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The Logic of Universal Dependencies

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Department of Linguistics and Philology

Based on collaborative work with Marie-Catherine de Marneffe, Filip Ginter, Yoav Goldberg, Jan Hajic, Christopher Manning, Ryan McDonald, Natalia Silveira, Slav Petrov, Sampo Pyysalo, Sebastian Schuster, Reut Tsarfaty, Francis Tyers, Daniel Zeman and many others

Introduction

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Growing interest in multilingual and cross-lingual NLP

- Multilingual evaluation campaigns to test generality of approaches
- Cross-lingual learning to support low-resource languages

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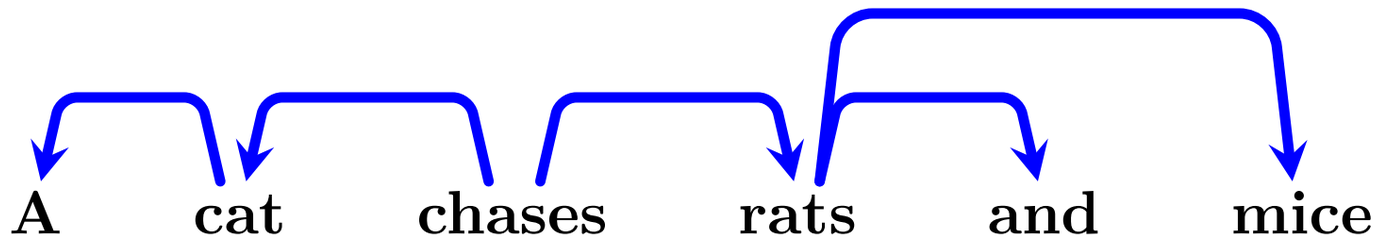
Growing awareness of methodological problems

- Current NLP relies heavily on linguistic annotation
- Annotation guidelines vary across languages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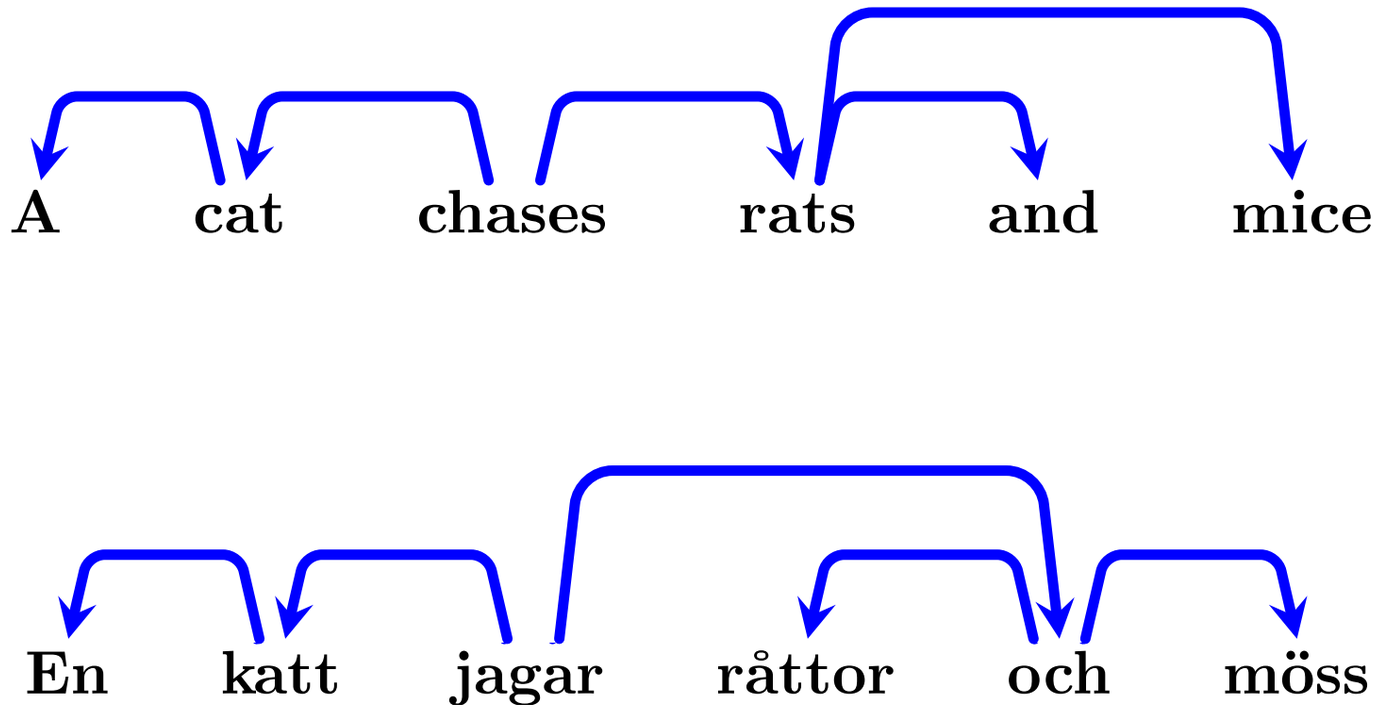
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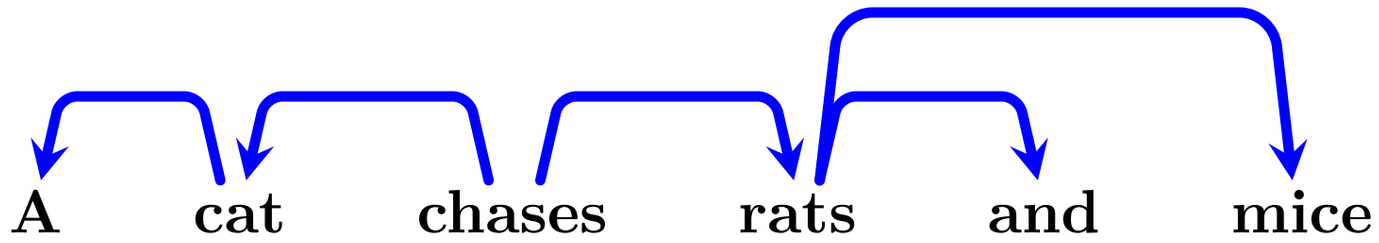
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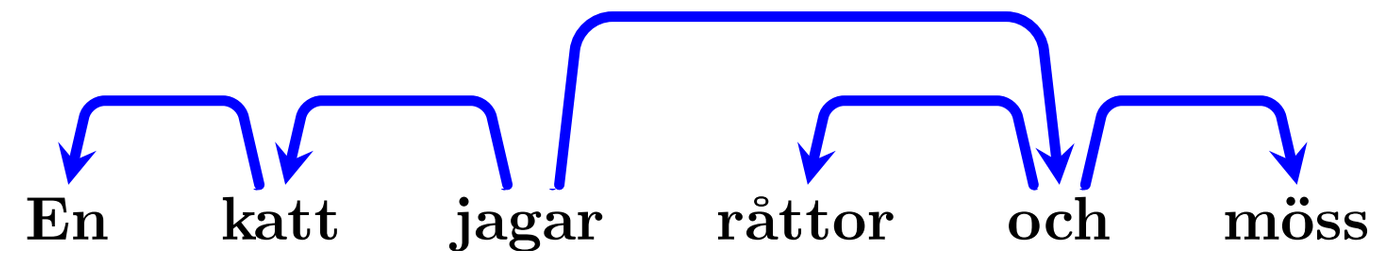
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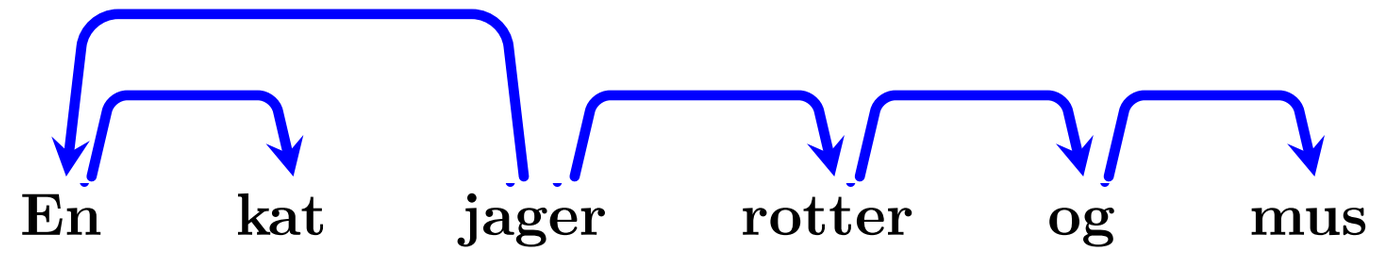
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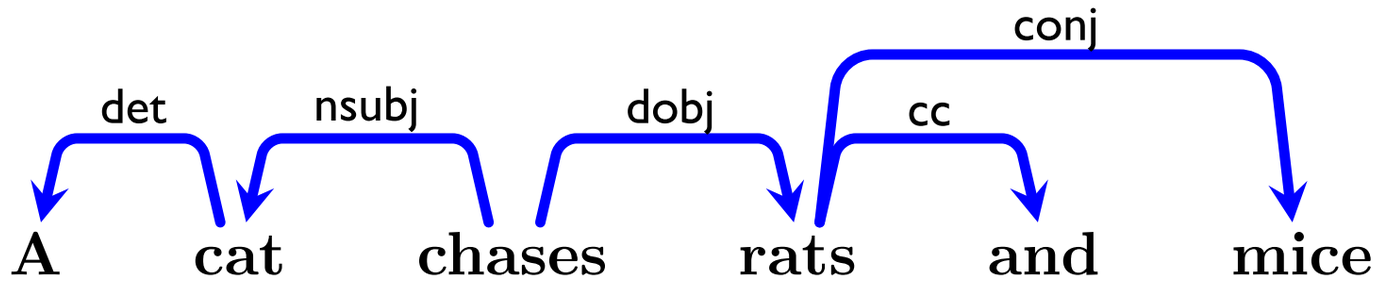
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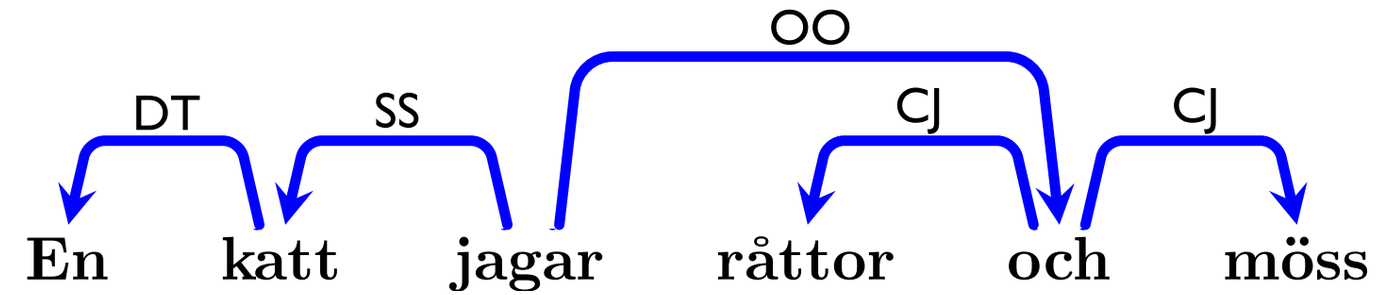
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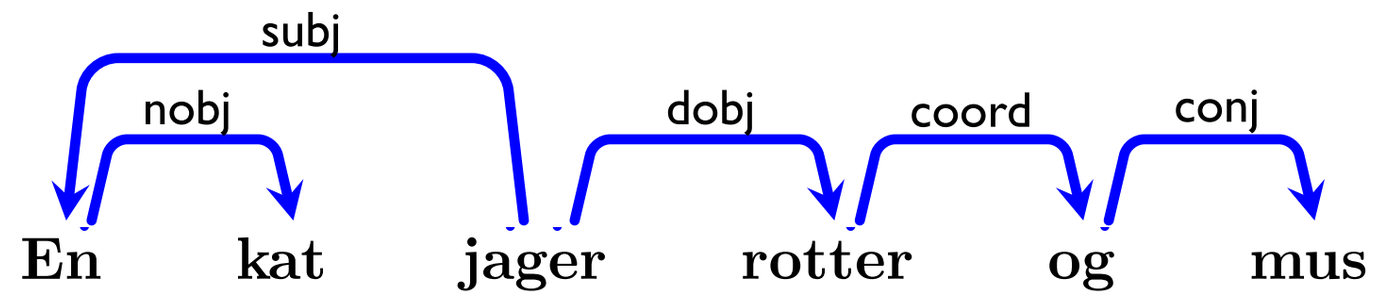
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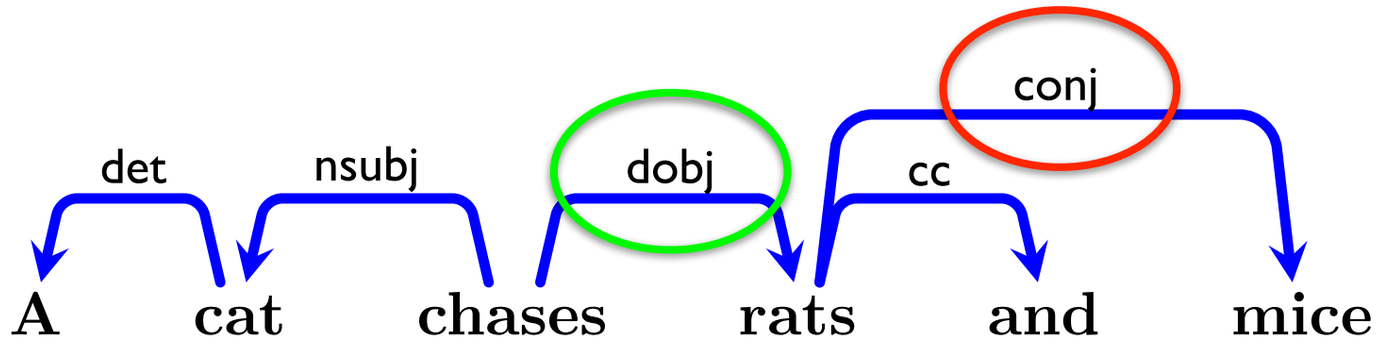
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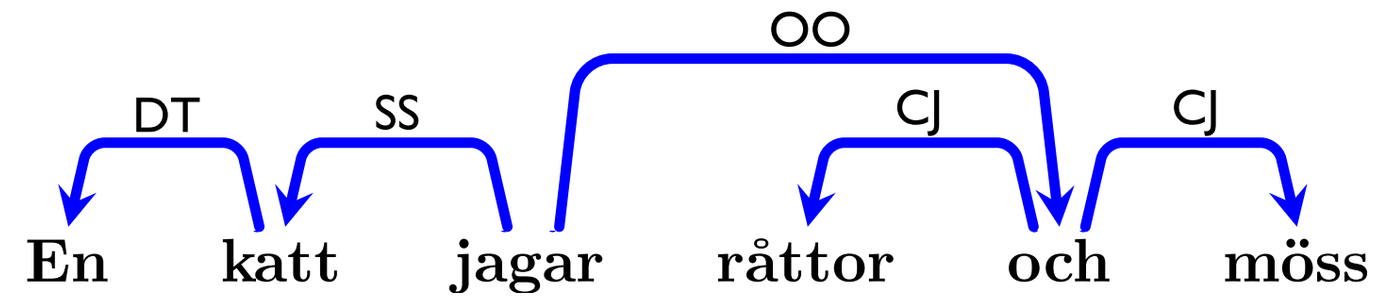
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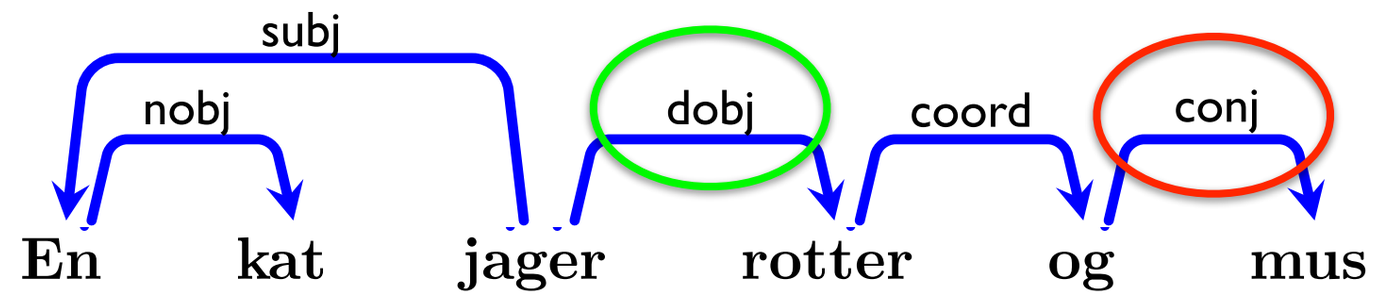
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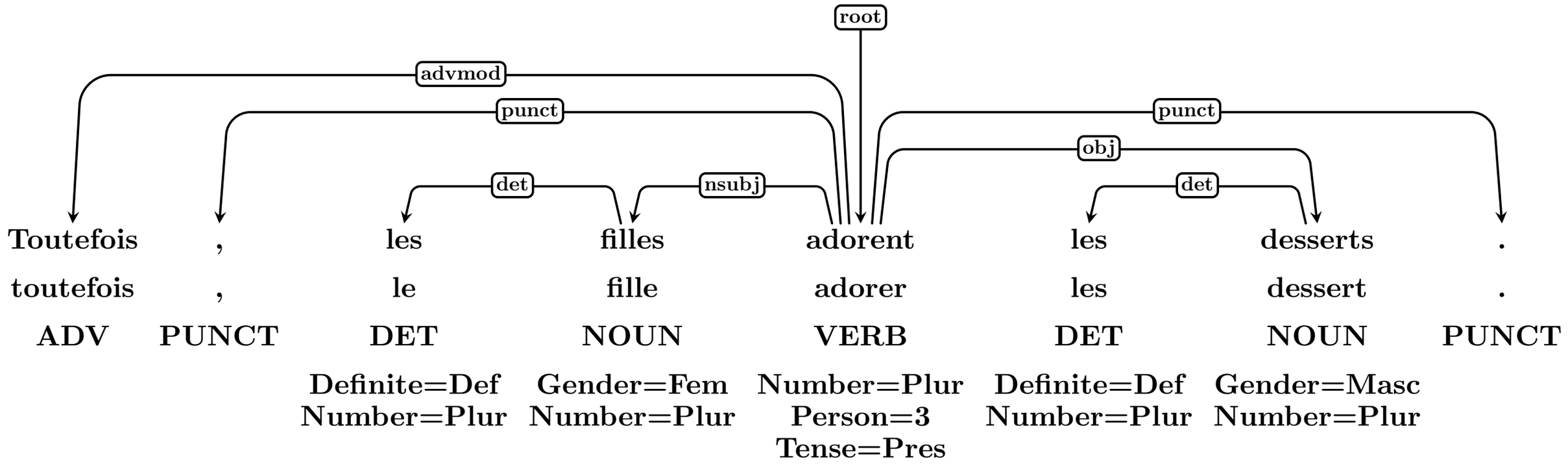
- Hard to make progress towards a universal parser

