Semantics & Discourse

— Adnominal Modification —

Philippe de Groote

Outline

Intersective adjectives

Abstract language

$$
\begin{aligned}
\text{ERIC} &: \text{NP} \\
\text{REBECCA} &: \text{NP} \\
\text{EVERYBODY} &: \text{NP} \\
\text{SOMEBODY} &: \text{NP} \\
\text{MAN} &: \text{N} \\
\text{WOMAN} &: \text{N} \\
\text{EVERY} &: \text{N} \rightarrow \text{NP} \\
\text{A} &: \text{N} \rightarrow \text{NP} \\
\text{FRENCH} &: \text{N} \rightarrow \text{N} \\
\text{LOVES} &: \text{NP} \rightarrow \text{NP} \rightarrow \text{S}
\end{aligned}
$$

Intersective adjectives

Semantic interpretation

$$\mathrm{N} := \mathrm{e} \to \mathrm{t}$$
$$\mathrm{NP} := (\mathrm{e} \to \mathrm{t}) \to \mathrm{t}$$
$$\mathrm{S} := \mathrm{t}$$

$$\mathrm{ERIC} := \lambda k.\, k\, \mathbf{e}$$
$$\mathrm{REBECCA} := \lambda k.\, k\, \mathbf{r}$$
$$\mathrm{EVERYBODY} := \lambda k.\, \forall x.\, k\, x$$
$$\mathrm{SOMEBODY} := \lambda k.\, \exists x.\, k\, x$$
$$\mathrm{MAN} := \lambda x.\, \mathbf{man}\, x$$
$$\mathrm{WOMAN} := \lambda x.\, \mathbf{woman}\, x$$
$$\mathrm{EVERY} := \lambda n.\, \lambda m.\, \forall x.\, (n\, x) \to (m\, x)$$
$$\mathrm{A} := \lambda n.\, \lambda m.\, \exists x.\, (n\, x) \wedge (m\, x)$$
$$\mathrm{FRENCH} := \lambda n.\, \lambda x.\, (n\, x) \wedge (\mathbf{french}\, x)$$
$$\mathrm{LOVES} := \lambda o.\, \lambda s.\, s\, (\lambda x.\, o\, (\lambda y.\, \mathbf{love}\, x\, y))$$

where: $\mathbf{french} : \mathrm{e} \to \mathrm{t}$

Nonintersective adjectives

paradoxical inferences

Rebecca is a French woman.

Rebecca is a violinist.

Therefore Rebecca is a French violinist.

Nonintersective adjectives

paradoxical inferences

Rebecca is a French woman.

Rebecca is a violinist.

Therefore Rebecca is a French violinist.

Eric is a skillful surgeon.

Eric is a violinist.

? Therefore Eric is a skillful violinist.

Classification

Adjective classification

Classification

Adjective classification

- **Intersective**: *French, sick, carnivorous, red, ...*

  $$[\![\mathrm{ADJ} + \mathrm{N}]\!] = [\![\mathrm{ADJ}]\!] \cap [\![\mathrm{N}]\!]$$

Classification

Adjective classification

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  $[\![\text{ADJ} + \text{N}]\!] = [\![\text{ADJ}]\!] \cap [\![\text{N}]\!]$
- **Subsective** but non intersective: *typical, recent, skillful, ...*

  $[\![\text{ADJ} + \text{N}]\!] \subset [\![\text{N}]\!]$

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  $[\![\mathrm{ADJ} + \mathrm{N}]\!] \subset [\![\mathrm{N}]\!]$
- **Privative**: *fake, former, spurious, ...*

  $[\![\mathrm{ADJ} + \mathrm{N}]\!] \cap [\![\mathrm{N}]\!] = \varnothing$

Classification

Adjective classification

- **Intersective**: *French, sick, carnivorous, red, ...*

  $$[\![\mathrm{ADJ} + \mathrm{N}]\!] = [\![\mathrm{ADJ}]\!] \cap [\![\mathrm{N}]\!]$$

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  $$[\![\mathrm{ADJ} + \mathrm{N}]\!] \subset [\![\mathrm{N}]\!]$$

- **Privative**: *fake, former, spurious, ...*

  $$[\![\mathrm{ADJ} + \mathrm{N}]\!] \cap [\![\mathrm{N}]\!] = \varnothing$$

- **Plain nonsubsective**: *alleged, arguable, putative, ...*

  $$[\![\mathrm{ADJ} + \mathrm{N}]\!] \not\subset [\![\mathrm{N}]\!]$$

Classification

Meaning postulates

Classification

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- **Intersective**:

  $$\mathrm{INT}(A) = \exists P. \forall Q\, x.\, A\, Q\, x \equiv (P\, x \wedge Q\, x)$$

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  $$\mathrm{SUB}(A) = \forall Q\, x.\, A\, Q\, x \to Q\, x$$

Classification

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- **Intersective**:

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  $$\mathrm{SUB}(A) = \forall Q\, x.\, A\, Q\, x \rightarrow Q\, x$$

- **Privative**:

  $$\mathrm{PRIV}(A) = \forall Q\, x.\, A\, Q\, x \rightarrow \neg(Q\, x)$$

Classification

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Beware!!!! Some intensionality involved!

