The Web of Linked Data

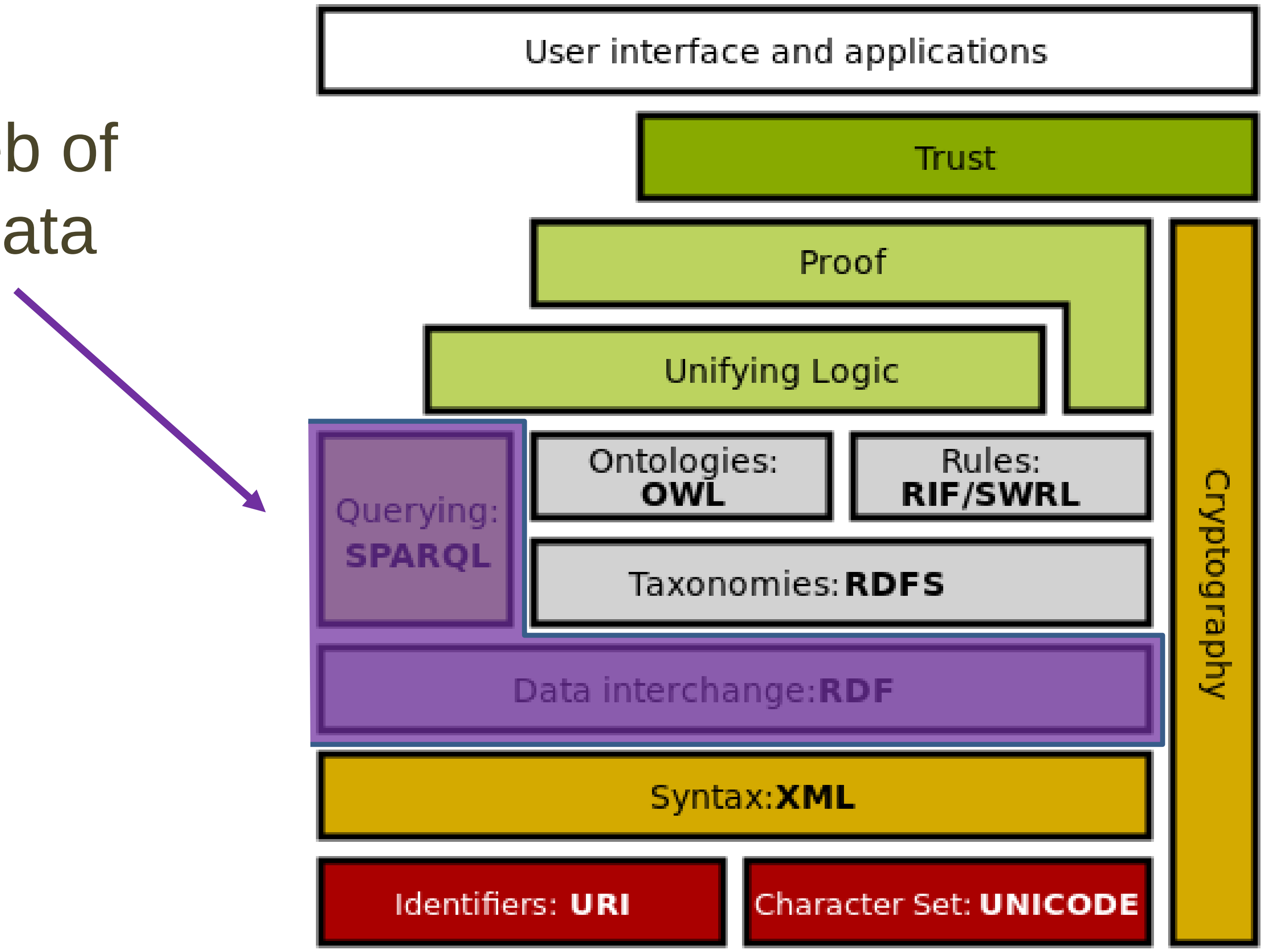
SPARQL &
THE LINKED DATA PROJECT

POLITECNICO DI TORINO

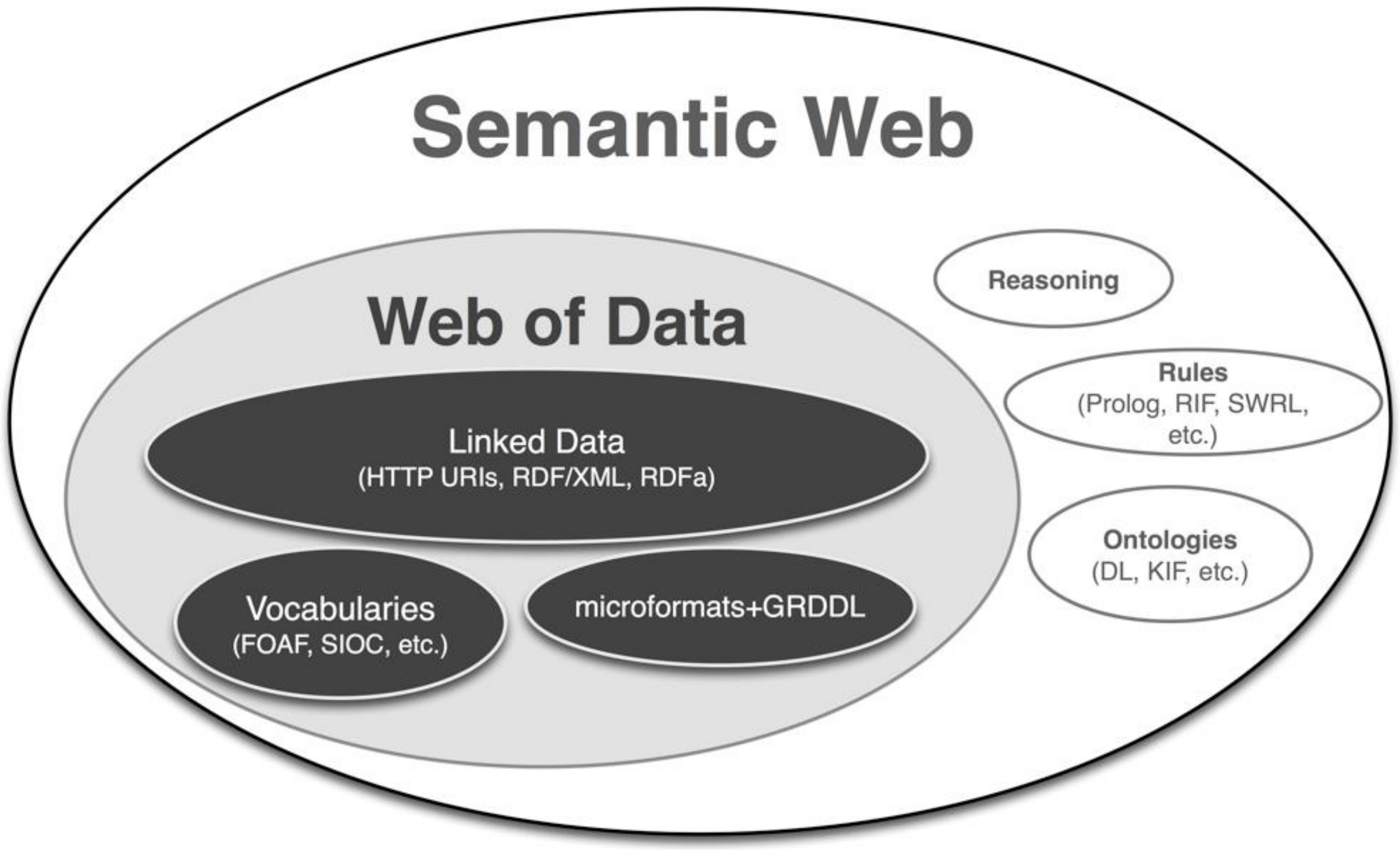
e-Lite

Semantic Web components

- The Web of linked data



The Web of linked data


Semantic Web
Web of Data
Linked Data (HTTP URIs, RDF/XML, RDFa)
Vocabularies (FOAF, SIOC, etc.)
microformats+GRDDL
Reasoning
Rules (Prolog, RIF, SWRL, etc.)
Ontologies (DL, KIF, etc.)

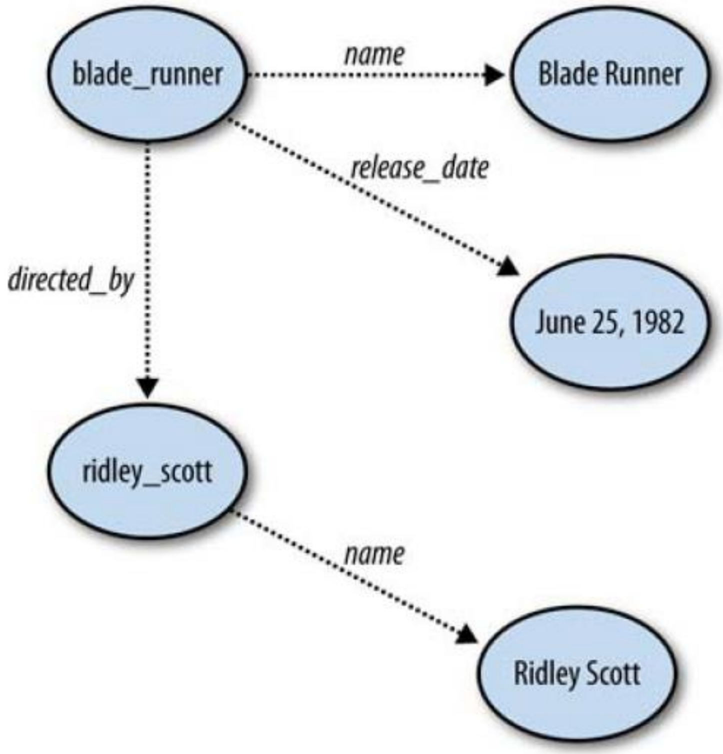
SPARQL BASICS

SPARQL Protocol and RDF Query Language (SPARQL)

- Simple protocol for querying remote databases over HTTP
  - SPARQL 1.0: W3C Recommendation January 15th, 2008
  - SPARQL 1.1: W3C Recommendation March 21st, 2013
- SPARQL queries RDF graphs
  - An RDF graph is a set of triples
- SPARQL can be used to express queries across diverse data sources, whether the data is stored natively as RDF or viewed as RDF via middleware

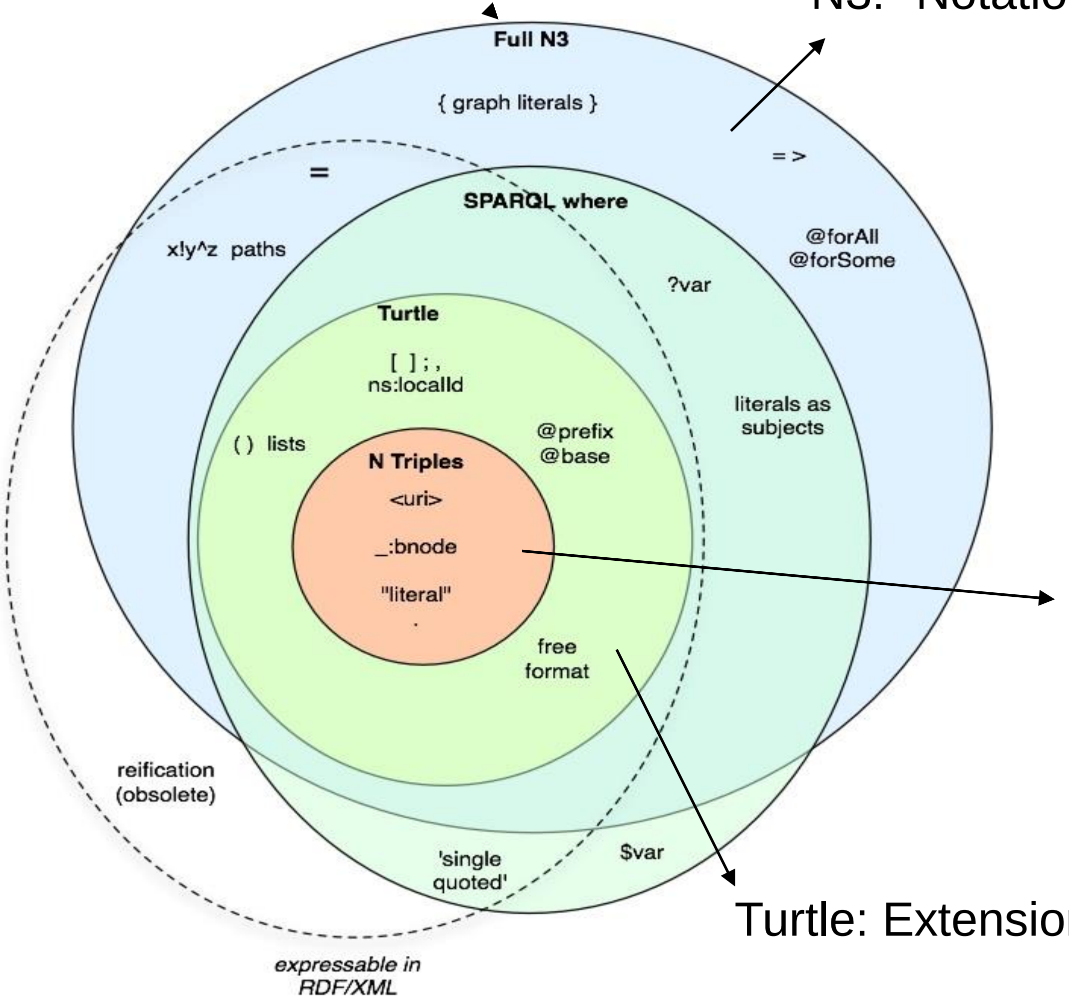
SPARQL and RDF

- It is the triples that matter, not the serialization
  - RDF/XML is the W3C recommendation but it not a good choice because it allows multiple ways to encode the same graph
- SPARQL uses the Turtle syntax, an N-Triples extension



SPARQL and RDF

N3: "Notation 3" - extensive formalism



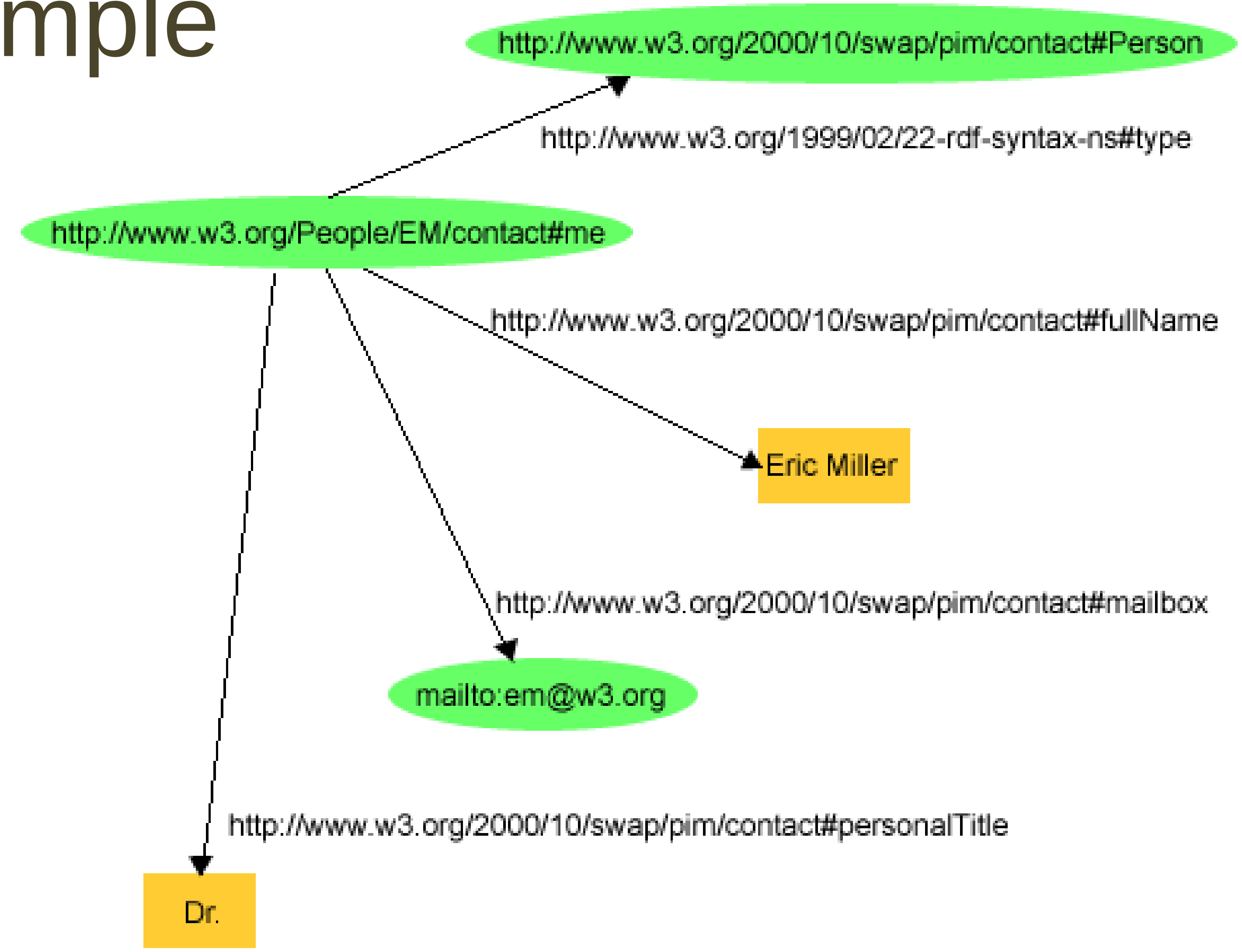
N-Triples: part of N3

Turtle: Extension of N-Triples (shortcuts)

Turtle - Terse RDF Triple Language

- A serialization format for RDF
- A subset of Tim Berners-Lee and Dan Connolly’s Notation 3 (N3) language
  - Unlike full N3, doesn’t go beyond RDF’s graph model
- A superset of the minimal N-Triples format
- Turtle has no official status with any standards organization, but has become popular amongst Semantic Web developers as a human-friendly alternative to RDF/XML

Example


http://www.w3.org/2000/10/swap/pim/contact#Person
http://www.w3.org/1999/02/22-rdf-syntax-ns#type
http://www.w3.org/People/EM/contact#me
http://www.w3.org/2000/10/swap/pim/contact#fullName
Eric Miller
http://www.w3.org/2000/10/swap/pim/contact#mailbox
mailto:em@w3.org
http://www.w3.org/2000/10/swap/pim/contact#personalTitle
Dr.

