

Knowledge Representation and Reasoning with Ontologies

Marco Rospocher

Commonsense Reasoning in Surgical Robotics
Doctoral Summer School
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Agenda

- What is an ontology?
- What could an ontology be useful for?
- Notable ontology examples
- Hands-on session: let's inspect an ontology with (web)Protégé!

- Slides and materials available at:

<https://bit.ly/MR-COSER2022>



Motivating example

- Searching for a surgical device in a document collection

 × 🔍

Motivating example

- Searching for a surgical device in a document collection
medical instrument for grasping

 × 🔍

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bipolar forceps

needle holder

Debakey forceps

Michel Suture Clip Applying Forceps

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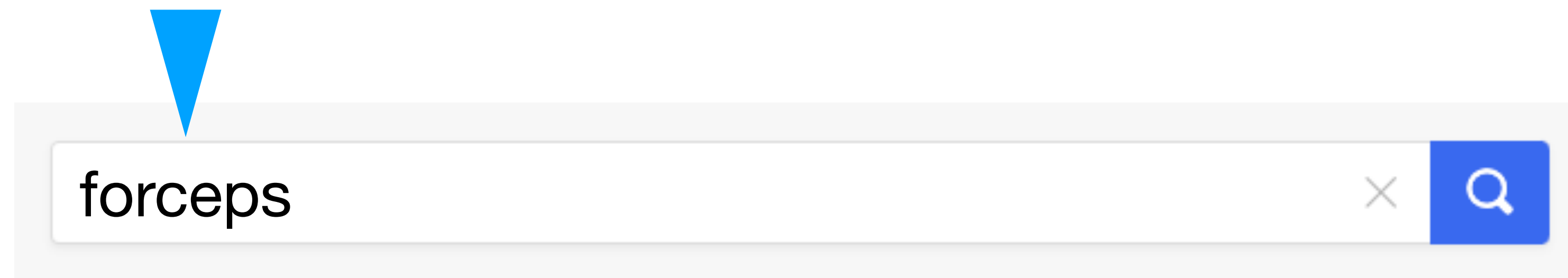
WPI Pean forceps

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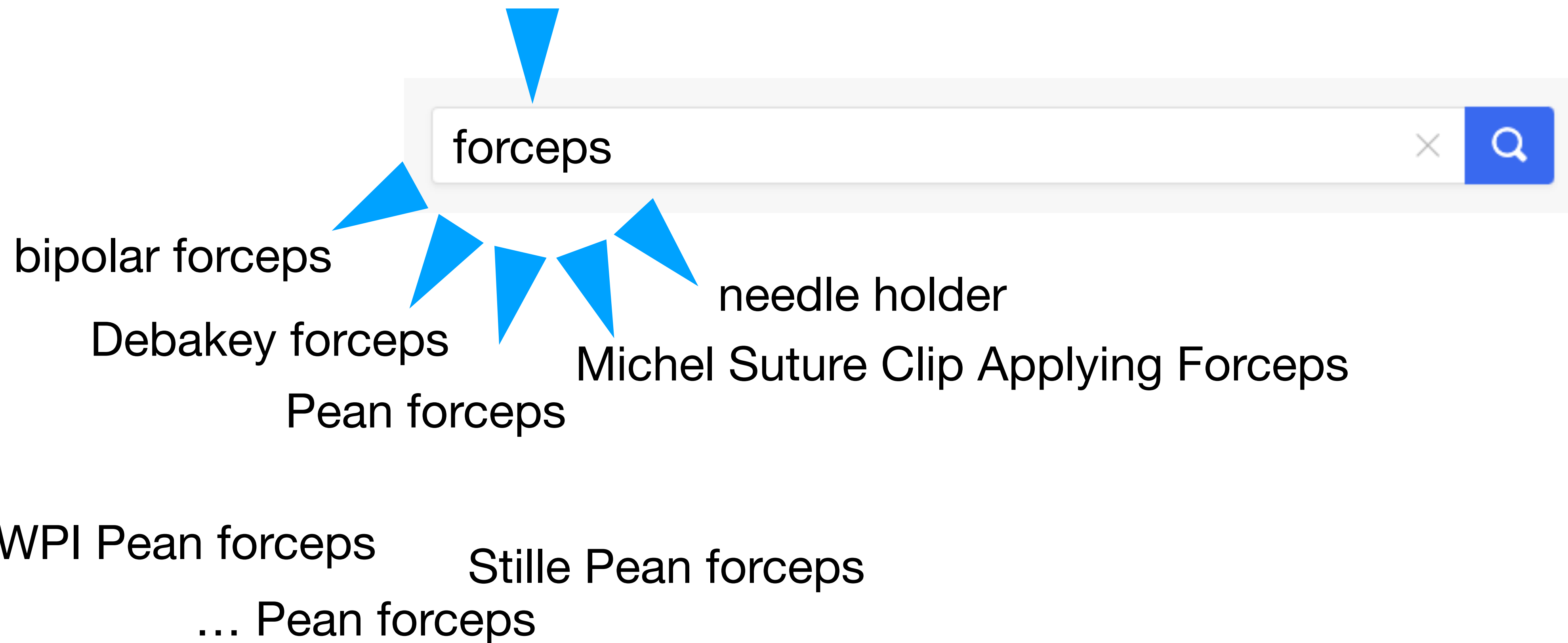
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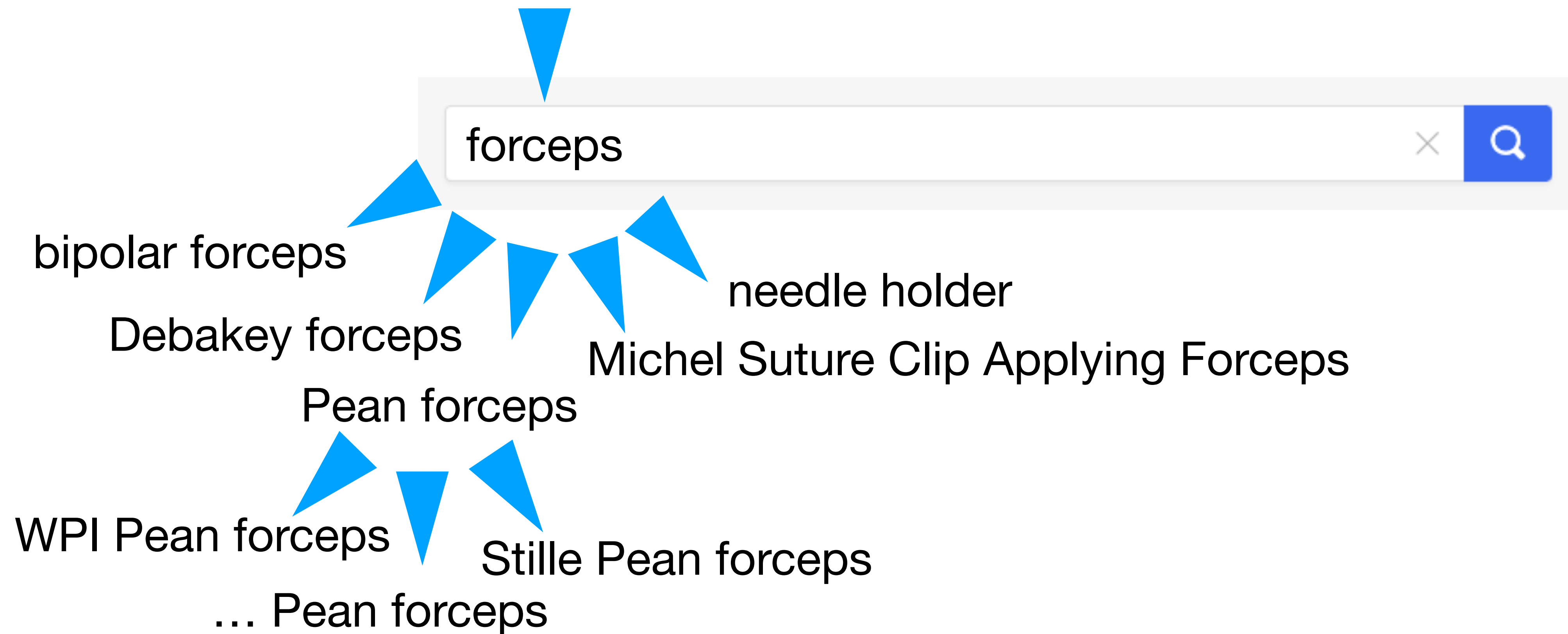
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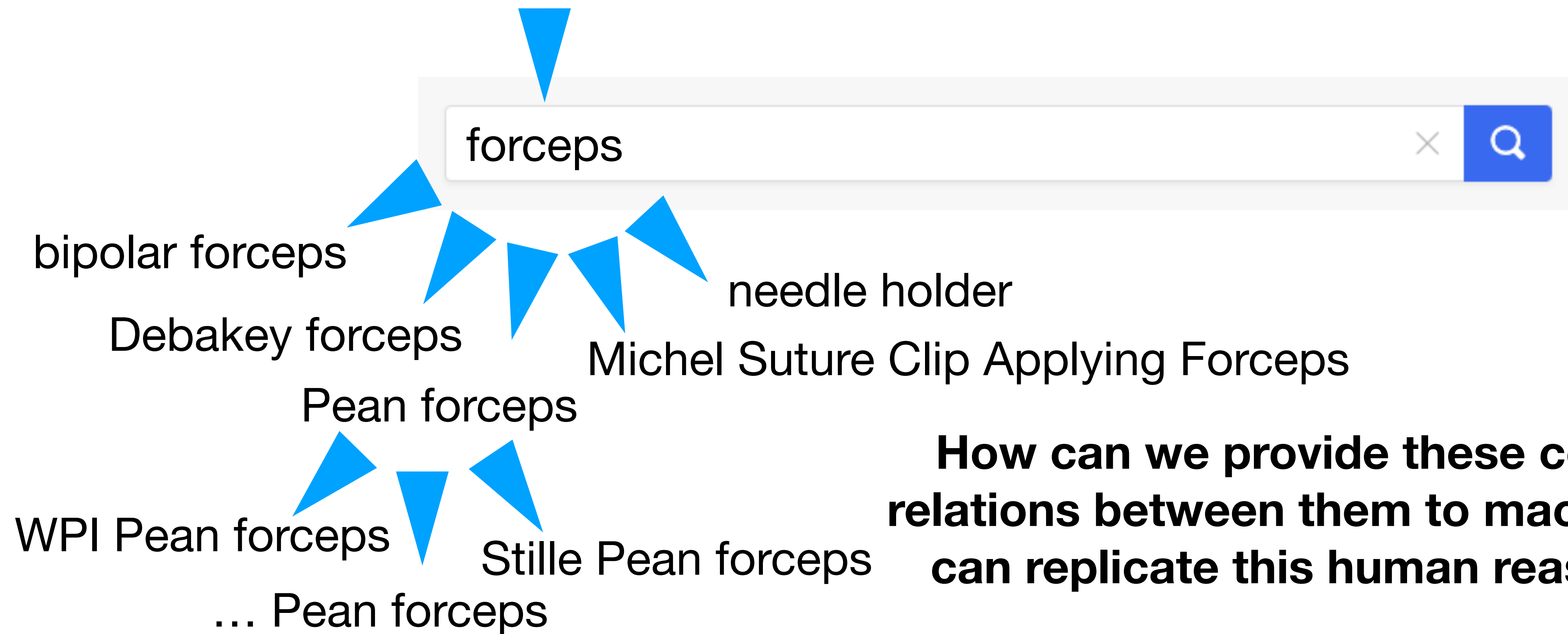
Motivating example

