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Semantic Web In Depth: Resource Description Framework

Dr Nicholas Gibbins
32/4037
nmg@ecs.soton.ac.uk

RDF syntax(es)

- RDF/XML is the standard syntax
  - Supported by almost all tools

- RDF/N3 (Notation3) is also widely used
  - Non-XML syntax
  - Not a standard
  - Patchy tool support
  - Primarily designed to be easy to write on whiteboards

- Other non-XML syntaxes exist
  - Turtle, NTriples, etc

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URIs and URIrefs

- Uniform Resource Identifiers are defined by RFC2396
  - http://example.org/
  - urn:isbn:0198537379
  - mailto:nmg@ecs.soton.ac.uk
- URI references (URIrefs) are URIs with optional fragment identifiers
  - http://example.org/index.html#Introduction
  - http://www.w3.org/1999/02/22-rdf-syntax-ns#type

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XML namespaces and qualified names

- RDF uses XML namespaces to refer to elements of domain vocabularies

```
xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
```

namespace abbreviation

namespace URI prefix

- Namespaces used to abbreviate URIrefs to qualified names (QNames)

```
http://www.w3.org/1999/02/22-rdf-syntax-ns#type
```

becomes

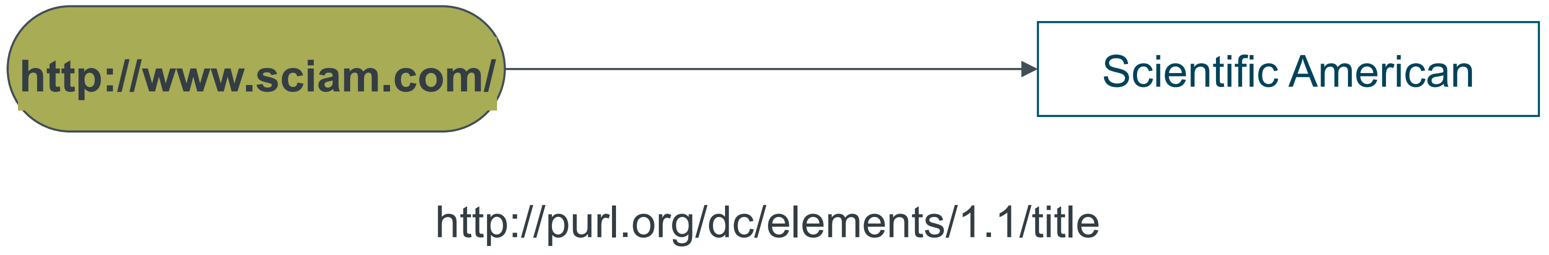
```
rdf:type
```

- QNames cannot be used in attribute values
  – Use the URIref instead

The anatomy of an RDF/XML file

[illegible]

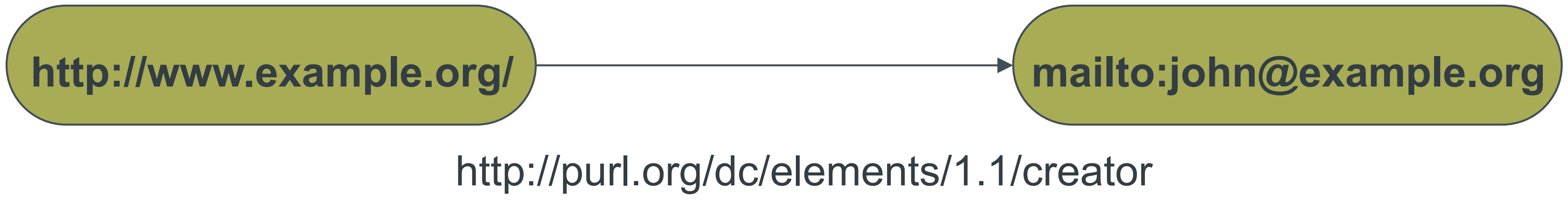
```
<?xml version="1.0"?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
         xmlns:dc="http://purl.org/dc/elements/1.1/">
  <rdf:Description rdf:about="http://www.sciam.com/">
    <dc:title>Scientific American</dc:title>
  </rdf:Description>
</rdf:RDF>
```



The anatomy of an RDF/XML file

- Resource-valued predicates use the rdf:resource attribute

```
<?xml version="1.0"?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
         xmlns:dc="http://purl.org/dc/elements/1.1/">
  <rdf:Description rdf:about="http://www.example.org/">
    <dc:creator rdf:resource="mailto:john@example.org"/>
  </rdf:Description>
</rdf:RDF>
```



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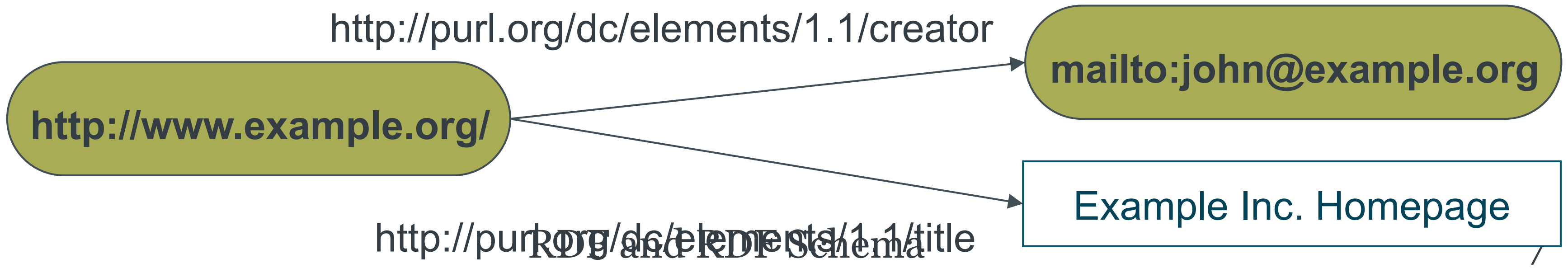
The anatomy of an RDF/XML file

- We can have multiple rdf:Description elements within an rdf:RDF element

```
<?xml version=“1.0”?>
<rdf:RDF xmlns:rdf=“http://www.w3.org/1999/02/22-rdf-syntax-ns#”
         xmlns:dc=“http://purl.org/dc/elements/1.1/”>
  <rdf:Description rdf:about=“http://www.example.org/”>
    <dc:title>Example Inc. Homepage</dc:title>
  </rdf:Description>
  <rdf:Description rdf:about=“http://www.example.org/”>
    <dc:creator rdf:resource=“mailto:john@example.org”/>
  </rdf:Description>
</rdf:RDF>
```


http://purl.org/dc/elements/1.1/creator
mailto:john@example.org
http://www.example.org/
Example Inc. Homepage
http://purl.org/dc/elements/1.1/title

