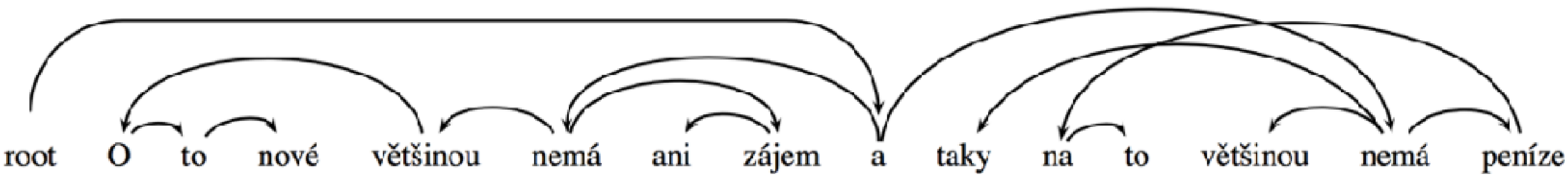


He is mostly not even interested in the new things and in most cases, he has no money for it either.

McDonald et al. 2006

Natural Language Processing

Info 159/259

Lecture 16: Dependency syntax (March 17, 2020)

David Bamman, UC Berkeley

Context-free grammar

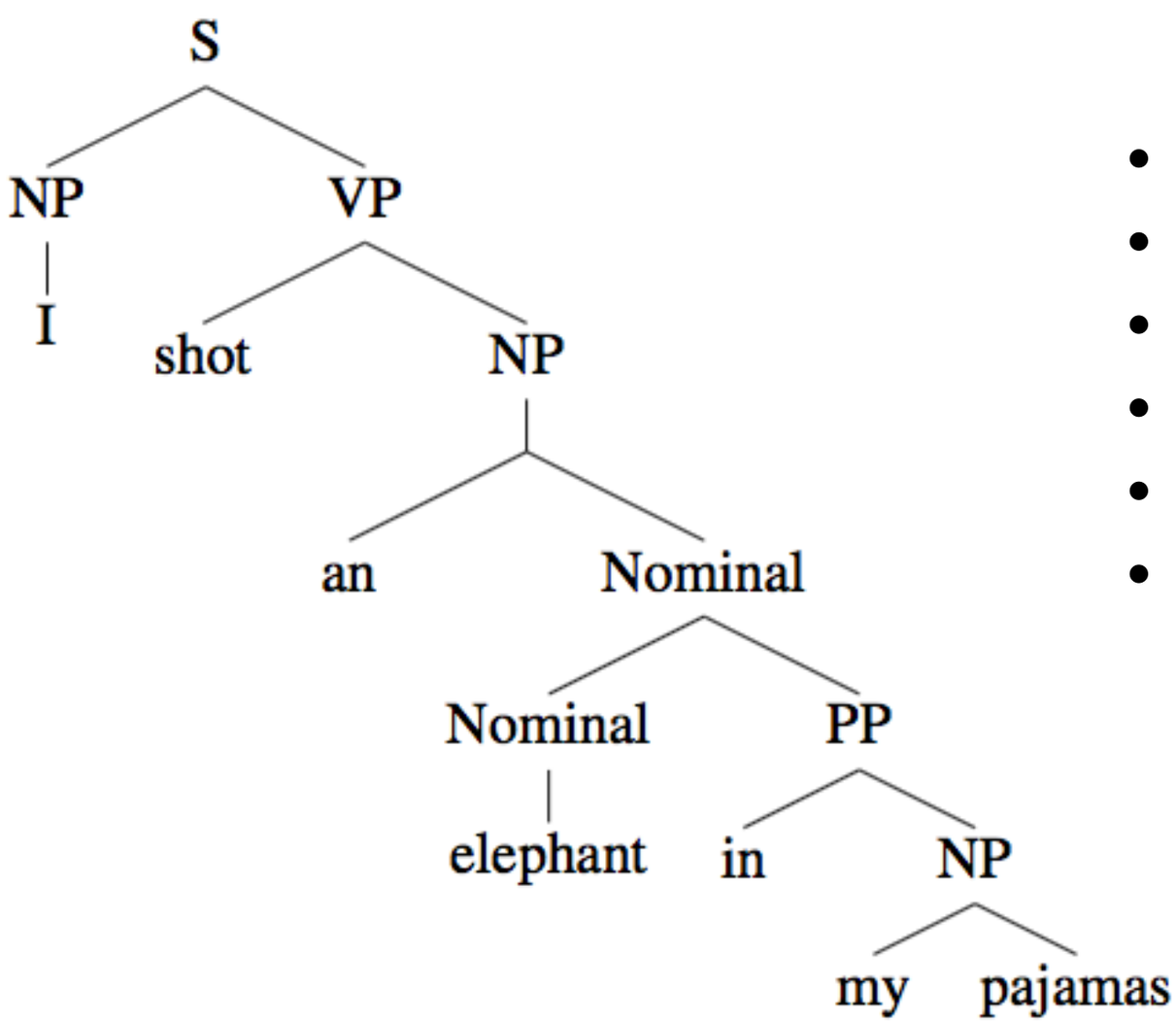
A context-free grammar defines how symbols in a language combine to form valid structures

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

non-terminals

lexicon/ terminals

Constituents



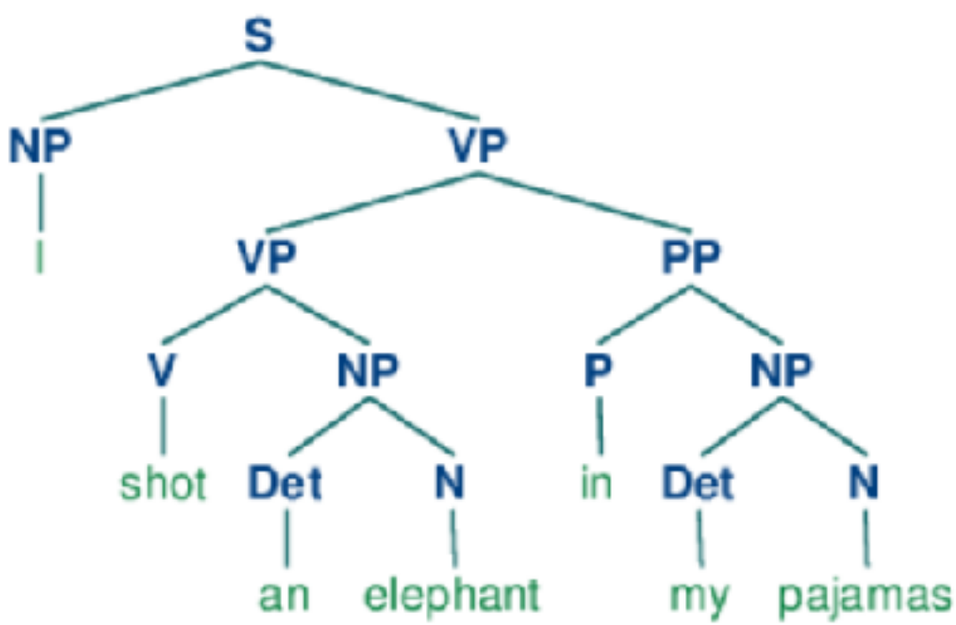
Every internal node is a phrase

- 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

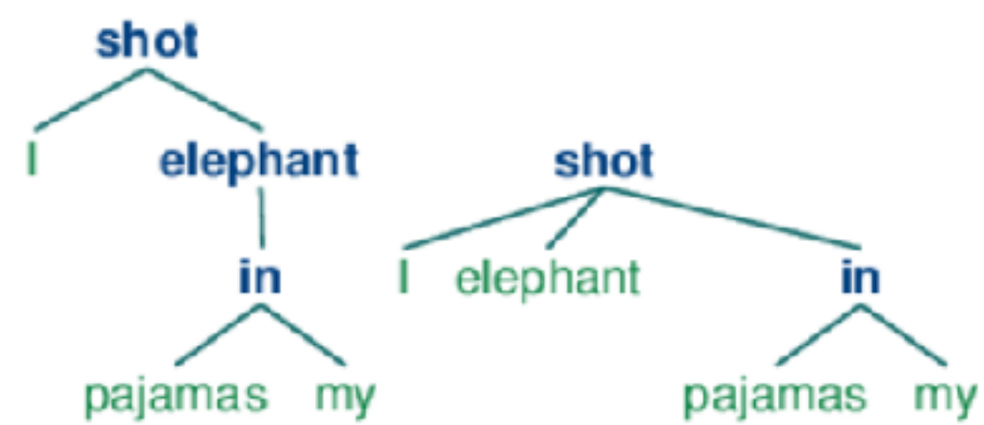
Formalisms

Phrase structure grammar
(Chomsky 1957)



two weeks ago

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

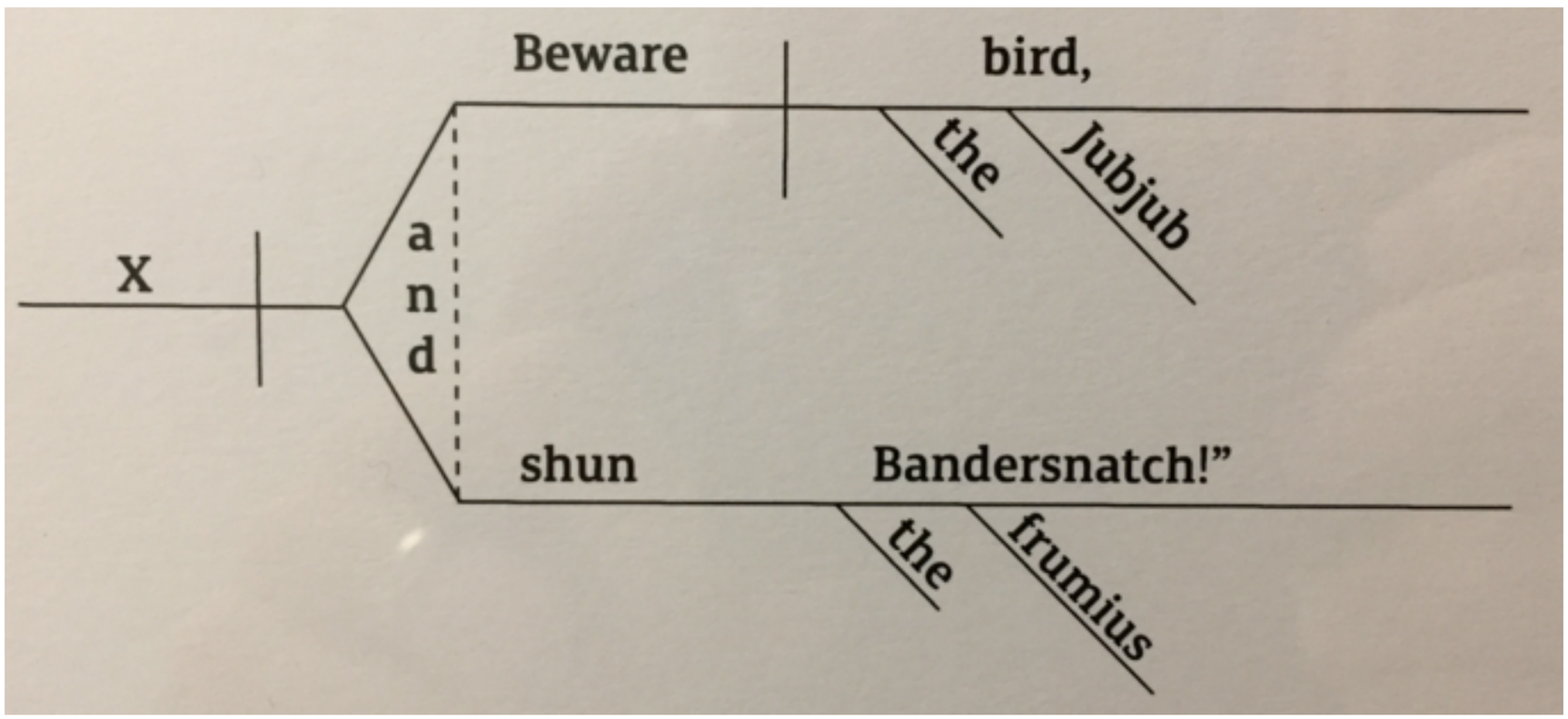


today

Dependency syntax

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

Dependency syntax



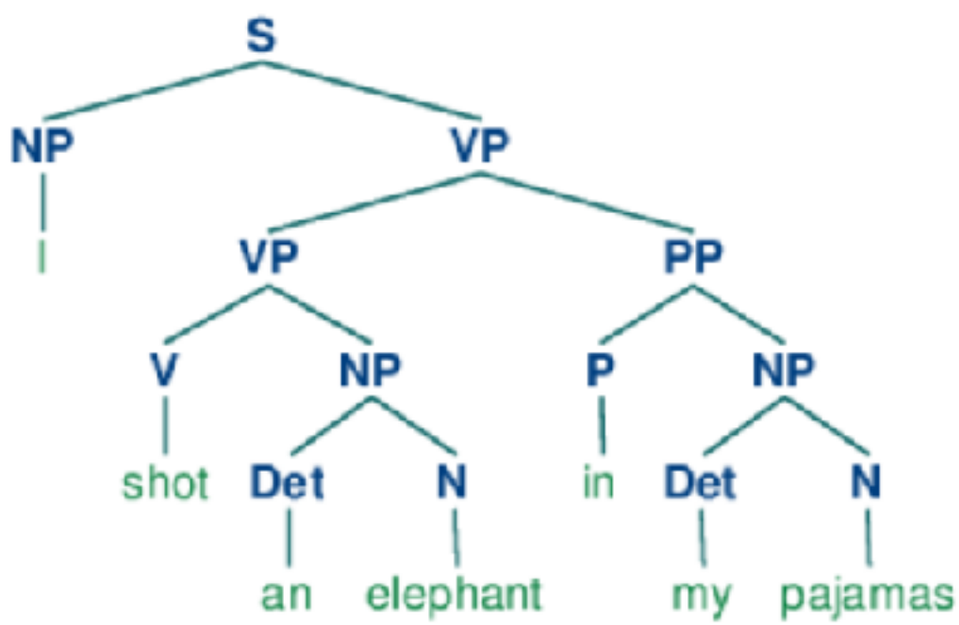
"Sentence diagramming"

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.”

