

INFO216: Knowledge Graphs

Andreas L. Opdahl
<Andreas.Opdahl@uib.no>



Lecture 2

- Themes:
 - Resource Description Framework (RDF)
 - some known from INFO116
 - some new stuff/more details (almost all of RDF)
 - RDFLib's basic API
 - creating and deleting graphs, input/output, listing statements, managing literals, type mappings
 - Semantic data sets and vocabularies (*if we have time!*)
 - useful web links
 - aid for project idea
 - *more later!*



Reading

- Sources:
 - Allemang & Hendler (2011):
Semantic Web for the Working Ontologist
chapter 3 (page 31-44)
 - materials in the wiki: wiki.uib.no/info216



Resource Description Framework (RDF)



Resource Description Framework (RDF)

- Each data set:
 - treated as a set of *triples*
 - can be physical or virtual
 - exportation can be partial
- The relations form a *directed graph*:
 - “nodes” connected by “arrows”
- “Nodes”:
 - either *are* or *represent resources*
 - “leaf nodes” can contain *literal values* (text, numbers, booleans...)
- “Arrows”:
 - relations between resources and literals

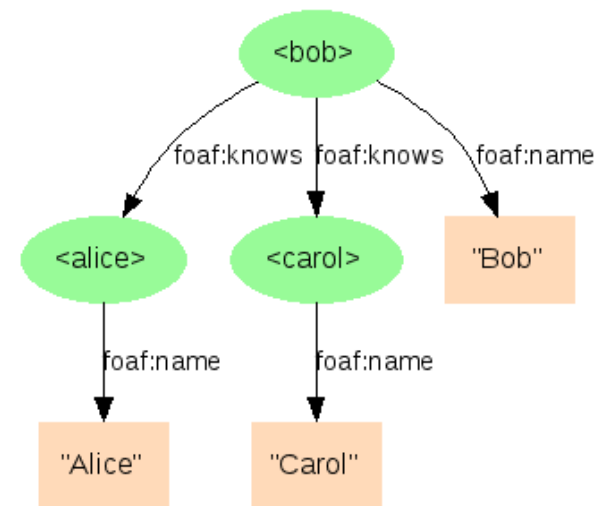


Statements (triples)

- Triples of *subject predicate object* .
 - ...or *subject predicate literal* .
- The subject:
 - must be a *resource* (\rightarrow rdfs:Resource)
 - *named* by an IRI or *anonymous* (*blank node*)
- The predicate:
 - must be a *property* (\rightarrow rdf:Property)
 - properties are resources too!
- The object:
 - either a resource (named or anonymous/blank)
 - or a constant *value* (\rightarrow rdfs:Literal)



- Triples of *subject predicate object* .
 - ...or of *subject predicate literal* .
 - Int. Resource Identifiers (IRIs)
 - serialisation in *Turtle*:



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

@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .

@prefix foaf: <http://xmlns.com/foaf/0.1/> .

:bob rdf:type foaf:Person .

:bob foaf:name "Bob" .

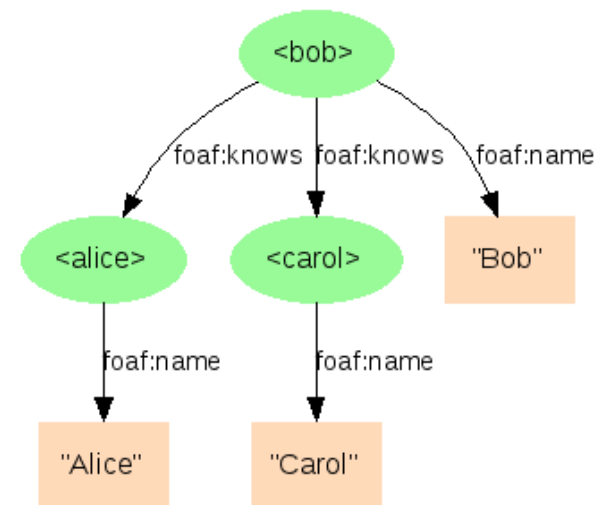
:bob foaf:mbox <mailto:alice@example.org> .

:bob foaf:knows :alice .

:bob foaf:knows :carol .



- Triples of *subject predicate object* .
 - ...or of *subject predicate literal* .
 - Int. Resource Identifiers (IRIs)
 - serialisation in *Turtle*:



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

@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .

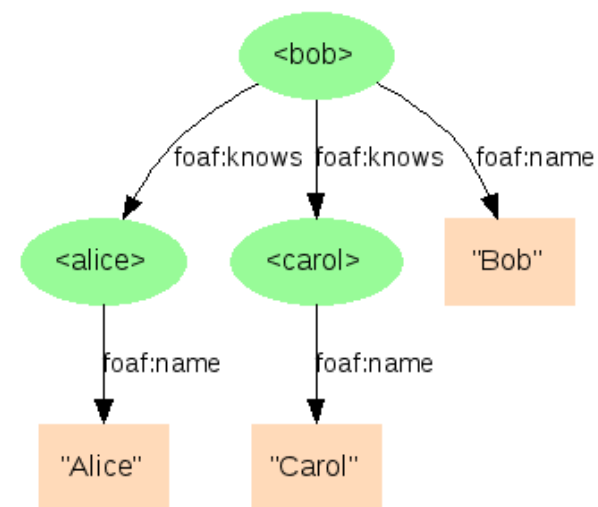
@prefix foaf: <http://xmlns.com/foaf/0.1/> .

```

:bob    rdf:type      foaf:Person ;
        foaf:name    "Bob" ;
        foaf:mbox    <mailto:alice@example.org> ;
        foaf:knows  :alice ;
        foaf:knows  :carol .
  
```



- Triples of *subject predicate object* .
 - ...or of *subject predicate literal* .
 - Int. Resource Identifiers (IRIs)
 - serialisation in *Turtle*:



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

@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .

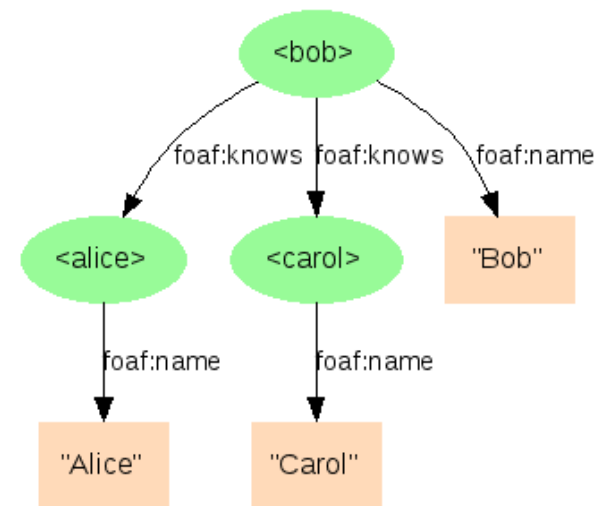
@prefix foaf: <http://xmlns.com/foaf/0.1/> .

```

:bob    rdf:type      foaf:Person ;
        foaf:name    "Bob" ;
        foaf:mbox    <mailto:alice@example.org> ;
        foaf:knows  :alice ,
                    :carol .
  
```



- Triples of *subject predicate object* .
 - ...or of *subject predicate literal* .
 - Int. Resource Identifiers (IRIs)
 - serialisation in *Turtle*:



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

@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .

@prefix foaf: <http://xmlns.com/foaf/0.1/> .

```

:bob    a          foaf:Person ;
        foaf:name  "Bob" ;
        foaf:mbox  <mailto:alice@example.org> ;
        foaf:knows :alice ,
                   :carol .

```



Prefixing

- XML Qualified Name (QName):
 - from “eXtensible Markup Language” (XML)
 - provides short forms for much used IRI bases
- Much used prefixes (here in Turtle syntax):
 - @prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
 - @prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
 - @prefix dc: <http://purl.org/dc/elements/1.1/> .
 - @prefix owl: <http://www.w3.org/2002/07/owl#> .
 - @prefix ex: <http://www.example.org/> .
 - @prefix xsd: <http://www.w3.org/2001/XMLSchema#> .
 - ...or self-defined prefixes
 - see <http://prefix.cc>
- Example:
 - <http://www.w3.org/2001/XMLSchema#string>
 - can now be written *xsd:string*



Semantic graphs and data sets

- *Graph*:
 - a collection of *triples/statements* (possibly none)
 - “*knowledge graphs*”
- *Data set (or “Conjunctive graph”)*:
 - a collection of graphs (at least one)
 - one of the graphs is *default/unnamed*
 - the others are *named*
 - from triples/statements:
 - *(subject, predicate, object)*
 - to quadruples (*quads*):
 - *(graph/“context”, subject, predicate, object)*



Resources (→ rdfs:Resource)

- Resources may be physical phenomena (including people and artefacts), information resources, concepts, constructs...
 - ...most things, really :-)
 - ...and information about them
- Can be the *subject* or *object* in a statement
 - but only rdf:Property can be *predicate*
- Can be:
 - *named* by an IRI
 - *anonymous* (blank *node*)
- Resources can have one or more *rdf:type*-s
 - dbpedia:Magnus_Carlsen *rdf:type* dbpedia:ChessPlayer



Internationalized Resource Identifier (IRI)

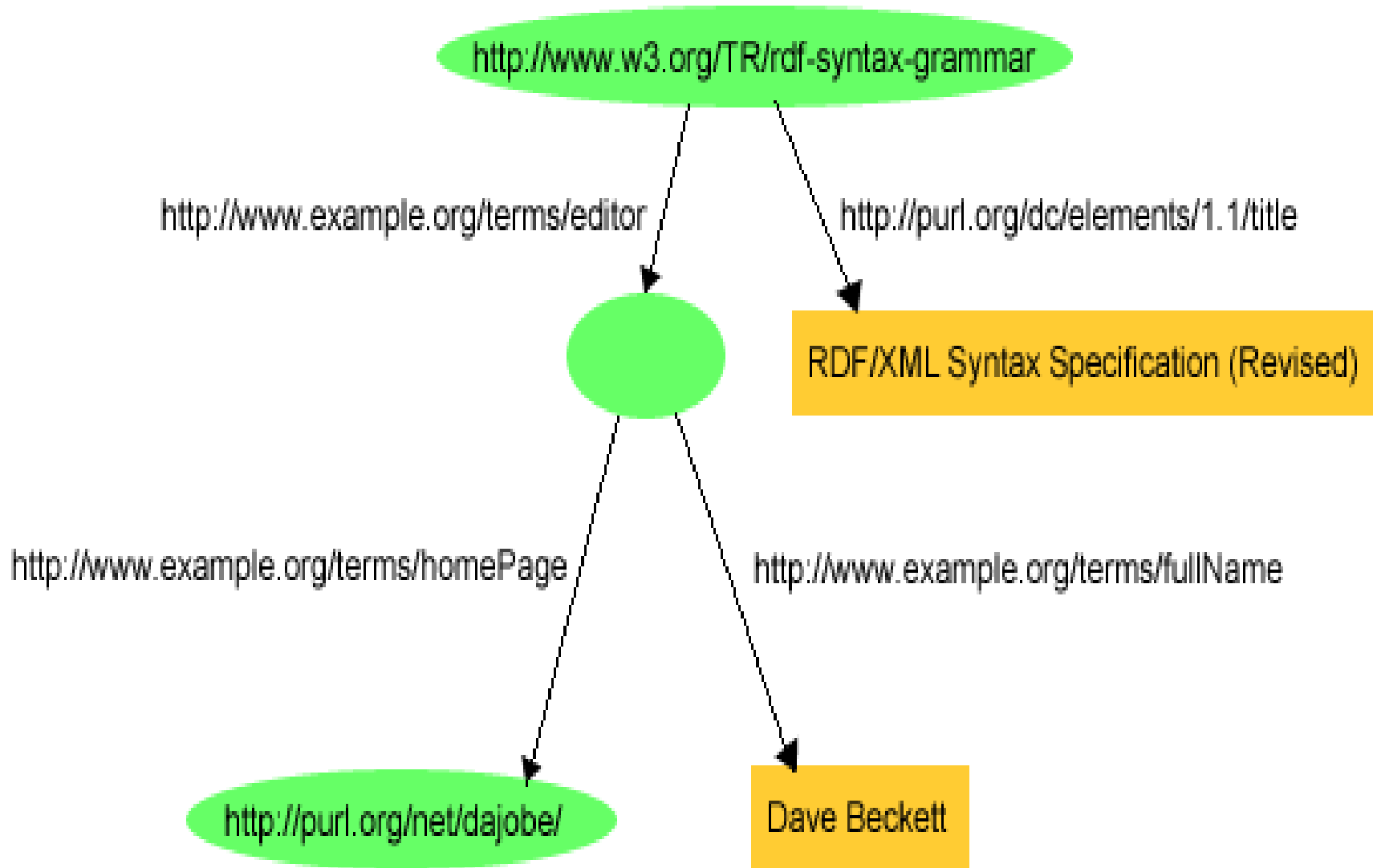
- Used to name (identify) resources:
 - URI – Uniform Resource Identifier
 - URL – a URI that is *dereferencable* (“Locator”)
 - URN – a URI that is used to name something
 - initially based on limited ASCII-character sets...
- Generalised into *International Resource Identifier (IRI)*
 - based on a *Unicode-character set* (UTF-8)
 - major security issue: homographic attacks
 - which domain is this? **uib.no**
 - also IRL, IRN...

