L95: Natural Language Syntax and Parsing
8) Unification-based Grammars and Parsing

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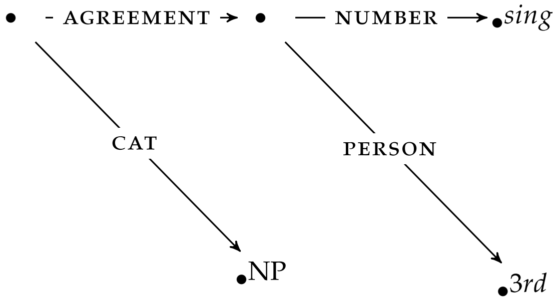
Reminder...

Last time we looked at lexicalisation and features to help us with:

- modelling structural dependency across the tree as a whole
  - e.g. correctly modelling *NP* expansion
- modelling the structural behaviour specific to a lexical item:
  - pp-attachment
  - subcategorisation
  - co-ordination

Alternative approach represents features in **DAGs**

Re-conceptualise words, non-terminal nodes and parses as **Directed Acyclic Graphs** which may be represented as **Attribute Value Matrices**

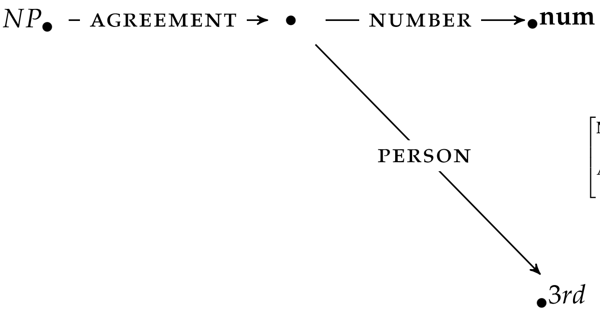


$$\begin{bmatrix} \textsc{cat} & \mathit{NP} \\ \textsc{agreement} & \begin{bmatrix} \textsc{number} & \mathit{sing} \\ \textsc{person} & \mathit{3rd} \end{bmatrix} \end{bmatrix}$$

We have **atomic values** at each of the terminal nodes and another **AVM**/**DAG** at all other nodes

Some grammars allow the **AVMs** to be **typed**

Typing facilitates grammar building. Hierarchies of AVM types can be used to automatically populate attributes

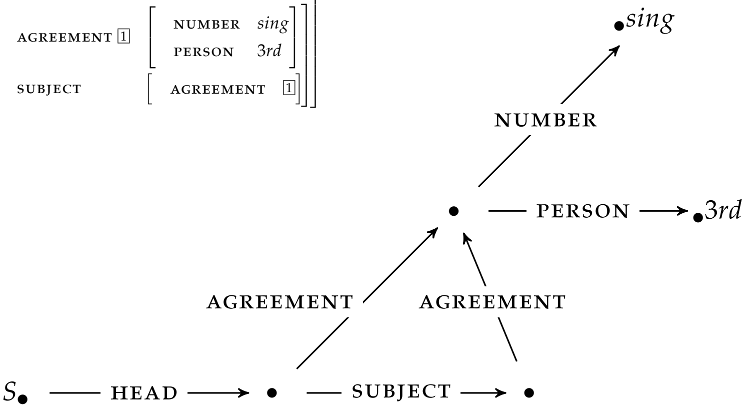


$$\begin{bmatrix} \textbf{NP} & \\ \text{AGREEMENT} & \begin{bmatrix} \textsc{number} & \textbf{num} \\ \textsc{person} & \textit{3rd} \end{bmatrix} \end{bmatrix}$$

An shorthand notation uses angle bracket notation to indicate attribute paths: e.g. <**NP** AGREEMENT PERSON> would represent the attribute path leading to the atomic value *3rd*.