Relative clauses

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\begin{aligned}
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\text{EVERY} &: \text{N} \rightarrow \text{NP} \\
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\text{FRENCH} &: \text{N} \rightarrow \text{N} \\
\text{LOVES} &: \text{NP} \rightarrow \text{NP} \rightarrow \text{S} \\
\text{WHO} &: (\text{NP} \rightarrow \text{S}) \rightarrow \text{N} \rightarrow \text{N}
\end{aligned}
$$

Relative clauses

Semantic interpretation

$$\begin{aligned}
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\mathrm{EVERY} &:= \lambda n.\, \lambda m.\, \forall x.\, (n\, x) \rightarrow (m\, x) \\
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\mathrm{FRENCH} &:= \lambda n.\, \lambda x.\, (n\, x) \wedge (\mathbf{french}\, x) \\
\mathrm{LOVES} &:= \lambda o.\, \lambda s.\, s\, (\lambda x.\, o\, (\lambda y.\, \mathbf{love}\, x\, y)) \\
\mathrm{WHO} &:= \lambda r.\, \lambda n.\, \lambda x.\, (n\, x) \wedge (r\, (\lambda k.\, k\, x))
\end{aligned}$$

Example

Every man who loves Rebecca loves a woman

Example

Every man who loves Rebecca loves a woman

$\textsc{loves}\,(\textsc{a woman})\,(\textsc{every}\,(\textsc{who}\,(\textsc{loves rebecca})\,\textsc{man}))$

Example

Every man who loves Rebecca loves a woman

$$\textsc{loves}\,(\textsc{a woman})\,(\textsc{every}\,(\textsc{who}\,(\textsc{loves rebecca})\,\textsc{man}))$$
$$= \quad (\lambda os.\, s\,(\lambda x.\, o\,(\lambda y.\, \mathbf{love}\, x\, y)))\,(\textsc{a woman})\,(\textsc{every}\,(\textsc{who}\,(\textsc{loves rebecca})\,\textsc{man}))$$

Example

Every man who loves Rebecca loves a woman

$$\begin{array}{ll} \text{LOVES}\,(\text{A WOMAN})\,(\text{EVERY}\,(\text{WHO}\,(\text{LOVES REBECCA})\,\text{MAN})) & \\ = & (\lambda os.\, s\,(\lambda x.\, o\,(\lambda y.\, \mathbf{love}\, x\, y))) \\ & \quad (\text{A WOMAN})\,(\text{EVERY}\,(\text{WHO}\,(\text{LOVES REBECCA})\,\text{MAN})) \\ \twoheadrightarrow_\beta & \text{EVERY}\,(\text{WHO}\,(\text{LOVES REBECCA})\,\text{MAN})\,(\lambda x.\, \text{A WOMAN}\,(\lambda y.\, \mathbf{love}\, x\, y)) \end{array}$$

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\begin{array}{ll}
\multicolumn{2}{l}{\text{LOVES}\,(\text{A WOMAN})\,(\text{EVERY}\,(\text{WHO}\,(\text{LOVES REBECCA})\,\text{MAN}))} \\
= & (\lambda os.\, s\,(\lambda x.\, o\,(\lambda y.\, \mathbf{love}\,x\,y))) \\
 & \qquad (\text{A WOMAN})\,(\text{EVERY}\,(\text{WHO}\,(\text{LOVES REBECCA})\,\text{MAN})) \\
\twoheadrightarrow_\beta & \text{EVERY}\,(\text{WHO}\,(\text{LOVES REBECCA})\,\text{MAN})\,(\lambda x.\, \text{A WOMAN}\,(\lambda y.\, \mathbf{love}\,x\,y)) \\
= & (\lambda nm.\, \forall x.\, (n\,x) \to (m\,x)) \\
 & \qquad (\text{WHO}\,(\text{LOVES REBECCA})\,\text{MAN})\,(\lambda x.\, \text{A WOMAN}\,(\lambda y.\, \mathbf{love}\,x\,y))
\end{array}
$$

Example

Every man who loves Rebecca loves a woman

$$
\begin{array}{ll}
\multicolumn{2}{l}{\textsc{loves}\,(\textsc{a woman})\,(\textsc{every}\,(\textsc{who}\,(\textsc{loves rebecca})\,\textsc{man}))} \\
= & (\lambda os.\, s\,(\lambda x.\, o\,(\lambda y.\, \mathbf{love}\, x\, y))) \\
 & \qquad (\textsc{a woman})\,(\textsc{every}\,(\textsc{who}\,(\textsc{loves rebecca})\,\textsc{man})) \\
\twoheadrightarrow_\beta & \textsc{every}\,(\textsc{who}\,(\textsc{loves rebecca})\,\textsc{man})\,(\lambda x.\,\textsc{a woman}\,(\lambda y.\,\mathbf{love}\, x\, y)) \\
= & (\lambda nm.\, \forall x.\, (n\, x) \rightarrow (m\, x)) \\
 & \qquad (\textsc{who}\,(\textsc{loves rebecca})\,\textsc{man})\,(\lambda x.\,\textsc{a woman}\,(\lambda y.\,\mathbf{love}\, x\, y)) \\
\twoheadrightarrow_\beta & \forall x.\, (\textsc{who}\,(\textsc{loves rebecca})\,\textsc{man}\, x) \rightarrow ((\lambda x.\,\textsc{a woman}\,(\lambda y.\,\mathbf{love}\, x\, y))\, x)
\end{array}
$$

