# Ontologies and OWL

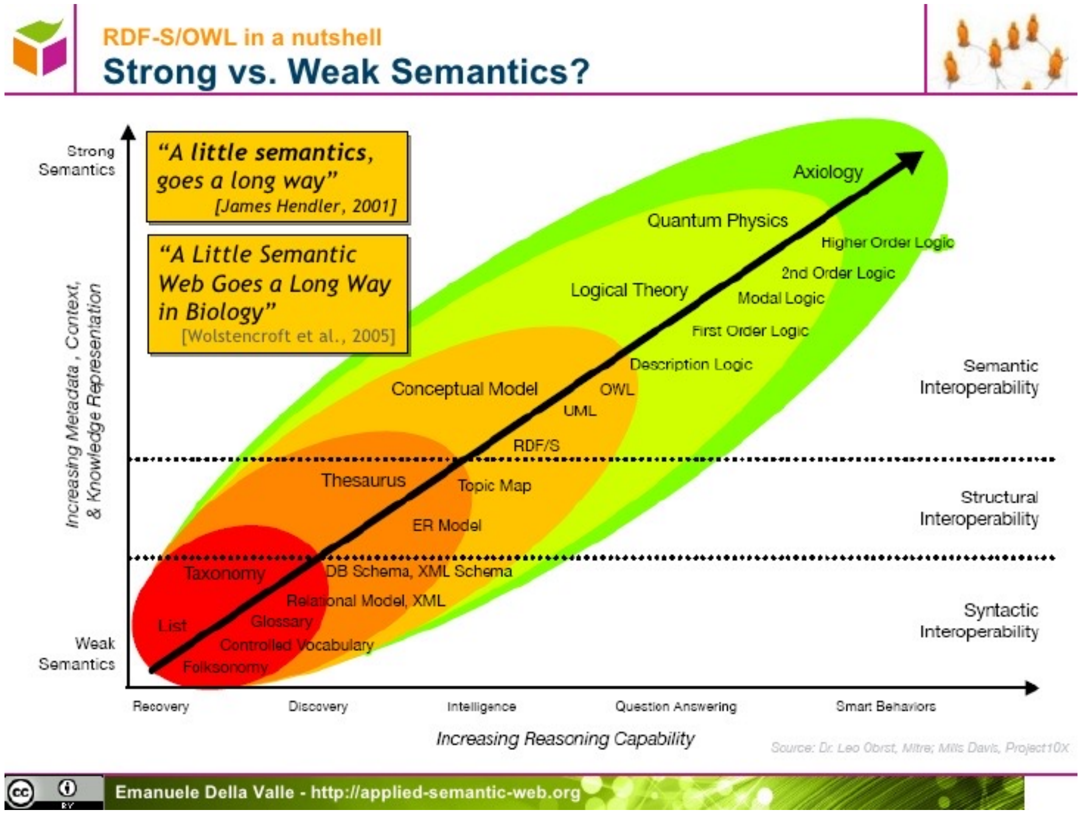
***Dr. Radu Mihailescu***

***Associate Professor***

# Recap

- Sharing knowledge requires embedding semantics with data
- RDF: graph model for knowledge
  - No type, no restrictions on terms
- RDFS: knowledge model extends RDF
  - Allows creating vocabularies (terminologies)
  - lacks means for details: no restriction on range and domain, no cardinality, other properties
- SKOS: builds on RDFS/RDF to create structured vocabularies
  - Taxonomies, thesauri…
  - Have limitations in expressiveness and reasoning
- Need for a language to express strong semantics

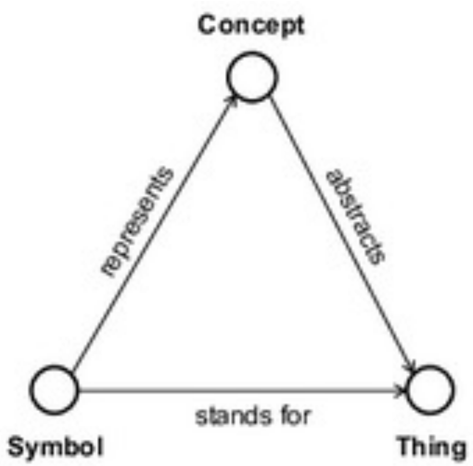
# Semantic spectrum

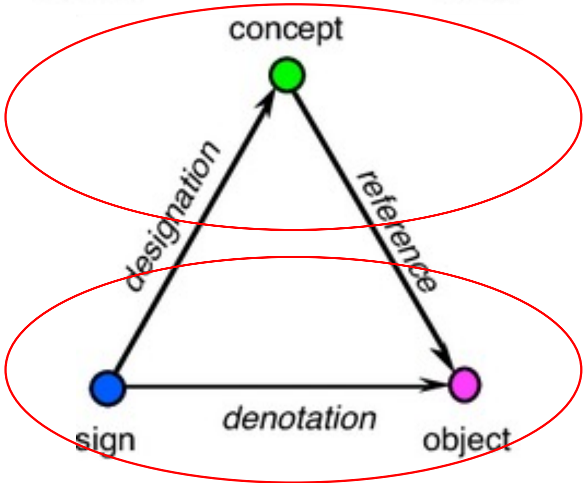


# What is an ontology

- **Metadata**
  - Data describing the content and meaning of resources and services
  - Requires parties to use the same terms
- **Terminologies**
  - Shared and common vocabularies
  - Used with search engines, software agents, librarians, authors…
  - Requires parties to use the same meaning
- **Ontologies**
  - Shared and common knowledge of a domain
  - Meant for exchange, search, and discovery

# The meaning triangle

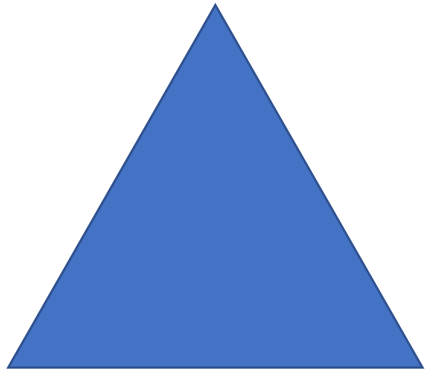



subjective

objective

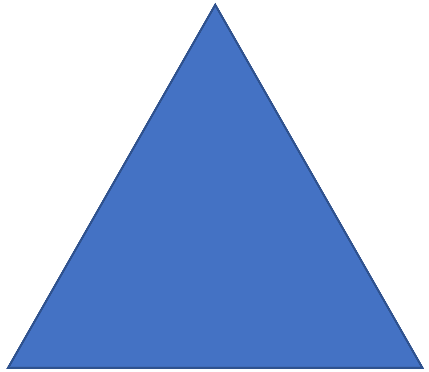
Thought



Symbol

Referent

(I would like to drink **camel** milk)



