Phonetics & Phonology
An Introduction

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Levels of Linguistic Analysis

Pragmatics

Semantics

Syntax

Morphology

Phonology

Phonetics

Overview

- Phonetics
- Phonology
- Computational Phonology

Phonetics

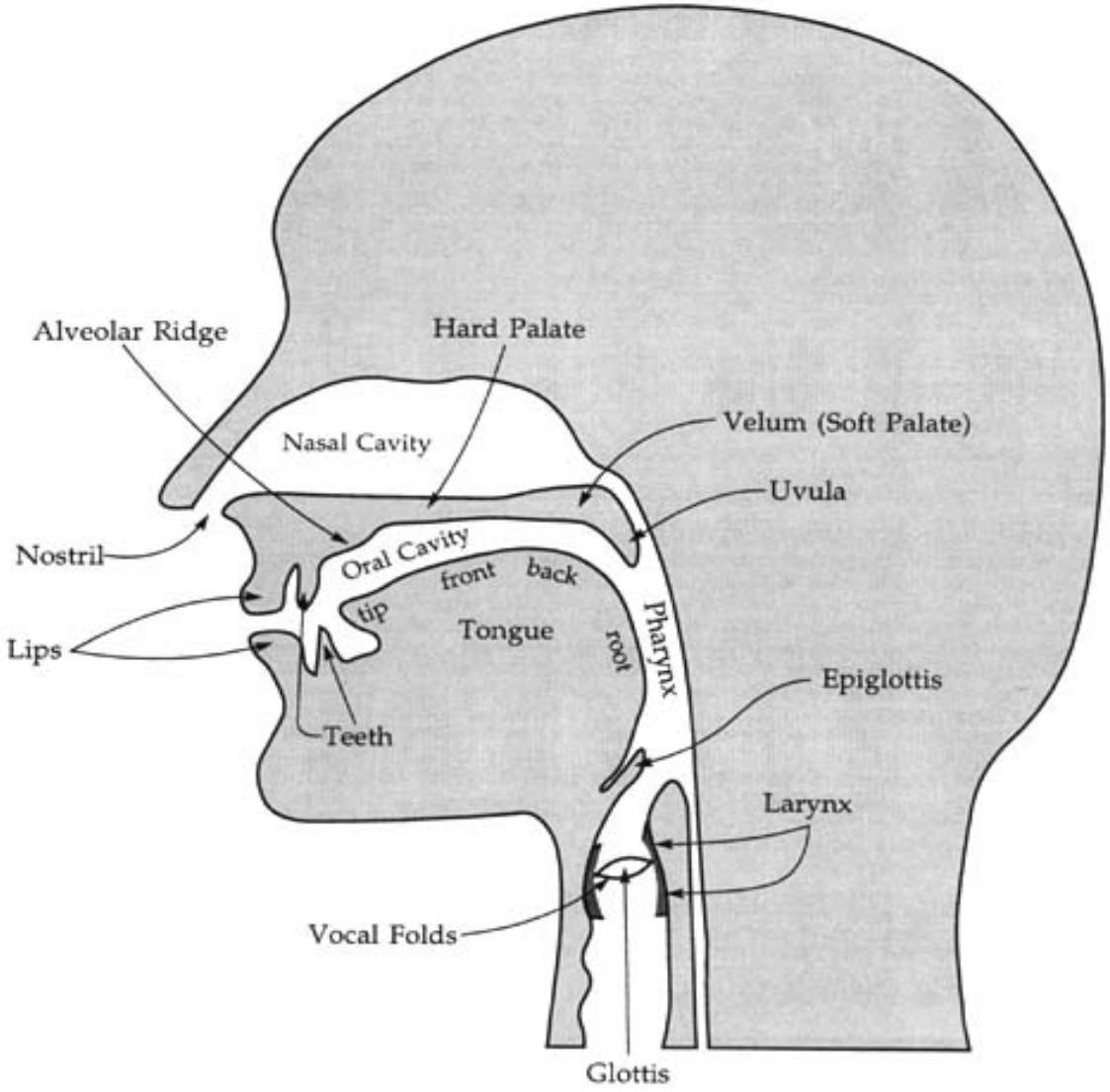
What is Phonetics ?

- Study of human speech as a physical phenomenon
  - Articulation
  - Acoustics
  - Perception

Articulatory Phonetics

- Study of how speech sounds are produced by human vocal apparatus
  - Anatomy of vocal organs
  - Air stream Mechanism
  - Voicing
  - Articulation

Anatomy of Vocal Organs



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Air-stream Mechanisms

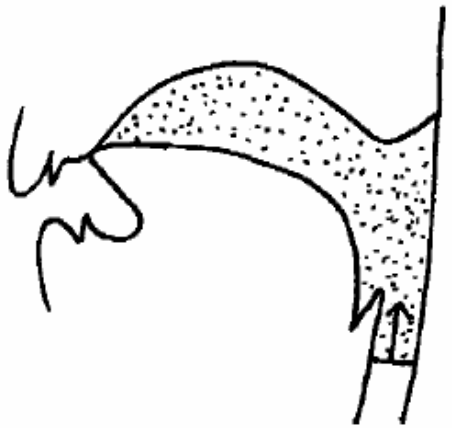
- Pulmonic
- Glottic
- Velaric

Pulmonic Sounds

- Air flow is directed outwards towards the oral cavity
- Pressure built by compression of lungs
  - English [p], [n], [s], [l], [e]

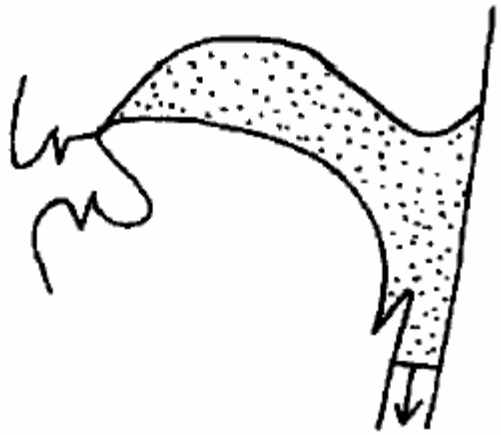
Glottic Egressive Sounds

- Air flow is directed outwards towards the oral cavity
- Pressure built by pushing up closed glottis
  - Georgian [p'], [t'], [k']



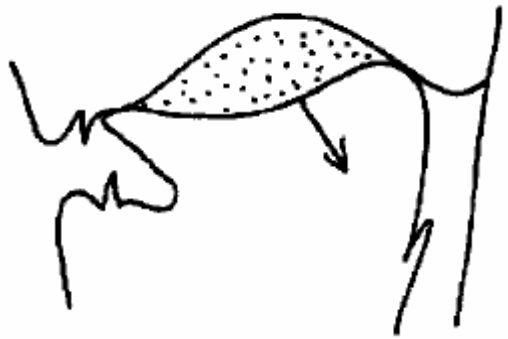
Glottic Ingressive Sounds

- Air flow is directed inwards from the oral cavity
- Pressure reduced by pulling down closed glottis
  - Hausa, Sindhi [ɓ,ɠ]



Velaric Sounds

- Air flow is directed inwards from the oral cavity
- Pressure reduced by forming velaric and alveolar closure and pulling down tongue
  - clicks