Tesnier 1959; Nivre 2005

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.

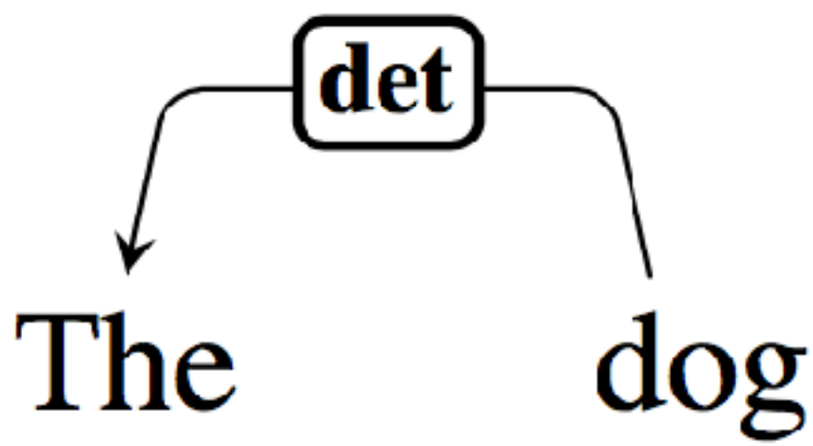
Tesnier 1959; Nivre 2005

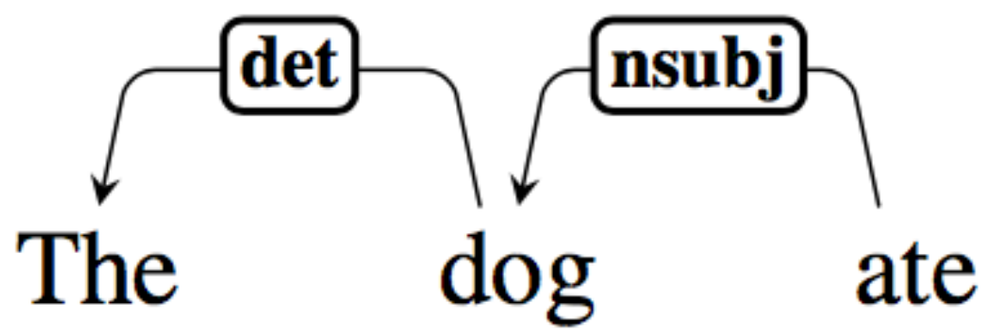
Dependency

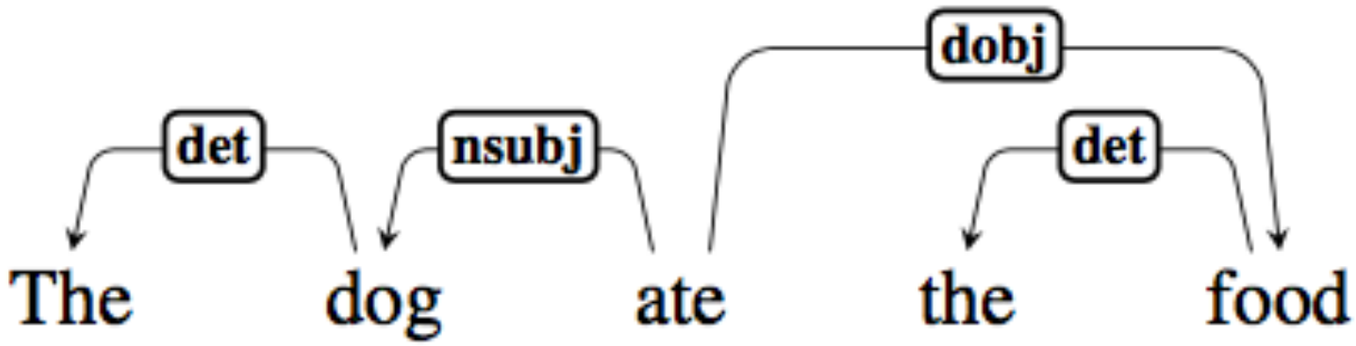
- How do we decide which of a pair of words is the head and which is the dependent?

Dependency

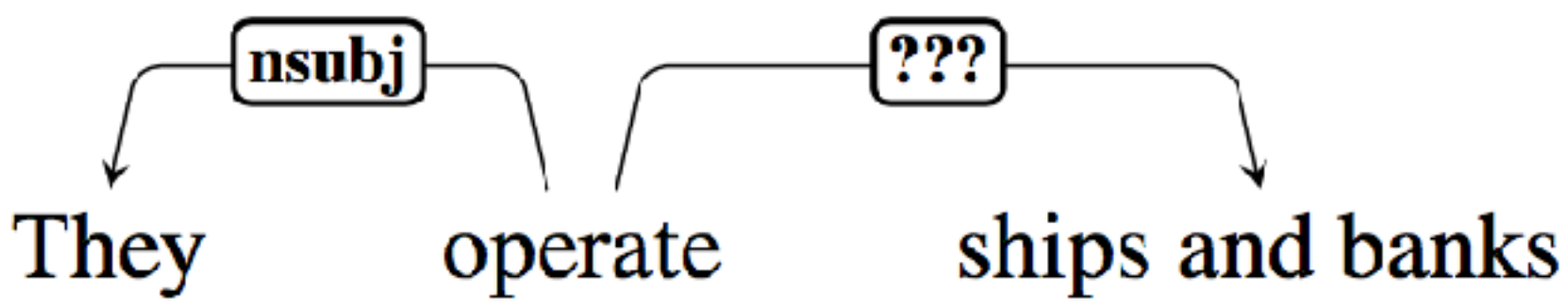
- Many (conflicting) frameworks:
    - Head determines the syntactic category of a construction
    - Head is obligatory; dependents are optional
    - Head selects dependents and determines whether the dependent is required
    - The form of the dependent depends on the head (e.g., agreement between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


det
The
dog


det
nsubj
The
dog
ate

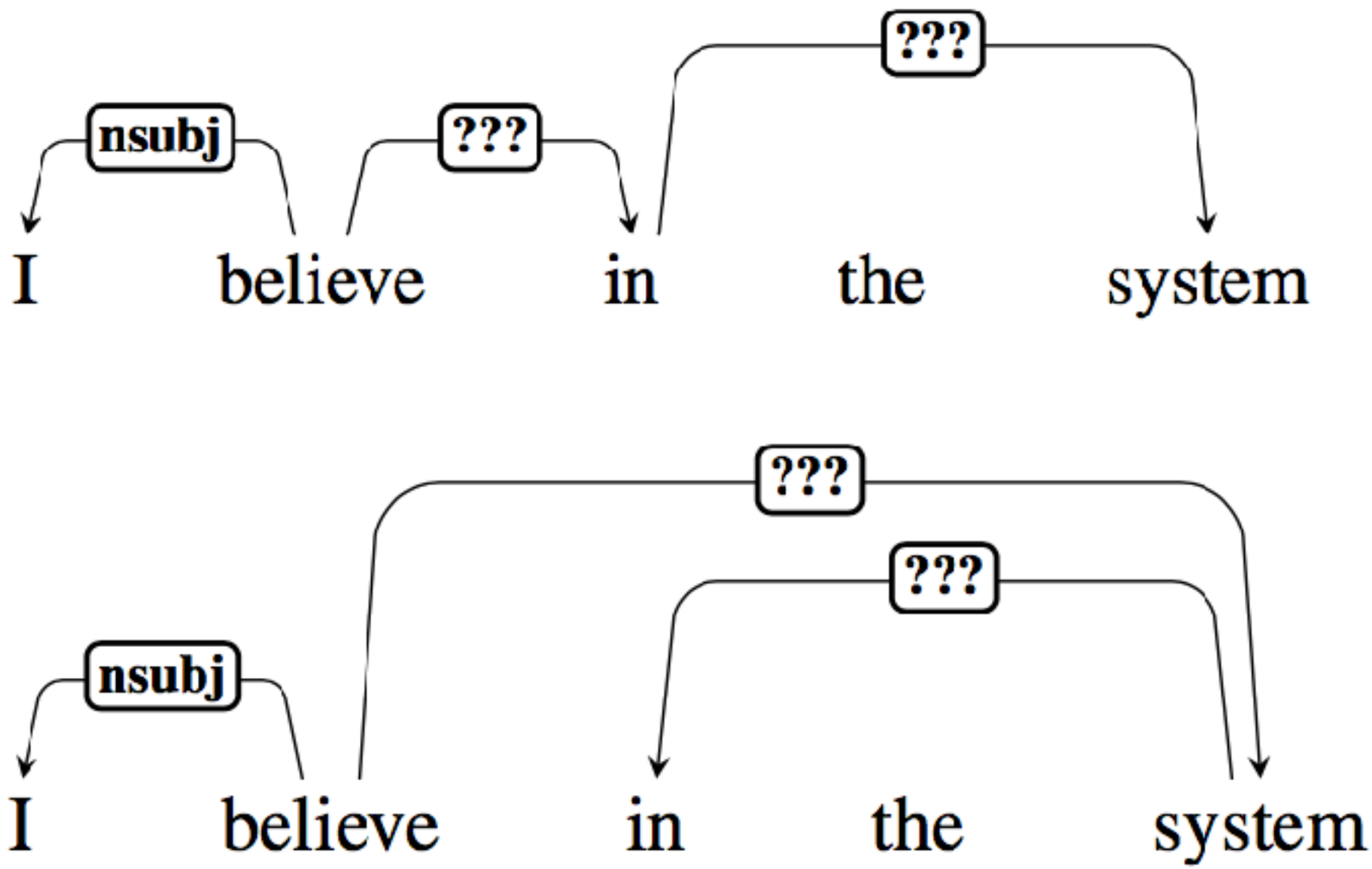

dobj
det
nsubj
det
The
dog
ate
the
food

Coordination



Nivre 2005

Case marking prepositions



Nivre 2005

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)

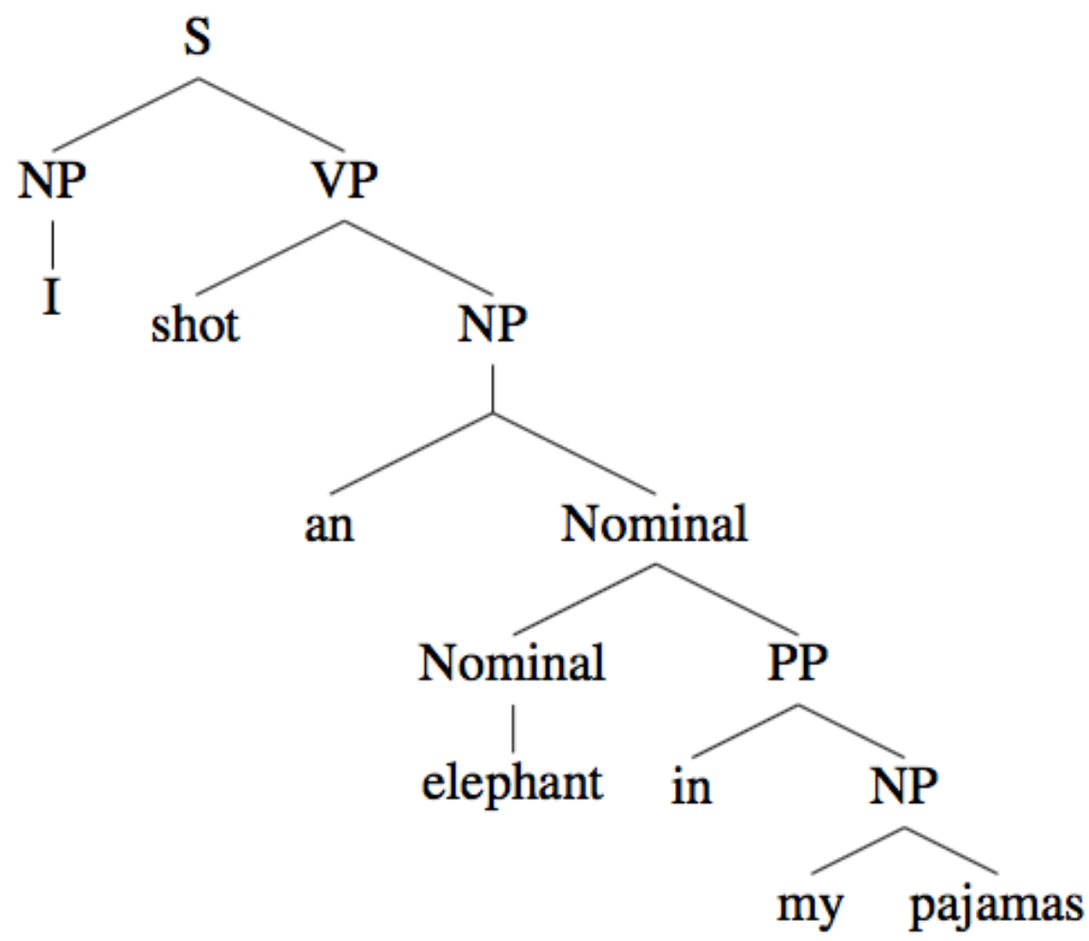
Trees

- 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 Thursday).

