



He is mostly not even interested in the new things and in most cases, he has no money for it either.

McDonald et al. 2006

Natural Language Processing

Info 159/259

Lecture 16: Dependency syntax (Oct 19, 2017)

David Bamman, UC Berkeley

Announcements

- No office hours 10/27; plan ahead and come see me during office hours this week 10/20 if you want to chat before 259 midterm reports due.

Context-free grammar

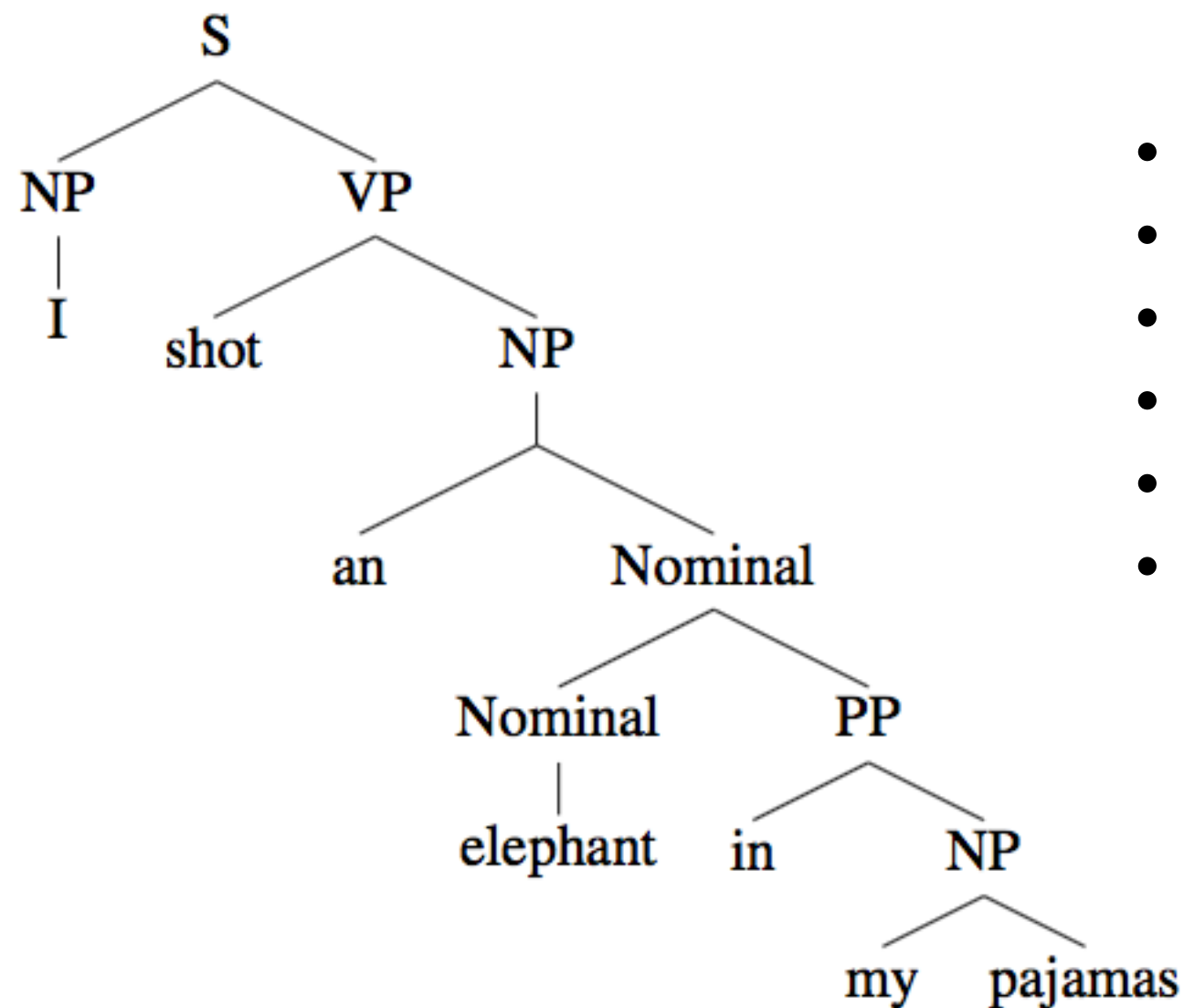
A context-free grammar defines how symbols in a language combine to form valid structures

NP	→	Det Nominal
NP	→	ProperNoun
Nominal	→	Noun Nominal Noun
Det	→	a the
Noun	→	flight

non-terminals

lexicon/
terminals

Constituents



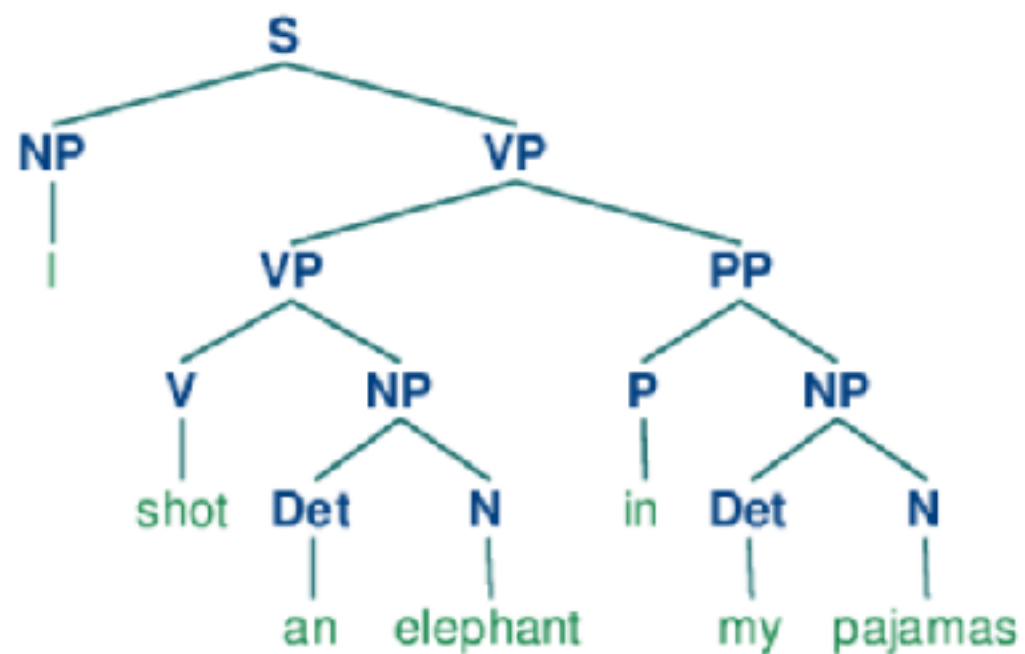
Every internal node is a phrase

- my pajamas
- in my pajamas
- elephant in my pajamas
- an elephant in my pajamas
- shot an elephant in my pajamas
- I shot an elephant in my pajamas

Each phrase could be replaced by another of the same type of constituent

Formalisms

Phrase structure grammar
(Chomsky 1957)



last week

Dependency grammar
(Mel'čuk 1988; Tesnière 1959; Pāṇini)

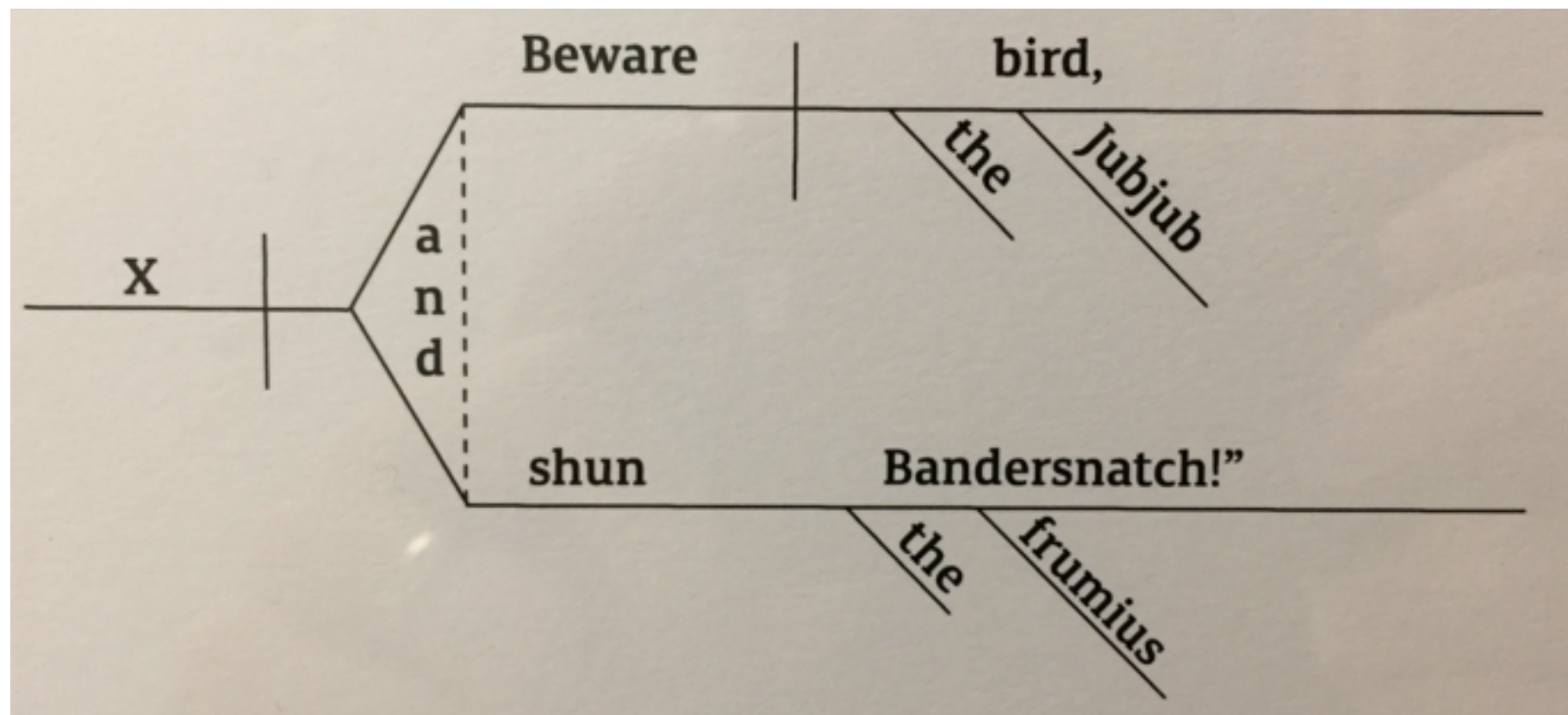


today

Dependency syntax

- Pānini grammar of Sanskrit (ca. 5th-century BCE)
- Medieval theories of grammar (Covington 1984)
- Tesnière, *Éléments de syntaxe structurale* (1959)
- Mel'čuk, *Dependency Syntax: Theory and Practice* (1988)
- Sgall, *Dependency-based formal description of language* (1994)

Dependency syntax

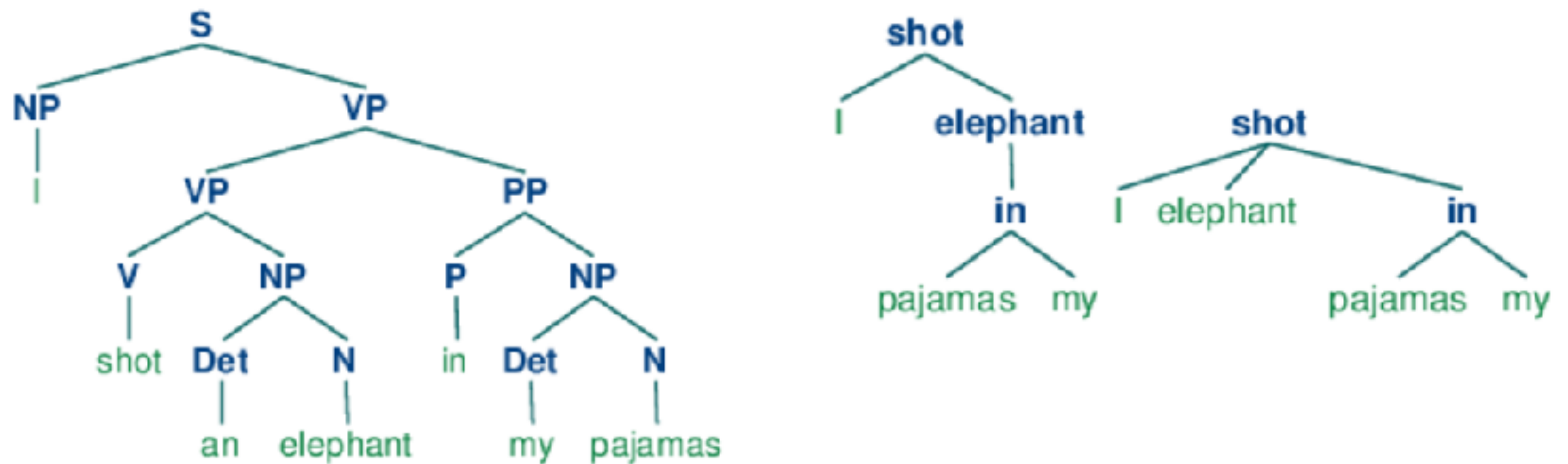


“Sentence diagramming”

Dependency syntax

- “Between the word and its neighbors, the mind perceives connections, the totality of which forms the structure of the sentence. The structural connections establish dependency relations between the words. Each connection in principle unites a superior and an inferior term.”

