Weakly-Supervised Grammar-Informed Bayesian CCG Parser Learning

Dan Garrette — UT-Austin
Chris Dyer — CMU
Jason Baldridge — UT-Austin
Noah A. Smith — CMU

Motivation

Annotating parse trees *by hand* is extremely difficult.

Motivation

Can we learn new parsers cheaply?

Motivation

Can we learn new parsers cheaply?

(cheaper = less supervision)

Motivation

When supervision is ***scarce***,
we have to be ***smarter*** about data.

Type-Level Supervision

Type-Level Supervision

- Unannotated text

- Incomplete tag dictionary: word ↦ {tags}

Type-Level Supervision

Used for part-of-speech tagging for 20+ years

[Kupiec, 1992]
[Merialdo, 1994]

Type-Level Supervision

Good tagger performance
even with low supervision

[Ravi & Knight, 2009]
[Das & Petrov, 2011]
[Garrette & Baldridge, 2013]
[Garrette *et al.*, 2013]

Combinatory Categorial Grammar (CCG)

CCG

[Steedman, 2000]
[Steedman and Baldridge, 2011]

CCG

Every word token is associated with a **category**

[Steedman, 2000]
[Steedman and Baldridge, 2011]

CCG

Every word token is associated with a **category**

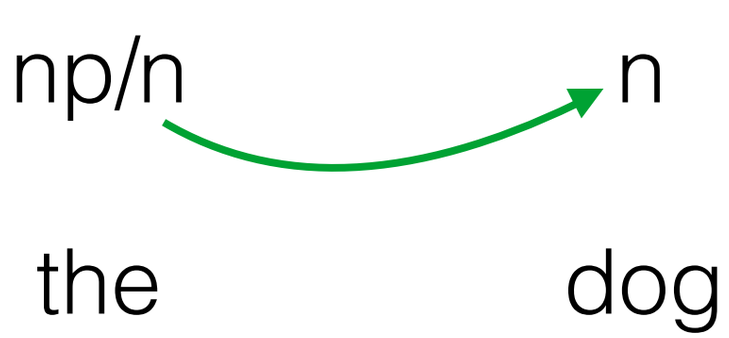
Categories **combine** to form categories of larger constituents

[Steedman, 2000]
[Steedman and Baldridge, 2011]

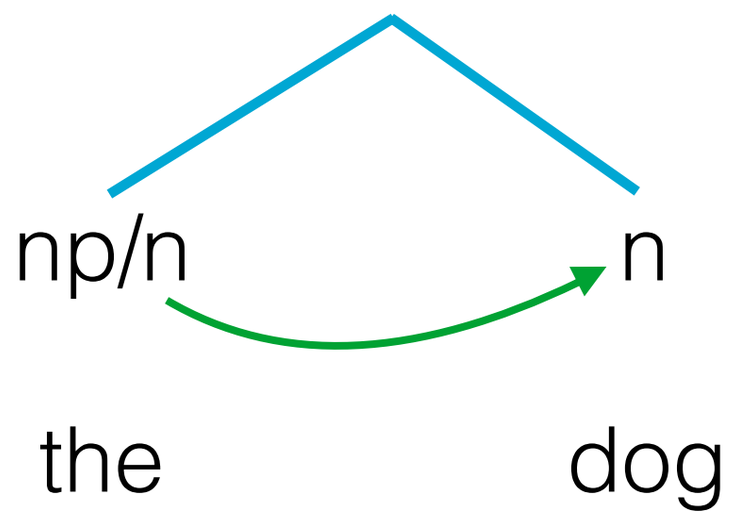
CCG

np/n	n
the	dog

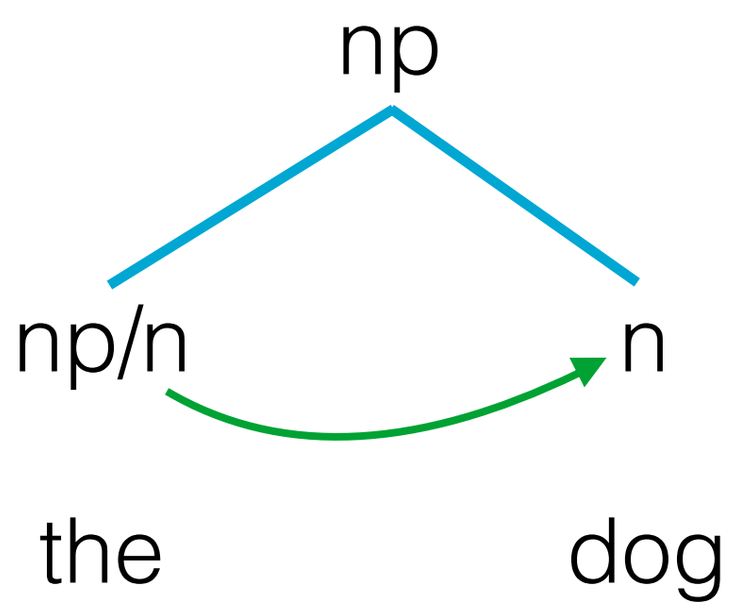
CCG



CCG



CCG

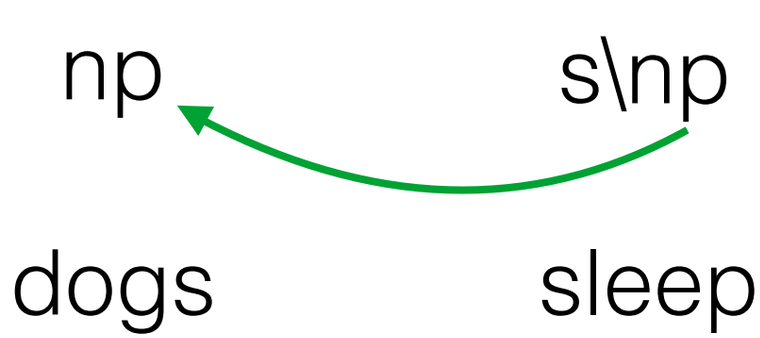


CCG

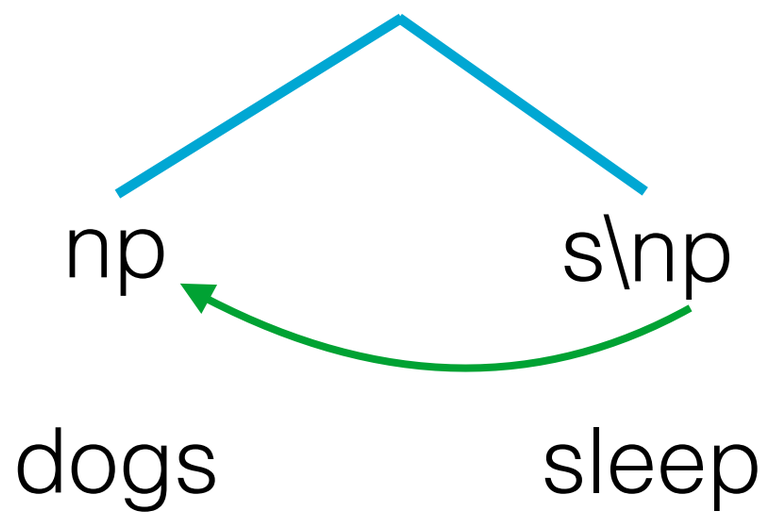
np s\np

dogs sleep

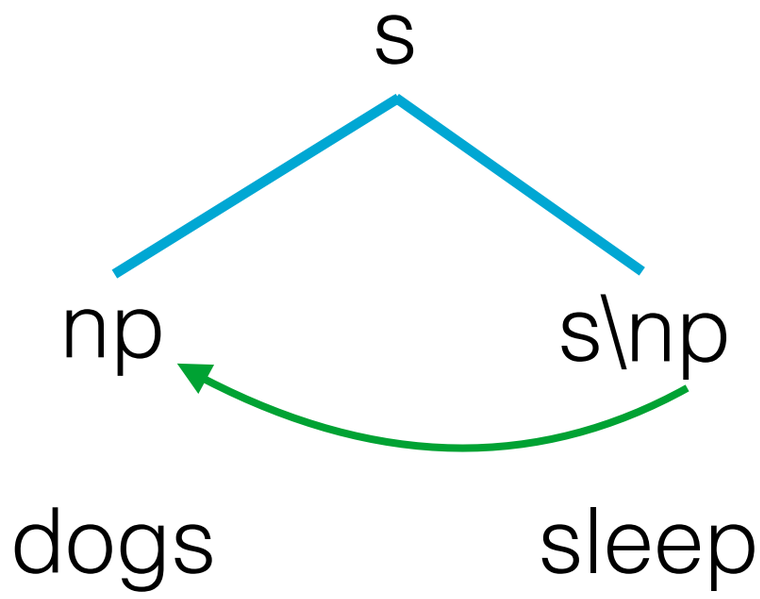
CCG



CCG



CCG



Type-Supervised CCG

the **lazy** **dogs** **wander**

Type-Supervised CCG

the	**lazy**	**dogs**	**wander**
np/n			

Type-Supervised CCG

the	**lazy**	**dogs**	**wander**
np/n	n/n		
	np		

Type-Supervised CCG

the	**lazy**	**dogs**	**wander**
np/n	n/n	n	
	np	np	
		(s\np)/np	

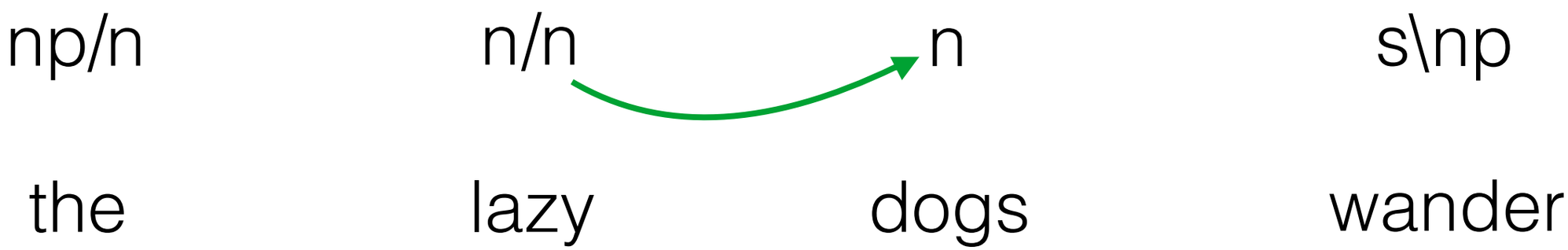
Type-Supervised CCG

the	**lazy**	**dogs**	**wander**
np/n	n/n	n	n
	np	np	n/n
		(s\np)/np	np/n
			s\np
			...

