

# Lecture 4

## Knowledge Base Queries & Linked Open Data

COMP 474/6741, Winter 2024

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## Slides Credit

- Includes slides by Ivan Herman, W3C [Her]

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# Vocabularies

# Vocabularies

- ▶ Data integration needs agreements on
  - terms
    - “translator”, “author”
  - categories used
    - “Person”, “literature”
  - relationships among those
    - “an author is also a Person...”, “historical fiction is a narrower term than fiction”
    - ie, new relationships can be deduced

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# Vocabularies

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- ▶ There is a need for “languages” to define such vocabularies
  - to define those vocabularies
  - to assign clear “semantics” on how new relationships can be deduced

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# Classes, resources, ...

- 
- ▶ Think of well known traditional vocabularies:
    - use the term “novel”
    - “every novel is a fiction”
    - “«The Glass Palace» is a novel”
    - etc.
  - ▶ RDFS defines resources and classes:
    - everything in RDF is a “resource”
    - “classes” are also resources, but...
    - ...they are also a collection of possible resources (i.e., “individuals”)
      - “fiction”, “novel”, ...

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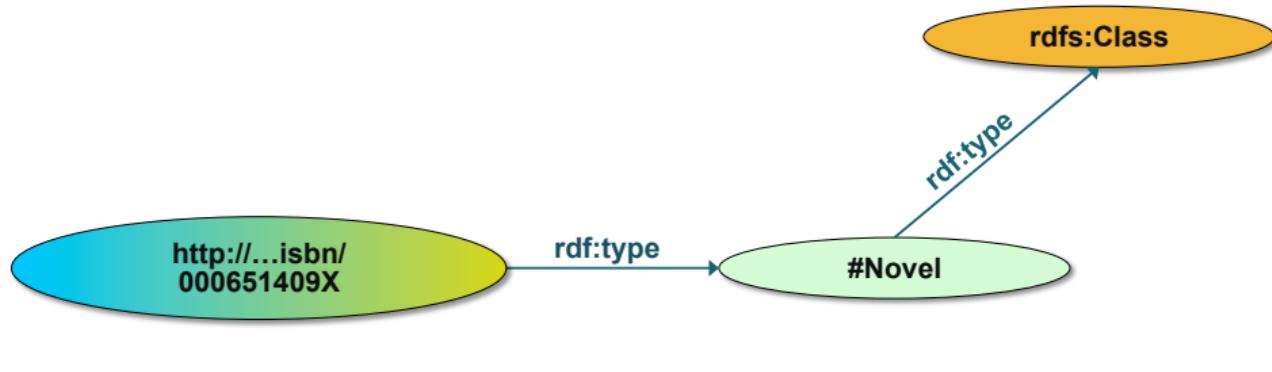
# Classes, resources, ... (cont.)

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- ▶ Relationships are defined among resources:
  - “typing”: an individual belongs to a specific class
    - “«The Glass Palace» is a novel”
    - to be more precise: “<http://.../000651409X>” is a novel”
  - “subclassing”: all instances of one are also the instances of the other (“every novel is a fiction”)
- ▶ RDFS formalizes these notions in RDF

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# Classes, resources in RDF(S)



- ▶ RDFS defines the meaning of these terms
  - (these are all special URI-s, we just use the namespace abbreviation)

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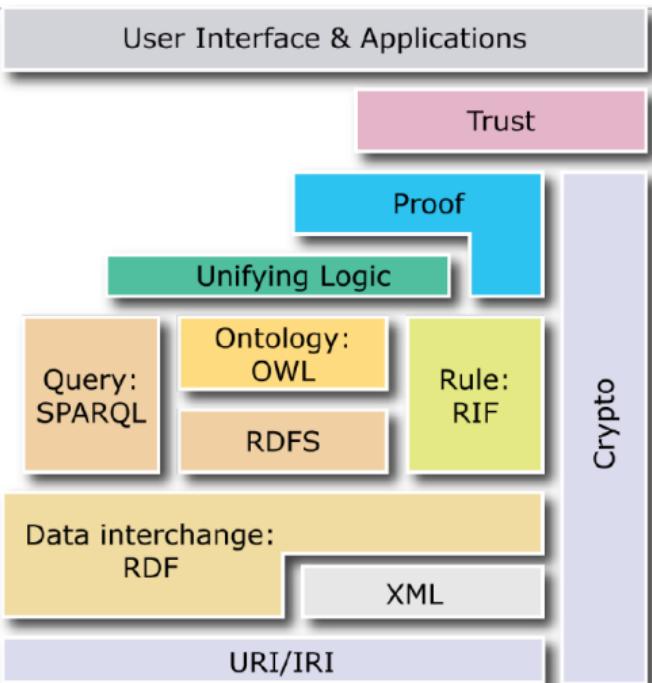
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## The Web Ontology Language (OWL)

- Current version OWL2 (2009)
- Different OWL2-Profiles (lite, full, etc.)
- Ontology language based on **Description Logics (DL)**
- Enables logic-based **reasoning**



<http://www.w3.org/TR/owl2-overview/>

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# OWL Species

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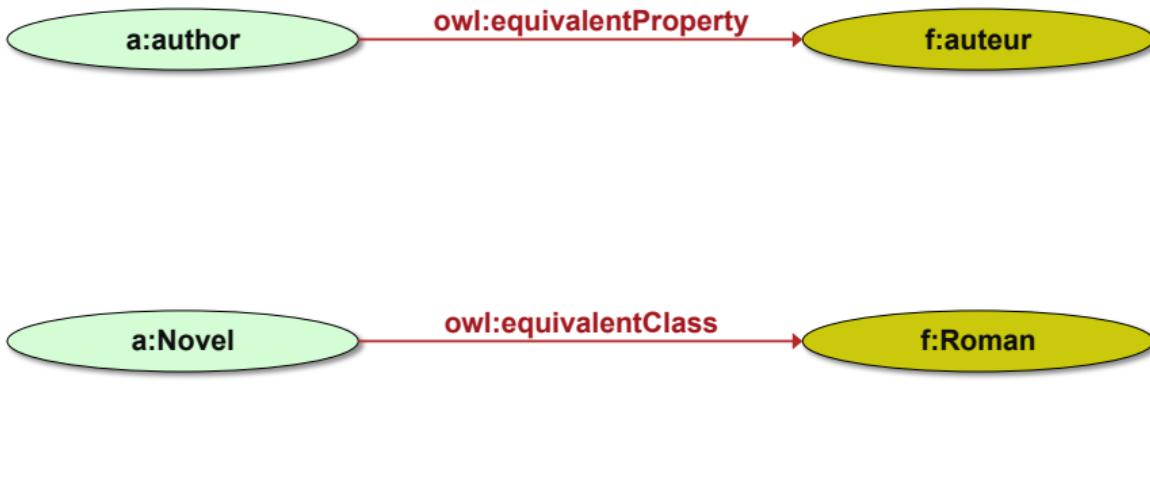
# Term equivalences

## ▶ For individuals:

- owl:sameAs: two URIs refer to the same concept (“individual”)
- owl:differentFrom: negation of owl:sameAs

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# Other example: connecting to French

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# Typical usage of owl:sameAs

- ▶ Linking our example of Amsterdam from one data set (DBpedia) to the other (Geonames):

```
<http://dbpedia.org/resource/Amsterdam>
owl:sameAs <http://sws.geonames.org/2759793>;
```

- ▶ This is the main mechanism of “Linking” in the Linked Open Data project

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→ Worksheet #3: Task 1

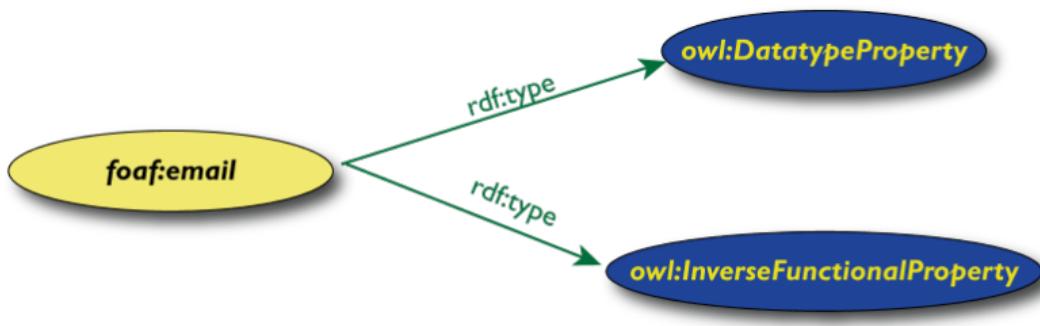
# Property characterization

- ▶ In OWL, one can characterize the behavior of properties (symmetric, transitive, functional, inverse functional, reflexive, irreflexive, ...)
- ▶ OWL also separates data and object properties
  - “datatype property” means that its range are typed literals

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# Characterization example

- ▶ “foaf:email” may be defined as “inverse functional”
  - i.e., two different subjects cannot have identical objects

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# What this means is...

- ▶ If the following holds in our triples:

```
:email rdf:type owl:InverseFunctionalProperty.
```

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# What this means is...

- ▶ If the following holds in our triples:

```
:email rdf:type owl:InverseFunctionalProperty.  
<A> :email "mailto:a@b.c".  
<B> :email "mailto:a@b.c".
```

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# What this means is...

- ▶ If the following holds in our triples:

```
:email rdf:type owl:InverseFunctionalProperty.  
<A> :email "mailto:a@b.c".  
<B> :email "mailto:a@b.c".
```

then, processed through OWL, the following holds, too:

```
<A> owl:sameAs <B>.
```

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# Inverse properties

- ▶ There may be an inverse relationship among properties, eg:

```
<somebook> ex:author <somebody>.  
ex:author owl:inverseOf ex:authorOf.
```

yields, in OWL:

```
<somebody> ex:authorOf <somebook>.
```

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# Classes in OWL

- ▶ In RDFS, you can subclass existing classes... that's all
- ▶ In OWL, you can construct classes from existing ones:
  - enumerate its content
  - through intersection, union, complement
  - etc

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# OWL DL and Description Logic

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- ▶ OWL DL can be interpreted as a variant of Description Logic
  - for connoisseurs: OWL (2) DL  $\approx$  *SROIQ(D)*
- ▶ Hence the results of this particular area of logic are directly applicable

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# Description Logic Formalism

- ▶ There is also a compact mathematical notation for axioms, assertions, etc:
  - Literature ≡ Novel ⊓ Short\_Story ⊓ Poetry
  - Listed\_Price ⊑ ∀ currency.Currencies
- ▶ You may see these in papers, books...

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# Ontologies examples

- ▶ eClassOwl: eBusiness ontology for products and services, 75,000 classes and 5,500 properties
- ▶ National Cancer Institute's ontology: about 58,000 classes
- ▶ Open Biomedical Ontologies Foundry: a collection of ontologies, including the Gene Ontology to describe gene and gene product attributes in any organism or protein sequence and annotation terminology and data (UniProt)
- ▶ BioPAX: for biological pathway data

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# Querying RDF graphs

- ▶ Remember the Python+RDFLib idiom:

```
for (s,p,o) in graph.triples((subject,None,None)) :  
    do_something(p,o);
```

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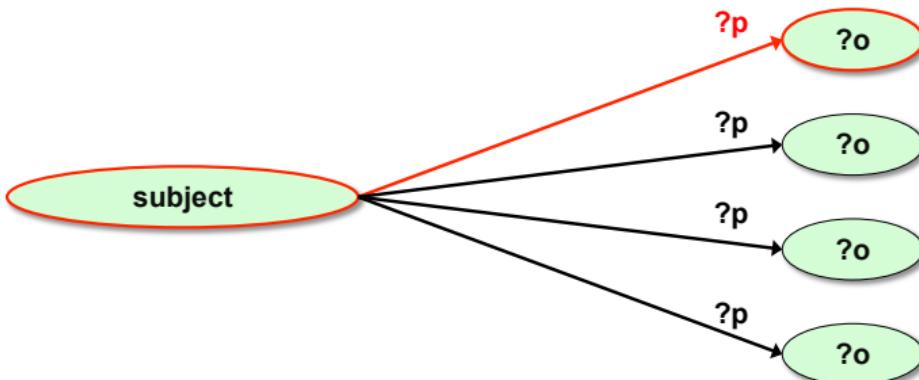
# Querying RDF graphs

- ▶ In practice, more complex queries into the RDF data are necessary
  - something like: “give me the (a,b) pair of resources, for which there is an x such that (x parent a) and (b brother x) holds” (ie, return the uncles)
    - these rules may become quite complex
- ▶ The goal of SPARQL (Query Language for RDF)

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# Analyze the Python+RDFLib example

```
for (s,p,o) in graph.triples((subject,None,None)) :  
    do_something(p,o);
```



# General: graph patterns

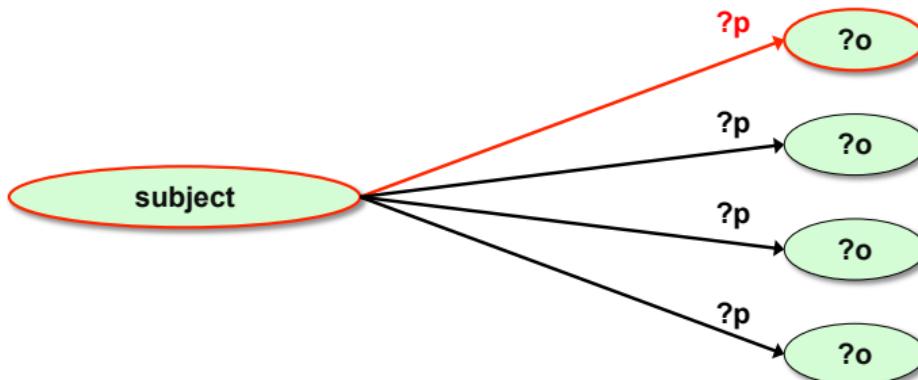
- ▶ The fundamental idea: use graph patterns
  - the pattern contains unbound symbols
  - by binding the symbols, subgraphs of the RDF graph are selected
  - if there is such a selection, the query returns the bound resources

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# Our Python example in SPARQL

```
SELECT ?p ?o  
WHERE {subject ?p ?o}
```

- ▶ The triples in WHERE define the graph pattern, with ?p and ?o “unbound” symbols
- ▶ The query returns all p,o pairs

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# Simple SPARQL example

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```
SELECT ?isbn ?price ?currency # note: not ?x!
WHERE {?isbn a:price ?x. ?x rdf:value ?price. ?x p:currency ?currency.}
```

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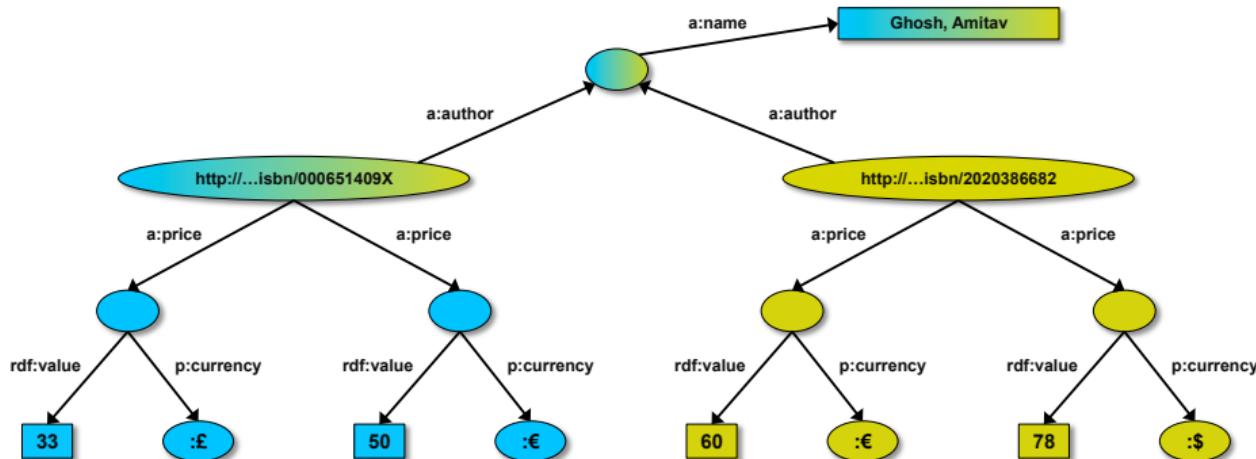
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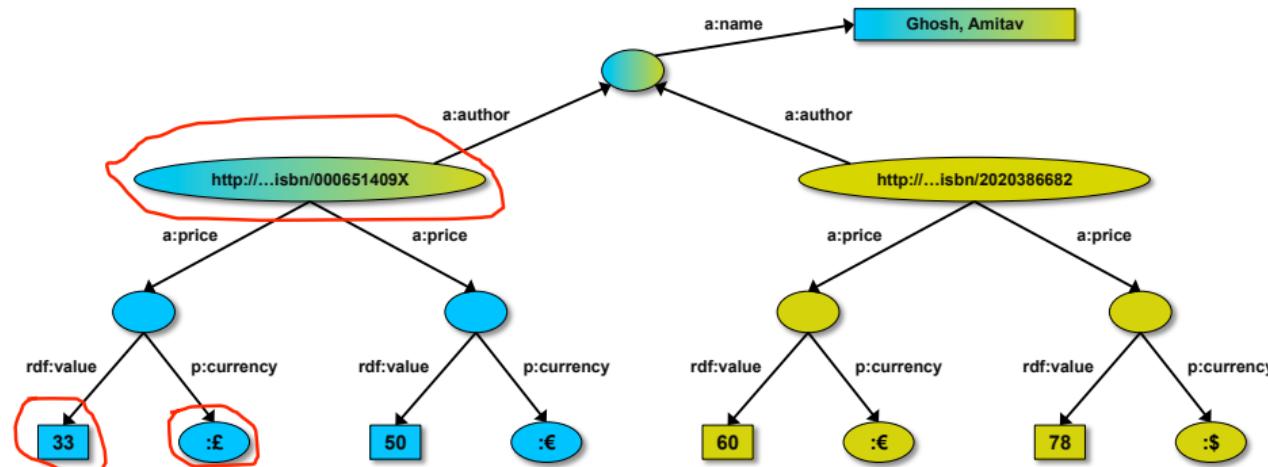
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# Simple SPARQL example