Dependency syntax



- Dependency syntax doesn't have non-terminal structure like a CFG; words are directly linked to each other.

Dependency syntax

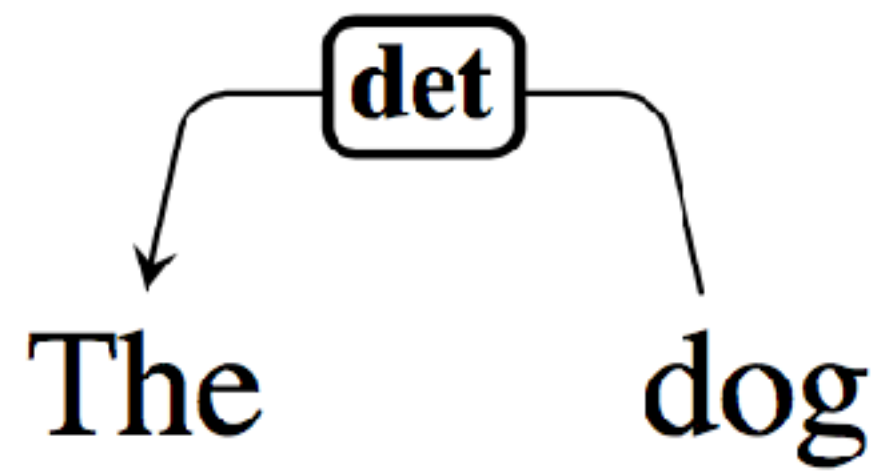
- Syntactic structure = *asymmetric*, *binary* relations between words.

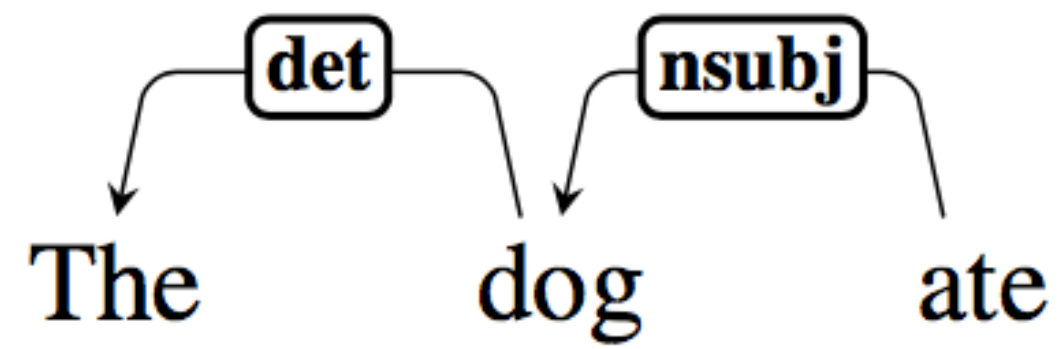
Dependency

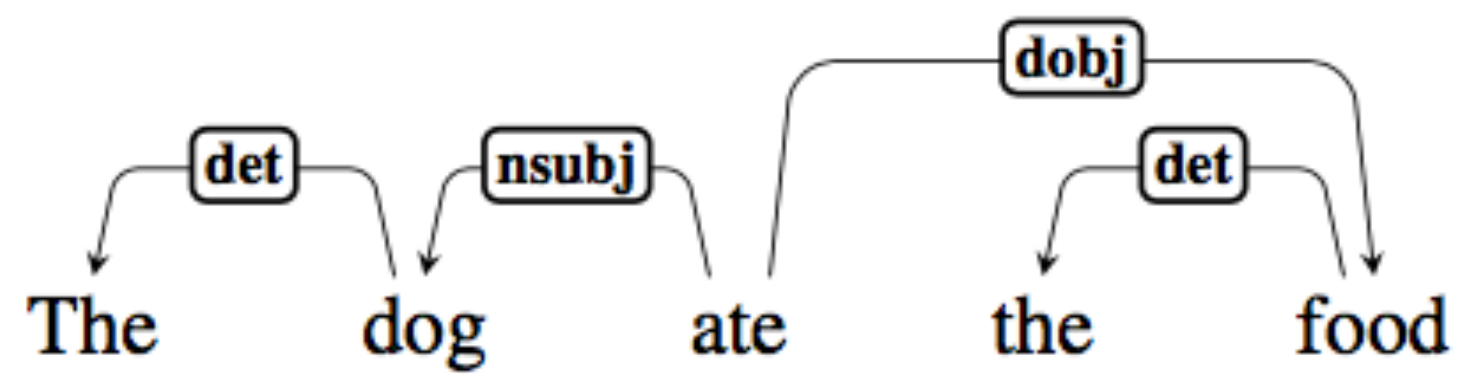
- How do we decide which of a pair of words is the **head** and which is the **dependent**?

Dependency

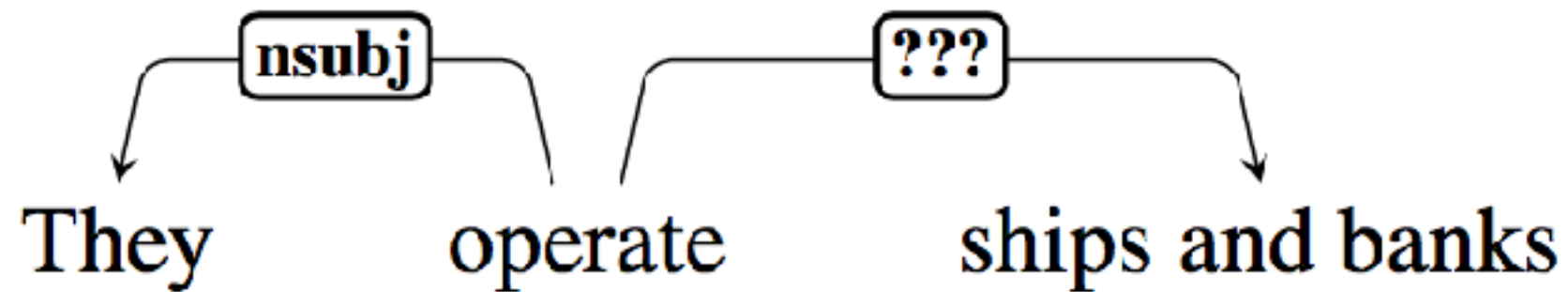
- Many (conflicting) frameworks:
 - Head determines the syntactic category of a construction
 - Head is obligatory; dependents are optional
 - Head selects dependents and determines whether the dependent is required
 - The form of the dependent depends on the head (e.g., agreement between nouns/verbs, adjectives/nouns)
 - The linear position of a dependent is specified with respect to the head.



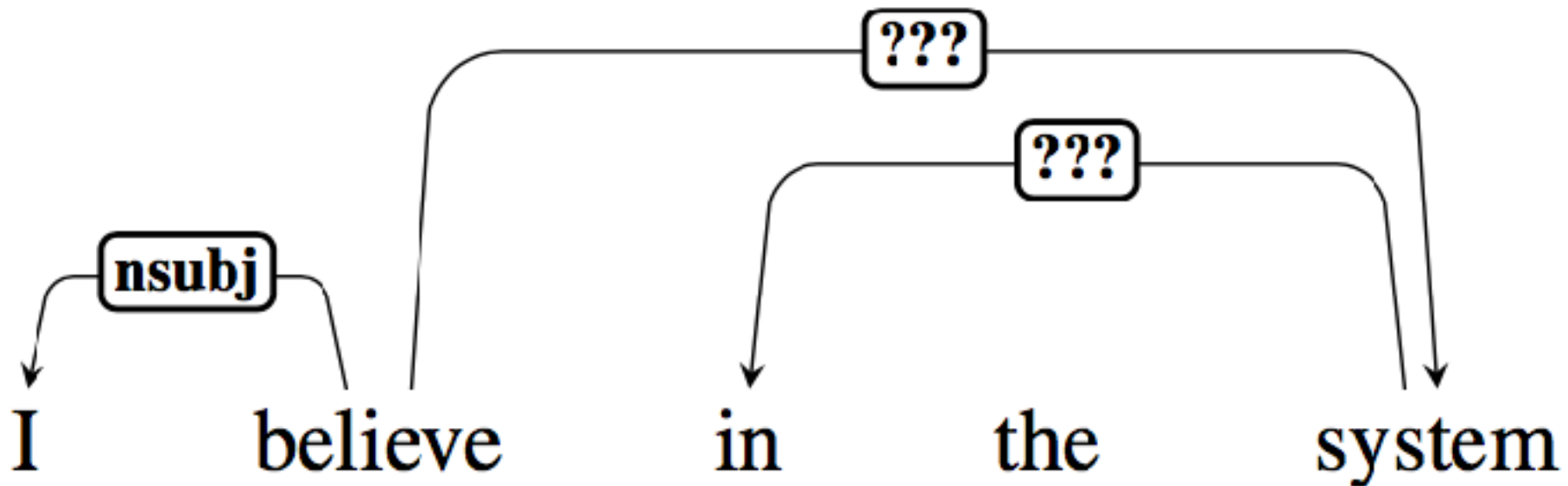
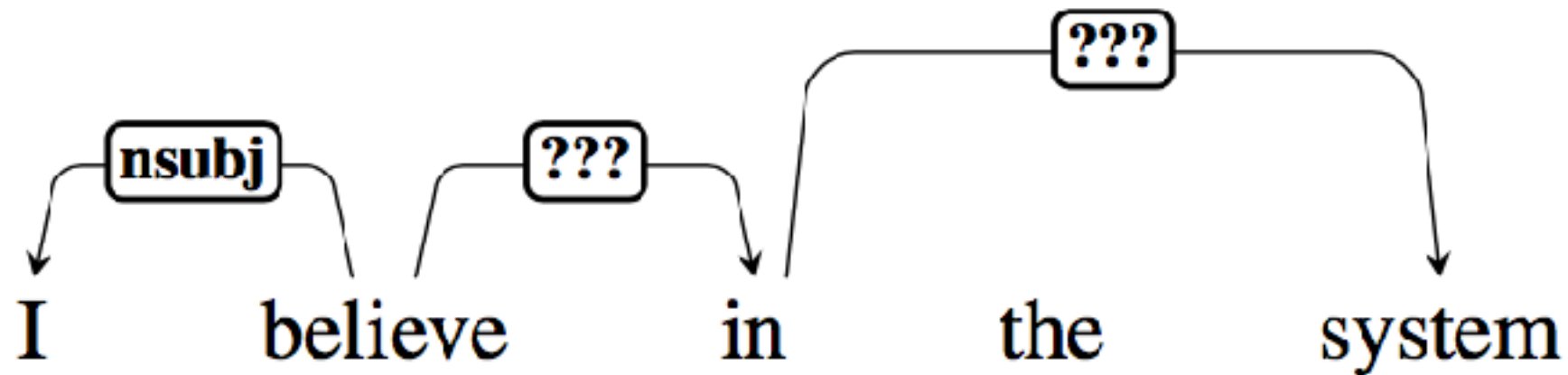