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Motivating example

- Searching for a surgical device in a document collection
medical instrument for grasping



How can we provide these concepts and the relations between them to machines so that they can replicate this human reasoning process?

Motivating example

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How can we provide these concepts and the relations between them to machines so that they can replicate this human reasoning process?

Ontologies!

Ontology

- An ontology is a **formal, explicit** specification of a **shared conceptualisation**

Gruber, T. (1993). A translation approach to portable ontology specifications. *Knowledge Acquisition*, 5, 199-220.

- Ontology in philosophy: systematic account of existence
- Ontology in AI/CS: exists = that can be represented

Ontology

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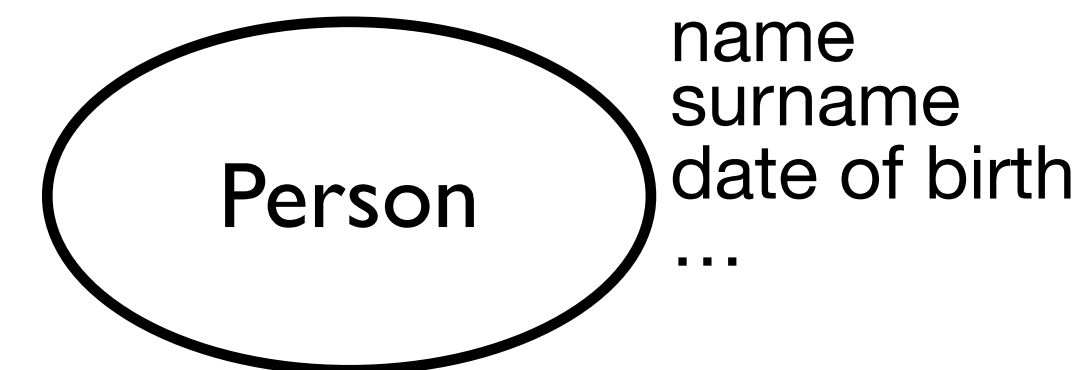
- conceptualisation:
 - abstract model: objects, concepts, and other entities that are assumed to exist in some area of interest and the relationships that hold among them
- shared:
 - all the stakeholders should understand the primitive terms in the appropriate way
- explicit:
 - all elements used in the conceptualisation must be defined
- formal:
 - must be machine understandable

Ontology: Ingredients

- **Individuals / Instances**
 - the objects of the domain of interest
- **Classes / Concepts**
 - “Categories” of the objects the ontology is supposed to describe
- **Relations / Properties (with possible constraints)**
 - describe how the objects are semantically related
- **Axioms**
 - express the knowledge we have about classes, relations, individuals

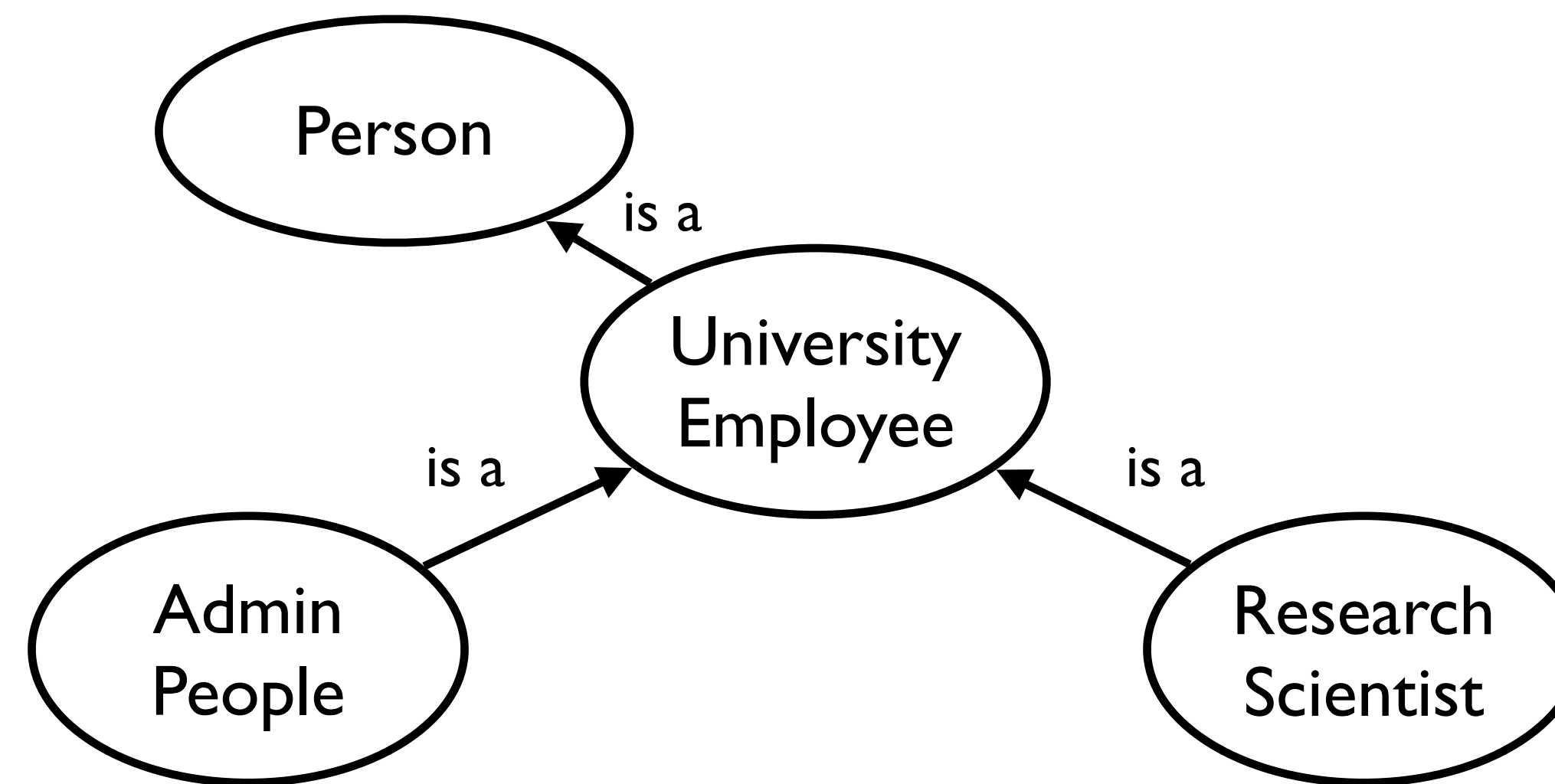
Ontology: Classes

- **Classes** (a.k.a. Concepts): abstract collections of objects that share some fundamental characteristics
 - Objects in the class are called **class members**
 - Intuition: think at classes as sets
 - Examples: Person, Animal, Organization, Surgical Device, Unicorn, ...
- Classes are characterised by means of **attributes**
 - Represented as named-value pairs
 - Values could be: numbers, strings, dates, ...
 - Examples:
 - for Person: name, surname, date of birth, ...
 - for Surgical Device: brand, size, reusability, ...