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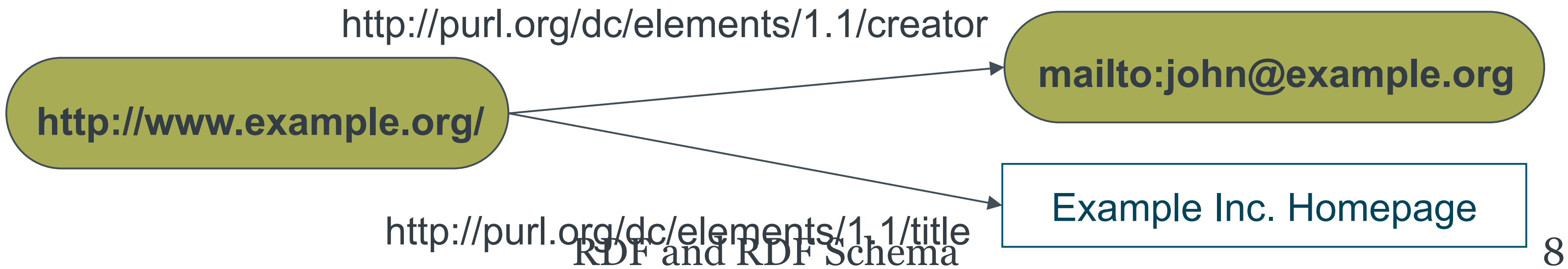
The anatomy of an RDF/XML file

- We can have multiple predicates within an rdf:Description element

```
<?xml version="1.0"?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
         xmlns:dc="http://purl.org/dc/elements/1.1/">
  <rdf:Description rdf:about="http://www.example.org/">
    <dc:title>Example Inc. Homepage</dc:title>
    <dc:creator rdf:resource="mailto:john@example.org"/>
  </rdf:Description>
</rdf:RDF>
```


http://purl.org/dc/elements/1.1/creator
mailto:john@example.org
http://www.example.org/
Example Inc. Homepage
http://purl.org/dc/elements/1.1/title

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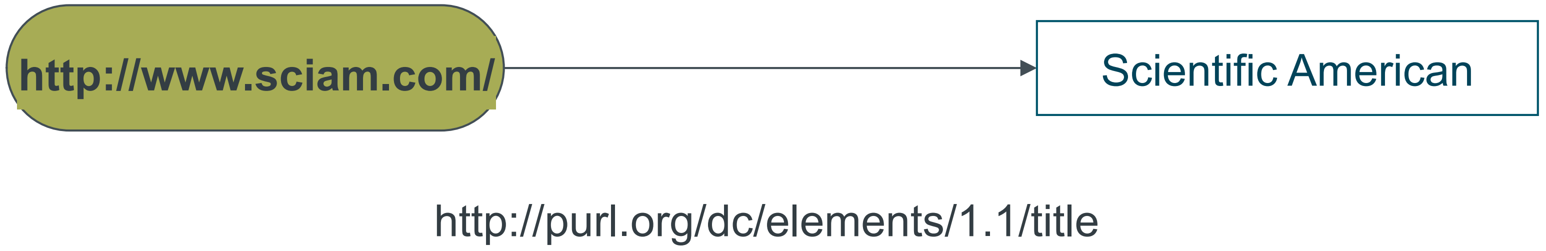
The anatomy of an NTriples file

```
<http://www.sciam.com/>
    <http://purl.org/dc/elements/1.1/title> "Scientific American" .
```



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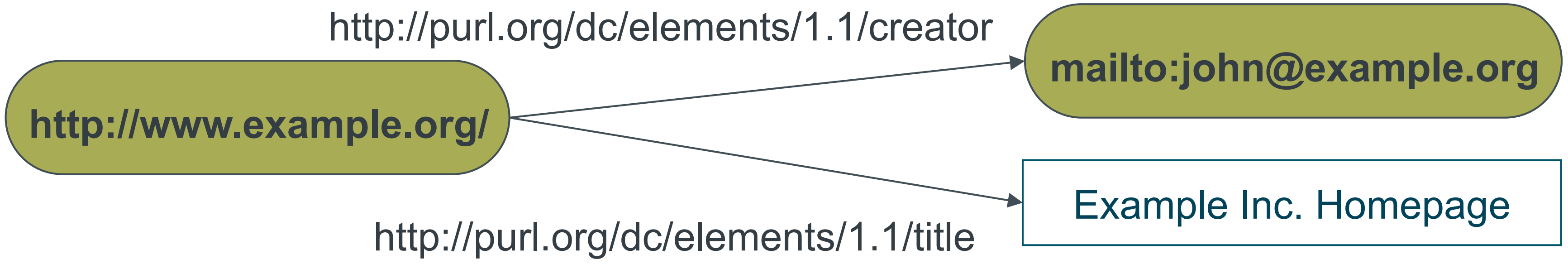
The anatomy of an Turtle/N3 file

```
<http://www.example.org>
    <http://purl.org/dc/elements/1.1/creator> <mailto:john@example.org> ;
    <http://purl.org/dc/elements/1.1/title> “Example Inc. Homepage” .
```

- Allows grouping of triples with common subject


http://purl.org/dc/elements/1.1/creator
mailto:john@example.org
http://www.example.org/
Example Inc. Homepage
http://purl.org/dc/elements/1.1/title

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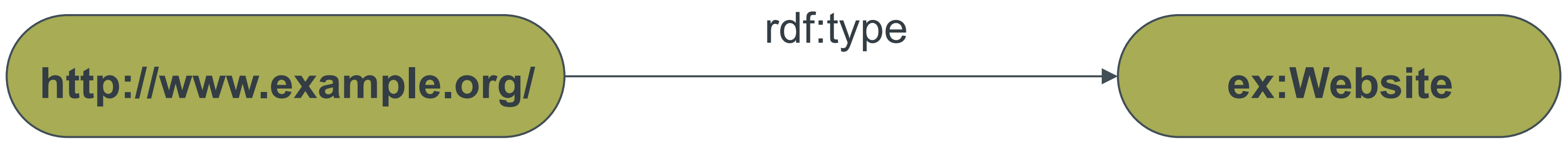
Class membership

- An object’s membership of a class is indicated using the rdf:type property

```
<?xml version=“1.0”?>
<rdf:RDF xmlns:rdf=“http://www.w3.org/1999/02/22-rdf-syntax-ns#”>
  <rdf:Description rdf:about=“http://www.example.org/”>
    <rdf:type rdf:resource=“http://example.org/ontology#Website”/>
  </rdf:Description>
</rdf:RDF>
```



Abbreviated forms – literal predicates

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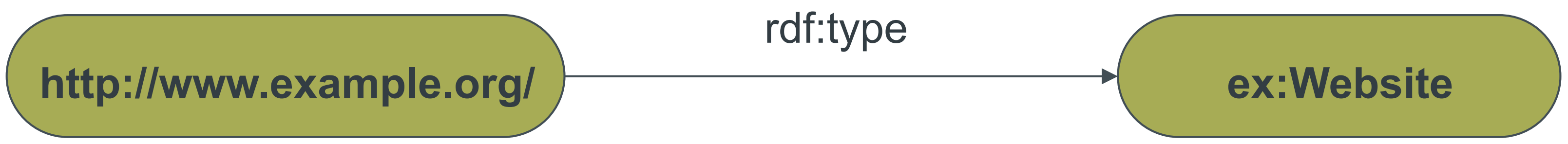
- Replace predicate element with attribute of same name on containing element

```
<?xml version="1.0"?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
         xmlns:dc="http://purl.org/dc/elements/1.1/">
  <rdf:Description rdf:about="http://www.example.org/"
                   dc:title="Example Inc. Homepage">
  </rdf:Description>
</rdf:RDF>
```

Abbreviated forms – class membership

- Replace rdf:Description with QName of class

```
<?xml version="1.0"?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
         xmlns:ex="http://example.org/ontology#">
  <ex:Website rdf:about="http://www.example.org/"/>
</rdf:RDF>
```