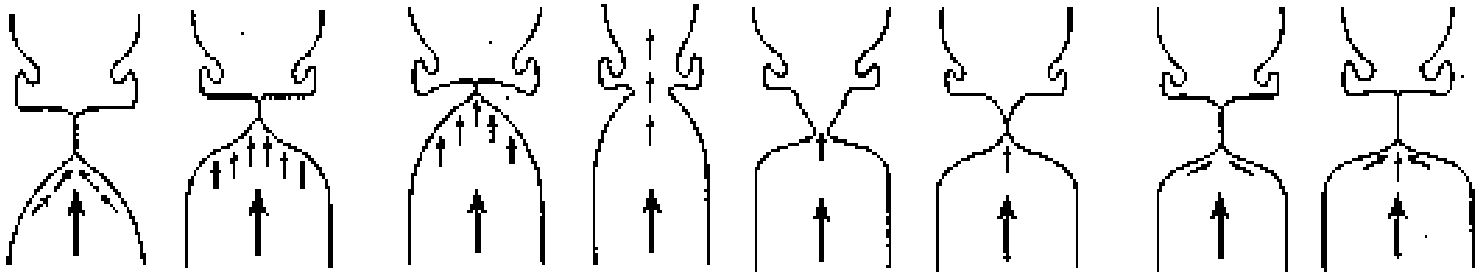


Articulatory Phonetics

- Study of how speech sounds are produced by human vocal apparatus
  - ✓ Anatomy of vocal organs
  - ✓ Air stream Mechanism
  - ❑ Voicing
  - ❑ Articulation

Bernoulli Effect

- Air pumped from the lungs applies pressure on closed glottis
- High pressure opens vocal cords
- High velocity air flow creates low pressure region pulling vocal cords together again
- Process is repeated, producing vibrations in the vocal cords



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Voicing

Voicelessness	p	s
Voice	b	z
Aspirated	p^h	
Breathy Voice	b^h	
Creak	b̰	a̰
Whisper		

[4]

Articulation

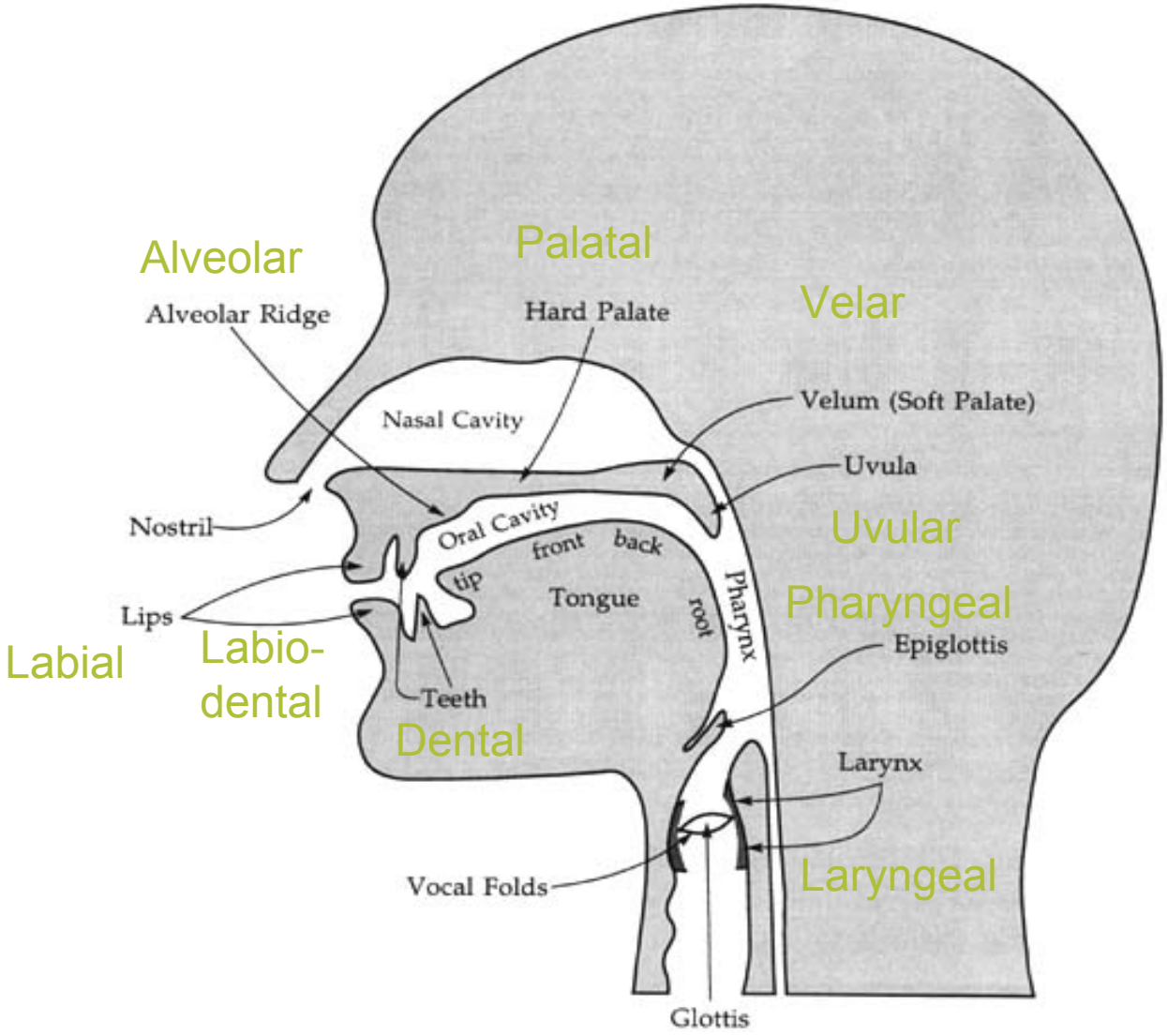
- Manners of Articulation
- Places of Articulation

Consonants – Manners of Articulation

Stop	t	p
Fricative	s	θ
Affricate	tʃ	dʒ
Approximant	ɹ	j
Nasal	n	m
Tap	ɾ	
Flap	ɽ	
Trill	r	ʙ
Lateral	l	ɬ

[4]

Places of Articulation



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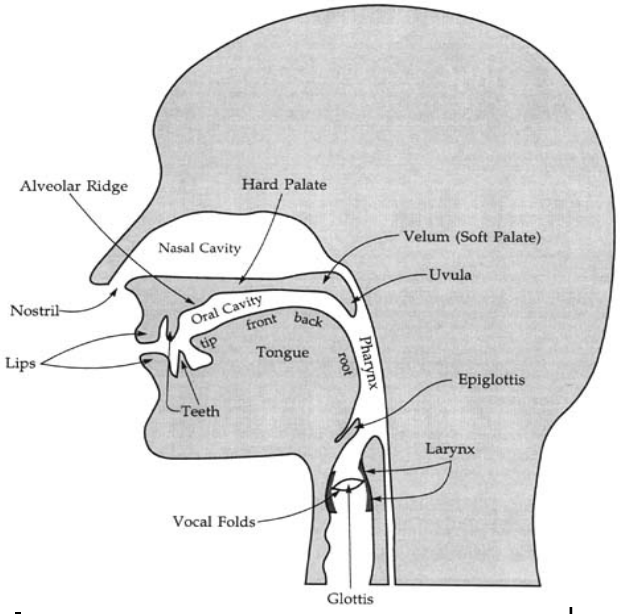
Consonants – Places of Articulation

[9]

Consonants – Places of Articulation

Bilabial	p	b
Labio-dental	ʋ	f
Dental	ð	t̪
Alveolar	ɹ	t
Retroflex	ɽ	ʂ
Palatal	ʃ	dʒ
Velar	x	ɣ
Uvular	ɢ	ɢ
Pharyngeal	ħ	ʕ
Glottal	h	ʔ
Multiple Places of Articulation	k͡p	



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Consonantal Sounds

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 ɢ		ʔ
Nasal	m	ɱ		n		ɳ	ɲ	ŋ	ɴ		
Trill	ʙ			r					ʀ		
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.

