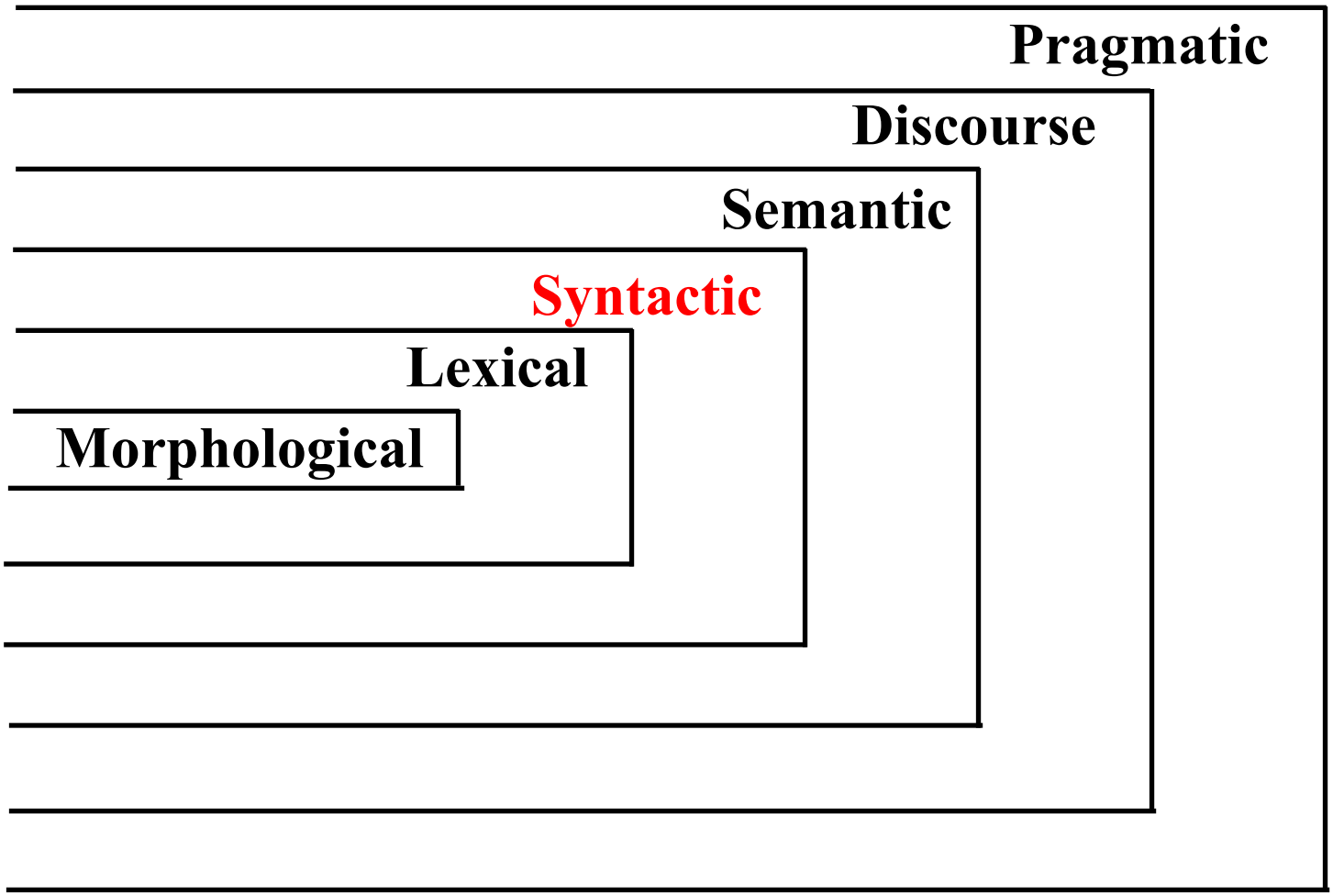
Context Free Grammars

Synchronic Model of Language



Syntactic Analysis

- Syntax expresses the way in which words are arranged together.
- The kind of implicit knowledge of your native language that you had mastered by the time you were 3 or 4 years old without explicit instruction
  - Do these word sequences fit together?

