Chapter 2

RDF Syntax 2

Topics

- Basic concepts of RDF
  - Resources, properties, values, statements, triples
  - URIs and URIrefs
  - RDF graphs
  - Literals, qnames
- Vocabularies and modeling
  - Vocabularies
  - Blank nodes, data modeling, types, reification
  - Lists, bags, collections
- Serialization of RDF graphs
  - XML, Turtle, Ntriples
- Critique of RDF

Types

RDF type

- RDF has a type predicate that links a resource to another that denotes its type
  - ex:john rdf:type foaf:Person .
  - <http://example.org/john > <http://www.w3.org/1999/02/22-rdf-syntax-ns#type> <http://xmlns.com/foaf/0.1/Person> .
- RDFS adds sub-type concept & constraints between predicates & types of their arguments
- OWL adds still more concepts operating on types

Data Modeling

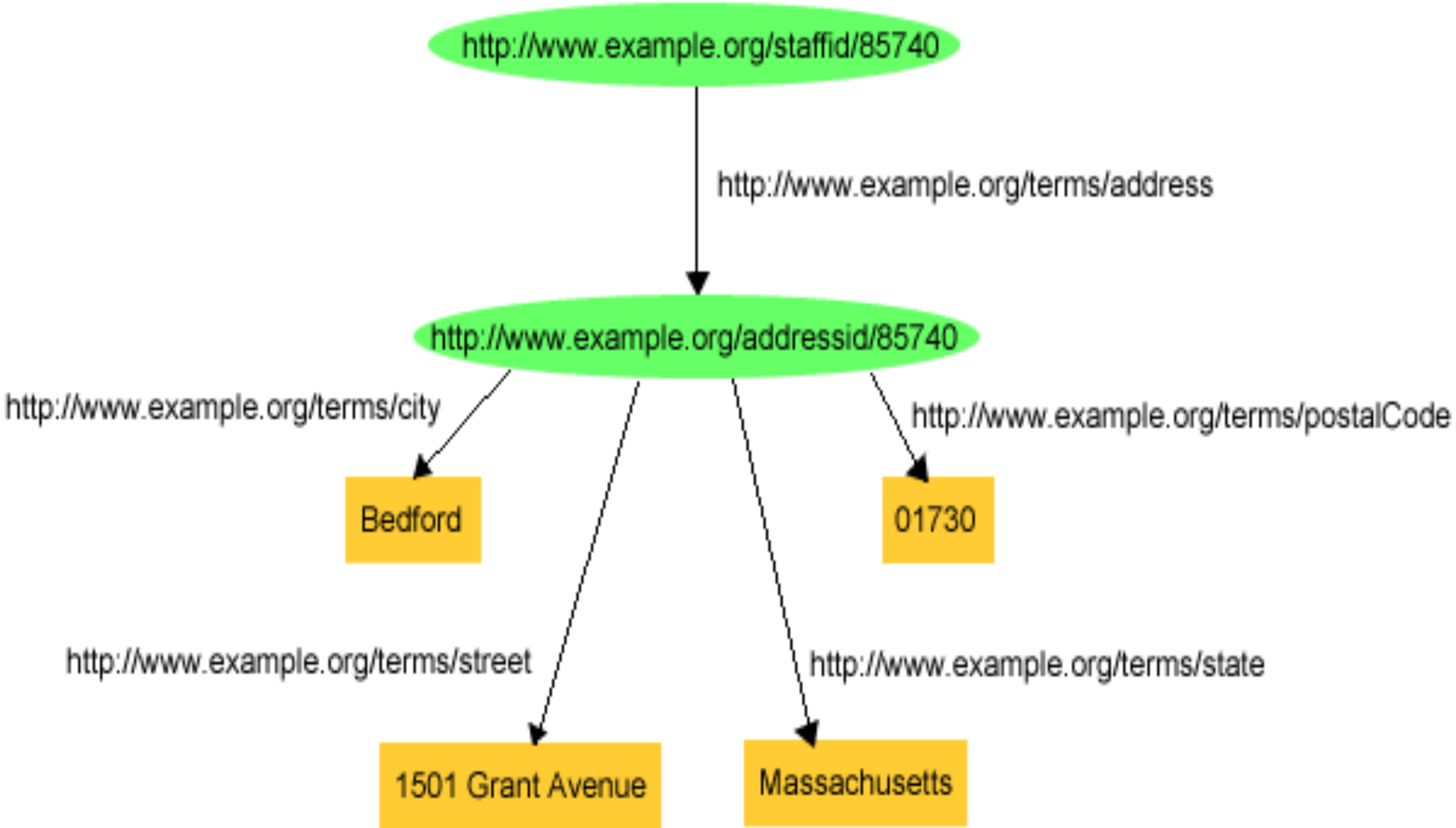
Structured Values in RDF

- Given the triple like:

  ex:857 exstaff:address "15 Grant Ave, Bedford, MA 01730".

