

# Semantic Theory

## Lecture 1 – Introduction

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# Information about this course

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## Contact information:

- Course website: <http://noortjejoost.github.io/teaching/ST16/index.html>
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## Prerequisites:

- This course assumes basic familiarity with first-order predicate logic

## Recommended literature:

- Gamut: Logic, Language, and Meaning, Vol. 2, University of Chicago Press, 1991
- Kamp and Reyle: From Discourse to Logic, Kluwer, 1993

# Exercises & exam

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## Final exam:

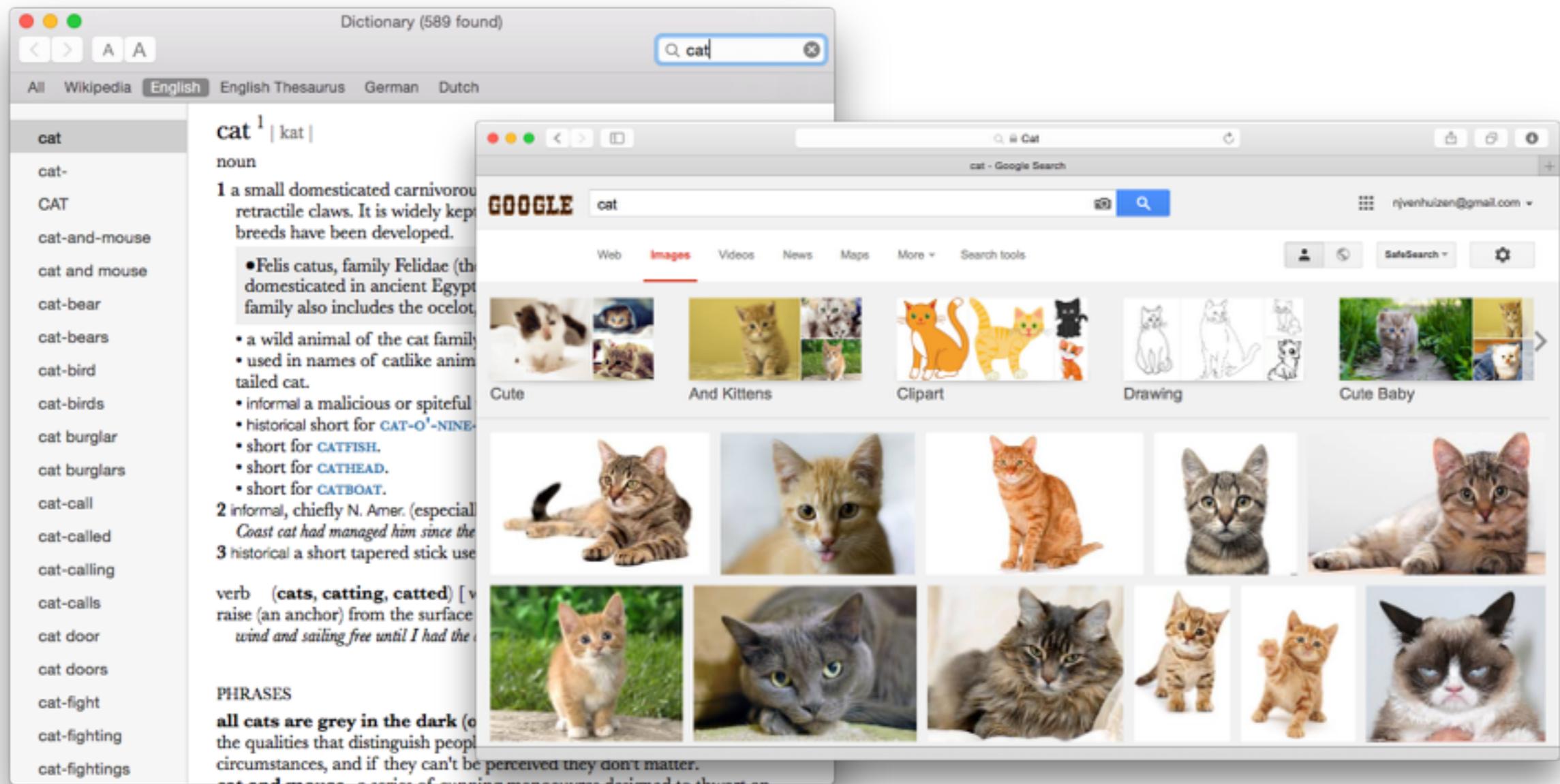
- You have to register: before Monday, July 11th
- Exam date to be confirmed

