The Semantic Web

DEFINITIONS & APPLICATIONS

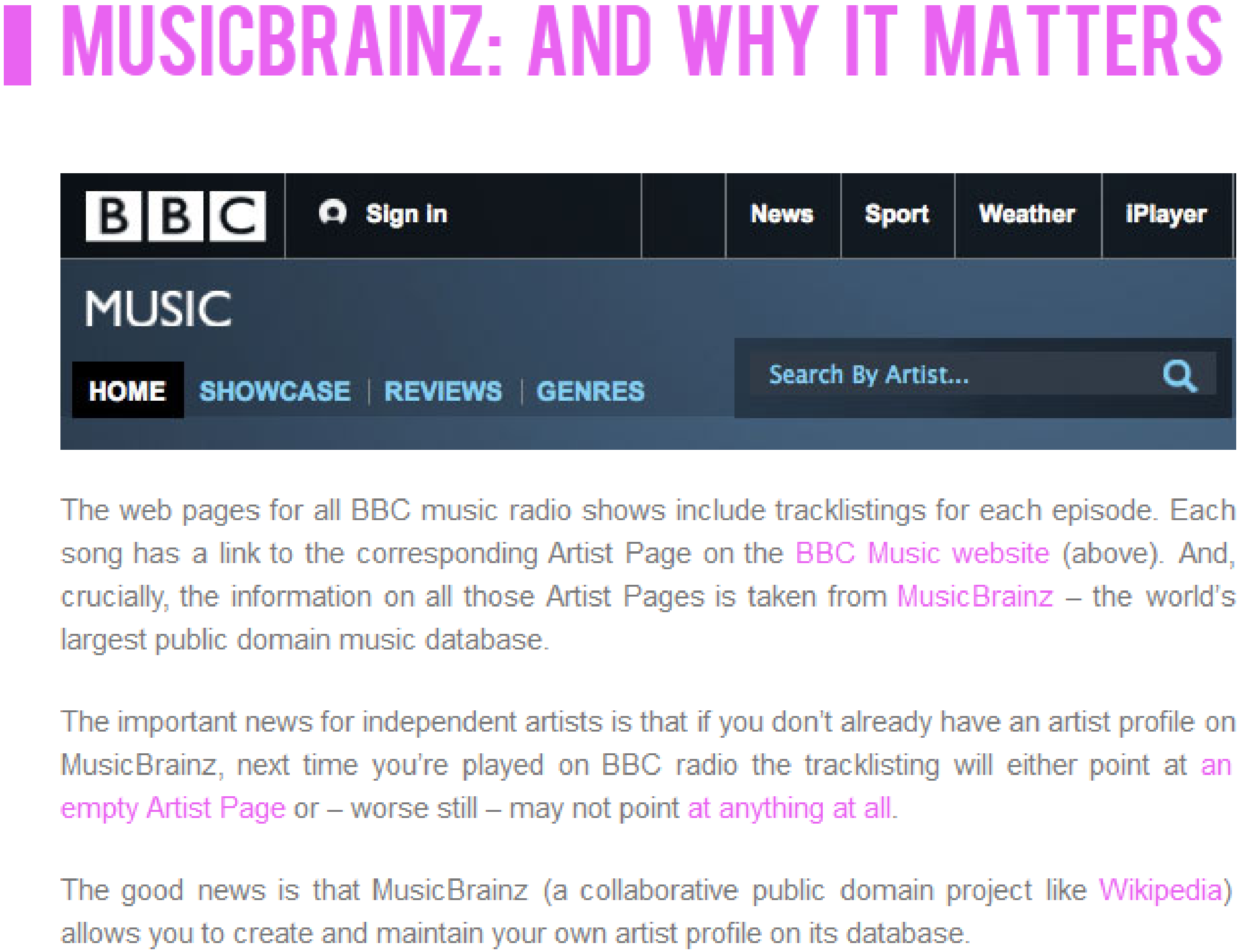
POLITECNICO
DI TORINO

e-Lite

Data on the Web

- There are more an more data on the Web
  - Government data, health related data, general knowledge, company information, flight information, restaurants,…
  - This is evident!!!
- More and more applications rely on the availability of that data
  - Is that equally evident?
  - Let’ s consider an example…

An example



MUSICBRAINZ: AND WHY IT MATTERS

The web pages for all BBC music radio shows include tracklistings for each episode. Each song has a link to the corresponding Artist Page on the BBC Music website (above). And, crucially, the information on all those Artist Pages is taken from MusicBrainz – the world's largest public domain music database.

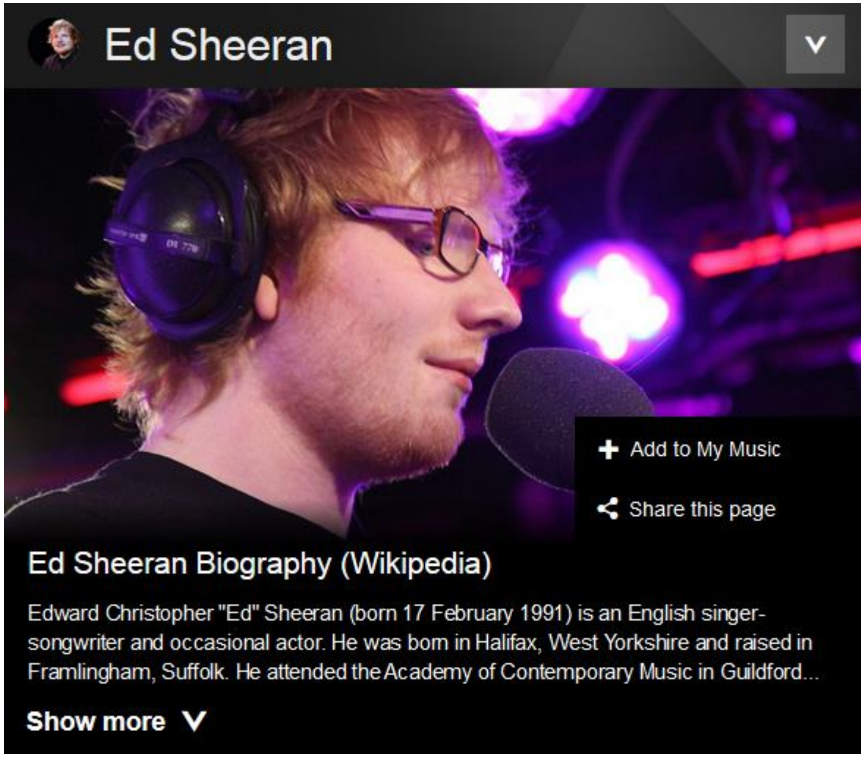
The important news for independent artists is that if you don't already have an artist profile on MusicBrainz, next time you're played on BBC radio the tracklisting will either point at an empty Artist Page or – worse still – may not point at anything at all.

The good news is that MusicBrainz (a collaborative public domain project like Wikipedia) allows you to create and maintain your own artist profile on its database.

http://freshonthenet.co.uk/musicbrainz/

How to build a music site (1)

- Site editors search the Web for new facts
  - May discover further links while searching
- They update the site manually
- And the site gets soon out-of-date



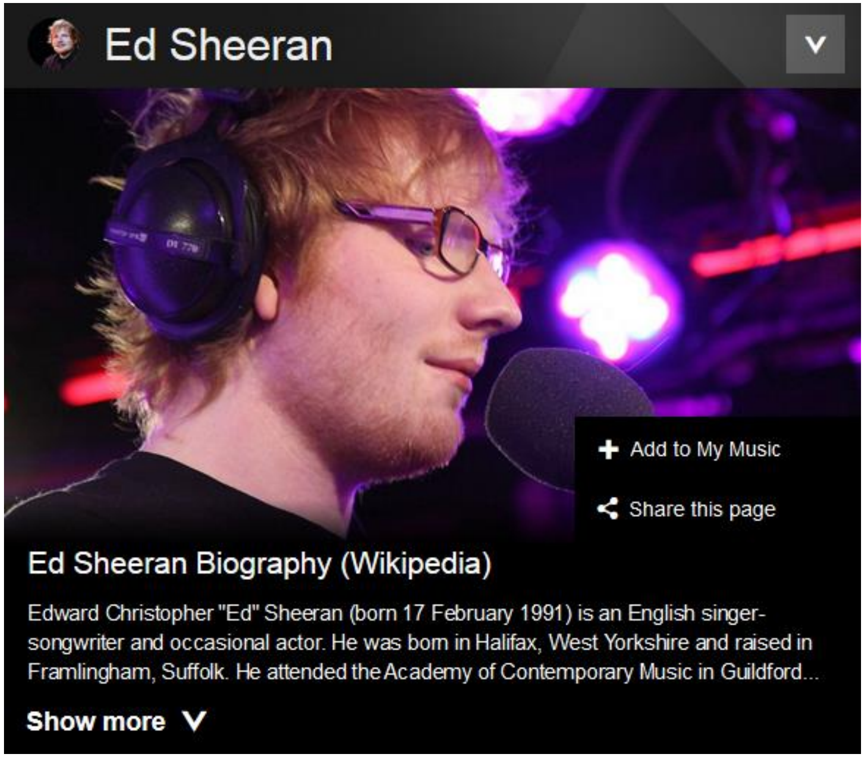
Ed Sheeran Biography (Wikipedia)

Edward Christopher "Ed" Sheeran (born 17 February 1991) is an English singer-songwriter and occasional actor. He was born in Halifax, West Yorkshire and raised in Framlingham, Suffolk. He attended the Academy of Contemporary Music in Guildford...

http://www.bbc.co.uk/music

How to build a music site (2)

- Editors search the Web for new data published on Web sites
- They “scrape” the sites with a program to extract the information
  - i.e., write some code to incorporate the new data
- Easily get out of date again…



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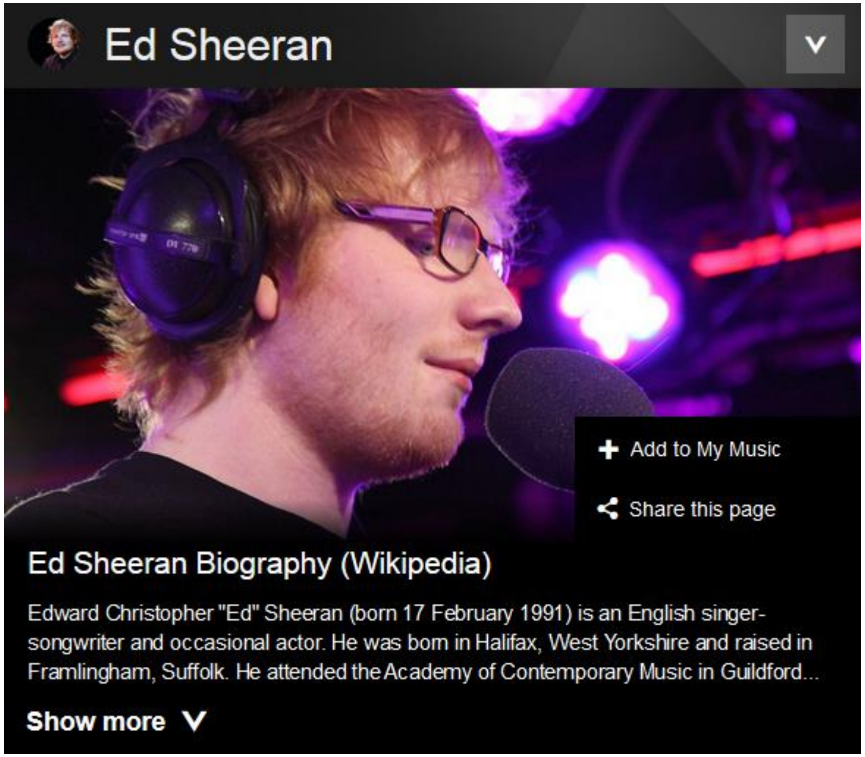
How to build a music site (3)

- Editors search the Web for new data via APIs
- They understand …
  - input, output, arguments, datatypes, …
- They write some code to incorporate the new data
- Easily get out of date again…



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The choice of the BBC

- Use external, public datasets
  - Wikipedia, MusicBrainz, …
- They are available as data
  - not APIs or hidden on a Web site
  - data can be extracted using, e.g., HTTP requests or standard queries
- In short …
  - Use the Web of data as a content management system
  - Use the community at large as content editors

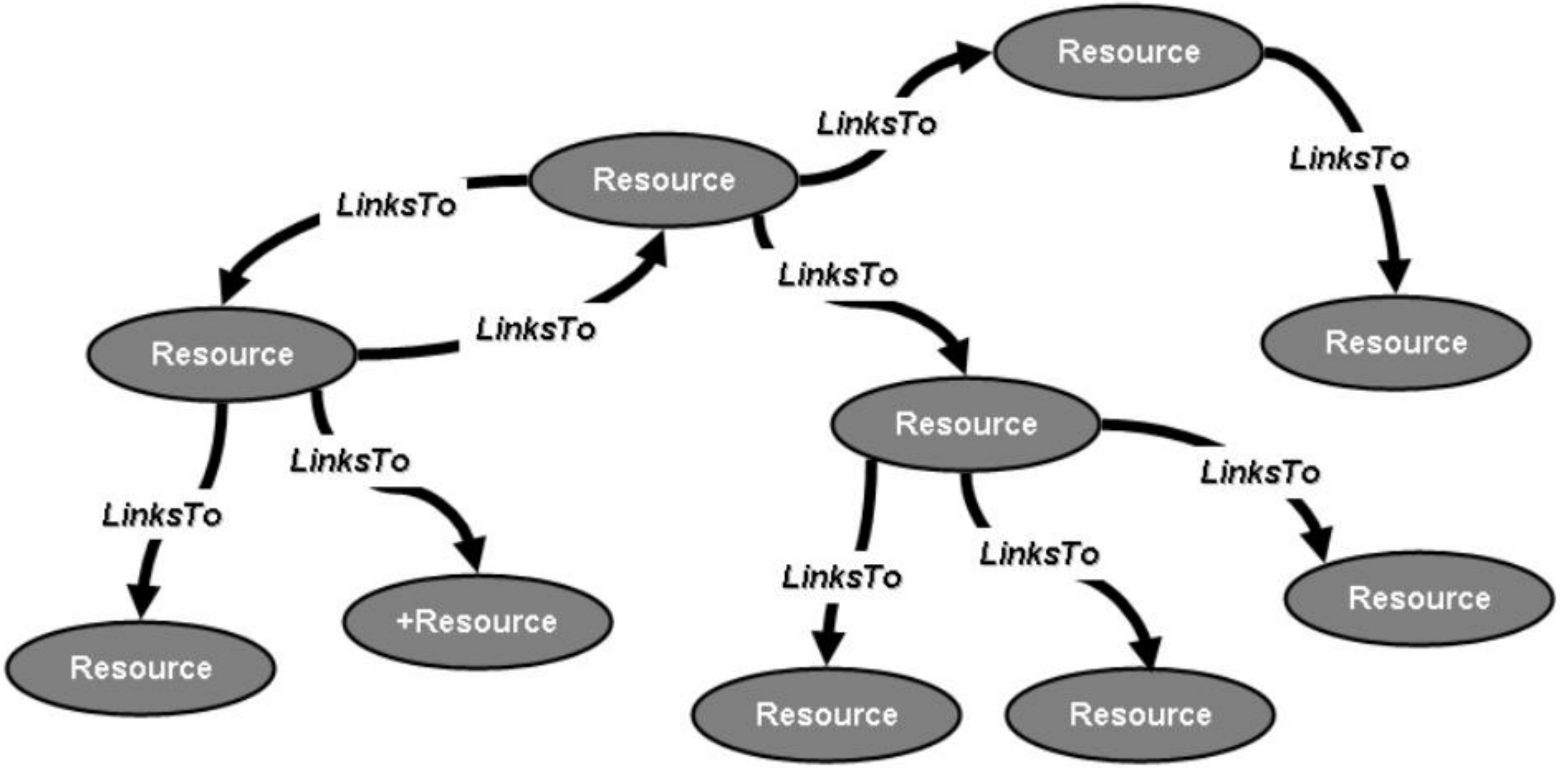
Data on the Web

- We need a proper infrastructure for a real Web of data
  - Data is available on the Web, and accessible via standard Web technologies
  - Data are interlinked over the Web: i.e., data can be integrated over the Web
- This is the role of the Semantic Web technologies

