Chapter 5, Sections 5.6-5.9:

Semantics

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Review: Semantic Compositionality

The meaning of a phrase is determined by:

- the meaning of its parts, and
- how those parts are put together

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Review: Words ...

- contribute predications
- provide one index in those predications, for use by words or phrases
- relate syntactic arguments to semantic arguments

$$\left\langle \text{slept}, \begin{bmatrix} \textit{word} & \\ \text{SYN} & \begin{bmatrix} \text{HEAD} & \textit{verb} \\ \text{VAL} & \begin{bmatrix} \text{SPR} & \langle\ \text{NP}_{j}\ \rangle \\ \text{COMPS} & \langle\ \rangle \end{bmatrix} \end{bmatrix} \\ \text{SEM} & \begin{bmatrix} \text{INDEX} & s_1 \\ \text{MODE} & \text{prop} \\ \text{RESTR} & \left\langle \begin{bmatrix} \text{RELN} & \text{sleep} \\ \text{SIT} & s_1 \\ \text{SLEEPER} & j \end{bmatrix}, \ldots \right\rangle \end{bmatrix} \end{bmatrix} \right\rangle$$

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Review: Grammar Rules ...

- identify feature structures across daughters

Head Specifier Rule

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

Head Complement Rule

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

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Review: Grammar Rules ...

- license trees which are subject to the semantic principles
  Semantic Inheritance Principle passes up MODE and INDEX from head daughter

S

$$\begin{bmatrix} \text{SEM} & \begin{bmatrix} \text{INDEX} & s_1 \\ \text{MODE} & \text{prop} \\ \text{RESTR} & \left\langle \begin{bmatrix} \text{RELN} & \text{name} \\ \text{NAME} & \text{Dana} \\ \text{NAMED} & i \end{bmatrix}, \begin{bmatrix} \text{RELN} & \text{sleep} \\ \text{SIT} & s_1 \\ \text{SLEEPER} & i \end{bmatrix}, \ldots \right\rangle \end{bmatrix} \end{bmatrix}$$

$\boxed{1}$NP

$$\begin{bmatrix} \text{SEM} & \begin{bmatrix} \text{INDEX} & i \\ \text{RESTR} & \left\langle \begin{bmatrix} \text{RELN} & \text{name} \\ \text{NAME} & \text{Dana} \\ \text{NAMED} & i \end{bmatrix} \right\rangle \end{bmatrix} \end{bmatrix}$$

VP

$$\begin{bmatrix} \text{SYN} & [\ \text{VAL} \ [\ \text{SPR} \ \langle \boxed{1} \rangle\ ]\ ] \\ \text{SEM} & \begin{bmatrix} \text{INDEX} & s_1 \\ \text{MODE} & \text{prop} \\ \text{RESTR} & \left\langle \begin{bmatrix} \text{RELN} & \text{sleep} \\ \text{SIT} & s_1 \\ \text{SLEEPER} & i \end{bmatrix}, \ldots \right\rangle \end{bmatrix} \end{bmatrix}$$

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Review: Grammar Rules ...

- license trees which are subject to the semantic principles

Semantic Inheritance Principle passes up MODE and INDEX from head daughter

Semantic Compositionality Principle gathers up predications from all daughters into the mother's RESTR list

S

$$\begin{bmatrix} \text{SEM} & \begin{bmatrix} \text{INDEX} & s_1 \\ \text{MODE} & \text{prop} \\ \text{RESTR} & \left\langle \begin{bmatrix} \text{RELN} & \text{name} \\ \text{NAME} & \text{Dana} \\ \text{NAMED} & i \end{bmatrix}, \begin{bmatrix} \text{RELN} & \text{sleep} \\ \text{SIT} & s_1 \\ \text{SLEEPER} & i \end{bmatrix}, \ldots \right\rangle \end{bmatrix} \end{bmatrix}$$

