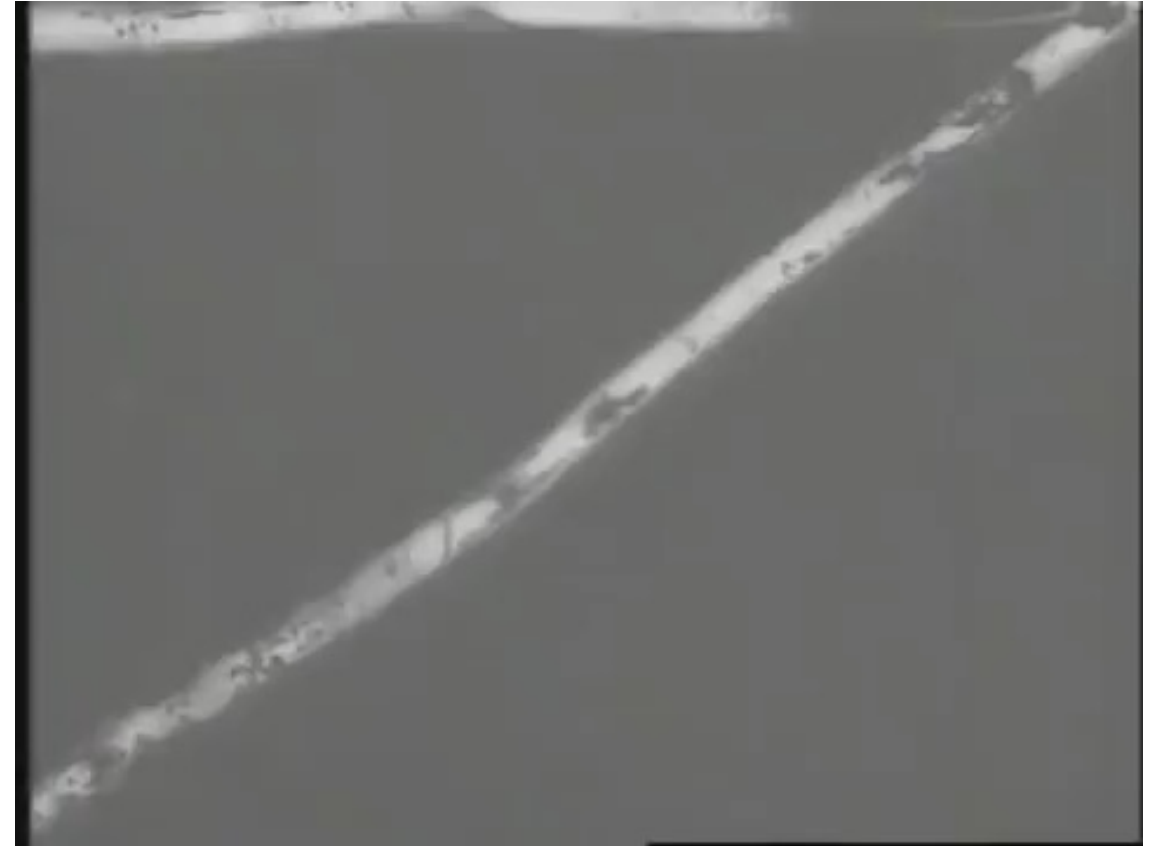# Articulation: Consonants

Place of Articulation:

Where in the vocal tract is the constriction made?

- **bilabial:** pat, bat, mat, with
- **labiodental:** fat, vat
- **interdental:** thigh, thy
- **alveolar:** tab, dab, sip, zip, nose, lab, red
- **post-alveolar:** leash, measure, church, judge
- **palatal:** yes
- **velar:** kill, gill, sing
- **glottal:** high

Sagittal section of the vocal tract

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Place of articulation

	Bilabial	Labiodental	Dental	Alveolar	Postalveolar	Retroflex	Palatal	Velar	Uvular	Pharyngeal	Glottal
Plosive	p b			t d		ʈ ɖ	c ɟ	k g	q ɢ		ʔ
Nasal	m	ɱ		n		ɳ	ɲ	ŋ	N		
Trill	ʙ			r					R		
Tap or Flap		ⱱ		ɾ		ɽ					
Fricative	ɸ β	f v	θ ð	s z	ʃ ʒ	ʂ ʐ	ç ʝ	x ɣ	χ ʁ	ħ ʕ	h ɦ
Lateral fricative				ɬ ɮ							
Approximant		ʋ		ɹ		ɻ	j	ɰ			
Lateral approximant				l		ɭ	ʎ	ʟ			

Symbols to the right in a cell are voiced, to the left are voiceless. Shaded areas denote articulations judged impossible.

Articulation: Consonants

Manner of Articulation:

How the airstream is constricted in the vocal tract?

- **stop/plosive:** pat, bat, tab, dab, kill, gill
- **fricative:** fat, vat, thigh, thy, sip, zip, ship, measure, high
- **affricate:** church, judge
- **nasal:** mat, nose
- **approximant:**
  - **liquid: lateral:** lab, **retroflex:** red
  - **glide:** with, yes