Universal Dependencies

http://universaldependencies.org



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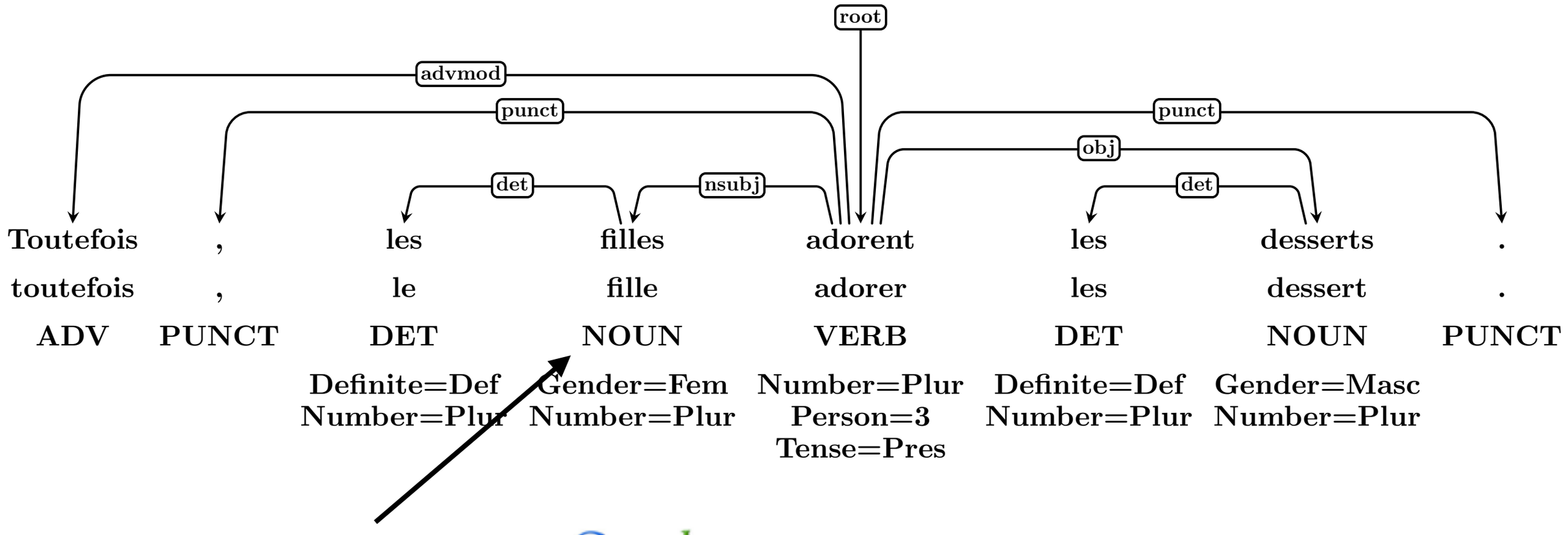

Part-of-speech tags Google

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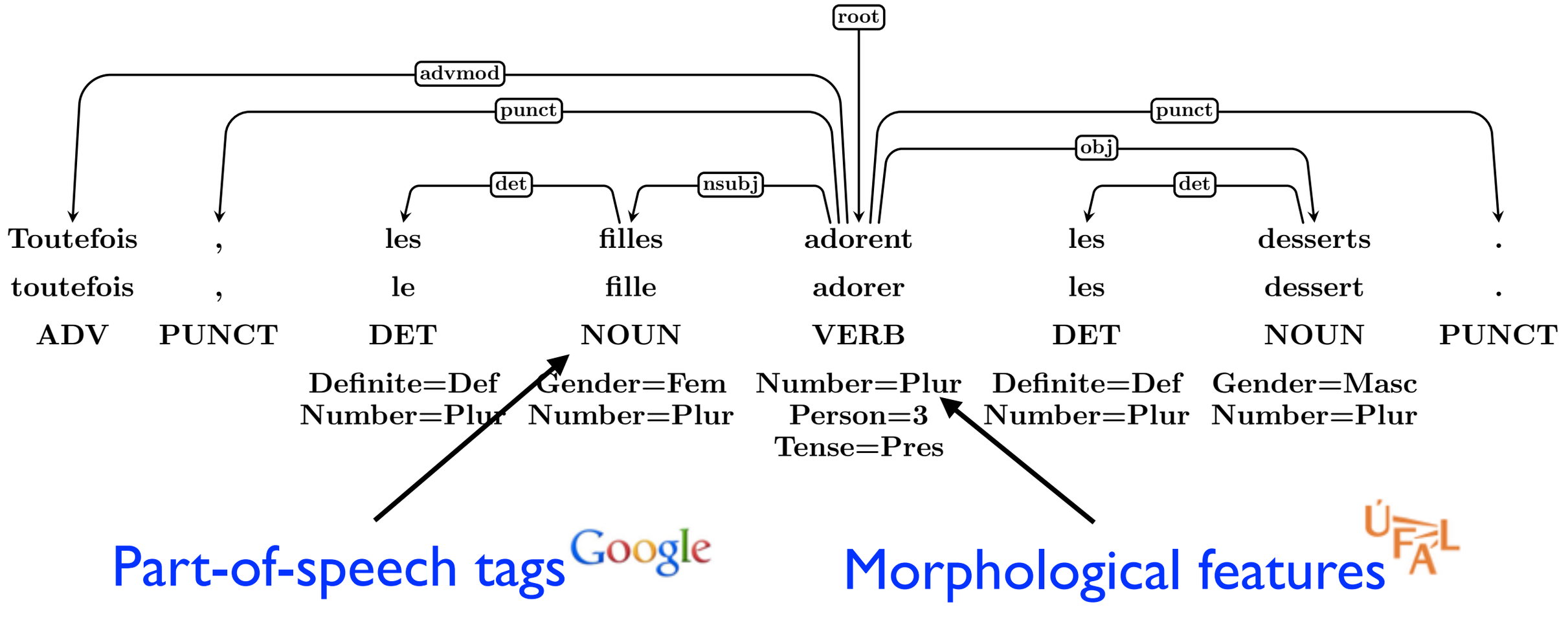

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Morphological features ÚFAL

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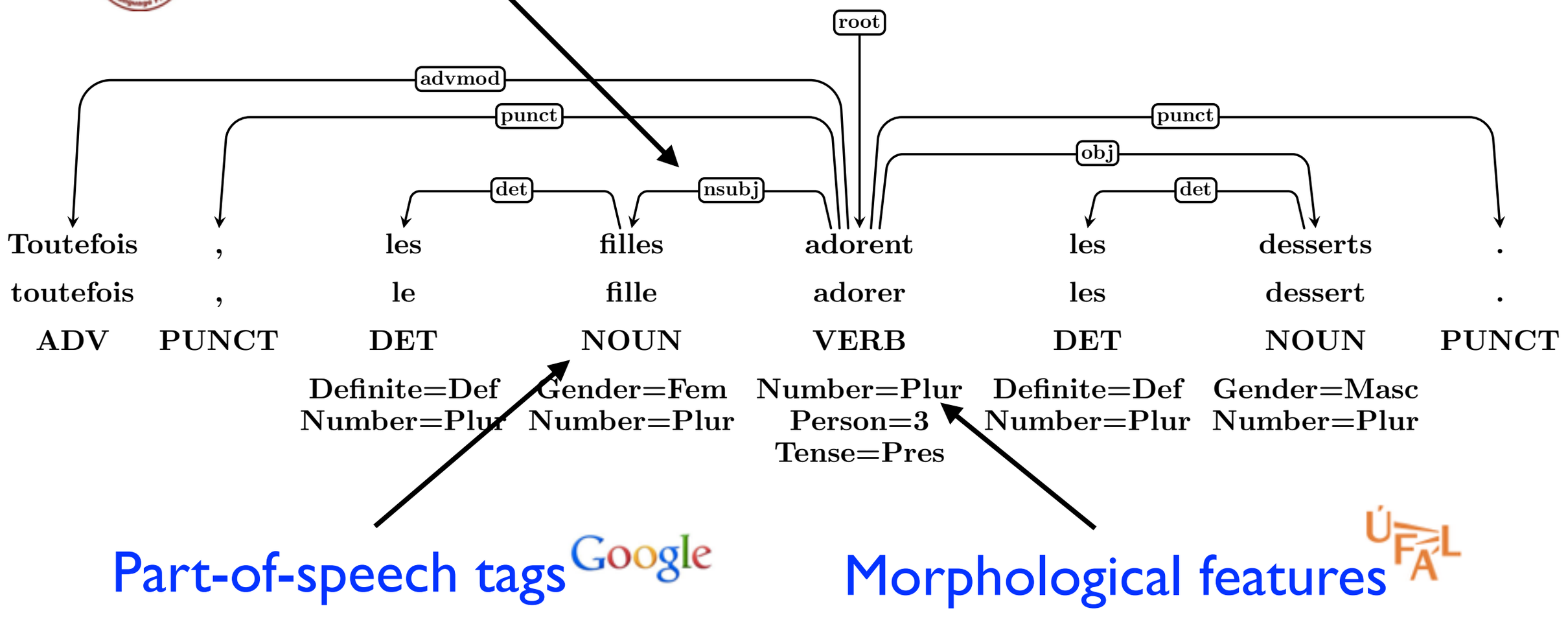
Dependency relations



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Brief history of UD:

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- Guidelines v1, October 2014
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Open community effort – anyone can contribute!

