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Make our Scientific Datasets Accessible and Interoperable on the Web

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Make our Scientific Datasets Accessible and Interoperable on the Web



RBDD2015, CNRS Database Network
Oct. 21st 2015



Franck MICHEL

I3S - UMR 7271, CNRS - Univ. Nice Sophia



Make our datasets accessible and interoperable on the Web...



- Not only because of H2020 requirement
- Linking data increases its value
 - Mash up with related data
 - Produce new knowledge
 - Opportunity for new (unexpected) usage
- Citizenship demand for access to public data (scientific, government...)
- ...



From a Web of Documents ...to a Web of Data

- ❑ Publication/interlinking of open datasets
 - Publish heterogeneous data in a **common format**
 - Using **common vocabularies**
- ❑ Driven by major initiatives, e.g.:
 - Linking Open Data
 - W3C Data Activity
 - Open Data hosting services... OpenAIRE, Zenodo...
- ❑ As well as other domain-specific projects
 - Bio2RDF, BioPortal

April 2008

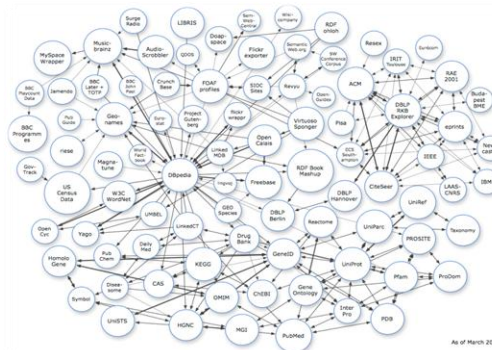


Sept. 2008



As of September 2008

March 2009

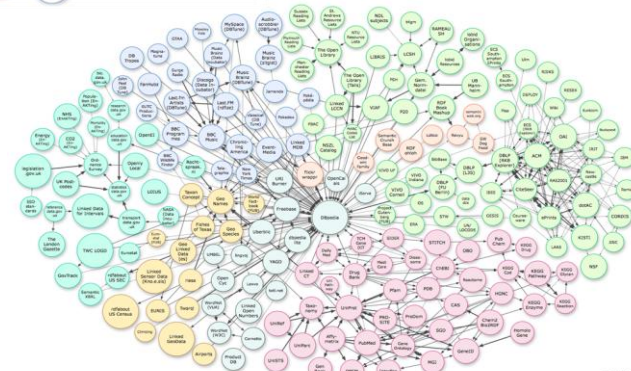


As of March 2009

May 2007

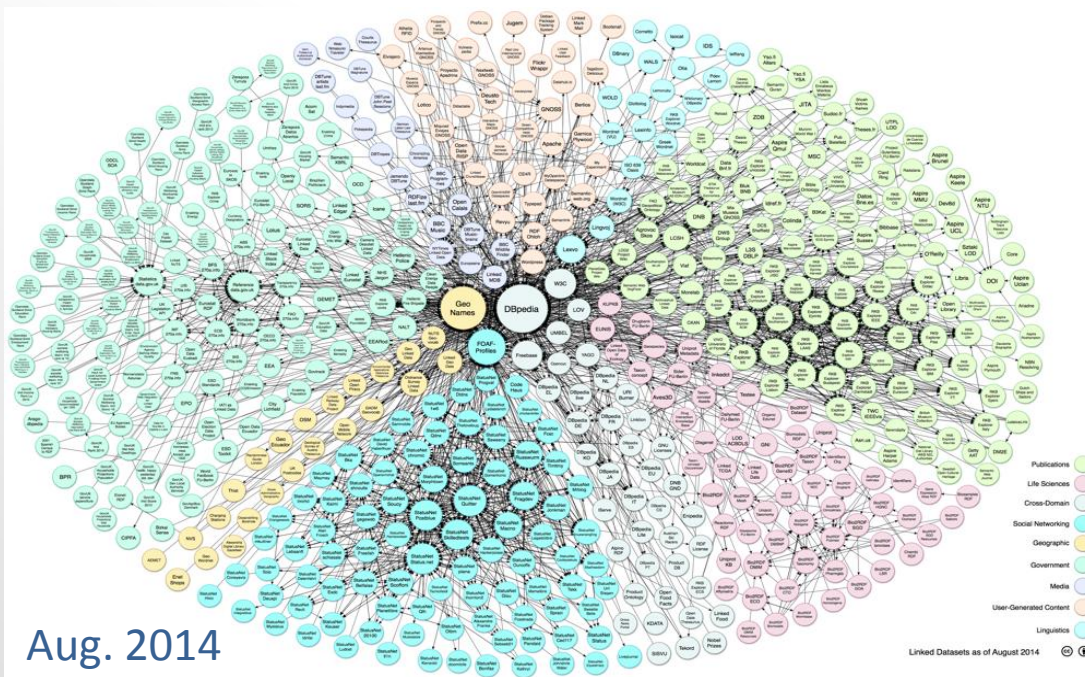


Linked Open Data Cloud



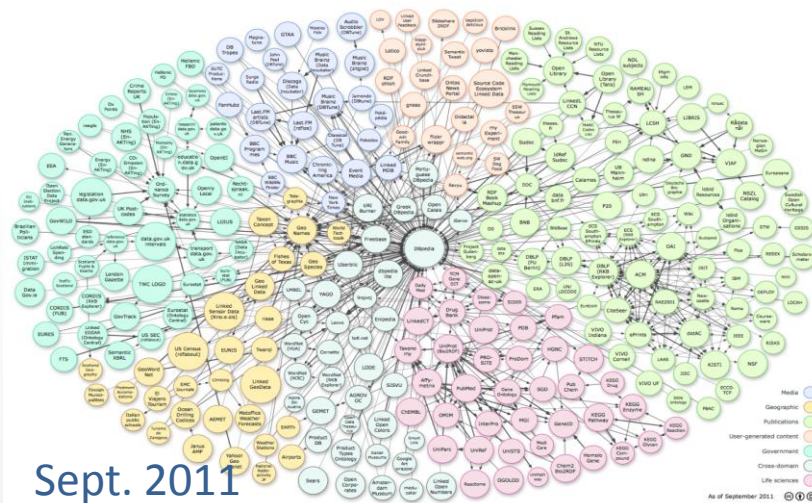
As of September 2010

Sept. 2010



Linked Datasets as of August 2014

Aug. 2014



As of September 2011

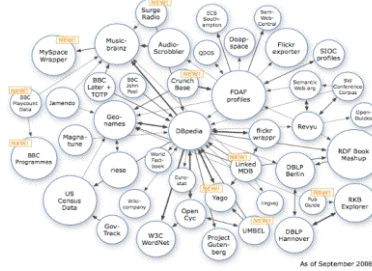
Sept. 2011

Linked Datasets as of Aug. 30th 2014. (c) R. Cyganiak & and A. Jentzsch

April 2008

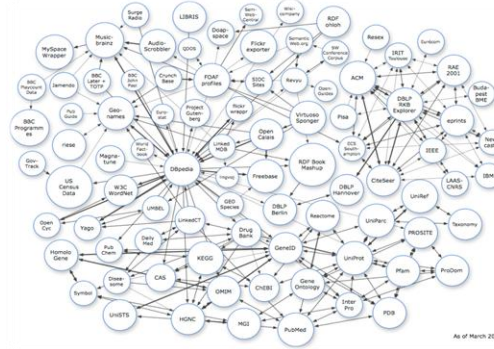


Sept. 2008



As of September 2008

March 2009

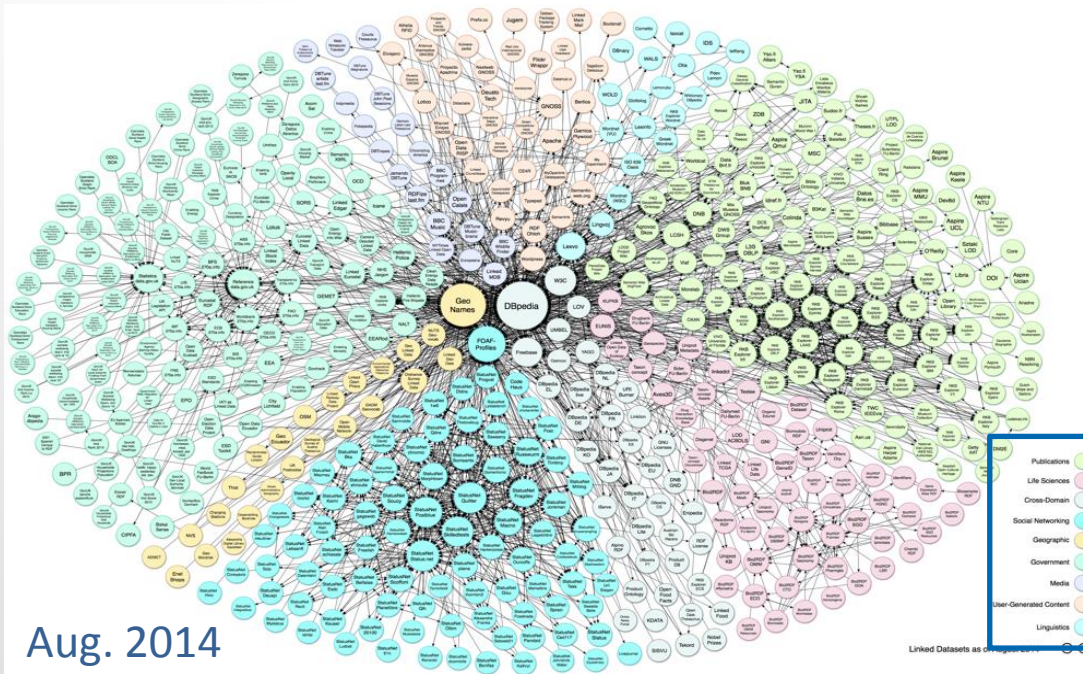


As of March 2009

May 2007












Linked Open Data Cloud



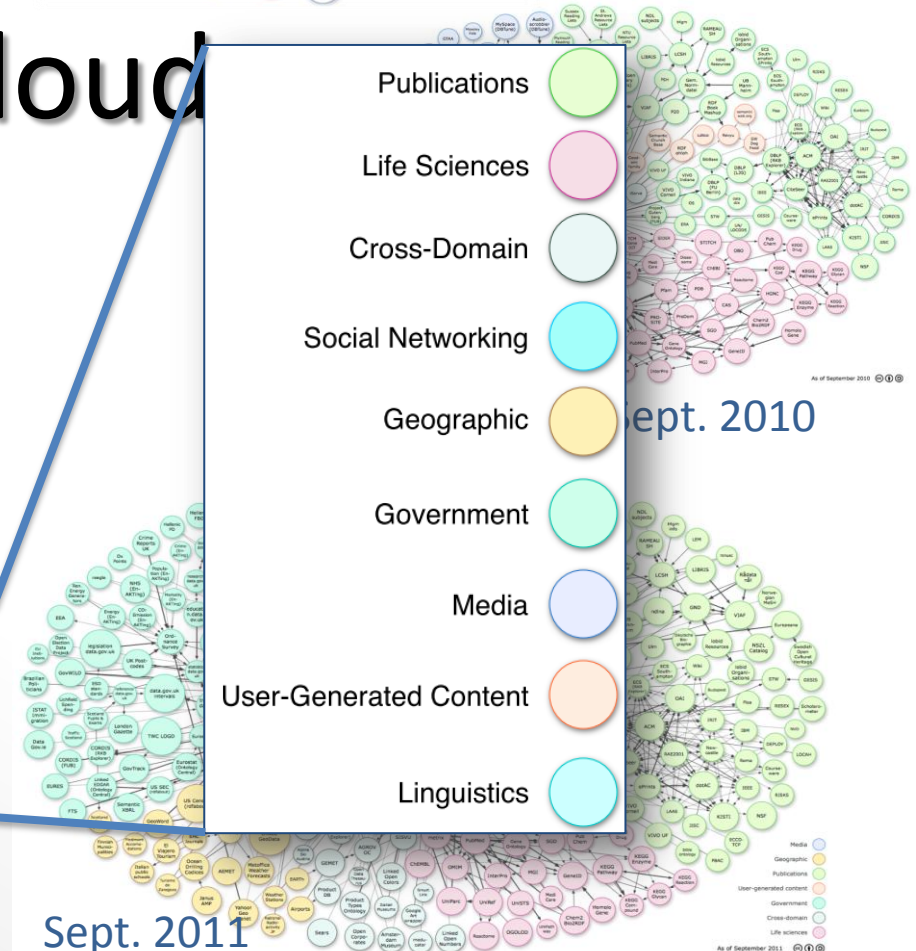
Aug. 2014

Linked Datasets as of August 2014

- Publications 
- Life Sciences 
- Cross-Domain 
- Social Networking 
- Geographic 
- Government 
- Media 
- User-Generated Content 
- Linguistics 

Sept. 2010

Sept. 2011



As of September 2011

Linked Datasets as of Aug. 30th 2014. (c) R. Cyganiak & and A. Jentzsch

An iceberg floating in the ocean. The tip of the iceberg is above the water line, and the much larger, submerged part is below. The sky is blue with light clouds, and the water is a deep blue. The text 'Visible Web' is in the top right, 'Deep Web' is in the bottom right, and a red speech bubble with 'you are here' points to the submerged part of the iceberg.

Visible Web

**you
are
here**

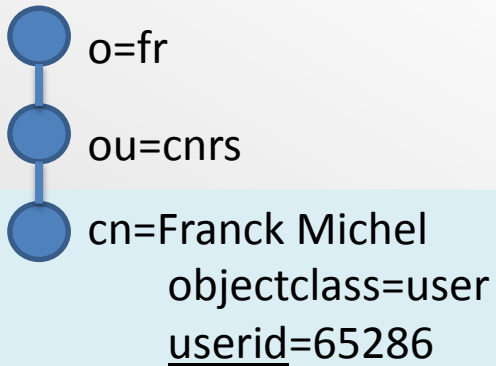
Deep Web

Heterogeneous data models

Tabular

ID	NAME	

Directory

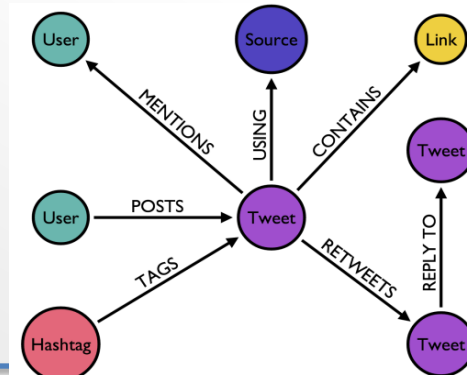


XML Native DBs, Document stores...

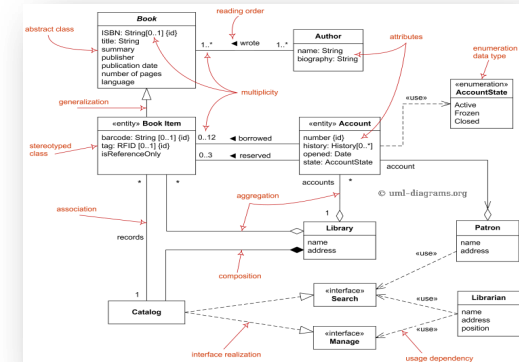
```

<Books>
  <Book ISBN="0553212419">
    <title>Sherlock Holmes: Complete Novels...</title>
    <author>Sir Arthur Conan Doyle</author>
  </Book>
  <Book ISBN="0743273567">
    <title>The Great Gatsby</title>
    <author>F. Scott Fitzgerald</author>
  </Book>
  <Book ISBN="0684826976">
    <title>Undaunted Courage</title>
    <author>Stephen E. Ambrose</author>
  </Book>
  <Book ISBN="0743203178">
    <title>Nothing Like It In the World</title>
    <author>Stephen E. Ambrose</author>
  </Book>
</Books>
  
```

Graph



Object-Oriented



Documents



Heterogeneous query capabilities

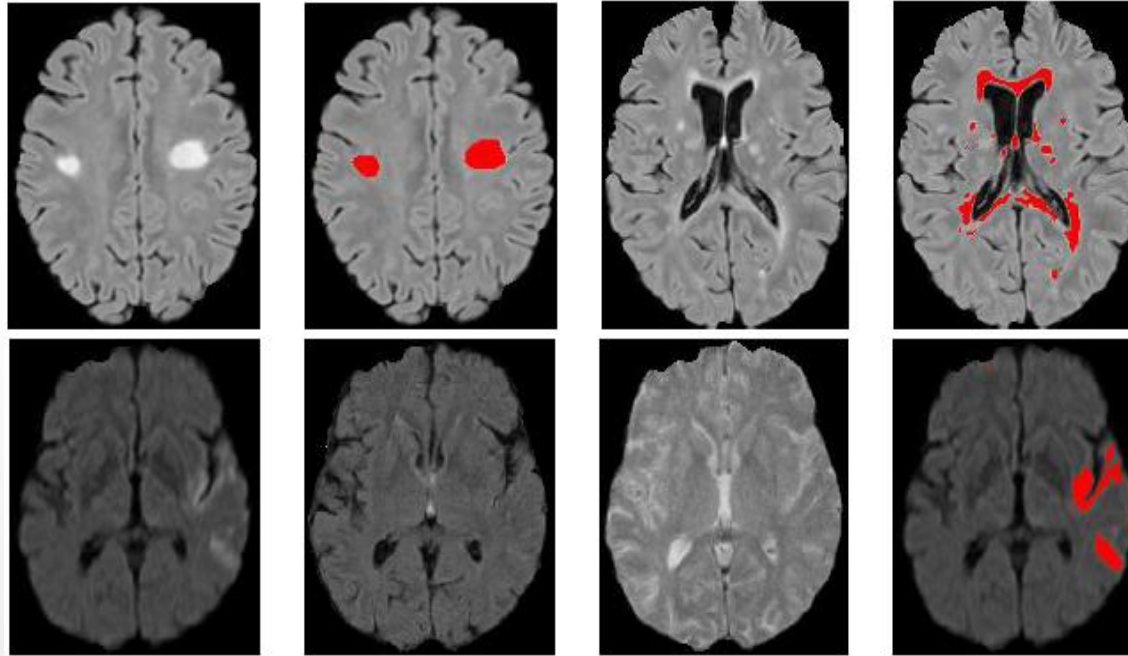
- ❑ RDBs, NewSQL => **SQL**
- ❑ XML native DBs => **XPath/XQuery**
- ❑ Graph - Neo4J: **Cypher**, Allegrograph: **SPARQL**
- ❑ Document - MongoDB, CouchDB:
similar **JS/JSON-based QL**
- ❑ Column – Cassandra (**CQL**), HIVE (**HQL**)
- ❑ Key-value – Riak, DynamoDB: low level **API**
- ❑ ...



Make our datasets accessible and interoperable on the Web...

