Semantic Theory
week 10 – DRT: Composition and Interpretation

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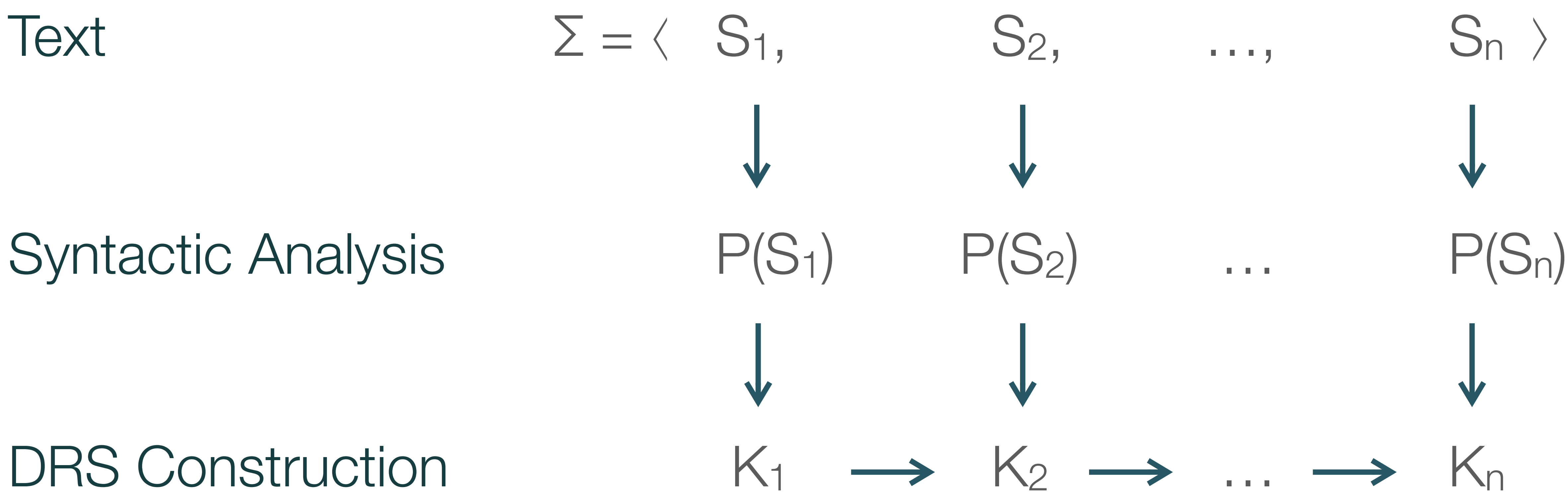
From text to DRS



DRS Construction Algorithm

Let the following be a well-formed, *reducible* DRS condition:

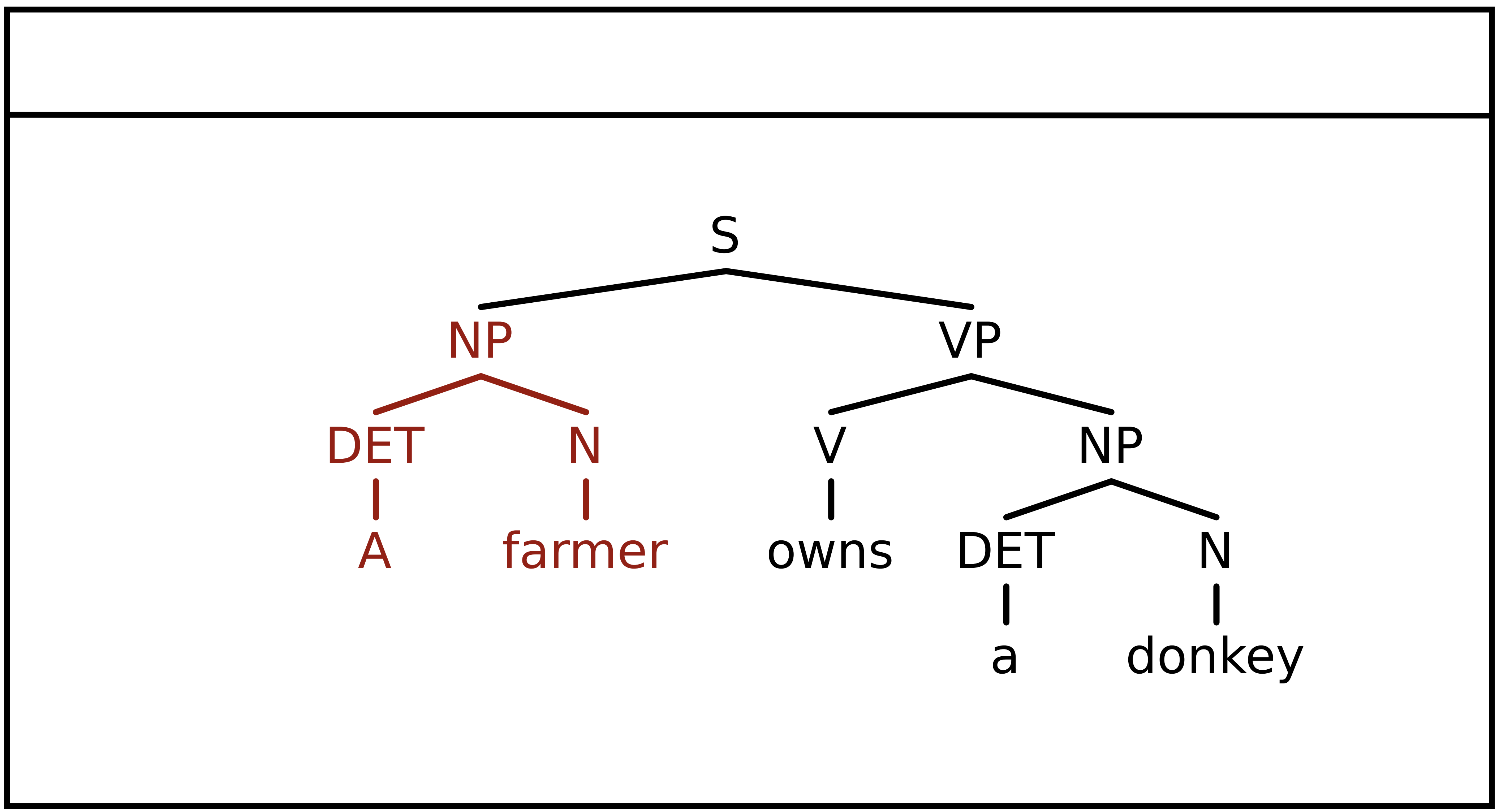
- Conditions of form α or α(x1, …, xn), where α is a context-free parse tree.

DRS construction algorithm:

- Given a text $\Sigma = \langle S_1, \ldots, S_n \rangle$, and a DRS K_0 (= ⟨∅, ∅⟩, by default)
- Repeat for i = 1, …, n:
  - Add parse tree $P(S_i)$ to the conditions of K_{i-1}.
  - Apply DRS construction rules to reducible conditions of K_{i-1}, until no reduction steps are possible any more.
  - The resulting DRS is K_i , the discourse representation of text $\langle S_1, \ldots, S_i \rangle$.

