Foundations of Language Science and Technology

Phonetics

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Bernd Möbius & Jürgen Trouvain

FR 4.7, Phonetics
Saarland University

UNIVERSITÄT DES SAARLANDES

Levels of linguistic description

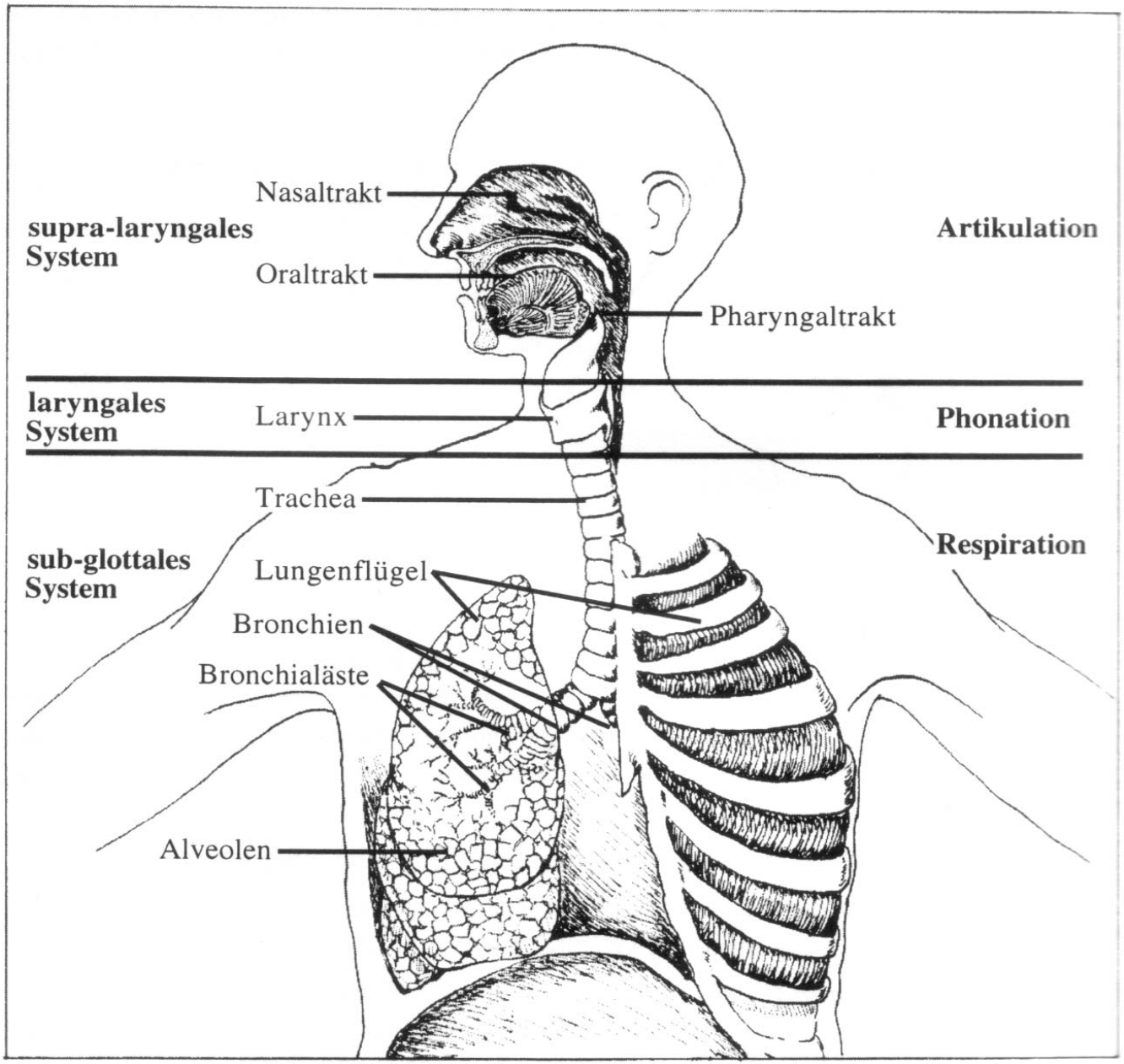
- Phonetics
- Phonology
- Morphology
- Lexicon
- Syntax
- Semantics
- Pragmatics

- Psycholinguistics
- …linguistics (socio, neuro, patho, …)

