Computational Phonology

Markedness – Defaults – Optimality

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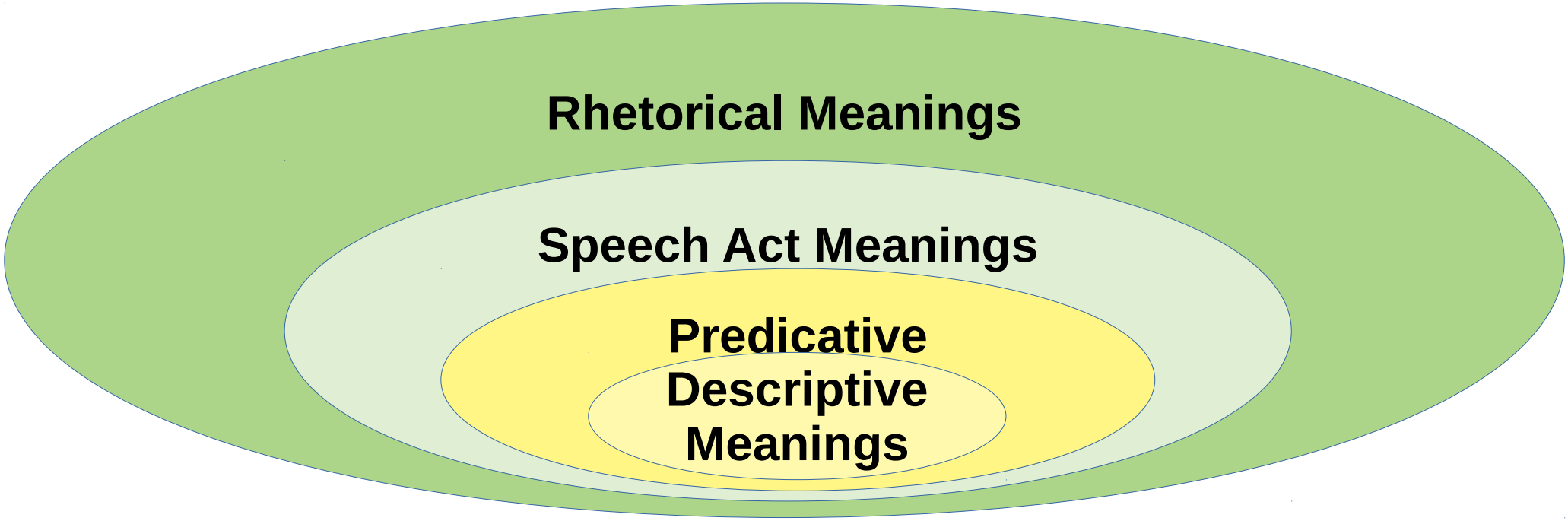
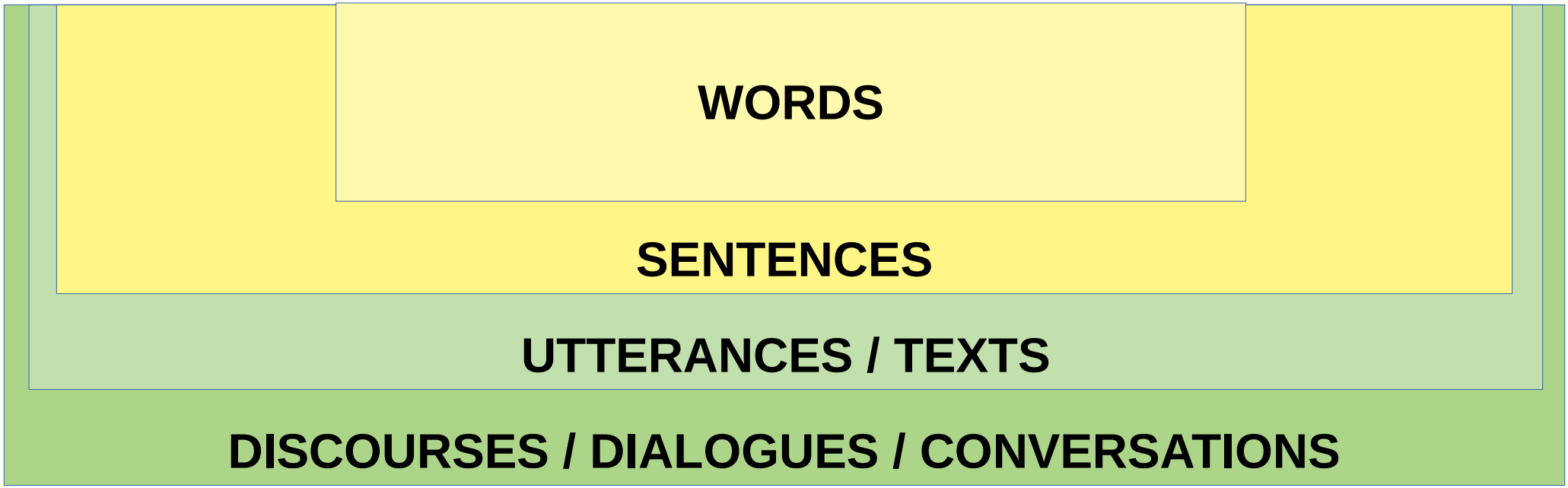
Background: Prosody in Communication

