# Parsing with Context Free Grammar

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# Parsing

- Parsing is the process of taking a string and a grammar and returning parse tree(s) for that string

*“The old dog the footsteps of the young.”*

| | |
|---|---|
| S → NP VP | VP → V |
| S → Aux NP VP | *VP -> V PP* |
| S -> VP | *PP -> Prep NP* |
| NP → Det Nom | N → old \| dog \| footsteps \| young |
| NP →PropN | V → dog \| eat \| sleep \| bark \| meow |
| Nom -> Adj N | Aux → does \| can |
| Nom → N | Prep →from \| to \| on \| of |
| Nom → N Nom | PropN → Fido \| Felix |
| *Nom → Nom PP* | Det → that \| this \| a \| the |
| VP → V NP | Adj -> old \| happy\| young |

# Parsing

- Parsing with CFGs refers to the task of assigning proper trees to input strings
- Proper: a tree that covers all and only the elements of the input and has an S at the top

# Syntactic Analysis (Parsing)

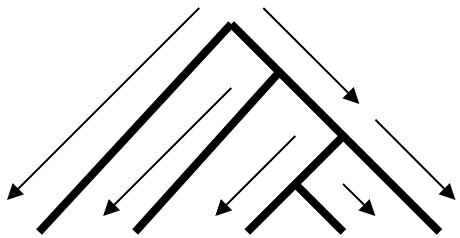
- Automatic methods of finding the syntactic structure for a sentence
  - Symbolic methods: a phrase grammar or another description of the structure of language is required.
    The chart parser.
  - Statistical methods: a text corpus with syntactic structures is needed (a treebank)

# Search Framework

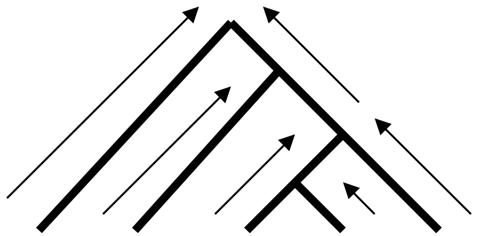
- Think about parsing as a form of search…
  - A search through the space of possible trees given an input sentence and grammar

# How to parse

- Top-down: Start at the top of the tree with an S node, and work your way down to the words.



- Bottom-up: Look for small pieces that you know how to assemble, and work your way up to larger pieces.



# Top-Down Search

- Builds from the root S node to the leaves
- Expectation-based
- Common top-down search strategy
  - Top-down, left-to-right, with backtracking
  - Try first rule s.t. LHS is S
  - Next expand all constituents on RHS
  - Iterate until all leaves are POS
  - Backtrack when candidate POS does not match POS of current word in input string

# *“The old dog the footsteps of the young.”*

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| *VP → V NP* | Adj -> old \| happy\| young |

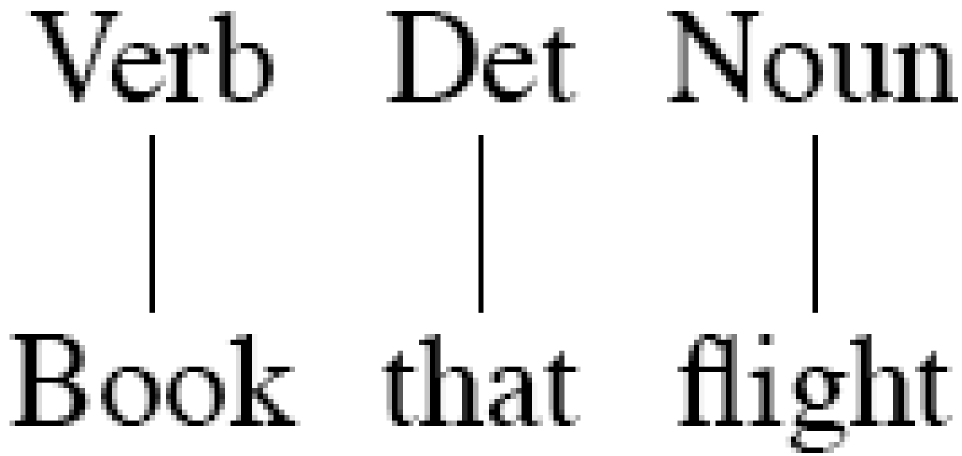
# Bottom-Up Parsing

- Of course, we also want trees that cover the input words. So we might also start with trees that link up with the words in the right way.
- Then work your way up from there to larger and larger trees.