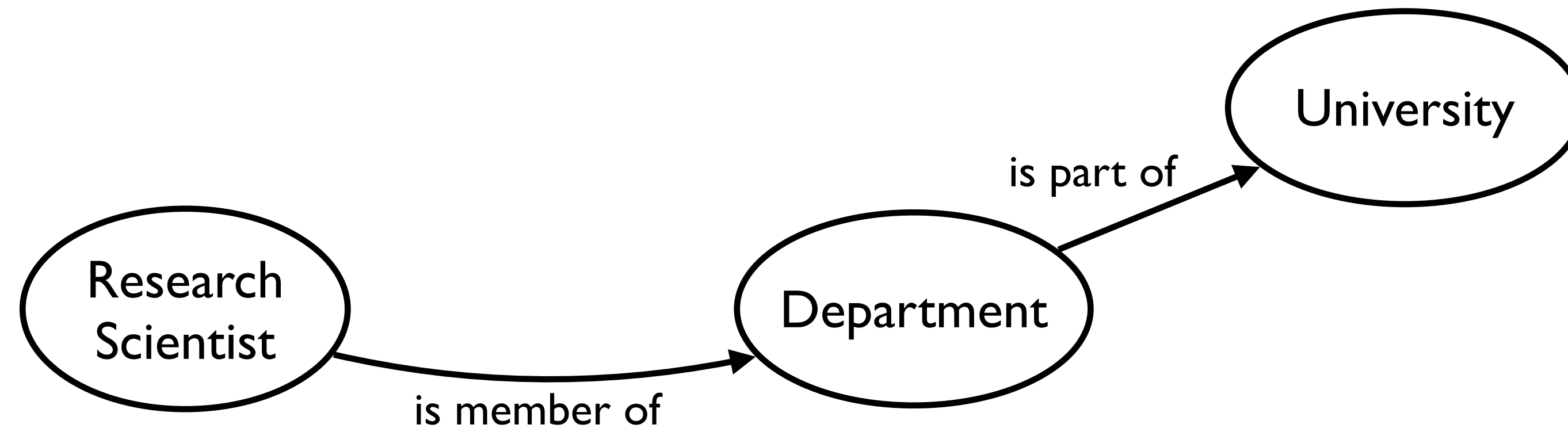
Ontology: Classes

- Classes are organised in a generalisation/specialisation hierarchy, i.e. a **taxonomy**
 - All members of the **subclass** are also members of the **superclass**
 - Intuition: think at subsets and supersets
 - Examples:



Ontology: Relations

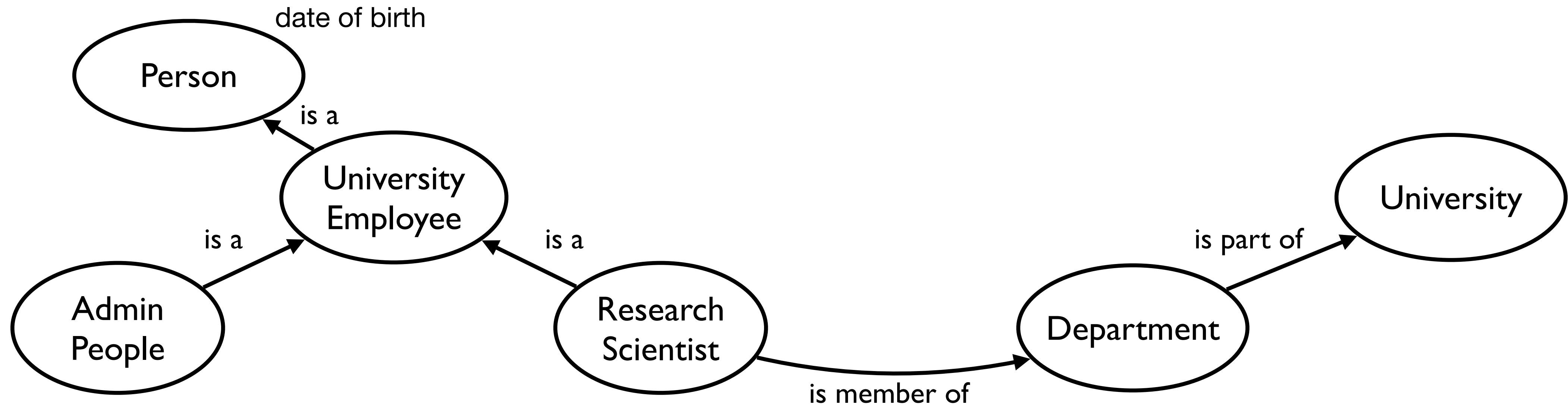
- Classes can be related via (binary) **relations**
 - Members of the first class (**domain**) can be related to members of the second class (**range**)
 - Examples:



- Relations can have the same classes as domain and range: e.g., friendOf relation on Person
- Attributes (values) vs Relations (objects)

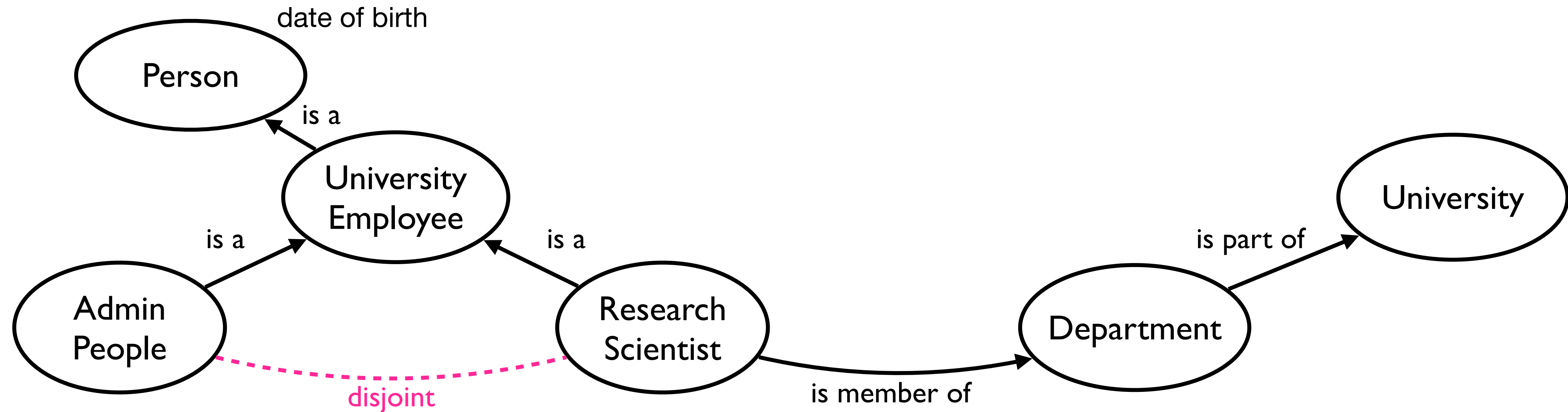
Ontology: Constraints

- **Constraints** can be defined to characterise the relations between classes or the usage of class attributes