Sagittal section of the vocal tract

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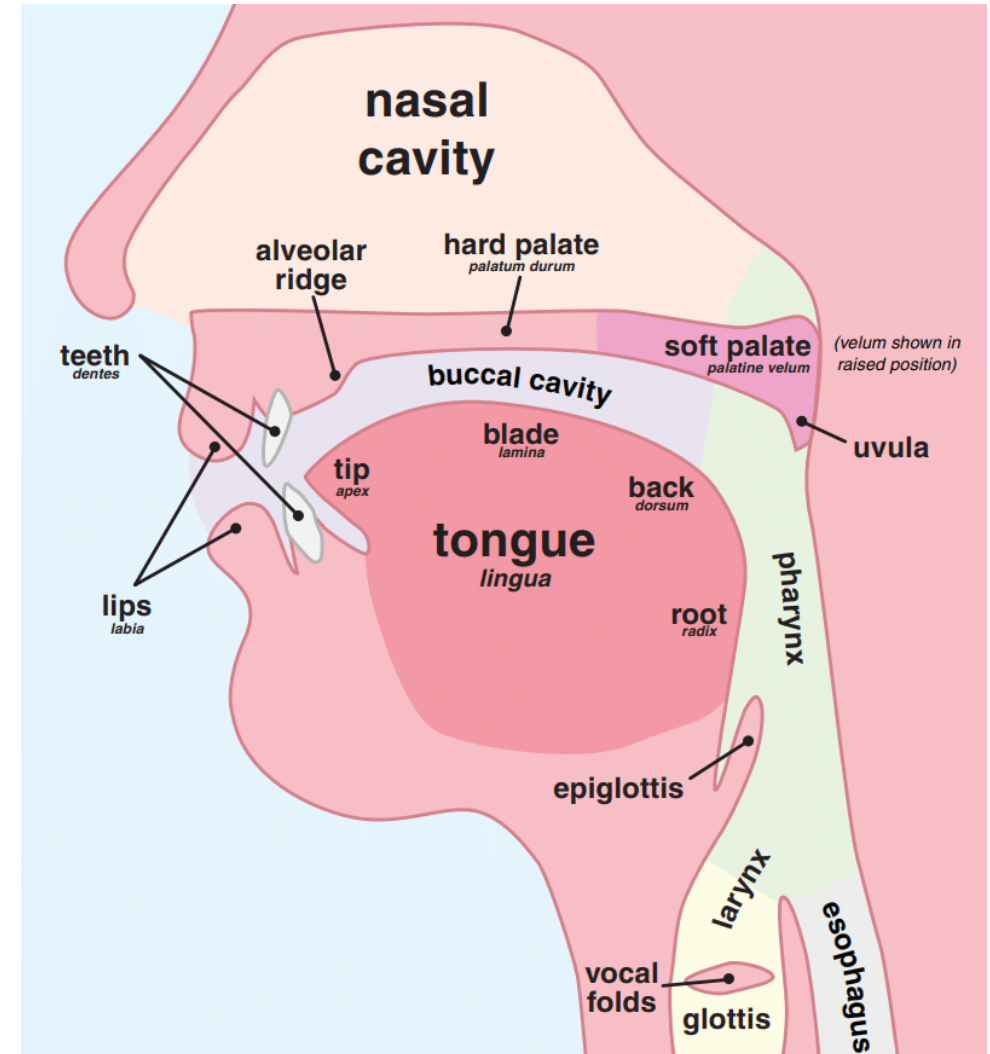
Manner of articulation

	Bilabial	Labiodental	Dental	Alveolar	Postalveolar	Retroflex	Palatal	Velar	Uvular	Pharyngeal	Glottal
Plosive	p b			t d		ʈ ɖ	c ɟ	k ɡ	q ɢ		ʔ
Nasal	m	ɱ		n		ɳ	ɲ	ŋ	N		
Trill	B			r					R		
Tap or Flap		ⱱ		ɾ		ɽ					
Fricative	ɸ β	f v	θ ð	s z	ʃ ʒ	ʂ ʐ	ç ʝ	x ɣ	χ ʁ	ħ ʕ	h ɦ
Lateral fricative				ɬ ɮ							
Approximant		ʋ		ɹ		ɻ	j	ɰ			
Lateral approximant				l		ɭ	ʎ	ʟ			

Symbols to the right in a cell are voiced, to the left are voiceless. Shaded areas denote articulations judged impossible.

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Investigating consonant articulation

Palatography:

X-Ray, real-time fMRI:

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Practice

What consonant sound could be produced with this articulation of the vocal tract?

Voicing?

Place?

Manner?

Play with the [Interactive Sagittal Section.](#)
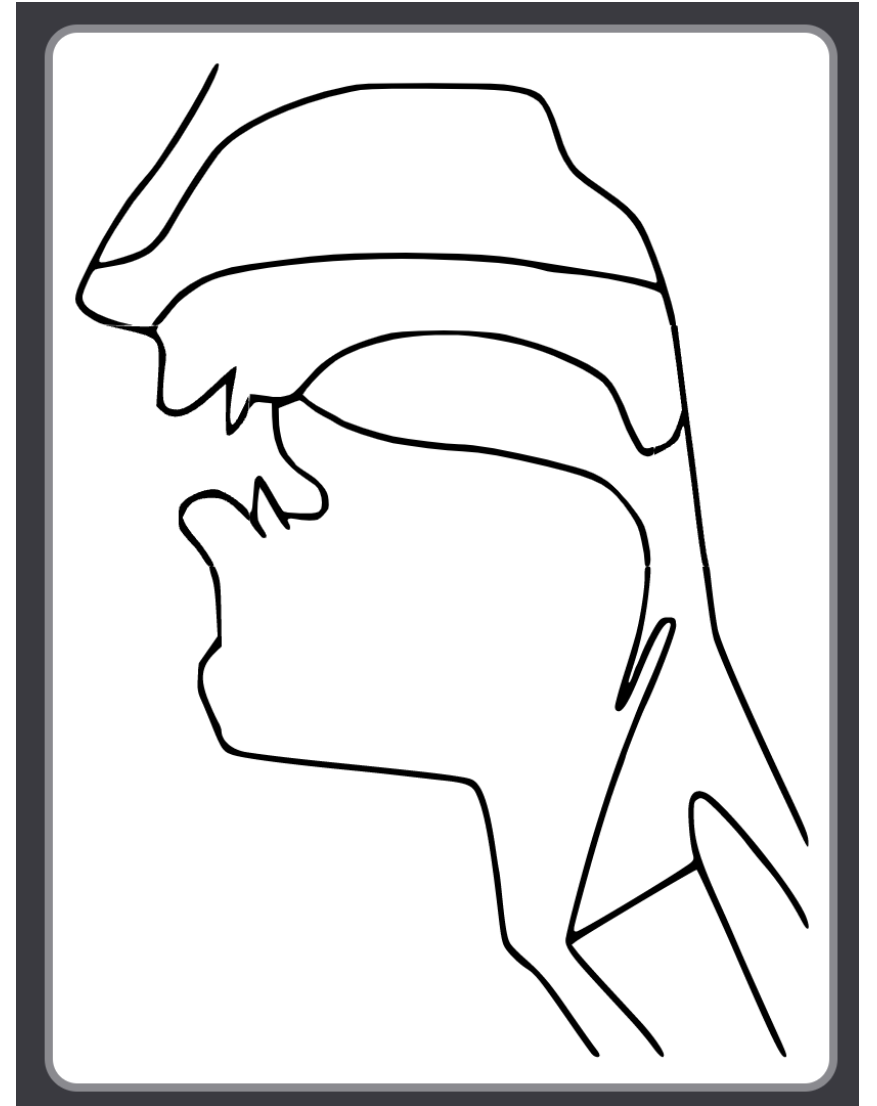
Articulation: Vowels

