

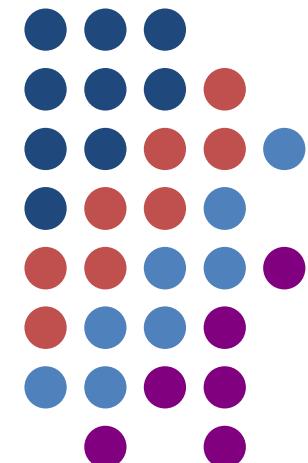
# Introduction to Ontology Concepts and Terminology

DC-2013 Tutorial

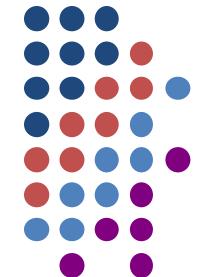
September 2, 2013

Steven J. Miller

University of Wisconsin-Milwaukee

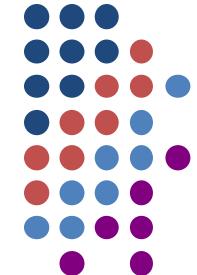


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# Welcome and Introductions

- Introduce ourselves to the group
- How many participants have a general idea of what the semantic web and linked data are about?
- How many have some familiarity with the Resource Description Framework (RDF) data model?



# Tutorial topics and outline

## 1. Tutorial Background Overview

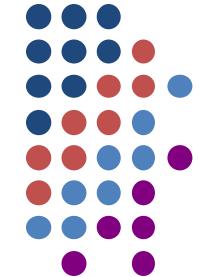
- The Semantic Web, Linked Data, and the Resource Description Framework

## 2. Ontology Basics and RDFS Tutorial

- Semantic modeling, domain ontologies, and RDF Vocabulary Description Language (RDFS) concepts and terminology
- Examples: domain ontologies, models, and schemas
- *Exercises*

## 3. OWL Overview Tutorial

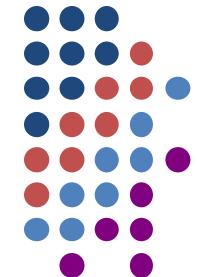
- Web Ontology Language (OWL): selected concepts and terminology
- *Exercises*



# Tutorial audience

Information professionals

- who have *little or no prior familiarity* with ontologies, RDFS, or OWL
- who want to gain an *introductory level* understanding of basic ontology concepts and terminology

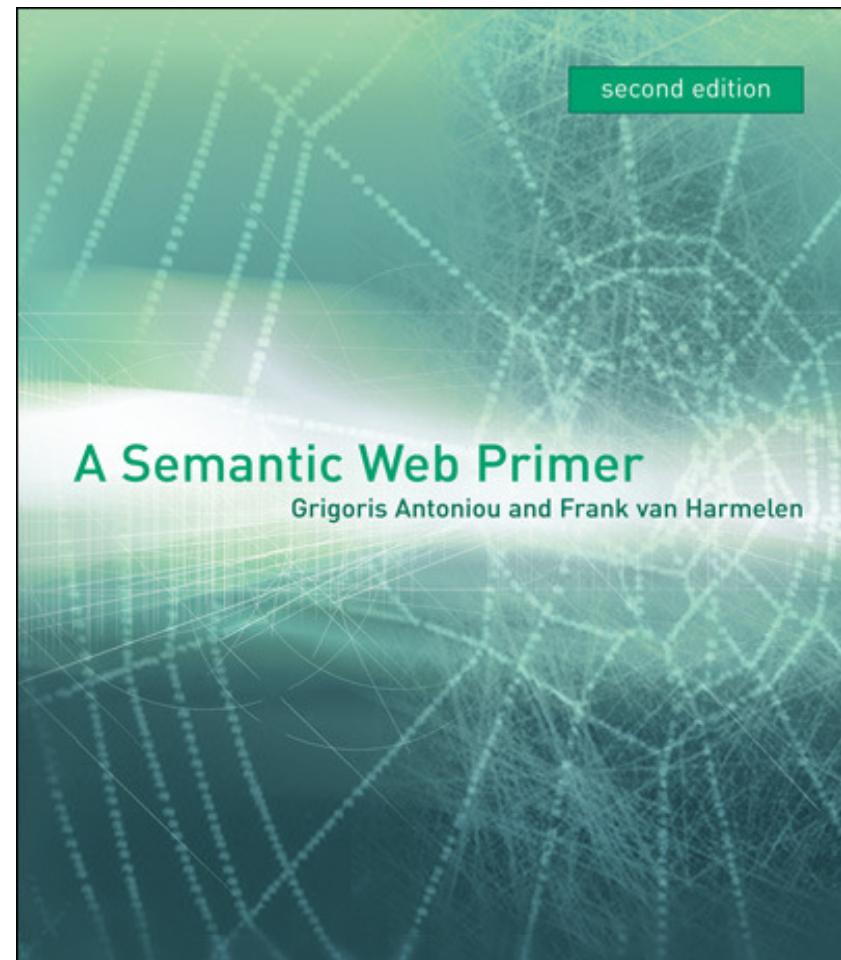
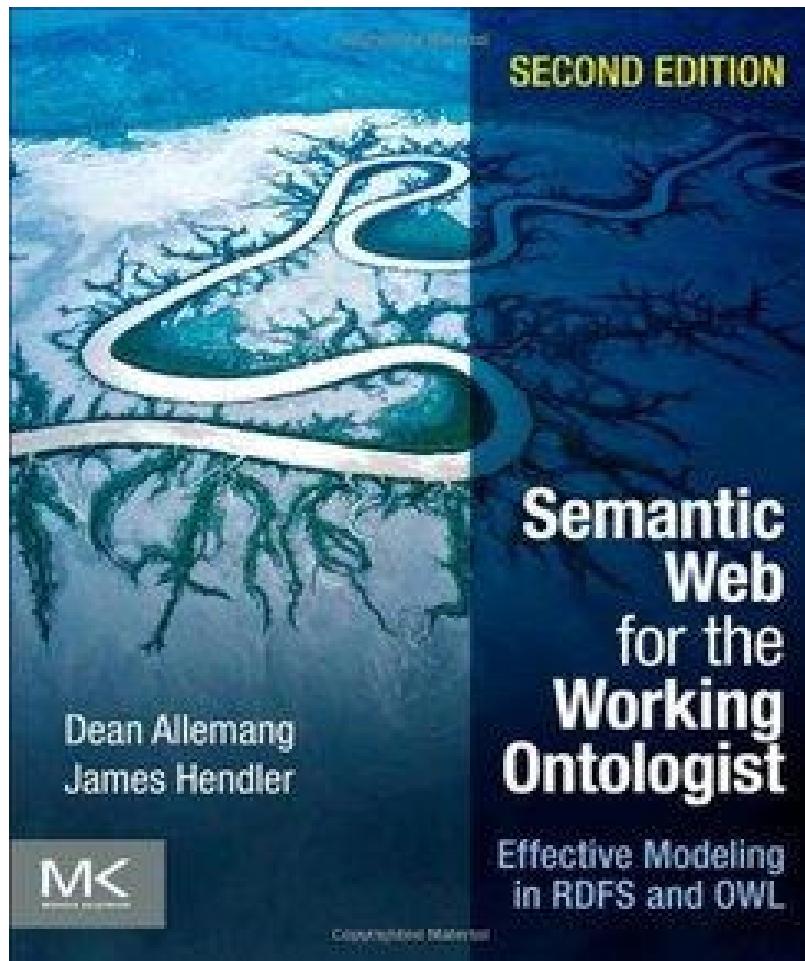


# Tutorial outcomes

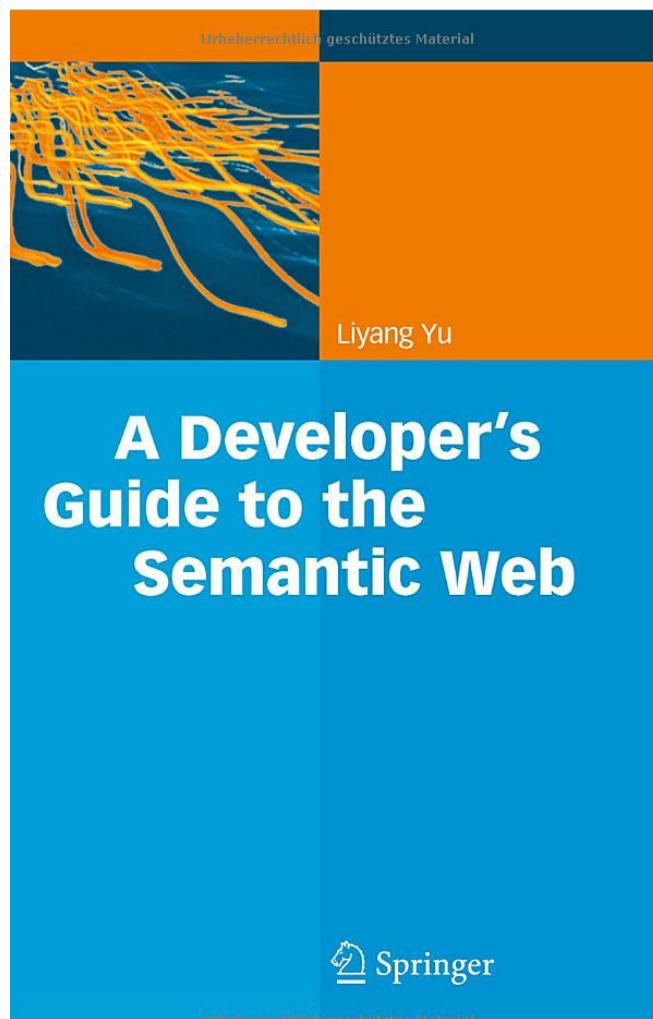
***At the conclusion of the tutorial, participants will:***

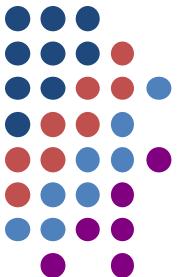
1. Understand basic RDFS ontology concepts such as classes, properties, instances, domain and range.
2. Understand how ontologies provide structure to RDF triples.
3. Be able to create a basic, beginning-level RDFS-compatible ontology.
4. Determine logical inferencing capabilities based on specific class, property, domain and range specifications.
5. Gain initial exposure to more complex OWL property and class specifications and their greater potential inferencing power.
6. Better understand: existing RDF-based ontologies such as BIBO, BIBFRAME, the BBC ontologies, and the Europeana Data Model; DCMI Metadata Terms specifications; and conceptual models such as the Dublin Core Abstract Model.
7. Be better able to understand and contribute to professional discussions about ontologies, ontology concepts, and ontology terminology on discussion lists, at conferences, and the like.

# Background Sources: Books (1)

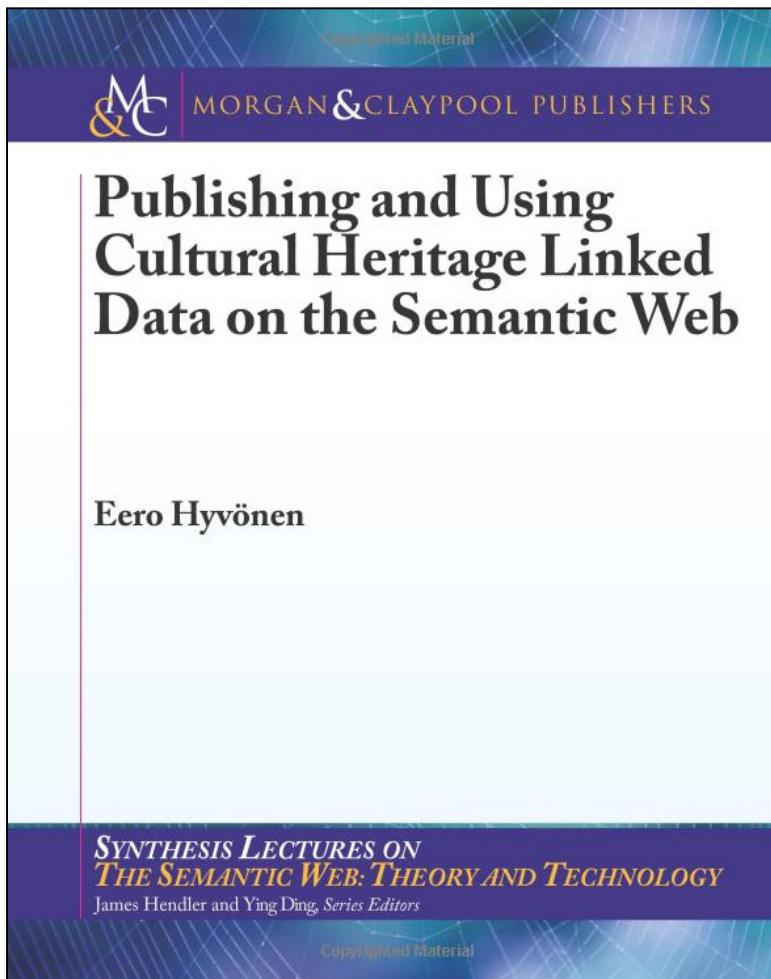


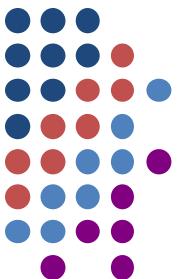
# Background Sources: Books (2)





# Background Sources: Books (3)





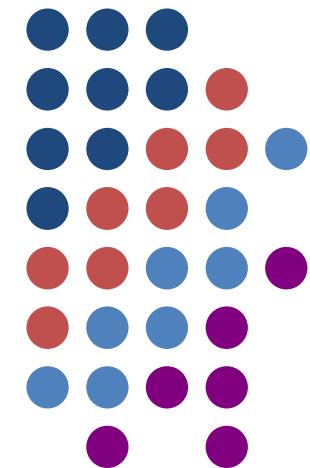
# Background Sources: Practical Guides

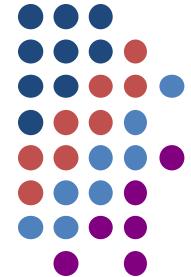
- Noy, Natalya F., and Deborah L. McGuinness. 2001. "**Ontology Development 101: A Guide to Creating Your First Ontology.**" Stanford Knowledge Systems Laboratory Technical Report KSL-01-05 and Stanford Medical Informatics Technical Report SMI-2001-0880.
  - Available online: <http://www-ksl.stanford.edu/people/dlm/papers/ontology-tutorial-noy-mcguinness.pdf>
- Horridge, Matthew. 2011. "**A Practical Guide To Building OWL Ontologies:** Using Protégé 4 and CO-ODE Tools." Edition 1.3. The University Of Manchester.
  - Available online:  
[http://owl.cs.manchester.ac.uk/tutorials/protegeowltutorial/resources/ProtegeOWLTutorialP4\\_v1\\_3.pdf](http://owl.cs.manchester.ac.uk/tutorials/protegeowltutorial/resources/ProtegeOWLTutorialP4_v1_3.pdf)
- For further information on these and other sources, see “Selected Readings and Resources” at the end of the tutorial materials

# Semantic Web, Linked Data, and RDF

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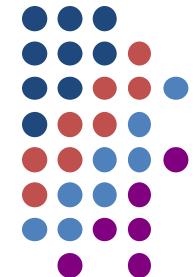
**Part 1:** Tutorial background  
overview





# Semantic Web (SW)

- **Current Web:** a web of linked *documents*
  - Unstructured data, connect by hyperlinks
  - Suitable for human consumption (but not for machines)
  - Queried by matching keywords in documents and using relevance ranking algorithms
- **Semantic Web:** a web of linked *data*
  - Structured data (metadata), carrying semantic meaning, connecting by semantically meaningful links
    - People, places, time periods, concepts, ...
  - Making parts of the Web more like a database, able to be queried like a database
  - Suitable for machine consumption –to better serve humans
  - Full-fledged semantics also enable machines to make logical inferences not explicitly stated by humans

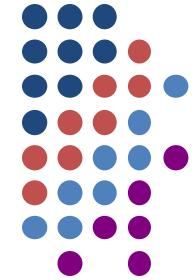


# Linked data (LD)

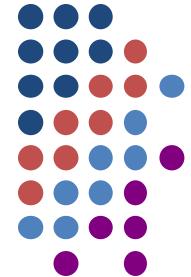
- Newer idea than that of the semantic web (SW)
  - But sometimes easier to think of SW as building on the ideas behind LD.
- LD not a specification, but a set of best practices for providing a data infrastructure that makes it easier to share data across the Web.
- SW technologies such as RDFS, OWL, and SPARQL can then be used to build applications around that data.
- Tim Berners-Lee: four principles of Linked Data:
  - 1. Use URIs as names for things. [URI = Uniform Resource Identifier]
  - 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.

**Source:** DuCharme, *Learning SPARQL*, 2<sup>nd</sup> ed. (O'Reilly, 2013), p. 41-42.

# From data silos to distributed knowledge



- Current data in databases **closed** to one another and to the web
  - Unconnected information and knowledge **silos**
- Semantic Web and Linked Data: **distributed** information and knowledge environments
  - Publishing data in an **open** Web environment
  - Making the data **linkable** to other data
  - Creating a vast **web of linked data**



# Semantic Web assumptions

- **Open World Assumption**

- **Closed world:** databases with tightly controlled content; all relevant information about an entity is included; inferences can be made accordingly
- **Open world:** uncontrolled open data; someone can always contribute something new about an entity
  - Machine inferencing must take this into account: “we may draw no conclusions that rely on assuming that the information available at any one point is all the information available”

- **Nonunique Naming Assumption**

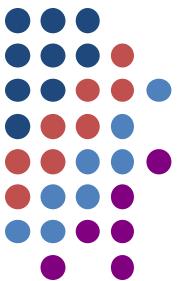
- **Unique names:** may hold in controlled databases or triple stores
- **Nonunique names:** in an open world context, different Web authors will use different URIs for the same entity / resource
  - Machine inferencing cannot assume that two entities with different URIs are different individuals

**Source:** Allemang and Hendler, *Semantic Web for the Working Ontologist*, Chapter 1.

# RDF: Resource Description Framework (1)

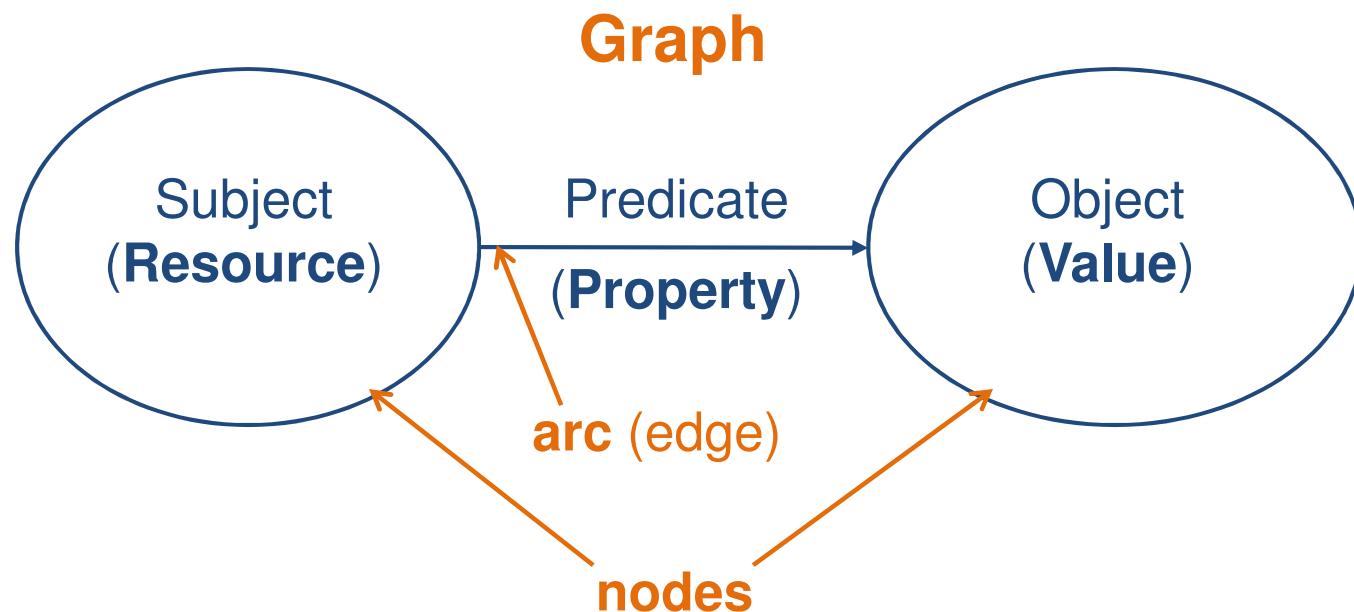


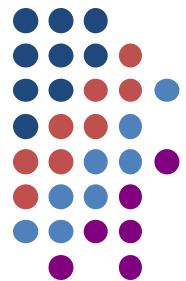
- The *Resource Description Framework (RDF)* provides a **graph-based data model** or framework for structuring data as **statements** about **resources**
  - A “resource” may be any “thing” that exists in the world: a person, place, event, book, museum object, but also an abstract concept
- Each statement is composed of a **subject**, **predicate**, and **object**.
- The subject of a statement is called a **resource**, the predicate is called a **property**, and the object is called a **value**.
- Each statement is a **triple**, consisting of these three components



# RDF: Resource Description Framework (2)

- In a graph diagram, “**nodes**” represent things; “**arcs**” (or “**edges**”) connect nodes and denote the relationship between them

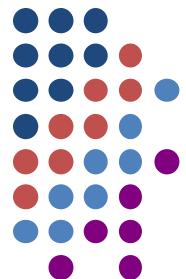




# Example of tabular database DC metadata record for digital image

Property	Value
Title	Manchester Street Bridge, Sauk County, Wisconsin
Date	1896
Creator	Lassig Bridge and Iron Works
Subject	Truss bridges
Format	128.9 ft. long; 13.7 ft. deck width
Coverage	Sauk County
Type	Still Image
Creator	Szarkowski, John
Date	1955
Format	35 mm.
Format	Black & white slide
Identifier	171, 33b-765
Relation	Paul J. Kramer Archival Photograph Collection
Relation	Bridges of Wisconsin
Rights	Copyright © 2009 Hagenville University
Format	image/jpeg
Identifier	WB0078736

# Example of the same metadata in XML



```
<metadata>
<oai_dc:dc  xmlns:oai_dc="http://www.openarchives.org/OAI/2.0/oai_dc/"
  xmlns:dc="http://purl.org/dc/elements/1.1/"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xsi:schemaLocation="http://www.openarchives.org/OAI/2.0/oai_dc/
  http://www.openarchives.org/OAI/2.0/oai_dc.xsd">

  <dc:title>Manchester Street Bridge, Sauk County, Wisconsin</dc:title>
  <dc:date>1896</dc:date>
  <dc:creator>Lassig Bridge and Iron Works</dc:creator>
  <dc:subject>Truss bridges</dc:subject>
  <dc:format>128.9 ft. long; 13.7 ft. deck width</dc:format>
  <dc:coverage>Sauk County</dc:coverage>
  <dc:type>Still Image</dc:type>
  <dc:creator>Szarkowski, John</dc:creator>
  <dc:date>1955</dc:date>
  <dc:format>35 mm.</dc:format>
  <dc:format>Black & white slide</dc:format>
  <dc:identifier>171, 33b-765</dc:identifier>
  <dc:relation>Paul J. Kramer Archival Photograph Collection</dc:relation>
  <dc:relation>Bridges of Wisconsin</dc:relation>
  <dc:rights>Copyright (c)2009 Hagenville University</dc:rights>
  <dc:format>image/jpeg</dc:format>
  <dc:identifier>WB0078736</dc:identifier>

</oai_dc:dc>
</metadata>
```

# URIs: Uniform Resource Identifiers

Used as *resources* (subjects) in RDF triples:

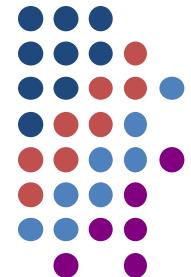
Resource (subject)	Property (predicate)	Value (object)
<a href="http://www.hdl.edu/WisBridges/WB0078736">http://www.hdl.edu/WisBridges/WB0078736</a>	Subject	Truss bridges
<a href="http://www.hdl.edu/WisBridges/WB0078736">http://www.hdl.edu/WisBridges/WB0078736</a>	Creator	Szarkowski, John

Used as *properties* in RDF triples:

Resource (subject)	Property (predicate)	Value (object)
<a href="http://www.hdl.edu/WisBridges/WB0078736">http://www.hdl.edu/WisBridges/WB0078736</a>	<a href="http://purl.org/dc/elements/1.1/subject">http://purl.org/dc/elements/1.1/subject</a>	Truss bridges
<a href="http://www.hdl.edu/WisBridges/WB0078736">http://www.hdl.edu/WisBridges/WB0078736</a>	<a href="http://purl.org/dc/elements/1.1/creator">http://purl.org/dc/elements/1.1/creator</a>	Szarkowski, John

Used as *values* in RDF triples:

Resource (subject)	Property (predicate)	Value (object)
<a href="http://www.hdl.edu/WisBridges/WB0078736">http://www.hdl.edu/WisBridges/WB0078736</a>	<a href="http://purl.org/dc/elements/1.1/subject">http://purl.org/dc/elements/1.1/subject</a>	<a href="http://id.loc.gov/vocabulary/graphicMaterials/tgm011115">http://id.loc.gov/vocabulary/graphicMaterials/tgm011115</a>
<a href="http://www.hdl.edu/WisBridges/WB0078736">http://www.hdl.edu/WisBridges/WB0078736</a>	<a href="http://purl.org/dc/elements/1.1/creator">http://purl.org/dc/elements/1.1/creator</a>	<a href="http://www.hdl.edu/nameauthority/938475">http://www.hdl.edu/nameauthority/938475</a>

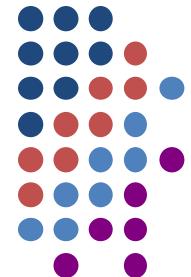


# Statements about a digital image

Resource (subject)	Property (predicate)	Value (object)
Digital Image WB0078736	hasTitle	Manchester Street Bridge, Sauk County, Wisconsin
Digital Image WB0078736	hasSubject	Truss bridges
Digital Image WB0078736	hasCreator	Szarkowski, John



RDF statements are **directed graphs**: the property goes in one direction, from the subject to the object



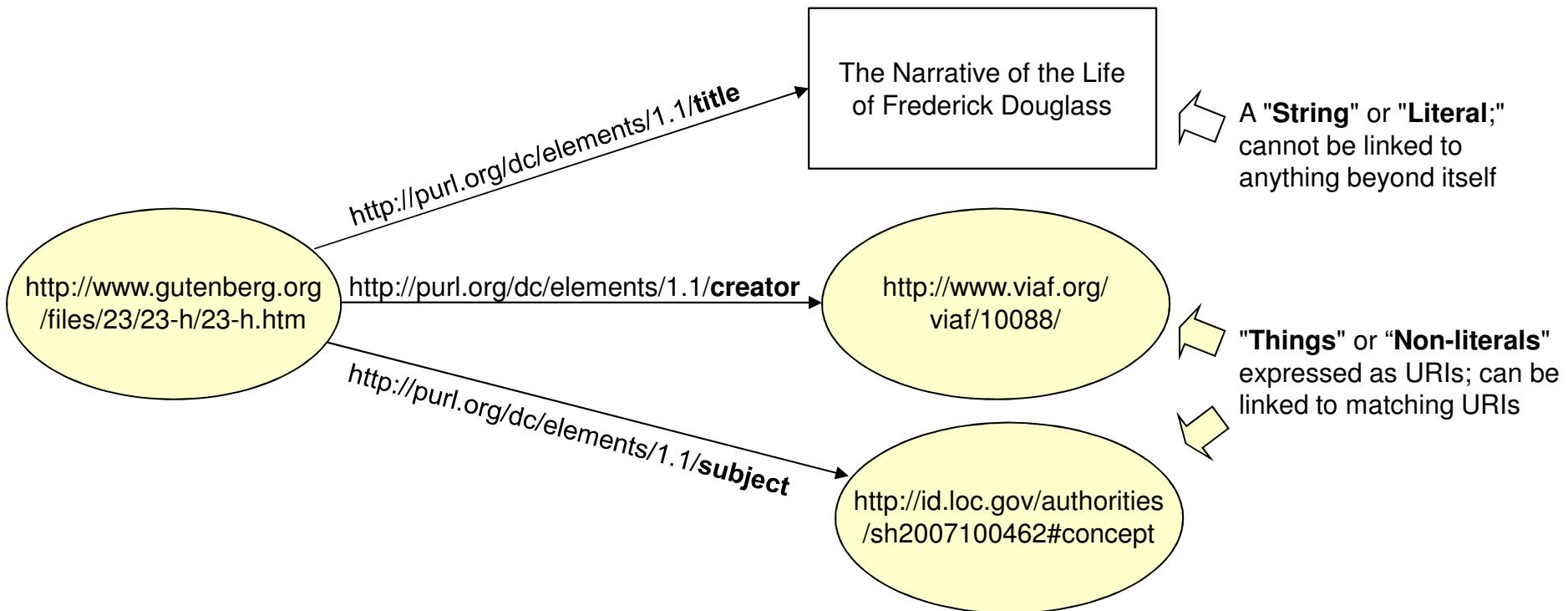
# Literals, Strings, and “Things”

