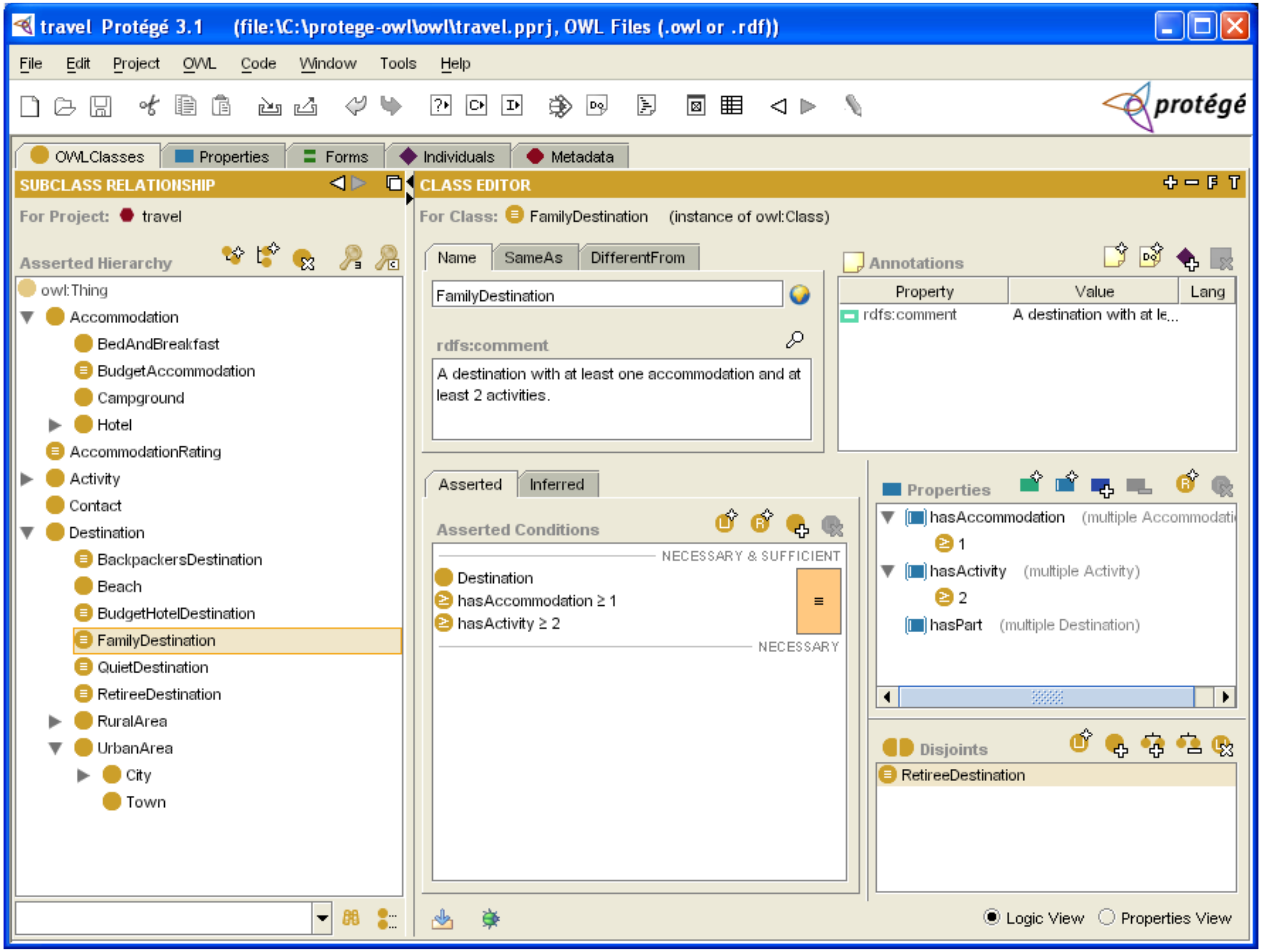
# Chapter 3
## RDF Schema

# Introduction

- RDF has a very simple data model
- RDF Schema (RDFS) enriches the data model, adding vocabulary and associated semantics for
  - Classes and subclasses
  - Properties and sub-properties
  - Typing of properties
- Support for describing simple ontologies
- Adds an object-oriented flavor
- But with a logic-oriented approach and using "open world" semantics

# RDFS is a simple KB Language




Several widely used Knowledge-Base tools can import and export in RDFS, including Stanford's Protégé KB editor

# RDFS Vocabulary

**RDFS introduces the following terms, giving each a meaning w.r.t. the rdf data model**

- Terms for classes
  - rdfs:Class
  - rdfs:subClassOf
- Terms for properties
  - rdfs:domain
  - rdfs:range
  - rdfs:subPropertyOf
- Special classes
  - rdfs:Resource
  - rdfs:Literal
  - rdfs:Datatype
- Terms for collections
  - rdfs:member
  - rdfs:Container
  - rdfs:ContainerMembershipProperty
- Special properties
  - rdfs:comment
  - rdfs:seeAlso
  - rdfs:isDefinedBy
  - rdfs:label

# Modeling the semantics in logic

- We could represent any triple with a binary predicate, e.g.
  - type(john, human)
  - age(john, 32)
  - subclass(human, animal)
- But traditionally we model a classes as a unary predicate
  - human(john)
  - age(john, 32)
  - subclass(human, animal)