Word order

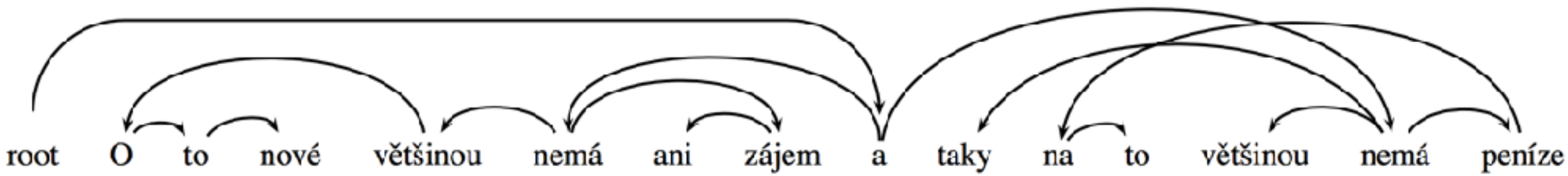
- Dependency relations belong to the structural order of a sentence, not the linear order.

- 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).

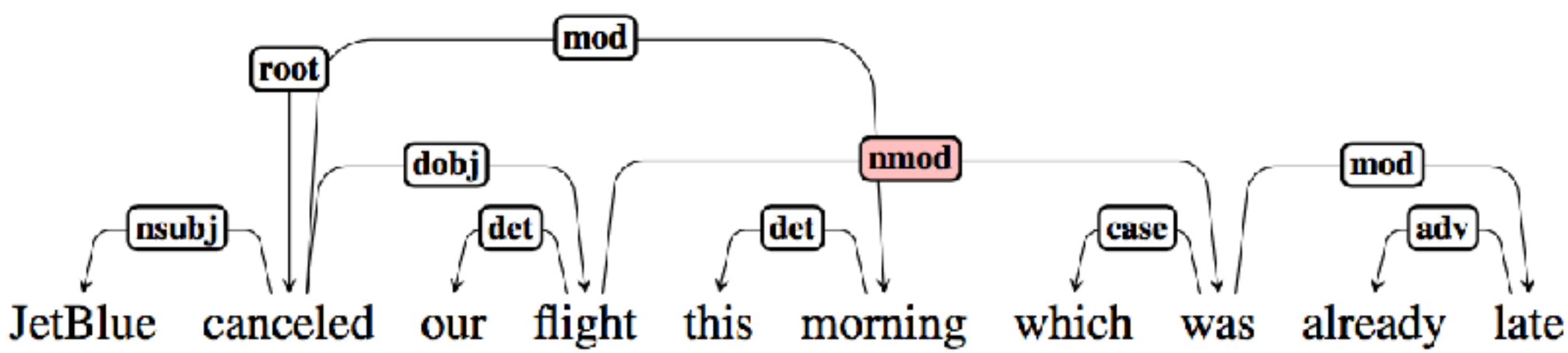


Tesnière 1959

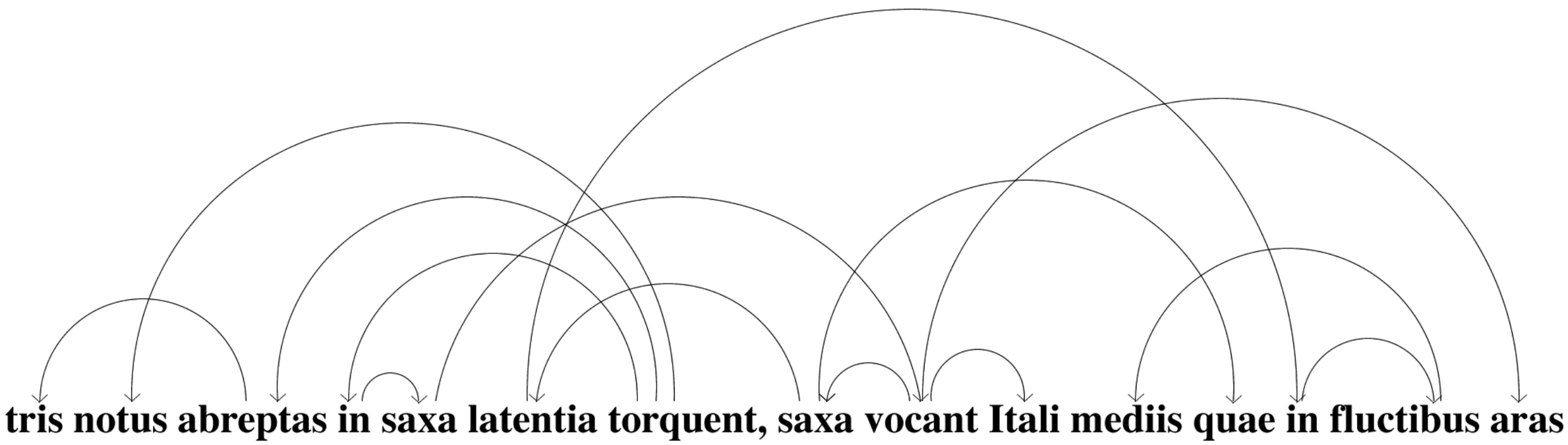
Free word order



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

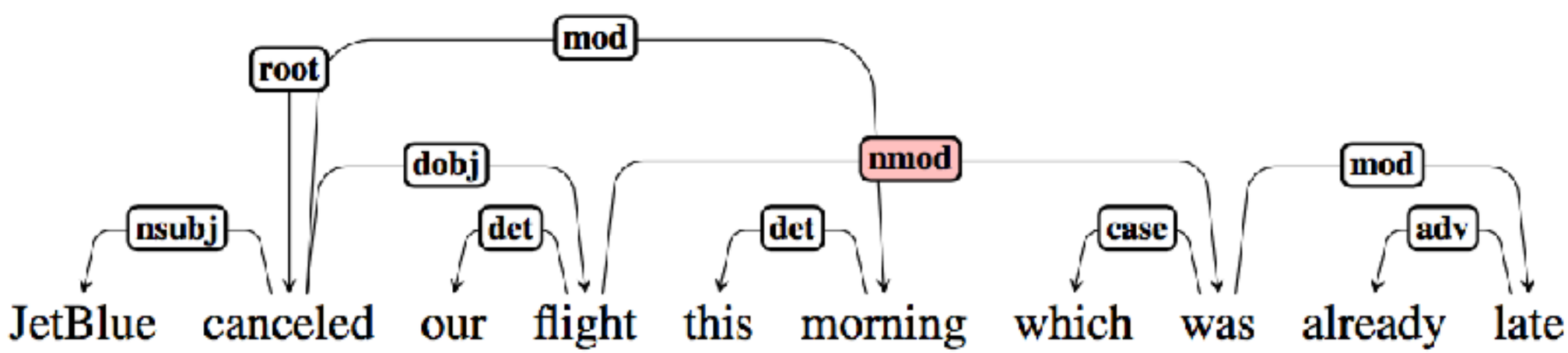


Free word order



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.



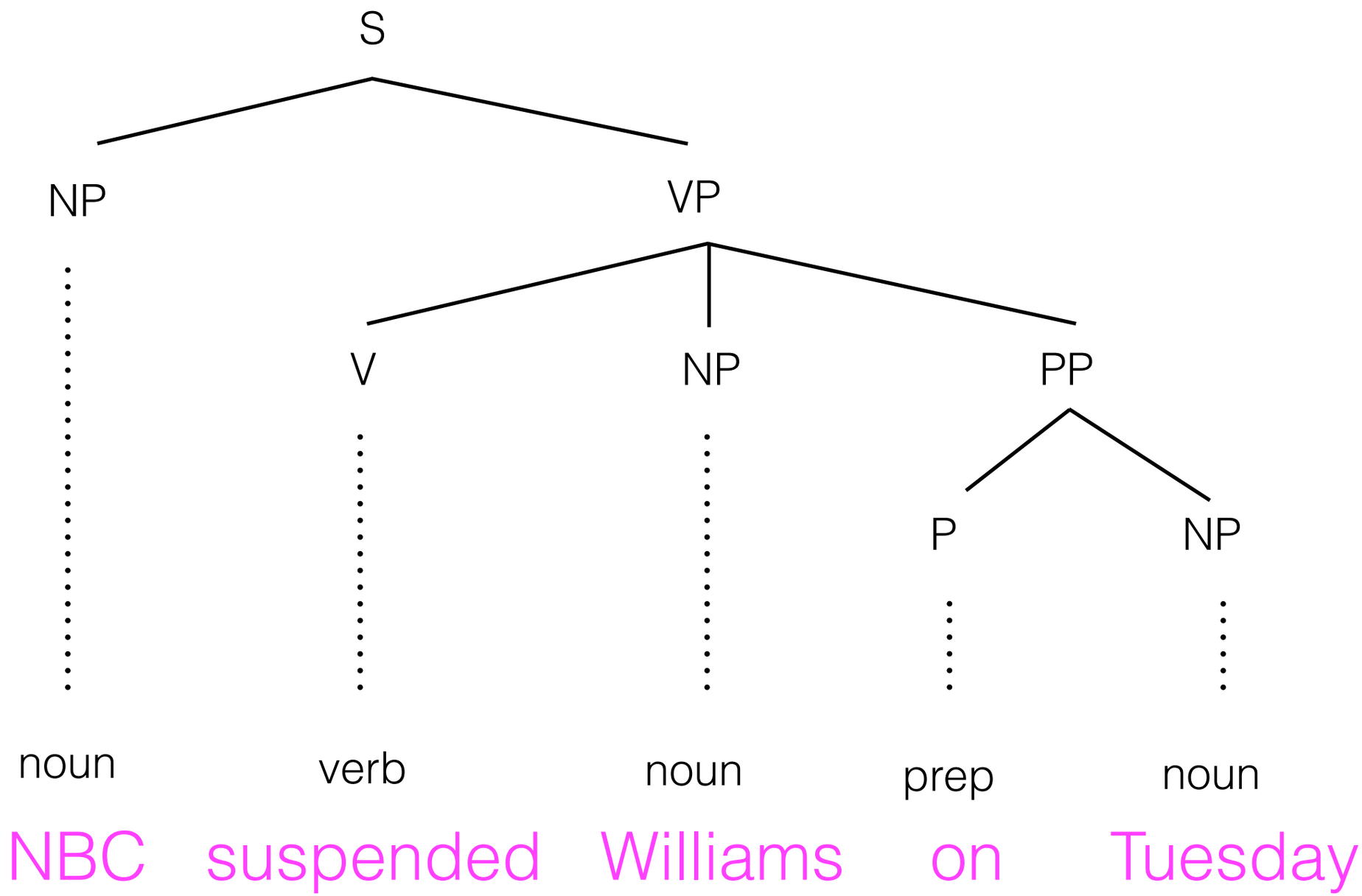
Dependencies vs constituents

- Dependency links are closer to semantic relationships; no need to infer the relationships from the structure of a tree

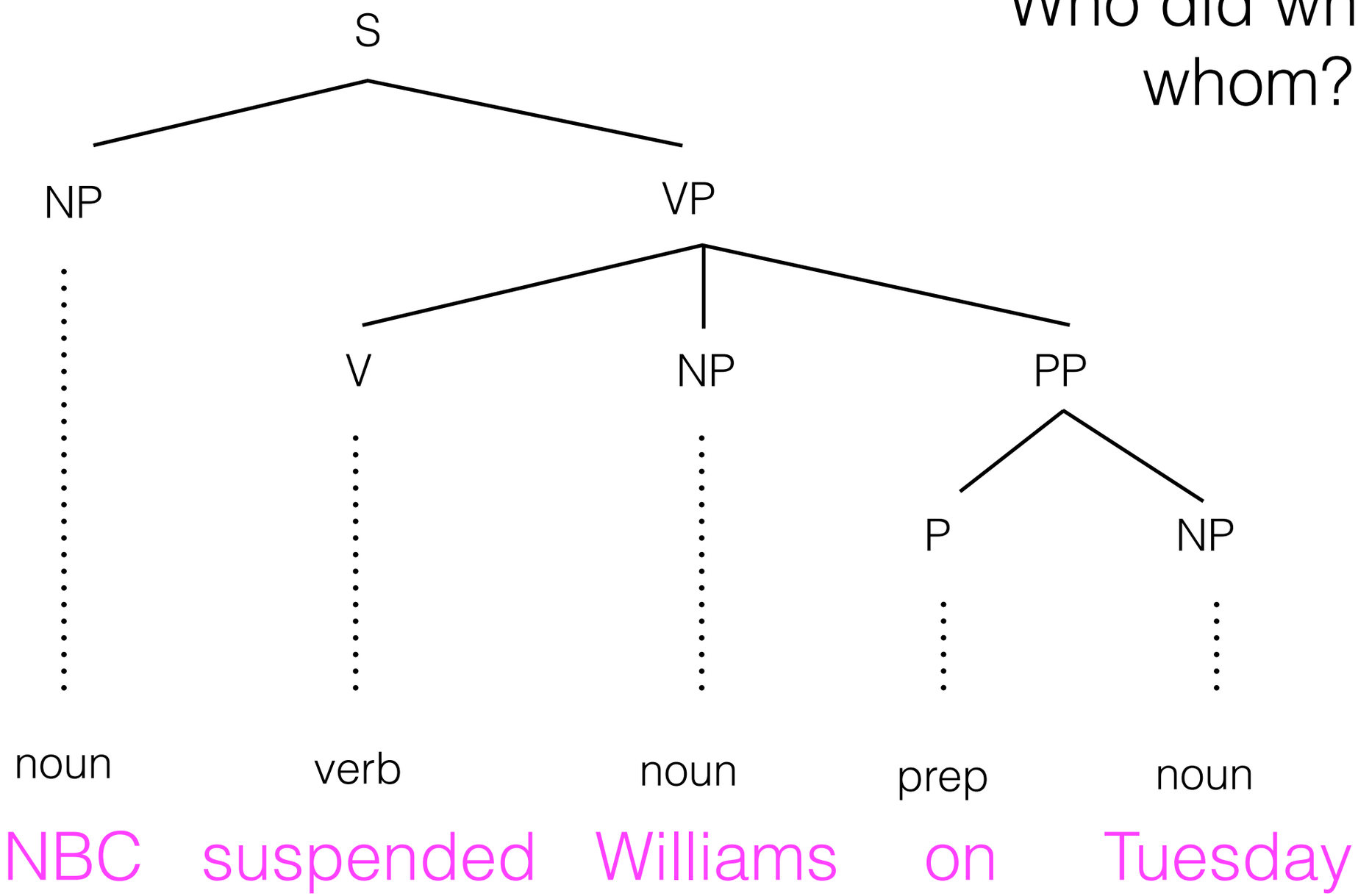
- A dependency tree contains one edge for each word, no intermediate hidden structures that also need to be learned for parsing.