<b>Resource (subject)</b>	<b>Property (predicate)</b>	<b>Value (object)</b>
EBook 23/23-h/23-h	DC Title	Narrative of the Life of Frederick Douglass
EBook 23/23-h/23-h	DC Creator	Douglass, Frederick, 1817-1895
EBook 23/23-h/23-h	DC Subject	African American abolitionists--Biography

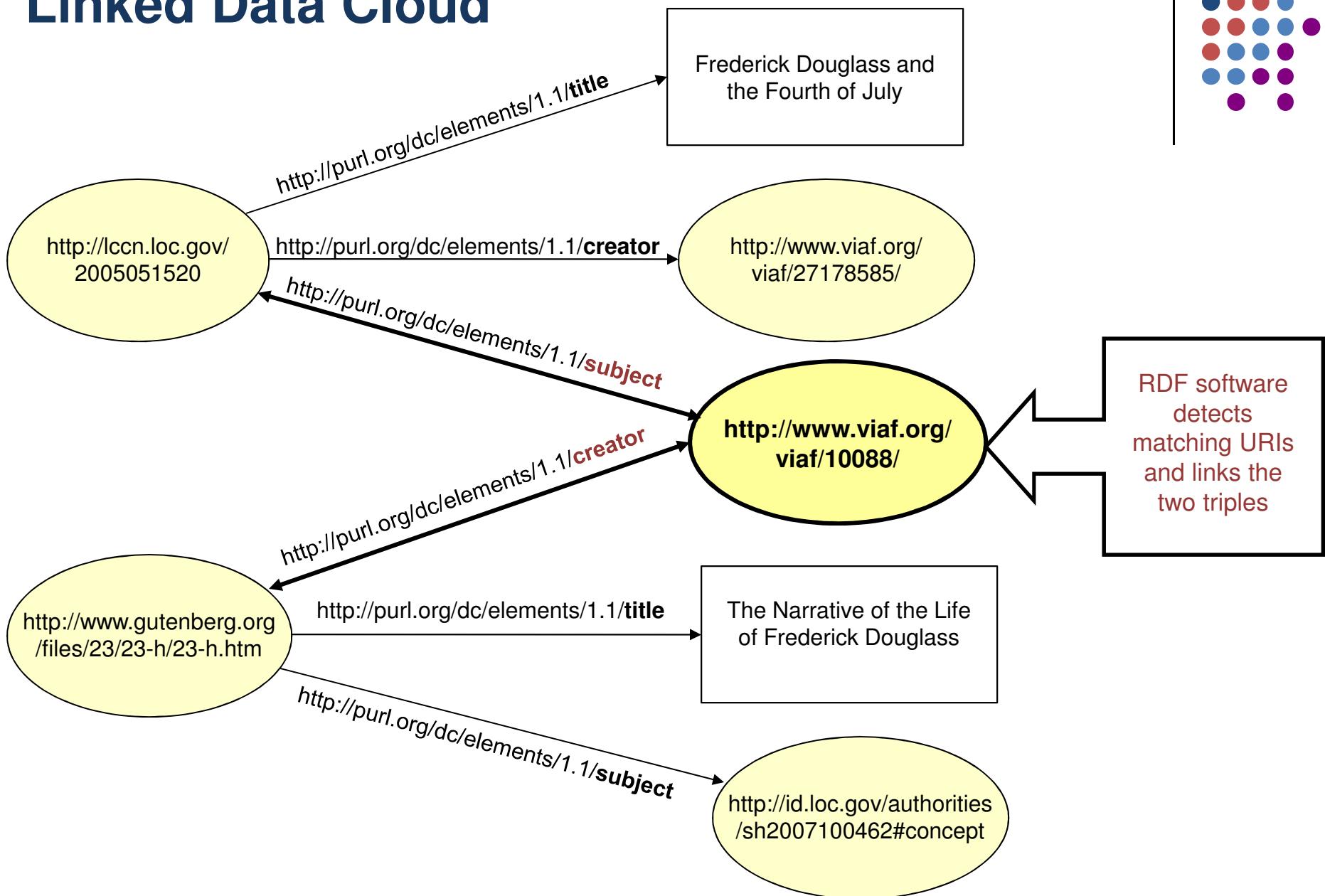
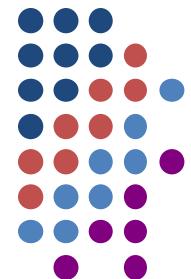
<b>Resource (subject)</b>	<b>Property (predicate)</b>	<b>Value (object)</b>
<a href="http://www.gutenberg.org/files/23/23-h/23-h.htm">http://www.gutenberg.org/files/23/23-h/23-h.htm</a>	<a href="http://purl.org/dc/elements/1.1/title">http://purl.org/dc/elements/1.1/title</a>	Narrative of the Life of Frederick Douglass
<a href="http://www.gutenberg.org/files/23/23-h/23-h.htm">http://www.gutenberg.org/files/23/23-h/23-h.htm</a>	<a href="http://purl.org/dc/elements/1.1/creator">http://purl.org/dc/elements/1.1/creator</a>	<a href="http://www.viaf.org/viaf/10088/">http://www.viaf.org/viaf/10088/</a>
<a href="http://www.gutenberg.org/files/23/23-h/23-h.htm">http://www.gutenberg.org/files/23/23-h/23-h.htm</a>	<a href="http://purl.org/dc/elements/1.1/subject">http://purl.org/dc/elements/1.1/subject</a>	<a href="http://id.loc.gov/authorities/sh2007100462#concept">http://id.loc.gov/authorities/sh2007100462#concept</a>

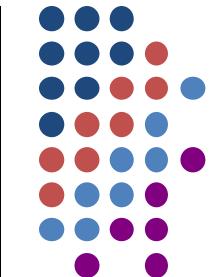


# Literals, Strings, and Things



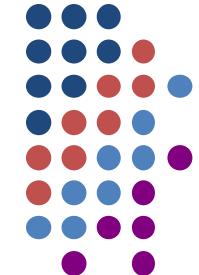
# The Power of Linking and Querying in the Linked Data Cloud





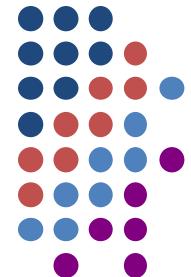
# RDF: URLs and literals

- Subjects and predicates of RDF triples *must* be URLs
  - In the form of http:// URLs
  - May or may not be “dereferenceable” (that is, referencing an actual location on the Web)
- Objects of RDF triples *may be either* URLs or literals
  - A “literal” is raw text that can be used instead of a resource/thing in RDF triples
  - A literal may be a string (of characters), an integer, a date, etc.



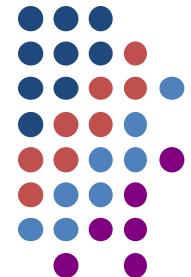
# Namespace prefixes

- XML namespace declarations in the opening element of an RDF file:
  - `xmlns:hdlwb="http://www.hdl.edu/WisBridges/"`
  - `xmlns:dc="http://purl.org/dc/elements/1.1/"`
  - `xmlns:viaf="http://www.viaf.org/viaf/"`
  - `xmlns:tgm="http://id.loc.gov/vocabulary/graphicMaterials/"`
- In the body of the RDF file, the prefix stands in place of the whole namespace URL in the triples:
  - `hdlwb:WB0078736 dc:creator viaf:110959125`
  - `hdlwb:WB0078736 dc:subject tgm:tgm011115`



# Serialization syntaxes for RDF

- Machine-readable syntaxes that *serialize* the triples
  - That is, express them as a *series* of characters that can be processed in a specified order by a computer with RDF software
- **RDF/XML**
  - the normative syntax for writing RDF
- **Notation 3 (N3)**
  - a shorthand, non-XML serialization of RDF
- **Turtle**
  - “Terse RDF Triple Language,” a subset of Notation 3
- **N-Triples**
  - A subset of Turtle



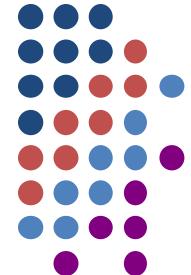
# Example 1 in RDF/XML syntax

```
<?xml version="1.0"?>

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

  <rdf:Description rdf:about="http://www.hdl.edu/WisBridges/WB0078736">
    <dc:title>Manchester Street Bridge, Sauk County, Wisconsin</dc:title>
    <dc:subject
      rdf:resource="http://id.loc.gov/vocabulary/graphicMaterials/tgm011115"/>
    <dc:creator rdf:resource="http://www.viaf.org/viaf/110959125"/>
  </rdf:Description>

</rdf:RDF>
```

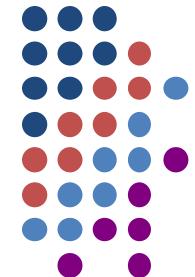


# Example 1 in N-Triples syntax

```
<http://www.hdl.edu/WisBridges/WB0078736>
<http://purl.org/dc/elements/1.1/title>
"Manchester Street Bridge, Sauk County, Wisconsin" .
```

```
<http://www.hdl.edu/WisBridges/WB0078736>
<http://purl.org/dc/elements/1.1/subject>
<http://id.loc.gov/vocabulary/graphicMaterials/tgm011115> .
```

```
<http://www.hdl.edu/WisBridges/WB0078736>
<http://purl.org/dc/elements/1.1/creator>
<http://www.viaf.org/viaf/110959125/> .
```



# Example 1 in Turtle syntax

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

```
@prefix hdlbr: <http://www.hdl.edu/WisBridges/> .
```

```
@prefix dc: http://purl.org/dc/elements/> .
```

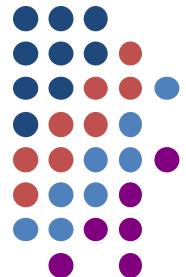
```
@prefix tgm: http://id.loc.gov/vocabulary/graphicMaterials/ .
```

```
@prefix viaf: http://www.viaf.org/viaf/ .
```

```
hdlbr:WB0078736 dc:title "Manchester Street Bridge, Sauk County,  
Wisconsin" .
```

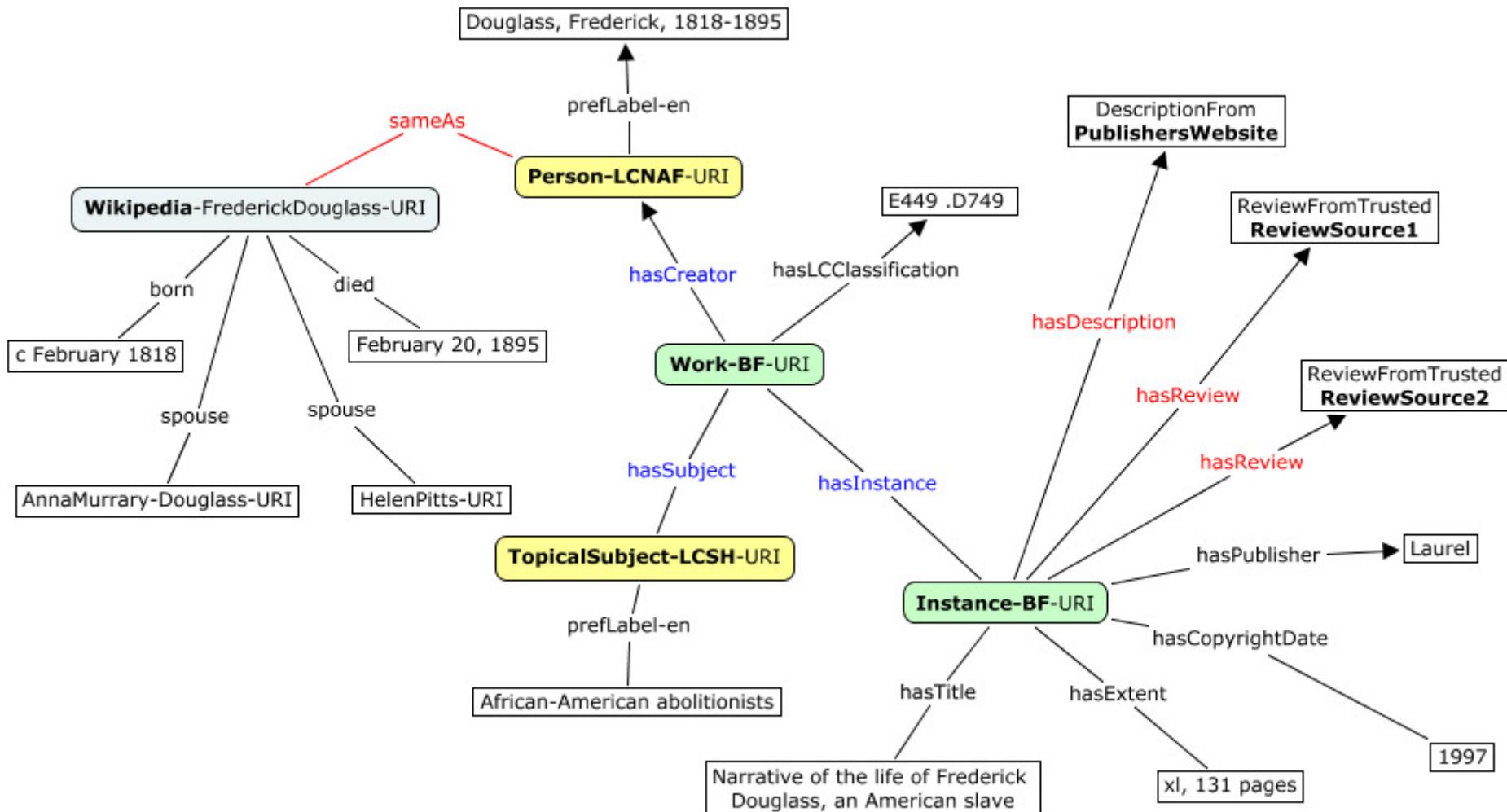
```
hdlbr:WB0078736 dc:subject tgm:tgm011115 .
```

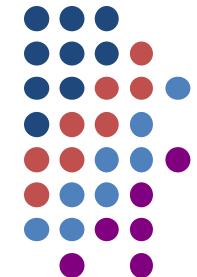
```
hdlbr:WB0078736 dc:creator viaf:110959125 .
```



# Distributed knowledge graph

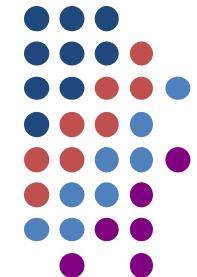
(partial invented draft to convey basic idea)





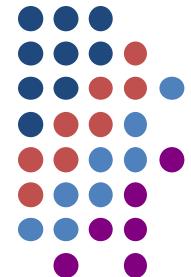
# RDF triple stores

- Databases (stores) of RDF triples
  - store and retrieve data in the form of triples
  - aka: graph databases
- Use a different data model than table-based flat or relational databases
  - Namely, the RDF triple / graph-based model
- Also have the ability to merge information from multiple data sources



# Querying RDF: SPARQL

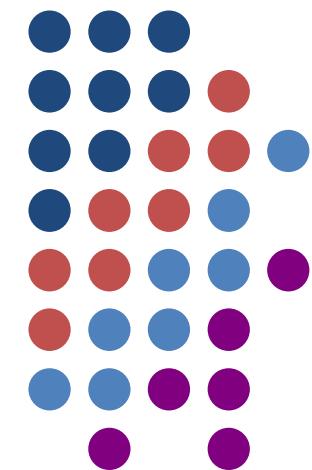
- Databases, including RDF triple stores, are useless unless they can be queried
- **SPARQL** is the query language for RDF, RDFS, and OWL
  - Acronym for: *SPARQL Protocol and RDF Query Language*
  - <http://www.w3.org/TR/rdf-sparql-query/>



# SPARQL: a one slide introduction ☺

- **Triple statements:**
  - `gb:/23-h dc:title "Narrative of the Life of Frederick Douglass"`
  - `gb:/23-h dc:creator viaf:DouglassFrederick`
  - `gb:/23-h dc:subject lcsh:AfricanAmericanAbolitionists`
- **SPARQL queries work like this** (conceptually; this is not the actual encoded syntax):
  - `gb:/23-h dc:title what?`
  - `gb:/23-h dc:creator who?`
  - `gb:/23-h dc:subject what?`
  - `what? dc:creator viaf:DouglassFrederick`
  - `what? dc:subject lcsh:AfricanAmericanAbolitionists`
- **In other words:**
  - Who is the creator of the Project Gutenberg ebook 23-h?
  - What are all of the works (within certain parameters) that were created by Frederick Douglass?
  - What are all of the works (within certain parameters) that have the LCSH subject heading African American abolitionists?
- SPARQL enables many other, much more complex queries using various parameters, but this is the basic idea

# Questions?

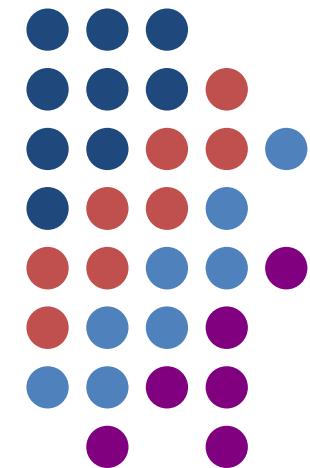


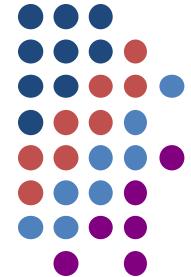
# Ontology Basics and RDFS

## (RDF Vocabulary Description Language)

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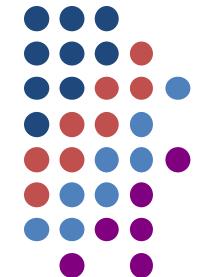
### Tutorial Part 2





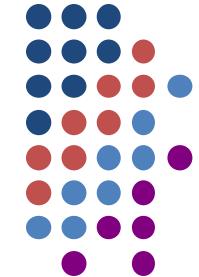
# Tutorial part 3 objectives

- Understand an **ontology** as a **semantic model** of a specific **knowledge domain**, defining its concepts and relationships
- Understand basic ontology building blocks, including **classes**, **subclasses**, **properties**, **subproperties**, **domain** and **range** specifications, and the principle of **inheritance**
- Understand how an ontology proper plus **instances** or **individuals** comprise a **knowledge-base** that can enable semantic **inferencing** and **querying** by machines
- Be able to create a beginning ontology using the components covered in this tutorial
- Be aware that **RDFS** (RDF Vocabulary Description Language) is an RDF-based language for expressing ontologies at a basic level



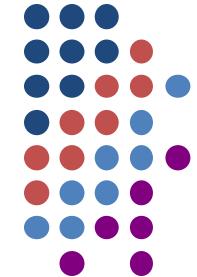
# Part 1 concepts & terminology

- Semantic modeling
- Knowledge domain
- Vocabulary
- Ontology
- Knowledge base
- RDFS
  - RDF Vocabulary
  - Description Language
  - (formerly RDF Schema)
- Class
- Subclass
- Property (or Slot)
- Subproperty
- Instance (or Individual)
- Inheritance
- Domain (of a property)
- Range (of a property)
- Inference



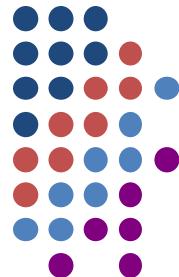
# Semantic modeling

- Compare the graph-based RDF data model with other data models (object oriented, entity-relationship, relational, hierarchical, etc.)
- Add **semantics** to RDF to model a **knowledge domain**
  - Semantics = meaning; in this context, machine-processable meaning
  - Also allow merging of information from different domains of knowledge
- Important terms:
  - **Vocabulary**: “a collection of terms given a well-defined meaning that is consistent across contexts”
  - **Ontology**: “allows you to define contextual relationships behind a defined vocabulary. It is the cornerstone of defining the knowledge domain.” –LinkedDataTools Tutorial 3.
- “*Ontologies, schemas, and vocabularies*, which all mean roughly the same thing, are RDF information about ... other RDF information.” – Joshua Tauberer



# Ontology

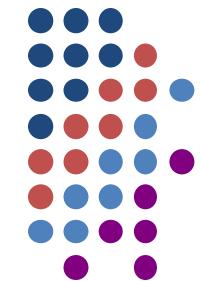
- Term from philosophy co-opted by computer science
- *Definitions*
  - “an explicit and formal specification of a conceptualization”
  - “defines the concepts and relationships used to describe and represent an area of knowledge” (W3C?)
  - a formal model of the things that exist in a specified knowledge domain and the relationships among those things
    - “things” may be concepts, works, persons, places, objects, events, etc.
- *Broadest sense:*
  - almost any kind of model, schema, or vocabulary; does not have to be encoded
- *More specific Semantic Web sense:*
  - a model encoded in an RDF-based ontology language (e.g., RDFS or OWL)
  - a computer-actionable model that enables logical inferencing: (e.g., OWL)



# Ontologies are one way to bring structure or constraints to RDF triples

- In a crude sense similar to DTDs or XML Schemas for XML data; or MARC tag tables for MARC data
- **Ontologies model a knowledge domain.**  
**Within that specified domain they establish:**
  - What kinds of resources can we make RDF statements about?
  - What RDF properties will we use to relate these resources to each other?
  - What can be the subject of a given RDF property?
  - What can be the object of a given RDF property?

# Core components of an ontology



- **1. Classes**

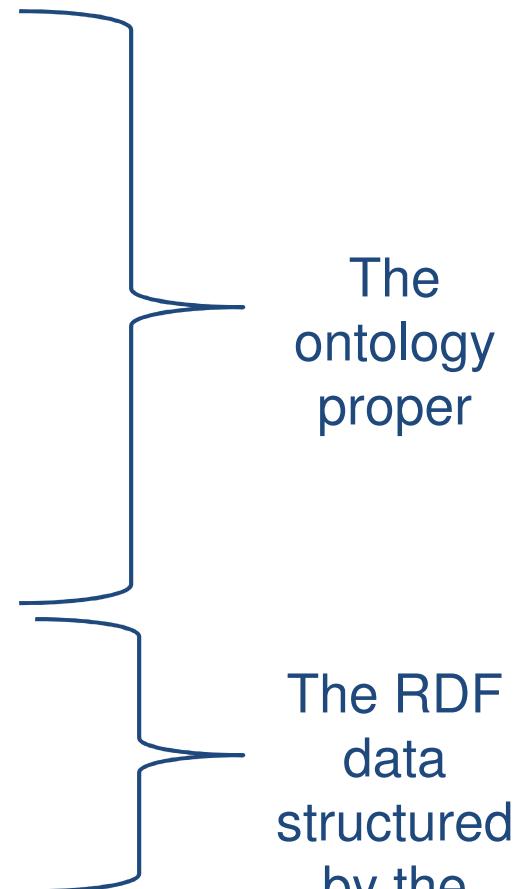
- May include **subclasses** (and superclasses)

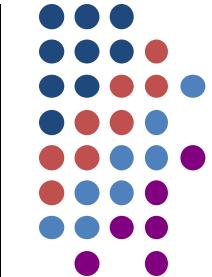
- **2. Properties**

- May include **subproperties** (and superproperties)
- Called “slots” in older terminology

- **3. Instances**

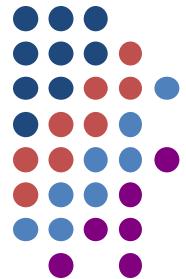
- Also called “**individuals**”
- Specific members of a class





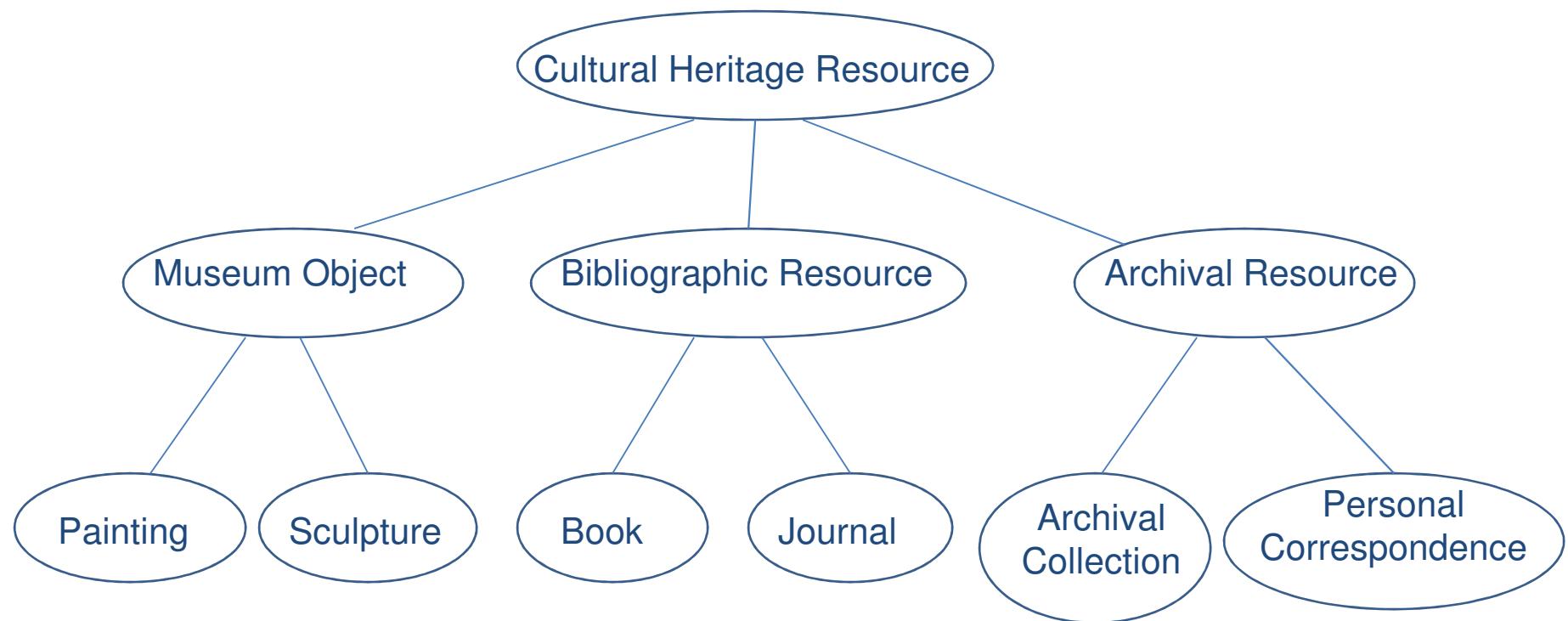
# (1) Classes

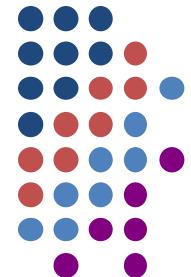
- A class is a **type** of *thing*.
  - A type of “resource” in the RDF sense: a type of person, place, object, concept, event, etc.
- Classes and subclasses form a hierarchical taxonomy
- Members of a subclass *inherit* the characteristics of their parent class (superclass)



# Class hierarchy example 1 (partial)

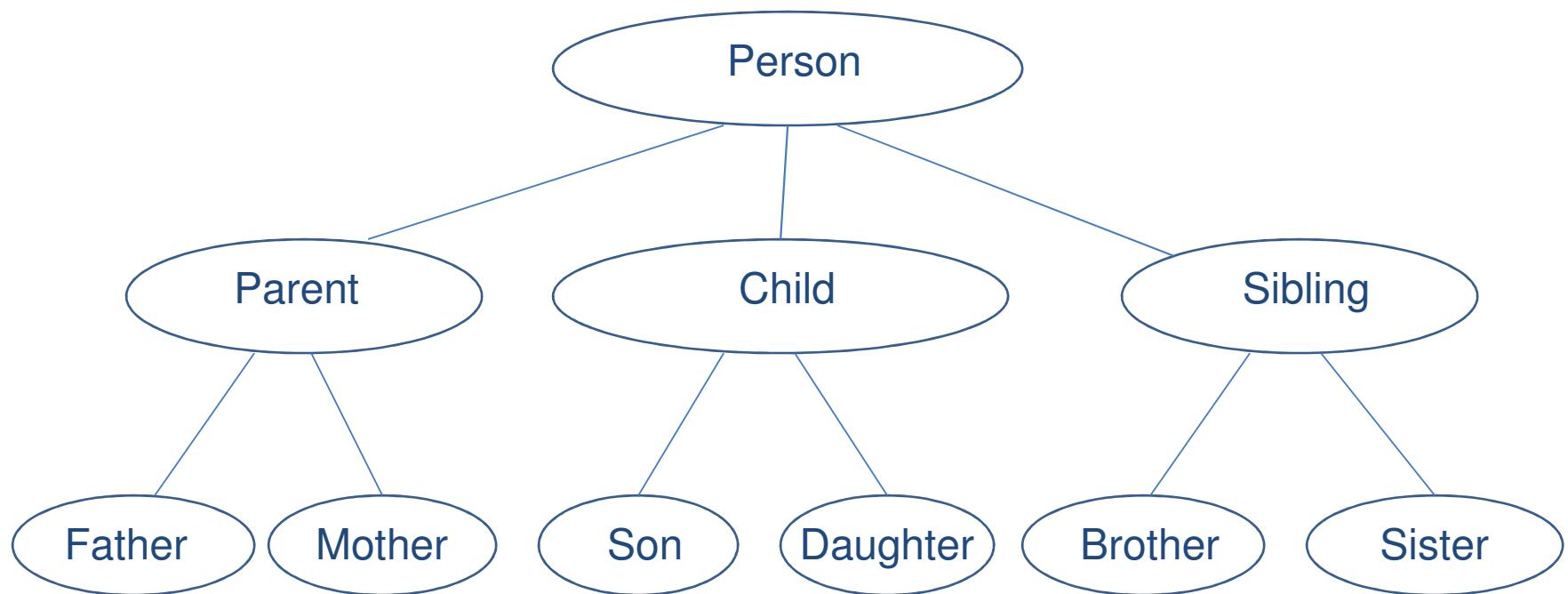
Types of resources specific to a  
**cultural heritage knowledge domain**

