

Parsing

UC Davis LIN 177
Winter 2022

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- Last time in LIN 177
 - CFG
 - PCFG
 - Extracting PCFG rules from trees
 - Parsing

Context Free Grammars

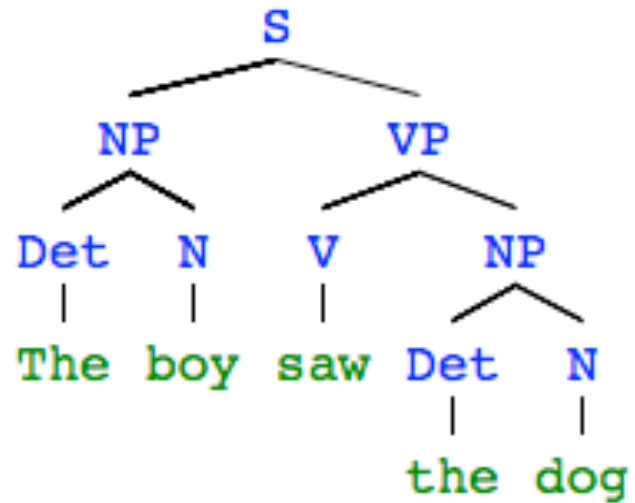
- A *context-free grammar* is a tuple $G = (N, \Sigma, R, S)$, where
 - N is a set of *nonterminal symbols*
 - (e.g. NP, VP, S)
 - Σ is a set of *terminal symbols*
 - (e.g. noun, verb)
 - (e.g. house, sees)
 - R is a set of *rules* (or *productions*) of the form $A \rightarrow \beta$, where $A \in N$ and $\beta \in (N \cup \Sigma)^*$
 - $S \in N$ is a *start symbol*

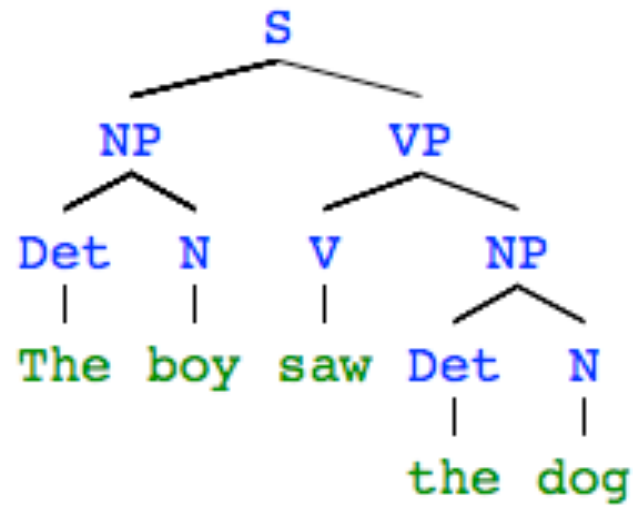
S \rightarrow NP VP
NP \rightarrow Det N
VP \rightarrow V NP
NP \rightarrow Det N PP
PP \rightarrow P NP
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Det \rightarrow the
N \rightarrow dog
N \rightarrow boy
N \rightarrow park
V \rightarrow saw
P \rightarrow in

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P \rightarrow in





(S (NP (Det (The)) (N (boy)))
(VP (V (saw))
(NP (Det (the)) (N (dog)))))

Top-Down Parsing

- Start with Start symbol
 - In our example, S
- Repeat this:
 - If the leftmost symbol is a terminal symbol, match it against the input
 - If everything matches, done
 - If the leftmost symbol is a non-terminal, expand it using a rule in the grammar
 - Find a rule that will lead to the right terminal symbol