$\boxed{1}$NP

$$\begin{bmatrix} \text{SEM} & \begin{bmatrix} \text{INDEX} & i \\ \text{RESTR} & \left\langle \begin{bmatrix} \text{RELN} & \text{name} \\ \text{NAME} & \text{Dana} \\ \text{NAMED} & i \end{bmatrix} \right\rangle \end{bmatrix} \end{bmatrix}$$

VP

$$\begin{bmatrix} \text{SYN} & [\ \text{VAL} & [\ \text{SPR} & \langle\ \boxed{1}\ \rangle\ ]\ ] \\ \text{SEM} & \begin{bmatrix} \text{INDEX} & s_1 \\ \text{MODE} & \text{prop} \\ \text{RESTR} & \left\langle \begin{bmatrix} \text{RELN} & \text{sleep} \\ \text{SIT} & s_1 \\ \text{SLEEPER} & i \end{bmatrix}, \ldots \right\rangle \end{bmatrix} \end{bmatrix}$$

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Other Aspects of Semantics

- Tense, Quantification (only touched on here)
- Modification
- Coordination
- Structural Ambiguity

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Modification

John put the car <u>in the garage</u>. ← complement: sister of verb (VP -> V NP PP)

vs.

John played the drums <u>in the garage</u>. ← mod: sister of VP (VP -> VP PP)

John noticed the lack <u>of a table</u>. ← comp: sister of noun (NOM -> N PP)

vs.

John noticed a chair <u>near a table</u>. ← mod: sister of NOM (NOM -> NOM PP)

Ch. 2: CFG rules for modification

NOM → NOM PP

VP → VP PP

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Modification

Till now: modifiers combine with Nom and VP, i.e., after complements but before specifiers

Ch. 3: Feature structure rule for VP and NOM modification

$$\begin{bmatrix} phrase & \\ \text{VAL} & \begin{bmatrix} \text{COMPS} & \text{itr} \\ \text{SPR} & - \end{bmatrix} \end{bmatrix} \rightarrow \mathbf{H}\begin{bmatrix} phrase & \\ \text{VAL} & \begin{bmatrix} \text{SPR} & - \end{bmatrix} \end{bmatrix} \text{PP}$$

But modifiers can combine with 'saturated' categories NP and S!

Terry likes the music and the poetry on the program.
Alex walks and Sandy reads books on Tuesdays.

Ch. 4: $[phrase] \rightarrow \mathbf{H}\begin{bmatrix} \text{VAL} & \begin{bmatrix} \text{COMPS} & \langle\ \rangle \end{bmatrix} \end{bmatrix} \text{PP}$

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Modification

What about adjectives and adverbs?

The **person** <u>responsible</u> confessed.

vs.

*The person **confessed** <u>responsible</u>.

Some modifiers can only combine with certain heads

Ch. 5: $[phrase] \rightarrow \mathbf{H}\boxed{1}\begin{bmatrix}\text{SYN}\begin{bmatrix}\text{VAL}\begin{bmatrix}\text{COMPS} & \langle\ \rangle\end{bmatrix}\end{bmatrix}\end{bmatrix}\ \begin{bmatrix}\text{SYN}\begin{bmatrix}\text{VAL}\begin{bmatrix}\text{COMPS} & \langle\ \rangle \\ \text{MOD} & \langle\ \boxed{1}\ \rangle\end{bmatrix}\end{bmatrix}\end{bmatrix}$

Ch. 5 (abbreviated): $[phrase] \rightarrow \mathbf{H}\boxed{1}\begin{bmatrix}\text{COMPS} & \langle\ \rangle\end{bmatrix}\ \begin{bmatrix}\text{COMPS} & \langle\ \rangle \\ \text{MOD} & \langle\ \boxed{1}\ \rangle\end{bmatrix}$

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Evolution of a Phrase Structure Rule

Ch. 2: $\text{X} \rightarrow \text{X}^{+}\ \text{CONJ}\ \text{X}$

Ch. 3: $\boxed{1} \rightarrow \boxed{1}^{+} \begin{bmatrix} word & \\ \text{HEAD} & conj \end{bmatrix} \boxed{1}$

John sniffed, tasted, and swallowed the wine.