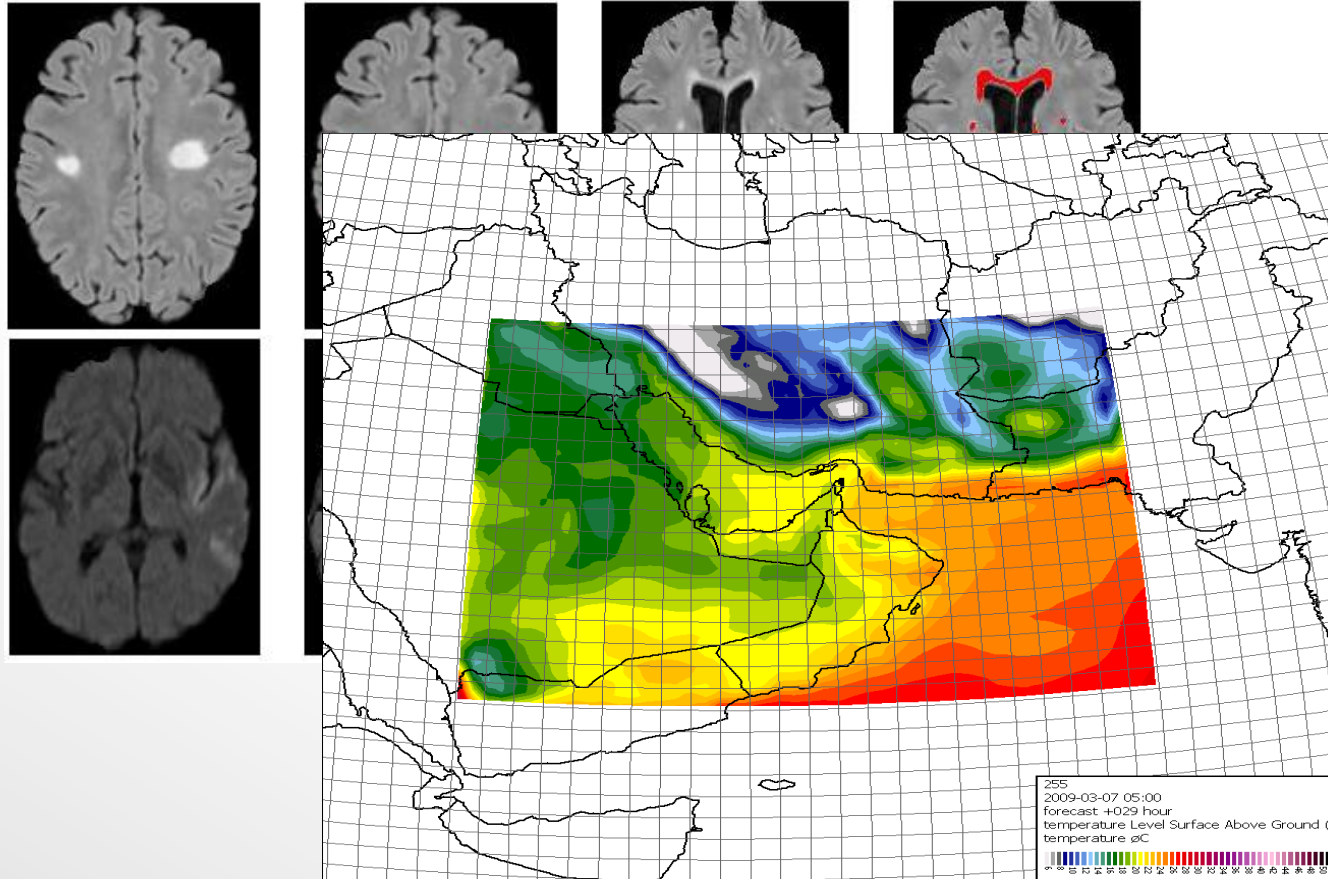


To you, your data may mean this...



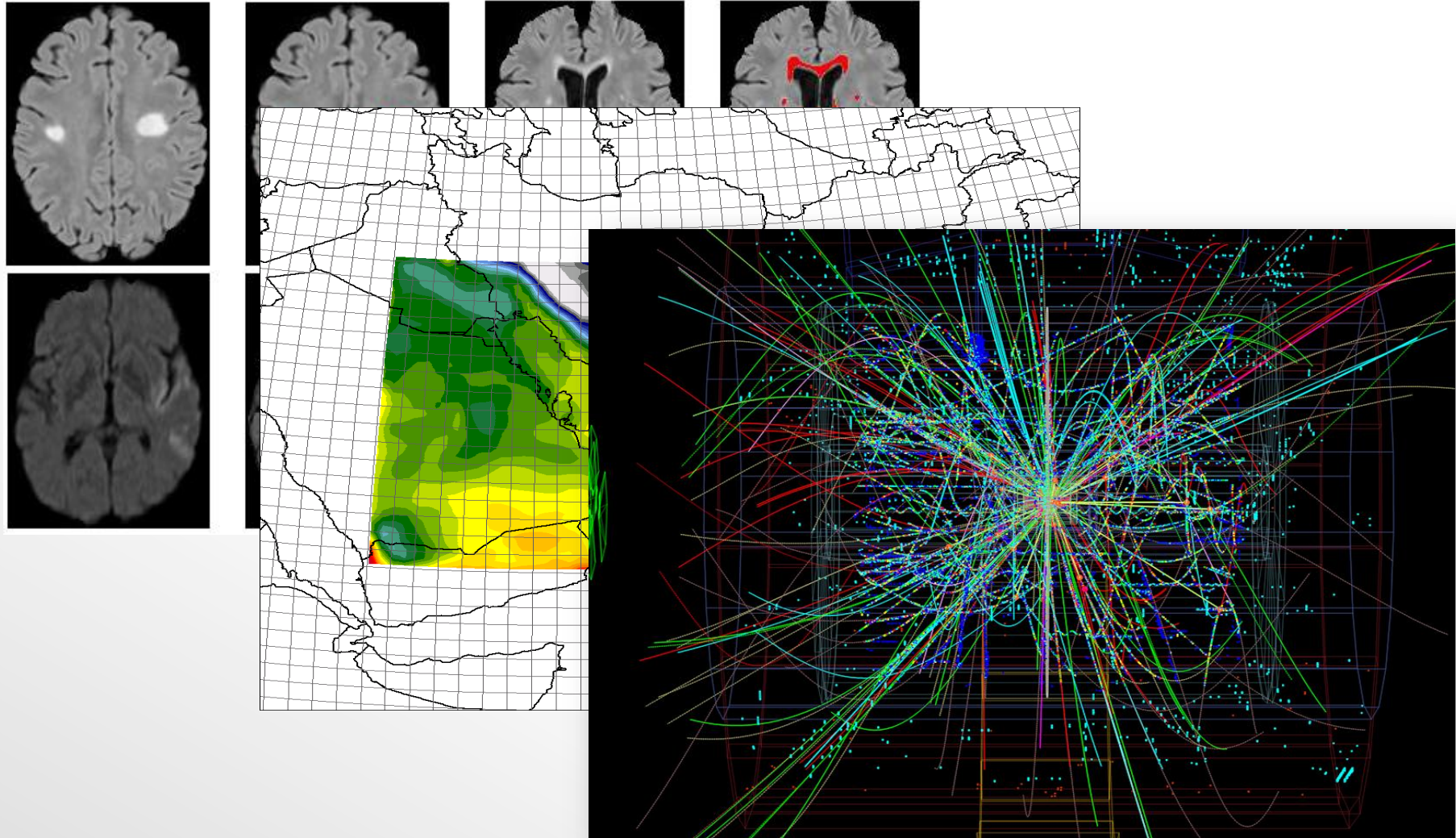
© NeuroLOG project

To you, your data may mean this...



© MicroStep-Mis. 3D meteorological modelling.

To you, your data may mean this...



© CERN. First proton-lead ion collisions recorded by ALICE

To others,
your data may mean that...

The key is Metadata

Finding, understanding, and reusing scientific datasets requires consistent, high-quality metadata

- ❑ Context: identification, authors, dates, license, version, reference articles
- ❑ Access: format, structure, location (dwld), query method
- ❑ Meaning:
 - What does it represent? What concepts, entities, semantics?
- ❑ Interpretation: units (cm or inches, left/right)...
- ❑ Provenance:
 - Acquired with what equipment? Parameters, protocols?
 - Derived from what dataset? With what processing?
 - Dataset-level or entity-level provenance
- ❑ Statistics
- ❑ Etc.

- Help access and understand CSV tabular data available on the web
 - Recommendations for **Metadata vocabulary for CSV data**
 - **Access methods** for CSV Metadata
 - *Mapping mechanism to transforming CSV into various Formats (e.g., RDF, JSON, or XML)*
- Annotations on a table or group of tables, columns...

*https://www.w3.org/standards/techs/csv#w3c_all



```
GID, Street, Species, Trim Cycle, Inventory Date
1, Addison Av, Celtis australis, 2010/10/18
2, Emerson St, Liquidambar styraciflua, 2010/06/02
```



GET tree-ops.csv



Content-Type: text/csv

Link: <http://example.org/tree-ops.json>; rel="..."

```
{ "@context": ["http://www.w3.org/ns/csvw", {"@language": "en"}],
  "url": "tree-ops.csv",
  "dc:title": "Tree Operations",
  "dc:license": { "@id":
    "http://opendefinition.org/licenses/cc-by/" },
  "dc:modified": { "@value": "2010-12-31", "@type": "xsd:date" },
  "tableSchema": {
    "columns": [ {
      "name": "GID", "titles": ["GID", "Generic Identifier"],
      "dc:description": "...",
      "datatype": "string", "required": true },
    {
      "name": " Street", "titles": "On Street",
      "dc:description": "The street that the tree is on.",
      "datatype": "string" }, ...
  ],
  "primaryKey": "GID", "aboutUrl": "#gid-{GID}" }
```

```
Species, Trim Cycle, Inventory Date
Celtis australis, 2010/10/18
Liquidambar styraciflua, 2010/06/02
```

*https://www.w3.org/standards/techs/csv#w3c_all

- ❑ Health Care and the Life Sciences
- ❑ Consensus among participating stakeholders on the description of datasets using RDF
- ❑ Data description, versioning, provenance, discovery, exchange, query, and retrieval

Used vocabularies

RDF, RDFS, XSD

Citation Typing Ontology

Data Catalog

Dublin Core Metadata Types, Dublin Core Metadata Terms

Friend-of-a-Friend

Collection Description Frequency Vocabulary

Identifiers.org vocabulary

Lexvo.org - Lexical Vocabulary

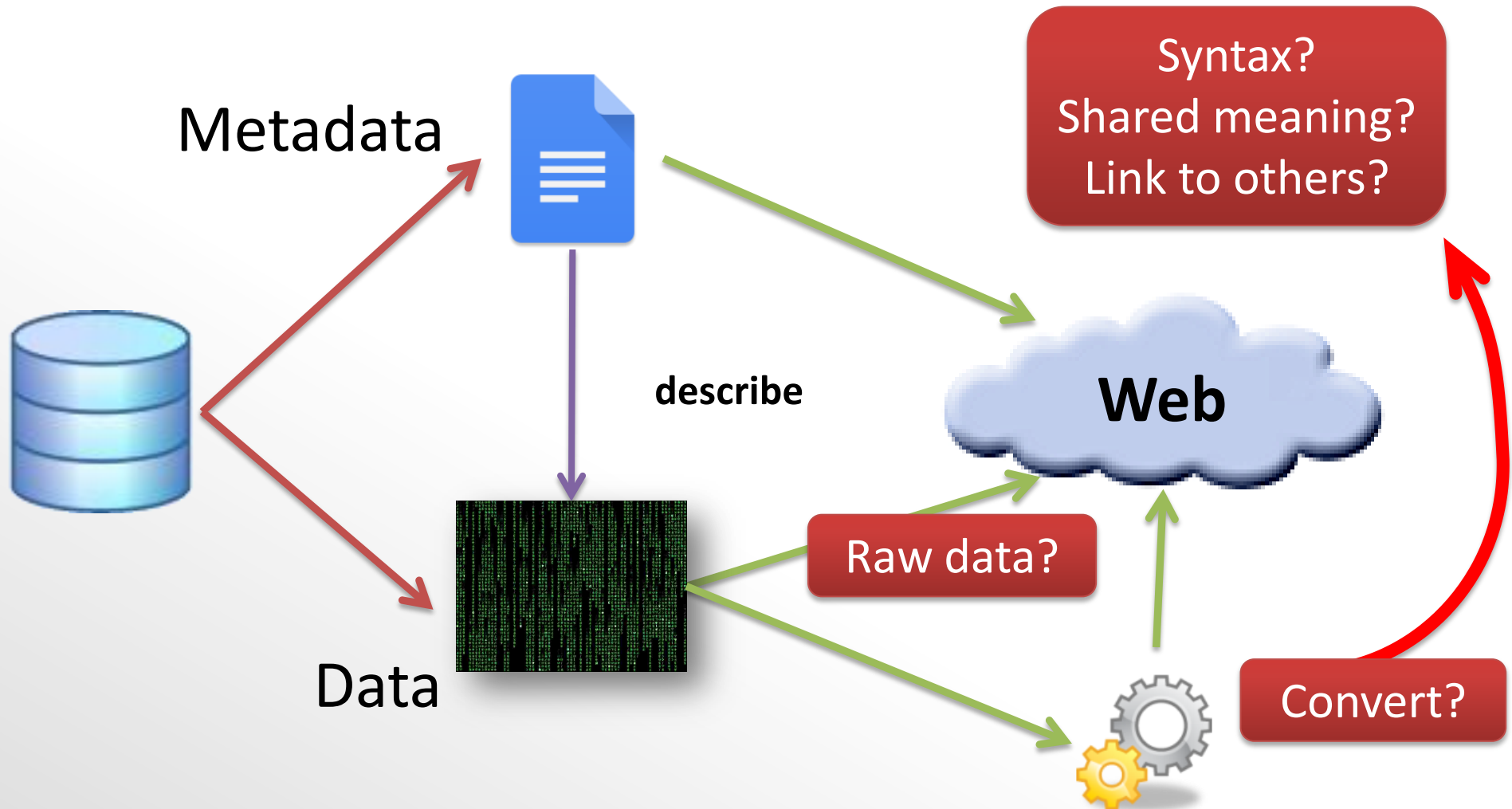
Provenance Authoring and Versioning ontology (PAV)

PROV Ontology

Semanticscience Integrated Ontology (SIO)

Vocabulary of Interlinked Datasets (VOID)

Challenges of publishing Metadata and/or Data?



Make our datasets accessible and interoperable on the Web...



- ❑ Have a common representation format
⇒ **Structural heterogeneity**
- ❑ Have common ways to describe the data
 - Vocabularies, ontologies, thesaurus...⇒ **Semantic heterogeneity**
- ❑ Have common ways to query the data

Agenda

- ❑ The Web of Data and the Semantic Web
- ❑ Create, reuse and link vocabularies
- ❑ Populate the Web of Data
- ❑ Publish Linked Open Data on the Web



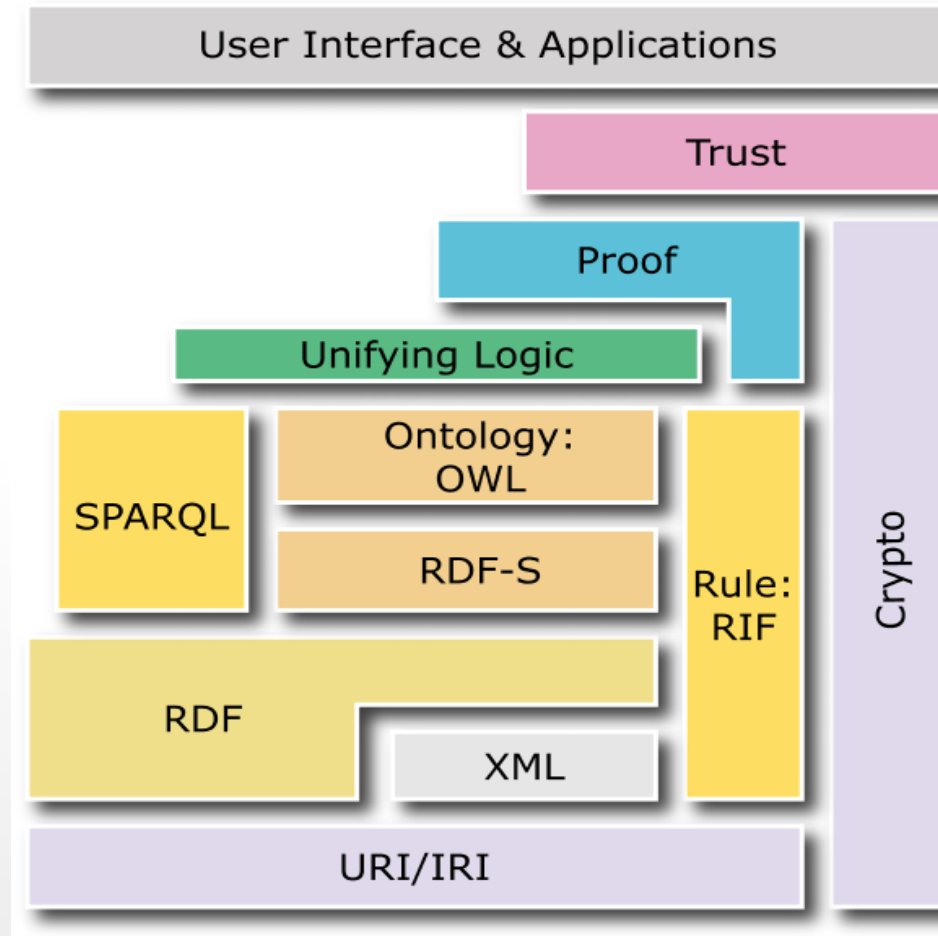
The Web of Data And the Semantic Web



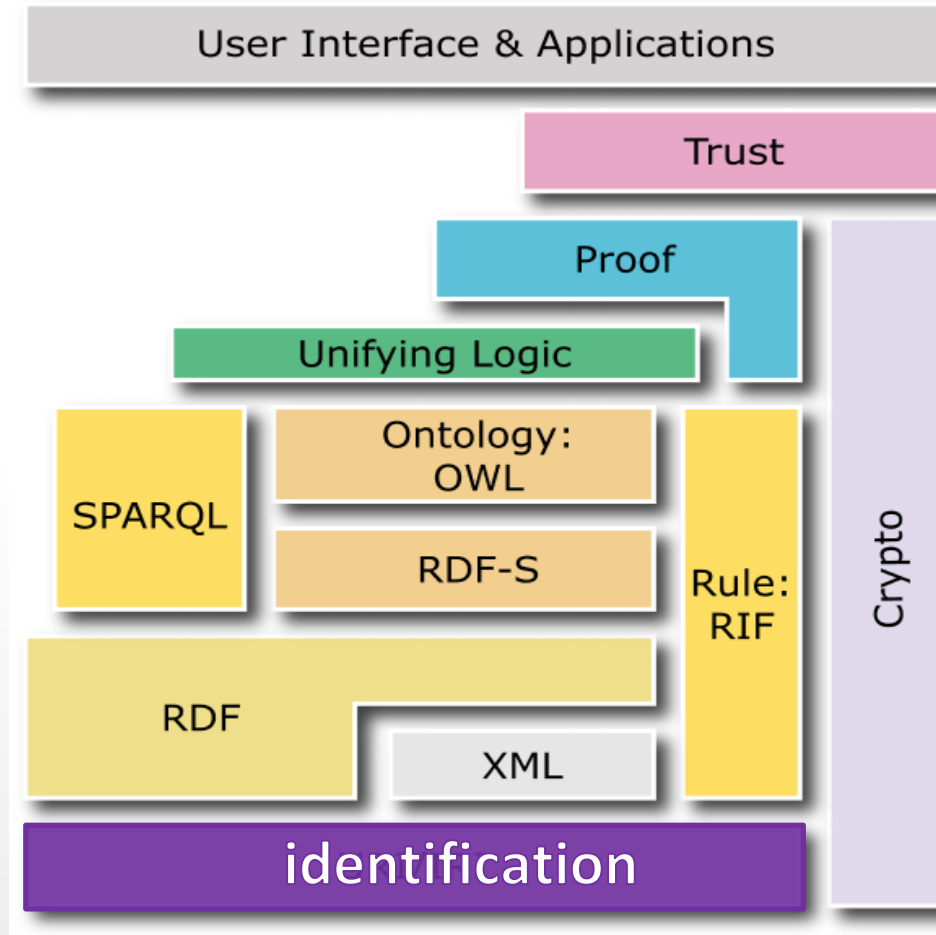
Source: C. Faron Zucker^[1], O. Corby^[1]. *Introduction au web de données et au web sémantique*. Séminaire INRA Open Data Dec. 2014.

^[1] INRIA Sophia Antipolis, CNRS, UNS.