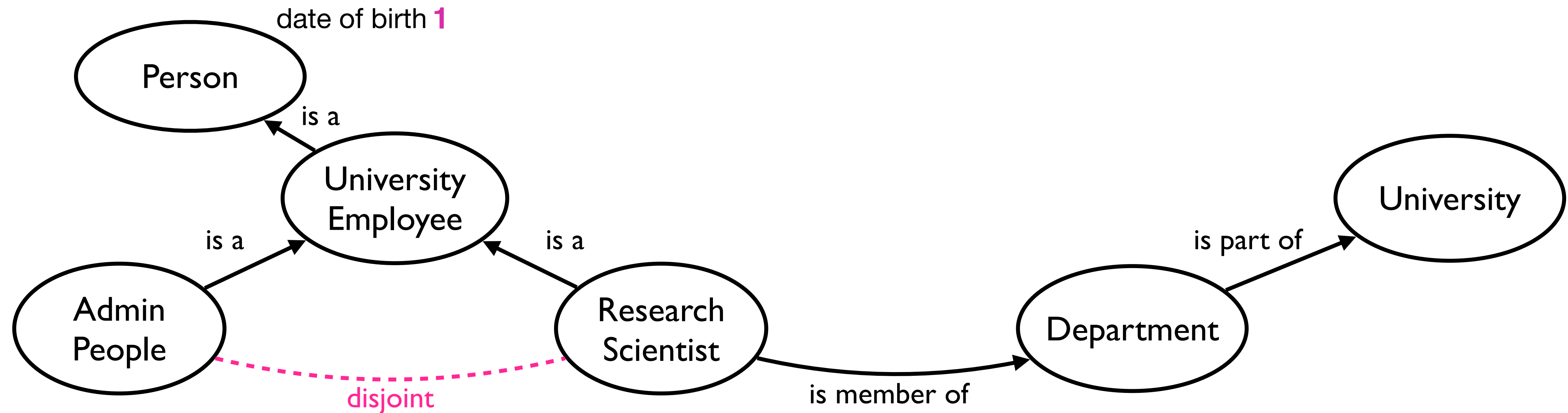
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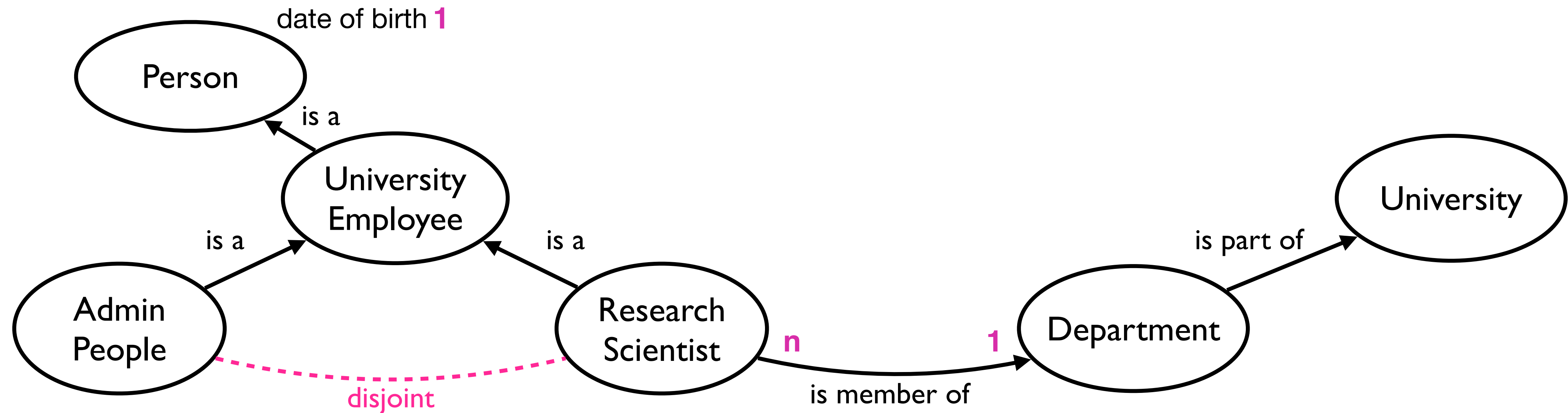
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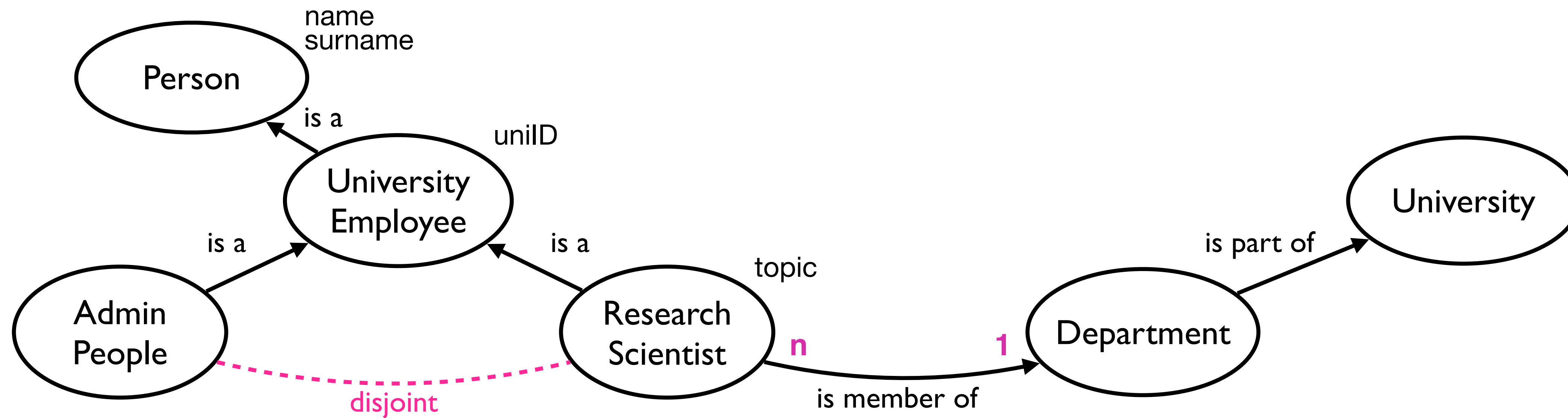
Ontology: Axioms

- Classes, relations, and constraints can be combined (**expressions**) and further characterised more precisely by means of formal **axioms**
- Examples:
 - the class of University Employee is exactly the union of classes Research Scientist and Admin People
 - a University Teacher is a University Employee who teaches at least a course offered by the University
 - a University Teacher cannot teach two courses concurrently
 - ...

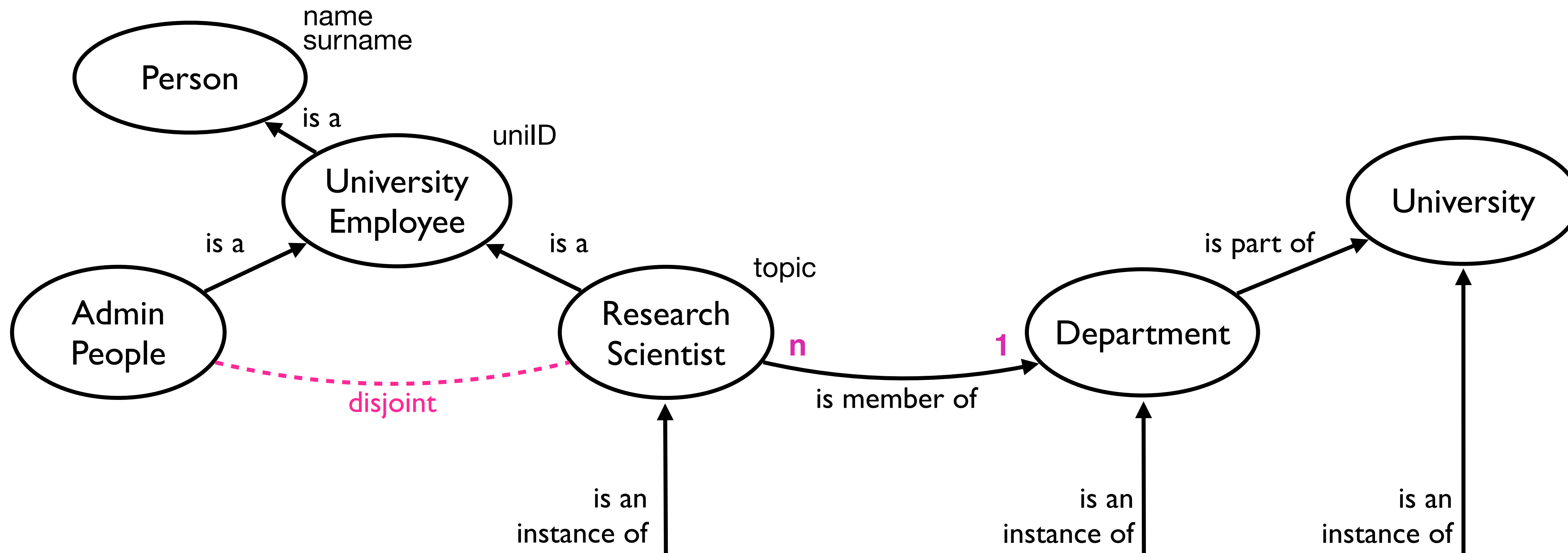
Ontology: Individuals

- **Individuals** are the objects of interest
 - characterised by means of classes and attributes
 - related to other individuals by means of relations

Ontology



Ontology



name = Marco
surname = Rospocher
uniID = XYZ123
topic = semantic web, information extraction