```
SELECT ?isbn ?price ?currency # note: not ?x!
WHERE {?isbn a:price ?x. ?x rdf:value ?price. ?x p:currency ?currency.}
```

Returns: [<...409X>,33,:£]



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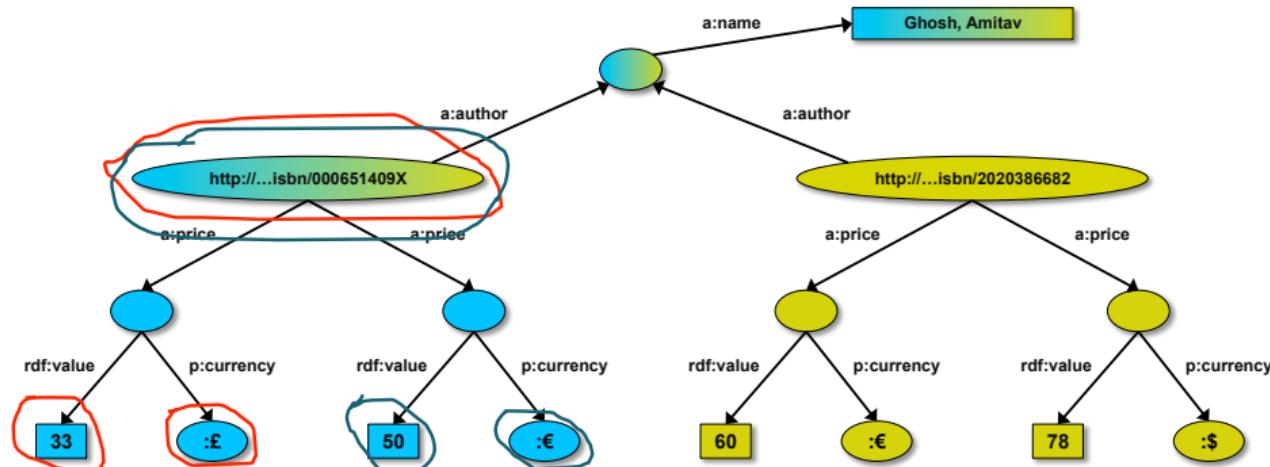
# Simple SPARQL example

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```
SELECT ?isbn ?price ?currency # note: not ?x!
WHERE {?isbn a:price ?x. ?x rdf:value ?price. ?x p:currency ?currency.}
```

Returns: [<...409X>,33,:£], [<...409X>,50,:€]



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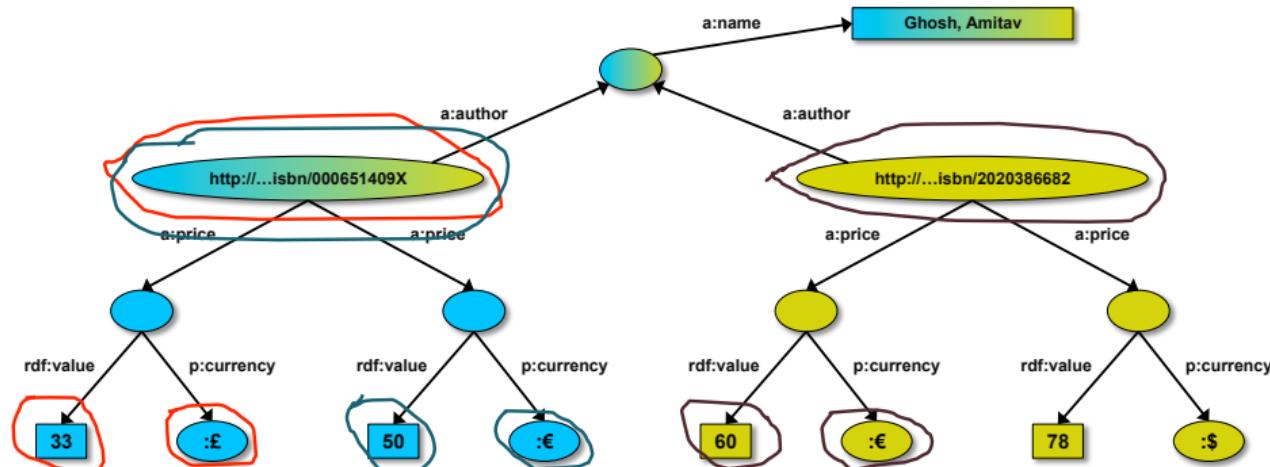
# Simple SPARQL example

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```
SELECT ?isbn ?price ?currency # note: not ?x!
WHERE {?isbn a:price ?x. ?x rdf:value ?price. ?x p:currency ?currency.}
```

Returns: [⟨...409X⟩,33,:£], [⟨...409X⟩,50,:€],  
[⟨...6682⟩,60,:€]



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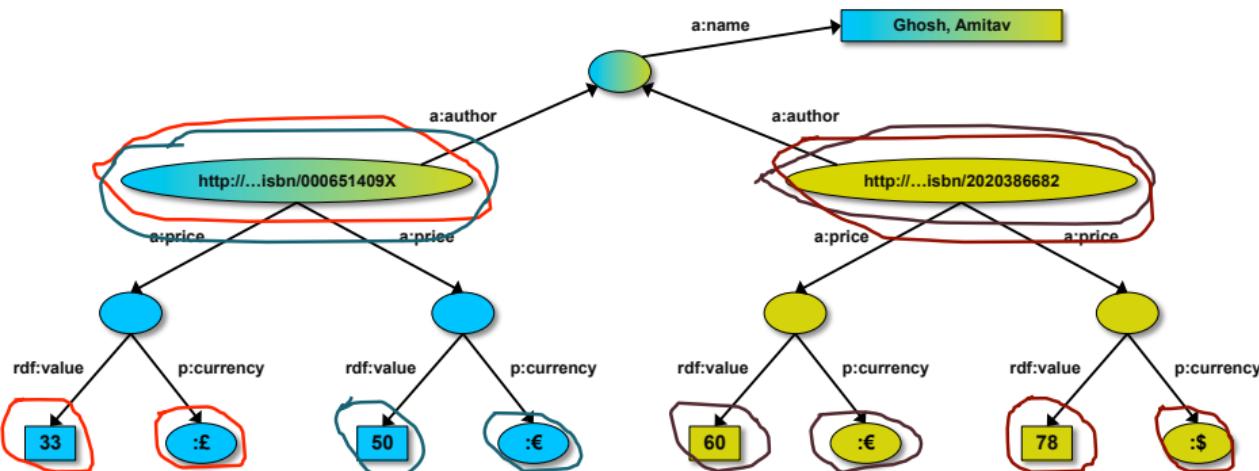
# Simple SPARQL example

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```
SELECT ?isbn ?price ?currency # note: not ?x!
WHERE {?isbn a:price ?x. ?x rdf:value ?price. ?x p:currency ?currency.}
```

Returns: [⟨...409X>,33,:£], [⟨...409X>,50,:€],  
[⟨...6682>,60,:€], [⟨...6682>,78,:\$]



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# Query RDF: (SPARQL)

Photo credit "reedster", Flickr

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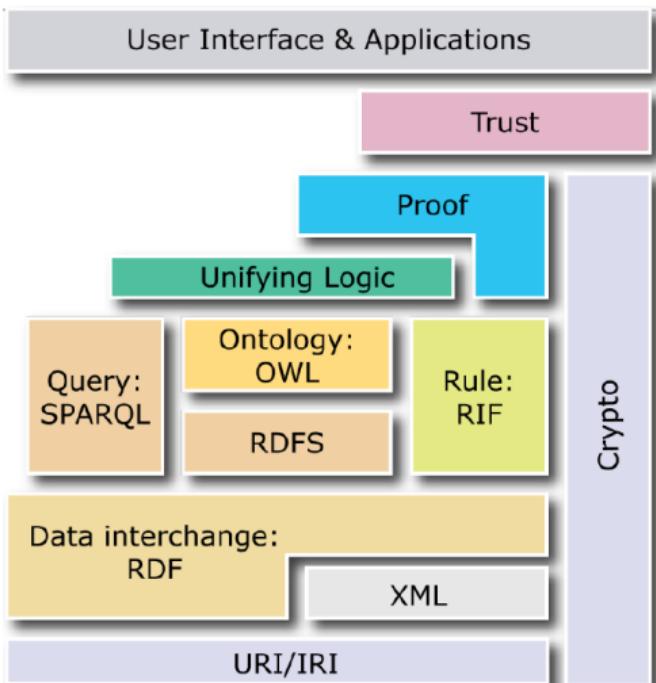
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## SPARQL W3C Standard

SPARQL stands for...

*"SPARQL Protocol And RDF Query Language"*

- Current version 1.1 (like RDF, RDFS, etc.)
- Language for querying graphs
- and a protocol for doing this over the web using a [SPARQL endpoint](#)
- Major difference between 1.0 and 1.1: modifying graphs via SPARQL (insert, delete etc.)



<https://www.w3.org/TR/sparql11-query/>



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## Describing a resource

Simple query that can be used when no information about a graph's content is available.

### Example 1

```
DESCRIBE <http://dbpedia.org/resource/Concordia_University>
```

### Example 2

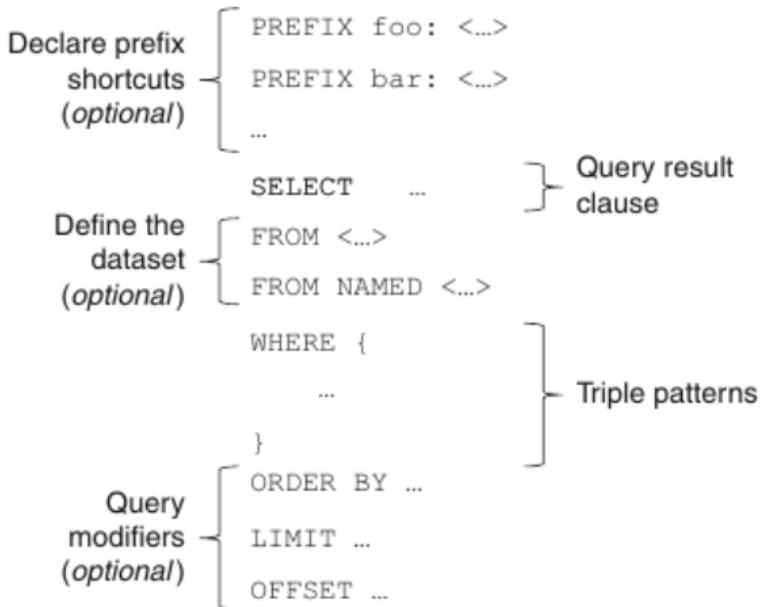
```
PREFIX geo: <http://www.w3.org/2003/01/geo/wgs84_pos#>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
DESCRIBE ?s
WHERE { ?s geo:lat "45.497002"^^xsd:float .
      ?s geo:long "-73.578003"^^xsd:float . }
```

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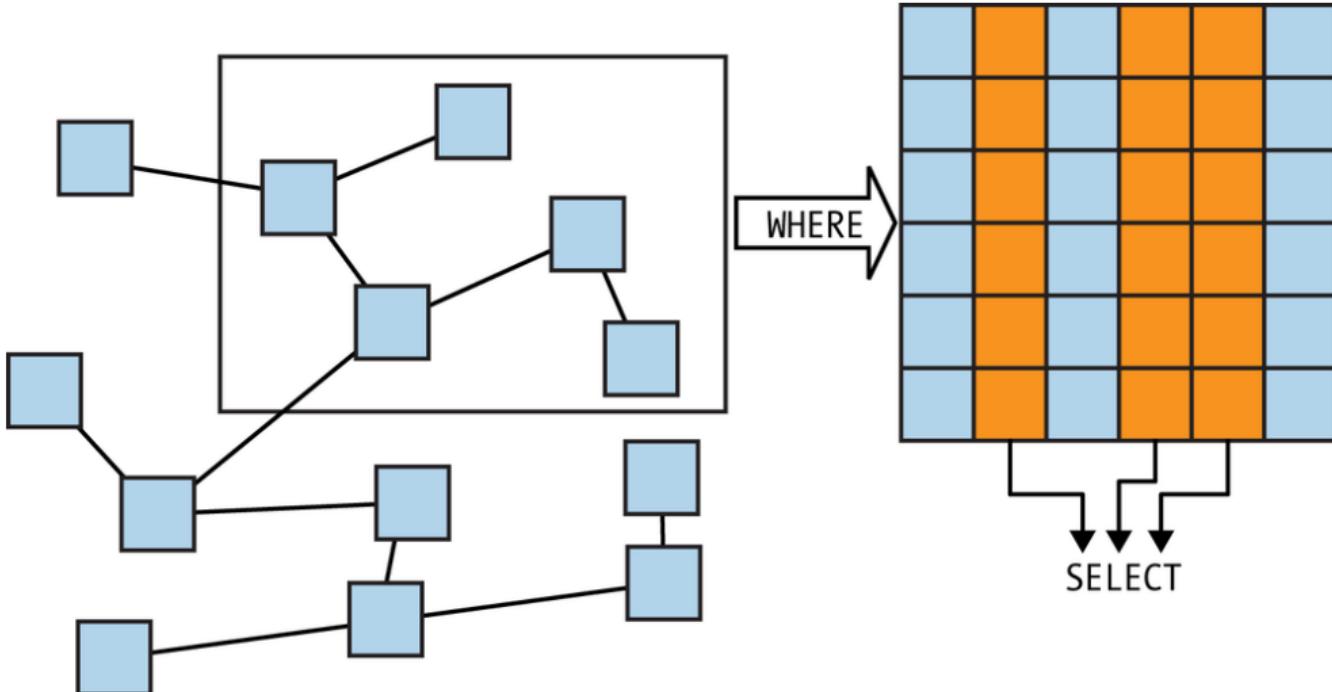
## Probably the most widely used type of SPARQL query

- Select triples from a graph that match a given triple pattern
- Like an RDF triple, except subject, predicate, and/or object may be a variable



# Select... where

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## Select: some details

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### DISTINCT

Use SELECT DISTINCT to remove redundant triples

### ORDER BY

Use ORDER BY to sort the result triples (e.g., ORDER BY ?amount)

### LIMIT

Use LIMIT to restrict the number of results (e.g., LIMIT 10)

### Functions

You can use functions like AVG(), MIN(), MAX(), COUNT(), SUM(), e.g.,

```
SELECT (MAX(?amount) as ?maxAmount)  
WHERE { ?meal e:amount ?amount . }
```

