Università di Roma
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Short notes about OWL[1]

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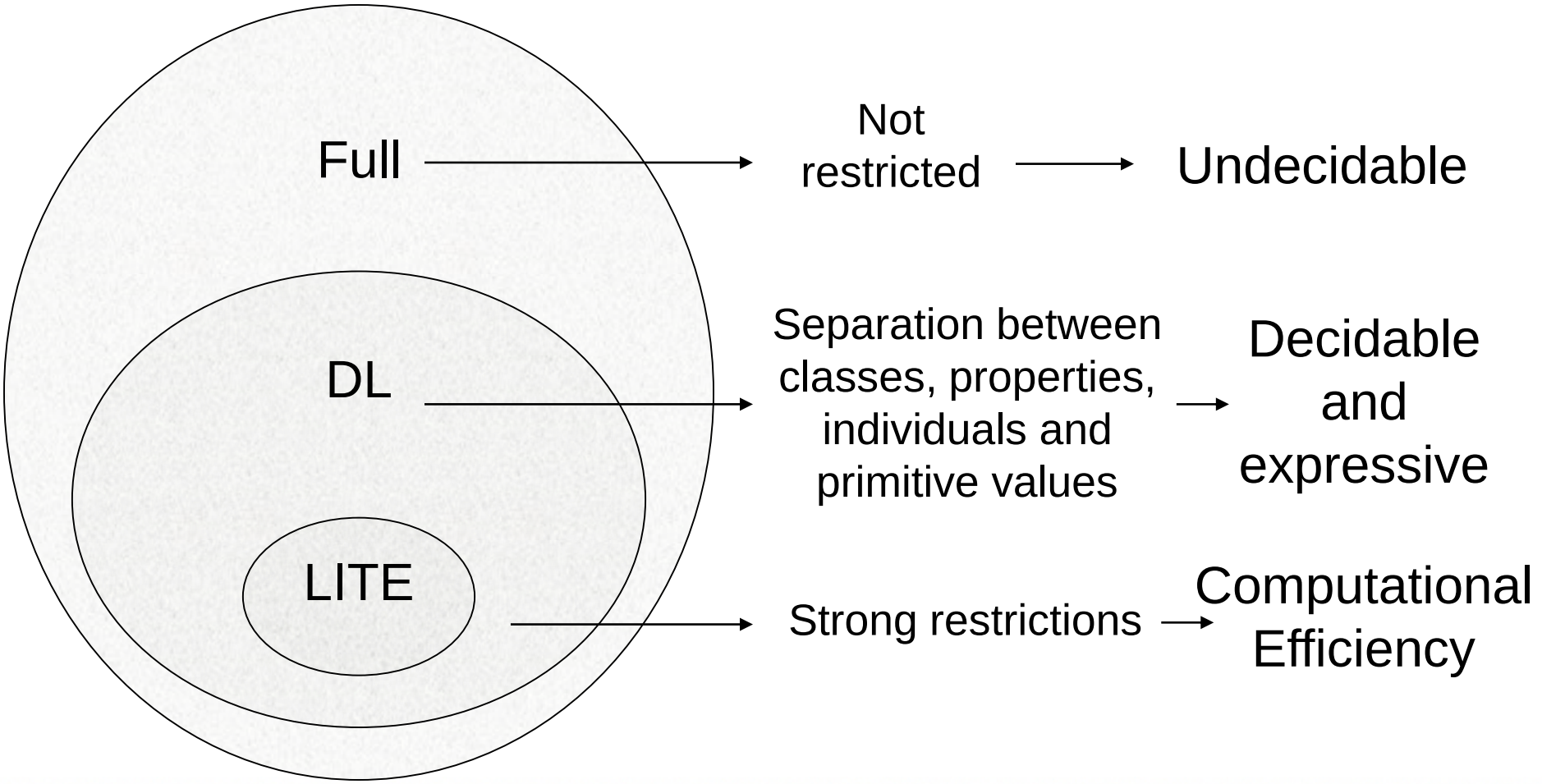
[1] this presentation is limited to OWL 1 features. A new version of OWL (OWL 2), which adds further features (thus remaining backward-compatible with the original OWL), has reached the status of W3C recommendation in 2012