- The boy saw the dog

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- The boy saw the dog

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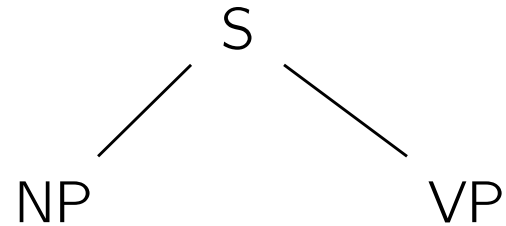
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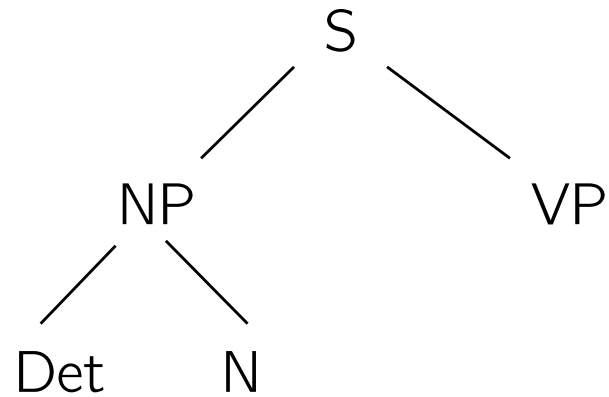
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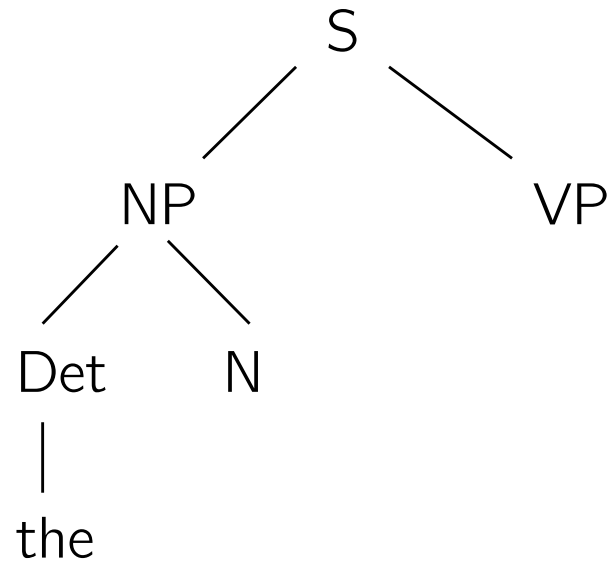
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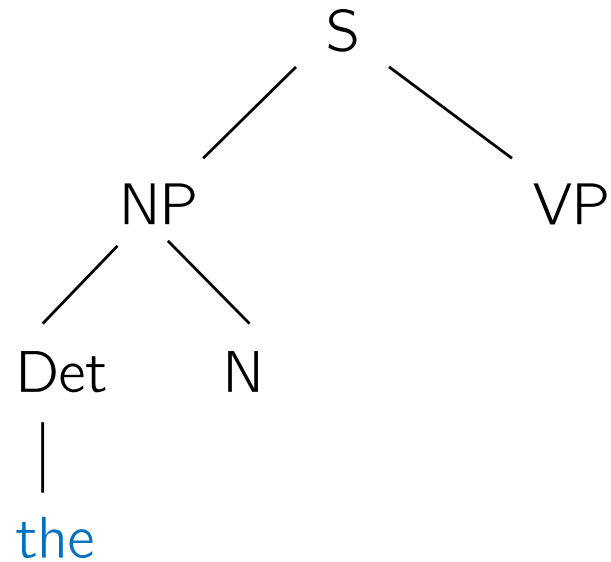
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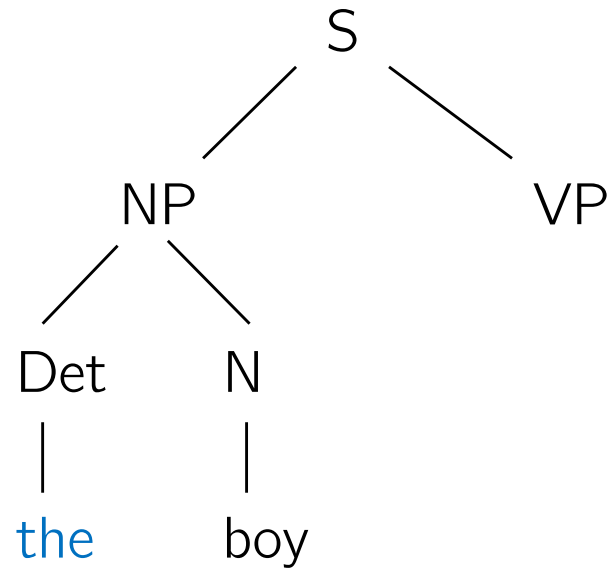
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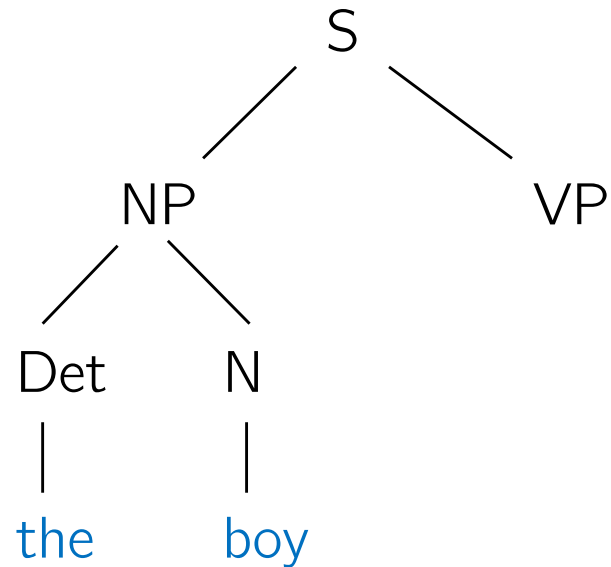
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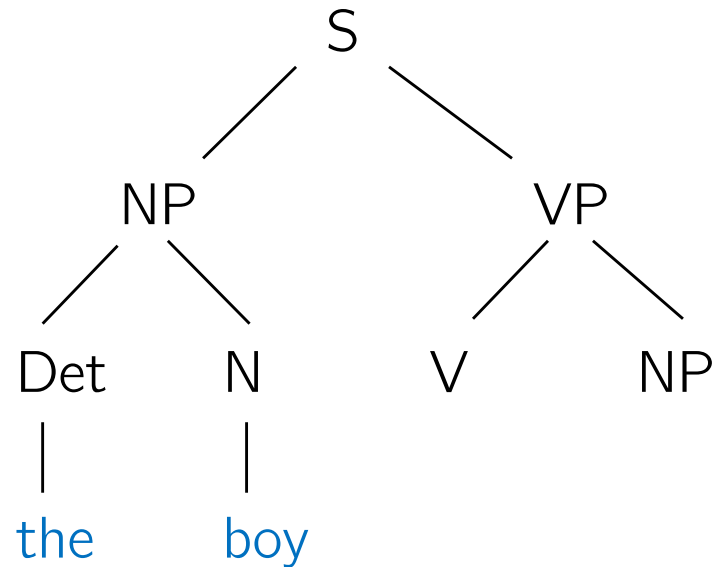
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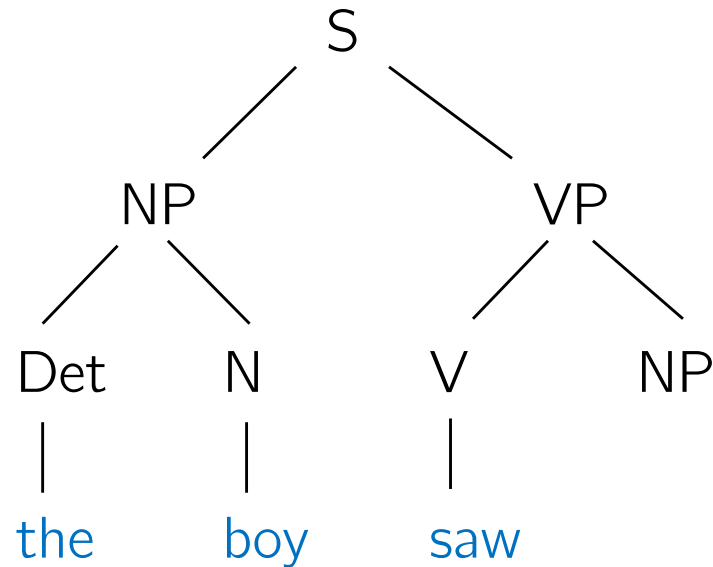
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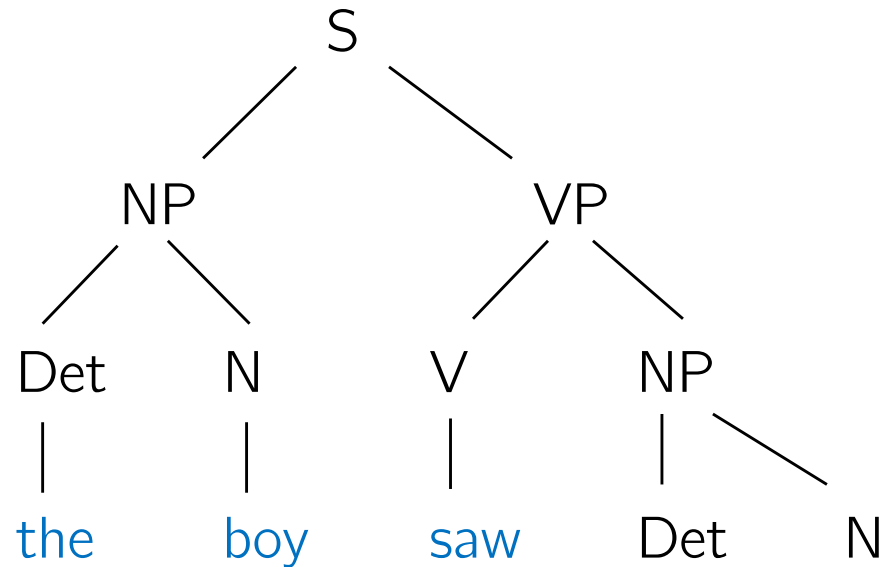
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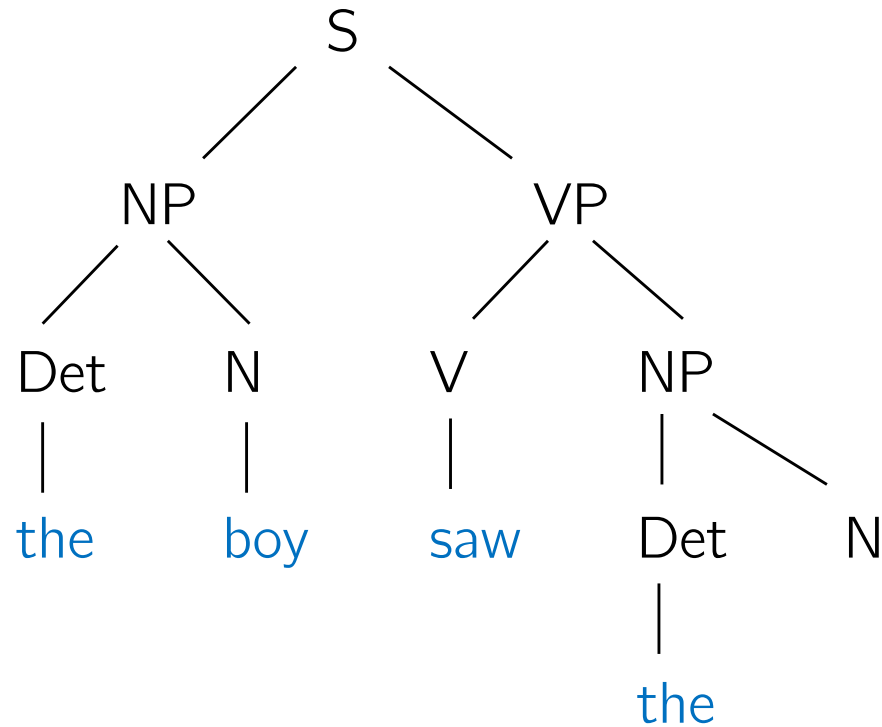
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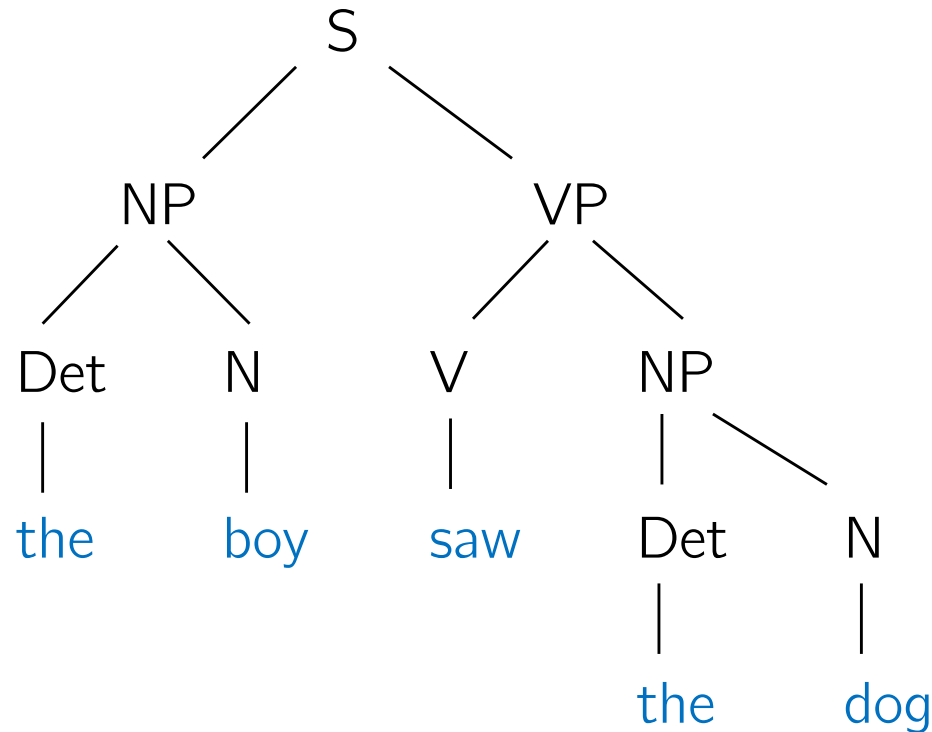
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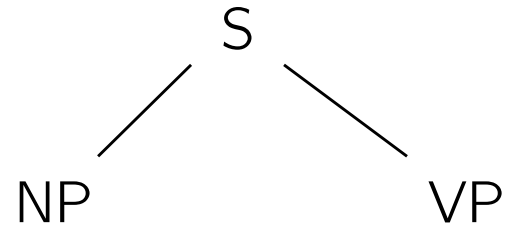
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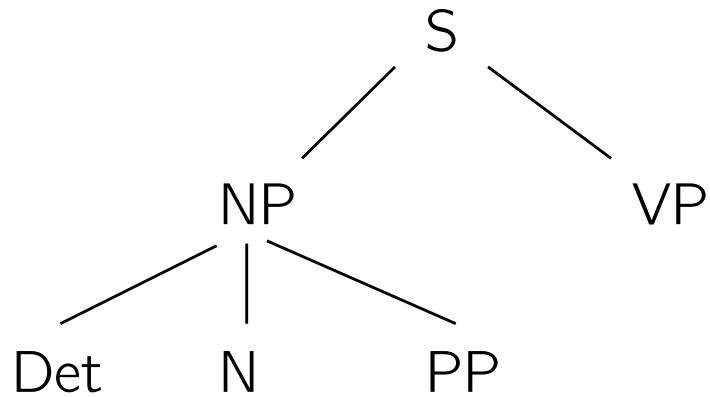
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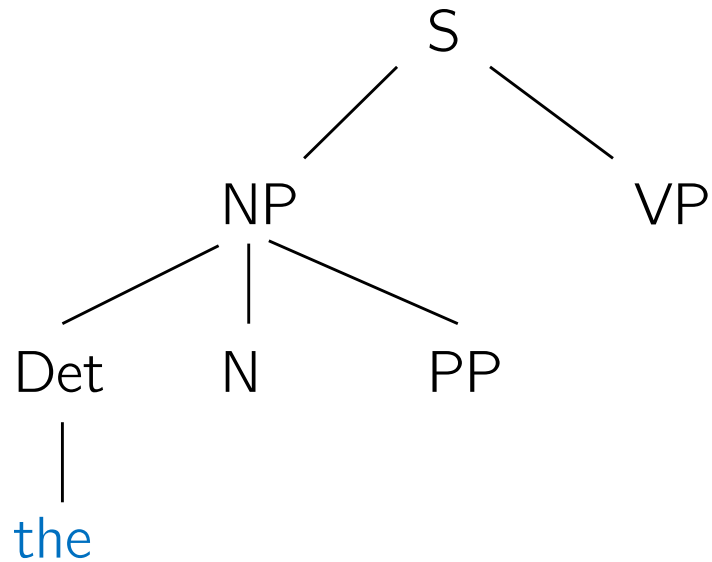
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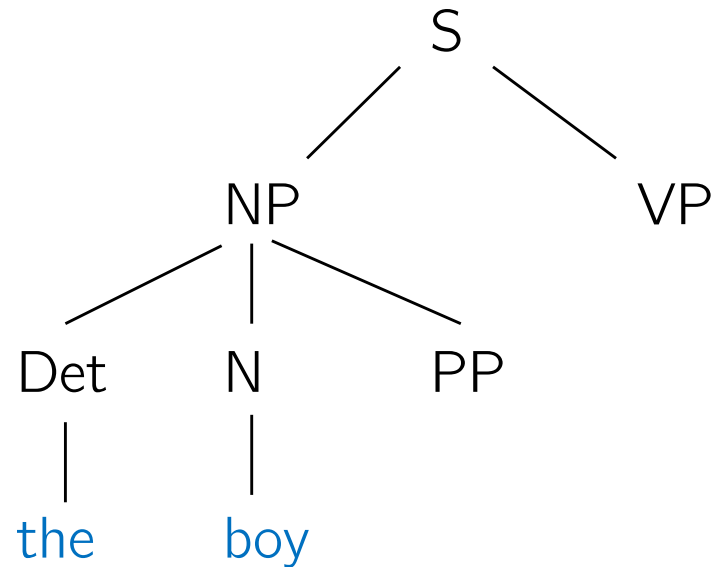
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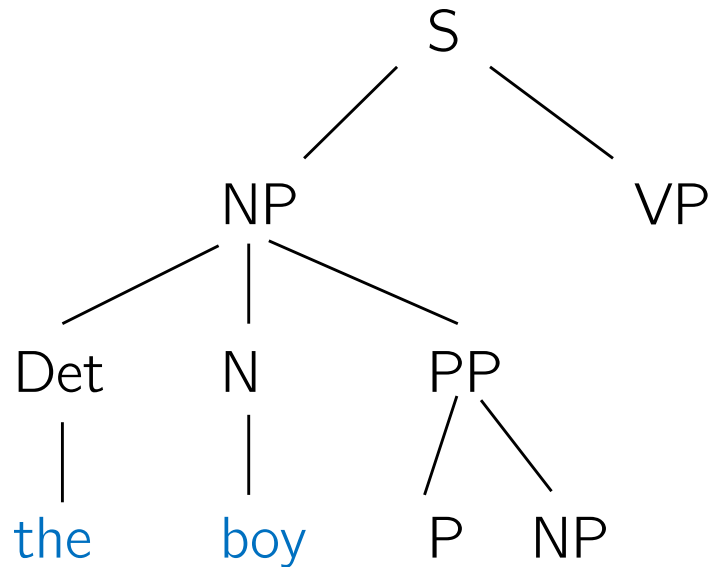
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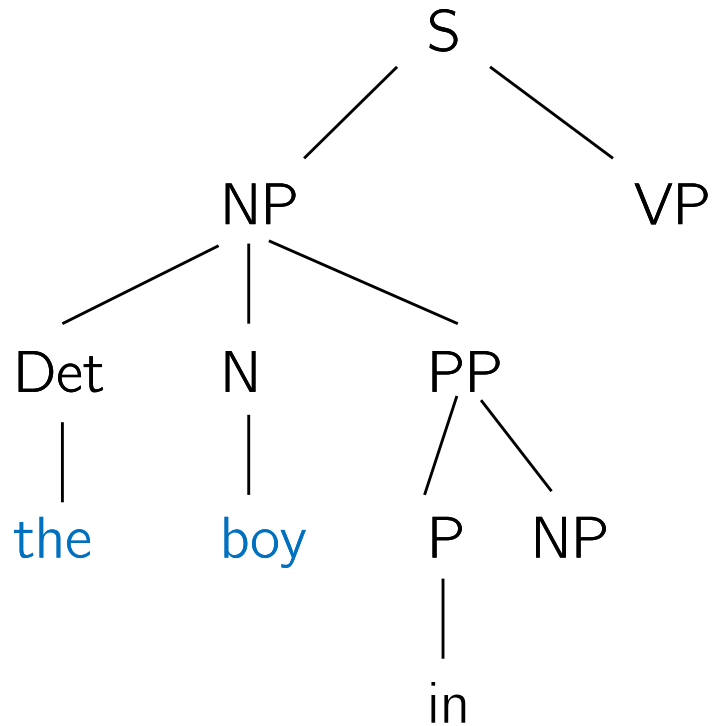
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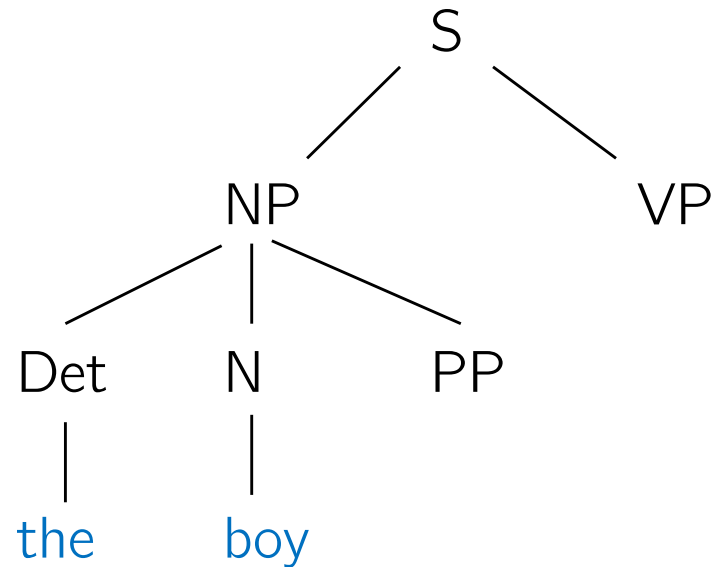
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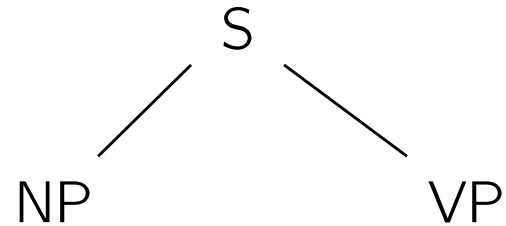
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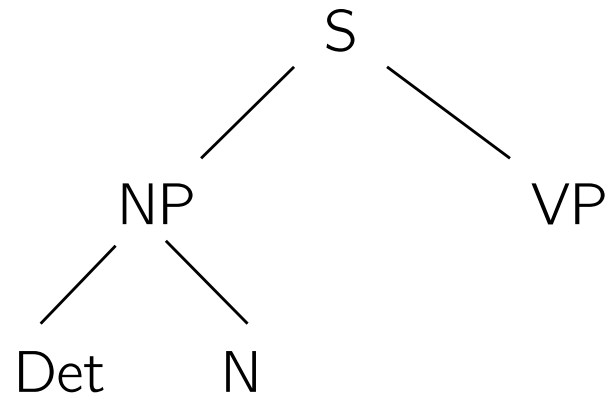
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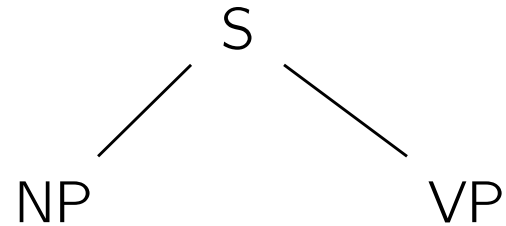
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N \rightarrow dog
N \rightarrow boy
V \rightarrow saw
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S