    I saw you yesterday

    you yesterday I year

    colorless green ideas sleep furiously (Chomsky)

    furiously sleep ideas green colorless
- NLP uses syntax to produce a structural analysis of the input sentence

Formal Grammar

- Rules that embody generalizations that hold for the symbols and combinations of symbols in a language for constructing acceptable sentences
  - grammar is most closely identified with syntax, but may contain elements of all levels of language
- Theoretical linguists use grammar
  - To indicate which are the well-formed sentences, defining that language
  - To show how variations of a 'deep-structure' are derived through 'transformations' on this 'deep-structure'
  - Competence' based – an ideal speaker's internalized ability to create and understand all sentences
- Applied uses
  - To assign a structural description to the linguistic elements of which an utterance is comprised
  - "…typically not consciously modeled after any particular linguistic theory, but as descriptions of phenomena that appeared in input text."
  - 'Performance' based – person's actual use of language

Context-Free Grammars

- Capture constituency and ordering
  - Ordering is
    - What are the rules that govern the ordering of words and bigger units in the language
  - Constituency is
  - How do words group into units and what we say about how the various kinds of units behave
  - A constituent is a sequence of words that behave as a unit
    - John talked [to the children] [about drugs].
    - John talked [about drugs] [to the children].
    - *John talked drugs to the children about (random reorder)
  - Constituents can be expanded or substituted for:
    - I sat [on the box/right on top of the box/there]
  - Other properties: Coordination, regular internal structure, no intrusion, fragments, semantics, …

Context-Free Grammar consists of:

- Non-terminal symbols

  S, NP, VP, etc. representing the constituents or categories of phrases

- Terminal symbols

  car, man, house, representing words in the lexicon

  - The rewrite rules will include lexical insertion rules

    (e.g. N = *car* | *man* | *house*)

- Rewrite rules / productions

  S → NP VP | VP

  (note use of | symbol to give alternate rhs of rules)

- A designated start symbol S

- A derivation is a sequence of rewrite rules applied to a string that exactly covers the items in that string