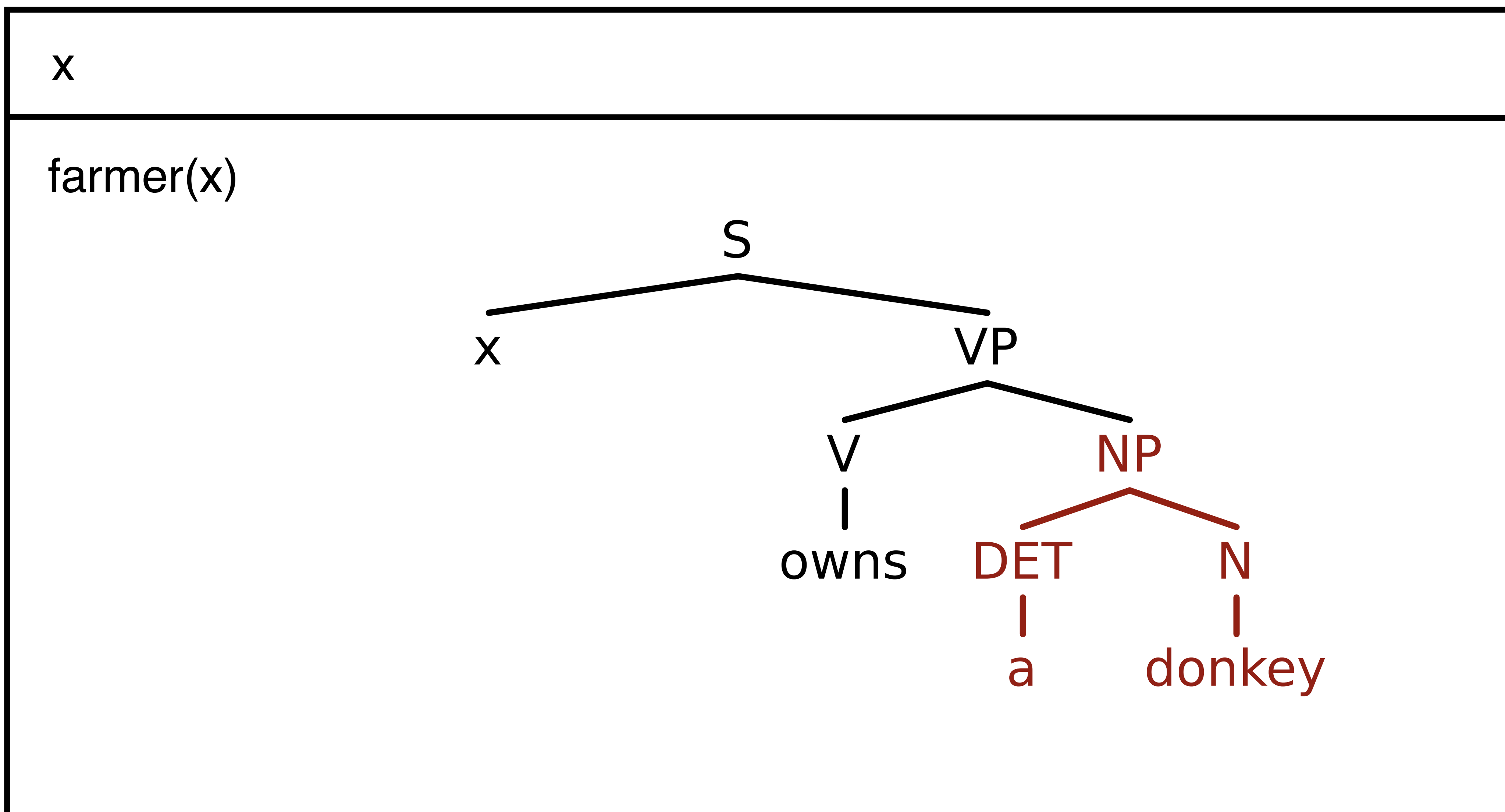
DRS Construction Example

- A farmer owns a donkey. He beats it.



DRS Construction Example

- A farmer owns a donkey. He beats it.



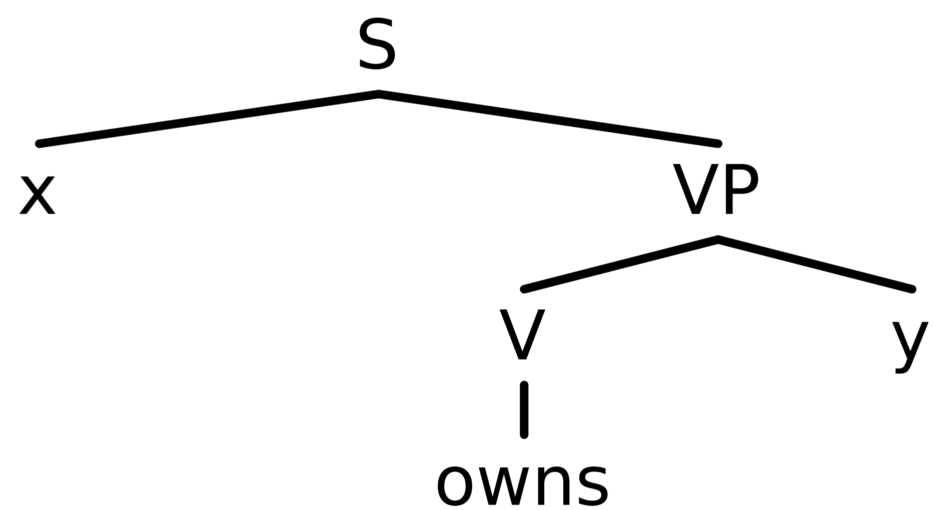
DRS Construction Example

- A farmer owns a donkey. He beats it.