- How can we best represent separate information for the street, city, state and zip code?
- Two possibilities:
  - Use four predicates (e.g., exstaff:street_address, …) to associate values with exstaff:857
  - Create an address resource to attach the four predicates to and link that to exstaff:address with the ex:address predicate

Structured Values in RDF



Structured Values in RDF

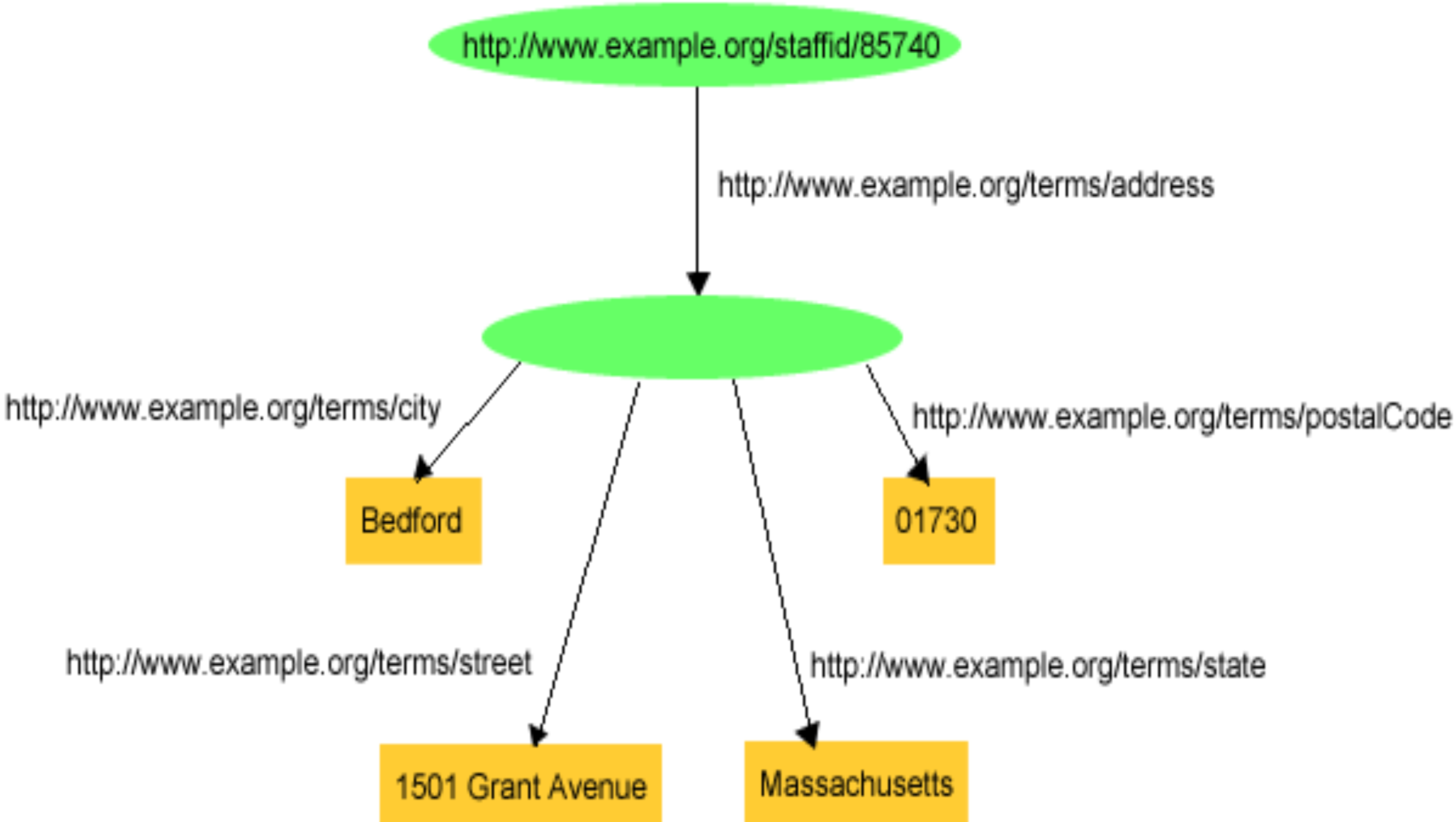
Or in triples notation:

exstaff:85740 exterms:address exaddressid:85740 .
exaddressid:85740 exterms:street "1501 Grant Ave" .
exaddressid:85740 exterms:city "Bedford" .
exaddressid:85740 exterms:state "MD" .
exaddressid:85740 exterms:postalCode "01730" .

Structured Values in RDF

- This approach involves adding **many “inter-mediate” URIrefs** (e.g., exaddressid:85740) for aggregate concepts like John's address
- Such concepts may never need to be referred to directly from outside a particular graph, and hence **may not require “universal” identifiers**
- RDF allows us to use **blank nodes** and **blank node identifiers** to deal with this issue
  - Node IDs in the _ namespace are bnodes, e.g. _:

Blank Node, aka bnode



Blank Nodes Using Triples

exstaff:85740 exterms:address ?? .

?? exterms:postalCode "01730" .

Exstaff:72120 exterms:address ??? .

??? exterms:postalCode "01702" .

