Ontologies and Semantic Web

Semantic Web - 4:
standards and languages for knowledge representation

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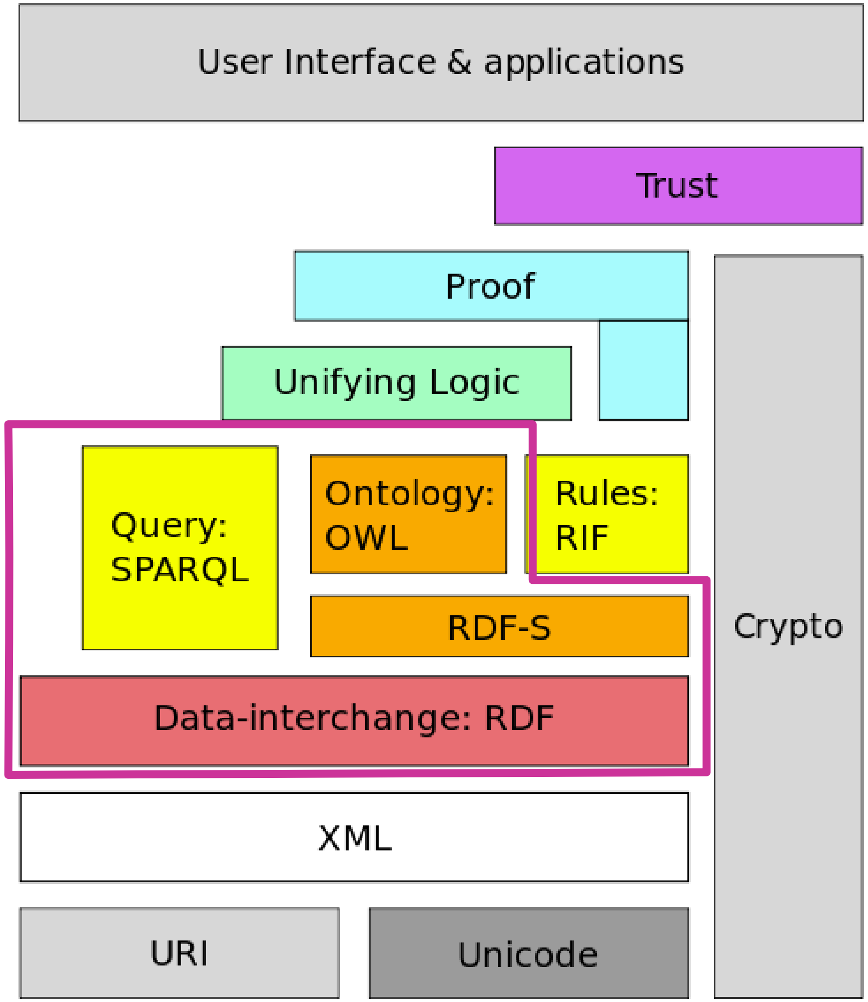
http://www.irit.fr/-Equipe-MELODI-

The Semantic Web layer cake (2006)



Semantic web specific blocks

Semantic

Syntax

naming

RDF vocabulary

- **Classes**

  rdf:Description – triple description
  rdf:Resource - the class resource, everything
  rdf:XMLLiteral - the class of XML literal values
  rdf:Property - the class of properties
  rdf:Statement - the class of RDF statements
  rdf:Alt, rdf:Bag, rdf:Seq - containers of alternatives, unordered containers, and ordered containers
  rdf:List - the class of RDF Lists
  rdf:nil - an instance of rdf:List representing the empty list

- **Properties**

  rdf:type - an instance of rdf:Property used to state that a resource is an instance of a class
  rdf:first - the first item in the subject RDF list
  rdf:rest - the rest of the subject RDF list after the first item
  rdf:value - idiomatic property used for structured values
  rdf:subject - the subject of the subject RDF statement
  rdf:predicate - the predicate of the subject RDF statement
  rdf:object - the object of the subject RDF statement

RDF: exercise 1

```
<?xml version="1.0" encoding="UTF-8"?>

<rdf:RDF
        xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
        xmlns:dc="http://purl.org/dc/elements/1.1/"
        xmlns:region="http://www.country-regions.fake/">
  <rdf:Description rdf:about="http://en.wikipedia.org/wiki/Oxford">
        <dc:title>Oxford</dc:title>
        <dc:coverage>Oxfordshire</dc:coverage>
        <dc:publisher>Wikipedia</dc:publisher>
        <region:population>10000</region:population>
        <region:principaltown rdf:resource="http://www.country-regions.fake/oxford"/>
 </rdf:Description>
</rdf:RDF>
```

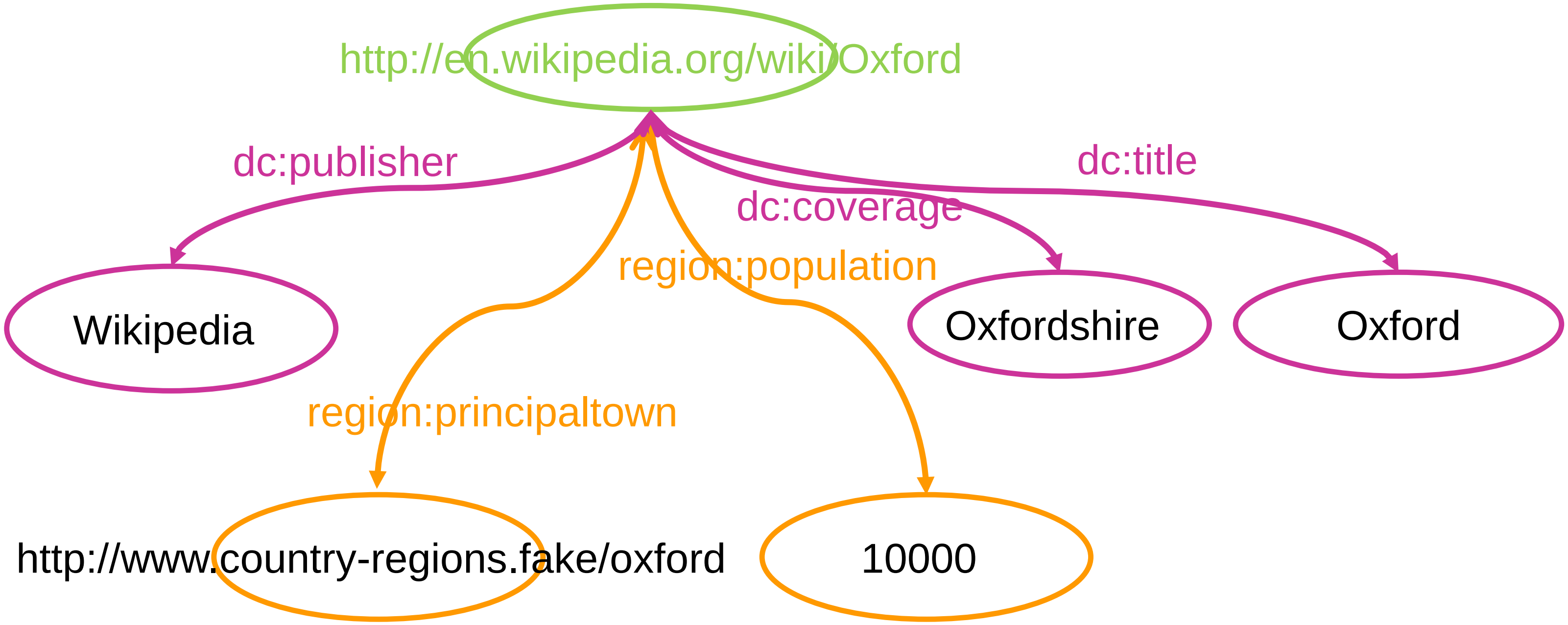
- Quel est la notation de RDF utilisée ?
- Quels sont les espaces de noms référencés et à quoi correspondent-ils ?
- Quel est l’entité principalement décrite ?
- Combien y a-t-il de triplets ?
- Réécrire la même information en TURTLE
- Dessiner le graphe correspondant