Coordination



Case marking prepositions



Trees

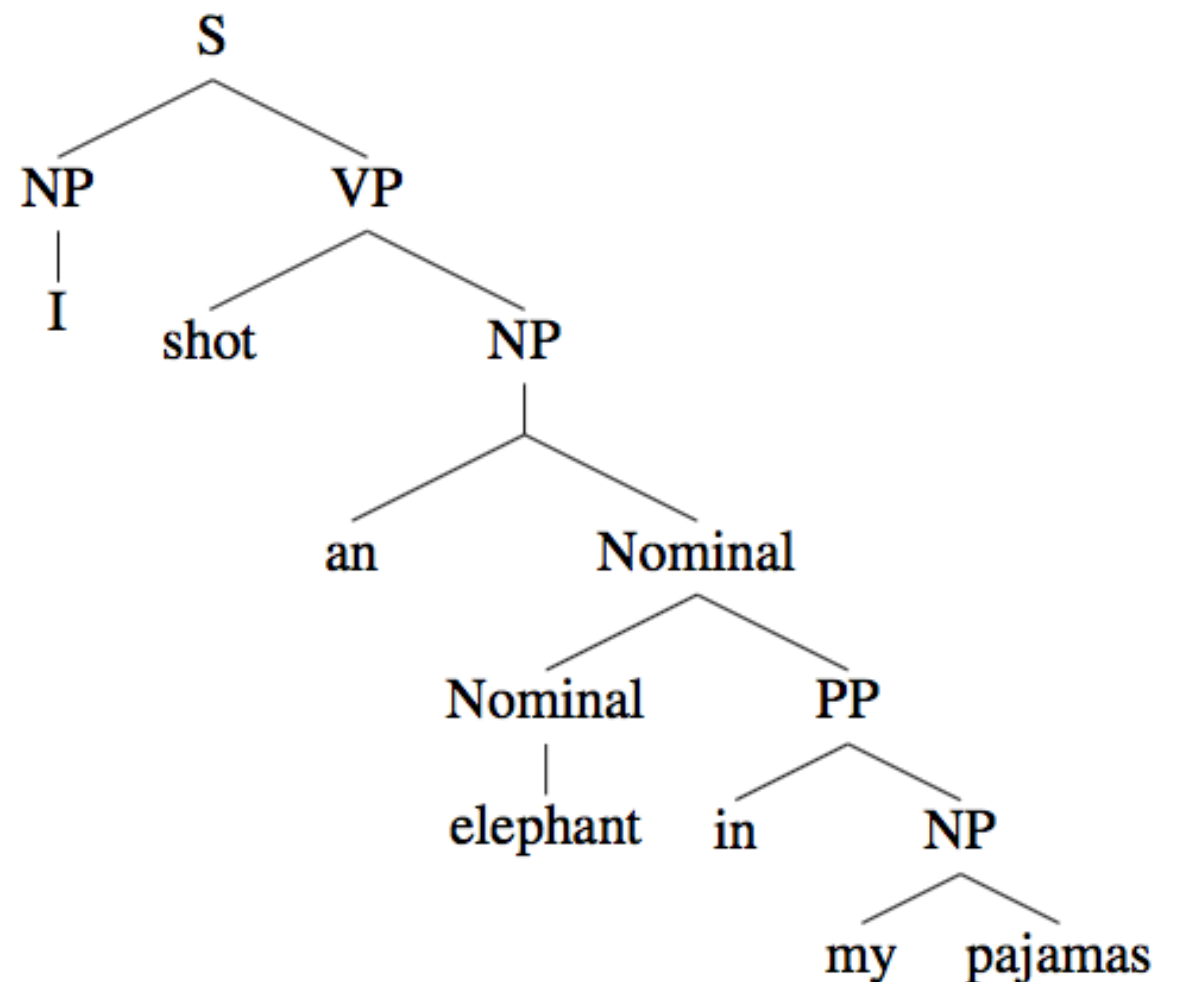
- A dependency structure is a directed graph $G = (V, A)$ consisting of a set of vertices V and arcs A between them. Typically constrained to form a **tree**:
 - Single root vertex with no incoming arcs
 - Every vertex has exactly one incoming arc except root (**single head constraint**)
 - There is a unique path from the root to each vertex in V (**acyclic constraint**)

Trees

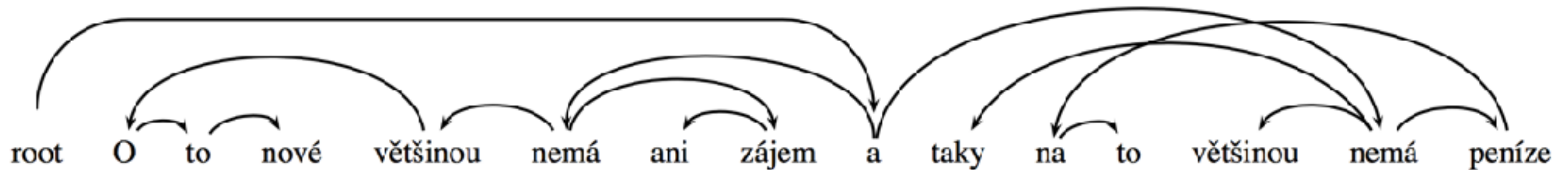
- Unlike phrase-structure trees, dependency trees aren't tied to the linear order of the words in a sentence.
- Adding a constraint derived from the linear order of words in a sentence allows for more efficient parsing algorithms (as we'll see on Tuesday).

Word order

- Dependency relations belong to the structural order of a sentence, not the **linear order**.
- This is different from a phrase-structure tree, where the syntax is constrained by the linear order of the sentence (a different linear order yields a different parse tree).

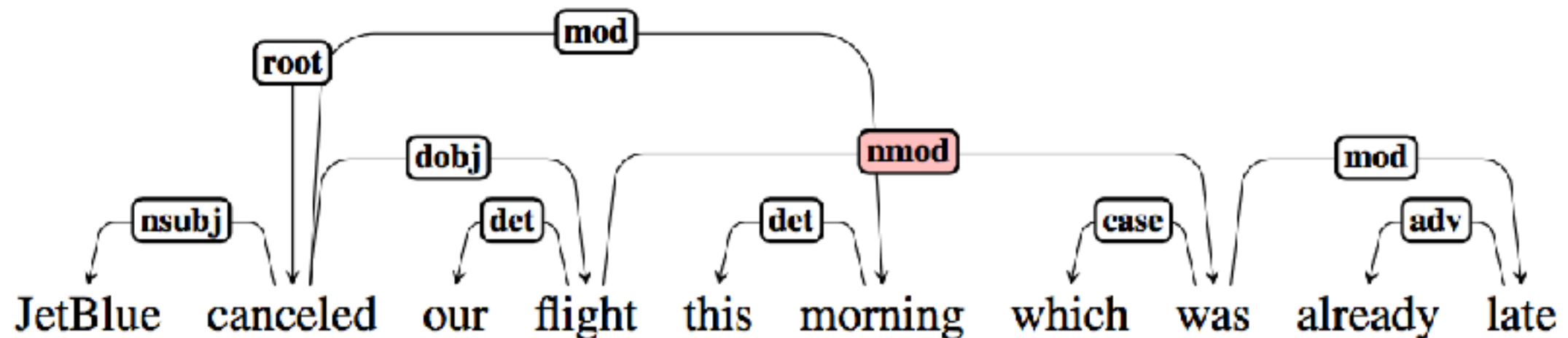


Free word order

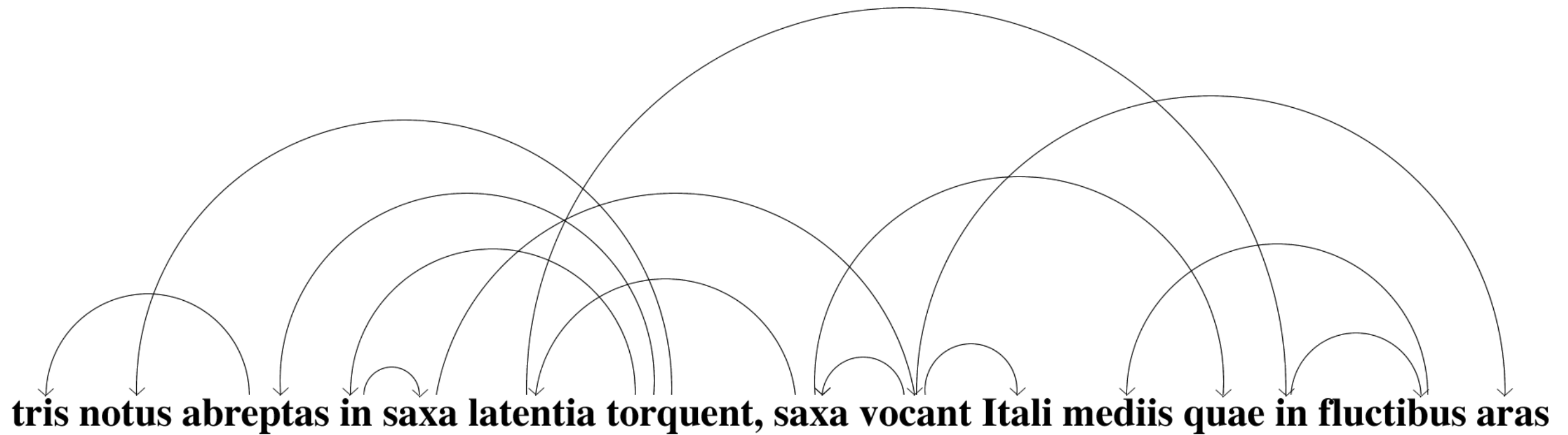


He is mostly not even interested in the new things and in most cases, he has no money for it either.

McDonald et al. 2006

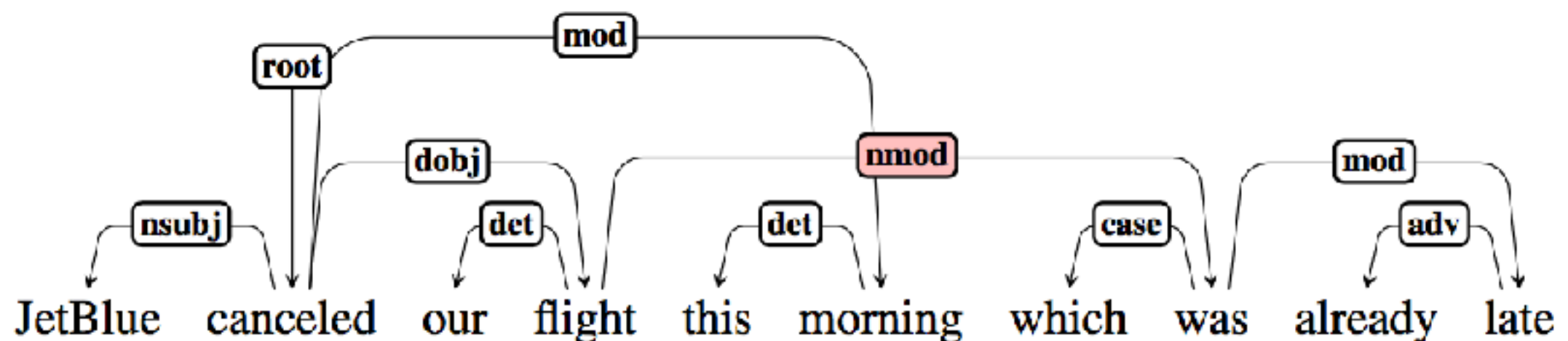


Free word order



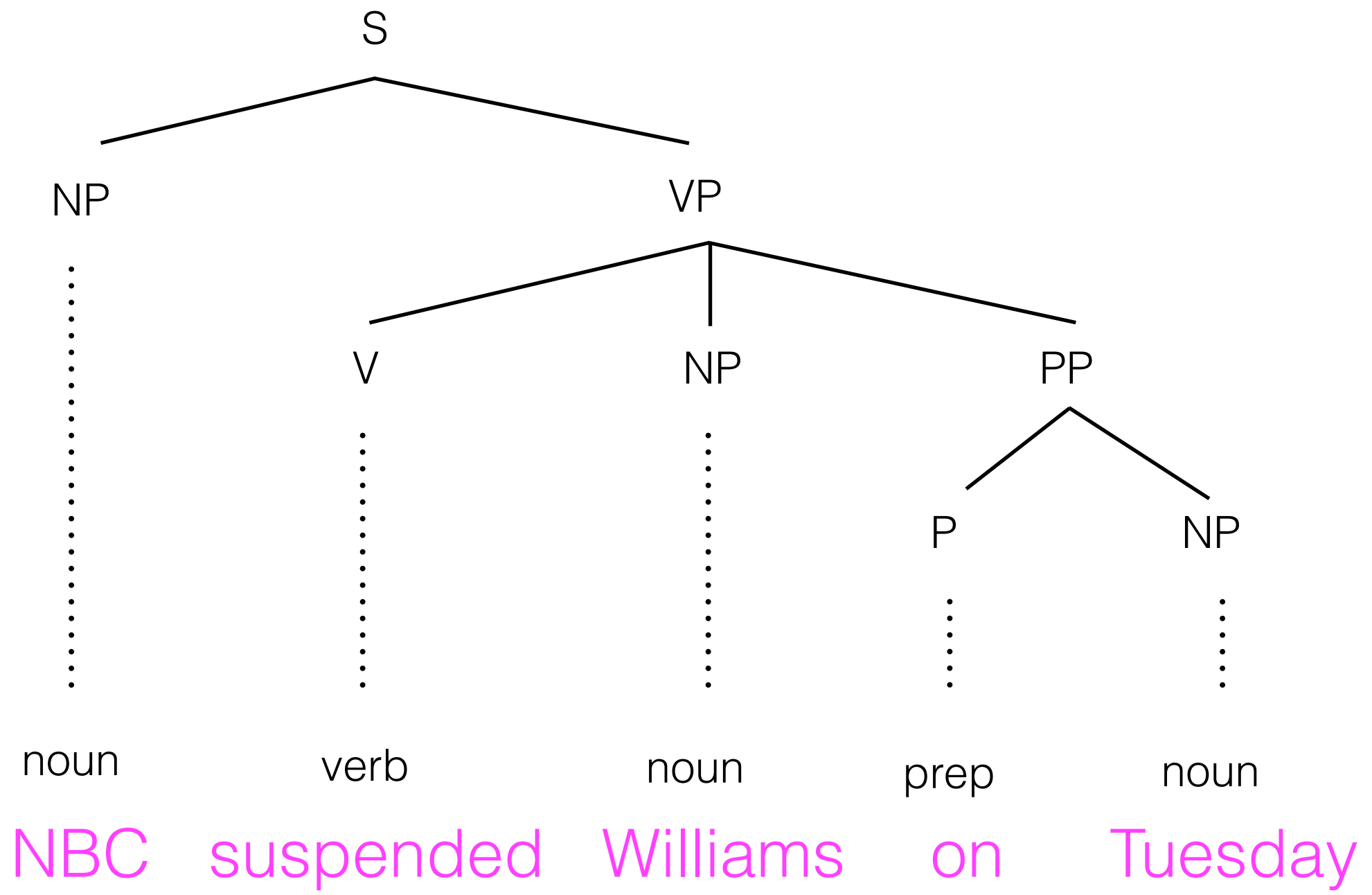
Projectivity

- An arc between a head and dependent is projective if there is a path from the head to every word between the head and dependent.