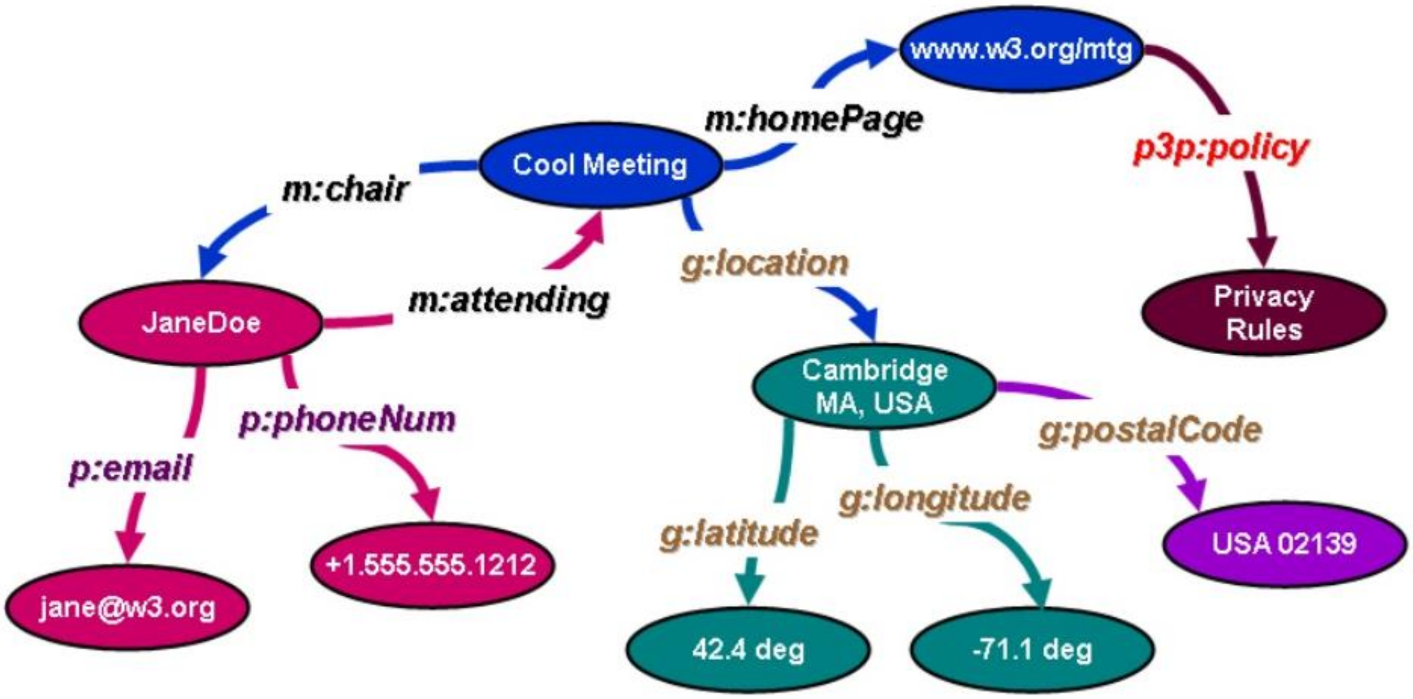
Definition

- The Semantic Web is a Web of linked data
  - dates and titles and numbers and chemical properties and any other data one might conceive of
- The ultimate goal of the Web of data is to enable computers to do more useful work and to develop systems that can support trusted interactions over the network
  - Web information must be machine-readable
- Semantic Web technologies enable people to create data stores on the Web, build vocabularies, and write rules for handling data

The Web is about documents

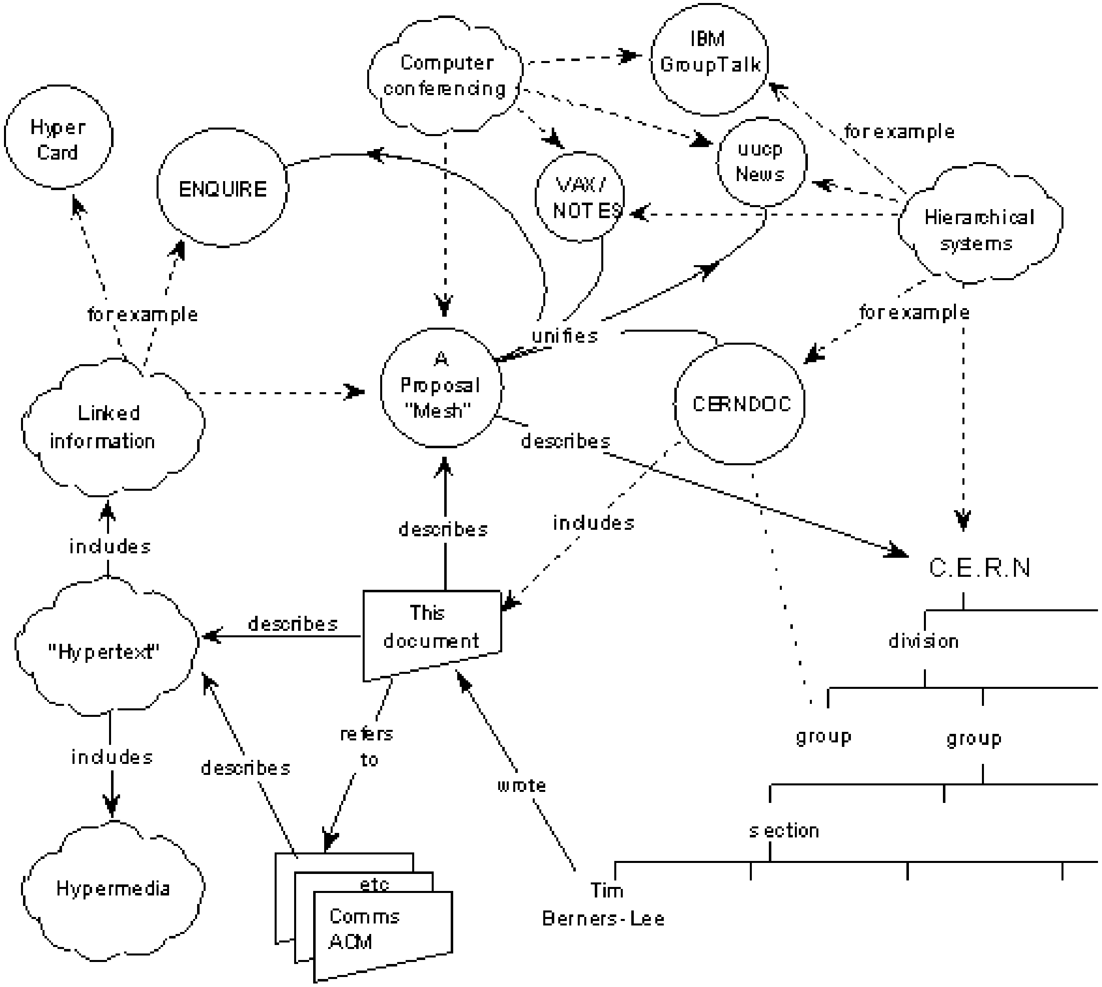


The Semantic Web is about “things”



A curiosity

- The original Web concept (1989)

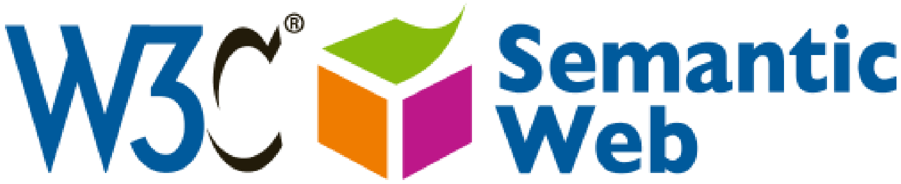


What is the Semantic Web?

- It’s a collection of standard technologies to realize a Web of Data
- It looks simple, but the devil is in the details
  - A common model has to be provided for machines to describe, query, …, the data and their connections
  - The “classification” of the terms can become very complex for specific knowledge areas: this is where ontologies, thesauri, …, enter the game

W3C GRDDL
W3C OWL
W3C SKOS
W3C POWDER
W3C RDFa
W3C SPARQL
W3C RDF

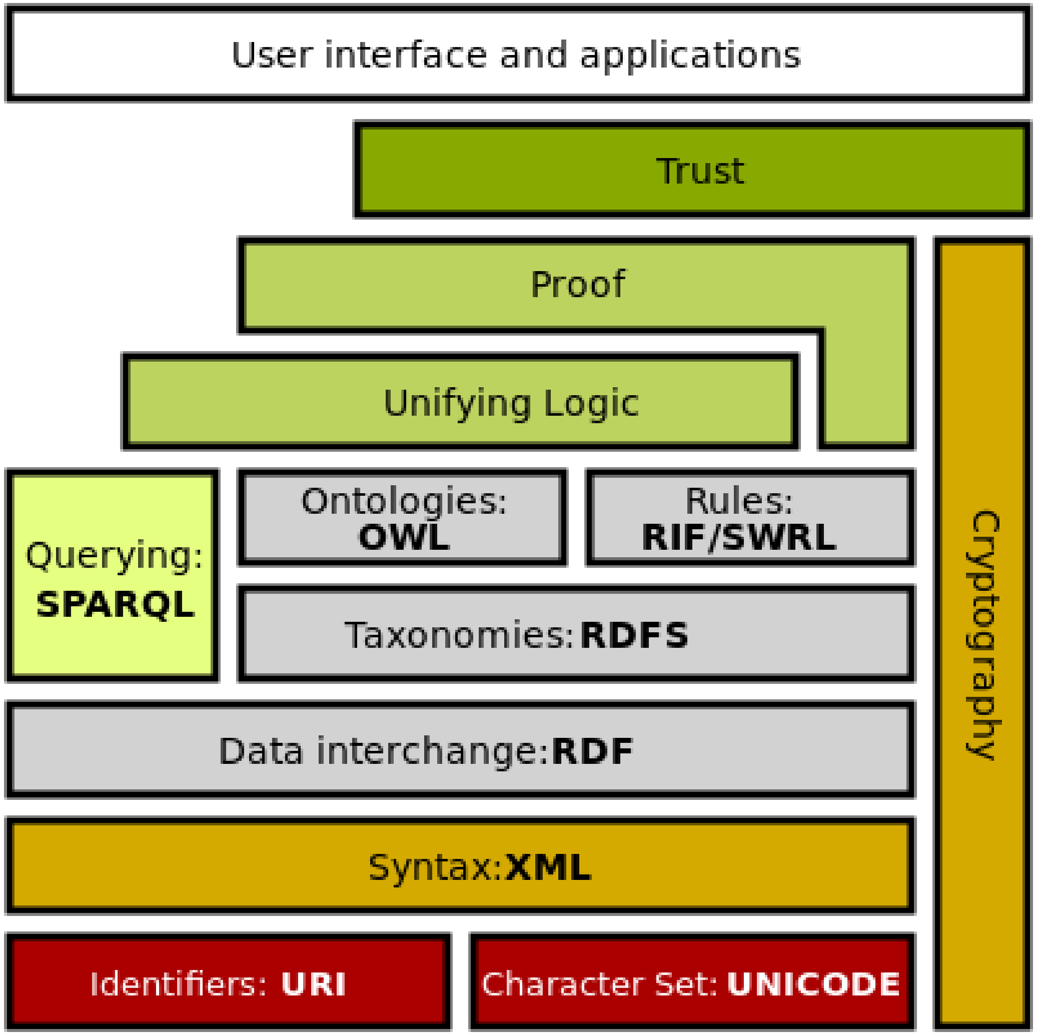
The W3C logo



- The three sides of the tri-color cube in the logo evoke the triplet of the RDF model
- The peeled back lid invites you to Open Your Data to the Semantic Web!

