

SWCLOS: A Semantic Web Processor on CLOS

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SWCLOS Web Site

- ✿ **<http://www-kasm.nii.ac.jp/~koide/SWCLOS2-en.htm>**
- ✿ **For installing free Allegro Common Lisp Express,
visit <http://www.franz.com/downloads/>**
- ✿ **For making mlisp image from Express version,
visit <http://www.franz.com/support/faq/index.html#s3q13>**



Objectives of This Tutorial

✿ For CLOS Hacker

- ✿ Provide an example of CLOS application
- ✿ Enlighten CLOS Semantics in Semantic Web

✿ For Lisper

- ✿ Provide a tool for Semantic Web Processing



What is SWCLOS?

- ❶ Semantic Web Processor on top of CLOS
- ❷ Processing Ontology in RDFS and OWL
- ❸ Input Ontology in S-expression, RDF/XML, Triples
- ❹ Output Ontology in S-expression , RDF/XML, Triples
- ❺ An Amalgam of CLOS and RDFS/OWL
- ❻ Pros
 - ✿ A tool for CLOS programmers for Semantic Web programming
- ❼ Cons
 - ✿ Unavailable for C# and Java Programmers

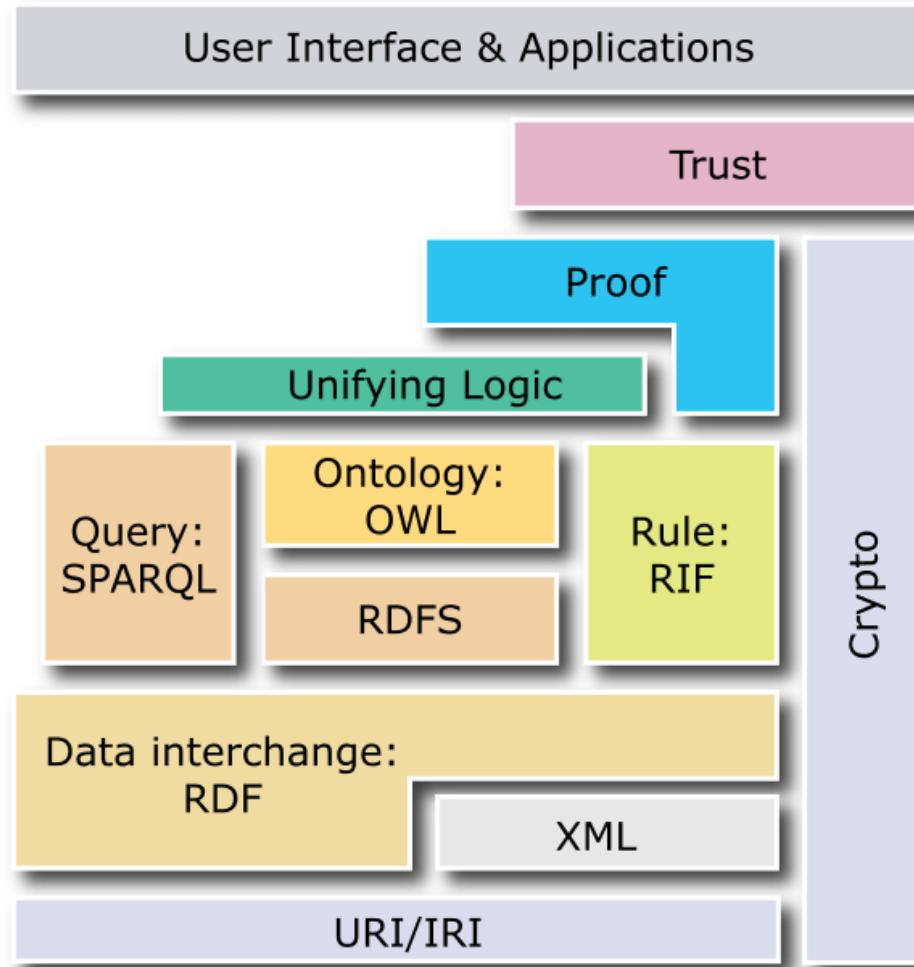


Agenda

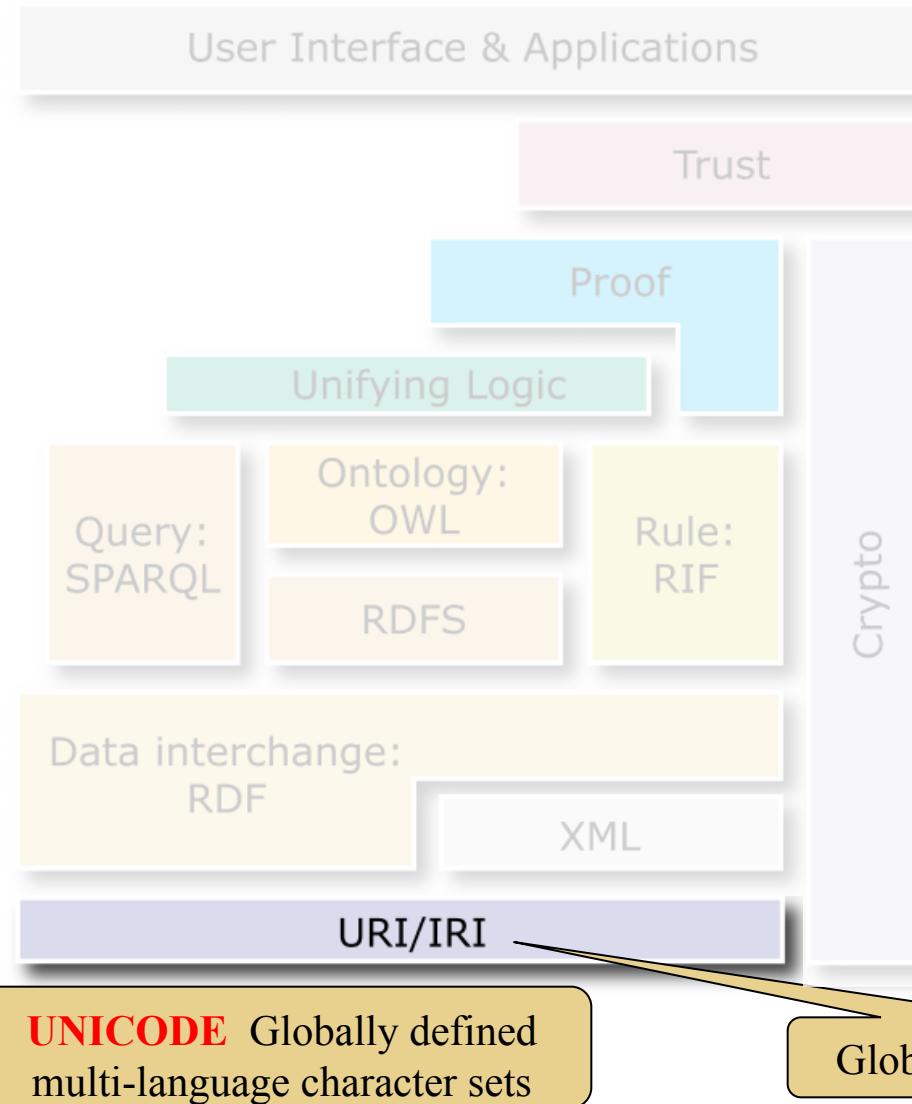
- ✿ **Gentle Introduction of Semantic Web**
 - ✿ **RDF Graph**
 - Introductory Example
 - ✿ **RDF and RDFS Vocabulary and Semantics**
 - rdf:type, rdfs:subClassOf
 - rdfs:domain, rdfs:range
 - rdfs:subPropertyOf
 - ✿ **OWL Vocabulary and Semantics**
 - Slot value restriction
 - Compound concepts
- ✿ **Advanced Talk**
 - ✿ **Semantics of RDF**
 - ✿ **Semantics of OWL**
- ✿ **Reflection**



Semantic Web Layer-cake



Semantic Web Layer-cake



UNICODE at Allegro Common Lisp

<http://www.franz.com/support/documentation/7.0/doc/iacl.htm>

Internally, all Lisp strings are represented as arrays of Unicode character codes. Each array element is exactly 16-bits wide, even if the string contains only 7-bit ASCII characters. This widening of strings causes a memory usage increase. However, since almost all initial Allegro CL strings are stored in memory-mapped files, the initial runtime memory usage difference between International Allegro CL and non-international Allegro CL is less than 5%.

Non-international (8-bit characters) Allegro CL:

```
> (char-code #\"é)  
163 ;;; This is the (8-bit) Latin-2 code.
```

International Allegro CL:

```
> (char-code #\"é)  
321 ;;; This is the Unicode code.
```



URI Library at Allegro Common Lisp

<http://www.franz.com/support/documentation/7.0/doc/uri.htm>

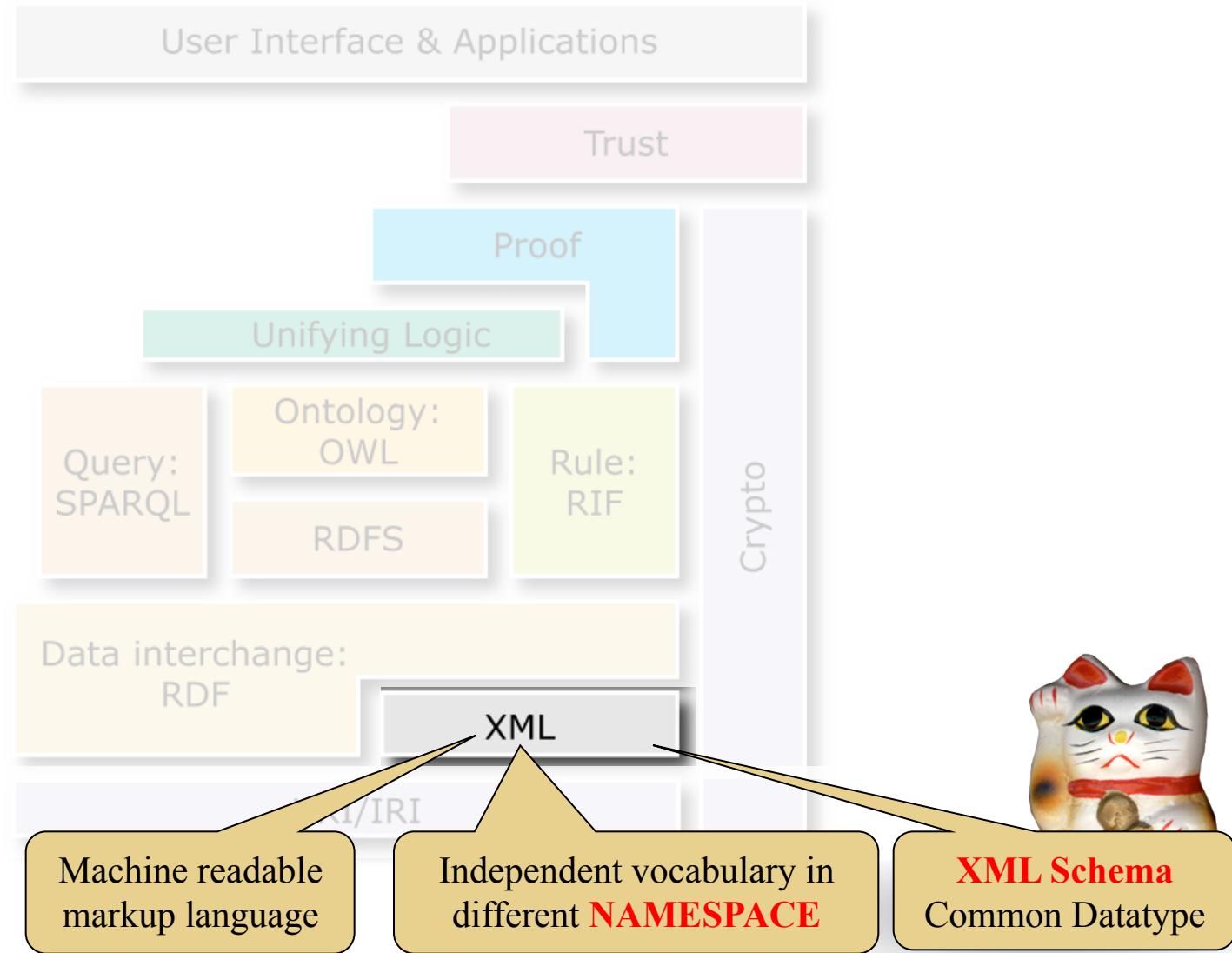
URI stands for *Universal Resource Identifier*. For a description of URIs, see RFC2396, which can be found in several places, including the IETF web site (<http://www.ietf.org/rfc/rfc2396.txt>) and the UCI/ICS web site (<http://www.ics.uci.edu/pub/ietf/uri/rfc2396.txt>).

We prefer the UCI/ICS one as it has more examples.

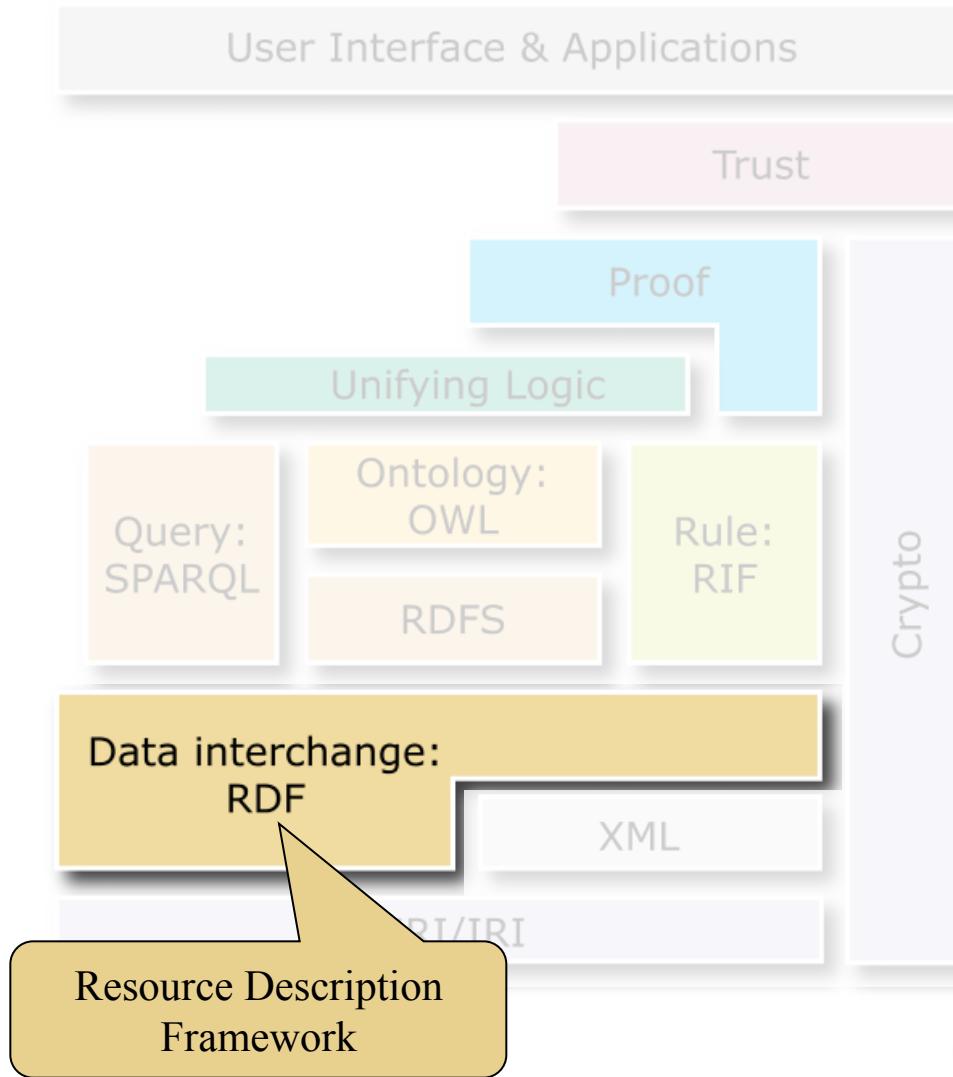
URIs are a superset in functionality and syntax to URLs (Universal Resource Locators) and URNs (Universal Resource Names). That is, RFC2396 updates and merges RFC1738 and RFC1808 into a single syntax, called the URI. It does exclude some portions of RFC1738 that define specific syntax of individual URL schemes.



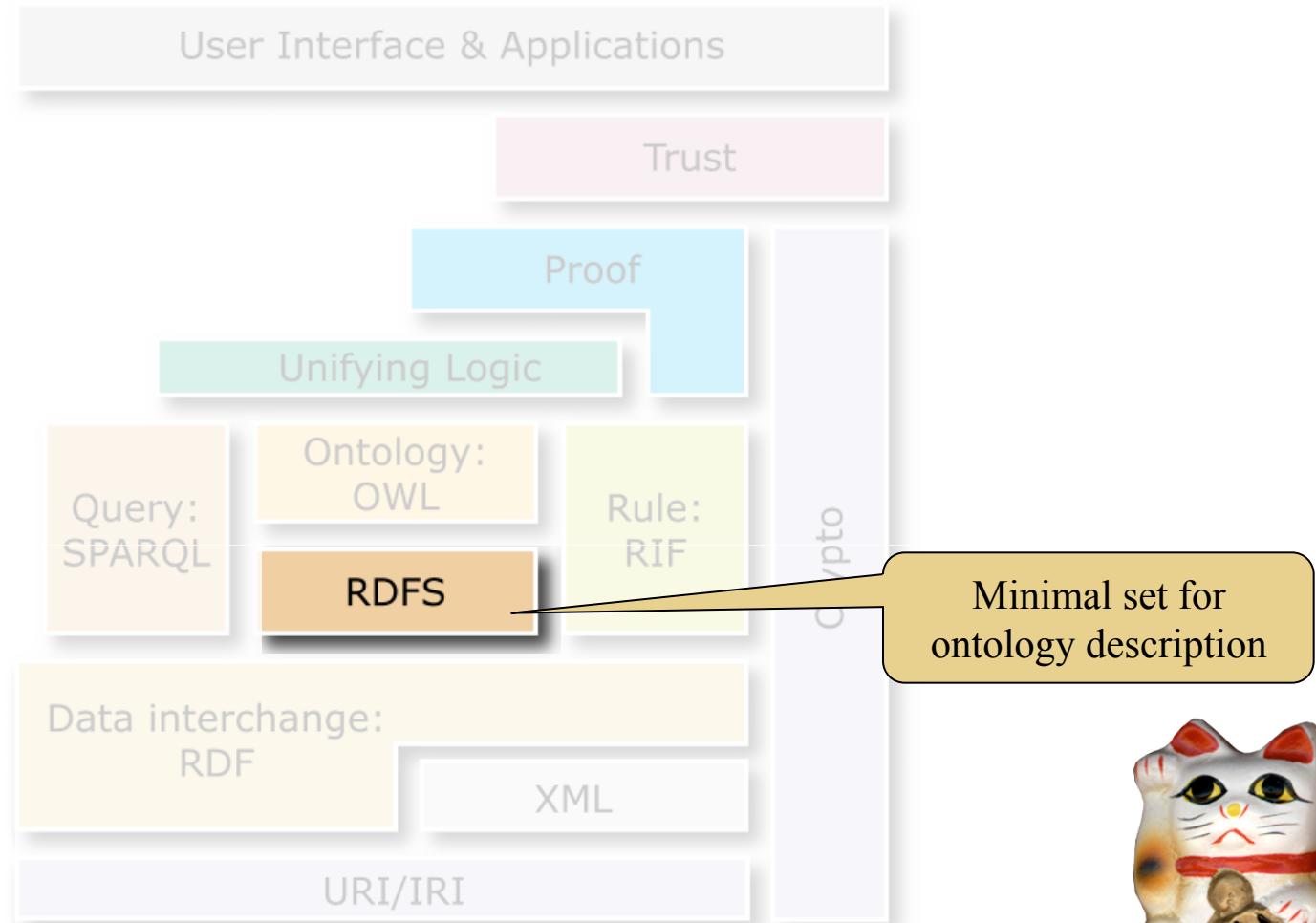
Semantic Web Layer-cake



Semantic Web Layer-cake



Semantic Web Layer-cake



Resource Description Framework

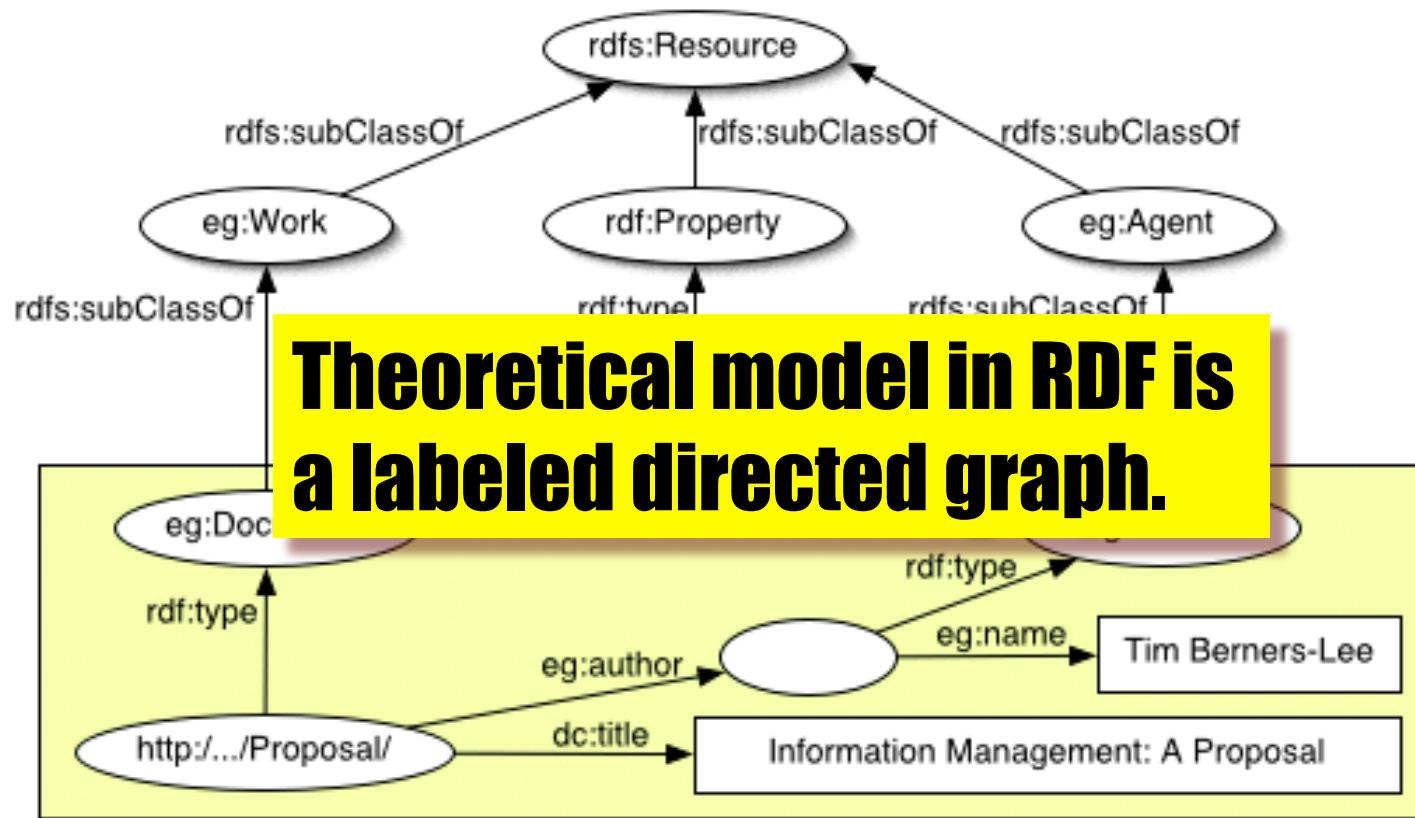
- ✿ **RDF Primer**
 - ✿ <http://www.w3.org/TR/rdf-primer/>
- ✿ **Concepts and Abstract Syntax**
 - ✿ <http://www.w3.org/TR/rdf-concepts/>
- ✿ **RDF/XML Syntax Specification**
 - ✿ <http://www.w3.org/TR/rdf-syntax-grammar/>
- ✿ **RDF Semantics**
 - ✿ <http://www.w3.org/TR/rdf-mt/>
- ✿ **RDF Vocabulary Description Language**
 - ✿ <http://www.w3.org/TR/rdf-schema/>
- ✿ **RDF Test Cases**
 - ✿ <http://www.w3.org/TR/rdf-testcases/>