- The boy saw the dog

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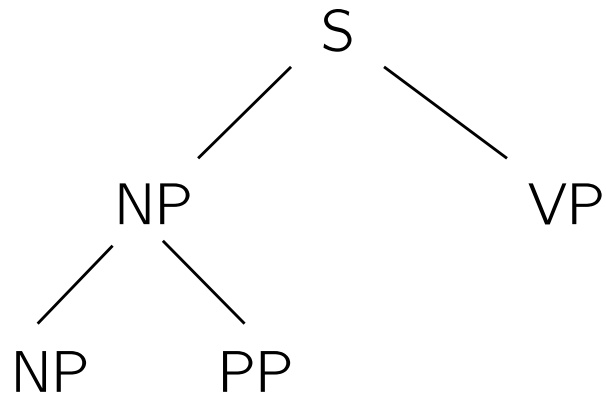
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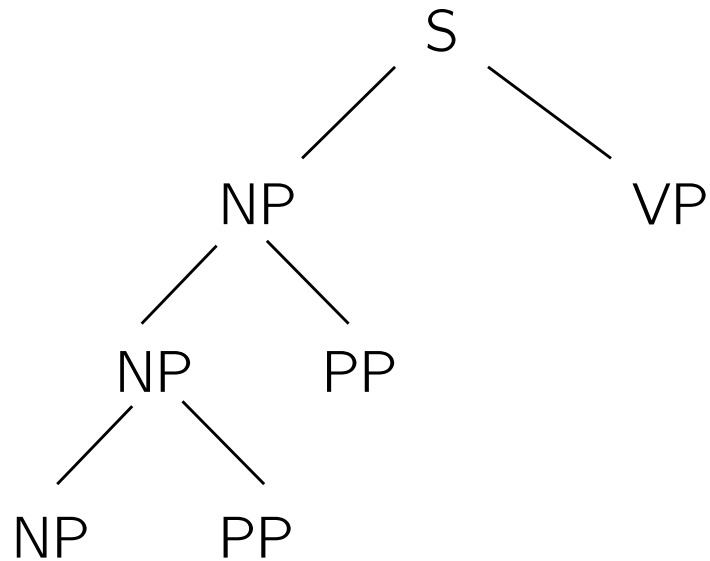
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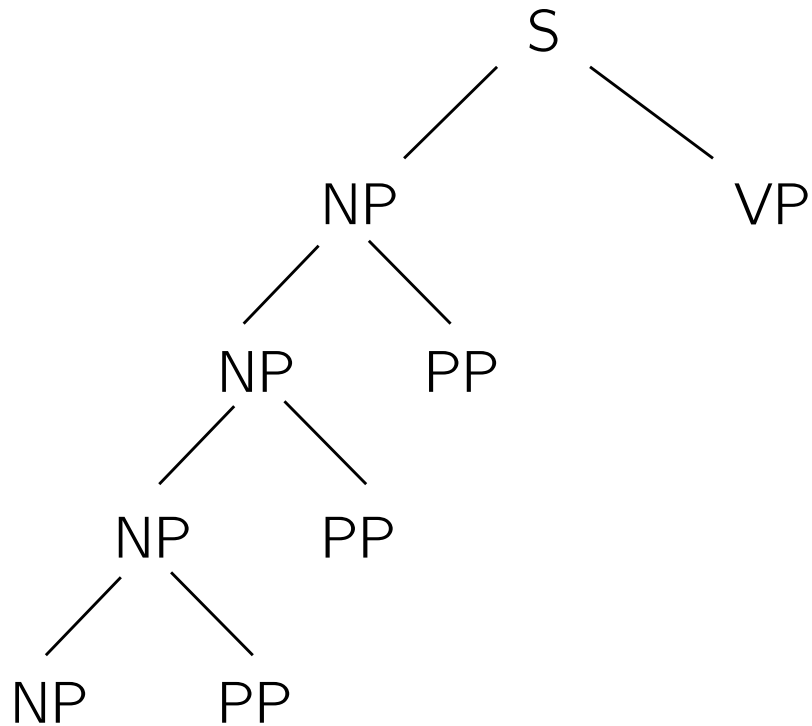
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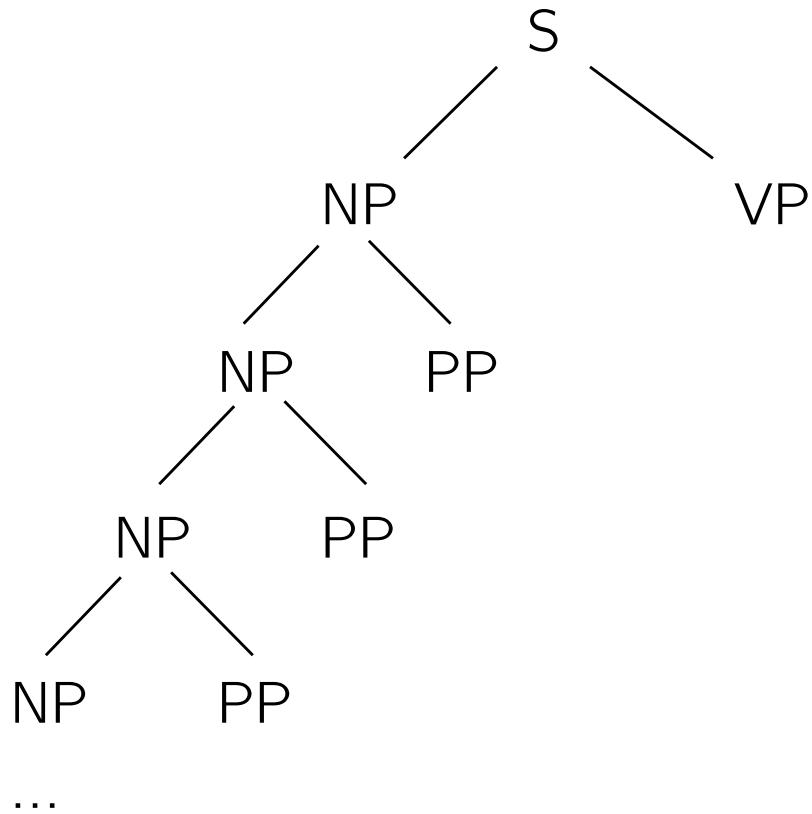
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Det	N	P	Det	N	V	Det	N
The	man	with	the	telescope	saw	the	dog

