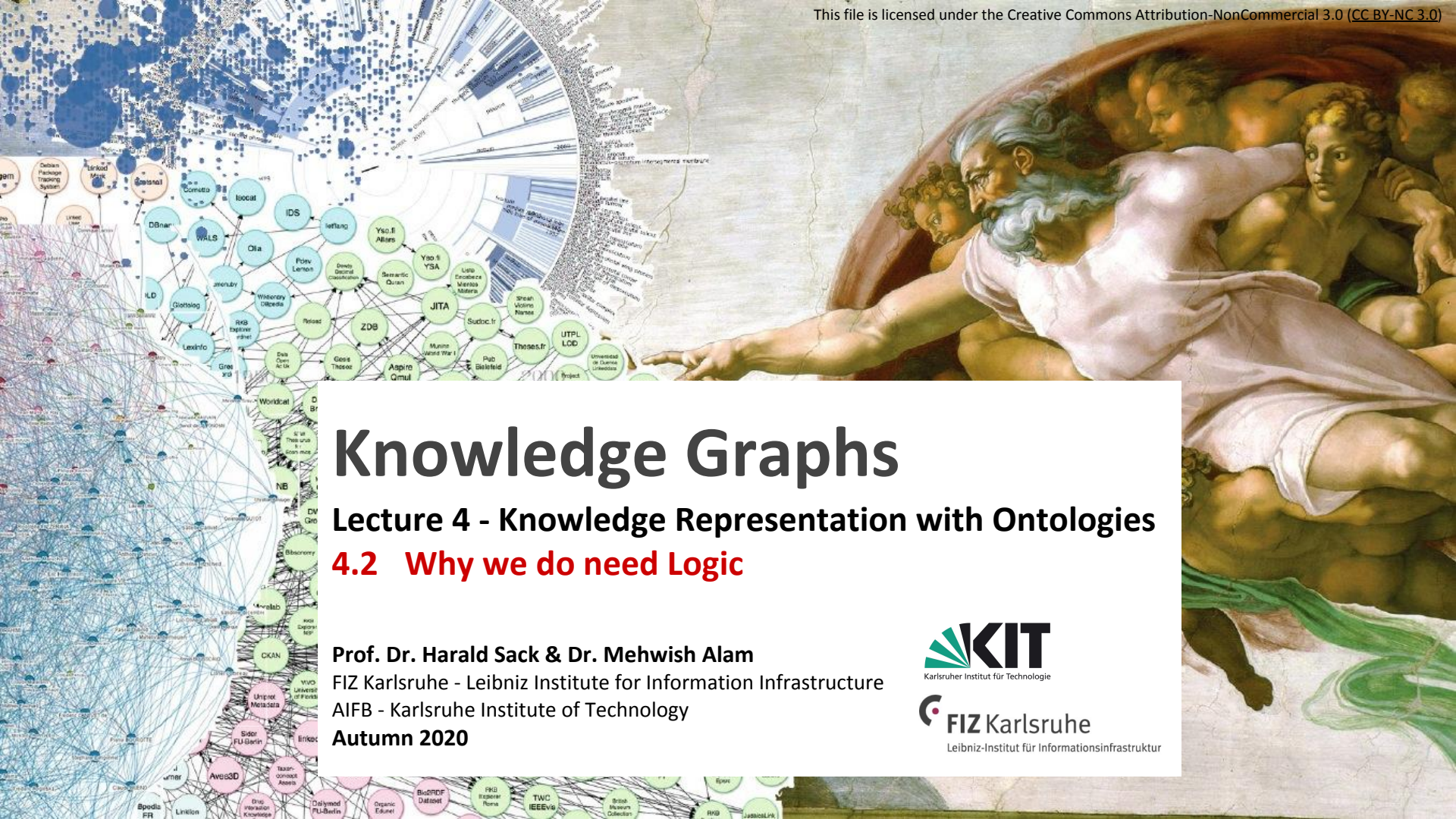

Knowledge Graphs

Lecture 4 - Knowledge Representation with Ontologies

4.2 Why we do need Logic

Prof. Dr. Harald Sack & Dr. Mehwish Alam
FIZ Karlsruhe - Leibniz Institute for Information Infrastructure
AIFB - Karlsruhe Institute of Technology
Autumn 2020