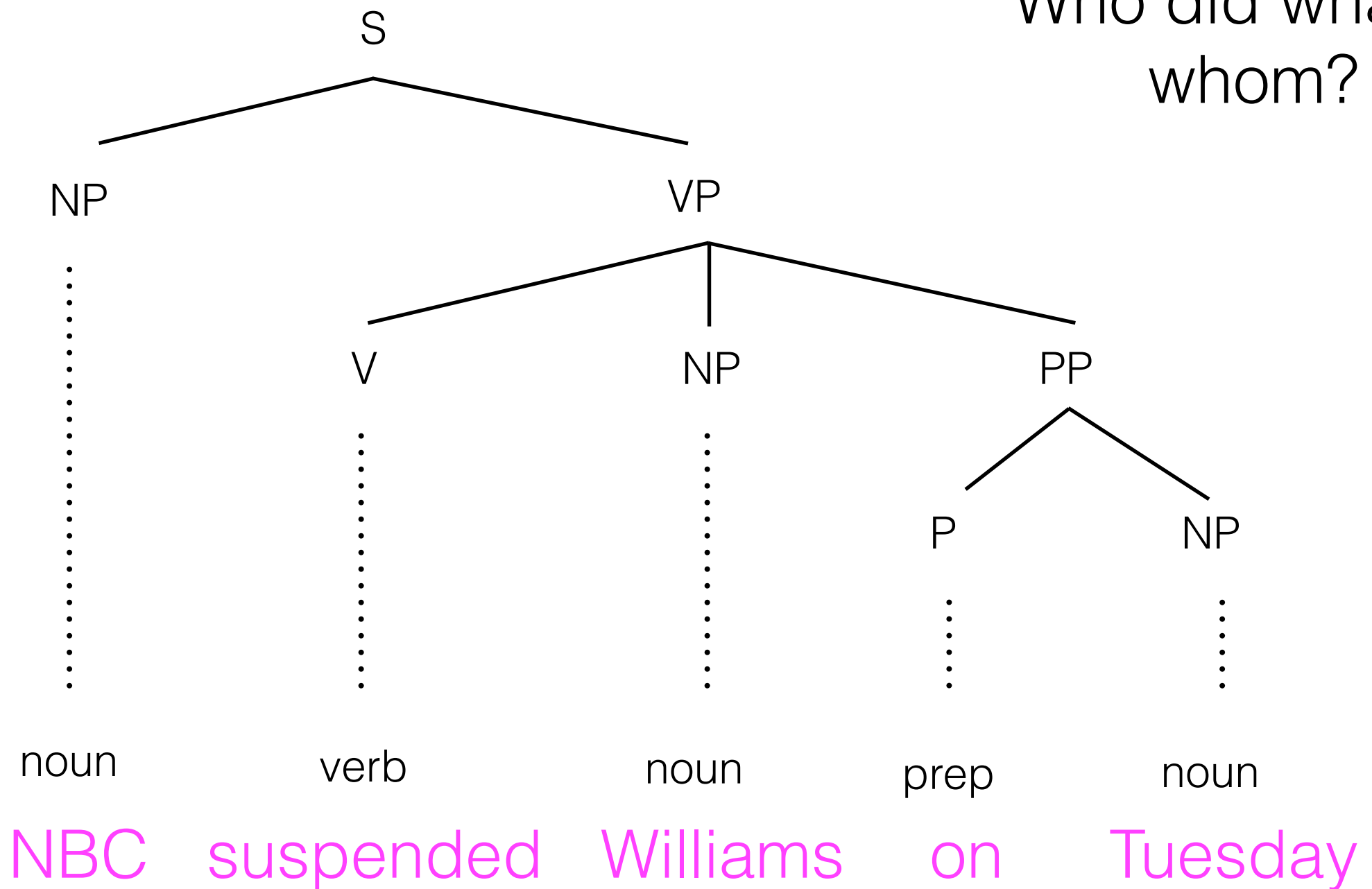


Dependencies vs constituents

- Dependency links are closer to semantic relationships; no need to infer the relationships from the structure of a tree
- A dependency tree contains one edge for each word, no intermediate hidden structures that also need to be learned for parsing.
- Easier to represent languages with free word order.

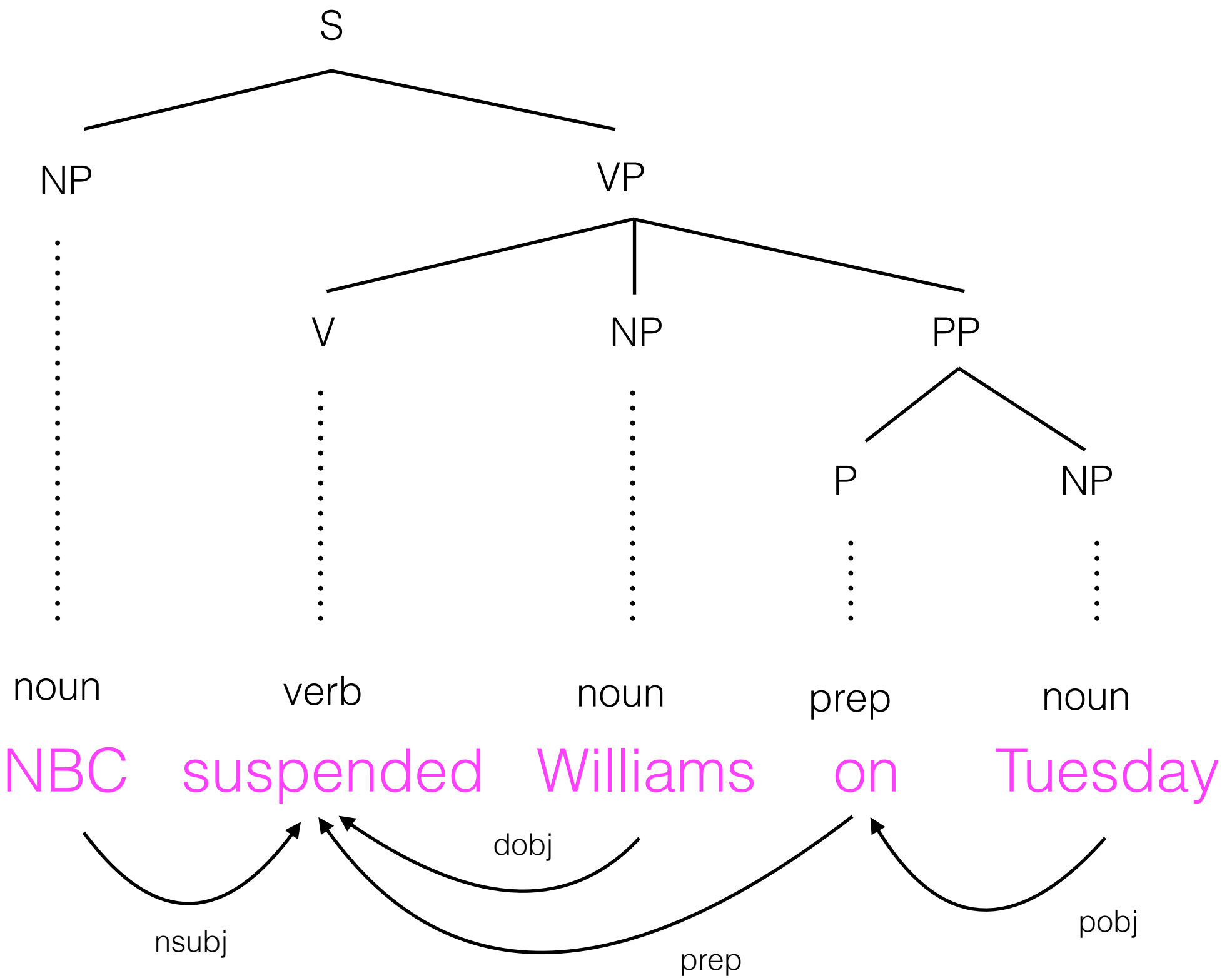


Who did what to
whom?



subject: $S \rightarrow \text{NP VP}$

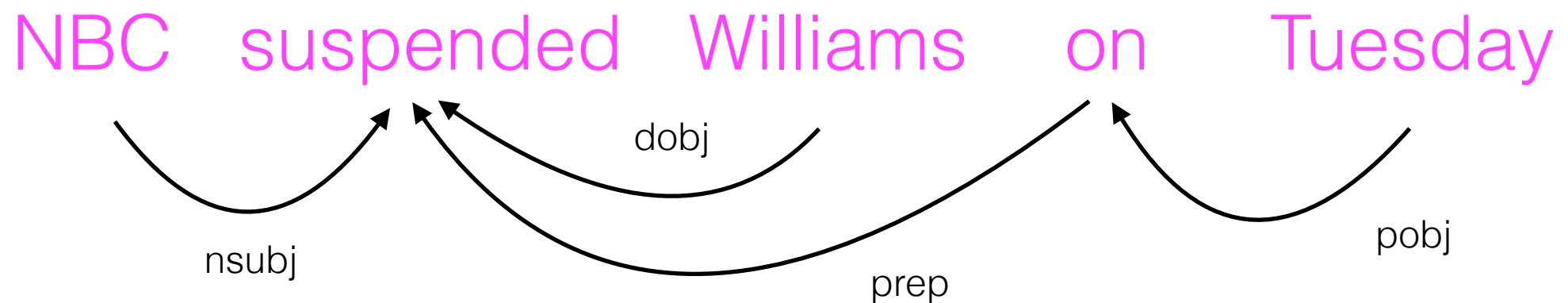
direct object: $S \rightarrow \text{NP (VP} \rightarrow \dots \text{NP} \dots \text{)}$



Dependency grammar

Captures binary relations between words

- nsubj(NBC, suspended)
- dobj(Williams, suspended)



Data

- NELL SVO triples
(604 million
nsubj+dobj
relations from 230B
words on the web

police	found	five .030 bullets	1
police	found	seven dead rebels	3
police	found	two hidden cameras	2
police	found	wanders lover	1
police	found	211 pounds	4
police	found	Marcia	3
police	found	bank draft	1
police	found	diskette	2
police	found	five marijuana plants	3
police	found	items used	1
police	found	judge	5

Dependency- Based Word Embeddings

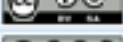
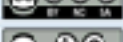
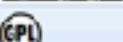
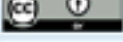
Levy & Goldberg,
ACL 2014

<http://irsrv2.cs.biu.ac.il:9998/>

Target Word	BoW5	BoW2	DEPS
batman	nightwing aquaman catwoman superman manhunter	superman superboy aquaman catwoman batgirl	superman superboy supergirl catwoman aquaman
hogwarts	dumbledore hallows half-blood malfoy snape	evernight sunnydale garderobe blandings collinwood	sunnydale collinwood calarts greendale millfield
turing	nondeterministic non-deterministic computability deterministic finite-state	non-deterministic finite-state nondeterministic buchi primality	pauling hotelling heting lessing hamming
florida	gainesville fla jacksonville tampa lauderdale	fla alabama gainesville tallahassee texas	texas louisiana georgia california carolina
object-oriented	aspect-oriented smalltalk event-driven prolog domain-specific	aspect-oriented event-driven objective-c dataflow 4gl	event-driven domain-specific rule-based data-driven human-centered
dancing	singing dance dances dancers tap-dancing	singing dance dances breakdancing clowning	singing rapping breakdancing miming busking