Two types:
- **monophthong**: single vowel: but, beet, bit, bet, bat, boot
- **diphthong**: two vowels in sequence: bite, bout, boy, boat, bait

Most audible sounds in speech
- Always voiced; No constriction in the vocal tract
  → the three descriptors for consonants are not helpful

How to describe vowels?
- **Tongue height:** raising/lowering the body of the tongue
- **Tongue advancement:** advancing/retracting the body of the tongue
- **Lip rounding:** rounding/spreading lips
- **Tenseness:** making movements with tense/lax gestures

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Articulation: Vowels

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Articulation: Vowels

Tongue advancement

Tongue height
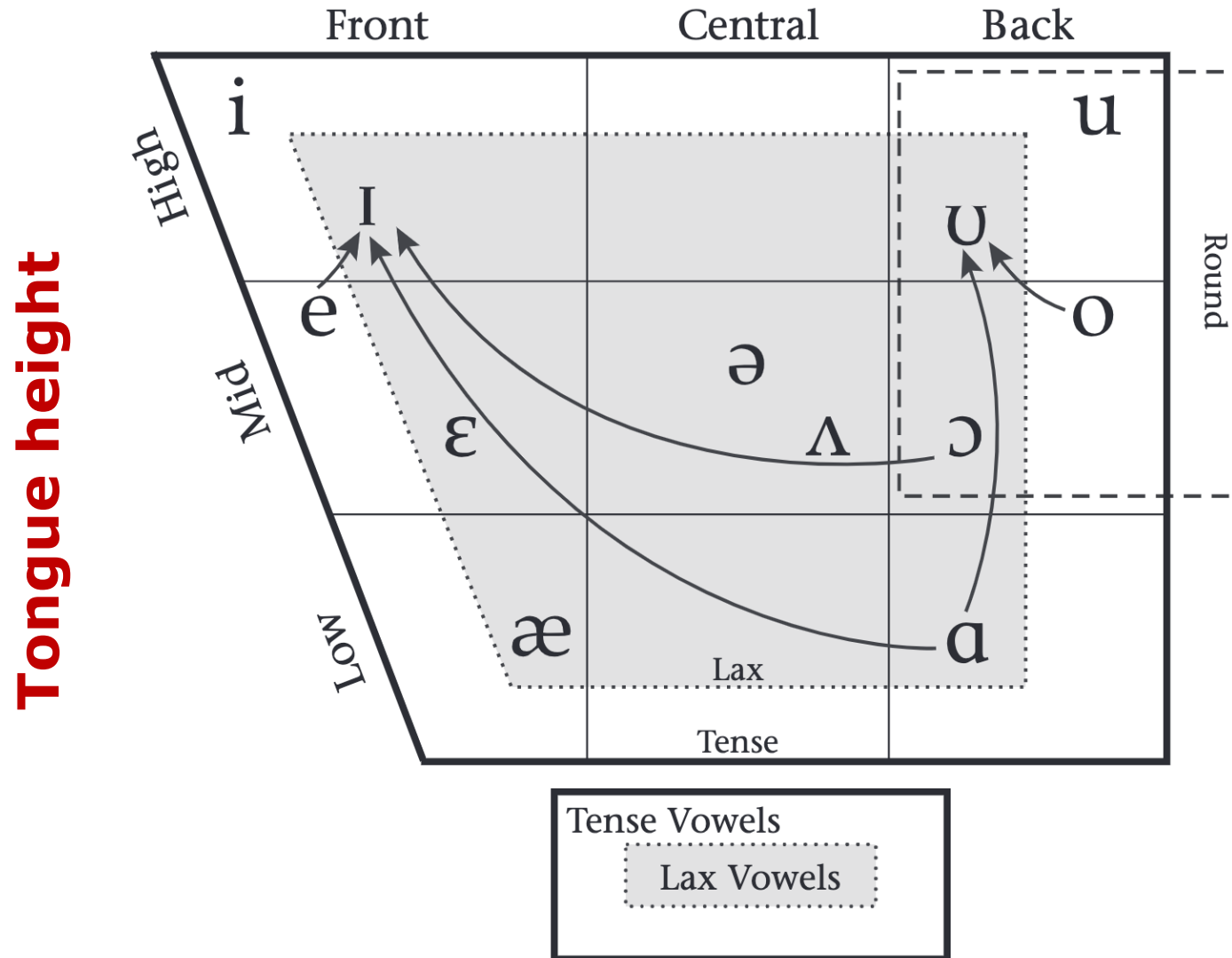
Diphthongs in English:

[eɪ]

[ɑɪ]

[ɔɪ]

[ɑʊ]

[oʊ]