## Exercise sheets:

- There will be (approx.) 8 exercise sheets throughout the weeks
- In order to be admitted to the exam, you can miss or fail at most 1 exercise sheet
- Exercises can be done in groups (up to 3 students)

# Semantic Theory

Semantic Theory is the study of linguistic meaning

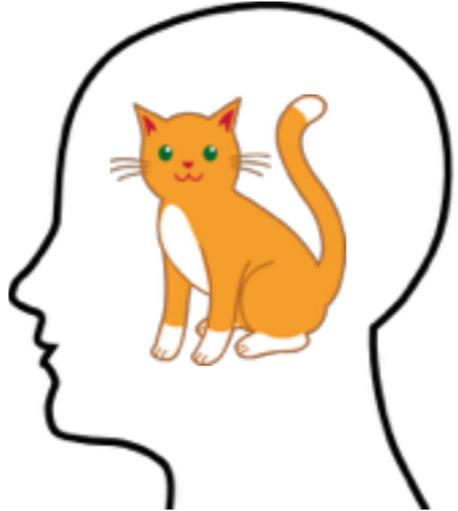
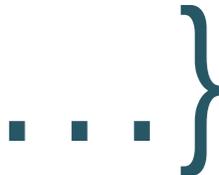


# A philosophical question: What is 'meaning'?

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“a small domesticated carnivorous mammal with soft fur, a short snout, and retractile claws”

“cat”

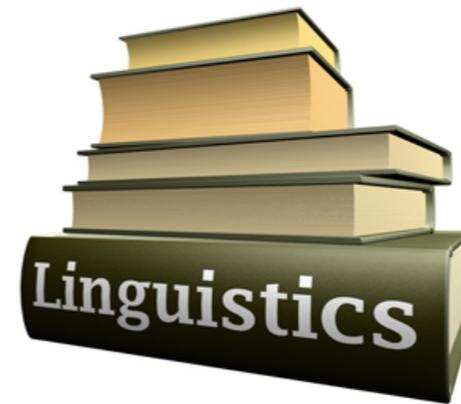
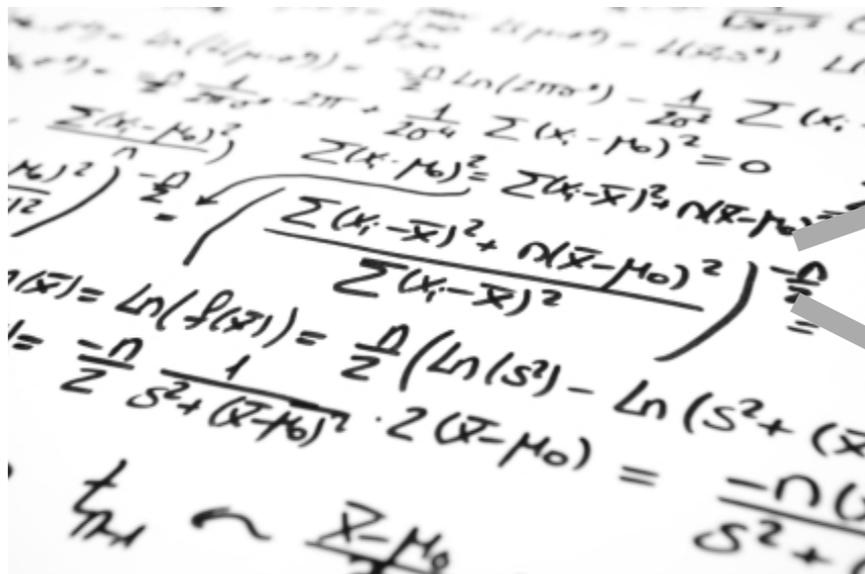


# Formal semantics

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The aim of formal semantics:

Capturing linguistic meaning in a formal (mathematical) system



# The development of formal semantics

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1933 — Bloomfield: “The statement of meanings is [...] the weak point in language-study, and will remain so until human knowledge advances very far beyond its present state.”