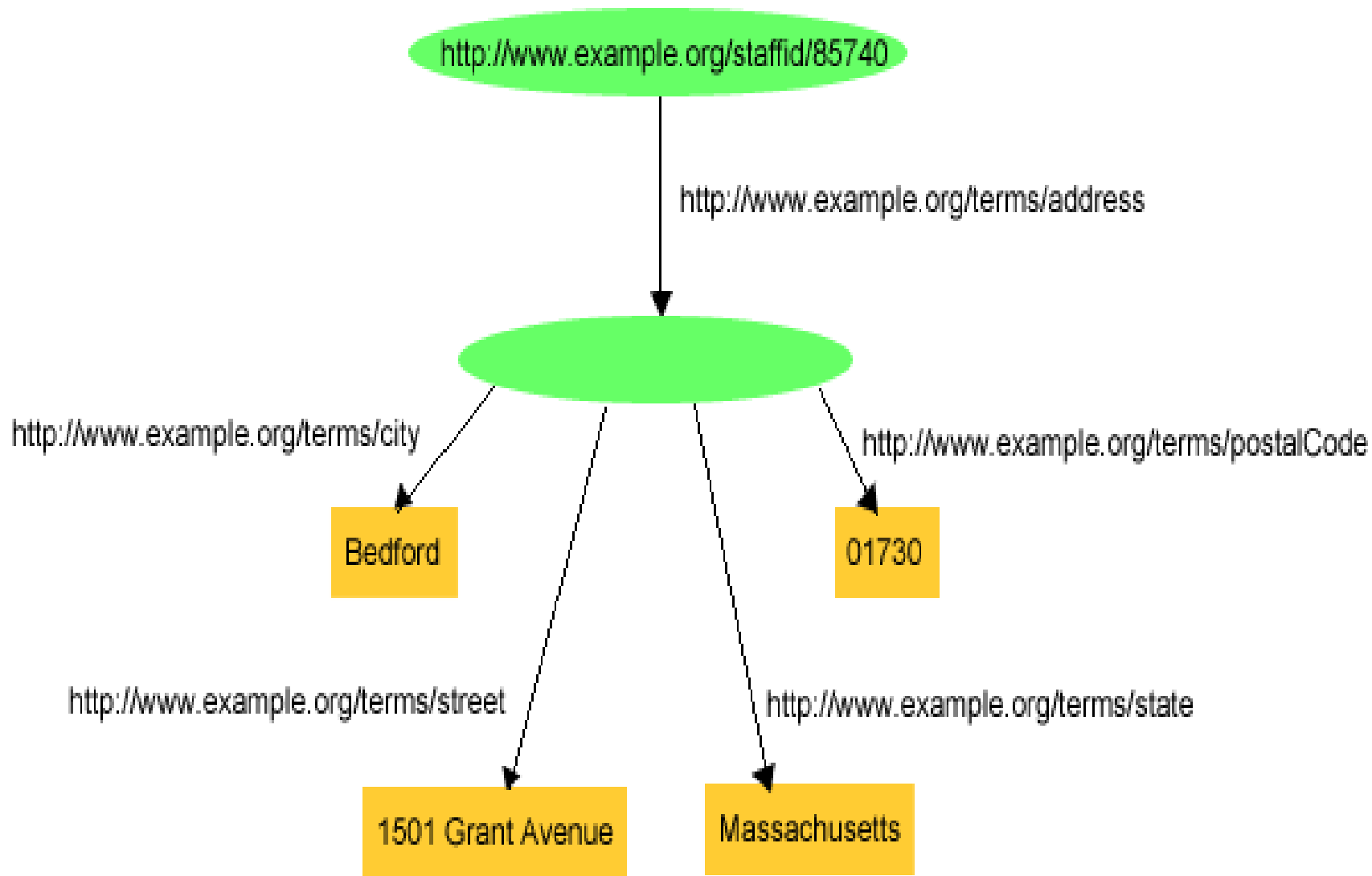


Anonymous resources (blank nodes)

- Some nodes have no IRIs:
 - cannot be referenced by other data sets
 - *can* be referenced by graphs in same data set
- Can have a (non-IRI) identifier, but
 - local identifier only meaningful inside the data set
 - *cannot be used to merge nodes from different data sets*
- Uses:
 - you are not sure of the IRI
 - you do not want to provide an IRI
 - logical grouping of related properties
 - *not supported by all RDF technologies*







Turtle syntax for blank nodes

```
<http://www.w3.org/TR/rdf-syntax-grammar>  
  <http://purl.org/dc/elements/1.1/title>  
    "RDF/XML Syntax Specification (Revised)" .
```

```
<http://www.w3.org/TR/rdf-syntax-grammar>  
  <http://www.example.org/terms/editor>
```

 **Each represents a *different* anon. node...**

```
<http://www.example.org/terms/homePage>  
  <http://purl.org/net/dajobe> .
```

```
<http://www.example.org/terms/fullName>  
  "Dave Beckett" .
```



Turtle syntax for blank nodes

```
<http://www.w3.org/TR/rdf-syntax-grammar>  
  <http://purl.org/dc/elements/1.1/title>  
    "RDF/XML Syntax Specification (Revised)" .
```

```
<http://www.w3.org/TR/rdf-syntax-grammar>  
  <http://www.example.org/terms/editor>  
    _:blank1 .
```

```
_:blank1  
  <http://www.example.org/terms/homePage>  
    <http://purl.org/net/dajobe> .
```

```
_:blank1  
  <http://www.example.org/terms/fullName>  
    "Dave Beckett" .
```