[10]

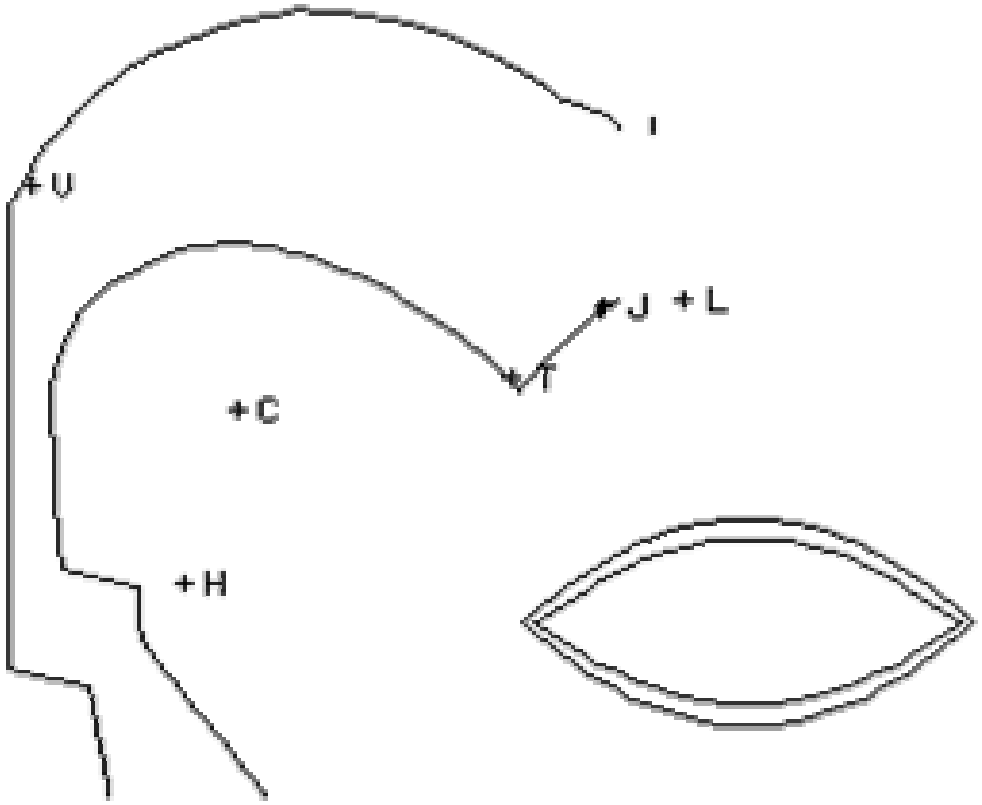
Vowel – Features

- Low / High
- Back / Front
- Round
- Nasal
- Long

Vowel – Minimal Pairs

Bag /bæg/	Big /bɪg/	(English)
Beat /bit/	bit /bɪt/	
Boot /but/	bait /bet/	

/a/ Vocal Tract Outline



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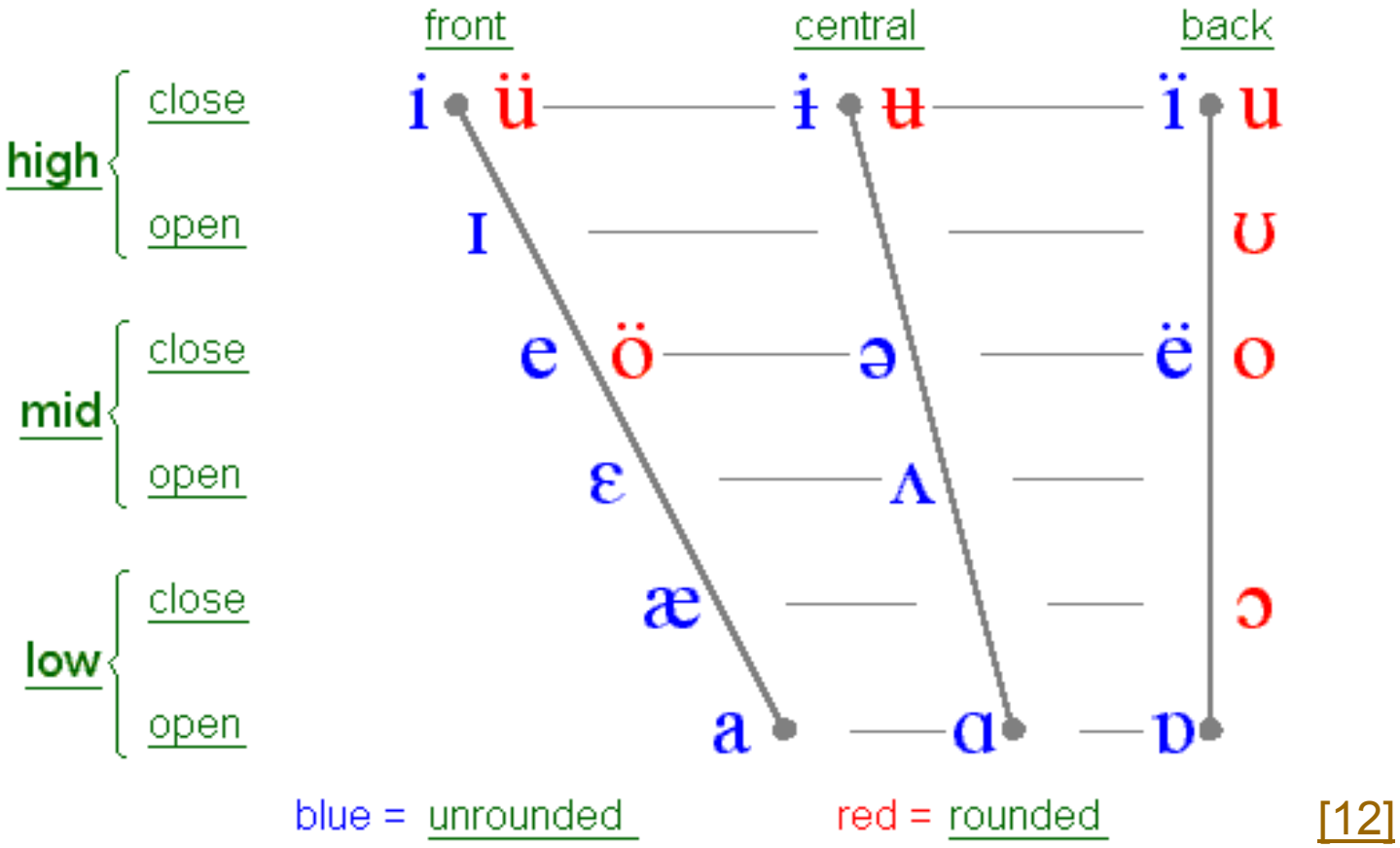
Vocalic Inventory

	Front		Central		Back	
	Unrounded	Rounded	Unrounded	Rounded	Unrounded	Rounded
High	i	y=ü	ɨ=ʉ		ɯ	u
Lower-high	ɪ		ɬ			ʊ
Higher-mid	e	ø=ö			ɤ	o
Mean-mid	Ɛ		ə	ɚ		Ω
Lower-mid	ɛ	œ		ʌ		ɔ
Higher-low	æ				ʌ	
Low	a		ɑ			ɒ

Vocalic Quadrilateral



[12]

Diphthongs

- Combination of two vocalic sounds
  - English:

[aj]	I, eye	[aj]
[aw]	cow	[kaw]

Gemination of Consonants

- Double/long consonants
  - English: “misspell”, “unknown”
  - Urdu “پتا”, “پتہ”

What is Phonetics ?

