Lecture 8:
Grammatical Representation:
Syntax and a little Morphology

What is Grammar?

- Several definitions:
  - The rules and principles that guide the structure of sentences in language
  - Regularities in the mapping between phonological form and semantic form
  - The way a language speaker organizes her experience with language, allowing her to make generalizations

Why do we need grammar?

- Grammatical analysis in NLP involves breaking the text into simpler parts and categorizing them
  - New sentences are the rule, rather than the exception (unlike new words)

- Two main motivations for grammar:
  - Structural Analysis: decomposing complex units into simpler sub-structures can assist learning and generalization
  - Semantic Information: grammatical structure often reflects semantic structure and distinctions

Text Strings are not Informative Enough, even with POS Tags

Q: Where were the crates taken?

The terrorists took the crates they found **to** the hangar

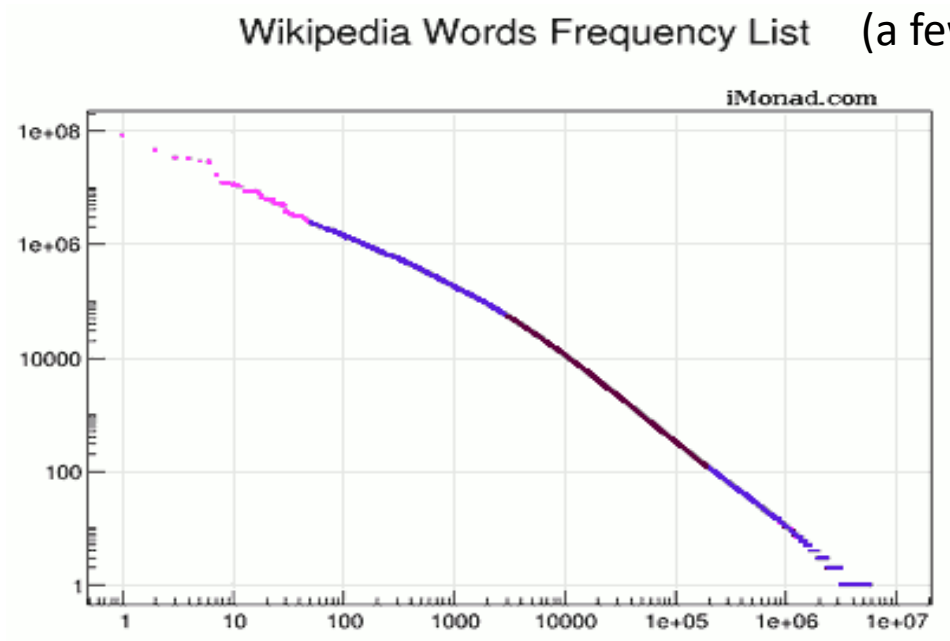
A: to the hangar

The terrorists took the crates they found **in** the hangar

A: ***not*** to the hangar

The Importance of Categorization

- Reminder: linguistic phenomena tend to have a power-law distribution

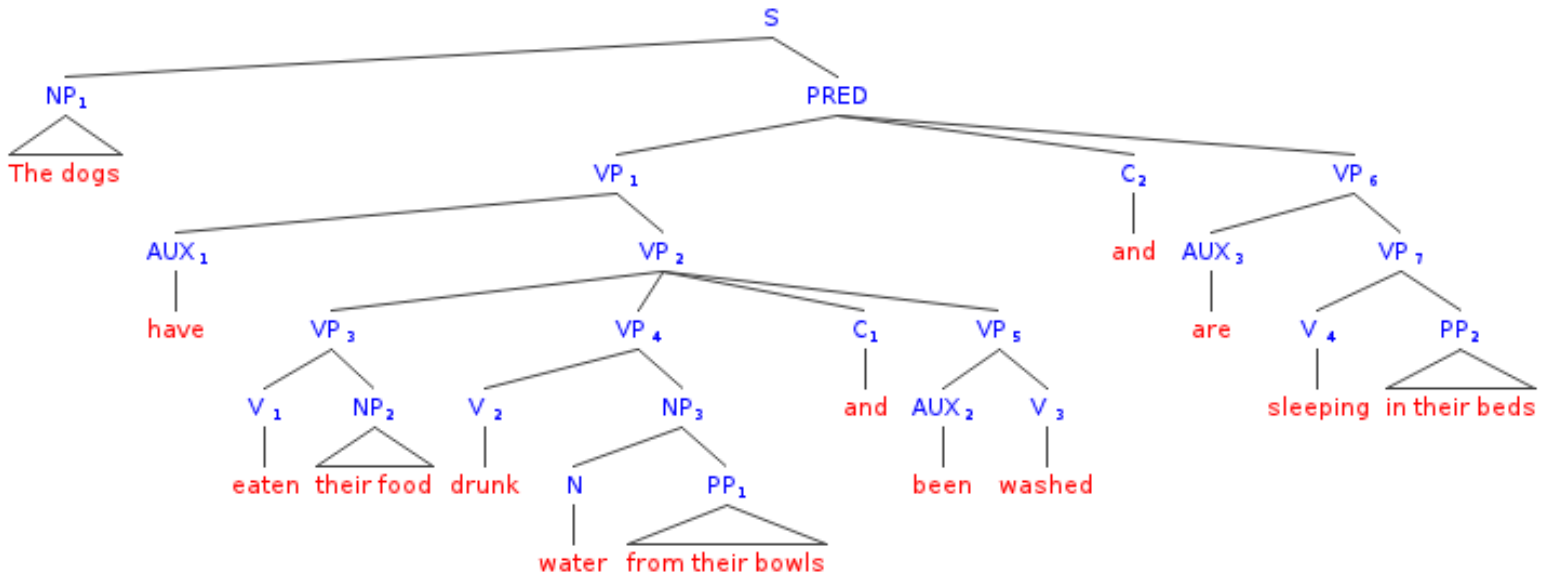


$$\text{freq} \propto \frac{1}{rank^c}$$

- Most word types are rare
- Many word instances are rare

The Importance of Categorization

- This means that for most types, we don't have meaningful statistics
  - Many types don't appear at all
- Categorization allows information to propagate from one type to another



