Ling 566
Oct 15, 2015
Semantics
Overview

• Some notes on the linguist’s stance
• Which aspects of semantics we’ll tackle
• Our formalization; Semantics Principles
• Building semantics of phrases
• Modification, coordination
• Structural ambiguity
The Linguist's Stance: Building a precise model

• Some of our statements are statements about how the model works:
  
  “[prep] and [AGR 3sing] can’t be combined because AGR is not a feature of the type prep.”

• Some of our statements are statements about how (we think) English or language in general works.
  “The determiners *a* and *many* only occur with count nouns, the determiner *much* only occurs with mass nouns, and the determiner *the* occurs with either.”

• Some are statements about how we code a particular linguistic fact within the model.
  “All count nouns are [SPR < [COUNT +]>].”
The Linguist's Stance:
A Vista on the Set of Possible English Sentences

• ... as a background against which linguistic elements (words, phrases) have a distribution

• ... as an arena in which linguistic elements “behave” in certain ways
So far, our grammar has no semantic representations. We have, however, been relying on semantic intuitions in our argumentation, and discussing semantic contrasts where they line up (or don't) with syntactic ones.

Examples?

- structural ambiguity
- S/NP parallelism
- count/mass distinction
- complements vs. modifiers
Our Slice of a World of Meanings
Aspects of meaning we won’t account for

- Pragmatics
- Fine-grained lexical semantics:

The meaning of *life* is *life’s*, or, in our case,

\[
\begin{bmatrix}
\text{RELN} & \text{life} \\
\text{INST} & i
\end{bmatrix}
\]
... the linguistic meaning of *Chris saved Pat* is a proposition that will be true just in case there is an actual situation that involves the saving of someone named Pat by someone named Chris.” (p. 140)
Our Slice of a World of Meanings

What we are accounting for is the compositionality of sentence meaning.

• How the pieces fit together

  Semantic arguments and indices

• How the meanings of the parts add up to the meaning of the whole.

  Appending RESTR lists up the tree
Semantics in Constraint-Based Grammar

• Constraints as (generalized) truth conditions
  • proposition: what must be the case for a proposition to be true
  • directive: what must happen for a directive to be fulfilled
  • question: the kind of situation the asker is asking about
  • reference: the kind of entity the speaker is referring to

• Syntax/semantics interface: Constraints on how syntactic arguments are related to semantic ones, and on how semantic information is compiled from different parts of the sentence.
Feature Geometry

\[
\begin{array}{c}
\text{SYN} \\
\text{VAL} \\
\text{SEM} \\
\end{array}
\begin{array}{c}
\text{HEAD} \ pos \\
\text{SPR} \ list(expression) \\
\text{COMPS} \ list(expression) \\
\text{MODE} \ \{ \text{prop, ques, dir, ref, none} \} \\
\text{INDEX} \ \{ \ i, j, k, \ldots s_1, s_2, \ldots \} \\
\text{RESTR} \ list(pred) \\
\end{array}
\]
How the Pieces Fit Together

\[
\langle \text{Dana} , \langle \text{word} \rangle \langle \text{SYN} \rangle \langle \text{VAL} \rangle \langle \text{SEM} \rangle \rangle
\]

\[
\text{word} \rightarrow \langle \text{word} \rangle \langle \text{SYN} \rangle \langle \text{VAL} \rangle \langle \text{SEM} \rangle
\]

\[
\text{SYN} \rightarrow \text{HEAD} \langle \text{noun} \rangle \langle \text{AGR} \rangle \langle 3\text{sing} \rangle \langle \text{VAL} \rangle \langle \text{SPR} \rangle \langle \text{COMPS} \rangle
\]

\[
\text{VAL} \rightarrow \text{INDEX} \langle \text{i} \rangle \langle \text{MODE} \rangle \langle \text{ref} \rangle
\]

\[
\text{SEM} \rightarrow \langle \text{RESTR} \rangle \langle \text{RELN} \rangle \langle \text{name} \rangle \langle \text{NAME} \rangle \langle \text{Dana} \rangle \langle \text{NAMED} \rangle \langle \text{i} \rangle
\]
How the Pieces Fit Together

<slept, word
SYN [+HEAD verb]
  [+VAL SPR [NP j]]
  [+COMPS ()]

SEM [+INDEX s₁]
  [+MODE prop]
  [+RESTR [RELN SIT s₁], ...]
  [+SLEEPER j]
The Pieces Together

S

NP

SEM

INDEX i

[ Dana ]

VP

[ SYN [ VAL [ SPR ⟨ I ⟩ ] ] ]

SEM

RESTR

[ RELN sleep ]

SIT

[ SLEEPER i ]

,...