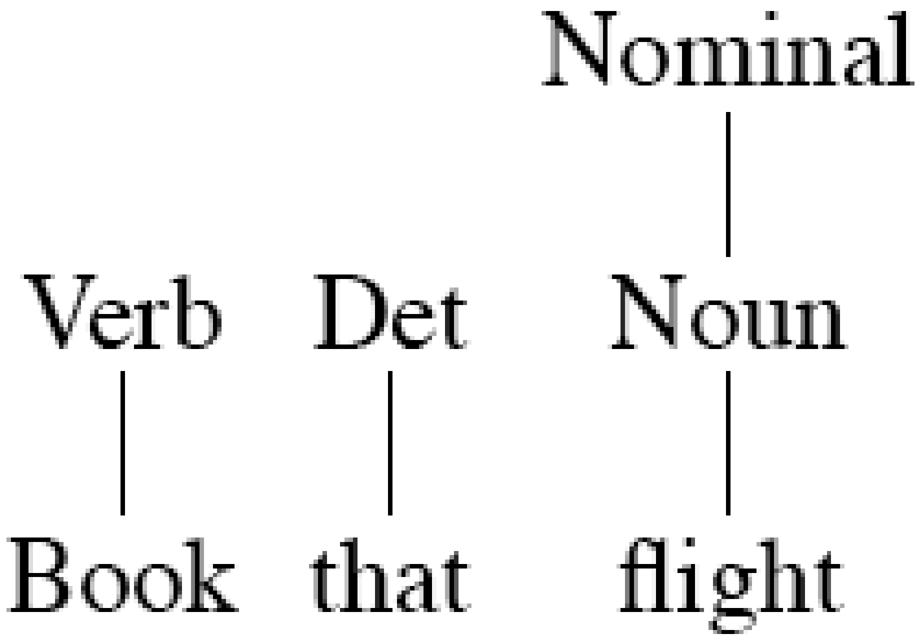
# Bottom-Up Search

Book that flight

# Bottom-Up Search



# Bottom-Up Search



