RDF and RDF Schema

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Main References

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Capítulo 4: Ontology languages

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Jena tutorials: *http://www.ibm.com/developerworks/xml/library/j-jena/index.html*
http://www.xml.com/pub/a/2001/05/23/jena.html

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SPARQL tutorials: *http://jena.sourceforge.net/ARQ/Tutorial/*
http://www.w3.org/2004/Talks/17Dec-sparql/intro/all.html
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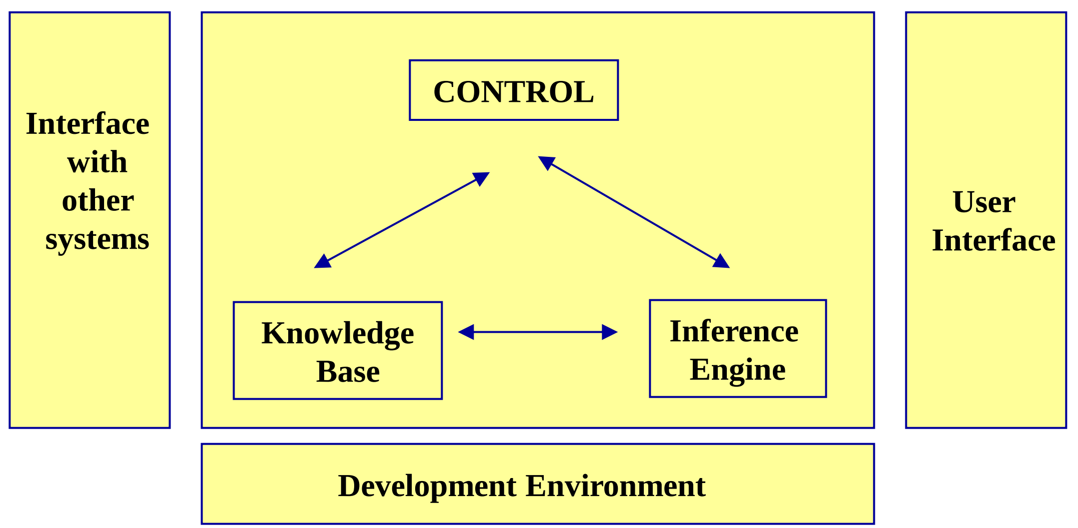
Common Architecture of a Knowledge-based System

Other interacting systems:
- Databases
- ...



- Explanation
- Knowlege capture

- Knowledge-based system generation tools
- Programming languages

Knowledge Representation Formalisms. A Summary

- **Knowledge representation**
  - To store knowledge so that programs can process it and achieve the verisimilitude of human intelligence
- **Knowledge representation formalisms/techniques**
  - Originated from theories of human information processing.
  - Since knowledge is used to achieve intelligent behavior, the fundamental goal of knowledge representation is to represent knowledge in a manner as to facilitate inferencing i.e. drawing conclusions from knowledge.
  - Some examples are:
    - First order logic
    - Semantic networks and conceptual maps
    - Frames
    - Description logic
    - Production rules
    - Fuzzy logic
    - Bayesian networks
    - Etc.

These are the ones that we will analyse

First order logic. Basic elements

We can establish mappings between logical symbols and domain objects (universe of discourse)

Constants / *First order logic*	*Set theory* / **Universe of discourse**
•a →	**•Socrates**
•b →	**•Plato**
•c →	**•Aristotle**

Predicate symbols

First order logic	*Set theory*
•h →	**person = {Socrates, Plato, Aristotle}**
•m →	**mortal = {Socrates, Plato, Aristotle}**
•t →	**masterOf = {(Socrates, Plato), (Plato, Aristotle)}**

Formulae

First order logic	*Set theory*
$\forall x\, (h(x) \rightarrow m(x))$ →	**person** $\subset$ **mortal**
$\exists x\, \exists y\, (h(x) \wedge h(y) \wedge t(x, y))$ →	**masterOf** $\neq \emptyset$ **in the domain of persons**
$h(a) \wedge h(b) \wedge h(c)$ →	**Socrates, Plato, Aristotle** $\in$ **person**

First order logic. Formalisation

- **Se tiene un robot que distribuye paquetes en oficinas. Se sabe que:**
  - Los paquetes de la habitación 27 son más pequeños que los de la habitación 28.
  - Todos los paquetes de la misma habitación son del mismo tamaño.
  - En un instante concreto el robot sabe que:
    - i) El paquete A está en la habitación 27 ó 28 (pero no sabe en cuál).
    - ii) El paquete B está en la habitación 27.
    - iii) El paquete B no es más pequeño que el A.
  - El robot quiere probar que el paquete A está en la habitación 27.

First order logic. Formalisation. Solution

- **Se tiene un robot que distribuye paquetes en oficinas. Se sabe que:**
  - Los paquetes de la habitación 27 son más pequeños que los de la habitación 28.

    $\forall x\ \forall y\ (paquete(x) \wedge situadoEn\ (x,h27) \wedge paquete(y) \wedge situadoEn\ (y,h28) \rightarrow menor(x,y))$
  - Todos los paquetes de la misma habitación son del mismo tamaño.

    $\forall x\ \forall y\ \forall h\ (paquete(x) \wedge paquete(y) \wedge habitacion(h) \wedge situadoEn\ (x,h) \wedge situadoEn\ (y,h) \rightarrow igual(x,y))$
  - En un instante concreto el robot sabe que:
    - i) El paquete A está en la habitación 27 ó 28 (pero no sabe en cuál).

      $paquete(a) \wedge habitacion(h27) \wedge habitacion(h28) \wedge (situadoEn(a,h27) \vee situadoEn(a,h28))$
    - ii) El paquete B está en la habitación 27.

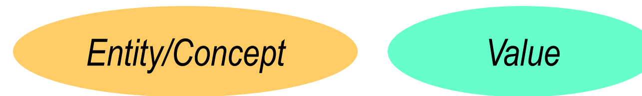
      $paquete(b) \wedge situadoEn(b,h27)$
    - iii) El paquete B no es más pequeño que el A.

      $\neg menor(b,a)$
  - El robot quiere probar que el paquete A está en la habitación 27.

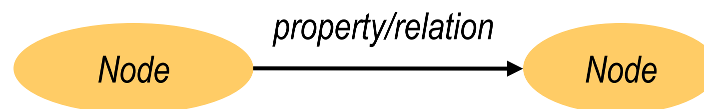
    ¿$situadoEn(a,h27)$?

Semantic Network. Basic elements

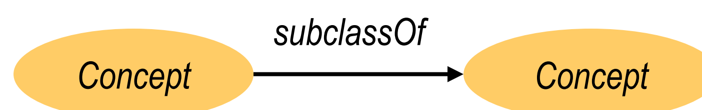
- **Nodes**
  - They represent entities or concepts, or values



- **Edges**
  - They represent properties or relations



- **The semantics (mapping to the real world) depends on the tags used for nodes and edges**
- **There is no predefined KR vocabulary**
  - Although sometimes there are *structural* edges

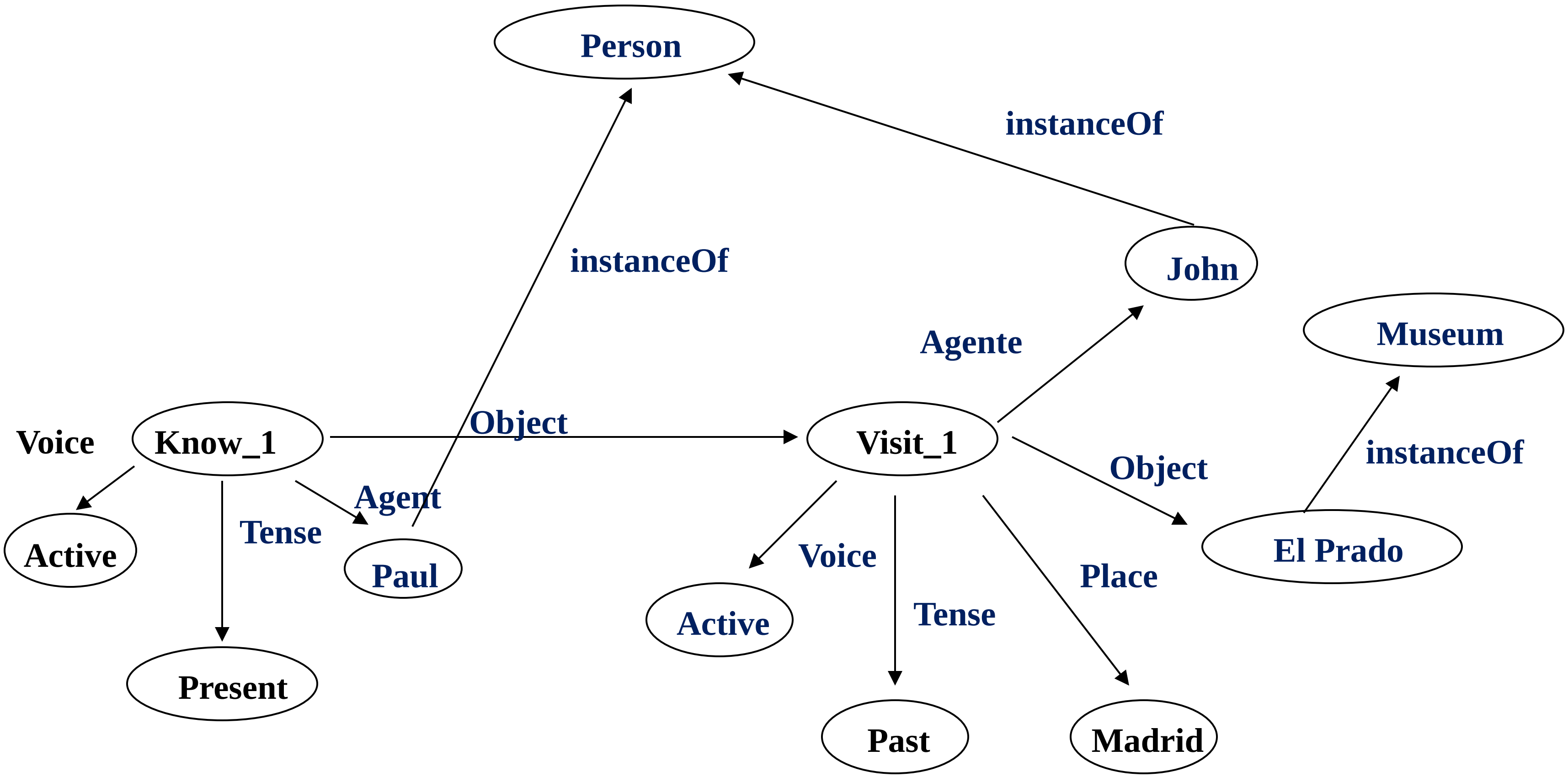


Semantic networks. Example

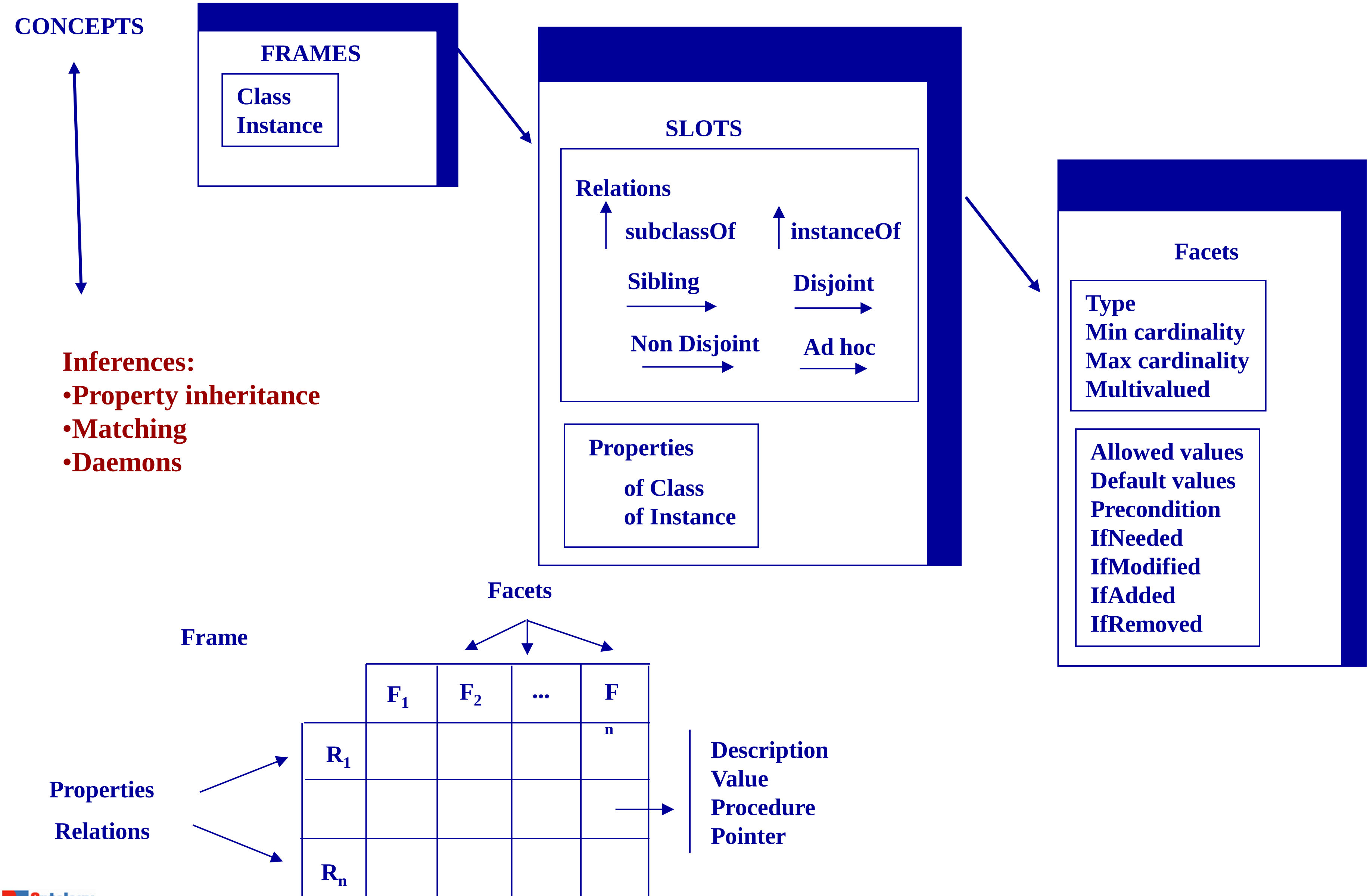
- **Paul and John are persons**
- **El Prado is a museum**
- **Paul knows that John visited El Prado in Madrid**

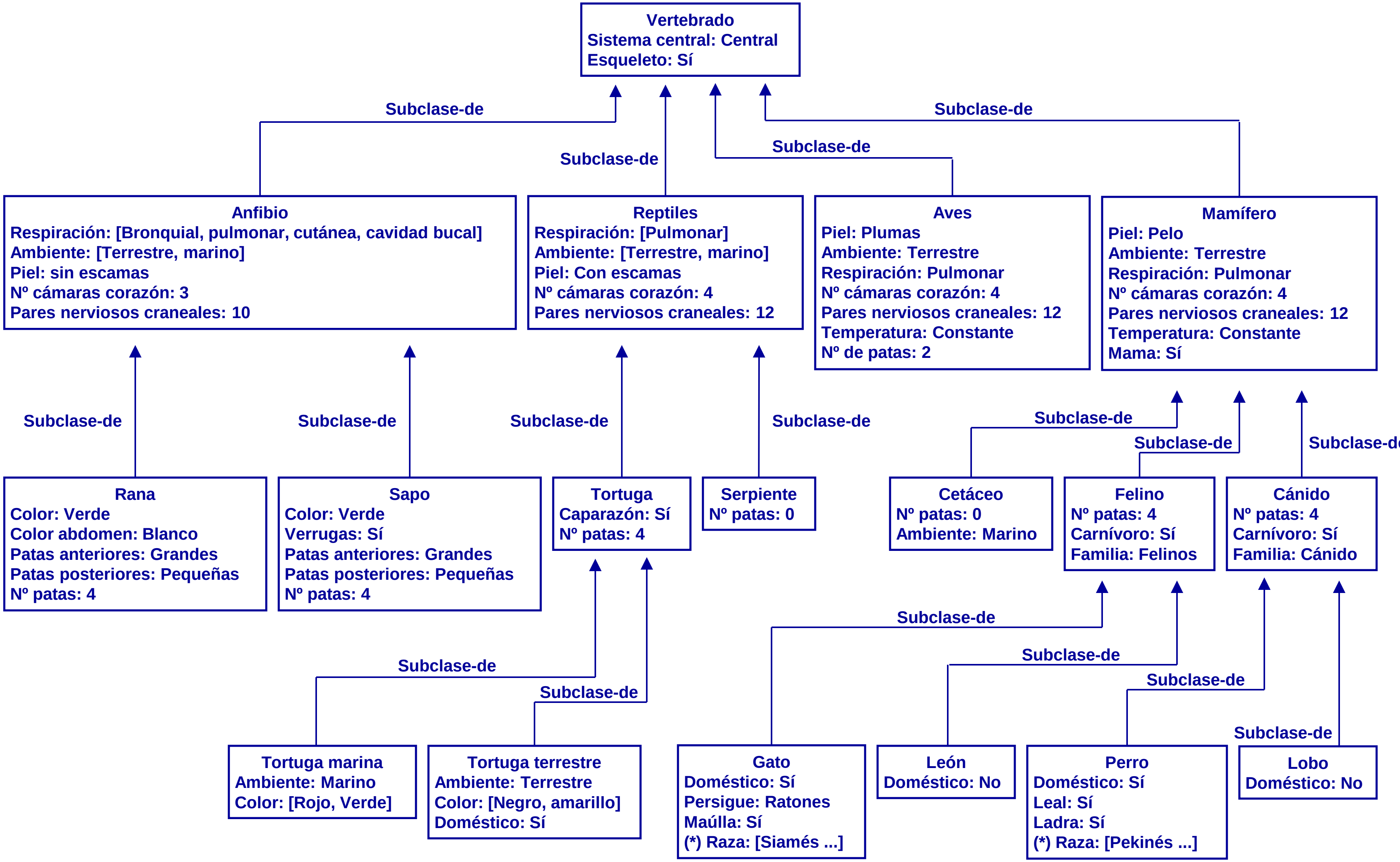
Semantic networks. Example. Solution

- Paul and John are persons
- El Prado is a museum
- Paul knows that John visited El Prado in Madrid



Frames. Basic elements





Vertebrado
Sistema central: Central
Esqueleto: Sí
Subclase-de
Subclase-de
Subclase-de
Subclase-de
Anfibio
Respiración: [Bronquial, pulmonar, cutánea, cavidad bucal]
Ambiente: [Terrestre, marino]
Piel: sin escamas
Nº cámaras corazón: 3
Pares nerviosos craneales: 10
Reptiles
Respiración: [Pulmonar]
Ambiente: [Terrestre, marino]
Piel: Con escamas
Nº cámaras corazón: 4
Pares nerviosos craneales: 12
Aves
Piel: Plumas
Ambiente: Terrestre
Respiración: Pulmonar
Nº cámaras corazón: 4
Pares nerviosos craneales: 12
Temperatura: Constante
Nº de patas: 2
Mamífero
Piel: Pelo
Ambiente: Terrestre
Respiración: Pulmonar
Nº cámaras corazón: 4
Pares nerviosos craneales: 12
Temperatura: Constante
Mama: Sí
Subclase-de
Subclase-de
Subclase-de
Subclase-de
Subclase-de
Subclase-de
Subclase-de
Rana
Color: Verde
Color abdomen: Blanco
Patas anteriores: Grandes
Patas posteriores: Pequeñas
Nº patas: 4
Sapo
Color: Verde
Verrugas: Sí
Patas anteriores: Grandes
Patas posteriores: Pequeñas
Nº patas: 4
Tortuga
Caparazón: Sí
Nº patas: 4
Serpiente
Nº patas: 0
Cetáceo
Nº patas: 0
Ambiente: Marino
Felino
Nº patas: 4
Carnívoro: Sí
Familia: Felinos
Cánido
Nº patas: 4
Carnívoro: Sí
Familia: Cánido
Subclase-de
Subclase-de
Subclase-de
Subclase-de
Subclase-de
Subclase-de
Tortuga marina
Ambiente: Marino
Color: [Rojo, Verde]
Tortuga terrestre
Ambiente: Terrestre
Color: [Negro, amarillo]
Doméstico: Sí
Gato
Doméstico: Sí
Persigue: Ratones
Maúlla: Sí
(*) Raza: [Siamés ...]
León
Doméstico: No
Perro
Doméstico: Sí
Leal: Sí
Ladra: Sí
(*) Raza: [Pekinés ...]
Lobo
Doméstico: No