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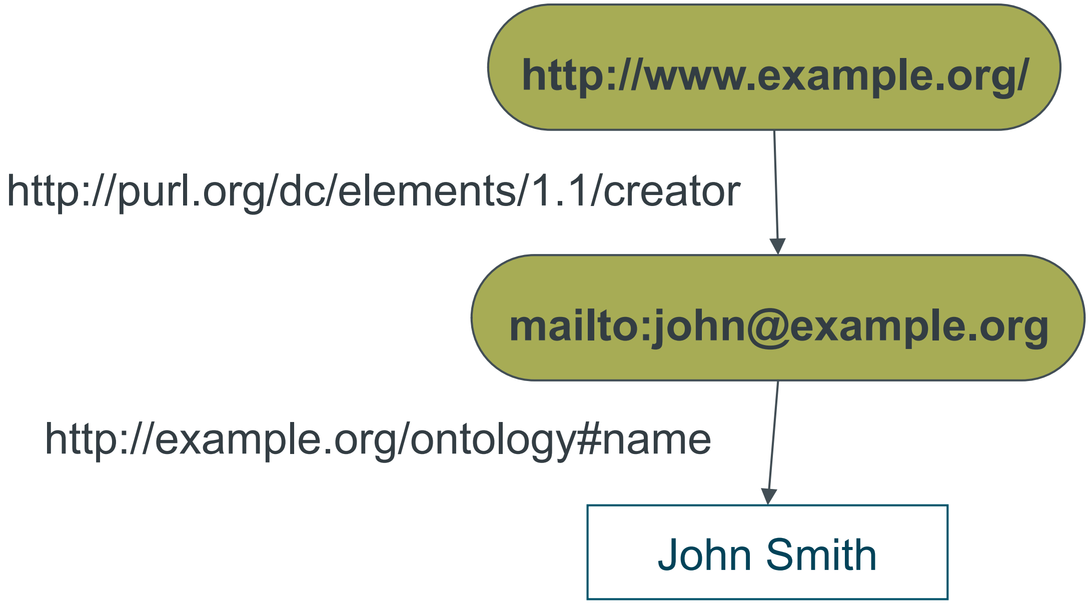
RDF/XML striped syntax

- Consider the following graph:


http://www.example.org/
http://purl.org/dc/elements/1.1/creator
mailto:john@example.org
http://example.org/ontology#name
John Smith

RDF/XML striped syntax

- Graph could be serialised using two rdf:Description elements

```
<?xml version="1.0"?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
         xmlns:dc="http://purl.org/dc/elements/1.1/"
         xmlns:ex="http://example.org/ontology#">
  <rdf:Description rdf:about="http://www.example.org/">
    <dc:creator rdf:resource="mailto:john@example.org"/>
  </rdf:Description>
  <rdf:Description rdf:about="mailto:john@example.org">
    <ex:name>John Smith</ex:name>
  </rdf:Description>
</rdf:RDF>
```

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RDF/XML striped syntax

- Alternatively, the second statement could be inserted within the predicate element of the first

```
<?xml version="1.0"?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
         xmlns:dc="http://purl.org/dc/elements/1.1/"
         xmlns:ex="http://example.org/ontology#">
  <rdf:Description rdf:about="http://www.example.org/">
    <dc:creator>
      <rdf:Description rdf:about="mailto:john@example.org">
        <ex:name>John Smith</ex:name>
      </rdf:Description>
    </dc:creator>
  </rdf:Description>
</rdf:RDF>
```

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RDF/XML striped syntax

- The syntax is striped because property and class elements are nested alternately

```
<?xml version="1.0"?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
         xmlns:dc="http://purl.org/dc/elements/1.1/"
         xmlns:ex="http://example.org/ontology#">
  <rdf:Description rdf:about="http://www.example.org/">
    <dc:creator>
      <rdf:Description rdf:about="mailto:john@example.org">
        <ex:name>John Smith</ex:name>
      </rdf:Description>
    </dc:creator>
  </rdf:Description>
</rdf:RDF>
```

Common RDF/XML idioms

- XML entities are defined for the XML namespace URI prefixes

```
<?xml version="1.0"?>
<!DOCTYPE rdf:RDF [
    <!ENTITY rdf 'http://www.w3.org/1999/02/22-rdf-syntax-ns#'>
    <!ENTITY dc  'http://purl.org/dc/elements/1.1/'>
    <!ENTITY ex  'http://example.org/ontology#'>
]>
<rdf:RDF xmlns:rdf="&rdf;"
         xmlns:dc="&dc;"
         xmlns:ex="&ex;">
```

- Used to abbreviate long URIrefs in attribute values (because QNames can't be used there)

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Common RDF/N3 idioms

- @prefix used to introduce QName abbreviations to N3 and Turtle documents:

```
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix dc: <http://purl.org/dc/elements/1.1/> .
@prefix ex: <http://example.org/ontology#> .

<http://www.example.org> dc:creator <mailto:john@example.org> ;
    rdf:type ex:Website .
```

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Common RDF idioms

- Assertions about the null URIref are about the RDF file itself

```
<?xml version="1.0"?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
         xmlns:dc="http://purl.org/dc/elements/1.1/">
  <rdf:Description rdf:about="">
    <dc:creator rdf:resource="mailto:nmg@ecs.soton.ac.uk"/>
  </rdf:Description>
</rdf:RDF>
```

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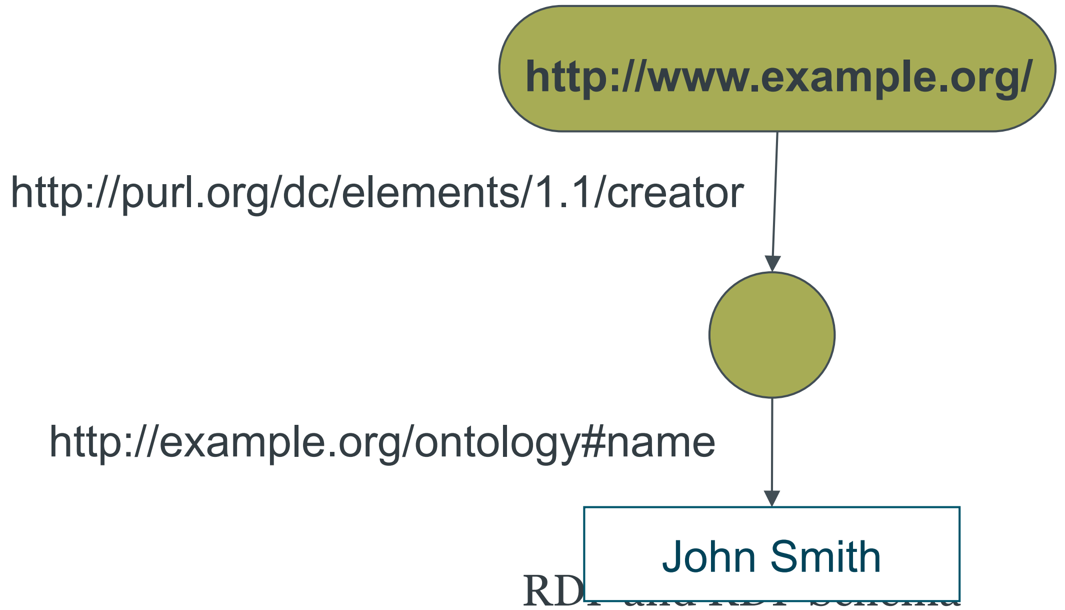
Blank nodes (bNodes)