Karlsruher Institut für Technologie

FIZ Karlsruhe
Leibniz-Institut für Informationsinfrastruktur

Knowledge Graphs

Lecture 4: Knowledge Representation with Ontologies

Why RDF(S) is not sufficient

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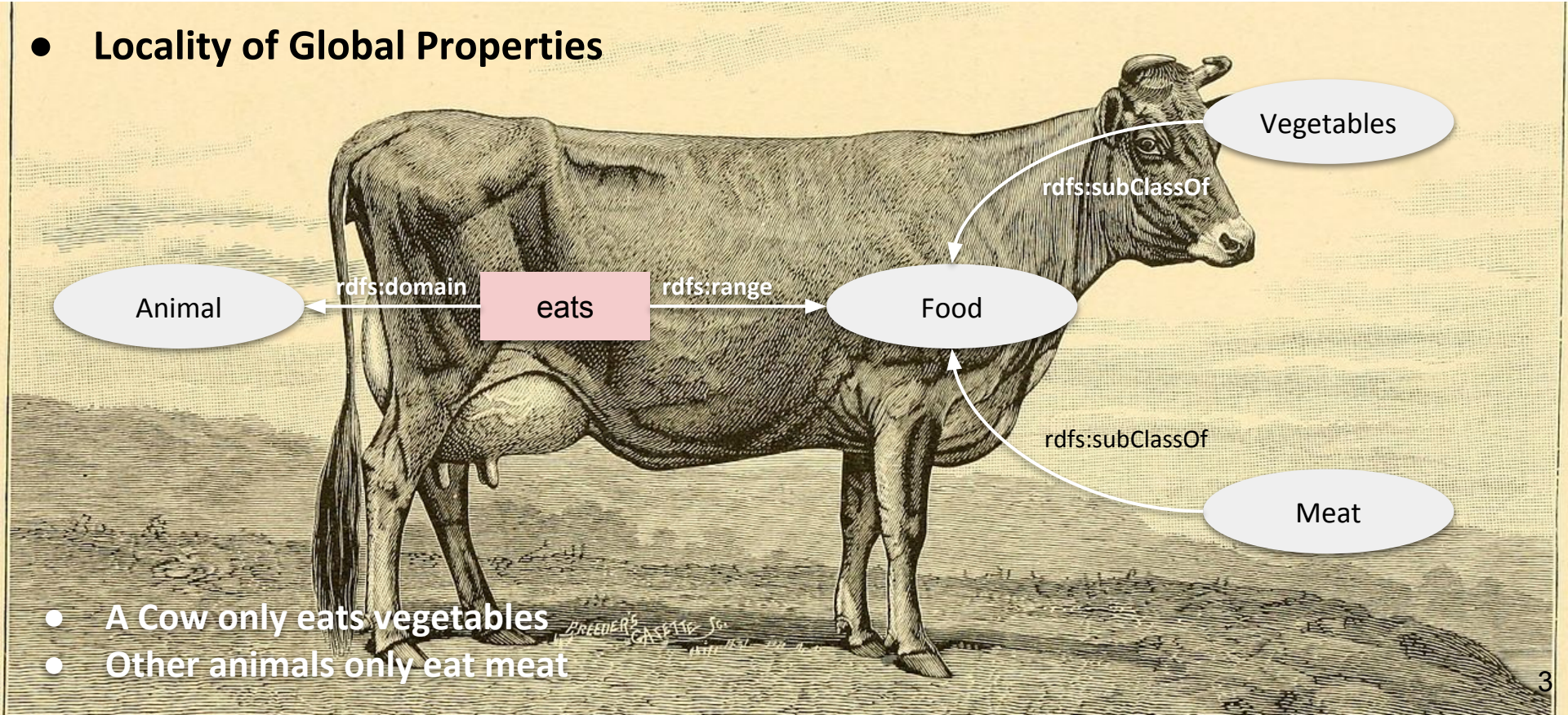
- **Locality of Global Properties**