Ch. 4: $\begin{bmatrix} \text{VAL} & \boxed{1} \end{bmatrix} \rightarrow \begin{bmatrix} \text{VAL} & \boxed{1} \end{bmatrix}^{+} \begin{bmatrix} word & \\ \text{HEAD} & conj \end{bmatrix} \begin{bmatrix} \text{VAL} & \boxed{1} \end{bmatrix}$

Ch. 5 (abbreviated):

$$\begin{bmatrix} \text{VAL} & \boxed{0} \\ \text{IND} & s_0 \end{bmatrix} \rightarrow \begin{bmatrix} \text{VAL} & \boxed{0} \\ \text{IND} & s_1 \end{bmatrix} \ldots \begin{bmatrix} \text{VAL} & \boxed{0} \\ \text{IND} & s_{n-1} \end{bmatrix} \begin{bmatrix} \text{HEAD} & conj \\ \text{IND} & s_0 \\ \text{RESTR} & \left\langle \begin{bmatrix} \text{ARGS} & \langle s_1 \ldots s_n \rangle \end{bmatrix} \right\rangle \end{bmatrix} \begin{bmatrix} \text{VAL} & \boxed{0} \\ \text{IND} & s_n \end{bmatrix}$$

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Combining Constraints and Coordination

Coordination Rule

$$\begin{bmatrix}\text{VAL} & \boxed{0}\\ \text{IND} & s_0\end{bmatrix} \rightarrow \begin{bmatrix}\text{VAL} & \boxed{0}\\ \text{IND} & s_1\end{bmatrix}\ldots\begin{bmatrix}\text{VAL} & \boxed{0}\\ \text{IND} & s_{n-1}\end{bmatrix}\begin{bmatrix}\text{HEAD} & conj\\ \text{IND} & s_0\\ \text{RESTR} & \left\langle\left[\text{ARGS}\ \langle s_1\ldots s_n\rangle\right]\right\rangle\end{bmatrix}\begin{bmatrix}\text{VAL} & \boxed{0}\\ \text{IND} & s_n\end{bmatrix}$$

Lexical Entry for a Conjunction

$$\left\langle \text{and}\ ,\ \begin{bmatrix}\text{SYN} & \begin{bmatrix}\text{HEAD} & conj\end{bmatrix}\\ \text{SEM} & \begin{bmatrix}\text{INDEX} & s\\ \text{MODE} & \text{none}\\ \text{RESTR} & \left\langle\begin{bmatrix}\text{RELN} & \text{and}\\ \text{SIT} & s\end{bmatrix}\right\rangle\end{bmatrix}\end{bmatrix}\right\rangle$$

Why do we need a special coordination rule? (2 reasons)