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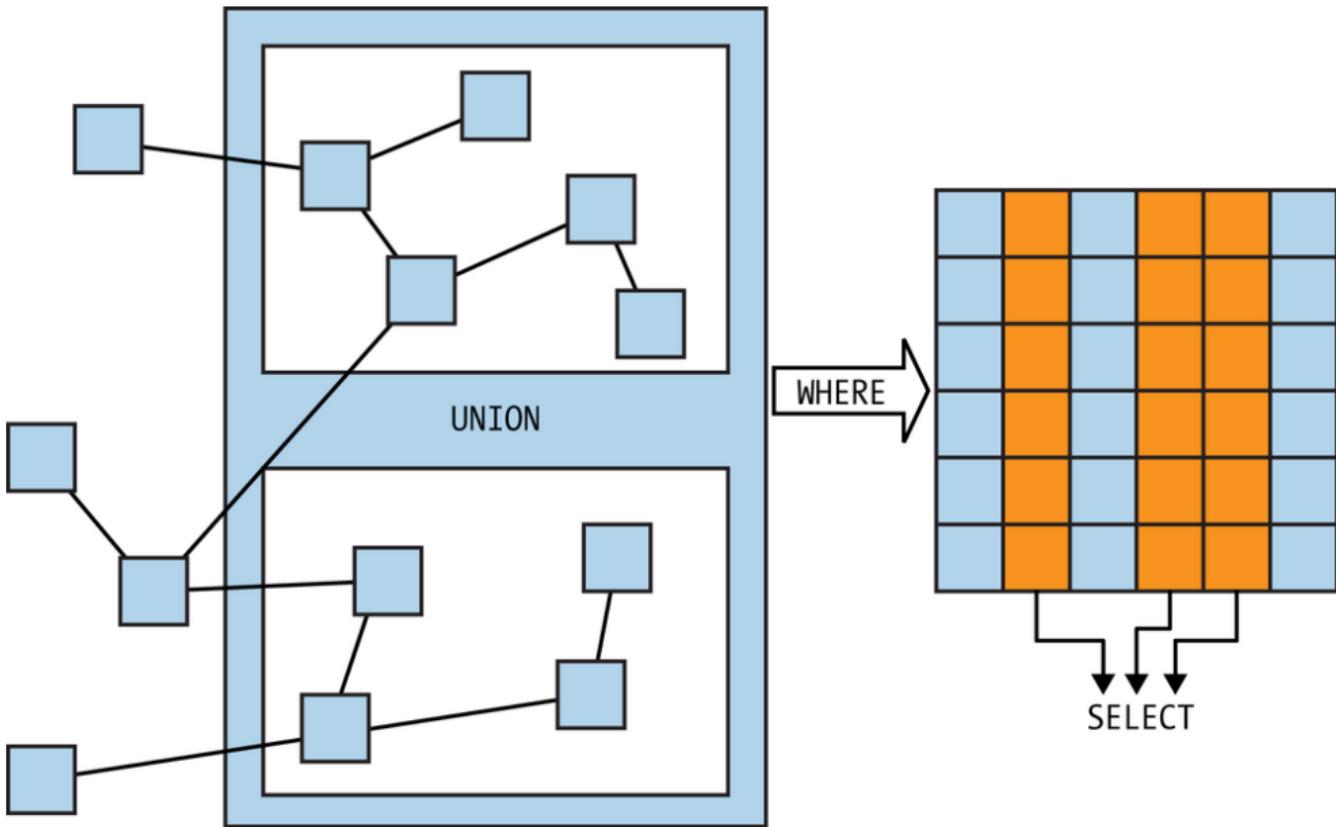
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## Example (using the Gene Ontology)

*“Find me the cellular processes that are either integral to or a refinement of signal transduction.”*

```
PREFIX go: <http://purl.org/obo/owl/GO#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX obo: <http://www.obofoundry.org/ro/ro.owl#>

SELECT DISTINCT ?label ?process
WHERE {
  { ?process obo:part_of go:GO_0007165 }      # "integral to"
    UNION
  { ?process rdfs:subClassOf go:GO_0007165 } # "refinement of"
  ?process rdfs:label ?label
}
```

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## Optional Information

Use the `OPTIONAL` keyword to match optional information, e.g.,

```
prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#>
prefix foaf: <http://xmlns.com/foaf/0.1/>
```

```
select ?name ?url
where {
    ?person foaf:name ?name .
    OPTIONAL { ?person rdfs:seeAlso ?url }
}
```

- This will return a person's URL, if there is one
- Without the `OPTIONAL`, persons without URLs would not have been matched

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# Optional pattern

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```
SELECT ?isbn ?price ?currency ?wiki
WHERE { ?isbn a:price ?x. ?x rdf:value ?price. ?x p:currency ?currency.
        OPTIONAL ?wiki w:isbn ?isbn. }
```

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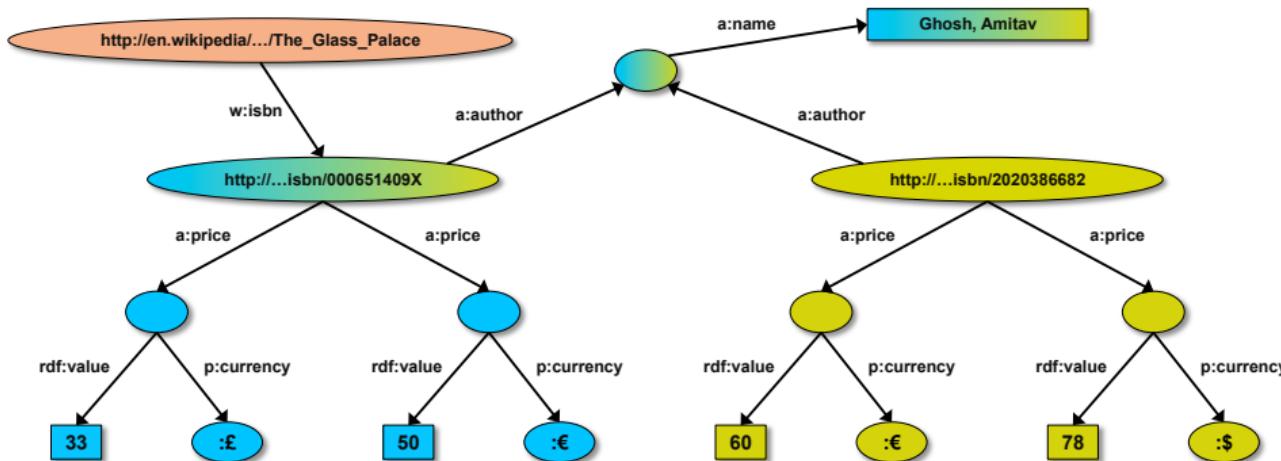
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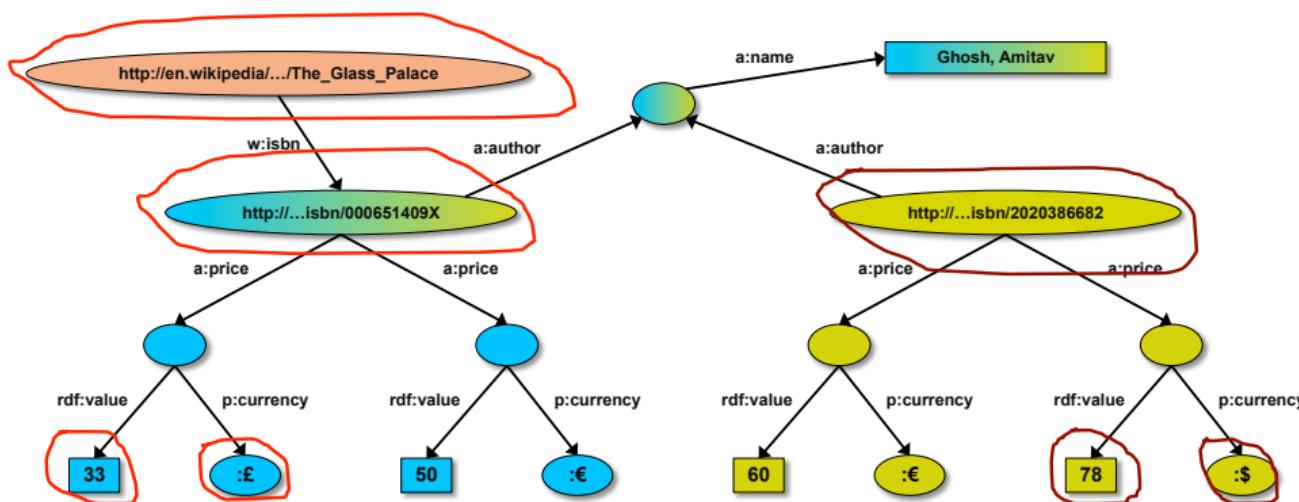
# Optional pattern

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```
SELECT ?isbn ?price ?currency ?wiki
WHERE { ?isbn a:price ?x. ?x rdf:value ?price. ?x p:currency ?currency .
        OPTIONAL ?wiki w:isbn ?isbn. }
```

Returns: [[<..09X>,33,:£,<...Palace>], ... , [<..6682>,78,:\$, ]]



→ Worksheet #3: Task 5

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## Filtering Information

Use a **FILTER** to remove results that were matched by WHERE, e.g.:

```
PREFIX dbr: <http://dbpedia.org/resource/>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
```

```
SELECT ?comment
WHERE {
    dbr:Linked_data rdfs:comment ?comment .
    FILTER (lang(?comment) = "en")
}
```

- Here, we restrict all matched abstracts to those with an English language tag.
- **FILTERs** can operate on numbers, strings, dates, URIs, or other data types and support regular expressions.

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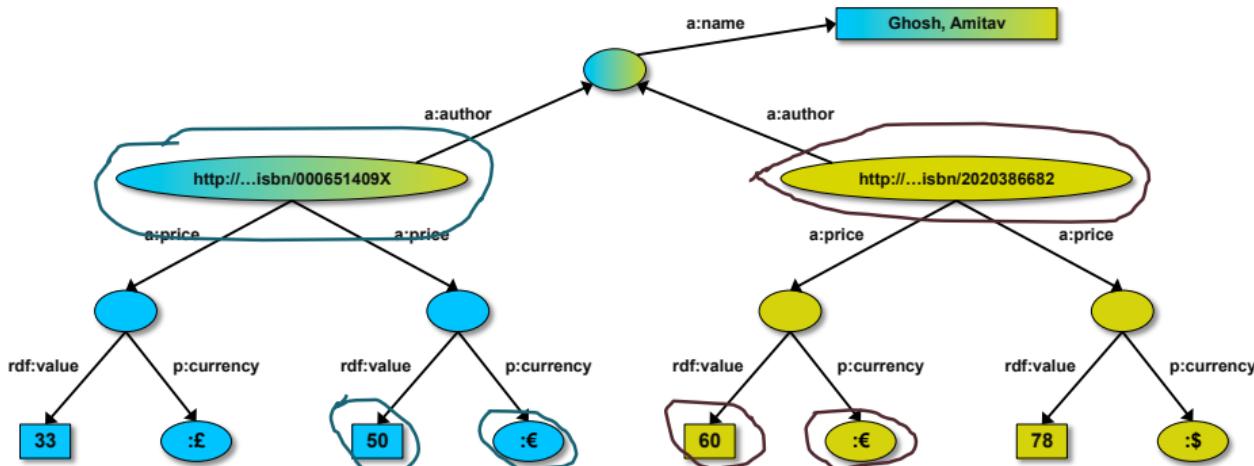
# Pattern constraints

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```
SELECT ?isbn ?price ?currency # note: not ?x!
WHERE { ?isbn a:price ?x. ?x rdf:value ?price. ?x p:currency ?currency .
        FILTER(?currency == :€) }
```

Returns: [<...409X>,50,:€], [<...6682>,60,:€]



→ Worksheet #3: Task 6

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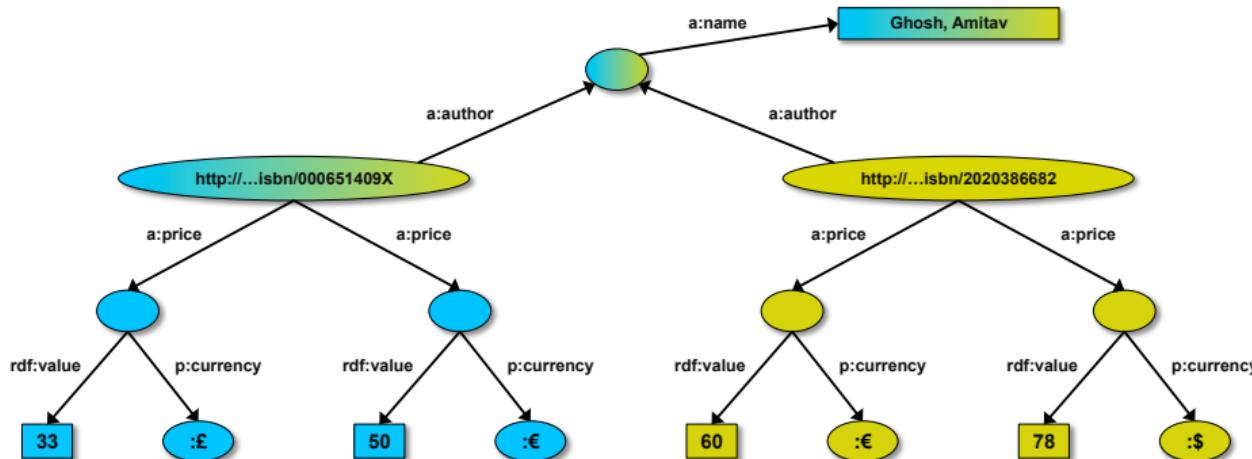
## Constructing a new graph

Can be used to re-construct a new graph from an existing one.

- For example, re-write triples from one vocabulary into another

# Construct a new graph

```
CONSTRUCT { ?isbn b:price ?price.
            ?isbn a:author ?y. ?y a:name ?name . }
WHERE { ?isbn a:price ?x. ?x rdf:value ?price. ?x p:currency ?currency .
       ?isbn a:author ?y. ?y a:name ?name .
       FILTER(?currency == :€) }
```



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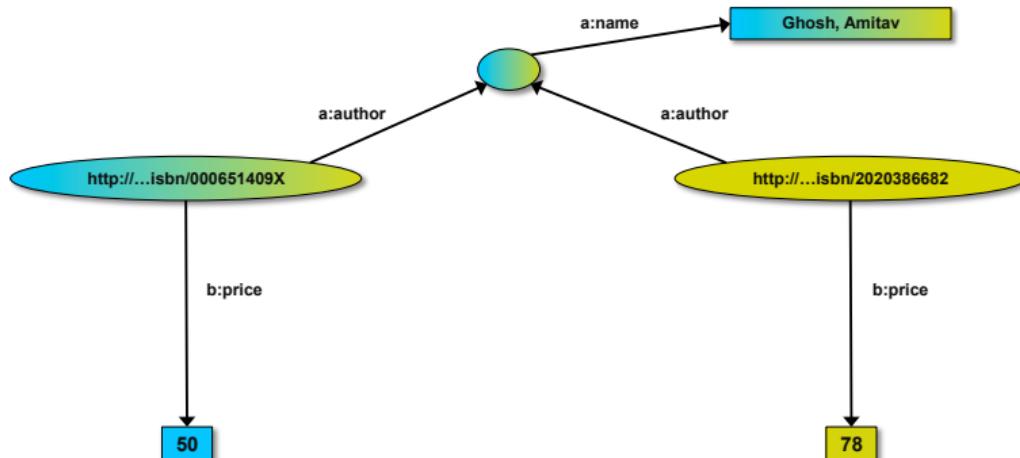
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# Construct a new graph

```
CONSTRUCT { ?isbn b:price ?price.
            ?isbn a:author ?y. ?y a:name ?name . }
WHERE { ?isbn a:price ?x. ?x rdf:value ?price. ?x p:currency ?currency .
       ?isbn a:author ?y. ?y a:name ?name .
       FILTER(?currency == :€) }
```



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## Asking a true/false question

```
ASK <graph pattern>
```

Returns `true` if the pattern can be matched in the graph, otherwise `false`

### Example

*Is Concordia University located in Mexico?*

```
ASK {  
    wd:Q326342 wdt:P17 wd:Q96  
}
```

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# Other SPARQL features

---

- ▶ Limit the number of returned results; remove duplicates, sort them, ...
- ▶ Specify several data sources (via URI-s) within the query
- ▶ Construct a graph combining a separate pattern and the query results
- ▶ Use datatypes and/or language tags when matching a pattern
- ▶ Aggregation of the results (min, max, average, etc.)
- ▶ Path expressions (a bit like regular expressions)

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# SPARQL usage in practice

---

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- ▶ SPARQL is usually used over the network
  - http request is sent to a SPARQL endpoint
  - result is the result of the SELECT, the CONSTRUCT,...
- ▶ Separate documents define the protocol and the result format
  - SPARQL Protocol for RDF with HTTP and SOAP bindings
  - SPARQL results in XML or JSON formats
- ▶ Big datasets usually offer “SPARQL endpoints” using this protocol

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# Remote query/reply example

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```
GET /qps?&query=SELECT+...+WHERE+... HTTP/1.1
User-Agent: my-sparql-client/0.0
Host: my.example

HTTP/1.1 200 OK
Server: my-sparql-server/0.0
Content-Type: application/sparql-results+xml

<?xml version="1.0" encoding="UTF-8"?>
<sparql xmlns="http://www.w3.org/2005/sparql-results#>
  <head>
    <variable name="a"/>
    ...
  </head>
  <results>
    <result ordered="false" distinct="false">
      <binding name="a"><uri>http:...</uri></binding>
      ...
    </result>
    <result> ... </result>
  </results>
</sparql>
```

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# SPARQL 1.1 Update

- 
- ▶ SPARQL CONSTRUCT returns a new, modified graph
    - the original data remains unchanged!
  - ▶ SPARQL 1.1 Update *modifies the original dataset!*

