Web Ontology Languages

- Different Web ontology language
- Web Ontology Language (OWL)
- OWL characteristics

Web Ontology Language Requirements

Desirable features identified for Web Ontology Language:

- Extends existing Web standards
  - Such as XML, RDF, RDFS
- Easy to understand and use
  - Should be based on familiar KR
- Formally specified
- Of “adequate” expressive power
- Possible to provide automated reasoning support

OWL: Web Ontology Language

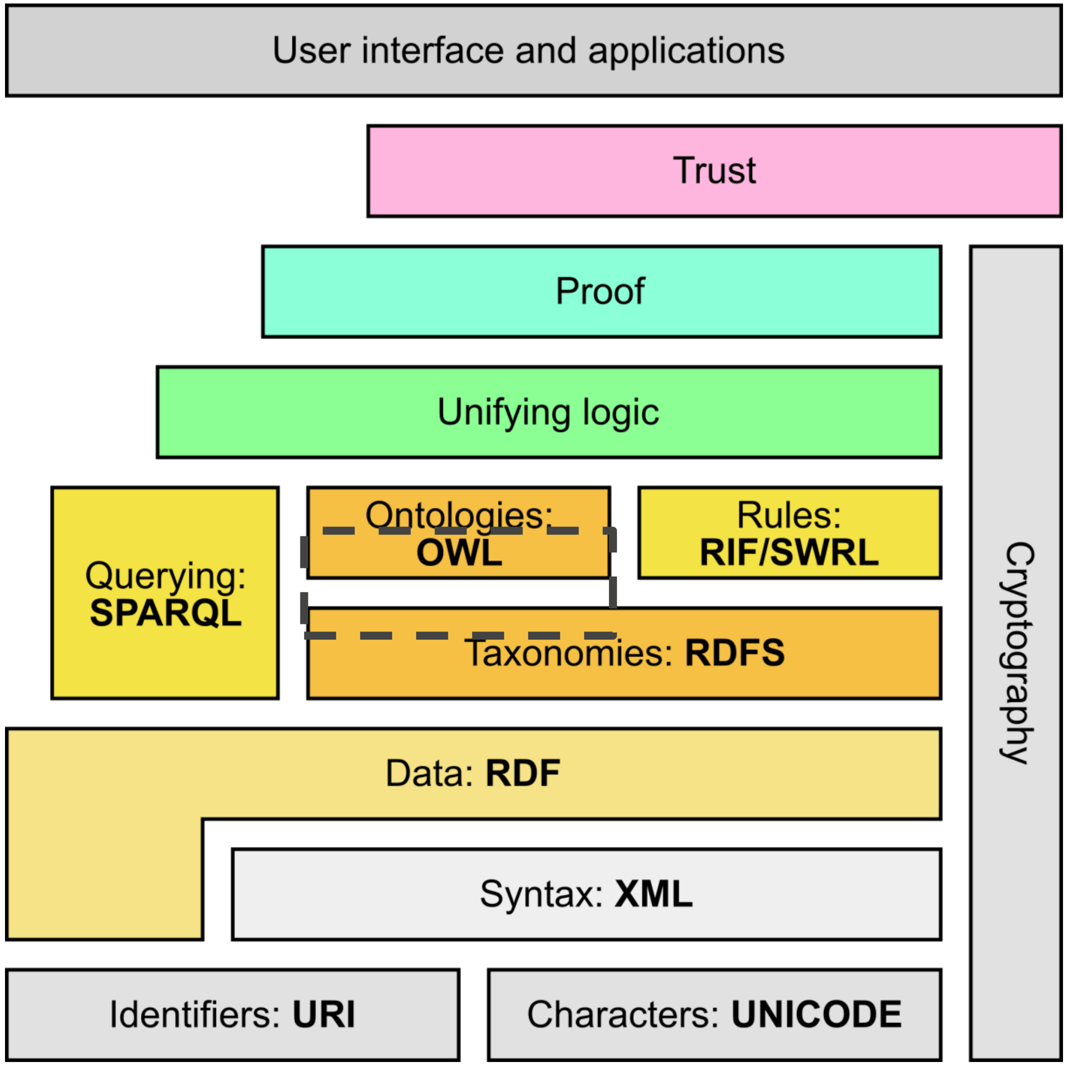
- The **Web Ontology Language** (**OWL**) is a family of knowledge representation languages or ontology languages for engineering ontologies or knowledge bases.
- **OWL DL** (Description Logic) designed to provide the maximum expressiveness possible while retaining computational completeness and availability of practical reasoning algorithms.
- OWL DL includes all OWL language constructs, but they can be used only under certain restrictions.

The built-in vocabulary for OWL all comes from the OWL namespace

http://www.w3.org/2002/07/owl#

http://www.w3.org/TR/owl-ref/	OWL	2004
http://www.w3.org/TR/owl2-overview/	OWL-2	2009

Semantic Web Stack



Adapted from http://en.wikipedia.org/wiki/Semantic_Web_Stack

Why OWL? Limitations of RDFS

- RDFS is too weak in describing resources with sufficient details, e.g.:
  - No localised range and domain constraints
    - Cannot say that the range of *isToughtBy* is only professor when applied to professors and lecturer when applied to lecturers
  - No cardinality constraints
    - Cannot say that a course is taught by at least one professor, or persons have exactly 2 parents
  - No transitive, inverse or symmetrical properties
    - Cannot say that isPartOf is a transitive property, that hasSupervisor is the inverse of isSupervisorOf, and, that friendOf is symmetrical
  - Disjoint classes
    - Cannot say that Under-Graduate and PhD. Students are two disjoint classes
  - Boolean combinations of classes
    - Sometimes we may need to build new classes by combining other classes using union, intersection, and complement (e.g. person is the disjoint union of the classes male and female)