# Classes and Instances

- We must distinguish between
  - Concrete "things" (individual objects) in the domain: *Discrete Math*, *Richard Chang,* etc.
  - Sets of individuals sharing properties called **classes**: lecturers, students, courses etc.
- Individual objects that belong to a class are referred to as **instances** of that class
- The relationship between instances and classes in RDF is through **rdf:type**

# Classes are Useful

Classes let us impose restrictions on what can be stated in an RDF document using the schema

- As in programming languages
  - E.g. A+1, where A is an array
- Disallow nonsense from being stated

# Preventing nonsensical Statements

- *Discrete Math* is taught by *Calculus*
  - We want courses to be taught by lecturers only
  - Restriction on values of the property *“is taught by”* (**range restriction**)
- *Room ITE228* is taught by *Richard Chang*
  - Only courses can be taught
  - This imposes a restriction on the objects to which the property can be applied (**domain restriction**)

# Class Hierarchies

- Classes can be organized in hierarchies
  - A is a **subclass** of B if every instance of A is also an instance of B
  - We also say that B is a **superclass** of A
- A subclass graph needn't be a tree
  - A class may have multiple superclasses
- In logic:
  - subclass(p, q) ⇔ p(x) => q(x)
  - subclass(p, q) ∧ p(x) => q(x)

# Domain and Range

- The domain and range properties let us associate classes with a property's subject and object, e.g.
- Only a course can be taught
  - domain(isTaughtBy, course)
- Only an academic staff member can teach
  - range(isTaughtBy, academicStaffMember)
- Semantics in logic:
  - domain(pred, aclass) $\wedge$ pred(subj, obj) => aclass(subj)
  - range(pred, aclass) $\wedge$ pred(subj, obj) => aclass(obj)

# Property Hierarchies

- Hierarchical relationships for properties
  - E.g., “is taught by” is a subproperty of “involves”
  - If a course C is taught by an academic staff member A, then C also involves A
- The converse is not necessarily true
  - E.g., A may be the teacher of the course C, or a TA who grades student homework but doesn’t teach
- Semantics in logic
  - subproperty(p, q) $\wedge$ p(subj, obj) => q(sub,obj)
  - e.g, subproperty(mother,parent), mother(p1, p2) => parent(p1, p2)

# RDF Layer vs RDF Schema Layer

- Discrete Math is taught by Richard Chang
- The schema is itself written in a formal language, RDF Schema, that can express its ingredients:
  - subClassOf, Class, Property, subPropertyOf, Resource, etc.

# RDF Schema in RDF

- RDFS’s modeling primitives are defined using resources and properties (RDF itself is used!)
- To declare that *“lecturer”* is a subclass of *“academic staff member”*
  - Define resources **lecturer**, **academicStaffMember**, and **subClassOf**
  - define property **subClassOf**
  - Write triple (**subClassOf, lecturer, academicStaffMember**)
- We use the XML-based syntax of RDF

# Core Classes

- **rdfs:Resource**: class of all resources
- **rdfs:Class**: class of all classes
- **rdfs:Literal**: class of all literals (strings)
- **rdf:Property**: class of all properties
- **rdf:Statement**: class of all reified statements

# Core Properties

- **rdf:type**: relates a resource to its class

  The resource is declared to be an instance of that class

- **rdfs:subClassOf**: relates a class to one of its superclasses

  All instances of a class are instances of its superclass

- **rdfs:subPropertyOf**: relates a property to one of its superproperties

# Core Properties

- **rdfs:domain**: specifies the domain of a property P
  - The class of those resources that may appear as subjects in a triple with predicate P
  - If the domain is not specified, then any resource can be the subject
- **rdfs:range**: specifies the range of a property P
  - The class of those resources that may appear as values in a triple with predicate P