Universal Dependencies

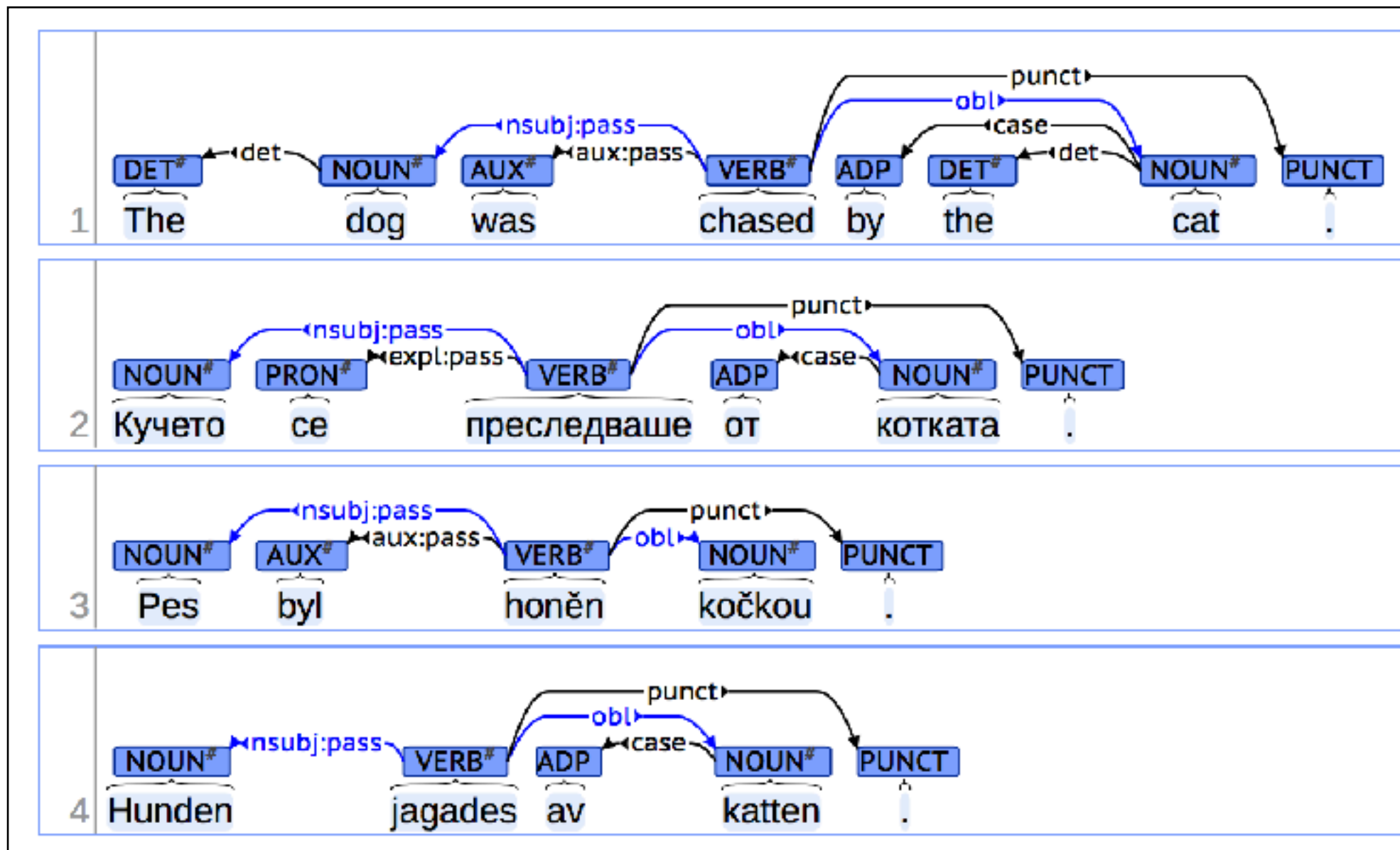
UD Treebanks

▶		Afrikaans	49K	(L)(F)	–				
▶		Ancient Greek	202K	(L)(F)			✓		
▶		Ancient Greek-PROIEL	211K	(L)(F)	–		✓		 
▶		Arabic	242K	(L)(F)	–		✓		
▶		Arabic-NYUAD	629K	(L)(F)	–		✓		
▶		Arabic-PUD	20K	(L)(F)	–				 W
▶		Basque	121K	(L)(F)			✓		 
▶		Belarusian	8K	(L)(F)	–		✓		
▶		Bulgarian	156K	(L)(F)		 ✓	✓		  
▶		Buryat	10K	(L)(F)	–				  
▶		Catalan	530K	(L)(F)		 ✓	✓		
▶		Chinese	123K	(L)(F)		 ✓	✓		W
▶		Chinese-CFL	7K	(L)					
▶		Chinese-PUD	21K	(F)	–				 W
▶		Coptic	4K	(L)(F)			✓		  
▶		Croatian	197K	(L)(F)	–	 ✓	✓		  W
▶		Czech	1,503K	(L)(F)		 ✓	✓		

Universal Dependencies

- Developing cross-linguistically consistent treebank annotation for many languages
- Goals:
 - Facilitating multilingual parser development
 - Cross-lingual learning
 - Parsing research from a language typology perspective.

Universal Dependencies



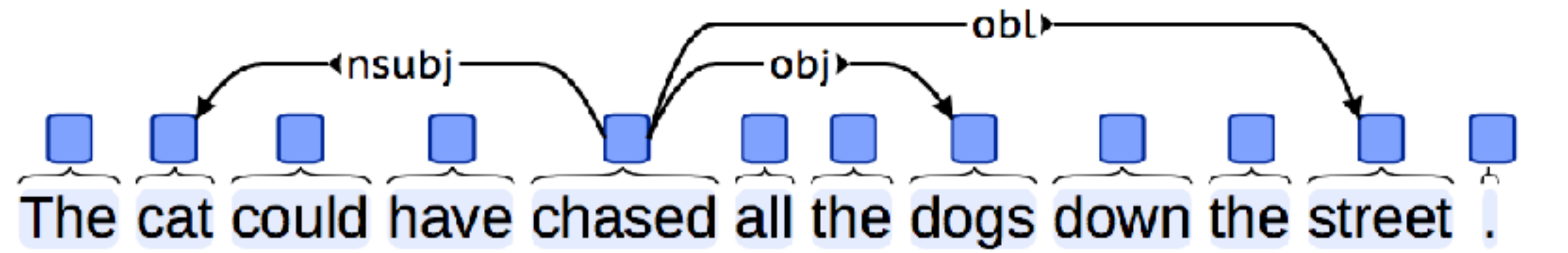
Homework 5

- Annotate the same data as homework 3 with universal dependency relations.

Relations to annotate

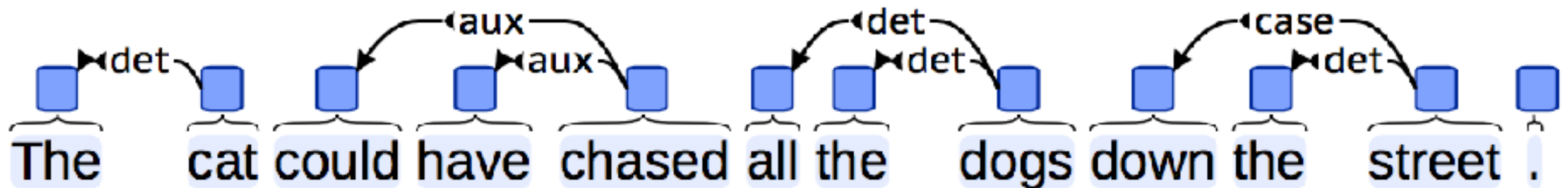
nsubj, nsubj:pass	subject of a verb
obj	direct object of a verb
iobj	indirect object of a verb
obl	oblique modifier of a verb
ccomp	clausal complement
advcl	adverbial clause modifier
acl, acl:rel	clausal modifier of noun
conj	conjunct in coordination

UD Principles



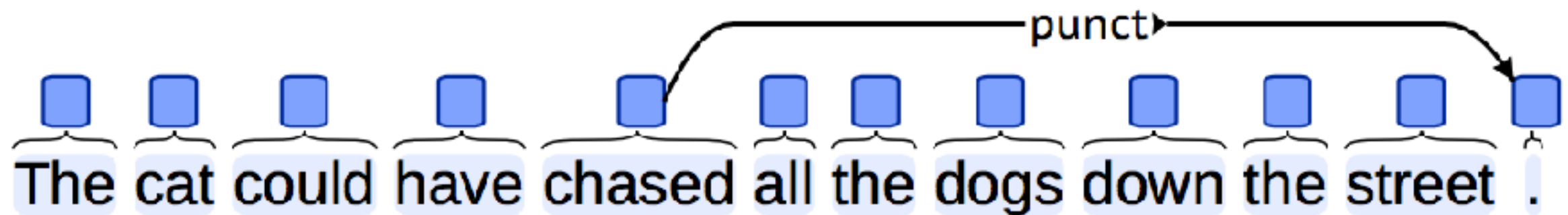
Dependency relations mainly hold between **content** words.

UD Principles



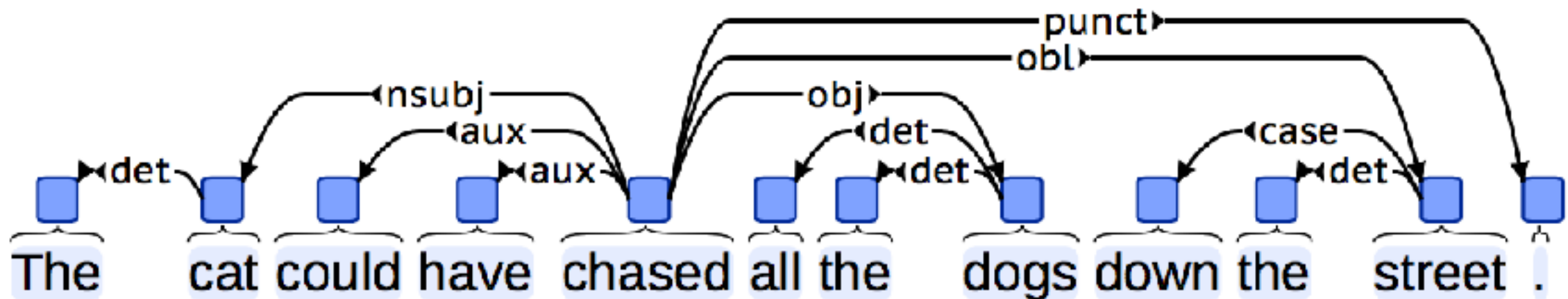
Function words dependent on closest related content word

UD Principles



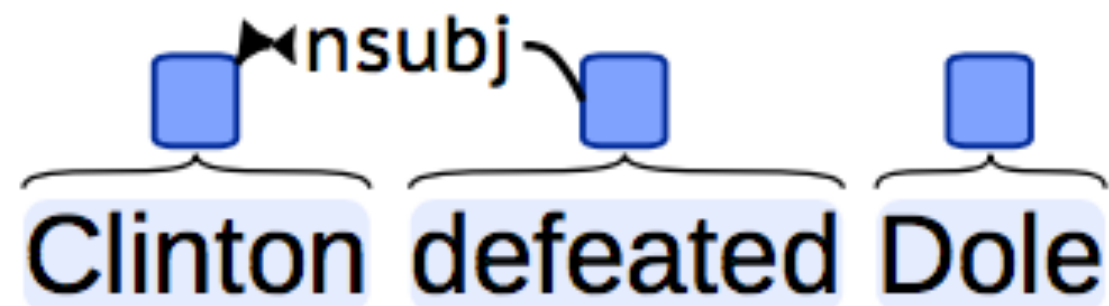
Punctuation typically depends on phrasal head

UD Principles



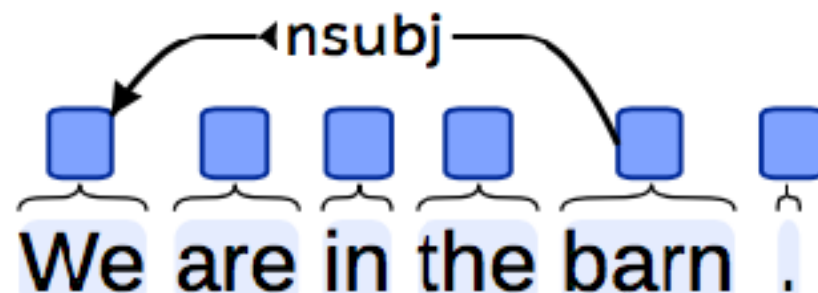
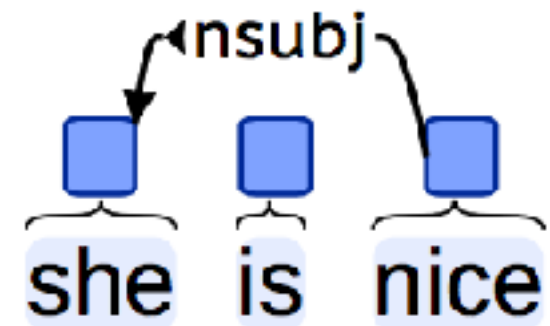
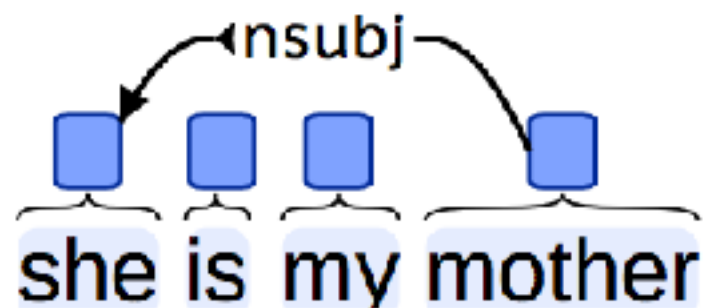
nsubj

