How the Grammar Works
Overview

• What we’re trying to do
• The pieces of our grammar
• Two extended examples
• Reflection on what we’ve done, what we still have to do
What We’re Trying To Do

- Objectives
  - Develop a theory of knowledge of language
  - Represent linguistic information explicitly enough to distinguish well-formed from ill-formed expressions
  - Be parsimonious, capturing linguistically significant generalizations.

- Why Formalize?
  - To formulate testable predictions
  - To check for consistency
  - To make it possible to get a computer to do it for us
How We Construct Sentences

- The Components of Our Grammar
  - Grammar rules
  - Lexical entries
  - Principles
  - Type hierarchy (very preliminary, so far)
  - Initial symbol (S, for now)

- We combine constraints from these components.

Q: *What says we have to combine them?*

A: The definition of well-formed structure
An Example

A cat slept.

- Can we build this with our tools?
- Given the constraints our grammar puts on well-formed sentences, is this one?
Lexical Entry for \( a \)

\[
\begin{align*}
\text{word} & \quad \begin{bmatrix}
\text{det} \\
\text{AGR} \\
\text{3sing} \\
\text{COUNT} \\
+ \\
\text{COMPS} \\
\langle \rangle \\
\text{SPR} \\
\langle \rangle \\
\text{MOD} \\
\langle \rangle \\
\end{bmatrix} \\
\text{HEAD} & \quad \text{none} \\
\text{VAL} & \quad j \\
\text{MODE} & \quad \text{RELN} \ a \\
\text{SEM} & \quad \text{BV} \\
\text{INDEX} & \quad j \\
\text{RESTR} & \quad \langle \rangle \\
\end{align*}
\]

- Is this a fully specified description?
- What features are unspecified?
- How many word structures can this entry license?
Lexical Entry for *cat*

- Which feature paths are abbreviated?
- Is this a fully specified description?
- What features are unspecified?
- How many word structures can this entry license?
Effect of Principles: the SHAC
Description of a Word Structure for *cat*

```
<table>
<thead>
<tr>
<th>word</th>
</tr>
</thead>
<tbody>
<tr>
<td>HEAD</td>
</tr>
<tr>
<td>noun[3sing]</td>
</tr>
<tr>
<td>AGR 2</td>
</tr>
<tr>
<td>GEND neut</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SYN</th>
</tr>
</thead>
<tbody>
<tr>
<td>VAL</td>
</tr>
<tr>
<td>SPR</td>
</tr>
<tr>
<td>D</td>
</tr>
<tr>
<td>AGR 2</td>
</tr>
<tr>
<td>COUNT +</td>
</tr>
<tr>
<td>INDEX k</td>
</tr>
<tr>
<td>COMPS ⟨⟩</td>
</tr>
<tr>
<td>MOD ⟨⟩</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>MODE ref</td>
</tr>
<tr>
<td>INDEX k</td>
</tr>
<tr>
<td>RESTR ⟨RELN cat⟩</td>
</tr>
<tr>
<td>INSTANCE k</td>
</tr>
</tbody>
</table>
```
Description of Word Structures for $a$

$$\begin{align*}
\text{word} & \\
\text{SYN} & \begin{bmatrix}
\text{HEAD} & \begin{bmatrix}
\text{det} \\
\text{AGR} & \text{3sing} \\
\text{COUNT} & + \\
\end{bmatrix} \\
\text{VAL} & \begin{bmatrix}
\text{COMPS} & \langle \rangle \\
\text{SPR} & \langle \rangle \\
\text{MOD} & \langle \rangle \\
\end{bmatrix}
\end{bmatrix} \\
\text{SEM} & \begin{bmatrix}
\text{MODE} & \text{none} \\
\text{INDEX} & j \\
\text{RESTR} & \left\langle \left[\text{RELN} a\right] \right\rangle \\
\text{SEM} & \left[\begin{bmatrix}
\text{RELN} a \\
\text{BV} & j
\end{bmatrix} \right] \\
a
\end{bmatrix}
\end{align*}$$
Building a Phrase
Constraints Contributed by Daughter Subtrees

[Diagram showing syntactic and semantic structures]
Constraints Contributed by the Grammar Rule

\[
\begin{align*}
\text{phrase} & \\
\text{SYN} & \left[ \text{VAL} \left[ \text{SPR} \langle \rangle \right] \right]
\end{align*}
\]
A Constraint Involving the SHAC

