HPSG Tutorial

LSA Linguistic Institute
Lexington KY
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Overview

- Introduction: Shared assumptions, high-level overview
- Key ideas
- Theoretical commitments
- Extensions

Shared assumptions

- Generative approach: Formal models of linguistic knowledge
- Competence/performance distinction
- Interest in modeling grammaticality
- Interest in modeling semantic compositionality
- Constituent structure
- Parts of speech
- X-bar theory

Key ideas

- Mono-stratal theory of grammar
- Language as a system of signs
- Typed feature structures
- Unification
- Strong lexicalism
- Capturing generalizations of different granularities

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Key ideas

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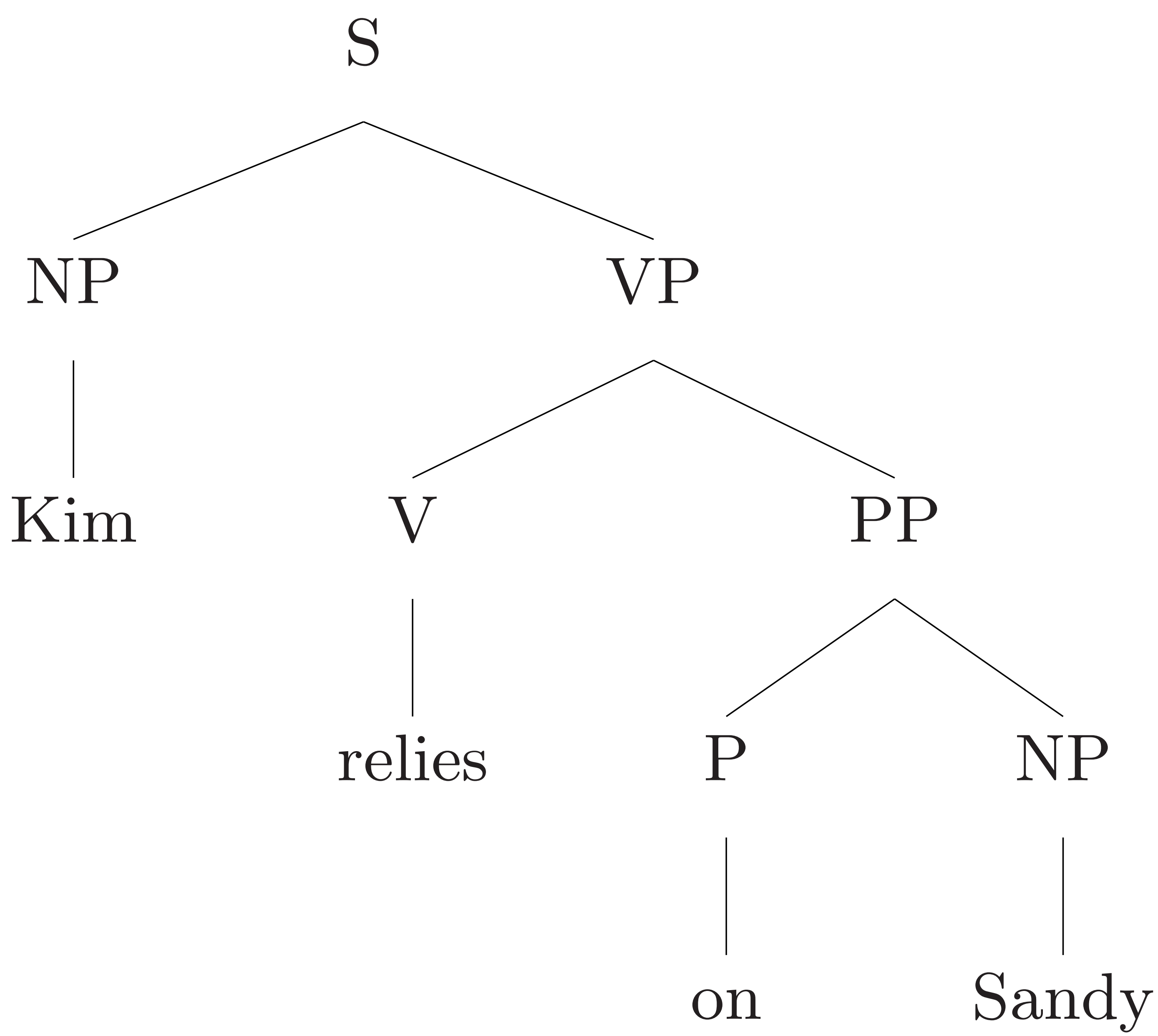
Key idea 1: Mono-stratal theory of grammar

- Each analysis pairs a string with one (detailed, elaborate) structure.
- This contrasts to the sequences of structures that constitute analyses in transformational approaches.
- Benefits:
  - Potentially enables integration with incremental parsing models
  - Compatible with psycholinguistic studies of language processing
  - Process-independent (parsing, generation, crossword puzzles, …)

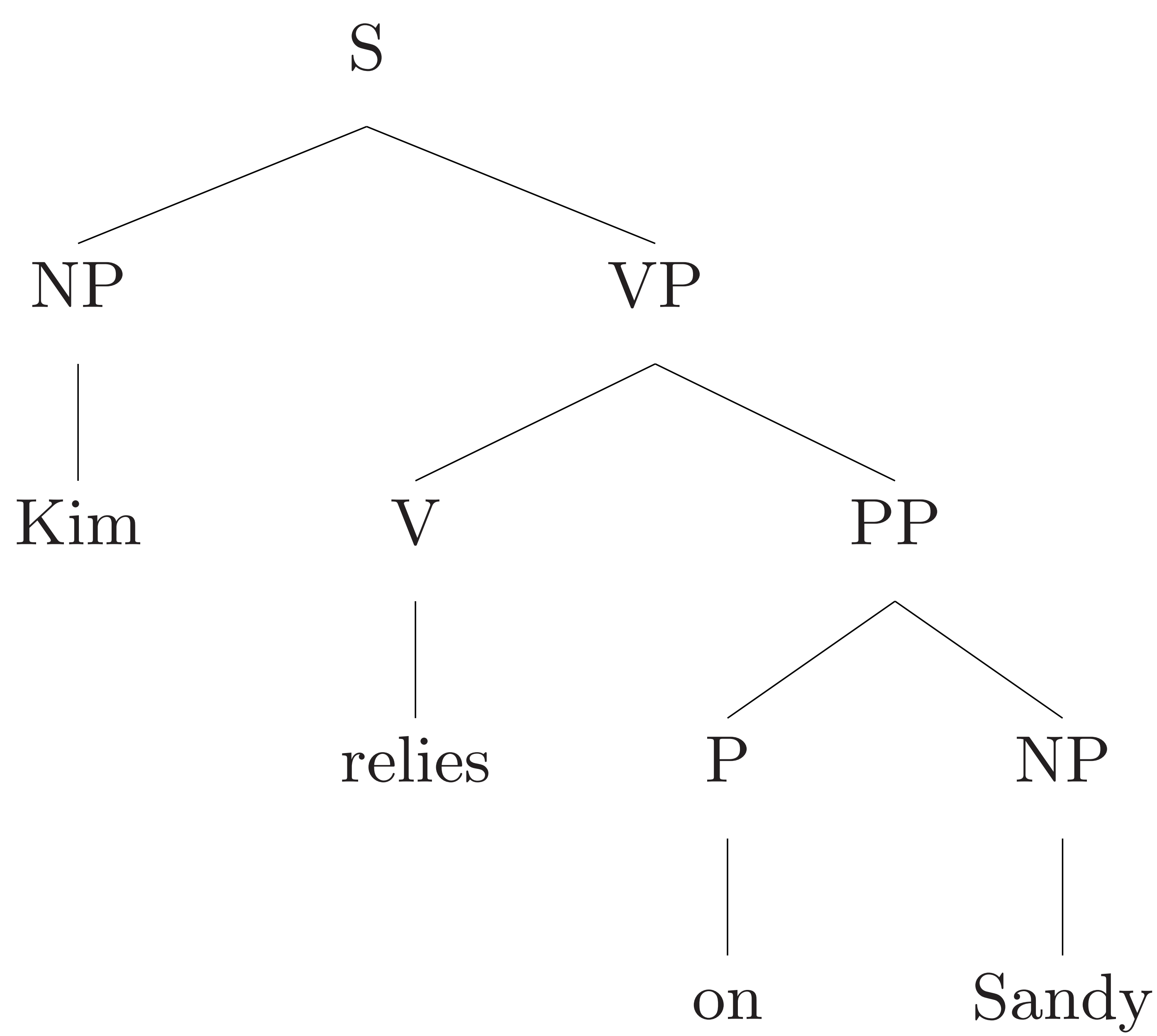
Example 1 (simple)



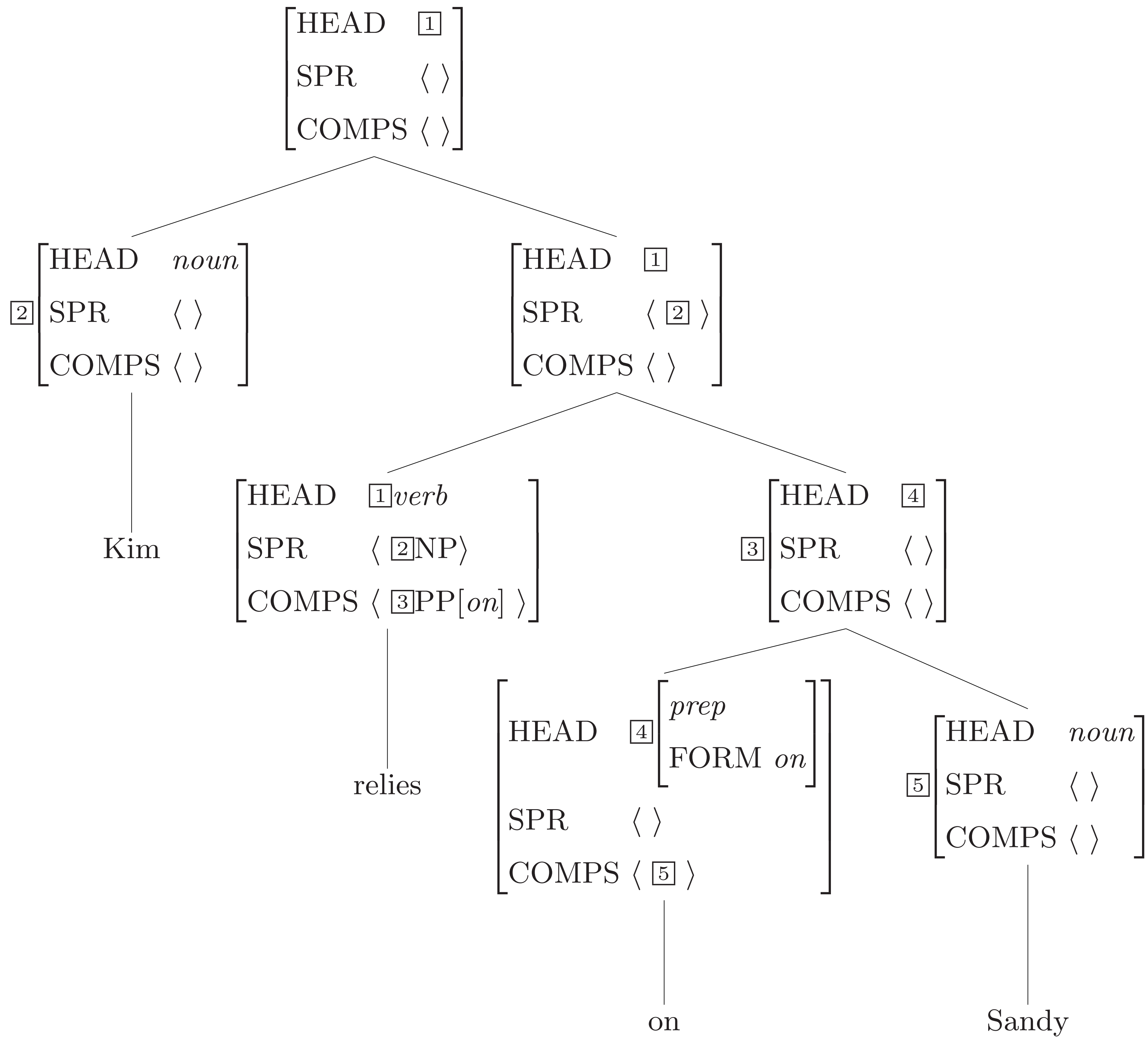
Ex 1: Semantics of S node

$$\begin{bmatrix} \text{INDEX} & \text{e1} \\ \text{RELS} & \left\langle \begin{bmatrix} \text{PRED} & \text{named} \\ \text{ARG0} & \text{x2} \\ \text{CARG} & \text{“Kim”} \end{bmatrix}, \begin{bmatrix} \text{PRED} & \text{rely\_on} \\ \text{ARG0} & \text{e1} \\ \text{ARG1} & \text{x2} \\ \text{ARG2} & \text{x3} \end{bmatrix}, \begin{bmatrix} \text{PRED} & \text{named} \\ \text{ARG0} & \text{x3} \\ \text{CARG} & \text{“Sandy”} \end{bmatrix} \right\rangle \end{bmatrix}$$

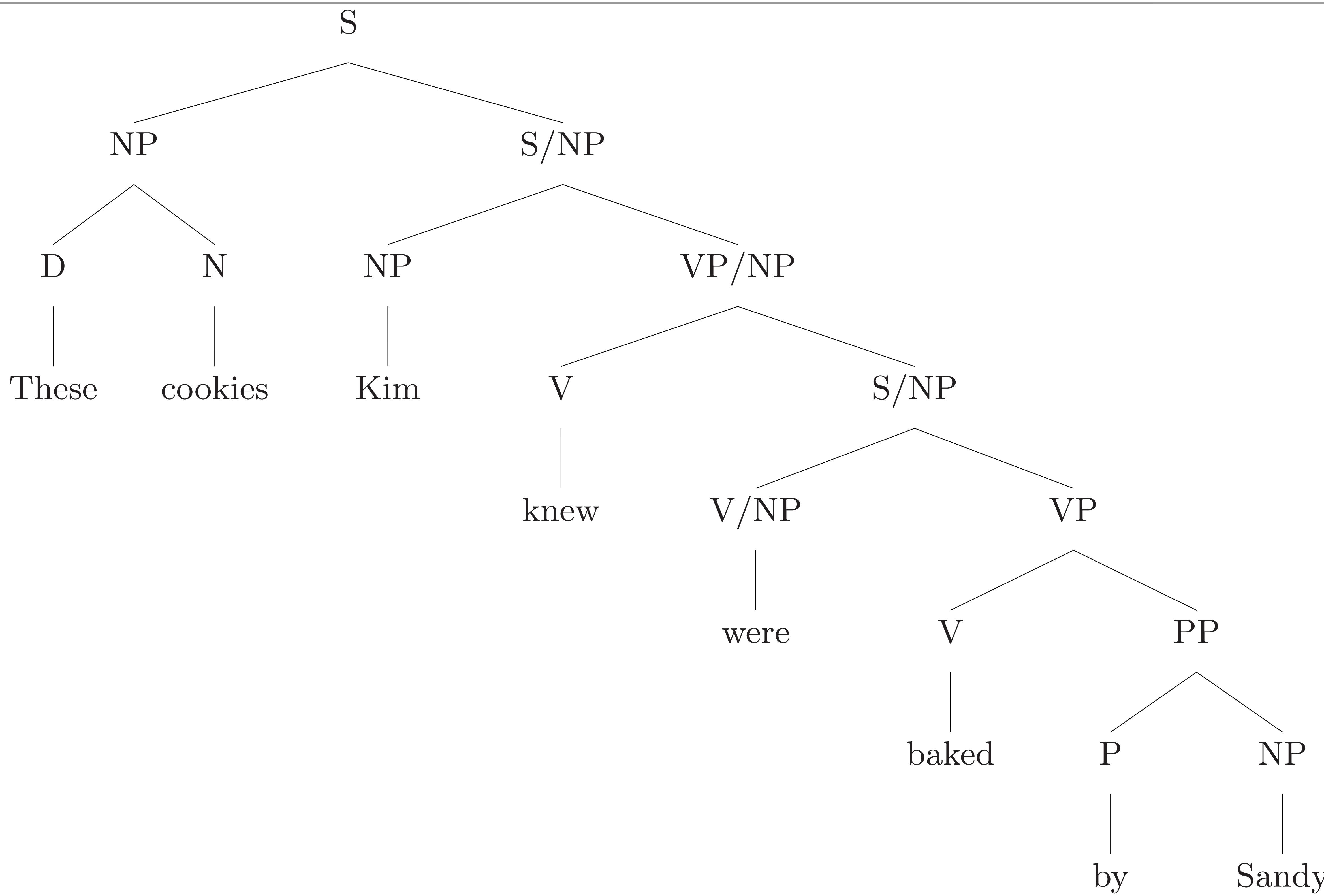
Example 1 (simple)



Ex 1: Partially unabbreviated

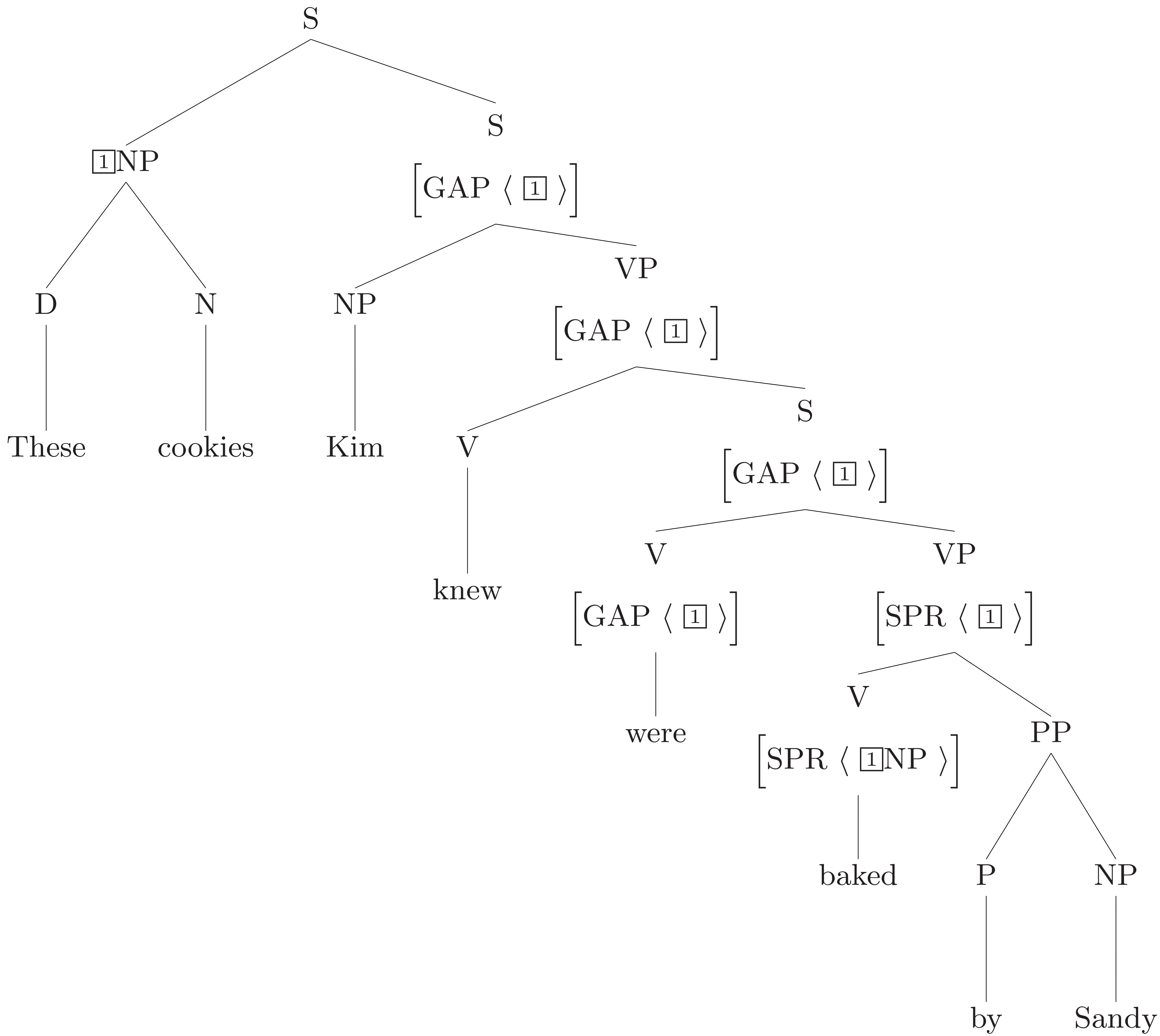


Example 2 (complex)