1957 — Chomsky: “there is little evidence that ‘intuition about meaning’ is at all useful in the actual investigation of linguistic form”



1970 — Montague: “There is in my opinion no important theoretical difference between natural languages and the artificial languages of logicians”



# Course Overview

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- Part I: Sentence semantics  
(compositional semantics)
- Part II: Lexical semantics
- Part III: Discourse semantics



Part I:  
Sentence semantics



# A basic semantic principle

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"For two sentences  $A$  and  $B$ , if in some possible situation  $A$  is true and  $B$  is false,  $A$  and  $B$  must have different meanings."

(M. Cresswell, 1975)

## Applied to logical representations:

- For a logical formula  $\alpha$  and a sentence  $A$ : If in some possible situation corresponding to a model structure  $M$ , sentence  $A$  is true, and  $\alpha$  is not, or vice versa, then  $\alpha$  is not an appropriate meaning representation for  $A$ .

# Sentence meaning

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## Truth-conditional semantics:

to know the meaning of a (declarative) sentence is to know what the world would have to be like for the sentence to be true:

Sentence meaning = truth-conditions

## Indirect interpretation:

1. Translate sentences into logical formulas:

Every student works  $\mapsto \forall x(\text{student}'(x) \rightarrow \text{work}'(x))$

2. Interpret these formulas in a logical model:

$\llbracket \forall x(\text{student}'(x) \rightarrow \text{work}'(x)) \rrbracket^{M,g} = 1$  iff  $V_M(\text{student}') \subseteq V_M(\text{work}')$

# Step 1: from sentence to formula

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## Propositional logic: Propositions as basic atoms

Syntax: propositions ( $p, q, \dots$ ), logical connectives ( $\neg, \wedge, \vee, \rightarrow, \leftrightarrow$ )

Semantics: truth tables — truth conditions, entailment

$p$	$q$	$p \& q$	$p \vee q$	$p \rightarrow q$	$p \leftrightarrow q$
T	T	T	T	T	T
T	F	F	T	F	F
F	T	F	T	T	F
F	F	F	F	T	T

## Predicate logic: Predicates and arguments

Syntax: predicates & terms ( $\text{Love}(j,m), \text{Mortal}(x), \dots$ ), quantifiers ( $\forall x \phi, \exists x \phi$ ), logical connectives ( $\wedge, \vee, \neg, \rightarrow, \leftrightarrow$ )