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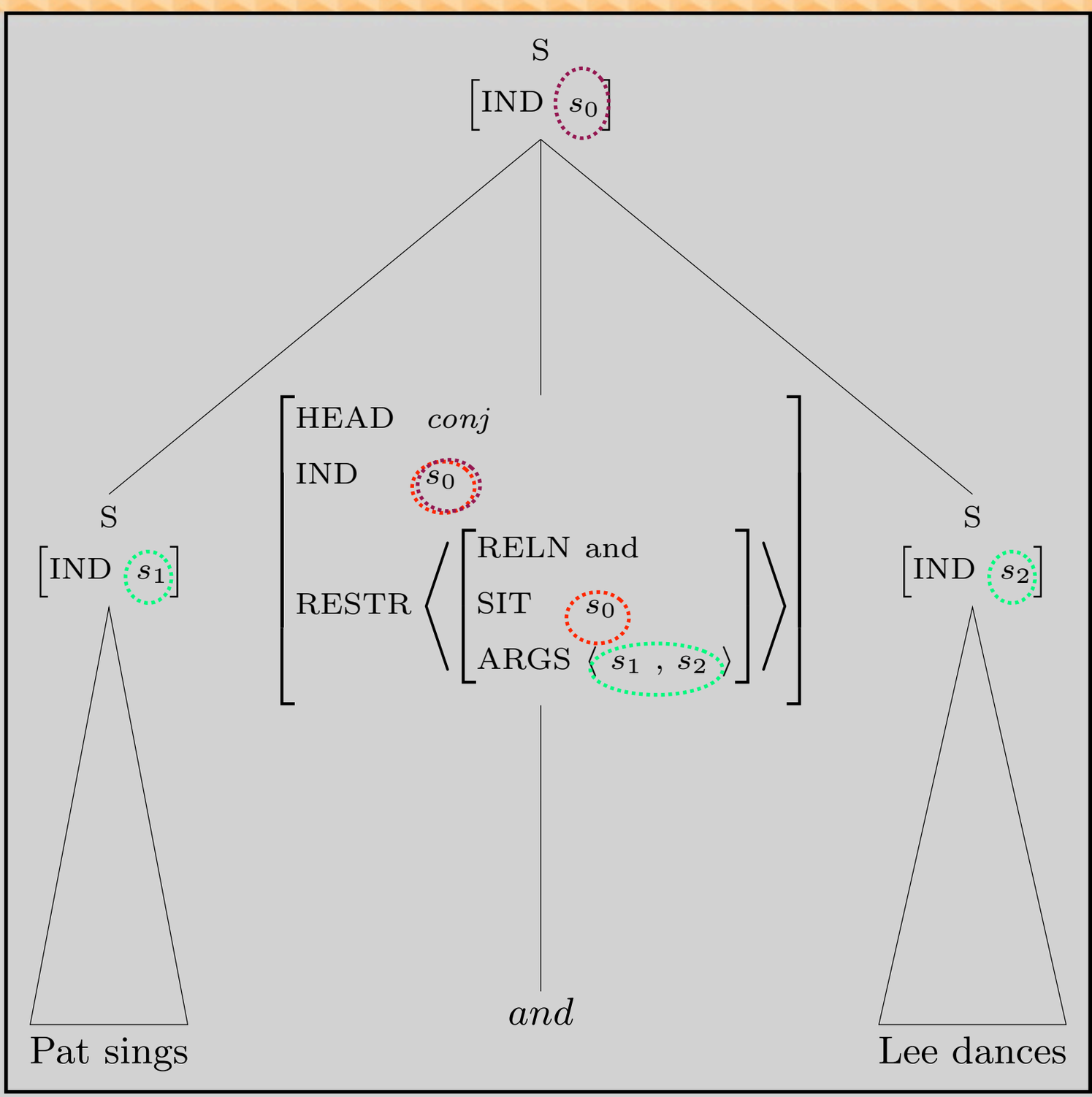
Combining Constraints and Coordination

Lexical Entry for *and*

$$\left\langle \text{and}\ ,\ \begin{bmatrix} \text{SYN} & \begin{bmatrix} \text{HEAD} & conj \end{bmatrix} \\ \text{SEM} & \begin{bmatrix} \text{INDEX} & s \\ \text{MODE} & \text{none} \\ \text{RESTR} & \left\langle \begin{bmatrix} \text{RELN} & \text{and} \\ \text{SIT} & s \end{bmatrix} \right\rangle \end{bmatrix} \end{bmatrix} \right\rangle$$