Derivation of syntax from grammar rules

- *Show top-down and bottom-up derivation of a parse tree.*

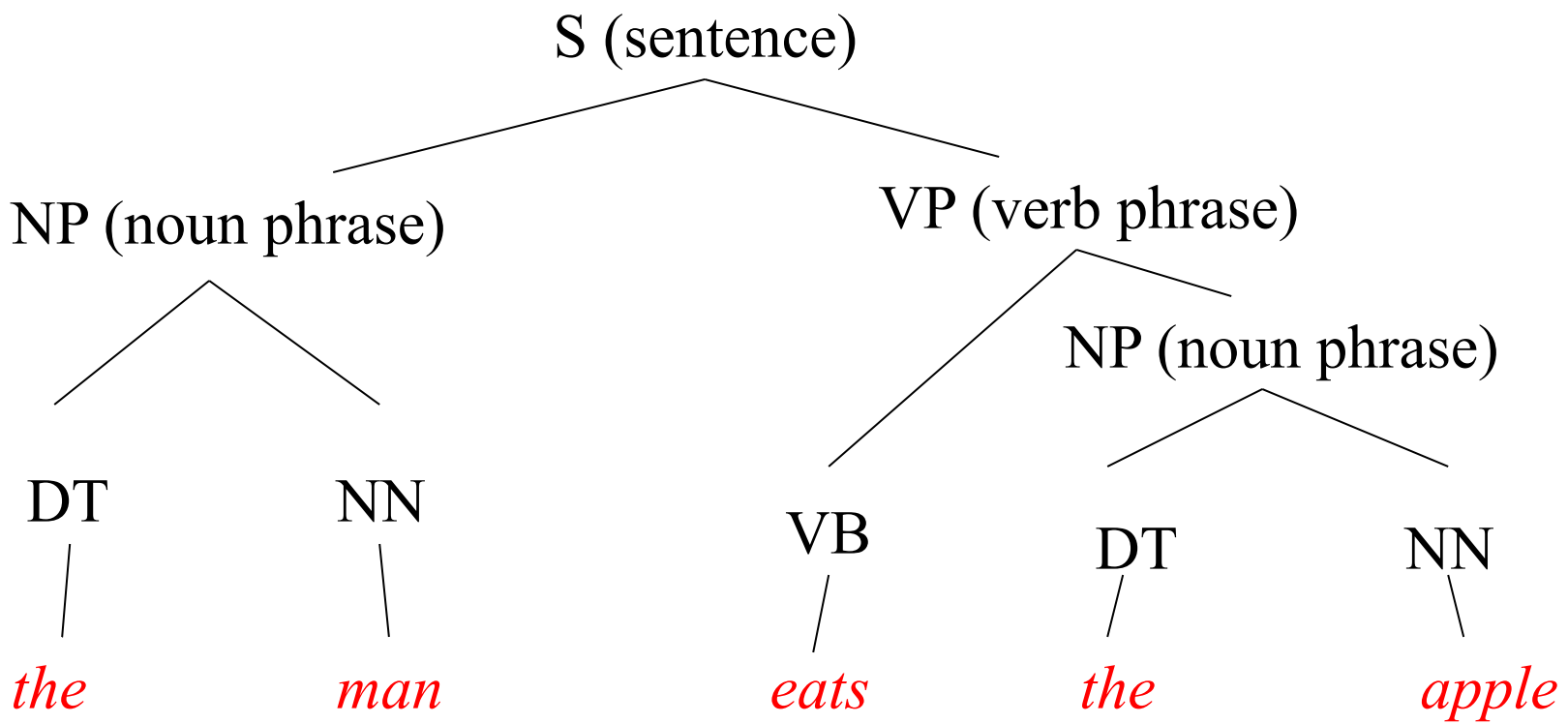
the *man* *eats* *the* *apple*

Context Free Grammar Rules:

S → NP VP
NP → DT NN
VP → VB NP
VP → VB

DT → *the* | ...
NN → *man* | apple | … (add words)
VB → *eats* | ...

Derivation of syntax from grammar rules



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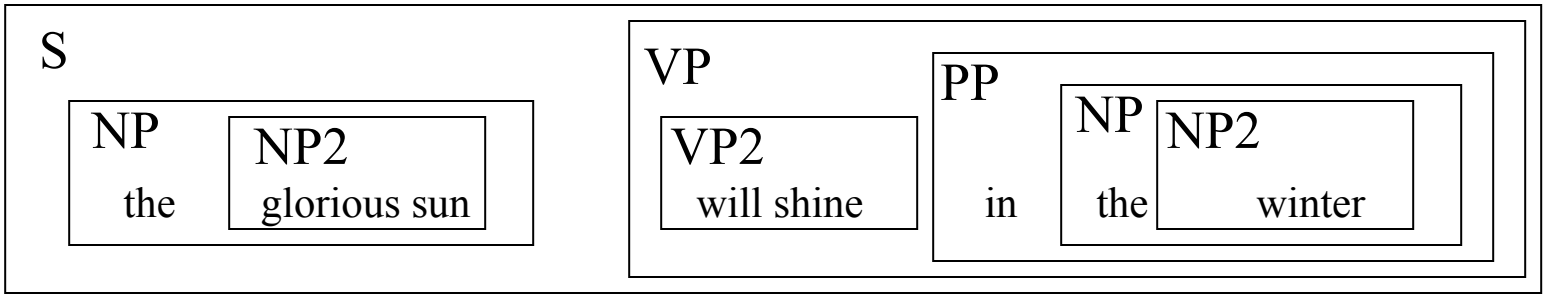
Notations for (constituent) syntactic structure