- We want to ensure that the bnodes for 85740’s and 72120’s addresses are distinct
- The graphical notation does this by using two different objects for the bnodes
- RDF allows us to assign an special ID to a bnode while still maintaining its blank node nature

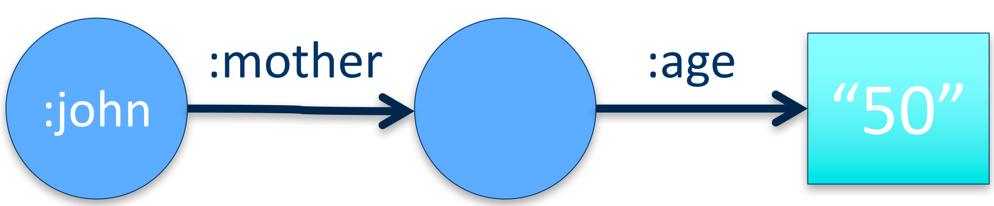
Blank Node Identifiers

exstaff:85740 exterms:address _:johnaddress .
_:johnaddress exterms:street "1501 Grant Avenue" .
_:johnaddress exterms:postalCode "01730" .

- Distinct bnode must have **different** bnode ids
- Bnode ids have significance only in a **single** graph
  - *dbpedia:Alan_Turing* refers to the same thing in every graph, but a bnode _:1 in two different graphs may not
  - Merging two graphs requires us to rename their bnode ids to avoid accidental conflation (e.g., _:1 => _:100)
- Bnode ids may only appear as subjects or objects and **not as predicates** in triples

Semantics of Blank Nodes

- In terms of **first-order logic**, blank nodes correspond to existentially quantified variables
- Another example: "John's mother is 50"
- **FOL:** $\exists x \; mother(john, x) \wedge age(x, 50)$
- **RDF:** :john :mother _32 . :_32 :age "50" .



Blank nodes are good for

- Representing **n-ary relationships** in RDF

  e.g., the relationship between John Smith and the street, city, state, and postal code components of his address

- To make statements about **resources that don’t have URIs** but are described by relationships with other resources that do

  e.g., John’s mother

Example

- To make statements about Jane Smith we could use her email address URI (mailto:jane@example.org) to denote her

- Well, if we do so, how are we going to record information both about **Jane's mailbox** (e.g., the server it is on) as well as about **Jane herself** (e.g., her current physical address)? Similarly, if we use her Web page URI etc.

Bnode Example

When Jane herself does not have a URI, a blank node provides a better way of modeling this situation

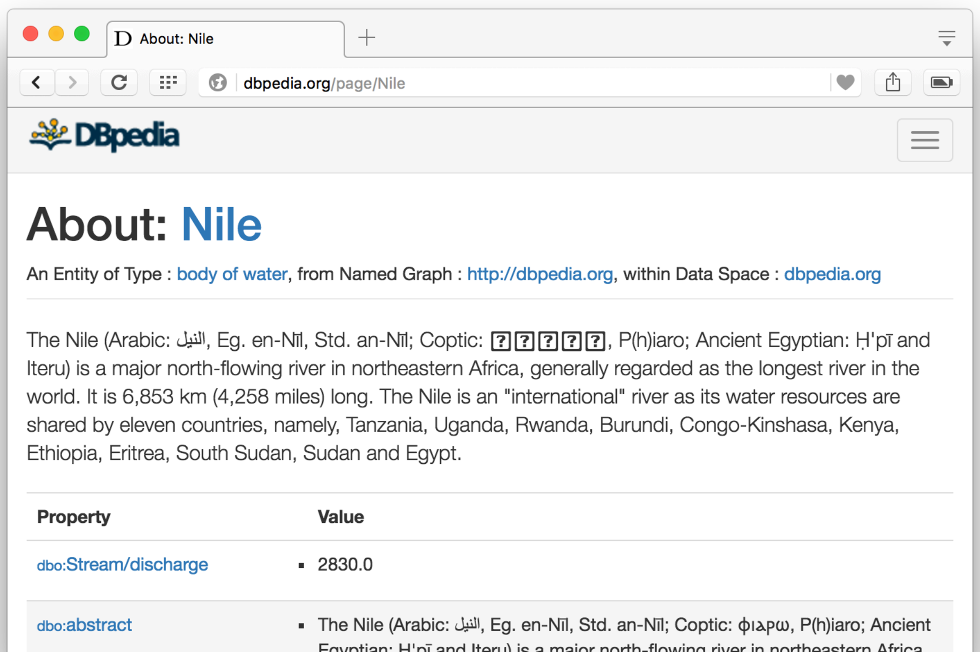
```
_:jane exterms:mailbox <mailto:jane@example.org> .
_:jane rdf:type exterms:Person .
_:jane exterms:name "Jane Smith" .
_:jane exterms:empID "23748" .
_:jane exterms:age "26" .
```

Another use case: Measurements

- What does this mean?

  [dbr:Nile] [dbp:length] "6853"^^xsd:integer

- We can click on [dbp:length] to see its definition



Another use case: Measurements

- What does this mean?

  dbr:Nile   dbp:length   "6853"^^xsd:integer

- We can click on dbp:length to see its definition

  dbp:length   rdf:type   rdf:Property .

  dbp:length   rdfs:label "Length"@en .