[phrase
  SYN [ VAL [ SPR ⟨ ⟩]]]

word
  word
    det
      HEAD
        AGR [ 3sing GEND neut]
        COUNT +
      [COMPS ⟨ ⟩]
      SPR ⟨ ⟩
      MOD ⟨ ⟩
    [MODE none]
    INDEX k
    SEM
      [RESTR ⟨ ⟩]

word
  head
    AGR [ 3sing GEND neut]
    [COUNT +]
    [INDEX k]
    [COMPS ⟨ ⟩]
    MOD ⟨ ⟩
  [MODE ref]
  INDEX k
  sem
    [RESTR ⟨ ⟩]
    [RELN cat]
    INDEX k
    INSTANCE k
Effects of the Valence Principle

[Diagram of linguistic analysis]

1. **phrase**
   - SYN
   - VAL
     - COMPS
     - MOD

2. **word**
   - SYN
   - VAL
     - MODE
     - INDEX
     - RESTR
   - det
     - AGR
     - COUNT
     - COMPS
     - SPR
     - MOD
     - RELN
     - BV

3. **word**
   - SYN
   - VAL
     - MODE
     - INDEX
     - RESTR
   - noun
     - AGR
     - 3sing
     - GEND

4. **word**
   - SYN
   - VAL
     - MODE
     - INDEX
     - RESTR
   - SPR
     - COMPS
     - MOD

5. **word**
   - SYN
   - VAL
     - MODE
     - INDEX
     - RESTR
   - RELN
Effects of the Head Feature Principle
Effects of the Semantic Inheritance Principle
Effects of the Semantic Compositionality Principle

\[
\begin{align*}
\text{phrase} & \\
& \overbrace{\begin{array}{c}
\text{SYN} \\
\text{VAL} \\
\text{SEM}
\end{array}}^\text{HEAD 6} \\
& \overbrace{\begin{array}{c}
\text{SPR} \langle \rangle \\
\text{COMPS} 3 \\
\text{MOD} 4
\end{array}}^\text{VAL}
\end{align*}
\]

\[
\begin{align*}
\text{word} & \\
& \overbrace{\begin{array}{c}
\text{SYN} \\
\text{VAL} \\
\text{SEM}
\end{array}}^\text{det} \\
& \overbrace{\begin{array}{c}
\text{COMPS} \langle \rangle \\
\text{SPR} \langle \rangle \\
\text{MOD} \langle \rangle
\end{array}}^\text{HEAD 2 AGR COUNT +}
\end{align*}
\]

\[
\begin{align*}
\text{word} & \\
& \overbrace{\begin{array}{c}
\text{SYN} \\
\text{VAL} \\
\text{SEM}
\end{array}}^\text{noun} \\
& \overbrace{\begin{array}{c}
\text{SPR} \langle 7 \rangle \\
\text{COMPS} 3\langle \rangle \\
\text{MOD} 4\langle \rangle
\end{array}}^\text{HEAD 6 AGR 2 3sing GEND neut}
\end{align*}
\]

\[
\begin{align*}
\text{word} & \\
& \overbrace{\begin{array}{c}
\text{SYN} \\
\text{VAL} \\
\text{SEM}
\end{array}}^\text{RELN a BV k} \\
& \overbrace{\begin{array}{c}
\text{RELN} \text{cat} \\
\text{INSTANCE} k
\end{array}}^\text{RESTRICT A + B}
\end{align*}
\]

\[
\begin{align*}
\text{word} & \\
& \overbrace{\begin{array}{c}
\text{SYN} \\
\text{VAL} \\
\text{SEM}
\end{array}}^\text{RELN a BV k} \\
& \overbrace{\begin{array}{c}
\text{RELN} \text{cat} \\
\text{INSTANCE} k
\end{array}}^\text{RESTRICT A + B}
\end{align*}
\]
Is the Mother Node Now Completely Specified?
Lexical Entry for *slept*

\[
\langle \text{slept,} \rangle
\]

- **word**: *slept*
- **SYN**: *verb*
  - **HEAD**: *NP_m*
  - **SPR**: *AGR [9]
  - **COMPS**: *
  - **MOD**: *
- **VAL**: *
- **SEM**: *
  - **INDEX**: *s_1*
  - **MODE**: *prop*
  - **RESTR**: *
    - **RELN**: *sleep*
    - **SIT**: *s_1*, ...
    - **SLEEPER**: *m*
Another Head-Specifier Phrase
RESTR of the S node

\[ \left\langle \left[ \begin{array}{c} \text{RELN} \\
\text{BV} \end{array} \right] , \left[ \begin{array}{c} \text{RELN} \\
\text{INST} \end{array} \right] , \left[ \begin{array}{c} \text{RELN} \\
\text{SLEEPER} \end{array} \right] \right\rangle \]
Another Example