Phonetics

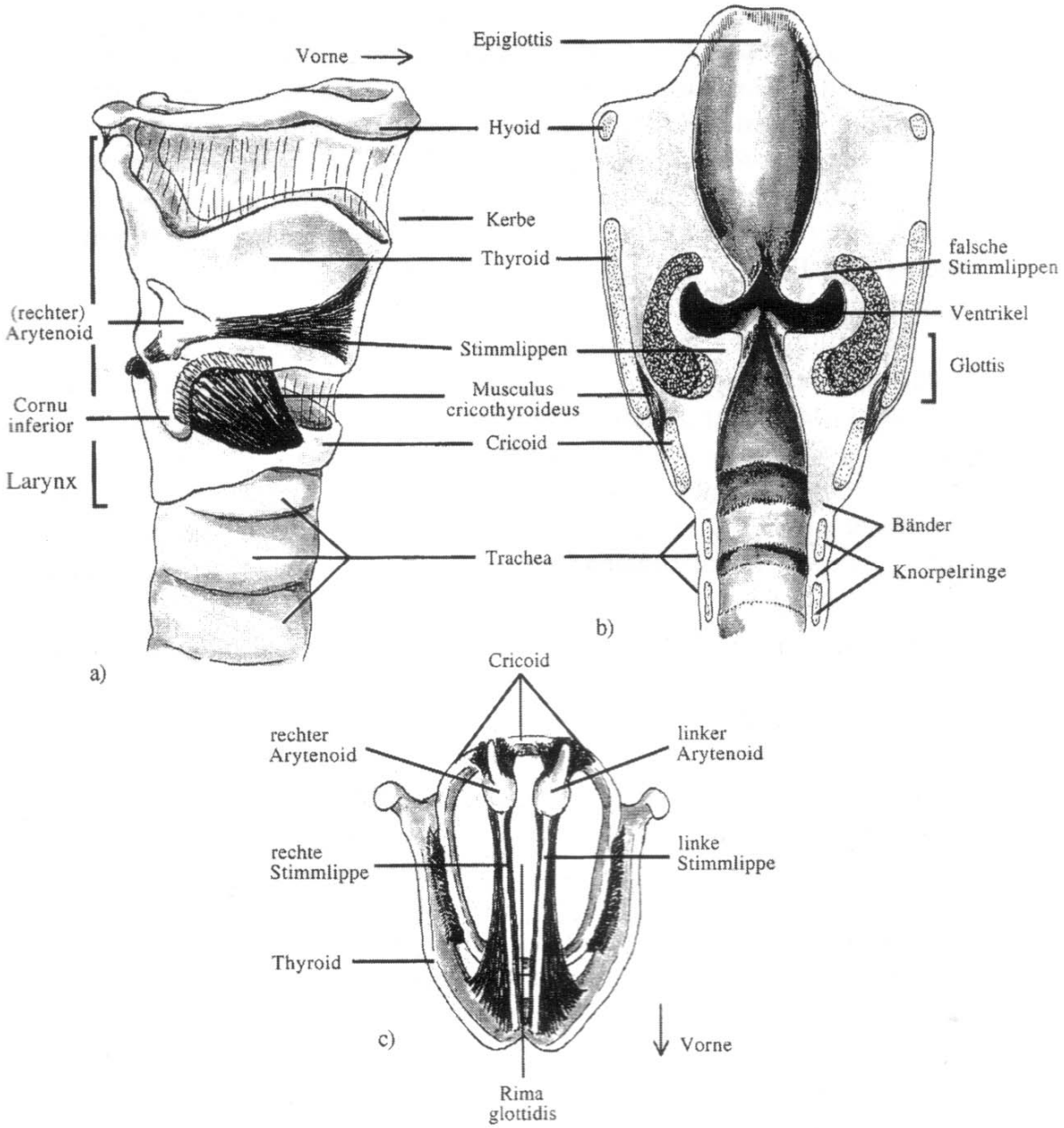
- Scientific study of *spoken language*
- Basic conditions and constraints of human speech production and perception
- How are speech sounds produced and perceived?
  - anatomy and physiology
  - speech production, phonation, articulation
  - speech acoustics, speech signal
  - speech perception
- Articulatory Phonetics, Acoustic Phonetics, Auditory-Perceptual Phonetics, Neurophonetics

Speech production organs



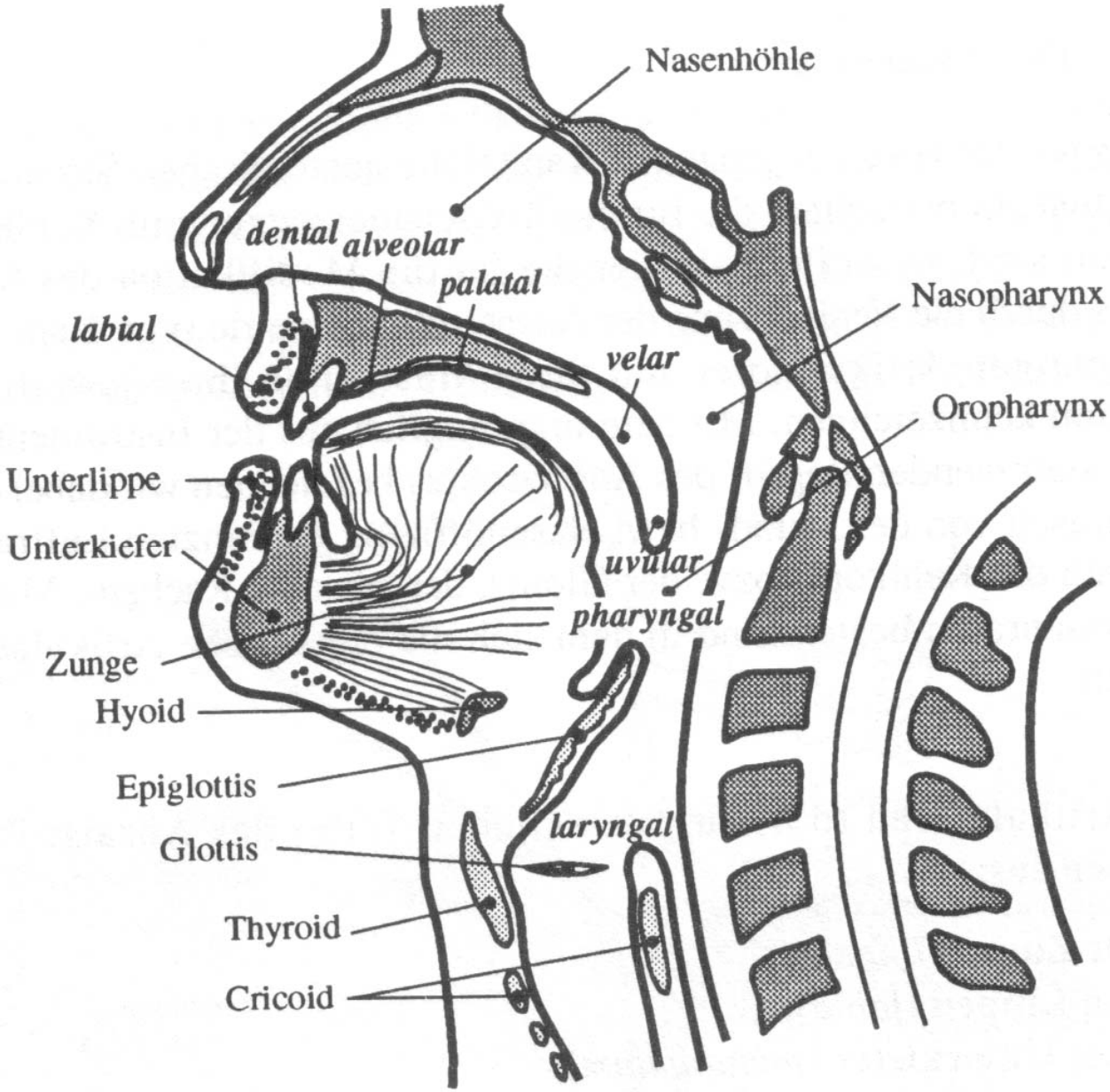
[Reetz,1999]