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# Ontology

- *An **explicit specification** of a **conceptualization** **(Gruber 1993)***
- An **ontology** describes the common words, concepts and relationships between concepts used to describe and represent knowledge in a specific domain
- The concept of ontology refers to different forms of knowledge representation, with weak to strong semantics
  - Taxonomy (structured vocabulary) – relational model
  - Thesaurus (words and synonyms) – entity relationship
  - Conceptual models (complex knowledge, concepts, properties, rules) - RDF/RDFS
  - Logical theory (rich complex consistent knowledge, axioms, inference rules) – OWL, Description Logic, First order logic
- An ontology is said to be well-formed if it is expressed in well-defined formalism that can be machine interpretable

# Ontology modelling

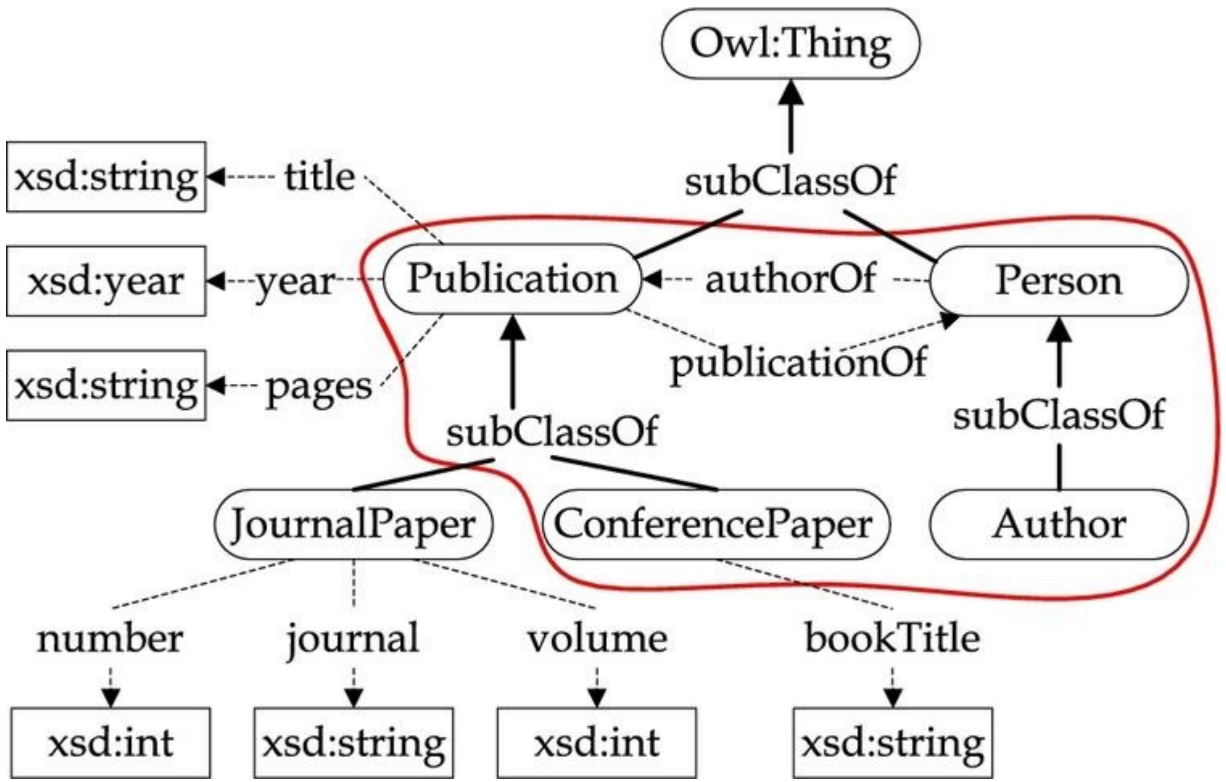
- Explicit description of a domain, in terms of
  - Concepts: classes, sets, types, predicates
  - Properties of concepts: attributes (named ***data properties***)
  - Relationships: relations between concepts (named ***object properties***)
  - Constraints (or axioms): constraints on properties and concepts such as type of values, range of values, cardinality…
  - Values: actual values, strings…
  - Individuals (instances): actual things, people, concepts…
- When ontology includes also individuals (actual data), it is called a knowledge base

# Relational Schema vs. Ontology

- Relational schema
  - Meant to organise data into databases
  - Relationships are implicit and require human or code to do the interpretation (semantics in the code or in the human mind)
  - Without semantics, no human or program can use the data in a meaningful way
- Ontology
  - Meant to share information along with semantics
  - Relationships defined formally (based on logical constructs)
  - Interpretation is possible by both human and machine

# Example

Simple ontology with informal representation



# Terminology

In semantic computing, we use two conventional terms:

- TBox
  - the ontology (knowledge model), with concepts and relationships…
- ABox
  - the data instances (individuals) as per the ontology

# OWL: Web Ontology Language

A knowledge  modelling language whose requirements are

- Extends existing Web standards: XML, RDF, RDFS
- Easy to understand and use: based on familiar KR idioms
- Formally specified - describes the meaning of knowledge precisely

- Having high expressive power
- Provides automated reasoning support

# OWL: what for?

- OWL is primarily concerned with defining terminology that can be used in RDF documents, i.e., classes and properties.
- OWL specifies the terminology in terms of classes and properties ad their characteristics
- Individuals (instances) can also be defined in an owl document

# Example of OWL

It is an RDF document

```
<rdf:RDF
    xmlns:owl ="http://www.w3.org/2002/07/owl#"
    xmlns:rdf ="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
    xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
    xmlns:xsd ="http://www.w3.org/2001/XMLSchema#">
```

Metadata about the ontology

```
    <owl:Ontology rdf:about="">
        <rdfs:comment>An example OWL ontology</rdfs:comment>
        <owl:imports rdf:resource="http://www.mydomain.org/persons"/>
        <rdfs:label>University Ontology</rdfs:label>
    </owl:Ontology>
```

