Short notes about OWL[1]

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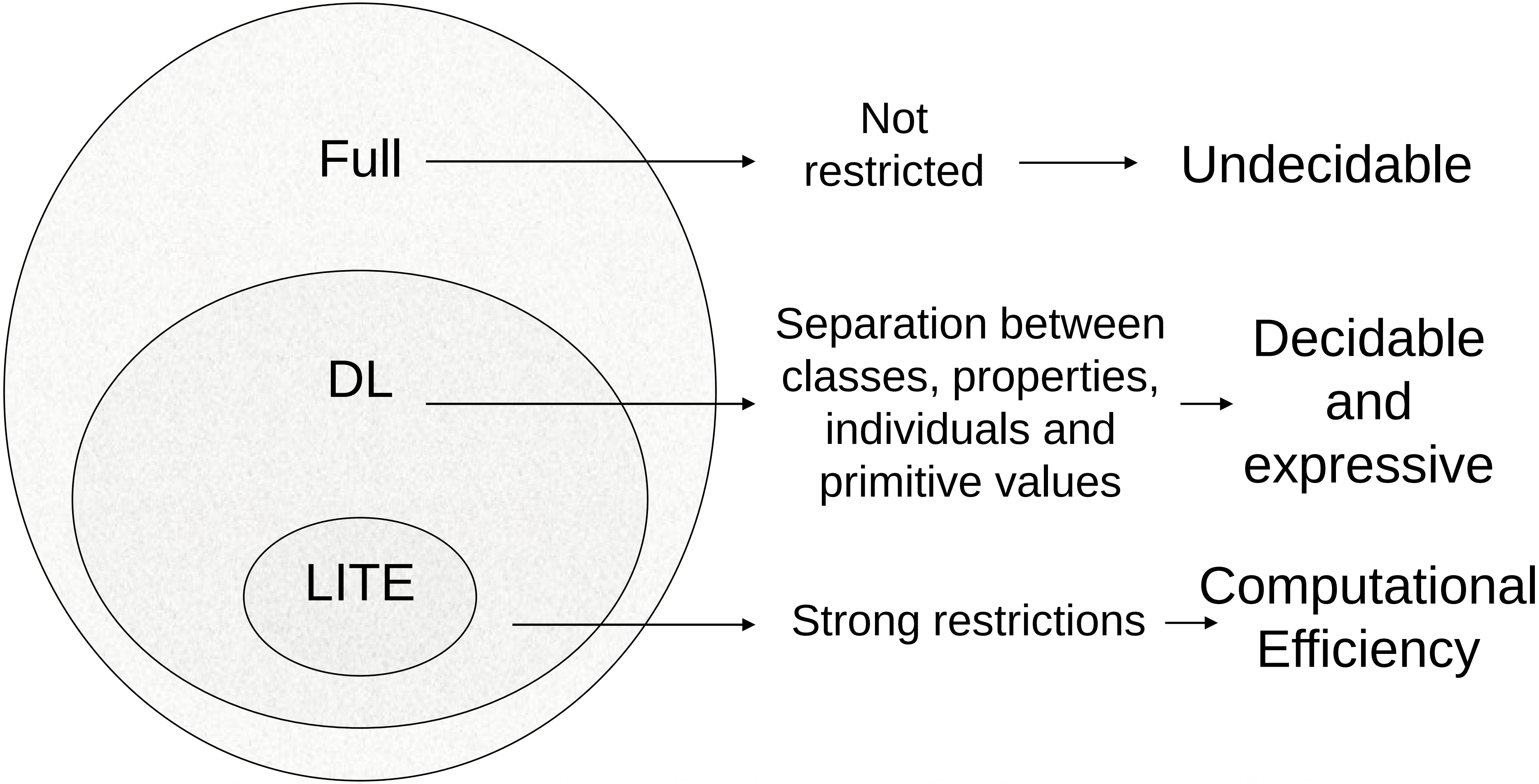
[1] this presentation is limited to OWL 1 features. A new version of OWL (OWL 2), which adds further features (thus remaining backward-compatible with the original OWL), has reached the status of W3C recommendation in 2012

OWL Sublanguages

Sublanguages defined upon restrictions on the use of OWL constructs



Full → Not restricted → Undecidable

DL → Separation between classes, properties, individuals and primitive values → Decidable and expressive

LITE → Strong restrictions → Computational Efficiency

Classes

Can be introduced by simply giving them a name

```
<owl:Class rdf:ID="Person" />
```

rdf:ID="Person" is equivalent to *rdf:about="#Person"* with the additional check that the same name is not used in another attribute *rdf:ID* in the scope of an *xml:base* value (or document, if none is given)

which can be used in order to describe their instances

```
<Person rdf:ID="manuel" />
```

or

```
<owl:Thing rdf:ID="manuel">
    <rdf:type rdf:resource="#Person" />
</owl:Thing>
```

Properties

- *datatype property*, relate individuals to literals
- *object property*, relate individuals among them
- *annotation property*, out of ontology semantics; useful in order to provide comments/documentation to the ontology (predefined annotation properties are: *owl:versionInfo*, *rdfs:label*, *rdfs:comment*, *rdfs:seeAlso*, and *rdfs:isDefinedBy*)
- *ontology property* (e.g. *owl:imports*), must have the class owl:Ontology as domain and range

Object Property

```
<owl:ObjectProperty rdf:ID=“loves”>
    <rdfs:domain rdf:resource=“#Person” />
    <rdfs:range rdf:resource=“#Person” />
    <rdfs:subPropertyOf rdf:resource=“#knows” />
</owl:ObjectProperty>
```