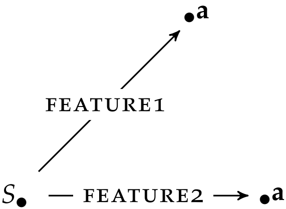
DAGs and AVMs may exhibit **re-entrancy**

$$
\begin{bmatrix}
\textbf{S} & \\
\textsc{head} & \begin{bmatrix} \textsc{agreement}\ \boxed{1} \begin{bmatrix} \textsc{number} & \textit{sing} \\ \textsc{person} & \textit{3rd} \end{bmatrix} \\ \textsc{subject} \quad \begin{bmatrix} \textsc{agreement} & \boxed{1} \end{bmatrix} \end{bmatrix}
\end{bmatrix}
$$



DAGs and AVMs may exhibit **re-entrancy**

1. Non re-entrant: $\begin{bmatrix} \textsc{Feature1} & \mathbf{a} \\ \textsc{Feature2} & \mathbf{a} \end{bmatrix}$



2. Re-entrant: $\begin{bmatrix} \textsc{Feature1} & \boxed{1}\ \mathbf{a} \\ \textsc{Feature2} & \boxed{1} \end{bmatrix}$

Parsing with DAGs involves **Unification**

- The unification of two DAGs is the most specific DAG which contains all the information in both of the original attribute-value structures.
- Unification fails if the two DAGs contain conflicting information.

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$$\begin{bmatrix}\text{FEATURE1} & \begin{bmatrix}\text{FEATURE2} & \boxed{1}\end{bmatrix} \\ \text{FEATURE3} \ \boxed{1} & \end{bmatrix} \sqcup \begin{bmatrix}\text{FEATURE3} & \mathit{a}\end{bmatrix}$$

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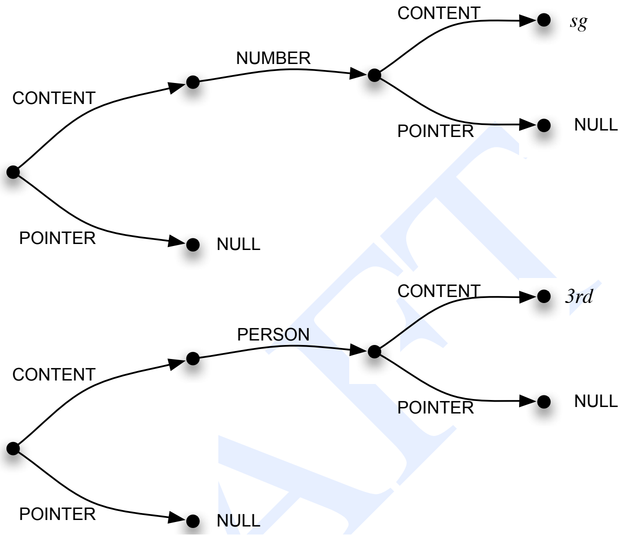
Unification examples...

Unification **algorithm** requires **extra** graph structure



From Jurafsky and Martin version 2

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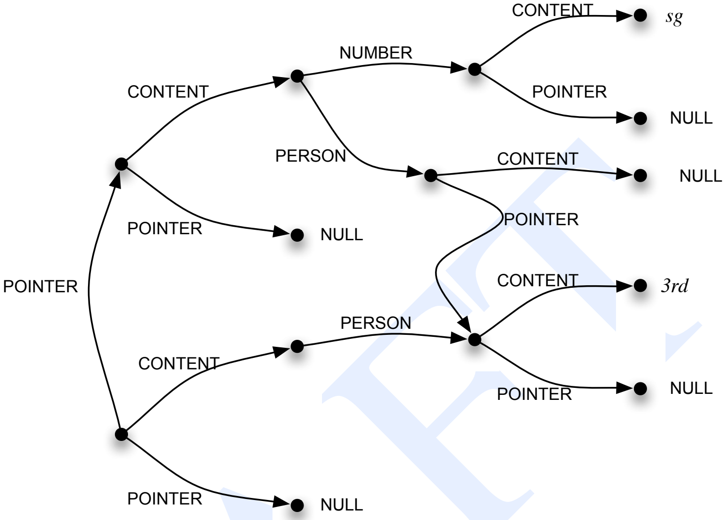