“Turtle” notation

```
<http://www.w3.org/People/EM/contact#me>
<http://www.w3.org/2000/10/swap/pim/contact#fullName>
"Eric Miller" .

<http://www.w3.org/People/EM/contact#me>
<http://www.w3.org/2000/10/swap/pim/contact#mailbox>
<mailto:em@w3.org> .

<http://www.w3.org/People/EM/contact#me>
<http://www.w3.org/2000/10/swap/pim/contact#personalTitle>
"Dr." .

<http://www.w3.org/People/EM/contact#me>
<http://www.w3.org/1999/02/22-rdf-syntax-ns#type>
<http://www.w3.org/2000/10/swap/pim/contact#Person> .
```

Turtle

- Simple triple:
  subject predicate object .

```
:john rdf:label "John" .
```

- Grouping triples:
  subject predicate object ; predicate object ...

```
:john
  rdf:label "John" ;
  rdf:type ex:Person ;
  ex:homePage http://example.org/johnspage/ .
```

Prefixes

- Mechanism for namespace abbreviation

```
@prefix abbr: <URI>
```

- Example:

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

- Default:

```
@prefix : <URI>
```

- Example:

```
@prefix : <http://example.org/myOntology#>
```

Identifiers

- URIs: <URI>

```
http://www.w3.org/1999/02/22-rdf-syntax-ns#
```

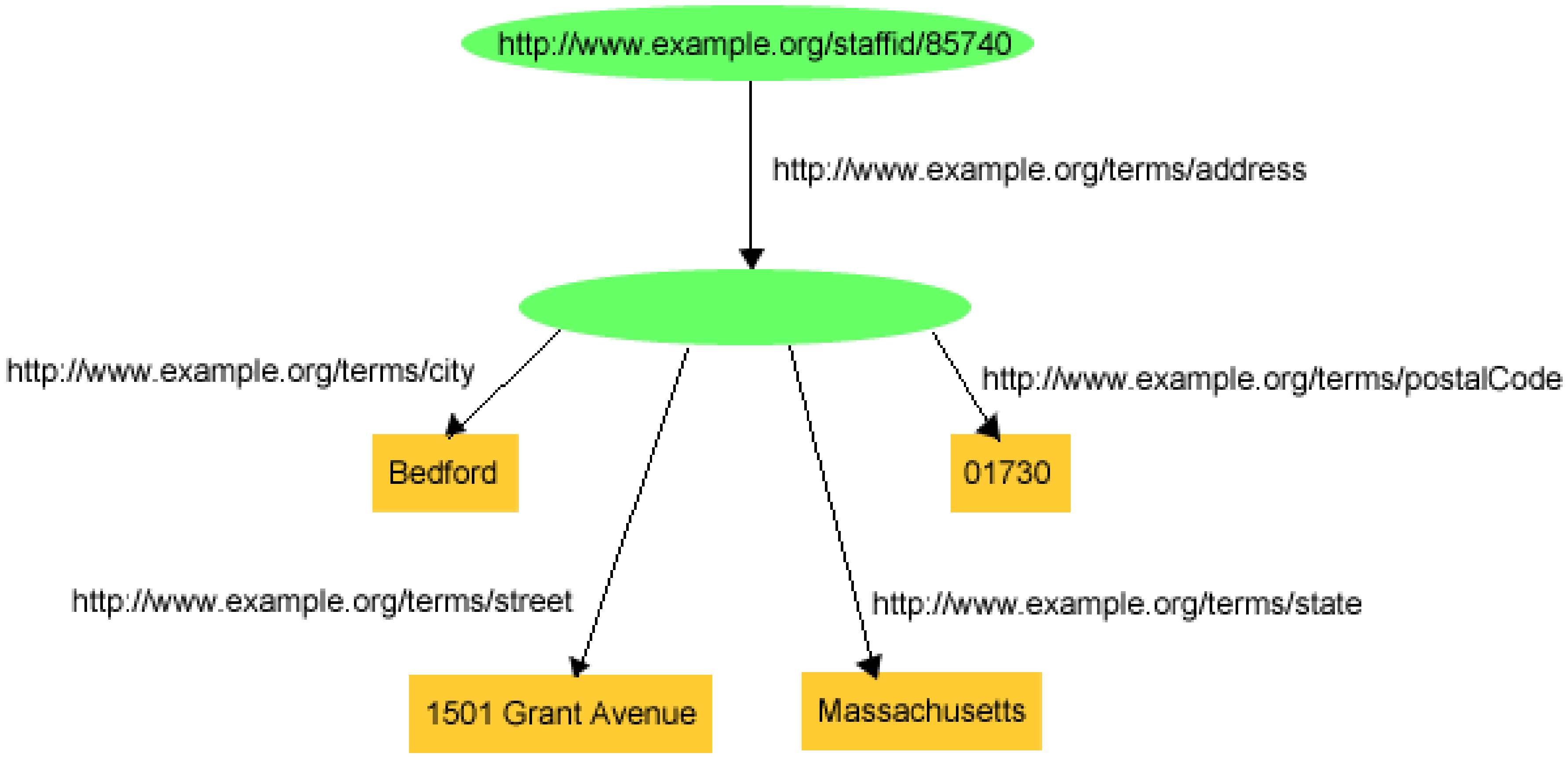
- Qnames (Qualified names)
  - `namespace-abbr?:localname`

```
rdf:type
dc:title
:hasName
```

- Literals
  - `"string"(@lang)?(^^type)?`

```
"John"
"Hello"@en-GB
"1.4"^^xsd:decimal
```

Blank nodes


http://www.example.org/staffid/85740
http://www.example.org/terms/address
http://www.example.org/terms/city
http://www.example.org/terms/postalCode
Bedford
01730
http://www.example.org/terms/street
http://www.example.org/terms/state
1501 Grant Avenue
Massachusetts

Blank nodes

- Simple blank node:
  - `[] or _:x`

```
:john ex:hasFather [] .
:john ex:hasFather _:x .
```

- Blank node as subject:
  - `[ predicate object ; predicate object ... ] .`

```
[ ex:hasName "John"] .
[ ex:authorOf :lotr ;
  ex:hasName "Tolkien"] .
```

Collections

- (object1 ... objectn)

```
:doc1 ex:hasAuthor (:john :mary) .
```

- Short for

```
:doc1 ex:hasAuthor
    [ rdf:first :john;
      rdf:rest [ rdf:first :mary;
      rdf:rest rdf:nil ]
    ] .
```

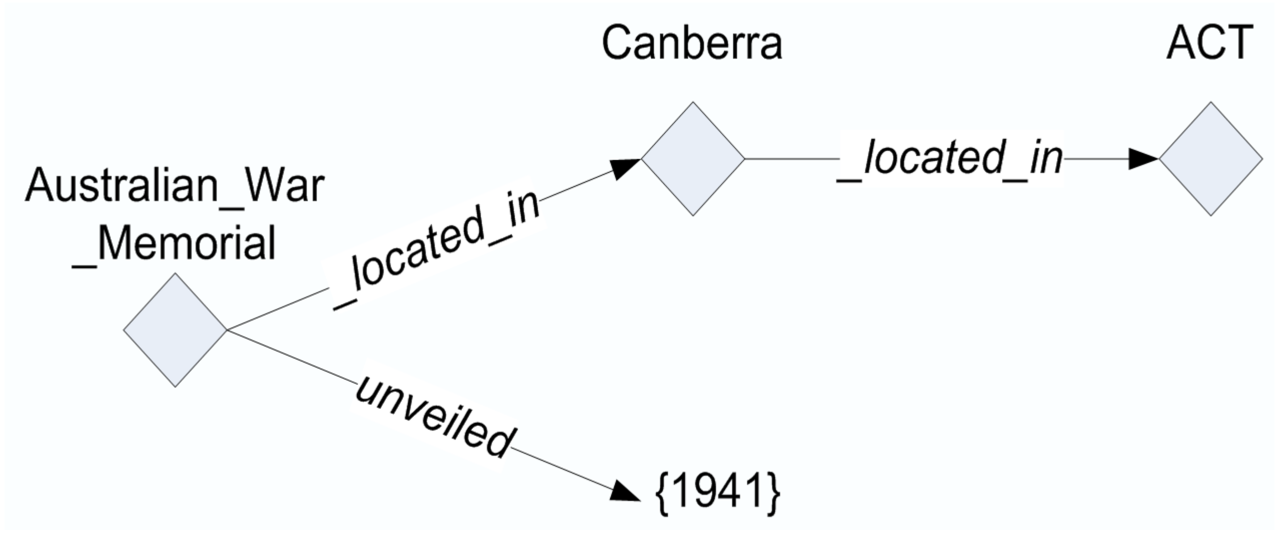
Example

```
@prefix rdf: http://www.w3.org/1999/02/22-rdf-syntaxns# .
@prefix dc: <http://purl.org/dc/elements/1.1/> .
@prefix : <http://example.org/#> .

<http://www.w3.org/TR/rdf-syntax-grammar>
  dc:title "RDF/XML Syntax Specification (Revised)" ;
  :editor [
    :fullName "Dave Beckett";
    :homePage <http://purl.org/net/dajobe/>
  ] .
```

RDF Triple stores

- Specialized databases for RDF triples
- Can ingest RDF in a variety of formats
- Support a query language (SPARQL)



Comparison

Relational database

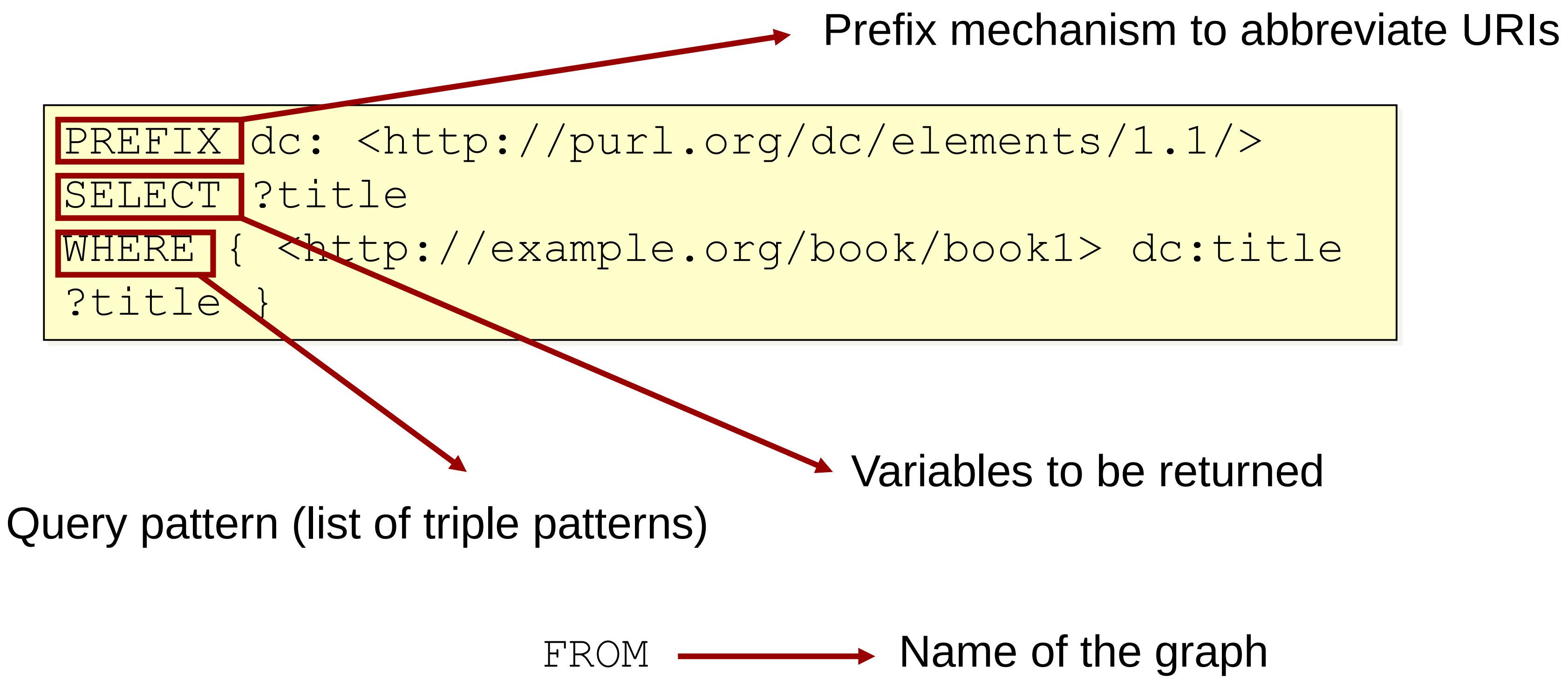
- Data model
  - Relational data (tables)
- Data instances
  - Records in tables
- Query support
  - SQL
- Indexing mechanisms
  - Optimized for evaluating queries as relational expressions

RDF Triple store

- Data model
  - RDF graphs
- Data instances
  - RDF triples
- Query support
  - SPARQL
- Indexing mechanisms
  - Optimized for evaluating queries as graph patterns

SPARQL

- Uses SQL-like syntax



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

Prefix mechanism to abbreviate URIs
Variables to be returned
Query pattern (list of triple patterns)
FROM
Name of the graph

SELECT

- Variables selection
- Variables: `?string`

```
?x
?title
?name
```

- Syntax: SELECT $\mathtt{var}_1$, …, $\mathtt{var}_n$

```
SELECT ?name
SELECT ?x,?title
```

WHERE

- Graph patterns to match
- Set of triples

```
{ (subject predicate object .)* }
```

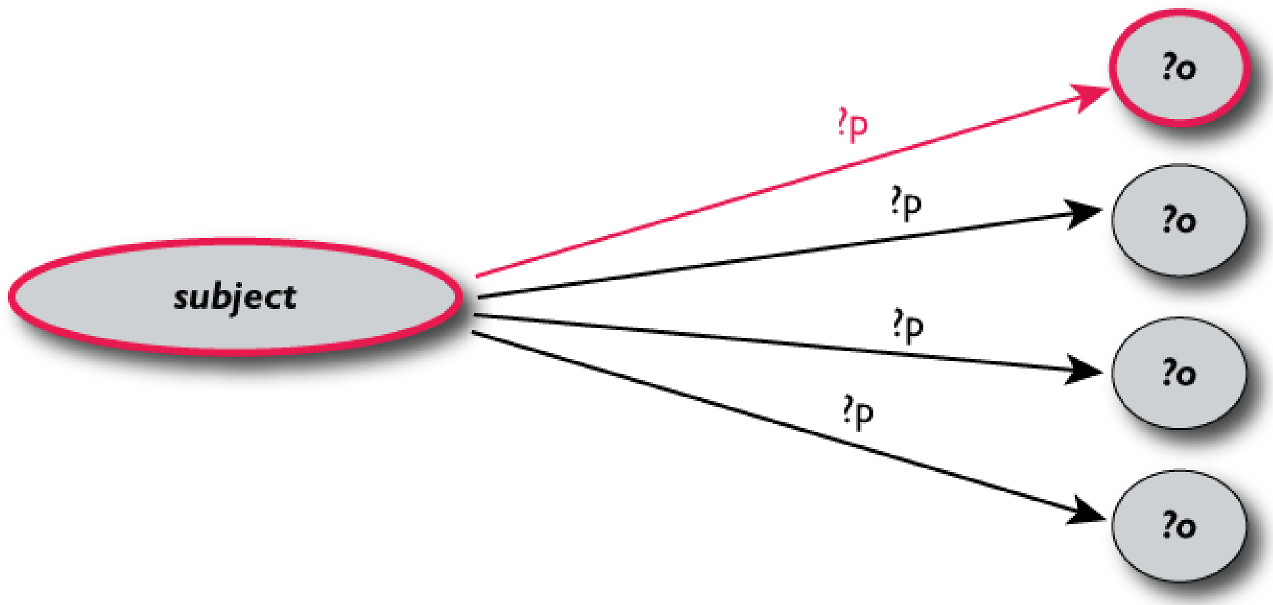
- Subject: URI, QName, Blank node, Literal, Variable
- Predicate: URI, QName, Blank node, Variable
- Object: URI, QName, Blank node, Literal, Variable

Graph patterns

- The pattern contains unbound symbols
- By binding the symbols (if possible), subgraphs of the RDF graph are selected
- If there is such a selection, the query returns the bound resources

Graph patterns

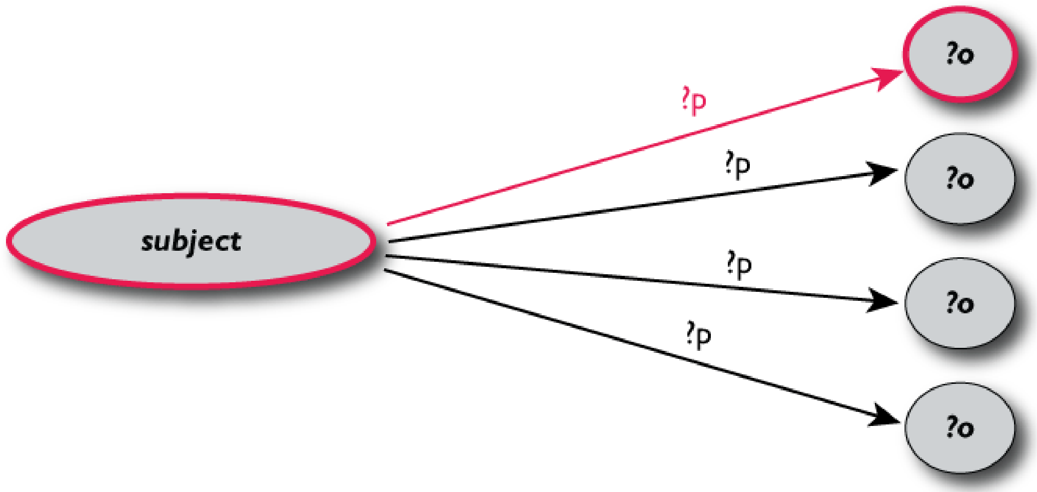
- (subject,?p,?o)
  - ?p and ?o are “unknowns”