- Semiotics: the study of signs and their meanings
  - Index: signifies something with a particular time, place or cause
  - Icon: signifies something which is similar to itself
  - Symbol: signifies something which is independent of its appearance, place, time or causal influence

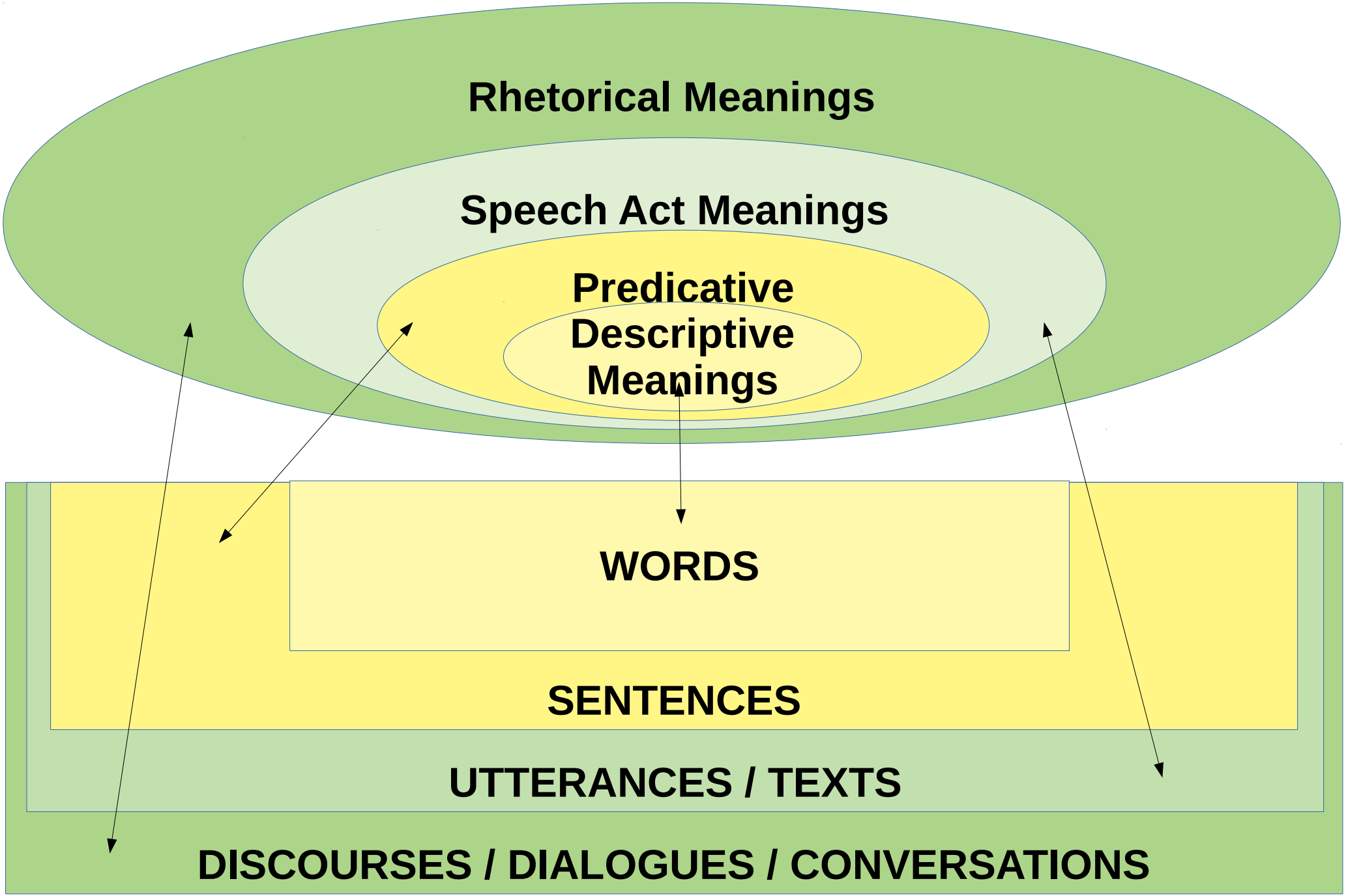
Kinds of Meanings to Communicate



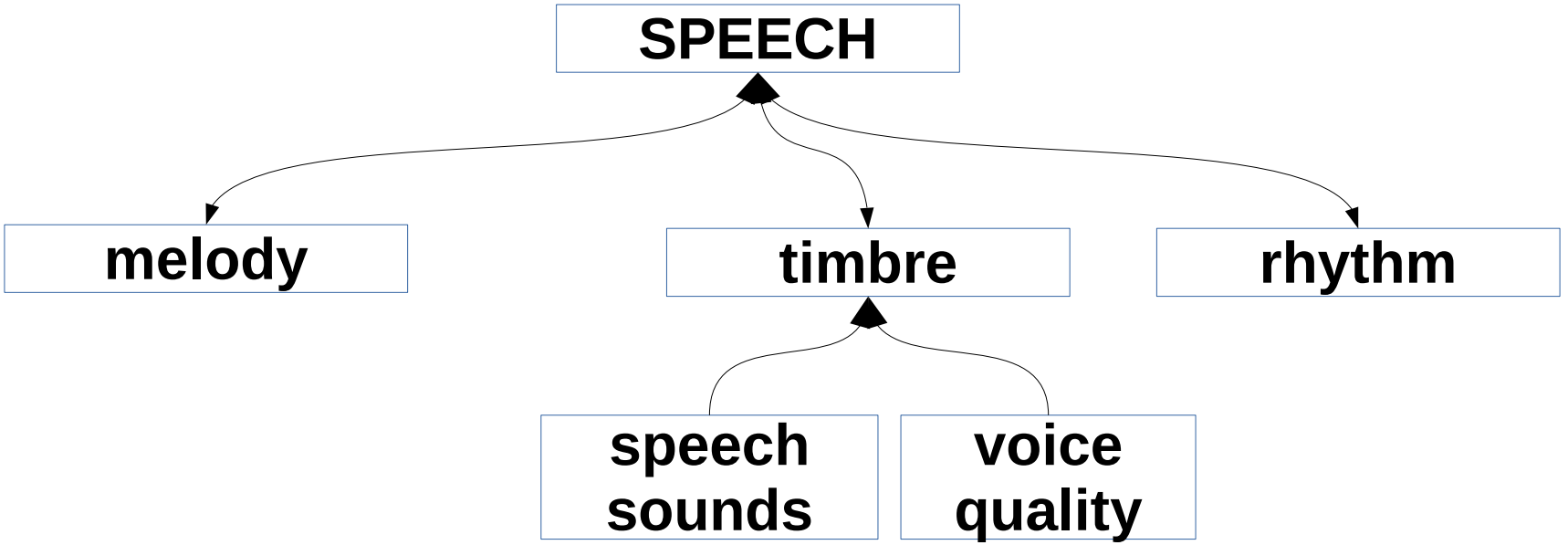
Kinds of Symbols to Communicate with

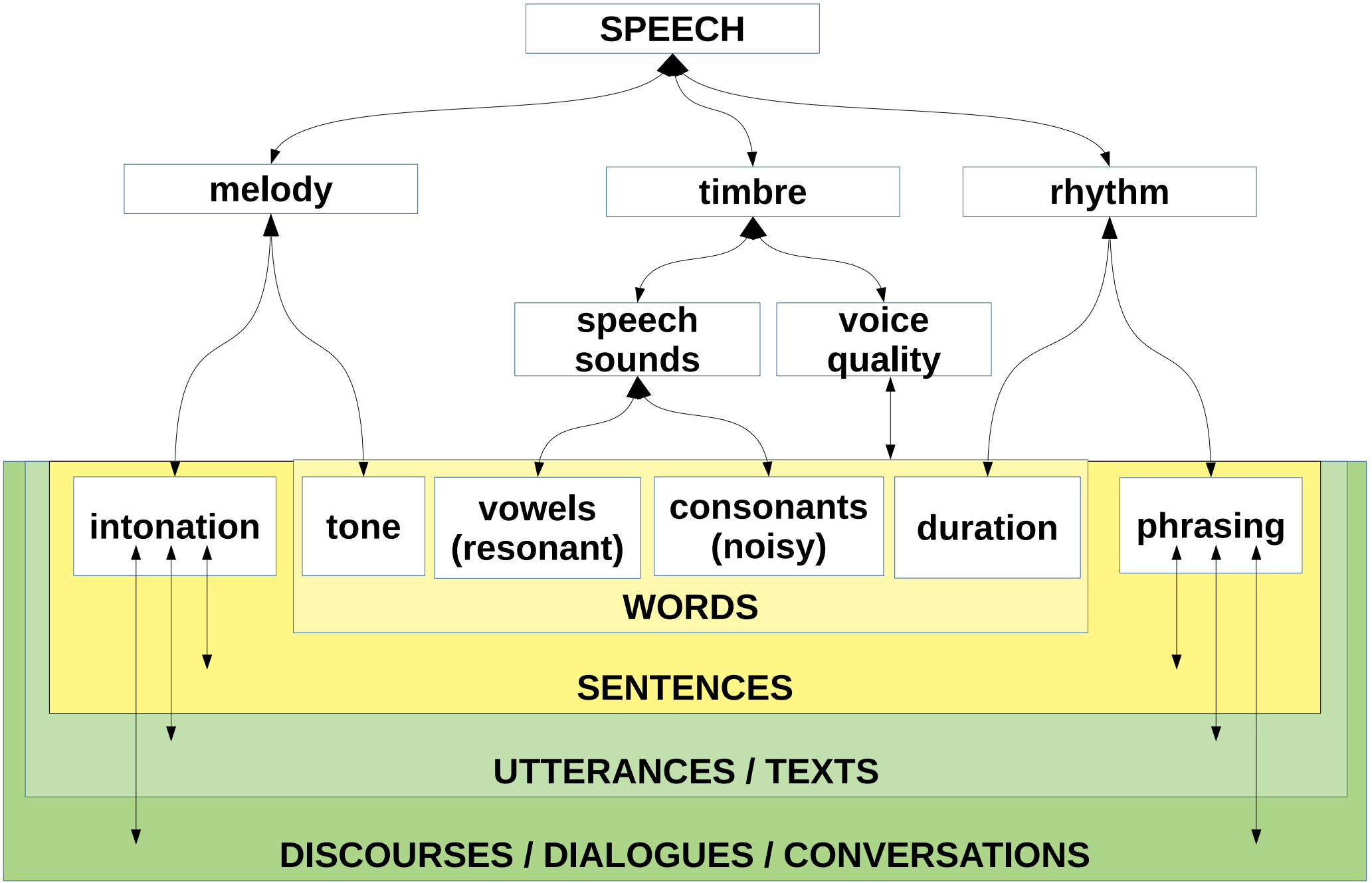


Complex Symbols and their meanings



Physical Signals to Communicate Symbols




SPEECH
melody
timbre
rhythm
speech sounds
voice quality
intonation
tone
vowels (resonant)
consonants (noisy)
duration
phrasing
WORDS
SENTENCES
UTTERANCES / TEXTS
DISCOURSES / DIALOGUES / CONVERSATIONS