From Jurafsky and Martin version 2

DAGs can be straighforwardly associated with the lexicon

$$\begin{bmatrix} \textbf{N} & \\ \textsc{agreement} & \begin{bmatrix} \textsc{person} & \textit{3rd} \\ \textsc{number} & \textit{plural} \end{bmatrix} \end{bmatrix} \rightarrow \{\text{fish, rivers, pools, they}\}$$

$$\text{V} \quad \rightarrow \quad \{\text{cans, fishes}\}$$

$$<\text{V } \textsc{agreement person}> = \textit{3rd}$$

$$<\text{V } \textsc{agreement number}> = \textit{sing}$$

$$\left\langle \text{they}, \begin{bmatrix} \textbf{N} & \\ \textsc{agreement} & \begin{bmatrix} \textsc{person} & \textit{3rd} \\ \textsc{number} & \textit{sing} \end{bmatrix} \end{bmatrix} \right\rangle$$

DAGs can be straighforwardly associated with the lexicon

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We can **modify** CFG algorithms to **parse** with DAGs

- We can use any CFG parsing algorithm if:
- associate attribute paths with CFG rules
- unify DAGs in the states

$S \rightarrow NP\ VP$

$< NP\ \ \textsc{head agreement} >=< VP\ \ \textsc{head agreement} >$

$< S\ \ \textsc{head} >=< VP\ \ \textsc{head} >$

- We would have items like $[X, [a, b], DAG]$ on the agenda or at each cell

Parsing example...

They like Peter

$$\begin{bmatrix}\textbf{S}\\ \text{AGREEMENT} & \boxed{1}\end{bmatrix} \rightarrow \begin{bmatrix}\textbf{NP}\\ \text{AGREEMENT} & \boxed{1}\end{bmatrix}\begin{bmatrix}\textbf{VP}\\ \text{AGREEMENT} & \boxed{1}\end{bmatrix}$$

$$\begin{bmatrix}\textbf{VP}\\ \text{AGREEMENT} & \boxed{1}\end{bmatrix} \rightarrow \begin{bmatrix}\textbf{V}\\ \text{AGREEMENT} & \boxed{1}\end{bmatrix}\begin{bmatrix}\textbf{NP}\\ \text{AGREEMENT} & \begin{bmatrix}\,\end{bmatrix}\end{bmatrix}$$

$$\begin{bmatrix}\textbf{V}\\ \text{AGREEMENT} & \begin{bmatrix}\text{PERSON} & 3rd\\ \text{NUMBER} & plural\end{bmatrix}\end{bmatrix} \rightarrow \{\text{like}\}$$

$$\begin{bmatrix}\textbf{V}\\ \text{AGREEMENT} & \begin{bmatrix}\text{PERSON} & 3rd\\ \text{NUMBER} & sing\end{bmatrix}\end{bmatrix} \rightarrow \{\text{likes}\}$$

$$\begin{bmatrix}\textbf{NP}\\ \text{AGREEMENT} & \begin{bmatrix}\text{PERSON} & 3rd\\ \text{NUMBER} & plural\end{bmatrix}\end{bmatrix} \rightarrow \{\text{fish, rivers, pools, they}\}$$

$$\begin{bmatrix}\textbf{NP}\\ \text{AGREEMENT} & \begin{bmatrix}\text{PERSON} & 3rd\\ \text{NUMBER} & sing\end{bmatrix}\end{bmatrix} \rightarrow \{\text{it, fish, Peter}\}$$

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Parsing example...

They like Peter

$$\begin{bmatrix} \textbf{S} & \\ \text{AGREEMENT} & \boxed{1} \end{bmatrix} \rightarrow \begin{bmatrix} \textbf{NP} & \\ \text{AGREEMENT} & \boxed{1} \end{bmatrix} \begin{bmatrix} \textbf{VP} & \\ \text{AGREEMENT} & \boxed{1} \begin{bmatrix} \text{PERSON} & 3rd \\ \text{NUMBER} & plural \end{bmatrix} \end{bmatrix}$$

$$\begin{bmatrix} \textbf{VP} & \\ \text{AGREEMENT} & \boxed{1} \begin{bmatrix} \text{PERSON} & 3rd \\ \text{NUMBER} & plural \end{bmatrix} \end{bmatrix} \rightarrow \begin{bmatrix} \textbf{V} & \\ \text{AGREEMENT} & \boxed{1} \begin{bmatrix} \text{PERSON} & 3rd \\ \text{NUMBER} & plural \end{bmatrix} \end{bmatrix} \begin{bmatrix} \textbf{NP} & \\ \text{AGREEMENT} & \begin{bmatrix} \text{PERSON} & 3rd \\ \text{NUMBER} & sing \end{bmatrix} \end{bmatrix}$$