- Syntactic subject of active verbs



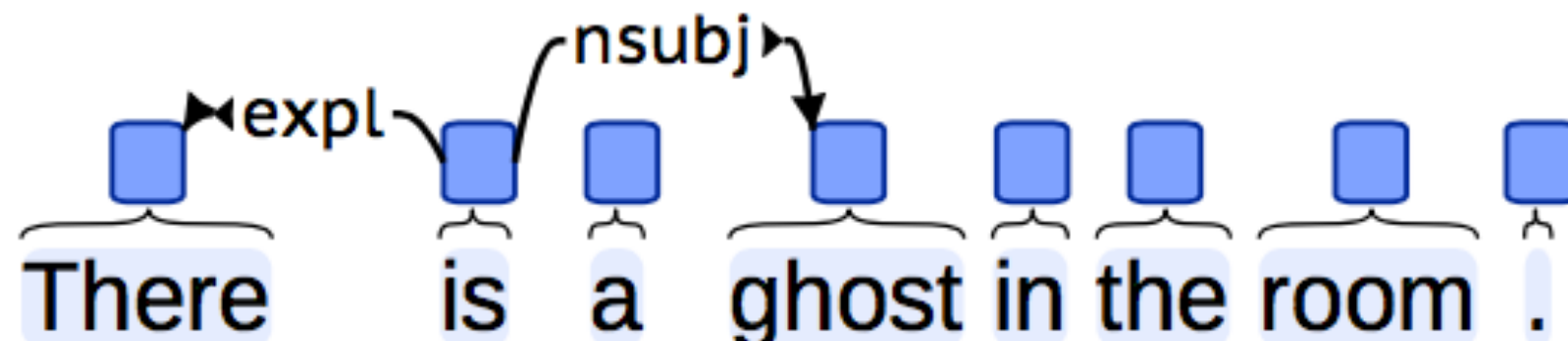
nsubj

- When the verb is copular (nominal/adjective predicatives like “she **is** my boss”), the subject depends on the complement.



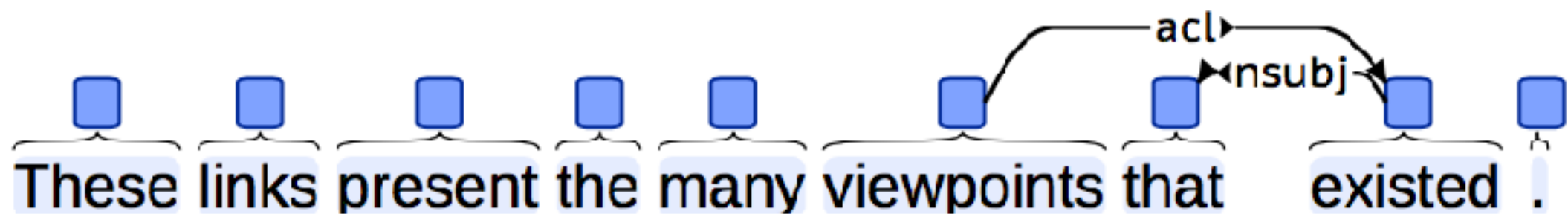
nsubj

- Expletives



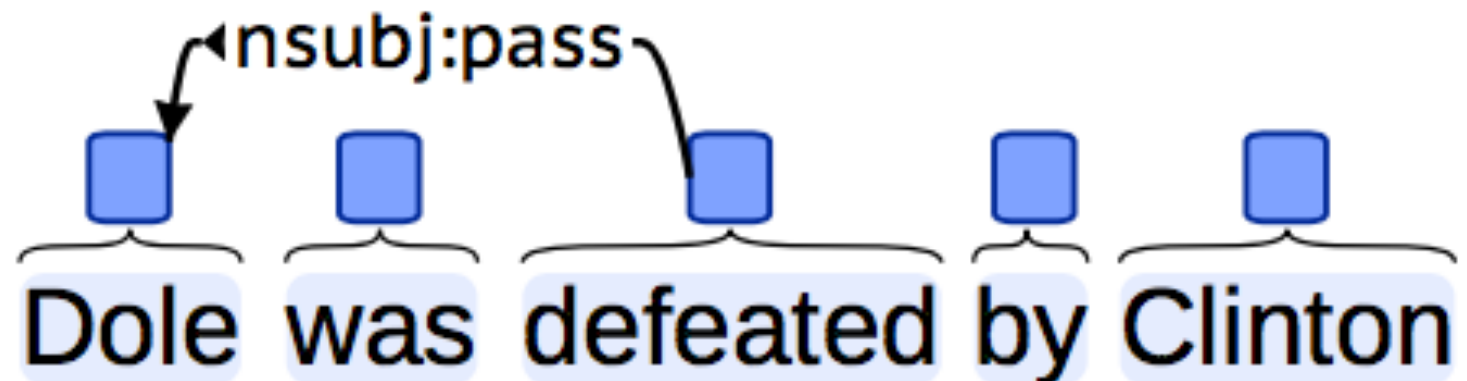
nsubj

- Relative clauses with finite verbs also often have syntactic subjects expressed.



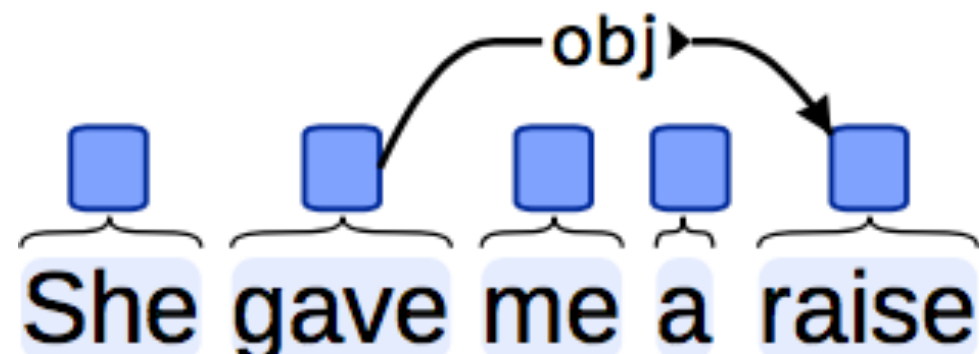
nsubj:pass

- Syntactic subject of passive verbs



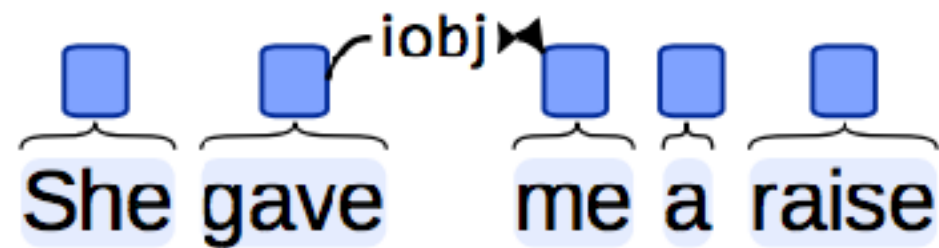
obj

- Generally, the entity that is acted upon as the **direct object** of the predicate.



iobj

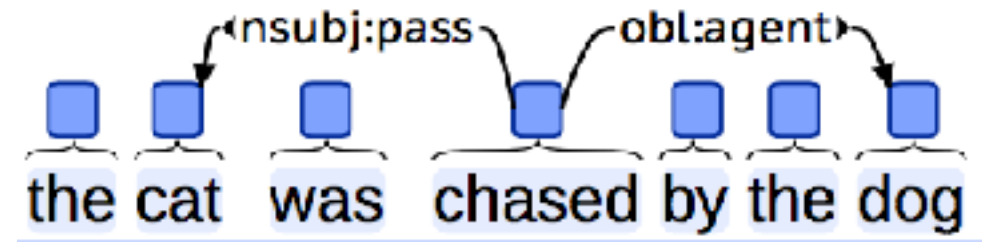
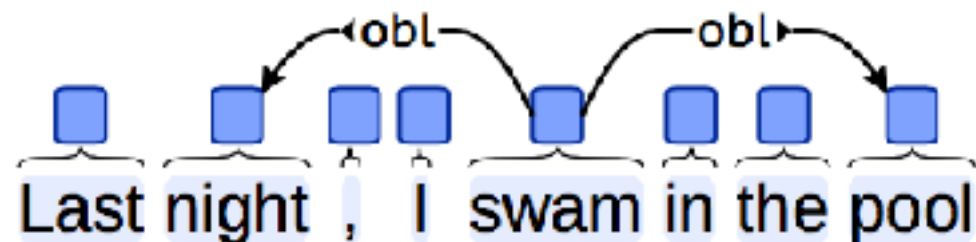
- Indirect object: recipients of ditransitive verbs of exchange (verbs requiring two objects)



nsubj		iobj		obj
She	teaches	her daughters		math
She	told	her daughtesr		a story

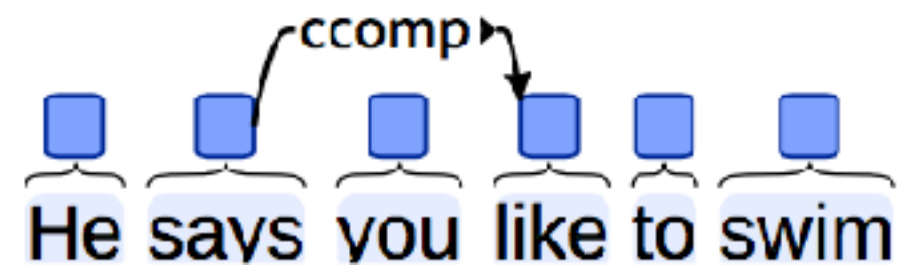
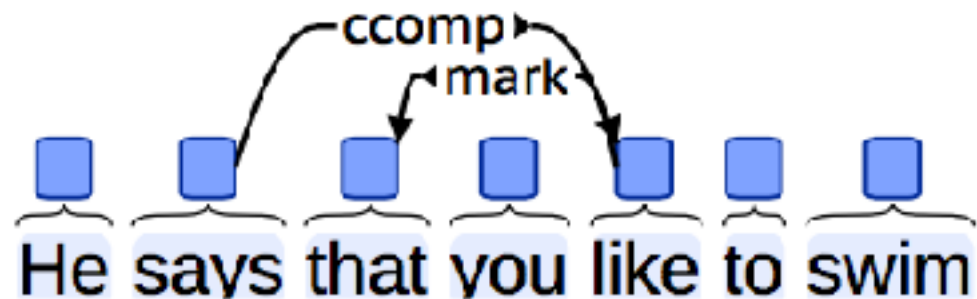
obl

- Any nominal functioning as non-required argument or adjunct of a verb, including temporal and locational nominal modifiers and agents of passive verbs



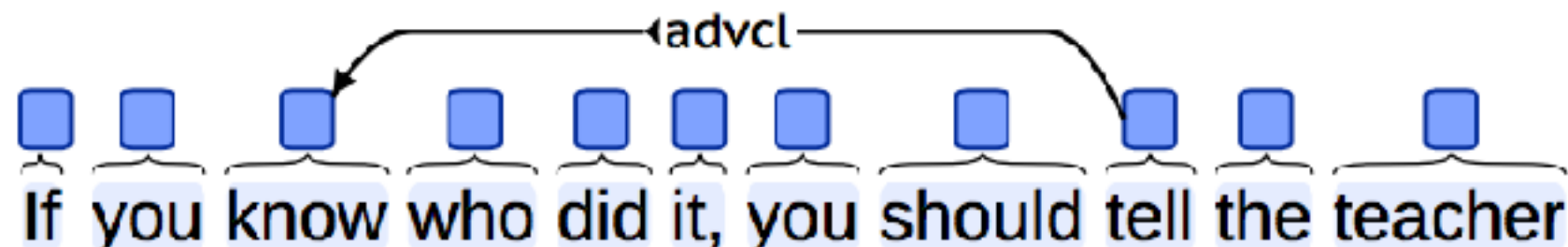
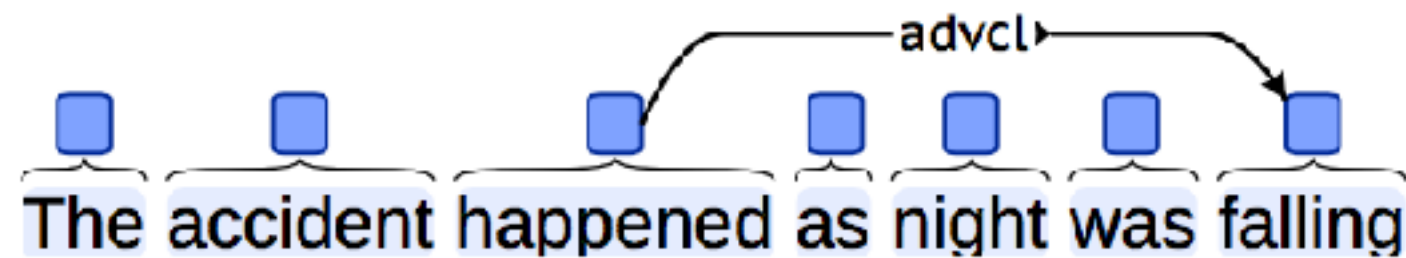
ccomp