exercise 1

```
<?xml version="1.0" encoding="UTF-8"?>

<rdf:RDF
        xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
        xmlns:dc="http://purl.org/dc/elements/1.1/"
        xmlns:region="http://www.country-regions.fake/">

  <rdf:Description rdf:about="http://en.wikipedia.org/wiki/Oxford">
        <dc:title>Oxford</dc:title>
        <dc:coverage>Oxfordshire</dc:coverage>
        <dc:publisher>Wikipedia</dc:publisher>
        <region:population>10000</region:population>
        <region:principaltown rdf:resource="http://www.country-regions.fake/oxford"/>
 </rdf:Description>

</rdf:RDF>
```

Exercice 1 en TURTLE

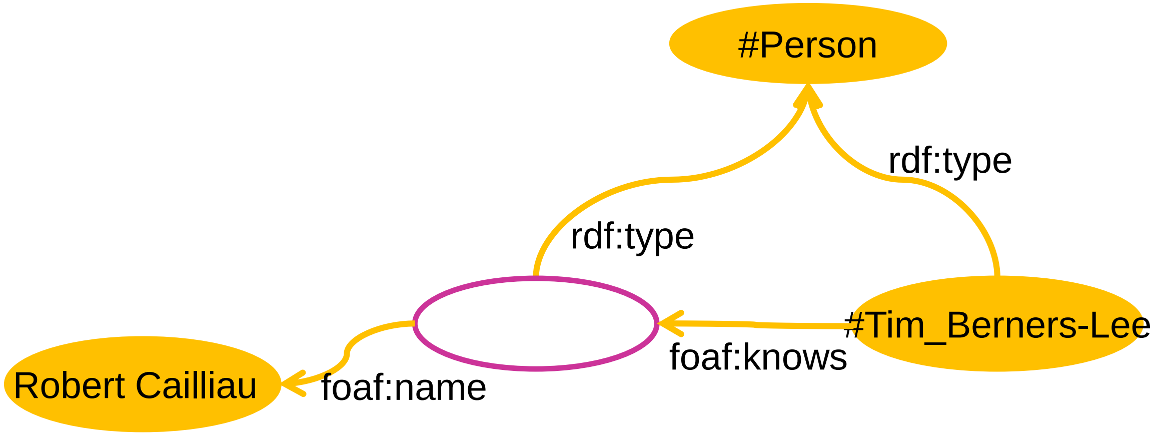
```
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix dc: <http://purl.org/dc/elements/1.1/> .
@prefix region: <http://www.country-regions.fake/> .

<http://en.wikipedia.org/wiki/Oxford>
        dc:title "Oxford " ;
        dc:coverage "Oxfordshire " ;
        dc:publisher "Wikipedia " ;
        region:population "1000 " ;
        region:principaltown <http://www.country-regions.fake/oxford> .
```


http://en.wikipedia.org/wiki/Oxford
dc:publisher
dc:title
dc:coverage
region:population
Wikipedia
Oxfordshire
Oxford
region:principaltown
http://www.country-regions.fake/oxford
10000

RDF semantics

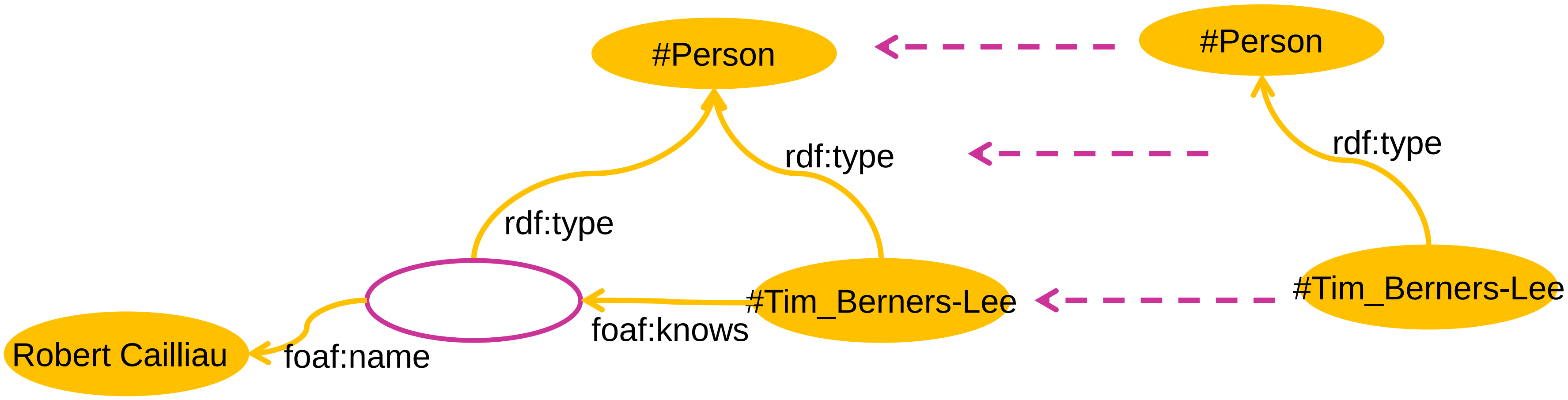
- Semantics in model theory
  - Triple: <s,p,o> is associated an atomic formula p(o,s)
  - Document: existential closure of the conjunction of atomic formulas
- Interpretation in predicate logic