- Easier to represent languages with free word order.

Covington 2001

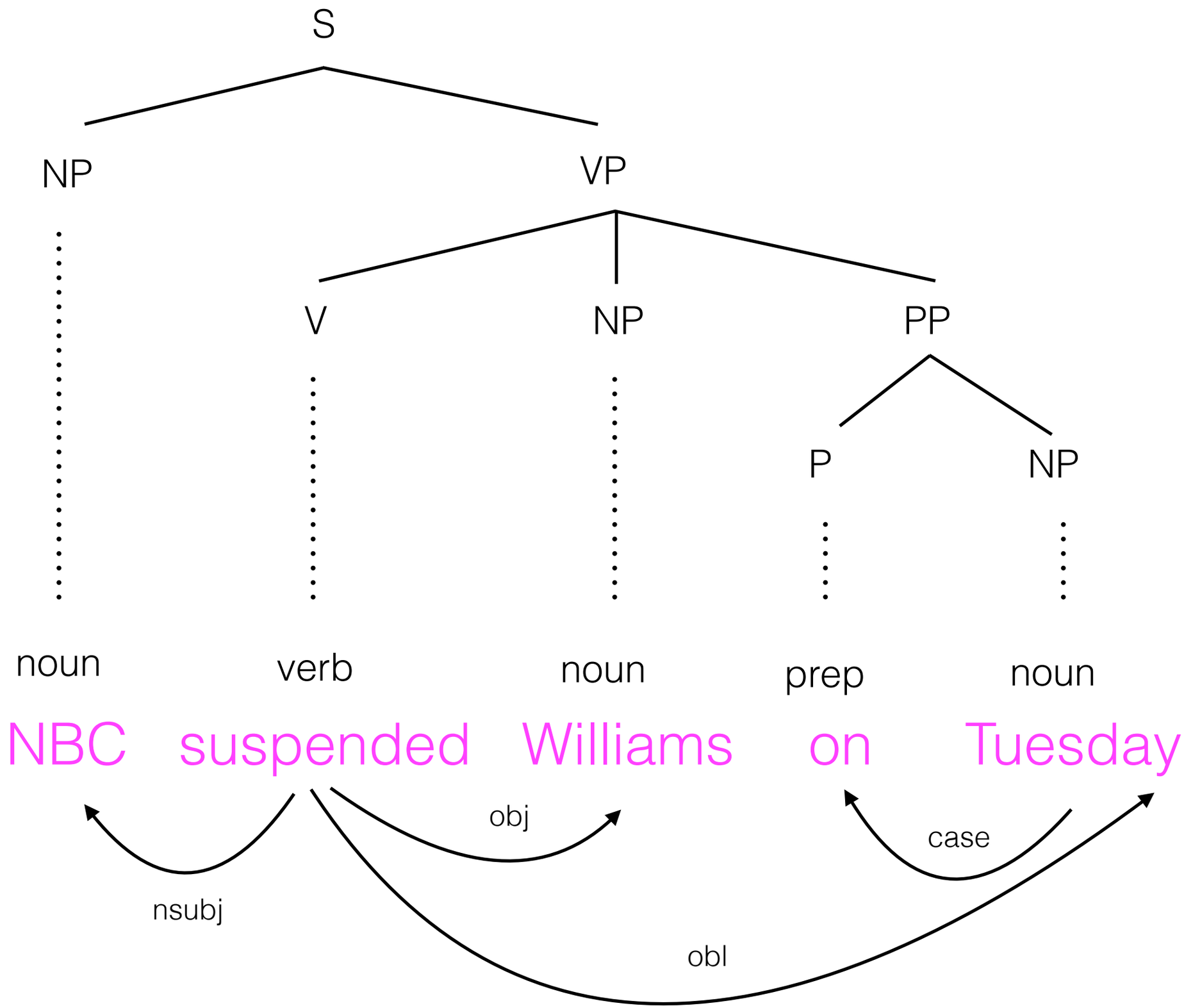

S
NP
VP
V
NP
PP
P
NP
noun
verb
noun
prep
noun
NBC
suspended
Williams
on
Tuesday

Who did what to whom?



subject: S → NP VP

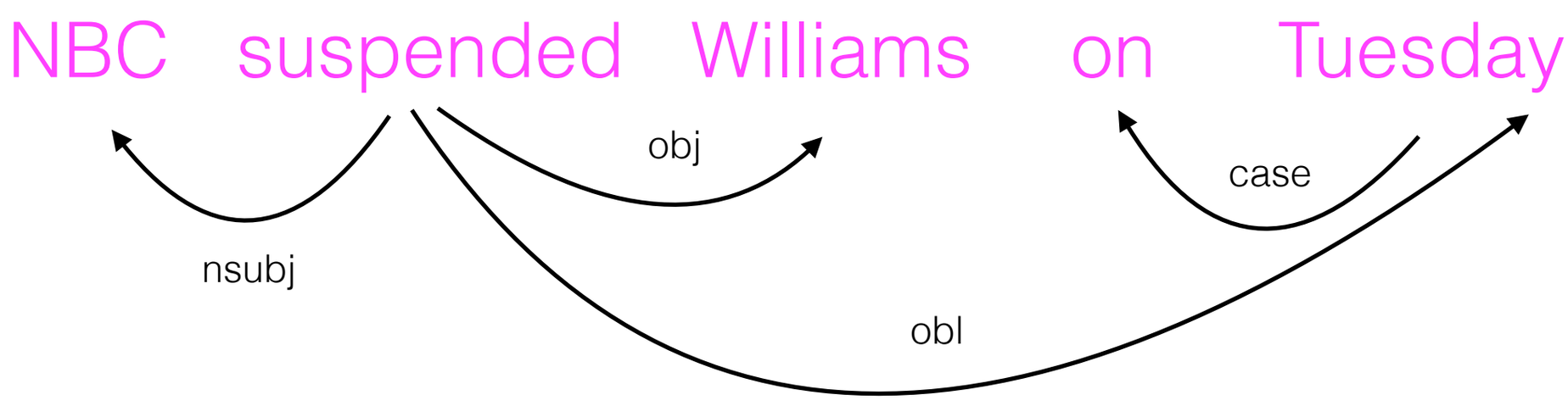
direct object: S → NP (VP → … NP …)


S
NP
VP
V
NP
PP
P
NP
noun
verb
noun
prep
noun
NBC
suspended
Williams
on
Tuesday
obj
case
nsubj
obl

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

http://universaldependencies.org

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.

http://universaldependencies.org

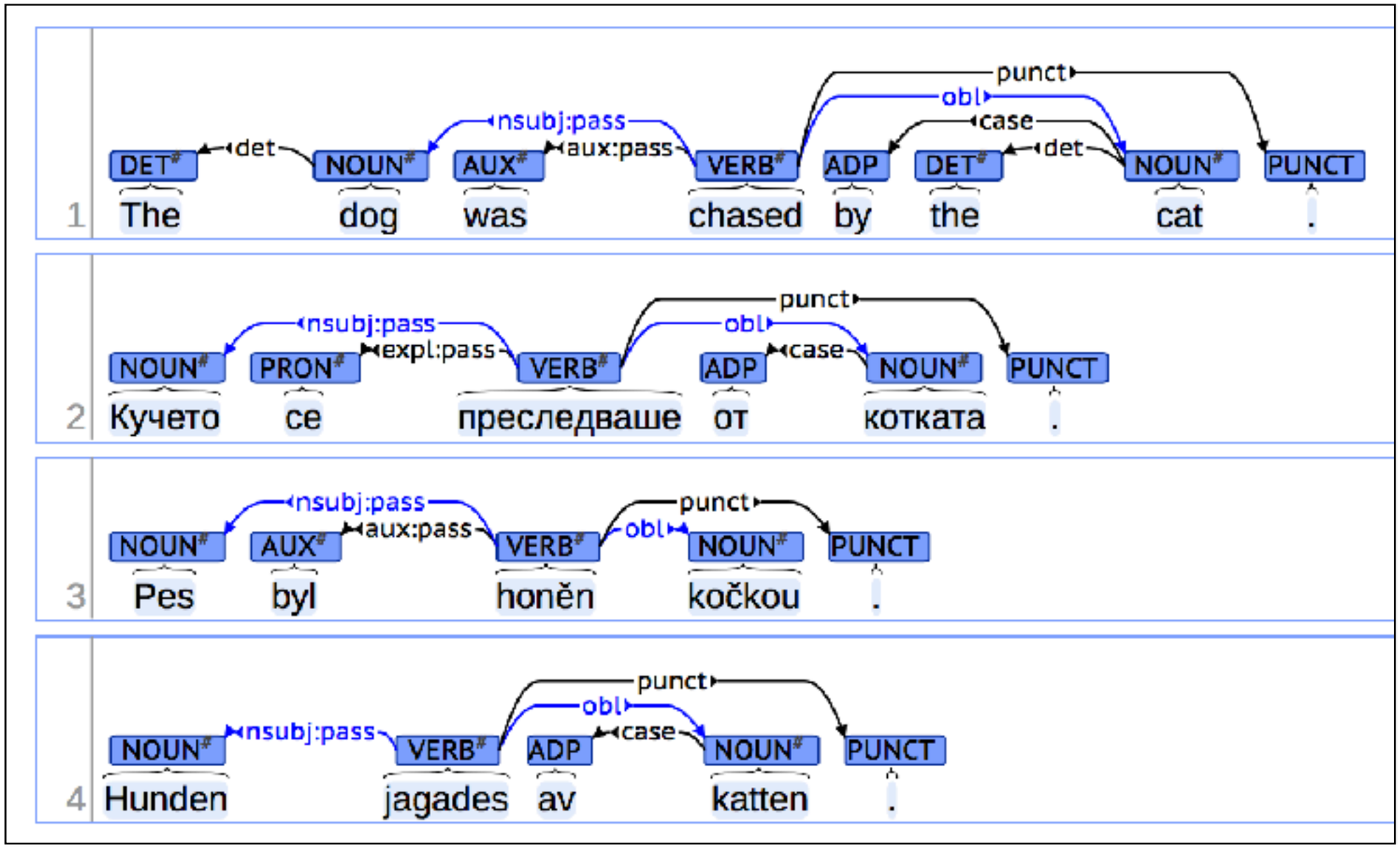
Universal Dependencies

English

Bulgarian

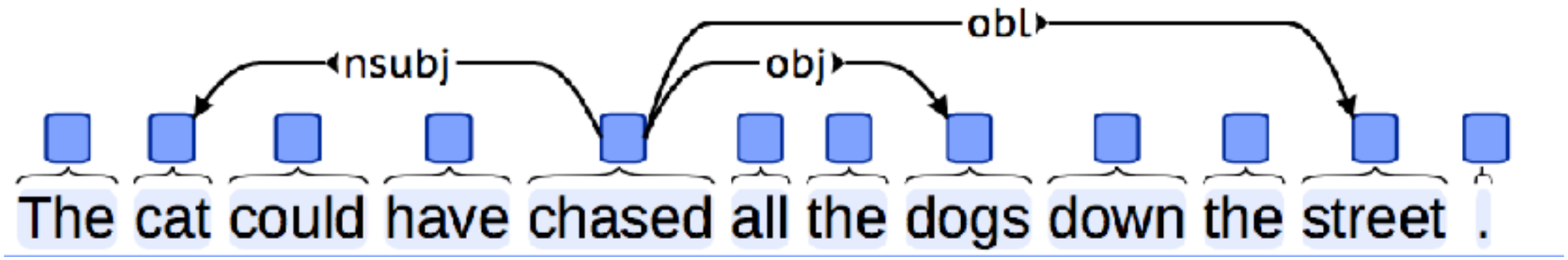
Czech

Swedish



http://universaldependencies.org

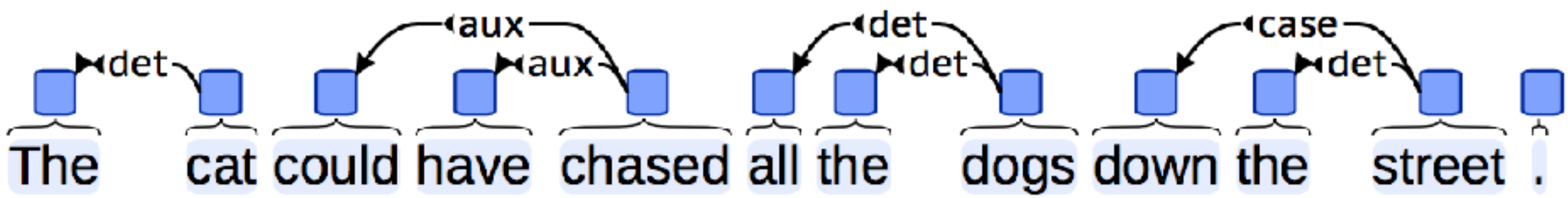
UD Principles



Dependency relations mainly hold between content words.