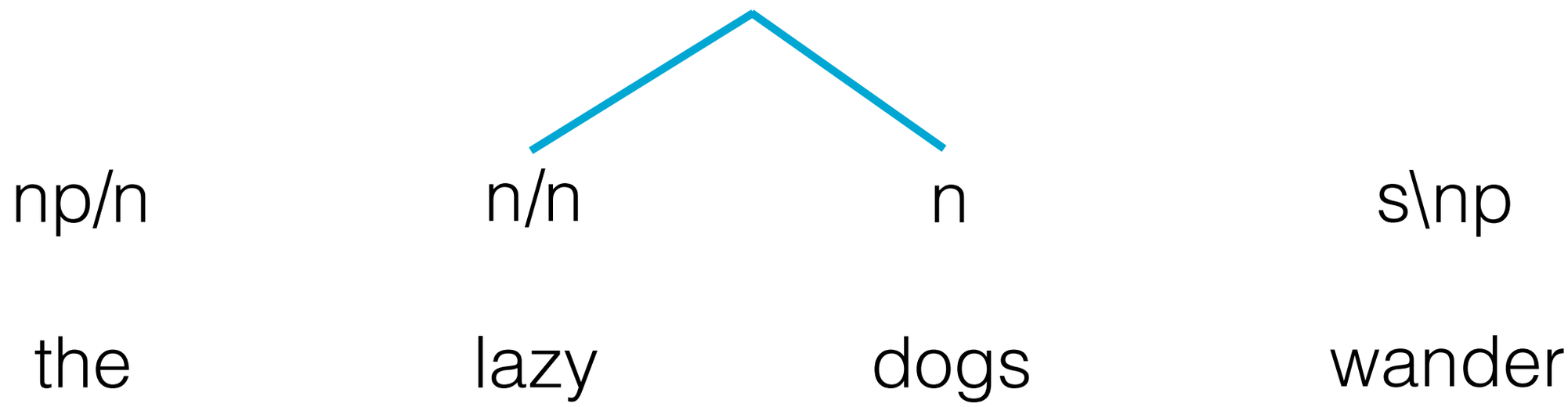
CCG Parsing

np/n	n/n	n	s\np
the	lazy	dogs	wander

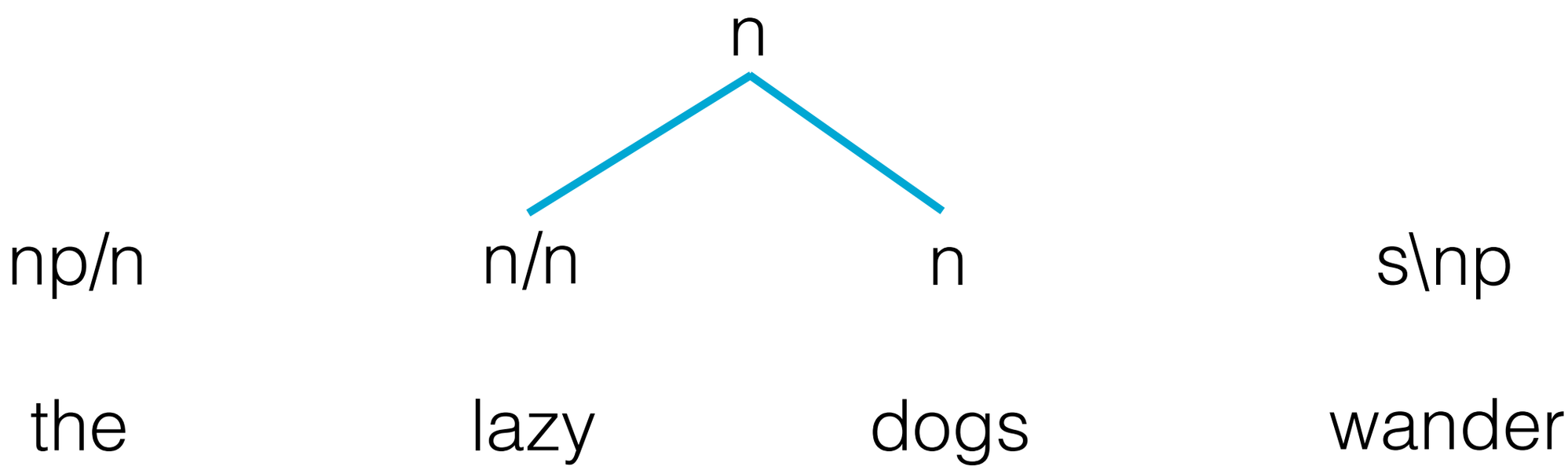
CCG Parsing



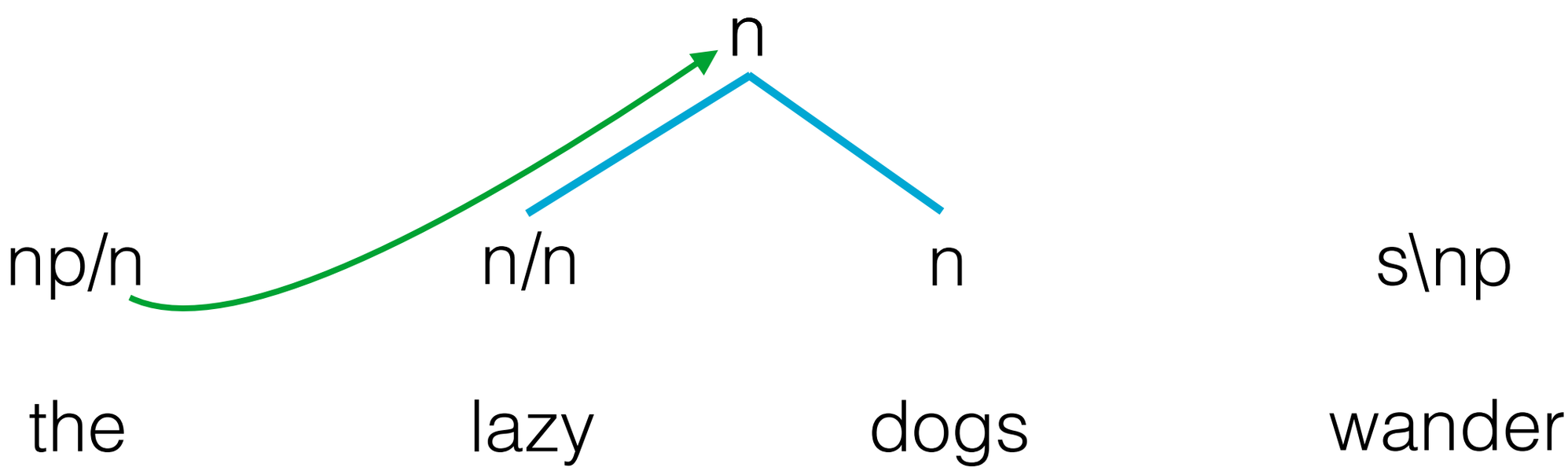
CCG Parsing



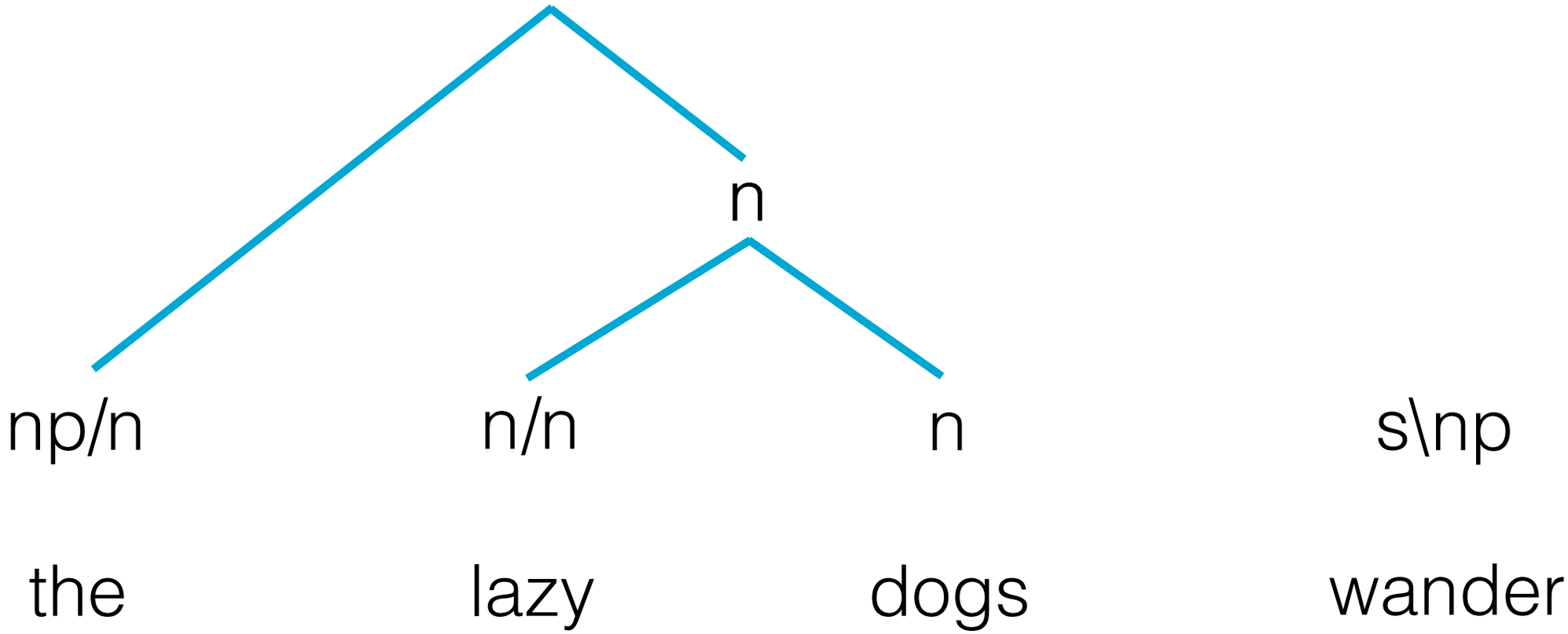
CCG Parsing



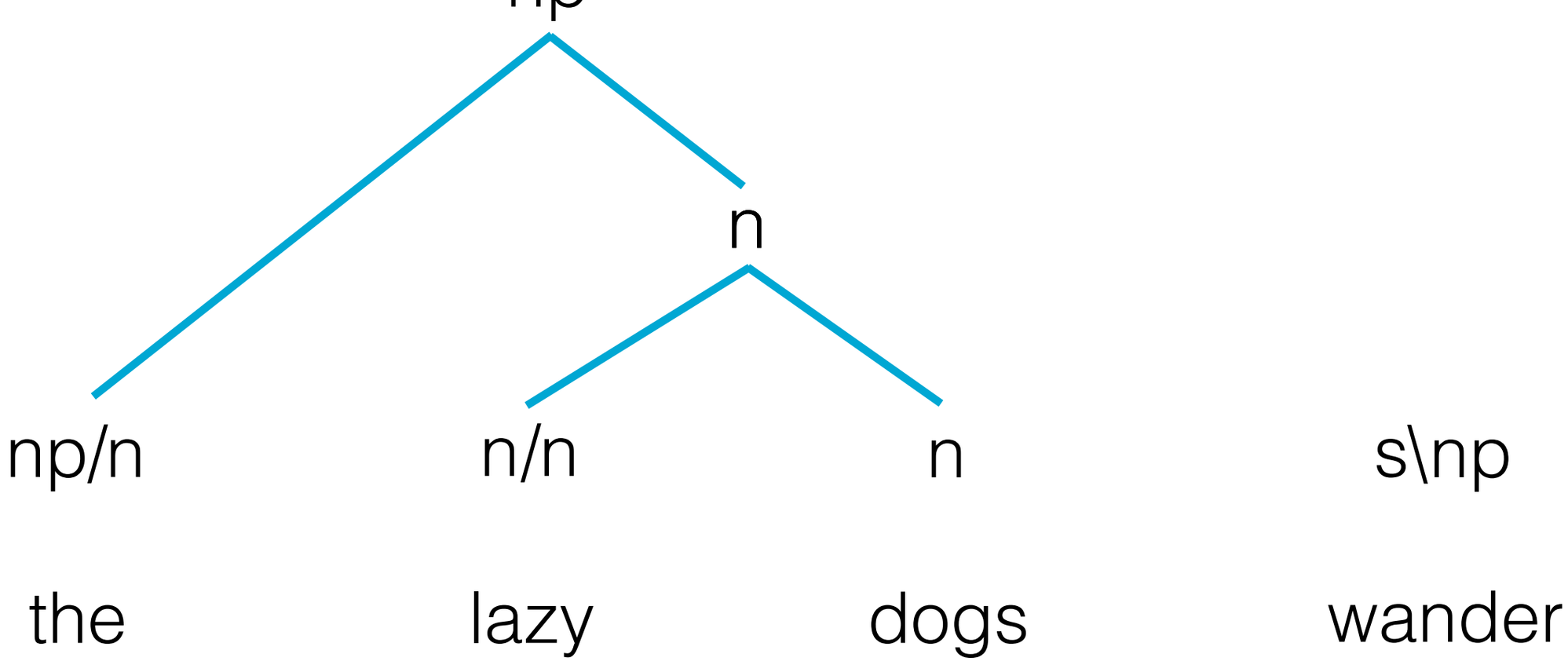
CCG Parsing



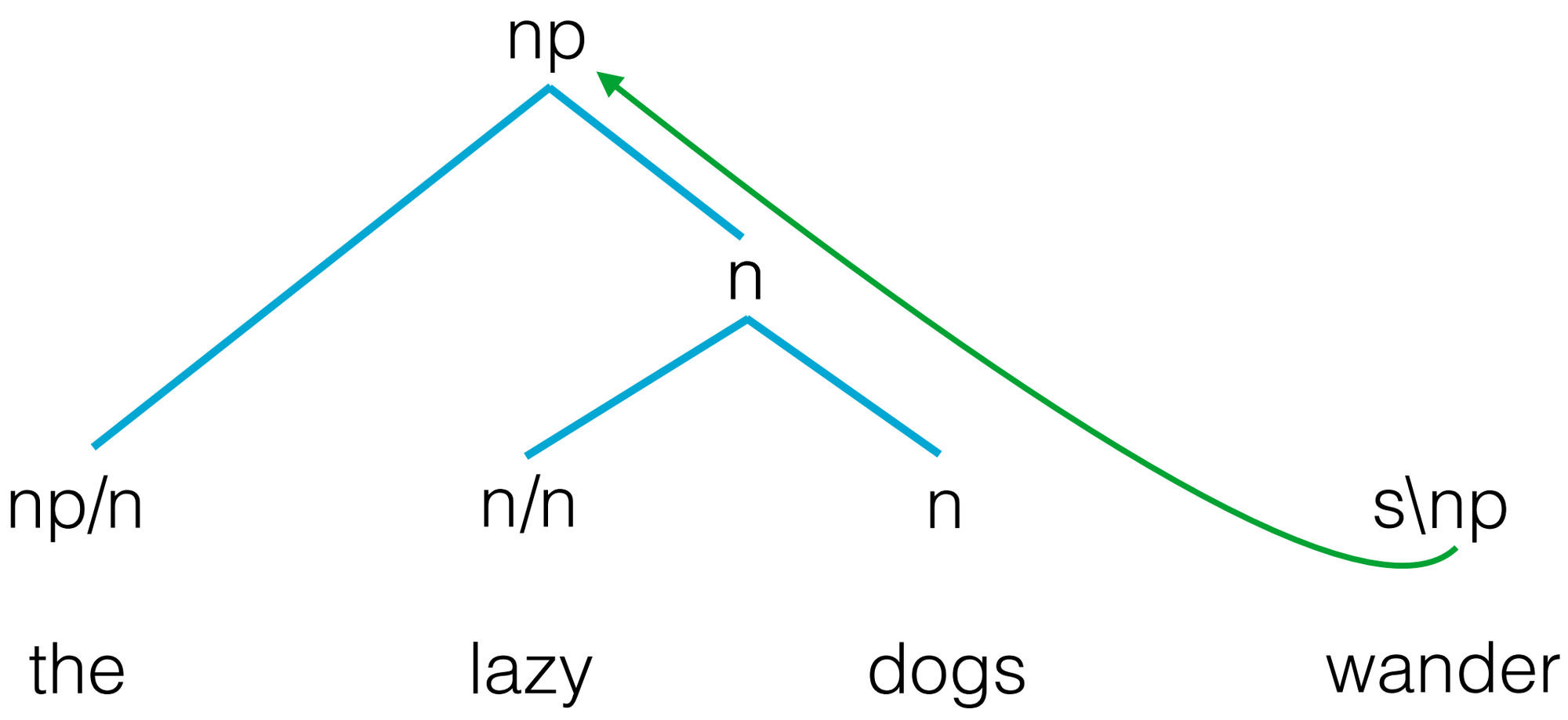
CCG Parsing



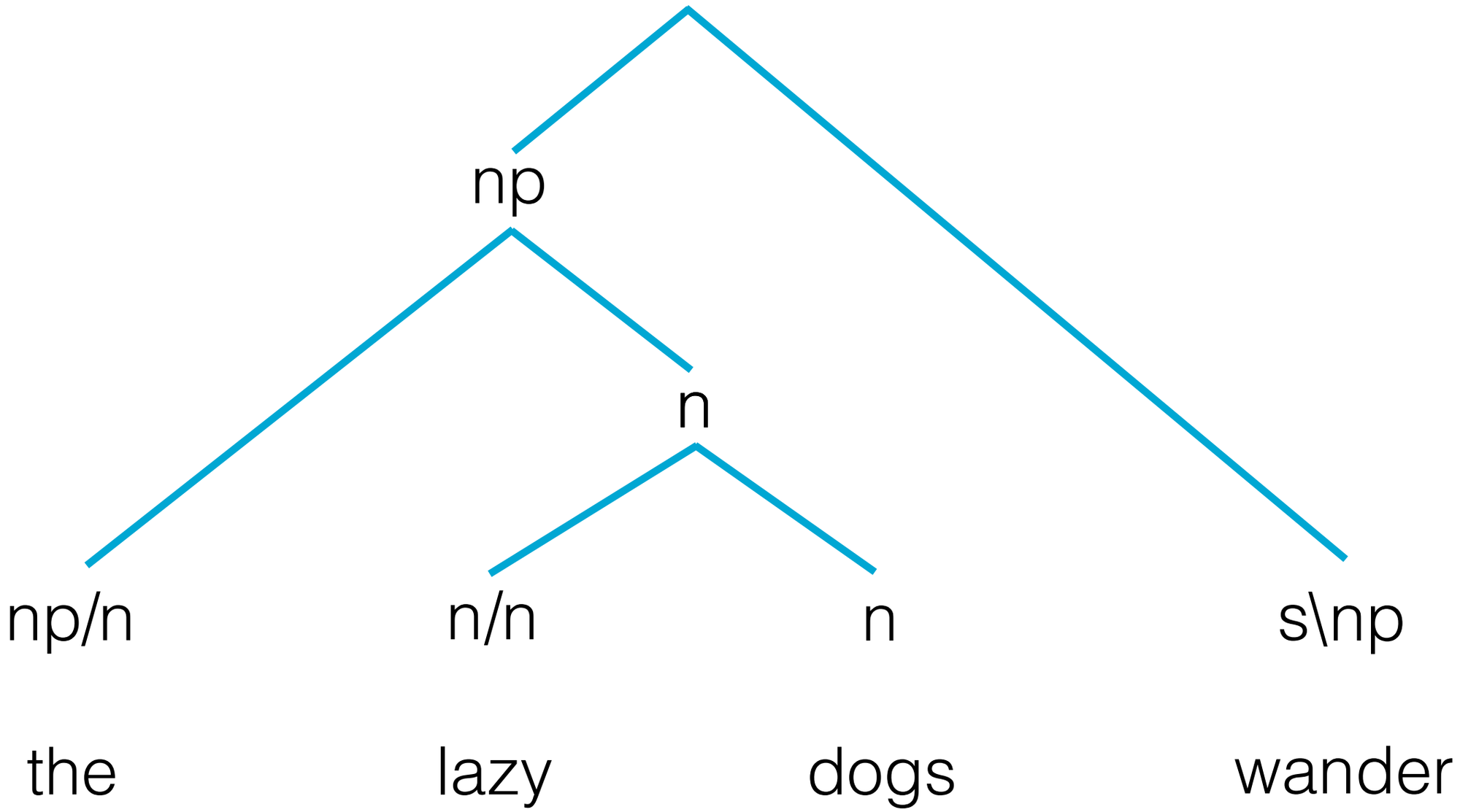
CCG Parsing



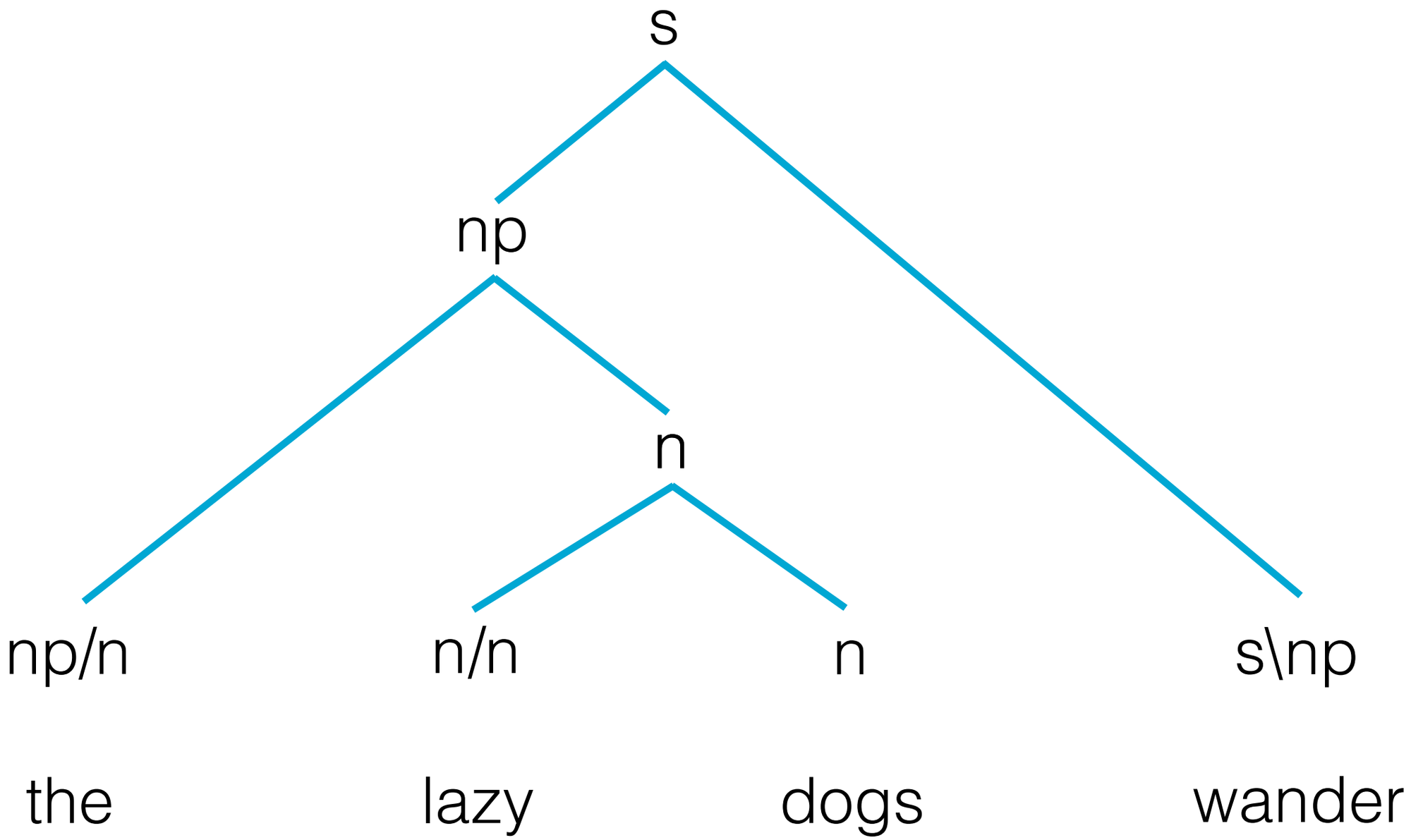
CCG Parsing



CCG Parsing



CCG Parsing



Why CCG?

Machine Translation

[Weese, Callison-Burch, and Lopez, 2012]

Semantic Parsing

[Zettlemoyer and Collins, 2005]

Type-Supervised CCG

Type-supervised learning for CCG
is highly *ambiguous*