∃x, (rdf:type(#Tim_Berners-Lee, #Person) ∧ rdf:type(x, #Person) ∧ foaf:knows(#Tim_Berners-Lee, x) ∧ faof:name(x, “Robert Cailliau”))



RDF semantics

- Reasoning mechanism
  - An RDF document is the consequence of another RDF document iff there is a graph homomorphisme between them
  - Goal = identifies all the consequences of a set of predicates



RDF: strengths and limitations

- compared with DB
  - better manages semi-structured data
  - “universal”
  - Adapted to the web
  - But very verbose, little efficiency for storage and querying
- Semantics
  - Logical model / model theory

RDF and the semantic web

- Difficulties with meta-data
  - May be missing
  - May be conflicting or erroneous
  - Reflect a point of view
  - Refer to local / specific types
- Difficulties to query different structural options

```
<foaf:Person  rdf:about="http://dbpedia.org/page/Tim_Berners-Lee">
<ex:hasActivity rdf:resource=#researcher”/>
</foaf:Person>

<foaf:Person  rdf:about="http://dbpedia.org/page/Marie_Curie">
rdf:type rdf:resource=#researcher”
</foaf:Person>

<ex:researcher rdf:about=“http://dbpedia.org/page/Albert_Einstein” />
```

which persons are researchers ?

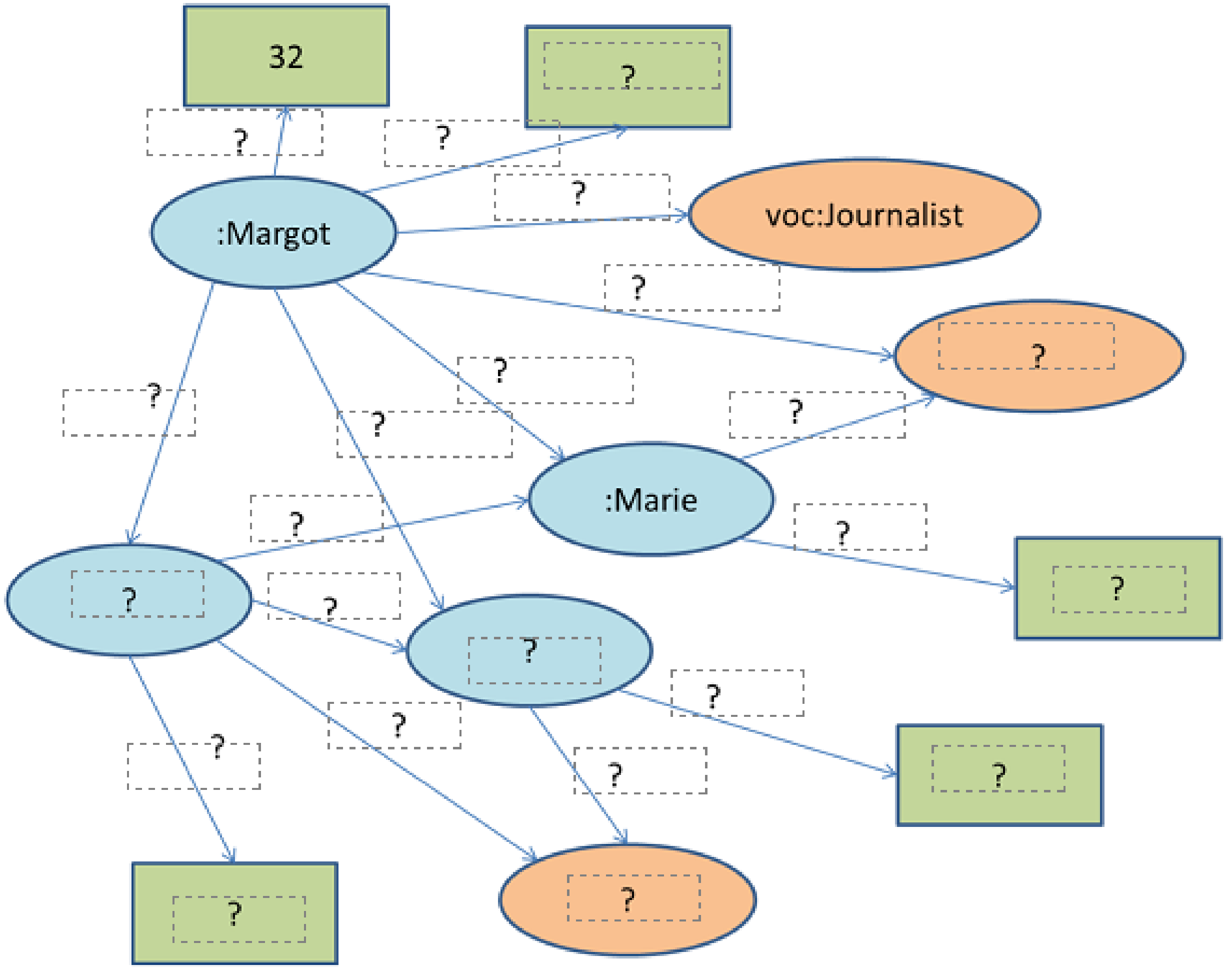
From RDF to RDFS

- **Need** to define properties for generic groups of individuals, such as the class of publishers, of organizations, or of persons
- **Solution**:
  - (XML) schema knowledge
  - RDF Schema (RDFS): part of the RDF W3C recommendation
  - Adequate for simple models, hierarchies of classes and instances

RDF:exercise 2

https://www.fun-mooc.fr/courses/inria/41002S02/session02/

- More about RDF
  - https://www.w3.org/TR/rdf11-primer/
- Margot est une femme journaliste, âgée de 32 ans, mariée à Arthur qui est un homme avec qui elle a deux enfants, Marie qui est une femme et Simon qui est un homme. Pour chaque personne, on spécifie aussi explicitement son prénom.
  - List the entities that will be resources
  - List the litterals
  - Define voc, a vocabulary with the needed rdf:Property,
  - Fill the graph