Turtle syntax for blank nodes

```
<http://www.w3.org/TR/rdf-syntax-grammar>  
  <http://purl.org/dc/elements/1.1/title>  
    "RDF/XML Syntax Specification (Revised)" ;  
  <http://www.example.org/terms/editor>  
    _:blank1 .
```

_:blank1

```
<http://www.example.org/terms/homePage>  
  <http://purl.org/net/dajobe> ;  
<http://www.example.org/terms/fullName>  
  "Dave Beckett" .
```



Turtle syntax for blank nodes

```
<http://www.w3.org/TR/rdf-syntax-grammar>  
  <http://purl.org/dc/elements/1.1/title>  
    "RDF/XML Syntax Specification (Revised)" ;  
  <http://www.example.org/terms/editor>
```

[] ← **[]** . → **Each represents a *different* anon. node...**

```
<http://www.example.org/terms/homePage>  
  <http://purl.org/net/dajobe> ;  
<http://www.example.org/terms/fullName>  
  "Dave Beckett" .
```



Turtle syntax for blank nodes

```
<http://www.w3.org/TR/rdf-syntax-grammar>  
  <http://purl.org/dc/elements/1.1/title>  
    "RDF/XML Syntax Specification (Revised)" ;  
<http://www.example.org/terms/editor>  
  [ <http://www.example.org/terms/homePage>  
    <http://purl.org/net/dajobe> ;  
    <http://www.example.org/terms/fullName>  
      "Dave Beckett" ] .
```



Properties (rdf:Property)

- Properties are resources that
 - express a relationship between resources
 - ...or between resources and literal values
- Is used as a *predicate* (or as subject or object)
- Example:
 - *name* is a property in the Dublin Core vocabulary
 - it can also be the subject in RDF statements:
 - `dc:name rdf:type rdf:Property .`
- *Convention: predicates are written with small initial letters*



Literals (rdf:Literal)

- **Untyped (simple) literals:** only a character string
 - f eks “29”
 - *can have a language code!*
“Göteborg”@”se”, “Gothenburg”@”en”
- **Typed literals:** a string + an IRI (ref)
 - the type is defined of the IRI
 - XML Schema Definition (XSD) language is common
 - two built-in RDF types: `rdf:XMLLiteral`, `rdf:HTML`
 - ...but other types can also be used
- Syntax depends on the serialisation, e.g., TURTLE:
 - “29”^^<<http://www.w3.org/2001/XMLSchema#integer>>
 - or with a prefix: “29”^^<xsd:integer>



XML Schema Definition (XSD)

- XSD types that can be used in RDF:
 - xsd:string, xsd:boolean, xsd:decimal, xsd:integer, xsd:float, xsd:double, xsd:dateTime, xsd:dateTimeStamp, xsd:time, xsd:date, xsd:gYearMonth, xsd:gYear, xsd:gMonthDay, xsd:gDay, xsd:gMonth, xsd:duration, xsd:yearMonthDuration, xsd:dayTimeDuration, xsd:hexBinary, xsd:base64Binary, xsd:anyURI, xsd:normalizedString, xsd:token, xsd:language, xsd:NMTOKEN, xsd:Name, xsd:NCName, xsd:positiveInteger, xsd:nonPositiveInteger, xsd:negativeInteger, xsd:long, xsd:int, xsd:short, xsd:byte, xsd:nonNegativeInteger, xsd:unsignedLong, xsd:unsignedInt, xsd:unsignedShort, xsd:unsignedByte
- Not all XML Schema types can be used in RDF:
 - *must be a set of string values*
 - *...that can be mapped into*
 - *...a well-defined value space*



Literals with dimensions

- Some literals have dimensions:
 - a weight can be a floating number and a weight unit
 - such literals can be represented by anonymous nodes
 - having one *rdf:value* and one *dimension* property
- Example:

```
exproduct:item10245    exterms:weight "2.4"^^xsd:decimal .
```
- Using *rdf:value*:

```
exproduct:item10245    exterms:weight _:weight10245 .
_:weight10245          rdf:value          "2.4"^^xsd:decimal .
_:weight10245          exterms:units    exunits:kilograms .
```
- *rdf:value* is not necessary here
 - ...offered by RDF as a *convention*
- ...*distinct vocabularies for units of measure (QUDT, OM...)*



Collections (rdf:List)

- Containers are not closed
 - we *cannot assume it only has the members we know of*
 - others can add more members to the list *without deleting triples* (i.e., *monotonically*)
- Collections (rdf:List-s):
 - can only have the listed members
 - `rdf:first` gives the first RDF node in the list
 - `rdf:rest` gives the rest of the list
 - `rdf:nil` is an empty list