x y

farmer(x)

donkey(y)



DRS Construction Example

- A farmer owns a donkey. He beats it.

x y
farmer(x) donkey(y) owns(x, y)

DRS Construction Example

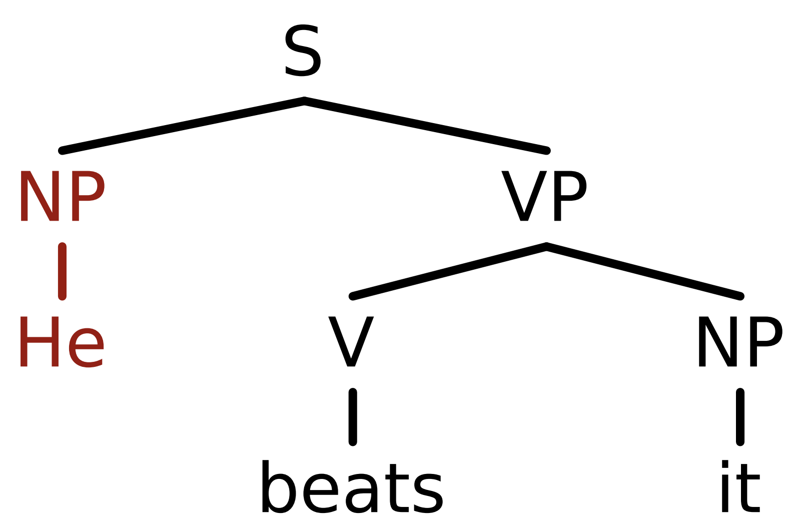
- A farmer owns a donkey. He beats it.

x y

farmer(x)

donkey(y)

owns(x, y)

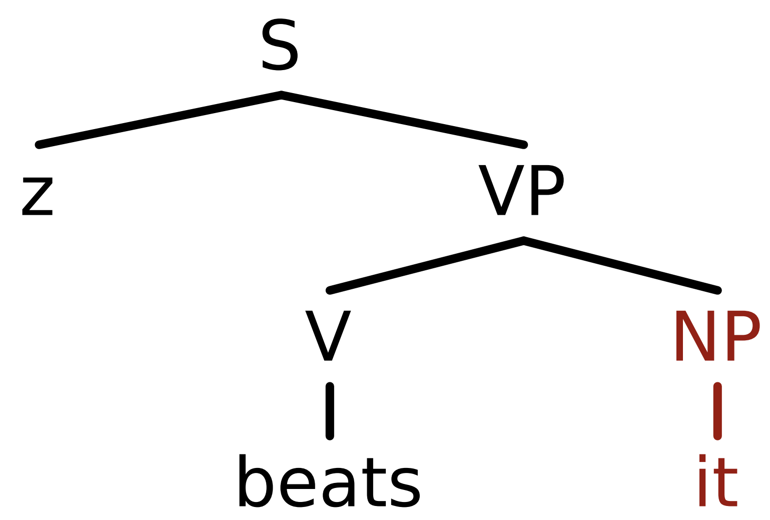


DRS Construction Example

- A farmer owns a donkey. He beats it.

x y z

farmer(x)
donkey(y)
owns(x, y)
z = x



DRS Construction Example

- A farmer owns a donkey. He beats it.

x y z u

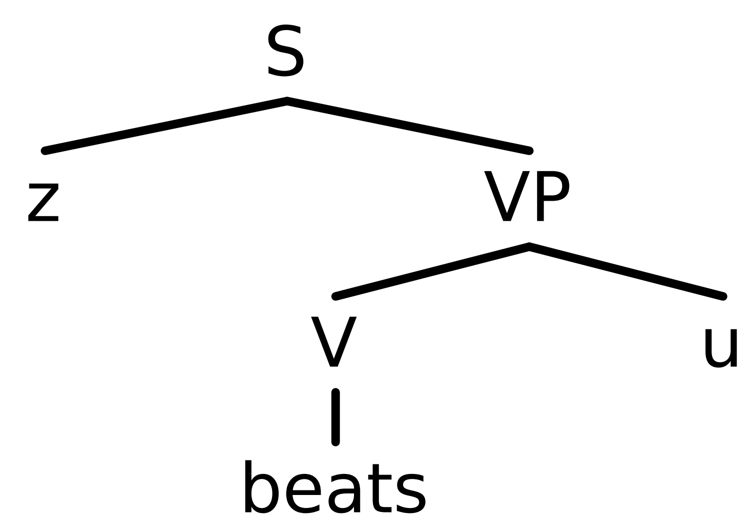
farmer(x)

donkey(y)

owns(x, y)

z = x

u = y



DRS Construction Example

- A farmer owns a donkey. He beats it.

