Compare

- \[ P(w_{1,m}) = P(w_1) \times \prod_{i=1}^{i=m} P(w_i/w_1, n-i) \rightarrow \text{Statistics (Speech)} \]

- \[ P(w_{1,m}) = \sum_{t \in \text{all parses}} P(t) \rightarrow \text{Statistics + Linguistics} \]

- \( w_{1,m} = \text{yield(s)} \rightarrow \text{linguistics} \)
Probability of a parse tree (cont.)

\[
P(t|s) = P(t | S_{1,l}) \\
= P( NP_{1,2}, DT_{1,1}, w_1, N_{2,2}, w_2, VP_{3,l}, V_{3,3}, w_3, PP_{4,l}, P_{4,4}, w_4, NP_{5,l}, w_5...l | S_{1,l})
\]

\[
= P( NP_{1,2}, VP_{3,l} | S_{1,l}) \times P( DT_{1,1}, N_{2,2} | NP_{1,2}) \times D(w_1 | DT_{1,1}) \times P(w_2 | N_{2,2}) \times P(V_{3,3}, PP_{4,l} | VP_{3,l}) \times P(w_3 | V_{3,3}) \times P( P_{4,4}, NP_{5,l} | PP_{4,l}) \times P(w_4 | P_{4,4}) \times P(w_5...l | NP_{5,l})
\]

(Using Chain Rule, Context Freeness and Ancestor Freeness)
<table>
<thead>
<tr>
<th>Rule</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>S $\rightarrow$ NP VP</td>
<td>1.0</td>
</tr>
<tr>
<td>NP $\rightarrow$ DT NN</td>
<td>0.5</td>
</tr>
<tr>
<td>NP $\rightarrow$ NNS</td>
<td>0.3</td>
</tr>
<tr>
<td>NP $\rightarrow$ NP PP</td>
<td>0.2</td>
</tr>
<tr>
<td>PP $\rightarrow$ P NP</td>
<td>1.0</td>
</tr>
<tr>
<td>VP $\rightarrow$ VP PP</td>
<td>0.6</td>
</tr>
<tr>
<td>VP $\rightarrow$ VBD NP</td>
<td>0.4</td>
</tr>
<tr>
<td>DT $\rightarrow$ the</td>
<td>1.0</td>
</tr>
<tr>
<td>NN $\rightarrow$ gunman</td>
<td>0.5</td>
</tr>
<tr>
<td>NN $\rightarrow$ building</td>
<td>0.5</td>
</tr>
<tr>
<td>VBD $\rightarrow$ sprayed</td>
<td>1.0</td>
</tr>
<tr>
<td>NNS $\rightarrow$ bullets</td>
<td>1.0</td>
</tr>
</tbody>
</table>
• The gunman sprayed the building with bullets.
Another Parse $t_2$

- The gunman sprayed the building with bullets.

$$P(t_2) = 1.0 \times 0.5 \times 1.0 \times 0.5 \times 0.4 \times 1.0 \times 0.2 \times 0.5 \times 1.0 \times 0.5 \times 1.0 \times 0.3 \times 1.0 = 0.0015$$
Complements and Adjuncts

or

Arguments and Adjuncts
Rules in bar notation: Noun

• NP → (D) N’
• N’ → (AP) N’
• N’ → N’ (PP)
• N’ → N (PP)
Rules in bar notation: Verb

• $VP \rightarrow V'$
• $V' \rightarrow V' \ (PP)$
• $V' \rightarrow V \ (NP)$
Rules in bar notation: Adjective

• $AP \rightarrow A'$
• $A' \rightarrow (AP) A'$
• $A' \rightarrow A (PP)$
Rules in bar notation: Preposition

- PP → P′
- P′ → P′ (PP)
- P′ → P (NP)
Introducing the “X factor”

• Let X stand for any category N, V, A, P
• Let XP stand for NP, VP, AP and PP
• Let X’ stand for N’, V’, A’ and P’
XP to X’

• Collect the first level rules
  – NP → (D) N’
  – VP → V’
  – AP → A’
  – PP → P’

• And produce
  – XP → (YP) X’
X’ to X’

• Collect the 2\textsuperscript{nd} level rules
  – N’ $\to$ (AP) N’ or N’ (PP)
  – V’ $\to$ V’ (PP)
  – A’ $\to$ (AP) A’
  – P’ $\to$ P’ (PP)

• And produce
  – X’ $\to$ (ZP) X’ or X (ZP)
X’ to X

• Collect the 3rd level rules
  – N’→ N (PP)
  – V’→ V (NP)
  – A’→ A (PP)
  – P’→ P (NP)
• And produce
  – X’→ X (WP)
Basic observations about X and X’

- $X' \rightarrow X$ (WP)
- $X' \rightarrow X'$ (ZP)
- X is called **Head**
- Phrases must have Heads: **Headedness** property
- Category of XP and X must match: **Endocentricity**
Basic observations about X and X’

- $X' \to X$ (WP)
- $X' \to X'$ (ZP)
- Sisters of X are **complements**
  - Roughly correspond to *objects*
- Sisters of X’ are **Adjuncts**
  - PPs and Adjectives are typical adjuncts
- We have *adjunct rules* and *complement rules*
Structural difference between complements and adjuncts

Diagram:

- XP
- X'
- X'
- X
- WP
- ZP
- Adjunct
- Complement
Complements and Adjuncts in NPs

NP

N'

N'

N'

PP

book

of poems

with red cover

ZP
Any number of Adjuncts

NP
   /  \
  N'   N'
     /  /  \  
    N'  PP  ZP
       /  /  \  /  \ 
      N  N  ZP  from Oxford Press

book

of poems

with red cover