<http://example.org/courses/6.001>

<http://example.org/students/vocab#students>

<http://example.org/students/Amy>

<http://www.w3.org/1999/02/22-rdf-syntax-ns#first>

<http://www.w3.org/1999/02/22-rdf-syntax-ns#rest>

<http://example.org/students/Mohamed>

<http://www.w3.org/1999/02/22-rdf-syntax-ns#first>

<http://www.w3.org/1999/02/22-rdf-syntax-ns#rest>

<http://example.org/students/Johann>

<http://www.w3.org/1999/02/22-rdf-syntax-ns#first>

<http://www.w3.org/1999/02/22-rdf-syntax-ns#rest>

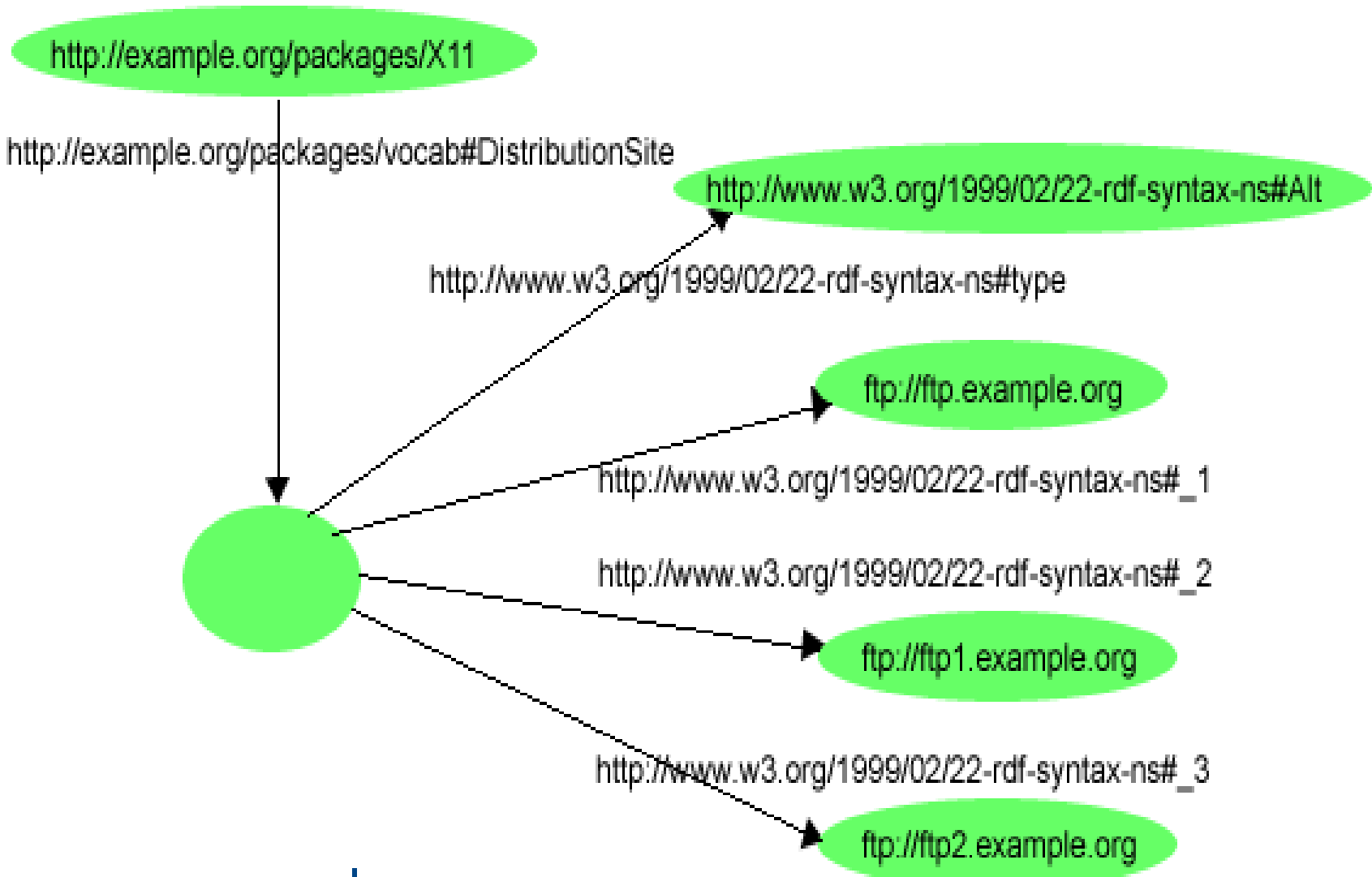
<http://www.w3.org/1999/02/22-rdf-syntax-ns#nil>



Containers (rdfs:Container)

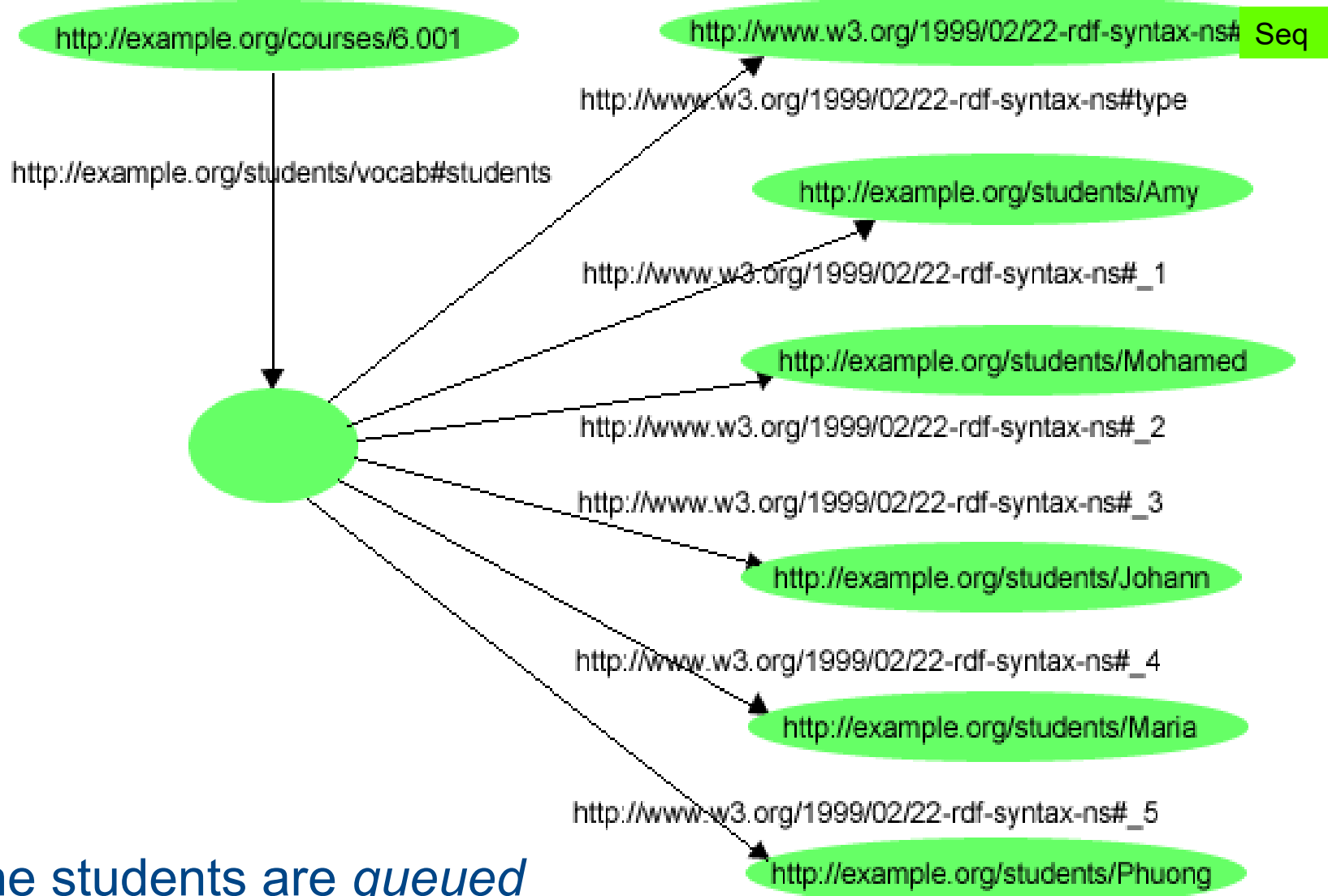
- Containers can be used when a subject is related in the same way to many RDF nodes that are
 - ordered and/or duplicated
 - (*regular properties* suffice when the RDF nodes are unordered and there are no duplicates)
- Container nodes are often anonymous (can have an IRI)
 - have RDF nodes as members (`rdfs:member`)
 - have special properties `rdf:_1`, `rdf:_2` etc. to pick out particular members
- `rdf:Alt` – several alternative resources
- `rdf:Seq` – lists of RDF nodes, can have duplicates
- `rdf:Bag` – orderless RDF nodes, can have duplicates