- Sometimes we have resources which we do not wish to identify with a URI
- These are *blank nodes* or *anonymous resources*


http://www.example.org/
http://purl.org/dc/elements/1.1/creator
http://example.org/ontology#name
John Smith

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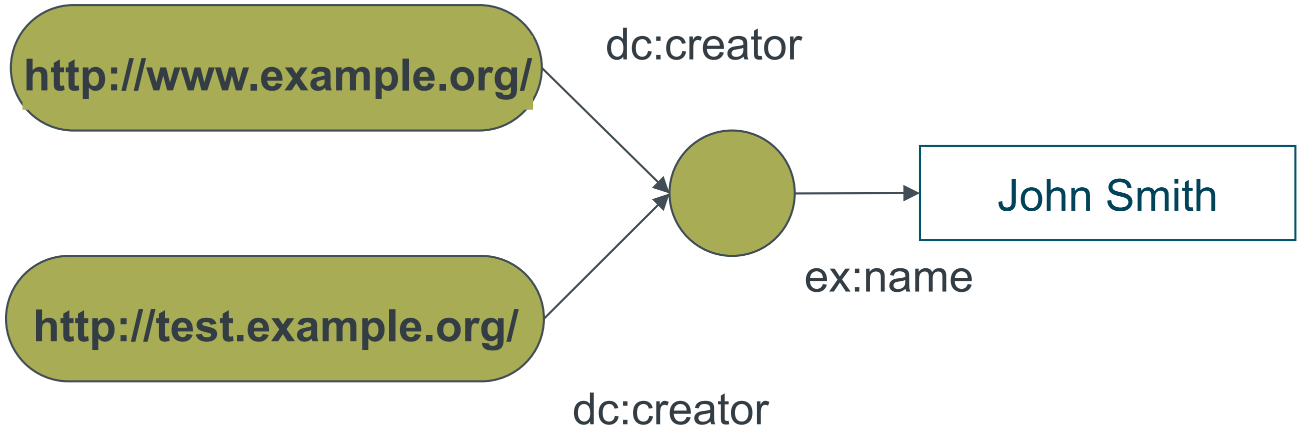
Blank nodes (bNodes)

- The striped syntax simplifies the RDF/XML serialisation – remove the rdf:about attribute

```
<?xml version="1.0"?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
         xmlns:dc="http://purl.org/dc/elements/1.1/"
         xmlns:ex="http://example.org/ontology#">
  <rdf:Description rdf:about="http://www.example.org/">
    <dc:creator>
      <rdf:Description>
        <ex:name>John Smith</ex:name>
      </rdf:Description>
    </dc:creator>
  </rdf:Description>
</rdf:RDF>
```

Blank nodes (bNodes)

- The striped syntax is not sufficient to represent all graphs containing blank nodes unambiguously



Blank nodes (bNodes)

```
<?xml version="1.0"?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
         xmlns:dc="http://purl.org/dc/elements/1.1/"
         xmlns:ex="http://example.org/ontology#">
  <rdf:Description rdf:about="http://www.example.org/">
    <dc:creator>
      <rdf:Description>
        <ex:name>John Smith</ex:name>
      </rdf:Description>
    </dc:creator>
  </rdf:Description>
  <rdf:Description rdf:about="http://test.example.org/">
    <dc:creator>
      <rdf:Description>
        <ex:name>John Smith</ex:name>
      </rdf:Description>
    </dc:creator>
  </rdf:Description>
</rdf:RDF>
```

Blank nodes and node IDs

- Ambiguities resulting from blank nodes are resolved by using *node IDs*
- Node IDs are identifiers which are local to a given serialisation of an RDF graph
- Node IDs are not guaranteed to remain unchanged when an RDF file is parsed and serialised
  - The identifier strings may change

  but

  - The graph structure will remain unchanged

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Blank nodes and node IDs

```
<?xml version="1.0"?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
         xmlns:dc="http://purl.org/dc/elements/1.1/"
         xmlns:ex="http://example.org/ontology#">
  <rdf:Description rdf:about="http://www.example.org/">
    <dc:creator rdf:nodeID="foo23"/>
  </rdf:Description>
  <rdf:Description rdf:about="http://test.example.org/">
    <dc:creator rdf:nodeID="foo23"/>
  </rdf:Description>
  <rdf:Description rdf:nodeID="foo23">
    <ex:name>John Smith</ex:name>
  </rdf:Description>
</rdf:RDF>
```

bNodes in N3 and Turtle

```
<http://www.example.org/> dc:creator [ ex:name “John Smith” ] .
```

- Or with nodeIDs:

```
<http://www.example.org/> dc:creator _:foo23 .
<http://test.example.org/> dc:creator _:foo23 .
_:foo23 ex:name “John Smith” .
```

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rdf:about versus rdf:ID

- So far, we have used the rdf:about attribute to specify the subjects of triples
  - rdf:about takes a URIref as a value
- rdf:ID can be used to declare a new URIref within a document
  - Within the file http://www.example.org/ontology

    ```
    <rdf:Description rdf:ID=“JohnSmith”>
    ```

    declares a new URIref http://www.example.org/ontology#JohnSmith
  - Analogous to the name and id attributes in HTML
  - Relative to xml:base attribute

Datatypes

- Literal values presented so far are plain and do not have a type
  - Many applications need to be able to distinguish between different typed literals
- RDF uses XML Schema datatypes

```
<rdf:Description rdf:about="http://www.example.org/">
  <dc:date
    rdf:datatype="http://www.w3.org/2001/XMLSchema#date">2003-05-23</dc:date>
</rdf:Description>
```

Multilingual support

- In addition to typed literals, RDF also provides support for language annotations on literals
- RDF uses XML’s multilingual support

```
<?xml version=“1.0”?>
<rdf:RDF xmlns:rdf=“http://www.w3.org/1999/02/22-rdf-syntax-ns#”
         xmlns:dc=“http://purl.org/dc/elements/1.1/”>
  <rdf:Description rdf:about=“http://www.example.org/foreword”>
    <dc:title xml:lang=“en”>Foreword</dc:title>
    <dc:title xml:lang=“fr”>Avant-propos</dc:title>
  </rdf:Description>
</rdf:RDF>
```