$$\begin{bmatrix} \textbf{V} & \\ \text{AGREEMENT} & \begin{bmatrix} \text{PERSON} & 3rd \\ \text{NUMBER} & plural \end{bmatrix} \end{bmatrix} \rightarrow \{\text{like}\}$$

$$\begin{bmatrix} \textbf{V} & \\ \text{AGREEMENT} & \begin{bmatrix} \text{PERSON} & 3rd \\ \text{NUMBER} & sing \end{bmatrix} \end{bmatrix} \rightarrow \{\text{likes}\}$$

$$\begin{bmatrix} \textbf{NP} & \\ \text{AGREEMENT} & \begin{bmatrix} \text{PERSON} & 3rd \\ \text{NUMBER} & plural \end{bmatrix} \end{bmatrix} \rightarrow \{\text{fish, rivers, pools, they}\}$$

$$\begin{bmatrix} \textbf{NP} & \\ \text{AGREEMENT} & \begin{bmatrix} \text{PERSON} & 3rd \\ \text{NUMBER} & sing \end{bmatrix} \end{bmatrix} \rightarrow \{\text{it, fish, Peter}\}$$

Parsing example...

They like Peter

$$\begin{bmatrix}\textbf{S} & \\ \text{AGREEMENT} & \boxed{1}\end{bmatrix} \rightarrow \begin{bmatrix}\textbf{NP} & \\ \text{AGREEMENT} & \boxed{1}\begin{bmatrix}\text{PERSON} & \mathit{3rd} \\ \text{NUMBER} & \mathit{plural}\end{bmatrix}\end{bmatrix} \begin{bmatrix}\textbf{VP} & \\ \text{AGREEMENT} & \boxed{1}\begin{bmatrix}\text{PERSON} & \mathit{3rd} \\ \text{NUMBER} & \mathit{plural}\end{bmatrix}\end{bmatrix}$$

$$\begin{bmatrix}\textbf{VP} & \\ \text{AGREEMENT} & \boxed{1}\begin{bmatrix}\text{PERSON} & \mathit{3rd} \\ \text{NUMBER} & \mathit{plural}\end{bmatrix}\end{bmatrix} \rightarrow \begin{bmatrix}\textbf{V} & \\ \text{AGREEMENT} & \boxed{1}\begin{bmatrix}\text{PERSON} & \mathit{3rd} \\ \text{NUMBER} & \mathit{plural}\end{bmatrix}\end{bmatrix} \begin{bmatrix}\textbf{NP} & \\ \text{AGREEMENT} & \begin{bmatrix}\text{PERSON} & \mathit{3rd} \\ \text{NUMBER} & \mathit{sing}\end{bmatrix}\end{bmatrix}$$

$$\begin{bmatrix}\textbf{V} & \\ \text{AGREEMENT} & \begin{bmatrix}\text{PERSON} & \mathit{3rd} \\ \text{NUMBER} & \mathit{plural}\end{bmatrix}\end{bmatrix} \rightarrow \{\text{like}\}$$

$$\begin{bmatrix}\textbf{V} & \\ \text{AGREEMENT} & \begin{bmatrix}\text{PERSON} & \mathit{3rd} \\ \text{NUMBER} & \mathit{sing}\end{bmatrix}\end{bmatrix} \rightarrow \{\text{likes}\}$$

$$\begin{bmatrix}\textbf{NP} & \\ \text{AGREEMENT} & \begin{bmatrix}\text{PERSON} & \mathit{3rd} \\ \text{NUMBER} & \mathit{plural}\end{bmatrix}\end{bmatrix} \rightarrow \{\text{fish, rivers, pools, they}\}$$

$$\begin{bmatrix}\textbf{NP} & \\ \text{AGREEMENT} & \begin{bmatrix}\text{PERSON} & \mathit{3rd} \\ \text{NUMBER} & \mathit{sing}\end{bmatrix}\end{bmatrix} \rightarrow \{\text{it, fish, Peter}\}$$

Parsing example...