Frames. Example

- **Men and women are persons**
- **A person can be married to another person**
- **Nobody can be a man and a woman at the same time**
- **John, Paul and Michael are men**
- **Mary and Anne are women**
- **John is married to Mary**
- **Paul is married to Anne**

Frames. Example

- Men and women are persons
- A person can be married to another person
- Nobody can be a man and a woman at the same time
- John, Paul and Michael are men
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- John is married to Mary
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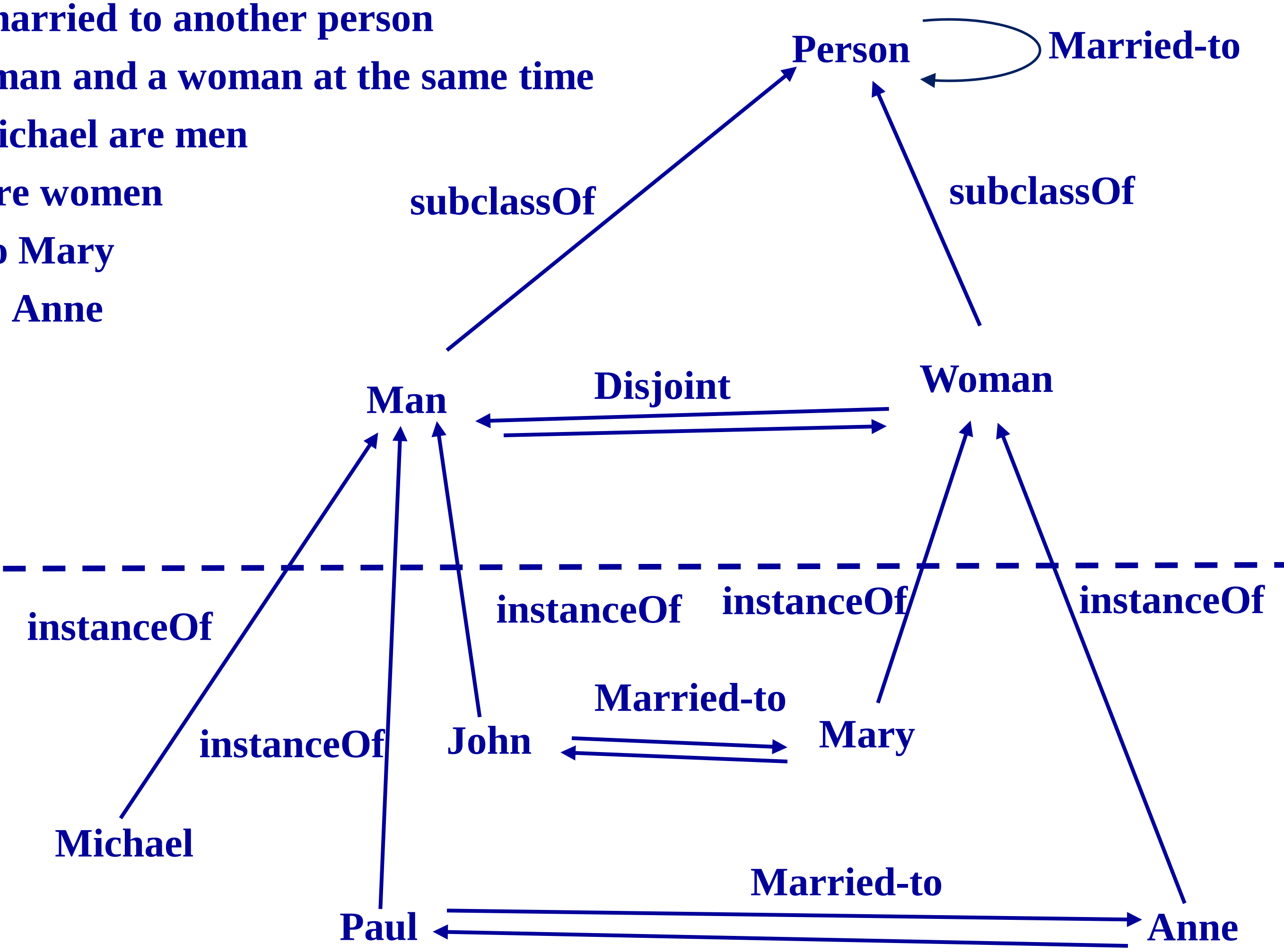
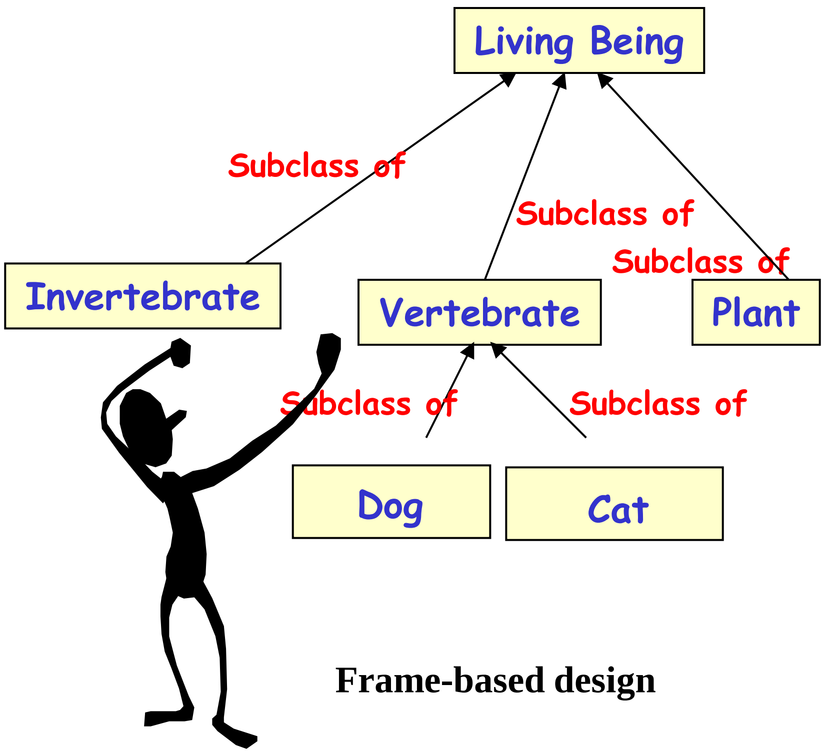
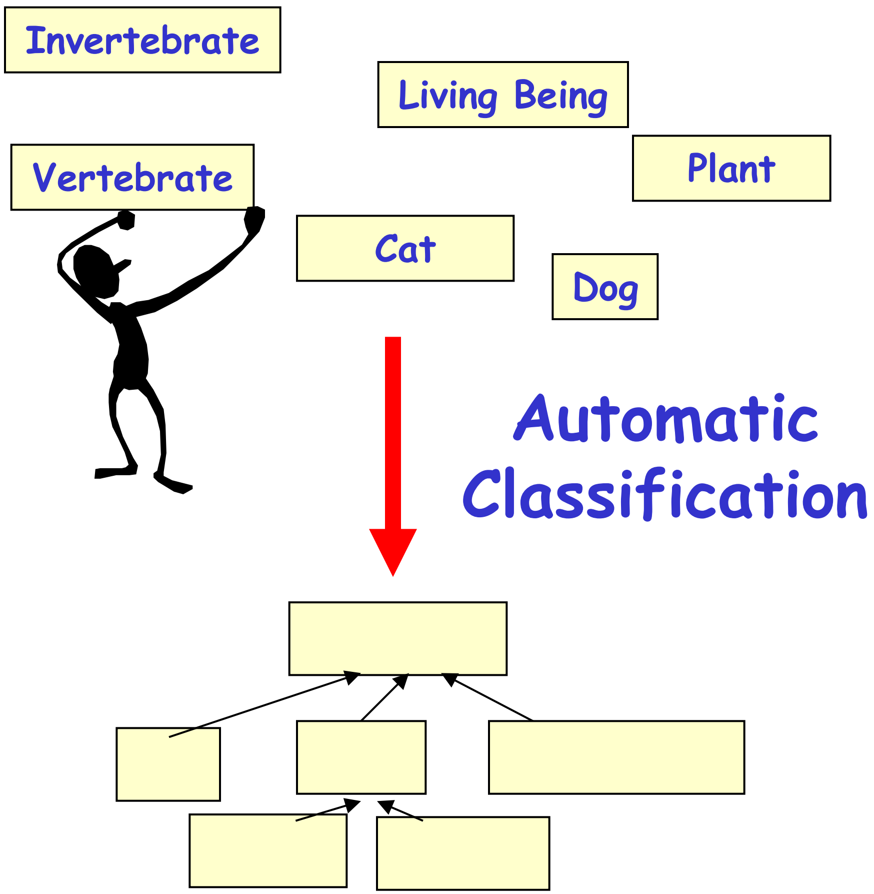


Description Logics. Basic elements

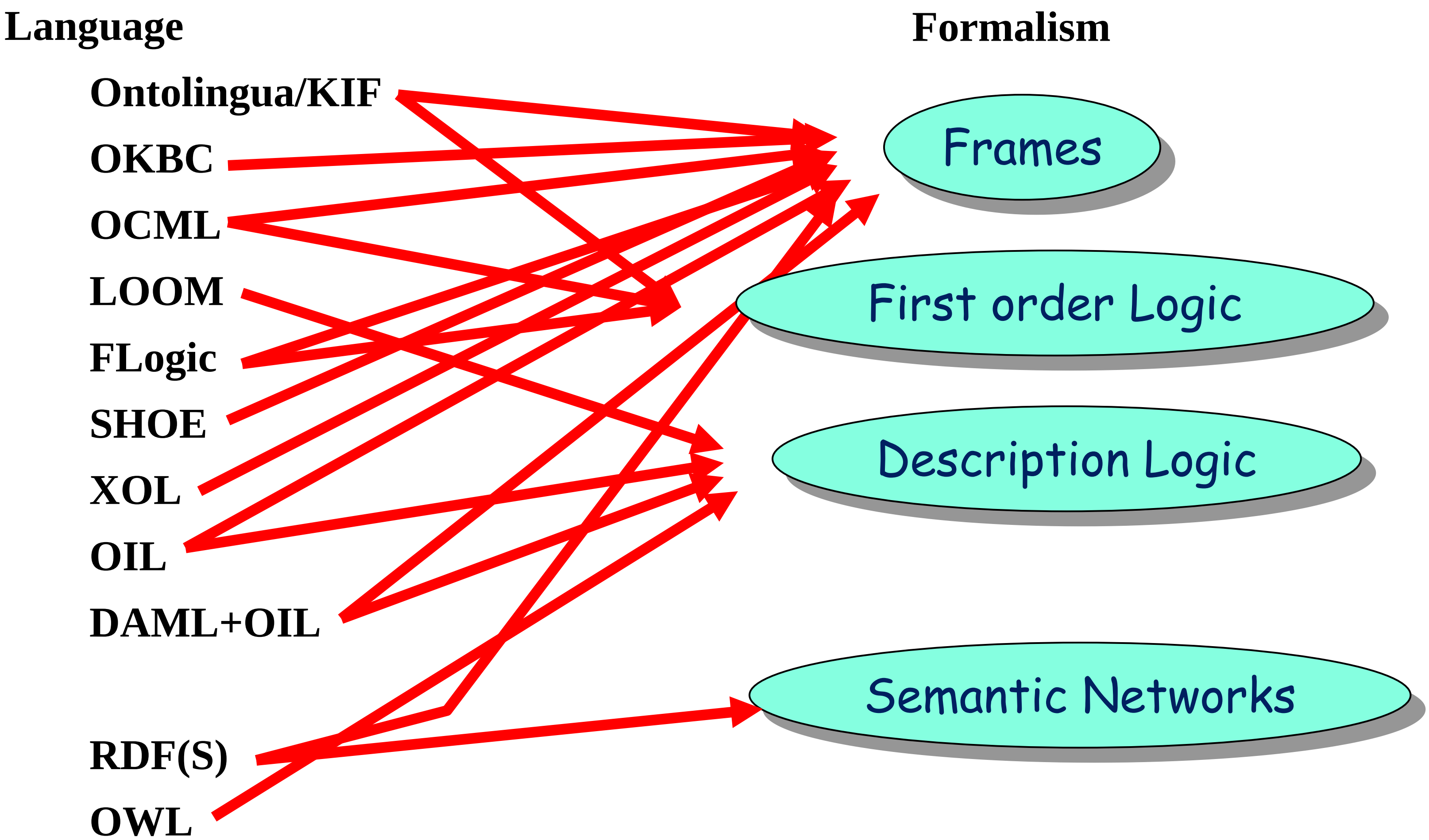
- A subset of first order logic with good reasoning properties
- Automatic classification



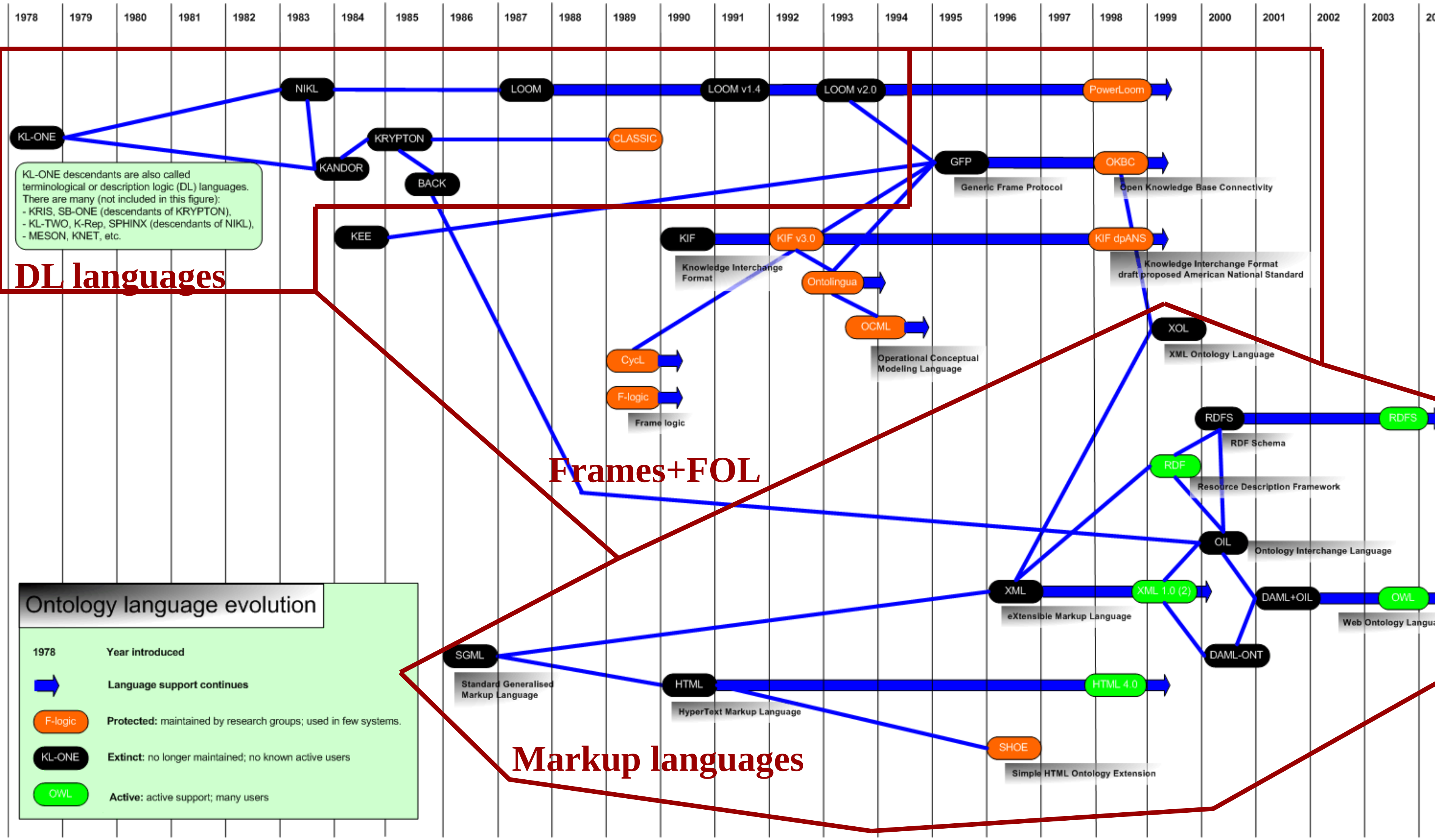
Frame-based design



KR Formalisms



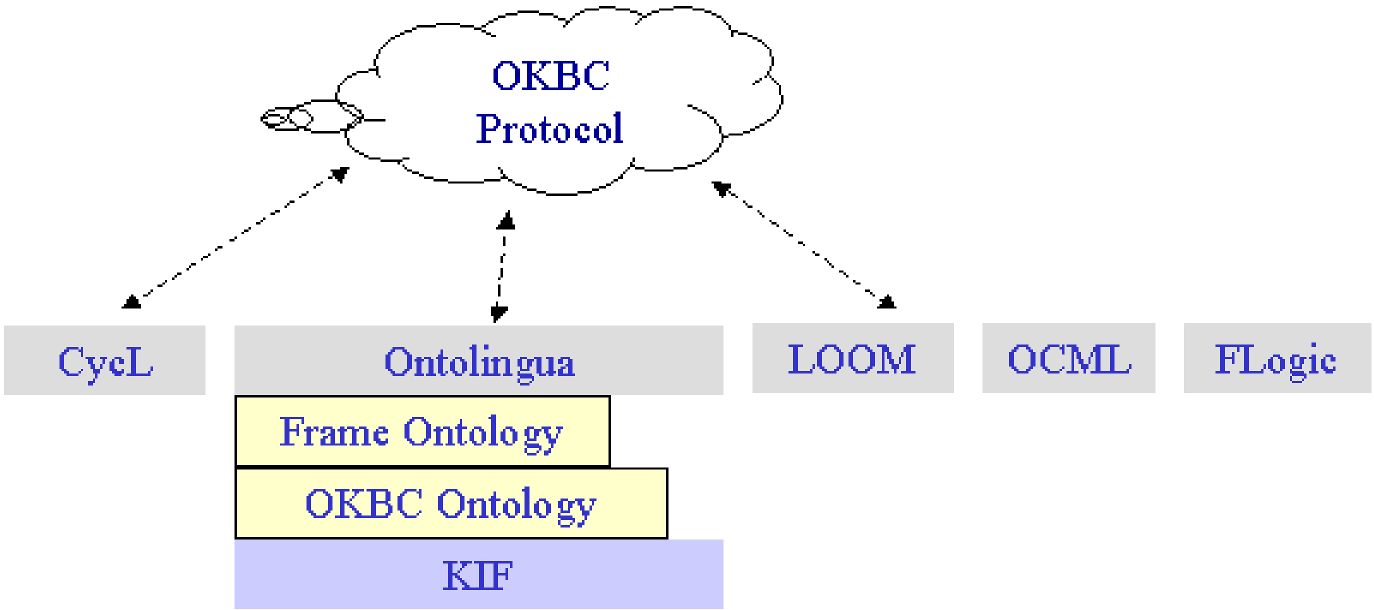
Ontology language evolution



Ontology Languages (I)