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Acoustic phonetics

Source
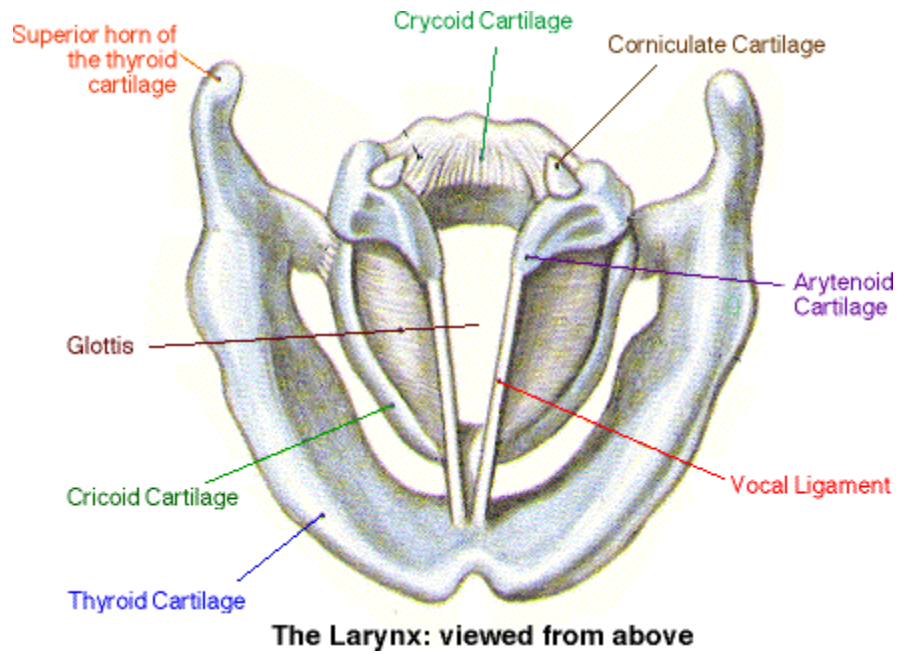
Filter

vocal folds vibration
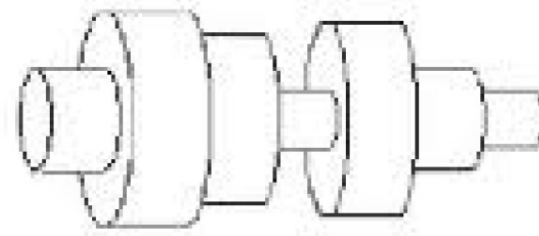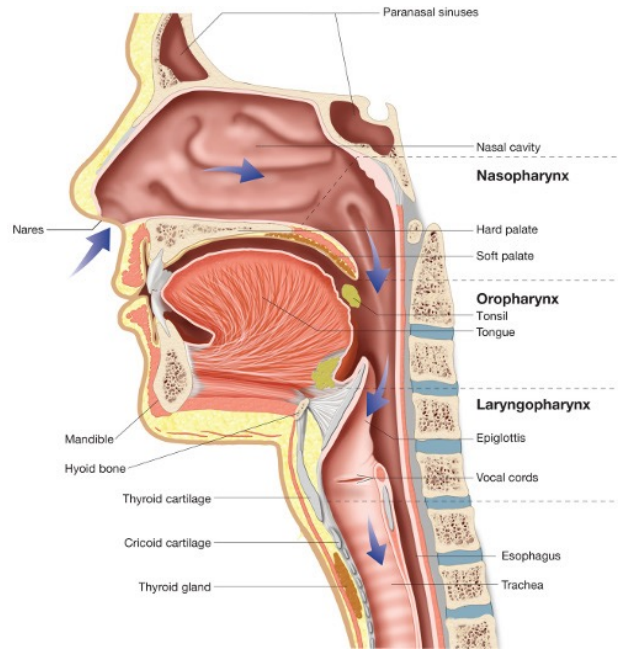
vocal tract series of tubes

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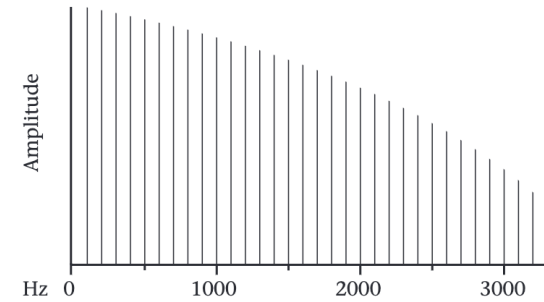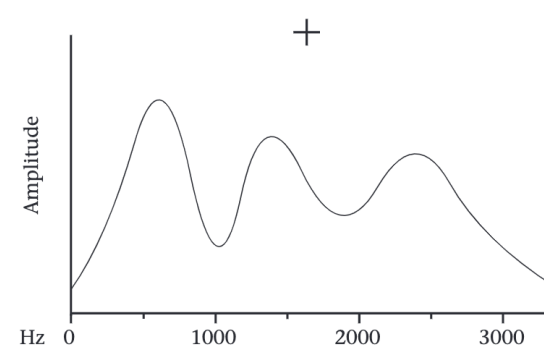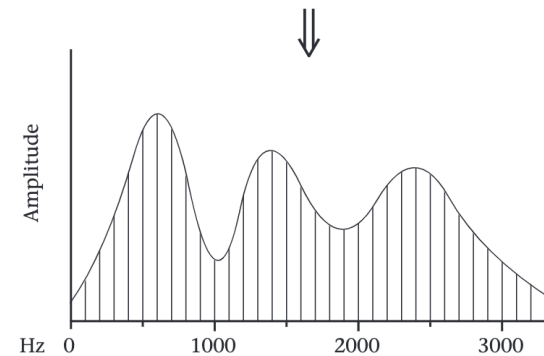
Simple sound waves

