Advanced Language Technologies

Module "Knowledge Technologies"
Jožef Stefan International Postgraduate School
Winter 2010 / Spring 200p

Lecture I.
Introduction to Language Technologies

Tomaž Erjavec

Technicalities

- Lecturer: http://nl.ijs.si/et/
  tomaz.erjavec@ijs.si

- Work: language resources for Slovene, linguistic annotation, standards, digital libraries
- Course homepage:
  http://nl.ijs.si/et/teach/mps10-hlt/
- Assesment: seminar work
  ½ quality of work, ½ quality of report
- Next lecture: May 12th
  - Presentation on topics we are working on at JSI
  - Possible seminar topics

Overview of the lecture

1. Computer processing of natural language
2. Some history
3. Applications
4. Levels of linguistic analysis

I. Computer processing of natural language

- Computational Linguistics:
  - a branch of computer science, that attempts to model the cognitive faculty of humans that enables us to produce/understand language
- Natural Language Processing:
  - a subfield of CL, dealing with specific computational methods to process language
- Human Language Technologies:
  - (the development of) useful programs to process language

Languages and computers

How do computers "understand" language?

(written) language is, for a computer, merely a sequence of characters (*strings*)

1. Tokenisation – splitting of text into tokens (words):
   - words are separated by spaces
   - words are separated by spaces or punctuation
   - words are separated by spaces or punctuation and space
   - *[2,3H]dexamethasone, $4.000.00, pre- and post-natal, etc.*

Problems

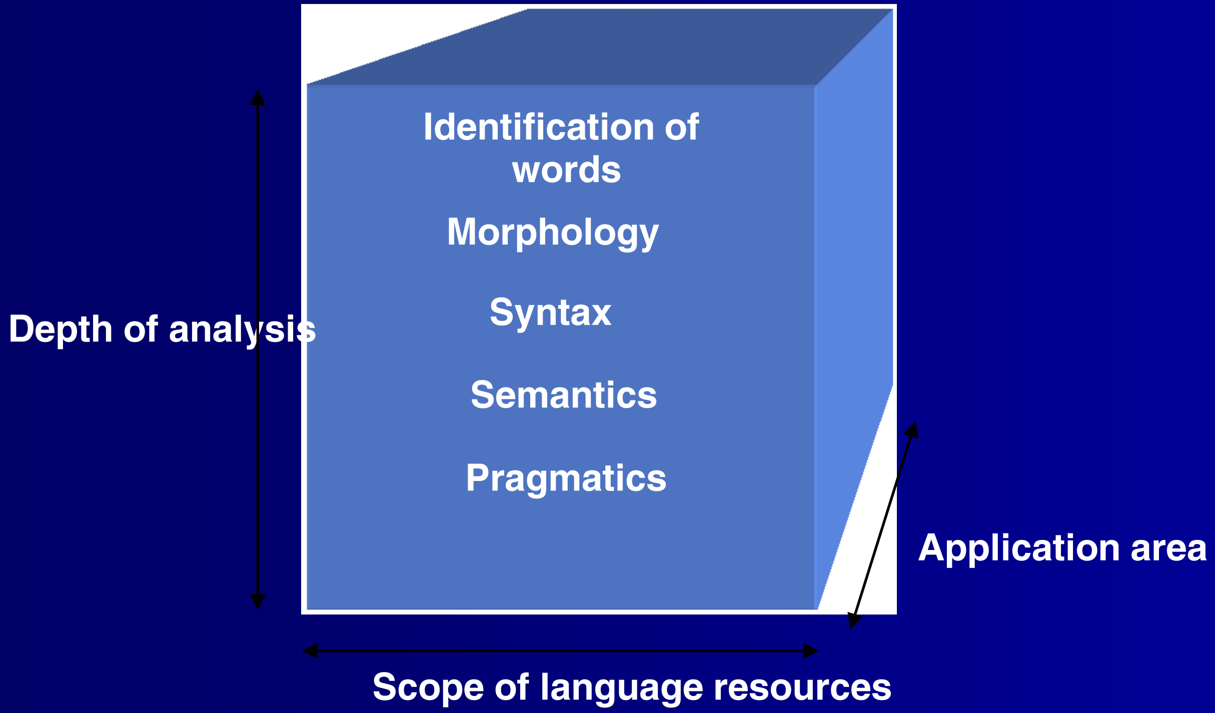
Languages have properties that humans find easy to process, but are very problematic for computers

- Ambiguity: many words, syntactic constructions, etc. have more than one interpretation
- Vagueness: many linguistic features are left implicit in the text
- Paraphrases: many concepts can be expressed in different ways

Humans use context and background knowledge; both are difficult for computers

- Time flies like an arrow.
- I saw the spy with the binoculars. He left the bank at 3 p.m.

The dimensions of the problem



Many applications require only a shallow level of analysis

Structuralist and empiricist views on language

- The structuralist approach:
  - Language is a limited and orderly system based on rules.
  - Automatic processing of language is possible with rules
  - Rules are written in accordance with language intuition
- The empirical approach:
  - Language is the sum total of all its manifestations
  - Generalisations are possible only on the basis of large collections of language data, which serve as a sample of the language (*corpora*)
  - Machine Learning: "*data-driven automatic inference of rules*"

Other names for the two approaches

- Rationalism vs. empiricism
- Competence vs. performance
- Deductive vs. Inductive:
  - Deductive method: from the general to specific; rules are derived from axioms and principles; verification of rules by observations
  - Inductive method: from the specific to the general; rules are derived from specific observations; falsification of rules by observations

Empirical approach

- Describing naturally occurring language data
- Objective (reproducible) statements about language
- Quantitative analysis: common patterns in language use
- Creation of robust tools by applying statistical and machine learning approaches to large amounts of language data
- Basis for empirical approach: corpora
- Empirical turn supported by rise in processing speed and storage, and the revolution in the availability of machine-readable texts (WWW)

II. The history of Computational Linguistics

- MT, empiricism (1950-70)
- Structuralism: generative linguistics (70-90)
- Data fights back (80-00)
- A happy marriage?
- The promise of the Web

The early years

- The promise (and need!) for machine translation
- The decade of optimism: 1954-1966
- *The spirit is willing but the flesh is weak ≠*
  The vodka is good but the meat is rotten
- ALPAC report 1966:
  no further investment in MT research; instead development of machine aids for translators, such as automatic dictionaries, and the continued support of basic research in computational linguistics
- also quantitative language (text/author) investigations

The Generative Paradigm

Noam Chomsky’s Transformational grammar: *Syntactic Structures* (1957)

Two levels of representation of the structure of sentences:

- an underlying, more abstract form, termed 'deep structure',
- the actual form of the sentence produced, called 'surface structure'.

