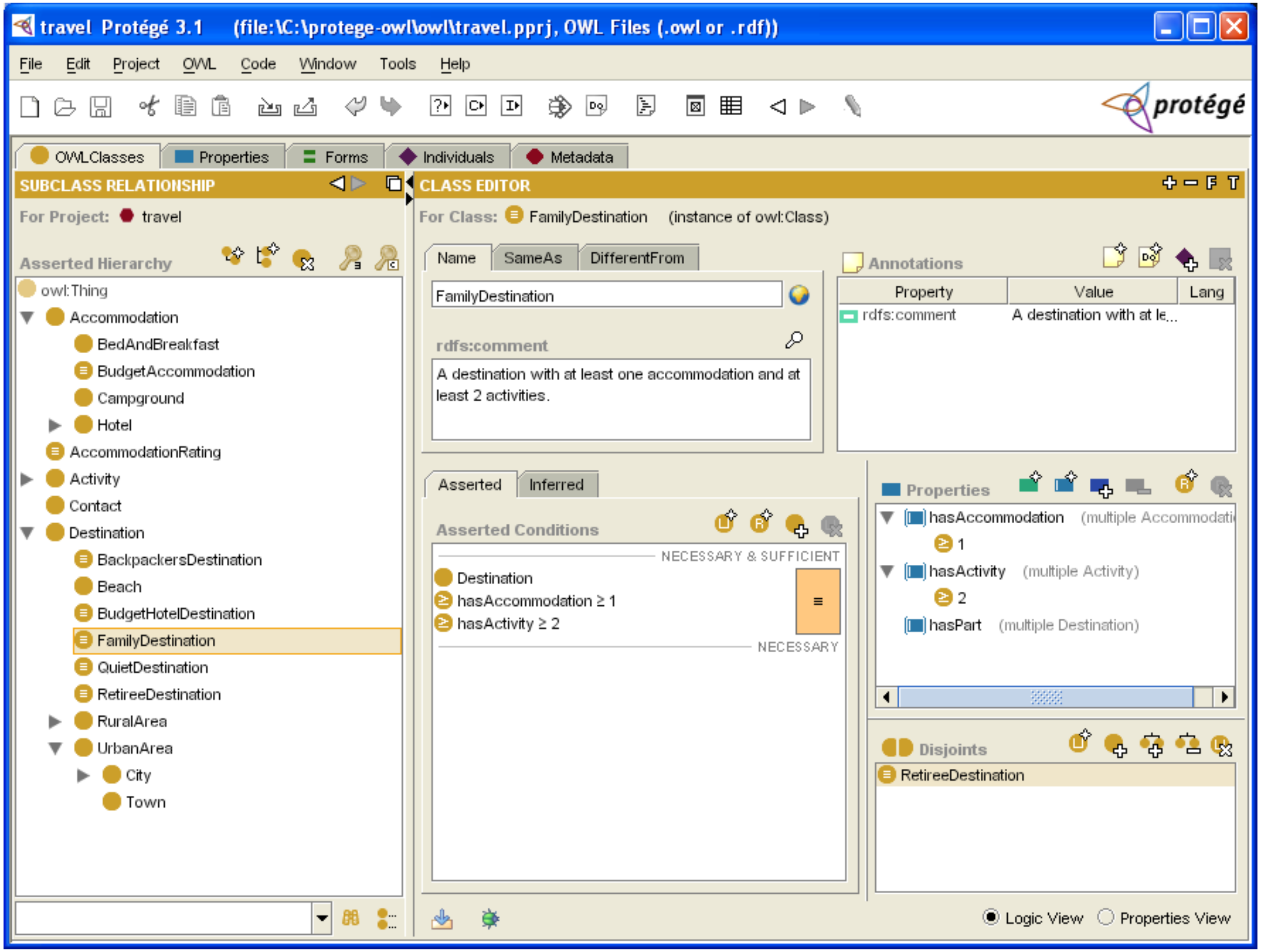
# Chapter 3

## RDF Schema

# Introduction

- RDF has a very simple data model
- RDF Schema (RDFS) enriches the data model, adding vocabulary & 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

**@PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>**

# Modeling the semantics in logic

- We could represent any RDF triple with a binary predicate in logic, e.g.

  **type(john, human)**
  age(john, 32)
  subclass(human, animal)

- But traditionally we model a class as a unary predicate

**human(john)**
age(john, 32)
subclass(human, animal)

# Classes and Instances

- We 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 belonging to a class are referred to as **instances** of that class
- Relationship between instances and classes in RDF is through **rdf:type**
- Note similarity to *classes* and *objects* in an OO prog. language (but RDF classes stand for **sets**)

# 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 by detecting contradictions
- Allow us to infer a type of an object from how it is used -- like type inference in a programming language

# 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 and only if every instance of A is also an instance of B
  - We also say that B is a **superclass** of 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 & range properties let us associate classes with a property’s subject and object
- 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 Schema in RDF

- RDFS's modelling 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**)

