

# ACS Syntax and Semantics of Natural Language

## Lecture 3: CCG – More Combinatory Rules



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- Some linguistic phenomena suggest the need for additional combinatory rules, eg:

*I offered, and may give, a flower to a policeman*

- Need to coordinate *offered* and *may give*, which means we need to make *may give* a constituent:

$$(S \setminus NP) / (S \setminus NP) \quad ((S \setminus NP) / PP) / NP \quad \Rightarrow \quad ((S \setminus NP) / PP) / NP \quad ?$$

$$X/Y \ (\dots (Y/Z)/W)/ \dots \Rightarrow_{\mathbf{B}^n} (\dots (X/Z)/W)/ \dots$$

- Can now combine *may* and *give*:

$$\frac{\frac{\textit{may}}{(S \setminus NP)/VP} \quad \frac{\textit{give}}{(VP/PP)/NP}}{((S \setminus NP)/PP)/NP} \rightarrow_{\mathbf{B}^n}$$

where  $VP = S \setminus NP$

[full derivation for *I offered, and may give, a flower to a policeman* left as an exercise for the reader]

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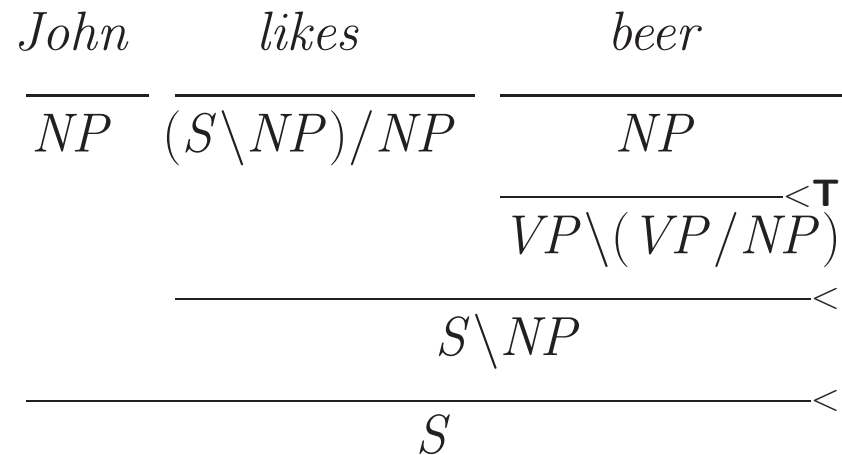
*give a teacher an apple and a policemen a flower*

- Looks like we need to coordinate *a teacher an apple* and *a policeman a flower*
- Can *a teacher an apple* really be a constituent?!
- Yes, if we allow backward type-raising and composition rules (once we allow these the derivation drops out)

$$X \Rightarrow_{\mathbf{T}} T / (T \setminus X) \quad \text{forward}$$

$$X \Rightarrow_{\mathbf{T}} T \setminus (T / X) \quad \text{backward}$$

- Now we have another derivation for a sentence like *John likes beer* (next slide)



where  $VP = S \setminus NP$

- This is an unproductive use of backward type-raising (leading to a “spurious” ambiguity)

# Backward Type-Raising for Argument Cluster Coordination 7

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$$\begin{array}{cccccc} \textit{give} & \textit{a teacher} & \textit{an apple} & \textit{and} & \textit{a policeman} & \textit{a flower} \\ \hline DTV & NP & NP & conj & NP & NP \\ \hline & \xrightarrow{<\mathbf{T}} & \xrightarrow{<\mathbf{T}} & & \xrightarrow{<\mathbf{T}} & \xrightarrow{<\mathbf{T}} \\ & TV \setminus DTV & VP \setminus TV & & TV \setminus DTV & VP \setminus TV \end{array}$$

where  $VP = S \setminus NP$ ,  $TV = (S \setminus NP) / NP$ ,  $DTV = ((S \setminus NP) / NP) / NP$

- Now we need a rule to combine  $TV \setminus DTV$  and  $VP \setminus TV$

# Backward Type-Raising for Argument Cluster Coordination 8

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$$\begin{array}{cccccc}
 \textit{give} & \textit{a teacher} & \textit{an apple} & \textit{and} & \textit{a policeman} & \textit{a flower} \\
 \hline
 DTV & NP & NP & conj & NP & NP \\
 \hline
 & \xrightarrow{<\mathbf{T}} & \xrightarrow{<\mathbf{T}} & & \xrightarrow{<\mathbf{T}} & \xrightarrow{<\mathbf{T}} \\
 & TV \setminus DTV & VP \setminus TV & & TV \setminus DTV & VP \setminus TV
 \end{array}$$