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Ancient Greek-PROIEL	211K						
Arabic	242K						
Arabic-NYUAD	629K						
Arabic-PUD	20K						
Basque	121K						
Belarusian	6K						
Bulgarian	156K						
Buryat	10K						
Catalan	530K						
Chinese	123K						
Chinese-PUD	21K						
Coptic	3K						
Croatian	197K						
Czech	1,330K						
Czech-CAC	493K						
Czech-CLTT	37K						
Czech-PUD	18K						
Danish	100K						
Dutch	209K						
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English	254K						
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French-Sequoia	68K						
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Galician-TreeGal	23K						
German	287K						
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Gothic	55K						
Greek	61K						
Hebrew	115K						
Hindi	351K						
Hindi-PUD	23K						
Hungarian	42K						
Indonesian	121K						
Indonesian-PUD	25K						
Irish	23K						
Italian	273K						
Italian-PUD	22K						
Italian-ParTUT	39K						
Japanese	186K						
Japanese-KTC	189K						
Japanese-PUD	26K						
Kazakh	10K						
Korean	74K						
Korean-PUD	22K						
Korean-Sejong	89K						
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Latin	29K						
Latin-ITTB	291K						
Latin-PROIEL	171K						
Latvian	54K						
Lithuanian	5K						
Maltese	2K						
North Sami	55K						
Norwegian-Bokmaal	310K						
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Old Church Slavonic	57K						

June, 2017:

- 56 languages
- 95 treebanks
- 13.9 million words
- 202 contributors
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Chief Cat Herder

Release and Documentation Task Force

Universal Guidelines Group

The UD Philosophy

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Maximize parallelism – but don't overdo it

- Don't annotate the same thing in different ways
- Don't make different things look the same
- Don't annotate things that are not there

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Universal taxonomy with language-specific elaboration

- Languages select from a universal pool of categories
- Allow language-specific extensions

Design Principles

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Dependency

- Widely used in practical NLP systems
- Available in treebanks for many languages

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Lexicalism

- Basic annotation units are words – syntactic words
- Words have morphological properties
- Words enter into syntactic relations

Morphology

Le **chat** **chasse** **les** **chiens** **.**

Morphology

Le	**chat**	**chasse**	**les**	**chiens**	**.**
le	**chat**	**chasser**	**le**	**chien**	**.**

- Lemma representing the semantic content of the word

Morphology

Le	**chat**	**chasse**	**les**	**chiens**	**.**
le	**chat**	**chasser**	**le**	**chien**	**.**
DET	**NOUN**	**VERB**	**DET**	**NOUN**	**PUNCT**

- Lemma representing the semantic content of the word
- Part-of-speech tag representing its grammatical class

Morphology

Open	Closed	Other
ADJ	ADP	PUNCT
ADV	AUX	SYM
INTJ	CCONJ	X
NOUN	DET	
PROPN	NUM	
VERB	PART	
	PRON	
	SCONJ	

Le … **hiens** **.**

le … **hien** **.**

DET **N** … **OUN** **PUNCT**

- Lemma rep … of the word
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Morphology

Le	chat	chasse	les	chiens	.
le	chat	chasser	le	chien	.
DET	NOUN	VERB	DET	NOUN	PUNCT
Definite=Def Gender=Masc Number=Sing	Gender=Masc Number=Sing	Mood=Ind Number=Sing Person=3 Tense=Pres VerbForm=Fin	Definite=Def Gender=Masc Number=Plur	Gender=Masc Number=Plur	

- Lemma representing the semantic content of the word
- Part-of-speech tag representing its grammatical class
- Features representing lexical and grammatical properties of the lemma or the particular word form

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Le				hiens	.
le				hien	.
DET	N			OUN	PUNCT
Definite=Def Gender=Masc Number=Sing	Gend Num			er=Masc er=Plur	

Lexical	Inflectional Nominal	Inflectional Verbal
PronType	Gender	VerbForm
NumType	Animacy	Mood
Poss	Number	Tense
Reflex	Case	Aspect
Foreign	Definite	Voice
Abbr	Degree	Evident
		Polarity
		Person
		Polite

- Lemma rep of the word
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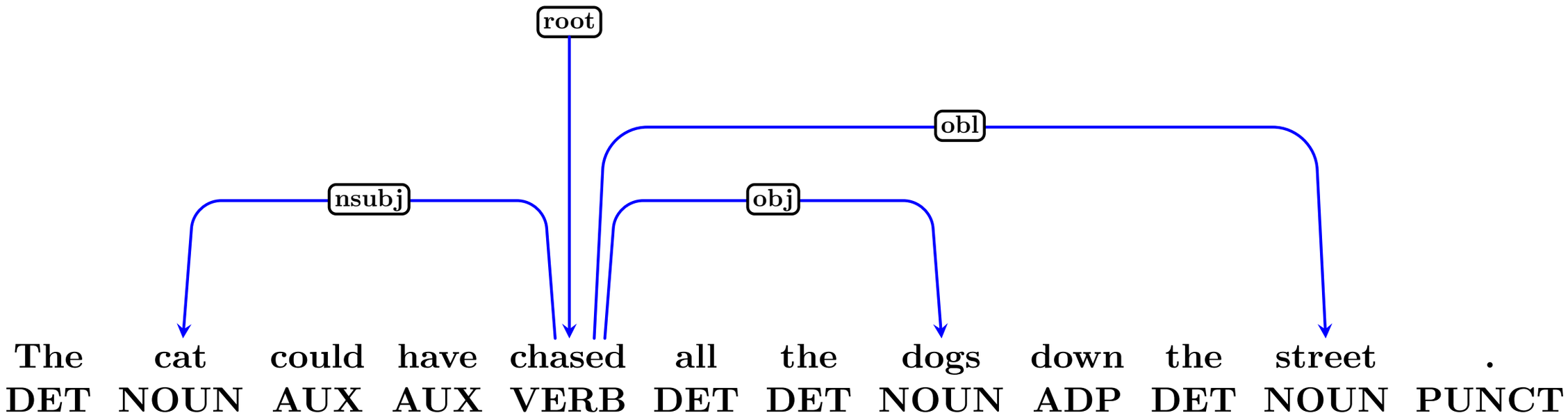
Syntax

The	cat	could	have	chased	all	the	dogs	down	the	street	.
DET	NOUN	AUX	AUX	VERB	DET	DET	NOUN	ADP	DET	NOUN	PUNCT

Syntax



- Content words are related by dependency relations

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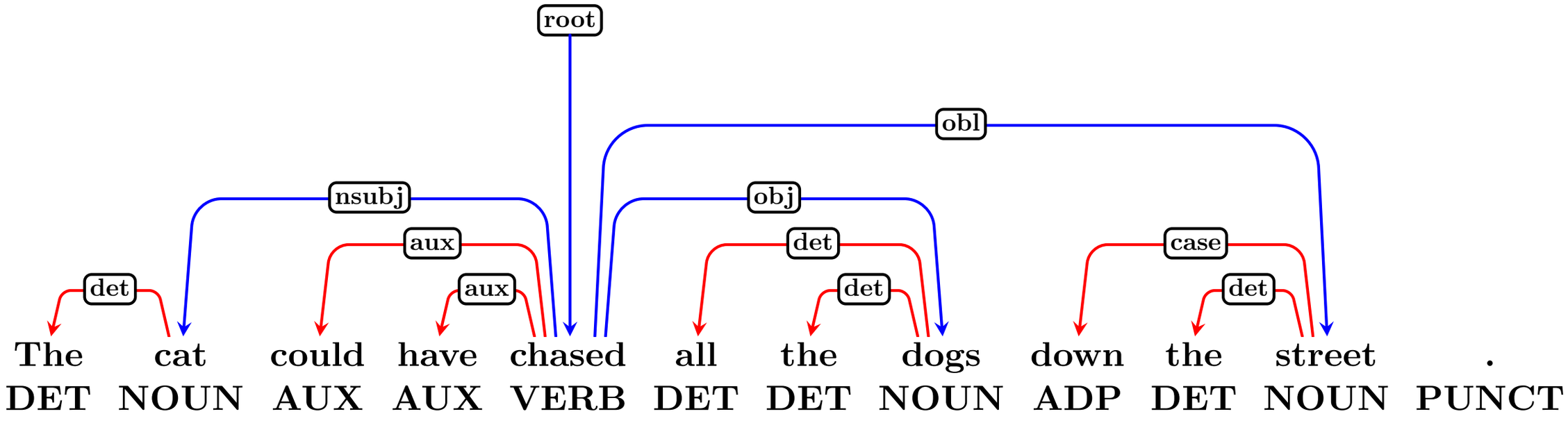

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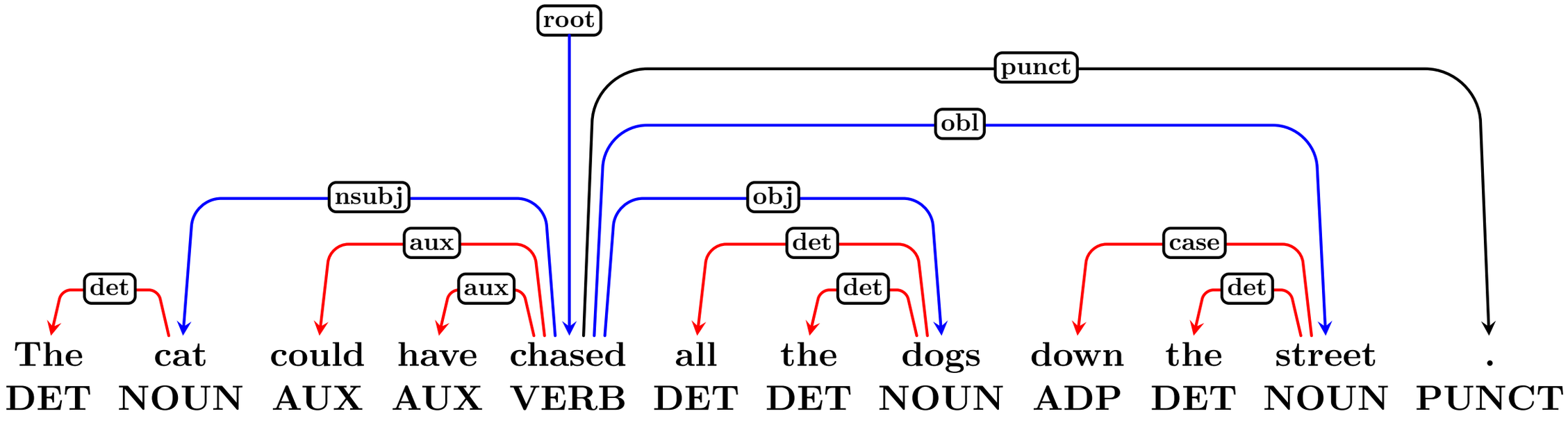

- Content words are related by dependency relations
- Function words attach to the content word they modify
- Punctuation attach to head of phrase or clause

Syntactic Relations

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Taxonomy of 37 universal syntactic relations

- Three types of structures: nominals, clauses, modifiers
- Core arguments vs. other dependents (not complements vs. adjuncts)

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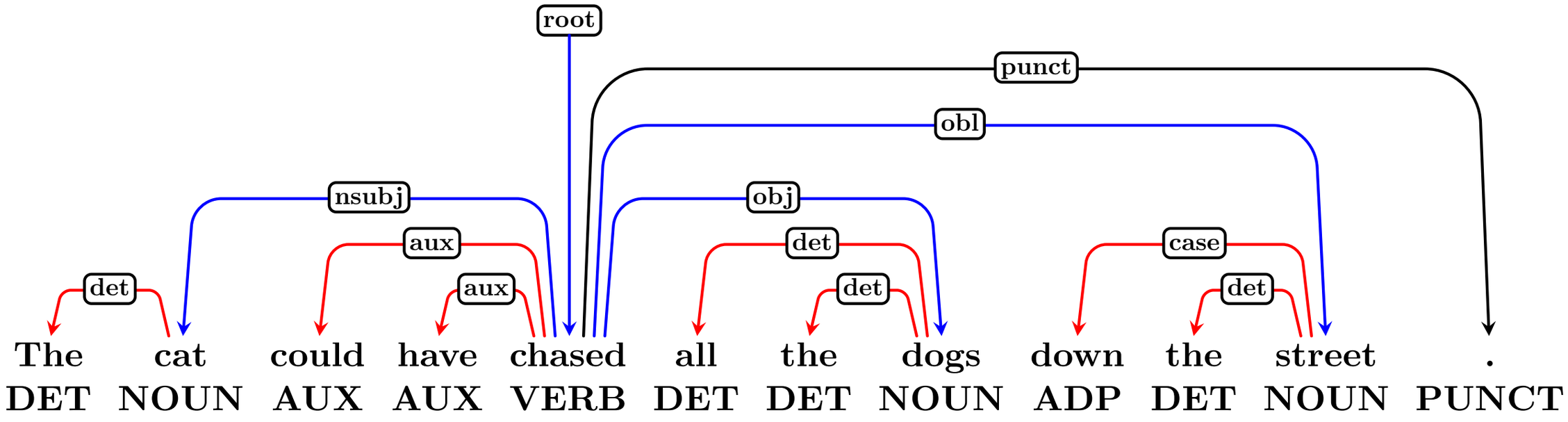
A two-level architecture

- Broad universal categories to allow cross-linguistic comparison
- Subtypes to capture language-specific phenomena

Syntactic Relations

	Nominal	Clause	Modifier Word	Function Word
Core Predicate Dep	nsubj obj iobj	csubj ccomp xcomp		
Non-Core Predicate Dep	obl vocative expl dislocated	advcl	advmod* discourse	aux cop mark
Nominal Dep	nmod appos nummod	acl	amod	det clf case
Coordination	**MWE**	**Loose**	**Special**	**Other**
conj cc	fixed flat compound	parataxis list	orphan goeswith reparandum	punct root dep