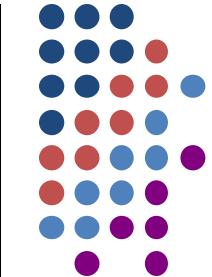




# Class hierarchy example 2 (partial)

Types of resources (things, instances, individuals) specific to a **family relationships knowledge domain**



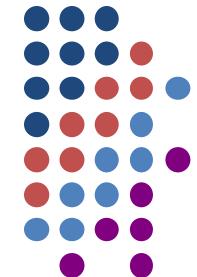


# Inheritance

- Members of a subclass inherit the characteristics and properties of their parent class (superclass)
- Everything true of the parent class is true also of the child or subclass
- A member of a subclass “is a”, or “is a kind of” its parent class
- Class<→>Subclass relationships must be very strictly logical in RDFS and OWL in order to enable correct computer inferencing

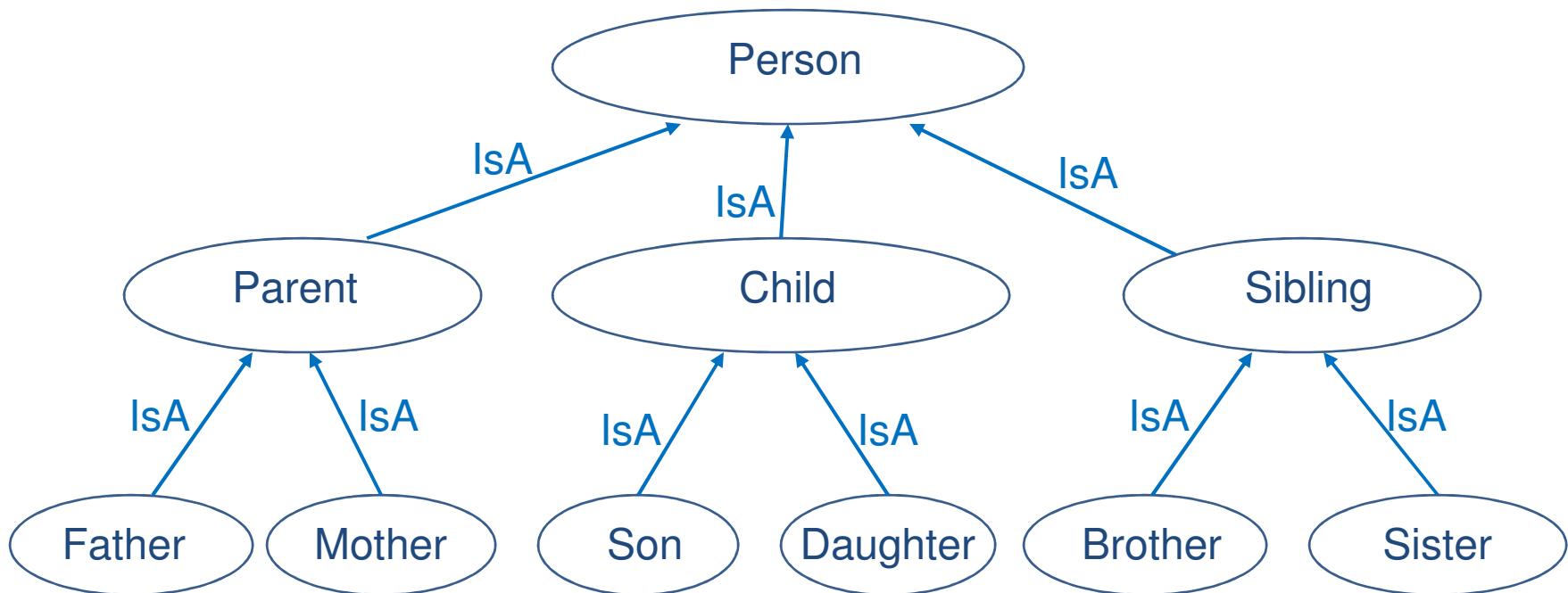
# Traditional controlled vocabulary & thesaural semantic relationships (Source: ANSI/NISO Z39.19)

Relationship	Type Example
<b>Equivalency</b>	
Synonymy	UN / United Nations
Lexical variants	pediatrics / paediatrics
Near synonymy	sea water / salt water
<b>Hierarchy</b>	
<b>Generic (or IsA)</b> (is a kind of)	bird / parrot ← RDFS/OWL <b>Class</b> relationship
<b>Instance (or IsA)</b> (is a specific instance of)	sea / Mediterranean Sea ← RDFS/OWL <b>Instance</b>
<b>Whole/Part</b> (actually meronymy, not hierarchy)	brain / brain stem ← <b>NOT</b> a RDFS/OWL Class relationship!!
<b>Associative</b>	
Cause / Effect	accident / injury
Process / Agent	velocity measurement / speedometer
Process / Counter-agent	fire / flame retardant
Action / Product	writing / publication
Action / Property	communication / communication skills
Action / Target	teaching / student
Concept or Object / Property	steel alloy / corrosion resistance
Concept or Object/ Origins	water / well
Concept or Object / Measurement Unit or Mechanism	chronometer / minute
Raw material / Product	grapes / wine
Discipline or Field / Object or Practitioner	neonatology / infant



# Class/subclass relationships

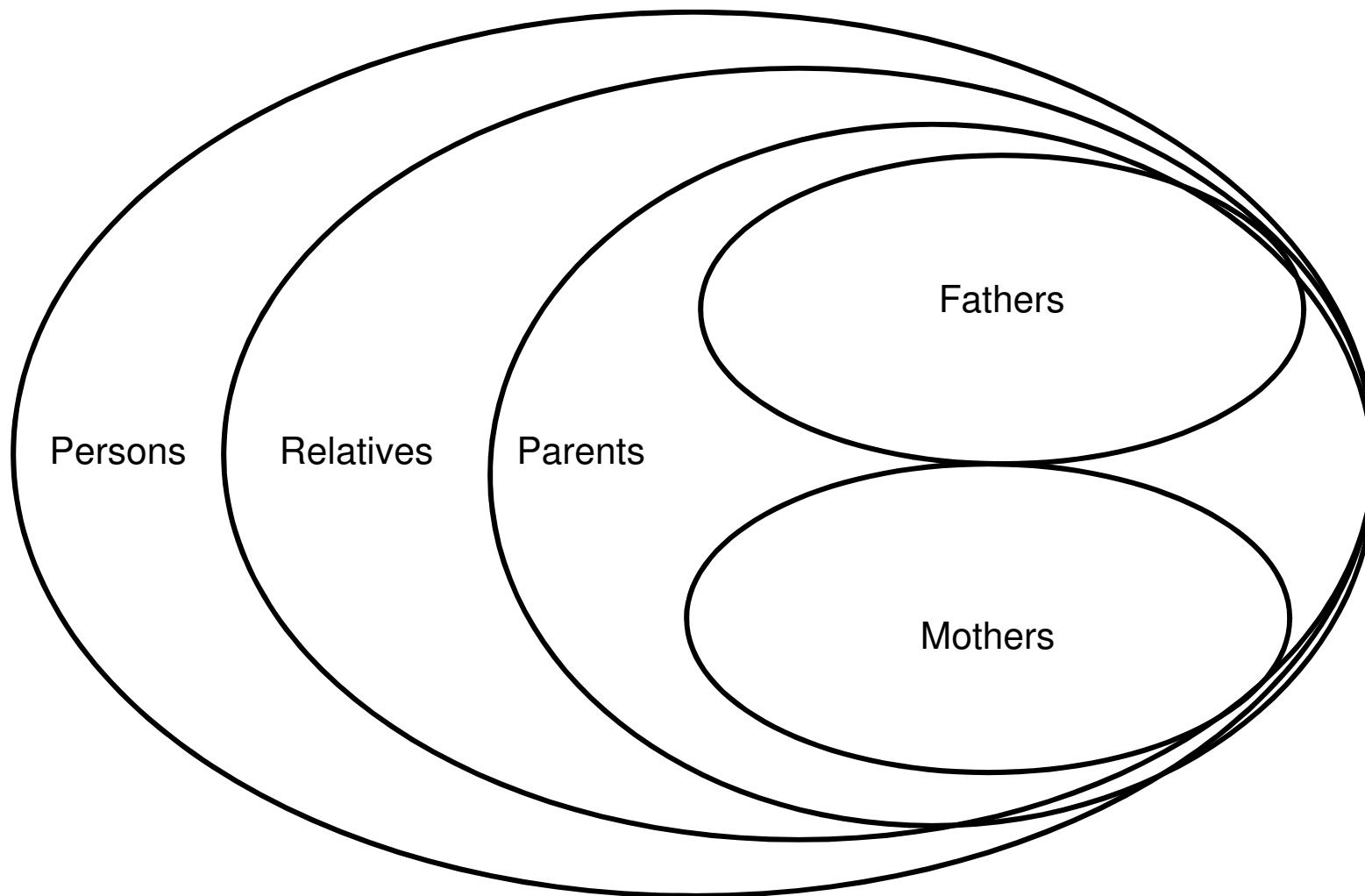
Each subclass **is a (is a type of)** its superclass.  
It inherits all of the properties of its parent class.

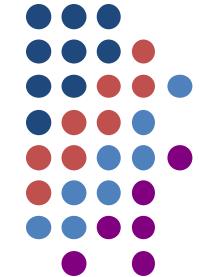




# Classes as sets and subsets

An alternative way to view classes, subclasses, and inheritance: as sets, represented by Venn style diagrams





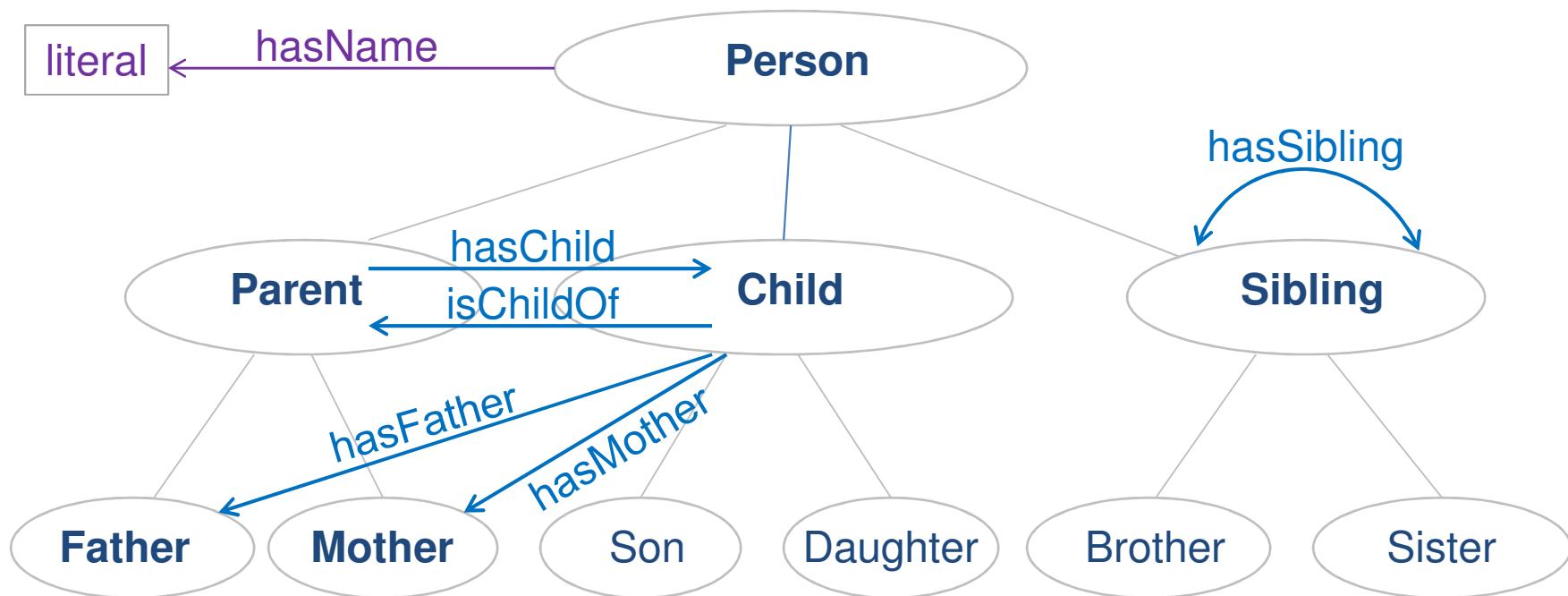
## (2) Properties

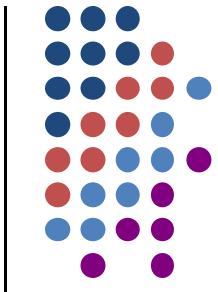
- **Predicates** in RDF
- Ontologies define a set of properties to be used in a specific knowledge domain
- Properties (predicates) connect or relate resources to each other
  - (subject – predicate --> object)
- In an ontology context, properties relate members of one class to members of another class, or to a literal



# Property example (partial)

Properties convey relationships between resources.  
In an ontology, they connect members of one class to members of another class (or to a literal)





# Domain and Range

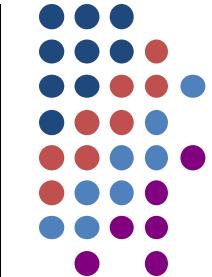
## Restrictions on properties (predicates in RDF triples)

- **Domain**

- restricts what kinds of resources or members of a class can be the ***subject*** of a given property in an RDF triple

- **Range**

- restricts what kinds of resources / members of a class or data types (literals) can be the ***object*** of a given property in an RDF triple



# Domain and Range

Restrict the possible values (instances) of subjects and object of a given property to members of a specific class or type

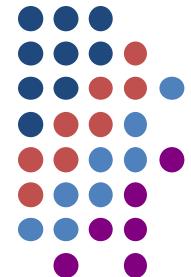


## Domain:

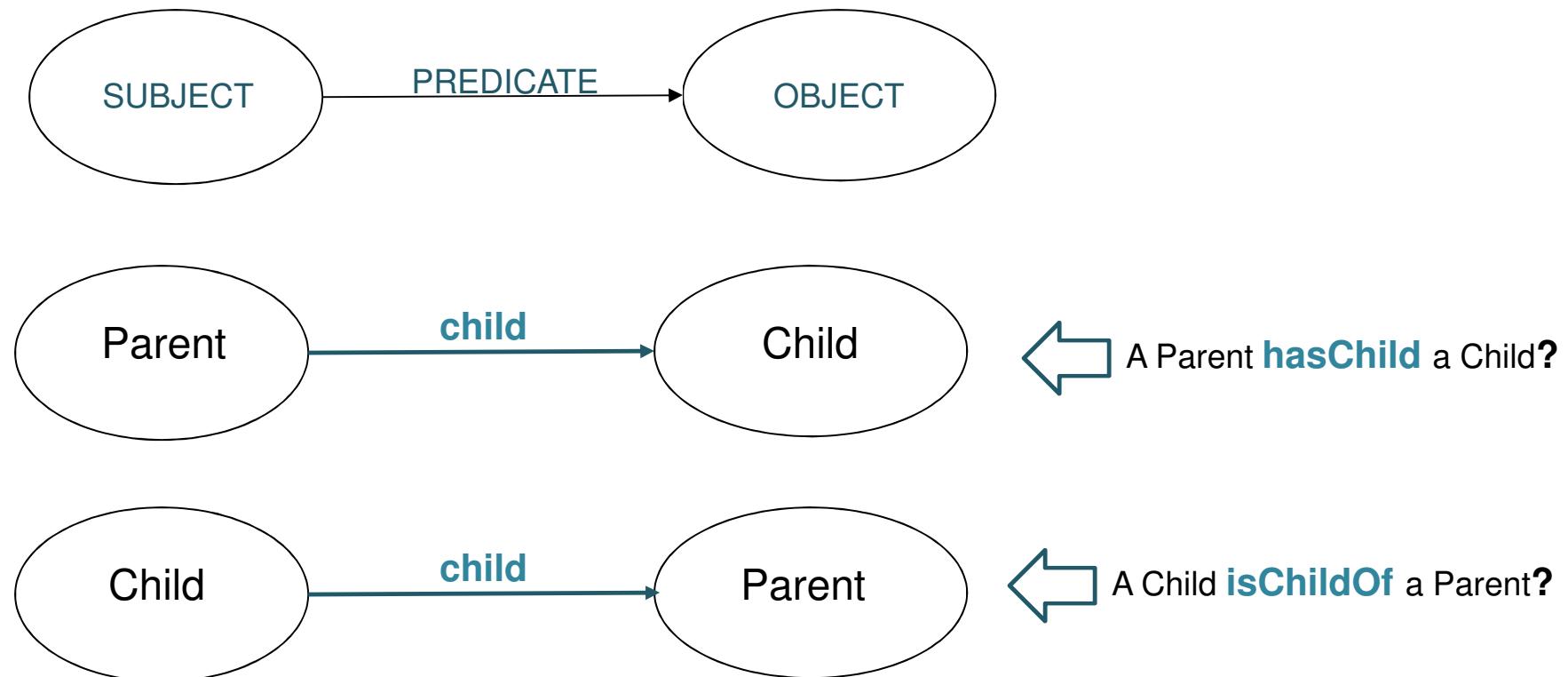
The **subject** of the property in the RDF triple must be a member of a specific class

## Range:

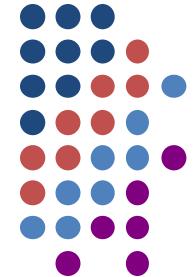
The **object** of the property in the RDF triple must be a member of a specific class [or a literal]



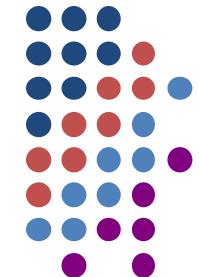
# Directed graph: what relationship does this *child* property indicate?



# Domain and range for “child” property



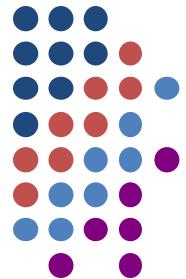
- **Property:** *child* [property]
  - **domain:** Parent [class]
  - **range:** Child [class]
- Therefore, only a member of the class Parent can be the RDF subject of the *child* property
- And only a member of the class Child can be the RDF object of the *child* property



# Inverse properties

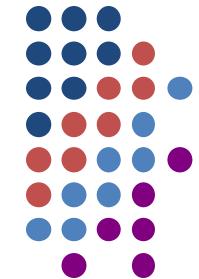
Some ontologies establish property names with clear directionality, and some ontologies include all inverse properties, for example:

- **Property:** *hasChild* [property]
  - **domain:** Parent [class]
  - **range:** Child [class]
  
- **Property:** *isChildOf* [property]
  - **domain:** Child [class]
  - **range:** Parent [class]



# Domain and range inheritance

- **Subproperties inherit the domain and range of their superproperties**
  - Unless more specific domain and range assertions are made for them
- *Example:*
  - Property: `isParentOf`
    - domain: `Parent`
    - range: `Child`
  - Property: `isFatherOf`
    - subPropertyOf `IsParentOf`
  - *Result:* `isFatherOf` inherits domain `Parent` and range `Child`  
But we can specify a narrower domain (and/or range when applicable):
    - Property: `isFatherOf`
      - domain: `Father`



## (3) Individuals

- Also called **Instances**
- The specific entities or concepts of interest to us
  - Concrete specific members or instances of classes
- For example:
  - David (by Michelangelo): member of the class Sculpture in a cultural heritage ontology
  - Maria I. Taylor: member of the class Mother in a family relationships ontology
- The actual data making up a graph database
  - Governed by the ontology proper



# Ontology statement examples

- **Class definition statements:**

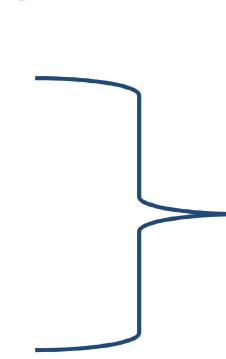
- Parent isA Class
- Mother isA Class
- Mother subClassOf Parent
- Child isA Class



The ontology proper

- **Property definition statements:**

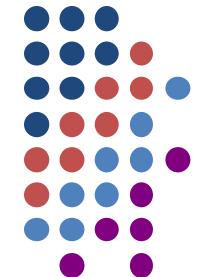
- isMotherOf isA Property
  - isMotherOf domain Mother
  - isMotherOf range Child



The RDF triple data structured by the ontology

- **Individual-instance statements:**

- MariaTaylor isA Mother
- AdamJTaylor isA Child
- MariaTaylor isMotherOf AdamJTaylor

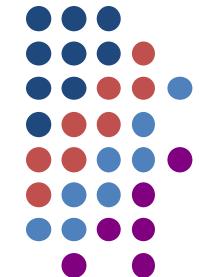


# Knowledge base

“Machine-readable knowledge bases store knowledge in a computer-readable form, usually for the purpose of having automated deductive reasoning applied to them. They contain a set of data, often in the form of rules that describe the knowledge in a logically consistent manner. An ontology can define the structure of stored data - what types of entities are recorded and what their relationships are. ... Such knowledge bases are also used by the semantic web.” --Wikipedia:  
[http://en.wikipedia.org/wiki/Knowledge\\_base](http://en.wikipedia.org/wiki/Knowledge_base)

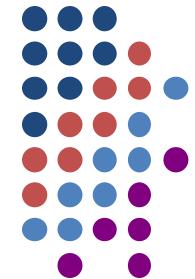
*For our purposes, a knowledge base is comprised of:*

- **An ontology proper**
  - Defines the structure of the RDF data, the allowable classes, properties, and their characteristics
- **Individuals: the RDF instance data**
  - Statements about the actual things of interest in the knowledge domain (such as specific persons, places, things, events, concepts); must conform to the ontology



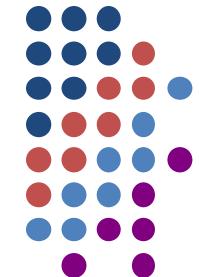
# RDFS

- **RDF Vocabulary Description Language**
  - Originally stood for: RDF Schema Language
- A simple, RDF-based language for encoding RDF ontologies
- An RDF/XML-based encoding syntax



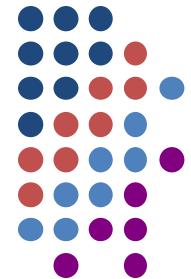
# Key RDFS elements

- **rdfs:Resource**
  - the class of all resources
- **rdfs:Class**
  - the class of all classes
- **rdfs:Literal**
  - the class of all literals (strings)
- **rdf:Property**
  - the class of all properties
- **rdf:type**
  - relates a resource to its class
- **rdfs:subClassOf**
  - relates a class to one of its superclasses
- **rdfs:subPropertyOf**
  - relates a property to one of its superproperties
- **rdfs:domain**
  - Specifies the domain of a property
  - Any resource that is the subject of that property is an instance of the domain class
- **rdfs:range**
  - Specifies the range of a property
  - Any resource that is the object (value) of that property is an instance of the range class



# RDFS notation options

- Examples on the next three slides
  1. RDFS in RDF/XML syntax
  2. A simplified notation for greater human readability
  3. A yet more simplified notation that will be used in the majority of slides in this workshop
- The emphasis is on understanding the concepts, the logical (RDF) statements, and the resulting logical inferencing capabilities rather than on reading RDF XML syntax code



# RDFS statement examples in RDF/XML

```
<?xml version="1.0"?>

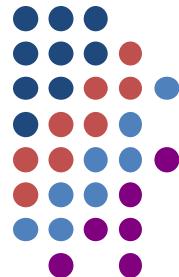
<rdf:RDF
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
  xml:base="http://abc.xyz/familyrelationshipsontology#">

  <rdfs:Class rdf:ID="Relative"/>

  <rdfs:Class rdf:ID="Parent">
    <rdfs:subClassOf rdf:resource="#Relative"/>
  </rdfs:Class>

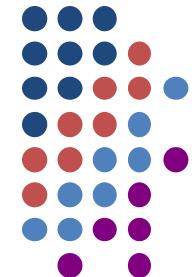
  <rdfs:Property rdf:ID="hasChild">
    <rdfs:domain rdf:resource="#Parent"/>
    <rdfs:range rdf:resource="#Child"/>
  </rdfs:Class>

  <rdf:Description> <rdf:about="fro:MarialTaylor">
    <rdf:type rdf:resource="fro:Parent">
      <fro:hasChild rdf:resource="fro:AdamJTaylor">
    </rdf:Description>
```



# RDFS statement examples (simplified notation)

- *Namespaces*
  - xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  - xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
  - xmlns:fro="http://abc.xyz/familyrelationshipsontology#"
- *Classes*
  - fro:Parent rdf:type rdfs:Class [rdfs:Class rdf:ID fro:Parent ]
  - fro:Parent rdfs:subcassOf fro:Relative
- *Properties*
  - fro:hasChild rdf:type rdf:Property [rdf:Property rdf:ID fro:hasChild]
  - fro:hasChild rdfs:domain fro:Parent
  - fro:hasChild rdfs:range fro:Child
- *Instances*
  - fro:MariaTaylor rdf:type fro:Parent
  - fro:MariaTaylor fro:hasChild fro:AdamJTaylor
- *Notice a mixture of rdf: and rdfs: elements in RDFS*

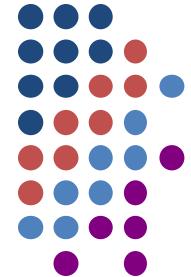


# RDFS statement examples

## (even more simplified notation)

- Parent isA Class
- Parent subClassOf Relative
  
- hasChild isA Property
- hasChild domain Parent
- hasChild domain Child
  
- MarialTaylor isA Parent
- MarialTaylor hasChild AdamJTaylor

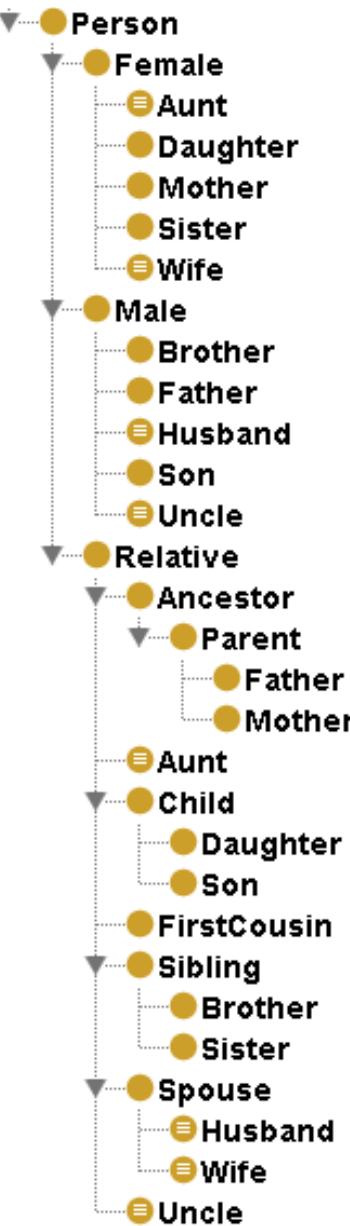
# Family relationships ontology example



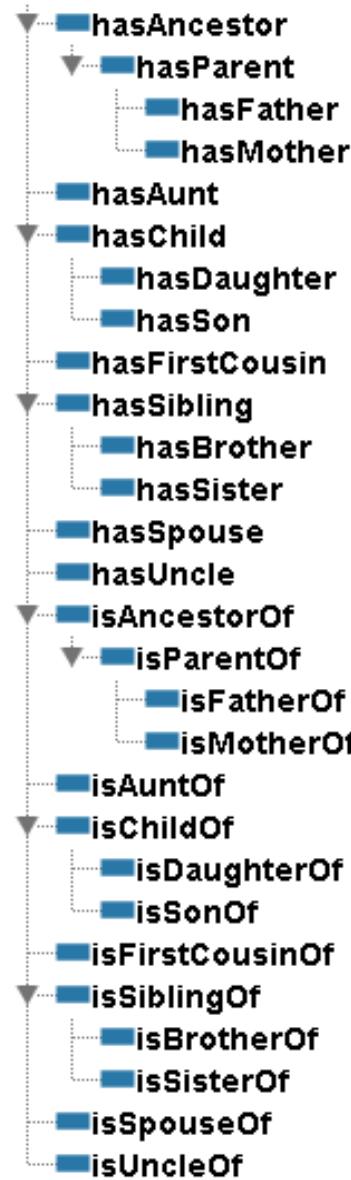
- Advantages
  - Familiarity of family classes and relationships
  - Easier to understand the ontology and individuals
    - inheritance, domains and ranges, property types and restrictions, and logical inferences
  - Generalizable to other knowledge domains