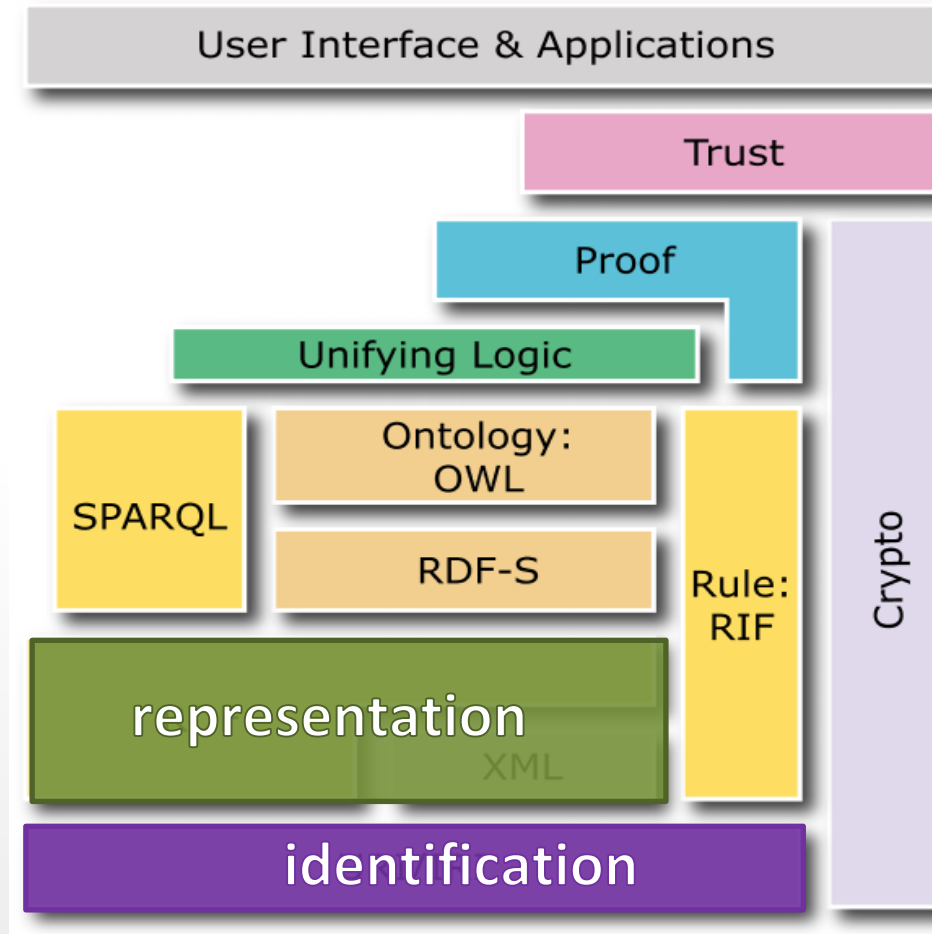
Standards of the Semantic Web



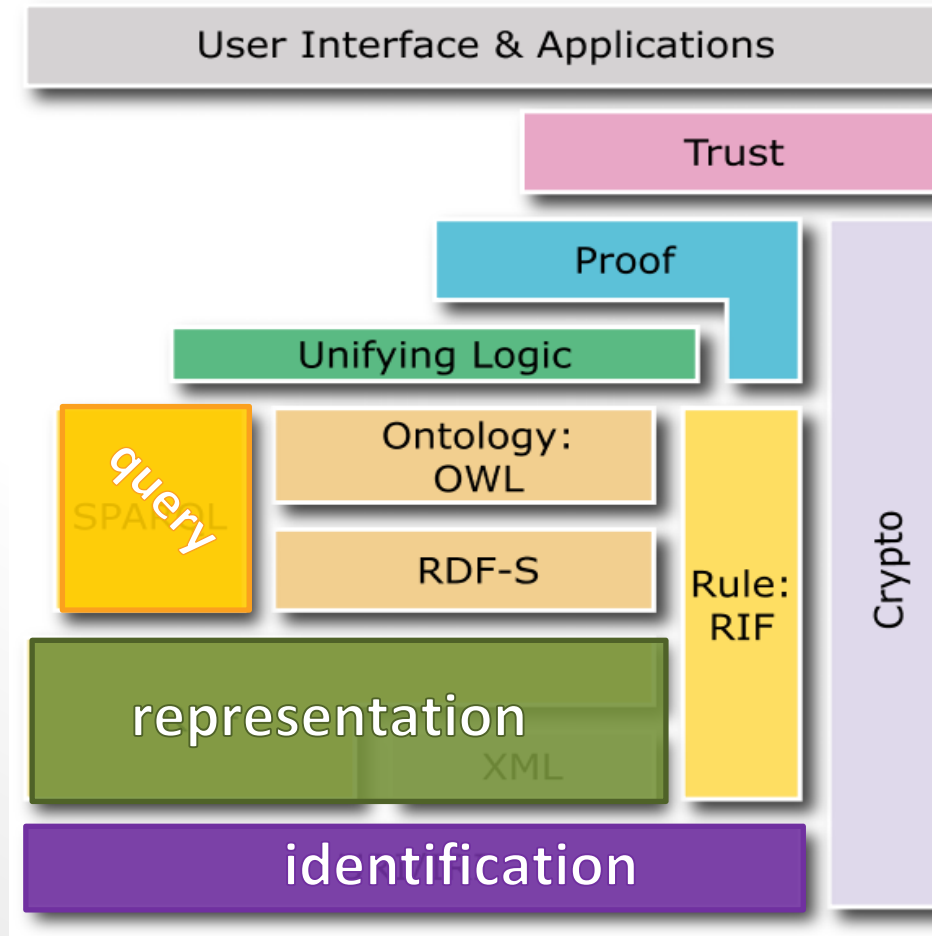
Standards of the Semantic Web



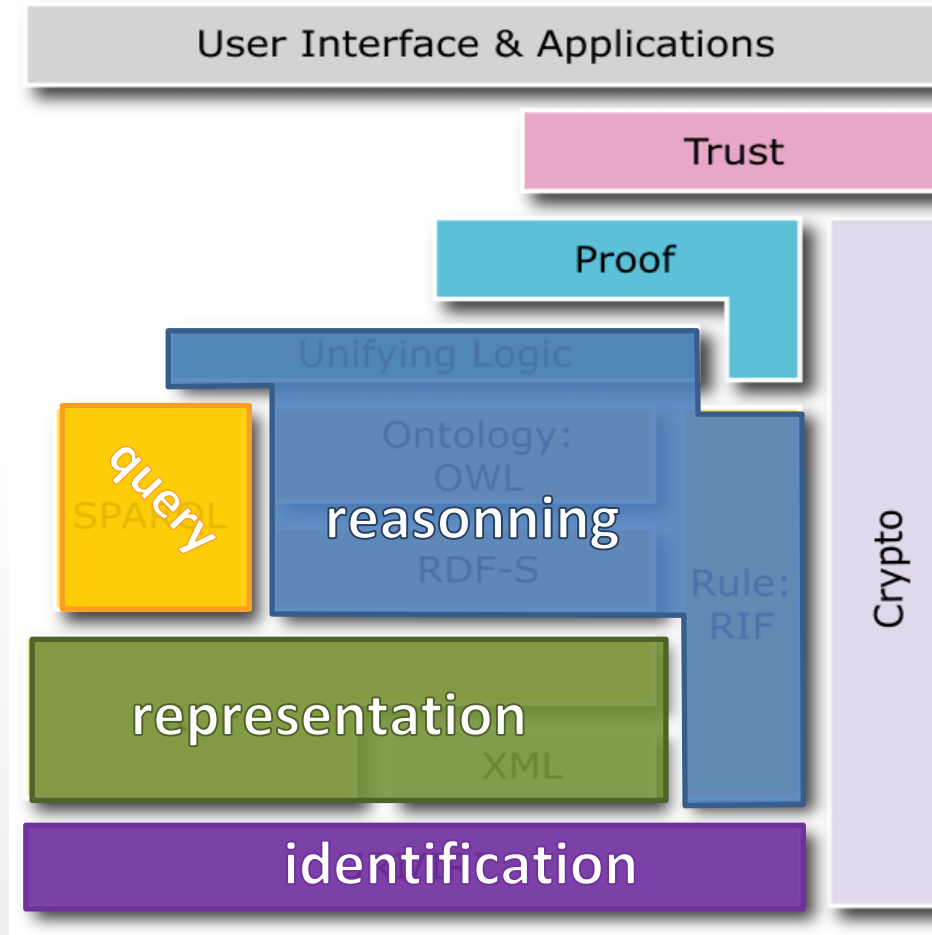
Standards of the Semantic Web



Standards of the Semantic Web

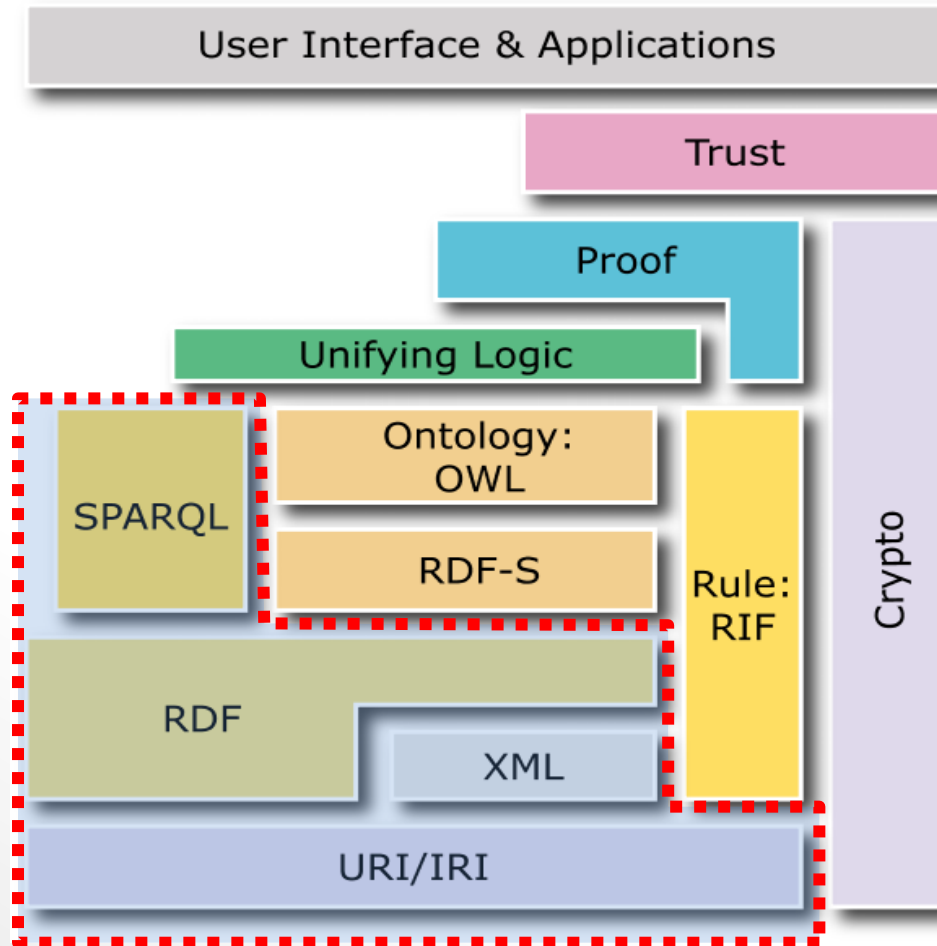


Standards of the Semantic Web



Standards of the Semantic Web

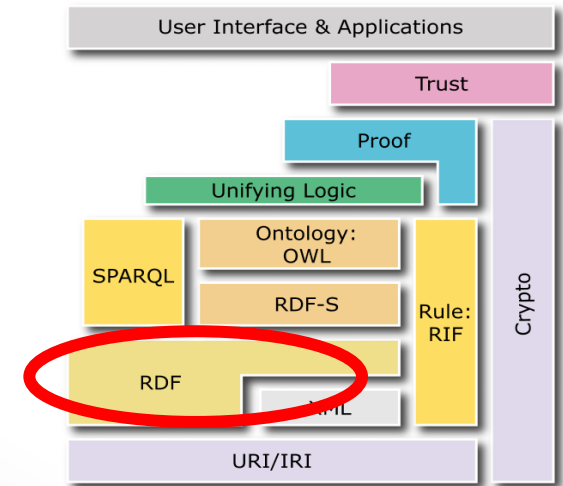
Web of Data



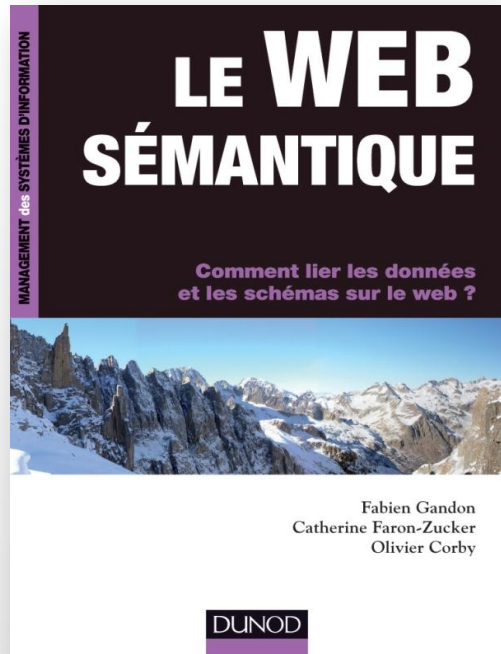
RDF is a model based on triples, *i.e.* any fact consists of 3 components:



(**subject**, **predicate**, **object**)



The Resource Description Framework



websem.html is a **texte**

websem.html has as author **Fabien**

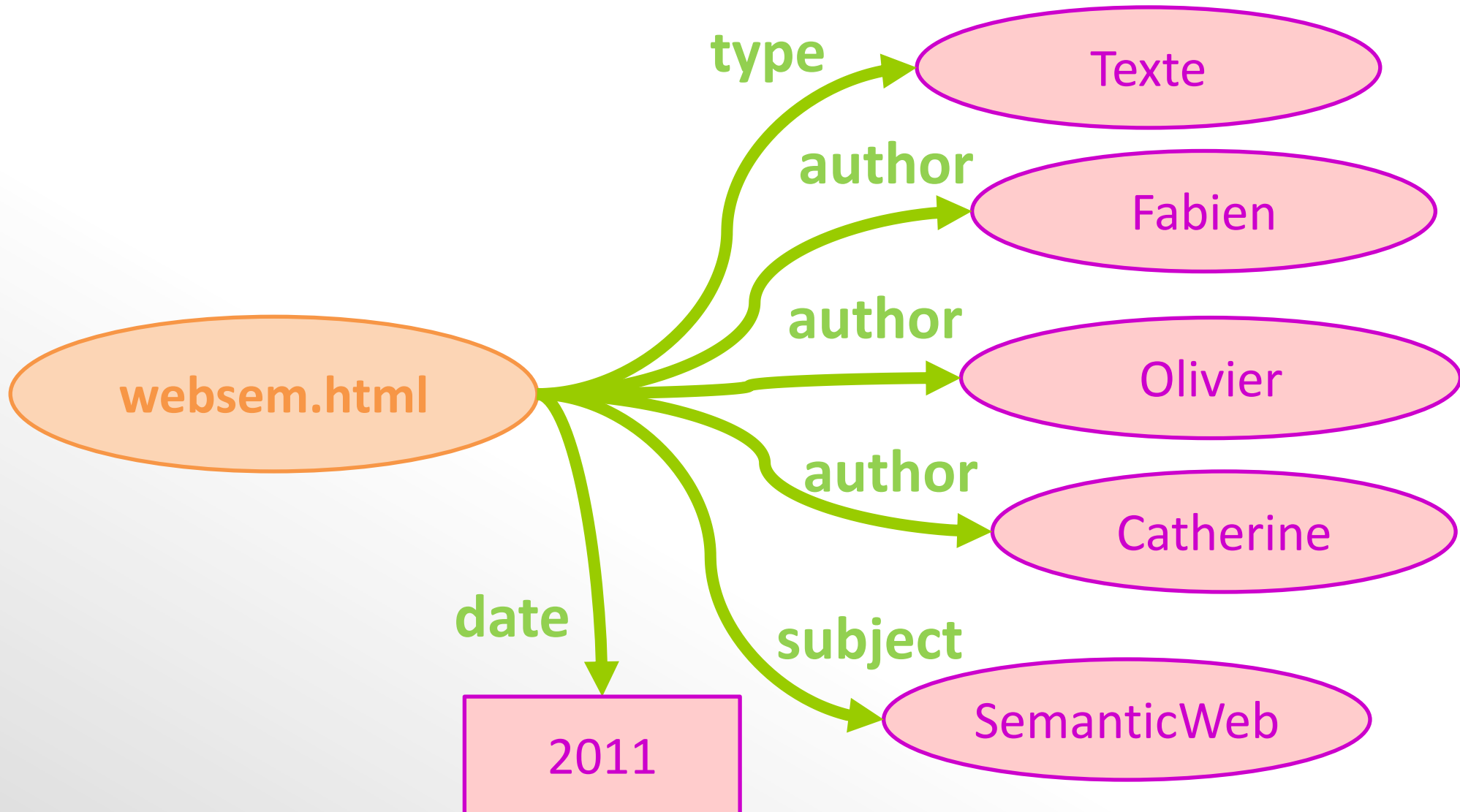
websem.html has as author **Olivier**

websem.html has as author **Catherine**

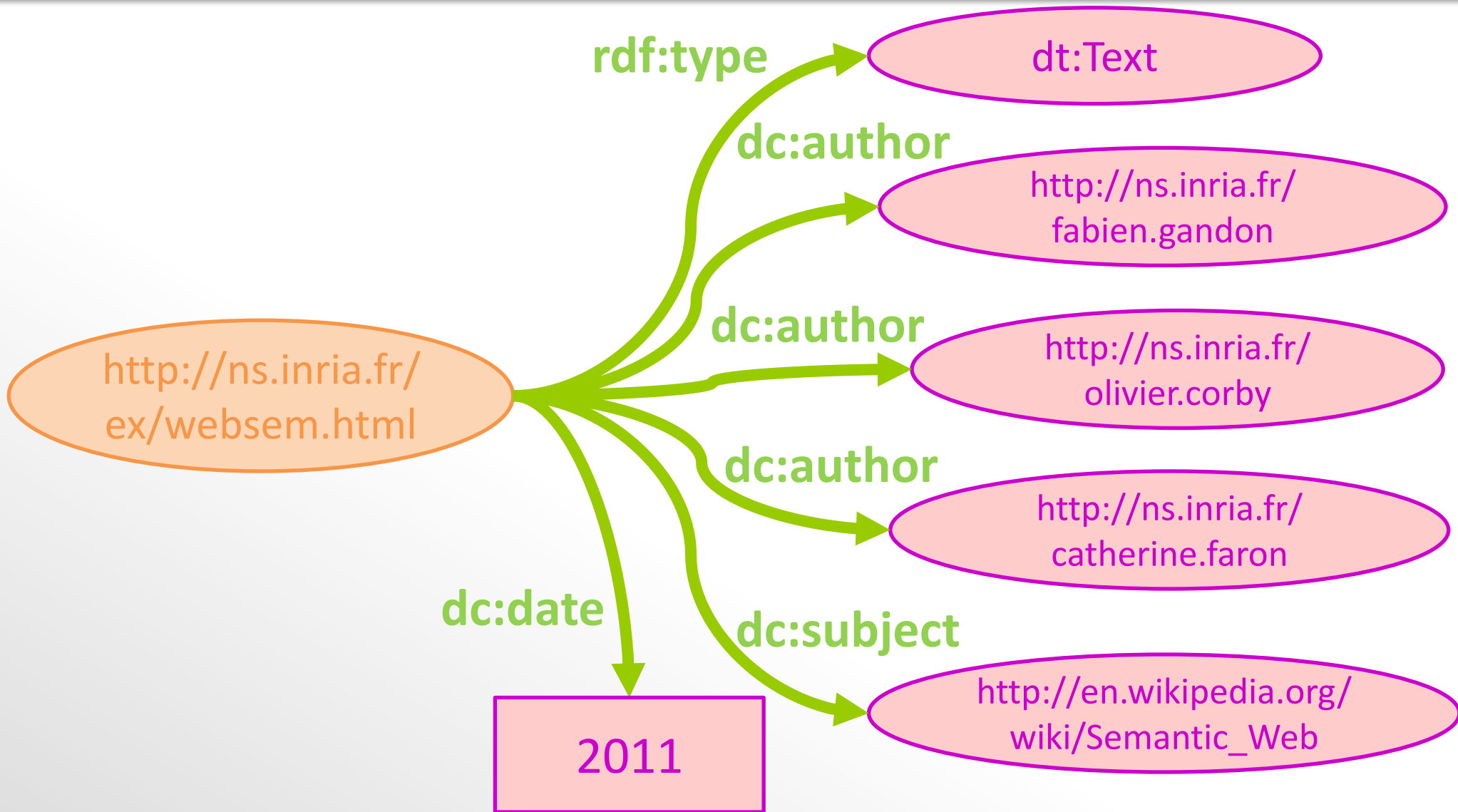
websem.html has as subject **Semantic Web**

websem.html was written in **2011**

The Resource Description Framework



The Resource Description Framework



The Resource Description Framework

N-Triples syntax

```
<http://inria.fr/ex/websem.html>  
  <http://purl.org/dc/elements/1.1/author>  
  <http://ns.inria.fr/catherine.faron> .
```

```
<http://inria.fr/ex/websem.html>  
  <http://purl.org/dc/elements/1.1/theme> "Semantic Web" .
```