- Unfortunately, the definition doesn't specify the unit of measurement. ☹

Another use case: Measurements

- What does this mean?

  dbr:Nile dbp:length "6853"^^xsd:integer

- Measurements typically have a numeric *value* and a *unit*
  - **Weight:** 2.4 pounds vs. 2.4 kilograms
  - **Length:** 5 miles vs. 5 kilometers
  - **Price:** 29.00 in US Dollars vs. 21.16 Euro
  - **Time:** 30 years vs. 3 milliseconds
- We can use a bnode to represent a measurement as a pair with a value and unit

Measurements

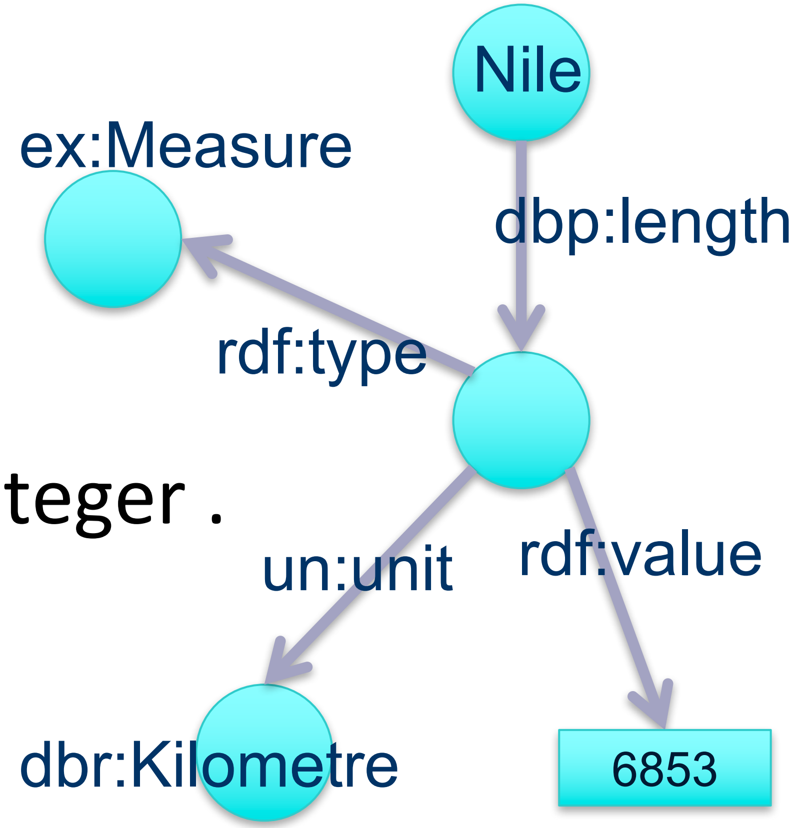
- What does this mean?

  dbr:Nile dbp:length _:1 .

  _:1 rdf:type ex:Measure .

  _:1 rdf:value ”6853"^^xsd:integer .

  _:1 un:units dbr:Kilometre .



- The RDF namespace has a *value* property but assigns no specific meaning to it

Serialization

RDF Serialization

- Abstract model for RDF is a graph
- Serialize as text for exchange, storage, viewing and editing in text editors
- The big three
  - XML/RDF – the original
  - Ntriples – simple, but verbose; good for processing
  - Turtle – compact, easy for people to read and write
- Special formats
  - Trig – a format for named graphs
  - RDFa – embed RDF in HTML attributes
  - JSON-LD – RDF statements as a JSON object

XML encoding for RDF

```
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
   xmlns:dc="http://purl.org/dc/elements/1.1/"
   xmlns:bib="http://daml.umbc.edu/ontologies/bib/">
<rdf:Description about="http://umbc.edu/~finin/talks/idm02/">
  <dc:title>Intelligent Information Systems on the Web </dc:Title>
  <dc:creator>
    <rdf:Description >
      <bib:name>Tim Finin</bib:Name>
      <bib:email>finin@umbc.edu</bib:Email>
      <bib:aff resource="http://umbc.edu/" />
    </rdf:Description>
  </dc:creator>
</rdfdescription>
</rdf:RDF>
```

RDF/XML is a W3C Standard widely used for storage and exchange

Being supplanted by other forms

Complex and confusing so we won’t spend time on it

Ntriples

- Good for ingesting into a program or store
- Sequence of triples each terminated with a "."
- URIs encased in angle brackets; no QNames; literals in double quotes

W3C Specification

- Trivial to parse/generate; common download format for RDF datasets (e.g., DBpedia)
- Uses lots of characters due to repeated URLs, but compresses well

```
<http://example.org/Turing><http://www.w3.org/1999/02/22-rdf-syntax-ns#type> <http://xmlns.com/foaf/0.1/Person> .
<http://example.org/Turing> <http://xmlns.com/foaf/0.1/name> "Alan Turing" .
<http://www.w3.org/2001/sw/RDFCore/ntriples/> <http://xmlns.com/foaf/0.1/mbox> <mailto:alan@turing.org> .
```

Turtle

- Ntriples ⊂ Turtle ⊂ N3
- Compact, easy to read and write and parse
- Qnames, [ ] notation for blank nodes, ; and ,

```
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix dc: <http://purl.org/dc/elements/1.1/> .
@prefix foaf: <http://xmlns.com/foaf/0.1/> .

<http://www.w3.org/TR/rdf-syntax-grammar>
  dc:title "RDF/XML Syntax Specification (Revised)" ;
  dc:creator [ foaf:name "Dave Beckett";
               foaf:mbox <mailto:dave@beckett.org> ,
                         <mailto:dbeck@gmail.com>
             ] .
```

Some details

- @PREFIX lines define namespace abbreviations
- Basic pattern is

```
Subj pred1 value1;
        pred2 value2;
        pred3 value3, value4 .
```

- Special notation for the rdf:type predicate

  :john **a foaf:Person;** foaf:name "John Smith" .