Speech production organs



[Reetz,1999]

Speech production organs

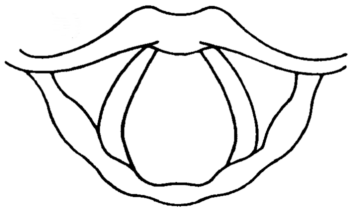


[Reetz,1999]

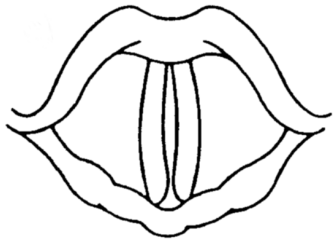
Phonation – the voice source

videos:
phonation (Esling) 0:37-end
articulation (Stevens/Perkell)

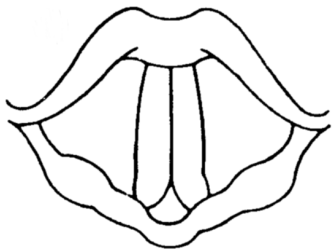
silent breathing



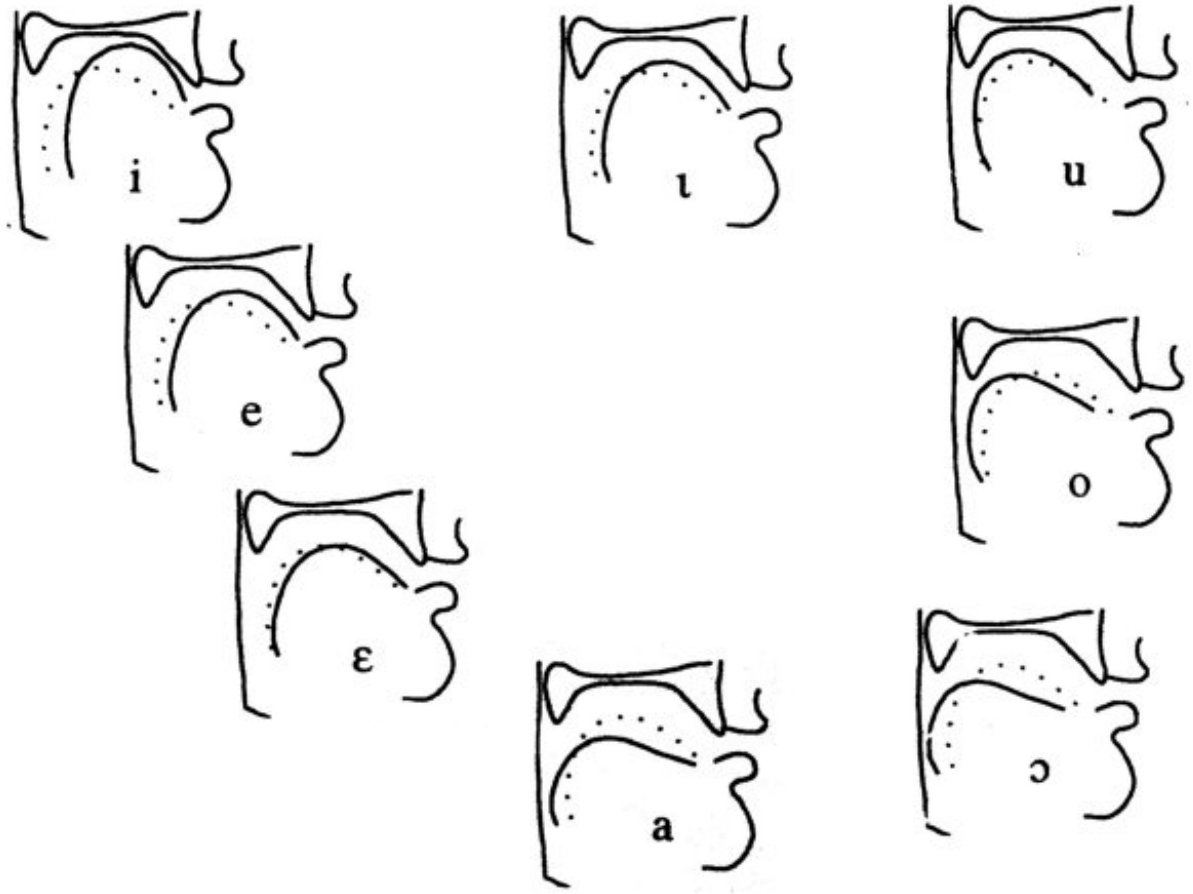
speaking (voiced)