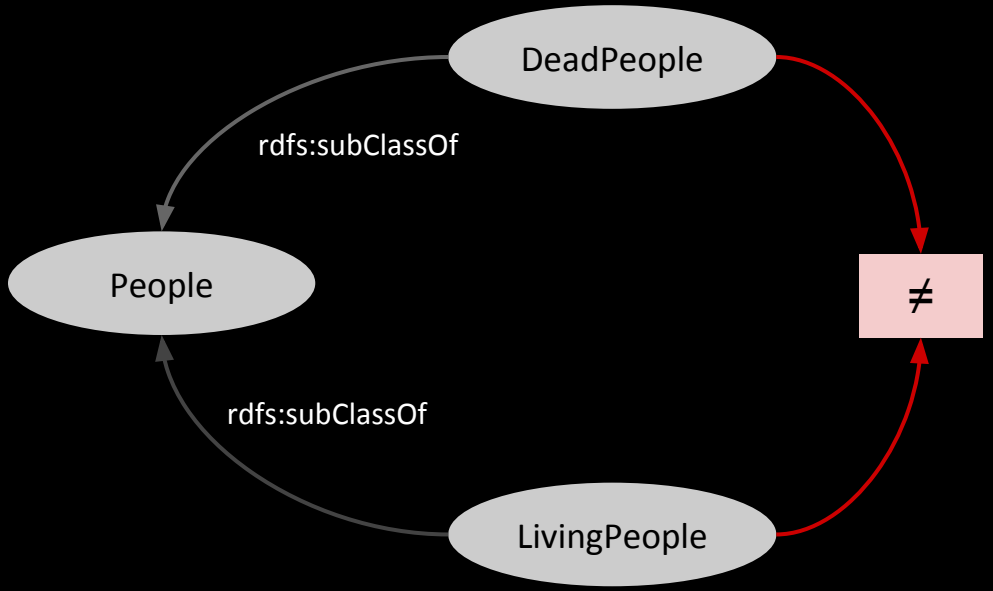


- A Cow only eats vegetables
- Other animals only eat meat

Why RDF(S) is not sufficient

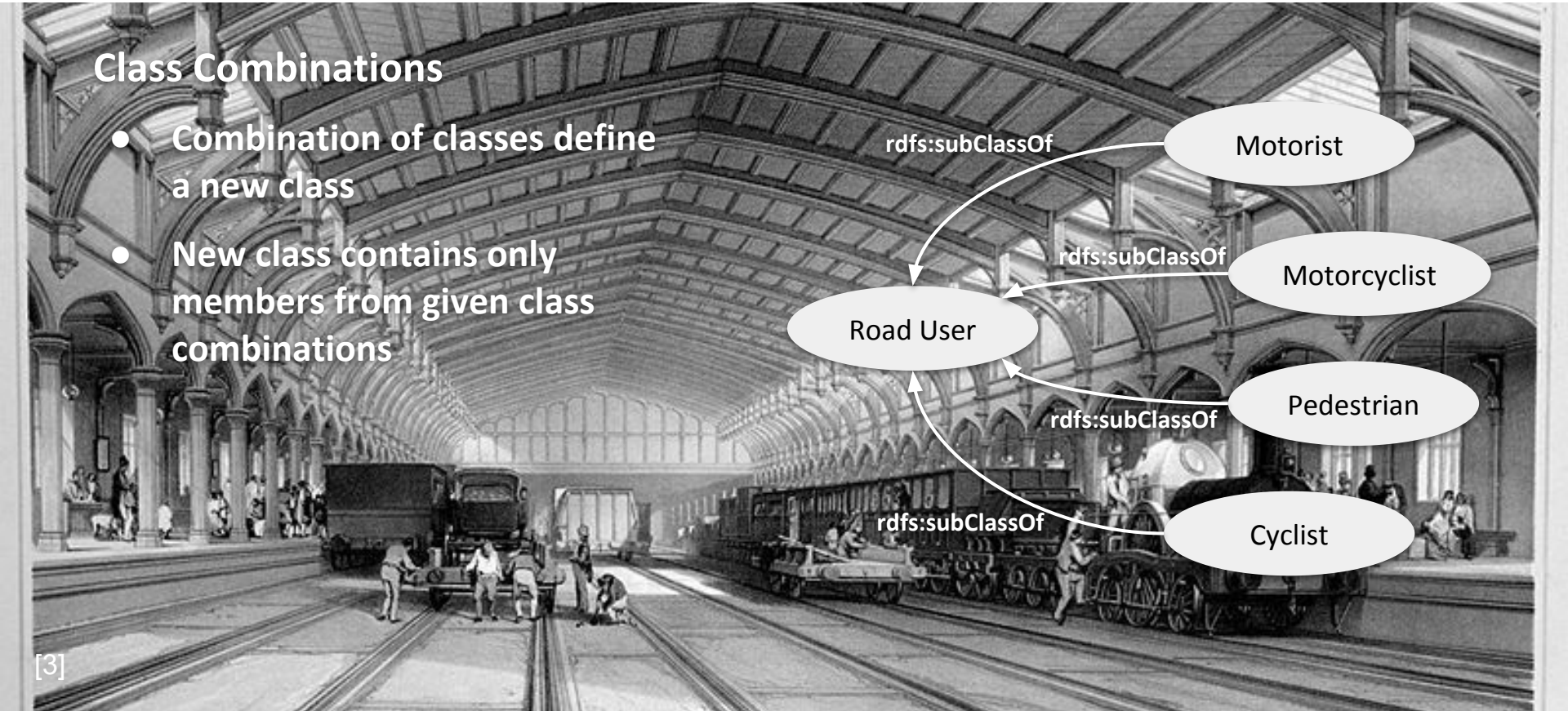

[2]

- **Disjunctive Classes**



- RDFS Subclass relation cannot express disjunctive class (subclass) membership

Why RDF(S) is not sufficient



[3]

Why RDF(S) is not sufficient

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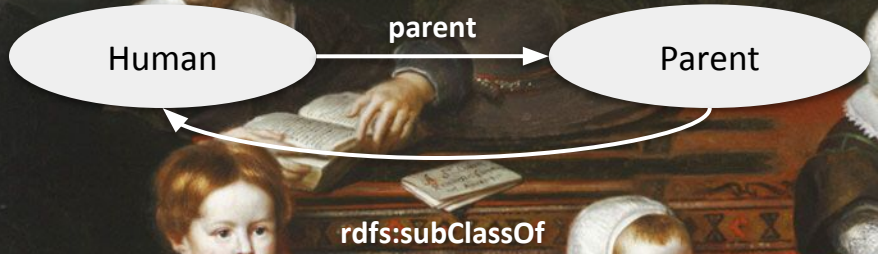
- Cardinality Constraints



- Every human (usually) has two parents

[4]

Why RDF(S) is not sufficient

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Special Property Constraints

- Transitivity (e.g. „is greater than“)
- Uniqueness (e.g. „is mother of“)
- Inversiveness (e.g. „is parent of“ and „is child of“)

General Problem of RDF(S)

- RDF(S) does not have the possibility of **negation**
  - `:harald rdf:type :Vegetarian .`
  - `:harald rdf:type :NonVegetarian .`
  - ...does not automatically generate a contradiction

Why RDF(S) is not sufficient

An **ontology** is an **explicit, formal specification of a shared conceptualization**.

acc. to Thomas R. Gruber: A Translation Approach to Portable Ontology Specifications.Knowledge Acquisition, 5(2):199-220, 1993.