Overview of Grammar: Words

Basic Linguistic Theory, Vol. 1-2, Dixon (2010)

- **Word:** surprisingly difficult to define
  - **Practical:** anything that is between two spaces
  - But: what about spoken language?
  - what about phrases whose spaces disappeared? ("kick start", "kickstart" or "kick-start"?)
  - What about languages that don't have spaces? (e.g., Mandarin Chinese)

Overview of Grammar: Words

- Sapir (1921): “one of the smallest, completely satisfying bits of isolated meaning into which the sentence resolves itself”

- Zirmunskij (1966): “the word is the most concise unit of language, which is independent in meaning and form”

- Bloomfield (1933): “a word, then, is a free form which does not consist entirely of (two or more) lesser free forms; in brief, a word is a *minimum free form*”
  - “free form” is interpreted to mean words that can occur on their own, with a given meaning
  - But: many words (“the”, “my”, “and”) cannot occur on their own

Overview of Grammar: Words

- We will distinguish between:
  - **Phonological words:** defined by phonological criteria, primarily: syllable structure, pause phenomena, prosodic features (such as stress or tone), phonological word boundary rules
  - **Grammatical words:** have a conventionalized meaning, can undergo morphological processes (e.g., affixation, reduplication, vowel shift)

Morphological Analysis

- Minimally: separating out clitics (*tokenization*)
  - John's → John + 's
  - Auf'm → auf 'm (German: auf+dem)
  - לבית הספר → ל+בית ה+ספר
- Base forms (lemmatization, omitting inflectional morphology)
  - takes → take
  - dogs → dog
  - יתנו → נתן (what about ינתנו?)
- Segmentation into morphemes:
  - renewal → re + new + al
  - nachgedacht → nach + ge__t + dach (denken)
  - מטבחונים → מטבח + ון + ים

Basic Syntactic Units: Clauses

- **Clause:**
  - Semantically: “the description of some activity, state or property”

- Simple clauses have a predicate, core arguments (usually subjects and objects), and non-core arguments (e.g., location, manner, instrument)
  - “John **kicked** the ball”
  - “The door **opened**”
  - “The door silently **opened**”
  - “John **opened** the door with a hammer”
  - “John is **tall**”

Inter-Clause Relations

- Three main inter-relations between clauses within a sentence: complement clauses, relative clauses, linked clauses, coordination
- Complement clauses:
  - Clauses that serve as an argument in another clause
    - "John said **he will kick the ball**"
    - "Mary convinced Paul **to join them**"
- Coordination:
    - "I got home and took a shower"
- Relative clauses:
  - Clauses that modify an argument of another clause
    - "John, **who has studied the language for years**, speaks German well"
    - "Dogs **that bark** never bite"
- Linked clauses:
    - After **he had studied it for years**, **John could speak German well**
    - Although **he had studied it for years**, **John could speak German well**

Basic Units: Noun Phrases

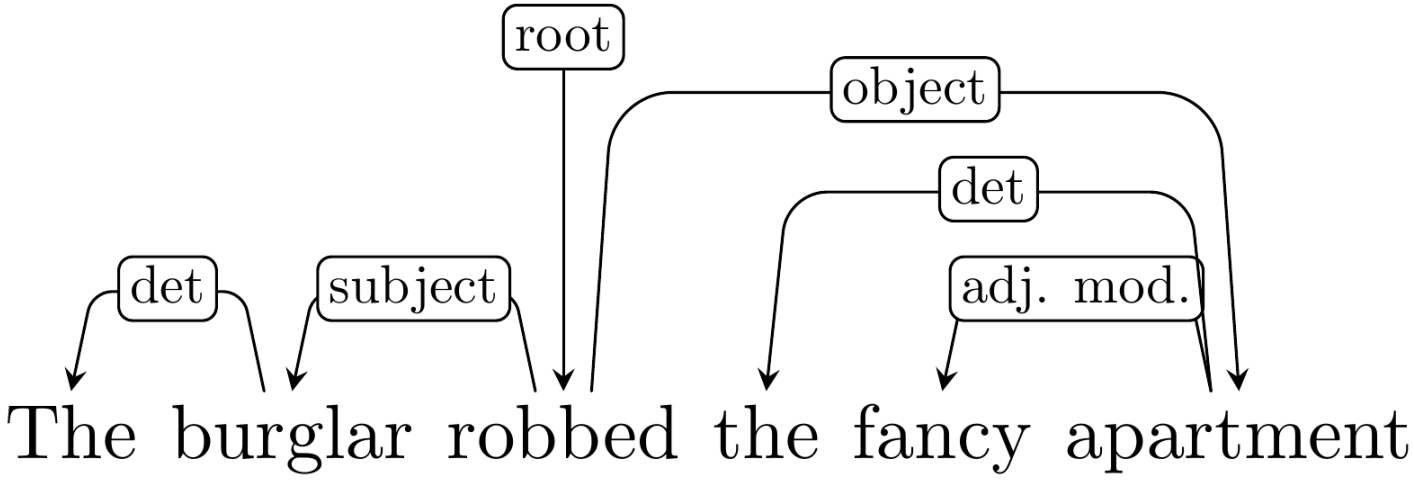
- **Noun phrase:** an argument of a clause is generally a noun phrase. Two major classes:
  - Proper nouns or names (of people, places, organizations etc.)
  - Common nouns, possibly along with some modifiers
    - Possible modifiers: adjectives (e.g., fast, thin), relative clauses, cardinals or ordinals (e.g., one, first), modifying nouns (e.g., shipping company)
  - Noun phrases generally have a *head*, a word that determines the sematic type of the whole phrase, and is an essential component of its meaning
    - Shipping **company**
    - Fast **runner**
    - The **man** who wasn't there