- Special notation for anonymous bnodes

  :john foaf:knows [a foaf:Person; foaf:nick "Bob"].

Notation3 or N3

- N3 was an early turtle-like notation developed by Tim_Berners Lee himself
- Included support for inference rules
  - See CWM for software
- Never became a recommended W3C standard
  - Some of its features were problematic for OWL
  - Supplanted by Turtle

Try…

- RDF examples: http://bit.ly/691rdf
- Simple.ttl

```
# A simple Turtle example

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

:john a foaf:Person;
  foaf:gender "Male";
  foaf:name "John Smith", "Johnny Smith";
  foaf:knows :mary,
          [a foaf:Person;
            foaf:mbox <mailto:mary.smith@gmail.com>] .

:mary a foaf:Person;
     foaf:name "Mary Smith" .
```

Notation translation

- Most modern Semantic Web software can read and write input in the three major serialization notations
  - E.g., Protégé, Jena, Sesame, …
- There are also simple programs that can convert between them
- rdf2rdf is a good example
  - Written in Java

Reification

Reification

- Sometimes we wish to make **statements about other statements**

  E.g., to record provenance data, probability, or to assert
  :john :believes { :mary :loves :john }

- We must be able to refer to a statement using an identifier

- RDF allows such reference through a reification mechanism which turns a statement into a resource

Reify

- Etymology: Latin *res* thing
- Date: 1854
- To regard (something abstract) as a material or concrete thing

Wikipedia: reification (computer science)

Reification is the act of making an abstract concept or low-level implementation detail of a programming language accessible to the programmer, often as a first-class object. For example,

- The C programming language reifies the low-level detail of memory addresses.
- The Scheme programming language reifies continuations (approximately, the call stack).
- In C#, reification is used to make parametric polymorphism implemented as generics a first-class feature of the language.
- …

Reification Example

:949352 uni:name “Grigoris Antoniou” .

reifies as

```
[a rdf:Statement;
   rdf:subject: :949352
   rdf:predicate uni:name;
   rdf:object “Grigoris Antoniou” ] .
```

Reification Example

```
<rdf:Description rdf:about="#949352”>
  <uni:name>Grigoris Antoniou</uni:name>
</rdf:Description>
```

reifies as

```
<rdf:Statement rdf:ID="StatementAbout949352">
  <rdf:subject rdf:resource="#949352"/>
  <rdf:predicate rdf:resource="http://example.org/uni-
      ns#name"/>
  <rdf:object>Grigoris Antoniou</rdf:object>
</rdf:Statement>
```

Another reification example

“Alice suspects that Bob loves Carol”

```
@prefix ep: <http://example.com/epistimology>
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>.
@prefix xsd: http://www.w3.org/2001/XMLSchema
:bob :loves :carol .
[:alice ep:believes
  [a rdf:Statement;
    rdf:subject :bob;
    rdf:predicate :loves;
    rdf:object :carol;
    ex:certainty “0.50”^^xsd:integer]
```

Reification

- **rdf:subject, rdf:predicate** & **rdf:object** allow us to access the parts of a statement
- The **ID** of the statement can be used to refer to it, as can be done for any description
- We write an **rdf:Description** if we don’t want to talk about a statement further
- We write an **rdf:Statement** if we wish to refer to a statement

Containers

Container Elements

- RDF has some vocabulary to describe collections of things and make statements about them
- E.g., we may wish to talk about the courses given by a particular lecturer
- The content of container elements are named **rdf:_1**, **rdf:_2**, etc.
  - Alternatively **rdf:li**
- Containers seem a bit messy in RDF, but are needed
- :john :teaches [a rdf:Bag; rdf:li :cmsc201, :cmsc202, cmsc345 .] .