Datatype Property

#Person is a relative IRI, which is then resolved relative to the current base IRI

```
<owl:DatatypeProperty rdf:ID=“name”>
    <rdfs:domain rdf:resource=“#Person” />
    <rdfs:range rdf:resource=“&xsd;string” />
</owl:DatatypeProperty>
```

In RDF/XML we can’t use prefixed names in attribute values. However, we can use DTD entities (e.g. &xsd;) that are defined with a value equal to the desired namespace IRI

Annotation Property

In **OWL DL** annotation properties have the following constraints:

- An annotation property must be explicitly typed as *owl:AnnotationProperty* (unless it is a predefined annotation property)
- Annotation properties are disjoint with other types of properties
- Annotation properties cannot be used in property axioms (e.g. it is not possible to state a domain, a range or a super property)

OWL 2 relaxed this constraint

- The value of an annotation property is either an individual, a data literal or a URI reference

Describing individuals

```
<Person rdf:ID=“armando”>
    <knows rdf:resource=“#manuel” />
    <name rdf:datatype=“&xsd;string”>Armando</name>
</Person>
<owl:Thing rdf:ID=“manuel”>
    <rdf:type rdf:resource=“#Person” />
    <name rdf:datatype=“&xsd;string”>Manuel</name>
</owl:Thing >
```

owl:differentFrom

```
<Person rdf:ID=“armando”>
    <owl:differentFrom rdf:resource=“#manuel” />
    <owl:differentFrom rdf:resource=“#andrea” />
</Person>
<owl:Thing rdf:ID=“manuel”>
     <owl:differentFrom rdf:resource=“#andrea” />
</owl:Thing>
<owl:Thing rdf:ID=“andrea” />
```

owl:AllDifferent

```
<owl:AllDifferent>
  <owl:distinctMembers
rdf:parseType="Collection">
    <owl:Thing rdf:about="#armando" />
    <owl:Thing rdf:about="#manuel" />
    <owl:Thing rdf:about="#andrea" />
  </owl:distinctMembers>
</owl:AllDifferent>
```

Class descriptions

Different kind of *class descriptions*

- A class *name* (URI)
- An exhaustive *enumeration* of its instances
- A *restriction on a property*
- *Intersection* of two or more classes
- *Union* of two or more classes
- The *complement* to a class

Name

```
<owl:Class rdf:ID="Human“ />
```

In *Description Logics* (DL) and *Manchester Syntax*

Human

In Manchester Syntax IRIs can be given in full or abbreviated as prefixed names (actually, the prefix and colon are optional)

Enumeration

We define a class through the set of individuals belonging to its extension

```
<owl:Class>
  <owl:oneOf rdf:parseType="Collection”>
    <owl:Thing rdf:about="#Europe”/>
    <owl:Thing rdf:about="#Africa”/>
    <owl:Thing rdf:about="#Asia”/>
    <owl:Thing rdf:about="#America”/>
    <owl:Thing rdf:about="#Australia”/>
    <owl:Thing rdf:about="#Antarctica”/>
  </owl:oneOf>
</owl:Class>
```

In *DL* and *Manchester Syntax*: {Europe, Africa, Asia, America, Australia, Antarctica}

Restriction on a property

A class is defined as the set of all individuals satisfying certain conditions on the use of a property.

- Value constraints
- Cardinality constraints

Value Restriction: owl:allValuesFrom

We define the class of individuals that have all values on a given property belonging to a certain class (if the property is an owl:ObjectProperty) or to a datarange (if an owl:DatatypeProperty)

```
<owl:Restriction>
  <owl:onProperty rdf:resource="#hasParent" />
  <owl:allValuesFrom rdf:resource="#Human"  />
</owl:Restriction>
```

In *DL*: ∀ hasParent . Human

In *Manchester Syntax*: hasParent only Human

Value Restriction owl:someValuesFrom

We define the class of individuals that have at least a value of a given property belonging to a certain class (if the property is an owl:ObjectProperty) or to a datarange (if an owl:DatatypeProperty)

```
<owl:Restriction>
  <owl:onProperty rdf:resource="#hasParent" />
  <owl:someValuesFrom rdf:resource="#Physician" />
</owl:Restriction>
```

In *DL*: ∃ hasParent . Physician

In *Manchester Syntax*: hasParent some Physician

Value Restriction owl:hasValue

We define the class of individuals that have a given property with at least a value semantically identical to a given one

```
<owl:Restriction>
  <owl:onProperty rdf:resource="#hasParent" />
  <owl:hasValue rdf:resource="#clinton" />
</owl:Restriction>
```

In *DL*: hasParent ∋ clinton

In *Manchester Syntax*: hasParent value clinton

Cardinality Restriction owl:maxCardinality

The class of all individuals that have maximum N semantically different values on a given property

```
<owl:Restriction>
  <owl:onProperty rdf:resource="#hasParent" />
  <owl:maxCardinality
rdf:datatype="&xsd;nonNegativeInteger">2</owl:maxCardinality>
</owl:Restriction>
```

In *DL*: ≤ 2 hasParent

In Manchester Syntax: hasParent max 2

Cardinality Restriction owl:minCardinality

The class of all individuals that have at least N semantically different values on a given property

```
<owl:Restriction>
  <owl:onProperty rdf:resource="#hasParent" />
  <owl:minCardinality
rdf:datatype="&xsd;nonNegativeInteger">2</owl:minCardinality>
</owl:Restriction>
```

In *DL*: ≥ 2 hasParent

In *Manchster Syntax*: hasParent min 2

Cardinality Restriction owl:cardinality

The class of all individuals having exactly N semantically different values on a given property

```
<owl:Restriction>
  <owl:onProperty rdf:resource="#hasParent" />
  <owl:cardinality
rdf:datatype="&xsd;nonNegativeInteger">2</owl:cardinality>
</owl:Restriction>
```