Introductory Example

Obsolete RDFS Document

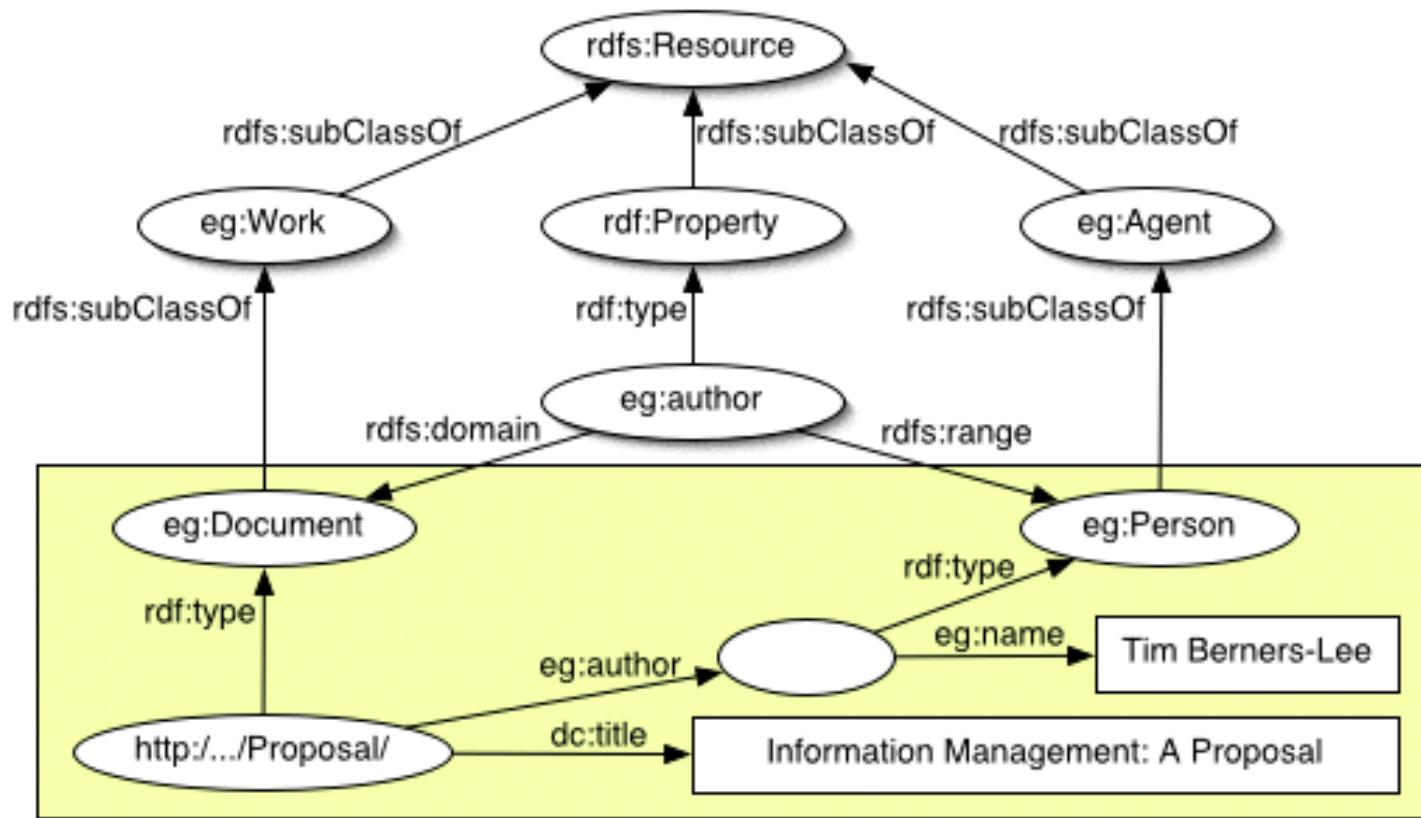
<http://www.w3.org/TR/2002/WD-rdf-schema-20021112/>



Introductory Example

Obsolete RDFS Document

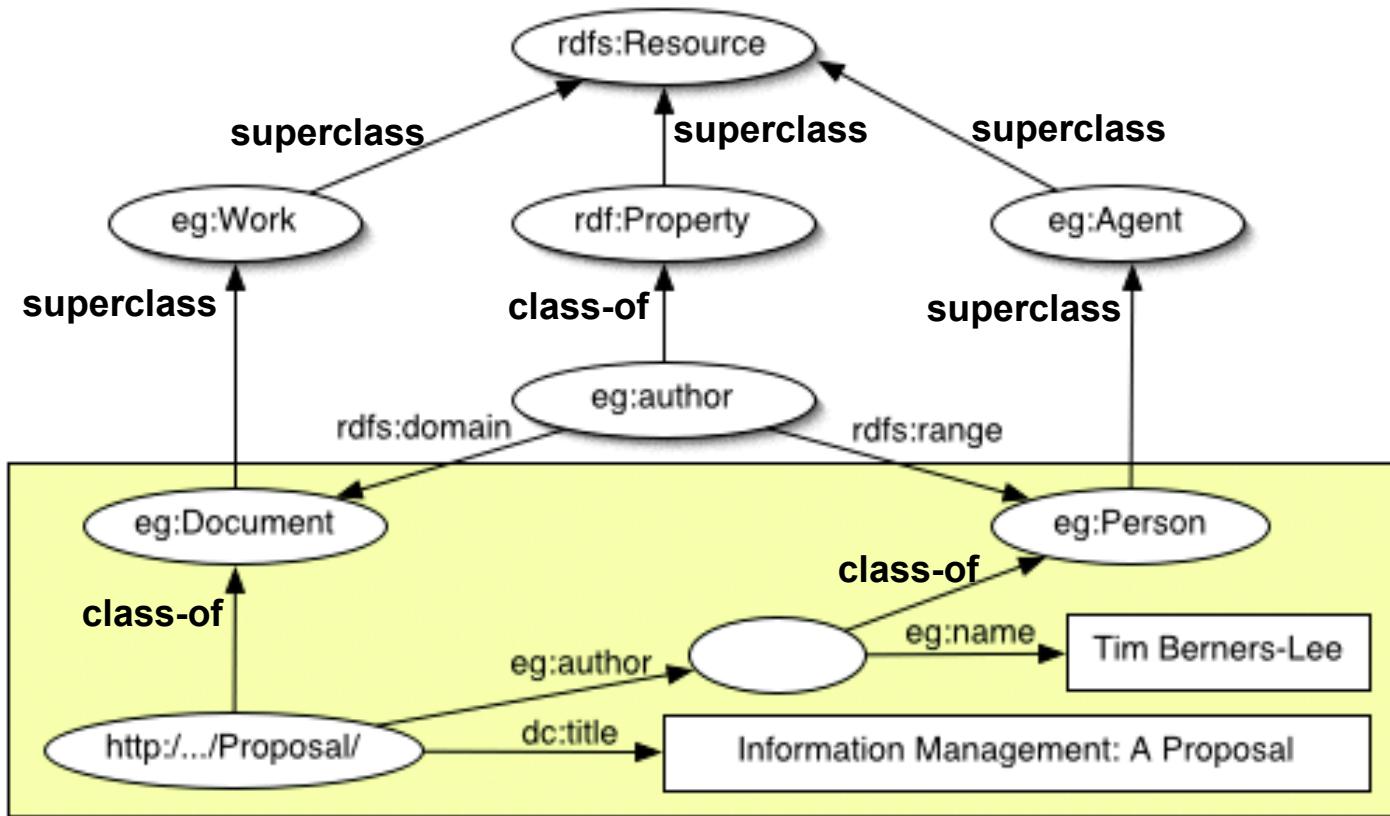
<http://www.w3.org/TR/2002/WD-rdf-schema-20021112/>



Introductory Example (Pure CLOS)

Obsolete RDFS Document

<http://www.w3.org/TR/2002/WD-rdf-schema-20021112/>



Introductory Example (Pure CLOS)

Obsolete RDFS Document

<http://www.w3.org/TR/2002/WD-rdf-schema-20021112/>

```
(defpackage rdf
  (:documentation "http://www.w3.org/1999/02/22-rdf-syntax-ns"))
(defpackage rdfs
  (:documentation "http://www.w3.org/2000/01/rdf-schema"))
(defpackage eg
  (:documentation "http://somewhere-for-eg/eg"))
(defpackage dc
  (:documentation
  "http://dublincore.org/2002/08/13/dces"))

(defclass rdfs::Resource () ((rdf::about :initarg :about)))
(defclass eg::Work (rdfs::Resource) ())
(defclass eg::Agent (rdfs::Resource) ())
(defclass eg::Person (eg::Agent)
  ((eg::name :initarg :name)))
(defclass eg::Document (eg::Work)
  ((eg::author :initarg :author :type eg::Person)
  (dc::title :initarg :title)))
```



Introductory Example (Pure CLOS)

Obsolete RDFS Document

<http://www.w3.org/TR/2002/WD-rdf-schema-20021112/>

```
(defclass rdfs::Resource () ((rdf::about :initarg :about)))
(defclass eg::work (rdfs::Resource) ())
(defclass eg::Agent (rdfs::Resource) ())
(defclass eg::Person (eg::Agent)
  ((eg::name :initarg :name)))
(defclass eg::Document (eg::work)
  ((eg::author :initarg :author :type eg::Person)
   (dc::title :initarg :title)))
```

Bind to the Name Symbol

```
(setq eg::Proposal
      (make-instance 'eg::Document
        :author (make-instance 'eg::Person :name "Tim Berners-Lee")
        :title "Information Management: A Proposal"
        :about "http://.../Proposal/"))
(describe eg::Proposal)
```

Lisp Native Function



Case Sensitive Lisp or Modern Lisp

ACL8.1 or 8.0 in Windows

Start → Program → Allegro CL → Modern ACL Images

→ Allegro CL (w IDE, Modern)

DO NOT SELECT ANSI image IN WINDOW

SWCLOS requires Case Sensitive Mode of ACL.



SWCLOS Web Site

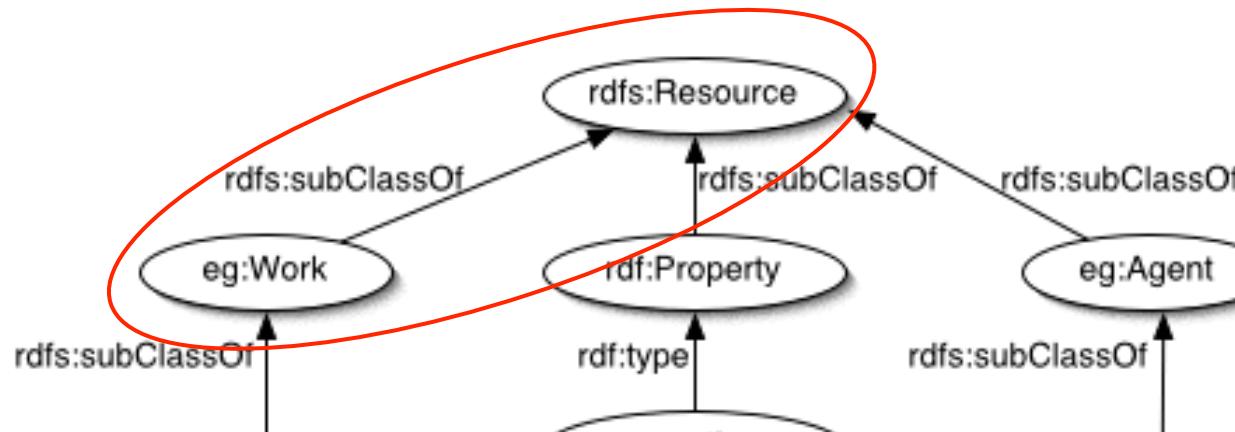
- ✿ **<http://www-kasm.nii.ac.jp/~koide/SWCLOS2-en.htm>**
- ✿ **For installing free Allegro Common Lisp Express,
visit <http://www.franz.com/downloads/>**
- ✿ **For making mlisp image from Express version,
visit <http://www.franz.com/support/faq/index.html#s3q13>**



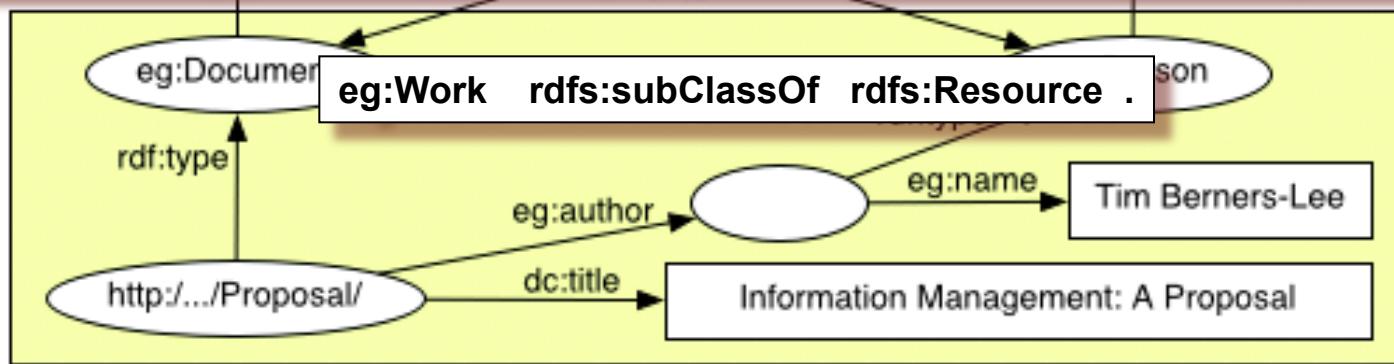
Introductory Example

Obsolete RDFS Document

<http://www.w3.org/TR/2002/WD-rdf-schema-20021112/>



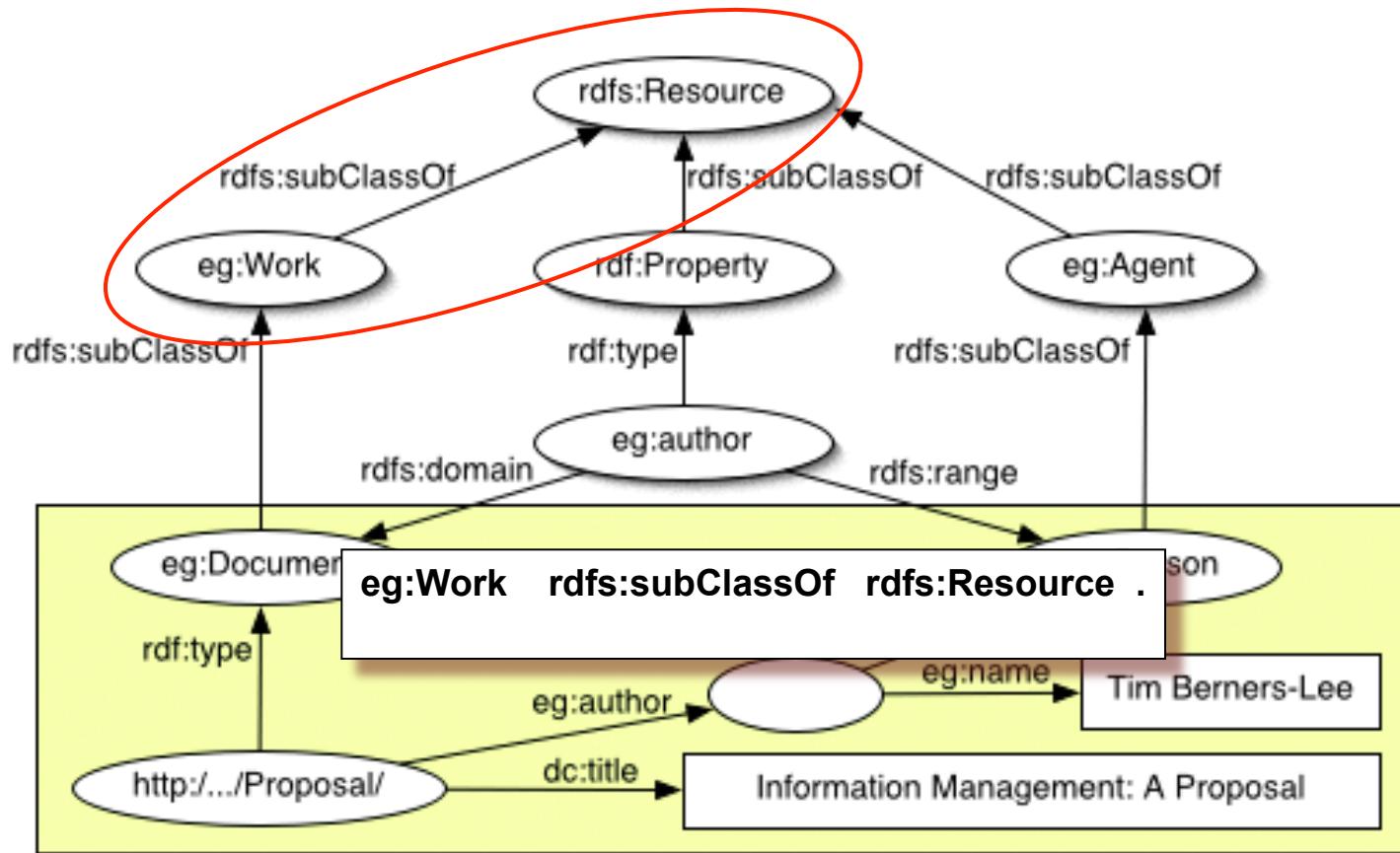
<<http://somewhere-for-eg/eg#Work>> <<http://www.w3.org/2000/01/rdf-schema#subClassOf>> <<http://www.w3.org/2000/01/rdf-schema#Resource>> .



Introductory Example

Obsolete RDFS Document

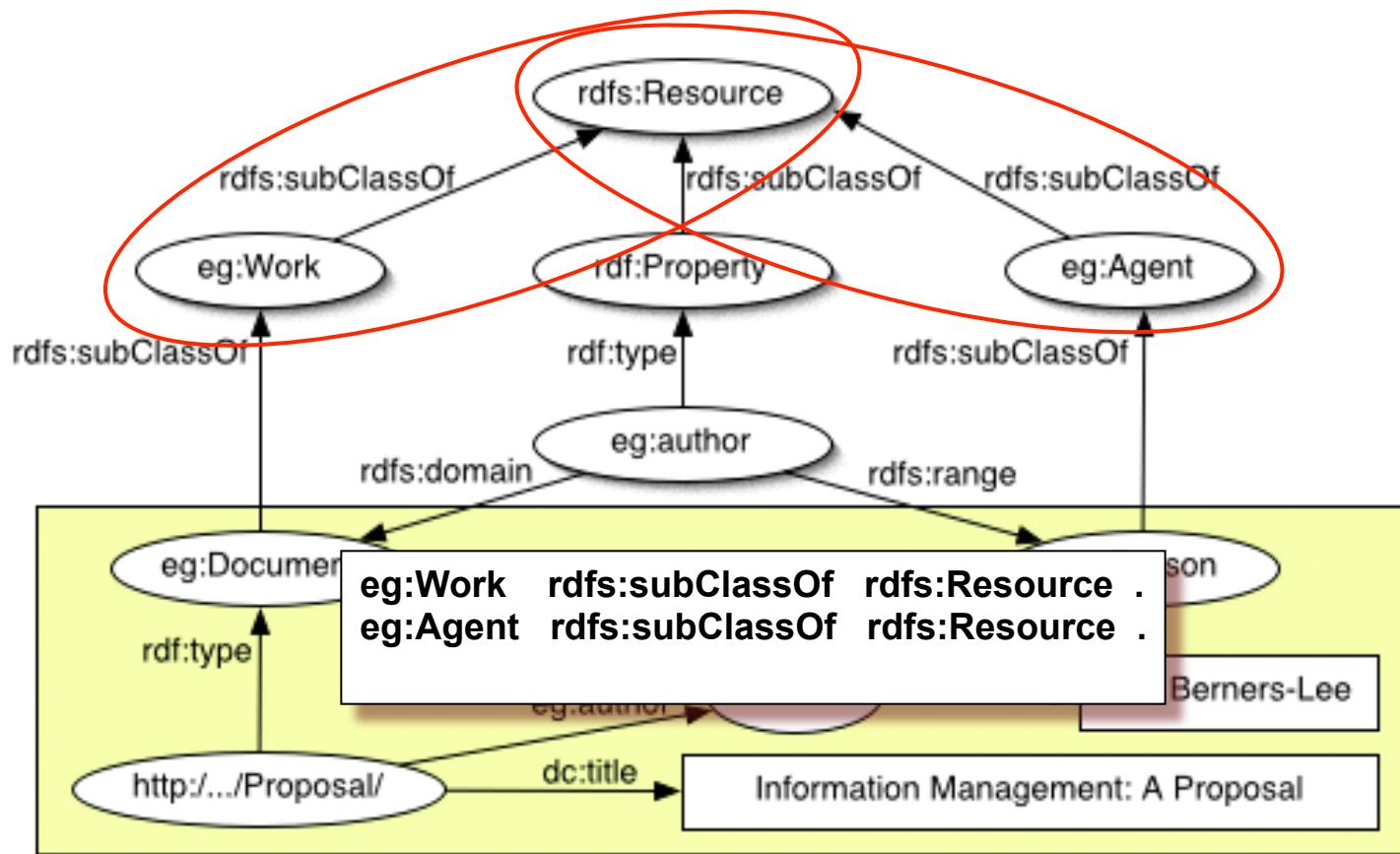
<http://www.w3.org/TR/2002/WD-rdf-schema-20021112/>



Introductory Example

Obsolete RDFS Document

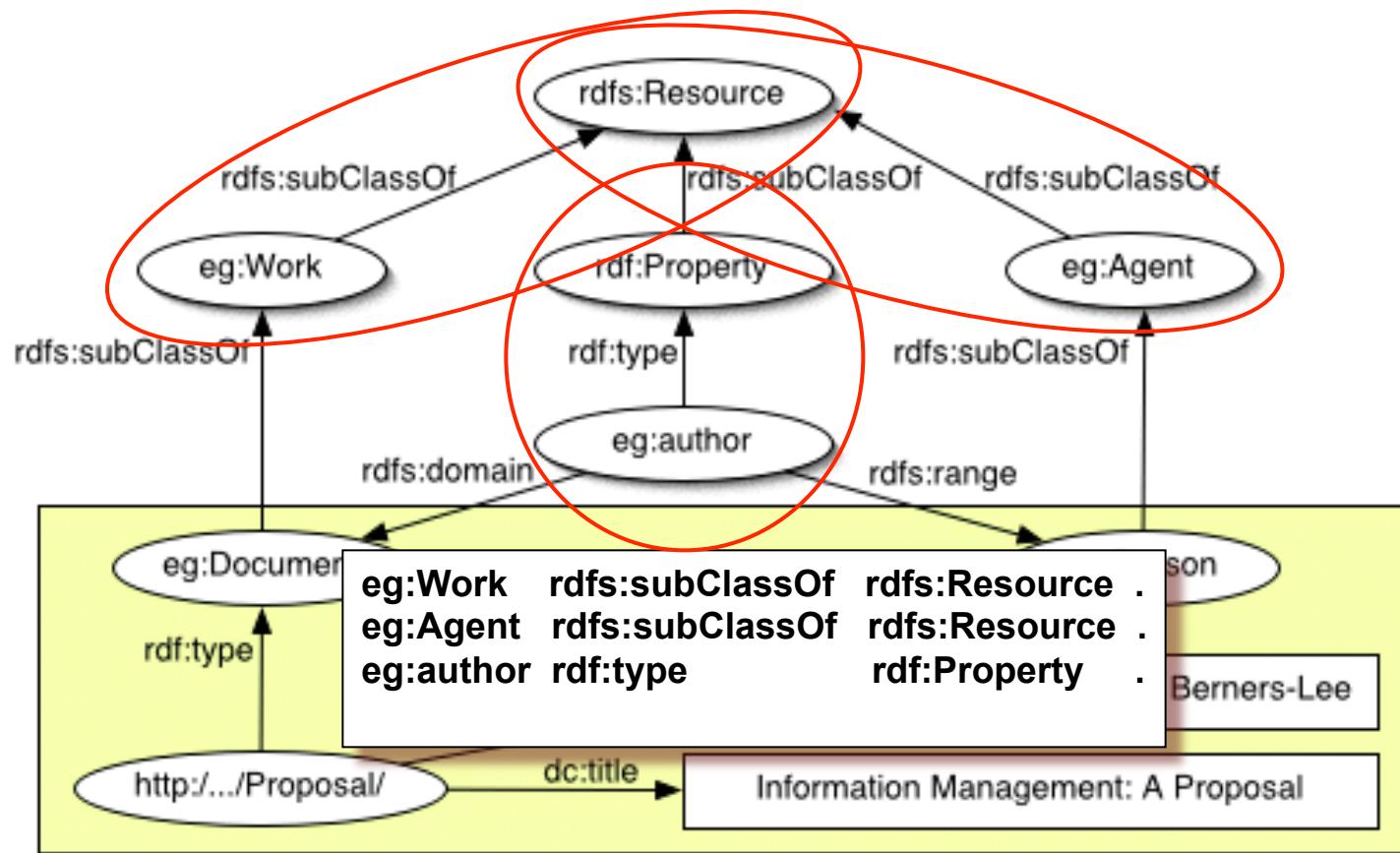
<http://www.w3.org/TR/2002/WD-rdf-schema-20021112/>