- Clausal complements, including **dialogue**



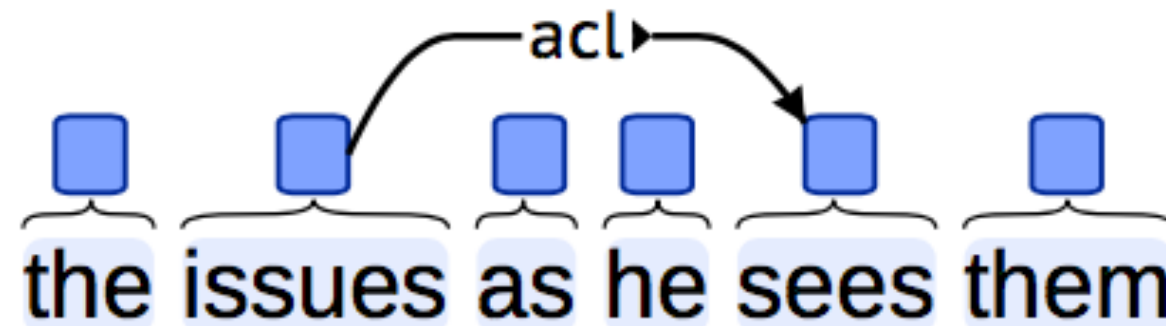
advcl

- A clause that modifies another predicate (temporal clauses, consequence, conditional clauses, purpose clauses)



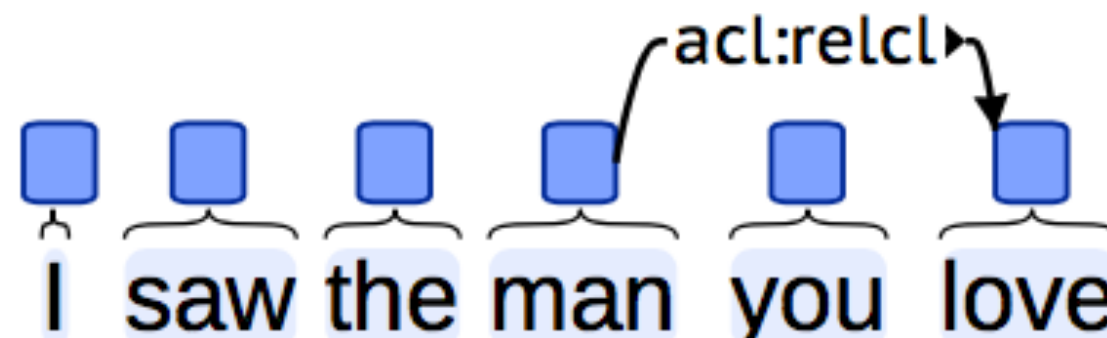
acl

- Clausal modifier of a nominal, including **relative clauses**. The head verb of the embedded clause modifies the nominal it qualifies



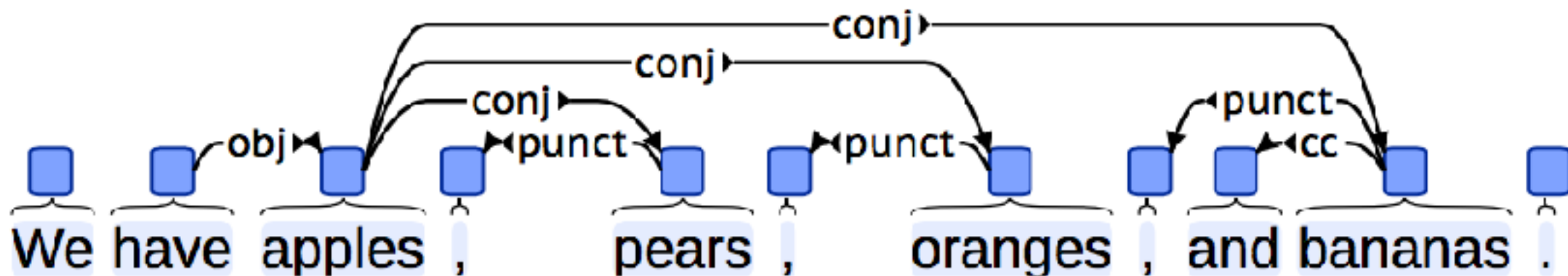
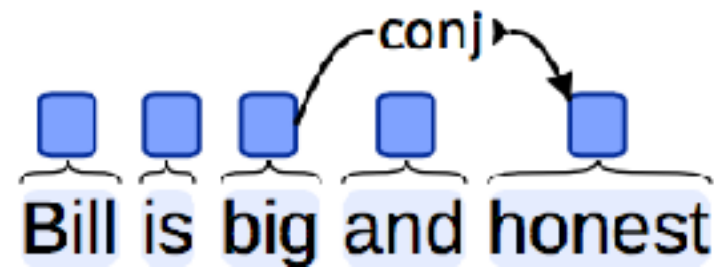
acl:relcl

- Clausal modifier of a nominal, including **relative clauses**. The head verb of the embedded clause modifies the nominal it qualifies

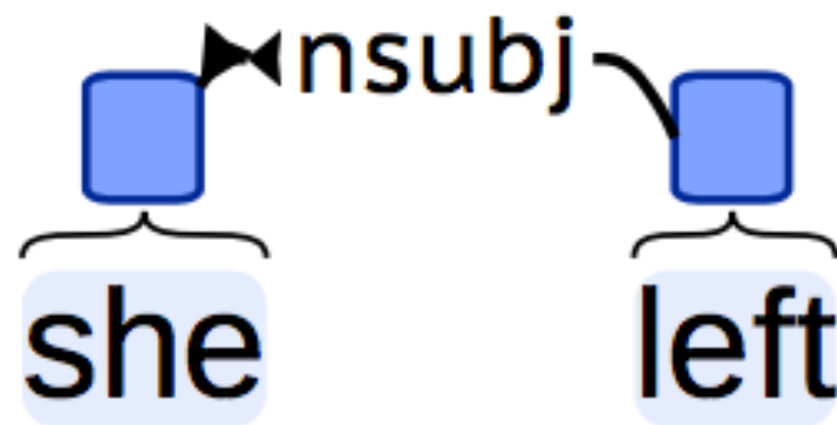


conj

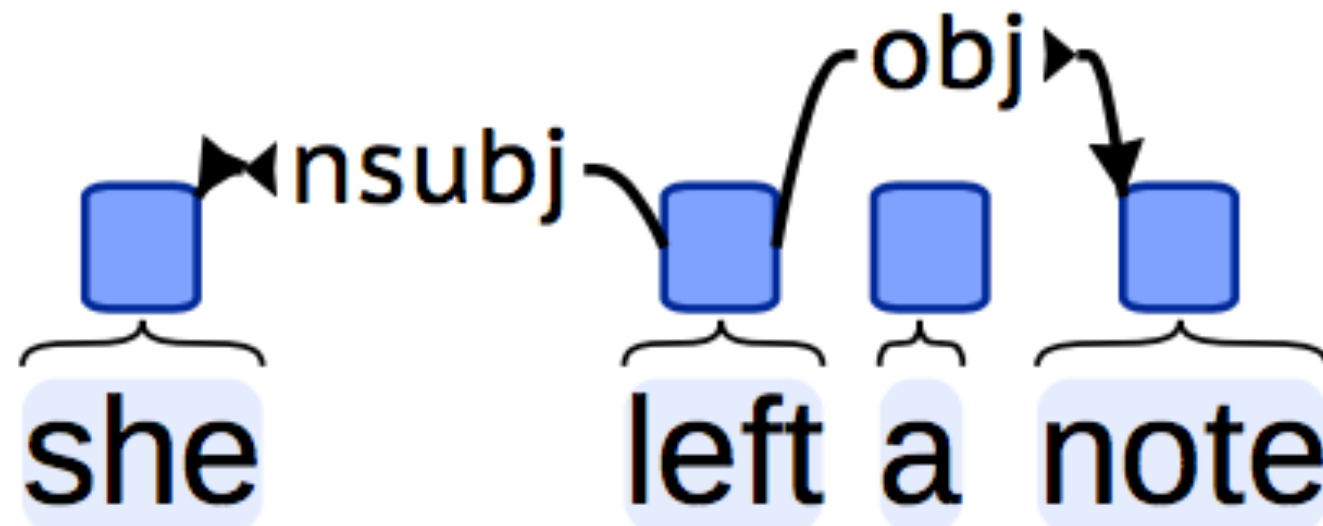
- The elements that are coordinated; the head is the **first** conjunct



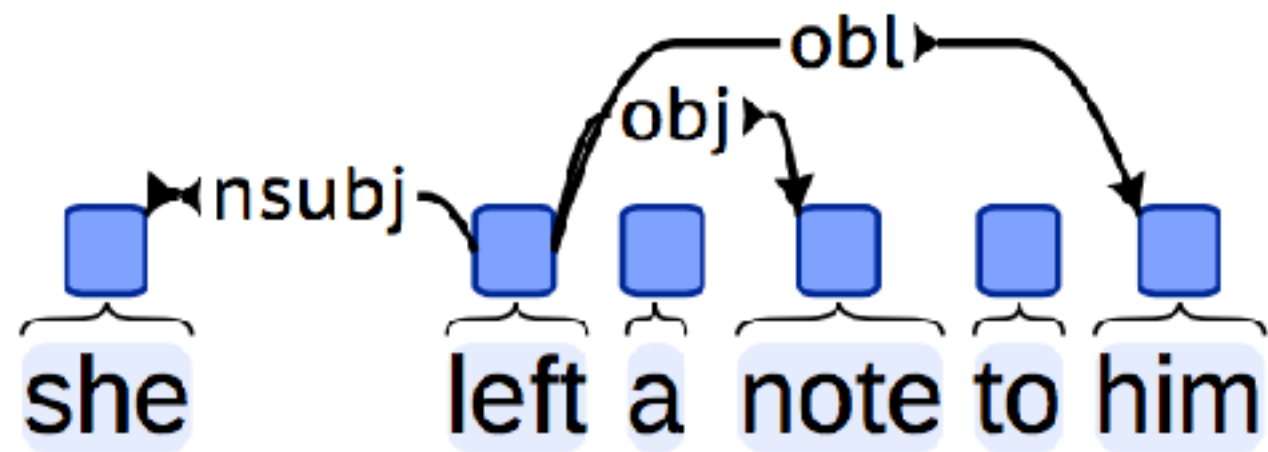
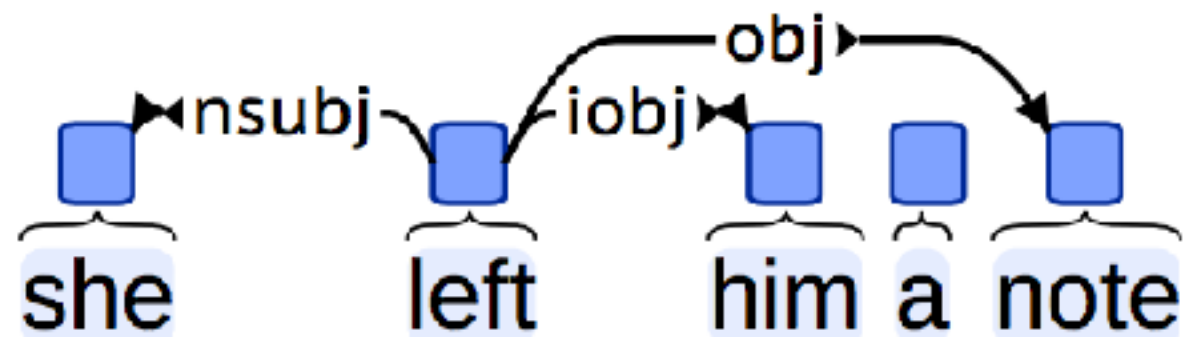
Intransitive verbs