Type-Supervised CCG

Type-supervised learning for CCG
is highly *ambiguous*

Penn Treebank
parts-of-speech

Type-Supervised CCG

Type-supervised learning for CCG
is highly *ambiguous*

Penn Treebank
parts-of-speech

48 tags

Type-Supervised CCG

Type-supervised learning for CCG
is highly *ambiguous*

Penn Treebank
parts-of-speech

48 tags

CCGBank
Categories

Type-Supervised CCG

Type-supervised learning for CCG
is highly *ambiguous*

Penn Treebank
parts-of-speech

48 tags

CCGBank
Categories

1,300+ categories

Our Strategy

The grammar formalism *itself*
can be used to guide learning

Our Strategy

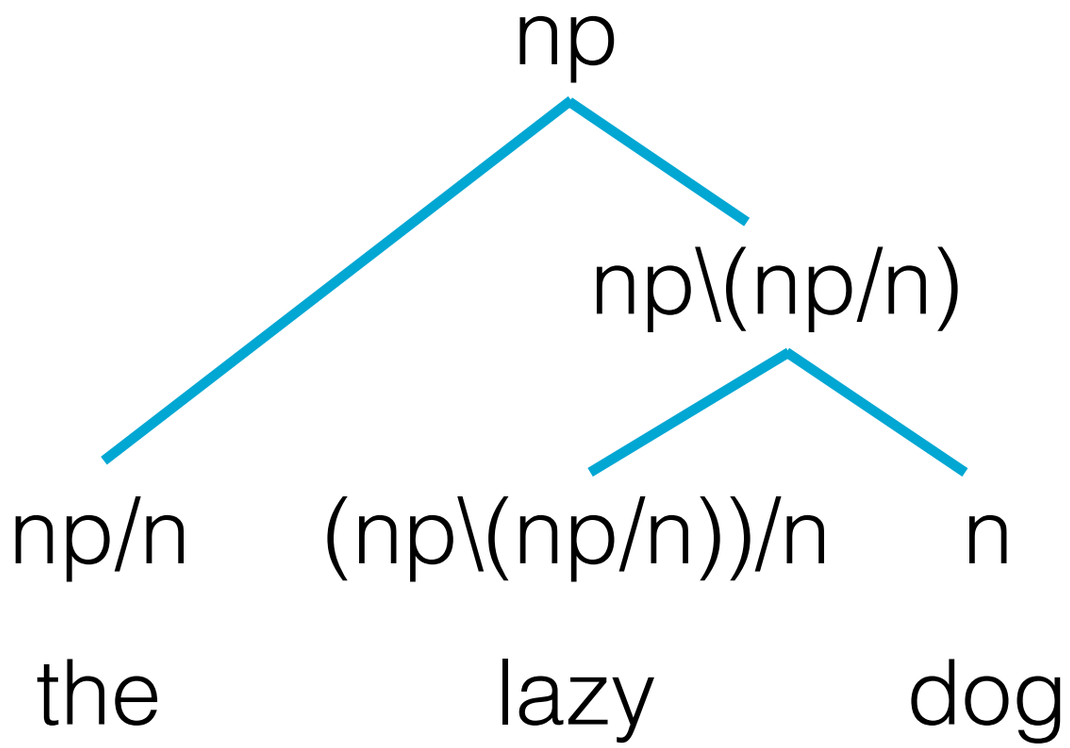
Incorporate *universal knowledge*
about grammar into learning