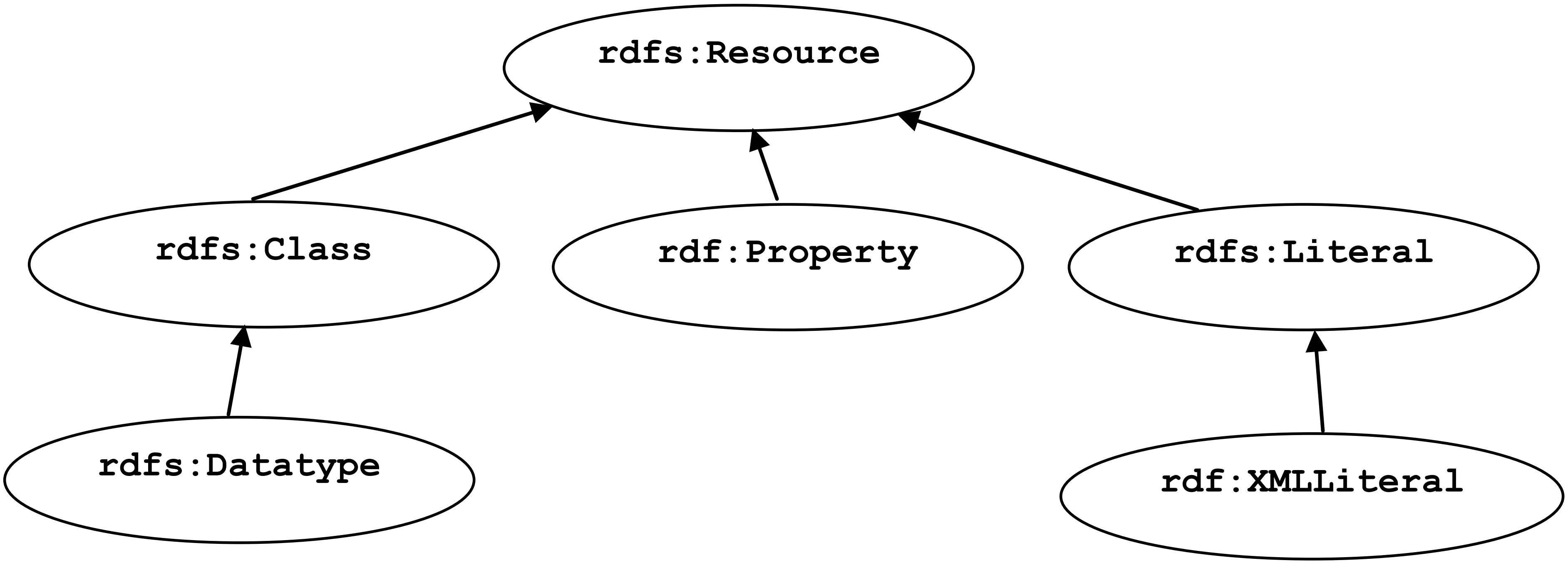
# Examples

```
<rdfs:Class rdf:about="#lecturer">
  <rdfs:subClassOf rdf:resource="#staffMember"/>
</rdfs:Class>

<rdf:Property rdf:ID="phone">
        <rdfs:domain rdf:resource="#staffMember"/>
        <rdfs:range rdf:resource="http://www.w3.org/
                2000/01/rdf-schema#Literal"/>
</rdf:Property>
```

# Relationships: Core Classes & Properties

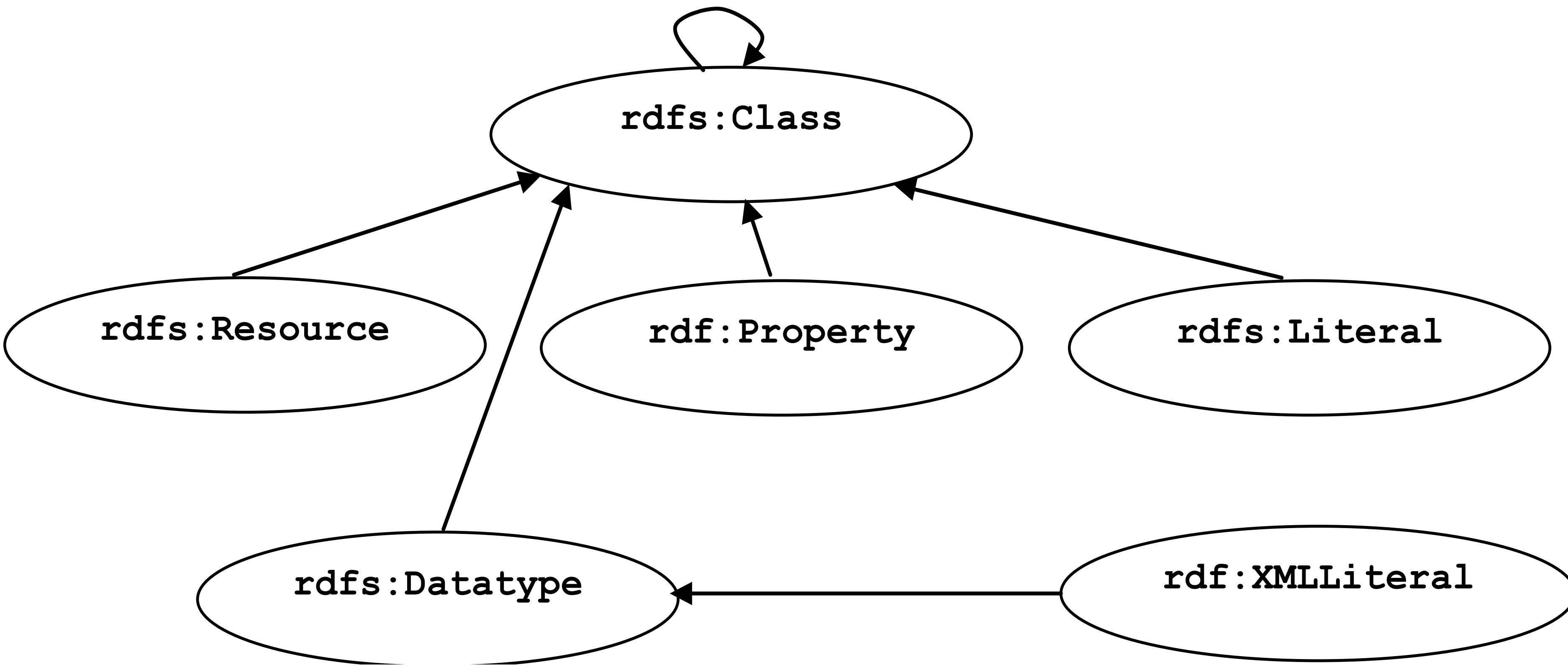
- **rdfs:subClassOf** and **rdfs:subPropertyOf** are transitive, by definition
- **rdfs:Class** is a subclass of **rdfs:Resource**
  - Because every class is a resource
- **rdfs:Resource** is an instance of **rdfs:Class**
  - **rdfs:Resource** is the class of all resources, so it is a class
- Every class is an instance of **rdfs:Class**
  - For the same reason