$S \rightarrow NP VP$	1.0
$NP \rightarrow Pro$	0.22
$NP \rightarrow Det N$	0.67
$NP \rightarrow NP PP$	0.11
$VP \rightarrow V NP$	0.75
$VP \rightarrow VP PP$	0.25
$PP \rightarrow P NP$	1.0

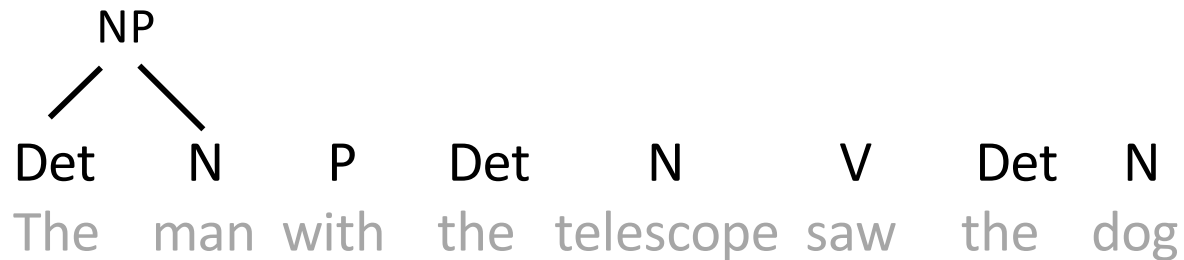
Det N P Det N V Det N
The man with the telescope saw the dog

$S \rightarrow NP VP$	1.0
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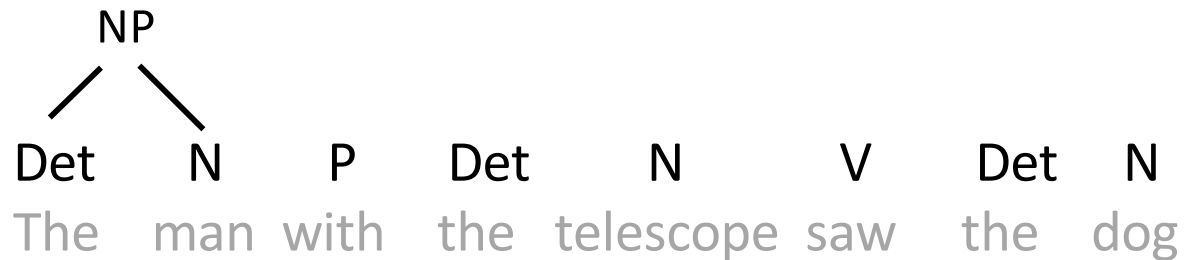
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0.67

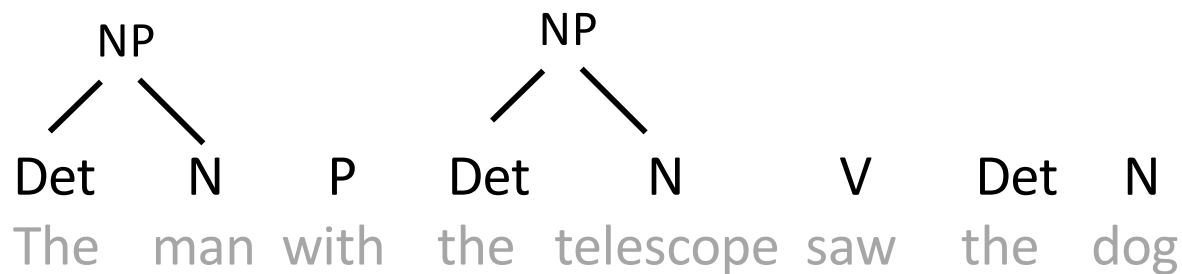
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Det N P Det N V Det N
 The man with the telescope saw the dog

$0.67 * 0.67$

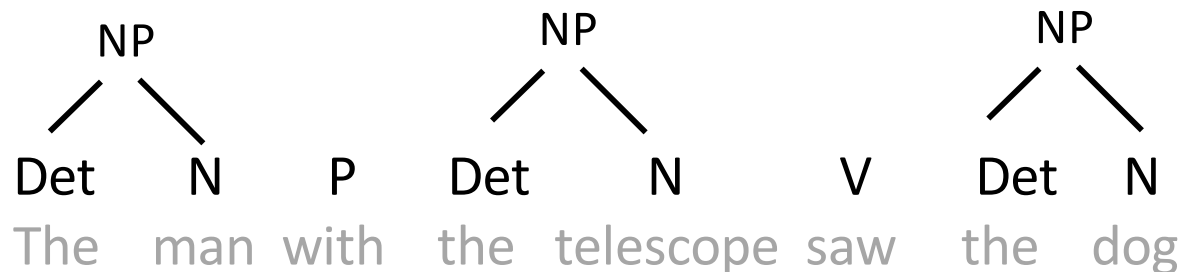
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Det N P Det N V Det N
 The man with the telescope saw the dog

$0.67 * 0.67 * 0.67$

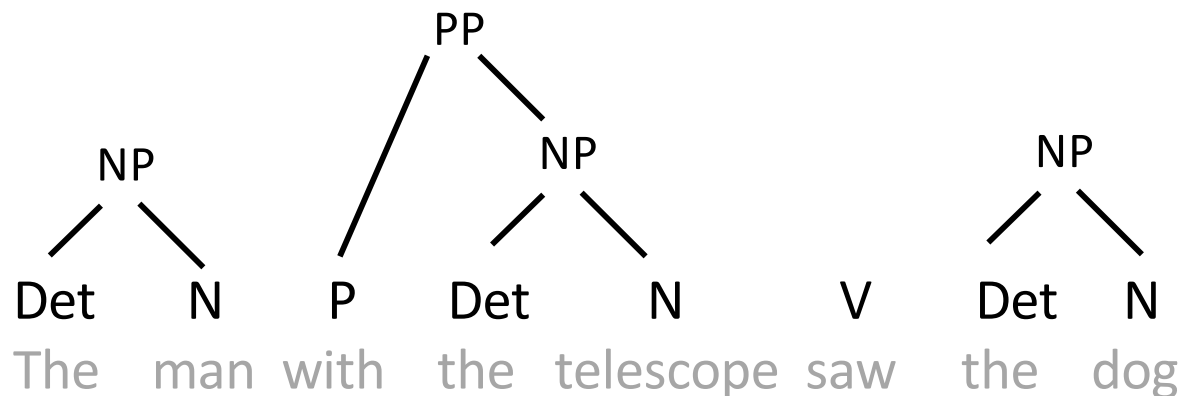
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Det N P Det N V Det N
 The man with the telescope saw the dog

$0.67 * 0.67 * 0.67 * 1.0$

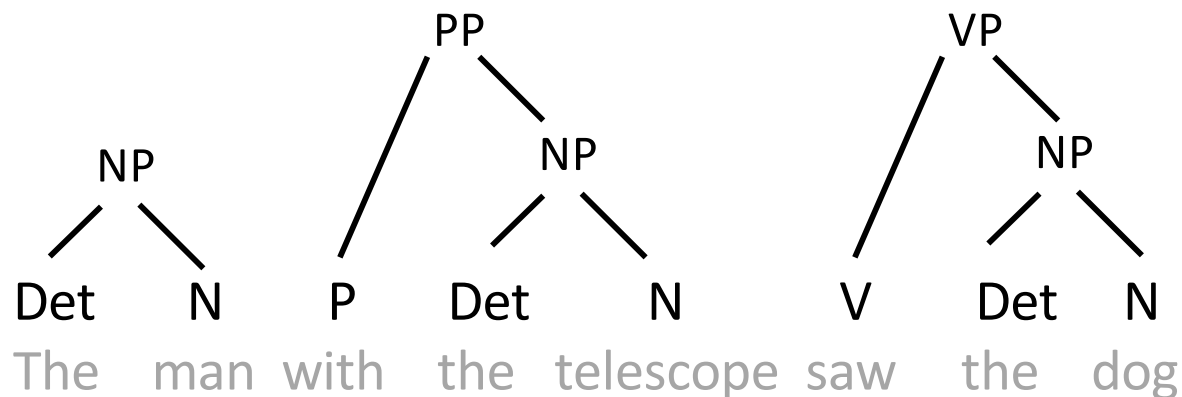
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Det N P Det N V Det N
 The man with the telescope saw the dog