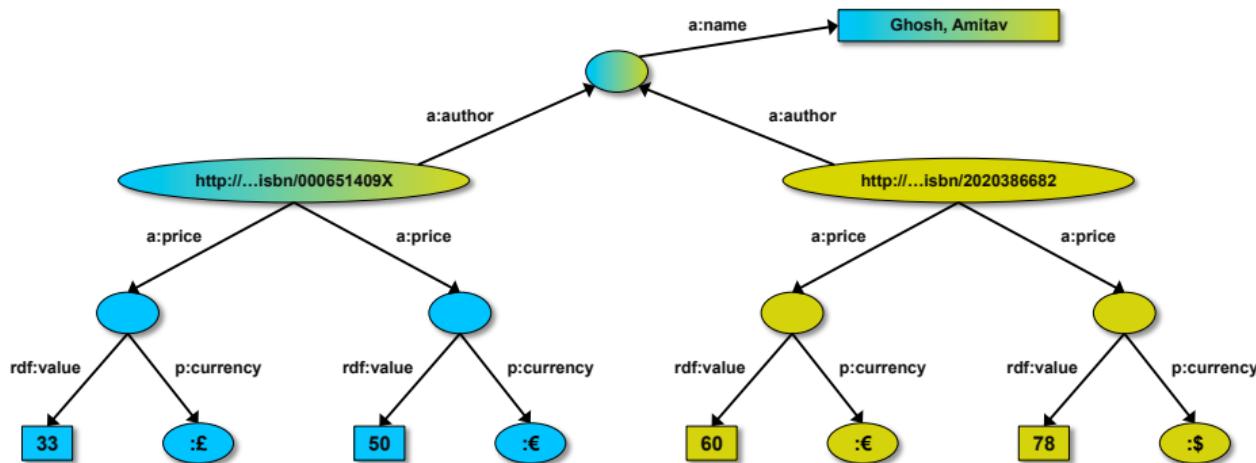
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# Update: insert

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```
INSERT {?isbn rdf:type frbr:Work}
WHERE  {?isbn a:price ?x. ?x rdf:value ?price. ?x p:currency ?currency.}
```



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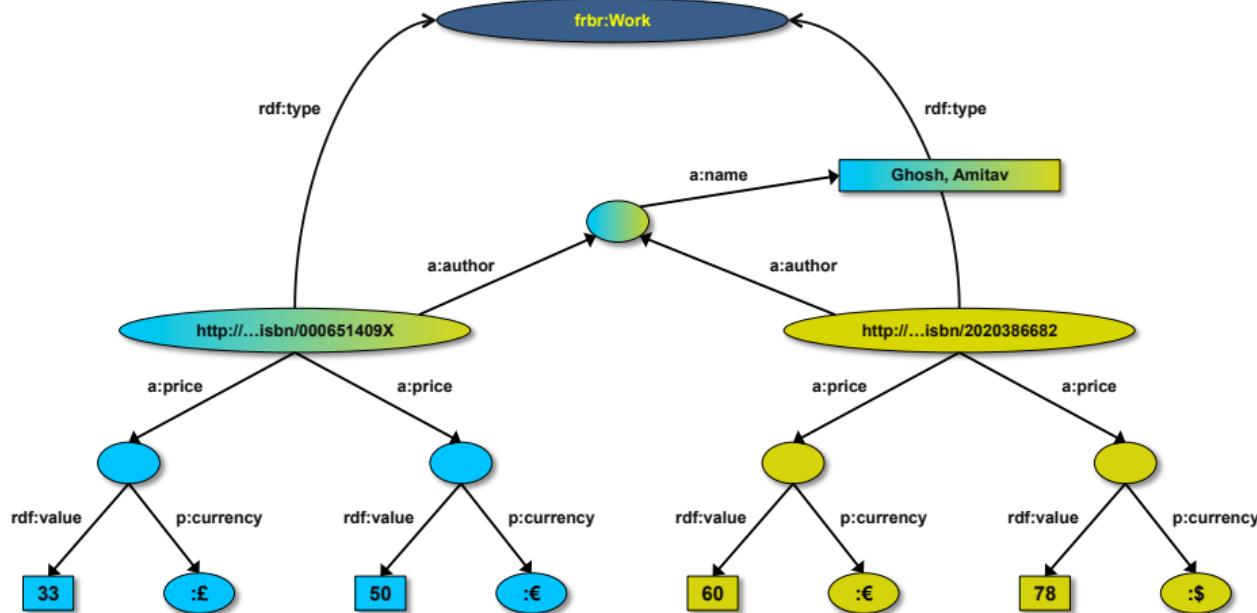
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# Update: insert

```
INSERT {?isbn rdf:type frbr:Work}
WHERE  {?isbn a:price ?x. ?x rdf:value ?price. ?x p:currency ?currency.}
```



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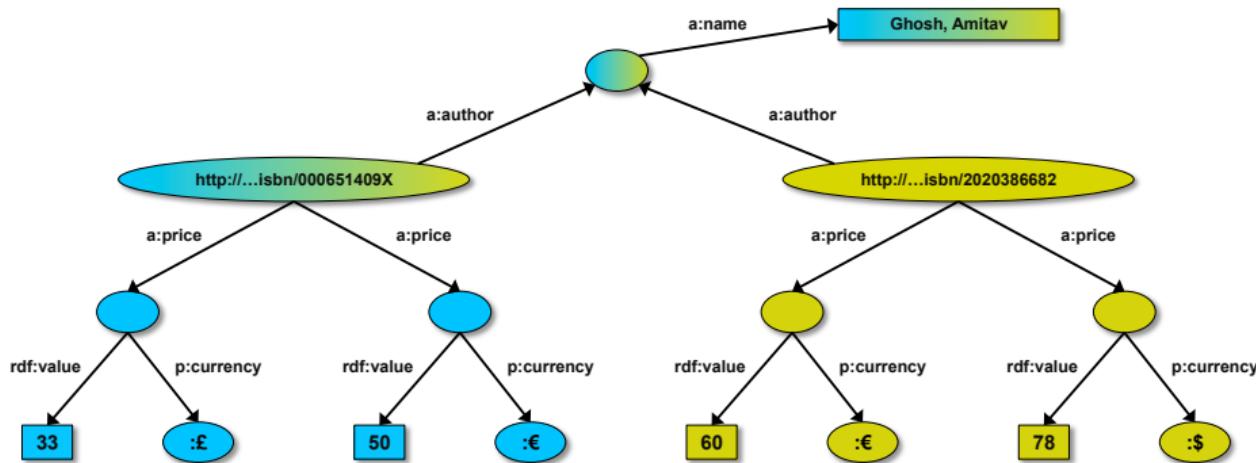
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# Update: delete

```
DELETE {?x p:currency ?currency}
WHERE  {?isbn a:price ?x. ?x rdf:value ?price. ?x p:currency ?currency.}
```



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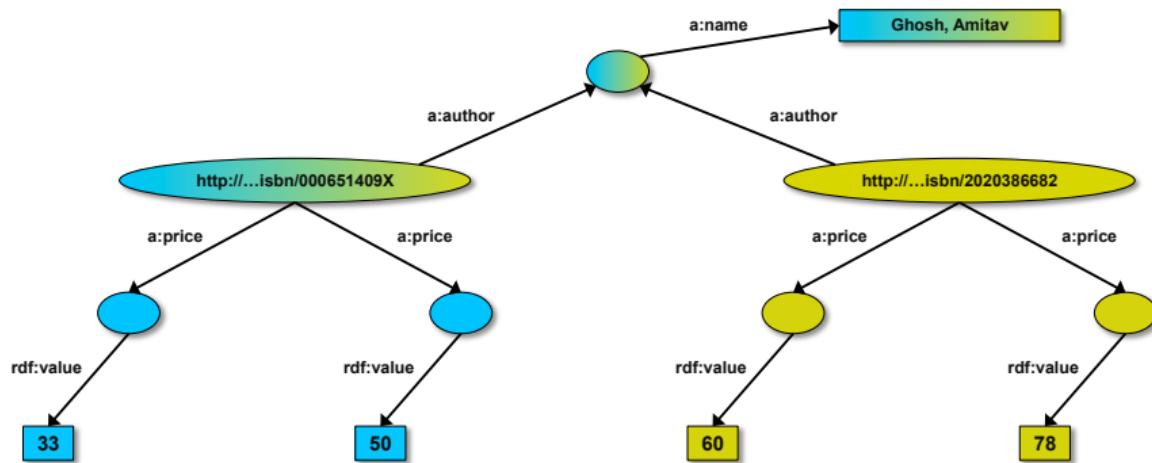
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# Update: delete

```
DELETE {?x p:currency ?currency}
WHERE  {?isbn a:price ?x. ?x rdf:value ?price. ?x p:currency ?currency.}
```



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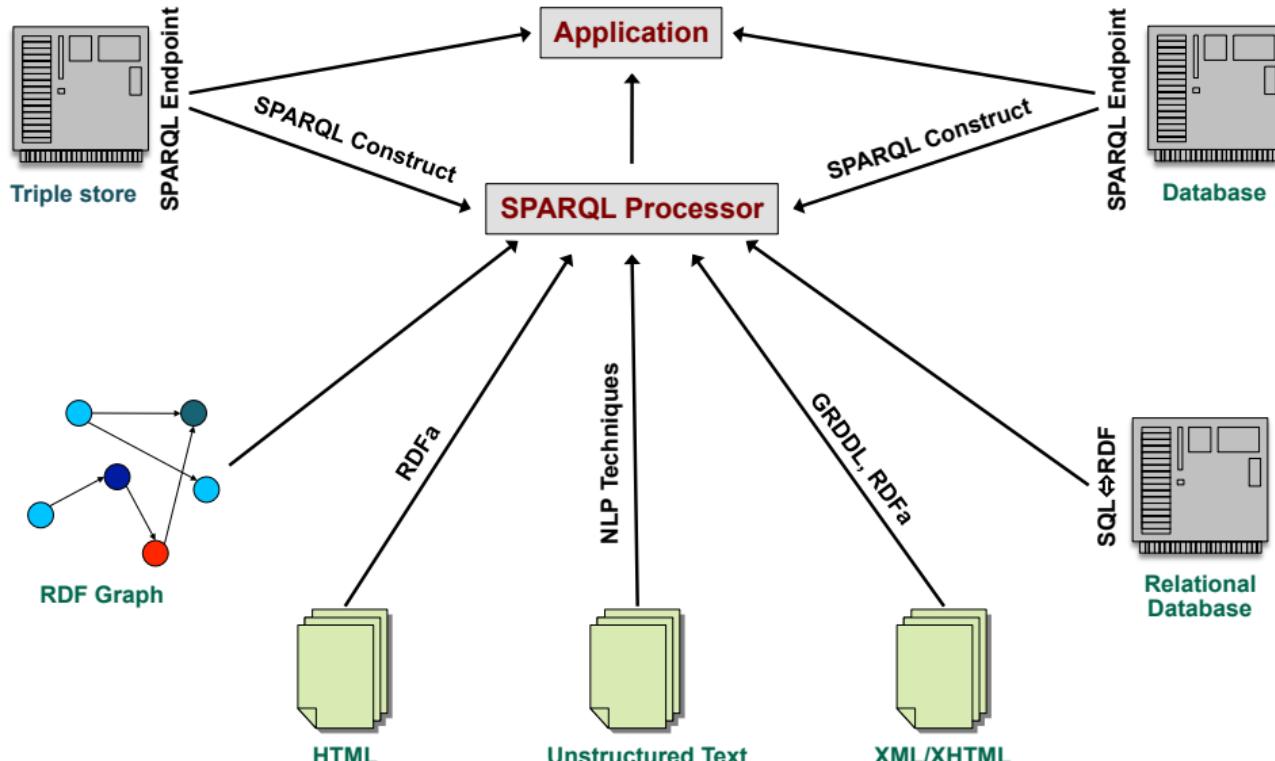
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# SPARQL as a unifying point

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## RDF Dataset

An RDF dataset may have multiple [named graphs](#) and at most one unnamed ("default") graph.

## Serialization

TriG: Extension of [Turtle](#) for named graphs  
See <https://www.w3.org/TR/trig/>

N-Quads: Extension of [N-Triples](#) for named graphs  
See <https://www.w3.org/TR/n-quads/>

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# TriG Example

René Witte



```
BASE    <http://example.org/>
PREFIX ...  
  
GRAPH <http://example.org/bob>
{
    <bob#me>
        a foaf:Person ;
        foaf:knows <alice#me> ;
        schema:birthDate "1990-07-04"^^xsd:date ;
        foaf:topic_interest wd:Q12418 .
}  
  
GRAPH <https://www.wikidata.org/wiki/Special:EntityData/Q12418>
{
    wd:Q12418
        dcterms:title "Mona Lisa" ;
        dcterms:creator <http://dbpedia.org/resource/Leonardo_da_Vinci> .
        <http://data.europeana.eu/item/04802/243FA8618938F4117025F17A8B813C5F9AA4D619>
            dcterms:subject wd:Q12418 .
}  
  
<http://example.org/bob>
    dcterms:publisher <http://example.org> ;
    dcterms:rights <http://creativecommons.org/licenses/by/3.0/> .
```

See <https://www.w3.org/TR/rdf11-primer/>

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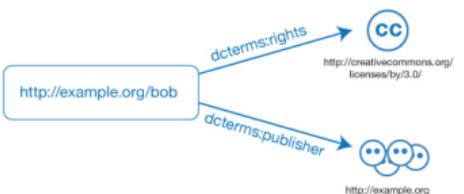
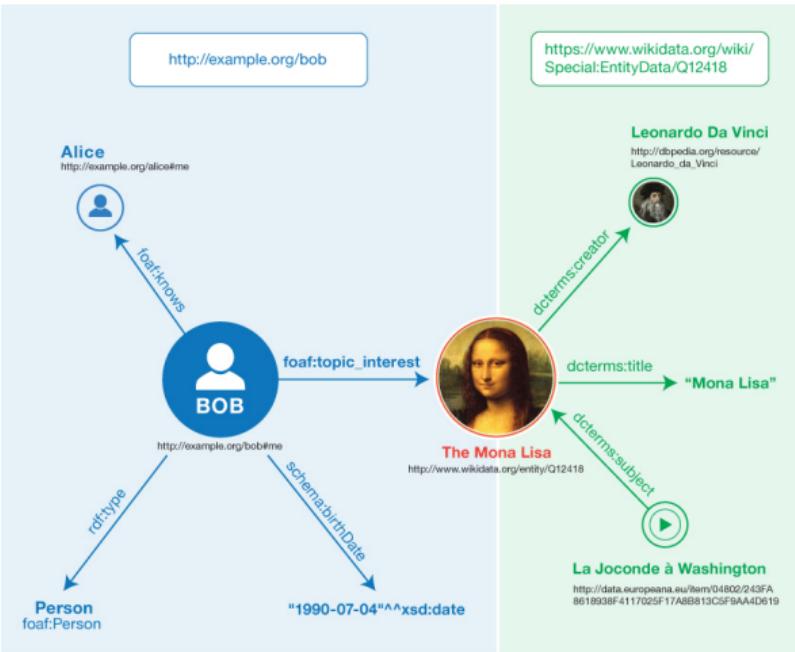
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# Named Graphs Example

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## N-Quads

N-Quads add a [fourth element](#) to a line, capturing the [graph IRI](#) of the triple described on that line

## Example

```
<http://example.org/bob#me> ←  
  <http://www.w3.org/1999/02/22-rdf-syntax-ns#type> ←  
    <http://xmlns.com/foaf/0.1/Person> <http://example.org/bob> .  
...  
<http://www.wikidata.org/entity/Q12418> <http://purl.org/dc/terms/title> ←  
  "Mona Lisa" <https://www.wikidata.org/wiki/Special:EntityData/Q12418> .  
...  
<http://example.org/bob> <http://purl.org/dc/terms/rights> ←  
  <http://creativecommons.org/licenses/by/3.0/> .
```

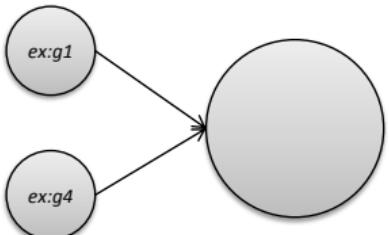
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A SPARQL queries a *default graph* (normally) and zero or more *named graphs* (when inside a **GRAPH** clause).

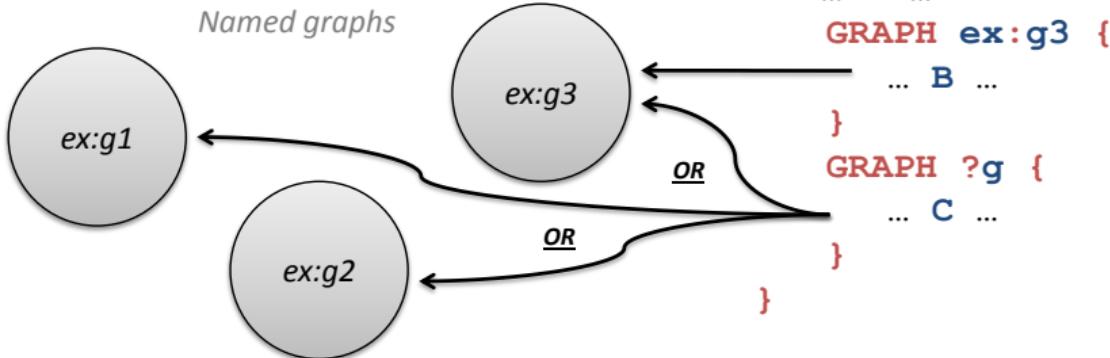
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Default graph  
(the merge of zero or more graphs)