Why OWL

Reasoning About Knowledge in Ontology Languages

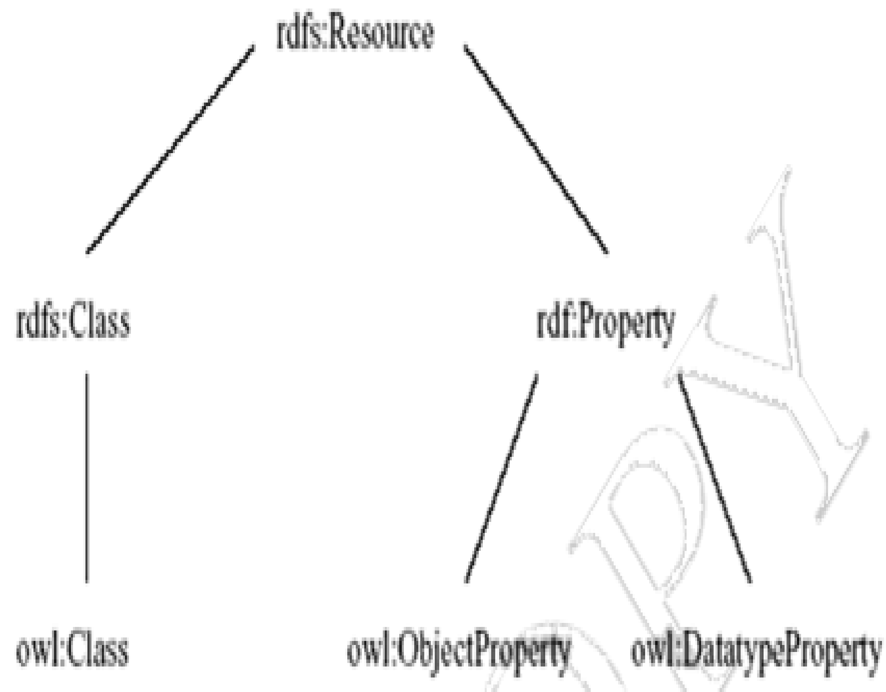
- Class membership
  - If x is an instance of a class C, and C is a subclass of D, then we can infer that x is an instance of D
- Equivalence of classes
  - If class A is equivalent to class B, and class B is equivalent to class C, then A is equivalent to C, too

Why OWL
Reasoning About Knowledge in Ontology Languages (2)

- Consistency
  - X instance of classes A and B, but A and B are disjoint
  - This is an indication of an error in the ontology
- Classification
  - Certain property-value pairs are a sufficient condition for membership in a class A; if an individual x satisfies such conditions, we can conclude that x must be an instance of A

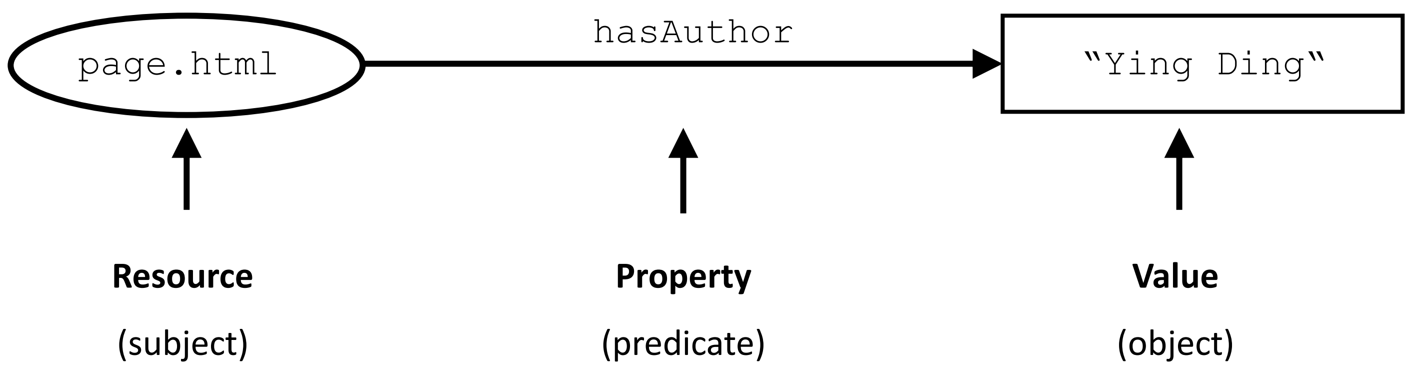
OWL Compatibility with RDF Schema

- All varieties of OWL use RDF for their syntax
- Instances are declared as in RDF, using RDF descriptions
- and typing information OWL constructors are specialisations of their RDF counterparts



OWL-RDFS Relationship

- Both use the same data model:



- OWL extends vocabulary and adds axioms to express more **complex relations of classes and properties**

Web Ontology Language (OWL)

OWL

- A richer ontology language.
- Relations between classes
  - e.g., disjointness
- Cardinality
  - e.g. “exactly one”
- Richer typing of properties
- Characteristics of properties (e.g., symmetry)

Simple Named Classes

- Every individual in the OWL world is a member of the class owl:Thing.
- Named classes
  - Example:

```
<owl:Class rdf:ID=“Staff"/>
<owl:Class rdf:ID=“Researcher"/>
<owl:Class rdf:ID=“Academic"/>
```

- The fundamental taxonomic constructor for classes is rdfs:subClassOf.
  - Example:

```
<owl:Class rdf:ID=“Researcher">
   <rdfs:subClassOf rdf:resource="#Staff" />
   ...
</owl:Class>
```

1. Class

- Basic concept (owl:Class) which is a subclass of rdfs:Class
- Subclasses as we know them from RDFS: rdfs:subClassOf
- – In particular, the following holds:
- owl:Class rdfs:subClassOf rdfs:Class .
- Two predefined classes: –
  - owl:Thing
  - owl:Nothing
- For each class c, the following axioms hold: –

  rdfs:subClassOf owl:Thing .

  owl:Nothing rdfs:subClassOf ?? .

- **owl:Thing** is the most general class, which contains everything
- **owl:Nothing** is the empty class

Class relationships

- In OWL, you can construct classes from existing ones:

1. enumerate its content (individuals that together form the instances of a class)
2. intersection of two or more class descriptions
3. the union of two or more class descriptions
4. the complement of a class description

An Example

- Woman $\equiv$ Person $\sqcap$ Female
- Man $\equiv$ Person $\sqcap$ $\neg$Woman
- Mother $\equiv$ Woman $\sqcap$ $\exists$hasChild.Person
- Father $\equiv$ Man $\sqcap$ $\exists$hasChild.Person
- Parent $\equiv$ Father $\sqcup$ Mother
- Grandmother $\equiv$ Mother $\sqcap$ $\exists$hasChild.Parent

We can further infer (though not explicitly stated):

→ Grandmother $\sqsubseteq$ Person

Grandmother $\sqsubseteq$ Man $\sqcup$ Woman

etc.

