CS114 Lecture 9

Syntax

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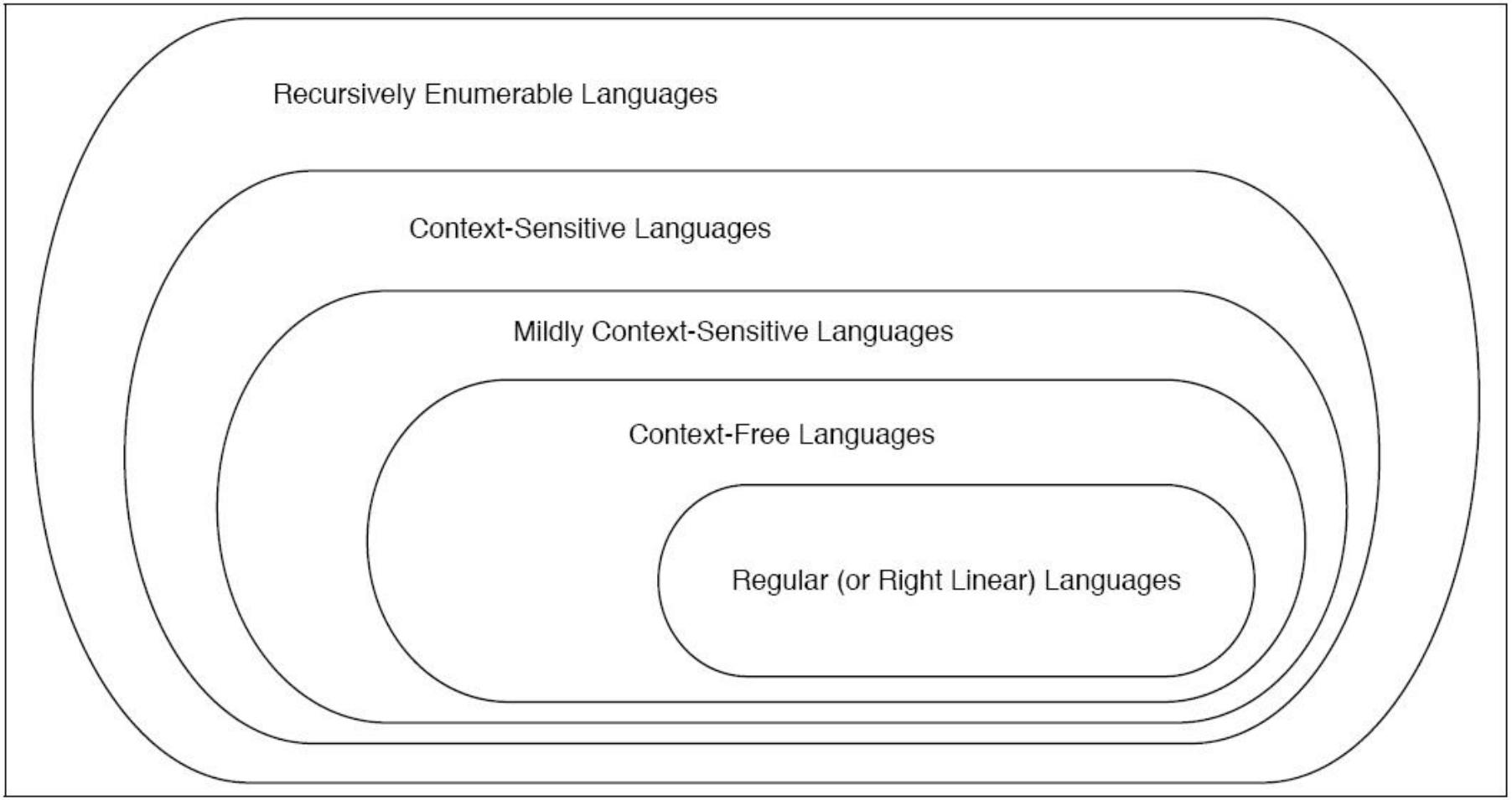
Thanks for Jurafsky & Martin & Prof. Pustejovksy for slides

Today

- Formal Grammars
- Context-free grammar
- Grammars for English
- Treebanks
- Dependency grammars
- Parsing