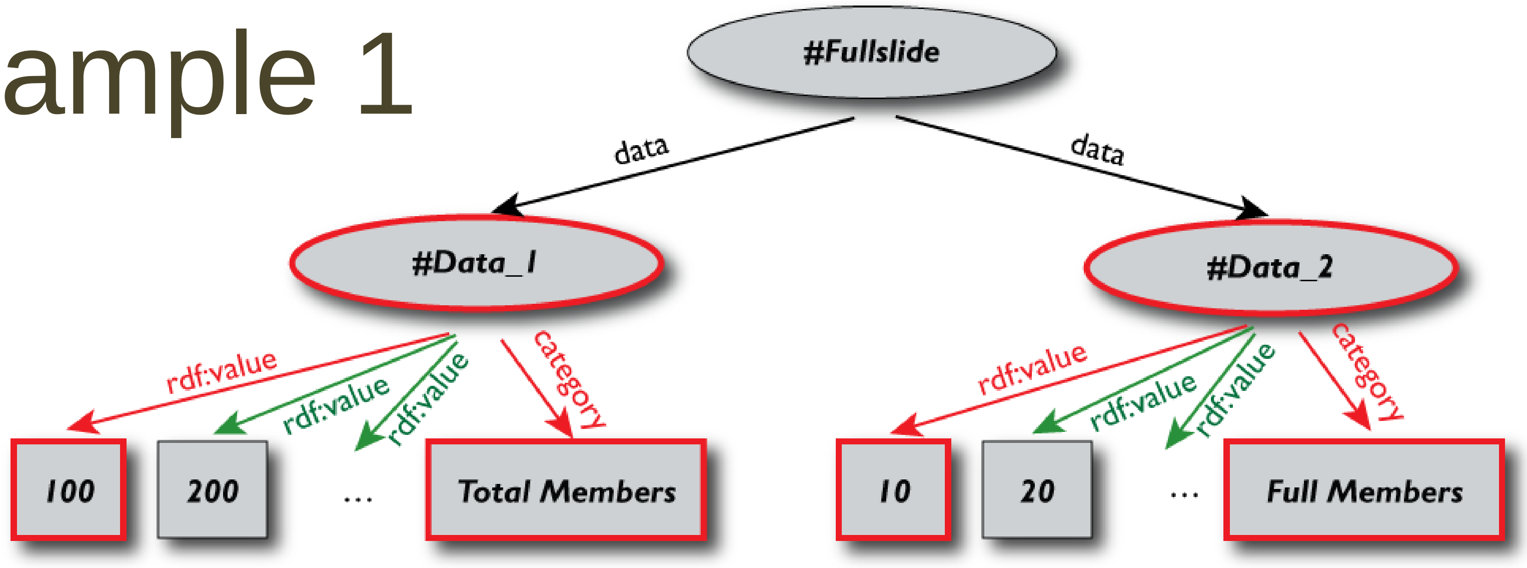
Graph patterns

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

- The triplets in WHERE define the graph pattern, with ?p and ?o “unbound” symbols
- The query returns the list of matching p,o pairs



Example 1

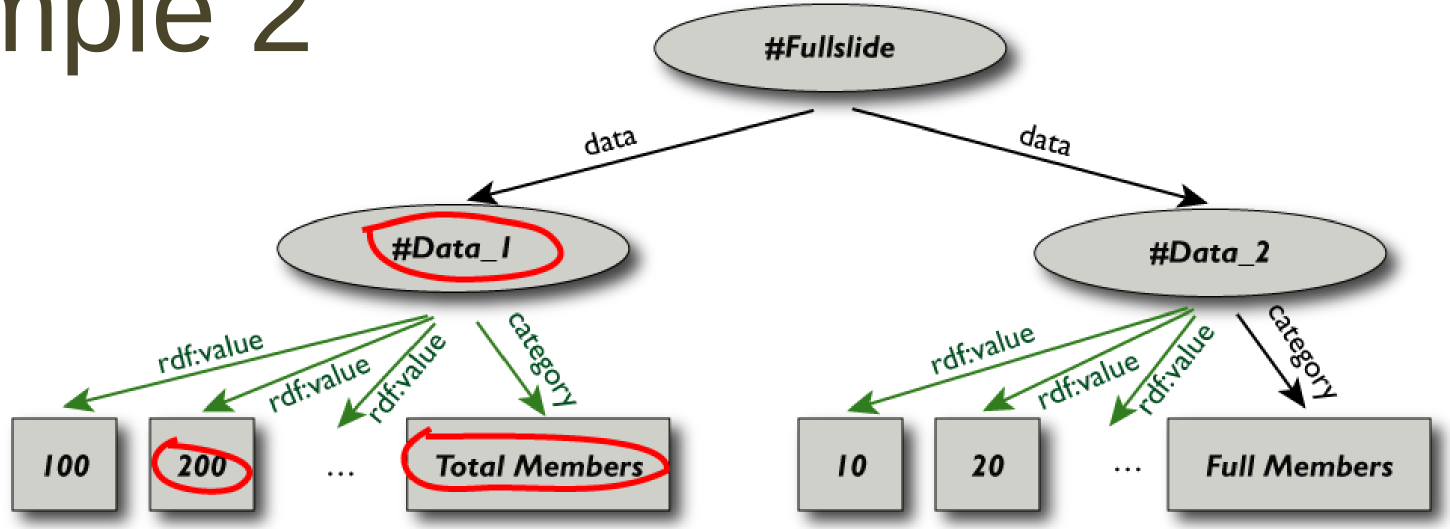


```
SELECT ?cat, ?val
WHERE { ?x rdf:value ?val .
        ?x category ?cat }
```

- Returns:

```
[["Total Members",100],["Total Members",200],…,
["Full Members",10],…]
```

Example 2

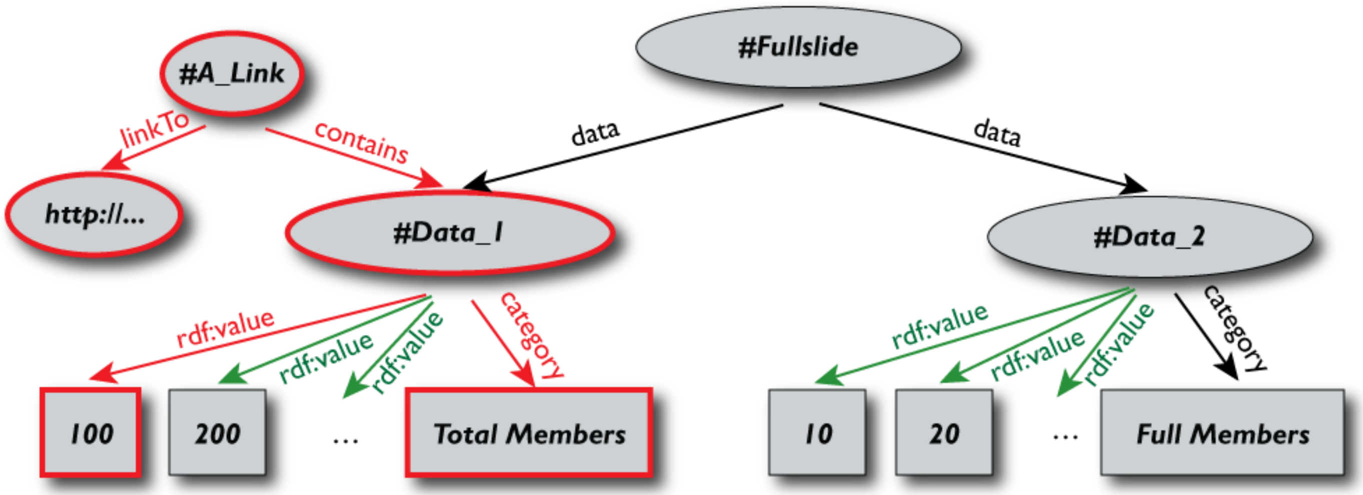


```
SELECT ?cat, ?val
WHERE { ?x rdf:value ?val .
        ?x category ?cat .
       FILTER(?val>=200) . }
```

- Returns:

```
[["Total Members",200],…]
```

Example 3

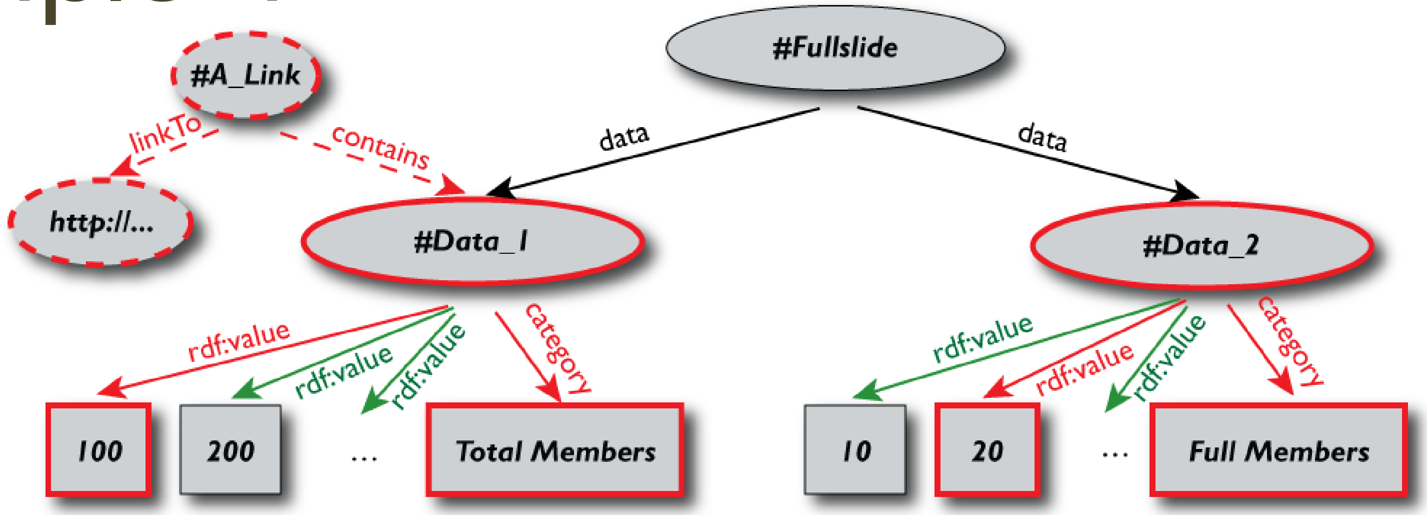


```
SELECT ?cat, ?val, ?uri
WHERE { ?x rdf:value ?val.
        ?x category ?cat.
        ?al contains ?x.
        ?al linkTo ?uri }
```

- Returns:

```
[["Total Members",100,http://...)],…,]
```

Example 4



```
SELECT ?cat, ?val, ?uri
WHERE  { ?x rdf:value ?val.
         ?x category ?cat.
OPTIONAL ?al contains ?x.
         ?al linkTo ?uri }
```

- Returns:

```
[["Total Members",100,http://...], …,
["Full Members",20, ],…,]
```

Other SPARQL Features

- Limit the number of returned results
- Remove duplicates, sort them,…
- Specify several data sources (via URIs) within the query (essentially, a merge)
- Construct a graph combining a separate pattern and the query results
- Use datatypes and/or language tags when matching a pattern

Other SPARQL Features

- Query types
  - Select: projections of variables and expressions
  - Construct: create triples (or graphs) based on query results
  - Ask: whether a query returns results (result is true/false)
  - Describe: describe resources in the graph

SPARQL use in practice

- Where to find meaningful RDF data to search?
- The Linked Data Project

THE LINKED DATA PROJECT

The Linked Data Project

- A fundamental prerequisite of the Semantic Web is the existence of large amounts of meaningfully interlinked RDF data on the Web
- Linked Data is not a specification, but a set of best practices for providing a data infrastructure that makes it easier to share data across the web
- You can then use semantic web technologies such as RDFS, OWL, and SPARQL to build applications around that data

The four principles of Linked Data

1. Use URIs as names for things
   - URIs are the best way available to uniquely identify things, and therefore to identify connections between things
2. Use HTTP URIs so that people can look up those names
   - You may have seen URIs that begin with ftp:, mailto:, or prefixes made up by a particular community, but using these other ones reduces interoperability, and interoperability is what it's all about

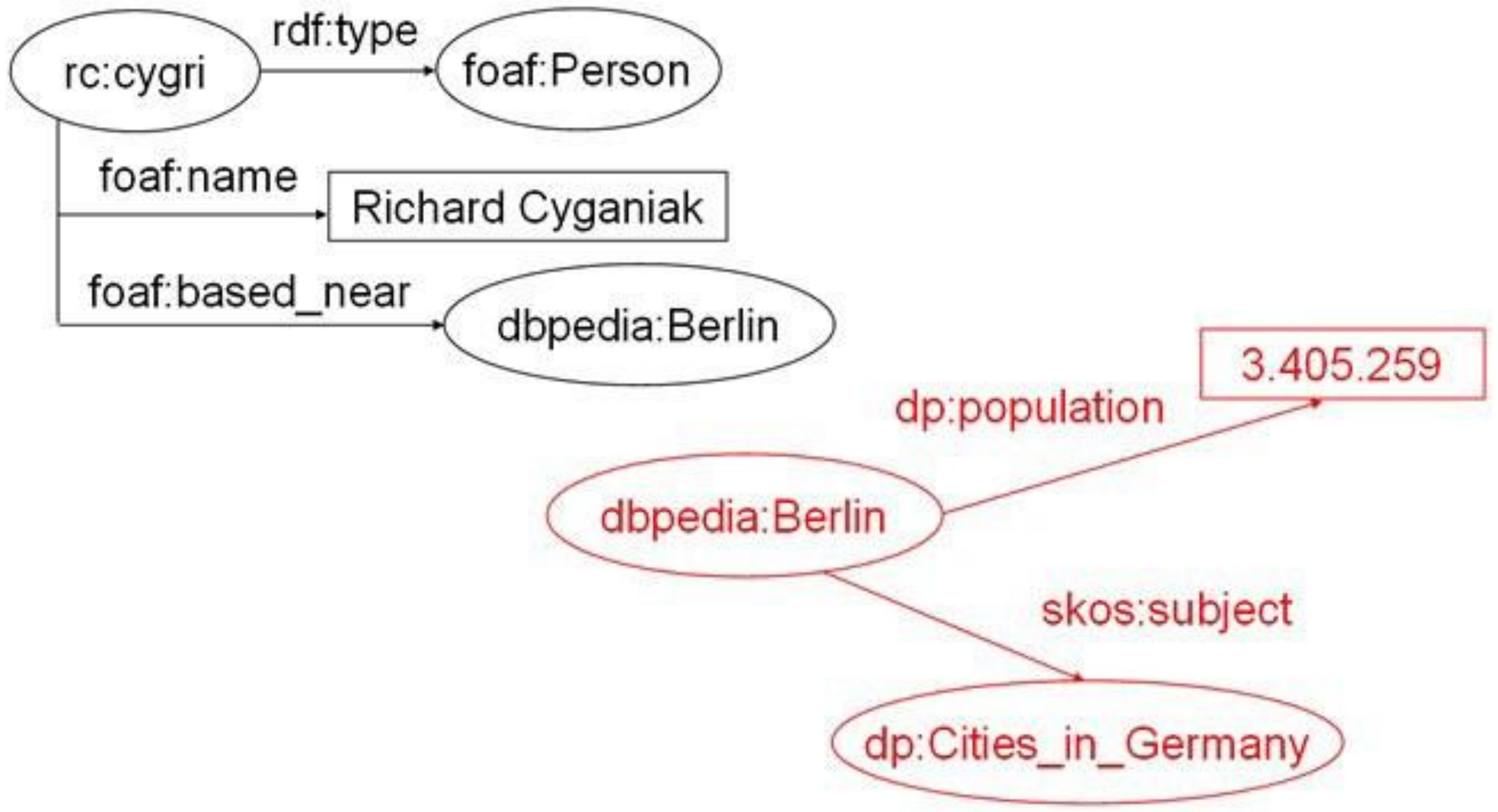
The four principles of Linked Data

3. When someone looks up a URI, provide useful information, using the standards (RDF/RDFS, SPARQL)
   - A URI can just be a name and not actually the address of a web page, but this principle says that you may as well put something there
   - It can be an HTML web page, or something else; whatever it is, it should use a recognized standard
   - RDFS and OWL let you spell out a list of terms and information about those terms and their relationships in a machine-readable way—readable, for example, by SPARQL queries
   - Because of this, if a URI that identifies a resource leads to RDFS or OWL declarations about that resource, this is a big help to applications.