OWL Class Elements

- owl:Class

```
<owl:Class rdf:ID="associateProfessor">
  <rdfs:subClassOf rdf:resource="#academicStaffMember"/>
</owl:Class>
```

- owl:disjoinWith

```
<owl:Class rdf:about="#associateProfessor">
  <owl:disjointWith rdf:resource="#professor"/>
  <owl:disjointWith rdf:resource="#assistantProfessor"/>
</owl:Class>
```

- owl:equivalentClass

```
<owl:Class rdf:ID="faculty">
  <owl:equivalentClass rdf:resource="#academicStaffMember"/>
</owl:Class>
```

OWL constructs for classes

OWL construct	Example
owl:Thing	
owl:Nothing	
intersectionOf($C_1 \ldots C_n$)	**Human $\sqcap$ Male**
unionOf($C_1 \ldots C_n$)	**Doctor $\sqcup$ Lawyer**
complementOf(C)	**$\neg$Male**
oneOf($a_1 \ldots a_n$)	**$\{$john, mary$\}$**
restriction(r allValuesFrom(C))	**$\forall$hasChild.Doctor**
restriction(r someValuesFrom(C))	**$\exists$hasChild.Doctor**
restriction(r minCardinality(C))	**≥ 2 hasChild.Lawyer**
restriction(r maxCardinality(C))	**≤ 2 hasChild.Lawyer**
restriction(r value(a))	**$\exists$citizen_of.$\{$France$\}$**

OWL class relationships

OWL axiom	Example
Class(A partial $C_1 \ldots C_n$))	**Human $\sqsubseteq$ Physical_Object**
Class(A complete $C_1 \ldots C_n$))	**Man $\equiv$ Human $\sqcap$ Male**
SubClassOf(C_1 C_2)	**Human $\sqsubseteq$ Animal $\sqcap$ Biped**
EquivalentClasses(C_1 C_2)	**Man $\equiv$ Human $\sqcap$ Male**
DisjointClasses(C_1 C_2)	**Male $\sqsubseteq$ $\neg$Female**
SameIndividual(a_1 a_2)	PresidentBush=G.W.Bush
DifferentIndividual(a_1 a_2)	Bush$\neq$Obama

Class definition in owl

A class expression is the name used for either:

1- a class name (a URI), or

2- an enumeration, enclosed in <owl:Class>...</owl:Class> tags, or

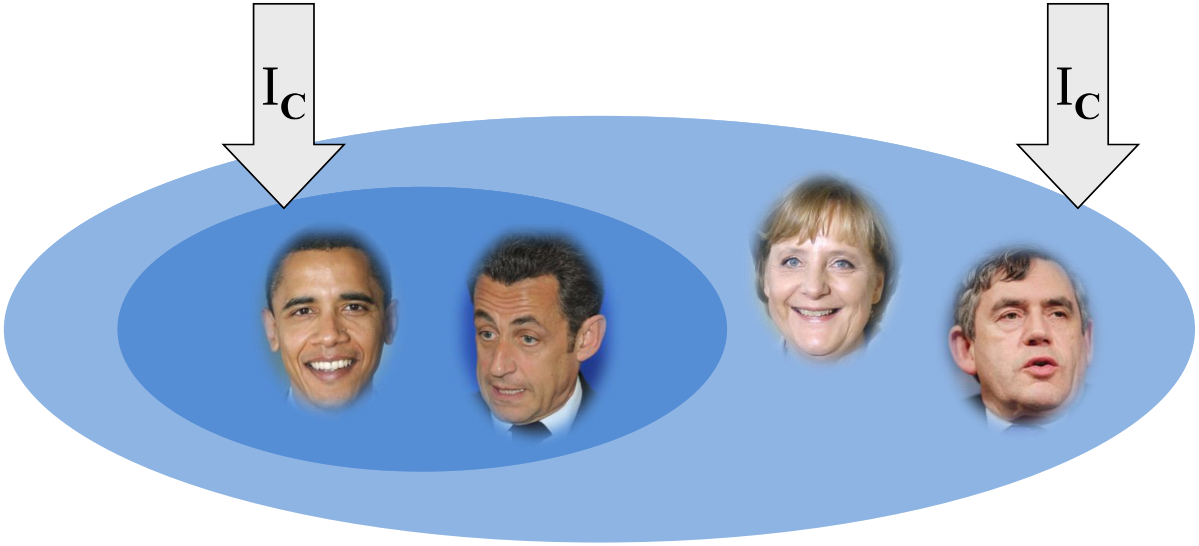
3- a property-restriction, or

4- a boolean combination of class expressions, enclosed in <rdfs:Class>...</rdfs:Class> tags

Class Inclusion

- classuri1 rdfs:subClassOf classuri2 .

- Example:
  ex:President rdfs:subClassOf ex:Politician



Class Enumeration

- A class description of the "enumeration" kind is defined with the owl:oneOf property that represents exactly the enumerated individuals, no more, no less.

- The value of this property must be a list of individuals that are the instancesof the class.

- This enables a class to be described by exhaustively enumerating its instances.

- The list of individuals is typically represented by RDF construct rdf:parseType="Collection"

Class Enumeration(cont.)

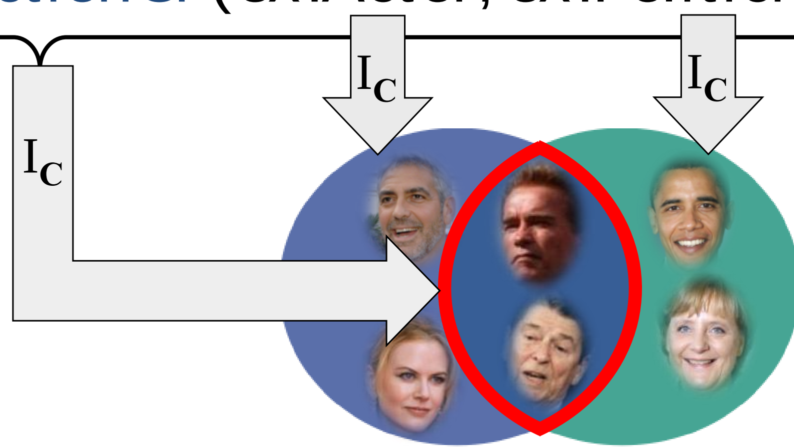
- This enables a class to be described by exhaustively enumerating its instances
- List of **individuals** that are the instances of the class

```
<owl:Class>   <owl:oneOf rdf:parseType="Collection">
          <owl:Thing rdf:about="#Eurasia"/>
          <owl:Thing rdf:about="#Africa"/>
          <owl:Thing rdf:about="#NorthAmerica"/>
          <owl:Thing rdf:about="#SouthAmerica"/>
          <owl:Thing rdf:about="#Australia"/>
          <owl:Thing rdf:about="#Antarctica"/>
          </owl:oneOf> </owl:Class>
```

The class extension of a class described with owl:oneOf contains exactly the enumerated individuals, no more, no less.