# Subclass Hierarchy of RDFS Primitives



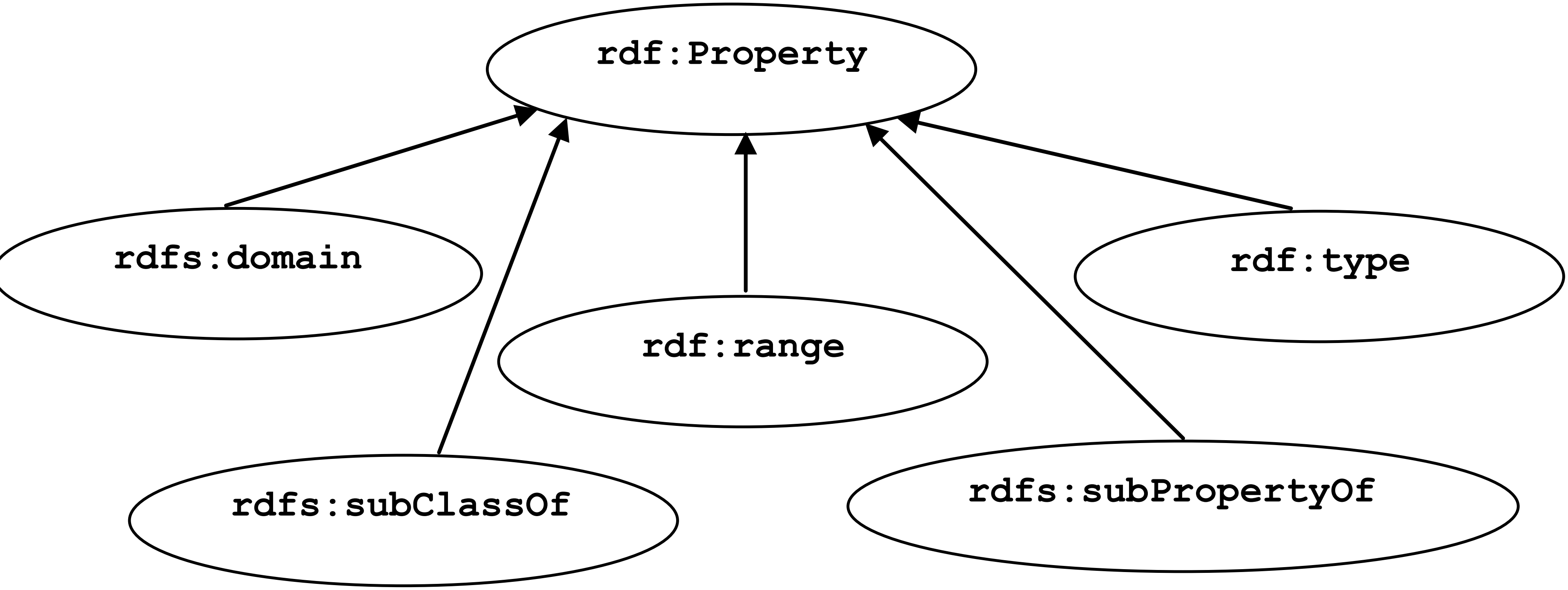

arrows represent the rdfs:subClassOf relation

# Instance Relationships of RDFS Primitives




arrows represent the rdf:type relation

# RDF and RDFS Property Instances




arrows represent the rdf:type relation

# Reification and Containers

- **rdf:subject**: relates a reified statement to its subject
- **rdf:predicate**: relates a reified statement to its predicate
- **rdf:object**: relates a reified statement to its object
- **rdf:Bag**: the class of bags
- **rdf:Seq**: the class of sequences
- **rdf:Alt**: the class of alternatives
- **rdfs:Container**: a superclass of all container classes, including the three above

# Utility Properties

- **rdfs:seeAlso** relates a resource to another resource that explains it
- **rdfs:isDefinedBy:** a subproperty of **rdfs:seeAlso** that relates a resource to the place where its definition, typically an RDF schema, is found
- **rfds:comment**. Comments, typically longer text, can be associated with a resource
- **rdfs:label**. A human-friendly label (name) is associated with a resource

# Ex: University Lecturers – Prefix

```
<rdf:RDF
    xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
    xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"


>
```

# Ex: University Lecturers -- Classes

```
<rdfs:Class rdf:ID="staffMember">
    <rdfs:comment>The class of staff members </rdfs:comment>
</rdfs:Class>

<rdfs:Class rdf:ID="academicStaffMember">
    <rdfs:comment>The class of academic staff members </rdfs:comment>
    <rdfs:subClassOf rdf:resource="#staffMember"/>
</rdfs:Class>

<rdfs:Class rdf:ID="lecturer">
    <rdfs:comment> The class of lecturers. All lecturers are academic staff
    members.
    </rdfs:comment>
    <rdfs:subClassOf rdf:resource="#academicStaffMember"/>
</rdfs:Class>

<rdfs:Class rdf:ID="course">
    <rdfs:comment>The class of courses</rdfs:comment>
</rdfs:Class>
```