Universal Knowledge

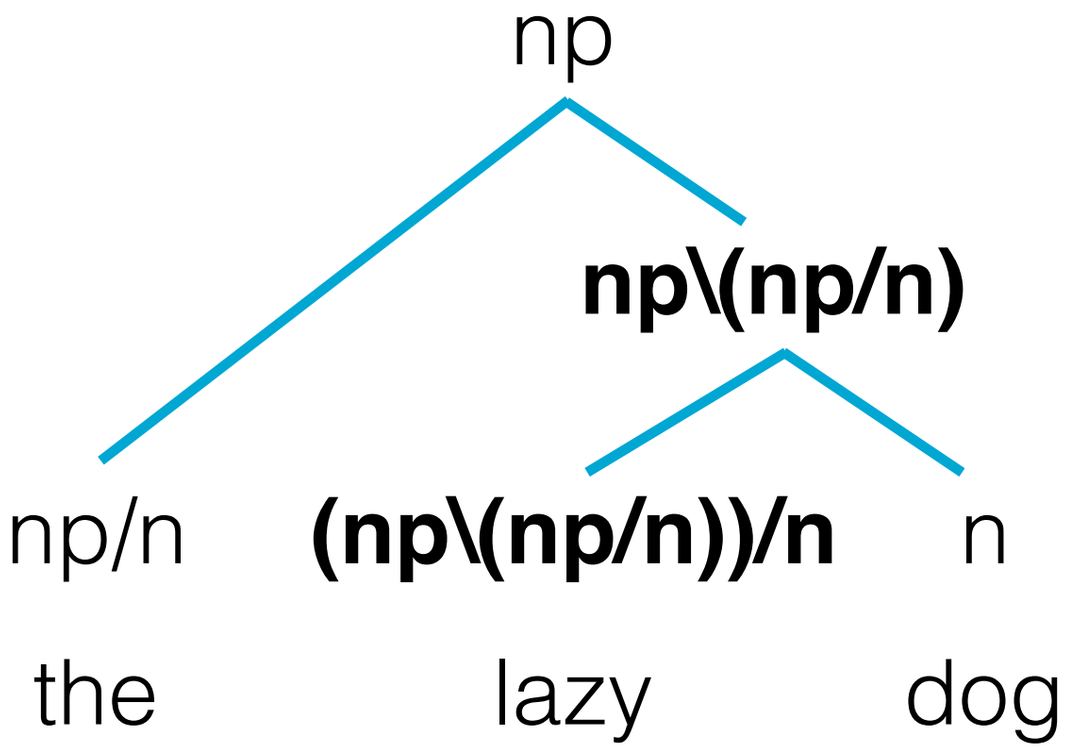
Prefer Simpler Categories

the lazy dog

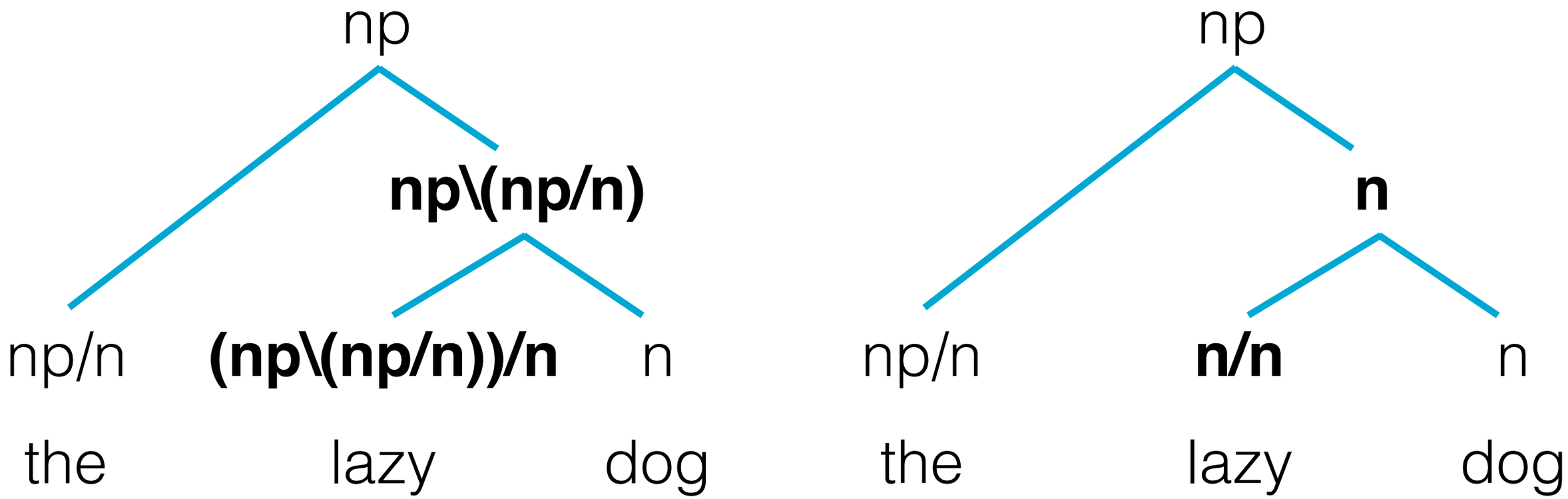
Prefer Simpler Categories



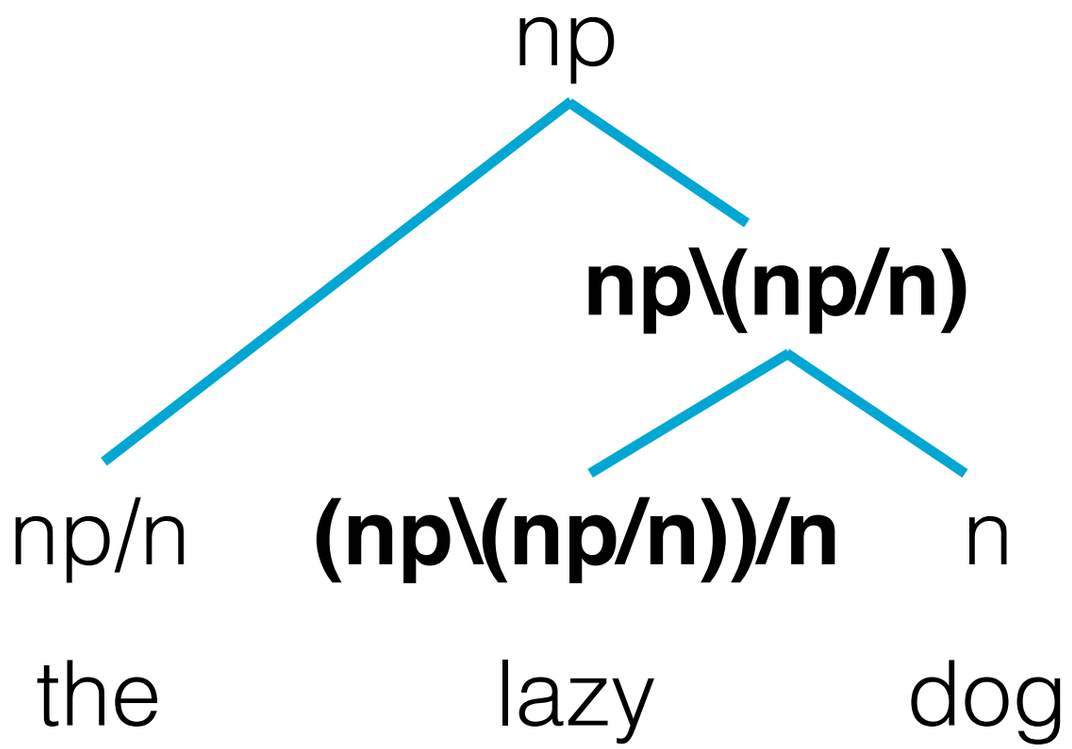
Prefer Simpler Categories

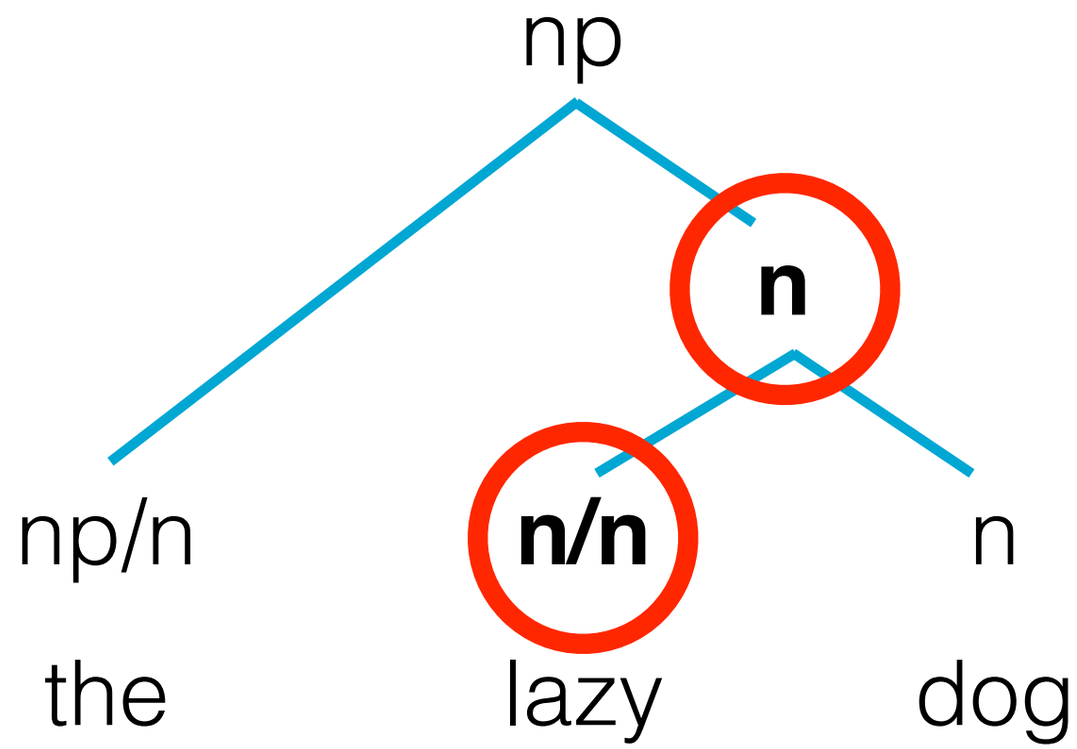


Prefer Simpler Categories



Prefer Simpler Categories





Prefer Simpler Categories

buy := $(s_b \backslash np)/np$

e.g. “Opponents don't **buy** such arguments.”

Prefer Simpler Categories

buy := $(s_b\backslash np)/np$ appears **342** times in CCGbank

e.g. “Opponents don't **buy** such arguments.”

Prefer Simpler Categories

buy := $(s_b\backslash np)/np$ appears **342** times in CCGbank

e.g. “Opponents don't **buy** such arguments.”

buy := $(((s_b\backslash np)/\mathbf{pp})/\mathbf{pp})/np$

“Tele-Communications agreed to **buy** half of Showtime Networks from Viacom (pp) for $ 225 million. (pp)”

Prefer Simpler Categories

buy := $(s_b\backslash np)/np$ appears **342** times in CCGbank

e.g. “Opponents don't **buy** such arguments.”

buy := $(((s_b\backslash np)/\mathbf{pp})/\mathbf{pp})/np$ appears **once**

“Tele-Communications agreed to **buy** half of Showtime Networks from Viacom (pp) for $ 225 million. (pp)”

Prefer Modifier Categories

Prefer Modifier Categories

$((s_b\backslash np)/np)/((s_b\backslash np)/np)$

Prefer Modifier Categories

((s[b]\np)/np)/((s[b]\np)/np)

Prefer Modifier Categories

$((s_b\backslash np)/np)/((s_b\backslash np)/np)$

Prefer Modifier Categories

$(s_b\backslash np)/np$

$((s_b\backslash np)/np)/((s_b\backslash np)/np)$

Prefer Modifier Categories

$(s_b\backslash np)/np$

transitive verb: (he) **hides** (the money)

$((s_b\backslash np)/np)/((s_b\backslash np)/np)$

Prefer Modifier Categories

$(s_b\backslash np)/np$

transitive verb: (he) **hides** (the money)

$((s_b\backslash np)/np)/((s_b\backslash np)/np)$

adverb: (he) **quickly** (hides) (the money)

Weighted Category Grammar

$a \longrightarrow$ {s, np, n,…}

$A \longrightarrow B / C$

$A \longrightarrow B \backslash C$

Weighted Category Grammar

$a \longrightarrow \{s, np, n, \ldots\} \qquad p_{atom}(a)$

$A \longrightarrow B \,/\, C$

$A \longrightarrow B \setminus C$

Weighted Category Grammar

$$a \longrightarrow \{s, np, n, \ldots\} \qquad p_{atom}(a) \times p_{term}$$

$$A \longrightarrow B \,/\, C$$

$$A \longrightarrow B \setminus C$$

Weighted Category Grammar

$a \longrightarrow \{s, np, n, \ldots\} \qquad p_{atom}(a) \times p_{term}$

$A \longrightarrow B \,/\, C \qquad \overline{p_{term}}$

$A \longrightarrow B \setminus C \qquad \overline{p_{term}}$

Weighted Category Grammar

$a \longrightarrow \{s, np, n, \ldots\} \qquad p_{atom}(a) \times p_{term}$

$A \longrightarrow B \,/\, C \qquad \overline{p_{term}} \times p_{fwd}$

$A \longrightarrow B \setminus C \qquad \overline{p_{term}}$

Weighted Category Grammar

$$a \longrightarrow \{s, np, n, \ldots\} \qquad p_{atom}(a) \times p_{term}$$

$$A \longrightarrow B \,/\, C \qquad \overline{p_{term}} \times p_{fwd}$$

$$A \longrightarrow B \setminus C \qquad \overline{p_{term}} \times \overline{p_{fwd}}$$

Weighted Category Grammar

a	$\longrightarrow$	{s, np, n,…}	$p_{atom}(a) \times p_{term}$
A	$\longrightarrow$	B / B	$\overline{p_{term}} \times p_{fwd} \times p_{mod}$
A	$\longrightarrow$	B / C	$\overline{p_{term}} \times p_{fwd}$
A	$\longrightarrow$	B \ B	$\overline{p_{term}} \times \overline{p_{fwd}} \times p_{mod}$
A	$\longrightarrow$	B \ C	$\overline{p_{term}} \times \overline{p_{fwd}}$

Weighted Category Grammar

a	⟶	{s, np, n,…}	$p_{atom}(a) \times p_{term}$
A	⟶	B / B	$\overline{p_{term}} \times p_{fwd} \times p_{mod}$
A	⟶	B / C	$\overline{p_{term}} \times p_{fwd} \times \overline{p_{mod}}$
A	⟶	B \ B	$\overline{p_{term}} \times \overline{p_{fwd}} \times p_{mod}$
A	⟶	B \ C	$\overline{p_{term}} \times \overline{p_{fwd}} \times \overline{p_{mod}}$

Weighted Category Grammar

$a \longrightarrow \{s, np, n, \ldots\} \qquad p_{atom}(a) \times p_{term}$

$A \longrightarrow B \,/\, B \qquad \overline{p_{term}} \times p_{fwd} \times p_{mod}$

$A \longrightarrow B \,/\, C \qquad \overline{p_{term}} \times p_{fwd} \times \overline{p_{mod}}$

$A \longrightarrow B \,\backslash\, B \qquad \overline{p_{term}} \times \overline{p_{fwd}} \times p_{mod}$

$A \longrightarrow B \,\backslash\, C \qquad \overline{p_{term}} \times \overline{p_{fwd}} \times \overline{p_{mod}}$

Weighted Category Grammar

$a \longrightarrow \{s, np, n, \ldots\} \qquad p_{atom}(a) \times p_{term}$

$A \longrightarrow B \,/\, B \qquad \overline{p_{term}} \times p_{fwd} \times p_{mod}$

$+$

$A \longrightarrow B \,/\, C \qquad \overline{p_{term}} \times p_{fwd} \times \overline{p_{mod}}$

$A \longrightarrow B \,\backslash\, B \qquad \overline{p_{term}} \times \overline{p_{fwd}} \times p_{mod}$

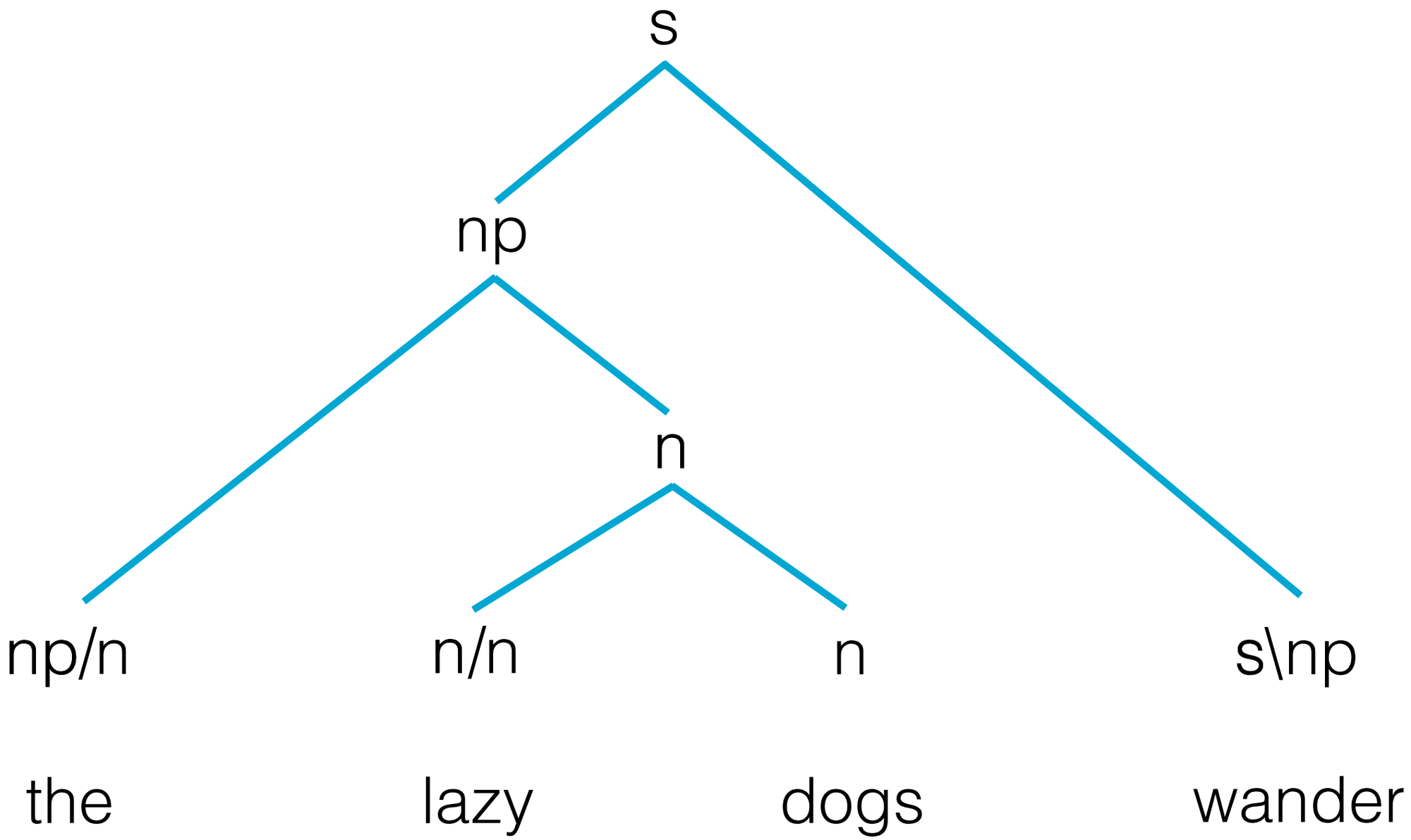
$+$

$A \longrightarrow B \,\backslash\, C \qquad \overline{p_{term}} \times \overline{p_{fwd}} \times \overline{p_{mod}}$

