

# Computational Linguistics

## Lecture 6

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# CFG: Formal definition

1. a set of non-terminal symbols (or ‘variables’)  $N$
2. a set of terminal symbols  $\Sigma$  (disjoint from  $N$ )
3. a set of productions  $P$ , each of the form  $A \rightarrow \alpha$ , where  $A$  is a non-terminal and  $\alpha$  is a string of symbols from the infinite set of strings  $(\Sigma \cup N)^*$ .
4. a designated start symbol  $S$



# Sentence Types

- **Declaratives:** A plane left.

$S \rightarrow NP VP$

- **Imperatives:** Leave!

$S \rightarrow VP$

- **Yes-No Questions:** Did the plane leave?

$S \rightarrow Aux NP VP$

- **WH Questions:** **wh- word** (who, where, what, which, how, why).

What airlines fly from Burbank to Denver?

$S \rightarrow WH-NP NP VP$

When did the plane leave?

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$S \rightarrow WH-NP Aux NP VP$

# CFG Concrete Example

- $N : \{S, NP, VP, DT, Vi, Vt, N\}$
- $S : \{S\}$
- $\Sigma: \{\text{sleeps, saw, woman, man, the}\}$
- $P.$

$S \rightarrow NP VP$

$VP \rightarrow Vi$

$VP \rightarrow Vt NP$

$NP \rightarrow DT N$

$Vi \rightarrow \text{sleeps}$

$Vt \rightarrow \text{saw}$

$N \rightarrow \text{man}$

$N \rightarrow \text{woman}$

$DT \rightarrow \text{the}$



# CFG Concrete Example

➤ Given the statement “The man sleeps”, is it valid on the aforementioned CFG?

➤ **Parsing**

S

NP VP

DT N VP

The N VP

The man VP

The man Vi

The man sleeps

**Rules Used**

$S \rightarrow NP VP$

$NP \rightarrow DT N$

$DT \rightarrow \text{The}$

$N \rightarrow \text{man}$

$VP \rightarrow Vi$

$Vi \rightarrow \text{sleeps}$

# CFG Ambiguity Example

- $V : \{S, NP, VP, PP, DT, Vi, Vt, N, P, Pr\}$
- $S : \{S\}$
- $\Sigma: \{\text{sleeps, saw, I, woman, girl, telescope, the, in, with}\}$
- $P:$