Introductory Example

Obsolete RDFS Document

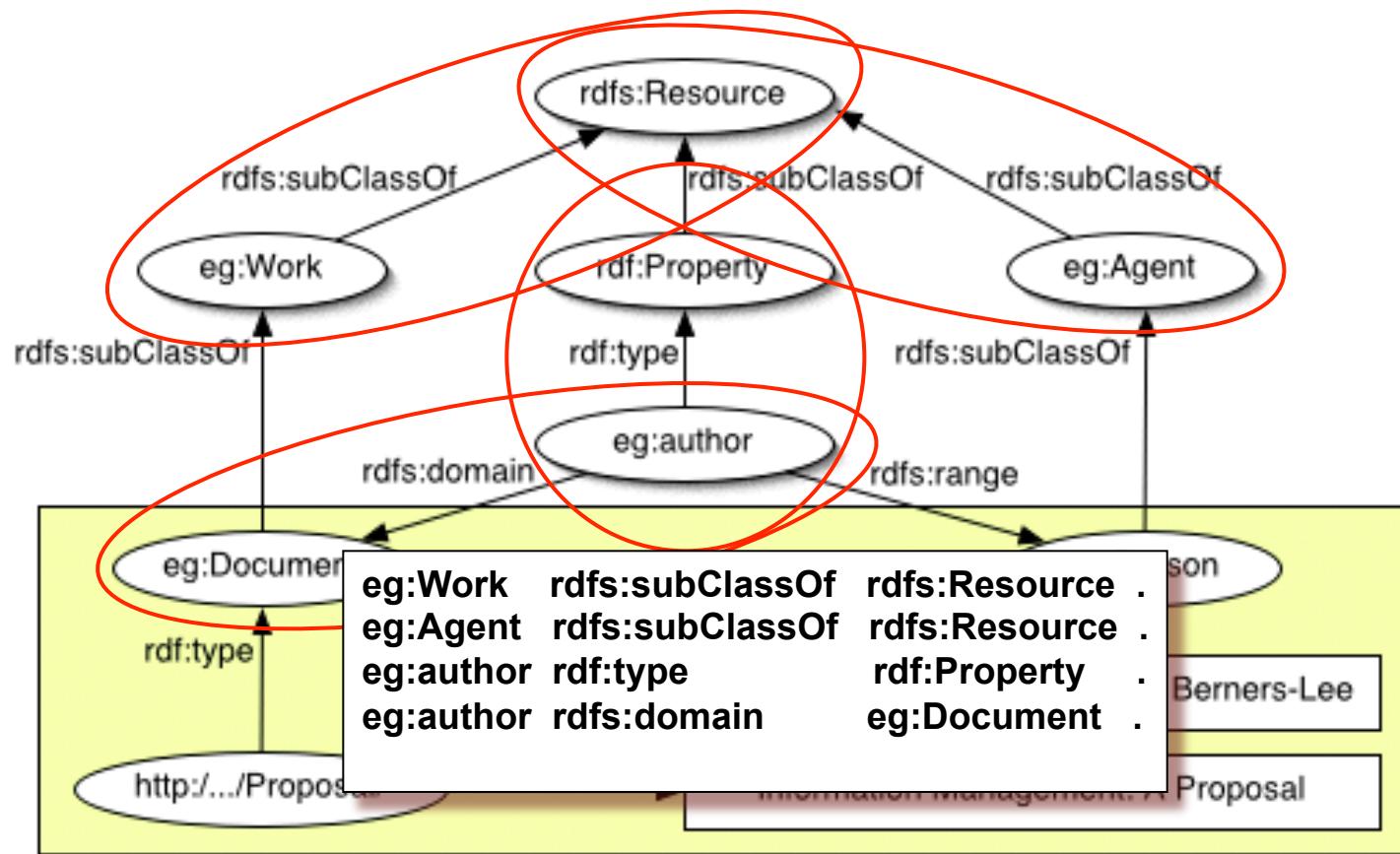
<http://www.w3.org/TR/2002/WD-rdf-schema-20021112/>



Introductory Example

Obsolete RDFS Document

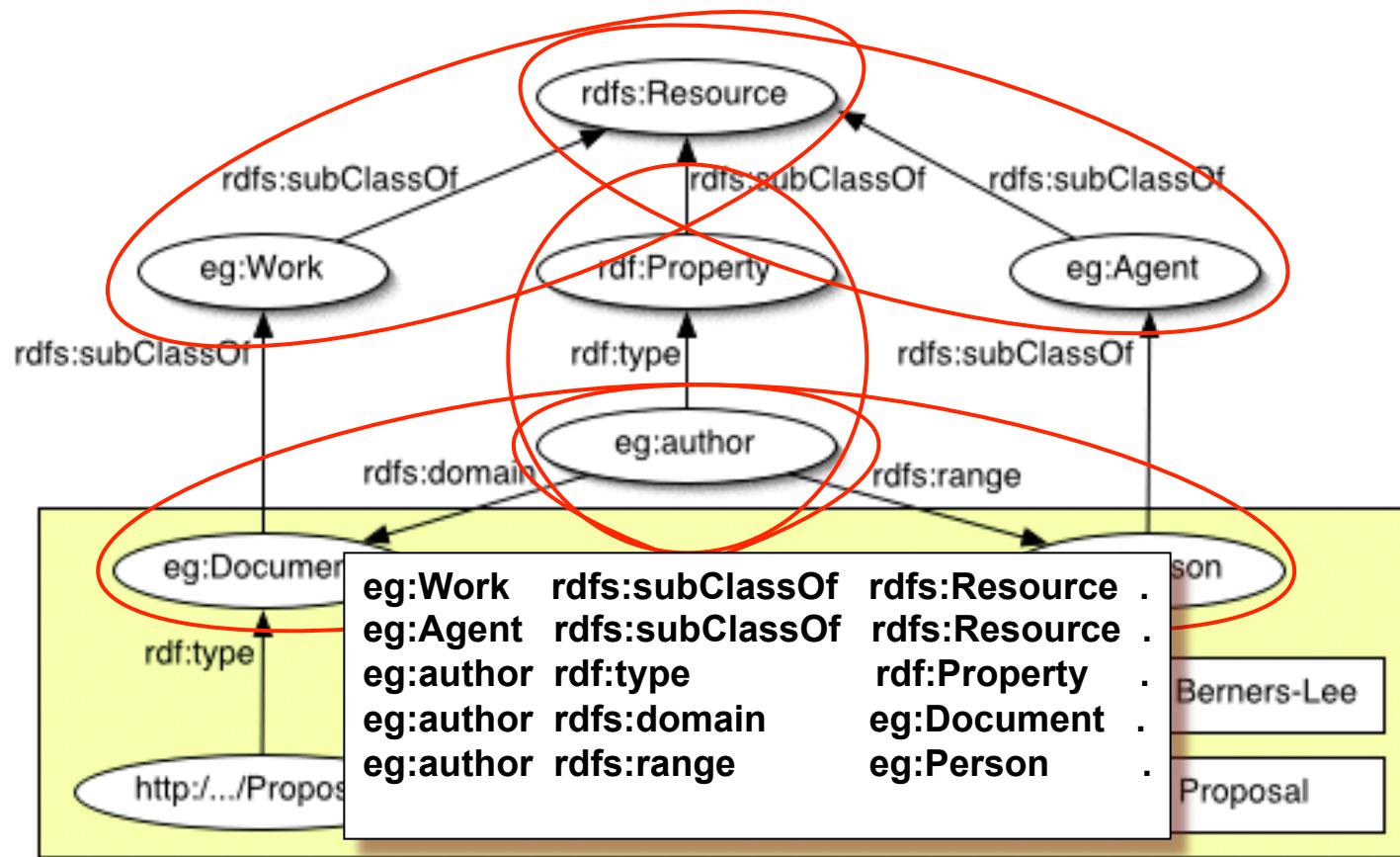
<http://www.w3.org/TR/2002/WD-rdf-schema-20021112/>



Introductory Example

Obsolete RDFS Document

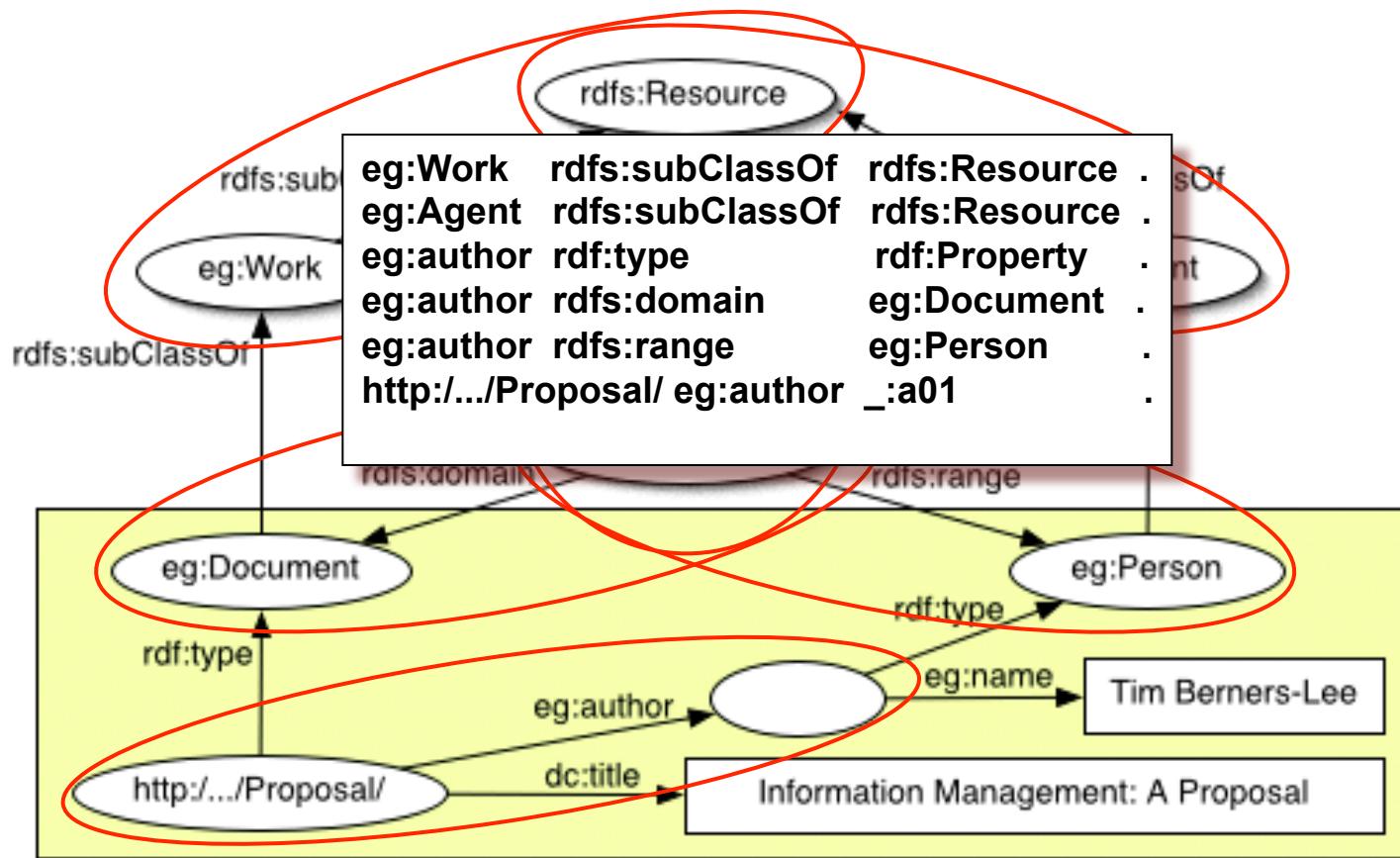
<http://www.w3.org/TR/2002/WD-rdf-schema-20021112/>



Introductory Example

Obsolete RDFS Document

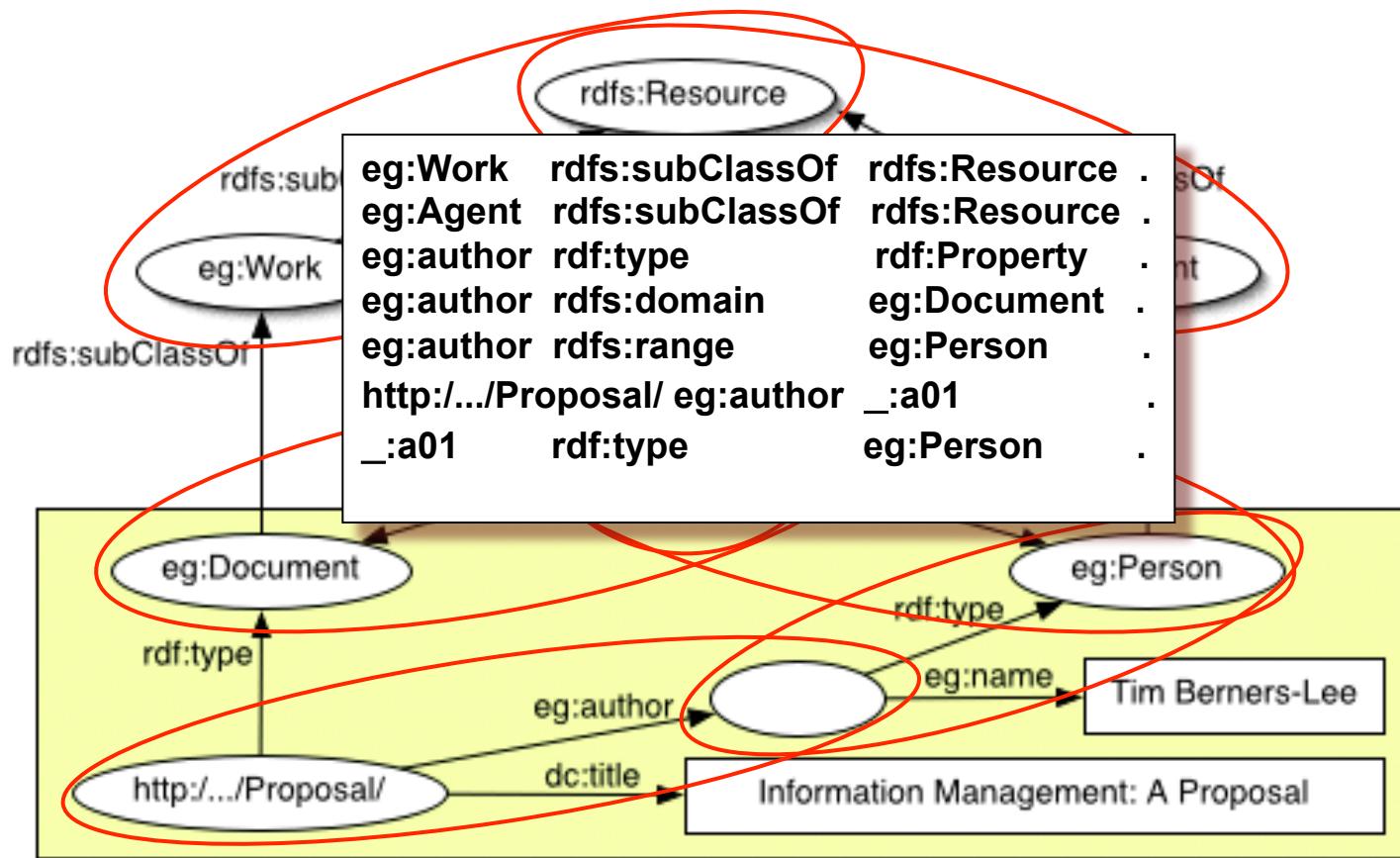
<http://www.w3.org/TR/2002/WD-rdf-schema-20021112/>



Introductory Example

Obsolete RDFS Document

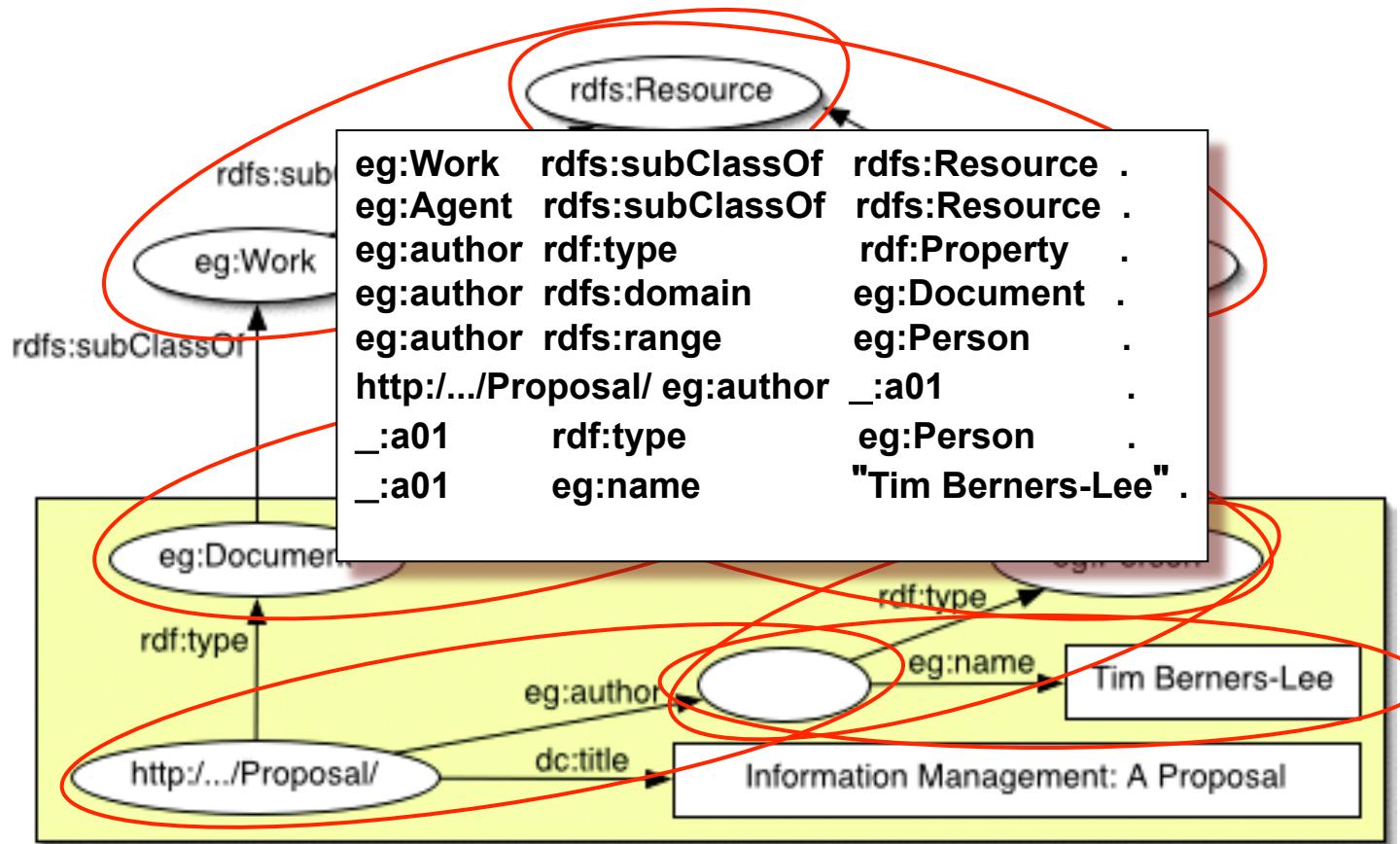
<http://www.w3.org/TR/2002/WD-rdf-schema-20021112/>



Introductory Example

Obsolete RDFS Document

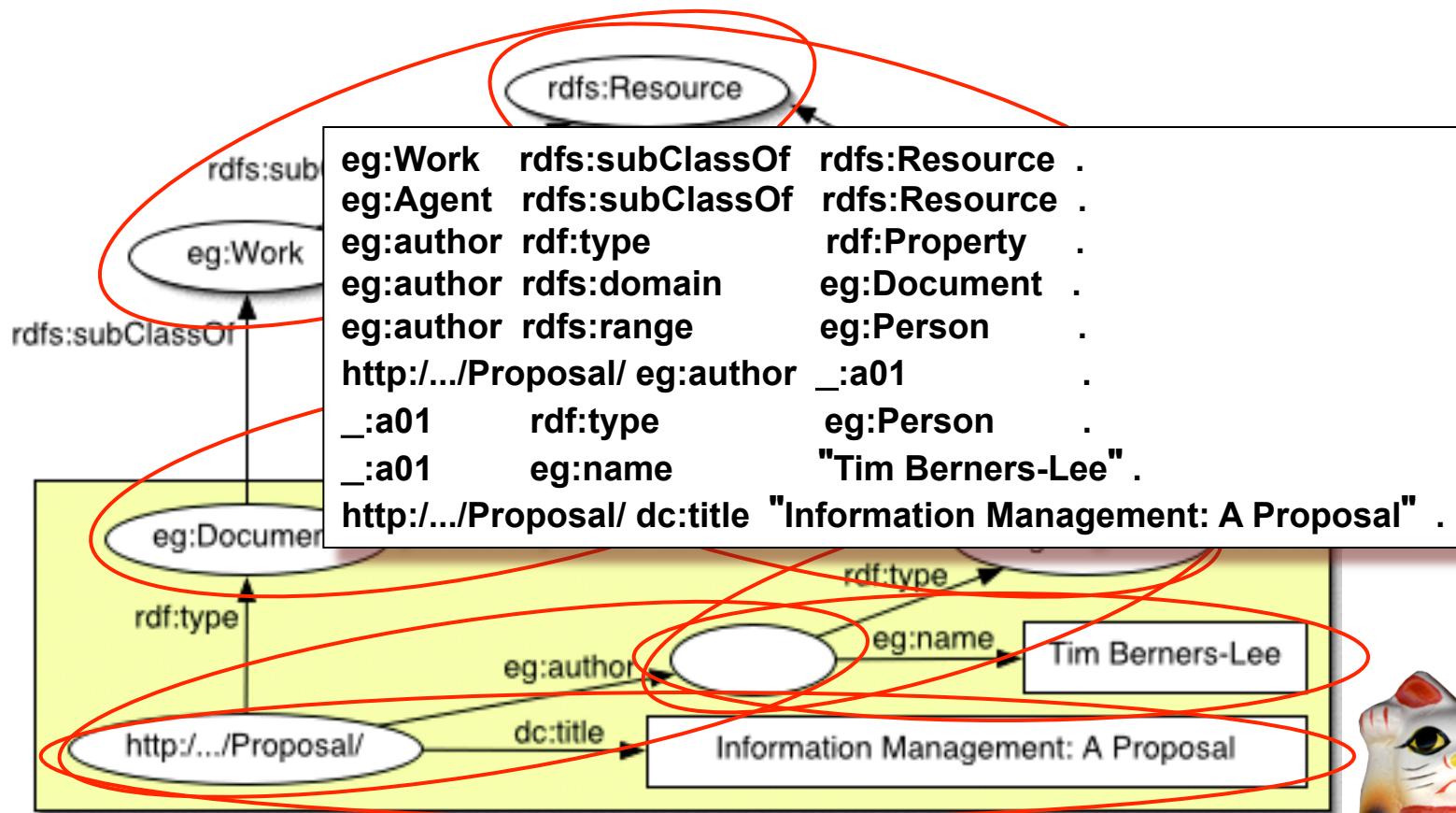
<http://www.w3.org/TR/2002/WD-rdf-schema-20021112/>



Introductory Example

Obsolete RDFS Document

<http://www.w3.org/TR/2002/WD-rdf-schema-20021112/>



Int
Obso
http://rdflib:
su

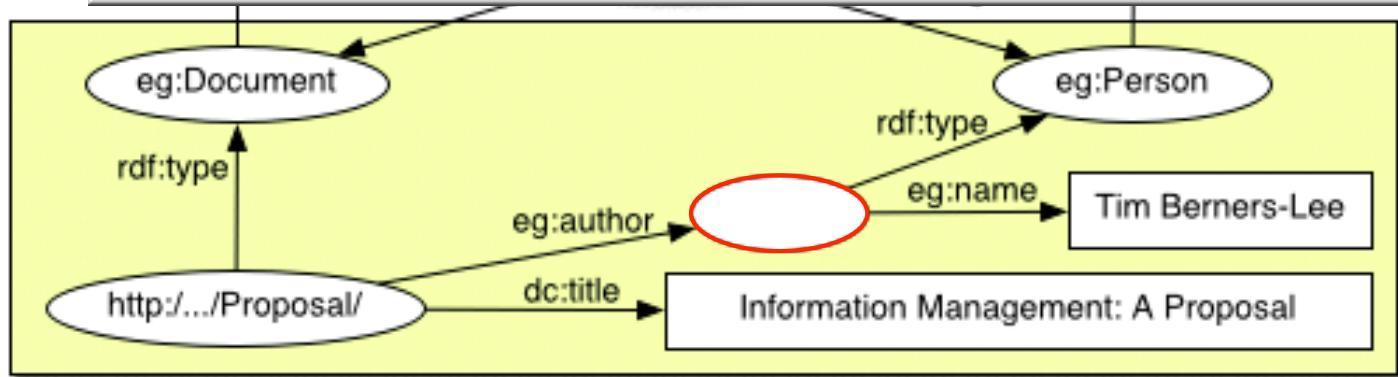
```
<?xml version="1.0" ?>
<!DOCTYPE rdf:RDF (View Source for full doctype...)>
- <rdf:RDF xmlns="http://galaxy-express.co.jp/semantic-web/example#" xmlns:eg="http://galaxy-express.co.jp/semantic-web/example#" xmlns:dc="http://dublincore.org/documents/2003/06/02/dces#" xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#" xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#">
- <rdf:Property rdf:ID="name">
  <rdfs:domain rdf:resource="#Person" />
  <rdfs:range rdf:resource="http://www.w3.org/2000/01/rdf-schema#Literal" />
</rdf:Property>
- <rdf:Property
  rdf:about="http://dublincore.org/documents/2003/06/02/dces#title">
  <rdfs:domain rdf:resource="#Document" />
  <rdfs:range rdf:resource="http://www.w3.org/2000/01/rdf-schema#Literal" />
</rdf:Property>
- <rdf:Property rdf:ID="author">
  <rdfs:domain rdf:resource="#Document" />
  <rdfs:range rdf:resource="#Person" />
</rdf:Property>
- <rdfs:Class rdf:ID="Person">
  <rdfs:subClassOf rdf:resource="#Agent" />
</rdfs:Class>
- <rdfs:Class rdf:ID="Document">
  <rdfs:subClassOf rdf:resource="#Work" />
</rdfs:Class>
- <eg:Document rdf:about="http://.../Proposal/">
  - <eg:author>
    - <eg:Person>
      <eg:name>Tim Berners-Lee</eg:name>
    </eg:Person>
  </eg:author>
  <dc:title>Information Management: A Proposal</dc:title>
</eg:Document>
</rdf:RDF>
```

rdfs:su

```

- <rdf:Property
  rdf:about="http://dublincore.org/documents/2003/06/02/dces#title">
  <rdfs:domain rdf:resource="#Document" />
  <rdfs:range rdf:resource="http://www.w3.org/2000/01/rdf-schema#Literal" />
</rdf:Property>
- <rdf:Property rdf:ID="author">
  <rdfs:domain rdf:resource="#Document" />
  <rdfs:range rdf:resource="#Person" />
</rdf:Property>
- <rdfs:Class rdf:ID="Person">
  <rdfs:subClassOf rdf:resource="#Agent" />
</rdfs:Class>
- <rdfs:Class rdf:ID="Document">
  <rdfs:subClassOf rdf:resource="#Work" />
</rdfs:Class>
- <eg:Document rdf:about="http://.../Proposal/">
  - <eg:author>
    - <eg:Person>
      <eg:name>Tim Berners-Lee</eg:name>
    </eg:Person>
  </eg:author>
  <dc:title>Information Management: A Proposal</dc:title>
</eg:Document>
</rdf:RDF>
```

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Introductory Example (SWCLOS)

Obsolete RDFS Document

<http://www.w3.org/TR/2002/WD-rdf-schema-20021112/>

Already defined in SWCLOS

```
(in-package gx-user)
rdfs:Resource → #<rdfs:Class rdfs:Resource>
(defpackage eg
  (:documentation "http://somewhere-for-eg/eg"))
(defpackage dc
  (:documentation
  "http://dublincore.org/2002/08/13/dces"))


```

```
(defResource eg::Work (rdfs:subClassOf rdfs:Resource))
(defResource eg::Agent (rdfs:subClassOf rdfs:Resource))
(defResource eg::Person (rdfs:subClassOf eg:Agent))
(defResource eg::Document (rdfs:subClassOf eg:Work))
```

```
(defProperty eg::author
  (rdfs:domain eg:Document)
  (rdfs:range eg:Person))
```

Double colons needed only at first

Single colon accepted secondly and after



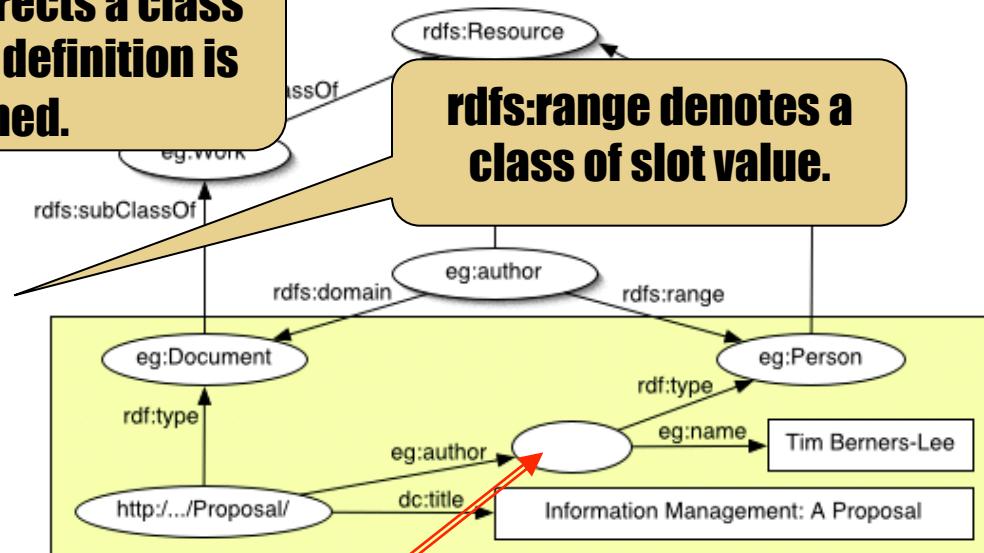
Introductory Example (SWCLOS)

Obsolete RDFS Document

<http://www.w3.org/TR/2002/WD-rdf-schema-20021112/>

rdfs:domain directs a class where the slot definition is attached.

```
(defProperty eg::name
  (rdfs:domain eg:Person)
  (rdfs:range rdfs:Literal))
(defProperty dc::title
  (rdfs:domain eg:Document)
  (rdfs:range rdfs:Literal))
```



```
(defIndividual eg::Proposal (rdf:type eg::Document)
  (eg:author (eg:Person (eg:name "Tim Berners-Lee")))
  (dc:title "Information Management: A Proposal")
  (rdf:about "http://.../Proposal/"))
```

A bnode is automatically created on demand.