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

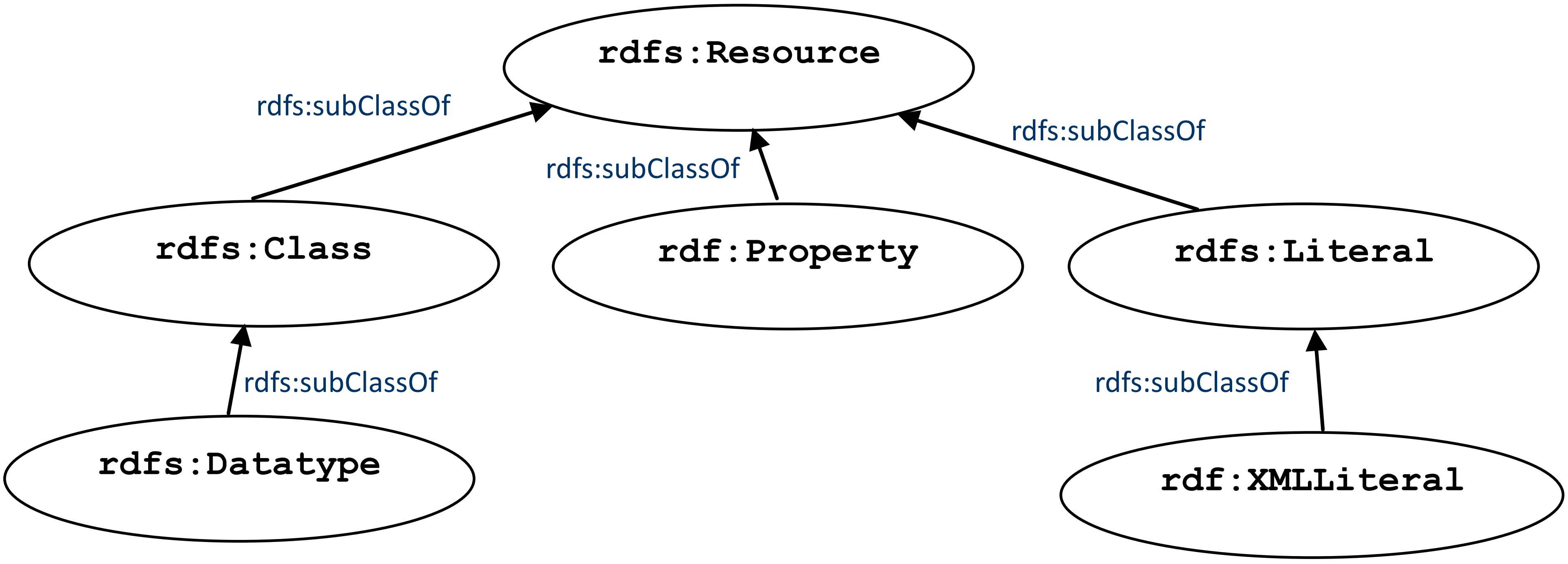
# Examples (in Turtle)

```
:lecturer a rdfs:Class;
        rdfs:subCLassOf :staffMember .

:phone a rdfs:Class;
      rdfs:domain :staffMember;
      rdfs:range rdfs:Literal .
```

# Relationships: Core Classes & Properties

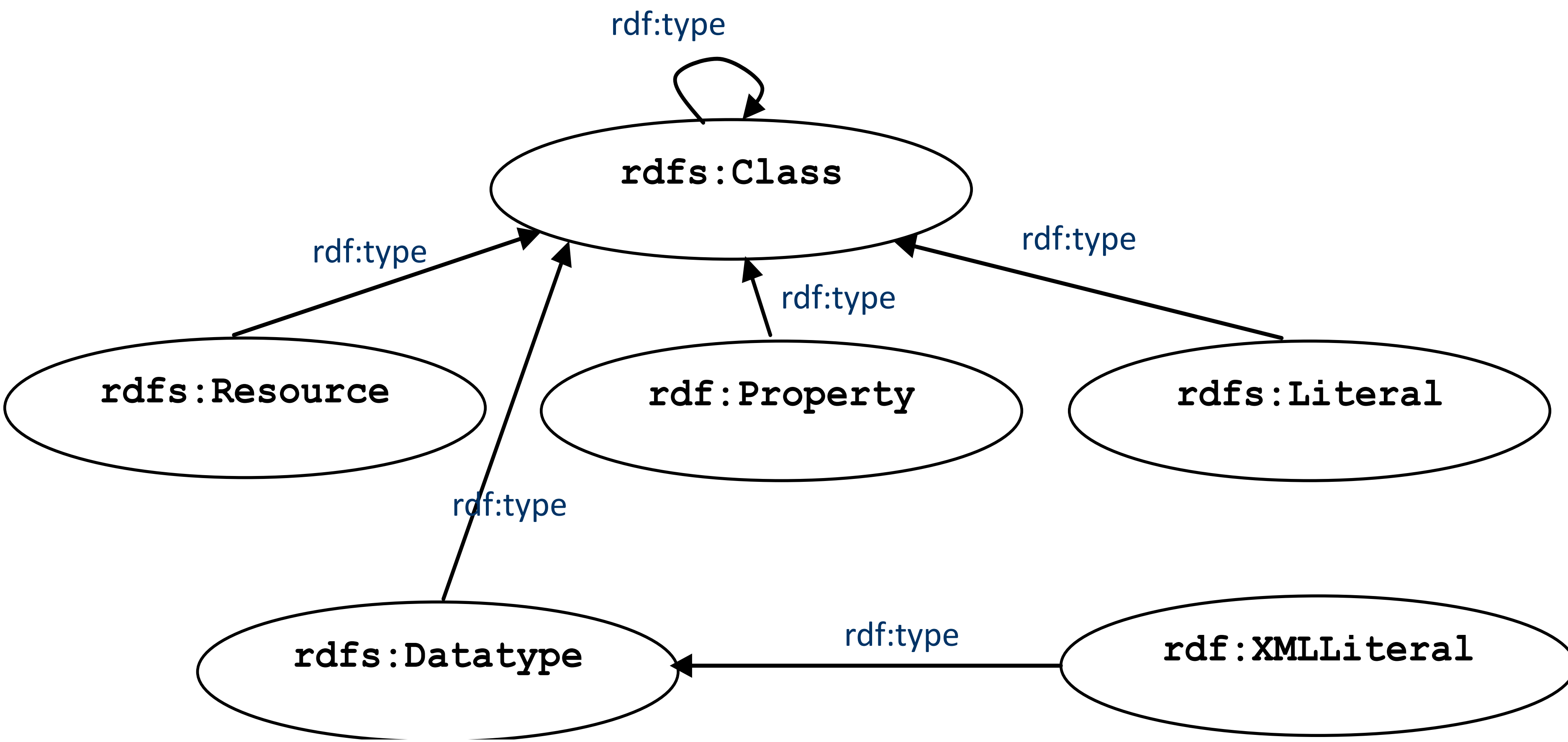
- **rdfs:subClassOf** and **rdfs:subPropertyOf** are transitive, by definition
- **rdfs:Class** is a subclass of **rdfs:Resource**
  - Because every class is a resource
- **rdfs:Resource** is an instance of **rdfs:Class**
  - **rdfs:Resource** is class of all resources, so it is a class
- Every class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