whispering

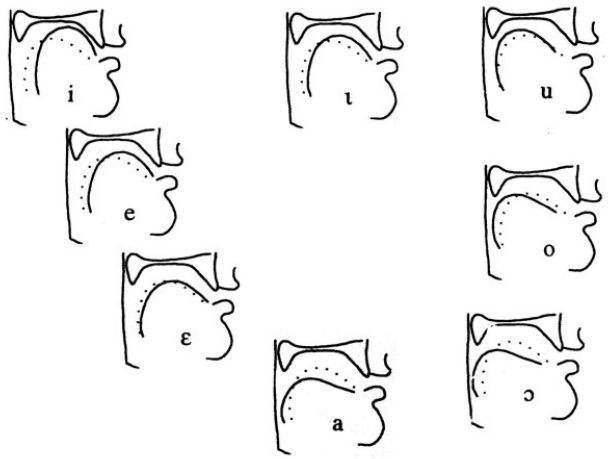


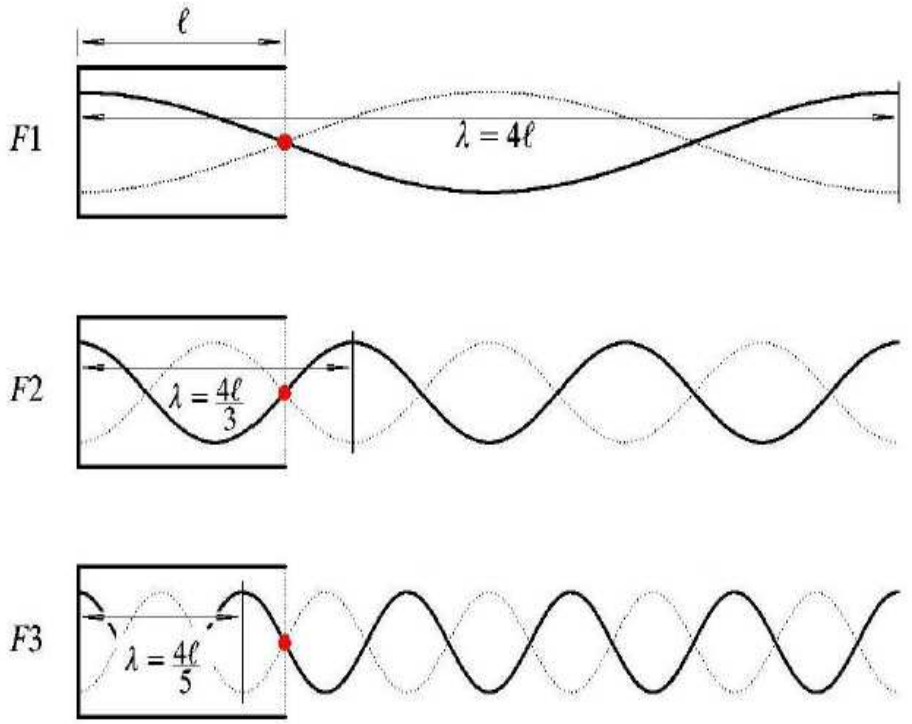
Articulation – the vocal tract



Vocal tract geometry (tongue position)
of some English vowels

Acoustic Phonetics





Sound pressure waves
of the first three formants

2.3.1 Ausgangspunkt Webster'sche Horngleichung (nach Ungeheuer, 1962)

Wir gehen nun von der Wellengleichung des Schnellenpotentials Φ für die Wellenausbreitung in einem Rohr veränderlichen Querschnittes, der sog. Webster'schen Horngleichung aus

$$\frac{\partial^2\Phi}{\partial x^2} + \frac{1}{A}\frac{\partial\Phi}{\partial x}\frac{dA}{dx} = \frac{1}{c^2}\frac{\partial^2\Phi}{\partial t^2} \tag{45}$$

mit den bekannten Randbedingungen:

$$v(t) = 0 \quad \Rightarrow \quad \frac{\partial\Phi}{\partial x} = 0 \quad [\text{Glottis}, x = 0] \tag{46}$$

$$p(t) = 0 \quad \Rightarrow \quad \Phi = 0 \quad [\text{Mundöffnung}, x = l] \tag{47}$$

Mit Hilfe der Trennung der Variablen

$$\Phi(x,t) = \varphi(x)\cdot\psi(t) \tag{48}$$

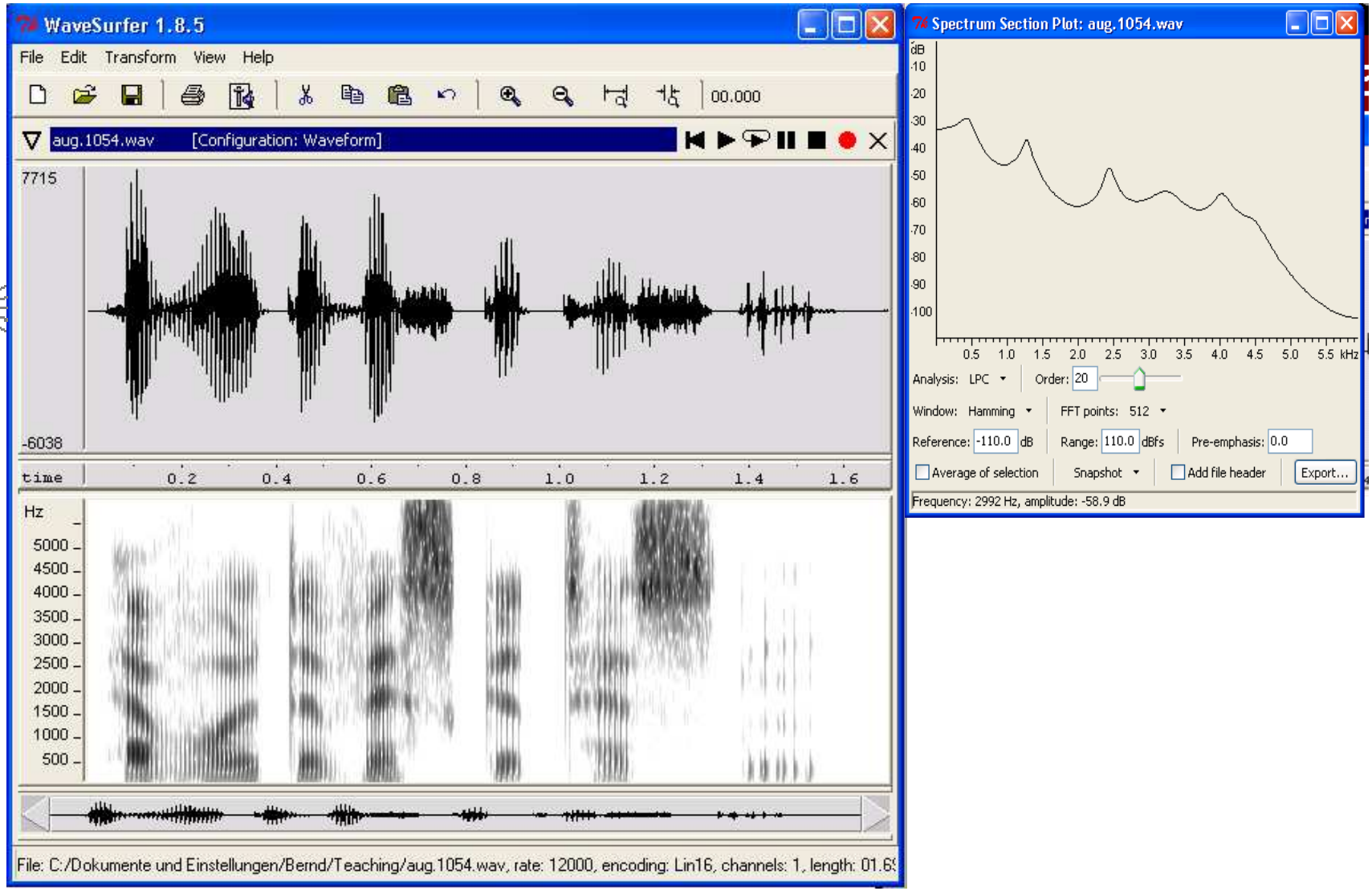
können wir (45) schreiben

$$\frac{1}{\varphi}\left[\frac{d^2\varphi}{dx^2} + \frac{1}{A}\frac{d\varphi}{dx}\frac{dA}{dx}\right] = \frac{1}{c^2\psi}\frac{d^2\psi}{dt^2} \tag{49}$$