Ex 2: Semantics of S node

$$
\begin{bmatrix}
\text{INDEX} & \text{e1} \\
\text{RELS} & \left\langle
\begin{matrix}
\begin{bmatrix} \text{PRED} & \text{know} \\ \text{ARG0} & \text{e1} \\ \text{ARG1} & \text{x2} \\ \text{ARG2} & \text{e3} \end{bmatrix},
\begin{bmatrix} \text{PRED} & \text{named} \\ \text{ARG0} & \text{x2} \\ \text{NAME} & \text{“Kim”} \end{bmatrix},
\begin{bmatrix} \text{PRED} & \text{bake} \\ \text{ARG0} & \text{e3} \\ \text{ARG1} & \text{x4} \\ \text{ARG2} & \text{x5} \end{bmatrix}, \\
\begin{bmatrix} \text{PRED} & \text{named} \\ \text{ARG0} & \text{x4} \\ \text{NAME} & \text{“Sandy”} \end{bmatrix},
\begin{bmatrix} \text{PRED} & \text{proximal} \\ \text{ARG1} & \text{x5} \end{bmatrix},
\begin{bmatrix} \text{PRED} & \text{cookie} \\ \text{ARG0} & \text{x5} \end{bmatrix}
\end{matrix}
\right\rangle
\end{bmatrix}
$$


S
1 NP
S
[GAP ⟨ 1 ⟩]
D
N
NP
VP
[GAP ⟨ 1 ⟩]
These
cookies
Kim
V
S
[GAP ⟨ 1 ⟩]
knew
V
[GAP ⟨ 1 ⟩]
VP
[SPR ⟨ 1 ⟩]
were
V
[SPR ⟨ 1 NP ⟩]
PP
baked
P
NP
by
Sandy

Key idea 1: Mono-stratal theory of grammar

- Each analysis pairs a string with one (detailed, elaborate) structure.
- This contrasts to the sequences of structures that constitute analyses in transformational approaches.
- Benefits:
  - Potentially enables integration with incremental parsing models
  - Compatible with psycholinguistic studies of language processing
  - Process-independent (parsing, generation, crossword puzzles, …)

Key ideas

- Mono-stratal theory of grammar
- Language as a system of signs
- Typed feature structures
- Unification
- Strong lexicalism
- Capturing generalizations of different granularities

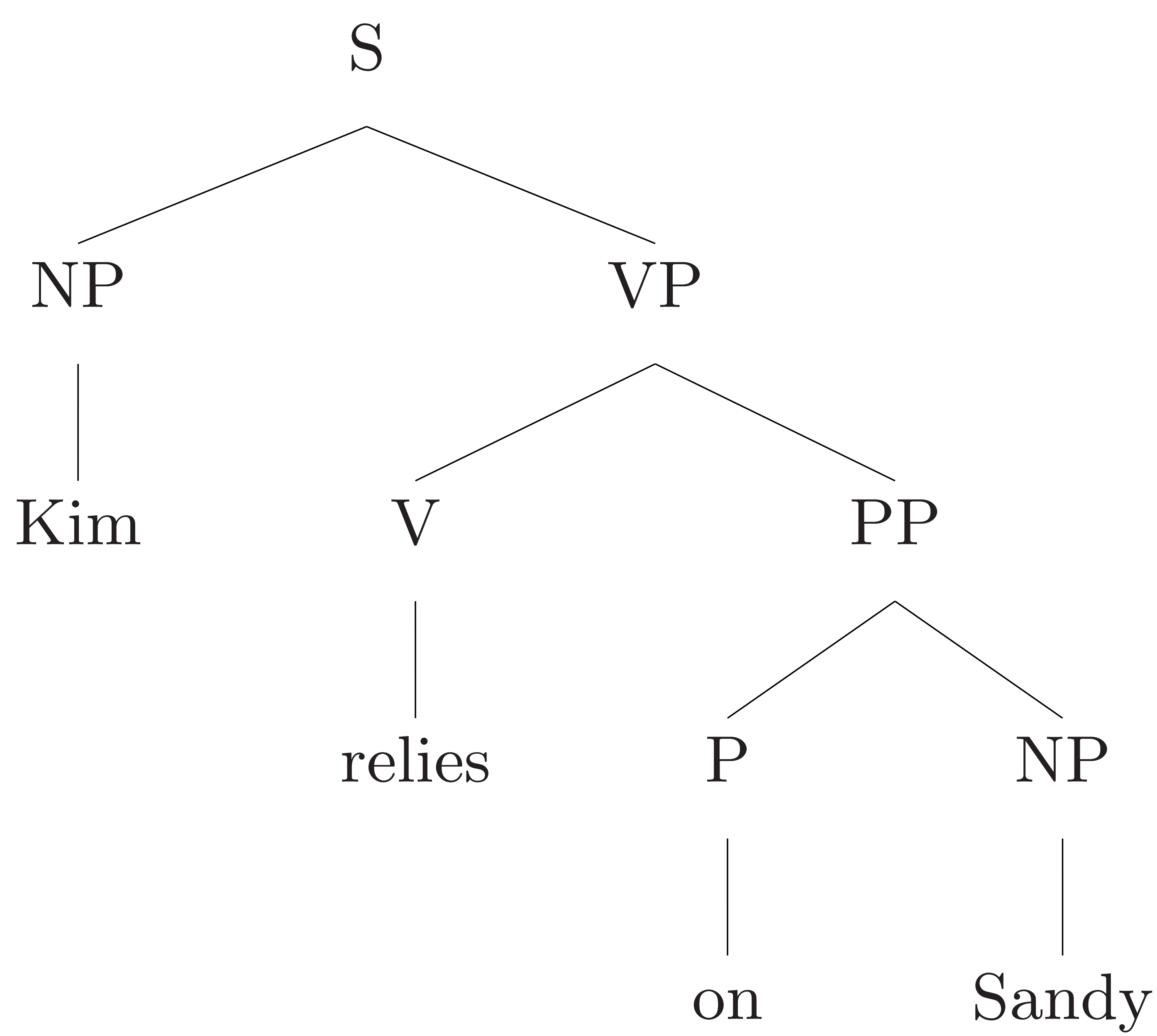
Key idea 2: Language as a system of signs

- Words and phrases are both modeled as pairings of form and meaning
- Phrase structure rules are also modeled as pairings of (constraints on) form and meaning
- In Sag et al's 2003 formulation, part of this information is abstracted out to principles: "Semantic Compositionality Principle" and "Semantic Inheritance Principle"

Key idea 2: Language as a system of signs

- Benefits:
  - Local compositionality, compatible with the rule-to-rule principle (cf. Szabó 2017)
  - Enables semantic/pragmatic processing of fragments

Ex 1: Reprise



Ex 1: Lexical entries

$$\left\langle \text{Kim} \; , \begin{bmatrix} \text{SYN} & \begin{bmatrix} \text{HEAD} & \textit{noun} \\ \text{VAL} & \begin{bmatrix} \text{SPR} & \langle\ \rangle \\ \text{COMPS} & \langle\ \rangle \end{bmatrix} \end{bmatrix} \\ \text{SEM} & \begin{bmatrix} \text{INDEX} & \text{x} \\ \text{RELS} & \left\langle \begin{bmatrix} \text{PRED} & \text{named} \\ \text{ARG0} & \text{x} \\ \text{NAME} & \text{``Kim''} \end{bmatrix} \right\rangle \end{bmatrix} \end{bmatrix} \right\rangle$$

Ex 1: Lexical entries

$$\left\langle \text{Sandy}\ , \begin{bmatrix} \text{SYN} & \begin{bmatrix} \text{HEAD} & \textit{noun} \\ \text{VAL} & \begin{bmatrix} \text{SPR} & \langle\ \rangle \\ \text{COMPS} & \langle\ \rangle \end{bmatrix} \end{bmatrix} \\ \text{SEM} & \begin{bmatrix} \text{INDEX} & \text{x} \\ \text{RELS} & \left\langle \begin{bmatrix} \text{PRED} & \text{named} \\ \text{ARG0} & \text{x} \\ \text{NAME} & \text{``Sandy''} \end{bmatrix} \right\rangle \end{bmatrix} \end{bmatrix} \right\rangle$$

Ex 1: Lexical entries

$$
\left\langle \text{rely} \;,\; \begin{bmatrix} \text{SYN} & \begin{bmatrix} \text{HEAD} & \textit{verb} \\ \text{VAL} & \begin{bmatrix} \text{SPR} & \langle\ \text{NP[INDEX x]}\ \rangle \\ \text{COMPS} & \langle\ \text{PP[INDEX y]}\ \rangle \end{bmatrix} \end{bmatrix} \\ \text{SEM} & \begin{bmatrix} \text{INDEX} & \text{e} \\ \text{RELS} & \left\langle \begin{bmatrix} \text{PRED} & \text{rely\_on} \\ \text{ARG0} & \text{e} \\ \text{ARG1} & \text{x} \\ \text{ARG2} & \text{y} \end{bmatrix} \right\rangle \end{bmatrix} \end{bmatrix} \right\rangle
$$

Ex 1: Lexical entries

$$
\left\langle \text{on}\ ,\ \begin{bmatrix} \text{SYN} & \begin{bmatrix} \text{HEAD} & \textit{prep} \\ \text{VAL} & \begin{bmatrix} \text{SPR} & \langle\ \rangle \\ \text{COMPS} & \langle\ \text{NP[INDEX x]}\ \rangle \end{bmatrix} \end{bmatrix} \\ \text{SEM} & \begin{bmatrix} \text{INDEX} & \text{x} \\ \text{RELS} & \langle\ \rangle \end{bmatrix} \end{bmatrix} \right\rangle
$$

Ex 1: Phrase structure rules

Head-Complement Rule

$$\begin{bmatrix} \textit{phrase} \\ \text{COMPS} \quad \langle\ \rangle \end{bmatrix} \rightarrow \mathbf{H}\begin{bmatrix} \textit{word} \\ \text{COMPS} \quad \langle\ \boxed{1}\ ,\ \ldots,\ \boxed{n}\ \rangle \end{bmatrix} \ \boxed{1}\ \ldots\ \boxed{n}$$

Head-Specifier Rule

$$\begin{bmatrix} \textit{phrase} \\ \text{SPR} \quad \langle\ \rangle \end{bmatrix} \rightarrow \boxed{1} \quad \mathbf{H}\begin{bmatrix} \text{SPR} \quad \langle\ \boxed{1}\ \rangle \\ \text{COMPS} \quad \langle\ \rangle \end{bmatrix}$$

Ex 1: Principles

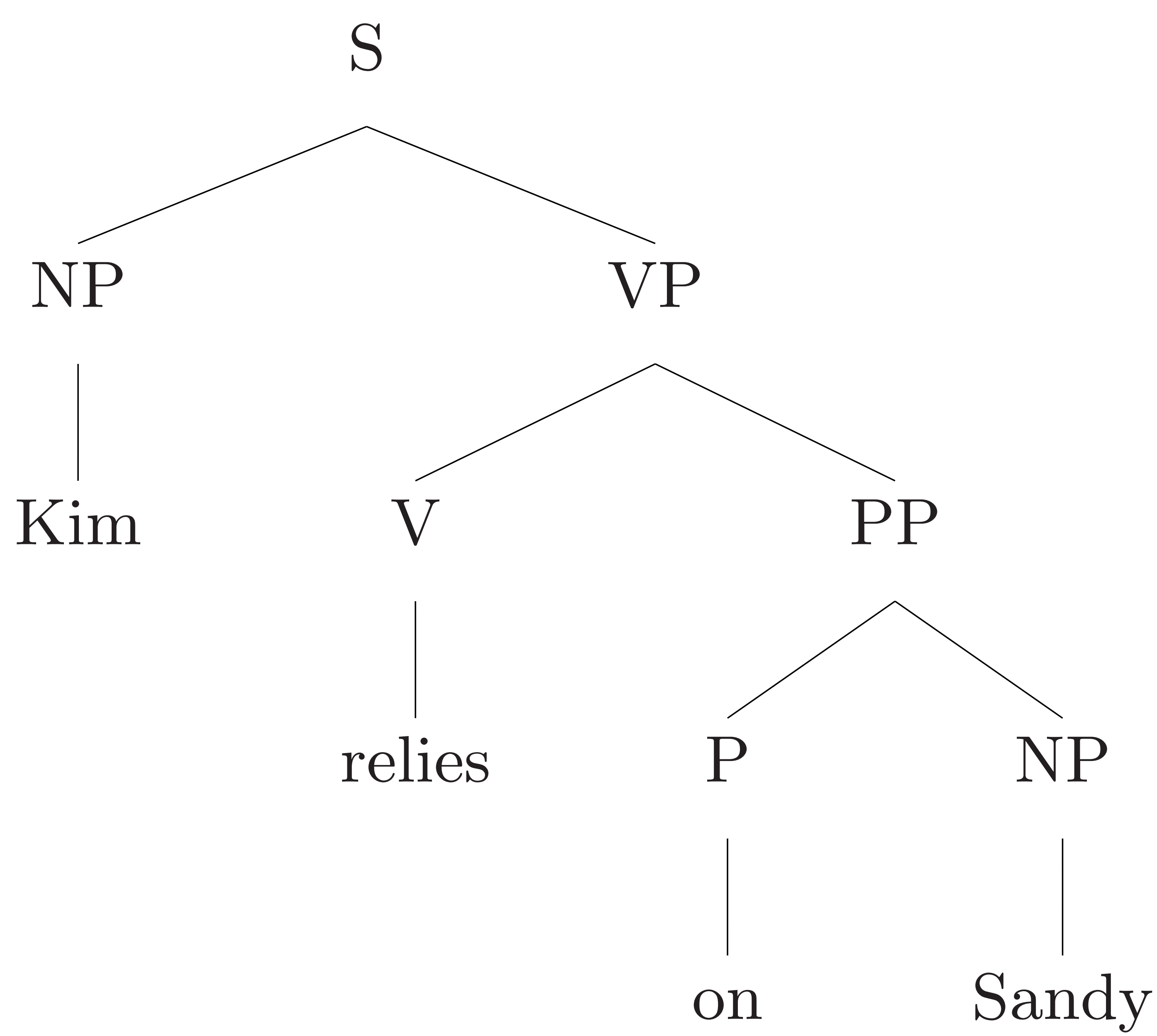
Semantic Compositionality Principle

$$\begin{bmatrix}\text{RELS} & \boxed{A_1} \oplus \ldots \oplus \boxed{A_n}\end{bmatrix} \rightarrow \begin{bmatrix}\text{RELS} & \boxed{A_1}\end{bmatrix} \ldots \begin{bmatrix}\text{RELS} & \boxed{A_n}\end{bmatrix}$$

Semantic Inheritance Principle

$$\begin{bmatrix}\text{INDEX} & \boxed{1}\end{bmatrix} \rightarrow \ldots\ \mathbf{H}\begin{bmatrix}\text{INDEX} & \boxed{1}\end{bmatrix} \ldots$$