OWL Sublanguages

Sublanguages defined upon restrictions on the use of OWL constructs



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

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

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

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

OWL 2 relaxed this constraint

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

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Different kind of *class descriptions*

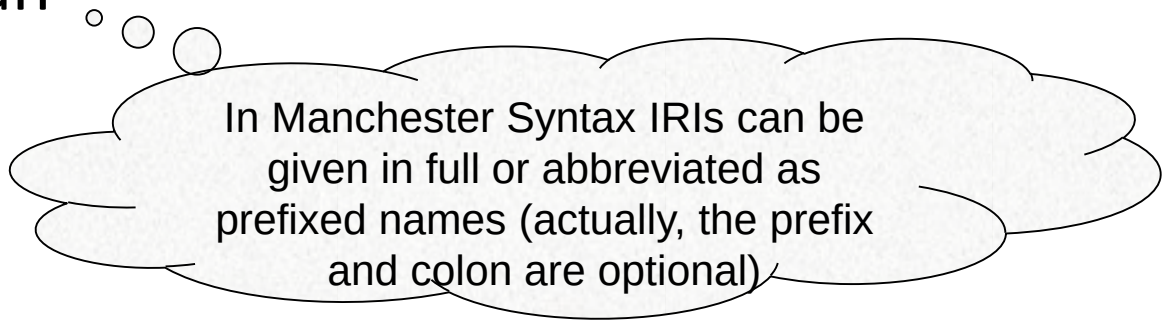
- A class *name* (URI)
- An exhaustive *enumeration* of its instances
- A *restriction on a property*
- *Intersection* of two or more classes
- *Union* of two or more classes
- The *complement* to a class

Name

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

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

Human



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

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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>
```

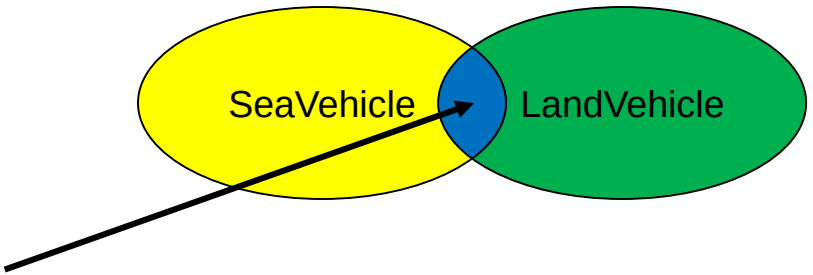
In *DL*: = 2 hasParent

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)

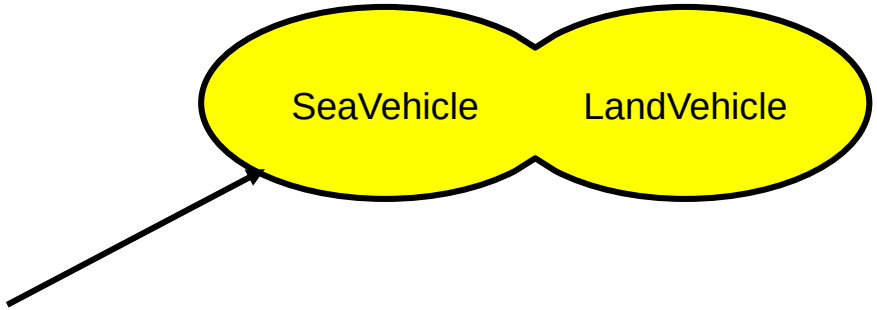
In Manchester Syntax, instead of using "and" it is possible to use "that" to write descriptions like the following (consisting in a collection of property restrictions):

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>
```