$S \rightarrow NP VP$

$N \rightarrow \text{girl}$

$VP \rightarrow Vi$

$N \rightarrow \text{woman}$

$VP \rightarrow Vt NP$

$N \rightarrow \text{telescope}$

$VP \rightarrow VP PP$

$NP \rightarrow DT N$

$DT \rightarrow \text{The}$

$NP \rightarrow Pr$

$P \rightarrow \text{in}$

$NP \rightarrow NP PP$

$P \rightarrow \text{with}$

$PP \rightarrow P NP$

$Pr \rightarrow \text{I}$

$Vi \rightarrow \text{sleeps}$

$Vt \rightarrow \text{saw}$



# CFG Ambiguity Example

I saw the girl with the telescope

## ➤ Parsing

S

NP VP

Pr VP

I VP

I Vt NP

I saw NP

I saw NP PP

I saw DT N PP

I saw the N PP

I saw the girl PP

I saw the girl P NP

I saw the girl with NP

I saw the girl with DT N

I saw the girl with the N

I saw the girl with the telescope

## Rules Used

S  $\rightarrow$  NP VP

NP  $\rightarrow$  Pr

Pr  $\rightarrow$  I

VP  $\rightarrow$  Vt NP

Vt  $\rightarrow$  saw

NP  $\rightarrow$  NP PP

NP  $\rightarrow$  DT N

DT  $\rightarrow$  the

N  $\rightarrow$  girl

PP  $\rightarrow$  P NP

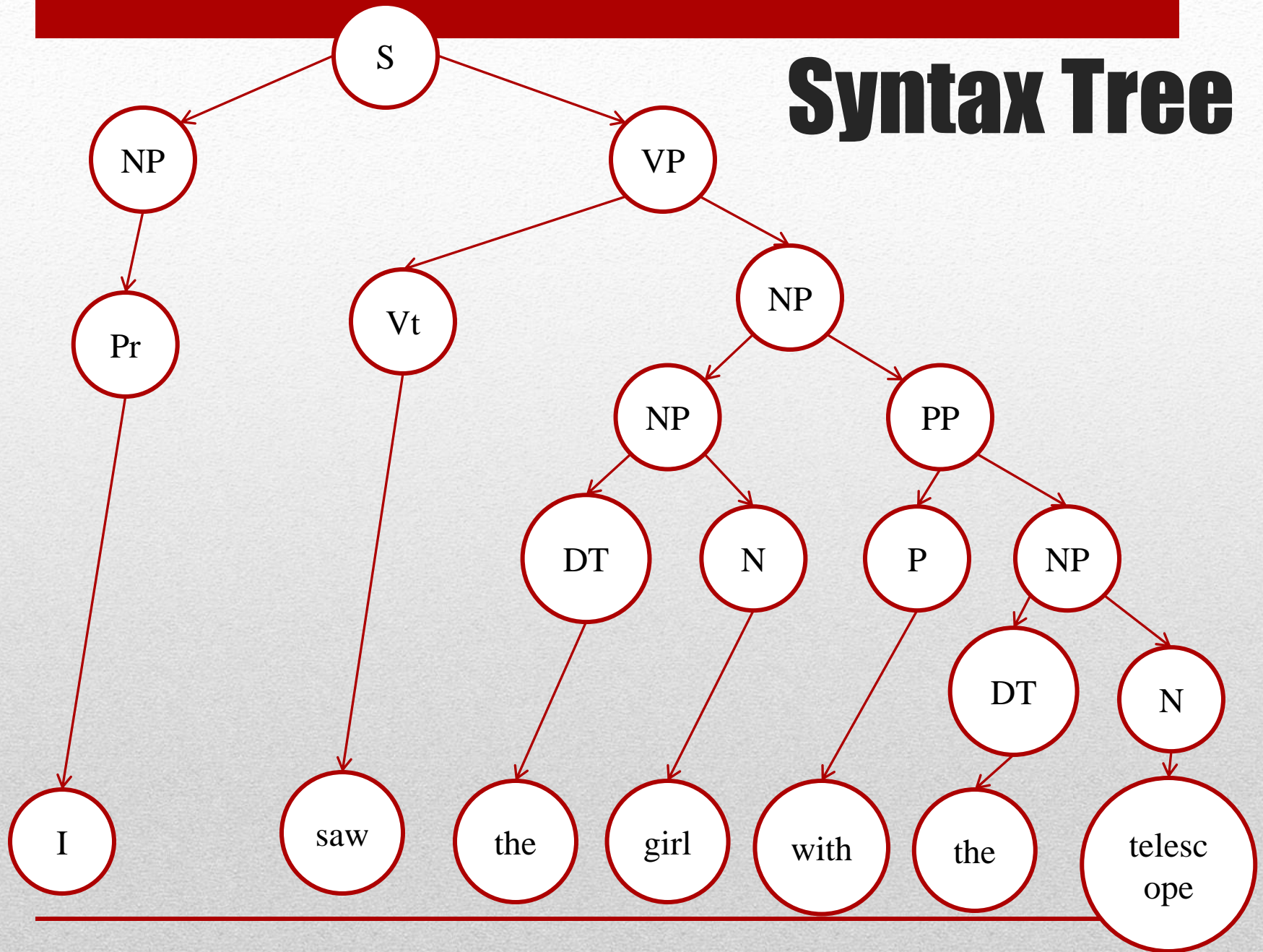
P  $\rightarrow$  with

NP  $\rightarrow$  DT N

DT  $\rightarrow$  the

N  $\rightarrow$  telescope