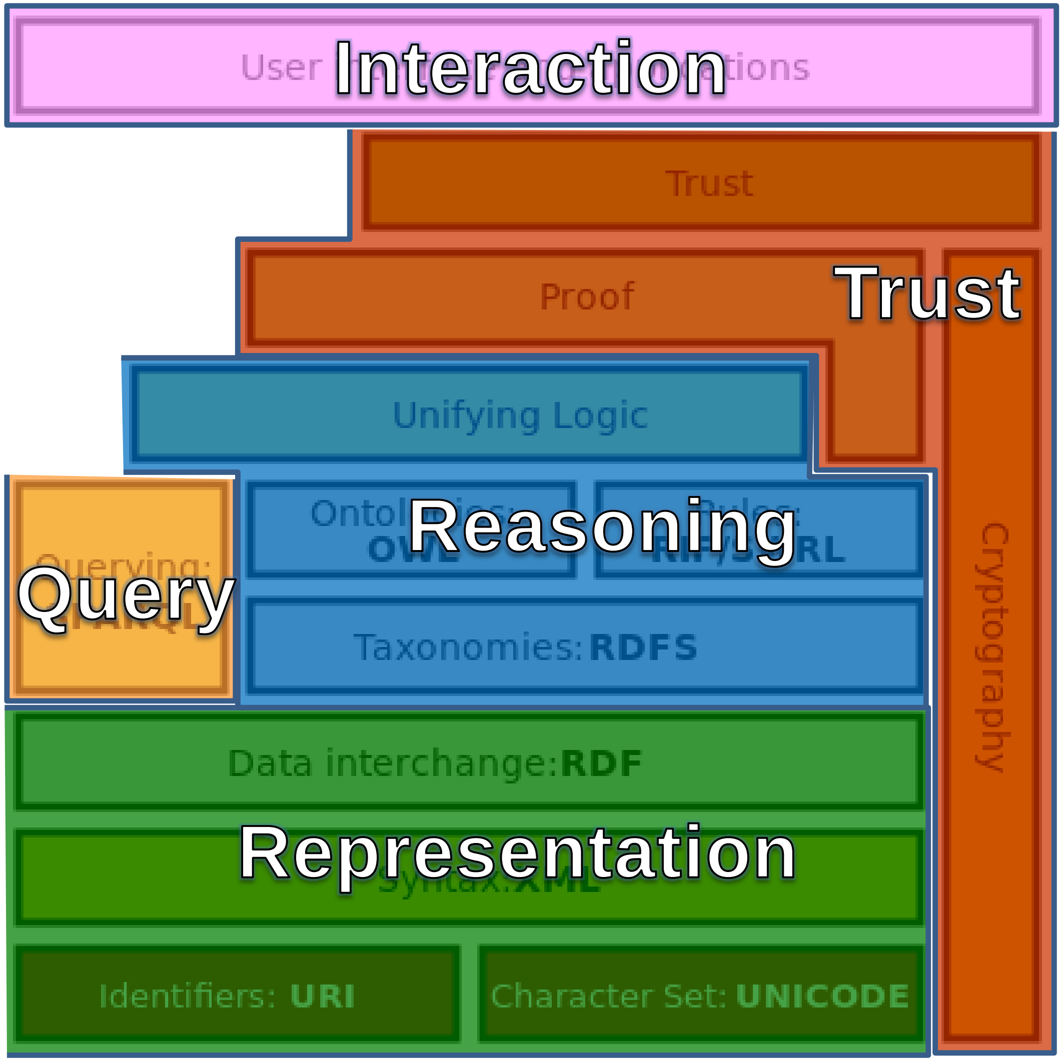
Semantic Web components

- The Semantic Web standard stack



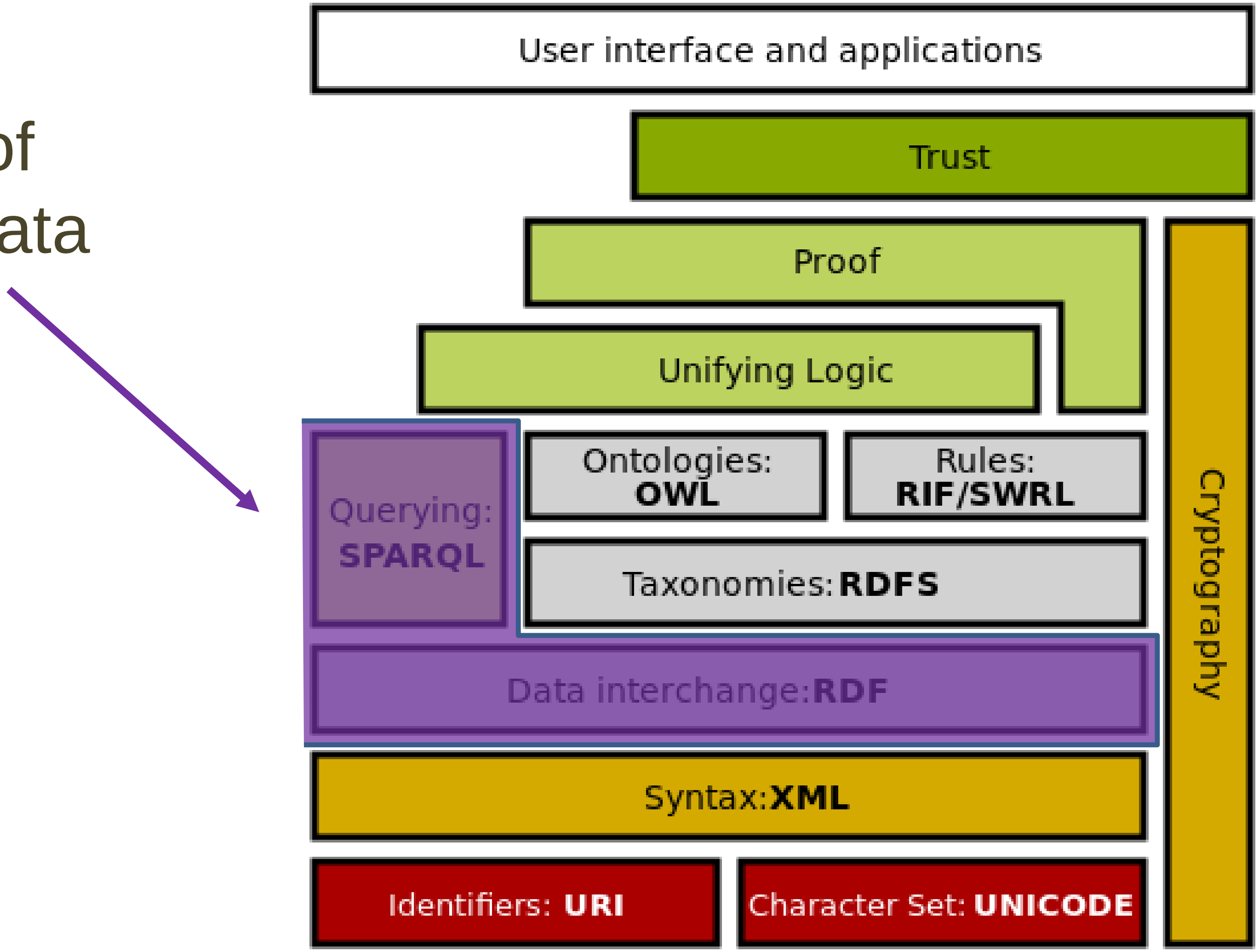
Semantic Web components

- We don’t have yet standard solutions for trust



Semantic Web components

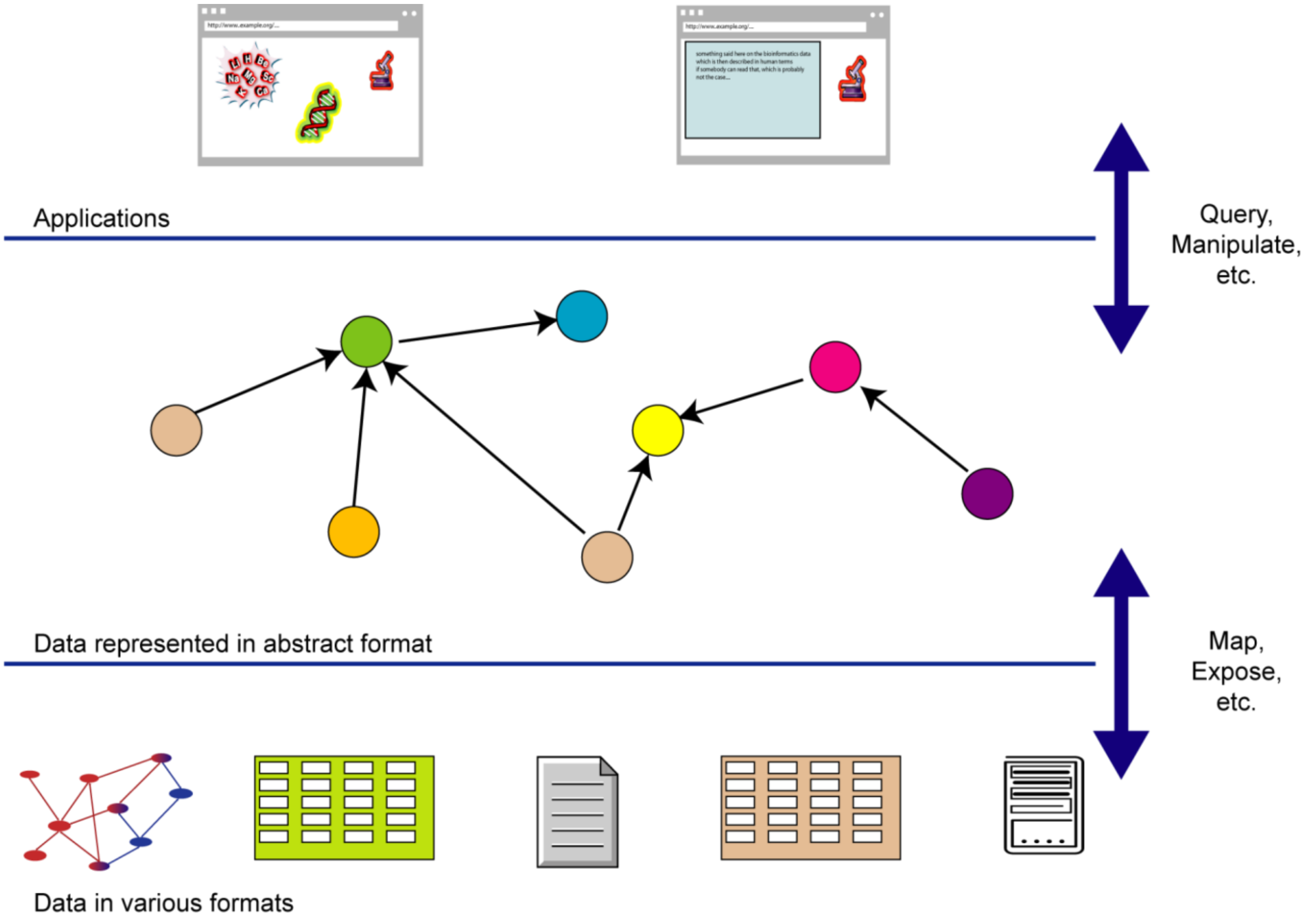
- A Web of linked data

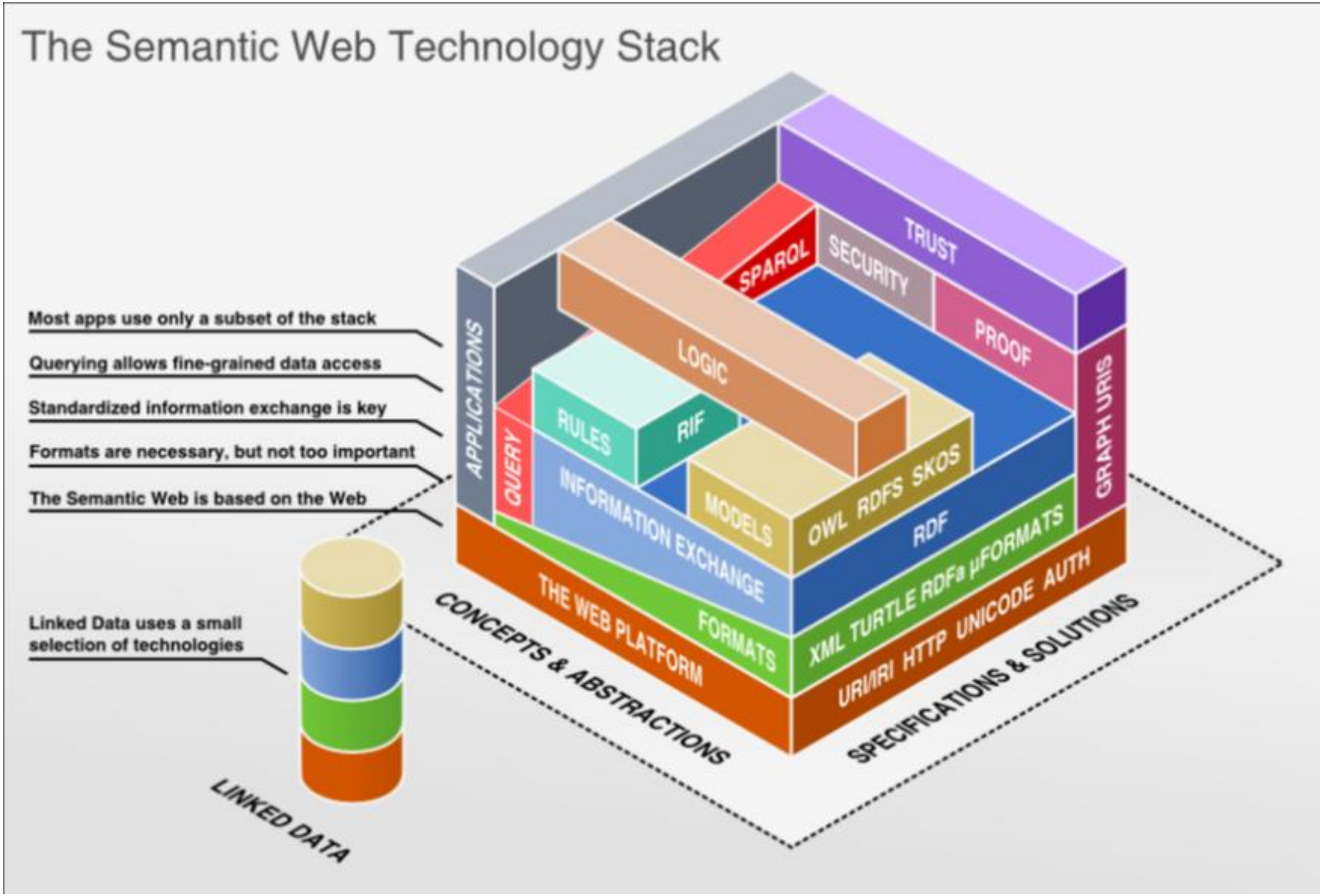


To summarize… Semantic Web is

- A common set of technologies
  - ...enables diverse uses
  - ...encourages interoperability
- A coherent set of technologies
  - …encourage incremental application
  - …provide a substantial base for innovation
- A standard set of technologies
  - ...reduces proprietary vendor lock-in
  - ...encourages many choices for tool sets

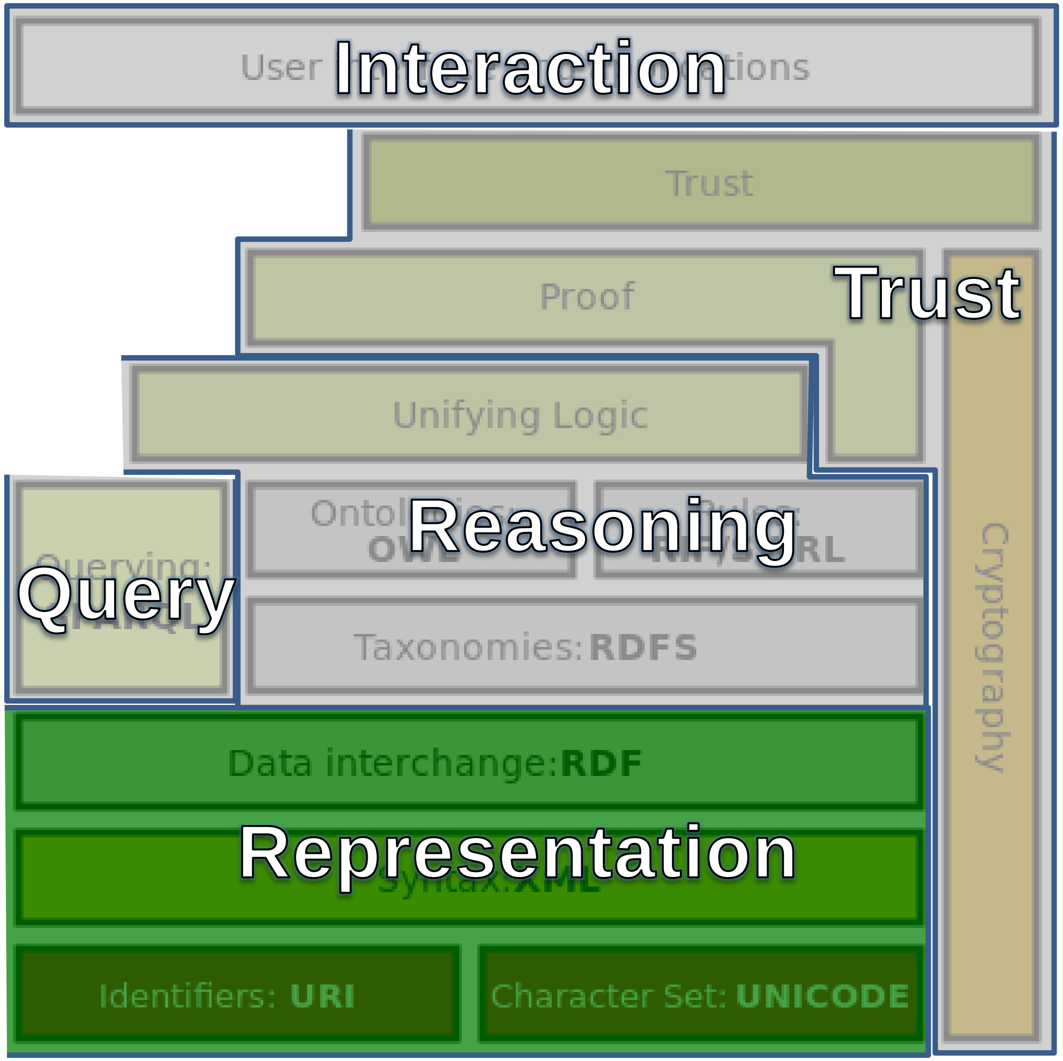
What do Semantic Web solutions look like?


http://www.example.org/...
Li H Be Na Mg Sc K Ca
http://www.example.org/...
something said here on the bioinformatics data which is then described in human terms if somebody can read that, which is probably not the case...
Applications
Query, Manipulate, etc.
Data represented in abstract format
Map, Expose, etc.
Data in various formats


The Semantic Web Technology Stack
Most apps use only a subset of the stack
Querying allows fine-grained data access
Standardized information exchange is key
Formats are necessary, but not too important
The Semantic Web is based on the Web
Linked Data uses a small selection of technologies
LINKED DATA
APPLICATIONS
QUERY
RULES
RIF
LOGIC
SPARQL
SECURITY
TRUST
PROOF
GRAPH URIS
INFORMATION EXCHANGE
MODELS
OWL RDFS SKOS
RDF
FORMATS
XML TURTLE RDFa µFORMATS
THE WEB PLATFORM
URI/IRI HTTP UNICODE AUTH
CONCEPTS & ABSTRACTIONS
SPECIFICATIONS & SOLUTIONS

Step 1: Representation

- The Semantic Web will enable machines to comprehend semantic documents and data, NOT human speech and writing



Metadata

- The Semantic Web foundation

THE TREE
THE DOOR
THE HOUSE
GARB CAN
SHIRT
PANTS
THE DOG
THE CAT

"Now! *That* should clear up a few things around here!"

Resource and description

The title of this resource is "Introduction to the Semantic Web"

This resource was created on January 16th, 2017

The author of this resource is L. Farinetti

This resource is suitable for PhD students

This resource is related to computer science, knowledge representation and metadata

Resource

- Resource
  - Content, format, …
  - Access method dependent on format (I can read it if I "know" its language)
- Standardization (i.e. common language for applications) ???
  - Practically impossible …
  - Huge amount of existing information
  - Hundreds of human languages
  - Hundreds of computer languages (other word for formats)

Description

- Resource description
  - Independent of the format (I can read “people’s comments” about the resource… provided that I know the language in which the comment is written)
- Standardization (i.e. common language for applications) ???
  - Feasible
  - Smaller amount of information, possibly new
  - Solution: define a standard language for writing comments (“metadata” in semantic web terminology)

Resource and description

The title of this resource is "Introduction to the Semantic Web"

This resource was created on January 16th, 2017

Metadata

Field name = field value

The author of this resource is L. Farinetti

This resource is suitable for PhD students

This resource is related to computer science, knowledge representation and metadata

Resource and description

Title = “Introduction to the Semantic Web”

Date = 2017-01-16

Author = L. Farinetti

Audience = PhD students

Topic = {computer science, knowledge representation, metadata}

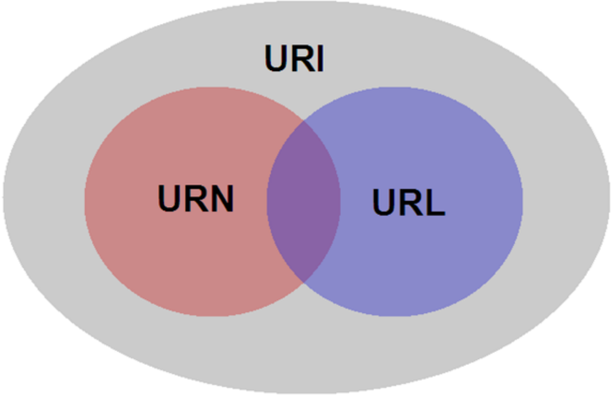
Meaningful metadata annotations

- Common language for describing resources
  - Resource description standards
- Common language for describing field names
  - Metadata standards
- Common language for describing field values
  - Metadata standards + controlled vocabularies
- Semantically rich descriptions to support reasoning
  - Knowledge representation techniques, ontologies

Common language for describing resources

- Resource Description Framework (RDF)
  - Resource = URI (retrievable, or not)
  - RDF is structured in statements
- A statement is a triple
  - Subject – predicate – object
  - Subject: a resource
  - Predicate: a verb / property / relationship
  - Object: a resource, or a literal string
- RDF has several syntaxes (Turtle, N3, …) and XML is one of those, known as RDF/XML
  - XML is a syntax while RDF is a data model

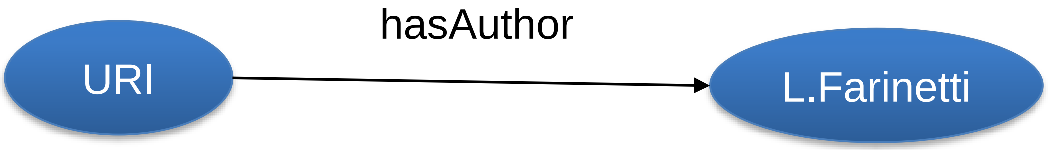
URIs: Uniform Resource Identifiers



- A URI provides a simple and extensible mean for identifying a resource
- A URI can be further classified as a locator (URL), a name (URN), or both
- A URL is a URI that, in addition to identifying a web resource, specifies the means of acting upon or obtaining the representation, specifying both its primary access mechanism and network location
- A URN is a URI that identifies a resource by name in a particular namespace
  - A URN can be used to talk about a resource without implying its location or how to access it