Example

Every man who loves Rebecca loves a woman

$$
\begin{array}{ll}
\multicolumn{2}{l}{\text{LOVES}\,(\text{A WOMAN})\,(\text{EVERY}\,(\text{WHO}\,(\text{LOVES REBECCA})\,\text{MAN}))} \\
= & (\lambda os.\, s\,(\lambda x.\, o\,(\lambda y.\, \mathbf{love}\,x\,y))) \\
& \qquad (\text{A WOMAN})\,(\text{EVERY}\,(\text{WHO}\,(\text{LOVES REBECCA})\,\text{MAN})) \\
\twoheadrightarrow_\beta & \text{EVERY}\,(\text{WHO}\,(\text{LOVES REBECCA})\,\text{MAN})\,(\lambda x.\, \text{A WOMAN}\,(\lambda y.\, \mathbf{love}\,x\,y)) \\
= & (\lambda nm.\, \forall x.\, (n\,x) \to (m\,x)) \\
& \qquad (\text{WHO}\,(\text{LOVES REBECCA})\,\text{MAN})\,(\lambda x.\, \text{A WOMAN}\,(\lambda y.\, \mathbf{love}\,x\,y)) \\
\twoheadrightarrow_\beta & \forall x.\, (\text{WHO}\,(\text{LOVES REBECCA})\,\text{MAN}\,x) \to ((\lambda x.\, \text{A WOMAN}\,(\lambda y.\, \mathbf{love}\,x\,y))\,x) \\
\twoheadrightarrow_\beta & \forall x.\, (\text{WHO}\,(\text{LOVES REBECCA})\,\text{MAN}\,x) \to (\text{A WOMAN}\,(\lambda y.\, \mathbf{love}\,x\,y))
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Example

Every man who loves Rebecca loves a woman

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& \text{LOVES}\,(\text{A WOMAN})\,(\text{EVERY}\,(\text{WHO}\,(\text{LOVES REBECCA})\,\text{MAN})) \\
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& \qquad (\text{A WOMAN})\,(\text{EVERY}\,(\text{WHO}\,(\text{LOVES REBECCA})\,\text{MAN})) \\
\twoheadrightarrow_\beta & \text{EVERY}\,(\text{WHO}\,(\text{LOVES REBECCA})\,\text{MAN})\,(\lambda x.\, \text{A WOMAN}\,(\lambda y.\, \mathbf{love}\, x\, y)) \\
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& \qquad (\text{WHO}\,(\text{LOVES REBECCA})\,\text{MAN})\,(\lambda x.\, \text{A WOMAN}\,(\lambda y.\, \mathbf{love}\, x\, y)) \\
\twoheadrightarrow_\beta & \forall x.\, (\text{WHO}\,(\text{LOVES REBECCA})\,\text{MAN}\, x) \to ((\lambda x.\, \text{A WOMAN}\,(\lambda y.\, \mathbf{love}\, x\, y))\, x) \\
\twoheadrightarrow_\beta & \forall x.\, (\text{WHO}\,(\text{LOVES REBECCA})\,\text{MAN}\, x) \to (\text{A WOMAN}\,(\lambda y.\, \mathbf{love}\, x\, y)) \\
= & \forall x.\, ((\lambda rnx.\, (n\, x) \land (r\,(\lambda k.\, k\, x)))\,(\text{LOVES REBECCA})\,\text{MAN}\, x) \\
& \qquad \to (\text{A WOMAN}\,(\lambda y.\, \mathbf{love}\, x\, y))
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& \text{LOVES}\,(\text{A WOMAN})\,(\text{EVERY}\,(\text{WHO}\,(\text{LOVES REBECCA})\,\text{MAN})) \\
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& \qquad (\text{WHO}\,(\text{LOVES REBECCA})\,\text{MAN})\,(\lambda x.\, \text{A WOMAN}\,(\lambda y.\, \mathbf{love}\, x\, y)) \\
\twoheadrightarrow_\beta & \forall x.\, (\text{WHO}\,(\text{LOVES REBECCA})\,\text{MAN}\, x) \to ((\lambda x.\, \text{A WOMAN}\,(\lambda y.\, \mathbf{love}\, x\, y))\, x) \\
\twoheadrightarrow_\beta & \forall x.\, (\text{WHO}\,(\text{LOVES REBECCA})\,\text{MAN}\, x) \to (\text{A WOMAN}\,(\lambda y.\, \mathbf{love}\, x\, y)) \\
= & \forall x.\, ((\lambda rnx.\, (n\, x) \wedge (r\,(\lambda k.\, k\, x)))\,(\text{LOVES REBECCA})\,\text{MAN}\, x) \\
& \qquad \to (\text{A WOMAN}\,(\lambda y.\, \mathbf{love}\, x\, y)) \\
\twoheadrightarrow_\beta & \forall x.\, (\text{MAN}\, x) \wedge (\text{LOVES REBECCA}\,(\lambda k.\, k\, x)) \to (\text{A WOMAN}\,(\lambda y.\, \mathbf{love}\, x\, y))
\end{array}
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Example