Ex 1: Licensing by phrase structure rules



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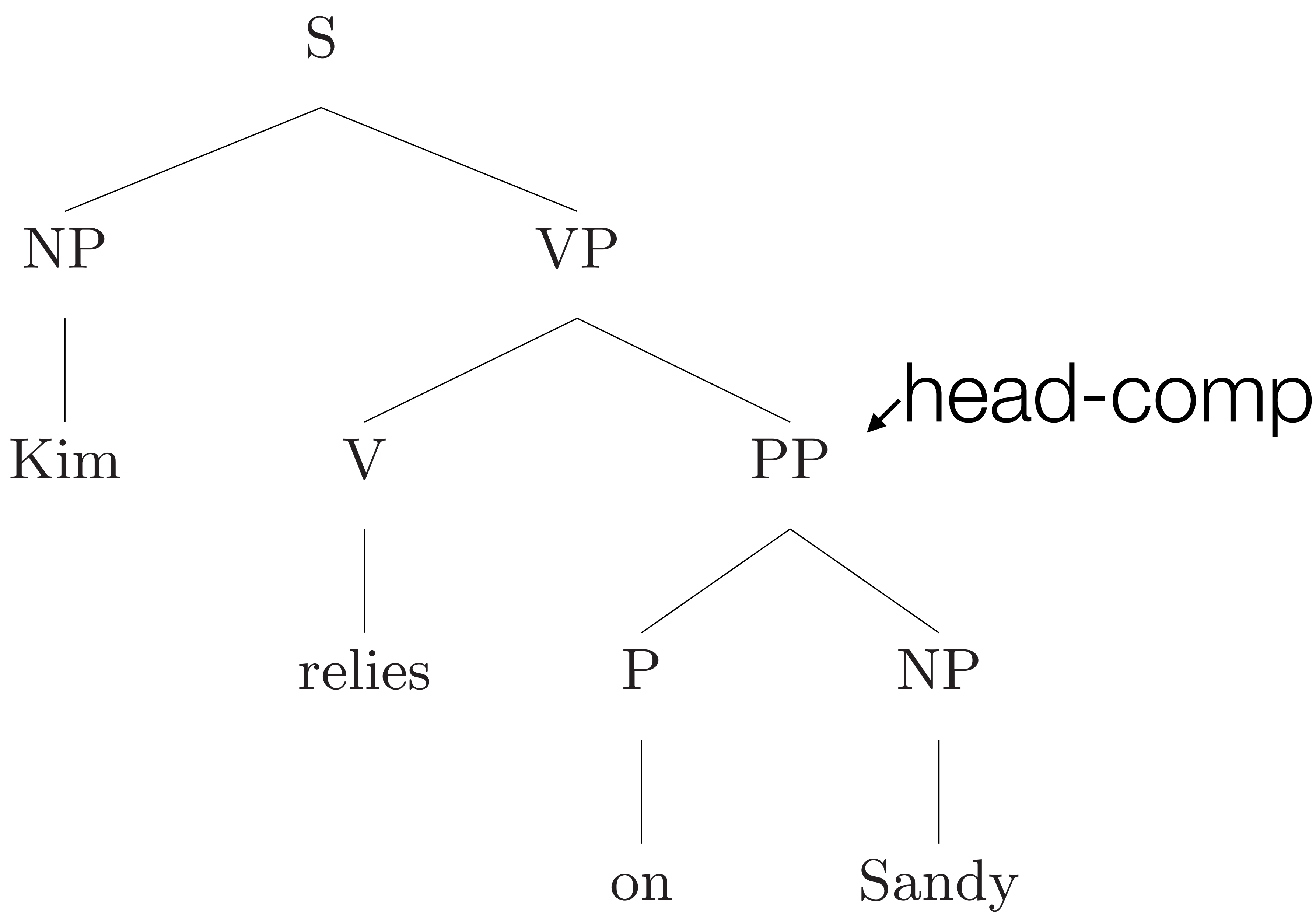
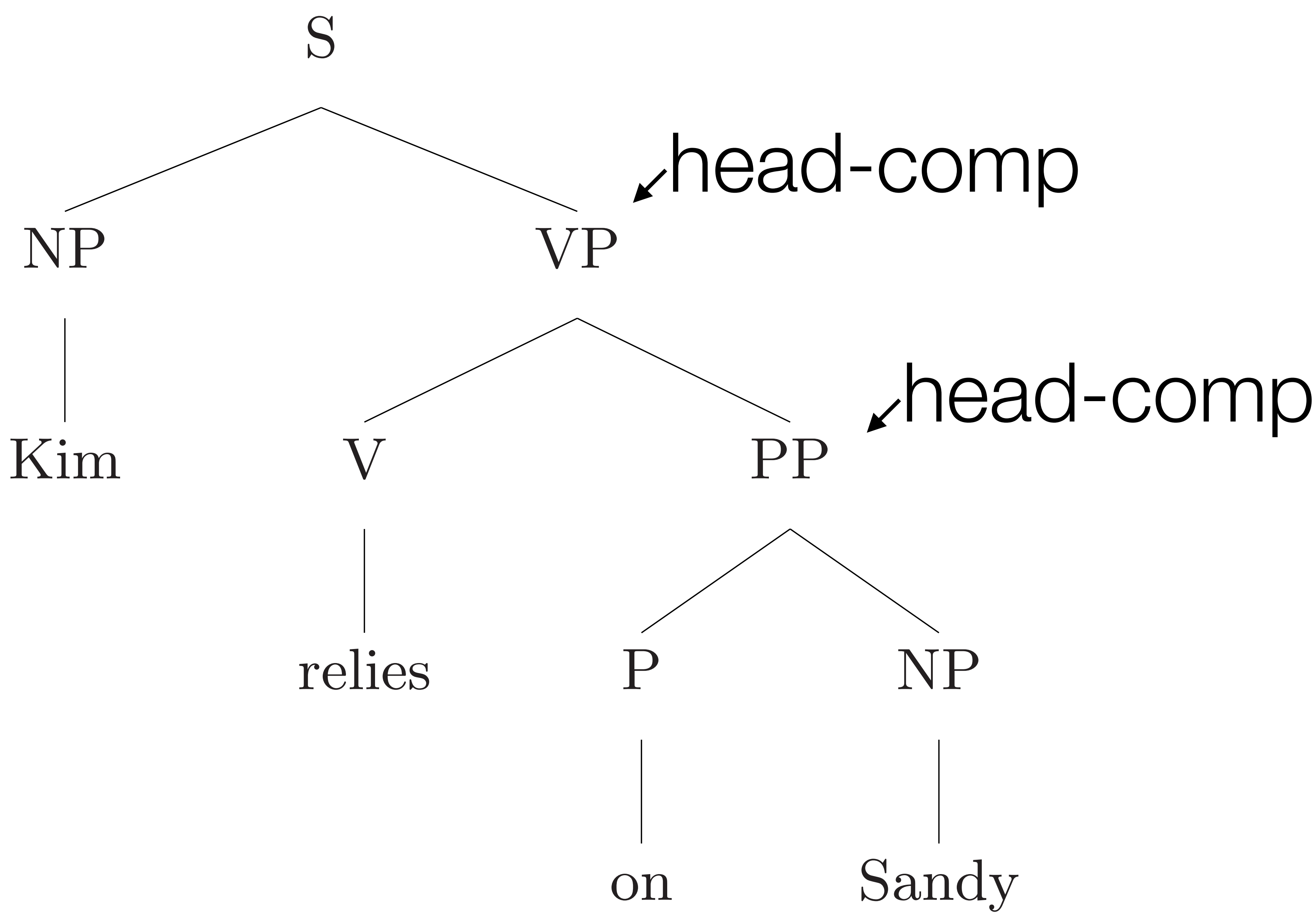


Ex 1: Licensing by phrase structure rules



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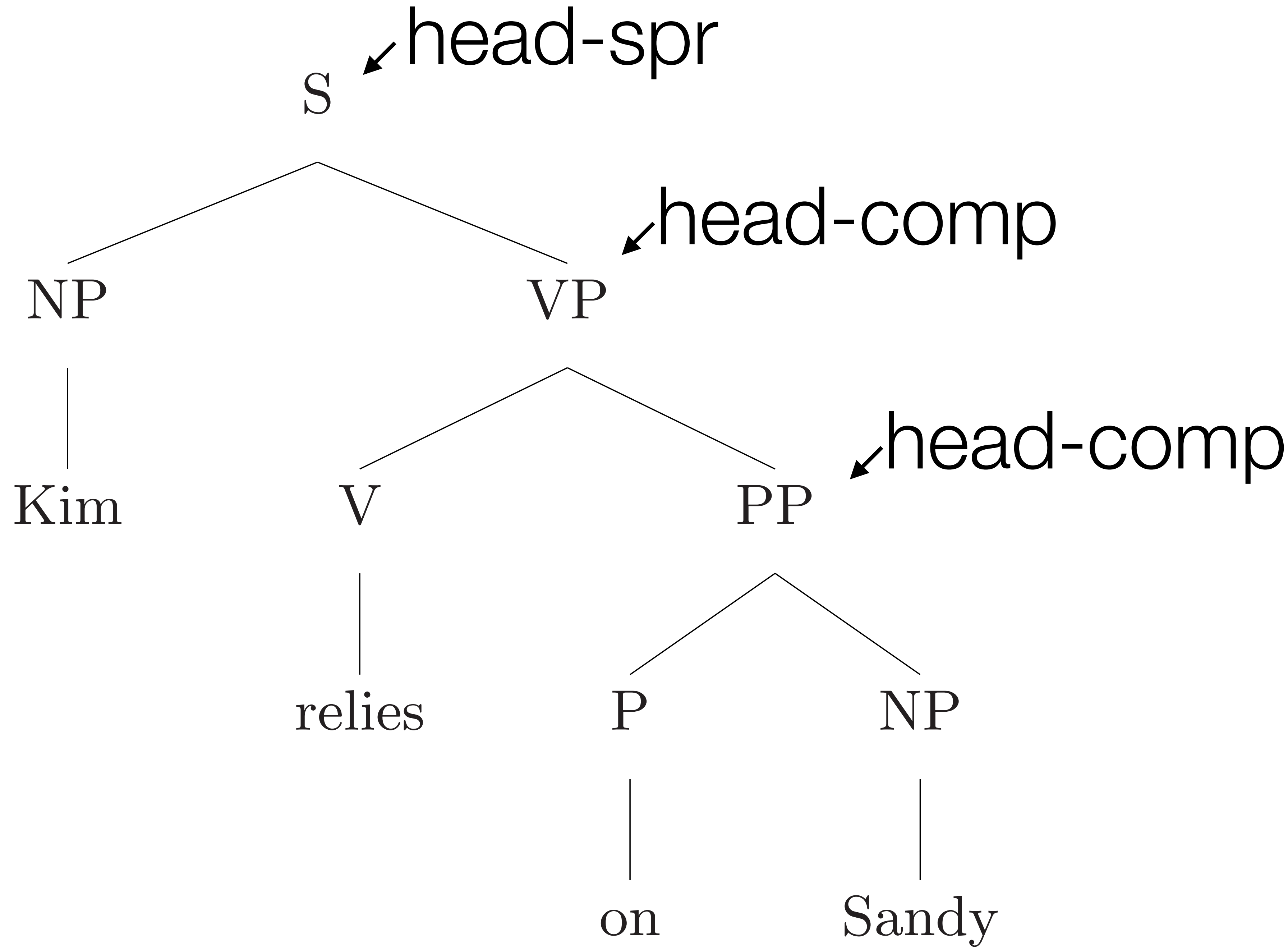
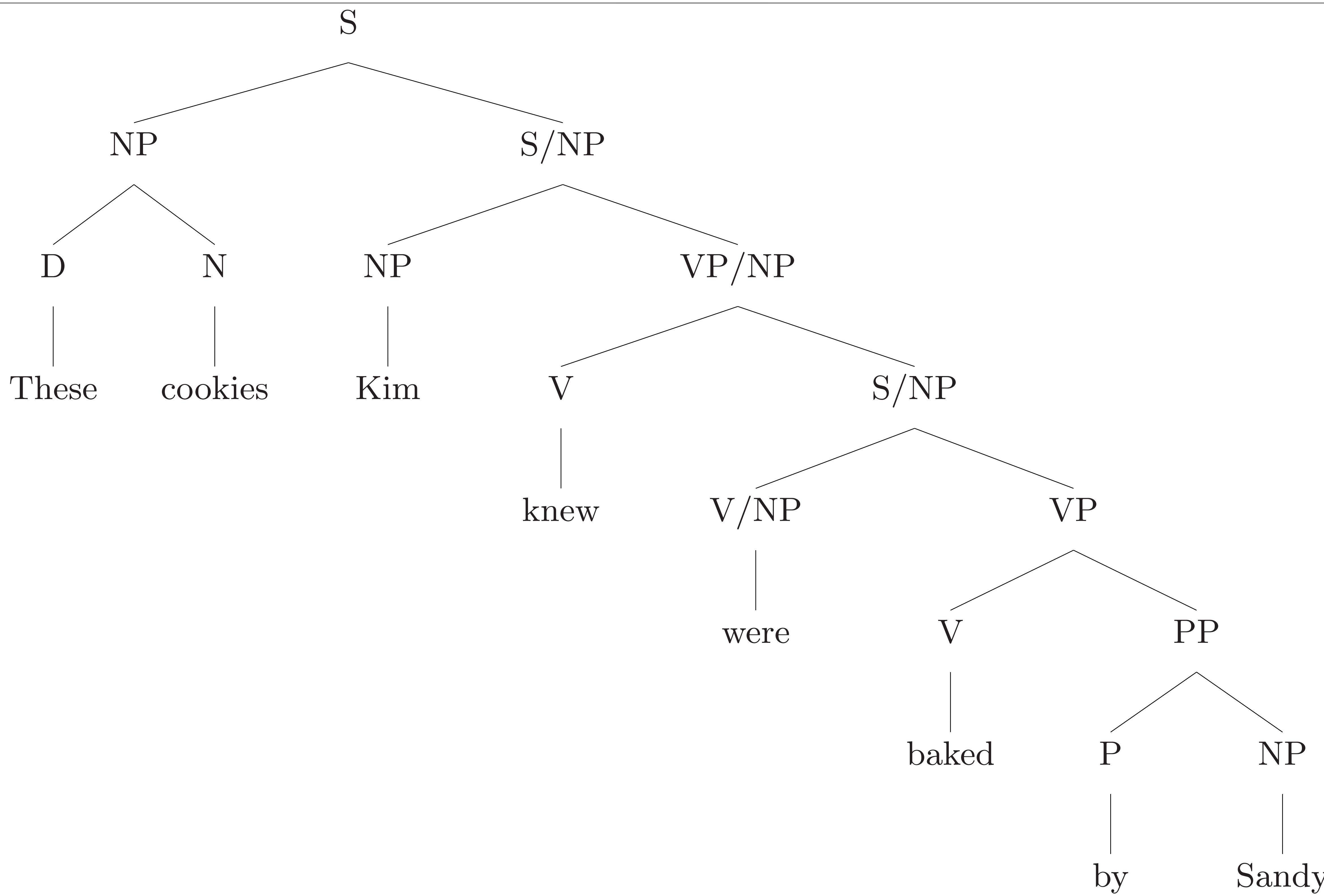


Ex 1: Semantics associated with VP node

$$\begin{bmatrix} \text{INDEX} & \text{e1} \\ \text{RELS} & \left\langle \begin{bmatrix} \text{PRED} & \text{rely\_on} \\ \text{ARG0} & \text{e1} \\ \text{ARG1} & \text{x2} \\ \text{ARG2} & \text{x3} \end{bmatrix}, \begin{bmatrix} \text{PRED} & \text{named} \\ \text{ARG0} & \text{x3} \\ \text{CARG} & \text{``Sandy''} \end{bmatrix} \right\rangle \end{bmatrix}$$

Ex 2: Reprise


S
NP
S/NP
D
N
NP
VP/NP
These
cookies
Kim
V
S/NP
knew
V/NP
VP
were
V
PP
baked
P
NP
by
Sandy

Ex 2: Semantics of S node

$$\begin{bmatrix} \text{INDEX} & \text{e1} \\ \text{RELS} & \left\langle \begin{matrix} \begin{bmatrix} \text{PRED} & \text{know} \\ \text{ARG0} & \text{e1} \\ \text{ARG1} & \text{x2} \\ \text{ARG2} & \text{e3} \end{bmatrix}, \begin{bmatrix} \text{PRED} & \text{named} \\ \text{ARG0} & \text{x2} \\ \text{NAME} & \text{“Kim”} \end{bmatrix}, \begin{bmatrix} \text{PRED} & \text{bake} \\ \text{ARG0} & \text{e3} \\ \text{ARG1} & \text{x4} \\ \text{ARG2} & \text{x5} \end{bmatrix}, \\ \begin{bmatrix} \text{PRED} & \text{named} \\ \text{ARG0} & \text{x4} \\ \text{NAME} & \text{“Sandy”} \end{bmatrix}, \begin{bmatrix} \text{PRED} & \text{proximal} \\ \text{ARG1} & \text{x5} \end{bmatrix}, \begin{bmatrix} \text{PRED} & \text{cookie} \\ \text{ARG0} & \text{x5} \end{bmatrix} \end{matrix} \right\rangle \end{bmatrix}$$

Ex 2: Semantics of S/NP node

$$
\begin{bmatrix}
\text{INDEX} & \text{e1} \\
\text{RELS} & \left\langle
\begin{bmatrix} \text{PRED} & \text{know} \\ \text{ARG0} & \text{e1} \\ \text{ARG1} & \text{x2} \\ \text{ARG2} & \text{e3} \end{bmatrix},
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\begin{bmatrix} \text{PRED} & \text{named} \\ \text{ARG0} & \text{x4} \\ \text{NAME} & \text{``Sandy''} \end{bmatrix}
\right\rangle
\end{bmatrix}
$$

Key idea 2: Language as a system of signs

- Words and phrases are both modeled as pairings of form and meaning
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Key idea 3: Typed feature structures

- A feature structure is a collection of feature-value pairs
- A feature structure describes a set of objects in the modeling domain which satisfy its constraints
- A feature structure is typically underspecified wrt to the objects it models
- Values can be atomic symbols or can themselves be feature structures

Feature structures: Examples

$$\begin{bmatrix} \text{PER 3rd} \\ \text{NUM sg} \end{bmatrix}$$

- What kinds of words might this be a partial description of?
- What kinds of phrases might this be a partial description of?
- In what ways is it underspecified?