Turtle syntax

```
@prefix dc: <http://purl.org/dc/elements/1.1/> .  
<http://inria.fr/ex/websem.html>  
  dc:author <http://ns.inria.fr/catherine.faron> ;  
  dc:theme "Semantic Web" .
```

The Resource Description Framework

XML Syntax

```
<rdf:RDF
```

```
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:dc="http://purl.org/dc/elements/1.1/">
```

```
<rdf:Description rdf:about="http://inria.fr/ex/websem.html">
```

```
  <dc:author
```

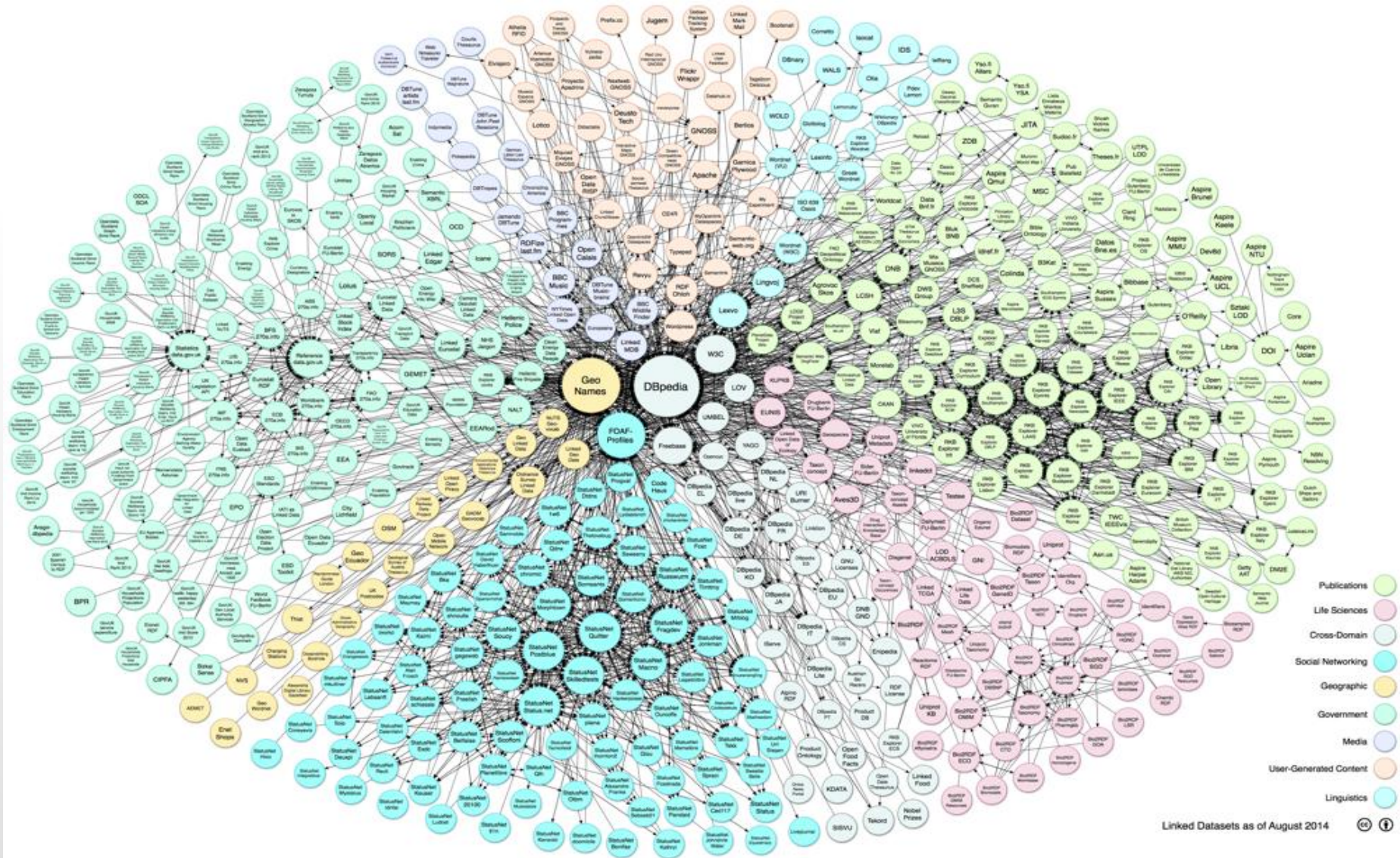
```
    rdf:resource="http://ns.inria.fr/catherine.faron"/>
```

```
  <dc:theme>Semantic Web</dc:theme>
```

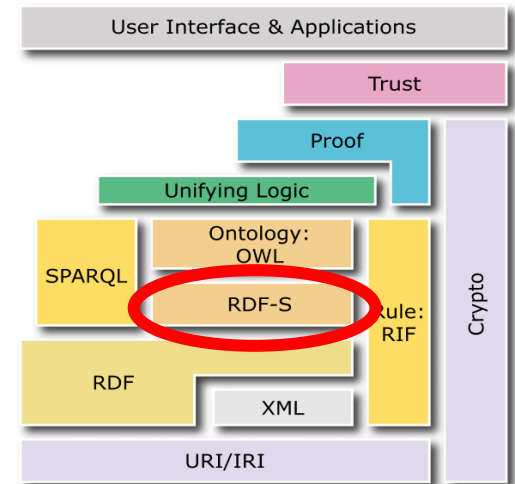
```
</rdf:Description>
```

```
</rdf:RDF>
```


Linked Open Data

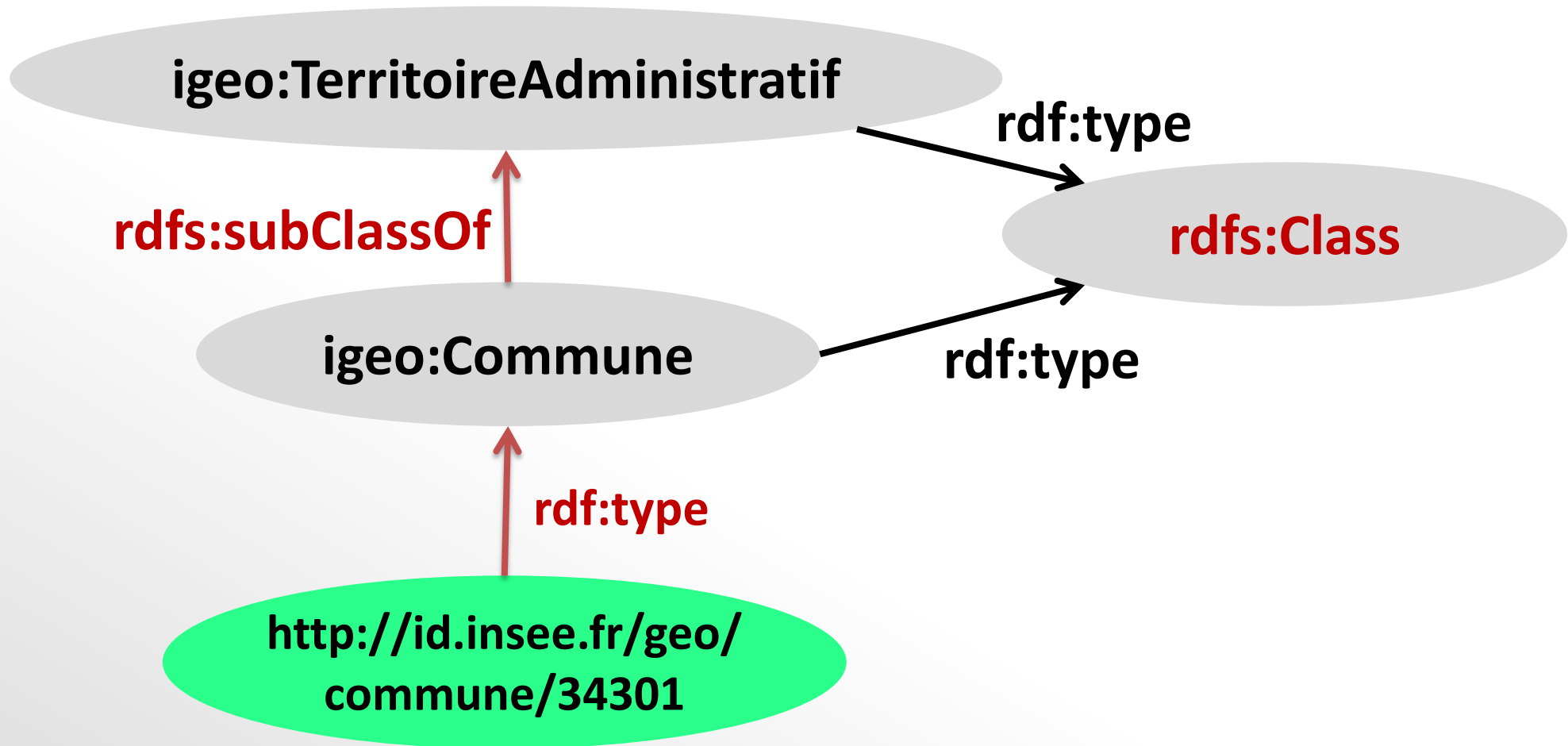


RDFSchemas define **classes** of resources, their **properties**, and organize their **hierarchies**



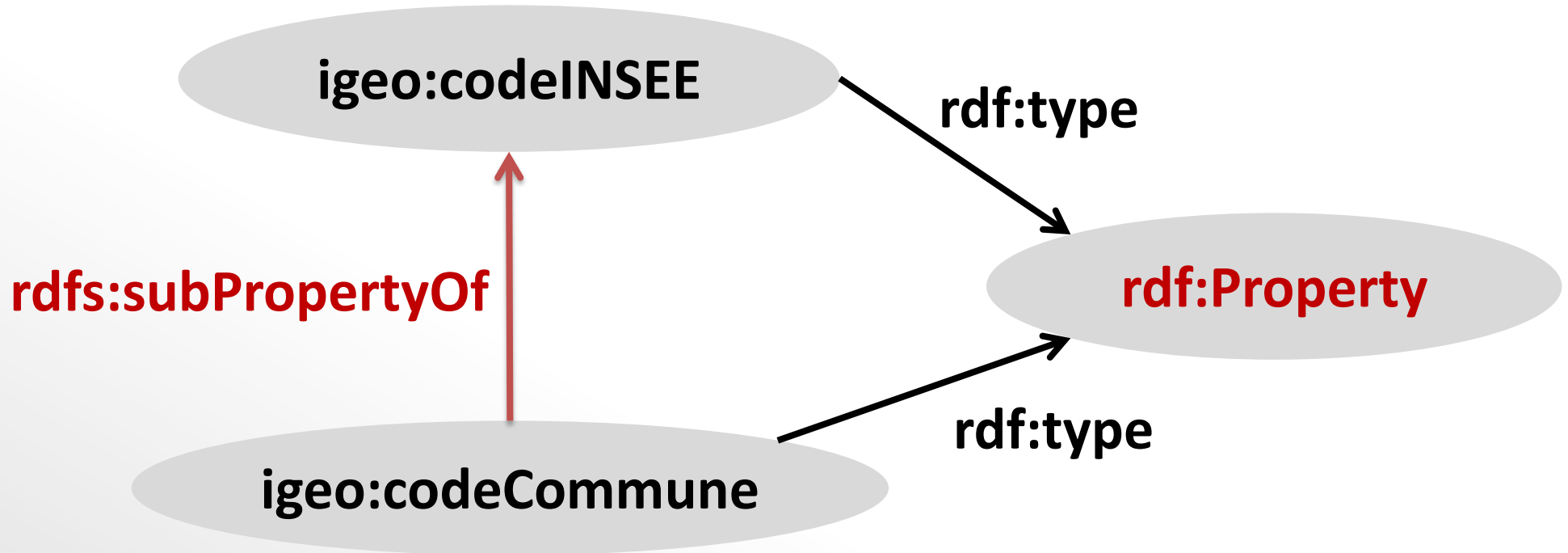
RDF Schema

```
@prefix igeo: <http://rdf.insee.fr/def/geo#> .
```



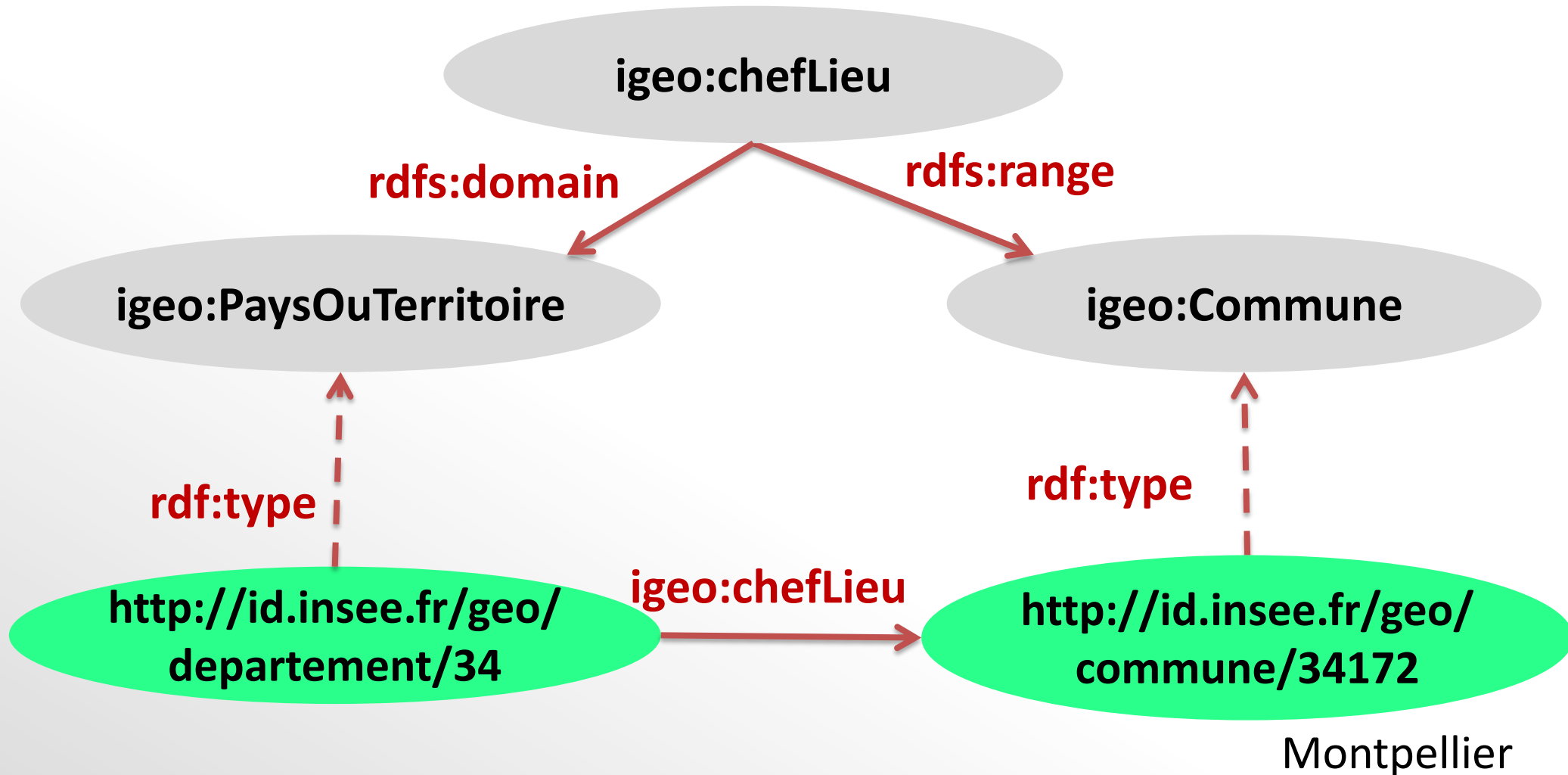
RDF Schema

```
@prefix igeo: <http://rdf.insee.fr/def/geo#> .
```



RDF Schema

```
@prefix igeo: <http://rdf.insee.fr/def/geo#> .
```



Query RDF with **SPARQL**

SPARQL Protocol and **RDF**
Query Language



- ❑ Query Language (using the Turtle syntax)
 - SPARQL 1.1 Query Language
 - SPARQL 1.1 Update
- ❑ Representation of query results
 - SPARQL Query Results Format XML, CSV/TCV, JSON
- ❑ Protocols
 - SPARQL 1.1 Protocol
 - SPARQL 1.1 Graph Store HTTP Protocol
- ❑ Entailments
 - SPARQL 1.1 Entailment Regimes

SPARQL: triple patterns

Turtle syntax with « ? » to mark **variables**:

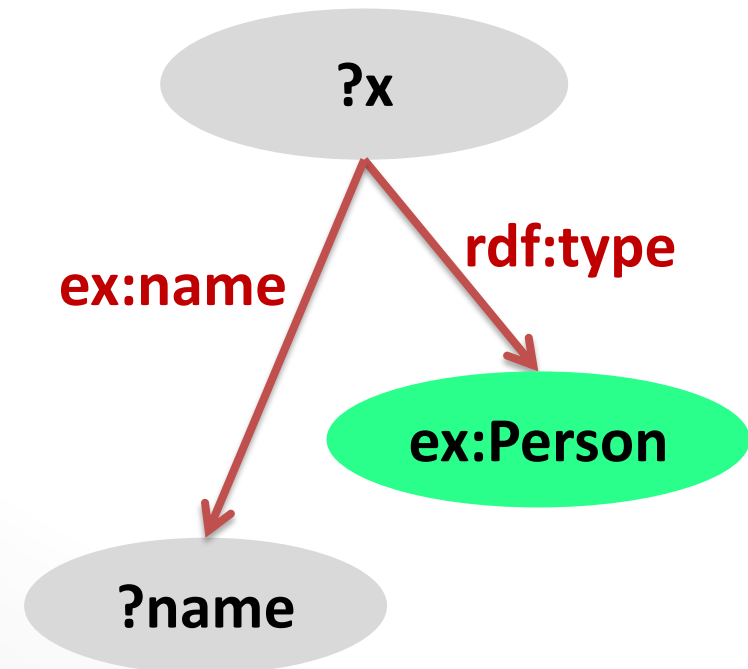
```
?x rdf:type ex:Person
```

Describe patterns of triples that we look for:

```
SELECT ?subject ?type  
WHERE { ?subject rdf:type ?type }
```

Default pattern: **conjunction** of triple patterns:

```
SELECT ?x WHERE  
{ ?x rdf:type ex:Person .  
  ?x ex:name ?name . }
```