Vocabulary

- voc:hasSpouse
- voc:hasChild
- voc:Man
- voc:Woman
- voc:Journalist

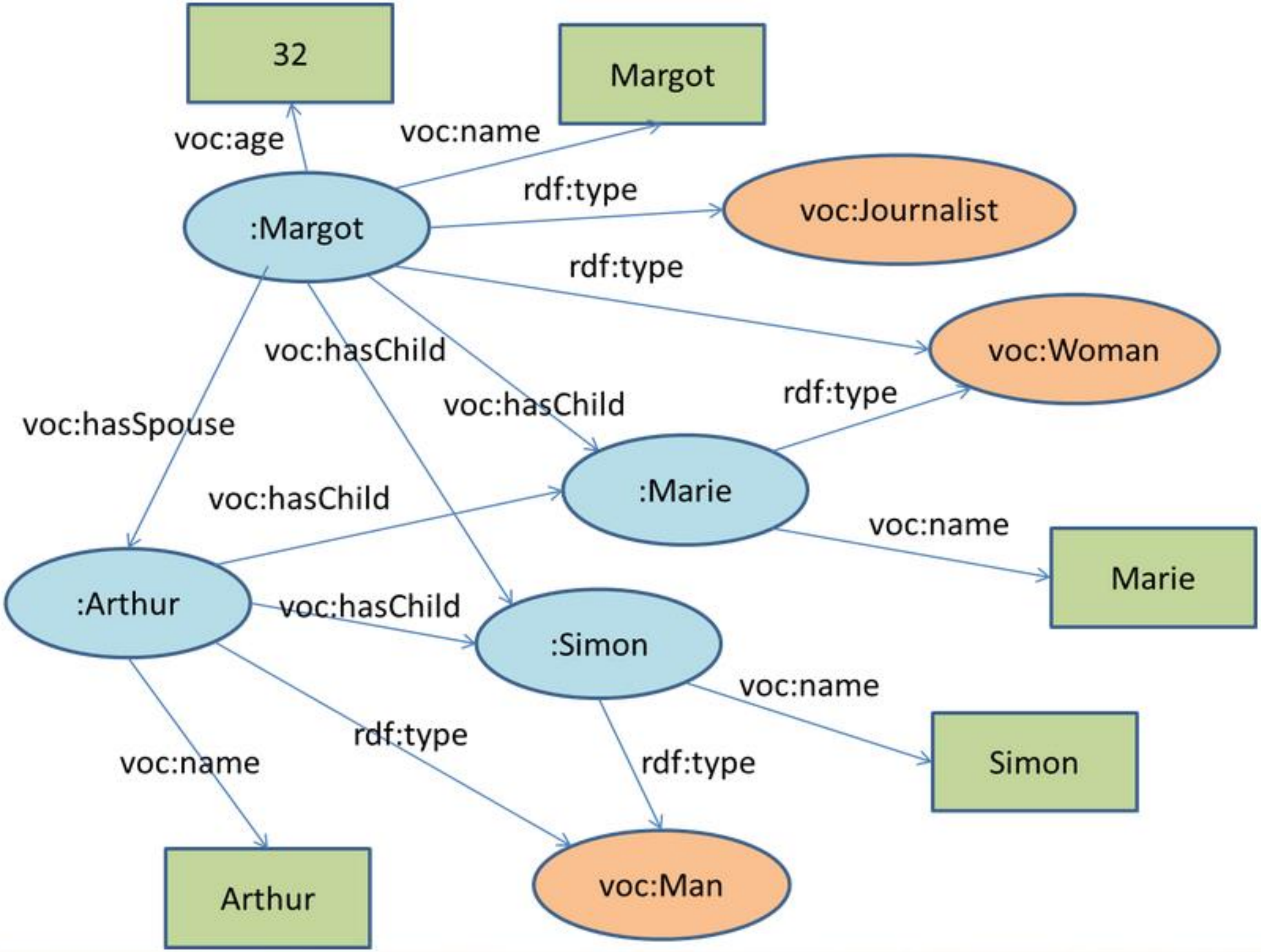
Entities

- :Margot
- :Marie
- :Simon
- :Arthur

Litterals

- « Marie »
- « Simon »
- « Arthur »
- « Margot »
- 32

SOLUTION


32
Margot
voc:age
voc:name
rdf:type
:Margot
voc:Journalist
rdf:type
voc:hasChild
voc:Woman
voc:hasChild
rdf:type
voc:hasSpouse
:Marie
voc:hasChild
voc:name
Marie
:Arthur
voc:hasChild
:Simon
voc:name
Simon
rdf:type
voc:name
rdf:type
Arthur
voc:Man

RDF-XML writing

```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE rdf:RDF [ <!ENTITY vocabulaire "http://www.unice.fr/voc"> <!ENTITY xsd "http://www.w3.org/2001/XMLSchema#">
]>
 <rdf:RDF   xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
        xmlns:voc="&vocabulaire;#"
        xml:base="http://www.unice.fr/data">

<AAA rdf:about="#Margot">
        <voc:name>Margot</voc:name>
        <voc:age rdf:datatype="http://www.w3.org/2001/XMLSchema#integer">32</voc:age>
        <BBB rdf:resource="#Arthur"></BBB>
        <voc:hasChild rdf:resource="#Simon"> </voc:hasChild>
        <voc:hasChild>
                <rdf:Description XXX="#Marie">
                        <voc:name>Marie</voc:name>
                        <rdf:type CCC=« voc:Woman"> </rdf:type>
                </rdf:Description>
                </voc:hasChild>
        <DDD rdf:resource=« voc:Journalist"></DDD>
</AAA>
<EEE rdf:about="#Arthur">
        <voc:name>Arthur</voc:name>
        <rdf:type rdf:resource=“voc:Man”>
        <voc:hasChild rdf:resource="#Simon"></voc:hasChild>
        <voc:hasChild rdf:resource="#Marie"></voc:hasChild>
</EEE>
<voc:Man rdf:about="#Simon">
        <voc:name>Simon</voc:name>
</voc:Man>
</rdf:RDF>
```

AAA = voc:Woman
BBB = voc:hasSpouse
CCC = rdf:resource
DDD = rdf:type
EEE = rdf:Description
XXX = rdf:about