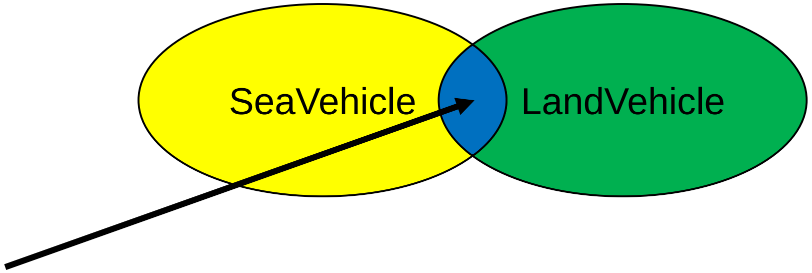
In *DL*: = 2 hasParent

In *Manchester Syntax*: hasParent exactly 2

Intersection owl:intersectionOf

The class of all individuals belonging to all of the classes listed in the intersection

```
<owl:Class>
  <owl:intersectionOf rdf:parseType="Collection">
    <owl:Class rdf:about="#LandVehicle" />
    <owl:Class rdf:about="#SeaVehicle" />
 </owl:intersectionOf>
</owl:Class>
```



In *DL*: LandVehicle ⊓ SeaVehicle

In *Manchester Syntax*: LandVehicle and SeaVehicle

Intersection owl:intersectionOf (cont’d)

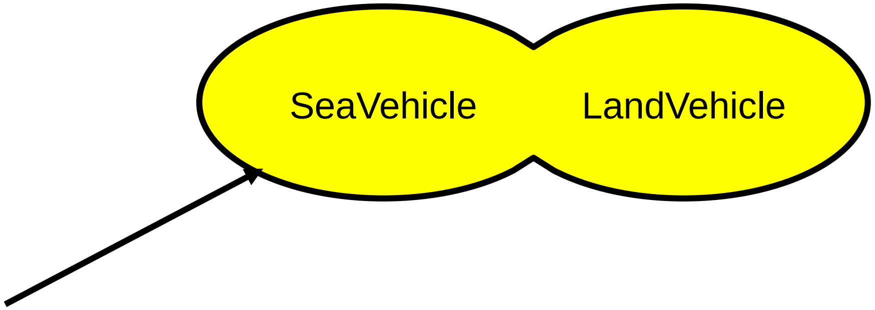
In Manchester Syntax, instead of using “and” it is possible to use “that” to write descriptions like the following (consisting in a collection of property restrictions):

Animal that eats min 1 and eats only Vegetables

Union owl:unionOf

The class of all individuals belonging to at least one of the classes listed in the union

```
<owl:Class>
  <owl:unionOf rdf:parseType="Collection">
    <owl:Class rdf:about="#LandVehicle" />
    <owl:Class rdf:about="#SeaVehicle" />
 </owl:unionOf>
</owl:Class>
```



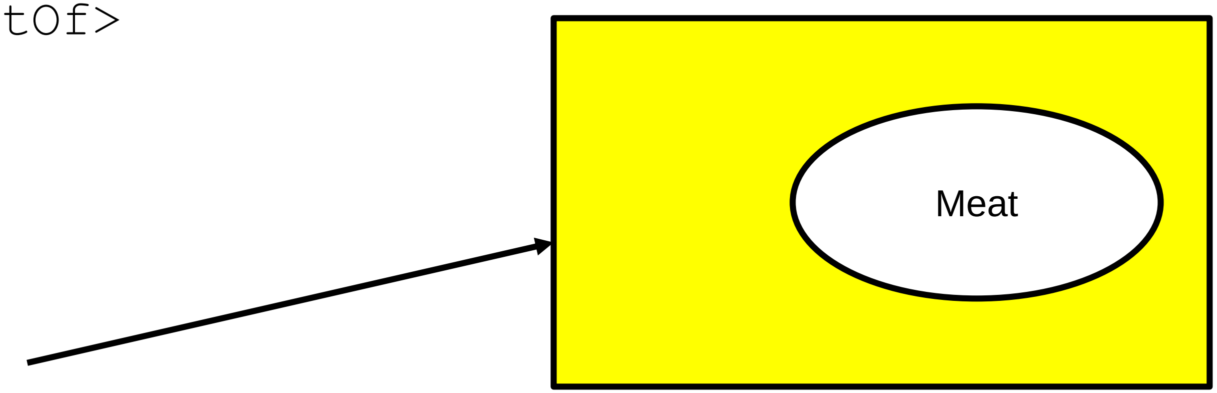
In *DL*: LandVehicle ⊔ SeaVehicle

In *Manchester Syntax*: LandVehicle or SeaVehicle

Complement owl:complementOf

The class of all individuals not belonging to a given class

```
<owl:Class>
  <owl:complementOf>
    <owl:Class rdf:about="#Meat"/>
  </owl:complementOf>
</owl:Class>
```



In *DL*: ¬Meat

In *Manchester Syntax*: not Meat

Operator Precedence

In decreasing order of precedence

- SOME, ONLY, VALUE, MIN, MAX, EXACTLY, THAT
- NOT
- AND
- OR

Italian AND Actor OR Musician	eats ALL Vegetable OR Meat
is parsed as	*is parsed as*
(Italian AND Actor) OR Musician	(eats ALL Vegetable) OR Meat