Basic Units: Syntactic Heads

- The notion of a *head* is used in a wider context than noun phrases
- The verb is considered the head of a clause:
  - Arguments and modifiers are considered its *dependents*
    - **John** ran **home** (“ran” is the head of the clause, “John” and “home” are its dependents)
    - **Bill stupidly** answered **the officer’s question** (“answered” is the head, “Bill”, “stupidly” and “the officer’s question” are its dependents)
- Some schemes view all syntactic relations as head-dependent relations (*dependency schemes*)

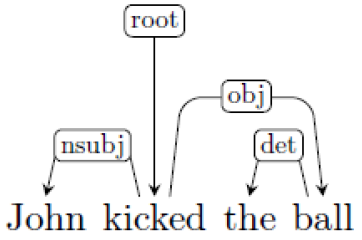
Dependency Parses

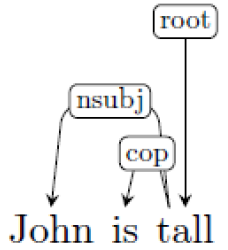
- Represent Syntax as head-dependent relations between words
  - Nodes are words, edges are relations
  - The arguments and modifiers of a word are its children
  - Edge labels mark the type of relation
  - The verb of the main clause is the root

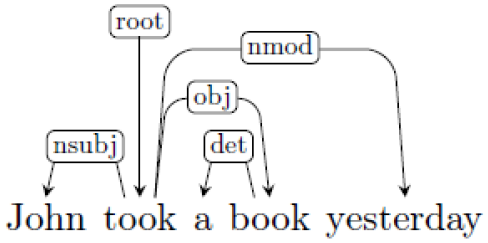


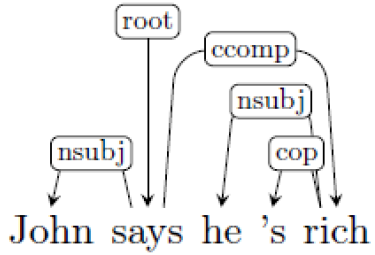
Example Annotations in *Universal Dependencies* Format

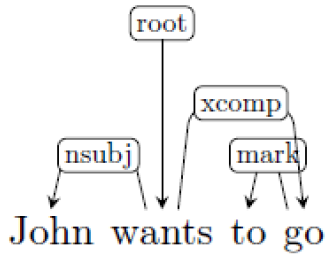
- Transitive clauses:
  - John kicked the ball
  - John took a book yesterday
- Copula clauses:
  - John is tall
- Complement clauses:
  - John says he's rich
  - John wants to go







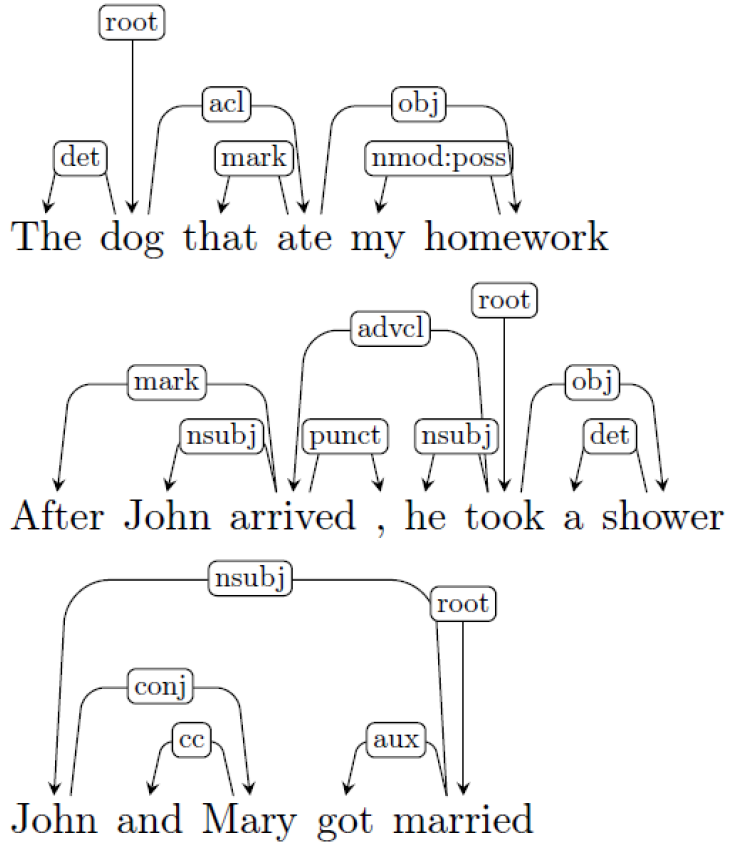




http://universaldependencies.org/
http://universaldependencies.org/u/dep/index.html