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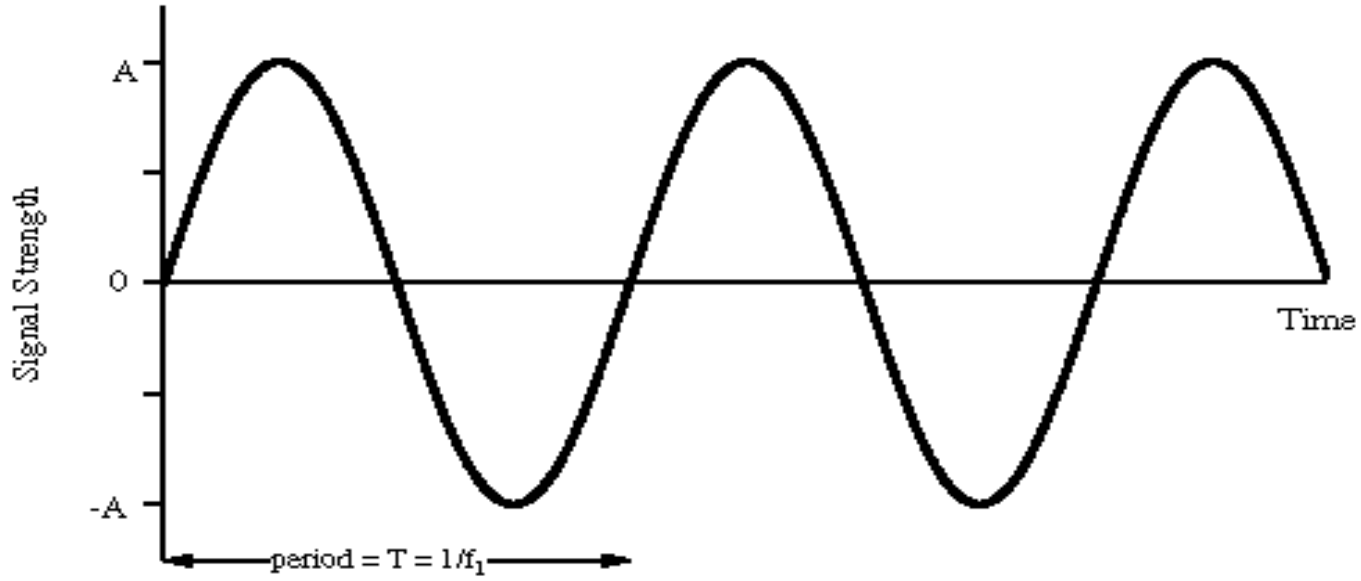
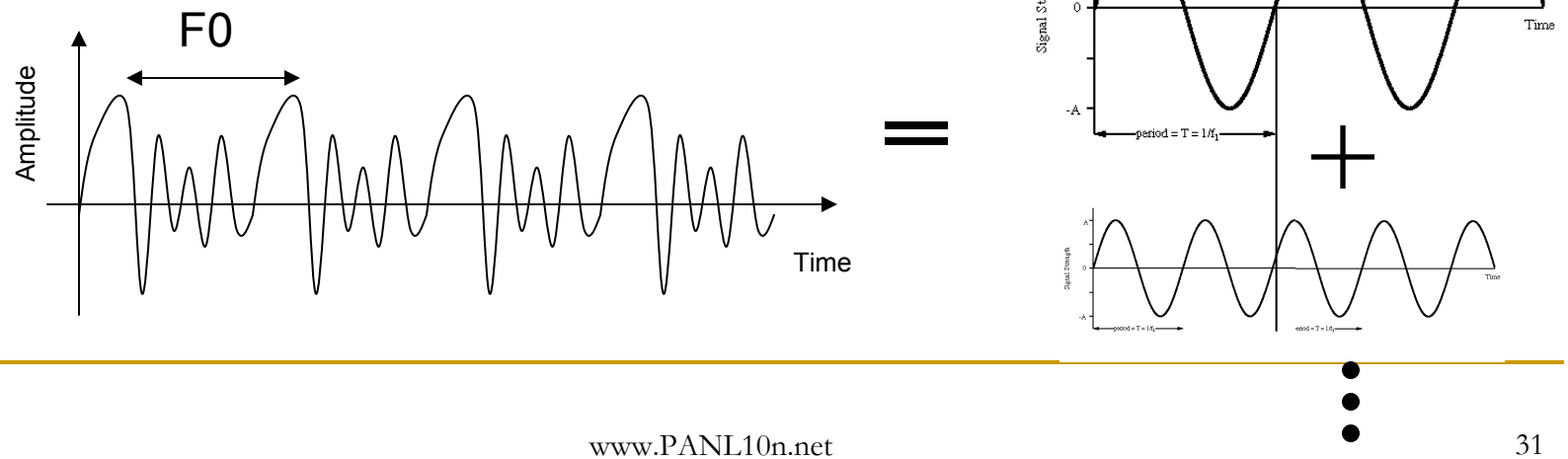
Periodic Sine Wave



- **Period**
  Time to complete one cycle (sec)
- **Frequency**
  Number of cycles per second (Hertz)
- **Amplitude**
  Maximum displacement of a periodic wave (dB)

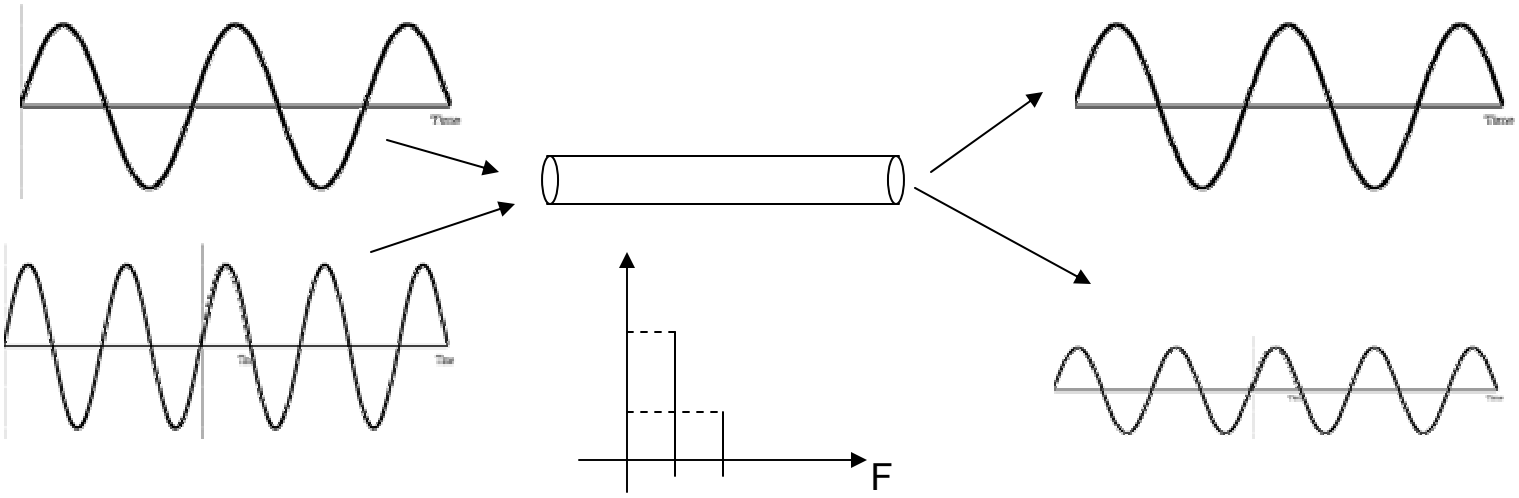
Complex Periodic Waves

- Sinewaves contain a single frequency
- Complex waves contain multiple frequency waves added together
- Complex periodic waves contain only Sine waves at base (fundamental) frequency (F0) and integral multiples of F0 (Fourier's Theorem)



Resonance

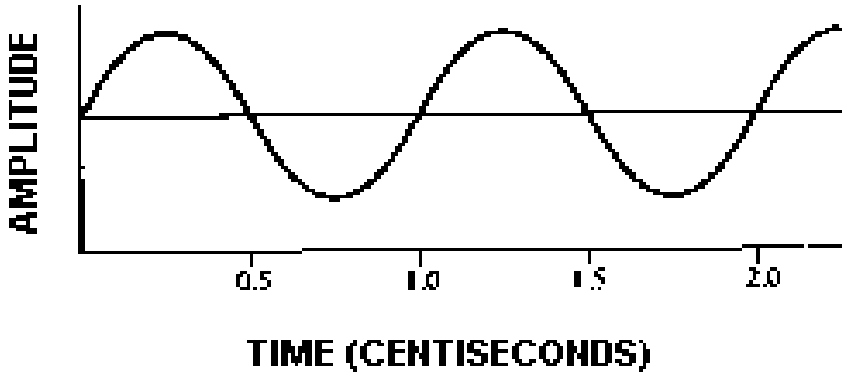
- Response of a system is not constant for signals at all frequencies. The frequency which gives largest response is called Resonance (frequency).