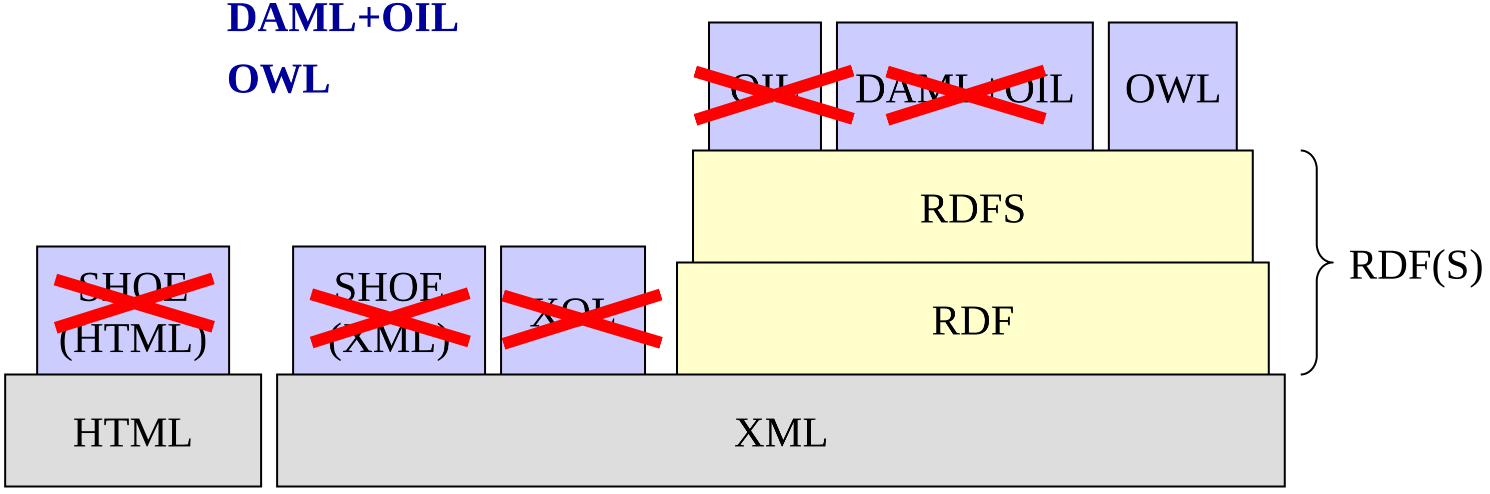
Traditional ontology languages

- **Ontolingua/KIF**
- **OKBC**
- **OCML**
- **LOOM**
- **FLogic**



Ontology Languages (II)

- Ontology markup languages
  - Standards & Recommendations of W3C
    - XML
    - RDF(S)
  - Ontology specification languages
    - SHOE
    - XOL
    - OIL
    - DAML+OIL
    - OWL



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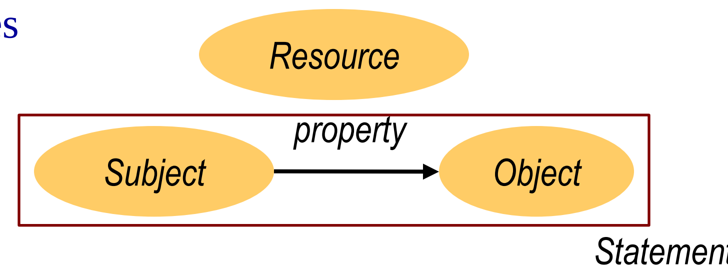
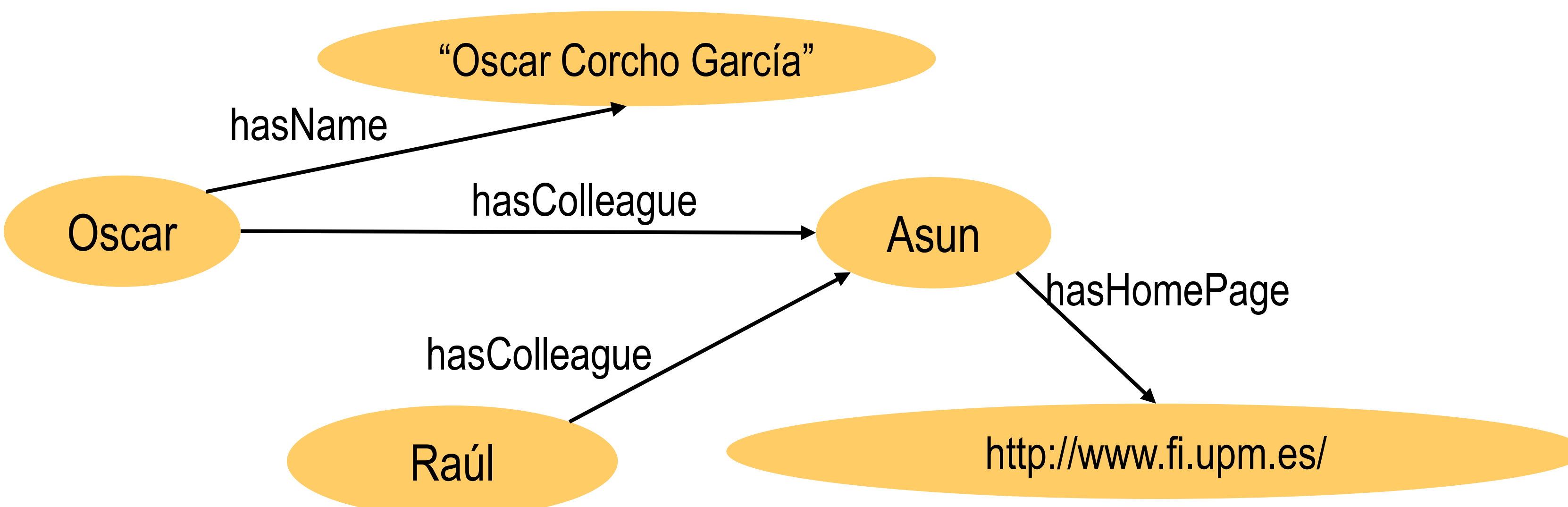
RDF: Resource Description Framework

- **W3C recommendation**
- **RDF is a basic KR language, based on semantic networks**
  - Useful to represent metadata and describe any type of information in a machine-accessible way (aka data model)
  - Resources are described in terms of properties and property values using RDF statements.
  - Statements are represented as triples, consisting of a subject, predicate and object. [S, P, O]



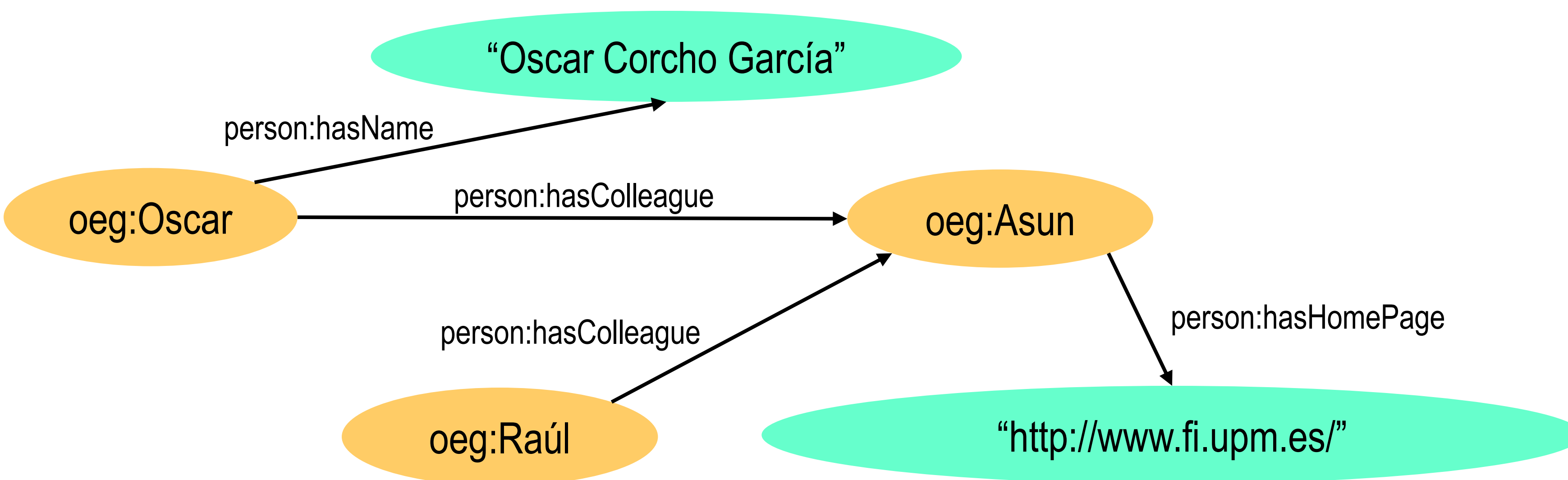


RDF (and other W3C Recommendations) and URIs

- A URI (Unique Resource Identifiers) is a Web identifier
  - e.g. `http://www.oeg-upm.net/ontologies/people#Oscar`
  - URI ≠ URL
    - If we open a Web browser and point to that URI, the corresponding object will not be downloaded or shown
    - If URLs work for **locating** uniquely (with no collisions) a Web page/resource, why not using the same approach for **identifying** Web resources?
  - Other valid URIs could be
    - ftp://www.oeg-upm.net/ontologies/people#Oscar
    - persons://www.oeg-upm.net/ontologies/people#Oscar
    - ...
- URIs allow identifying
  - Individuals: `http://www.oeg-upm.net/ontologies/people#Oscar`
  - Kinds of things: `http://www.ontologies.org/ontologies/people#Person`
  - Properties of those things: `http://www.ontologies.org/ontologies/people#hasColleague`

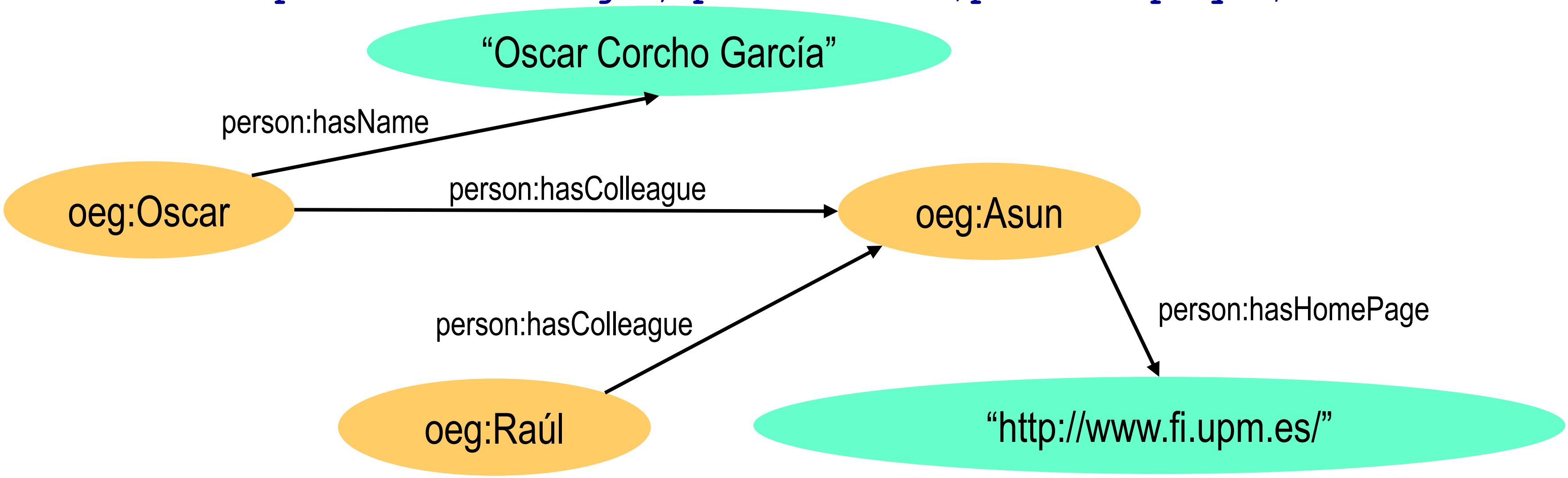
RDF (and other W3C Recommendations) and URIs

- For practical purposes, especially if handwritten, URIs are shortened using XML namespaces
  - xmlns:oeg="`http://www.oeg-upm.net/ontologies/people#`"
  - oeg:Oscar is equivalent to `http://www.oeg-upm.net/ontologies/people#Oscar`



RDF (and other W3C Recommendations) and URIs

- A set of URIs is sometimes known as a vocabulary
  - The RDF Vocabulary
    - The set of URIs used to describe the RDF concepts: **`rdf:Property`**, **`rdf:Resource`**, **`rdf:type`**, `etc.`
  - The RDFS Vocabulary
    - The set of URIs used in describing RDF Schema: **`rdfs:Class`**, **`rdfs:domain`**, `etc.`
  - The 'Person' Vocabulary
    - **`person:hasColleague`**, **`person:Person`**, **`person:Employee`**, `etc.`



RDF Serialisations

- **Normative**
  - RDF/XML (www.w3.org/TR/rdf-syntax-grammar/)
- **Alternative (for human consumption)**
  - N3 (http://www.w3.org/DesignIssues/Notation3.html)
  - Turtle (http://www.dajobe.org/2004/01/turtle/)
  - TriX (http://www.w3.org/2004/03/trix/)
  - …

Important note: the order of RDF statements in a serialisation does not affect the behaviour of a parser/application

RDF Serialisations. RDF/XML

```xml
<?xml version="1.0"?>
<rdf:RDF
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:person="http://www.ontologies.org/ontologies/people#"
  xmlns="http://www.oeg-upm.net/ontologies/people#"
  xml:base="http://www.oeg-upm.net/ontologies/people">

  <rdf:Property rdf:about="http://www.ontologies.org/ontologies/people#hasHomePage"/>
  <rdf:Property rdf:about="http://www.ontologies.org/ontologies/people#hasColleague"/>
  <rdf:Property rdf:about="http://www.ontologies.org/ontologies/people#hasName"/>

  <rdf:Description rdf:about="#Raúl"/>
  <rdf:Description rdf:about="#Asun">
    <person:hasColleague rdf:resource="#Raúl"/>
    <person:hasHomePage>http://www.fi.upm.es</person:hasHomePage>
  </rdf:Description>
  <rdf:Description rdf:about="#Oscar">
    <person:hasColleague rdf:resource="#Asun"/>
    <person:hasName>Oscar Corcho García</person:hasName>
  </rdf:Description>

</rdf:RDF>
```

RDF Serialisations. N3

```
@base  <http://www.oeg-upm.net/ontologies/people >
@prefix person: <http://www.ontologies.org/ontologies/people#>
:Asun    person:hasColleague :Raúl ;
         person:hasHomePage “http://www.fi.upm.es/”.
:Oscar   person:hasColleague :Asun ;
         person:hasName “Oscar Corcho García”.
```

Exercise

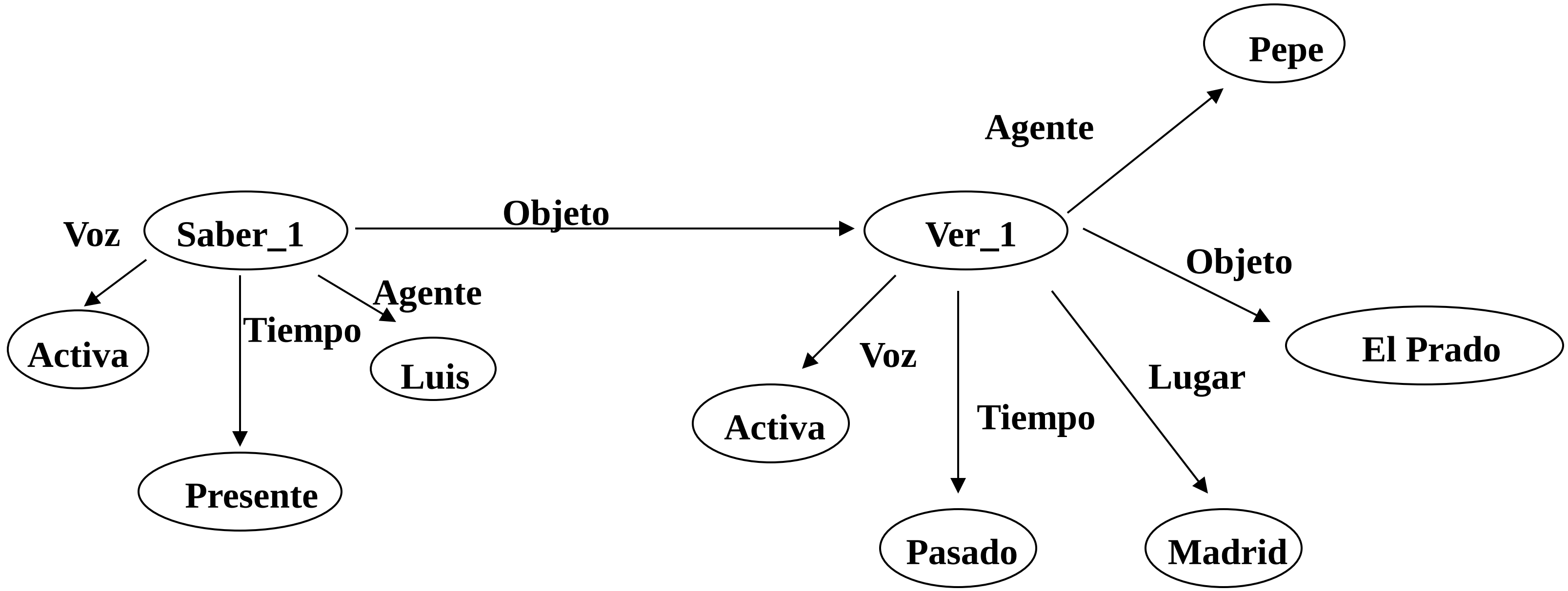
- **Objective**
  - **Get used to the different syntaxes of RDF**
- **Tasks**
  - **Take the text of an RDF file and create its corresponding graph**
  - **Take an RDF graph and create its corresponding RDF/XML and N3 files**

Exercise 1.a. Create a graph from a text file

- **Open the file StickyNote_PureRDF.rdf**
- **Create the corresponding graph from it**
- **Compare your graph with those of your colleagues**