Complex Classes: Intersection

- [owl:intersectionOf (class1 , ... , classn)]
- I_C([owl:intersectionOf (class1 , ... , classn)])
  = I_C(class1) Å … Å I_C(classn)
- Example:
  [owl:intersectionOf (ex:Actor, ex:Politician)]



2. Intersection

- The **owl:intersectionOf** links a class to a list of class descriptions.

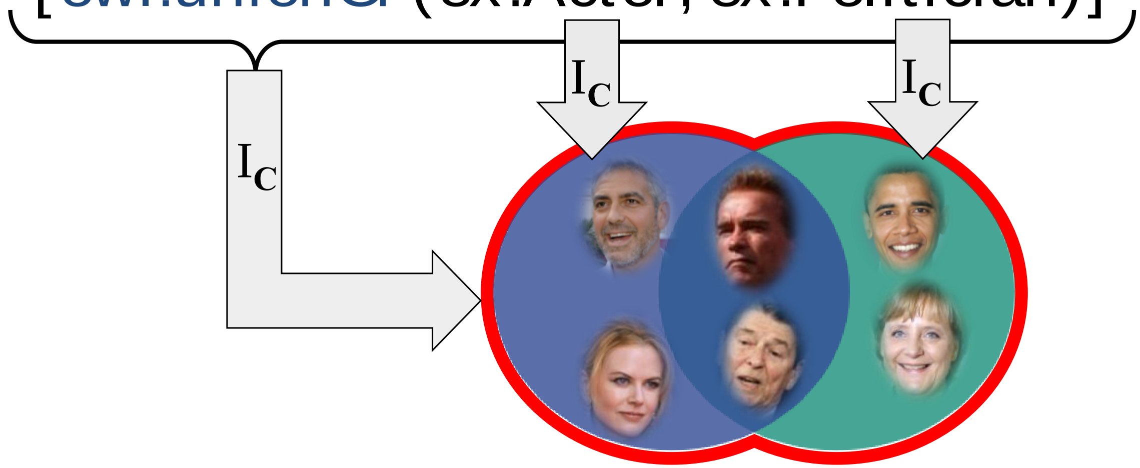
- **owl:intersectionOf:**

```
<owl:Class rdf:ID="SugaryBread">
    <owl:intersectionOf rdf:parseType="Collection">
        <owl:Class rdf:about="#Bread">
        <owl:Class rdf:about="#SweetFood"/>
    </owl:intersectionOf>
</owl:Class>
```

Complex Classes: Union

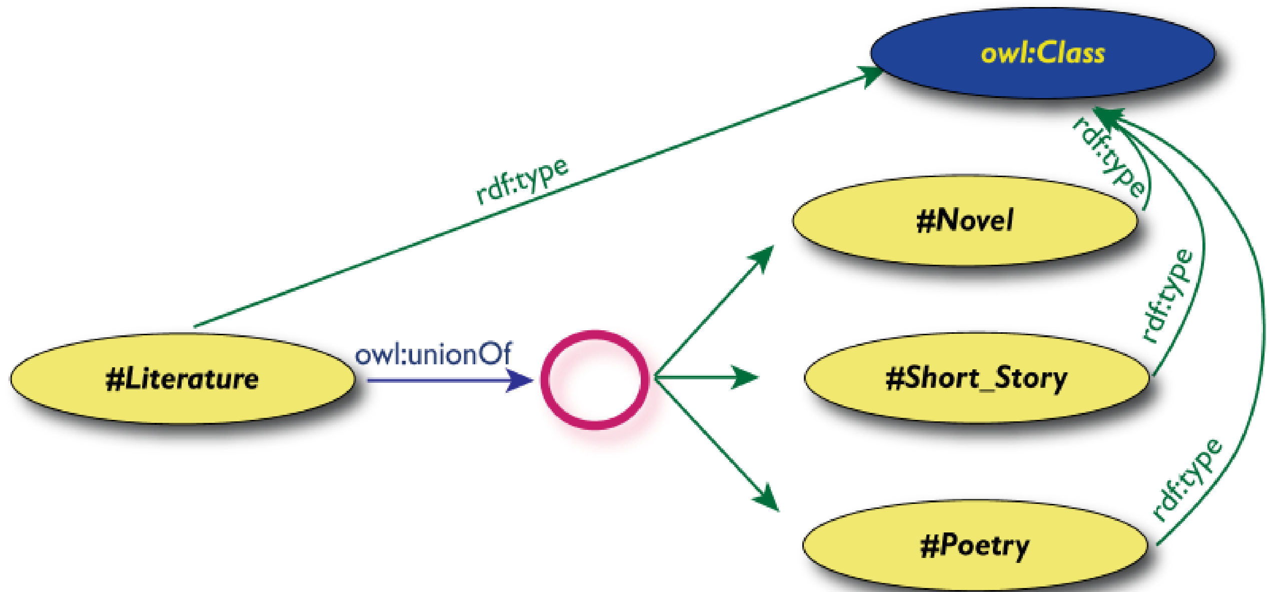
- [owl:unionOf (class1 , ... , classn)]
- I_C([owl:unionOf (class1 , ... , classn)])
  = I_C(class1) [… [I_C(classn)
- Example:

  [owl:unionOf (ex:Actor, ex:Politician)]



3-Union of classes

- Essentially, like a set-theoretical union:




```
<owl:Class rdf:ID="Literature">
   <owl:unionOf rdf:parseType="Collection">
       <owl:Class rdf:about="#Novel"/>
       <owl:Class rdf:about="#Short_Story"/>
       <owl:Class rdf:about="#Poetry"/>
       …
   </owl:unionOf>
</owl:Class>
```