Formal Languages: Chomsky Hierarchy



(not so) Formal definitions

- Regular grammars (regular expressions)
  - Left or right linear $S \rightarrow aA$
- Context free grammars
  - $a^n b^n$ $S \rightarrow aSb \mid ab$
  - The dog the cat liked ate tuna.
- Context sensitive
  - $a^n b^n c^n$ $aB \rightarrow Ba$
  - Mary and John liked steak and sushi respectively
- Mildly context sensitive
  - Tree Adjoining grammars, Head Grammars …

Syntax

- By grammar, or syntax, we have in mind the kind of implicit knowledge of your native language that you had mastered by the time you were 3 years old without explicit instruction
- Not the kind of stuff you were later taught in "grammar" school

Syntax

- Why should you care?
- Grammars (and parsing) are key components in many applications
  - Grammar checkers
  - Dialogue management
  - Question answering
  - Information extraction
  - Machine translation

Syntax

- Key notions that we'll cover
  - Constituency
  - Grammatical relations and Dependency
    - Heads
- Key formalism
  - Context-free grammars
- Resources
  - Treebanks

Constituency

- The basic idea here is that groups of words within utterances can be shown to act as single units.
- And in a given language, these units form coherent classes that can be be shown to behave in similar ways
  - With respect to their internal structure
  - And with respect to other units in the language

Constituency

- Internal structure
  - We can describe an internal structure to the class (might have to use disjunctions of somewhat unlike sub-classes to do this).
- External behavior
  - For example, we can say that noun phrases can come before verbs

Constituency

- For example, it makes sense to the say that the following are all ***noun phrases*** in English...

Harry the Horse	a high-class spot such as Mindy's
the Broadway coppers	the reason he comes into the Hot Box
they	three parties from Brooklyn

- Why? One piece of evidence is that they can all precede verbs.
  - This is external evidence

Grammars and Constituency

- Of course, there's nothing easy or obvious about how we come up with right set of constituents and the rules that govern how they combine...
- That's why there are so many different theories of grammar and competing analyses of the same data.
- The approach to grammar, and the analyses, adopted here are very generic (and don't correspond to any modern linguistic theory of grammar).

Context-Free Grammars

- Context-free grammars (CFGs)
  - Also known as
    - Phrase structure grammars
    - Backus-Naur form
- Consist of
  - Rules
  - Terminals
  - Non-terminals

Context-Free Grammars

- Terminals
  - We'll take these to be words (for now)
- Non-Terminals
  - The constituents in a language
    - Like noun phrase, verb phrase and sentence
- Rules
  - Rules are equations that consist of a single non-terminal on the left and any number of terminals and non-terminals on the right.

Some NP Rules

- Here are some rules for our noun phrases

$$
\begin{aligned}
NP &\rightarrow Det\ Nominal \\
NP &\rightarrow ProperNoun \\
Nominal &\rightarrow Noun \mid Nominal\ Noun
\end{aligned}
$$

- Together, these describe two kinds of NPs.
  - One that consists of a determiner followed by a nominal
  - And another that says that proper names are NPs.
  - The third rule illustrates two things
    - An explicit disjunction
      - Two kinds of nominals
    - A recursive definition
      - Same non-terminal on the right and left-side of the rule