$0.67 * 0.67 * 0.67 * 1.0 * 0.75$

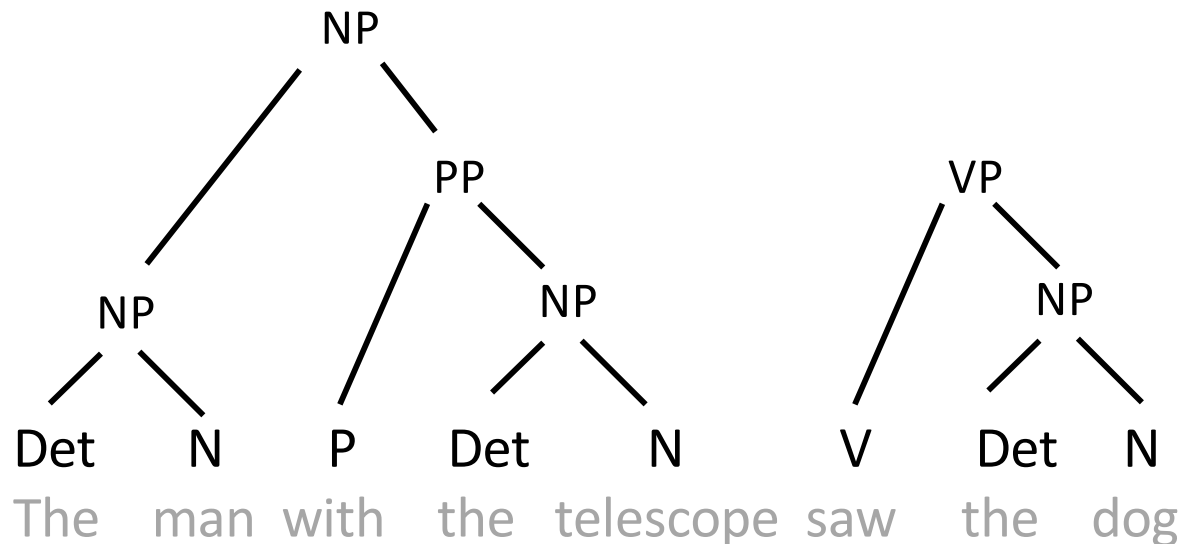
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Det N P Det N V Det N
 The man with the telescope saw the dog

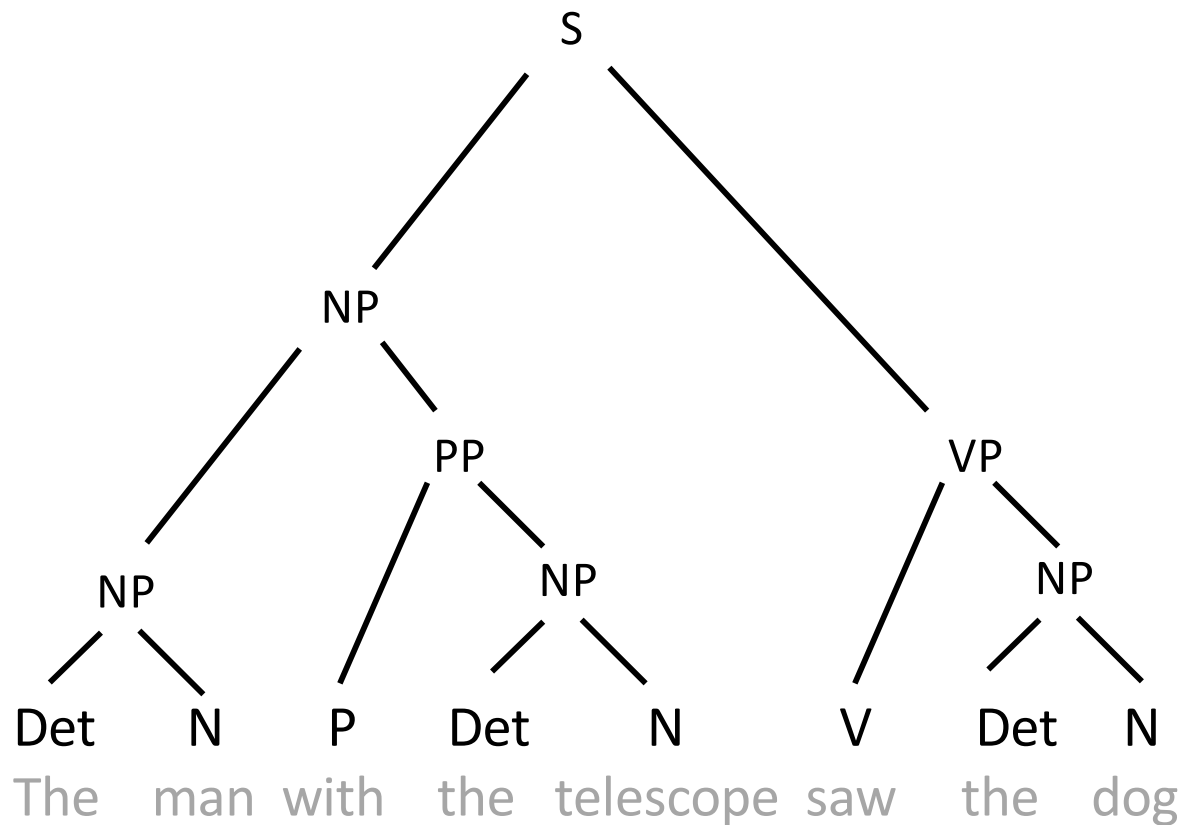
$0.67 * 0.67 * 0.67 * 1.0 * 0.75 * 0.11$

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Det N P Det N V Det N
 The man with the telescope saw the dog

$0.67 * 0.67 * 0.67 * 1.0 * 0.75 * 0.11 * 1.0$



$S \rightarrow NP VP$	1.0
-----------------------	-----

$NP \rightarrow Pro$	0.22
----------------------	------

$NP \rightarrow Det N$	0.67
------------------------	------

$NP \rightarrow NP PP$	0.11
------------------------	------

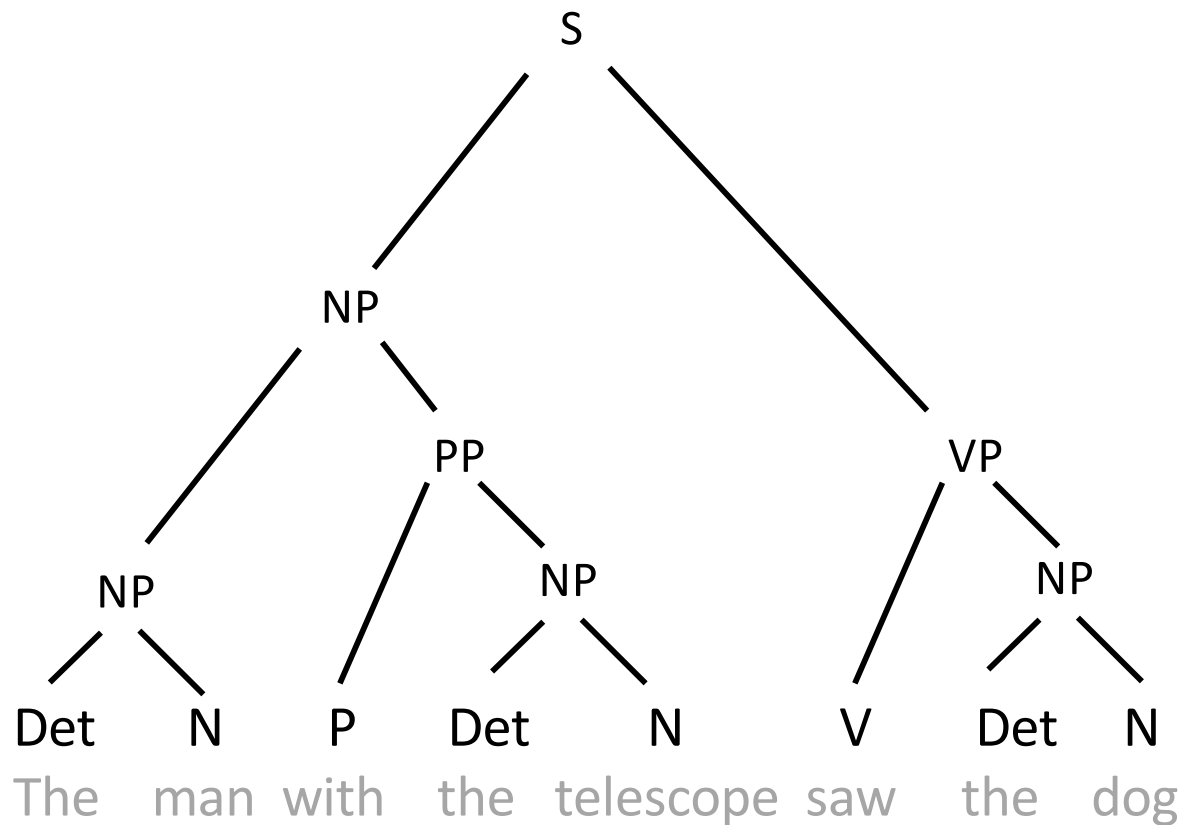
$VP \rightarrow V NP$	0.75
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$VP \rightarrow VP PP$	0.25
------------------------	------

$PP \rightarrow P NP$	1.0
-----------------------	-----

Det N P Det N V Det N
 The man with the telescope saw the dog

$$0.67 * 0.67 * 0.67 * 1.0 * 0.75 * 0.11 * 1.0 = 0.025$$



$S \rightarrow NP VP$	1.0
-----------------------	-----

$NP \rightarrow Pro$	0.22
----------------------	------

$NP \rightarrow Det N$	0.67
------------------------	------

$NP \rightarrow NP PP$	0.11
------------------------	------

$VP \rightarrow V NP$	0.75
-----------------------	------

$VP \rightarrow VP PP$	0.25
------------------------	------

$PP \rightarrow P NP$	1.0
-----------------------	-----

- Prolog can tell us which sentences are in the language defined by the grammar.

$s \rightarrow np, vp.$

$np \rightarrow det, n.$

$vp \rightarrow v, np.$

$det \rightarrow [the].$

$det \rightarrow [a].$

$n \rightarrow [boy].$

$n \rightarrow [dog].$

$v \rightarrow [saw].$

- Here we add a new property (def/indef) to determiners. If a determiner is `det(def)`, we need to call it `det(def)` when we use it in a rule. The `np` rule now only allows `det(def)`, and not `det(indef)`.