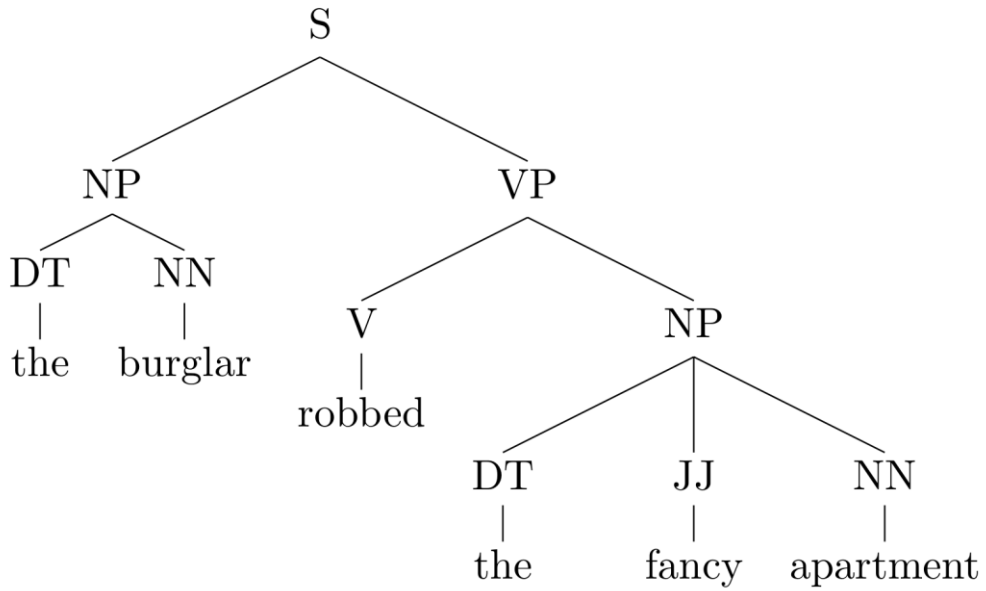
Example Annotations in *Universal Dependencies* Format

- Relative Clauses:
  - The dog that ate my homework
- Subordinate clauses:
  - After John came home, he took a shower
- Coordination:
  - John and Mary got married



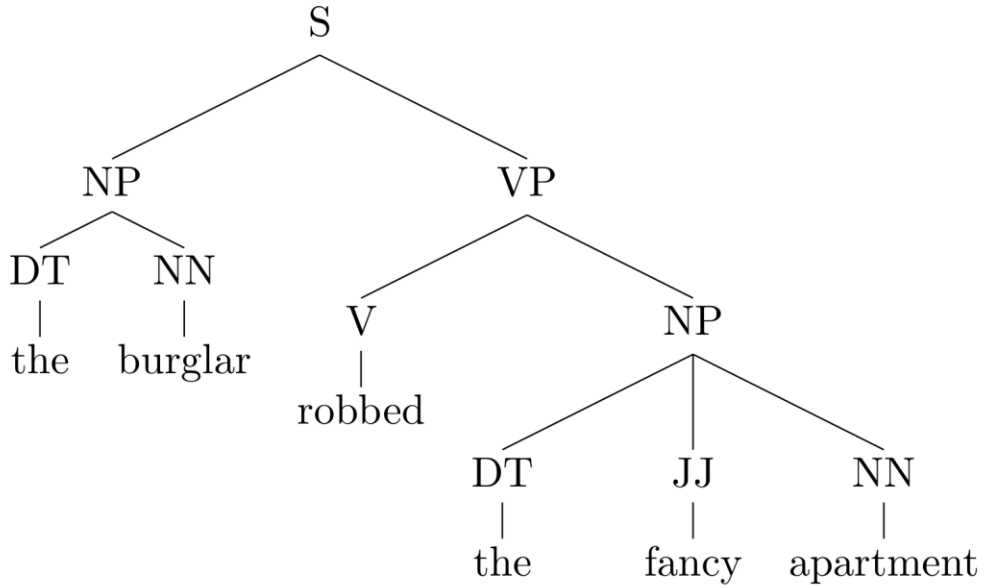
Two Common Representations Types

- ***Phrase-based (constituency) parses:*** represent the sentence as a collection of nested phrases
  - Words are at the leaves
  - Non-terminal labels represent the phrase type. This is determined by the type of the headword (e.g., Noun Phrases (NP) are phrases headed by a noun)



Information from Syntactic Structure

1. Phrases
2. Grammatical relations
3. A proxy to semantics
4. Syntactic disambiguation



Information from Syntactic Structure

- Phrases:
  - Syntactic structure decomposes the sentence to sub-strings
  - These can be useful for applications
  - For example: in machine translation, it is sometimes possible to phrase translation rules as re-ordering of phrases, rather than of words

Machine Translation Example

- Compare English with Japanese glosses:

"IBM bought Lotus"

"IBM Lotus bought"

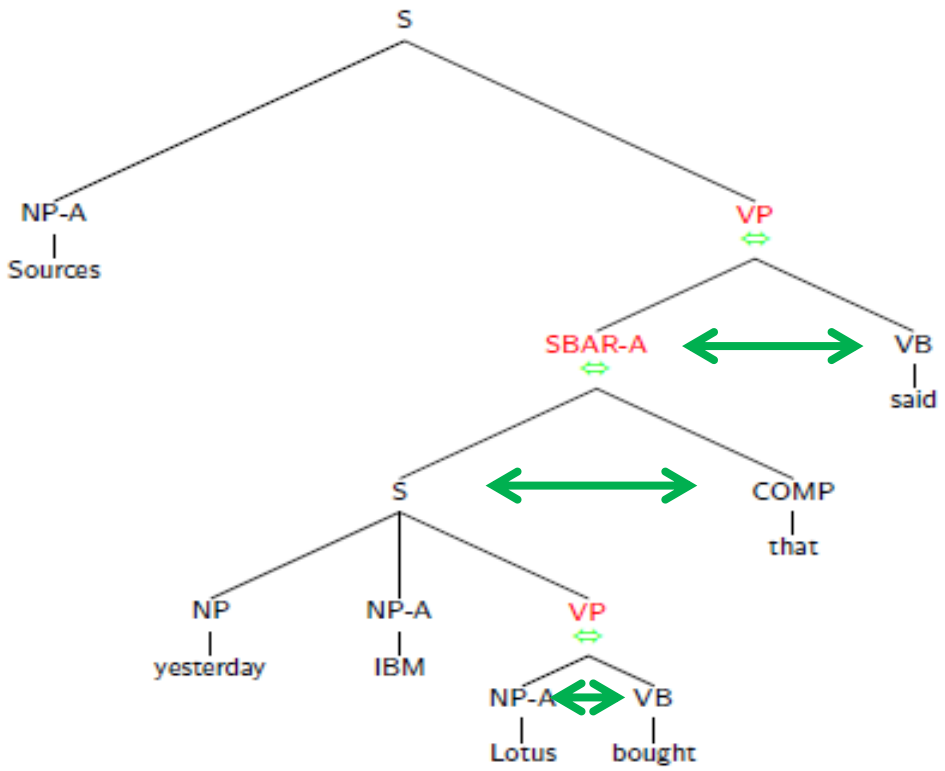
"Sources said that IBM bought Lotus yesterday"