The Primacy of Content Words



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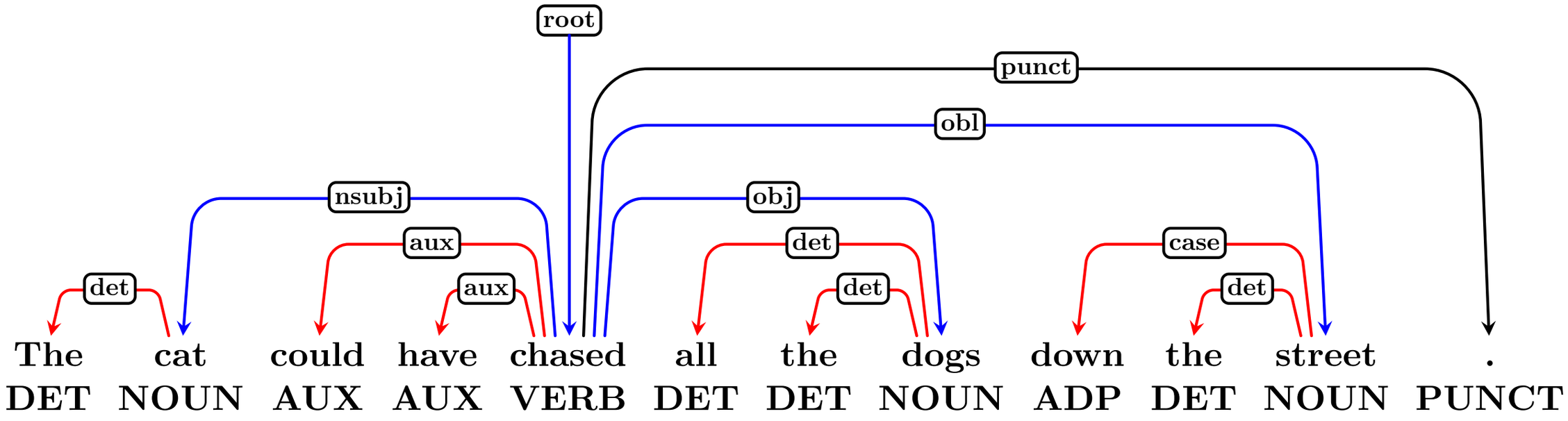
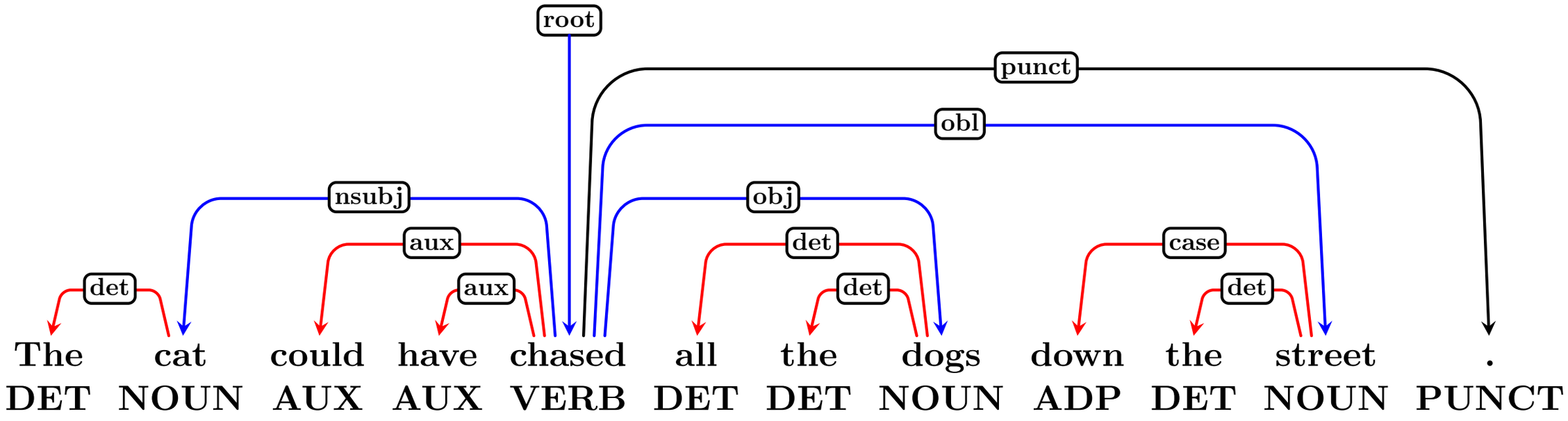


Dubious Linguistics?

"Such an approach to the syntax of natural languages is contrary to most work in theoretical syntax in the past 35 years, regardless of whether this work is constituency- or dependency-based." (Groß and Osborne, 2015)

The Primacy of Content Words



Bad for parsing?

"It is now fairly well known that, while dependency representations in which content words are made heads tend to help semantically oriented downstream applications, dependency parsing numbers are higher if you make auxiliary verbs heads […] and if you make prepositions the head of prepositional phrases." (De Marneffe et al., 2014)

Manning's Law

The secret to understanding the design of UD is to realize that it is a very subtle compromise between approximately 6 things:

1. **UD needs to be satisfactory on linguistic analysis grounds for individual languages.**
2. **UD needs to be good for linguistic typology, i.e., providing a suitable basis for bringing out cross-linguistic parallelism across languages and language families.**
3. **UD must be suitable for rapid, consistent annotation by a human annotator.**
4. **UD must be suitable for computer parsing with high accuracy.**
5. **UD must be easily comprehended and used by a non-linguist, whether a language learner or an engineer with prosaic needs for language processing.**
6. **UD must support well downstream language understanding tasks (relation extraction, reading comprehension, machine translation, …).**

It's easy to come up with a proposal that improves UD on one of these dimensions. The interesting and difficult part is to improve UD while remaining sensitive to all these dimensions.

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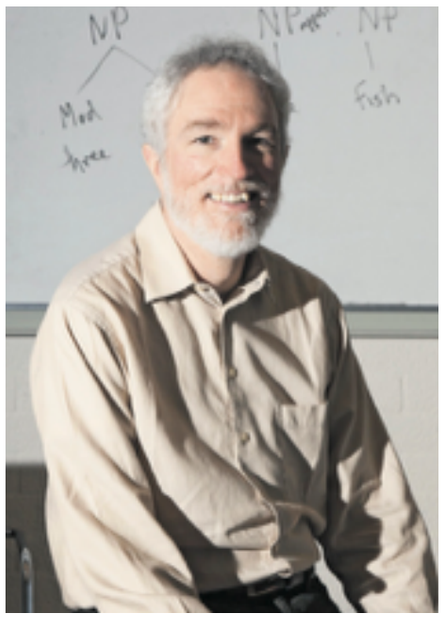
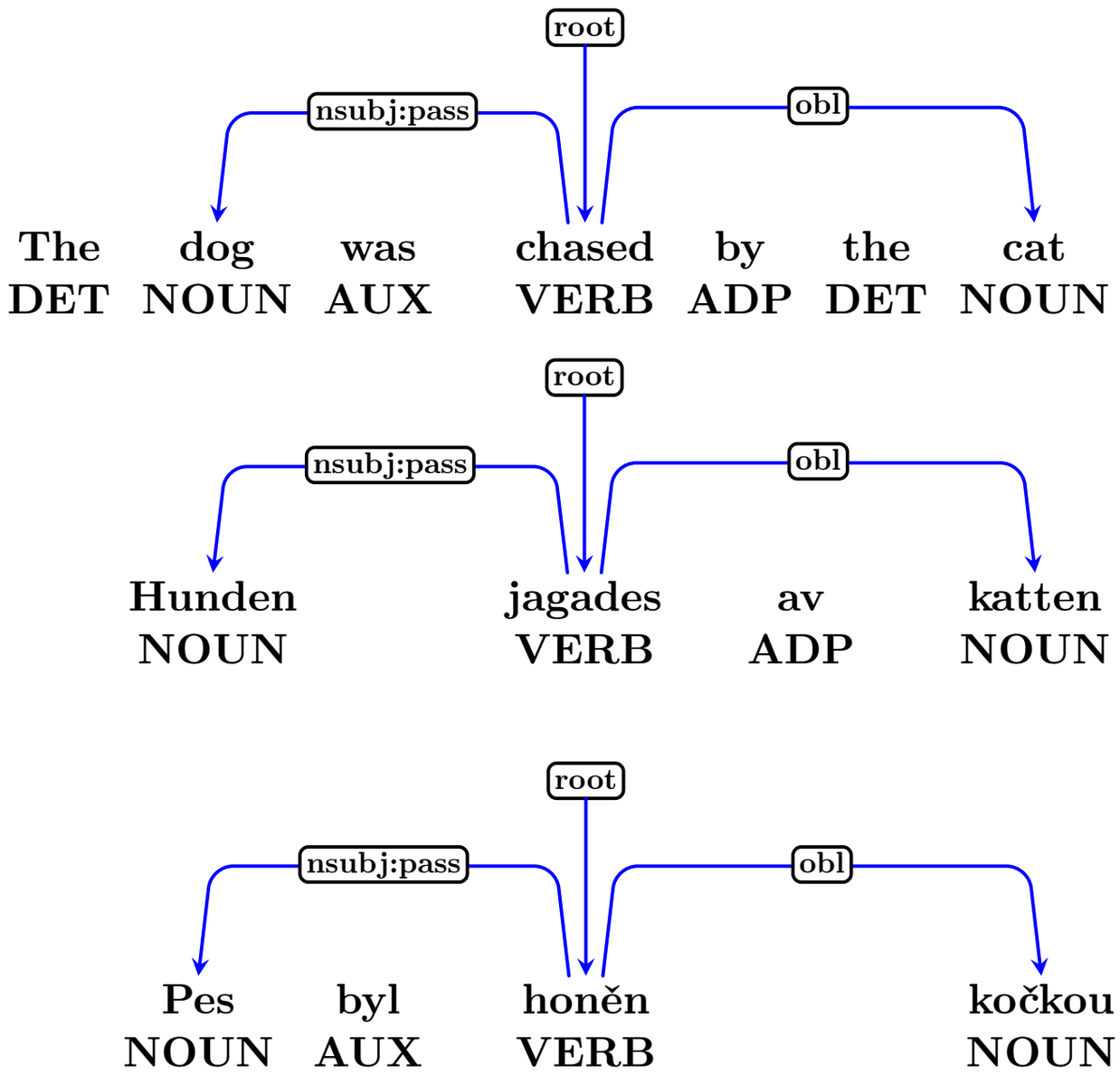
Linguistic Typology