They like Peter

$$\begin{bmatrix}\textbf{S} & & \\ \text{AGREEMENT} & \boxed{1} & \begin{bmatrix}\text{PERSON} & \mathit{3rd} \\ \text{NUMBER} & \mathit{plural}\end{bmatrix}\end{bmatrix} \rightarrow \begin{bmatrix}\textbf{NP} & & \\ \text{AGREEMENT} & \boxed{1} & \begin{bmatrix}\text{PERSON} & \mathit{3rd} \\ \text{NUMBER} & \mathit{plural}\end{bmatrix}\end{bmatrix} \begin{bmatrix}\textbf{VP} & & \\ \text{AGREEMENT} & \boxed{1} & \begin{bmatrix}\text{PERSON} & \mathit{3rd} \\ \text{NUMBER} & \mathit{plural}\end{bmatrix}\end{bmatrix}$$

$$\begin{bmatrix}\textbf{VP} & & \\ \text{AGREEMENT} & \boxed{1} & \begin{bmatrix}\text{PERSON} & \mathit{3rd} \\ \text{NUMBER} & \mathit{plural}\end{bmatrix}\end{bmatrix} \rightarrow \begin{bmatrix}\textbf{V} & & \\ \text{AGREEMENT} & \boxed{1} & \begin{bmatrix}\text{PERSON} & \mathit{3rd} \\ \text{NUMBER} & \mathit{plural}\end{bmatrix}\end{bmatrix} \begin{bmatrix}\textbf{NP} & \\ \text{AGREEMENT} & \begin{bmatrix}\text{PERSON} & \mathit{3rd} \\ \text{NUMBER} & \mathit{sing}\end{bmatrix}\end{bmatrix}$$

$$\begin{bmatrix}\textbf{V} & \\ \text{AGREEMENT} & \begin{bmatrix}\text{PERSON} & \mathit{3rd} \\ \text{NUMBER} & \mathit{plural}\end{bmatrix}\end{bmatrix} \rightarrow \{\text{like}\}$$

$$\begin{bmatrix}\textbf{V} & \\ \text{AGREEMENT} & \begin{bmatrix}\text{PERSON} & \mathit{3rd} \\ \text{NUMBER} & \mathit{sing}\end{bmatrix}\end{bmatrix} \rightarrow \{\text{likes}\}$$

$$\begin{bmatrix}\textbf{NP} & \\ \text{AGREEMENT} & \begin{bmatrix}\text{PERSON} & \mathit{3rd} \\ \text{NUMBER} & \mathit{plural}\end{bmatrix}\end{bmatrix} \rightarrow \{\text{fish, rivers, pools, they}\}$$

$$\begin{bmatrix}\textbf{NP} & \\ \text{AGREEMENT} & \begin{bmatrix}\text{PERSON} & \mathit{3rd} \\ \text{NUMBER} & \mathit{sing}\end{bmatrix}\end{bmatrix} \rightarrow \{\text{it, fish, Peter}\}$$

Parsing example...

They likes Peter

$$\begin{bmatrix}\textbf{S} & \\ \text{AGREEMENT} & \boxed{1}\end{bmatrix} \rightarrow \begin{bmatrix}\textbf{NP} & & \\ \text{AGREEMENT} & \boxed{1} & \begin{bmatrix}\text{PERSON} & \mathit{3rd} \\ \text{NUMBER} & \mathit{plural}\end{bmatrix}\end{bmatrix} \begin{bmatrix}\textbf{VP} & & \\ \text{AGREEMENT} & \boxed{1} & \begin{bmatrix}\text{PERSON} & \mathit{3rd} \\ \text{NUMBER} & \mathit{sing}\end{bmatrix}\end{bmatrix}$$