Coordination Rule

$$\begin{bmatrix} \text{VAL} & \boxed{0} \\ \text{IND} & s_0 \end{bmatrix} \rightarrow \begin{bmatrix} \text{VAL} & \boxed{0} \\ \text{IND} & s_1 \end{bmatrix} \ldots \begin{bmatrix} \text{VAL} & \boxed{0} \\ \text{IND} & s_{n-1} \end{bmatrix} \begin{bmatrix} \text{HEAD} & conj \\ \text{IND} & s_0 \\ \text{RESTR} & \left\langle \begin{bmatrix} \text{ARGS} & \langle s_1 \ldots s_n \rangle \end{bmatrix} \right\rangle \end{bmatrix} \begin{bmatrix} \text{VAL} & \boxed{0} \\ \text{IND} & s_n \end{bmatrix}$$

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Structural Ambiguity

Pat sings and Lee dances frequently.

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Lexical Entry for *frequently*

$$\left\langle \text{frequently}\ ,\ \begin{bmatrix} \text{SYN} & \begin{bmatrix} \text{HEAD} & adv \\ \text{VAL} & \begin{bmatrix} \text{MOD} & \left\langle \begin{bmatrix} \text{S} \\ \text{INDEX} \quad s_1 \end{bmatrix} \right\rangle \\ \text{SPR} & \langle\ \rangle \\ \text{COMPS} & \langle\ \rangle \end{bmatrix} \end{bmatrix} \\ \text{SEM} & \begin{bmatrix} \text{MODE} & \text{none} \\ \text{RESTR} & \left\langle \begin{bmatrix} \text{RELN} & \textbf{frequently} \\ \text{ARG} & s_1 \end{bmatrix} \right\rangle \end{bmatrix} \end{bmatrix} \right\rangle$$

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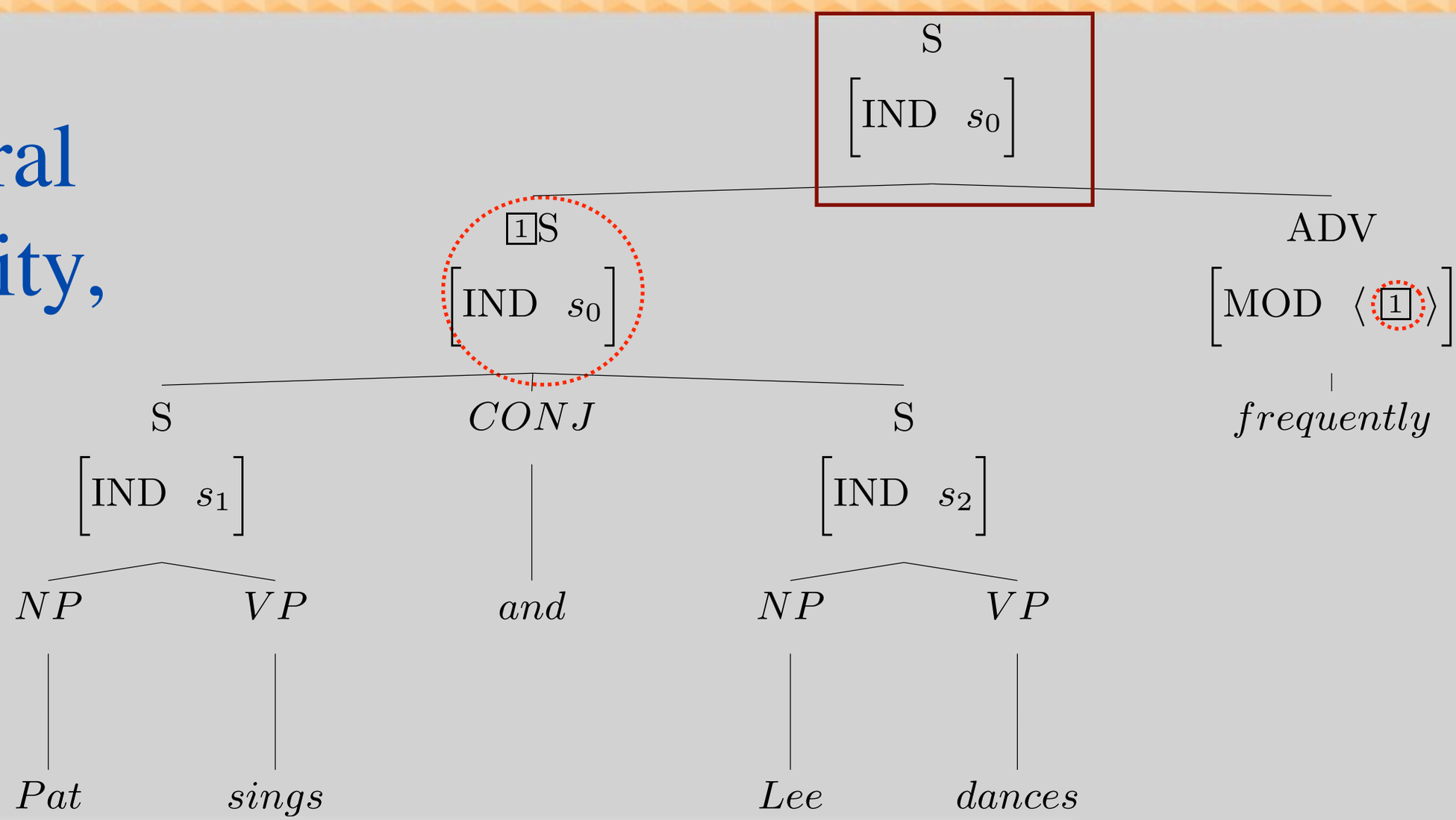
Structural Ambiguity, Tree I