# Subclass Hierarchy of RDFS Primitives



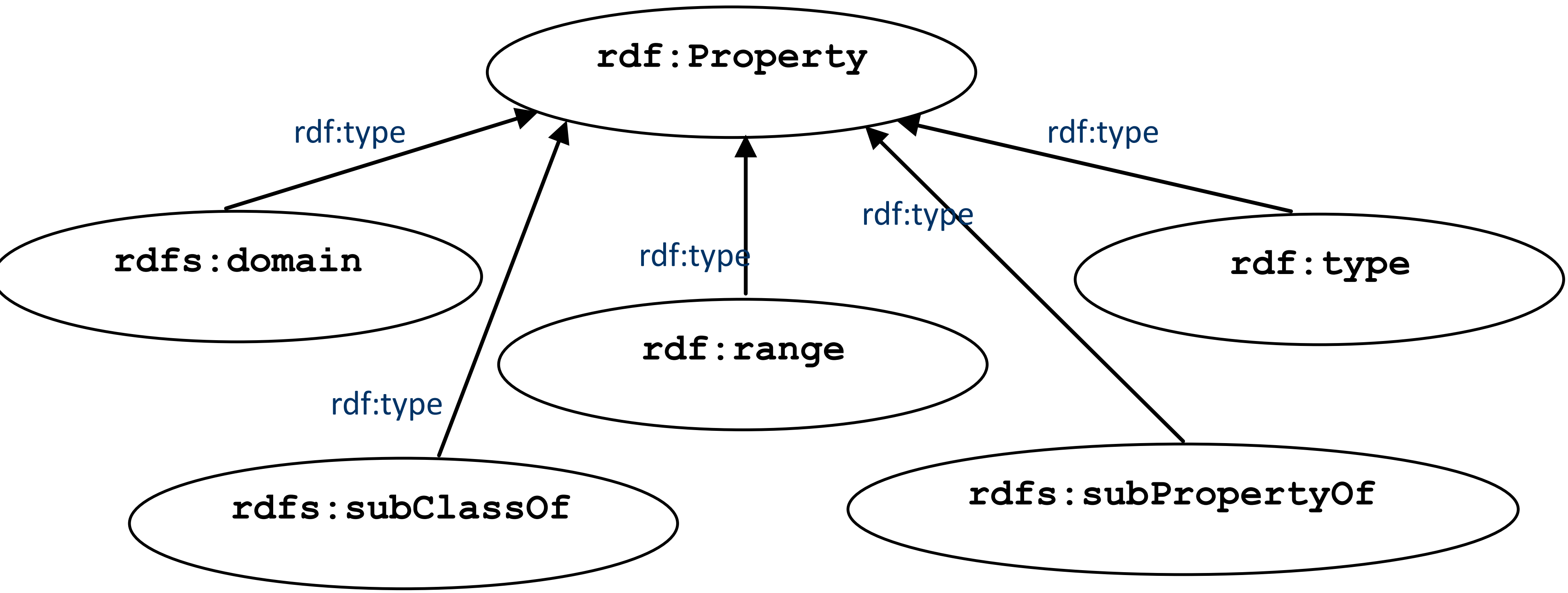

arrows represent the rdfs:subClassOf relation

# Instance Relationships of RDFS Primitives




arrows represent the rdf:type relation

# RDF and RDFS Property Instances

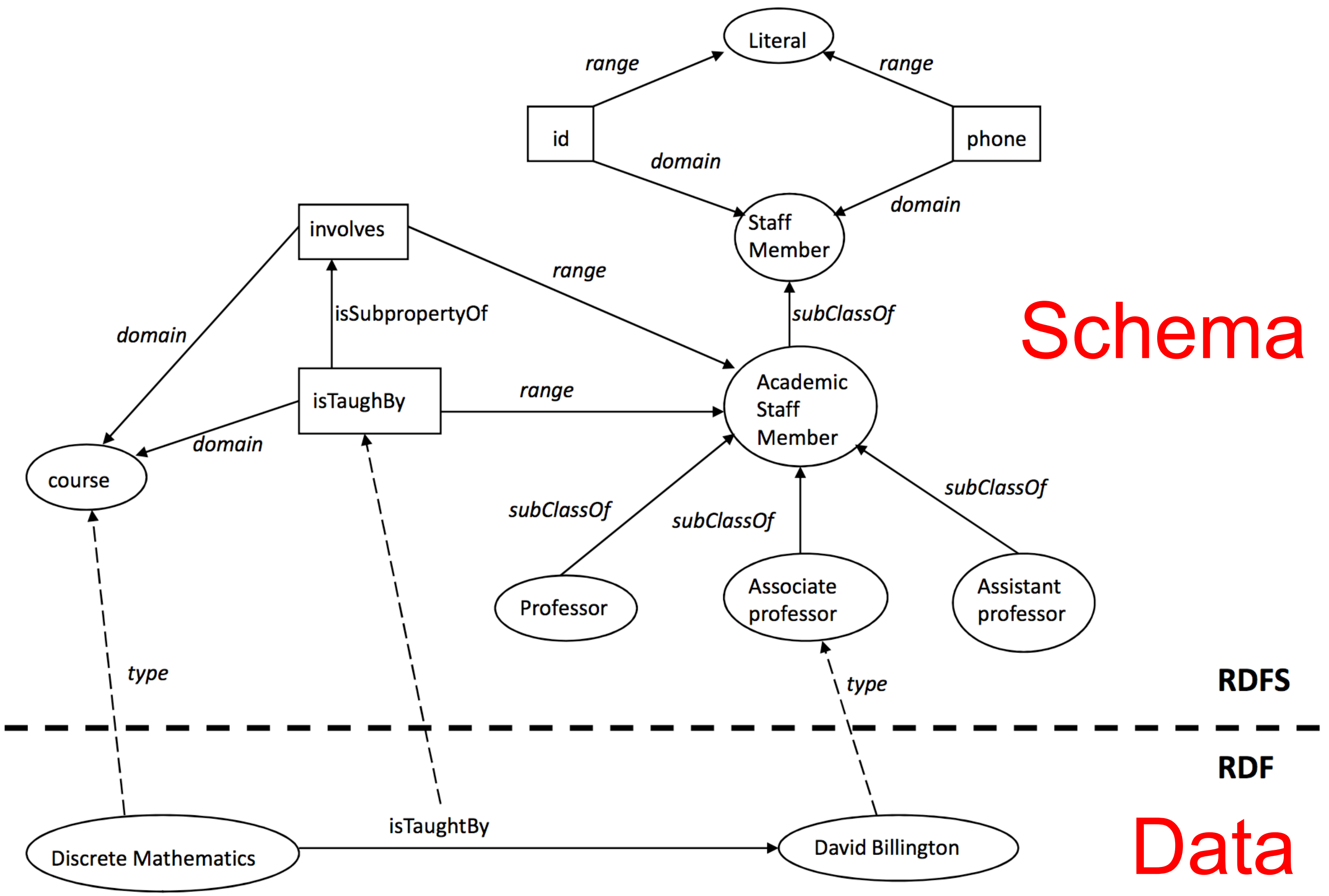



arrows represent the rdf:type relation

# 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

# Data and schema




Syntactically it's all just RDF. The data part only uses RDF vocabulary and the schema part uses RDFS vocabulary