Introductory Example

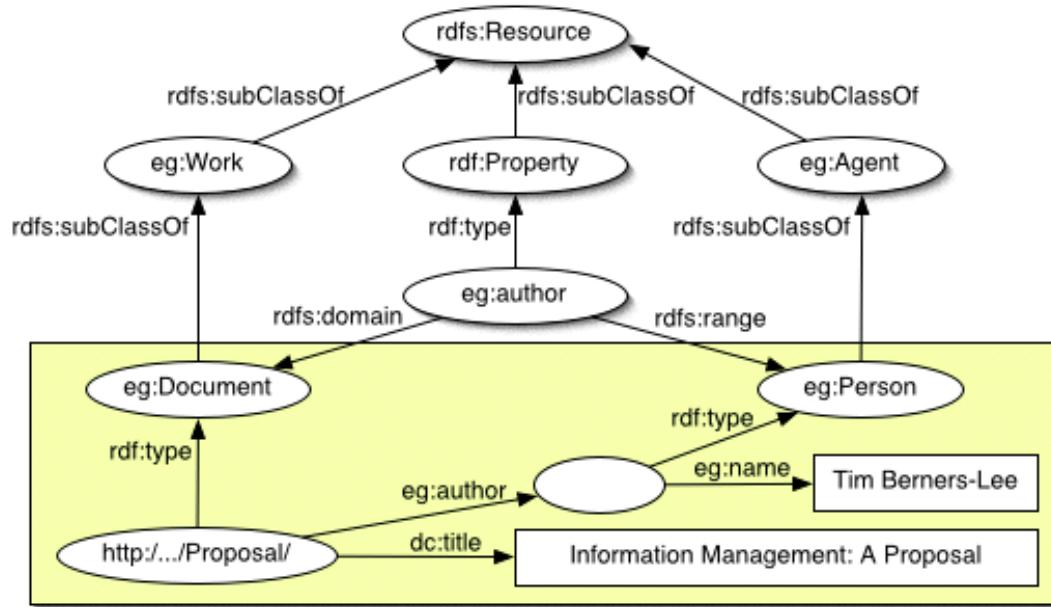
Obsolete RDFS Document

<http://www.w3.org/TR/2002/WD-rdf-schema-20021112/>

eg:Person →
eg:author →
eg:Proposal →

(describe eg:Proposal) →
(get-form eg:Proposal) →

(write-xml eg:Proposal)



The RDF/XML form of eg:Proposal is printed.

(-> eg:Proposal dc:title) →
(-> eg:Proposal eg:author eg:name) →
(-> eg:Proposal eg:author rdf:type) →

ELW

Start from 1st parameter and travel the graph along with the path

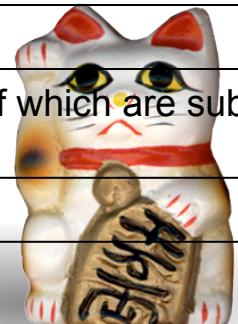


RDF Vocabulary Description Language 1.0: RDF Schema

W3C Recommendation 10 February 2004

RDF Classes

Class name	comment
rdfs:Resource	The class resource, everything.
rdfs:Literal	The class of literal values, e.g. textual strings and integers.
rdf:XMLLiteral	The class of XML literals values.
rdfs:Class	The class of classes.
rdf:Property	The class of RDF properties.
rdfs:Datatype	The class of RDF datatypes.
rdf:Statement	The class of RDF statements.
rdf:Bag	The class of unordered containers.
rdf:Seq	The class of ordered containers.
rdf:Alt	The class of containers of alternatives.
rdfs:Container	The class of RDF containers.
rdfs:ContainerMembershipProperty	The class of container membership properties, rdf:_1, rdf:_2, ..., all of which are sub-properties of 'member'.
rdf:List	The class of RDF Lists.



RDF Vocabulary Description Language 1.0: RDF Schema

W3C Recommendation 10 February 2004

RDF Properties

Property name	comment	domain	range
rdf:type	The subject is an instance of a class.	rdfs:Resource	rdfs:Class
rdfs:subClassOf	The subject is a subclass of a class.	rdfs:Class	rdfs:Class
rdfs:subPropertyOf	The subject is a subproperty of a property.	rdf:Property	rdf:Property
rdfs:domain	A domain of the subject property.	rdf:Property	rdfs:Class
rdfs:range	A range of the subject property.	rdf:Property	rdfs:Class
rdfs:label	A human-readable name for the subject.	rdfs:Resource	rdfs:Literal
rdfs:comment	A description of the subject resource.	rdfs:Resource	rdfs:Literal
rdfs:member	A member of the subject resource.	rdfs:Resource	rdfs:Resource
rdf:first	The first item in the subject RDF list.	rdf:List	rdfs:Resource
rdf:rest	The rest of the subject RDF list after the first item.	rdf:List	rdf:List
rdfs:seeAlso	Further information about the subject resource.	rdfs:Resource	rdfs:Resource
rdfs:isDefinedBy	The definition of the subject resource.	rdfs:Resource	rdfs:Resource
rdf:value	Idiomatic property used for structured values (see the RDF Primer for an example of its usage).	rdfs:Resource	rdfs:Resource
rdf:subject	The subject of the subject RDF statement.	rdf:Statement	rdfs:Resource
rdf:predicate	The predicate of the subject RDF statement.	rdf:Statement	rdfs:Resource
rdf:object	The object of the subject RDF statement.	rdf:Statement	rdfs:Resource

Entailment Rules

<http://www.w3.org/TR/rdf-mt/>

Rule Name	If E contains:	then add:
rdfs1	uuu aaa III. where III is a plain literal (with or without a language tag).	_:nnn rdf:type rdfs:Literal . where _:nnn identifies a blank node allocated to III by rule rule lg.
rdfs2	aaa rdfs:domain xxx . uuu aaa yyy .	uuu rdf:type xxx .
rdfs3	aaa rdfs:range xxx . uuu aaa vvv .	vvv rdf:type xxx .
rdfs4a	uuu aaa xxx .	uuu rdf:type rdfs:Resource .
rdfs4b	uuu aaa vvv.	vvv rdf:type rdfs:Resource .
rdfs5	uuu rdfs:subPropertyOf vvv . vvv rdfs:subPropertyOf xxx .	uuu rdfs:subPropertyOf xxx .
rdfs6	uuu rdf:type rdf:Property .	uuu rdfs:subPropertyOf uuu ,
rdfs7	aaa rdfs:subPropertyOf bbb . uuu aaa yyy .	uuu bbb yyy .
rdfs8	uuu rdf:type rdfs:Class .	uuu rdfs:subClassOf rdfs:Resource



Entailment Rules

<http://www.w3.org/TR/rdf-mt/>

Subsumption Rule

Rule Name	If E contains:	then add:
rdfs9	uuu rdfs:subClassOf xxx . vvv rdf:type uuu .	vvv rdf:type xxx .
rdfs10	uuu rdf:type rdfs:Class .	uuu rdfs:subClassOf uuu .
rdfs11	uuu rdfs:subClassOf vvv . vvv rdfs:subClassOf xxx .	uuu rdfs:subClassOf xxx .
rdfs12	uuu rdf:type rdfs:ContainerMembershipProperty .	uuu rdfs:subPropertyOf rdfs:member .
rdfs13	uuu rdf:type rdfs:Datatype .	uuu rdfs:subClassOf rdfs:Literal .

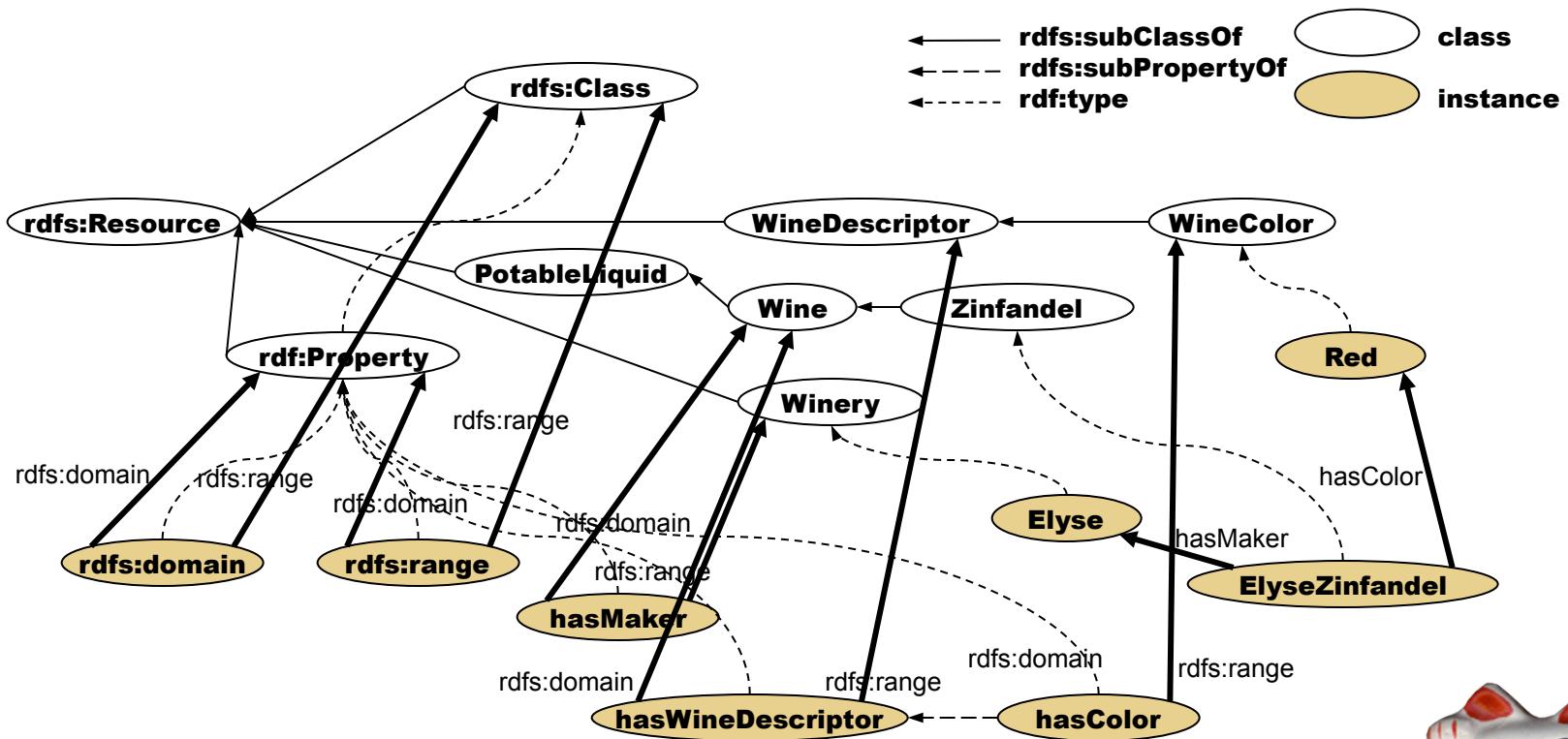
Transitivity Rule

```

(defclass xxx () ())
(setq vvv (make-instance (defclass uuu (xxx) ())))
(typep vvv xxx) → true
(defclass xxx () ())
(defclass vvv (xxx) ()) (defclass uuu (vvv) ())
(subtypep 'uuu 'xxx) → true
  
```

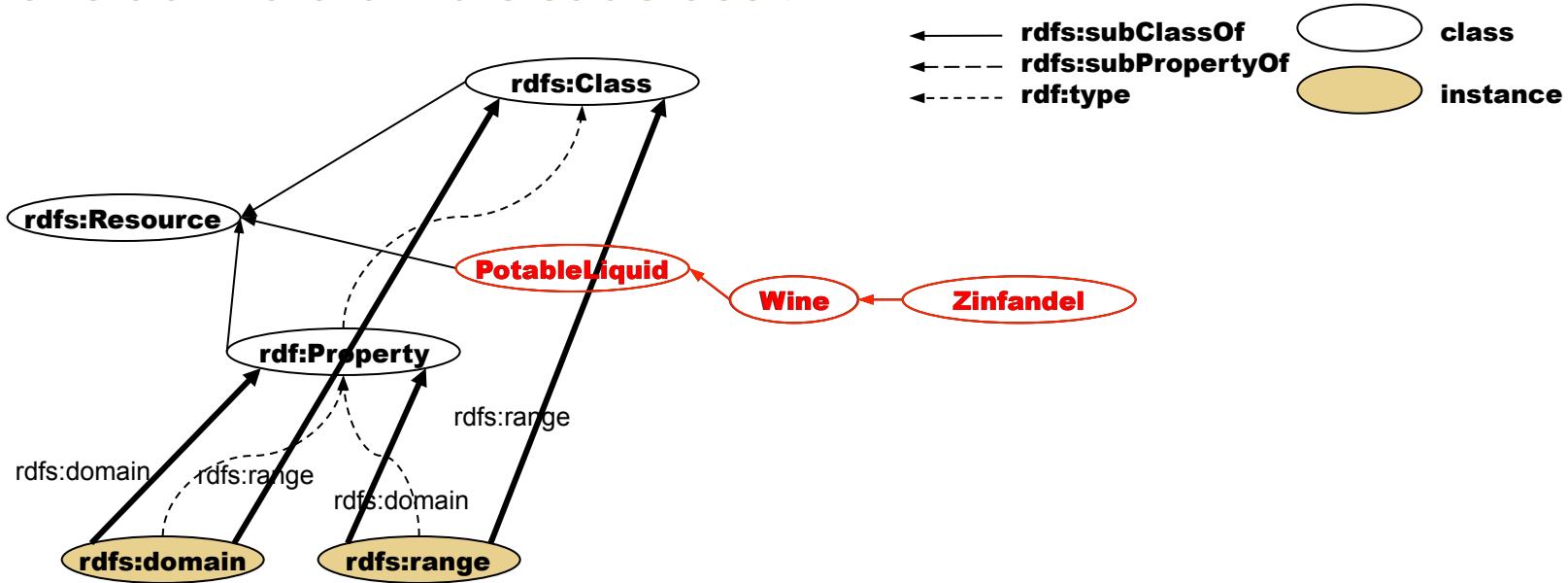


Subsumption rule in Wine Ontology (RDFS)



Subsumption rule in Wine Ontology (RDFS)

Transition rule of rdfs:subClassOf



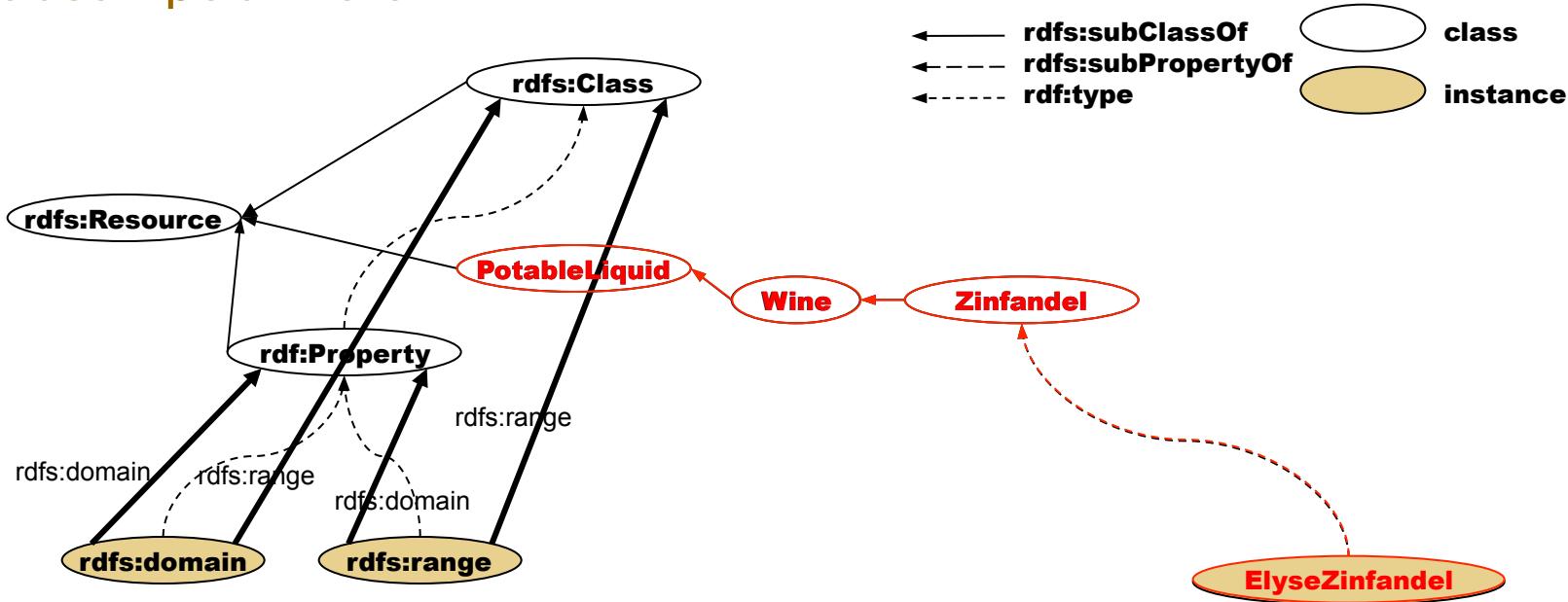
Rdfs rule 11

(subtypep vin:Zinfandel food:PotableLiquid) → t



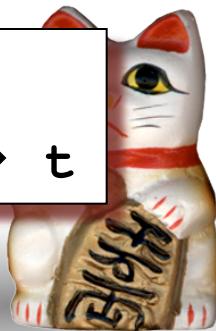
Subsumption rule in Wine Ontology (RDFS)

Subsumption rule



Rdfs rule 9

(typep vin:ElyseZinfandel food:PotableLiquid) → t



Summary of Introduction

- ✿ Case sensitive lisp
- ✿ A QName is represented as an exported lisp symbol.
- ✿ Namespace is realized by using lisp package.
- ✿ A resource of RDF is created as a CLOS object, and bound to the QName.
- ✿ rdf:type to class-of (type-of) mapping
- ✿ rdfs:subClassOf to superclass mapping
- ✿ Define Macro defResource, defIndividual, and defProperty



Entailment Rules

<http://www.w3.org/TR/rdf-mt/>

Domain Entailment

Rule Name	If E contains:	then add:
rdfs1	uuu aaa III. where III is a plain literal (with or without a language tag).	_:nnn rdf:type rdfs:literal . where _:nnn identifies a blank node allocated to III by rule rule lg.
rdfs2	aaa rdfs:domain xxx . uuu aaa yyy .	uuu rdf:type'xxx .
rdfs3	aaa rdfs:range xxx . uuu aaa vvv .	vvv rdf:type'xxx .
rdfs4a	uuu aaa xxx .	uuu rdf:type rdfs:Resource .
rdfs4b	uuu aaa vvv.	vvv rdf:type rdfs:Resource .
rdfs5	uuu rdfs:subPropertyOf vvv . vvv rdfs:subPropertyOf xxx .	uuu rdfs:subP
rdfs6	uuu rdf:type rdf:Property .	uuu rdfs:subPropertyOf uuu ,
rdfs7	aaa rdfs:subPropertyOf bbb . uuu aaa yyy .	uuu bbb yyy .
rdfs8	uuu rdf:type rdfs:Class .	uuu rdfs:subClassOf rdfs:Resource

Range Entailment



Entailment Rules

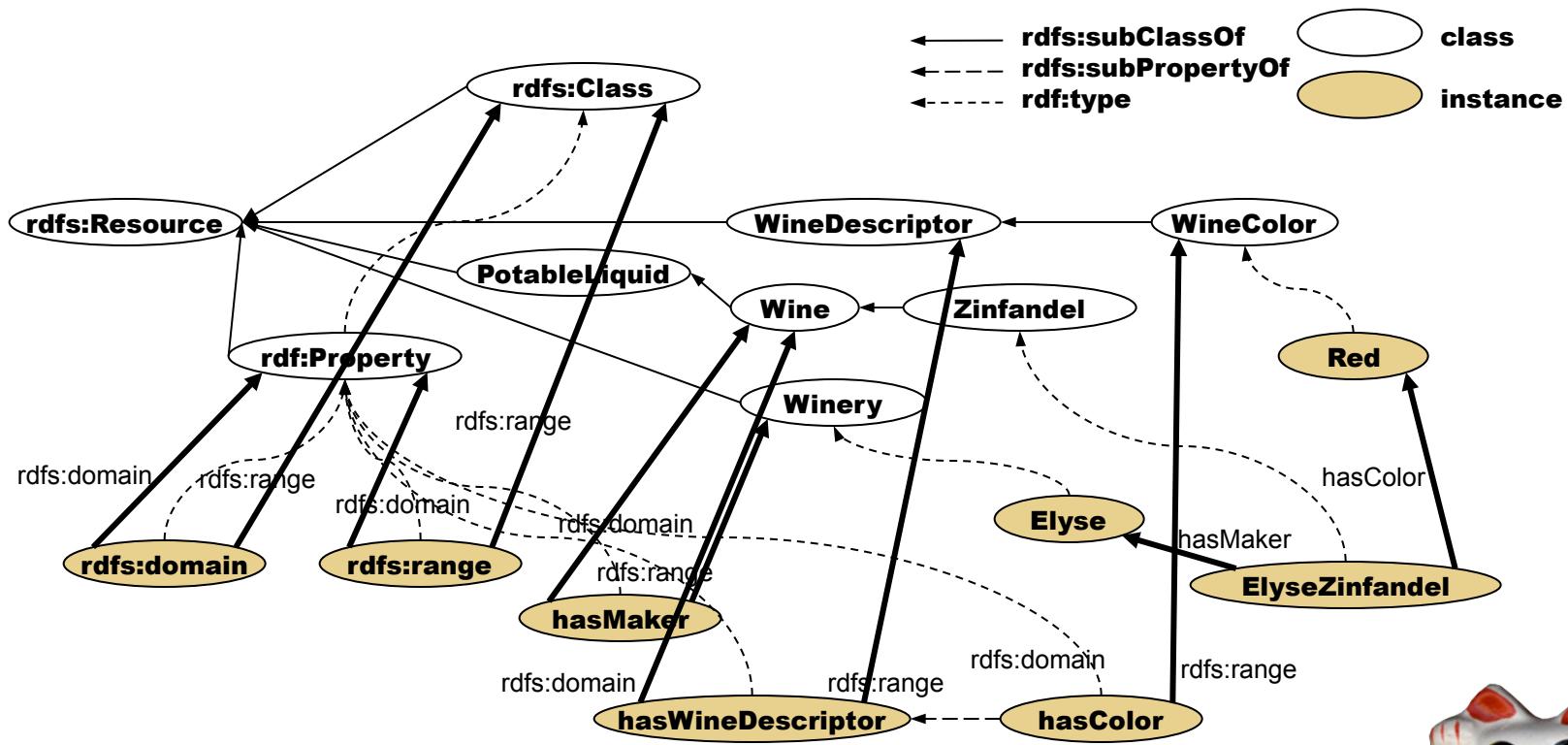
<http://www.w3.org/TR/rdf-mt/>

Rule Name	If E contains:	then add:
rdfs1	uuu aaa III. where III is a plain literal (with or without a language tag).	_:nnn rdf:type rdfs:Literal . where _:nnn identifies a blank node allocated to III by rule rule lg.
rdfs2	aaa rdfs:domain xxx . uuu aaa yyy .	uuu rdf:type xxx .
rdfs3	aaa rdfs:range xxx . uuu aaa vvv .	vvv rdf:type xxx .
rdfs4a	uuu aaa xxx .	uuu rdf:type rdfs:Resource .
rdfs4b	uuu aaa vvv.	vvv rdf:type rdfs:Resource .
rdfs5	uuu rdfs:subPropertyOf vvv . vvv rdfs:subPropertyOf xxx .	uuu rdfs:subPropertyOf xxx .
rdfs6	uuu rdf:type rdf:Property .	uuu rdfs:subPropertyOf uuu .
rdfs7	aaa rdfs:subPropertyOf bbb . uuu aaa yyy .	uuu bbb yyy .
rdfs8	uuu rdf:type rdfs:Class .	uuu rdfs:subClassOf rdfs:Resource