Deep structure is represented in the form of a hierarchical tree diagram, or "phrase structure tree," depicting the abstract grammatical relationships between the words and phrases within a sentence.

A system of formal rules specifies how deep structures are to be transformed into surface structures.

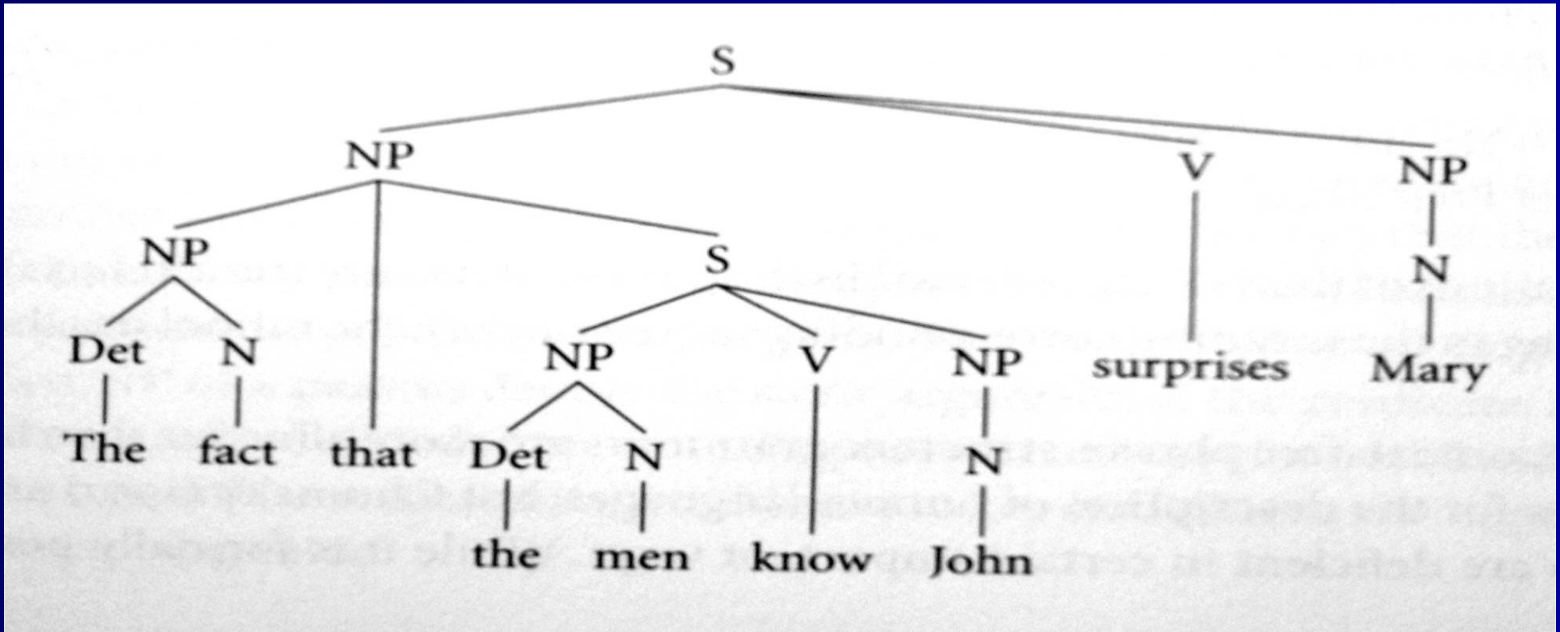
Phrase structure rules and derivation trees

S → NP V NP

NP → N

NP → Det N

NP → NP that S



Characteristics of generative grammar

- Research mostly in syntax, but also phonology, morphology and semantics (as well as language development, cognitive linguistics)
- Cognitive modelling and generative capacity; search for linguistic universals
- First strict formal specifications (at first), but problems of overpremissivness
- Chomsky's Development: Transformational Grammar (1957, 1964), …, Government and Binding/Principles and Parameters (1981), Minimalism (1995)

Computational linguistics

- Focus in the 70’s is on cognitive simulation (with long term practical prospects..)
- The applied branch of CompLing is called *Natural Language Processing*
- Initially following Chomsky’s theory + developing efficient methods for parsing
- Early 80’s: unification based grammars (artificial intelligence, logic programming, constraint satisfaction, inheritance reasoning, object oriented programming,..)

Problems

Disadvantage of rule-based (deep-knowledge) systems:

- Coverage (lexicon)
- Robustness (ill-formed input)
- Speed (polynomial complexity)
- Preferences (the problem of ambiguity: "*Time flies like an arrow*")
- Applicability?
  (more useful to know what is the name of a company than to know the deep parse of a sentence)
- EUROTRA and VERBMOBIL: success or disaster?

Back to data

- Late 1980’s: applied methods based on data (language resources)
- The increasing role of the lexicon
- (Re)emergence of corpora
- 90’s: Human language technologies
- Data-driven shallow (knowledge-poor) methods
- Inductive approaches, esp. statistical ones (PoS tagging, collocation identification)
- Importance of evaluation (resources, methods)

The new millennium

The emergence of the Web:

- Large and getting larger
- Multilinguality
- Simple to access, but hard to digest → Semantic Web

The promise of mobile, ‘invisible’ interfaces; HLT in the role of middle-ware

III. HLT applications

- Speech technologies
- Machine translation
- Question answering
- Information retrieval and extraction
- Text summarisation
- Text mining
- Dialogue systems
- Multimodal and multimedia systems

- Computer assisted:
  authoring; language learning; translating; lexicology; language research

More HLT applications

- Corpus tools
  - concordance software
  - tools for statistical analysis of corpora
  - tools for compiling corpora
  - tools for aligning corpora
  - tools for annotating corpora
- Translation tools
  - programs for terminology databases
  - translation memory programs
  - machine translation

Speech technologies

- speech synthesis
- speech recognition
- speaker verification

- spoken dialogue systems
- speech-to-speech translation
- speech prosody: emotional speech
- audio-visual speech (talking heads)

Machine translation

Perfect MT would require the problem of NL understanding to be solved first!