The photos of the suspect disappeared yesterday.
Head Features from Lexical Entries

S

NP

[HEADdet] the

[HEADnoun] photos

[HEADprep] of

[HEADdet] the

[HEADnoun] suspect

VP

[HEADverb] disappeared

[HEADadverb] yesterday

[HEADnoun] suspect
Head Features from Lexical Entries, plus HFP
Lexicon, Rules, and the
Required identities: Grammar

Rules

\[ S \]

\[ 1NP \]

\[ 2D \]

\[ \text{the} \]

\[ N \]

\[ \text{photos} \]

\[ P \]

\[ \text{of} \]

\[ 5D \]

\[ \text{the} \]

\[ N \]

\[ \text{suspect} \]

\[ 3PP \]

\[ \text{disappeared} \]

\[ 6V \]

\[ \text{yesterday} \]

\[ \text{NOM} \]

\[ \text{[SPR} \langle 2 \rangle \text{]} \]

\[ \text{[COMPS} \langle 3 \rangle \text{]} \]

\[ \text{[SPR} \langle 1 \rangle \text{]} \]

\[ \text{[MOD} \langle 6 \rangle \text{]} \]
Two Semantic Features: the Lexicon & SIP

```
the photos of the suspect disappeared yesterday.
```

### Diagram

```
```

[MODE prop
INDEX s3]

[MODE ref
INDEX j]

[MODE none
INDEX j]

the

[MODE ref
INDEX i]

disappeared

[MODE prop
INDEX s3]

[MODE none
INDEX s4]

yesterday

[MODE ref
INDEX k]

[MODE ref
INDEX k]

[MODE ref
INDEX k]

[MODE none
INDEX k]

[MODE ref
INDEX k]

[MODE prop
INDEX s3]

[MODE none
INDEX j]

photos

[MODE none
INDEX k]

of

[MODE ref
INDEX k]

[MODE ref
INDEX k]

[MODE ref
INDEX k]

the

```
RESTR Values and the SCP

A ⊕ B ⊕ C ⊕ D ⊕ E ⊕ F ⊕ G

A ⊕ B ⊕ C ⊕ D ⊕ E

A
⟨[RELN the BV j]⟩

B ⊕ C ⊕ D ⊕ E

B
⟨[RELN photo INST CONTENT j k]⟩

C ⊕ D ⊕ E

C
⟨⟩

D ⊕ E

D
⟨[RELN the BV k]⟩

E
⟨[RELN suspect INST k]⟩

E
⟨[RELN yest. ARG s3]⟩

F
⟨[RELN disap. SIT s3 D-ER j]⟩

Disappeared

G
⟨[RELN the BV j]⟩

The

The

The

The

The

The

Yesterday
An Ungrammatical Example

What’s wrong with this sentence?
An Ungrammatical Example

The Valence Principle

*S

NP
[CASE acc] them

VP
[SPR ⟨1⟩]

V
[sent]

NP
[SPR ⟨1 NP[nom]⟩]

NP
us

D
a

N
letter
An Ungrammatical Example

Head Specifier Rule

*\( S \)

\[\begin{align*}
&\text{NP}^\text{Π} \\
&\text{[CASE} \text{ acc]} \\
&\text{them}
\end{align*}\]

\[\begin{align*}
&\text{VP} \\
&\text{[SPR} \langle \text{Π}\rangle \text{]} \\
&\text{V} \\
&\text{sent}
\end{align*}\]

\[\begin{align*}
&\text{NP} \\
&\text{us}
\end{align*}\]

\[\begin{align*}
&\text{NP} \\
&\text{D} \\
&\text{a} \\
&\text{N} \\
&\text{letter}
\end{align*}\]

← contradiction →
Exercise in Critical Thinking

- Our grammar has come a long way since Ch 2, as we've added ways of representing different kinds of information:
  - generalizations across categories
  - semantics
  - particular linguistic phenomena: valence, agreement, modification
- What else might we add? What facts about language are as yet unrepresented in our model?
Overview

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• The pieces of our grammar
• Two extended examples
• Reflection on what we’ve done, what we still have to do