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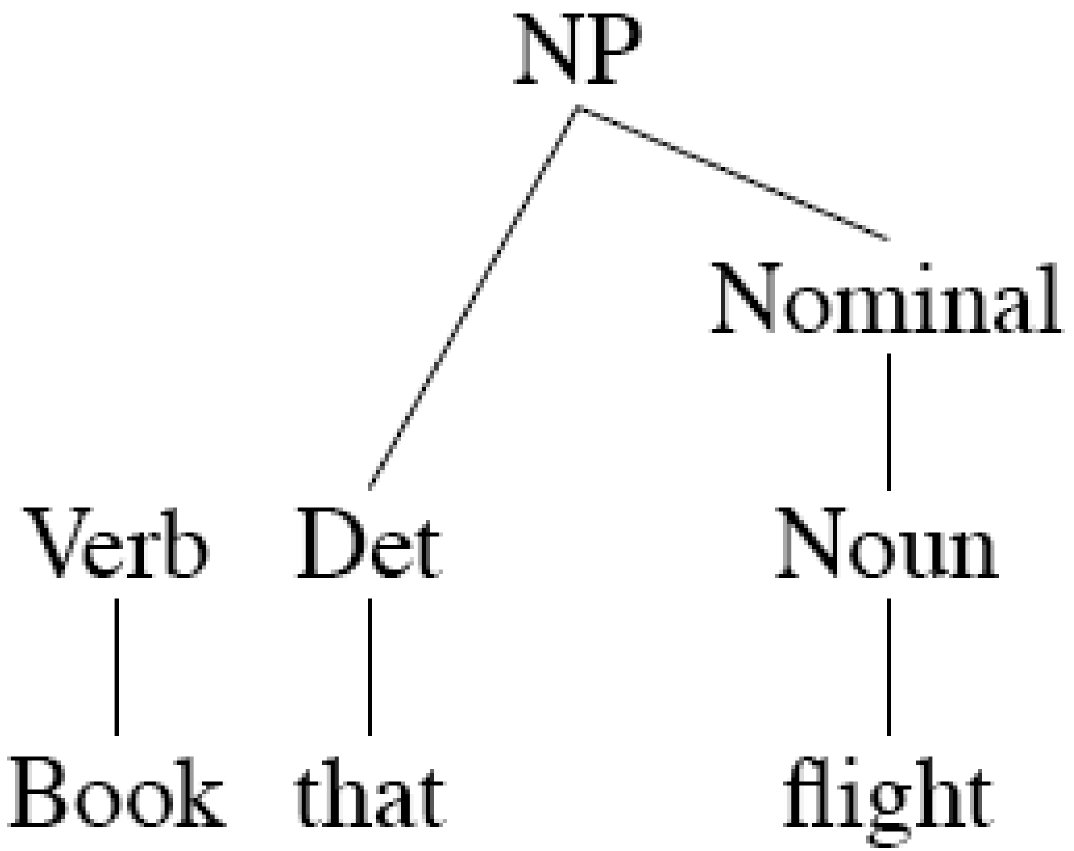
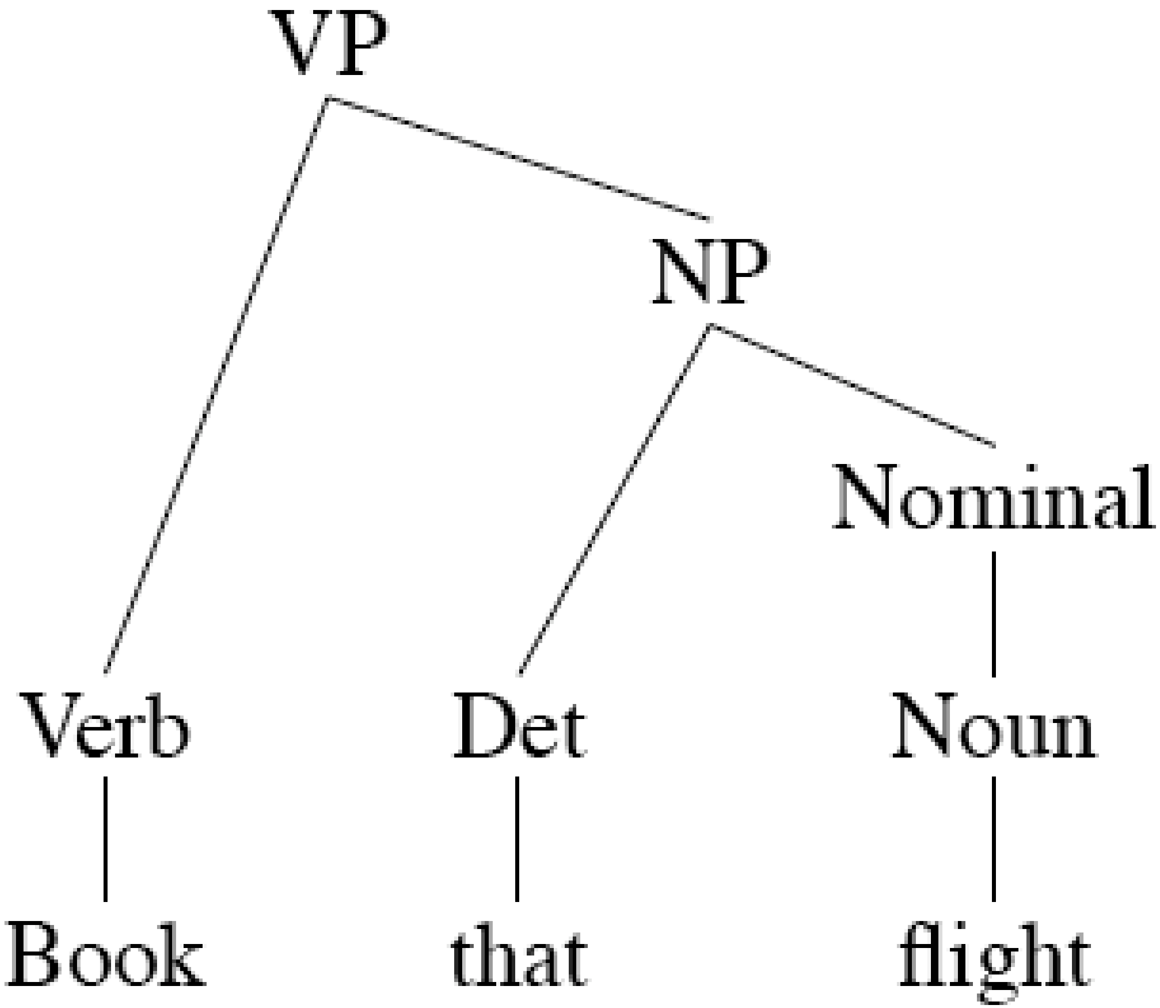