[ slept ]
A More Detailed View of the Same Tree

```
S
  SEM
  INDEX
  MODE
  RESTR

1NP
  SEM
  INDEX
  RESTR
  RELN name
  NAME Dana
  NAMED i

VP
  SYN
  VAL
  SPR 1

  SEM
  RESTR
  RELN sleep
  SIT s1
  SLEEPER i
```

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To Fill in Semantics for the S-node

We need the Semantics Principles

• The Semantic Inheritance Principle:

In any headed phrase, the mother's MODE and INDEX are identical to those of the head daughter.

• The Semantic Compositionality Principle:
Semantic Inheritance Illustrated
To Fill in Semantics for the S-node

We need the Semantics Principles

• The Semantic Inheritance Principle:
  
  In any headed phrase, the mother's MODE and INDEX are identical to those of the head daughter.

• The Semantic Compositionality Principle:
  
  In any well-formed phrase structure, the mother's RESTR value is the sum of the RESTR values of the daughter.
Semantic Compositionality Illustrated

\[
S = \begin{bmatrix}
\text{INDEX } s_1 \\
\text{MODE } \text{prop} \\
\text{SEM} \\
\text{RESTRICTION} \\
\langle \begin{bmatrix} \text{RELN } \text{name} \\
\text{NAME } \text{Dana} \\
\text{NAMED } i \end{bmatrix}, \begin{bmatrix} \text{RELN } \text{sleep} \\
\text{SIT } s_1 \\
\text{SLEEPER } i \end{bmatrix}, \ldots \rangle
\end{bmatrix}
\]

\[
\text{INP} \quad \text{VP}
\]

\[
\begin{bmatrix}
\text{INDEX } i \\
\text{RESTRICTION} \\
\langle \begin{bmatrix} \text{RELN } \text{name} \\
\text{NAME } \text{Dana} \\
\text{NAMED } i \end{bmatrix} \rangle \\
\text{SEM} \\
\end{bmatrix}
\]

\[
\begin{bmatrix}
\text{SYN} \ [ \text{VAL} \ [ \text{SPR} \ \langle 1 \rangle ]] \\
\text{SEM} \\
\text{RESTRICTION} \\
\langle \begin{bmatrix} \text{RELN } \text{sleep} \\
\text{SIT } s_1 \\
\text{SLEEPER } i \end{bmatrix}, \ldots \rangle \\
\end{bmatrix}
\]

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What Identifies Indices?

```
S
  └── VP[SPR ⟨1⟩]
    └── VP
      └── PP

[1] NP
  └── D
    └── the
  └── NOM
    └── cat

[1] SPR
  └── RESTR
    ├── RELN
    │   └── sleep
    └── SIT
      └── SLEEPER
        └── slept
          └── on the mat
```
Summary: Words ...

- contribute predication
- ‘expose’ one index in those predication, for use by words or phrases
- relate syntactic arguments to semantic arguments

\[
\begin{align*}
\text{SYN} & : \text{word} \\
\text{VAL} & : \text{HEAD} \quad \text{verb} \\
\text{COMPS} & : \text{SPR} \quad \langle \text{NP}_j \rangle \\
\text{INDEX} & : s_1 \\
\text{MODE} & : \text{prop} \\
\text{SEM} & : \text{RESTR} \\
\text{RELN} & : \text{sleep} \\
\text{SIT} & : s_1 \\
\text{SLEEPER} & : j 
\end{align*}
\]
Summary: Grammar Rules...