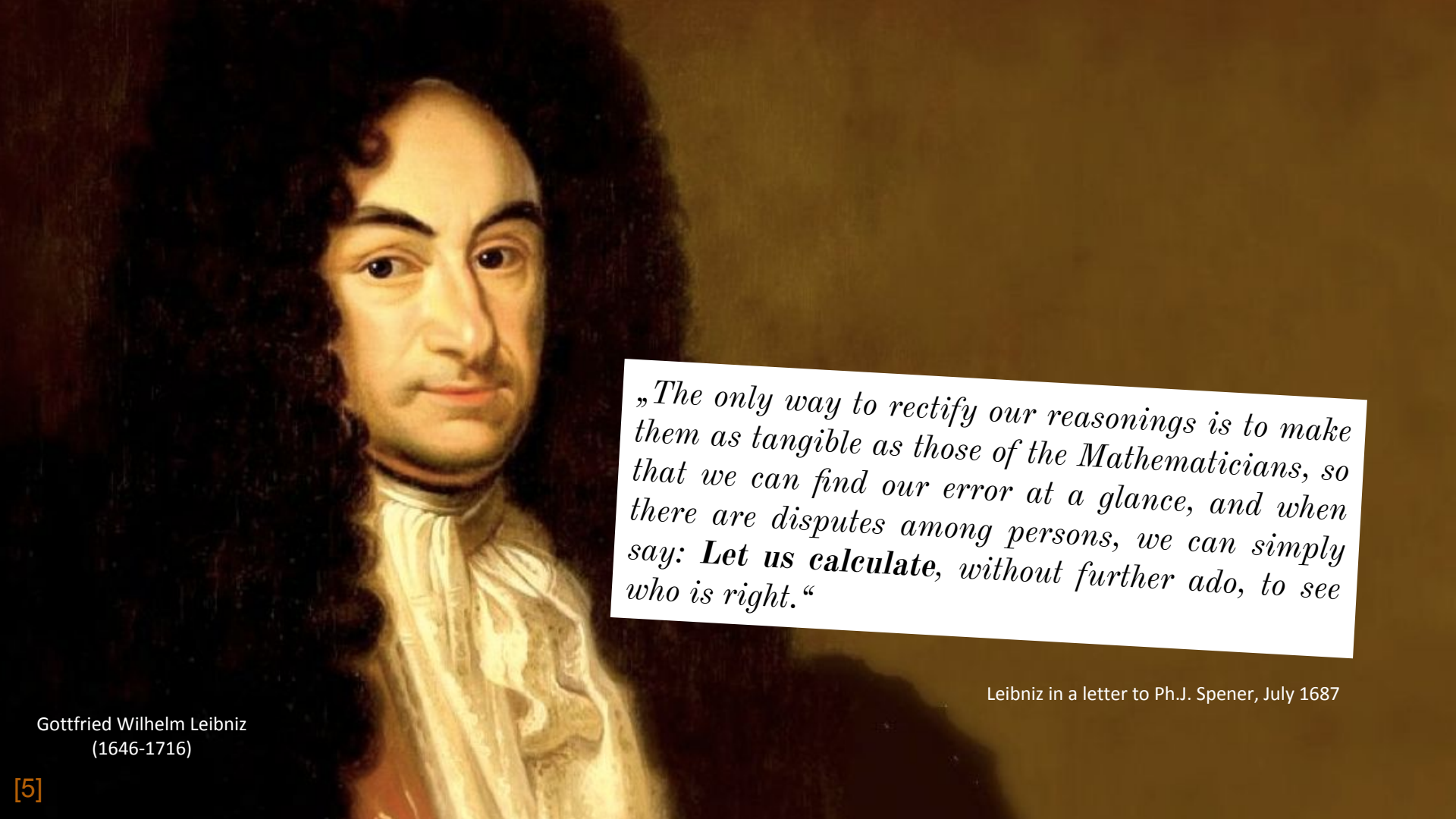
formal (machine readable) semantics

mathematical logic

The Foundations of Logic

- Definition (for our lecture):
  Logic is the study of how to make formal correct deductions and inferences.