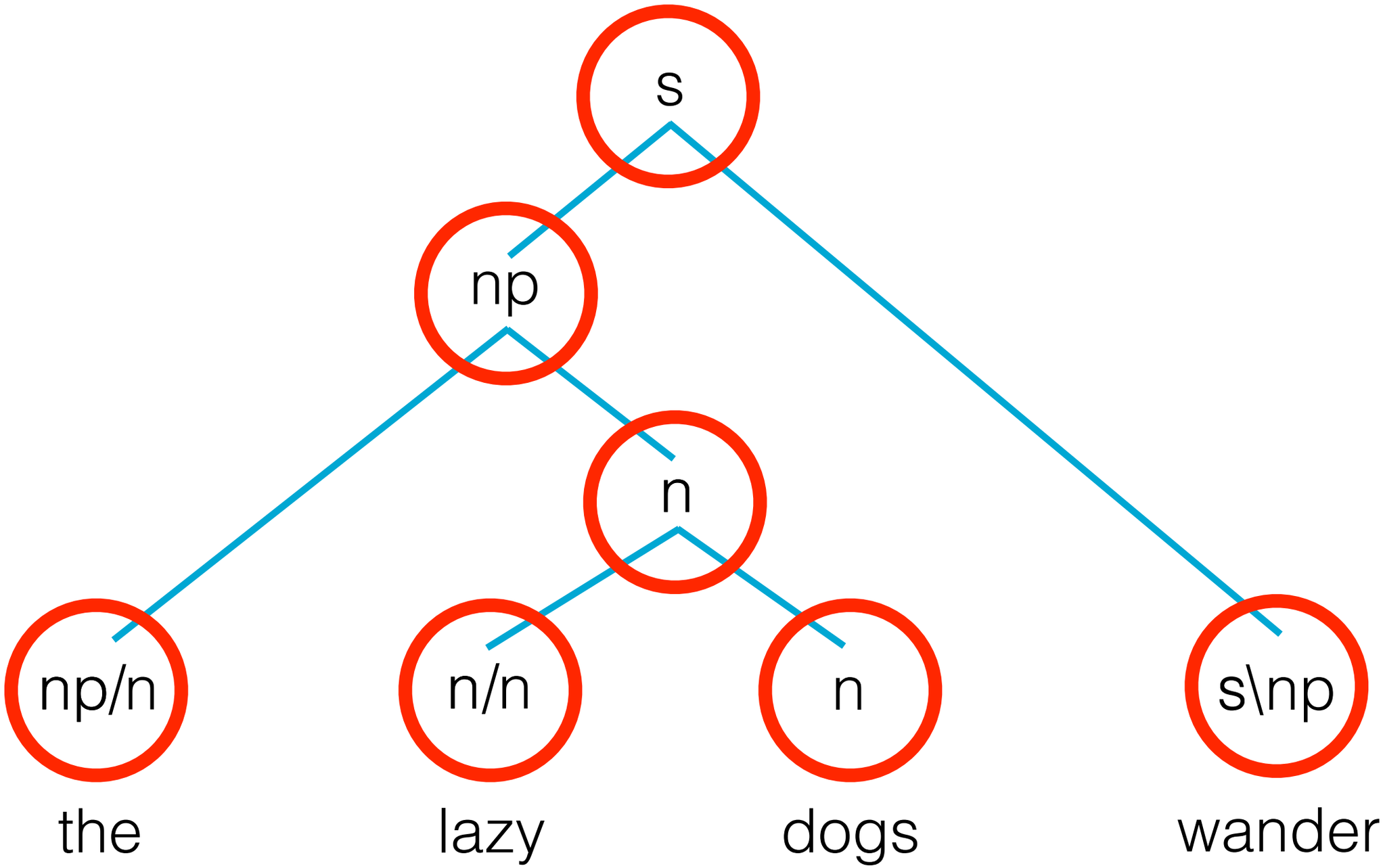
Prefer Likely Categories

np/n	n/n	n	s\np
the	lazy	dogs	wander

Prefer Likely Categories



Prefer Likely Categories



Type-Supervised Learning

unlabeled corpus

tag dictionary

Type-Supervised Learning

unlabeled corpus

tag dictionary

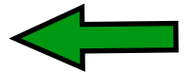
same as
POS tagging

Type-Supervised Learning

unlabeled corpus

tag dictionary

same as
POS tagging

universal properties of the CCG formalism 

Posterior Inference

[Johnson, Griffiths, and Goldwater, 2007]

Posterior Inference

PCFG

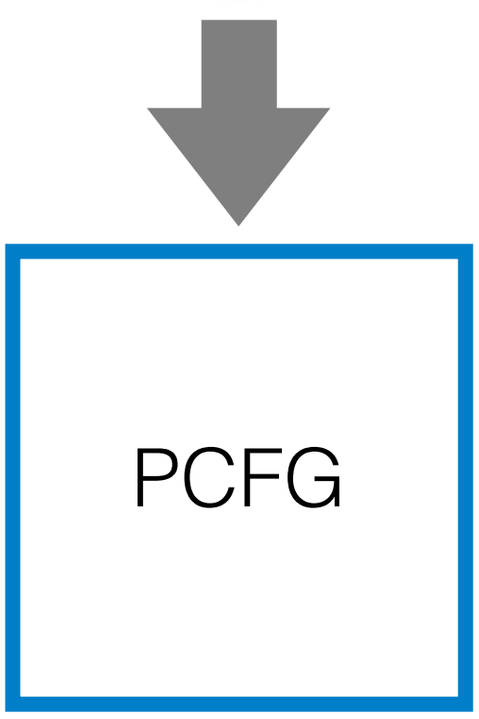
Posterior Inference

Priors (simple is good)

PCFG

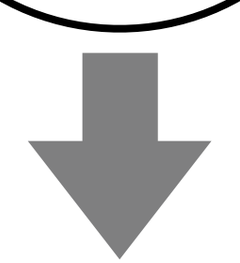
Posterior Inference

Priors (simple is good)



Posterior Inference

Priors (simple is good)

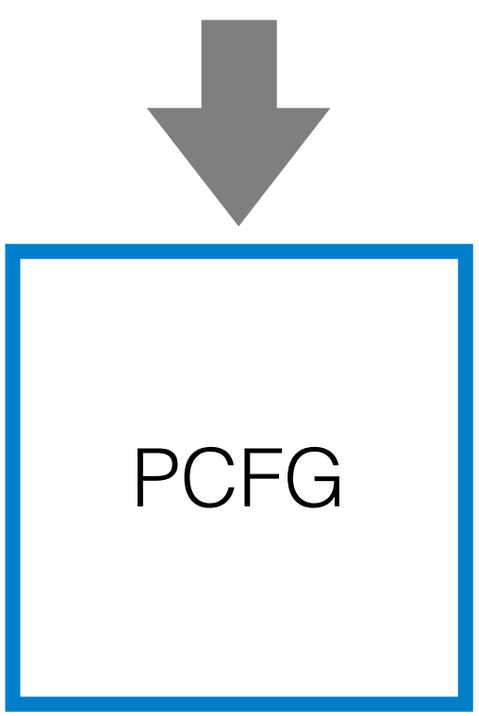


PCFG

the lazy dogs wander

Posterior Inference

Priors (simple is good)

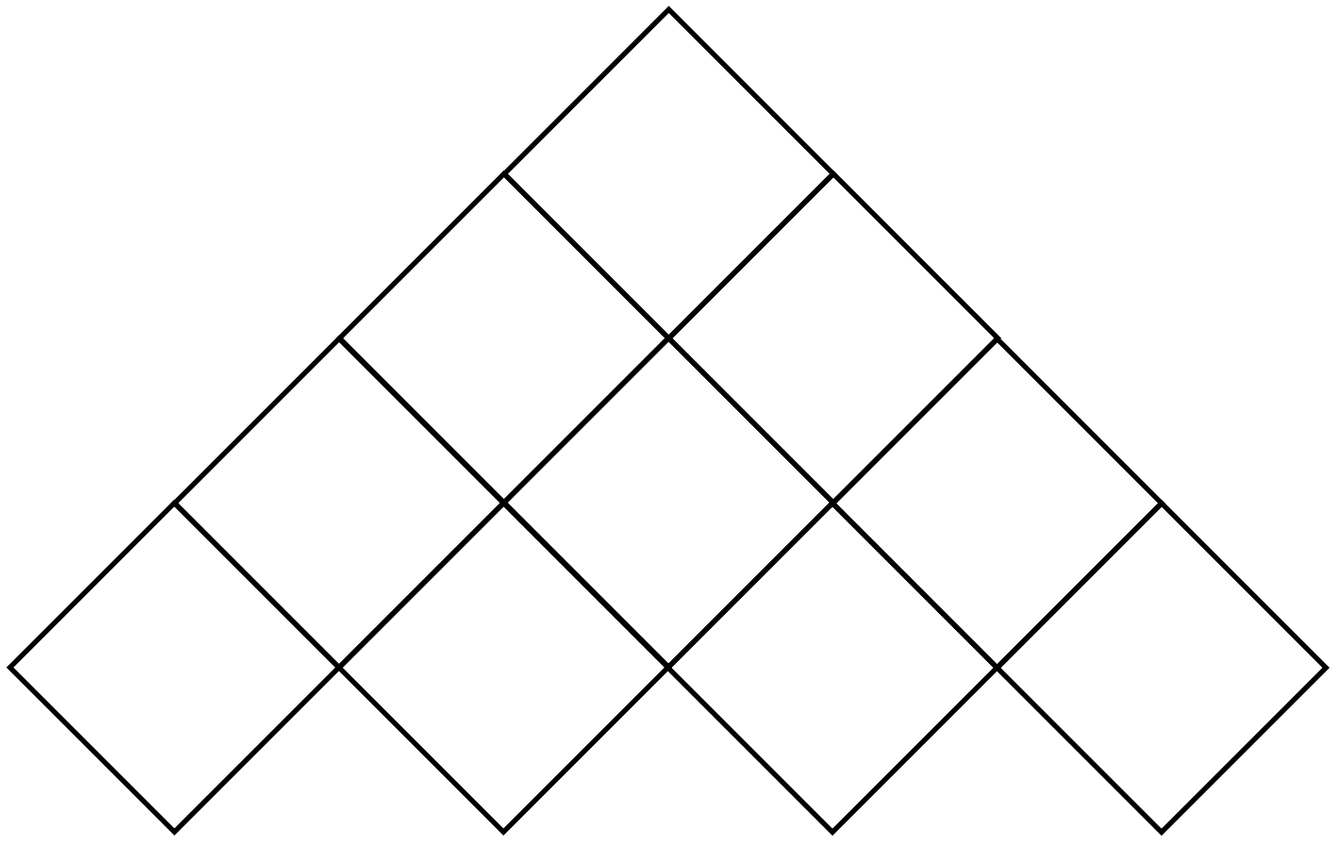


the	lazy	dogs	wander
np/n	n/n	n	n
	np	np	n/n
		(s\np)/np	np/n
			s\np
			...

Posterior Inference

Priors (simple is good)

PCFG

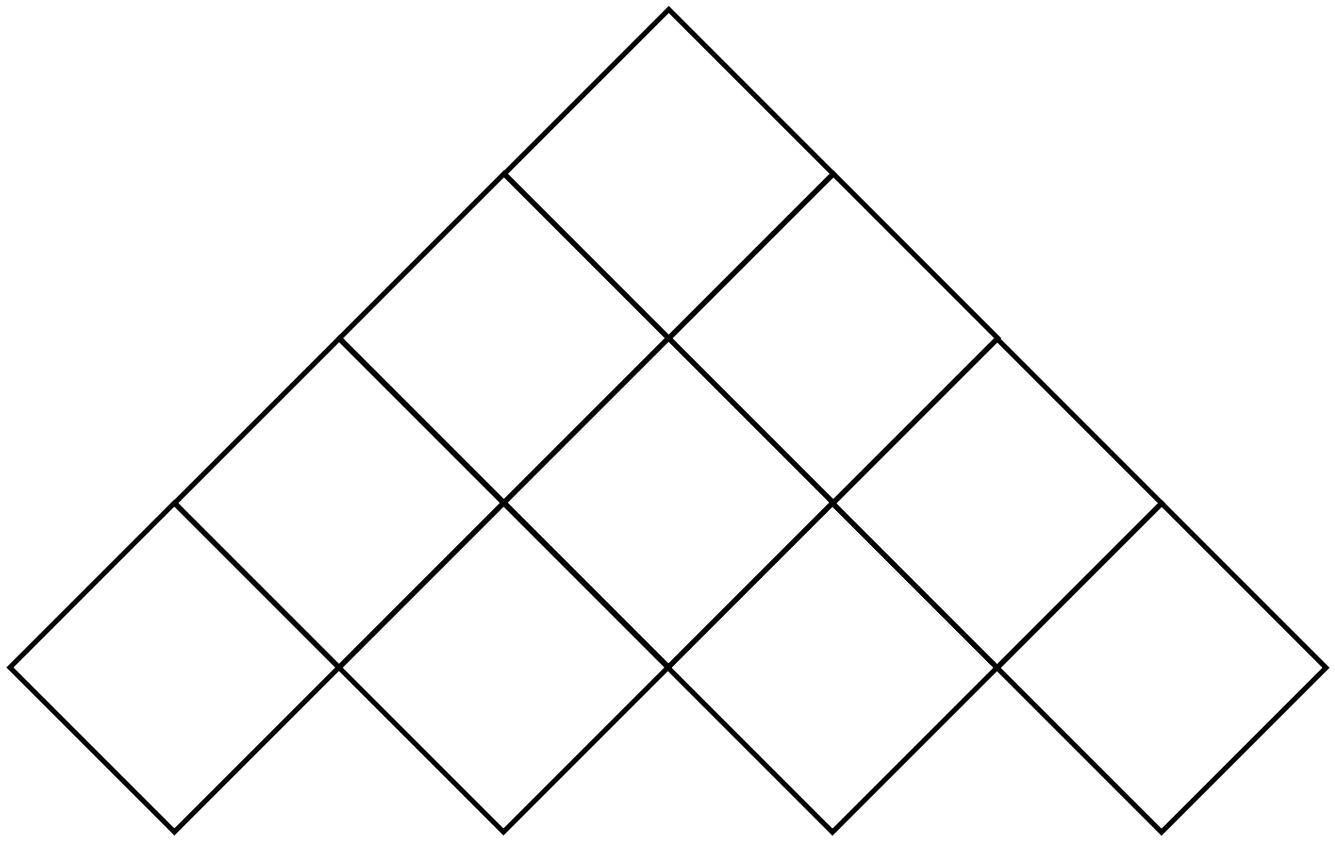


the	lazy	dogs	wander
np/n	n/n	n	n
	np	np	n/n
		(s\np)/np	np/n
			s\np
			...