`s --> np, vp.`

`np --> det(def), n.`

`vp --> v, np.`

`det(def) --> [the].`

`det(indef) --> [a].`

`n --> [boy].`

`n --> [dog].`

`v --> [saw].`

- But instead of saying `det(def)` in the rule, we can use a variable. In the grammar below, the variable `D` will take on the value `def` or `indef` as necessary, but we don't do anything with that value.

`s --> np, vp.`

`np --> det(D), n.`

`vp --> v, np.`

`det(def) --> [the].`

`det(indef) --> [a].`

`n --> [boy].`

`n --> [dog].`

`v --> [saw].`

- Now we pass that value to the resulting np. So an np made with a det(def) will be np(def), and an np made with a det(indef) will be np(indef). We update the rules where we use an np. But we don't use the def/indef property of the np.

s --> np(A), vp.

np(D) --> det(D), n.

vp --> v, np(B).

det(def) --> [the].

det(indef) --> [a].

n --> [boy].

n --> [dog].

v --> [saw].

- Finally, we can pass the def/indef property of the np to the s.

$s(A) \rightarrow np(A), vp.$

$np(D) \rightarrow det(D), n.$

$vp \rightarrow v, np(B).$

$det(def) \rightarrow [the].$

$det(indef) \rightarrow [a].$

$n \rightarrow [boy].$

$n \rightarrow [dog].$

$v \rightarrow [saw].$

- Now the s will have the same def/indef value as the determiner used in the first np. (The np inside the vp also has a def/indef value, but we don't use it anywhere in this grammar.)

$s(A) \rightarrow np(A), vp.$

$np(D) \rightarrow det(D), n.$

$vp \rightarrow v, np(B).$

$det(def) \rightarrow [the].$

$det(indef) \rightarrow [a].$

$n \rightarrow [boy].$

$n \rightarrow [dog].$

$v \rightarrow [saw].$

- We could keep track of the def/indef value of both the first np and the np inside the vp. For the np inside the vp, we just pass the value to the vp. Then, when we use the vp, it will have a def/indef value. And we can pass that value to s.

$s(\text{definiteness}(\text{subj}(A), \text{obj}(C))) \rightarrow \text{np}(A), \text{vp}(C).$

$\text{np}(D) \rightarrow \text{det}(D), n.$

$\text{vp}(B) \rightarrow v, \text{np}(B).$

$\text{det}(\text{def}) \rightarrow [\text{the}].$

$\text{det}(\text{indef}) \rightarrow [a].$

$n \rightarrow [\text{boy}].$

$n \rightarrow [\text{dog}].$

$v \rightarrow [\text{saw}].$

- We can see the what this grammar generates:

```
?- s(X,Y,[]).
```

```
X = definiteness(subj(def), obj(def)),
```

```
Y = [the, boy, saw, the, boy]
```

```
X = definiteness(subj(def), obj(def)),
```

```
Y = [the, boy, saw, the, dog]
```

```
X = definiteness(subj(def), obj(indef)),
```

```
Y = [the, boy, saw, a, boy]
```

```
X = definiteness(subj(def), obj(indef)),
```

```
Y = [the, boy, saw, a, dog]
```

```
X = definiteness(subj(def), obj(def)),
```

```
Y = [the, dog, saw, the, boy]
```

```
X = definiteness(subj(def), obj(def)),
```

```
Y = [the, dog, saw, the, dog]
```

```
X = definiteness(subj(def), obj(indef)),
```

```
Y = [the, dog, saw, a, boy]
```

```
X = definiteness(subj(def), obj(indef)),
```

```
Y = [the, dog, saw, a, dog]
```

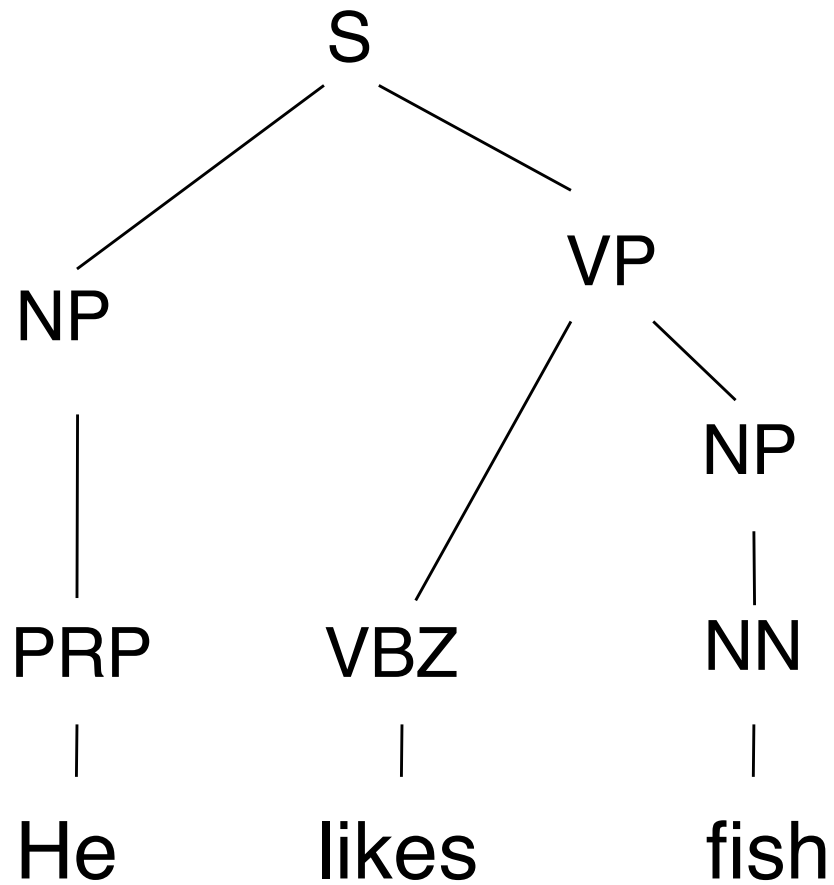
```
X = definiteness(subj(indef), obj(def)),
```

```
...
```