Common language for describing resources

- Diagram



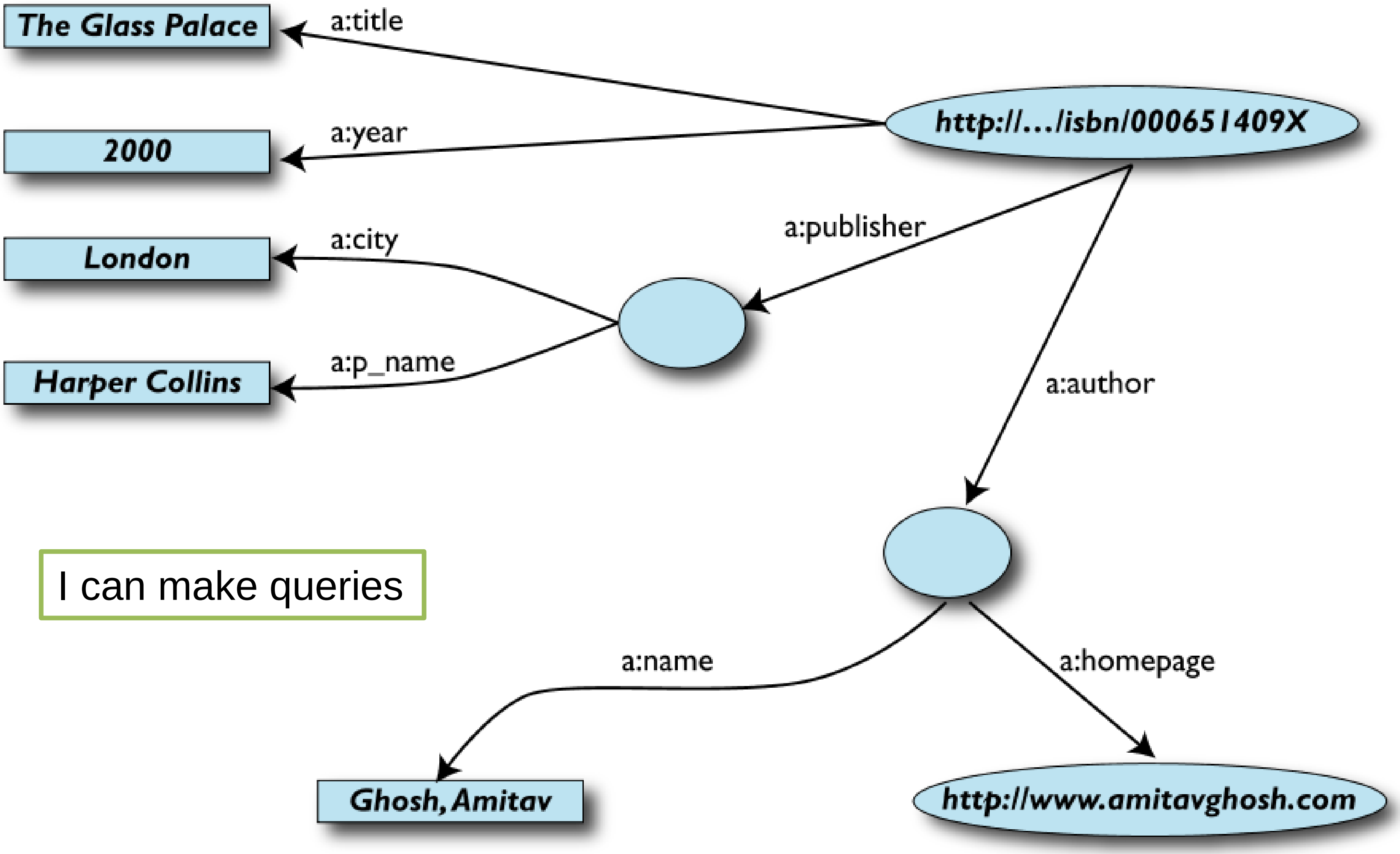
- Simple RDF assertion (triple)

```
triple (hasAuthor, URI, L.Farinetti)
```

- RDF in XML syntax

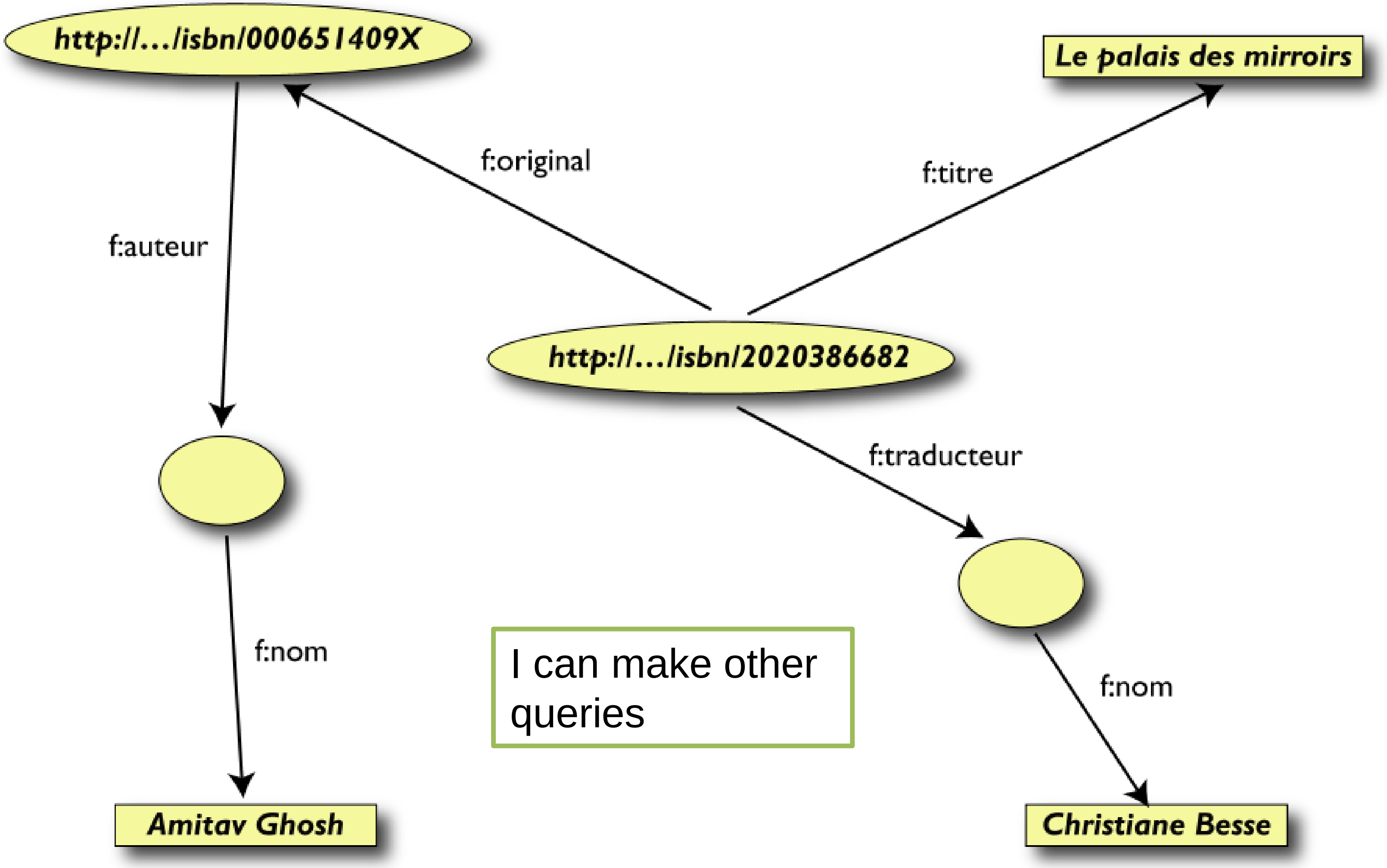
```
<RDF  xmlns="http://www.w3.org/TR/ … " >
  <Description about="http://www.polito.it/semweb/intro">
       <Author>L.Farinetti</Author>
  </Description>
</RDF>
```

A RDF example (1): some statements



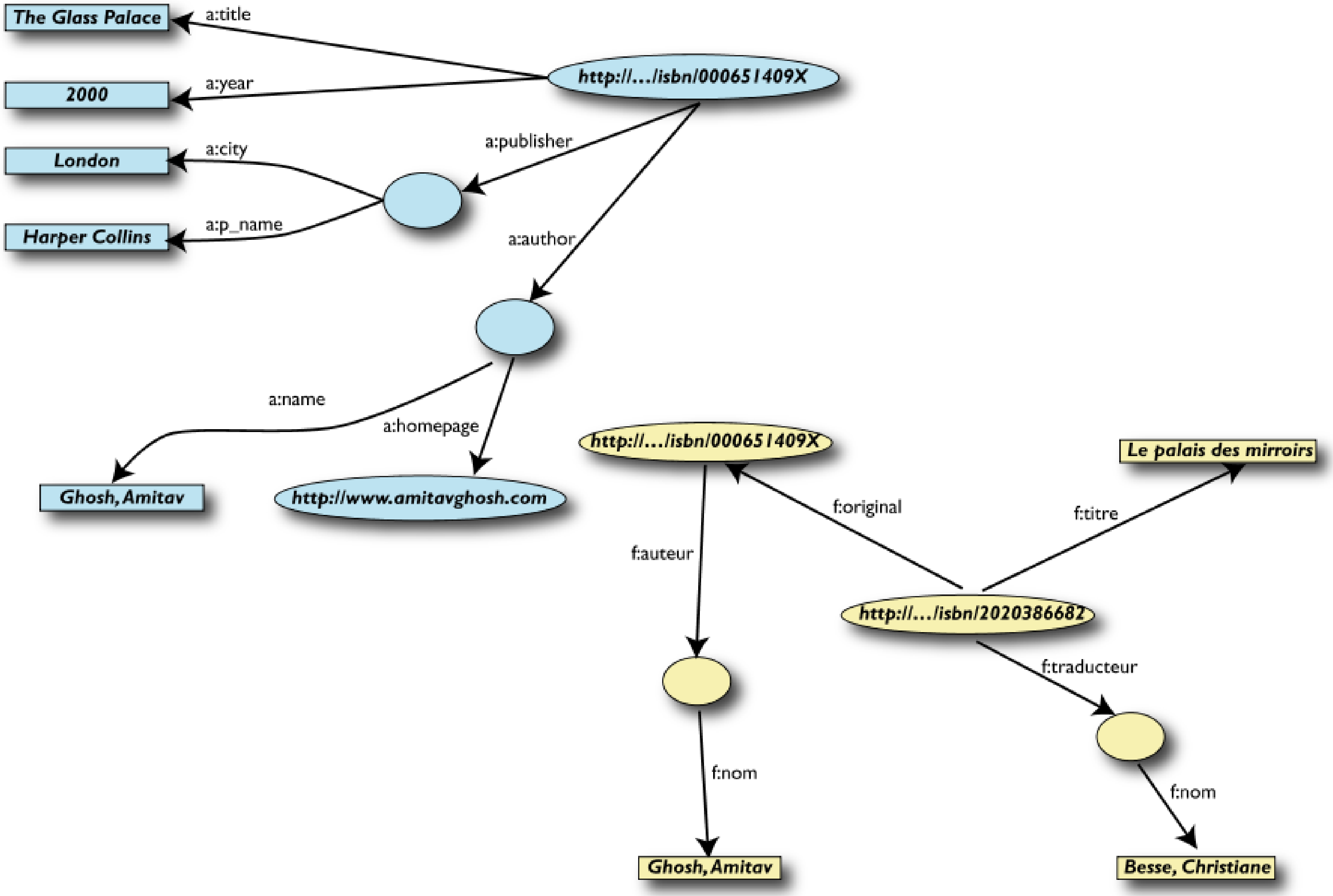
I can make queries

A RDF example (2): other statements

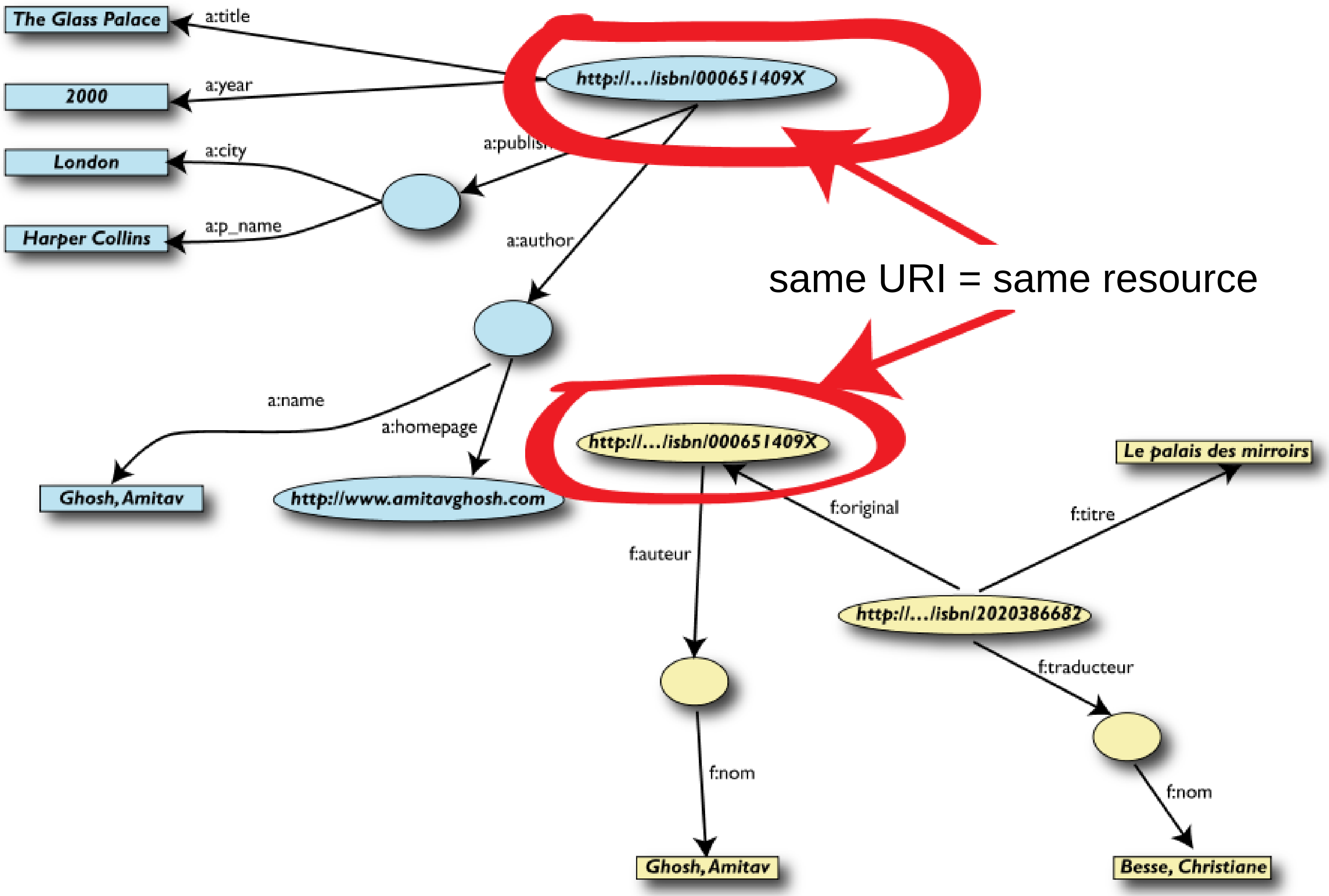


I can make other queries

A RDF example (3): same book!