Key idea 3: Typed feature structures

- Adding *types* to the notion of feature structures allows:
  - Specification of which features are appropriate for which types (i.e. which features co-occur)
  - Specification of which values are appropriate for which features (on a given type)
  - Inheritance of constraints (feature appropriateness, feature values) from supertypes
  - Further constraints on unification

Feature co-occurrence

- All signs have features SYN (syntactic form) and SEM (meaning):

$$synsem\text{:} \begin{bmatrix} \text{SYN} & \textit{syn-cat} \\ \text{SEM} & \textit{sem-cat} \end{bmatrix}$$

Feature-value appropriateness

- The values of the valence features are all lists of *expressions*:

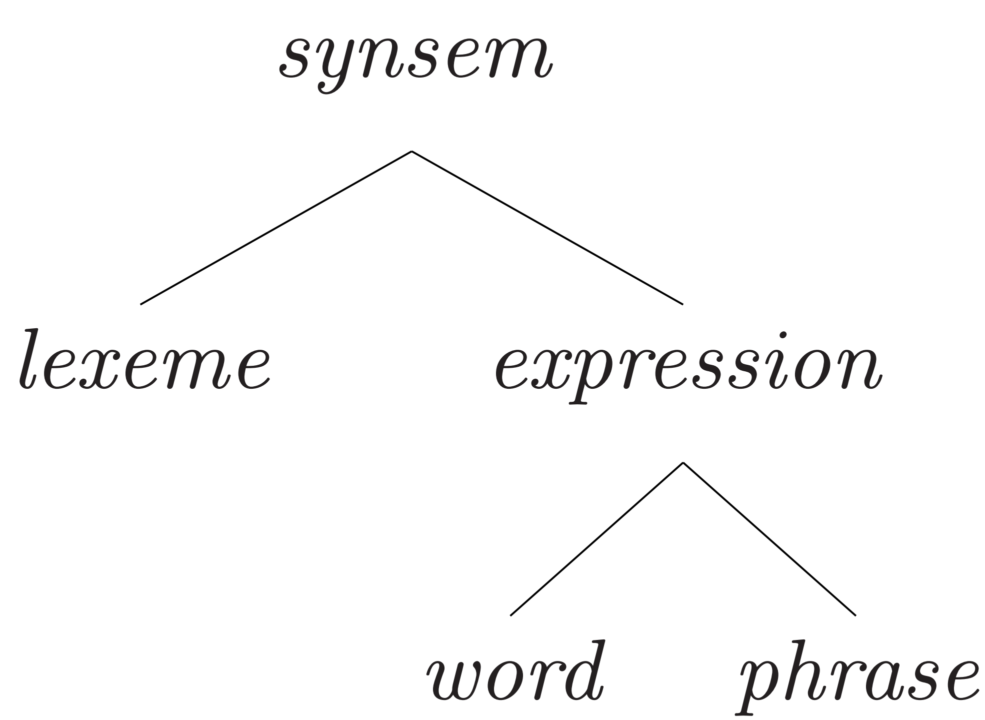
$$val\text{-}cat\text{: } \begin{bmatrix} \text{SPR} & list(expression) \\ \text{COMPS} & list(expression) \\ \text{MOD} & list(expression) \end{bmatrix}$$

Feature and feature-value inheritance

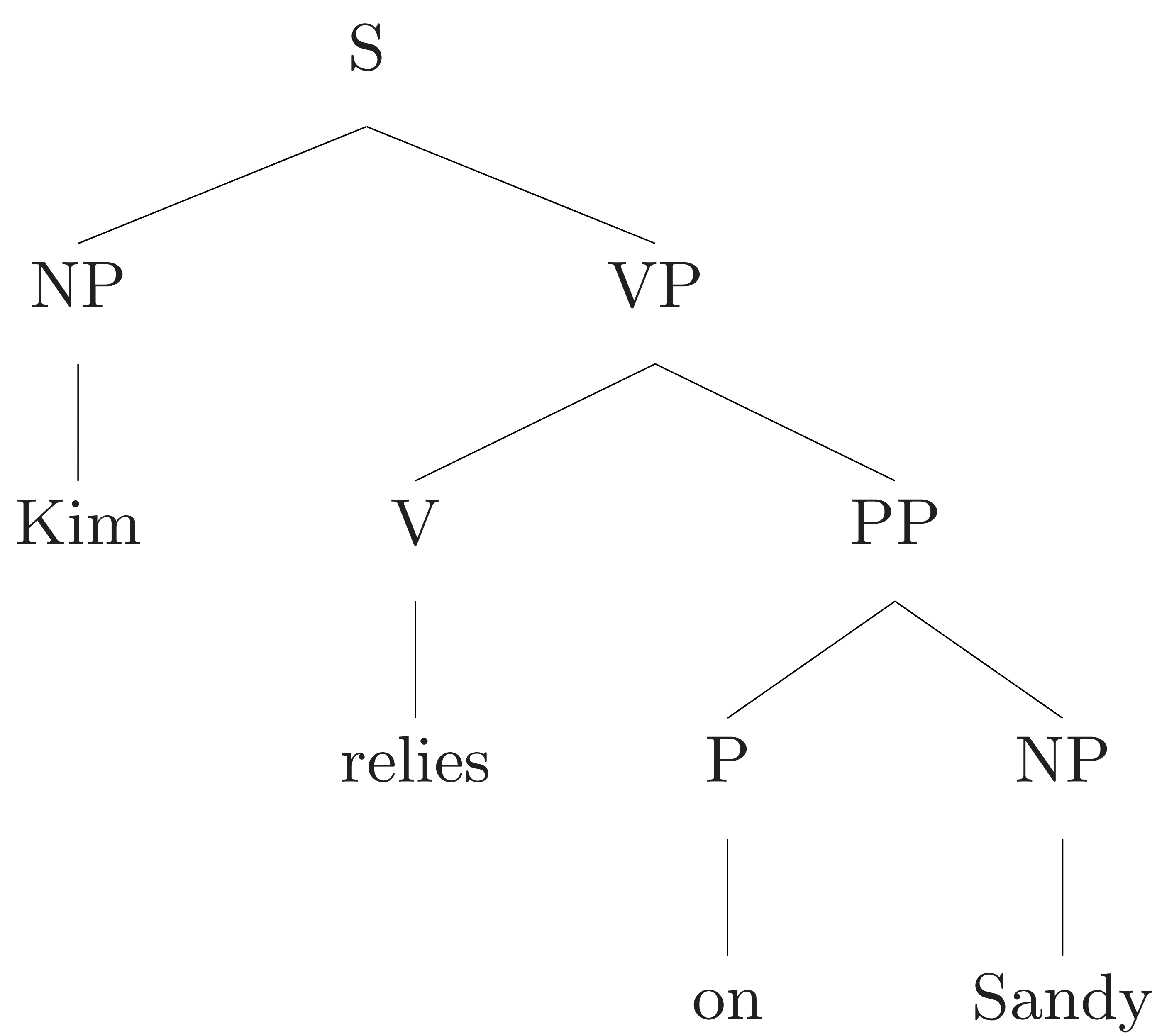
- All signs have features SYN (syntactic form) and SEM (meaning):

$$synsem\text{:}\ \begin{bmatrix} \mathrm{SYN} & \textit{syn-cat} \\ \mathrm{SEM} & \textit{sem-cat} \end{bmatrix}$$

- This is inherited by lexical items and phrases:



Example 1

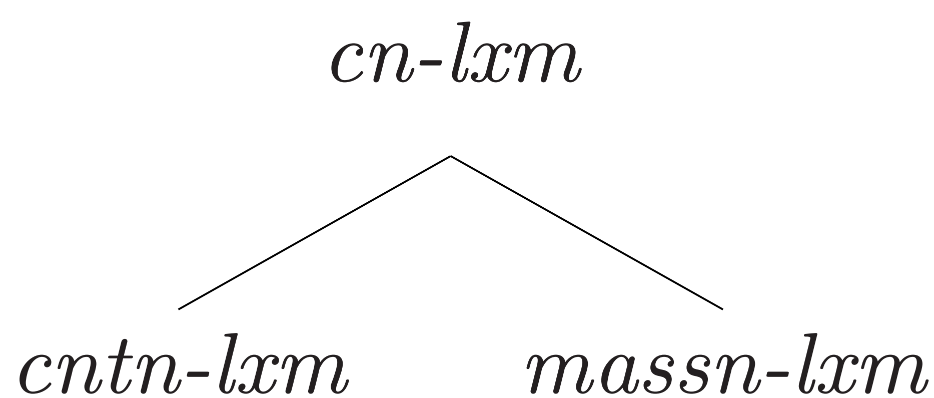


Feature and feature-value inheritance

- All common nouns are ‘nouny’ and 3rd person:

$$\textit{cn-lxm}: \begin{bmatrix} \text{SYN} & \begin{bmatrix} \text{HEAD} & \begin{bmatrix} \textit{noun} & \\ \text{AGR} & \begin{bmatrix} \text{PER 3rd} \end{bmatrix} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

- This is inherited by both count nouns and mass nouns:



(Flickinger 1987, Malouf 2000)

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Key idea 4: Unification

- An HPSG grammar consists of partial constraints on well-formed trees
    - Lexical entries
    - Phrase structure rules
    - Lexical rules
    - General principles
    - Initial symbol
- These constraints are combined via the operation of unification
- Any combination that succeeds licenses well-formed utterances

Unification: Informal definition

- Take two feature structures
- If they contradict each other: Unification fails
- Otherwise, create a new feature structure combining the information from each of them (and nothing more)

Unification: Formal definition

- A complex feature structure D subsumes a complex feature structure D′ if and only if D(l) $\sqsubseteq$ D′(l) for all l $\in$ dom(D) and D′(p) = D′(q) for all paths p and q such that D(p) = D(q).
    - By "=" here and elsewhere we mean token identity, i.e., that the paths share a common value.
- In formal terms, we define the unification of two feature structures D′ and D′′ as the most general feature structure D, such that D′ $\sqsubseteq$ D and D′′ $\sqsubseteq$ D. We notate this D = D′ $\sqcup$ D′′.

(Shieber 2003:12-14)

Unification: examples

$$\begin{bmatrix}\text{PER} & \text{3rd}\end{bmatrix} \quad \& \quad \begin{bmatrix}\text{NUM} & \text{sg}\end{bmatrix}$$

Unification: examples

$$\begin{bmatrix}\text{PER} & \text{3rd}\end{bmatrix} \quad \& \quad \begin{bmatrix}\text{NUM} & \text{sg}\end{bmatrix}$$

$$\begin{bmatrix}\text{PER} & \text{3rd} \\ \text{NUM} & \text{sg}\end{bmatrix}$$

Unification: examples

$$\begin{bmatrix}\text{NUM} & \text{sg}\end{bmatrix} \quad \& \quad \begin{bmatrix}\text{PER} & \text{3rd}\end{bmatrix}$$

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$$\begin{bmatrix}\text{NUM} & \text{sg}\end{bmatrix} \quad \& \quad \begin{bmatrix}\text{PER} & \text{3rd}\end{bmatrix}$$

$$\begin{bmatrix}\text{PER} & \text{3rd} \\ \text{NUM} & \text{sg}\end{bmatrix}$$

Unification: examples

$$\begin{bmatrix} \text{PER} & \text{3rd} \\ \text{NUM} & \text{sg} \end{bmatrix} \quad \& \quad \begin{bmatrix} \text{PER} & \text{3rd} \end{bmatrix}$$

Unification: examples

$$\begin{bmatrix} \text{PER} & \text{3rd} \\ \text{NUM} & \text{sg} \end{bmatrix} \quad \& \quad \begin{bmatrix} \text{PER} & \text{3rd} \end{bmatrix}$$

$$\begin{bmatrix} \text{PER} & \text{3rd} \\ \text{NUM} & \text{sg} \end{bmatrix}$$

Unification: examples

$$\begin{bmatrix} \text{PER} & \text{2nd} \\ \text{NUM} & \text{sg} \end{bmatrix} \quad \& \quad \begin{bmatrix} \text{PER} & \text{3rd} \end{bmatrix}$$

Unification: examples

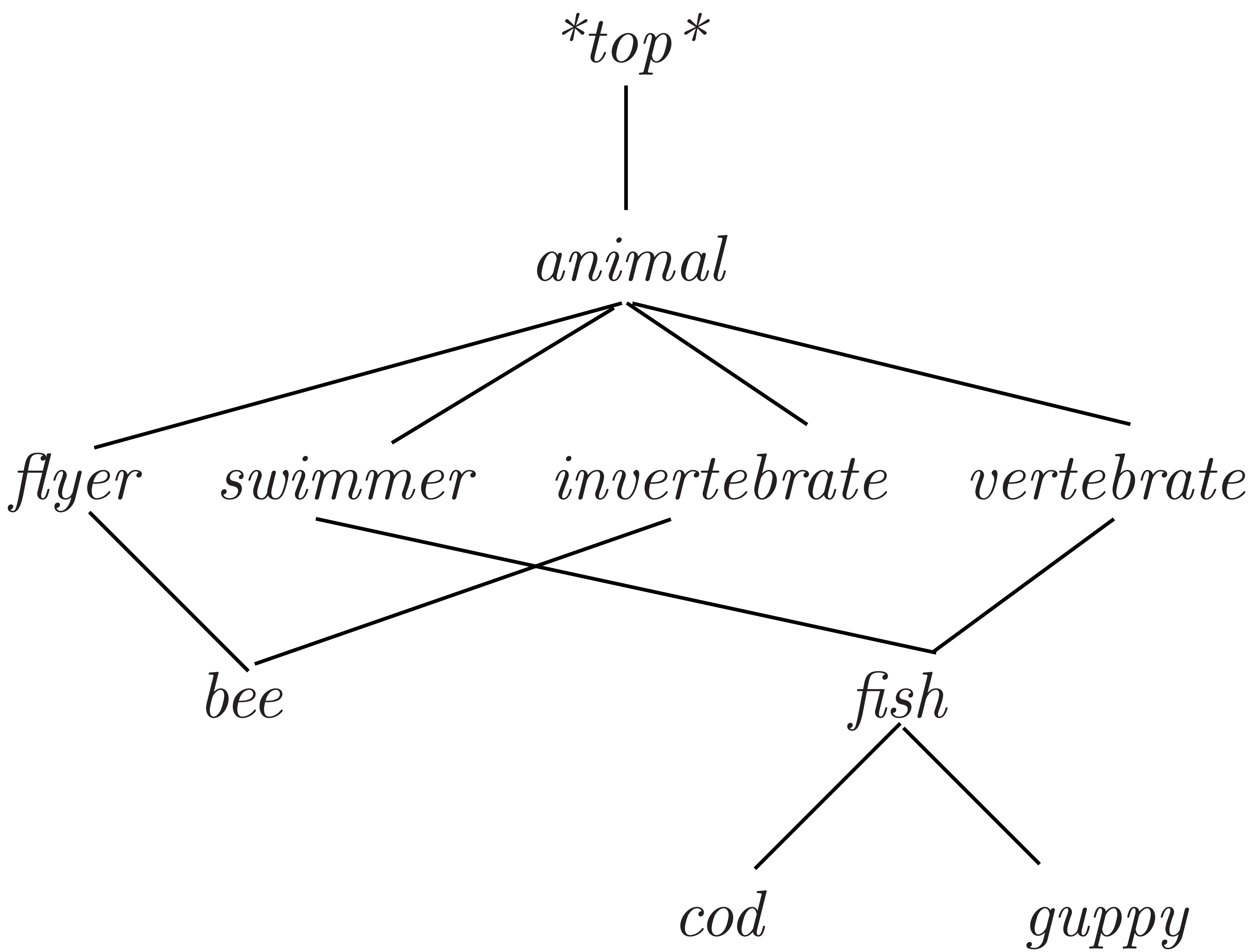
$$\begin{bmatrix} \text{PER} & \text{2nd} \\ \text{NUM} & \text{sg} \end{bmatrix} \quad \& \quad \begin{bmatrix} \text{PER} & \text{3rd} \end{bmatrix}$$

$$\phi$$

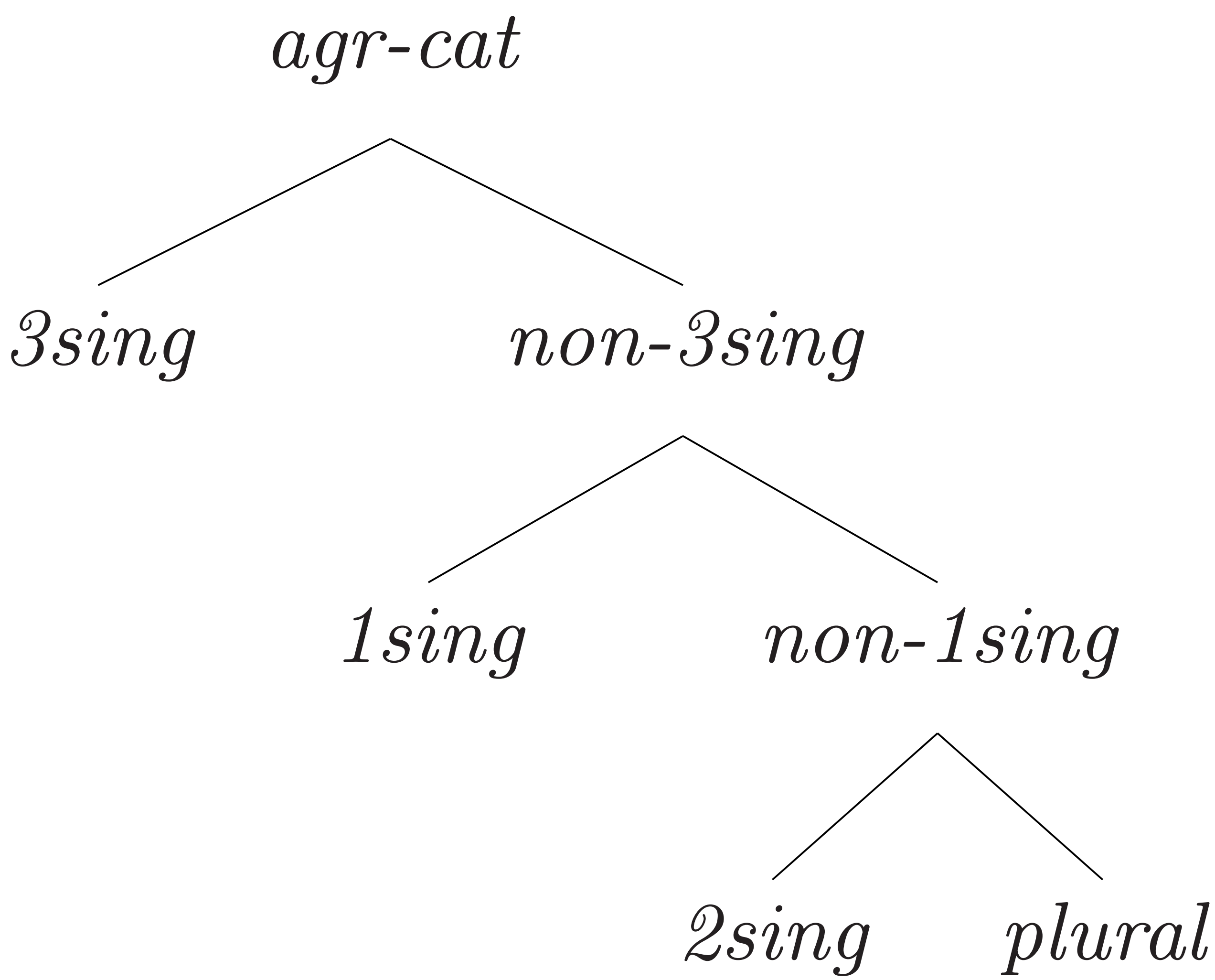
Types and unification

- Two feature structures are consistent (recursive definition) if:
  - They are of compatible type
  - For any features present in both, their values are consistent
- Two types are compatible if:
  - They are the same, or
  - One is a subtype of the other, or
  - They share a mutual subtype
- ‘Types unify to subtype’