Three Types of Container Elements

- **rdf:Bag** an unordered container, allowing multiple occurrences

  e.g., members of the faculty, documents in a folder

- **rdf:Seq** an ordered container, which may contain multiple occurrences

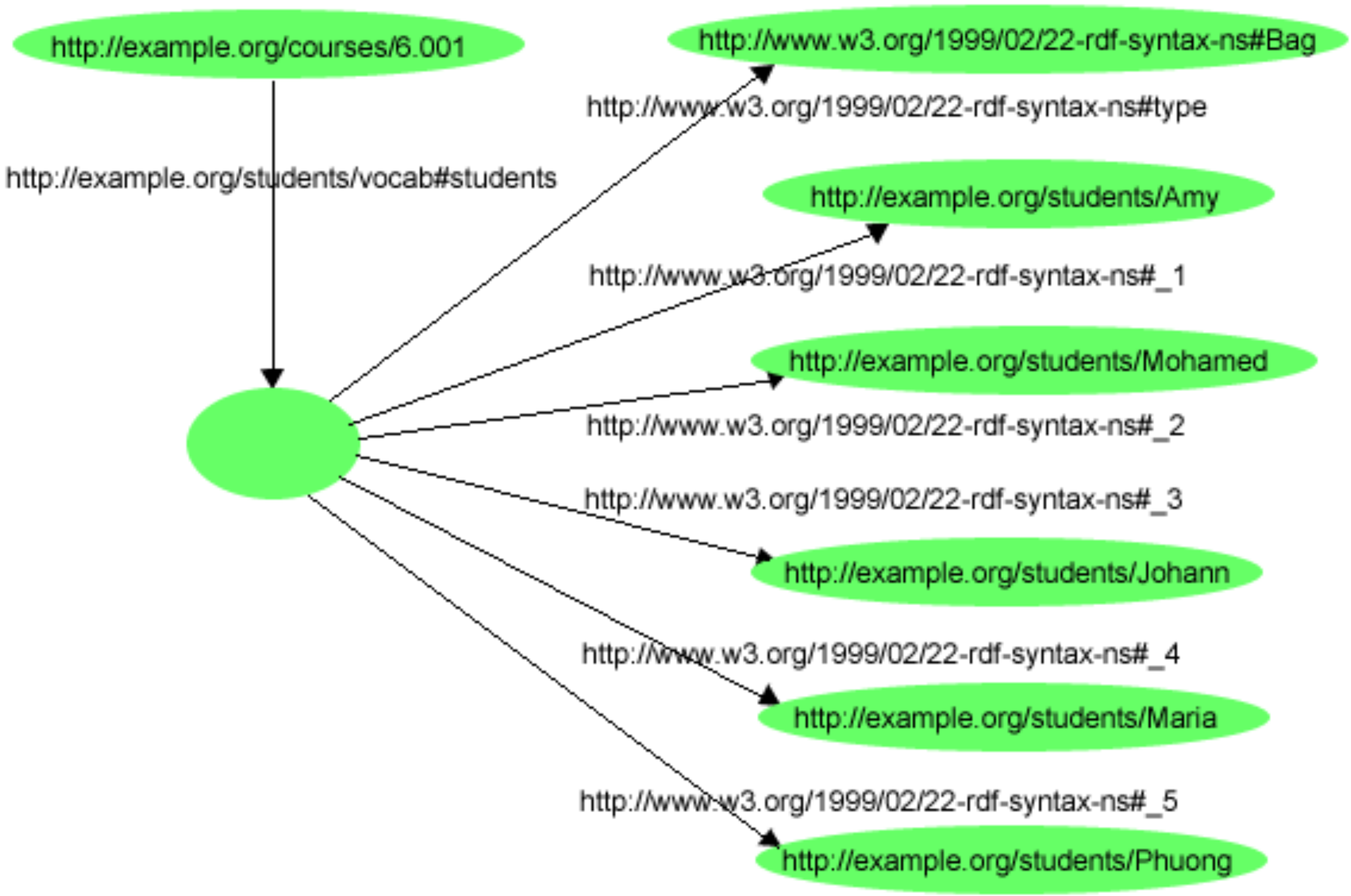
  e.g., modules of a course, items on an agenda, alphabetized list of staff members

- **rdf:Alt** a set of alternatives

  e.g., the document home site and its mirrors, translations of a document in various languages

Example for a Bag

Let's describe a course with a collection of students



Example for a Bag

```
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>.
@prefix s:   <http://example.org/students/vocab#>.
<http://example.org/courses/6.001>
   s:students [
      a rdf:Bag;
      rdf:_1 <http://example.org/students/Amy>;
      rdf:_2 <http://example.org/students/Mohamed>;
      rdf:_3 <http://example.org/students/Johann>;
      rdf:_4 <http://example.org/students/Maria>;
      rdf:_5 <http://example.org/students/Phuong>.
   ].
```

Example for Alternative

```
<uni:course rdf:ID="CIT1111"
        uni:courseName="Discrete Mathematics">
    <uni:lecturer>
        <rdf:Alt>
            <rdf:li rdf:resource="#949352"/>
            <rdf:li rdf:resource="#949318"/>
        </rdf:Alt>
    </uni:lecturer>
</uni:course>
```

Rdf:ID Attribute for Container Elements

```
<uni:lecturer rdf:ID="949318"
              uni:name="David Billington">
   <uni:coursesTaught>
      <rdf:Bag rdf:ID="DBcourses">
         <rdf:_1 rdf:resource="#CIT1111"/>
         <rdf:_2 rdf:resource="#CIT3112"/>
      </rdf:Bag>
   </uni:coursesTaught>
</uni:lecturer>
```

Bags and Seqs are never full!

- RDF’s semantics is “open world”, so…
  - Not possible ”to close” the container, to say: “these are **all** elements, there are no more”
  - RDF is a graph, with no way to exclude the possibility that there is another graph somewhere describing additional members
- Lists are collections with only the specified members mentioned.
- Described using a linked list pattern via:
  - rdf:List, rdf:first, rdf:rest, rdf:nil

Open vs. closed world semantics

- Reasoning systems make a distinction between open and closed world semantics
  - OWS: being unable to prove that something is true or false says nothing about its veracity
  - CWS: what cannot be proven to be true is false
- Default model for Semantic Web is OWS