# Ex: University Lecturers -- Properties

```
<rdf:Property rdf:ID="isTaughtBy">
   <rdfs:comment>Assigns lecturers to courses. </rdfs:comment>
   <rdfs:domain rdf:resource="#course"/>
   <rdfs:range rdf:resource="#lecturer"/>
</rdf:Property>
<rdf:Property rdf:ID="teaches">
   <rdfs:comment>Assigns courses to lecturers. </rdfs:comment>
   <rdfs:domain rdf:resource="#lecturer"/>
   <rdfs:range rdf:resource="#course"/>
</rdf:Property>
```

# Ex: University Lecturers -- Instances

```
<uni:lecturer rdf:ID="949318"
    uni:name="Richard Chang"
    uni:title="Associate Professor">
    <uni:teaches rdf:resource="#CIT1111"/>
    <uni:teaches rdf:resource="#CIT3112"/>
</uni:lecturer>
<uni:lecturer rdf:ID="949352"
    uni:name="Grigoris Antoniou"
    uni:title="Professor">
    <uni:teaches rdf:resource="#CIT1112"/>
    <uni:teaches rdf:resource="#CIT1113"/>
</uni:lecturer>
<uni:course rdf:ID="CIT1111"
    uni:courseName="Discrete Mathematics">
    <uni:isTaughtBy rdf:resource="#949318"/>
</uni:course>
<uni:course rdf:ID="CIT1112"
    uni:courseName="Concrete Mathematics">
    <uni:isTaughtBy rdf:resource="#949352"/>
</uni:course>
```

# Example: A University

<rdfs:Class rdf:ID="lecturer">

<rdfs:comment>

The class of lecturers. All lecturers are academic staff members.

</rdfs:comment>

<rdfs:subClassOf rdf:resource="#academicStaffMember"/>

</rdfs:Class>

# Example: A University

```
<rdfs:Class rdf:ID="course">
  <rdfs:comment>The class of courses</rdfs:comment>
</rdfs:Class>

<rdf:Property rdf:ID="isTaughtBy">
  <rdfs:comment>
    Inherits its domain ("course") and range ("lecturer")
    from its superproperty "involves”
  </rdfs:comment>
  <rdfs:subPropertyOf rdf:resource="#involves"/>
</rdf:Property>
```

# Example: A University

```
<rdf:Property rdf:ID="phone">
  <rdfs:comment>
    It is a property of staff members
    and takes literals as values.
  </rdfs:comment>
  <rdfs:domain rdf:resource="#staffMember"/>
  <rdfs:range rdf:resource="http://www.w3.org/
    2000/01/rdf-schema#Literal"/>
</rdf:Property>
```

# RDF and RDFS Namespaces

- The RDF, RDFS and OWL namespaces specify some constraints on the 'languages'
  - http://www.w3.org/1999/02/22-rdf-syntax-ns#
  - http://www.w3.org/2000/01/rdf-schema#
  - http://www.w3.org/2002/07/owl#
- Strangely, each uses terms from all three to define its own terms
- Don't be confused: the real semantics of the terms isn't specified in the namespace files

# RDF Namespace

```
<rdf:RDF
   xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
   xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
   xmlns:owl="http://www.w3.org/2002/07/owl#"
   xmlns:dc="http://purl.org/dc/elements/1.1/">

 <owl:Ontology
    rdf:about="http://www.w3.org/2000/01/rdf-schema#"
    dc:title="The RDF Schema vocabulary (RDFS)"/>

<rdfs:Class rdf:about="http://www.w3.org/2000/01/rdf-schema#Resource">
  <rdfs:isDefinedBy rdf:resource="http://www.w3.org/2000/01/rdf-schema#"/>
  <rdfs:label>Resource</rdfs:label>
  <rdfs:comment>The class resource, everything.</rdfs:comment>
</rdfs:Class>

…
```

# RDF Namespace example

This example shows how RDFS terms are used to say something important about the RDF *predicate* property

```
<rdf:Property
        rdf:ID="predicate"
        rdfs:comment="Identifies the property of a
                      statement in reified form"/>
  <rdfs:domain rdf:resource="#Statement"/>
  <rdfs:range rdf:resource="#Property"/>
</rdf:Property>
```