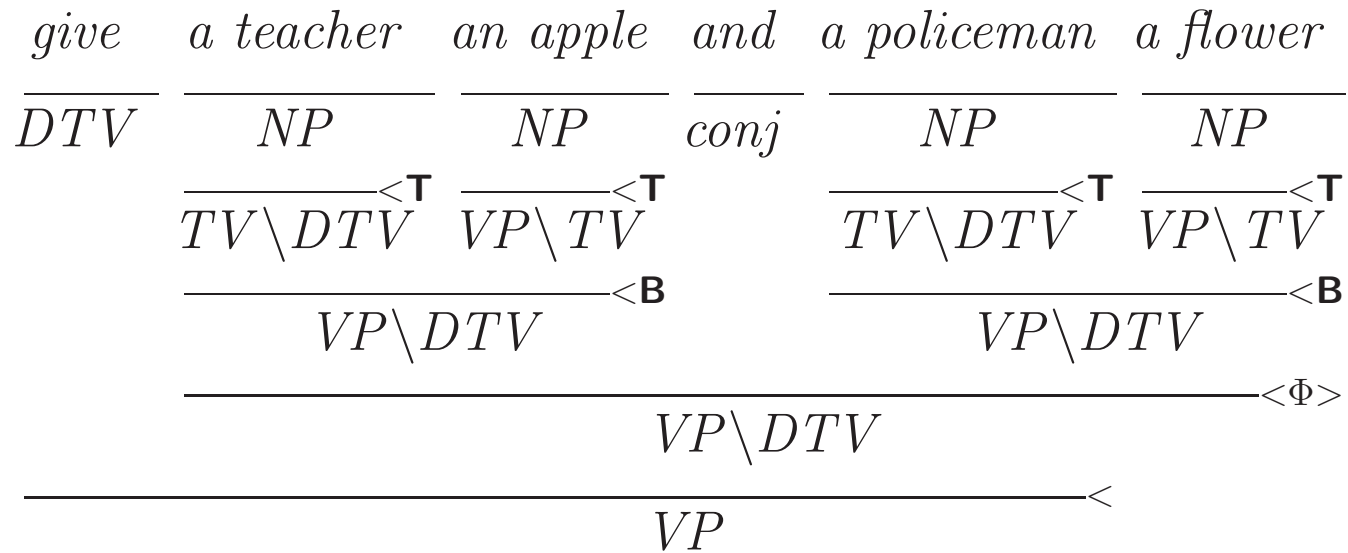
where  $VP = S \setminus NP$ ,  $TV = (S \setminus NP) / NP$ ,  $DTV = ((S \setminus NP) / NP) / NP$

- Now we need a rule to combine  $TV \setminus DTV$  and  $VP \setminus TV$
- Backward Composition ( $< \mathbf{B}$ ):

$$Y \setminus Z \quad X \setminus Y \quad \Rightarrow_{\mathbf{B}} \quad X \setminus Z$$



# Full Derivation for Argument Cluster Coordination



where  $VP = S \setminus NP$ ,  $TV = (S \setminus NP) / NP$ ,  $DTV = ((S \setminus NP) / NP) / NP$

*I shall buy today and cook tomorrow some mushrooms*

- *buy today* and *cook tomorrow* need to be constituents
- *buy* has category  $(S \setminus NP) / NP$  and *today* has category  $(S \setminus NP) \setminus (S \setminus NP)$
- No rule so far allows us to combine these; but this one will:

$$Y/Z \ X \setminus Y \Rightarrow_{\mathbf{B}} X/Z \quad (< \mathbf{B}_x)$$

$$VP/NP \ VP \setminus VP \Rightarrow_{\mathbf{B}} VP/NP$$

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- Steedman (2000) has extensive discussion of this issue
  - Various constraints are proposed on linguistic grounds, in order to prevent excessive overgeneration
  - Multi-modal CCG (Baldrige) provides a principled mechanism for applying constraints (although we won't cover this extension of CCG in this course)
  - From a practical perspective we're less concerned about overgeneration, since we have a probability model to rule out unlikely constituents
    - although putting constraints on when certain rules can apply can have a large impact on efficiency [give example from C&C parser]

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- The Syntactic Process, Mark Steedman, 2000, MIT Press
  - Combinatory Categorical Grammar, Steedman and Baldrige, 2007, available from Mark's webpage