$$\begin{bmatrix}\textbf{VP} & & \\ \text{AGREEMENT} & \boxed{1} & \begin{bmatrix}\text{PERSON} & \mathit{3rd} \\ \text{NUMBER} & \mathit{sing}\end{bmatrix}\end{bmatrix} \rightarrow \begin{bmatrix}\textbf{V} & & \\ \text{AGREEMENT} & \boxed{1} & \begin{bmatrix}\text{PERSON} & \mathit{3rd} \\ \text{NUMBER} & \mathit{sing}\end{bmatrix}\end{bmatrix} \begin{bmatrix}\textbf{NP} & \\ \text{AGREEMENT} & \begin{bmatrix}\text{PERSON} & \mathit{3rd} \\ \text{NUMBER} & \mathit{sing}\end{bmatrix}\end{bmatrix}$$

$$\begin{bmatrix}\textbf{V} & \\ \text{AGREEMENT} & \begin{bmatrix}\text{PERSON} & \mathit{3rd} \\ \text{NUMBER} & \mathit{plural}\end{bmatrix}\end{bmatrix} \rightarrow \{\text{like}\}$$

$$\begin{bmatrix}\textbf{V} & \\ \text{AGREEMENT} & \begin{bmatrix}\text{PERSON} & \mathit{3rd} \\ \text{NUMBER} & \mathit{sing}\end{bmatrix}\end{bmatrix} \rightarrow \{\text{likes}\}$$

$$\begin{bmatrix}\textbf{NP} & \\ \text{AGREEMENT} & \begin{bmatrix}\text{PERSON} & \mathit{3rd} \\ \text{NUMBER} & \mathit{plural}\end{bmatrix}\end{bmatrix} \rightarrow \{\text{fish, rivers, pools, they}\}$$

$$\begin{bmatrix}\textbf{NP} & \\ \text{AGREEMENT} & \begin{bmatrix}\text{PERSON} & \mathit{3rd} \\ \text{NUMBER} & \mathit{sing}\end{bmatrix}\end{bmatrix} \rightarrow \{\text{it, fish, Peter}\}$$

Parsing example...

They likes Peter — UNIFICATION FAILS BECAUSE OF CO-INDEXATION

$$\begin{bmatrix}\textbf{S}\\ \text{AGREEMENT} & \boxed{1}\end{bmatrix} \rightarrow \begin{bmatrix}\textbf{NP}\\ \text{AGREEMENT} & \boxed{1}\begin{bmatrix}\text{PERSON} & \textit{3rd}\\ \text{NUMBER} & \textit{plural}\end{bmatrix}\end{bmatrix} \begin{bmatrix}\textbf{VP}\\ \text{AGREEMENT} & \boxed{1}\begin{bmatrix}\text{PERSON} & \textit{3rd}\\ \text{NUMBER} & \textit{sing}\end{bmatrix}\end{bmatrix}$$

$$\begin{bmatrix}\textbf{VP}\\ \text{AGREEMENT} & \boxed{1}\begin{bmatrix}\text{PERSON} & \textit{3rd}\\ \text{NUMBER} & \textit{sing}\end{bmatrix}\end{bmatrix} \rightarrow \begin{bmatrix}\textbf{V}\\ \text{AGREEMENT} & \boxed{1}\begin{bmatrix}\text{PERSON} & \textit{3rd}\\ \text{NUMBER} & \textit{sing}\end{bmatrix}\end{bmatrix} \begin{bmatrix}\textbf{NP}\\ \text{AGREEMENT} & \begin{bmatrix}\text{PERSON} & \textit{3rd}\\ \text{NUMBER} & \textit{sing}\end{bmatrix}\end{bmatrix}$$

$$\begin{bmatrix}\textbf{V}\\ \text{AGREEMENT} & \begin{bmatrix}\text{PERSON} & \textit{3rd}\\ \text{NUMBER} & \textit{plural}\end{bmatrix}\end{bmatrix} \rightarrow \{\text{like}\}$$

$$\begin{bmatrix}\textbf{V}\\ \text{AGREEMENT} & \begin{bmatrix}\text{PERSON} & \textit{3rd}\\ \text{NUMBER} & \textit{sing}\end{bmatrix}\end{bmatrix} \rightarrow \{\text{likes}\}$$

$$\begin{bmatrix}\textbf{NP}\\ \text{AGREEMENT} & \begin{bmatrix}\text{PERSON} & \textit{3rd}\\ \text{NUMBER} & \textit{plural}\end{bmatrix}\end{bmatrix} \rightarrow \{\text{fish, rivers, pools, they}\}$$

$$\begin{bmatrix}\textbf{NP}\\ \text{AGREEMENT} & \begin{bmatrix}\text{PERSON} & \textit{3rd}\\ \text{NUMBER} & \textit{sing}\end{bmatrix}\end{bmatrix} \rightarrow \{\text{it, fish, Peter}\}$$