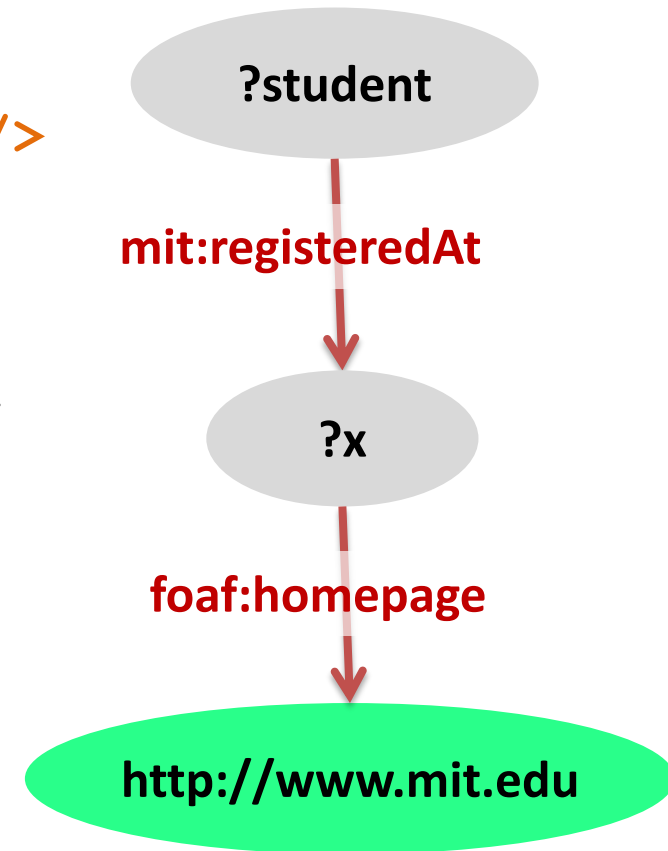
SPARQL: namespace prefixes

Declare prefixes of used vocabularies:

```
PREFIX mit: <http://www.mit.edu#>
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
SELECT ?student
WHERE {
  ?student mit:registeredAt ?x .
  ?x foaf:homepage <http://www.mit.edu> .
}
```

Declare a base namespace for relative URIs:

```
BASE <http://www.example.org/people#>
SELECT ?student
WHERE { ?student foaf:knows <Ted> . }
```



SPARQL: language and typed literals

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
SELECT ?x ?f WHERE {
  ?x foaf:name "Fabien"@fr ; foaf:knows ?f .
}
```

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
SELECT ?x WHERE {
  ?x foaf:name "Fabien"@fr ;
     foaf:age "21"^^xsd:integer .
}
```


SPARQL: optional pattern

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
SELECT ?person ?name
WHERE {
  ?person foaf:homepage <http://fabien.info> .
  OPTIONAL { ?person foaf:name ?name . }
}
```

 Variable `?name` is potentially **unbound**.

SPARQL alternative pattern

Merge the results of two graph patterns:

```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
SELECT ?person ?name
WHERE {
  ?person foaf:name ?name .
  { ?person foaf:homepage <http://fabien.info> . }
  UNION
  { ?person foaf:homepage <http://bafien.org> . }
}
```

SPARQL filters

```
PREFIX ex: <http://inria.fr/schema#>
SELECT ?person ?name
WHERE {
  ?person rdf:type ex:Person; ex:name ?name; ex:age ?age .
  FILTER (xsd:integer(?age) >= 18)
}
```

Other examples:

```
FILTER(?name IN ("fabien", "olivier", "catherine"))
```

```
FILTER(if (langMatches(lang(?name), "FR"), ?age>=21))
```

```
FILTER NOT EXISTS {?x foaf:age -1}
```

SPARQL additional features

❑ Subtract results

```
WHERE { ?x a ex:Person MINUS { ?x a ex:John } }
```

❑ Bind values

```
?person foaf:name ?name .
```

```
VALUES ?name { "Peter" "Pietro" "Pedro" "Pierre" }
```

❑ Property paths

```
?x foaf:knows+ ?friend .
```

❑ From

```
FROM <http://www.mit.edu/data.rdf>
```

```
SELECT ?student
```

```
WHERE { ?student mit:registeredAt ?x . }
```

SPARQL XML results

```
<?xml version="1.0"?>
<sparql xmlns="http://www.w3.org/2005/sparql-results#">
  <head><variable name="student"/></head>
  <results>
    <result>
      <binding name="student">
        <uri>http://www.mit.edu/data.rdf#ndieng</uri>
      </binding>
    </result>
    <result>
      <binding name="student">
        <uri>http://www.mit.edu/data.rdf#jdoe</uri>
      </binding>
    </result>
  </results>
</sparql>
```


RDF/SPARQL @ French national inst. of statistics



DataLift



Institut national de la statistique
et des études économiques

Mesurer pour comprendre

SPARQL endpoint

Description du nœud <<http://id.insee.fr/geo/departement/971>>

Rechercher dans

Sujet	Prédicat	Objet
http://id.insee.fr/geo/departement/971	http://www.w3.org/1999/02/22-rdf-syntax-ns#type	http://rdf.insee.fr/def/geo#Departement
http://id.insee.fr/geo/departement/971	http://www.w3.org/2002/07/owl#sameAs	http://data.ign.fr/id/geofla/departement/971
http://id.insee.fr/geo/departement/971	http://www.w3.org/2002/07/owl#sameAs	http://nuts.geovocab.org/id/FRA10
http://id.insee.fr/geo/departement/971	http://www.w3.org/2002/07/owl#sameAs	http://fr.dbpedia.org/resource/Guadeloupe
http://id.insee.fr/geo/departement/971	http://rdf.insee.fr/def/demo#population	http://id.insee.fr/demo/populationLegale/departement/971/2010
http://id.insee.fr/geo/departement/971	http://rdf.insee.fr/def/demo#population	http://id.insee.fr/demo/populationLegale/departement/971/2011
http://id.insee.fr/geo/departement/971	http://rdf.insee.fr/def/demo#population	http://id.insee.fr/demo/populationLegale/departement/971/2012
http://id.insee.fr/geo/departement/971	http://rdf.insee.fr/def/geo#subdivisionDe	http://id.insee.fr/geo/region/01

RDF/SPARQL @ French National Library (BnF)



Charles Perrault (1628-1703)



Pays : **France**
Langue : **français**
Sexe : **masculin**
Naissance : **Paris, 12-01-1628**
Mort : **Paris, 16-05-1703**

Note : Homme de lettres, conteur, membre de l'Académie française (1671). - Contrôleur général de la Surintendance des bâtiments du roi. - Les contes ont été publiés en 1697 sous le nom de son fils : Perrault d'Armancour

Domaines : Littérature

Outils

- Imprimer la page
- Exporter en PDF
- Signaler un problème sur la page

Citer la page

Permalien: <http://data.bnf.fr/ark:/12148/cb119>



Télécharger les données

Télécharger en RDF

Télécharger en JSON

Le Web sémantique dans data.bnf.fr

RDF/SPARQL @ French National Library (BnF)



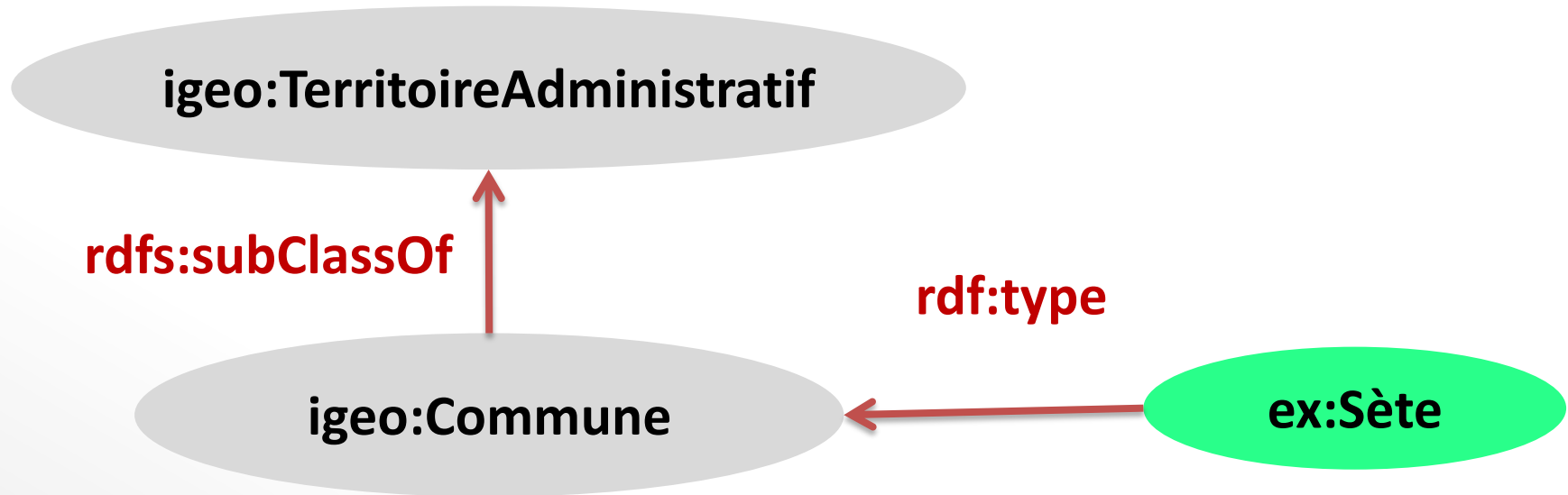
Charles Perrault (1628-1703)

Pays :

France

```
<rdf:Description rdf:about="http://data.bnf.fr/ark:/12148/cb119192165#foaf:Person">
  <foaf:familyName>Perrault</foaf:familyName>
  <bnf-onto:firstYear rdf:datatype="http://www.w3.org/2001/XMLSchema#integer">1628</bnf-onto:firstYear>
  <foaf:gender>male</foaf:gender>
  <rdagroup2elements:dateOfBirth rdf:resource="http://data.bnf.fr/date/1628/">
  <owl:sameAs rdf:resource="http://dbpedia.org/resource/Charles_Perrault"/>
  <bio:death>1703-05-16</bio:death>
  <rdagroup2elements:placeOfBirth>Paris</rdagroup2elements:placeOfBirth>
  <owl:sameAs rdf:resource="http://viaf.org/viaf/34461426"/>
  <foaf:depiction rdf:resource="http://gallica.bnf.fr/ark:/12148/bpt6k1020573.thumbnail"/>
  <rdagroup2elements:fieldOfActivityOfThePerson rdf:resource="http://dewey.info/class/80"/>
  <rdagroup2elements:dateOfDeath rdf:resource="http://data.bnf.fr/date/1703/">
  <rdf:type rdf:resource="http://xmlns.com/foaf/0.1/Person"/>
  <foaf:birthday>01-12</foaf:birthday>
  <foaf:depiction rdf:resource="http://gallica.bnf.fr/ark:/12148/bpt6k6154661t.thumbnail"/>
```

RDFS Entailment: infer new knowledge

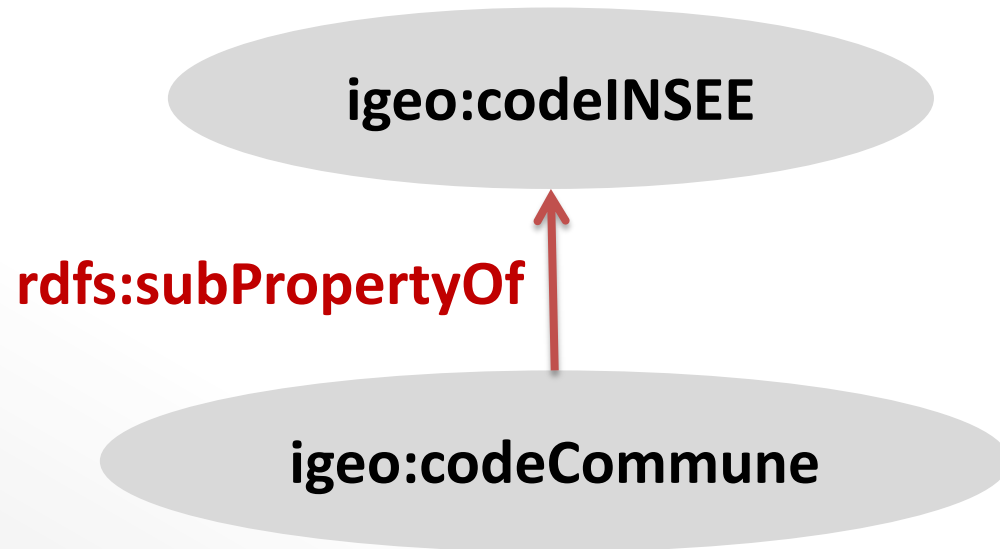


```
PREFIX igeo:<http://rdf.insee.fr/def/geo#>
```

```
SELECT ?x
```

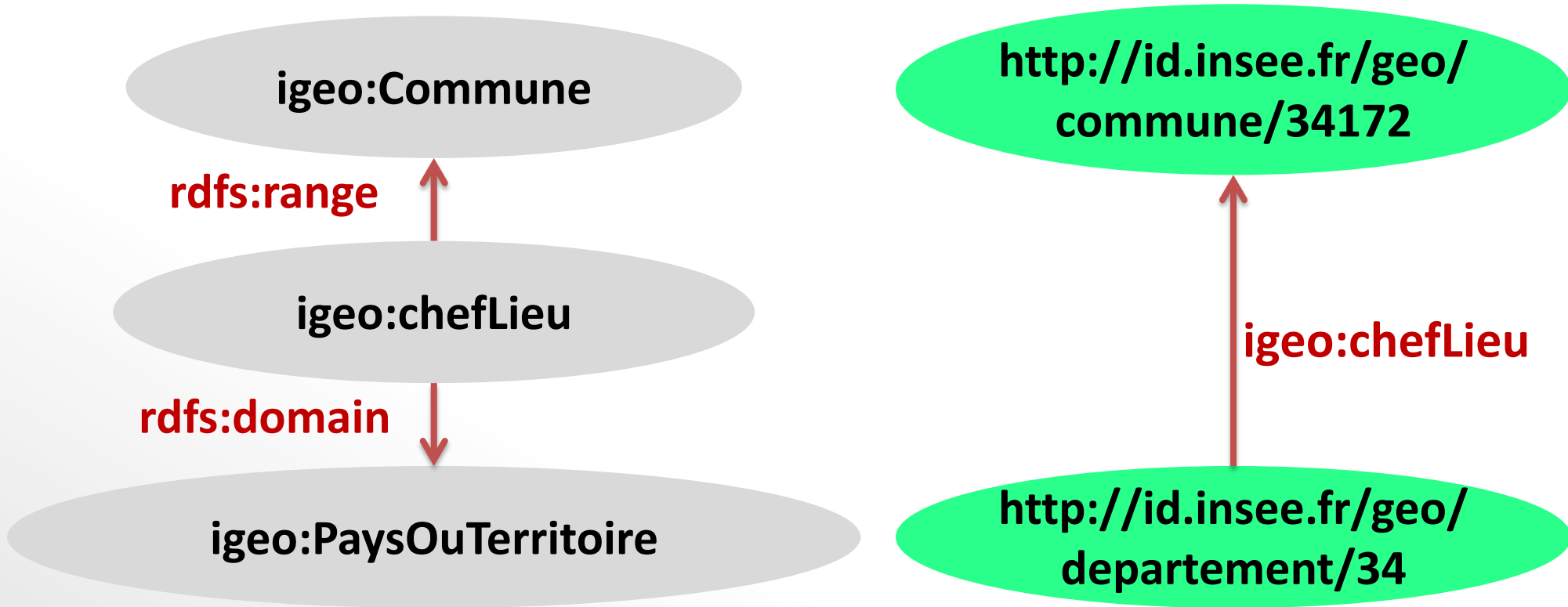
```
WHERE { ?x rdf:type igeo:TerritoireAdministratif }
```

RDFS Entailment: infer new knowledge



```
PREFIX igeo:<http://rdf.insee.fr/def/geo#>  
SELECT  ?x ?code  
WHERE { ?x igeo:codeINSEE ?code }
```

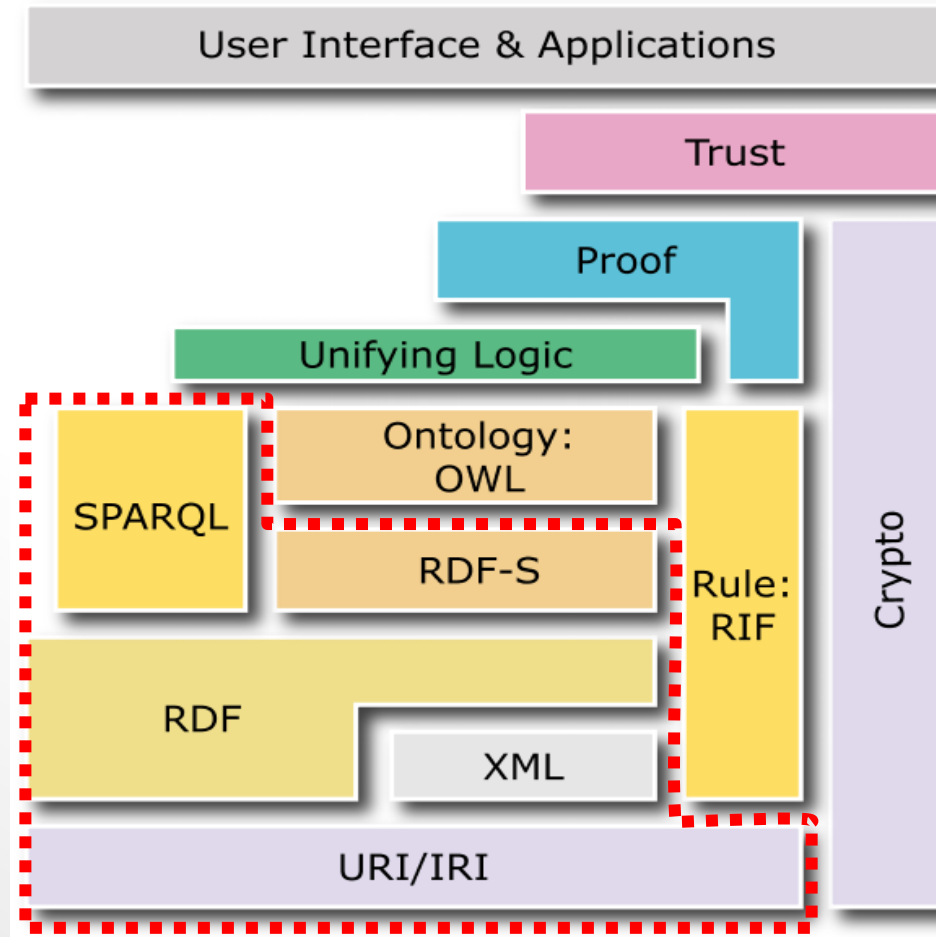
RDFS Entailment: infer new knowledge

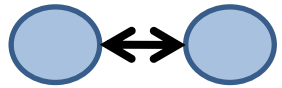