RDF TURTLE notation

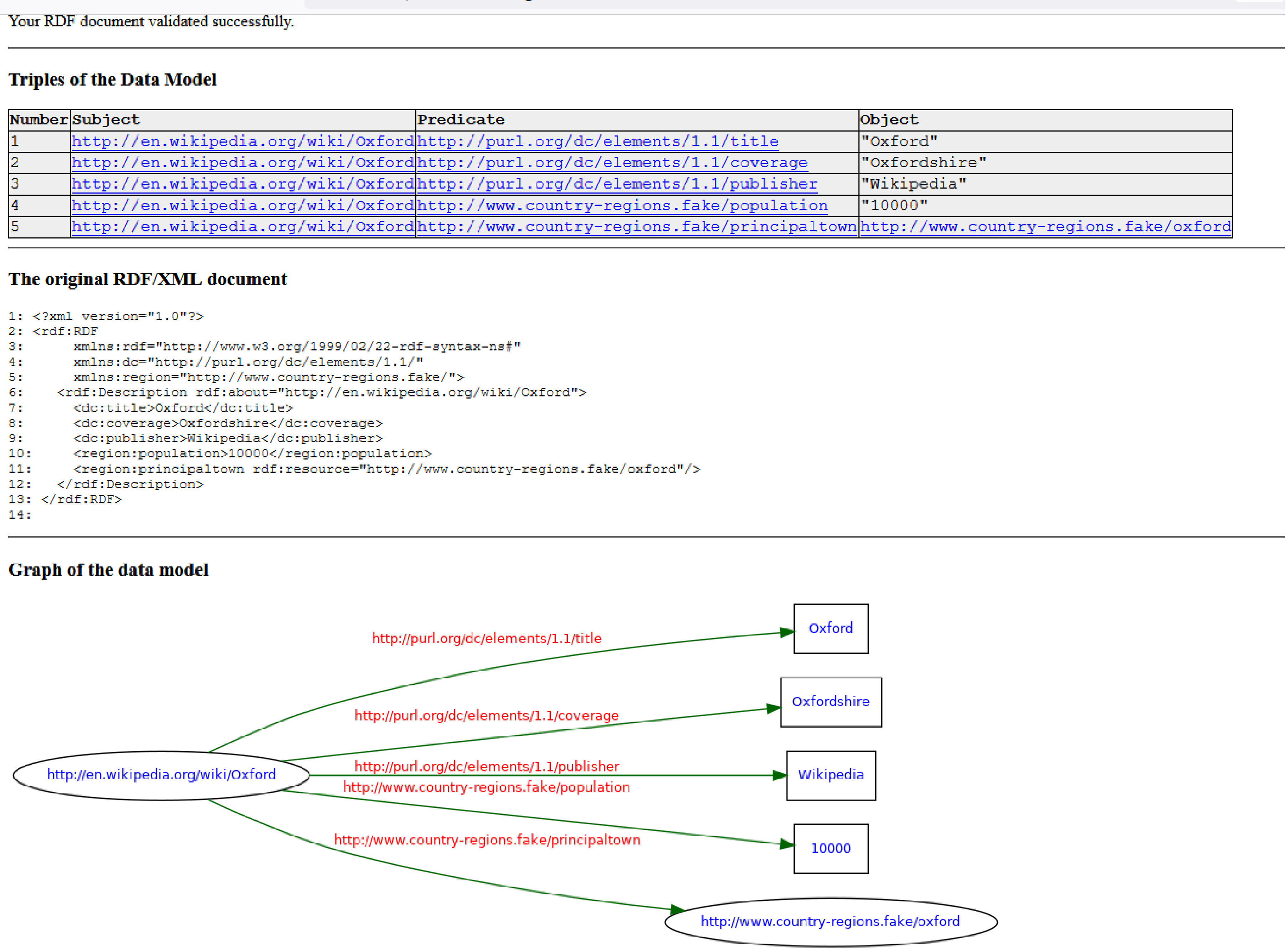
```
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix voc: <http://www.unice.fr/voc#> .
@prefix xml: <http://www.w3.org/XML/1998/namespace> .
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .

<http://www.unice.fr/data#Margot> a voc:Journalist AAA BBB ;
    voc:age "32"^^xsd:string ;
    voc:hasChild <http://www.unice.fr/data#Marie>, <CCC>;
    voc:hasSpouse <http://www.unice.fr/data#Arthur> ;
    voc:name "Margot" .
<http://www.unice.fr/data#Arthur> DDD voc:Man ;
    voc:hasChild <http://www.unice.fr/data#Marie>, <http://www.unice.fr/data#Simon> ;
    voc:name "Arthur" .
<http://www.unice.fr/data#Marie> a voc:Woman ;
    voc:name « Marie" .
<EEE> a FFF ;
    GGG HHH .
```

Advanced checking

- To check the actual equivalence of the statements given as solutions of the two previous excercises, you can use RDF Translator, an on-line service

http://rdf-translator.appspot.com/

- You can use the W3C on-line validation service, http://www.w3.org/RDF/Validator/, to get the list of triples and visualize them as a graph.



Your RDF document validated successfully.

Triples of the Data Model

Number	Subject	Predicate	Object
1	http://en.wikipedia.org/wiki/Oxford	http://purl.org/dc/elements/1.1/title	"Oxford"
2	http://en.wikipedia.org/wiki/Oxford	http://purl.org/dc/elements/1.1/coverage	"Oxfordshire"
3	http://en.wikipedia.org/wiki/Oxford	http://purl.org/dc/elements/1.1/publisher	"Wikipedia"
4	http://en.wikipedia.org/wiki/Oxford	http://www.country-regions.fake/population	"10000"
5	http://en.wikipedia.org/wiki/Oxford	http://www.country-regions.fake/principaltown	http://www.country-regions.fake/oxford

The original RDF/XML document

```
<?xml version="1.0"?>
<rdf:RDF
     xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
     xmlns:dc="http://purl.org/dc/elements/1.1/"
     xmlns:region="http://www.country-regions.fake/">
   <rdf:Description rdf:about="http://en.wikipedia.org/wiki/Oxford">
     <dc:title>Oxford</dc:title>
     <dc:coverage>Oxfordshire</dc:coverage>
     <dc:publisher>Wikipedia</dc:publisher>
     <region:population>10000</region:population>
     <region:principaltown rdf:resource="http://www.country-regions.fake/oxford"/>
   </rdf:Description>
</rdf:RDF>

```

Graph of the data model

http://purl.org/dc/elements/1.1/title
Oxford
http://purl.org/dc/elements/1.1/coverage
Oxfordshire
http://en.wikipedia.org/wiki/Oxford
http://purl.org/dc/elements/1.1/publisher
Wikipedia
http://www.country-regions.fake/population
10000
http://www.country-regions.fake/principaltown
http://www.country-regions.fake/oxford

Checking RDF models

- Extracting RDF from RDFa annotated pages
  - RDFa Distiller and Parser http://www.w3.org/2012/pyRdfa/
  - Y. Herman, web service
- Checking RDFa annotations
  - RDFa validator (web service) http://www.w3.org/2012/pyRdfa/Validator.html