L0 Grammar

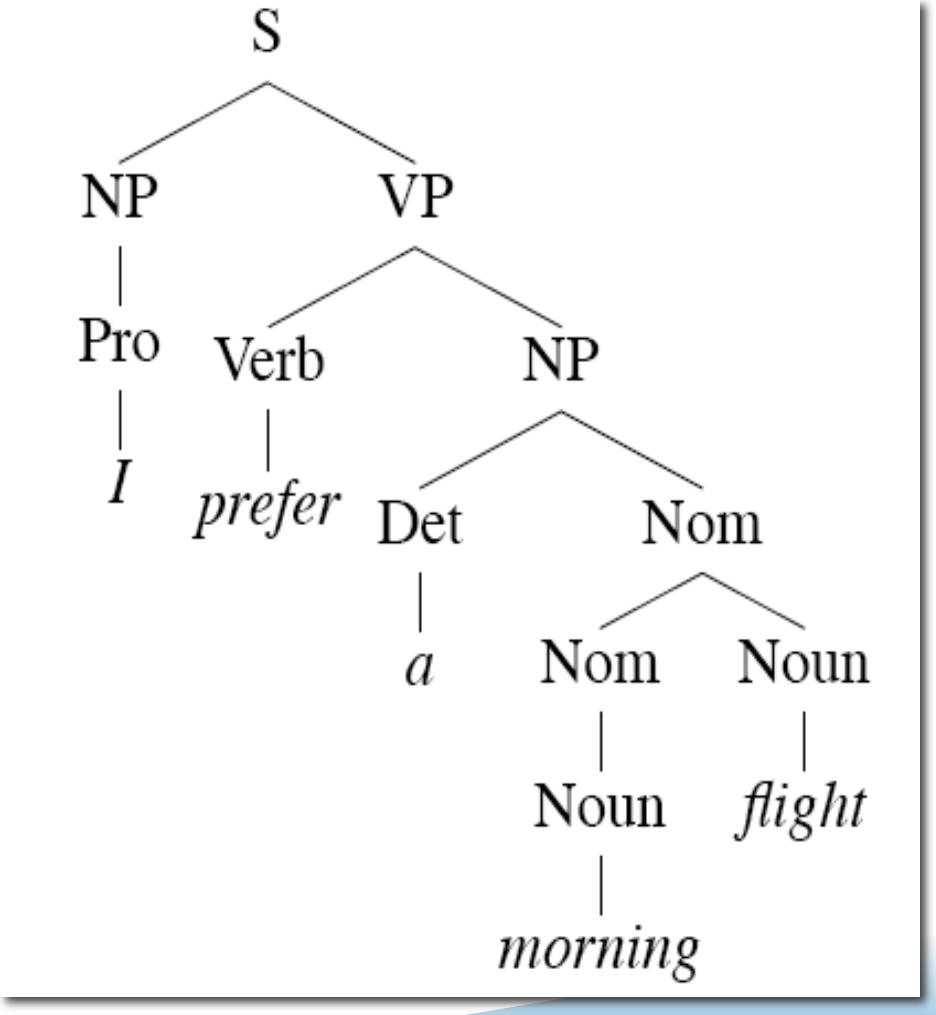
Grammar Rules			Examples
S	→	*NP VP*	I + want a morning flight
NP	→	*Pronoun*	I
	|	*Proper-Noun*	Los Angeles
	|	*Det Nominal*	a + flight
Nominal	→	*Nominal Noun*	morning + flight
	|	*Noun*	flights
VP	→	*Verb*	do
	|	*Verb NP*	want + a flight
	|	*Verb NP PP*	leave + Boston + in the morning
	|	*Verb PP*	leaving + on Thursday
PP	→	*Preposition NP*	from + Los Angeles

Generativity

- As with FSAs and FSTs, you can view these rules as either analysis or synthesis machines
  - Generate strings in the language
  - Reject strings not in the language
  - Impose structures (trees) on strings in the language

Derivations

- A derivation is a sequence of rules applied to a string that *accounts* for that string
  - Covers all the elements in the string
  - Covers only the elements in the string



Definition

- More formally, a CFG consists of

N a set of **non-terminal symbols** (or **variables**)

Σ a set of **terminal symbols** (disjoint from N)

R a set of **rules** or productions, each of the form $A \rightarrow \beta$,
where A is a non-terminal,
β is a string of symbols from the infinite set of strings $(\Sigma \cup N)*$

S a designated **start symbol**

Parsing

- Parsing is the process of taking a string and a grammar and returning a (multiple?) parse tree(s) for that string
- It is completely analogous to running a finite-state transducer with a tape
  - It's just more powerful
    - Remember this means that there are languages we can capture with CFGs that we can't capture with finite-state methods
    - More on this when we get to Ch. 13.