There are several *alternative* distribution sites.





The students are *queued up* in order for the course.



Reified statements (triples)

- Regular statement:

exproducts:item10245 exterm:weight "2.4"^^xsd:decimal .

- Reified statement (*reification quad*):

exproducts:triple12345 rdf:type rdf:Statement .

exproducts:triple12345 rdf:subject exproducts:item10245 .

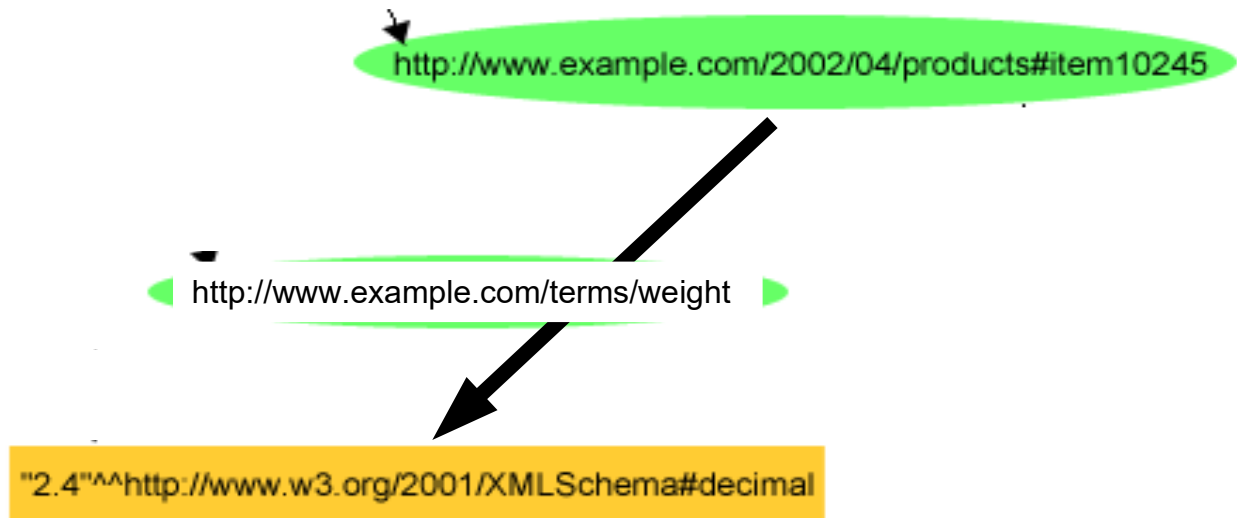
exproducts:triple12345 rdf:predicate exterm:weight .

exproducts:triple12345 rdf:object "2.4"^^xsd:decimal .

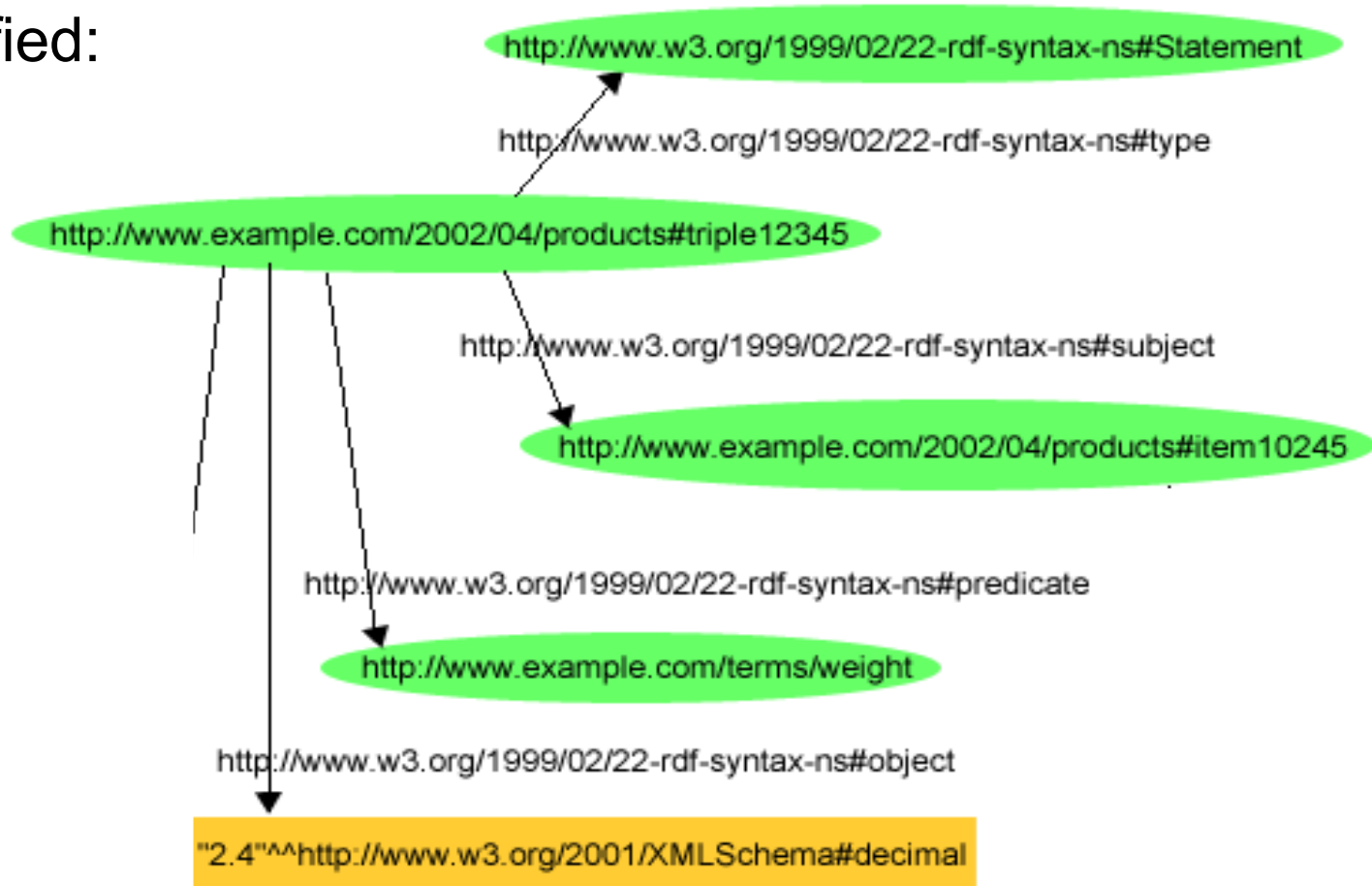
- Reification *gives the triple an identifier (IRI)*
- Reification “unpacks” a triple into four new ones:
 - **new type:** rdf:Statement
 - **new properties:** rdf:subject, rdf:predicate, rdf:object
- We can now make *statements about statements*:
 - “<Trippel-X> is valid from <dato> until <dato>.”
 - “<dbpedia:Wikipedia> claims that <trippel-Y>.”