x y z u
farmer(x) donkey(y) owns(x, y) z = x u = y beat(z, u)

Construction Rules: Indefinite NPs

Triggering configuration:

- a reducible condition α in DRS K, with [S [NP β] [VP γ]] or [VP [V γ] [NP β]] as a substructure
- β is εδ, where ε is an indefinite article

Actions:

(i) Add a new DR x to U_K;

(ii) Replace β in α by x;

(iii) Add δ(x) to C_K.

Construction Rules: Personal Pronouns

Triggering configuration:

- a global DRS K^*, and some $K \leq K^*$, such that α is a reducible condition in DRS K, with [S [NP β] [VP γ]] or [VP [V γ] [NP β]] as a substructure
- β is a personal pronoun

Actions:

(i) Add a new DR x to U_K;

(ii) Replace β in α by x;

(iii) Select an appropriate DR y that is accessible from α in K^* and add $x = y$ to C_K

A constraint on DRS construction

Problem: The basic DRS construction algorithm can derive DRSs for both of the following sentences, with the indicated anaphoric binding:

(1) [A professor]$_i$ recommends a book that she$_i$ likes

(2) She$_i$ recommends a book that [a professor]$_i$ likes

Solution: If two different triggering configurations occur in a reducible condition, then first apply the construction rule to the highest triggering configuration.

- *The highest triggering configuration* is the one whose top node dominates the top nodes of all other triggering configurations.

From text to DRS

Text	$\Sigma = \langle$	S_1,	S_2,	…,	S_n $\rangle$
		↓	↓		↓
Syntactic Analysis		$P(S_1)$	$P(S_2)$	…	$P(S_n)$
		↓	↓		↓
DRS Construction		K_1 →	K_2 →	… →	K_n
					↓

Interpretation by model embedding: Truth-conditions of Σ

DRS Interpretation

Given a DRS K = $\langle U_K, C_K \rangle$, with $U_K \subseteq U_D$

Let M = $\langle U_M, V_M \rangle$ be a FOL model structure appropriate for K, i.e. a model structure that provides interpretations for all predicates and relations occurring in K

DRS K is *true* in model M *iff*

- there is an embedding function for K in M which verifies all conditions in K

… where: an embedding of K into M is a (partial) function **f** from U_D to U_M such that $U_K \subseteq$ Dom(**f**).

Verifying embedding

An embedding **f** of K in M verifies K in M (**f** $\vDash_M$ K) iff **f** verifies every condition $\alpha \in C_K$