- identify feature structures (including the INDEX value) across daughters

Head Specifier Rule

\[
\begin{align*}
\text{phrase} & \quad \text{SYN} \left[ \text{VAL} \left[ \text{SPR } \langle \rangle \right] \right] \\
\rightarrow & \quad 1 \quad H \quad \text{SYN} \left[ \text{VAL} \left[ \text{SPR} \langle 1 \rangle \right] \right] \\
\end{align*}
\]

Head Complement Rule

\[
\begin{align*}
\text{phrase} & \quad \text{SYN} \left[ \text{VAL} \left[ \text{COMPS } \langle \rangle \right] \right] \\
\rightarrow & \quad \text{word} \quad H \quad \text{SYN} \left[ \text{VAL} \left[ \text{COMPS } \langle 1, \ldots, n \rangle \right] \right] \\
\end{align*}
\]

Head Modifier Rule

\[
\begin{align*}
\text{phrase} & \quad \rightarrow \quad H \quad 1 \quad \text{SYN} \left[ \text{COMPS } \langle \rangle \right] \\
& \quad \text{SYN} \left[ \text{VAL} \left[ \text{COMPS } \langle \rangle \right] \right] \\
& \quad 1 \quad \ldots \quad n \\
\end{align*}
\]
Summary: Grammar Rules...

- identify feature structures (including the INDEX value) across daughters
- license trees which are subject to the semantic principles
  - SIP ‘passes up’ MODE and INDEX from head daughter
Summary: Grammar Rules ...

- identify feature structures (including the INDEX value) across daughters
- license trees which are subject to the semantic principles
  - SIP ‘passes up’ MODE and INDEX from head daughter
  - SCP: ‘gathers up’ predications (RESTR list) from all daughters

\[
\begin{align*}
S & = \left[ \begin{array}{c}
\text{INDEX } s_1 \\
\text{MODE } \text{prop}
\end{array} \right] \\
\text{SEM} & = \left[ \begin{array}{c}
\text{RESTR} \\
\text{RELN } \text{name}
\end{array} \right] \\
\text{RESTR} & = \left[ \begin{array}{c}
\text{name} \\
\text{NAME } \text{Dana} \\
\text{NAMED } i
\end{array} \right]
\end{align*}
\]
Other Aspects of Semantics

• Tense, Quantification (only touched on here)
• Modification
• Coordination
• Structural Ambiguity
Evolution of a Phrase Structure Rule

Ch. 2: \[ \text{NOM} \rightarrow \text{NOM PP} \]
      \[ \text{VP} \rightarrow \text{VP PP} \]

Ch. 3:
\[
\begin{align*}
\text{phrase} \\
\text{VAL} \\
\text{SPR} \\
\end{align*}
\rightarrow
\begin{align*}
H \\
\text{phrase} \\
\text{VAL} \\
\text{SPR} \\
\end{align*}
\]

Ch. 4:
\[
\text{[phrase]} \rightarrow \begin{align*}
H \\
\text{VAL} \\
\text{COMPS} \langle \rangle \\
\end{align*}
\]

Ch. 5:
\[
\text{[phrase]} \rightarrow \begin{align*}
H^1 \\
\text{SYN} \\
\text{VAL} \\
\text{COMPS} \langle \rangle \\
\end{align*}
\begin{align*}
\text{SYN} \\
\text{VAL} \\
\text{COMPS} \langle \rangle \\
\end{align*}
\]

Ch. 5 (abbreviated):
\[
\text{[phrase]} \rightarrow \begin{align*}
H^1 \\
\text{COMPS} \langle \rangle \\
\end{align*}
\begin{align*}
\text{COMPS} \langle \rangle \\
\text{MOD} \langle 1 \rangle \\
\end{align*}
\]
Evolution of Another Phrase Structure Rule

Ch. 2: \( X \rightarrow X^+ \text{ CONJ } X \)

Ch. 3: \( 1 \rightarrow 1^+ \begin{bmatrix} \text{word} \\ \text{HEAD conj} \end{bmatrix} 1 \)

Ch. 4: \( \begin{bmatrix} \text{VAL } 1 \end{bmatrix} \rightarrow \begin{bmatrix} \text{VAL } 1 \end{bmatrix}^+ \begin{bmatrix} \text{word} \\ \text{HEAD conj} \end{bmatrix} \begin{bmatrix} \text{VAL } 1 \end{bmatrix} \)