"Sources yesterday IBM Lotus bought that said"

- It is difficult to phrase the possible permutations in terms of words, easier in terms of phrases

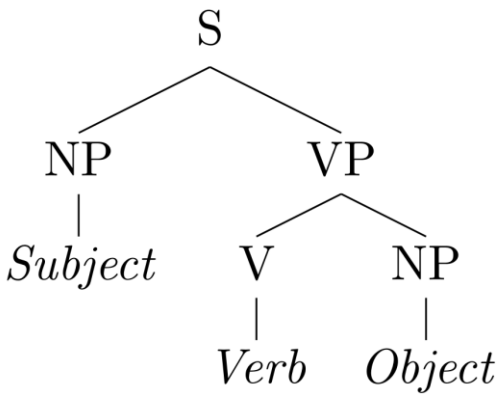
Machine Translation Example

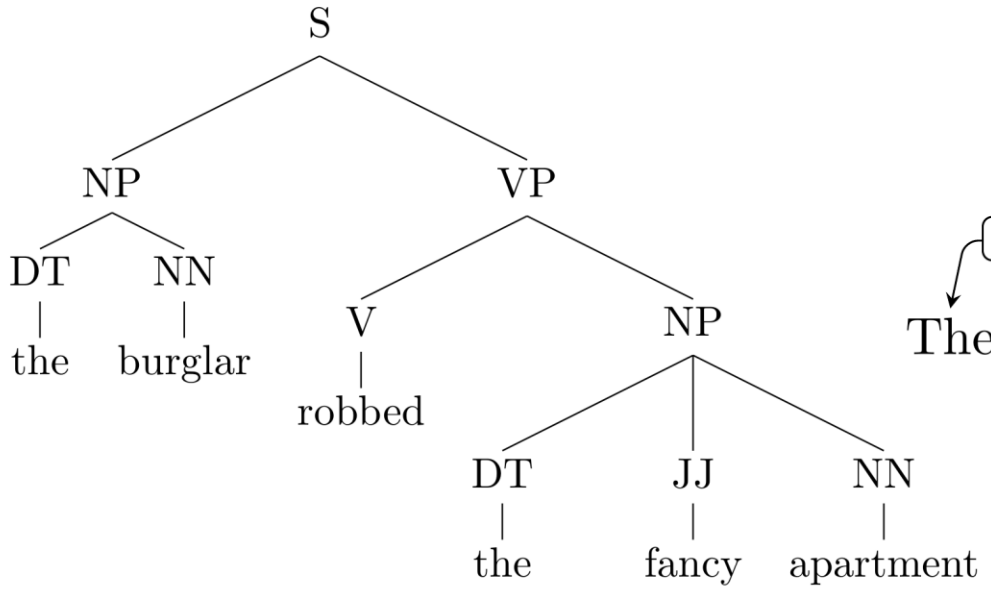
- This can be seen by comparing English and Japanese phrase structures:

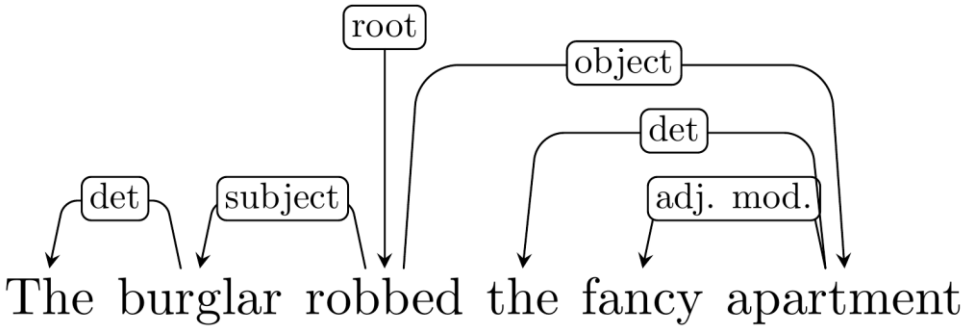


Information from Syntactic Structure

- Extracting grammatical relations
  - With dependencies, they are more explicit



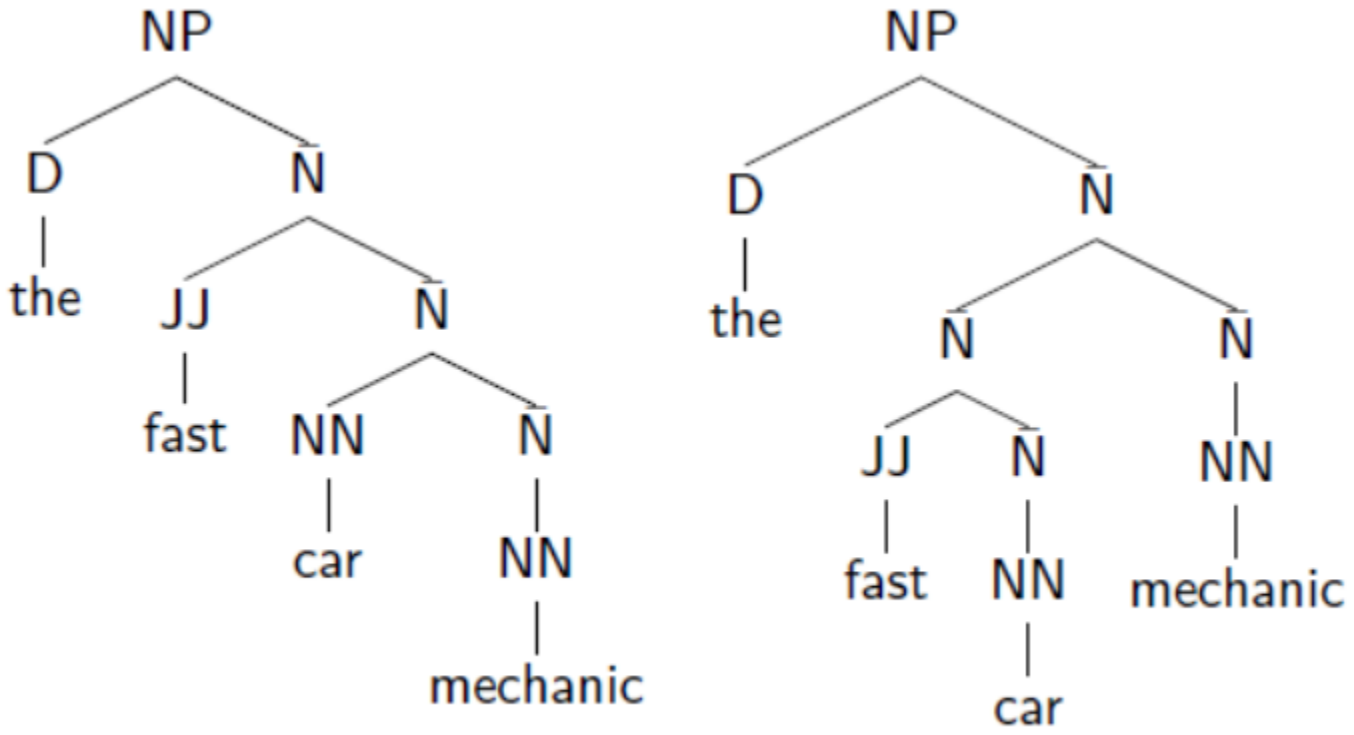




- *the burglar* is the **subject** of robbed
- *the fancy apartment* is the **object** of robbed

Information from Syntactic Structure

- Syntactic disambiguation: (adjective scope)



Examples of Syntactic Ambiguity

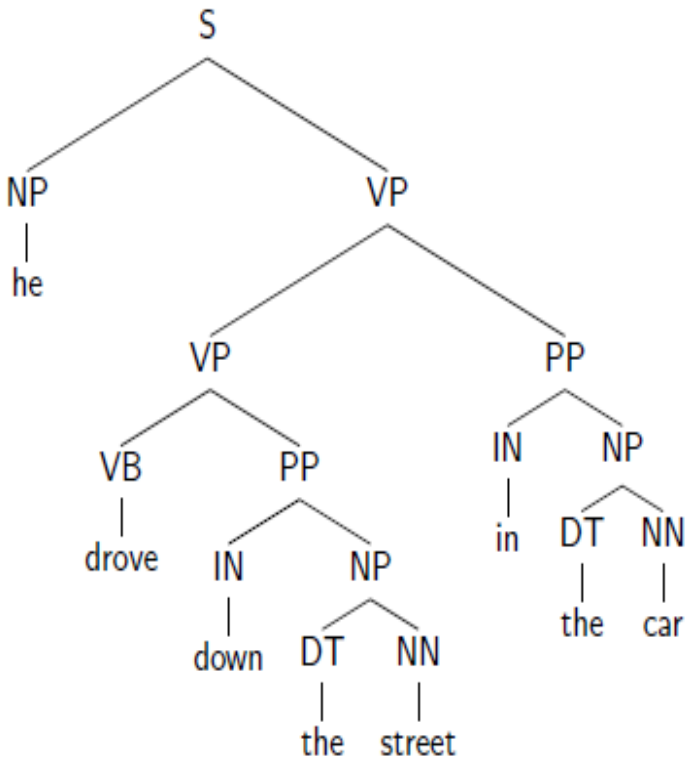
- Prepositional phrases:
  - *They cooked the beans in the pot on the stove*
- Particle vs. preposition:
  - *The puppy tore up the staircase*
- Complement structures
  - *The tourists objected to the guide that they couldn't hear*
  - *She knows you like the back of her hand*
- Gerund vs. participial adjective
  - *Visiting relatives can be boring*
  - *Changing schedules frequently confused passengers*

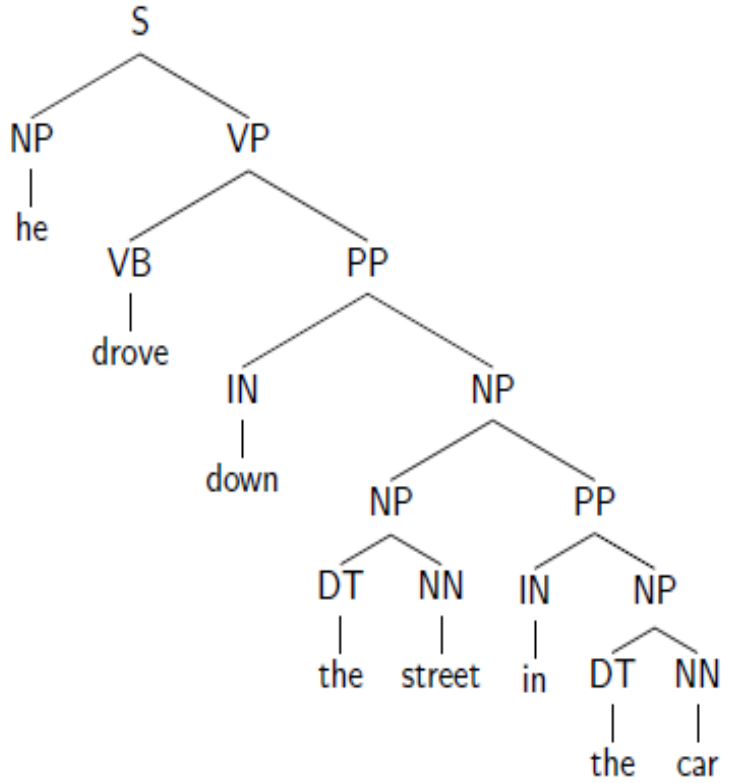
Examples of Syntactic Ambiguity

- Modifier scope within NPs
  - impractical design requirements
  - plastic cup holder
- Multiple gap constructions
  - The chicken is ready to eat.
  - The contractors are rich enough to sue.
- Coordination scope:
  - Small rats and mice can squeeze into holes or cracks in the wall.