# Family Relationships Ontology

## Classes



## Properties



## Properties (continued)

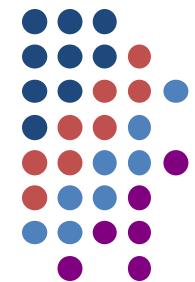


## Instances/Individuals

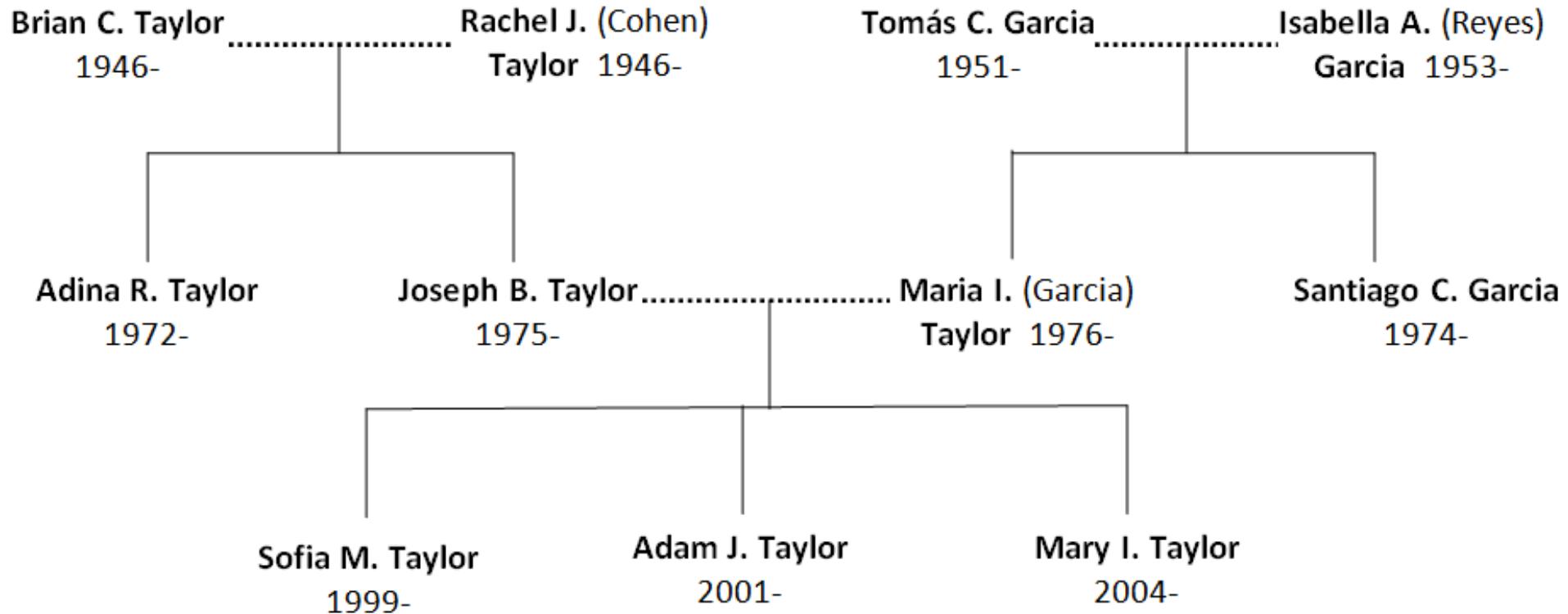
- ◆ AdamJTaylor
- ◆ AdinaRTaylor
- ◆ BrianCTaylor
- ◆ IsabellaAGarcia
- ◆ JosephBTaylor
- ◆ MarialTaylor
- ◆ MaryITaylor
- ◆ RachelJCohen
- ◆ SantiagoCGarcia
- ◆ SofiaMTaylor
- ◆ TomasCGarcia

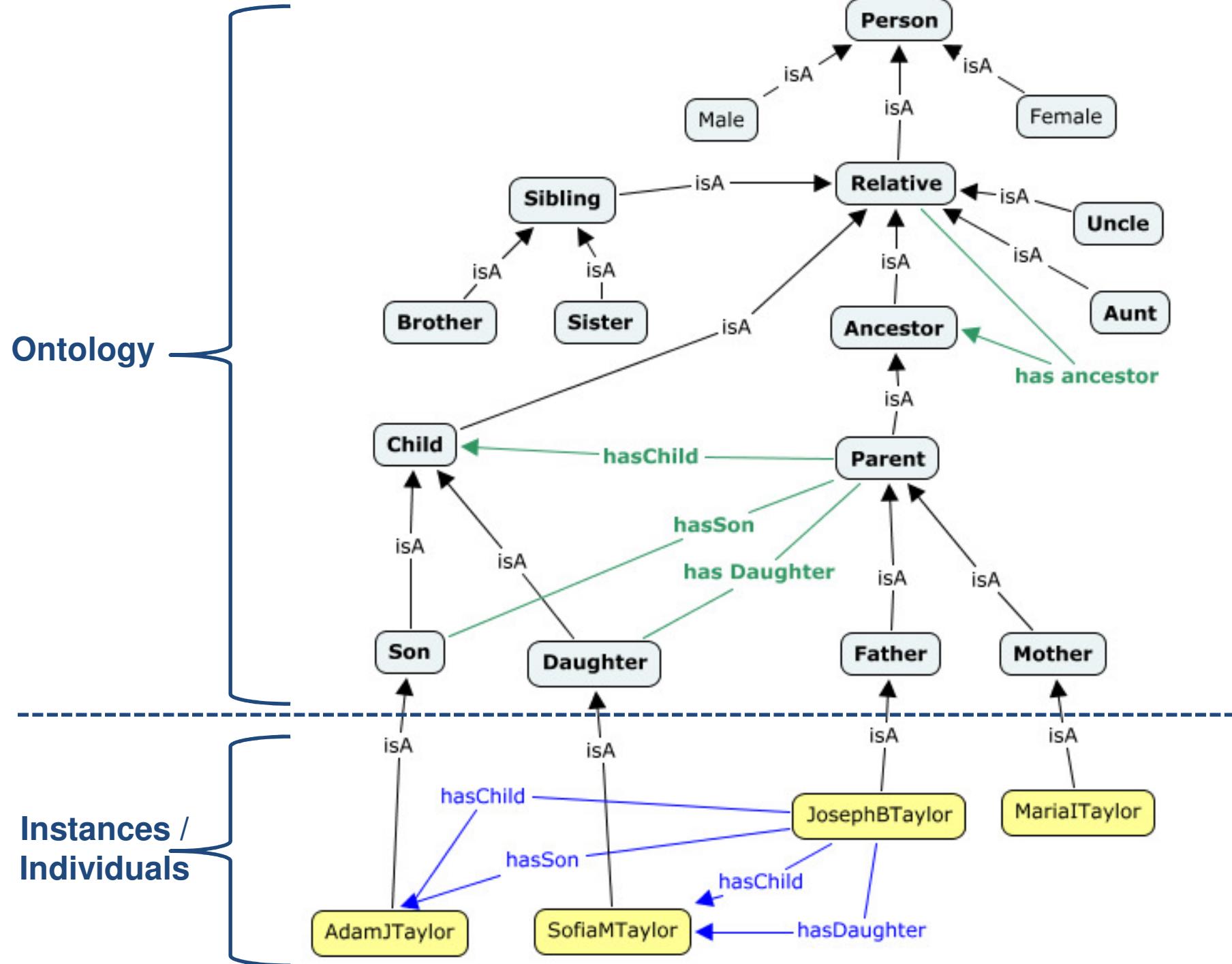
# Family relationships instances

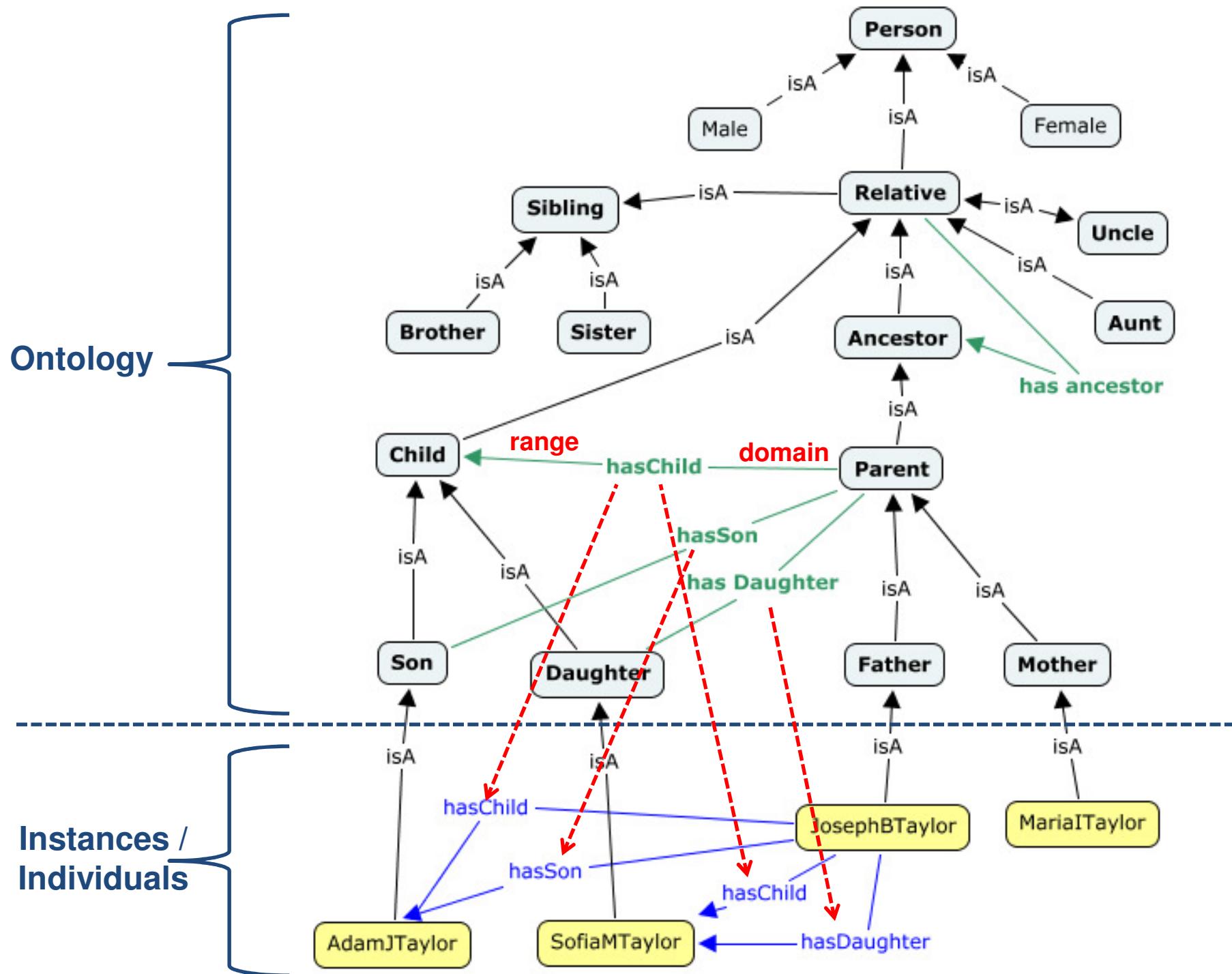
## (traditional family tree)

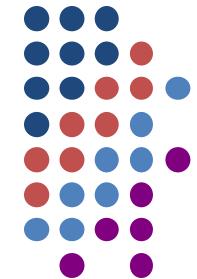


### Taylor-Garcia Family Tree









# Inferencing

- **Semantics based IF ... THEN on inference rules**
- Computers can make inferences not directly stated by a human being
- **RDF**
  - Allows some lightweight inferencing
  - Based especially on shared URIs for resources and properties, and resulting linked data graphs
- **RDFS**
  - Enables much greater inferencing based on class/subclass, property/subproperty and resulting inheritance relationships, and domain and range specifications
- **OWL**
  - Enables yet more powerful inferencing based on the use of specific types of properties
  - As we will see in the part 4 of this tutorial



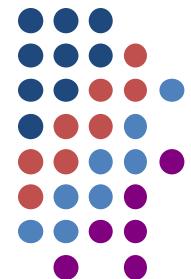
# Inferences expressed as statements

- **Statements:**

- Relative isA Class
- Relative subClassOf Person
- Parent isA Class
- Parent subClassOf Relative
- Mother isA Class
- Mother subClassOf Parent
- isMotherOf isA Property
  - isMotherOf domain Mother
  - isMotherOf range Child
- isMotherOf subPropertyOf isParentOf
- **MariaTaylor isMotherOf AdamJTaylor**

- **Inferences:**

- MariaTaylor isA Mother
- MariaTaylor isA Parent
- MariaTaylor isA Relative
- MariaTaylor isParentOf AdamJTaylor
- AdamJTaylor isA Child



# Further inferences displayed in Protégé

Usage: SofiaMTaylor

Show:  this  different

Found 5 uses of SofiaMTaylor

▼ ♦ **SofiaMTaylor**

- ♦ Individual: SofiaMTaylor
- ♦ SofiaMTaylor hasMother MarialTaylor
- ♦ SofiaMTaylor hasBrother AdamJTaylor
- ♦ SofiaMTaylor **Type** Person
- ♦ SofiaMTaylor hasFather JosephBTaylor

Description: SofiaMTaylor

Types +

- **Person** @ × ○
- Child ? @
- Sibling ? @

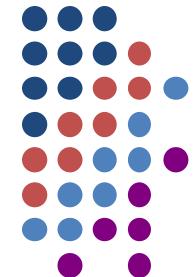
Same individuals +

Different individuals +

Property assertions: SofiaMTaylor

Object property assertions +

- **hasBrother AdamJTaylor**
- **hasMother MarialTaylor**
- **hasFather JosephBTaylor**
- hasParent MarialTaylor
- hasParent JosephBTaylor
- hasAncestor MarialTaylor
- hasAncestor JosephBTaylor
- hasSibling AdamJTaylor



# Ontology editors (software)

Two of the best known and most widely used

- **TopBraid Composer** by TopQuadrant
  - [http://www.topquadrant.com/products/TB\\_Composer.html](http://www.topquadrant.com/products/TB_Composer.html)
- **Protégé** from Stanford University
  - Free, open source ontology editor and knowledge-base framework: <http://protege.stanford.edu/>
  - See information in "Selected Resources" at the end of the tutorial materials

[HOME](#) | [OVERVIEW](#) | [DOCUMENTATION](#) | [DOWNLOADS](#) | [SUPPORT](#) | [COMMUNITY](#) | [WIKI](#) | [ABOUT US](#)Search: 

## welcome to protégé

### news

**June 2–5, 2013**  
[WebProtégé Tutorial](#)  
SemTechBiz 2013  
San Francisco, California  
Use code "BMIR" for 40% off

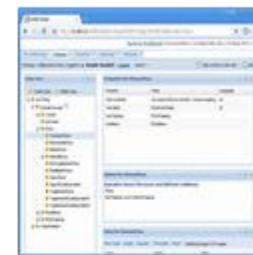
**Sept 2–4, 2013**  
[Protégé-OWL Short Course](#)  
Vienna, Austria



Protégé is a **free, open source** ontology editor and knowledge-base framework.

The Protégé platform supports modeling ontologies via a [web client](#) or a [desktop client](#). Protégé ontologies can be developed in a variety of formats including OWL, RDF(S), and XML Schema.

Protégé is based on Java, is extensible, and provides a plug-and-play environment that makes it a flexible base for rapid prototyping and application development.

[go to WebProtégé](#)[go to Protégé](#)

Protégé is supported by a [strong community](#) of developers and academic, government and corporate users, who are using Protégé for knowledge solutions in areas as diverse as biomedicine, intelligence gathering, and corporate modeling.

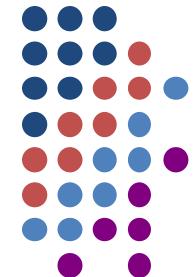
### community

<a href="#">Registered Users</a>	224,474
<a href="#">protege-users</a> list members	17,198
<a href="#">protege-discussion</a> list members	2,418
<a href="#">protege-owl</a> list members	2,384

Protégé is available from this site as a **free download** along with [plug-ins](#) and [ontologies](#).

### downloads

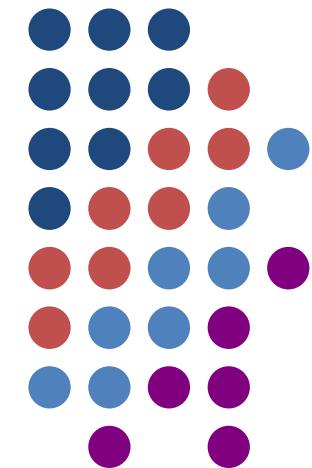
<a href="#">WebProtégé build 103</a>	May 20, 2013
<a href="#">Protégé 4.3</a>	Apr 15, 2013
<a href="#">Protégé 3.5</a>	April 24, 2013



# Tutorial part 2 summary

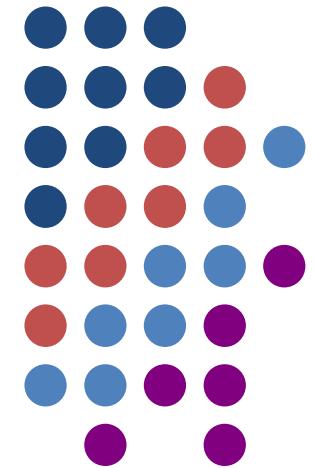
- Ontologies are **models** of the entities of interest to a particular domain and the relationships among those entities
- RDF-based ontologies are machine readable and actionable
  - Basic-level RDF ontologies are encoded in **RDFS**: RDF Vocabulary Description Language
- *Ontologies consist of:*
  - **Classes**: *types of entities*
    - Usually in class-subclass **hierarchies**
  - **Properties**: designating *relationships among entities* (members of classes)
    - Usually in property-subproperty **hierarchies**
    - **Domain and range** specifications about allowable subjects and object of properties
  - **Instances** or **individuals** tied to the ontology proper; must conform to the model
- Ontologies allow **logical inferences**
  - based on class and property hierarchies (inheritance) and domain and range specifications

# Questions?



# Examples

**Domain ontologies, models, or schemas** that use classes, properties, domain, range, class and property hierarchies



# CIDOC CRM ontology

CIDOC: International Committee for Documentation

The screenshot shows the CIDOC CRM website homepage. At the top left is the ICOM logo (International Council of Museums). In the center, the title "The CIDOC Conceptual Reference Model" is displayed. At the top right is the CIDOC CRM logo. A navigation bar below the title includes links for Home, The CIDOC CRM, Activities, People, Resources, FRBR-CRM, and External References. On the left side, there is a sidebar with a "Site Search" input field and a "GO" button. Below the search is a "Current Page: What is CIDOC CRM" link. Further down the sidebar are links for Who we are, Sitemap, WIKI Forum, Official Release, and What's New?. The main content area features a section titled "What is the CIDOC CRM" which defines the model as a framework for describing concepts and relationships in cultural heritage documentation. It also explains the model's purpose in promoting shared understanding and providing a common language for domain experts. A note at the bottom states that the CIDOC CRM is an ISO standard. At the bottom right, there is a summary: "CIDOC = International Committee for Documentation" and "CRM = Conceptual Reference Model". The footer contains links for Site hosted by FORTH and Last Updated: 18-01-2013.

**CIDOC CRM Home page**

**What is the CIDOC CRM**

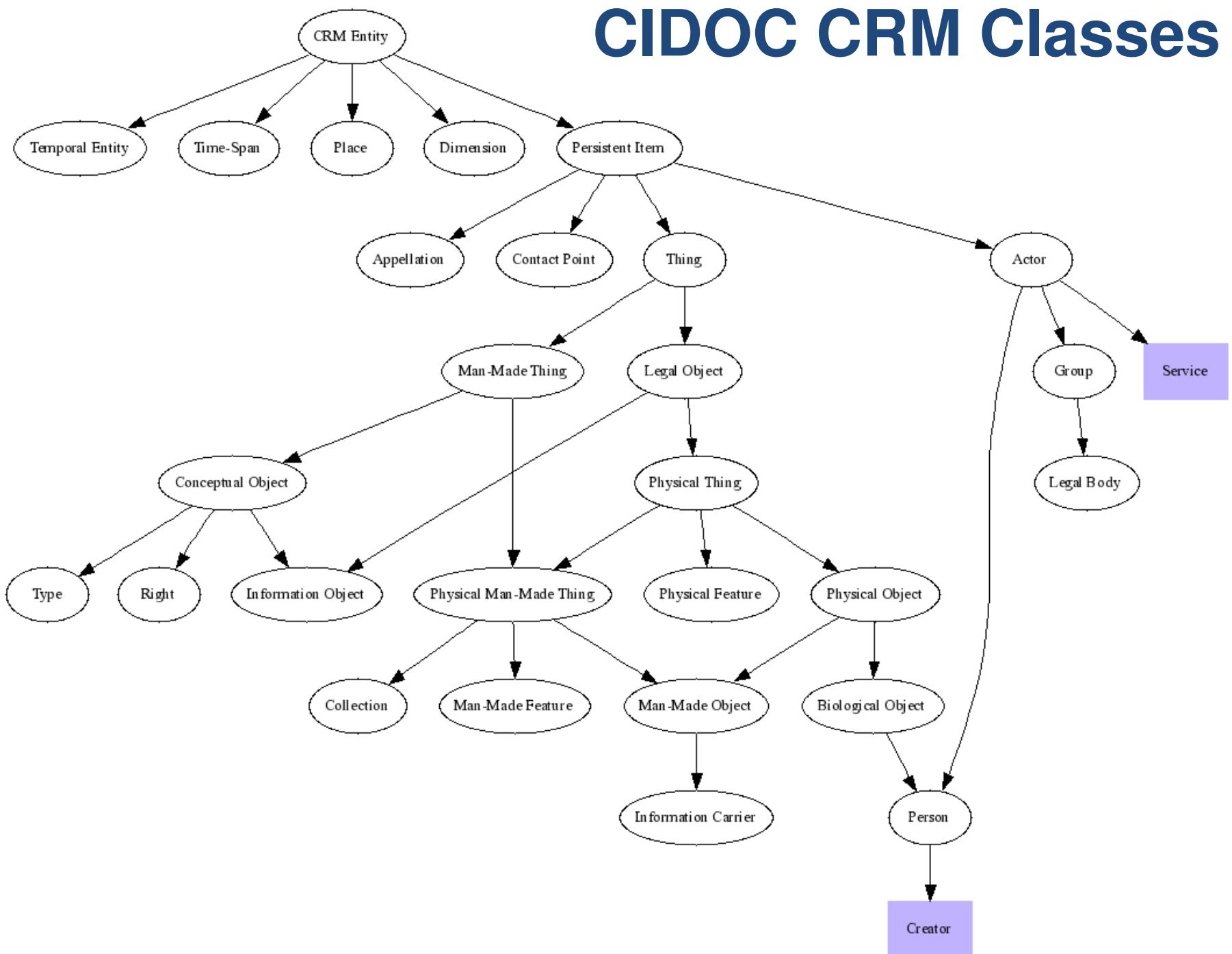
The **CIDOC Conceptual Reference Model (CRM)** provides definitions and a formal structure for describing the implicit and explicit concepts and relationships used in cultural heritage documentation.

The **CIDOC CRM** is intended to promote a shared understanding of cultural heritage information by providing a common and extensible semantic framework that any cultural heritage information can be mapped to. It is intended to be a common language for domain experts and implementers to formulate requirements for information systems and to serve as a guide for good practice of conceptual modelling. In this way, it can provide the "semantic glue" needed to mediate between different sources of cultural heritage information, such as that published by museums, libraries and archives.

The **CIDOC CRM** is the culmination of over 10 years work by the **CIDOC Documentation Standards Working Group** and **CIDOC CRM SIG** which are working groups of **CIDOC**. Since 9/12/2006 it is official standard **ISO 21127:2006**.

**CIDOC** = International Committee for Documentation  
**CRM** = Conceptual Reference Model

# CIDOC CRM Classes



# CIDOC CRM Properties

Property id	Property Name	Entity - Domain	Entity - Range
P1	is identified by (identifies)	E1 CRM Entity	E41 Appellation
P2	has type (is type of)	E1 CRM Entity	E55 Type
P3	has note	E1 CRM Entity	E62 String
P4	has time-span (is time-span of)	E2 Temporal Entity	E52 Time-Span
P7	took place at (witnessed)	E4 Period	E53 Place
P10	falls within (contains)	E4 Period	E4 Period
P12	occurred in the presence of (was present at)	E5 Event	E77 Persistent Item
P11	- had participant (participated in)	E5 Event	E39 Actor
P14	- - carried out by (performed)	E7 Activity	E39 Actor
P16	- used specific object (was used for)	E7 Activity	E70 Thing
P31	- has modified (was modified by)	E11 Modification	E24 Physical Man-Made Thing
P108	- - has produced (was produced by)	E12 Production	E24 Physical Man-Made Thing
P92	- brought into existence (was brought into existence by)	E63 Beginning of Existence	E77 Persistent Item
P108	- - has produced (was produced by)	E12 Production	E24 Physical Man-Made Thing
P94	- - has created (was created by)	E65 Creation	E28 Conceptual Object
P93	- took out of existence (was taken out of existence by)	E64 End of Existence	E77 Persistent Item
P15	was influenced by (influenced)	E7 Activity	E1 CRM Entity
P16	- used specific object (was used for)	E7 Activity	E70 Thing
P20	had specific purpose (was purpose of)	E7 Activity	E5 Event
P43	has dimension (is dimension of)	E70 Thing	E54 Dimension
P46	is composed of (forms part of)	E18 Physical Thing	E18 Physical Thing
P59	has section (is located on or within)	E18 Physical Thing	E53 Place
P67	refers to ( is referred to by)	E89 Propositional Object	E1 CRM Entity
P75	possesses (is possessed by)	E39 Actor	E30 Right
P81	ongoing throughout	E52 Time-Span	E61 Time Primitive
P82	at some time within	E52 Time-Span	E61 Time Primitive
P89	falls within (contains)	E53 Place	E53 Place
P104	is subject to (applies to)	E72 Legal Object	E30 Right
P106	is composed of (forms part of)	E90 Symbolic Object	E90 Symbolic Object
P107	has current or former member (is current or former member of)	E74 Group	E39 Actor
P127	has broader term (has narrower term)	E55 Type	E55 Type
P128	carries (is carried by)	E24 Physical Man-Made Thing	E90 Symbolic Object
P130	shows features of (features are also found on)	E70 Thing	E70 Thing
P140	assigned attribute to (was attributed by)	E13 Attribute Assignment	E1 CRM Entity
P141	assigned (was assigned by)	E13 Attribute Assignment	E1 CRM Entity
P148	has component (is component of)	E89 Propositional Object	E89 Propositional Object

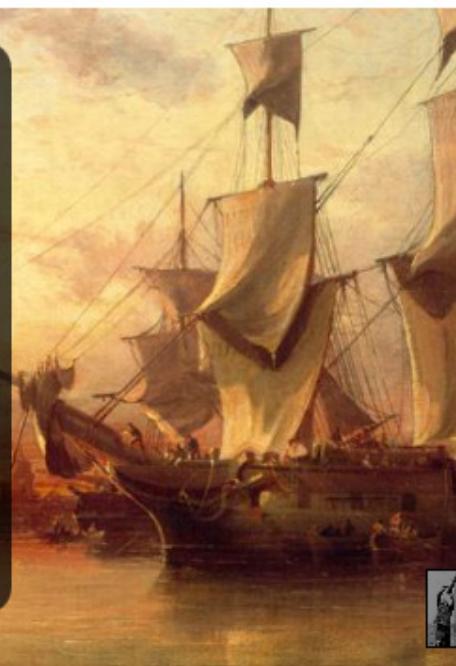
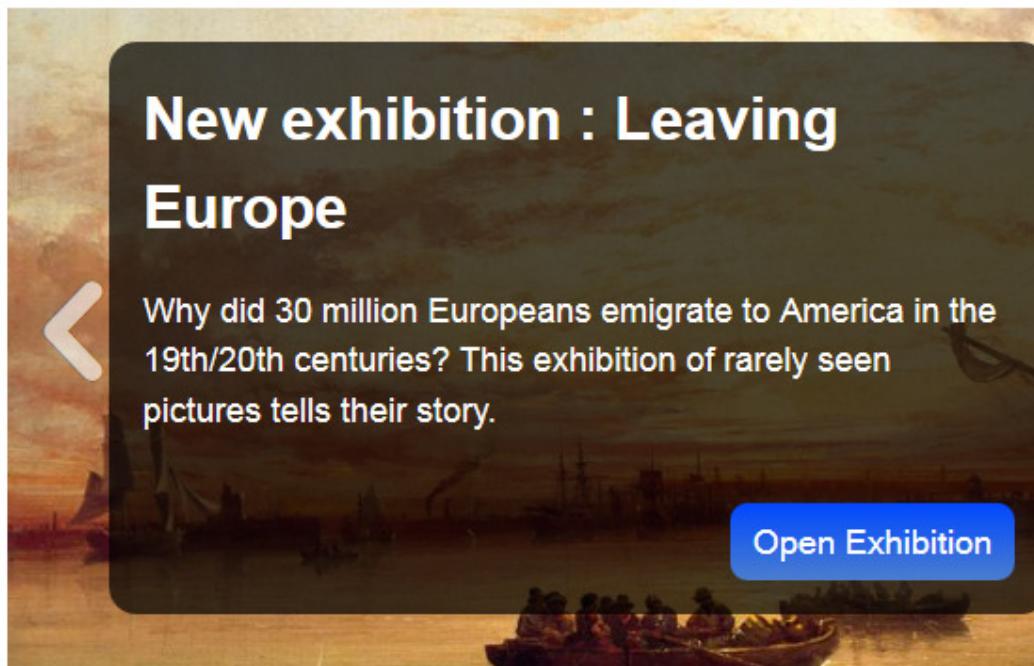


Search ▾

**New exhibition : Leaving Europe**

Why did 30 million Europeans emigrate to America in the 19th/20th centuries? This exhibition of rarely seen pictures tells their story.