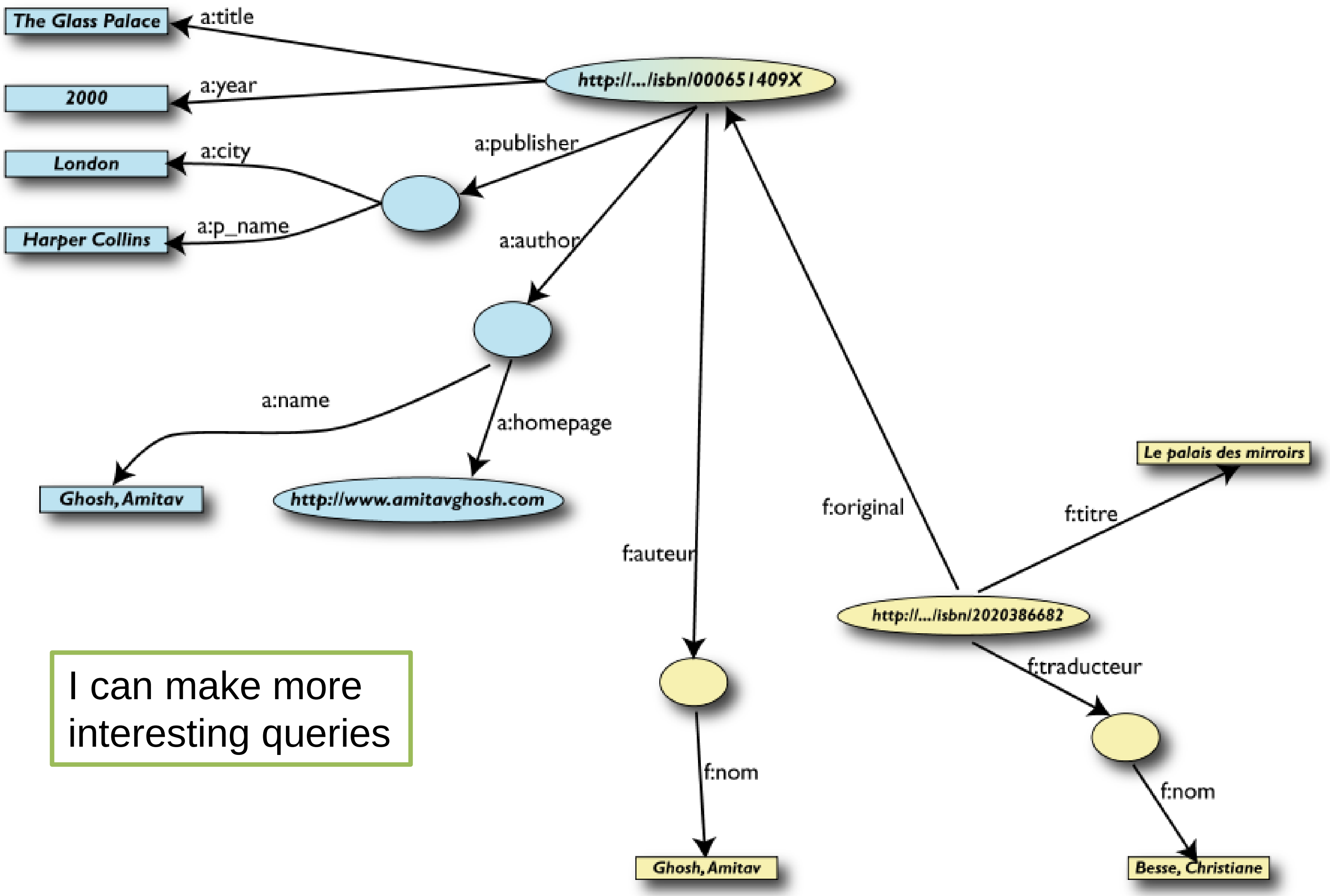


A RDF example (4): same URI



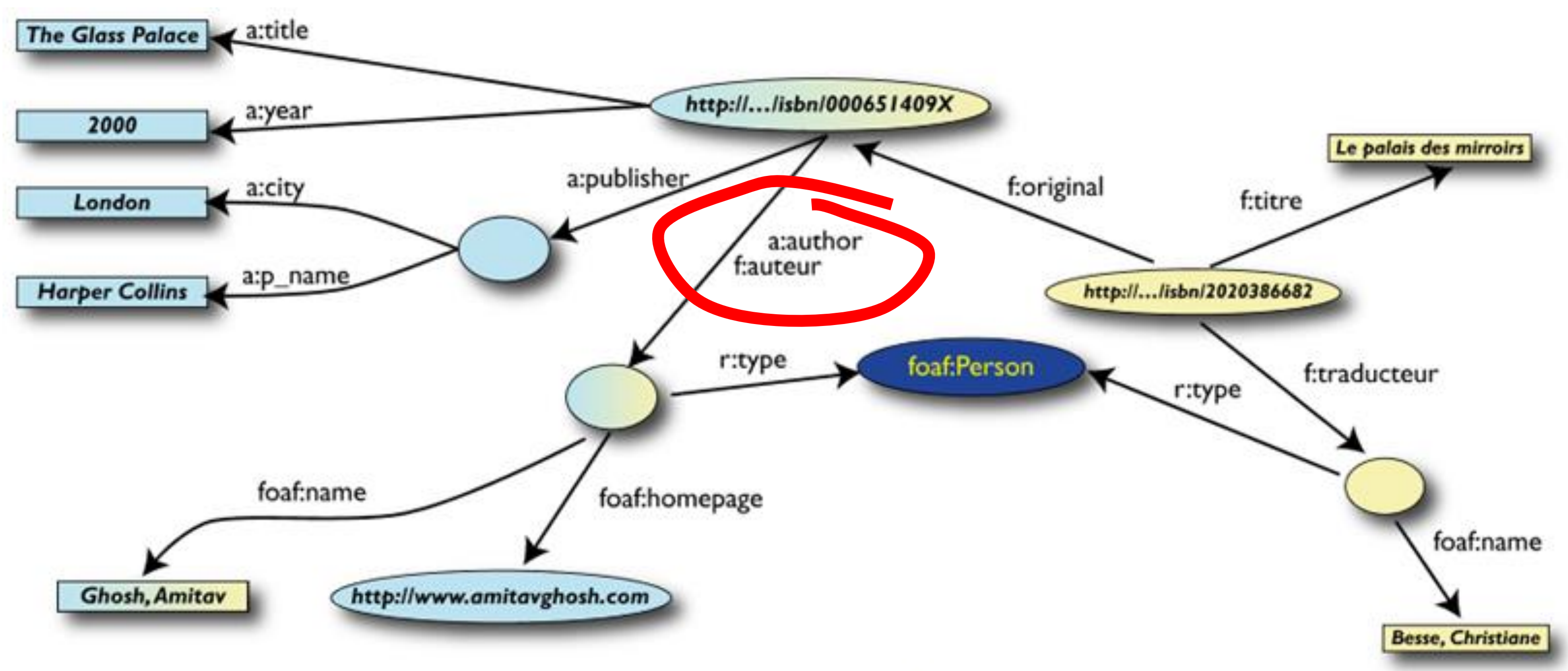
same URI = same resource

A RDF example (5): merge



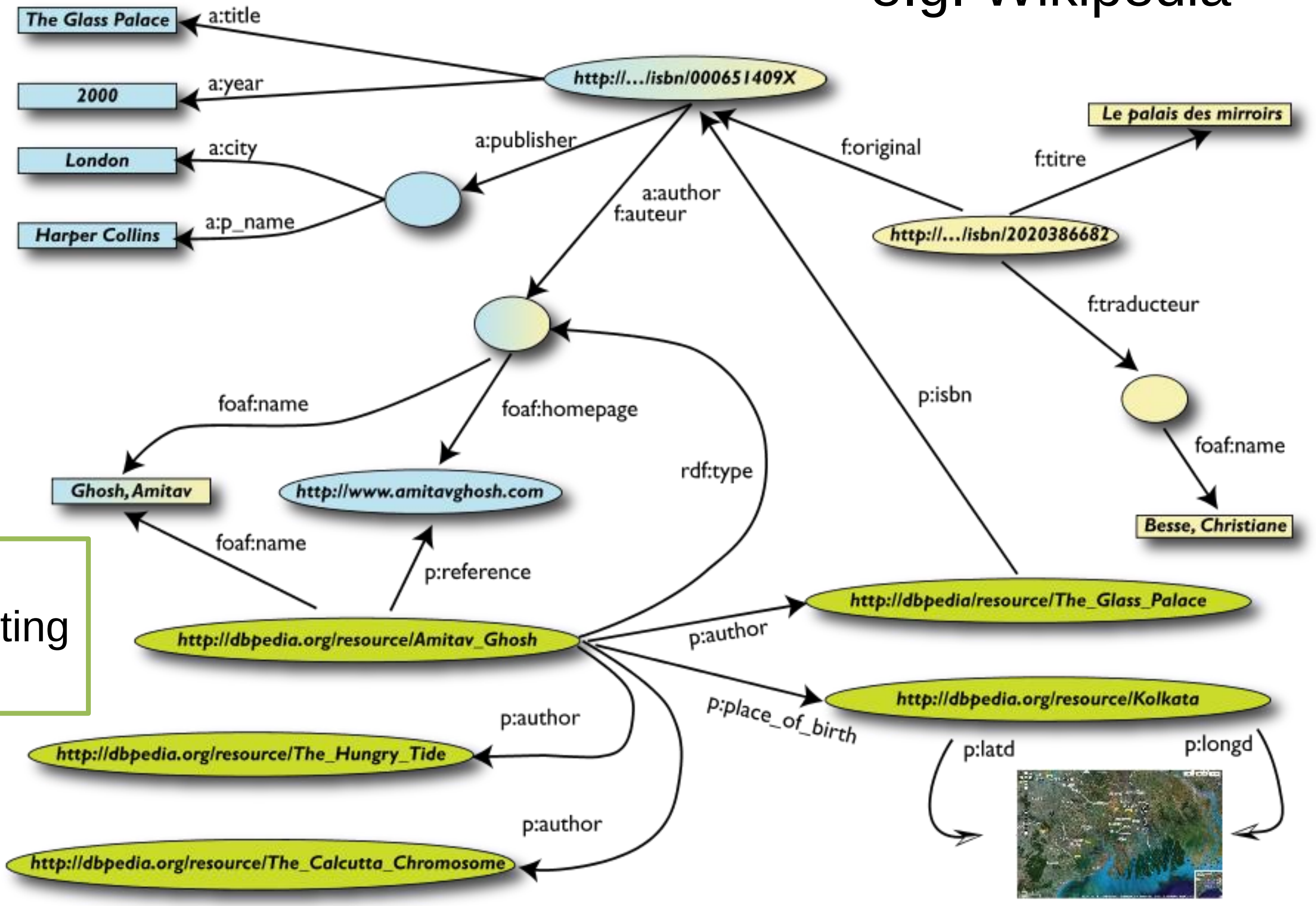
I can make more interesting queries

A RDF example (6): use extra knowledge



A RDF example (7): combine with different dataset

e.g. Wikipedia



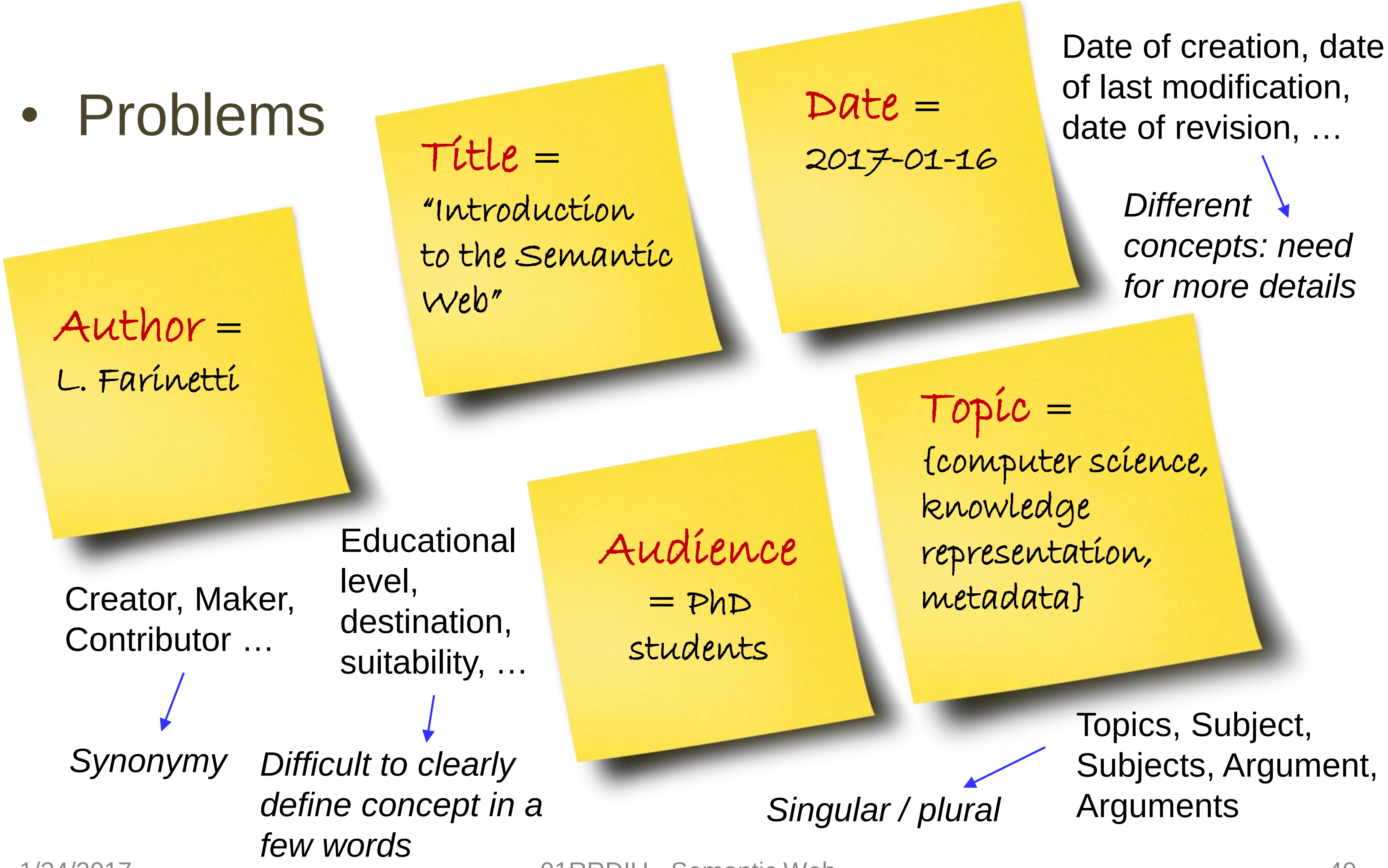
I can make very interesting queries

A RDF example (8): add more "power"

- We could add extra knowledge to the merged datasets
    - e.g., a full classification of various types of library data
    - geographical information
    - …
- This is where ontologies, extra rules, …, come in
    - ontologies/rule sets can be relatively simple and small, or huge, or anything in between…
- Even more powerful queries can be asked as a result

Common language for field names

- Problems



Author = L. Farinetti

Creator, Maker, Contributor …

Synonymy

Title = "Introduction to the Semantic Web"

Educational level, destination, suitability, …

Difficult to clearly define concept in a few words

Audience = PhD students

Date = 2017-01-16

Date of creation, date of last modification, date of revision, …

Different concepts: need for more details

Topic = {computer science, knowledge representation, metadata}

Topics, Subject, Subjects, Argument, Arguments

Singular / plural

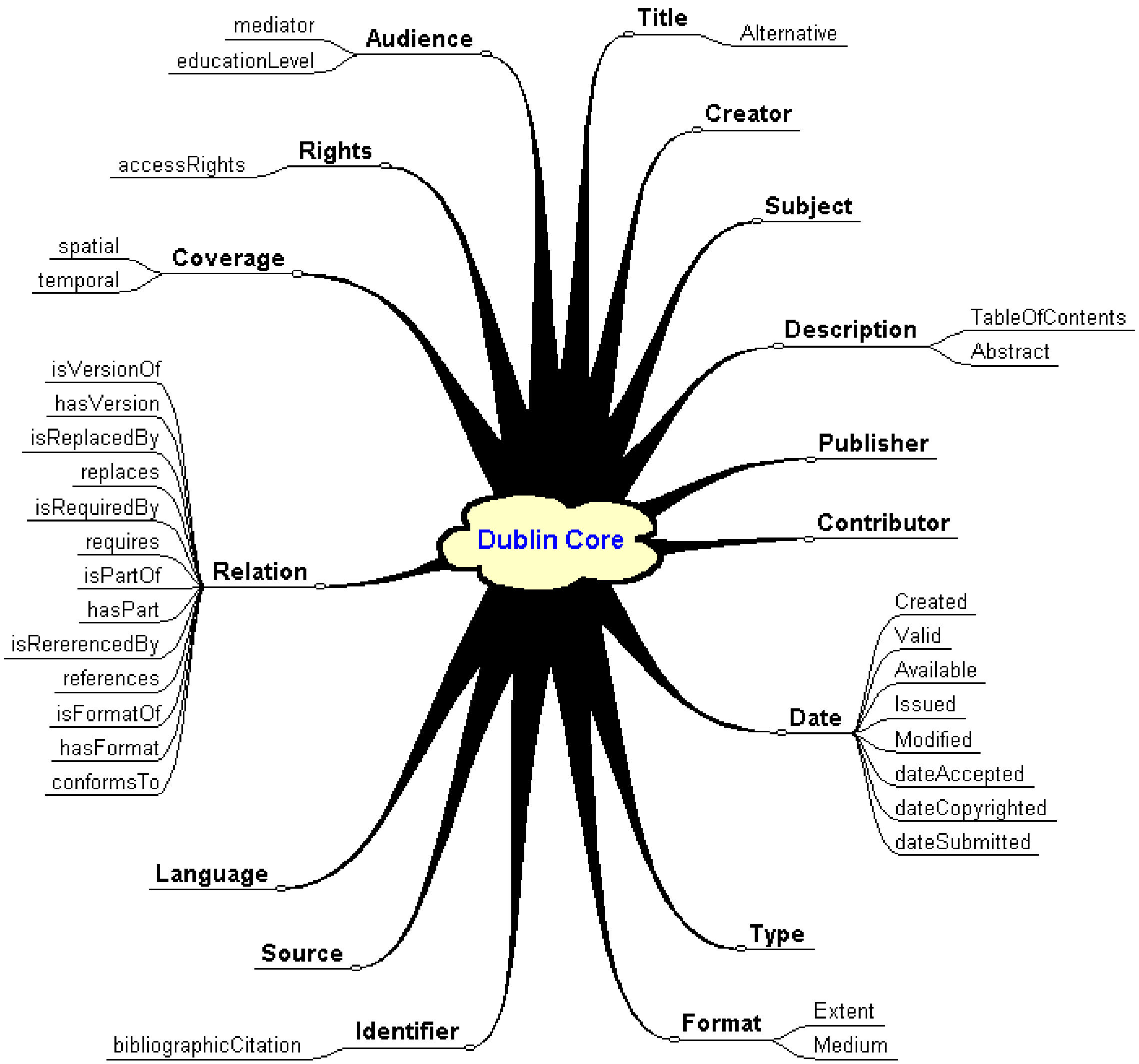
Common language for field names

- Solution: metadata standards
- Many standardization bodies are involved
- Standards may be general …
  - e.g. Dublin Core (DC)
- … or may depend on goal, context, domain, …
  - e. g. educational resources (IEEE LOM), multimedia resources (MPEG-7), images (VRA), people (FOAF, IEEE PAPI), geospatial resources (GSDGM), bibliographical resources (MARC, OAI), cultural heritage resources (CIDOC CRM)

Example: Dublin Core

Dublin Core Metadata Initiative®

Making it easier to find information.