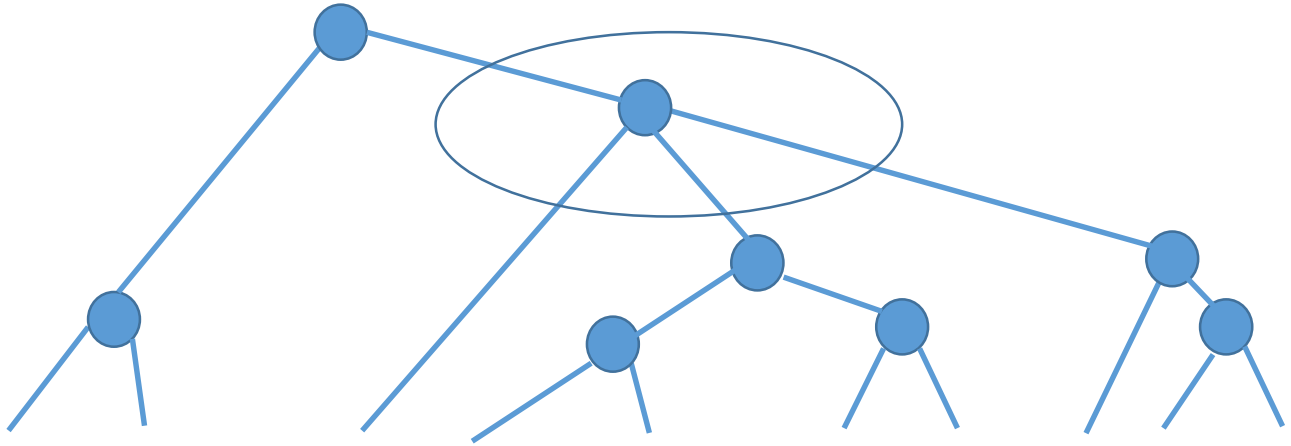
Information from Syntactic Structure

- Syntactic disambiguation: (prepositional phrase attachment)