Ch. 5: \( \begin{bmatrix} \text{SYN } \begin{bmatrix} \text{VAL } 0 \end{bmatrix} \\ \text{SEM } \begin{bmatrix} \text{IND } s_0 \end{bmatrix} \end{bmatrix} \rightarrow \begin{bmatrix} \text{SYN } \begin{bmatrix} \text{VAL } 0 \end{bmatrix} \\ \text{SEM } \begin{bmatrix} \text{IND } s_1 \end{bmatrix} \vdots \begin{bmatrix} \text{SEM } \begin{bmatrix} \text{IND } s_{n-1} \end{bmatrix} \end{bmatrix} \end{bmatrix} \begin{bmatrix} \text{SYN } \begin{bmatrix} \text{HEAD conj} \\ \text{IND } s_0 \end{bmatrix} \\ \text{SEM } \text{RESTR } \langle \text{ARGS } \langle s_1 \ldots s_n \rangle \rangle \end{bmatrix} \begin{bmatrix} \text{SYN } \begin{bmatrix} \text{VAL } 0 \end{bmatrix} \\ \text{SEM } \begin{bmatrix} \text{IND } s_n \end{bmatrix} \end{bmatrix} \)

Ch. 5 (abbreviated):

\( \begin{bmatrix} \text{VAL } 0 \\ \text{IND } s_0 \end{bmatrix} \rightarrow \begin{bmatrix} \text{VAL } 0 \\ \text{IND } s_1 \end{bmatrix} \ldots \begin{bmatrix} \text{VAL } 0 \\ \text{IND } s_{n-1} \end{bmatrix} \begin{bmatrix} \text{HEAD conj} \\ \text{IND } s_0 \end{bmatrix} \text{RESTR } \langle \text{ARGS } \langle s_1 \ldots s_n \rangle \rangle \begin{bmatrix} \text{VAL } 0 \\ \text{IND } s_n \end{bmatrix} \)
Combining Constraints and Coordination

Coordination Rule

\[
\begin{bmatrix}
\text{VAL } 0 \\
\text{IND } s_0
\end{bmatrix} \rightarrow
\begin{bmatrix}
\text{VAL } 0 \\
\text{IND } s_1
\end{bmatrix} \ldots
\begin{bmatrix}
\text{VAL } 0 \\
\text{IND } s_{n-1}
\end{bmatrix} \begin{bmatrix}
\text{HEAD } conj \\
\text{IND } s_0 \\
\text{RESTR } \langle \text{ARGS } \langle s_1 \ldots s_n \rangle \rangle \\
\text{IND } s_n
\end{bmatrix}
\]

Lexical Entry for a Conjunction

\[
\langle \text{and} , \\
\text{SEM }
\begin{bmatrix}
\text{SYN} \\
\text{HEAD } conj \\
\text{INDEX } s \\
\text{MODE } \text{none} \\
\text{RESTR } \langle \text{RELN } \langle \text{SIT } s \rangle \rangle
\end{bmatrix}
\rangle
\]
Combining Constraints and Coordination

Lexical Entry for *and*

\[
\left\langle \text{and} , \begin{bmatrix}
\text{SYN} & \begin{bmatrix}
\text{HEAD} & \text{conj}
\end{bmatrix} \\
\text{INDEX} & s \\
\text{MODE} & \text{none}
\end{bmatrix}
\right\rangle
\]

\[
\left\langle \text{RELN} & \begin{bmatrix}
\text{and} & s
\end{bmatrix}
\right\rangle
\]

Coordination Rule

\[
\begin{bmatrix}
\text{VAL} & 0 \\
\text{IND} & s_0
\end{bmatrix}
\rightarrow
\begin{bmatrix}
\text{VAL} & 0 \\
\text{IND} & s_1
\end{bmatrix}
\rightarrow
\cdots
\rightarrow
\begin{bmatrix}
\text{VAL} & 0 \\
\text{IND} & s_{n-1}
\end{bmatrix}
\]

\[
\left\langle \text{HEAD} & \text{conj} \\
\text{IND} & s_0 \\
\text{RESTR} & \begin{bmatrix}
\text{ARGS} & \{s_1 \ldots s_n\}
\end{bmatrix}
\right\rangle
\]