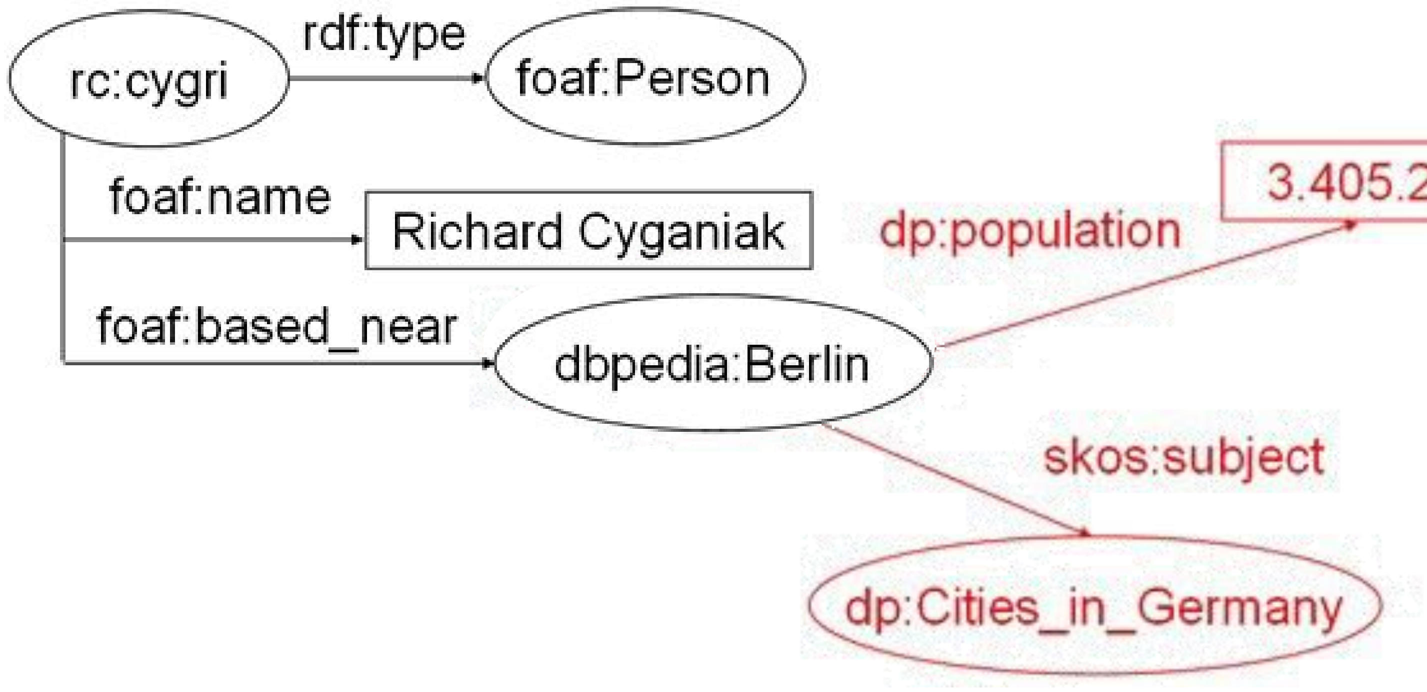
The four principles of Linked Data

4. Include links to other URIs so that they can discover more things
   - Imagine if none of the original HTML pages had a elements to link them to other pages: it wouldn’t have been much of a web
   - In addition to the HTML linking element, various RDF vocabularies provide other properties as a way to say “this data (or this element of data) has a specific relationship to another resource on the web.”
   - When applications can follow these links, they can do interesting new things

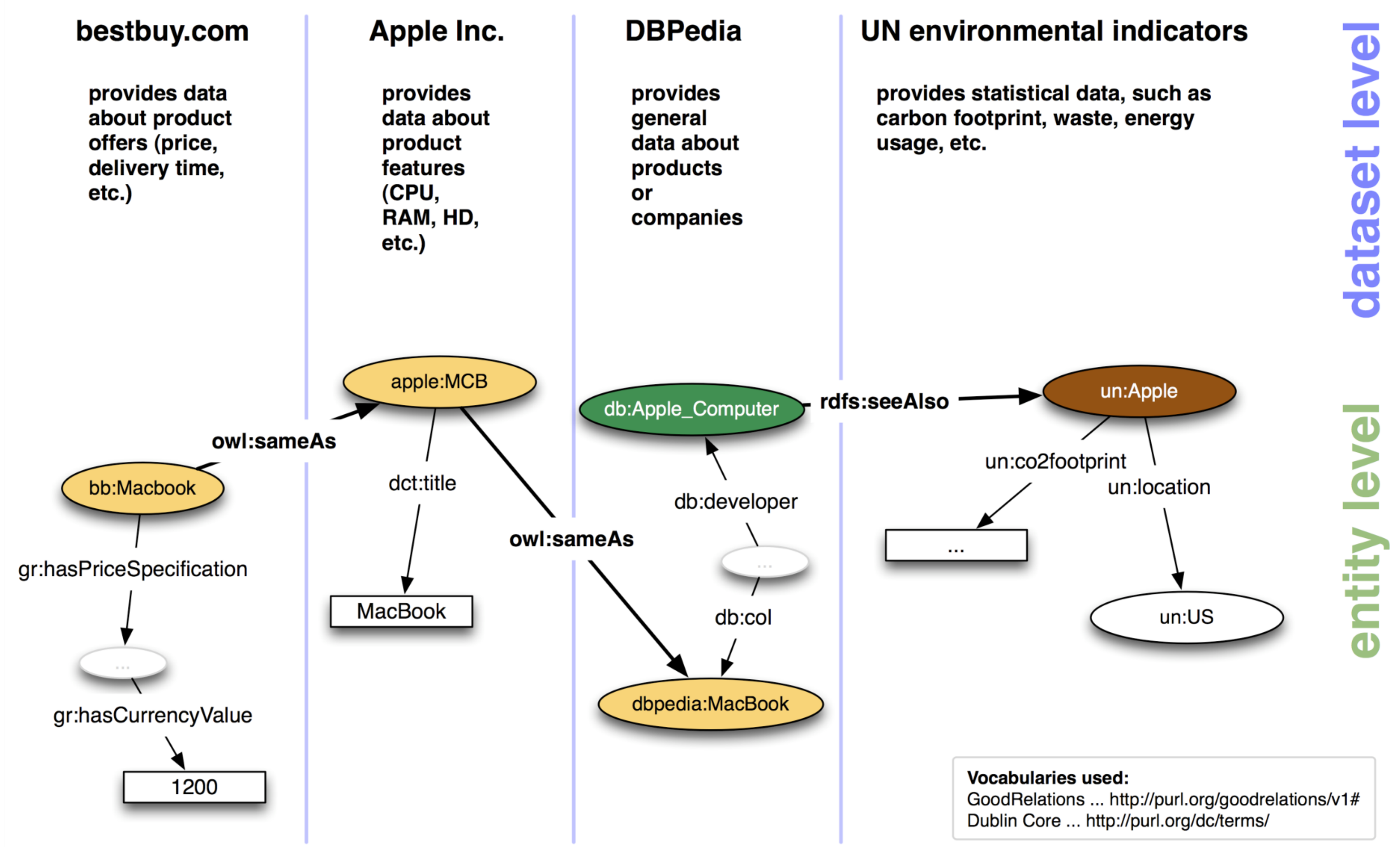
Linked Data example



Linked Data example



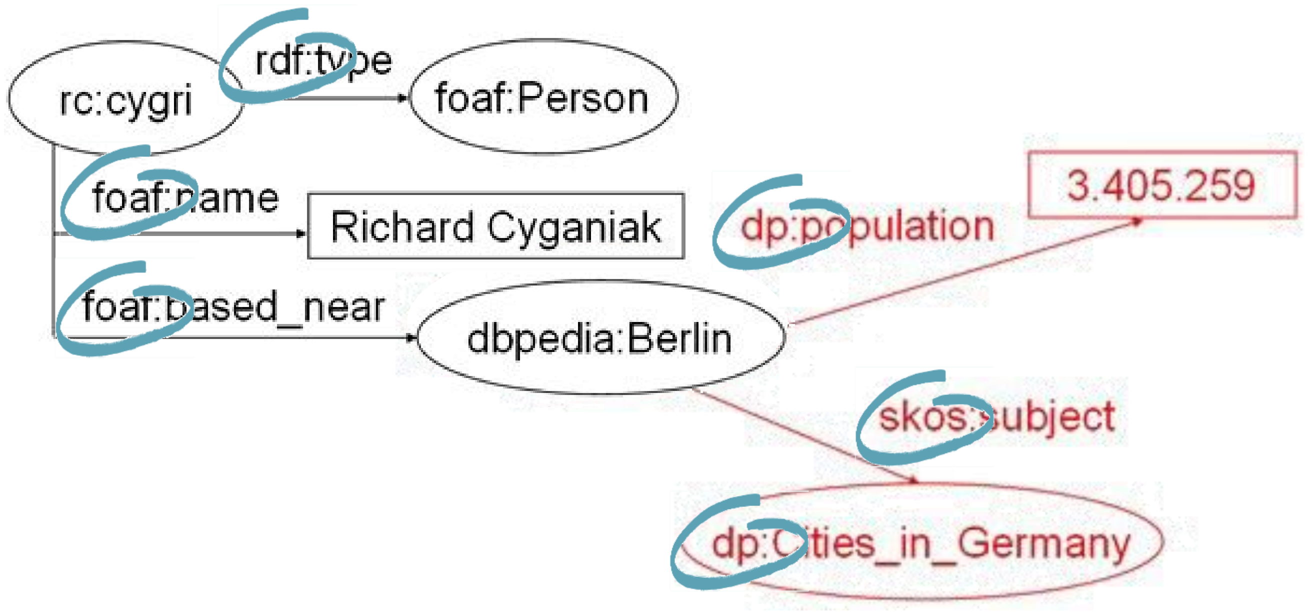
Linked Data example


bestbuy.com
provides data about product offers (price, delivery time, etc.)
Apple Inc.
provides data about product features (CPU, RAM, HD, etc.)
DBPedia
provides general data about products or companies
UN environmental indicators
provides statistical data, such as carbon footprint, waste, energy usage, etc.
dataset level
entity level
apple:MCB
owl:sameAs
bb:Macbook
gr:hasPriceSpecification
...
gr:hasCurrencyValue
1200
dct:title
MacBook
owl:sameAs
db:Apple_Computer
rdfs:seeAlso
un:Apple
db:developer
...
db:col
dbpedia:MacBook
un:co2footprint
un:location
...
un:US

Vocabularies used:
GoodRelations ... http://purl.org/goodrelations/v1#
Dublin Core ... http://purl.org/dc/terms/

Vocabularies

- Define terms (classes and properties)
- Typically RDFS or OWL family



Some commonly used RDF vocabularies

- Friend of a Friend (FOAF)
  - Defines classes and properties for representing information about people and their relationships
  - Project: http://www.foaf-project.org/
  - Namespace: http://xmlns.com/foaf/0.1/

- Description of a Project (DOAP)
  - Describes software projects
  - Project: http://trac.usefulinc.com/doap
  - Namespace: http://usefulinc.com/ns/doap#
- Dublin Core (DC)
  - Describes generic resources
  - Project: http://dublincore.org/documents/dcq-rdf-xml/
  - Namespace: http://purl.org/dc/elements/1.1/

Some commonly used RDF vocabularies

- Semantically-Interlinked Online Communities (SIOC)
  - Represents content from blogs, wikis, forums, mailinglists, chats, …
  - Project: http://sioc-project.org/
  - Namespace: http://rdfs.org/sioc/ns#
- Vocabulary of Interlinked Datasets (VoiD)
  - Describes the interlinking relationship between datasets
  - Project: http://semanticweb.org/wiki/VoiD, http://vocab.deri.ie/void
  - Namespace: http://rdfs.org/ns/void#
- vCard
  - Describes people and organisations
  - Project: http://www.w3.org/TR/vcard-rdf/
  - Namespace: http://www.w3.org/2006/vcard/ns#

Some commonly used RDF vocabularies

- Web Ontology Language (OWL)
  - Describes classes and relations
  - Project: http://www.w3.org/TR/owl2-overview/
  - Namespace: http://www.w3.org/ns/owl2-xml
- Simple Knowledge Organisation System (SKOS)
  - Supports the use of thesauri, classification schemes, subject heading systems and taxonomies
  - Project: http://www.w3.org/2004/02/skos/
  - Namespace: http://www.w3.org/2004/02/skos/core#

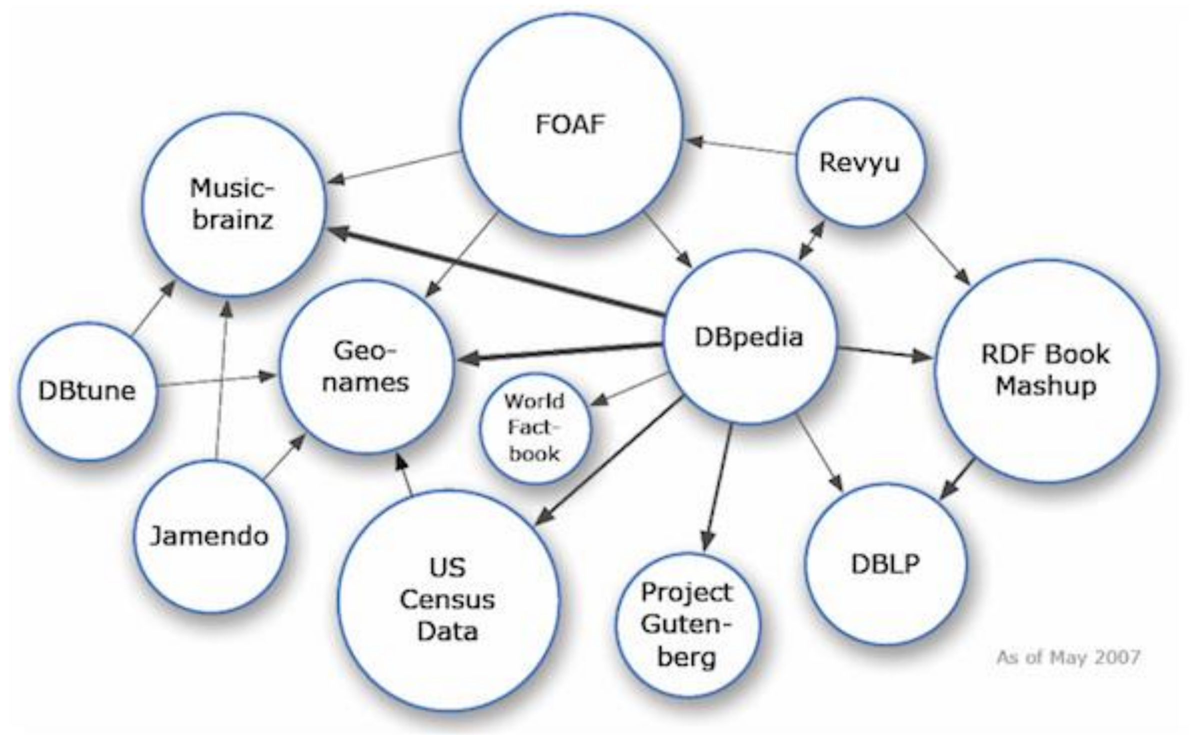
Some commonly used RDF vocabularies

- RDF Schema (RDFS)
  - Provides a data-modelling vocabulary for RDF data
  - Project: http://www.w3.org/TR/rdf-schema/
  - Namespace: http://www.w3.org/2000/01/rdf-schema#
- XML Schema Datatypes
  - Describes the properties and the content of RDF vocabularies
  - Project: http://www.w3.org/TR/xmlschema-2/
  - Namespace: http://www.w3.org/2001/XMLSchema#

Guidance

- To name things: rdfs:label, foaf:name, skos:prefLabel
- To describe people: FOAF, vCard
- To describe projects: DOAP
- To describe Web pages and other publications: dc:creator, dc:description, …
- To describe an RDF schema/vocabulary/ontology: VoiD
- To describe addresses: vCard
- To model simple data: RDF, RDFS, vocabularies
- To model existing taxonomies: SKOS
- To model complex data and/or allow for logical inference: OWL

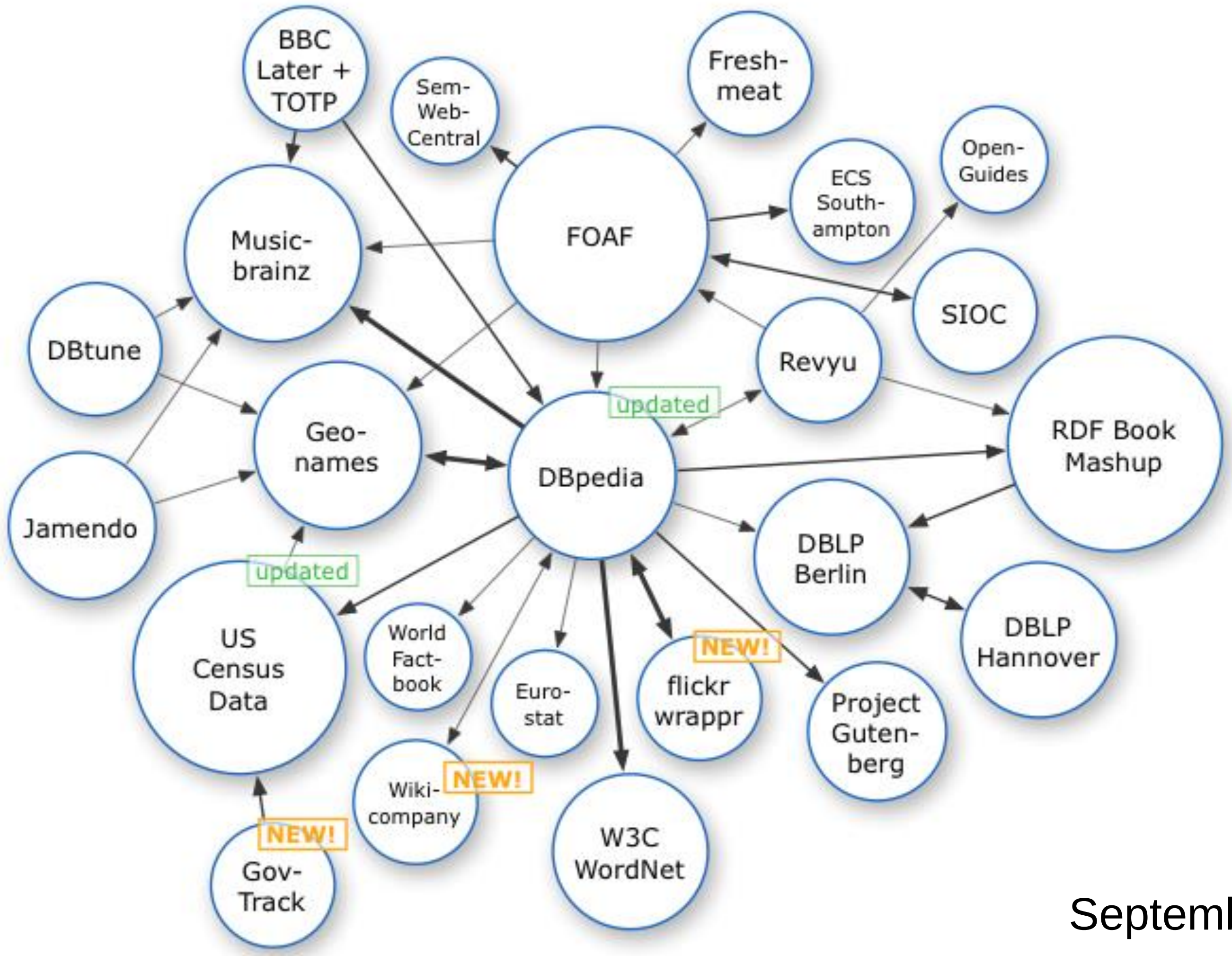
THE LINKED OPEN DATA CLOUD


FOAF
Revyu
Music-brainz
DBpedia
RDF Book Mashup
DBtune
Geo-names
World Fact-book
Jamendo
US Census Data
Project Guten-berg
DBLP
As of May 2007