Objectives

- Primary aim: to survey a selection of non-mainstream approaches to phonological modelling
- Secondary aim: to discuss computation of the three structural dimensions of the architecture of language and speech:
  - Composition: *ranked*, *grouped*, *parallel syntagmatic relations*
  - Classification: *paradigmatic relations*
  - Interpretation: *modelling relations*
- Tertiary aim: To claim that markedness, defaults and optimality are related, in the form of
  - 'logical preferences': *ranking*, *elsewhere conditions*, *exceptions*
  - 'empirical preferences': *frequency*, *familiarity*, *statistics*

Non-mainstream?

- Approaches driven by focus on
  - *Processes*
  - *Performance*
  - *Applications*
  - *Utility: support for analysis and prediction*
  - *‘Big data’*
  - *Operational models that really work*
- But also on
  - Holistic views of language and speech as a whole
    - ‘un système où tout se tient’
  - The architecture of language and speech
  - Complete models rather than ‘cherry-picking’ of specific problems

    however, ‘cherry-picking’ is enjoyable, so that, too, ...

Sciences as Paradigms or Fashions?

- Take phonology...

  Everyone does distributional structural phonology
  then everyone does generative phonology
  then everyone does metrical phonology
  then everyone does autosegmental phonology
  then everyone does optimality theoretic phonology
  then everyone does harmony phonology
  … What's next?

Varium et mutabile semper ...