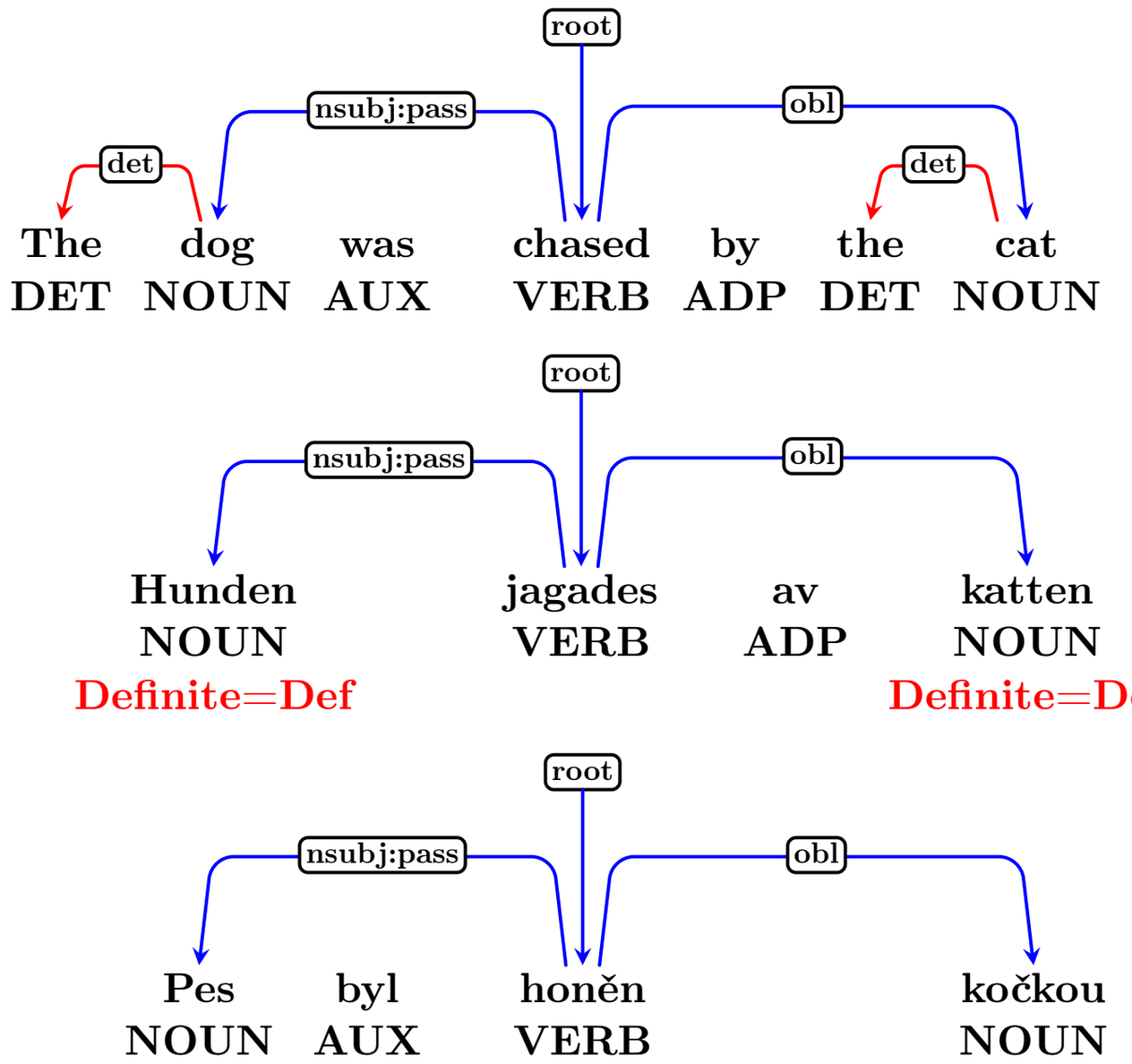


With contributions by William Croft

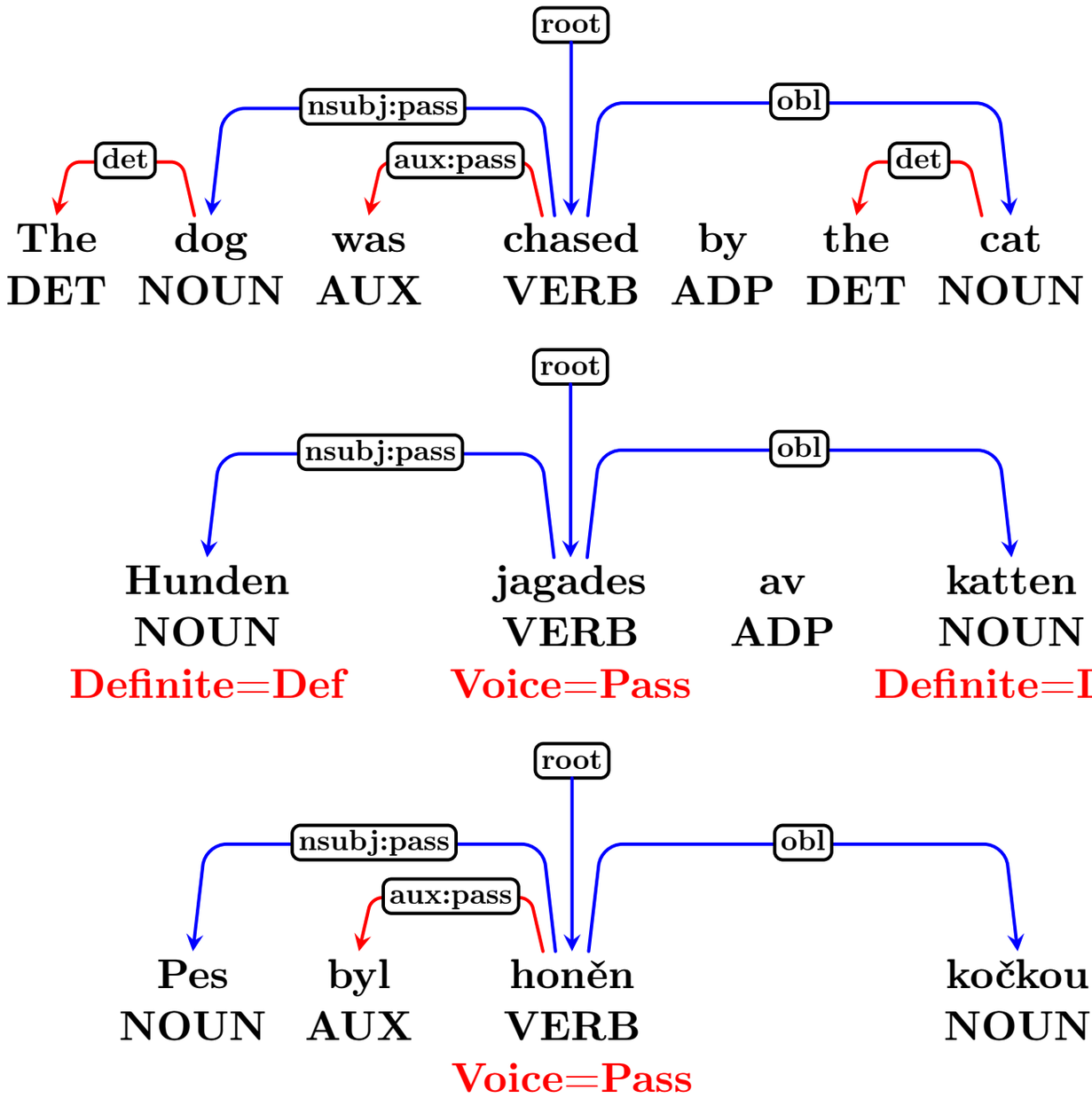
Similarities and Differences



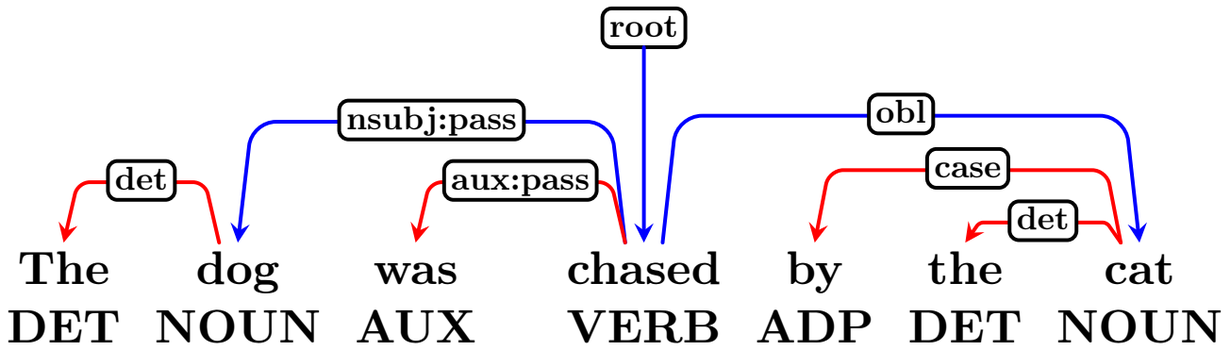
Similarities and Differences

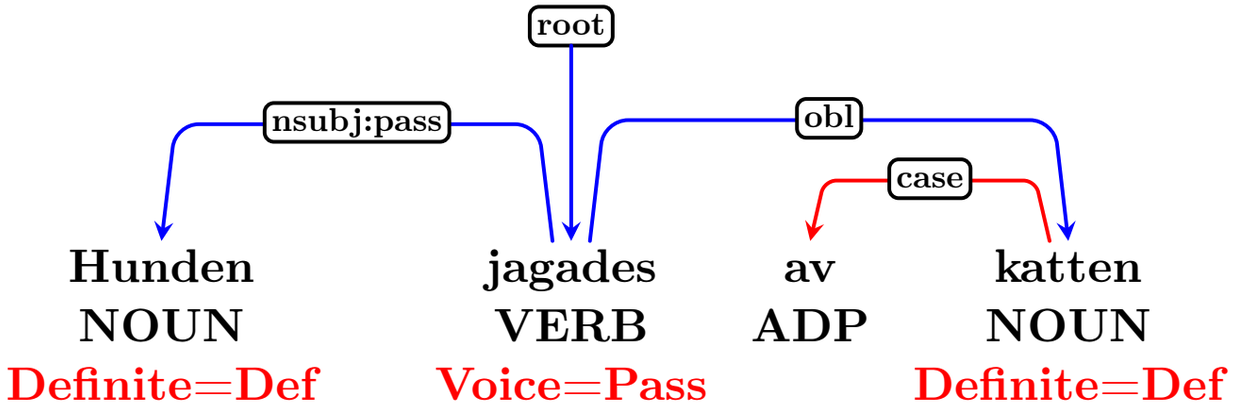


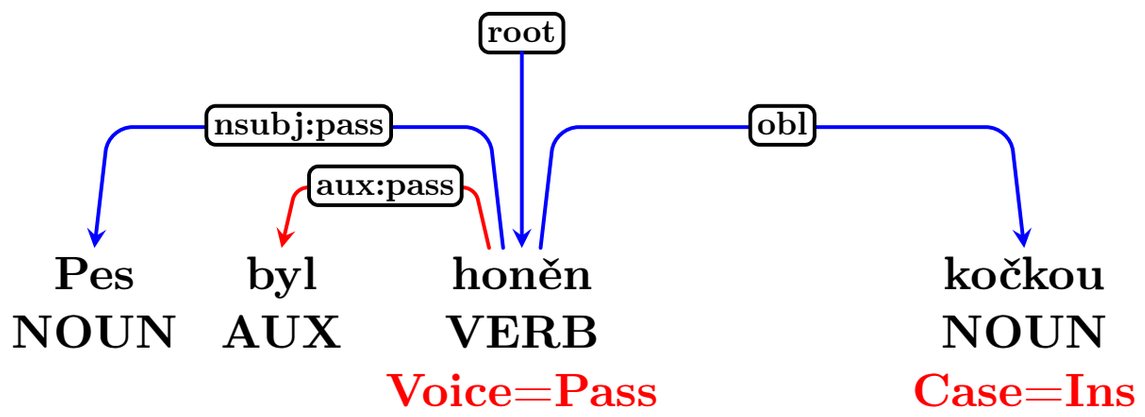
Similarities and Differences



Similarities and Differences







What is universal?

What is universal?

- Descriptive categories – language-specific, cannot be equated across languages
- Comparative concepts – created by typologists for cross-linguistic comparison

Haspelmath (2010) Comparative Concepts and Descriptive Categories in Crosslinguistic Studies

What is universal?

- Descriptive categories – language-specific, cannot be equated across languages
- Comparative concepts – created by typologists for cross-linguistic comparison

Haspelmath (2010) Comparative Concepts and Descriptive Categories in Crosslinguistic Studies

- Construction – whatever structure is used to express a function, universal by definition
- Strategy – a specific, cross-linguistically definable structure used to express a function

Croft et al. (2017) Linguistic Typology Meets Universal Dependencies

Construction

Strategies

predication of object concept

inflected copula

English:
Ivan is the best dancer.

Russian:
Ivan lučšij tancor

zero copula/zero inflection

Croft et al. (2017) Linguistic Typology Meets Universal Dependencies

- A universal annotation scheme should have a classification of constructions, not strategies, as its universal foundational layer

Croft et al. (2017) Linguistic Typology Meets Universal Dependencies

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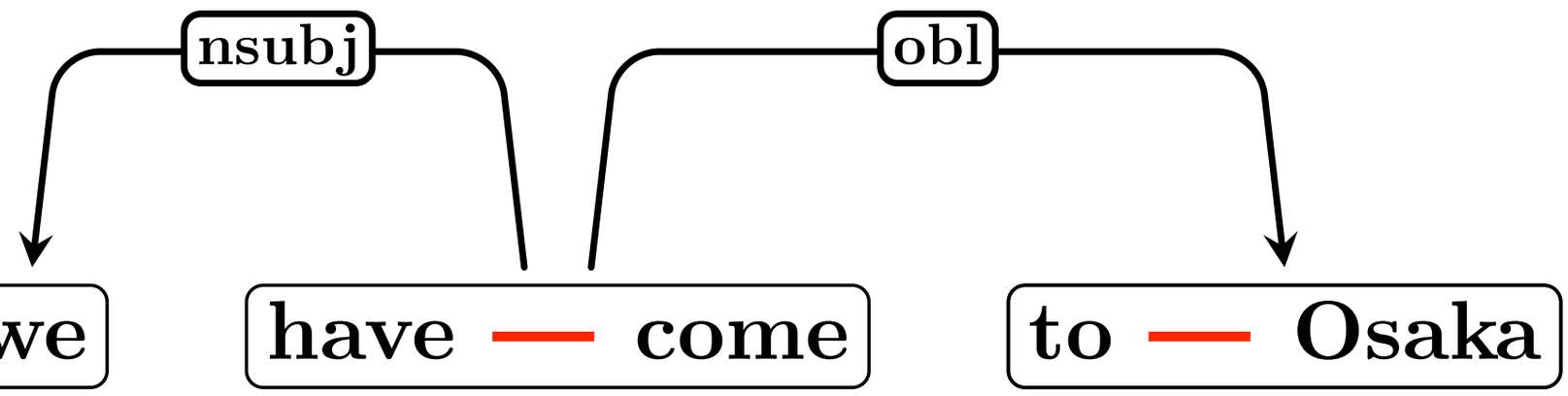
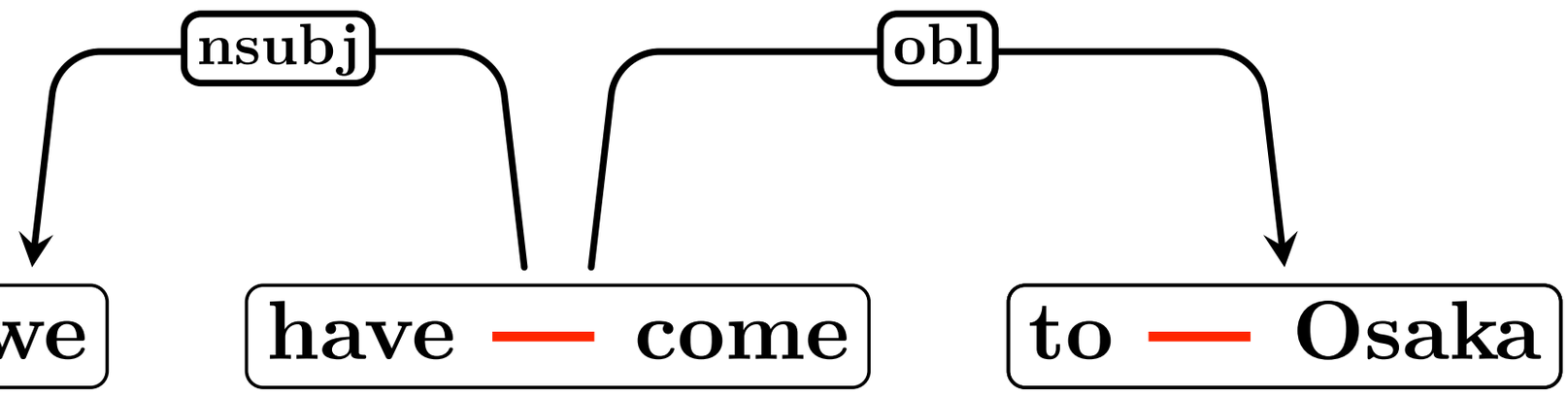
Croft et al. (2017) Linguistic Typology Meets Universal Dependencies

- A universal annotation scheme should have a classification of constructions, not strategies, as its universal foundational layer
- However, common recurrent strategies can and should be included as well
- The primacy of content words in UD is good, because function words such as copulas are strategies and not found in every language
- This means that the topology of dependency trees in UD are basically fine from a typological-universal point of view