Domain & Range in Wine Ontology

(RDFS)

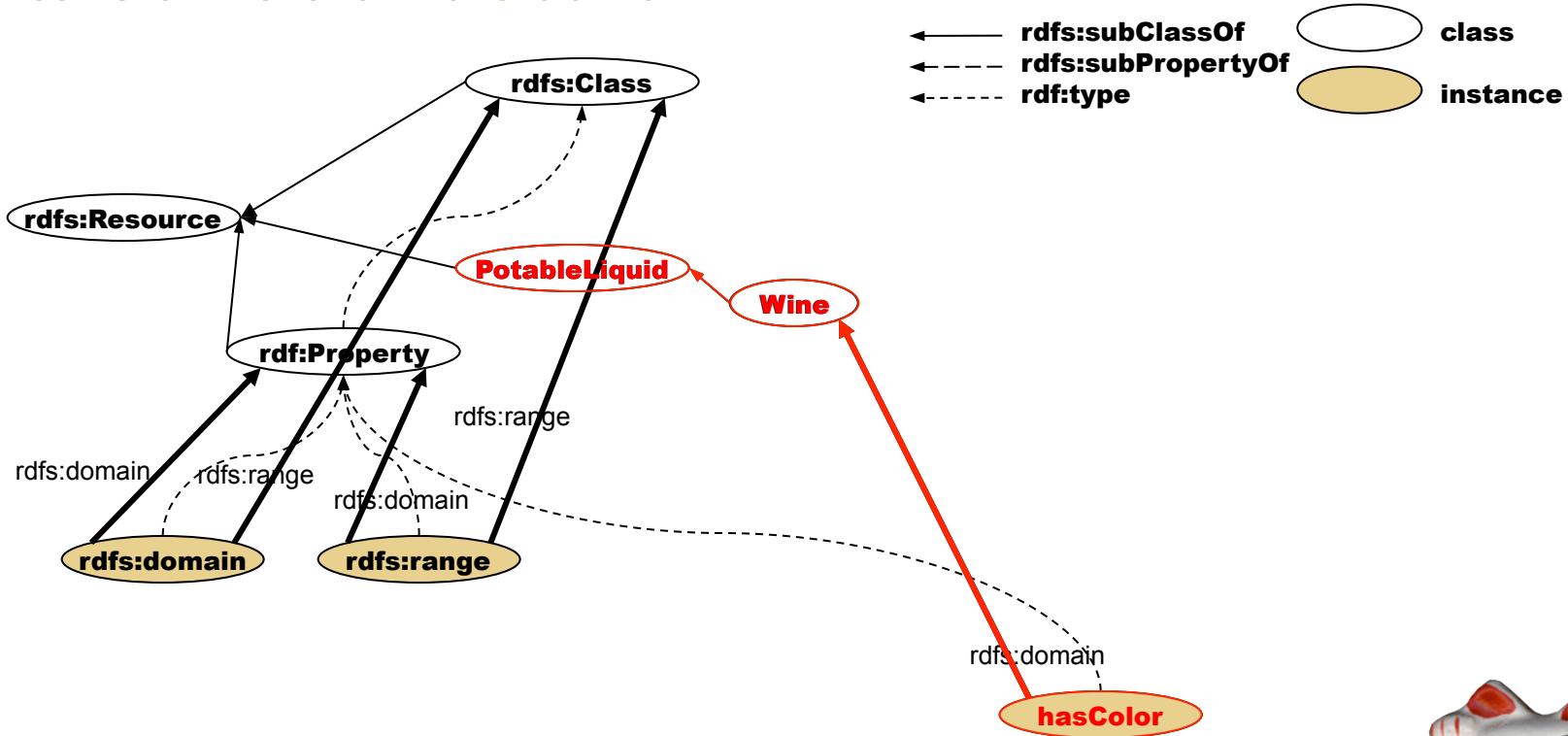


rdfs:domain: classes that are reachable from a subject node with a path of `rdf:type → rdfs:subClassOf`
rdfs:range: classes that are reachable from an object node with a path of `rdf:type → rdfs:subClassOf`



Domain & Range in Wine Ontology (RDFS)

Extension rule of rdfs:domain



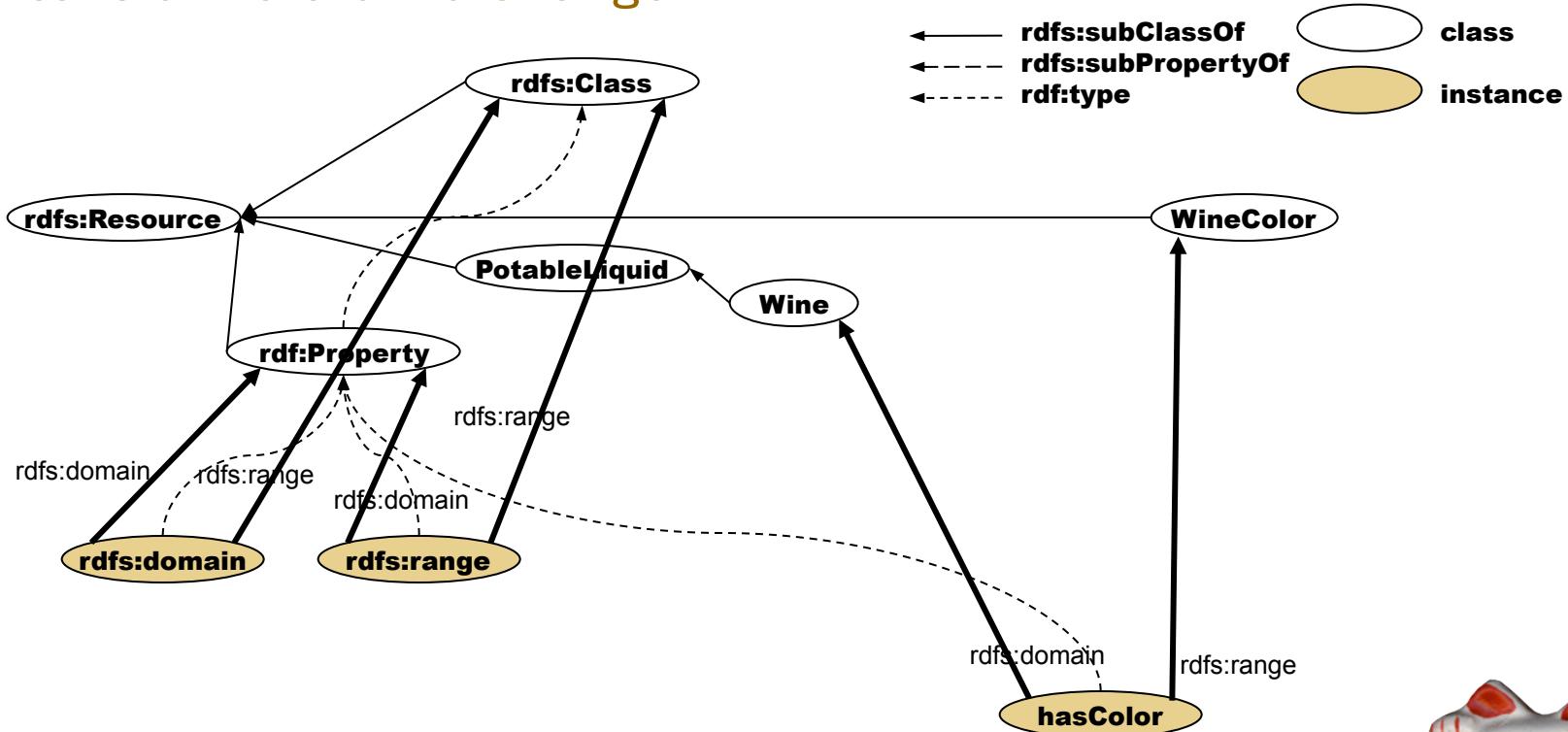
Ext rule 1

(domainp vin:hasColor food:PotableLiquid) → t



Domain & Range in Wine Ontology

Extension rule of rdfs:range

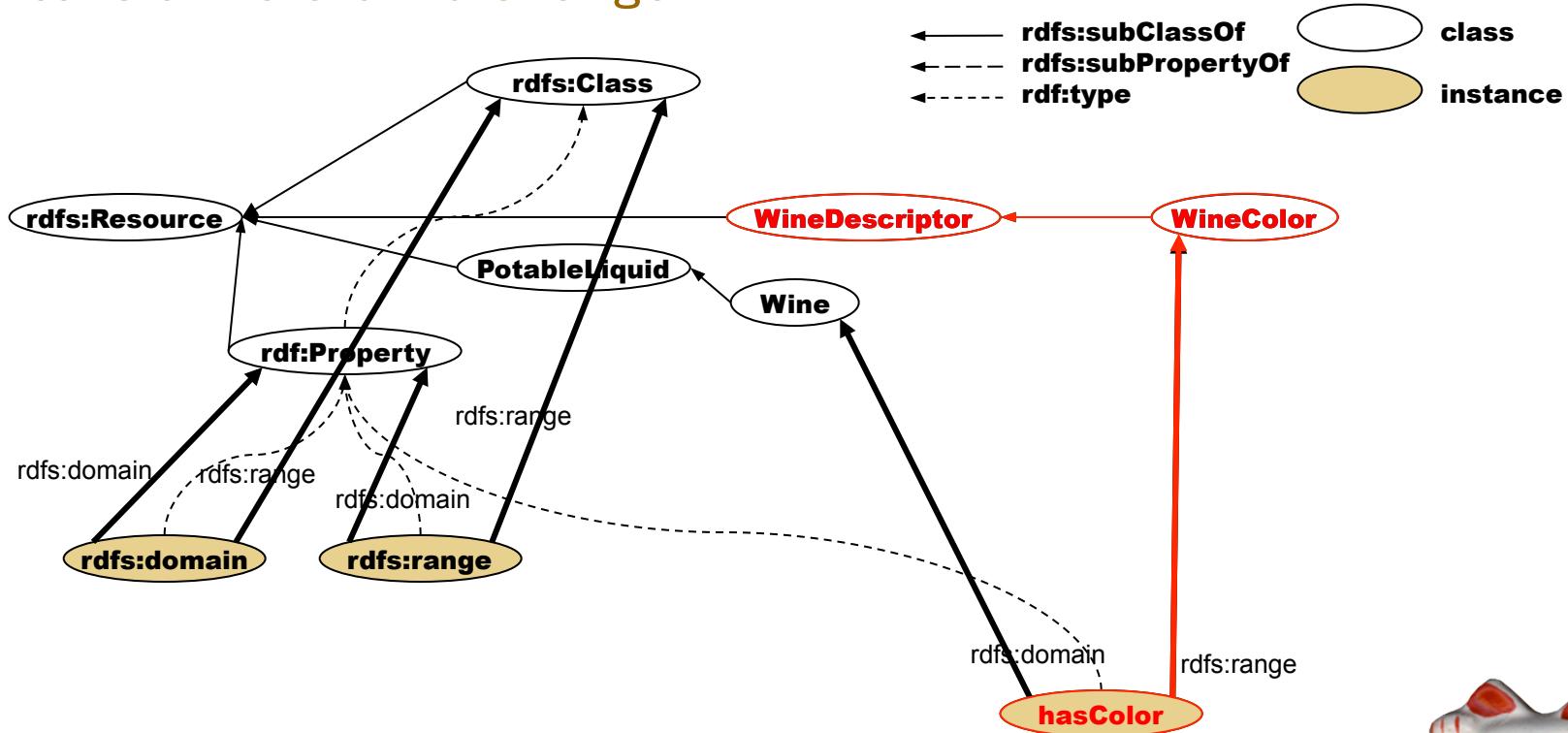


```
(defTriple vin:hasColor rdfs:range vin:WineColor)
(defTriple vin:WineColor rdfs:subClassOf vin:WineDescriptor)
```



Domain & Range in Wine Ontology (RDFS)

Extension rule of rdfs:range



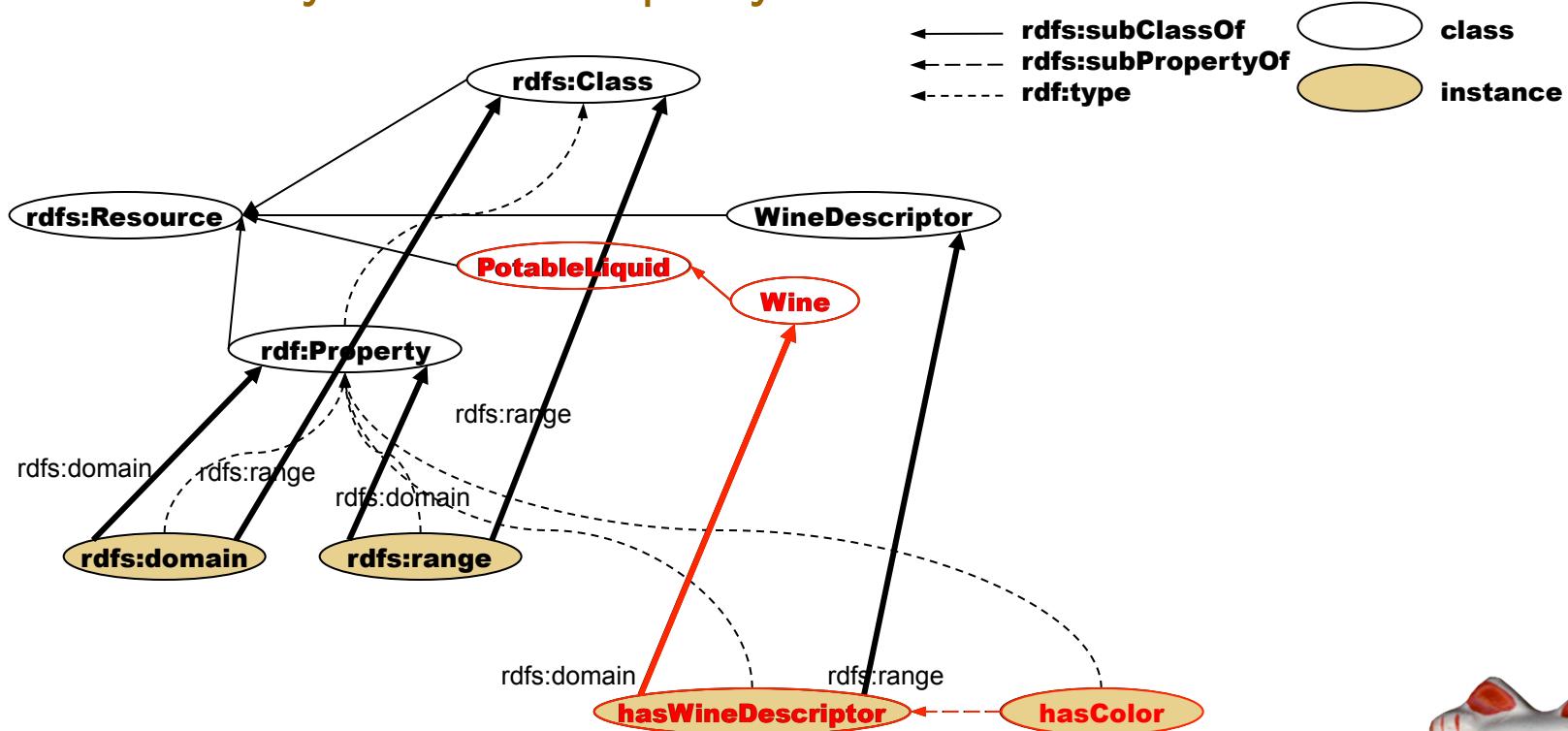
Ext rule 2

(rangeP vin:hasColor vin:WineDescriptor) → t



Domain & Range in Wine Ontology (RDFS)

Inheritance by rdfs:subPropertyOf



Ext rule 3

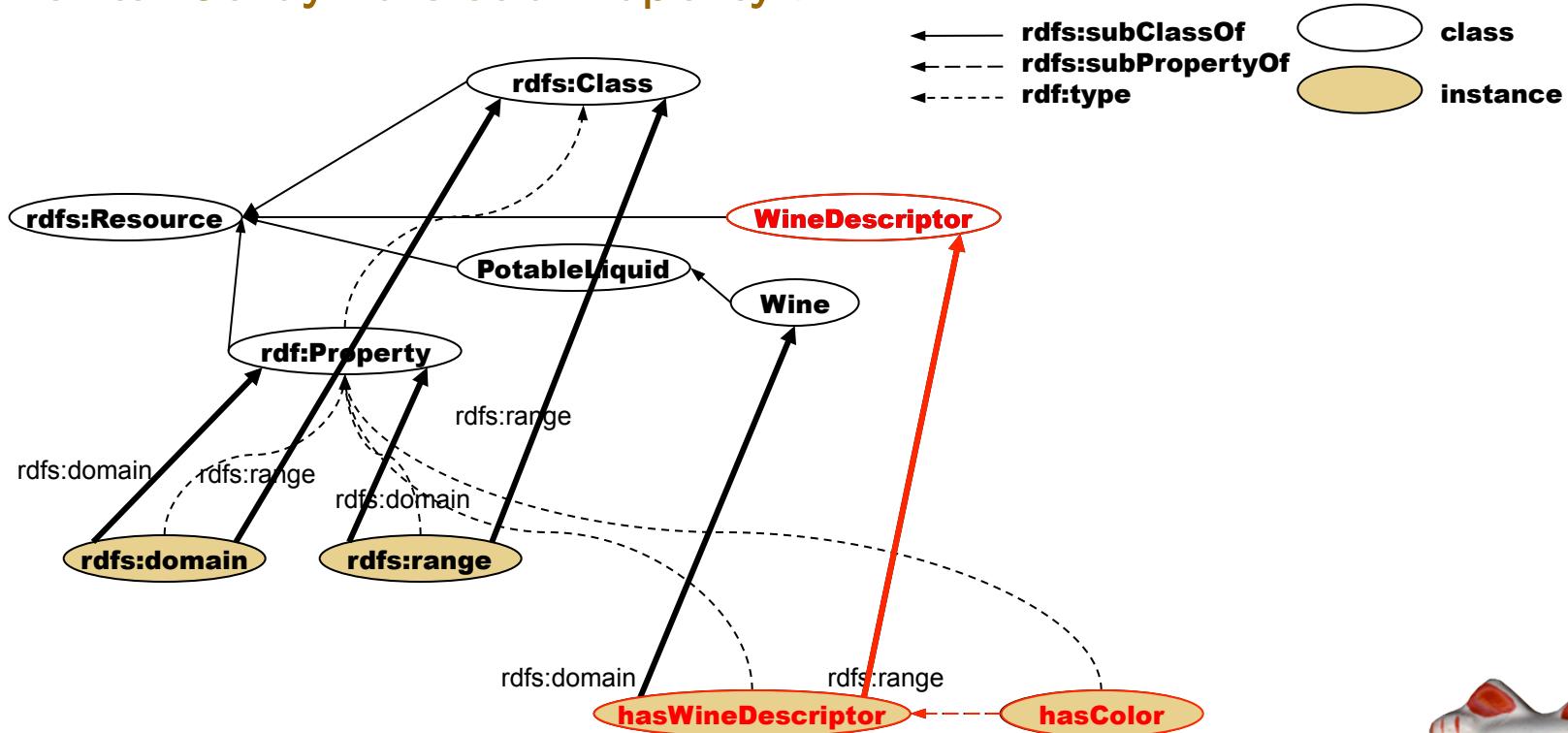
(domainp vin:hasColor food:PotableLiquid) → t

ELW2009, Jenova vin:hasWineDescriptor)



Domain & Range in Wine Ontology (RDFS)

Inheritance by rdfs:subPropertyOf



Ext rule 4

(rangeP vin:hasColor vin:WineDescriptor) → t

ELW2009, Jenova vin:hasWineDescriptor)



Domain & Range in Wine Ontology

(RDFS)

```
(defpackage vin)
(defpackage food)
(in-package gx-user)
```

```
(defResource vin::wine (rdfs:subClassOf food::PotableLiquid))
(defProperty vin::haswineDescriptor (rdfs:domain vin:wine))
(defProperty vin::hasColor
  (rdfs:subPropertyOf vin:haswineDescriptor))
```

```
(rdfs:domain vin:haswineDescriptor) →
(rdfs:domain vin:hasColor)* →
(domain-value vin:haswineDescriptor) →
(domain-value vin:hasColor) →
(get-domain vin:haswineDescriptor) →
(get-domain vin:hasColor)
```

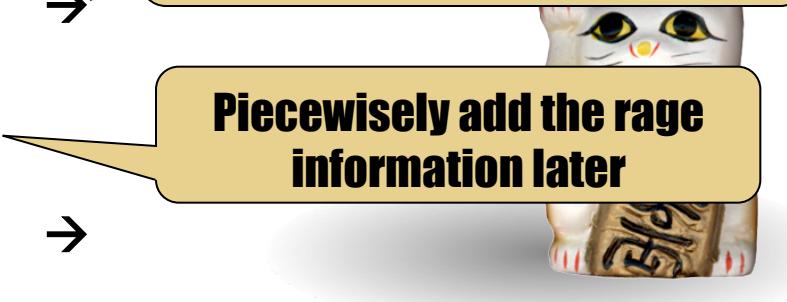
rdfs:domain method causes an error for unbound value

get-domain inherits the value from super-properties

Piecewisely add the range information later

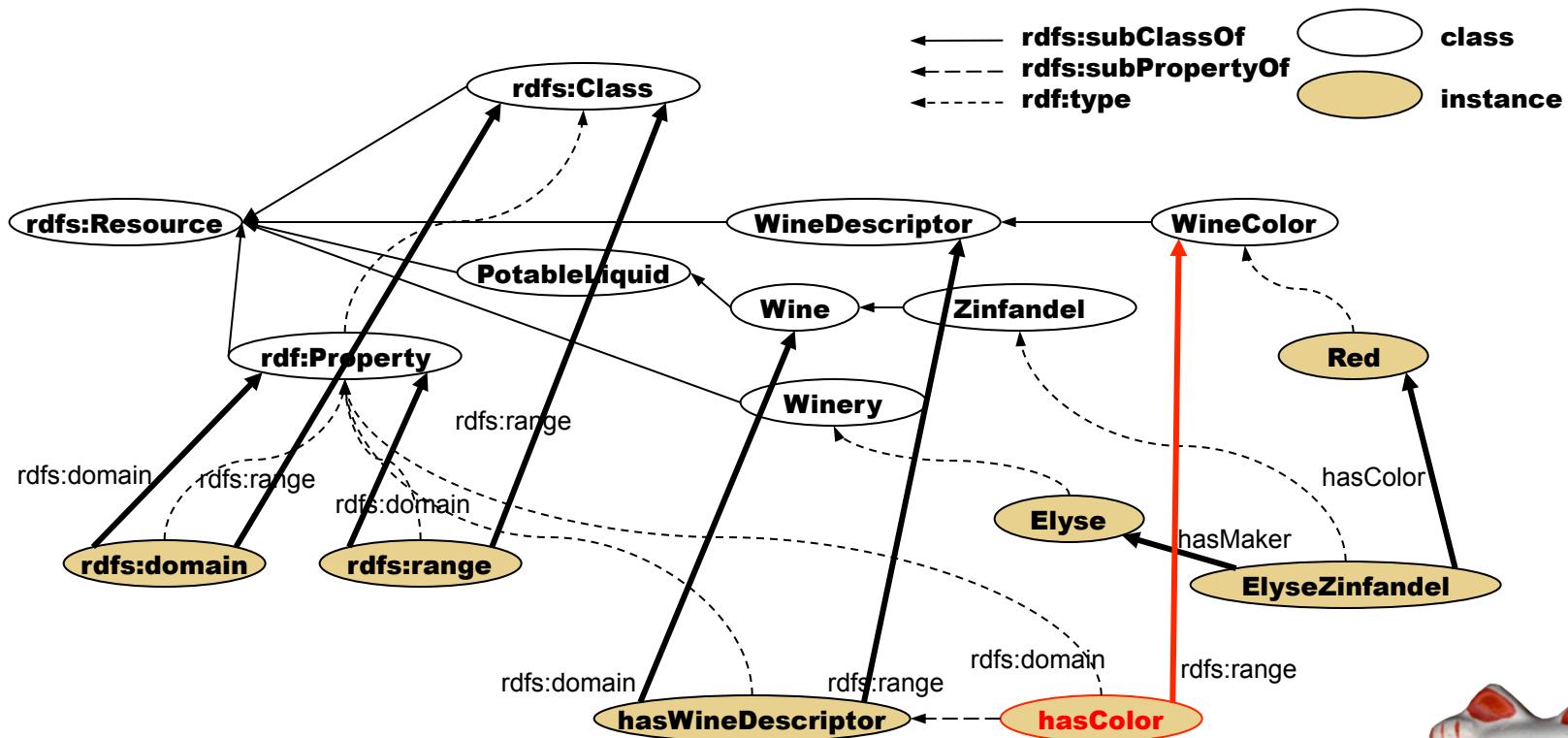
```
(defProperty vin:haswineDescriptor
  (rdfs:range vin::wineDescriptor))
(get-range vin:hasColor)
```