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Structural Ambiguity, Tree I

\[
\begin{array}{c}
\text{S} \\
\text{IND } s_0 \\
\end{array}
\]

\[
\begin{array}{c}
\text{CONJ} \\
\text{S} \\
\text{IND } s_0 \\
\end{array}
\]

\[
\begin{array}{c}
\text{S} \\
\text{ING } s_1 \\
\end{array}
\]

\[
\begin{array}{c}
\text{NP} \\
\text{Pat} \\
\end{array}
\]

\[
\begin{array}{c}
\text{VP} \\
\text{sings} \\
\end{array}
\]

\[
\begin{array}{c}
\text{S} \\
\text{IND } s_2 \\
\end{array}
\]

\[
\begin{array}{c}
\text{NP} \\
\text{Lee} \\
\end{array}
\]

\[
\begin{array}{c}
\text{VP} \\
\text{dances} \\
\end{array}
\]

\[
\begin{array}{c}
\text{ADV} \\
\text{frequently} \\
\end{array}
\]

\[
\begin{array}{c}
\text{IND } s_0 \\
\end{array}
\]

\[
\begin{array}{c}
\text{MODE } \text{prop} \\
\end{array}
\]

\[
\begin{array}{c}
\text{RESTR} \\
\end{array}
\]

\[
\begin{array}{c}
\text{RELN name} \\
\text{NAME Pat} \\
\text{NAMED } k \\
\end{array}
\]

\[
\begin{array}{c}
\text{RELN sing} \\
\text{SIT } s_1 \\
\text{SINGER } k \\
\end{array}
\]

\[
\begin{array}{c}
\text{RELN and} \\
\text{SIT } s_0 \\
\text{ARGS } \langle s_1, s_2 \rangle \\
\end{array}
\]

\[
\begin{array}{c}
\text{RELN frequently} \\
\end{array}
\]

\[
\begin{array}{c}
\text{ARG } s_0 \\
\end{array}
\]

\[
\begin{array}{c}
\text{RELN dance} \\
\text{SIT } s_2 \\
\text{DANCER } j \\
\end{array}
\]

\[
\begin{array}{c}
\text{RELN name} \\
\text{NAME Lee} \\
\text{NAMED } j \\
\end{array}
\]
Structural Ambiguity, Tree II

S
  [IND s₀]
  S
  [IND s₁]
    NP
    Pat
    VP
    sings
  CONJ
  S
  [IND s₂]
    NP
    Lee
    VP
    dances
    ADV
    [MOD ⟨Ⅱ⟩]
    frequently

[IND s₀]
  MODE prop
  RESTR
  [RELN name]
  NAME Pat
  [RELN sing]
  SIT s₁
  [RELN and]
  SIT s₀
  [ARGS ⟨s₁, s₂⟩]
  [RELN name]
  NAME Lee
  [RELN dance]
  SIT s₂
  [RELN frequently]
  ARG s₂
  [RELN name]
  NAME j
  [RELN DANCER]
  [RELN ARG s₂]
Question About Structural Ambiguity

Why isn’t this a possible semantic representation for the string *Pat sings and Lee dances frequently*?

\[
\begin{align*}
\text{IND} & \quad s_0 \\
\text{MODE} & \quad \text{prop} \\
\text{RESTR} & \quad \langle \\
& \quad \left[ \begin{array}{c}
\text{RELN} \\
\text{NAME} \\
\text{NAMED}
\end{array} \right] \\
& \quad \left( \begin{array}{c}
\text{name} \\
\text{Pat} \\
k
\end{array} \right), \\
& \quad \left[ \begin{array}{c}
\text{RELN} \\
\text{SIT} \\
\text{SINGER}
\end{array} \right] \\
& \quad \left( \begin{array}{c}
\text{sing} \\
\text{s}_1 \\
k
\end{array} \right), \\
& \quad \left[ \begin{array}{c}
\text{RELN} \\
\text{and} \\
\text{ARGS}
\end{array} \right] \\
& \quad \left( \begin{array}{c}
\text{name} \\
\text{Lee} \\
j
\end{array} \right), \\
& \quad \left[ \begin{array}{c}
\text{RELN} \\
\text{DANCER}
\end{array} \right] \\
& \quad \left( \begin{array}{c}
\text{dance} \\
\text{s}_2 \\
j
\end{array} \right), \\
& \quad \text{ARGS} \left\langle s_1, s_2 \right\rangle, \\
& \quad \left[ \begin{array}{c}
\text{RELN} \\
\text{frequently}
\end{array} \right] \\
& \quad \left( \begin{array}{c}
\text{ARG} \\
\text{s}_1
\end{array} \right)
\end{align*}
\]
Semantic Compositionality