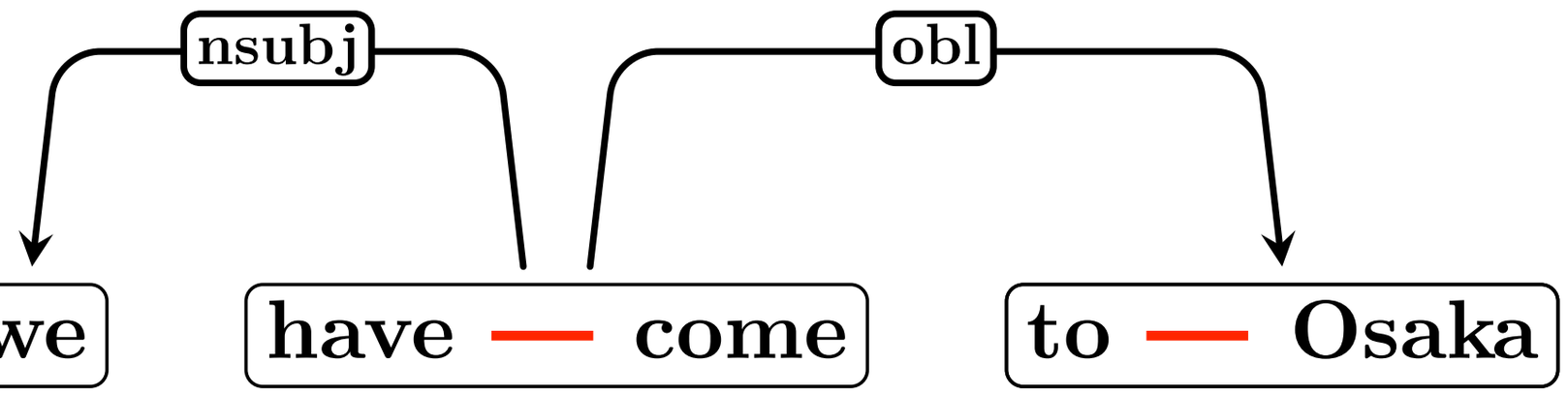
Croft et al. (2017) Linguistic Typology Meets Universal Dependencies



dependency	nucleus



dependency	nucleus
karaka	vibhakti



dependency	nucleus
karaka	vibhakti
kakariuke	bunsetsu

Conclusion – Part I

The primacy of content words

- Perhaps incompatible with some approaches to theoretical syntax
- Compatible with current approaches to linguistic typology
- Consistent with older traditions of dependency grammar

Natural Language Understanding

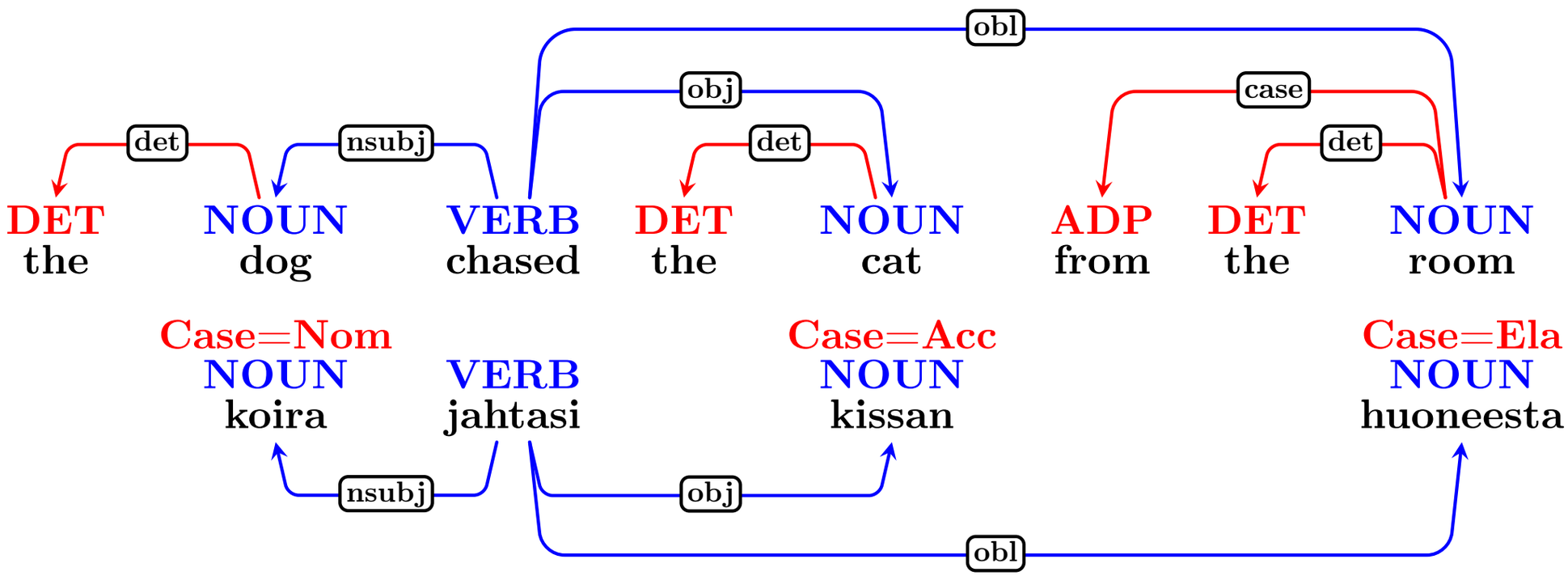






With contributions (and slides) by Siva Reddy et al.

From Syntax to Semantics



- Direct relations from predicates to arguments/modifiers
- Cross-linguistically consistent patterns
- Universal syntax-semantics interface?

UDepLambda



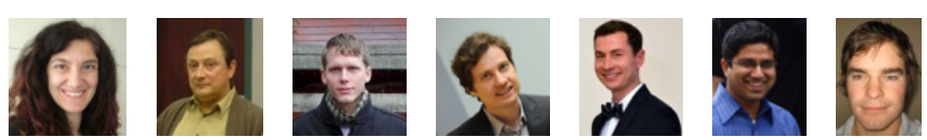




UDepLambda

Goals

- From dependencies to logical forms
- Compositional, language-agnostic conversion
- Dependency tree dictates the semantics



UDepLambda

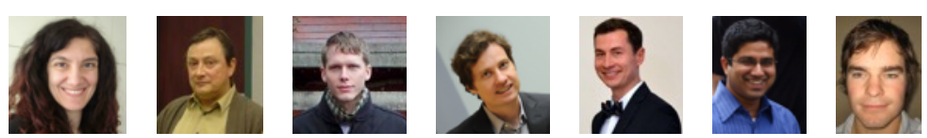
Goals

- From dependencies to logical forms
- Compositional, language-agnostic conversion
- Dependency tree dictates the semantics

Compositionality

The semantics of a complex expression is determined by the semantics of its constituent expressions and the rules used to combine them

- Complex expressions are dependency trees
- Constituent expressions are subtrees
- Rules are dependency labels



Why Dependencies?

Dependency Tree to Semantics

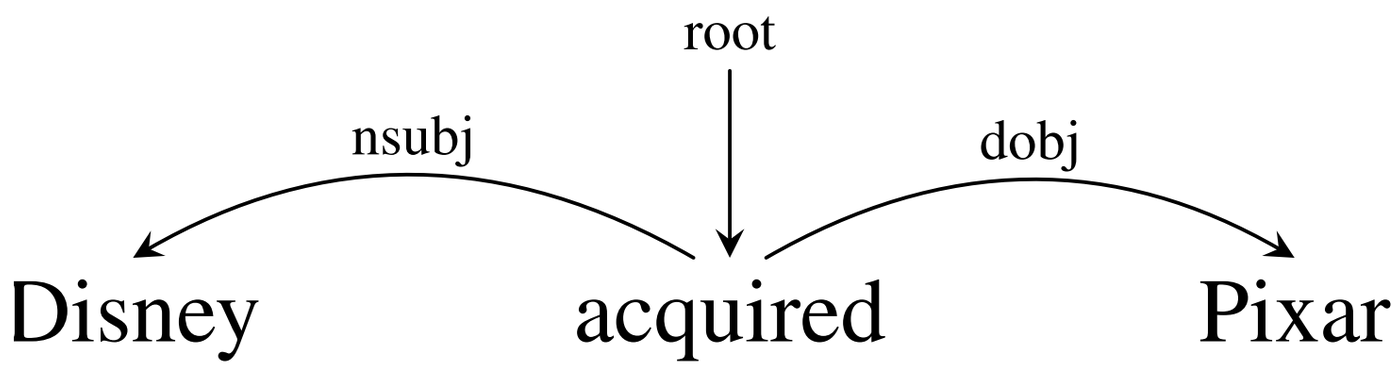
Dependencies lack a formal theory of semantics

CCG

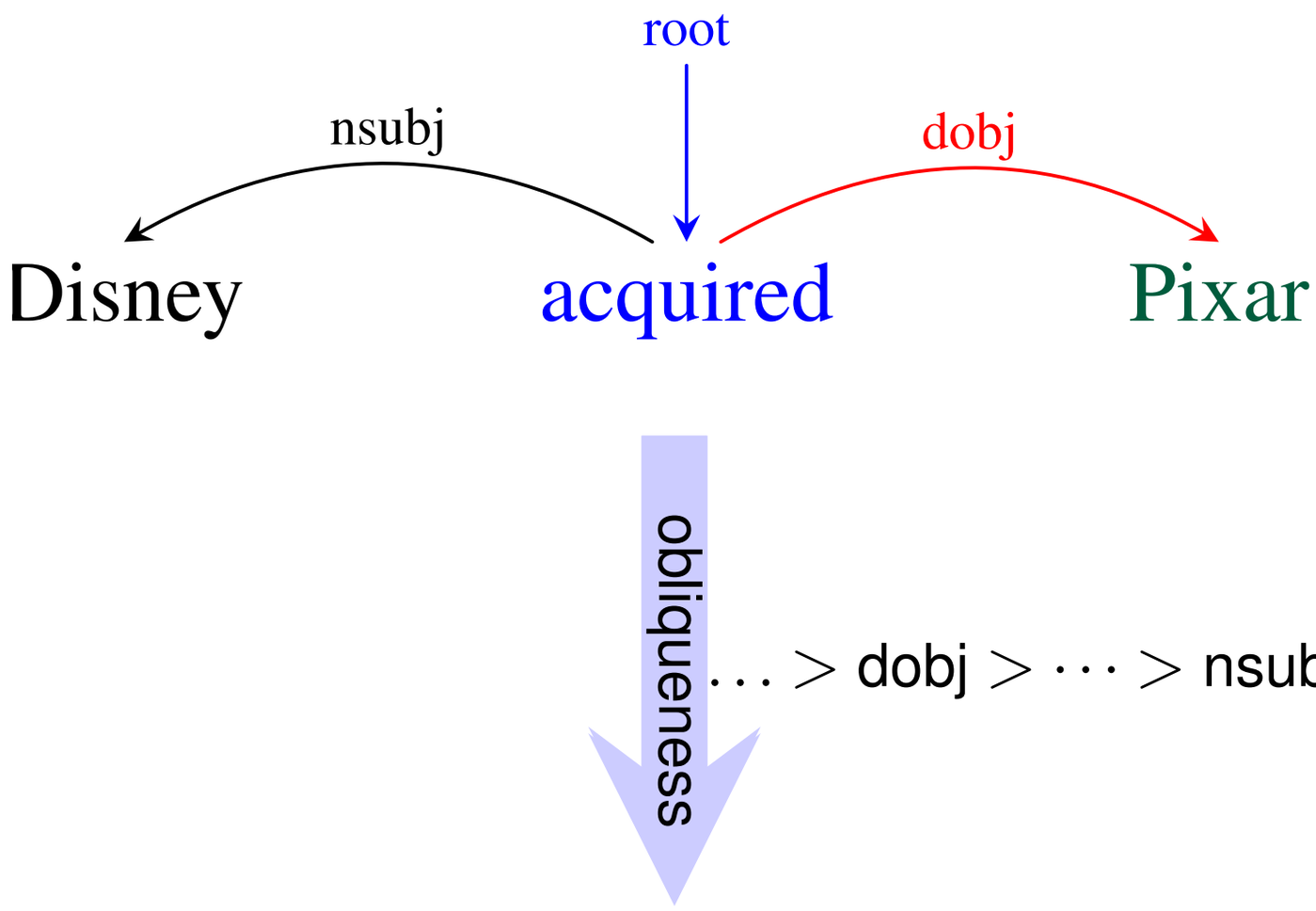
$$\dfrac{\dfrac{\text{Disney}}{NP} \quad \dfrac{\text{acquired}}{S\backslash NP/NP} \quad \dfrac{\text{Pixar}}{NP}}{\dfrac{\text{Disney} \quad \lambda y\lambda x\lambda e.\ \text{acquired}(e) \wedge \text{arg}_1(e,x) \wedge \text{arg}_2(e,y) \quad \text{Pixar}}{\dfrac{S\backslash NP}{\dfrac{\lambda e.\ \text{acquired}(e) \wedge \text{arg}_1(e,\text{Disney}) \wedge \text{arg}_2(e,\text{Pixar})}{S}}<}}>$$