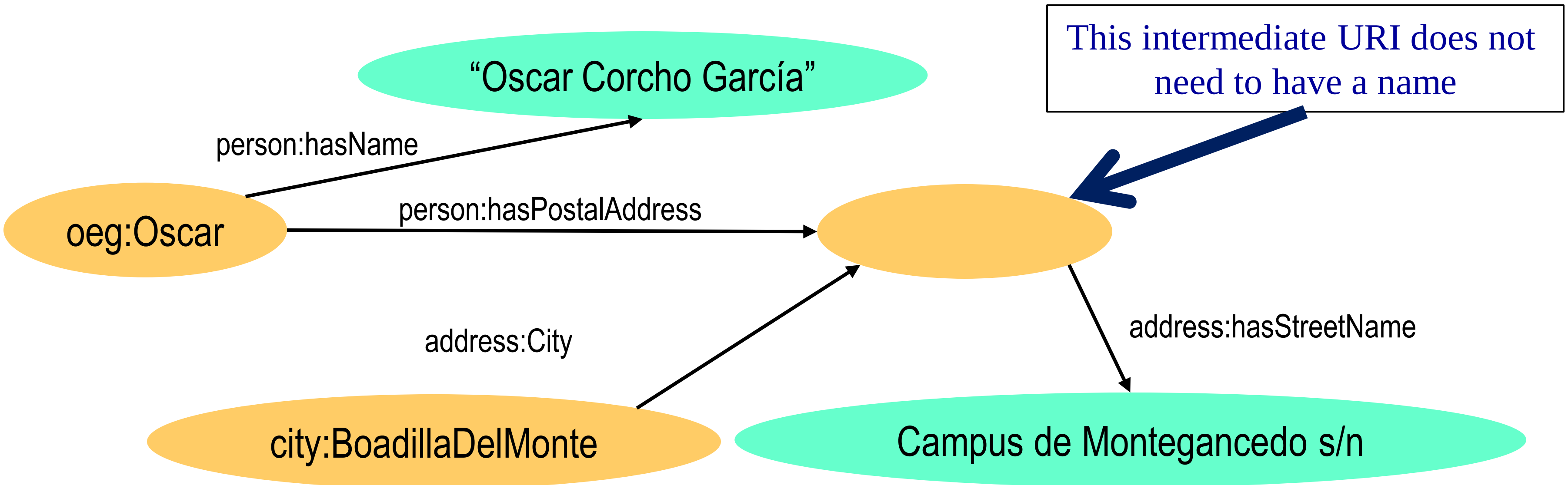
Exercise 1.b. Create RDF/XML and N3 text files from an RDF graph

- Transform the following graph into RDF/XML and N3 syntaxes



Blank nodes: structured property values

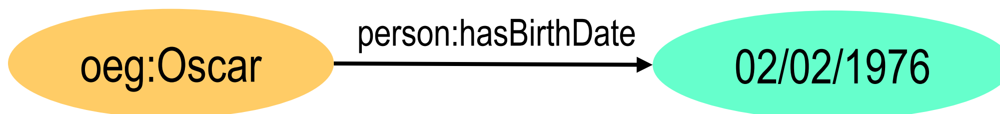
- Most real-world data involves structures that are more complicated than sets of RDF triple statements



- In RDF/XML, it is an <rdf:Description> node with no rdf:about
- In N3, it is an _:oscarAddress

Typed literals

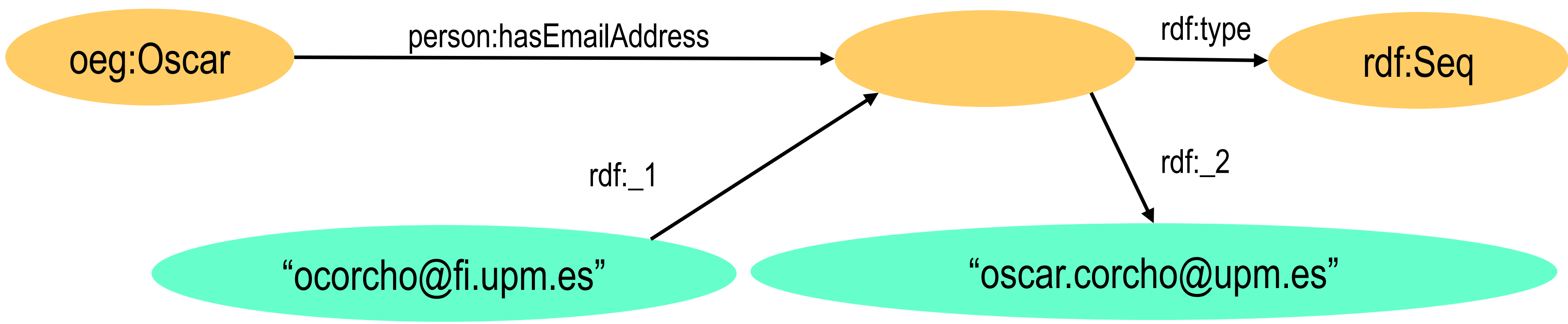
- **So far, all values have been presented as strings**
- **XML Schema datatypes can be used to specify values (objects in some RDF triple statements)**



- **In RDF/XML, this is expressed as:**
  - <rdf:Description rdf:about=”#Oscar”>
    <person:hasBirthDate
    rdf:datatype="http://www.w3.org/2001/XMLSchema#date">02/02/1976
    </person:hasBirthDate>
    </rdf:Description>
- **In N3, this is expressed as:**
  - oeg:Oscar person:hasBirthDate ”02/02/1976”^xsd:date .

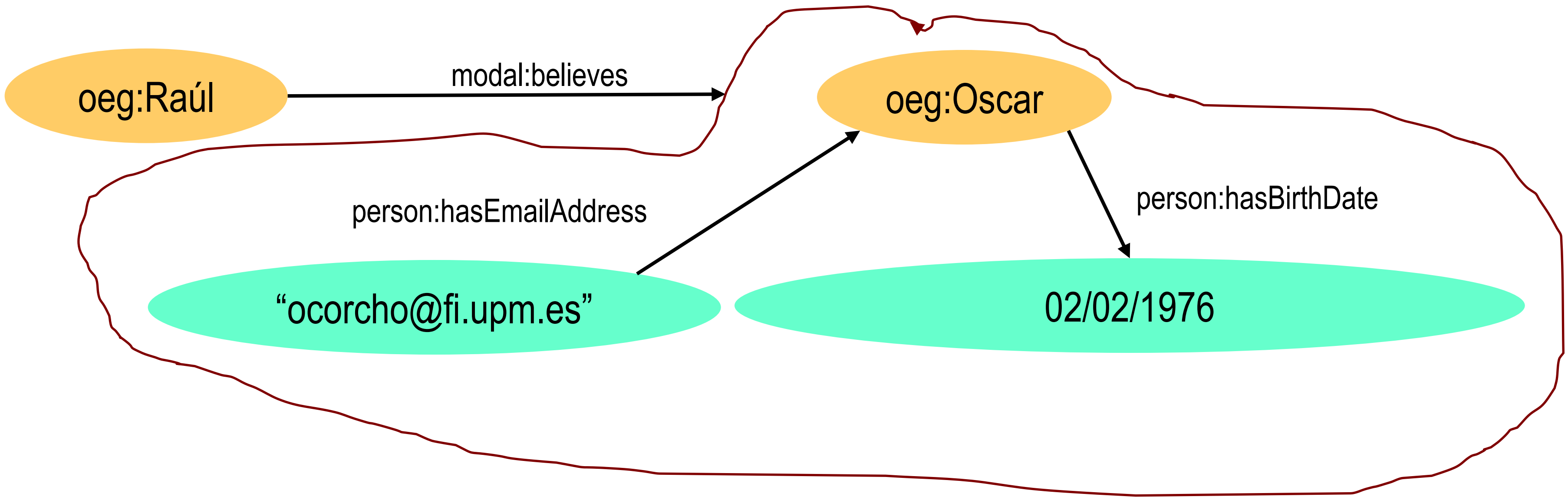
RDF Containers

- **There is often the need to describe groups of things**
  - A book was created by several authors
  - A lesson is taught by several persons
  - etc.
- **RDF provides a container vocabulary**
  - rdf:Bag → A group of resources or literals, possibly including duplicate members, where the order of members is not significant.
  - rdf:Seq → A group of resources or literals, possibly including duplicate members, where the order of members is significant.
  - rdf:Alt → A group of resources or literals that are alternatives (typically for a single value of a property).



RDF Reification

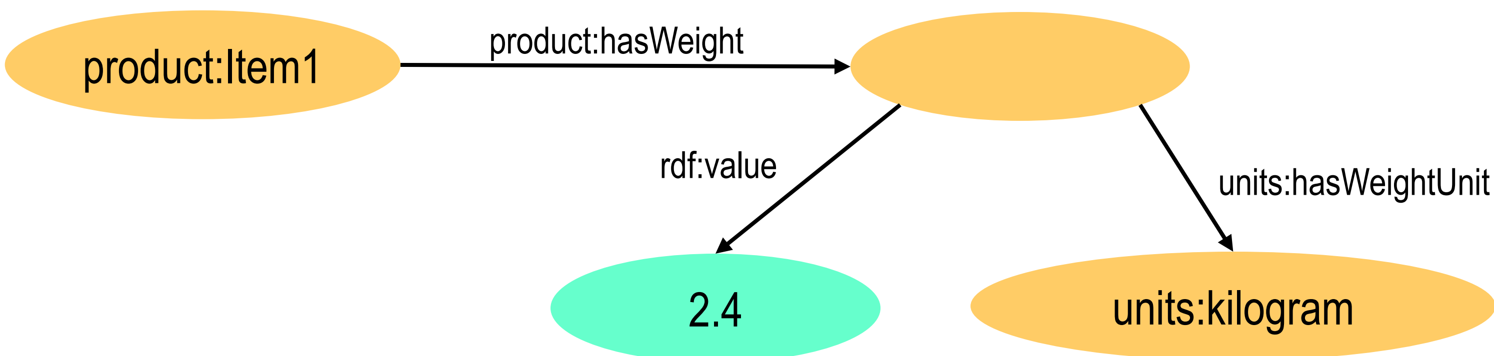
- **RDF statements about other RDF statements**
  - "Raúl believes that Oscar's birthdate is on Feb 2nd, 1976 and that his e-mail address is ocorcho@fi.upm.es"



- **RDF Reification**
  - Allows expressing beliefs (and other modalities)
  - Allows expressing trust models, digital signatures,etc.
  - Allows expressing metadata about metadata

Main value of a structured value (scarcely used)

- **Sometimes one of the values of a structured value is the main one**
  - The weight of an item is 2.4 kilograms.
  - The most important value is 2.4, which is expressed with rdf:value



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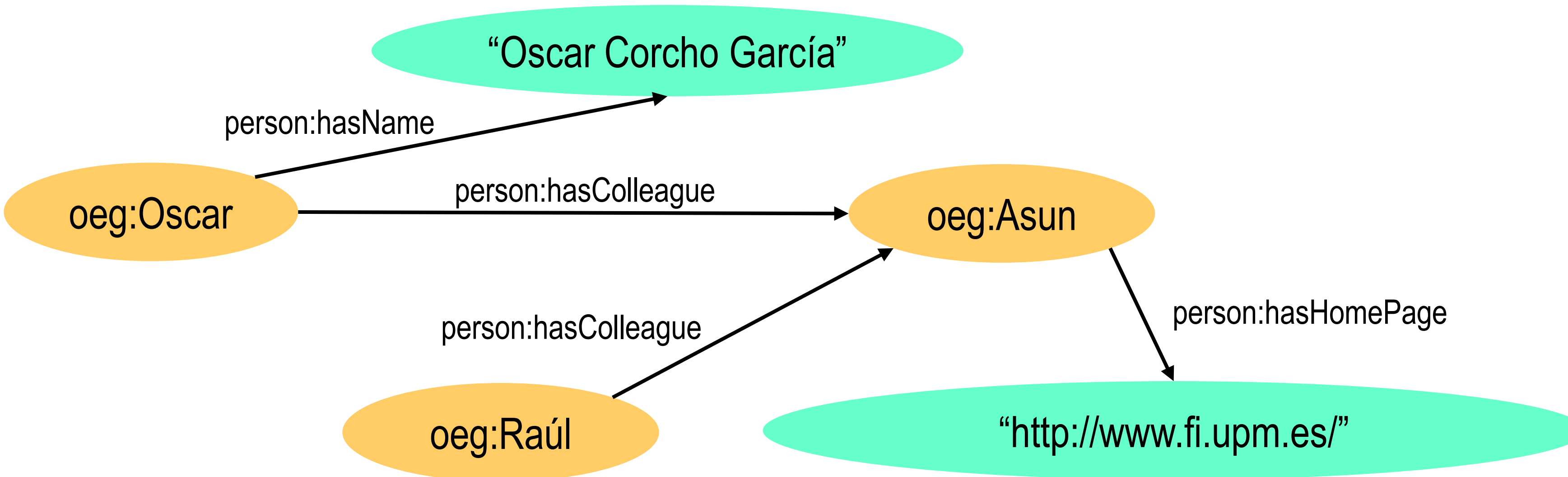
RDF inference. Graph matching techniques

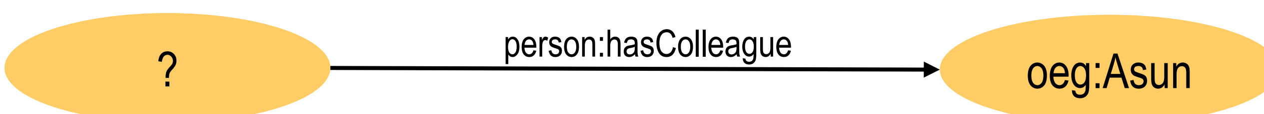
- **RDF inference is based on graph matching techniques**
- **Basically, the RDF inference process consists of the following steps:**
  - Transform an RDF query into a template graph that has to be matched against the RDF graph
    - It contains constant and variable nodes, and constant and variable edges between nodes.
  - Match against the RDF graph, taking into account constant nodes and edges.
  - Provide a solution for variable nodes and edges.

RDF inference. Examples (I)

- **Sample RDF graph**



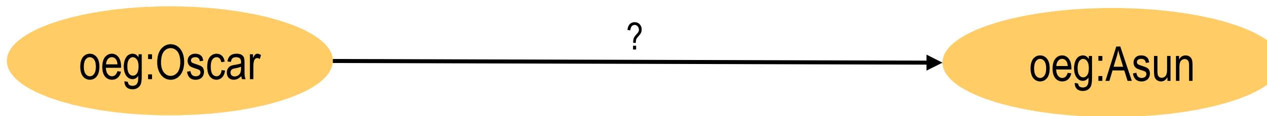
- **Query: "Tell me who are the persons who have Asun as a colleague"**



  - Result: oeg:Oscar and oeg:Raúl

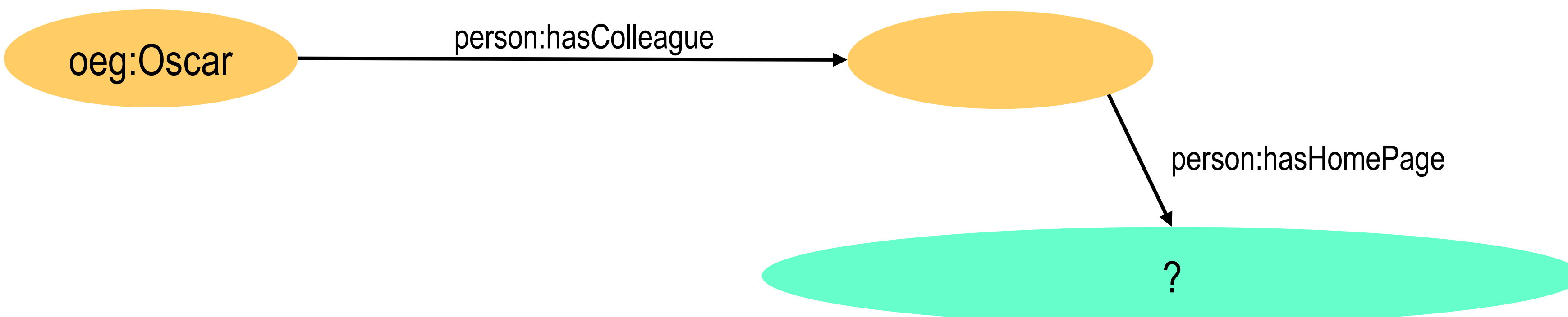
RDF inference. Examples (II)

- **Query: “Tell me which are the relationships between Oscar and Asun”**



  – Result: oeg:hasColleague

- **Query: “Tell me the homepage of Oscar colleagues”**



  – Result: “http://www.fi.upm.es/”

RDF inference. Entailment rules

Rule Name	if E contains	then add
rdf1	uuu aaa yyy .	aaa `rdf:type rdf:Property .`
rdf2	uuu aaa lll . where lll is a well-typed XML literal .	_:nnn `rdf:type rdf:XMLLiteral .` where _:nnn identifies a blank node allocated to lll by rule lg.

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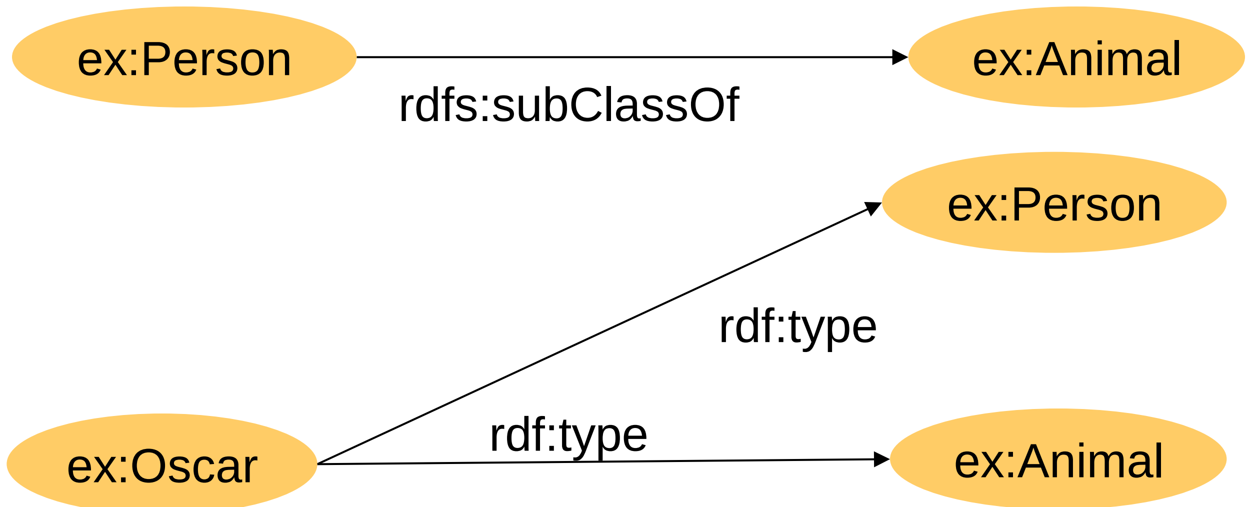
RDFS: RDF Schema

- **W3C Recommendation**
- **RDF Schema extends RDF to enable talking about classes of resources, and the properties to be used with them.**
  - Class definition: rdfs:Class, rdfs:subClassOf
  - Property definition: rdfs:subPropertyOf, rdfs:range, rdfs:domain
  - Other primitives: rdfs:comment, rdfs:label, rdfs:seeAlso, rdfs:isDefinedBy
- **RDFS vocabulary adds constraints on models, e.g.:**
  - $\forall$x,y,z type(x,y) and subClassOf(y,z) $\rightarrow$ type(x,z)



RDF(S) = RDF + RDF Schema. RDF/XML syntax

```
<?xml version="1.0"?>
<rdf:RDF
   xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
   xmlns:person="http://www.ontologies.org/ontologies/people#"
   xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
   xmlns="http://www.oeg-upm.net/ontologies/people#"
   xml:base="http://www.oeg-upm.net/ontologies/people">
  <rdfs:Class rdf:about="http://www.ontologies.org/ontologies/people#Professor">
    <rdfs:subClassOf>
      <rdfs:Class rdf:about="http://www.ontologies.org/ontologies/people#Person"/>
    </rdfs:subClassOf>
   </rdfs:Class>
   <rdfs:Class rdf:about="http://www.ontologies.org/ontologies/people#Lecturer">
    <rdfs:subClassOf rdf:resource="http://www.ontologies.org/ontologies/people#Person"/>
   </rdfs:Class>
   <rdfs:Class rdf:about="http://www.ontologies.org/ontologies/people#PhDStudent">
     <rdfs:subClassOf rdf:resource="http://www.ontologies.org/ontologies/people#Person"/>
   </rdfs:Class>

  …
```