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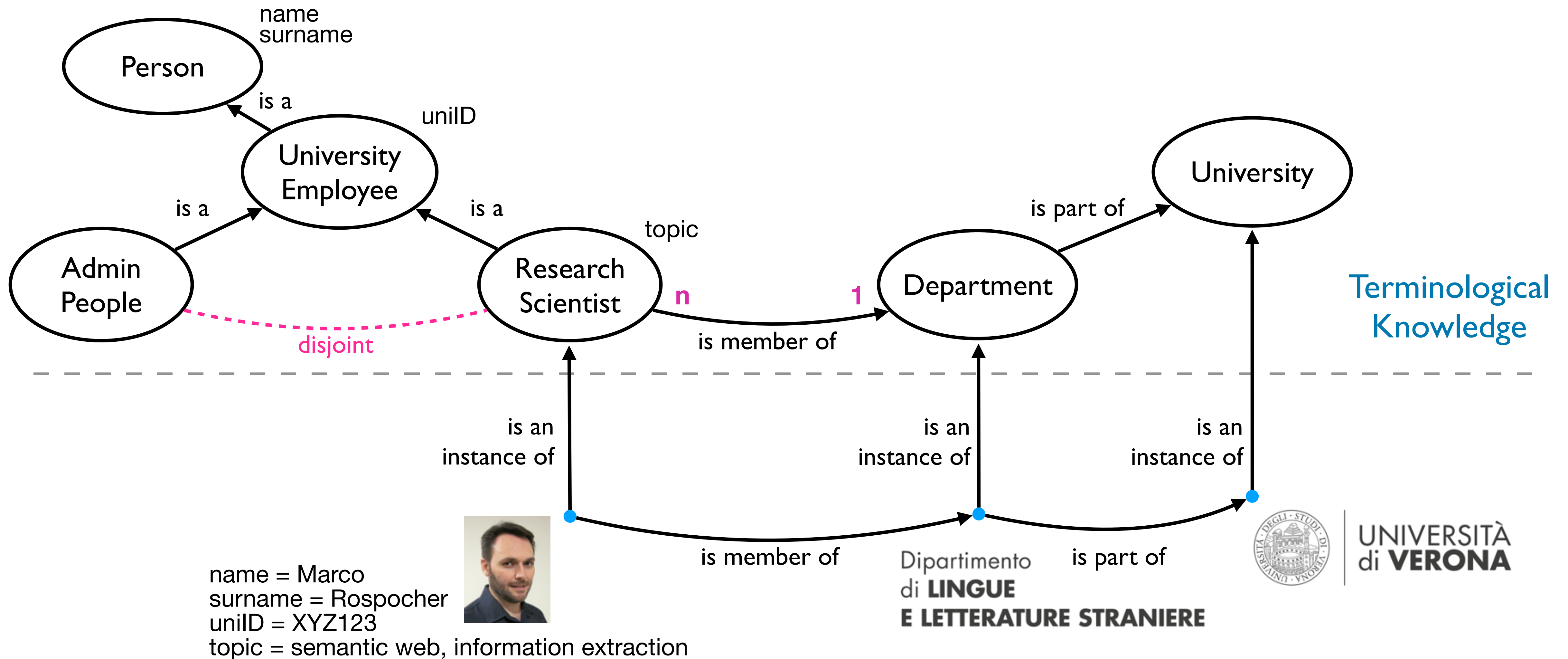
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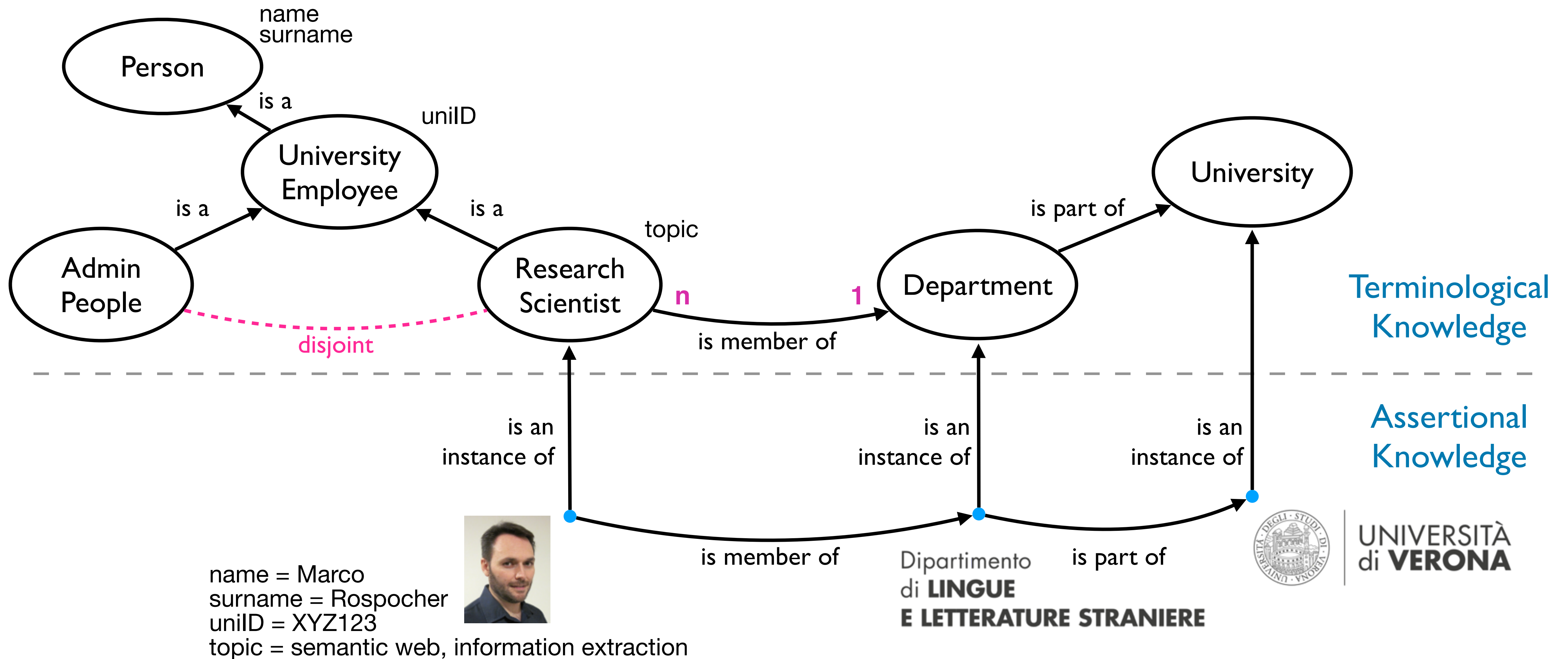
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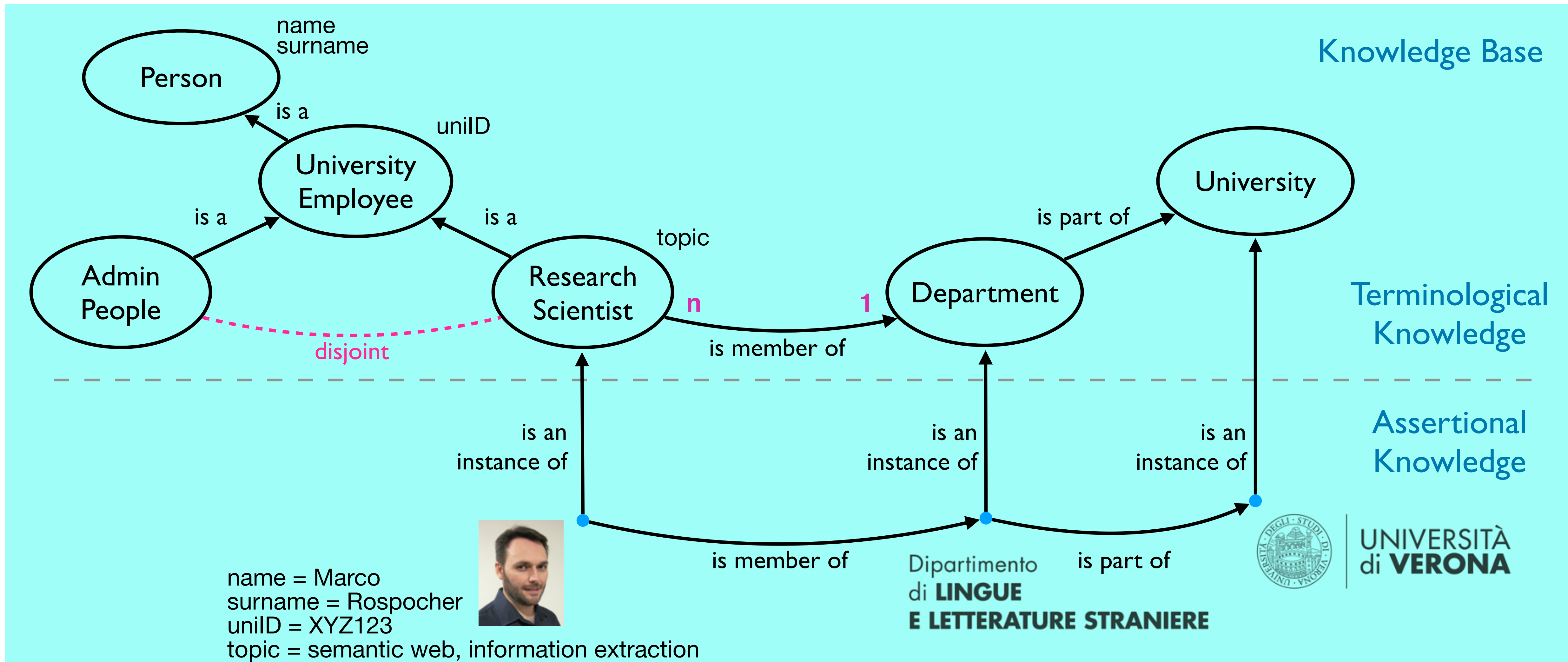
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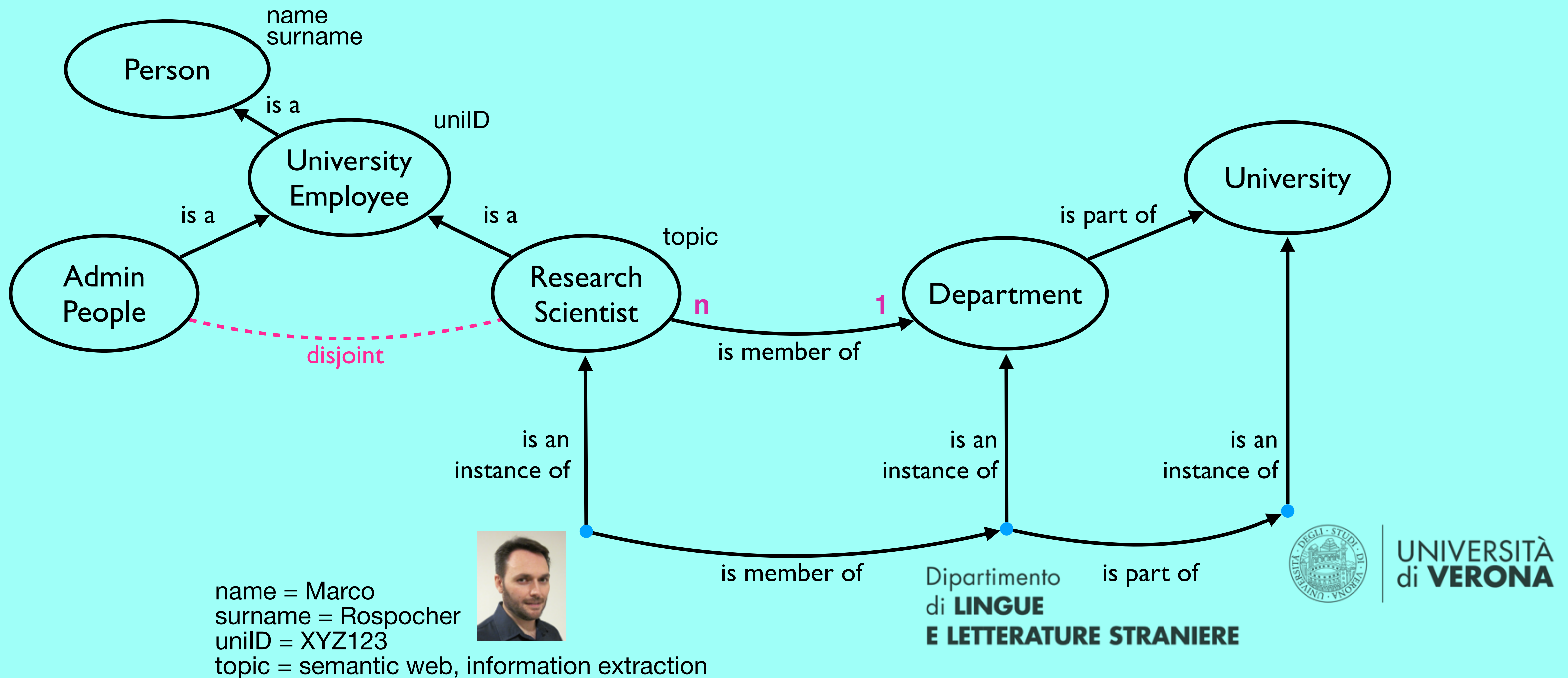