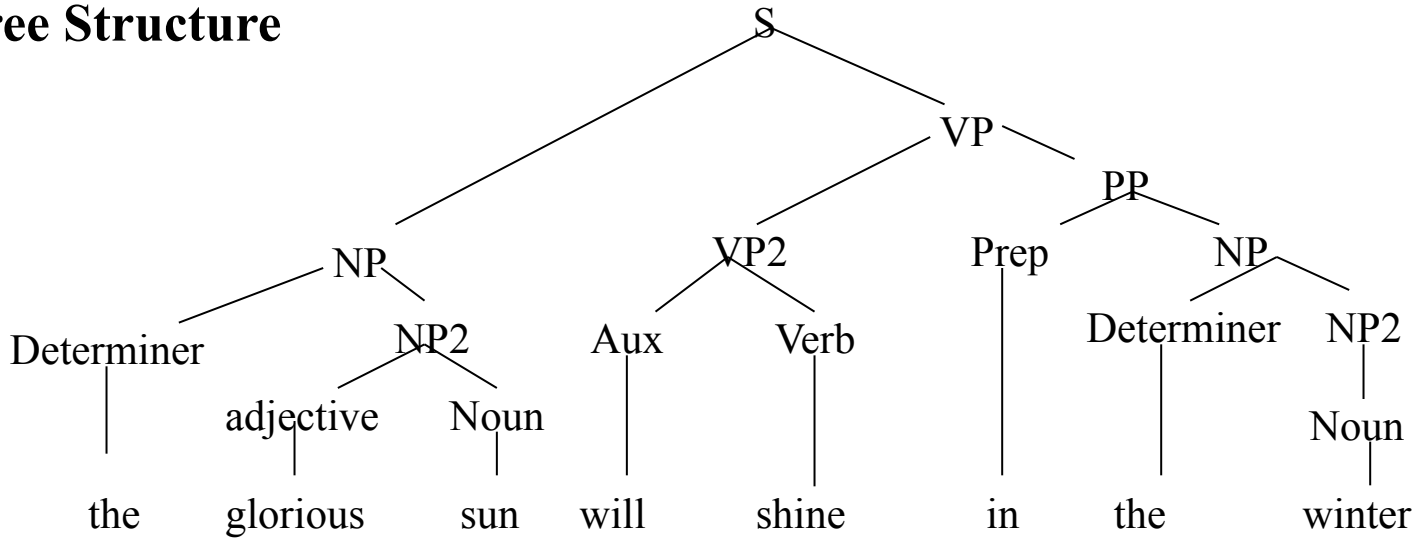
Bracketed text

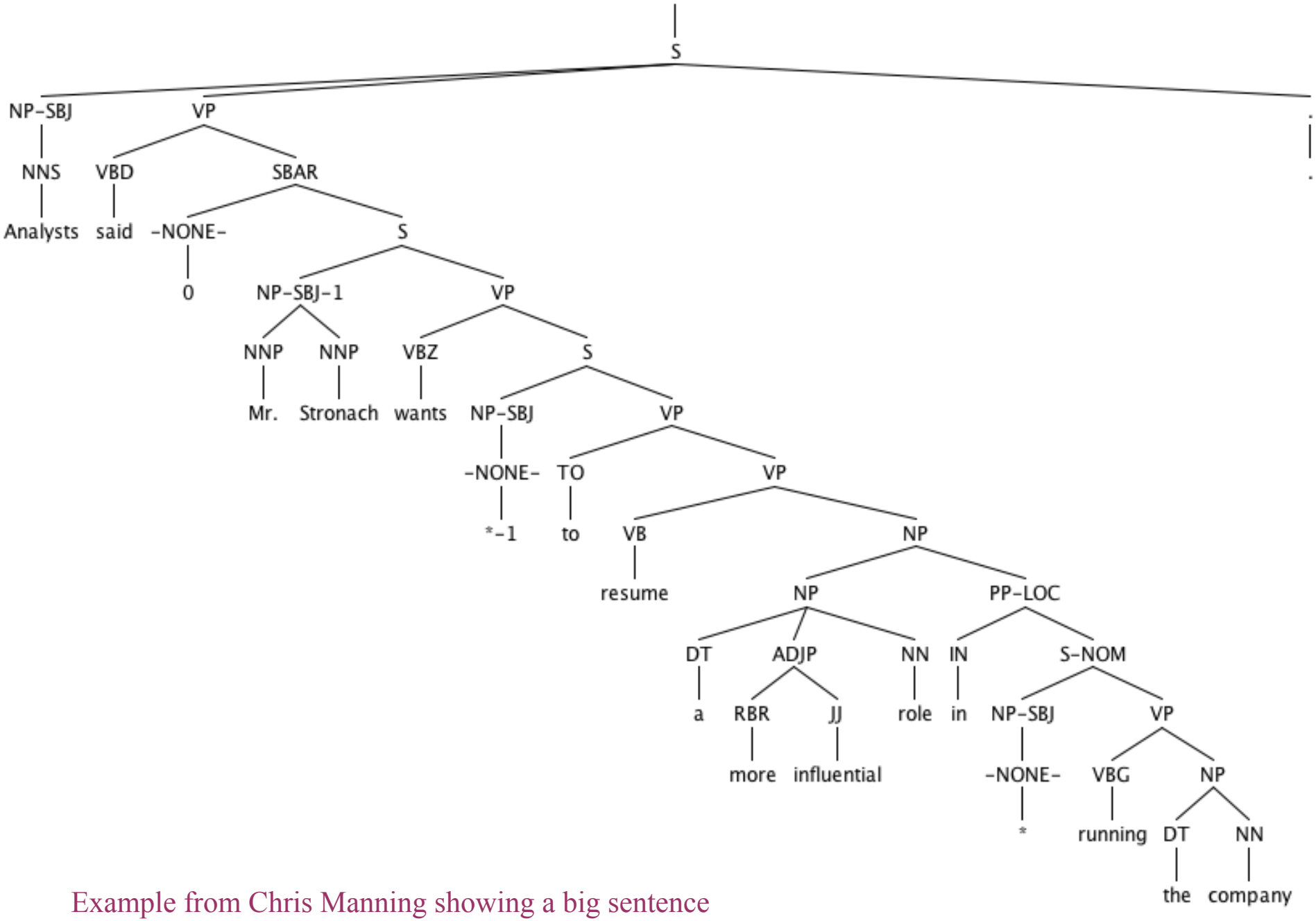
$[_S\ [_{NP}$ the $[\ _{NP2}$ glorious sun]] $[_{VP}\ [_{VP2}$ will shine] $[_{PP}$ in $[\ _{NP}$ the $[\ _{NP2}$ winter]]]]]

Nested Boxes



Tree Structure





Example from Chris Manning showing a big sentence with nested constituents and empty elements.

Generativity vs. Parsing

- You can view these rules as either synthesis or analysis machines
  - Generate strings in the language
  - Reject strings not in the language
  - Impose structures (trees) on strings in the language
- The latter two are the analysis tasks of parsing
  - Parsing is the process of finding a derivation (i. e. sequence of productions) leading from the START symbol to a TERMINAL symbol (or TERMINALS to START symbol)
  - Shows how a particular sentence ***could be*** generated by the rules of the grammar
  - If sentence is structurally ambiguous, more than one possible derivation is produced

Context-Free Grammars

- Why Context-Free?
  - The notion of context in CFGs has nothing to do with the ordinary meaning of the word context in language.
  - All it really means is that the non-terminal on the left-hand side of a rule can be replaced regardless of context
    - Context-sensitive grammars allow context to be placed on the left-hand side of the rewrite rule
- In programming languages, and other uses of CFGs in Computer Science, notably XML, CFGS are
  - Unambiguous
    - Assign at most, 1 structural description to a string
  - Parsable in time linearly proportional to the length of the string