Die linke Hälfte hängt nur von x ab, die rechte nur von t. Damit können beide als gleich einer Konstante gesehen werden, die mit $-\Lambda$ bezeichnet sei:

$$\frac{1}{\varphi}\left[\frac{d^2\varphi}{dx^2} + \frac{1}{A}\frac{d\varphi}{dx}\frac{dA}{dx}\right] = -\Lambda = \frac{1}{c^2\psi}\frac{d^2\psi}{dt^2} \tag{50}$$

Acoustic speech signal



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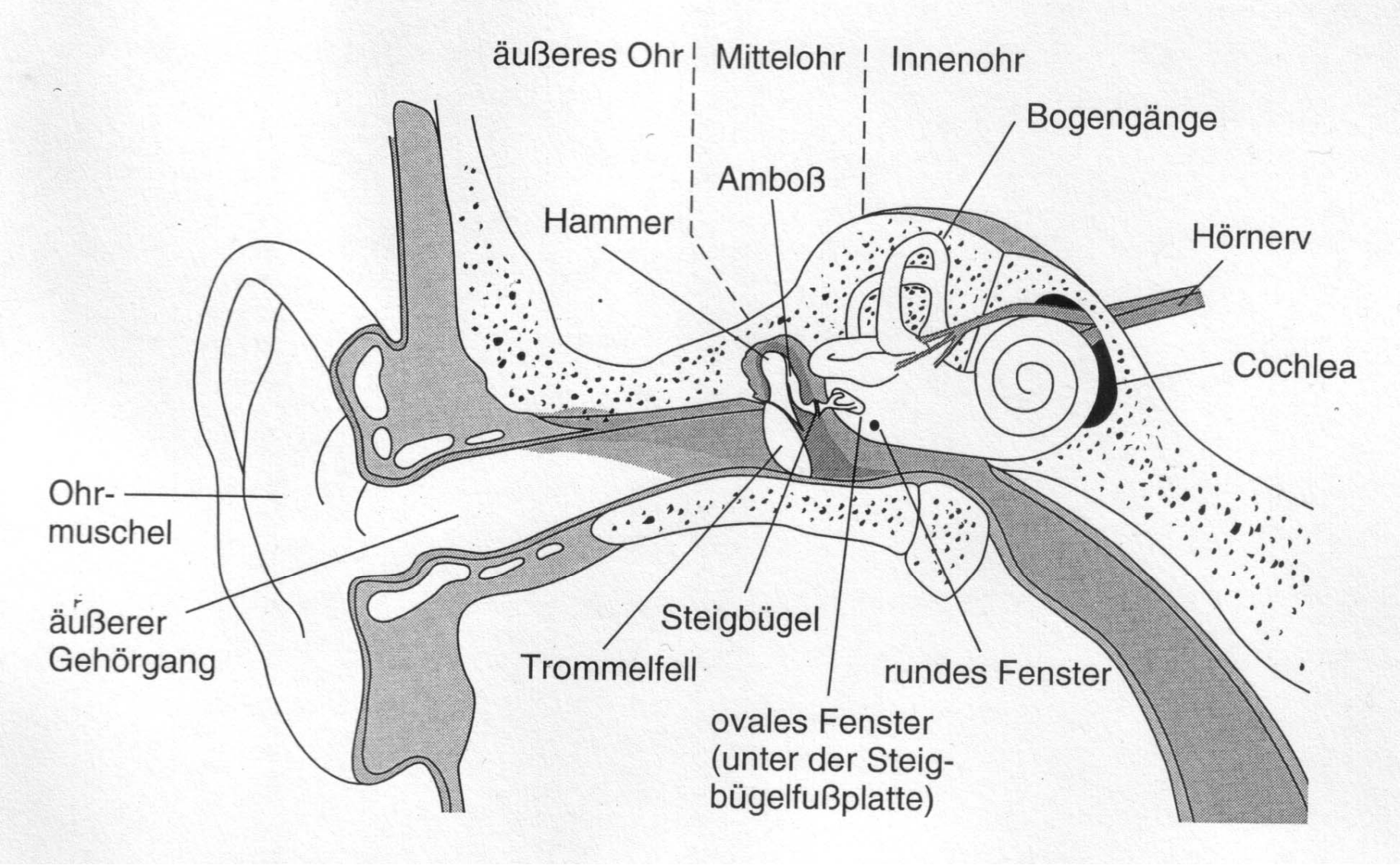
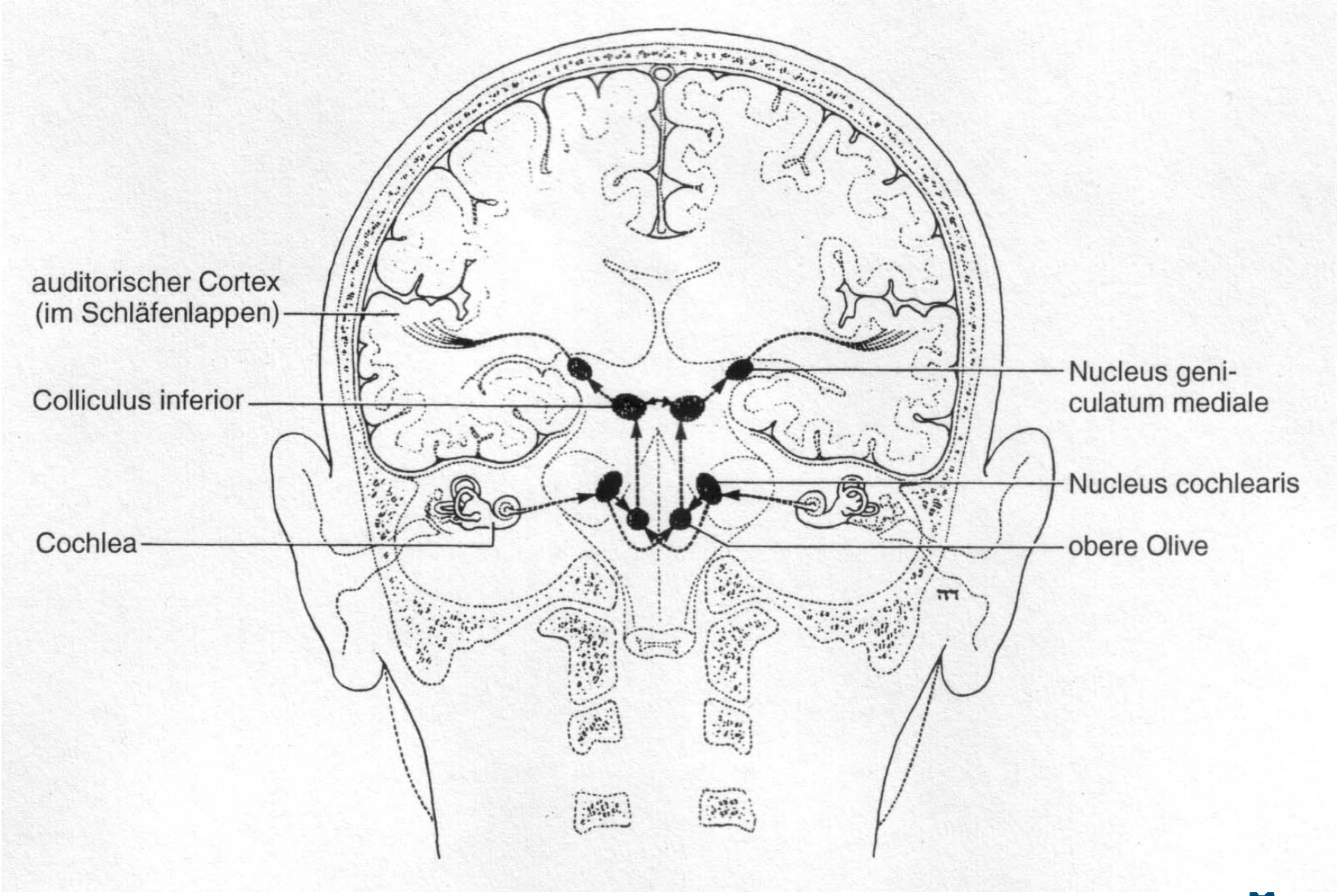
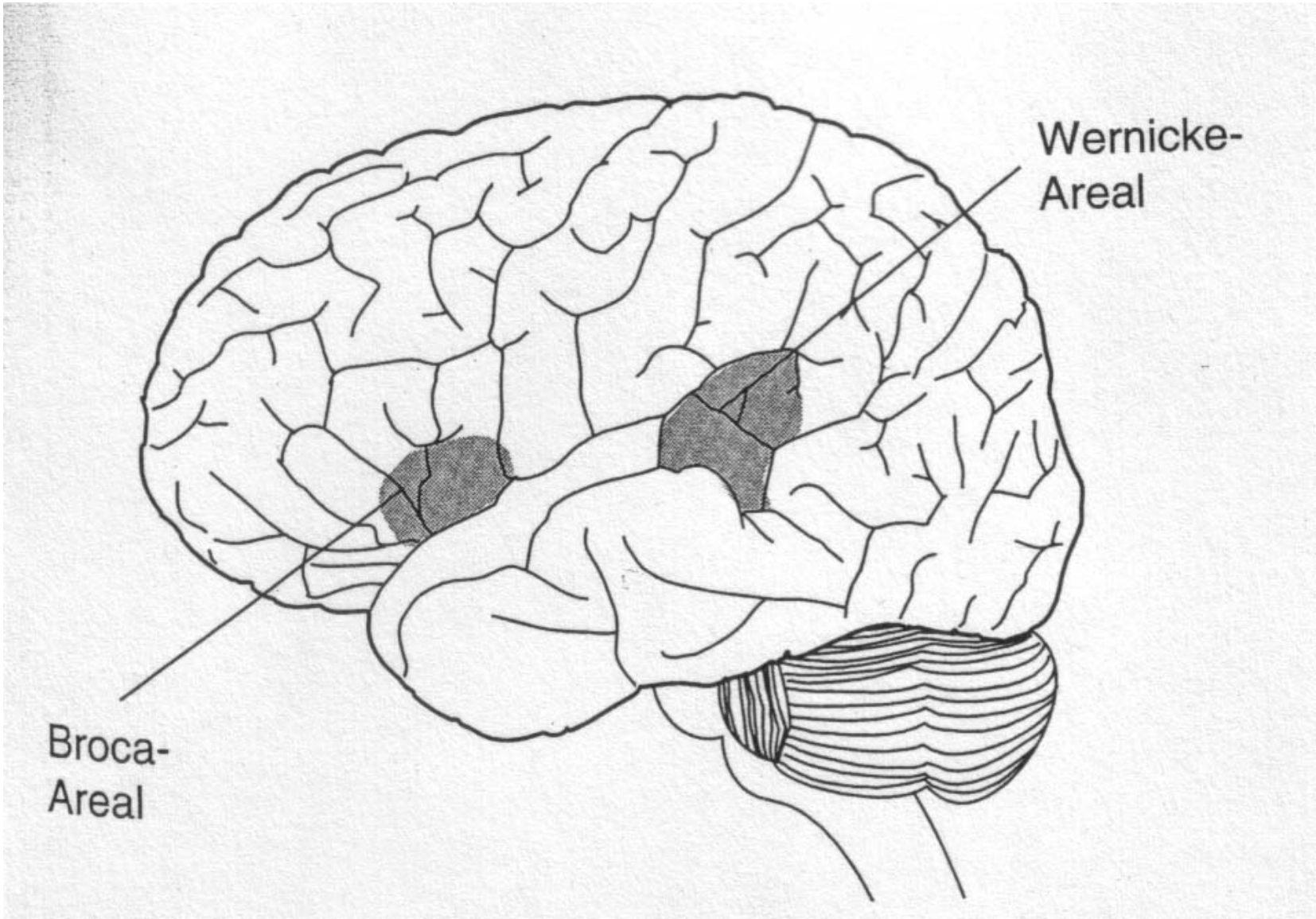
Auditory system



Auditory system



Language processing areas in the brain



Phoneticians

- What do phoneticians actually do?
  - we *observe* how people say things
  - we *describe* spoken language at the level of pronunciation
  - we *measure* pronunciation events
  - we *model* pronunciation behavior
  - we *explain* the communicative contribution of pronunciation patterns
  - we construct *theories, hypotheses and models* of phonetic events – and we test them experimentally

Phoneticians and speech sounds

- What are the vowels of English (and German and …) like?
  - "The cat sat on the mat."