Hierarchy of classes

```
    <owl:Class rdf:ID="academicStaffMember"></owl:Class>
    <owl:Class rdf:ID="associateProfessor">
        <rdfs:subClassOf rdf:resource="#academicStaffMember"/>
     </owl:Class>
     …
</rdf:RDF>
```

# Another example

```
<!DOCTYPE rdf:RDF [
   <!ENTITY owl "http://www.w3.org/2002/07/owl#">]>
<rdf:RDF xmlns:owl ="http://www.w3.org/2002/07/owl#"
      xmlns:rdf ="http:/,            )/02/22-rdf-syntax-ns#"
      xmlns:rdfs="http:/,            )/01/rdf-schema#">
```

Namespaces

```
<owl:Ontology rdf:about="">
   <rdfs:label>My Ontolo         el>
   <rdfs:comment>An example ontology</rdfs:comment>
</owl:Ontology>
```

metadata

```
<owl:Class rdf:ID="Person" />
<owl:Class rdf:ID="Man">
   <rdfs:subClassOf rdf:resource="#Person" />
</owl:Class>
```

Class hierarchy

```
<owl:ObjectProperty rdf:ID="hasChild" />
<owl:ObjectProperty rdf:ID="hasDaughter">
   <rdfs:subPropertyOf rdf:resource="#hasChild" />
</owl:ObjectProperty>
```

Object property hierarchy

Data property

```
<owl:DatatypeProperty rdf:ID="age" />
```

Object property

```
<owl:ObjectProperty rdf:ID="isParentOf">
   <owl:inverseOf rdf:resource="#isChildOf"
</owl:ObjectProperty>
```

Object property

```
<owl:ObjectProperty rdf:ID="isTallerThan">
   <rdf:type rdf:resource="&owl;TransitivePr
</owl:ObjectProperty>
```

Object property

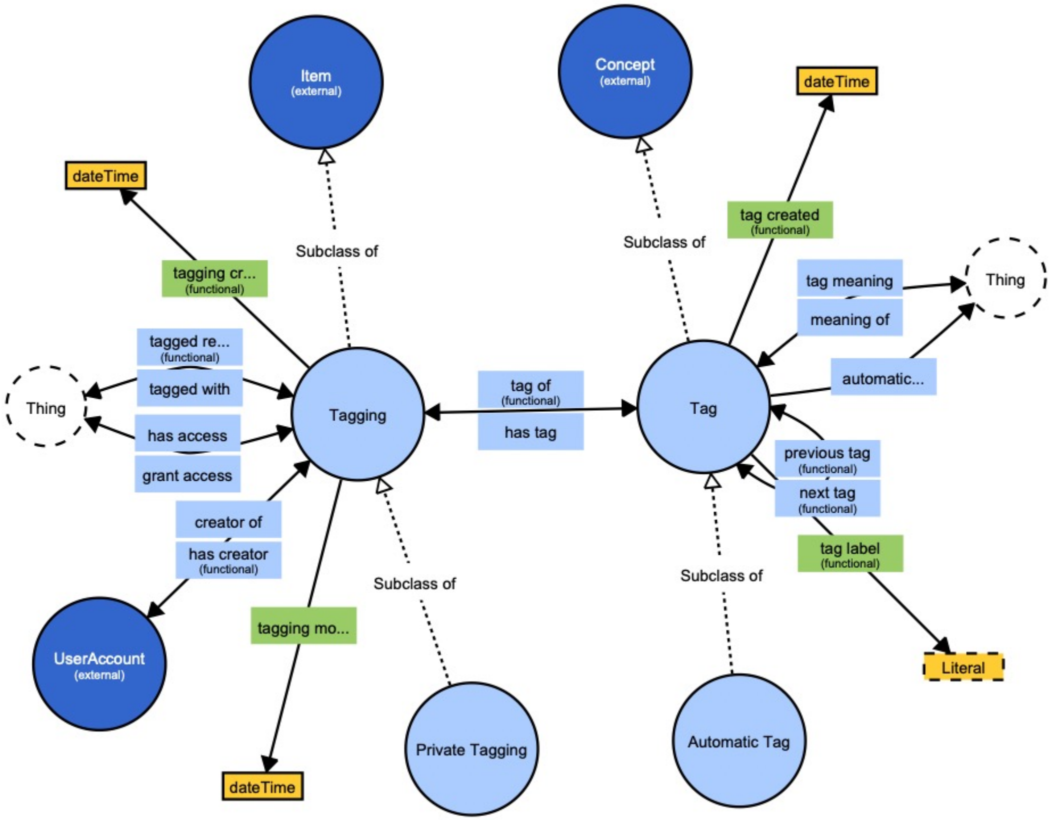
```
<owl:ObjectProperty rdf:ID="isFriendOf">
   <rdf:type rdf:resource="&owl;SymmetricPro
</owl:ObjectProperty>
```

Object property with its own characteristics

```
<owl:ObjectProperty rdf:ID="hasSSN">
   <rdf:type rdf:resource="&owl;FunctionalProperty" />
   <rdf:type rdf:resource="&owl;InverseFunctionalProperty" />
</owl:ObjectProperty
</rdf:RDF>
```

# VOWL Representation

Defines a visual language for the user-oriented representation of ontologies.




Graphical primitives used in VOWL

| Primitive | Application | Primitive | Application |
|---|---|---|---|
| | classes | | datatypes, property labels |
| | properties | | special classes/properties |
| | property directions | text<br>number<br>symbol | labels, cardinalities |

Excerpt of the VOWL color scheme

| Name | Color | Application |
|---|---|---|
| General | | classes, object properties, disjointness |
| External | | external classes and properties |
| Deprecated | | deprecated classes and properties |
| Datatype | | datatypes, literals |
| Datatype property | | datatype properties |
| Highlighting | | circles, rectangles, lines, borders, arrows |