Every man who loves Rebecca loves a woman

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\text{LOVES}\,(\text{A WOMAN})\,(\text{EVERY}\,(\text{WHO}\,(\text{LOVES REBECCA})\,\text{MAN})) & \\
\quad = & (\lambda os.\, s\,(\lambda x.\, o\,(\lambda y.\, \mathbf{love}\, x\, y))) \\
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 & \qquad (\text{WHO}\,(\text{LOVES REBECCA})\,\text{MAN})\,(\lambda x.\, \text{A WOMAN}\,(\lambda y.\, \mathbf{love}\, x\, y)) \\
\twoheadrightarrow_\beta & \forall x.\, (\text{WHO}\,(\text{LOVES REBECCA})\,\text{MAN}\, x) \rightarrow ((\lambda x.\, \text{A WOMAN}\,(\lambda y.\, \mathbf{love}\, x\, y))\, x) \\
\twoheadrightarrow_\beta & \forall x.\, (\text{WHO}\,(\text{LOVES REBECCA})\,\text{MAN}\, x) \rightarrow (\text{A WOMAN}\,(\lambda y.\, \mathbf{love}\, x\, y)) \\
\quad = & \forall x.\, ((\lambda rnx.\, (n\, x) \wedge (r\,(\lambda k.\, k\, x)))\,(\text{LOVES REBECCA})\,\text{MAN}\, x) \\
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\twoheadrightarrow_\beta & \forall x.\, (\text{MAN}\, x) \wedge (\text{LOVES REBECCA}\,(\lambda k.\, k\, x)) \rightarrow (\text{A WOMAN}\,(\lambda y.\, \mathbf{love}\, x\, y)) \\
\quad = & \forall x.\, ((\lambda x.\, \mathbf{man}\, x)\, x) \wedge (\text{LOVES REBECCA}\,(\lambda k.\, k\, x)) \\
 & \qquad \rightarrow (\text{A WOMAN}\,(\lambda y.\, \mathbf{love}\, x\, y))
\end{array}
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Example

Every man who loves Rebecca loves a woman

$$
\begin{array}{ll}
\multicolumn{2}{l}{\text{LOVES}\,(\text{A WOMAN})\,(\text{EVERY}\,(\text{WHO}\,(\text{LOVES REBECCA})\,\text{MAN}))} \\
= & (\lambda os.\, s\,(\lambda x.\, o\,(\lambda y.\, \mathbf{love}\, x\, y))) \\
& \qquad (\text{A WOMAN})\,(\text{EVERY}\,(\text{WHO}\,(\text{LOVES REBECCA})\,\text{MAN})) \\
\twoheadrightarrow_\beta & \text{EVERY}\,(\text{WHO}\,(\text{LOVES REBECCA})\,\text{MAN})\,(\lambda x.\, \text{A WOMAN}\,(\lambda y.\, \mathbf{love}\, x\, y)) \\
= & (\lambda nm.\, \forall x.\, (n\, x) \to (m\, x)) \\
& \qquad (\text{WHO}\,(\text{LOVES REBECCA})\,\text{MAN})\,(\lambda x.\, \text{A WOMAN}\,(\lambda y.\, \mathbf{love}\, x\, y)) \\
\twoheadrightarrow_\beta & \forall x.\, (\text{WHO}\,(\text{LOVES REBECCA})\,\text{MAN}\, x) \to ((\lambda x.\, \text{A WOMAN}\,(\lambda y.\, \mathbf{love}\, x\, y))\, x) \\
\twoheadrightarrow_\beta & \forall x.\, (\text{WHO}\,(\text{LOVES REBECCA})\,\text{MAN}\, x) \to (\text{A WOMAN}\,(\lambda y.\, \mathbf{love}\, x\, y)) \\
= & \forall x.\, ((\lambda rnx.\, (n\, x) \land (r\,(\lambda k.\, k\, x)))\,(\text{LOVES REBECCA})\,\text{MAN}\, x) \\
& \qquad \to (\text{A WOMAN}\,(\lambda y.\, \mathbf{love}\, x\, y)) \\
\twoheadrightarrow_\beta & \forall x.\, (\text{MAN}\, x) \land (\text{LOVES REBECCA}\,(\lambda k.\, k\, x)) \to (\text{A WOMAN}\,(\lambda y.\, \mathbf{love}\, x\, y)) \\
= & \forall x.\, ((\lambda x.\, \mathbf{man}\, x)\, x) \land (\text{LOVES REBECCA}\,(\lambda k.\, k\, x)) \\
& \qquad \to (\text{A WOMAN}\,(\lambda y.\, \mathbf{love}\, x\, y)) \\
\twoheadrightarrow_\beta & \forall x.\, (\mathbf{man}\, x) \land (\text{LOVES REBECCA}\,(\lambda k.\, k\, x)) \to (\text{A WOMAN}\,(\lambda y.\, \mathbf{love}\, x\, y))
\end{array}
$$