# 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 in turtle

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

<http://www.w3.org/1999/02/22-rdf-syntax-ns#>
  a owl:Ontology ;
  dc:title "The RDF Vocabulary (RDF)" ;
  dc:description "This is the RDF Schema for the RDF vocabulary defined in the RDF
     namespace." .

rdf:type a rdf:Property ;
  rdfs:isDefinedBy <http://www.w3.org/1999/02/22-rdf-syntax-ns#> ;
  rdfs:label "type" ;
  rdfs:comment "The subject is an instance of a class." ;
  rdfs:range rdfs:Class ;
  rdfs:domain rdfs:Resource .
```

# RDF Namespace example

```
rdf:Statement a rdfs:Class ;
  rdfs:subClassOf rdfs:Resource ;
  rdfs:comment "The class of RDF statements." .

rdf:subject a rdf:Property ;
  rdfs:domain rdf:Statement ;
  rdfs:range rdfs:Resource .

rdf:predicate a rdf:Property ;
  rdfs:domain rdf:Statement ;
  rdfs:range rdfs:Resource .
```

# 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 defined globally and not encapsulated as attributes in class definitions
  - We can define new properties w/o changing class
  - Properties can have properties

    :mother rdfs:subPropertyOf :parent; rdf:type :FamilyRelation.
  - But: can’t narrow domain & 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.
```

# Ontology and Data

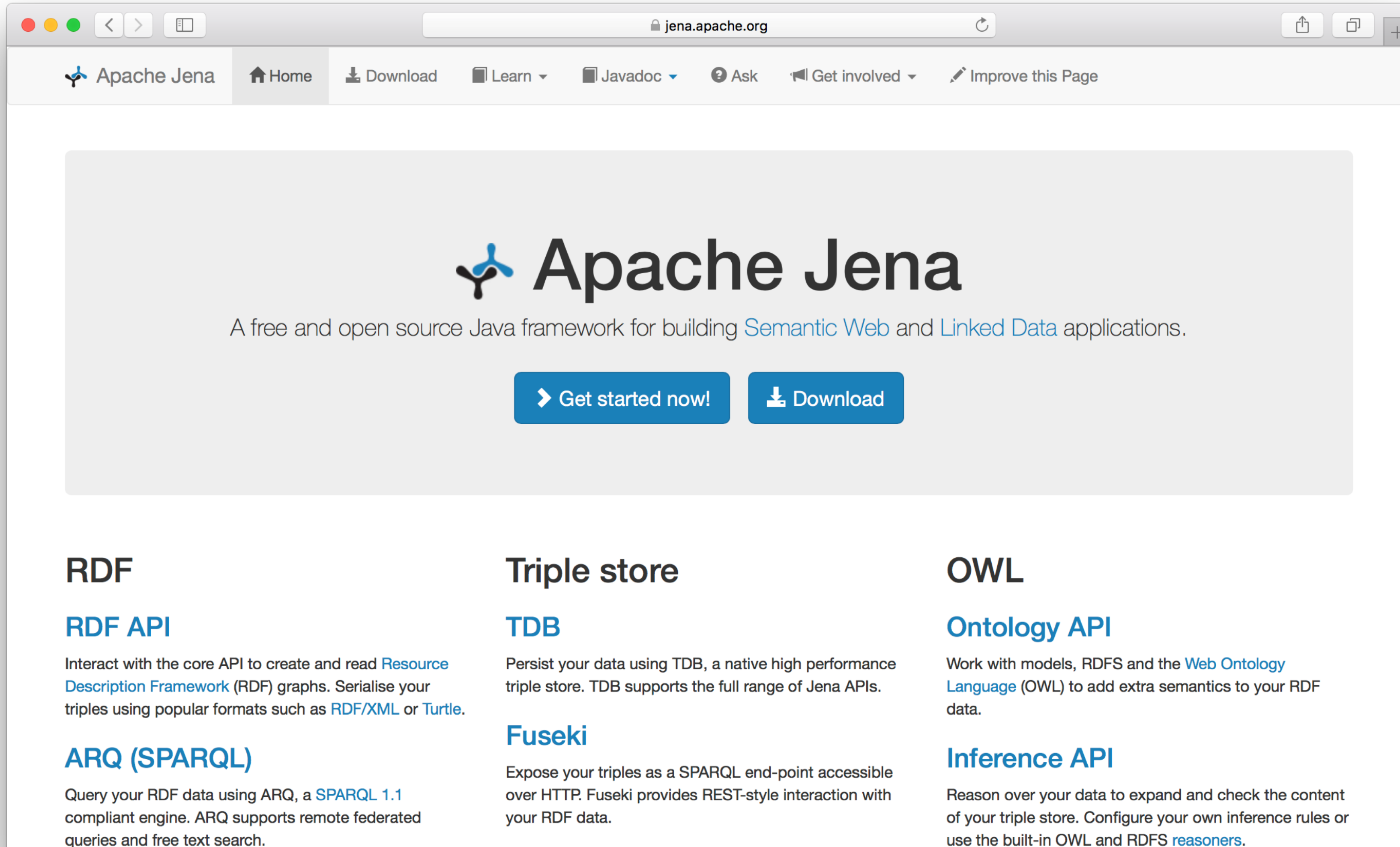
Let’s follow best practice and separate our ontology (i.e., schema) file from the data

```
# A simple Biology ontology

@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.
```

```
# Some biological data

@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#> .
@prefix :  <http://finin.org/example/#> .

# fido’s  a dog!
:fido a bio:Dog.

# john’s human & has offspring fido
:john a bio:Human;
   bio:offspring :fido.
```