RDF(S) = RDF + RDF Schema. RDF/XML syntax

```
…
  <rdf:Property rdf:about="http://www.ontologies.org/ontologies/people#hasHomePage"/>
  <rdf:Property rdf:about="http://www.ontologies.org/ontologies/people#hasColleague">
    <rdfs:domain rdf:resource=" http://www.ontologies.org/ontologies/people#Person"/>
    <rdfs:range rdf:resource=" http://www.ontologies.org/ontologies/people#Person"/>
  </rdf:Property>
  <rdf:Property rdf:about="http://www.ontologies.org/ontologies/people#hasName">
    <rdfs:domain rdf:resource="http://www.w3.org/2002/07/owl#Thing"/>
  </rdf:Property>

  <person:PhDStudent rdf:ID="Raúl"/>
  <person:Professor rdf:ID="Asun">
      <person:hasColleague rdf:resource="#Raúl"/>
      <person:hasHomePage>http://www.fi.upm.es</person:hasHomePage>
  </person:Professor>
  <person:Lecturer rdf:ID="Oscar">
      <person:hasColleague rdf:resource="#Asun"/>
      <person:hasName>Oscar Corcho García</person:hasName>
  </person:Lecturer>
</rdf:RDF>
```


RDF(S) Serialisations. N3

```
@base  <http://www.oeg-upm.net/ontologies/people >
@prefix person: <http://www.ontologies.org/ontologies/people#>
person:hasColleague          a rdf:Property;
                             rdfs:domain person:Person;
                             rdfs:range person:Person.
person:Professor rdfs:subClassOf person:Person.
person:Lecturer rdfs:subClassOf person:Person.
person:PhDStudent rdfs:subClassOf person:Person.
:Asun     a person:Professor;
          person:hasColleague :Raúl ;
          person:hasHomePage “http://www.fi.upm.es/”.
:Oscar    a person:Lecturer;
          person:hasColleague :Asun ;
          person:hasName “Oscar Corcho García”.
:Raúl     a person:PhDStudent.
```

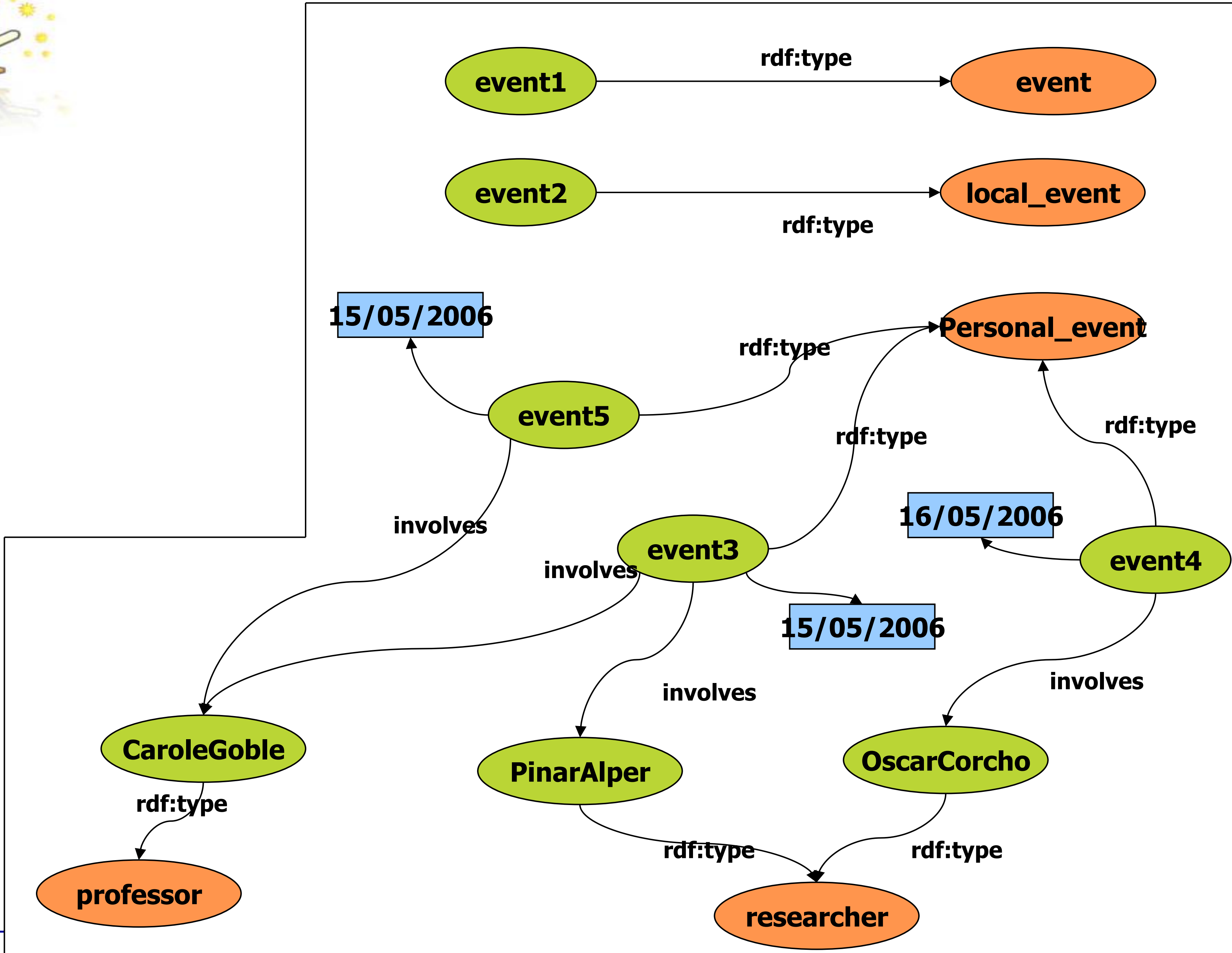
a is equivalent to rdf:type

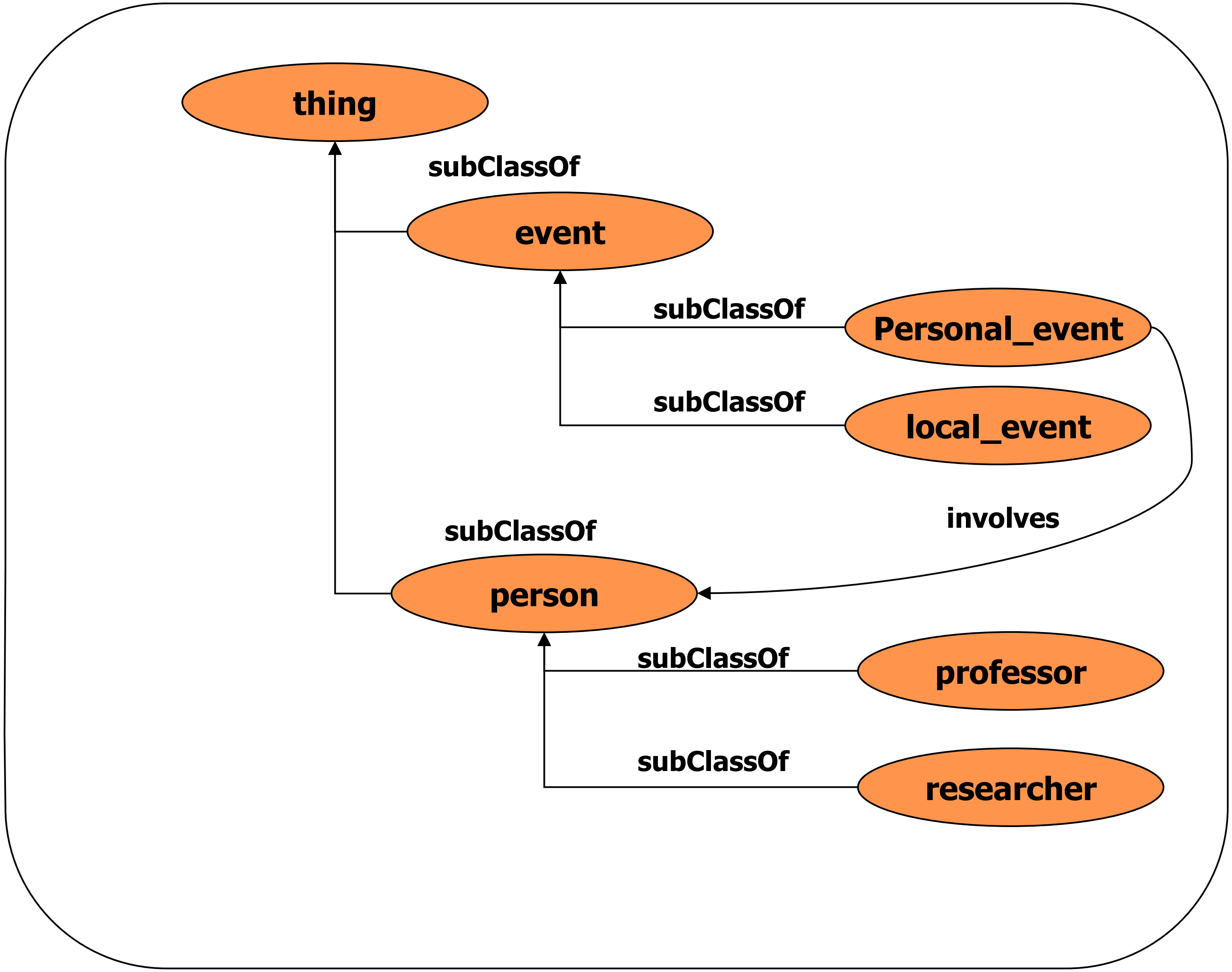
Exercise

- **Objective**
  - **Get used to the different syntaxes of RDF(S)**
- **Tasks**
  - **Take the text of an RDF(S) file and create its corresponding graph**
  - **Take an RDF(S) graph and create its corresponding RDF/XML and N3 files**

Exercise 2.a. Create a graph from a text file

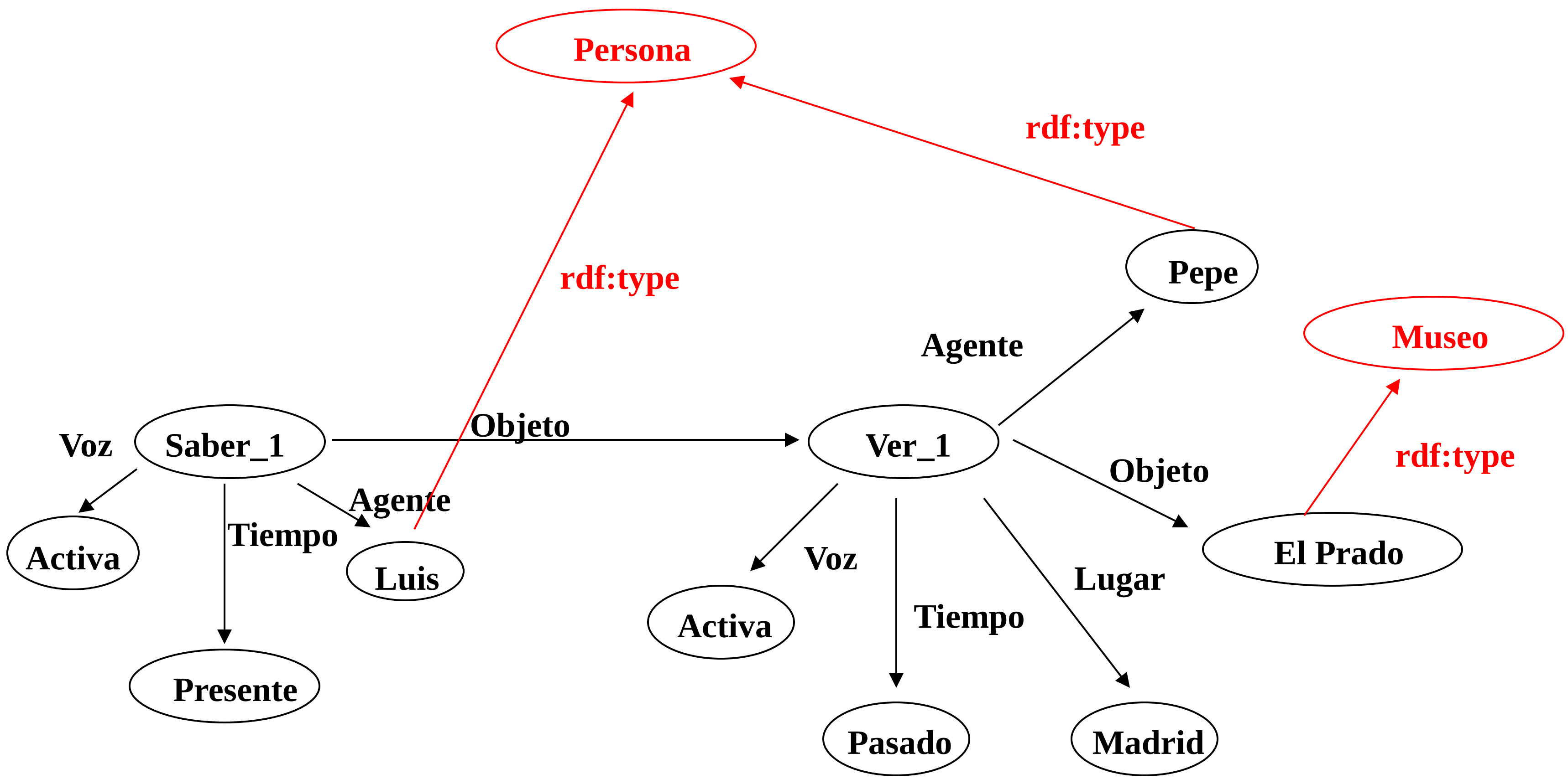
- **Open the files StickyNote.rdf and StickyNote.rdfs**
- **Create the corresponding graph from them**
- **Compare your graph with those of your colleagues**


event1
rdf:type
event
event2
local_event
rdf:type
15/05/2006
rdf:type
Personal_event
event5
rdf:type
rdf:type
16/05/2006
involves
event3
event4
involves
15/05/2006
involves
involves
CaroleGoble
PinarAlper
OscarCorcho
rdf:type
rdf:type
rdf:type
professor
researcher


thing
subClassOf
event
subClassOf
Personal_event
subClassOf
local_event
involves
subClassOf
person
subClassOf
professor
subClassOf
researcher

Exercise 2.b. Create RDF/XML and N3 text files from an RDF(S) graph

- **Transform the following graph into RDF/XML and N3 syntaxes**



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RDF(S) inference. Entailment rules

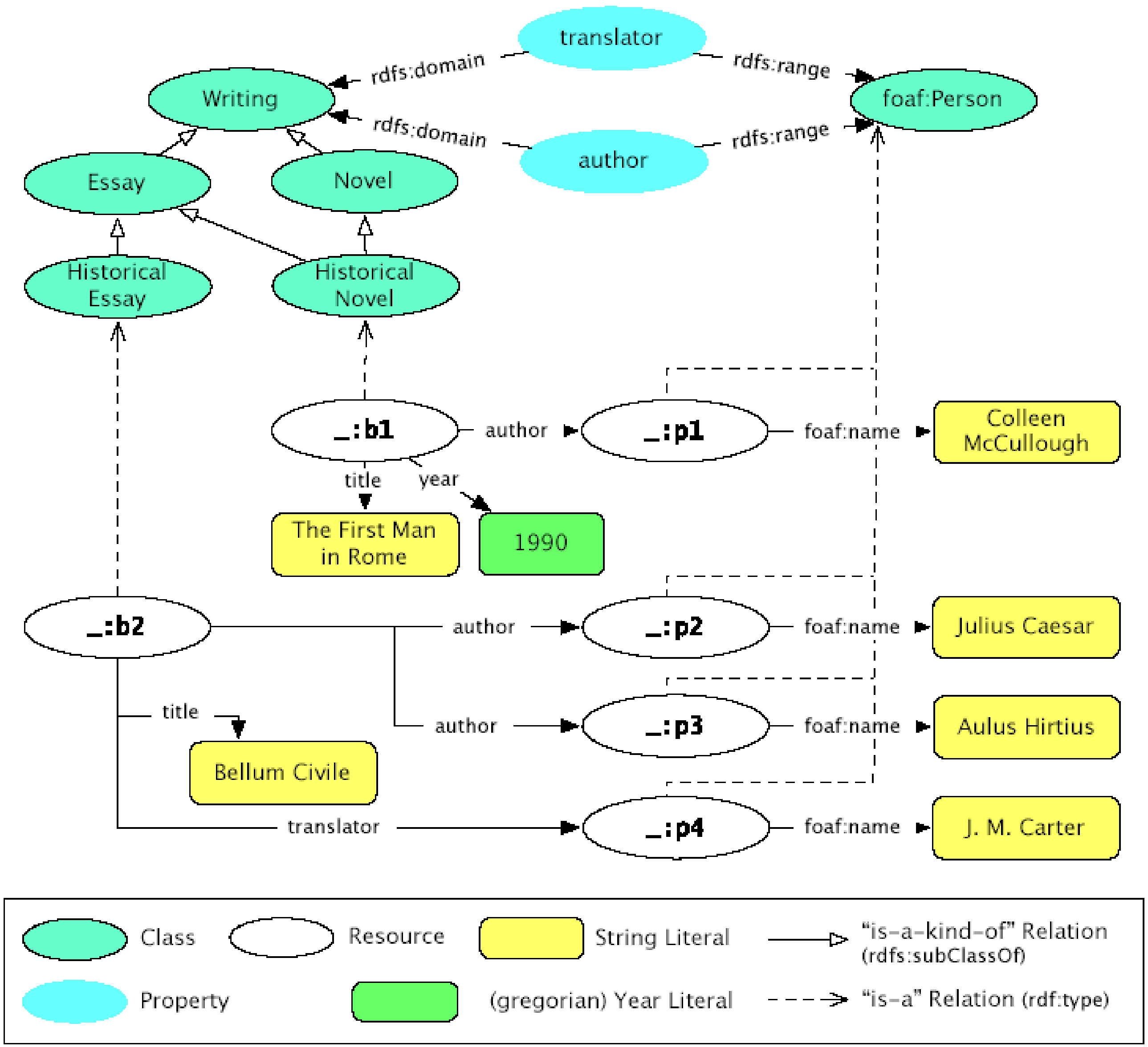
Rule Name	If E contains:	then add:
rdfs1	uuu aaa lll. where lll is a plain literal (with or without a language tag).	_:nnn `rdf:type rdfs:Literal .` where _:nnn identifies a blank node allocated to lll by rule rule lg.
rdfs2	aaa `rdfs:domain` XXX . uuu aaa yyy .	uuu `rdf:type` XXX .
rdfs3	aaa `rdfs:range` XXX . uuu aaa vvv .	vvv `rdf:type` XXX .
rdfs4a	uuu aaa xxx .	uuu `rdf:type rdfs:Resource .`
rdfs4b	uuu aaa vvv.	vvv `rdf:type rdfs:Resource .`
rdfs5	uuu `rdfs:subPropertyOf` vvv . vvv `rdfs:subPropertyOf` XXX .	uuu `rdfs:subPropertyOf` XXX .
rdfs6	uuu `rdf:type rdf:Property .`	uuu `rdfs:subPropertyOf` uuu .
rdfs7	aaa `rdfs:subPropertyOf` bbb . uuu aaa yyy .	uuu bbb yyy .
rdfs8	uuu `rdf:type rdfs:Class .`	uuu `rdfs:subClassOf rdfs:Resource .`
rdfs9	uuu `rdfs:subClassOf` XXX . vvv `rdf:type` uuu .	vvv `rdf:type` XXX .
rdfs10	uuu `rdf:type rdfs:Class .`	uuu `rdfs:subClassOf` uuu .
rdfs11	uuu `rdfs:subClassOf` vvv . vvv `rdfs:subClassOf` XXX .	uuu `rdfs:subClassOf` XXX .
rdfs12	uuu `rdf:type rdfs:ContainerMembershipProperty .`	uuu `rdfs:subPropertyOf rdfs:member .`
rdfs13	uuu `rdf:type rdfs:Datatype .`	uuu `rdfs:subClassOf rdfs:Literal .`

RDF(S) inference. Additional inferences

ext1	UUU rdfs:domain VVV . VVV rdfs:subClassOf ZZZ .	UUU rdfs:domain ZZZ .
ext2	UUU rdfs:range VVV . VVV rdfs:subClassOf ZZZ .	UUU rdfs:range ZZZ .
ext3	UUU rdfs:domain VVV . WWW rdfs:subPropertyOf UUU .	WWW rdfs:domain VVV .
ext4	UUU rdfs:range VVV . WWW rdfs:subPropertyOf UUU .	WWW rdfs:range VVV .
ext5	rdf:type rdfs:subPropertyOf WWW . WWW rdfs:domain VVV .	rdfs:Resource rdfs:subClassOf VVV .
ext6	rdfs:subClassOf rdfs:subPropertyOf WWW . WWW rdfs:domain VVV .	rdfs:Class rdfs:subClassOf VVV .
ext7	rdfs:subPropertyOf rdfs:subPropertyOf WWW . WWW rdfs:domain VVV .	rdf:Property rdfs:subClassOf VVV .
ext8	rdfs:subClassOf rdfs:subPropertyOf WWW . WWW rdfs:range VVV .	rdfs:Class rdfs:subClassOf VVV .
ext9	rdfs:subPropertyOf rdfs:subPropertyOf WWW . WWW rdfs:range VVV .	rdf:Property rdfs:subClassOf VVV .