Amplitude

Frequency

$y(t) = \mathbf{1.0}\ sin(100\ 2\pi\ t)$

$y(t) = 1.0\ sin(\mathbf{100}\ 2\pi\ t)$

$y(t) = \mathbf{0.5}\ sin(200\ 2\pi\ t)$

$y(t) = 1.0\ sin(\mathbf{200}\ 2\pi\ t)$

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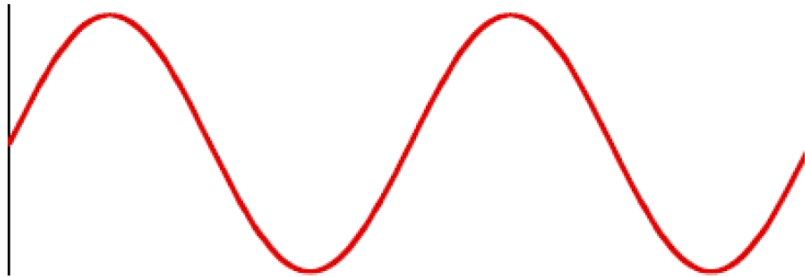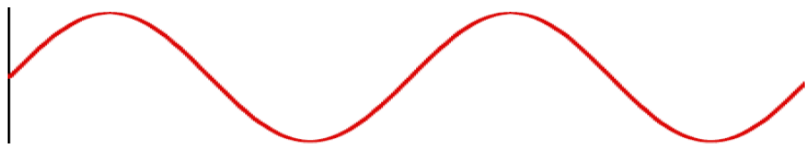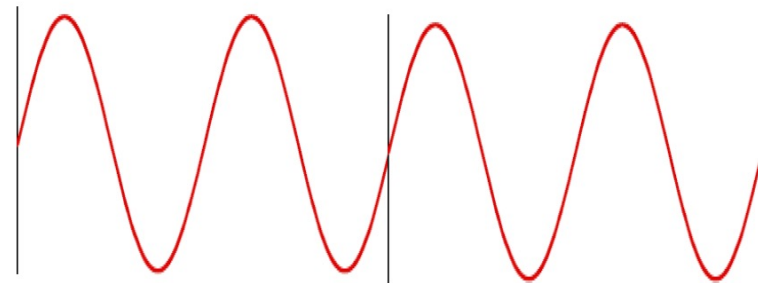
Complex sound waves

- **fundamental frequency (pitch/f0):** the lowest frequency of a periodic waveform

- **harmonics:** multiples of the fundamental frequency
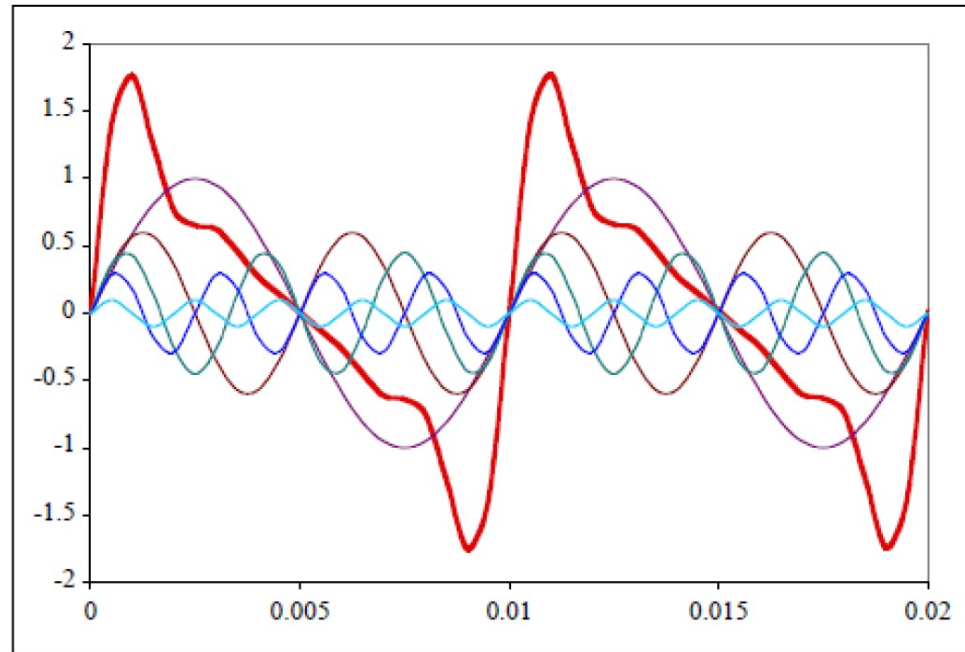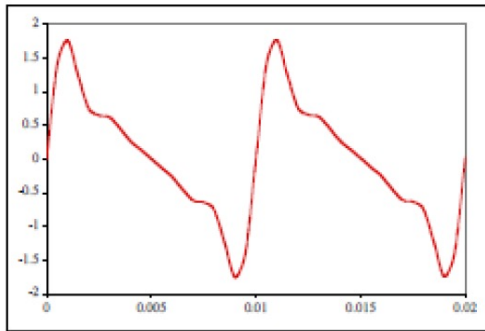
$$y(t) = 1.0\ sin(100\ 2\pi\ t) + 0.6\ sin(200\ 2\pi\ t) + 0.45\ sin(300\ 2\pi\ t) + 0.3\ sin(400\ 2\pi\ t) + \ldots$$

Spectrogram

- Three acoustic dimensions: frequency, time, amplitude

frequency (Hz)

6000
5000
4000
3000
2000
1000
0

[ɑ   d   ɑ]

