• Some linguistic phenomena suggest the need for additional combinatorial rules, eg:

\[ I \text{ offered, and may give, a flower to a policeman } \]

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

\[ (S \backslash NP) / (S \backslash NP) \quad ((S \backslash NP) / PP) / NP \Rightarrow ((S \backslash NP) / PP) / NP \]
Generalised Forward Composition

\[ X / Y \ (\ldots (Y / Z) / W) / \ldots \Rightarrow_{B^n} \ (\ldots (X / Z) / W) / \ldots \]

• Can now combine *may* and *give*:

\[
\begin{array}{ccc}
\text{may} & \text{give} \\
(S \backslash NP) / VP & (VP / PP) / NP \\
\hline
((S \backslash NP) / PP) / NP \\
\end{array} \Rightarrow_{B^n}
\]

where \( VP = S \backslash NP \)

[full derivation for *I offered, and may give, a flower to a policeman* left as an exercise for the reader]
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)
Type-Raising (Forward and Backward)

\[
X \Rightarrow_T T/(T\backslash X) \quad \text{forward}
\]
\[
X \Rightarrow_T T\backslash(T/X) \quad \text{backward}
\]

- Now we have another derivation for a sentence like *John likes beer* (next slide)
Example Derivation for Backward Type-Raising

\[
\begin{array}{c}
John & \text{likes} & \text{beer} \\
NP & (S\backslash NP)/NP & NP \\
& & \text{T} \\
& VP/(VP/NP) & < \\
& S\backslash NP & < \\
& S & < \\
\end{array}
\]

where \( VP = S\backslash NP \)

- This is an unproductive use of backward type-raising (leading to a “spurious” ambiguity)
give a teacher an apple and a policeman a flower

\[
\begin{array}{llll}
give & \text{a teacher} & \text{an apple} & \text{and} \\
DTV & NP & NP & conj \\
TV \setminus DTV & VP \setminus TV & NP & NP
\end{array}
\]

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 \( VP \setminus TV \)
give a teacher an apple and a policeman a flower

\[
\begin{array}{cccc}
\text{give} & \text{a teacher} & \text{an apple} & \text{and} & \text{a policeman} & \text{a flower} \\
\overline{DTV} & \overline{NP} & \overline{NP} & \overline{conj} & \overline{NP} & \overline{NP} \\
\overline{TV\setminus DTV} & \overline{VP\setminus TV} & \overline{VP\setminus TV} & \overline{TV\setminus DTV} & \overline{VP\setminus TV}
\end{array}
\]

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 (\(< B\)):

\[
Y\setminus Z \quad X\setminus Y \quad \Rightarrow_B \quad X\setminus Z
\]
give a teacher an apple and a policeman a flower

\[ \text{where } VP = S\!\setminus\!NP, \ TV = (S\!\setminus\!NP)/NP, \ DTV = ((S\!\setminus\!NP)/NP)/NP \]
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:

\[
Y/Z \ X\setminus Y \ \Rightarrow_B \ X/Z \ (< B_x) \\
VP/NP \ VP\setminus VP \ \Rightarrow_B \ VP/NP
\]
How do we decide what rules are allowed?

- Steedman (2000) has extensive discussion of this issue
- Various constraints are proposed on linguistic grounds, in order to prevent excessive overgeneration
- Multi-modal CCG (Baldridge) 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]
References

- The Syntactic Process, Mark Steedman, 2000, MIT Press
- Combinatory Categorial Grammar, Steedman and Baldridge, 2007, available from Mark’s webpage