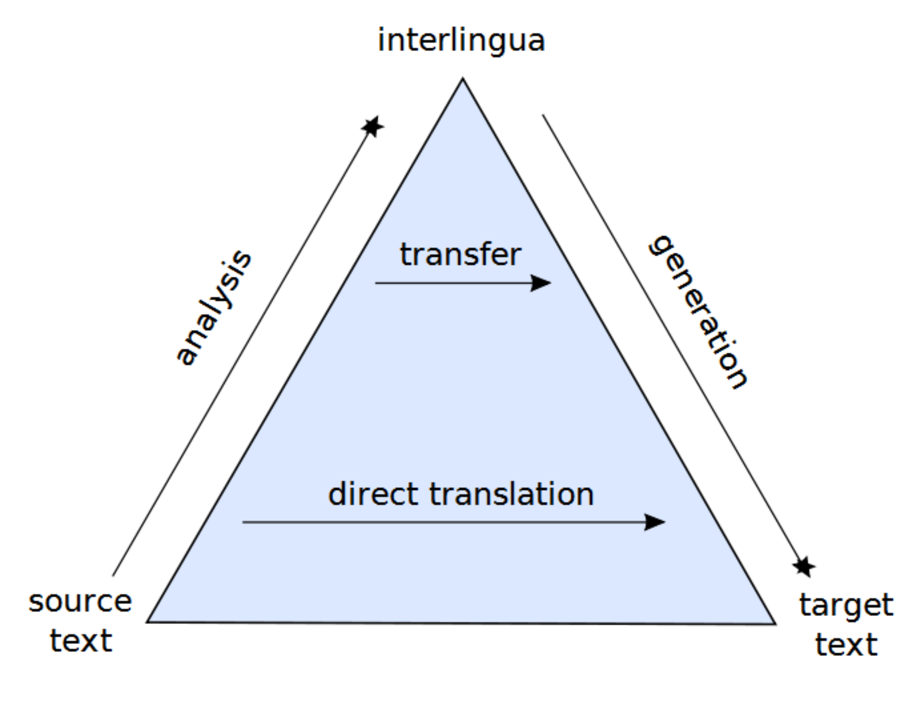
Types of MT:

- Fully automatic MT (Google translate, babel fish)
- Human-aided MT (pre and post-processing)
- Machine aided HT (translation memories)

Problem of evaluation:

- automatic (BLEU, METEOR)
- manual (expensive!)

Rule based MT



- Analysis and generation rules + lexicons
- Altavista: babel fish
- Problems:
  very expensive to develop, difficult to debug, gaps in knowledge
- Option for closely related langauges

Statistical MT

- Parallel corpora:
  text in original language + translation
- Texts are first aligned by sentences
- On the basis of parallel corpora only: induce statistical model of translation
- Noisy channel model, introduced by researchers working at IBM:
  very influential approach
- Now used in Google translate
- Difficult getting enough parallel text