```
SELECT ?x WHERE { ?x rdf:type igeo:Commune }
```

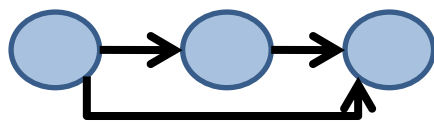
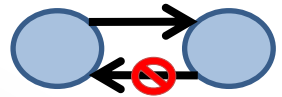
```
SELECT ?x WHERE { ?x rdf:type igeo:PaysOuTerritoire }
```


So far, so good...





symetric prop.



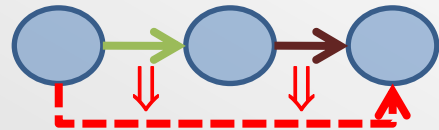
prop. disjunction



cardinality



indiv. prop. negation



chained prop.



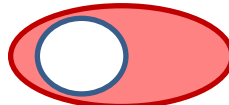
class disjunction



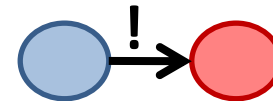
def. by union



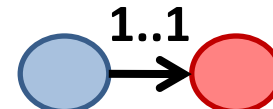
def. by intersection



def. by complement



def. by restriction



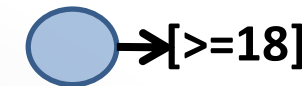
def. by cardinality



def. by equivalence



def. by enumeration

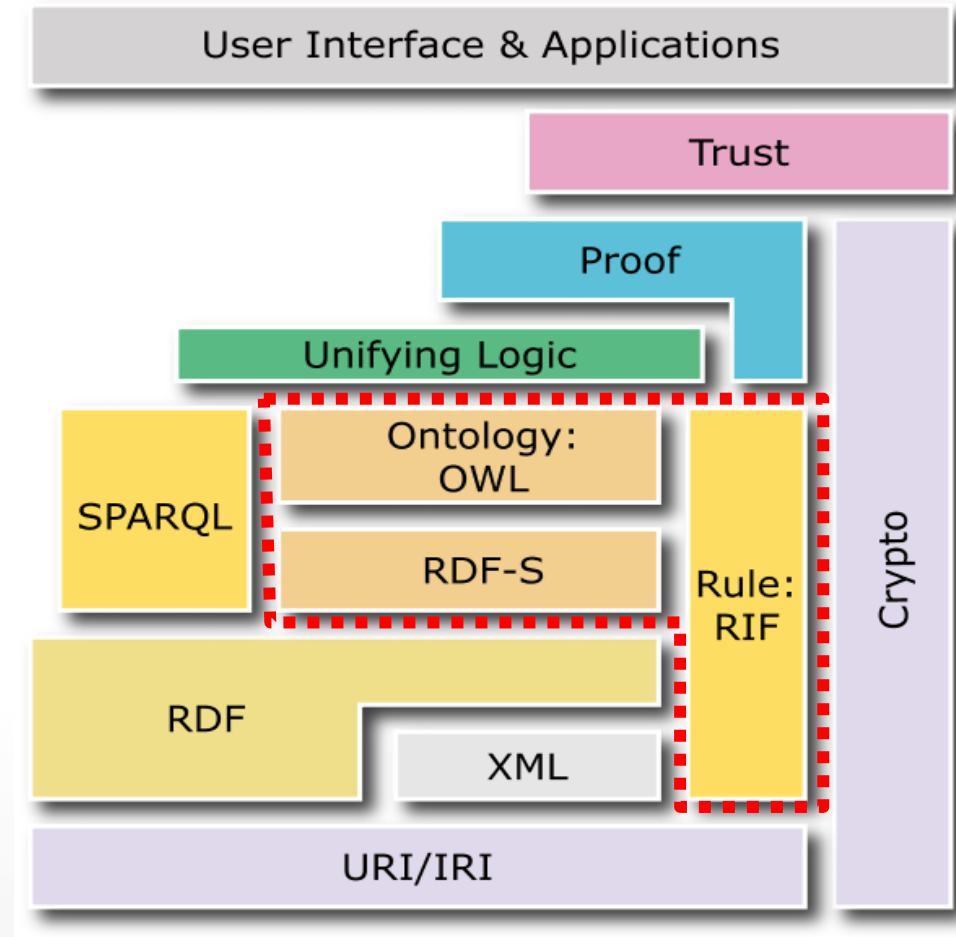


def. by value restrict.

...

Web of Data vs. Semantic Web

Web of Data: first step in the deployment of the **Semantic Web**



Make our datasets accessible and interoperable on the Web...



*What
languages
can you
speak?*

Definitions



□ Taxonomy:

- Practice and science of classification
- Hierarchical categorization of controlled classes/terms
- Nested classes under broader categories

□ Thesaurus

- Networked collection of controlled vocabulary terms, grouped according to various types of relationship, e.g. similarity of meaning (synonyms, antonyms),

□ Ontology

- Formal semantic description for the taxonomy terms, properties and interrelationships between categories in a domain of discourse, to facilitate conceptual search and natural language queries.

□ Folksonomy

- Collaborative/social tagging, social classification...
- Tag category schemes
- No (not necessarily) hierarchical categorization

Create, reuse and link vocabularies

Create my own vocabulary

- ❑ May seem easier: *“I do whatever I want”*
- ❑ Can be derived from an existing schema, e.g.:
 - RDB: table -> class, column -> property, primary key -> resource URI
 - Thesaurus -> list of classes or SKOS Concepts
- ❑ But modeling implies choosing a point of view...
 - E.g. biologist vs. geneticist, surgeon vs. anatomist, history...
 - Domain experts must be involved
- ❑ Risk: create an island of data
- ❑ How to link my vocabulary/dataset with other related ones?



Create, reuse and link vocabularies

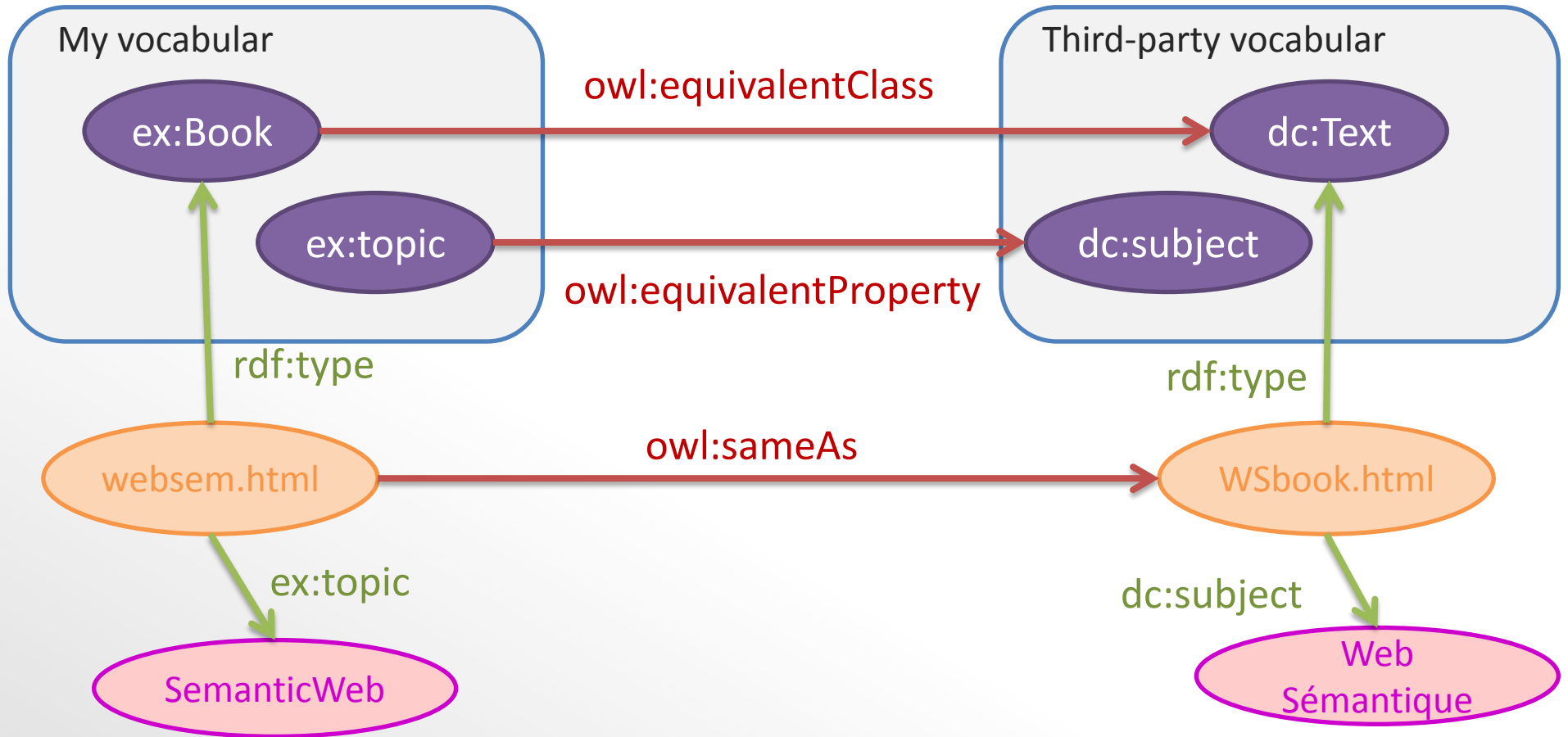
Reuse existing vocabularies

- ❑ Where to look for: vocab./ontologies catalogs (see later)
- ❑ Difficulty to find the appropriate description
 - Partial coverage of the domain I'm dealing with
 - E.g. geographical area
 - Granularity: level of details
 - Too many (cumbersome), not enough (useless)
 - Different points of view

Frequently, a mixed approach is used

- Reuse + create
- Need for interlinking => alignment

Link ontologies (very basic)



Link ontologies (basics)

❑ Classes

- owl:equivalentClass, owl:disjointWith, rdfs:subClassOf,

❑ Properties

- owl:equivalentProperty, owl:inverseOf, rdfs:subPropertyOf

❑ Individuals

- owl:sameAs, owl:differentFrom, owl:allDifferent

❑ rdfs:seeAlso

- Indicate a resource that might provide additional information about the subject resource

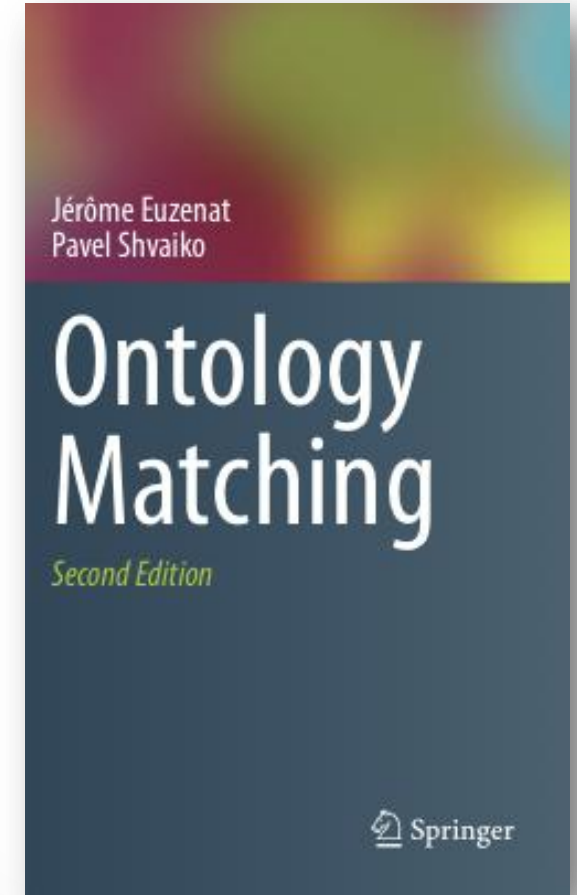
❑ SKOS concepts

- skos:exactMatch: transitive
- skos:closeMatch, skos:relatedMatch
- skos:narrowMatch, skos:broaderMatch

Link ontologies ... a complex topic

Ontology matching: “representing declaratively relations between heterogeneous models”

- ❑ Discovery of matching between classes, properties
- ❑ Discovery of matching between individuals
- ❑ Named Entity Recognition, Entity matching, text-mining...



RDF-based standard to represent controlled vocabularies:
glossary, dictionary, taxonomy, thesaurus...

Bridge the gap between existing KOSs and the SW and LD

Definition and documentation of classification systems

- ❑ SKOS concepts
 - `skos:Concept`
- ❑ Labels and classification codes
 - `skos:prefLabel`, `skos:altLabel`, `skos:notation...`
- ❑ Documentation
 - `skos:definition`, `skos:changeNote`, `skos:editorialNote`, `skos:example`, etc.
- ❑ SKOS schemas
 - `skos:ConceptScheme`, `skos:hasTopConcept`, `skos:isTopConceptOf`

Semantic relations between concepts

- ❑ Hierarchy of collections of concepts
 - `skos:Collection`, `skos:OrderedCollection`, `skos:member...`
- ❑ Semantic network and Hierarchies of concepts
 - `skos:related`
 - `skos:broader`, `skos:narrower`
- ❑ Alignment of schemas
 - `skos:closeMatch`, `skos:exactMatch`
 - `skos:relatedMatch`, `skos:broadMatch`, `skos:narrowMatch`

Linked Open Vocabularies

TERMS taxonomic rank

154 results

wlo:TaxonRank (wlo) 0.556
n/a (use in LOD)
<http://purl.org/ontology/wo/TaxonRank>
rdfs:label Taxonomic Rank @en-gb
localName TaxonRank
rdfs:comment Generic concept for Species. @en-gb

uniprot:rank (uniprot)
20,876 occurrences in 2 LOD datasets
<http://purl.uniprot.org/core/rank>
rdfs:comment The rank of a taxon.
localName rank

vivo:rank (vivo) 0.416
83 occurrences in 2 LOD datasets
<http://vivoweb.org/ontology/core#rank>
rdfs:label rank
localName rank

frbrer:P3041 (frbrer)
35,870 occurrences in 1 LOD datasets
<http://iflastandards.info/ns/fr/frbr/frbrer/P3041>

BBC Wildlife Ontology

UniProt: protein sequence and functional information.

Type
vocabulary >

Tag
Biology (62)
General & Upper (29)
Society (29)
Health (8)

Taxonomic Rank	
URI	http://purl.org/ontology/wo/TaxonRank
Description	Generic concept for a taxonomic rank such as a Genus or Species.
Subclasses	Class , Family , Genus , Kingdom , Order , Phylum , Species
Properties	adaptation , class , conservationStatus , family , genus , growsIn , habitat , kingdom , livesIn , name , order , phylum , species

Linked Open Vocabularies

Metadata

URI	http://purl.uniprot.org/core/
Namespace	http://purl.uniprot.org/core/
Description	Properties and classes used for protein annotation @en
Language	English en
Creator	The UniProt Consortium http://www.uniprot.org
Comment	<p>(2013-03-21) Bernard Vatant: Frequent changes are indicated by the LOV-Bot checking this vocabulary on a daily basis, but it's unclear whether they correspond to significant modifications. Neither versioning or history metadata are provided by the source.</p> <p>(2012-12-04) Ghislain Atemezing: Update of classes and properties. Although it seems different from the information found on the documentation.</p> <p>(2014-03-24) Bernard Vatant: Still no metadata. Backup version uploaded.</p> <p>(2015-03-24) Bernard Vatant: Deleted empty versions. Impossible to upload a new backup version, the content negotiation on the namespace leads to http://www.uniprot.org/core/.rdf, which is an empty RDF file.</p>

Statistics

Classes	159
Properties	134
Datatypes	0
Instances	60

Expressivity

RDF RDFS OWL

Tags

Biology

LOD

Vocabulary used in 3 datasets

154 results

uniprot.org
20,876 occurrences
<http://purl.uniprot.org/core/>
rdfs:comment
localName

vivo:rank
83 occurrences
<http://vivo.library.yale.edu/vivo/ontology/vivo:rank>
rdfs:label
localName rank

frbrer:P3041 (frbrer)
35,870 occurrences in 1 LOD datasets
<http://iflastandards.info/ns/fr/frbr/frbrer/P3041>

UniProt: protein sequence and functional information.

Society (29)
Health (8)

Other catalogs of vocabularies

- ❑ Schemapedia (?) <http://schemapedia.org>

- ❑ **schema.org**

“Create, maintain, and promote schemas for structured data on the Internet, on web pages, in email messages, and beyond”.

Controlled set of curated vocabularies: cars, TV series, arts, administrations, diseases...

- ❑ **DERI Vocabularies** <http://vocab.deri.ie/>

URI space for RDFS vocabularies and OWL ontologies maintained at DERI.
No search interface.

- ❑ **NCBO BioPortal** <http://bioportal.bioontology.org/ontologies/>

- ❑ **TDWG - Biodiversity Information Standards**

<http://www.tdwg.org/standards/>

TDWG - Taxonomic Databases Working Group

And your favorite web search engine...

General

Domain specific

Practical use case: TAXREF



CD_NOM : Unique identifier of the scientific name

CD_SUP : Identifier of the upper taxon in the classification

CD_REF : Identifier of the reference taxon

RANG : taxonomical rank

1	REGNE	PHYLUM	CLASSE	ORDRE	FAMILLE	GROUP1	GROUP2_INP	CD_NOM	CD_TAXS	CD_REF	RANG	LB_NOM	LB_AUTEUR	NOM_COMPLET	NOM_COMP	NOM_
189650	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	186227	186224	186227	FM	Delphinidae	Gray, 1821	Delphinidae Gra	Delphinidae	Delphi
189651	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	535142	186227	535142	GN	Cephalorhynchus	Gray, 1846	Cephalorhynchu	<i>Cephalorhynchus	Cepha
189652	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	535143	535142	535143	ES	Cephalorhynchus commersonii	(Lacépède, 1804	Cephalorhynchu	<i>Cephalorhynchus	Cepha
189653	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	589259	535142	535143	ES	Cephalorhynchus commersoni	Yanez, 1948	Cephalorhynchu	<i>Cephalorhynchus	Cepha
189654	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	586998	535142	535143	ES	Delphinus commersonii	Lacépède, 1804	Delphinus comm	<i>Delphinus	Cepha
189655	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	577923	535142	535143	ES	Lagenorhynchus burmeisteri	Moreno, 1892	Lagenorhynchus	<i>Lagenorhynchus	Cepha
189656	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	586999	535142	535143	ES	Lagenorhynchus floweri	Moreno, 1892	Lagenorhynchus	<i>Lagenorhynchus	Cepha
189657	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	577966	535142	535143	ES	Phocoena commersonii	Lesson, 1827	Phocoena comm	<i>Phocoena	Cepha
189658	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	191591	186227	191591	GN	Delphinus	Linnaeus, 1758	Delphinus Linna	<i>Delphinus	Delphi
189659	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	361079	191591	361079	ES	Delphinus capensis	Gray, 1828	Delphinus capen	<i>Delphinus	Delphi
189660	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	589323	191591	361079	ES	Delphinus bairdi	Norris & Prescott	Delphinus bairdi	<i>Delphinus	Delphi
189661	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	60880	191591	361079	ES	Delphinus bairdii	Dall, 1873	Delphinus bairdi	<i>Delphinus	Delphi
189662	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	589339	191591	361079	ES	Delphinus dussumieri	Blanford, 1891	Delphinus dussum	<i>Delphinus	Delphi
189663	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	589370	191591	361079	ES	Delphinus frithii	Blyth, 1859	Delphinus frithii	<i>Delphinus	Delphi
189664	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	589383	191591	361079	ES	Delphinus longirostris	G. Cuvier, 1829	Delphinus longir	<i>Delphinus	Delphi
189665	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	589385	191591	361079	ES	Delphinus major	Gray, 1866	Delphinus major	<i>Delphinus	Delphi
189666	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	589394	191591	361079	ES	Delphinus microps	Burmeister, 186	Delphinus micro	<i>Delphinus	Delphi
189667	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	589395	191591	361079	ES	Delphinus moorei	Gray, 1866	Delphinus moore	<i>Delphinus	Delphi
189668	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	589415	191591	361079	ES	Delphinus sao	Gray, 1850	Delphinus sao	<i>Delphinus	Delphi
189669	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	669537	361079	669537	SSES	Delphinus capensis tropicalis	Jefferson & Van	Delphinus capen	<i>Delphinus	Delphi
189670	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	60878	191591	60878	ES	Delphinus delphis	Linnaeus, 1758	Delphinus delph	<i>Delphinus	Delphi
189671	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	589316	191591	60878	ES	Delphinus albimanus	Peale, 1848	Delphinus albim	<i>Delphinus	Delphi
189672	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	589319	191591	60878	ES	Delphinus algeriensis	Loche, 1860	Delphinus algeri	<i>Delphinus	Delphi
189673	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	551374	191591	60878	ES	Delphinus delphus	Linnaeus, 1758	Delphinus delph	<i>Delphinus	Delphi
189674	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	589344	191591	60878	ES	Delphinus forsteri	Gray, 1846	Delphinus forste	<i>Delphinus	Delphi
189675	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	589368	191591	60878	ES	Delphinus fulvifasciatus	Wagner, 1846	Delphinus fulvif	<i>Delphinus	Delphi
189676	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	589369	191591	60878	ES	Delphinus fulvofasciatus	True, 1889	Delphinus fulvof	<i>Delphinus	Delphi

Practical use case: Taxref



CD_NOM : Unique identifier of the scientific name

CD_SUP : Identifier of the upper taxon in the classification

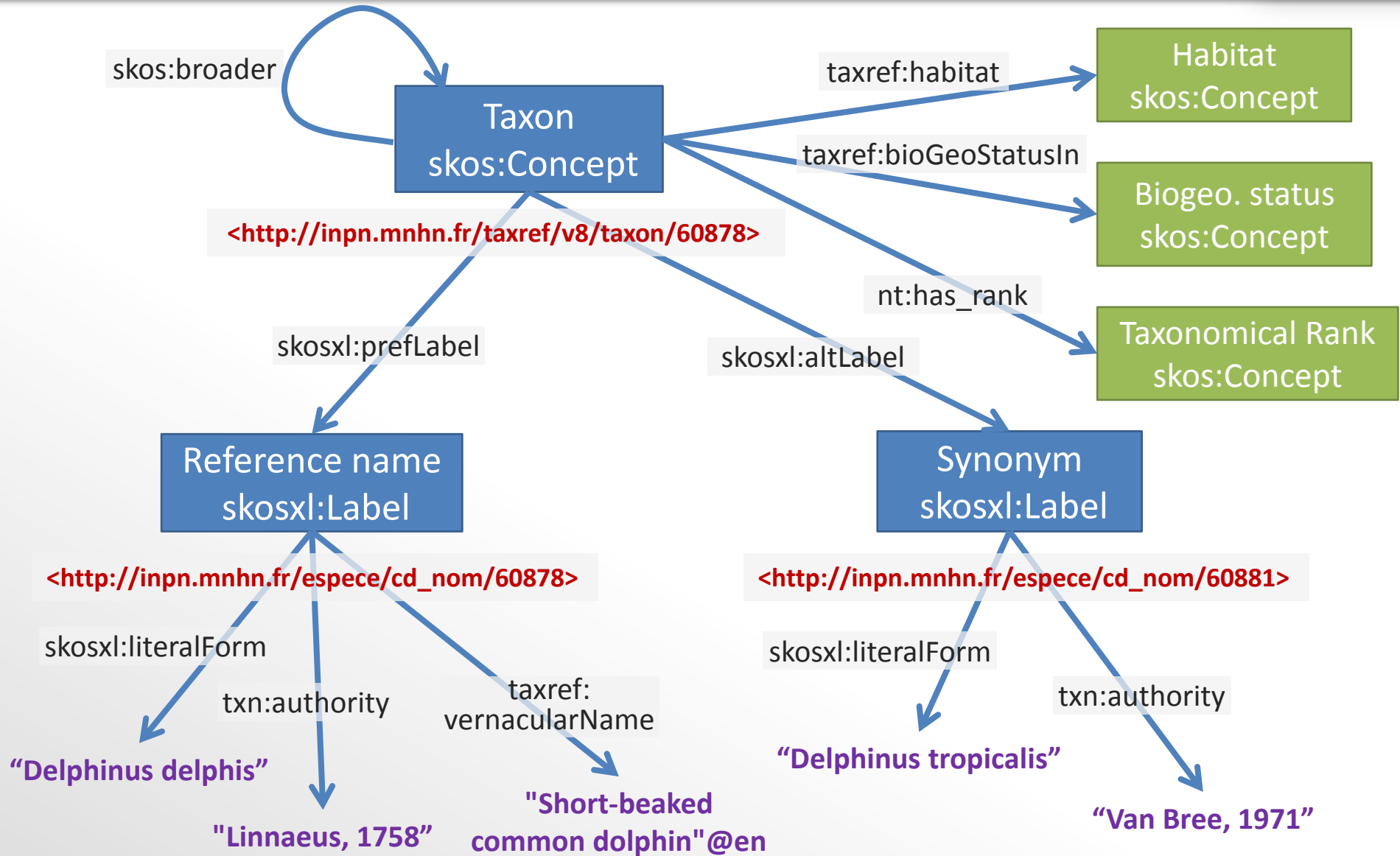
CD_REF : Identifier of the reference taxon

RANG : taxonomical rank

1	REGNE	PHYLUM	CLASSE	ORDRE	FAMILLE	GROUP1	GROUP2_INP	CD_NOM	CD_TAXS	CD_REF	RANG	LB_NOM	LB_AUTEUR	NOM_COMPLET	NOM_COMP	NOM_
189650	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	186227	186224	186227	FM	Delphinidae	Gray, 1821	Delphinidae Gra	Delphinidae	Delphi
189651	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	535142	186227	535142	GN	Cephalorhynchus	Gray, 1846	Cephalorhynchu	<i>Cephalorh	Cepha
189652	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	535143	535142	535143	ES	Cephalorhynchus commersonii	(Lacépède, 1804	Cephalorhynchu	<i>Cephalorh	Cepha
189653	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	589253	535142	535143	ES	Cephalorhynchus commersoni	Yanez, 1948	Cephalorhynchu	<i>Cephalorh	Cepha
189654	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	586998	535142	535143	ES	Delphinus commersonii	Lacépède, 1804	Delphinus comm	<i>Delphinu	Cepha
189655	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	589253	535142	535143	ES	Delphinus commersonii	Lacépède, 1804	Delphinus comm	<i>Delphinu	Cepha
189656	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	589253	535142	535143	ES	Delphinus commersonii	Lacépède, 1804	Delphinus comm	<i>Delphinu	Cepha
189657	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	589253	535142	535143	ES	Delphinus commersonii	Lacépède, 1804	Delphinus comm	<i>Delphinu	Cepha
189658	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	589253	535142	535143	ES	Delphinus commersonii	Lacépède, 1804	Delphinus comm	<i>Delphinu	Cepha
189659	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	589253	535142	535143	ES	Delphinus commersonii	Lacépède, 1804	Delphinus comm	<i>Delphinu	Cepha
189660	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	589253	535142	535143	ES	Delphinus commersonii	Lacépède, 1804	Delphinus comm	<i>Delphinu	Cepha
189661	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	589253	535142	535143	ES	Delphinus commersonii	Lacépède, 1804	Delphinus comm	<i>Delphinu	Cepha
189662	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	589253	535142	535143	ES	Delphinus commersonii	Lacépède, 1804	Delphinus comm	<i>Delphinu	Cepha
189663	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	589376	191591	581079	ES	Delphinus frithii	Bryan, 1859	Delphinus frithii	<i>Delphinu	Delphi
189664	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	589383	191591	361079	ES	Delphinus longirostris	G. Cuvier, 1829	Delphinus longir	<i>Delphinu	Delphi
189665	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	589385	191591	361079	ES	Delphinus major	Gray, 1866	Delphinus major	<i>Delphinu	Delphi
189666	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	589394	191591	361079	ES	Delphinus microps	Burmeister, 186	Delphinus micro	<i>Delphinu	Delphi
189667	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	589395	191591	361079	ES	Delphinus moorei	Gray, 1866	Delphinus moor	<i>Delphinu	Delphi
189668	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	589415	191591	361079	ES	Delphinus sao	Gray, 1850	Delphinus sao Gr	<i>Delphinu	Delphi
189669	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	669537	361079	669537	SSES	Delphinus capensis tropicalis	Jefferson & Van	Delphinus capen	<i>Delphinu	Delphi
189670	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	60878	191591	60878	ES	Delphinus delphis	Linnaeus, 1758	Delphinus delph	<i>Delphinu	Delphi
189671	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	589316	191591	60878	ES	Delphinus albimanus	Peale, 1848	Delphinus albim	<i>Delphinu	Delphi
189672	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	589319	191591	60878	ES	Delphinus algeriensis	Loche, 1860	Delphinus algeri	<i>Delphinu	Delphi
189673	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	551374	191591	60878	ES	Delphinus delphus	Linnaeus, 1758	Delphinus delph	<i>Delphinu	Delphi
189674	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	589344	191591	60878	ES	Delphinus forsteri	Gray, 1846	Delphinus forste	<i>Delphinu	Delphi
189675	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	589368	191591	60878	ES	Delphinus fulvifasciatus	Wagner, 1846	Delphinus fulvif	<i>Delphinu	Delphi
189676	Animalia	Chordata	Mammalia	Cetacea	Delphinidae	Chordés	Mammifères	589369	191591	60878	ES	Delphinus fulvofasciatus	True, 1889	Delphinus fulvof	<i>Delphinu	Delphi

How to translate this table into a thesaurus exploitable as a semantic reference using semantic web technologies?

TAXREF SKOS Modelling



TAXREF: Alignments with domain ontologies

“Static” (hand-made) alignments:

predicates, reference values (habitats, taxonomical ranks)

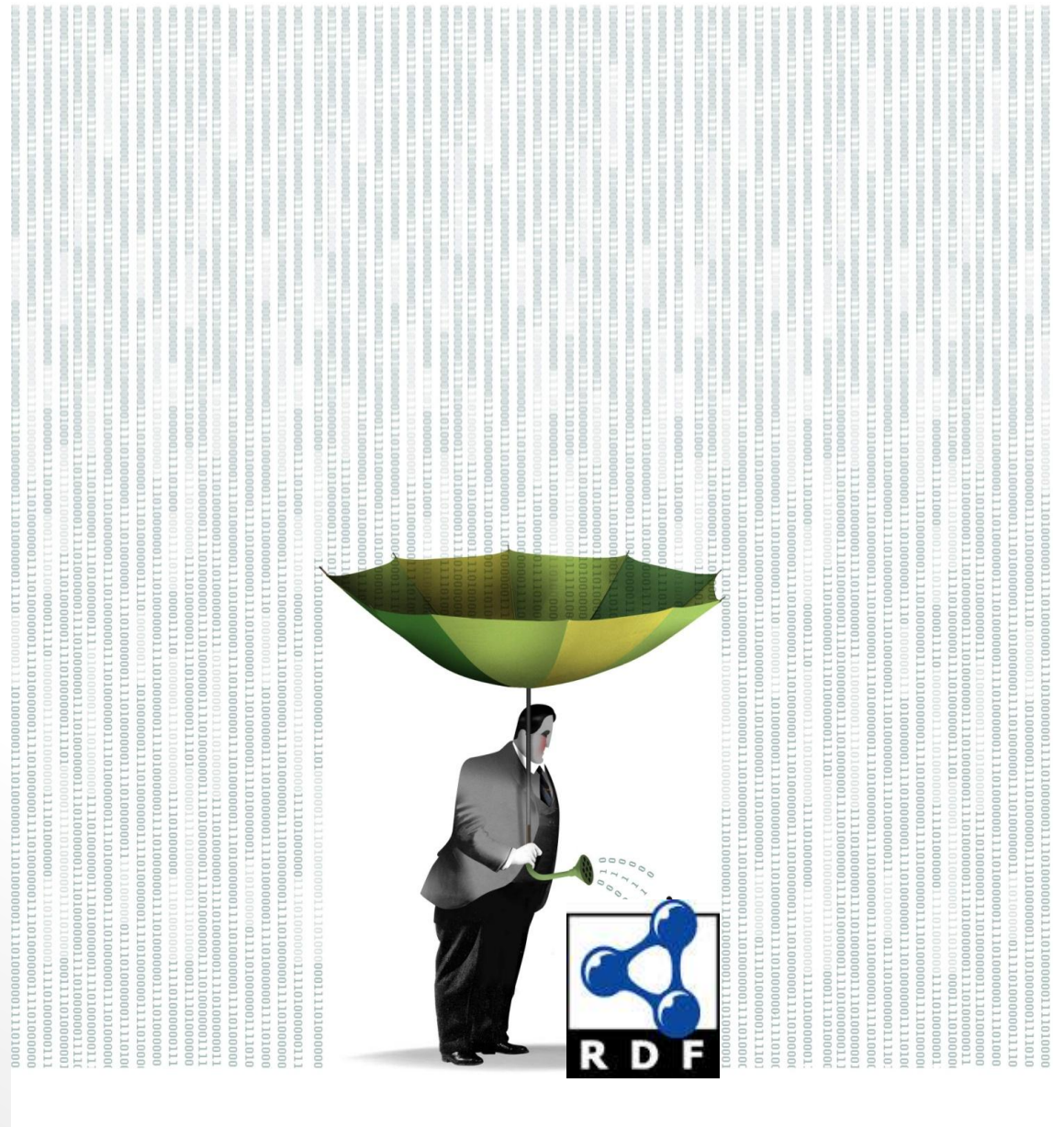
- ❑ **TaxonConcept Ontology**: properties habitat and authority, taxonomic ranks
- ❑ **NCBI Organismal Classification**: property has_rank, taxonomic ranks
- ❑ **GeoSpecies Knowledge Base**: taxonomic ranks
- ❑ **ENVO Environment Ontology**: habitats
- ❑ **Geonames**: mainland France and overseas territories
- ❑ **Darwin Core Terms**: properties occurrenceStatus, locationID
- ❑ **TDWG Occurrence Status Terms**: biogeographical statuses
- ❑ **World Geographical Scheme for Recording Plant Distributions**

TAXREF: Alignments with domain ontologies

Alignment of taxa and names done in a second step

- Automate search of matches within other taxonomical references
 - **DBpedia**
 - **NCBI Organismal Classification**
 - **Agrovoc**
 - **BnF**
 - **Encyclopedia of Life**
 - **Vertebrate Taxonomy Ontology**
- Difficulties
 - Spelling differences
 - Disagreements: reference vs. synonym, taxonomical rank
 - owl:sameAs (individuals), owl:equivalentClass (classes), rdfs:seeAlso, skos:exactMatch, skos:closeMatch, skos:relatedMatch (concepts)...

Populate the Web of Data



Many methods for many data sources

- ❑ HTML: RDFa, Microformats
- ❑ XML, XHTML
 - XPath: RML
 - XQuery: XSPARQL, SPARQL2XQuery
 - XSLT: Gleaning Resource Descriptions from Dialects of Languages (GRDDL), Scissor-Lift
- ❑ CSV/TSV/Spreadsheets: CSV on the web (W3C WG)
- ❑ RDBs (next slides)
- ❑ NoSQL stores (MongoDB...): xR2RML (next slides)
- ❑ Integration frameworks
 - DataLift, Asio Tool Suite, Talend (with Semantic Web plugin?)

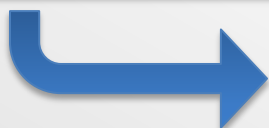
RDFa: RDF in HTML attributes



: http://rbdd.cnrs.fr