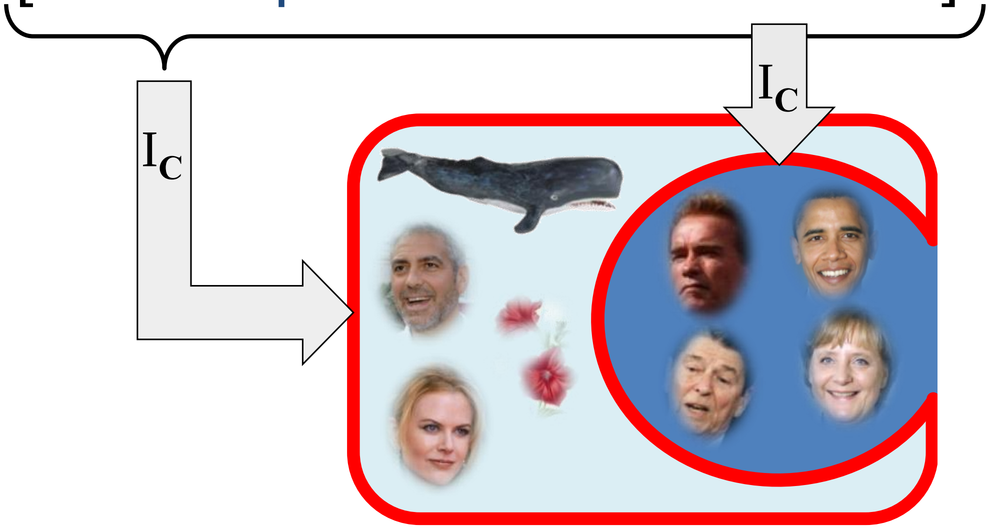
Union of classes **(cont..)**

owl:unionOf element

```
<owl:Class rdf:ID="Fruit">
    <owl:unionOf rdf:parseType="Collection">
        <owl:Class rdf:about="#SweetFruit" />
        <owl:Class rdf:about="#NonSweetFruit" />
    </owl:unionOf>
</owl:Class>
```

Complex Classes: Complement

- [owl:complementOf class]
- I_C([owl:complementOf class]) = Δ - I_C(class)
- Example:
  [owl:complementOf ex:Politician]



4-Complement of classes

```
<owl:Class rdf:about="#course">
    <rdfs:subClassOf>
        <owl:Restriction>
            <owl:complementOf rdf:resource="#staffMember"/>
        </owl:Restriction>
    </rdfs:subClassOf>
</owl:Class>
```

Class Axioms

- Class axioms typically contain additional components that state necessary and/or sufficient characteristics of a class
- OWL contains three language constructs for combining class descriptions into class axioms:

1. rdfs:subClassOf : a class description is a subset of another class description.
2. owl:equivalentClass : a class description is exactly the same as another class description.
3. owl:disjointWith a class description has no members in common with the other class description.

Class Axioms (cont.)

- owl:disjointWith

```
<owl:Class rdf:about="Mammal">
  <rdfs:subClassOf rdf:resource="#Animal"/>
  <owl:disjointWith rdf:resource="#Reptile"/>
</owl:Class>
```

```
<owl:Class rdf:about="#associateProfessor">
   <owl:disjointWith rdf:resource="#professor"/>
   <owl:disjointWith  rdf:resource="#assistantProfessor"/>
</owl:Class>
```

Class Axioms(cont.)

owl:equivalentClass defines equivalence of classes

```
<owl:Class rdf:about="# faculty">
   <owl:equivalentClass rdf:resource="#academicStaffMember"/>
</owl:Class>
```

- owl:equivalentClass

```
<owl:Class rdf:about="#US_President">
<equivalentClass
    rdf:resource="#PrincipalResidentOfWhiteHouse"/>
</owl:Class>
```

OWL Properties

- Individuals in OWL are related by *properties*. There are two types of property in OWL:

1. **Object properties** (owl:ObjectProperty relates individuals (instances) of two OWL classes.

2. **Datatype properties** (owl:DatatypeProperty) relates individuals (instances) of OWL classes to literal values.

OWL Properties

- Datatype Property

```
<owl:DatatypeProperty rdf:ID="FName"/>
  <rdfs:domain rdf:resource="#Staff" />
  <rdfs:range rdf:resource="&rdfs;Literal"/>
</owl:DatatypeProperty>
```

- Object Property

```
<owl:ObjectProperty rdf:ID="hasParent">
   <rdfs:domain rdf:resource="#Animal"/>
   <rdfs:range rdf:resource="#Animal"/>
</owl:ObjectProperty>
```

OWL Property Elements

- Object property (relate objects to other objects)

```
<owl:ObjectProperty rdf:ID="teaches">
  <rdfs:range rdf:resource="#course"/>
  <rdfs:domain rdf:resource="#academicStaffMember"/>
  <owl:inverseOf rdf:resource="#isTaughtBy"/>
</owl:ObjectProperty>
```

- Data type property (relate objects to datatype values)

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

Simple Properties- Example

- Using DatatypeProperty

<owl:Class rdf:ID= “hasName" />
<owl:DatatypeProperty rdf:ID= “nameValue" />

<rdfs:domain rdf:resource="#PhDStudent" />
<rdfs:range rdf:resource="&xsd; string"/>
</owl:DatatypeProperty>

Property Characteristics in OWL

- Datatype Properties:
  DataProperty(pp:service_number range(xsd:integer))

- Property Hierarchy:
  SubPropertyOf(pp:has_pet pp:likes)

- Algebraic properties:
  ObjectProperty(pp:married_to Symmetric)
  ObjectProperty(pp:ancestor_of Transitive)
  ObjectProperty(pp:passport_nr Functional)

Property Characteristics

- OWL also allows for specifying that properties are:
  - Functional
  - inverse
  - Transitive
  - Equivalent

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 tutor who marks student homework but does not teach C.