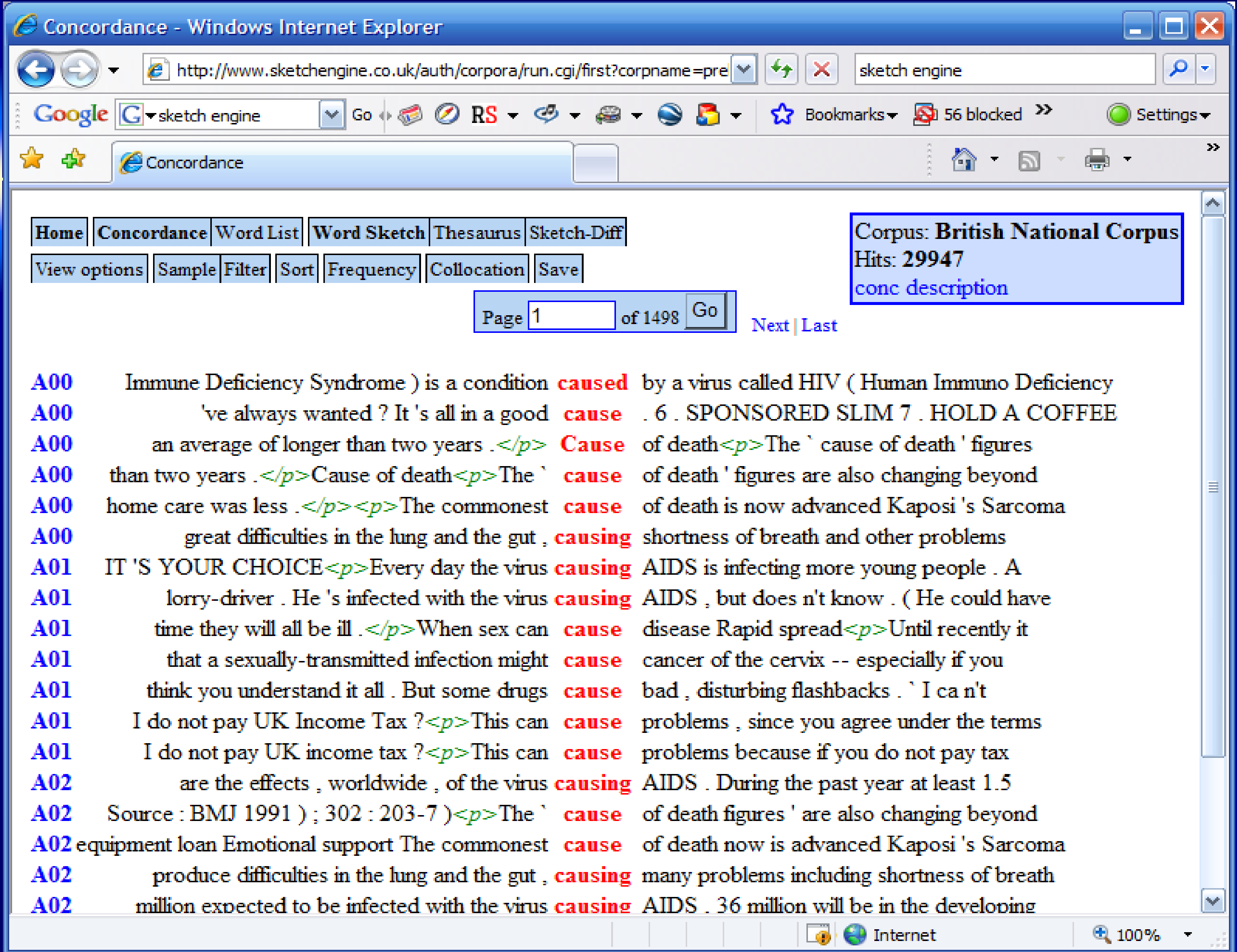
Information retrieval and extraction

- **Information retrieval** (**IR**)
  searching for documents, for information within documents and for metadata about documents.
  - "bag of words" approach
- **Information extraction** (**IE**)
  a type of IR whose goal is to automatically extract structured information, i.e. categorized and contextually and semantically well-defined data from a certain domain, from unstructured machine-readable documents.
- Related area: **Named Entity Recognition**
  - identify names, dates, numeric expression in text

Corpus linguistics

- Large collection of texts, uniformly encoded and chosen according to linguistic criteria = **corpus**
- Corpora can be (manually, automatically) annotated with linguistic information (e.g. PoS, lemma)
- Used as datasets for
  - linguistic investigations (lexicography!)
  - traning or testing of programs

Concordances



Corpus: **British National Corpus**
Hits: **29947**

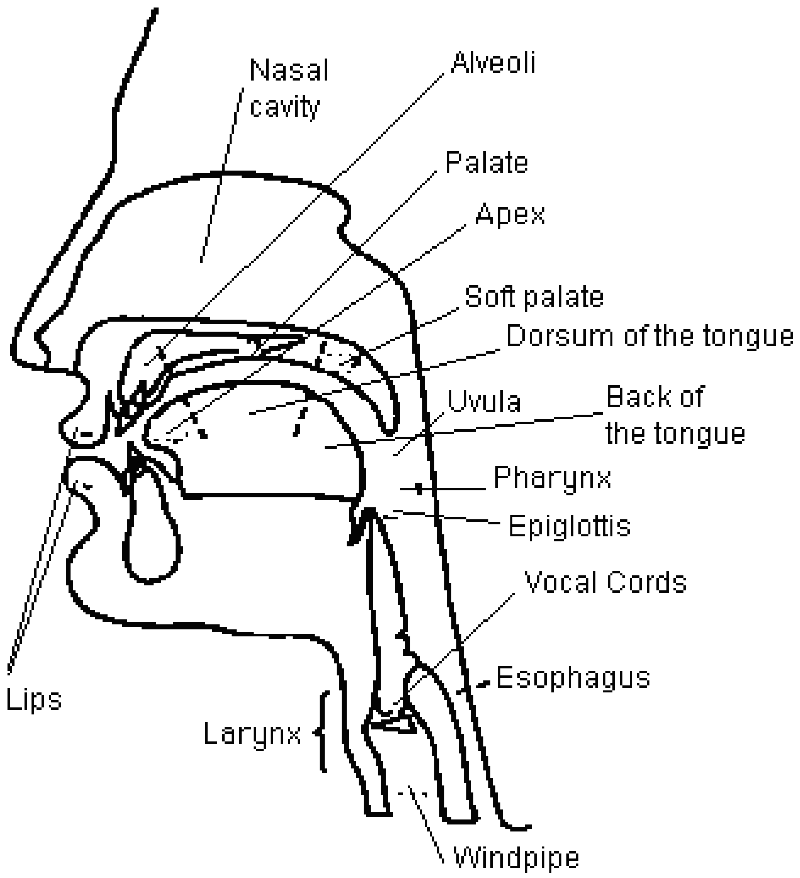
A00	Immune Deficiency Syndrome) is a condition	caused	by a virus called HIV (Human Immuno Deficiency
A00	've always wanted ? It 's all in a good	cause	. 6 . SPONSORED SLIM 7 . HOLD A COFFEE
A00	an average of longer than two years .</p>	Cause	of death<p>The ` cause of death ' figures
A00	than two years .</p>Cause of death<p>The `	cause	of death ' figures are also changing beyond
A00	home care was less .</p><p>The commonest	cause	of death is now advanced Kaposi 's Sarcoma
A00	great difficulties in the lung and the gut ,	causing	shortness of breath and other problems
A01	IT 'S YOUR CHOICE<p>Every day the virus	causing	AIDS is infecting more young people . A
A01	lorry-driver . He 's infected with the virus	causing	AIDS , but does n't know . (He could have
A01	time they will all be ill .</p>When sex can	cause	disease Rapid spread<p>Until recently it
A01	that a sexually-transmitted infection might	cause	cancer of the cervix -- especially if you
A01	think you understand it all . But some drugs	cause	bad , disturbing flashbacks . ` I ca n't
A01	I do not pay UK Income Tax ?<p>This can	cause	problems , since you agree under the terms
A01	I do not pay UK income tax ?<p>This can	cause	problems because if you do not pay tax
A02	are the effects , worldwide , of the virus	causing	AIDS . During the past year at least 1.5
A02	Source : BMJ 1991) ; 302 : 203-7)<p>The `	cause	of death figures ' are also changing beyond
A02	equipment loan Emotional support The commonest	cause	of death now is advanced Kaposi 's Sarcoma
A02	produce difficulties in the lung and the gut ,	causing	many problems including shortness of breath
A02	million expected to be infected with the virus	causing	AIDS . 36 million will be in the developing