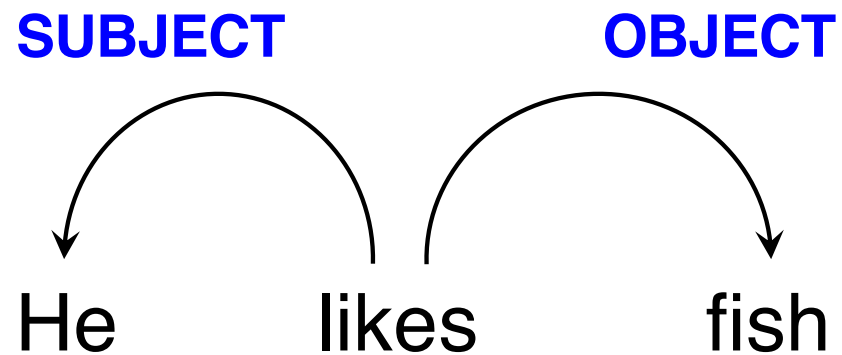
Syntactic Analysis

He likes fish

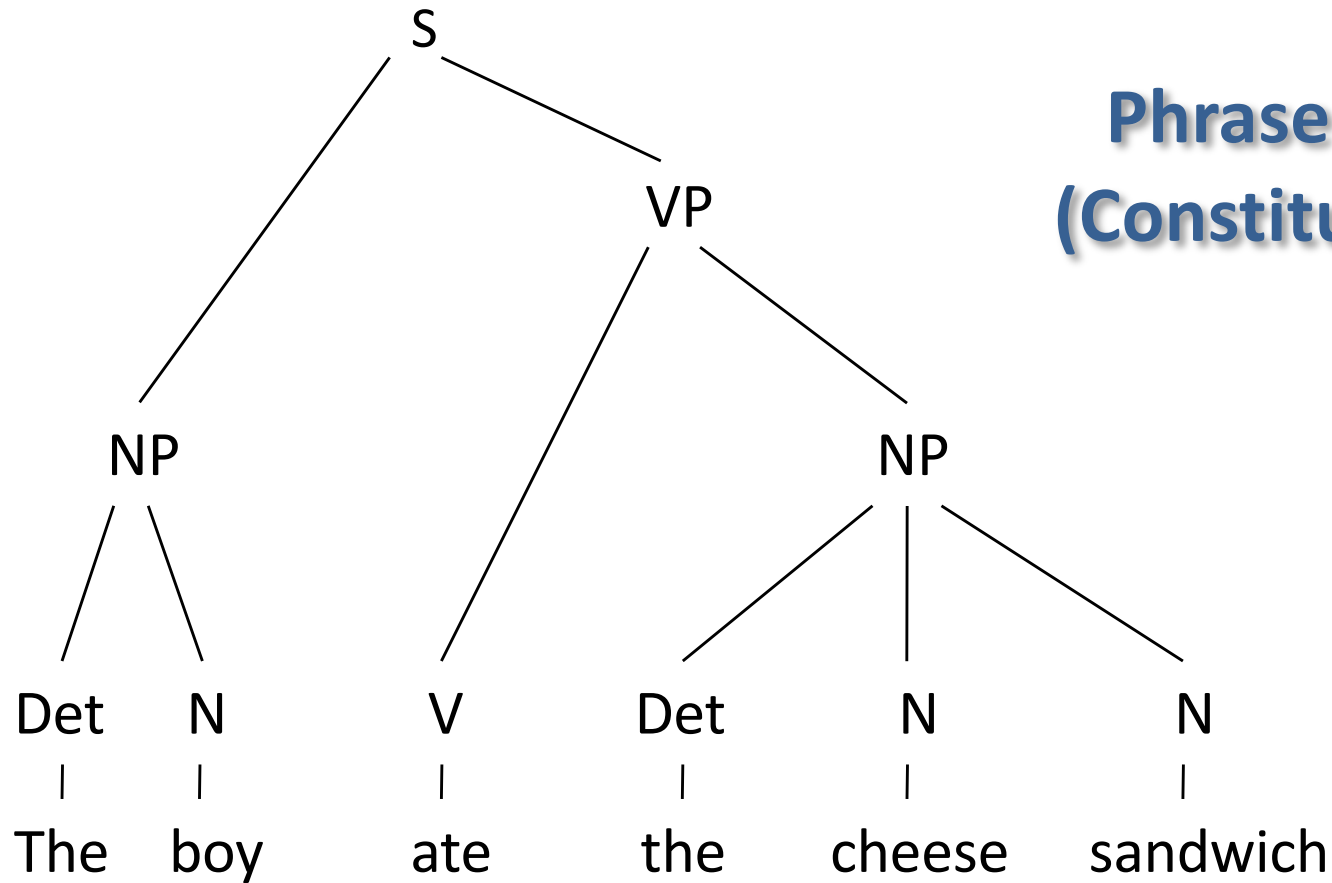
Syntactic Analysis



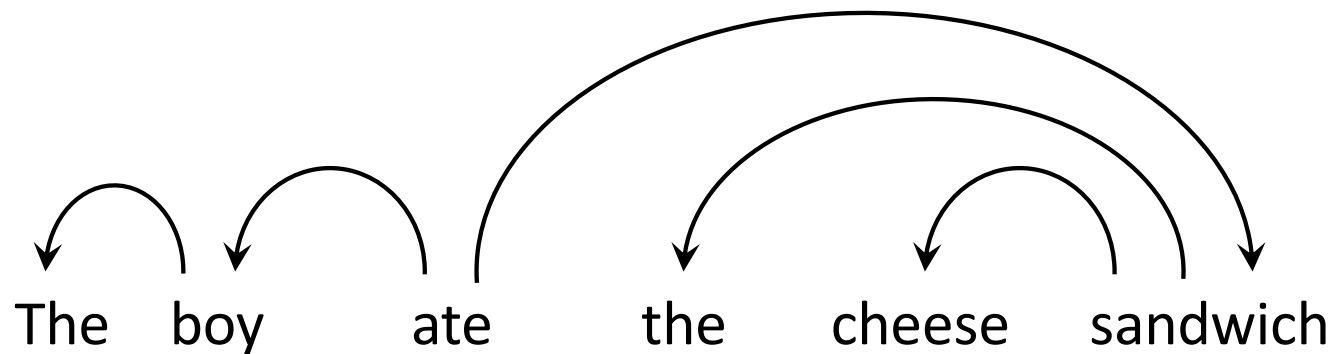
Syntactic Analysis

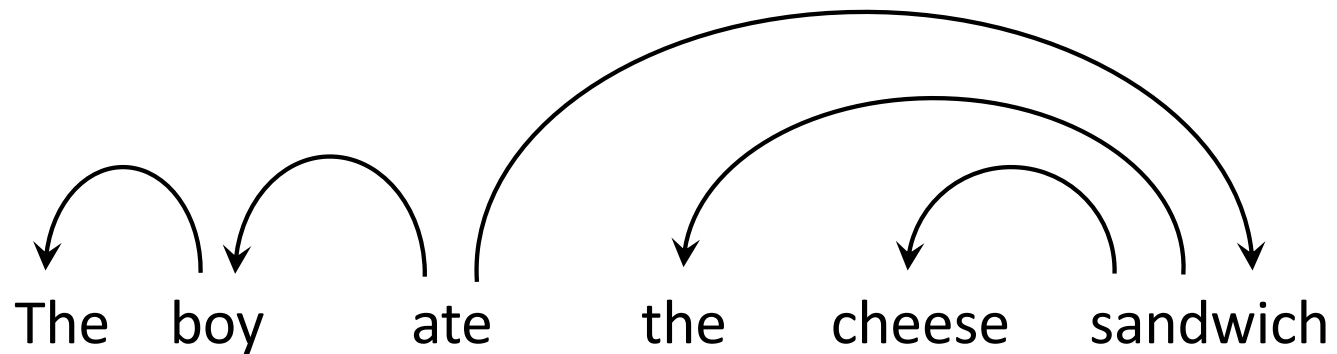
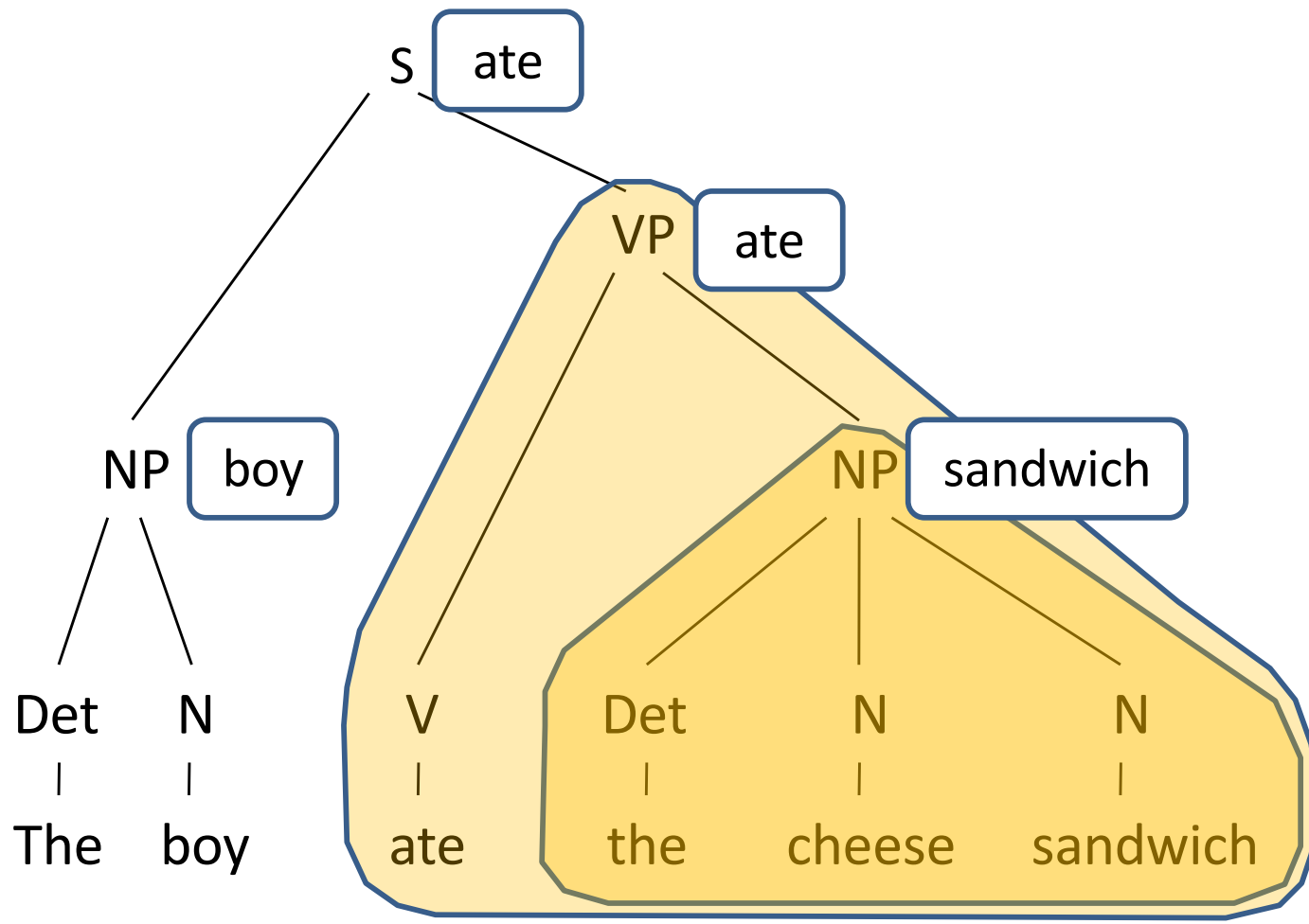


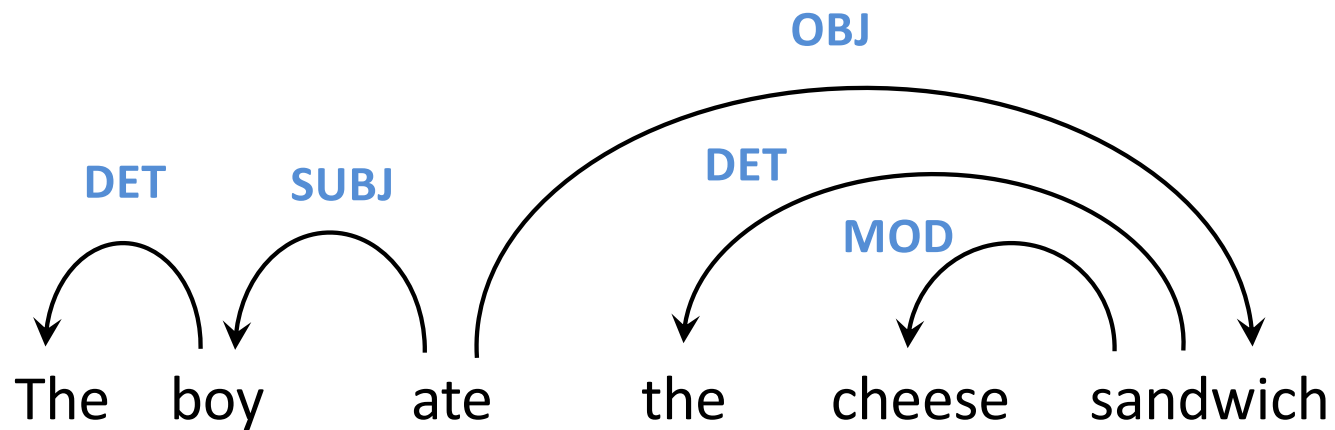
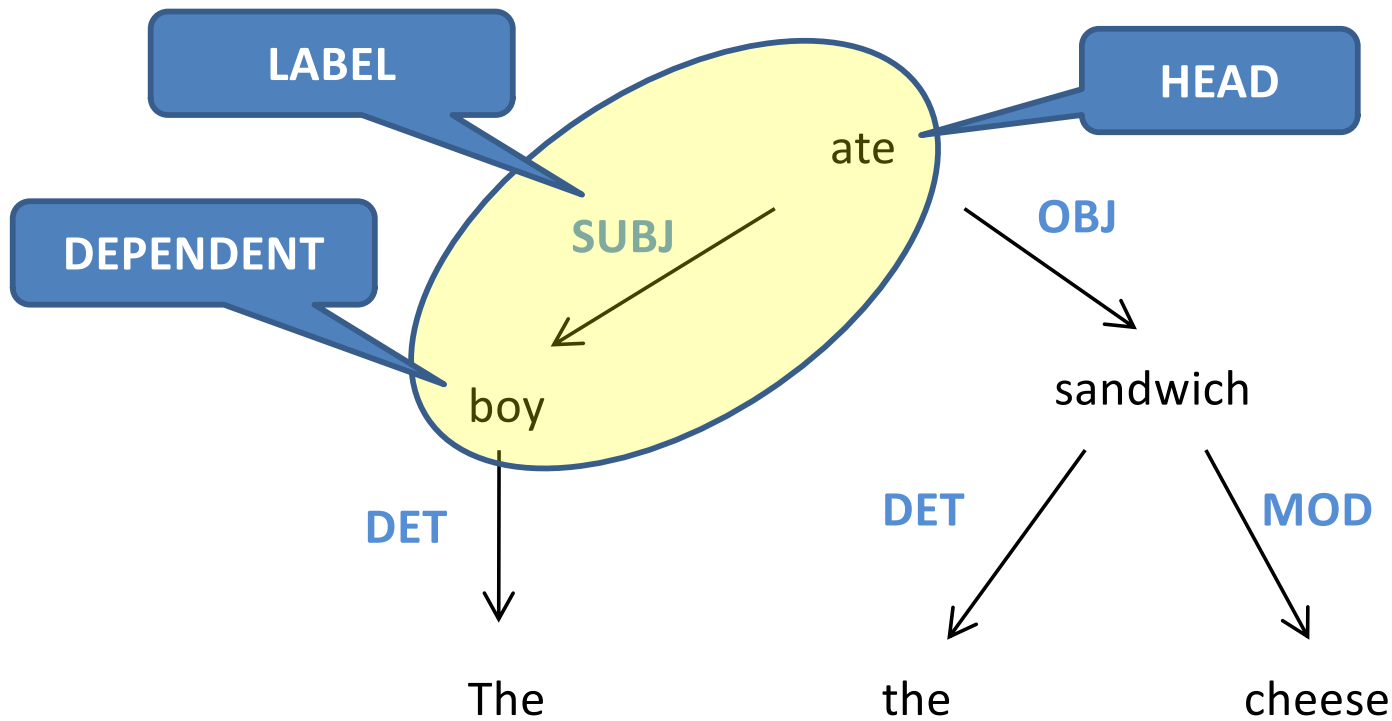
Phrase Structure Tree (Constituent Structure)