- But let's take a look at phonology as a science

Phonology as Science

- A science is defined by
  - A domain grounded in basic intuitions. Here: *speech sounds*
  - Methods which analyse this domain
    - Empirical methods: *observation, measurement*
    - Formal methods: *structural modelling, numerical analysis*
  - Refinements of the methods
  - Extension of the domain by means of the refined methods
- Domains are developed by
  - Initial intuition: *sounds, syllables, words, tones, ...*
  - Definition
    - Clarification: *what we are doing*
    - Delimitation: what we are not doing
  - Explication
    - Symbolisation: *representation of categories and structures*
    - Formalisation: *premises, inference, hypotheses*

Phonology and Phonetics: two complementary sciences

Phonology:

- Intuition:
  - sound systems
    - contrastive categories
    - structures
- Empirical methods:
  - expert judgments on intuitions
- Formal methods:
  - set theory
    - inventories
  - Algebra
    - structures
  - logics
    - constraints
    - conditions

Phonology and Phonetics: two complementary sciences

Phonetics:

- Intuition:
  - speech sounds are physical events
- Empirical methods:
  - Measurement with instruments and software
  - Visualisation in 3 dimensions:
    - time, frequency, magnitude
- Formal methods:
  - transforms
  - statistical analysis
  - machine learning

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and combinations of these two domains

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Phonology as a Science needs Computation

Empirical methods

- Intuitive recognition
  - of observed or self-generated utterances
- Systematisation
  - of utterance data
- Segmentation and classification
  - hierarchical grouping
  - hierarchical classification

- Two modes of inference:
  - Deductive phonology
    - Derive hypothesis, test
  - Inductive phonology:
    - Statistical generalisation from data, classification
    - Corpus phonology

Phonology as a Science needs Computation

Formal methods:

- Model testing
  - Large scale
  - Precise
  - Reproducible
- Models
  - Syntagmatic:
    - compositional relations (typically: grammar)
  - Paradigmatic:
    - classificatory relations (typically: lexicon)
  - Hypostatic:
    - mapping relations between levels (as in phonological rules)

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Computation

- A classical four dimensional model:
  - Requirements specification:
    - A holistic view: a complete system, not bits and pieces
    - What is required? Use cases?
    - Accessibility, sustainability, interoperability, robustness, ...
  - Design:
    - Requirements orientated algorithms and data structures
    - Requirements orientated user interfaces
  - Implementation:
    - Modelling design with a programming language
    - Programming
  - Evaluation:
    - Testing and revision of each of the above phases
  - Distribution:
    - According to use cases

Phonology and Computation

Computing Phonology

- Descriptive phonology:
  - Domain:
    - *pick specific descriptive issues*
  - Method:
    - *model the domain locally using accepted paradigms*

- Computational phonology:
  - Domain:
    - *pick the entire lexicon, the entire prosodic system*
      - Why? *Un système où tout se tient!*
  - Method:
    - *Find a calculus, an algebra, a logic fo model the domain*
    - *Ensure*
      - precision, consistency, reproducibility
      - Explicit mathematical foundation
      - Implementation with automatic derivation of hypotheses

Computing with Phonology

- Theoretical computational phonology:
  - Mathematical foundations
  - Processing theory
- Descriptive computational phonology – typically *deductive*
  - Software models
    - Phonological theories
    - Psycholinguistic theories
- Speech engineering – typically *inductive*
  - Clinical applications
    - Diagnostic
    - Therapeutic practice
    - Prosthetics
  - Speech technology
    - Automatic speech recognition
    - Text-to-speech synthesis

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Types of Computing in Phonology

- Syntagmatic computing (composition)
  - Well-formedness of category combinations
    - Serial: strings, hierarchical grouping
    - Parallel: distinctive features, autosegmental tiers

- Paradigmatic computing (classification)
  - Sets: classification, categorisation
  - Properties: criteria for identifying sets

- Interpretative computing (observability)
    - Categorial ←→ physical representation levels
    - Mapping:
      - Derivation (Generative Phonology)
      - Transduction (Finite State Phonology)
      - Selection (Optimality Theory)

Domains of Computational Phonology

- Syntagmatic (compositional) relations:
  - Autosegmental phonology
  - Feature geometry
  - Metrical phonology
  - Finite state phonology

- Paradigmatic (classificatory) relations:
  - Theories of the phonology in lexicon
  - Approaches to optionality, ambiguity, neutralisation, markedness
  - Inheritance phonologies

- Interpretative relations:
  - Text-to-Speech (TTS), Automatic Speech Recognition
  - Generative phonologies
  - Optimality theoretic phonologies

To be continued