- Languages identified by ISO369 two letter codes

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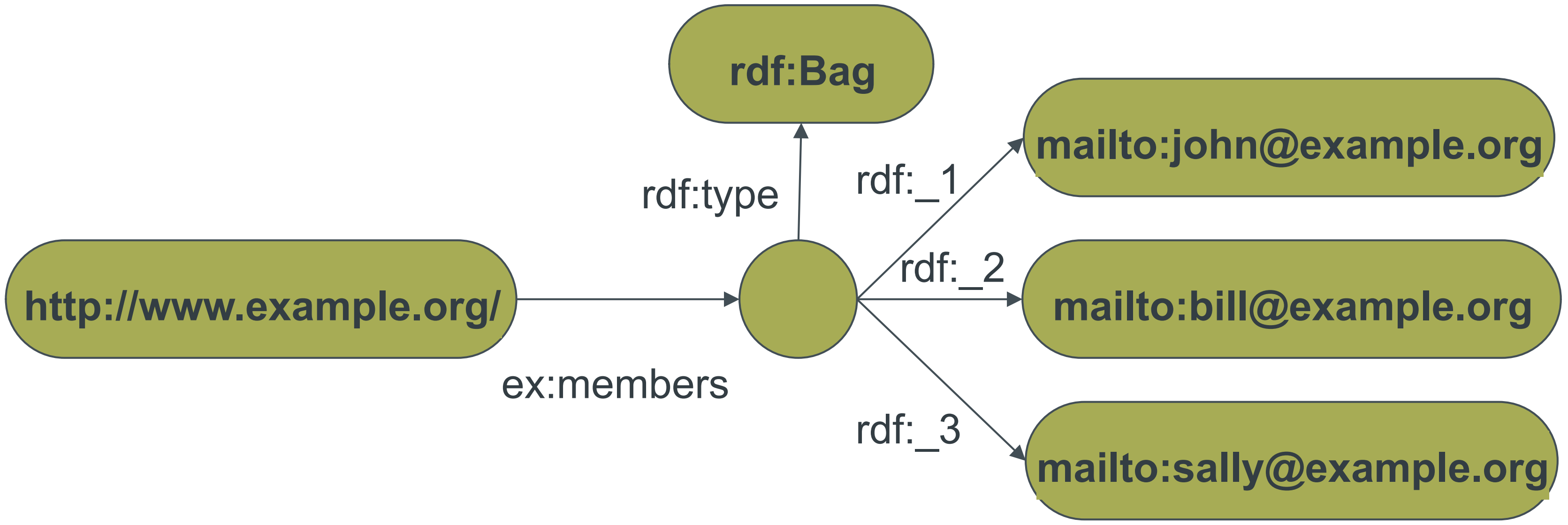
Containers

- RDF provides means for describing groups of objects
- Membership in the group is denoted by the ordinal properties rdf:_1, rdf:_2, etc



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Containers

- Three types of container are available in RDF
  - rdf:Bag – an unordered group, possibly with duplicates
  - rdf:Seq – an ordered group
  - rdf:Alt – a group of alternatives (translations, media types, etc)

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Containers

- Special syntax for expressing collections
  - rdf:li is a convenience element which is replaced with ordinal elements by RDF parsers

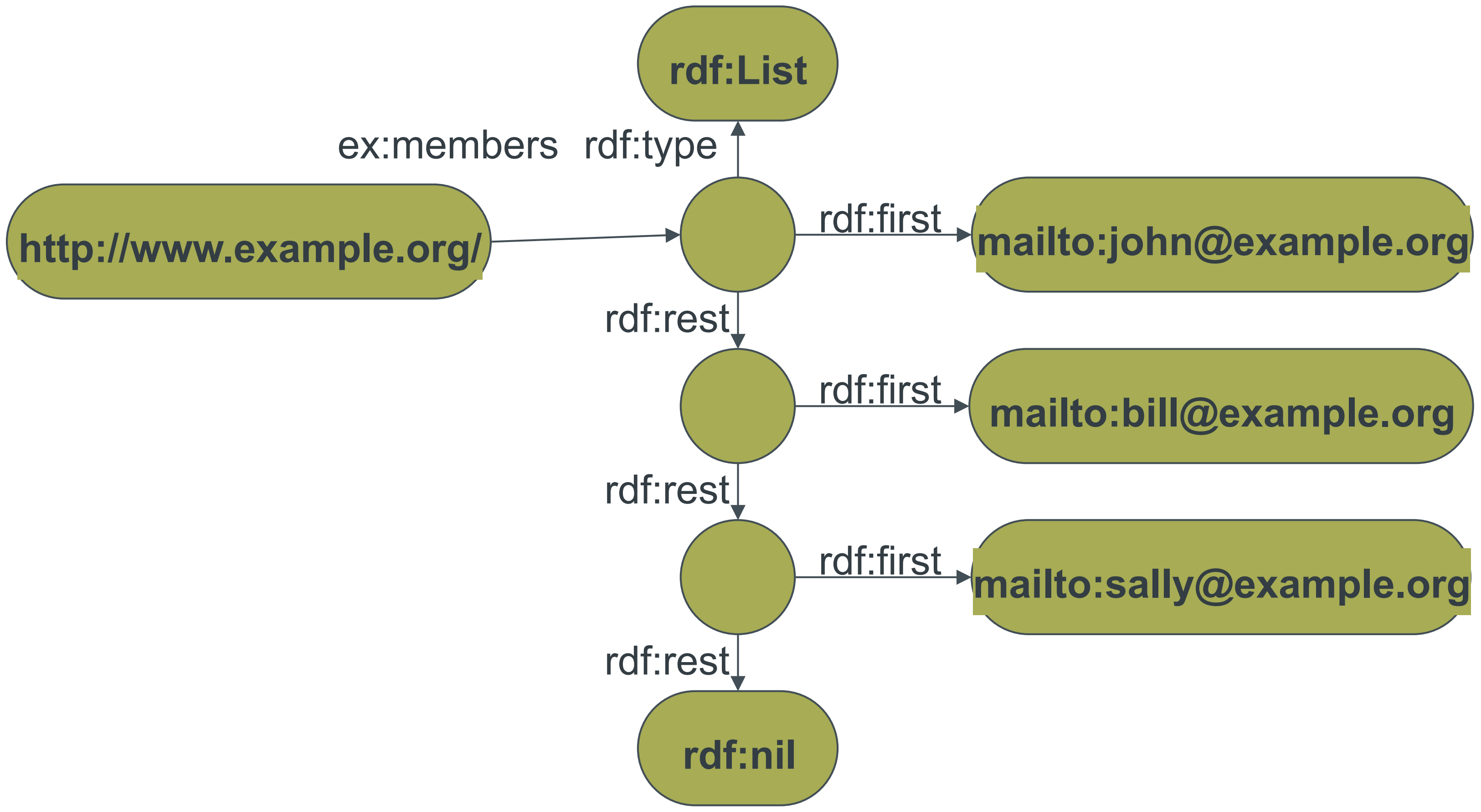
```
<?xml version="1.0"?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
         xmlns:ex="http://example.org/ontology#">
  <rdf:Description rdf:about="http://www.example.org/">
    <ex:members>
      <rdf:Bag>
        <rdf:li rdf:resource="mailto:john@example.org"/>
        <rdf:li rdf:resource="mailto:bill@example.org"/>
        <rdf:li rdf:resource="mailto:sally@example.org"/>
      </rdf:Bag>
    </ex:members>
  </rdf:Description>
</rdf:RDF>
```

Collections

- Collections are a different way of expressing ordered groups in RDF
  – Containers are mutable – a third party could add new members to a container
  – Collections are immutable – cannot be altered without rendering the collection ill-formed

- Similar to cons/car/cdr lists in Lisp

Collections



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Collections

- As before, special syntax for expressing collections
  - rdf:parseType indicates special parse rules for an element

```
<?xml version="1.0"?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
         xmlns:ex="http://example.org/ontology#">
  <rdf:Description rdf:about="http://www.example.org/">
    <ex:members rdf:parseType="Collection">
      <rdf:Description rdf:about="mailto:john@example.org"/>
      <rdf:Description rdf:about="mailto:bill@example.org"/>
      <rdf:Description rdf:about="mailto:sally@example.org"/>
    </ex:members>
  </rdf:Description>
</rdf:RDF>
```

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RDF Status

- Original version published in 1999
- Working group (RDF Core) formed in April 2001
- Revised version published in early 2004

RDF references

- RDF homepage at W3C
  - http://www.w3.org/RDF/
- RDF Core homepage
  - http://www.w3.org/2001/sw/RDFCore/
- RDF/N3 Primer
  - http://www.w3.org/2000/10/swap/Primer.html
- XML Schema Part 2: Datatypes
  - http://www.w3.org/TR/xmlschema-2/