http://universaldependencies.org/u/overview/syntax.html

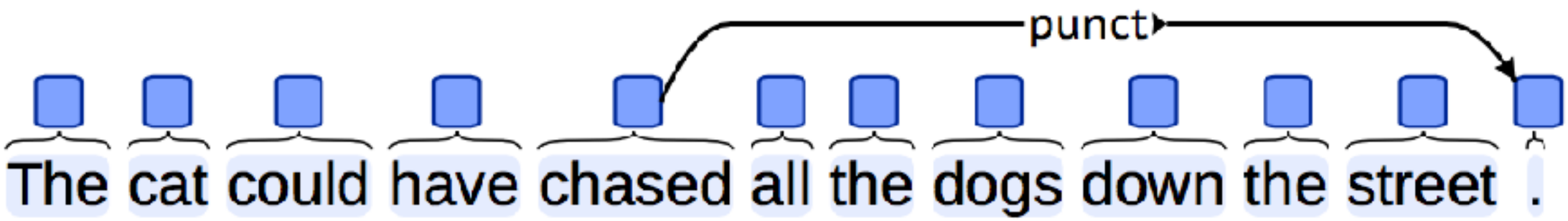
UD Principles



Function words dependent on closest related content word

http://universaldependencies.org/u/overview/syntax.html

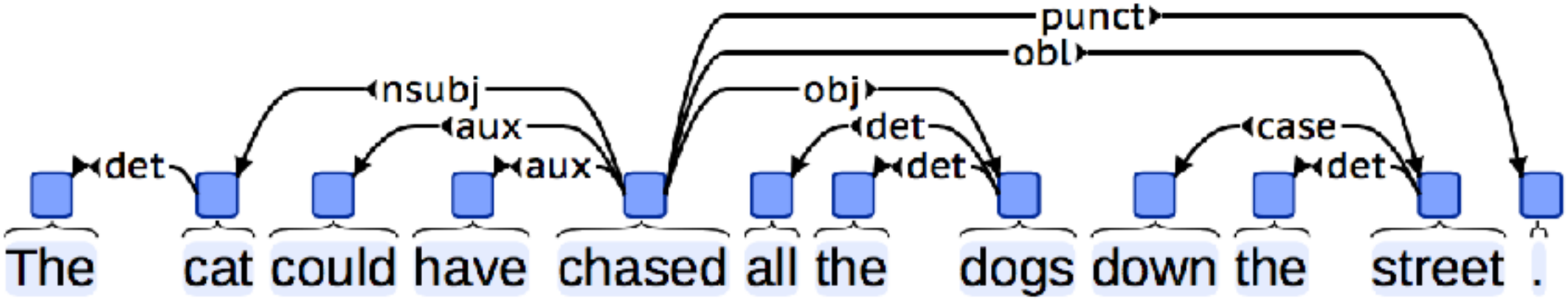
UD Principles



Punctuation typically depends on phrasal head

http://universaldependencies.org/u/overview/syntax.html

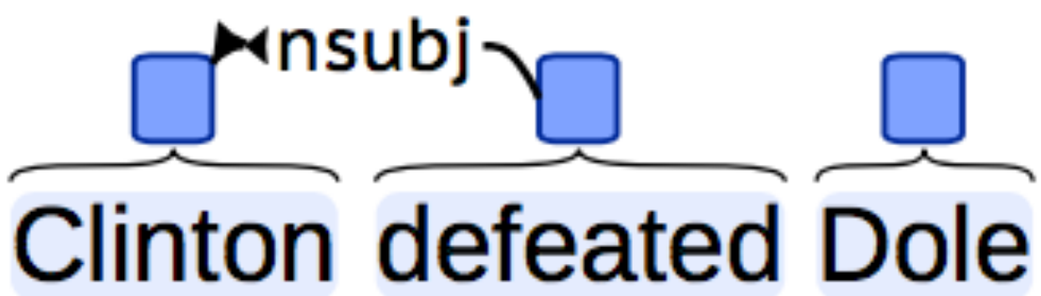
UD Principles



http://universaldependencies.org/u/overview/syntax.html

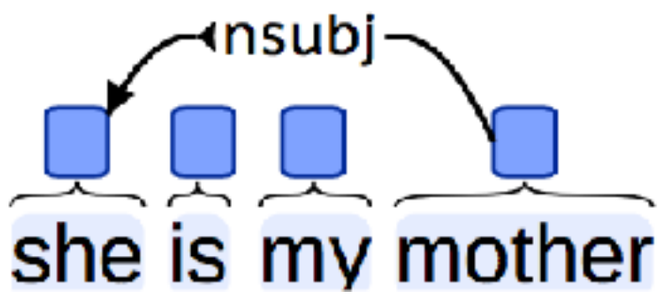
nsubj

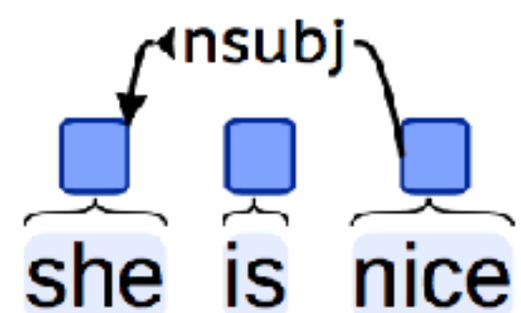
- Syntactic subject of active verbs

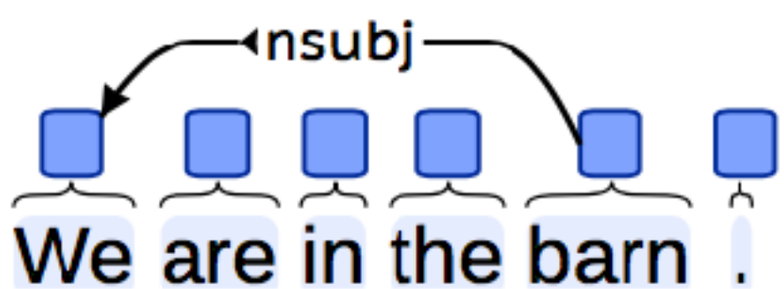


nsubj

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

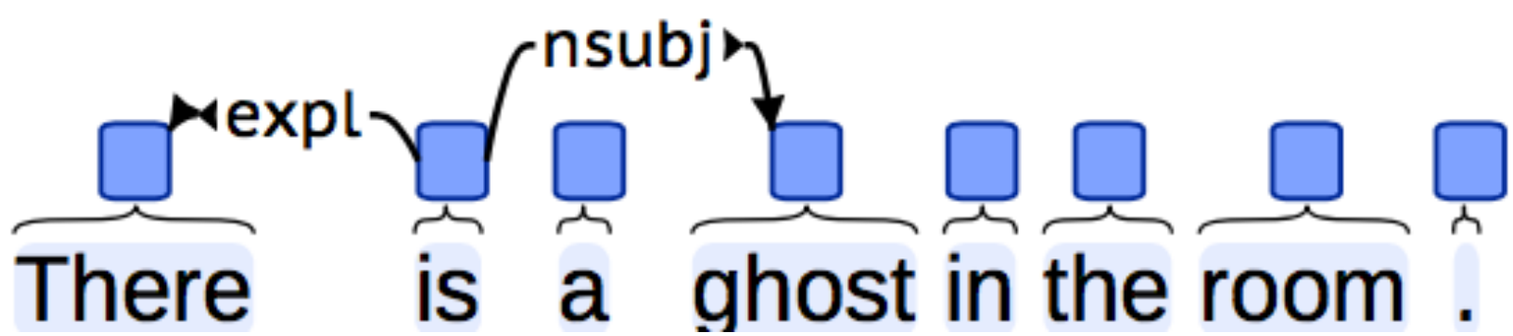






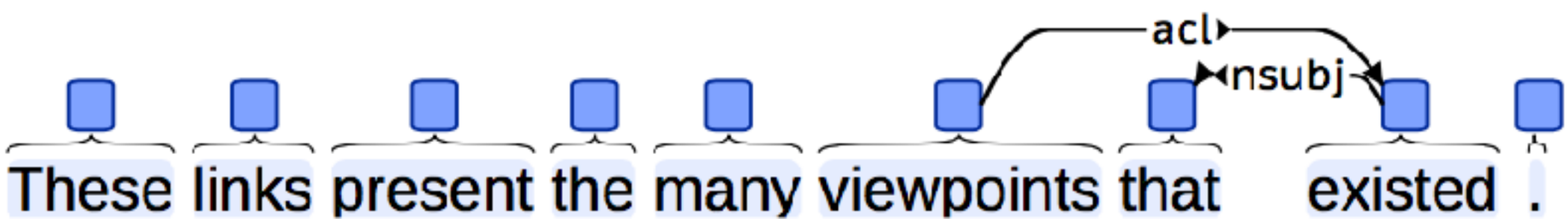
nsubj

- Expletives



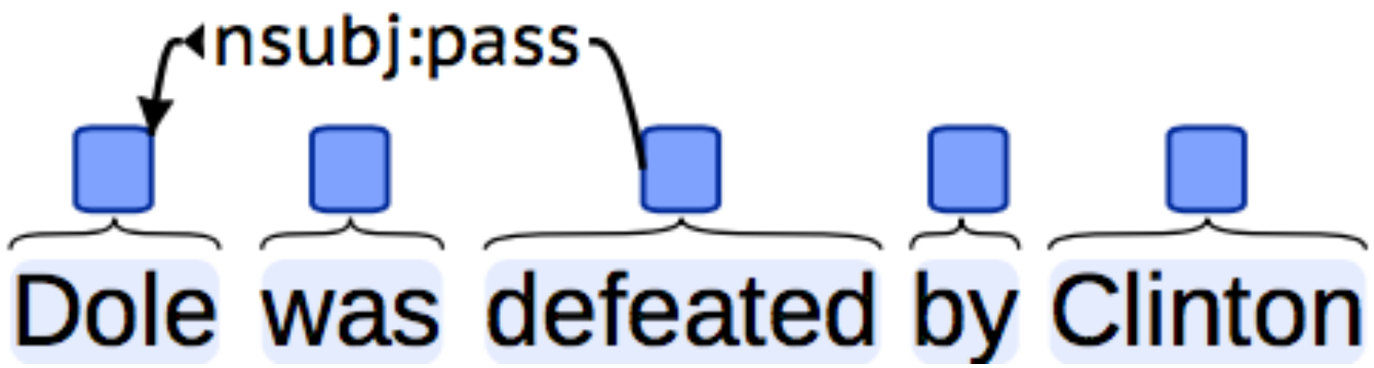
nsubj

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



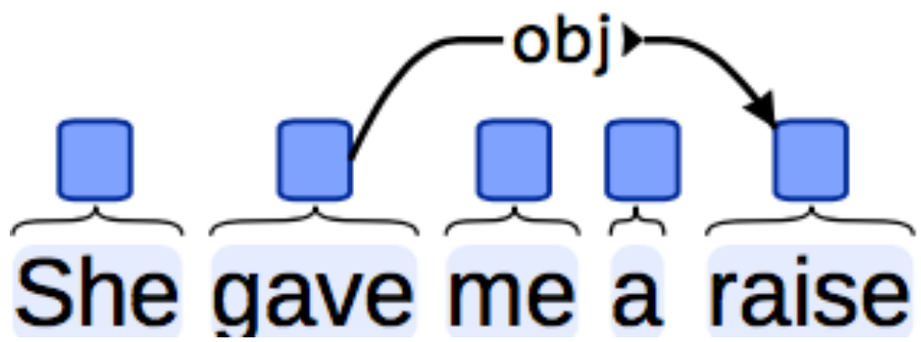
nsubj:pass

- Syntactic subject of passive verbs



obj

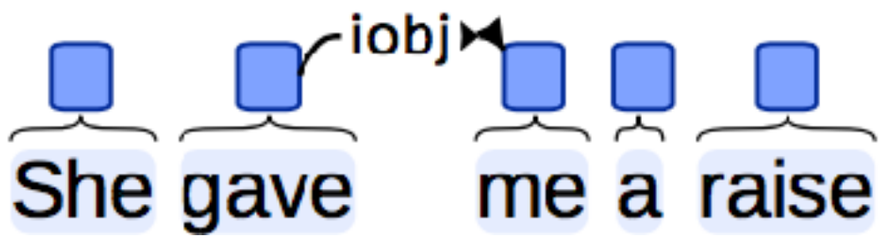
- Generally, the entity that is acted upon as the direct object of the predicate.



- Note the term for a direct object in older versions of Universal Dependencies (e.g., described in SLP3) is “dobj”.

iobj

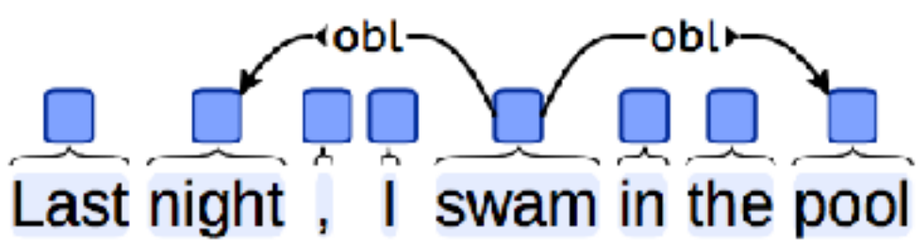
- Indirect object: recipients of ditransitive verbs of exchange (verbs requiring two objects)