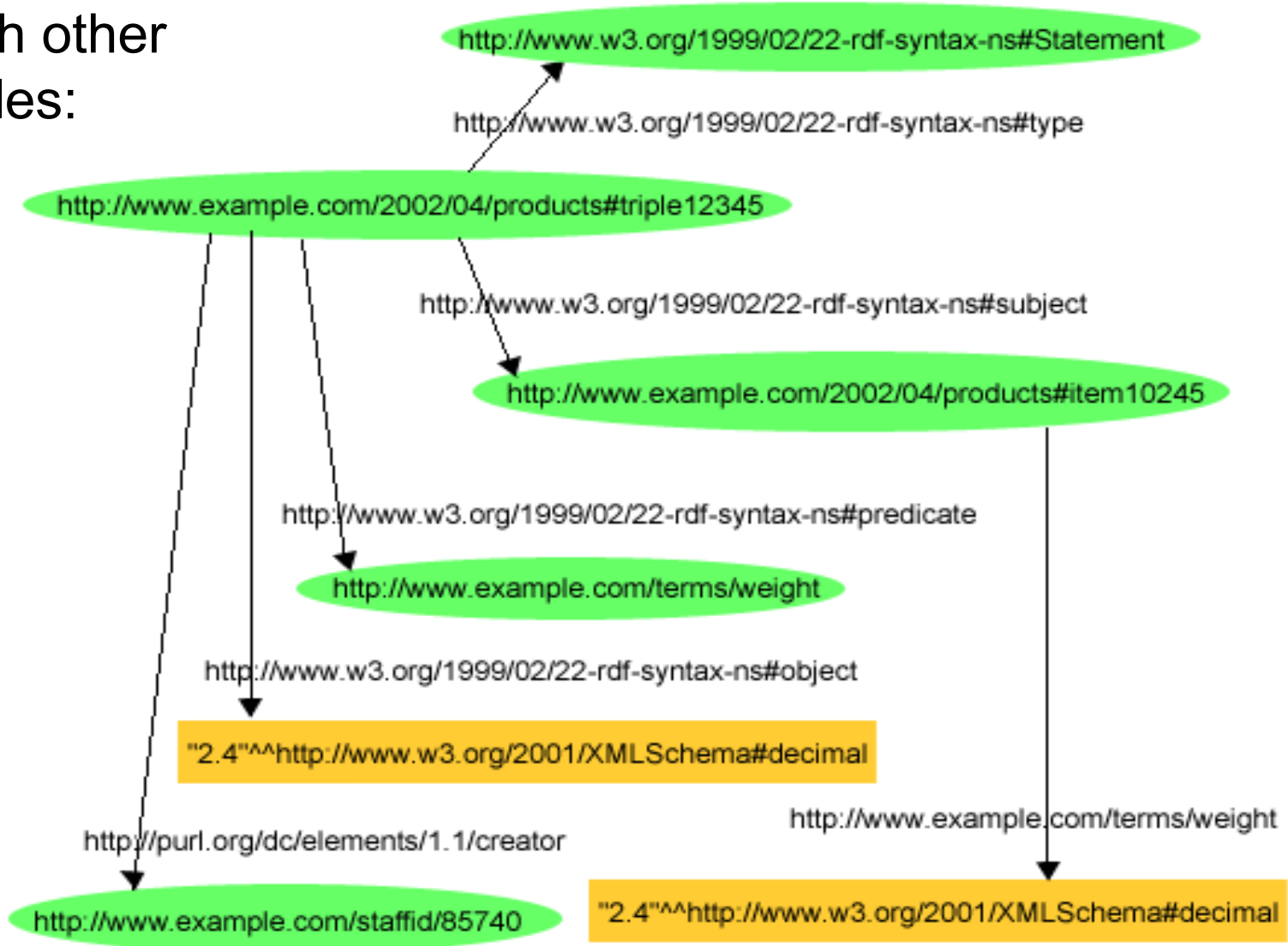
Non-reified:



Reified:



With other
triples:



RDFLib's Basic API



Possible plan for the lab

- Creating a Java project in Eclipse
- Creating a model (graph)
- **Adding statements to a model (triple)**
- Serialising (writing) and parsing (reading) RDF
- Listing statements in a model
- Prefix mapping
- Using vocabularies
- Using schemagen

Focus on Jena...

The Java-part does not have to be so hard!

(Expert in Java already? Try to do it in Scala!)