Semantics: model structures and variable assignments

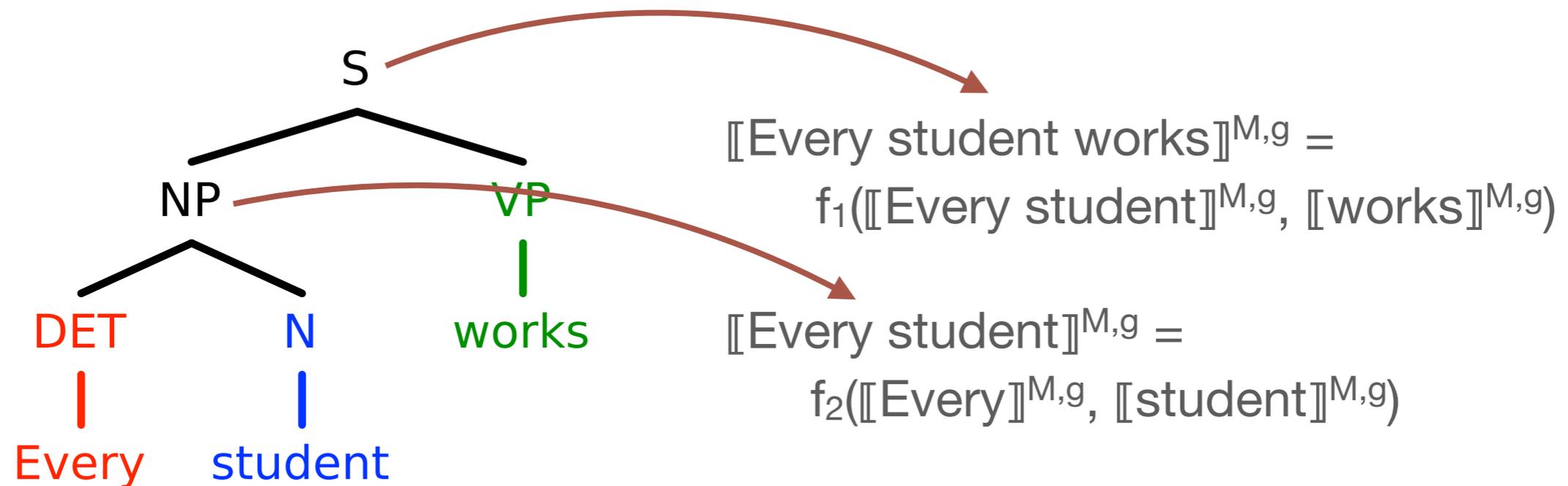
# Compositionality

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## The principle of compositionality:

The meaning of a complex expression is a function of the meanings of its parts and of the syntactic rules by which they are combined (Partee et al., 1993)

- *Every student works*

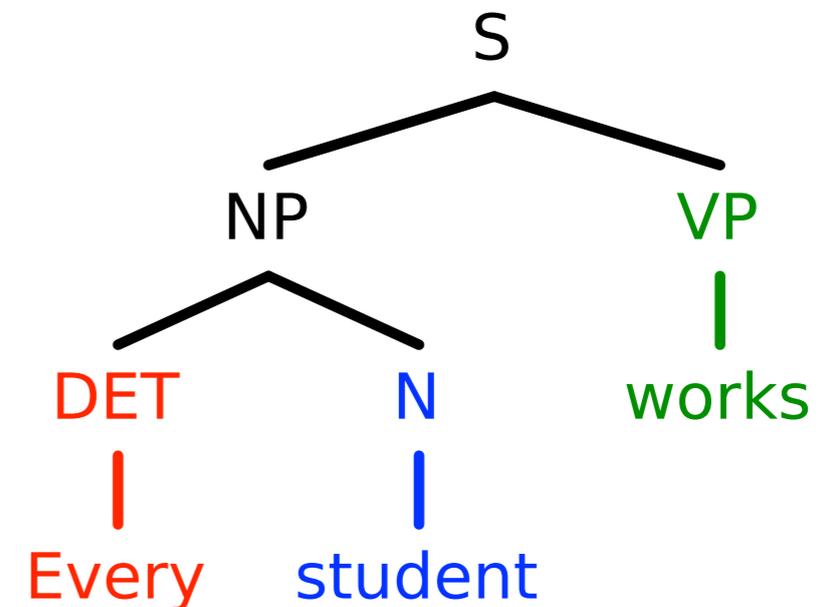


# Compositional Semantics Construction

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## Semantic lexicon:

- every  $\mapsto \lambda P \lambda Q \forall x (P(x) \rightarrow Q(x))$
- student  $\mapsto \text{student}'$
- works  $\mapsto \text{work}'$



## Semantics construction:

- $\lambda P \lambda Q \forall x (P(x) \rightarrow Q(x))(\text{student}') \Rightarrow_{\beta} \lambda Q \forall x (\text{student}'(x) \rightarrow Q(x))$
- $\lambda Q \forall x (\text{student}'(x) \rightarrow Q(x))(\text{work}') \Rightarrow_{\beta} \forall x (\text{student}'(x) \rightarrow \text{work}'(x))$