Property Axioms(cont.)
Equivalent Properties

owl:equivalentProperty

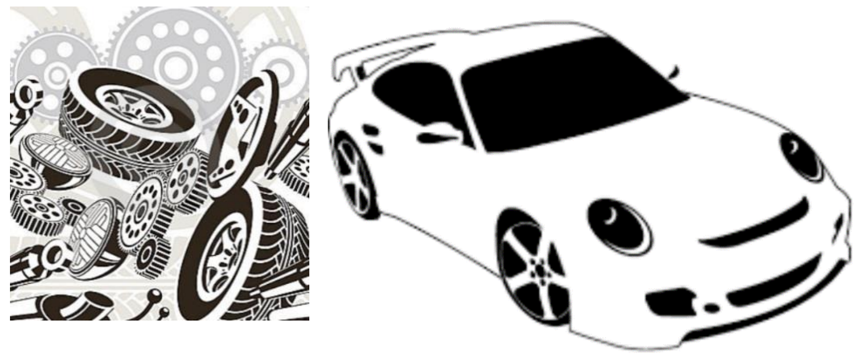
```
<owl:ObjectProperty rdf:ID="lecturesIn">
    <owl:equivalentProperty
        rdf:resource="#teaches"/>
</owl:ObjectProperty>
```

Flavors of a Partonomy

isPartOf

isIngradientOf

isComponentOf



isMemberOf

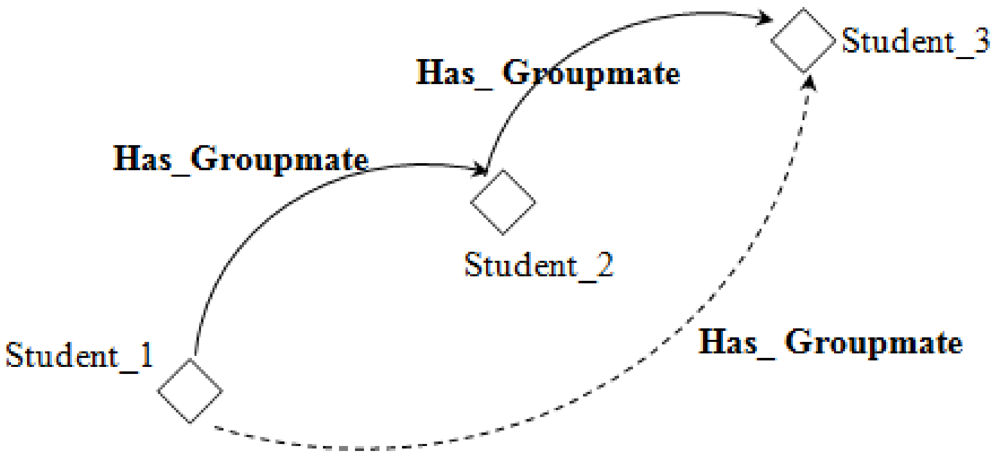
isContainedIn

isPieceOf

Transitive property Example

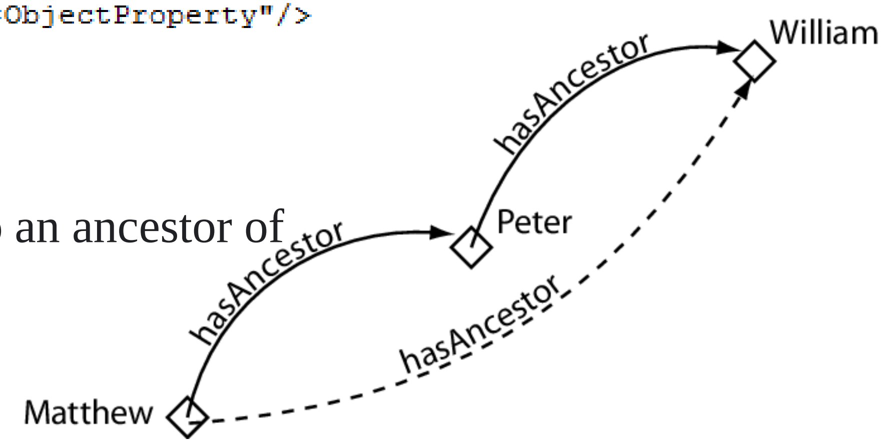
- Consider part_of property which has the characteristic of being transitive.
- If a property P is transitive, and the property relates individual a to individual b, and also individual b to individual c, then we can infer that individual a is related to individual c via property P.
- Example: is greater than, is taller than , etc

Transitive property




```
<owl:TransitiveProperty rdf:ID="Has_Groupmate">
    <rdfs:range rdf:resource="#Student"/>
    <rdfs:domain rdf:resource="#Student"/>
    <rdf:type
rdf:resource="http://www.w3.org/2002/07/owl#ObjectProperty"/>
  </owl:TransitiveProperty>
```

Any ancestor of an ancestor of mine is also an ancestor of mine.



Property Axioms(cont.)
Inverse Properties

```
<owl:ObjectProperty rdf:ID="teaches">
   <rdfs:range rdf:resource="#course"/>
   <rdfs:domain rdf:resource=
         "#academicStaffMember"/>
   <owl:inverseOf rdf:resource="#isTaughtBy"/>
</owl:ObjectProperty>
```

Property Axioms(cont.) functional property

- A functional property is a property that can have only one (unique) value y for each instance x

- Example: a woman can have at most one husband

```
<owl:ObjectProperty rdf:ID=”has-husband">
<rdf:type rdf:resource="&owl;FunctionalProperty" />
<rdfs:domain rdf:resource="#Woman" />
<rdfs:range  rdf:resource="#Man" />
</owl:ObjectProperty>
```

- Both object properties and datatype properties can be declared as "functional".

Property restrictions

- A property restriction is a special kind of class description.
- OWL distinguishes two kinds of property restrictions: value constraints and cardinality constraints.
- Property restrictions have the following general form:

<owl:Restriction>

<owl:onProperty rdf:resource="(some property)" />

(precisely one value or cardinality constraint)

</owl:Restriction>

Property restrictions (cont..)