An ontology language: OWL

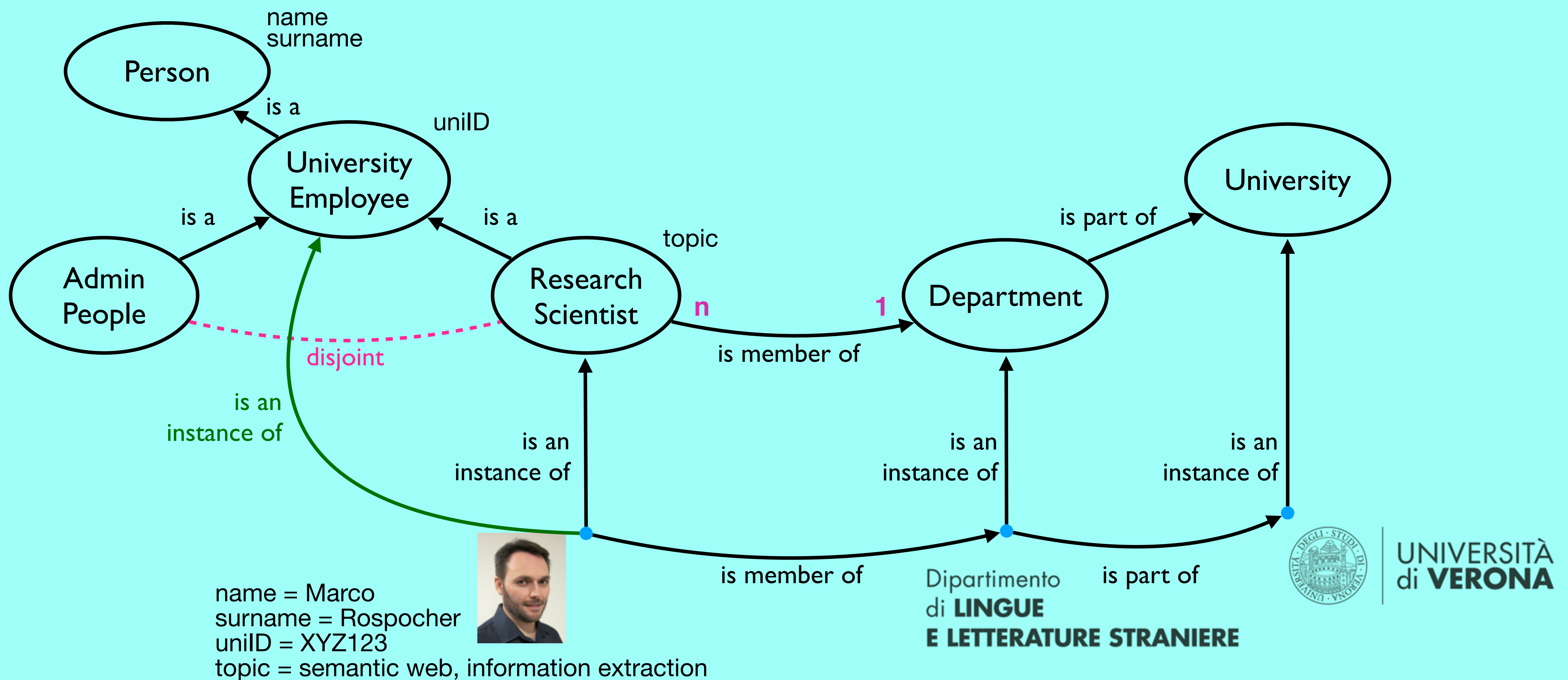


- <https://www.w3.org/OWL/>
- A language, with formally defined meaning, for developing ontologies
 - It provides the primitives for declaring classes, relations, individual, axioms, ...
 - It is a declarative language
- A computational logic-based language:
 - knowledge can be exploited by computer programs, e.g., to derive new (implicit) knowledge, to check the consistency of the available knowledge