Non-linguistic example



Types and unification: examples

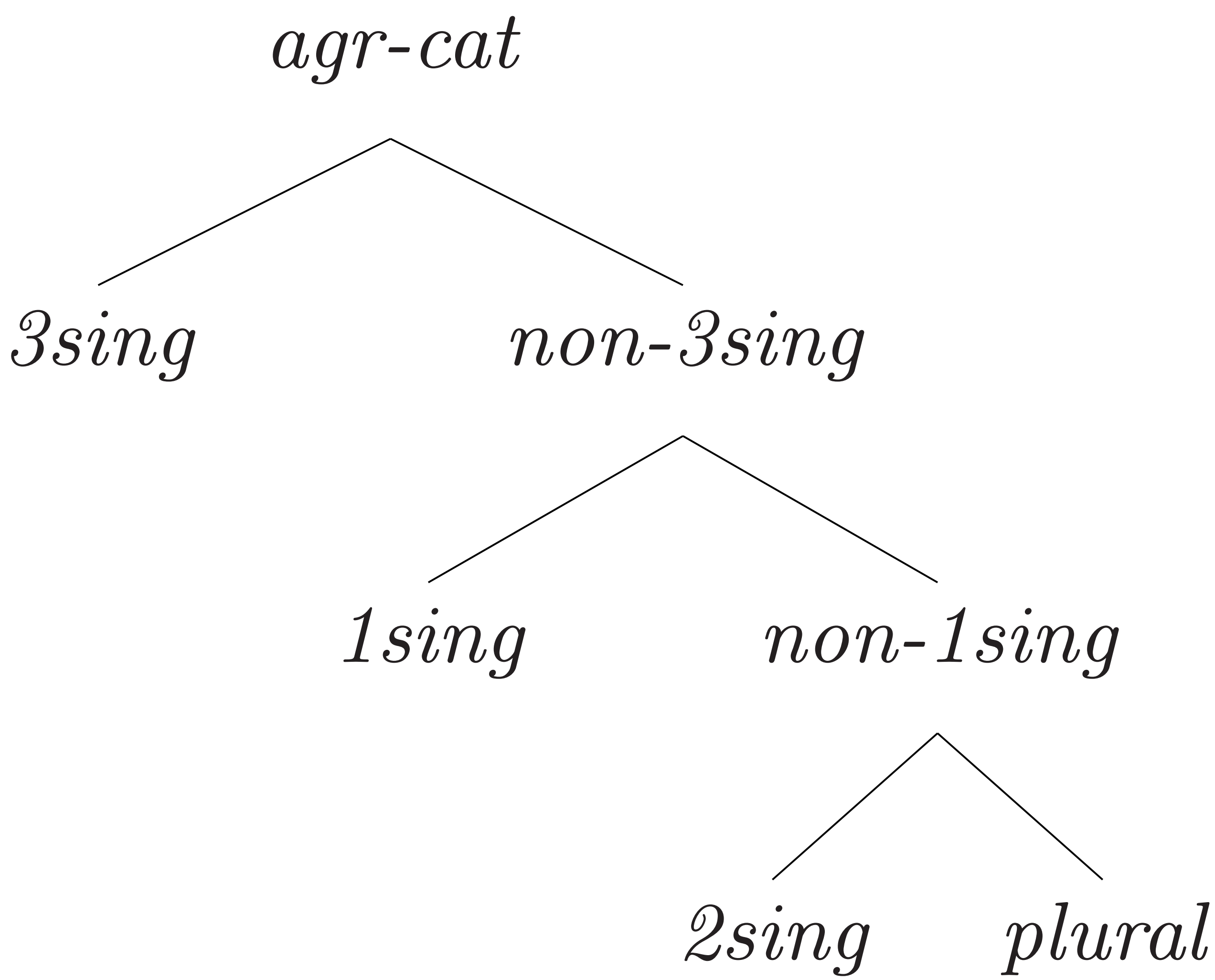


$$\textit{agr-cat}: \begin{bmatrix} \text{PER} & \{\text{1st, 2nd, 3rd}\} \\ \text{NUM} & \{\text{sg, pl}\} \end{bmatrix}$$

$$\textit{3sing}: \begin{bmatrix} \text{PER} & \text{3rd} \\ \text{NUM} & \text{sg} \\ \text{GEND} & \{\text{masc, fem, neut}\} \end{bmatrix}$$

$$\textit{plural}: \begin{bmatrix} \text{NUM} & \text{pl} \end{bmatrix}$$

Types and unification: examples



$$\textit{agr-cat}: \begin{bmatrix} \text{PER} & \{\text{1st, 2nd, 3rd}\} \\ \text{NUM} & \{\text{sg, pl}\} \end{bmatrix}$$

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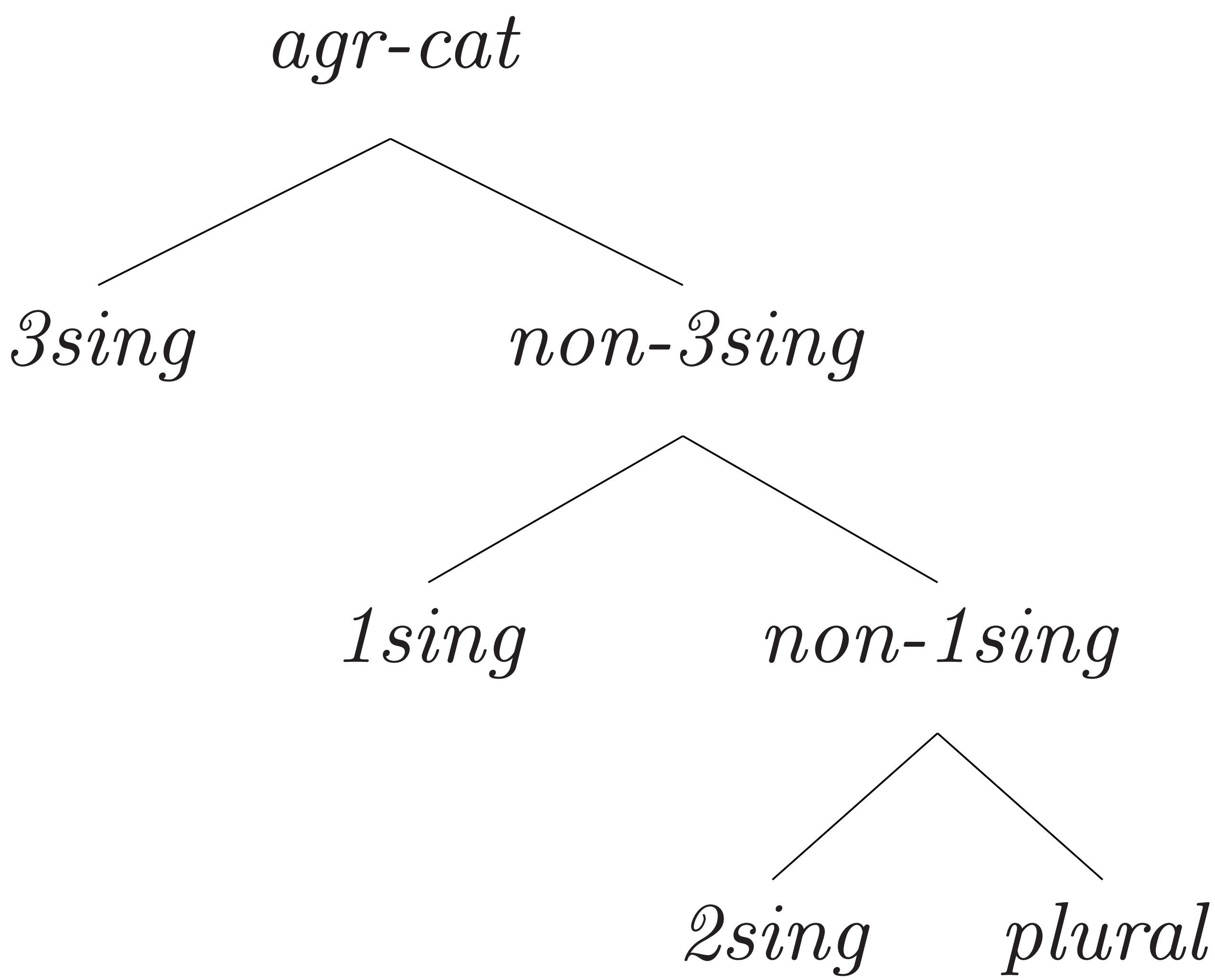
$$\textit{plural}: \begin{bmatrix} \text{NUM} & \text{pl} \end{bmatrix}$$

$$\begin{bmatrix} \textit{agr-cat} & \\ \text{PER} & \text{1st} \end{bmatrix} \ \& \ \ \textit{plural}$$

Types and unification: examples



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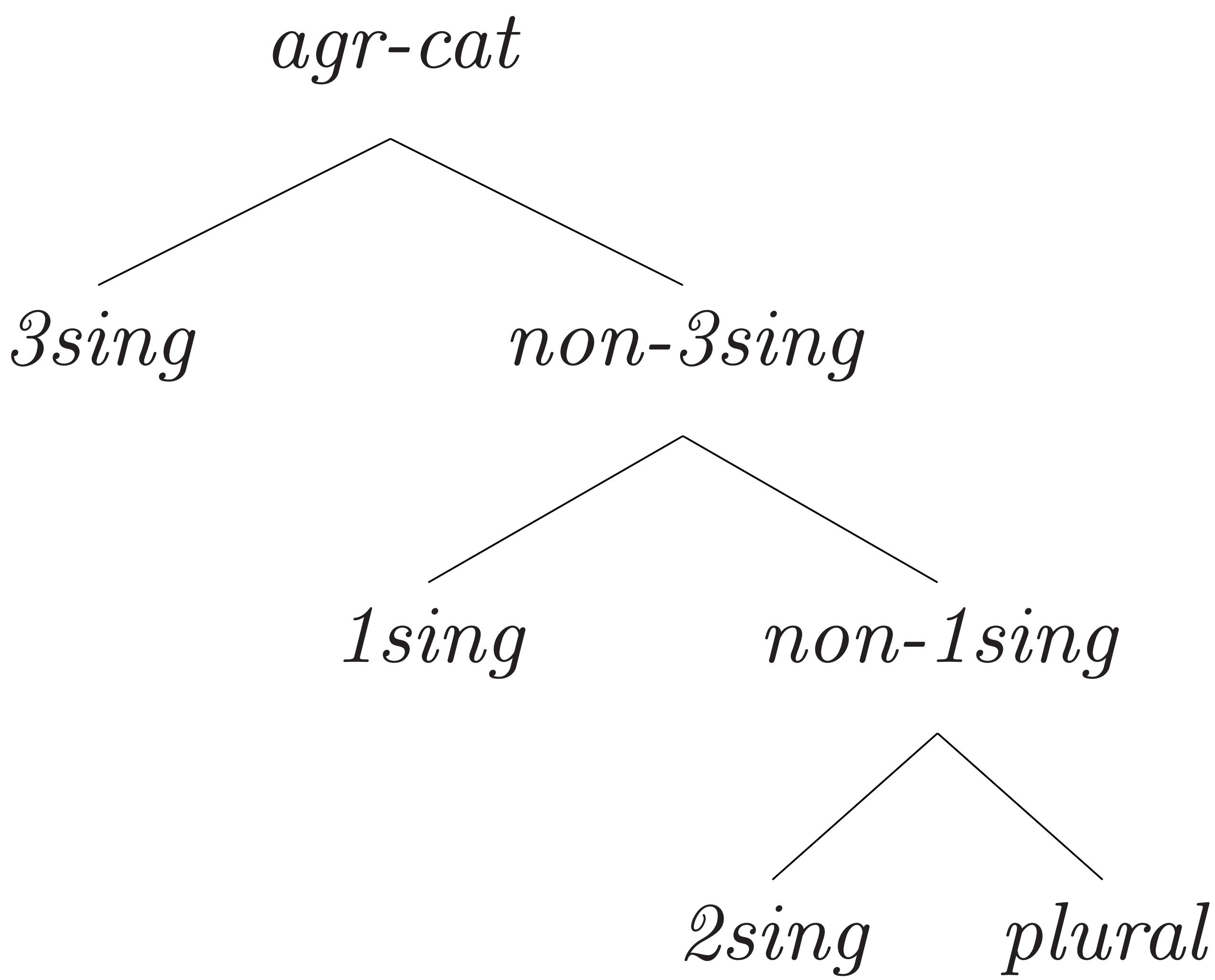
$$\textit{plural}: \begin{bmatrix} \text{NUM} & \text{pl} \end{bmatrix}$$

$$\begin{bmatrix} \textit{agr-cat} & \\ \text{PER} & \text{1st} \end{bmatrix} \;\&\; \textit{plural} \quad = \begin{bmatrix} \textit{plural} & \\ \text{PER} & \text{1st} \\ \text{NUM} & \text{pl} \end{bmatrix}$$

Types and unification: examples

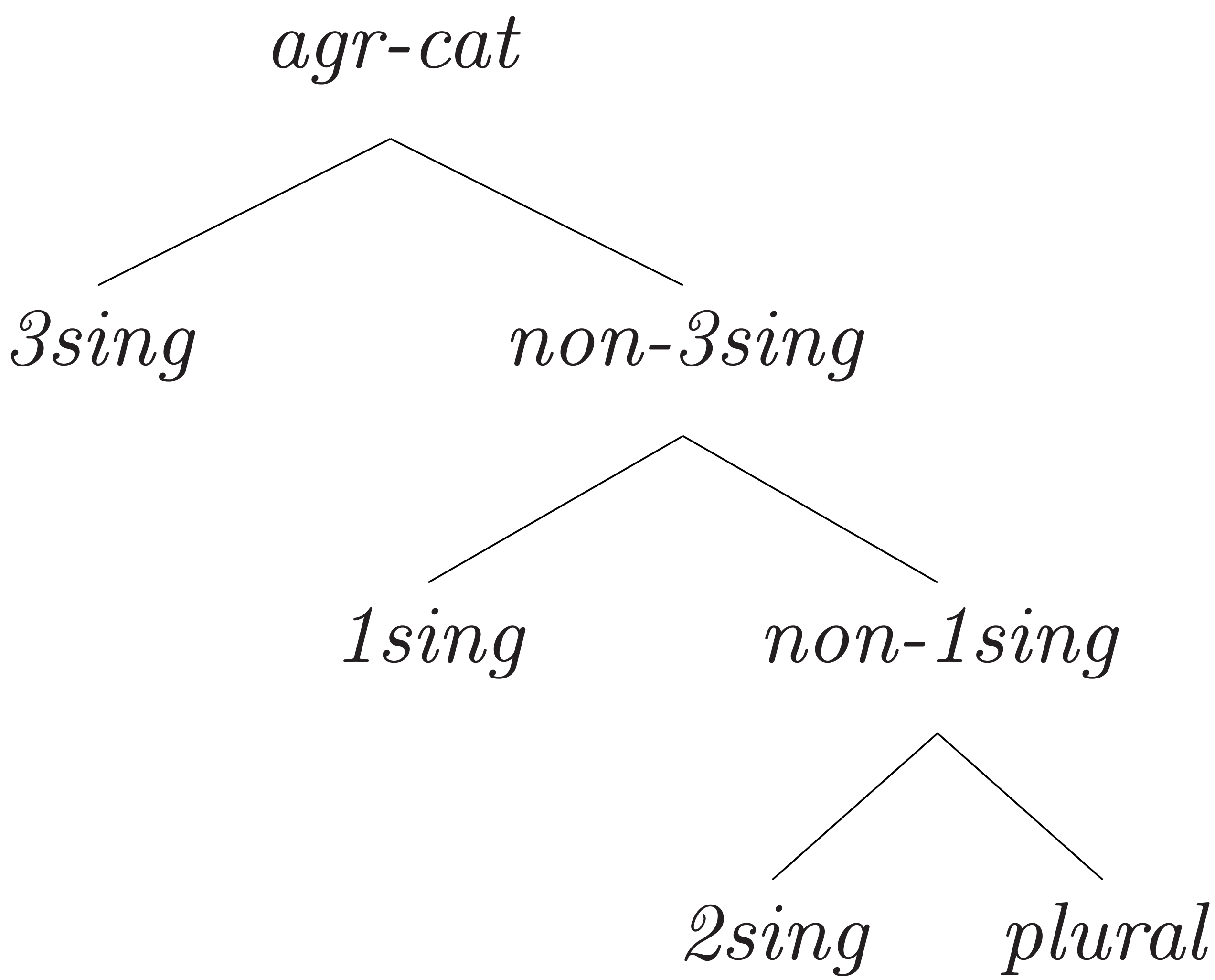


$$\textit{agr-cat}: \begin{bmatrix} \text{PER} & \{\text{1st, 2nd, 3rd}\} \\ \text{NUM} & \{\text{sg, pl}\} \end{bmatrix}$$

$$\textit{3sing}: \begin{bmatrix} \text{PER} & \text{3rd} \\ \text{NUM} & \text{sg} \\ \text{GEND} & \{\text{masc, fem, neut}\} \end{bmatrix}$$

$$\textit{plural}: \begin{bmatrix} \text{NUM} & \text{pl} \end{bmatrix}$$

Types and unification: examples



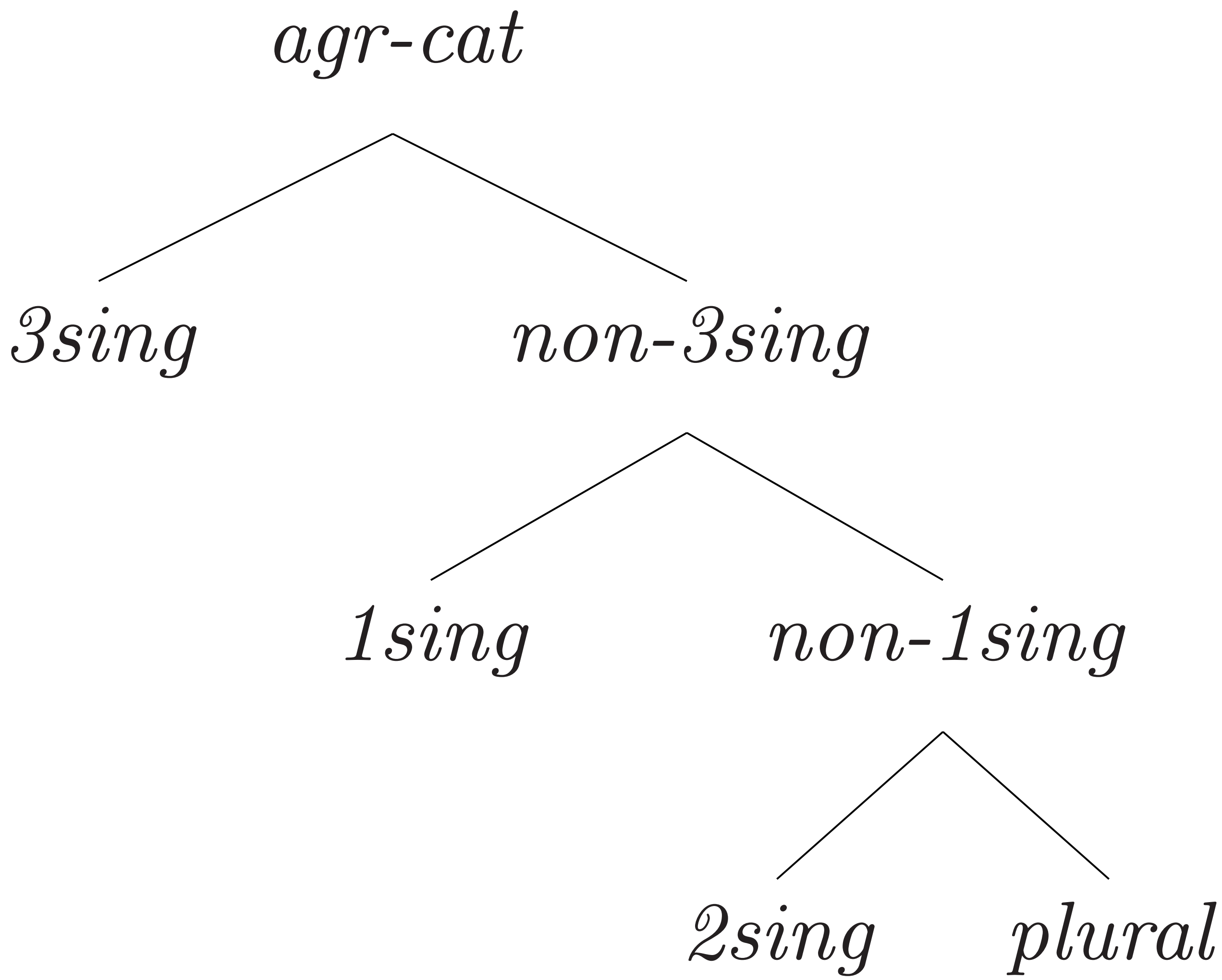
$$\textit{agr-cat}: \begin{bmatrix} \text{PER} & \{\text{1st, 2nd, 3rd}\} \\ \text{NUM} & \{\text{sg, pl}\} \end{bmatrix}$$

$$\textit{3sing}: \begin{bmatrix} \text{PER} & \text{3rd} \\ \text{NUM} & \text{sg} \\ \text{GEND} & \{\text{masc, fem, neut}\} \end{bmatrix}$$

$$\textit{plural}: \begin{bmatrix} \text{NUM} & \text{pl} \end{bmatrix}$$

$$\begin{bmatrix} \text{GEND} & \text{fem} \end{bmatrix} \;\&\; \begin{bmatrix} \text{NUM} & \text{pl} \end{bmatrix}$$