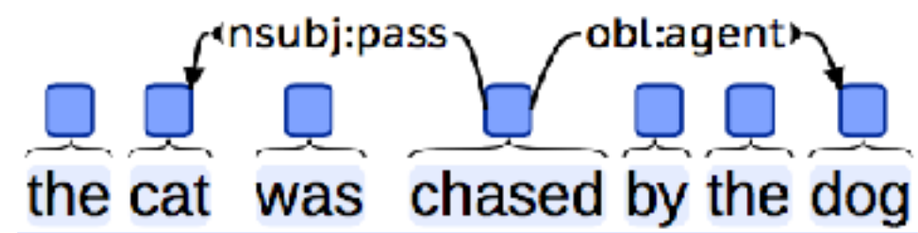


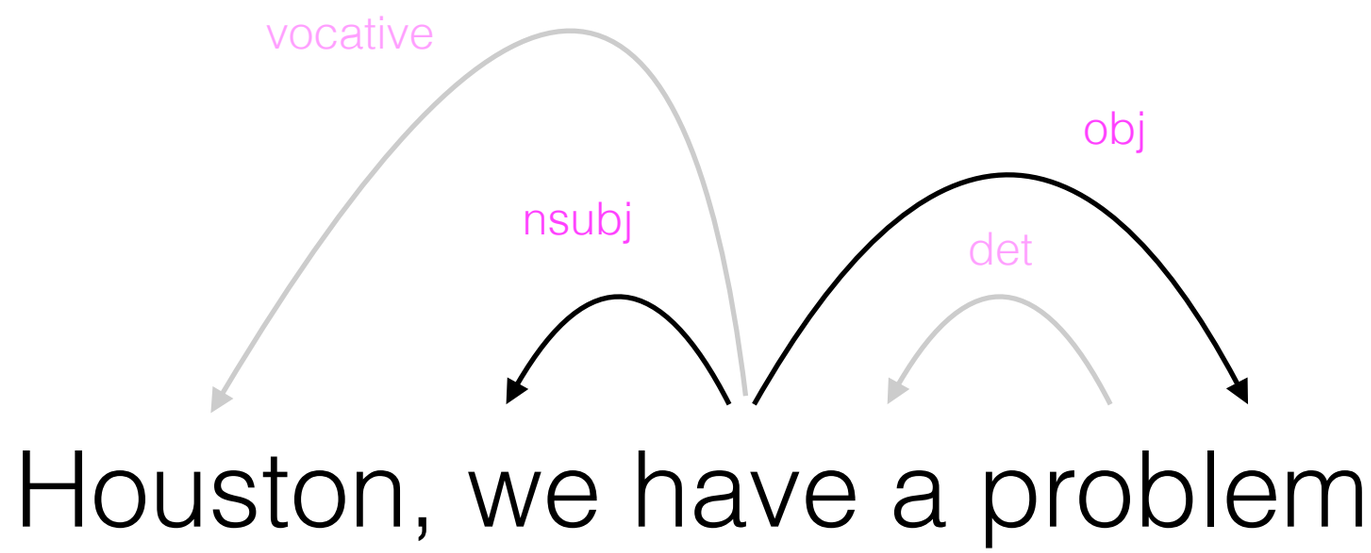
nsubj		iobj	obj
She	teaches	her daughters	math
She	told	her daughters	a story

obl

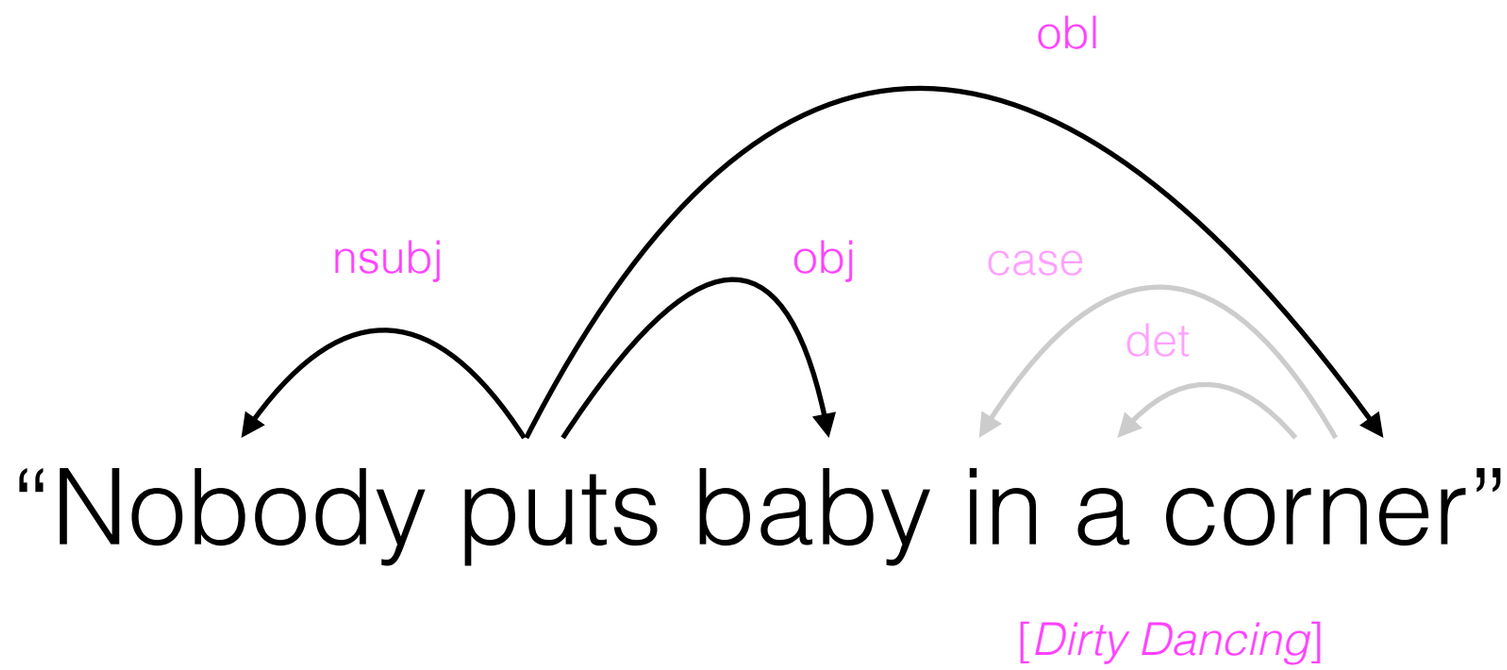
- Any nominal functioning as non-required argument or adjunct of a verb, including temporal and locational nominal modifiers and agents of passive verbs

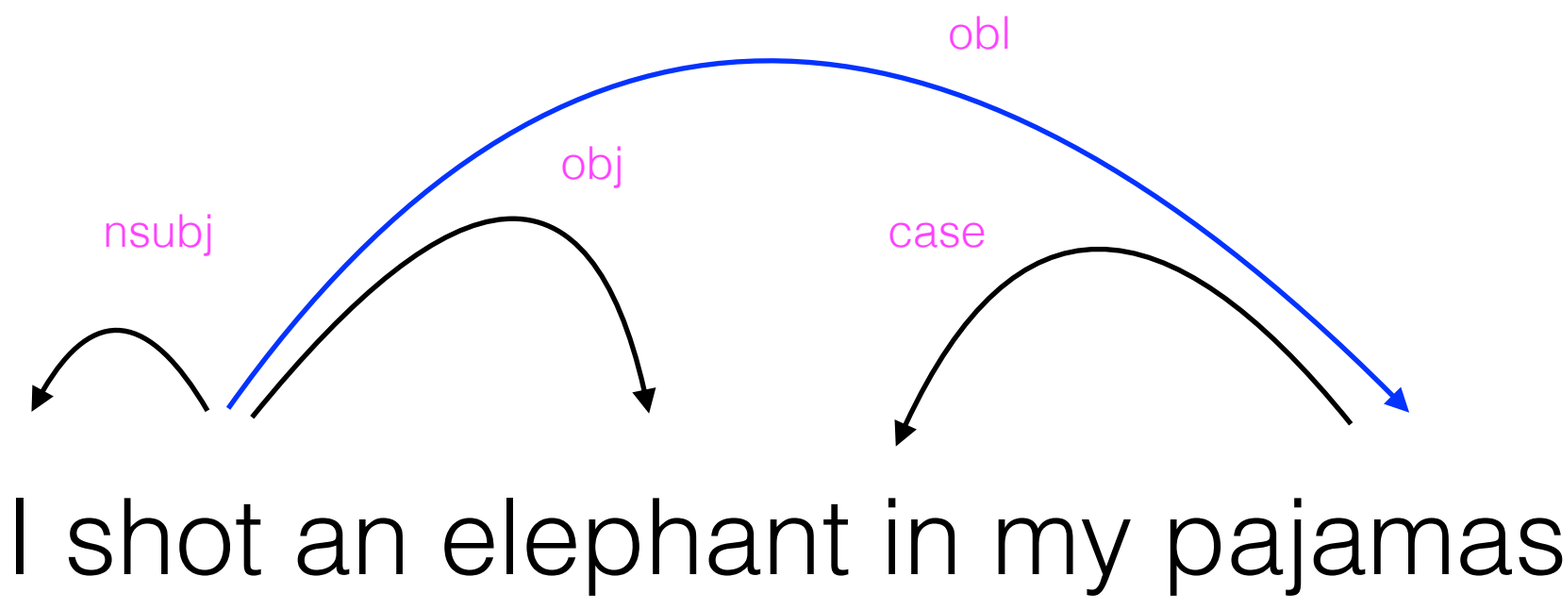


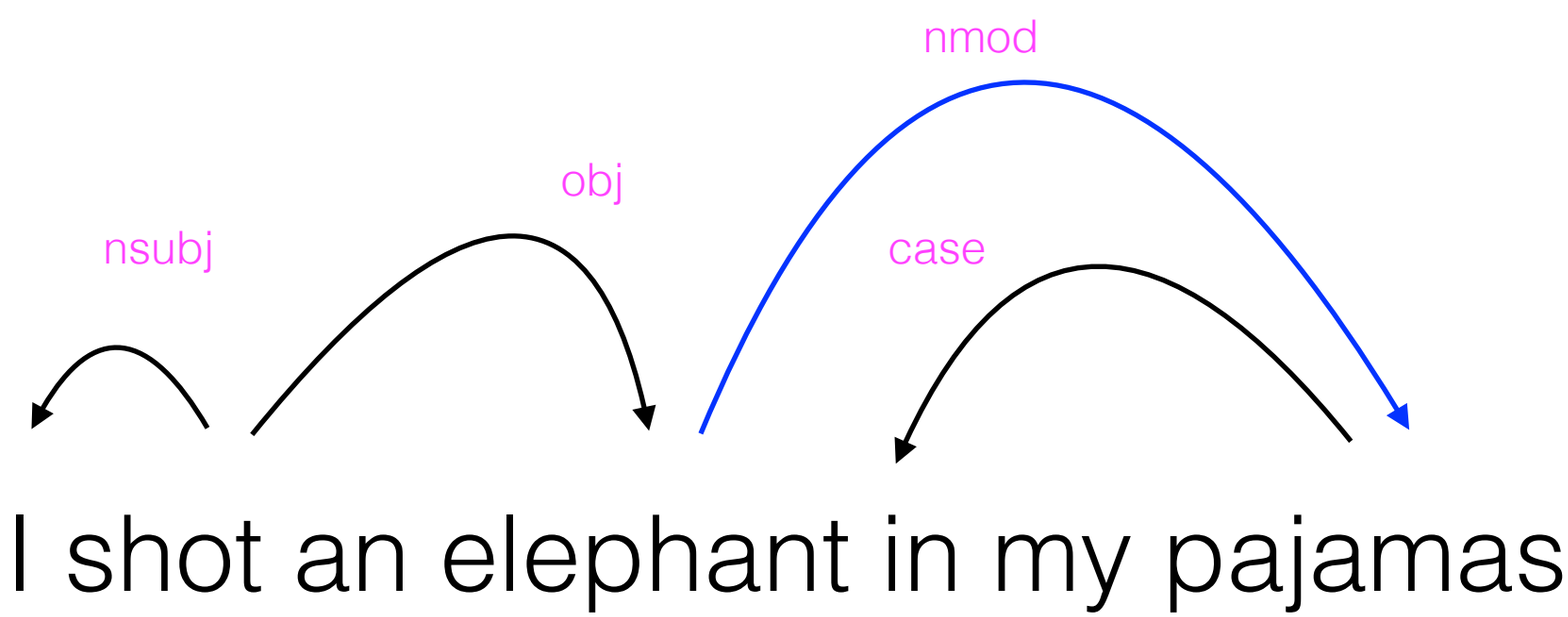




[Apollo 13]

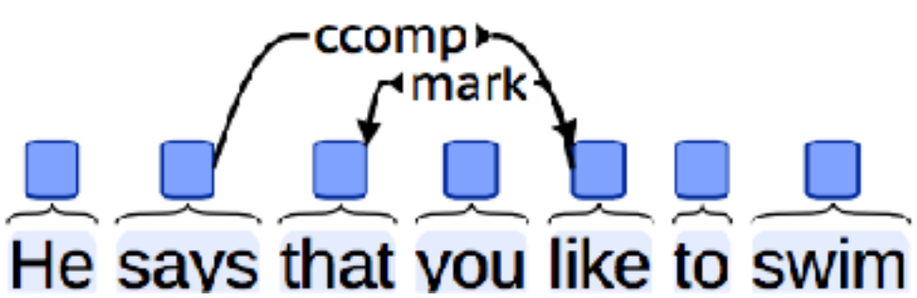

obl
nsubj
obj
case
det
“Nobody puts baby in a corner”
[*Dirty Dancing*]

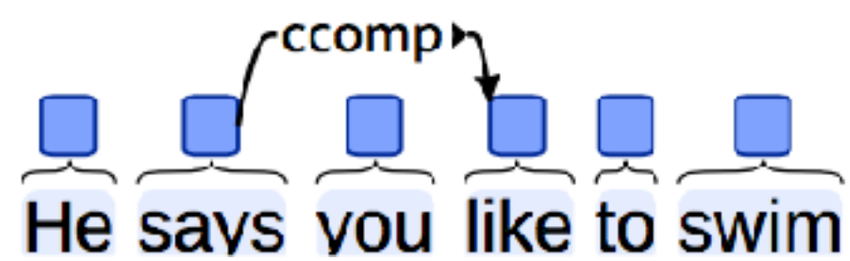

obl
obj
nsubj
case
I shot an elephant in my pajamas


nmod
obj
nsubj
case
I shot an elephant in my pajamas

ccomp

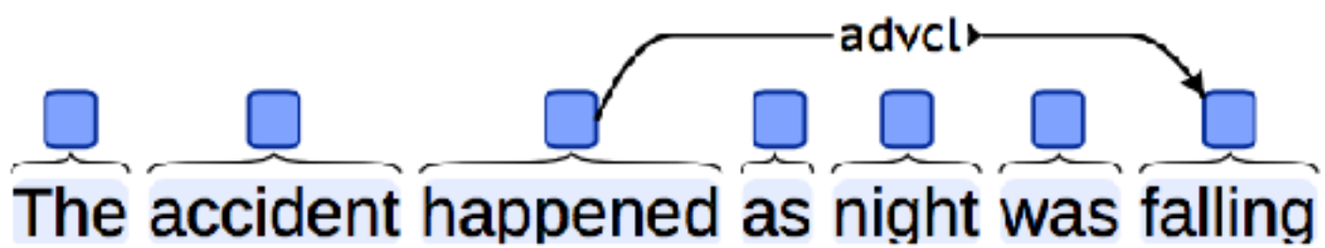
- Clausal complements, including dialogue