IV. Levels of linguistic analysis

- Phonetics
- Phonology
- Morphology
- Syntax
- Semantics
- Discourse analysis
- Pragmatics
- + Lexicology

Phonetics

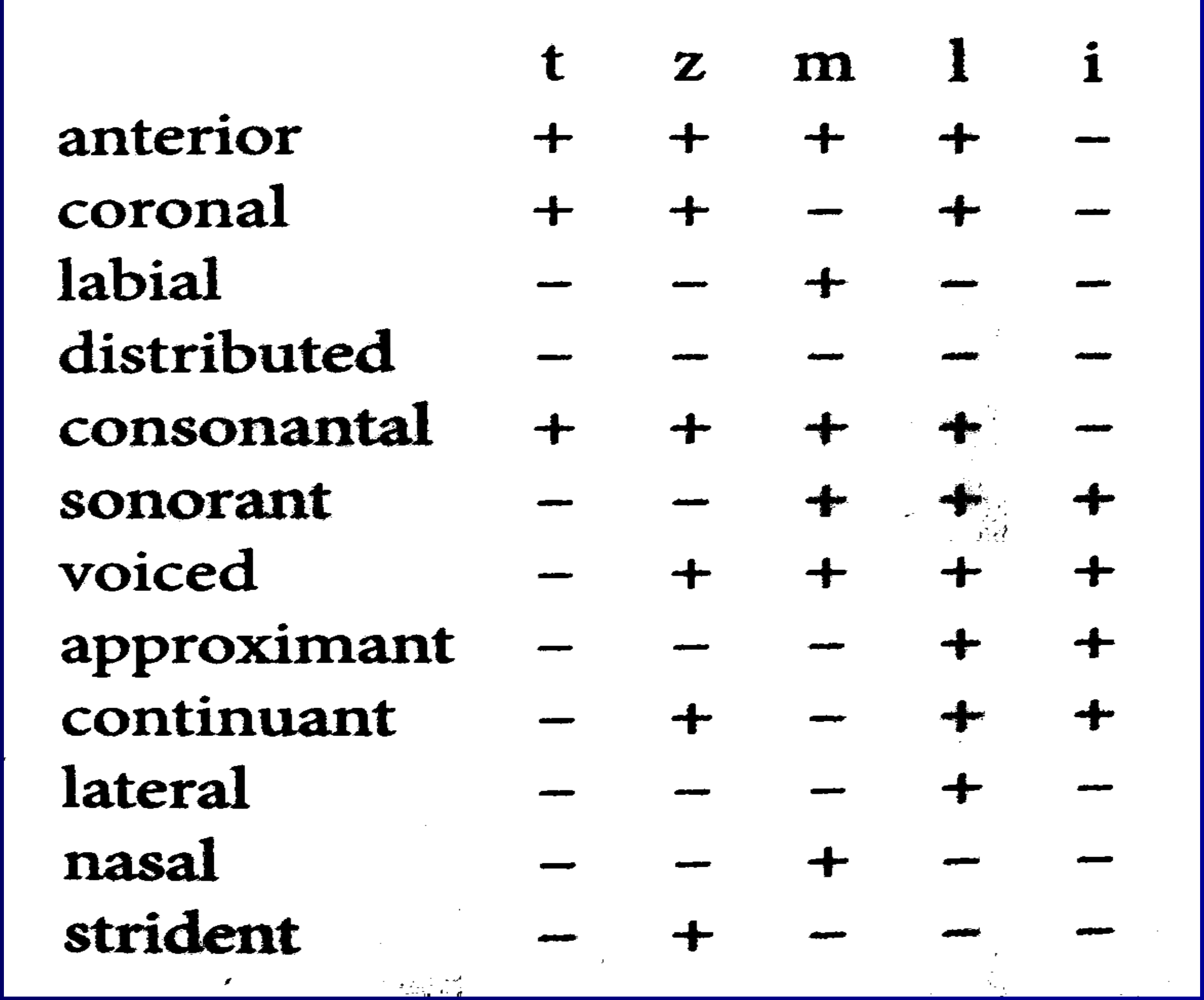
- Studies how sounds are produced; methods for description, classification, transcription
- Articulatory phonetics (how sounds are made)
- Acoustic phonetics (physical properties of speech sounds)
- Auditory phonetics (perceptual response to speech sounds)