- **A value Constraint**

  1- owl:allValuesFrom

  2- owl:someValuesFrom

  3- owl:hasValue

- **Cardinality Constraint**

  1- owl:maxCardinality

  2- owl:minCardinality

  3- owl:cardinality

Property Restrictions

- A (restriction) class is achieved through an **owl:Restriction** element
- This element contains an **owl:onProperty** element and one or more restriction declarations
- One type defines cardinality restrictions (at least one, at most 3,…)

Property Restrictions (2)

- The other type defines restrictions on the kinds of values the property may take
  - **owl:allValuesFrom** specifies universal quantification
  - **owl:hasValue** specifies a specific value
  - **owl:someValuesFrom** specifies existential quantification

owl:allValuesFrom

```
<owl:Class rdf:about="#firstYearCourse">
   <rdfs:subClassOf>
     <owl:Restriction>
       <owl:onProperty rdf:resource="#isTaughtBy"/>
       <owl:allValuesFrom
            rdf:resource="#Professor"/>
    </owl:Restriction>
   </rdfs:subClassOf>
</owl:Class>
```

owl:someValuesFrom

```
<owl:Class rdf:about="#academicStaffMember">
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty rdf:resource="#teaches"/>
      <owl:someValuesFrom rdf:resource=
            "#undergraduateCourse"/>
    </owl:Restriction>
  </rdfs:subClassOf>
</owl:Class>
```

owl:hasValue

```
<owl:Class rdf:about="#mathCourse">
    <rdfs:subClassOf>
        <owl:Restriction>
            <owl:onProperty rdf:resource=
            "#isTaughtBy"/>
            <owl:hasValue rdf:resource=
        "#949352"/>
        </owl:Restriction>
    </rdfs:subClassOf>
</owl:Class>
```

Cardinality Restrictions

- We can specify minimum and maximum number using **owl:minCardinality** and **owl:maxCardinality**
- It is possible to specify a precise number by using the same minimum and maximum number
- For convenience, OWL offers also **owl:cardinality**

Cardinality Restrictions (2)

owl:minCardinality constraint describes a class of all individuals that have at least N semantically distinct values

For example:

```
<owl:Class rdf:about="#course">
    <rdfs:subClassOf>
        <owl:Restriction>
            <owl:onProperty rdf:resource="#isTaughtBy"/>
            <owl:minCardinality rdf:datatype=
            "&xsd;nonNegativeInteger">1

            </owl:minCardinality>
        </owl:Restriction>
    </rdfs:subClassOf>
</owl:Class>
```

Cardinality Restrictions (3)

```
<owl:Class rdf:ID=“PhDStudent">
   <rdfs:subClassOf  rdf:resource=“#DeptMembers"/>
   <rdfs:subClassOf>
      <owl:Restriction>
        <owl:onProperty rdf:resource="#hasSupervisor"/>
        <owl:minCardinality
              rdf:datatype="&xsd;nonNegativeInteger">1
     </owl:minCardinality>
    </owl:Restriction>
</rdfs:subClassOf>
...

</owl:Class>
```

Property Inherence in OWL

- Some “features” of OWL are “inherited”. Others are not. For example:

- (a subPropertyOf b) and (b inverseOf c) doesn't imply (a inverseOf c)
- (a subPropertyOf b) and (b equivalentPropertyOf c) doesn't imply (a equivalentPropertyOf c)
- (a subPropertyOf b) and (b type TransitiveProperty) doesn't imply (a type TransitiveProperty)

Individuals (Instances)

- Individuals enable us to describe members of a class.
- On the **web**, such an assumption is **not possible**. The same person could be referred to in many different ways (i.e. with different URI references).
- OWL does not make this assumption (unless explicitly stated).

Declaring Instances

Instances of classes are declared as in RDF:

```
<rdf:Description rdf:ID=“XYZ">
      <rdf:type rdf:resource=   "#academicStaffMember"/>
</rdf:Description>
<academicStaffMember rdf:ID=“XYZ">
          <uni:age rdf:datatype="&xsd;integer"> 39<uni:age>
</academicStaffMember>
```

Individuals (Instances)

- OWL provides three constructs for stating facts about the **identity of individuals**:

1. owl:sameAs: is used to state that two URI references refer to the same individual.
2. owl:differentFrom: is used to state that two URI references refer to different individuals.
3. owl:AllDifferent: provides an idiom for stating that a list of individuals are all different.

Individuals (Instances)

- Example:

```
<rdf:Description
   rdf:about="#William_Jefferson_Clinton">
<owl:sameAs rdf:resource="#BillClinton"/>
</rdf:Description>

<rdf:Description rdf:about="#Obama">
<owl:differentFrom  rdf:resource="#BillClinton"/>
</rdf:Description>
```

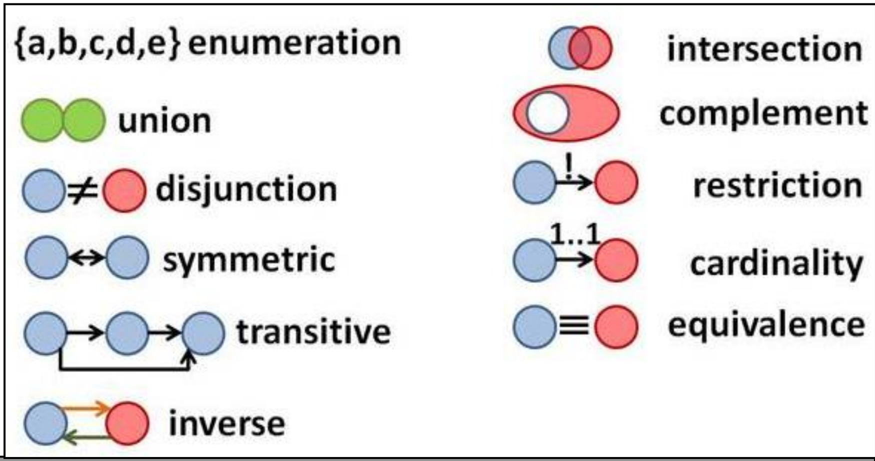
Individuals (Instances)

- Example:

```
<owl:AllDifferent>
<owl:distinctMembers rdf:parseType="Collection">
<Opera rdf:about="#Don_Giovanni"/>
<Opera rdf:about="#Nozze_di_Figaro"/>
<Opera rdf:about="#Cosi_fan_tutte"/>
<Opera rdf:about="#Tosca"/>
<Opera rdf:about="#Turandot"/>
<Opera rdf:about="#Salome"/>
</owl:distinctMembers>
</owl:AllDifferent>
```