Exercise

- **Objective**
  - **Understand how to RDF(S) reasoning works**
- **Tasks**
  - **Generate all possible RDF triples that can be inferred from an RDF(S) graph**



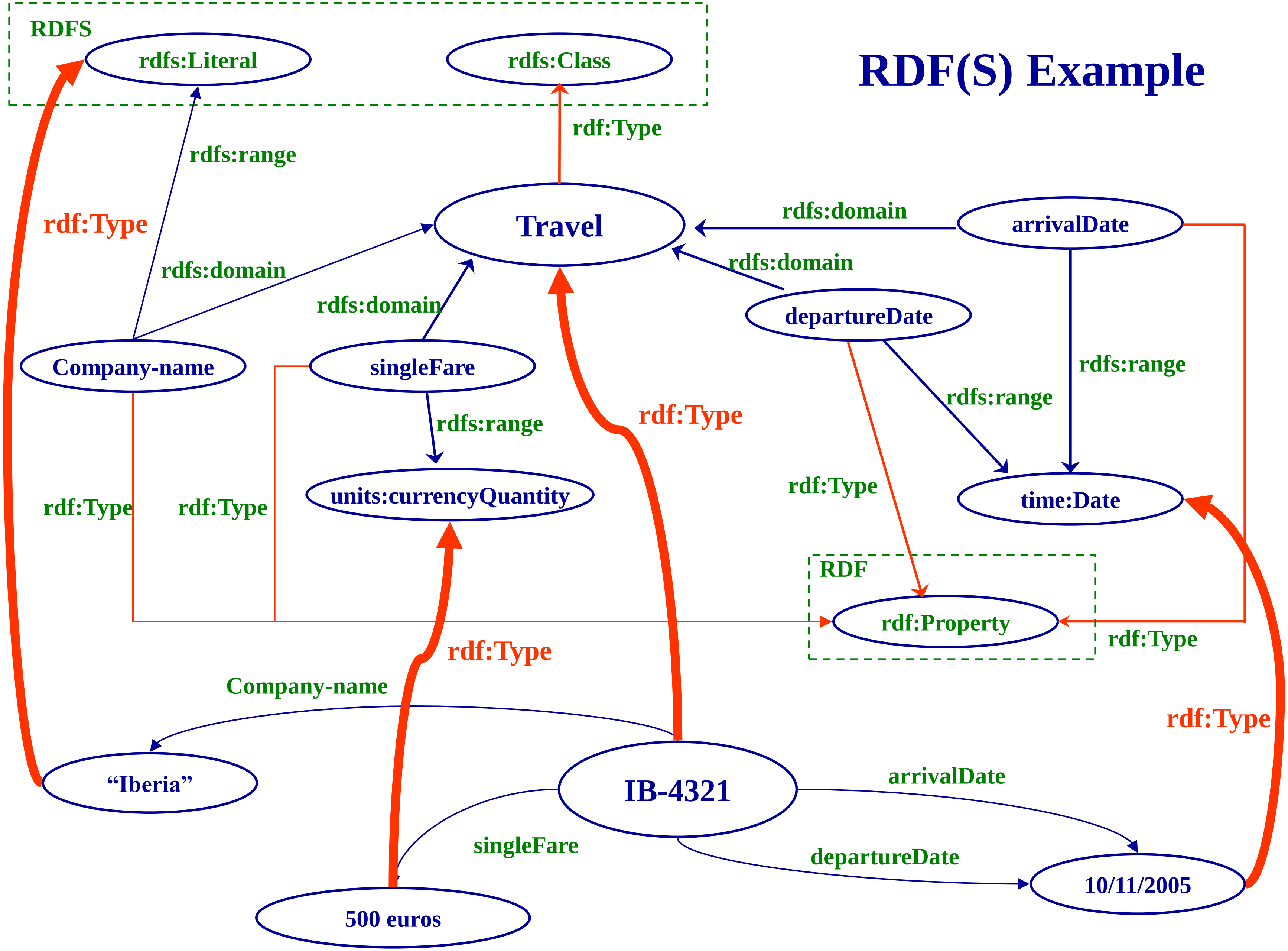
translator
rdfs:domain
rdfs:range
Writing
foaf:Person
rdfs:domain
author
rdfs:range
Essay
Novel
Historical Essay
Historical Novel
_:b1
author
_:p1
foaf:name
Colleen McCullough
title
year
The First Man in Rome
1990
_:b2
author
_:p2
foaf:name
Julius Caesar
title
author
_:p3
foaf:name
Aulus Hirtius
Bellum Civile
translator
_:p4
foaf:name
J. M. Carter
Class
Resource
String Literal
"is-a-kind-of" Relation (rdfs:subClassOf)
Property
(gregorian) Year Literal
"is-a" Relation (rdf:type)

Exercise

•**Objective**
- **Understand how to use an RDF(S) development tool to create RDF(S) ontologies**

•**Tasks**
- **Create the previous ontologies in an RDF(S) development tool**

RDF(S) Example



Exercise

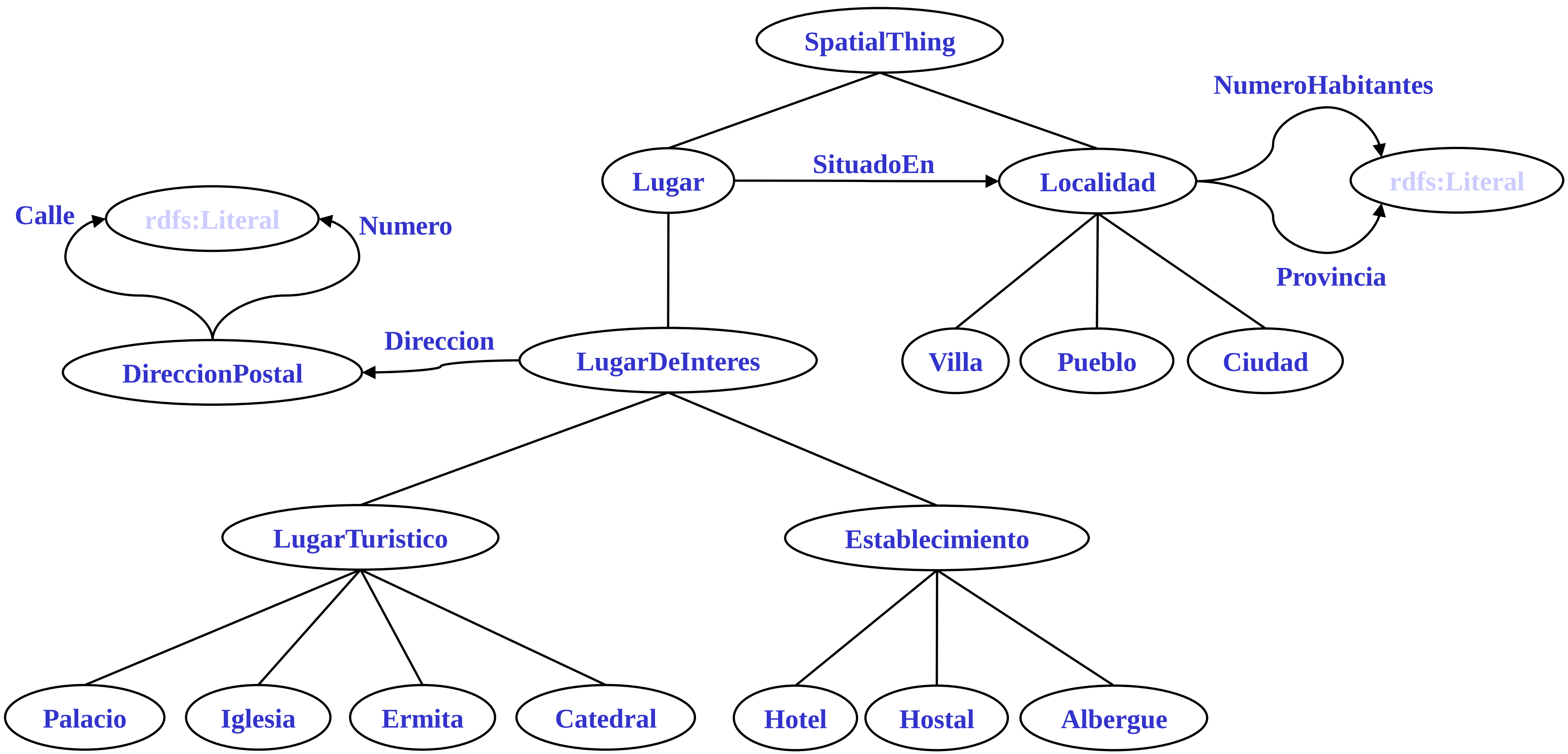
- **Objective**
  - **Understand the features of RDF(S) for implementing ontologies, including its limitations**
- **Tasks**
  - **Take the ontologies previously defined and create their graphs**
    - **First only include the vocabulary from the domain**
    - **Then include references to the RDF and RDFS vocabularies**

Domain description

- Un lugar puede ser un lugar de interés.
- Los lugares de interés pueden ser lugares turísticos o establecimientos, pero no las dos cosas a la vez.
- Los lugares turísticos pueden ser palacios, iglesias, ermitas y catedrales.
- Los establecimientos pueden ser hoteles, hostales o albergues.
- Un lugar está situado en una localidad, la cual a su vez puede ser una villa, un pueblo o una ciudad.
- Un lugar de interés tiene una dirección postal que incluye su calle y su número.
- Las localidades tienen un número de habitantes.
- Las localidades se encuentran situadas en provincias.

- Covarrubias es un pueblo con 634 habitantes de la provincia de Burgos.
- El restaurante “El Galo” está situado en Covarrubias, en la calle Mayor, número 5.
- Una de las iglesias de Covarrubias está en la calle de Santo Tomás.

Sample resulting ontology



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Sample RDF APIs

RDF libraries for different languages:
- Java, Python, C, C++, C#, .Net, Javascript, Tcl/Tk, PHP, Lisp, Obj-C, Prolog, Perl, Ruby, Haskell
- List in http://esw.w3.org/topic/SemanticWebTools

Usually related to a RDF repository

- **Multilanguage:**
  - Redland RDF Application Framework (C, Perl, PHP, Python and Ruby): http://www.redland.opensource.ac.uk/
- **Java:**
  - Jena: http://jena.sourceforge.net/
  - Sesame: http://www.openrdf.org/
- **PHP:**
  - RAP - RDF API for PHP: http://www4.wiwiss.fu-berlin.de/bizer/rdfapi/
- **Python:**
  - RDFLib: http://rdflib.net/
  - Pyrple: http://infomesh.net/pyrple/

Jena

- **Java framework for building Semantic Web applications**
- **Open source software from HP Labs:**
- **The Jena framework includes:**
  - A RDF API
  - An OWL API
  - Reading and writing RDF in RDF/XML, N3 and N-Triples
  - In-memory and persistent storage
  - A rule based inference engine
  - SPARQL query engine

Sesame

- **A framework for *storage*, *querying* and *inferencing* of RDF and RDF Schema**
- **A Java Library for handling RDF**
- **A Database Server for (remote) access to *repositories* of RDF data**
- **Highly expressive query and transformation languages**
  - SeRQL, SPARQL
- **Various backends**
  - Native Store
  - RDBMS (MySQL, Oracle 10, DB2, PostgreSQL)
  - main memory
- **Reasoning support**
  - RDF Schema reasoner
  - OWL DLP (OWLIM)
  - domain reasoning (custom rule engine)

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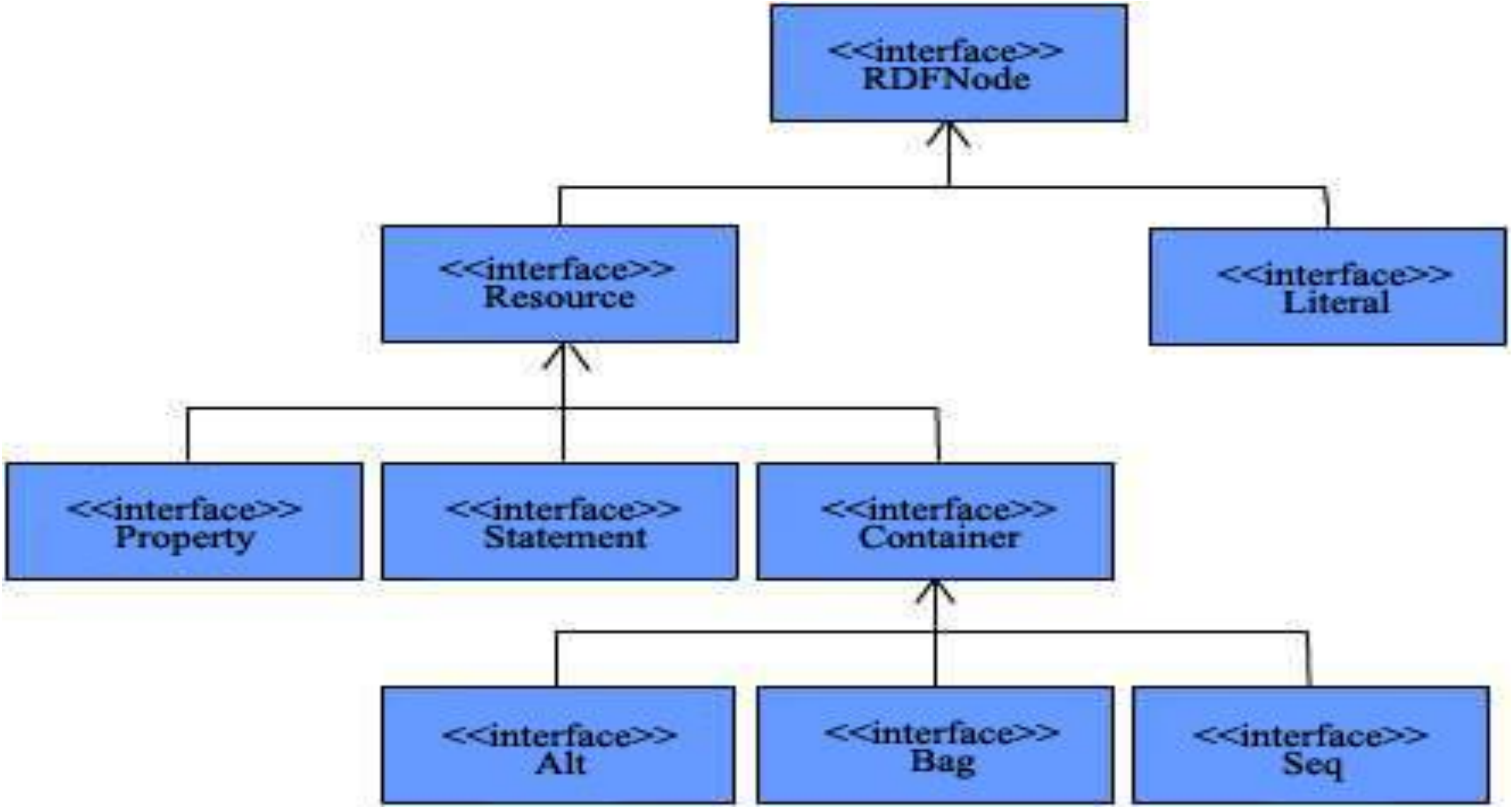
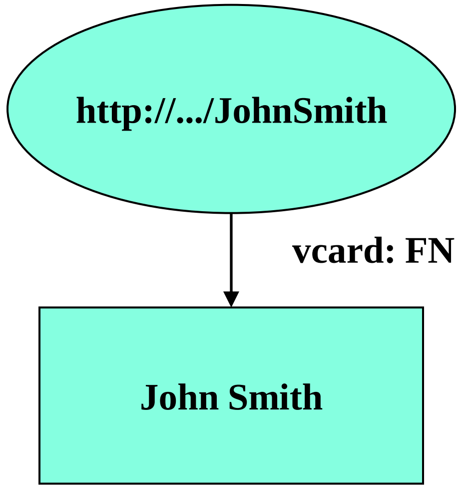
Jena API Structure

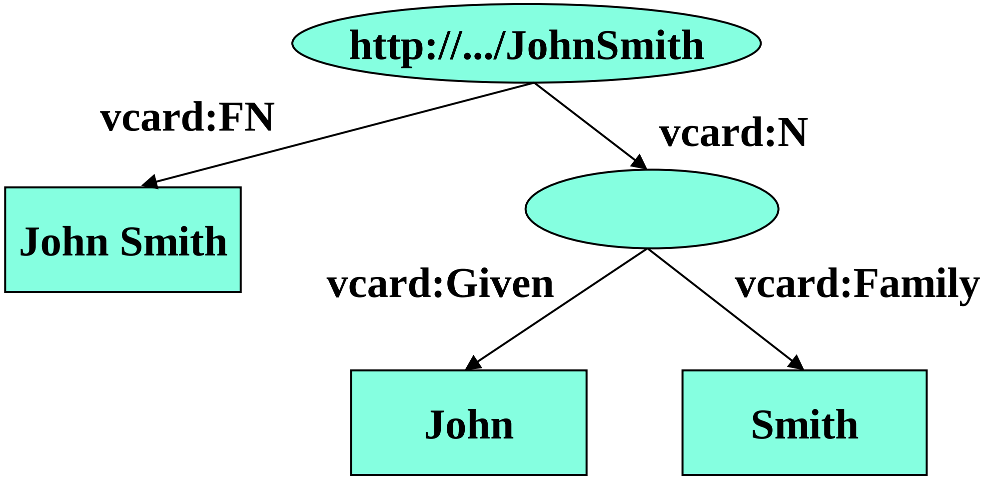


Data Model




```
// some definitions
static String personURI = "http://somewhere/JohnSmith";
static String fullName = "John Smith";
// create an empty Model
Model model = ModelFactory.createDefaultModel();
// create the resource
Resource johnSmith = model.createResource(personURI);
// add the property
johnSmith.addProperty(VCARD.FN, fullName);
```

Another data model




```
// some definitions
String personURI = "http://somewhere/JohnSmith"; String givenName = "John";
String familyName = "Smith";
String fullName = givenName + " " + familyName;
// create an empty
Model Model model = ModelFactory.createDefaultModel();
// create the resource
// and add the properties cascading style
Resource johnSmith = model.createResource(personURI)
    .addProperty(VCARD.FN, fullName)
    .addProperty(VCARD.N, model.createResource()
    .addProperty(VCARD.Given, givenName)
    .addProperty(VCARD.Family, familyName));
```