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Semantic Web in Depth: RDF Schema

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Using RDF to define RDFS

- RDFS is an RDF vocabulary which contains:

- Classes for defining classes and properties
- Properties for defining basic characteristics of classes and properties
  - Global property domains and ranges
- Some ancillary properties
  - Defined by, see also

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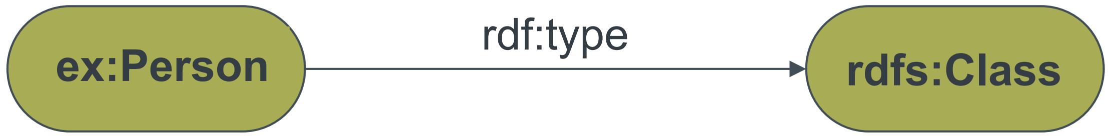
RDF Schema class definitions

- We wish to define the class Person



```
<rdf:Description rdf:about="#Person">
  <rdf:type rdf:about="&rdfs;Class"/>
</rdf:Description>
```

```
<rdfs:Class rdf:about="#Person"/>
```

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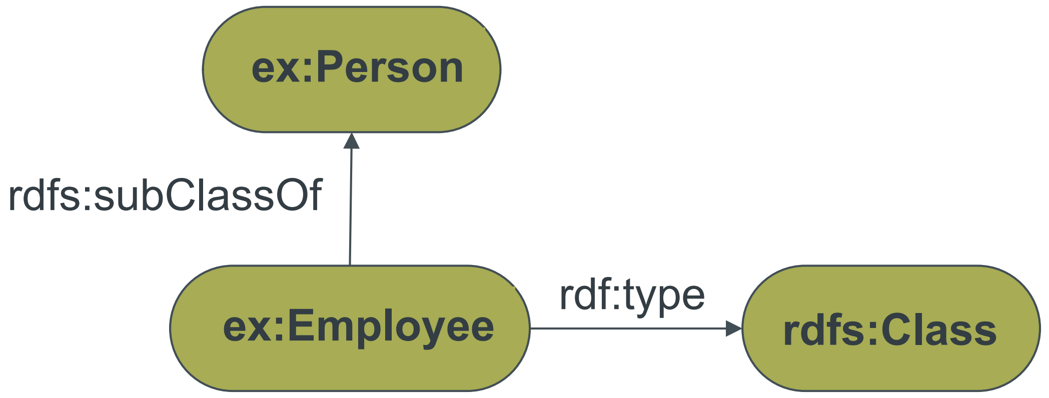
RDF Schema class definitions

- Employee is a subclass of Person



$$\begin{tikzcd}
\text{ex:Person} & \\
\text{ex:Employee} \arrow[u, "\text{rdfs:subClassOf}"] \arrow[r, "\text{rdf:type}"] & \text{rdfs:Class}
\end{tikzcd}$$

```
<rdfs:Class rdf:about="#Employee">
  <rdfs:subClassOf rdf:resource="#Person"/>
</rdfs:Class>
```

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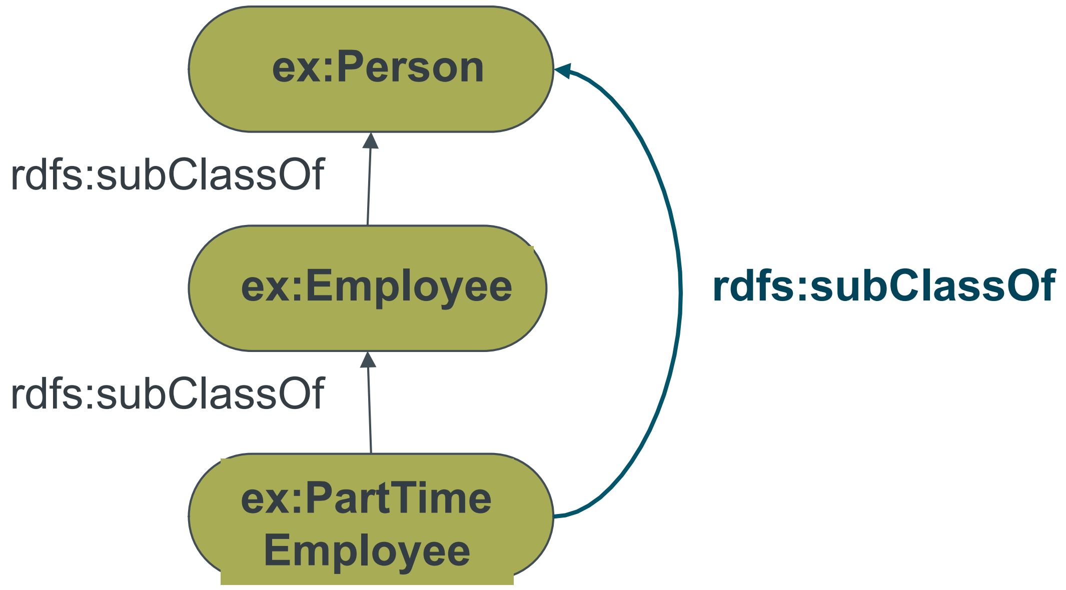
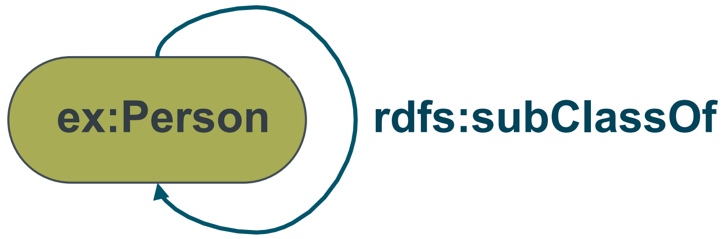
RDF Schema class semantics

- rdfs:subClassOf is transitive
  - (A rdfs:subClassOf B) and (B rdfs:subClassOf C) implies (A rdfs:subClassOf C)



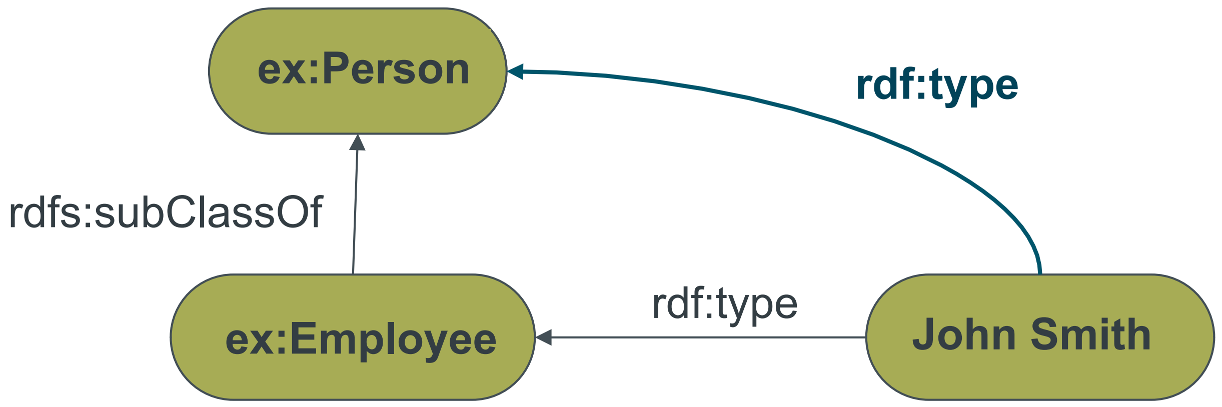
RDF Schema class semantics

- rdfs:subClassOf is reflexive
  - All classes are subclasses of themselves



RDF Schema class semantics

- rdf:type distributes over rdf:subClassOf
  - (A rdfs:subClassOf B) and (C rdf:type A) implies (C rdf:type B)