[Open Exhibition](#)



## From the blog



### [Betsy, Angel of Prisons](#)

Elizabeth Gurney, or Betsy as she was known, was born on 21 May



### [Europeana Twinsies: Classic Masterpieces with a Twist](#)

Choose a language

Choose a language

English

Basque

Български

Català

Čeština

Dansk

Deutsch

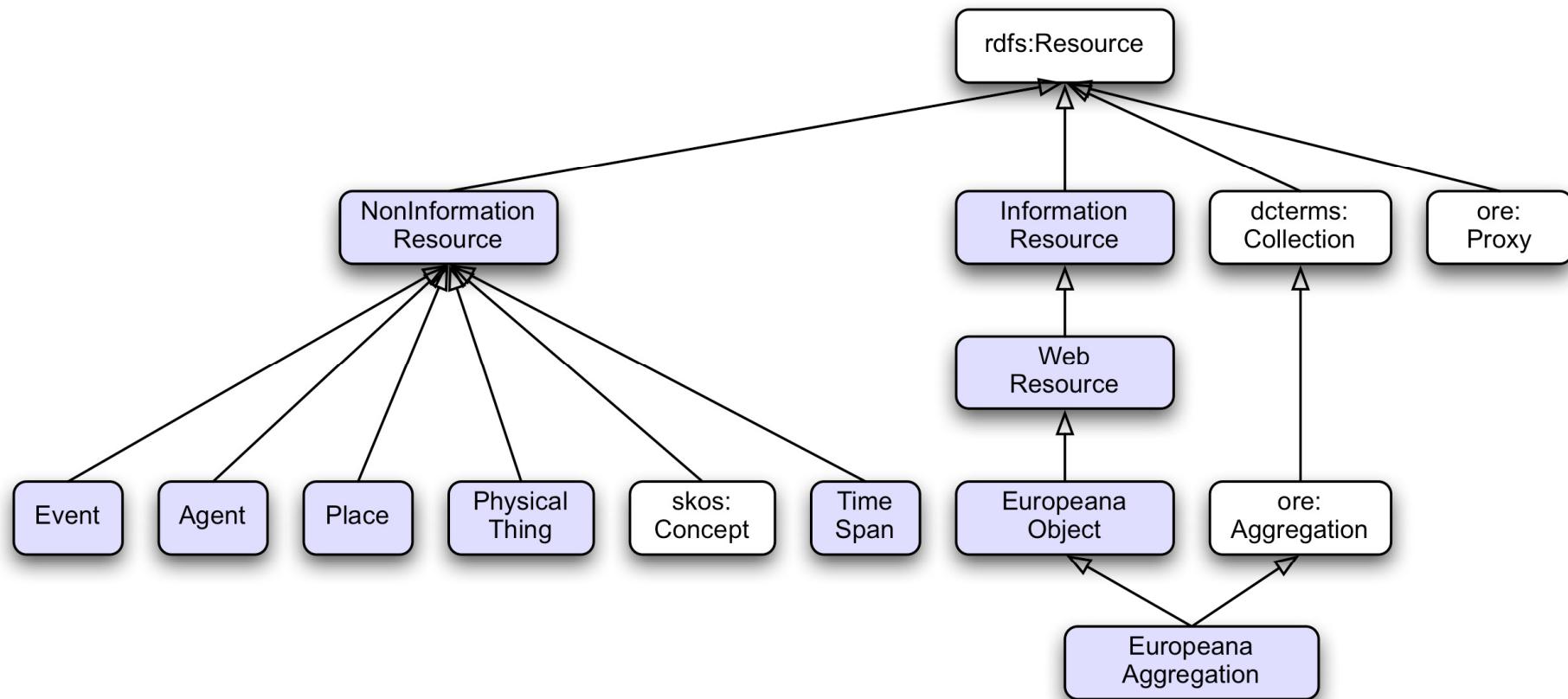
Ελληνικά

Español

Eesti

Français

# Europeana Data Model (EDM) Class Hierarchy

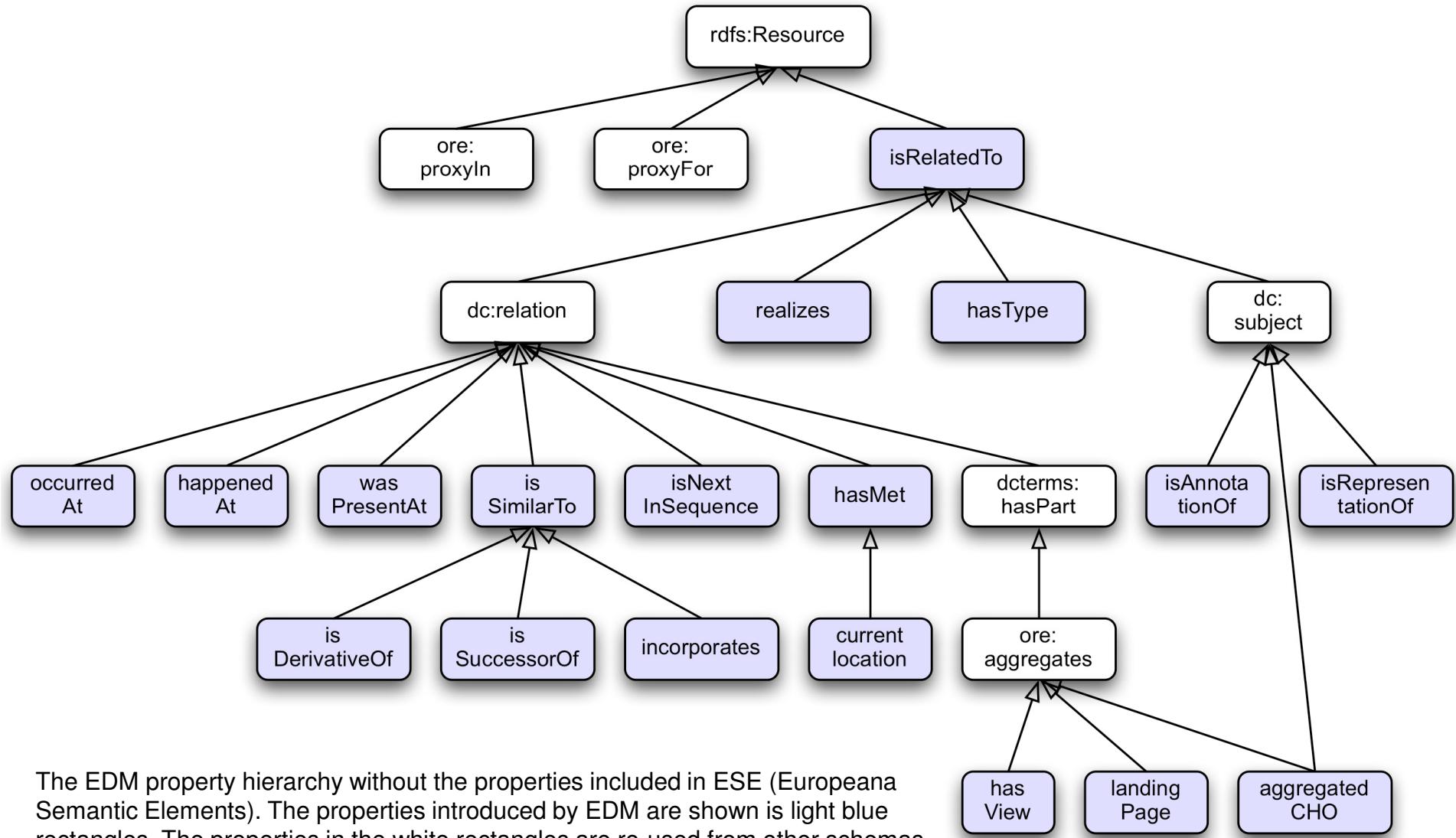


The classes introduced by EDM are shown in light blue rectangles. The classes in the white rectangles are re-used from other schemas; the schema is indicated before the colon.

Source: <http://pro.europeana.eu/documents/900548/0d0f6ec3-1905-4c4f-96c8-1d817c03123c>

# Europeana Data Model (EDM)

## Property Hierarchy



# EDM “happened at” property

## 3.2.2 Happened At

Property name: happenedAt	
Namespace	europeana
URI	<a href="http://www.europeana.eu/schemas/edm/happenedAt">http://www.europeana.eu/schemas/edm/happenedAt</a>
Label	happened at
Definition	This property associates an event with the place at which the event happened.
Subproperty of	dc:relation
Equivalent property	P7_took_place_at (CIDOC CRM)
Domain	ens:Event
Range	ens:Place
Europeana note	
Obligation & Occurrence	An event may have happened at 0 to 1 place, and a place may have 0 to many events that happened at it.
Example	The creation of Mona Lisa happened at Florence. The excavation of the Egyptian Amphora L2409 happened at Heraklion, Crete.
Rationale	This property is useful for supporting discoveries concerning places (where query) since it relates a place to the events which happened at that place. In addition, it can be used to browse specific events.

<http://bibliontology.com/>

The Bibliographic Ontology



News Specification Changelog ▾ Examples Projects Community Login

Navigation

- Recent posts

## Welcome to the Bibliographic Ontology Website



# The Bibliographic Ontology

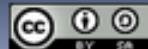
This is the official Web site for the Bibliographic Ontology, known as BIBO (namespace: *bibo*). Here you may find the BIBO [specification](#), [examples](#) of its use, links to [news](#) and [blog postings](#), [projects](#) that are using or extending BIBO, and links to where the [community](#) discusses the specification and exchanges information.

Frédéric Giasson and Bruce D'Arcus, co-editors

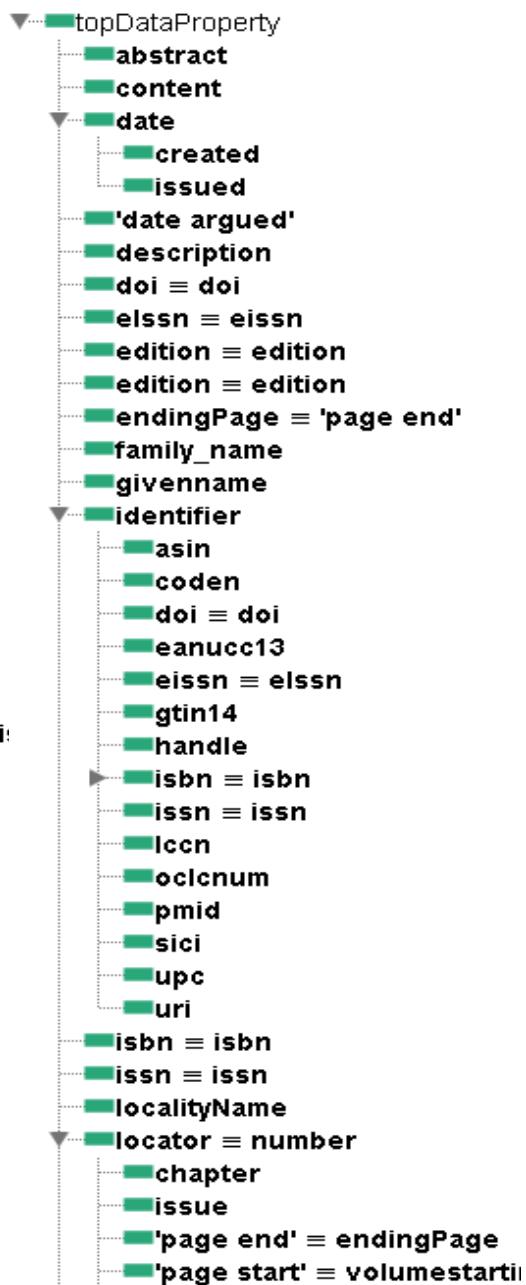
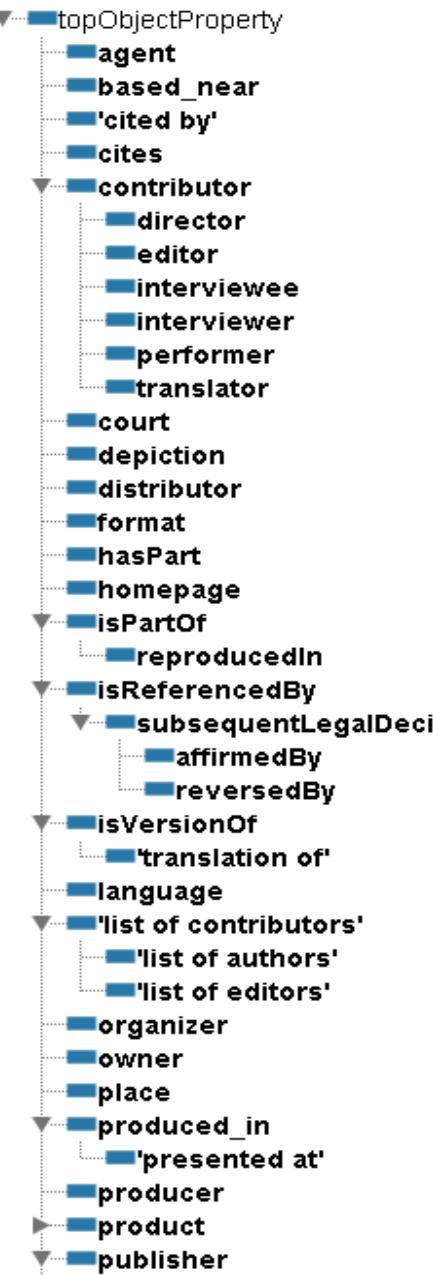
Drupal

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Site hosted by  Structured Dynamics LLC.



# BIBO: The Bibliographic Ontology



# BIBO “performer” property: domain and range

The screenshot shows the Protege ontology editor interface. On the left, the 'Object property hierarchy: performer' is displayed, showing various properties under categories like topObjectProperty, contributor, isPartOf, etc. The 'performer' property is highlighted in the 'contributor' category. On the right, the 'Annotations: performer' tab is selected, displaying the following information:

- Annotations**:
  - label: performer
  - isDefinedBy: [type: anyURI] <http://purl.org/ontology/bibo/>
  - term\_status: stable
- Characteristic**:
  - Functional
  - Inverse functional
  - Transitive
  - Symmetric
  - Asymmetric
  - Reflexive
  - Irreflexive
- Description: performer**:
  - Equivalent To: +
  - Sub Property Of: + **contributor**
  - Inverse Of: +
  - Domains (intersection): + **Performance**
  - Ranges (intersection): + **Agent**

A red box highlights the 'Description: performer' section.

# BIBFRAME Model Overview



The [Bibliographic Framework Transition Initiative](#) is an undertaking by the [Library of Congress](#) and the community to better accommodate future needs of the library community. A major focus of the initiative will be to determine a transition path for the MARC 21 exchange format to more Web based, Linked Data standards. [Zepheira](#) and The Library of Congress are working together to develop a Linked Data model, vocabulary and enabling tools / services for supporting this Initiative.

[BIBFRAME.ORG](#) is a central hub for this effort.

## Getting started

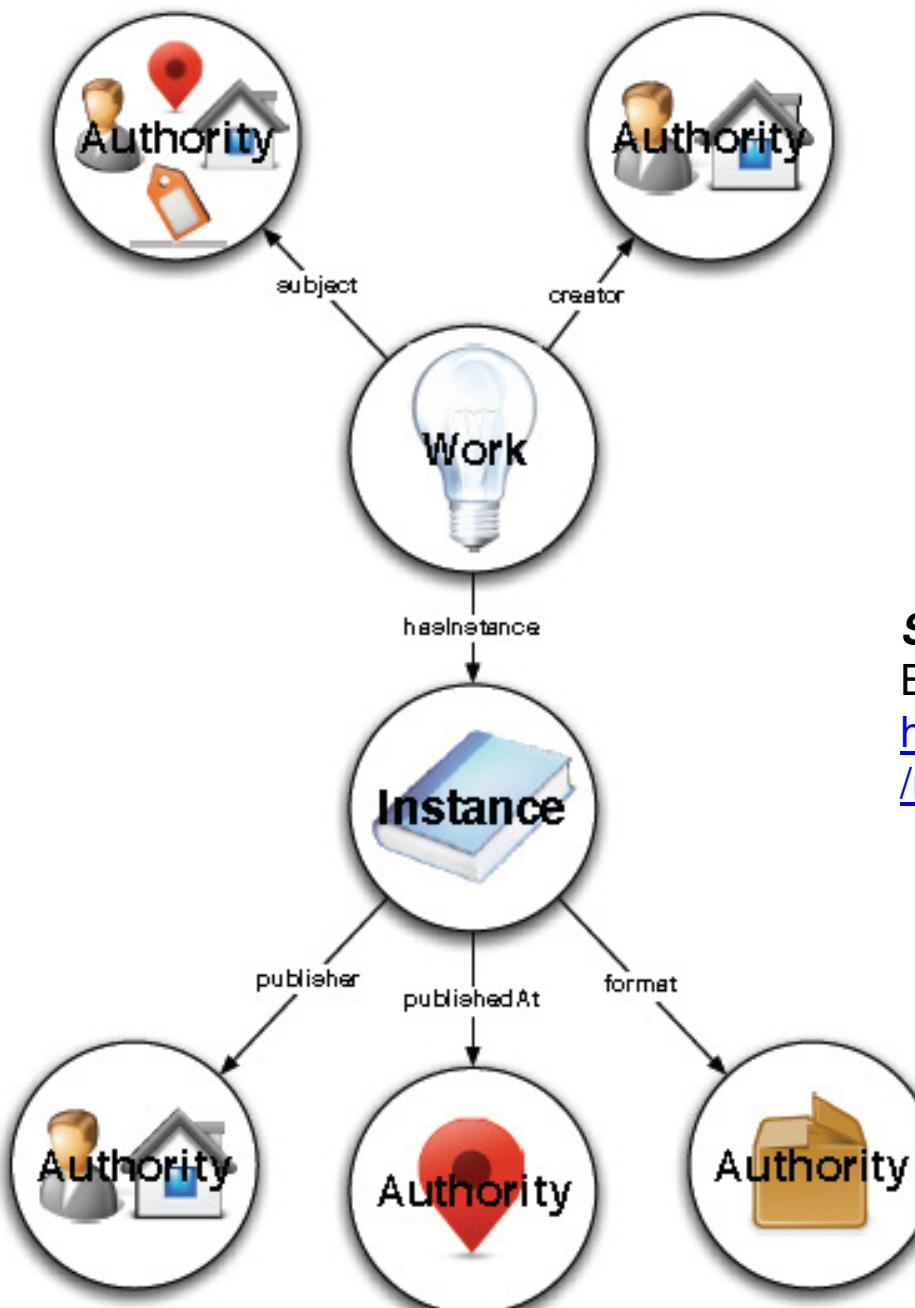
- New to BIBFRAME? A good place to start is the [BIBFRAME Model Primer \(PDF\)](#).
- Want to see library data described in the BIBFRAME Model? Check out the [demonstration area](#).
- You can also see your MARC data in BIBFRAME by using [online tools](#).
- Explore the BIBFRAME [vocabulary](#) along with [supporting documentation](#).
- If you code and you want to experiment, head over to the BIBFRAME [code repository](#) on GitHub.
- Interested in participating? See how on the [contribute page](#).

## Recent updates

- [On BIBFRAME Authority - Discussion Paper \(NEW - 10 May 2013\)](#)
- [BIBFRAME Annotation Model - Community Draft \(NEW - 2 May 2013\)](#)
- [Vocabulary updates \(Ongoing\)](#)
- [MARC21 to BIBFRAME Transformation updates \(Ongoing\)](#)

# BIBFRAME model: main classes

- **Creative Work**
  - a resource reflecting a conceptual essence of the cataloging item.
- **Instance**
  - a resource reflecting an individual, material embodiment of the Work.
- **Authority**
  - a resource reflecting key authority concepts that have defined relationships reflected in the Work and Instance. Examples of Authority Resources include [People](#), [Places](#), [Topics](#), [Organizations](#), etc.
- **Annotation**
  - a resource that decorates other BIBFRAME resources with additional information. Examples of such annotations include Library Holdings information, cover art and reviews.



**Source of diagrams:**  
BIBFRAME Model Primer:  
<http://www.loc.gov/bibframe/pdf/marcld-report-11-21-2012.pdf>

Figure 1: A graphical representation of the BIBFRAME Linked Data model defining the relation between Work and Instance resources and their contextualization to Web addressable Authority resources.

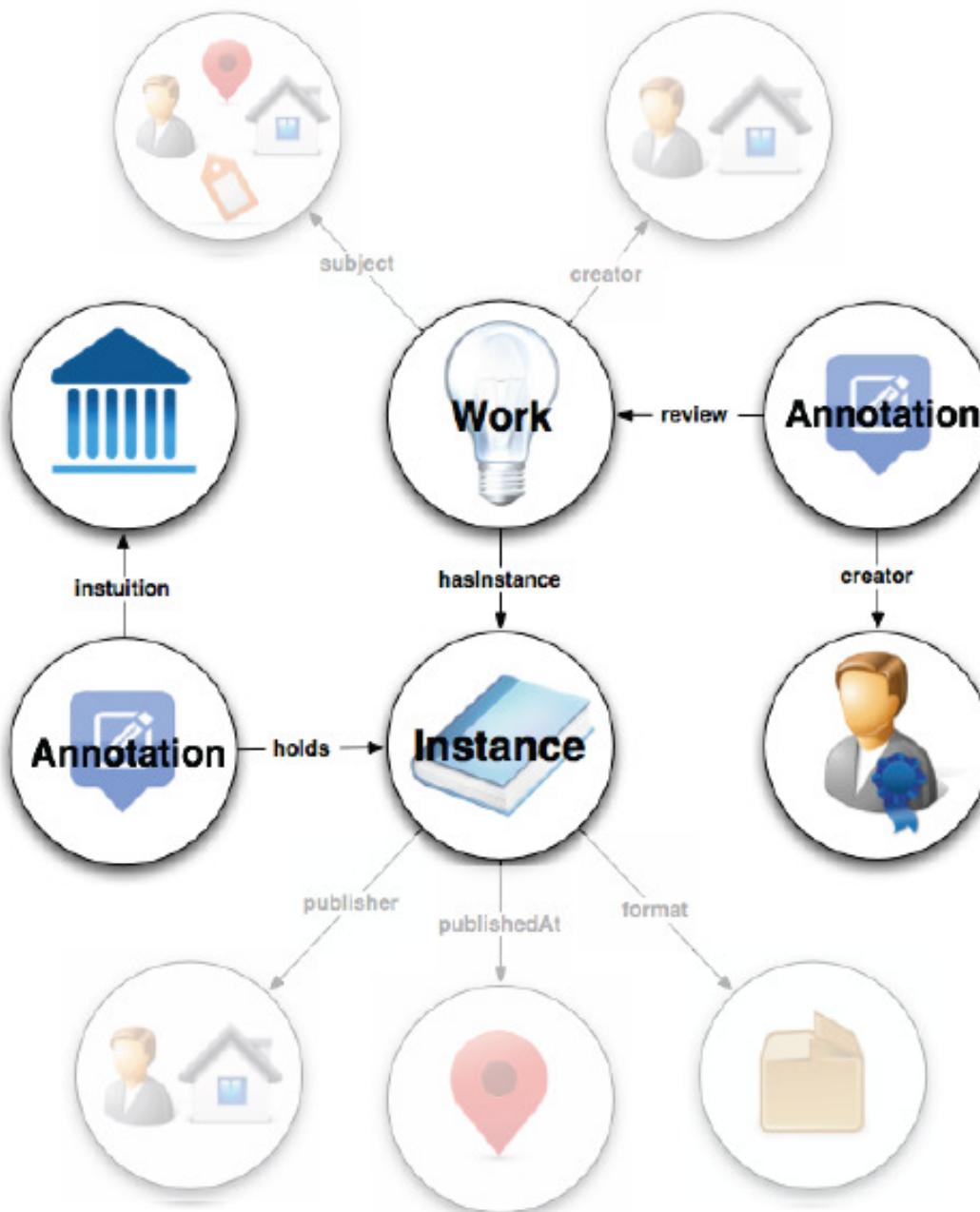


Figure 2: A graphical representation of the BIBFRAME Linked Data model in the context of a flexible annotation framework.

# Resource

**BIBFRAME.ORG****Properties used with Resource**

Property	Label	Expected value	MARC Mapping	Related RDA Note
authorizedAccessPoint	Authorized access point			
description	Description of resource			
identifier	identifier			
label	Label for resource			
relatedResource	Related resource		787 700,710,711, with \$t and i2 not 2 730,740, and i2 not 2	

**More specific Resource types**

Class	Label	MARC Mapping	Related RDA Note
Annotation	Annotation	856	
Authority	Authority		
Instance	Instance	856... 260	
Work	Work		

Class hierarchy

## Coverage of Content (Property)

***Coverage of Content*** Property

Used with: [Work](#)

Expected value(s): [CoverageEntity](#) OR Literal



Property



Domain



Range

# DCMI Metadata Terms:

<http://dublincore.org/documents/dcmi-terms/>



Dublin Core® Metadata Initiative  
*Making it easier to find information.*

Home    Metadata Basics    DCMI Specifications    Community and Events    Join/Support    About Us

Enter keyword  Search

## DCMI Metadata Terms

**Title:** DCMI Metadata Terms

**Creator:** DCMI Usage Board

**Identifier:** <http://dublincore.org/documents/2012/06/14/dcmi-terms/>

**Date Issued:** 2012-06-14

**Latest Version:** <http://dublincore.org/documents/dcmi-terms/>

**Replaces:** <http://dublincore.org/documents/2010/10/11/dcmi-terms/>

**Translations:** <http://dublincore.org/resources/translations/>

**Document** This is a DCMI Recommendation.  
**Status:**

**Description:** This document is an up-to-date specification of all metadata terms maintained by the Dublin Core Metadata Initiative, including properties, vocabulary encoding schemes, syntax encoding schemes, and classes.