time
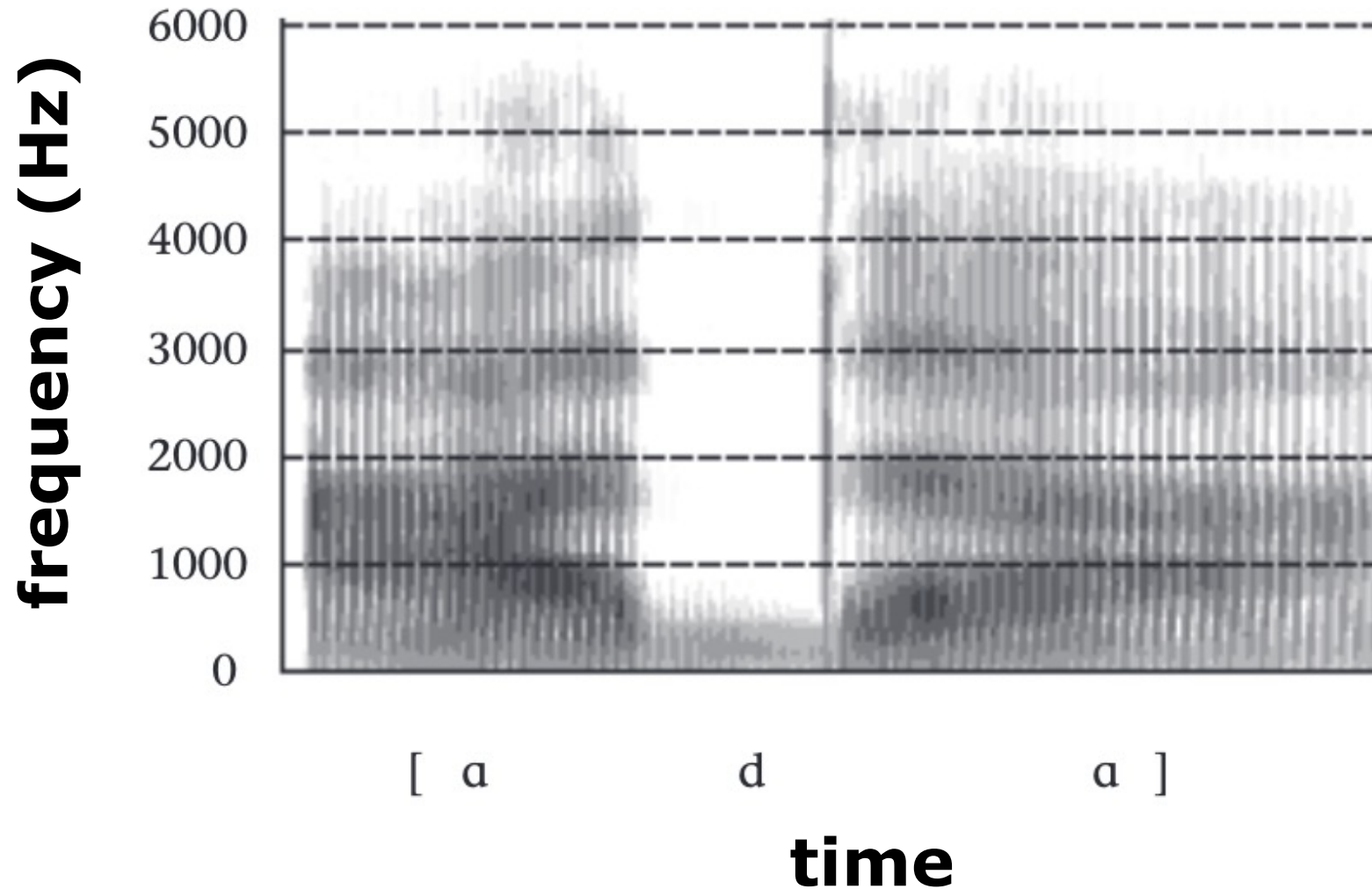
darkness: amplitude

Spectrogram: Vowels

In the production of vowels, the filtering effect of the vocal tract produces amplitude at certain frequencies

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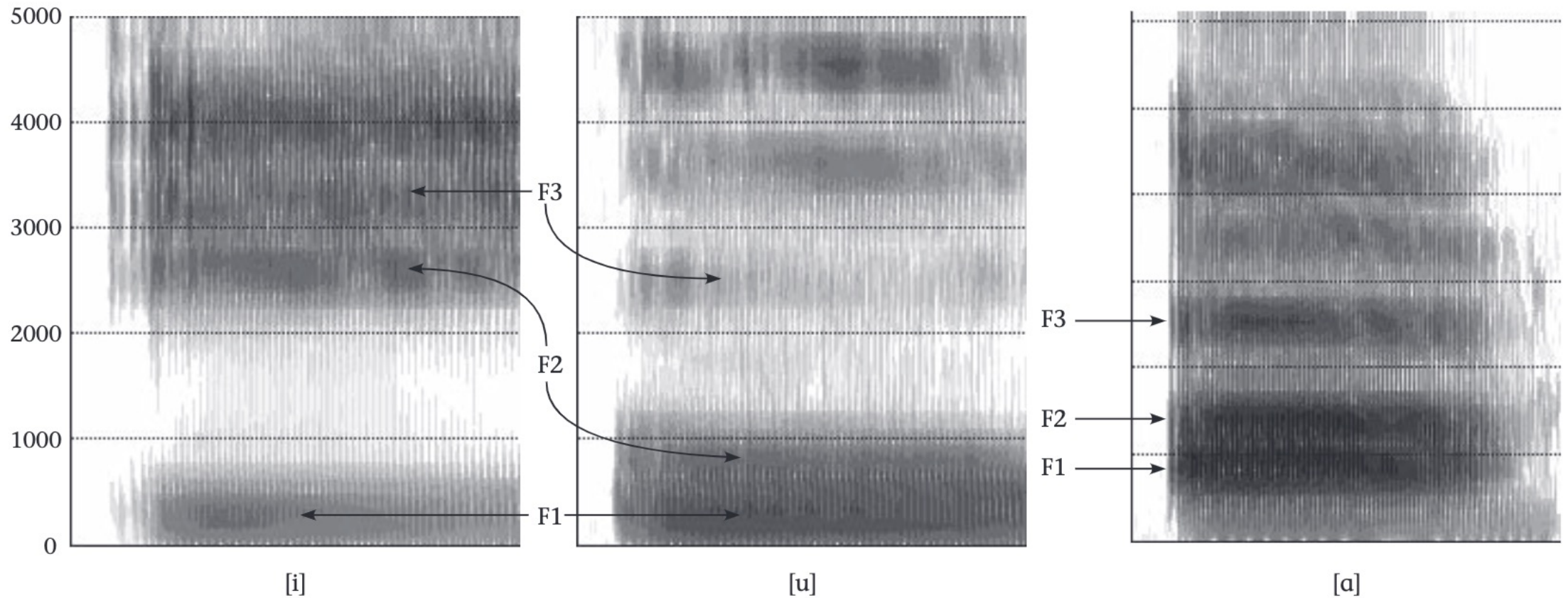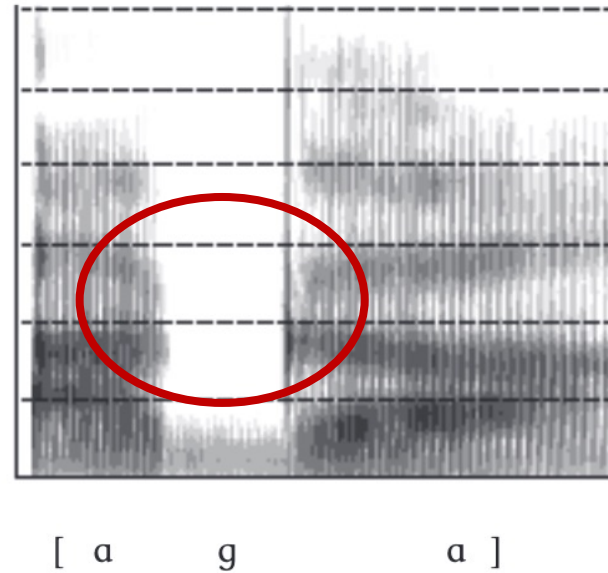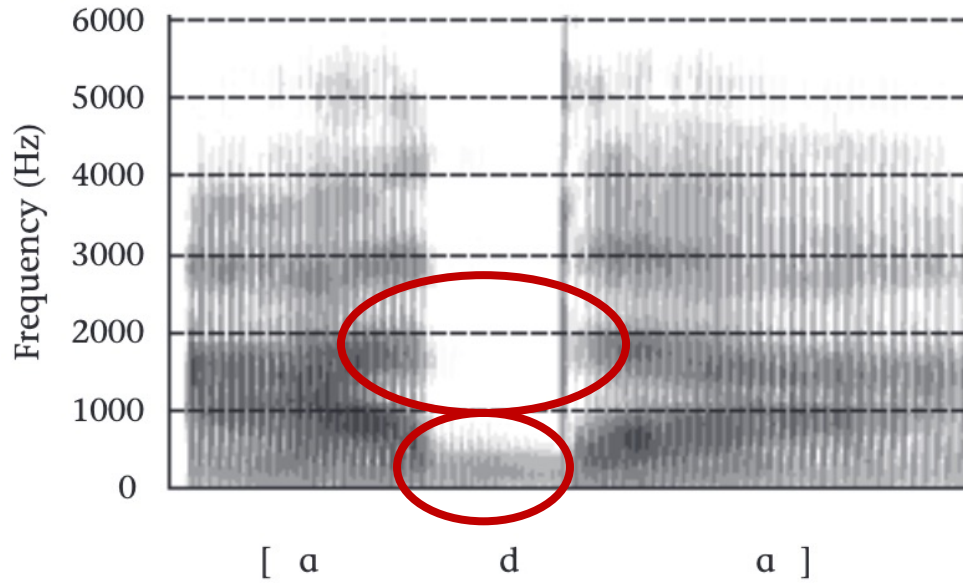
Spectrogram: Stops