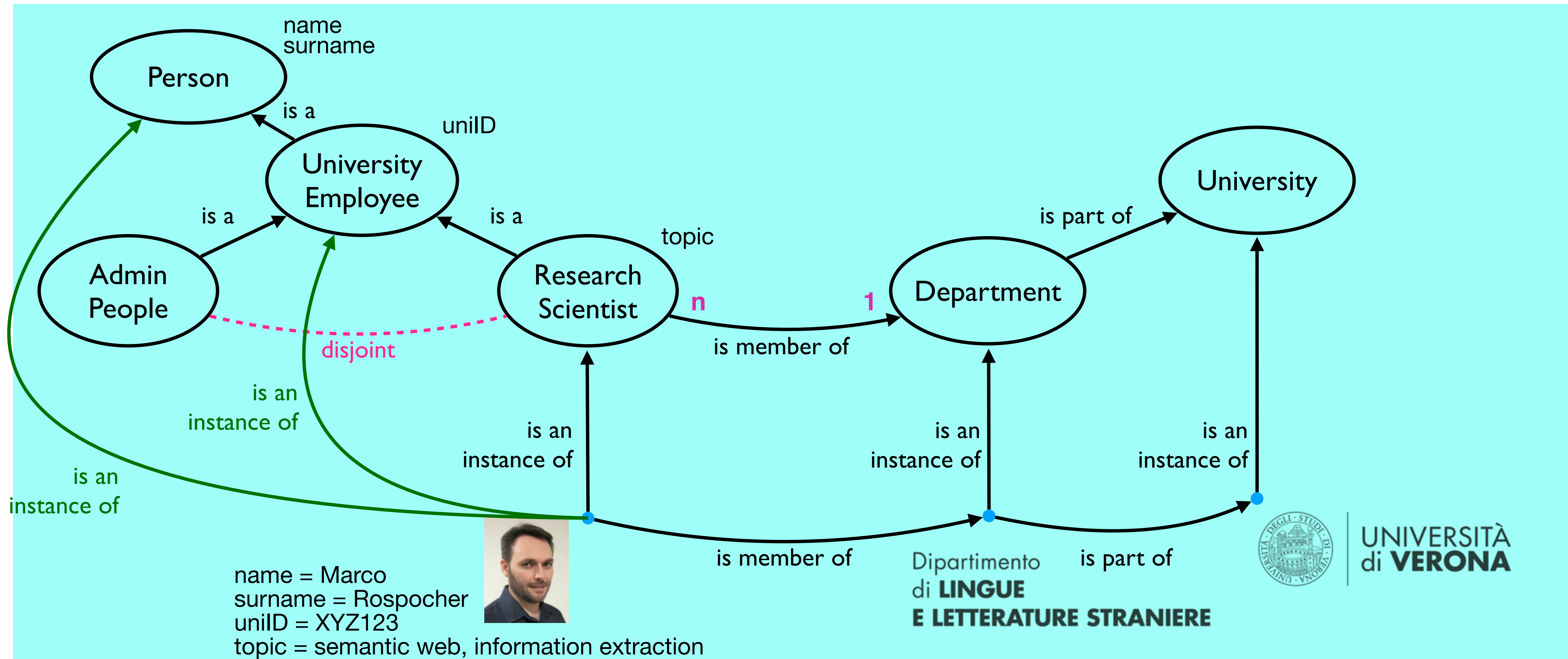
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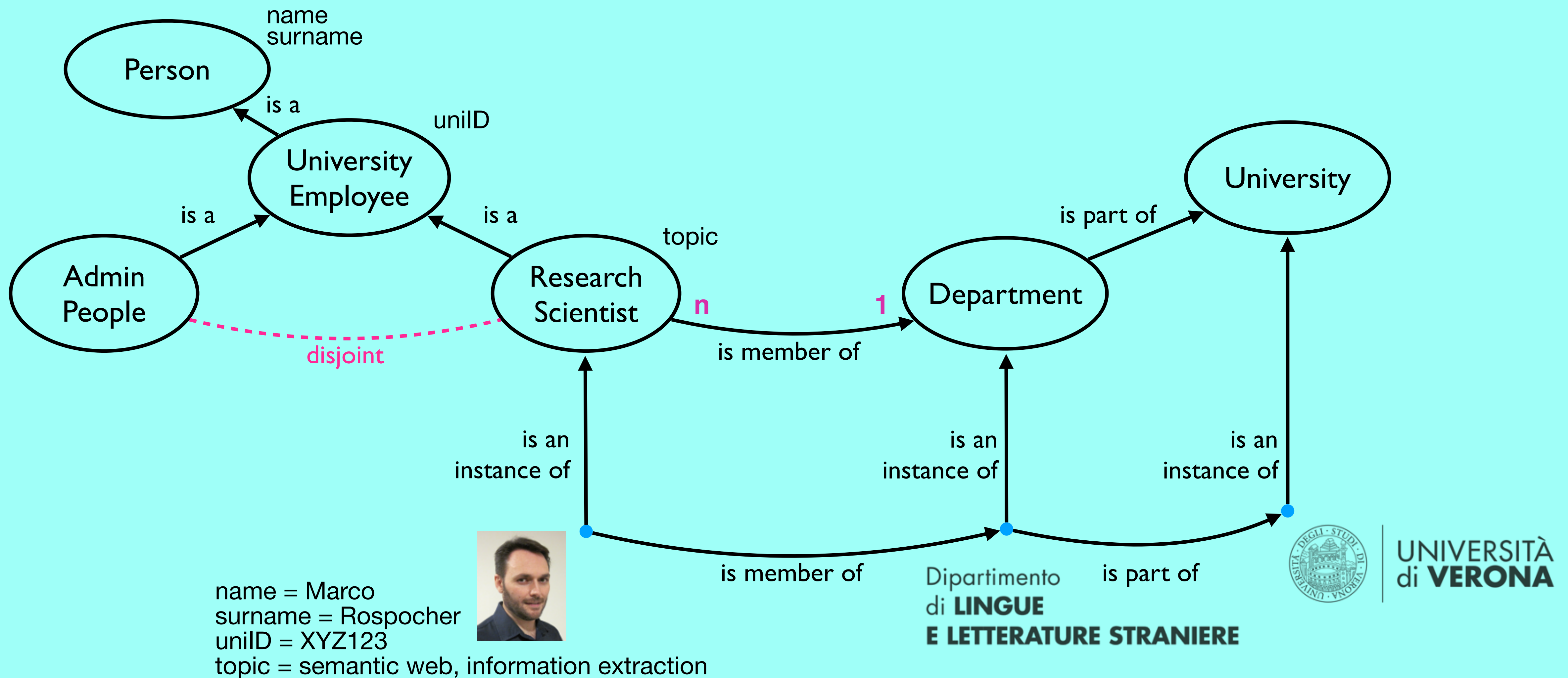
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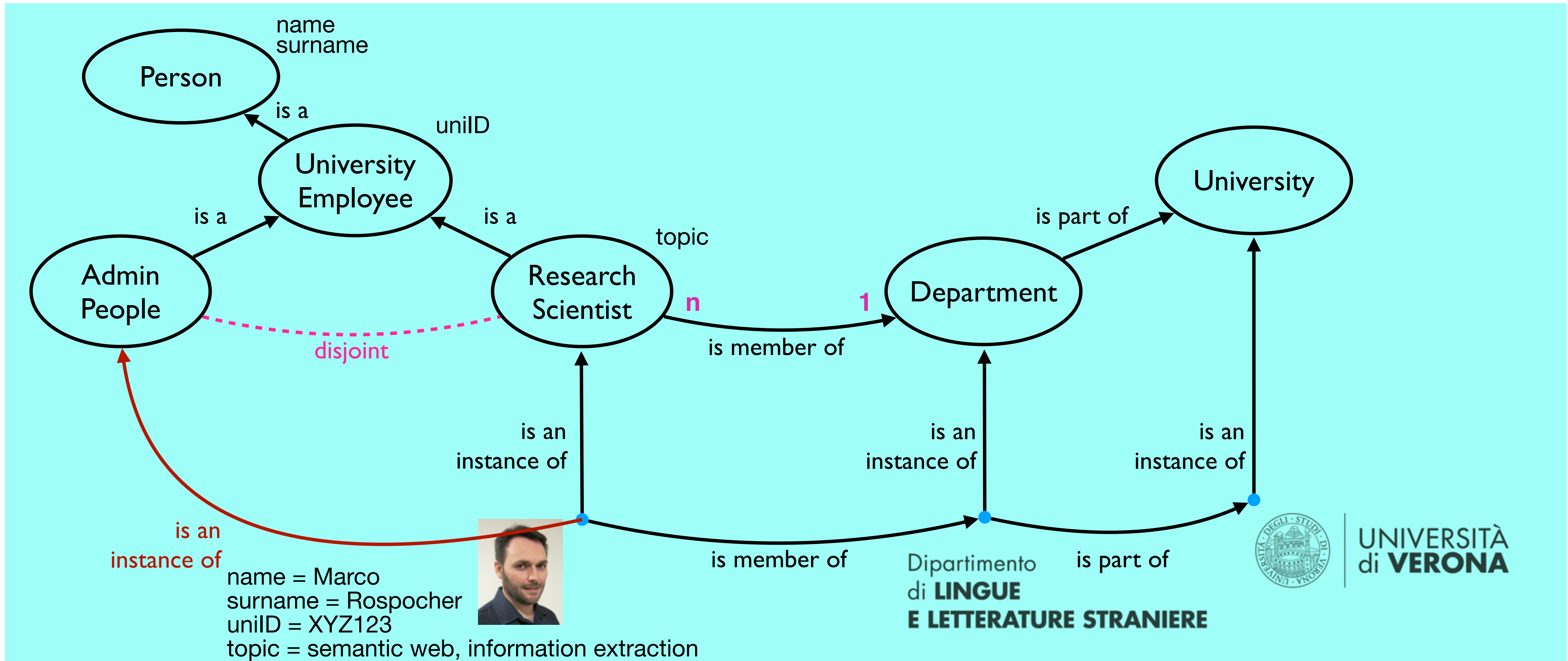
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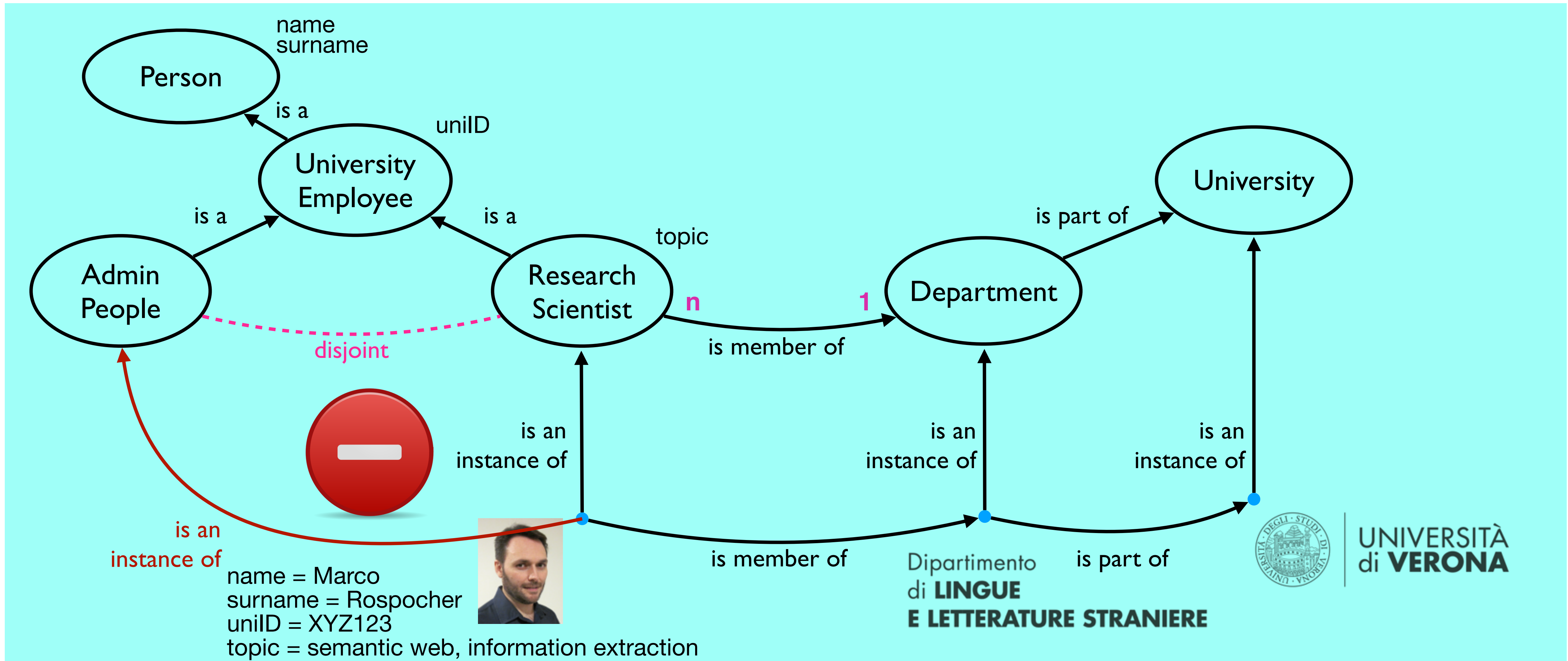
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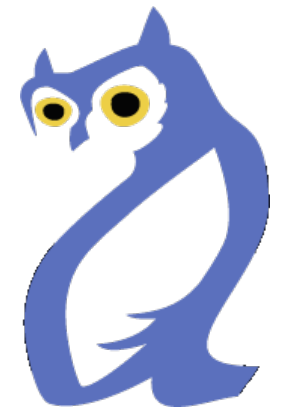
Ontology