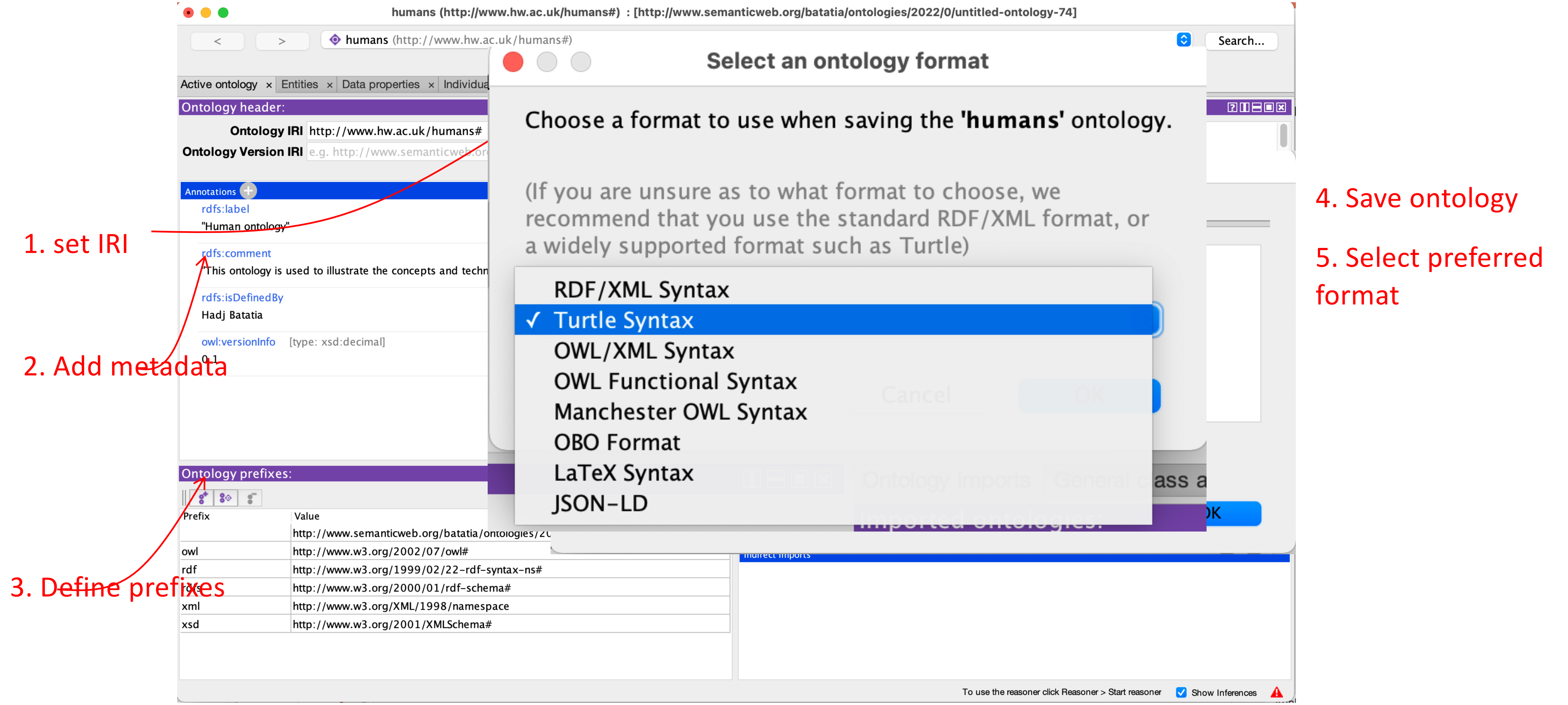
# Reasoning with OWL

- Consistency checking: No contradictions
  - ABox does not contradict TBox (instances compliant with ontology)
- Concept satisfiability: possibility of adding individuals from class
  - Can a class have individuals?
- Classification: create full inheritance hierarchy to answer questions
  - Does class A subsumes class B?
- Realisation: compute the direct type (class) of each individual
  - What class does individual X belongs to?
  - Realisation can be done after classification as we need the full inheritance hierarchy

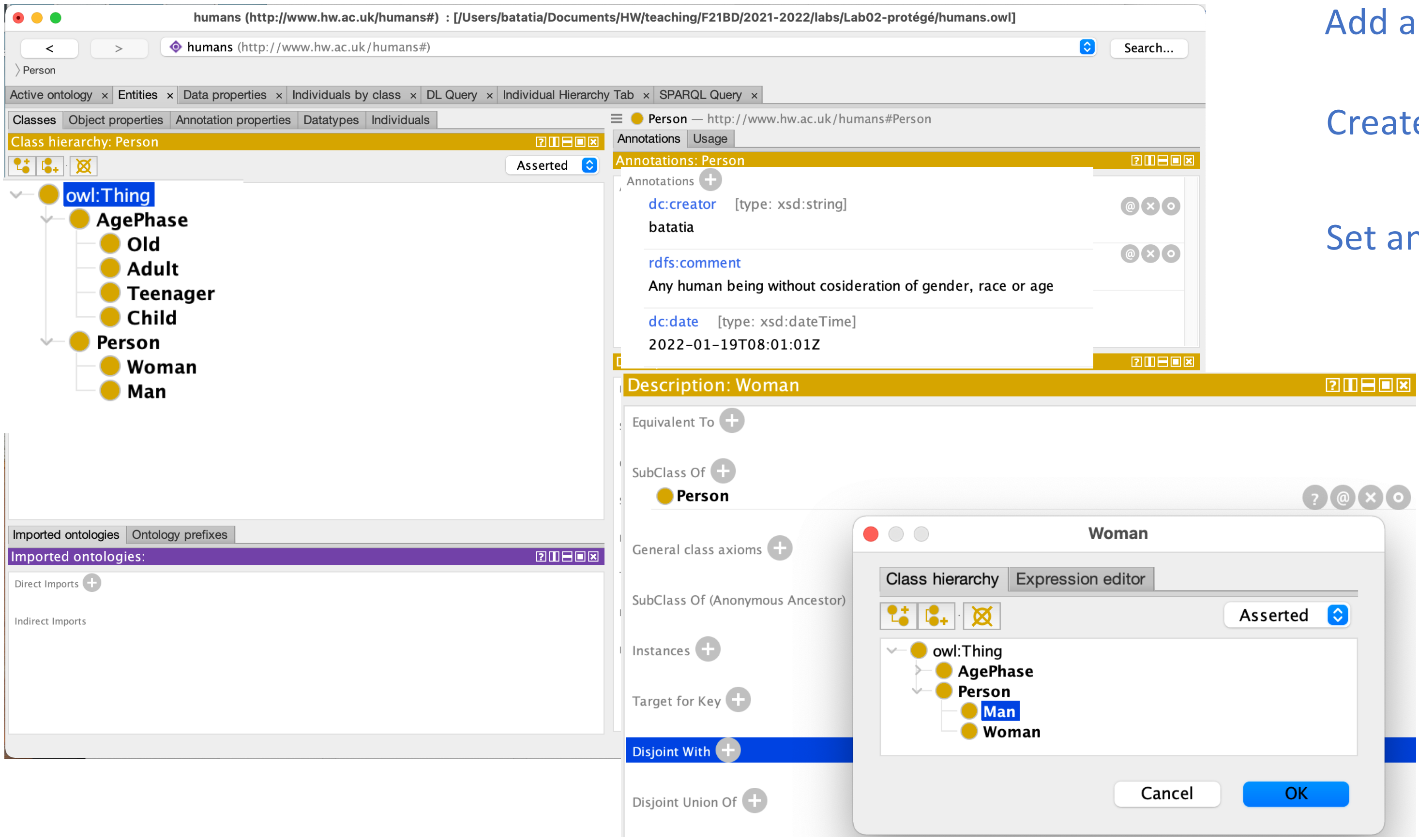
# Protégé

- Protégé is an open source ontology editor using OWL
- It allows creating through a graphical user interface all components of the ontology
- Can be downloaded freely from https://protege.Stanford.edu
- It provides a number of views to suit the need of the user at different stages of the ontology engineering process