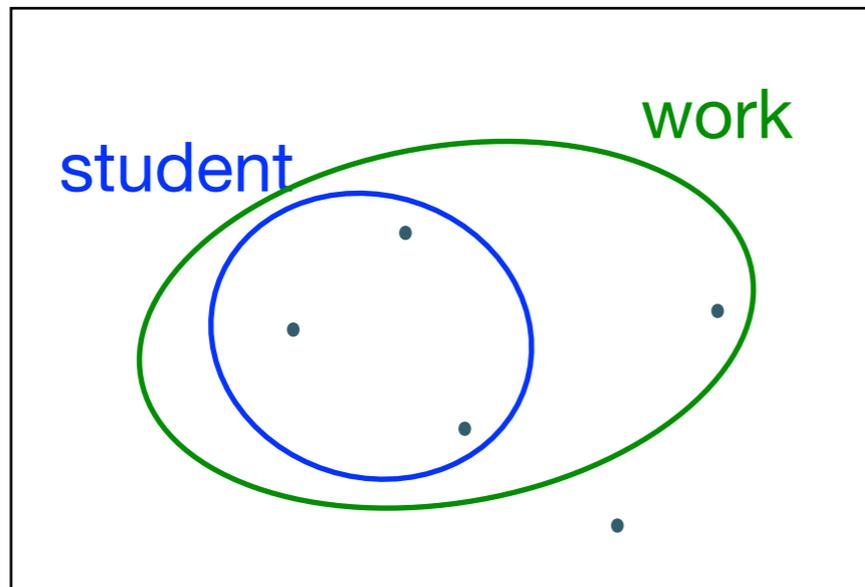
# Step 2: from formula to model

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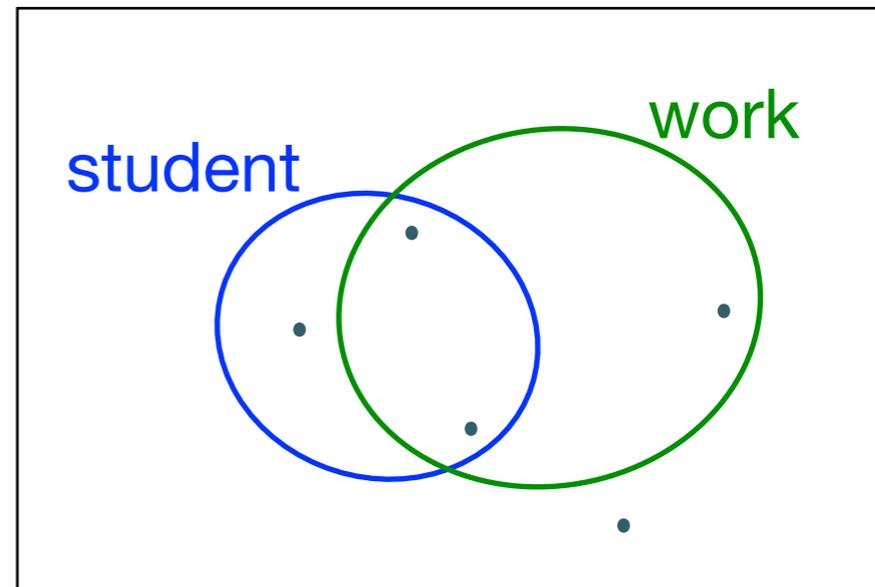
Every student works

$\llbracket \forall x(\text{student}'(x) \rightarrow \text{work}'(x)) \rrbracket^{M,g} = 1$  iff  $V_M(\text{student}') \subseteq V_M(\text{work}')$

M1:



M2:



# Issues for sentence semantics

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## Interpretation of adjectives

1. a. Jumbo is a grey elephant  $\mapsto$  Jumbo is grey
- b. Jumbo is a small elephant  $\not\mapsto$  Jumbo is small

## Quantifier scope

2. An American flag was hanging in front of every building
3. Every student speaks two foreign languages
4. A representative of every company saw most samples

## Monotonicity and generalised quantifiers

5. All children came home late  $\mapsto$  All children came home
6. No children came home late  $\not\mapsto$  No children came home

# Part II: Lexical semantics



# Zooming in: the meaning of words

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## Lexical semantics revisited:

- student  $\mapsto$  **student'** ... what does the ' stand for?



## Structured approaches to the lexicon:

Lexical meaning as relations between concepts in a model

- a “student” is someone who studies
- a “bachelor” is a man who is not married

# Issues for lexical semantics

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## Event-denoting expressions

1. a. Bill saw an elephant.  
b. Bill saw an accident.  
c. Bill saw the children play.

## Verb alternatives and semantic roles

2. a. The window broke.  
b. A rock broke the window.  
c. John broke the window with a rock.