    SBE: ?? GA: ?? German: ??
  - "The computer is broken."

    SBE: ?? GA: ?? German: ??
  - Can you *hear* the differences?
  - Can you *describe* the differences?
  - Can you say *why* there are differences?

Phoneticians and speech sounds

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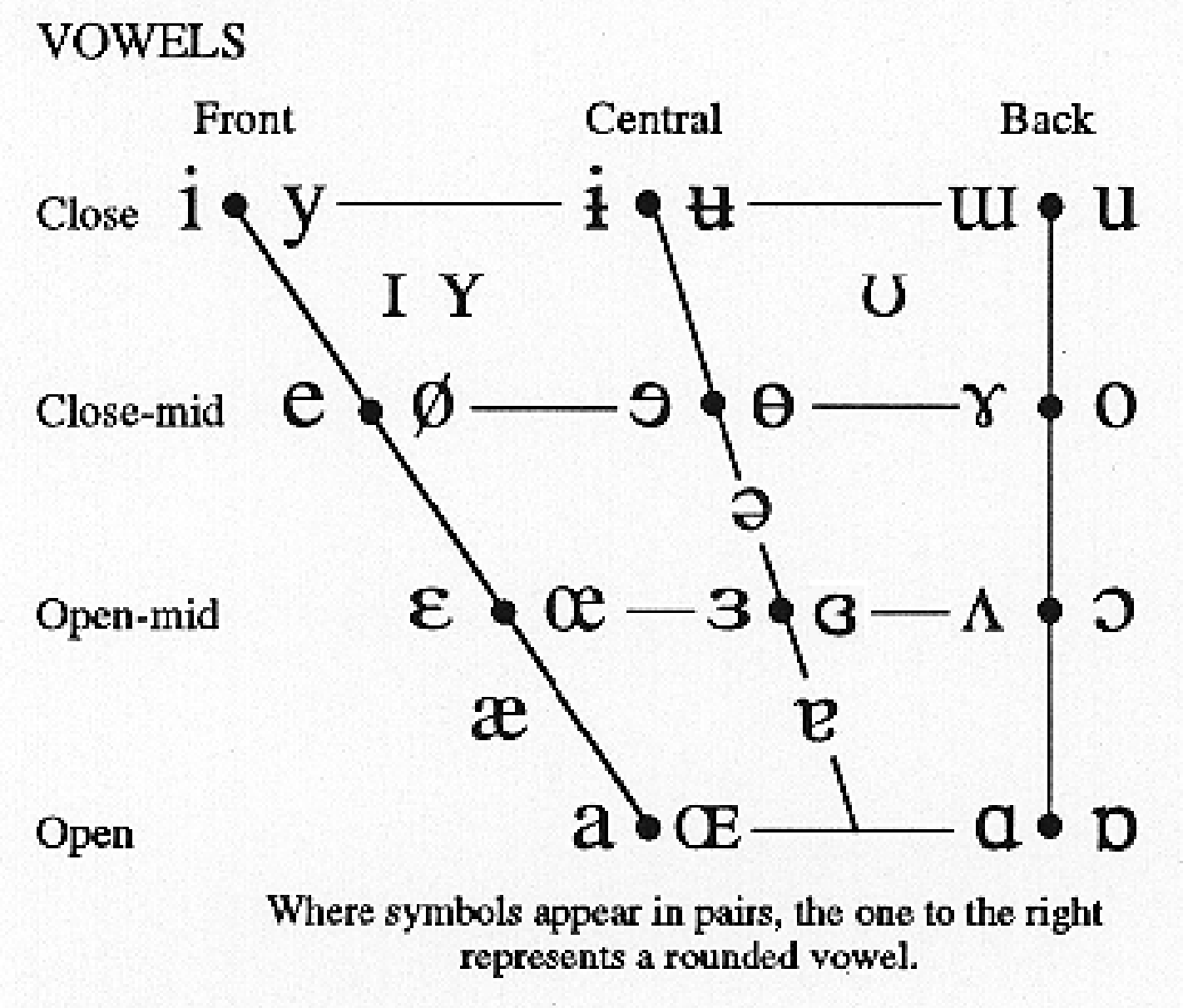
  - Can you say *why* there are differences?

Phonetic transcription - IPA

- Phonetic transcription (German, standard text)
  - "Einst stritten sich Nordwind und Sonne…"
  - [ˈʔaɪns ʃtʁɪtn zɪç ˈnɔɐtvɪnt ʊnt ˈzɔnə]
- IPA = International Phonetic Association
  - aim: universal phonetic alphabet, capable of describing all speech sounds of all languages
  - aim: universal classification systems for all speech sounds
  - founded in Paris in 1886
  - last revision: Kiel 1989 (alphabet 1995/96)

IPA: vowels


VOWELS
Front
Central
Back
Close
Close-mid
Open-mid
Open
i y ɨ ʉ ɯ u
ɪ ʏ ʊ
e ø ɘ ɵ ɤ o
ə
ɛ œ ɜ ɞ ʌ ɔ
æ ɐ
a ɶ ɑ ɒ
Where symbols appear in pairs, the one to the right represents a rounded vowel.

IPA: consonants

THE INTERNATIONAL PHONETIC ALPHABET (revised to 1993)

CONSONANTS (PULMONIC)

	Bilabial	Labiodental	Dental	Alveolar	Postalveolar	Retroflex	Palatal	Velar	Uvular	Pharyngeal	Glottal
Plosive	p b			t d		ʈ ɖ	c ɟ	k g	q G		ʔ
Nasal	m	ɱ		n		ɳ	ɲ	ŋ	N		
Trill	B			r					R		
Tap or Flap				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			

Where symbols appear in pairs, the one to the right represents a voiced consonant. Shaded areas denote articulations judged impossible.