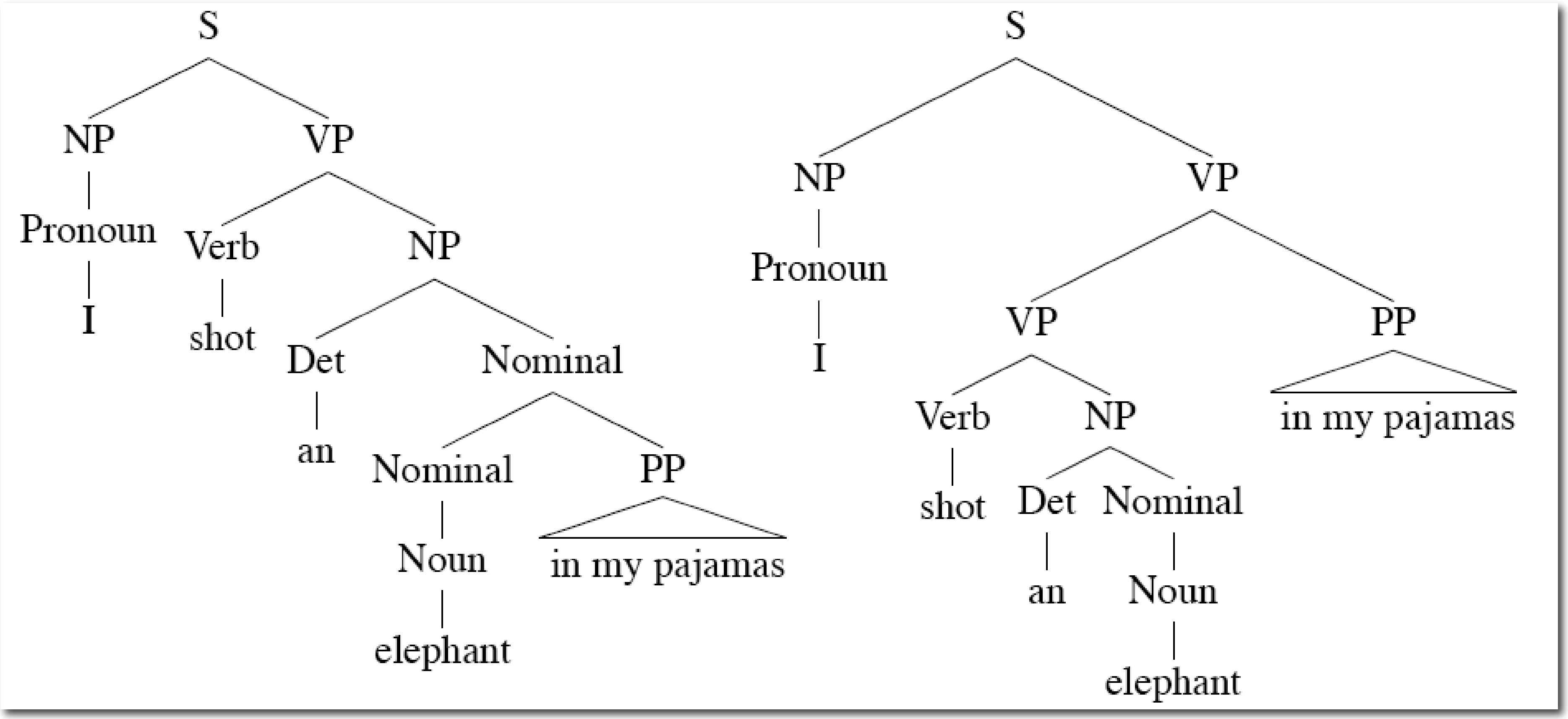
# Bottom-Up Search



# Issues

- Ambiguity
- Shared subproblems

# Ambiguity

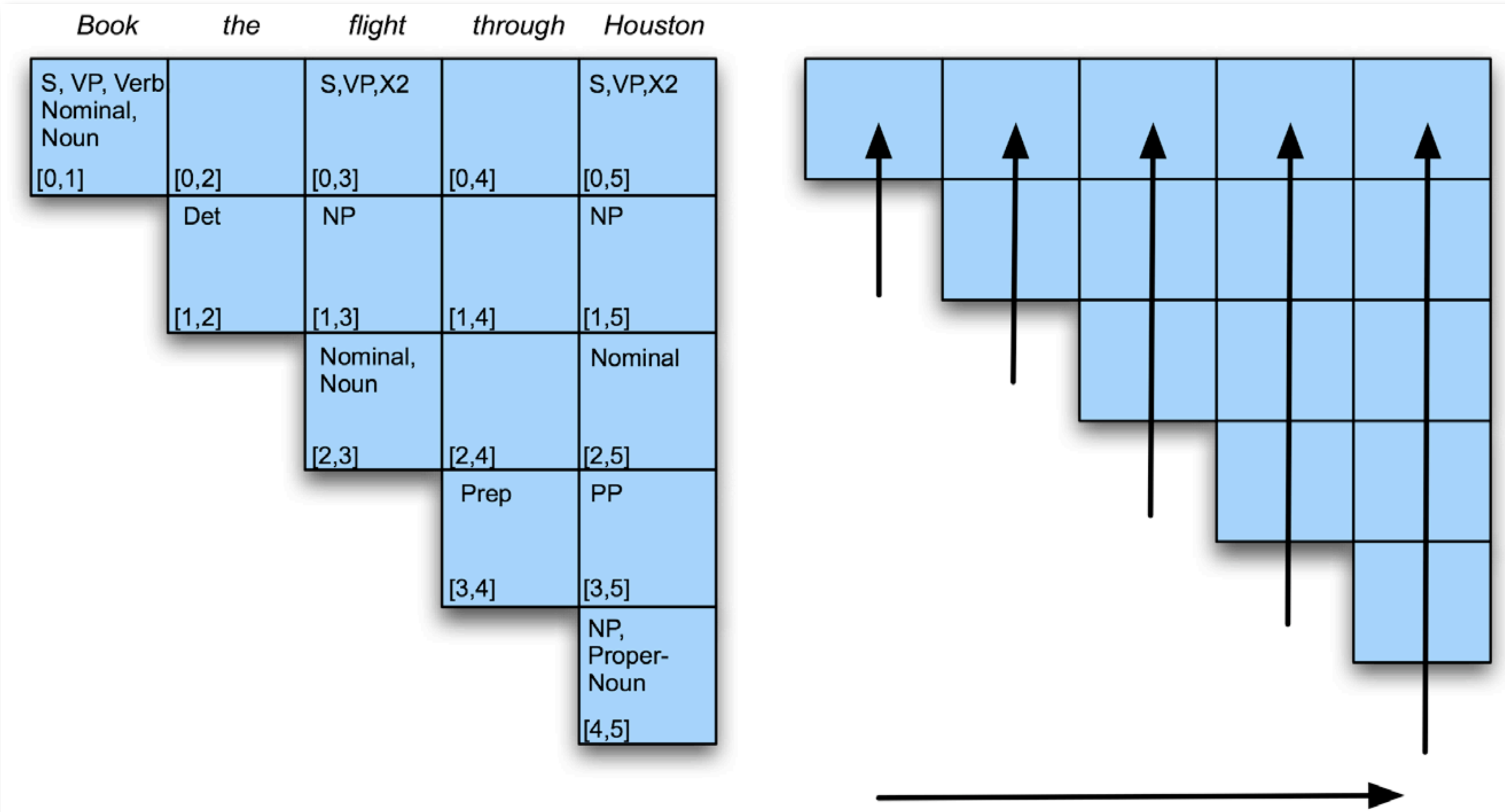


S
NP
VP
Pronoun
Verb
NP
I
shot
Det
Nominal
an
Nominal
PP
Noun
in my pajamas
elephant
S
NP
VP
Pronoun
VP
PP
I
Verb
NP
in my pajamas
shot
Det
Nominal
an
Noun
elephant