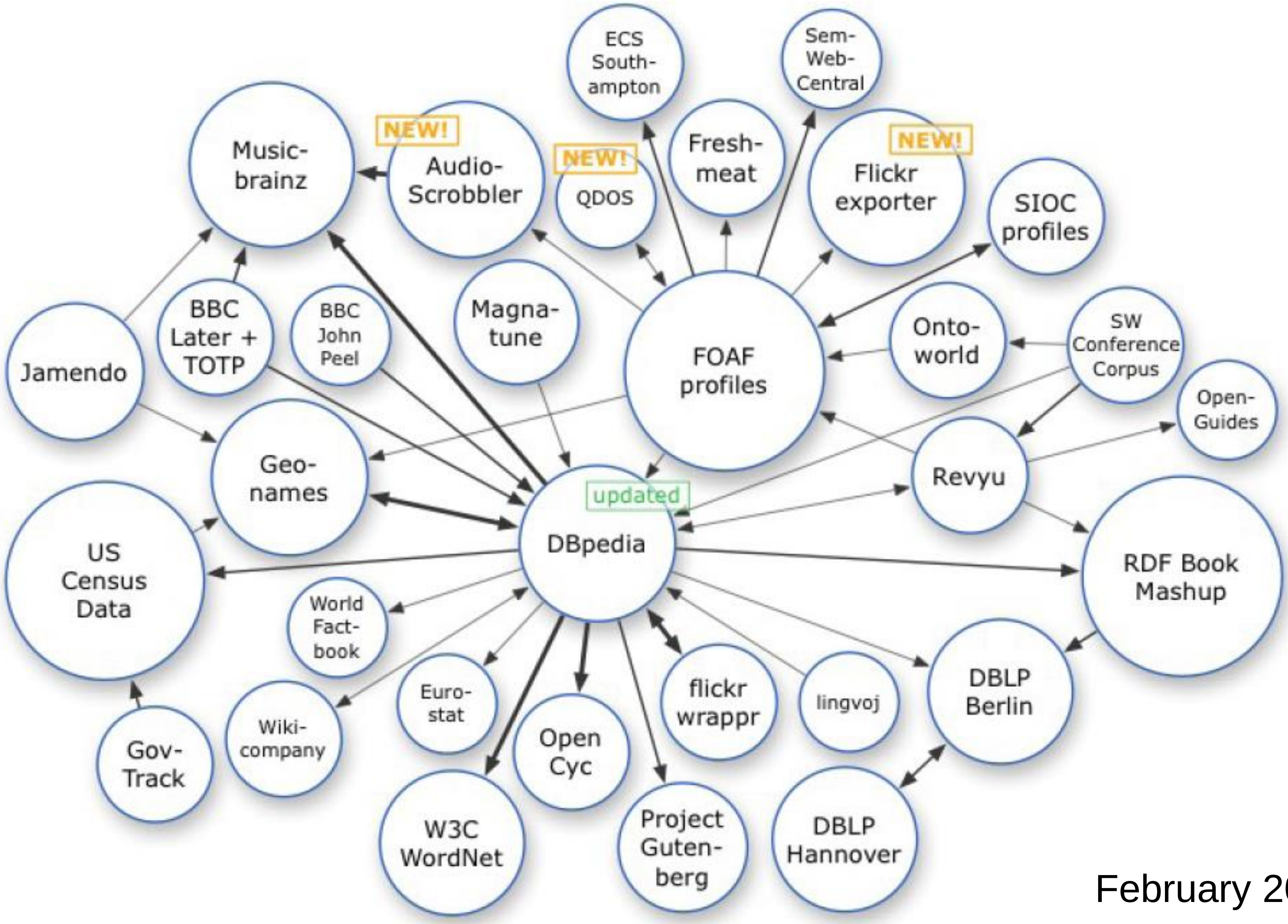
May 2007

The first contributors

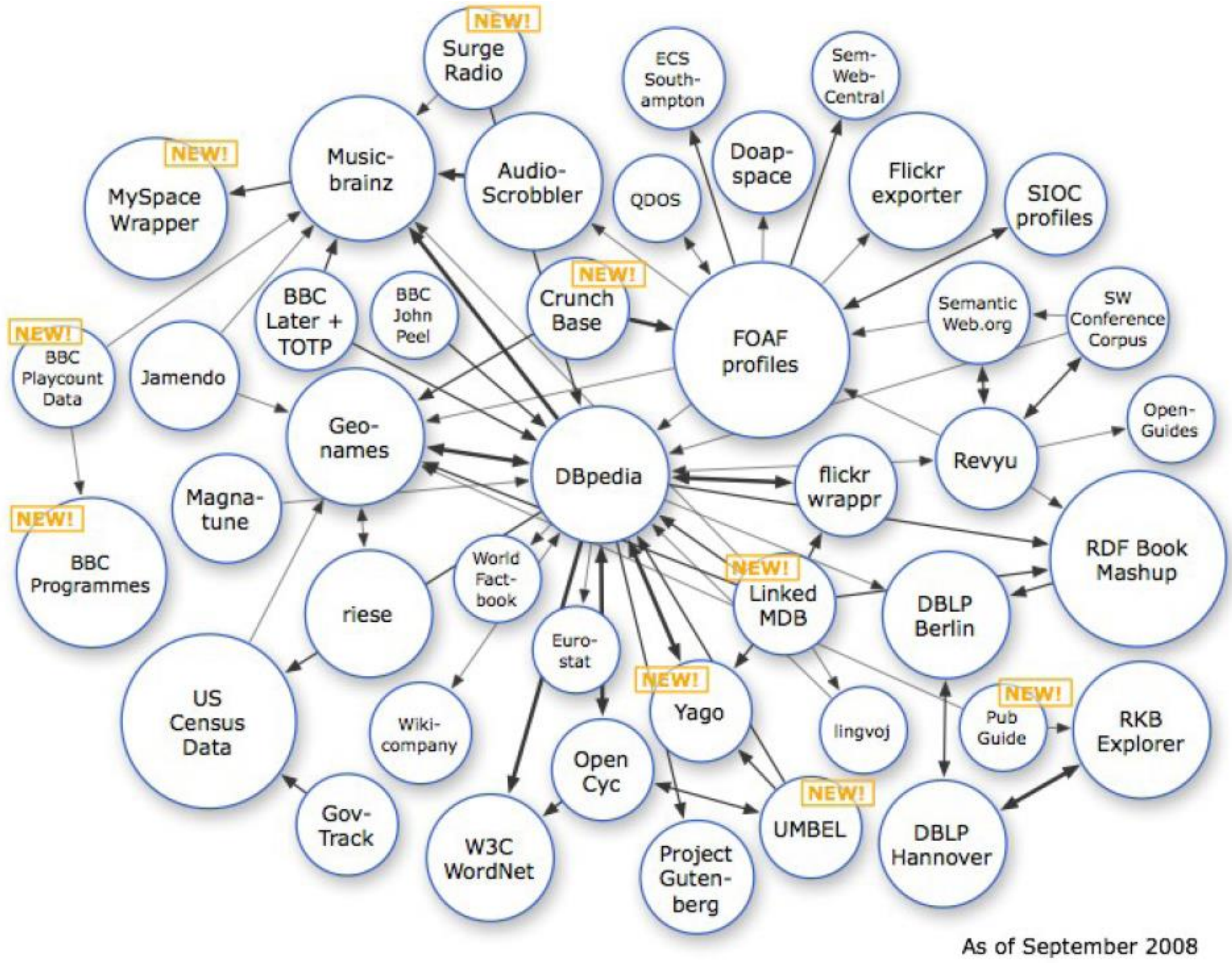
- DBLP Computer science bibliography
  - Richard Cyganiak, Chris Bizer (FU Berlin)
- DBpedia Structured information from Wikipedia
  - Universität Leipzig, FU Berlin, OpenLink
- DBtune, Jamendo Creative Commons music repositories
  - Yves Raimond (University of London)
- Geonames World-wide geographical database
  - Bernard Vatant (Mondeca), Marc Wick (Geonames)
- Musicbrainz Music and artist database
  - Frederick Giasson, Kingsley Idehen (Zitgist)
- Project Gutenberg Literary works in the public domain
  - Piet Hensel, Hans Butschalowsky (FU Berlin)
- Revyu Community reviews about anything
  - Tom Heath, Enrico Motta (Open University)
- RDF Book Mashup Books from the Amazon API
  - Tobias Gauß, Chris Bizer (FU Berlin)
- US Census Data Statistical information about the U.S.
  - Josh Tauberer (University of Pennsylvania), OpenLink
- World Factbook Country statistics, compiled by CIA
  - Piet Hensel, Hans Butschalowsky (FU Berlin)

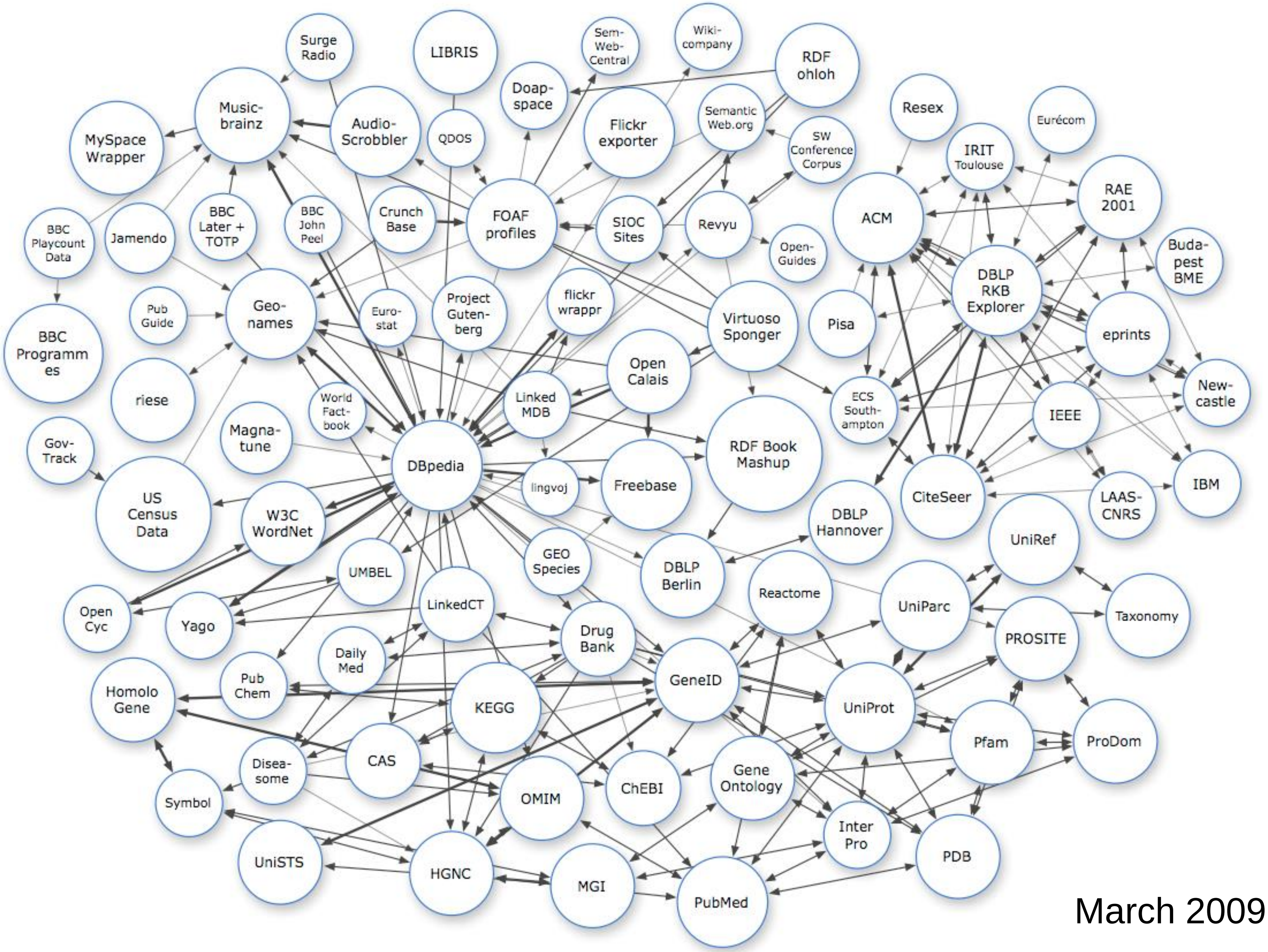


September 2007



February 2008


Surge Radio
NEW!
ECS Southampton
Sem-Web-Central
MySpace Wrapper
NEW!
Music-brainz
Audio-Scrobbler
QDOS
Doap-space
Flickr exporter
SIOC profiles
BBC Later + TOTP
BBC John Peel
Crunch Base
NEW!
FOAF profiles
Semantic Web.org
SW Conference Corpus
BBC Playcount Data
NEW!
Jamendo
Geo-names
DBpedia
Revyu
Open-Guides
Magna-tune
flickr wrappr
RDF Book Mashup
BBC Programmes
NEW!
riese
World Fact-book
Linked MDB
NEW!
DBLP Berlin
Euro-stat
US Census Data
Wiki-company
Yago
NEW!
lingvoj
Pub Guide
NEW!
RKB Explorer
Gov-Track
W3C WordNet
Open Cyc
Project Guten-berg
UMBEL
NEW!
DBLP Hannover
As of September 2008


Surge Radio
LIBRIS
Sem-Web-Central
Wiki-company
RDF ohloh
Doap-space
Music-brainz
Audio-Scrobbler
QDOS
Flickr exporter
Semantic Web.org
SW Conference Corpus
Resex
Eurécom
MySpace Wrapper
IRIT Toulouse
RAE 2001
BBC Playcount Data
Jamendo
BBC Later + TOTP
BBC John Peel
Crunch Base
FOAF profiles
SIOC Sites
Revyu
ACM
Open-Guides
Buda-pest BME
DBLP RKB Explorer
BBC Programmes
Pub Guide
Geo-names
Euro-stat
Project Guten-berg
flickr wrappr
Virtuoso Sponger
Pisa
eprints
Open Calais
riese
World Fact-book
Linked MDB
ECS South-ampton
IEEE
New-castle
Gov-Track
Magna-tune
DBpedia
RDF Book Mashup
lingvoj
Freebase
CiteSeer
LAAS-CNRS
IBM
US Census Data
W3C WordNet
DBLP Hannover
UniRef
UMBEL
GEO Species
DBLP Berlin
Reactome
UniParc
Taxonomy
Open Cyc
Yago
LinkedCT
Drug Bank
PROSITE
Daily Med
Homolo Gene
Pub Chem
KEGG
GeneID
UniProt
Pfam
ProDom
CAS
Disea-some
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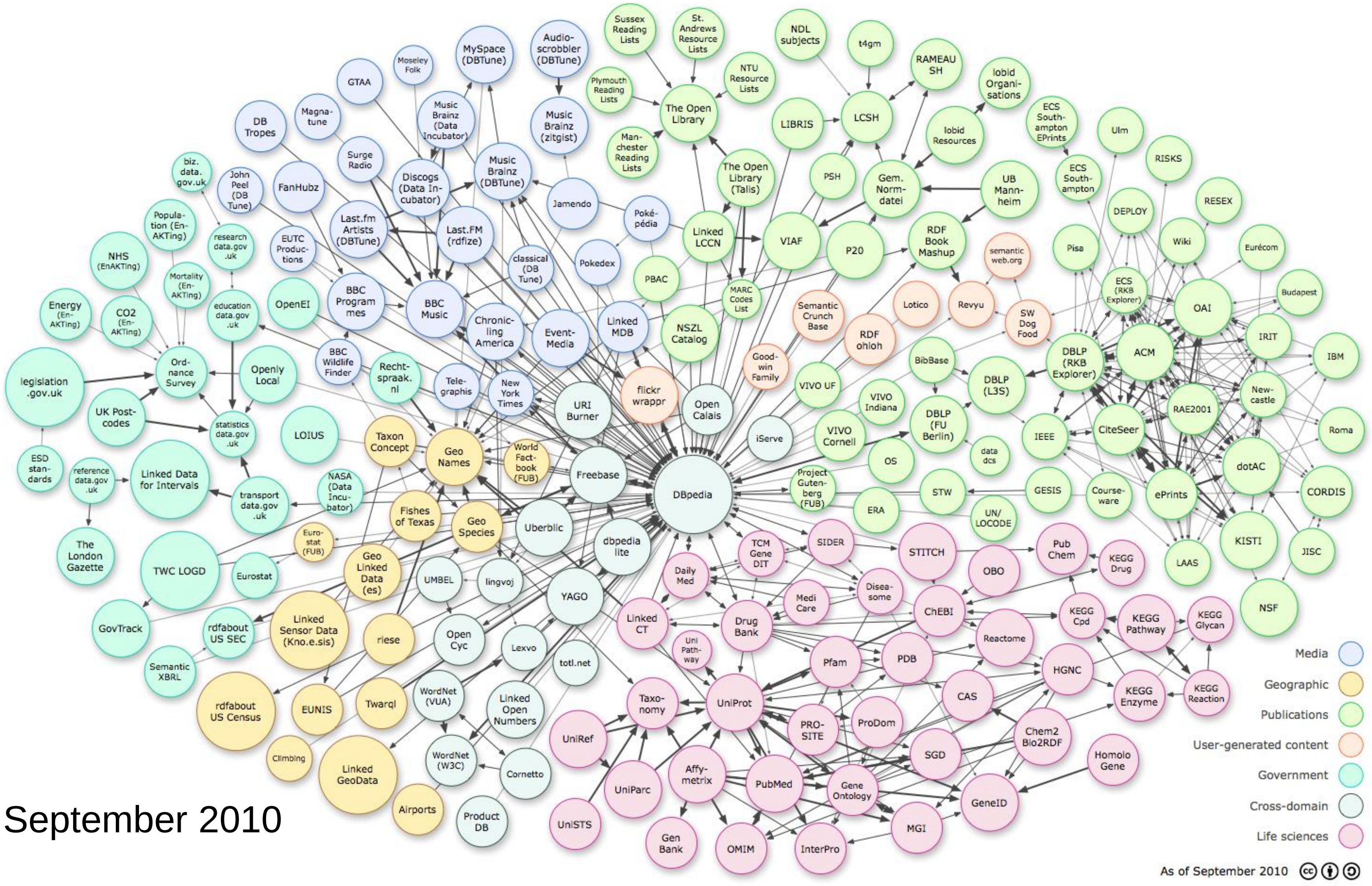
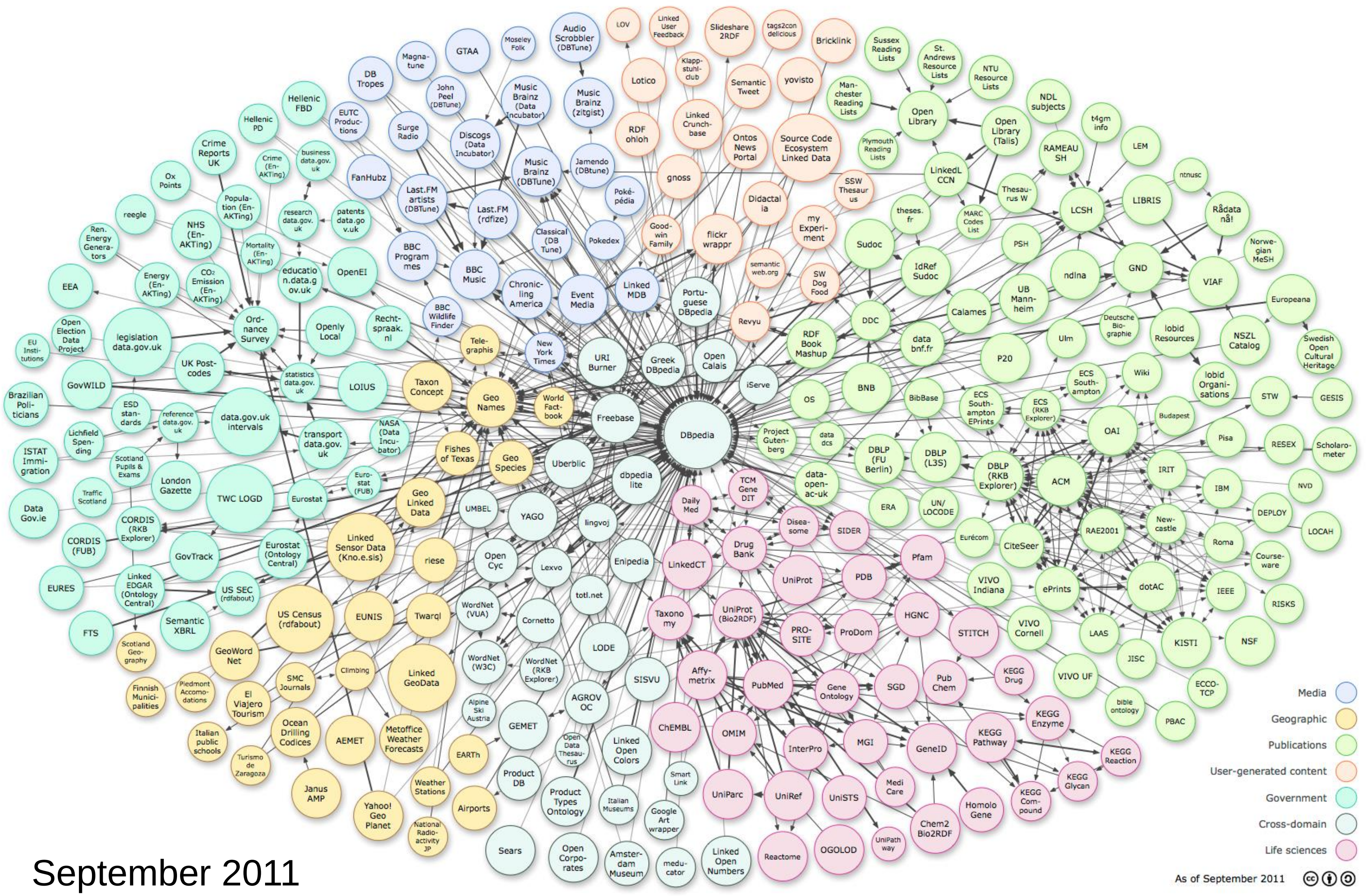
UniSTS
HGNC
MGI
PubMed