Dublin Core

Title
Alternative

Creator

Subject

Description
TableOfContents
Abstract

Publisher

Contributor

Date
Created
Valid
Available
Issued
Modified
dateAccepted
dateCopyrighted
dateSubmitted

Type

Format
Extent
Medium

Identifier
bibliographicCitation

Source

Language

Relation
isVersionOf
hasVersion
isReplacedBy
replaces
isRequiredBy
requires
isPartOf
hasPart
isRererencedBy
references
isFormatOf
hasFormat
conformsTo

Coverage
spatial
temporal

Rights
accessRights

Audience
mediator
educationLevel

Common language for field values

- Problems
  - Value type

Title = "Introduction to the Semantic Web"

type = string

Date = 2017-01-16

type = date

Author = L. Farinetti

type = string
"standard" format?
Laura Farinetti,
Farinetti Laura,
Farinetti L., …

Common language for field values

- Problems
  - Value type
  - Value restrictions? Freedom vs shared understanding

Audience

= PhD students

any value?
list of possible values?

Topic = {computer science, knowledge representation, metadata}

any value?
any number of values?

Quality

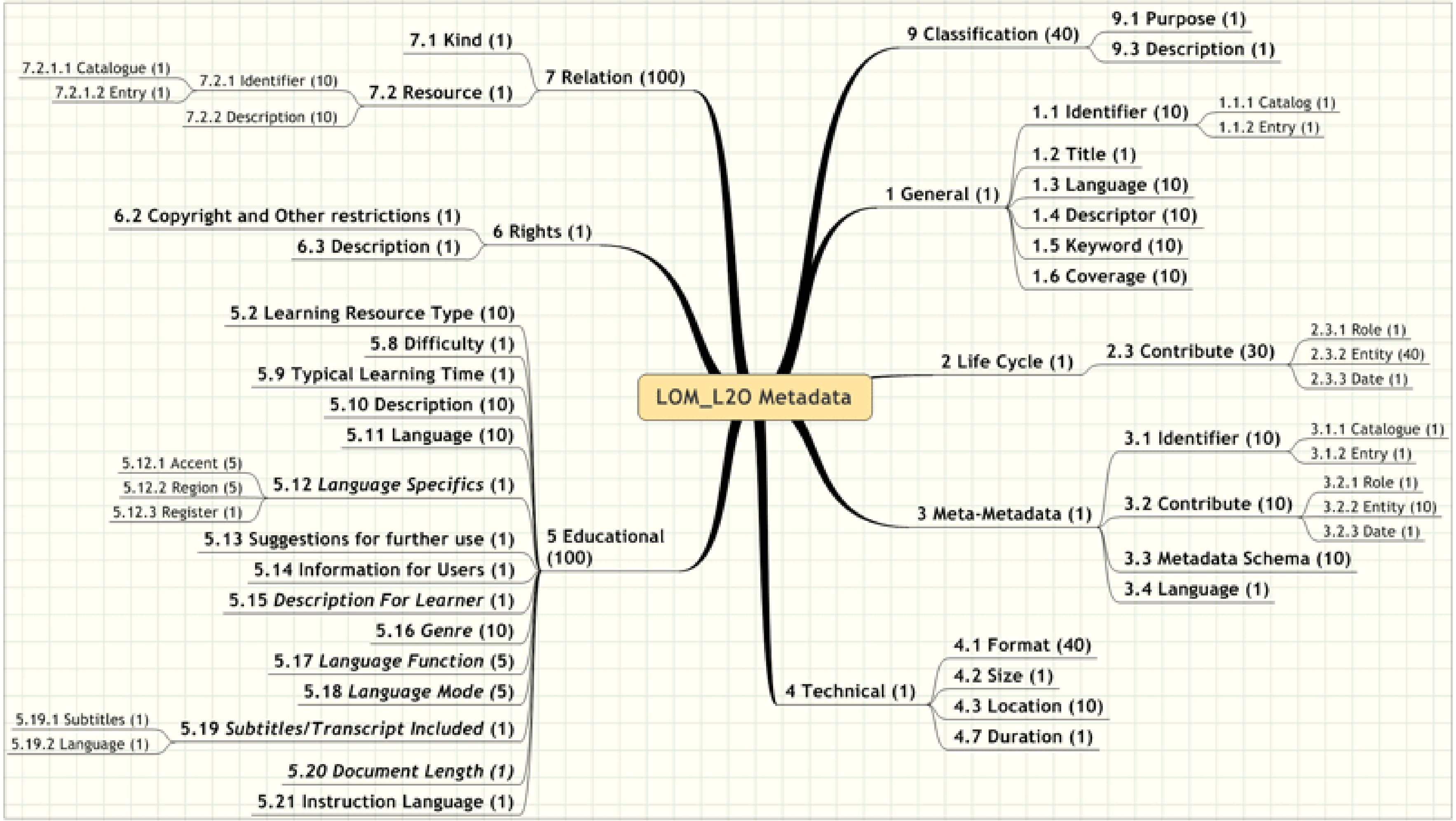
= high

High, medium, low?
1 to 5?
any value?

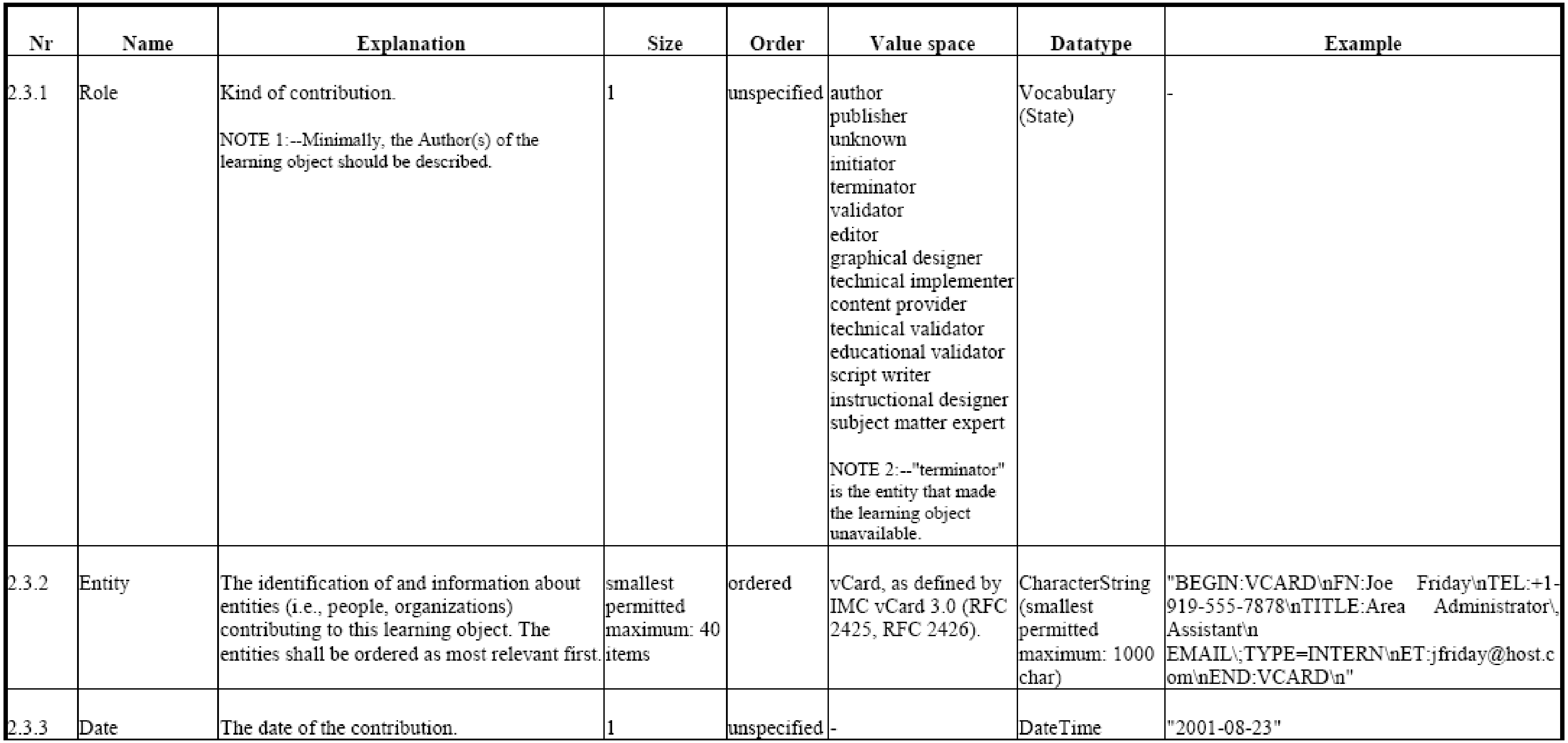
Common language for field values

- Solution: metadata standards + controlled vocabularies
- Metadata standards
  - Only some, and partially
- Controlled vocabularies
  - Explicit list of possible values

Example: IEEE LOM



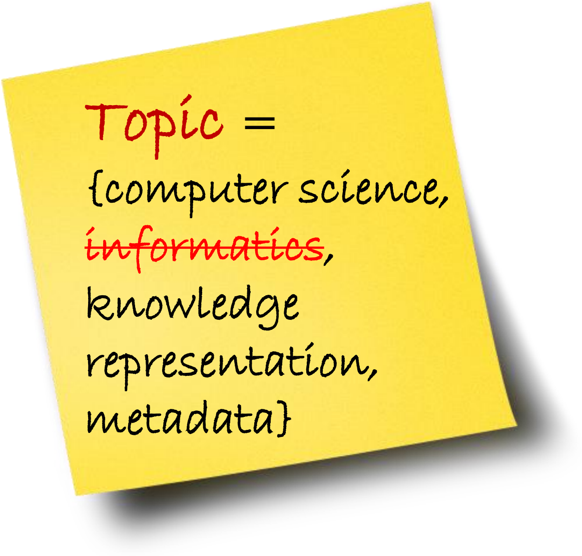
Example: IEEE LOM



Nr	Name	Explanation	Size	Order	Value space	Datatype	Example
2.3.1	Role	Kind of contribution. NOTE 1:--Minimally, the Author(s) of the learning object should be described.	1	unspecified	author publisher unknown initiator terminator validator editor graphical designer technical implementer content provider technical validator educational validator script writer instructional designer subject matter expert NOTE 2:--"terminator" is the entity that made the learning object unavailable.	Vocabulary (State)	-
2.3.2	Entity	The identification of and information about entities (i.e., people, organizations) contributing to this learning object. The entities shall be ordered as most relevant first.	smallest permitted maximum: 40 items	ordered	vCard, as defined by IMC vCard 3.0 (RFC 2425, RFC 2426).	CharacterString (smallest permitted maximum: 1000 char)	"BEGIN:VCARD\nFN:Joe Friday\nTEL:+1-919-555-7878\nTITLE:Area Administrator\, Assistant\n EMAIL\;TYPE=INTERN\nET:jfriday@host.com\nEND:VCARD\n"
2.3.3	Date	The date of the contribution.	1	unspecified	-	DateTime	"2001-08-23"

… + controlled vocabularies

- A closed list of named subjects, which can be used for classification
- Metadata field values are restricted to a list of terms (selected by experts)

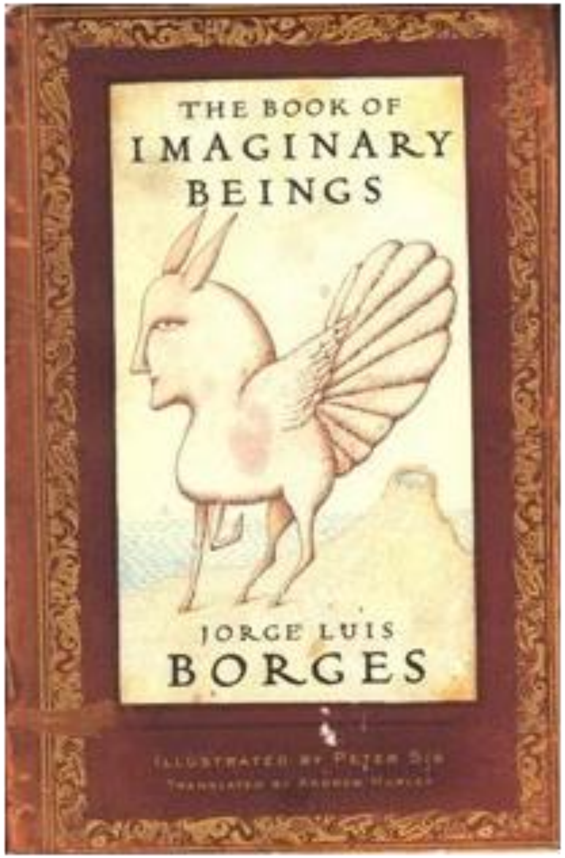


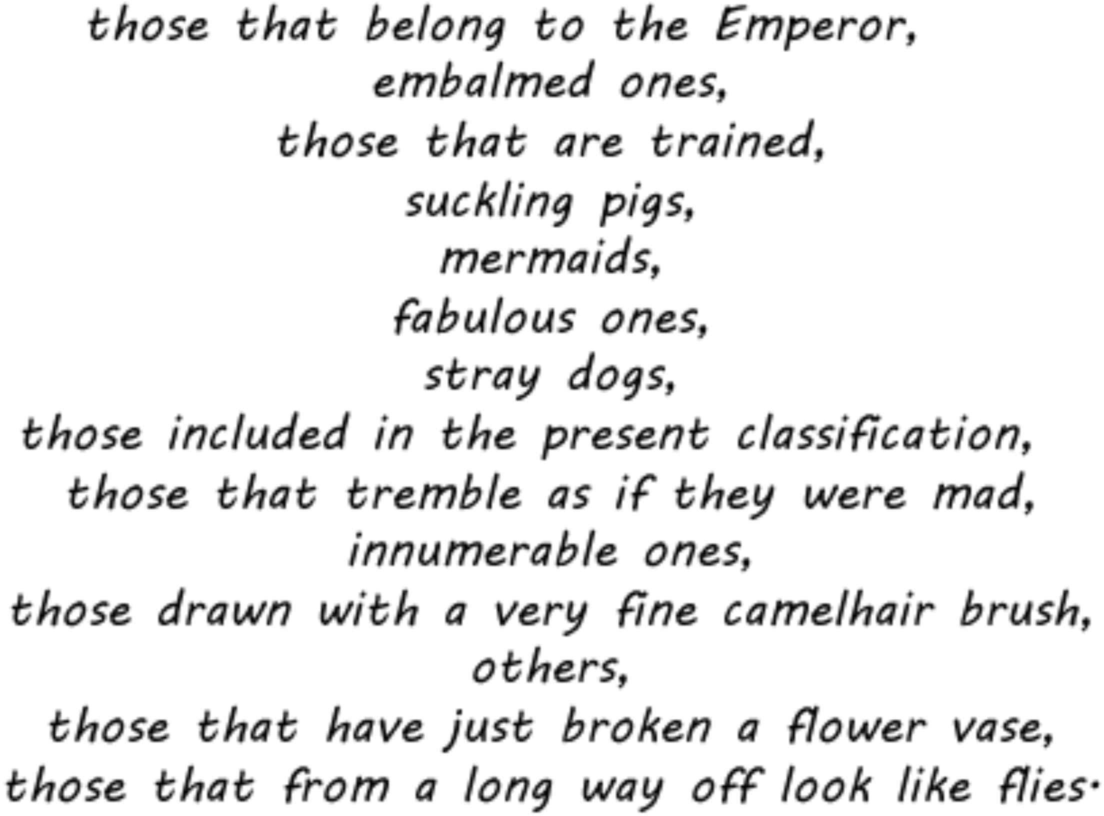
Topic =
{computer science,
~~informatics~~,
knowledge
representation,
metadata}