Class Axioms

OWL supports the following axioms concerning classes

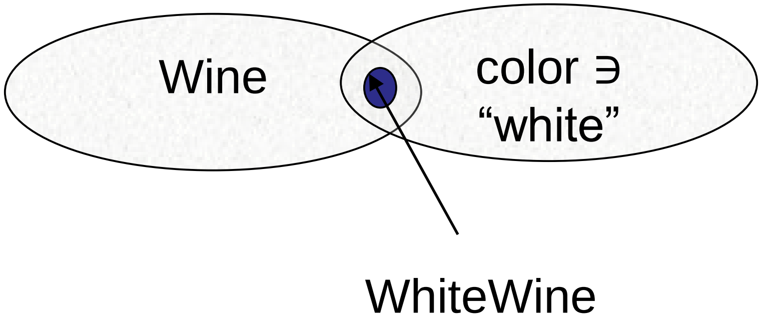
- `rdfs:subClassOf`
- `owl:equivalentClass`
- `owl:disjointWith`

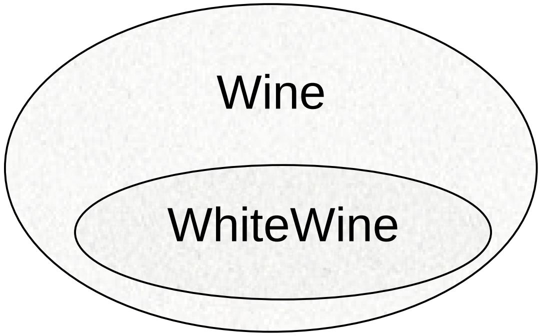
rdfs:subClassOf

```
<owl:Class rdf:ID=“aClass”>
     <rdfs:subClassOf>
          class expression
     </rdfs:subCassOf>
</owl:Class>


<owl:Class rdf:ID=“aClass”>
     <rdfs:subClassOf rdf:resource=“class” />
</owl:Class>
```

rdfs:subClassOf

```
<owl:Class rdf:ID=“WhiteWine”>
   <rdfs:subClassOf>
      <owl:Class>
         <owl:intersectionOf parseType=“Collection”>
            <owl:Class rdf:about=“#Wine” />
            <owl:Restriction>
               <owl:onProperty rdf:resource=“color” />
               <owl:hasValue rdf:datatype="&xsd;string">white</owl:hasValue>
            </owl:Restriction>
         </ owl:intersectionOf>
      </owl:Class>
   </rdfs:subCassOf>
</owl:Class>

<owl:Class rdf:id=“WhiteWine”>
   <rdfs:subClassOf rdf:resource=“Wine” />
</owl:Class>
```



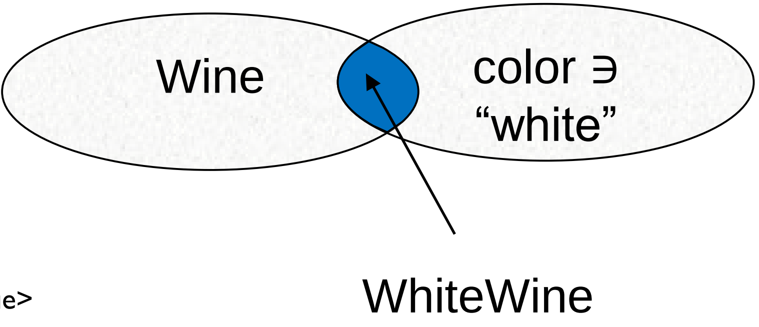


owl:equivalentClass

```
<owl:Class rdf:ID=“aClass”>
      <owl:equivalentClass>
            class expression
      </owl:equivalentClass >
</owl:Class>


<owl:Class rdf:ID=“aClass”>
      <owl:equivalentClass rdf:resource=“class” />
</owl:Class>
```

owl:equivalentClass

```
<owl:Class rdf:id=“WhiteWine”>
  <owl:equivalentClass>
    <owl:Class>
      <owl:intersectionOf parseType=“Collection”>
        <owl:Class rdf:about=“#Wine” />
        <owl:Restriction>
          <owl:onProperty rdf:resource=“color” />
          <owl:hasValue rdf:datatype="&xsd;string">white</owl:hasValue>
        </owl:Restriction>
      </ owl:intersectionOf>
    </owl:Class>
  </owl:equivalentClass>
</owl:Class>

<owl:Class rdf:id=“WhiteWine”>
  <owl:equivalentClass rdf:resource=“http://other.com/WhiteWine” />
</owl:Class>
```



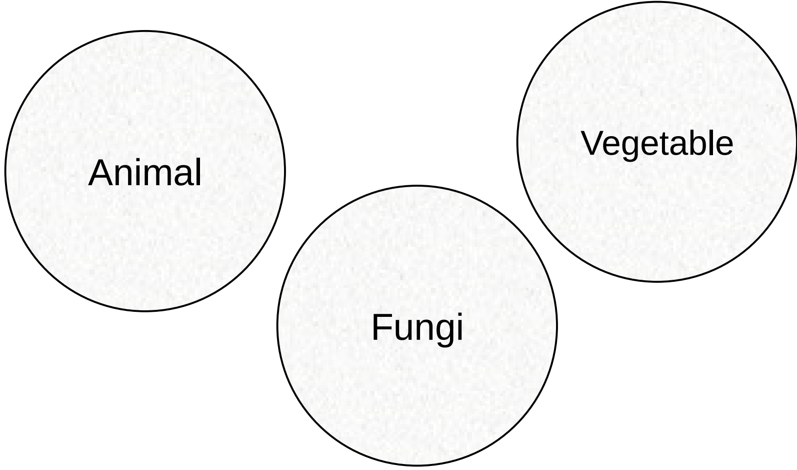
owl:disjointWith

```
<owl:Class rdf:id=“aClass”>
     <owl:DisjointWith>
           class expression
     </owl:disjointWith>
</owl:Class>

<owl:Class rdf:id=“aClass”>
     <owl:disjointWith rdf:resource=“class” />
</owl:Class>
```

owl:disjointWith

```
<owl:Class rdf:ID=“Animal”>
    <owl:disjointWith rdf:resource=“#Vegetable” />
    <owl:disjointWith rdf:resource=“#Fungi” />
</owl:Class>
<owl:Class rdf:ID=“Vegetale”>
       <owl:disjointWith rdf:resource=“#Fungi” />
</owl:Class>
<owl:Class rdf:ID=“Fungi” />
```