Posterior Inference

Priors (simple is good)

PCFG

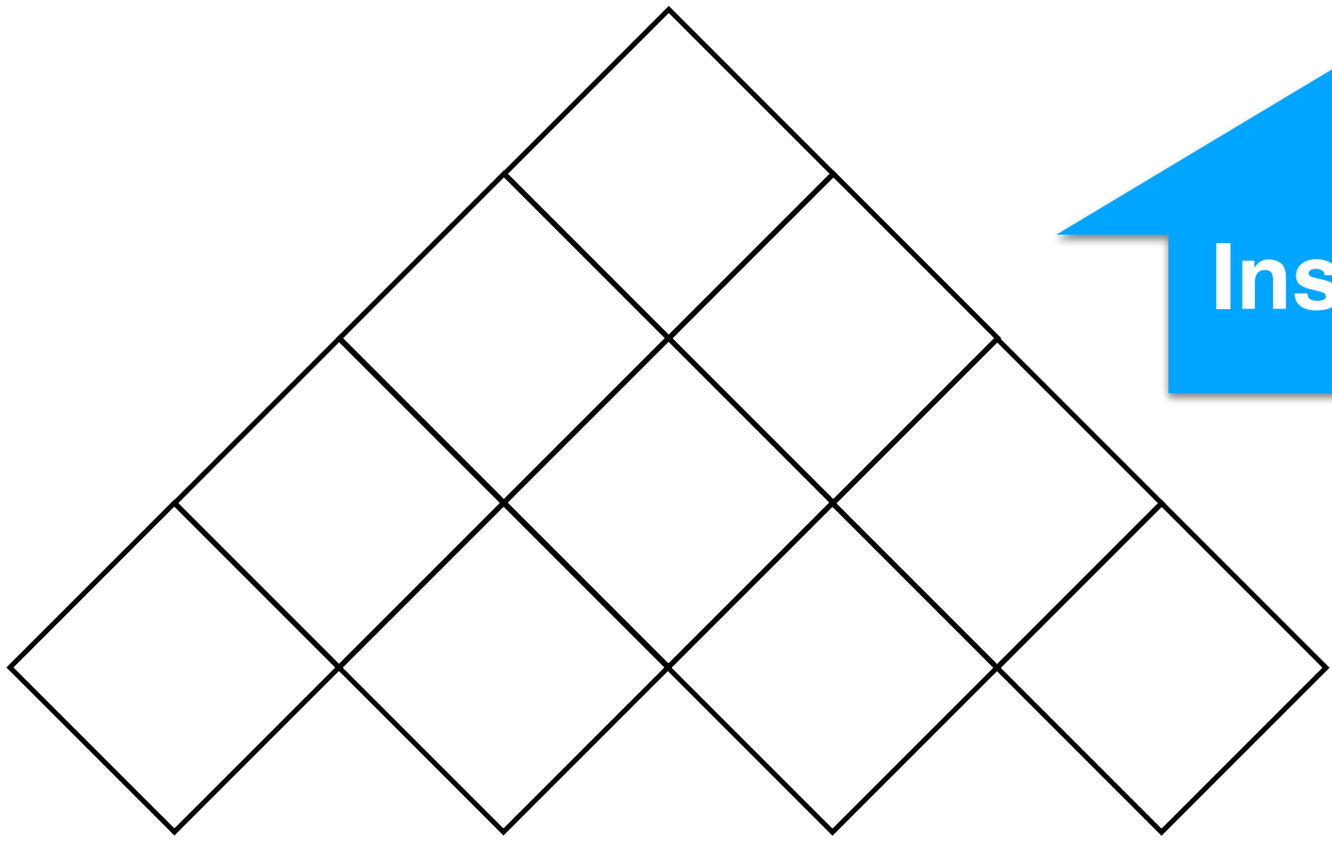


the	lazy	dogs	wander
np/n	n/n	n	n
	np	np	n/n
		(s\np)/np	np/n
			s\np
			...

Posterior Inference

Priors (simple is good)

PCFG



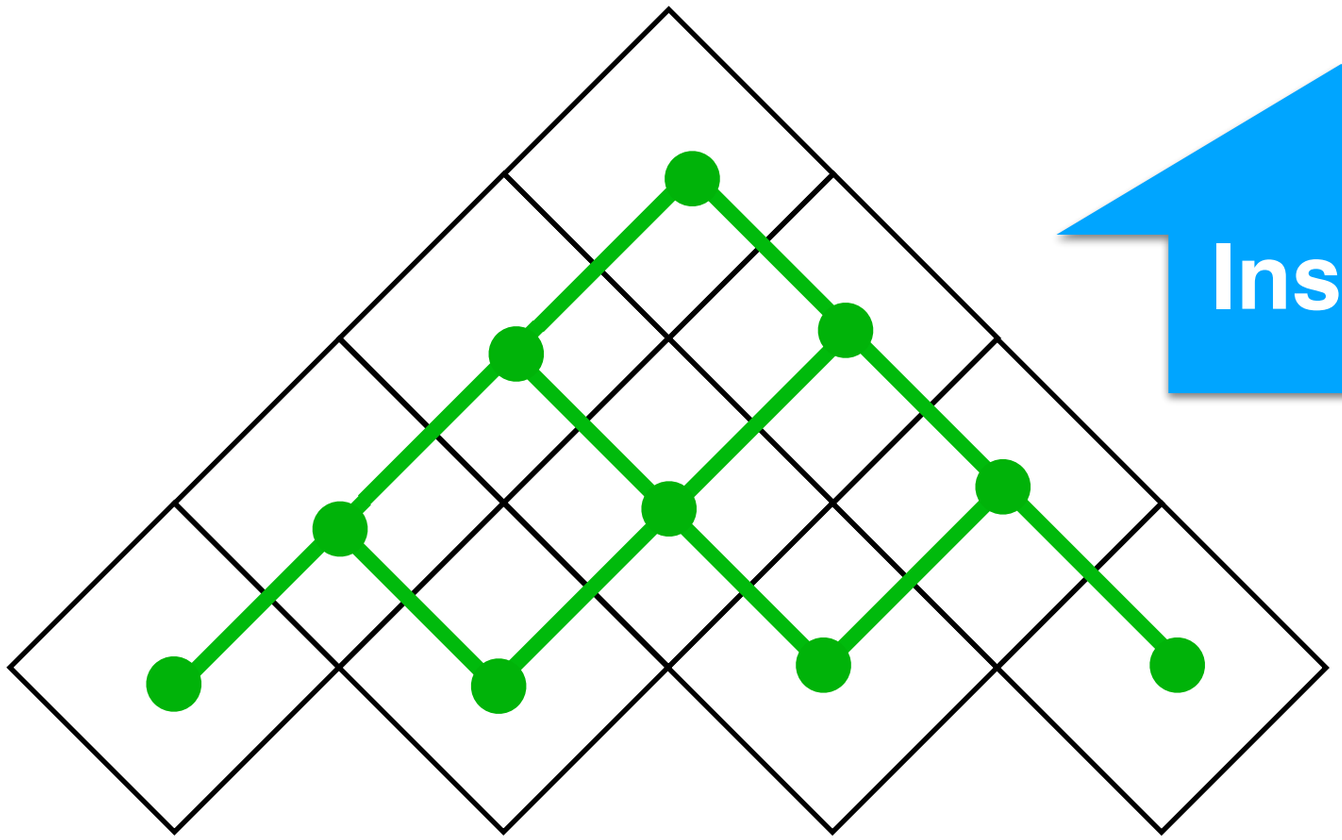
Inside

the	lazy	dogs	wander
np/n	n/n	n	n
	np	np	n/n
		(s\np)/np	np/n
			s\np
			...

Posterior Inference

Priors (simple is good)

PCFG

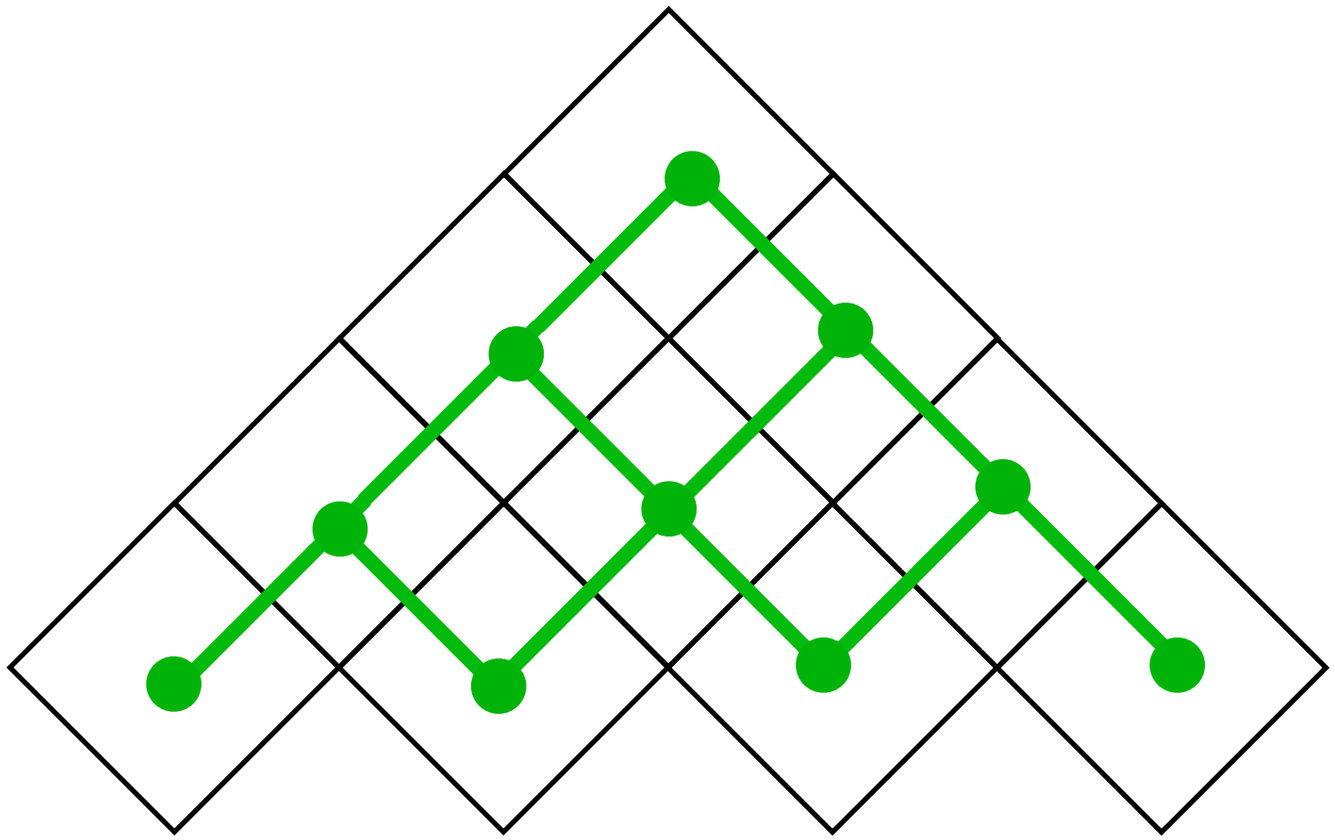


the	lazy	dogs	wander
np/n	n/n	n	n
	np	np	n/n
		(s\np)/np	np/n
			s\np
			...

Posterior Inference

Priors (simple is good)

PCFG

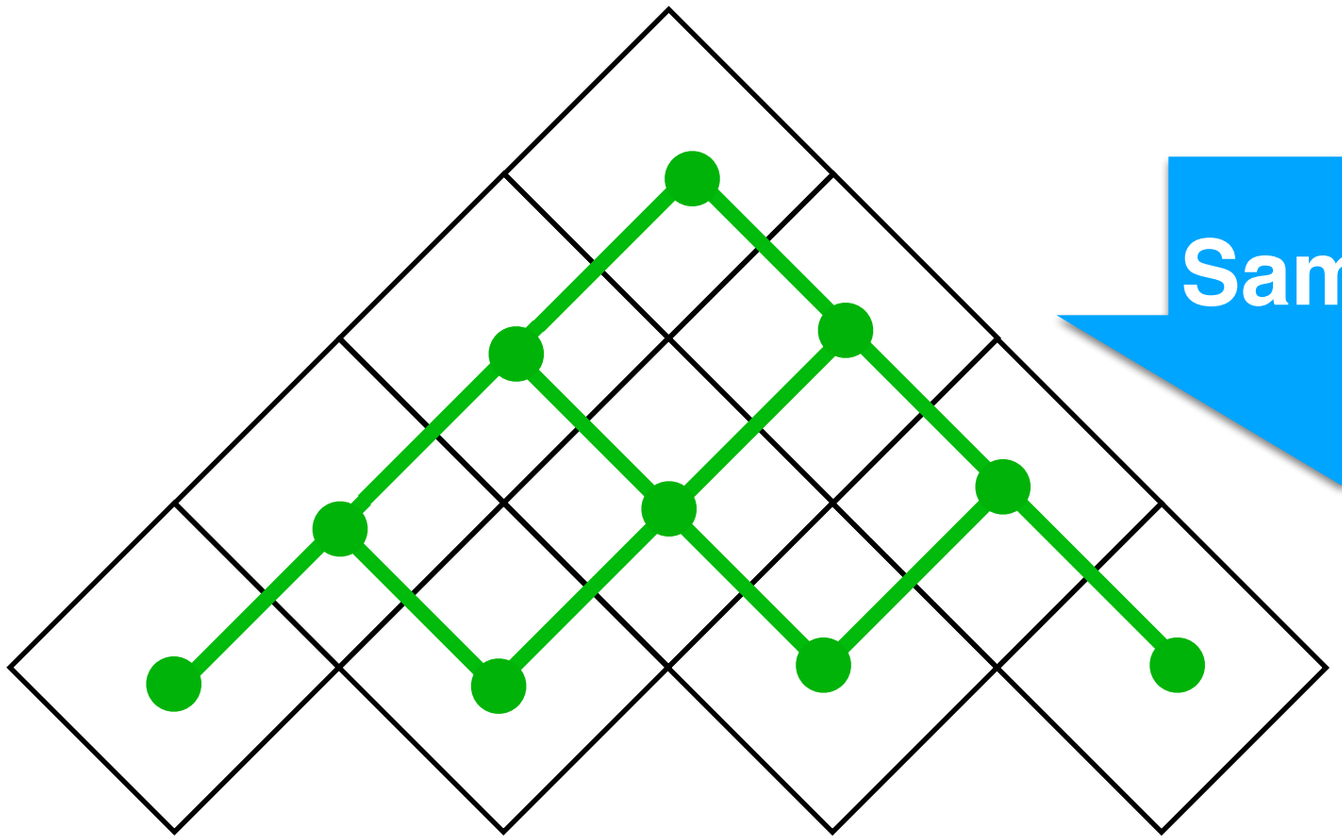


the	lazy	dogs	wander
np/n	n/n	n	n
	np	np	n/n
		(s\np)/np	np/n
			s\np
			...