From RDF to RDFS

- **Need** to define properties for generic groups of individuals, such as the class of publishers, of organizations, or of persons
- **Solution**:
  - (XML) schema knowledge
  - RDF Schema (RDFS): part of the RDF W3C recommendation
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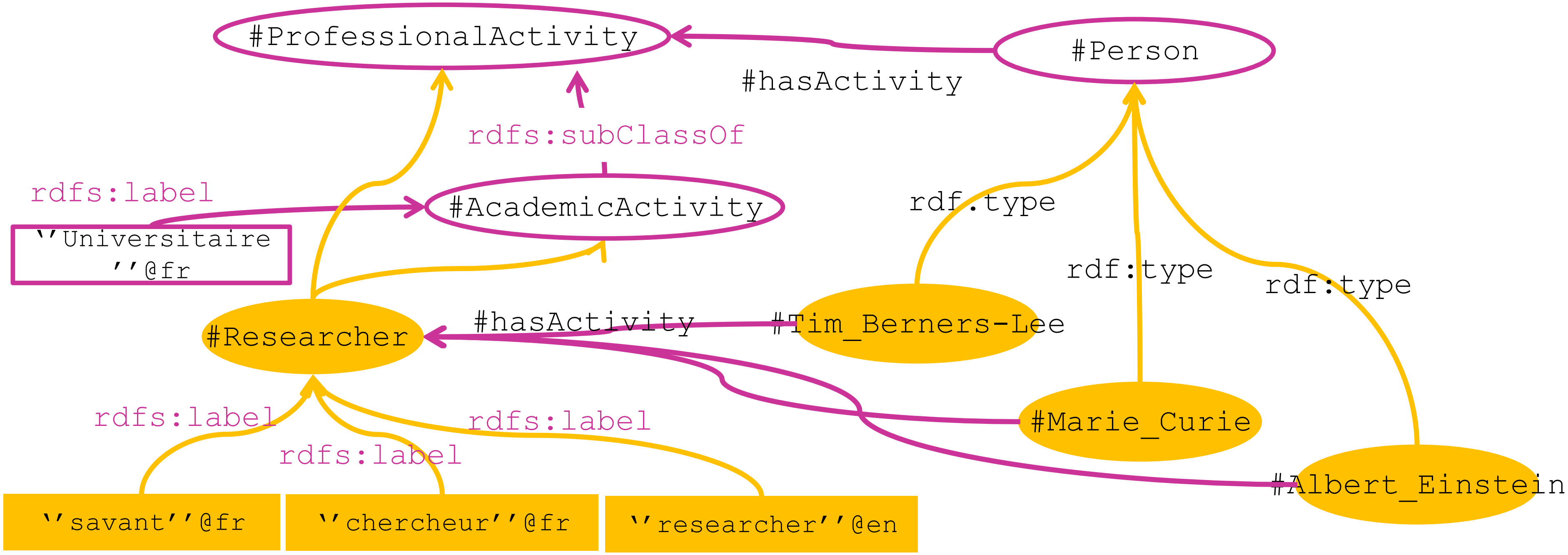
RDF SChema