d: F2 : 1700-1800 Hz   g: "velar pinch"   b: lowered F1 and F2
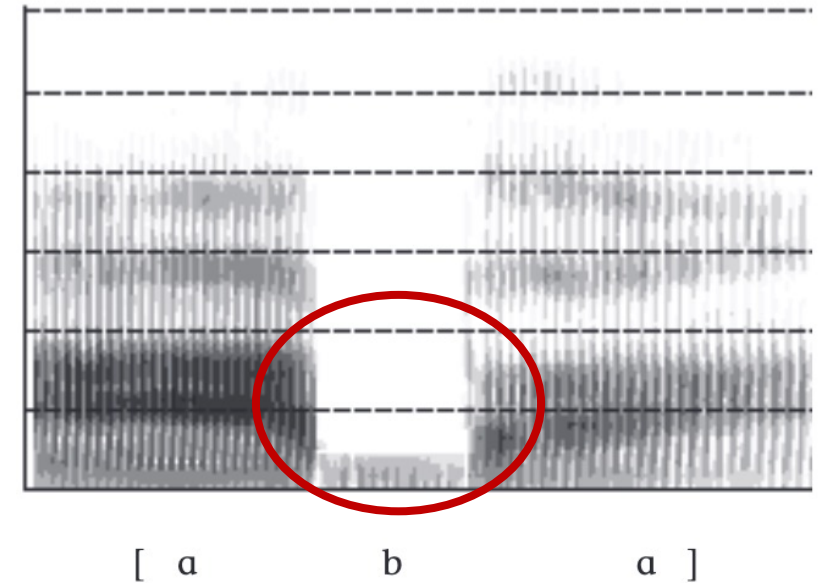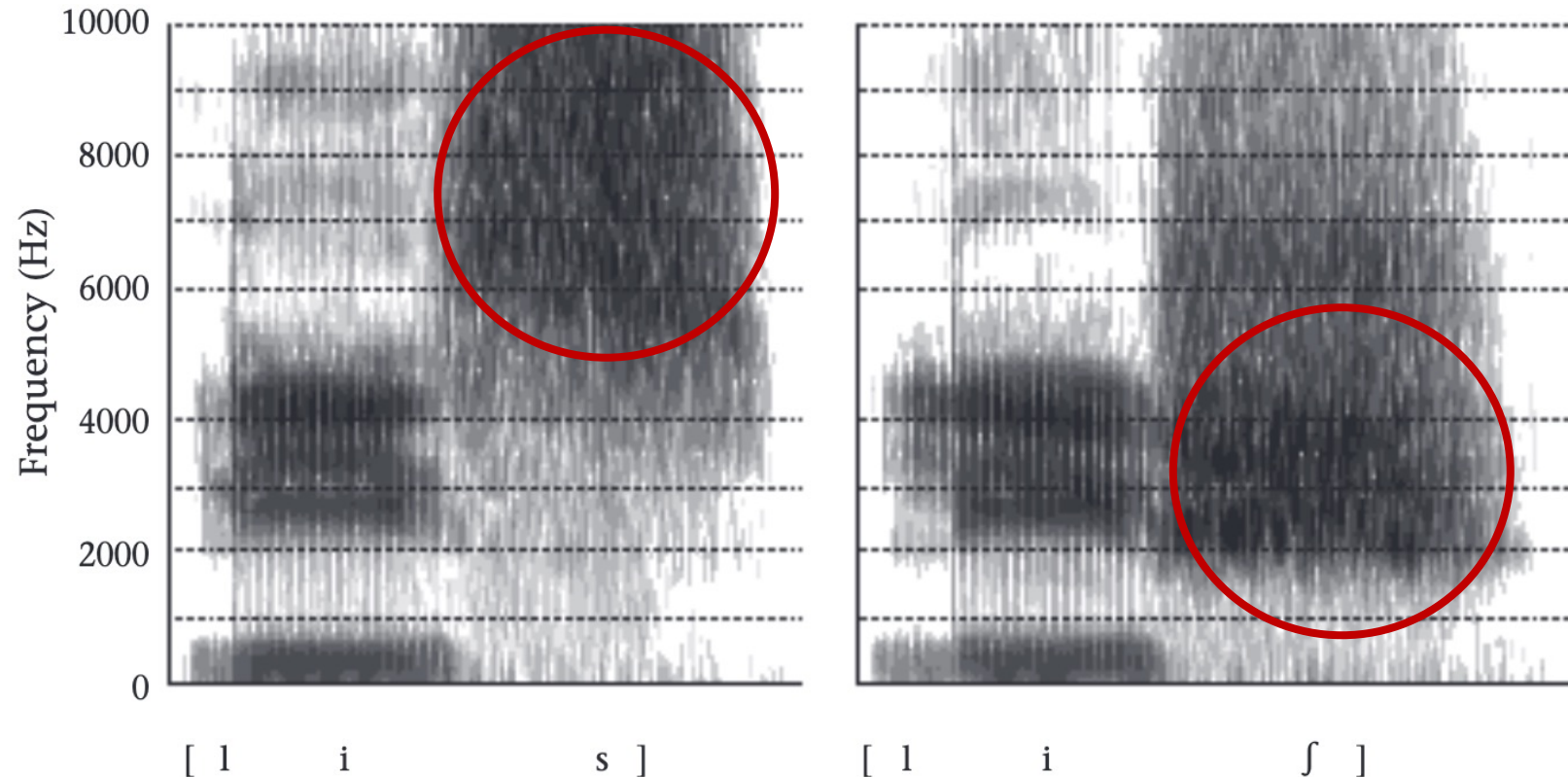