# 1. Creating an ontology



# 2. Create class hierarchy




Use meaningful names

Add annotations to each class

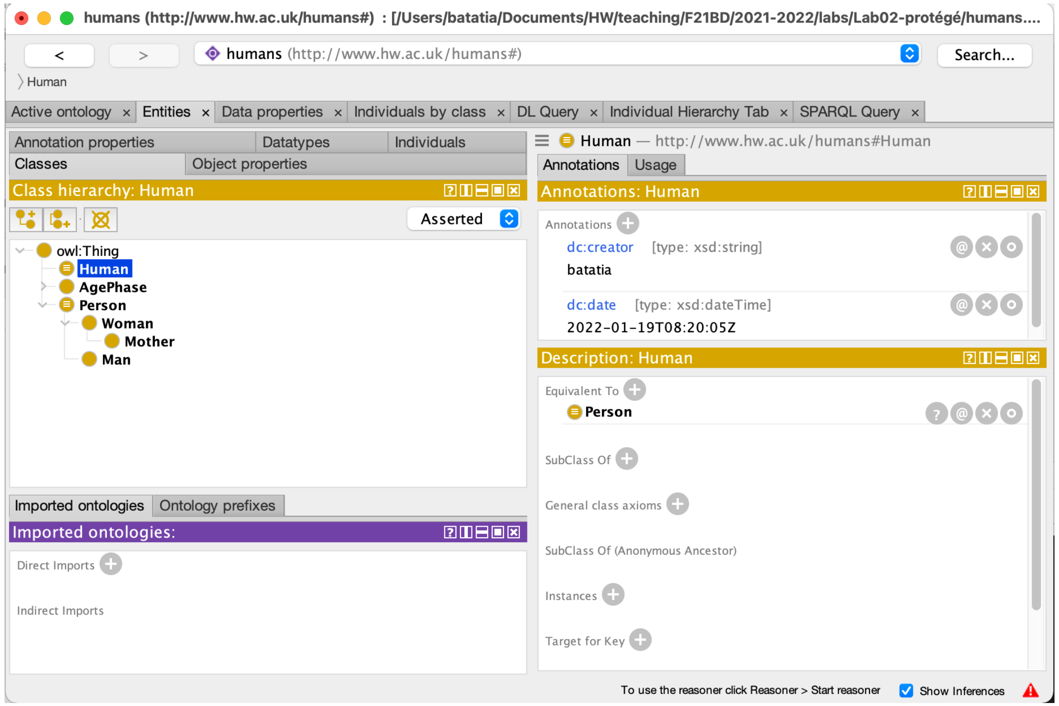
Create a hierarchy

Set any class characteristics, example disjoint

# owl:equivalentClass

- Two classes that refer to the same things
- Written in Turtle format

:Human owl:equivalentClass :Person



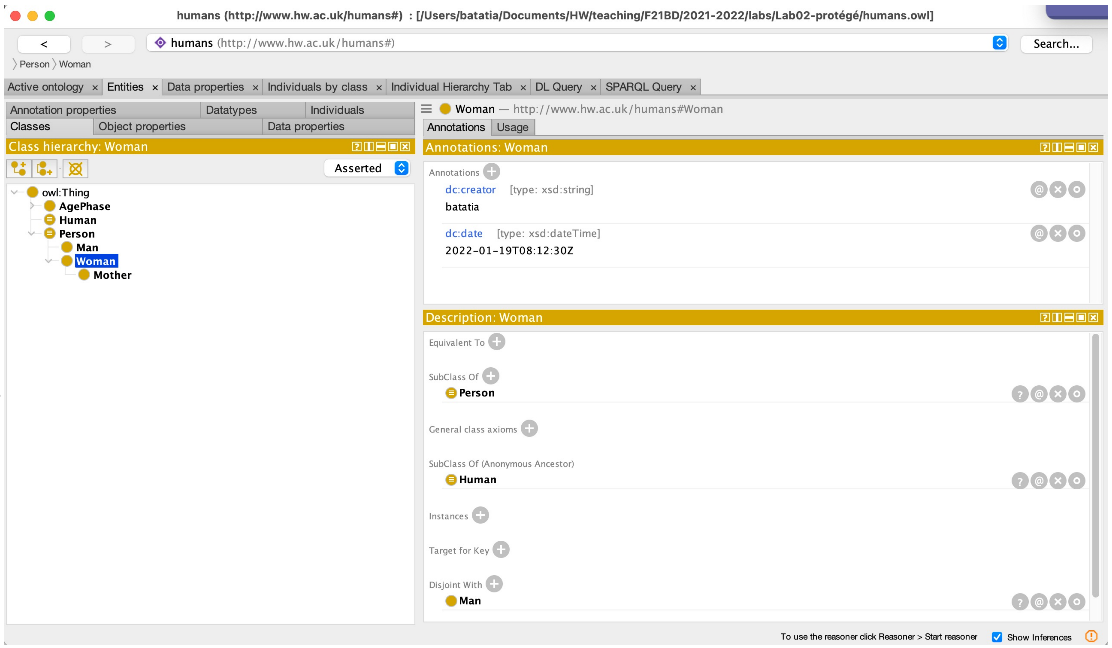
# Disjoint classes

- When individuals cannot belong to two classes, these classes are declared disjoint

:Man owl:disjointWith :Woman ;

- We can also make one class disjoint from a list of classes, this gives in turtle (a collection):

[ rdf:type owl:AllDisjointClasses ; owl:members ( :C1 :C2 :C3 ) ] .