Types and unification: examples



$$\textit{agr-cat}: \begin{bmatrix} \text{PER} & \{\text{1st, 2nd, 3rd}\} \\ \text{NUM} & \{\text{sg, pl}\} \end{bmatrix}$$

$$\textit{3sing}: \begin{bmatrix} \text{PER} & \text{3rd} \\ \text{NUM} & \text{sg} \\ \text{GEND} & \{\text{masc, fem, neut}\} \end{bmatrix}$$

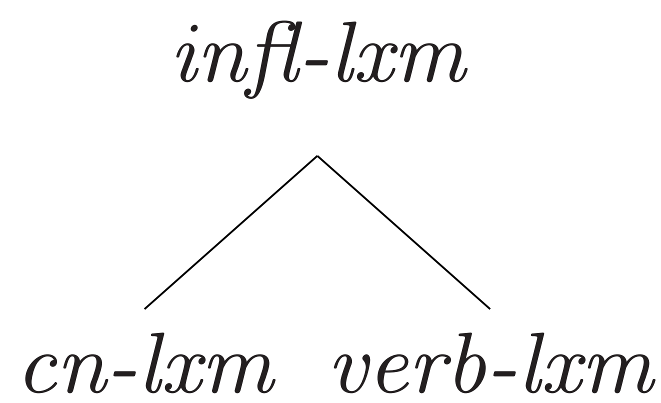
$$\textit{plural}: \begin{bmatrix} \text{NUM} & \text{pl} \end{bmatrix}$$

$$\begin{bmatrix} \text{GEND} & \text{fem} \end{bmatrix} \;\&\; \begin{bmatrix} \text{NUM} & \text{pl} \end{bmatrix} = \phi$$

Identity constraints

- So far, we've only seen features being constrained to have particular values
- The formalism also allows us to relate feature values to each other
    - Identity constraints
    - (Some variants): Further relational constraints

Identity constraints: Specifier-head agreement



$$\textit{infl-lxm}: \begin{bmatrix} \text{SYN} & \begin{bmatrix} \text{HEAD} & \begin{bmatrix}\text{AGR} & \boxed{1}\end{bmatrix} \\ \text{VAL} & \begin{bmatrix} \text{SPR} & \left\langle \begin{bmatrix} \text{SYN} & \begin{bmatrix}\text{HEAD} & \begin{bmatrix}\text{AGR} & \boxed{1}\end{bmatrix}\end{bmatrix}\end{bmatrix}\right\rangle \end{bmatrix}\end{bmatrix}\end{bmatrix}$$

Identity constraints: Semantic principles

Semantic Compositionality Principle

$$\begin{bmatrix}\text{RELS} & \boxed{A_1} \oplus \ldots \oplus \boxed{A_n}\end{bmatrix} \rightarrow \begin{bmatrix}\text{RELS} & \boxed{A_1}\end{bmatrix} \ldots \begin{bmatrix}\text{RELS} & \boxed{A_n}\end{bmatrix}$$

Semantic Inheritance Principle

$$\begin{bmatrix}\text{INDEX} & \boxed{1}\end{bmatrix} \rightarrow \ldots\ \mathbf{H}\begin{bmatrix}\text{INDEX} & \boxed{1}\end{bmatrix} \ldots$$

Identity constraints: Two more principles

Head Feature Principle

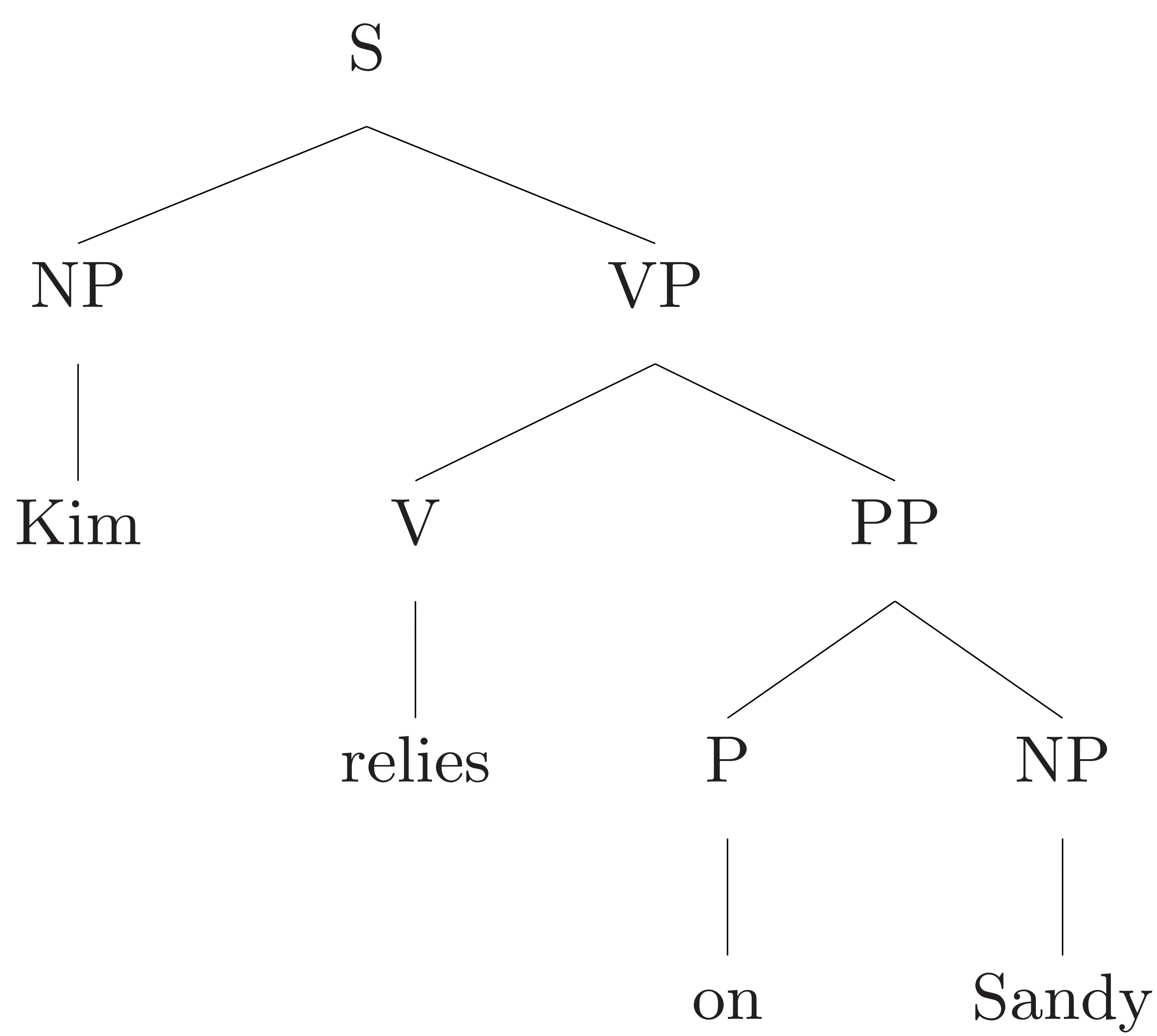
$$\begin{bmatrix}\text{HEAD} & \boxed{1}\end{bmatrix} \rightarrow \ldots\ \mathbf{H}\begin{bmatrix}\text{HEAD} & \boxed{1}\end{bmatrix} \ldots$$

Valence Principle

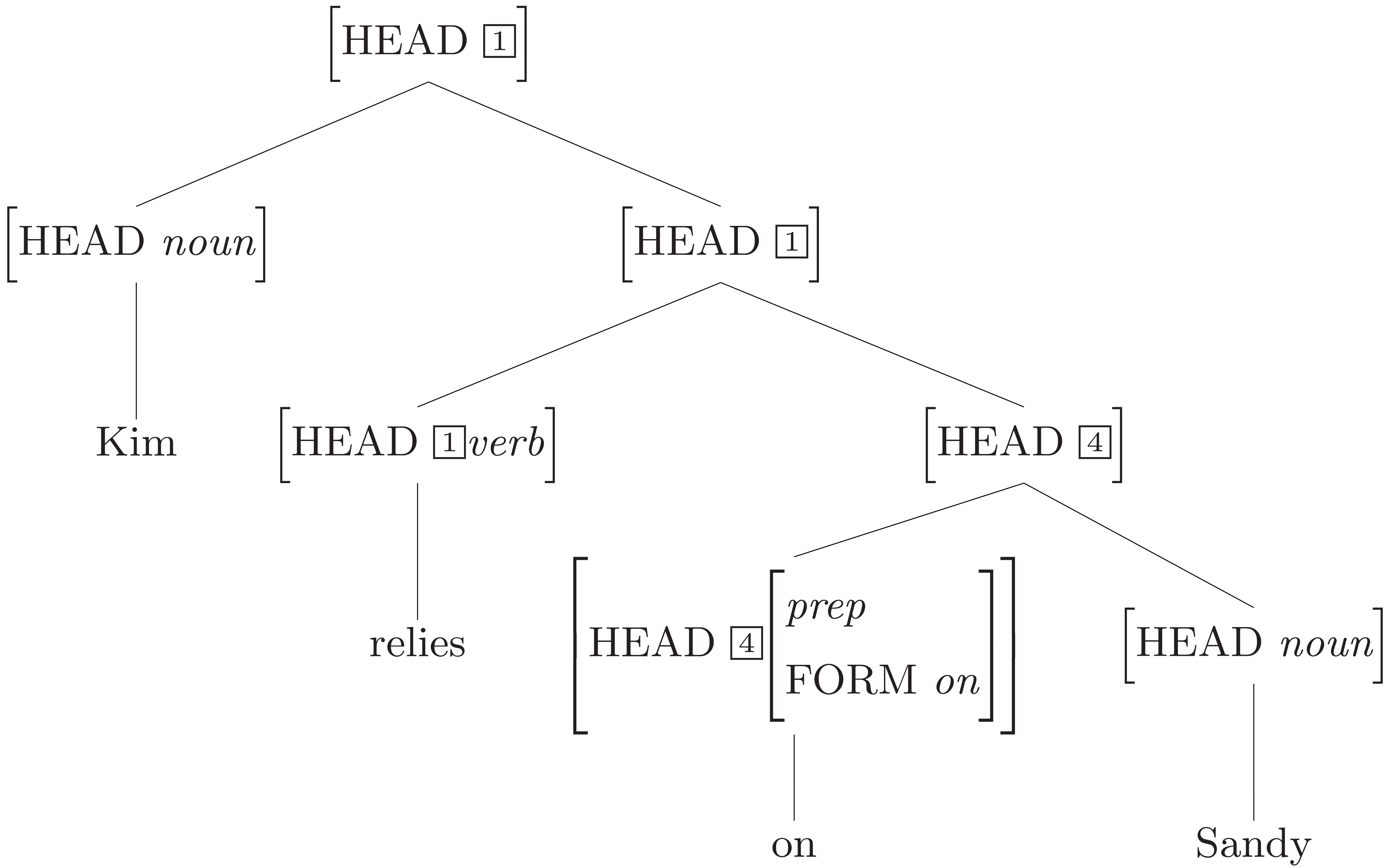
$$\begin{bmatrix}\text{SPR} & \boxed{A}\end{bmatrix} \rightarrow \ldots\ \mathbf{H}\begin{bmatrix}\text{SPR} & \boxed{A}\end{bmatrix} \ldots$$

... unless the rule says otherwise

Head Feature Principle in action



Head Feature Principle in action



Identity constraints: Phrase structure rules

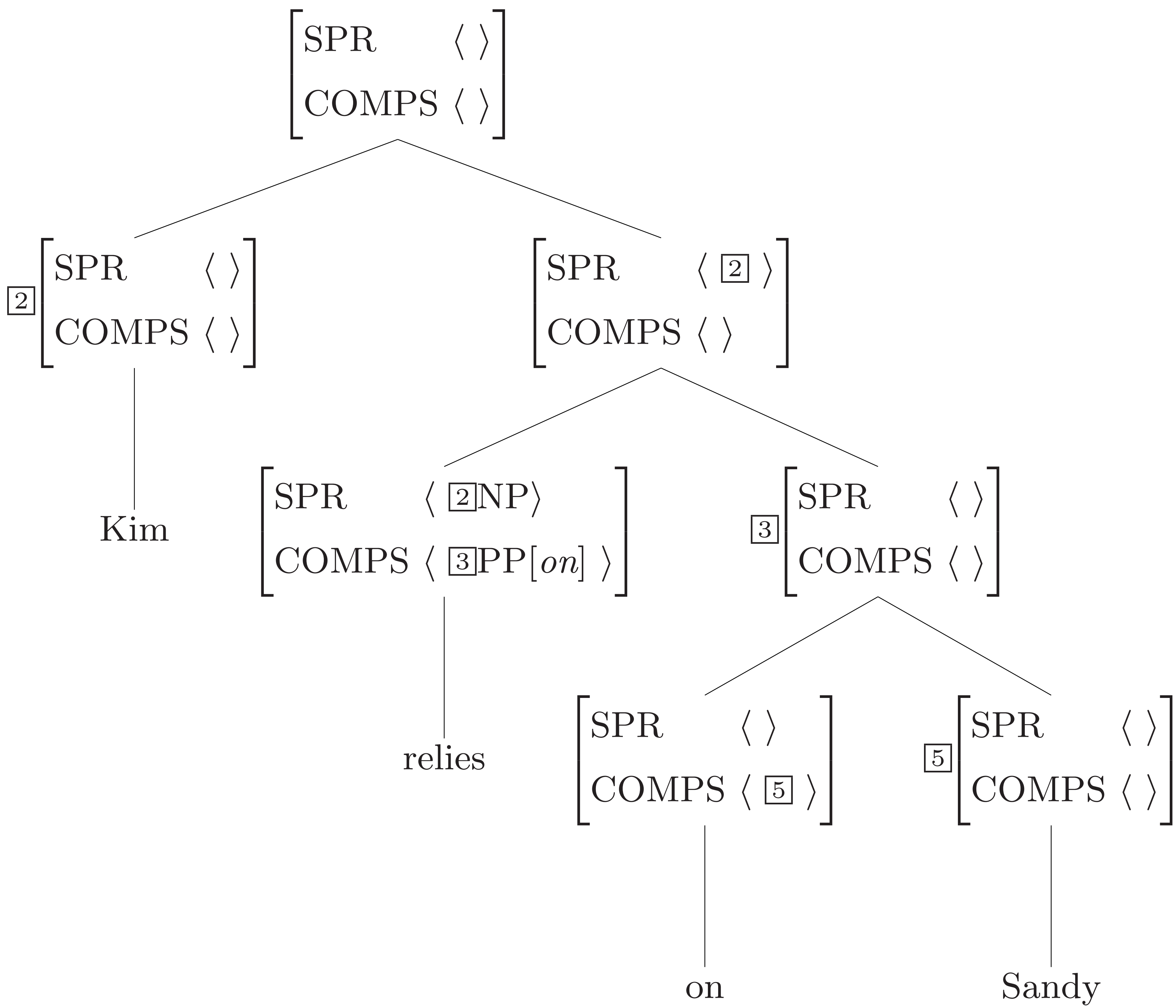
Head-Complement Rule

$$\begin{bmatrix} \textit{phrase} & \\ \text{COMPS} & \langle\ \rangle \end{bmatrix} \rightarrow \mathbf{H}\begin{bmatrix} \textit{word} & \\ \text{COMPS} & \langle \boxed{1}\ , \ldots, \boxed{n}\ \rangle \end{bmatrix} \boxed{1} \ldots \boxed{n}$$

Head-Specifier Rule

$$\begin{bmatrix} \textit{phrase} & \\ \text{SPR} & \langle\ \rangle \end{bmatrix} \rightarrow \boxed{1} \quad \mathbf{H}\begin{bmatrix} \text{SPR} & \langle \boxed{1} \rangle \\ \text{COMPS} & \langle\ \rangle \end{bmatrix}$$

Identities from Phrase Structure Rules in Action



Identity are constraints critical for building semantic representations

$$
\left\langle \text{rely} \;,\; \begin{bmatrix} \text{SYN} & \begin{bmatrix} \text{HEAD} & \textit{verb} \\ \text{VAL} & \begin{bmatrix} \text{SPR} & \langle\ \text{NP[INDEX x]}\ \rangle \\ \text{COMPS} & \langle\ \text{PP[INDEX y]}\ \rangle \end{bmatrix} \end{bmatrix} \\ \text{SEM} & \begin{bmatrix} \text{INDEX} & \text{e} \\ \text{RELS} & \left\langle \begin{bmatrix} \text{PRED} & \text{rely\_on} \\ \text{ARG0} & \text{e} \\ \text{ARG1} & \text{x} \\ \text{ARG2} & \text{y} \end{bmatrix} \right\rangle \end{bmatrix} \end{bmatrix} \right\rangle
$$

Identity are constraints critical for building semantic representations

$$\left\langle \text{rely} \;, \begin{bmatrix} \text{SYN} & \begin{bmatrix} \text{HEAD} & \textit{verb} \\ \text{VAL} & \begin{bmatrix} \text{SPR} & \langle \text{ NP[INDEX } \boxed{1}] \text{ } \rangle \\ \text{COMPS} & \langle \text{ PP[INDEX } \boxed{2}] \text{ } \rangle \end{bmatrix} \end{bmatrix} \\ \text{SEM} & \begin{bmatrix} \text{INDEX} & \boxed{3} \\ \text{RELS} & \left\langle \begin{bmatrix} \text{PRED} & \text{rely\_on} \\ \text{ARG0} & \boxed{3} \\ \text{ARG1} & \boxed{1} \\ \text{ARG2} & \boxed{2} \end{bmatrix} \right\rangle \end{bmatrix} \end{bmatrix} \right\rangle$$