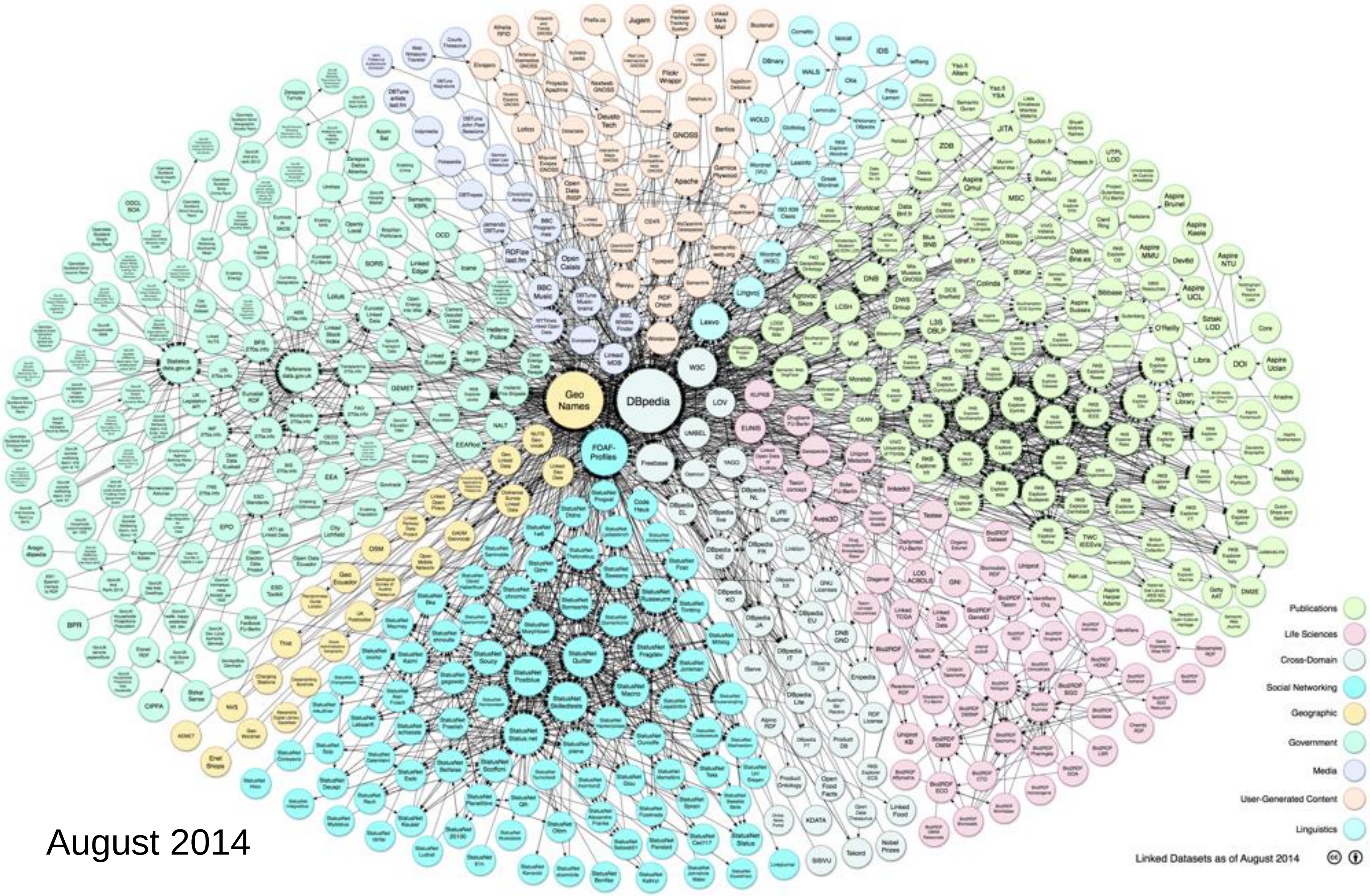
March 2009



September 2010



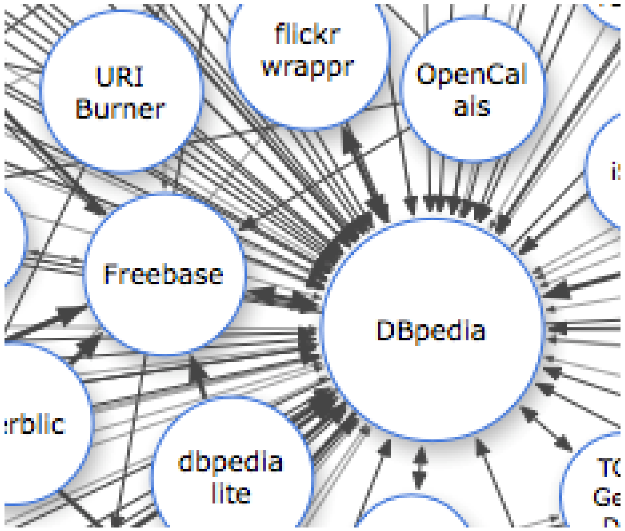
September 2011


Geo Names
DBpedia
FOAF-Profiles
Publications
Life Sciences
Cross-Domain
Social Networking
Geographic
Government
Media
User-Generated Content
Linguistics
Linked Datasets as of August 2014

August 2014

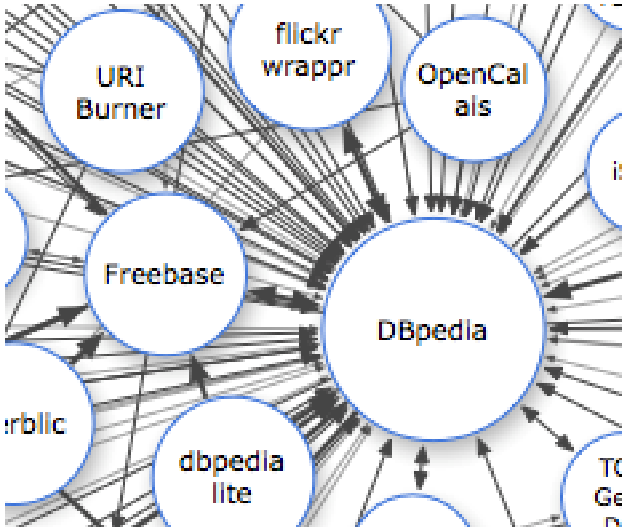
Datasets

- A dataset is a set of RDF triples that are published, maintained or aggregated by a single provider

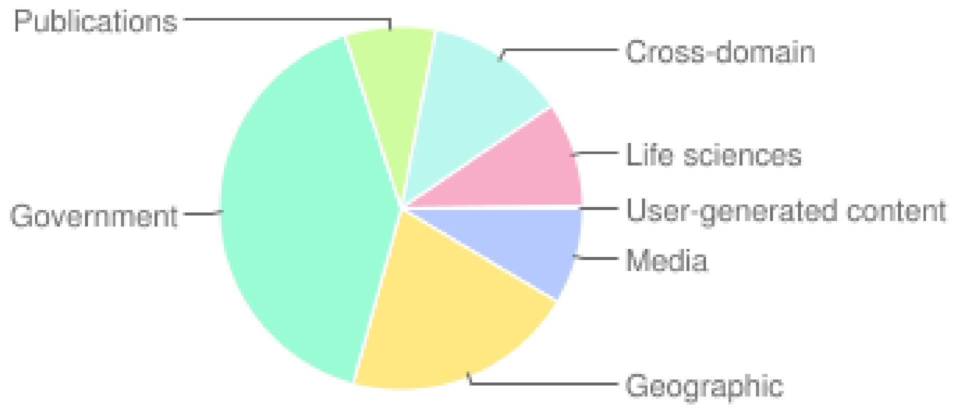


Linksets

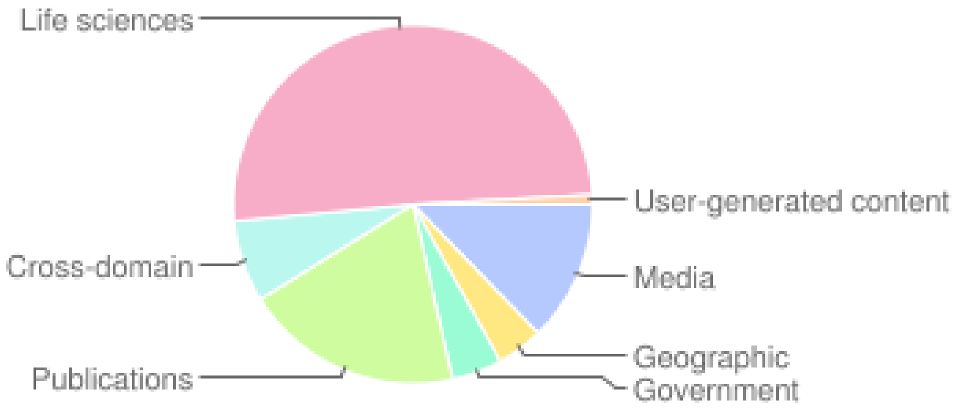
- An RDF link is an RDF triple whose subject and object are described in different datasets
- A linkset is a collection of such RDF links between two datasets



LOD cloud statistics



triples distribution



links distribution

http://lod-cloud.net/state/

SPARQL SYNTAX: EXAMPLES ON OPEN DATASETS

Some popular data sets

- Dbpedia
  - http://wiki.dbpedia.org/Downloads2014
- WikiData
  - http://dumps.wikimedia.org/wikidatawiki/
- GeoNames
  - http://download.geonames.org/all-geonames-rdf.zip
- LinkedGeoData
  - http://downloads.linkedgeodata.org/releases/
- Open Directory
  - http://rdf.dmoz.org/
- MusicBrainz
  - ftp://ftp.musicbrainz.org/pub/musicbrainz/data/

SPARQL endpoints

- An endpoint, also called a processor, is a service that accepts and processes SPARQL queries and returns results in different formats
- SPARQL is both a query language and a protocol
  - The language defines the query syntax
  - The protocol is used to describe how a SPARQL client (such as one accessible via a web browser) talks to a SPARQL endpoint/processor (e.g. http://dbpedia.org/sparql) both in an abstract sense and using a concrete implementation based on WSDL 2.0 (Web Service Definition Language)

SPARQL endpoints

- Accept queries and returns results via HTTP
  - Generic endpoints queries any web-accessible RDF data
  - Specific endpoints are hardwired to query against particular datasets
- The results of SPARQL queries can be returned in a variety of formats:
  - XML, JSON, RDF, HTML
  - JSON (JavaScript Object Notation): lightweight computer data interchange format; text-based, human-readable format for representing simple data structures and associative arrays

Examples of SPARQL endpoints

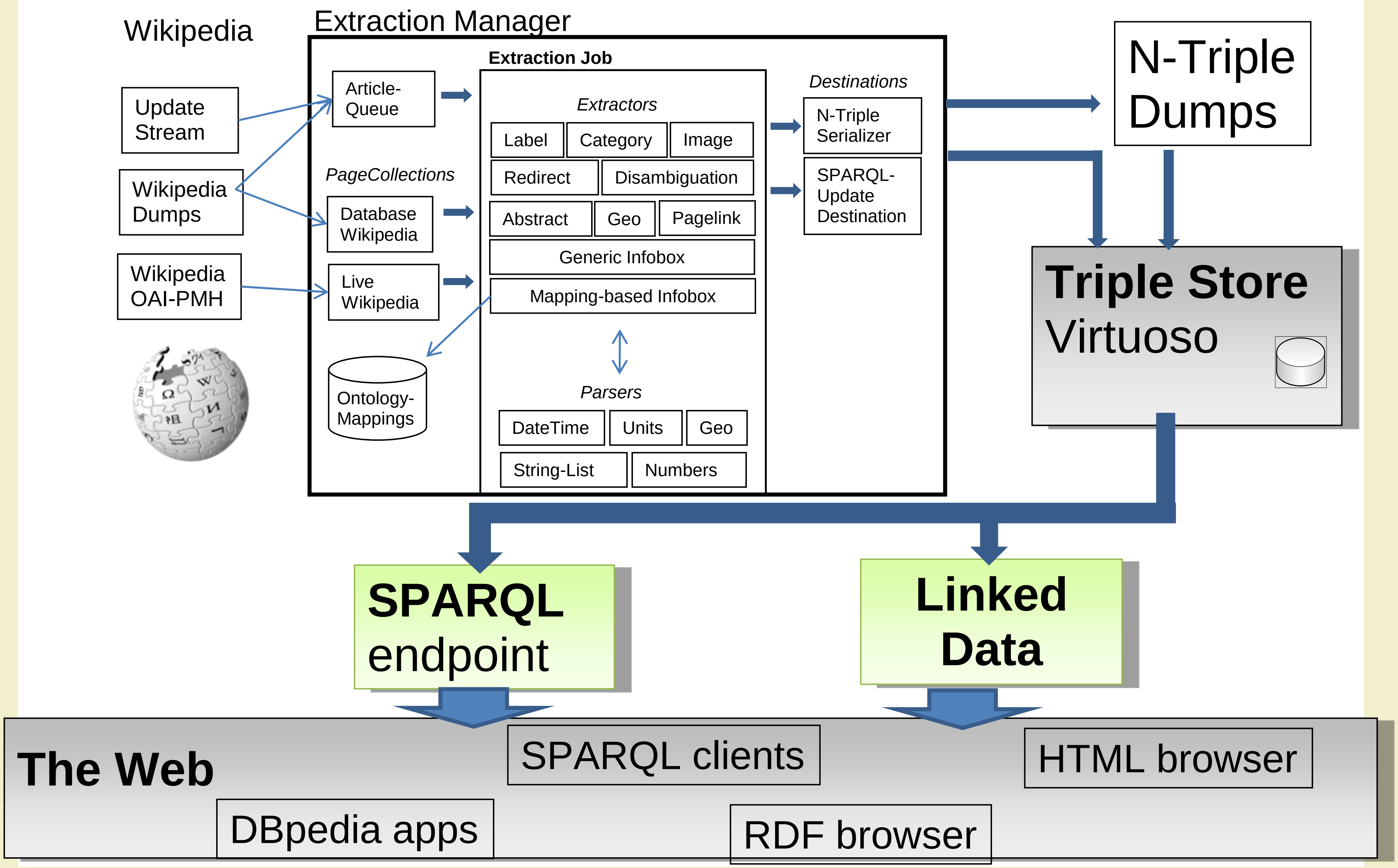
- Generic endpoints queries any web-accessible RDF data
  - OpenLink Virtuoso SPARQL Query Editor
    http://demo.openlinksw.com/sparql/
- DBpedia SPARQL interactive endpoints (example)
  - Virtuoso SPARQL Query Editor
    http://dbpedia.org/sparql/
  - SPARQL Explorer
    http://dbpedia.org/snorql/
  - Interactive SPARQL Query Builder by OpenLink
    http://dbpedia.org/isparql/
- Camera.it SPARQL interactive endpoints (example)
  - Virtuoso SPARQL Query Editor
    http://dati.camera.it/sparql