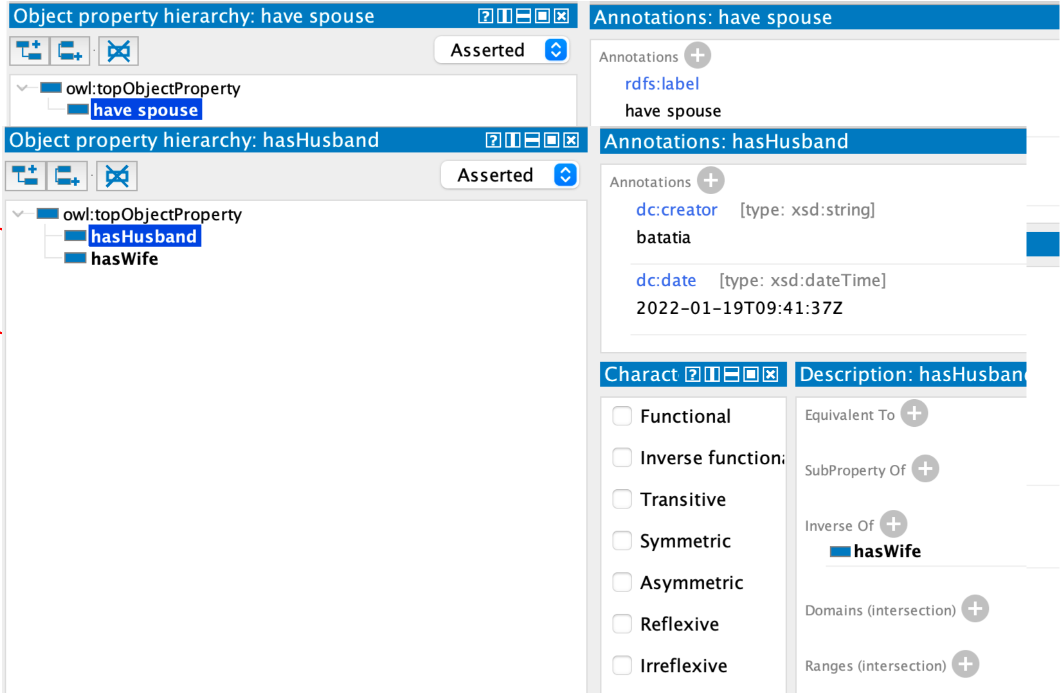


# 3. Create object properties (relationships)

- Use verbs to avoid ambiguity with classes
- Add any characteristics

```
:marriedTo a rdf:Property.
```

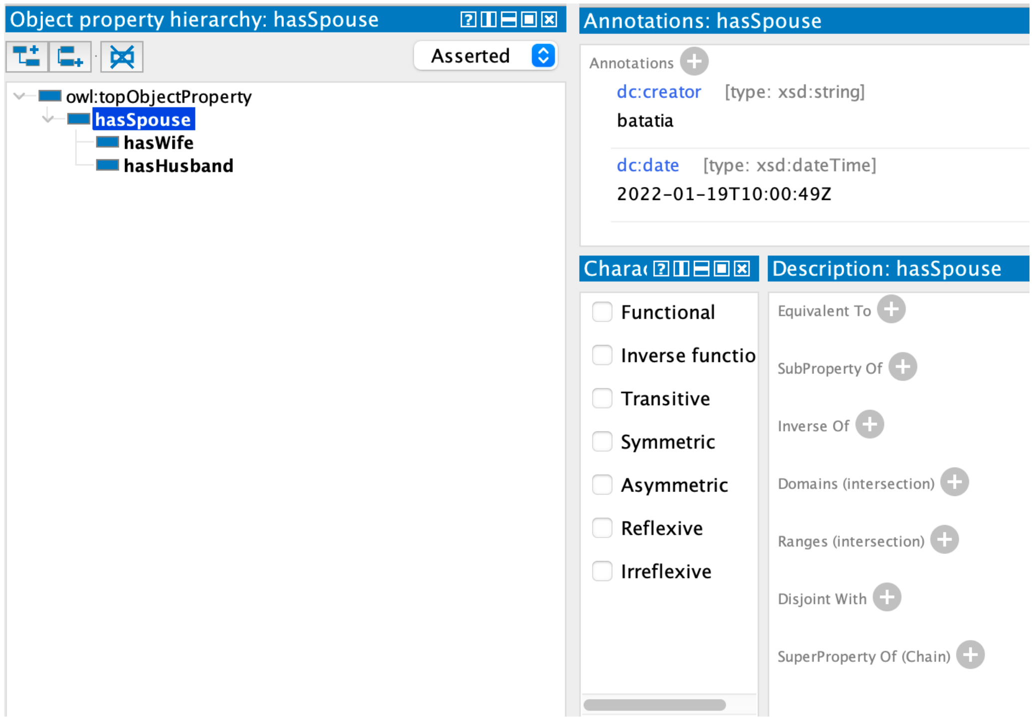
- Add :hasHusband
- Make it inverse of :hasWife



# Property hierarchy

- Properties can be in a hierarchy
- Example

:hasWife rdfs:subPropertyOf :hasSpouse .



# Domain and range

- Restrict the type of subject and object for a property
- Example

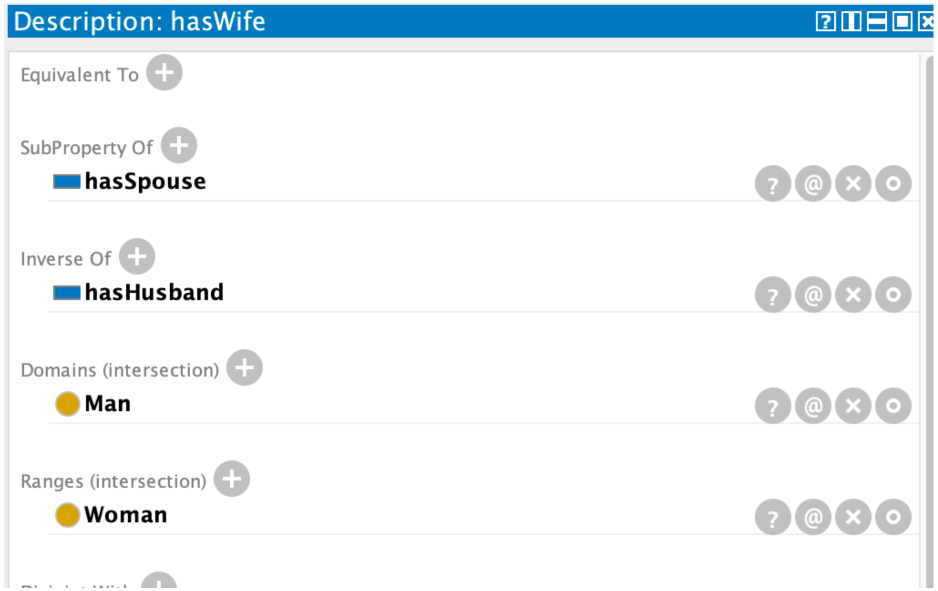
:hasWife rdf:type owl:ObjectProperty ;

rdfs:subPropertyOf :hasSpouse ;

rdf:type owl:AsymmetricProperty ;