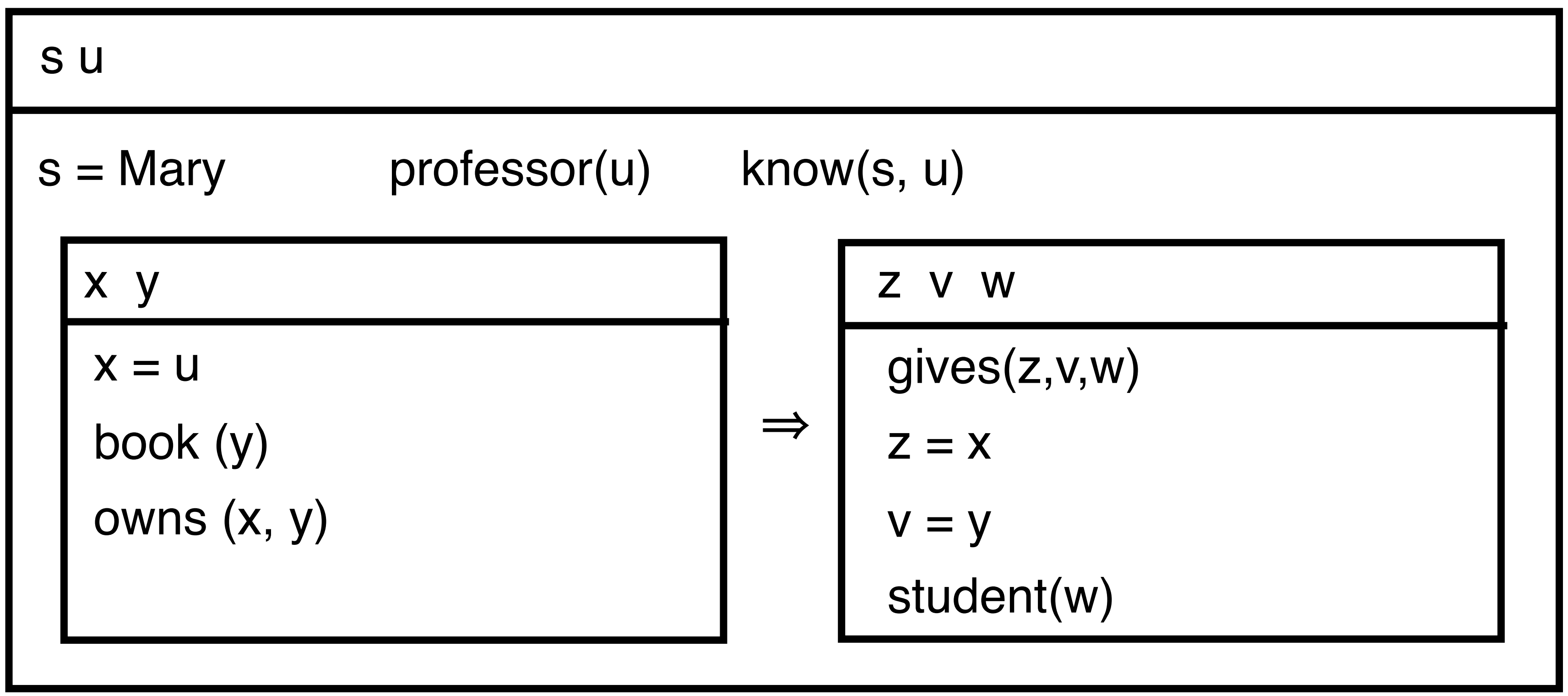
- **f** $\vDash_M R(x_1, \ldots, x_n)$ iff $\langle \mathbf{f}(x_1), \ldots, \mathbf{f}(x_n) \rangle \in V_M(R)$
- **f** $\vDash_M x = y$ iff $\mathbf{f}(x) = \mathbf{f}(y)$
- **f** $\vDash_M x = a$ iff $\mathbf{f}(x) = V_M(a)$
- **f** $\vDash_M \neg K_1$ iff there is no **g** $\supseteq_{U_{K1}}$ **f** such that g $\vDash_M K_1$
- **f** $\vDash_M K_1 \Rightarrow K_2$ iff for all **g** $\supseteq_{U_{K1}}$ **f** such that **g** $\vDash_M K_1$

  there is a **h** $\supseteq_{U_{K2}}$ **g** such that **h** $\vDash_M K_2$
- **f** $\vDash_M K_1 \vee K_2$ iff there is a $\mathbf{g_1} \supseteq_{U_{K1}}$ **f** such that $\mathbf{g_1} \vDash_M K_1$

  or there is a $\mathbf{g_2} \supseteq_{U_{K2}}$ **f** such that $\mathbf{g_2} \vDash_M K_2$

Verifying embedding: example

Mary knows a professor. If he owns a book, he gives it to a student.



…is **true** in $M = \langle U_M, V_M \rangle$ *iff* there is an $\mathbf{f} :: U_D \to U_M$, (with $\{s,u\} \subseteq Dom(\mathbf{f})$) such that:

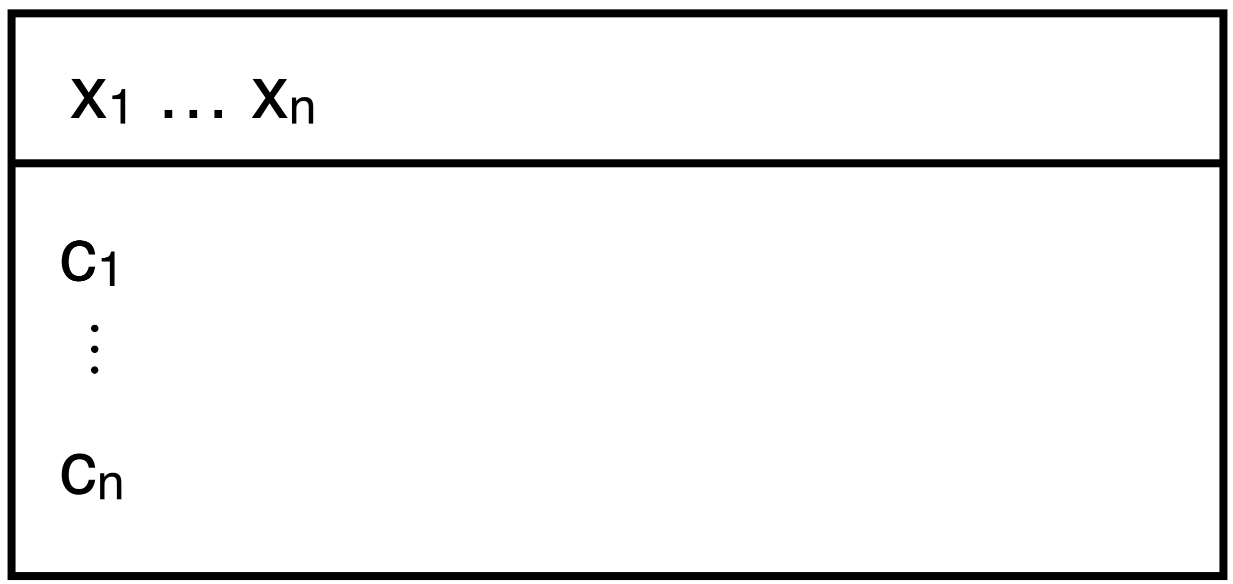
$\mathbf{f}(s) = V_M(\text{Mary})$ & $\mathbf{f}(u) \in V_M(\text{prof'})$ & $\langle \mathbf{f}(s), \mathbf{f}(u) \rangle \in V_M(\text{know})$,

and for all $\mathbf{g} \supseteq_{\{x,y\}} \mathbf{f}$ s.t. $\mathbf{g}(x) = \mathbf{g}(u)$ $(=\mathbf{f}(u))$ & $\mathbf{g}(y) \in V_M(\text{book})$ & $\langle \mathbf{g}(x), \mathbf{g}(y) \rangle \in V_M(\text{own})$,

there is a $\mathbf{h} \supseteq_{\{z,\ v,\ w\}} \mathbf{g}$ s.t. $\langle \mathbf{h}(z), \mathbf{h}(v), \mathbf{h}(w) \rangle \in V_M(\text{give})$ & $\mathbf{h}(z) = \mathbf{h}(x)$ $(=\mathbf{g}(x))$ & … etc.

Translation of DRSs to FOL

Consider DRS $K = \langle\{x_1, \ldots, x_n\}, \{c_1, \ldots, c_k\}\rangle$



K is truth-conditionally equivalent to the following FOL formula:

$$\exists x_1 \ldots \exists x_n [c_1 \wedge \ldots \wedge c_k]$$

DRT is non-compositional

- DRT is non-compositional on truth conditions: The difference in discourse-semantic status of the text pairs is not predictable through the (identical) truth conditions of its component sentences.

- Since structural information which cannot be reduced to truth conditions is required to compute the semantic value of texts, DRT is called a *representational* theory of meaning.