# Dynamic Programming

- DP search methods fill tables with partial results and thereby
  - Avoid doing avoidable repeated work
  - Solve exponential problems in polynomial time (ok, not really)
  - Efficiently store ambiguous structures with shared sub-parts.
- We'll cover one approach that corresponds to a bottom-up strategy
  - CKY

# CKY Algorithm



# CKY Algorithm

**function** CKY-PARSE(*words, grammar*) **returns** *table*

**for** $j \leftarrow$ **from** 1 **to** LENGTH(*words*) **do**

Looping over the columns

$table[j-1, j] \leftarrow \{A \mid A \rightarrow words[j] \in gram$

Filling the bottom cell

**for** $i \leftarrow$ **from** $j-2$ **downto** 0 **do**

Filling row i in column j

**for** $k \leftarrow i+1$ **to** $j-1$ **do**

Looping over the possible split locations between i and j.

$table[i,j] \leftarrow table[i,j] \cup$

$\{A \mid A \rightarrow BC \in grammar,$

$B \in table[i,k],$

$C \in table[k,j]\}$

Check the grammar for rules that link the constituents in [i,k] with those in [k,j]. For each rule found store the LHS of the rule in cell [i,j].

# Treebank

- A syntactically annotated corpus where every sentence is paired with a corresponding tree.
- The Penn Treebank project
  - treebanks from the Brown, Switchboard, ATIS, and Wall Street Journal corpora of English
  - treebanks in Arabic and Chinese.
- Others
  - the Prague Dependency Treebank for Czech,
  - the Negra treebank for German, and
  - the Susanne treebank for English
  - Universal Dependencies Treebank

# Penn Treebank

- Penn TreeBank is a widely used treebank.

Most well known part is the Wall Street Journal section of the Penn TreeBank.

- 1 M words from the 1987-1989 Wall Street Journal.

```
( (S (`` ``)
    (S-TPC-2
      (NP-SBJ-1 (PRP We) )
      (VP (MD would)
        (VP (VB have)
          (S
            (NP-SBJ (-NONE- *-1) )
            (VP (TO to)
              (VP (VB wait)
                (SBAR-TMP (IN until)
                  (S
                    (NP-SBJ (PRP we) )
                    (VP (VBP have)
                      (VP (VBN collected)
                        (PP-CLR (IN on)
                          (NP (DT those)(NNS assets)))))))))))))
    (, ,) ('' '')
    (NP-SBJ (PRP he) )
    (VP (VBD said)
      (S (-NONE- *T*-2) ))
    (. .) ))
```

```
((S
   (NP-SBJ (DT That)
     (JJ cold) (, ,)
     (JJ empty) (NN sky) )
   (VP (VBD was)
     (ADJP-PRD (JJ full)
       (PP (IN of)
         (NP (NN fire)
           (CC and)
           (NN light) ))))
   (. .) ))
```

(a)

```
((S
   (NP-SBJ The/DT flight/NN )
   (VP should/MD
     (VP arrive/VB
       (PP-TMP at/IN
         (NP eleven/CD a.m/RB ))
       (NP-TMP tomorrow/NN )))))
```

(b)