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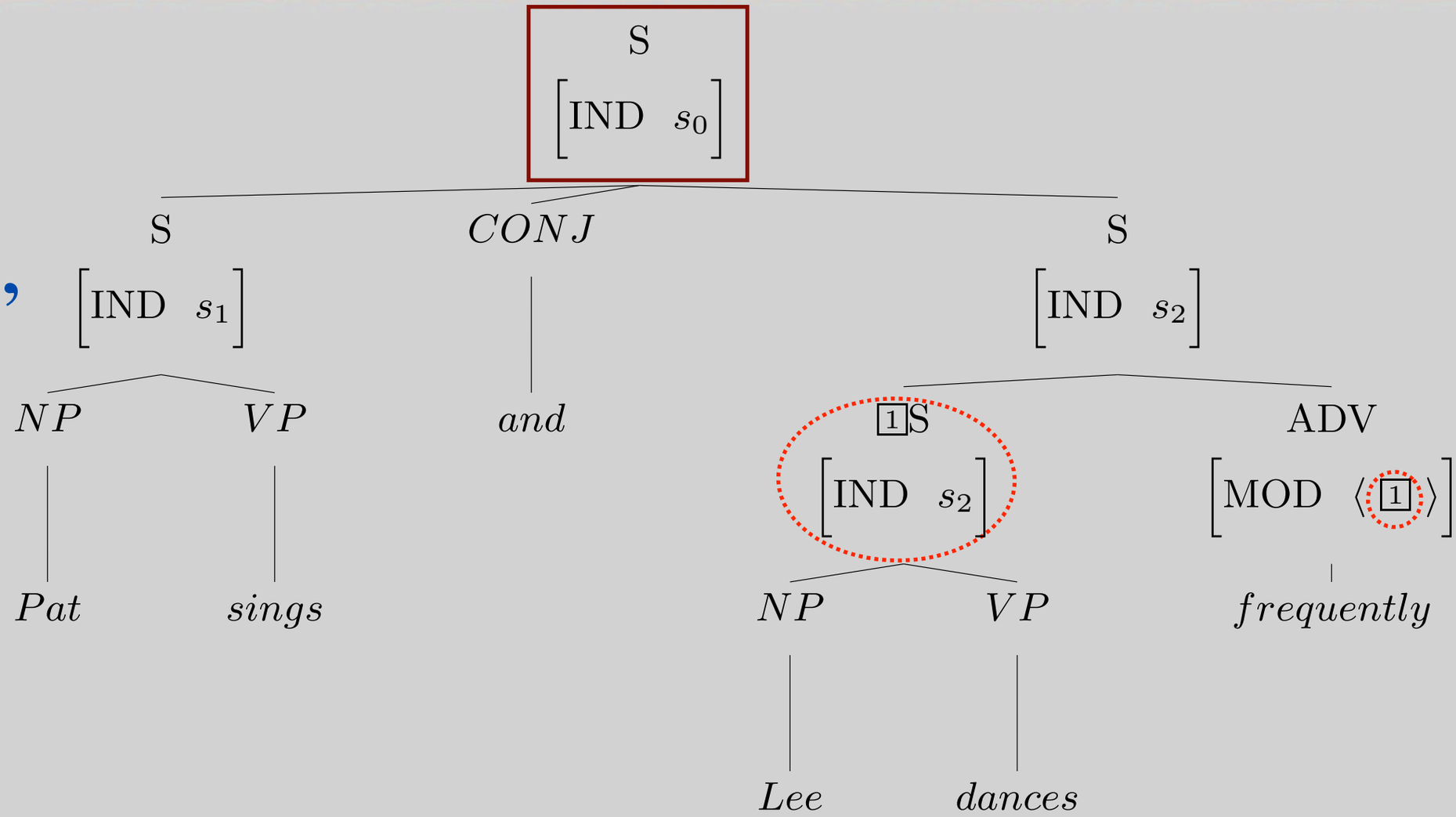
Structural Ambiguity, Tree II