Example

$$= \quad \forall x. (\mathbf{man}\, x) \wedge ((\lambda os. s\, (\lambda x. o\, (\lambda y. \mathbf{love}\, x\, y)))\, \text{REBECCA}\, (\lambda k. k\, x)) \\ \rightarrow (\text{A WOMAN}\, (\lambda y. \mathbf{love}\, x\, y))$$

Example

$$
\begin{aligned}
= \quad & \forall x.\, (\mathbf{man}\, x) \wedge ((\lambda os.\, s\, (\lambda x.\, o\, (\lambda y.\, \mathbf{love}\, x\, y)))\, \text{REBECCA}\, (\lambda k.\, k\, x)) \\
& \qquad \rightarrow (\text{A WOMAN}\, (\lambda y.\, \mathbf{love}\, x\, y)) \\
\twoheadrightarrow_\beta \quad & \forall x.\, (\mathbf{man}\, x) \wedge ((\lambda k.\, k\, x)\, (\lambda x.\, \text{REBECCA}\, (\lambda y.\, \mathbf{love}\, x\, y))) \\
& \qquad \rightarrow (\text{A WOMAN}\, (\lambda y.\, \mathbf{love}\, x\, y))
\end{aligned}
$$

Example

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\begin{aligned}
= \quad & \forall x.\, (\mathbf{man}\, x) \wedge ((\lambda os.\, s\, (\lambda x.\, o\, (\lambda y.\, \mathbf{love}\, x\, y)))\ \text{REBECCA}\ (\lambda k.\, k\, x)) \\
& \qquad \rightarrow (\text{A WOMAN}\ (\lambda y.\, \mathbf{love}\, x\, y)) \\
\twoheadrightarrow_\beta \quad & \forall x.\, (\mathbf{man}\, x) \wedge ((\lambda k.\, k\, x)\, (\lambda x.\, \text{REBECCA}\ (\lambda y.\, \mathbf{love}\, x\, y))) \\
& \qquad \rightarrow (\text{A WOMAN}\ (\lambda y.\, \mathbf{love}\, x\, y)) \\
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\end{aligned}
$$

Example

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\begin{aligned}
= \quad & \forall x.\,(\mathbf{man}\,x) \wedge ((\lambda os.\,s\,(\lambda x.\,o\,(\lambda y.\,\mathbf{love}\,x\,y)))\ \text{REBECCA}\ (\lambda k.\,k\,x)) \\
& \qquad \rightarrow (\text{A WOMAN}\ (\lambda y.\,\mathbf{love}\,x\,y)) \\
\twoheadrightarrow_\beta \quad & \forall x.\,(\mathbf{man}\,x) \wedge ((\lambda k.\,k\,x)\,(\lambda x.\,\text{REBECCA}\ (\lambda y.\,\mathbf{love}\,x\,y))) \\
& \qquad \rightarrow (\text{A WOMAN}\ (\lambda y.\,\mathbf{love}\,x\,y)) \\
\twoheadrightarrow_\beta \quad & \forall x.\,(\mathbf{man}\,x) \wedge (\text{REBECCA}\ (\lambda y.\,\mathbf{love}\,x\,y)) \rightarrow (\text{A WOMAN}\ (\lambda y.\,\mathbf{love}\,x\,y)) \\
= \quad & \forall x.\,(\mathbf{man}\,x) \wedge ((\lambda k.\,k\,\mathbf{r})\,(\lambda y.\,\mathbf{love}\,x\,y)) \rightarrow (\text{A WOMAN}\ (\lambda y.\,\mathbf{love}\,x\,y))
\end{aligned}
$$