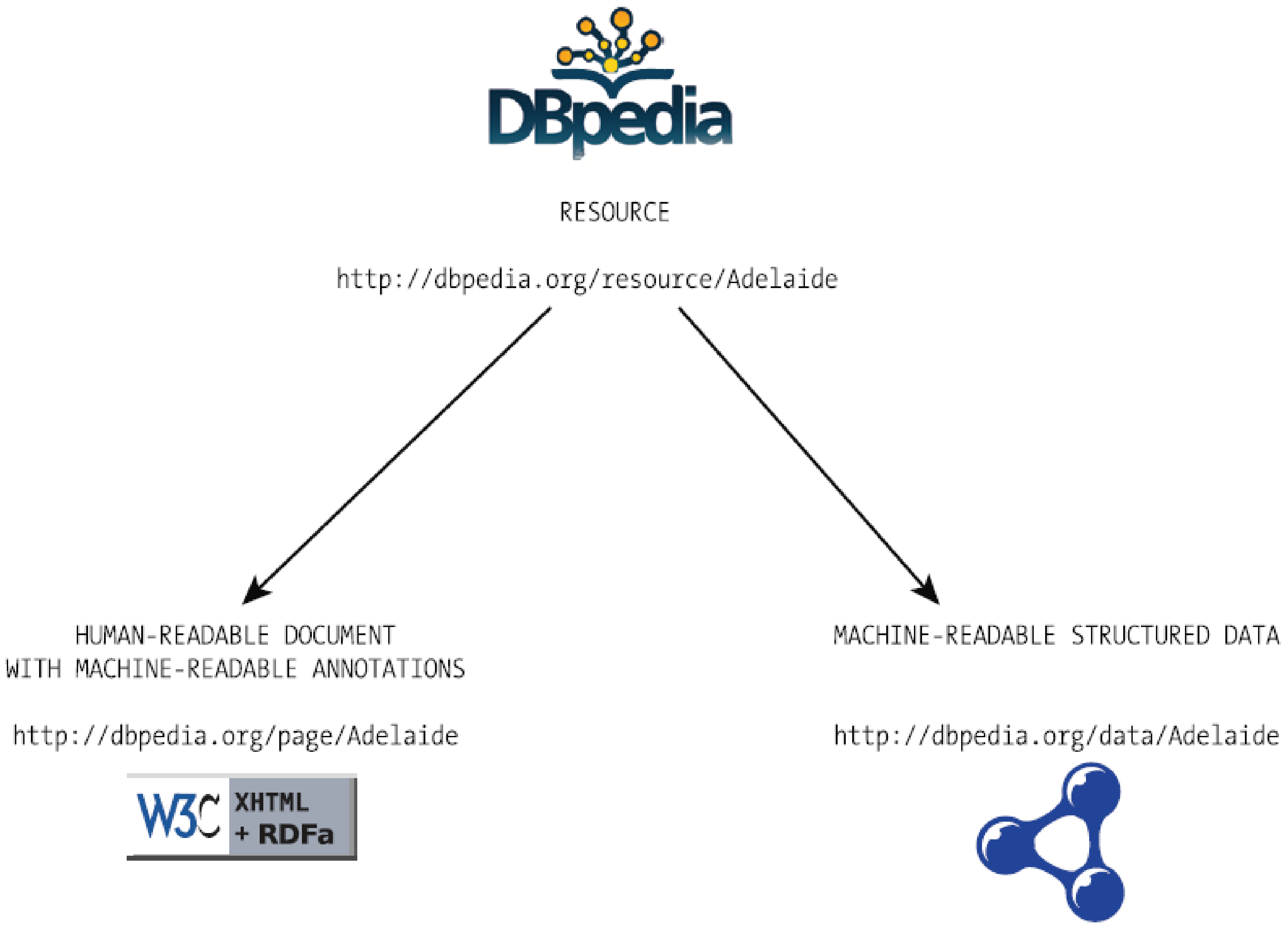
DBpedia

- DBpedia provides a complementary service to Wikipedia by exposing knowledge in a quality-controlled form compatible with tools covering ad-hoc structured data querying, business intelligence & analytics, entity extraction, natural language processing, reasoning & inference, machine learning services, and artificial intelligence in general
  - 130 Wikimedia projects, in particular the English Wikipedia, Commons, Wikidata and over 100 Wikipedia language editions
- Data is published strictly in line with Linked Data principles using open standards

http://wiki.dbpedia.org/OnlineAccess

DBpedia Architecture




DBpedia
RESOURCE
http://dbpedia.org/resource/Adelaide
HUMAN-READABLE DOCUMENT
WITH MACHINE-READABLE ANNOTATIONS
http://dbpedia.org/page/Adelaide
W3C XHTML + RDFa
MACHINE-READABLE STRUCTURED DATA
http://dbpedia.org/data/Adelaide

DBpedia resources return XHTML or RDF through content negotiation

SPARQL query structure

- A SPARQL query includes, in order
  - Prefix declarations, for abbreviating URIs
  - A result clause, identifying what information to return from the query
  - The query pattern, specifying what to query for in the underlying dataset
  - Query modifiers: slicing, ordering, and otherwise rearranging query results

SPARQL query structure

- A SPARQL query includes, in order

```
# prefix declarations
PREFIX foo: <http://example.com/resources/>
...
# result clause
SELECT ...
# query pattern
WHERE {
    ...
}
# query modifiers
ORDER BY ...
```

Example 1 – simple triple pattern

- In DBpedia
  - Find all subjects (?person) linked to :Turin with the dbo:birthplace predicate
  - Then return all the values of ?person.
- In other words, find all people that were born in Turin

```
PREFIX : <http://dbpedia.org/resource/>
PREFIX dbo: <http://dbpedia.org/ontology/>
SELECT ?person
WHERE {
  ?person dbo:birthPlace :Turin .
}
```

- To find predefined DBpedia prefixes
  - https://dbpedia.org/sparql?nsdecl

Example 2 – simple triple pattern

- List all the places and the people that were born there

```
PREFIX : <http://dbpedia.org/resource/>
PREFIX dbo: <http://dbpedia.org/ontology/>
SELECT ?place ?person
WHERE {
  ?person dbo:birthPlace ?place .
}
```

Example 3 – multiple triple pattern

- List all the names and the birthdates of the people that were born in Turin

```
PREFIX : <http://dbpedia.org/resource/>
PREFIX dbo: <http://dbpedia.org/ontology/>
PREFIX foaf:  <http://xmlns.com/foaf/0.1/>
SELECT ?name ?birth
WHERE
{       ?person dbo:birthPlace :Turin .
        ?person dbo:birthDate ?birth .
        ?person foaf:name ?name .
}
```

Example 3 – multiple triple pattern

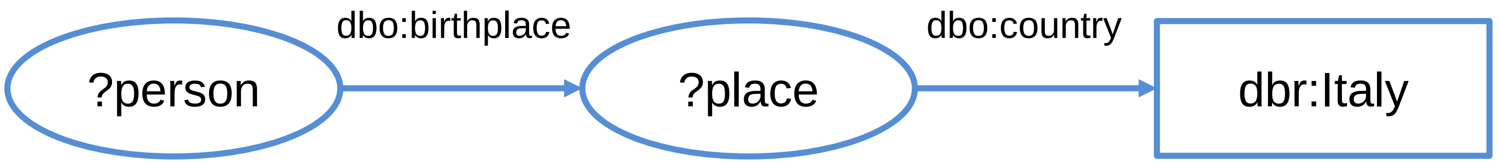
- List all the names and the birthdates of the people hat were born in Turin
- The same, but grouping triplets
- It is possible to convert data types

```
PREFIX : <http://dbpedia.org/resource/>
PREFIX dbo: <http://dbpedia.org/ontology/>
PREFIX foaf:  <http://xmlns.com/foaf/0.1/>
SELECT STR(?name) ?birth
WHERE
{       ?person dbo:birthPlace :Turin ;
                dbo:birthDate ?birth ;
                foaf:name ?name .
}
```

Data type conversion

Example 4 – traversing a graph

- Find all the people that were born anywhere in Italy



```
PREFIX : <http://dbpedia.org/resource/>
PREFIX dbo: <http://dbpedia.org/ontology/>
PREFIX dbr: <http://dbpedia.org/resource/>
SELECT ?person ?place
WHERE {
  ?person dbo:birthPlace ?place .
  ?place dbo:country dbr:Italy .
}
```

Example 5 – LIMIT modifier

- LIMIT
  - limits the number of rows returned by query
- Find the fist 25 people that were born anywhere in Italy

```
PREFIX : <http://dbpedia.org/resource/>
PREFIX dbo: <http://dbpedia.org/ontology/>
PREFIX dbr: <http://dbpedia.org/resource/>
SELECT ?person ?place
WHERE {
  ?person dbo:birthPlace ?place .
  ?place dbo:country dbr:Italy .
} LIMIT 25
```

Example 6 – ORDER BY modifier

- ORDER BY
  - Sorts the query solutions on the value of one or more variables
- Find the fist 25 people that were born anywhere in Italy sorted by name in descending order

```
PREFIX : <http://dbpedia.org/resource/>
PREFIX dbo: <http://dbpedia.org/ontology/>
PREFIX dbr: <http://dbpedia.org/resource/>
PREFIX foaf:  <http://xmlns.com/foaf/0.1/>
SELECT STR(?name) ?place
WHERE {
  ?person dbo:birthPlace ?place ;
          foaf:name ?name .
  ?place dbo:country dbr:Italy .
} ORDER BY DESC(STR(?name))
LIMIT 25
```

Example 7 – SPARQL filters

- FILTER constraints use boolean conditions to filter out unwanted query results
- Find all the people that were born in Turin after 1960, in alphabetical order

```
PREFIX : <http://dbpedia.org/resource/>
PREFIX dbo: <http://dbpedia.org/ontology/>
PREFIX foaf:  <http://xmlns.com/foaf/0.1/>
SELECT ?name ?birth ?person
WHERE {
  ?person dbo:birthPlace :Turin .
  ?person dbo:birthDate ?birth .
  ?person foaf:name ?name .
  FILTER (?birth > "1960-01-01"^^xsd:date) .
} ORDER BY ?name
```

SPARQL filters

- Conditions on literal values
- Syntax

```
FILTER expression
```

- Examples

Pay attention to data types!!!
XML Schema data types

```
FILTER (?age > 30)
FILTER (?birth > "1960-01-01"^^xsd:date)
FILTER isIRI(?x)
FILTER !BOUND(?y)
```

SPARQL filters

- `BOUND(var)`
  - true if var is bound in query answer
  - false, otherwise
  - `!BOUND(var)` enables negation-as-failure
- Testing types
  - `isIRI(A)`: A is an “Internationalized Resource Identifier”
  - `isBLANK(A)`: A is a blank node
  - `isLITERAL(A)`: A is a literal

SPARQL filters

- Comparison between RDF terms

```
A = B
A != B
```

- Comparison between Numeric and Date types

```
A = B
A != B
A <= B
A >= B
A < B
A > B
```

- Boolean AND/OR

```
A && B
A || B
```

- Basic arithmetics

```
A + B
A - B
A * B
A / B
```

Example 8 – SPARQL filters

- Find the musicians that were born in Turin
- The SPARQL keyword a is a shortcut for the common predicate rdf:type (class of a resource)

```
PREFIX : <http://dbpedia.org/resource/>
PREFIX dbo: <http://dbpedia.org/ontology/>
PREFIX foaf:  <http://xmlns.com/foaf/0.1/>
SELECT ?name ?birth ?description ?person
WHERE {
      ?person a dbo:MusicalArtist .
      ?person dbo:birthPlace :Turin .
      ?person dbo:birthDate ?birth .
      ?person foaf:name ?name .
      ?person rdfs:comment ?description .
      FILTER (LANG(?description) = 'en') .
} ORDER BY ?name
```

Example 9 – SPARQL filters

- Find the musicians that were born in a country with a population higher than 10,000,000 people, but not in the United States

```
PREFIX : <http://dbpedia.org/resource/>
PREFIX dbo: <http://dbpedia.org/ontology/>
PREFIX foaf:  <http://xmlns.com/foaf/0.1/>
SELECT ?name ?birth ?countryOfBirth ?population
WHERE {
      ?person a dbo:MusicalArtist .
      ?person dbo:birthPlace ?countryOfBirth .
      ?countryOfBirth a dbo:Country ;
          dbo:populationTotal ?population .
      ?person dbo:birthDate ?birth .
      ?person foaf:name ?name .
      FILTER ((?population > 10000000) &&
              (?countryOfBirth != :United_States)) .
} ORDER BY ?name
```

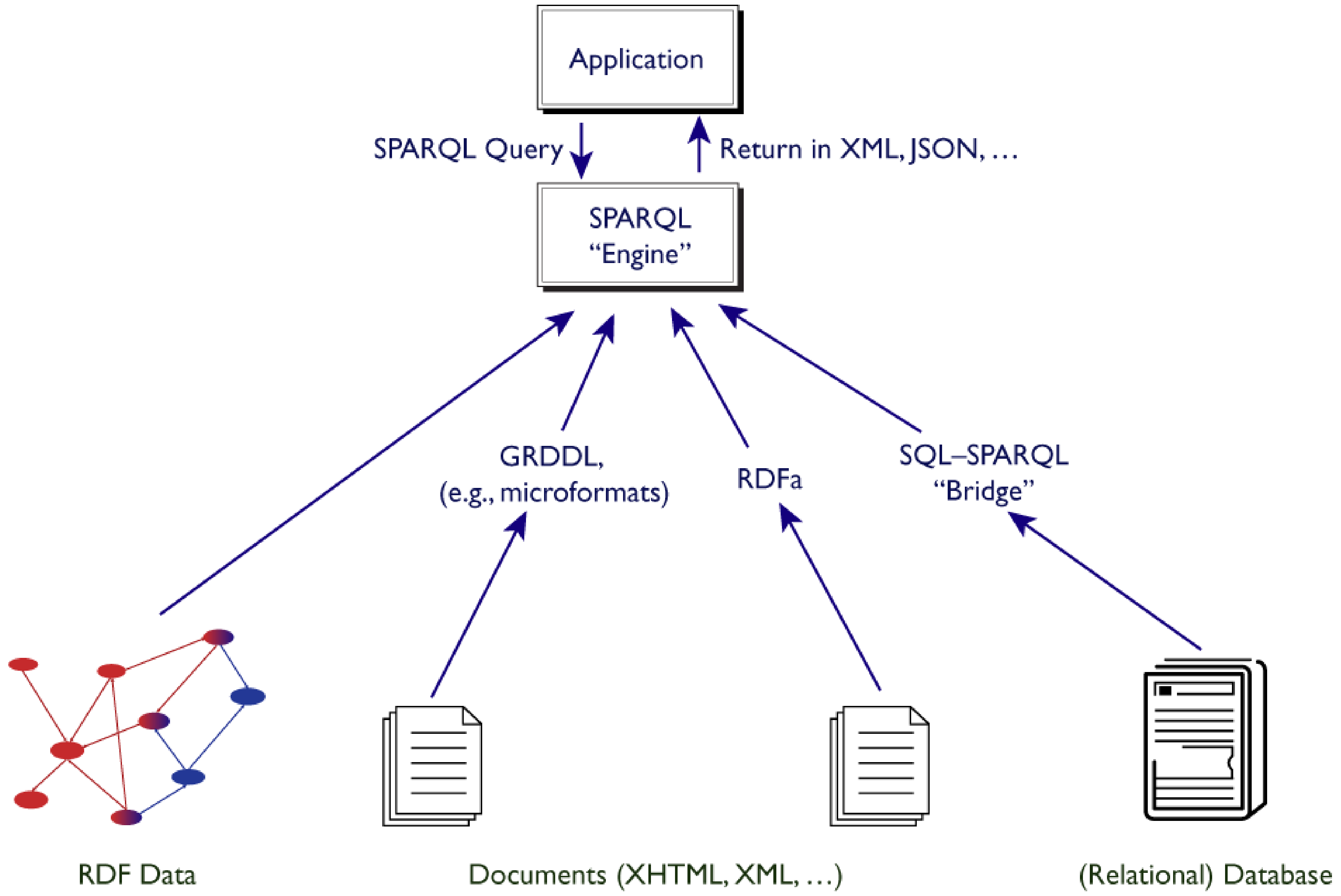
Example 10 – OPTIONAL patterns

- OPTIONAL tries to match a graph pattern, but doesn't fail the whole query if the optional match fails
  - If an OPTIONAL pattern fails to match for a particular solution, any variables in that pattern remain unbound (no value) for that solution
- Find the musicians that were born in Turin, and show their image (when possible)

```
SELECT ?name ?birth ?thumbnail
WHERE {
      ?person a dbo:MusicalArtist .
      ?person dbo:birthPlace :Turin .
      ?person dbo:birthDate ?birth .
      ?person foaf:name ?name .
      OPTIONAL { ?person dbo:thumbnail ?thumbnail . }
} ORDER BY ?name
```

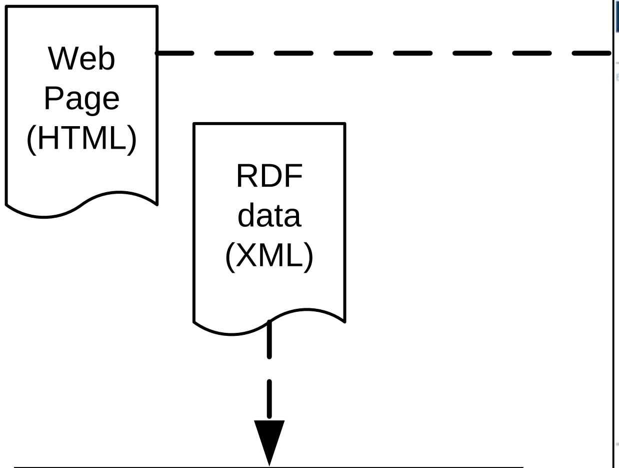
PROVIDING RDF DATA

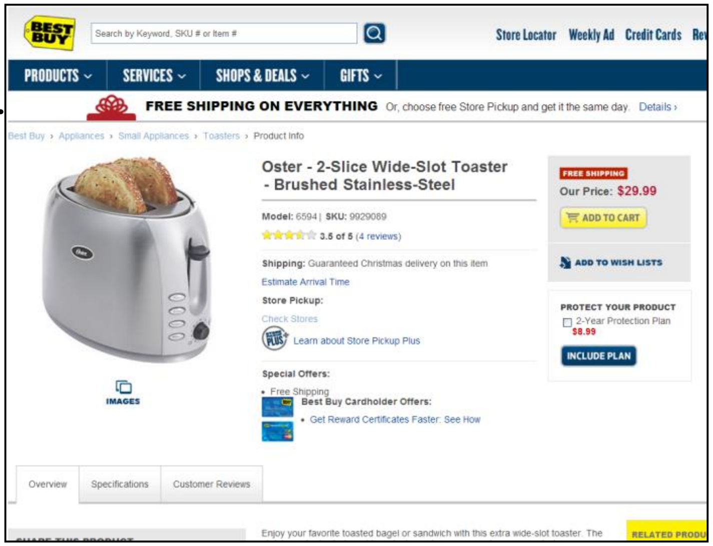
How to provide RDF data?