## Table of Contents

1. [Introduction and Definitions](#)
2. [Properties in the /terms/ namespace](#)
3. [Properties in the /elements/1.1/ namespace](#)
4. [Vocabulary Encoding Schemes](#)
5. [Syntax Encoding Schemes](#)
6. [Classes](#)
7. [DCMI Type Vocabulary](#)

# DCMI Metadata Terms

## Index of Terms

Properties in the /terms/ namespace	<a href="#">abstract</a> , <a href="#">accessRights</a> , <a href="#">accrualMethod</a> , <a href="#">accrualPeriodicity</a> , <a href="#">accrualPolicy</a> , <a href="#">alternative</a> , <a href="#">audience</a> , <a href="#">available</a> , <a href="#">bibliographicCitation</a> , <a href="#">conformsTo</a> , <a href="#">contributor</a> , <a href="#">coverage</a> , <a href="#">created</a> , <a href="#">creator</a> , <a href="#">date</a> , <a href="#">dateAccepted</a> , <a href="#">dateCopyrighted</a> , <a href="#">dateSubmitted</a> , <a href="#">description</a> , <a href="#">educationLevel</a> , <a href="#">extent</a> , <a href="#">format</a> , <a href="#">hasFormat</a> , <a href="#">hasPart</a> , <a href="#">hasVersion</a> , <a href="#">identifier</a> , <a href="#">instructionalMethod</a> , <a href="#">isFormatOf</a> , <a href="#">isPartOf</a> , <a href="#">isReferencedBy</a> , <a href="#">isReplacedBy</a> , <a href="#">isRequiredBy</a> , <a href="#">issued</a> , <a href="#">isVersionOf</a> , <a href="#">language</a> , <a href="#">license</a> , <a href="#">mediator</a> , <a href="#">medium</a> , <a href="#">modified</a> , <a href="#">provenance</a> , <a href="#">publisher</a> , <a href="#">references</a> , <a href="#">relation</a> , <a href="#">replaces</a> , <a href="#">requires</a> , <a href="#">rights</a> , <a href="#">rightsHolder</a> , <a href="#">source</a> , <a href="#">spatial</a> , <a href="#">subject</a> , <a href="#">tableOfContents</a> , <a href="#">temporal</a> , <a href="#">title</a> , <a href="#">type</a> , <a href="#">valid</a>
Properties in the /elements/1.1/ namespace	<a href="#">contributor</a> , <a href="#">coverage</a> , <a href="#">creator</a> , <a href="#">date</a> , <a href="#">description</a> , <a href="#">format</a> , <a href="#">identifier</a> , <a href="#">language</a> , <a href="#">publisher</a> , <a href="#">relation</a> , <a href="#">rights</a> , <a href="#">source</a> , <a href="#">subject</a> , <a href="#">title</a> , <a href="#">type</a>
Vocabulary Encoding Schemes	<a href="#">DCMIType</a> , <a href="#">DDC</a> , <a href="#">IMT</a> , <a href="#">LCC</a> , <a href="#">LCSH</a> , <a href="#">MESH</a> , <a href="#">NLM</a> , <a href="#">TGN</a> , <a href="#">UDC</a>
Syntax Encoding Schemes	<a href="#">Box</a> , <a href="#">ISO3166</a> , <a href="#">ISO639-2</a> , <a href="#">ISO639-3</a> , <a href="#">Period</a> , <a href="#">Point</a> , <a href="#">RFC1766</a> , <a href="#">RFC3066</a> , <a href="#">RFC4646</a> , <a href="#">RFC5646</a> , <a href="#">URI</a> , <a href="#">W3CDTE</a>
Classes	<a href="#">Agent</a> , <a href="#">AgentClass</a> , <a href="#">BibliographicResource</a> , <a href="#">FileFormat</a> , <a href="#">Frequency</a> , <a href="#">Jurisdiction</a> , <a href="#">LicenseDocument</a> , <a href="#">LinguisticSystem</a> , <a href="#">Location</a> , <a href="#">LocationPeriodOrJurisdiction</a> , <a href="#">MediaType</a> , <a href="#">MediaTypeOrExtent</a> , <a href="#">MethodOfAccrual</a> , <a href="#">MethodOfInstruction</a> , <a href="#">PeriodOfTime</a> , <a href="#">PhysicalMedium</a> , <a href="#">PhysicalResource</a> , <a href="#">Policy</a> , <a href="#">ProvenanceStatement</a> , <a href="#">RightsStatement</a> , <a href="#">SizeOrDuration</a> , <a href="#">Standard</a>
DCMI Type Vocabulary	<a href="#">Collection</a> , <a href="#">Dataset</a> , <a href="#">Event</a> , <a href="#">Image</a> , <a href="#">InteractiveResource</a> , <a href="#">MovingImage</a> , <a href="#">PhysicalObject</a> , <a href="#">Service</a> , <a href="#">Software</a> , <a href="#">Sound</a> , <a href="#">StillImage</a> , <a href="#">Text</a>
Terms related to the DCMI Abstract Model	<a href="#">memberOf</a> , <a href="#">VocabularyEncodingScheme</a>

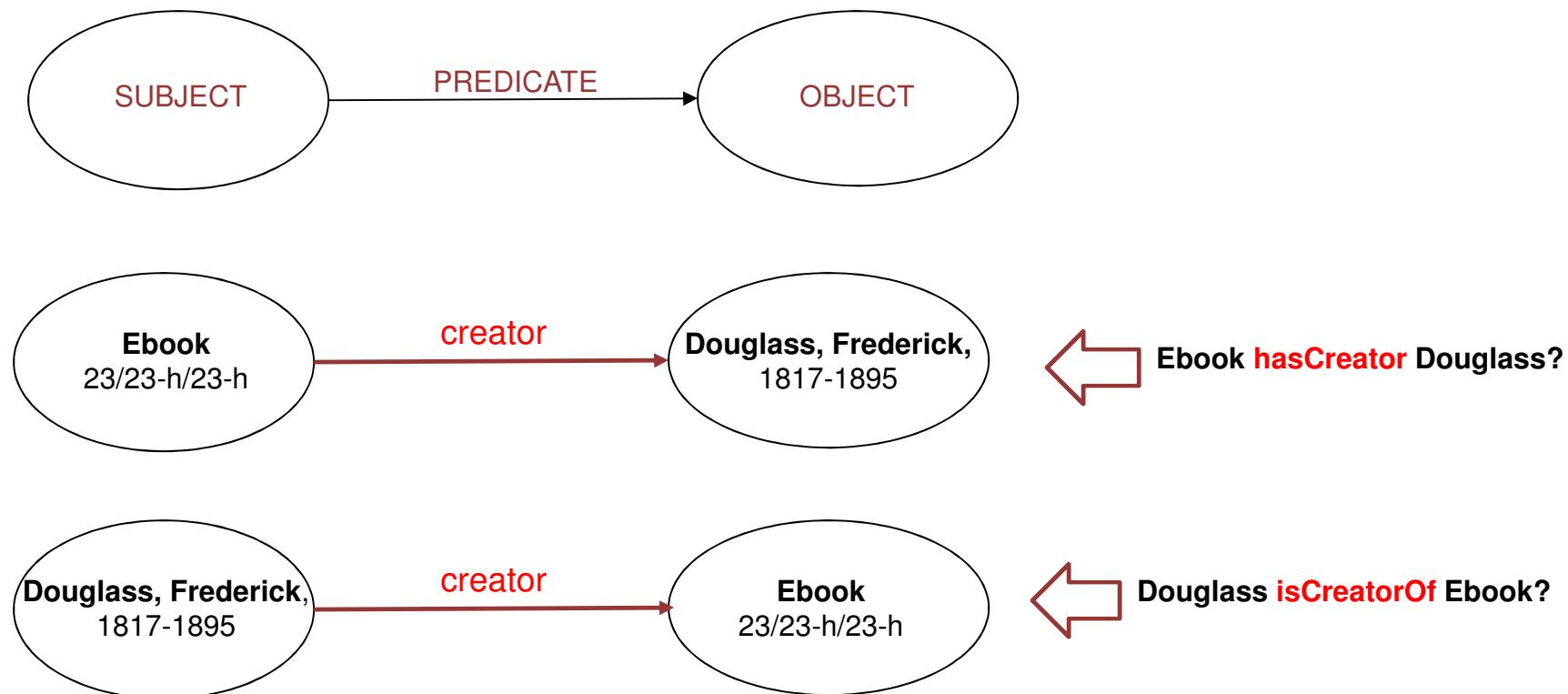
# DC medium property

<b>Term Name:</b> <b>medium</b>	
<b>URI:</b>	<a href="http://purl.org/dc/terms/medium">http://purl.org/dc/terms/medium</a>
<b>Label:</b>	Medium
<b>Definition:</b>	The material or physical carrier of the resource.
<b>Type of Term:</b>	<a href="#">Property</a>
<b>Refines:</b>	<a href="http://purl.org/dc/elements/1.1/format">http://purl.org/dc/elements/1.1/format</a>
<b>Refines:</b>	<a href="http://purl.org/dc/terms/format">http://purl.org/dc/terms/format</a>
<b>Has Domain:</b>	<a href="http://purl.org/dc/terms/PhysicalResource">http://purl.org/dc/terms/PhysicalResource</a>
<b>Has Range:</b>	<a href="http://purl.org/dc/terms/PhysicalMedium">http://purl.org/dc/terms/PhysicalMedium</a>
<b>Version:</b>	<a href="http://dublincore.org/usage/terms/history/#medium-003">http://dublincore.org/usage/terms/history/#medium-003</a>

# DC physicalMedium & physicalResource Classes

<b>Term Name:</b> PhysicalMedium	
<b>URI:</b>	<a href="http://purl.org/dc/terms/PhysicalMedium">http://purl.org/dc/terms/PhysicalMedium</a>
<b>Label:</b>	Physical Medium
<b>Definition:</b>	A physical material or carrier.
<b>Comment:</b>	Examples include paper, canvas, or DVD.
<b>Type of Term:</b>	Class
<b>Narrower Than:</b>	<a href="http://purl.org/dc/terms/MediaType">http://purl.org/dc/terms/MediaType</a>
<b>Version:</b>	<a href="http://dublincore.org/usage/terms/history/#PhysicalMedium-001">http://dublincore.org/usage/terms/history/#PhysicalMedium-001</a>
<b>Term Name:</b> PhysicalResource	
<b>URI:</b>	<a href="http://purl.org/dc/terms/PhysicalResource">http://purl.org/dc/terms/PhysicalResource</a>
<b>Label:</b>	Physical Resource
<b>Definition:</b>	A material thing.
<b>Type of Term:</b>	Class
<b>Version:</b>	<a href="http://dublincore.org/usage/terms/history/#PhysicalResource-001">http://dublincore.org/usage/terms/history/#PhysicalResource-001</a>

# Directed graph: what relationship does the DC property “creator” indicate?



# DCMI Metadata Terms: range declaration of creator property

<http://dublincore.org/documents/dcmi-terms/#terms-creator>

Term Name: creator	
<b>URI:</b>	<a href="http://purl.org/dc/terms/creator">http://purl.org/dc/terms/creator</a>
<b>Label:</b>	Creator
<b>Definition:</b>	An entity primarily responsible for making the resource.
<b>Comment:</b>	Examples of a Creator include a person, an organization, or a service.
<b>Type of Term:</b>	<a href="#">Property</a>
<b>Refines:</b>	<a href="http://purl.org/dc/elements/1.1/creator">http://purl.org/dc/elements/1.1/creator</a>
<b>Refines:</b>	<a href="http://purl.org/dc/terms/contributor">http://purl.org/dc/terms/contributor</a>
<b>Has Range:</b>	<a href="http://purl.org/dc/terms/Agent">http://purl.org/dc/terms/Agent</a>
<b>Version:</b>	<a href="http://dublincore.org/usage/terms/history/#creatorT-002">http://dublincore.org/usage/terms/history/#creatorT-002</a>
<b>EquivalentProperty:</b>	<a href="http://xmlns.com/foaf/0.1/maker">http://xmlns.com/foaf/0.1/maker</a>

The object of the predicate dc/terms/creator must be a member of the class dc/terms/agent

# DCMI Metadata Terms: Agent class defined

<http://dublincore.org/documents/dcmi-terms/#terms-Agent>

<b>Term Name:</b> Agent	
<b>URI:</b>	<a href="http://purl.org/dc/terms/Agent">http://purl.org/dc/terms/Agent</a>
<b>Label:</b>	Agent
<b>Definition:</b>	A resource that acts or has the power to act.
<b>Comment:</b>	Examples of Agent include person, organization, and software agent.
<b>Type of Term:</b>	Class
<b>Instance Of:</b>	<a href="http://purl.org/dc/terms/AgentClass">http://purl.org/dc/terms/AgentClass</a>
<b>Version:</b>	<a href="http://dublincore.org/usage/terms/history/#Agent-001">http://dublincore.org/usage/terms/history/#Agent-001</a>

# Therefore:

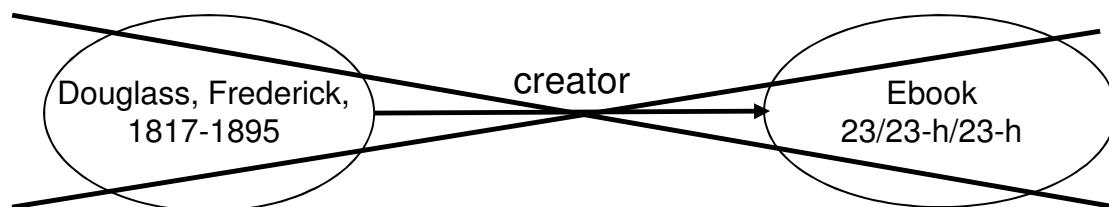


The **Object** of the triple must be a member of the **Agent class**. **Douglass** can be an Agent but the **Ebook** cannot.

Correct:



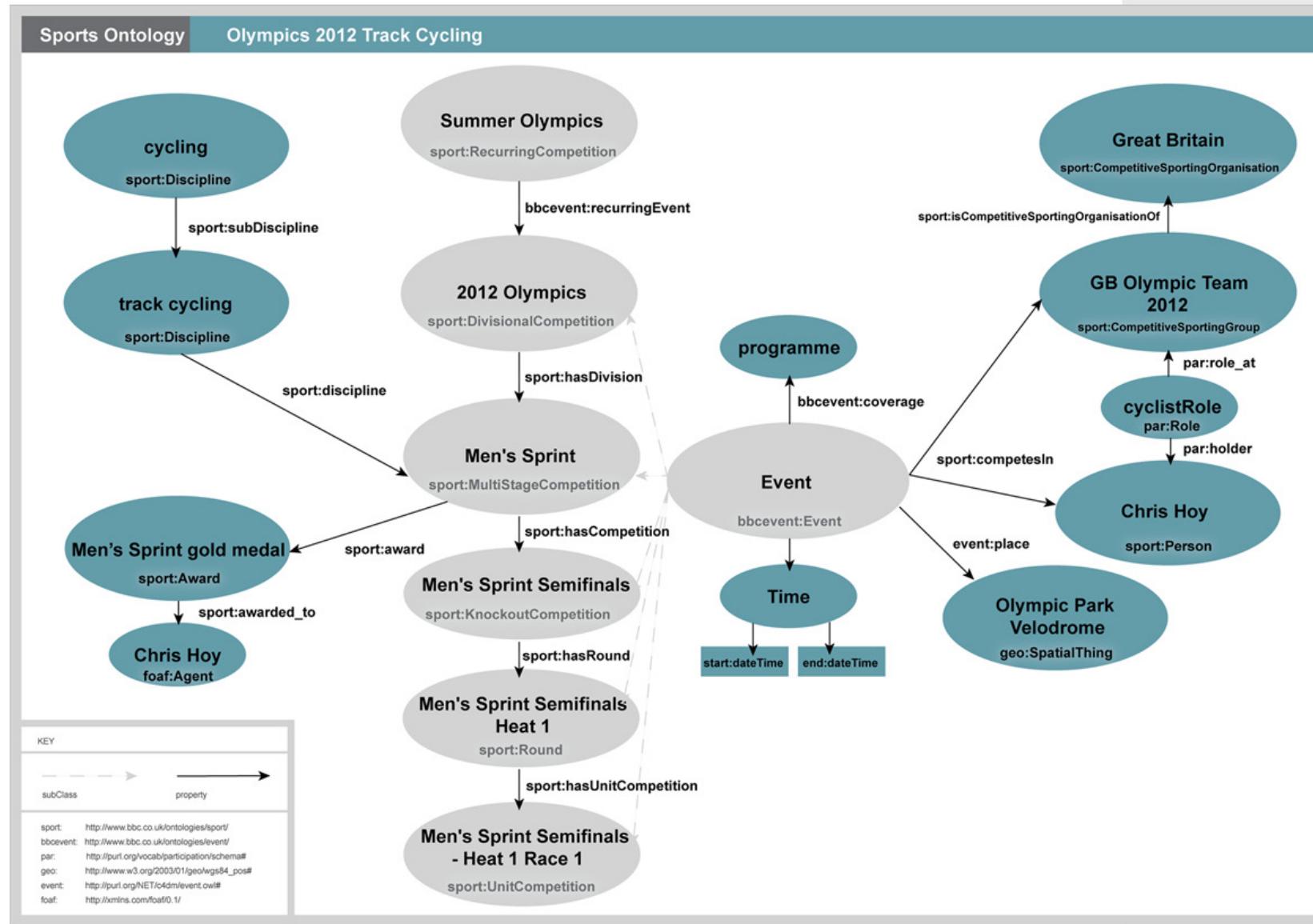
Incorrect:



# BBC Sport Ontology

## Vocabulary Diagram

The following diagram illustrates the relationships between the key classes in the ontology as applied to the Olympic cycling.



# BBC Sport Ontology

## Overview Of Terms

An alphabetical index of the ontology terms, divided into classes, properties and individuals. All the terms are hyperlinked to their detailed description for quick reference.

**Classes:** | [Competition](#) | [CompetitionType](#) | [CompetitiveSportingGroup](#) | [CompetitiveSportingOrganisation](#) | [DivisionalCompetition](#) | [EventGender](#) | [FootballManagerRole](#) | [FootballPlayerRole](#) | [GroupCompetition](#) | [KnockoutCompetition](#) | [LeagueCompetition](#) | [Match](#) | [MultiRoundCompetition](#) | [MultiStageCompetition](#) | [RecurringCompetition](#) | [Round](#) | [Session](#) | [SportGoverningBody](#) | [SportingOrganisation](#) | [SportsDiscipline](#) | [UnitCompetition](#)

**Properties:** | [awayCompetitor](#) | [competesIn](#) | [competitionType](#) | [discipline](#) | [eventGender](#) | [firstRound](#) | [firstSession](#) | [firstUnitCompetition](#) | [hasRound](#) | [hasCompetitor](#) | [hasGroup](#) | [hasMatch](#) | [hasSession](#) | [hasStage](#) | [hasUnitCompetition](#) | [homeCompetitor](#) | [isCompetitiveSportingOrganisationOf](#) | [isGroupOf](#) | [isMatchOf](#) | [isRoundOf](#) | [isSessionOf](#) | [isStageOf](#) | [lastRound](#) | [lastSession](#) | [lastUnitCompetition](#) | [nextSession](#) | [nextUnitCompetition](#) | [prevSession](#) | [prevUnitCompetition](#) | [roundNumber](#) | [subDiscipline](#)

# BBC Sport Ontology

## Property: hasMatch

Label	has match
Status	
Range	<a href="#">Match</a>
Domain	<a href="#">Round</a>

associates a round with a match.

## Property: hasSession

Label	has session
Status	
Sub-Properties	<a href="#">firstSession</a> <a href="#">lastSession</a>
Range	<a href="#">Session</a>
Domain	<a href="#">Competition</a>

associates a competition with a session.

## Property: hasStage

Label	has stage
Status	
Sub-Properties	<a href="#">firstStage</a> <a href="#">lastStage</a>
Range	<a href="#">Competition</a>

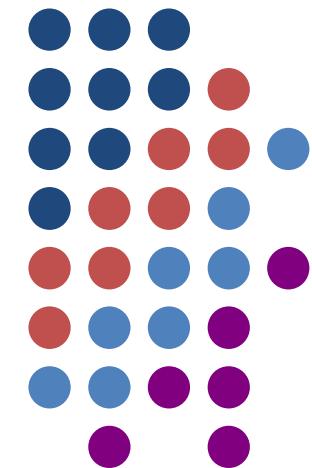
associates a multi stage competition to the stages that it contains.

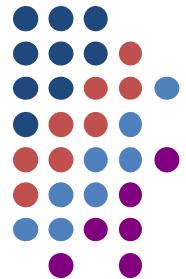
## Property: hasUnitCompetition

Label	has unit competition
Status	
Sub-Properties	<a href="#">firstUnitCompetition</a> <a href="#">hasMatch</a> <a href="#">lastUnitCompetition</a>
Range	<a href="#">UnitCompetition</a>

associates a round to a unit competition in that round.

# Questions?





# Exercise 1:

## Ontology Basics & RDFS

1. Identify correct and incorrect hierarchical class and property relationships and property domain and range declarations.
2. Distinguish classes from instances (individuals).
3. Determine logical inferences that can be made based on a set of statements.

## Exercise 1: Ontology Basics and RDFS (Tutorial Part 2)

### 1. Ontology Classes and Properties:

Identify correct and incorrect hierarchical class and property relationships and property domain and range declarations for an imaginary cultural heritage ontology.

#### Classes:

- Cultural Heritage Resource
  - Bibliographic Resource
    - Book
    - Journal
      - Journal Article
  - Museum Object
    - Painting
    - Sculpture
- Continent
  - Country
    - Region
    - City
- Agent
  - Creator
    - Author
    - Composer
    - Painter
    - Sculptor
  - Contributor
    - Editor
    - Illustrator

#### Properties:

- isCreatorOf
  - isPainterOf
  - isSculptorOf
- isCreatorOf
  - domain: Creator
  - range: Museum Object
- isPainterOf
  - domain: Painting
  - range: Painter
- isAuthorOf
  - domain: Author
  - range: Bibliographic Resource

### 2. Which of the following are classes and which are instances (individuals)?

- Addis Ababa
- Africa
- City
- Continent
- Country
- Ethiopia
- Europe
- France
- Lisbon
- Paris
- Portugal

**3. Logical Inferences.****A. Based on the following statements, what inferences can we make about Person123?**

Agent IsA Class  
Creator subClassOf Agent  
Author subClassOf Creator  
Painter subClassOf Creator  
Sculptor subClassOf Creator  
Person123 isA Painter

**B. Based on the following statements, what inferences can we make about WorkABC?**

CulturalHeritageResource isA Class  
MusicalComposition subClassOf CulturalHeritageResource  
Symphony subClassOf MusicalComposition  
WorkABC isA Symphony

**C. Based on the following statements, what inferences can be made about Person456 and about WorkABC?**

isCreatorOf isA Property  
    domain: Creator  
    range: CulturalHeritageResource  
isComposerOf isA Property  
    subPropertyOf isCreatorOf  
Person 456 isComposerOf WorkABC

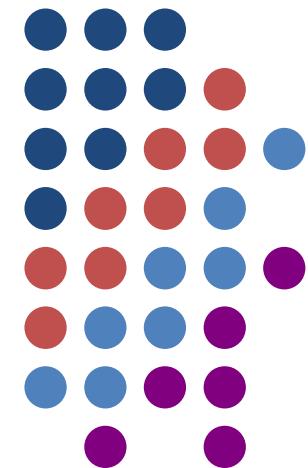
**D. Based on the following new statement, in addition to what is stated in C above, what new inferences can we make about Person 456 and WorkABC?**

isComposerOf isA Property  
    domain Composer  
    range MusicalComposition

# OWL Overview: Web Ontology Language

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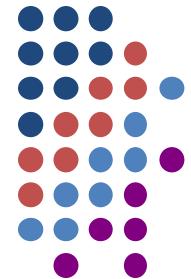
**Tutorial Part 3**





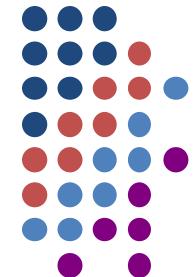
# Tutorial part 4 objectives

- Be aware that OWL Web Ontology Language is a full-fledged ontology language with a much higher level of expressive power and logical reasoning / inferencing capabilities than RDFS
- Be exposed to some of OWL's property characteristics and other constructs and the inferences they enable, including:
  - Inverse, symmetric, transitive, functional, and inverse functional properties, cardinality restrictions, and building anonymous equivalent classes
- Understand the kinds of queries that an OWL ontology and knowledge-base could be able to answer for end users



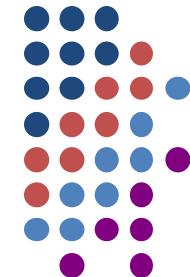
# OWL goes beyond RDFS

- RDFS deals primarily with:
  - classes, subclasses, properties, subproperties, domain and range
- OWL is a full-fledged ontology language
  - Not a direct extension of RDFS, but does builds on it
  - Is usually expressed in RDF/XML
  - May be represented graphically (often based on UML)
- OWL allows for much fuller reasoning and inferencing by enabling specifications for:
  - Relations between classes (disjointness, equivalence, union, intersection)
  - Cardinality (minimum, maximum, exact number)
  - Equality (same as)
  - Richer typing of properties (object vs. datatype, specific datatypes)
  - Characteristics of properties / special properties (transitive, symmetric, functional, inverse functional)
  - Enumerated classes



# OWL elements (1)

- **Class and individual elements**
  - owl:Class
  - owl:Thing
  - owl:Nothing
  - owl:NamedIndividual
- **RDFS elements used in OWL**
  - rdfs:subClassOf
  - rdf:Property
  - rdfs:subPropertyOf
  - rdfs:domain
  - rdfs:range
- **Datatype specification**
  - xsd:datatypes
- **Property characteristics**
  - owl:ObjectProperty
  - owl:DatatypeProperty
  - owl:inverseOf
  - owl:TransitiveProperty
  - owl:SymmetricProperty
  - owl:FunctionalProperty
  - owl:InverseFunctionalProperty
- **Cardinality restrictions**
  - owl:minCardinality
  - owl:maxCardinality
  - owl:cardinality

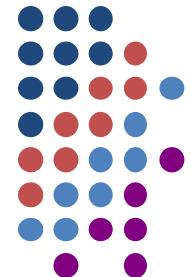


# OWL elements (2)

- **Equality/inequality**
  - owl:equivalentClass
  - owl:equivalentProperty
  - owl:sameAs
  - owl:differentFrom
  - owl:AllDifferent
  - owl:distinctMembers
- **Property restrictions**
  - owl:Restriction
  - owl:onProperty
  - owl:allValuesFrom
  - owl:someValuesFrom
- **Class intersection**
  - owl:intersectionOf

## OWL DL & OWL Full:

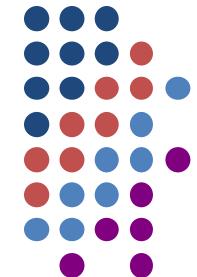
- **Class axioms**
  - owl:oneOf, dataRange
  - owl:disjointWith
  - owl:equivalentClass
    - (applied to class expressions)
  - rdfs:subClassOf
    - (applied to class expressions)
- **Boolean combinations of class expressions**
  - owl:unionOf
  - owl:complementOf
  - owl:intersectionOf
- **Property information**
  - owl:hasValue



# OWL elements (3)

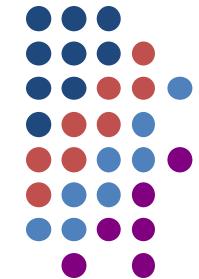
- **Ontology header information**
  - owl:Ontology
  - owl:imports
- **Ontology versioning information**
  - owl:versionInfo
  - owl:priorVersion
  - owl:backwardCompatibleWith
  - owl:incompatibleWith
  - owl:DeprecatedClass
  - owl:DeprecatedProperty

- **OWL versions**
  - OWL 1
  - OWL 2
- **OWL 1 sublanguages**
  - OWL Lite
  - OWL DL
  - OWL Full



# OWL basic elements

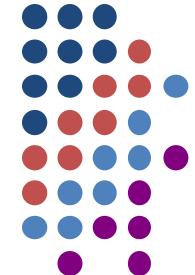
- **owl:Class**
  - a subclass of rdfs:Class
- **owl:Thing**
  - the most general class, which contains everything



# OWL properties

In OWL there are two basic kinds of properties

- **Object properties**, which relate objects to other objects
  - When the value of the RDF triple is another “resource” or “thing” represented with a linkable URI
  - e.g. isTaughtBy, supervises, hasChild, isChildOf, creates, createdBy, etc.
- **Data type properties**, which relate objects to datatype values
  - When the value of the RDF triple is a literal value
  - E.g. hasPhoneNumber, hasTitle, hasBirthdate, etc.