Phonology

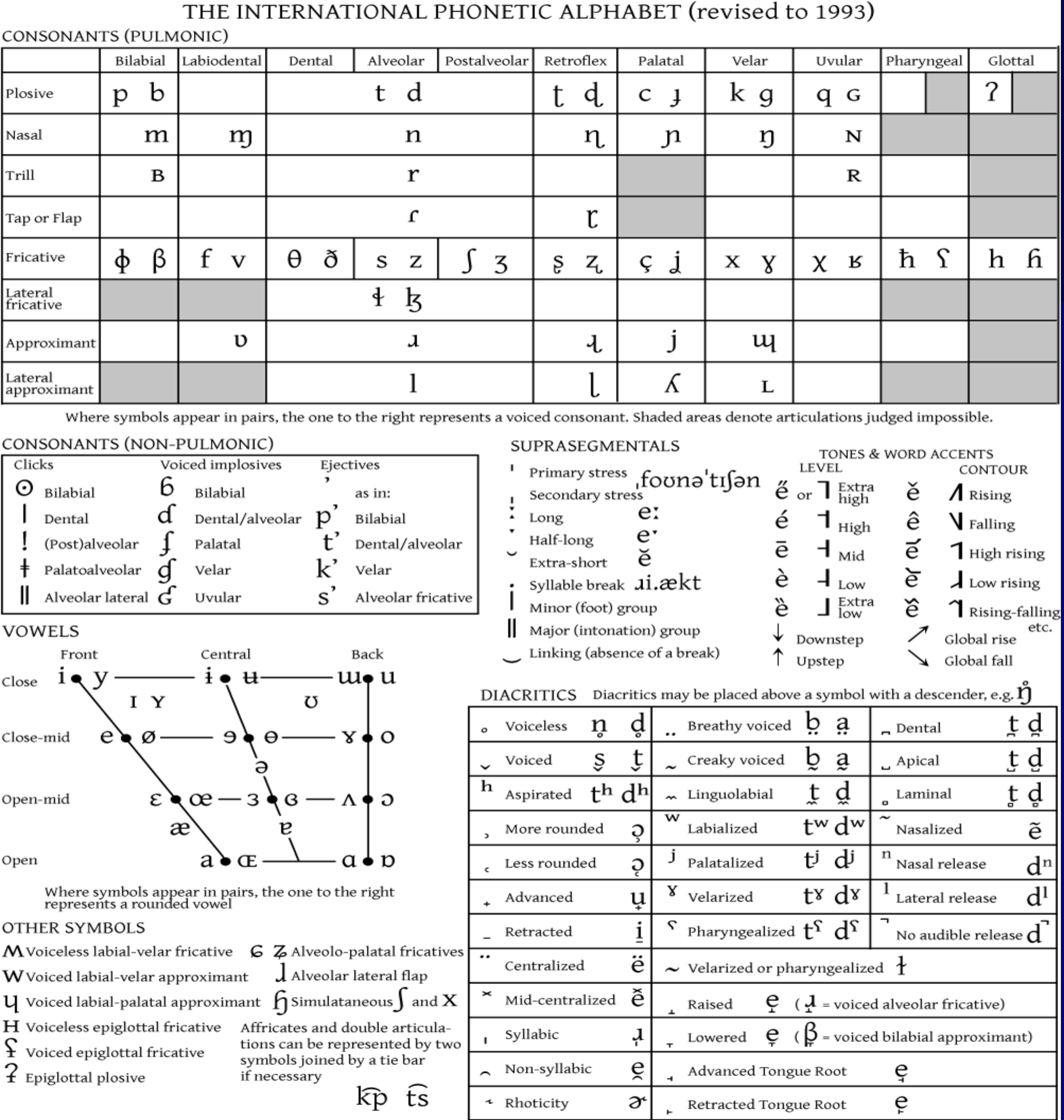
- Studies the sound systems of a language (of all the sounds humans can produce, only a small number are used distinctively in one language)
- The sounds are organised in a system of contrasts; can be analysed e.g. in terms of *phonemes* or *distinctive features*

Distinctive features



	t	z	m	l	i
anterior	+	+	+	+	−
coronal	+	+	−	+	−
labial	−	−	+	−	−
distributed	−	−	−	−	−
consonantal	+	+	+	+	−
sonorant	−	−	+	+	+
voiced	−	+	+	+	+
approximant	−	−	−	+	+
continuant	−	+	−	+	+
lateral	−	−	−	+	−
nasal	−	−	+	−	−
strident	−	+	−	−	−

I P A



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 ɡ	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.

CONSONANTS (NON-PULMONIC)

Clicks		Voiced implosives		Ejectives	
ʘ	Bilabial	ɓ	Bilabial	ʼ	as in:
ǀ	Dental	ɗ	Dental/alveolar	pʼ	Bilabial
ǃ	(Post)alveolar	ʄ	Palatal	tʼ	Dental/alveolar
ǂ	Palatoalveolar	ɠ	Velar	kʼ	Velar
ǁ	Alveolar lateral	ʛ	Uvular	sʼ	Alveolar fricative

VOWELS

	Front		Central		Back
Close	i • y		ɨ • ʉ		ɯ • u
		ɪ ʏ		ʊ	
Close-mid	e • ø		ɘ • ɵ		ɤ • o
			ə		
Open-mid		ɛ • œ	ɜ • ɞ		ʌ • ɔ
		æ	ɐ		
Open			a • ɶ		ɑ • ɒ

Where symbols appear in pairs, the one to the right represents a rounded vowel

OTHER SYMBOLS

ʍ Voiceless labial-velar fricative

w Voiced labial-velar approximant

ɥ Voiced labial-palatal approximant

ʜ Voiceless epiglottal fricative

ʢ Voiced epiglottal fricative

ʡ Epiglottal plosive

ɕ ʑ Alveolo-palatal fricatives

ɺ Alveolar lateral flap

ɧ Simulataneous ʃ and x

Affricates and double articulations can be represented by two symbols joined by a tie bar if necessary

k͡p t͡s

SUPRASEGMENTALS

ˈ	Primary stress	ˌfoʊnəˈtɪʃən
ˌ	Secondary stress	
ː	Long	eː
ˑ	Half-long	eˑ
˘	Extra-short	ĕ
.	Syllable break	ɹi.ækt
|	Minor (foot) group	
‖	Major (intonation) group	
‿	Linking (absence of a break)	

TONES & WORD ACCENTS

LEVEL			CONTOUR		
e̋ or	˥	Extra high	ě	˩˥	Rising
é	˦	High	ê	˥˩	Falling
ē	˧	Mid	e᷄	˦˥	High rising
è	˨	Low	e᷅	˩˨	Low rising
ȅ	˩	Extra low	e᷈	˧˦˧	Rising-falling
ꜜ		Downstep	↗		Global rise
ꜛ		Upstep	↘		Global fall

etc.

DIACRITICS

Diacritics may be placed above a symbol with a descender, e.g. ŋ̊

̥	Voiceless	n̥ d̥	̤	Breathy voiced	b̤ a̤	̪	Dental	t̪ d̪
̬	Voiced	s̬ t̬	̰	Creaky voiced	b̰ a̰	̺	Apical	t̺ d̺
ʰ	Aspirated	tʰ dʰ	̼	Linguolabial	t̼ d̼	̻	Laminal	t̻ d̻
̹	More rounded	ɔ̹	ʷ	Labialized	tʷ dʷ	̃	Nasalized	ẽ
̜	Less rounded	ɔ̜	ʲ	Palatalized	tʲ dʲ	ⁿ	Nasal release	dⁿ
̟	Advanced	u̟	ˠ	Velarized	tˠ dˠ	ˡ	Lateral release	dˡ
̠	Retracted	i̠	ˤ	Pharyngealized	tˤ dˤ	̚	No audible release	d̚
̈	Centralized	ë	̴	Velarized or pharyngealized ɫ				
̽	Mid-centralized	e̽	̝	Raised	e̝ (ɹ̝ = voiced alveolar fricative)			
̩	Syllabic	ɹ̩	̞	Lowered	e̞ (β̞ = voiced bilabial approximant)			
̯	Non-syllabic	e̯	̘	Advanced Tongue Root	e̘			
˞	Rhoticity	ɚ	̙	Retracted Tongue Root	e̙			