OWL on one Slide

- **Symmetric**: if P(x, y) then P(y, x)
- **Transitive**: if P(x,y) and P(y,z) then P(x, z)
- **Functional**: if P(x,y) and P(x,z) then y=z
- **InverseOf**: if P1(x,y) then P2(y,x)
- **InverseFunctional**: if P(y,x) and P(z,x) then y=z
- **allValuesFrom**: P(x,y) and y=allValuesFrom(C)
- **someValuesFrom**: P(x,y) and y=someValuesFrom(C)
- **hasValue**: P(x,y) and y=hasValue(v)
- **cardinality**: cardinality(P) = N
- **minCardinality**: minCardinality(P) = N
- **maxCardinality**: maxCardinality(P) = N
- **equivalentProperty**: P1 = P2
- **intersectionOf**: C = intersectionOf(C1, C2, …)
- **unionOf**: C = unionOf(C1, C2, …)
- **complementOf**: C = complementOf(C1)
- **oneOf**: C = one of(v1, v2, …)
- **equivalentClass**: C1 = C2
- **disjointWith**: C1 != C2
- **sameIndividualAs**: I1 = I2
- **differentFrom**: I1 != I2
- **AllDifferent**: I1 != I2, I1 != I3, I2 != I3, …
- **Thing**: I1, I2, …



Legend:
Properties are indicated by: P, P1, P2, etc
Specific classes are indicated by: x, y, z
Generic classes are indicated by: C, C1, C2
Values are indicated by: v, v1, v2
Instance documents are indicated by: I1, I2, I3, etc.
A number is indicated by: N
P(x,y) is read as: “property P relates x to y”

Example:

- One of the clearer human-readable syntaxes

```
Class(SpicyPizza complete
      annotation(rdfs:label "PizzaTemperada”)
      annotation(rdfs:comment "Any pizza that has a
            spicy topping is a SpicyPizza”)
            restriction(hasTopping
someValuesFrom(SpicyTopping))
)
```

OWL Syntax: N3

- Recommended for human-readable fragments

```
default:SpicyPizza
    a owl:Class ;
    rdfs:comment "Any pizza that has a spicy topping is a
                                SpicyPizza”;
    rdfs:label "PizzaTemperada”;
    owl:equivalentClass
          [ a owl:Class ;
            owl:intersectionOf (default:Pizza [ a owl:Restriction ;
                    owl:onProperty default:hasTopping ;
                    owl:someValuesFrom default:SpicyTopping
                   ])
          ] .
```

OWL Syntax: RDF/XML

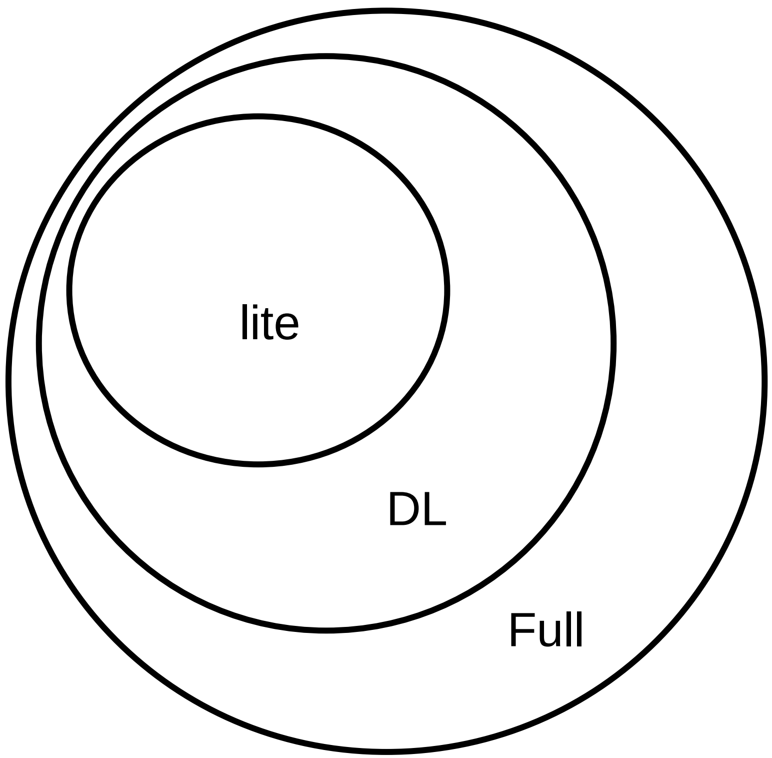
- Recommended for serialisation

```xml
<owl:Class rdf:ID="SpicyPizza">
  <rdfs:label xml:lang="pt">PizzaTemperada</rdfs:label>
  <rdfs:comment xml:lang="en">Any pizza that has a spicy topping is a SpicyPizza</rdfs:comment>
  <owl:equivalentClass>
    <owl:Class>
      <owl:intersectionOf rdf:parseType="Collection">
        <owl:Class rdf:about="#Pizza"/>
        <owl:Restriction>
          <owl:onProperty>
            <owl:ObjectProperty rdf:about="#hasTopping"/>
          </owl:onProperty>
          <owl:someValuesFrom rdf:resource="#SpicyTopping"/>
        </owl:Restriction>
      </owl:intersectionOf>
    </owl:Class>
  </owl:equivalentClass>
</owl:Class>
```

OWL Dialects

- OWL Lite
  - Classification hierarchy
  - Simple constraints
- OWL DL
  - Maximal expressiveness while maintaining tractability
  - Standard formalization in a DL
- OWL Full
  - Very high expressiveness
  - Losing tractability
  - All syntactic freedom of RDF (self-modifying)): e.g. statements about statements are possible. Meta-modeling as well.

OWL comes in 3 Dialects



1. Lite

partially restricted to aid learning curve

2. DL = Description Logic

   Description Logics are a fragment of First Order Logic (FOL) that can be reasoned with

3. Full

unrestricted use of OWL constructs, but cannot reason

Three Species of OWL

- W3C'sWeb Ontology Working Group defined OWL as three different sublanguages:
  - OWL Full
  - OWL DL
  - OWL Lite
- Each sublanguage geared toward fulfilling different aspects of requirements

Summary

- RDF (Resource Description Framework) is a simple language for expressing RDF statements.
- RDF/XML is syntax to express a RDF graph as a XML document.
- RDFS (RDF Schema) extends the vocabulary of simple RDF.
- OWL further extends the RDFS vocabulary to allow more complex inference and reasoning.
- SPARQL (Search Protocol and RDF Query Language or "sparkle") is a query language for semantic data similar to SQL.