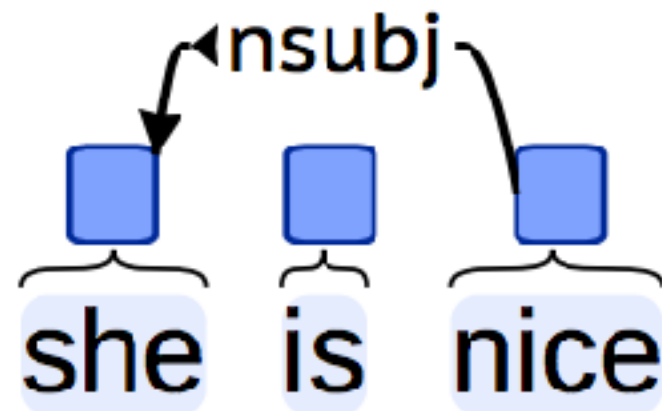
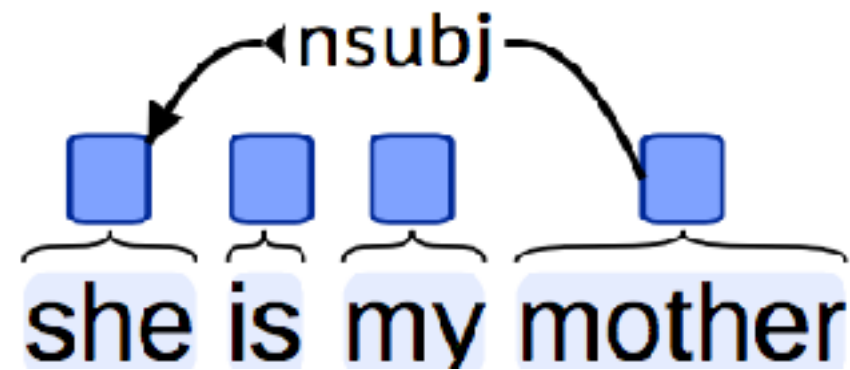
Transitive verbs



Ditransitive verbs



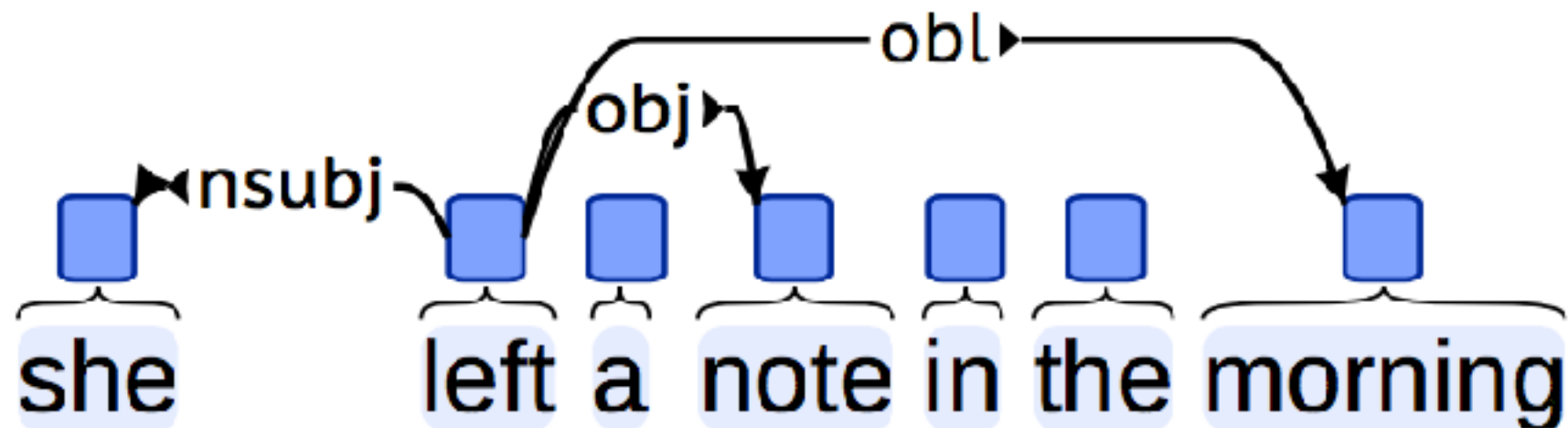
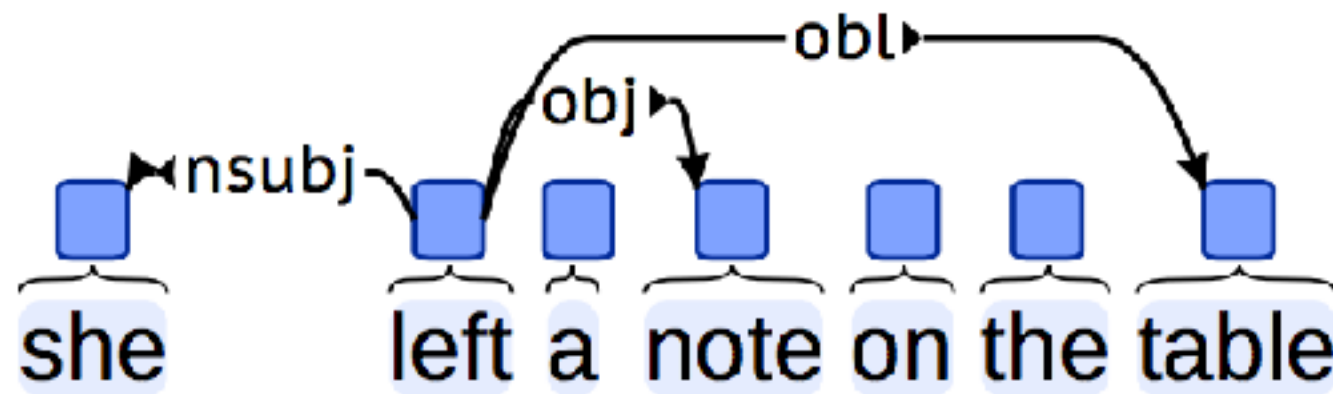
Nonverbal predication

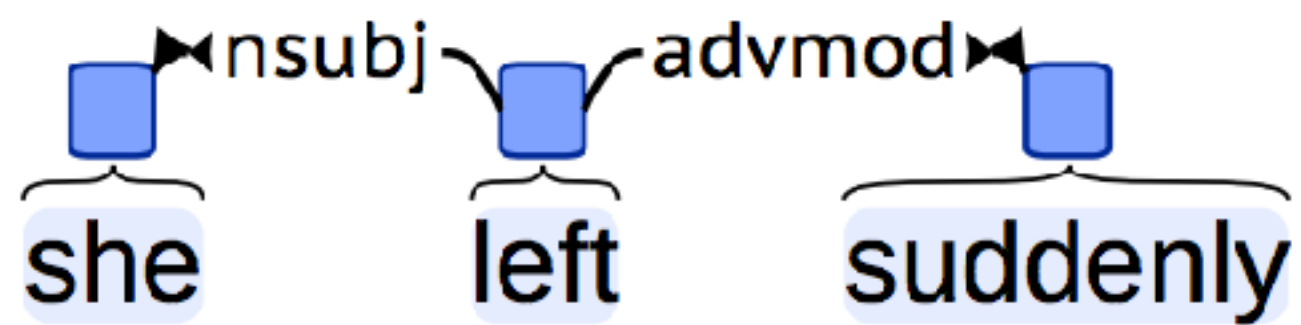


Nonverbal predication

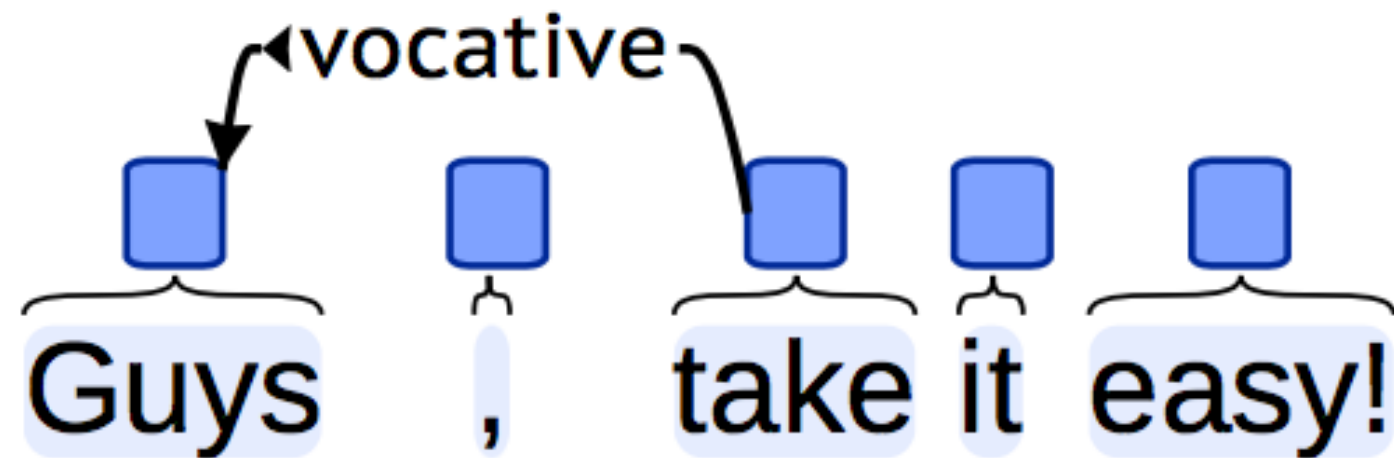
- Equation (aka identification): “she is my mother”
- Attribution: “she is nice”
- Location: “she is in the bathroom”
- Possession: “the book is hers”
- Benefaction: “the book is for her”
- Existence: “there is food (in the kitchen)”

Oblique nominals

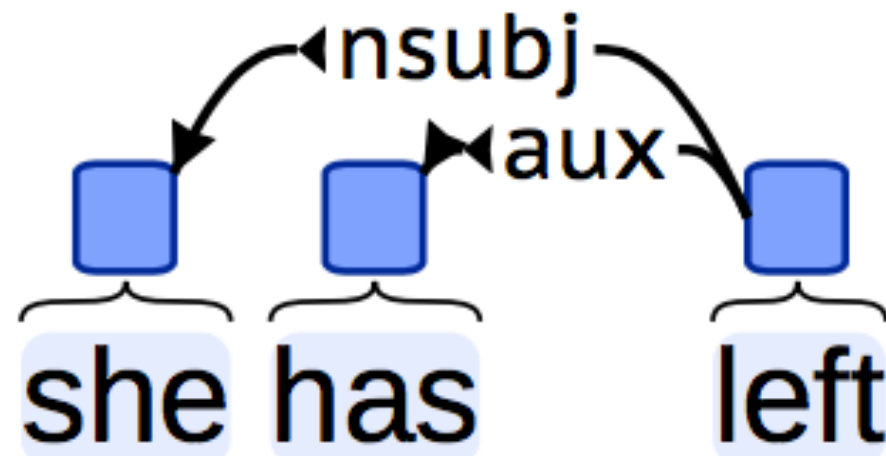




Vocatives

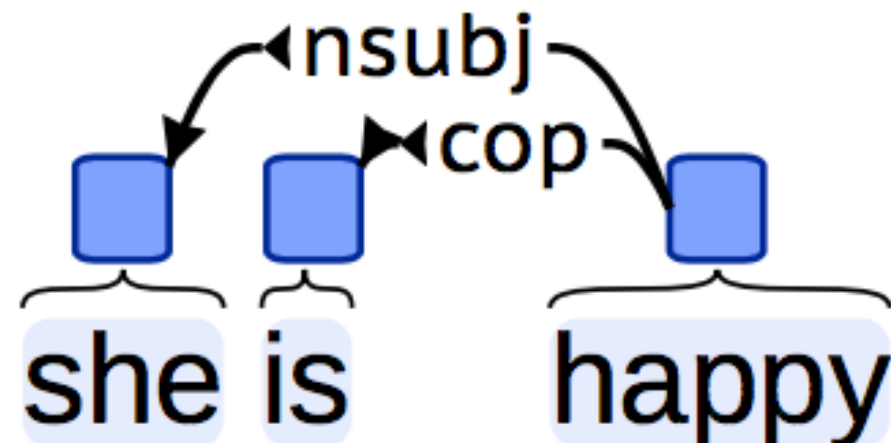


Aux



aux adds tense, aspect, mood, voice or evidentiality

cop



cop links a non-verbal predicate to subject

“Open the pod bay doors, HAL”

[David Bowman, *2001*]

“Nobody puts baby in a corner”

[Johnny Castle, *Dirty Dancing*]

Relations to annotate

nsubj, nsubj:pass	subject of a verb
obj	direct object of a verb
iobj	indirect object of a verb
ccomp	clausal complement
advcl	adverbial clause modifier
acl, acl:rel	clausal modifier of noun
conj	conjunct in coordination

Tuesday

- Algorithms for dependency parsing
 - Shift-reduce parsing
 - Graph-based parsing