Morphology

- Studies the structure and form of words
- Basic unit of meaning: *morpheme*
- Morphemes pair meaning with form, and combine to make words:
  e.g. *dogs* → *dog/DOG,Noun + -s/plural*
- Process complicated by exceptions and mutations
- Morphology as the interface between phonology and syntax (and the lexicon)

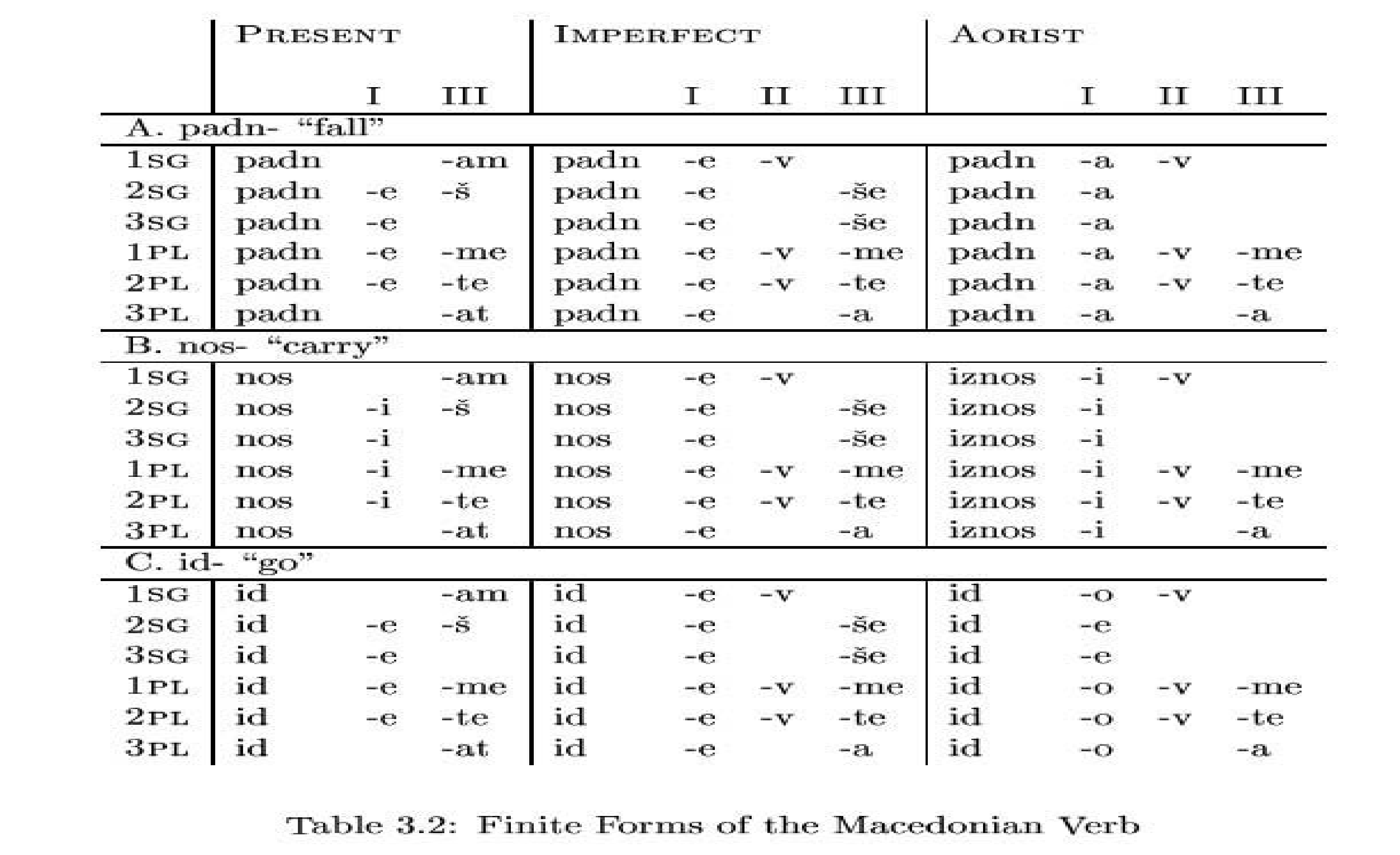
Types of morphological processes

- Inflection (syntax-driven):
  run, runs, running, ran
  gledati, gledam, gleda, glej, gledal,...
- Derivation (word-formation):
  to run, a run, runny, runner, re-run, ...
  gledati, zagledati, pogledati, pogled, ogledalo,...
- Compounding (word-formation):
  zvezdogled,
  Herzkreislaufwiederbelebung

Inflectional Morphology

- Mapping of form to (syntactic) function
- *dogs* → *dog + s* / DOG [N,pl]
- In search of regularities: *talk/walk; talks/walks; talked/walked; talking/walking*
- Exceptions: *take/took, wolf/wolves, sheep/sheep*
- English (relatively) simple; inflection much richer in e.g. Slavic languages