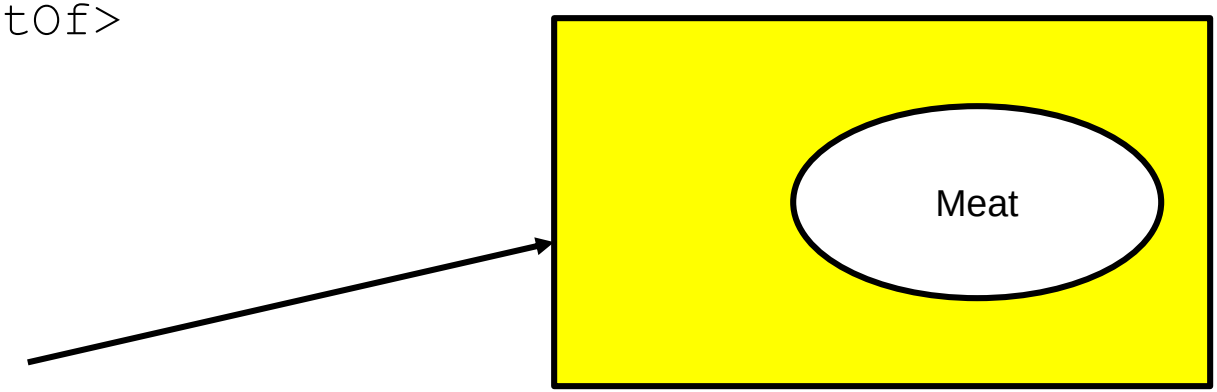
In *DL*: LandVehicle ⊔ SeaVehicle

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

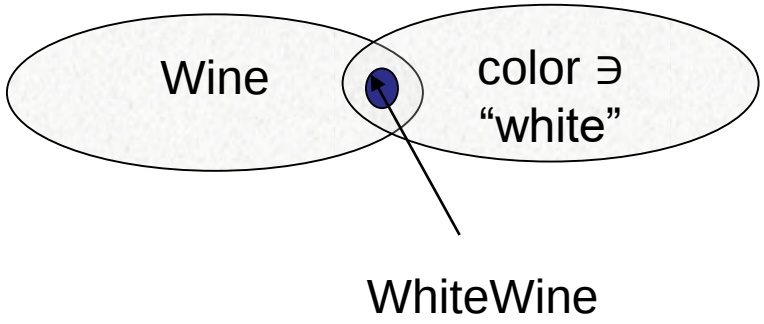
- `rdfs:subClassOf`
- `owl:equivalentClass`
- `owl:disjointWith`

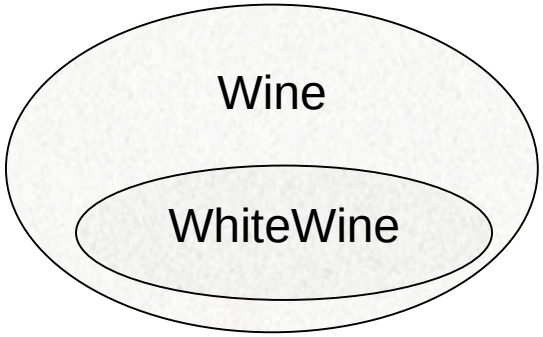
rdfs:subClassOf

```
<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>
```



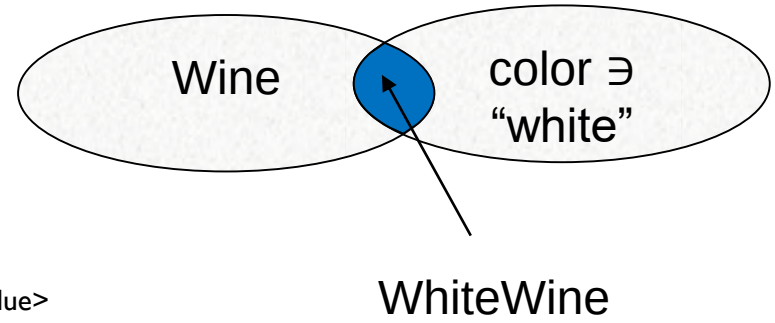


owl:equivalentClass

```
<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>
```