- Why “formal logic”? ⇒ to enable automation



„The only way to rectify our reasonings is to make them as tangible as those of the Mathematicians, so that we can find our error at a glance, and when there are disputes among persons, we can simply say: ***Let us calculate****, without further ado, to see who is right.“*

Leibniz in a letter to Ph.J. Spener, July 1687

Gottfried Wilhelm Leibniz
(1646-1716)

[5]

The Foundations of Logic

- **Syntax**: *symbols without meaning*
  defines rules, how to construct well-formed and valid sequences of symbols (strings)
- **Semantic**: *meaning of syntax*
  defines rules how the meaning of complex sequences of symbols can be derived from atomic sequences of symbols.

Syntax

```
If (i<0) then display ("negative account!")
```

assignment of meaning

print the message "negative account!", if the account balance is negative

The Importance of Semantics

- Why should I care about semantics?

Well, from a philosophical POV, we need to specify the relationship between statements in the logic and the existential phenomena they describe.

Bertrand Russell (1872-1970) [6]

The Importance of Semantics

- Why should I care about semantics?

Well, from a philosophical POV, we need to specify the relationship between statements in the logic and the existential phenomena they describe.

Bertrand Russell (1872-1970) [6]

- That's OK, but I don't get paid for philosophy.

From a practical POV, in order to specify, build and test (ontology-based) tools/systems we need to precisely define relationships (like entailment) between logical statements – this defines the intended behaviour of tools/systems.

Cordial thanks to Ian Horrocks' seminar slides!!

Variants of Semantics

- e.g. programming languages

Syntax

```
FUNCTION
f(n:natural):natural;
BEGIN
     IF n=0 THEN f:=1
     ELSE f:=n*f(n-1);
END;
```

computation of the factorial

intentional semantics

- *„the meaning intended by the user“*
- *restricts the set of all possible models (meanings) to the meaning intended by the (human) user*

Variants of Semantics

- e.g. programming languages

Syntax

```
FUNCTION
f(n:natural):natural;
BEGIN
     IF n=0 THEN f:=1
     ELSE f:=n*f(n-1);
END;
```

computation of the factorial

$f: n \rightarrow n!$

formal semantics

*aims to express the meaning of symbol sequences (programs) in a **formal language**, in a way that assertions over the symbol sequences (programs) can be proven by the application of deduction rules.*

Variants of Semantics

- e.g. programming languages

Syntax

```
FUNCTION
f(n:natural):natural;
BEGIN
     IF n=0 THEN f:=1
     ELSE f:=n*f(n-1);
END;
```

computation of the factorial

$f: n \rightarrow n!$

behaviour of the program at execution

procedural semantics

the meaning of a language expression (program) is the procedure that takes place internally, whenever the expression does occur.

Semantics and Mathematical Logic

- How do I define the semantics of a mathematical logic?

*In mathematical logic we define the semantics in terms of **models** (a model theory). A model is supposed to be an analogue of (part of) the world being modeled.*

Bertrand Russell (1872-1970) [6]

Model-theoretic Semantics

Alfred Tarski
(1901-1983) [7]