Subject-based classification

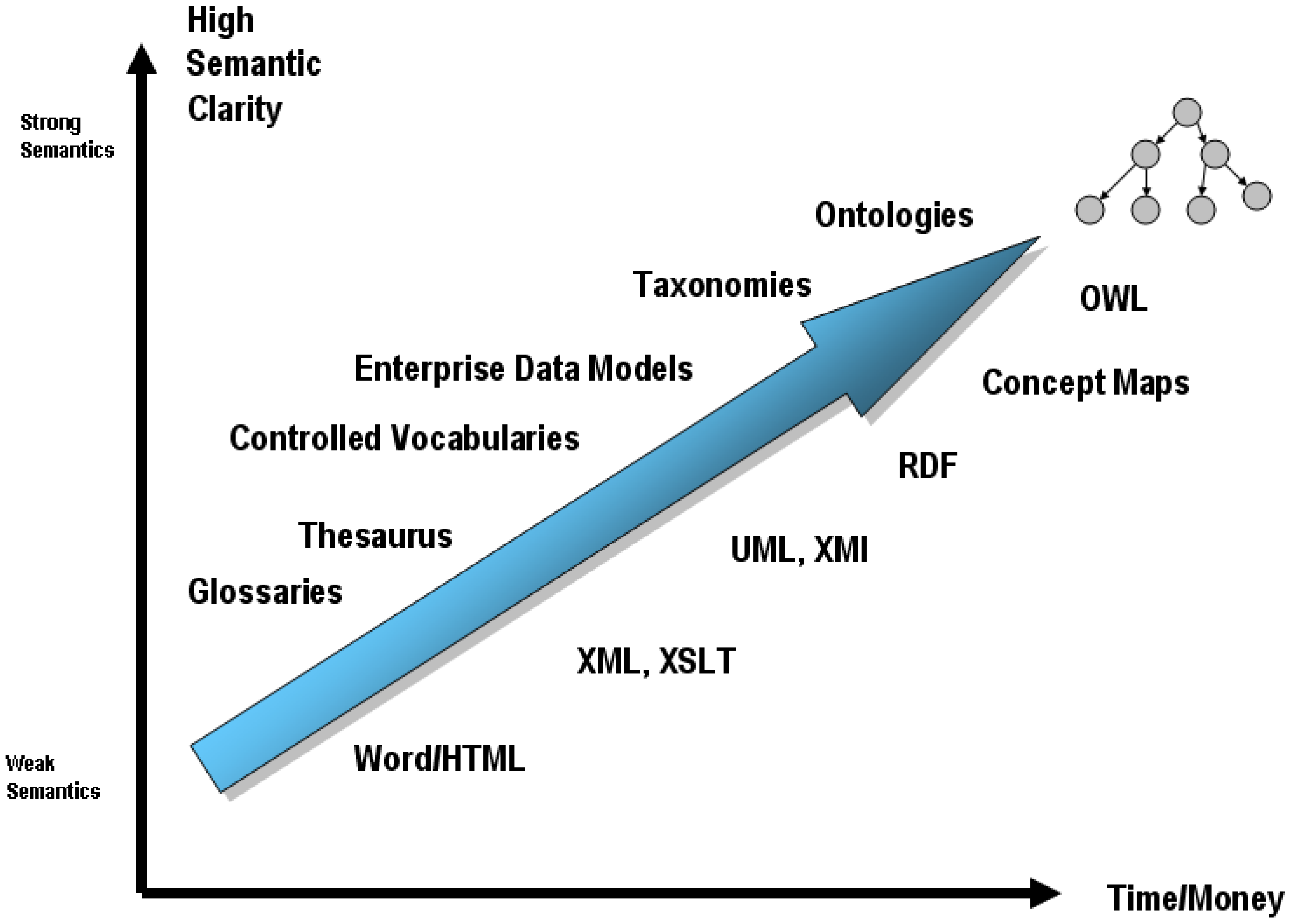
- Any form of content classification that groups objects by their subjects
  - e.g the use of keywords to classify papers
- Metadata fields describe what the objects are about by listing discrete subjects inside a subject-based classification
- Important: difference between describing the objects being classified and describing the subjects used to classify them
  - Metadata describe objects
  - Subject-based classification is the approach to describe subject

Subject-based classification




those that belong to the Emperor,
embalmed ones,
those that are trained,
suckling pigs,
mermaids,
fabulous ones,
stray dogs,
those included in the present classification,
those that tremble as if they were mad,
innumerable ones,
those drawn with a very fine camelhair brush,
others,
those that have just broken a flower vase,
those that from a long way off look like flies.

Subject-based classification

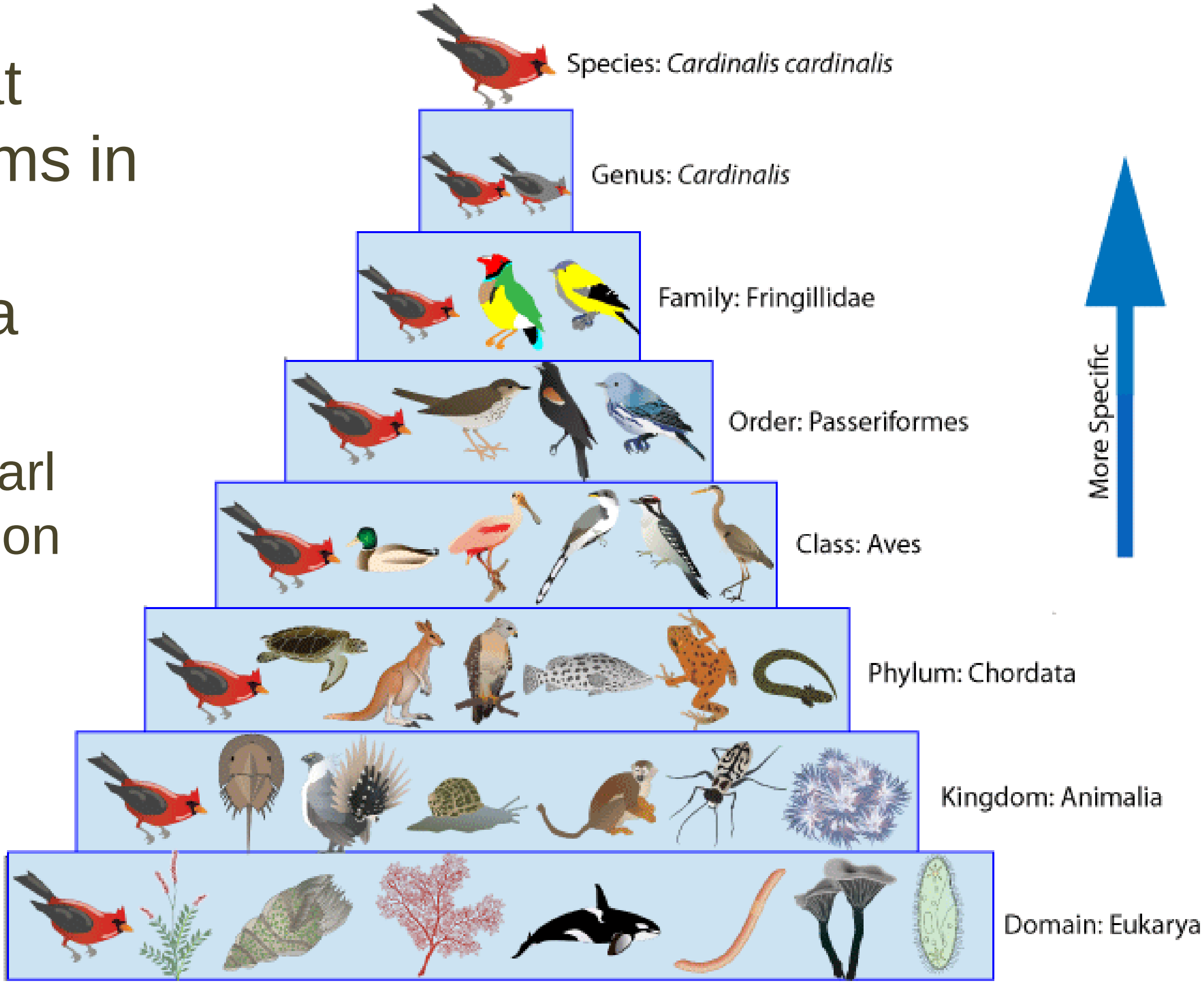


Controlled vocabulary

- Goal
  - Prevent authors from defining terms that are meaningless, too broad or too narrow
  - Prevent authors from misspelling
  - Prevent different authors from choosing slightly different forms of the same term
- Simplest form: list of terms (or “pick list”)
- Reduces ambiguity inherent in normal human languages
- Solves the problems of homographs, homonyms, synonyms and polysemes by ensuring
  - That each concept is described using only one authorized term
  - That each authorized term in the controlled vocabulary describes only one concept

Taxonomy

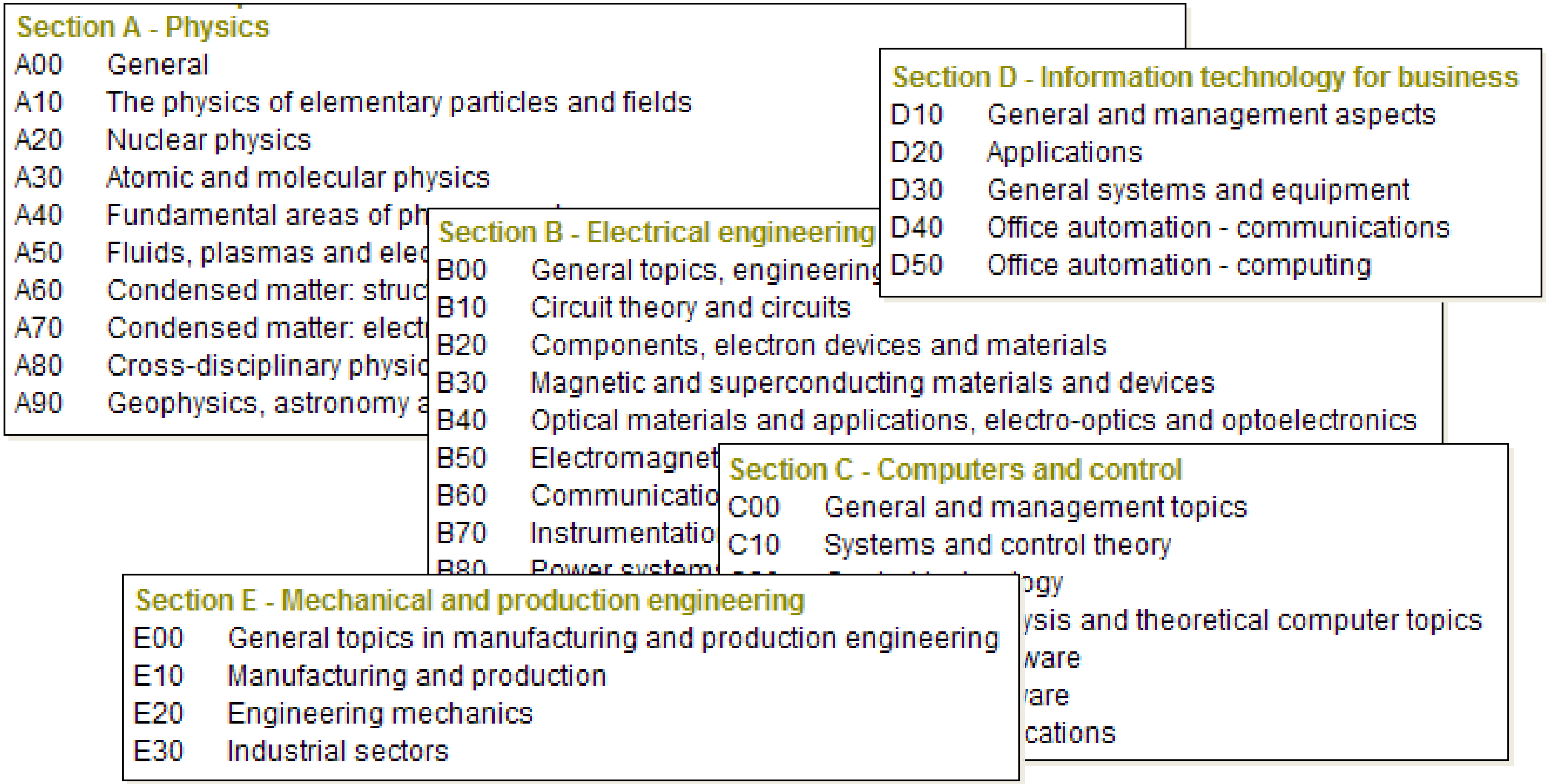
- Subject-based classification that arranges the terms in the controlled vocabulary into a hierarchy
  - Dates back to Carl Linnæus's work on zoological and botanical classification (18th century)



Taxonomy example: INSPEC

- Objective: to index quality research literature in physics and engineering

http://www.theiet.org/publishing/inspec/index.cfm



Section A - Physics

A00	General
A10	The physics of elementary particles and fields
A20	Nuclear physics
A30	Atomic and molecular physics
A40	Fundamental areas of ph
A50	Fluids, plasmas and elec
A60	Condensed matter: struc
A70	Condensed matter: electr
A80	Cross-disciplinary physic
A90	Geophysics, astronomy a

Section B - Electrical engineering

B00	General topics, engineering
B10	Circuit theory and circuits
B20	Components, electron devices and materials
B30	Magnetic and superconducting materials and devices
B40	Optical materials and applications, electro-optics and optoelectronics
B50	Electromagnet
B60	Communicatio
B70	Instrumentatio
B80	Power system

Section D - Information technology for business

D10	General and management aspects
D20	Applications
D30	General systems and equipment
D40	Office automation - communications
D50	Office automation - computing

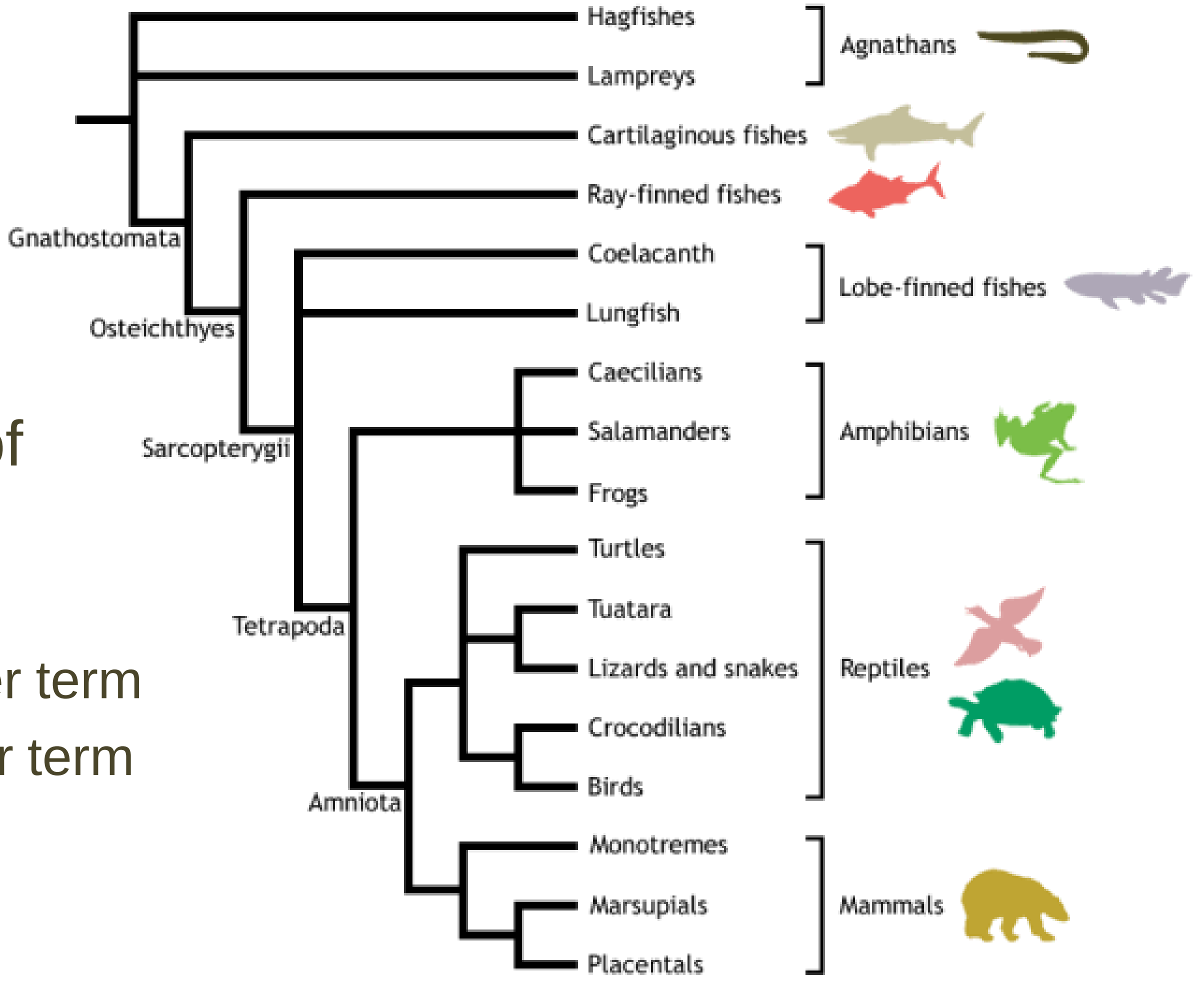
Section C - Computers and control

C00	General and management topics
C10	Systems and control theory
	ogy
	ysis and theoretical computer topics
	ware
	vare
	cations

Section E - Mechanical and production engineering

E00	General topics in manufacturing and production engineering
E10	Manufacturing and production
E20	Engineering mechanics
E30	Industrial sectors