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Two Semantic Meanings

$$\begin{bmatrix} \text{IND} & s_0 \\ \text{MODE} & \text{prop} \\ \text{RESTR} & \left\langle \begin{bmatrix} \text{RELN} & \text{name} \\ \text{NAME} & \text{Pat} \\ \text{NAMED} & k \end{bmatrix}, \begin{bmatrix} \text{RELN} & \text{sing} \\ \text{SIT} & s_1 \\ \text{SINGER} & k \end{bmatrix}, \begin{bmatrix} \text{RELN} & \text{and} \\ \text{SIT} & s_0 \\ \text{ARGS} & \langle\, s_1 \,,\, s_2 \,\rangle \end{bmatrix}, \begin{bmatrix} \text{RELN} & \text{name} \\ \text{NAME} & \text{Lee} \\ \text{NAMED} & j \end{bmatrix}, \begin{bmatrix} \text{RELN} & \text{dance} \\ \text{SIT} & s_2 \\ \text{DANCER} & j \end{bmatrix}, \begin{bmatrix} \text{RELN} & \text{frequently} \\ \text{ARG} & s_0 \end{bmatrix} \right\rangle \end{bmatrix}$$

$$\begin{bmatrix} \text{IND} & s_0 \\ \text{MODE} & \text{prop} \\ \text{RESTR} & \left\langle \begin{bmatrix} \text{RELN} & \text{name} \\ \text{NAME} & \text{Pat} \\ \text{NAMED} & k \end{bmatrix}, \begin{bmatrix} \text{RELN} & \text{sing} \\ \text{SIT} & s_1 \\ \text{SINGER} & k \end{bmatrix}, \begin{bmatrix} \text{RELN} & \text{and} \\ \text{SIT} & s_0 \\ \text{ARGS} & \langle\, s_1 \,,\, s_2 \,\rangle \end{bmatrix}, \begin{bmatrix} \text{RELN} & \text{name} \\ \text{NAME} & \text{Lee} \\ \text{NAMED} & j \end{bmatrix}, \begin{bmatrix} \text{RELN} & \text{dance} \\ \text{SIT} & s_2 \\ \text{DANCER} & j \end{bmatrix}, \begin{bmatrix} \text{RELN} & \text{frequently} \\ \text{ARG} & s_2 \end{bmatrix} \right\rangle \end{bmatrix}$$