An English Grammar Fragment

- Sentences
- Noun phrases
  - Agreement
- Verb phrases
  - Subcategorization

Sentence Types

- Declaratives: *A plane left.*

  S → NP VP

- Imperatives: *Leave!*

  S → VP

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

  S → Aux NP VP

- WH Questions: *When did the plane leave?*

  S → WH-NP Aux NP VP

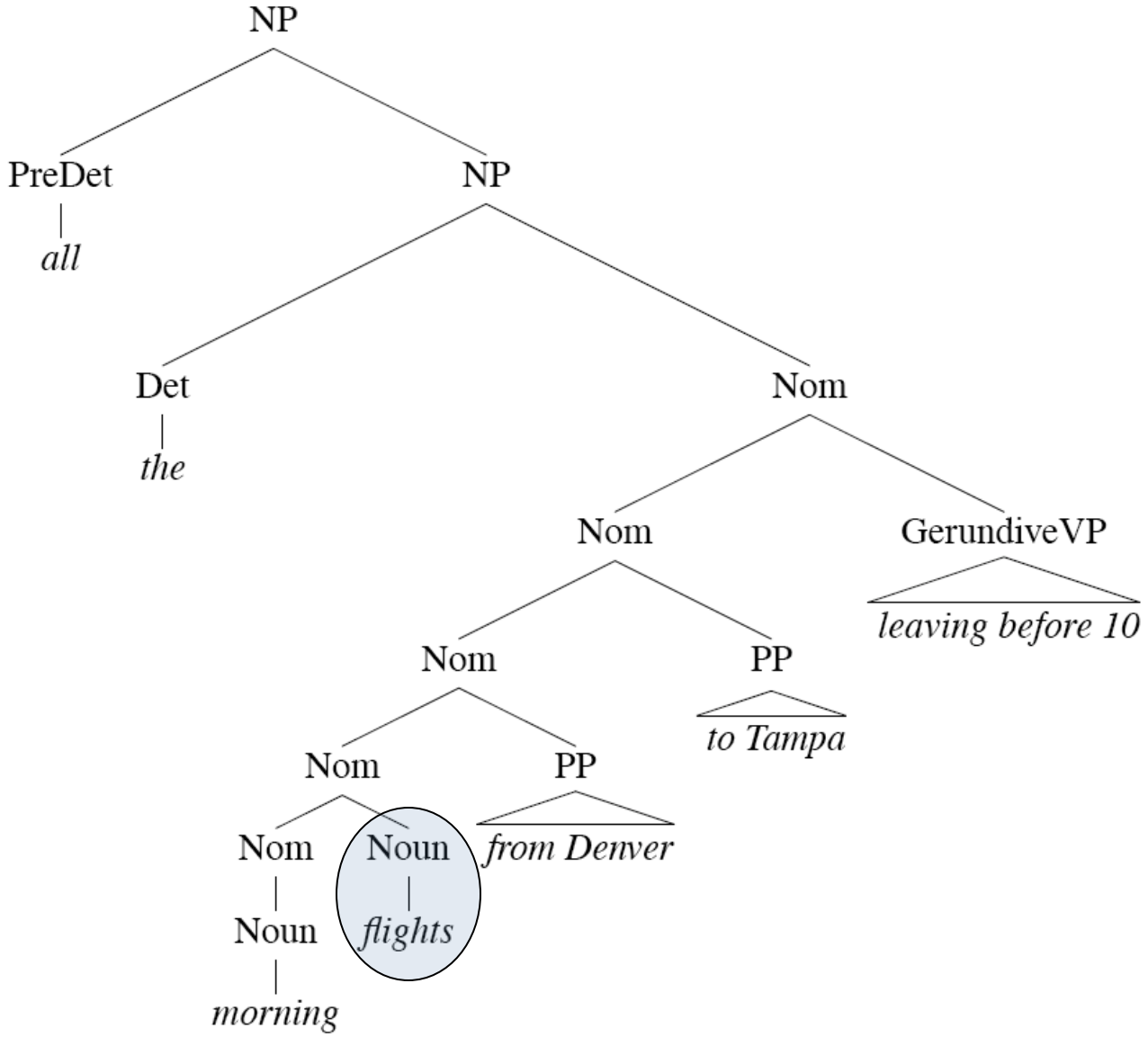
Noun Phrases

- Let's consider the following rule in more detail...

  NP → Det Nominal

- Most of the complexity of English noun phrases is hidden in this rule.
- Consider the derivation for the following example
  - *All the morning flights from Denver to Tampa leaving before 10*

Noun Phrases



NP Structure

- Clearly this NP is really about *flights*. That's the central criticial noun in this NP. Let's call that the *head*.
- We can dissect this kind of NP into the stuff that can come before the head, and the stuff that can come after it.