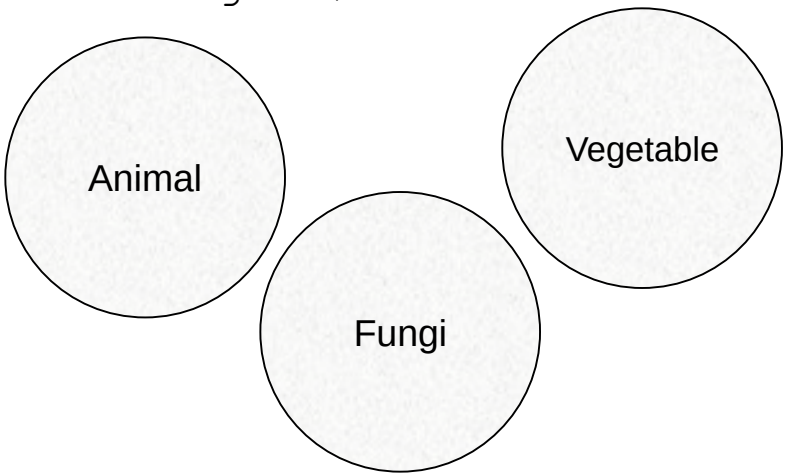
owl:disjointWith

```
<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="Vegetable">
      <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:

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

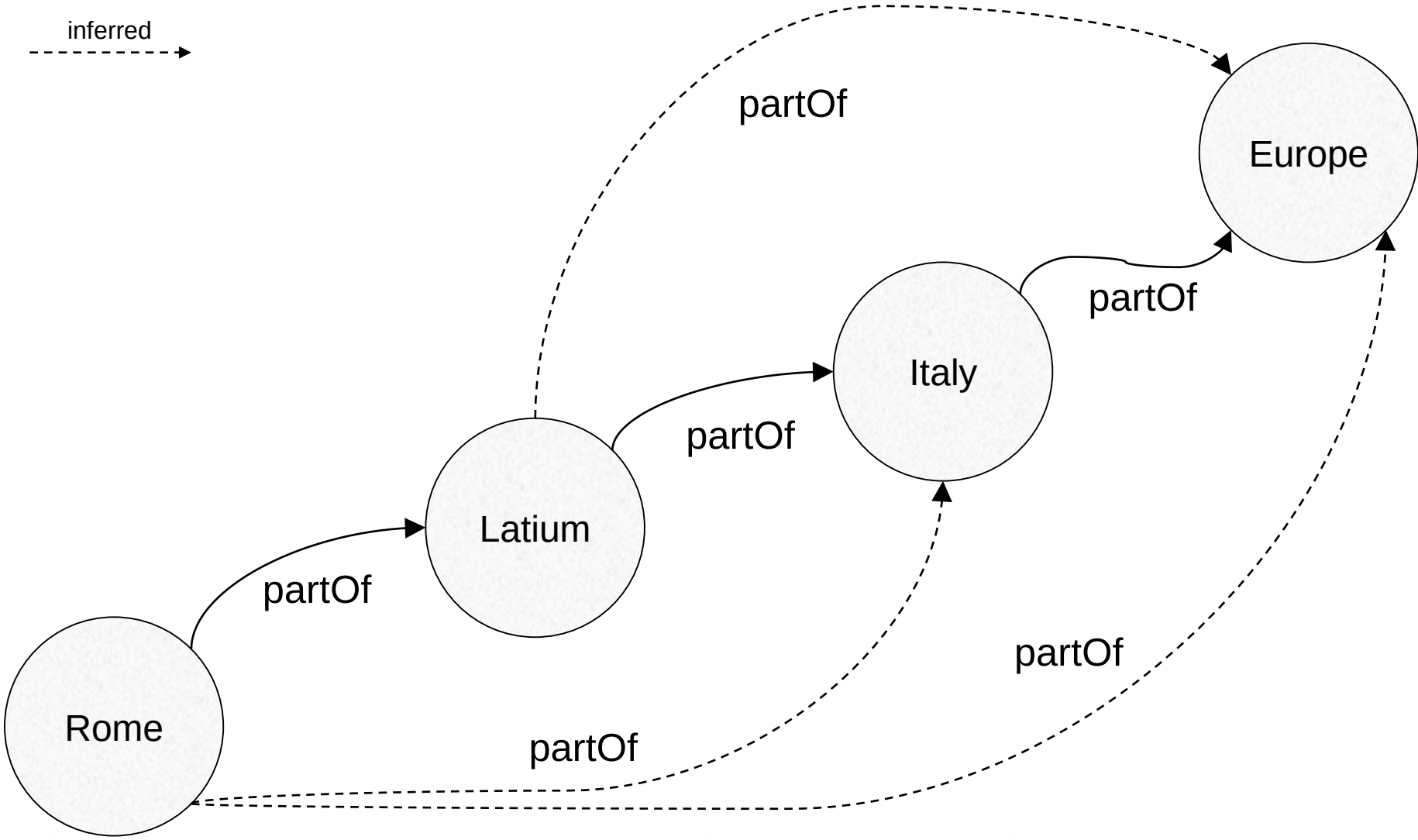
owl:TransitiveProperty