Posterior Inference

Priors (simple is good)

PCFG



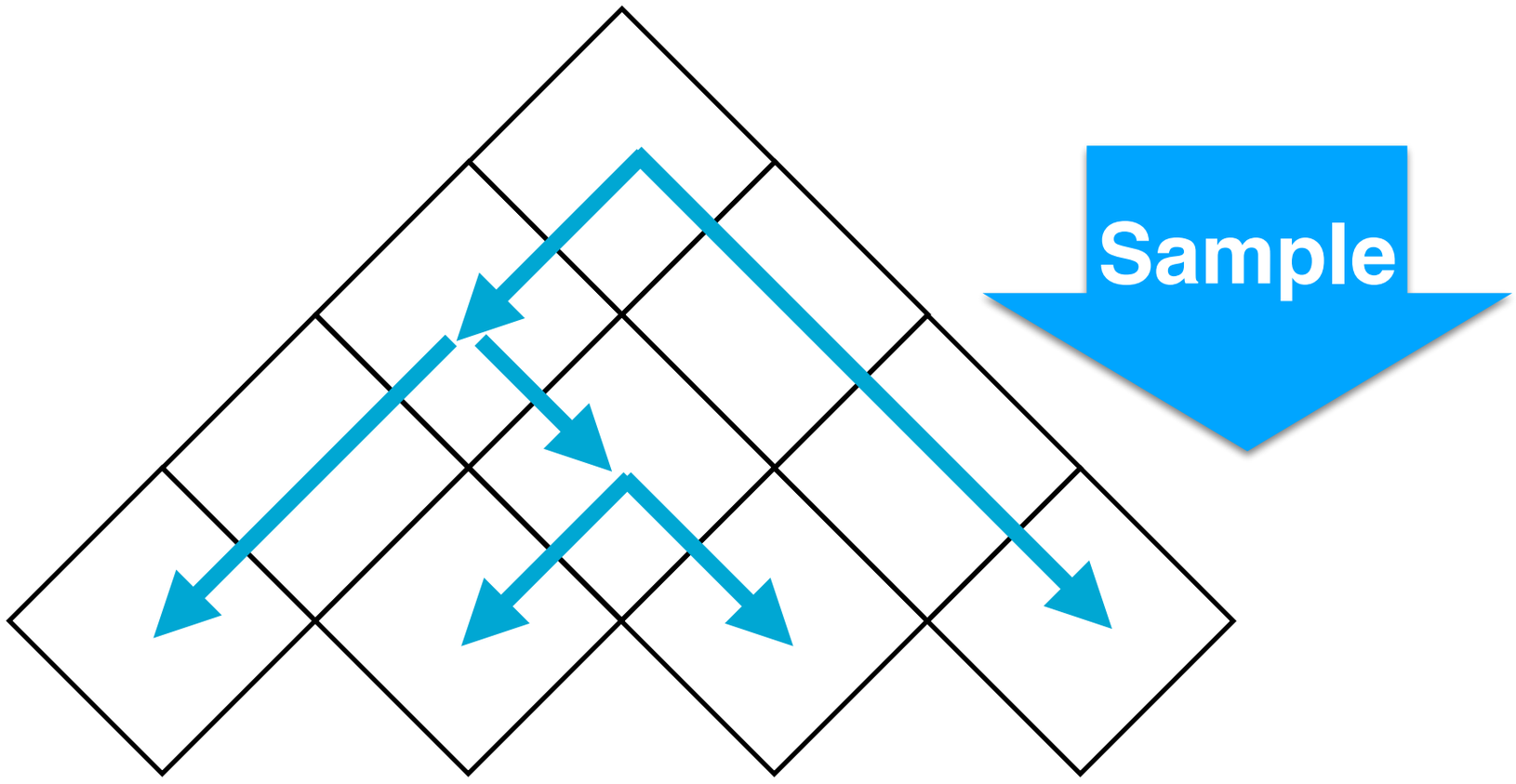
Sample

the	lazy	dogs	wander
np/n	n/n	n	n
	np	np	n/n
		(s\np)/np	np/n
			s\np
			...

Posterior Inference

Priors (simple is good)

PCFG

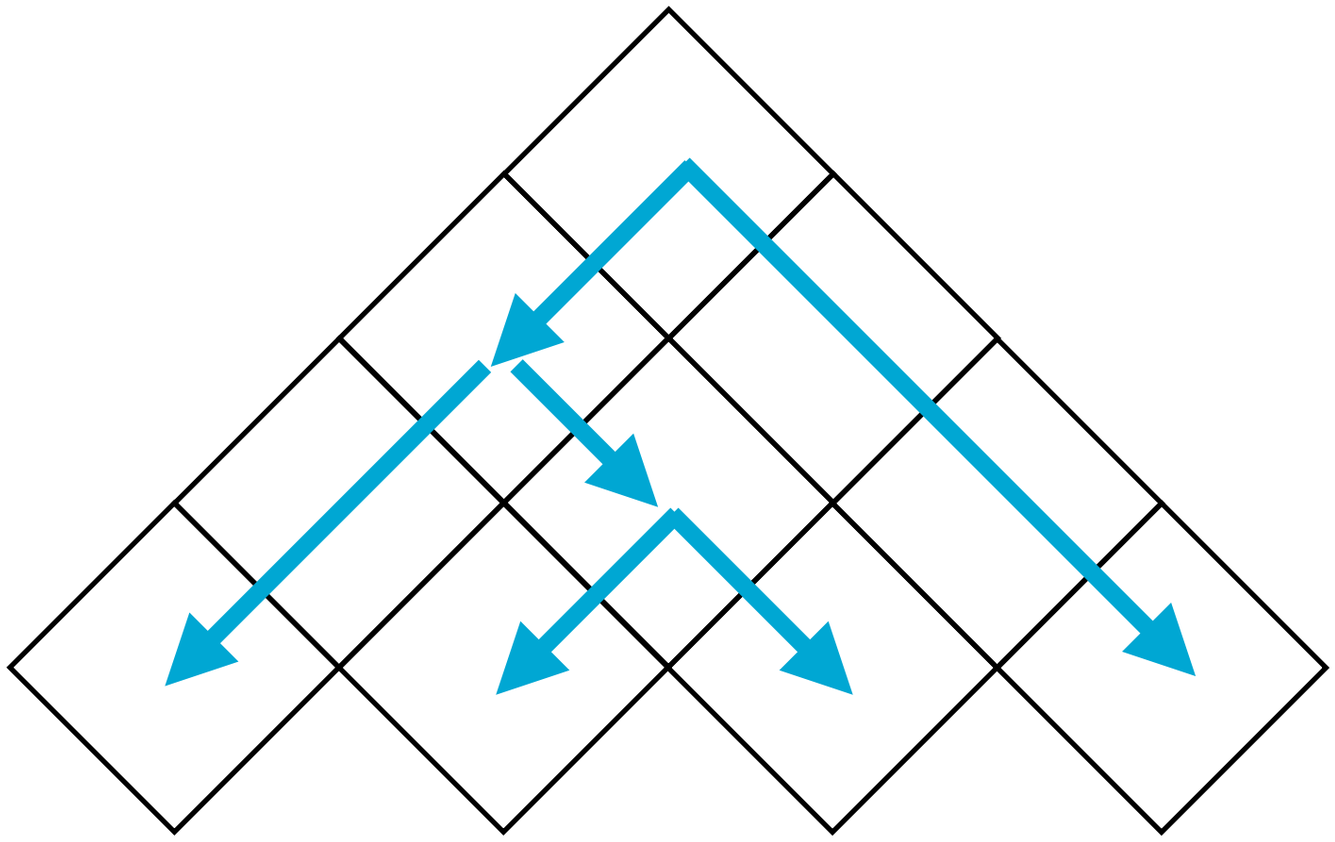


the	lazy	dogs	wander
np/n	n/n	n	n
	np	np	n/n
		(s\np)/np	np/n
			s\np
			...

Posterior Inference

Priors (simple is good)

PCFG

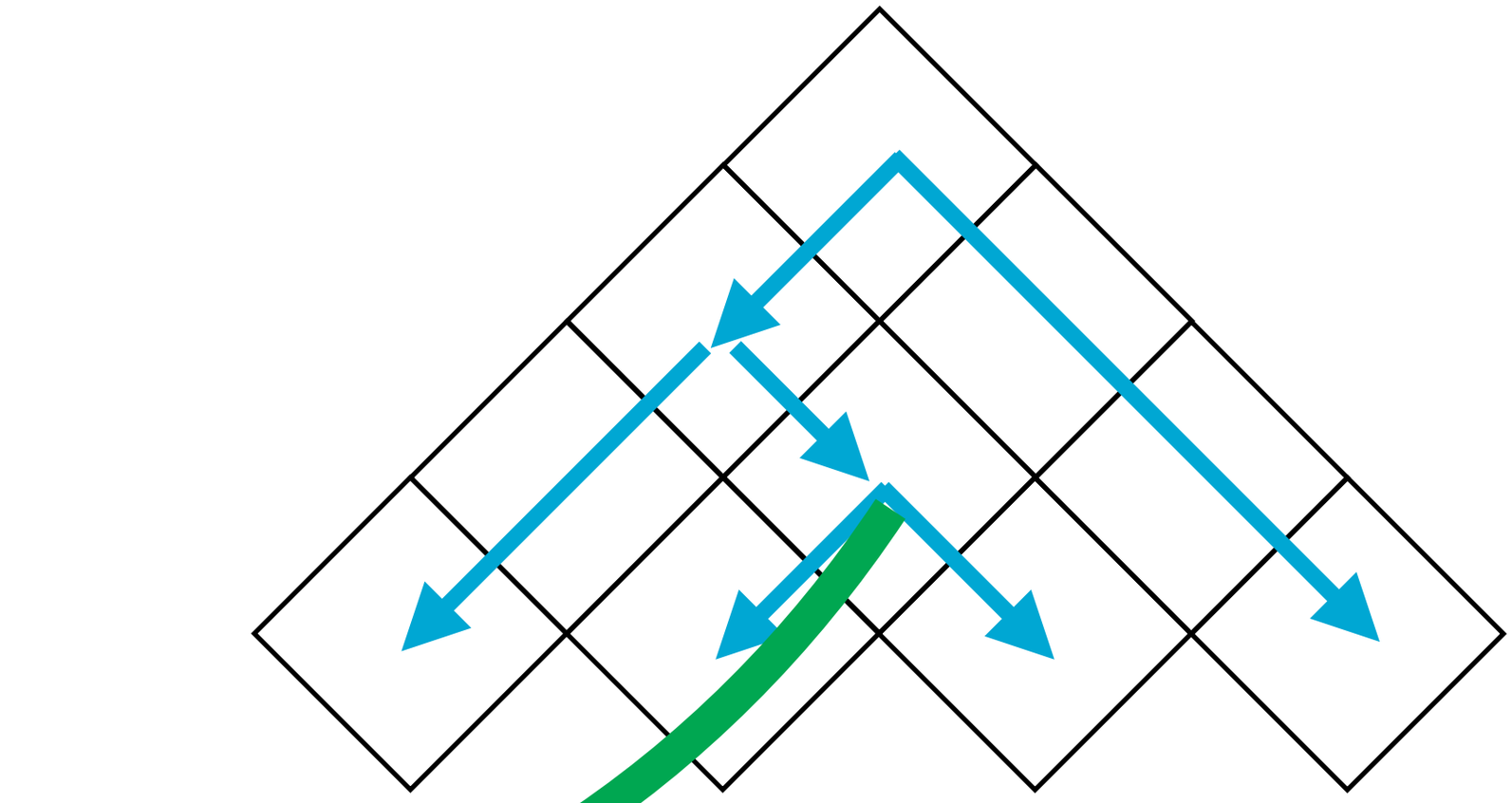


the	lazy	dogs	wander
np/n	n/n	n	n
	np	np	n/n
		(s\np)/np	np/n
			s\np
			...