Determiners

- Noun phrases can start with determiners...
- Determiners can be
  - Simple lexical items: *the, this, a, an*, etc.
    - A car
  - Or simple possessives
    - John's car
  - Or complex recursive versions of that
    - John's sister's husband's son's car

Nominals

- Contains the head and any pre- and post-modifiers of the head.
  - Pre-
    - Quantifiers, cardinals, ordinals...
      - Three cars
    - Adjectives and Aps
      - large cars
    - Ordering constraints
      - Three large cars
      - ?large three cars

Postmodifiers

- Three kinds
  - Prepositional phrases
    - From Seattle
  - Non-finite clauses
    - Arriving before noon
  - Relative clauses
    - That serve breakfast
- Same general (recursive) rule to handle these
  - *Nominal → Nominal PP*
  - *Nominal → Nominal GerundVP*
  - *Nominal → Nominal RelClause*

Agreement

- By ***agreement***, we have in mind constraints that hold among various constituents that take part in a rule or set of rules
- For example, in English, determiners and the head nouns in NPs have to agree in their number.

This flight

Those flights

*This flights

*Those flight

Problem

- Our earlier NP rules are clearly deficient since they don't capture this constraint
  - *NP → Det Nominal*
    - Accepts, and assigns correct structures, to grammatical examples (*this flight*)
    - But its also happy with incorrect examples (*these flight)
  - Such a rule is said to *overgenerate.*
  - We'll come back to this in a bit

Verb Phrases

- English *VP*s consist of a head verb along with 0 or more following constituents which we'll call *arguments*.

$VP \rightarrow Verb$ disappear
$VP \rightarrow Verb\ NP$ prefer a morning flight
$VP \rightarrow Verb\ NP\ PP$ leave Boston in the morning
$VP \rightarrow Verb\ PP$ leaving on Thursday

Subcategorization

- But, even though there are many valid VP rules in English, not all verbs are allowed to participate in all those VP rules.
- We can subcategorize the verbs in a language according to the sets of VP rules that they participate in.
- This is a modern take on the traditional notion of transitive/intransitive.
- Modern grammars may have 100s or such classes.

Subcategorization

- Sneeze: John sneezed
- Find: Please find [a flight to NY]$_{NP}$
- Give: Give [me]$_{NP}$[a cheaper fare]$_{NP}$
- Help: Can you help [me]$_{NP}$[with a flight]$_{PP}$
- Prefer: I prefer [to leave earlier]$_{TO\text{-}VP}$
- Told: I was told [United has a flight]$_{S}$
- …

Subcategorization

- *John sneezed the book
- *I prefer United has a flight
- *Give with a flight

- As with agreement phenomena, we need a way to formally express the constraints

Why?

- Right now, the various rules for VPs *overgenerate*.
  - They permit the presence of strings containing verbs and arguments that don't go together
  - For example
    - VP -> V NP
  - therefore

    Sneezed the book is a VP since "sneeze" is a verb and "the book" is a valid NP

Possible CFG Solution

- Possible solution for agreement.
- Can use the same trick for all the verb/VP classes.

- SgS -> SgNP SgVP
- PlS -> PlNp PlVP
- SgNP -> SgDet SgNom
- PlNP -> PlDet PlNom
- PlVP -> PlV NP
- SgVP ->SgV Np
- …

CFG Solution for Agreement

- It works and stays within the power of CFGs
- But its ugly
- And it doesn't scale all that well because of the interaction among the various constraints explodes the number of rules in our grammar.

The Point

- CFGs appear to be just about what we need to account for a lot of basic syntactic structure in English.
- But there are problems
  - That can be dealt with adequately, although not elegantly, by staying within the CFG framework.
- There are simpler, more elegant, solutions that take us out of the CFG framework (beyond its formal power)
  - LFG, HPSG, Construction grammar, XTAG, etc.
  - Chapter 15 explores the unification approach in more detail

“A little beyond” CFGs

- Regular grammars (regular expressions)
  - Left or right linear $S \rightarrow aA$
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Treebanks

- Treebanks are corpora in which each sentence has been paired with a parse tree (presumably the right one).
- These are generally created
  - By first parsing the collection with an automatic parser
  - And then having human annotators correct each parse as necessary.
- This generally requires detailed annotation guidelines that provide a POS tagset, a grammar and instructions for how to deal with particular grammatical constructions.