```
<body vocab="http://schema.org/">
  <div resource="/jrbdd2015" typeof="Event">
    <h2 property="title">RBDD 2015</h2>
    <p>Date: <span property="startDate">2015-10-20</span></p>
    ...
    <p>Conduire et construire un plan de gestion des données.
      <a property="url"
        href="http://rbdd.cnrs.fr/spip.php?article179">More...</a>
    </p>
  </div>
</body>
```



```
prefix sch: <http://schema.org/>
<http://rbdd.cnrs.fr/jrbdd2015>
  rdf:type sch:Event ;
  sch:title "RBDD 2015";
  sch:startDate "2015-10-20" ;
  sch:url <http://rbdd.cnrs.fr/spip.php?article179> .
```


Translation of RDBs to RDF (RDB2RDF)

- ❑ Various initial motivations
 - Web of Data, Linked Data
 - OBDA
 - Ontology learning
 - Schema mapping...
- ❑ Historical products: D2RQ, Virtuoso...
- ❑ R2RML
 - 2012 W3C recommendation, mapping language, several implementations
- ❑ Several methods: direct mapping vs. domain-specific

Direct Mapping of RDB to RDF

Table: PEOPLE		
ID	FNAME	ADDR (FK ADDRESS/ID)
7	Catherine	18
8	Olivier	22
...

```
<PEOPLE/ID=7> rdf:type <PEOPLE> .  
<PEOPLE/ID=7> <PEOPLE#FNAME> "Catherine" .  
<PEOPLE/ID=7> <PEOPLE#ADDR> <ADDRESS/ID=18> .  
  
<PEOPLE/ID=8> rdf:type <People> .  
<PEOPLE/ID=8> <PEOPLE#FNAME> "Olivier" .  
<PEOPLE/ID=8> <PEOPLE#ADDR> <ADDRESS/ID=22> .
```

Customized Mapping of RDB to RDF



```
<#TriplesMap1>
```

```
rr:logicalTable [ rr:tableName "PEOPLE" ];
```

```
rr:subjectMap [
```

```
  rr:template "http://i3s.wimmics.org/staff/{ID}";
```

```
  rr:class ex:Teacher;
```

```
];
```

```
rr:predicateObjectMap [
```

```
  rr:predicate foaf:name;
```

```
  rr:objectMap [ rr:column "FNAME" ];
```

```
].
```



```
<http://i3s.wimmics.org/staff/7> rdf:type ex:Teacher.  
<http://i3s.wimmics.org/staff/7> foaf:name "Catherine".  
<http://i3s.wimmics.org/staff/8> rdf:type ex:Teacher.  
<http://i3s.wimmics.org/staff/8> foaf:name "Olivier".
```

xR2RML: Mapping of heterogeneous DBs to RDF

- ❑ Uniform language to describe mappings from most common types of DB to RDF
- ❑ Extends R2RML and RML
- ❑ Features:
 - Allow **any declarative query language**
 - Allow **any syntax to reference data elements** from query results (column name, attribute name, JSONPath, XPath...)
 - Generate **RDF lists and containers** (bag, sequence, alternate)
 - Support **mixed content**, e.g. XML value in relational column
- ❑ Implementation for MongoDB
 - Data Materialization
 - Query rewriting

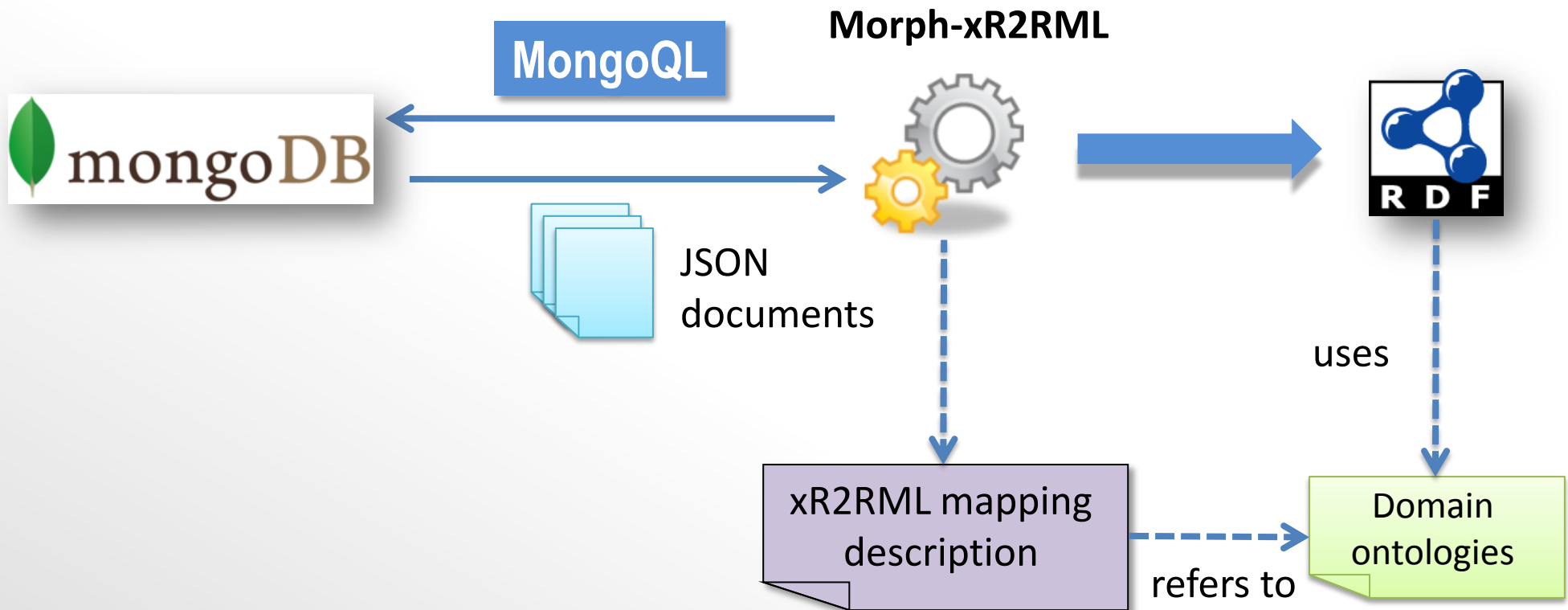
xR2RML mapping example

```
<#TriplesMap>
  xrr:logicalSource [
    xrr:query "db.studies.find({ studyid:{ $exists:true } )";
  ];