Key Constituents for English

- English has headed phrase structure
  - X-bar theory: in natural languages, phrases are headed by particular kinds of word that has modifiers and qualifiers around them (specifiers, adjuncts, and complements)
- Verb Phrases VP → … VB* …
- Noun Phrases NP → … NN* …
- Adjective Phrases ADJP → … JJ* …
- Adverb Phrases ADVP → … RB* …
- Sentences (and clauses): SBAR → S | SINV | SQ …
  - Sentences, inverted sentences, direct questions, … can also appear in larger clause structure SBAR where sentence is preceded by *that*
- Plus minor phrase types:
  - QP (quantifier phrase in NP, PP (prepositional phrase), CONJP (multi word constructions: *as well as*), INTJ (interjections), etc.

e.g. Penn Treebank Tags: http://bulba.sdsu.edu/jeanette/thesis/PennTags.html

Sentences

- Sentences
  - 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 Aux NP VP

Noun Phrases

- Noun phrases have a head noun with pre and post-modifiers
  - Determiners, Cardinals, Ordinals, Quantifiers and Adjective Phrases are all optional, indicated here with parentheses
    NP -> (DT) (Card) (Ord) (Quan) (AP) Noun
    Noun -> NN | NP | NPS | NNS
  - Post-modifiers include prepositional phrases, gerundive phrases, and relative clauses
    the man [from Moscow]
    any flights [arriving after 11pm] (gerundive)
    the spy[who came in from the cold] (relative clause)

Some examples on these slides are from the Jurafsky and Martin text and from Jim Martin's online course materials.

Recursive Rules

- One type of Noun phrase is a Noun Phrase followed by a Prepositional phrase
  - * NP -> NP PP
    PP -> Prep NP
- Of course, this is what makes syntax interesting

  flights from Denver

  flights from Denver to Miami

  flights from Denver to Miami in February

  flights from Denver to Miami in February on a Friday

  flights from Denver to Miami in February on a Friday under $300

  flights from Denver to Miami in February on a Friday under $300 with lunch

  – Syntax trees for these examples also need rules for NP -> Noun, etc.

* This grammar illustrates the recursion, but may not give the best derivation for these phrases!

Verb Phrases

- Simple Verb phrases

VP -> Verb	*leave*
| Verb NP	*leave Boston*
| Verb NP PP	*leave Boston in the morning*
| Verb PP	*leave in the morning*

- Verbs may also be followed by a clause

  VP -> Verb S

  I think I would like to take a 9:30 flight

- The phrase or clause following a verb is sometimes called the complementizer

Conjunctive Constructions

- S -> S and S
  - John went to NY and Mary followed him
- NP -> NP and NP
- VP -> VP and VP
- …
- In fact the right rule for English is

  X -> X and X

Problems

- Context-Free Grammars can represent many parts of natural language adequately
- Here are some of the problems that are difficult to represent in a CFG:
  - Agreement
  - Subcategorization
  - Movement (for want of a better term)

Agreement

- This dog
- Those dogs

- *This dogs
- *Those dog

- This dog eats
- Those dogs eat

- *This dog eat
- *Those dogs eats

- In English,
  - subjects and verbs have to agree in person and number
  - Determiners and nouns have to agree in number
- Many languages have agreement systems that are far more complex than this.
- Solution can be either to add rules with agreement or to have a layer on the grammar called the features

Subcategorization

- Subcategorization expresses the constraints that a particular verb (sometimes called the predicate) places on the number and syntactic types of arguments it wants to take (occur with).
  - 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

- Should these be correct?
  - John sneezed the book
  - I prefer United has a flight
  - Give with a flight
- 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
- Now *overgeneration* is a problem for a generative approach.
  - The grammar should represent all and only the strings in a language
- From a practical point of view... Not so clear that there's a problem

Movement

- Consider the verb “booked” in the following example:
  - [[My travel agent]$_{NP}$ [booked [the flight]$_{NP}$]$_{VP}$]$_{S}$

- i.e. “book” is a straightforward transitive verb. It expects a single NP arg within the VP as an argument, and a single NP arg as the subject.