Ontology



An ontology language: OWL



- Current version: OWL 2
 - Different profiles/fragments: OWL 2 EL, OWL 2 QL, OWL 2 RL \subseteq OWL 2 DL \subseteq OWL 2 Full
 - Formal semantics:
 - the Direct Semantics (OWL 2 DL): decidable
 - the RDF-Based Semantics (OWL 2 Full): undecidable
- Language developed for building ontologies for the Web (c.f., Semantic Web)
 - Open world assumption
 - NO unique name assumption

What could an ontology be useful for?

- To favour human and machine communication
- To favour programs and data interoperability
- To empower machines with human-like / commonsense reasoning capabilities
- To model the data of a given application
- To annotate data with precise semantics
- ...

- Ontologies enable the construction of intelligent information systems:
 - document / information retrieval applications
 - systems providing recommendations / decision support / personalised information
 - ...

Ontologies: some notable examples

- Many ontologies were developed for the biomedical / health domain
 - The **Disease Ontology**: <https://disease-ontology.org/>
 - “a standardized ontology for human disease with the purpose of providing the biomedical community with consistent, reusable and sustainable descriptions of human disease terms, phenotype characteristics and related medical vocabulary disease concepts”
 - **Gene Ontology (GO)**: <http://geneontology.org/>
 - “the world’s largest source of information on the functions of genes. This knowledge is both human-readable and machine-readable, and is a foundation for computational analysis of large-scale molecular biology and genetics experiments in biomedical research.”
 - **Foundational Model of Anatomy (FMA) Ontology**: <http://si.washington.edu/projects/fma>
 - “classes or types and relationships necessary for the symbolic representation of the phenotypic structure of the human body”

Ontologies: some notable examples

- **OntoSPM**: an ontology for **Surgical Process Models (SPM)**
 - <https://ontospm.univ-rennes1.fr/doku.php?id=ontology>
 - It formally defines: medical / surgical equipment, surgical procedure stage, action, ...
 - Based on the Basic Formal Ontology (BFO)
 - Built from existing ontological resources:
 - Information Artifacts Ontology (IAO)
 - Ontology of Biomedical Investigation (OBI)
 - Foundation Model of Anatomy (FMA)
 - Pathology (MPATH)
 - We will dig in it in a few minutes...

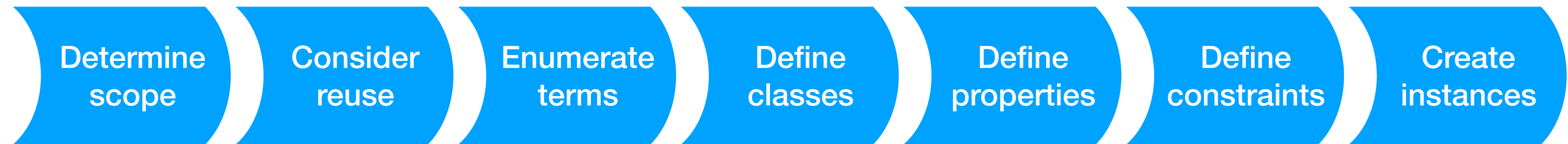
Commonsense knowledge ontologies

- **Cyc** (and OpenCyc / ResearcCyc): <http://www.cyc.com/>
 - “to assemble a comprehensive ontology and knowledge base that spans the basic concepts and rules about how the world works” (i.e., human common sense)
- **ConceptNet** (from Open Mind Common Sense): <https://conceptnet.io/>
 - “freely-available semantic network, designed to help computers understand the meanings of words that people use”
- Other knowledge bases / ontologies of **encyclopaedic** knowledge:
 - **DBpedia** (<https://www.dbpedia.org/>) / **YAGO** (<https://yago-knowledge.org/>) / **BabelNET** (<https://babelnet.org/>)

Building ontologies: a methodology

- Many methodologies for developing ontologies were proposed
- An example: **Ontology 101**

Noy, N. F. & McGuinness, D. L. (2001). *Ontology Development 101: A Guide to Creating Your First Ontology*



- It may look like a waterfall process, although in practice it is a more agile / iterative process

Building ontologies: a tool



- A free, open source ontology editor: <https://protege.stanford.edu/>
- Available in two versions:
 - Desktop application (installation required)
 - Online, web-based application (registration required)

Open questions

- What are the main challenges to face when developing a (commonsense) ontology?
- What kind of competences and skills are needed to build a (commonsense) ontology?
- How can the quality of a (commonsense) ontology be evaluated?

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Slides and Materials:

<https://bit.ly/MR-COSER2022>



github.com/rospocher/explicit-lyrics-detection/

KnowledgeStore

knowledgestore.fbk.eu



github.com/dkmfbk/TextOwl

MOKI

the Modelling Wiki ---

moki.fbk.eu

Hands-on Session



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Exercise: browsing an ontology

- OntoSPM: an ontology for Surgical Process Models (SPM)
 - Original version (with multiple ontology imports): <https://ontospm.univ-rennes1.fr/doku.php?id=ontology>
 - Download the (merged) versions available here: <https://bit.ly/MR-COSER2022>

Exercises

- What is the domain and what is the range of the property “**months**” (<http://medicis/spm.owl/OntoSPM#months>)? What about “**duration_description_of**” (http://medicis/spm.owl/OntoSPM#duration_description_of) property?
- Find all the classes (from the more specific one to the more general one) that are super classes of class “**liver**” (http://purl.obolibrary.org/obo/FMA_7197)
- Find all the siblings of class “**making_a_bandage**” (http://medicis/spm.owl/OntoSPM#making_a_bandage)
- Find all the subclasses of “**forceps**” (<http://medicis/spm.owl/OntoSPM#forceps>)
- How (and where) can you add a new typology of **needle** to the ontology?