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Semantic Compositionality

Why isn't this a possible semantic representation for the string *Pat sings and Lee dances frequently*?

$$\begin{bmatrix} \text{IND} & s_0 \\ \text{MODE} & \text{prop} \\ \text{RESTR} & \left\langle \begin{bmatrix} \text{RELN} & \text{name} \\ \text{NAME} & \text{Pat} \\ \text{NAMED} & k \end{bmatrix}, \begin{bmatrix} \text{RELN} & \text{sing} \\ \text{SIT} & s_1 \\ \text{SINGER} & k \end{bmatrix}, \begin{bmatrix} \text{RELN} & \text{and} \\ \text{SIT} & s_0 \\ \text{ARGS} & \langle\, s_1 \,,\, s_2 \,\rangle \end{bmatrix}, \begin{bmatrix} \text{RELN} & \text{name} \\ \text{NAME} & \text{Lee} \\ \text{NAMED} & j \end{bmatrix}, \begin{bmatrix} \text{RELN} & \text{dance} \\ \text{SIT} & s_2 \\ \text{DANCER} & j \end{bmatrix}, \begin{bmatrix} \text{RELN} & \text{frequently} \\ \text{ARG} & s_1 \end{bmatrix} \right\rangle \end{bmatrix}$$

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Semantic Compositionality

$$\begin{bmatrix} \text{INDEX} & s_0 \\ \text{MODE} & \text{prop} \\ \text{RESTR} & \left\langle \begin{matrix} \begin{bmatrix} \text{RELN} & \text{name} \\ \text{NAME} & \text{Pat} \\ \text{NAMED} & k \end{bmatrix}, \begin{bmatrix} \text{RELN} & \text{sing} \\ \text{SIT} & s_1 \\ \text{SINGER} & k \end{bmatrix} \begin{bmatrix} \text{RELN} & \text{and} \\ \text{SIT} & s_0 \\ \text{ARGS} & \langle s_1, s_2 \rangle \end{bmatrix}, \\ \begin{bmatrix} \text{RELN} & \text{name} \\ \text{NAME} & \text{Lee} \\ \text{NAMED} & j \end{bmatrix}, \begin{bmatrix} \text{RELN} & \text{dance} \\ \text{SIT} & s_2 \\ \text{DANCER} & j \end{bmatrix} \begin{bmatrix} \text{RELN} & \text{frequently} \\ \text{ARG} & s_0 \end{bmatrix} \end{matrix} \right\rangle \end{bmatrix}$$

$$\begin{bmatrix} \text{INDEX} & s_0 \\ \text{MODE} & \text{prop} \\ \text{RESTR} & \left\langle \begin{matrix} \begin{bmatrix} \text{RELN} & \text{name} \\ \text{NAME} & \text{Pat} \\ \text{NAMED} & k \end{bmatrix}, \begin{bmatrix} \text{RELN} & \text{sing} \\ \text{SIT} & s_1 \\ \text{SINGER} & k \end{bmatrix} \begin{bmatrix} \text{RELN} & \text{and} \\ \text{SIT} & s_0 \\ \text{ARGS} & \langle s_1, s_2 \rangle \end{bmatrix}, \\ \begin{bmatrix} \text{RELN} & \text{name} \\ \text{NAME} & \text{Lee} \\ \text{NAMED} & j \end{bmatrix}, \begin{bmatrix} \text{RELN} & \text{dance} \\ \text{SIT} & s_2 \\ \text{DANCER} & j \end{bmatrix} \begin{bmatrix} \text{RELN} & \text{frequently} \\ \text{ARG} & s_2 \end{bmatrix} \end{matrix} \right\rangle \end{bmatrix}$$

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