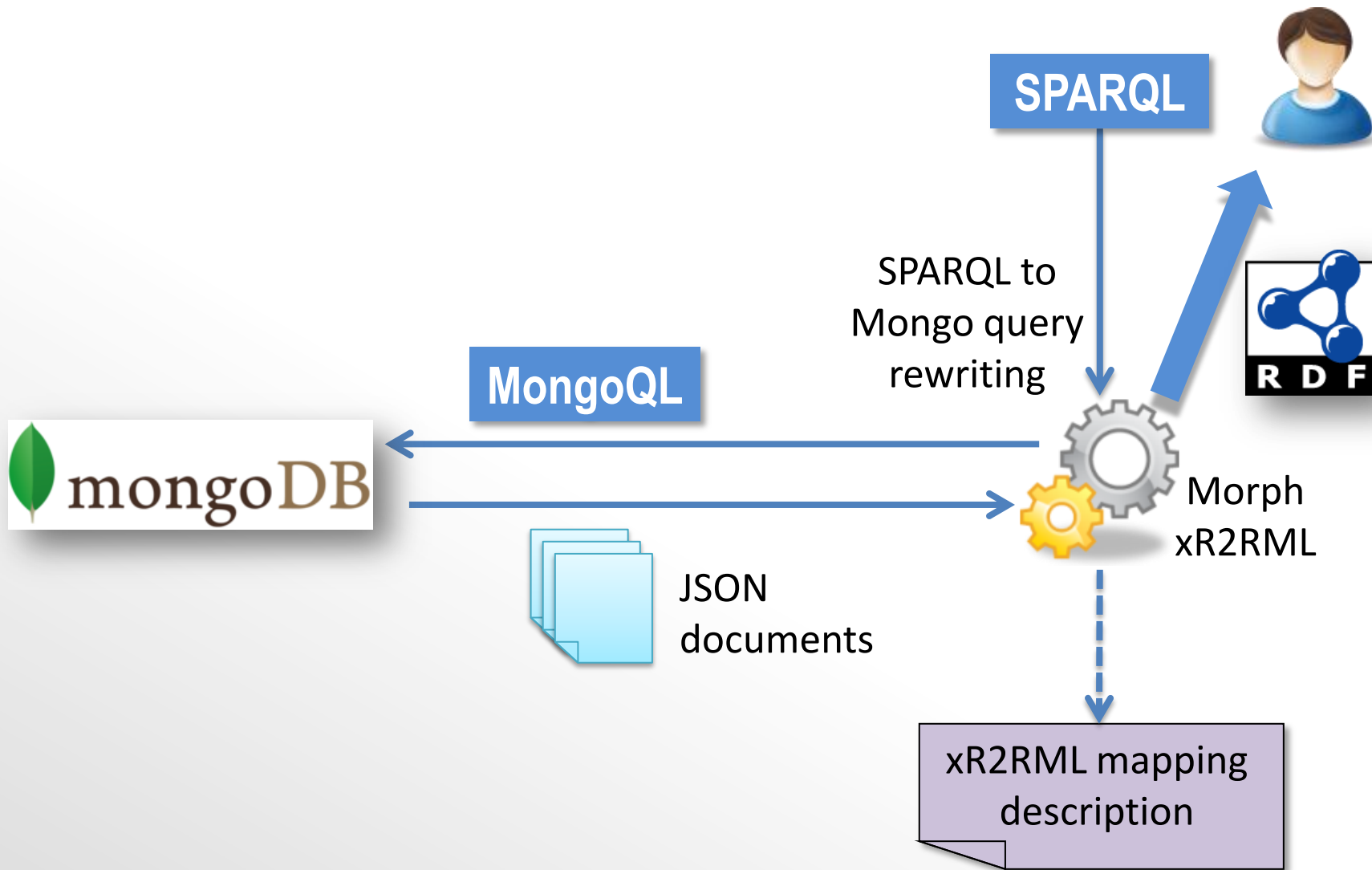
  rr:subjectMap [
    rr:template "http://example.org/study#{$.studyid}";
    rr:class ex:Study
  ];

  rr:predicateObjectMap [
    rr:predicate ex:involves;
    rr:objectMap [
      xrr:reference "$.centres.*.name" ];
  ];
```

xR2RML in practice: data materialization



xR2RML in practice: query rewriting



Publish Linked Open Data on the Web



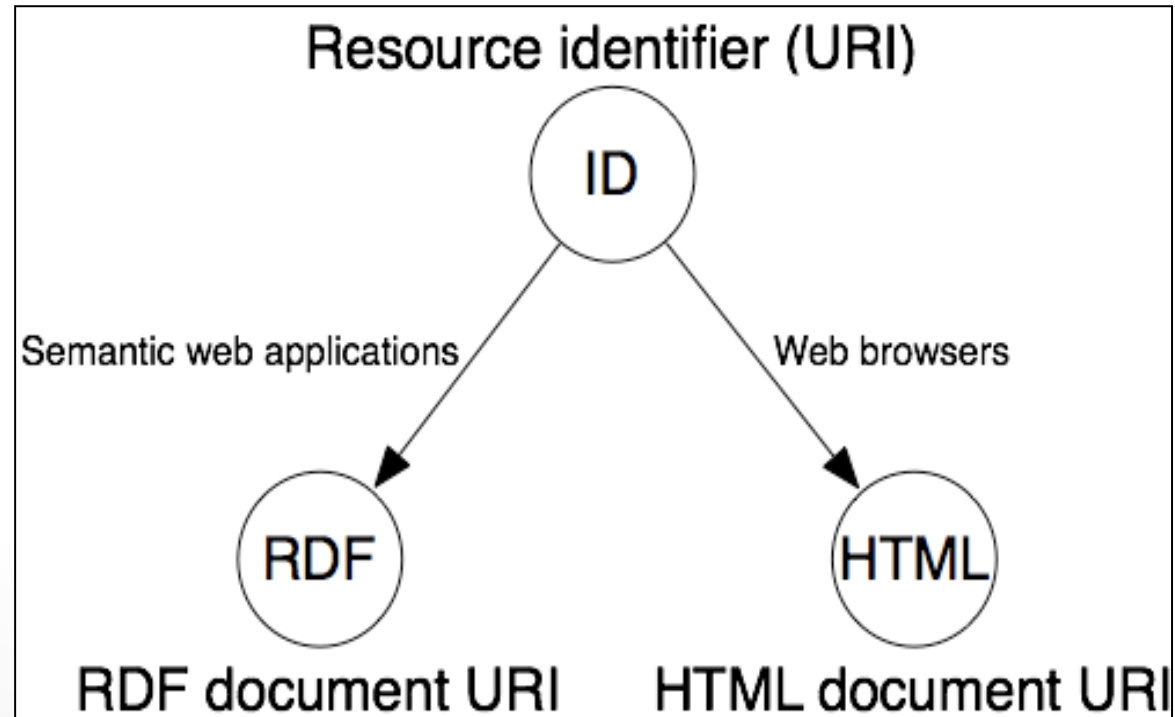
Linked Data rules

1. Use URIs as names for things
2. Use HTTP URIs so that people can look up those names
3. When someone looks up a URI, provide useful information, using the standards (RDF*, SPARQL)
4. Include links to other URIs, so that they can discover more things



Using URIs to look up information resources

- Dereferencing the URI returns a representation of the document
 - Either a direct link to the representation: the URI is a URL
 - Or content negotiation links to an appropriate representation



Source: <http://www.w3.org/TR/cooluris/>

Using URIs to look up information resources

HTTP content negotiation



```
GET /people/cv_alice HTTP/1.1
Host: www.example.com
Accept: text/html application/xhtml+xml
Accept-Language: en, de
```



```
HTTP/1.1 200 OK
Content-Type: text/html
Content-Language: en
Content-Location: http://www.example.com/cv_alice.en.html

<html ...>
...
```

Using URIs to look up information resources

HTTP content negotiation



```
GET /people/cv_alice HTTP/1.1
Host: www.example.com
Accept: text/html, application/xhtml+xml
Accept-Language: en, de
```



```
HTTP/1.1 302 Found
Location:
http://www.example.com/cv_alice.en.html
```

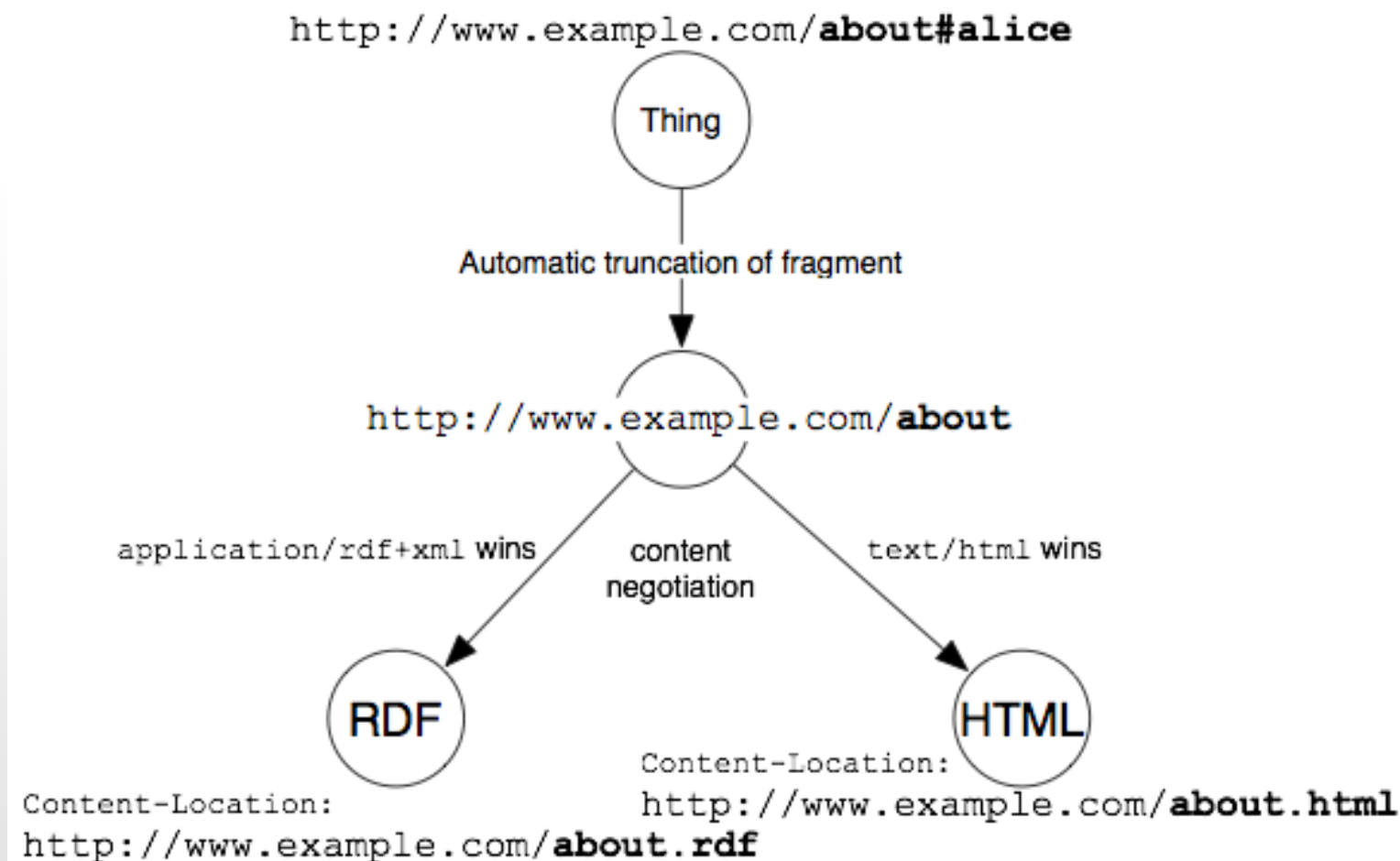
```
GET /cv_alice.en.html HTTP/1.1
Host: www.example.com
...
```

```
HTTP/1.1 200 OK
Content-Type: text/html
Content-Language: en
```

```
<html ...>
...
```


Using URIs to look up real-world objects

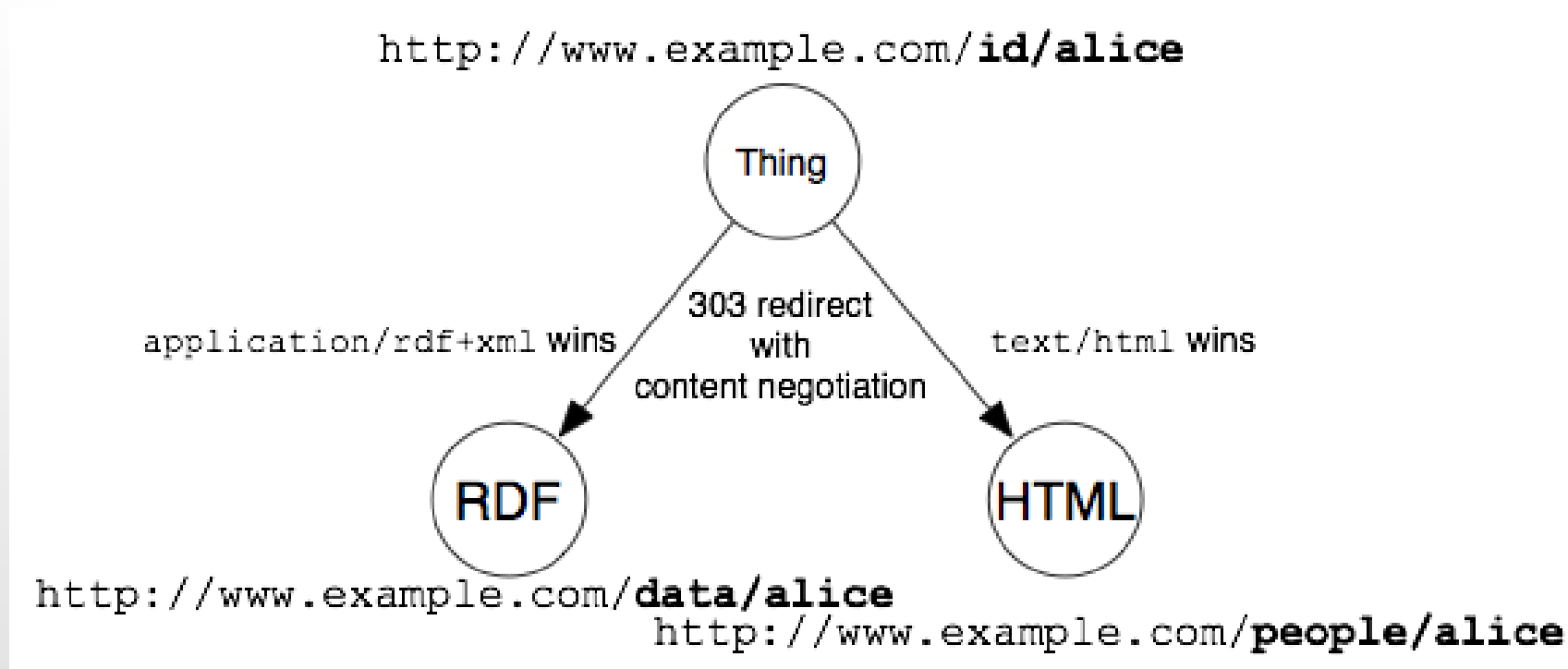
- One option: use Hash URIs for non-document resources



Source: <http://www.w3.org/TR/cooluris/>

Using URIs to look up real-world objects

- Use HTTP 303 forwarding to an information resource
 - **303 See Other**: the requested resource is not a regular Web doc. There is no suitable representation for the resource, but we can provide information about the resource



Source: <http://www.w3.org/TR/cooluris/>

Reference documentation

- ❑ Cool URIs for the Semantic Web.

W3C Interest Group Note 03 December 2008

<http://www.w3.org/TR/cooluris/>

- ❑ Dereferencing HTTP URIs

Draft Tag Finding 04 October 2007

<http://www.w3.org/2001/tag/doc/httpRange-14/HttpRange-14.html>



Data curation

- Main idea: better publish less data but publish useful data
 - Choose an appropriate modeling
 - Choose appropriate vocabularies
 - Include high quality metadata, provenance information
 - Deal with privacy issues
 - Interlink
- Time consuming activity => significant cost
- Need skilled scientists who know the data, the software...
 - Under-valued, no reward: data must become citable like any scientific publication => **Data Paper**



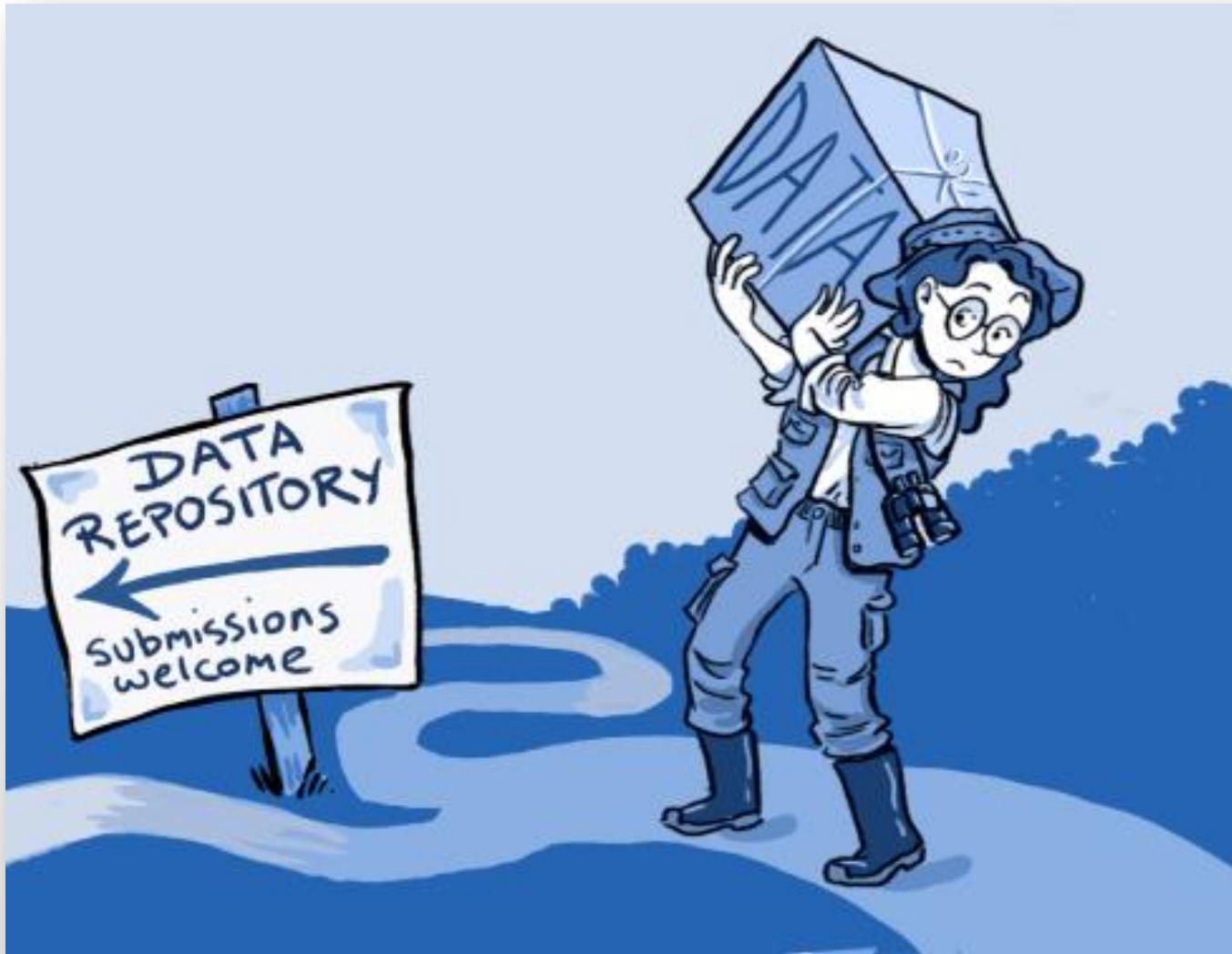
BioMedBridges ENVRI CRISP DASISH

Realising the full potential of research data: common challenges in data management, sharing and integration across scientific disciplines

Version: 3

Date: 20 December 2013

Authors: L. Field (CERN), S. Suhr (EMBL-EBI), J. Ison (EMBL-EBI), W. Los (UVA), P. Wittenburg (MPI), D. Broeder (MPI), A. Hardisty (Cardiff University), S. Repo (ELIXIR), A. Jenkinson (EMBL-EBI)



**Thank
you!**