# Apache Jena

Apache Jena is a suite of high-quality, well-maintained, opensource tools in Java for semantic web technology



# Jena’s riot command

- Jena has a set of command line tools
- Riot can convert between serializations and also do simple rdfs inference
- Let’s try it on the example

```
riot --rdfs=bio0.ttl --output=ttl mybio0.ttl
```

# Riot rdfs inference

```
bio> riot --rdfs=bio0.ttl --output=ttl mybio0.ttl
@prefix :  <http://finin.org/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#> .

:fido   rdf:type  bio:Dog ;
        rdf:type  bio:Animal .

:john   rdf:type       bio:Human ;
        rdf:type       bio:Animal ;
        bio:offspring  :fido ;
        rdf:type       bio:Animal .

:fido   rdf:type  bio:Animal .

bio>
```

# 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?

# 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.

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 as in most programming languges
- Lack of *negation* & *open world assumption* in RDF+RDFS makes detecting such contradictions **impossible!**
  - Can’t say that Dog and Human are disjoint classes
  - Not knowing any individuals who are both doesn’t mean it’s not possible

# 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.
```

# 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.

Consider adding:

**:john bio:hasPet :spot**

# No disjunctions or union types

What does this mean?

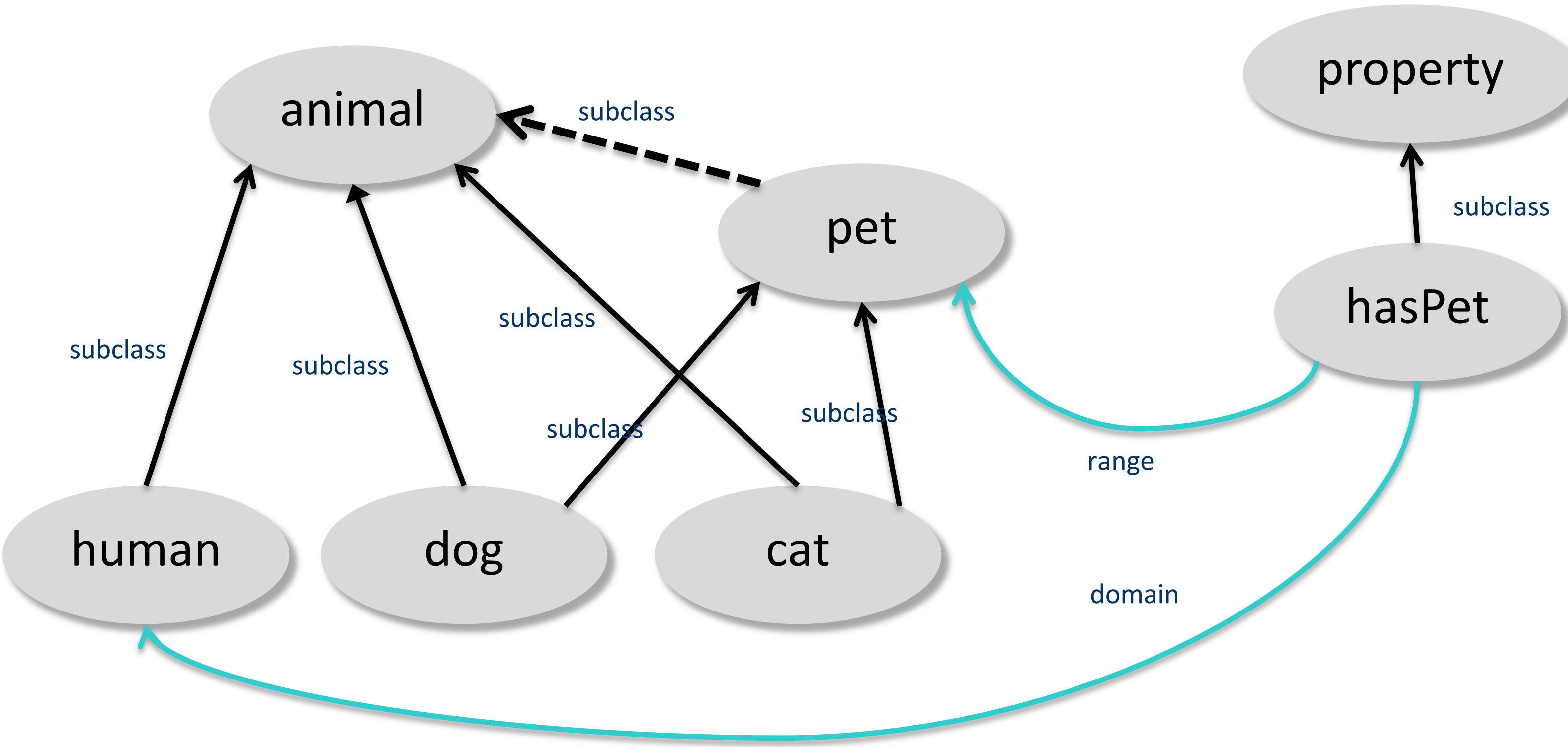
```
bio:Human rdfs:subClassOf bio:Animal.
bio:Cat rdfs:subClassOf bio:Animal.
bio:Dog rdfs:subClassOf bio:Animal.
bio:hasPet a rdfs:Property;
  rdfs:domain bio:Human;
  rdfs:range bio:Dog;
  rdfs:range bio:Cat.
```