Limit of taxonomies

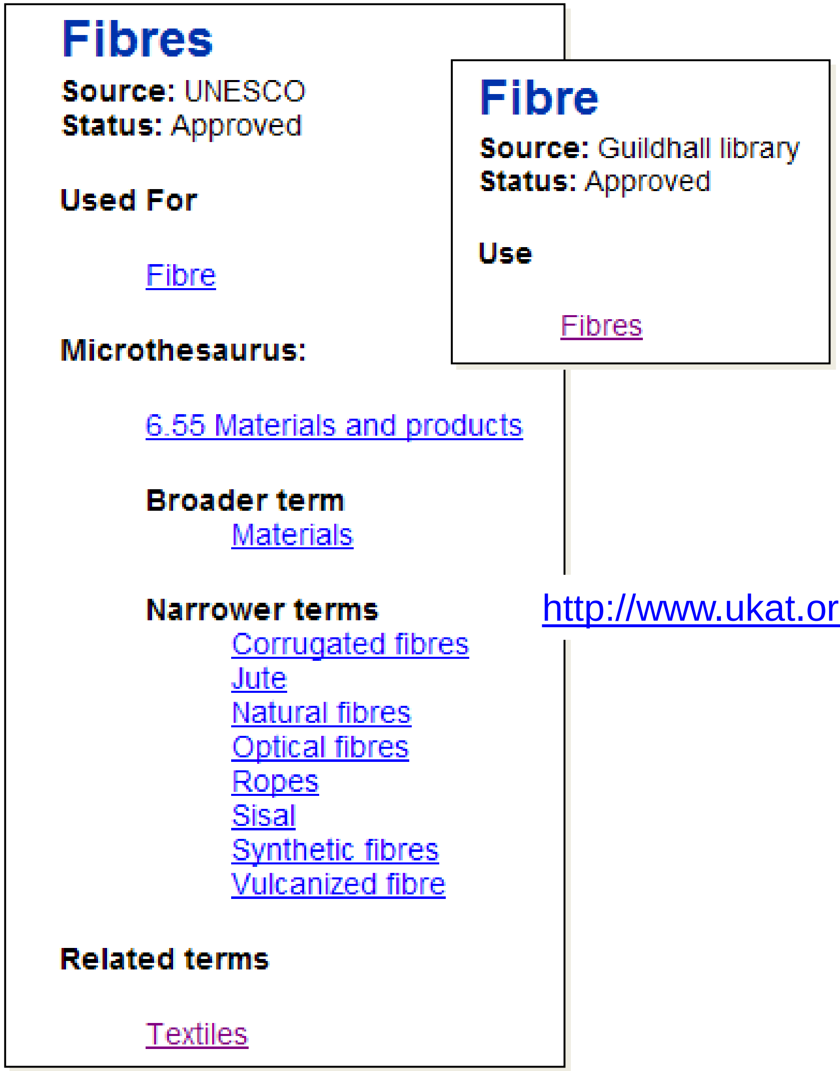


- Only two kinds of relationships between terms
  - Parent = broader term
  - Child = narrower term

Thesaurus

- Extends taxonomies
  - subjects are arranged in a hierarchy
- Other statements can be made about the subjects
  - BT – broader term
  - NT - narrower term (inverse of BT)
  - SN – scope note
  - USE
  - UF – used for (inverse of USE)
  - TT – top term
  - RT – related term

Thesaurus example



Fibres

Source: UNESCO
Status: Approved

Used For

Fibre

Microthesaurus:

6.55 Materials and products

Broader term

Materials

Narrower terms

Corrugated fibres
Jute
Natural fibres
Optical fibres
Ropes
Sisal
Synthetic fibres
Vulcanized fibre

Related terms

Textiles

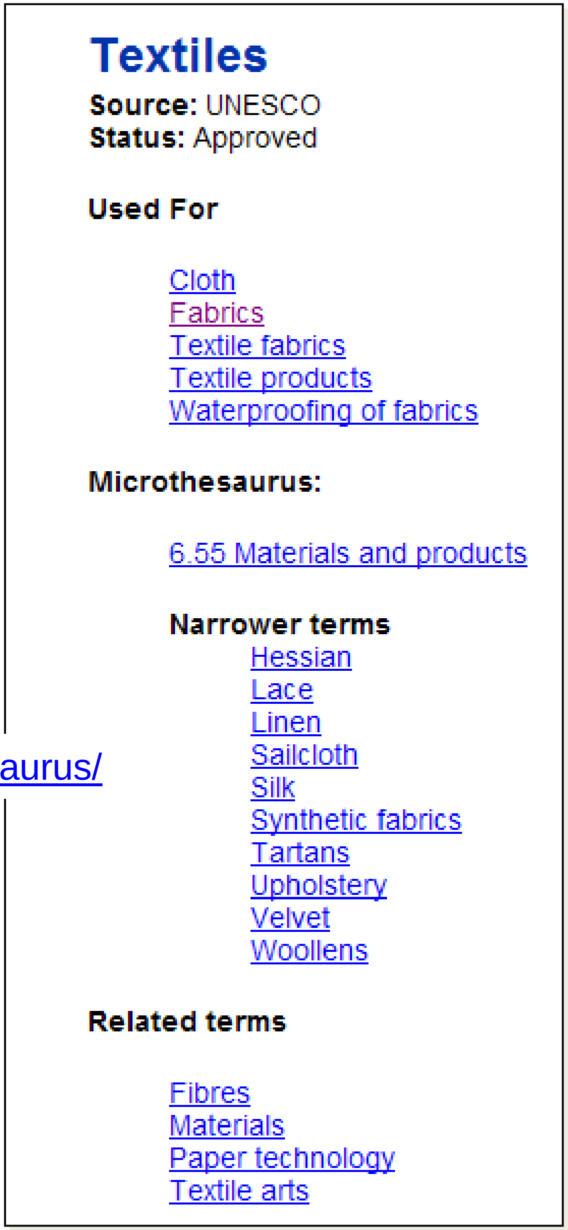
Fibre

Source: Guildhall library
Status: Approved

Use

Fibres

http://www.ukat.org.uk/thesaurus/



Textiles

Source: UNESCO
Status: Approved

Used For

Cloth
Fabrics
Textile fabrics
Textile products
Waterproofing of fabrics

Microthesaurus:

6.55 Materials and products

Narrower terms

Hessian
Lace
Linen
Sailcloth
Silk
Synthetic fabrics
Tartans
Upholstery
Velvet
Woollens

Related terms

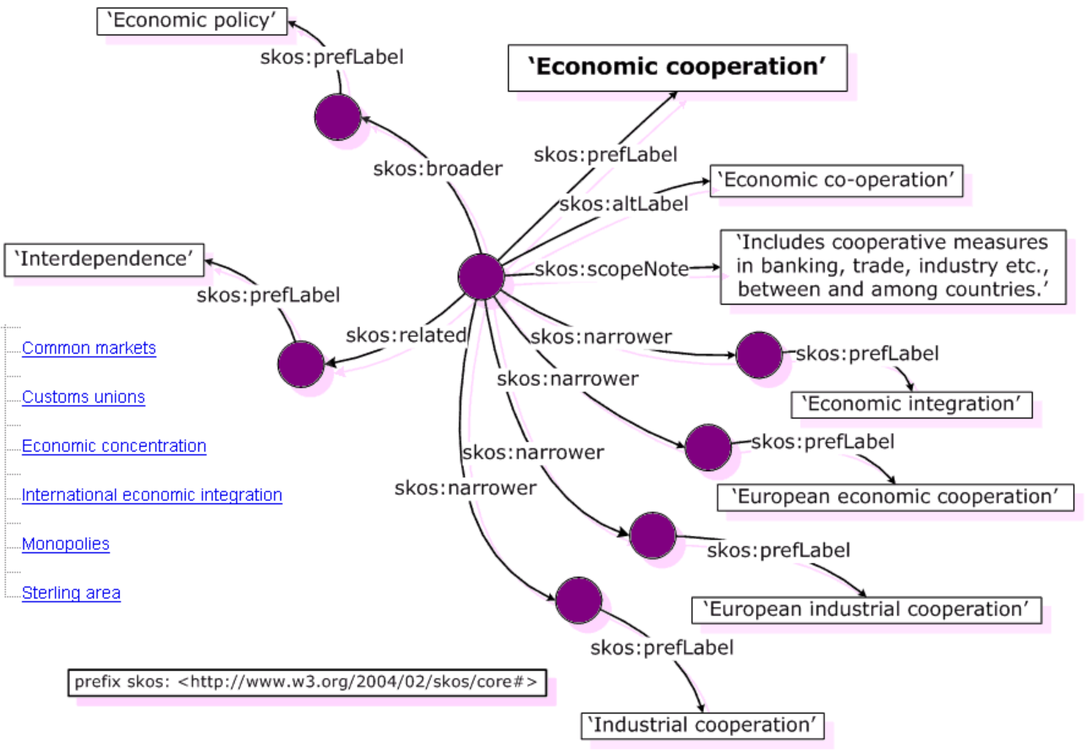
Fibres
Materials
Paper technology
Textile arts

UKAT

6.25 Economics

- Business cycles
- Economic conditions
- Economic policy
  - Counter-inflation policy
  - Economic cooperation
    - Economic integration
      - Common markets
      - Customs unions
      - Economic concentration
      - International economic integration
      - Monopolies
      - Sterling area
    - European economic cooperation
    - European industrial cooperation
    - Industrial cooperation
  - Economic legislation
  - Economic planning
  - Economic reform
  - Incomes policy
  - Nationalization
  - Price policy
  - Privatization
  - Structural adjustment
- Economic systems
- Economic theory
- Economics
- Income and wealth
- Interdependence
  - Economic relations
- National accounting

RDF / SKOS



prefix skos: <http://www.w3.org/2004/02/skos/core#>

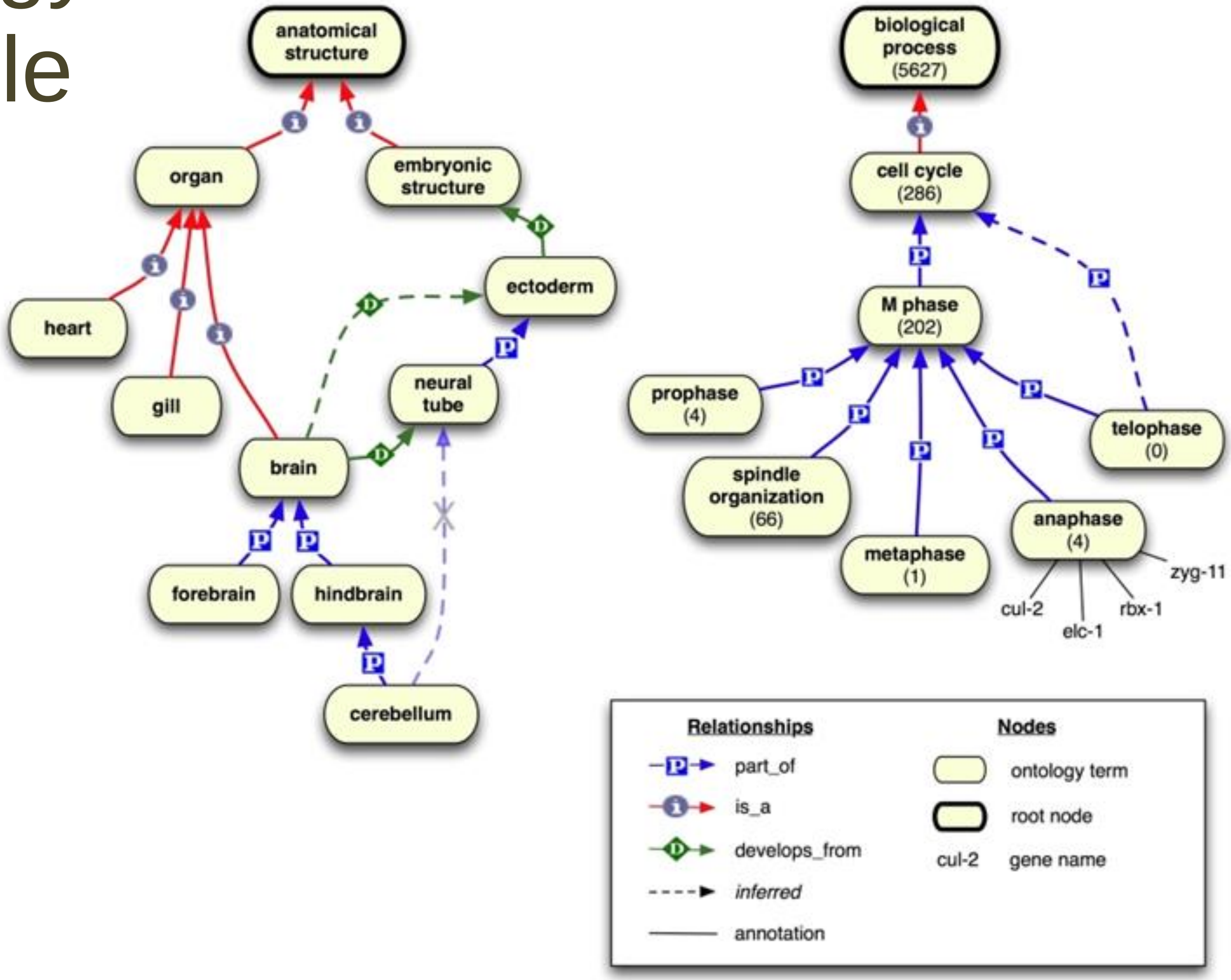
UK Archival Thesaurus (UKAT)

SKOS: Simple Knowledge Organization System

Ontology

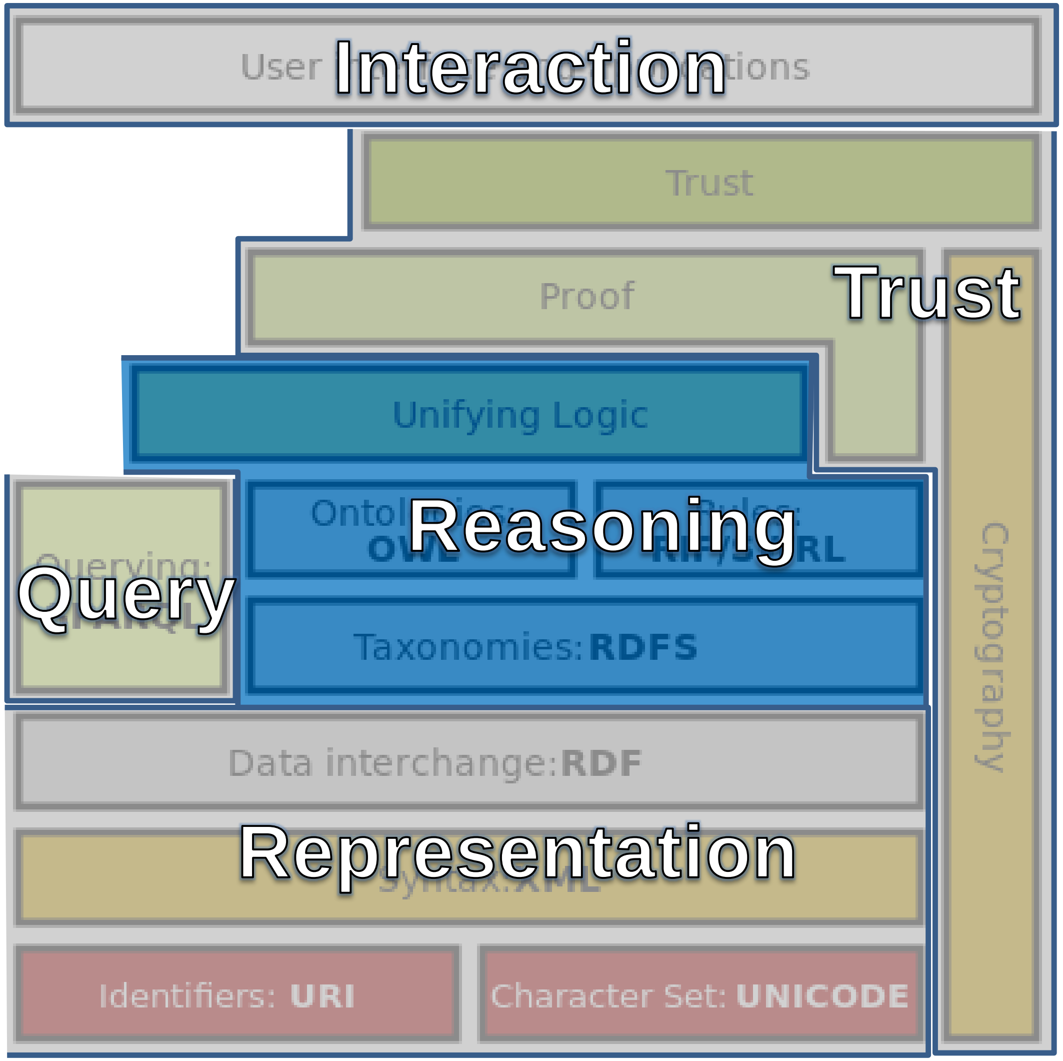
- Model for describing the world that consists of a set of types, properties, and relationships
- Extends the other subject-based classification approaches
  - Has open vocabularies
  - Has open relationship types (not just BT/NT, RT and USE/UF)

Ontology example



Semantically rich descriptions to support search

- Step 2: reasoning
- Ontologies



References

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  - https://www.w3.org/standards/semanticweb/
- W3C Tutorial on Semantic Web
  - https://www.w3.org/Consortium/Offices/Presentations/RDFTutorial/
- Lee Feigenbaum, “The Semantic Web Landscape”
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