Sound Wave

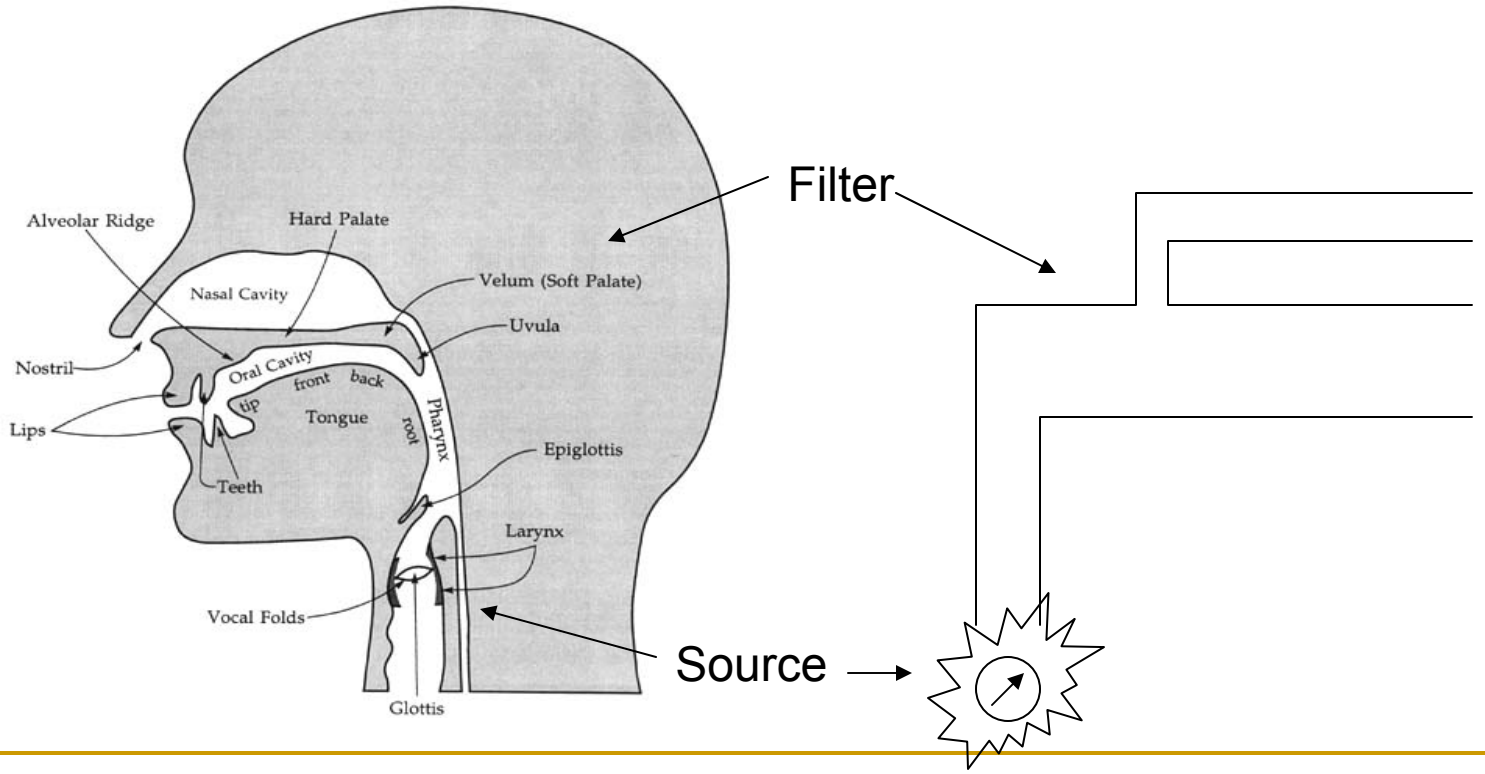
- Sound waves are formed by longitudinal movement of particles creating high and low pressure regions called compressions and rarefactions

  - Graph of pressure at each point in time



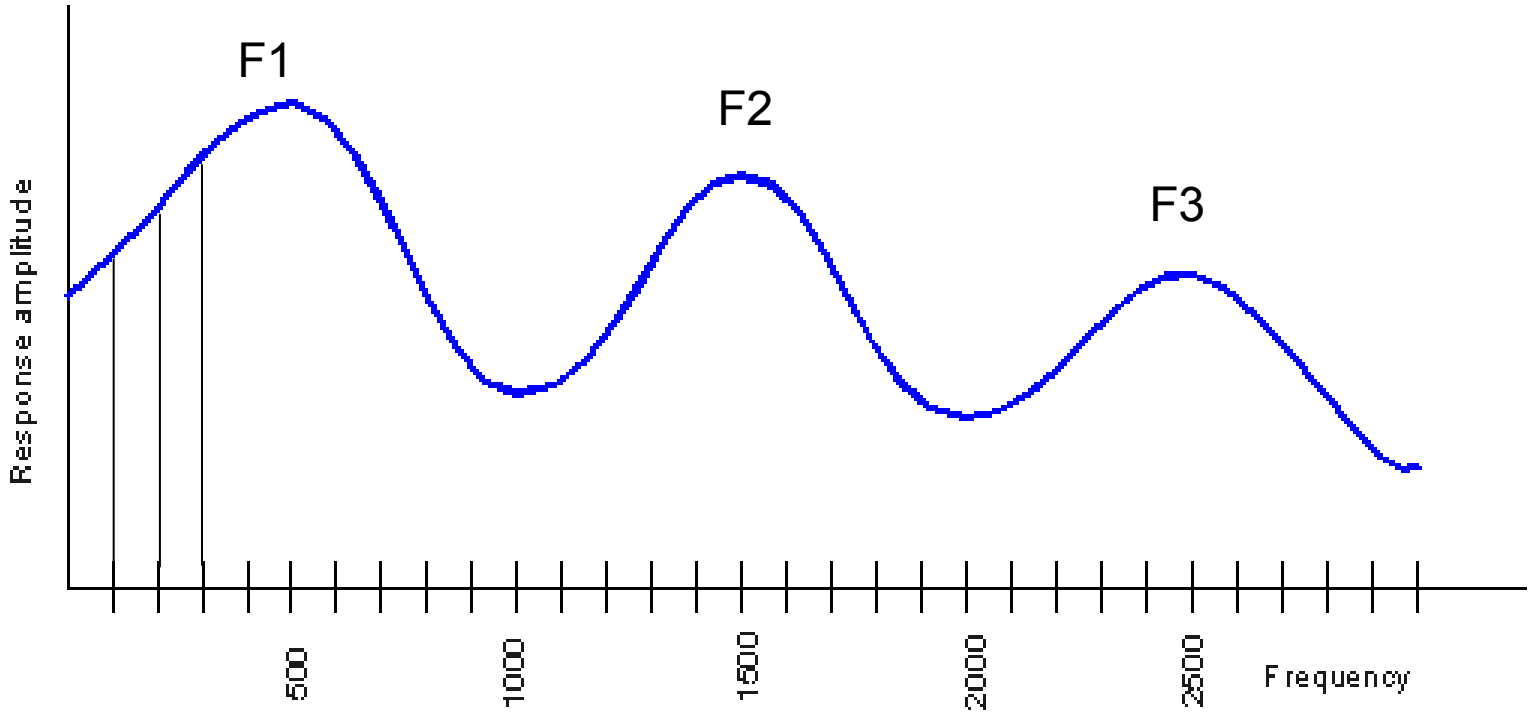
Acoustic Phonetics

- Source-Filter Model



Source-Filter Theory: Filter

- Response curve with tongue in neutral position
- Resonances are called *Formants* (F1, F2, F3, …)