ELW2009, Jenova



Domain & Range in Wine Ontology

(RDFS)



Domain & Range in Wine Ontology

(RDFS)

```
(defProperty vin::hasColor (rdfs:range vin::wineColor))
(defResource vin:wineColor (rdfs:subClassof vin:wineDescriptor))
```

```
(defIndividual vin::ElyseZinfandel (rdf:type vin::Zinfandel)
  (vin:hasColor vin::Red))
```

```
(type-of vin:ElyseZinfandel)      →
(c1:type-of vin:ElyseZinfandel)   →
(collect-all-supers vin:Zinfandel) →
(collect-all-subtypes vin:wine)    →
(type-of vin:Red)                 →
```

```
(defIndividual vin::Numericwine (vin:hasColor 123))*
```

```
(defProperty vin::hasMaker
  (rdfs:domain vin:wine)
  (rdfs:range vin:Winery))
```

```
(defIndividual vin:ElyseZinfandel (vin:hasMaker vin:Elyse))
(type-of vin:Elyse)               →
(get-form vin:ElyseZinfandel)     →
```

SWCLOS checks the range

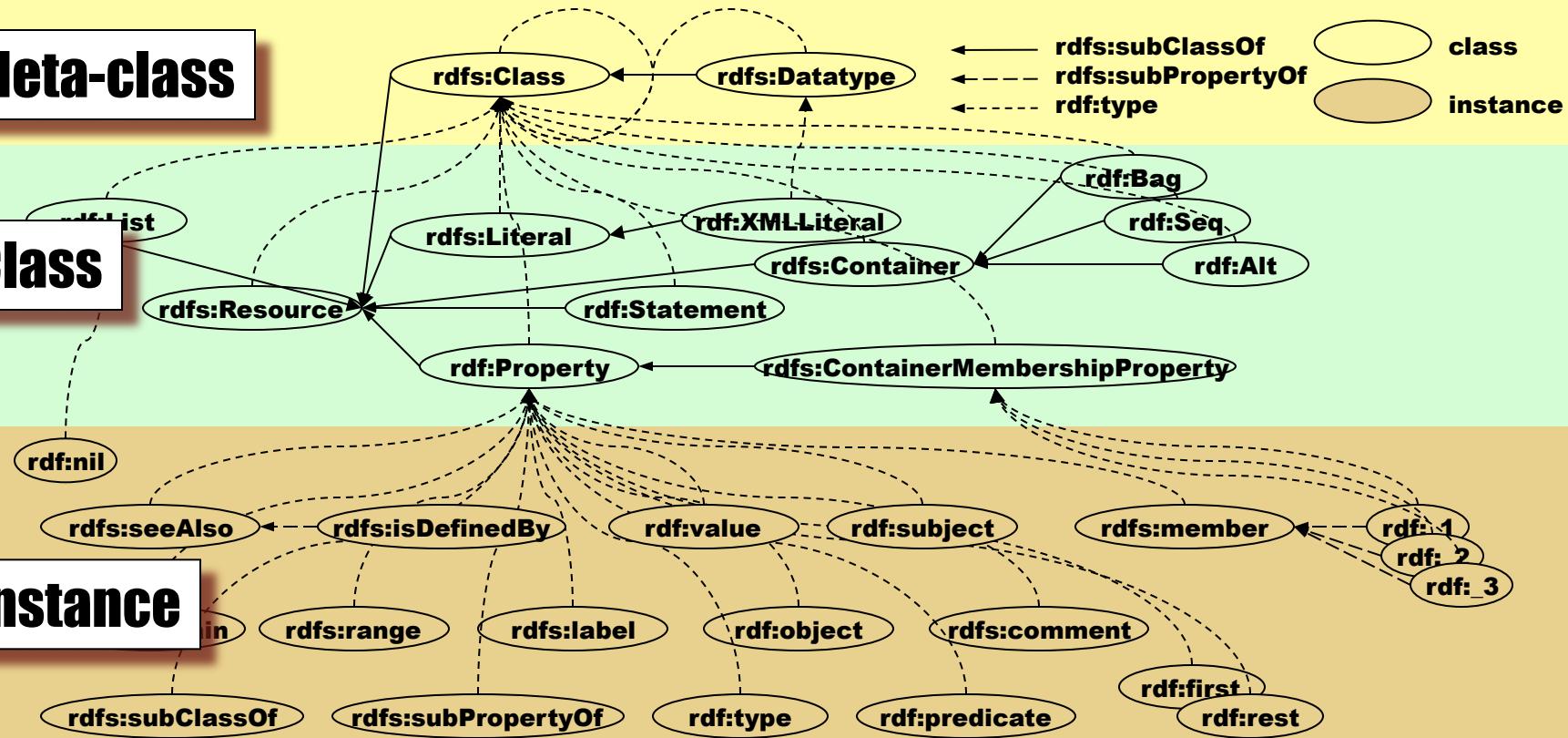


Hierarchical Structure of RDFS

Meta-class

Class

Instance

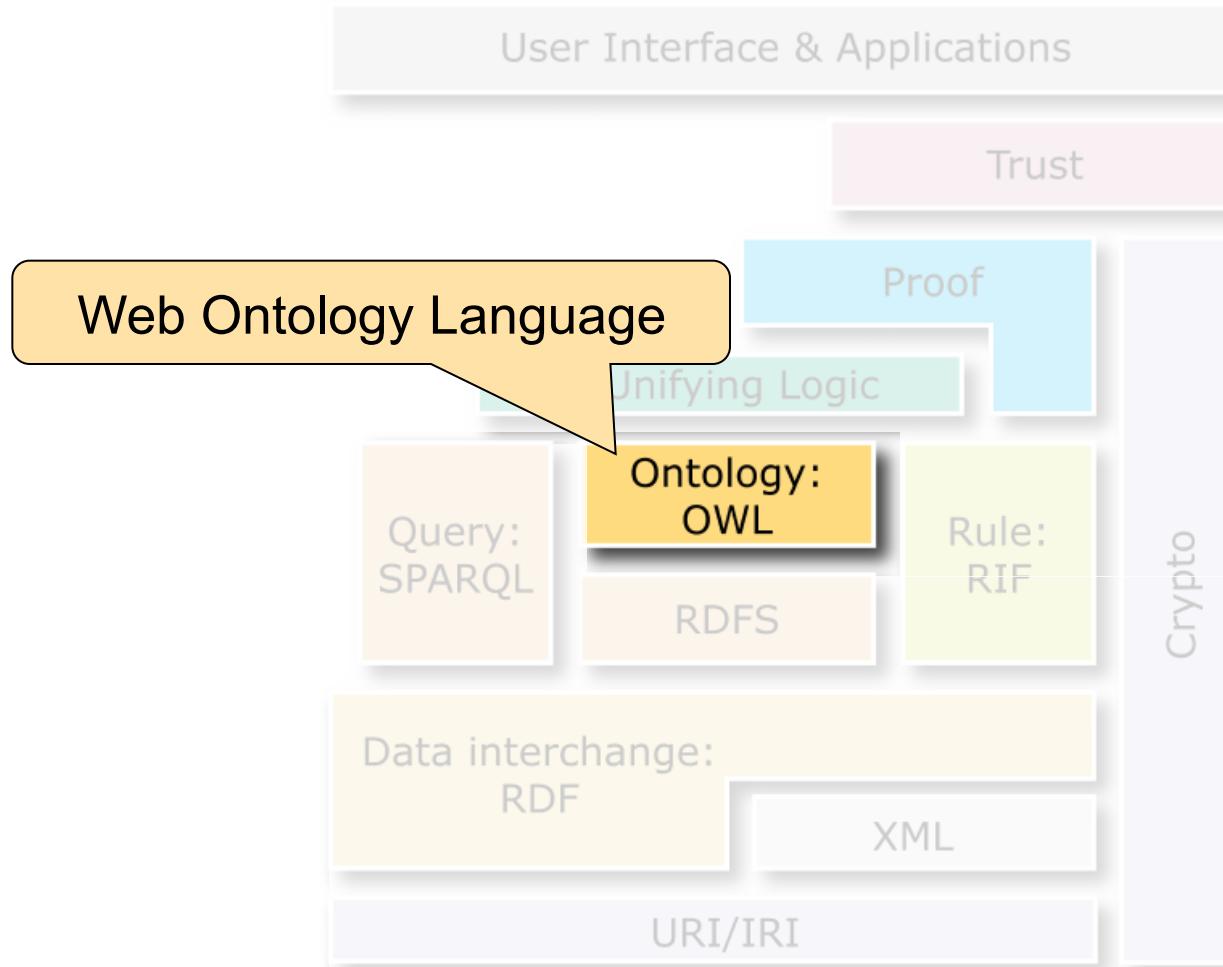


Summary of RDFS

- ✿ **Meta-classes, classes, and instances**
- ✿ **rdfs:domain indicates a class where the slot definition is attached.**
- ✿ **rdfs:range denotes a class of slot value.**
- ✿ **An instance of rdf:Property has super-sub concept.**
- ✿ **Domain and range value is inherited.**
- ✿ **13 RDFS axioms**
- ✿ **Piecewise ontology adding**
- ✿ **Forward reference and proactive entailment**



Semantic Web Layer-cake



Web Ontology Language

❖ OWL Overview

- ✿ <http://www.w3.org/TR/owl-features/>

❖ OWL Guide

- ✿ <http://www.w3.org/TR/owl-guide/>

❖ OWL Reference

- ✿ <http://www.w3.org/TR/owl-ref/>

❖ OWL Semantics and Abstract Syntax

- ✿ <http://www.w3.org/TR/owl-semantics/>

❖ OWL Test Cases

- ✿ <http://www.w3.org/TR/owl-test/>

❖ OWL Use Cases and Requirements

- ✿ <http://www.w3.org/TR/webont-req/>



Three sub languages of OWL

◆ OWL Lite

- ◆ supports users primarily needing a classification hierarchy and simple constraints. It should be simpler to provide tool support for OWL Lite than the other sublanguages.

◆ OWL DL

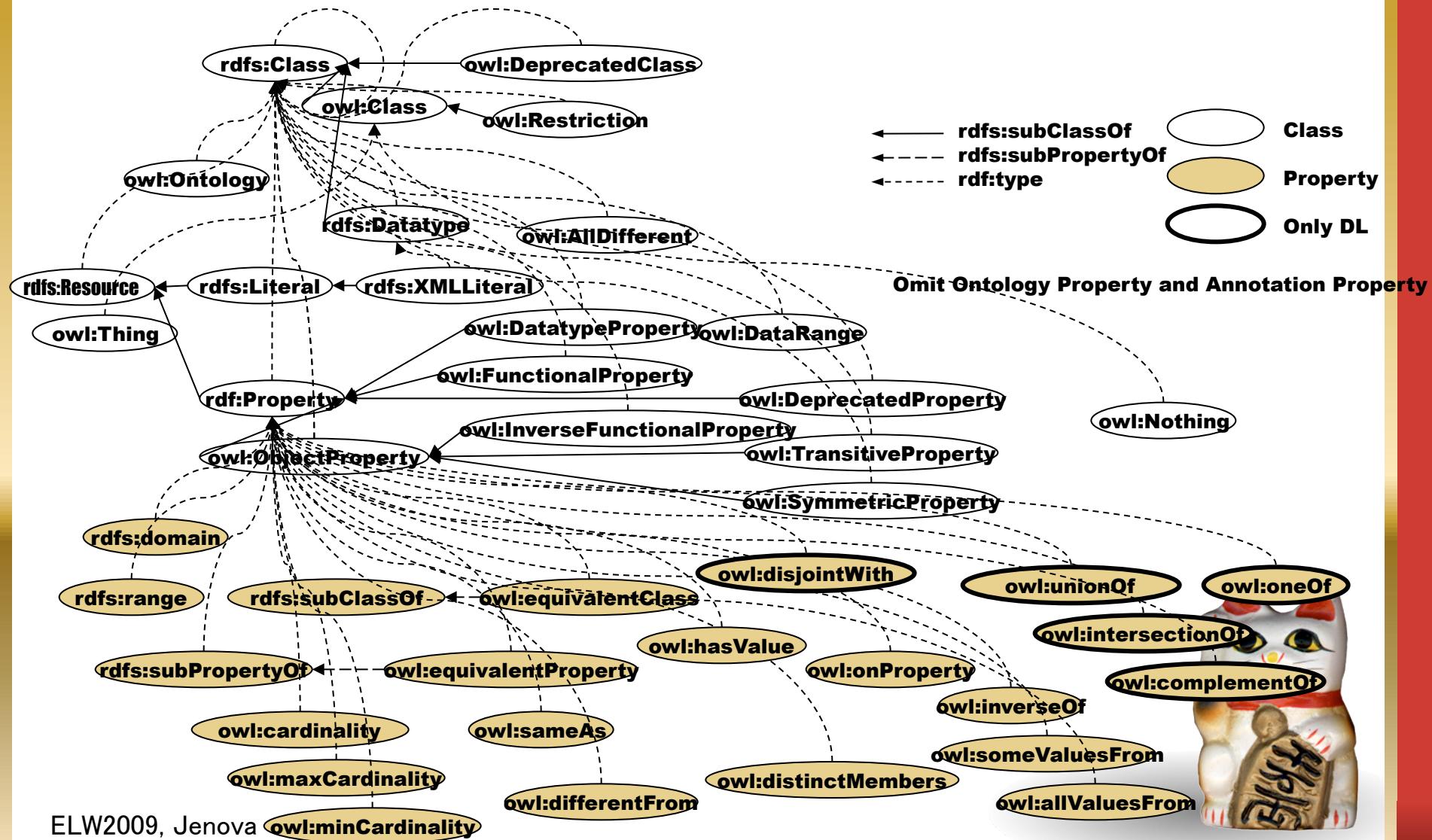
- ◆ supports users who want the maximum expressiveness while retaining computational completeness (all conclusions are guaranteed to be computable) and decidability (all computations will finish in finite time).

◆ OWL Full

- ◆ is meant for users who want maximum expressiveness and the syntactic freedom of RDF with no computational guarantees. For example, in OWL Full a class can be treated simultaneously as a collection of individuals and as an individual in its own right.



Web Ontology Language - OWL



Local Range Restrictions

✿ owl:allValuesFrom

- ✿ the values of the property are all members of the class indicated (if they exist)

✿ owl:someValuesFrom

- ✿ at least one value of the property is an instance of the class indicated

✿ owl:hasValue

- ✿ a class of all individuals for which the property concerned has at least one value semantically equal to the value (it may have other values as well)

✿ Cardinality

- ✿ owl:maxCardinality to specify an upper bound
- owl:minCardinality to specify a lower bound
- owl:cardinality to specify an exact number of elements



owl:allValuesFrom

Reboot Lisp!
Load SWCLOS OWL and
Wine Ontology and Food Ontology

```

(defConcept House (rdf:type owl:Class))
(defIndividual MyHouse (rdf:type House))
(defIndividual MyHomeMadeWine (rdf:type vin:Wine)
  (vin:hasMaker MyHouse))
warning: owl:allvaluesFrom entail of vin:hasMaker: change class of #<House
MyHouse> to #<owl:Class vin:Winery>.
warning: #<House MyHouse> is additionally classified to #<owl:Class vin:Winery>.

```

MyHouse → #<House.4 MyHouse>

(type-of MyHouse) → (House vin:Winery)

(get-form vin:Wine) →

```

(owl:Class vin:Wine (rdf:about #<uri http://www.w3.org/TR/2003/PR-owl-guide-20031209/wine#Wine>)
(rdfs:label common-lisp:nil common-lisp:nil)
(rdfs:subClassOf food:PotableLiquid
  (owl:Restriction (owl:onProperty vin:hasMaker)
    (owl:cardinality "1"^^xsd:nonNegativeInteger))
  (owl:Restriction (owl:onProperty vin:hasMaker)
    (owl:allValuesFrom vin:Winery)))
  (owl:Restriction (owl:onProperty vin:madeFromGrape)
    (owl:minCardinality "1"^^xsd:nonNegativeInteger))
  (owl:Restriction (owl:onProperty vin:hasSugar)
    (owl:cardinality "1"^^xsd:nonNegativeInteger))
  (owl:Restriction (owl:onProperty vin:hasFlavor)
    (owl:cardinality "1"^^xsd:nonNegativeInteger))
  (owl:Restriction (owl:onProperty vin:hasBody)
    (owl:cardinality "1"^^xsd:nonNegativeInteger)))

```

multiple classes



owl:someValuesFrom

(get-form vin:Wine) →

```

(owl:Class vin:Wine
  (rdf:about #<uri http://www.w3.org/TR/2003/PR-owl-guide-20031209/wine#wine>)
  (rdfs:subClassOf food:PotableLiquid
    (owl:Restriction (owl:onProperty vin:hasMaker)
      (owl:cardinality "1"^^xsd:nonNegativeInteger))
    (owl:Restriction (owl:onProperty vin:hasMaker)
      (owl:allValuesFrom vin:winery)))
    (owl:Restriction (owl:onProperty vin:madeFromGrape)
      (owl:minCardinality "1"^^xsd:nonNegativeInteger))
    (owl:Restriction (owl:onProperty vin:hasSugar)
      (owl:cardinality "1"^^xsd:nonNegativeInteger))
    (owl:Restriction (owl:onProperty vin:hasFlavor)
      (owl:cardinality "1"^^xsd:nonNegativeInteger))
    (owl:Restriction (owl:onProperty vin:hasBody)
      (owl:cardinality "1"^^xsd:nonNegativeInteger))
    (owl:Restriction (owl:onProperty vin:hasColor)
      (owl:cardinality "1"^^xsd:nonNegativeInteger))
    (owl:Restriction (owl:onProperty vin:locatedIn)
      (owl:someValuesFrom vin:Region))))
```

**This statement claims that there must be vin:locatedIn slot in Wine instances,
And one of the slot values must be a region.**



owl:hasValue

```

(get-form vin:Chardonnay) →
(owl:Class vin:Chardonnay
(rdfs:subClassOf (owl:Restriction (owl:onProperty vin:hasColor)
(owl:hasvalue vin:white))
(owl:Restriction (owl:onProperty vin:hasBody)
(owl:allvaluesFrom
(owl:Class (owl:oneOf vin:Full vin:Medium))))
(owl:Restriction (owl:onProperty vin:hasFlavor)
(owl:allvaluesFrom
(owl:Class (owl:oneOf vin:Strong vin:Moderate))))))
(owl:intersectionof
vin:wine
(owl:Restriction (owl:onProperty vin:madeFromGrape)
(owl:hasvalue vin:ChardonnayGrape))
(owl:Restriction (owl:onProperty vin:madeFromGrape)
(owl:maxCardinality "1"^^xsd:nonNegativeInteger)))

```

**This statement claims the definition of vin:Cardonnay, that is,
it is made from Cardonnay Grape .**



Cardinality

```
(put-value vin:ElyseZinfandel 'vin:hasSugar vin:Sweet)
Error: invalid slot value for range: #<vin:WineSugar vin:Sweet> for range
#<gx::fills vin:hasSugar.vin:Dry>
```

(get-form vin:wine) →

```
(owl:Class vin:wine (rdf:about #<uri http://www.w3.org/TR/2004/REC-owl-features-20040210/OWL-Semantics.html#vin:wine>)
(rdfs:subClassOf food:PotableLiquid
  (owl:Restriction (owl:onProperty vin:hasSugar)
    (owl:cardinality "1"^^xsd:nonNegativeInteger))
  (owl:Restriction (owl:onProperty vin:hasMaker)
    (owl:allValuesFrom vin:Winery)))
  (owl:Restriction (owl:onProperty vin:madeFromGrape)
    (owl:minCardinality "1"^^xsd:nonNegativeInteger))
  (owl:Restriction (owl:onProperty vin:hasSugar)
    (owl:cardinality "1"^^xsd:nonNegativeInteger))
  (owl:Restriction (owl:onProperty vin:hasFlavor)
    (owl:cardinality "1"^^xsd:nonNegativeInteger))
  (owl:Restriction (owl:onProperty vin:hasBody)
    (owl:cardinality "1"^^xsd:nonNegativeInteger))
  (owl:Restriction (owl:onProperty vin:hasColor)
    (owl:cardinality "1"^^xsd:nonNegativeInteger))
  (owl:Restriction (owl:onProperty vin:locatedIn)
    (owl:someValuesFrom vin:Region))))
```



Cardinality

```
(defResource Blendedwine (rdf:type owl:Class)
  (rdfs:subClassOf
    vin:Wine
    (owl:Restriction (owl:onProperty vin:madeFromGrape)
                      (owl:minCardinality 2))
    (owl:Restriction (owl:onProperty vin:hasColor)
                      (owl:minCardinality 2))))
```

```
(defIndividual MyBlendedwine (rdf:type Blendedwine)
  (vin:hasColor vin:Red vin:white))
```

Error: Unsatisfiability by cardinality for Blendedwine vin:hasColor

Slot values must be satisfiable to the constraint.

minCardinality ≤ maxCardinality



Equality and Difference/Disjoint

- ❶ **owl:sameAs**
- ❷ **owl:differentFrom**
- ❸ **owl:AllDifferent - owl:distinctMembers**
- ❹ **owl:equivalentClass**
- ❺ **owl:disjointWith**

For Individuals

For Classes



Different Individuals

(owl-different-p vin:Dry vin:offDry) → true

(owl-different-p vin:offDry vin:Sweet) → true

(owl-different-p vin:Sweet vin:Dry) → true

(get-form vin:Dry) →

(vin:wineSugar vin:Dry

(rdf:about

<http://www.w3.org/TR/2003/PR-owl-guide-20031209/wine#Dry>))

(get-form vin:Sweet) →

(vin:wineSugar vin:Sweet

(rdf:about

<http://www.w3.org/TR/2003/PR-owl-guide-20031209/wine#Sweet>)

(owl:differentFrom vin:Dry))

(get-form vin:OffDry) →

(vin:wineSugar vin:OffDry

(rdf:about

<http://www.w3.org/TR/2003/PR-owl-guide-20031209/wine#OffDry>)

(owl:differentFrom vin:Dry vin:Sweet))



Different Individuals

```
(owl-different-p vin:Red vin:white) → true
(owl-different-p vin:white vin:Rose) → true
(owl-different-p vin:Rose vin:Red) → true
(get-form vin:Red) → (vin:wineColor vin:Red (rdf:about <http://w
(get-form vin:white) → (vin:wineColor vin:white (rdf:about <http
```

```
<owl:AllDifferent>
  <owl:distinctMembers rdf:parseType="Collection">
    <vin:wineColor rdf:about="#Red" />
    <vin:wineColor rdf:about="#white" />
    <vin:wineColor rdf:about="#Rose" />
  </owl:distinctMembers>
</owl:AllDifferent>
```



Same Individuals

```
*nonUNA* → nil
```

```
(owl-different-p vin:SonomaRegion vin:NapaRegion) → true
```

```
(let ((*nonUNA* t))
```

```
  (owl-different-p vin:SonomaRegion vin:NapaRegion)) → true
```

```
(owl-same-p vin:SonomaRegion vin:NapaRegion) → nil
```

```
(get-form vin:SonomaRegion) →
```

```
(vin:Region vin:SonomaRegion
```

```
  (vin:locatedIn vin:CaliforniaRegion)
```

```
  (vin:adjacentRegion vin:MendocinoRegion))
```

Graph matching for nonUNA

```
(get-form vin:NapaRegion) →
```

```
(vin:Region vin:NapaRegion
```

```
  (vin:locatedIn vin:CaliforniaRegi
```

collect-all-extensions-of collects all pairs on the relation of the property in memory.

```
(collect-all-extensions-of owl:sameAs) →
```

```
((#<owl:Thing food:white> #<vin:WineColor vin:white>)
```

```
(#<owl:Thing food:Rose> #<vin:WineColor vin:Rose>)
```

```
(#<owl:Thing food:Red> #<vin:WineColor vin:Red>)
```

```
(#<owl:Thing food:Sweet> #<vin:WineSugar vin:Sweet>)
```

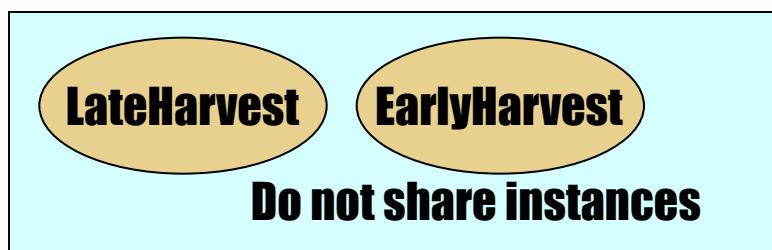
```
(#<owl:Thing food:OffDry> #<vin:WineSugar vin:offdry>)
```



Disjoint Class

```
(collect-all-extensions-of owl:disjointwith) →
((#<owl:Class vin:LateHarvest> #<owl:Class vin:EarlyHarvest>
 (#<owl:Class food:PotableLiquid> #<owl:Class food:EdibleThing>
 (#<owl:Class food:Meat> #<owl:Class food:Fruit>)...)
```

```
(disjoint-p vin:LateHarvest vin:EarlyHarvest) → true
(get-form vin:LateHarvest) →
owl:Class vin:LateHarvest
(rdf:about <http://www.w3.org/TR/2003/PR-owl-guide-20031209/wine>
(rdfs:subClassOf vin:wine
(owl:Restriction (owl:onProperty vin:hasSugar) (owl:hasValue v)
(owl:Restriction (owl:onProperty vin:hasFlavor) (owl:allvaluesF
(owl:disjointwith vin:EarlyHarvest))
```



Equivalent Class

(owl-equivalent-p food:wine vin:wine) → true

(get-form food:wine) →

(owl:Class food:wine (owl:equivalentClass vin:wine))

(owl-equivalent-p vin:DryWine vin:Tablewine) → true

(get-form vin:DryWine) →

(owl:Class vin:DryWine

(rdf:about <http://www.w3.org/TR/2003/PR-owl-guide-20031209/wine#DryWine)

(owl:intersectionOf

vin:wine

(owl:Restriction (owl:onProperty vin:hasSugar) (owl:hasValue vin:Dry))

(get-form vin:Tablewine) →

(owl:Class vin:Tablewine

(rdf:about <http://www.w3.org/TR/2003/PR-owl-guide-20031209/wine#Tablewi

(owl:intersectionOf

vin:wine

(owl:Restriction (owl:onProperty vin:hasSugar) (owl:hasValue vin:Dry))

IntersectionOf is descriptive and definitive.