## Plurals and collective predicates

3. Bill and Mary met  $\neq$  Bill met
4. Five students carried three pianos upstairs.

# Part III: Discourse semantics



# Beyond the sentence boundary

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## Limitations of sentence-level semantics:

- Anaphora
  1. John hit Bill. He hit him back.
  2. If a farmer owns a donkey, he feeds it.
- Discourse relations
  3. John fell. Mary helped him up.
  4. John fell. Mary pushed him.
- Presuppositions
  5. a. Bill regrets that his cat has died.
    - b. Bill doesn't regret that his cat has died

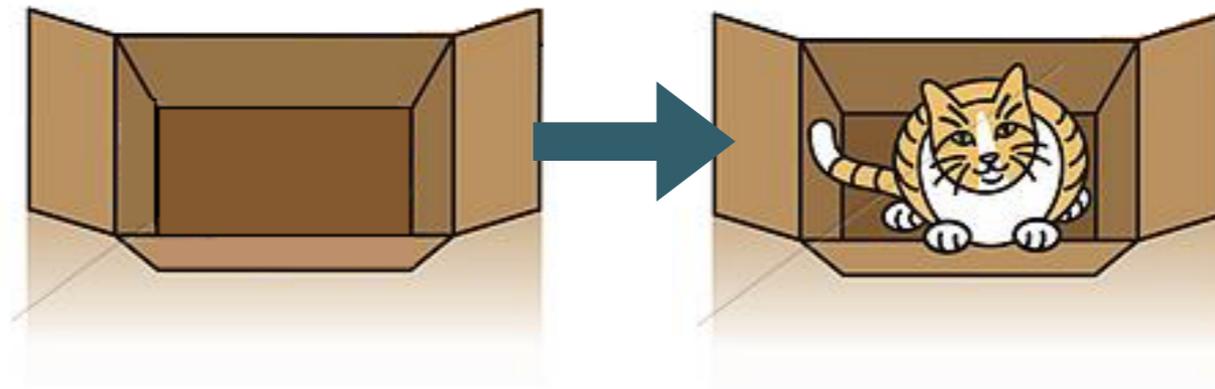
# Dynamic Semantics

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## Revisiting the idea of meaning as truth-conditions

- There is more to meaning than truth-conditions
- Meaning is context-dependent
- Meaning is dynamic: it keeps changing