Example

$$
\begin{array}{rl}
= & \forall x.\,(\mathbf{man}\,x) \wedge ((\lambda os.\,s\,(\lambda x.\,o\,(\lambda y.\,\mathbf{love}\,x\,y)))\,\textsc{rebecca}\,(\lambda k.\,k\,x)) \\
 & \qquad \to (\textsc{a woman}\,(\lambda y.\,\mathbf{love}\,x\,y)) \\
\twoheadrightarrow_\beta & \forall x.\,(\mathbf{man}\,x) \wedge ((\lambda k.\,k\,x)\,(\lambda x.\,\textsc{rebecca}\,(\lambda y.\,\mathbf{love}\,x\,y))) \\
 & \qquad \to (\textsc{a woman}\,(\lambda y.\,\mathbf{love}\,x\,y)) \\
\twoheadrightarrow_\beta & \forall x.\,(\mathbf{man}\,x) \wedge (\textsc{rebecca}\,(\lambda y.\,\mathbf{love}\,x\,y)) \to (\textsc{a woman}\,(\lambda y.\,\mathbf{love}\,x\,y)) \\
= & \forall x.\,(\mathbf{man}\,x) \wedge ((\lambda k.\,k\,\mathbf{r})\,(\lambda y.\,\mathbf{love}\,x\,y)) \to (\textsc{a woman}\,(\lambda y.\,\mathbf{love}\,x\,y)) \\
\twoheadrightarrow_\beta & \forall x.\,(\mathbf{man}\,x) \wedge (\mathbf{loves}\,x\,\mathbf{r}) \to (\textsc{a woman}\,(\lambda y.\,\mathbf{love}\,x\,y))
\end{array}
$$

Example

$$
\begin{array}{rl}
= & \forall x.\,(\mathbf{man}\,x) \wedge ((\lambda os.\,s\,(\lambda x.\,o\,(\lambda y.\,\mathbf{love}\,x\,y)))\,\text{REBECCA}\,(\lambda k.\,k\,x)) \\
 & \qquad \rightarrow (\text{A WOMAN}\,(\lambda y.\,\mathbf{love}\,x\,y)) \\
\twoheadrightarrow_\beta & \forall x.\,(\mathbf{man}\,x) \wedge ((\lambda k.\,k\,x)\,(\lambda x.\,\text{REBECCA}\,(\lambda y.\,\mathbf{love}\,x\,y))) \\
 & \qquad \rightarrow (\text{A WOMAN}\,(\lambda y.\,\mathbf{love}\,x\,y)) \\
\twoheadrightarrow_\beta & \forall x.\,(\mathbf{man}\,x) \wedge (\text{REBECCA}\,(\lambda y.\,\mathbf{love}\,x\,y)) \rightarrow (\text{A WOMAN}\,(\lambda y.\,\mathbf{love}\,x\,y)) \\
= & \forall x.\,(\mathbf{man}\,x) \wedge ((\lambda k.\,k\,\mathbf{r})\,(\lambda y.\,\mathbf{love}\,x\,y)) \rightarrow (\text{A WOMAN}\,(\lambda y.\,\mathbf{love}\,x\,y)) \\
\twoheadrightarrow_\beta & \forall x.\,(\mathbf{man}\,x) \wedge (\mathbf{loves}\,x\,\mathbf{r}) \rightarrow (\text{A WOMAN}\,(\lambda y.\,\mathbf{love}\,x\,y)) \\
= & \forall x.\,(\mathbf{man}\,x) \wedge (\mathbf{loves}\,x\,\mathbf{r}) \\
 & \qquad \rightarrow ((\lambda nm.\,\exists y.\,(n\,y) \wedge (m\,y))\,\text{WOMAN}\,(\lambda y.\,\mathbf{love}\,x\,y))
\end{array}
$$

Example

$$
\begin{array}{rl}
= & \forall x.\,(\mathbf{man}\,x) \wedge ((\lambda os.\,s\,(\lambda x.\,o\,(\lambda y.\,\mathbf{love}\,x\,y)))\;\textsc{rebecca}\;(\lambda k.\,k\,x)) \\
 & \qquad \rightarrow (\textsc{a woman}\;(\lambda y.\,\mathbf{love}\,x\,y)) \\
\twoheadrightarrow_\beta & \forall x.\,(\mathbf{man}\,x) \wedge ((\lambda k.\,k\,x)\,(\lambda x.\,\textsc{rebecca}\;(\lambda y.\,\mathbf{love}\,x\,y))) \\
 & \qquad \rightarrow (\textsc{a woman}\;(\lambda y.\,\mathbf{love}\,x\,y)) \\
\twoheadrightarrow_\beta & \forall x.\,(\mathbf{man}\,x) \wedge (\textsc{rebecca}\;(\lambda y.\,\mathbf{love}\,x\,y)) \rightarrow (\textsc{a woman}\;(\lambda y.\,\mathbf{love}\,x\,y)) \\
= & \forall x.\,(\mathbf{man}\,x) \wedge ((\lambda k.\,k\,\mathbf{r})\,(\lambda y.\,\mathbf{love}\,x\,y)) \rightarrow (\textsc{a woman}\;(\lambda y.\,\mathbf{love}\,x\,y)) \\
\twoheadrightarrow_\beta & \forall x.\,(\mathbf{man}\,x) \wedge (\mathbf{loves}\,x\,\mathbf{r}) \rightarrow (\textsc{a woman}\;(\lambda y.\,\mathbf{love}\,x\,y)) \\
= & \forall x.\,(\mathbf{man}\,x) \wedge (\mathbf{loves}\,x\,\mathbf{r}) \\
 & \qquad \rightarrow ((\lambda nm.\,\exists y.\,(n\,y) \wedge (m\,y))\;\textsc{woman}\;(\lambda y.\,\mathbf{love}\,x\,y)) \\
\twoheadrightarrow_\beta & \forall x.\,(\mathbf{man}\,x) \wedge (\mathbf{loves}\,x\,\mathbf{r}) \rightarrow (\exists y.\,(\textsc{woman}\;y) \wedge ((\lambda y.\,\mathbf{love}\,x\,y)\,y))
\end{array}
$$