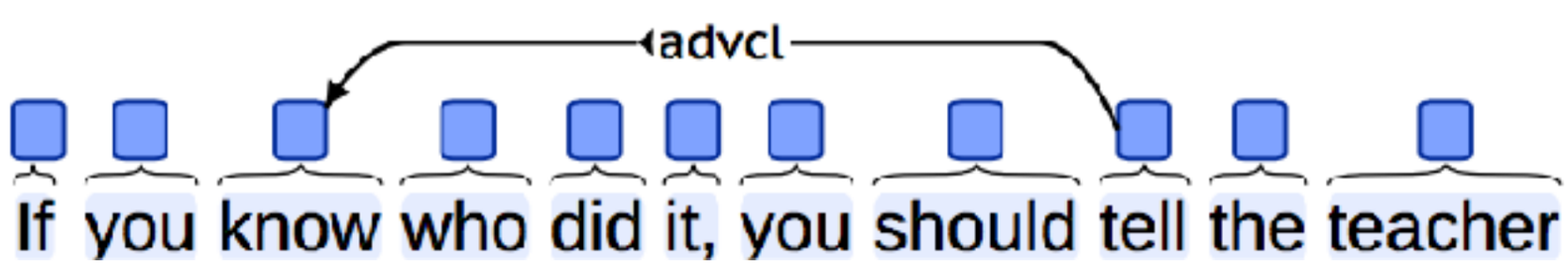




advcl

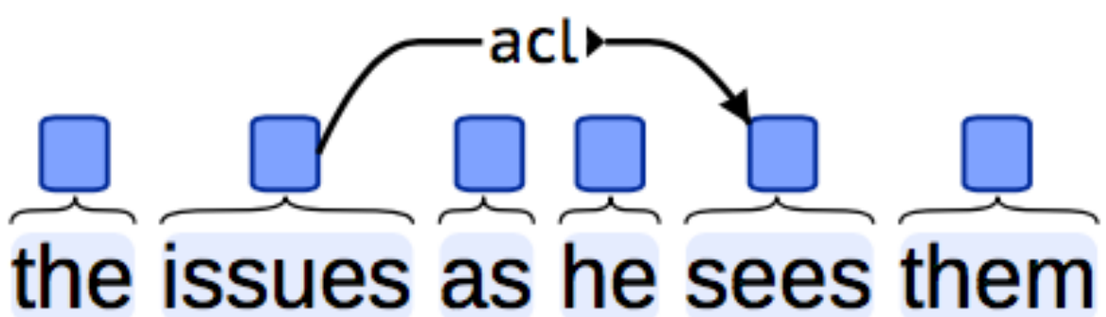
- A clause that modifies another predicate (temporal clauses, consequence, conditional clauses, purpose clauses)





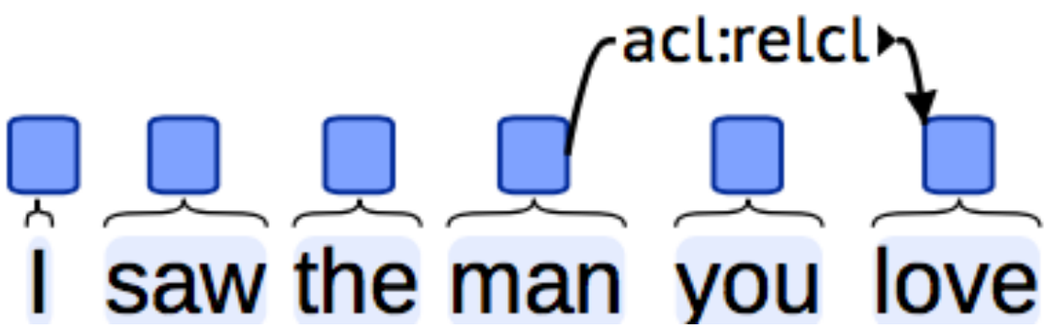
acl

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



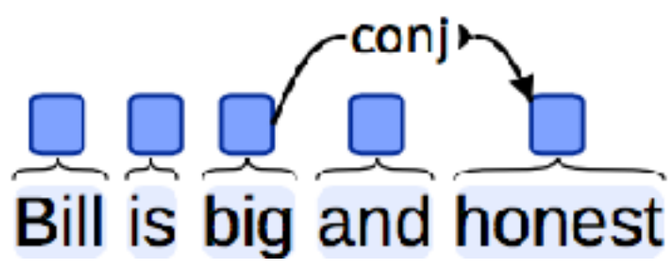
acl:relcl

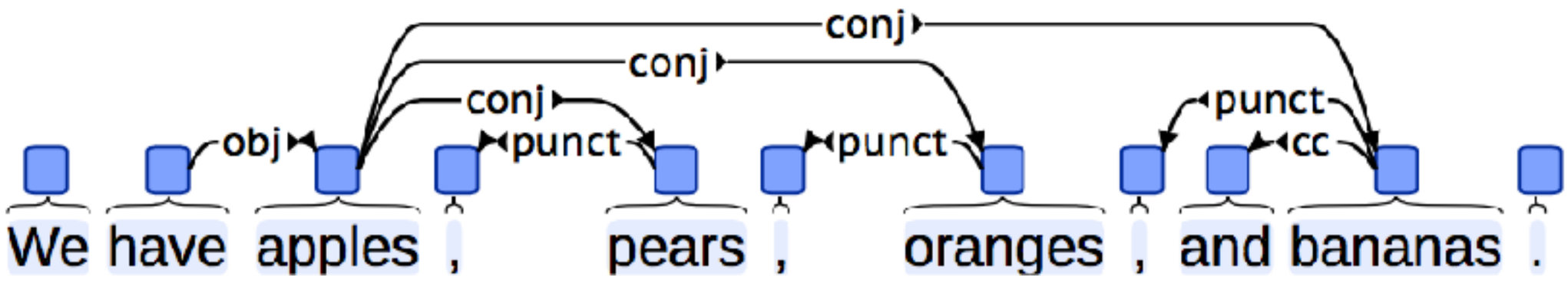
- Clausal modifier of a nominal, including relative clauses. The head verb of the embedded clause modifies the nominal it qualifies