Typing and Combinator Rules allow
Synchronous Syntax-Semantics interface

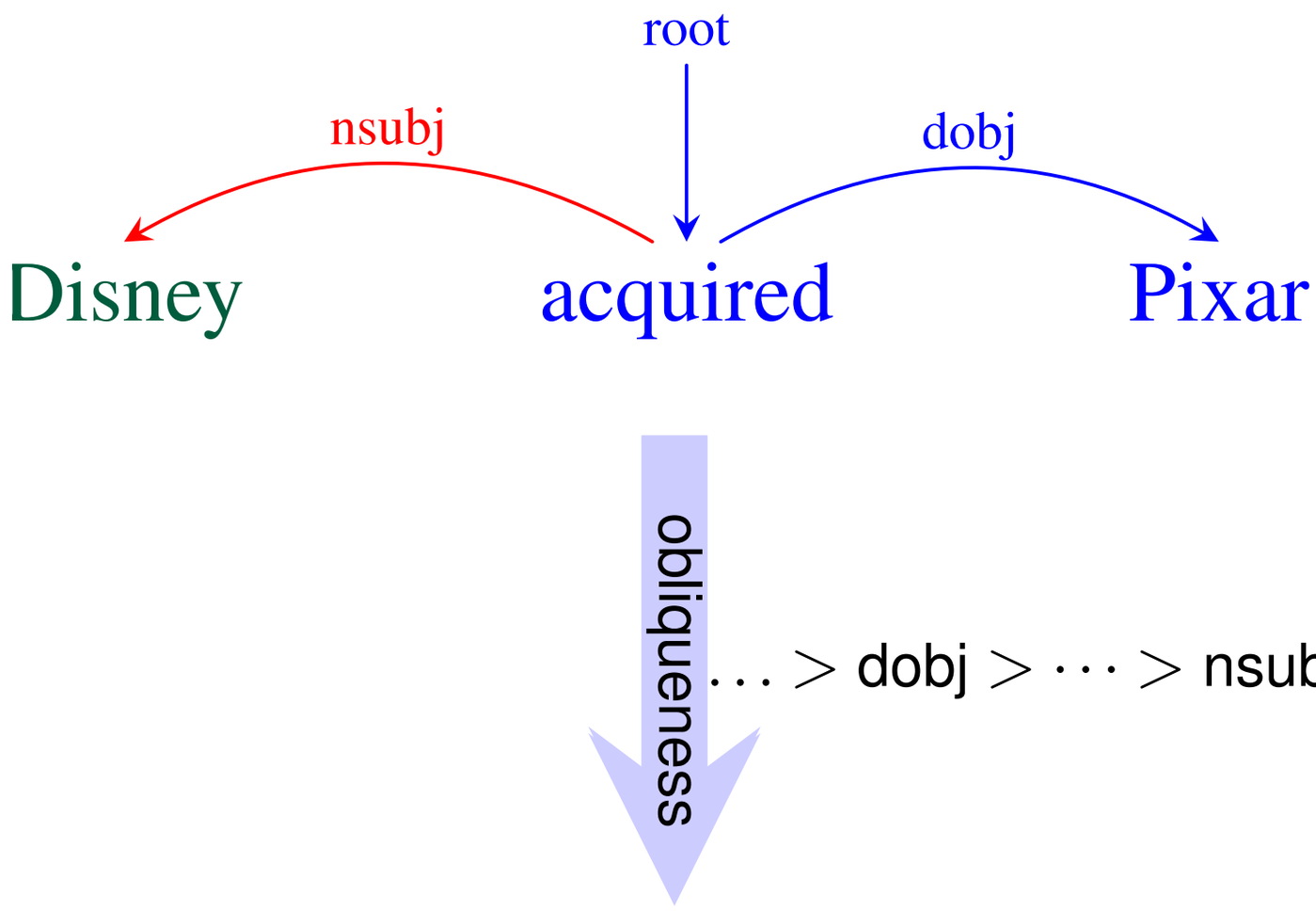
- Easy to annotate (with UD annotation scheme)
- Treebanks exist in many languages
- Robust, efficient, accurate parsers



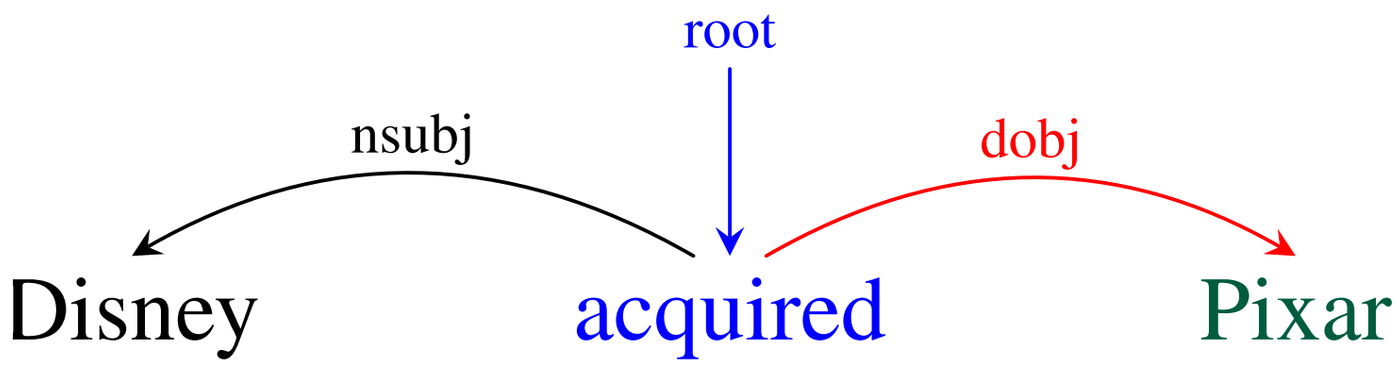
Dependency labels drive the composition



(dobj acquired Pixar)



(nsubj (dobj acquired Pixar) Disney)



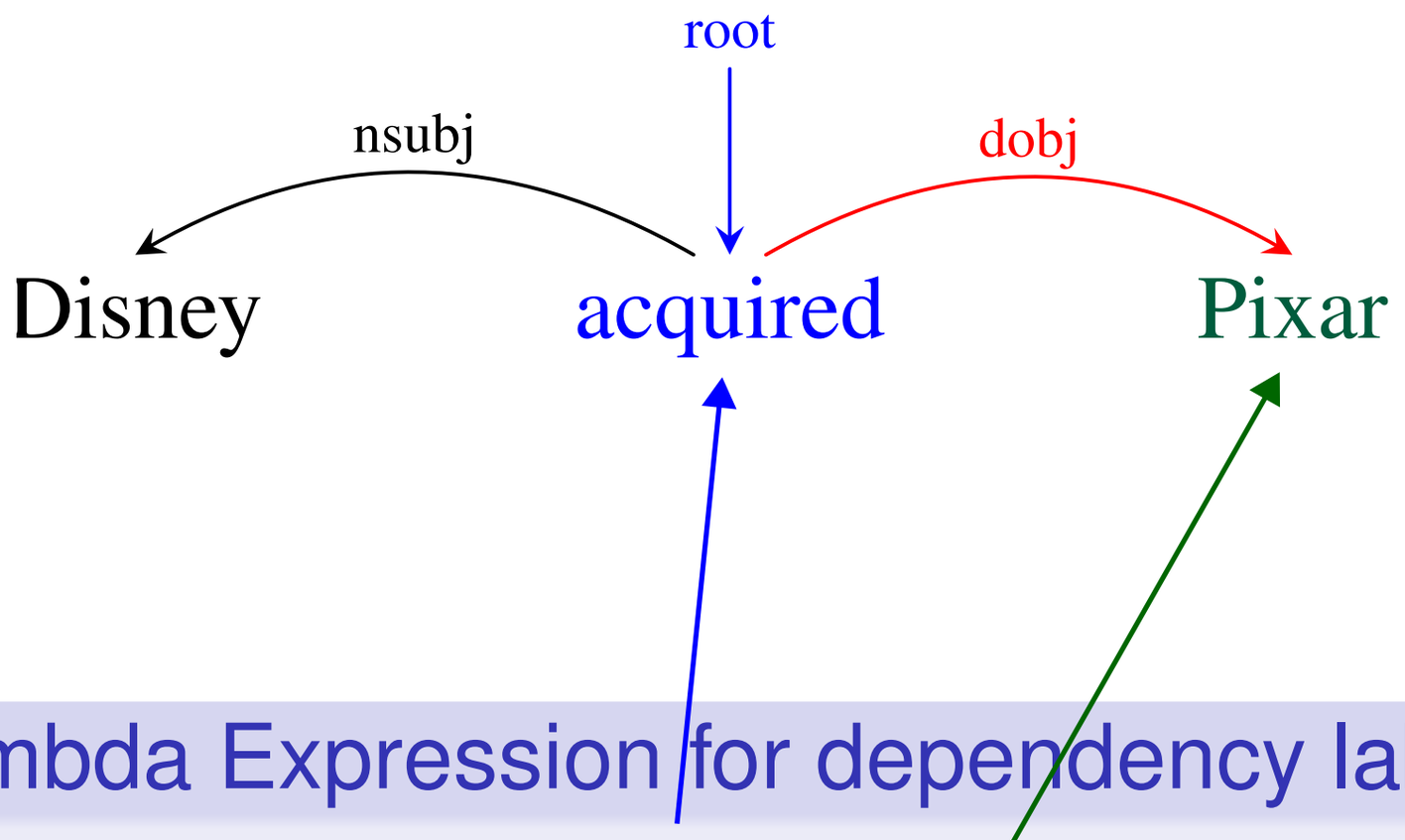
Lambda Expression for words

$$\text{acquired} \Rightarrow \lambda \mathbf{x_a} x_e . \text{acquired}(x_e) \quad \Rightarrow \textbf{TYPE} = \textbf{Ind} \times \textbf{Event} \rightarrow \textbf{Bool}$$

$$\text{Pixar} \Rightarrow \lambda x_a \mathbf{x_e} . \text{Pixar}(x_a) \quad \Rightarrow \textbf{TYPE} = \textbf{Ind} \times \textbf{Event} \rightarrow \textbf{Bool}$$

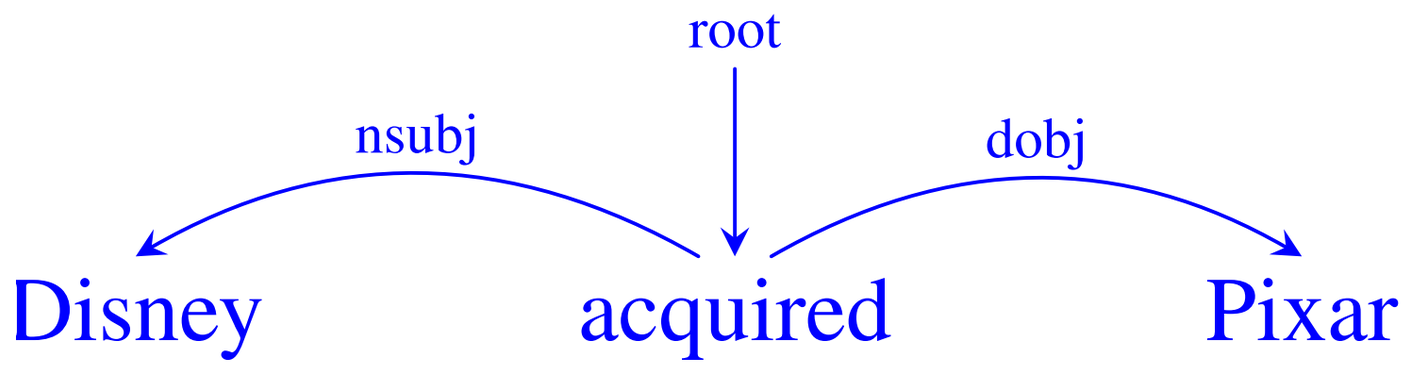
All constituents are of the same lambda expression type

TYPE[acquired] = **TYPE**[Pixar] = **TYPE**[(dobj acquired Pixar)]



Lambda Expression for dependency labels

$$\text{dobj} \Rightarrow \lambda \mathbf{f}\ \lambda \mathbf{g}\ \lambda \mathbf{z}\ .\ \exists \mathbf{x}\ .\ \mathbf{f}(\mathbf{z}) \quad \wedge \quad \mathbf{g}(\mathbf{x}) \quad \wedge \quad \mathbf{arg_2}(\mathbf{z_e}, \mathbf{x_a})$$



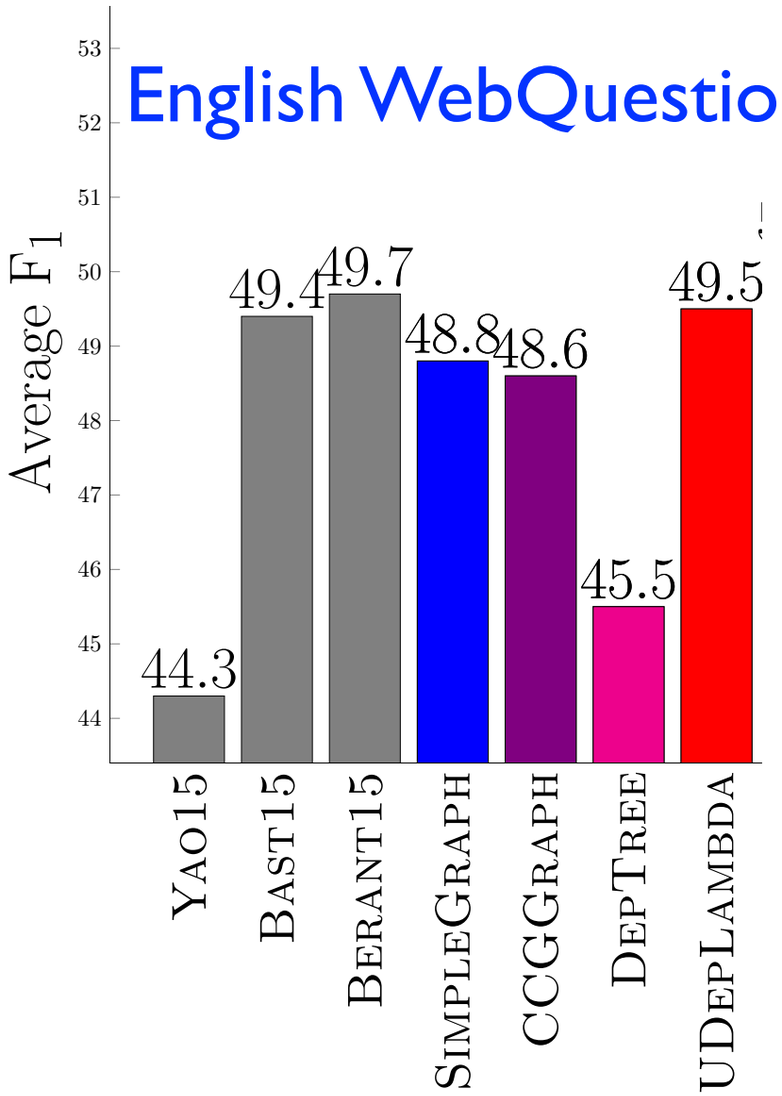
(nsubj (dobj acquired Pixar) Disney)

$$\lambda z.\exists xy.\text{acquired}(z_e) \wedge \text{Pixar}(y_a) \wedge \text{Disney}(x_a) \wedge \text{arg}_1(z_e, x_a) \wedge \text{arg}_2(z_e, y_a)$$