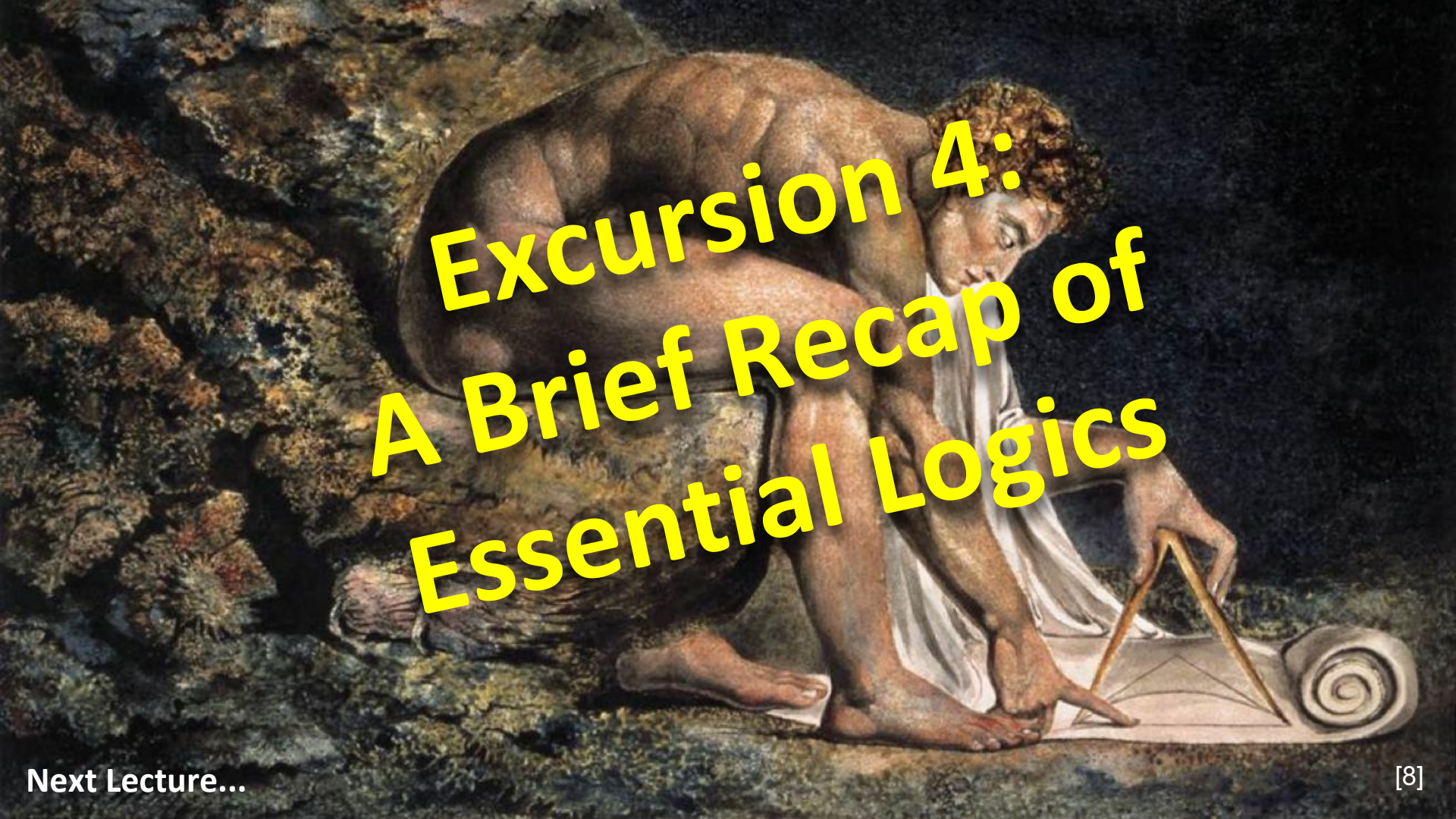
- **Model-theoretic semantics** performs the semantic interpretation of artificial and natural languages by *„identifying meaning with an exact and formally defined interpretation with a model“*
- = **formal Interpretation with a model**

- e.g. model-theoretic semantics of **propositional logic**
  - assignment of truth values ***„true“*** and ***„false“*** to atomic assertions and
  - description of logical connectives with ***truth tables***

Model-theoretic Semantics

- Any logic **L := (S , ⊨)** consists of
  (1) a **set of statements S** and
  (2) an **entailment relation ⊨**
- Let $\Phi \subseteq S$ and $\varphi \in S$: $\Phi \models \varphi$

  „φ *is a logical consequence of Φ*“ or
  „*from the assertions of Φ follows the assertion* φ“
- If for 2 assertions $\varphi, \psi \in S$
  both $\{\varphi\} \models \psi$ and $\{\psi\} \models \varphi$,
  then both assertions φ and ψ are logically equivalent: $\varphi \equiv \psi$



Next Lecture...

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