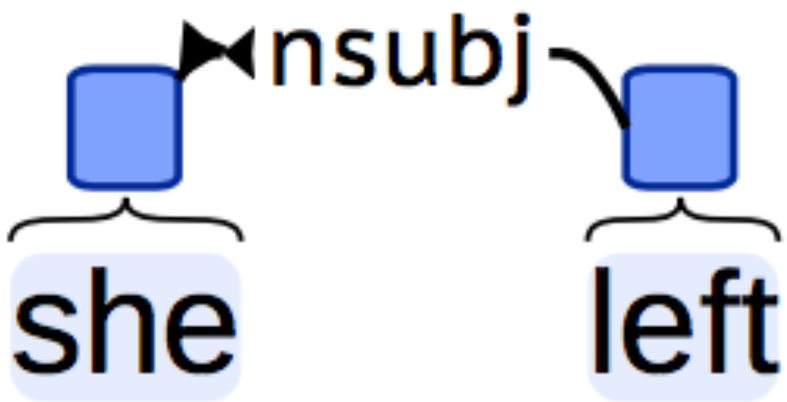
conj

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

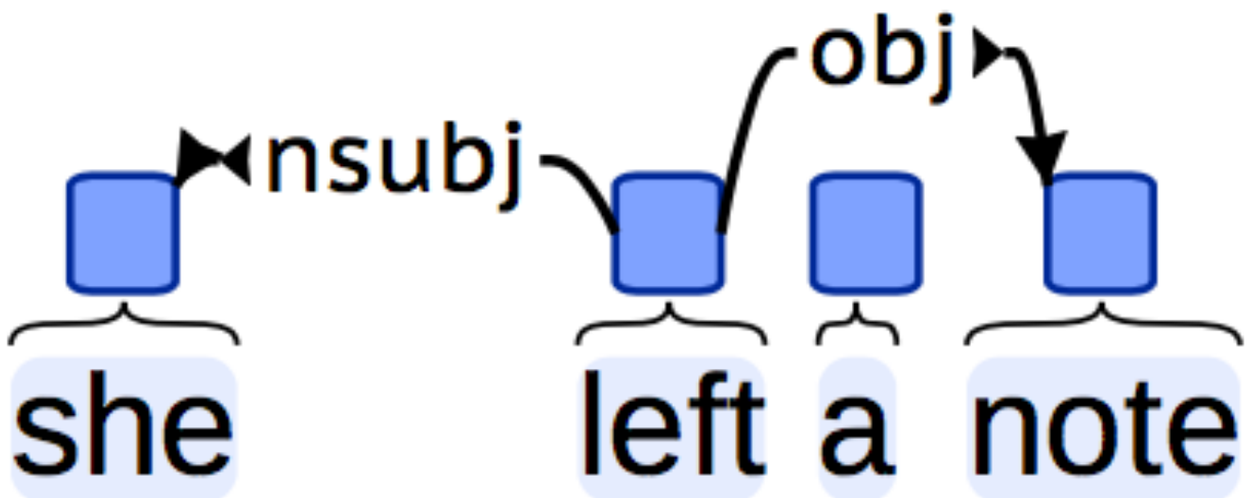




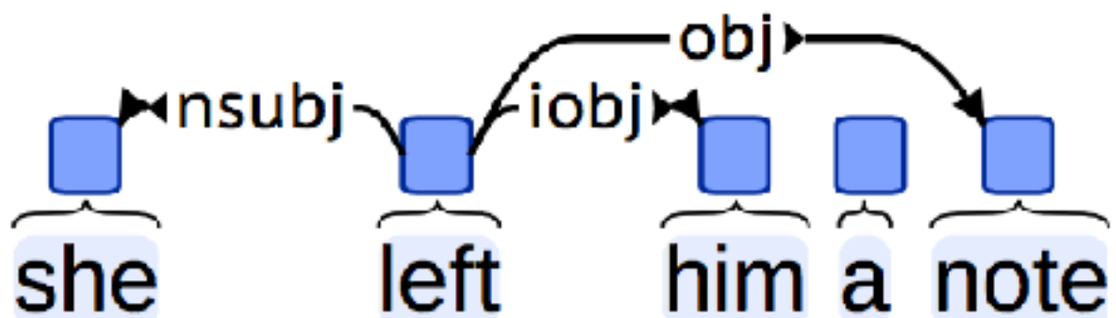
Intransitive verbs

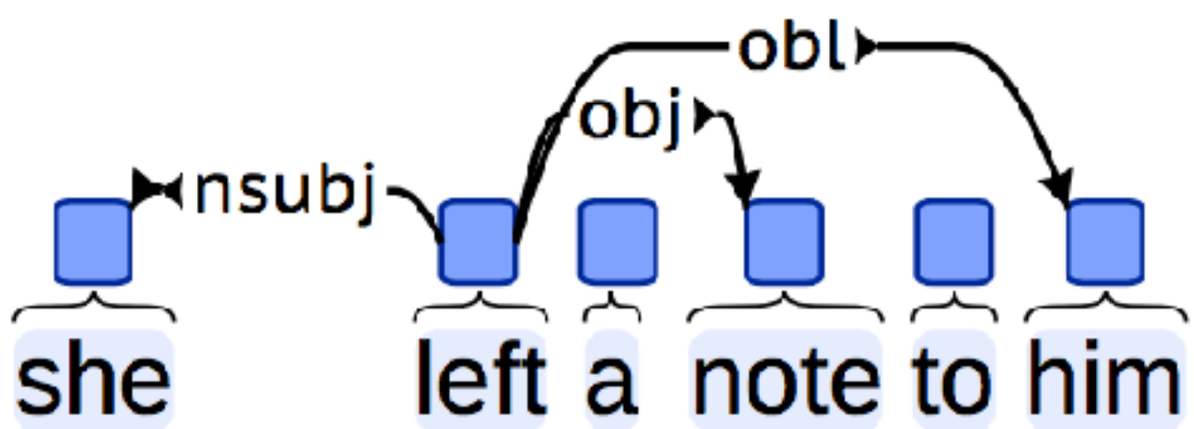


Transitive verbs

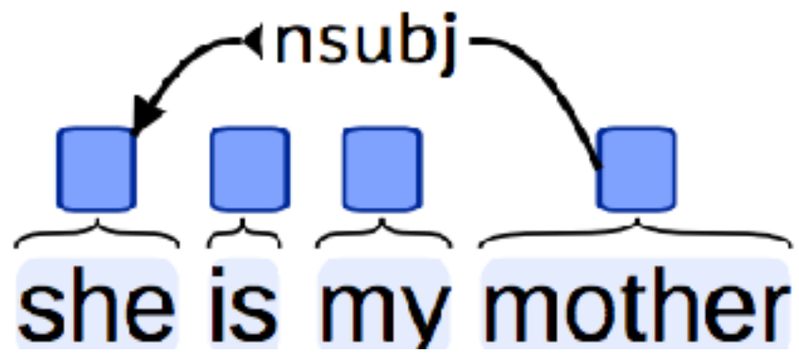


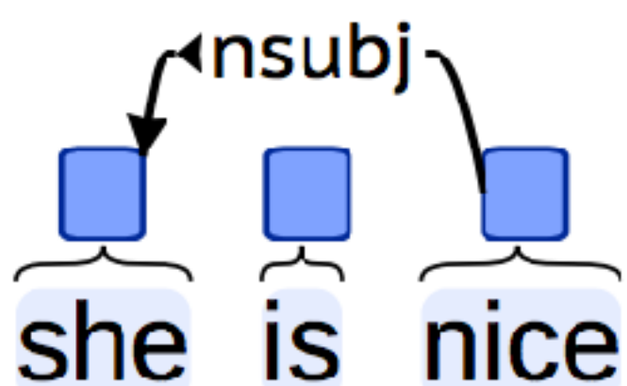
Ditransitive verbs





Nonverbal predication

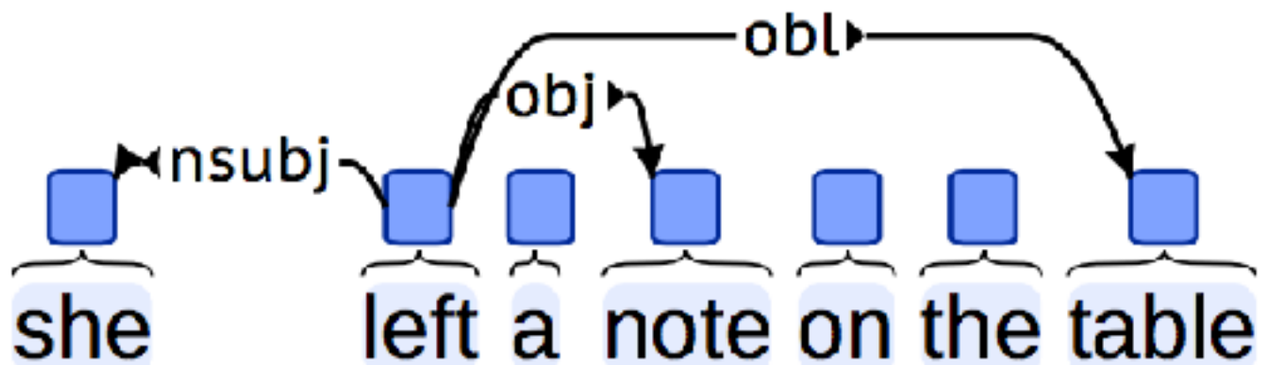


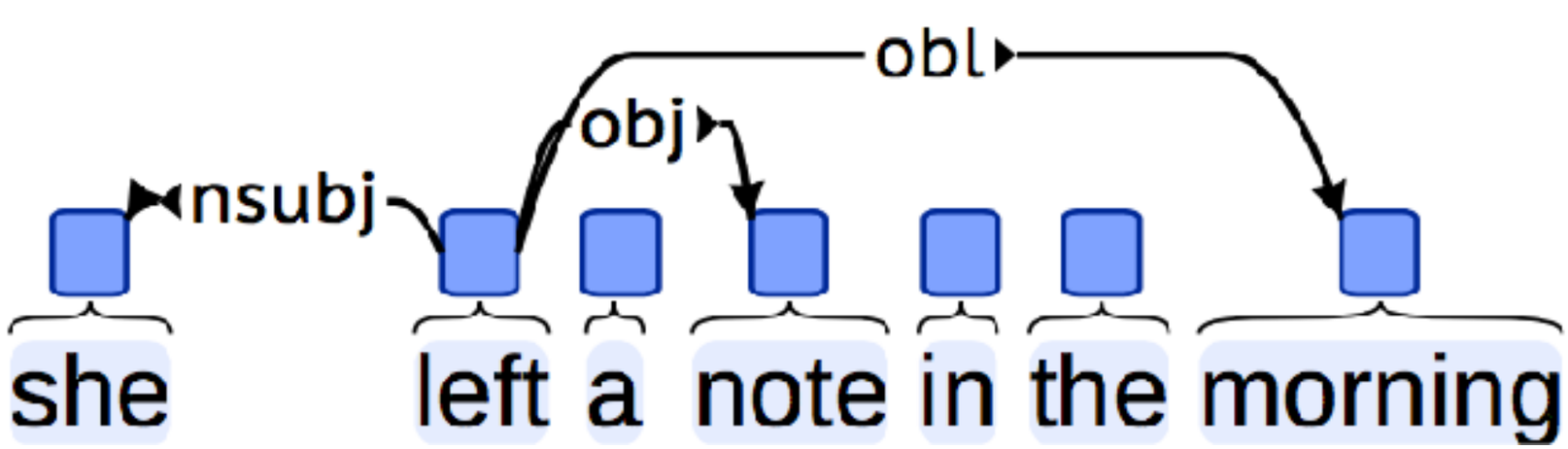


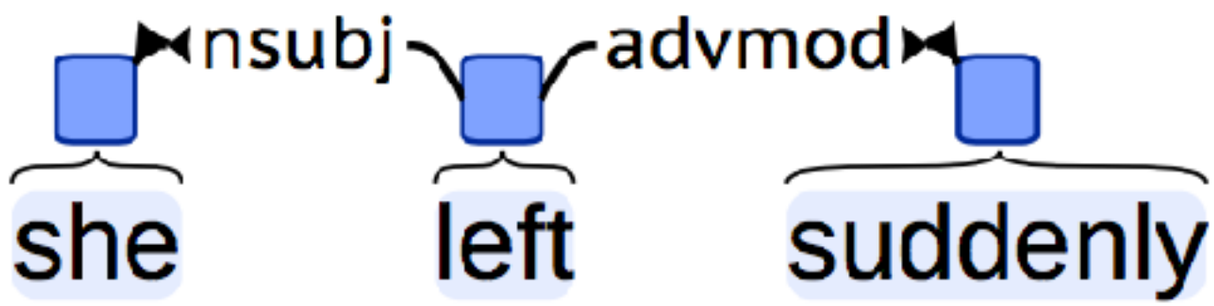
Nonverbal predication

- 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)”

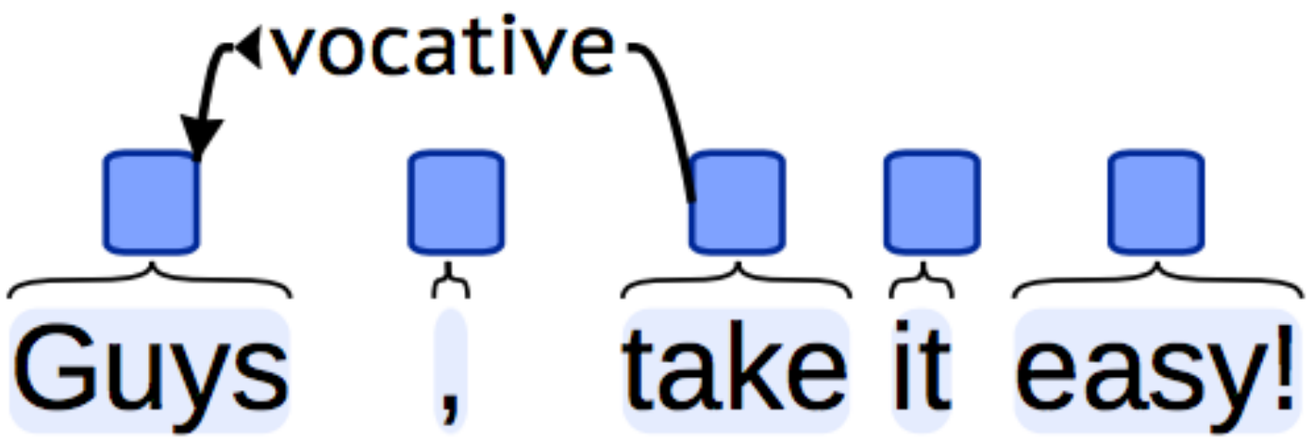
Oblique nominals



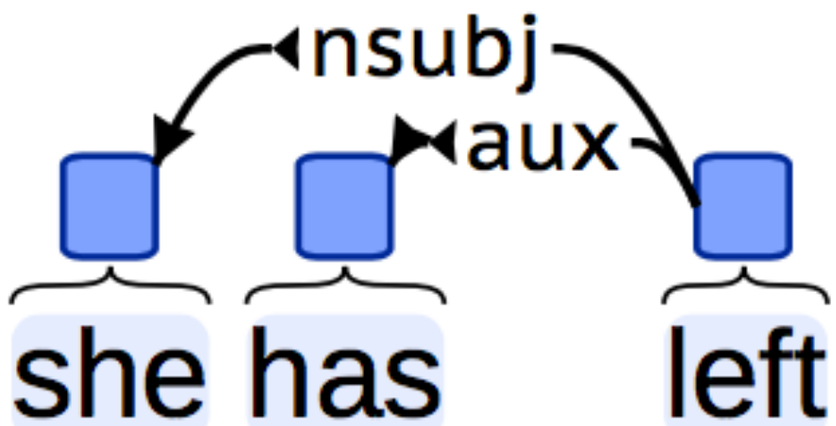



nsubj
advmod
she
left
suddenly

Vocatives

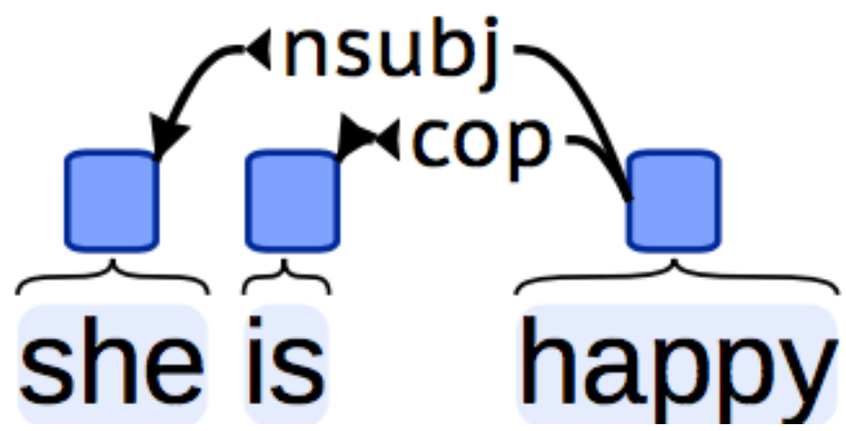


Aux

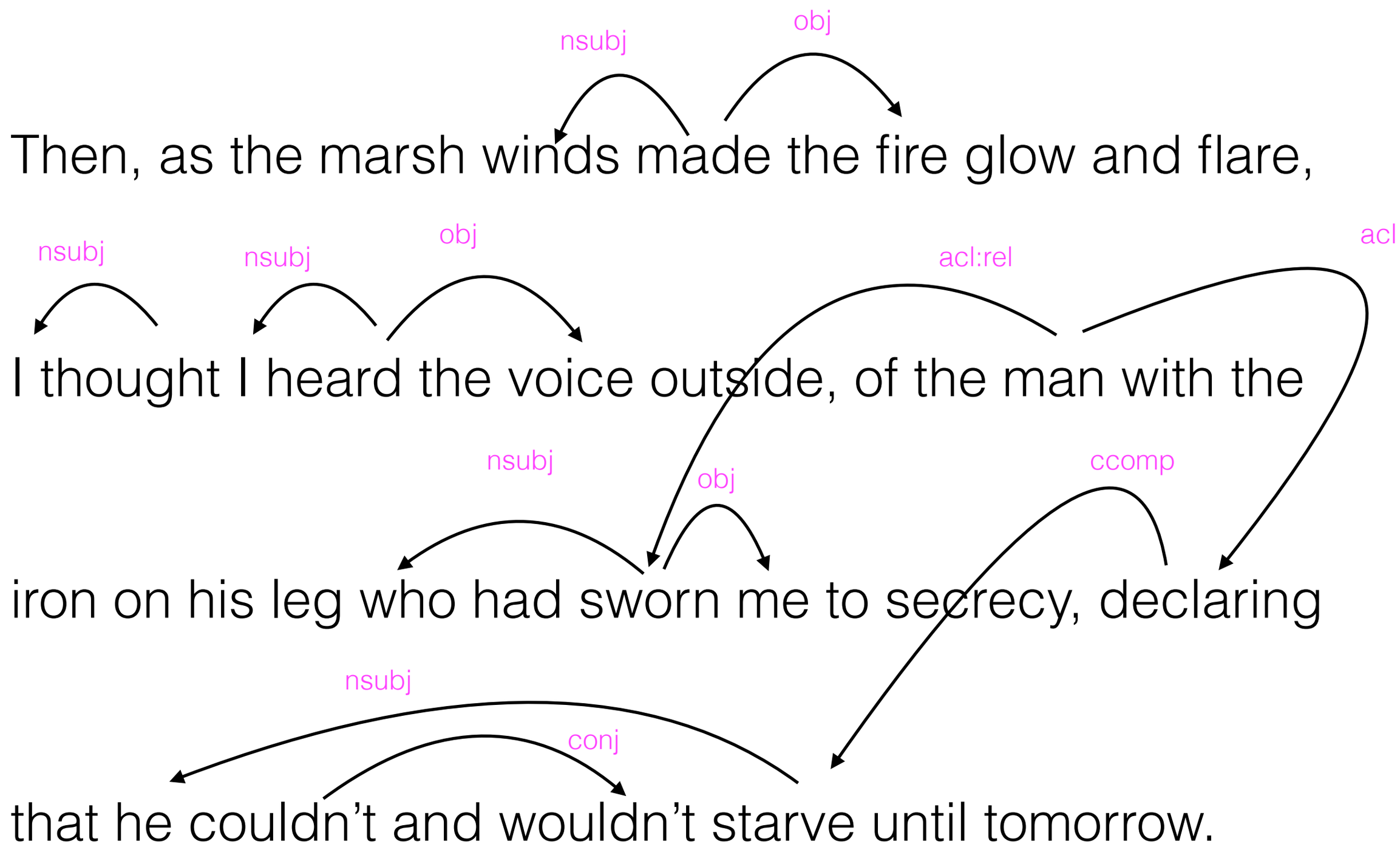


aux adds tense, aspect, mood, voice or evidentiality

cop



cop links a non-verbal predicate to subject



[Great Expectations]

Thursday

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