Solution: Meaning = context-change potential

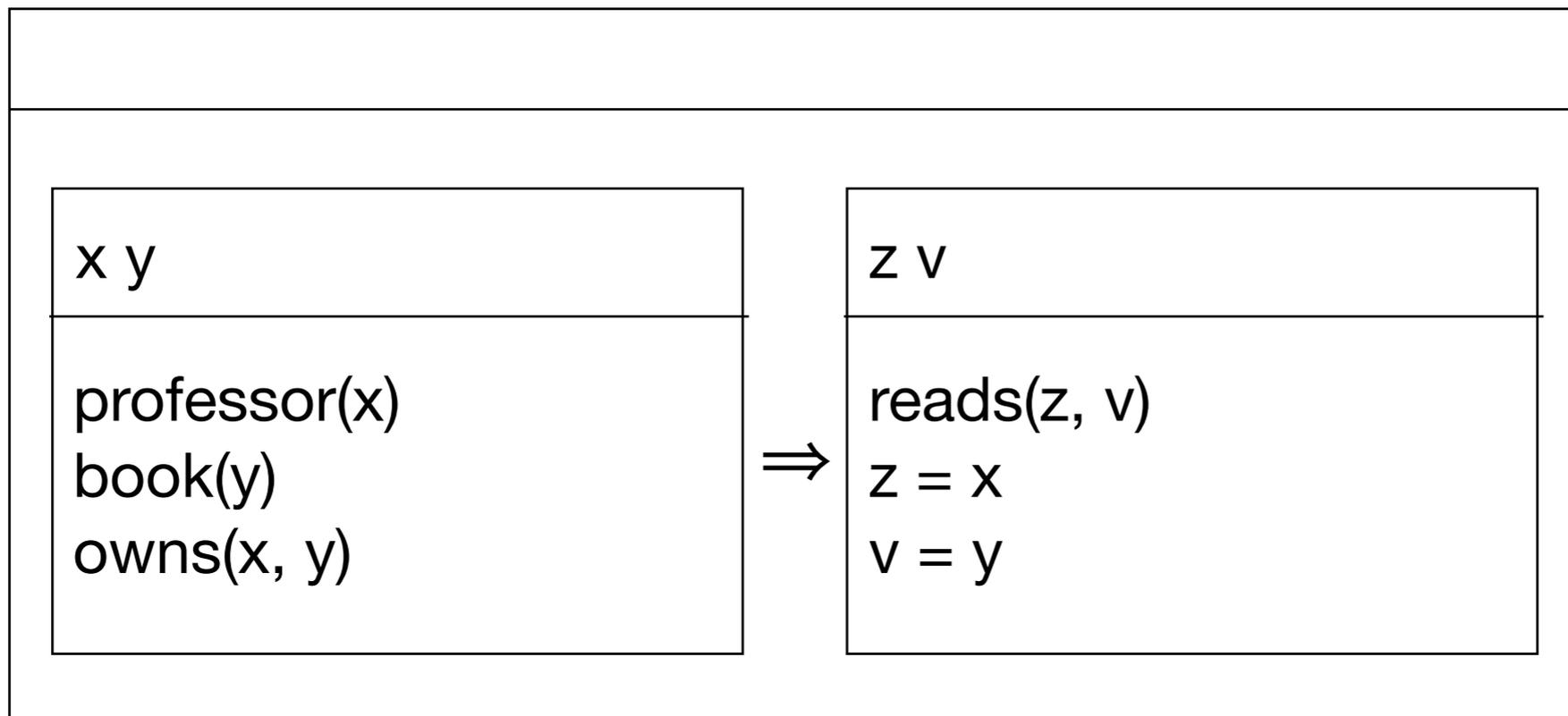


# Discourse Representation Theory

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*If a professor owns a book, he reads it.*

- $\forall x \forall y [\text{professor}(x) \wedge \text{book}(y) \wedge \text{own}(x, y) \rightarrow \text{read}(x, y)]$



# Applications of DRT

The image shows a web browser window displaying a document analysis tool. The browser address bar shows `gmb.let.rug.nl`. The page header includes the Groningen University logo and navigation links like `explore`, `challenges`, `semantic lexicon`, `search`, `news feed`, `statistics`, `warnings`, and `users`. A user is logged in as `noortje` (Master Annotator). The document being viewed is `Document 481 of 10102, ID: 88 / 0480`. The status is `accepted`. Below the document information, there are tabs for `metadata`, `raw`, `tokens`, `sentences`, `discourse`, `8 bits of wisdom`, and `0 warnings`. The main content area shows a list of entities and their relationships, organized into groups `k1` through `k5`. For example, `k1` includes `people(x1)`, `touch(e1)`, and `Experiencer(e1, x1)`. `k2` includes `people(x7)`, `ride(e2)`, and `Agent(e2, x7)`. `k3` includes `named(x17, u.s.-departments, org)` and `named(x19, energy, org)`. `k4` includes `named(x29, vca, org)` and `of(x30, x29)`. `k5` includes `named(x34, vca, org)` and `of(x30, x34)`. The relationships are represented as `of(x, y)` and `like(x, y)`. Overlaid on the right side of the browser window is a terminal window titled `PDRT - ghc - 114x39`. The terminal shows the following commands and output:

```
Prelude Data.DRS> DRS [DRSRef "x"] [Rel (DRSRel "Luke") [DRSRef "x"]]  
size: 3 sentences  
last processed: 14 April 2015, 17:16:53  
C&C tools: 2554  
Update to latest version: 2554  
Preliminary document: report issue  
Filter by part: [dropdown]  
Filter by status: accepted [dropdown]  
Filter by subcorpus: [dropdown]  
Warnings: [dropdown]  
Prelude Data.DRS> DRS [DRSRef "y"] [Rel (DRSRel "father") [DRSRef "y"], Rel (DRSRel "of") [DRSRef "x", DRSRef "y"], Neg (DRS [] [Rel (DRSRel "like") [DRSRef "x", DRSRef "y"]])]  
search  
y  
father(y)  
of(x,y)  
like(x,y)  
Prelude Data.DRS> printMerge luke doesntlikehisfather  
x y  
Luke(x) + father(y) of(x,y) = Luke(x) father(y) of(x,y)  
like(x,y) like(x,y)
```



# Current issues in Semantic Theory

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- Where is the border between semantics and pragmatics?
- What do (or: can) formal semantic theories say about the way meaning is stored and created in the human brain?
- How can we use formal semantics for practical purposes (for example to improve machine translation)?

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