  This was a design decision made early on

Open vs. closed world semantics

- Classical logic uses Open World Semantics

  Being unable to prove P=NP doesn't convince us that it's false

- Database systems typically assume CWS

  The DB includes all trains between NYC and DC

- Prolog's unprovable operator (not or \+) supports CWS

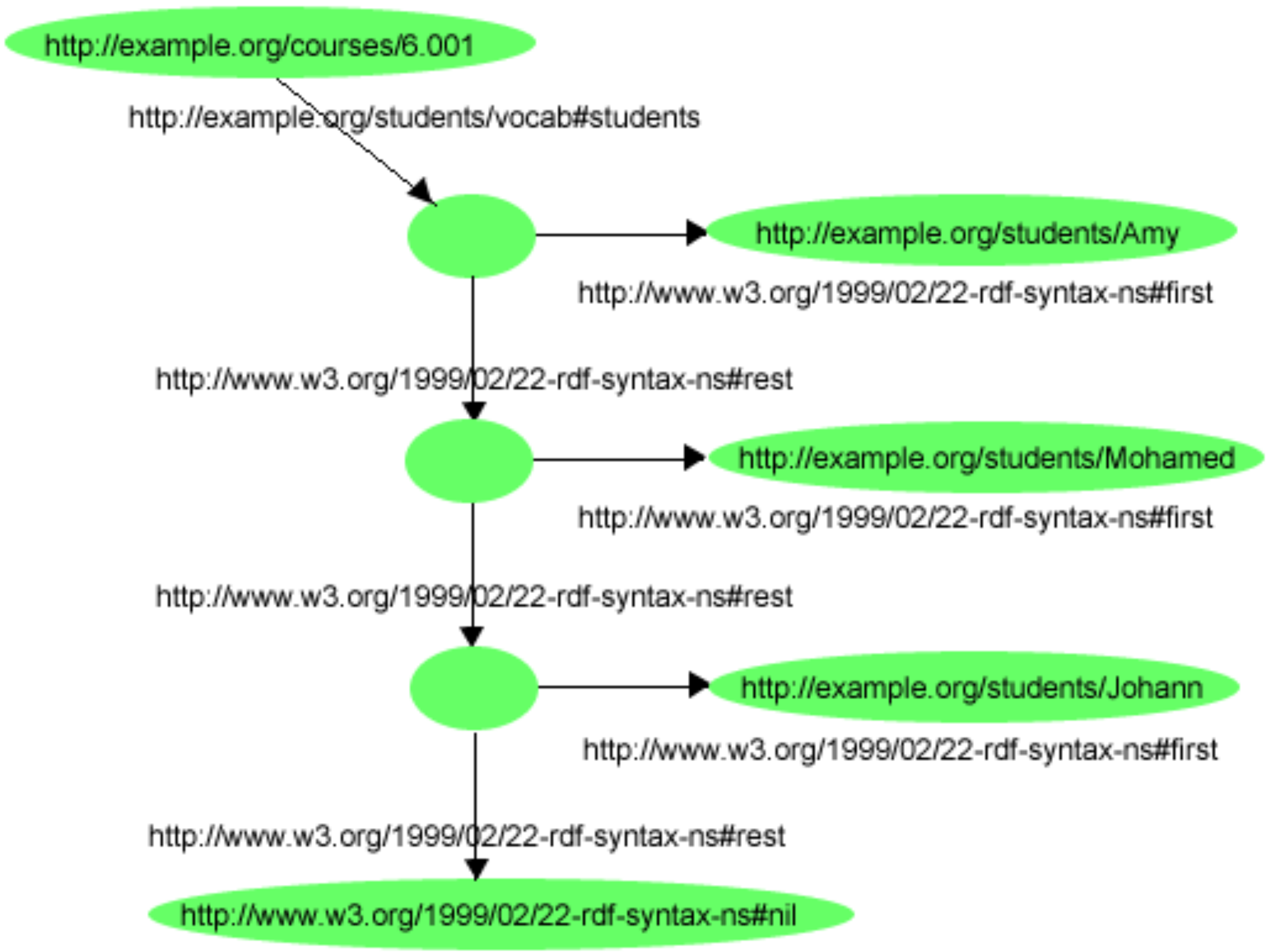
  flys(x) :- bird(x), \+ flightless(x).

  flightless(x) :- penguin(x); ostrich(x); emu(x).

- Some systems let us specify for which predicates we have complete knowledge and for which we don't
  - If UMBC's DB doesn't list you as registered for CMSC691, you are not registered
  - UMBC's DB system knows some of your minors but not all

RDF Lists

An ordered list of the three students in a class



RDF Lists

```
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>.
@prefix s:   <http://example.org/students/vocab#>.

<http://example.org/courses/6.001>
  s:students
  [a rdf:List;
   rdf:first <http://example.org/students/Amy>;
   rdf:rest [a rdf:list
            rdf:first <http://example.org/students/Mohamed>;
            rdf:rest [a rdf:List;
                     rdf:first <http://example.org/students/Johann>;
                     rdf:rest rdf:nil ] ] ] .
```

RDF Lists

Turtle has special syntax to represent lists:

```
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>.
@prefix s:   <http://example.org/students/vocab#>.

<http://example.org/courses/6.001>
    s:students (
        <http://example.org/students/Amy>
        <http://example.org/students/Mohamed>
        <http://example.org/students/Johann>
    ).
```