Movement

- But what about?
  - Which flight do you want me to have the travel agent book?
- The direct object argument to "book" isn't appearing in the right place. It is in fact a long way from where it's supposed to appear.
- And note that it's separated from its verb by 2 other verbs.
- In Penn Treebank, these types of movement are annotated by have an empty Trace constituent appear in the right place.

The Point about CFGs

- 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)
  - For example, Feature Structures for CFGs place constraints on how the rules can be applied

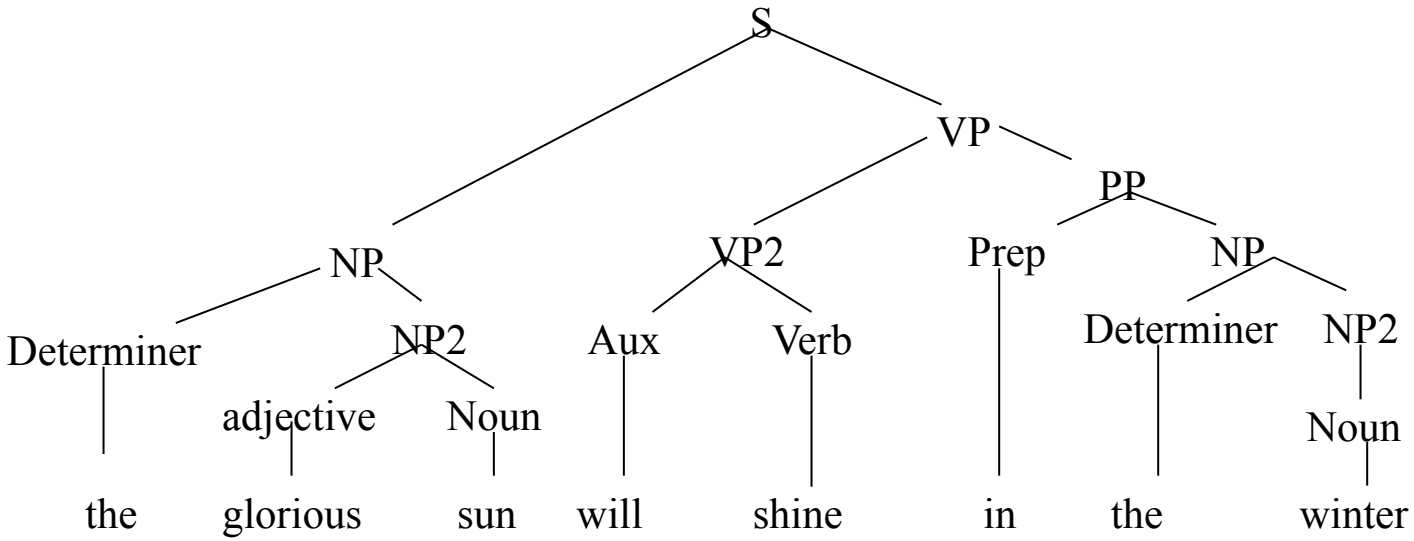
In-class exercise

Dependency Grammars

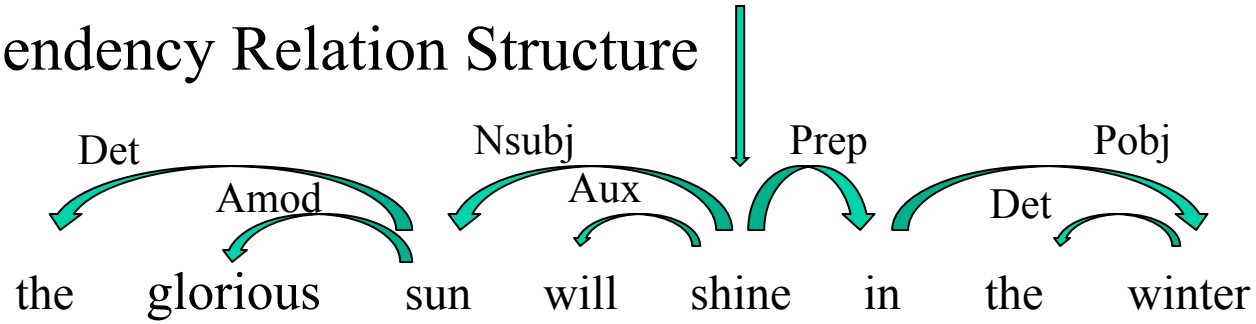
- Dependency grammars offer a different way to represent syntactic structure
  - CFGs represent constituents in a parse tree that can derive the words of a sentence
  - Dependency grammars represent syntactic dependency relations between words that show the syntactic structure
  - Typed dependency grammars label those relations as to what the syntactic structure is
- Syntactic structure is the set of relations between a word (aka the head word) and its dependents.