Subcategorization is captured by the feature constraints

$$\begin{bmatrix} \textbf{S} \\ \text{HEAD} \ \boxed{1} \end{bmatrix} \rightarrow \boxed{2} \begin{bmatrix} \textbf{NP} \\ \text{HEAD} \ \begin{bmatrix} \text{AGREEMENT} \ \boxed{3} \end{bmatrix} \end{bmatrix} \begin{bmatrix} \textbf{VP} \\ \text{HEAD} \ \boxed{1} \ \begin{bmatrix} \text{AGREEMENT} \ \boxed{3} \end{bmatrix} \\ \text{SUBJ} \ \boxed{2} \end{bmatrix}$$

$$\begin{bmatrix} \textbf{VP} \\ \text{HEAD} \ \boxed{1} \\ \text{SUBJ} \ \boxed{3} \end{bmatrix} \rightarrow \begin{bmatrix} \textbf{V} \\ \text{HEAD} \ \boxed{1} \\ \text{OBJ} \ \boxed{2} \\ \text{SUBJ} \ \boxed{3} \end{bmatrix} \boxed{2} \begin{bmatrix} \end{bmatrix}$$

Subcategorization is captured by the feature constraints

$$\begin{bmatrix} \textbf{S} \\ \textsc{head}\ \boxed{1} \end{bmatrix} \rightarrow \boxed{2}\begin{bmatrix} \textbf{NP} & \\ \textsc{head} & \begin{bmatrix} \textsc{agreement} & \boxed{3} \end{bmatrix} \end{bmatrix} \begin{bmatrix} \textbf{VP} & \\ \textsc{head}\ \boxed{1} & \begin{bmatrix} \textsc{agreement} & \boxed{3} \end{bmatrix} \\ \textsc{subj}\ \boxed{2} & \end{bmatrix}$$

$$\begin{bmatrix} \textbf{VP} & \\ \textsc{head} & \boxed{1} \\ \textsc{subj} & \boxed{3} \end{bmatrix} \rightarrow \begin{bmatrix} \textbf{V} & \\ \textsc{head} & \boxed{1} \\ \textsc{obj} & \boxed{2} \\ \textsc{subj} & \boxed{3} \end{bmatrix} \boxed{2}\begin{bmatrix} \ \end{bmatrix}$$

$$\left\langle \text{can}, \begin{bmatrix} \textbf{V} & \\ \textsc{head} & \begin{bmatrix} \textsc{agreement} & \begin{bmatrix} \ \end{bmatrix} \end{bmatrix} \\ \textsc{obj} & \begin{bmatrix} \textbf{VP} & \\ \textsc{head} & \begin{bmatrix} \ \end{bmatrix} \end{bmatrix} \\ \textsc{subj} & \begin{bmatrix} \textbf{NP} & \\ \textsc{head} & \begin{bmatrix} \ \end{bmatrix} \end{bmatrix} \end{bmatrix} \right\rangle$$

Subcategorization is captured by the feature constraints

$$\begin{bmatrix}\textbf{S}\\ \textsc{head}\ \boxed{1}\end{bmatrix} \rightarrow \boxed{2}\begin{bmatrix}\textbf{NP}\\ \textsc{head} & \begin{bmatrix}\textsc{agreement} & \boxed{3}\end{bmatrix}\end{bmatrix}\begin{bmatrix}\textbf{VP}\\ \textsc{head}\ \boxed{1} & \begin{bmatrix}\textsc{agreement} & \boxed{3}\end{bmatrix}\\ \textsc{subj}\ \boxed{2}\end{bmatrix}$$