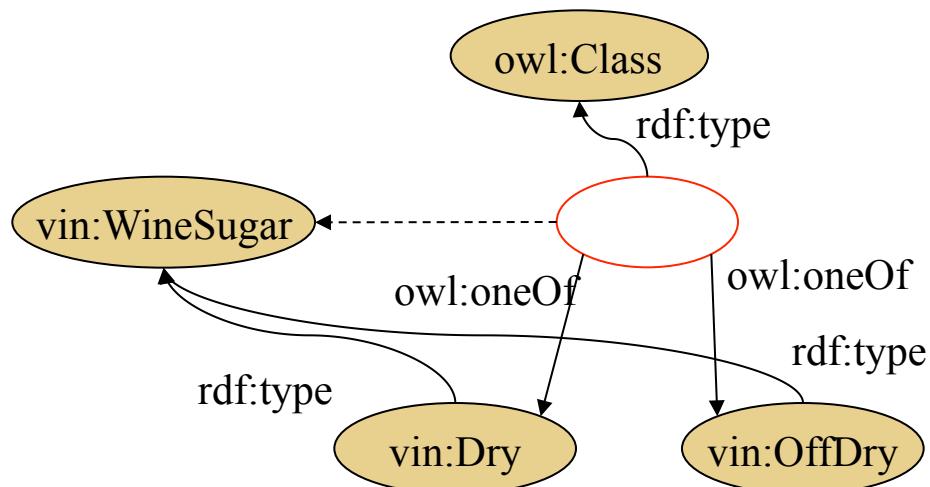


owl:oneOf

```

(pprint (get-form vin:EarlyHarvest)) →
(owl:Class vin:EarlyHarvest
(rdfs:subClassof
vin:wine
(owl:Restriction (owl:onProperty vin:hasSugar)
(owl:allValuesFrom
(owl:Class (owl:oneOf vin:Dry vin:OffDry))))))
(get-range vin:hasSugar) → #<owl:Class vin:WineSugar>
(get-form vin:WineSugar)
→ (owl:Class vin:WineSugar (rdfs:subClassof vin:WineTaste)
(owl:oneOf vin:Sweet vin:OffDry vin:Dry))

```



Composite Concepts

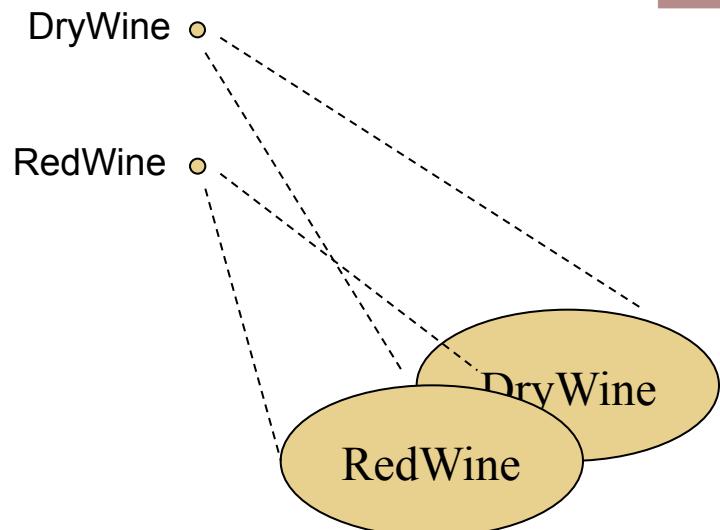
- ✿ **owl:intersectionOf**
- ✿ **owl:unionOf**
- ✿ **owl:complementOf**



Intersection of Concepts

```
(get-form vin:DryRedwine) →  
(owl:Class vin:DryRedwine  
  (owl:intersectionOf vin:Drywine vin:Redwine))  
(subsumed-p vin:DryRedwine vin:Drywine) → true  
(subsumed-p vin:DryRedwine vin:Redwine) → true
```

DryRedWine \equiv DryWine \sqcap RedWine

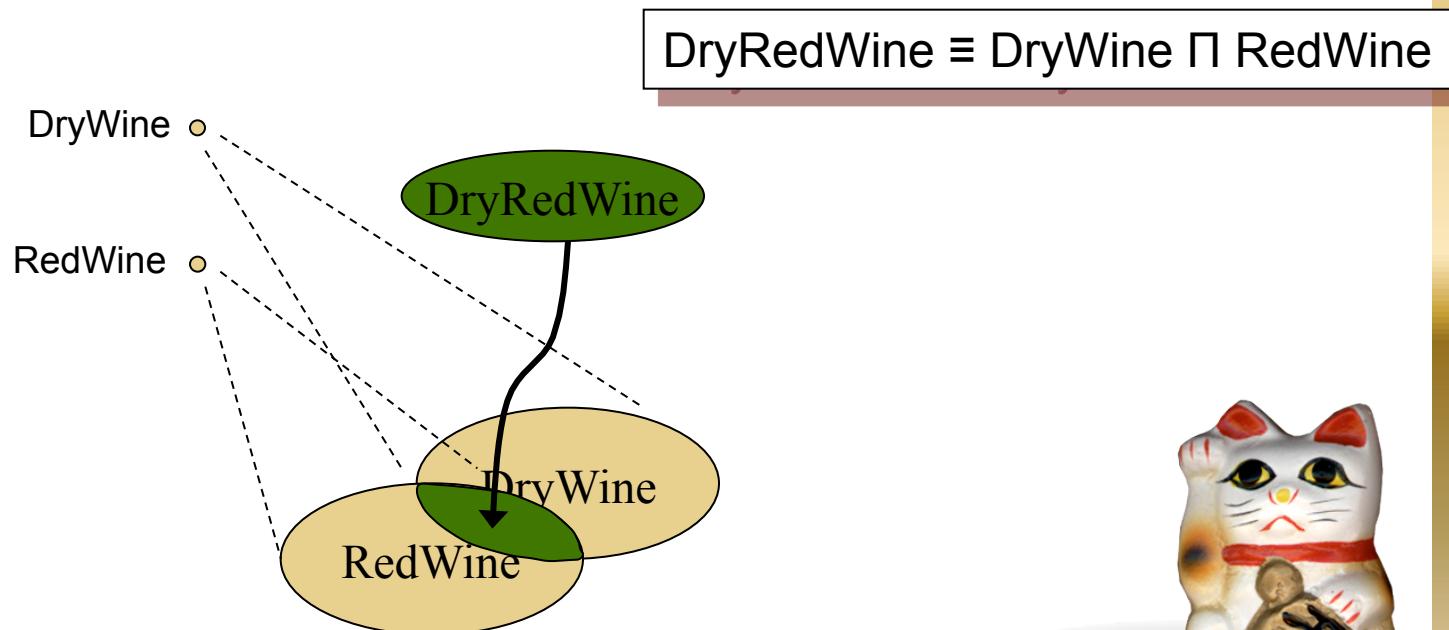


Intersection of Concepts

```

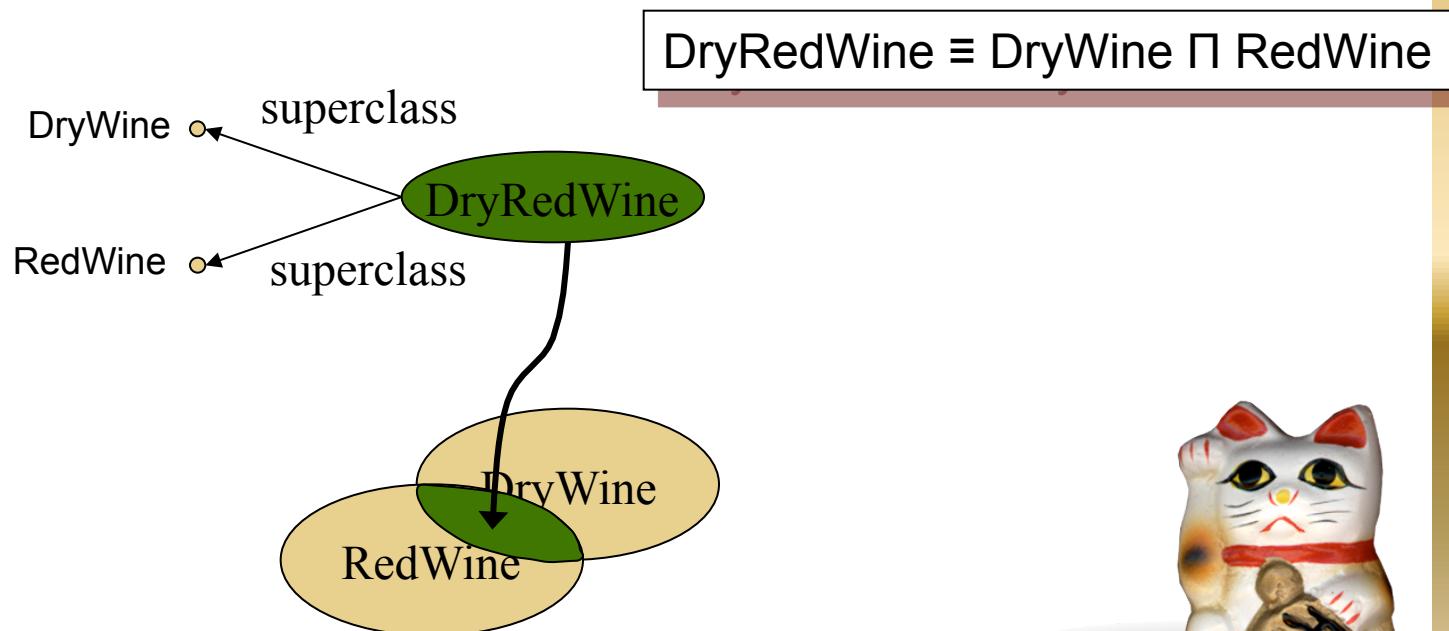
(get-form vin:DryRedwine) →
(owl:Class vin:DryRedwine
 (owl:intersectionOf vin:Drywine vin:Redwine))
(subsumed-p vin:DryRedwine vin:Drywine) → true
(subsumed-p vin:DryRedwine vin:Redwine) → true

```



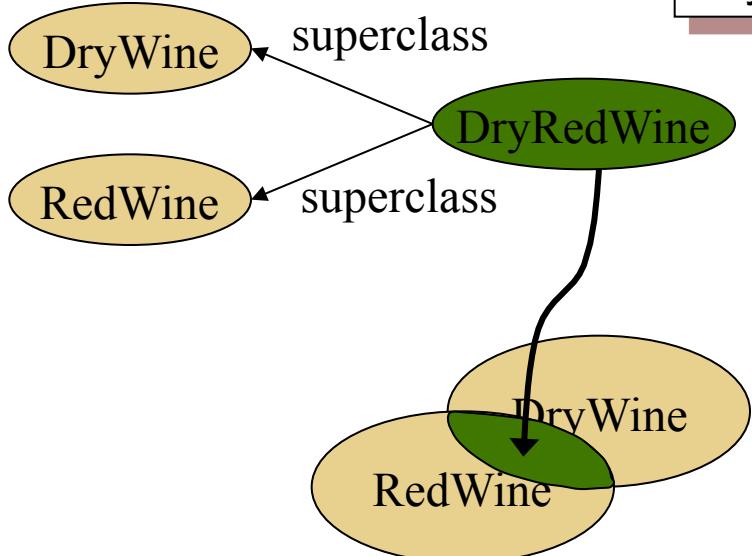
Intersection of Concepts

```
(get-form vin:DryRedwine) →
(owl:Class vin:DryRedwine
  (owl:intersectionOf vin:Drywine vin:Redwine))
(subsumed-p vin:DryRedwine vin:Drywine) → true
(subsumed-p vin:DryRedwine vin:Redwine) → true
```



Intersection of Concepts

```
(get-form vin:DryRedwine) →
(owl:Class vin:DryRedwine
  (owl:intersectionOf vin:Drywine vin:Redwine))
(subsumed-p vin:DryRedwine vin:Drywine) → true
(subsumed-p vin:DryRedwine vin:Redwine) → true
```



$$\text{DryRedWine} \equiv \text{DryWine} \sqcap \text{RedWine}$$



Intersection of Concepts

$(\text{owl}-\text{equivalent-p } \text{vin:Drywine } \text{vin:Tablewine}) \rightarrow \text{ true}$
 $(\text{owl}-\text{same-p } \text{vin:Drywine } \text{vin:Tablewine}) \rightarrow \text{ nil}$

$(\text{get-form } \text{vin:Drywine}) \rightarrow$

$(\text{owl:Class } \text{vin:Drywine} \ (\text{rdf:about } <\text{http://www.w3.org/TR/2003/}$
 $\text{owl:intersectionOf}$

vin:wine

$(\text{owl:hasValueRestriction} \ (\text{owl:onProperty } \text{vin:hasSugar})$
 $\text{ (owl:hasValue } \text{vin:Dry})))$

DryWine ≡ TableWine

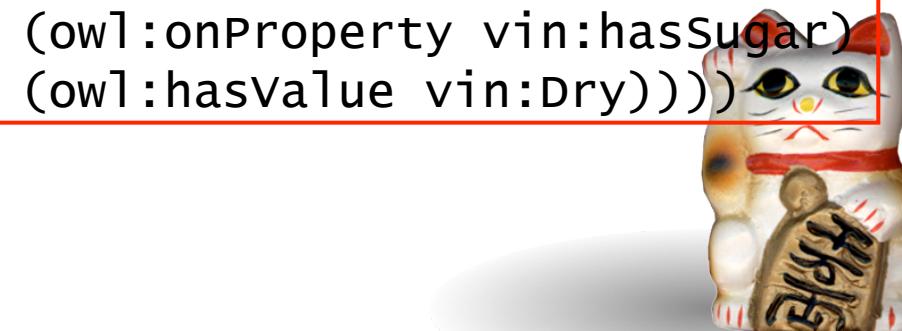
$(\text{get-form } \text{vin:Tablewine}) \rightarrow$

$(\text{owl:Class } \text{vin:Tablewine} \ (\text{rdf:about } <\text{http://www.w3.org/TR/200}$

$\text{owl:intersectionOf}$

vin:wine

$(\text{owl:hasValueRestriction} \ (\text{owl:onProperty } \text{vin:hasSugar})$
 $\text{ (owl:hasValue } \text{vin:Dry})))$



Intersection of Concepts

(get-form vin:Redwine) →

```

owl:Class vin:Redwine
(rdf:about <http://www.w3.org/TR/2003/PR-owl-guide-20031209/wine#Redwine>)
owl:intersectionof
  vin:wine
  (owl:Restriction (owl:onProperty vin:hasColor)
    (owl:hasValue vin:Red)))

```

RedWine ⊑ Wine

(get-form vin:RedTablewine) →

```

owl:Class vin:RedTablewine
owl:intersectionof
  vin:Tablewine
  (owl:Restriction (owl:onProperty vin:hasColor)
    (owl:hasValue vin:Red)))

```

RedTableWine ⊑ TableWine ⊑ Wine

(subsumed-p vin:RedTablewine vin:Tablewine) → true



Intersection of Concepts

(get-form vin:Redwine) →

(owl:Class vin:Redwine

(rdf:about #<uri http://www.w3.org/TR/2003/PR-owl-guide-20031209/wine#Redwine>)

(owl:intersectionof

vin:wine

(owl:Restriction (owl:onProperty vin:hasColor)
 (owl:hasValue vin:Red))))

RedWine ⊑ Wine

(get-form vin:RedTablewine) →

(owl:Class vin:RedTablewine

(owl:intersectionof

vin:Tablewine

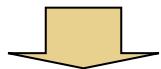
RedTableWine ⊑ TableWine ⊑ Wine

(owl:Restriction (owl:onProperty vin:hasColor)
 (owl:hasValue vin:Red))))

(subsumed-p vin:RedTablewine vin:Tablewine) → true

(subsumed-p vin:RedTablewine vin:Redwine) → true

vin:Tablewine ⊆ vin:Wine



vin:RedTablewine ⊆ vin:Redwine



Intersection of Concepts

```
(get-form vin:zinfandel) →  
(owl:Class vin:Zinfandel (rdf:about <http://www.w3.org/TR/2003/PR-owl-gui  
(rdfs:subClassOf  
  (owl:Restriction (owl:onProperty vin:hasColor) (owl:hasValue vin:Red))  
  (owl:Restriction (owl:onProperty vin:hasSugar) (owl:hasValue vin:Dry))  
  (owl:Restriction (owl:onProperty vin:hasBody)  
    (owl:allValuesFrom (owl:Class #)))  
  (owl:Restriction (owl:onProperty vin:hasFlavor)  
    (owl:allValuesFrom (owl:Class #))))  
  
(owl:intersectionOf  
  vin:wine  
  (owl:Restriction (owl:onProperty vin:madeFromGrape)  
    (owl:hasValue vin:ZinfandelGrape))  
  (owl:Restriction (owl:onProperty vin:madeFromGrape)  
    (owl:maxCardinality "1"^^xsd:nonNegativeInteger))))
```



Intersection of Concepts

```
(get-form vin:zinfandel) →  
(owl:Class vin:zinfandel (rdf:about <http://www.w3.org/TR/2003/PR-owl-guide-20030225#owlClass>)  
(rdfs:subClassOf  
  (owl:Restriction (owl:onProperty vin:hasColor) (owl:hasValue vin:Red))  
  (owl:Restriction (owl:onProperty vin:hasSugar) (owl:hasValue vin:Dry))  
  (owl:Restriction (owl:onProperty vin:hasBody)  
    (owl:allValuesFrom (owl:Class #)))  
  (owl:Restriction (owl:onProperty vin:hasFlavor)  
    (owl:allValuesFrom (owl:Class #))))  
  
(owl:intersectionOf  
  vin:wine  
  (owl:Restriction (owl:onProperty vin:madeFromGrape)  
    (owl:hasValue vin:zinfandelGrape))  
  (owl:Restriction (owl:onProperty vin:madeFromGrape)  
    (owl:hasValue vin:zinfandel)))
```



Intersection of Concepts

Zinfandel ⊑ RedWine

(subsumed-p vin:Zinfandel vin:Redwine) → true

(get-form vin:Zinfandel) →

(owl:Class vin:Zinfandel (rdf:about <http://www.w3.org/TR/2003/PR-owl-guide#SubClassOf)

(rdfs:subClassOf

(owl:Restriction (owl:onProperty vin:hasColor) (owl:hasValue vin:Red))

(owl:Restriction (owl:onProperty vin:hasSugar) (owl:hasValue vin:Dry))

(owl:Restriction (owl:onProperty vin:hasBody)

(owl:allValuesFrom (owl:Class #)))

(owl:Restriction (owl:onProperty vin:hasFlavor)

(owl:allValuesFrom (owl:Class #))))

(owl:intersectionOf

vin:wine

(owl:Restriction (owl:onProperty vin:madeFromGrape)

(owl:hasValue vin:ZinfandelGrape))

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(owl:Restriction (owl:onProperty vin:madeFromGrape)



Intersection of Concepts

Zinfandel ⊑ RedWine

```
(get-form vin:Redwine) →
(owl:Class vin:Redwine
(rdf:about <http://www.w3.org/TR/2003/PR-owl-guide-20031209/wine#Redwine>
(owl:intersectionOf
  vin:Wine
  (owl:Restriction (owl:onProperty vin:hasColor)
    (owl:hasValue vin:Red))))
```

```
(get-form vin:Zinfandel) →
(owl:Class vin:Zinfandel (rdf:about <http://www.w3.org/TR/2003/PR-owl-gui
(rdfs:subClassOf
  (owl:Restriction (owl:onProperty vin:hasColor) (owl:hasValue vin:Red))
  (owl:Restriction (owl:onProperty vin:hasSugar) (owl:hasValue vin:Dry))
  (owl:Restriction (owl:onProperty vin:hasBody)
    (owl:allValuesFrom (owl:Class #)))
  (owl:Restriction (owl:onProperty vin:hasFlavor)
    (owl:allValuesFrom (owl:Class #))))
```

```
(owl:intersectionOf
  vin:Wine
  (owl:Restriction (owl:onProperty vin:madeFromGrape)
    (owl:hasValue vin:ZinfandelGrape))
  (owl:Restriction (owl:onProperty vin:madeFromGrape)
```



Intersection of Concepts

Zinfandel ⊑ TableWine

(subsumed-p vin:Zinfandel vin:Tablewine) → true

(get-form vin:Zinfandel) →

```

owl:Class vin:Zinfandel (rdf:about <http://www.w3.org/TR/2003/PR-owl-guide-20030225#Zinfandel>)
(rdfs:subClassOf
  (owl:Restriction (owl:onProperty vin:hasColor) (owl:hasValue vin:Red))
  (owl:Restriction (owl:onProperty vin:hasSugar) (owl:hasValue vin:Dry))
  (owl:Restriction (owl:onProperty vin:hasBody)
    (owl:allValuesFrom (owl:Class #)))
  (owl:Restriction (owl:onProperty vin:hasFlavor)
    (owl:allValuesFrom (owl:Class #))))

```

owl:intersectionOf

vin:wine

```

(owl:Restriction (owl:onProperty vin:madeFromGrape)
  (owl:hasValue vin:ZinfandelGrape))

```

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```

(owl:Restriction (owl:onProperty vin:madeFromGrape)
  (owl:hasValue vin:Zinfandel))

```



Intersection of Concepts

Zinfandel ⊑ TableWine

(get-form vin:Tablewine) →

(owl:Class vin:Tablewine

(rdf:about <http://www.w3.org/TR/2003/PR-owl-guide-20031209/wine#Tablewi

(owl:intersectionOf

vin:wine

(owl:Restriction (owl:onProperty vin:hasSugar)
 (owl:hasValue vin:Dry))))

(get-form vin:Zinfandel) →

(owl:Class vin:Zinfandel (rdf:about <http://www.w3.org/TR/2003/PR-owl-gui

(rdfs:subClassOf

(owl:Restriction (owl:onProperty vin:hasColor) (owl:hasValue vin:Red))

(owl:Restriction (owl:onProperty vin:hasSugar) (owl:hasValue vin:Dry))

(owl:Restriction (owl:onProperty vin:hasBody)
 (owl:allValuesFrom (owl:Class #)))

(owl:Restriction (owl:onProperty vin:hasFlavor)
 (owl:allValuesFrom (owl:Class #))))

(owl:intersectionOf

vin:wine

(owl:Restriction (owl:onProperty vin:madeFromGrape)
 (owl:hasValue vin:ZinfandelGrape))

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(owl:Restriction (owl:onProperty vin:madeFromGrape)



Intersection of Concepts

ElyseZinfandel \in RedWine

(typep vin:ElyseZinfandel vin:Redwine) → true

```
(get-form vin:ElyseZinfandel) →
(vin:Zinfandel vin:ElyseZinfandel
(vin:hasMaker vin:Elyse)
(vin:hasSugar vin:Dry)
(vin:hasFlavor vin:Moderate)
(vin:hasBody vin:Full)
(vin:locatedIn vin:NapaRegion)
(vin:hasColor vin:Red)
(vin:madeFromGrape vin:zinfandelGrape))
```

```
(get-form vin:Redwine) →
(owl:Class vin:Redwine
(rdf:about <http://www.w3.org/TR/2003/PR-owl-guide-20031209/wine
owl:intersectionof
vin:wine
owl:Restriction (owl:onProperty vin:hasColor)
(owl:hasValue vin:Red))))
```

Zinfandel \sqsubseteq Wine



Intersection of Concepts

ElyseZinfandel \in TableWine

(typep vin:ElyseZinfandel vin:Tablewine) \rightarrow true

```

(get-form vin:ElyseZinfandel) →
(vin:Zinfandel vin:ElyseZinfandel)
(vin:hasMaker vin:Elyse)
(vin:hasSugar vin:Dry)
(vin:hasFlavor vin:Moderate)
(vin:hasBody vin:Full)
(vin:locatedIn vin:NapaRegion)
(vin:hasColor vin:Red)
(vin:madeFromGrape vin:zinfandelGrape))

```

(get-form vin:Tablewine) →

(owl:Class vin:Tablewine

Zinfandel \sqsubseteq Wine

(rdf:about <http://www.w3.org/TR/2003/PR-owl-guide-20031209/wine

(owl:intersectionof

vin:wine

(owl:Restriction (owl:onProperty vin:hasSugar)
(owl:hasValue vin:Dry))))



Intersection of Concepts

```

(get-form vin:MariettaOldvinesRed) →
(vin:RedTablewine vin:MariettaOldvinesRed
(vin:hasMaker vin:Marietta)
(vin:hasSugar vin:Dry)
(vin:hasFlavor vin:Moderate)
(vin:hasBody vin:Medium)
(vin:locatedIn vin:SonomaRegion)
(vin:hasColor vin:Red))

```

MariettaOldVinesRed ⊑ RedWine