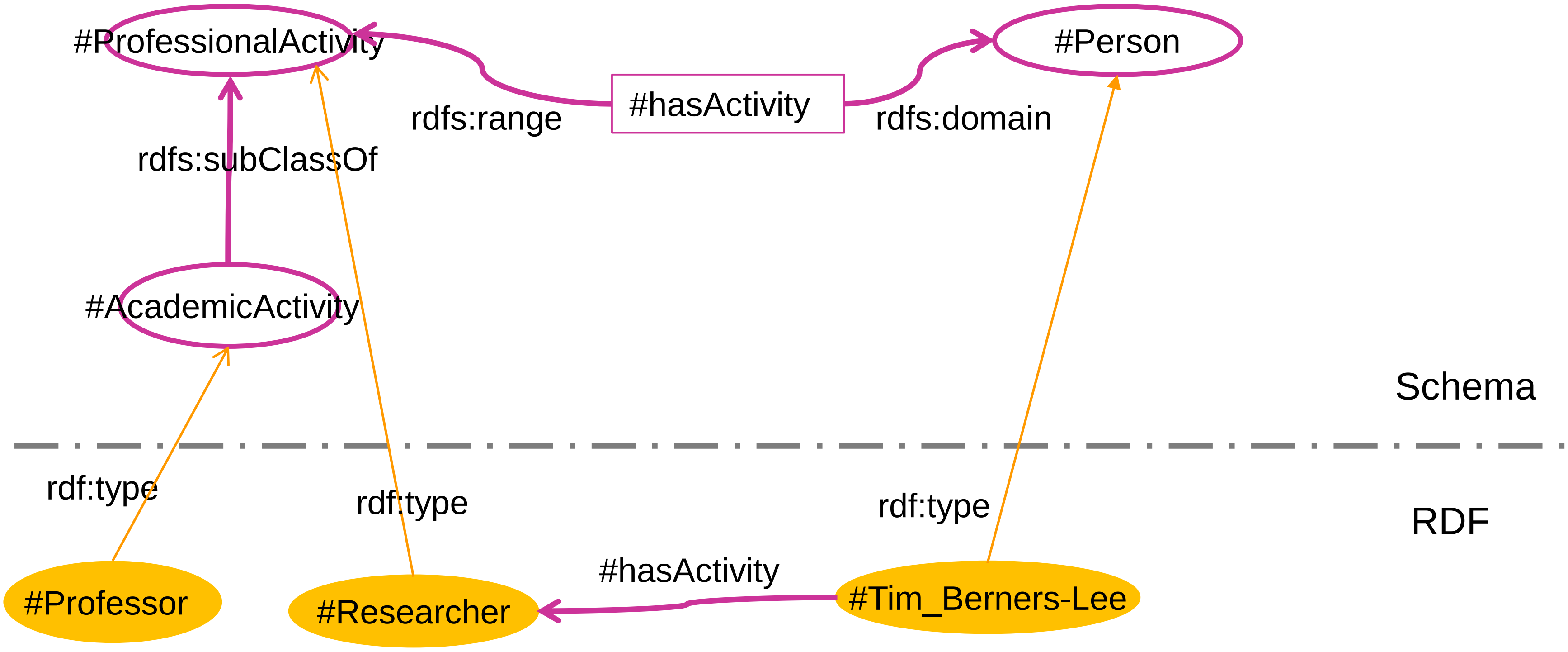
RDF and shared (formal) vocabularies



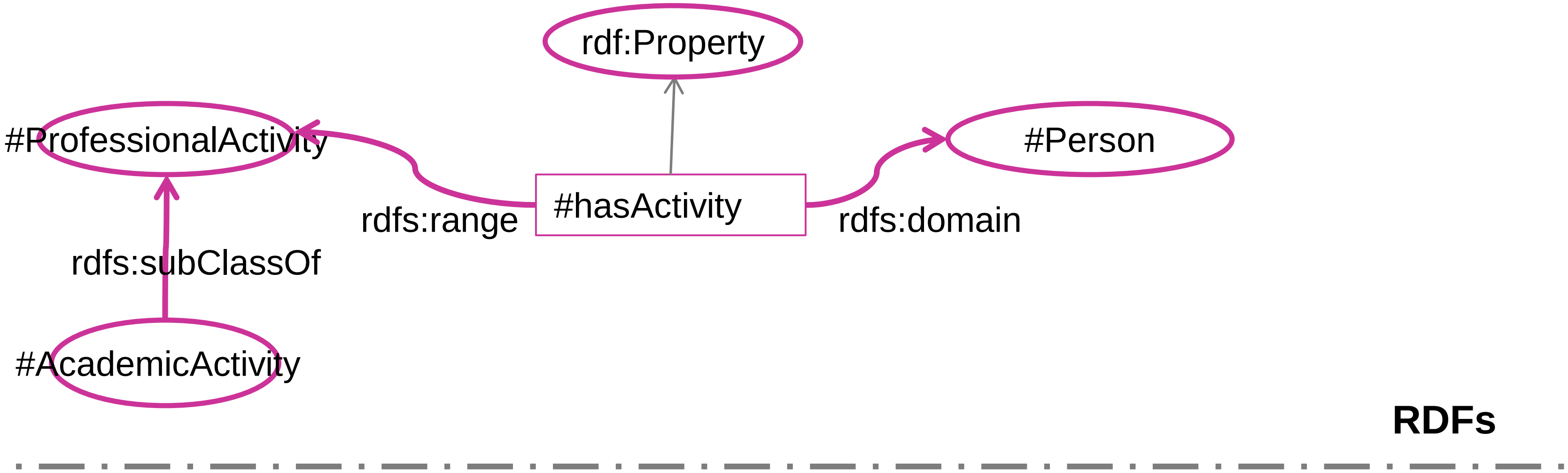
- Give the status of “class” to types `rdfs:Class`
- Organize types in a hierarchy `rdfs:subClassOf`
- Distinguish identifiers (ID) from natural language labelling of entities/classes: `rdfs:label`
- Reach a semantic agreement: ontologies

RDF and RDFS (RDFSchema)

- RDF schema: labelled and oriented graph made of RDF triples
- Property oriented



RDFS and RDF



- rdfs:Class: defined as rdfs:Resources
- 3 triples define a property
  - Property rdf:type rdf:Property #hasActivity rdf:type rdf:Property
  - Property rdfs:domain Class1 #hasActivity rdfs:domain #Person
  - Property rdfs:range Class2 #hasActivity rdfs:range #ProfessionalActivity
- rdfs:subClassOf defined as a rdf:Property

RDFS `xml:base` : give a URI to your own vocabulary

XML Syntax

```
<rdf:RDF
   xml:base="http://www.irit.fr/MELODI/ontologies/humans.rdfs"
   xmlns:rdf ="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
   xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#">
(…)
</rdf:RDF>
```

Turtle syntax

```
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#>
@base <http://www.irit.fr/MELODI/ontologies/humans.rdfs>
(…)
```

RDFS main classes

- rdfs:Resource
  - Super class of any rdfs resource
- rdfs:Class
  - Ex: N7:students, N7:N7_students, are types of rdfs:Class
  - A URI can have one or several types
- rdfs:subClassOf
  - Ex: N7:N7_students rdfs:subClassOf N7:students
- rdfs:Literal
  - Ex: xsd^year, integer, rdfs:Datatype, rdfs:XMLLiteral are sub-classes of (rdfs:subClassOf) rdfs:Literal
  - 2008, “10”, “Tim Berners Lee” are instances of (rdf:type) rdfs:Literal
- rdf:Statement
  - Instances: (#Tim_Berners-Lee, #hasBirthYear, “1955”)

RDFS semantics

- rdf:type
- rdfs:subClassOf
  - Instance-Class `#Michael rdf:type #ErasmusStudent`
  - Class-Class `#ErasmusStudent rdfs:subClassOf #Student`
  - Infered triple `#Michael rdf:type #Student`

```
<?xml version="1.0"?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
xmlns:xsd="http://www.w3.org/2001/xmlschema#"
xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
xmlns:ex="http://www.irit.fr/ontology/ex#">

<rdfs:Class rdf:about="#ErasmusStudent">
       <rdfs:subClassOf rdf:resource="#Student"/>
</rdfs:Class>
<ex:ErasmusStudent  rdf:about="#Michael" />
</rdf:RDF>
```

RDFS property definition

- rdfs:domain and rdfs:range

```
<rdf:Property rdf:ID=“#isPartOf">
      <rdfs:domain rdf:resource=“#materialObject"/>
      <rdfs:range rdf:resource=“#materialObject"/>
</rdf:Property>
```

- rdfs:subPropertyOf

```
<rdf:Property rdf:about=“#DoorFunctionalPartOf">
      <rdfs:subPropertyOf  rdf:resource=“# isPartOf” />
      <rdfs:domain rdf:resource=“#handle"/      → =“#handle rdfs:subClassOf  #materialObject
      <rdfs:range rdf:resource=“#door"/ → =“#door rdfs:subClassOf  #materialObject
</rdf:Property>
```

- Semantics

(truc ,*#doorFunctionalPartOf, bidule)* →

((truc, rdf:type, rdf:resource=“#handle“) ∧ (bidule, rdf:type, rdf:resource=“#door“) ∧ (truc ,*#isPartOf, bidule)*)

RDFS semantics

- Semantics of rdfs:subClassOf

  a rdfs:subClassOf b means

  ∀ x ((x rdf:type a) → (x rdf:type b))

  - Defines a hierarchy of classes
  - Transitive and reflexive

- Semantics of rdfs:domain and rdfs:range

  P rdfs:domain C1 and P rdfs:range C2 means

  ∀ x,y (x P y) → ((x rdf:type C1) and (y rdf:type C2))

RDFS property definition

- property restrictions are interpreted globally and conjunctively, e.g.
  - ex:authorOf rdfs:range ex:Cookbook .
  - ex:authorOf rdfs:range ex:Storybook .
- means: everything which is authored by somebody is both a cookbook and a storybook
- thus: always use most generic classes for domain/range statements