The above classes cannot have any instance in common



Property Facets

With OWL it is possible to express different characteristics (facets) of properties:

- owl:TransitiveProperty
- owl:SymmetricProperty
- owl:FunctionalProperty
- owl:inverseOf
- owl:InverseFunctionalProperty

owl:TransitiveProperty

if a property P is declared to be *transitive* then, for each: x, y, z, it holds that:

$$\frac{x\ P\ y \qquad y\ P\ z}{x\ P\ z}$$

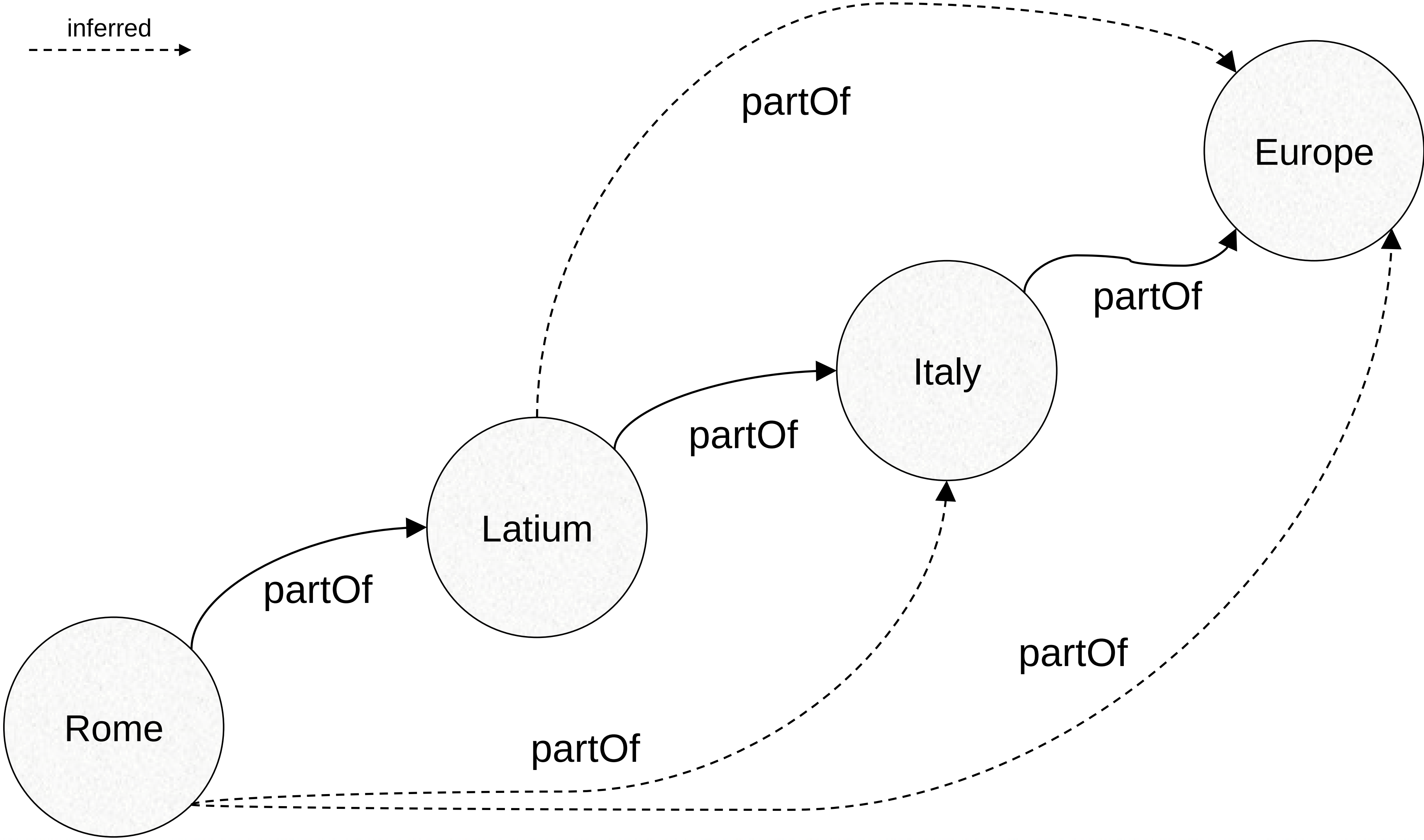
owl:TransitiveProperty

```
<owl:TransitiveProperty rdf:ID=“partOf” />
```

or

```
<owl:ObjectProperty rdf:ID=“partOf” />
    <rdf:type
rdf:resource=“&owl;TransitiveProperty” />
</owl:ObjectProperty>
```

owl:TransitiveProperty



owl:SymmetricProperty

if a property P is declared to be *symmetric* then, for each: x, y it holds that:

$$\frac{x\ P\ y}{y\ P\ x}$$

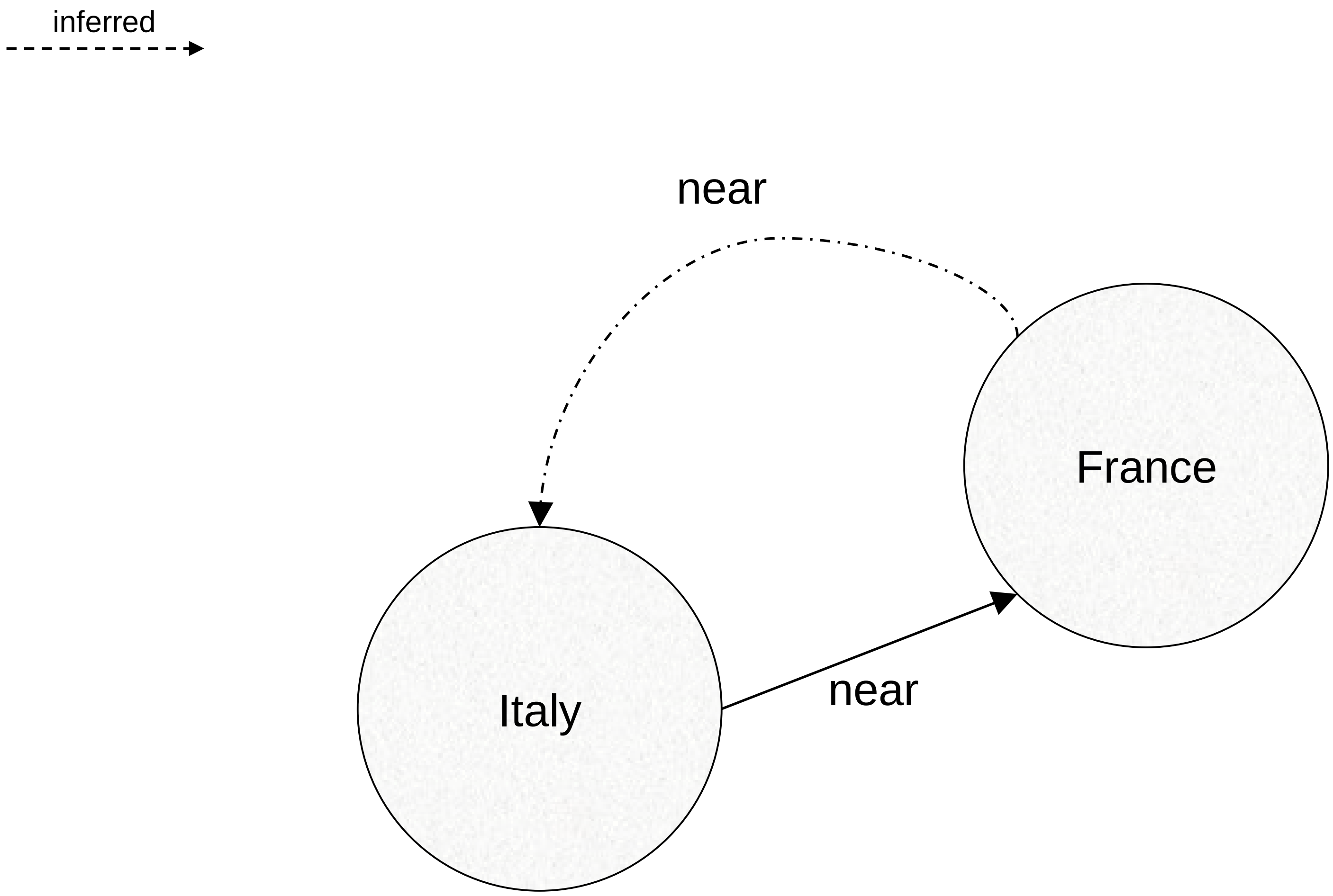
owl:SymmetricProperty

```
<owl:SymmetricProperty rdf:ID=“near” />
```

or

```
<owl:ObjectProperty rdf:ID=“near” />
    <rdf:type rdf:resource=“&owl;
SymmetricProperty” />
</owl:ObjectProperty>
```

owl:SymmetricProperty



owl:FunctionalProperty

if a property P is declared to be *functional* then, for each: x, y, z it holds that:

$$\frac{x\ P\ y \qquad x\ P\ z}{y = z}$$

Any resource can have (at most) one value (unique) for a functional property

owl:FunctionalProperty

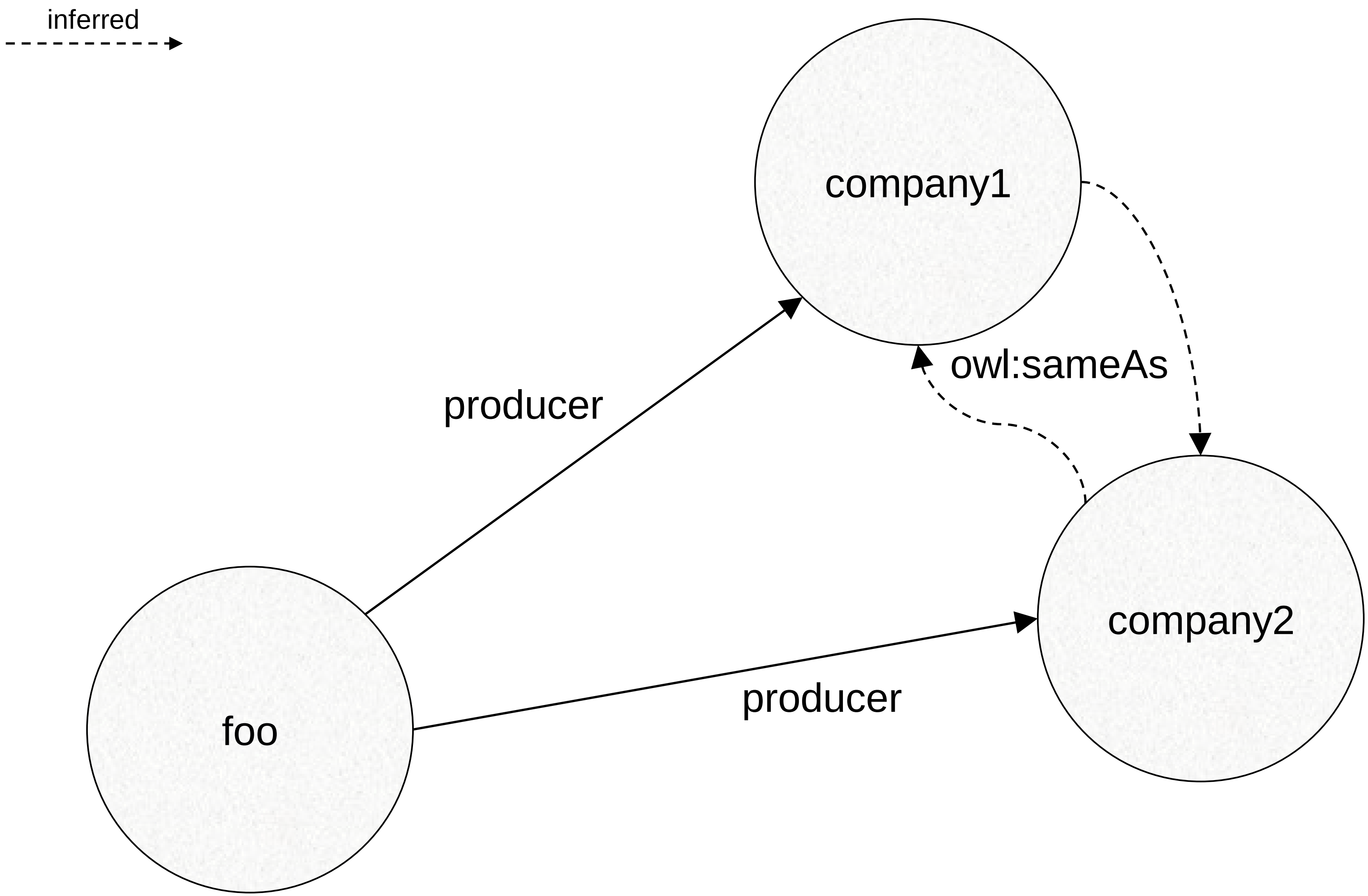
```
<owl:FunctionalProperty rdf:ID=“produttore” />
```

or

```
<owl:ObjectProperty rdf:ID=“produttore” />
    <rdf:type rdf:resource=“&owl;
FunctionalProperty” />
</owl:ObjectProperty>
```

Even datatypeproperties can be functional

owl:FunctionalProperty



owl:inverseOf

`X hasChild Y` if and only if `Y hasParent X`

```
<owl:ObjectProperty rdf:ID="hasChild">
  <owl:inverseOf rdf:resource="#hasParent"/>
</owl:ObjectProperty>
```

owl:InverseFunctionalProperty

if a property P is declared to be *inverseFunctional* then,

for each: x, y, z it holds that:

$$\frac{x\ P\ z \qquad y\ P\ z}{x = y}$$

The object of an inverse functional property uniquely determines the subject, i.e. it's a unique identifier

owl:InverseFunctionalProperty

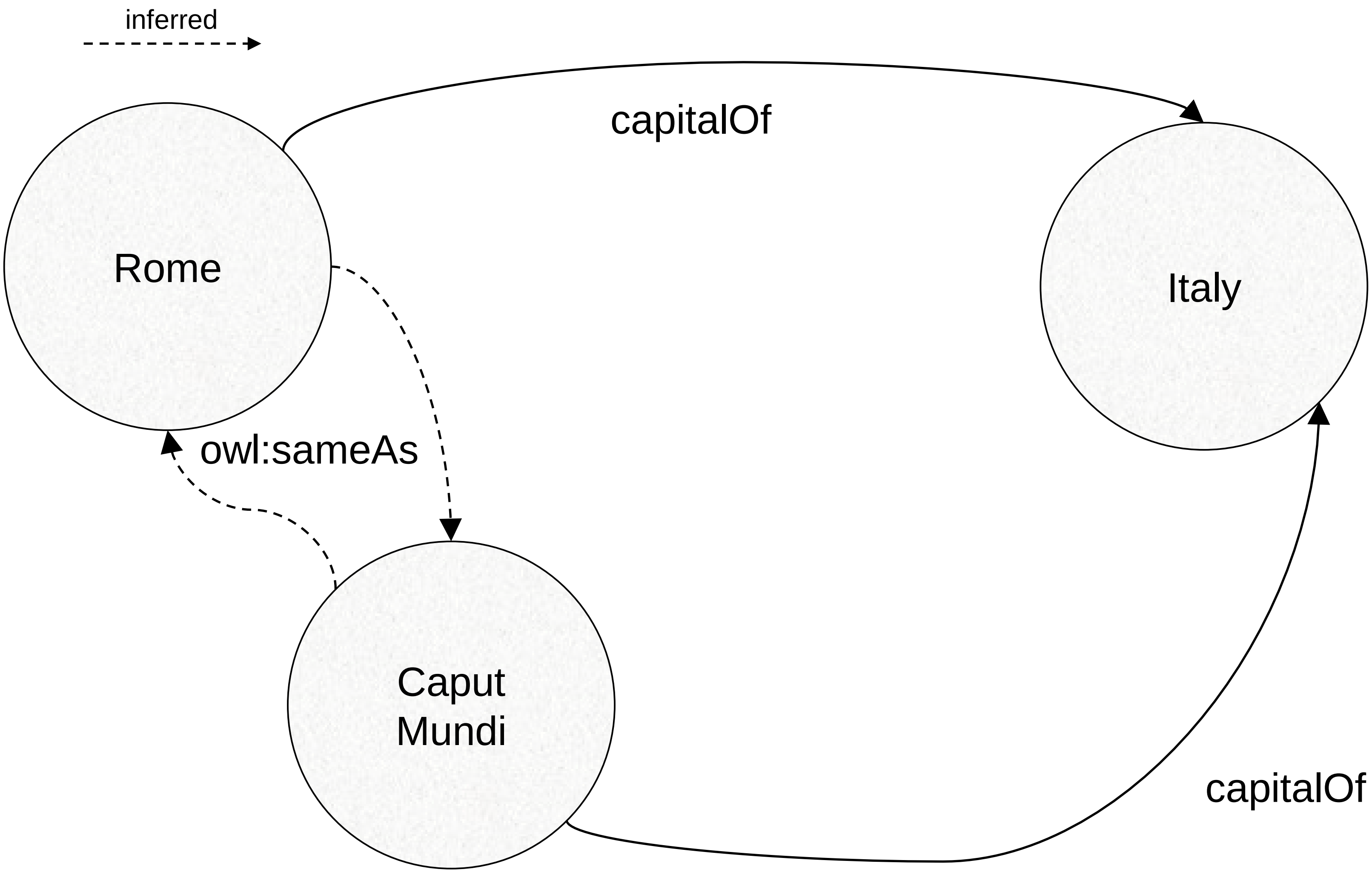
```
<owl:InverseFunctionalProperty rdf:ID=“capitalOf” />
```