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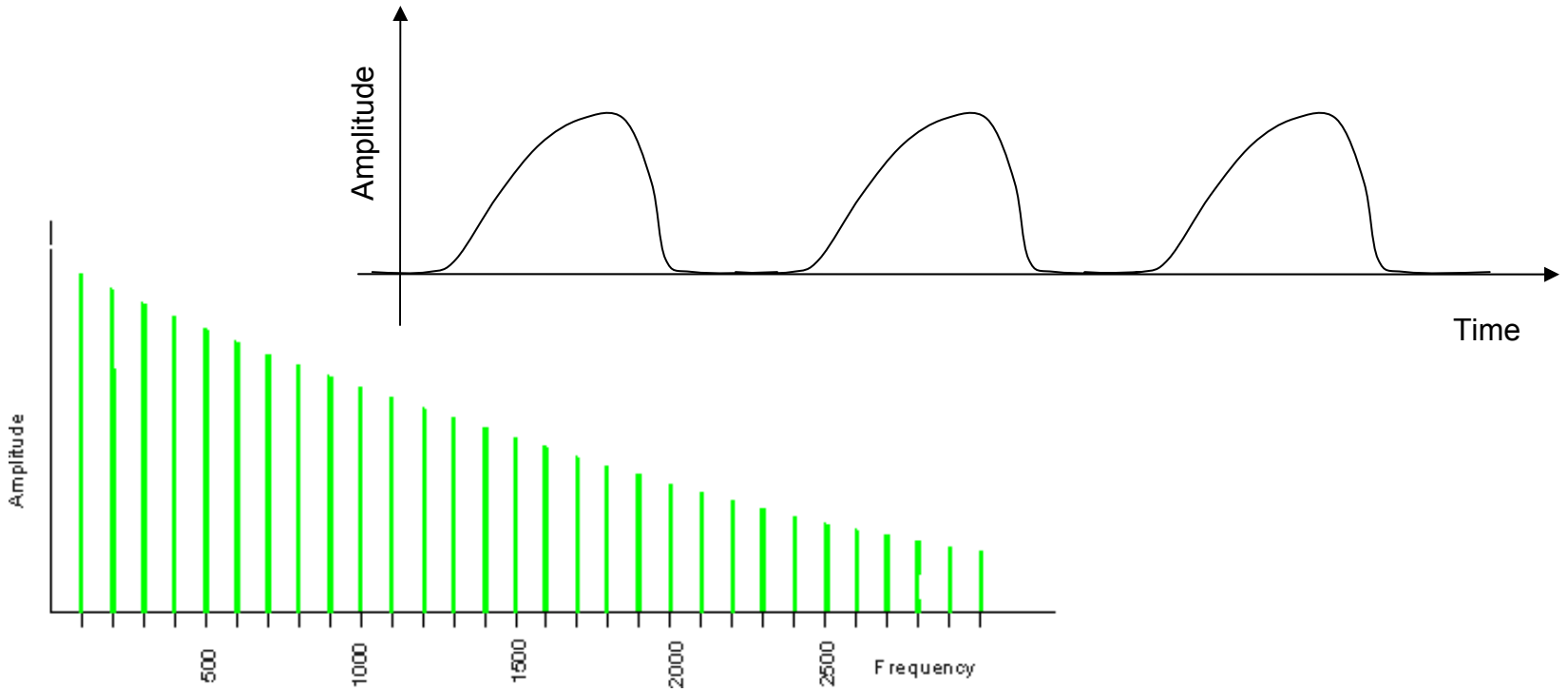
Source-Filter Theory: Source

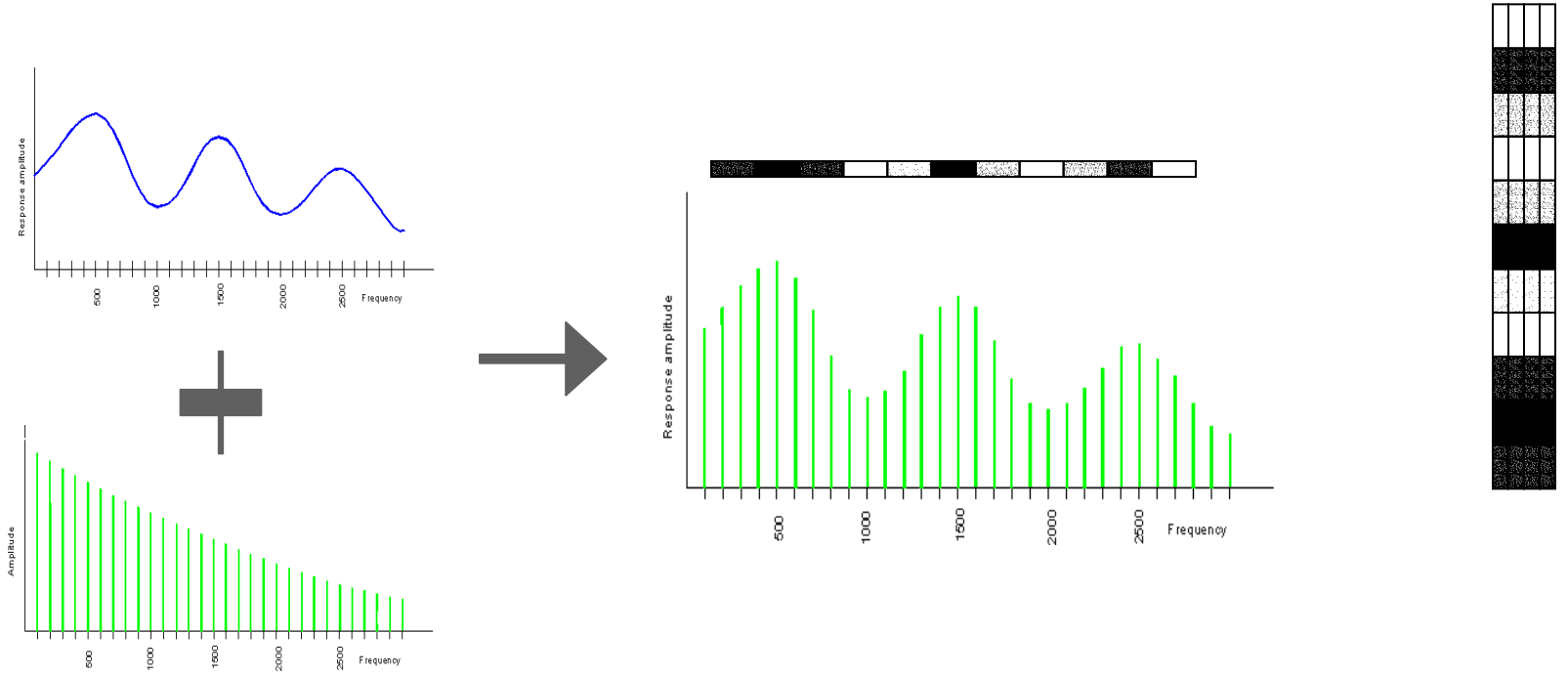
- Waveform and spectrum of the glottal pulse



[15]