Penn Treebank

- Penn TreeBank is a widely used treebank.
  - Most well known 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) ))
(. .) ))
```

Treebank Grammars

- Treebanks implicitly define a grammar for the language covered in the treebank.
- Simply take the local rules that make up the sub-trees in all the trees in the collection and you have a grammar.
- Not complete, but if you have decent size corpus, you'll have a grammar with decent coverage.

Treebank Grammars

- Such grammars tend to be very flat due to the fact that they tend to avoid recursion.
  - To ease the annotators burden
- For example, the Penn Treebank has 4500 different rules for VPs. Among them...

VP → VBD PP

VP → VBD PP PP

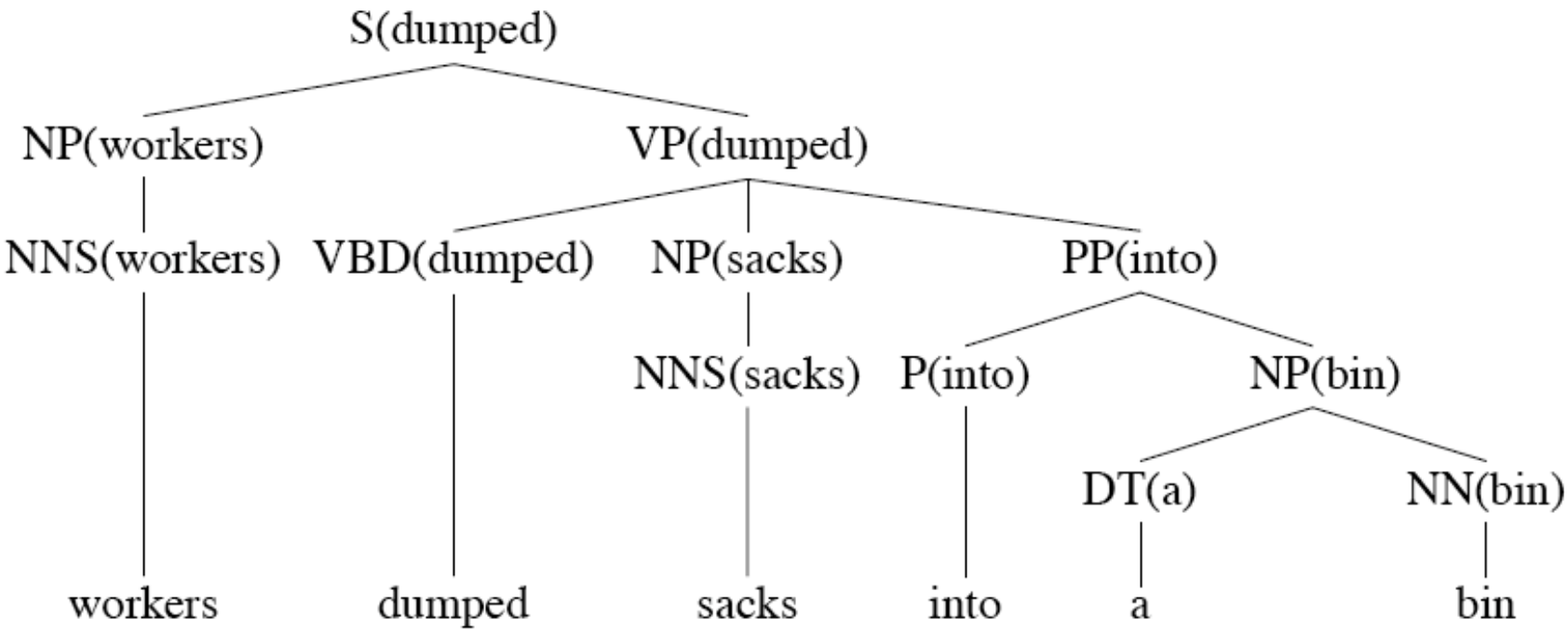
VP → VBD PP PP PP

VP → VBD PP PP PP PP

Heads in Trees

- Finding heads in treebank trees is a task that arises frequently in many applications.
  - Particularly important in statistical parsing
- We can visualize this task by annotating the nodes of a parse tree with the heads of each corresponding node.

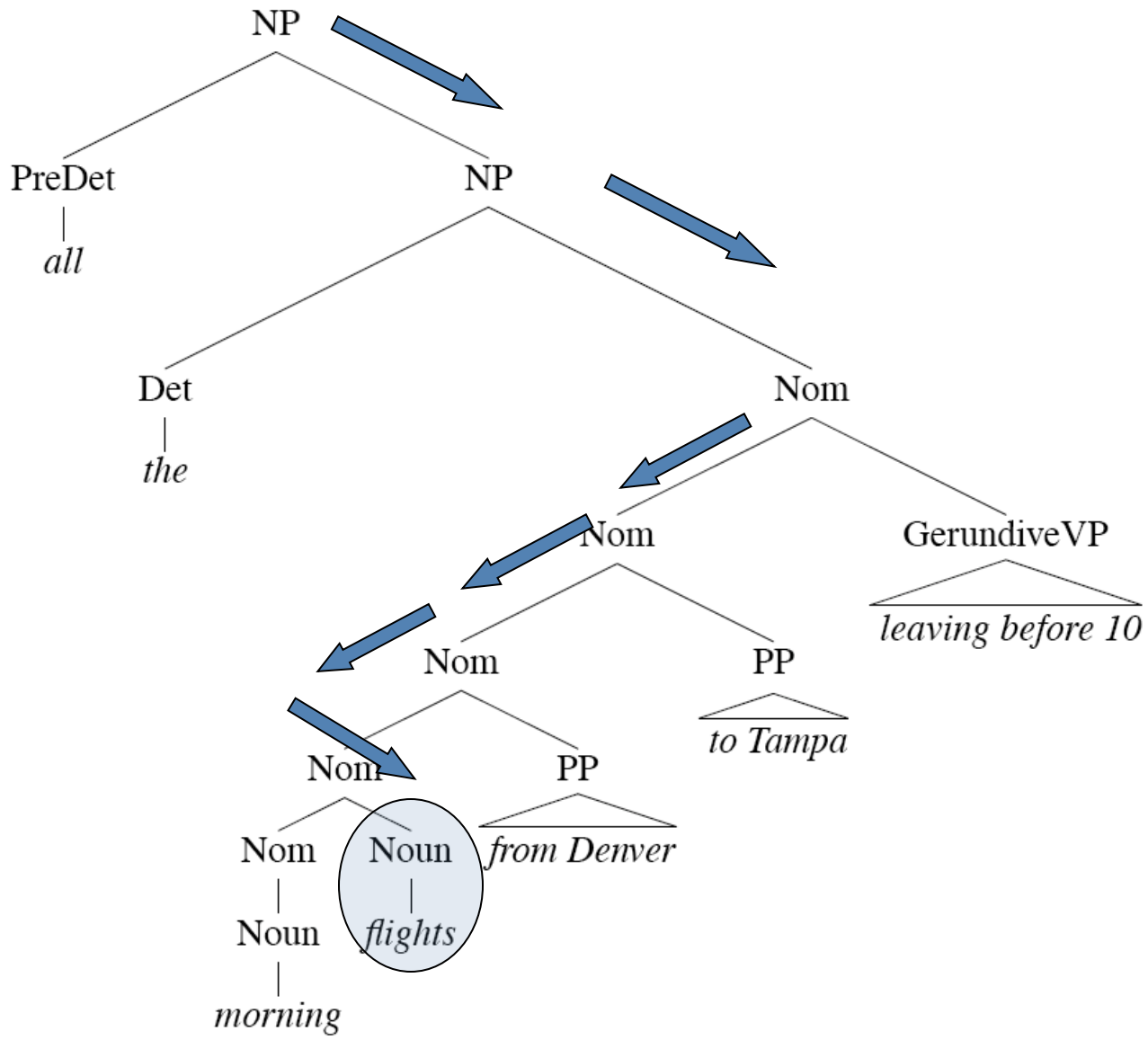
Lexically Decorated Tree



Head Finding