# RDF Namespace

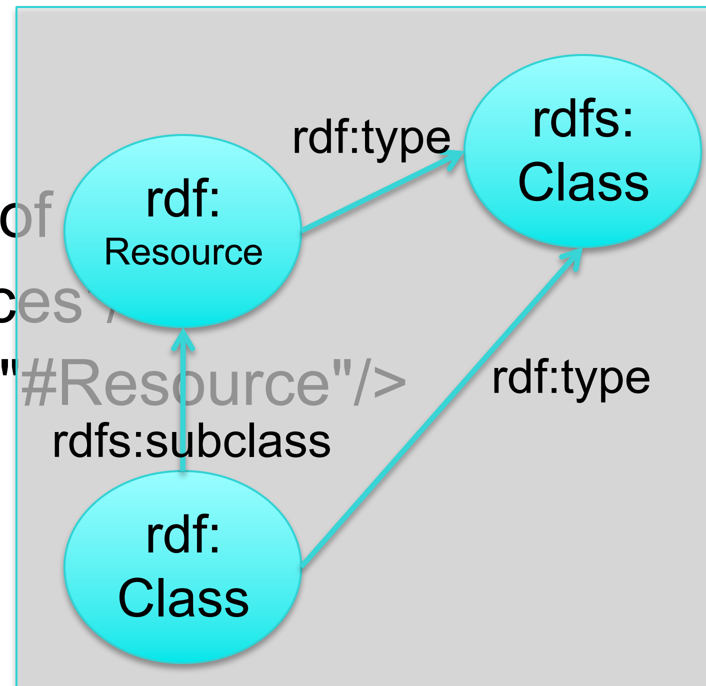
Define rdf:Resource and rdf:Class as instances of rdfs:Class & rdf:Class as a subclass of rdf:Resource

```
<rdfs:Class rdf:ID="Resource"
        rdfs:comment="The most general class"/>

<rdfs:Class rdf:ID="Class"
            rdfs:comment="The concept of classes.
                    All classes are resources"/>
        <rdfs:subClassOf rdf:resource="#Resource"/>
</rdfs:Class>
```

# RDF Namespace

Define rdf:Resource and rdf:Class as instances of rdfs:Class & rdf:Class as a subclass of rdf:Resource

```
<rdfs:Class rdf:ID="Resource"
      rdfs:comment="The most general class"/>

<rdfs:Class rdf:ID="Class"
         rdfs:comment="The concept of
                All classes are resources"/>
      <rdfs:subClassOf rdf:resource="#Resource"/>
</rdfs:Class>
```



# RDFS Namespace

```
<rdf:RDF … xmlns:dc="http://purl.org/dc/elements/1.1/">
…
<rdfs:Class rdf:about="http://www.w3.org/2000/01/rdf-schema#Class">
  <rdfs:isDefinedBy rdf:resource="http://www.w3.org/2000/01/rdf-schema#"/>
  <rdfs:label>Class</rdfs:label>
  <rdfs:comment>The class of classes.</rdfs:comment>
  <rdfs:subClassOf rdf:resource="http://www.w3.org/2000/01/rdf-schema#Resource"/>
</rdfs:Class>

<rdf:Property rdf:about="http://www.w3.org/2000/01/rdf-schema#subClassOf">
  <rdfs:isDefinedBy rdf:resource="http://www.w3.org/2000/01/rdf-schema#"/>
  <rdfs:label>subClassOf</rdfs:label>
  <rdfs:comment>The subject is a subclass of a class.</rdfs:comment>
  <rdfs:range rdf:resource="http://www.w3.org/2000/01/rdf-schema#Class"/>
  <rdfs:domain rdf:resource="http://www.w3.org/2000/01/rdf-schema#Class"/>
</rdf:Property>
    …
```

# Namespaces vs. Semantics

- Consider **rdfs:subClassOf**
  - The namespace specifies only that it applies to classes and has a class as a value
  - The meaning of being a subclass not specified
- The meaning cannot be expressed in RDF
  - If it could RDF Schema would be unnecessary
- External definition of semantics required
  - Respected by RDF/RDFS processing software

# RDFS vs. OO Models

- In OO models, an object class defines the properties that apply to it
  - Adding a new property means modifying the class
- In RDF, properties are defined globally and aren't encapsulated as attributes in the class definition
  - One can define new properties w/o changing the class
  - Properties can have properties

    :mother rdfs:subPropertyOf :parent; rdf:type :FamilyRelation.
  - You can't narrow the domain and range of properties in a subclass

# Example

```
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix bio: <http://example.com/biology#> .
bio:Animal a rdfs:Class.
Bio:offspring a rdfs:Property;
   rdfs:domain bio:Animal;
   rdfs:range bio:Animal.
bio:Human rdfs:subClassOf bio:Animal.
bio:Dog rdfs:subClassOf bio:Animal.
:fido a bio:Dog.
:john a bio:Human;
   bio:offspring :fido.
```

There is no way to say that the offspring of humans are humans and the offspring of dogs are dogs.

# Example

Bio:child rdfs:subPropertyOf bio:offspring;
  rdfs:domain bio:Human;
  rdfs:range bio:Human.
Bio:puppy rdfs:subPropertyOf bio:offspring;
  rdfs:domain bio:Dog;
  rdfs:range bio:Dog.
:john bio:child :mary.
:fido bio:puppy :rover.

What do we know after each of the last two triples are asserted?

Suppose we also assert:
- :john bio:puppy :rover
- :john bio:child :fido

# Not like types in OO systems

- Classes differ from types in OO systems in how they are used.
  - They are not *constraints* on well-formedness
- The lack of *negation* and the *open world assumption* in RDF+RDFS make it impossible to detect contradictions
  - Can't say that Dog and Human are disjoint classes
  - Not knowing that there are individuals who are both doesn't mean it's not true