# Syntax Tree





# CFG Ambiguity Example

I saw the girl with the telescope

## ➤ Parsing

S

NP VP

Pr VP

I VP

I VP PP

I Vt NP PP

I saw NP PP

I saw DT N PP

I saw the N PP

I saw the girl PP

I saw the girl P NP

I saw the girl with NP

I saw the girl with DT N

I saw the girl with the N

I saw the girl with the telescope

## Rules Used

S  $\rightarrow$  NP VP

NP  $\rightarrow$  Pr

Pr  $\rightarrow$  I

VP  $\rightarrow$  VP PP

VP  $\rightarrow$  Vt NP

Vt  $\rightarrow$  saw

NP  $\rightarrow$  DT N

DT  $\rightarrow$  the

N  $\rightarrow$  girl

PP  $\rightarrow$  P NP

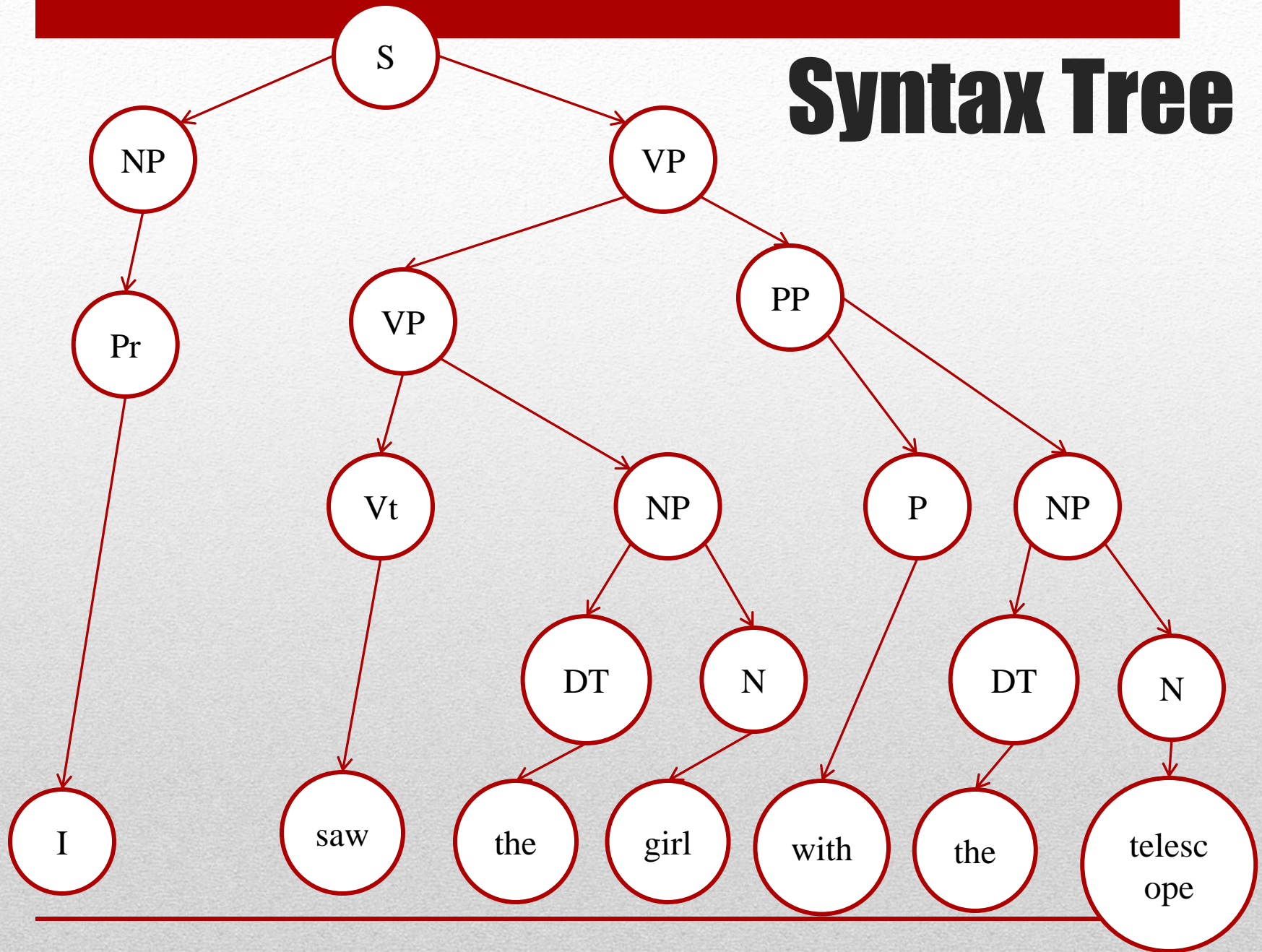