```
:john bio:hasPet :spot
=>
:john a bio:Human,
         bio:Animal.
:spot a bio:Dog, bio:Cat,
         bio:Animal.
```

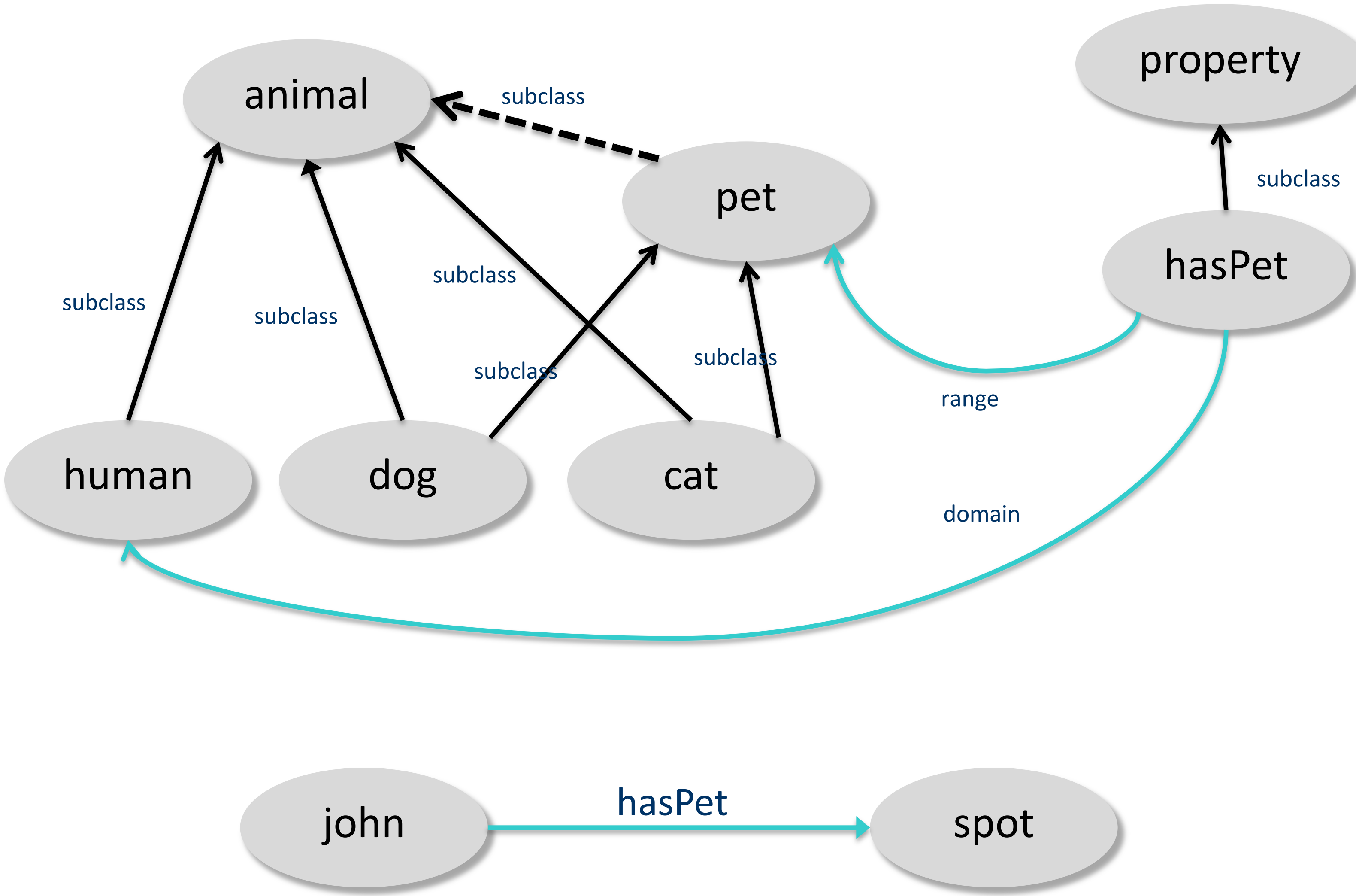
# What do we want to say?

- Many different possibilities
  - Only a dog or cat can be an object of 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's possible for some dogs and some cats to be pets
- Not all of these can be said in RDF+RDFS
- We can express all of these in OWL *(I think)*

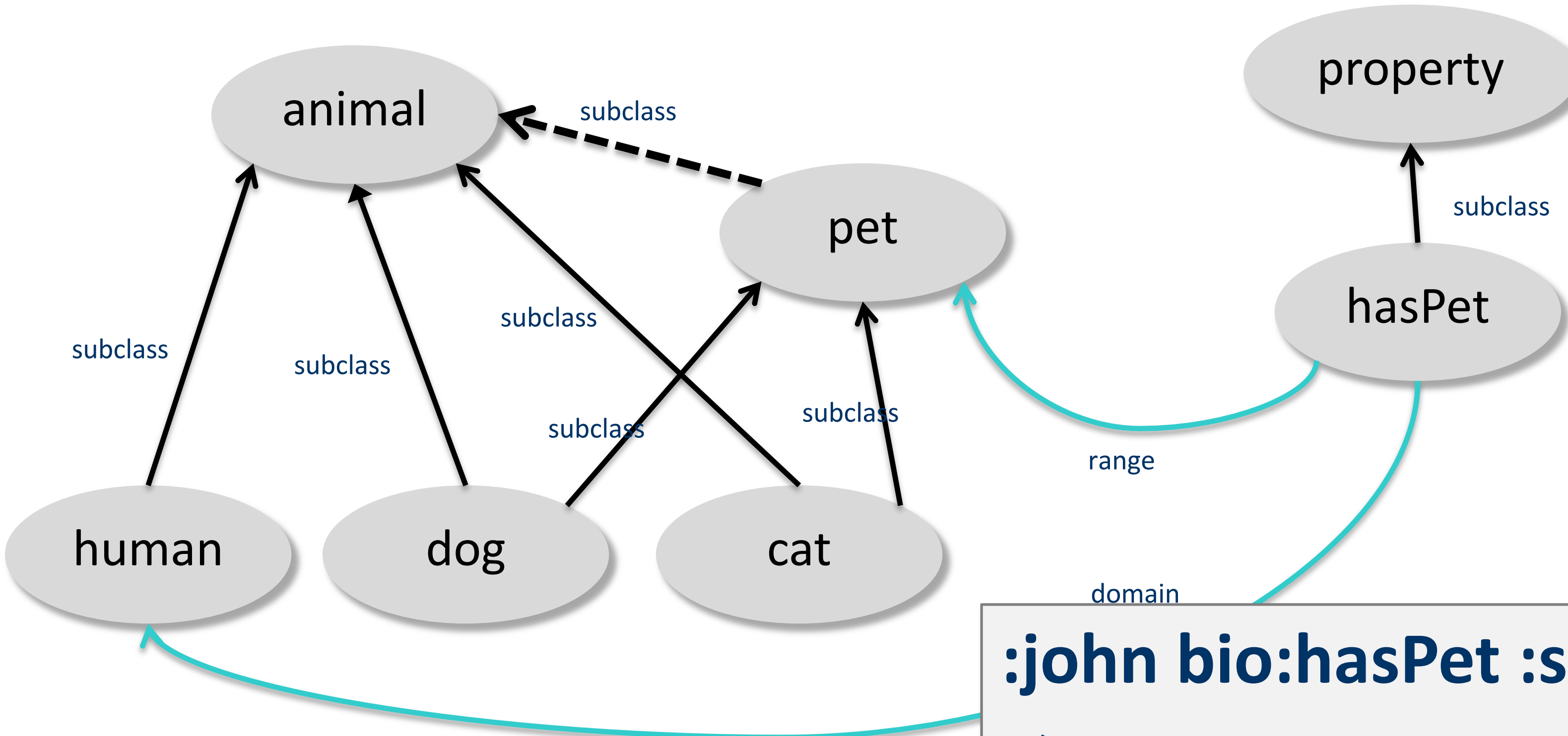
# What do we want to say?



# What do we want to say?



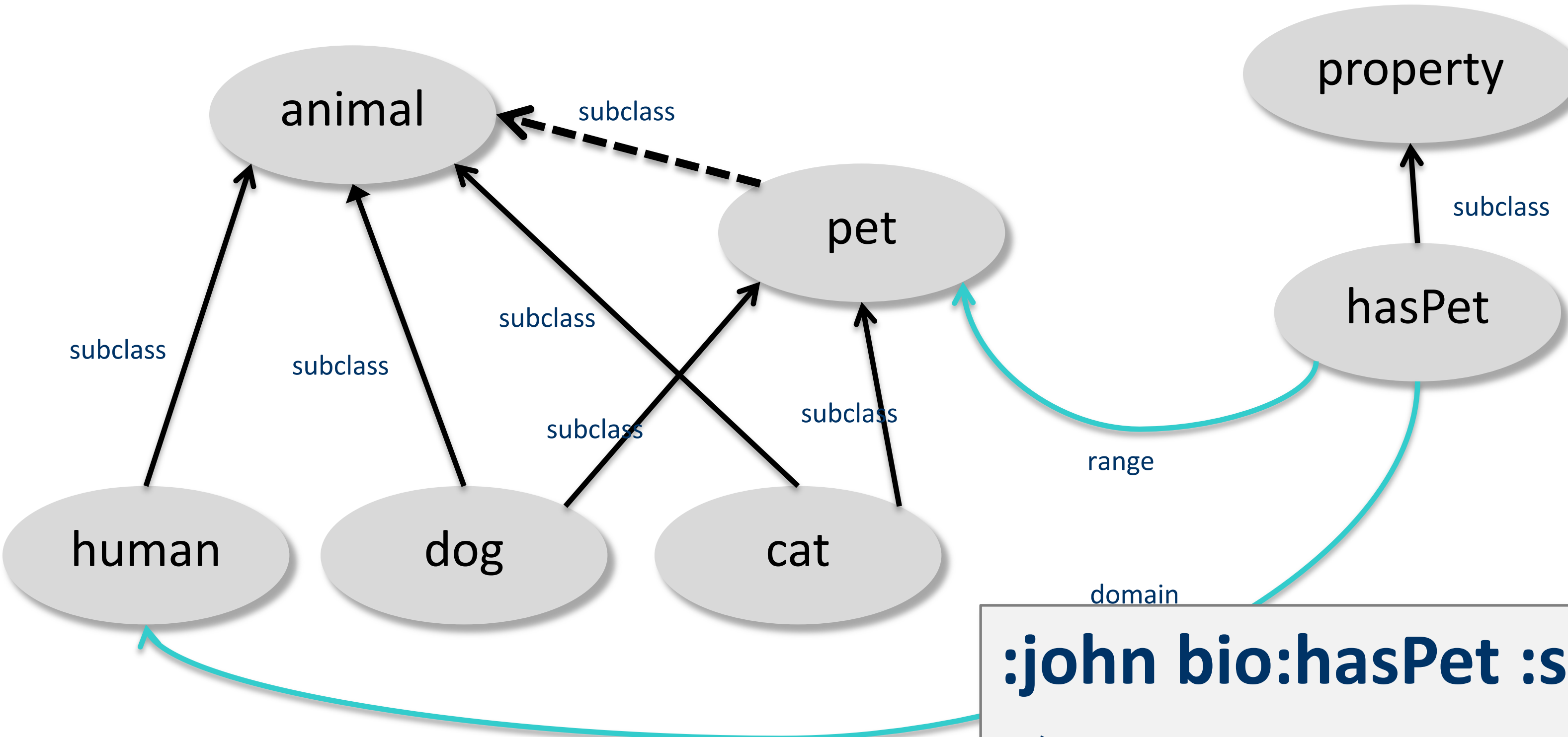
# What do we want to say?




All dogs are pets
All cats are pets
All pets are animals

**:john bio:hasPet :spot**
=>
:john a bio:Human,
bio:Animal.
:spot a bio:Pet,
bio:Animal.

# What do we want to say?




**:john bio:hasPet :spot**

=>

:john a bio:Human,
bio:Animal.

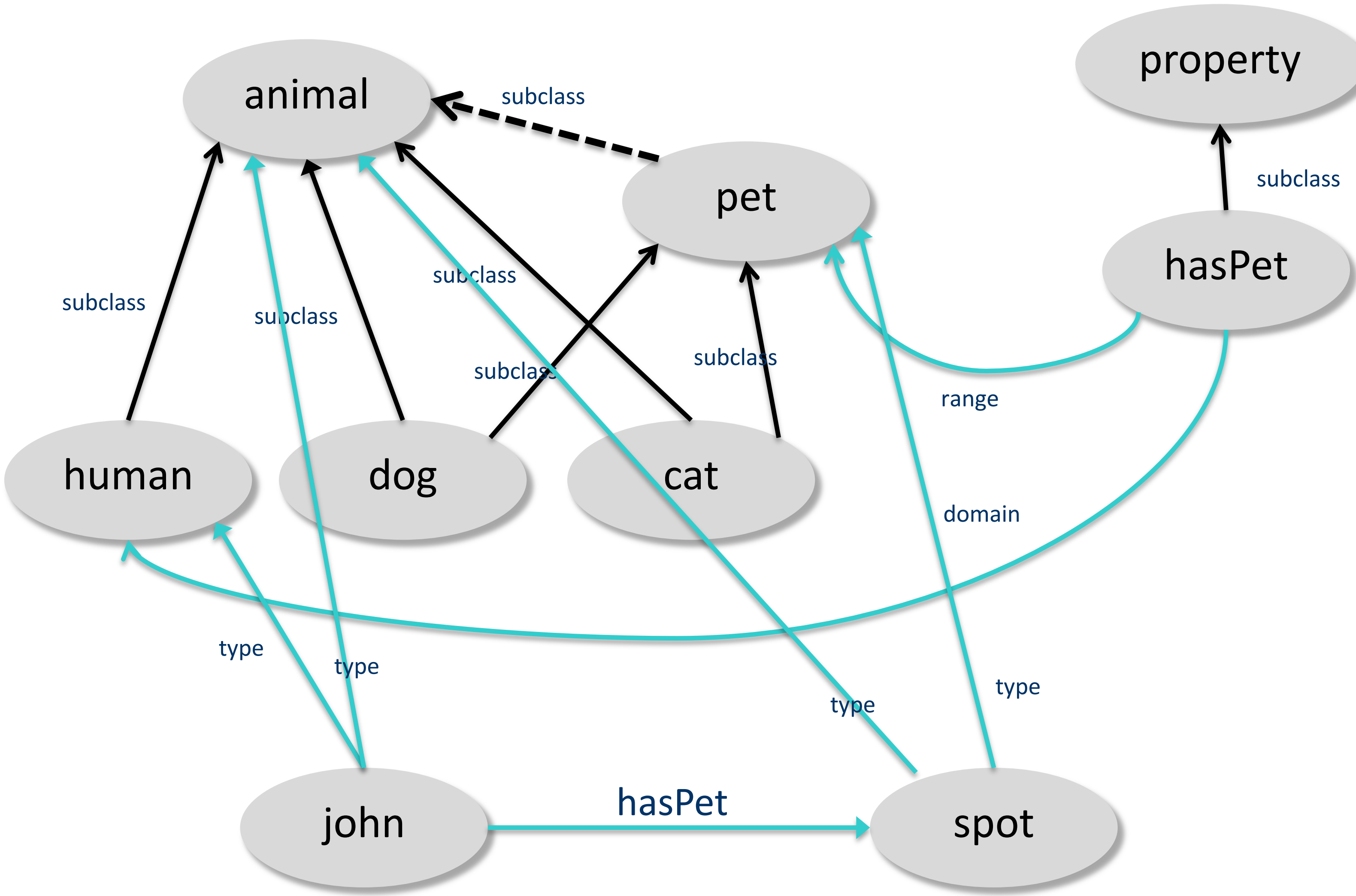
:spot a bio:Pet,
bio:Animal.

All dogs are pets

All cats are pets