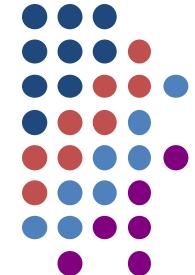


# OWL datatype properties

OWL makes use of XML Schema data types

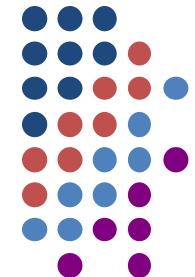
- xsd datatypes recommended for use with OWL:  
<http://www.w3.org/TR/owl-guide/#Datatypes1>
- For example, among others:
  - xsd:string
  - xsd:integer
  - xsd:nonNegativeInteger
  - xsd:date
  - xsd:boolean
- And: rdfs:Literal
- In OWL XML they are referenced:

```
<owl:DatatypeProperty rdf:ID="hasAge">
  <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema
    #nonNegativeInteger"/>
</owl:DatatypeProperty>
```



# OWL element examples

- The ontology begins with **owl:Ontology**
- Classes are defined using **owl:Class**
  - **owl:Class** **rdf:ID** **fro:Parent**
  - **fro:Parent** **rdfs:subClassOf** **fro:Relative**
- Object properties
  - **owl:ObjectProperty** **rdf:ID** **fro:hasParent**
  - **fro:hasParent** **rdfs:domain** **fro:Child**
- Datatype properties and ranges
  - **owl:DatatypeProperty** **rdf:ID** **fro:hasBirthdate**
  - **fro:hasBirthdate** **rdfs:range** **XMLSchema#date**
- Notice a mixture of **rdf:**, **rdfs:**, and **owl:** elements in OWL

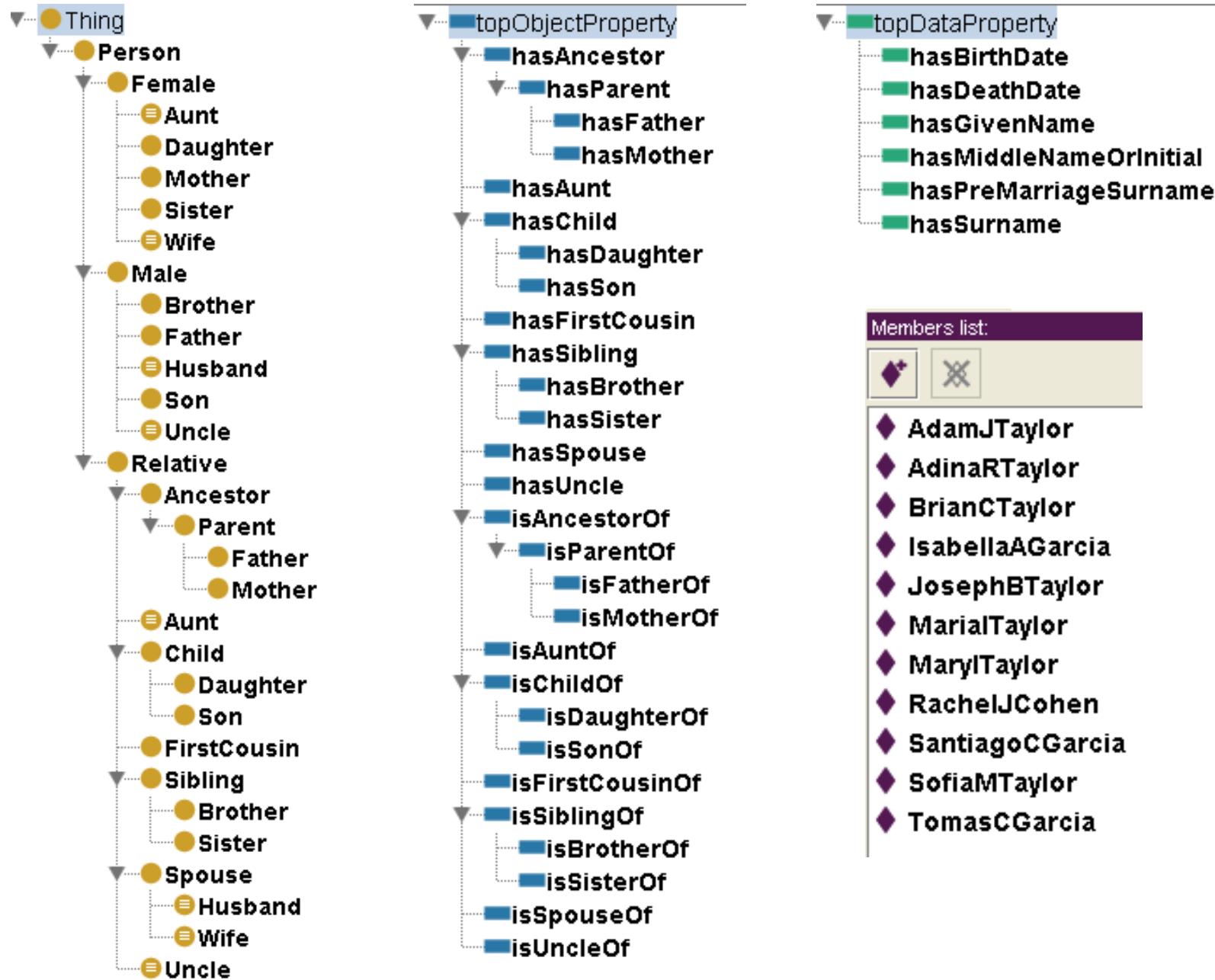


# Simplified workshop notation

(examples from previous slide)

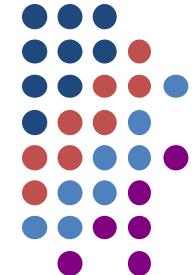
- Parent isA Class
- Parent subClassOf Relative
- hasParent isA ObjectProperty
- hasParent domain Child
- hasBirthdate isA DatatypeProperty
- hasBirthdate range XMLSchema#date

# Family Relationships Ontology



Members list:
AdamJTaylor
AdinaRTaylor
BrianCTaylor
IsabellaAGarcia
JosephBTaylor
MariaTaylor
MaryITaylor
RachelJCohen
SantiagoCGarcia
SofiaMTaylor
TomasCGarcia

# Inverse properties (owl:inverseOf)



- **Statements:**

- isParentOf inverseOf hasParent
- MariaITaylor isParentOf AdamJTaylor
- isParentOf subPropertyOf hasAncestor

- **Inferences:**

- hasParent inverseOf isParentOf
- AdamJTaylor hasParent MariaITaylor
- AdamJTaylor hasAncestor MariaITaylor

Characteristics: hasSibl

- Functional
- Inverse functional
- Transitive
- Symmetric
- Asymmetric
- Reflexive
- Irreflexive

Description: hasSibling

Domains (intersection)

**Sibling**

Ranges (intersection)

**Sibling**

Equivalent object properties

Super properties

Inverse properties

**isSiblingOf**

Disjoint properties

Property chains

## Inverse property declaration:

- hasSibling **isInverseOf** isSiblingOf

## Individual statement:

SofiaMTaylor **isSiblingOf** AdamJTaylor

## Inference:

- AdamJTaylor **isSiblingOf** SofiaMTaylor

Usage: AdamJTaylor

Show:  this  different

Found 4 uses of AdamJTaylor

- AdamJTaylor
  - Individual: AdamJTaylor
  - AdamJTaylor **Type** Person
- MariaTaylor
  - MariaTaylor isMotherOf AdamJTaylor

Description: AdamJTaylor

Types

Person

Brother

Child

Same individuals

Different individuals

Property assertions: AdamJTaylor

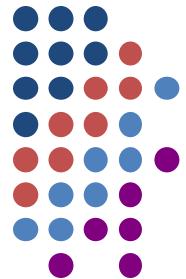
Object property assertions

**isSiblingOf SofiaMTaylor**

Data property assertions

Negative object property assertions

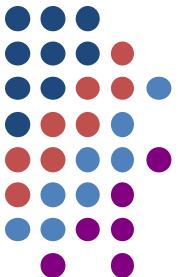
Negative data property assertions



# OWL special properties (1)

(Source: W3C OWL Web Ontology Language Overview:  
<http://www.w3.org/TR/owl-features/>)

- **OWL Symmetric Property:** If a property is symmetric, then if the pair (x,y) is an instance of the symmetric property P, then the pair (y,x) is also an instance of P.
  - For example, friend may be stated to be a symmetric property. Then a reasoner that is given that Frank is a friend of Deborah can deduce that Deborah is a friend of Frank.
- **OWL TransitiveProperty:** If a property is transitive, then if the pair (x,y) is an instance of the transitive property P, and the pair (y,z) is an instance of P, then the pair (x,z) is also an instance of P.
  - For example, if ancestor is stated to be transitive, and if Sara is an ancestor of Louise (i.e., (Sara,Louise) is an instance of the property ancestor) and Louise is an ancestor of Deborah (i.e., (Louise,Deborah) is an instance of the property ancestor), then a reasoner can deduce that Sara is an ancestor of Deborah (i.e., (Sara,Deborah) is an instance of the property ancestor).
  - OWL Lite (and OWL DL) impose the side condition that transitive properties (and their superproperties) cannot have a maxCardinality 1 restriction. Without this side-condition, OWL Lite and OWL DL would become undecidable languages. See the property axiom section of the OWL Semantics and Abstract Syntax document for more information.



# Symmetric properties (owl:SymmetricProperty)

- **Statements:**
  - hasSibling isA SymmetricProperty
  - SofiaMTaylor hasSibling AdamJTaylor
- **Inferences:**
  - AdamJTaylor hasSibling SofiaMTaylor



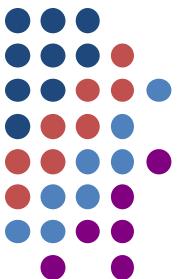
# Transitive properties (owl:TransitiveProperty)

- **Statements:**

- isAncestorOf isA TransitiveProperty
- BrianCTaylor isAncestorOf JosephBTaylor
- JosephBTaylor isAncestorOf SofiaMTaylor

- **Inferences:**

- BrianCTaylor isAncestorOf SofiaMTaylor

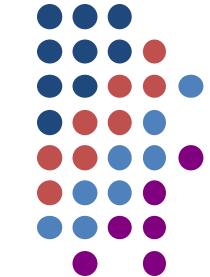


# OWL special properties (2)

(Source: W3C OWL Web Ontology Language Overview:  
<http://www.w3.org/TR/owl-features/>)

- **OWL Functional Property:** If a property is a FunctionalProperty, then it has no more than one value for each individual (it may have no values for an individual). This characteristic has been referred to as having a unique property. FunctionalProperty is shorthand for stating that the property's minimum cardinality is zero and its maximum cardinality is 1.
  - For example, *hasPrimaryEmployer* may be stated to be a FunctionalProperty. From this a reasoner may deduce that no individual may have more than one primary employer. This does not imply that every Person must have at least one primary employer however.
- **OWL Inverse Functional Property:** If a property is inverse functional then the inverse of the property is functional. Thus the inverse of the property has at most one value for each individual. This characteristic has also been referred to as an unambiguous property.
  - For example, *hasUSSocialSecurityNumber* (a unique identifier for United States residents) may be stated to be inverse functional (or unambiguous). The inverse of this property (which may be referred to as *isTheSocialSecurityNumberFor*) has at most one value for any individual in the class of social security numbers. Thus any one person's social security number is the only value for their *isTheSocialSecurityNumberFor* property.
  - From this a reasoner can deduce that no two different individual instances of Person have the identical US Social Security Number.
  - Also, a reasoner can deduce that if two instances of Person have the same social security number, then those two instances refer to the same individual.

# Functional properties (owl:FunctionalProperty)



- **Statements:**

- hasBirthdate isA FunctionalProperty
- SofiaMTaylor hasBirthdate “1999-01-15”
- SofiaMTaylor hasBirthdate “1999-01-05”

- **Inferences:**

- Error in ontology: an individual may have only one unique value for the hasBirthdate property

**Characteristics: hasBirthDate**

Functional

**Description: hasBirthDate**

Domains (intersection) +

Person

Ranges +

Literal

**Property assertions: SofiaMTaylor**

Object property assertions +

**hasBrother AdamJTaylor**

**hasMother MariaTaylor**

**hasFather JosephBTaylor**

Data property assertions +

**hasBirthDate "1999-01-15"**

**hasBirthDate "1999-01-31"**

**Ontology Error Notification in Protégé**

Help for inconsistent ontologies

Your ontology is inconsistent which means that the OWL reasoner will no longer be able to provide any useful information about the ontology.

You have several options at this point:

- Click the Explain button to try the Protege
- If you think you know what the problem is
- Some reasoners come with command line options for inconsistent ontologies.

"Bad" Individuals Inconsistent Classes Hot spots

Double click on the individuals listed below to see an explanation of an inconsistency.

Each individual in the list below corresponds to a reason why the ontology is inconsistent.

SofiaMTaylor

Axioms

**Functional: hasBirthDate**

◆ **SofiaMTaylor hasBirthDate "1999-01-15"**

◆ **SofiaMTaylor hasBirthDate "1999-01-31"**



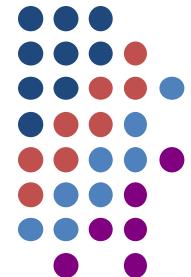
# Functional properties (owl:FunctionalProperty)

- **Statements:**

- hasMother isA FunctionalProperty
- SofiaMTaylor hasMother MarialTaylor
- SofiaMTaylor hasMother MarialGarciaTaylor

- **Inferences:**

- SofiaMTaylor may have only one individual who is her mother
- Because of the non-unique names assumption, however, in OWL (and Protégé) there is no error because there can be no inference that MarialTaylor[URI] and MarialGarciaTaylor[URI] are different individuals
- In this hypothetical case, they are in fact the same individual with two different URIs



# SW and OWL assumptions

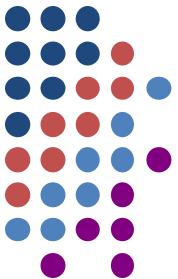
- **Open World Assumption**

- **Closed world:** databases with tightly controlled content; all relevant information about an entity is included; inferences can be made accordingly
- **Open world:** uncontrolled open data; someone can always contribute something new about an entity
  - Machine inferencing must take this into account: “we may draw no conclusions that rely on assuming that the information available at any one point is all the information available”

- **Nonunique Naming Assumption**

- **Unique names:** may hold in controlled databases or triple stores
- **Nonunique names:** in an open world context, different Web authors will use different URIs for the same entity / resource
  - Machine inferencing cannot assume that two entities with different URIs are different individuals

**Source:** Allemang and Hendler, *Semantic Web for the Working Ontologist*, Chapter 1.



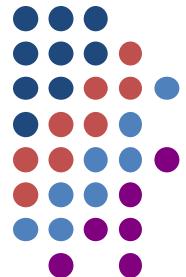
# Different individuals (owl:differentFrom)

- **Statements:**

- hasMother isA FunctionalProperty
- SofiaMTaylor hasMother MarialTaylor
- SofiaMTaylor hasMother AdinaRTaylor
- MarialTaylor differentFrom AdinaRTaylor

- **Inferences:**

- Error in ontology: one individual may have only one other individual as the value of the hasMother property, and these two have now been asserted to be different individuals



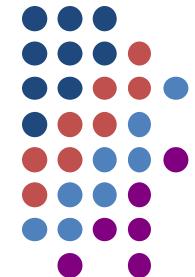
# Inverse functional properties (owl:InverseFunctionalProperty)

- **Statements:**

- hasUSPassportNumber isA InverseFunctionalProperty
- MariaTaylor hasUSPassportNumber "12345678"
- JosephBTaylor hasUSPassportNumber "12345678"

- **Inferences:**

- Only one individual may have any given passport number (for a specific country)
- No error in the inferencing, however, because the non-unique names assumption does not allow the conclusion that the URIs for MariaTaylor and JosephBTaylor are for different individuals



# Different individuals (owl:differentFrom)

- **Statements:**

- hasUSPassportNumber isA FunctionalProperty
- MariaITaylor hasUSPassportNumber 12345678
- JosephBTaylor hasUSPassportNumber 12345678
- MariaITaylor differentFrom JosephBTaylor

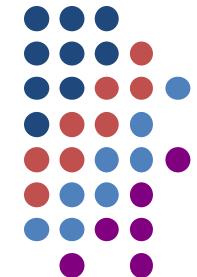
- **Inferences:**

- Error in ontology: different individuals cannot have the same value for the hasUSPassportNumber property

# A better inverse functional property example

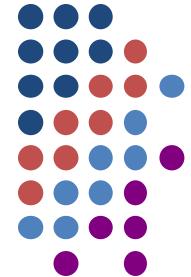


- A health care network assigns unique patient IDs
- Different doctors offices, clinics, and hospitals in the network are beginning to share medical records within new semantic environment
- **Statements:**
  - hasPatientID isA InverseFunctionalProperty
  - *Doctor Lee's office:*
    - Linda-A-Brown-URI hadAppointmentDate "2013-02-06"
    - Linda-A-Brown-URI treatedFor xyzDisease
    - Linda-A-Brown-URI hasPatientID 987654
  - Hilltop Hospital
    - Linda-A-Porter-URI admittedOn "2013-05-10"
    - Linda-A-Porter-URI dischargedOn "2013-05-12"
    - Linda-A-Porter-URI treatedFor abcDisease
    - Linda-A-Porter-URI hasPatientID 987654
- **Inferences:**
  - Linda-A-Brown-URI and Linda-A-Porter-URI are the same individual
  - This individual has been treated for xyzDisease and abcDisease
  - This individual had an appointment with Dr. Lee on February 6, 2013 and was in Hilltop Hospital May 10-12, 2013
  - etc.



# Disjoint classes (owl:disjointWith)

- An individual can be a member of at most one of any set of classes declared to be disjointWith each other
- **Statements:**
  - Father disjointWith Mother [i.e., biological parents]
  - ~~Parent disjointWith Child~~ ←incorrect! why?
  - JosephBTaylor isA Father
- **Inference:**
  - JosephBTaylor cannot be a Mother
- **Statements:**
  - JosephBTaylor isA Father
  - JosephBTaylor isA Mother
- **Inference:**
  - Error in ontology: the last two statements above cannot both be true. Because the Father and Mother classes are disjoint, the same individual cannot be a member of both classes



# OWL restrictions, equality, etc.

- Cardinality restrictions
  - owl:minCardinality
  - owl:maxCardinality
  - owl:Cardinality
- OWL property restrictions
  - owl:Restriction
  - owl:onProperty
  - owl:allValuesFrom
    - specifies *universal* quantification
  - owl:hasValue
    - specifies a specific value
  - owl:someValuesFrom
    - specifies *existential* quantification
- Equality/inequality
  - equivalentClass
  - equivalentProperty
  - sameAs
  - differentFrom
  - AllDifferent
  - distinctMembers
- Class intersection
  - intersectionOf

# Maximum cardinality

- **Statements**

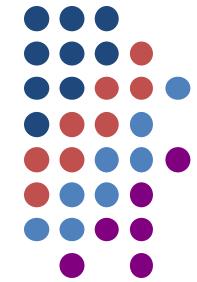
- hasParent isA ObjectProperty
- hasParent range **Restriction:**
  - onProperty resource **hasParent**
  - onClass resource **Parent**
  - **maxCardinality** datatype **nonNegativeInteger “2”**
- MariaTaylor hasParent TomásCGarcia
- MariaTaylor hasParent IsabellaAGarcia
- MariaTaylor hasParent SofiaGTaylor



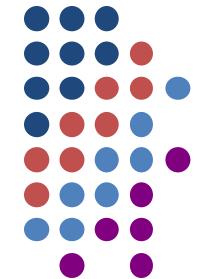
- **Inferences**

- Any individual may have a maximum of two individuals as the values of the hasParent property
- It cannot be inferred that any of the above individuals are not the same individual, following the non-unique names assumption
- But if all three were declared differentFrom each other, there would be an ontology error

# Maximum cardinality: OWL RDF/XML

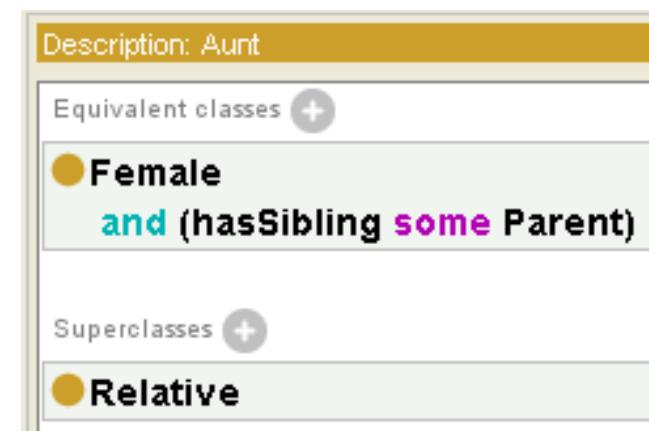


```
<owl:ObjectProperty rdf:about="fro;hasParent">
  <rdfs:range>
    <owl:Restriction>
      <owl:onProperty rdf:resource="fro;hasParent"/>
      <owl:onClass rdf:resource="fro;Parent"/>
      <owl:maxCardinality
        rdf:datatype="&xsd;nonNegativeInteger">2</owl:
        maxQualifiedCardinality>
    </owl:Restriction>
  </rdfs:range>
</owl:ObjectProperty>
```

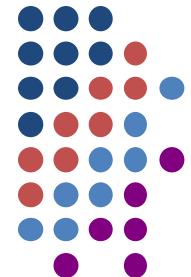


# Anonymous equivalent class, class intersection, and equality (owl:equivalentClass, owl:intersectionOf, owl:Restriction, owl:someValuesFrom)

- Define the Aunt class as equivalent to the class of all Relatives which are Female and have at least one Sibling that is a member of the Parent class:
- Aunt subClassOf Relative
- Aunt isA equivalentClass:
  - intersectionOf:
    - isA Female
    - Restriction:
      - hasSibling
      - someValuesFrom Parent
- This class is an "**anonymous class**" or "**unnamed class**," which is the equivalent of the intersection of the characteristics asserted above. All of our other classes so far have been "**named classes**."

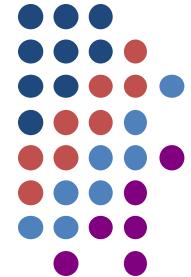


# Equivalent class, class intersection, and equality: OWL RDF/XML

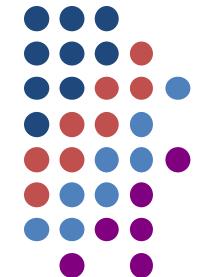


```
<owl:Class rdf:about="fro.owl#Aunt">
  <rdfs:subClassOf rdf:resource="fro.owl#Relative"/>
  <owl:equivalentClass>
    <owl:Class>
      <owl:intersectionOf rdf:parseType="Collection">
        <rdf:Description rdf:about="fro.owl#Female"/>
        <owl:Restriction>
          <owl:onProperty rdf:resource="fro.owl#hasSibling"/>
          <owl:someValuesFrom rdf:resource="fro.owl#Parent"/>
        </owl:Restriction>
      </owl:intersectionOf>
    </owl:Class>
  </owl:equivalentClass>
</owl:Class>
```

# Inferences from previous equivalent class assertions



- **Statements:**
  - AdinaRTaylor isA Relative
  - AdinaRTaylor isA Female
  - AdinaRTaylor hasSibling JosephBTaylor
  - JosephBTaylor isA Parent
- **Inferences:**
  - AdinaRTaylor isA Aunt

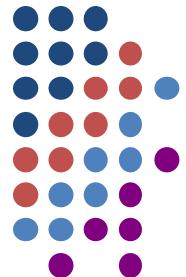


# Equivalent class example 2

- Define the Husband class as equivalent to the class of all Persons which are Male and have at least one Spouse that is a member of the Person class
- Husband subClassOf Person
- Husband isA equivalentClass:
  - intersectionOf:
    - isA Male
    - Restriction:
      - hasSpouse
      - someValuesFrom Person



[Side note: in this particular model, the husband's spouse may be either female or male, such that two men or two women may be spouses to each other, two men may be husbands to each other, and two women may be wives to each other]



# Protégé inference examples

- Protégé OWL 4.2 includes two software reasoners: FaCT++ and Hermit

**Three statements I made about JosephBTaylor**  
(one class membership and two property assertions):

The screenshot shows two panels from the Protégé ontology editor:

- Description: JosephBTaylor**: This panel shows the class membership statement. It has a "Types" section containing a yellow circle icon followed by the text "Person".
- Property assertions: JosephBTaylor**: This panel shows the two property assertions. It has an "Object property assertions" section containing:
  - hasMother RachelJCohen
  - hasFather BrianCTaylor

Both the "Person" entry in the first panel and the two entries in the second panel are highlighted with a red rectangular box.

Description: JosephBTaylor

Types +

- Person
- Brother
- Father
- Husband
- Son

Property assertions: JosephBTaylor

Object property assertions +

- hasMother RachelJCohen
- hasFather BrianCTaylor
- hasParent RachelJCohen
- hasParent BrianCTaylor
- hasAncestor RachelJCohen
- hasAncestor BrianCTaylor
- isSpouseOf MarialTaylor
- hasSibling AdinaRTaylor
- isFatherOf SofiaMTaylor
- isFatherOf AdamJTaylor
- isFatherOf MaryITaylor
- isParentOf SofiaMTaylor
- isParentOf AdamJTaylor
- isParentOf MaryITaylor
- isSiblingOf AdinaRTaylor
- isChildOf BrianCTaylor
- isAncestorOf SofiaMTaylor
- isAncestorOf AdamJTaylor
- isAncestorOf MaryITaylor

## Inferences about JosephBTaylor:

Various class and property relationship inferences made by the FaCT++ Reasoner  
--made on the basis of class and property hierarchies, domain and range declarations, various OWL property type declarations, and property relations stated about other individuals

# Inferences about AdinaRTaylor

The image shows a screenshot of an ontology editor interface. It consists of two main panels: "Description: AdinaRTaylor" on the left and "Property assertions: AdinaRTaylor" on the right.