German vowels

IPA	SAMPA	Beispiel	IPA	SAMPA	Beispiel
iː	i:	Miete	ɪ	I	Mitte
yː	y:	Hüte	ʏ	Y	Hütte
eː	e:	beten	ɛ	E	betten
ɛː	E:	bäten			
øː	2:	Höhle	œ	9	Hölle
uː	u:	Stuhl	ʊ	U	Stulle
oː	o:	Robe	ɔ	O	Robbe
aː	a:	Haken	a	a	hacken
ə	@	Lehre	ɐ	6	Lehrer
aɪ	aI	Seite	aʊ	aU	Laube
ɔʏ	OY	heute			

German consonants

IPA	SAMPA	Beispiel	IPA	SAMPA	Beispiel
p	p	Panne	b	b	Bank
t	t	Tanne	d	d	Dank
k	k	Kanne	g	g	ganz
ʔ	?	Abend	h	h	Hand
f	f	fein	v	v	Wein
s	s	reißen	z	z	reisen
ʃ	S	Schein	ʒ	Z	Genie
ç	C	dich	x	x	Dach
m	m	Miete	l	l	Leiter
n	n	Niete	r	r	Reiter
ŋ	N	Klang	j	j	jeder

Vowels and consonants: perception

- We don't identify the individual speech sounds as they reach our ears
- The syllable (C*VC*) is probably the smallest unit of speech perception
- The consonants by themselves contribute less than the vowels by themselves to our understanding of a spoken utterance (because they don't form syllables!?)
  (but they contribute more to the understanding of an utterance if there is one unchanging vowel than the vowels do with one unchanging consonant!)
- What about written vowels and consonants?

Written vowels and consonants

- __e _ea__e_ _o_e_a__ _o_ _o_o__o_:
  _a__e_ __ou_y i_ __e _o__i__ _i__
  a _e_ _u__y __e___ i_ __e a__e__oo_.

Written vowels and consonants

- Th_ w__th_r f_r_c_st f_r t_m_rr_w:
  r_th_r cl__d_ _n th_ m_rn_ng w_th
  _ f_w s_nn_ sp_lls _n th_ _ft_rn__n.

Written vowels and consonants

- The weather forecast for tomorrow:
  rather cloudy in the morning with
  a few sunny spells in the afternoon.

- but cf. speech:
  - only consonants 
  - only vowels 
  - original 

Written vowels and consonants

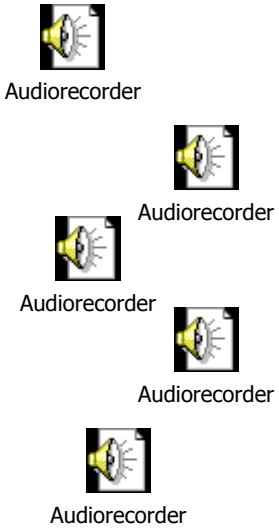
- The information in the vowels is greater, but we need the temporal structure (the rhythm) of the utterance
- Speech rhythm: a compound of syllable structure and the weight (duration, prominence) of vowels
- Speech demo:
  - only vowels, without silences 
  - only vowels, with silences 
  - only vowels, monotonous 
  - original 

Connected speech

- We perceive connected speech by chunks
- Syllables are prominent vowels surrounded by (less prominent) consonants
- Sentences are built from phrases that are built from words that are built from syllables that are built from vowels that are surrounded by consonants
- Prosody (intonation, duration, intensity) helps make important chunks more prominent than others

Connected speech

- "The president will be elected for a period of four years."
- Speech:
  - natural, connected
  - chain of isolated words
  - natural, silences between words
  - chain of isolated words, no silences
  - isolated vs. connected function words
- Production effort reflects importance of words (longer+louder+unreduced = more care and effort)



Phoneticians and speech corpora

- We make recordings of spoken language
  - choice of type of speech, speaker, and signal
  - choices determine our analysis
    - *speech* type: basic sound types, precise vs. casual speech; monolog, discourse, dialog
    - *speaker* type (e.g., regional or "standard" speakers)
    - *signal* type (acoustic=microphone, electromyographic, physiological, neurological, EGG, EPG, MEG, fMRI)
  - signal type determines experimental set-up: only the acoustic signal allows natural recordings

Tools

- Popular speech analysis software
  - Praat (www.praat.org, by Paul Boersma & David Weenink, Phonetics Amsterdam)
  - WaveSurfer (www.speech.kth.se/wavesurfer/, by scientists at Stockholm Technical University - KTH)
  - ESPS/Xwaves (now available again for Unix/Linux)
- Other popular tools
  - sox – audio format conversion
  - R statistics software (http://cran.r-project.org/)
  - Matlab, HTK, FSM

Applications

- Understanding the mechanisms of speech, i.e. the processes of production and perception, is indispensable for work on
  - foreign language teaching and learning
  - pronunciation dictionaries
  - speech pathology and disorders, clinical phonetics
  - forensic phonetics
  - speech technology (automatic speech recognition, speech synthesis, speech-to-speech translation, dialog systems)

Suggested readings

- Victoria Fromkin, Robert Rodman, Nina Hyams (^{9}2011): An Introduction to Language. Wadsworth. Chapter 4.
  [covers basic articulatory phonetics only]
- John Clark, Colin Yallop, Janet Fletcher (^{3}2007): An Introduction to Phonetics and Phonology. Blackwell.
- IPA (ed.) (1999): Handbook of the International Phonetic Association. Cambridge University Press. http://www.arts.gla.ac.uk/IPA/index.html

Suggested exercises

- Try to find long lists of monosyllabic rhymes, viz. monosyllabic words differing only in the initial consonant(s) (e.g., rat/bat/spat/... or hand/band/stand/...). Try to find rhymes for all *English* vowels.
- For each consonant in the table for *German* (slide 22), try to find three words: one with the respective sound in initial, one in final and one in medial position (e.g., [m]: Mann, kam, Hammer). Which sounds do *not* occur in some position(s)?
- Exercises 1, 2, 3, 6, 9, 11, 17 in Fromkin et al. p. 221ff.
- Read aloud the text in exercise 8, p. 223

Thanks!