Critique of RDF

RDF Critique: Properties

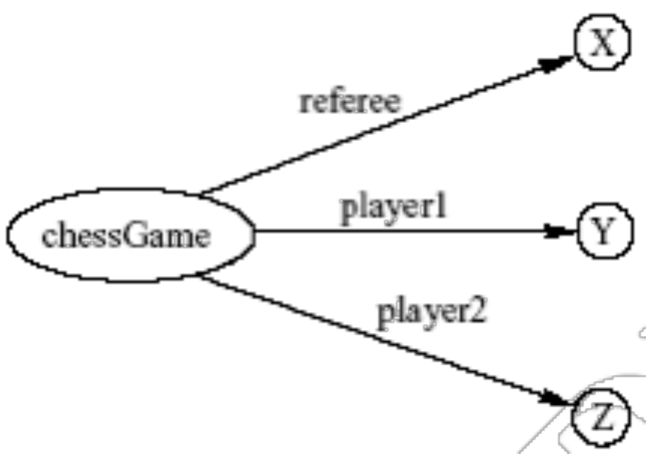
- Properties are special kinds of resources
  - Properties can be used as the object in an object-attribute-value triple (statement)
  - Defined **independent** of resources
- This possibility offers flexibility
- But it is unusual for modelling languages and OO programming languages
- It can be confusing for modellers

RDF Critique: Binary Predicates

- RDF uses only binary properties
  - This is a restriction because often we use predicates with more than two arguments
  - But binary predicates can simulate these
- Example: **referee(X, Y, Z)**
  - **X** is the referee in a chess game between players **Y** and **Z**

RDF Critique: Binary Predicates

- We introduce:
  - a new auxiliary resource **chessGame**
  - the binary predicates **ref**, **player1**, and **player2**
- We can represent **referee(X,Y,Z)** as:



RDF Critique: Reification

- The reification mechanism is quite powerful
- It appears misplaced in a simple language like RDF
- Making statements about statements introduces a level of complexity that is not necessary for a basic layer of the Semantic Web
- Instead, it would have appeared more natural to include it in more powerful layers, which provide richer representational capabilities

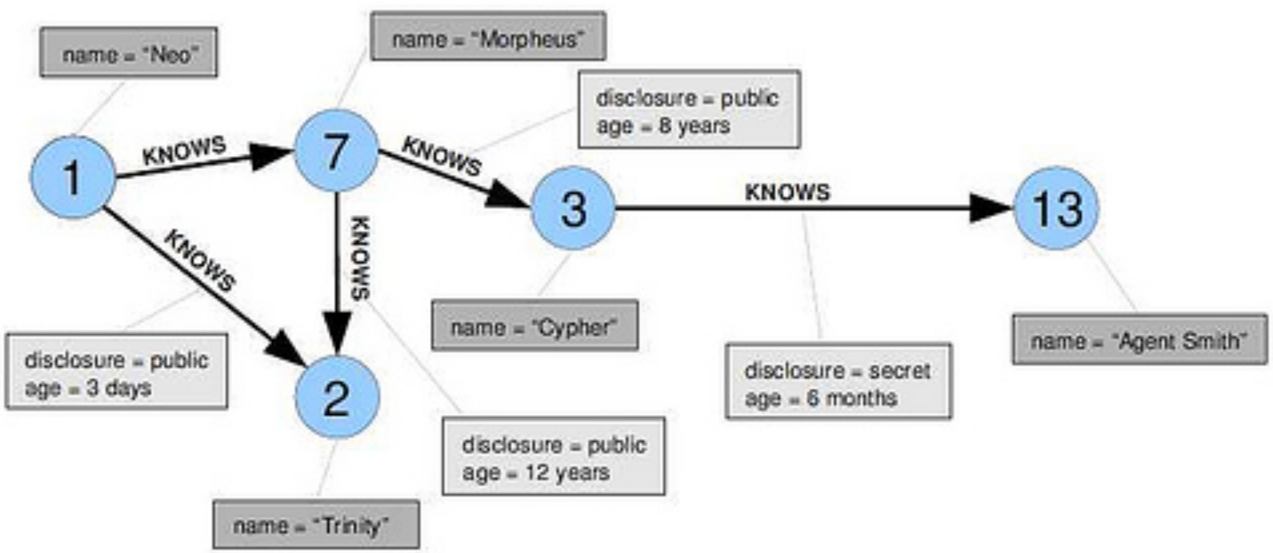
RDF Critique: Graph Representation

- The simple graph or network representation has more drawbacks
- Linear languages introduce ways to represent this with parentheses or a way to represent a block structure
- Scoping, for example, is clumsy at best in RDF

  believe(john, and (love(bob, carol), love(carol, bob))
- Some of these are addressed through the notion of a *named graph* in RDF

RDF graph model is simple

- RDF's graph model is a simple one
- Neo4J is a popular graph database where both nodes and links can have properties



RDF Critique: Summary

- RDF has its idiosyncrasies and is not an optimal modeling language **but**
- It is already a de facto standard
- It has sufficient expressive power
  - Reasonable foundation on which to build
- Using RDF offers the benefit that information maps unambiguously to a model

Conclusion

Topics

- Basic concepts of RDF
  - Resources, properties, values, statements, triples
  - URIs and URIrefs
  - RDF graphs
  - Literals, qnames
- Vocabularies and modeling
  - Vocabularies
  - Blank nodes, data modeling, types, reification
  - Lists, bags, collections
- Serialization of RDF graphs
  - XML, Turtle, Ntriples
- Critique of RDF