```
(typep vin:MariettaOldvinesRed vin:Redwine) → true
```

```

(get-form vin:Redwine) →
owl:Class vin:Redwine
(rdf:about <http://www.w3.org/TR/2003/PR-owl-guide-20031209/wine>
owl:intersectionof
  vin:Wine
  (owl:Restriction (owl:onProperty vin:hasColor)
    (owl:hasValue vin:Red))))

```



Intersection of Concepts

```

(get-form vin:MariettaOldvinesRed) →
(vin:RedTablewine vin:MariettaOldvinesRed
(vin:hasMaker vin:Marietta)
(vin:hasSugar vin:Dry)
(vin:hasFlavor vin:Moderate)
(vin:hasBody vin:Medium)
(vin:locatedIn vin:SonomaRegion)
(vin:hasColor vin:Red))

```

MariettaOldVinesRed ⊑ TableWine

```
(typep vin:MariettaOldvinesRed vin:Tablewine) → true
```

```

(get-form vin:Tablewine)→
owl:Class vin:Tablewine
(rdf:about #<uri http://www.w3.org/TR/2003/PR-owl-guide-20031209
owl:intersectionof
vin:Wine
(owl:Restriction (owl:onProperty vin:hasSugar)
(owl:hasValue vin:Dry))))

```



Intersection of Concepts

TableWine \equiv Wine \sqcap hasSugar.Dry

RedWine \equiv Wine \sqcap hasColor.Red

Zinfandel \equiv Wine \sqcap madeFromGrape.ZinfandelGrape

Zinfandel \sqsubseteq hasColor.Red

Zinfandel \sqsubseteq hasSugar.Dry

Zinfandel \sqsubseteq \forall hasBody.{Full, Medium}

Zinfandel \sqsubseteq \forall hasFlavor.{Moderate, Strong}

Zinfandel \sqsubseteq RedWine

Zinfandel \sqsubseteq TableWine



Intersection of Concepts

TableWine \equiv Wine \sqcap hasSugar.Dry

RedWine \equiv Wine \sqcap hasColor.Red

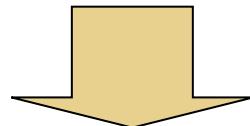
Zinfandel \equiv Wine \sqcap madeFromGrape.ZinfandelGrape

Zinfandel \sqsubseteq hasColor.Red

Zinfandel \sqsubseteq hasSugar.Dry

Zinfandel \sqsubseteq \forall hasBody.{Full, Medium}

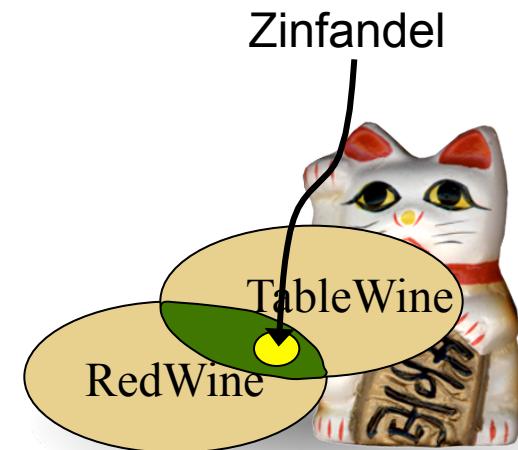
Zinfandel \sqsubseteq \forall hasFlavor.{Moderate, Strong}



Entail

Zinfandel \sqsubseteq RedWine

Zinfandel \sqsubseteq TableWine



Intersection of Concepts

$\text{DryWine} \equiv \text{Wine} \sqcap \exists \text{hasSugar}.\text{Dry}$

$\text{DryWhiteWine} \equiv \text{DryWine} \sqcap \text{WhiteWine}$

$\text{WhiteNonSweetWine} \equiv \text{WhiteWine} \sqcap \forall \text{hasSugar}.\{\text{Dry}, \text{OffDry}\}$

DryWhiteWine vs. WhiteNonSweetWine
Which subsumes which?

$(\text{subsumed-p } \text{vin:WhiteNonSweetwine } \text{ vin:Drywhitewine}) \rightarrow \text{false}$
 $(\text{subsumed-p } \text{vin:Drywhitewine } \text{ vin:whiteNonSweetwine}) \rightarrow \text{true}$

$\text{DryWhiteWine} \sqsubseteq \text{WhiteNonSweetWine}$



Intersection of Concepts(Complex)

(subsumed-p vin:whiteNonSweetwine vin:Drywhitewine) → false
 (subsumed-p vin:Drywhitewine vin:whiteNonSweetwine) → true

(get-form vin:whiteNonSweetwine) →
 (owl:Class vin:whiteNonSweetwine
 (owl:intersectionOf vin:whitewine
 (owl:Restriction (owl:onProperty vin:hasSugar)
 (owl:allValuesFrom
 (owl:Class (owl:oneOf vin:Dry vin:offDry))))))
 (get-form vin:DryWhitewine) →
 (owl:Class vin:Drywhitewine
 (owl:intersectionOf vin:Drywine vin:whitewine))

(get-form vin:Drywine) →
 (owl:Class vin:Drywine
 (rdf:about #<uri http://www.w3.org/TR/2003/PR-owl-guide-20031209/vin
 (owl:intersectionOf
 vin:wine
 (owl:Restriction
 (owl:onProperty vin:hasSugar) (owl:hasValue vin:Dry))))
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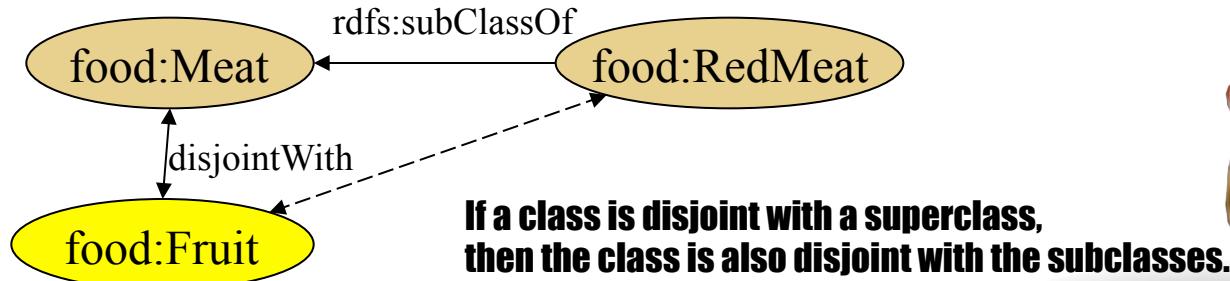


Satisfiability Checking

```
(defConcept TheSpecialCourse (rdf:type owl:Class)
  (owl:intersectionOf
    food:RedMeatCourse
    (owl:Restriction (owl:onProperty food:hasFood)
      (owl:allValuesFrom food:Fruit))))
```

```
(defIndividual No1specialCourse (rdf:type TheSpecialCourse)
  (food:hasFood food:BeefCurry food:Bananas))
```

Error: food:SweetFruit of #<food:SweetFruit food:Bananas> is disjoint to allvaluesFrom #<owl:Class food:RedMeat> in (#<owl:Class food:RedMeatCourse>).

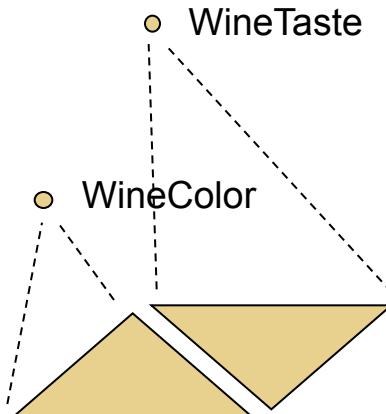


Union of Concepts

```
(get-form vin:WineDescriptor) →
(owl:Class vin:WineDescriptor
(rdfs:comment "Made WineDescriptor unionType of tastes and color")
(owl:unionOf vin:WineTaste vin:WineColor))
```

```
(subsumed-p vin:WineTaste vin:WineDescriptor) → true
(subsumed-p vin:WineColor vin:WineDescriptor) → true
```

```
(typep vin:Red vin:WineDescriptor) → true
```

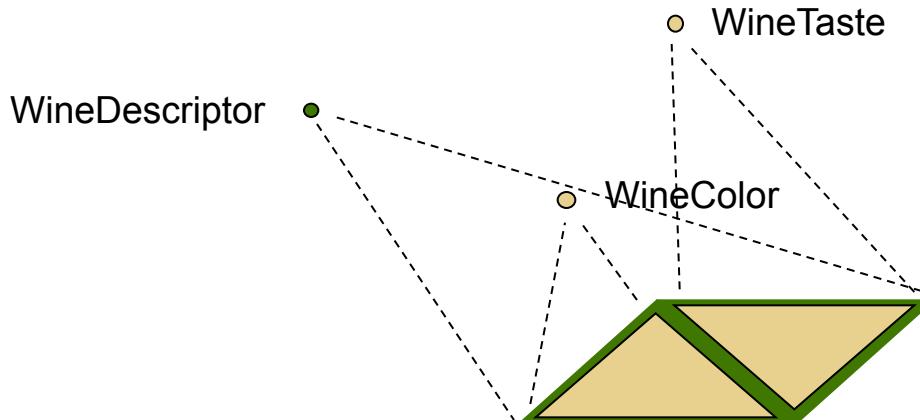


Union of Concepts

```
(get-form vin:WineDescriptor) →
(owl:Class vin:WineDescriptor
(rdfs:comment "Made WineDescriptor unionType of tastes and color")
(owl:unionOf vin:WineTaste vin:WineColor))
```

```
(subsumed-p vin:WineTaste vin:WineDescriptor) → true
(subsumed-p vin:WineColor vin:WineDescriptor) → true
```

```
(typep vin:Red vin:WineDescriptor) → true
```

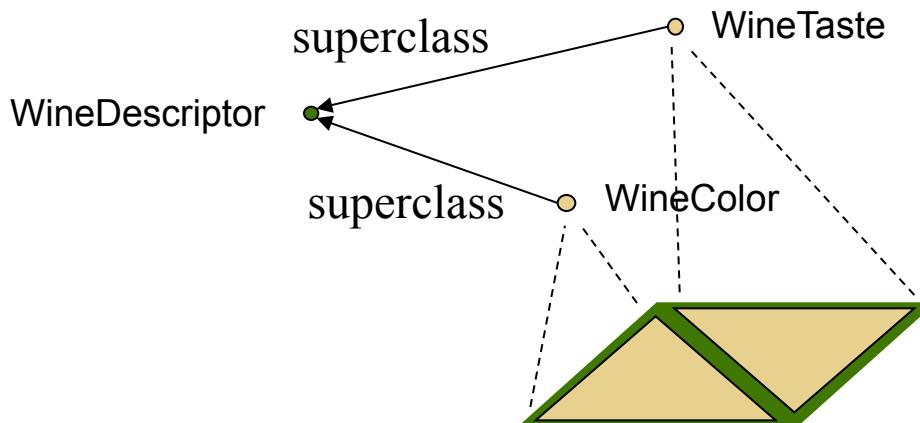


Union of Concepts

```
(get-form vin:WineDescriptor) →
(owl:Class vin:WineDescriptor
  (rdfs:comment "Made WineDescriptor unionType of tastes and color")
  (owl:unionOf vin:WineTaste vin:WineColor))
```

```
(subsumed-p vin:WineTaste vin:WineDescriptor) → true
(subsumed-p vin:WineColor vin:WineDescriptor) → true
```

```
(typep vin:Red vin:WineDescriptor) → true
```

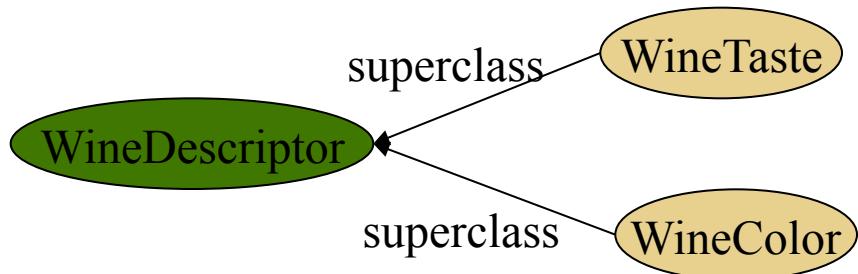


Union of Concepts

```
(get-form vin:WineDescriptor) →
(owl:Class vin:WineDescriptor
(rdfs:comment "Made WineDescriptor unionType of tastes and color")
(owl:unionOf vin:WineTaste vin:WineColor))
```

```
(subsumed-p vin:WineTaste vin:WineDescriptor) → true
(subsumed-p vin:WineColor vin:WineDescriptor) → true
```

```
(typep vin:Red vin:WineDescriptor) → true
```



Complement of a Class

(collect-all-extensions-of owl:complementof) →

((#<owl:Class owl:Nothing> #<owl:Class owl:Thing>)

(#<owl:Class common-lisp:nil> #<owl:Class owl:Nothing>)

(#<owl:Class food:NonConsumableThing> #<owl:Class food:ConsumableThing>)

(disjoint-p food:NonConsumableThing food:ConsumableThing)

→ true

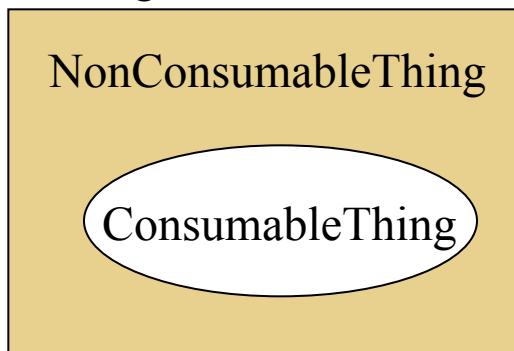
(superclasses-of food:ConsumableThing) →

(#<owl:Class owl:Thing>)

(superclasses-of food:NonConsumableThing) →

(#<owl:Class owl:Thing>)

Thing



Family Ontology

```
(defIndividual Female (rdf:type Gender)
  (owl:differentFrom Male))
```

Warning: Range entail by rdf:type: Gender rdf:type rdfs:Class.

Warning: Subclass of Gender is entailed to owl:Thing by domain constraint of other properties.

Warning: Range entailx3 by owl:differentFrom: Male rdf:type owl:Thing.

```
(defResource Person (rdf:type owl:Class)
  (owl:intersectionOf
```

Human

```
  (owl:Restriction (owl:onProperty hasGender)
    (owl:cardinality 1))))
```

Warning: Range entailx3 by owl:intersectionOf: Human rdf:type owl:Class.

Warning: Range entailx3 by owl:onProperty: hasGender rdf:type rdf:Propert

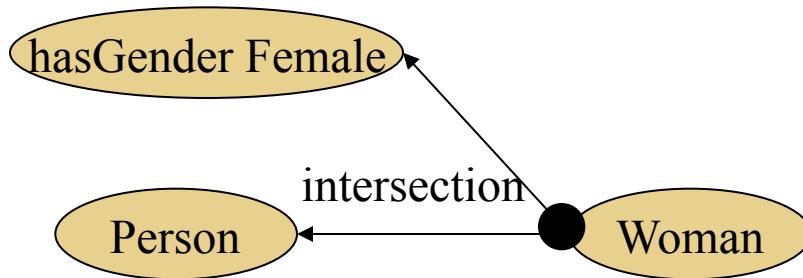
```
(defResource Woman (rdf:type owl:Class)
  (owl:intersectionOf
```

Person

```
  (owl:Restriction (owl:onProperty hasGender)
    (owl:hasValue Female))))
```



Family Ontology

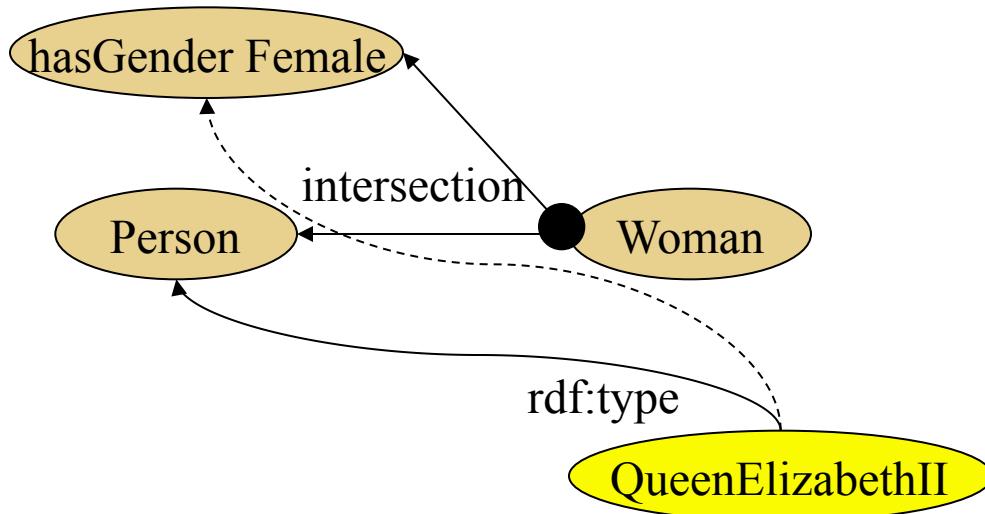


```
(defIndividual QueenElizabethII (rdf:type Person)  
  (hasGender Female))
```

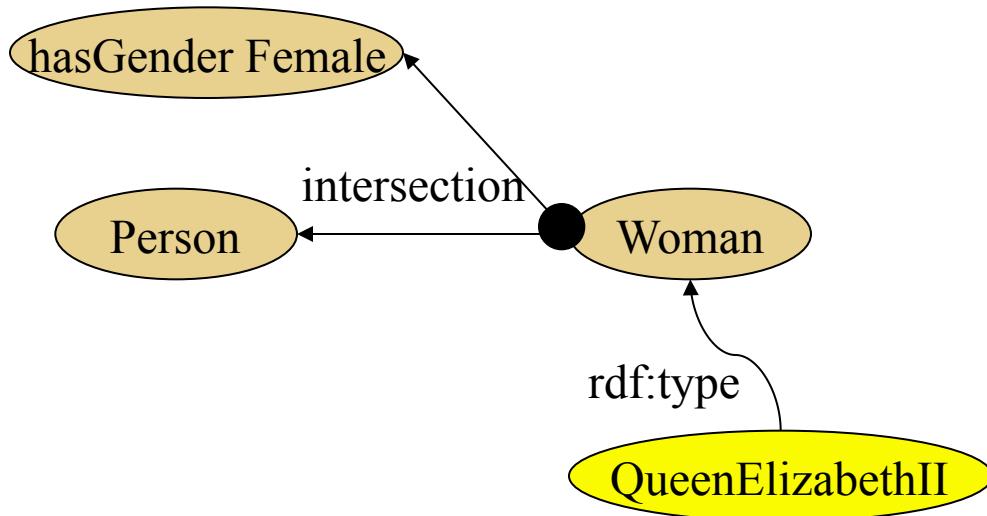
Warning: Entailed in refining: #<Person QueenElizabethII> to Woman.
#<Woman QueenElizabethII>



Family Ontology



Family Ontology



Useful Properties in OWL

- ✿ **owl:FunctionalProperty**
- ✿ **owl:InverseFunctionalProperty**
- ✿ **owl:TransitiveProperty**

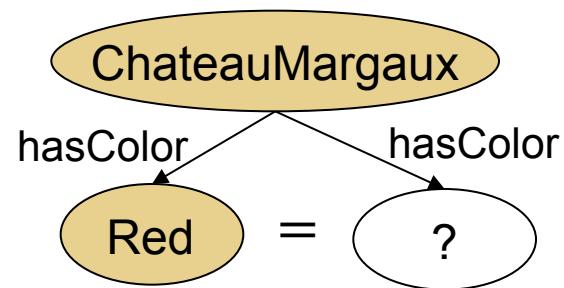


Functional Property

```

(get-form vin:hasColor) →
(owl:objectProperty vin:hasColor
 (rdf:type owl:FunctionalProperty)
 (rdfs:domain vin:wine)
 (rdfs:range vin:wineColor)
 (rdfs:subPropertyOf vin:haswineDescriptor))
(-> vin:ChateauMargaux vin:hasColor) →
(#<owl:Thing food:Red> #<vin:wineColor vin:Red>)
(owl-same-p food:Red vin:Red) → true

```



```

(defIndividual vin:ChateauMargaux (vin:hasColor 赤))
Warning: Range entailx3 by vin:hasColor: 赤 rdf:type vin:wineColor.
Warning: #<vin:wineColor 赤> should be one of (#<vin:wineColor
vin:white> #<vin:wineColor vin:Rose> #<vin:wineColor vin:Red>).
#<vin:Margaux vin:ChateauMargaux>

```

```

(owl-same-p 赤 vin:Red) → true
(-> vin:ChateauMargaux vin:hasColor) →
(#<vin:wineColor 赤> #<owl:Thing food:Red> #<vin:wineColor vin:Red>)

```



Inverse Functional Property

```
(defProperty hasSocialSecurityNumber
  (rdf:type owl:InverseFunctionalProperty)
  (rdfs:domain (owl:Class Person))
  (rdfs:range SocialSecurityNumber)) →
```

Warning: Range entailx3 by rdfs:range:
SocialSecurityNumber rdf:type rdfs:Class.

```
#<owl:InverseFunctionalProperty hasSocialSecurityNumber>
(defIndividual Seiji (rdf:type Person)
```

```
  (hasSocialSecurityNumber
    (SocialSecurityNumber (rdf:value 12345))))
```

```
(defIndividual Koide (rdf:type Person)
  (hasSocialSecurityNumber
```

```
  (SocialSecurityNumber (rdf:value 12345))))
```

```
(owl-same-p Seiji Koide) → true
```



Transitive Property

```

(get-form vin:locatedIn) →
owl:TransitiveProperty vin:locatedIn
  (rdfs:domain owl:Thing) (rdfs:range vin:Region)
(subsumed-p vin:MargauxRegion vin:MedocRegion) → true
(subsumed-p vin:MedocRegion vin:BordeauxRegion) → true
(subsumed-p vin:MargauxRegion vin:BordeauxRegion) → true
(subsumed-p vin:Margaux vin:Medoc) → true
(subsumed-p vin:Medoc vin:Bordeaux) → true
(subsumed-p vin:Margaux vin:Bordeaux) → true
(get-form vin:Margaux) →
  
```

```

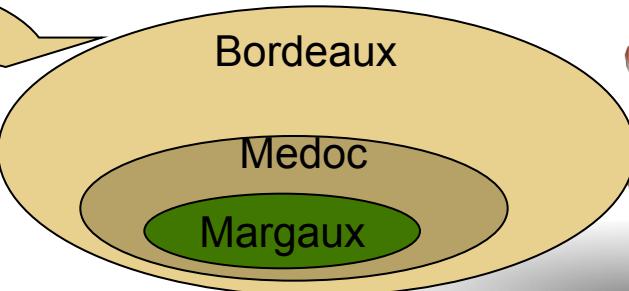
    (owl:hasValueRestriction
      (owl:onProperty vin:locatedIn)
      (owl:hasValue vin:XXX-Region))
  
```

BordeauxRegion



MedocRegion

ELW2009, Jenova



Miscellaneous Utilities

(collect-all-instances vin:Wine) →

```

(#<vin:Beaujolais vin:ChateauMorganBeaujolais> #<vin:Margaux vin:ChateauMargaux>
#<vin:Pauillac vin:ChateauLafiteRothschildPauillac>
#<vin:Sauternes vin:ChateauDYchemSauterne>
#<vin:StEmilion vin:ChateauChevalBlancStEmilion>
#<vin:CotesDOr vin:ClosDeVougeotCotesDOr>
#<vin:whiteBurgundy vin:PulignyMontrachetwhiteBurgundy>
#<vin:whiteBurgundy vin:CortonMontrachetwhiteBurgundy>
#<vin:Meursault vin:ChateauDeMeursaultMeursault>
#<vin:CabernetFranc vin:whitehallLaneCabernetFranc> ...)

```

(dah vin:Wine) →

```

(vin:Wine (vin:Alsatianwine) (vin:Americanwine)
 (vin:Beaujolais vin:ChateauMorganBeaujolais)
 (vin:Bordeaux
  (vin:Medoc (vin:Margaux vin:ChateauMargaux)
   (vin:Pauillac vin:ChateauLafiteRothschildPauillac))
  (vin:RedBordeaux) (vin:Sauternes vin:ChateauDYchemSauterne)
  (vin:StEmilion vin:ChateauChevalBlancStEmilion) (vin:whiteBordeaux))
 (vin:Burgundy (vin:RedBurgundy (vin:CotesDOr vin:ClosDeVougeotCotesDOr))
  (vin:whiteBurgundy (vin:Meursault vin:ChateauDeMeursaultMeursault)))
 (vin:CabernetFranc vin:whitehallLaneCabernetFranc)
 (vin:CabernetSauvignon vin:SantaCruzMountainVineyardCabernetSauvignon
  vin:PageMillWineryCabernetSauvignon vin:MariettaCabernetSauvignon
  vin:FormanCabernetSauvignon)
 (vin:Texaswine) (vin:Californiawine)
 (vin:Chardonnay vin:PeterMcCoyChardonnay vin:MountadamChardonnay
  vin:MountEdenvineyardEdnavalleyChardonnay vin:FormanChardonnay vin:BancroftChardonnay)

```



Conclusion

- ✿ **Semantic Web Processor SWCLOS is demonstrated with hands-on materials.**
- ✿ **SWCLOS is almost completed, but it is still evolving.**
- ✿ **To DO**
 - ✿ **Undo, Dependency, SW-oriented Graph GUI, RDF Gate, SW-REPL, etc.**
- ✿ **Open Source**
 - ✿ **Everything is permitted except change package-name gx , and class name galaxy and galaxy-class**

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