\[
\begin{align*}
\text{IND } s_0 \\
\text{MODE } \text{prop} \\
\text{RESTR} \\
\begin{cases}
\text{RELN name} \quad \text{RELN sing} \quad \text{RELN and} \\
\text{NAME Pat} \quad \text{SIT } s_1 \quad \text{SIT } s_0 \\
\text{NAMED k} \quad \text{SINGER k} \\
\text{NAME Lee} \quad \text{SIT } s_2 \\
\text{NAMED j} \quad \text{DANCER j} \\
\end{cases}
\end{align*}
\]
Reading Questions

• Are things like SAVER and SAVED analogous to theta roles?

• If the names are specific to each predicate, how do different grammar writers agree on them?

• What's with the overly specific semantic role labels (LOVER, LOVED, etc)? Why not go with something more general, like AGENT, PATIENT, …or SUBJ, OBJ, ...

• Thing #68
Reading Questions

• Do all predications ultimately come from lexical entries?

• To clarify, the RESTR in a semantic structure represents the conditions needed to satisfy the INDEX, correct? Can the RESTR include additional restrictions that are unrelated to the INDEX?

• According to the footnote on page 144, the sum operator for the Semantic Compositionality Principle is not commutative, so \(<A, B> \neq <B, A>\) and so on, but also goes on to say that the ordering of these lists has no semantic value. Is it absolutely necessary to impose this restriction in this particular instance, and does this restriction ever become a problem when applying this principle?
Reading Questions

• It seems like a strong possibility that the list of conditions may become too general or too specific. Are there guidelines to follow when creating truth conditions to ensure that the RESTR values are accurate?

• How is ambiguity handled?

• Tags: Why letters in some places and boxed numbers in others?
• "Colorless green ideas sleep furiously." Does our system ignore the issue of what kind of entities can sleep? (And similarly how we modify with adjectives and adverbs.) Are we ok as long as there is a thing, i, that is sleeping?
Reading Questions

• Can we handle modifiers that appear to the left of their heads?

• If a PP that is being used as a complement (as opposed to a modifier, recalling the discussion in 4.2.3) this would still be handled using the HCR? Would the MOD be empty for this type of PP?
• Do parsing applications that include a combined syntactic and semantic analysis provide more accuracy than a stand-alone parser respectively? And by how much? Does the incorporation of semantic objects in syntax models serve solely to paint a more complete picture of language use, or is the semantic feature structure able to influence the syntactic structure; for instance, to solve certain ambiguities that cannot be handled by syntax alone?
Reading Questions

• What all motivation is there for adding in the semantic information of Ch 5?

• Summary at each node of what's going on below it might be easily leveraged by a NLU application.

• Ability to disambiguate sentences like *Every family was saved by a dog*

• Are these reasons valid and are there additional reasons?
Reading Questions

• "the feature structures satisfying our sentence descriptions must resolve the scope of quantifiers, [but] the descriptions themselves need not" - huh?

• What would be an example of a sentence that can be represented now, that predicate logic couldn't handle? Or an example of a sentence that humans wouldn't even resolve the scope of?
Reading Questions

• How could we extend this rule-based grammar to handle pragmatics? I think it makes sense to focus on semantics first. We need to describe the dictionary meanings of words before even looking at contextual meanings. I remember reading that the US Secret Service recently wanted software to detect sarcasm in social media, which seems like a tall order for any grammar built for computers. What work has been done on pragmatics in NLP?
Reading Questions

• How would the proposed modeling of semantics account for the dependencies between sentences? Most of the time the meaning and semantics of a certain sentence is completely dependent on the context given by the surrounding sentences, then how would we account for this?
Reading Questions

• Does HPSG have a formal theory of pragmatics, for which semantic representations (like the ones described in the textbook) are the input? Or, can pragmatic information be encoded into feature structures directly? More broadly, do theories of pragmatics usually depend on a particular semantic formalism?
Overview

• Some notes on the linguist’s stance
• Which aspects of semantics we’ll tackle
• Our formalization; Semantics Principles
• Building semantics of phrases
• Modification, coordination
• Structural ambiguity
• Next time: How the grammar works