Statements

```
// list the statements in the Model
StmtIterator iter = model.listStatements();
// print out the predicate, subject and object of each statement
while (iter.hasNext())
{
   Statement stmt = iter.nextStatement(); // get next statement
   Resource subject = stmt.getSubject(); // get the subject
   Property predicate = stmt.getPredicate(); // get the predicate
   RDFNode object = stmt.getObject(); // get the object
   System.out.print(subject.toString());
   System.out.print(" " + predicate.toString() + " ");
   if (object instanceof Resource) {
       System.out.print(object.toString());
    }
    else { // object is a literal
       System.out.print(" \"" + object.toString() + "\"");
    }
    System.out.println(" .");
} // end of while
```

```
http://somewhere/JohnSmith http://www.w3.org/2001/vcard-rdf/3.0#N anon:14df86:ecc3dee17b:-7fff

anon:14df86:ecc3dee17b:-7fff http://www.w3.org/2001/vcard-rdf/3.0#Family "Smith"

anon:14df86:ecc3dee17b:-7fff http://www.w3.org/2001/vcard-rdf/3.0#Given "John"

http://somewhere/JohnSmith http://www.w3.org/2001/vcard-rdf/3.0#FN
    "John Smith" .
```

Writing RDF

```
Model model = ModelFactory.createDefaultModel();
Resource jsmith =
model.createResource("http://somewhere/johnsmith")
     .addProperty(VCARD.FN, "John Smith")
     .addProperty(VCARD.N, model.createResource()
     .addProperty(VCARD.Given,"John")
     .addProperty(VCARD.Family, "Smith"));
model.write(new PrintWriter(System.out));
```

```
model.write(System.out, "RDF/XML-ABBREV");

model.write(System.out, "N-TRIPLE");
```

```
<rdf:RDF
  xmlns:rdf='http://www.w3.org/1999/02/22-rdf-syntax-ns#'
  xmlns:vcard='http://www.w3.org/2001/vcard-rdf/3.0#'
 >
  <rdf:Description rdf:nodeID='A0'>
    <vcard:Given>John</vcard:Given>
    <vcard:Family>Smith</vcard:Family>
  </rdf:Description>
  <rdf:Description rdf:about='http://somewhere/johnsmith'>
    <vcard:FN>John Smith</vcard:FN>
    <vcard:N rdf:nodeID='A0'/>
  </rdf:Description>
</rdf:RDF>
```

Reading RDF

```
// create an empty model
Model model = ModelFactory.createDefaultModel();

// use the FileManager to find the input file
InputStream in = FileManager.get().open( inputFileName );
if (in == null) {
    throw new IllegalArgumentException("File not found");
}

// read the RDF/XML file
model.read(in, "");

// write it to standard out
model.write(System.out);
```

```
<rdf:RDF
  xmlns:rdf='http://www.w3.org/1999/02/22-rdf-syntax-ns#'
  xmlns:vcard='http://www.w3.org/2001/vcard-rdf/3.0#'
 >
  <rdf:Description rdf:nodeID="A0">
    <vcard:Family>Smith</vcard:Family>
    <vcard:Given>John</vcard:Given>
  </rdf:Description>
  <rdf:Description rdf:about='http://somewhere/JohnSmith/'>
    <vcard:FN>John Smith</vcard:FN>
    <vcard:N rdf:nodeID="A0"/>
  </rdf:Description>
...
</rdf:RDF>
```

Navigating a model

```
// retrieve the John Smith vcard resource from the model
Resource vcard = model.getResource(johnSmithURI);
```

Three ways of retrieving property values:

```
// retrieve the value of the N property
Resource name = (Resource) vcard.getProperty(VCARD.N).getObject();

// retrieve the value of the N property
Resource name = vcard.getProperty(VCARD.N).getResource();

// retrieve the given name property
String fullName = vcard.getProperty(VCARD.N).getString();
```

Multiple values in properties

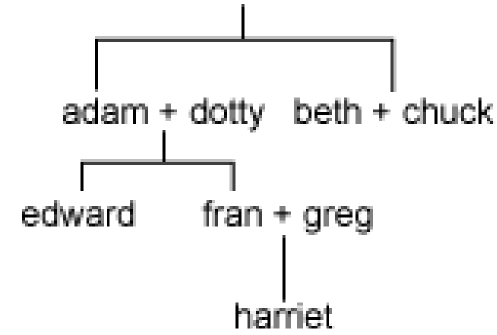
```
// add two nickname properties to vcard
vcard.addProperty(VCARD.NICKNAME, "Smithy")
     .addProperty(VCARD.NICKNAME, "Adman");

// set up the output
System.out.println("The nicknames of \"" + fullName + "\" are:");

// list the nicknames
StmtIterator iter = vcard.listProperties(VCARD.NICKNAME);
while (iter.hasNext()) {
  System.out.println(" " + iter.nextStatement() .getObject() .toString());
}
```


Querying a model

```
// select all the resources with a VCARD.FN property
ResIterator iter = model.listSubjectsWithProperty(VCARD.FN);
if (iter.hasNext()) {
  System.out.println("The database contains vcards for:");
  while (iter.hasNext()) {
    System.out.println(" " + iter.nextStatement()
                                        .getProperty(VCARD.FN) .getString());
  }
} else {
  System.out.println("No vcards were found in the database");
}
```

```
The database contains vcards for:
 Sarah Jones
 John Smith
 Matt Jones
 Becky Smith
```

Create resources




```
// URI declarations
String familyUri = "http://family/";
String relationshipUri = "http://purl.org/vocab/relationship/";

// Create an empty Model
Model model = ModelFactory.createDefaultModel();

// Create a Resource for each family member, identified by their URI
Resource adam = model.createResource(familyUri+"adam");
Resource beth = model.createResource(familyUri+"beth");
Resource dotty = model.createResource(familyUri+"dotty");
// and so on for other family members

// Create properties for the different types of relationship to represent
Property childOf = model.createProperty(relationshipUri,"childOf");
Property parentOf = model.createProperty(relationshipUri,"parentOf");
Property siblingOf = model.createProperty(relationshipUri,"siblingOf");
Property spouseOf = model.createProperty(relationshipUri,"spouseOf");

// Add properties to adam describing relationships to other family members
adam.addProperty(siblingOf,beth);
adam.addProperty(spouseOf,dotty);
adam.addProperty(parentOf,edward);

// Can also create statements directly . . .
Statement statement = model.createStatement(adam,parentOf,fran);

// but remember to add the created statement to the model
model.add(statement);
```

Querying a model

```
// List everyone in the model who has a child:
ResIterator parents = model.listSubjectsWithProperty(parentOf);

// Because subjects of statements are Resources, the method returned a ResIterator
while (parents.hasNext()) {

  // ResIterator has a typed nextResource() method
  Resource person = parents.nextResource();

  // Print the URI of the resource
  System.out.println(person.getURI());
}

// Can also find all the parents by getting the objects of all "childOf" statements
// Objects of statements could be Resources or literals, so the Iterator returned
// contains RDFNodes
NodeIterator moreParents = model.listObjectsOfProperty(childOf);

// To find all the siblings of a specific person, the model itself can be queried
NodeIterator siblings = model.listObjectsOfProperty(edward, siblingOf);

// But it's more elegant to ask the Resource directly
// This method yields an iterator over Statements
StmtIterator moreSiblings = edward.listProperties(siblingOf);
```

Using selectors to query a model

```
// Find the exact statement "adam is a spouse of dotty"
model.listStatements(adam,spouseOf,dotty);

// Find all statements with adam as the subject and dotty as the object
model.listStatements(adam,null,dotty);

// Find any statements made about adam
model.listStatements(adam,null,null);

// Find any statement with the siblingOf property
model.listStatements(null,siblingOf,null);
```

Exercise

- **Objective**
  - **Understand how to use an RDF(S) management API**
- **Tasks**
  - **Read an ontology in RDF(S) from two files:**
    - **GP_Santiago.rdf (conceptualization)**
    - **GP_Santiago.rdfs (instances)**
  - **Write the class hierarchy of the ontology, including the instances of each class**

Hands-on

- **To read an ontology in RDF(S) from two files:**
  - GP_Santiago.rdf (conceptualization)
  - GP_Santiago.rdfs (instances)
- **To write the class hierarchy of the ontology, including the instances of each class:**

```
Class Practica2:MedioTransporte
  Class Practica2:Tren
  Class Practica2:Bicicleta
    Instance Practica2:GP_Santiago_Instance_70
  Class Practica2:Automovil
  Class Practica2:AutoBus
  Class Practica2:APie
Class Practica2:InfraEstructuraTransporte
  Class Practica2:ViaFerrea
  Class Practica2:Sendero
  Class Practica2:Carretera
    Instance Practica2:A6
...
```

Set up

- **Requirements:**
  - Java JDK 5
  - Eclipse (optional)

- **Create a directory for your project**
- **Install Jena from the USB:**
  - Unzip *Jena-2.5.5.zip/**lib*** in the project directory
- **Copy the ontologies from the USB:**
  - Copy *ontologies/**rdf*** in the project directory

Or copy the JenaProjectTemplate directory in your computer

- **In Eclipse:**
  - Create a new Java project (from existing source)
  - Append the Jena libraries to your classpath if needed (check JDK libs)
  - Write Java code using the Jena API

    http://jena.sourceforge.net/javadoc/index.html
  - Compile
  - Run

Hints

- **Create ontology model:**

```
public static OntModel
  createOntologyModel(OntModelSpec spec)
```

- **Read the ontology in the file**

```
Model read(java.lang.String url)
```

- **Add all the statements in another model to this model**

```
Model add(Model m)
```


More hints

- **List root classes**

```
ExtendedIterator listHierarchyRootClasses()
```

- **List subclasses of a class**

```
ExtendedIterator listSubClasses(boolean
  direct)
```

- **List instances of a class**

```
ExtendedIterator listInstances(boolean direct)
```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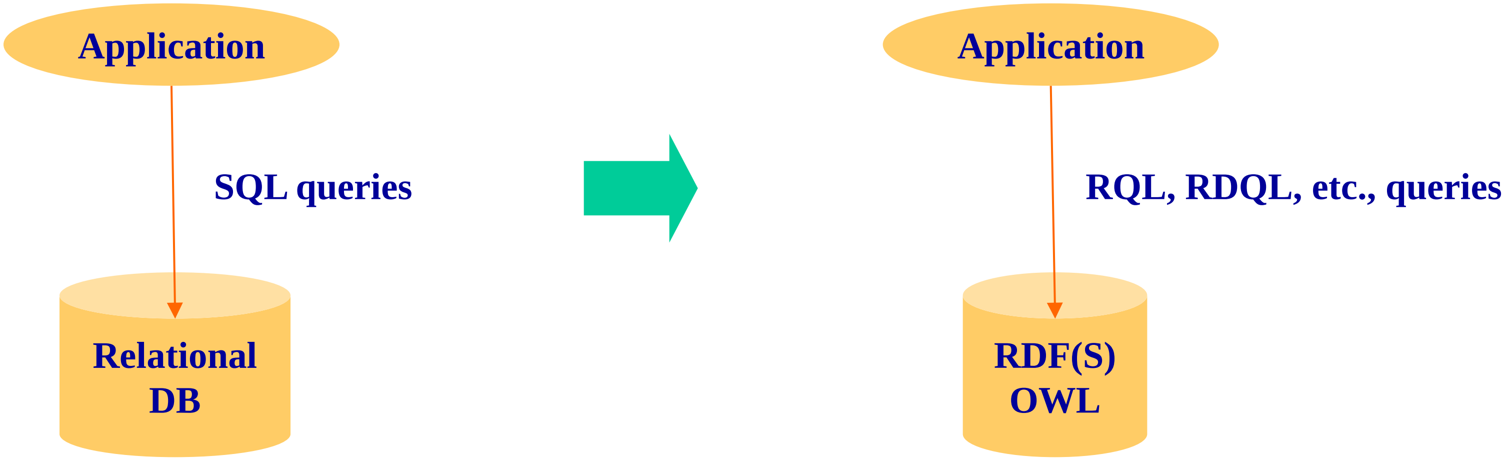
RDF(S) query languages

- **Languages developed to allow accessing datasets expressed in RDF(S) (and in some cases OWL)**



- **Supported by the most important language APIs**
  - Jena (HP labs)
  - Sesame (Aduna)
  - Boca (IBM)
  - ...
- **There are some differences wrt languages like SQL, such as**
  - Combination of different sources
  - Trust management
  - Open World Assumption

Query types

- **Selection and extraction**
  - "Select all the essays, together with their authors and their authors' names".
  - "Select everything that is related to the book 'Bellum Civille'"
- **Reduction**: we specify what it should not be returned
  - "Select everything except for the ontological information and the book translators"
- **Restructuring**: the original structure is changed in the final result
  - "Invert the relationship 'author' by 'is author of'"
- **Aggregation**
  - "Return all the essays together with the mean number of authors per essay"
- **Combination and inferences**
  - "Combine the information of a book called 'La guerra civil' and whose author is Julius Caesar with the book whose identifier is 'Bellum Civille'"
  - "Select all the essays, together with its authors and author names", *including also the instances of the subclasses of Essay*.
  - "Obtain the relationship 'coauthor' among persons who have written the same book".

RDF(S) query language families

- **SquishQL Family**
  - SquishQL
  - rdfDB Query Language
  - RDQL
  - BRQL
  - TriQL
- **XPath, XSLT, Xquery**
  - XQuery for RDF
  - XsRQL
  - TreeHugger and RDFTwig
  - RDFT, Nexus Query Language
  - RDFPath, Rpath and RXPath
  - Versa

Triple database Query structure

XML repository Query syntax

- **RQL Family**
  - RQL
  - SeRQL
  - eRQL
- **Controlled natural language**
  - Metalog
- **Other**
  - Algae
  - iTQL
  - N3QL
  - PerlRDF Query Language
  - RDEVICE Deductive Language
  - RDFQBE
  - RDFQL
  - TRIPLE
  - WQL

Description graphs Query semantics

SPARQL

W3C Recommendation

15 January 2008

SPARQL

- **SPARQL P**rotocol **a**nd **R**DF **Q**uery **L**anguage
- **Supported by:** Jena, Sesame, IBM Boca, etc.
- **Features**
  - It supports most of the aforementioned queries
  - It supports datatype reasoning (datatypes can be requested instead of actual values)
  - The domain vocabulary and the knowledge representation vocabulary are treated differently by the query interpreters.
  - It allows making queries over properties with multiple values, over multiple properties of a resource and over reifications
  - Queries can contain optional statements
  - Some implementations support aggregation queries
- **Limitations**
  - Neither set operations nor existential or universal quantifiers can be included in the queries
  - It does not support recursive queries

SPARQL is also a protocol

- SPARQL is a Query Language ...:
  Find names and websites of contributors to PlanetRDF:

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
SELECT ?name ?website
FROM <http://planetrdf.com/bloggers.rdf>
WHERE {
     ?person foaf:weblog ?website .
     ?person foaf:name ?name .
     ?website a foaf:Document }
```

- ... and a Protocol.

```
http://.../qps?query-lang=http://www.w3.org/TR/rdf-sparql-query/
&graph-id=http://planetrdf.com/bloggers.rdf&query=PREFIXfoaf:
<http://xmlns.com/foaf/0.1/...
```

- Services running SPARQL queries over a set of graphs
- A transport protocol for invoking the service
- Based on ideas from earlier protocol work such as Joseki
- Describing the service with Web Service technologies

A simple SPARQL query

Data:

```
@prefix dc: <http://purl.org/dc/elements/1.1/> .
@prefix : <http://example.org/book/> .
:book1 dc:title "SPARQL Tutorial" .
```

Query:

```
SELECT ?title
WHERE
{
  <http://example.org/book/book1> <http://purl.org/dc/elements/1.1/title> ?title .
}
```

Query result:

title
"SPARQL Tutorial"

- **A pattern is *matched* against the RDF data**
- **Each way a pattern can be matched yields a solution**
- **The sequence of solutions is filtered by: Project, distinct, order, limit/offset**
- **One of the result forms is applied: SELECT, CONSTRUCT, DESCRIBE, ASK**

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Turtle: URIs, blank nodes, literals

- **URIs**

  Enclosed in <>

  ```
  <URI>
  ```

  or

  ```
  @prefix prefix <http://....>
  prefix:name
  ```

- **Blank Nodes**

  ```
  :name
  ```

  or

  `[]` for a Blank Node used once

- **Literals**

  ```
  "Literal"
  "Literal"@language
  """Long literal with
  newlines"""
  ```

- **Datatyped Literals**

  "lexical form"^^datatype URI

  ```
  "10"^^xsd:integer
  "2006-09-04"^^xsd:date
  ```

Turtle: Triples and abbreviations

- **Triples separated by .**

  `:a :b :c . :d :e :f .`
- **Common triple predicate and subject:**

  `:a :b :c, :d .`

  which is the same as `:a :b :c . :a :b :d .`
- **Common triple subject:**

  `:a :b :c; :d :e .`

  which is the same as: `:a :b :c . :a :d :e .`
- **Blank node as a subject**

  `:a :b [ :c :d ]`

  which is the same as: `:a :b _:x . _:x :c :d .`
  for blank node `_:x`
- **RDF Collections**
  - `:a :b ( :c :d :e :f )`
    which is short for many triples

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Graph patterns

- **Basic Graph Patterns**, where a set of triple patterns must match
- **Group Graph Pattern**, where a set of graph patterns must all match
- **Optional Graph patterns**, where additional patterns may extend the solution
- **Alternative Graph Pattern**, where two or more possible patterns are tried
- **Patterns on Named Graphs**, where patterns are matched against named graphs

Basic graph patterns: Multiple matches

```
@prefix foaf:  <http://xmlns.com/foaf/0.1/> .

_:a  foaf:name   "Johnny Lee Outlaw" .
_:a  foaf:mbox   <mailto:jlow@example.com> .
_:b  foaf:name   "Peter Goodguy" .
_:b  foaf:mbox   <mailto:peter@example.org> .
_:c  foaf:mbox   <mailto:carol@example.org> .
```

```
PREFIX foaf:   <http://xmlns.com/foaf/0.1/>
SELECT ?name ?mbox
WHERE
  { ?x foaf:name ?name .
    ?x foaf:mbox ?mbox }
```

name	mbox
"Johnny Lee Outlaw"	<mailto:jlow@example.com>
"Peter Goodguy"	<mailto:peter@example.org>

Basic graph patterns: Matching RDF literals

```
@prefix dt:   <http://example.org/datatype#> .
@prefix ns:   <http://example.org/ns#> .
@prefix :     <http://example.org/ns#> .
@prefix xsd:  <http://www.w3.org/2001/XMLSchema#> .

:x   ns:p     "cat"@en .
:y   ns:p     "42"^^xsd:integer .
:z   ns:p     "abc"^^dt:specialDatatype .
```

```
SELECT ?v WHERE { ?v ?p "cat" }
```

v

```
SELECT ?v WHERE { ?v ?p "cat"@en }
```

v
<http://example.org/ns#x>

```
SELECT ?v WHERE { ?v ?p 42 }
```

v
<http://example.org/ns#y>

```
SELECT ?v WHERE { ?v ?p "abc"^^<http://example.org/datatype#specialDatatype> }
```

v
<http://example.org/ns#z>

Basic graph patterns: Blank node labels in query results

```
@prefix foaf:  <http://xmlns.com/foaf/0.1/> .