P  $\rightarrow$  with

NP  $\rightarrow$  DT N

DT  $\rightarrow$  the

N  $\rightarrow$  telescope

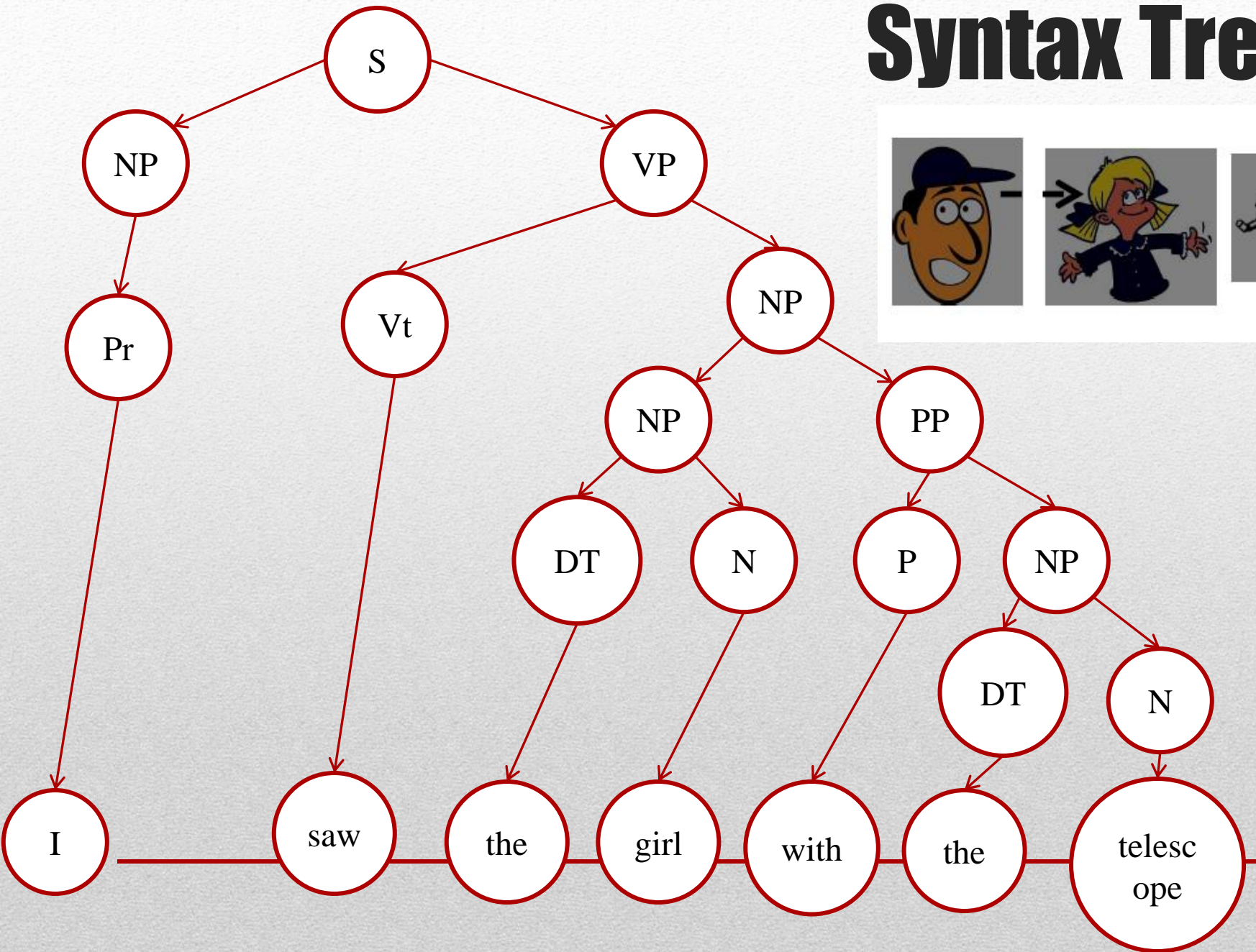
# Syntax Tree





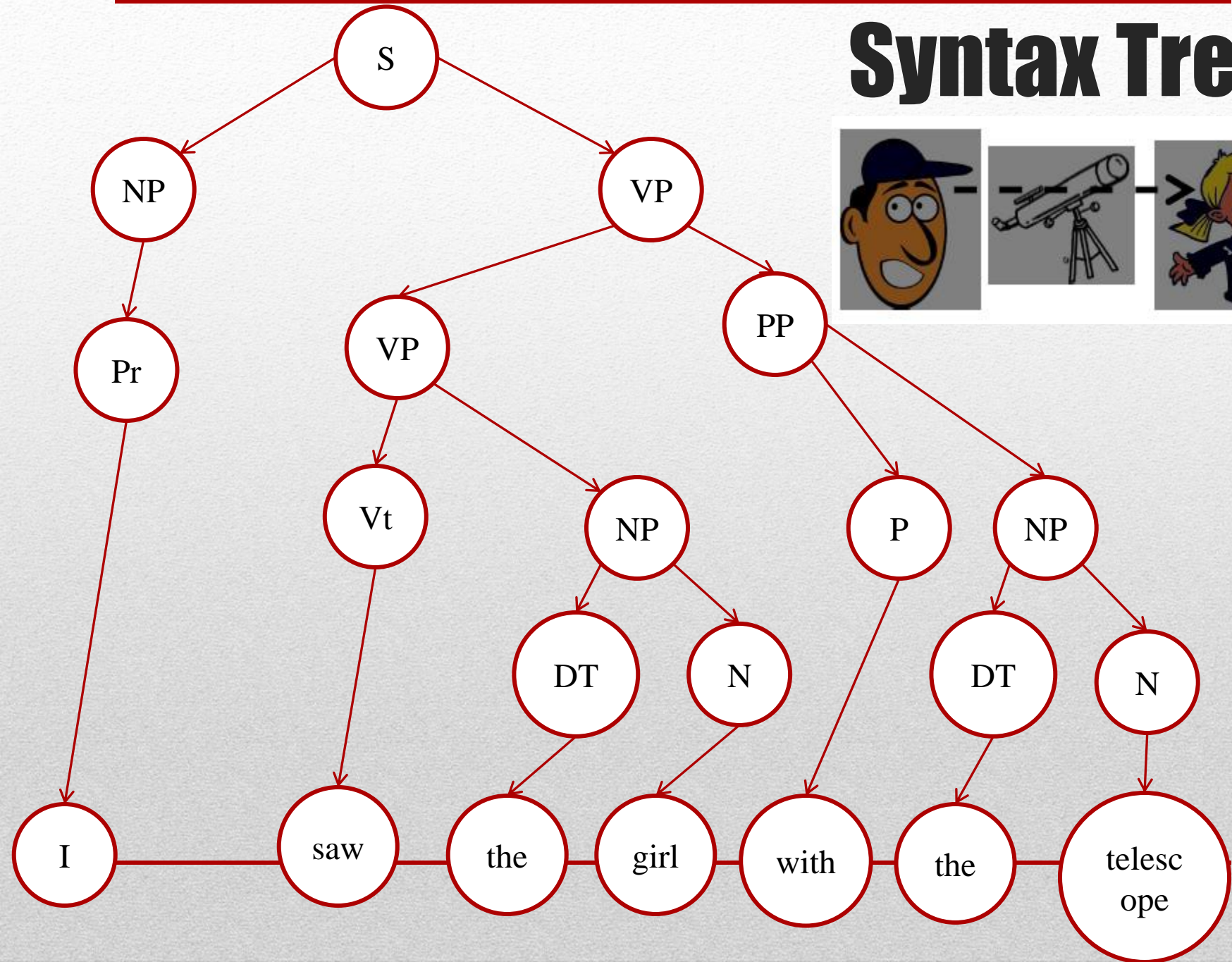
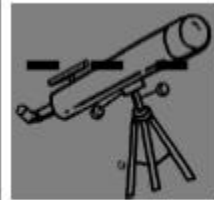
- **Ambiguous grammar** is a context-free **grammar** for which there exists a string that can have more than one leftmost derivation or parse tree

# Syntax Tree





# Syntax Tree



# Derivations and Parsing

- **Derivation:** Given the sequence of rules, generate strings
- **Parsing:** given the string and the grammar, recover the derivation.