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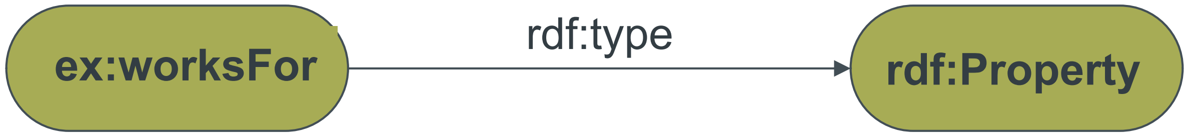
RDF Schema property definitions

- We wish to define the property worksFor



```
<rdf:Description rdf:about="#worksFor">
  <rdf:type rdf:resource="&rdf;Property"/>
</rdf:Description>
```

```
<rdf:Property rdf:about="#worksFor"/>
```

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RDF Schema property definitions

- Important difference between RDF and object oriented programming languages
  - OO languages define classes in terms of the properties they have
  - RDF defines properties in terms of the classes whose instances they relate to each other

- The *domain* of a property is the class that the property runs *from*
- The *range* of a property is the class that a property runs *to*

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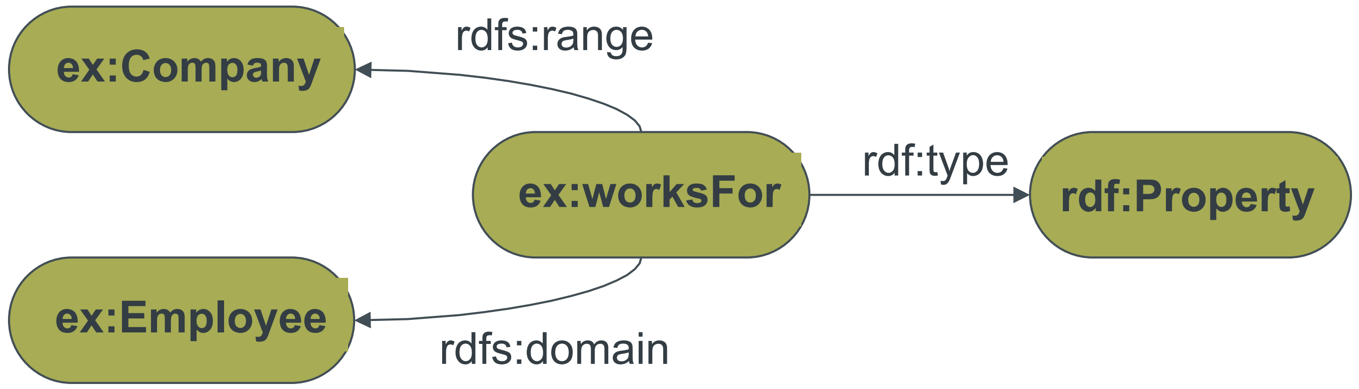
RDF Schema property definitions

- The property worksFor relates objects of class Employee to objects of class Company



```
<rdf:Property rdf:about="#worksFor">
  <rdfs:domain rdf:resource="#Employee"/>
  <rdfs:range rdf:resource="#Company"/>
</rdf:Property>
```

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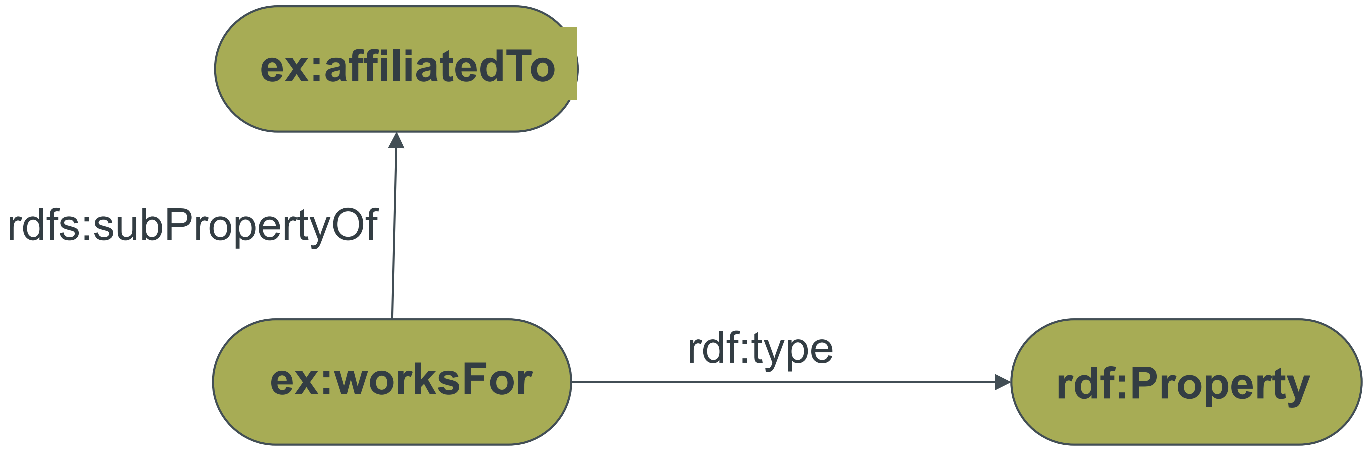
RDF Schema property definitions

- Specialisation exists in properties as well as classes
  - worksFor is a subproperty of affiliatedTo



```
<rdf:Property rdf:about="#worksFor">
  <rdfs:subPropertyOf rdf:resource="#affiliatedTo"/>
</rdf:Property>
```