Identity are constraints critical for building semantic representations

$$\left\langle \text{rely}\ , \begin{bmatrix} \text{SYN} & \begin{bmatrix} \text{HEAD} & \textit{verb} \\ \text{VAL} & \begin{bmatrix} \text{SPR} & \langle\ \text{NP[INDEX x]}\ \rangle \\ \text{COMPS} & \langle\ \text{PP[INDEX y]}\ \rangle \end{bmatrix} \end{bmatrix} \\ \text{SEM} & \begin{bmatrix} \text{INDEX} & \text{e} \\ \text{RELS} & \left\langle \begin{bmatrix} \text{PRED} & \text{rely\_on} \\ \text{ARG0} & \text{e} \\ \text{ARG1} & \text{x} \\ \text{ARG2} & \text{y} \end{bmatrix} \right\rangle \end{bmatrix} \end{bmatrix} \right\rangle$$

Identity are constraints critical for building semantic representations

$$
\left\langle \text{Kim} \; , \begin{bmatrix} \text{SYN} & \begin{bmatrix} \text{HEAD} & \textit{noun} \\ \text{VAL} & \begin{bmatrix} \text{SPR} & \langle\;\rangle \\ \text{COMPS} & \langle\;\rangle \end{bmatrix} \end{bmatrix} \\ \text{SEM} & \begin{bmatrix} \text{INDEX} & \text{x} \\ \text{RELS} & \left\langle \begin{bmatrix} \text{PRED} & \text{named} \\ \text{ARG0} & \text{x} \\ \text{NAME} & \text{“Kim”} \end{bmatrix} \right\rangle \end{bmatrix} \end{bmatrix} \right\rangle
$$

Ex 1: Semantics of S node

$$
\begin{bmatrix}
\text{INDEX} & \text{e1} \\
\text{RELS} & \left\langle
\begin{bmatrix}
\text{PRED} & \text{named} \\
\text{ARG0} & \text{x2} \\
\text{CARG} & \text{“Kim”}
\end{bmatrix},
\begin{bmatrix}
\text{PRED} & \text{rely\_on} \\
\text{ARG0} & \text{e1} \\
\text{ARG1} & \text{x2} \\
\text{ARG2} & \text{x3}
\end{bmatrix},
\begin{bmatrix}
\text{PRED} & \text{named} \\
\text{ARG0} & \text{x3} \\
\text{CARG} & \text{“Sandy”}
\end{bmatrix}
\right\rangle
\end{bmatrix}
$$

Identity constraints and long-distance dependencies

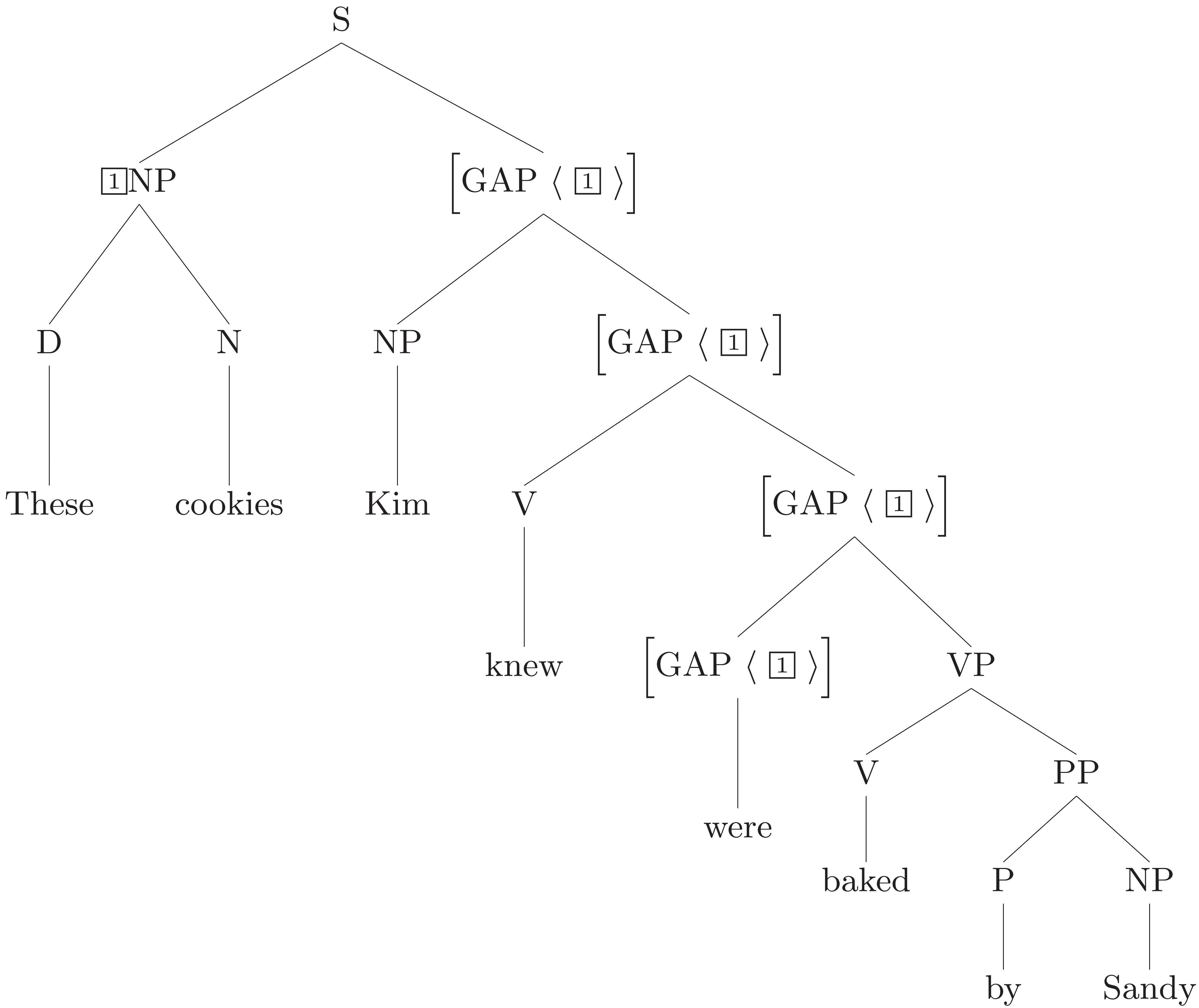
Head-Filler Rule

$$\begin{bmatrix} \textit{phrase} \end{bmatrix} \rightarrow \boxed{1}\begin{bmatrix} \text{GAP} & \langle\ \rangle \end{bmatrix} \quad \mathbf{H}\begin{bmatrix} \text{HEAD} & \begin{bmatrix} \textit{verb} & \\ \text{FORM} & \text{fin} \end{bmatrix} \\ \text{VAL} & \begin{bmatrix} \text{SPR} & \langle\ \rangle \\ \text{COMPS} & \langle\ \rangle \end{bmatrix} \\ \text{GAP} & \langle\ \boxed{1}\ \rangle \end{bmatrix}$$

Identity constraints and long-distance dependencies

Gap Principle (Simplified)

$$\begin{bmatrix}\text{GAP} & \boxed{A_1} \oplus \ldots \oplus \boxed{A_n}\end{bmatrix} \rightarrow \begin{bmatrix}\text{GAP} & \boxed{A_1}\end{bmatrix} \ldots \begin{bmatrix}\text{GAP} & \boxed{A_n}\end{bmatrix}$$


S
1 NP
[GAP ⟨ 1 ⟩]
D
N
NP
[GAP ⟨ 1 ⟩]
These
cookies
Kim
V
[GAP ⟨ 1 ⟩]
knew
[GAP ⟨ 1 ⟩]
VP
V
PP
were
baked
P
NP
by
Sandy

Key idea 4: Unification

- An HPSG grammar consists of partial constraints on well-formed trees
  - Lexical entries
  - Phrase structure rules
  - Lexical rules
  - General principles
  - Initial symbol
- These constraints are combined via the operation of unification
- Any combination that succeeds licenses well-formed utterances

Key ideas

- Mono-stratal theory of grammar
- Language as a system of signs
- Typed feature structures
- Unification
- Strong lexicalism
- Capturing generalizations of different granularities

Key idea 5: Strong lexicalism

- Lexical Integrity Hypothesis:
  - Words are built out of different structural elements and by different principles of composition than syntactic phrases (Bresnan & Mchombo 1995:181)
- Most linguistic information is stored as constraints on lexical entries
- The lexical type hierarchy captures generalizations across lexical entries
- Lexical rules capture further generalizations (agreement, paraphrase relations)

Rich lexical entries: Selected PP construction

$$
\left\langle \text{rely}\ ,\ \begin{bmatrix} \text{SYN} & \begin{bmatrix} \text{HEAD} & \textit{verb} \\ \text{VAL} & \begin{bmatrix} \text{SPR} & \left\langle \begin{matrix} \text{NP} \\ \begin{bmatrix} \text{INDEX} & \text{x} \end{bmatrix} \end{matrix} \right\rangle \\ \text{COMPS} & \left\langle \begin{matrix} \text{PP} \\ \begin{bmatrix} \text{FORM} & \text{on} \\ \text{INDEX} & \text{y} \end{bmatrix} \end{matrix} \right\rangle \end{bmatrix} \end{bmatrix} \\ \text{SEM} & \begin{bmatrix} \text{INDEX} & \text{e} \\ \text{RELS} & \left\langle \begin{bmatrix} \text{PRED} & \text{rely\_on} \\ \text{ARG0} & \text{e} \\ \text{ARG1} & \text{x} \\ \text{ARG2} & \text{y} \end{bmatrix} \right\rangle \end{bmatrix} \end{bmatrix} \right\rangle
$$

Rich lexical entires: Raising verbs (ex: *be*)

$$\left\langle \text{be}\ ,\ \begin{bmatrix} \text{SYN} & \begin{bmatrix} \text{HEAD} & \begin{bmatrix} \textit{verb} & \\ \text{AUX} & + \end{bmatrix} \\ \text{VAL} & \begin{bmatrix} \text{SPR} & \langle\ \boxed{1}\ \rangle \\ \text{COMPS} & \left\langle \begin{matrix} \text{VP} \\ \begin{bmatrix} \text{PRED} & + \\ \text{SPR} & \langle\ \boxed{1}\ \rangle \\ \text{INDEX} & \text{e} \end{bmatrix} \end{matrix} \right\rangle \end{bmatrix} \end{bmatrix} \\ \text{SEM} & \begin{bmatrix} \text{INDEX} & \text{e} \\ \text{RELS} & \langle\ \rangle \end{bmatrix} \end{bmatrix} \right\rangle$$

Lexical rules: Case, agreement

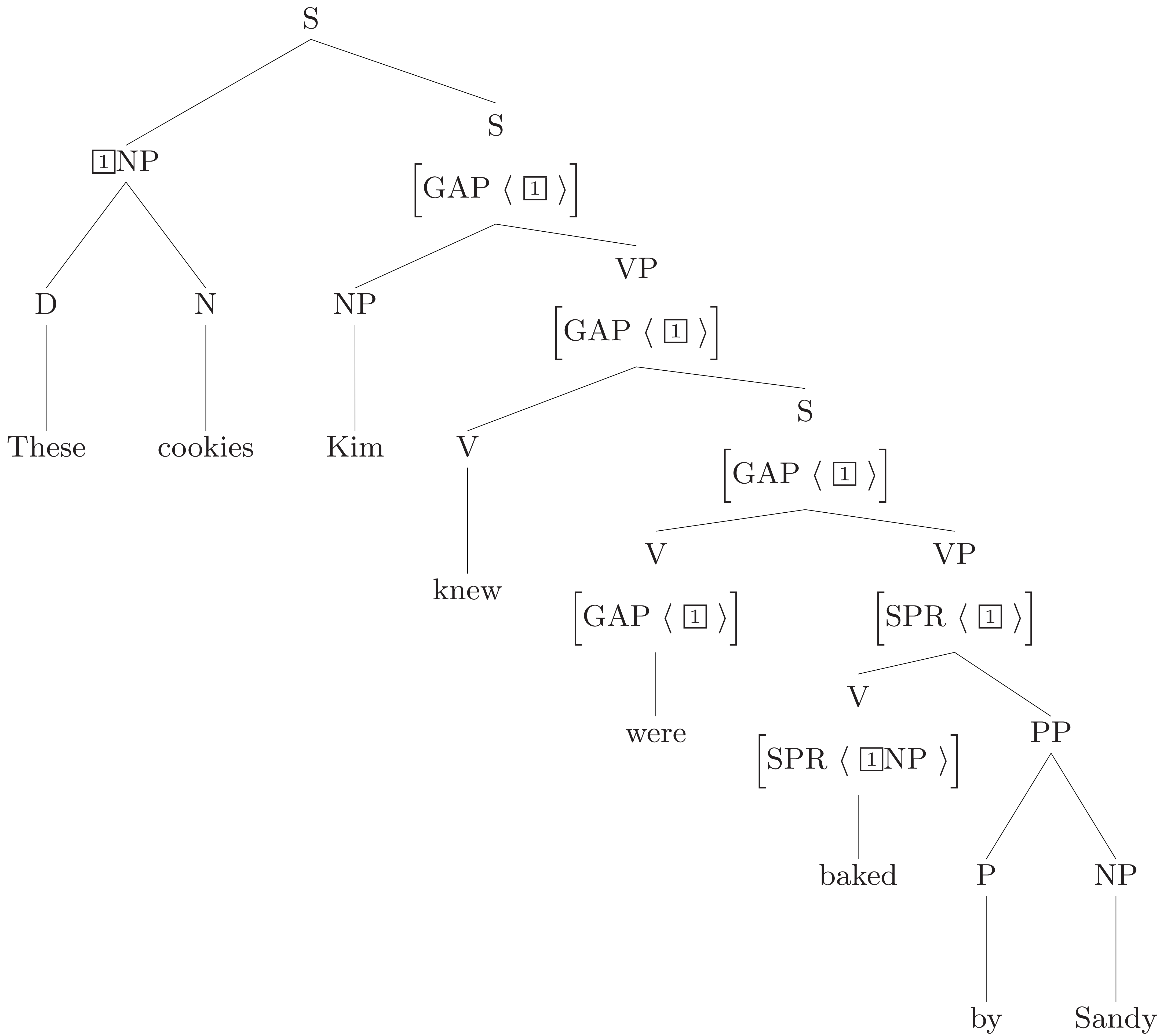
3rd-Singular Verb Lexical Rule

$$\begin{bmatrix} \text{INPUT} & \left\langle \boxed{1}\ ,\ \textit{verb-lxm} \right\rangle \\ \text{OUTPUT} & \left\langle \text{F}_{3SG}(\boxed{1})\ ,\ \begin{bmatrix} \text{SYN} & \begin{bmatrix} \text{HEAD} & \begin{bmatrix} \text{FORM} & \text{fin} \\ \text{AGR} & \textit{3sing} \end{bmatrix} \\ \text{VAL} & \begin{bmatrix} \text{SPR} & \langle \begin{bmatrix} \text{CASE} & \text{nom} \end{bmatrix} \rangle \end{bmatrix} \end{bmatrix} \\ \text{SEM} & \begin{bmatrix} \text{INDEX} & \begin{bmatrix} \text{TAM} & \text{pres} \end{bmatrix} \end{bmatrix} \end{bmatrix} \right\rangle \end{bmatrix}$$

Lexical rules: Passive

Passive Lexical Rule

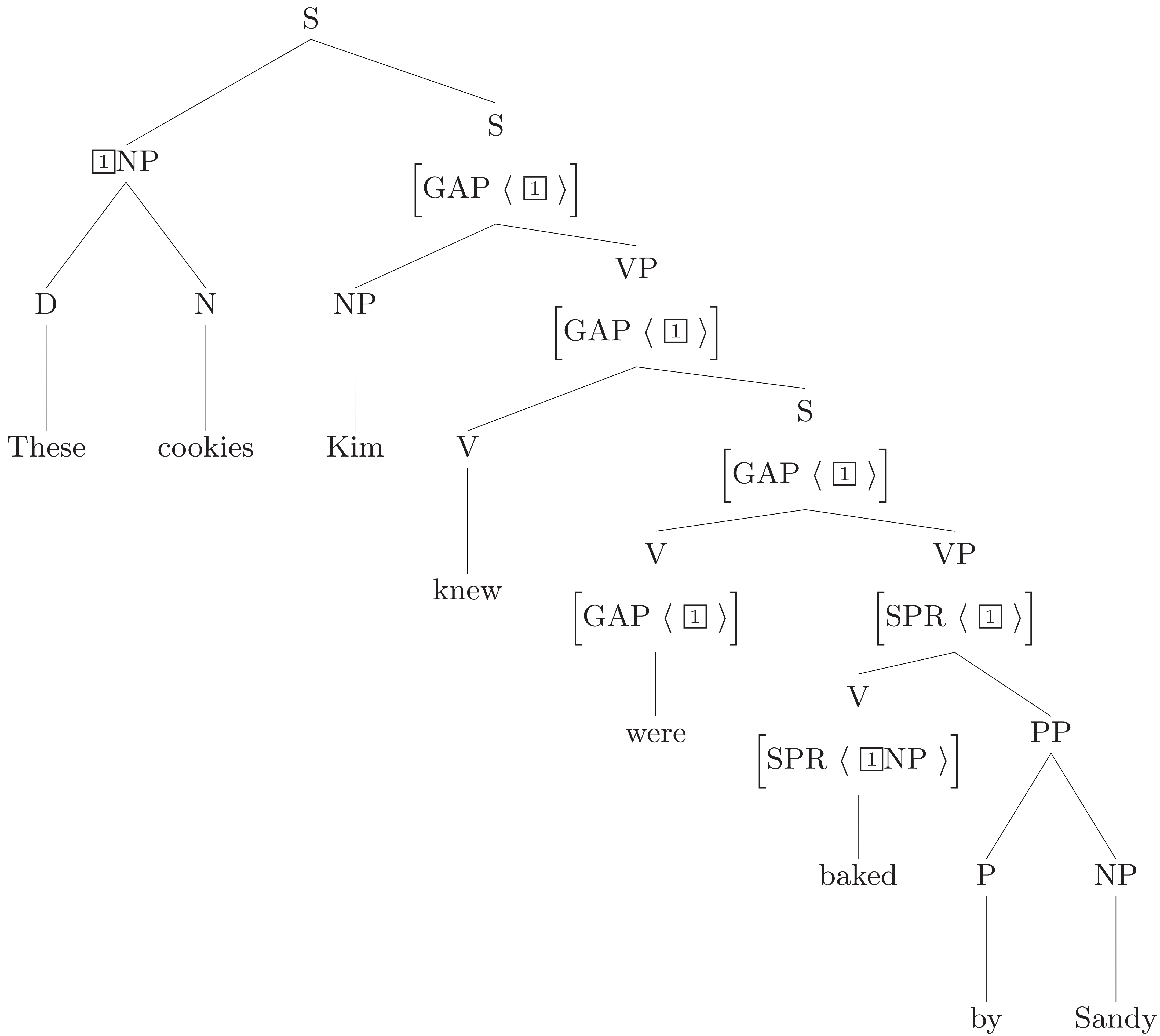
$$
\begin{bmatrix}
\text{INPUT} & \left\langle \boxed{1}\ , \begin{bmatrix} \textit{tv-lxm} & \\ \text{SYN} & \begin{bmatrix} \text{HEAD} & \begin{bmatrix} \text{PRED} & - \end{bmatrix} \\ \text{VAL} & \begin{bmatrix} \text{SPR} & \langle \begin{bmatrix} \text{INDEX} & \text{x} \end{bmatrix} \rangle \\ \text{COMPS} & \langle \boxed{2} \rangle \oplus \boxed{A} \end{bmatrix} \end{bmatrix} \end{bmatrix} \right\rangle \\
\text{OUTPUT} & \left\langle \text{F}_{PSP}(\boxed{1})\ , \begin{bmatrix} \textit{part-lxm} & \\ \text{SYN} & \begin{bmatrix} \text{HEAD} & \begin{bmatrix} \text{FORM} & \text{pass} \\ \text{PRED} & + \end{bmatrix} \\ \text{VAL} & \begin{bmatrix} \text{SPR} & \langle \boxed{2} \rangle \\ \text{COMPS} & \boxed{A} \oplus \left\langle \left(\begin{matrix} \text{PP} \\ \begin{bmatrix} \text{FORM} & \text{by} \\ \text{INDEX} & \text{x} \end{bmatrix} \end{matrix} \right) \right\rangle \end{bmatrix} \end{bmatrix} \end{bmatrix} \right\rangle
\end{bmatrix}
$$