Examples

- Context Free Grammar Tree Structure



- Dependency Relation Structure

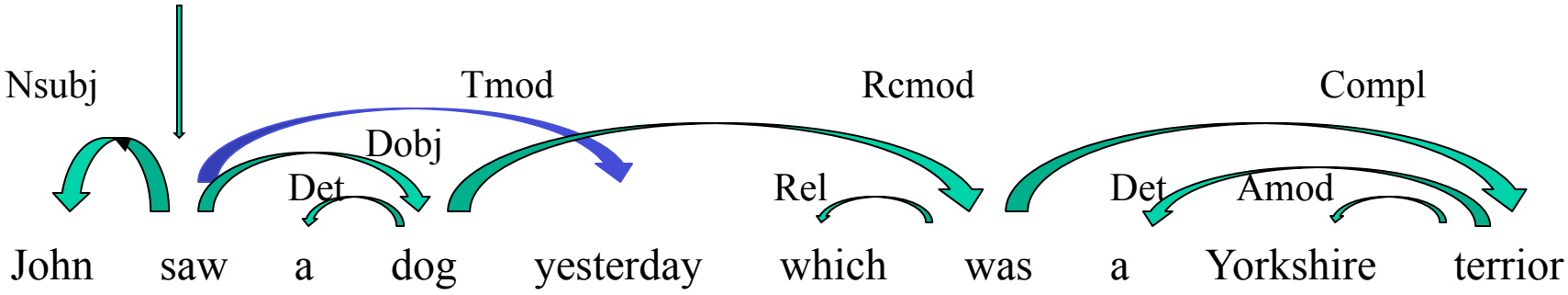


Dependency Relations

- The set of Grammar Relations has varied in number
  - 48 in the Stanford dependency parser
  - 59 in Minipar, a dependency parser from Dekang Lin
  - 106 in Link, a related link grammar parser from CMU
- The examples on the previous page used those from the Stanford dependency parser
  - De Marneffe, MacCartney and Manning, Generating Typed Dependency Parses from Phrase Structure Parses, LREC (Language Resources and Evaluation Conference), 2006.

Projective vs. Non-Projective

- In the dependency graph as depicted in the previous example, with the words in sentence order, if no arcs cross, then it is a projective tree
- If there are crossing arcs, then it is a non-projective tree



- CoNLL (Conference on Natural Language Learning) 2006 had dependency parsing as the shared task on 13 languages, not including English. Out of the languages which had non-projective sentences in the treebanks, from 0.5% to 5% of the sentences were non-projective.

Dependency Grammar vs. CFG

- Dependency grammars and CFGs are strongly equivalent
  - Generate the same sentences and make the same structural analysis
    - Haim Gaifman, 1965, “Dependency systems and phrase structure systems”.

- Provided that the CFGs are restricted in that one word or phrase can be designated as its “head”
  - This restriction also accepted by linguists in X-bar theory
    - Proposed by Chomsky and further developed by Ray Jackendoff, 1977, “X-bar-Syntax: A Study of Phrase Structure”
  - Note that the head of a noun phrase is a noun, the head of a verb phrase is a verb, etc.