All pets are animals

# 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 also
- 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.

- rdf:type links an individual to a class it belongs to
- rdfs:subClass links a class to a super-class it is part of

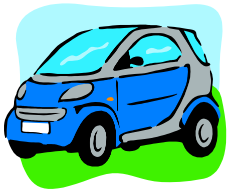
- Adds richness to language but causes problems
  - In OWL DL you can't do this
  - OWL has it's own notion of a Class, owl:Class

# Inheritance is simple

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

# *Set Based Model Theory Example*

**World**



**Model**

Daisy isA Cow

Cow kindOf Animal

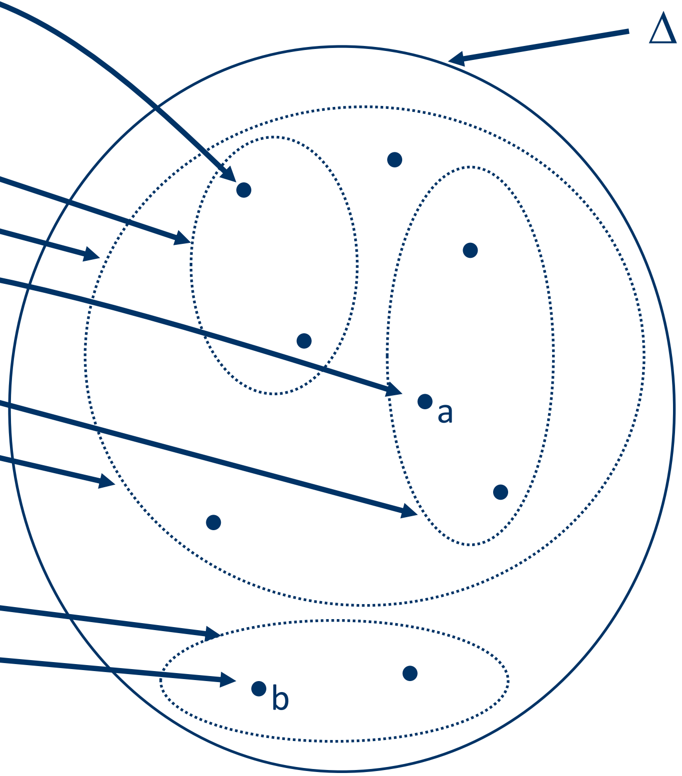
Mary isA Person

Person kindOf Animal

Z123ABC isA Car

Mary drives Z123ABC

**Interpretation**




{... list of facts
about individuals ...}

# 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

## RDFS too weak to describe resources in detail

- No *localised range and domain* constraints

  Can’t say range of hasChild is person when applied to persons and elephant when applied to elephants

- No *existence/cardinality* constraints

  Can’t say all *instances* of person have a mother that is a person, or that persons have exactly two parents

- No *transitive, inverse or symmetrical* properties

  Can’t say isPartOf is a transitive property, hasPart is the inverse of isPartOf or that touches is symmetrical

We need RDF terms providing these and other features: this is where OWL comes in

# RDF Conclusions

- Simple **data model** based on a **graph,** independent of serializations (e.g., XML or N3)
- Has a **formal semantics** providing a dependable basis for reasoning about the meaning of RDF expressions
- Has an XML serialization, can use XML schema datatypes
- **Open world assumption:** anyone can make statements about any resource
- RDFS adds vocabulary with well defined semantics (e.g., Class, subClassOf, etc.)
- OWL addresses some of RDFS's limitations adding richness (and complexity)