```
PREFIX ex: <...>
SELECT ...
FROM ex:g1
FROM ex:g4
FROM NAMED ex:g1
FROM NAMED ex:g2
FROM NAMED ex:g3
WHERE {
```



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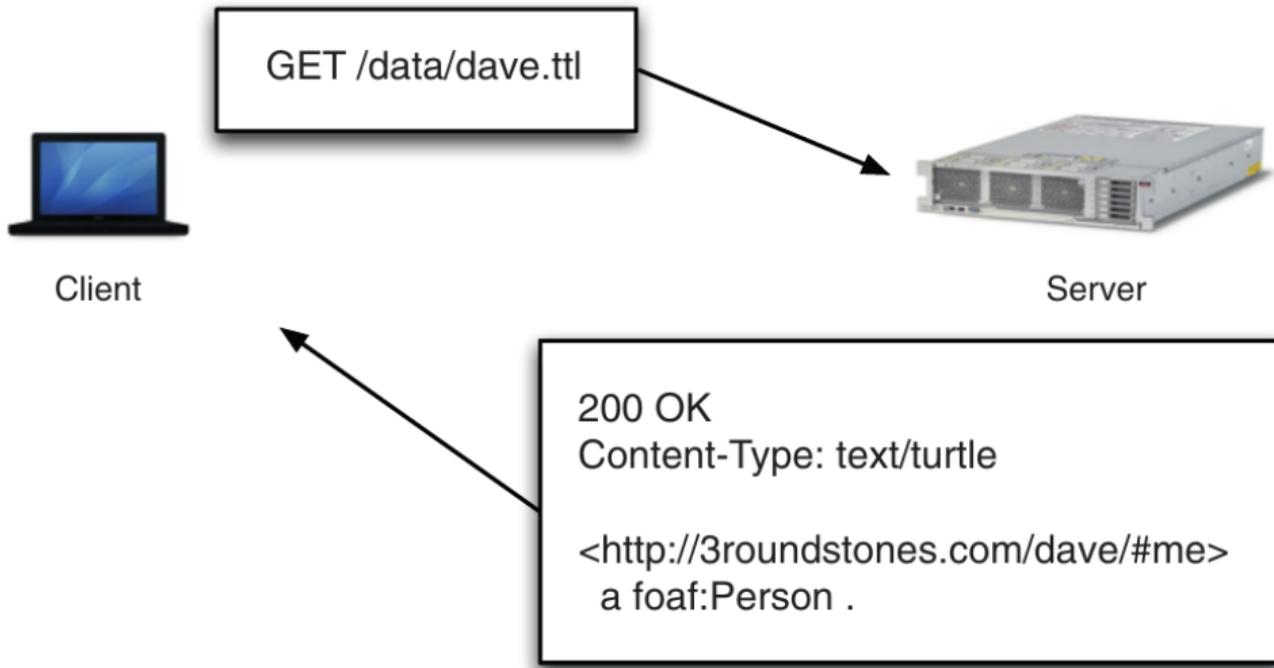
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# Simple HTTP Request

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# SPARQL Over HTTP (the SPARQL Protocol)

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`http://host.domain.com/sparql/endpoint?<parameters>`

where `<parameters>` can include:

`query=<encoded query string>`

e.g. `SELECT+*%0DWHERE+{ ... }`

`default-graph-uri=<encoded graph URI>`

e.g. `http%3A%2F%2Fexmaple.com%2Ffoo...`

n.b. zero or more occurrences of `default-graph-uri`

`named-graph-uri=<encoded graph URI>`

e.g. `http%3A%2F%2Fexmaple.com%2Fbar...`

n.b. zero or more occurrences of `named-graph-uri`

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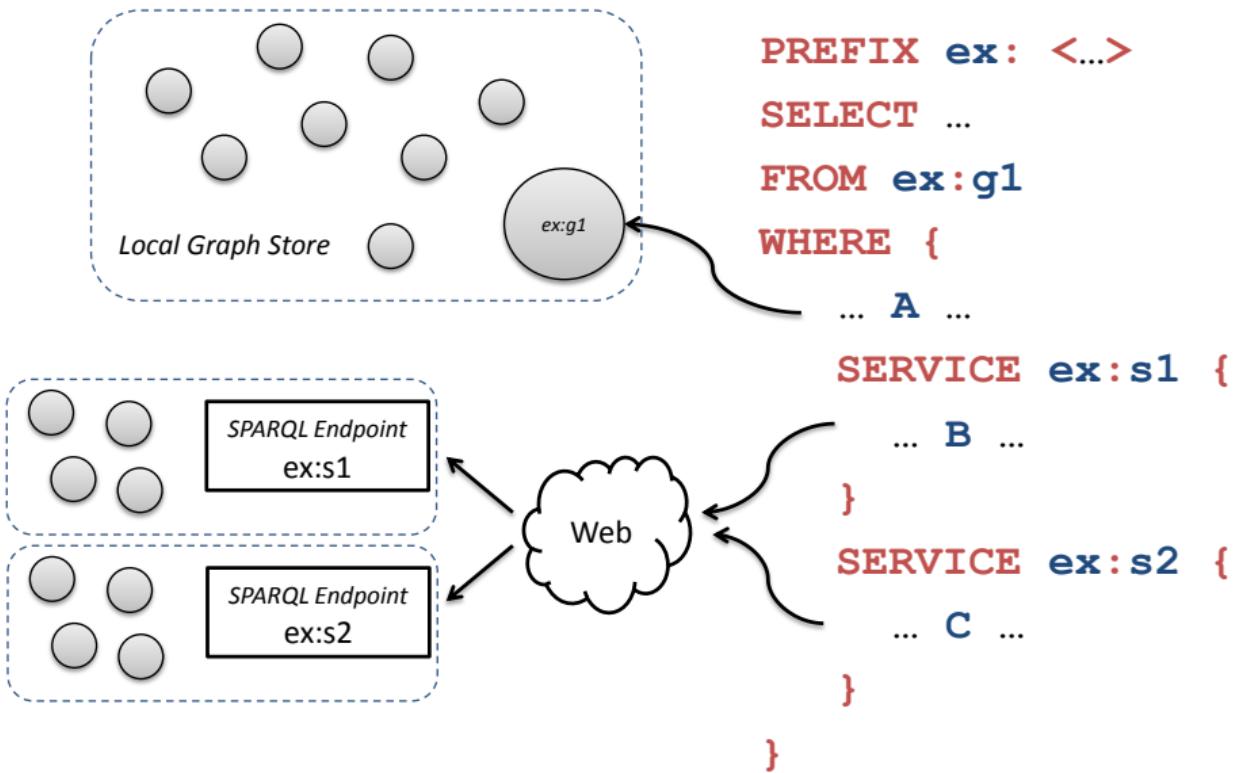
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HTTP GET or POST. Graphs given in the protocol override graphs given in the query.

# Federated Query (SPARQL 1.1)


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## Examples

**Commercial:** Virtuoso (OpenLink Software); has “open source edition” at <https://github.com/openlink/virtuoso-opensource>

**Cloud:** Amazon AWS Neptune, see <https://aws.amazon.com/neptune/>

**Open Source:** Apache Jena, see <https://jena.apache.org/>



AWS re:Invent 2017 - Amazon Neptune: Fast, Reliable Graph Database Built for the Cloud

<https://www.youtube.com/watch?v=Rl6UwE7kLio>

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# Apache Jena Fuseki

Apache Jena Fuseki is a SPARQL server. It can run as a operating system service, as a Java web application (WAR file), and as a standalone server. It provides security (using [Apache Shiro](#)) and has a user interface for server monitoring and administration.

It provides the SPARQL 1.1 [protocols for query and update](#) as well as the [SPARQL Graph Store protocol](#).

Fuseki is tightly integrated with [TDB](#) to provide a robust, transactional persistent storage layer, and incorporates [Jena text query](#). It can be used to provide the protocol engine for other RDF query and storage systems.

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The Jena users mailing list is the place to get help with Fuseki.

See <https://jena.apache.org/documentation/fuseki2/index.html>

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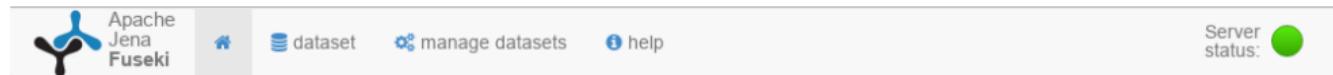
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# Apache Fuseki (Standalone Server Mode)

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The screenshot shows the Apache Jena Fuseki web interface. At the top, there is a navigation bar with the Apache Jena Fuseki logo, a home icon, a dataset icon, a manage datasets icon, a help icon, and a 'Server status' indicator showing a green circle. Below the navigation bar, the title 'Apache Jena Fuseki' is displayed, followed by the text 'Version 2.0.0. Uptime: 0m 12s'. The main content area is titled 'Datasets on this server' and contains the message 'There are no datasets on this server yet. [Add one.](#)'. A callout box provides instructions on how to perform actions on the server, listing three options: 'Dataset', 'Manage datasets', and 'Help'.

ⓘ Use the following pages to perform actions or tasks on this server:

- Dataset** Run queries and modify datasets hosted by this server.
- Manage datasets** Administer the datasets on this server, including adding datasets, uploading data and performing backups.
- Help** Summary of commands and links to online documentation.

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Dataset: /foo

query

upload files

edit

info

## SPARQL query

To try out some SPARQL queries against the selected dataset, enter your query here.

EXAMPLE QUERIES

Selection of triples

Selection of classes

PREFIXES

rdf

rdfs

owl

xsd

SPARQL ENDPOINT

http://localhost:3030/foo/sparql

CONTENT TYPE (SELECT)

JSON

CONTENT TYPE (GRAPH)

Turtle



```
1
2
3 SELECT ?subject ?predicate ?object
4 WHERE {
5   ?subject ?predicate ?object
6 }
7 LIMIT 25
```

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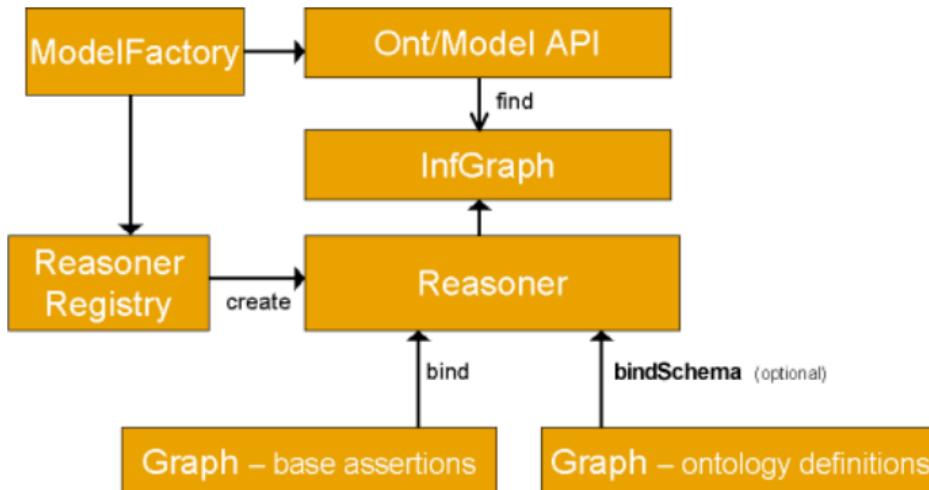
## Remember these...

```
ex:Student rdfs:subClassOf foaf:Person  
ex:Joe a ex:Student
```

What happens when you query for all foaf:Persons?

### Reasoning Engine

- RDFlib will return empty result
- Requires inference support (e.g., RDFS reasoner, OWL reasoner)



See <https://jena.apache.org/documentation/inference/>

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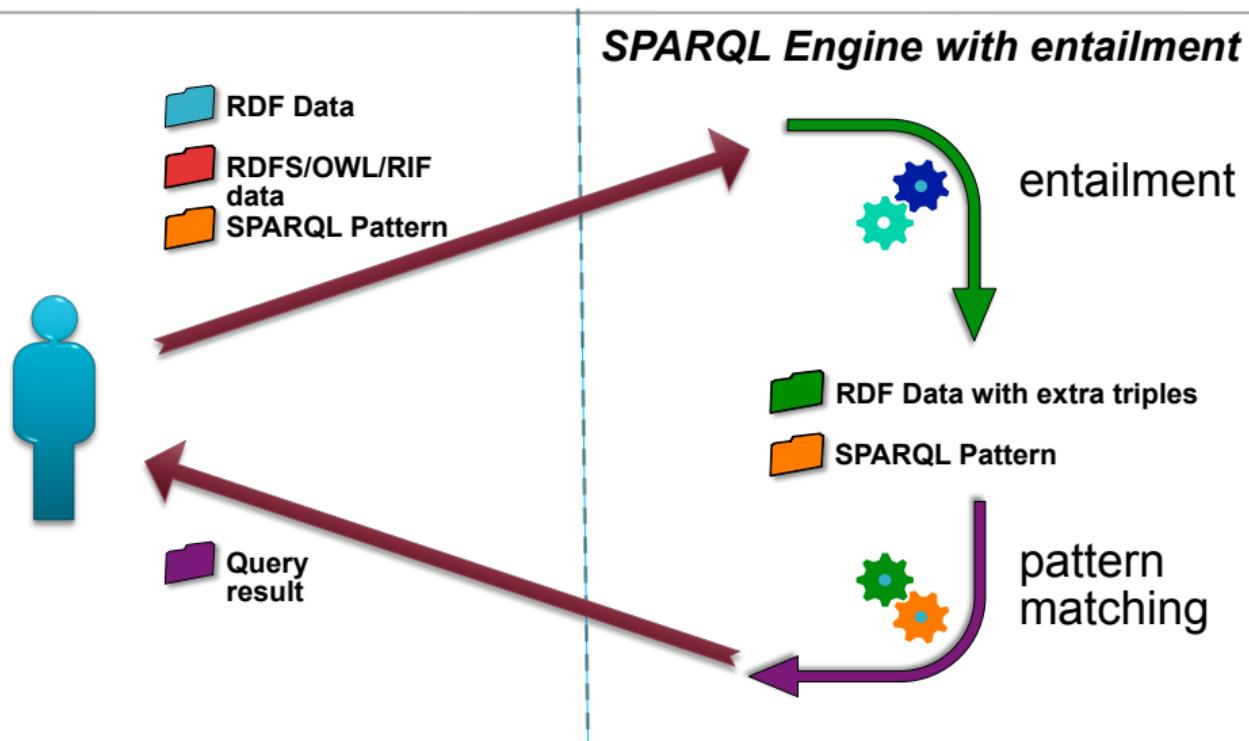
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# SPARQL 1.1 and RDFS/OWL/RIF

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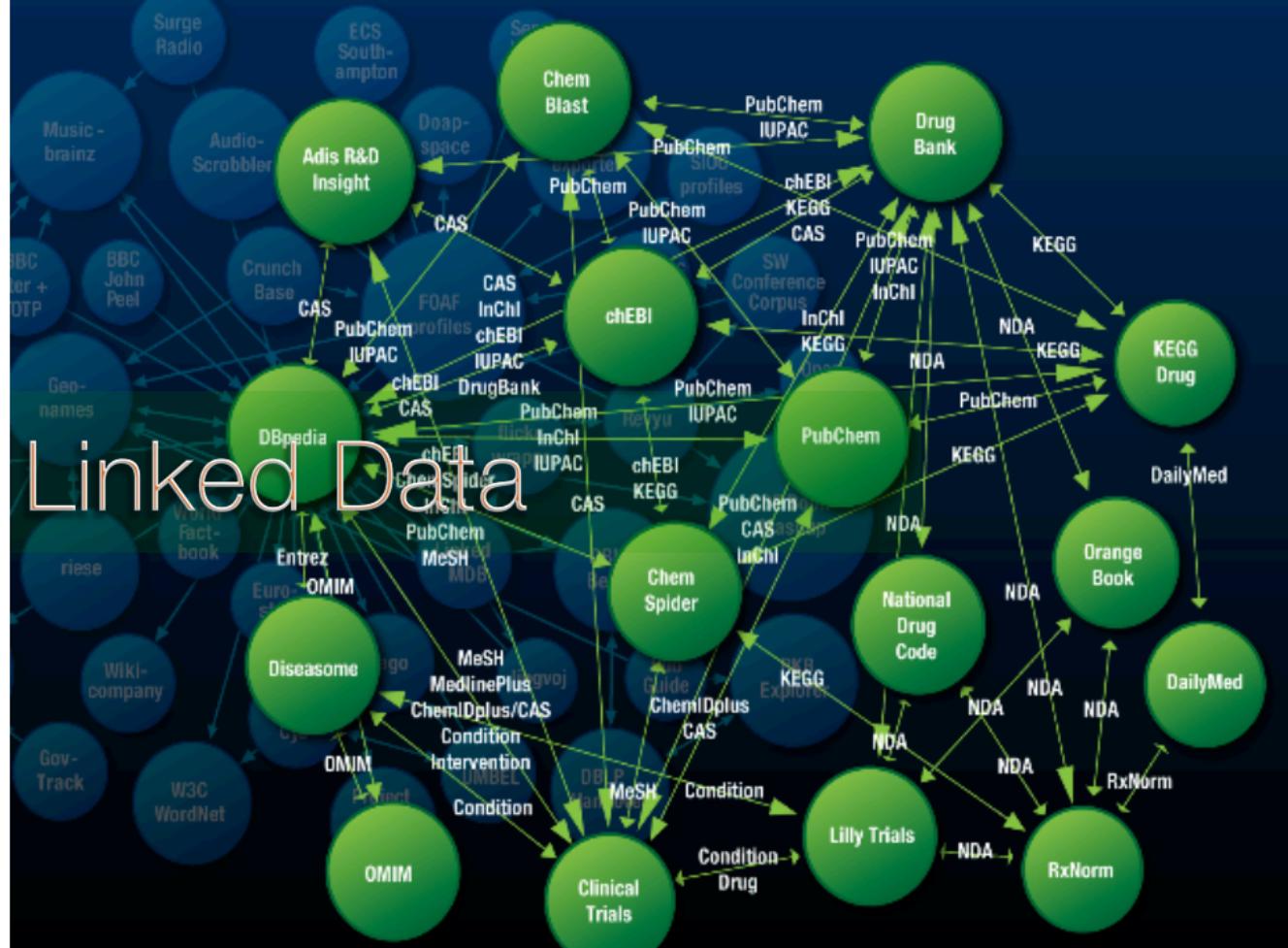
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# Linked Data “Project”

- ▶ Goal: “expose” datasets on the Web
  - remember the importance of data!
- ▶ Set links among the data items from different datasets
  - we want to avoid the silo effects

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# Is your data 5 Star?

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- 1 ★ Available on the web (whatever format), but with an open license
- 2 ★★ Available as machine-readable structured data (e.g., excel instead of an image scan)
- 3 ★★★ As before, but using a non-proprietary format (e.g., CSV instead of excel)
- 4 ★★★★ All the above, plus use open standards (RDF & Co.) to identify things, so that people could point at your stuff
- 5 ★★★★★ All the above, plus link your data to other people's data to provide context

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# Example data source: DBpedia

- ▶ DBpedia is a community effort to
  - extract structured (“infobox”) information from Wikipedia
  - provide a query endpoint to the dataset
  - interlink the DBpedia dataset with other datasets on the Web



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# Extracting structured data from Wikipedia

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```
@prefix dbpedia <http://dbpedia.org/resource/>.  
@prefix dbterm <http://dbpedia.org/property/>.
```