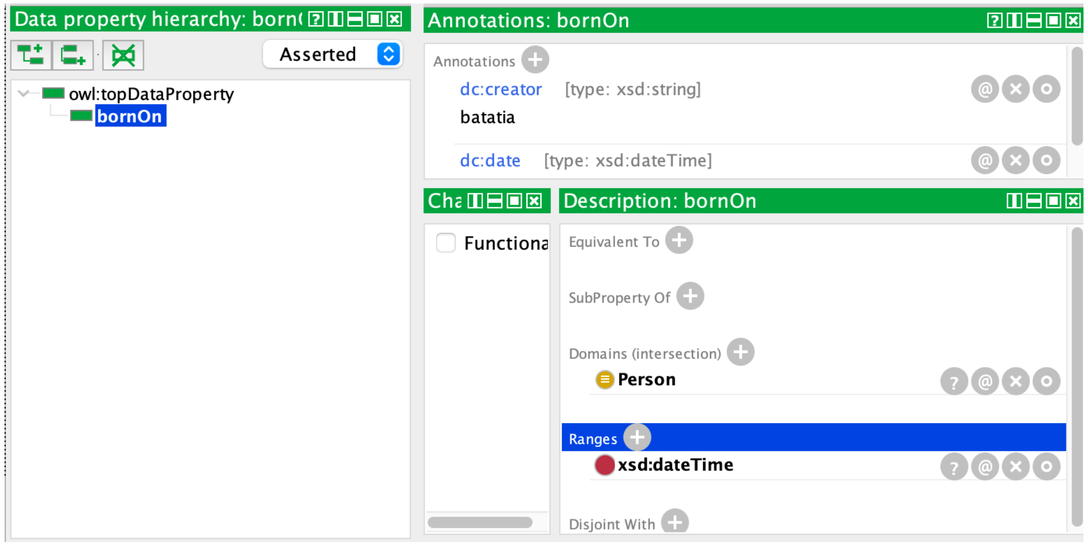
rdfs:domain :Man ;

rdfs:range :Woman.



# 4. Data properties

- These are attributes to describe individuals from classes
- Example




```
###  http://www.hw.ac.uk/humans#bornOn
:bornOn rdf:type owl:DatatypeProperty ;
        rdfs:domain :Person ;
        rdfs:range xsd:dateTime ;
        <http://purl.org/dc/elements/1.1/creator> "batatia"^^xsd:string ;
        <http://purl.org/dc/elements/1.1/date> "2022-01-19T10:10:38Z"^^xsd:dateTime .
```

# 5. Add individuals

- Add individuals (instances)
- Define their type (class)

:Mary rdf:type owl:NamedIndividual :Woman ;

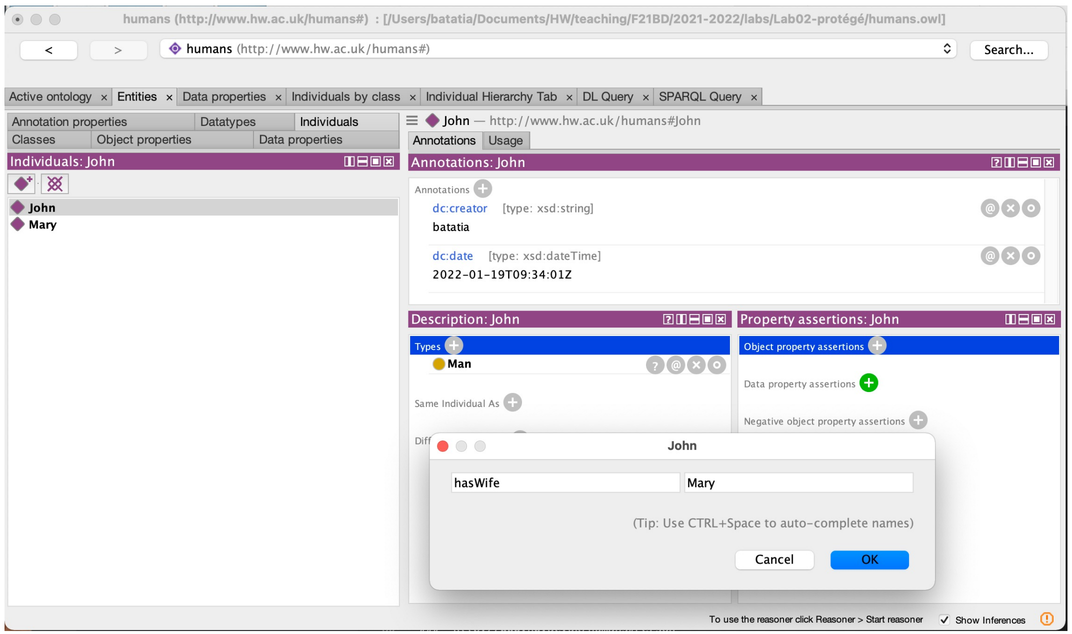
- Assert their properties

    :John :hasWife :Mary;