Example

$$
\begin{array}{rl}
= & \forall x.\,(\mathbf{man}\,x) \wedge ((\lambda os.\,s\,(\lambda x.\,o\,(\lambda y.\,\mathbf{love}\,x\,y)))\ \textsc{rebecca}\,(\lambda k.\,k\,x)) \\
 & \qquad \rightarrow (\textsc{a woman}\,(\lambda y.\,\mathbf{love}\,x\,y)) \\
\twoheadrightarrow_\beta & \forall x.\,(\mathbf{man}\,x) \wedge ((\lambda k.\,k\,x)\,(\lambda x.\,\textsc{rebecca}\,(\lambda y.\,\mathbf{love}\,x\,y))) \\
 & \qquad \rightarrow (\textsc{a woman}\,(\lambda y.\,\mathbf{love}\,x\,y)) \\
\twoheadrightarrow_\beta & \forall x.\,(\mathbf{man}\,x) \wedge (\textsc{rebecca}\,(\lambda y.\,\mathbf{love}\,x\,y)) \rightarrow (\textsc{a woman}\,(\lambda y.\,\mathbf{love}\,x\,y)) \\
= & \forall x.\,(\mathbf{man}\,x) \wedge ((\lambda k.\,k\,\mathbf{r})\,(\lambda y.\,\mathbf{love}\,x\,y)) \rightarrow (\textsc{a woman}\,(\lambda y.\,\mathbf{love}\,x\,y)) \\
\twoheadrightarrow_\beta & \forall x.\,(\mathbf{man}\,x) \wedge (\mathbf{loves}\,x\,\mathbf{r}) \rightarrow (\textsc{a woman}\,(\lambda y.\,\mathbf{love}\,x\,y)) \\
= & \forall x.\,(\mathbf{man}\,x) \wedge (\mathbf{loves}\,x\,\mathbf{r}) \\
 & \qquad \rightarrow ((\lambda nm.\,\exists y.\,(n\,y) \wedge (m\,y))\ \textsc{woman}\,(\lambda y.\,\mathbf{love}\,x\,y)) \\
\twoheadrightarrow_\beta & \forall x.\,(\mathbf{man}\,x) \wedge (\mathbf{loves}\,x\,\mathbf{r}) \rightarrow (\exists y.\,(\textsc{woman}\,y) \wedge ((\lambda y.\,\mathbf{love}\,x\,y)\,y)) \\
\twoheadrightarrow_\beta & \forall x.\,(\mathbf{man}\,x) \wedge (\mathbf{loves}\,x\,\mathbf{r}) \rightarrow (\exists y.\,(\textsc{woman}\,y) \wedge (\mathbf{love}\,x\,y))
\end{array}
$$

Example

$$
\begin{array}{ll}
= & \forall x.\,(\mathbf{man}\,x) \wedge ((\lambda os.\,s\,(\lambda x.\,o\,(\lambda y.\,\mathbf{love}\,x\,y)))\,\text{REBECCA}\,(\lambda k.\,k\,x)) \\
 & \qquad \to (\text{A WOMAN}\,(\lambda y.\,\mathbf{love}\,x\,y)) \\
\twoheadrightarrow_\beta & \forall x.\,(\mathbf{man}\,x) \wedge ((\lambda k.\,k\,x)\,(\lambda x.\,\text{REBECCA}\,(\lambda y.\,\mathbf{love}\,x\,y))) \\
 & \qquad \to (\text{A WOMAN}\,(\lambda y.\,\mathbf{love}\,x\,y)) \\
\twoheadrightarrow_\beta & \forall x.\,(\mathbf{man}\,x) \wedge (\text{REBECCA}\,(\lambda y.\,\mathbf{love}\,x\,y)) \to (\text{A WOMAN}\,(\lambda y.\,\mathbf{love}\,x\,y)) \\
= & \forall x.\,(\mathbf{man}\,x) \wedge ((\lambda k.\,k\,\mathbf{r})\,(\lambda y.\,\mathbf{love}\,x\,y)) \to (\text{A WOMAN}\,(\lambda y.\,\mathbf{love}\,x\,y)) \\
\twoheadrightarrow_\beta & \forall x.\,(\mathbf{man}\,x) \wedge (\mathbf{loves}\,x\,\mathbf{r}) \to (\text{A WOMAN}\,(\lambda y.\,\mathbf{love}\,x\,y)) \\
= & \forall x.\,(\mathbf{man}\,x) \wedge (\mathbf{loves}\,x\,\mathbf{r}) \\
 & \qquad \to ((\lambda nm.\,\exists y.\,(n\,y) \wedge (m\,y))\,\text{WOMAN}\,(\lambda y.\,\mathbf{love}\,x\,y)) \\
\twoheadrightarrow_\beta & \forall x.\,(\mathbf{man}\,x) \wedge (\mathbf{loves}\,x\,\mathbf{r}) \to (\exists y.\,(\text{WOMAN}\,y) \wedge ((\lambda y.\,\mathbf{love}\,x\,y)\,y)) \\
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= & \forall x.\,(\mathbf{man}\,x) \wedge (\mathbf{loves}\,x\,\mathbf{r}) \to (\exists y.\,((\lambda x.\,\mathbf{woman}\,x)\,y) \wedge (\mathbf{love}\,x\,y))
\end{array}
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Example