dbpedia:**Amsterdam**

```
dbterm:officialName "Amsterdam" ;  
dbterm:longd "4" ;  
dbterm:longm "53" ;  
dbterm:longs "32" ;  
dbterm:website <http://www.amsterdam.nl> ;  
dbterm:populationUrban "1364422" ;  
dbterm:areaTotalKm "219" ;  
...  
...
```

dbpedia:**ABN\_AMRO**

```
dbterm:location dbpedia:Amsterdam ;  
...  
...
```

Amsterdam	
- Municipality / City -	
	
Coordinates:	52°22'23"N 4°53'32"E
Country	Netherlands
Province	North Holland
COROP	Amsterdam
Boroughs	Boroughs
Government	
- Mayor	Eberhard van der Laan (PvdA)
- Aldermen	Carolin Gijssels Hans Gerson Maarten van Poeleest Freek Ossel Marjke Vos
- Secretary	Henk de Jong
Area <sup>[1][2]</sup>	
- Municipality / City	219 km <sup>2</sup> (84.6 sq mi)
- Land	166 km <sup>2</sup> (64.1 sq mi)
- Water	53 km <sup>2</sup> (20.5 sq mi)
- Urban	1,003 km <sup>2</sup> (387.3 sq mi)
- Metro	1,815 km <sup>2</sup> (700.8 sq mi)
Elevation <sup>[3]</sup>	2 m (7 ft)
Population (June 2009) <sup>[4][5]</sup>	
- Municipality / City	762,057
- Density	4,459/km <sup>2</sup> (11,548.8/sq mi)
- Urban	1,364,422
- Metro	2,158,372
- Demonym	Amsterdammer
Time zone	CET (UTC+01)
- Summer (DST)	CEST (UTC+02) (UTC)
Postal codes	1011–1109
Area code(s)	020
Website	<a href="http://www.amsterdam.nl">www.amsterdam.nl</a>

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# Automatic links among open datasets

```
<http://dbpedia.org/resource/Amsterdam> ←  
owl:sameAs <http://rdf.freebase.com/ns/...> ;  
owl:sameAs <http://sws.geonames.org/2759793> ;  
...
```

```
<http://sws.geonames.org/2759793>  
owl:sameAs <http://dbpedia.org/resource/Amsterdam>  
wgs84_pos:lat "52.3666667" ;  
wgs84_pos:long "4.8833333" ;  
geo:inCountry <http://www.geonames.org/countries/#NL> ;  
...
```

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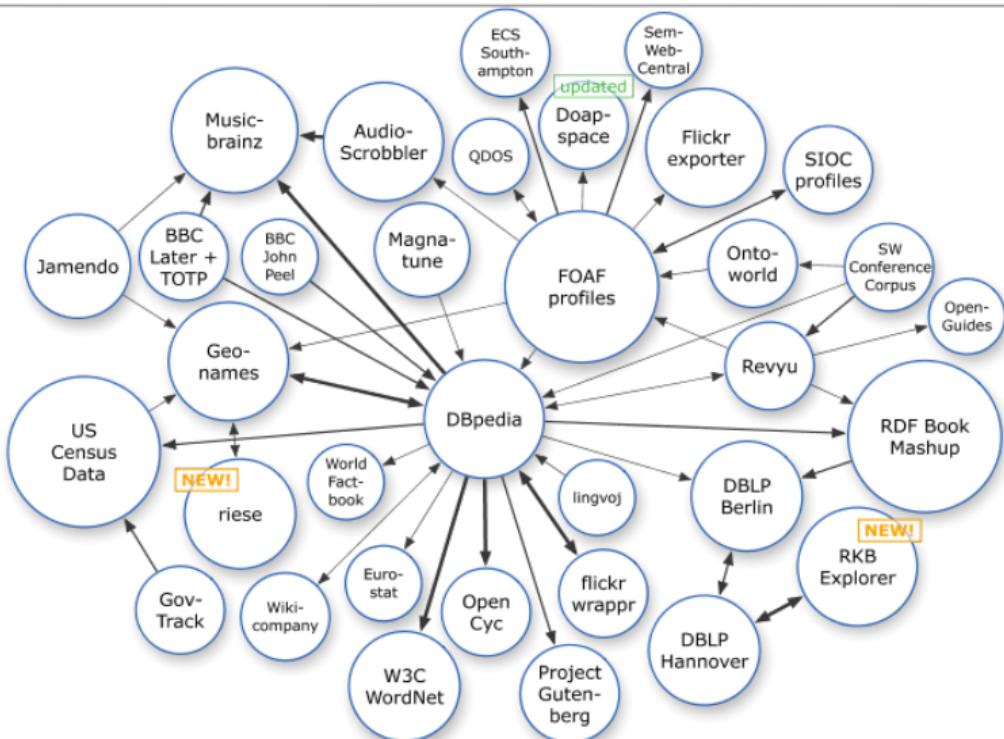
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Processors can switch automatically from one to the other...

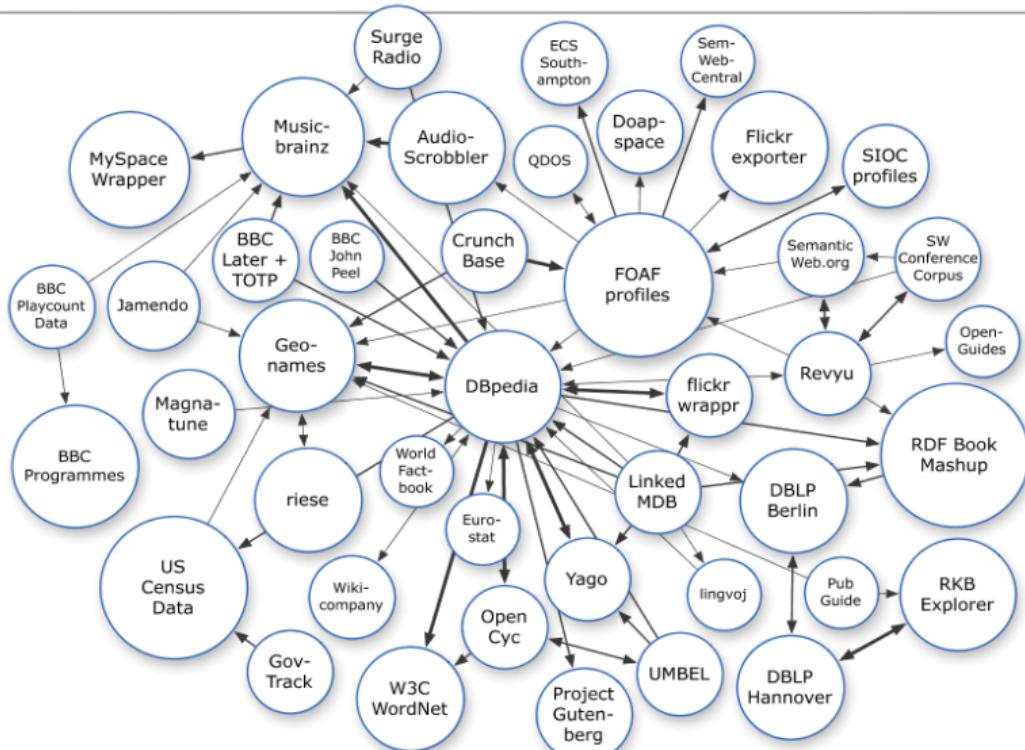
# The LOD “cloud”, March 2008



*Courtesy of Richard Cyganiak and Anja Jentzsch*

# The LOD “cloud”, September 2008

René Witte



As of September 2008

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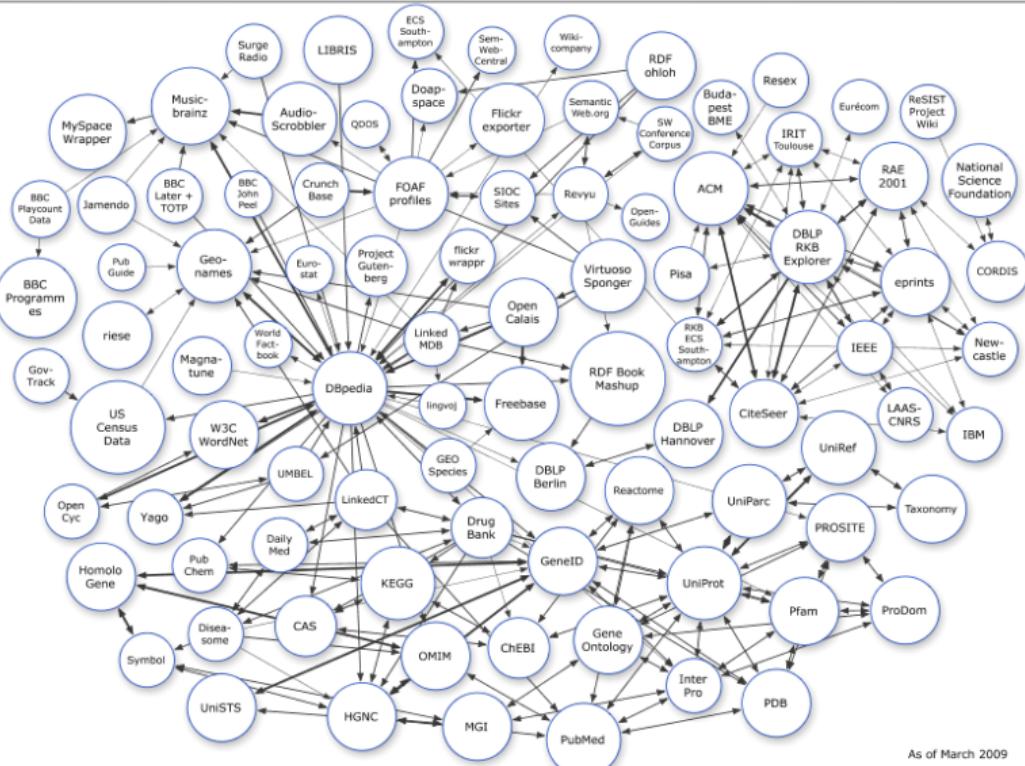
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# The LOD “cloud”, March 2009

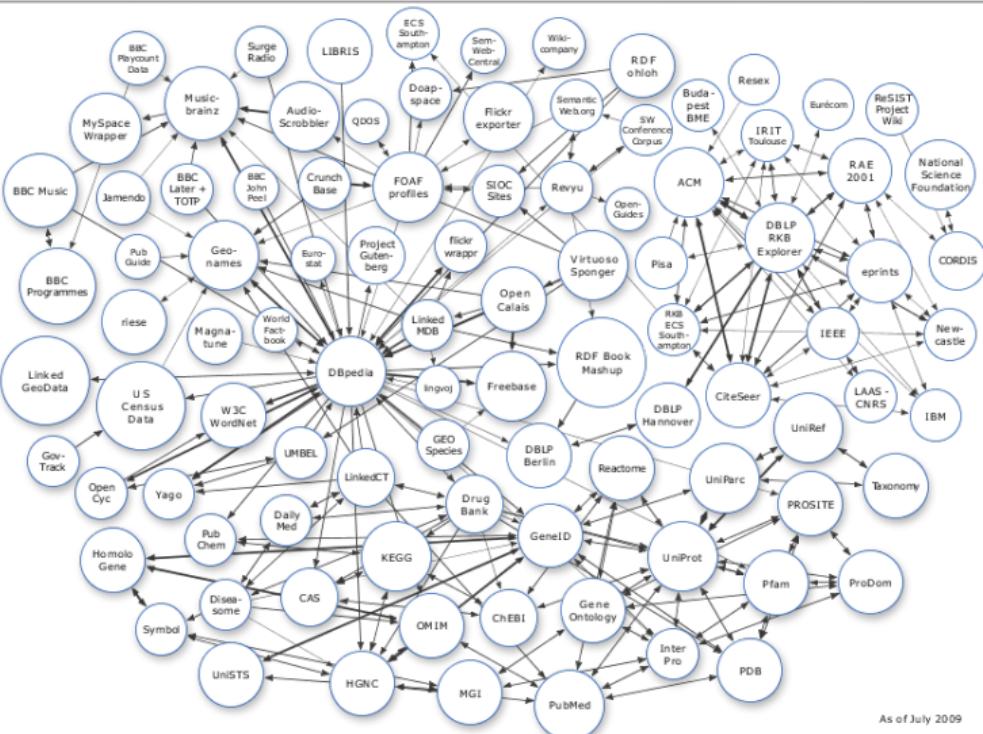
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# The LOD “cloud”, June 2009