However…

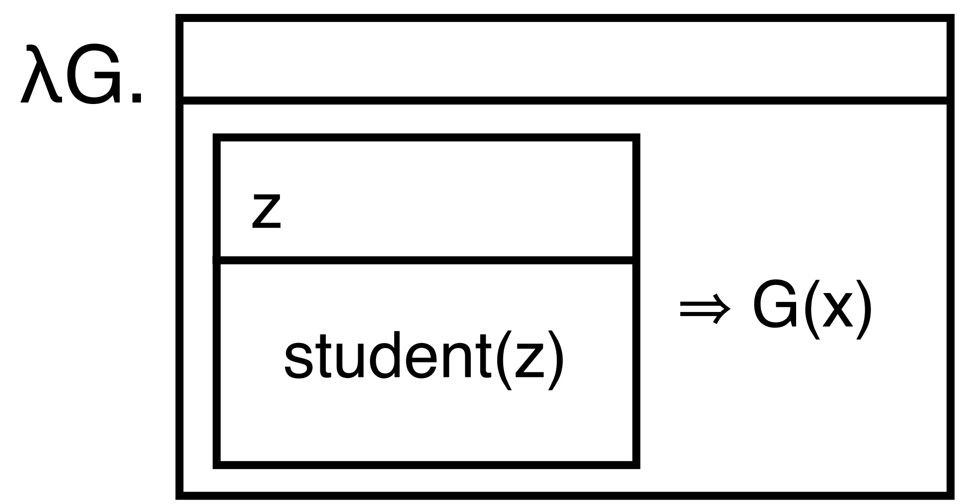
Wait a minute …

- Why can’t we just combine type theoretic semantics and DRT?
- Use λ-abstraction and reduction as we did before, but:
- Assume that the target representations which we want to arrive at are not First-Order Logic formulas, but DRSs.
- The result is called λ-DRT.

λ-DRSs

An expression in λ-DRT consists of a lambda prefix and a partially instantiated DRS.

- *every student :: ⟨⟨e, t⟩, t⟩* ↦



Alternative notation: λG [∅ | [z | student(z)] ⇒ G(z)]

- *works :: ⟨e, t⟩* ↦ λx [∅ | work(x)]

λ-DRT: β-reduction

Every student works

$\mapsto$ λG[∅ | [z | student(z)] ⇒ G(z)]](λx [∅ | work(x)])

$\Rightarrow^{\beta}$ [∅ | [z | student(z)] ⇒ (λx [∅ | work(x)])(z)]

$\Rightarrow^{\beta}$ [∅ | [z | student(z)] ⇒ [∅ | work(z)]]

(Naïve) Merge

The "merge" operation on DRSs combines two DRSs (conditions and universes).

- Let $K_1 = [\ U_1 \mid C_1\ ]$ and $K_2 = [\ U_2 \mid C_2\ ]$.

Merge: $K_1 + K_2 = [\ U_1 \cup U_2 \mid C_1 \cup C_2\ ]$

Merge: An example

- *a student* $\mapsto$ λG ([z | student(z)] + G(z))
- *works* $\mapsto$ λx [∅ | work(x)]

A student works $\mapsto$ λG ([z | student(z)] + G(z)) (λx[∅ | work(x)])

$\Rightarrow^{\beta}$ [z | student(z)] + λx[∅ | work(x)](z)

$\Rightarrow^{\beta}$ [z | student(z)] + [∅ | work(z)]

$\Rightarrow^{\beta}$ [z | student(z), work(z)]

Compositional analysis

- *Mary* $\mapsto$ $\lambda G\,([\,z \mid z = \text{Mary}\,] + G(z))$
- she $\mapsto$ $\lambda G.G(z)$

Mary works. She is successful.

$$\mapsto \lambda K\,\lambda K'(K + K')([\,z \mid z = \text{Mary}, \text{work}(z)])([\;\mid \text{successful}(z)])$$

$$\Rightarrow^{\beta} \lambda K'([\,z \mid z = \text{Mary}, \text{work}(z)] + K')([\;\mid \text{successful}(z)])$$

$$\Rightarrow^{\beta} [\,z \mid z = \text{Mary}, \text{work}(z)] + ([\;\mid \text{successful}(z)])$$

$$\Rightarrow^{\beta} [z \mid z = \text{Mary}, \text{work}(z), \text{successful}(z)]$$

Merge again

The "merge" operation on DRSs combines two DRSs (conditions and universes).

- Let K_1 = [U_1 | C_1] and K_2 = [U_2 | C_2].

Merge: $K_1 + K_2 \Rightarrow [\ U_1 \cup U_2 \mid C_1 \cup C_2\ ]$

under the assumption that no discourse referent $u \in U_2$ occurs free in a condition $\gamma \in C_1$.

Variable capturing

In λ-DRT, discourse referents are captured via the interaction of β-reduction and DRS-binding:

- λK'([z | student(z), work(z)] + K')([| successful(z)])

  $\Rightarrow^{\beta}$ [z | student(z), work(z)] + [| successful(z)]

  $\Rightarrow^{\beta}$ [z | student(z), work(z), successful(z)]

But the β-reduced DRS must still be *equivalent* to the original DRS!

So, the potential for capturing discourse referents must be captured into the interpretation of a λ-DRS. Possible, but tricky.