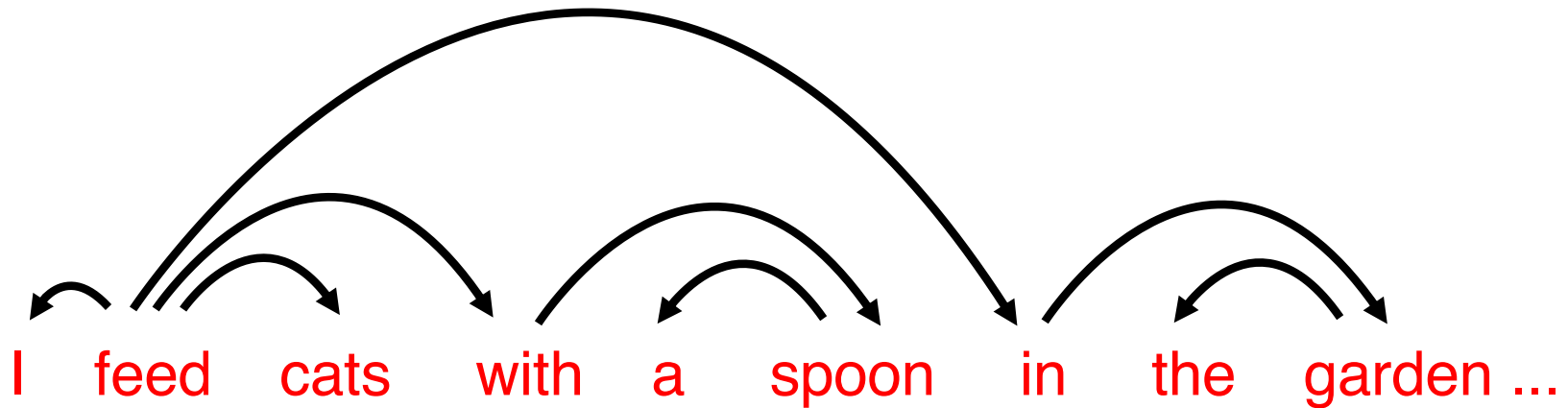
Dependency Structure

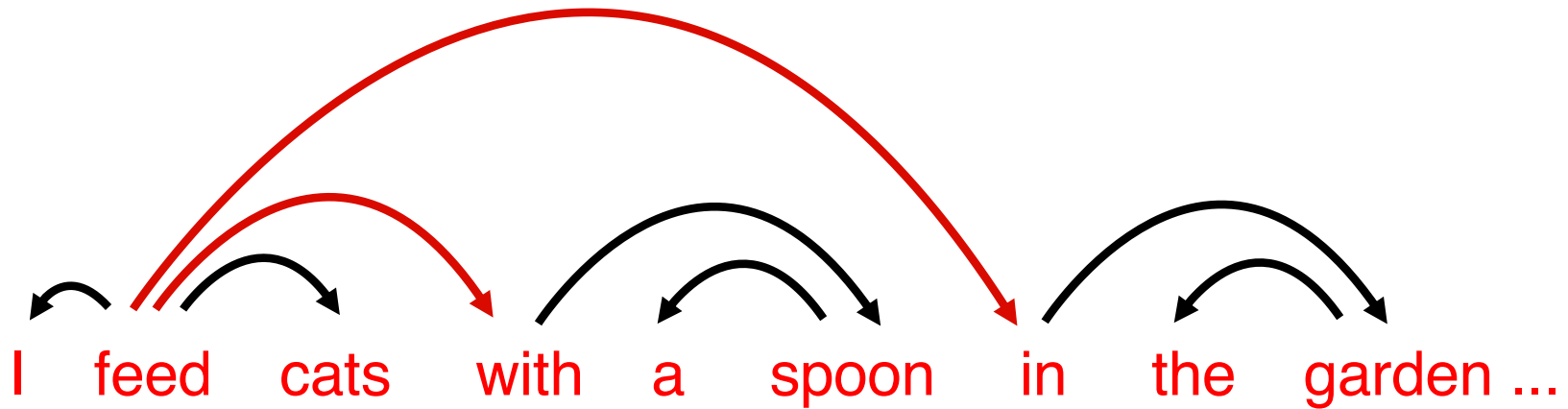




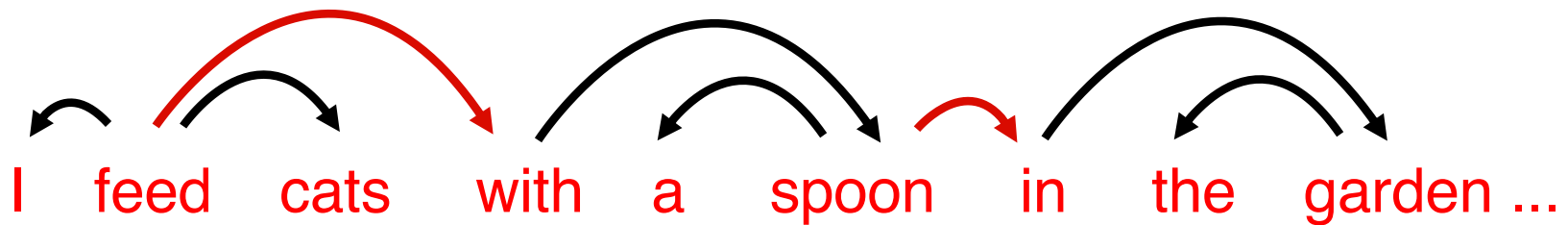


Structural Ambiguity

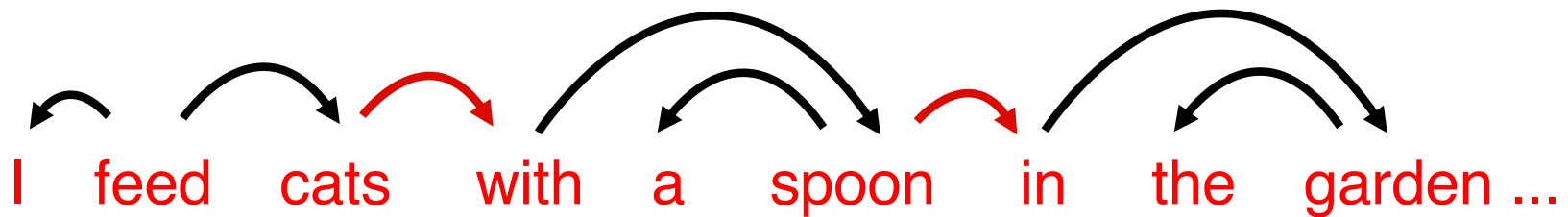




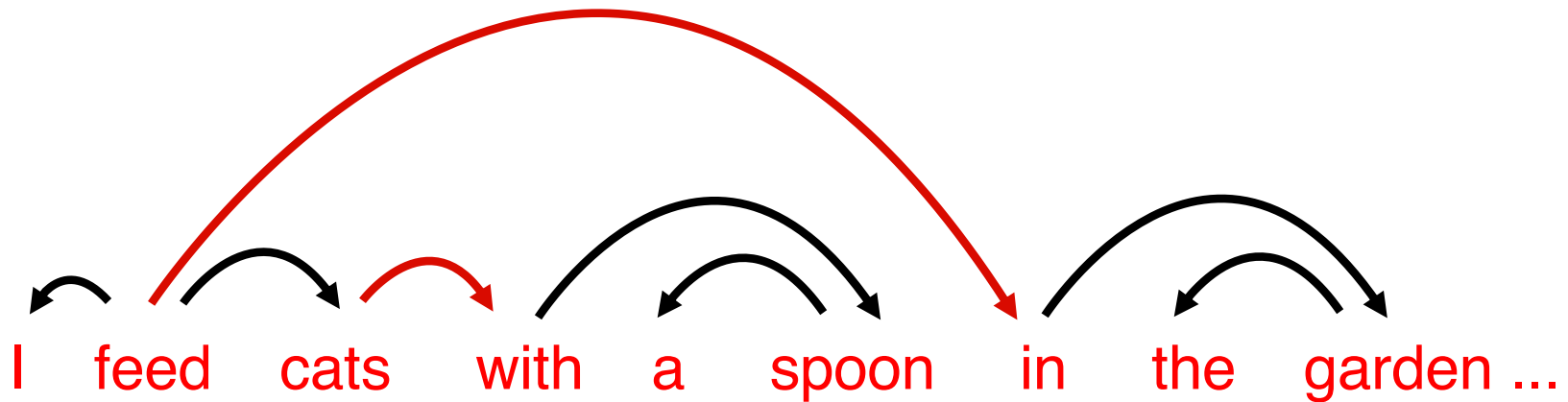
- I use a spoon to feed cats, and I do this in the garden



- I use a spoon to feed cats, the spoon is in the garden



- I feed cats, the cats have a spoon, the spoon is in the garden



- I feed cats, the cats have a spoon, the feeding takes place in the garden