voice bar

Spectrogram: Fricatives

Aperiodic sounds
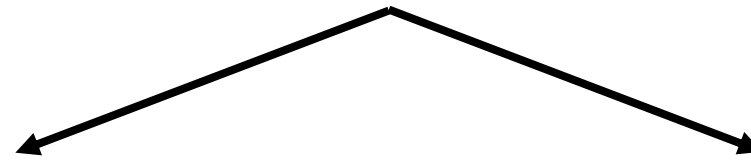
[s]: 6-9 kHz   [ʃ]:2-4 kHz

Auditory phonetics

- What are the most fundamental units listeners extract from the speech signal?

  - **general auditory approach:** We hear sounds
  - **motor theory of speech:** We hear gestures

Motor theory of speech perception

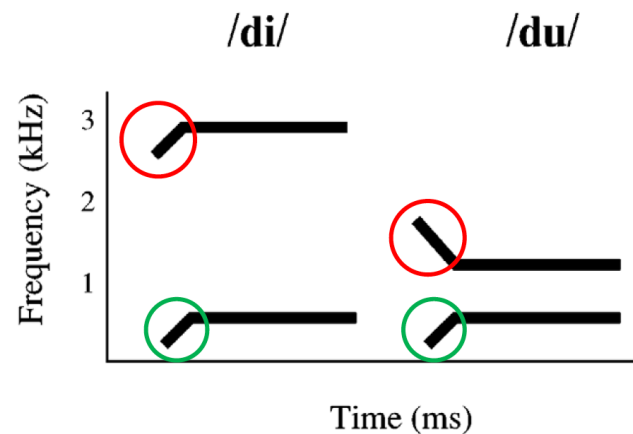Phonemes related to both acoustics and articulation

[d]

acoustics
formants increase or
decrease in transitions
depending on vowels

articulation
abduct vocal folds
close lips

these relations are more invariant

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Motor theory of speech perception

- General audition and learning cannot account for uniqueness of human ability to perceive speech

- Speech-specific linguistic module is needed

acoustic signal → intended articulatory gestures

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General auditory approach

- acoustic events are the objects of perception

- no special speech-module, perception uses the same perceptual systems and learning mechanisms that other animals have

/di/   /du/

Frequency (kHz)

Time (ms)
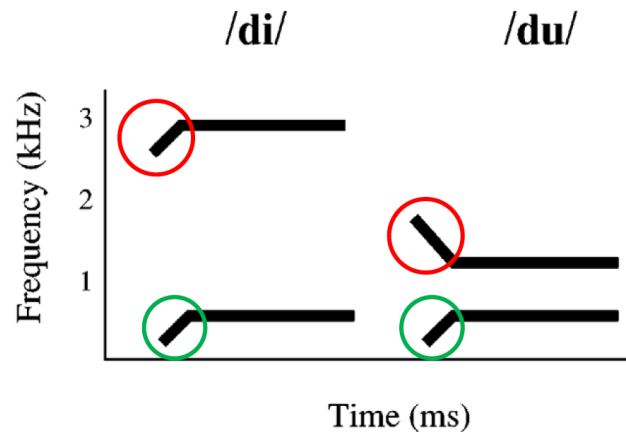
- context dependence of acoustics is tractable: listeners make use of multiple cues can interpret cues with acoustic context

- birds can be trained to recognize consonants, and can then correctly recognize them in novel vowel contexts
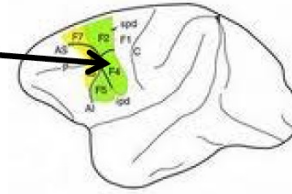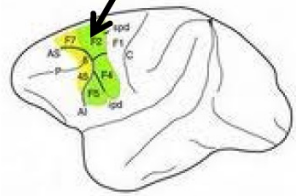
McGurk Effect: Evidence for motor theory?

Motor theory: gestures are specified visually and acoustically

General auditory theory: general mechanisms of perception allow visual cue-phoneme mappings

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Mirror neurons: Evidence for motor theory?

motor neurons activate when a monkey eats banana

monkey eating a banana

subset of the same motor neurons activate when a monkey watches another monkey eating a banana

mechanism for understanding actions/gestures?

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Evidence from neuroscience

against motor theory:
- people with lesions of motor cortex exhibit normal discrimination
- activity in auditory cortex during perception is far more robust than in other areas

for motor theory:
- activity in motor cortex associated with perception disruption of motor cortex (through TMS) influences perception