# No disjunctions or union types

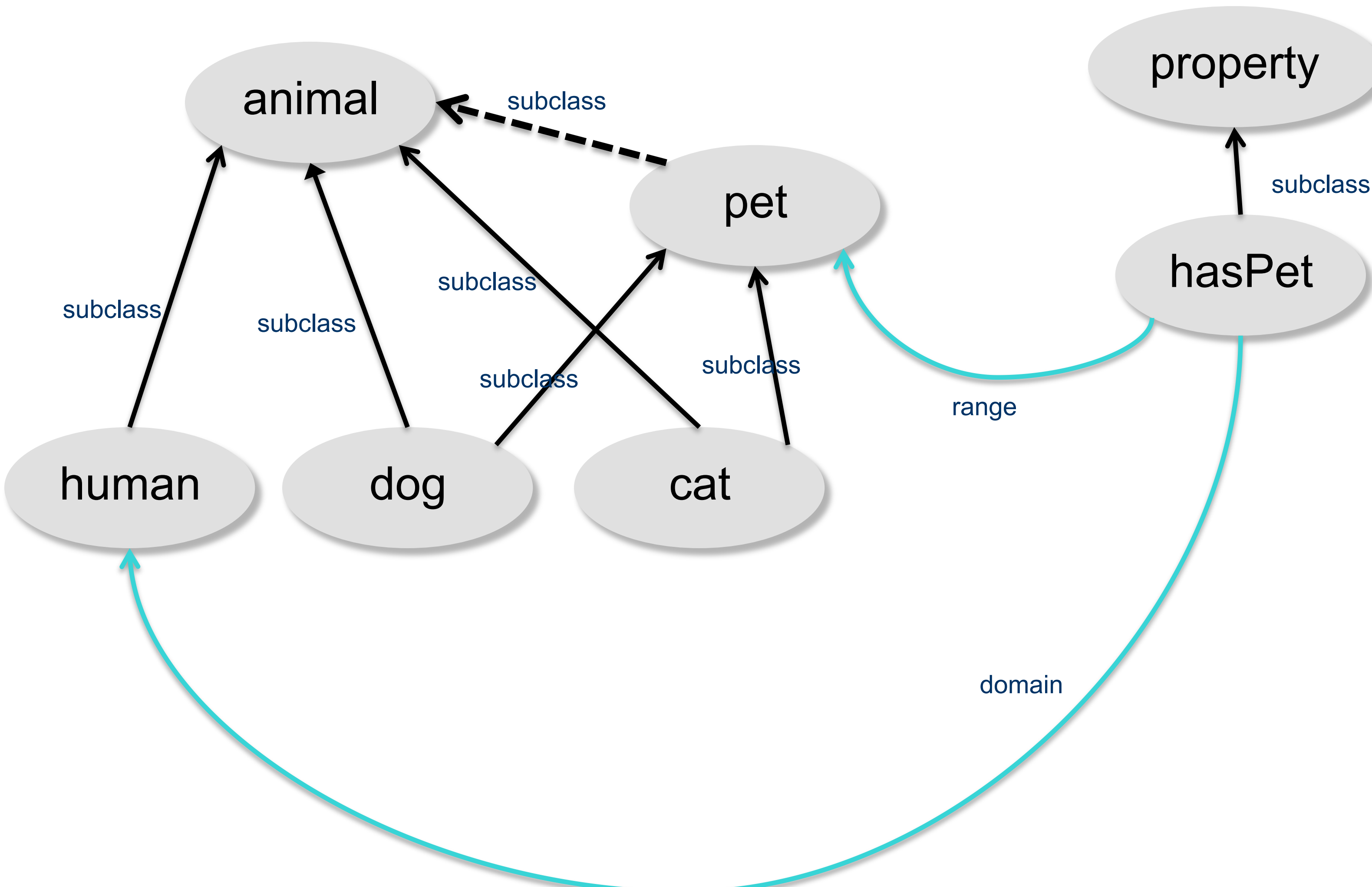
What does this mean?

```
Bio:Human rdfs:subClassOf bio:Animal.
bio:Cat rdfs:subClassOf bio:Animal.
Bio:Dog rdfs:subClassOf bio:Animal.
bio:hasPet a rdfs:Property;
  rdfs:domain bio:Human;
  rdfs:range bio:Dog;
  rdfs:range bio:Cat.
```

# What do we want to say?

- There are many different possibilities
  - Only a dog or a cat can be the object of a hasPet property.
  - Dogs and cats and maybe other animals are possible as pets.
  - Dogs and cats and maybe other things, not necessarily animals, are possible as pets.
  - All dogs and all cats are pets.
  - It is possible for some dogs and for some cats to be pets.
- Not all of these can be said in RDF+RDFS

# What do we want to say?



# Classes and individuals are not disjoint

- In OO systems a thing is either a class or object
  - Many KR systems are like this: you are either an instance or a class, not both.
- Not so in RDFS

  bio:Species rdf:type rdfs:Class.