```
<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:

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

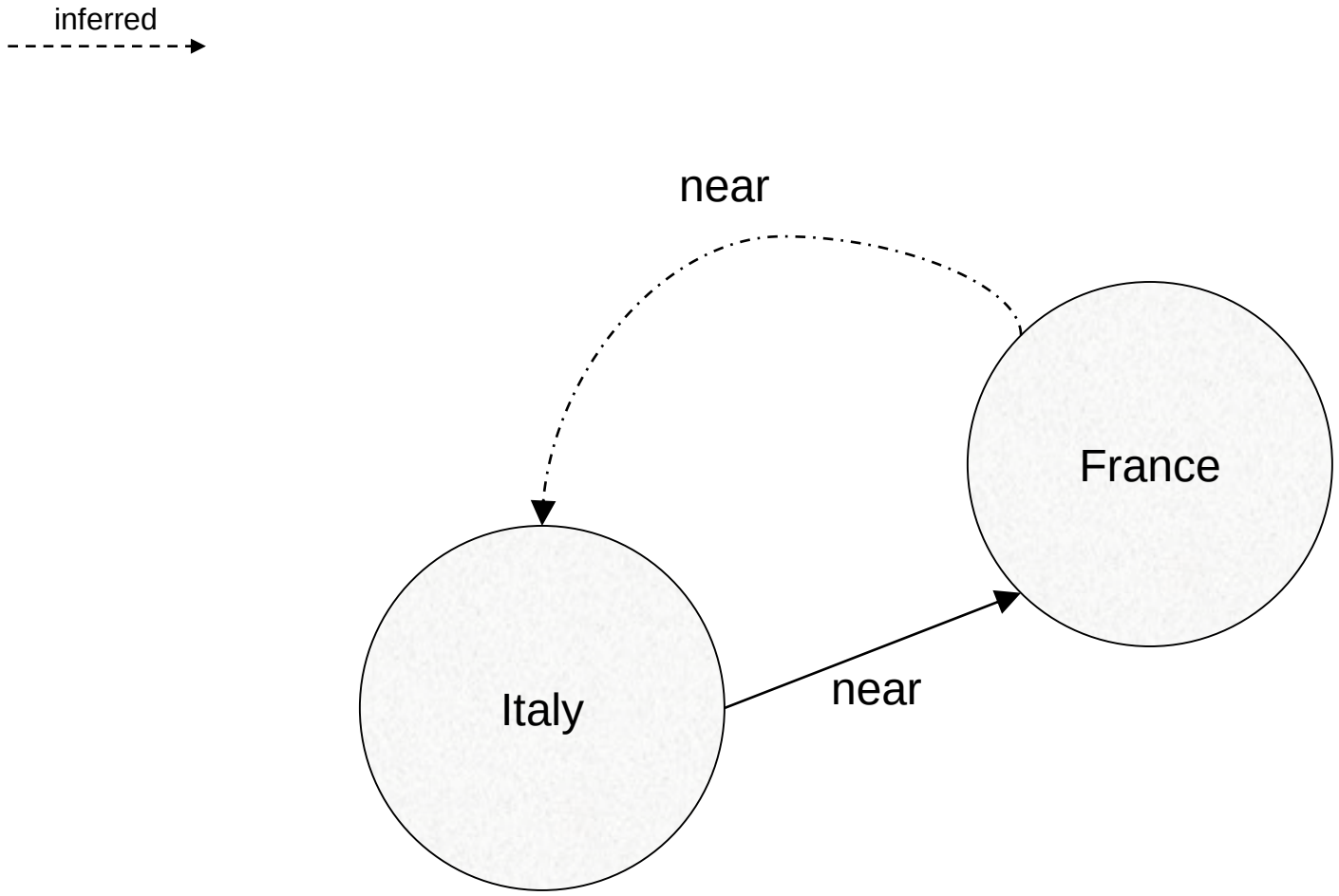
owl:SymmetricProperty

```
<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:

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

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

owl:FunctionalProperty

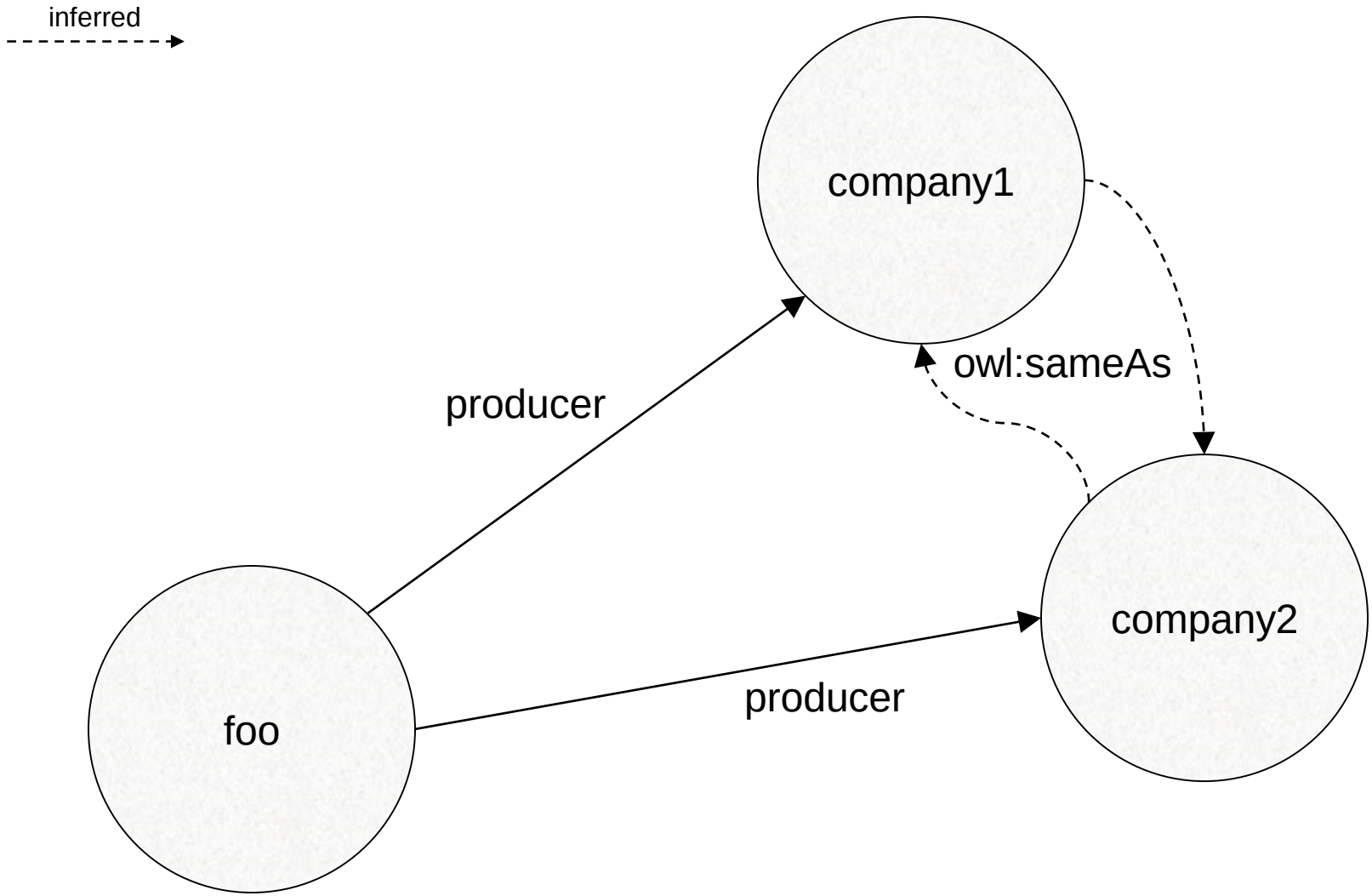