Macedonian verb paradigm



	PRESENT			IMPERFECT				AORIST			
		I	III		I	II	III		I	II	III
A. padn- “fall”											
1SG	padn		-am	padn	-e	-v		padn	-a	-v	
2SG	padn	-e	-š	padn	-e		-še	padn	-a		
3SG	padn	-e		padn	-e		-še	padn	-a		
1PL	padn	-e	-me	padn	-e	-v	-me	padn	-a	-v	-me
2PL	padn	-e	-te	padn	-e	-v	-te	padn	-a	-v	-te
3PL	padn		-at	padn	-e		-a	padn	-a		-a
B. nos- “carry”											
1SG	nos		-am	nos	-e	-v		iznos	-i	-v	
2SG	nos	-i	-š	nos	-e		-še	iznos	-i		
3SG	nos	-i		nos	-e		-še	iznos	-i		
1PL	nos	-i	-me	nos	-e	-v	-me	iznos	-i	-v	-me
2PL	nos	-i	-te	nos	-e	-v	-te	iznos	-i	-v	-te
3PL	nos		-at	nos	-e		-a	iznos	-i		-a
C. id- “go”											
1SG	id		-am	id	-e	-v		id	-o	-v	
2SG	id	-e	-š	id	-e		-še	id	-e		
3SG	id	-e		id	-e		-še	id	-e		
1PL	id	-e	-me	id	-e	-v	-me	id	-o	-v	-me
2PL	id	-e	-te	id	-e	-v	-te	id	-o	-v	-te
3PL	id		-at	id	-e		-a	id	-o		-a

Table 3.2: Finite Forms of the Macedonian Verb

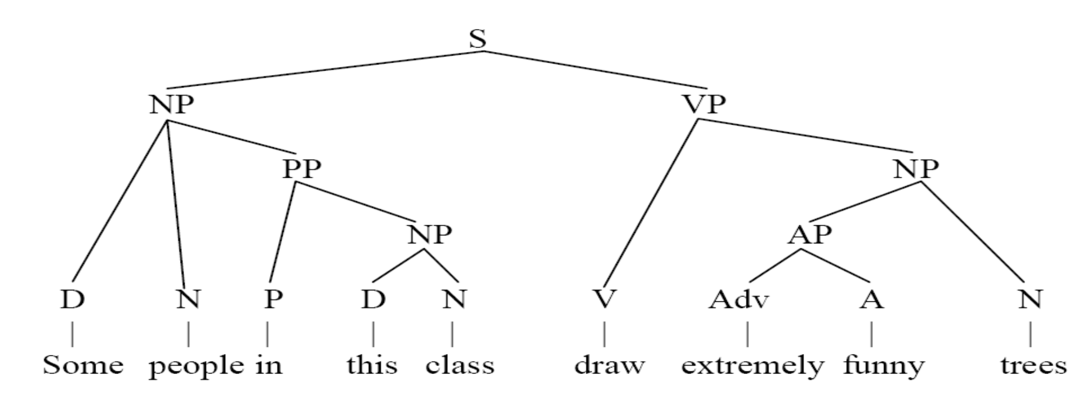
Syntax

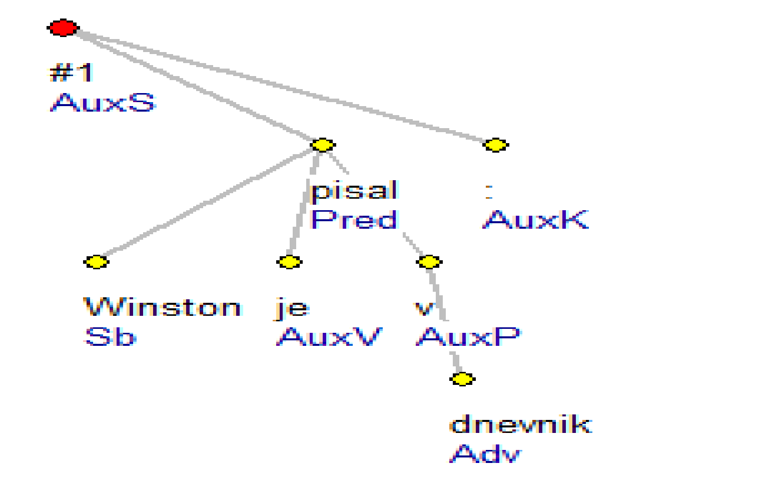
- How are words arranged to form sentences?
  **I milk like*
  I saw the man on the hill with a telescope.
- The study of rules which reveal the structure of sentences (typically tree-based)
- A "pre-processing step" for semantic analysis
- Common terms:
  Subject, Predicate, Object,
  Verb phrase, Noun phrase, Prepositional phr.,
  Head, Complement, Adjunct,…

Syntactic theories

- Transformational Syntax
  N. Chomsky: TG, GB, Minimalism
- Distinguishes two levels of structure: deep and surface; rules mediate between the two
- Logic and Unification based approaches ('80s) : FUG, TAG, GPSG, HPSG, …
- Phrase based vs. dependency based approaches

Example of a phrase structure and a dependency tree





Semantics

- The study of *meaning* in language
- Very old discipline, esp. philosophical semantics (Plato, Aristotle)
- Under which conditions are statements true or false; problems of quantification
- The meaning of words – lexical semantics
  spinster = unmarried female → **my brother is a spinster*

Discourse analysis and Pragmatics

- Discourse analysis: the study of connected sentences – behavioural units (anaphora, cohesion, connectivity)
- Pragmatics: language from the point of view of the users (choices, constraints, effect; pragmatic competence; speech acts; presupposition)
- Dialogue studies (turn taking, task orientation)

Lexicology

- The study of the vocabulary (lexis / lexemes) of a language (a lexical “entry” can describe less or more than one word)
- Lexica can contain a variety of information: sound, pronunciation, spelling, syntactic behaviour, definition, examples, translations, related words
- Dictionaries, mental lexicon, digital lexica
- Plays an increasingly important role in theories and computer applications
- Ontologies: WordNet, Semantic Web

HLT research fields

- **Phonetics and phonology**: speech synthesis and recognition
- **Morphology**: morphological analysis, part-of-speech tagging, lemmatisation, recognition of unknown words
- **Syntax**: determining the constituent parts of a sentence (NP, VP) and their syntactic function (Subject, Predicate, Object)
- **Semantics**: word-sense disambiguation, automatic induction of semantic resources (thesauri, ontologies)
- **Multiulingual technologies**: extracting translation equivalents from corpora, machine translation
- **Internet**: information extraction, text mining, advanced search engines

Further reading

- Language Technology World
  http://www.lt-world.org/
- The Association for Computational Linguistics
  http://www.aclweb.org/ (c.f. Resources)
- Natural Language Processing – course materials
  http://www.cs.cornell.edu/Courses/cs674/2003sp/