- The standard way to do head finding is to use a simple set of tree traversal rules specific to each non-terminal in the grammar.

Noun Phrases



Treebank Uses

- Treebanks (and headfinding) are particularly critical to the development of statistical parsers
  - Chapter 14
- Also valuable to *Corpus Linguistics*
  - Investigating the empirical details of various constructions in a given language

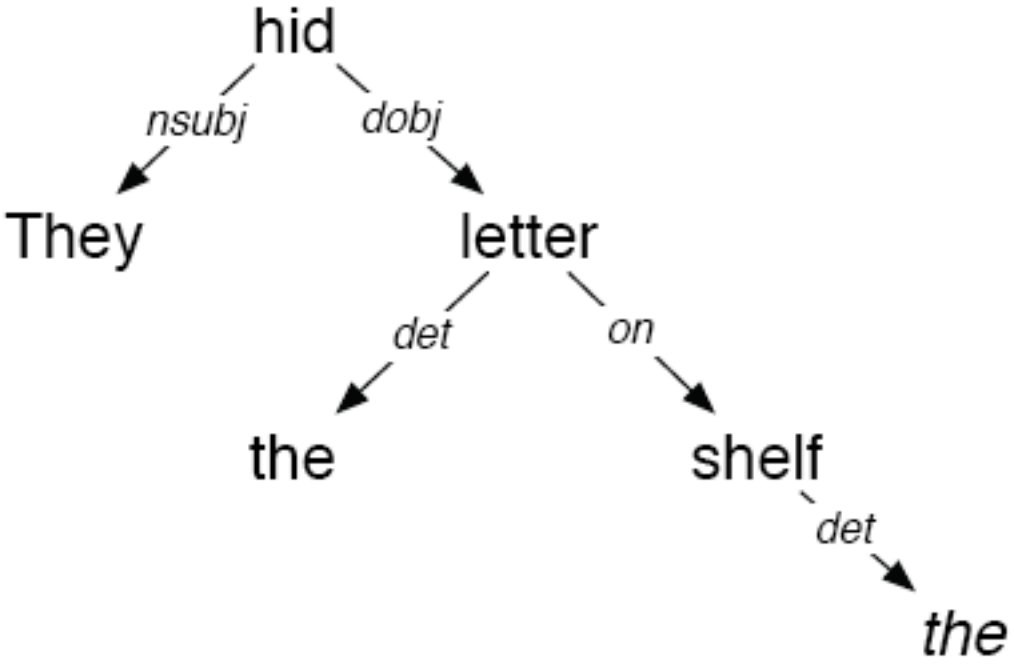
Dependency Grammars

- In CFG-style phrase-structure grammars the main focus is on *constituents.*
- But it turns out you can get a lot done with just binary relations among the words in an utterance.
- In a dependency grammar framework, a parse is a tree where
  - the nodes stand for the words in an utterance
  - The links between the words represent dependency relations between pairs of words.
    - Relations may be typed (labeled), or not.

Dependency Relations

Argument Dependencies	Description
nsubj	nominal subject
csubj	clausal subject
dobj	direct object
iobj	indirect object
pobj	object of preposition
Modifier Dependencies	**Description**
tmod	temporal modifier
appos	appositional modifier
det	determiner
prep	prepositional modifier

Dependency Parse



They hid the letter on the shelf

Dependency Parsing

- The dependency approach has a number of advantages over full phrase-structure parsing.
  - Deals well with free word order languages where the constituent structure is quite fluid
  - Parsing is much faster than CFG-bases parsers
  - Dependency structure often captures the syntactic relations needed by later applications
    - CFG-based approaches often extract this same information from trees anyway.

Dependency Parsing

- There are two modern approaches to dependency parsing
  - Optimization-based approaches that search a space of trees for the tree that *best* matches some criteria
  - Shift-reduce approaches that greedily take actions based on the current word and state.

Summary

- Context-free grammars can be used to model various facts about the syntax of a language.
- When paired with parsers, such grammars consititute a critical component in many applications.
- Constituency is a key phenomena easily captured with CFG rules.
  - But agreement and subcategorization do pose significant problems
- Treebanks pair sentences in corpus with their corresponding trees.