- No need to assert that

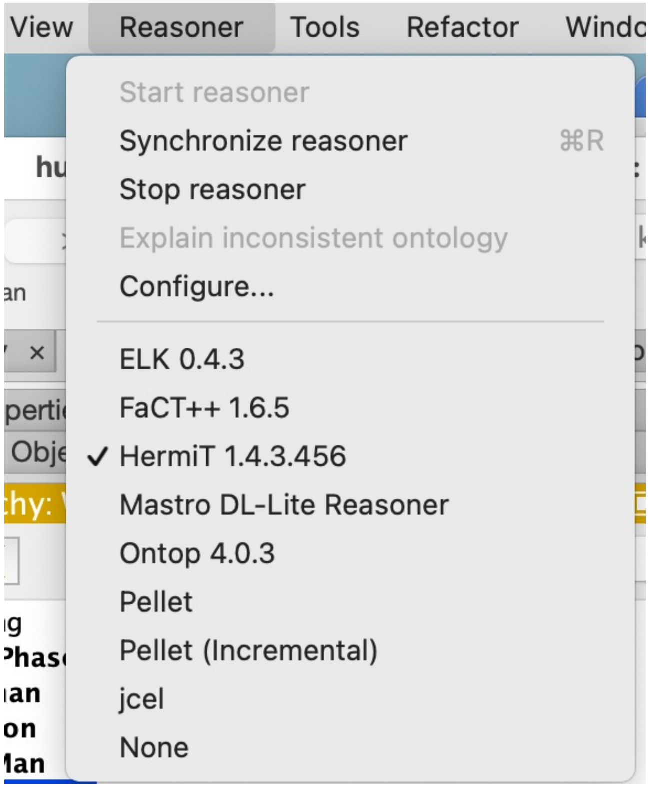
:Mary :hasHusband :John;

- It will be discovered by reasoner…

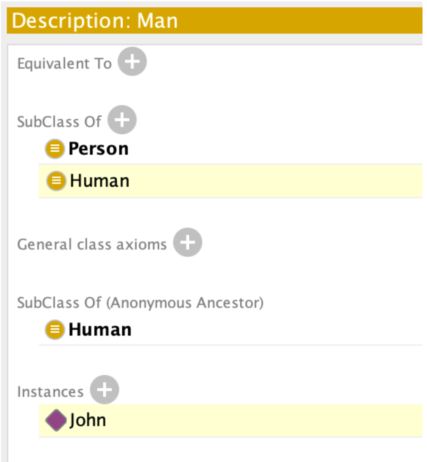


# Protégé: using a reasoner

- A reasoner is an algorithm that applies local inference to discover
  - Inconsistencies (any contradiction)
  - Subsumptions (class inheritance)
  - Realisations (individuals of classes)
- By applying class and property characteristics (inverseOf, symmetric…), find new relationships

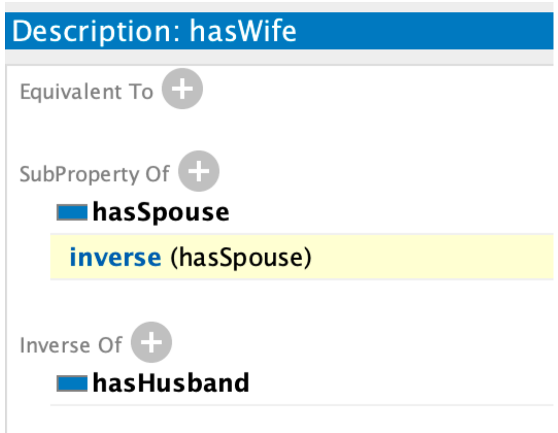


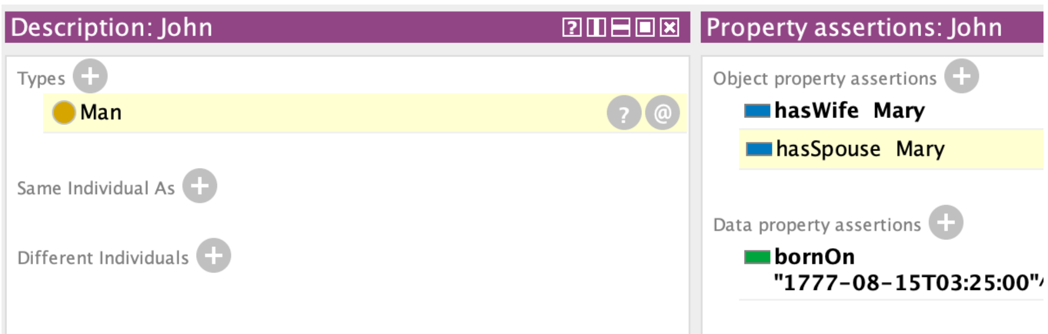
# Inferred information in yellow



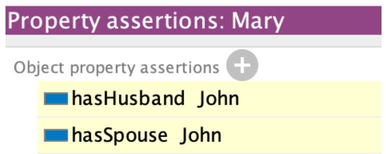

Class Man

Property hasWife




Individual John




Individual Mary

# Principles when creating an ontology

- There exists no unique perfect knowledge model for a domain
  - The model should serve your application
- An ontology cannot be created at once
  - An iterative process is required to refine the ontology multiple times to consider various use cases
- Classes and properties should be as close as possible to the real/physical objects of your domain
  - Consider nouns for classes and verbs for properties

# Process of creating an ontology

1. Determine scope and domain of ontology
2. Consider reusing existing ontologies
3. Enumerate important terms in the ontology
4. Define the classes and class hierarchy
5. Define the properties of classes
   - Properties:
6. Relationships
7. Define restrictions on properties
   - Value type (String, Number, Boolean, Enumerated, Instance)
   - Value cardinality
8. Define the instances

# Ontology Development Process

*determine scope* | *consider reuse* | *enumerate terms* | *define classes* | *define properties* | *define constraints* | *create instances*

*In reality - an iterative process:*

*determine scope* | *consider reuse* | *enumerate terms* | *consider reuse* | *define classes* | *enumerate terms* | *define classes*

*define properties* | *define classes* | *define properties* | *define constraints* | *create instances* | *define classes* | *create instances*

*consider reuse* | *define properties* | *define constraints* | *create instances*

# Rules for FAIR vocabularies (deployment)

1. *Provide a license that allows repurposing*
2. *Determine the content governance arrangements*
3. *Check minimal term definition completeness*
4. *Select a domain and service for the web identifiers, i.e. a namespace*
5. *Design an identifier schema and pattern*
6. *Create a semantic-standards based vocabulary – **Interoperability***
7. *Add rich metadata – **Reusability***
8. *Register the vocabulary, e.g. with LOV – **Findability***
9. *Make the IRIs resolve – **Accessibility***
10. *Implement a process for maintaining the vocabulary*

# Semantic-standards compliant vocabulary

1. Identify terms
2. Encode term labels and synonyms
3. Add textual definitions
4. Add notes or comments for clarifications
5. Add codes and symbols
6. Define the hierarchy of terms
7. Encode relationships
8. Define subsets
9. Define and document the whole vocabulary

# Next

Advanced

**OWL**