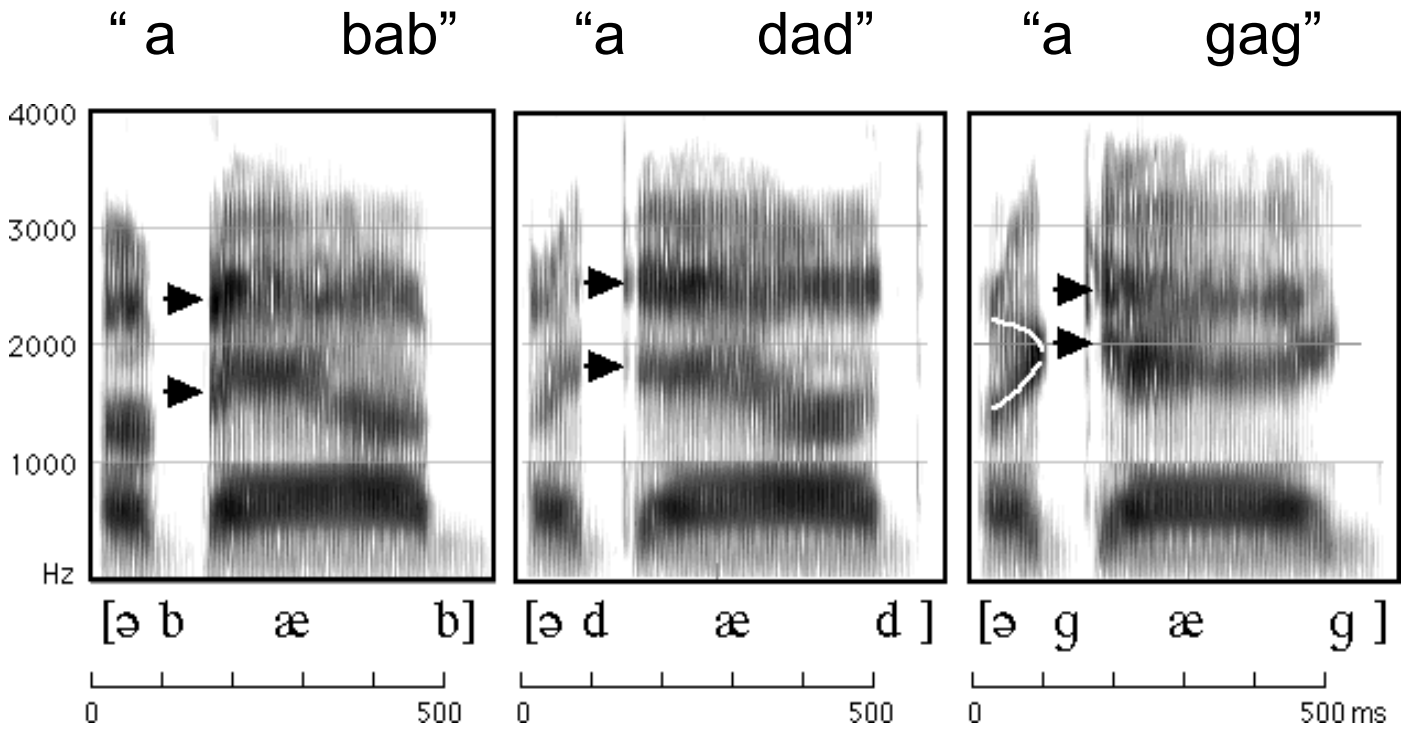
Source-Filter Theory

- Combining the two results in results in spectrum of short vowel ‘ə’ (schwa)



Spectrogram

A spectrogram is a time-frequency-amplitude graph representing sound



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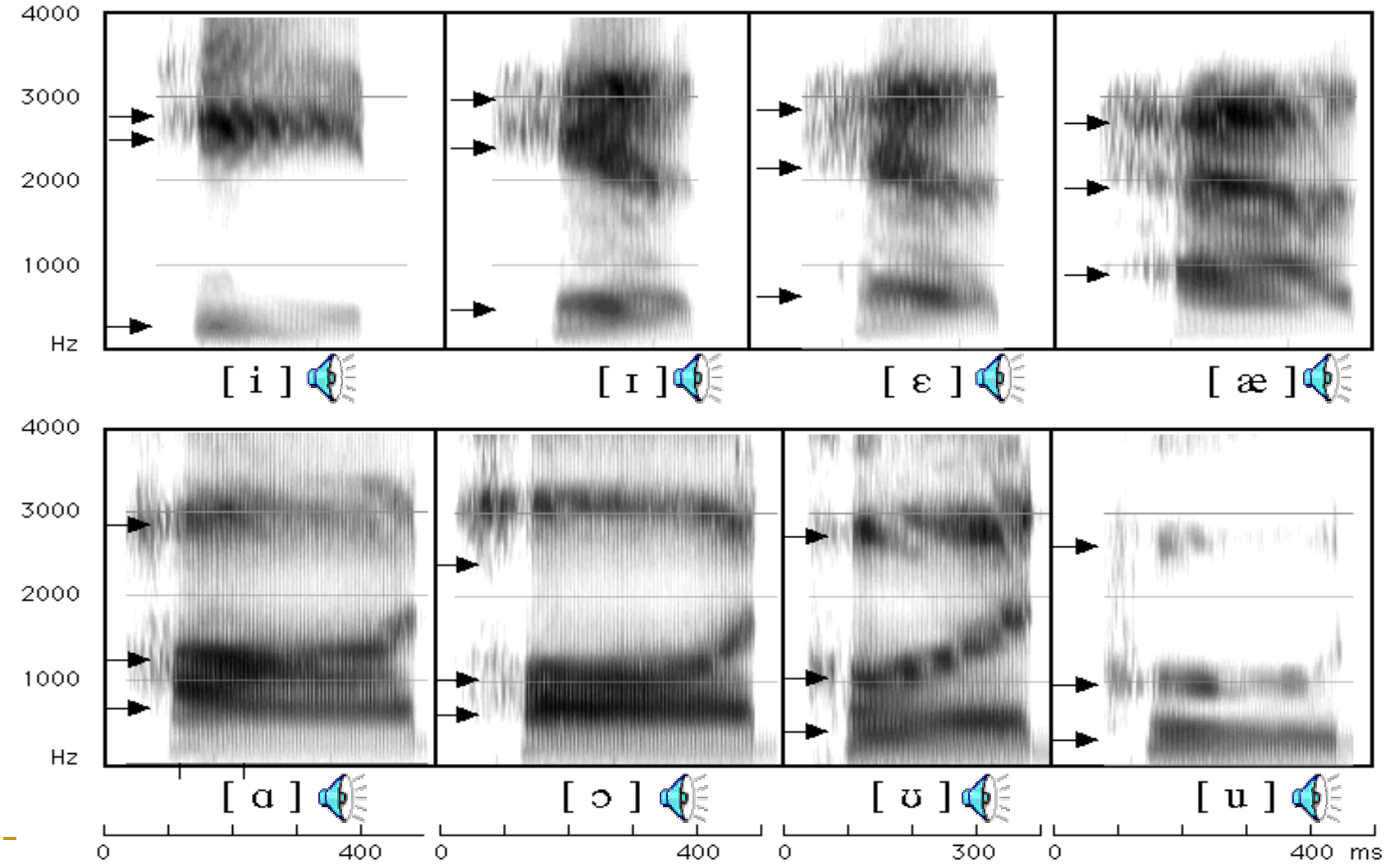
Spectrogram



[16] [17]

What is Phonetics ?

- Study of human speech as a physical phenomenon
  - ✓ Articulation
  - ✓ Acoustics
  - ❑ Perception

Speech Perception

- Acoustic signal is highly variable but perception is very stable (invariant)
- How do map physical variance to perceptual invariance?
  - Intrinsic vs. extrinsic normalization
  - Categorical perception
  - Articulatory Invariance - recreation of articulatory gestures
  - Acoustic Invariance - stable regions in speech within articulatory variability
  - …?

Phonology

What is Phonology?

- Study of how sounds interact in various languages (phonetics → conceptual representation)
  - Segmental phenomena
    - Phonemic Inventory and Allophony
    - Sound-change rules and ordering
  - Supra-segmental phenomena
    - Syllabification
    - Prominence
    - Tones
    - Intonation

Phoneme?