_:a  foaf:name   "Alice" .
_:b  foaf:name   "Bob" .
```

```
PREFIX foaf:   <http://xmlns.com/foaf/0.1/>
SELECT ?x ?name
WHERE  { ?x foaf:name ?name }
```

x	name
_:c	"Alice"
_:d	"Bob"

=

x	name
_:r	"Alice"
_:s	"Bob"

Group graph pattern

```
PREFIX foaf:    <http://xmlns.com/foaf/0.1/>
SELECT ?name ?mbox
WHERE  { { ?x foaf:name ?name . }
         { ?x foaf:mbox ?mbox . }
       }
```

```
SELECT ?x
WHERE {}
```

```
PREFIX foaf:    <http://xmlns.com/foaf/0.1/>
SELECT ?name ?mbox
WHERE  { { ?x foaf:name ?name . }
         { ?x foaf:mbox ?mbox . FILTER regex(?name, "Smith")}
       }
```

Optional graph patterns

```
@prefix foaf:       <http://xmlns.com/foaf/0.1/> .
@prefix rdf:        <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .

_:a  rdf:type        foaf:Person .
_:a  foaf:name       "Alice" .
_:a  foaf:mbox       <mailto:alice@example.com> .
_:a  foaf:mbox       <mailto:alice@work.example> .

_:b  rdf:type        foaf:Person .
_:b  foaf:name       "Bob" .
```

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
SELECT ?name ?mbox
WHERE  { ?x foaf:name  ?name .
         OPTIONAL { ?x  foaf:mbox  ?mbox }
       }
```

name	mbox
"Alice"	<mailto:alice@example.com>
"Alice"	<mailto:alice@work.example>
“Bob"	

Multiple optional graph patterns

```
@prefix foaf:       <http://xmlns.com/foaf/0.1/> .

_:a  foaf:name       "Alice" .
_:a  foaf:homepage   <http://work.example.org/alice/> .

_:b  foaf:name       "Bob" .
_:b  foaf:mbox       <mailto:bob@work.example> .
```

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
SELECT ?name ?mbox ?hpage
WHERE  { ?x foaf:name  ?name .
         OPTIONAL { ?x foaf:mbox ?mbox } .
         OPTIONAL { ?x foaf:homepage ?hpage }
       }
```

name	mbox	hpage
"Alice"		<http://work.example.org/alice/>
“Bob"	<mailto:bob@work.example>	

Alternative graph patterns

```
@prefix dc10:  <http://purl.org/dc/elements/1.0/> .
@prefix dc11:  <http://purl.org/dc/elements/1.1/> .

_:a  dc10:title     "SPARQL Query Language Tutorial" .
_:a  dc10:creator   "Alice" .
_:b  dc11:title     "SPARQL Protocol Tutorial" .
_:b  dc11:creator   "Bob" .
_:c  dc10:title     "SPARQL" .
_:c  dc11:title     "SPARQL (updated)" .
```

```
PREFIX dc10:  <http://purl.org/dc/elements/1.0/>
PREFIX dc11:  <http://purl.org/dc/elements/1.1/>
SELECT ?title
WHERE  { { ?book dc10:title  ?title } UNION
         { ?book dc11:title  ?title } }
```

title
"SPARQL Protocol Tutorial"
"SPARQL"
"SPARQL (updated)"
"SPARQL Query Language Tutorial"

```
SELECT ?x ?y
WHERE  { { ?book dc10:title ?x } UNION
         { ?book dc11:title  ?y } }
```

x	y
	"SPARQL (updated)"
	"SPARQL Protocol Tutorial"
"SPARQL"	
"SPARQL Query Language Tutorial"	

```
SELECT ?title ?author
WHERE
  { { ?book dc10:title ?title . ?book dc10:creator ?author }
    UNION
    { ?book dc11:title ?title . ?book dc11:creator ?author }}
```

author	title
"Alice"	"SPARQL Protocol Tutorial"
“Bob”	"SPARQL Query Language Tutorial"

Patterns on named graphs

```
# Named graph: http://example.org/foaf/aliceFoaf
@prefix foaf:<http://.../foaf/0.1/> .
@prefix rdf:<http://.../1999/02/22-rdf-syntax-ns#> .
@prefix rdfs:<http://.../2000/01/rdf-schema#> .

_:a  foaf:name     "Alice" .
_:a  foaf:mbox     <mailto:alice@work.example> .
_:a  foaf:knows    _:b .

_:b  foaf:name     "Bob" .
_:b  foaf:mbox     <mailto:bob@work.example> .
_:b  foaf:nick     "Bobby" .
_:b  rdfs:seeAlso  <http://example.org/foaf/bobFoaf> .

<http://example.org/foaf/bobFoaf>
     rdf:type      foaf:PersonalProfileDocument .
```

```
# Named graph: http://example.org/foaf/bobFoaf
@prefix foaf:<http://.../foaf/0.1/> .
@prefix rdf:<http://.../1999/02/22-rdf-syntax-ns#> .
@prefix rdfs:<http://.../2000/01/rdf-schema#> .

_:z  foaf:mbox     <mailto:bob@work.example> .
_:z  rdfs:seeAlso  <http://example.org/foaf/bobFoaf> .
_:z  foaf:nick     "Robert" .

<http://example.org/foaf/bobFoaf>
     rdf:type      foaf:PersonalProfileDocument .
```


Patterns on named graphs II

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>

SELECT ?src ?bobNick
FROM NAMED <http://example.org/foaf/aliceFoaf>
FROM NAMED <http://example.org/foaf/bobFoaf>
WHERE
  {
    GRAPH ?src
    { ?x foaf:mbox <mailto:bob@work.example> .
      ?x foaf:nick ?bobNick
    }
  }
```

src	bobNick
<http://example.org/foaf/aliceFoaf>	"Bobby"
<http://example.org/foaf/bobFoaf>	"Robert"

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
PREFIX data: <http://example.org/foaf/>

SELECT ?nick
FROM NAMED <http://example.org/foaf/aliceFoaf>
FROM NAMED <http://example.org/foaf/bobFoaf>
WHERE
  {
     GRAPH data:bobFoaf {
         ?x foaf:mbox <mailto:bob@work.example> .
         ?x foaf:nick ?nick }
  }
```

nick
"Robert"

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Restricting values

```
@prefix dc:   <http://purl.org/dc/elements/1.1/> .
@prefix :     <http://example.org/book/> .
@prefix ns:   <http://example.org/ns#> .

:book1  dc:title  "SPARQL Tutorial" .
:book1  ns:price  42 .
:book2  dc:title  "The Semantic Web" .
:book2  ns:price  23 .
```

```
PREFIX  dc:  <http://purl.org/dc/elements/1.1/>
SELECT  ?title
WHERE   { ?x dc:title ?title
          FILTER regex(?title, "^SPARQL")
        }
```

title
"SPARQL Tutorial"

```
PREFIX  dc:  <http://purl.org/dc/elements/1.1/>
SELECT  ?title
WHERE   { ?x dc:title ?title
          FILTER regex(?title, "web", "i" )
        }
```

title
"The Semantic Web"

```
PREFIX  dc:  <http://purl.org/dc/elements/1.1/>
PREFIX  ns:  <http://example.org/ns#>
SELECT  ?title ?price
WHERE   { ?x ns:price ?price .
          FILTER (?price < 30.5)
          ?x dc:title ?title . }
```

title	price
"The Semantic Web"	23

Value tests

- Based on XQuery 1.0 and XPath 2.0 Function and Operators
- XSD boolean, string, integer, decimal, float, double, dateTime
- Notation <, >, =, <=, >= and != for value comparison Apply to any type
- BOUND, isURI, isBLANK, isLITERAL
- REGEX, LANG, DATATYPE, STR (lexical form)
- Function call for casting and extensions functions

Solution sequences and modifiers

- **Order modifier:** put the solutions in order

```
SELECT ?name
WHERE { ?x foaf:name ?name ; :empId ?emp }
ORDER BY ?name DESC(?emp)
```

- **Projection modifier:** choose certain variables

```
SELECT ?name
WHERE
 { ?x foaf:name ?name }
```

- **Distinct modifier:** ensure solutions in the sequence are unique

```
SELECT DISTINCT ?name
WHERE { ?x foaf:name ?name }
```

- **Reduced modifier:** permit elimination of some non-unique solutions

```
SELECT REDUCED ?name
WHERE { ?x foaf:name ?name }
```

- **Offset modifier:** control where the solutions start from in the overall sequence of solutions

```
SELECT  ?name WHERE { ?x foaf:name ?name }
ORDER BY ?name
LIMIT   5
OFFSET  10
```

- **Limit modifier:** restrict the number of solutions

```
SELECT ?name
WHERE { ?x foaf:name ?name }
LIMIT 20
```


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SPARQL query forms

- **SELECT**
  - Returns all, or a subset of, the variables bound in a query pattern match.
- **CONSTRUCT**
  - Returns an RDF graph constructed by substituting variables in a set of triple templates.
- **ASK**
  - Returns a boolean indicating whether a query pattern matches or not.
- **DESCRIBE**
  - Returns an RDF graph that describes the resources found.

SPARQL query forms: SELECT

```
@prefix  foaf:  <http://xmlns.com/foaf/0.1/> .

_:a    foaf:name   "Alice" .
_:a    foaf:knows  _:b .
_:a    foaf:knows  _:c .

_:b    foaf:name   "Bob" .

_:c    foaf:name   "Clare" .
_:c    foaf:nick   "CT" .
```

```
PREFIX foaf:    <http://xmlns.com/foaf/0.1/>
SELECT ?nameX ?nameY ?nickY
WHERE
  { ?x foaf:knows ?y ;
       foaf:name ?nameX .
    ?y foaf:name ?nameY .
    OPTIONAL { ?y foaf:nick ?nickY }
  }
```

nameX	nameY	nickY
"Alice"	"Bob"	
"Alice"	"Clare"	"CT"

SPARQL query forms: CONSTRUCT

```
@prefix  foaf:  <http://xmlns.com/foaf/0.1/> .

_:a    foaf:name   "Alice" .
_:a    foaf:mbox   <mailto:alice@example.org> .
```

```
PREFIX foaf:    <http://xmlns.com/foaf/0.1/>
PREFIX vcard:   <http://www.w3.org/2001/vcard-rdf/3.0#>

CONSTRUCT   { <http://example.org/person#Alice> vcard:FN ?name }

WHERE       { ?x foaf:name ?name }
```

Query result:

```
@prefix vcard: <http://www.w3.org/2001/vcard-rdf/3.0#> .

<http://example.org/person#Alice> vcard:FN "Alice" .
```

SPARQL query forms: ASK

```
@prefix foaf:       <http://xmlns.com/foaf/0.1/> .

_:a  foaf:name       "Alice" .
_:a  foaf:homepage   <http://work.example.org/alice/> .

_:b  foaf:name       "Bob" .
_:b  foaf:mbox       <mailto:bob@work.example> .
```

```
PREFIX foaf:    <http://xmlns.com/foaf/0.1/>
ASK  { ?x foaf:name  "Alice" }
```

Query result:

```
yes
```


SPARQL query forms: DESCRIBE

```
PREFIX ent:  <http://org.example.com/employees#>
DESCRIBE ?x WHERE { ?x ent:employeeId "1234" }
```

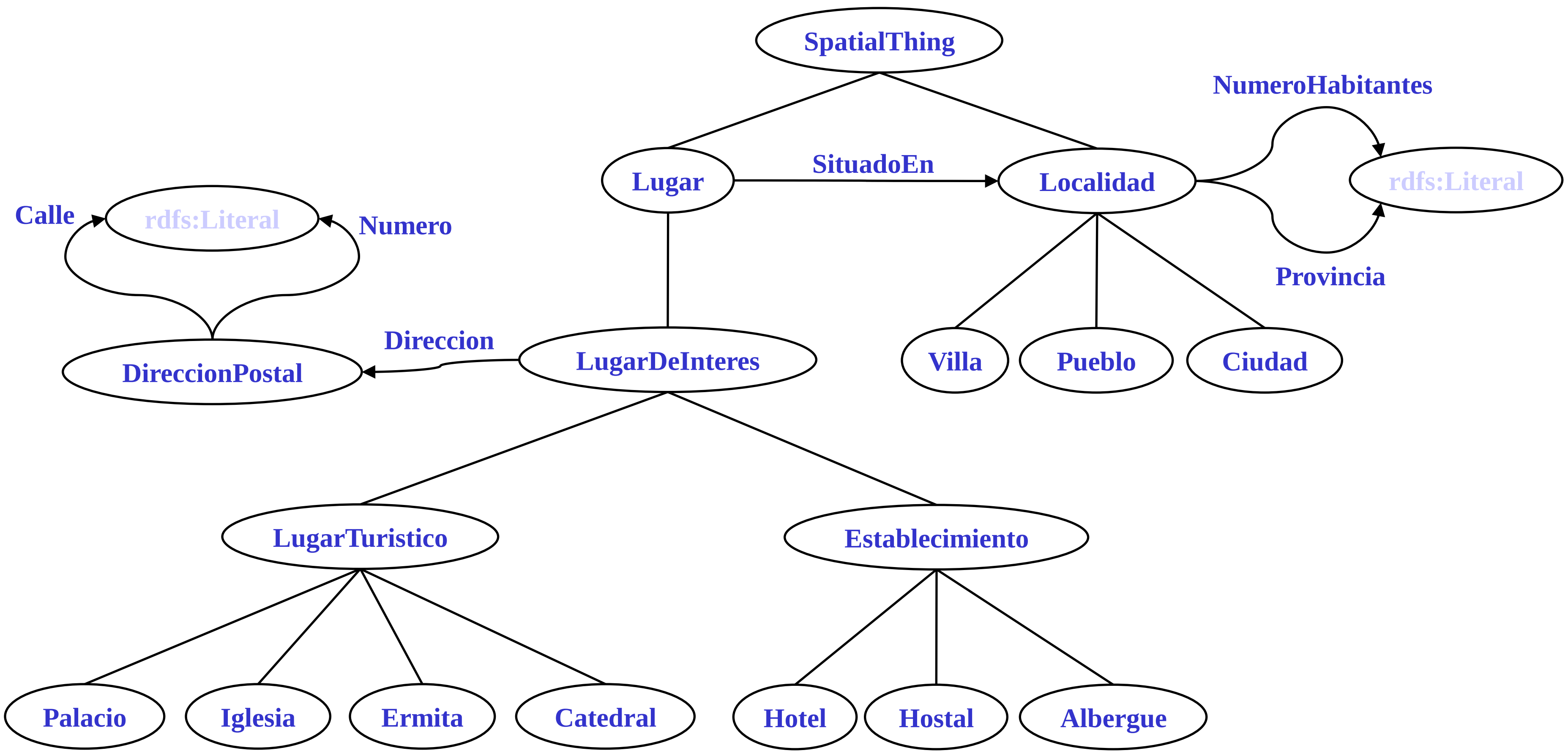
Query result:

```
@prefix foaf:   <http://xmlns.com/foaf/0.1/> .
@prefix vcard:  <http://www.w3.org/2001/vcard-rdf/3.0> .
@prefix exOrg:  <http://org.example.com/employees#> .
@prefix rdf:    <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix owl:    <http://www.w3.org/2002/07/owl#>

_:a     exOrg:employeeId    "1234" ;

        foaf:mbox_sha1sum   "ABCD1234" ;
        vcard:N
         [ vcard:Family       "Smith" ;
           vcard:Given        "John"  ] .

foaf:mbox_sha1sum  rdf:type  owl:InverseFunctionalProperty .
```

Exercise

- **Objective**
  - **Understand how to perform SPARQL queries**
- **Tasks**
  - **Perform a set of SPARQL queries over the sample ontology.**
    - **Browse to:**
      - **http://my.computer.ip:8080/openrdf-workbench**
    - **Select repository GP-native-rdfs**
    - **Select the Query option from the left menu**

Sample ontology



Queries on the model

1) Get all the classes

```
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
SELECT ?x WHERE { ?x a rdfs:Class. }
```

2) Get the subclasses of the class *Establecimiento*

```
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX pr: <http://GP-onto.fi.upm.es/Practica2#>
SELECT ?x WHERE { ?x rdfs:subClassOf pr:Establecimiento. }
```

3) Get the instances of the class *Ciudad*

```
PREFIX pr: <http://GP-onto.fi.upm.es/Practica2#>
SELECT ?x WHERE { ?x a pr:Ciudad. }
```

Queries on the instances

4) Get the number of inhabitants of *Santiago de Compostela*

```
PREFIX pr: <http://GP-onto.fi.upm.es/Practica2#>
SELECT ?x WHERE { pr:Santiago_de_Compostela pr:NumeroHabitantes ?x. }
```

5) Get the number of inhabitants of *Santiago de Compostela* and of *Arzua*

```
PREFIX pr: <http://GP-onto.fi.upm.es/Practica2#>
SELECT ?x WHERE {
                  {pr:Santiago_de_Compostela pr:NumeroHabitantes ?x.}
                  UNION
                  {pr:Arzua pr:NumeroHabitantes ?x.}
                }
```

6) Get different places with the inhabitants number, ordering the results by the name of the place (ascending)

```
PREFIX pr: <http://GP-onto.fi.upm.es/Practica2#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
SELECT ?x ?y  WHERE { $sitio pr:NumeroHabitantes ?y;
                             rdfs:label ?x.}
ORDER BY ASC(?x)
```

Queries on the instances II

7) Get all the instances of *Localidad* with their inhabitant number (if it exists)

```
PREFIX pr: <http://GP-onto.fi.upm.es/Practica2#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
SELECT ?x ?y  WHERE { $sitio a pr:Localidad;
                             rdfs:label ?x.
                      OPTIONAL {$sitio pr:NumeroHabitantes ?y.} }
```

8) Get all the places with more than 200.000 inhabitants

```
PREFIX pr: <http://GP-onto.fi.upm.es/Practica2#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
SELECT ?x ?y  WHERE { $sitio pr:NumeroHabitantes ?y;
                             rdfs:label ?x.
                      FILTER(?y > 200000) }
```

9) Get postal data of *Pazo de Breogan (calle, número, localidad, provincia)*

```
PREFIX pr: <http://GP-onto.fi.upm.es/Practica2#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
SELECT ?calle ?numero ?poblacion ?provincia
WHERE { pr:Pazo_Breogan pr:SituadoEn $pob;
                        pr:Direccion $dir.
        $pob rdfs:label ?poblacion;
             pr:Provincia ?provincia.
        $dir pr:Calle ?calle;
             pr:Numero ?numero.}
```

Queries with inference

10) Get the subclasses of class *Lugar*

```
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX pr: <http://GP-onto.fi.upm.es/Practica2#>
SELECT ?x WHERE { ?x rdfs:subClassOf pr:Lugar. }
```

11) Get the instances of class *Localidad*

```
PREFIX pr: <http://GP-onto.fi.upm.es/Practica2#>
SELECT ?x WHERE { ?x a pr:Localidad. }
```

Special query (SELECT *)

12) Get the values of all the variables in the query

```
PREFIX pr: <http://GP-onto.fi.upm.es/Practica2#>
SELECT * WHERE { ?x pr:NumeroHabitantes ?y. }
```

Different query forms

13) Describe the resource with *rdfs:label* "*Madrid*"

```
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
DESCRIBE ?x WHERE { ?x rdfs:label "Madrid". }
```

14) Construct the RDF(S) graph that directly relates all the touristic places with their respective provinces, using a new property called "*estaEn*".

```
PREFIX pr: <http://GP-onto.fi.upm.es/Practica2#>
CONSTRUCT {?x pr:estaEn ?y}
WHERE {
        ?x a pr:LugarTuristico;
             pr:SituadoEn $pob.
        $pob pr:Provincia ?y. }
```

15) Ask if there is some instance of *Pueblo*

```
PREFIX pr: <http://GP-onto.fi.upm.es/Practica2#>
ASK WHERE {?a a pr:Pueblo}
```

16) Ask if there is some instance of *Ermita*

```
PREFIX pr: <http://GP-onto.fi.upm.es/Practica2#>
ASK WHERE {?a a pr:Ermita}
```

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