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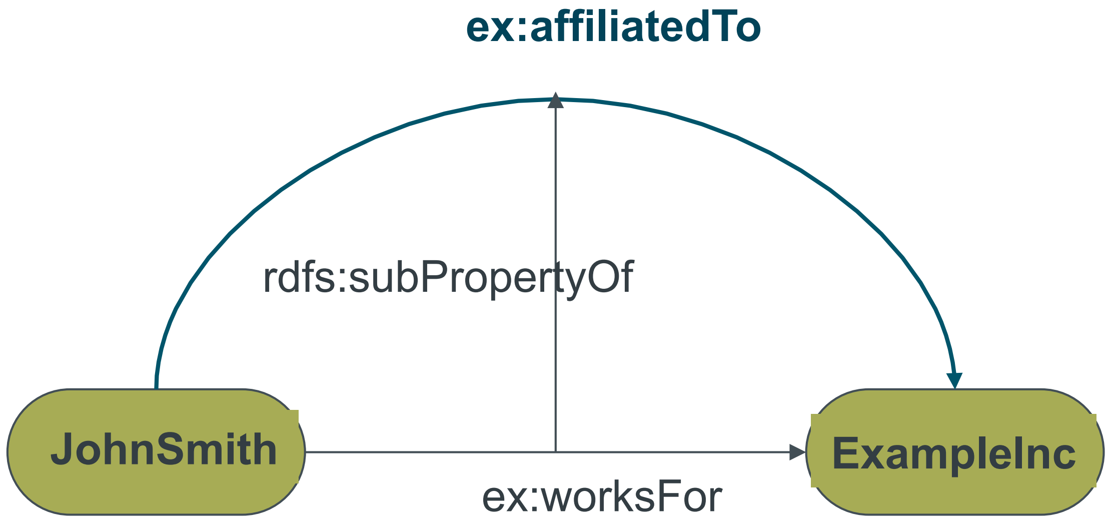
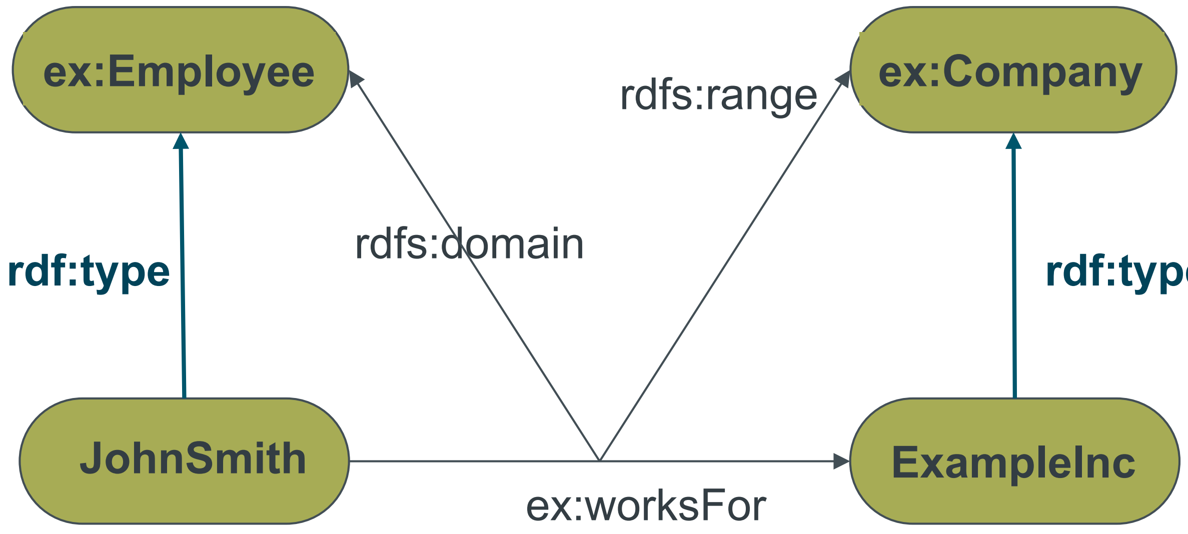
RDF Schema property semantics

- rdfs:subPropertyOf is transitive and reflexive
- Entailment of superproperties



RDF Schema property semantics

- Type entailments from range and domain constraints



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RDF Schema predefined classes

- rdfs:Class
- rdf:Property (note different namespace)
- rdfs:Resource
- rdfs:Literal
- rdfs:Datatype
- rdf:XMLLiteral

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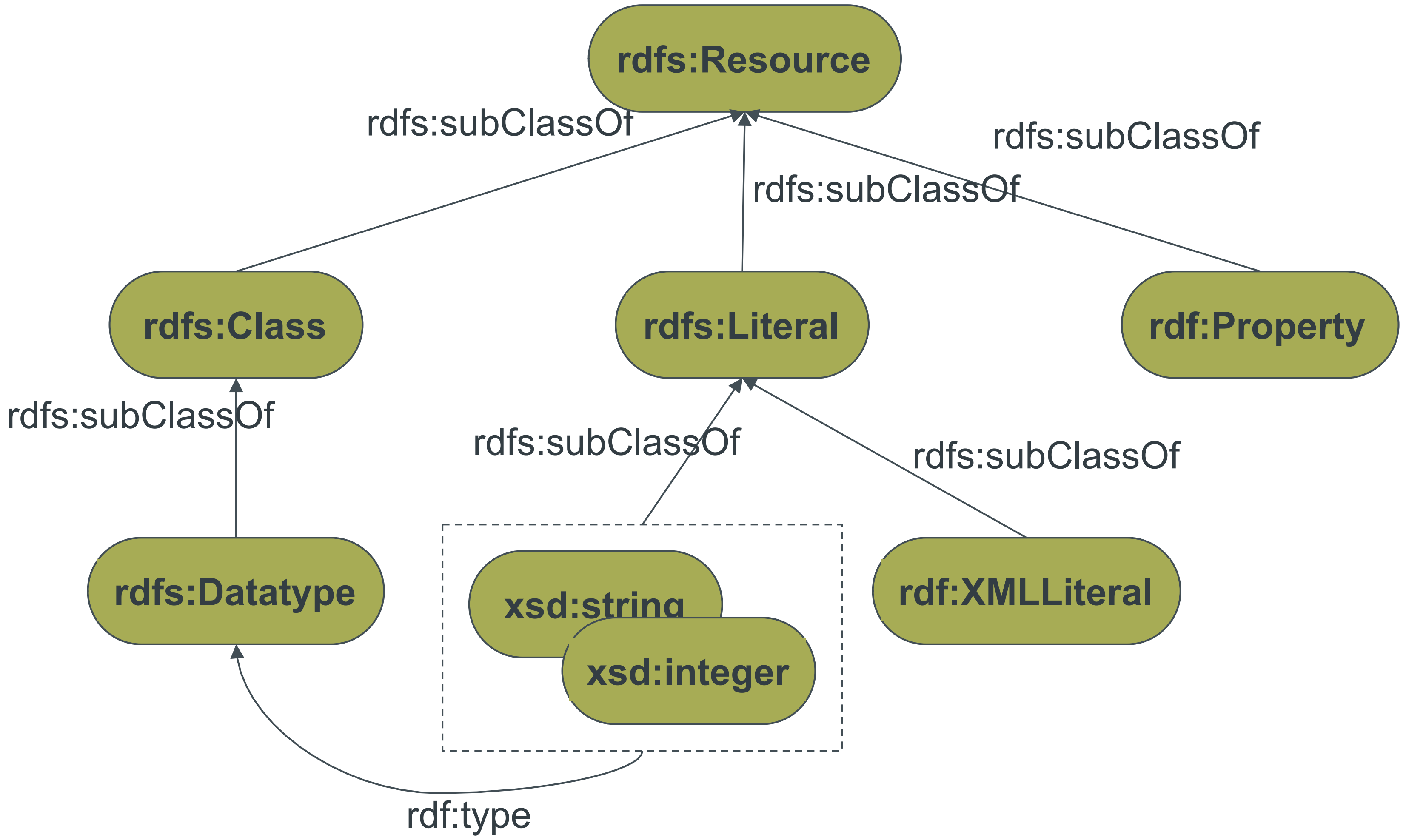
RDF Schema predefined classes



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RDF Schema ancillary features

- rdfs:label is used to give a human-readable name for a resource

```
<rdf:Description rdf:about="#person-01269">
  <rdfs:label>John Smith</rdfs:label>
</rdf:Description>
```

- rdfs:comment is used to give a human-readable description for a resource

```
<rdfs:Class rdf:about="#Employee">
  <rdfs:comment>A person who works.</rdfs:comment>
</rdfs:Class>
```

RDF Schema ancillary features

- rdfs:seeAlso is used to indicate a resource which can be retrieved to give more information about something
- rdfs:isDefinedBy indicates a resource which is responsible for the definition of something
  - A subproperty of rdfs:seeAlso

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RDF Schema Status

- Original version contemporary with RDF
- Revised version published in early 2004