$$\begin{bmatrix}\textbf{VP}\\ \textsc{head} & \boxed{1}\\ \textsc{subj} & \boxed{3}\end{bmatrix} \rightarrow \begin{bmatrix}\textbf{V}\\ \textsc{head} & \boxed{1}\\ \textsc{obj} & \boxed{2}\\ \textsc{subj} & \boxed{3}\end{bmatrix}\ \boxed{2}\begin{bmatrix}\ \end{bmatrix}$$

$$\left\langle \text{can}, \begin{bmatrix}\textbf{V}\\ \textsc{head} & \begin{bmatrix}\textsc{agreement} & \begin{bmatrix}\ \end{bmatrix}\end{bmatrix}\\ \textsc{obj} & \begin{bmatrix}\textbf{VP}\\ \textsc{head} & \begin{bmatrix}\ \end{bmatrix}\end{bmatrix}\\ \textsc{subj} & \begin{bmatrix}\textbf{NP}\\ \textsc{head} & \begin{bmatrix}\ \end{bmatrix}\end{bmatrix}\end{bmatrix}\right\rangle \left\langle \text{cans}, \begin{bmatrix}\textbf{V}\\ \textsc{head} & \begin{bmatrix}\textsc{agreement} & \begin{bmatrix}\textsc{person} & \textit{3rd}\\ \textsc{number} & \textit{sing}\end{bmatrix}\end{bmatrix}\\ \textsc{obj} & \begin{bmatrix}\textbf{NP}\\ \textsc{head} & \begin{bmatrix}\ \end{bmatrix}\end{bmatrix}\\ \textsc{subj} & \begin{bmatrix}\textbf{NP}\\ \textsc{head} & \begin{bmatrix}\ \end{bmatrix}\end{bmatrix}\end{bmatrix}\right\rangle$$

Alternatively use **unification as the parsing operation**

Alternatively we can use **unification as the parsing operation** instead of just for feature checking:

- $X_0 \rightarrow X_1 X_2$

  $< X_1 \text{ HEAD AGREEMENT } >=< X_2 \text{ HEAD AGREEMENT } >$

  $< X_0 \text{ HEAD } >=< X_1 \text{ HEAD } >$

- $X_0 \rightarrow X_1 X_2$

  $< X_0 \text{ HEAD } >< X_1 \text{ HEAD } >$

  $< X_2 \text{ CAT } >= PP$

- $X_0 \rightarrow X_1 \textit{ and } X_2$

  $< X_0 \text{ CAT } >< X_1 \text{ CAT } >$

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  $< X_0 \ \text{CAT} >< X_1 \ \text{CAT} >$

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Lexical AVMs may be derived through unification

- We have assumed we have a lexicon entry for all the inflected forms of a word.
- With a morphological analysis step we can return a word its stem and affixes and then build the AVM from the pieces: *foxes* $\rightarrow$ *fox^s*

$$\left\langle \hat{}s, \begin{bmatrix} \textsc{head} & \begin{bmatrix} \mathbf{N} & \\ \textsc{agreement} & pl \end{bmatrix} \end{bmatrix} \right\rangle$$

$$\left\langle \text{fox}, \begin{bmatrix} \textsc{head} & \begin{bmatrix} \mathbf{N} & \\ \textsc{agreement} & [\,] \end{bmatrix} \end{bmatrix} \right\rangle$$

$$\begin{bmatrix} \textsc{head} & \begin{bmatrix} \mathbf{N} & \\ \textsc{agreement} & pl \end{bmatrix} \end{bmatrix} \sqcup \begin{bmatrix} \textsc{head} & \begin{bmatrix} \mathbf{N} & \\ \textsc{agreement} & [\,] \end{bmatrix} \end{bmatrix} = \begin{bmatrix} \textsc{head} & \begin{bmatrix} \mathbf{N} & \\ \textsc{agreement} & pl \end{bmatrix} \end{bmatrix}$$

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Unification based parsing in the wild...

- Focus on adequacy for a wide range of languages as well as tractable for parsing
- Examples include **Lexical Functional Grammar, LFG** (Bresnan and Kaplan) and **Head-driven Phrase Structure Grammar, HPSG** (Pollard and Sag)
- Grammars tend to incorporate aspects of morphology, syntax and compositional semantics:

If you are interested see: `http://www.delph-in.net`