RDFS additional properties

- used to add human-readable information (comments or names)
  - rdfs:label : assigns an alternative name (encoded as literal) to an arbitrary ressource
  - rdfs:comment : assigns a more comprehensive comment (also literal)
  - rdfs:seeAlso, rdfs:definedBy : refer to resources (URIs) containing further information about the subject resource

RDFS for lightweight ontologies

- Certain semantic aspects of a domain of interest
- Hierarchy of classes
- Domain and range of properties
  - `#Human rdfs:subClassOf #Primate`
  - `#SpeaksWith rdf:type rdfs:Property`
  - `#SpeaksWith rdfs:domain #Human`
  - `#SpeaksWith rdfs:range #Human`
  - (a, #SpeaksWith,b) -> `a rdf:type #Human` (and consequently also `a rdf:type #primate`)
- No cardinality constraint, no negation, no disjunction

RDFa: inserting RDF into HTML pages

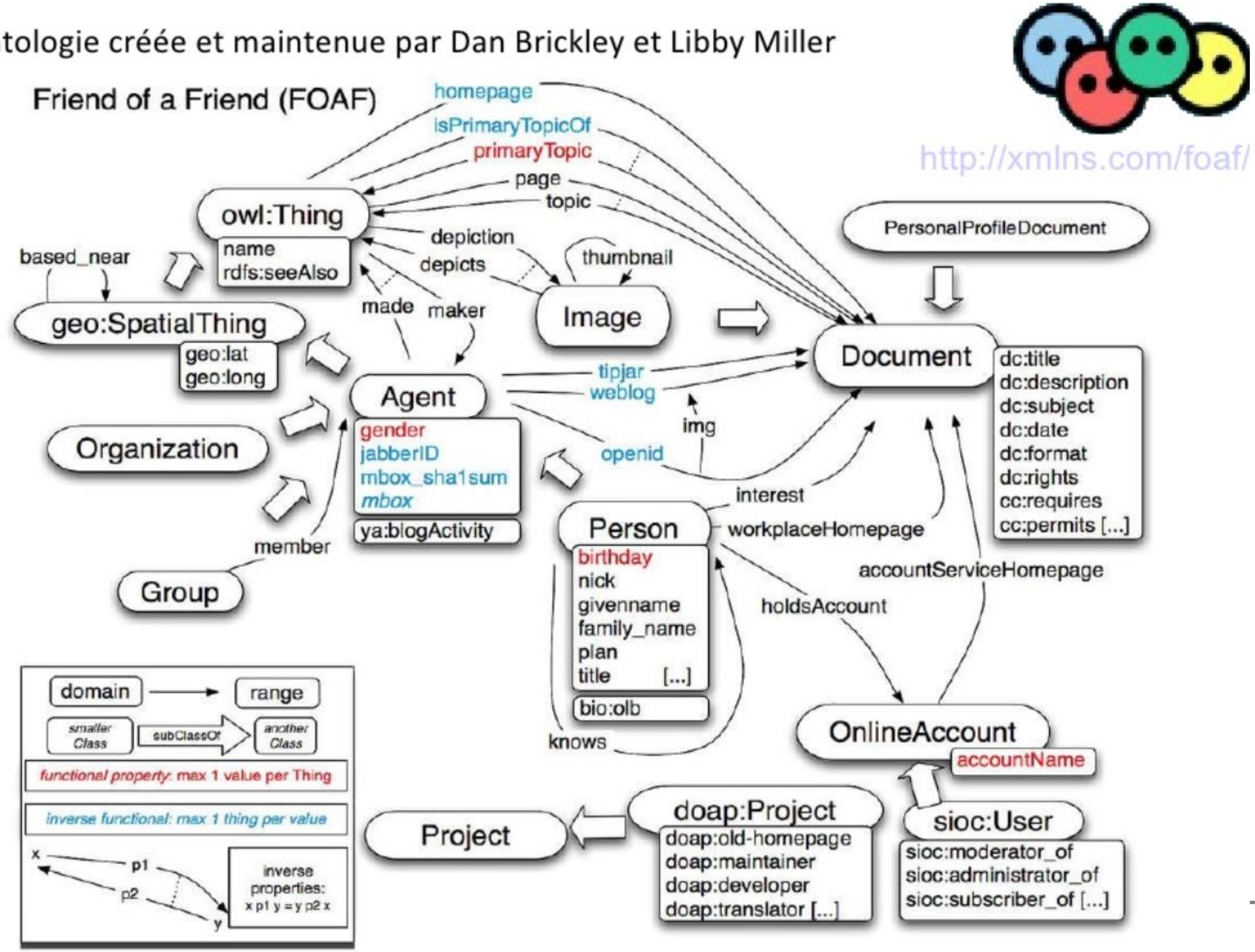
```
<!DOCTYPE html PUBLIC “-//W3C/DTD XHTML+RDFa1.0//EN”
“http://www.w3.org/MarkUp/DTD/xhtml-rdfa-1.dtd”>
<html
    xmlns="http://www.w3.org/1999/xhtml"
    xmlns:foaf=http://xmlns.com/foaf/0.1/
    xmlns:dc=http://purl.org/dc/terms/>                xml:lang=“fr">
          <head>
             <title >Description de Tim Berners Lee en XHTML + RDFa</title>
          </head>
          <body>
              <div typeof=“foaf:person” about=“http://www.w3.org/People/Berners-Lee/card#i>
               Le <span rel=“dc:creator” href=“http://www.w3.org”> créateur du W3C</span> a
    pour nom Le <span property=“foaf:name”> Timothy Berners-Lee</span> et pour surnom
    <span property=“foaf:nick”> Timbl</span>.
               </div>
          </body>
</html>
```

RDF and RDFS vocabularies : examples

- FOAF persons
- DC Dublin Core : http://dublincore.org/schemas/rdfs/
- SKOS : thesaurus and vocabularies

FOAF

Ontologie créée et maintenue par Dan Brickley et Libby Miller



Towards ontology representation

- Class definition
  - Identify the type, nature of each entity on the web
    - Tim Berners-Lee est une personne
    - Une personne est un être vivant
  - In RDFs, any resource has a type which is rdfs:Class
- Properties
  - Entities have features or properties
  - In RDFs, resources have rdfs:properties
- Classes and properties are defined in RDFs (formal) vocabularies

Towards ontology representation

- Reasoning capabilities
  - Make explicit some of the hidden assumptions behind classes and properties
    - If a person A worksWith a person B, then B worksWith V
  - In RDF, such inferences have to be clearly written as rules or axioms or properties
    - worksWith is a simetric property
  - Logic rewriting of RDFs models make it possible to infer new facts and new knowledge.