Creating models and statements

- Creation:
 - Model model = ModelFactory.createDefaultModel();
 - Resource res = model.createResource(*resIRI*);
 - Property prop = model.createProperty(*propIRI*);
 - Literal literal = model.createLiteral(...);
- Add triple:
 - res.addProperty(prop, *objectRes*);
 - res.addProperty(prop, *literalString*);
 - res.addLiteral(prop, *literalValue*);



Serialising and parsing

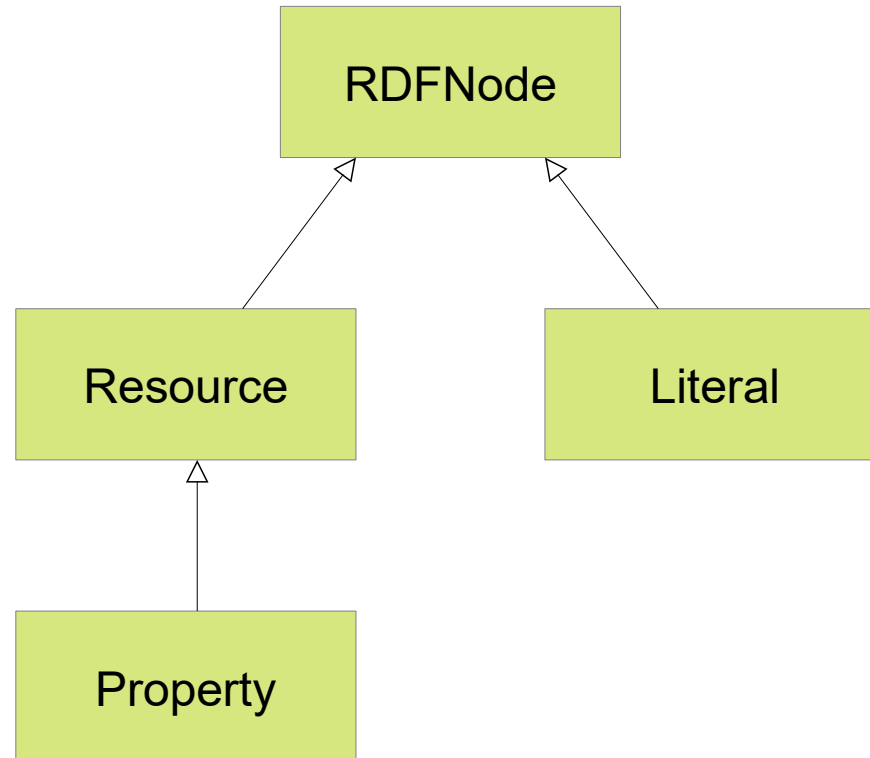
- Serialising:
 - `model.write(System.out);`
 - `model.write(System.out, "N-TRIPLE");`
 - `model.write(new FileOutputStream(pathStr), "TURTLE");`
 - Parsing:
 - `model.read(new FileInputStream("file:pathStr"), baseRlstr, "TURTLE");`
- ...needs enclosing `try { ... } catch (Exception e) { }` block



Listing statements

- Retrieving statements (triples):
 - StmtIterator stmts = model.listStatements();
 - stmts = model.listStatements(*subj*, *pred*, *obj*);
- Iterating:
 - for (Statement stmt : stmts.toList()) {
 ...*do something with stmt*...
}
 - Resource subj = stmt.getSubject();
 - Property pred = stmt.getPredicate();
 - RDFType obj = stmt.getObject();





Deleting statements and closing models

- Remove triple(s):
 - `res.removeAll(prop);`
 - `res.removeProperties();`
- Close model when finished:
 - `model.close();`



Vocabularies

- Predefined resources, properties (and some other fields) for common vocabulary terms (IRIs):
 - VCARD.NAME, VCARD.EMAIL, VCARD.PHOTO
 - DC_11.title, DC_11.subject, DC_11.creator
 - XSD.xstring, XSD.xint, XSD.date, XSD.anyURI
 - RDF.type, RDF.Property
 - RDFS.Resource, RDFS.Class, RDFS.Literal, RDFS.Datatype, RDFS.subClassOf, RDFS.subPropertyOf
 - OWL.sameAs, OWL.differentFrom, OWL.equivalentClass, OWL.disjointWith, OWL.equivalentProperty
- Jena's **schemagen**-verktøy kan brukes til å generere flere vokabularklasser



Prefix mapping

- Qualified names (qnames):
 - IRI written as prefix + identifier
 - `http://purl.org/dc/elements/1.1/author`
 - written as `dc:author`
 - `http://www.w3.org/2001/XMLSchema#string`
 - written as `xsd:string`
- `model.setNsPrefix(prefixStr, iriStr);`
- `model.getNsPrefixIRI(prefixStr);` *// returnerer iriStr*
- `model.getNsIRIPrefix(iriStr);` *// returnerer prefixStr*
- `model.removeNsPrefix(prefixStr);`



Semantic data sets and vocabularies

(quick overview to help
you find project ideas!)



Quick overview of...

- *Semantic vocabularies*
 - semantic resources (in RDFS, OWL...) that define:
 - standard IRIs for *types of resources*
 - standard IRIs for *properties*
 - standard types for *literals*
- *Semantic data sets*
 - free/open RDF-graphs that define:
 - standard IRIs for *individual resources*
 - perhaps also also their own vocabularies



Places to start

- Open and semantic:
 - open semantic data sets: <http://lod-cloud.net>
 - vocabularies: <http://lov.okfn.org/dataset/lov/>
 - overview and statistics: <http://stats.lod2.eu/>
- Open data in general:
 - internationally: <http://datahub.io> or <http://ckan.net>
 - Norge: <http://data.norge.no>
 - EU: <https://open-data.europa.eu>
 - Storbritannia: <http://data.gov.uk>
 - USA: <http://data.gov>



The LOD cloud...

- <http://www.lod-cloud.net/>
 - statistics at www.lod-cloud.net/state
 - 570 data sources (LOD-cloud, 2014)
 - based on data from DataHub (+ some crawling)
 - datahub.io or ckan.net
 - an open data portal
 - not necessarily semantic
 - LOD cloud group: www.ckan.net/group/lodcloud
 - ...also based on LOD crawling
- <http://lodstats.aksw.org/> *is more recent (less restrictive?!)*
 - ca 150 000M triples from ca 3000 data sets



Important vocabularies