- Mental concept representing a physical sound
- Many to many mapping between phoneme and a phone within a language
- English /t/
  - aspirated in “tunafish”
  - unaspirated in “starfish”
  - dental before labio-dental
  - flapped in “buttercup”

Phonological Features

- Phoneme = set of features that are true at a given time for a particular phonemic unit (phonological features) (Auto-segmental theory)
- Values of features can by unary or binary (+/- for present/absent)

[18]

Phonological Features

- **Contrastive function**:

  Each phoneme differs from others in at least one feature

- **Descriptive function**:

  Accurately describes phonetic nature of a sound (may include redundant, non-contrastive features)

- **Classificatory function**:

  Explains and allows generalizations and common phonological processes

[18]

English Consonant Features

	m	n	ŋ	p	t	k	b	d	g	f	θ	s	ʃ	x	ʍ	h	v	ð	z	ʒ	l	r	w	j
[Consonantal]	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	−	−
[Sonorant]	+	+	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+	+	+	+
[Continuant]	−	−	−	−	−	−	−	−	−	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
[Anterior]	+	+	−	+	+	−	+	+	−	+	+	+	−	−	−	−	+	+	+	−	+	−	−	−
[Coronal]	−	+	−	−	+	−	−	+	−	−	+	+	+	−	−	−	−	+	+	+	+	+	−	−
[Strident]	−	−	−	−	−	−	−	−	−	+	−	+	+	−	−	−	+	−	+	+	−	−	−	−
[Round]	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+	−	−	−	−	−	−	−	+	−
[High]	−	−	+	−	−	+	−	−	+	−	−	−	+	+	+	−	−	−	−	+	−	−	+	+
[Low]	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+	−	−	−	−	−	−	−	−
[Back]	−	−	+	−	−	+	−	−	+	−	−	−	−	−	+	−	−	−	−	−	−	−	+	−
[Tense]	−	−	−	+	+	+	−	−	−	+	+	+	+	−	−	−	−	−	−	−	−	−	−	−
[Voice]	+	+	+	−	−	−	+	+	+	−	−	−	−	−	−	−	+	+	+	+	+	+	+	+
[Nasal]	+	+	+	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−
[Lateral]	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	+	−	−	−

[18]

English Vowel Features

	i	ɪ	u	ʊ	ɛ	ə	ɜ	ʌ	ɑ	a	ɔ	ɒ
[consonantal]	−	−	−	−	−	−	−	−	−	−	−	−
[sonorant]	+	+	+	+	+	+	+	+	+	+	+	+
[continuant]	+	+	+	+	+	+	+	+	+	+	+	+
[back]	−	−	+	+	−	−	−	+	+	−	+	+
[high]	+	+	+	+	−	−	−	−	−	−	−	−
[low]	−	−	−	−	−	−	−	+	+	+	−	+
[round]	−	−	+	+	−	+	+	−	−	−	+	+
[tense]	+	−	+	−	−	−	+	−	+	−	+	−

[18]

Phonological Rules

- Humans are lazy so compromise articulation to reduce effort
- Compromise in Articulation changes the sound
- Constituents of a phonological rules are
  - Phonemes to be modified due to a rule
  - Conditioning context in which the rule has to be fired
  - Change that occurs in a sound after the rule has been fired
- Rules are sometimes ordered in a language

Types of Phonological Rules

- Assimilation
  - Addition of features due to neighboring phonemes

phone book /fonbuk/ ⇒ [fombuk]

n → [+bilabial] / __ [+bilabial, +voiced, +stop]

- Dissimilation
  - Deletion of features due to neighboring phonemes

fifths: /fɪfθs/ ⇒ [fɪfts]

[7]

Types of Phonological Rules

- Insertion / Deletion
  - Addition or deletion of an entire phone

warmth: /wɔrmθ/ ⇒ [wɔrmpθ]

- Metathesis
  - Change order of phonemes

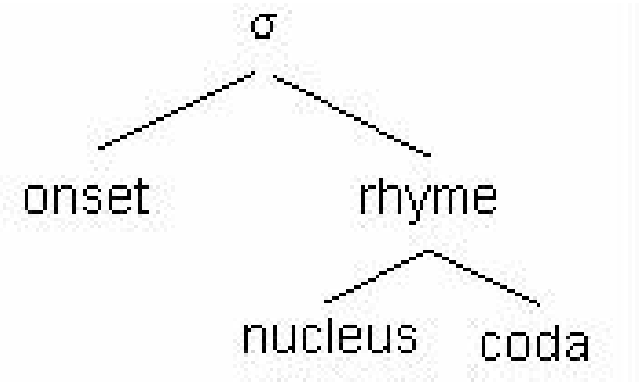
prescribe => perscribe

ask => aks

[7]

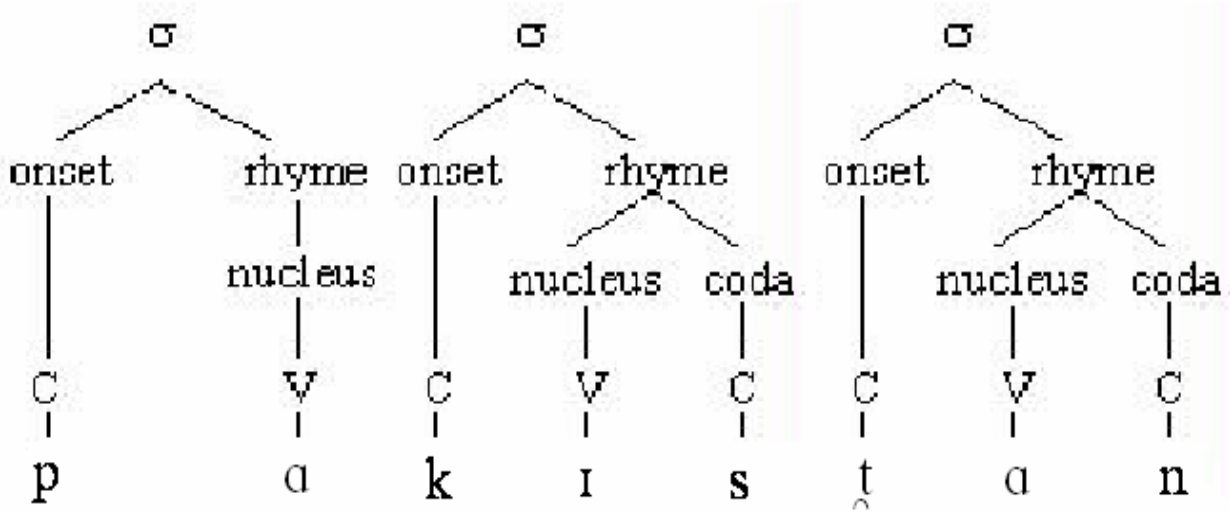
Syllable

- A syllable is a unit of sound composed of
  - A central peak of sonority (usually a vowel), and
  - Consonants that cluster around this central peak



Syllable Structure

Syllable structure of Urdu word پاکستان /pakɪsʈan/



Syllabification

- Syllabification is the process of dividing words into syllables
  - Nuclear Projection
    - Maximal Onset Principle
    - Sonority Sequencing Principle
  - Template based Matching
    - Templates: V, CV, CVC, CVCC
    - Direction of largest template application: RTL, LTR

Prominence

- Syllable(s) in a word may be more prominent than others
- Prominence can change meaning
  - Spanish:
    - *término*, 'end' (noun), *termíno*, 'I'm finishing'
      terminó, 'she/he finished'
  - English
    - 'ob.ject, ob.'ject
    - 'con.tent, con.'tent
- Syllable vs. stress timed languages
  - Final heavy syllable is stressed, no secondary stress
    - Sensitive to segmental "quantity" or moras
  - Every odd syllable is stress, First has primary stress

Intonation

- You are going!
- You are going.
- You are going?

- Intonation carries linguistic meaning, e.g. emotion, intention, etc.
- Realized primarily through variation of F0 over a sentence
- Multiple theories of how intonation is computed and realized, e.g. Pierrehumbert (TOBI), IPO, Fujisaki, etc.

Computational Phonology

- Letter-to-sound rules (?)
  - Regular, heuristic, statistical
- Sound change rules
  - FST
  - Rule base
- Syllabification algorithm
  - Template or sonority based algorithm
- Stress-assignment algorithm
  - Stress-assignment algorithm
- Intonation assignment algorithm
  - Rule-based algorithm – based on syntactic parse (?)
  - Corpus based (Machine Learning) algorithm
  - Other corpus based approaches

Thank you

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