or

```
<owl:ObjectProperty rdf:ID=“capitalOf” />
    <rdf:type rdf:resource=“&owl;
InverseFunctionalProperty” />
</owl:ObjectProperty>
```

In OWL DL: only object properties can be inverseFunctional

owl:InverseFunctionalProperty



owl:Ontology

An instance of the class *owl:Ontology* can be used to express metadata about an ontology (e.g. creator, version, etc…)

It can be also used to (transitively) import other ontologies (in order to include their axioms)

```
<owl:Ontology rdf:about=“”>
        <rdfs:label xml:lang=“en”>An example ontology</rdfs:label>
        <owl:imports rdf:resource=“http://purl.org/dc/elements/1.1/” />
        <dc:creator>Manuel Fiorelli</dc:creator>
</owl:Ontology>
```

An example RDF/XML file (1/4)

```
<?xml version="1.0"?>
<!DOCTYPE rdf:RDF [
      <!ENTITY foaf "http://xmlns.com/foaf/0.1/">
]>
<rdf:RDF xmlns="http://example.org#"
     xml:base="http://example.org"
     xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
     xmlns:owl="http://www.w3.org/2002/07/owl#"
     xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
     xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
     xmlns:foaf="http://xmlns.com/foaf/0.1/"
     xmlns:base="http://example.org"> <!-- continues on the next slide -->
```

Entity declaration!!!!

An example RDF/XML file (2/4)

```
<owl:Ontology rdf:about="http://example.org">
    <owl:imports rdf:resource="http://xmlns.com/foaf/0.1/" />
</owl:Ontology>


<owl:Class rdf:ID="EducationalInstitution">
    <rdfs:subClassOf rdf:resource="&foaf;Organization" />
    <rdfs:label xml:lang="en">educational institution</rdfs:label>
    <rdfs:label xml:lang="it">istituto d'istruzione</rdfs:label>
</owl:Class>
<!-- continues on the next slide -->
```

An example RDF/XML file (3/4)

```
<owl:Class rdf:ID="Student">
    <owl:equivalentClass>
        <owl:Class>
            <owl:intersectionOf rdf:parseType="Collection">
                <rdf:Description rdf:about="&foaf;Person" />
                <owl:Restriction>
                    <owl:onProperty rdf:resource="#enrolledIn" />
                    <owl:someValuesFrom rdf:resource="#EducationalInstitution" />
                </owl:Restriction>
            </owl:intersectionOf>
        </owl:Class>
    </owl:equivalentClass>
    <rdfs:label xml:lang="en">student</rdfs:label>
    <rdfs:label xml:lang="it">studente</rdfs:label>
</owl:Class>
```

<!-- continues on the next slide -->

An example RDF/XML file (4/4)

```
    <owl:ObjectProperty rdf:ID="enrolledIn">
        <rdfs:label xml:lang="en">enrolled in</rdfs:label>
        <rdfs:label xml:lang="it">iscritto a</rdfs:label>
    </owl:ObjectProperty>
</rdf:RDF>
```

An example Turle file (1/3)

```
@prefix : <http://example.org#> .
@prefix owl: <http://www.w3.org/2002/07/owl#> .
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix xml: <http://www.w3.org/XML/1998/namespace> .
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .
@prefix base: <http://example.org> .
@prefix foaf: <http://xmlns.com/foaf/0.1/> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@base <http://example.org> .

<http://example.org> rdf:type owl:Ontology ;
                     owl:imports foaf: .
# continues on the next slide
```

An example Turle file (2/3)

```
:enrolledIn rdf:type owl:ObjectProperty ;
        rdfs:label "enrolled in"@en ,
                 "iscritto a"@it .
:EducationalInstitution rdf:type owl:Class ;
                rdfs:subClassOf foaf:Organization ;
                rdfs:label "educational institution"@en ,
                         "istituto d'istruzione"@it .
# continues on the next slide
```

An example Turle file (3/3)

```
:Student rdf:type owl:Class ;
       owl:equivalentClass [ owl:intersectionOf ( foaf:Person
                                      [ rdf:type owl:Restriction ;
                                        owl:onProperty :enrolledIn ;
                                        owl:someValuesFrom :EducationalInstitution
                                      ]
                                    ) ;
                       rdf:type owl:Class
                     ] ;
       rdfs:label "student"@en ,
                "studente"@it .
```

Useful References

OWL 1

- OWL Web Ontology Language. Guide (https://www.w3.org/TR/owl-guide/)
- OWL Web Ontology Language. Reference (https://www.w3.org/TR/owl-ref/)