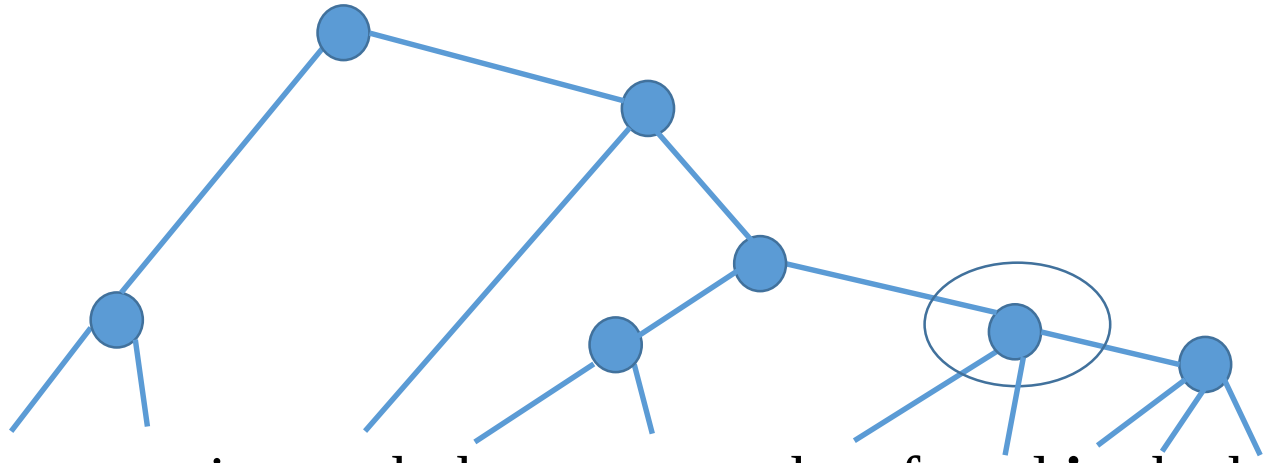




Information from Syntactic Structure



The terrorists took the weapons they found **to** the hangar

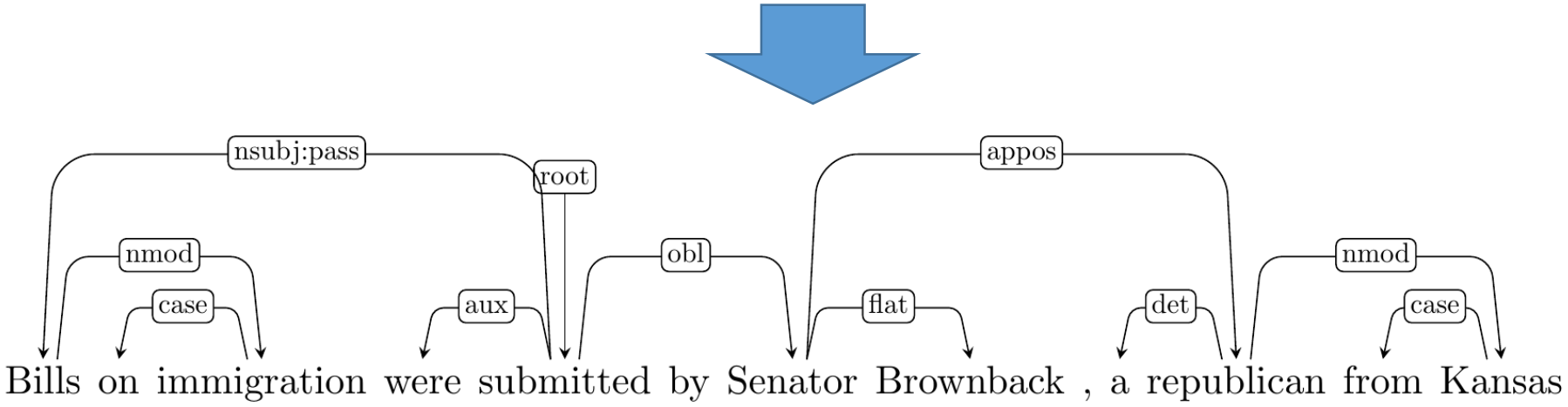


The terrorists took the weapons they found **in** the hangar

A Proxy to Semantics

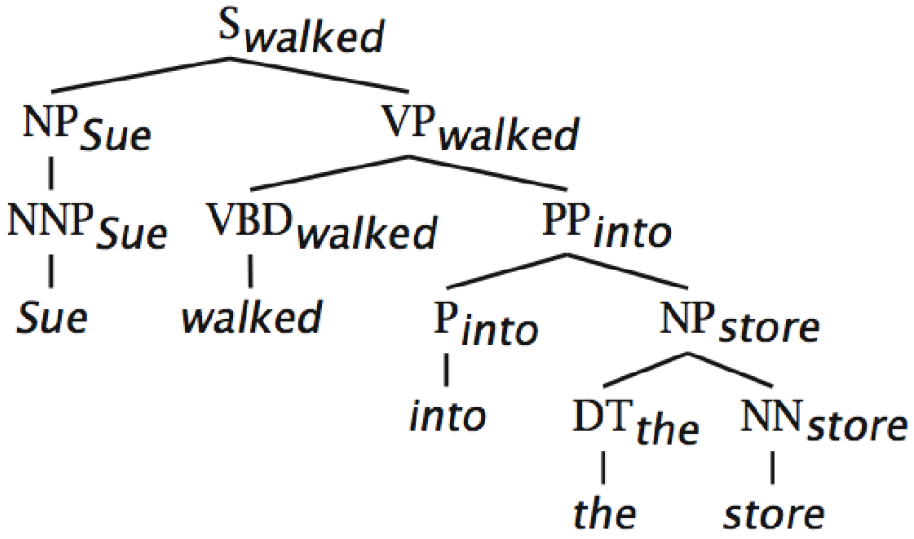
- Syntactic structure provides valuable semantic information that can serve downstream applications, such as paraphrasing, machine translation, summarization etc.

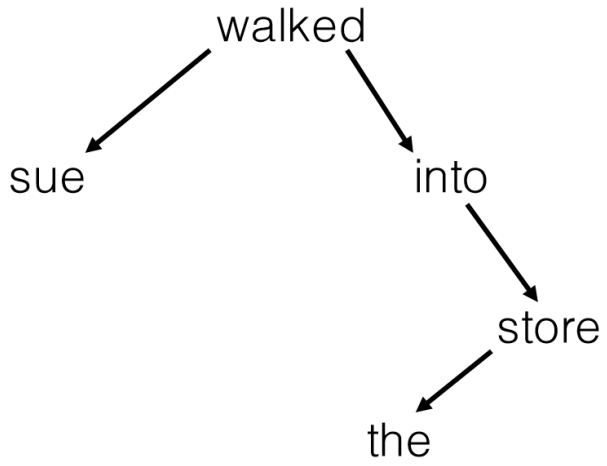
Bills on immigration were submitted by
Senator Brownback, a republican from Kansas



Dependency and Constituency Structures

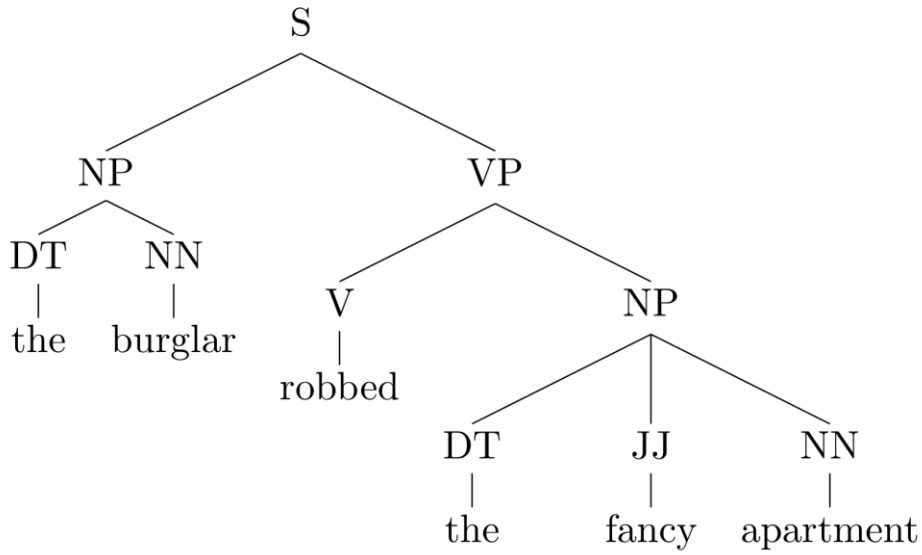
- Dependency grammars have heads
  - Not native to constituency trees
- With head rules → extract dependency structure from constituency tree
  - Other direction is trickier!





Headed Phrase Structure

- Phrases are often headed by particular word types with some modifiers:
  - VP → … Verb …
  - NP → … Noun …
  - ADJP → … Adjective …
  - ADVP → … Adverb …



- This captures a dependency between that particular word and its siblings