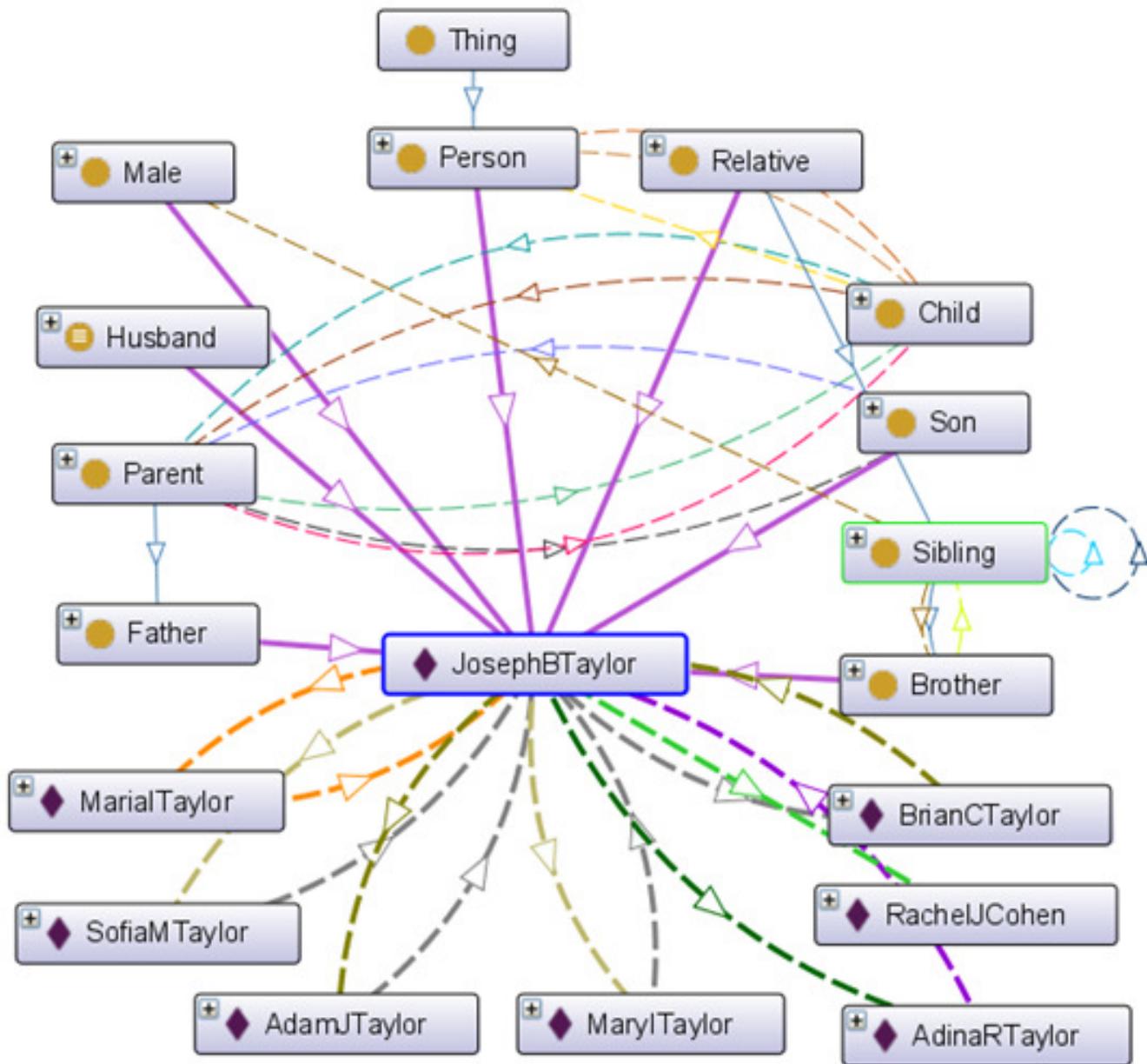
**Description: AdinaRTaylor**

- Types**:
  - Person
  - Aunt
  - Daughter
- Same individuals**: (empty)
- Different individuals**: (empty)

**Property assertions: AdinaRTaylor**

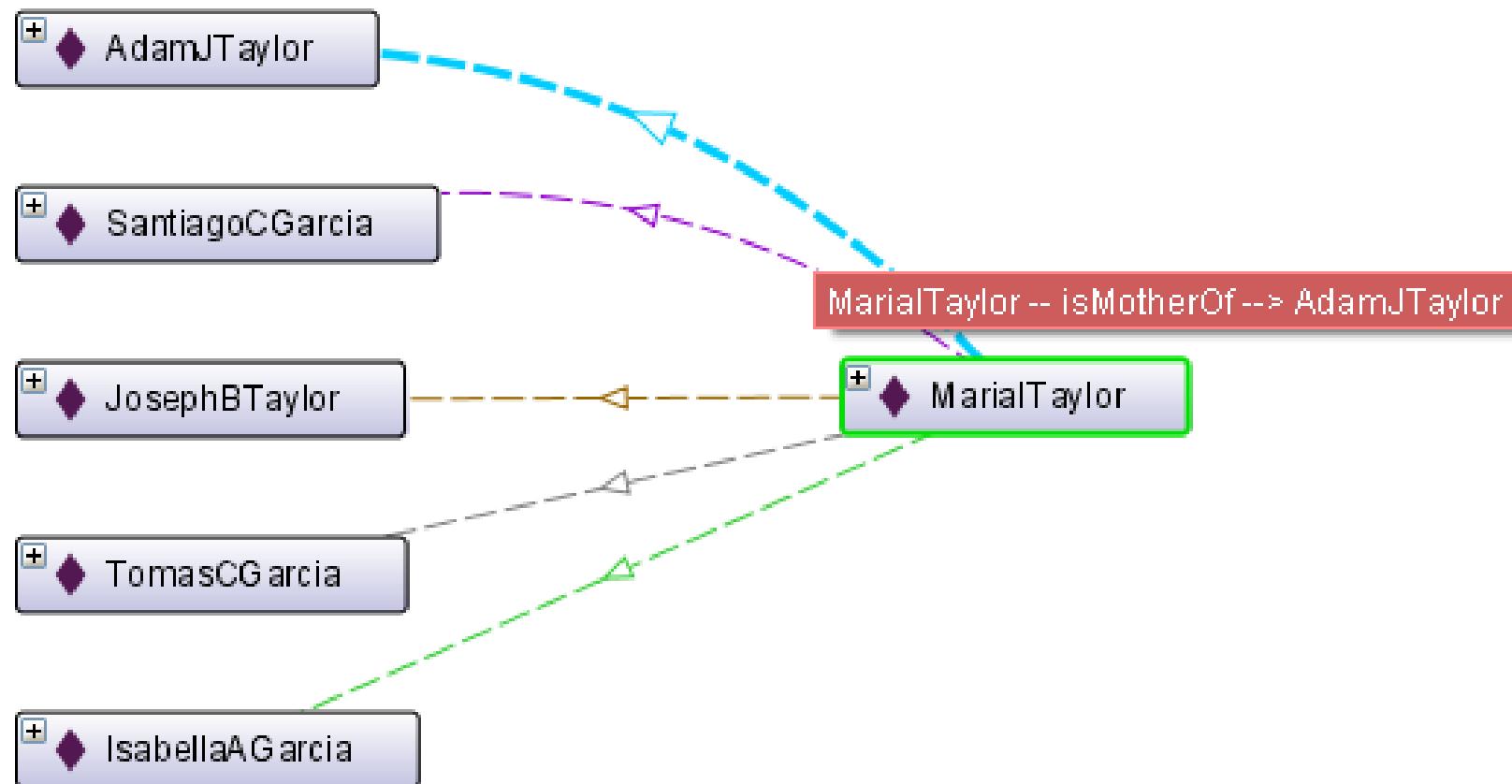
- Object property assertions**:
  - hasBrother JosephBTaylor
  - hasSibling JosephBTaylor
  - isSiblingOf JosephBTaylor
  - isChildOf BrianCTaylor
- Data property assertions**: (empty)
- Negative object property assertions**: (empty)
- Negative data property assertions**: (empty)

# Class membership and individual relationships graph for JosephBTaylor, generated by OntoGraf in Protégé



Arc Types	
	<input type="text"/> type filter text
<input checked="" type="checkbox"/>	has individual
<input checked="" type="checkbox"/>	has subclass
<input checked="" type="checkbox"/>	hasBrother
<input checked="" type="checkbox"/>	hasBrother (Domain>Range)
<input checked="" type="checkbox"/>	hasChild (Domain>Range)
<input checked="" type="checkbox"/>	hasDaughter
<input checked="" type="checkbox"/>	hasFather
<input checked="" type="checkbox"/>	hasFather(Subclass all)
<input checked="" type="checkbox"/>	hasMother
<input checked="" type="checkbox"/>	hasMother(Subclass all)
<input checked="" type="checkbox"/>	hasParent (Domain>Range)
<input checked="" type="checkbox"/>	hasParent(Subclass all)
<input checked="" type="checkbox"/>	hasSibling (Domain>Range)
<input checked="" type="checkbox"/>	hasSister
<input checked="" type="checkbox"/>	hasSon
<input checked="" type="checkbox"/>	hasSon (Domain>Range)
<input checked="" type="checkbox"/>	hasSpouse
<input checked="" type="checkbox"/>	isBrotherOf (Domain>Range)
<input checked="" type="checkbox"/>	isChildOf (Domain>Range)
<input checked="" type="checkbox"/>	isParentOf (Domain>Range)
<input checked="" type="checkbox"/>	isSiblingOf (Domain>Range)
<input checked="" type="checkbox"/>	isSonOf (Domain>Range)

# Mouseover an arc in OntoGraf: displays relationship (triple statement)



# Mouseover an individual in OntoGraph: displays URI and property assertions

SofiaMTaylor

URI: <http://www.semanticweb.org/ontologies/2013/3/FamilyRelationsOntology33.owl#SofiaMTaylor>

Object property assertions:

- SofiaMTaylor has Brother AdamJTaylor
- SofiaMTaylor has Mother MarialTaylor
- SofiaMTaylor has Father JosephBTaylor

Data property assertions:

- SofiaMTaylor has BirthDate "1999-01-15"

# Protégé: View of the Mother Class

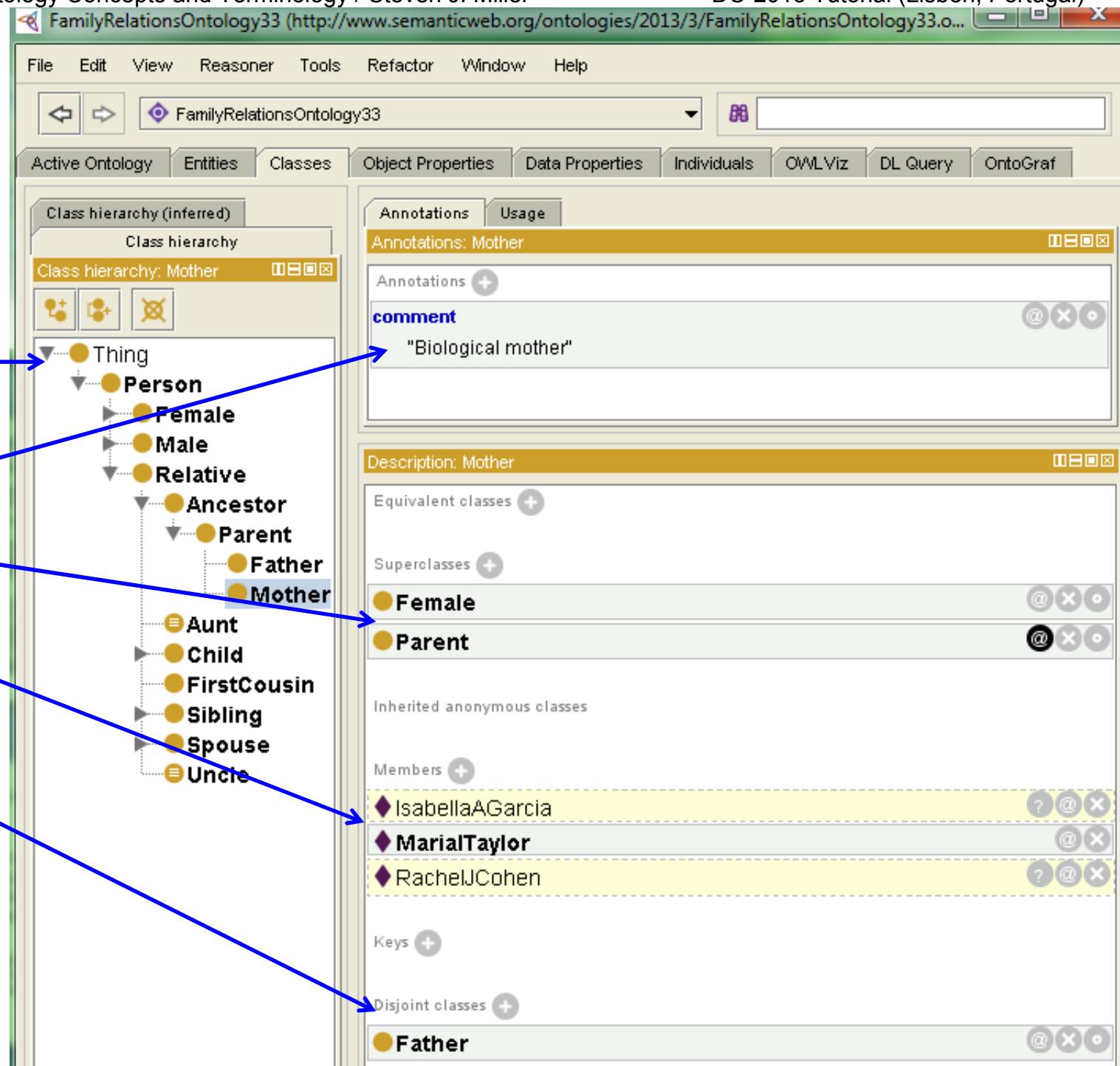
Class hierarchy

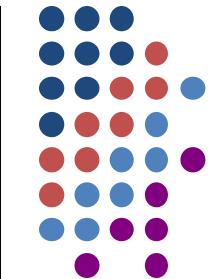
Annotations

Superclasses

Members

Disjoint  
classes



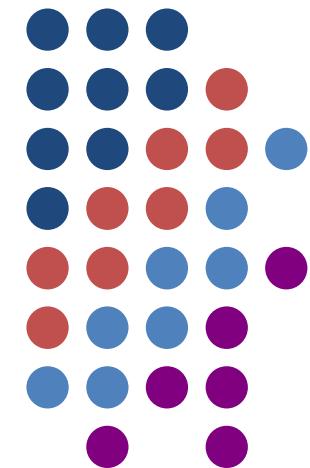


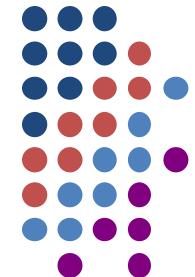
# Query examples

The Family Relationships Ontology and Knowledge Base will allow such queries as the following to be answered:

- Who are the parents of TomasCGarcia?
- Where were they born, what were their birthdates, who were their other children?
- Who are all of the ancestors of SofiaMTaylor?
- Give me all of the female ancestors of JosephBTaylor who were born between 1800 and 1950
- Give me all of the male relatives of SantiagoCGarcia who were not parents
- etc.

# Questions?





## Exercise 2: OWL Ontologies

1. Determine which properties are likely to be Object Properties and Datatype Properties in OWL.
2. Match a set of properties to relevant OWL property types.
3. Determine which OWL property would be useful for relating two resources to each other.
4. Determine logical inferences that can be made based on a set of statements.
5. Brainstorm ideas for classes, properties, inferences, and query possibilities for domain ontologies & knowledge-bases for:
  - A. 2016 Summer Olympic Games
  - B. Health care symptoms, diseases, and treatments

## Exercise 2: OWL Ontology Overview (Tutorial Part 3)

**1. Which of the following are likely to be Object Properties and which Datatype Properties in OWL? (Context: a cultural heritage resource ontology.)**

- coAuthoredWith
- hasUniqueArtistNameID
- isRevisionOf
- wasBornIn

**2. Match each property in the left column with a relevant OWL property type in the right column:**

Ontology Properties	OWL Property Types
<b>coAuthoredWith</b>	<b>Functional</b>
• Domain: Author	<b>Inverse Functional</b>
• Range: Author	
<b>hasUniqueArtistNameID</b>	<b>Symmetric</b>
• Domain: Artist	<b>Transitive</b>
• Range: string	
<b>isRevisionOf</b>	
• Domain: ArtWork	
• Range: ArtWork	
<b>wasBornIn</b>	
domain: Creator	
range: City	

**3. Which OWL property would be useful for relating the following resources to each other?**

- Library of Congress Name Authority file (LCNAF) URI <http://id.loc.gov/authorities/names/n81046163> for Aung San Suu Kyi [1945-, Burmese opposition politician].
- Virtual International Authority File (VIAF) URI <http://viaf.org/viaf/112144921> for Aung San Suu Kyi [1945-, Burmese opposition politician].

**4. Logical inferences.****A. Based on the following statements, what inferences can we make about Person456?**

coAuthoredWith isA SymmetricProperty  
Person123 coAuthoredWith Person456

**B. Based on the following statements, what inferences can we make about WorkABC and WorkDEF?**

isRevisionOf isA TransitiveProperty  
WorkABC isRevisionOf WorkDEF  
WorkDEF isRevisionOf WorkGHI  
WorkGHI isRevisionOf WorkXYZ

**C. Based on the following statements, what inferences can we make about the Artist Name ID number "1234567"?**

hasUniqueArtistNameID isA InverseFunctionalProperty  
Person123 hasUniqueArtistNameID "1234567"

**D. Suppose that your ontology includes the classes and properties stated below. How could you create a new class of all Expressionist painters using the OWL anonymous equivalent class capabilities?**

Painter isA Class  
ArtisticStyle isA Class  
Mannerism subClassOf ArtisticStyle  
Expressionism subClassOf ArtisticStyle  
Cubism subClassOf ArtisticStyle  
hasArtistcStyle isA Property  
domain: Artist  
Range: ArtisticStyle

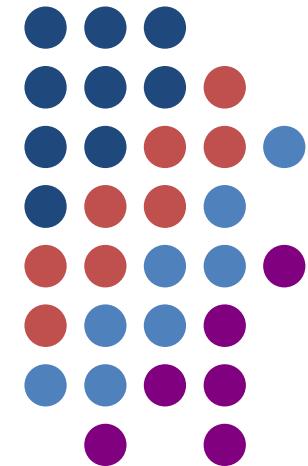
**5. Brainstorm ideas for classes, properties, inferences, and especially query possibilities that might be used in domain ontologies and knowledge-bases for:**

- A. 2016 Summer Olympic Games
- B. Health care symptoms, diseases, and treatments (for laypeople and health care providers)

# Tutorial Conclusion

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Final Questions, Comments,  
Discussion?



## Selected Readings and Resources

### Books:

**Detailed technical introductions to RDF, ontologies, RDFS, OWL, reasoning, querying, applications, etc:**

- Antoniou, Grigoris, and Frank van Harmelen. 2008. *A Semantic Web Primer*. Third edition. Cambridge, MA: MIT Press. ISBN: 978-0262018289.
- Yu, Liyang. 2011. *A Developer's Guide to the Semantic Web*. Berlin: Springer. ISBN: 978-3642159695.
- Allemang, Dean, and James Hendler. 2011. *Semantic Web for the Working Ontologist: Effective Modeling in RDFS and OWL*. Second Edition. Waltham, MA : Morgan Kaufmann/Elsevier. ISBN: 978-0123859655.

**Detailed technical introduction to SPARQL:**

- DuCharme, Bob. 2013. Learning SPARQL: Querying and Updating with SPARQL 1.1. Second edition. O'Reilly.

**General overview of Linked Data and Semantic Web for cultural heritage data:**

- Hyvönen, Eero. 2012. *Publishing and Using Cultural Heritage Linked Data on the Semantic Web*. Morgan & Claypool. ISBN: 978-1608459971.

### Selected W3C Standards Documents:

- Semantic Web Standards: <http://www.w3.org/standards/semanticweb/>
- Linked Data: <http://www.w3.org/standards/semanticweb/data>
- Ontologies/Vocabularies: <http://www.w3.org/standards/semanticweb/ontology.html>
- RDF Resource Description Framework: <http://www.w3.org/standards/techs/rdf>
  - RDF Primer: <http://www.w3.org/TR/2004/REC-rdf-primer-20040210/>
- RDFS: RDF Vocabulary Description Language 1.0: RDF Schema: <http://www.w3.org/TR/2004/REC-rdf-schema-20040210/>
- OWL Web Ontology Language: <http://www.w3.org/standards/techs/owl>
  - OWL Web Ontology Language Guide: <http://www.w3.org/TR/2004/REC-owl-guide-20040210/>
  - OWL 2 Web Ontology Language Primer (Second Edition): <http://www.w3.org/TR/2012/REC-owl2-primer-20121211/>
- Query: <http://www.w3.org/standards/semanticweb/query>
- Inference: <http://www.w3.org/standards/semanticweb/inference.html>
- SKOS: <http://www.w3.org/2004/02/skos/>

### Ontology Creation:

**A good, practical introduction to creating an ontology:**

- Noy, Natalya F., and Deborah L. McGuinness. 2001. "Ontology Development 101: A Guide to Creating Your First Ontology." Stanford Knowledge Systems Laboratory Technical Report KSL-01-05 and Stanford Medical Informatics Technical Report SMI-2001-0880.

Available online: <http://www-ksl.stanford.edu/people/dlm/papers/ontology-tutorial-noy-mcguinness.pdf>

- It refers to some aspects of an older version or Protégé, but 95% of it remains valid and relevant.

### Protégé Ontology Editor

- <http://protege.stanford.edu/>
- Protégé is a free, open source ontology editor and knowledge-base framework.
- The Protégé platform supports modeling ontologies via a web client or a desktop client. Protégé ontologies can be developed in a variety of formats including OWL, RDF(S), and XML Schema.
- There are several versions of Protégé available for download. I have been using Protégé 4.1 for OWL Ontologies. There is now a Protégé 4.3 available, as well as a new WebProtege which I have not used myself.

### A good, full-fledged tutorial for Protégé-OWL:

- Horridge, Matthew. 2011. "A Practical Guide To Building OWL Ontologies: Using Protégé 4 and CO-ODE Tools." Edition 1.3. The University Of Manchester. Available online: [http://owl.cs.manchester.ac.uk/tutorials/protegeowltutorial/resources/ProtegeOWLTutorialP4\\_v1\\_3.pdf](http://owl.cs.manchester.ac.uk/tutorials/protegeowltutorial/resources/ProtegeOWLTutorialP4_v1_3.pdf)
- This tutorial document takes you through using Protégé OWL to build an OWL ontology step-by-step.

### Other RDF and ontology editors to be aware of:

- TopBraid Composer: [http://www.topquadrant.com/products/TB\\_Composer.html](http://www.topquadrant.com/products/TB_Composer.html)
- Altova SemanticWorks: <http://www.altova.com/semanticworks.html>

### Domain Ontology Examples:

- ABC Ontology and Model: <http://www.nii.ac.jp/dc2001/proceedings/product/paper-26.pdf>
  - RDFS: p. 170-171; Graphical illustrations: p. 172-176
- BBC Programmes Ontology: <http://purl.org/ontology/po/>
  - RDF/N3 file (not RDF/XML): [http://www.bbc.co.uk/go/ontologies/programmes/2009-09-07.shtml/ext/\\_auto/-/http://purl.org/ontology/po/2009-09-07.n3](http://www.bbc.co.uk/go/ontologies/programmes/2009-09-07.shtml/ext/_auto/-/http://purl.org/ontology/po/2009-09-07.n3)
- BBC Wildlife Ontology: <http://purl.org/ontology/wo/>
- BIBO: The Bibliographic Ontology: <http://bibliontology.com/>
  - Explore the ontology: [http://bibotools.googlecode.com/svn/bibo\\_ontology/trunk/doc/index.html](http://bibotools.googlecode.com/svn/bibo_ontology/trunk/doc/index.html)
  - OWL RDF file: <http://purl.org/ontology/bibo/>
- GeoNames Ontology: <http://www.geonames.org/ontology/documentation.html>
  - OWL RDF file: [http://www.geonames.org/ontology/ontology\\_v3.01.rdf](http://www.geonames.org/ontology/ontology_v3.01.rdf)
- Music Ontology Specification: <http://www.musicontology.com/>
  - OWL file: <http://motools.sourceforge.net/doc/musicontology.rdfs>

**Ontology Libraries:**

- Protégé Ontology Library: [http://protegewiki.stanford.edu/wiki/Protege\\_Ontology\\_Library](http://protegewiki.stanford.edu/wiki/Protege_Ontology_Library)
- Swoogle: <http://swoogle.umbc.edu/>
- SemWebCentral: <http://www.semwebcentral.org/>
- Ontology Engineering Group: <http://www.oeg-upm.net/>
- Open Biological and Biomedical Ontologies: <http://obofoundry.org/>
- W3C ontology repositories: [http://www.w3.org/wiki/Ontology\\_repositories](http://www.w3.org/wiki/Ontology_repositories)
- SchemaWeb: <http://www.schemaweb.info/>

**Articles, Papers, Presentations, Tutorials, Videos, Technical Documents, Websites:****Introduction to RDF, Semantic Web and Linked Data**

- Sporny, Manu. 2007. "Introduction to the Semantic Web." YouTube. <http://www.youtube.com/watch?v=OGg8A2zfWKg>
- Sporny, Manu. 2008. "RDFa Basics." YouTube. <http://www.youtube.com/watch?v=ldl0m-5zLz4&feature=related>
  - Note: RDFa is one of several methods of using RDA on the Web. The video includes a nice introduction to RDF and triples in general but also includes many specifics of the N3 encoding syntax.
- LinkedDataTools.com. Semantic Web Primer. Online Tutorials. <http://www.linkeddatatools.com/semantic-web-basics>
- Tauberer, Joshua. [2005]. "Quick Intro to RDF." <http://www.rdfabout.com/quickintro.xpd>
- Tauberer, Joshua. 2008. "What Is RDF and What Is It Good For?" RDF: About. Last modified January. <http://www.rdfabout.com/intro/>

**OWL Ontologies**

- Costello, Roger L., and David B. Jacobs. 1999. "OWL Web Ontology Language" [Tutorial]. <http://sce.umkc.edu/~leeyu/class/CS560/Lecture/Owl1.pdf>
- Costello, Roger L., and David B. Jacobs. 2003. "The Robber and the Speeder (version 2)." [http://weichselbraun.net/ir/pdf/examples/example4\\_robber\\_and\\_speeder\\_extended.pdf](http://weichselbraun.net/ir/pdf/examples/example4_robber_and_speeder_extended.pdf)

**Libraries, RDA, Bibliographic Data, Linked Data, and the Semantic Web**

- Baker, Thomas. 2012. "Libraries, languages of description, and linked data: a Dublin Core perspective." *Library Hi Tech*, Vol. 30 Issue 1, p. 116-133.
- Baker, Thomas, et al. 2011. "Library Linked Data Incubator Group Final Report." October 25. <http://www.w3.org/2005/Incubator/lld/XGR-lld-20111025/>
- Coyle, Karen. 2010. Understanding the Semantic Web: Bibliographic Data and Metadata. *Library Technology Reports*, vol. 46, no. 1. Chicago: American Library Association.
- Coyle, Karen. 2010. RDA Vocabularies for a Twenty-first Century Data Environment. *Library Technology Reports*, vol. 46, no. 2. Chicago: American Library Association.
- Hillmann, Diane, Karen Coyle, Jon Phipps, and Gordon Dunsire. 2010. "RDA Vocabularies: Process, Outcome, Use." *D-Lib Magazine* 16, no. 1/2 (January/February). <http://www.dlib.org/dlib/january10/hillmann/01hillmann.html>
- The RDA (Resource Description and Access) Vocabularies in the Open Metadata Registry: <http://rdvocab.info/>
- Library of Congress Linked Data Service: Authorities and Vocabularies: <http://id.loc.gov/>

**BIBFRAME**

- BIBFRAME.ORG website: <http://bibframe.org/>
- Library of Congress. 2012. "Bibliographic Framework as a Web of Data: Linked Data Model and Supporting Services." November 21, 2012.  
<http://www.loc.gov/marc/transition/pdf/marcld-report-11-21-2012.pdf>
- Bibliographic Framework Transition Initiative website: <http://www.loc.gov/marc/transition/>.
  - Latest announcements: <http://www.loc.gov/marc/transition/news/>.

**Dublin Core Metadata Initiative (DCMI)**

- Dekkers, Max. 2010. "Dublin Core in the Early Web Revolution." Presentation at Joint NISO/DCMI Webinar, August 25.  
[http://dublincore.org/resources/training/NISO\\_Webinar\\_20100825/dcmi-webinar-01.pdf](http://dublincore.org/resources/training/NISO_Webinar_20100825/dcmi-webinar-01.pdf)
- NISO/DCMI. 2010. "Dublin Core: The Road from Metadata Formats to Linked Data." Joint NISO/DCMI Webinar, August 25. Presentation slides by Makx Dekkers and Thomas Baker.  
<http://www.dublincore.org/resources/training/>
- DCMI Metadata Terms: <http://dublincore.org/documents/dcmi-terms/>
- DCMI Abstract Model: <http://dublincore.org/documents/abstract-model/>

**SKOS**

- SKOS (Simple Knowledge Organization System) - Dublin Core 2011 tutorial, Antoine Isaac, 2011-9-21: Presentation slides: [http://dublincore.org/resources/training/dc-2011/Tutorial\\_Isaac.pdf](http://dublincore.org/resources/training/dc-2011/Tutorial_Isaac.pdf)
- SKOS Simple Knowledge Organization System website: <http://www.w3.org/2004/02/skos/>
- SKOS Primer: <http://www.w3.org/TR/skos-primer/>

**Europeana**

- Europeana. 2012. "Linked Open Data – What is it?" Vimeo (3.5 min.)  
<http://vimeo.com/36752317>
- Isaac, Antoine, Robina Clayphan, and Bernhard Haslhofer. 2012. "Europeana: Moving to Linked Open Data." *Information Standards Quarterly*, Spring/Summer, 24(2/3):34-40.
- Doerr, Martin, et al. 2010. "The Europeana Data Model (EDM)." World Library and Information Congress: 76th IFLA General Conference And Assembly, 10-15 August 2010, Gothenburg, Sweden. <http://conference.ifla.org/past/ifla76/149-doerr-en.pdf>
- Europeana Data Model (EDM) Documentation. <http://pro.europeana.eu/edm-documentation>

**Google**

- Google: "Rich snippets (microdata, microformats, and RDFa)." <http://www.google.com/support/webmasters/bin/answer.py?answer=99170>
- Google. The Knowledge Graph.  
<http://www.google.com/insidesearch/features/search/knowledge.html>
- "Introducing the Knowledge Graph: things, not strings." May 16, 2012. Google blog. Posted by Amit Singhal. <http://googleblog.blogspot.com/2012/05/introducing-knowledge-graph-things-not.html#!/2012/05/introducing-knowledge-graph-things-not.html>

## How to View XML, RDF, SKOS, and OWL (.xml., .rdf, .owl) files

### Viewing files in their native XML or other serialization (encoding) formats.

- You may click on the link to an RDF, SKOS, or other file, and in some cases it will display in your browser, other times it won't.
- You may choose to open the file, or save the file to your computer and then open it, in a plain text editor like Notepad.
- I recommend the free **Notepad++** text editor as usually preferable for display and reading the file.

### Viewing triples and graphs

- You may copy and paste RDF XML code into the input box in the **W3C RDF Validation Service** at <http://www.w3.org/RDF/Validator/>.
- You may select to display the results as Triples only, Graph only, or both. Click on Parse RDF to see the results.
- An alternative below the direct input box is to **check by URI**, copying and pasting or manually entering the URI for the RDF XML file and making the same display selections. Click on Parse URI.
- This works for BIBFRAME and SLOS files as well as other RDF files.

### Viewing ontologies in an ontology editor

- Besides viewing the native XML, you may also view OWL ontology files in an ontology editor.
- You may download the free **Protégé OWL ontology editor** from <http://protege.stanford.edu/>. I currently use Protégé 4.2, but there is now a 4.3 available.
- You may open an ontology file such as the Bibliographic Ontology Specification (BIBO) in Protégé from its URL or save the file to your computer and open it from there software from also open. The URL for the BIBO ontology file is <http://purl.org/ontology/bibo/>. It is also available from this page: <http://bibliontology.com/specification>.
- For anyone interested, I will make my Family Relationships Ontology file available to you after the workshop at a URL address I will give later.