```
<owl:FunctionalProperty rdf:ID="produttore" />
```

or

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

Even datatype properties 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:

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

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

owl:InverseFunctionalProperty

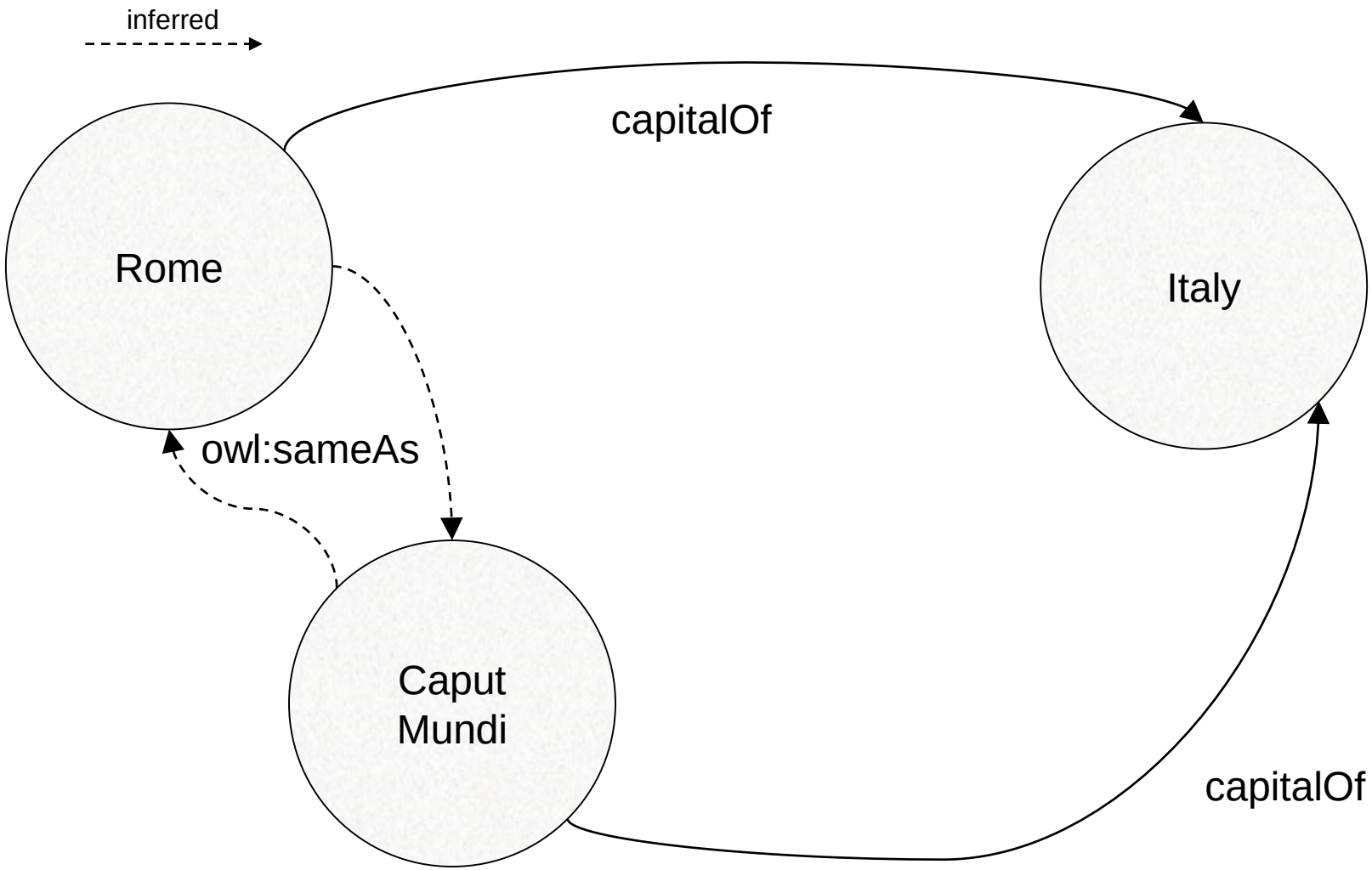
```
<owl:InverseFunctionalProperty rdf:ID="capitalOf" />
```

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

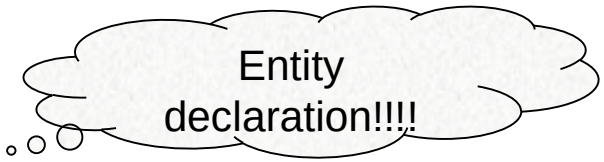
An instance of the class *owl:Ontology* can be used to express metadata about an ontology (e.g. creator, version, etc…)

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 -->
```



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/)