**Figure 11.7** Parsed sentences from the LDC Treebank3 version of the Brown (a) and ATIS (b) corpora.

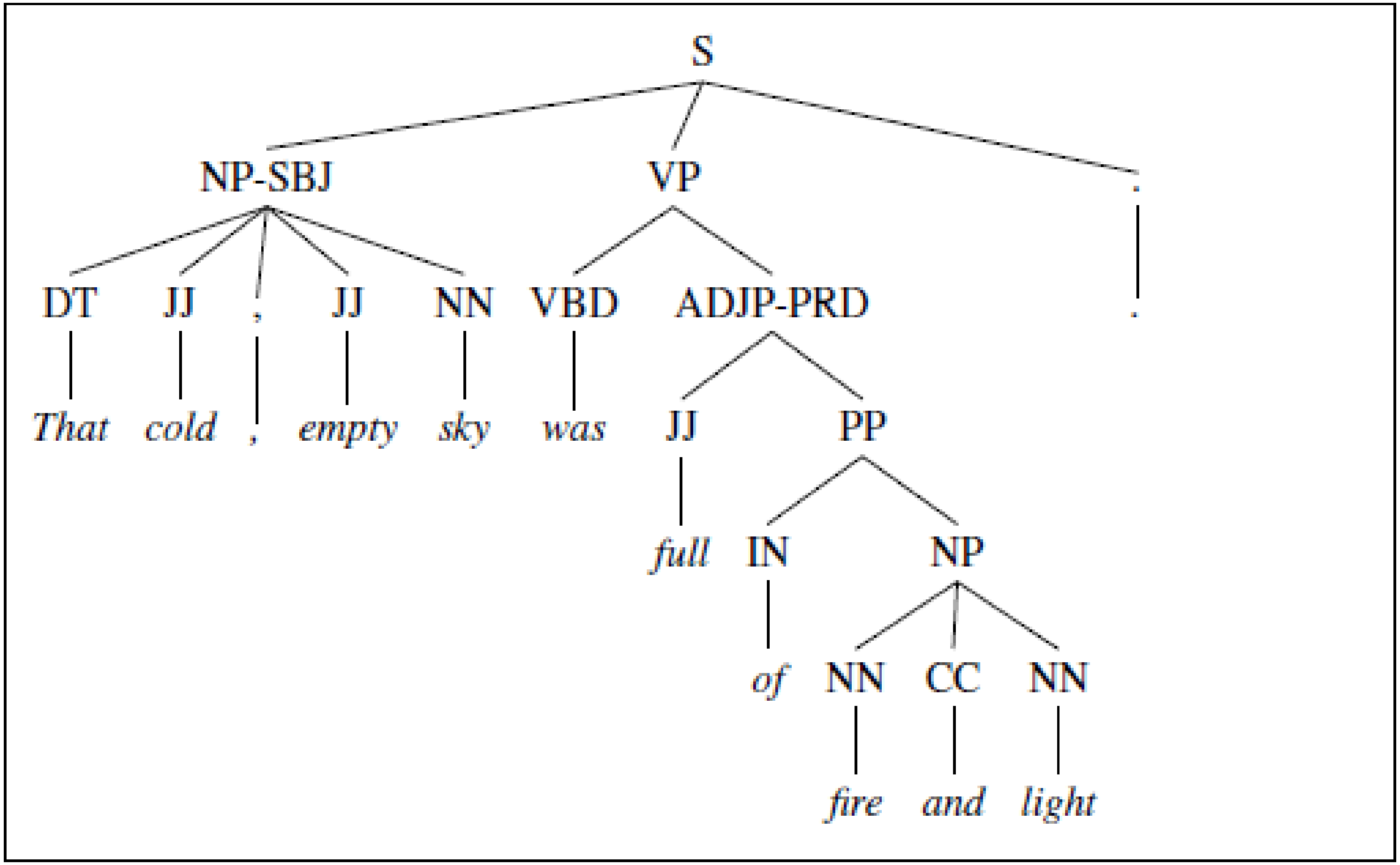



**Figure 11.8** The tree corresponding to the Brown corpus sentence in the previous figure.

# Treebanks as Grammars

- The sentences in a treebank implicitly constitute a grammar of the language represented by the corpus being annotated.

- Simply take the local rules that make up the sub-trees in all the trees in the collection and you have a grammar
  - The WSJ section gives us about 12k rules

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- The sentences in a treebank implicitly constitute a grammar of the language represented by the corpus being annotated.
- Simply take the local rules that make up the sub-trees in all the trees in the collection and you have a grammar
  - The WSJ section gives us about 12k rules if you do this
- Treebanks (and head-finding) are particularly critical to the development of statistical parsers