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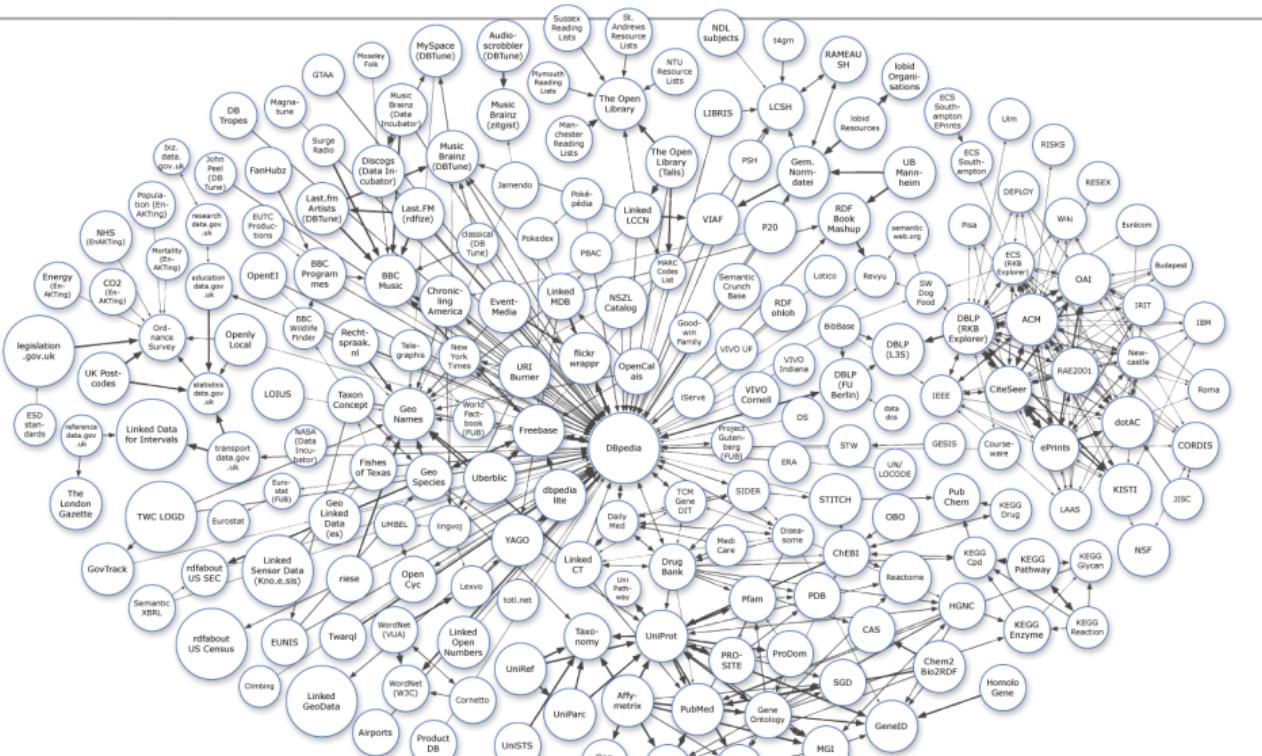
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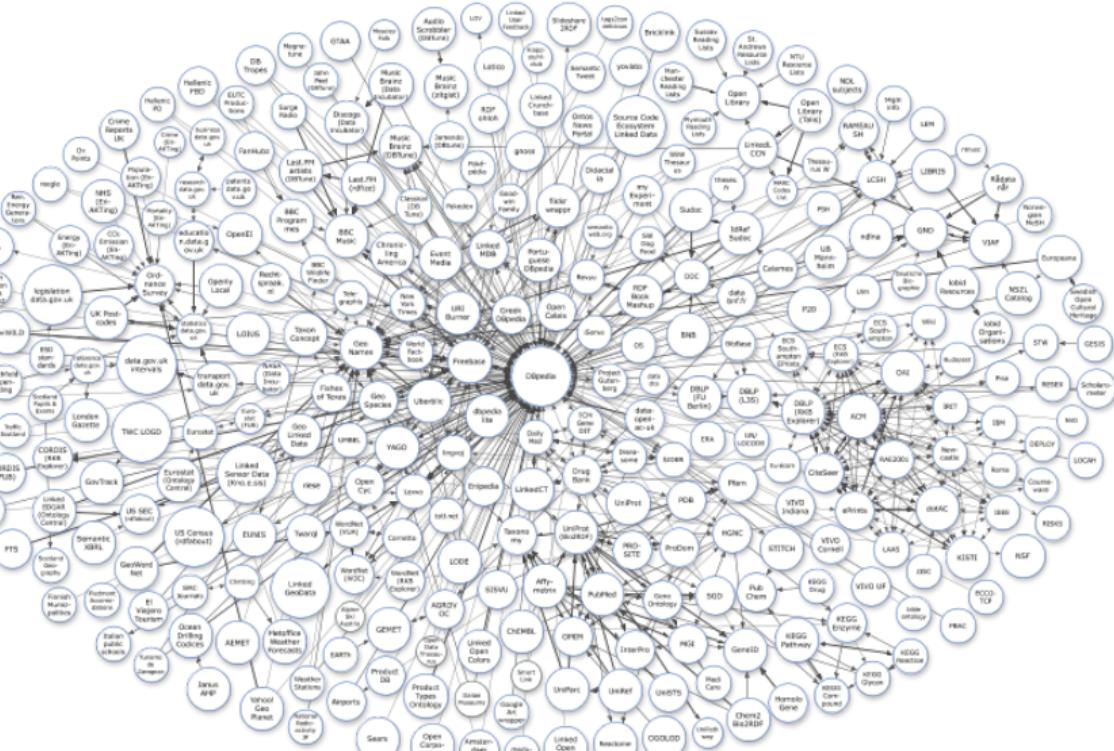
## Notes and Further Reading

# The LOD “cloud”, September 2010



As of September 2010

# The LOD “cloud”, September 2011



Courtesy of Richard Cyganiak and Anja Jentzsch

As of September 2011



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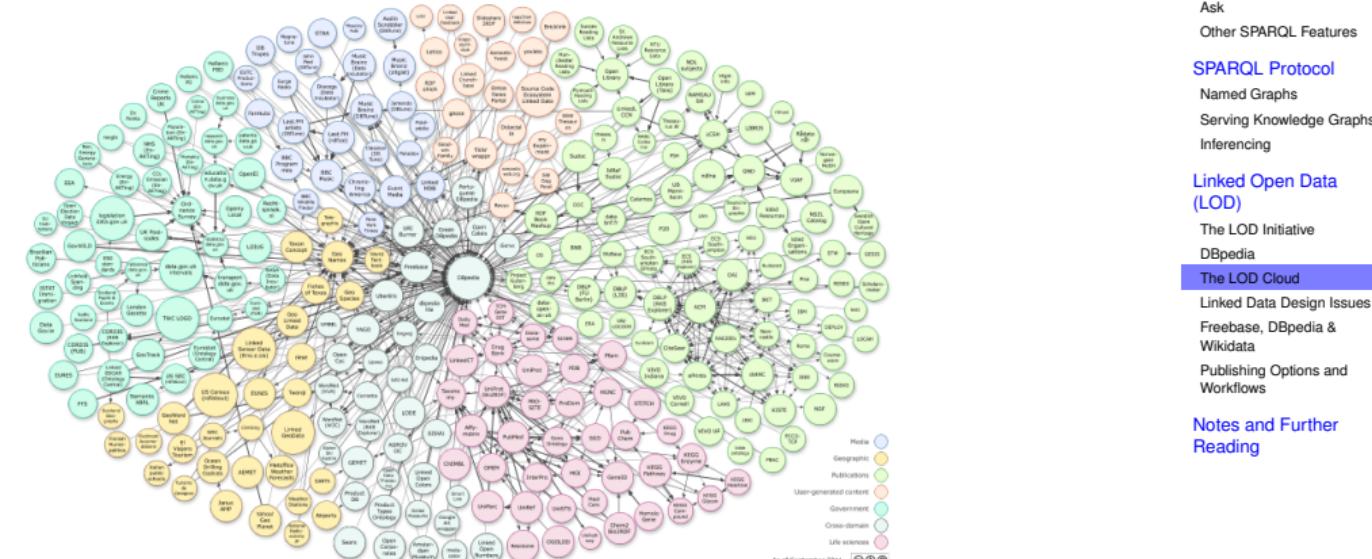
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# Application specific portions of the cloud

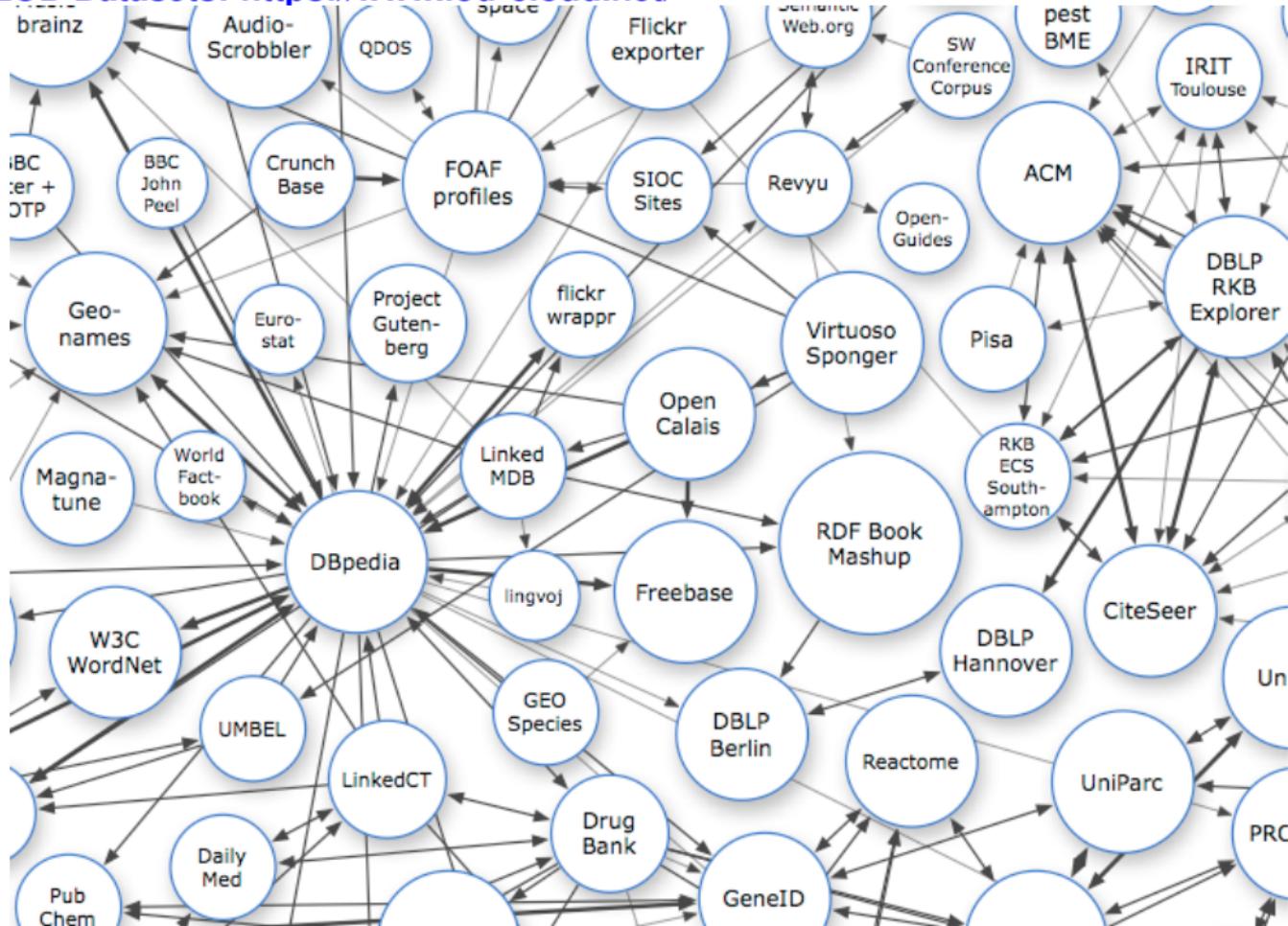
- ▶ Eg, “bio” related datasets
    - done, partially, by the “Linking Open Drug Data” task force of the HCLS IG at W3C



*Courtesy of Richard Cyganiak and Anja Jentzsch*

# LOD Datasets: <https://www.lod-cloud.net/>

René Witte



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## Origin

First proposed by Tim Berners-Lee in 2006

<https://www.w3.org/DesignIssues/LinkedData.html>

## What's a "link"?

Technically, a **link** is a triple where

- the **subject** IRI is in one graph (namespace) and
- the **predicate** and/or **object** are in a different graph (namespace)

## Types of Links

**Identity Link:** points to the same object or concept in another knowledge graph  
(e.g., Canada in DBpedia and Wikidata)

**Relationship Link:** points to other objects related to a given one (e.g., from a person to the city they live in)

**Vocabulary Link:** between data and their vocabulary term  
(e.g., IRI is a `foaf:Person`) or between vocabulary terms  
(e.g., `ex:Student rdfs:subClassOf foaf:Person`)

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## Instance Level

Creating links on the **instance level** (IRIs):

`owl:sameAs` Most widely used, but makes strong assumptions about both IRIs being identical (it is *symmetric* and *transitive*)

`rdfs:seeAlso` Just a reference, makes no claim about the IRIs being identical (no specific semantics)

using vocabularies e.g., `skos:exactMatch`, `foaf:knows`

## Schema Level

Two graphs can also be linked on the **schema level**:

- Using `owl:equivalentClass` and `owl:equivalentProperty`
- Using `rdfs:subClassOf` and `rdfs:subPropertyOf`
- Using vocabularies, e.g., `skos:broadMatch` or `skos:narrowMatch`

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## The “four 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.

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# How to create your own URIs

René Witte



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Follow these best practices when creating sets of URIs.



Name things using HTTP URIs.

Adopt generally accepted guidance about designing URI sets.

### URI naming guidelines

A Proposal For Governmental Data URIs

Designing Uri Sets Uk Public Sector

Use a domain that you control.

Do not use someone else's domain.

Use natural keys.

Avoid: `http://.../984d6a`

Use instead: `http://.../baked_goods/bread/rye-12`

Use neutral URIs.

Do not include implementation details in your names.

Do not include version numbers or technology names.

Use fragment identifiers with caution.

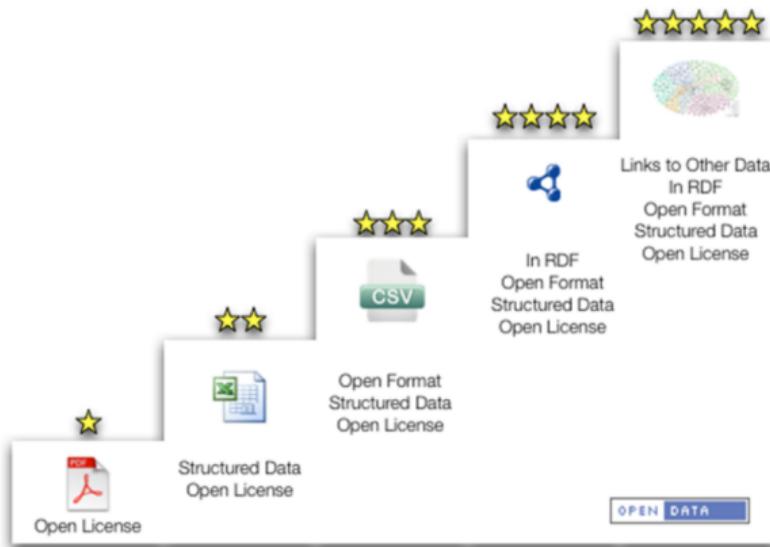
Avoid: `http://example.com/id/vocabulary#linked_data`

Use instead: `http://example.com/id/vocabulary/linked_data/`

## Major Points

To create a knowledge base in LOD-compliant format:

- ① Make your data “5-star”
- ② Create URIs following the guidelines
- ③ Select appropriate vocabularies
- ④ Extend existing vocabularies if necessary
- ⑤ Link your data to other knowledge graphs
- ⑥ Publish your knowledge graph on the web



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René Witte



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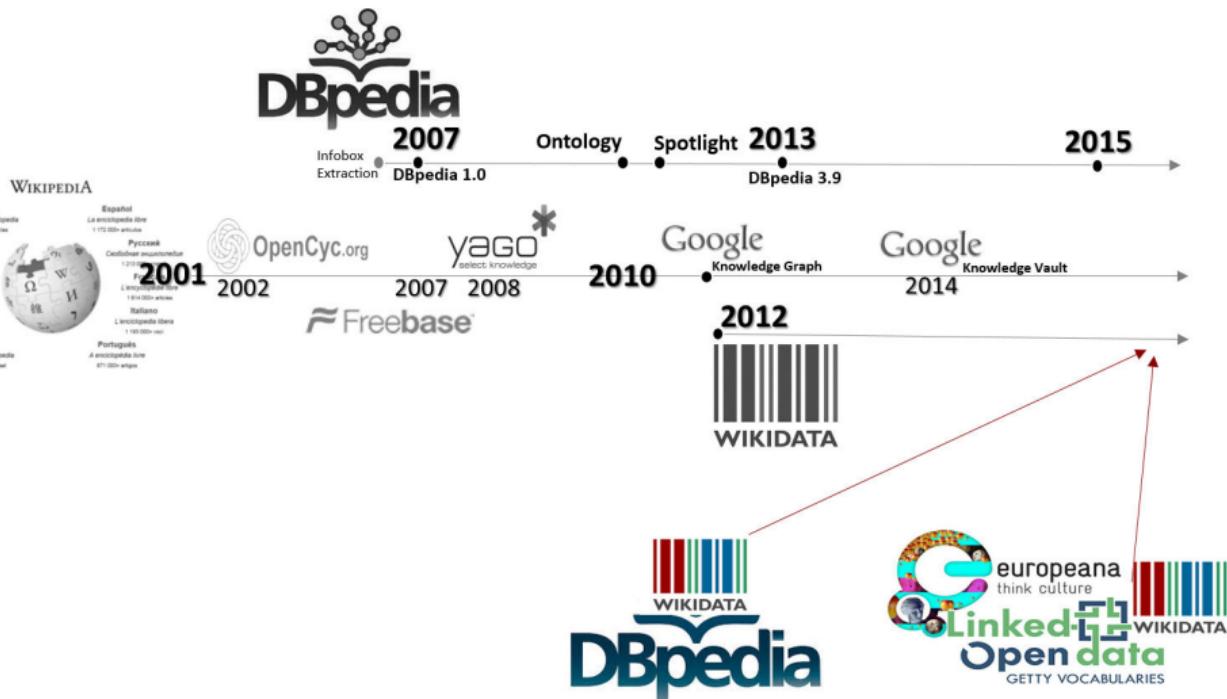
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## Freebase