Posterior Inference

Priors (simple is good)

PCFG

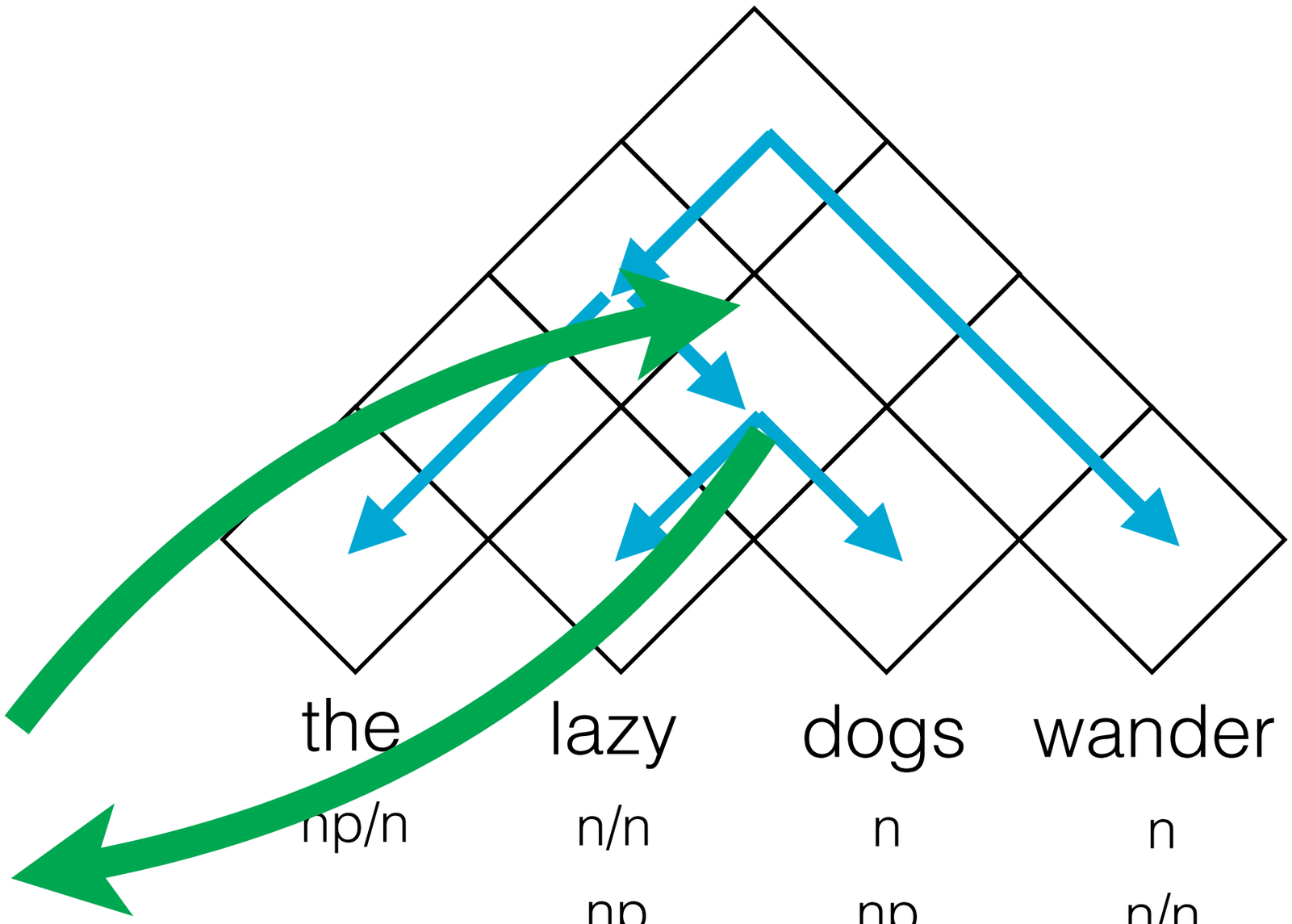


the	lazy	dogs	wander
np/n	n/n	n	n
	np	np	n/n
		(s\np)/np	np/n
			s\np
			...

Posterior Inference

Priors (simple is good)

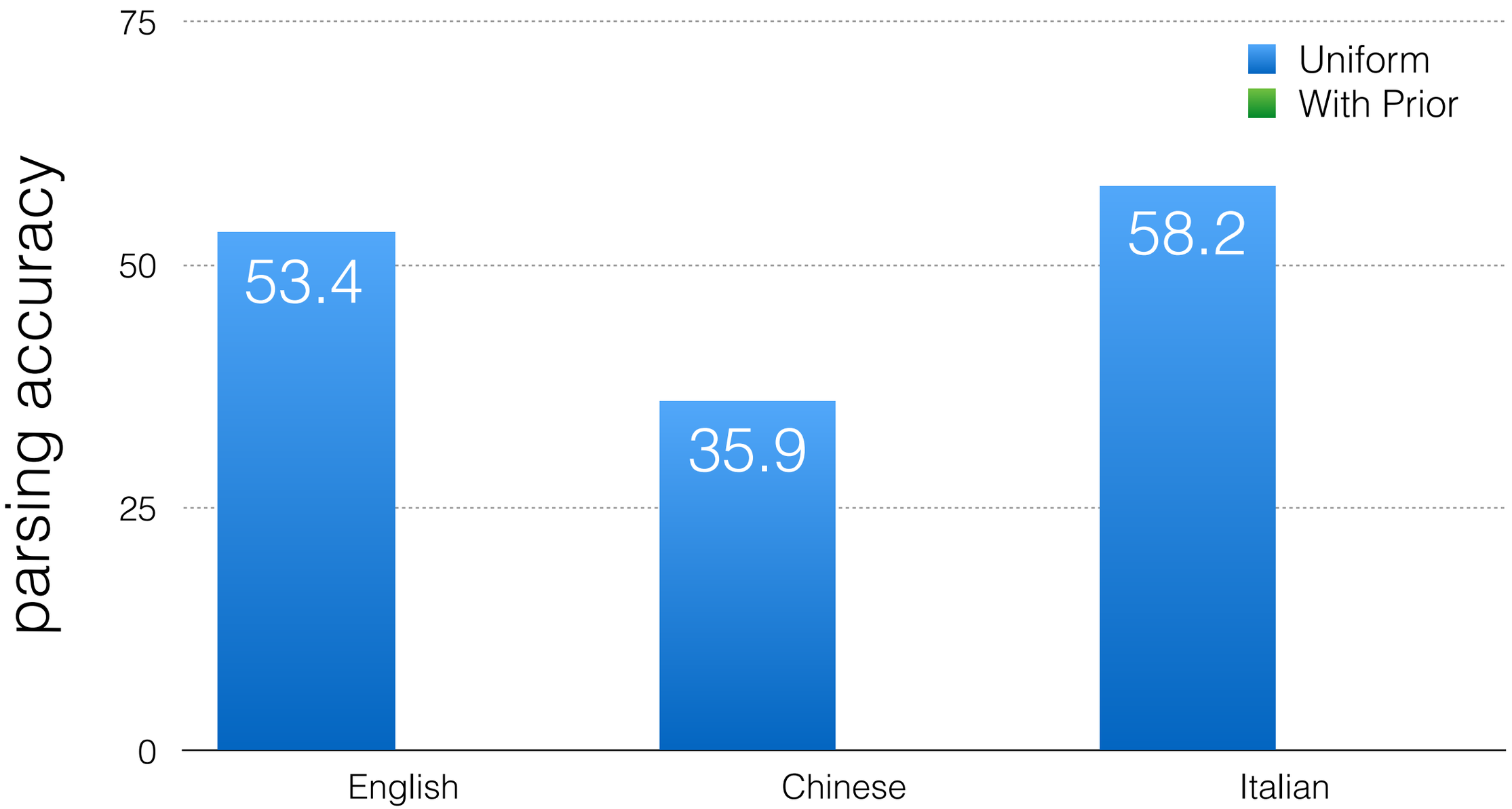
PCFG



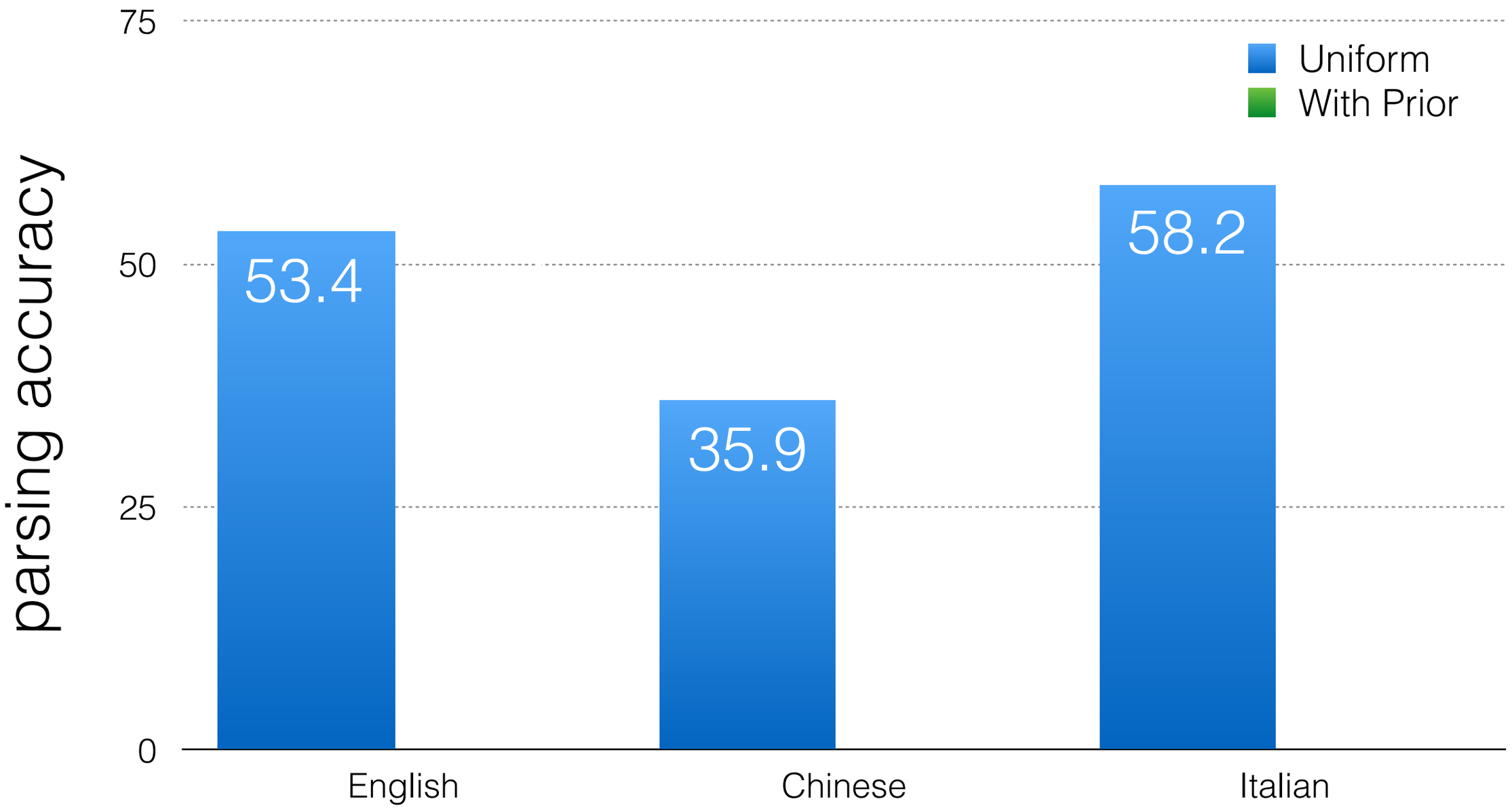
the	lazy	dogs	wander
np/n	n/n	n	n
	np	np	n/n
		(s\np)/np	np/n
			s\np
			...

Results

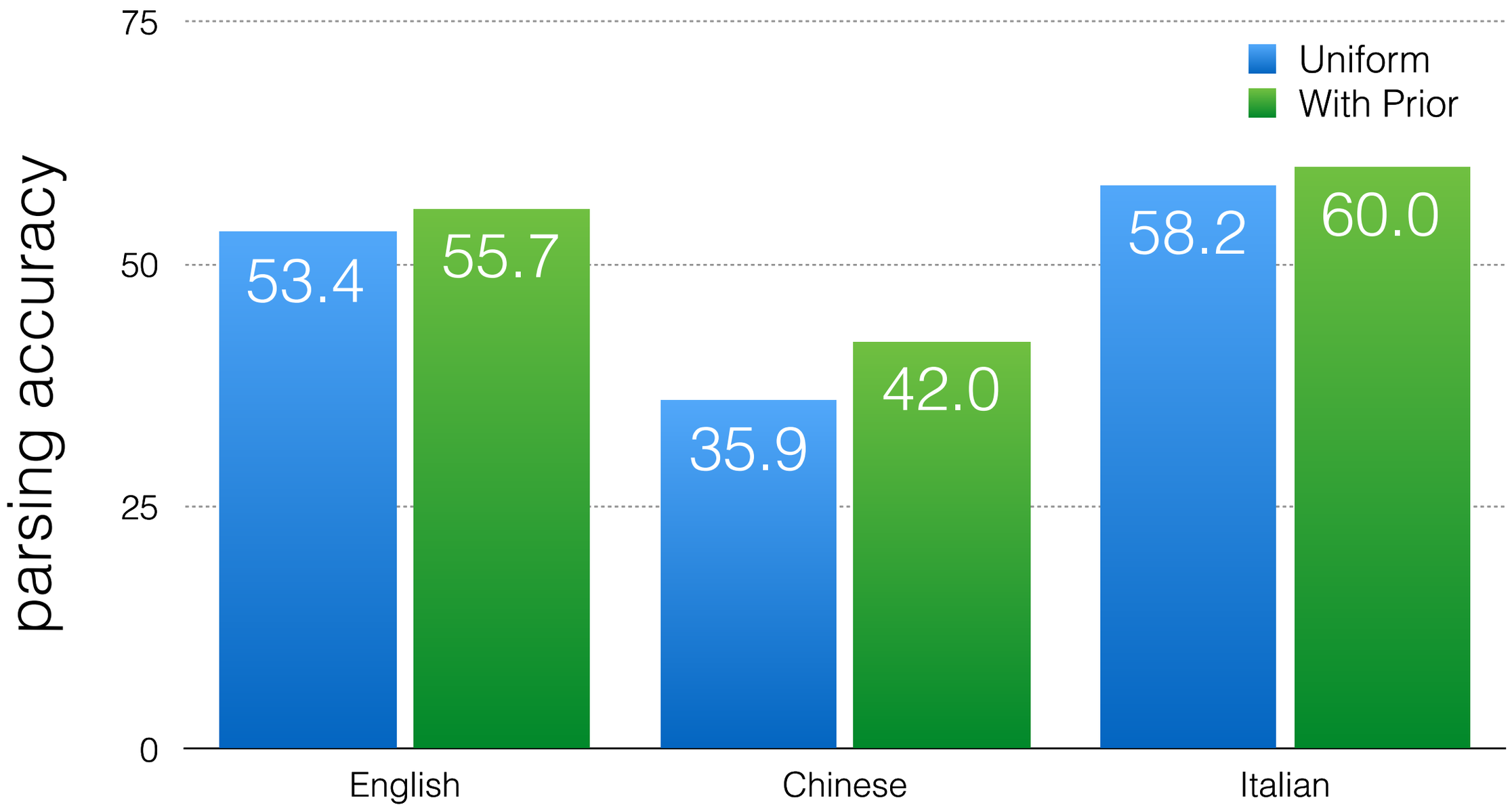
CCG Parsing Results



CCG Parsing Results



CCG Parsing Results



Conclusion

Using **universal grammatical knowledge**
can make better use of weak supervision