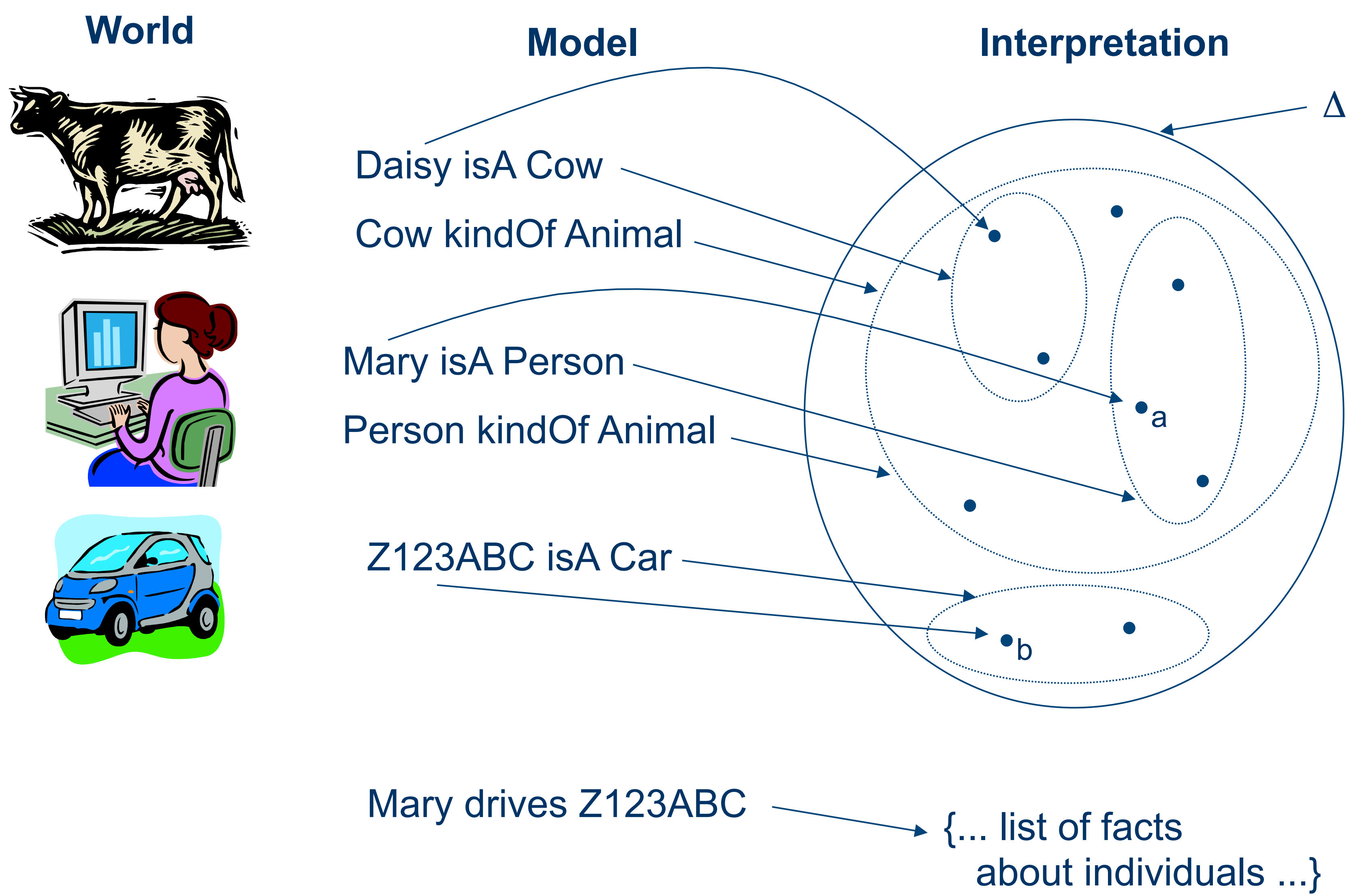
  bio:Dog rdf:type rdfs:Species; rdfs:subClassOf bio:Animal.

  :fido rdf:type bio:Dog.
- Adds richness to the language but causes problems, too
  - In OWL lite and OWL DL you can’t do this.
  - OWL has it’s own notion of a Class, owl:Class

# Inheritance is simple

- No defaults, overriding, shadowing
- What you say about a class is necessarily true of all sub-classes
- A class’ properties are not inherited by its members.
  - Can’t say “Dog’s are normally friendly” or even “All dogs are friendly”
  - The meaning of the Dog class is a set of individuals

# *Set Based Model Theory Example*



# Is RDF(S) better than XML?

Q: For a specific application, should I use XML or RDF?

A: It depends…

- XML's model is
  - a tree, i.e., a strong hierarchy
  - applications may rely on hierarchy position
  - relatively simple syntax and structure
  - not easy to *combine* trees
- RDF's model is
  - a *loose* collections of relations
  - applications may do “database”-like search
  - not easy to recover hierarchy
  - easy to combine relations in one big collection
  - great for the integration of heterogeneous information

# Problems with RDFS

- RDFS **too weak** to describe resources in sufficient detail, e.g.:
  - No *localised range and domain* constraints

    Can’t say that the range of hasChild is person when applied to persons and elephant when applied to elephants
  - No *existence/cardinality* constraints

    Can’t say that all *instances* of person have a mother that is also a person, or that persons have exactly 2 parents
  - No *transitive, inverse or symmetrical* properties

    Can’t say that isPartOf is a transitive property, that hasPart is the inverse of isPartOf or that touches is symmetrical
- We need RDF terms providing these and other features.

# Conclusions

- RDF is a simple data model based on a graph
  - Independent on any serialization (e.g., XML or N3)
- RDF has a formal semantics providing a dependable basis for reasoning about the meaning of RDF expressions
- RDF has an extensible URI-based vocabulary
- RDF has an XML serialization and can use values represented as XML schema datatypes
- Anyone can make statements about any resource (open world assumption)
- RDFS builds on RDF's foundation by adding vocabulary with well defined semantics (e.g., Class, subClassOf, etc.)
- OWL addresses some of RDFS's limitations adding richness (and complexity).