S
1 NP
S [GAP ⟨ 1 ⟩]
D
N
NP
VP [GAP ⟨ 1 ⟩]
These
cookies
Kim
V
S [GAP ⟨ 1 ⟩]
knew
V [GAP ⟨ 1 ⟩]
VP [SPR ⟨ 1 ⟩]
were
V [SPR ⟨ 1 NP ⟩]
PP
baked
P
NP
by
Sandy

Lexical rules: Subject extraction

Subject Extraction Lexical Rule

$$
\begin{bmatrix}
\text{INPUT} & \left\langle \boxed{1}\,, \begin{bmatrix} \text{SYN} & \begin{bmatrix} \text{HEAD} & \begin{bmatrix} \textit{verb} \\ \text{FORM} & \text{fin} \end{bmatrix} \\ \text{VAL} & \begin{bmatrix} \text{SPR} & \langle\ \boxed{2}\ \rangle \\ \text{COMPS} & \boxed{A} \end{bmatrix} \\ \text{GAP} & \langle\ \rangle \end{bmatrix} \end{bmatrix} \right\rangle \\
\text{OUTPUT} & \left\langle \boxed{1}\,, \begin{bmatrix} \text{SYN} & \begin{bmatrix} \text{VAL} & \begin{bmatrix} \text{SPR} & \langle\ \rangle \\ \text{COMPS} & \boxed{A} \end{bmatrix} \\ \text{GAP} & \langle\ \boxed{2}\ \rangle \end{bmatrix} \end{bmatrix} \right\rangle
\end{bmatrix}
$$


S
1 NP
S [GAP ⟨ 1 ⟩]
D
N
NP
VP [GAP ⟨ 1 ⟩]
These
cookies
Kim
V
S [GAP ⟨ 1 ⟩]
knew
V [GAP ⟨ 1 ⟩]
VP [SPR ⟨ 1 ⟩]
were
V [SPR ⟨ 1 NP ⟩]
PP
baked
P
NP
by
Sandy

Aside: Morphology

- SWB sweep morphophonology under the carpet, but there is a lot of work on morphology in and with HPSG
  - Orgun 1996
  - Bonami & Crysmann 2013
  - … and many others!

Key idea 5: Strong lexicalism

- Lexical Integrity Hypothesis:
  - Words are built out of different structural elements and by different principles of composition than syntactic phrases (Bresnan & Mchombo 1995:181)
- Most linguistic information is stored as constraints on lexical entries
- The lexical type hierarchy captures generalizations across lexical entries
- Lexical rules capture further generalizations (agreement, paraphrase relations)

Key ideas

- Mono-stratal theory of grammar
- Language as a system of signs
- Typed feature structures
- Unification
- Strong lexicalism
- Capturing generalizations of different granularities

Key idea 6: Capturing generalizations at different granularities

- End goal is a parsimonious description of entire languages (as in Construction Grammar)

- Broad generalizations like the Head Feature Principle, the Head Complement Rule, lexical type for common nouns feature in the analyses of many sentences

- The statement of such broad generalizations should be compatible with the description of minute idiosyncrasies:

    - *Kim can't leave.* v. *Kim mustn't leave.*

    - *Beware of the dog!* v. **I bewared the dog.*

Key ideas

- Mono-stratal theory of grammar
- Language as a system of signs
- Typed feature structures
- Unification
- Strong lexicalism
- Capturing generalizations of different granularities

Overview

- Introduction: Shared assumptions, high-level overview
- Key ideas
- Theoretical commitments
- Extensions

Theoretical commitments

- Formal precision
- Dissociate theory and formalism (e.g. Bender 2008)
- Bottom-up approach to language universals (e.g. Mueller 2015a)
- Performance-plausible competence grammar (e.g. Sag & Wasow 2011)
- Process independence (parsing, generation, crossword puzzles…)
- Uniform representation of many levels (syntax, semantics, pragmatics; e.g. Green 1996, Michaelis 2009, Song 2017)

Extensions

- Separating tectogrammatical structure from phenogrammatical structure
- Constructions & Sign-Based Construction Grammar
- Grammar Matrix

Tectogrammatical v. phenogrammatical structure

- Tectogrammatical structure: The ‘order’ in which constituents are combined
- Phenogrammatical structure: The order of elements in the surface string
- Reape’s (1994) linearization theory:
    - Phonological/orthographic form is represented as feature
    - Phonological/orthographic form of the mother is a function of the forms of the daughters
    - That function can be other than a simple append

Tectogrammatical v. phenogrammatical structure

- Linearization theory has been applied in:
  - Analysis of word order domains in Germanic languages (e.g. Reape 1994, Kathol 1995, Müller 1995)
  - Analysis of radical free word order in Australian languages (Donohue & Sag 1999)
- Roots go back to notion of linear precedence as separate from immediate dominance in GPSG (Gazdar et al 1985)
- Complicates parsing algorithms

Constructions & Sign-Based Construction Grammar

- Construction Grammar (Fillmore & Kay 1993) introduces the notion of the *constructicon*
    - A rich collection of phrase structure rules
    - Some very general
    - Some idiosyncratic (e.g. *What's X doing Y?* (Kay & Fillmore 1999))
- Handle both core & periphery in one grammar
- Constructions, like lexical types, organized into a type hierarchy to capture generalizations

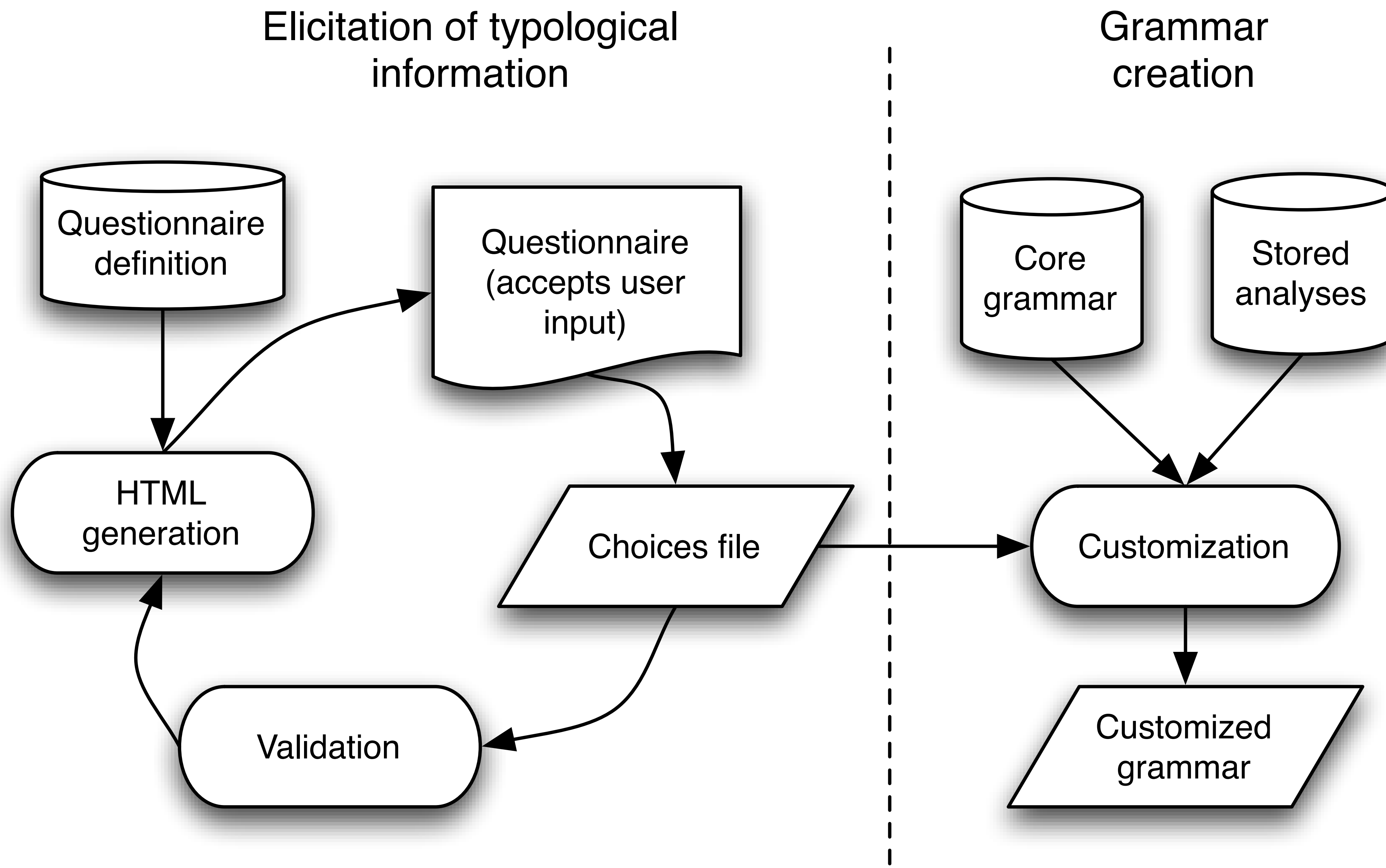
Constructions & Sign-Based Construction Grammar

- Adopted in the LinGO project (Flickinger 2000, 2011) from early on
- Formalized in SBCG (Michaelis 2009, Boas & Sag 2012)

The LinGO Grammar Matrix

- Leverage what has been learned in large-scale long-term grammar engineering projects to support the development of implemented grammars for more languages (Bender et al 2002)
- Bring together breadth of typological analysis with depth of precision syntactic analysis
- Online resource that pairs a core grammar with a ‘customization system’ that allows users to create a grammar fragment for any language (Bender et al 2010)

Grammar Matrix Customization System



(Bender et al 2010)

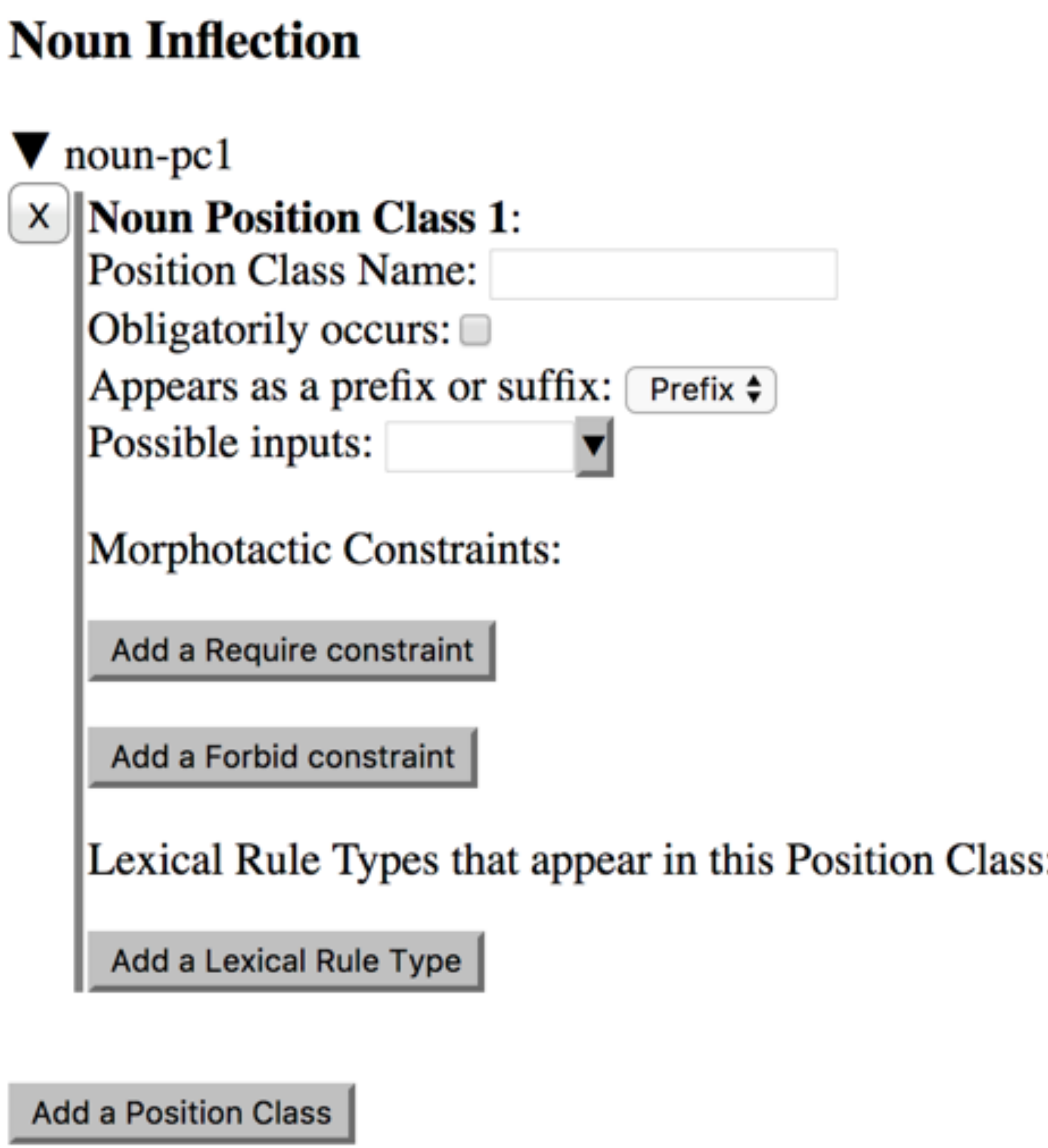
Grammar Matrix Customization System

- * General Information
- * Word Order
- Number
- * Person
- Gender
- * Case
- Direct-inverse
- Tense, Aspect and Mood
- Other Features
- Sentential Negation
- Coordination
- Matrix Yes/No Questions
- Information Structure
- Argument Optionality
- ? Lexicon
- Morphology
- Import Toolbox Lexicon
- Test Sentences
- Test by Generation Options

Archive type: (●) .tar.gz ( ) .zip

[Create Grammar] [Test by Generation]

Grammar Matrix Customization System



Ling 567 at UW

- 10 week course
- Develop grammars for different languages on the basis of (a) descriptive grammars and (b) the Grammar Matrix
- For fun, wrap up with an ‘MT extravaganza’

Ling 567 languages since 2004

567 languages - 2017

lat/long data mostly from wals.info; map by batchgeo.com

Languages - cupcaked

Grammar coverage (shared)

- Basic word order
- Case
- Agreement
- Personal pronouns
- Tense/aspect
- Sentential negation
- Argument optionality
- Matrix yes-no questions
- Coordination
- Modification (adjective, adverb)
- Non-verbal predicates
- Clausal complements
- Wh questions
- Possessives

Set up

- Transfer-based MT: Grammars parse and generate, mapping surface strings to semantic representations in MRS
- Grammars developed on the basis of the Grammar Matrix, facilitating harmonized semantic representations
- Quasi lexical interlingua (English lemmatas as PRED values)
- ‘semi’ (Semantic Interface) maps variable properties (PNG, TAM, COG-ST, INFO-STR) from grammar internal space to interlingual space. Lossy mapping, provides defaults
- One ‘accommodation’ transfer grammar per language, instantiating shared transfer rules

Input sentences

1. Dogs sleep
2. Dogs chase cars
3. I chase you
4. Dogs eat
5. The dogs chase cars
6. The dogs dont chase cars
7. I think that you know that dogs chase cars
8. I ask whether you know that dogs chase cars
9. Cats and dogs chase cars
10. Dogs chase cars and cats chase dogs
11. Cats chase dogs and sleep
12. Do cats chase dogs
13. Hungry dogs eat
14. Dogs eat quickly
15. The dogs are hungry
16. The dogs are in the park
17. The dogs are the cats
18. Who sleeps
19. What do the dogs chase
20. What do you think the dogs chase
21. Who asked what the dogs chase
22. I asked what the dogs chased
23. The dog’s car sleeps
24. My dogs sleep

Items with end-to-end output: Final (transfer rule propagation)

	abz	eng	flr	ilo	kaz	khr	kkk	shu	sje	tur
abz	16	16	14	17	14	14	13	14	16	15
eng	17	24	18	22	19	20	14	22	24	24
flr	10	13	19	13	11	11	8	12	14	13
ilo	12	19	16	22	15	14	13	19	19	18
kaz	14	15	12	14	19	12	13	14	16	15
khr	14	17	15	16	15	17	10	15	17	17
kkk	13	14	12	14	13	12	14	14	14	13
shu	15	22	16	20	17	18	14	22	22	22
sje	15	20	16	17	16	16	12	18	22	20
tur	16	24	18	19	19	21	14	22	24	24

(‘run18’ [18])

Overview

- Introduction: Shared assumptions, high-level overview
- Key ideas
- Theoretical commitments
- Extensions

To learn more:

- Sag et al 2003 (textbook)
- Pollard and Sag 1994
- Müller 2015b
- Boas & Sag 2012
- Copestake et al 2005

To learn more:

- The HPSG bibliography:

https://hpsg.hu-berlin.de/HPSG-Bib/

- And…

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