- One of the first major public knowledge graphs, started in 2007
- Startup *Metaweb* bought by Google in 2010
- Shutdown in 2016...
- ...but data was donated to [Wikidata](#)

	<b>Freebase™</b>
<b>Type of site</b>	Online database
<b>Available in</b>	English
<b>Owner</b>	Metaweb Technologies ( <a href="#">Google</a> )
<b>URL</b>	<a href="http://www.freebase.com">www.freebase.com</a> ↗
<b>Commercial</b>	No
<b>Registration</b>	Optional
<b>Launched</b>	3 March 2007; 13 years ago
<b>Current status</b>	Offline (since 2 May 2016), succeeded by <a href="#">Wikidata</a> <sup>[1][2]</sup>
<b>Content license</b>	Creative Commons Attribution License

 [Browse using](#) ↘ [Formats](#) ↘

<a href="#">rdfs:label</a>	■ Kobe Bryant (en)
<a href="#">rdfs:seeAlso</a>	■ <a href="#">dbr&gt;List_of_career_achievements_by_Kobe_Bryant</a>
<a href="#">owl:sameAs</a>	■ <a href="http://data.europa.eu/euodp/jrc-names/Kobe_Bryant">http://data.europa.eu/euodp/jrc-names/Kobe_Bryant</a> ■ <a href="#">dbpedia-sq:Kobe Bryant</a> ■ <a href="#">dbpedia-ka:Kobe Bryant</a> ■ <a href="#">freebase:Kobe Bryant</a>

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# Global and Unified Access to Knowledge Graphs

[DBPEDIA BLOG](#)

Tutorial at September 1, 2021

## DBpedia Tutorial at LDK 2021

January 14, 2021 by Julia Holze

We are happy to announce that we will organize a DBpedia Tutorial on September 1, 2021 in Zaragoza, Spain. This DBpedia tutorial will be part of the Language, Data and Knowledge conference 2021. Building upon the success of the previous events held in Galway, Ireland in 2017, and in Leipzig, Germany in 2019, this conference will bring together researchers from across disciplines concerned with the acquisition, curation and use of language data in the context of data science and knowledge-based applications.

[Read more](#)

## DBpedia Tutorial at LDK 2021

# DBpedia: Part of Watson's brain

René Witte



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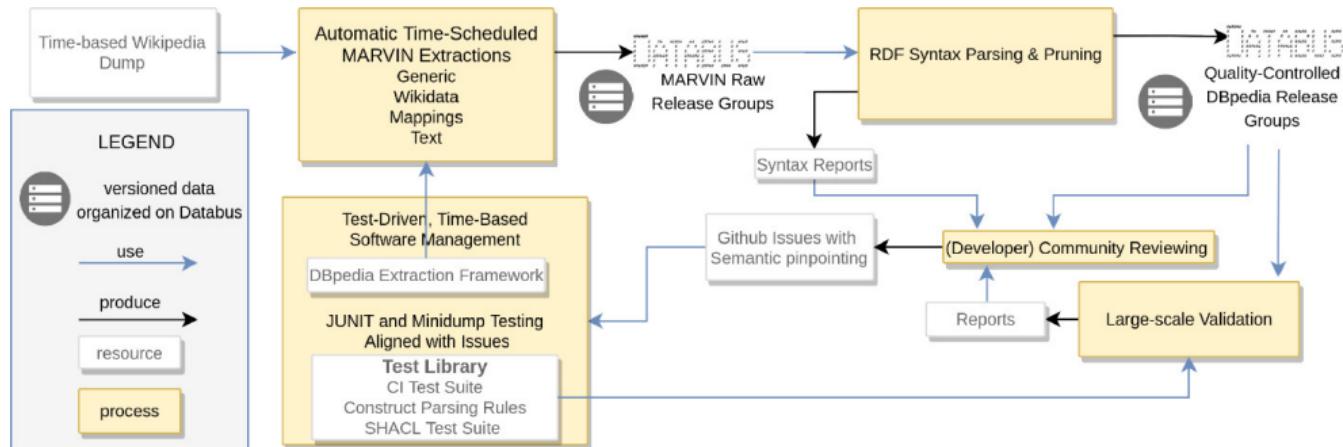
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# DBpedia Release Cycle

René Witte



"The New DBpedia Release Cycle: Increasing Agility and Efficiency in Knowledge Extraction Workflows" (IHDE20)

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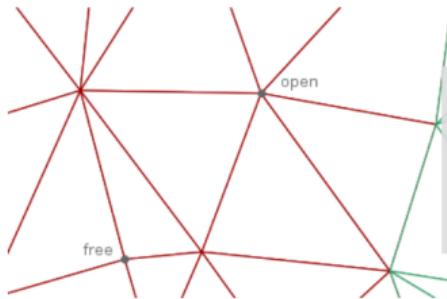
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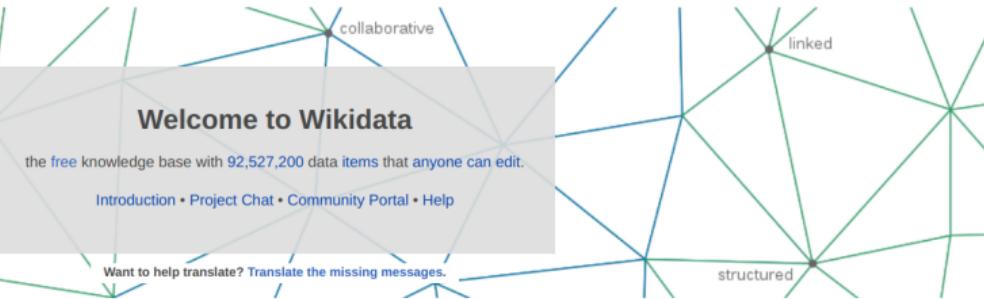
Join the consultation about the Universal Code of Conduct and take the online survey! [dismiss]

# Welcome to Wikidata

the free knowledge base with 92,527,200 data items that anyone can edit.

Introduction • Project Chat • Community Portal • Help

Want to help translate? Translate the missing messages.



## Welcome!

Wikidata is a free and open knowledge base that can be read and edited by both humans and machines.

Wikidata acts as central storage for the **structured data** of its Wikimedia sister projects including Wikipedia, Wikivoyage, Wiktionary, Wikisource, and others.

Wikidata also provides support to many other sites and services beyond just Wikimedia projects! The content of Wikidata is available under a free license, exported using standard formats, and can be interlinked to other open data sets on the linked data web.

## Get involved

For a complete starters' guide, visit the [community portal](#).

### Learn about Wikidata

- What is Wikidata? Read the [Wikidata introduction](#).
- Explore Wikidata by looking at a featured showcase item for author [Douglas Adams](#) (Q42).
- Get started with Wikidata's [SPARQL query service](#).

### Contribute to Wikidata

- Learn to edit Wikidata: follow the [tutorials](#).
- Work with other volunteers on a subject that interests you: [join a WikiProject](#).
- Individuals and organizations can also [donate data](#).

## Learn about data

New to the wonderful world of data? Develop and improve your data literacy through content designed to get you up to speed and feeling comfortable with the fundamentals in no time.



Item: [Earth](#) (Qz)



Property: [highest point](#) (P610)



custom value:  
[Mount Everest](#)  
(Q513)

## Current highlights

- 2021 Clásica de Almería (Q103950409)
- Tour de la Provence 2021 (Q101085154)
- 2021 Grand Prix Gazipaşa (Q105321988)
- Britten-Norman BN-2 Islander (Q921019) (pictured)
- Mary Wilson (Q2302368)



# Wikidata: Wiki principle applied to structured data

English

Item Discussion

Read View history

Search Wikidata

## Concordia University (Q326342)

university in Montreal, Quebec, Canada

edit

Sir George Williams University | Loyola College, Montreal | Concordia university (Montréal, Canada) | Concordia

▼ In more languages

Configure

Language	Label	Description	Also known as
English	Concordia University	university in Montreal, Quebec, Canada	Sir George Williams University Loyola College, Montreal Concordia university (Montréal, ... Concordia
German	Concordia University	Universität in Kanada	Concordia-Universität
French	Université Concordia	université québécoise née de la fusion de l'Université Sir George Williams et du Collège Loyola à Montréal, en août 1974	Université Sir George Williams Université Concordia (Montréal, ...
Italian	Università Concordia	No description defined	Concordia University

All entered languages

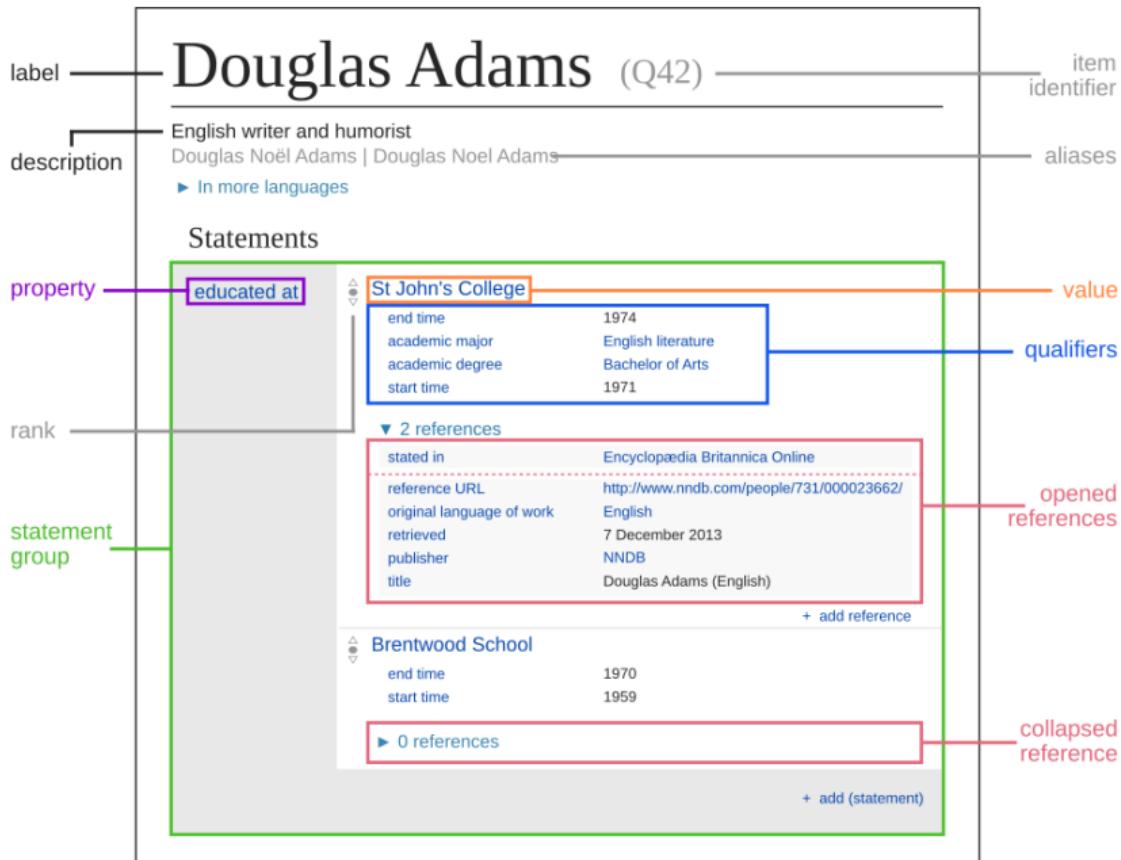
## Statements

instance of	university	edit
	▼ 0 references	+ add reference

+ add value

Wikipedia (25 entries) edit

ar	جامعة كونكورديا
ast	Universidá Concordia
atj	Université Concordia
azb	کونکوردیا سیلهم بوردو
de	Concordia University
el	Πανεπιστήμιο Κονκόρδια
en	Concordia University
eo	Universitato Concordia
es	Universidad Concordia
et	Concordia ülikool (Kanada)
fa	دانشگاه کنکوردیا
fi	Concordia-yliopisto
fr	Université Concordia
he	אוניברסיטת קונקורדייה
it	Università Concordia
ja	コンコルディア大学
ko	콘코디아 대학교
nl	Concordia-universiteit (Montreal)
pl	Uniwersytet Concordia
pt	Universidade Concórdia
ru	Университет Конкордия
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tl	Pamantasan ng Concordia


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## Approaches

- Community-constructed (e.g., Freebase, Wikidata)
- (Semi-)Automatically constructed (e.g., DBpedia, BabelNet)
- Exported from other data sources (e.g., MusicBrainz)



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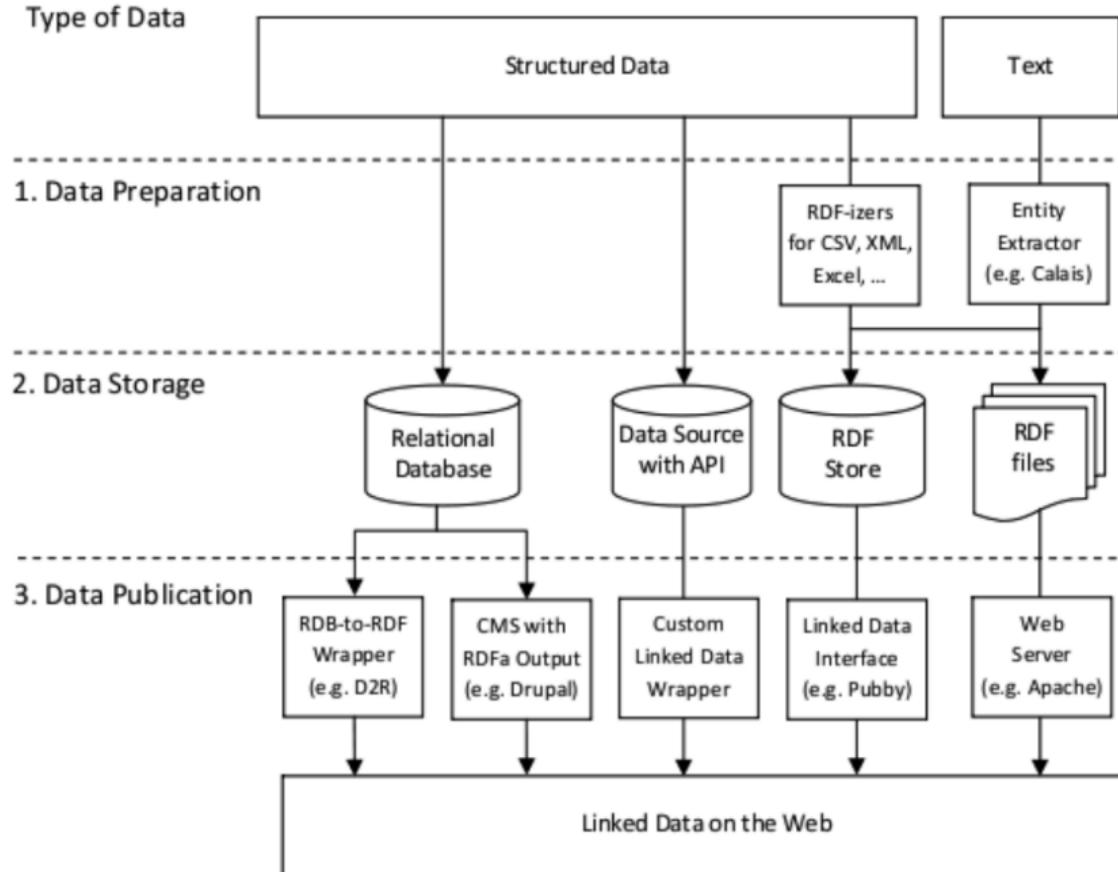
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## Required

- [Yu14, Chapter 6] (SPARQL)
- [Yu14, Chapter 9] (Linked Open Data)

## Supplemental

- [DuC13] (Learning SPARQL)
- [WZRH14, Chapter 5] (SPARQL)
- SPARQL 1.1 Overview, <https://www.w3.org/TR/sparql11-overview/>
- [Yu14, Chapter 8] (DBpedia)
- [Yu14, Chapter 12] (Wikidata)

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