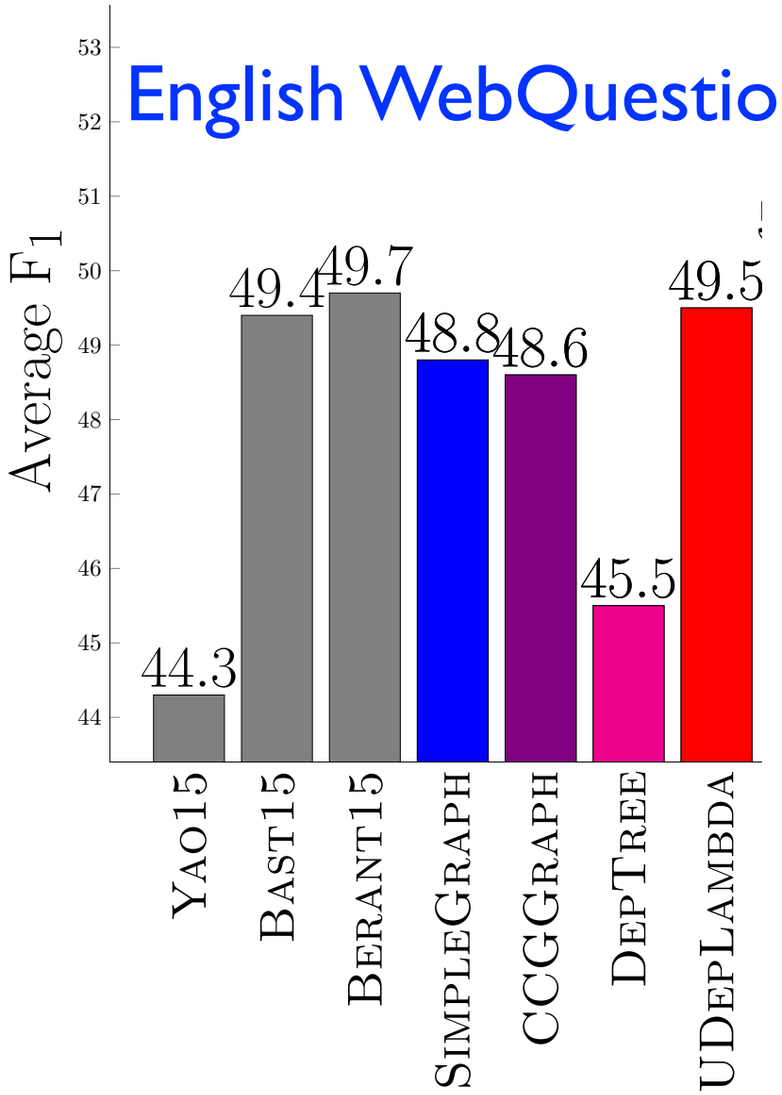
Comparison with CCG

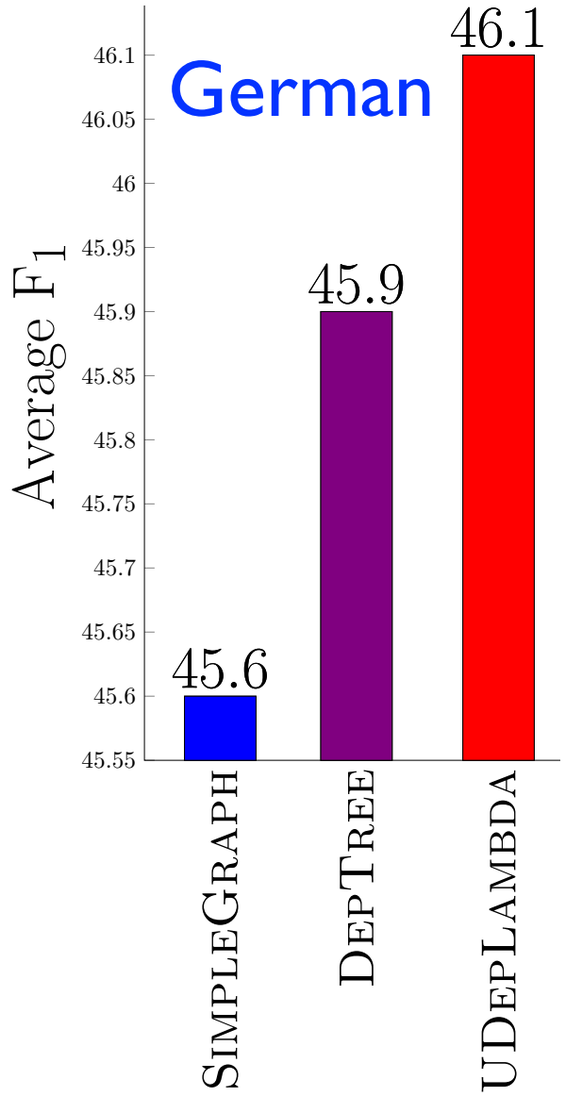
CCG	UDepLambda
Lexicalized semantics	Simple lexical semantics
Words drive composition	Dependencies drive composition
Argument and adjunct distinction	Every dependent is an adjunct
Complex types are powerful	Simplicity gives robustness

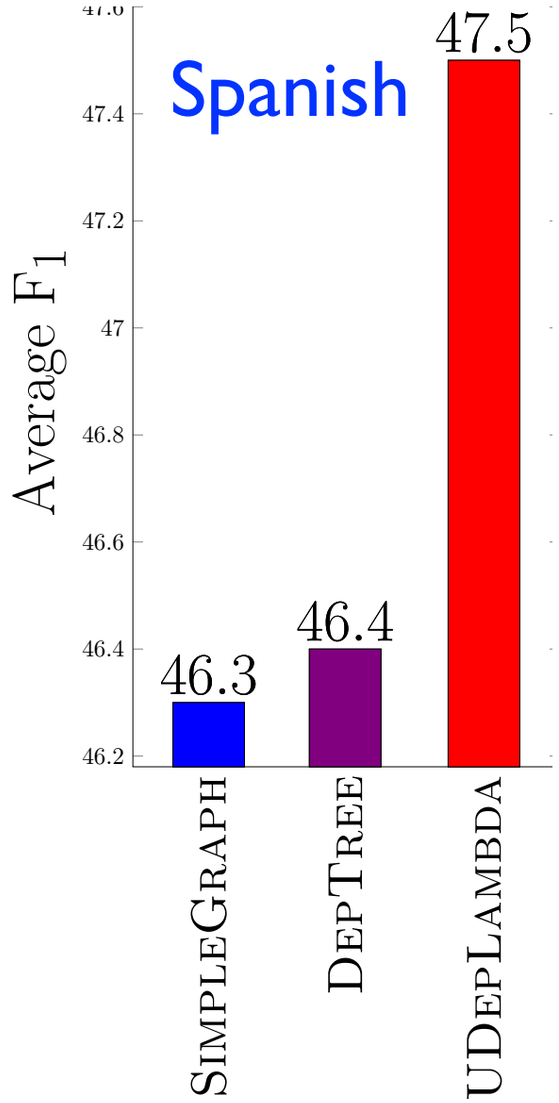
Freebase Semantic Parsing



Freebase Semantic Parsing





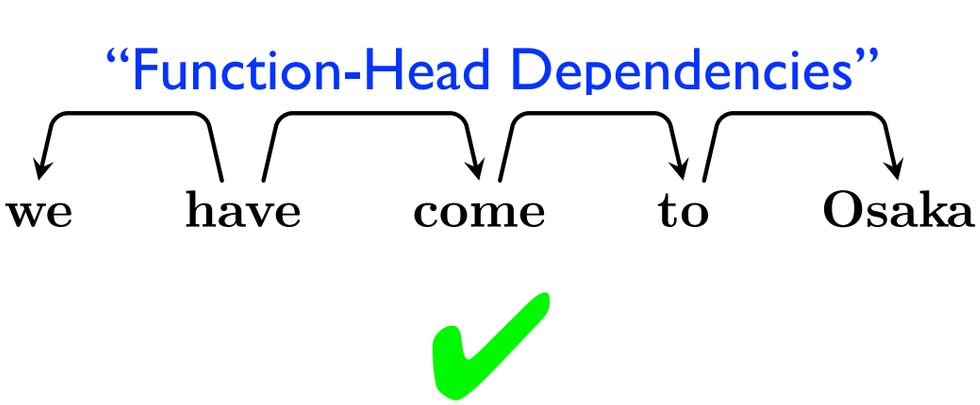


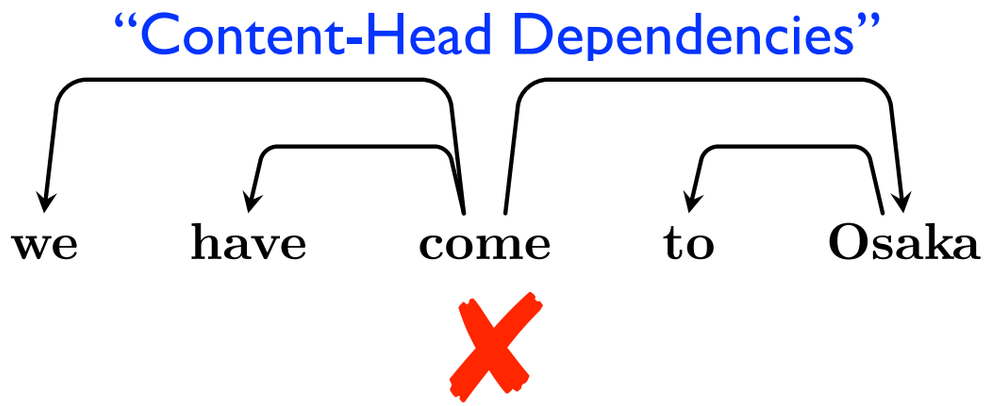
Conclusion – Part II

The primacy of content words

- Supports dependency-driven compositional semantics
- Generalizes across languages – universal semantic parsing?
- Useful for downstream natural language understanding tasks

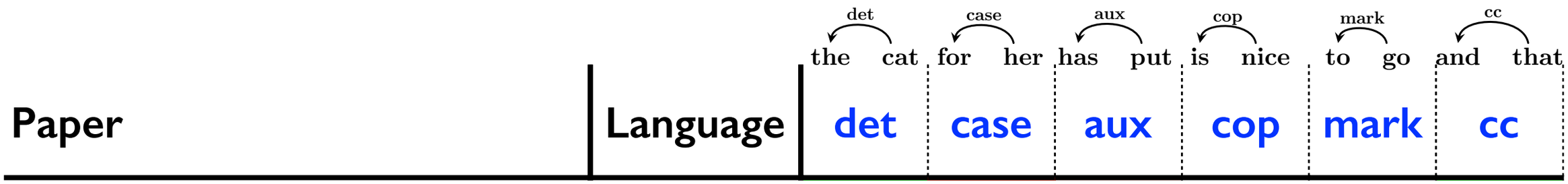
Syntactic Parsing





Conventional wisdom

- Dependency trees with "function heads" are easier to parse
- Possibly related to dependency length minimisation
- Based on scattered empirical (and anecdotal) evidence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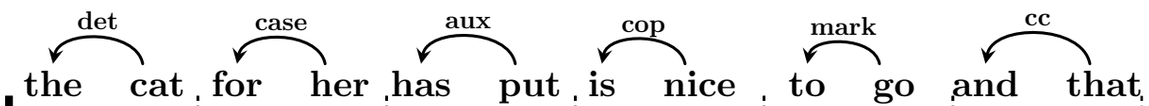
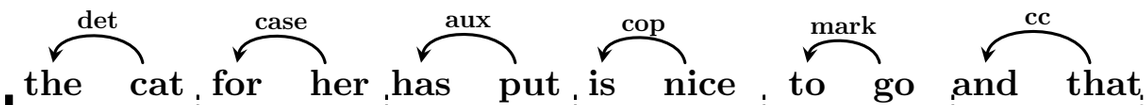
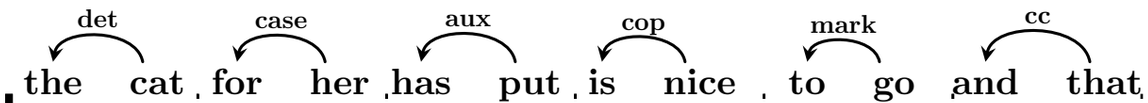
Paper	Language	det	case	aux	cop	mark	cc
Schwartz et al. (2012)	English						





Paper	Language	det	case	aux	cop	mark	cc
Schwartz et al. (2012)	English						
Silveira and Manning (2015)	English						

Paper	Language	 det	case	aux	cop	mark	cc
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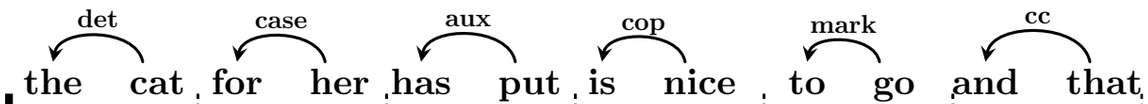
Attardi et al. (2015)	Italian						



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Rosa (2015)	Multi						

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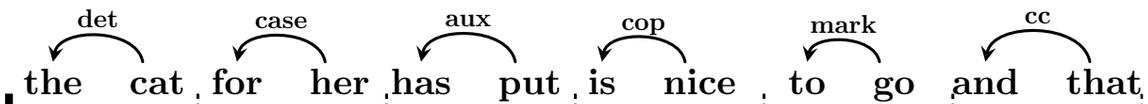
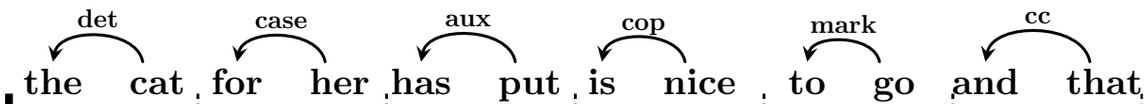
De Lhoneux and Nivre (2016)	Multi						





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De Lhoneux and Nivre (2016)	Multi						
Wisniewski and Lacroix (2017)	Multi						

Conclusion – Part III

The primacy of content words

- Not universally harmful for monolingual syntactic parsing
- Arguably superior for cross-lingual parsing
- Neural dependency parsers less sensitive to representations?

Universal Dependencies

Designed to fulfill multiple purposes/requirements

- Meaningful linguistic analysis within and across languages
- Syntactic parsing in monolingual and cross-lingual settings
- Useful information for downstream language understanding tasks

Gives priority to dependencies between content words

Thanks to all UD contributors!

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