From HTML to RDF

- Problem: usually HTML content and RDF data are separate





Search by Keyword, SKU # or Item #

Store Locator Weekly Ad Credit Cards Rev

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Model: 6594 | SKU: 9929089

3.5 of 5 (4 reviews)

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FREE SHIPPING

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ADD TO WISH LISTS

PROTECT YOUR PRODUCT

2-Year Protection Plan $8.99

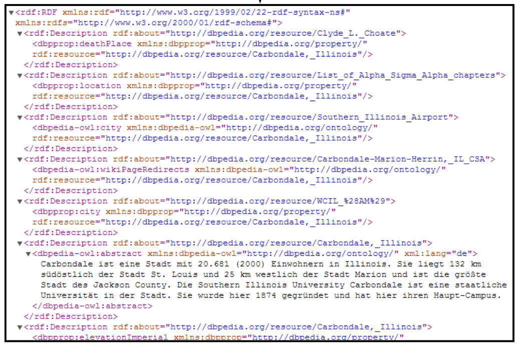
INCLUDE PLAN

IMAGES

Overview | Specifications | Customer Reviews

Enjoy your favorite toasted bagel or sandwich with this extra wide-slot toaster. The

RELATED PRODU



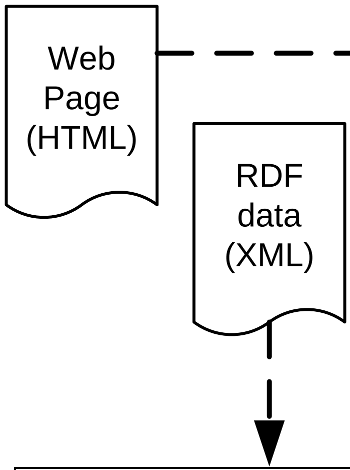
```
▼<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
 xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#">
 ▼<rdf:Description rdf:about="http://dbpedia.org/resource/Clyde_L._Choate">
    <dbpprop:deathPlace xmlns:dbpprop="http://dbpedia.org/property/"
    rdf:resource="http://dbpedia.org/resource/Carbondale,_Illinois"/>
  </rdf:Description>
 ▼<rdf:Description rdf:about="http://dbpedia.org/resource/List_of_Alpha_Sigma_Alpha_chapters">
    <dbpprop:location xmlns:dbpprop="http://dbpedia.org/property/"
    rdf:resource="http://dbpedia.org/resource/Carbondale,_Illinois"/>
  </rdf:Description>
 ▼<rdf:Description rdf:about="http://dbpedia.org/resource/Southern_Illinois_Airport">
    <dbpedia-owl:city xmlns:dbpedia-owl="http://dbpedia.org/ontology/"
    rdf:resource="http://dbpedia.org/resource/Carbondale,_Illinois"/>
  </rdf:Description>
 ▼<rdf:Description rdf:about="http://dbpedia.org/resource/Carbondale-Marion-Herrin,_IL_CSA">
    <dbpedia-owl:wikiPageRedirects xmlns:dbpedia-owl="http://dbpedia.org/ontology/"
    rdf:resource="http://dbpedia.org/resource/Carbondale,_Illinois"/>
  </rdf:Description>
 ▼<rdf:Description rdf:about="http://dbpedia.org/resource/WCIL_%28AM%29">
    <dbpprop:city xmlns:dbpprop="http://dbpedia.org/property/"
    rdf:resource="http://dbpedia.org/resource/Carbondale,_Illinois"/>
  </rdf:Description>
 ▼<rdf:Description rdf:about="http://dbpedia.org/resource/Carbondale,_Illinois">
  ▼<dbpedia-owl:abstract xmlns:dbpedia-owl="http://dbpedia.org/ontology/" xml:lang="de">
     Carbondale ist eine Stadt mit 20.681 (2000) Einwohnern in Illinois. Sie liegt 132 km
     südöstlich der Stadt St. Louis und 25 km westlich der Stadt Marion und ist die größte
     Stadt des Jackson County. Die Southern Illinois University Carbondale ist eine staatliche
     Universität in der Stadt. Sie wurde hier 1874 gegründet und hat hier ihren Haupt-Campus.
    </dbpedia-owl:abstract>
  </rdf:Description>
 ▼<rdf:Description rdf:about="http://dbpedia.org/resource/Carbondale,_Illinois">
    <dbpprop:elevationImperial xmlns:dbpprop="http://dbpedia.org/property/"
```

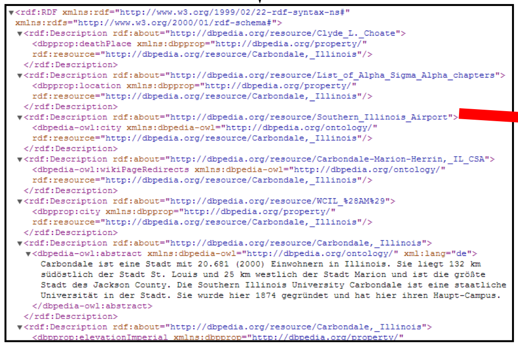
From HTML to RDF

- Separate HTML content and RDF data
- Maintenance problem
  - Both need to be managed separately
  - RDF content and web content have much overlap (redundancy)
  - RDF/XML difficult to author: extra overhead
- Verification problem
  - How to check differences as content changes?
- Visibility problem
  - Easy to ignore the RDF content (out of sight, out of mind)

From HTML to RDF

- Solution: embed RDF into web content using RDFa





```
▼<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
 xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#">
 ▼<rdf:Description rdf:about="http://dbpedia.org/resource/Clyde_L._Choate">
   <dbpprop:deathPlace xmlns:dbpprop="http://dbpedia.org/property/"
   rdf:resource="http://dbpedia.org/resource/Carbondale,_Illinois"/>
  </rdf:Description>
 ▼<rdf:Description rdf:about="http://dbpedia.org/resource/List_of_Alpha_Sigma_Alpha_chapters">
   <dbpprop:location xmlns:dbpprop="http://dbpedia.org/property/"
   rdf:resource="http://dbpedia.org/resource/Carbondale,_Illinois"/>
  </rdf:Description>
 ▼<rdf:Description rdf:about="http://dbpedia.org/resource/Southern_Illinois_Airport">
   <dbpedia-owl:city xmlns:dbpedia-owl="http://dbpedia.org/ontology/"
   rdf:resource="http://dbpedia.org/resource/Carbondale,_Illinois"/>
  </rdf:Description>
 ▼<rdf:Description rdf:about="http://dbpedia.org/resource/Carbondale-Marion-Herrin,_IL_CSA">
   <dbpedia-owl:wikiPageRedirects xmlns:dbpedia-owl="http://dbpedia.org/ontology/"
   rdf:resource="http://dbpedia.org/resource/Carbondale,_Illinois"/>
  </rdf:Description>
 ▼<rdf:Description rdf:about="http://dbpedia.org/resource/WCIL_%28AM%29">
   <dbpprop:city xmlns:dbpprop="http://dbpedia.org/property/"
   rdf:resource="http://dbpedia.org/resource/Carbondale,_Illinois"/>
  </rdf:Description>
 ▼<rdf:Description rdf:about="http://dbpedia.org/resource/Carbondale,_Illinois">
  ▼<dbpedia-owl:abstract xmlns:dbpedia-owl="http://dbpedia.org/ontology/" xml:lang="de">
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   </dbpedia-owl:abstract>
  </rdf:Description>
 ▼<rdf:Description rdf:about="http://dbpedia.org/resource/Carbondale,_Illinois">
   <dbpprop:elevationImperial xmlns:dbpprop="http://dbpedia.org/property/"
```

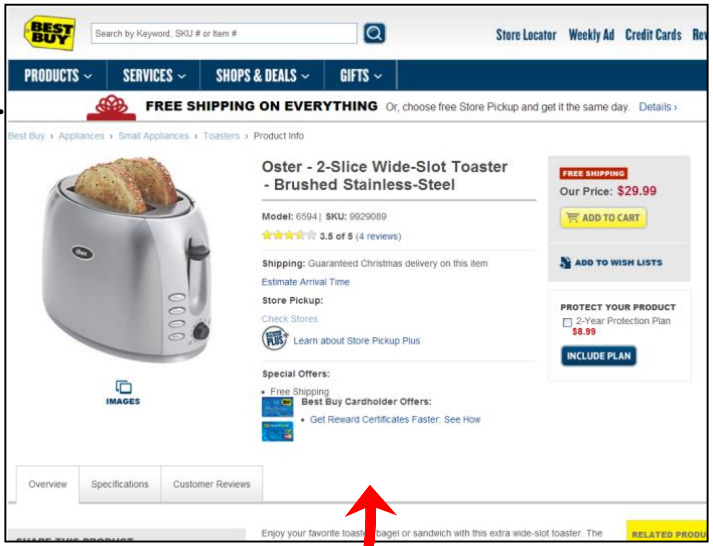

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Model: 6594 | SKU: 9929089

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FREE SHIPPING

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PROTECT YOUR PRODUCT

☐ 2-Year Protection Plan $8.99

Enjoy your favorite toast, bagel or sandwich with this extra wide-slot toaster. The

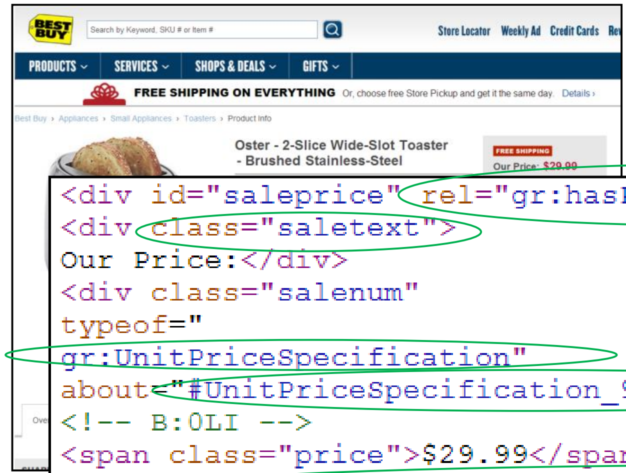
‘Embed’ RDF into HTML

RDFa

- W3C Recommendation (March 17th, 2015)
- RDFa (Resource Description Framework in Attributes) adds a set of attribute-level extensions to HTML5, XHTML and various XML-based document types for embedding rich metadata within Web documents
- The RDF data-model mapping enables its use for embedding RDF subject-predicate-object expressions within XHTML documents. It also enables the extraction of RDF model triples by compliant user agents

RDFa

- Extra (RDFa) markup is ignored by web browsers


BEST BUY
Search by Keyword, SKU # or Item #
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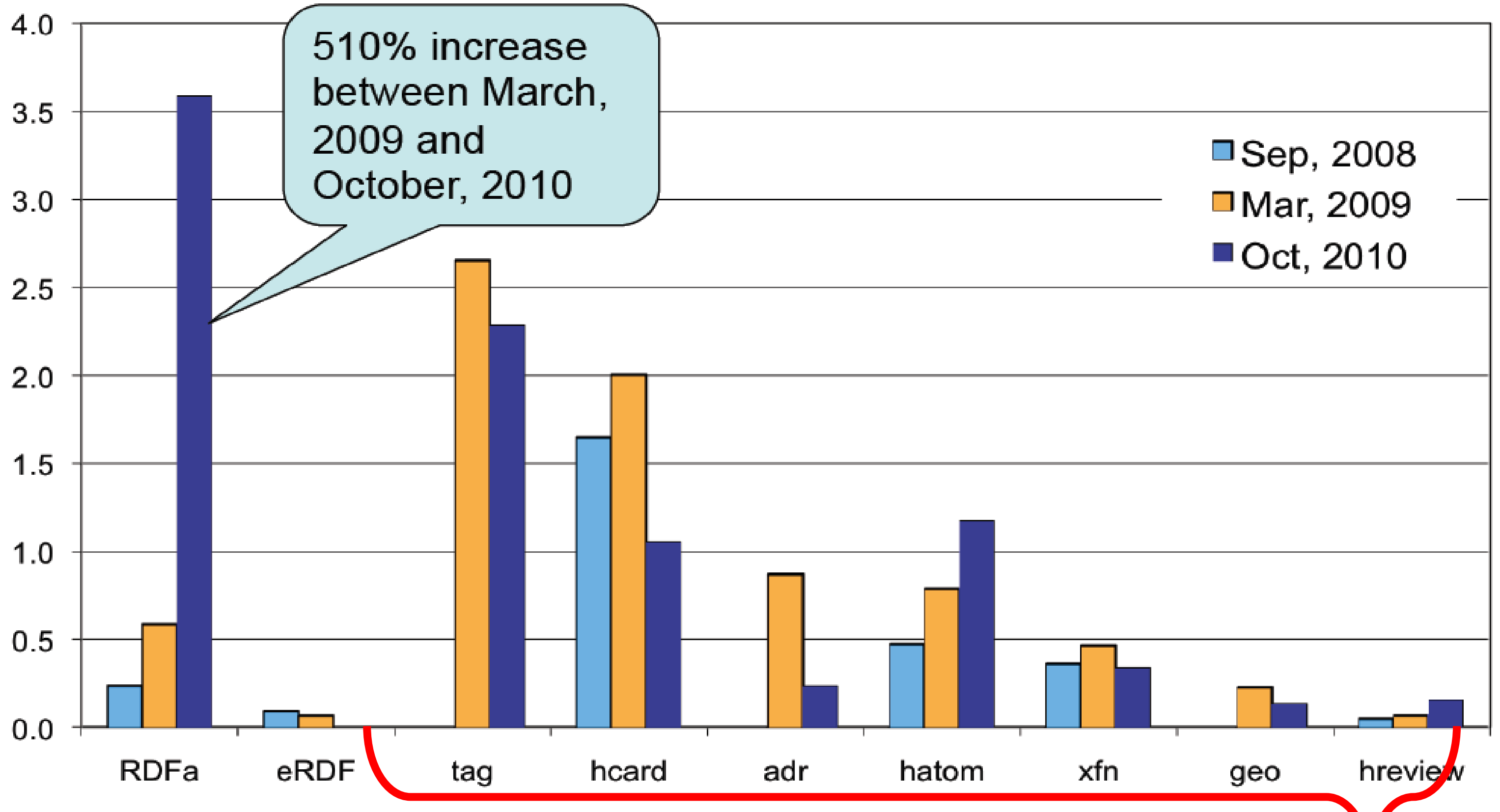
Best Buy › Appliances › Small Appliances › Toasters › Product Info

Oster - 2-Slice Wide-Slot Toaster - Brushed Stainless-Steel

Our Price: $29.99

```
<div id="saleprice" rel="gr:hasPriceSpecification">
<div class="saletext">
Our Price:</div>
<div class="salenum"
typeof="
gr:UnitPriceSpecification"
about="#UnitPriceSpecification_9929089_sale">
<!-- B:OLI -->
<span class="price">$29.99</span>
<span property="gr:hasCurrencyValue" datatype="xsd:float" content="29.99"></span>
<span property="gr:hasCurrency" datatype="xsd:string" content="USD"></span>
<span property="gr:hasUnitOfMeasurement" datatype="xsd:string" content="C62"></span>
<span property="gr:valueAddedTaxIncluded" datatype="xsd:boolean" content="true"></span>
<!-- E:OLI -->
</div>
</div>
```

RDFa is not the only solution …



Percentage of URLs with embedded metadata in various formats

Source: Peter Mika (Yahoo!), RDFa, 2011

microformats

Rich snippets

- Several solutions for embedding semantic data in Web
- Three syntaxes known (by Google) as “rich snippets”
  - Microformats
  - RDFa
  - HTML microdata
- All three are supported by Google, while microdata is the “recommended” syntax

First came microformats

- Microformats emerged around 2005
- Some key principles
  - Start by solving simple, specific problems
  - Design for humans first, machines second
- Wide deployment
  - Used on billions of Web pages
- Formats exist for marking up atom feeds, calendars, addresses and contact info, geo-location, multimedia, news, products, recipes, reviews, resumes, social relationships, etc.

Microformats example

```
<div class="vcard">
  <a class="fn org url"
     href="http://www.commerce.net/">CommerceNet</a>
  <div class="adr">
    <span class="type">Work</span>:
    <div class="street-address">169 University Avenue</div>
    <span class="locality">Palo Alto</span>,
    <abbr class="region"
      title="California">CA</abbr>&nbsp;&nbsp;
    <span class="postal-code">94301</span>
    <div class="country-name">USA</div>
  </div>
  <div class="tel">
    <span class="type">Work</span> +1-650-289-4040
  </div>
  <div>Email:
    <span class="email">info@commerce.net</span>
  </div>
</div>
```

Then came RDFa

- RDFa aims to bridge the gap between human oriented HTML and machine-oriented RDF documents
- Provides XHTML attributes to indicate machine understandable information
- Uses the RDF data model, and Semantic Web vocabularies directly

Last but not least, microdata

- Microdata syntax is based on nested groups of name-value pairs
- HTML microdata specification includes
  - An unambiguous parsing model
  - An algorithm to convert microdata to RDF
- Compatible with the Semantic Web via mappings

Microdata example

```
<div itemscope itemtype="http://schema.org/Movie">
  <h1 itemprop="name"&g;Avatar</h1>
  <div itemprop="director" itemscope
    itemtype="http://schema.org/Person"> Director:
    <span itemprop="name">James Cameron</span>(born
    <span itemprop="birthDate">August 16, 1954)</span>
  </div>
  <span itemprop="genre">Science fiction</span>
  <a href="../movies/avatar-theatrical-trailer.html"
    itemprop="trailer">Trailer</a>
</div>
```

GRDDL: from XML to RDF

- GRDDL is a mechanism for Gleaning Resource Descriptions from Dialects of Languages
- GRDDL specification introduces markup based on existing standards for declaring that an XML document includes data compatible with the Resource Description Framework (RDF) and for linking to algorithms (typically represented in XSLT), for extracting this data from the document

References

- W3C Semantic Web
  - https://www.w3.org/standards/semanticweb/
- B. DuCharme, “Learning SPARQL – 2nd edition”, O’Reilly Media
- http://www.cambridgesemantics.com/semantic-university/sparql-by-example
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