$$
\begin{array}{ll}
= & \forall x. (\mathbf{man}\, x) \wedge ((\lambda os. s\, (\lambda x. o\, (\lambda y. \mathbf{love}\, x\, y)))\, \text{REBECCA}\, (\lambda k. k\, x)) \\
& \qquad \rightarrow (\text{A WOMAN}\, (\lambda y. \mathbf{love}\, x\, y)) \\
\twoheadrightarrow_\beta & \forall x. (\mathbf{man}\, x) \wedge ((\lambda k. k\, x)\, (\lambda x. \text{REBECCA}\, (\lambda y. \mathbf{love}\, x\, y))) \\
& \qquad \rightarrow (\text{A WOMAN}\, (\lambda y. \mathbf{love}\, x\, y)) \\
\twoheadrightarrow_\beta & \forall x. (\mathbf{man}\, x) \wedge (\text{REBECCA}\, (\lambda y. \mathbf{love}\, x\, y)) \rightarrow (\text{A WOMAN}\, (\lambda y. \mathbf{love}\, x\, y)) \\
= & \forall x. (\mathbf{man}\, x) \wedge ((\lambda k. k\, \mathbf{r})\, (\lambda y. \mathbf{love}\, x\, y)) \rightarrow (\text{A WOMAN}\, (\lambda y. \mathbf{love}\, x\, y)) \\
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= & \forall x. (\mathbf{man}\, x) \wedge (\mathbf{loves}\, x\, \mathbf{r}) \\
& \qquad \rightarrow ((\lambda nm. \exists y. (n\, y) \wedge (m\, y))\, \text{WOMAN}\, (\lambda y. \mathbf{love}\, x\, y)) \\
\twoheadrightarrow_\beta & \forall x. (\mathbf{man}\, x) \wedge (\mathbf{loves}\, x\, \mathbf{r}) \rightarrow (\exists y. (\text{WOMAN}\, y) \wedge ((\lambda y. \mathbf{love}\, x\, y)\, y)) \\
\twoheadrightarrow_\beta & \forall x. (\mathbf{man}\, x) \wedge (\mathbf{loves}\, x\, \mathbf{r}) \rightarrow (\exists y. (\text{WOMAN}\, y) \wedge (\mathbf{love}\, x\, y)) \\
= & \forall x. (\mathbf{man}\, x) \wedge (\mathbf{loves}\, x\, \mathbf{r}) \rightarrow (\exists y. ((\lambda x. \mathbf{woman}\, x)\, y) \wedge (\mathbf{love}\, x\, y)) \\
\twoheadrightarrow_\beta & \forall x. (\mathbf{man}\, x) \wedge (\mathbf{loves}\, x\, \mathbf{r}) \rightarrow (\exists y. (\mathbf{woman}\, y) \wedge (\mathbf{love}\, x\, y))
\end{array}
$$

Appositive relative clause

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Example

Eric, who loves Rebecca, is a happy man.

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Abstract syntax

$\textsc{who} : (\mathrm{NP} \to \mathrm{S}) \to \mathrm{NP} \to \mathrm{NP}$

Appositive relative clause

Example

Eric, who loves Rebecca, is a happy man.

Abstract syntax

$\textsc{who} : (\mathrm{NP} \rightarrow \mathrm{S}) \rightarrow \mathrm{NP} \rightarrow \mathrm{NP}$

Semantic interpretation

$\textsc{who} := \lambda r.\, \lambda n.\, \lambda p.\, n\, (\lambda x.\, (p\, x) \wedge (r\, (\lambda k.\, k\, x)))$

Appositive relative clause

Example

Eric, who loves Rebecca, is a happy man.

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$\textsc{who} : (\mathrm{NP} \rightarrow \mathrm{S}) \rightarrow \mathrm{NP} \rightarrow \mathrm{NP}$

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$\textsc{who} := \lambda r.\, \lambda n.\, \lambda p.\, n\,(\lambda x.\,(p\,x) \wedge (r\,(\lambda k.\,k\,x)))$